SMART LOW-COST RELIABLE HYBRID E- BICYCLE

B.E. ELECTRONIC ENGINEERING, BATCH 2019F

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DEPARTMENT OF ELECTRONIC ENGINEERING

DAWOOD UNIVERSITY OF ENGINEERING AND TECHNOLOGY, KARACHI

JULY 2023

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Report submitted in partial fulfillment of the requirement.

for the degree

of Bachelor of Engineering

in Electronic Engineering

DEPARTMENT OF ELECTRONIC ENGINEERING

DAWOOD UNIVERSITY OF ENGINEERING AND TECHNOLOGY, KARACHI

JULY 2023

Department of Electronic Engineering

Dawood University of Engineering & Technology, Karachi

CERTIFICATE

This project **"SMART Low-Cost Reliable Hybrid E Bicycle"** presented by **Hammad Ahmed Khan, Zaheer Uddin Shaikh, Muhammad Aurangzaib Khan and Muhammad Usman Mazhar** under the direction of their project advisor's and approved by the project examination committee, has been presented to and accepted as it satisfies the academic requirements in respect of project work prescribed by the Department of Electronic Engineering in partial fulfillment of the requirements for Bachelor of Engineering in Electronic Engineering.

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SMART Low-Cost Reliable Hybrid E Bicycle

Sustainable Development Goals

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	SDG 9 ✓	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3 ✓	Good Health and Well Being	SDG 11	Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13 ✓	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7 ✓	Affordable and Clean Energy	SDG 15 ✓	Life on Land
SDG 8 ✓	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

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ABSTRACT

This final year project aims to design and develop a 3-way charging for hybrid bicycle that can be powered by three different sources of energy, including human pedaling, solar energy, and grid electricity. The primary objective of the project is to create a sustainable and eco-friendly mode of Urban Mobility that is affordable and accessible to everyone. To achieve this, the project involves a comprehensive literature review of hybrid bicycle technology, solar energy, and energy storage systems. A prototype of the hybrid bicycle is being designed and built, incorporating a custom electronic control system that allows for the seamless integration of the three power sources. Preliminary testing of the prototype has shown promising results, with the electronic speed controller circuit being able to control the motor speed and solar charging is done using mppt. Further, pedal assist charging is done through a geared motor. The next phase of the project involves the design of a three-way powered circuit utilizing renewable resources and pedal-assist charging, with a primary focus on enhancing its performance. efficiency, and safety. Overall, the bicycle is capable of providing speed of 25kph and with a range of more than 30kph on battery with multiple charging sources available. MPPT charge controller is able to produce 2.38 A & pedal assist charging system is able to produce 1.5A on light pedaling, enabling it to charge in 5 hours from electric source at 4A, in 5 hours from Solar if battery is 40-50%, and 30 minutes of pedaling can add 5- 10% of charge on normal pedaling. The outcomes of this project have significant implications for the transportation industry, as it demonstrates the potential of hybrid bicycles as a sustainable and eco-friendly mode of Urban Mobility. The project also contributes to the ongoing research and development of renewable energy systems and provides a foundation for further investigation and refinement of hybrid bicycle technology.

CHAPTER ONE

INTRODUCTION

1.1 Overview

The target of this project is to conduct experimental research for the development of a low-cost and durable Electric bicycle that is capable of competing with other commonly used modes of traveling. Moreover, the characteristics of a bike will be designed as per the need for sustainability and social well-being options. For both options, the proposed E-bicycle containing sustainable ways of energy sources can potentially mitigate challenges such as accelerating rate of greenhouse emission gases, mobility challenges of disabled & elderly, increasing rate of diabetes & obesity, and ease of transportation in congested cities.

In addition, the recent surge in fuel and gas, the especially import-based economy of Pakistan, also demands an affordable and competent mode of travelling.

Figure 1. 1 Trend of Petrol price hike [1]

Air pollution caused by motor vehicles is a major environmental issue, responsible for 41% of global air pollution. With fuel reserves rapidly depleting and prices increasing, alternative transportation solutions are necessary.

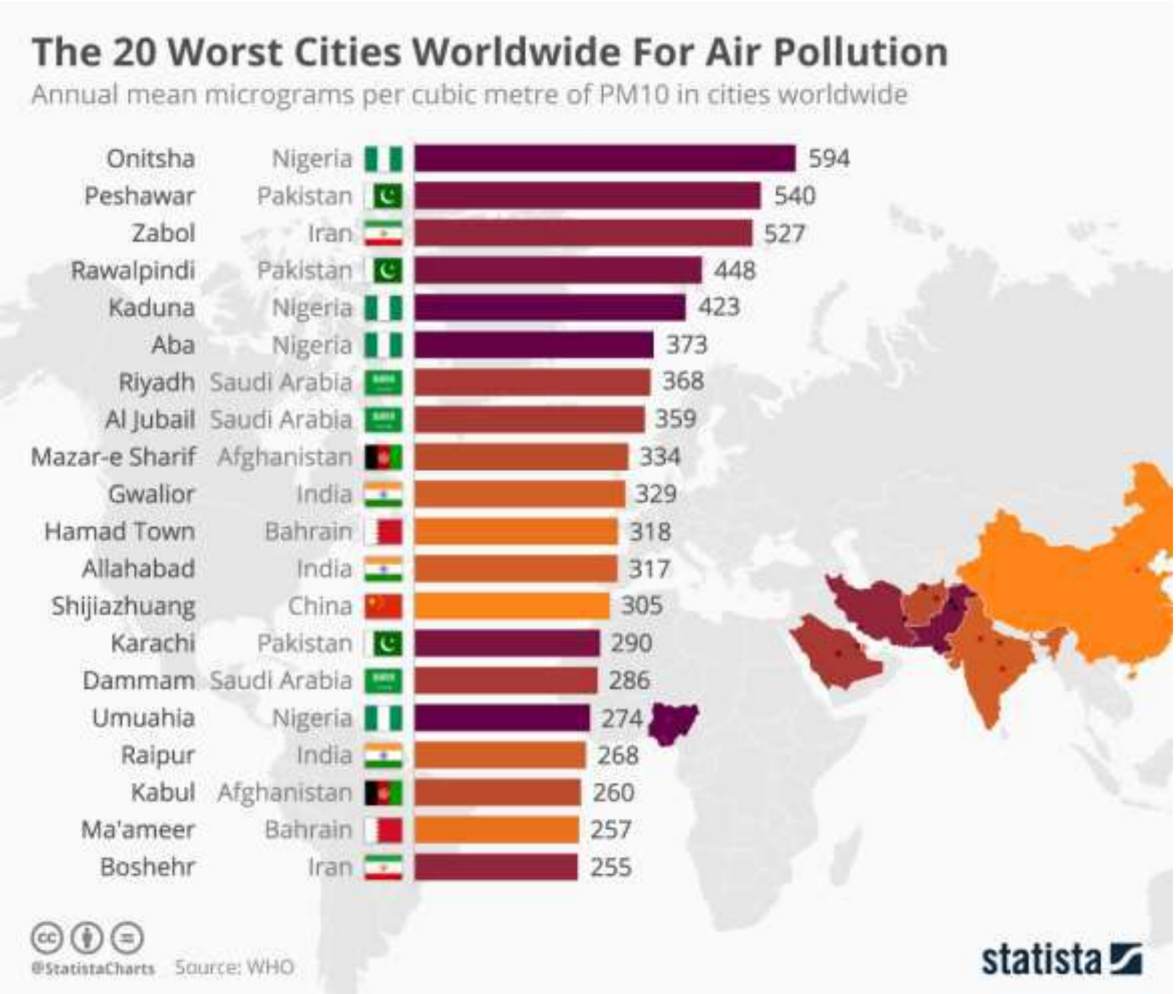


Figure 1. 2 Air Pollution Graph according to countries [2]

Our proposed solution is to design an eco-friendly and economical three resource chargeable bicycle including Electric Power, Solar Power, and Regenerative Power. The proposed e-bike demonstrates a sustainable electric system with the integration of multiple sensors for ensuring standard functionality. The end product would be a reliable, secure, and low-cost transportation solution with modern features. Moreover, it also contributes towards a more sustainable future, reduction in carbon footprint and will help to ensure a healthier planet for generations to come.

The project aims to develop a sustainable and eco-friendly mode of transportation that combine human power with renewable energy sources. The 3-way charging hybrid bicycle will be equipped with a solar panel, a regenerative braking system, and a plug-in charging system, providing multiple charging options to the user. The project will utilize the latest advancements in hybrid bicycle technology, solar energy, and energy storage systems to address the limitations of traditional bicycles, such as limited range, lack of power, and limited charging options. The project will focus on the design and development of the hybrid bicycle, as well as testing and evaluation of its performance. The proposed 3-way charging hybrid bicycle has the potential to provide a convenient and sustainable mode of transportation that can be used in urban and rural areas. The project aims to contribute to the ongoing research and development of hybrid bicycles and renewable energy systems and to provide a viable alternative to traditional modes of transportation.

1.2 Motivation

The transportation sector is a significant contributor to greenhouse gas emissions, which are a major contributor to global climate change. Therefore, the development of sustainable and eco-friendly modes of transportation has become a critical concern in recent years. Hybrid bicycles are one approach to address this issue, which combines human power with electrical energy to reduce carbon emissions and increase energy efficiency. The proposed project aims to develop a 3-way charging hybrid bicycle that uses solar energy, pedal assist charging, and plug-in charging to provide a sustainable and reliable mode of transportation. The current global energy crisis and concerns about the environment have led to a renewed focus on sustainable modes of transportation. Electric bicycles, or e-bikes, have become increasingly popular due to their convenience, affordability, and eco-friendliness. However, traditional e-bikes are limited by the capacity of their batteries and the range they can travel before needing to be recharged.

1.3 Background

To address these limitations, this project proposes a smart hybrid e-bicycle that incorporates three power sources: solar panels, pedaling power generation, and commercial power. The solar panels provide a renewable and clean energy source, while the pedaling power generation system allows riders to generate electricity while pedaling, thereby extending the e-bike's range. The commercial power source is intended to act as a backup power supply. The 3-way charging hybrid bicycle is designed to harness the power of renewable energy sources and provide a convenient and eco-friendly alternative to traditional bicycles and cars. The hybrid bicycle will be equipped with a lightweight frame, a battery-powered electric motor, and a solar panel that will allow it to be charged through solar energy. Additionally, the bicycle will be equipped with a regenerative braking system that captures energy from braking and stores it in the battery for later use. The bicycle can also be charged using a plug-in charging system, providing flexibility and convenience to the user.

1.4 Problem Statement

Traditional bicycles have limited range, lack of power, and are typically not equipped with multiple charging options. Additionally, reliance on fossil fuels for transportation has contributed to environmental degradation, air pollution, and climate change. As a result, there is a growing demand for sustainable and eco-friendly transportation options that combine human power with renewable energy sources. The problem statement for this project is to address the limitations of traditional bicycles and develop a sustainable mode of transportation that provides multiple charging options, is equipped with renewable energy sources, and can be used in urban and rural areas. The proposed solution is a 3-way charging hybrid bicycle that utilizes solar energy, regenerative braking, and plug-in charging systems to provide an eco-friendly, convenient, and reliable mode of transportation. The development of the 3-way charging hybrid bicycle will require a multidisciplinary approach that integrates the latest advancements in hybrid bicycle technology, solar energy, and energy storage systems. The project aims to address the challenges associated with traditional bicycles and provide a viable alternative that promotes sustainable transportation and reduces reliance on fossil fuels.

1.5 Project Objectives

- To design & develop a 3-channel charge controller to charge the battery through 3 different sources efficiently.
- To design and develop an Electronic Speed Controller (ESC) for high power DC motors.
- To integrate BMS to charge the battery efficiently.
- To manufacture a complete low-weight durable design of the e-bicycle with infotainment system to monitor bicycle state and parameters.

1.6 Project Benefits

The remainder of this report will provide an overview of the current state of knowledge on hybrid bicycle technology, solar energy, and energy storage systems, as well as the methodology and results of the proposed project. The report will also discuss the potential applications and benefits of the 3-way charging hybrid bicycle, as well as the future directions for research and development in this field. The goal of this project is to develop a sustainable and efficient mode of personal transportation that reduces carbon emissions and conserves energy while providing a practical and reliable means of transportation for daily use. By incorporating multiple power sources and a three-phase switch circuit, we aim to enhance the capabilities and appeal of e-bikes as a viable alternative to traditional transportation methods.

CHAPTER TWO

LITERATURE REVIEW

2.1 Electronic Speed Controller

An Electronic Speed Controller (ESC) is a device that controls the speed and direction of a motor by adjusting the voltage and current supplied to it. ESCs are commonly used in various applications, including drones, electric vehicles, and electric bicycles. In this literature review, we will discuss the different types of ESCs and their applications.

One type of ESC is the brushed DC motor controller, which is used to control the speed and direction of a brushed DC motor. The brushed DC motor controller consists of a microcontroller, a power MOSFET, and a feedback circuit. The microcontroller monitors the motor's speed and adjusts the voltage and current supplied to it through the power MOSFET to maintain a constant speed. [3]

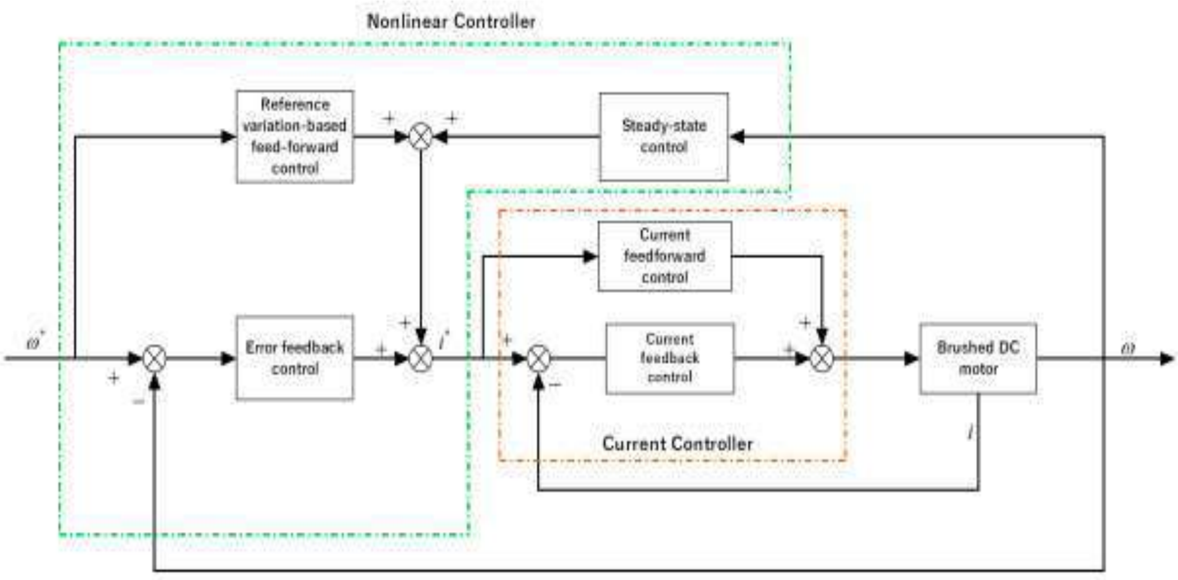


Figure 2. 1 The system control diagram [3]

Another type of ESC is the brushless DC motor controller, which is used to control the speed and direction of a brushless DC motor. The brushless DC motor controller consists of a microcontroller, a power MOSFET, and a three-phase bridge circuit. The microcontroller generates the driving signals for the three-phase bridge circuit to commutate the motor and adjust the voltage and current supplied to it to maintain a constant speed. [4]

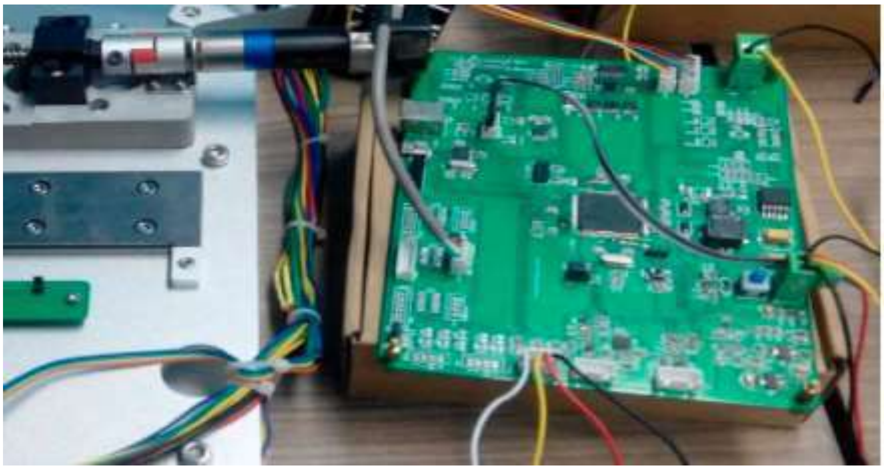


Figure 2. 2 The overall structure of the system [4]

ESC technology has also been applied to electric bicycles, where it is used to control the speed and power output of the motor. The ESC for electric bicycles usually features a closed-loop control system that monitors the speed and torque of the motor and adjusts the voltage and current supplied to it to maintain a constant speed and prevent overheating. [5]

In conclusion, electronic speed controllers are essential devices in various applications that require precise motor control. Brushed and brushless DC motor controllers are widely used in drones and electric vehicles, while ESCs for electric bicycles typically feature closed-loop control systems. As technology advances, ESCs are expected to become more efficient and compact, enabling even more applications in the future.

In our project, we have designed ESC for selected PMDC brushed gear motor according to our requirement and application.

2.2 Three Channel Circuit

This literature review aims to provide an overview of the current state of knowledge on hybrid bicycle technology, solar energy, and energy storage systems, which are the key components of the proposed 3-way charging hybrid bicycle. The development of hybrid bicycles, which combine human pedaling power with an electric motor, has led to research into innovative charging circuits that can harness multiple sources of energy. One such circuit is the three-way charging circuit that uses solar power, regeneration through the bicycle's wheel, and plug-in charging to charge the bicycle's battery.

Multi-channel charge control circuits are widely used in battery charging applications that require charging from multiple power sources, such as solar panels, USB ports, and AC adapters. These circuits are designed to manage the charging process, ensuring the battery is charged safely and efficiently from multiple sources. This literature review aims to provide an overview of the current state-of-the-art in multi-channel charge control circuits.

A multi-channel charge control circuit typically consists of a microcontroller or a dedicated charge controller IC that manages the charging process. The circuit can detect the presence of different power sources and select the appropriate source for charging the battery. In addition, it can monitor the charging process, adjust the charging parameters based on the battery's condition, and provide protection against overcharging, overvoltage, and overcurrent.

In recent years, various multi-channel charge input circuits have been proposed and developed. One such example is a three-channel battery charger for electric vehicles, which combines a wireless power transfer system with a DC power input and a photovoltaic input[4].The circuit uses a microcontroller to optimize the charging process, ensuring that the battery is charged in the most efficient and safe manner. Another example is a multi-input battery charger for portable devices, which combines a USB input, a solar panel input, and a DC jack input [5]. The circuit uses a power management IC to manage the charging process, and a microcontroller to optimize the charging rate based on the available power sources.

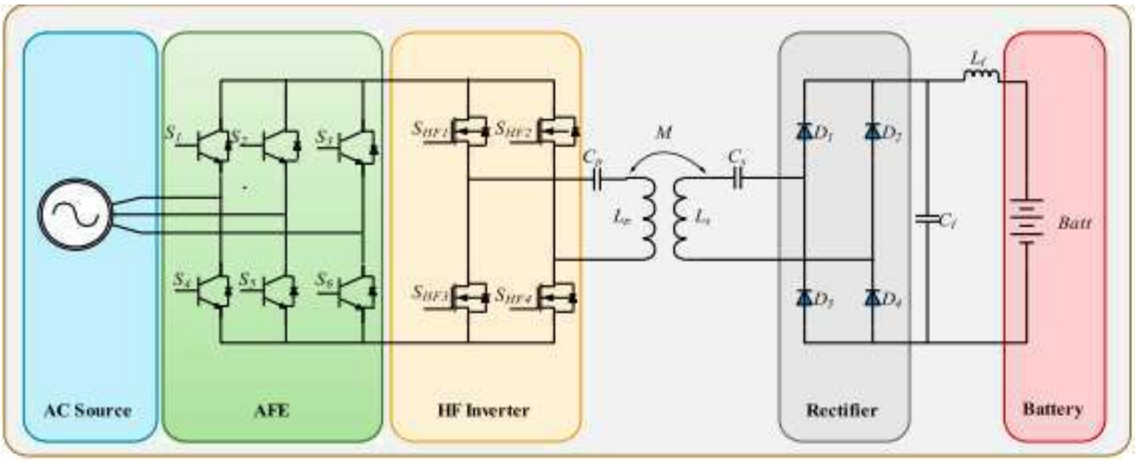


Figure 2. 3 Structure of the inductive power transfer system [7]

Despite the recent advancements, there are still some challenges in the development of multi-channel charge input circuits. One challenge is the integration of different power sources into a single circuit, which requires complex power management and control algorithms. Another challenge is the need for high efficiency and reliability, as the charging rate can be affected by various factors such as temperature, humidity, and input voltage fluctuations. Finally, the safety and protection of the battery is also a critical concern, as the battery can be damaged or even catch fire if not charged properly.

2.3 Regenerative Resources For Electric Vehicles

Electric vehicles (EVs) and electric bicycles (e-bikes) are becoming increasingly popular as a means of transportation. One of the challenges of these vehicles is their limited range, which is mainly due to the limited energy storage capacity of their batteries. To extend the range of EVs and e-bikes, regenerative braking systems have been developed to recover some of the kinetic energy lost during braking.

Regenerative braking is achieved by using an electric motor as a generator during braking. When the vehicle's brakes are applied, the electric motor is used to slow down the vehicle and at the same time, it generates electrical energy, which is then stored in the battery. The energy recovered through regenerative braking can increase the range of EVs and e-bikes by up to 30% [8].

In addition to regenerative braking, there are other potential sources of regenerative charging for EVs and e-bikes. For example, solar panels can be integrated into the design of the vehicles to provide additional charging when parked or during use. Some studies have found that solar panels can provide up to 30% of the energy needed to power an e-bike [9].

Another potential source of regenerative charging is the use of wireless charging technology. Wireless charging allows for the transfer of electrical energy between two coils without the need for physical contact. Studies have found that wireless charging can provide up to 90% efficiency, making it a promising solution for regenerative charging [10].

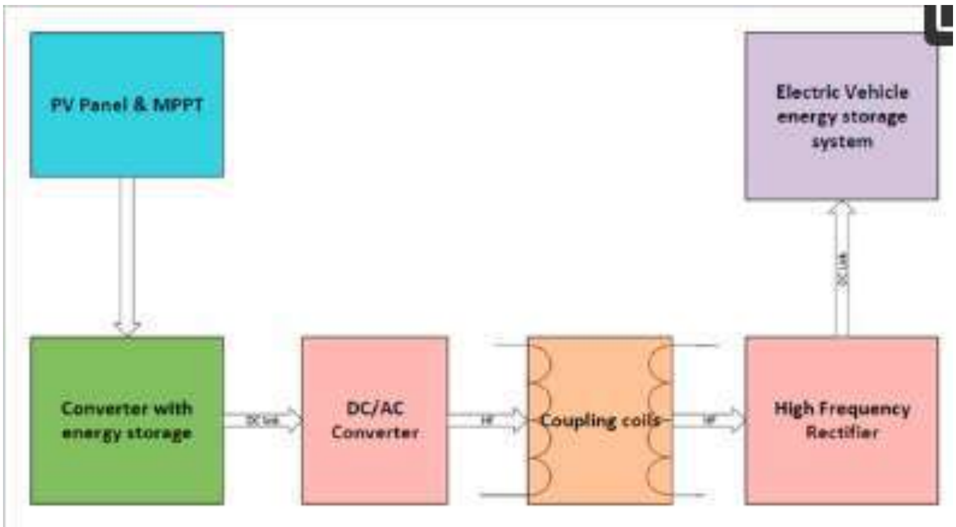


Figure 2. 4 Overview of wireless charging powered by a solar panel [10]

Overall, regenerative charging is a promising technology for increasing the range and reducing the charging time of EVs and e-bikes. While regenerative braking is currently the most common form of regenerative charging, other technologies such as solar panels and wireless charging show potential for future development.

2.4 Renewable Resources to Charge Battery

The increasing demand for electric vehicles (EVs) and electric bicycles (e-bikes) has created a need for alternative charging sources to reduce dependence on the conventional power grid. Solar energy has been identified as a promising source of renewable energy for charging EVs and e-bikes. This literature review aims to explore the current state of research on the use of solar energy as a charging resource for E-bikes.The use of solar energy for charging e-bikes has gained popularity due to the convenience and portability of e-bikes. Solar charging stations can be set up in public areas such as parks, enabling e-bike riders to charge their bikes while enjoying the outdoors. Studies have shown that solar charging for e-bikes is a viable and sustainable solution, reducing carbon emissions and promoting a more active lifestyle [9]. However, the limited capacity of PV cells and the high cost of solar panels are barriers to widespread adoption of solar charging for e-bikes.

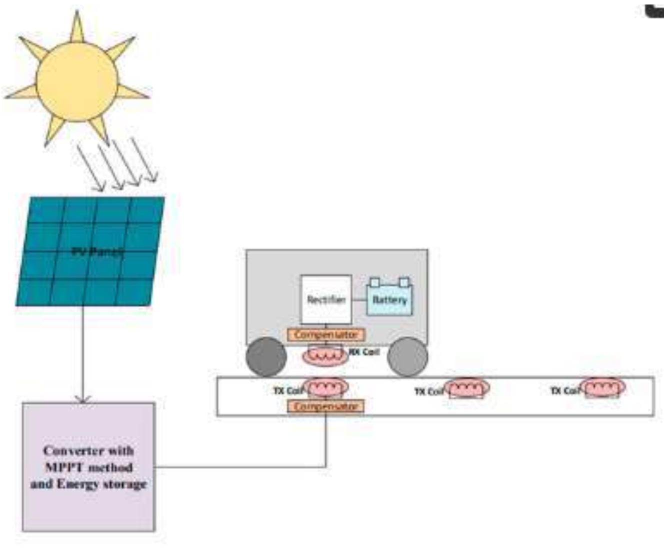


Figure 2. 5 Basic diagram of dynamic wireless electric vehicle charging system. [11]

2.5 Hybrid Electric Bicycles – HEBs

A published paper "Conversation of Traditional Bicycle to E-Bicycle" study that supports the use of e-bikes as a sustainable transportation option based on the travel behavior of e-bikers. E-bikers tend to travel longer distances than traditional cyclists and the cycling infrastructure should be expanded to accommodate this demand. The project was based on the following block diagram.

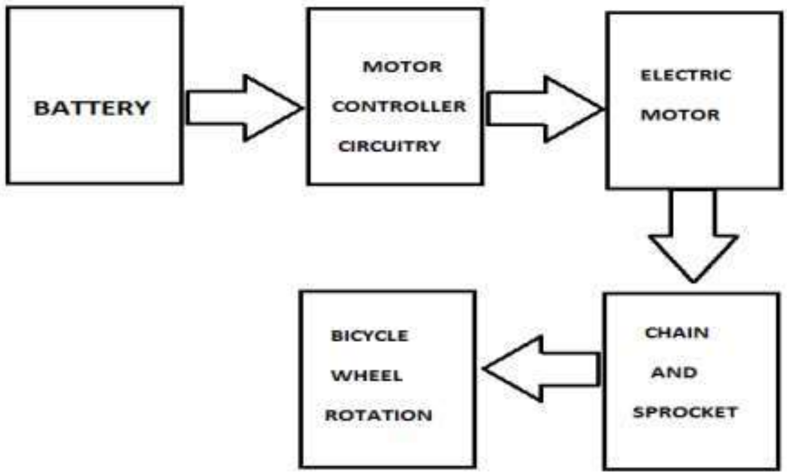


Figure 2. 6 Block diagram for "conversation of bicycle to E bicycle" [12]

Its strengths were, Simple interfacing, convenient and the limitations were, No renewable resource, No self-charging feature, No infotainment system. [12]

Another study of a published literature, "Energy Efficient Hybrid Electric Bike with Multi - Transmission System" summarizes, The article describes the benefits of a hybrid bike that can be powered by both gasoline and electricity, making it more efficient and cost-effective than traditional bikes. It is also eco-friendly, causing less pollution, and a good solution for hiking fuel costs.

Block diagram and technical specifications are shown below:

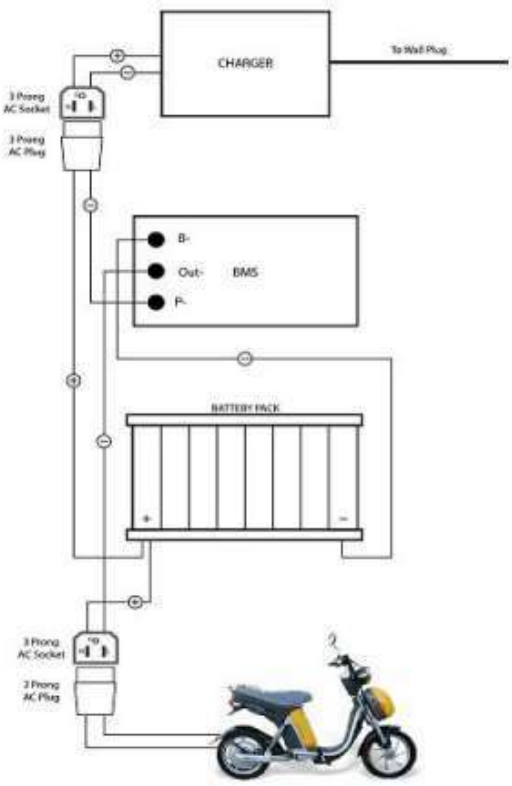


Figure 2. 7 : technical specifications [12]

Table 2. 1 Technical Specification [12]

Technical Specifications of HYBRID BIKE	
Engine Displacement	59.90 cc
Engine Type	Single cylinder, 2- stroke, forced air cooled.
Engine Starting	Electric/ Kick start
Maximum Power	3.5 bhp @ 5500 rpm
Maximum Torque	4.5 Nm @ 5000 rpm
Top Speed	60 kmph
BLDC Motor	800W
Battery Type	VRLA Deep Discharge
Battery Spec.	12V,20Ah(4 nos)
Rear Brake	Drum brakes 130 mm dia
Front Suspension	Telescopic Suspensions at front
Rear Suspension	Helical spring and Hydraulic damper
Front Tyre	2.75 X 10
Rear Tyre	2.75 X 10
Wheelbase	120 mm
Width	1,220 mm
Height	1,060 mm
Length	1,685 mm
Weight	7,9.5 kg
Petrol Tank Capacity	3.5 litres

The limitations were Carbon emission, Complexity and not reliable. And the strengths are Dual power transmission Fuel, economy, good power output. [13].

The outcomes of this project are shown below:

Table 2. 2 BLDC Motor [13]

TECHNICAL DETAILS	
Motor (BLDC HUB Motor)	800 W
Battery Type	VRLA Deep Discharge
Battery (VRLA Deep Discharge)	20 Ah
Electricity Consumption	3.2 Units/Charge
Charging Time	6 to 8 Hrs

Another literature review of paper "Embedded Based SMART Bicycle" summarizes,

Table 2. 3 Motor [13]

Engine Displacement	59.90cc
Engine Type	Single Cylinder, 2 stroke
Cooling type	Forced air cooled
Starting	Kick start
Mileage	45kmpl
Max power	3.5 bhp@5500rpm
Max torque	4.5 Nm@5000 rpm
Top speed	60 kmph

The study highlights that e-bikes can encourage physical activity among individuals who typically undertake less exercise or are unable to use a traditional bike due to personal physical limitations or geographical location. The availability of e-bikes can significantly influence travel behavior and stimulate interest in sport, leading to increased participation in physical activity.

The limitations are low-capacity Battery. The project was based on following block diagram:

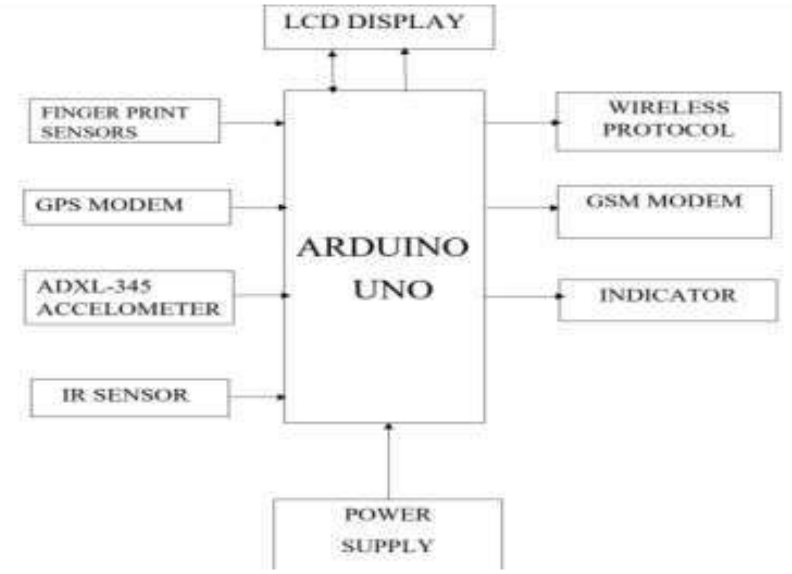


Figure 2. 8 : Block diagram for SMART bicycle [13]

And the design methodology is shown below:

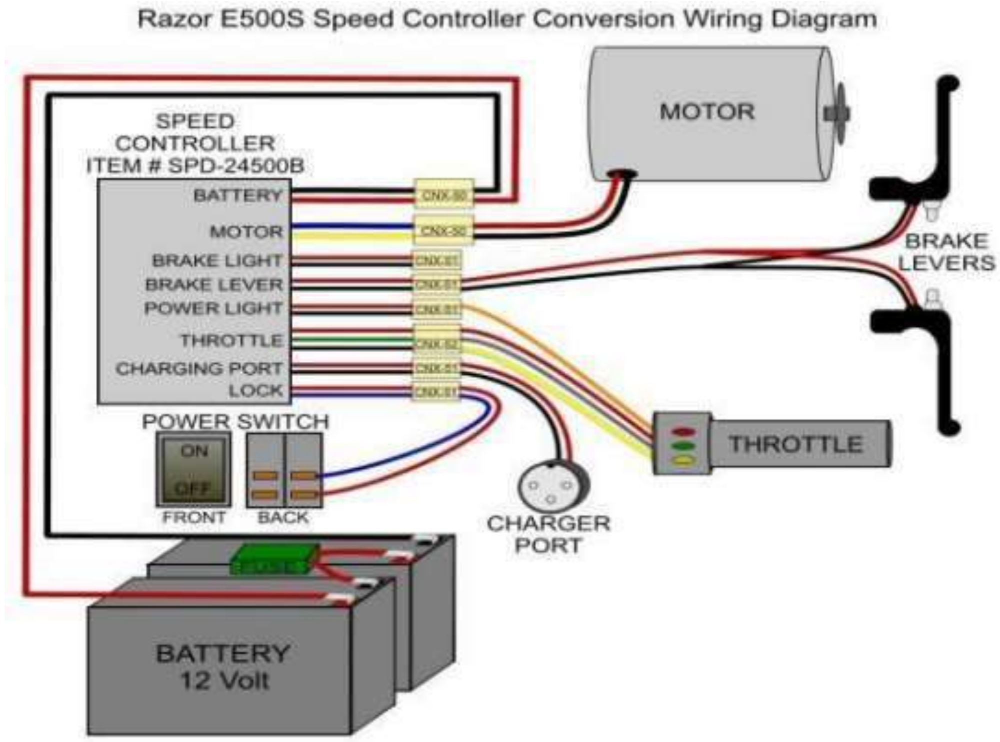


Figure 2. 9 Design methodology [14]

framework/structure is not provided, no load management, Simple and inconvenient design of Esc No regenerative power source. [14]

One more literature review "DESIGN A SMART E-BICYCLE WITH THREE WAY CHARGING MECHANISUM" summarizes to, The self-charging electric bicycle is a modification of the existing electric bike, suitable for short-distance travel on city or country roads. The bike can

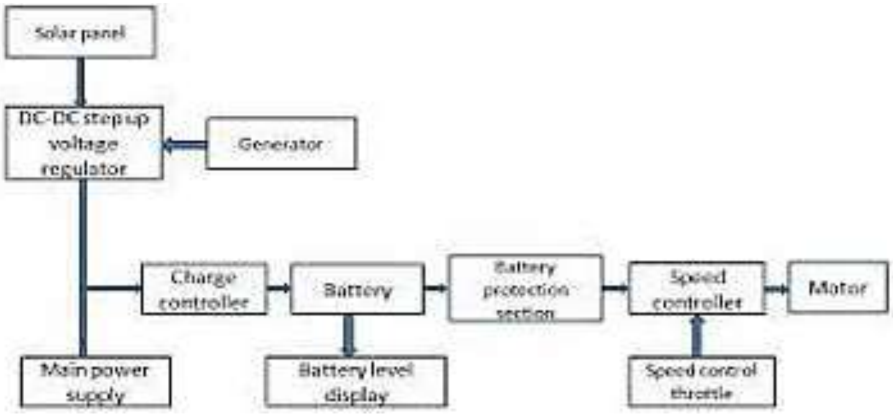


Figure 2. 10 Block diagram for E bicycle with 3-way charging [14]

be charged with an AC adapter and manually pedaled in case of any issues. It's also more economical compared to a normal vehicle, as charging costs are lower. The block diagram is shown below:

The limitations are, No battery management system, no mppt for charging efficiency, smaller batteries. [15]

The last literature review of paper "Overview of the Ways to Design an Electric Bicycle", this summarizes to, this paper presents a classification of approaches to designing an electric bicycle, grouped into three categories: system level domain design, electrical engineering domain design, mechanical engineering domain design. The main issues and solutions are presented. The project design was based on the following methodology. [16]

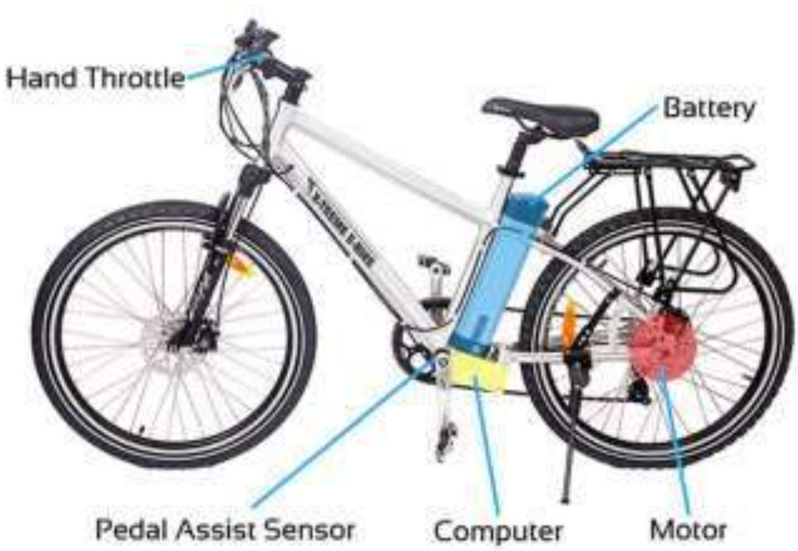


Figure 2. 11 Project Design [16]

2.6 Battery

The most common energy storage systems used in hybrid bicycles are lithium-ion batteries, which are lightweight, efficient, and have a long lifespan. A detailed comparison chart between different types of batteries is given below:

Table 2. 4 Battery Specifications

TYPE	ENERGY DENSITY (Wh/Kg)	ENERGY EFFICIENCY (%)	POWER DENSITY (W/Kg)	CYCLE LIFE	SELF DISCHARGE (MONTH)
Li-Ion	100-250	75-90	1800	500-2000	5-10
Ni-Cd	40-60	60-90	140-180	500-2000	10-15
Ni-MH	30-80	70	250-1000	500-100	30
Lead Acid	30-40	70-90	180	200-2000	3-4

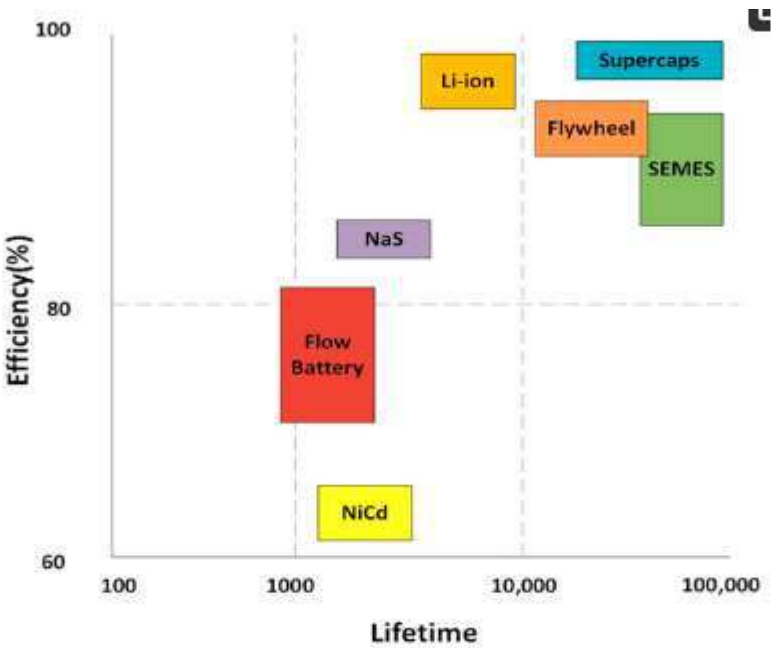


Figure 2. 12 Types of batteries according to operating time and efficiency [17]

2.7 Speed Measurement

The Paper titled "Design and Implementation of an Electric Bicycle with Speed Control and Battery Monitoring System" aims to enhance the safety, efficiency, and user experience of electric bicycles while optimizing battery usage. The study introduces an innovative speed control mechanism that incorporates advanced sensor technology and a microcontroller-based control system. By continuously monitoring the bicycle's speed in real-time and adjusting the power delivered to the motor accordingly, the system ensures a consistent and safe speed, thereby improving rider safety and control. The effectiveness of this novel mechanism is demonstrated through empirical experiments and comparative analyses. Furthermore, the paper discusses the integration of a battery monitoring system that employs sensors and algorithms to track important battery parameters, enabling users to make informed decisions about charging and maintenance. This optimization of battery usage contributes to its longevity and improves the overall efficiency of the electric bicycle. The findings of this research provide valuable insights for the development of advanced electric bicycles, promoting sustainable and efficient transportation options.[17]

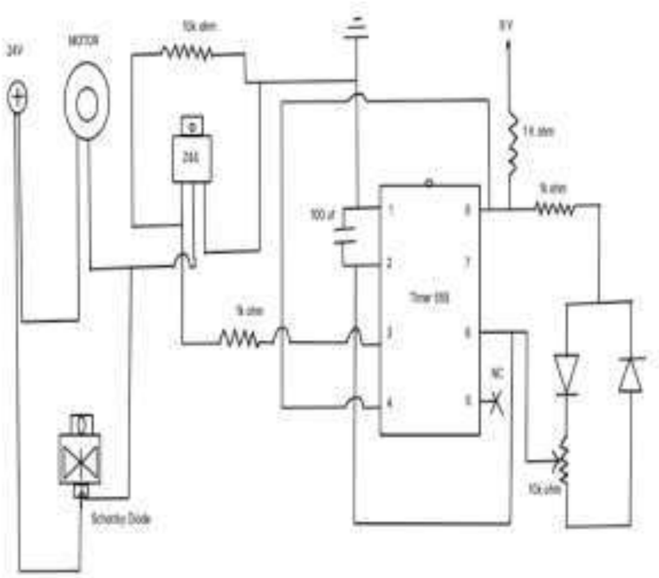


Figure 2. 13 Speed controlling circuit [17]

Table 2. 5 Voltage Vs Speed [17]

Voltage (V)	Speed (rpm)
3.7	40
7.4	92
11.1	145
14.8	200
18.5	245
22.2	301

Another paper titled "Design of Bicycle's Speed Measurement System Using Hall Effect Sensor" offers a comprehensive exploration of a novel system developed for real-time speed measurement of bicycles. The primary objective of this study is to create a dependable and precise system capable of capturing the speed of bicycles, thus enabling applications like fitness tracking, performance analysis, and safety enhancement.[18] The system leverages the utility of a Hall Effect sensor, renowned for its proficiency in detecting magnetic fields. By strategically situating the sensor in proximity to the bicycle's wheel, it can detect the passage of magnets attached to the wheel spokes. This interaction between the sensor and the magnets facilitates the computation of the bicycle's speed.

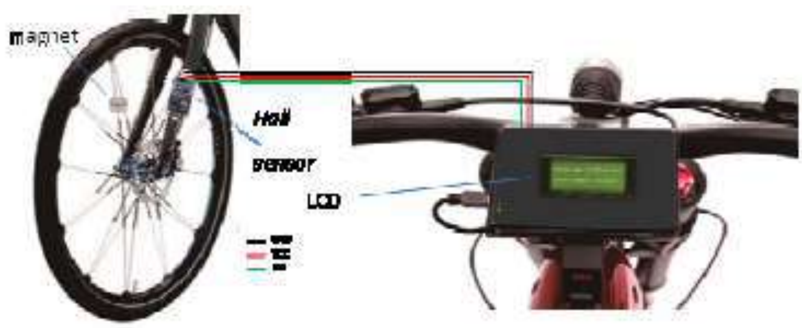


Figure 2. 14 System Design [18]

The research methodology encompasses an extensive analysis of the Hall Effect sensor and its characteristics, ensuring its suitability for measuring speed within the bicycle context. The integration of the sensor into the bicycle's framework is accompanied by the development of requisite circuitry to process the sensor's output signals. Calibration procedures are implemented to establish an accurate correlation between the sensor's readings and the actual speed of the bicycle.[18]

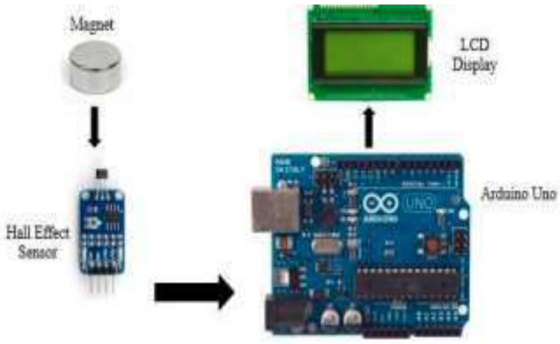


Figure 2. 15 Hardware Design [18]

Table 2. 6 Testing Results of Hall Effect Sensor [18]

No.	Magnetic Distance to Sensor (cm)	Voltage (mV)
1	0	881
2	1	578
3	2	504
4	3	496
5	4	494
6	≥5 (without magnet)	492

Table 2. 7 Detection Time of Hall Effect Sensor [18]

No.	Time (s)	Number of Rotation	Detection Time / rotation (ms)
1	10	92	107-110
2	30	284	101-109
3	60	542	108-111

2.8 Smart Monitoring System

The research paper titled "Smart Bike Monitoring System for Cyclist via Internet of Things (IoT)" provides a comprehensive overview of an innovative monitoring system that integrates IoT technologies to enhance the cycling experience. The primary objective of this study is to develop a smart system that enables real-time monitoring and data analysis for cyclists, leading to improved performance tracking, safety measures, and overall cycling experience.[19]

The proposed monitoring system utilizes IoT technologies to establish connectivity between sensors placed on the bicycle and the cyclist's smartphone or a central server. These sensors collect and transmit a wide range of data, including speed, distance traveled, heart rate, GPS location, and environmental conditions.

The research methodology involves careful selection and integration of appropriate sensors, development of communication protocols, and design of a user-friendly interface for data visualization and analysis. Additionally, data processing algorithms are implemented to extract valuable insights from the collected data, such as performance metrics, health indicators, and personalized recommendations for training and safety.

The effectiveness of the monitoring system is evaluated through rigorous experiments, demonstrating its ability to provide real-time data to cyclists. By utilizing IoT connectivity, cyclists can access and analyze their performance data conveniently on their smartphones or through a web-based platform. This empowers them to make informed decisions, set goals, and optimize their training routines. The system also incorporates automatic emergency notifications to designated contacts in the case of accidents or unusual events. [19]

Another study of paper titled "Informatics and Infotainment System for Smart E-Bike Using Raspberry Pi" provides an overview of an advanced system designed to enhance the functionality and user experience of electric bicycles (E-bikes). The proposed system utilizes the Raspberry Pi, a versatile single-board computer, as the central component for processing and managing informatics and infotainment functionalities. Various sensors, including GPS, accelerometer, and environmental sensors, are integrated into the system to gather real-time data on factors such as location, speed, and environmental conditions.

The research methodology involves the integration of hardware components, development of software applications, and user interface design. The informatics aspect focuses on providing riders with essential information, such as speed, distance traveled, battery status, and navigation assistance. On the other hand, the infotainment aspect offers entertainment features such as music playback, voice commands, and connectivity with smartphones or other devices.

Figure 2. 16 Raspberry pi connections with sensors [17]

The results demonstrate that the informatics and infotainment system successfully enhances the overall E-bike riding experience by providing riders with valuable information and entertainment options. The informatics features enable riders to stay informed about their ride progress, battery status, and navigation, while the infotainment features offer entertainment and connectivity options, improving safety, convenience, and enjoyment. [20]

Figure 2. 17 Ride metrics dashboard[19]

2.9 Brake Detection in bikes or bicycle

The research paper titled "Brake Detection for Electric Bicycles using Inertial Measurement Units" offers an in-depth overview of a brake detection system specifically designed for electric bicycles. The study focuses on utilizing Inertial Measurement Units (IMUs) comprising accelerometers and gyroscopes to capture and analyze the bicycle's motion and orientation. By monitoring changes in acceleration and angular velocity, the system accurately identifies the unique patterns associated with braking.[21]

The methodology involves integrating IMUs onto the electric bicycle and developing dedicated algorithms to process the sensor data. These algorithms are designed to detect the specific braking patterns observed during deceleration and convert them into reliable brake detection signals.

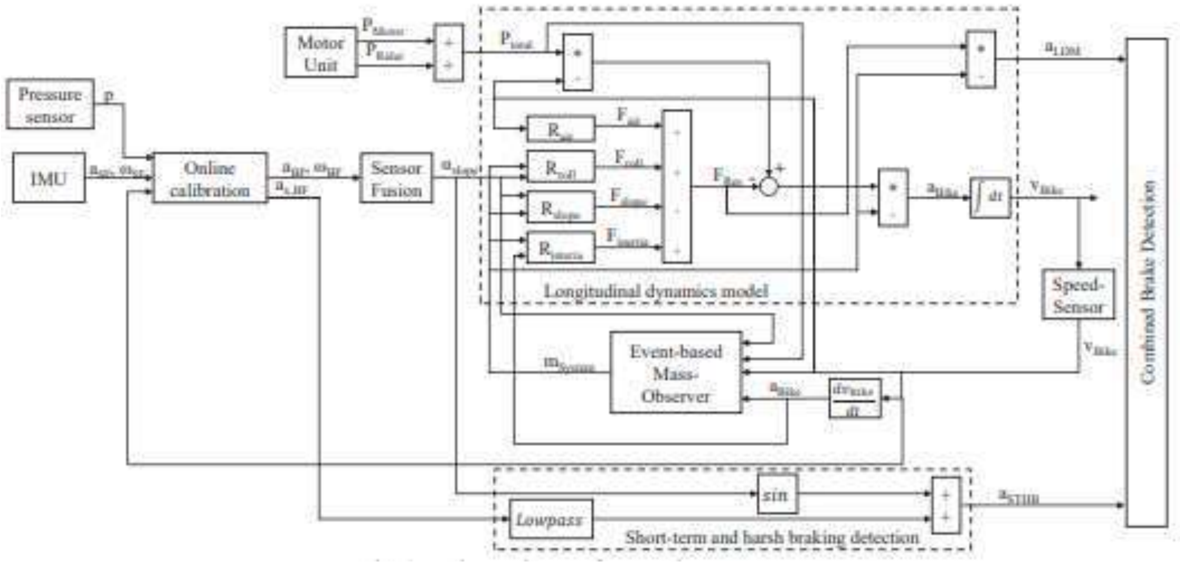


Figure 2. 18 Flow chart of complete system.[21]

The system is tested under various real-world scenarios, including different speeds, terrains, and braking intensities, to assess its accuracy and reliability. The results are compared with ground truth measurements to ensure the system effectively identifies braking events.

The experimental findings demonstrate the system's high levels of accuracy and reliability in brake detection using IMUs. It successfully detects braking events in real-time, enabling timely response and control of the electric bicycle. The system proves robust against external factors like vibrations and terrain variations, ensuring its practicality in real-world situations.[21]

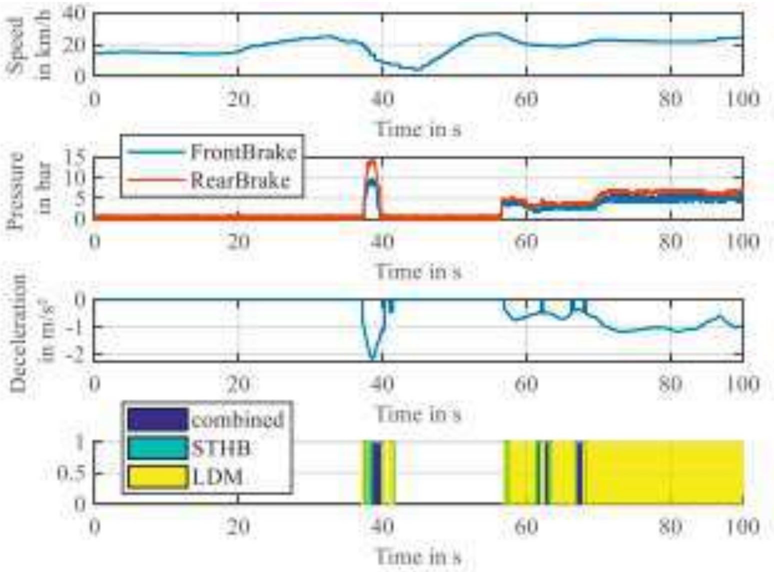


Figure 2. 19 Brake detection and brake intensity estimation[21]

Another paper titled "An Anti-lock Braking System for Bicycles" presents a comprehensive overview of a novel braking system designed specifically for bicycles. The ABS utilizes advanced sensing technologies and control algorithms to prevent the wheels from locking up during braking, thereby improving stability and reducing the risk of accidents. The system incorporates sensors that measure wheel speed, acceleration, and other relevant parameters to continuously monitor the braking process. The methodology involves the design and implementation of the ABS hardware and software components. The hardware consists of sensors, actuators, and a control unit, while the software includes algorithms for real-time data processing and brake modulation. Extensive testing and optimization are conducted to ensure the system's effectiveness and reliability.

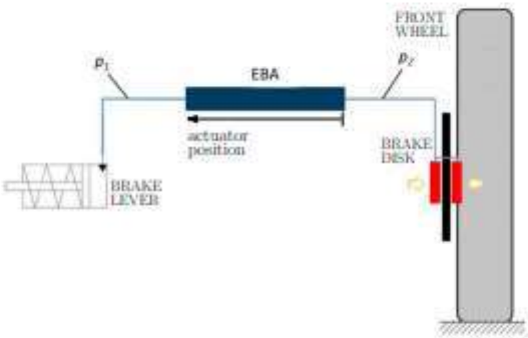


Figure 2. 20 A schematic representation of the ABS system [21]

Figure 2. 21 Bicycle equipped with the ABS system [21]

The results demonstrate that the developed anti-lock braking system significantly improves the braking performance of bicycles. It effectively prevents wheel lock-up, allowing riders to maintain better control and stability even under challenging braking conditions such as wet or uneven surfaces.[20]

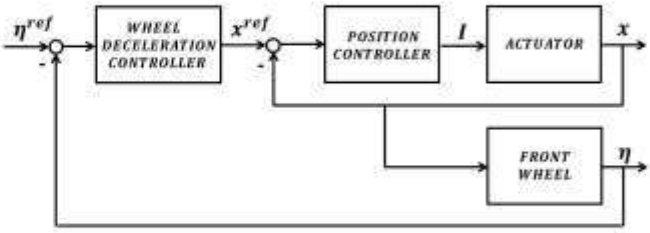


Figure 2. 22 ABS block scheme [22]

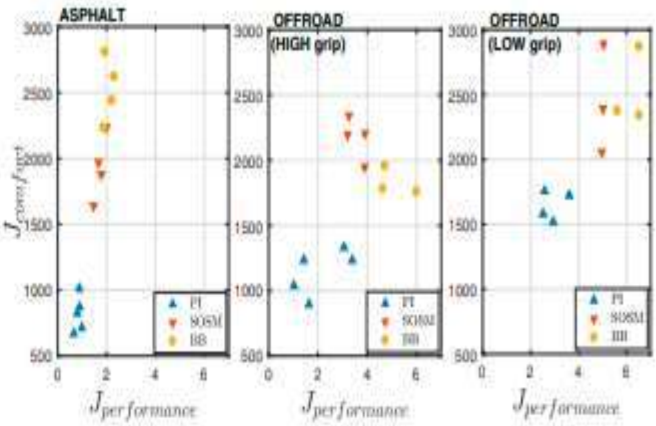


Figure 2. 23 Wheel deceleration control: cost functions [22]

2.10 Battery Information System

The paper titled "Real-time Battery Capacity Estimation Based on Opportunistic Measurements" provides an overview of a study focused on developing a real-time battery capacity estimation technique. The objective of this research is to design an accurate and efficient method for estimating the remaining capacity of batteries during operation. [21]. The technique utilizes opportunistic measurements, such as voltage and current readings, obtained during the regular operation of the battery system. By analyzing these measurements and employing advanced algorithms, the system can estimate the remaining battery capacity in real-time.

The research methodology involves collecting data from various battery systems and developing mathematical models and algorithms for capacity estimation. These models take into account battery chemistry, temperature, and discharge characteristics to ensure accurate estimations.[23]

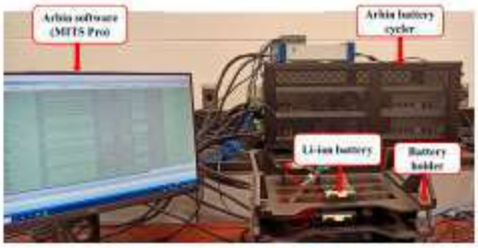


Figure 2. 24 Experimental setup for battery testing [23]

Extensive testing and validation are conducted to evaluate the performance of the battery capacity estimation technique. The method is compared with traditional methods and validated using different battery chemistries and operating conditions to demonstrate its accuracy and versatility.

The experimental results demonstrate that the developed real-time battery capacity estimation technique achieves high levels of accuracy and efficiency. It provides reliable estimations of the remaining battery capacity during operation, enabling users to make informed decisions regarding energy management and optimize battery utilization.[23]

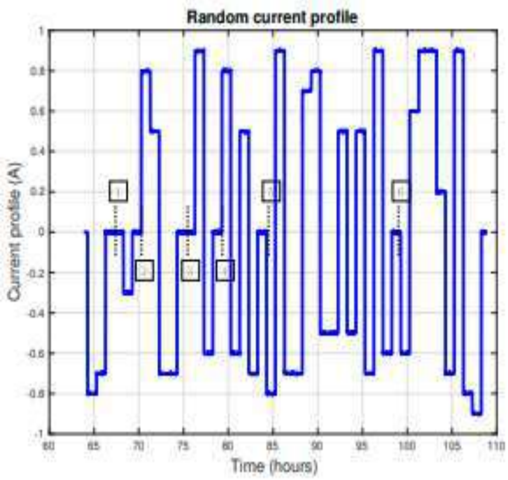


Figure 2. 25 C1212 Current profile [23]

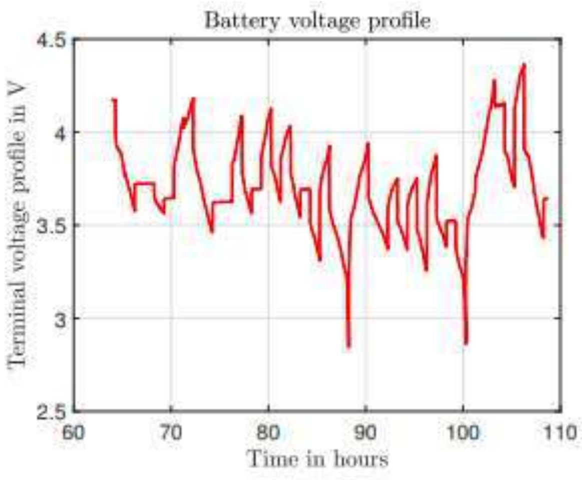


Figure 2. 26 C1212 voltage profile [23]

Another study of paper titled "A Battery Capacity Estimation Method Using Surface Temperature Change under Constant Current Charge Scenario" provides a comprehensive overview of a study focused on developing a practical and accurate method for estimating battery capacity. By monitoring temperature variations and utilizing advanced algorithms, the proposed method estimates the remaining capacity of the battery. The research methodology involves conducting controlled experiments with different battery chemistries and charge scenarios to collect data on surface temperature change. Mathematical models and algorithms are then developed to establish the relationship between temperature change and battery capacity.

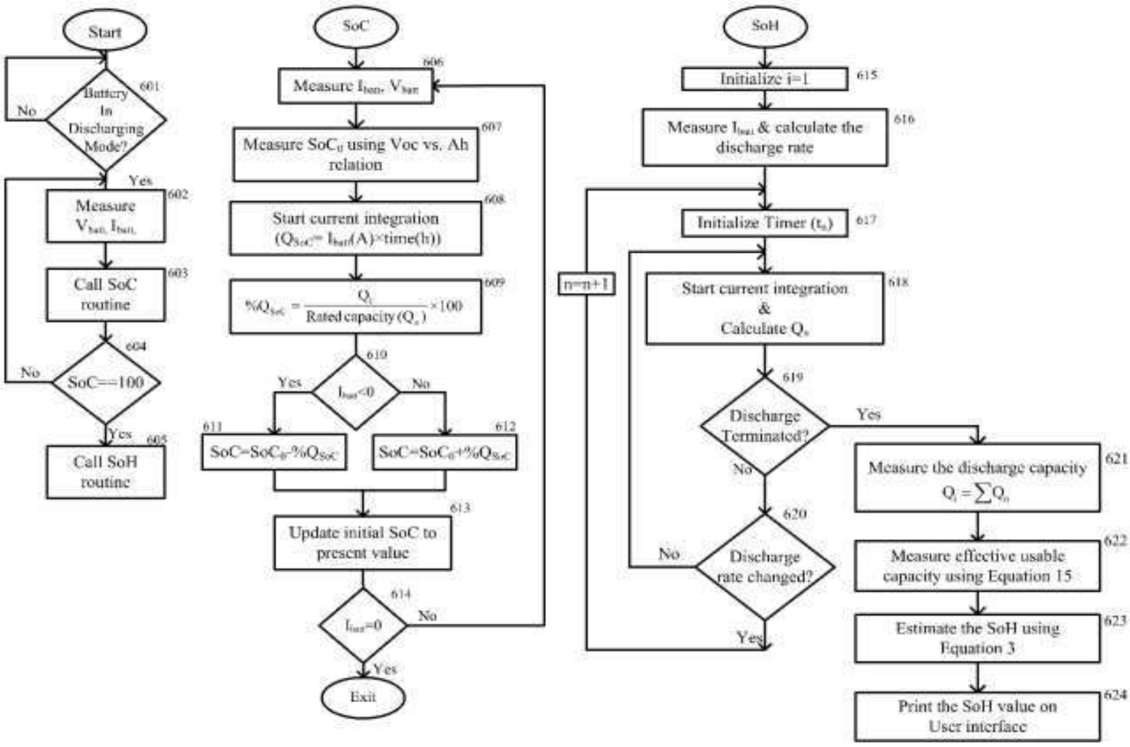


Figure 2. 27 Flow chart of the Li-Ion battery SoH estimation technique [23]

Extensive testing and validation are carried out to evaluate the performance of the battery capacity estimation method. Comparisons with traditional estimation techniques and validation across various charging scenarios demonstrate the accuracy and effectiveness of the proposed method. The experimental results showcase that the developed battery capacity estimation method, which utilizes surface temperature change during constant current charging, provides accurate estimations. It offers valuable insights into the remaining battery capacity, enabling users to assess battery health and make informed decisions regarding charging and usage.

CHAPTER THREE

DESIGN METHODOLOGY

3.1 Design Concept & Implementation

To begin, we will start with the Research & Selection of techniques essential for design of electronic circuitry. Our Project is divided into two main steps:

- To design and develop 3-channel charge control circuitry to insure efficient charging of battery with Electric supply, Solar charging & Pedal assist charging.
- Design & Development of Electronic Speed Controller – ESC.

Our First step will be to research & development of ESC, & to integrate ESC with bicycle and motor to ensure proper functioning of the base model.

Initially, the designed circuitry will be simulated with different configurations and design techniques, after detailed circuit analysis, better simulated approach will be implemented for the development of Electronic Speed Controller. Multiple parameters monitoring will be done including Current level and Brake detection to ensure safety of motor and ESC.

After the development of Electronic Speed Controller, simulated techniques for 3- channel hybrid charging circuit will be implemented and detailed hardware circuit analysis will be performed to ensure maximum output efficiency in order to efficiently charge the battery. Further the charge controller will be connected with an infotainment screen to display multiple parameters of the bicycle including battery details and speed.

At last, final product will be tested and improvised as per the standards to ensure the successful completion of the project objectives.

The design concept of the 3-way charging hybrid bicycle involves the seamless integration of human pedaling, solar energy, and grid electricity to create a sustainable, eco-friendly, and affordable mode of transportation. This innovative bicycle design incorporates multiple energy sources to enhance versatility, reliability, and overall performance.

The hybrid bicycle retains the traditional pedal-powered mechanism, allowing riders to utilize their own physical energy for propulsion. This not only promotes physical activity and personal well-being but also serves as a backup power source when other energy reserves are depleted or unavailable.

In addition to human power, the hybrid bicycle incorporates solar energy as a renewable energy source. Strategically positioned solar panels are integrated into the bicycle's frame or auxiliary components, enabling the capture of sunlight and its conversion into electrical energy. Advanced technologies such as Maximum Power Point Tracking (MPPT) are utilized to optimize energy conversion, maximizing the efficiency of solar charging. The harvested solar energy is stored in a rechargeable battery pack.

The hybrid bicycle allows for charging from the conventional grid electricity supply, providing flexibility and convenience. The power control unit of the bicycle facilitates seamless switching between energy sources, automatically managing the charging process and ensuring optimal energy utilization. This feature is particularly useful in situations where the other energy sources are insufficient or unavailable, allowing riders to rely on grid electricity to power the bicycle.

Furthermore, the hybrid bicycle allows for charging from the conventional grid electricity supply, providing flexibility and convenience. The power control unit of the bicycle facilitates seamless switching between energy sources, automatically managing the charging process and ensuring optimal energy utilization. This feature is particularly useful in situations where the other energy sources are insufficient or unavailable, allowing riders to rely on grid electricity to power the bicycle.

In order to achieve the goal of making a Sustainable Smart-Low-Cost Reliable Hybrid E Bicycle different structural approaches have been made. Different designs are suggested in which one with more Sustainable is chosen. Firstly, we proposed a 3D model to implement our design.

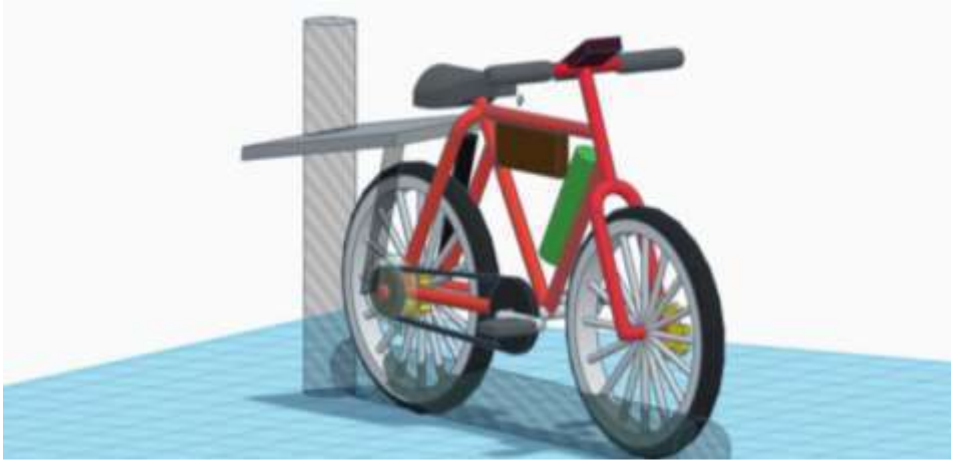


Figure 3. 1 3D model of E-Bike.

This particular design focuses on achieving a remarkable level of stability and an equal distribution of balance when it comes to road grip. To achieve this, a carefully engineered configuration has been put in place. Let's delve into the intricate details.

Starting with the power source, a 24-volt, 20-Ampere hour battery has been seamlessly integrated into the structure of the bicycle. This battery is strategically attached to the down tube, ensuring optimal weight distribution and overall stability. Moving along, the circuitry is securely fastened to the top tube, providing a centralized location for all electrical components and facilitating efficient connectivity.

Now, let's explore the implementation of renewable energy. A 20-watt solar panel has been ingeniously affixed to the seat stay. Through the use of a sturdy stand and nuts, this solar panel is positioned to harness sunlight and convert it into usable electrical energy. By tapping into this sustainable power source, the bicycle becomes more environmentally friendly and reduces reliance on conventional charging methods.

The next crucial element is the regenerative gear motor, situated on the down tube. This motor is specifically designed to work in conjunction with the front derailleur, utilizing a chain mechanism. Operating at an impressive 48 volts and 330 revolutions per minute (rpm), this regenerative gear motor serves the purpose of generating energy as the bicycle moves forward. This innovative feature ensures that the bicycle becomes partially self-sustaining, enabling the recovery and storage of energy during rides.

In addition to the regenerative gear motor, another motor with a power output of 250 watts is incorporated into the design. This motor is cleverly attached to the chain stays using a robust bracket and nut assembly. The motor is then seamlessly integrated into the system by connecting it to the derailleur hanger via a chain mechanism. This setup further enhances the overall power and performance of the bicycle, providing an extra boost when needed and making uphill climbs or challenging terrains more manageable.

To provide the rider with crucial information, an OLED display is thoughtfully positioned on the stem of the cycle. This display serves as a user-friendly interface, offering real-time data such as the cycle's speed, battery performance, and remaining charge percentage. With this information readily available, riders can easily monitor their cycling experience and make informed decisions during their journeys.

Lastly, the design incorporates a shifter mechanism that grants riders control over the gear motor's activation. This feature allows users to switch the gear motor on or off according to their needs and preferences. By providing this flexibility, riders can maximize the efficiency of the electric assistance and optimize their overall cycling experience.

3.2 Block diagram of SMART Hybrid E bicycle

Design Block Diagram is shown below.

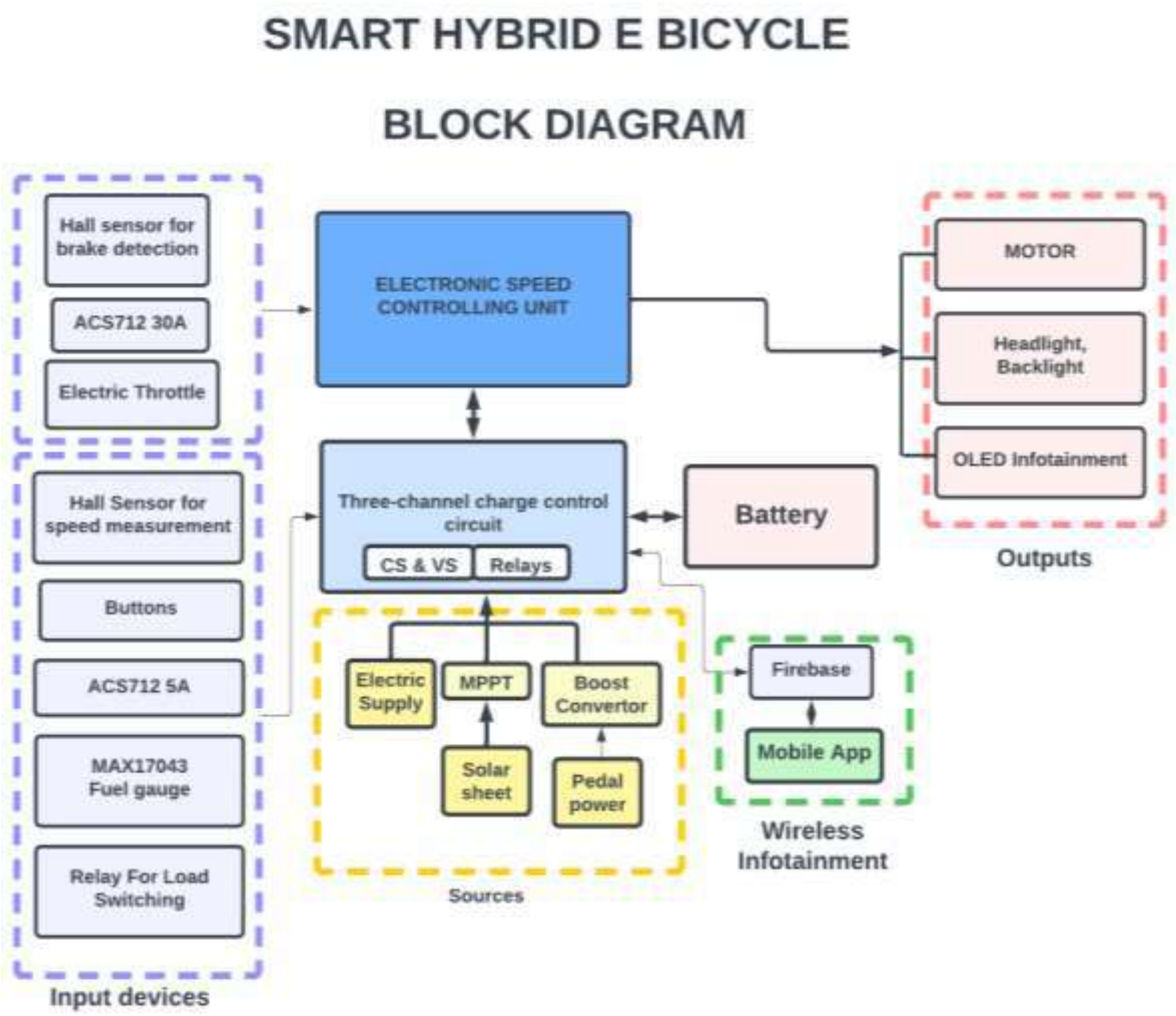


Figure 3. 2 Block diagram

3.3 Workflow diagram of complete project

Workflow diagram or flow chart for project methodology is shown below, it represents the working flow of the project:

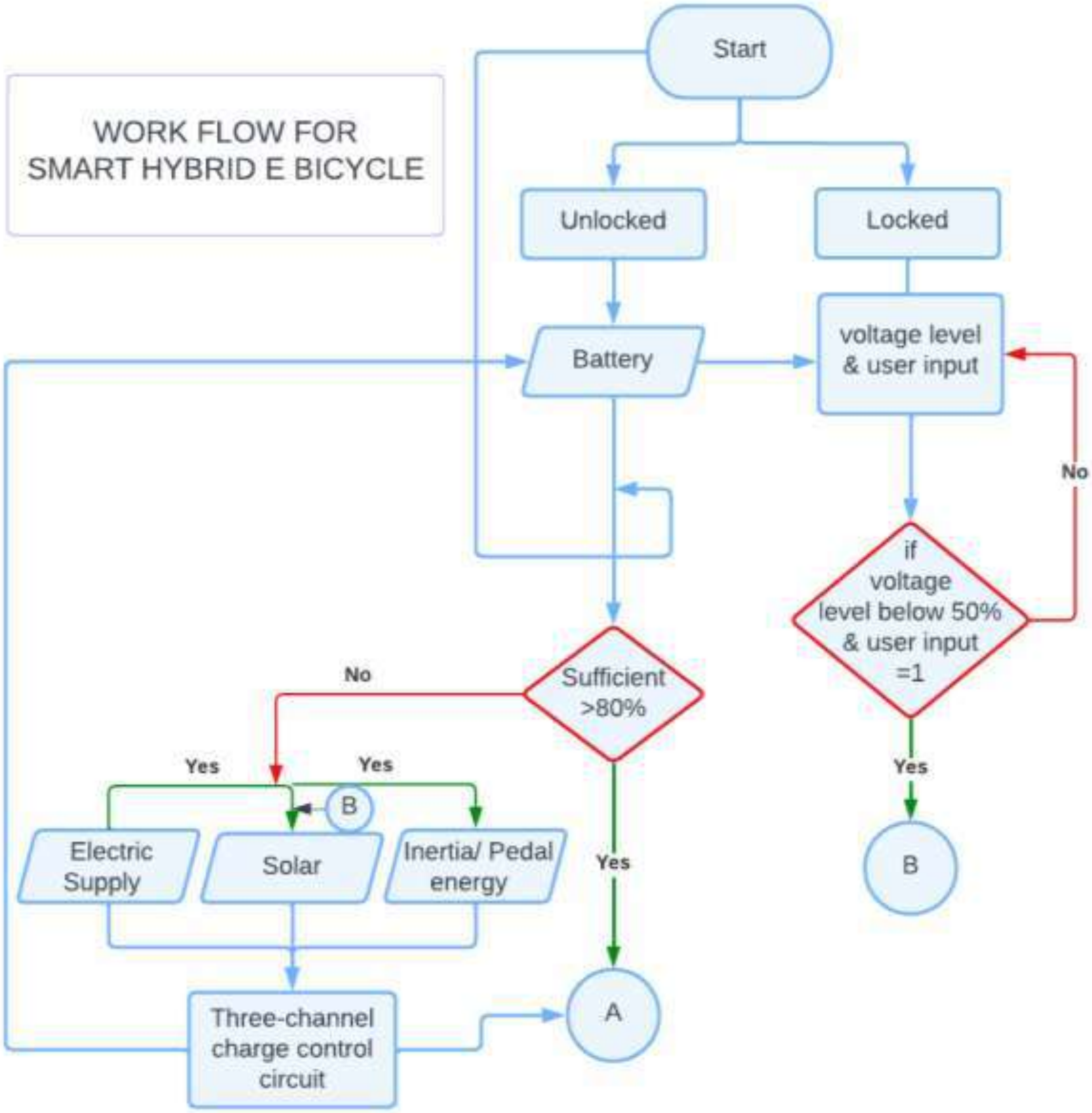


Figure 3. 3 : Workflow (A)

Continued,

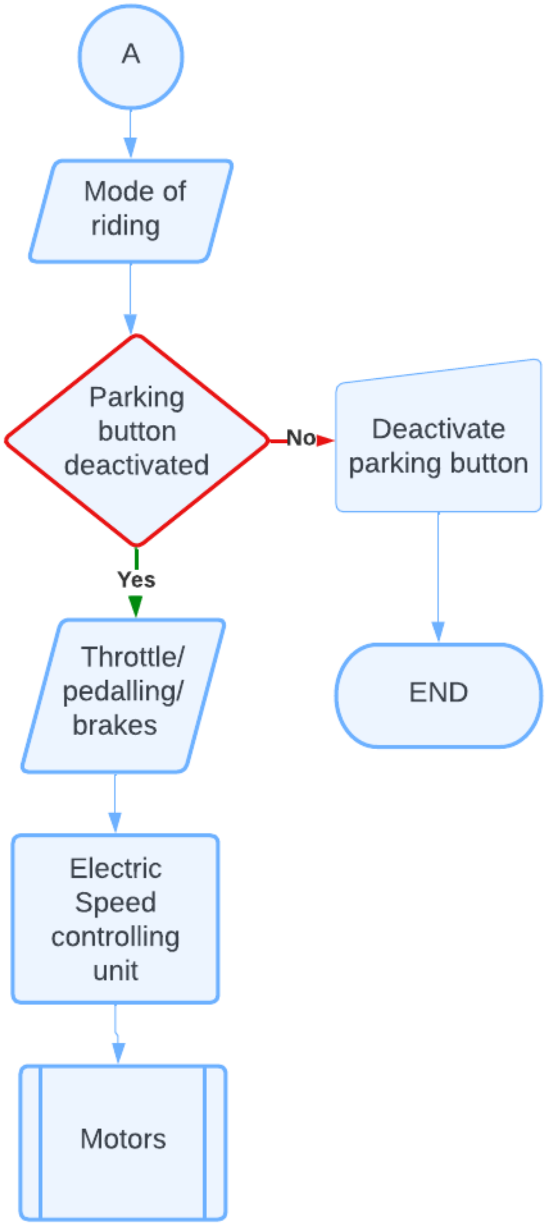


Figure 3. 4 : Workflow (B)

3.4 Electronic Speed Controller Design

3.5 ESC for Brushless Motor

Simulation for Electronic Speed Controller for Brushless DC Motor is shown below

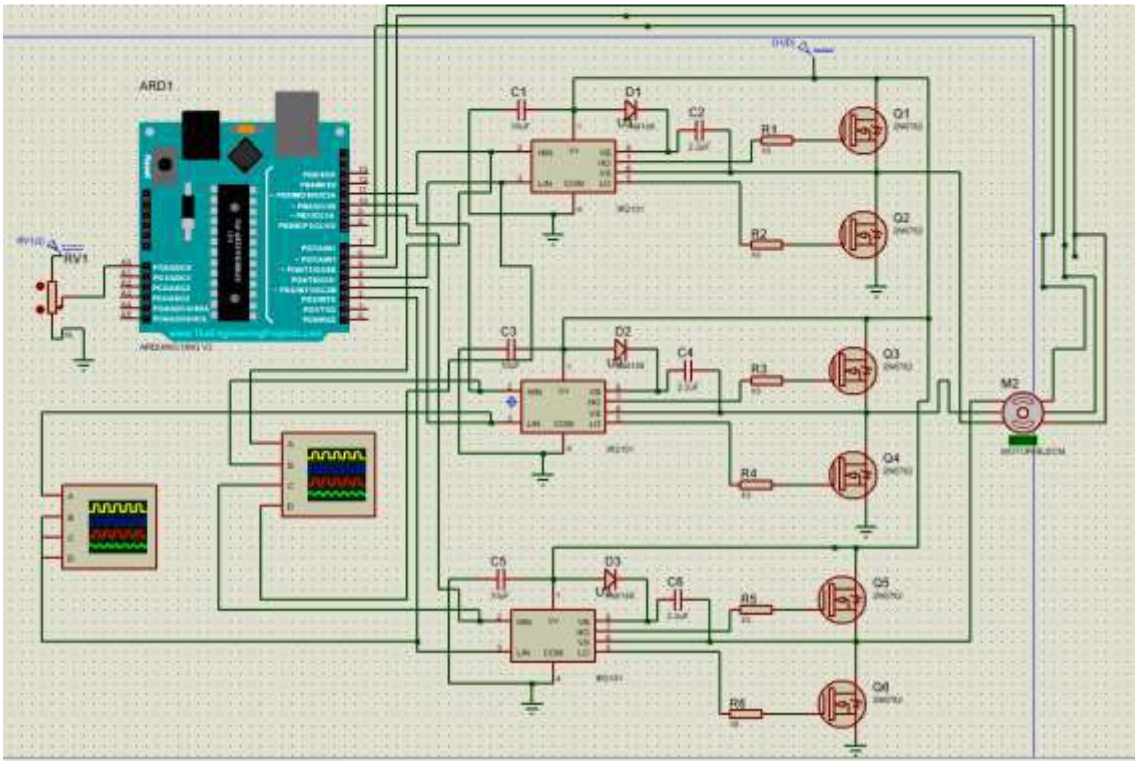


Figure 3. 5 : ESC for Brushless Motor Circuit

3.5.1. Hall Sensors output

Hall Sensor Output for each simultaneous phase is shown below, according to these output phase will be triggered.

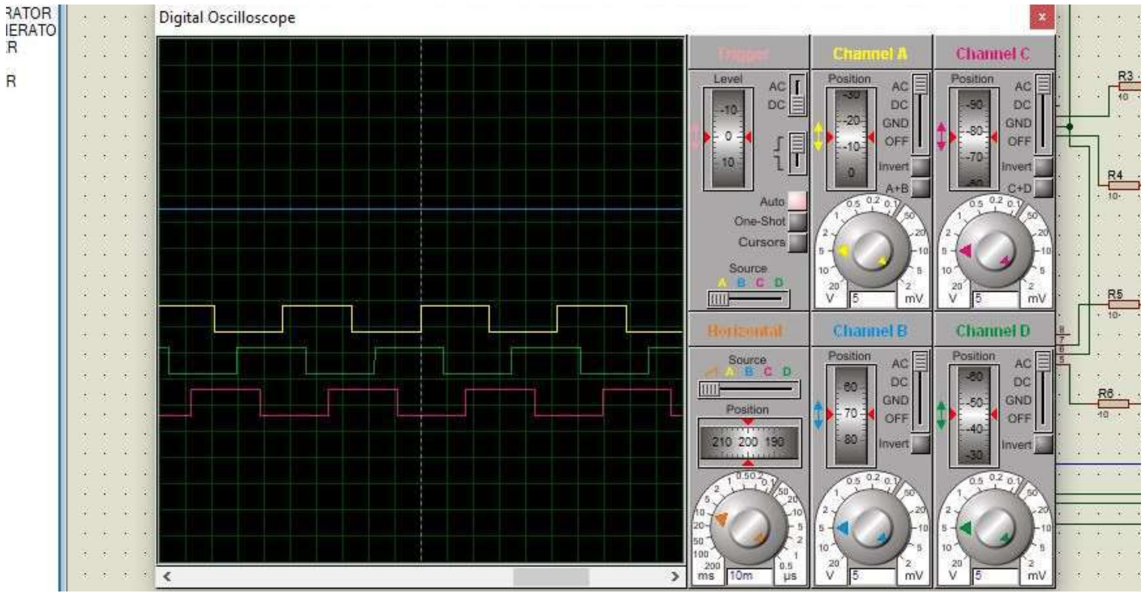


Figure 3. 6 hall sensor result

The BLDC motor is 3 phase motor and works according to the following timing diagram

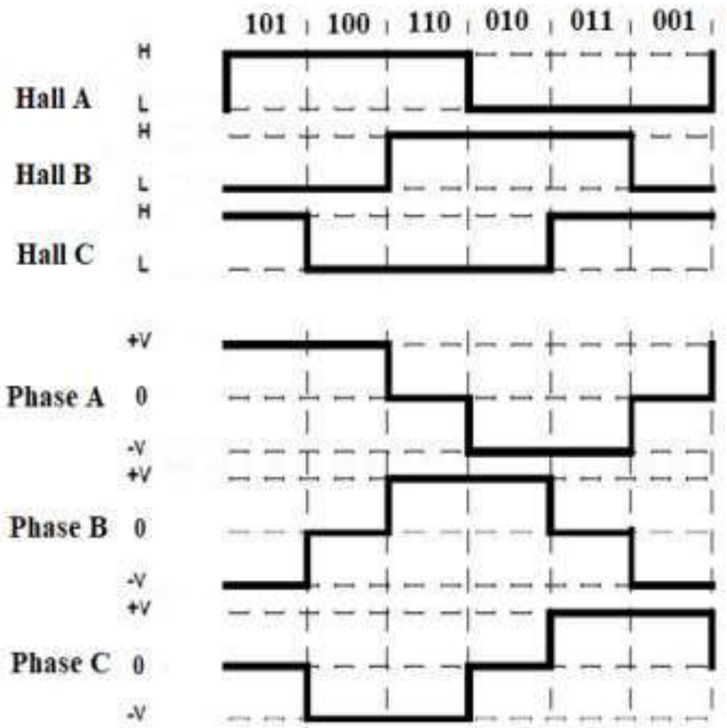


Figure 3. 7 Hall sensor output (3-phase)

and the algorithm is based on this methodology. It is based on 6 MOSFETS connected in 3 Half bridge configurations and each half bridge configuration is used to active each phase accordingly.

The phase is selected according to hall sensor input, and this procedure is done by an MCU.

3.5.2. Algorithm

1. Define the pin numbers of the three hall effect sensors, throttle input, six pins connected to the motor controller, and a pin connected to an LED.
2. Create an array of size 8 and initialize all elements to 255. This array will hold the motor states that correspond to the hall effect sensor readings.

   <u>In the setup function:</u>

3. Start the serial communication at a baud rate of 115200.
4. Set the LED pin as an output and turn it on.
5. Set the six pins connected to the motor controller as outputs.

6. Set the hall effect sensor pins as inputs.
7. Set the throttle input pin as an input.
8. Call the identifyHalls function to determine the motor states that correspond to each hall effect sensor reading.

   In the loop function:
9. Call the readThrottle function to get the throttle input value.
10. Repeat the following steps 200 times:
11. Call the getHalls function to read the current hall effect sensor values.
12. Use the hall effect sensor values to determine the current motor state using the hallToMotor array.
13. Call the writePWM function to set the motor controller pins to the correct values based on the motor state and throttle input.
14. Define the identifyHalls function:
15. For each possible motor state (0-5), do the following:
16. Determine the next motor state by adding 1 and taking the result modulo 6.
17. Print a message indicating the current motor state.
18. Repeat the following steps 200 times:
19. Set the motor controller pins to the current motor state with a duty cycle of 20.
20. Set the motor controller pins to the next motor state with a duty cycle of 20.
21. Call the getHalls function to read the current hall effect sensor values and use the hall effect sensor values to determine the motor state that corresponds to those values.
22. Store the motor state in the hallToMotor array at the index corresponding to the hall effect sensor values plus 1.
23. Set the motor controller pins to 0 and turn off the motor.
24. Print the contents of the hallToMotor array.
25. Define the writePWM function:
26. If the throttle input value is 0, turn off all motor controller pins.

27. Based on the current motor state and throttle input value, set the motor controller pins to the appropriate values.
28. Define the writePhases function:
29. Set the duty cycle for the A, B, and C phases of the motor controller using the analogWrite function.
30. Set the state (high or low) of the A, B, and C phase enable pins using the digitalWrite function.
31. Define the getHalls function:
32. Create an array of size 3 to hold the hall effect sensor readings for each sensor.
33. For Hall_Sam number of times:
34. Read the value of each hall effect sensor and add it to the corresponding element in the hallCounts array.
35. If all three hall effect sensors are high, return 0.
36. Otherwise, use the hallCounts array to determine which hall effect sensor(s) are high and return the corresponding motor state (1-6) by adding 1 for each high hall effect sensor.

3.6 ESC for PMDC Motor

3.6.1. Schematic

Schematic diagram for implemented ESC for PMDC motor is shown below, schematics and PCB designing is done on EasyEDA.

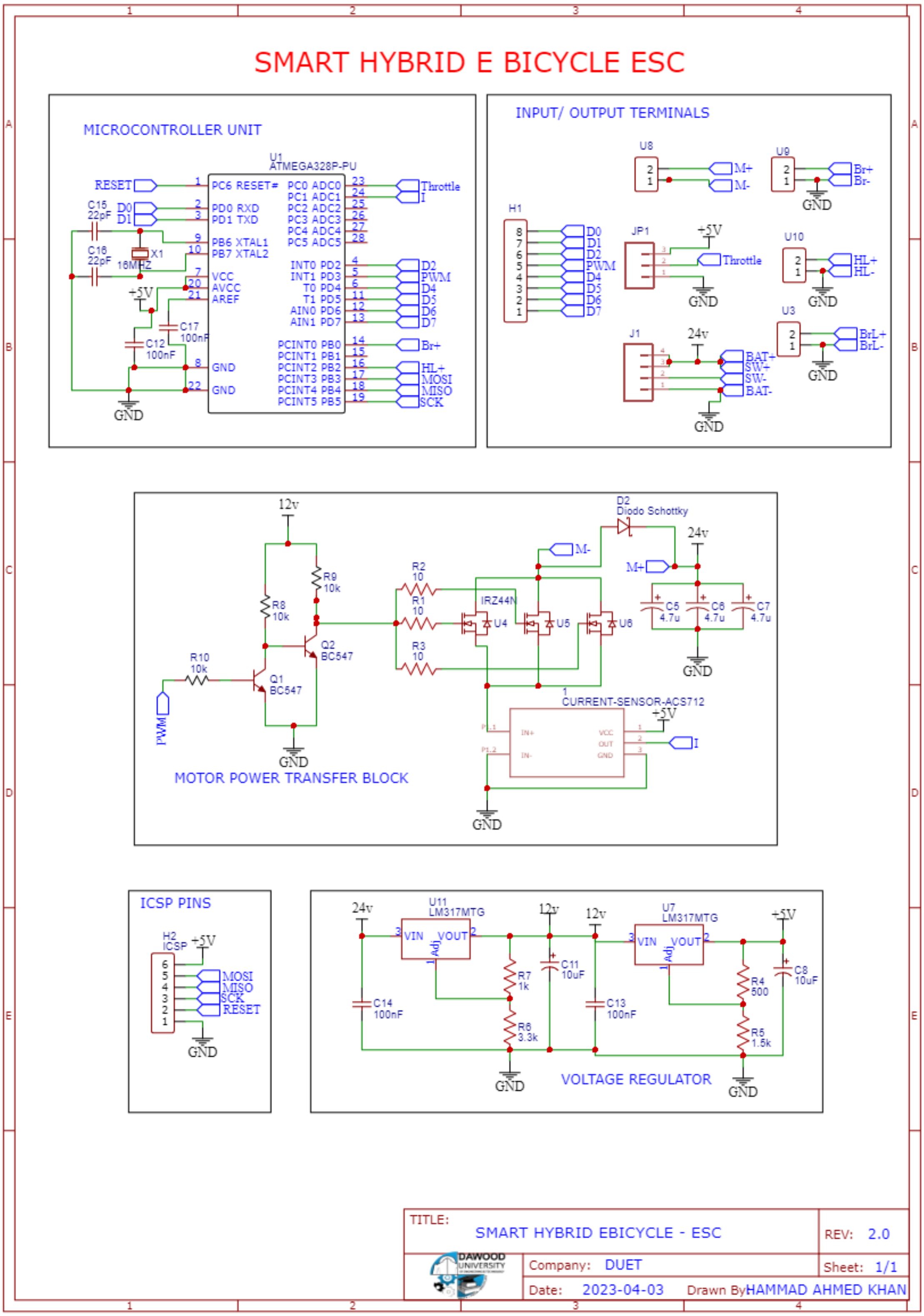


Figure 3. 8 Smart Hybrid e-bike ESC

3.6.2. The hardware of ESC

Hardware implementation for ESC with Geared PMDC motor integrated with Electric Throttle is shown below. Integrated motor is DC 24V 250 Watt brushed motor, with peak current of 13A, it is integrated with 3 MOSFETs in parallel to handle this much current. Schottky diode is placed in parallel to motor to remove back emf surges.

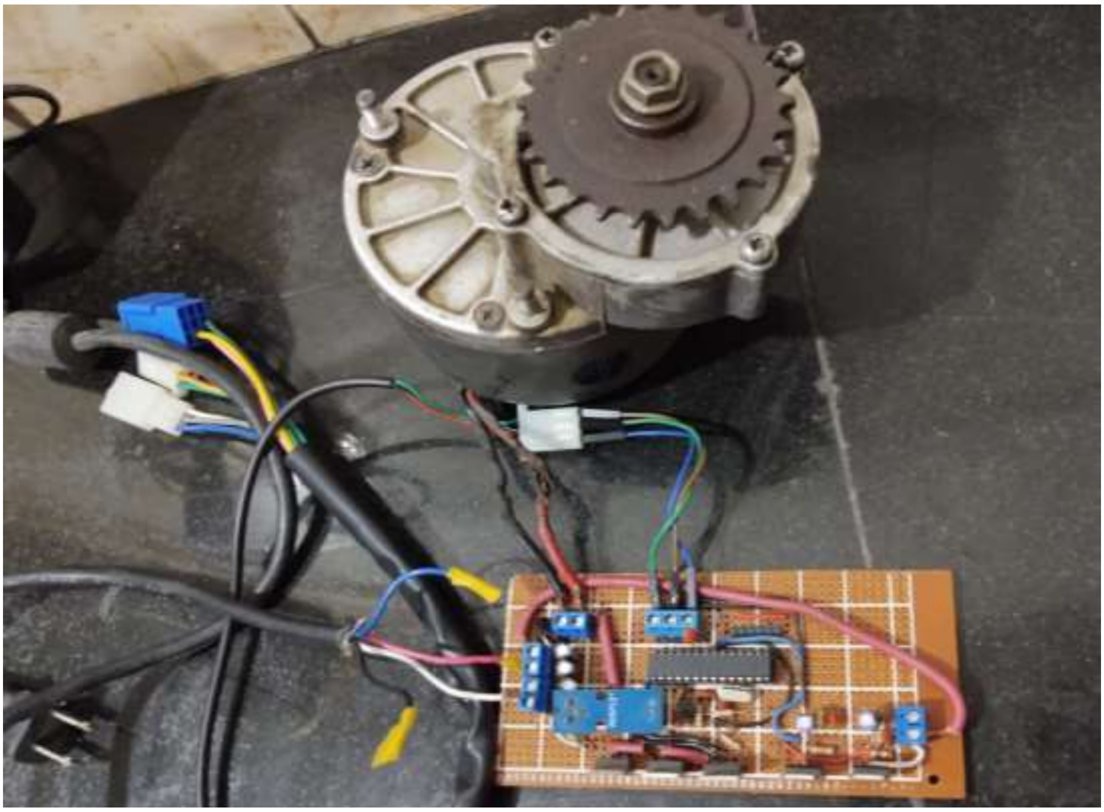


Figure 3. 10 Hardware Of ESC (A)

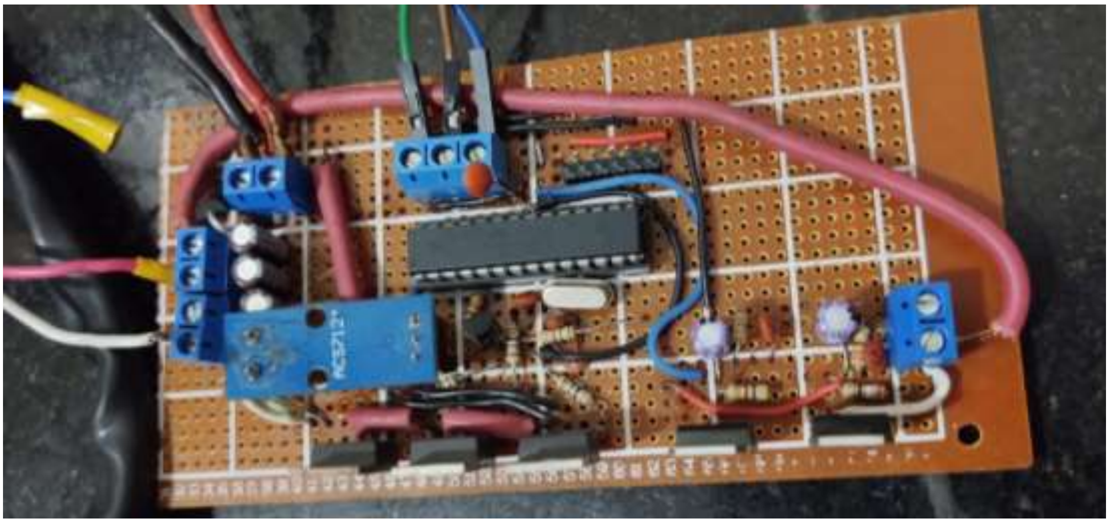


Figure 3. 9 Hardware Of ESC (B)

3.6.3. PCB Design

PCB design for PMDC Electronic Speed Controller is shown below, it is designed on EasyEDA

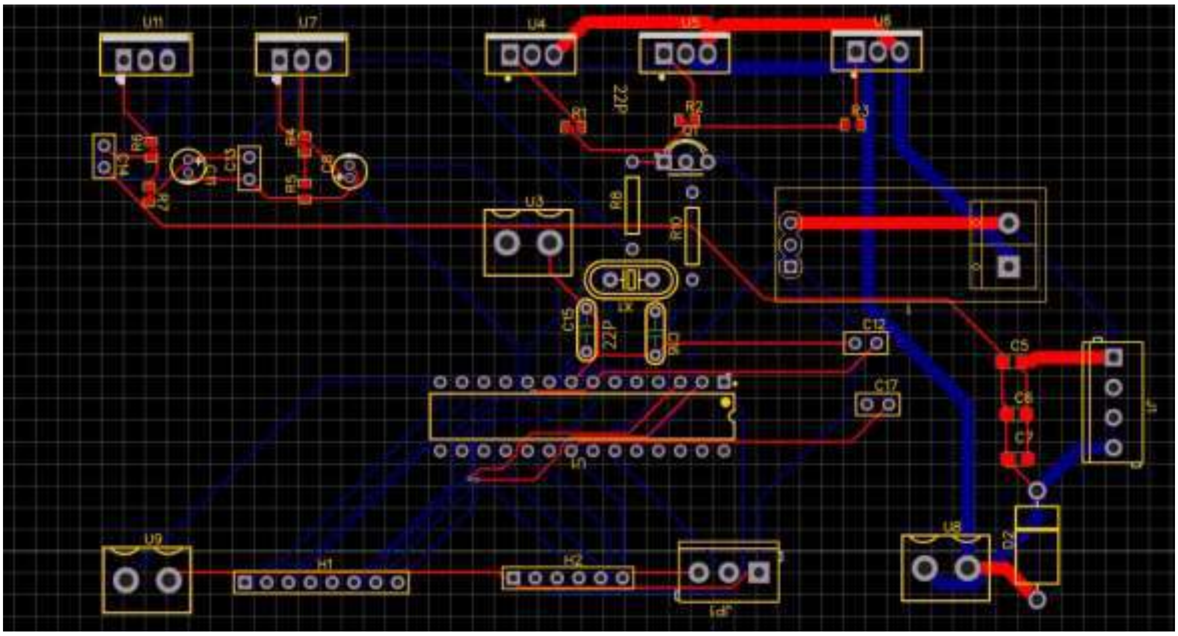


Figure 3. 11 PCB Design

3.6.4. 3D model

Shown below is the 3d model for the same PCB design.

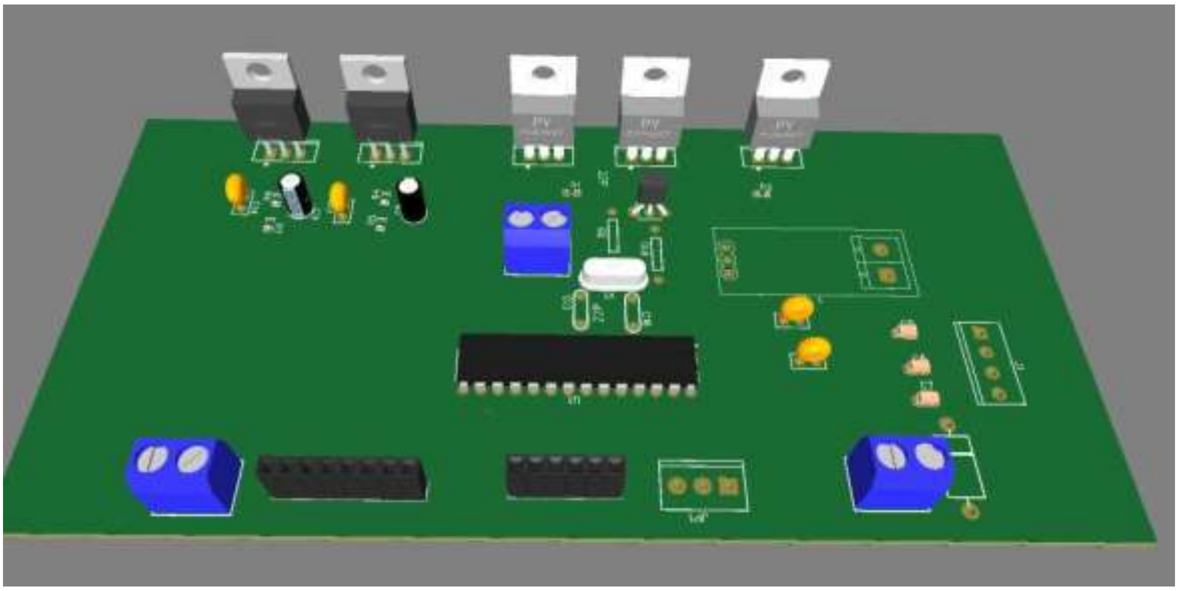


Figure 3. 12 3D Model

Our ESC design is based on multiple blocks as shown in schematic:

Controlling Unit: This block consists of microcontroller and essential components that are to be integrated to Microcontroller for its functioning i.e.: Xtal, capacitors etc. This block controls every peripheral connected to our ESC; it actually commands all other connected IOs.

Voltage Regulator Block: This block in integrated to step down high voltage according to our requirement, we require 5v for microcontroller, current sensor, and electric throttle integration and 12v to switch MOSFETS. The voltage divider IC works on the following circuit configuration.

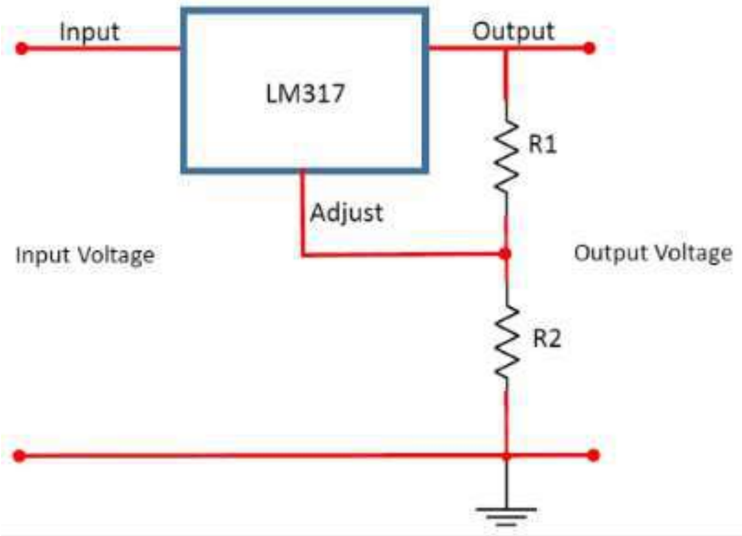


Figure 3. 13 LM317

Figure 3. 14 : LM317 workflow

And the resister values are calculated through following formula:

$$V_{Out}=1.25(1+R1/R2)$$

Power Bridge Block: MOSFETS are used to handle power required to drive high torque motor, maximum current drawn by motor is 13 amps, to draw this current safely and for a long period we are using 3 MOSFETS in parallel to divide the load.

ICSP block: This block is for SPI communication used to upload code in the Atmega328pu microcontroller used. Through these pins we can change firmware of our electronic speed Controller. These pins include +5v and Gnd pins to power microcontroller through an external source in absence of on board power.

3.6.5. Algorithm

The code is an implementation of a controller for an electric bike. The controller reads the throttle input and controls the electric motor's speed and current consumption using pulse width modulation (PWM).

Declare and initialize variables and constants

1. currentMax: maximum current allowed, in amperes
2. multiplier: voltage-to-current conversion factor for the ACS712 current sensor, in volts/ampere
3. throttleIn: analog input pin for the Electric throttle.
4. currentIn: analog input pin for the ACS712 current sensor
5. brakeIn: digital input pin for the brake switch
6. brakeLight: digital output pin for the brake light LEDs
7. PWM_inv: digital output pin for the pulse width modulation signal
8. pwm: current PWM duty cycle value, ranging from 0 to 255

setup() function:

1. Set the input/output pins
2. Enable the hall sensor interrupt
3. Configure the PWM signal frequency
4. Set the PWM signal to high to turn off the MOSFET switch

loop() function:

1. Calculate the time elapsed since the last loop iteration
2. Calculate the motor RPM based on the time elapsed between two consecutive hall sensor interrupts
3. Check if the brake switch is pressed
    I. Turn off the brake light
    II. Read the throttle potentiometer value and map it to a PWM duty cycle value
    III. If the throttle is above a minimum value, read the current sensor value and calculate the motor current consumption
    IV. Adjust the PWM duty cycle value based on the throttle and current sensor values
    V. If the motor power is enabled, set the PWM signal to the adjusted duty cycle value
    VI. If the throttle is below the minimum value, set the PWM duty cycle to zero
4. If the brake switch is not pressed, turn off the motor power, set the PWM duty cycle to zero, and turn on the brake light LED

3.7 Three – Channel charge control Circuit

3.7.1. Schematic

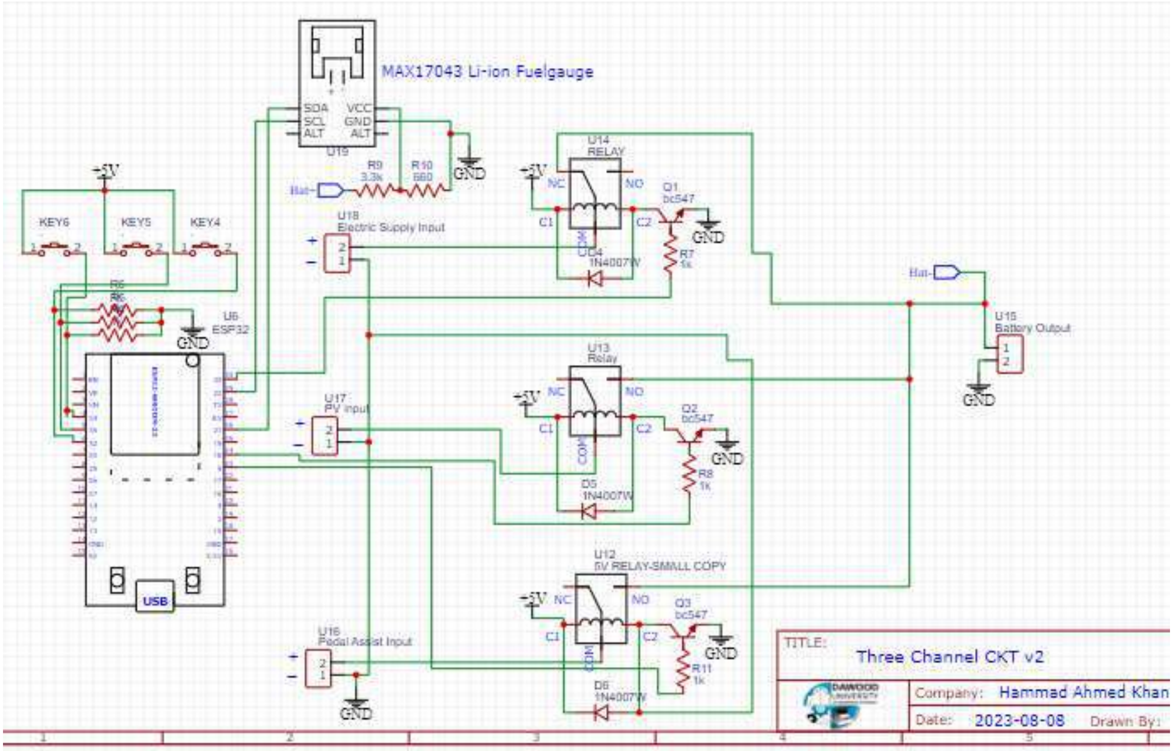


Figure 3. 15 3- Channel Charge Circuit Schematic

The Design of 3-channel circuit includes current sensing as well as battery capacity monitoring using MAX17043, the schematic is designed on EasyEDA.

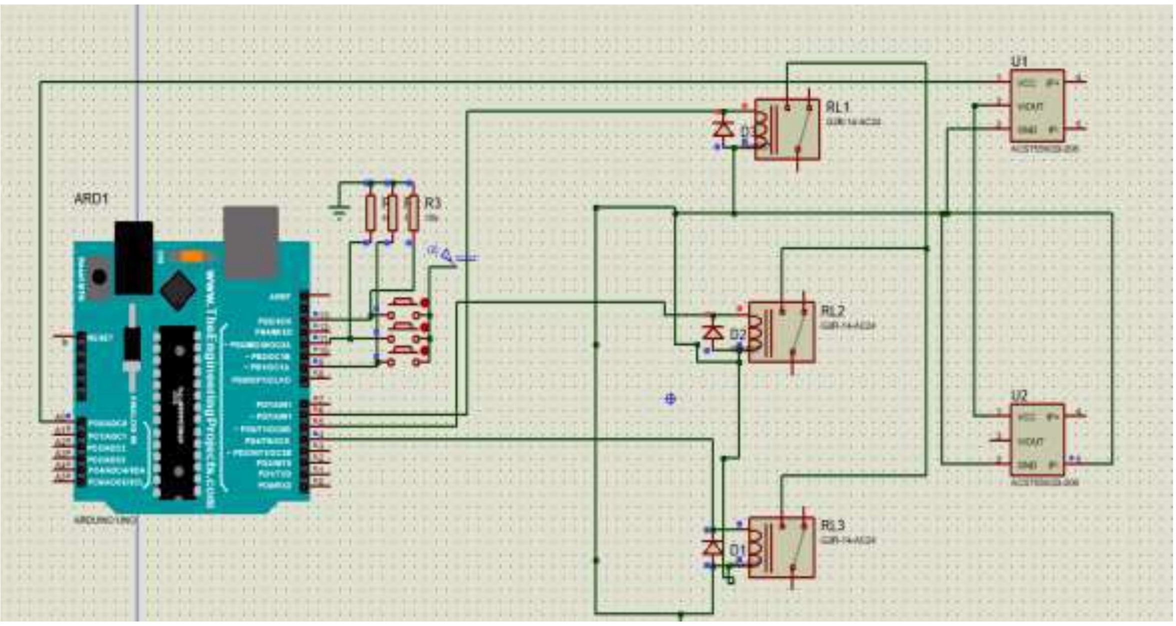


Figure 3. 17 Three- Channel Charge Circuit Simulation

The functioning of the three-channel charge controller is based on a dynamic switching principle, allowing for seamless transitions between different inputs as per the user's requirement. This intelligent controller utilizes a microcontroller unit (MCU) to generate switching signals that trigger relays, enabling the flow of current through the appropriate channels to charge the battery.

To achieve this, the MCU employs a clever mechanism where it alters the relay's state from normally open to normally closed, effectively creating a path for the current to pass through and reach the battery. This intelligent switching mechanism ensures efficient utilization of available power sources and optimizes the charging process.

To facilitate user interaction and control, a button system has been thoughtfully integrated onto the handle of the cycle. This ergonomic arrangement allows riders to conveniently trigger the MCU, initiating the switching process between different charging inputs. By simply pressing the designated buttons, users can seamlessly switch between power sources, enabling them to adapt the charging process according to the availability and priority of each input.

The overall methodology of this charge controller is grounded in a switch mode configuration, which provides numerous benefits in terms of efficiency and adaptability. By intelligently managing the flow of current, this controller minimizes power wastage and ensures that the battery is charged optimally.

As part of the continuous improvement and refinement of this charge controller, future enhancements may involve the integration of voltage and current sensing elements. These additional components will allow for accurate monitoring and measurement of the charging process, providing valuable information to the user regarding the voltage and current levels at different stages.

By incorporating these advancements, the charge controller can offer a more comprehensive and detailed understanding of the charging process, enabling users to make informed decisions regarding their power sources and charging priorities.

3.7.2. Algorithm:

I. Include the required libraries for the OLED display, Hall sensor, and Fuel gauge.

II. Define the pins for the Hall sensor, Solar, Pedal, and Electric outputs and inputs.

III. Define the wheel diameter, calculate the wheel circumference, and initialize the variables for the last time, last revolution, and current speed.

IV. In the setup function, begin the Wire communication, start the serial communication, initialize the Fuel Gauge, and initialize the OLED display.

V. Set the text size, color, and cursor position for the OLED display.

VI. Read the inputs for the Solar, Pedal, and Electric outputs.

VII. If the Solar input is HIGH, set the Solar output to HIGH and the Pedal and Electric outputs to LOW. Display "SOLAR" on the OLED display.

VIII. If the Pedal input is HIGH, set the Pedal output to HIGH and the Solar and Electric outputs to LOW. Display "PEDAL" on the OLED display.

IX. If the Electric input is HIGH, set the Electric output to HIGH and the Solar and Pedal outputs to LOW. Display "ELECTRIC" on the OLED display.

X. Read the Hall sensor value and count the revolutions, Low value will be read as hall sensor is interfaced in pull up configuration.

XI. Calculate the speed once per second by dividing the number of revolutions in the past second by the time elapsed since the last calculation.

XII. Use the formula to calculate the current speed in meters per second and update the last time and last revolution variables.

XIII. Display the current speed on the OLED display. Clear the OLED & repeat the loop.

3.7.3. PCB design

PCB design for relay based Three Channel circuit is shown below, PCB is designed on KiCAD.

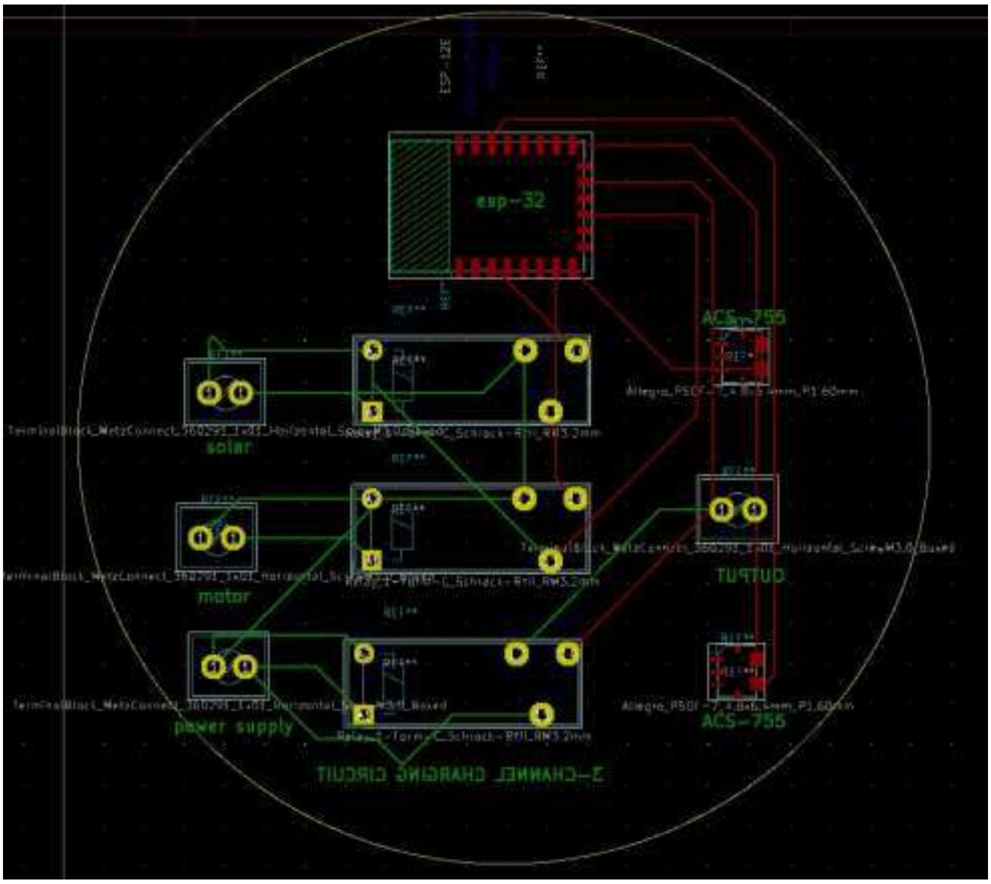


Figure 3. 18 3- channel PCB design

3.7.4. 3D model

3D model for the same 3d design is shown below,

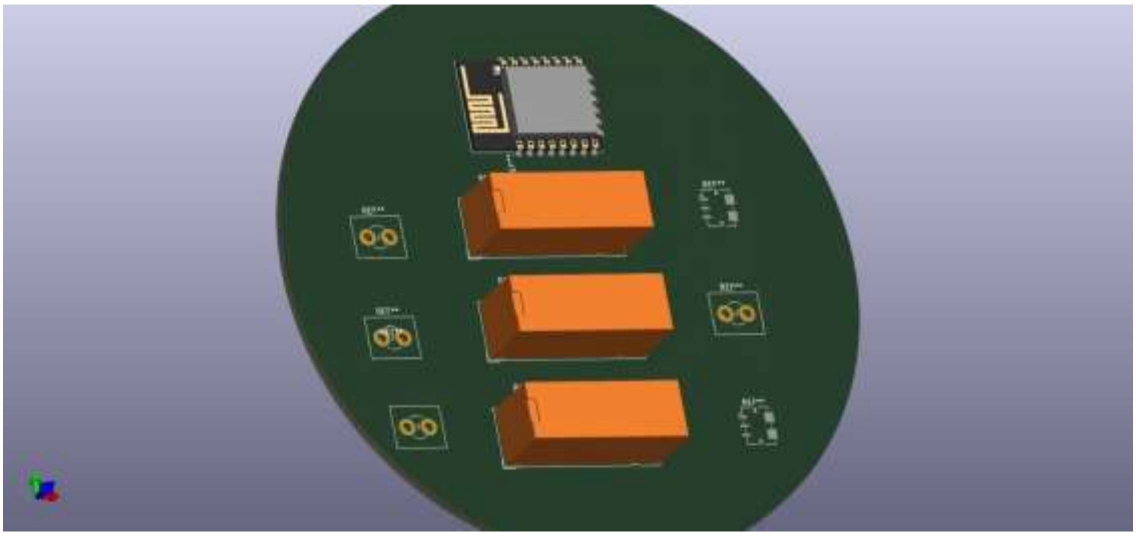


Figure 3. 19 3-channel 3D Model

3.8 Charging Percentage Calculation

Charging Percentage is calculated based on the discharge curve given below:

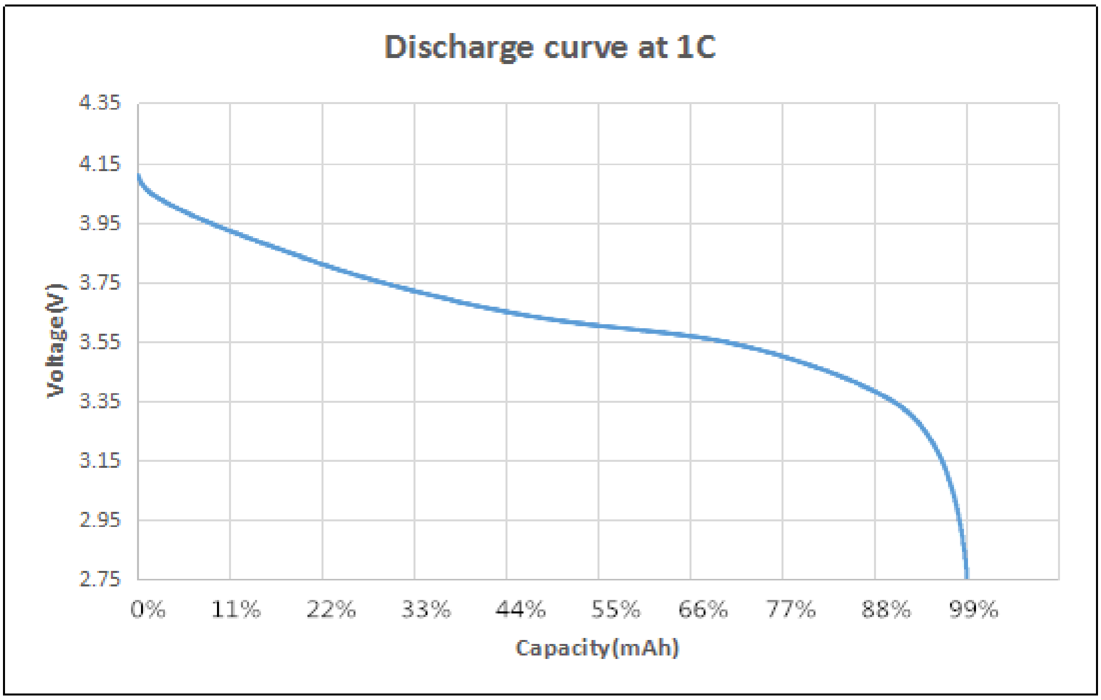


Figure 3. 20 Discharging curve of lithium ion [25]

to calculate the charge capacity accurately we are using a fuel gauge IC based on I2C communication. The IC is named as MAX17043.

3.9 Speed Measurement:

Speed measurement is done through hall sensor, a hall sensor is placed on pilar of the bicycle and a magnet is attached to one rim support wire and it measures speed based on the number of rotation.

3.10 Energy Regeneration/ Pedal assist charging:

A 24V geared motor is used along with pedal for energy regeneration and charging through pedaling, it is connected with boost converter to provide regulated voltage. We have set regulated output at 25.5 to charge battery with maximum efficiency and capacity. Using a geared motor enable us to pedal less as compare to gearless, like if a gearless motor require 3200 rpms to generate 24V, the same motor can go as low as 300 rpm. We need 10.5 volt atleast from the motor to produce desired output from boost converter.

3.11 Project CAD design

Our proposed design for Hybrid E Bicycle is shown below, this design features a folding technique to fold 4 solar panel to improve weight management and balance of the cycle..

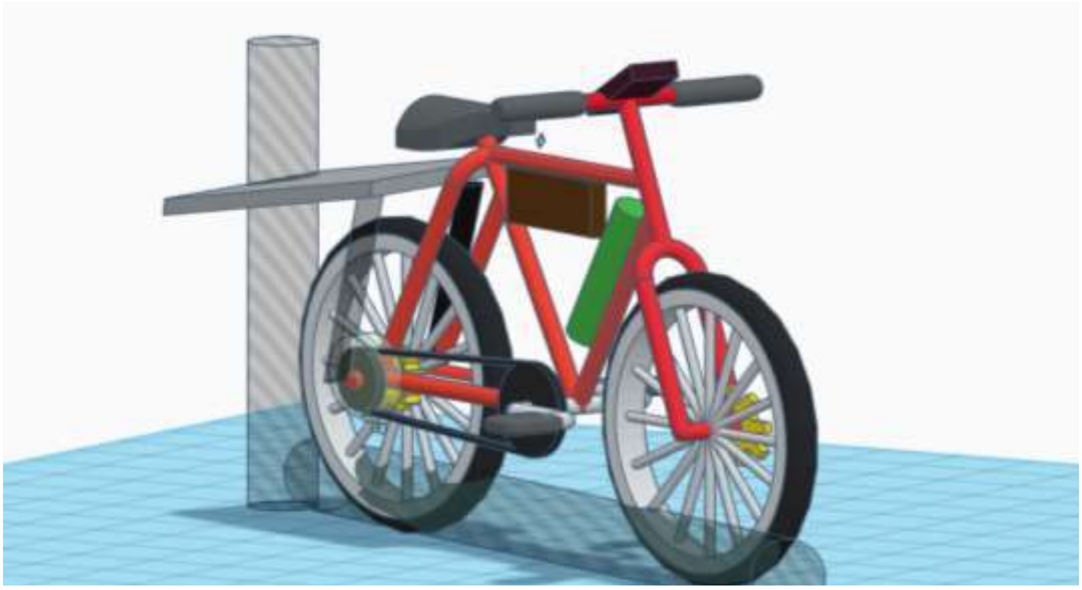


Figure 3. 21 Project Design (A)

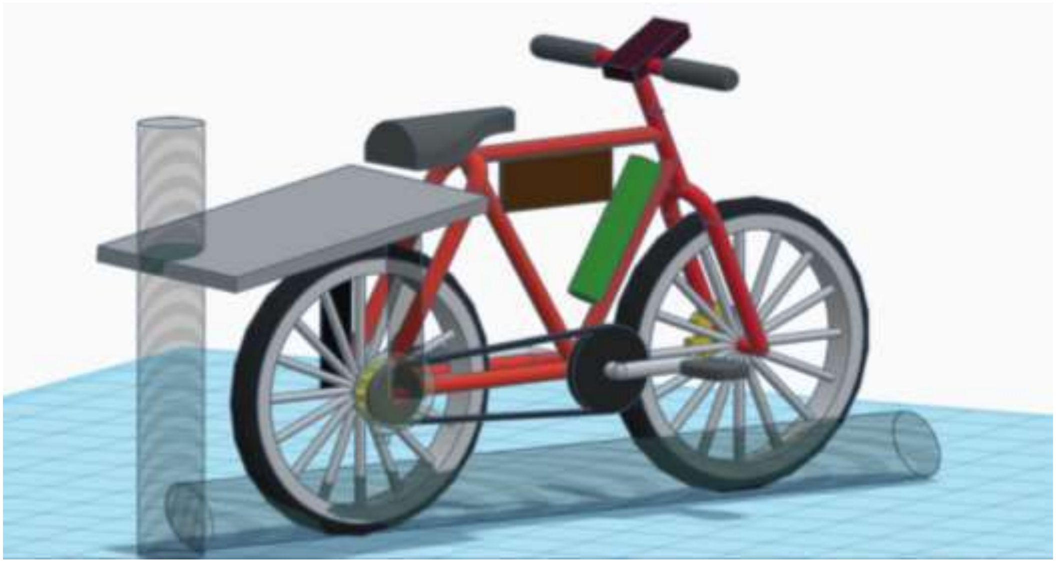


Figure 3. 22 Project Design (B)

3.11.1 Motor Holding Bracket CAD Design

This custom-made design will be used to integrate our dc motor shown in fig. With the E bicycle. The CAD Model is designed on Autodesk Inventor.

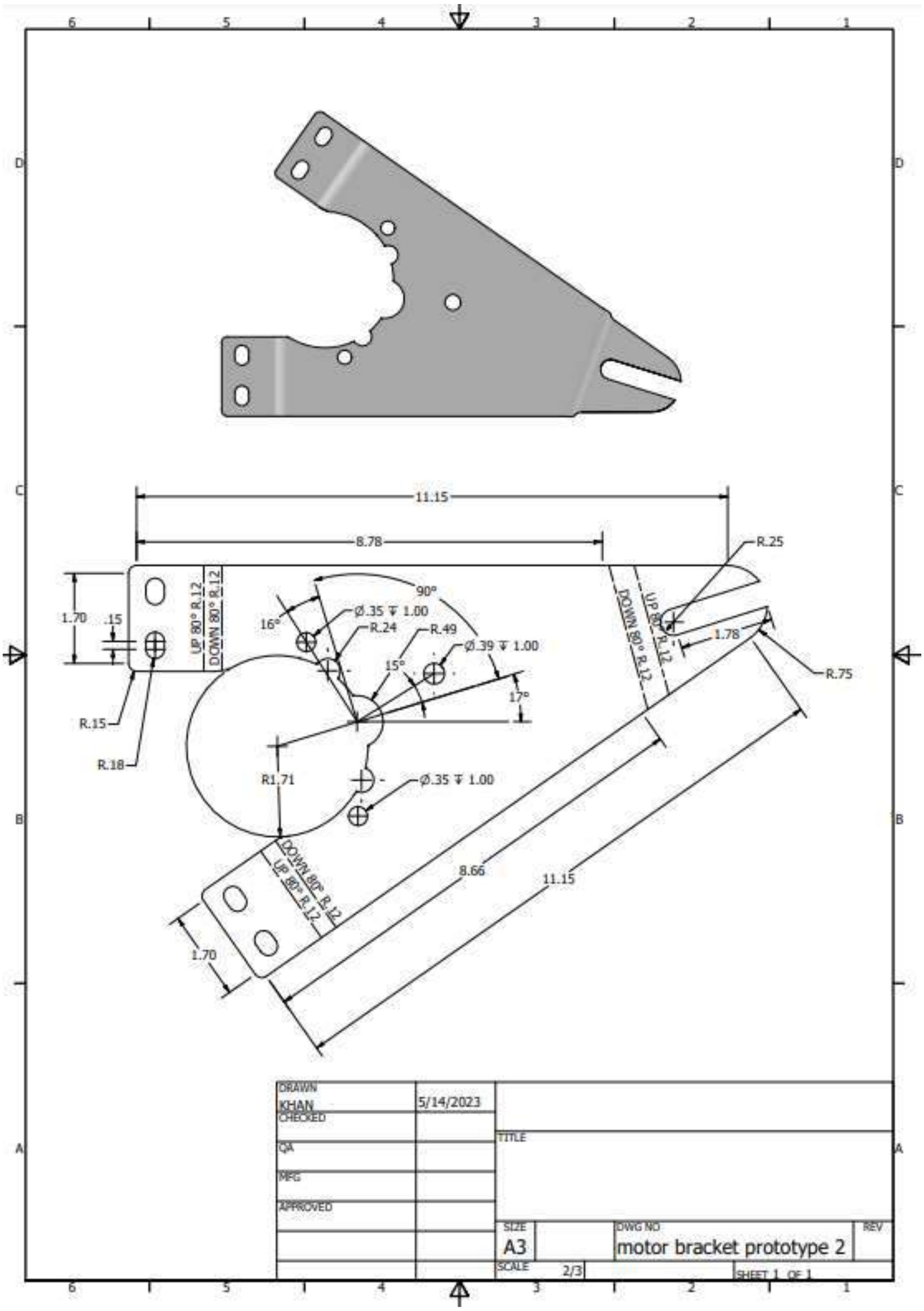


Figure 3. 23 Motor Holding Bracket

3.11.2 Motor and bracket placement

Placement for CAD motor holding bracket design on cycle pillars is shown below

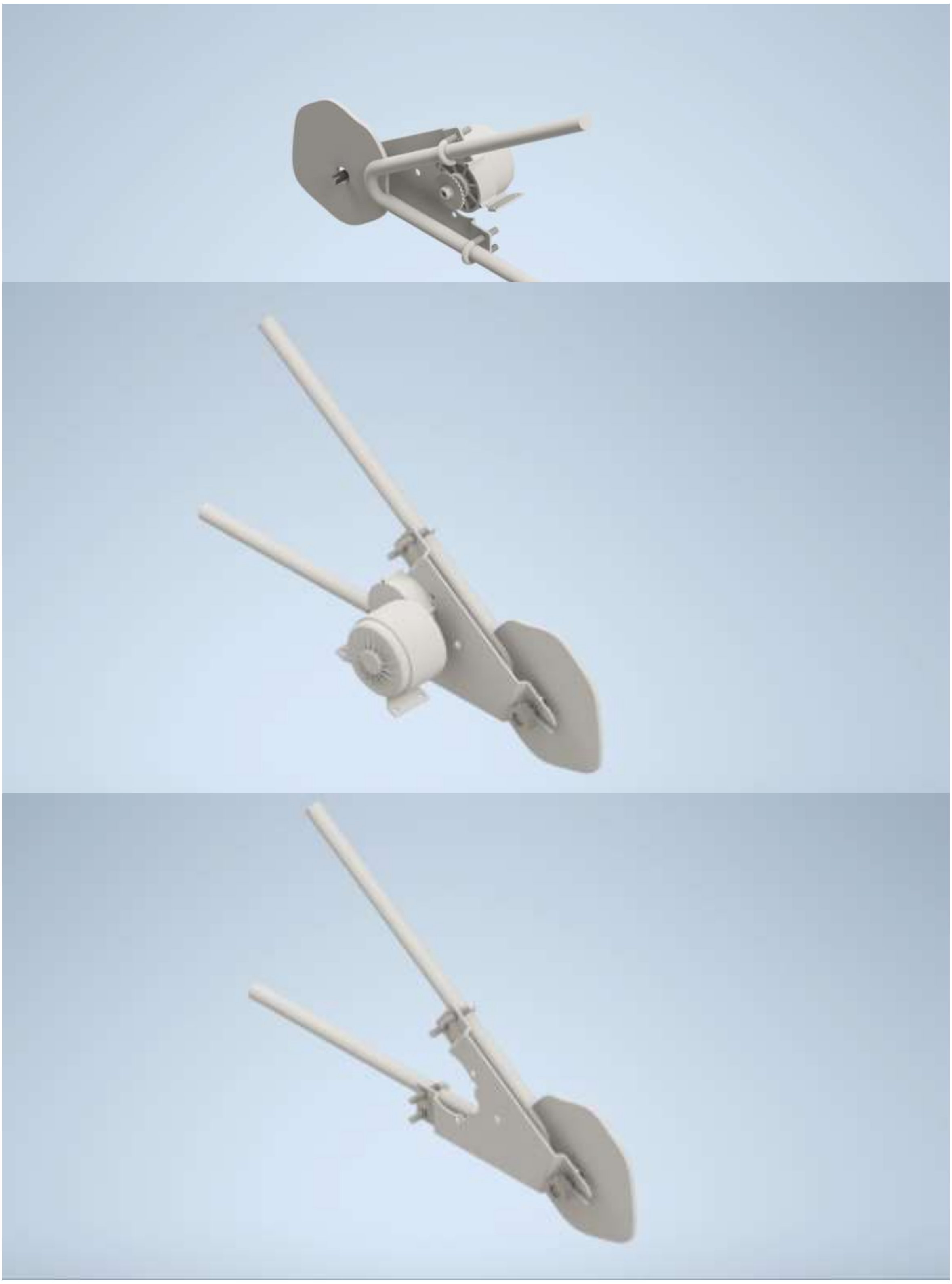


Figure 3. 24 CAD model of bracket

3.12 Solar Panel Configuration

We have decided to use 4 panels of 20 watts, with 2s & 2p configuration making it 24v & 80 watts. Because single panel is of 12v hence, 2 panels are connected in series to add the voltage according to our battery requirements.

Peak charging voltage of panel is 17.9 and the charging current is 1.2 A, hence overall, the maximum working voltage and Current are 35.8V & 2.4 A.

The Solar panel wiring diagram is shown below:

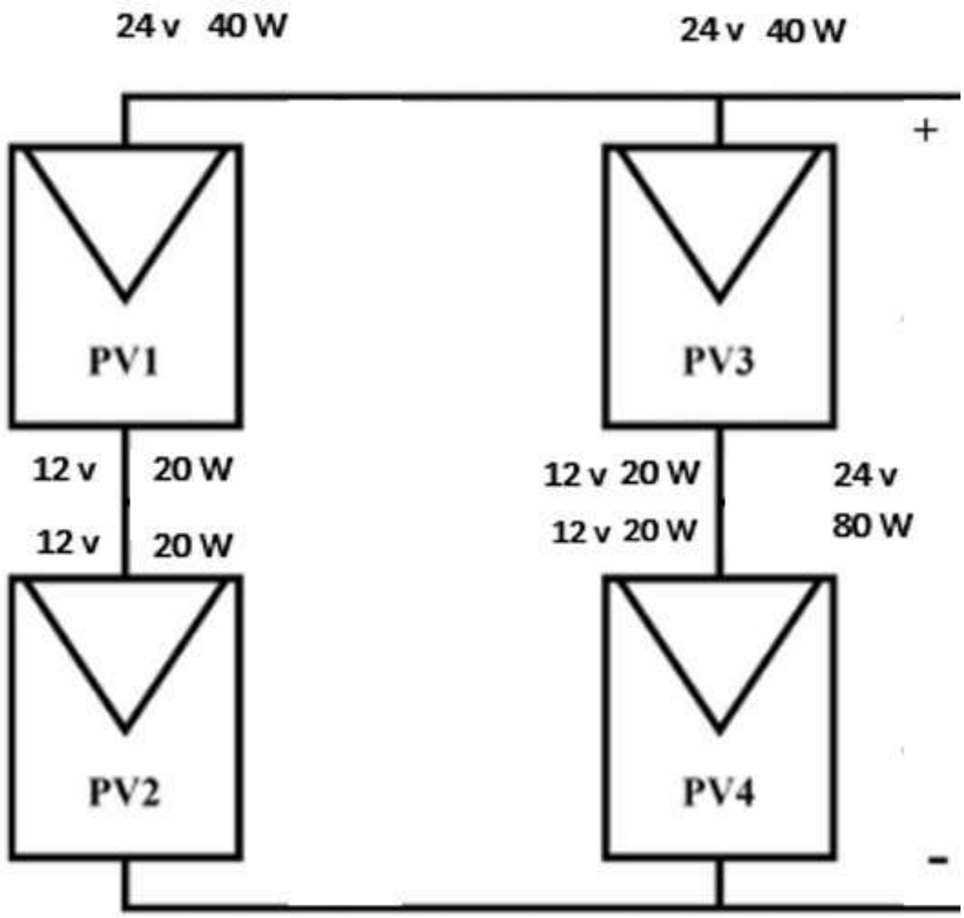


Figure 3. 25 Solar panel wiring diagram [9]

3.13 System Hardware

3.13.1. Geared PMDC-Motor

A 250-watt 24-volt geared motor is a type of electric motor used in electric bicycles, scooters, and other small electric vehicles. The motor has a maximum power output of 250 watts and operates on a 24-volt electrical system.

Figure 3. 26 GEARED PMDC-MOTOR [26]

The motor is designed with a gear reduction system that allows it to deliver high torque at low speeds, making it ideal for use in electric bicycles and scooters. The gear reduction system also helps to improve the efficiency of the motor, allowing it to operate with less energy consumption and heat generation.

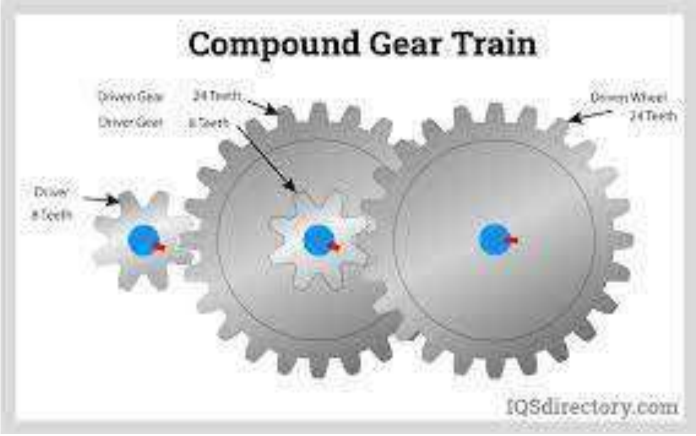


Figure 3. 27 Compound Gear Train [26]

The motor is typically compact and lightweight, making it easy to install on bicycles and other small vehicles. It may feature a brushless design for increased durability and reduced maintenance needs. The motor may also include a variety of safety features, such as overheat protection and speed limiters, to ensure safe and reliable operation.

Overall, the 250-watt 24-volt geared motor is a popular choice for electric bicycles and other small electric vehicles due to its high torque, efficiency, and ease of installation.

Its general information includes:

- Rated Speed: 360 RPM.
- Full load Current: ≤13.4A.
- No load Current: ≤2.2A.
- Torque Constant: 0.8 Nm. (8.15 kg-cm).

3.13.2. MPPT Charge Controller

The MPPT charge controller works by constantly monitoring the output voltage and current of the solar panel or wind turbine and adjusting the voltage to maintain the maximum power point (MPPT) vice. This ensures that the maximum amount of power is transferred from the renewable energy source to the battery, which increases the overall efficiency of the charging process.

Figure 3. 28 MPPT Charge Controller

Load Discharge Current: 20A

Output Power: 300W

Normally Open: 24 Hours Load Output

Efficiency: ≥95%

- We have decided to use 4 panels of 20 watts, with 2s & 2p configuration making it 24v & 80 watts.
- Peak charging voltage of panel is 17.9 and the charging current is 1.2 A, hence overall, the maximum working voltage and Current are 35.8V & 2.4 A.
- MPPT charge controller with output voltage 25.2 will be used to charge 24 v.

3.13.3. Battery

- 18650 Li-ion cells will be used, which are of 4.2 nominal voltage and the current capacity of the cell is 2500 mAh.
- 6 cells will be integrated in series to provide 24 v and 8 of these packs will be connected in parallel to provide a nominal over all capacity of 20Ah. Also known as 6s & 8p configuration.
- The calculated weight of the battery will be approx. 2kg. As, each cell weighs 42gm.

Figure 3. 29 batteries

3.13.4. Current Sensor

ACS-712 20A Current Sensor will be used to measure current in different aspects of project, in ESC it will be used to measure motor current to ensure prevention of motor burning, in charge control circuit it will be used to measure current input to battery to provide details about charging time and ensure safe charging of battery.

Figure 3. 30 ACS-712 (Current Sensor)

3.13.5. Power MOSFET

The IRZ44N is a type of MOSFET transistor that is commonly used in electronic circuits for switching and amplification applications. MOSFET stands for Metal Oxide Semiconductor Field Effect Transistor.

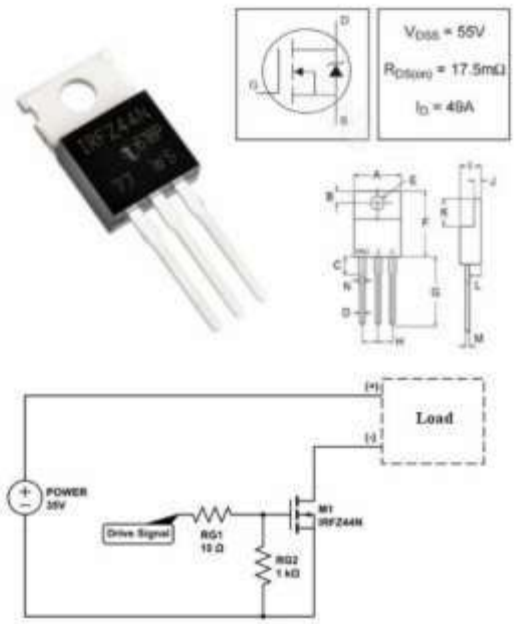


Figure 3. 31 Power MOSFET

The IRZ44N MOSFET transistor is designed to operate with high efficiency and low power consumption. It has a low gate threshold voltage, which means that it can be easily controlled by a small voltage applied to its gate. The transistor has a high switching speed and is capable of handling high currents and voltages.

The IRZ44N MOSFET transistor is commonly used in power electronics applications such as voltage regulators, motor control circuits, and switching power supplies. Its high efficiency and low power consumption make it suitable for use in battery-powered applications, such as electric bicycles and scooters.

The transistor typically comes in a small surface mount package, making it easy to incorporate into electronic circuits. It may also feature various protection features, such as overvoltage protection, overcurrent protection, and thermal shutdown, to ensure safe and reliable operation.

3.13.6. Max17043 Lipo Fuel Gauge

The MAX17043 single-cell Lithium Battery Fuel Gauge employs an I2C interface for easy interfacing with microcontrollers. It features an ultra-low operating current with the real-time tracking of the relative state of charge (SOC) of the battery through Maxim's patented algorithm. This eliminates the need for full-to-empty relearning and offset accumulation errors.

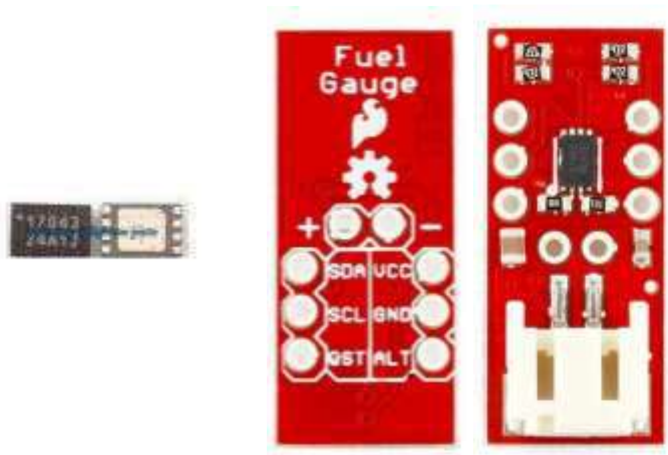


Figure 3. 32 Fuel Gauge [27]

The module also features a low battery power alert interrupt function. When the battery power falls below a specified threshold, the ALR pin generates a falling pulse to trigger the external interrupt of the controller. You will find it a great help to estimate the battery life by learning the power consumption of the system with this module. The breakout is as follows:

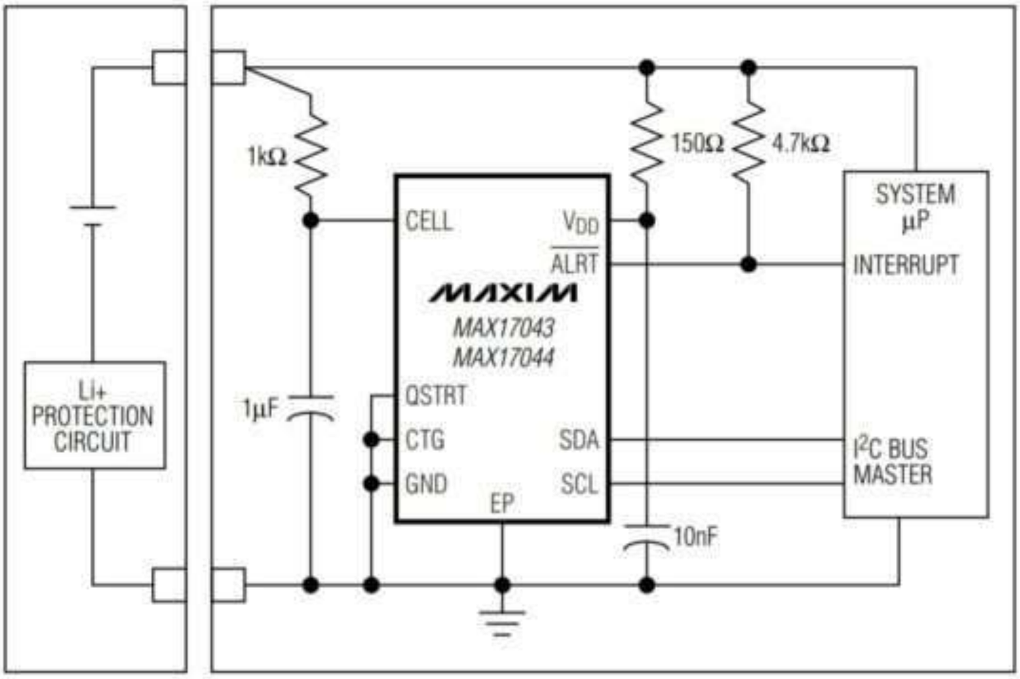


Figure 3. 33 Schematic MAX17043 [27]

Alt pin:

Alt pin is basically the Alert pin, and it can be used to receive a signal for lower battery state of charge. When the battery is low from a threshold value it passes a signal to mcu, we can connect it to the interrupt pin of the mcu as a indication of low battery as well as it can be left unconnected and still the state can be viewed through i2c.

Figure 3. 34 Fuel Guage ALT

3.13.7. Fuel Gauge Specifications

- Input Voltage (VCC): 3.3V~6.0V
- Battery Input Voltage (BAT IN): 2.5V~4.2V
- Battery Type: 3.7V Li-polymer/Li-ion battery
- Operating Current: 50 uA
- Precision: ±12.5mV Accuracy to 5.00V

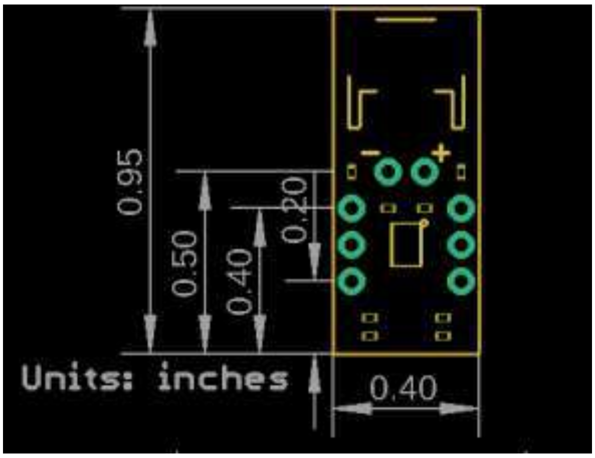


Figure 3. 35 MAX17043 Dimensions [27]

3.13.8. Geared DC motor for regeneration

Figure 3. 36 Geared DC motor

Model NO.	BG90-B6D250-24UG-30S-38-1
Structure and Working Principle	Brush
Type	Z2
Brand	Bg Motor
Noise	65dB
Power	250W
Rotation Direction	Ccw and Cw
Product Name	90mm Brushed DC Motor
Weight	3.7 kg

Table 2. 8 Motor Specification

Gear: Geared motor is used with lower gear ratio, so that it is easier to pedal.

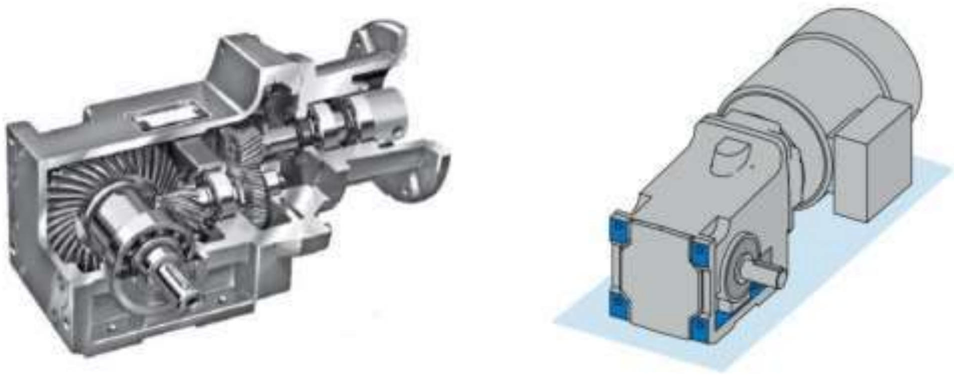


Figure 3. 37 Gear

S.no		
1	Model	24V
2	Motor Power	200 W
3	Ratio	10
4	Output speed (rpm)	330

Table 2. 9 Gear Specification

3.13.9. 18650 Li-ion Lipolymer Battery BMS

This product is 6 string 24V 6-Cell lithium battery power protection board With Balance circuit Split-mouth 40A discharge current. Protection board with overcharge protection,

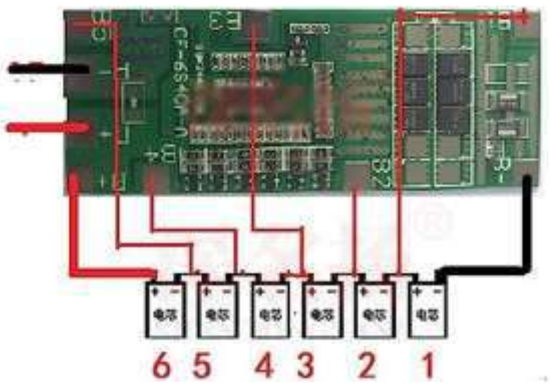


Figure 3. 38 BMS Input (A)

over discharge protection, over current protection, short circuit protection. The charging voltage is 25.2 V, having max 40A current.

Figure 3. 39 BMS Input (B)

3.13.10. MCU

We are using two MCUs,

- For ESC we are using standalone microcontroller Atmega328p.
- For three-channel Circuit, we are using Esp-32 NodeMCU.

3.13.11. Atmega328p

Atmega328p is a general-purpose single chip microcontroller. It was created by Atmel as a part of "AVR mega" family of microcontrollers. It have a Harvard architecture 8 bit

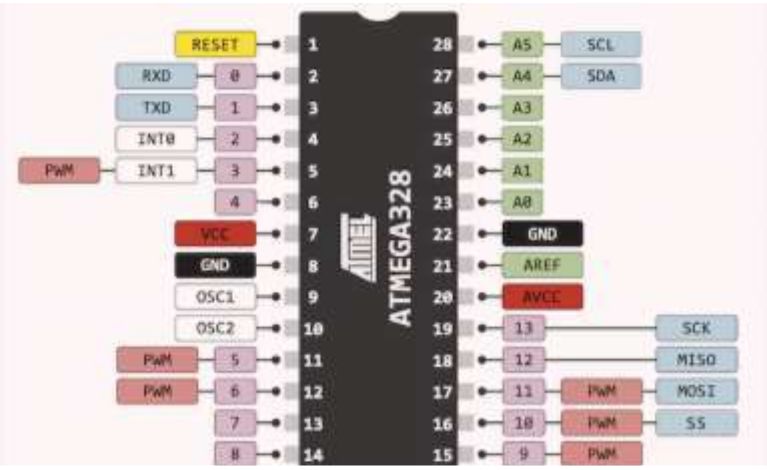


Figure 3. 41 Atmega328p Pinout

Figure 3. 40 Atmega328p

processor. It's operating voltages are between 1.8v to 5.5 volts. It can be run on either internal oscillator clock (1MHz) or external oscillator clock.

Table 2. 10 Atmega328p specification

Parameter	Value
Architecture	8 bit AVR MCU
Max CPU speed	20 MHz
Performance metric	20M Instructions/Sec at 20 MHz
Flash	32 KB
S-RAM	2 KB
EEPROM	1 KB
Package pin count	28 or 32
Capacitive touch-sensing channels	16
Max I/O pins	23
External-interrupt pins	3
ADC	10-bit, 6 channels
PWM channel	8-bit

3.13.12. Esp32 NodeMCU

Esp32 is a low power SOC Microcontroller, it has dual mode Wifi and Bluetooth integrated. It is integrated with Tensilica Xtensa LX6 microprocessor which comes with both single and dual core architecture. It includes a built-in onboard antenna unit for Wireless communication. It is designed and developed by Espressif Systems, a China based company.

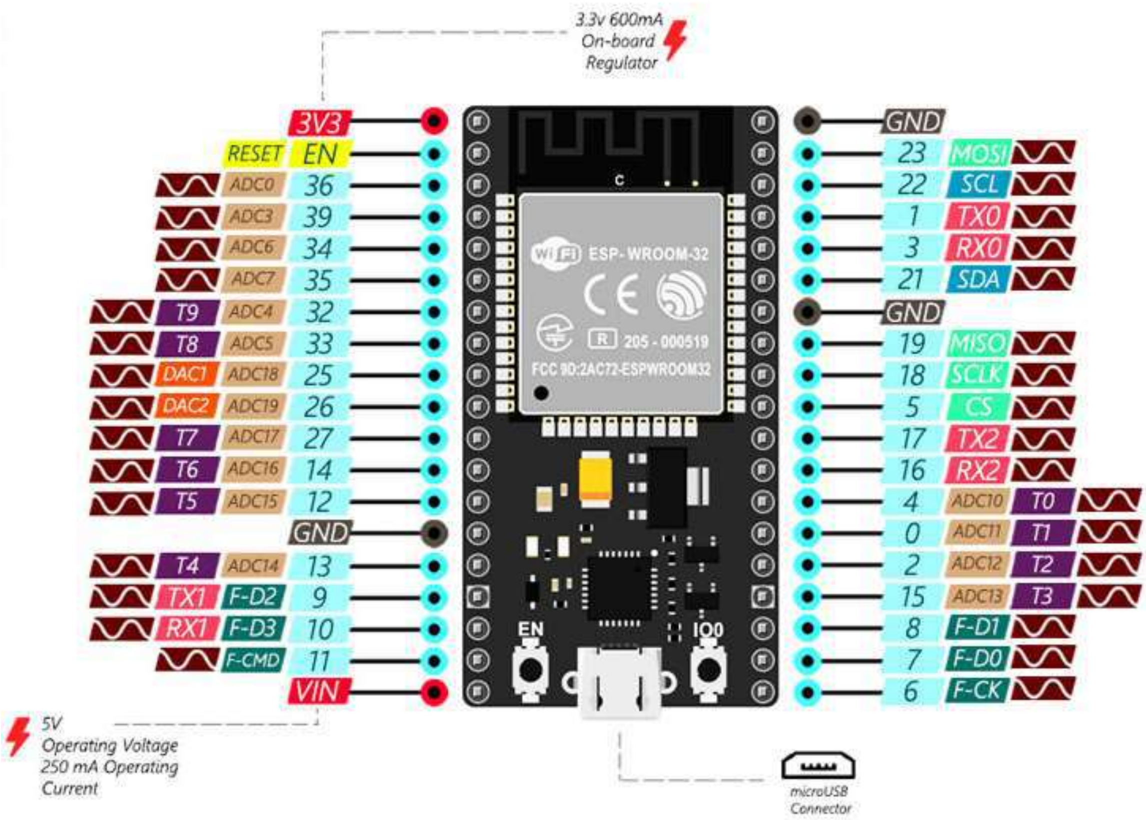


Figure 3. 42 ESP-32 Pinout

Table 2. 11 ESP-32 specification

Parameter	Description
Module	ESP32 wroom module
Wi-Fi	Wi-Fi: 802.11 b/g/n

Bluetooth	v4.2 BR/EDR and BLE
Operating Voltages	5v – 3.3v
SPI Flash:	32 Mbit
Interfaces	UART/GPIO/ADC/DAC/SDIO/SD card /PWM/I2C/I2S
Xtal	40MHz
I/O Ports	30 - 38
ADC resolution	12bit
Hall Sensor	Yes, integrated onboard
Touch Input	Available

3.13.13. Relay

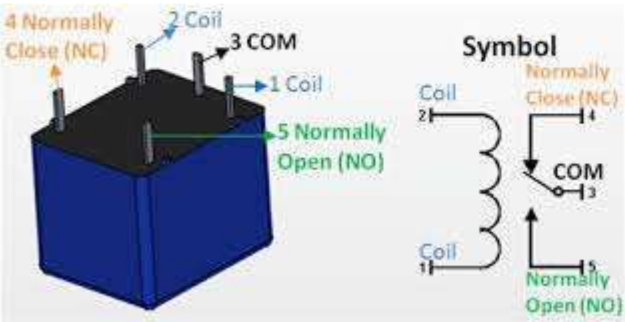
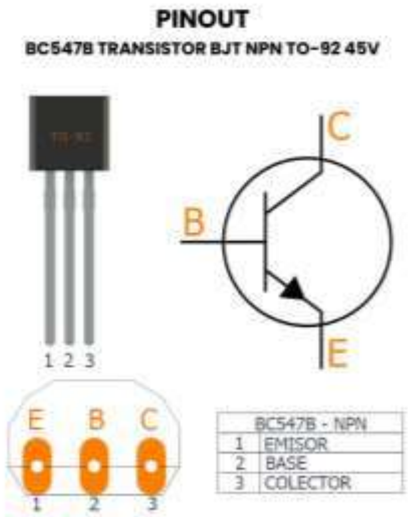


Figure 3. 44 Relay Pinout

Figure 3. 43 Relay

We are using 6v relay for switching purpose, it can switch either DC voltages or AC voltages, it is being used in our 3 channel circuit for switching purpose between 3 sources i.e: Solar power, pedal power and Conventional Electric supply.

3.13.14. Transistor



Transistors are being used for switching mosfets in ESC, and for activating relay in three-channel Circuit. Relay and Mosfets could not be activated directly as they require more voltage then a microcontroller can provide. Lower Voltages relay can be activated through microcontroller as well as Logic based Mosfets can be activated through microcontrollers. We are using a bc547 npn transistor for relay and Mosfet switching.

3.13.15. Diode

Diodes are Semiconductor device, we are using diodes here for protection from back emf or reverse voltages from relay switching and DC motor. For Relay switching we are using 1n4007 general purpose diode and for blocking motor back EMF we are using Schottky diode. Schottky diodes are diodes with specialty of Fast recovery as motor generates back emf or reverse voltage more often due to this reason we are using 1N5822 diodes to make our Electronic Speed Controller Safe.

3.13.16. Boost Converter

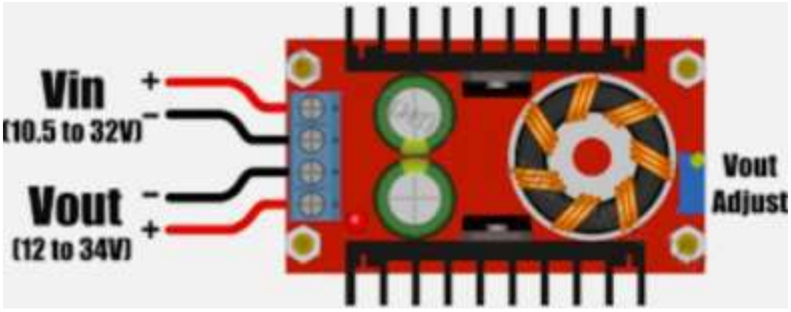


Figure 3. 47 boost Converter Pinout

Figure 3. 46 boost converter

Boost Converter is being used to boost the voltages being generated by regenerative motor, it is a 150 watt boost converter. It have an adjustable output upto maximum 34v, we will require 25.5 volt to charge the battery, additional voltage regulator of 25.5 v will be added to insure safe output. It requires a minimum of 10.5v to start generating output.

3.13.17. OLED Screen

OLED Screen of 1.3inch is being used. It works on i2C communication and have an i2c address of 0x3C, the i2c address can be modified to use and additional screen by connecting a resister on given junctions on the backside of the module.

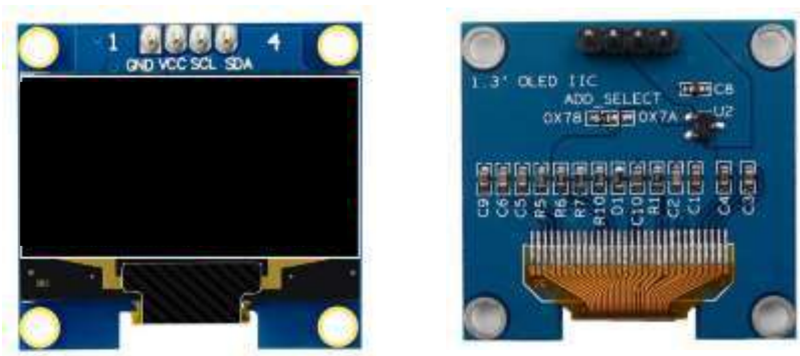


Figure 3. 48 OLED Display

This OLED screen is based on a driver SH1106 instead of SD1306 being used in other 0.96” and 0.92” Oleds, to used it a different driver library have to be modified according to esp32 in order to use this library.

3.13.18. Hall Sensor

We are using A3144 Hall sensors, 2 for brake detection and integrated with ESC, one for speed measurement integrated with 3 channel circuit. It gives low output when a magnet gets in range with magnetic field and is interfaced in pullup configuration.

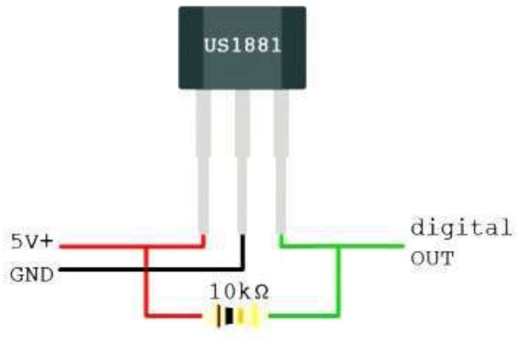


Figure 3. 49 Hall Sensor US1881

CHAPTER FOUR

RESULTS & DISCUSSIONS

4.1 Simulation & Hardware Implementation of ESC – Electronic Speed Controller

Simulation for Power bridge circuit and hardware implementation of ESC with integrated Electric Throttle and Motor at output is shown below;

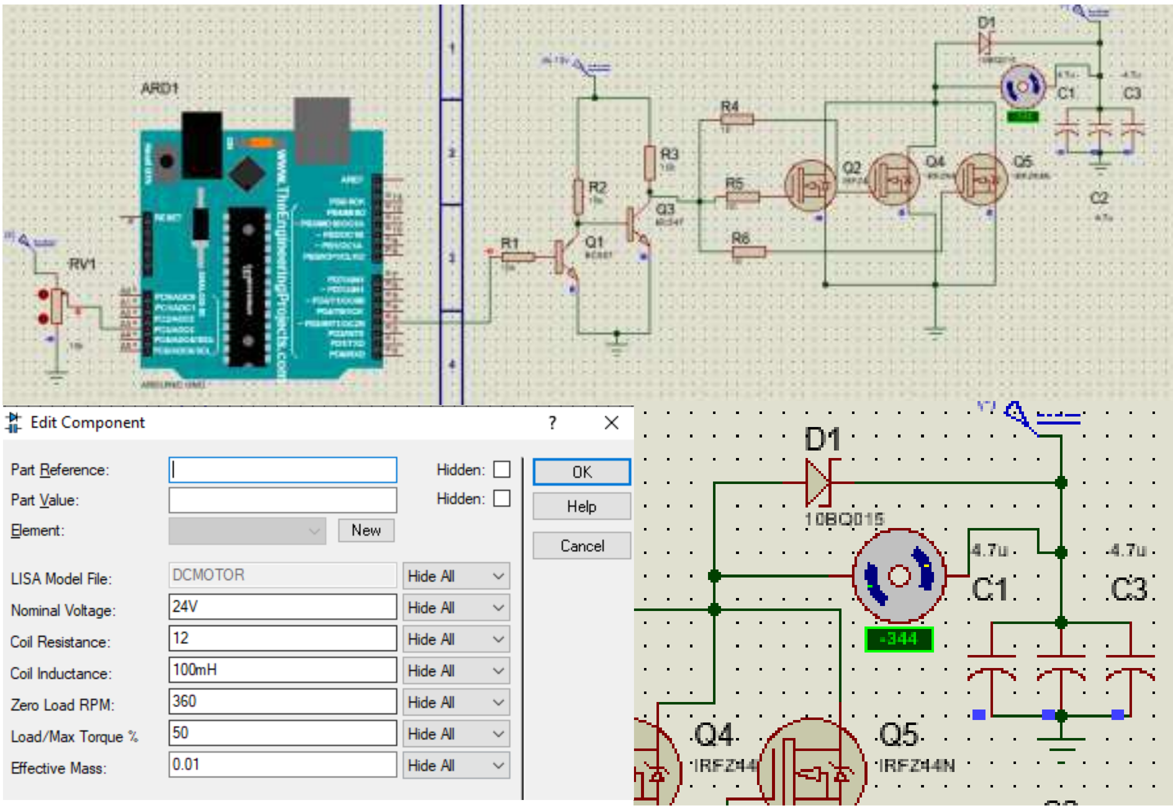


Figure 4. 6-2 Simulation for ESC

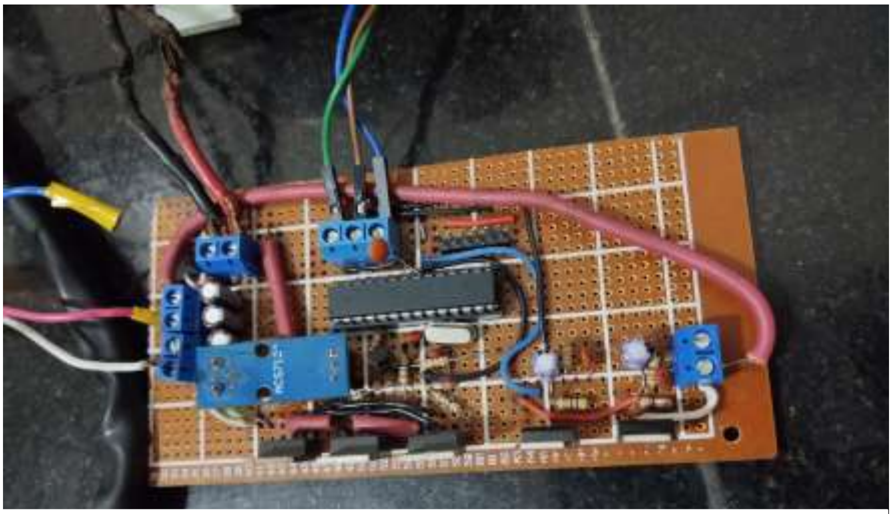


Figure 4. 6-1 Hardware for ESC

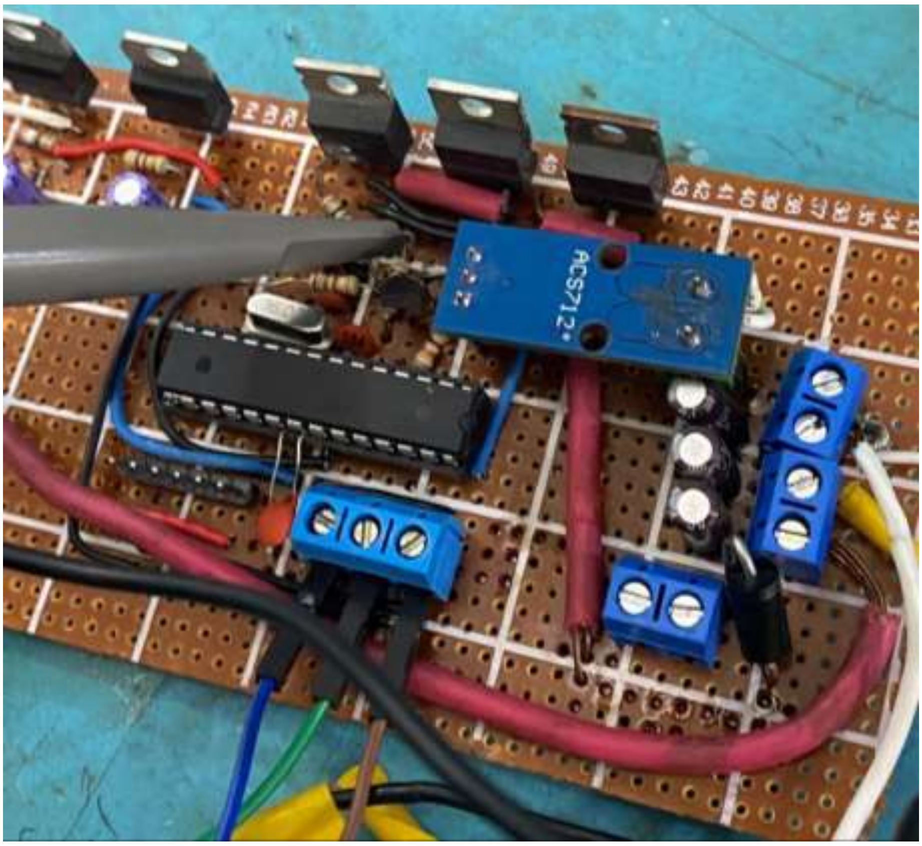


Figure 4. 6-3 Hardware Of ESC

Connected ICSP pins to update firmware:

ICSP pins are separated to make it easy to update Firmware just with these pins instead of dislocating the microcontroller.

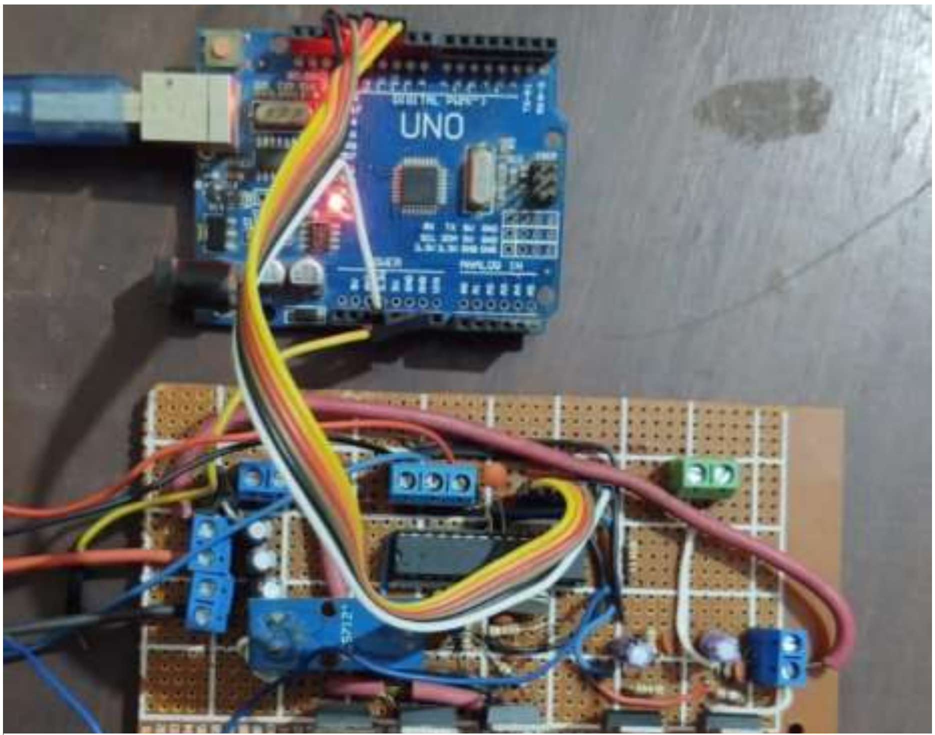


Figure 4. 6-4 ICSP Pins Configuration

Analysis of ESC circuit on oscilloscope is shown below, analysis include testing of MOSFETs triggering to ensure proper activation of All three MOSFETS which will result in proper current handling through MOSFET bridge. It is verified through Gate and Drain terminal waveforms shown in fig. 4.5 and fig. 4.6.

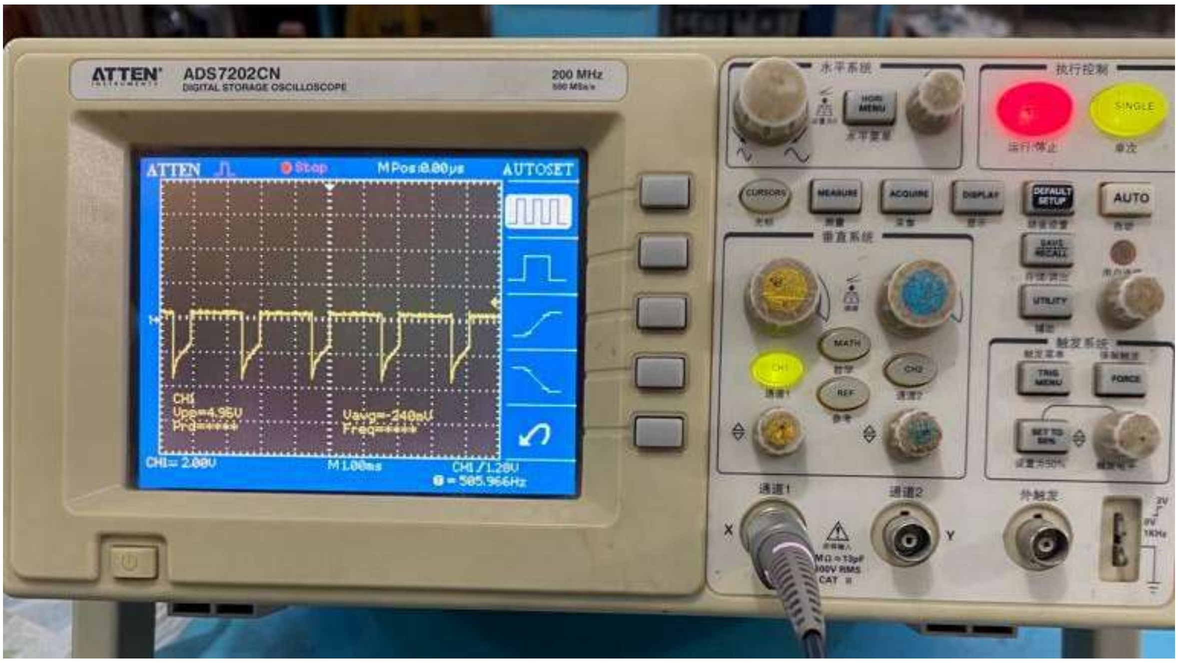


Figure 4. 6-5 Oscilloscope results for Drain Waveform

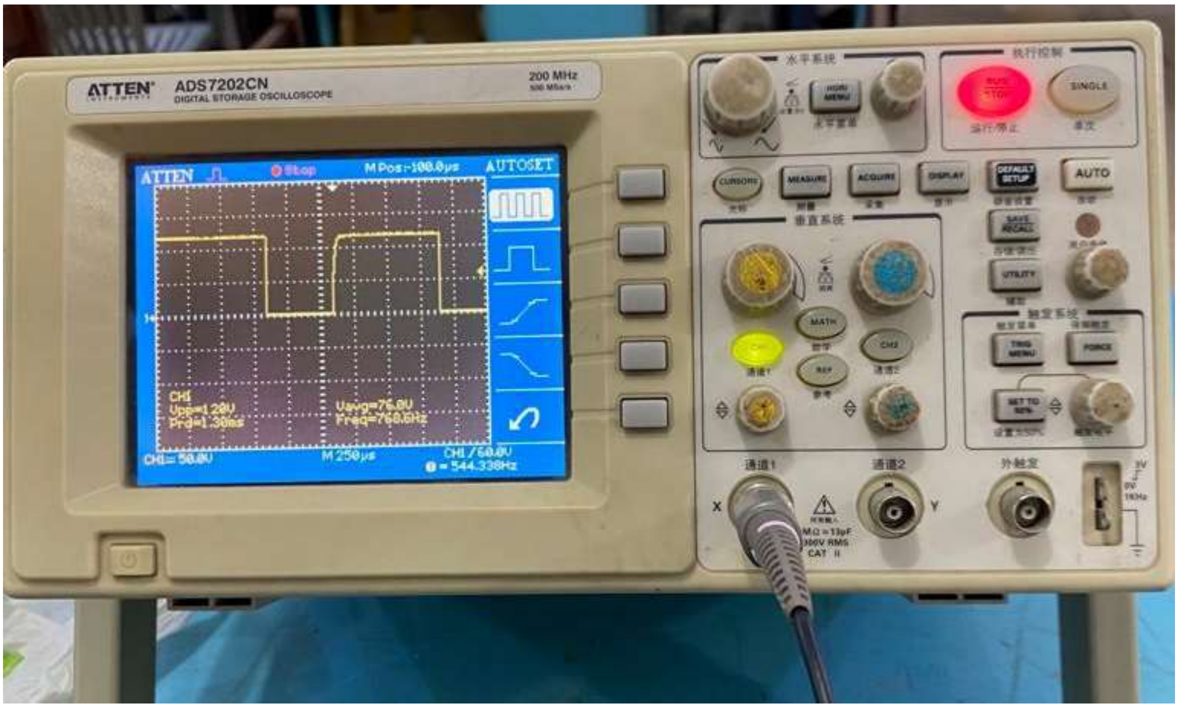


Figure 4. 6-6 oscilloscope result of gate waveforms

4.2 Three-Channel Circuit

Three Channel Circuit Controls Switch mode according to supply selected to charge, other features are to calculate battery percentage and monitor battery voltage efficiently and display important parameters on the infotainment system.

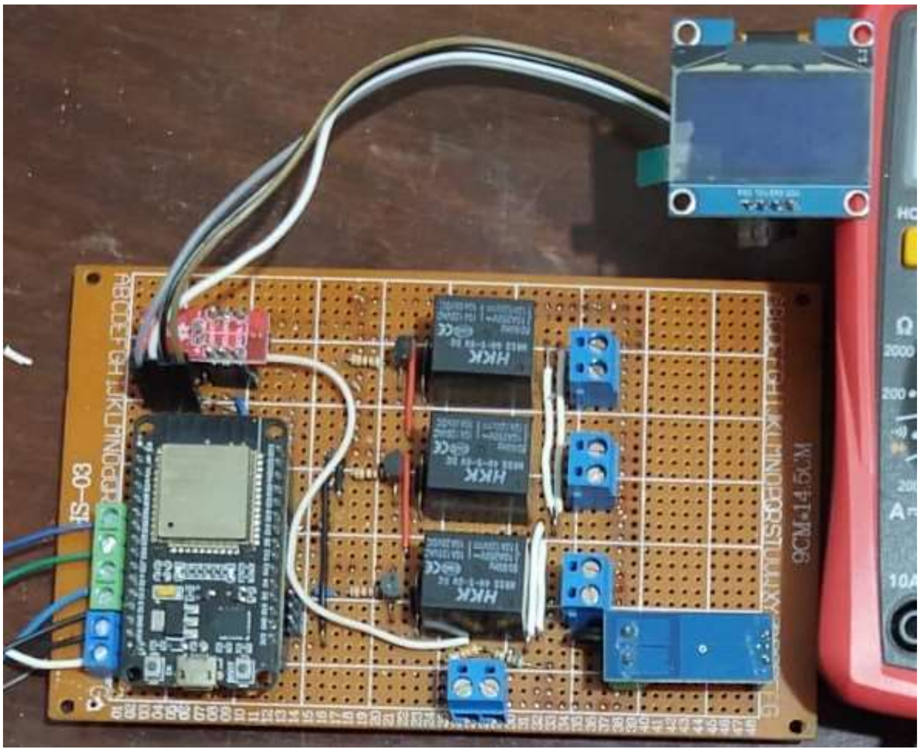


Figure 4. 6-7 Hardware for 3-channel

Simulation Results for switch mode three – channel circuit is shown below.

Simulation results for three channel circuit with basic functionality of switching.

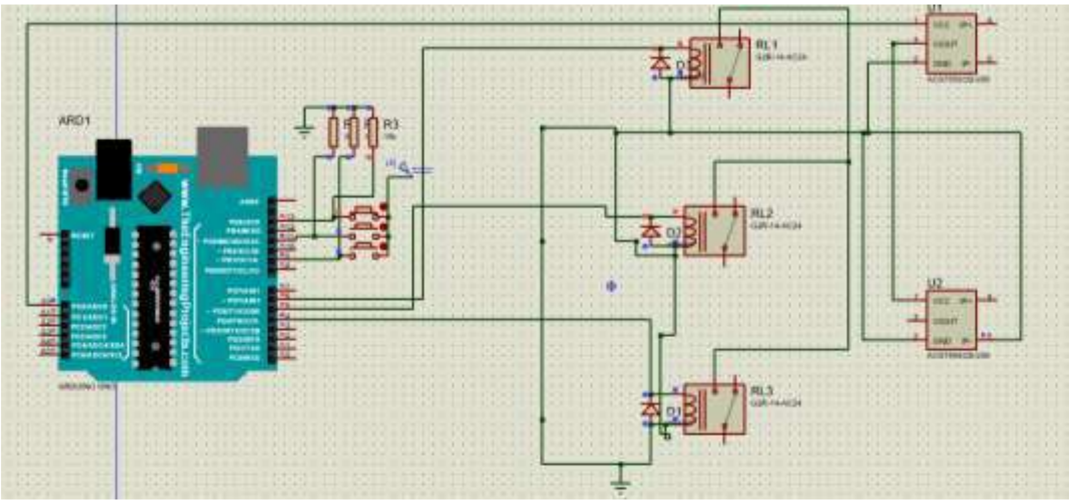


Figure 4. 6-8 Simulation

4.3 Results for Three-channel Circuit

Battery percentage and voltage shown in picture below with Mobile app infotainment system.

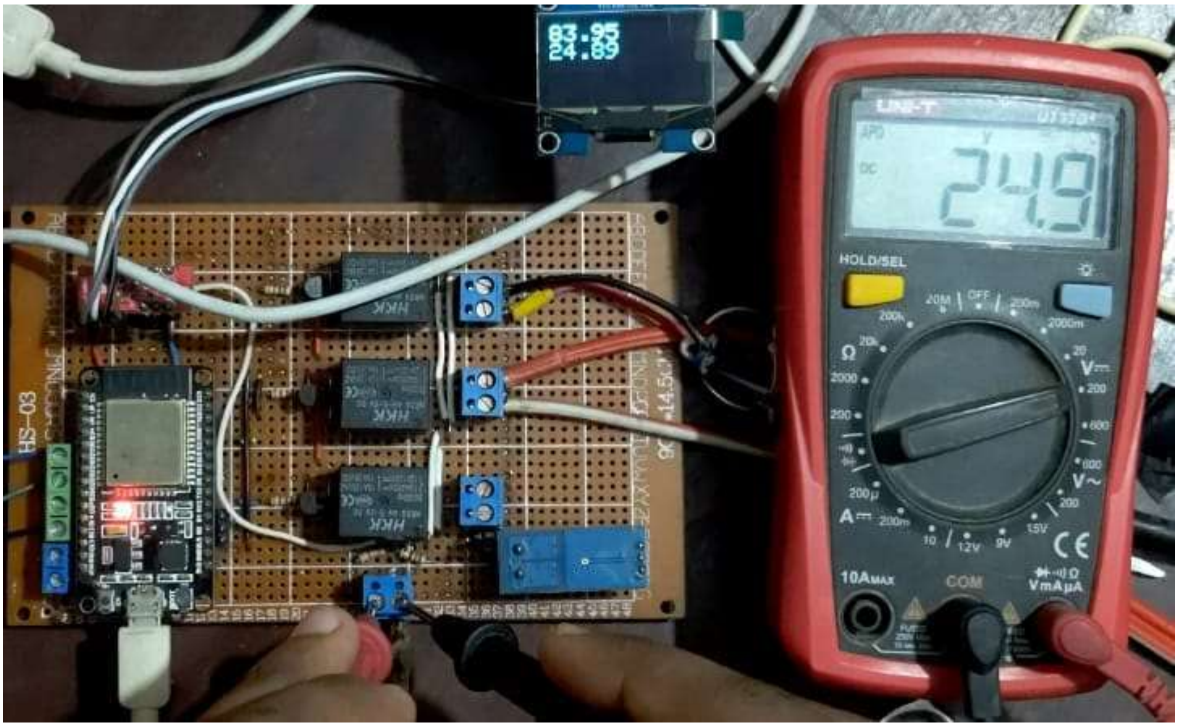


Figure 4. 6-9 Three Channel Results

Serial Port output for the above running firmware is shown below:

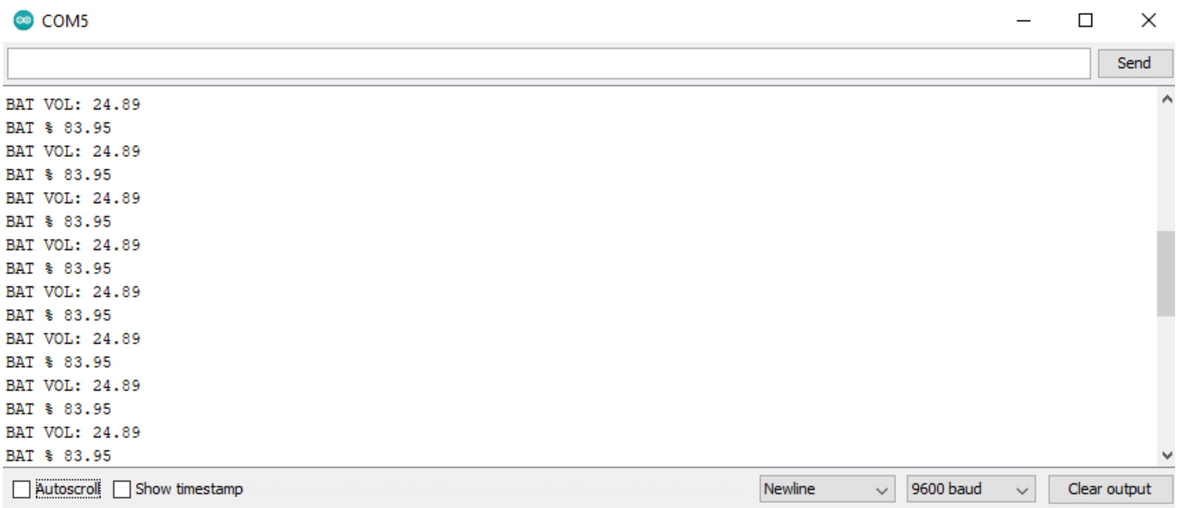


Figure 4. 6-10 Serial Monitor Output

4.4 Mobile Application

Mobile application is designed to control switch mode and monitor necessary parameters remotely.

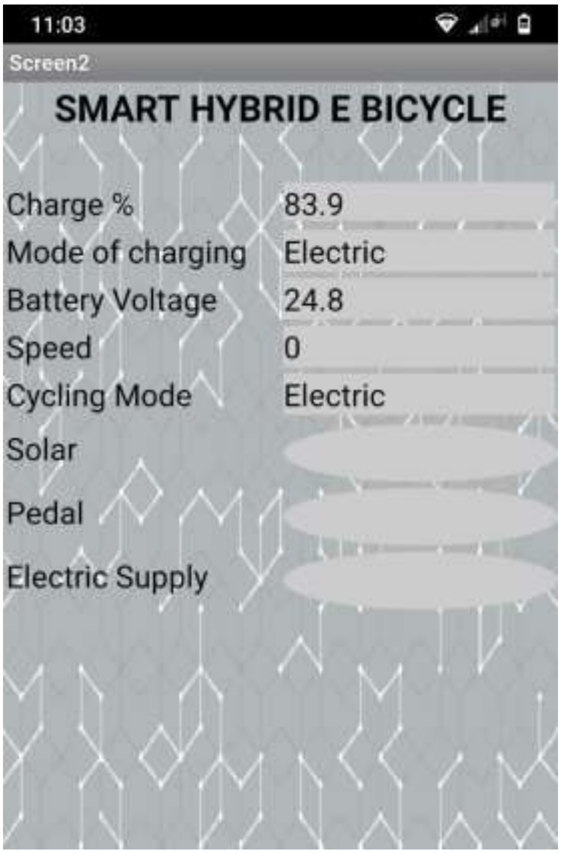


Figure 4. 6-11 Mobile App GUI

It is implemented through Firebase real-time database as shown below:

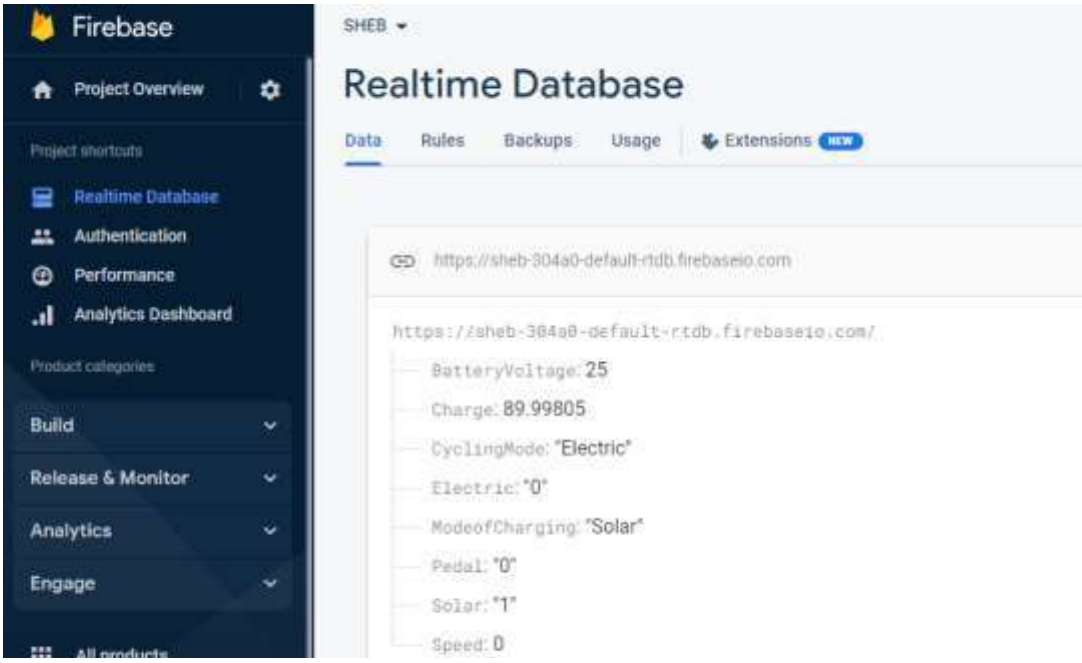


Figure 4. 6-12 Firebase Console

4.5 MPPT Charge Controller & Solar Configuration

Mppt charge controller was connected with 2s and 2p configuration from 4 12V 20watt panel, making it 24V 80Watt in terms of size. Solar panel are providing more than 40V on maximum irradiation, Oscilloscope analysis and initial testing of mppt output is shown below with Solar Configuration:

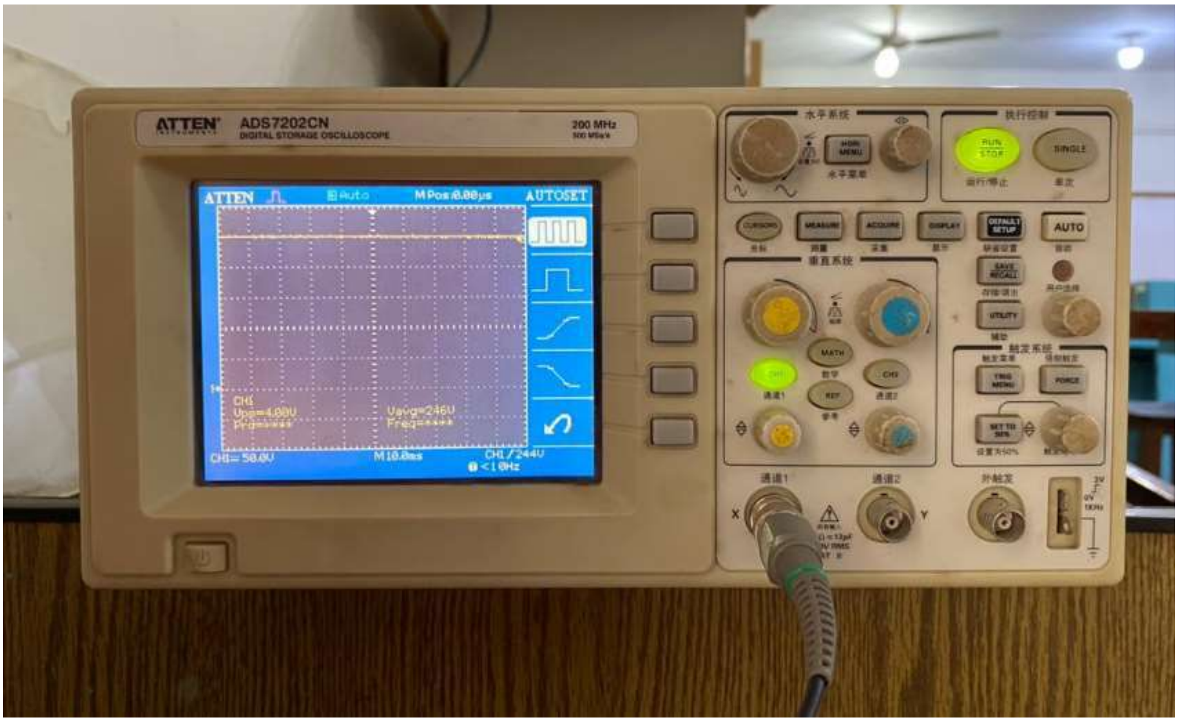


Figure 4. 6-13 MPPT Solar Charge

4.6 Overall Hardware

Overall Assembled hardware pictures are attached below, solar panel is detachable, it's frame can be attached and detached according to will.

Figure 4. 6-14 Assembled Hardware

CHAPTER FIVE

CONCLUSION

For the betterment of environmental and economic situation of the country our proposed idea is to design and develop a Low cost, reliable and economical electrical transport with a properly integrated charge control system to enhance the riding experience of the user by providing better performance with better distance range. Our focus is on using renewable and regenerative energy sources to create self-sustaining and reliable means of transportation through effective and productive strategies. We strive to provide a safe, healthy, and enjoyable travel experience for all. The proposed design will be based on standalone systems that can be used for different purposes and to make different versions with less or more features. By incorporating multiple power sources, this e-bicycle offers enhanced flexibility and reduced reliance on a single energy supply. The option to charge the battery from the power grid provides convenient charging capabilities at any location with electricity access. The integration of a solar panel presents an eco-friendly alternative, harnessing clean energy from the sun and minimizing dependence on non-renewable resources. Furthermore, the inclusion of pedaling as a power source not only promotes physical activity but also enables the rider to actively contribute to the battery's charging process. The integration of an MPPT controller plays a vital role in maximizing the efficiency of the solar charging system, optimizing power output from the solar panel and ensuring efficient utilization of available sunlight. This feature significantly enhances the overall energy efficiency of the e-bicycle, making it an environmentally conscious and cost-effective mode of transportation. Additionally, the custom-designed electronic speed controller offers precise speed control through a throttle mechanism, enhancing user experience and ensuring rider safety.

This smart hybrid e-bicycle, with its diversified power sources, efficient charging mechanisms, and user-friendly features, effectively addresses the crucial challenges of sustainable transportation. It contributes to reducing carbon emissions, promoting energy efficiency, and providing an affordable alternative to conventional transportation methods.

5.1 Future Works:

1. Battery Advancements: Investigate advanced battery technologies, such as solid-state batteries or improved Li-ion battery chemistries, to enhance energy density, battery life, and charging efficiency.

2. Power Generation and Harvesting: Explore additional renewable energy sources, such as wind energy, to diversify the e-bicycle's power generation capabilities. Study energy harvesting techniques to capture and utilize wasted energy from rider movements.

3. Smart Energy Management: Develop intelligent energy management algorithms and systems to optimize power allocation among different power sources, considering energy availability, efficiency, and user preferences.

4. Connectivity and Data Analysis: Integrate connectivity features to enable real-time monitoring and data analysis of the e-bicycle's performance, energy usage, and charging patterns. Utilize this data to gain insights for further optimization, predictive maintenance.

5. Lightweight Materials and Design: Explore the utilization of lightweight and sustainable materials in the e-bicycle's construction to reduce weight and increase energy efficiency. Investigate aerodynamic design enhancements to minimize air resistance and extend the e-bicycle's range.

6. Add GPS for Cycle Security and location tracking through GSM module.

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Appendix A

Code For ESC

```
#define Throttle A3
#define Pwm 3
#define Hall 8
#define test 13
#define ADC_AMP A5
#define Max 13
float getAnalogAmp();

void setup() {
Serial.begin(9600);
pinMode(Throttle,INPUT);
pinMode(Pwm,OUTPUT);
pinMode(Hall,INPUT);
pinMode(test,OUTPUT);
}
void loop() {
int Throttlee = analogRead(Throttle);
int pwm= map (Throttlee, 175, 880, 0, 255);
analogWrite(Pwm, 255-pwm);
Serial.println(255-pwm);
int hall=digitalRead(Hall);
Serial.println(hall);

if(hall==1){
  digitalWrite(Pwm,255);
  }
  else{
    digitalWrite(Pwm,0);
  }
int Amps= getAnalogAmp();
if (Amps> Max){
```

```
  digitalWrite(Pwm,255); //Stop motor
  }
}
float getAnalogAmp()
{
  //Measuring Current Using ACS712

  int   sampling = 250;

  double mVperAmp = 100; // use 185 for 5A Module, 100 for 20A Module, and 66 for
30A Module
  float ACSoffset = 2470.345;

  double RawValue = 0;
  double V = 0;
  double Amps = 0;

  for(int i=0; i<sampling; i++)
    {
    RawValue += analogRead(ADC_AMP);
    delay(1);
    }

  RawValue /= sampling;

  V = (RawValue / 1023.0) * 5000; // Gets you mV
  Amps = ((V - ACSoffset) / mVperAmp);

  Serial.print( "Amps:");
  Serial.println( Amps );
  return Amps;
}
```

Appendix B

Code For 3-Channel Circuit

```
#include <SPI.h>
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SH1106.h>
#include "MAX17043.h"

#include <WiFi.h>
#include <FirebaseESP32.h>
#include <ESP32Servo.h>
#define FIREBASE_HOST ""
#define FIREBASE_AUTH ""
#define ssid "" //Enter wifi name/ssid
#define password "" //Enter wifi password
FirebaseData Control1;
FirebaseData Control2;
FirebaseData Control3;
FirebaseData Monitor1;
FirebaseData Monitor2;
FirebaseData Monitor3;
FirebaseData Monitor4;
FirebaseData Monitor5;
FirebaseJson json;

#define Hall 32
#define Solar_Out 5
#define Pedal_Out 18
#define Electric_Out 23
#define Solar_In 12
#define Pedal_In 27
#define Electric_In 26
```

```
#define OLED_SDA 21
#define OLED_SCL 22

const float wheelDiameter = 0.5588; // in meters
const float wheelCircumference = wheelDiameter * 3.14159; // in meters

unsigned long lastTime;
unsigned long lastRevolution;
float currentSpeed;

Adafruit_SH1106 display(21, 22);

int hall_reads = 0;

#define ADC_AMP = 34;      // pin where the OUT pin from sensor is connected on
Arduino

void setup()   {
  Wire.begin();
Serial.begin(115200);
FuelGauge.begin();
 FuelGauge.reset();
 //FuelGauge.quickstart();
 delay(250);

  /* initialize OLED with I2C address 0x3C */
  display.begin(SH1106_SWITCHCAPVCC, 0x3C);
  display.clearDisplay();
  //delay(2000);
  pinMode(Hall, INPUT_PULLUP);
  lastTime = millis();
  lastRevolution = 0;
  currentSpeed = 0.0;
```

```
 pinMode(Hall,INPUT);
 pinMode(Solar_In,INPUT);
 pinMode(Pedal_In,INPUT);
 pinMode(Electric_In,INPUT);
 pinMode(Solar_Out,OUTPUT);
 pinMode(Electric_Out,OUTPUT);
 pinMode(Pedal_Out,OUTPUT);
}

void loop() {

  Serial.println("Loop start");

FuelGauge.wake();
FuelGauge.quickstart();
delay(100);

Serial.println(FuelGauge.adc());
Serial.println(FuelGauge.voltage());
  float volmv= FuelGauge.voltage();
  float vol= (volmv/1000);
  float comp=(vol*6);
  Serial.println(comp);
  float SOC= (FuelGauge.percent()/2);



//Serial.println(FuelGauge.compensation(), HEX);
delay(500);

  /* set text size, color, cursor position,
  set buffer with  Hello world and show off*/
  display.setTextSize(2);
  display.setTextColor(WHITE);
  display.setCursor(0,0);
```

```
  display.println(SOC);
display.println (comp);
  //display.display();

  delay(200);

  int Sol = digitalRead(Solar_In);
  int Ped = digitalRead(Pedal_In);
  int Elec = digitalRead(Electric_In);

    Firebase.getString(Control1,"/Electric/");
  Serial.println(Control1.stringData());
  String strVal1 =  Control1.stringData();
  int Elect=strVal1.toInt();

  Firebase.getString(Control2,"/Solar/");
  Serial.println(Control2.stringData());
  String strVal2 =  Control2.stringData();
  int Sola=strVal2.toInt();

  Firebase.getString(Control3,"/Pedal/");
  Serial.println(Control3.stringData());
  String strVal3 =  Control3.stringData();
  int Peda=strVal3.toInt();

  if (Sol == 1||Sola==1){
  digitalWrite(Solar_Out,HIGH);
  digitalWrite(Pedal_Out,LOW);
  digitalWrite(Electric_Out,LOW);
  }
  if (Ped == 1||Peda==1){
  digitalWrite(Solar_Out,LOW);
  digitalWrite(Pedal_Out,HIGH);
  digitalWrite(Electric_Out,LOW);
```

```
 //display.println("PEDAL");
 }
 if (Elec == 1||Elect==1){
 digitalWrite(Solar_Out,LOW);
 digitalWrite(Pedal_Out,LOW);
 digitalWrite(Electric_Out,HIGH);

  display.println("ELECTRIC");
  display.display();
 }
 int hallSensorValue = digitalRead(Hall);
 if (hallSensorValue == LOW) {
   lastRevolution++;
 }

 // calculate the speed once per second
 unsigned long currentTime = millis();
 if (currentTime - lastTime >= 1000) {
   float revolutionsPerSecond = (float)(lastRevolution) / (float)(currentTime - lastTime) *
1000.0;
   currentSpeed = (wheelCircumference * revolutionsPerSecond) / 60.0;
   lastTime = currentTime;
   lastRevolution = 0;

   Serial.print("Current speed: ");
   Serial.print(currentSpeed);
   Serial.println(" mph");

 }
display.clearDisplay();
float current = getAnalogAmp();
Serial.println(ADC_AMP);
display.println(ADC_AMP);
display.display();
```

```
Firebase.setInt(Monitor1, "/BatteryVoltage/", Comp);
Firebase.setInt(Monitor2, "/Charge/", SOC);
Firebase.setInt(Monitor3, "/CyclingMode/", CycMode);
Firebase.setInt(Monitor4, "/Speed/", currentSpeed);
Firebase.setInt(Monitor5, "/ModeofCharging/", Mode);
}

float getAnalogAmp()
{
  //Measuring Current Using ACS712
  int   sampling = 250;
  double mVperAmp = 185; // use 185 for 5A Module, 100 for 20A Module, and 66 for
30A Module
  float ACSoffset = 2470.345;

  double RawValue = 0;
  double V = 0;
  double Amps = 0;

  for(int i=0; i<sampling; i++)
    {
    RawValue += analogRead(ADC_AMP);
    delay(1);
    }

  RawValue /= sampling;

  V = (RawValue / 4069.0) * 5000; // Gets you mV
  Amps = ((V - ACSoffset) / mVperAmp);

  Serial.print( "Amps:");
  Serial.println( Amps );
  return Amps;
}
```

Appendix C

List of Components

List of Components:

Table 2.12 List of Components

S.No	Component Name
1	Atmega328pu Microcontroller
2	ESP32 NodeMCU
3	16 MHz Crystal Oscillator & 22pf Caps x2
4	IRZ44N N-channel MOSFETs
5	LM317
6	LM7805
7	BC547 Transistor npn
8	Electric Throttle
9	1N4007 Diode
10	1N5822 Schottky Diode
11	ACS712
12	Relays
13	Electric Throttle
14	1.3" OLED Screen
15	LED lights
16	Terminal Blocks
17	250Watt 24V DC geared motor
18	24V geared motor for regeneration
19	Boost Converter
20	general and 15A Switches
21	4x12V 20-Watt Solar panels (24V required)
22	MPPT Charge Controller
23	MAX17043 Battery Fuel Gauge
24	25.2V battery pack (48 Li-ion Cells)
25	6s 40A BMS
26	Heat Sink and Thermal paste
27	Heat shrink tube
28	Connecting Wires and 15A supported Wire
29	Freewheel Sprocket
30	Capacitors
31	Resistors

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