DESIGN OF A SOLAR-POWERED MINIATURE WATER SURFACE CLEANING ROBOT

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A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of B.Sc in EEE

Department of Electrical and Electronic engineering
Brac University
August, 2023

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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

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Ethics Statement

We hereby declare and affirm that this project, "Design of a Solar-Powered Miniature Water Surface Cleaning Robot," fulfills the requirements set forth for the final year design project (FYDP). It has been collaboratively developed by all members of our group, pooling our collective knowledge and skills. The project's analysis includes comprehensive supplementary resources, such as a thorough literature review and accurate data collection, all of which have been duly referenced. With the invaluable guidance of our mentors and the support of our university, we have successfully translated the project's concepts into practical implementation.

Abstract/ Executive Summary

According to study, there is a growing demand for solar-powered water surface cleaning robots that can effectively clean larger areas without being limited by battery life. Current water surface cleaning robots can be modified with various electrical mechanisms to enhance their cleaning capacity. Most users prefer a system that provides extended cleaning range while maintaining simplicity, without the need for additional attachments or complex setups. This paper aims to explore an efficient approach to implementing and regulating a solar-powered system for water surface cleaning robots. The objective is to develop a high-performing water surface cleaning robot with a solar-powered system that can be easily integrated into existing widely available conversion kits. This study aims to lay the groundwork for creating a more efficient and effective solution for water surface cleaning robots. By harnessing solar power, the robot's battery life and cleaning range can be significantly extended, allowing for longer and more thorough cleaning operations.

Keywords: DC Motor, Motor Driver, Servo Motor, Bluetooth Control Robot, Floating Waste, Water Pollution, Solar PV Array.

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Chapter 1: Introduction- [CO1, CO2, CO10]

1.1 Introduction

The rapid advancement of economies has not only enhanced the availability of daily necessities but has also resulted in a significant increase in the volume of domestic waste being produced [1][2]. In many developing nations, proper methods for recycling and waste management are still in their infancy, leading to haphazard disposal practices. Consequently, a substantial amount of this waste finds its way into water bodies. This discarded waste encompasses items such as plastic bags, plastic bottles, foam containers, and paper scraps, most of which consist of non-biodegradable synthetic materials.

In Bangladesh, the issue of maintaining clean water surfaces is of utmost importance, given the detrimental impact of pollution on the environment [3]. The buildup of dry garbage floating on the water surface can hamper water drainage in city canals and result in flooding. Therefore, it is necessary to clean the surface of the water frequently. To prevent the unwanted presence of disease, cleanliness in the water body is crucial. To pursue a sustainable water body, it is necessary to keep the water clean. As a result, the emergence of water surface cleaning robots has gained prominence. These robots offer a promising alternative for maintaining pristine water surfaces. They can navigate efficiently, powered by environmentally friendly technologies, and carry out cleaning operations without the need for harmful chemicals or detergents.

Our project aims to overcome water pollution and clean the water, which can be extremely beneficial to live beings. Also, if we use our project appropriately, it has the potential to become a significant security benefit. The boat is entirely powered by solar energy, which is completely free. This boat will not require any external energy supply, which saves money. During the day, the boat will store energy using the sun's rays that land on the solar panel, the boat will begin operating and collecting waste when necessary.

This paper introduces a solar-powered water surface cleaning robot designed to combat water pollution and contribute to environmental sustainability. The methodology employed in its development involved a comprehensive problem definition, literature review, and establishment of design specifications. The robot's architecture includes a solar power generation system, cleaning mechanism, and thin foldable robotic forearm. Findings from experimentation demonstrated the robot's efficient cleaning performance, its effective utilization of solar energy, and its navigation capabilities in various water pollution scenarios. Conflicting requirements emerged concerning speed versus efficiency, cost versus performance, durability versus weight, and versatility versus specialization. Striking a balance between these requirements proved crucial in optimizing the robot's design and effectiveness. In conclusion, this solar-powered water surface cleaning robot holds promise as an innovative and environmentally friendly solution to address water pollution, and further research could refine its capabilities and broaden its potential applications.

By employing such robots, Bangladesh can effectively tackle the issue of water pollution caused by transportation activities, leading to cleaner and healthier water bodies for the benefit of both the environment and the population.

1.1.1 Problem Statement

Nowadays, we notice a lot of rubbish floating on the river, which pollutes the water and obstructs the flow of water [4]. Waste is an ongoing environmental problem that hasn't yet been adequately tackled. We frequently discovered trash dumped into rivers, streams, or reservoirs from various locations. The buildup of dry garbage floating on the river's surface can hamper water drainage in city canals and result in flooding. Therefore, it is necessary to clean the surface of the water frequently.

The goal is to create technology that can operate in water areas and offer an alternative solution to the issue of garbage in water areas. The planned applied research is anticipated to provide an alternate means of catastrophe prevention, particularly for floods. Wastes were previously cleaned by humans, which required a lot of labor, and in some portions, it was tough for humans to reach the wastes where they were stored. In almost every area in our country, these wastes were cleaned by humans, but different developed countries are now using robots to clean those wastes. To solve this problem in our country, we are designing a robot that can clean all the floating waste. It will be environment-friendly, low in cost, and can be controlled by a single person by remote control.

A water surface cleaning robot could be a solution to cleaning waste that is floating on water rather than human labor [5]. As Bangladesh is a land of rivers, this robot would help to keep those water bodies clean. These functions may save a lot of human effort and provide a sustainable solution to the pervasive problem. We should concentrate more on producing this kind of robot in our country, which can significantly lower the cost of the robot while maintaining a high level of functionality.

1.1.2 Background Study

In the present era, the concern for quick and cost-effective services has become a priority for people. Unfortunately, the issue of pollution in water, characterized by floating rubbish and obstructed water flow, has caught our attention [6]. To address this problem effectively while minimizing costs and water waste, a project involving a water-cleaning robot has emerged as a fitting solution. This robot is designed to remove floating waste from water bodies without causing harm, thereby promoting cost savings and preserving the invaluable resource of clean water.

The significance of clean water cannot be overstated, as it is essential for all living beings. However, human activities have resulted in the pollution of lakes and rivers. Our project aims to combat water pollution and clean the water, benefiting all forms of life. Furthermore, if appropriately implemented, this project holds the potential to provide significant security benefits. The robot operates solely on solar energy, harnessing the freely available power of the sun. With no need for external energy sources, this boat not only saves money but also contributes to a sustainable and eco-friendly approach.

The boat efficiently stores solar energy during the day through its solar panels, enabling it to operate and collect waste whenever necessary. The issue of waste remains an ongoing environmental concern, with trash being indiscriminately dumped into rivers, streams, and reservoirs from various sources. The accumulation of solid waste on the water's surface hampers water drainage in urban canals, leading to flooding. Regular cleaning of the water surface is therefore crucial to prevent the spread of diseases and maintain a sustainable water ecosystem.

Our robot is an integral part of the ongoing USAID program called Nobo Jatra, which envisions a world where every child grows up in communities with access to clean water, free from need and full of promise. Clean water is recognized as a fundamental human right, and Bangladesh has made significant progress in achieving universal access to improved water sources [7]. This research aims to provide an alternative solution to the waste problem in water areas through the development of robotics technology capable of operating in aquatic environments.

To achieve this goal, we have adopted the ADDIE approach, involving the analysis, design, construction, implementation, and evaluation of the robotic cleaning system. Various researchers have already conducted numerous studies on robots designed to clean the water surface [8],[9]. This project aims to create a more versatile and efficient system by utilizing an aqua robot with the potential to expand its capabilities in the future.

The robot's functionalities are diverse and include the removal of algae, leaves, and debris, spraying targeted pesticides, testing water quality, and transporting cargo autonomously. These functions not

only reduce the need for human labor but also provide a long-term solution to the widespread problem of water pollution. Although well-designed algorithms for ground navigation and waste collection already exist for land-based robots and swarms [10], applying them directly to aquatic surfaces poses challenges due to the dynamic environment, propulsion systems, and the precise determination of the robot's position based on relative velocity and acceleration.
Before proposing our own solution, it is essential to review existing research and work in the field. Numerous prototypes of water trash collecting systems, autonomous robots, and waste processing technologies have been developed. For instance, wireless communication-based water surface robots [11], remotely controlled river cleaning devices [12], and systems utilizing proximity sensors or image processing methods for trash detection have been explored [13]. Additionally, devices employing water wheel-driven conveyor mechanisms [14] and controllers with Wi-Fi modules for wireless control [15] have been developed.
The aforementioned studies provide valuable insights into the field and the challenges associated with water cleaning. Our technology aims to overcome these obstacles by combining features and mechanisms from different industries into one compact, cost-effective, and scalable system. By incorporating various sensors and mechanisms, we can maintain the cleanliness of water bodies more effectively and efficiently.
Overall, our project endeavors to address the pressing issue of water pollution by developing a state-of-the-art robotics technology specifically designed for water areas. By employing an eco-friendly and solar-powered cleaning robot, we aim to create a sustainable solution that reduces costs, minimizes water waste, and safeguards the availability of clean water for all living beings.

1.1.3 Literature Gap

The background research conducted for the development of water surface cleaning robots reveals substantial gaps in the current literature. The need for advancements in the entire system, including customizable features, is evident. Key areas lacking in research include optimization techniques for the cleaning mechanism, increasing cleaning speed and coverage area, reducing the size and weight of the robot, integrating intelligent navigation and obstacle avoidance systems, and improving water filtration and purification capabilities [16]. These gaps hinder the maneuverability, efficiency, and overall effectiveness of water surface cleaning robots. Addressing these gaps through further research and innovation will contribute to the advancement and feasibility of these robots, leading to more efficient and sustainable water maintenance practices [17].

1.1.4 Relevance to Current and Future Industry

Future research in water surface cleaning robots should prioritize real-world data collection to overcome the limitations of laboratory experiments.

Integration of advanced algorithms, such as machine learning or artificial intelligence, can optimize decision-making and adaptability to varying water conditions, debris types, and real-time sensor feedback. Specialized water quality sensors will enhance the robots' ability to assess pH levels, dissolved oxygen, and pollutant concentrations, enabling targeted cleaning strategies[18]. Exploring alternative propulsion systems, like thrusters or water-jet propulsion, improves maneuverability in challenging water conditions and enhances access to difficult-to-reach areas[19]. Lightweight and corrosion-resistant materials will enhance energy efficiency and durability.

To drive adoption, understanding market demands and forming partnerships with stakeholders are crucial. Demonstrating cost-effectiveness, efficiency, and environmental benefits will encourage implementation in diverse water maintenance applications.

In summary, future research should focus on real-world data, advanced algorithms, specialized sensors, alternative propulsion, and material improvements, to develop efficient and commercially viable water surface cleaning robots that contribute to sustainable water maintenance practices

1.2 Objectives, Requirements, Specification and Constraints

1.2.1. Objectives

In the face of the modern world's challenges, it has become evident that the existing and future issues of pollution demand high-technology solutions. One of the critical areas in need of attention is the cleaning and preservation of our water bodies. In this regard, the development of a technologically advanced water surface cleaning robot emerges as the ideal solution. This essay aims to highlight the goals that can drive the creation of such a robot, emphasizing its potential to revolutionize water body maintenance.

- Designing an efficient and versatile water surface cleaning robot.
- Fabricating a robust and durable mechanical design.
- Implementing a cost-effective system to address pollution and congestion.

1.2.2 Functional and Nonfunctional Requirements

Functional Requirements:

Ability to Navigate: The robot is able to navigate across the water surface and can reach the areas that require cleaning.

Cleaning Mechanism: The robot has a cleaning mechanism that can effectively remove bottles, debris, and other solid floating pollutants from the water surface. Here we use foldable robotic forearms and nets to collect the waste.

Power Source: The robot has a proper power source that can provide sufficient power to operate for a prolonged period of time without needing frequent recharging or refueling and we also have a backup battery for emergencies.

Durability: Our robot is durable and capable of withstanding harsh weather conditions, high water turbulence, and other environmental challenges.

Remote Control: The robot is controlled remotely to adjust its cleaning speed, direction, and other parameters.

Maintenance: This robot is easy to maintain, with replaceable parts and they are low in cost.

Non Functional Requirement:

Reliability: Our robot is reliable, with minimal downtime and a low probability of failures or malfunctions during operation.

Speed and Efficiency: The robot is fast and efficient in cleaning the water surface, with a high cleaning rate and coverage.

Noise Level: This robot produces minimal noise during operation to avoid disturbing nearby residents or wildlife.

Size and Weight: The robot is compact and lightweight, to facilitate transportation and deployment on various water bodies.

User-friendly Interface: This robot has a user-friendly interface for easy operation and monitoring.

Sustainability: The robot is designed with sustainable materials and technologies, with minimal environmental impact.

Interoperability: The robot is able to integrate with other systems and technologies, to enable effective data sharing and analysis.

Cost: The robot is cost-effective, with a reasonable price point that reflects its value and capabilities.

Safety: The robot is designed with safety features to prevent accidents and ensure the safety of nearby people and animals. It should also be able to detect and avoid any dangerous substances or situations in the water.

1.2.3 Specifications

System Level:

Every design project must always meet the demands and requirements identified by the user or other stakeholders.So we have designed this robot in such a way that this robot can meet all the needs of its stake holders.The robot is designed in such a way that it is compact in size and can move very easily in water surface. The robot is designed with low maintenance requirements and is tough enough to endure exposure to water and other factors.It costs less to manufacture and also the maintenance cost is low too.

Table 1: Table of System level requirements from existing work done in this area.

System Level	Specifications
Size and Design	The robot is designed in such a way that it is compact and can move easily on the water surface. The size of the robot is such that it can clean large areas of the water surface in a reasonable amount of time. The robot has a dimension of "609.6 × 482.6 × 254 mm".
Maneuverability	The robot is capable of moving in all directions, including forward, backward, left, and right, to cover the entire water surface.
Maintenance and Durability	The robot is designed to require minimal maintenance and be durable enough to withstand exposure to water and other elements.

Cost-effectiveness	The robot is designed in such a way that it is cost-effective to manufacture and maintain, while still being effective in cleaning the water surface.
Power Requirement	Based on the hypothetical values, the total power consumption can be 24 Watts
Operating Time	After going through an estimate calculation a 4500mAh 11.1V 3S Li-Po battery, can potentially operate the robot for approximately 1.5 hours on a full charge. It will increase as the solar is contentiously charging the battery.

Table 2: Table of System level requirements from stakeholder

System Level	**Specifications**
Power Source	The robot has a reliable and efficient power source that can sustain its operation for a reasonable amount of time.
Cleaning Mechanism	The robot has an efficient cleaning mechanism such as a conveyor belt, thin foldable robotic forearm or front scooper, side scooper that can remove debris, dirt, and other contaminants from the water surface.
Communication System	The robot is able to communicate with the user or operator through the Bluetooth module, providing real-time feedback on its cleaning progress and any issues that may arise.
Controller	HC-05 bluetooth module is used here so that anyone with minimum knowledge about electric vehicles can run it. It requires no internet connection or any other additional support

Component Level:

Table3: Table of Component level specification and descriptions

Components	Model	Component Description	Specification
Solar Panel	30 Watt Solar Panel Poly	Charges the DC battery to power up the robot	**Output power**: 30 watt **Material:** Polycrystalline silicon **Voltage:** 12V **Dimension:** 21.5 x 13.4 x 1.1 inches
Solar Panel Charge Controller	MPPT Solar Charge Controller	Maximize the power output from the solar panel under varying environmental conditions.	**Module Properties:** Non-isolated buck module (BUCK) **Input voltage:** 6-36V **Output voltage:** 1.25-32V continuously adjustable (the default output 5V) MPPT voltage setting range: 6-36V **Output current range:** 0.05-5A (The default output current is 3A) Operating temperature: -40 ~ + 85 degree **Operating frequency:** 180KHz Conversion efficiency: up to 95% (efficiency, input & output voltage, current and pressure-related) **Short circuit protection**: Yes **Over temperature protection:** (automatically shut off the output after overtemperature) Module dimensions:60 x 31 x 22 mm(without meter)

Li-Po Battery	4500mAh 11.1V 3S	Receive charge from solar panel and power the whole robot	**Weight :** 182 gm **Voltage:** 11.1V **Capacity:** 4500mAh **Cell Type**: Li-polymer **Configurations:** 3S **Continuous Discharge Rate:** 25C **Max Burst Rate:** 90C **Discharge(Output) Lead:** T Plug **Connector** **Charging(Balancing) Lead: JST-XHR** **Wire Length:** 100mm **Operating Temperature Range:** -20℃to 60℃ **PVC color:** Silver and Black
Gear Motor	12V Gear Motor High Torque 1000 RPM	Gear motor will be connected to propellers. It is designed to generate a high amount of thrust, pushing water behind the vehicle or device and propelling it forward	**Voltage**: 12V **No- Load Current**: 0.2A **Full Load Current**: 1.2A **Rated RPM**: 1000 **Full (Stall) Load Torque**: 20 Kg-cm **Size**:Motor length 84mm , Body diameter 37mm, Shaft diameter: 6mm, Shaft length: 30mm
Propellers	Gemfan 8045 Carbon Nylon Propeller	The propeller works by displacing the water pulling it behind itself, this movement of water then results in the vehicle or device being pushed forward from the resulting pressure difference	**Length**: 8 inch **Pitch**: 4.5 inch **No. of Blades**: 2 **Shaft Diameter**: 905mm **Weight**: 18gm

Processing unit	Arduino Nano R3	The Arduino Nano is a microcontroller board based on the Atmega328P microcontroller. Capable to process data with digital I/O and analog data reading capability	**Micro-controller :** ATmega328P. **Operating Voltage** : 5V. **Input Voltage (recommended)** : 7-12V. **Digital I/O Pins** : 14 (of which 6 provide PWM output). **Analog Input Pins** : 6. **Clock Speed**: 16 MHz **SRAM**: 2 **EEPROM**: 1kb(ATmega328) Flash Memory: 32 kb
Bluetooth module	HC-05	The HC05 bluetooth module is a UART serial converter module that can simply send UART data over wireless bluetooth.	**Frequency Range:** 2.4 GHz ISM band **Operating Voltage:** 3.3 V **Operating Current:** 50 mA **Speed:** Speed: Asynchronous: 2.1Mbps(Max) / 160 kbps, **Synchronous:** 1Mbps/1Mbps
Servo Motor	MG996R 10kg Servo	It will be connected to the rudder. It will control the direction of the robot	**Operating Voltage (VDC)**: 4.8 ~ 6.6 **Gear Type**: Metal gear **Stall Torque @ 4.8V (Kg-Cm)**: 9.4 **Stall Torque @6.6V (Kg-Cm)**: 11 **No. of teeth**: 25 **Dimension**: Length 40.7mm, Width 19.7, Height 42.9, Weight 55gm

1.2.4 Technical and Non-technical Consideration and Constraints in Design Process

1. Short Life Span: As the robot will operate on water, water may damage the electrical elements if it enters the sealed box. Rust will also be an issue to reduce the lifespan. The estimated average lifespan of a water-cleaning robot is 4-5 years.

2. Load Carrying: As it is a miniature water cleaning robot, it cannot carry more waste. Users need to frequently unload the waste. This will consume more time and labor.

3. Fear of Drowning: As it is a miniature water-cleaning robot, it may not handle the extreme wave of water. In that case, the robot may sink into the water. Side by side, if the robot gathers extra load, then its capacity and water wave are present, and the robot may have the possibility to sink.

1.2.5 Applicable compliance, standards, and codes

• International Organization For Standardization: ISO 13849-1:2015 provides safety requirements and guidance on the principles for the design and integration of safety-related parts of control systems (SRP/CS), including the design of the software.

• IEEE 1872.2-2021

IEEE Standard for Autonomous Robotics (AuR) Ontology

This standard extends IEEE Std 1872-2015, IEEE Standard for Ontologies for Robotics and Automation, to represent additional domain-specific concepts, definitions, and axioms commonly used in Autonomous Robotics (AuR). This standard is generic and can be used in many ways--for example, to specify the domain knowledge needed to unambiguously describe the design patterns of AuR systems; to represent AuR system architectures in a unified way; or as a guideline to build autonomous systems consisting of robots operating in various environments

• IEEE 2700-2017

IEEE Standard for Sensor Performance Parameter Definitions

A common framework for sensor performance specification terminology, units, conditions, and limits is provided. Specifically, the accelerometer, magnetometer, gyrometer/ gyroscope, accelerometer/magnetometer/gyroscope combination sensors, barometer/pressure sensors, hygrometer/humidity sensors, temperature sensors, light sensors (ambient and RGB), and proximity sensors are discussed.

• EN(European Norm)Standard

EN 60500 Underwater acoustics - Hydrophones - Properties of hydrophones in the frequency range 1 Hz to 500 kHz - IEC 60500:2017 specifies the relevant characteristics and properties of hydrophones in the frequency range 1 Hz to 500 kHz and specifies how to report these characteristics. Provides guidance on the choice of a hydrophone with appropriate performance for a specific application.

1.3 Systematic Overview/summary of the Proposed Project

After conducting a literature review and considering the stakeholders' requirements, we have determined that our system for the solar-powered water surface cleaning robot should be based on a regenerative energy harvesting mechanism. This approach proves effective in enhancing the robot's dynamics and extending battery life. Our solar-powered water surface cleaning robot is designed to efficiently clean and maintain the cleanliness of water bodies while utilizing gear motor and a sustainable power source. The robot incorporates solar energy to power its operations and employs advanced cleaning mechanisms to remove debris, pollutants, and contaminants from water surfaces.

Key Points:

Drivetrain of the Robot: The drivetrain of our robot consists of a DC motor integrated into the system, which drives the cleaning mechanisms and propels the robot across the water surface. By using a direct drive system, we eliminate the need for a braking mechanism and reduce friction losses that could occur with additional components.

Power Source: The main power source for our robot is a solar panel system. We utilize a photovoltaic (PV) panel with an output of approximately 300W-350W to harness solar energy. The solar panel charges a battery that powers the DC motor and other components of the robot, ensuring continuous operation even during periods of limited sunlight.

Cleaning Mechanisms: Our robot is equipped with advanced cleaning mechanisms specifically designed for efficient water surface cleaning. These mechanisms, driven by the DC motor, remove debris, pollutants, and contaminants from the water surface, helping to maintain the cleanliness and ecological balance of the water body.

Control Unit: The control unit serves as the central system for managing the robot's operations. It coordinates the movements of the DC motor, monitors the battery level, and controls the cleaning mechanisms. The control unit ensures optimal performance and efficiency, while also providing safety features and protection against potential hazards.

Efficiency and Sustainability: By harnessing solar power as the primary energy source, the robot operates in an energy-efficient and sustainable manner. The use of renewable energy reduces reliance on conventional power sources and minimizes environmental impact. Additionally, the robot's efficient cleaning mechanisms optimize water surface cleaning while conserving energy and maximizing battery life.

By utilizing a DC motor and a solar power source, our solar powered miniature water surface cleaning robot offers an eco-friendly and sustainable solution for maintaining clean water ecosystems.

1.4 Conclusion

The goal of this design is to create a water surface cleaning robot that is specifically optimized for efficient operation in various aquatic environments. The significance of this system lies in the development of a versatile and cost-effective control circuit, while incorporating advanced cleaning capabilities for effective water surface cleaning. By integrating cutting-edge technology and innovative cleaning mechanisms, the design aims to enhance the robot's adaptability and cleaning efficiency. Specialized features such as water quality sensors and targeted cleaning strategies ensure the robot can detect and remove contaminants, contributing to improved water cleanliness and environmental sustainability. The emphasis on adaptability and cost-effectiveness underscores the intention to create a design that can easily integrate into existing water maintenance systems, making it a practical solution for a wide range of applications. Overall, this design concept addresses the need for effective water surface cleaning and has the potential to significantly contribute to sustainable water management practices.

Chapter 2: Project Design Approach [CO5, CO6]

2.1 Introduction:

This chapter's main focus is on outlining the various techniques we'll take to our suggested project. The system's workflow describes the overarching concept of how the system will behave in various scenarios. Additionally, this section discusses the features and specifications of the entire system. The methods chosen will depend on the conditions, guidelines, and restrictions.

2.2 Identify Multiple Design Approach

2.2.1 Design Approach 01

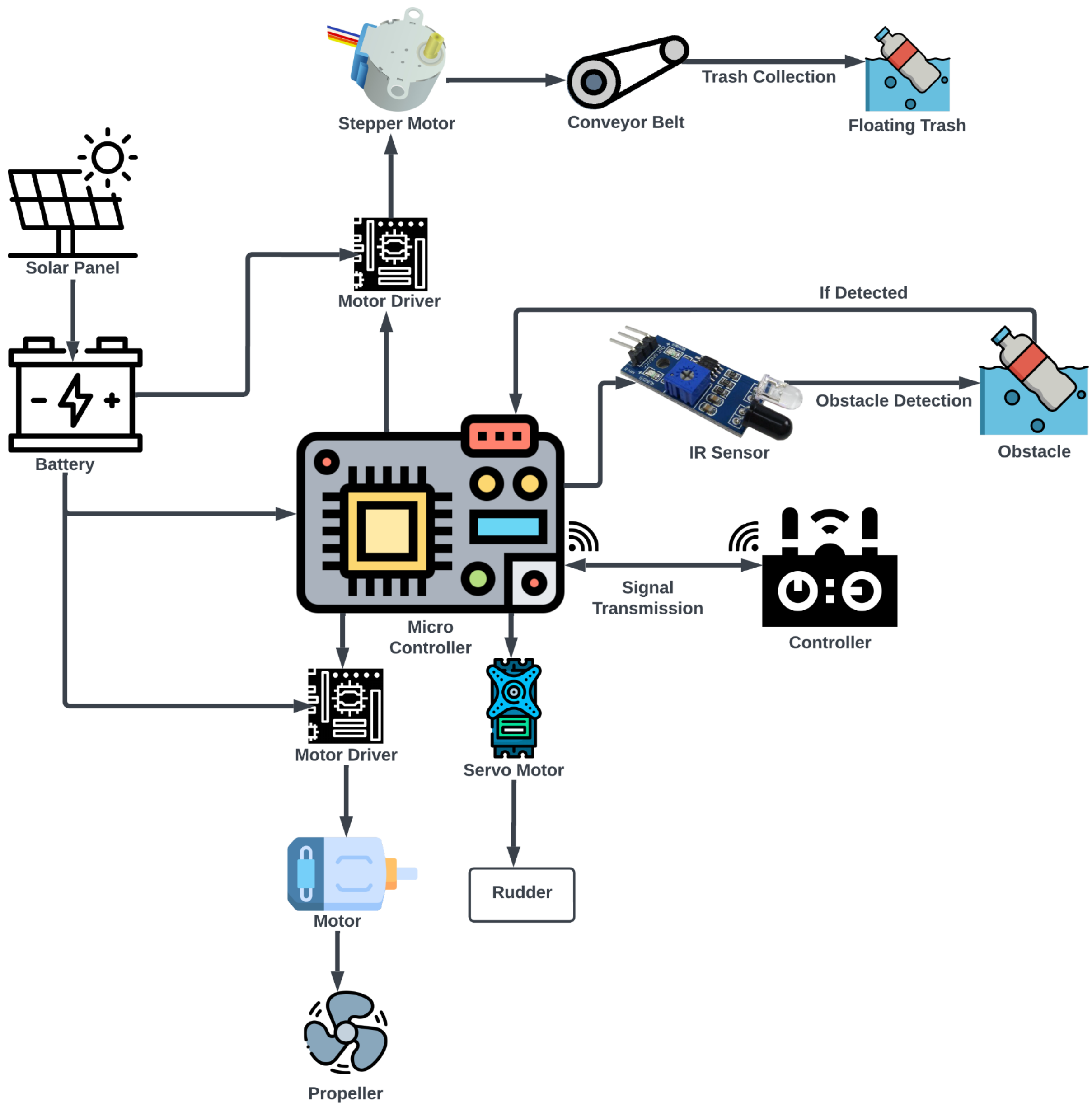

Figure 1: Block Diagram of Design Approach 01

●Use of conveyor belt
●Used solar panel to power the battery
●Semi-automatic system
●No GPS tracking system is available
●Motors & Motor Drivers

2.2.2 Design Approach 02

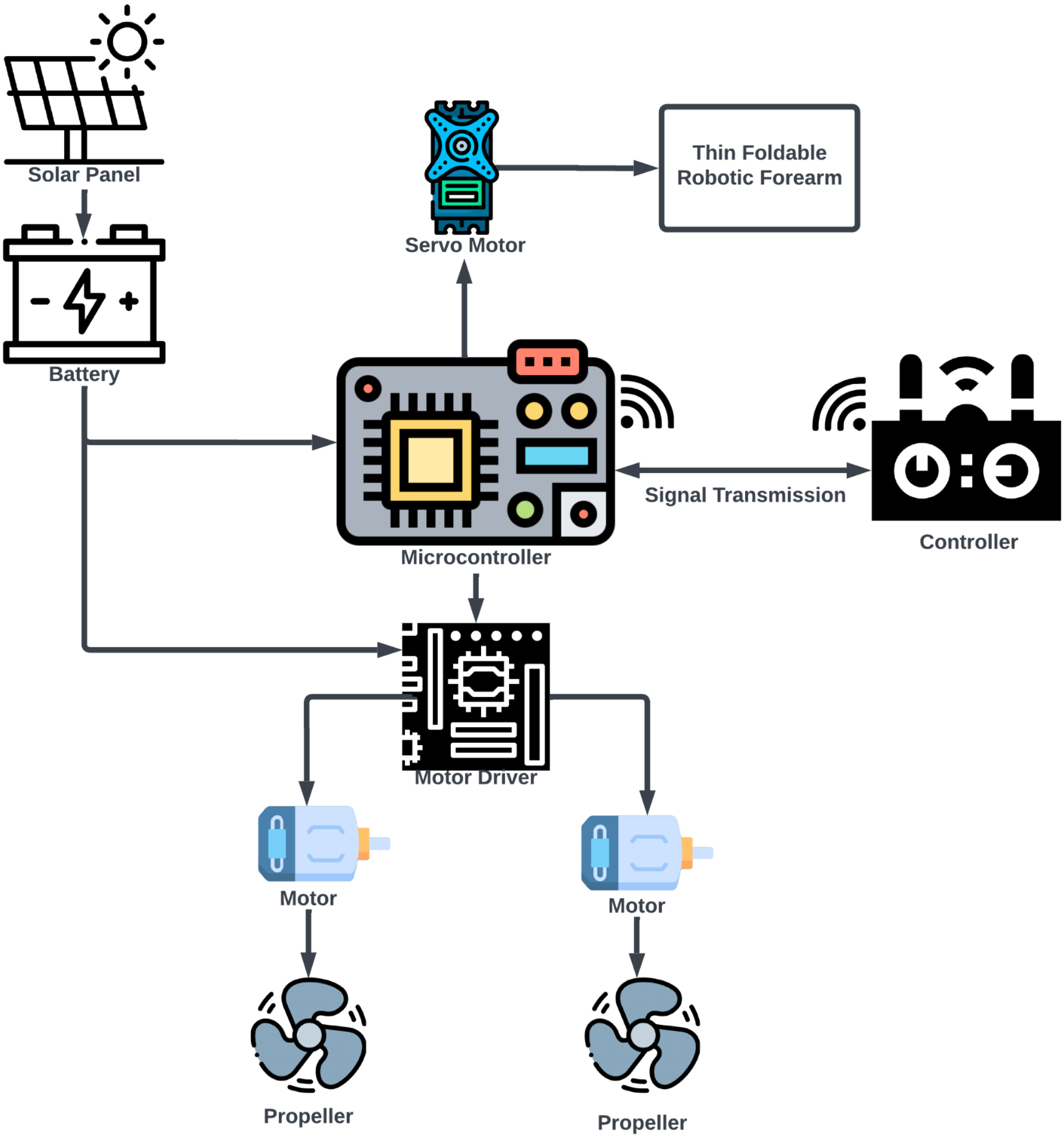

Figure 2: Block Diagram of Design Approach 02

- Use of Thin Robotic Forearm
- Usage of Bluetooth Module
- Use of Solar Panel to Power The Battery
- Motors & Motor Drivers

2.2.3 Design Approach 03

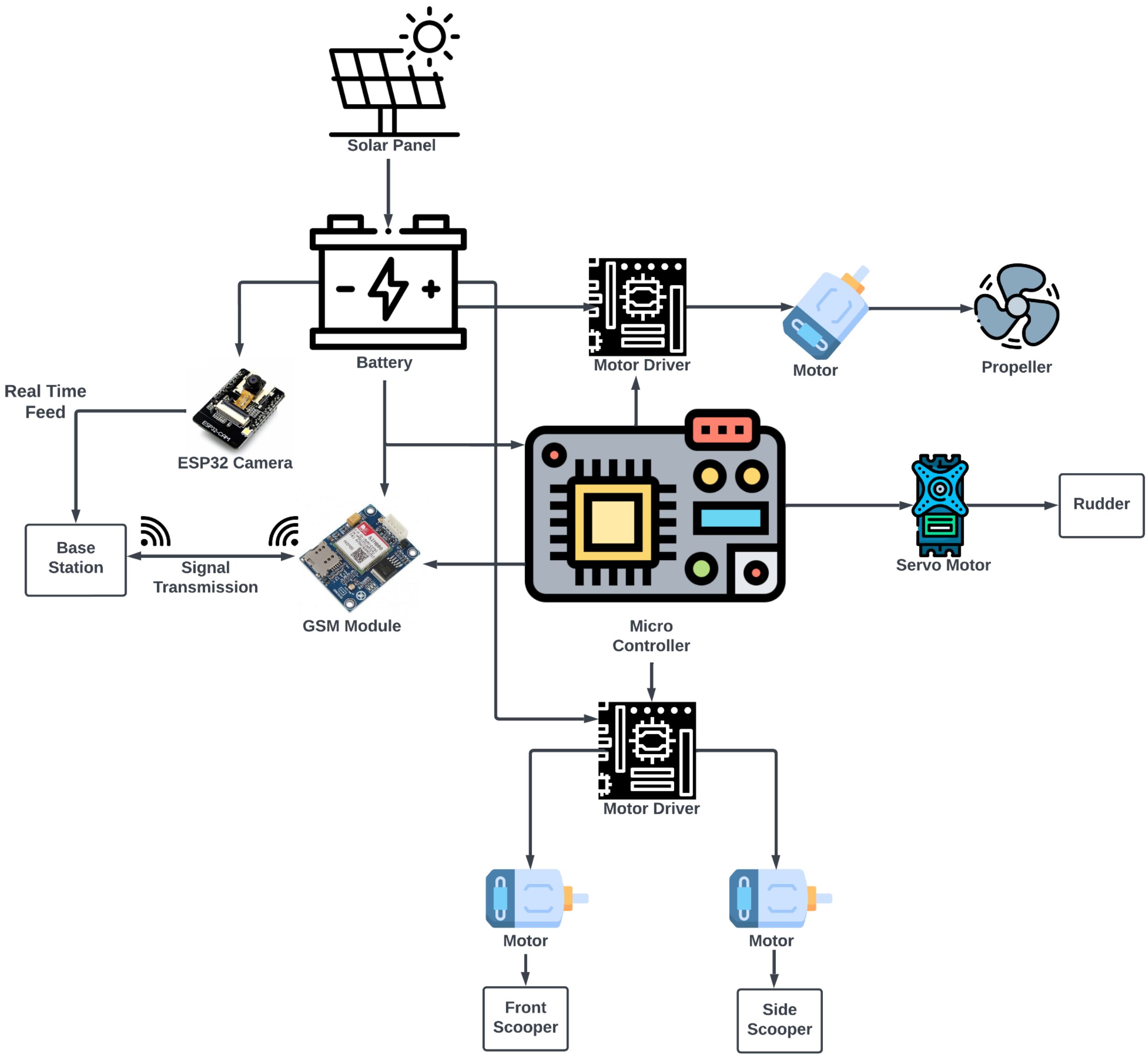

Figure 3: Block Diagram of Design Approach 03

- GSM Based Controlling Unit
- Location Tracking Available
- Availability of Bluetooth Camera for Real Time Feedback
- Usage of Front Scooper & Side Scooper
- Motors & Motor Drivers

2.3 Describe Multiple Design Approach

2.3.1 Design Approach 01

In our initial strategy, we'll try to create a robot that runs on solar power to clear up floating rubbish on the water's surface. The solar panel will be used to recharge the battery. A microcontroller will be mounted on the robot's upper deck. To control the robot, a microcontroller will be coupled with an RC transmitter and receiver module. The microcontroller will send a signal to the motor through the motor driver. The motor will have propellers attached, the motor's speed will be controlled by RC remote.

To identify obstructions in front of our robot, we will employ an IR sensor. In order to clean the water surface, we will first manually operate our robot using an RC controller close to the intended cleaning region. The IR sensor will then detect any floating wastes in the vicinity of our robot and send a signal to the microcontroller. The conveyor belt motor will then get a signal from the microcontroller via the motor driver and begin to operate, automatically collecting the floating debris.

2.3.2 Design Approach 02

In our second design strategy, two hulls in the shape of cylinders will be constructed, and a deck will be added on top. On top of that deck, solar panels, batteries, and the robot's control system will be installed. Thin foldable robotic forearm will be installed in front of the trash cage that will be mounted underneath the deck. The forearm will be close as soon as floating rubbish enters the cage. A microcontroller will be utilized in conjunction with a bluetooth module and receiver module to control the robot. Through the motor driver, the microcontroller will transmit a signal to the motor. Propellers will be attached to the motor, and a bluetooth module will control the motor's speed.

2.3.3 Design Approach 03

In our third strategy, we'll use GSM module data transmission to control the robot from our ground station. The ground station sends the order to the GSM module. The microcontroller will operate the motor in accordance with the basic instruction sent via the GSM module. Solar panels will charge the robot battery, which is its primary power source. The robot's upper side will have solar panels affixed to it. For the real-time feed, a bluetooth camera will be present. The base station will get the live feed from the camera.

We will employ a front scooper and two side scoopers to collect the trash. Waste that will float sideways will be collected using side scoopers. Here, the scoopers will be powered by servo motors. The servo motors begin to operate after they get the signal from the microcontroller through the motor driver.

2.4 Analysis of Multiple Design Approach

Table 4 : Table of analyzing multiple design approach

Features	Design 1	Design 2	Design 3
Waste Collection Mechanism	This design uses a conveyor belt to collect the dirt	This design has two collapsible gates below the boat deck.During garbage collection,the collapsible gates open and the collected garbage is deposited inside the floating cage	This design uses front Scooper, side Scooper to collect waste
Waste Collection Rate	It has moderate waste collection rate	It has also moderate waste collection rate	It has Higher waste collection Than Design 1 and Design 2
Waste Detection Mechanism	This design manage to detect waste by using IR sensor	In this design the robot will control manually. So the robot manually collect wastages.That is why it has no waste detection mechanism	In this design, the robot can be controlled from a distance,so we can see the images of the waste from a distance by using a bluetooth camera
Direction Control Mechanism	The design uses a bluetooth module so that the robot can be manually controlled without any hindrance	This design also uses a bluetooth module to control the robot and it is also easy to control a robot with bluetooth module	In this design we have used GSM module so that we can control the robot remotely
Cost Effectiveness	This design is average in terms of cost effectiveness since it may attain performance effectiveness	This design is economical since it may be constructed with some less expensive components and yet function adequately	This design cost higher than the other two design due to its expensive components

2.5 Conclusion

In conclusion, many design methods, each with special features and requirements, are presented for the creation of a solar-powered miniature water surface cleaning robot. Design Approach 01 concentrates on employing a solar-powered conveyor belt to gather floating trash. For trash detection and human control, it uses an IR sensor and an RC transmitter. Although it only collects waste at a moderate rate, it offers a workable economic option.A more inventive design with cylinder hulls and a collapsible fence for waste collection is presented in Design Approach 2. It allows manual operation and uses a Bluetooth module for control. Due to the use of less expensive components, this method proves to be cost-effective and the trash collection rate is likewise reasonable.The most cutting-edge choice is Design Approach 03, which makes use of a GSM module for remote control and a Bluetooth camera for real-time feedback. It uses front and side scoopers to gather waste, outperforming other designs in terms of waste collection rate. The incorporation of pricey components, however, raises the expense of this strategy.The choice of design strategy will ultimately depend on the particular project needs, financial limitations, and performance expectations. To make sure the robot adheres to ethical ideals and benefits the environment, ethical factors like environmental effect and responsible resource usage should be incorporated into the design. Whatever design strategy is chosen, upholding professional obligations and moral standards will enable the creation and effective use of a solar-powered small water surface cleaning robot.

Chapter 3: Use of Modern Engineering and IT Tool. [CO9]

3.1 Introduction

The development and viability testing of a complex engineering project requires the utilization of modern engineering and IT tools. During the circuit construction phase, a specific tool was employed to research and validate the concept. Subsequently, multiple technical tools were utilized to establish the prototype and facilitate the project's implementation.

3.2 Select Appropriate Engineering and IT Tools

3.2.1 Software Tool Selection

Table 5 : Table of software tool selection

IT Tools		Specification (version)
1	Proteus	v8.12
2	Arduino IDE	v2.1.1
3	Tinkercad	Online tool

3.2.2 Hardware Tool Selection

Table 6 : Table of hardware tool selection

Tools	Model
Arduino	Arduino Nano
Bluetooth Module	HC 05
DC Motor	6v DC Gear Motor, 1000 RPM
Servo Motor	MG995
Li-ion Battery	3.7v 6800mAh
Motor Driver	L298N

3.3 Use of Modern Engineering and IT Tools

3.3.1 Description Of Software Tools

• **Proteus:** Proteus is a software tool that allows for the simulation and design of electronic circuits. It provides a virtual environment where you can design, test, and verify the functionality of various electronic components and systems. For your water surface cleaning robot project, you can utilize Proteus to simulate and validate the control and behavior of the robot's electronic systems.

By employing Proteus, we can design and simulate the robot's circuitry, including the motor control, sensors, and any other electronic components necessary for its operation. The software enables you to test and optimize the performance of these components before implementing them physically.

• **Arduino IDE:** The Arduino IDE is a popular software tool used for programming microcontrollers such as the Arduino board. It provides an intuitive and user-friendly interface that allows developers to write, compile, and upload code to their boards with ease.Moreover, the Arduino IDE is open-source and has a large community of contributors constantly adding new libraries and features. This community-driven approach has resulted in an extensive library of third-party libraries and examples that can be easily incorporated into any project.

• **Tinkercad:** Tinkercad is a 3D design tool that simplifies the creation of complex models for designers of all skill levels. Its drag-and-drop interface and extensive shape library make it easy to create custom designs or modify existing models. With Tinkercad's editing tools, users can adjust, resize, and mirror shapes, providing a high level of customization and flexibility. Additionally, Tinkercad features a range of tools for editing and manipulating shapes, including resizing, rotating, and mirroring. This makes it easy to create custom shapes and modify existing designs.

Overall, Tinkercad's user-friendly interface and integration with 3D printing services make it an ideal choice for designers looking to create complex models with ease.

3.3.2 Description Of Hardware Tools

• **Lithium-Ion Battery:** Lithium-Ion battery with ratings of 24V, and 10Ah has a longer lifespan approximately 2-4 years than any other type of Lithium battery which is more suitable for electric bikes. This battery can serve power at 960 watts for 1 hour [14].

• **Solar Panel:** Monocrystalline solar panel is a panel that is constructed with a monocrystalline solar cell. This type of solar panel has more efficiency than polycrystalline solar panels.

• **Solar Charge Controller:** Converts unstable DC source to stable DC source to charge the battery using solar input. It works as a boost converter as well when needed.

• **DC Motor:** A DC motor is an electrical device that converts electrical energy into mechanical motion. It consists of a stationary part called the stator and a rotating part called the rotor. The stator has coils that create a magnetic field when current flows through them, while the rotor carries the armature winding and the commutator. When current is applied to the stator, the interaction between the stator's magnetic field and the rotor's magnetic field causes the rotor to rotate. This rotational motion can be harnessed for various applications, such as driving machinery, vehicles, or robots, by controlling the voltage and current supplied to the motor.

• **Servo Motor:** A servo motor is a compact rotary actuator widely used for precise angular control in various applications. It consists of a motor, gearbox, and control circuitry. By receiving a control signal, typically a PWM signal, the servo motor adjusts its position to match the desired angle. This closed-loop system continuously compares the current position with the target position and makes necessary adjustments, ensuring accurate and responsive control. Servo motors are valued for their high torque, excellent positional accuracy, and availability in different sizes and power ratings.

• **Motor Driver:** The L298N is a motor driver IC widely used to control and drive DC motors or bipolar stepper motors. It offers dual H-bridge channels for independent motor control, allowing direction and speed regulation. With support for PWM control and built-in protection features, it simplifies motor control in various applications. The module is commonly used with microcontrollers like Arduino or Raspberry Pi, where digital signals control motor behavior. The L298N's versatility, high current and voltage handling capability, and integrated features make it a popular choice for robotics, automation, and other projects requiring efficient and precise motor control.

• **Propeller:** A propeller is a rotating blade assembly used to generate thrust in aviation and marine applications. It consists of twisted blades mounted on a central hub, converting rotational motion into forward or backward propulsion. In aviation, propellers are essential for piston-powered aircraft, drawing in air to create thrust for flight. In marine applications, propellers propel boats and ships by pushing against water. The size, shape, and pitch of the blades vary depending on the specific application. Propellers can be powered by various engines, including internal combustion engines or electric motors. They play a vital role in enabling efficient and controlled movement in air and water transportation.

• **Arduino Nano:** The Arduino Nano is a widely-used microcontroller board based on the ATmega328P. It offers a versatile platform for prototyping and developing electronic projects. With its digital and analog input/output pins, PWM capabilities, and communication interfaces like UART, I2C, and SPI, it can interface with a variety of sensors, actuators, and other components. The Arduino Nano is programmable using the Arduino IDE and language, making it accessible for both beginners and experienced developers. It can be powered via USB or an external power source and is compatible with numerous shields and expansion boards, making it an ideal choice for creating interactive projects, robotics, and IoT applications.

• **Multimeter:** It is used for measuring the voltage and current during our experiment.

• **Soldering Iron:** High voltage of electric supply is used for increasing the temperature of the metal alloy which is used for soldering.

3.4 Conclusion

In this chapter, we have compiled a comprehensive list of engineering tools utilized for their specific responsibilities in the project. These tools were selected based on their user-friendly interfaces, extensive libraries, remarkable adaptability, and product availability. We have included both hardware and software tools that were essential in constructing the prototype. For simulation purposes, Proteus was employed, while the necessary equipment for the hardware component was also incorporated. Effective planning and a clear understanding of the desired products are crucial in building any system. Therefore, we have outlined the diverse engineering tools used in this chapter, along with their designated responsibilities.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution. [CO7]

4.1 Introduction

In order to determine the optimal approach, three different designs have been proposed in this project. The objective of these designs is to compare and analyze various aspects such as efficiency, cost-effectiveness, and maneuverability. In this chapter, we will implement the methodologies outlined in the design approaches using the Proteus software. These optimized solutions aim to demonstrate the reliability and effectiveness of the designs to stakeholders involved in the project.

4.2 Optimization of Multiple Design Approach

4.2.1 Design Approach 01

The configuration of design - 1, as demonstrated in figure below, includes Arduino boards due to its processing power, available GPIO pins, low power consumption and overall user-friendly environment. For the communication protocol, we have used a Bluetooth module that can give signals to the robot to operate. An IR sensor is used to detect trash. By following the signals from the IR sensor, the robot will be operated by an operator through that path and through the conveyor belt the robot will collect the floating trash.

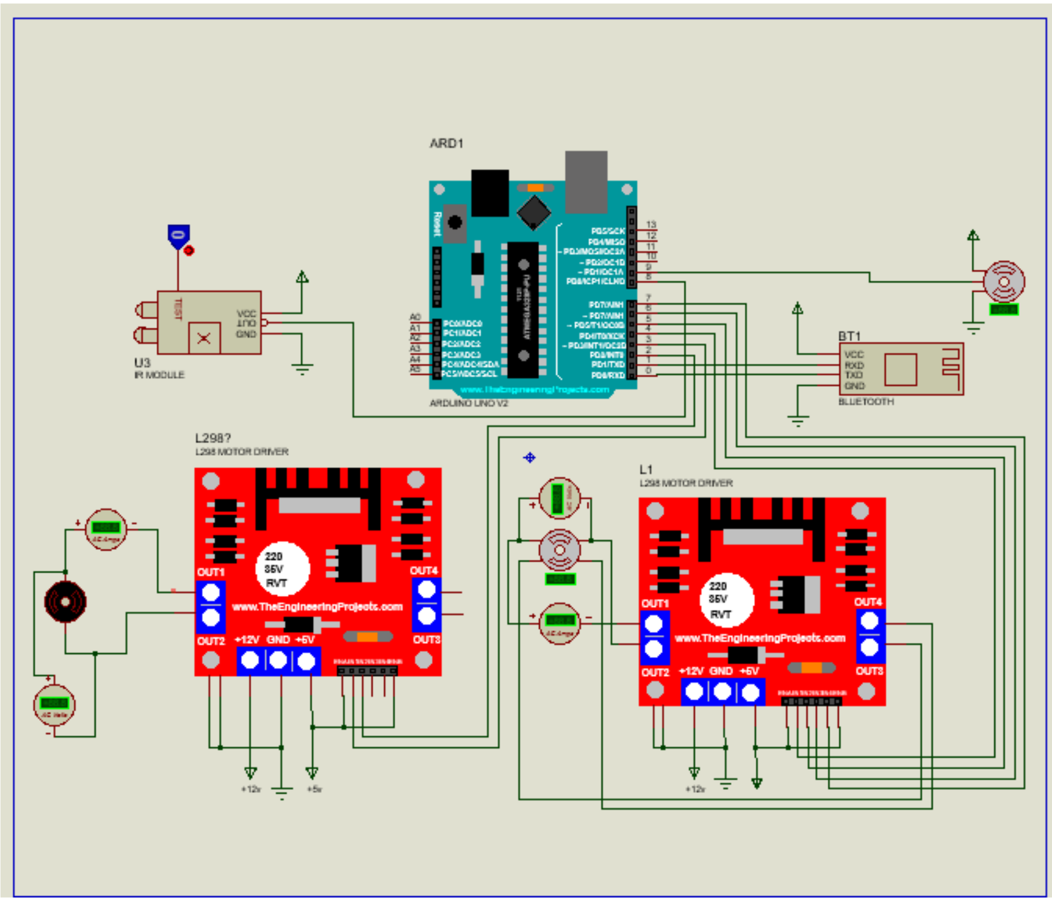

Figure 4: Schematic Diagram of Design 1

Charging Mechanism: The solar panel will charge the battery because the project is based on solar-power. Here, the photovoltaic effect is used by the solar panels to convert solar energy into electrical energy. Direct current (DC) energy is produced and passes through the solar charge controller to charge the battery safely and effectively. The battery will power the entire system after it has been charged.

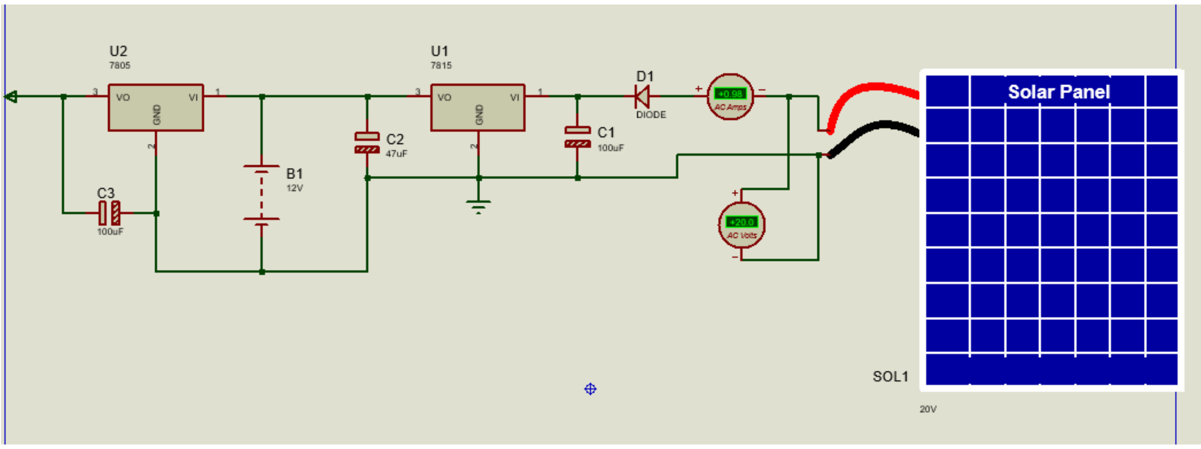

Figure 5: Schematic Diagram of charging mechanism

Control Mechanism: To control the robot Bluetooth module-based control mechanism is implemented in the system. An IR sensor is implemented here to give the user signal about the location of trash. According to that signal, the user will drive the robot using the Bluetooth module and collect the trash using the conveyor. To perform all these operations a microcontroller is used. For controlling the motors, 2 motor drivers were used.

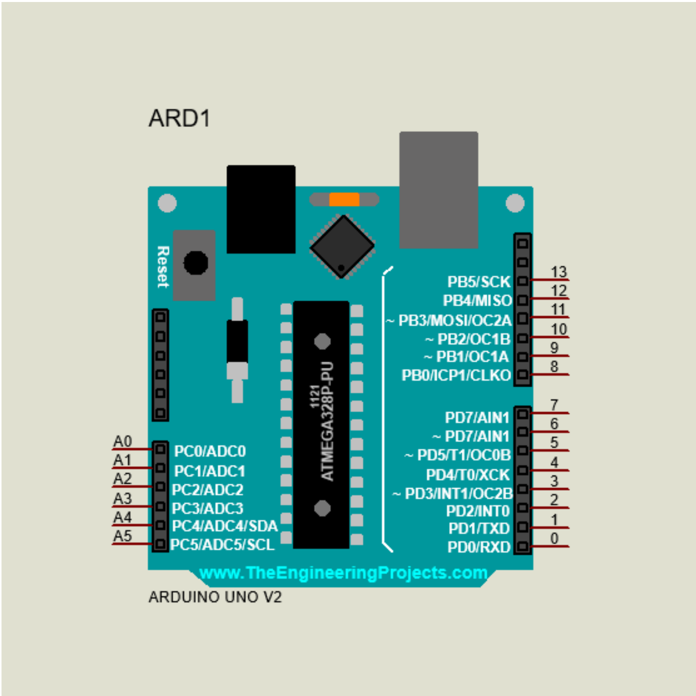

Figure 6: Schematic Diagram of Arduino Uno microcontroller

We are utilizing an Arduino Uno microcontroller to operate the robot. The battery will be attached to it. To it are the motor drivers attached. When a command is given from the Bluetooth module, the device processes it and sends a signal to the motor through motor drivers.

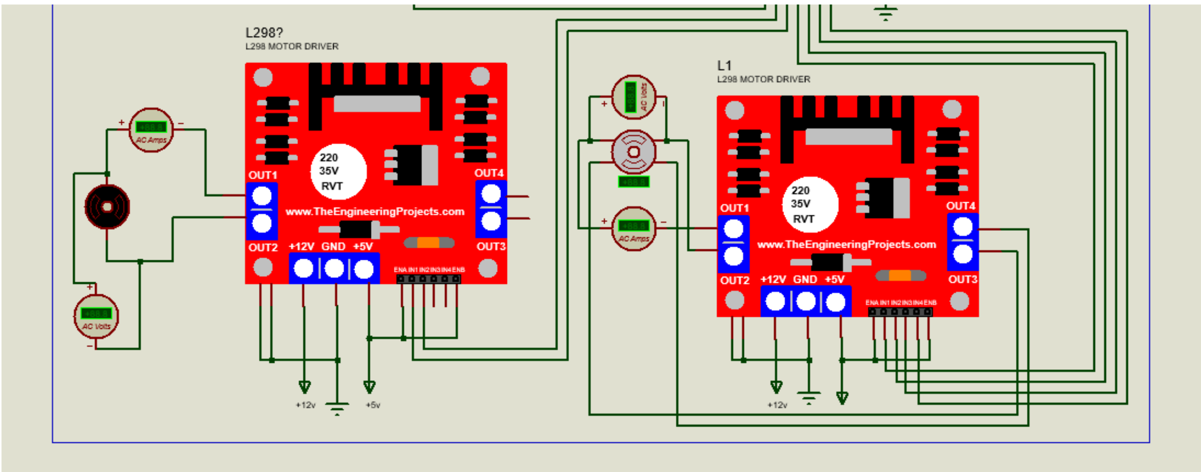

Figure 7: Schematic Diagram of L298 motor driver

L298N motor driver is used to run the motors. According to the command given by the Bluetooth, the motors will operate. Power is given to the motor through these motor drivers. For this design 2 motor drivers are used.

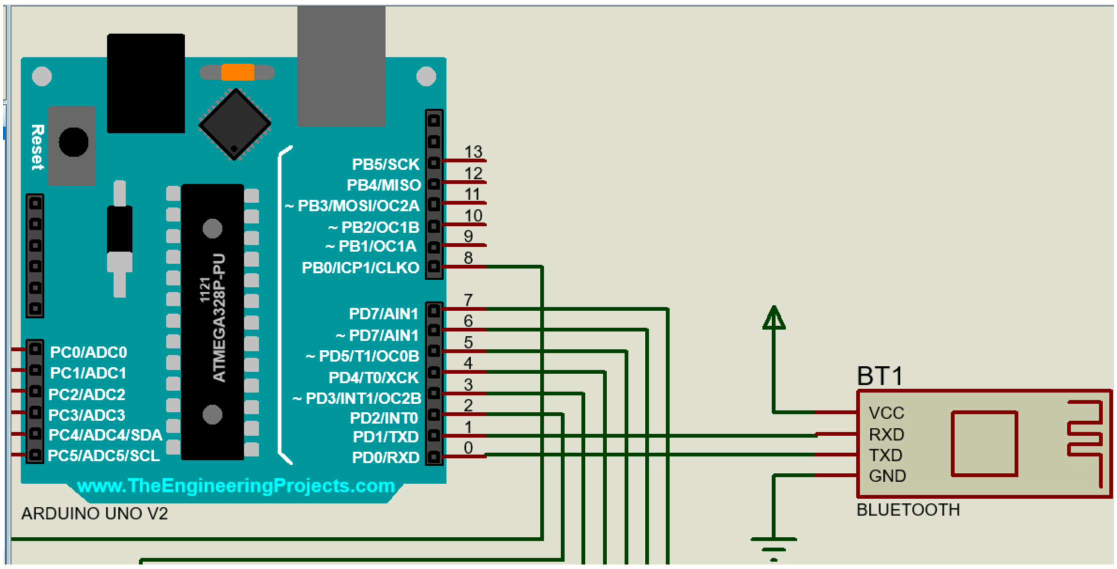

Figure 8: Schematic Diagram of Microcontroller and Virtual Terminal

For the simulation purpose, we are using a virtual terminal to give commands to the robot as there is no such module for Bluetooth in Proteus. By this, we give commands to the robot about its operation.

Driving Mechanism: As we already mentioned, the robot is controlled by a Bluetooth module. Despite the fact that the Proteus Bluetooth module does not exist, we are using a virtual terminal for this example.
The robot will operate according to the command given by the virtual terminal.

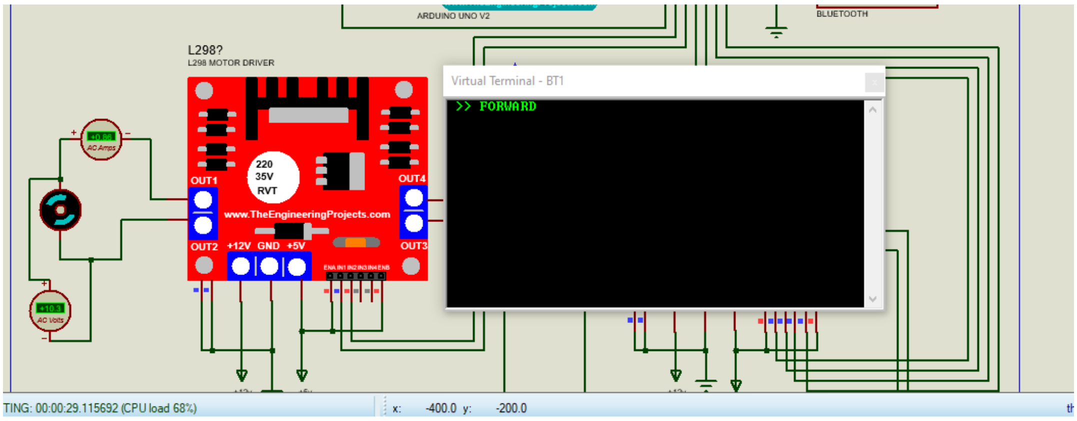

Figure 9: Schematic Diagram of motor driver and control key(Virtual Terminal)

For giving commands for operation, a virtual terminal is being used here. If the user presses the ‘F’ button the DC motor connected to the motor driver will start and drive the robot forward.

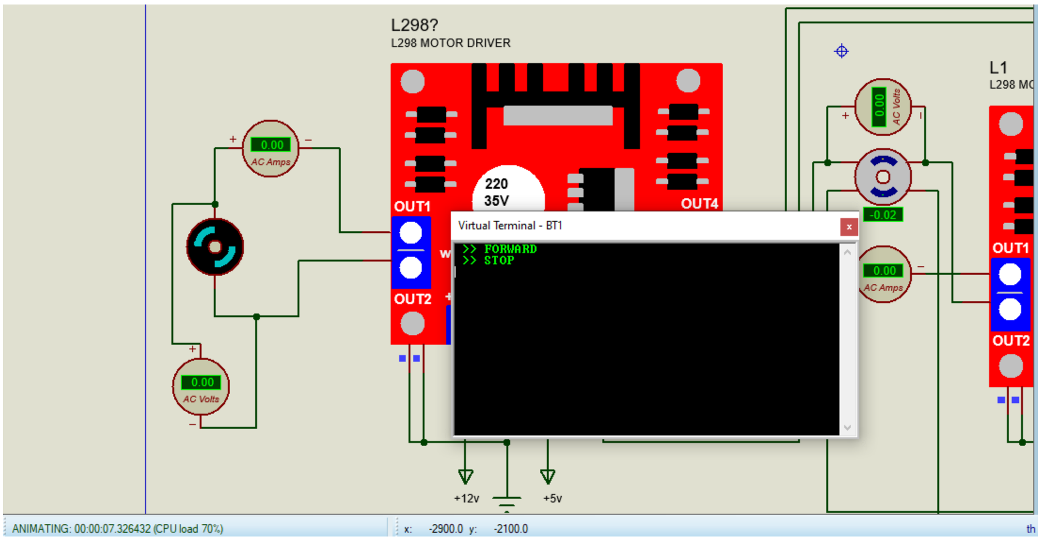

Figure 10: Schematic Diagram of motor driver and control key(Virtual Terminal)

Here, if the operator wants to stop the robot moving forward, ‘S’ button needs to be pressed. This will stop the DC motor and restrict the robot from moving forward.

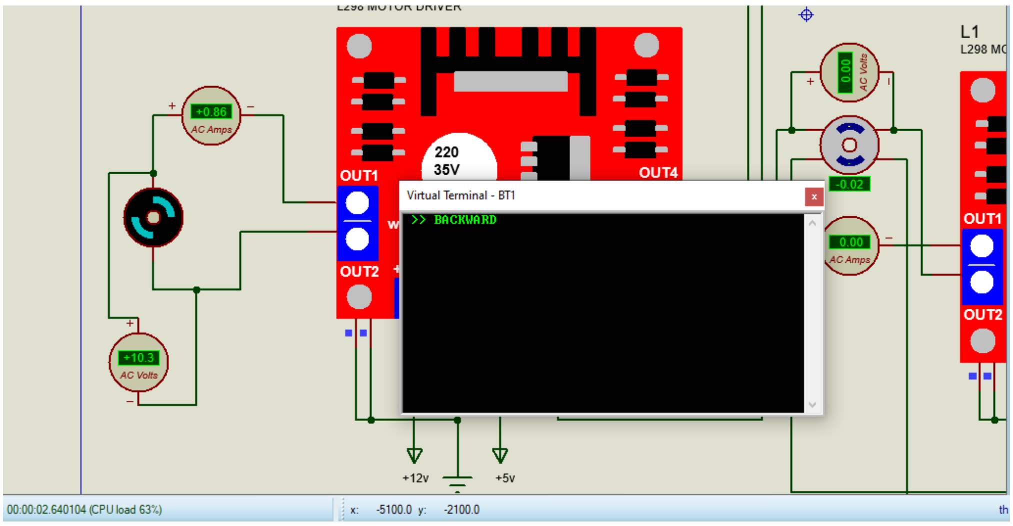

Figure 11: Schematic Diagram of motor driver and control key(Virtual Terminal)

‘B’ button will be used to move the robot backward. Users might need to move the robot backward for cleaning purposes or might unload the trash or might be for any unwanted circumstances. For those purposes this backward option is being used here.

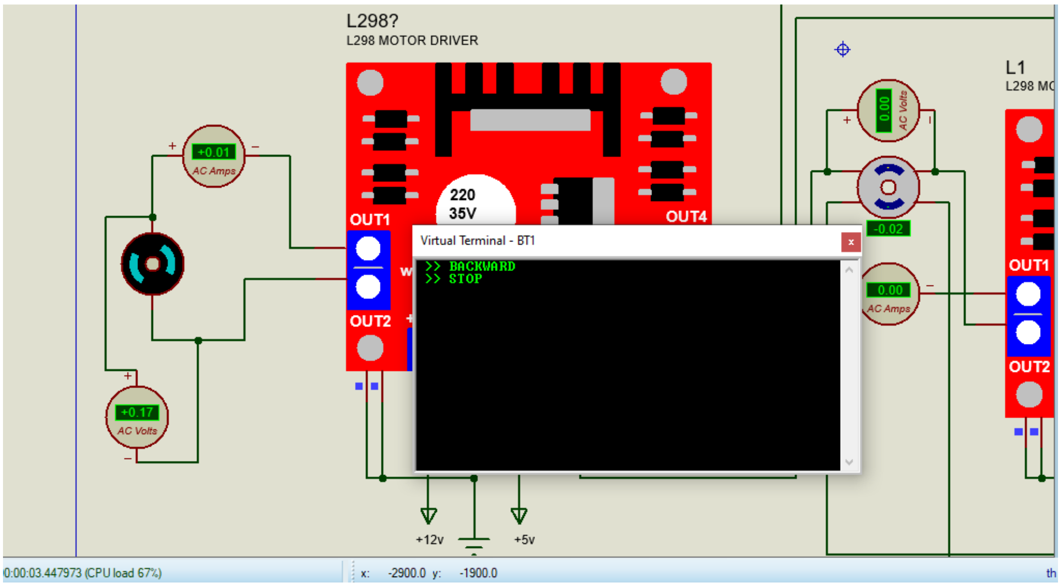

Figure 12: Schematic Diagram of motor driver and control key(Virtual Terminal)

Again like forward there is also a stop option for backward driving. The same key ‘S’ will be used to stop the motor.

For giving the direction to the robot a servo motor is being used. This will give the robot command about the direction. We can move the robot left and right by using keys to the virtual terminal.

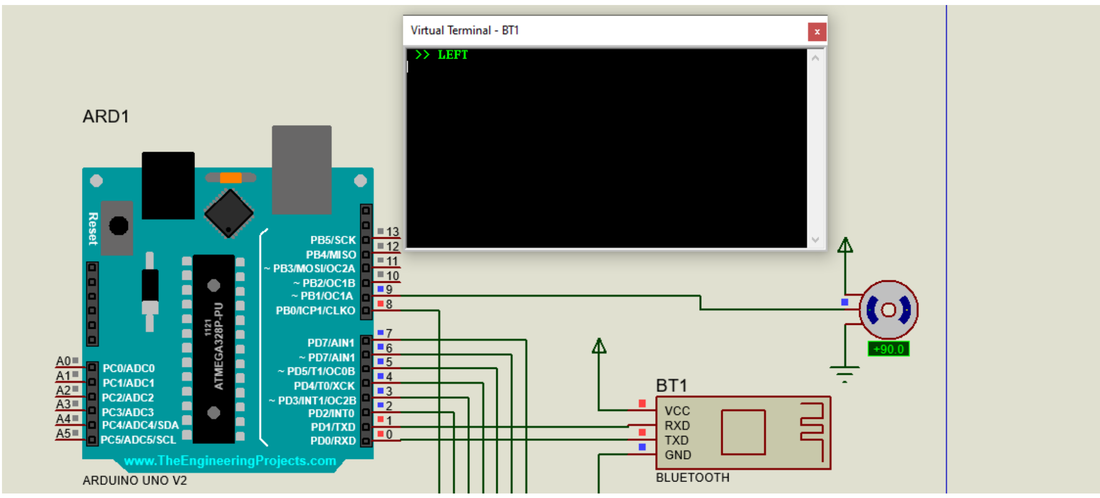

Figure 13: Schematic Diagram of Microcontroller and control key (Virtual Terminal)

Key ‘L’ is being used here to move the robot towards the left.

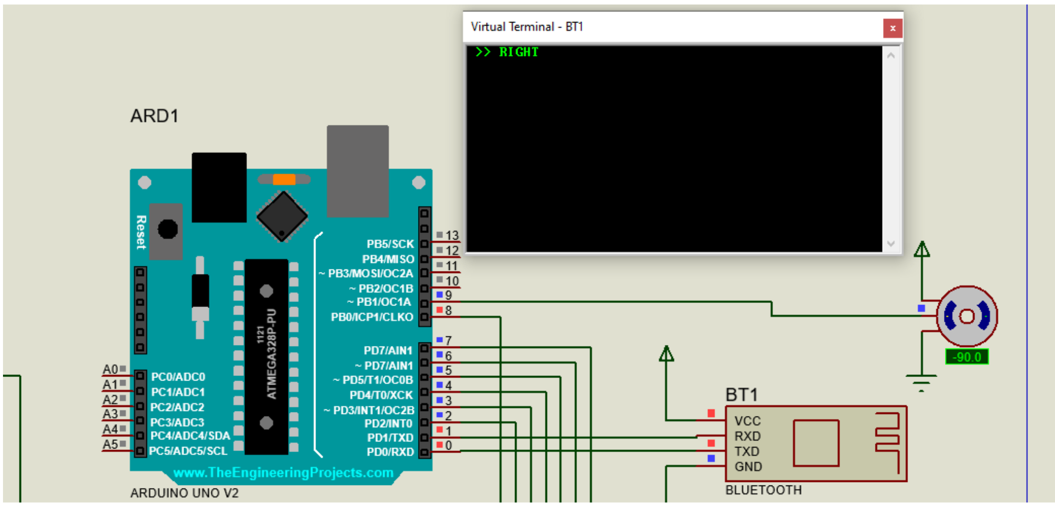

Figure 14: Schematic Diagram of Microcontroller and control key (Virtual Terminal)

Key ‘R’ is being used here to move the robot towards the right.

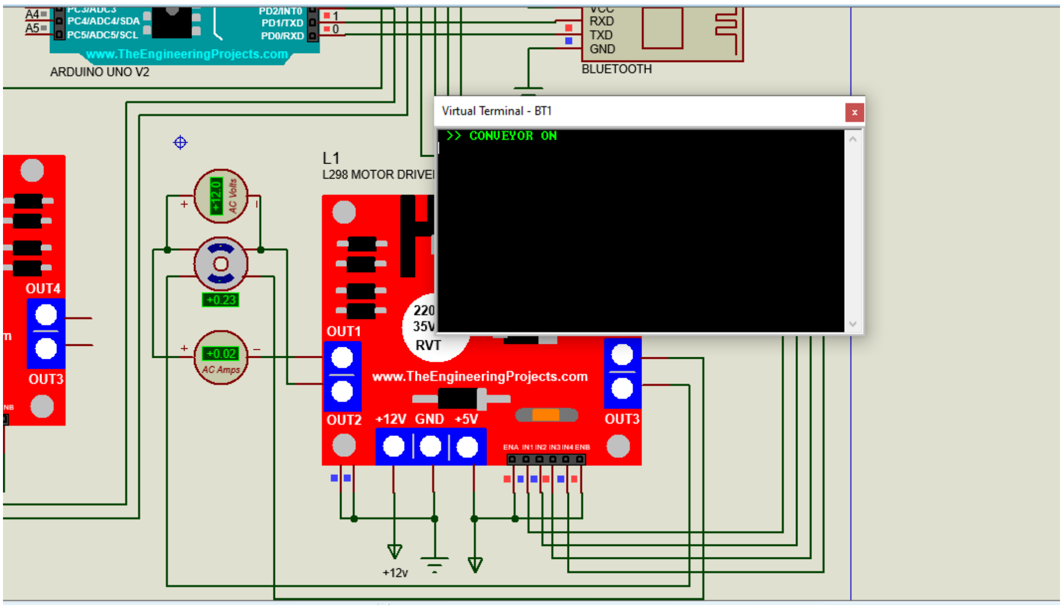

Figure 15: Schematic Diagram of motor driver and control key(Virtual Terminal)

By pressing ‘1’ conveyor belt will turn on

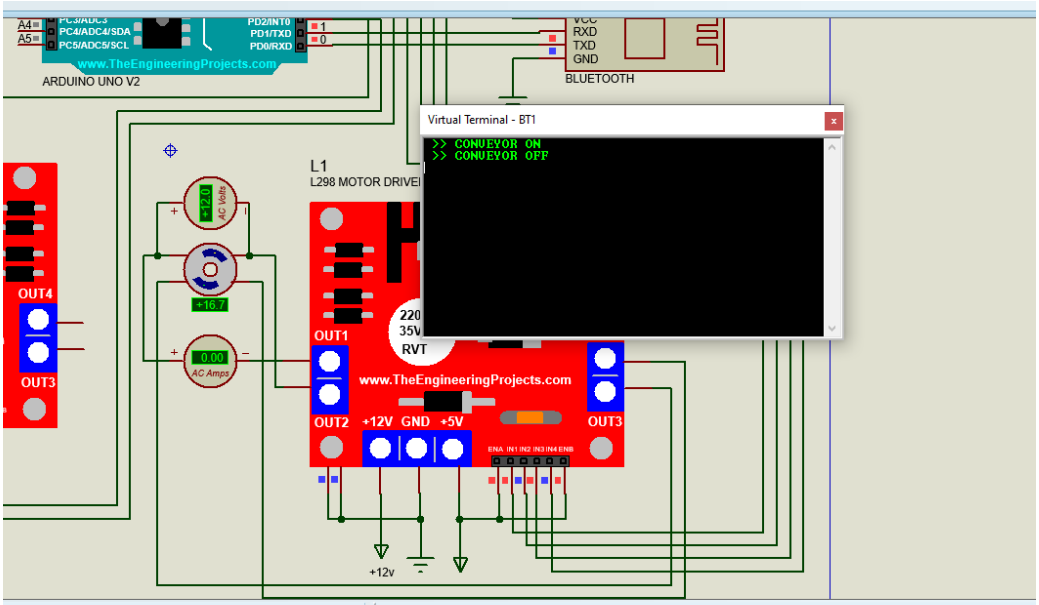

Figure 16: Schematic Diagram of motor driver and control key(Virtual Terminal)

By pressing '0' conveyor belt will turn off

Trash Collection: Here, a conveyor belt is connected to the stepper motor for collecting the trash. We also add an IR sensor for detecting the trash when the IR sensor sends a signal to the Arduino then the Arduino sends commands to the motor driver the stepper motor starts for on the conveyor belt. As we already mentioned, there is an IR sensor. Despite the fact that the Proteus IR sensor does not exist, we are using a virtual terminal for this example. When we press 1 the conveyor belt is on and collects trash, when we press 0, it will stop.

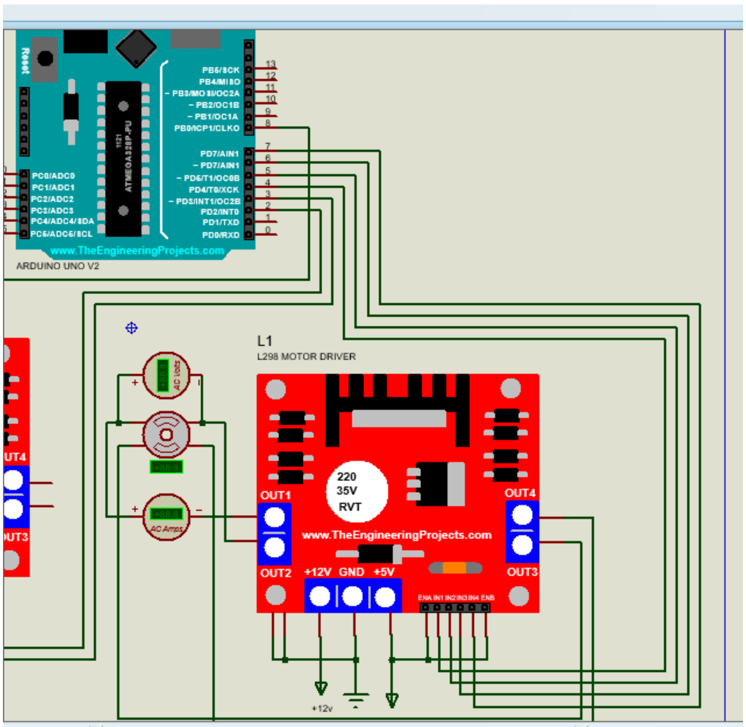

Figure 17: Schematic Diagram of motor driver and stepper motor

Trash Detection System: An IR sensor is being used to detect floating trash. The sensor will detect the object and give a signal to the user. It detects and measures the infrared radiation emitted by objects in its field of view. It also detects the movement of an object within its range and can inform the user through an output signal such as an audible alarm, a visual indicator, or a notification on a mobile device.

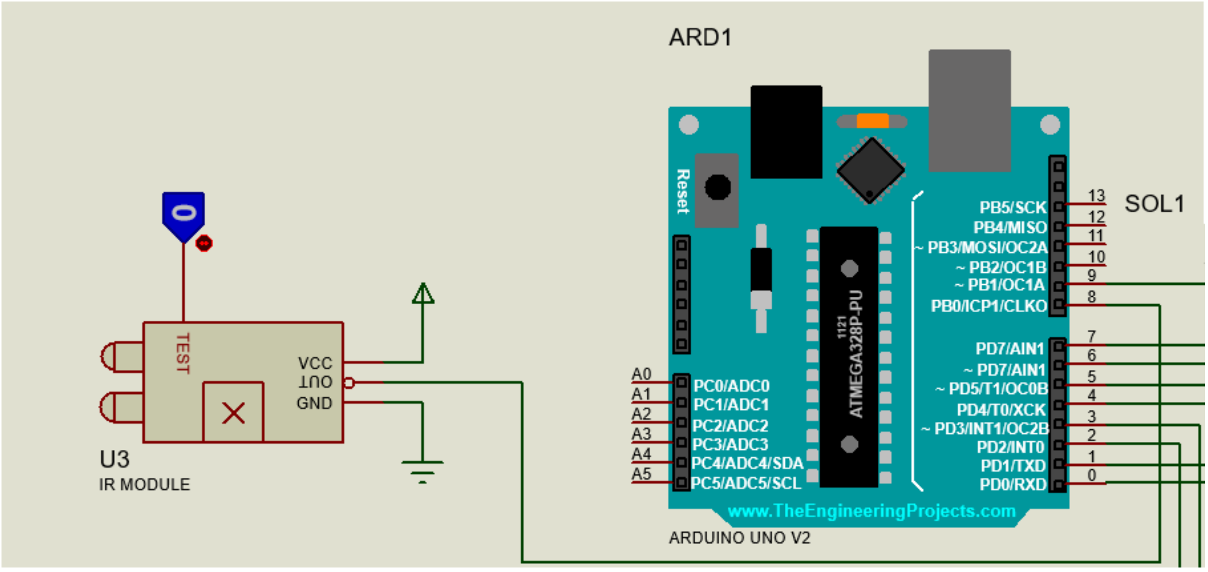

Figure 18: Schematic Diagram of IR module

Here, an IR module is used to detect the trash. The IR module gives a signal to the user about the location of floating trash so that the user can collect more trash efficiently.

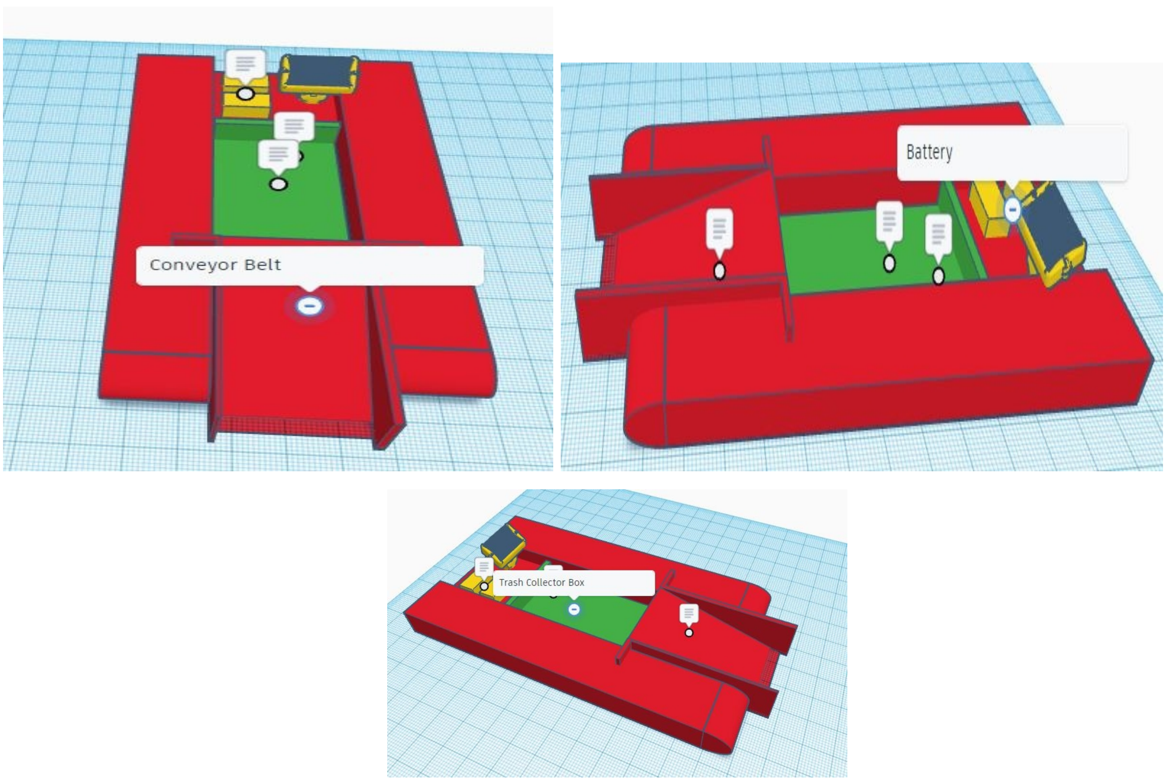

Figure 19: 3D model of design 1

Simulation Graph for Design 1:

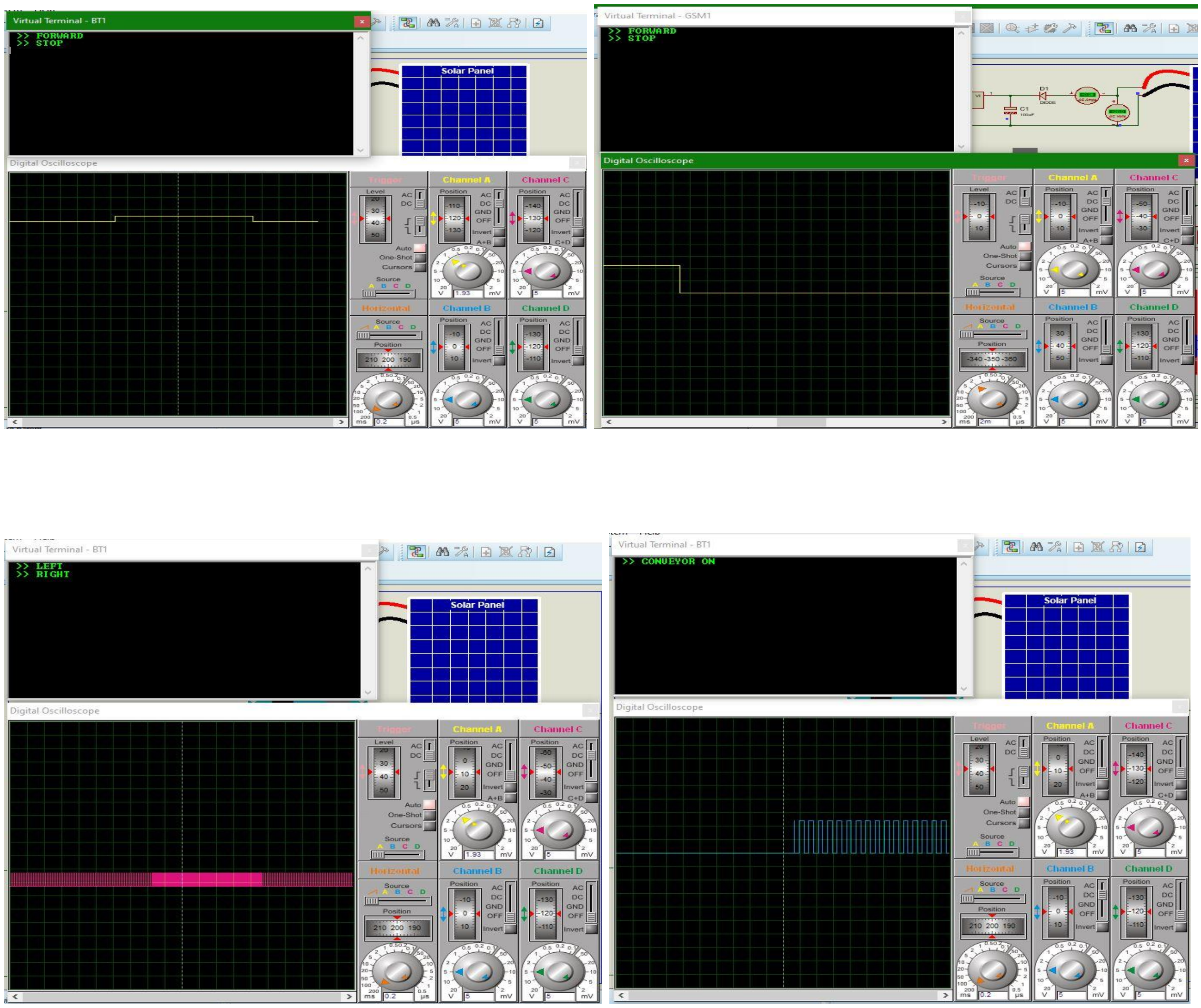

Figure 20: Simulation graph for left and right of Design 1

4.2.2 Design Approach 02

The configuration of design 02, as shown in figure below, consists of an Arduino UNO board for its processing unit, one motor driver L298N for controlling the DC motors, and a Bluetooth module HC-05 is used for giving command to the robot. Here 2 DC motors are used for moving the robot towards the forward, left and right direction. Also a servo motor is connected to the microcontroller for controlling the thin collapsible fence. Since we do not have any bluetooth module for Proteus, we are using a virtual terminal as a bluetooth module.

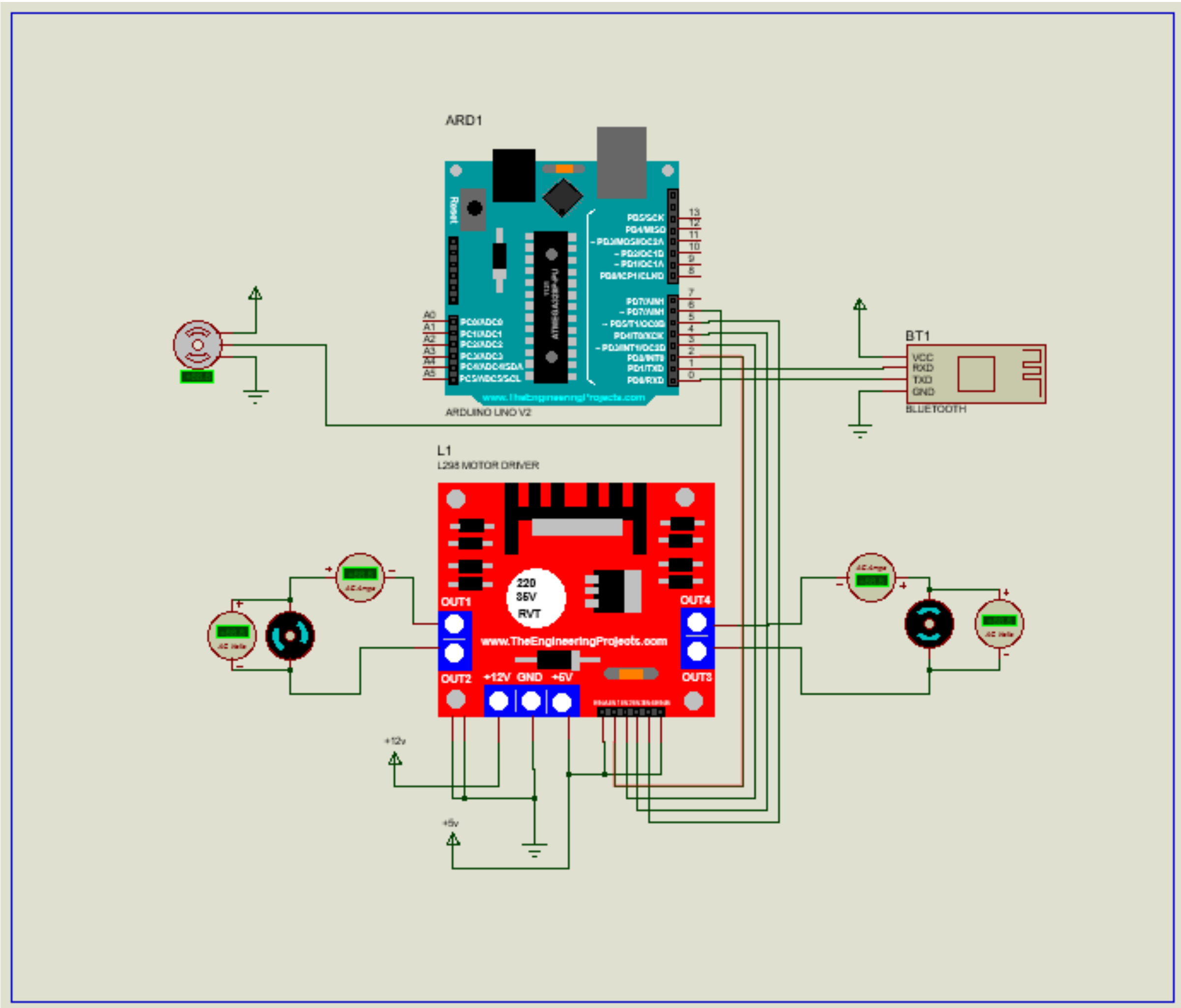

Figure 21: Schematic Diagram of Design 2

Charging Mechanism: Charging mechanism for this design is the same as design 1.To charge a battery using a solar panel, we need a solar charge controller and a DC battery. The solar charge controller regulates the voltage and current from the solar panel to the battery, ensuring that the battery is not overcharged or undercharged, which can damage the battery.The battery stores the energy from the solar panel as chemical energy, and when it needs to be recharged, the charge controller detects this and starts the charging process again.

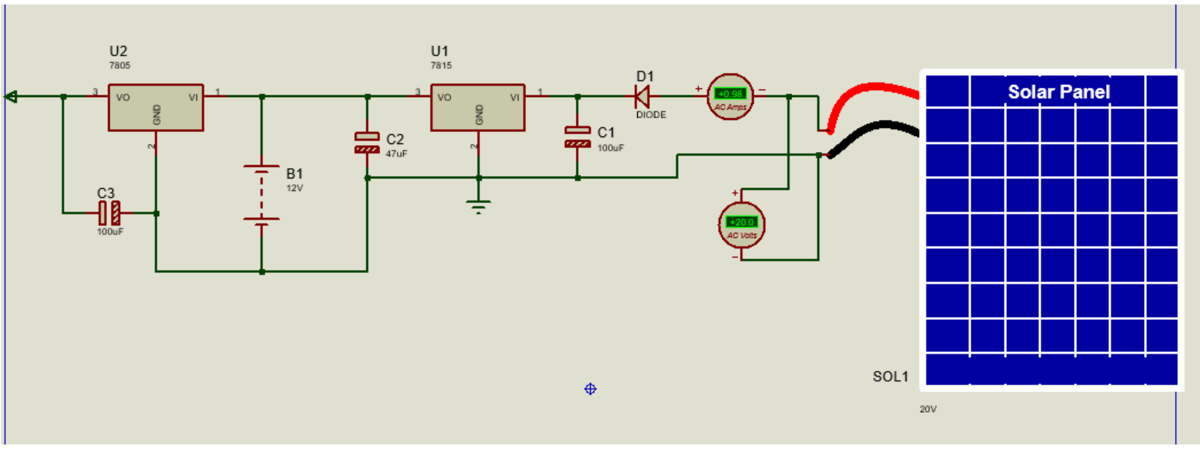

Figure 22: Schematic Diagram of charging mechanism

Control Mechanism: We are utilizing an Arduino Uno microcontroller to operate the robot. The battery will be attached to it. To it are the motor drivers attached. When a command is given from the Bluetooth module, the device processes it and sends a signal to the motor through motor drivers.

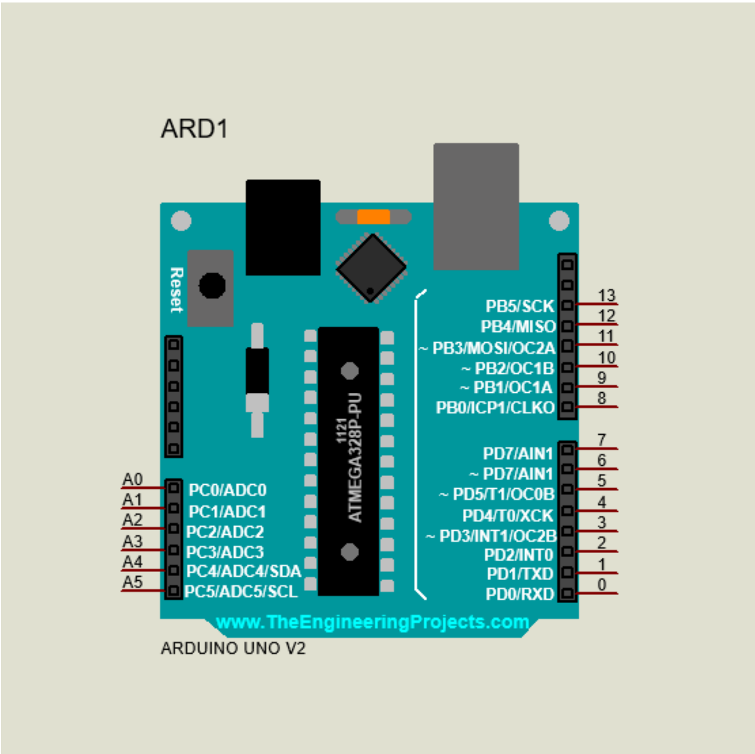

Figure 23: Schematic Diagram of microcontroller

Our robot's operation is powered by an ArduinoUno microcontroller, which is connected to a battery. The motor drivers are also connected to the microcontroller. Whenever we send a command from the Bluetooth module, the ArduinoUno processes the command and sends a signal to the motor via the motor drivers. In other words, the Bluetooth module serves as the input device, the ArduinoUno processes the command, and the motor drivers translate the signal into movement for the robot's motors.

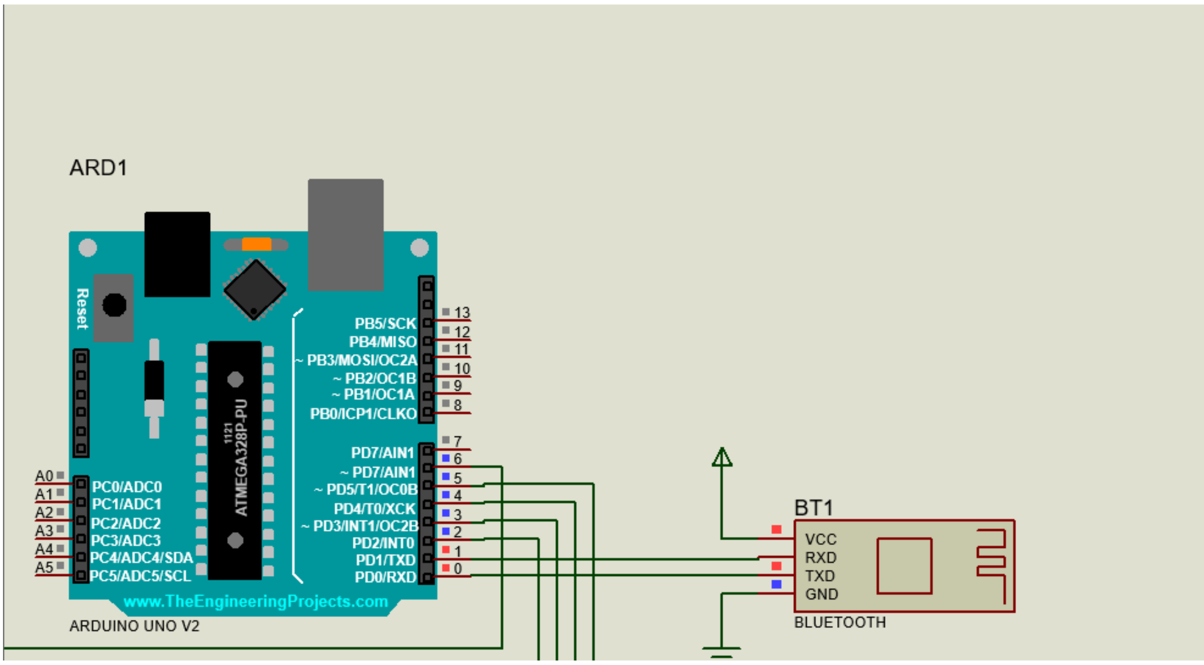

Figure 24: Schematic Diagram of microcontroller and bluetooth module

For giving command to the robot bluetooth module is used. This will make communication with the robot to the user. Here the HC-05 bluetooth module is being used.

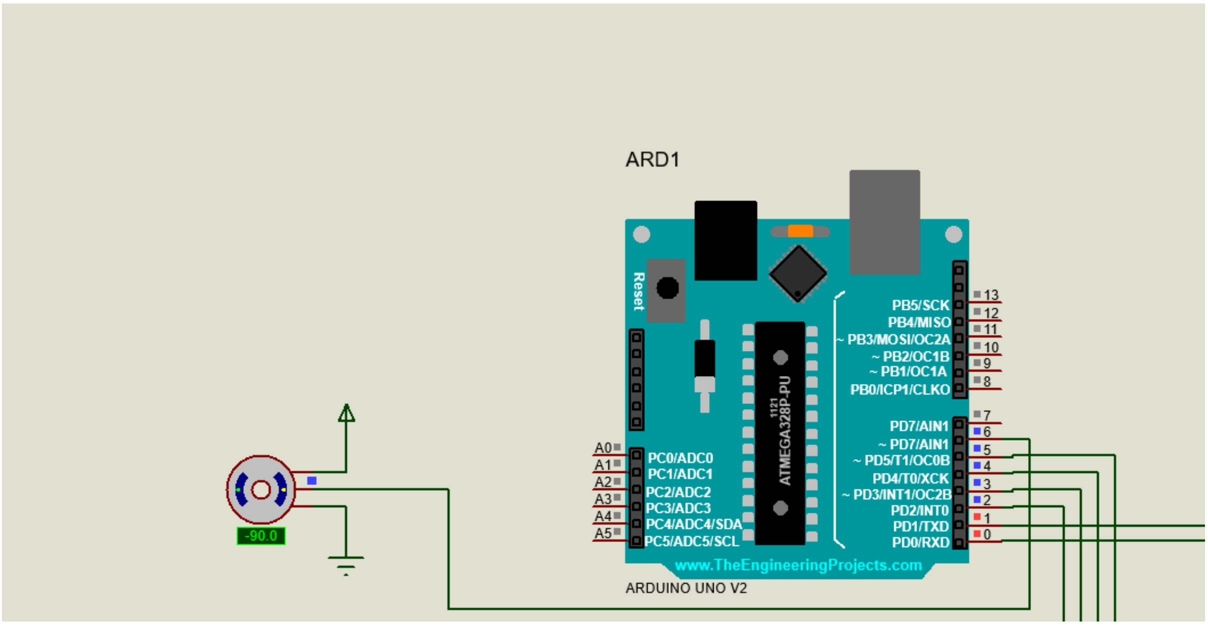

Figure 25: Schematic Diagram of microcontroller and servo motor

Servo motor is used here to control the thin collapsible fence of the robot. The servo motor can typically rotate up to 180 degrees, so you can adjust the angle of the fence accordingly.

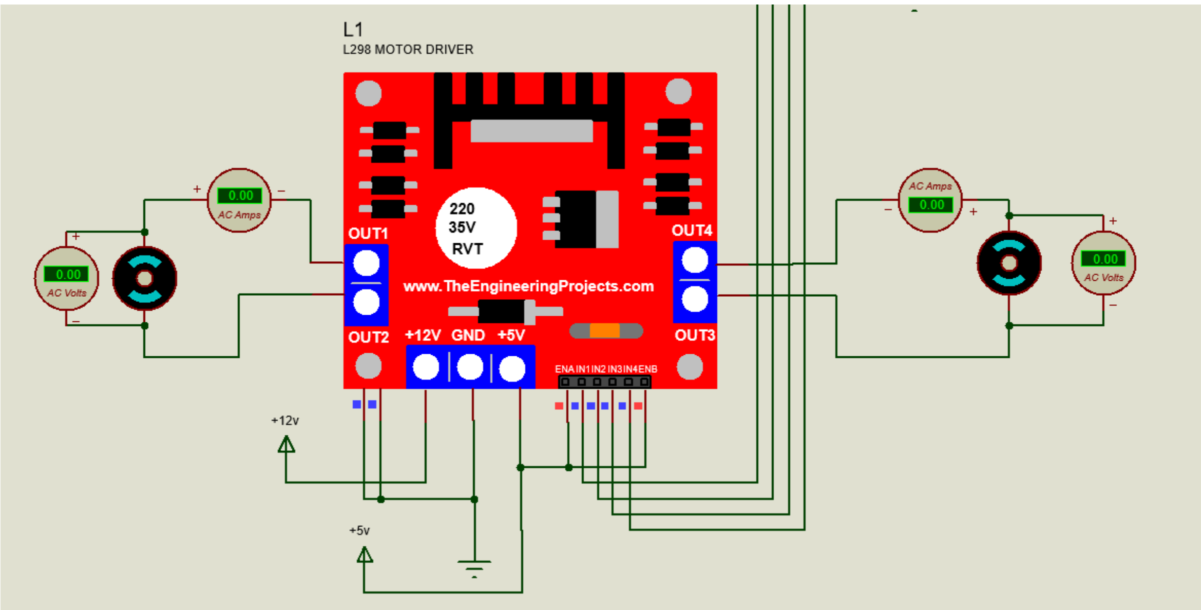

Figure 26: Schematic Diagram motor driver L298N and DC motors

For moving the robot forward we have used 2 DC motors here. One motor driver L298N is used to control those two motors. Motors will receive power from the motor driver that is connected to the battery.

Driving Mechanism: As we already mentioned, the robot is controlled by a Bluetooth module. The two DC motors are used to run the robot in forward,right and in left direction Despite the fact that the Proteus Bluetooth module does not exist, we are using a virtual terminal for this example.

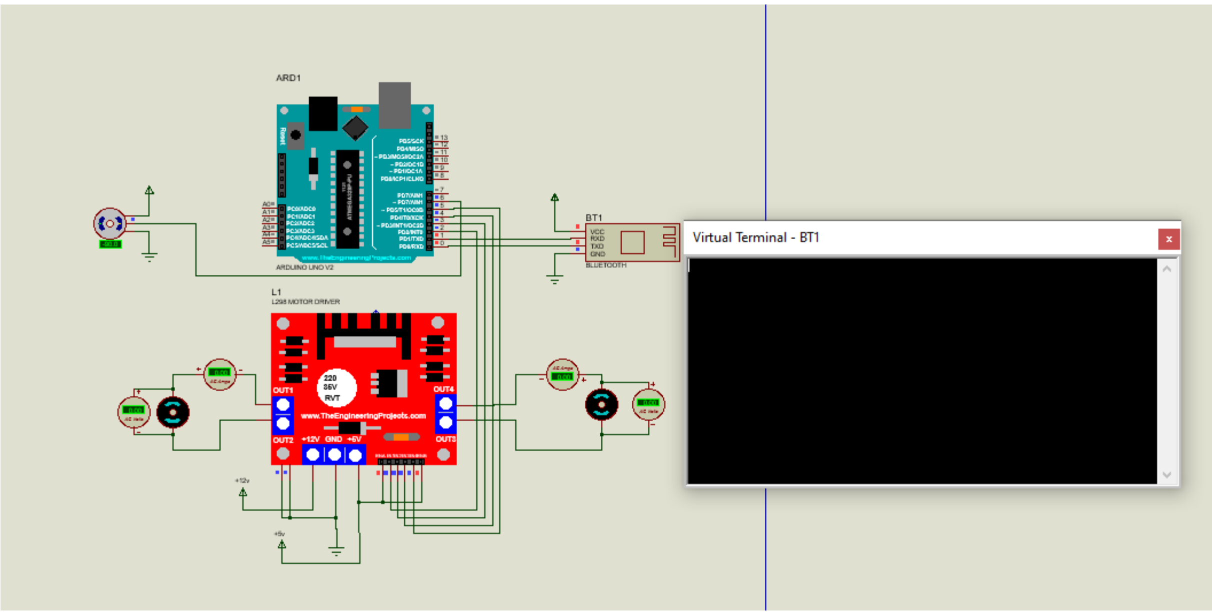

Figure 27: Schematic Diagram of design 2 with Controller (Virtual Terminal)

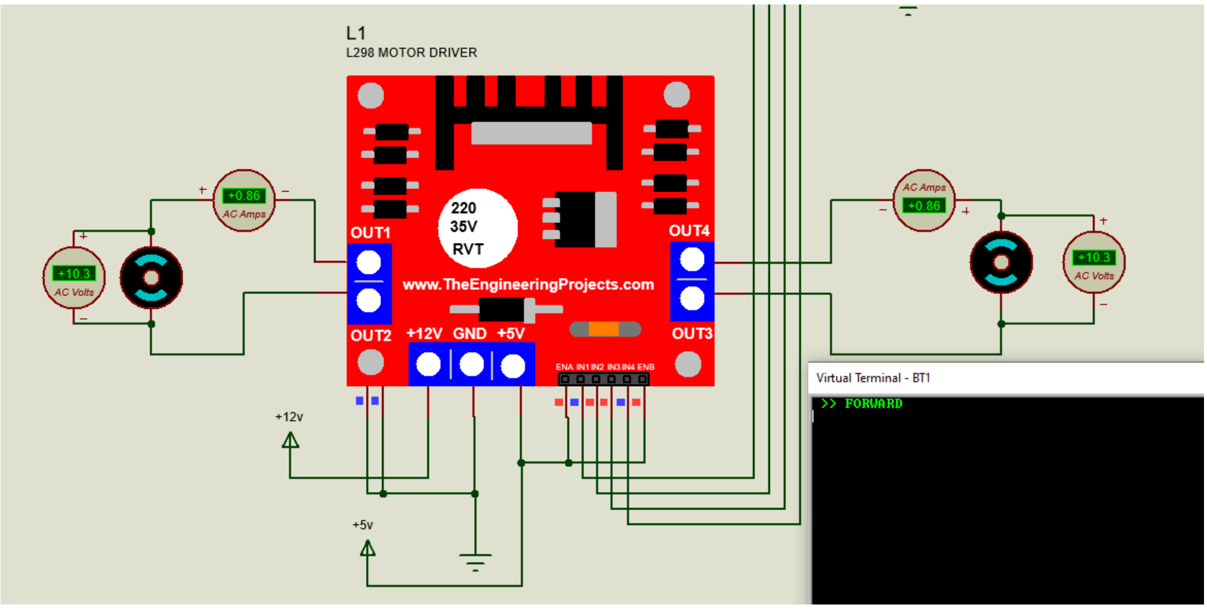

Figure 28: Schematic Diagram for moving the robot forward

The figure above shows if the key ‘F’ is pressed the 2 DC motor will start to operate and drive the robot forward.

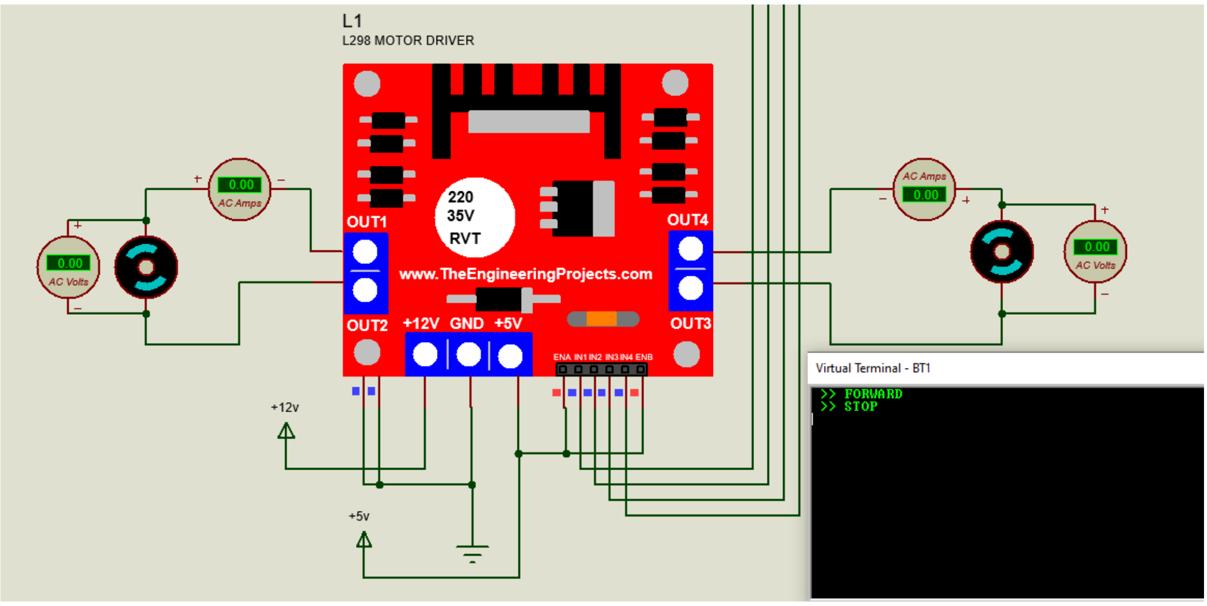

Figure 29: Schematic Diagram for moving the robot forward and stop

Here we have an additional option to stop the robot for any need. For that ‘S’ button needs to be pressed. When the ‘S’ button is pressed the robot stops all of its operation.

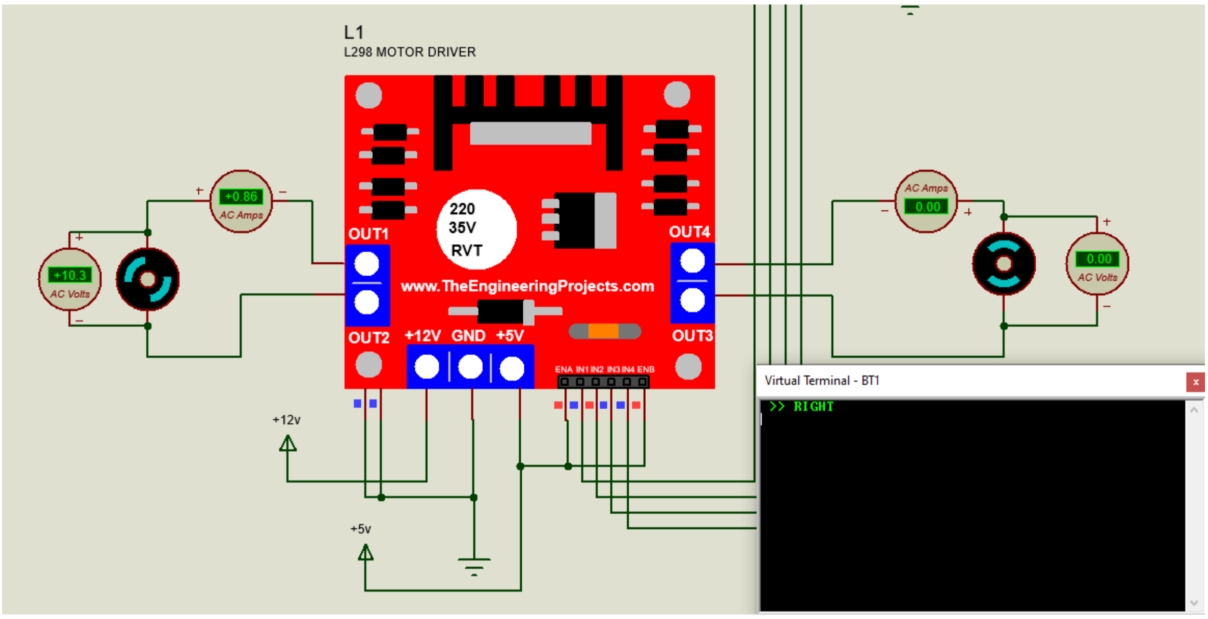

Figure 30: Schematic Diagram for moving the robot towards right

‘R’ button indicates the robot to move toward the right direction. In that case only one DC motor will operate as the result the robot will start moving in that direction.

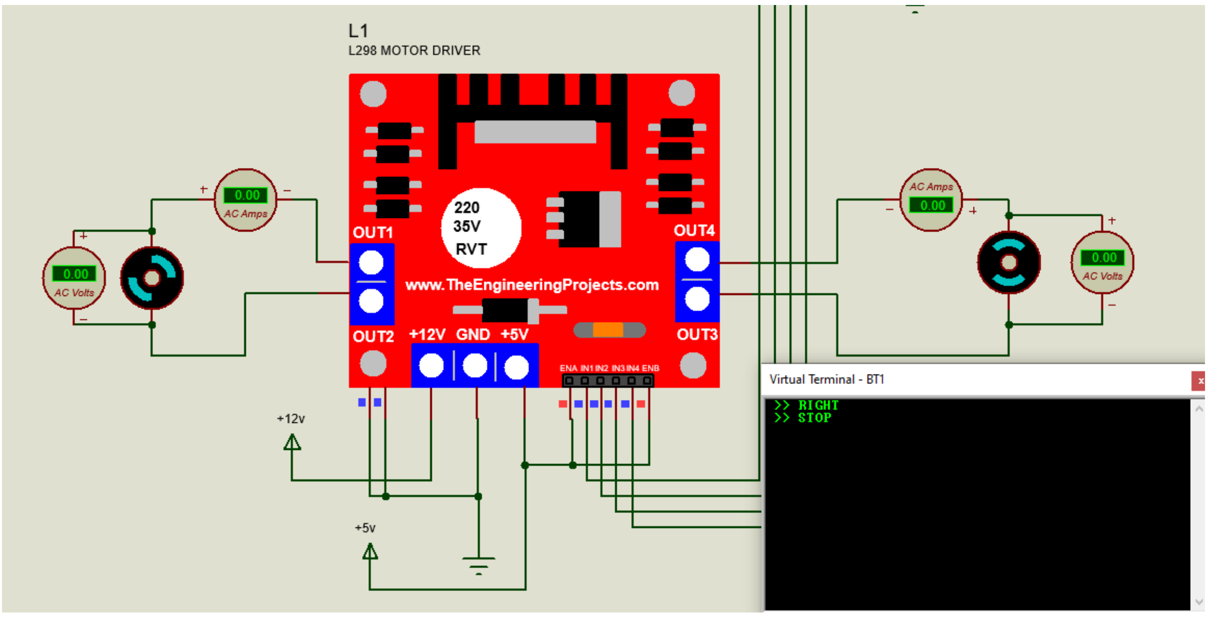

Figure 31: Schematic Diagram for moving the robot towards right and stop

Again the stop button ‘S’ needs to be pressed if the operator needs to stop the robot moveing towards the right.

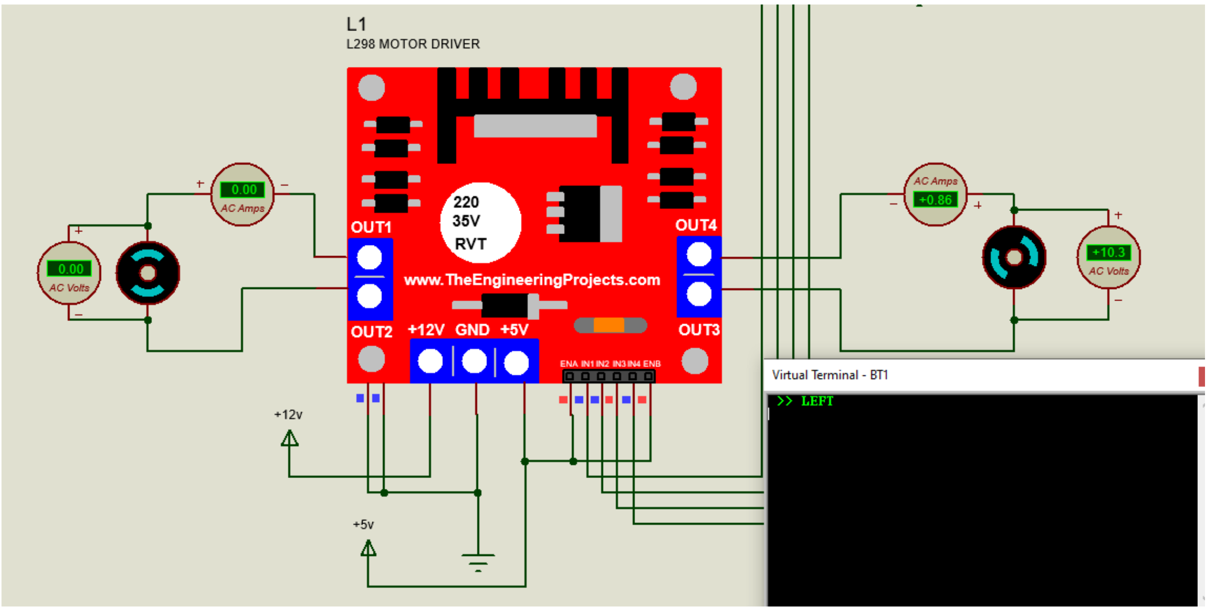

Figure 32: Schematic Diagram for moving the robot towards left

For moving the robot towards the left direction ‘L’ button needs to be pressed. The motor connected to the left side will only then operate and drive the robot towards the left.

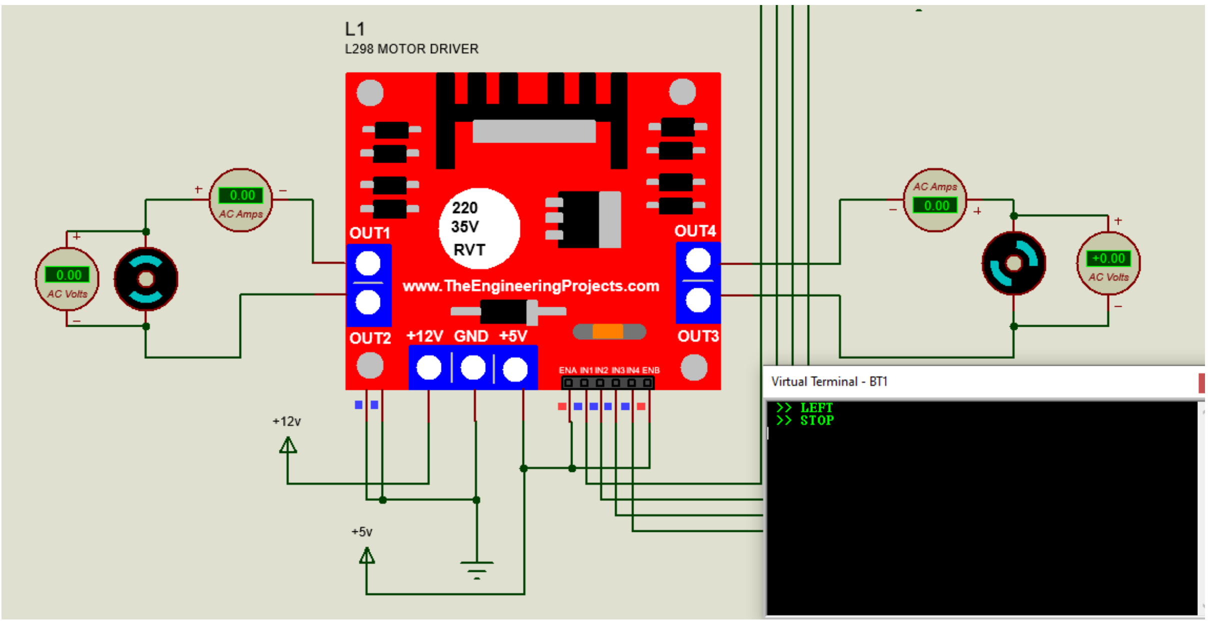

Figure 33: Schematic Diagram for moving the robot towards left and stop

For stopping the robot continuously moving toward the left again ‘S’ button will be pressed. This will stop all the functions that were operating that time.

Trash Collection: Using a servo motor to control a thin collapsible fence on a floating water surface cleaning robot can help improve the efficiency and effectiveness of the cleaning process, by allowing the robot to navigate around obstacles and avoid getting tangled in debris. According to the operator the gate will open and close for collection and carrying the trash safely.

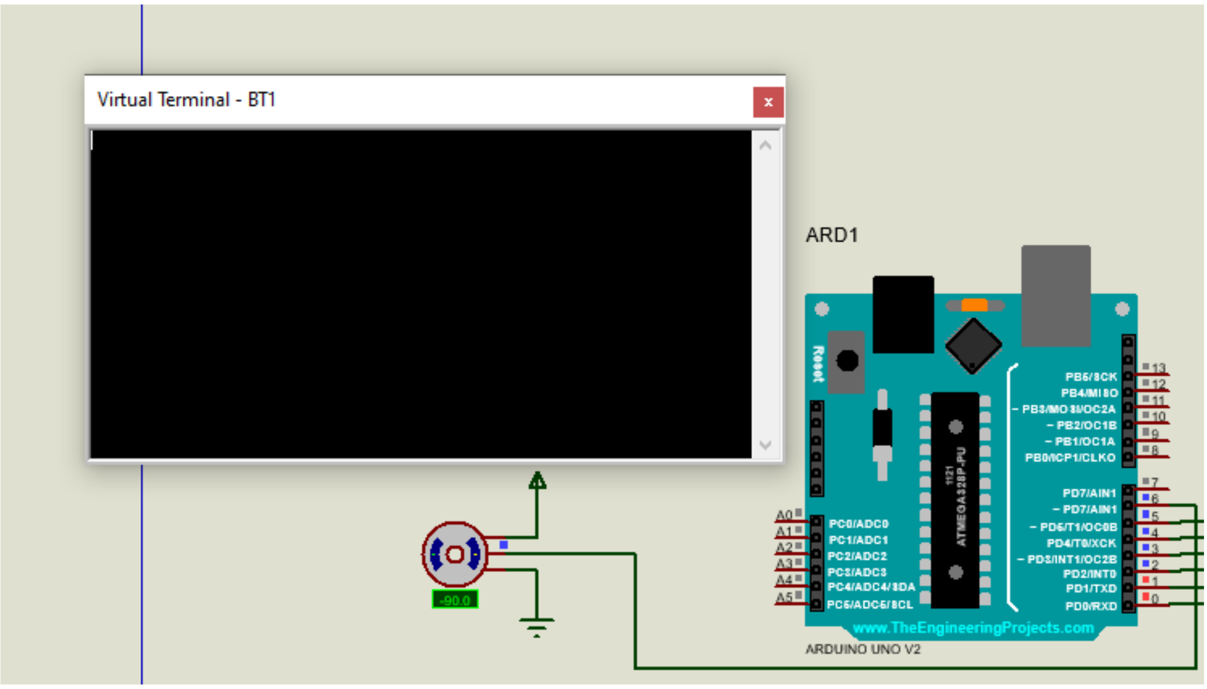

Figure 34: Schematic Diagram for controlling collapsible gate

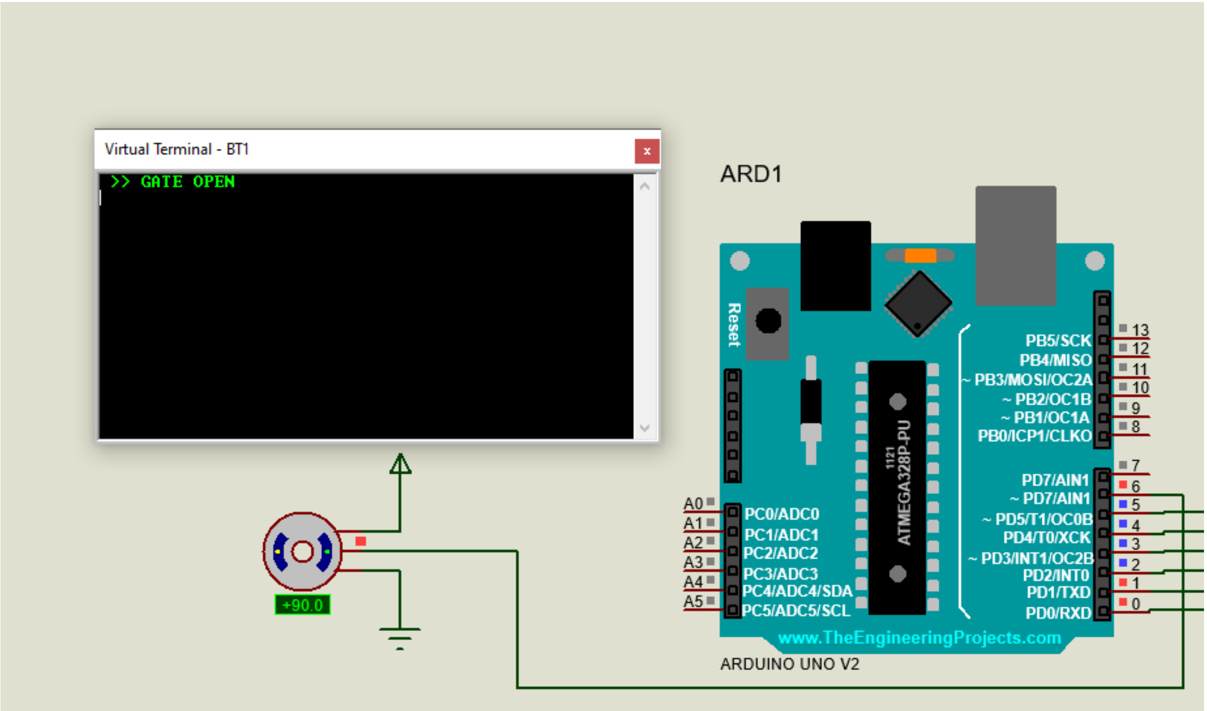

Figure 35: Schematic Diagram for controlling collapsible gate when it is open

The figure above shows the driving mechanism of a servo motor that is connected to the collapsible gate. Here, to open the gate ‘O’ button is used. When the operator needs to collect trash, pressing the ‘O’ button will open the gate and all trash is stored inside the robot.

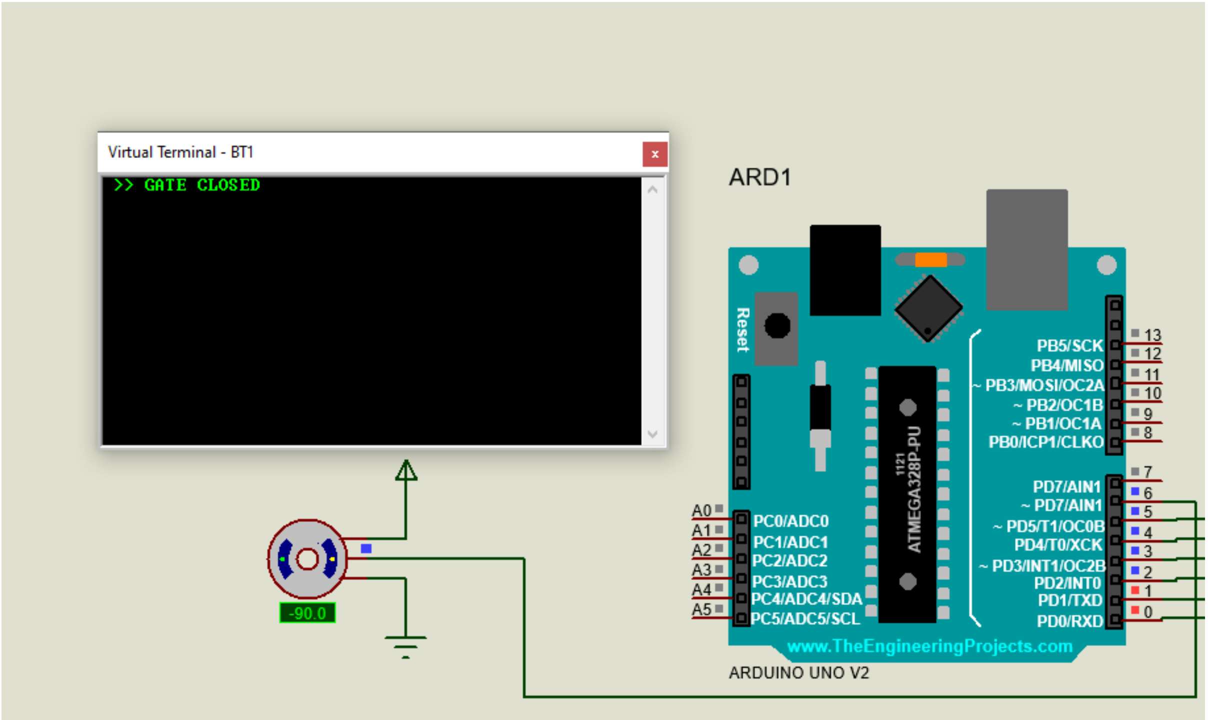

Figure 36: Schematic Diagram for controlling collapsible gate when it is close

'C' button is for closing the gate. This would be helpling the robot for not gathering any other trash and also to stop the trashes for going outside again

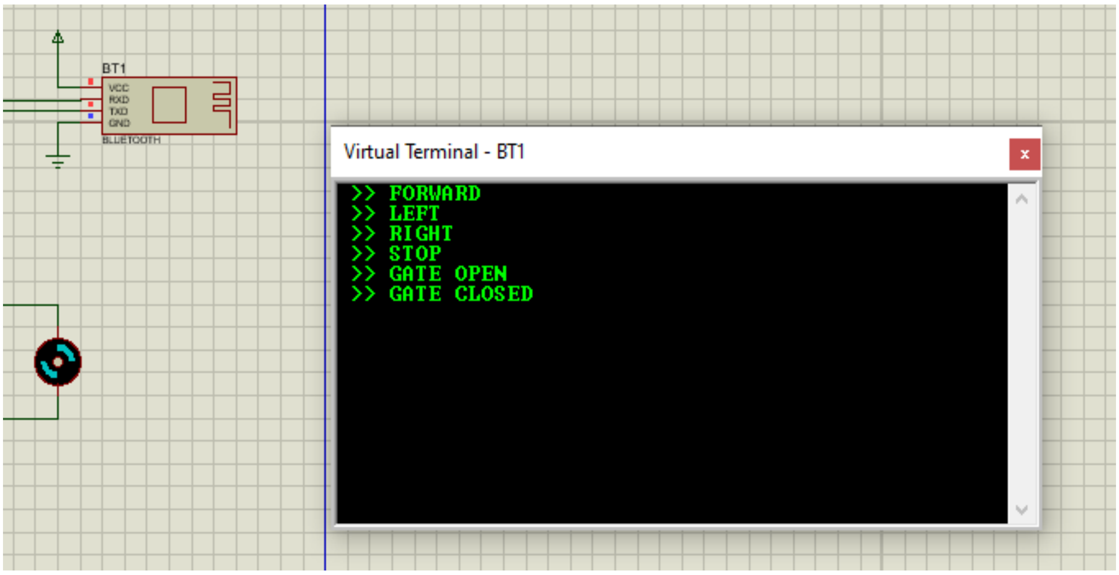

Figure 37: Schematic Diagram of Virtual terminal have all key for design 2

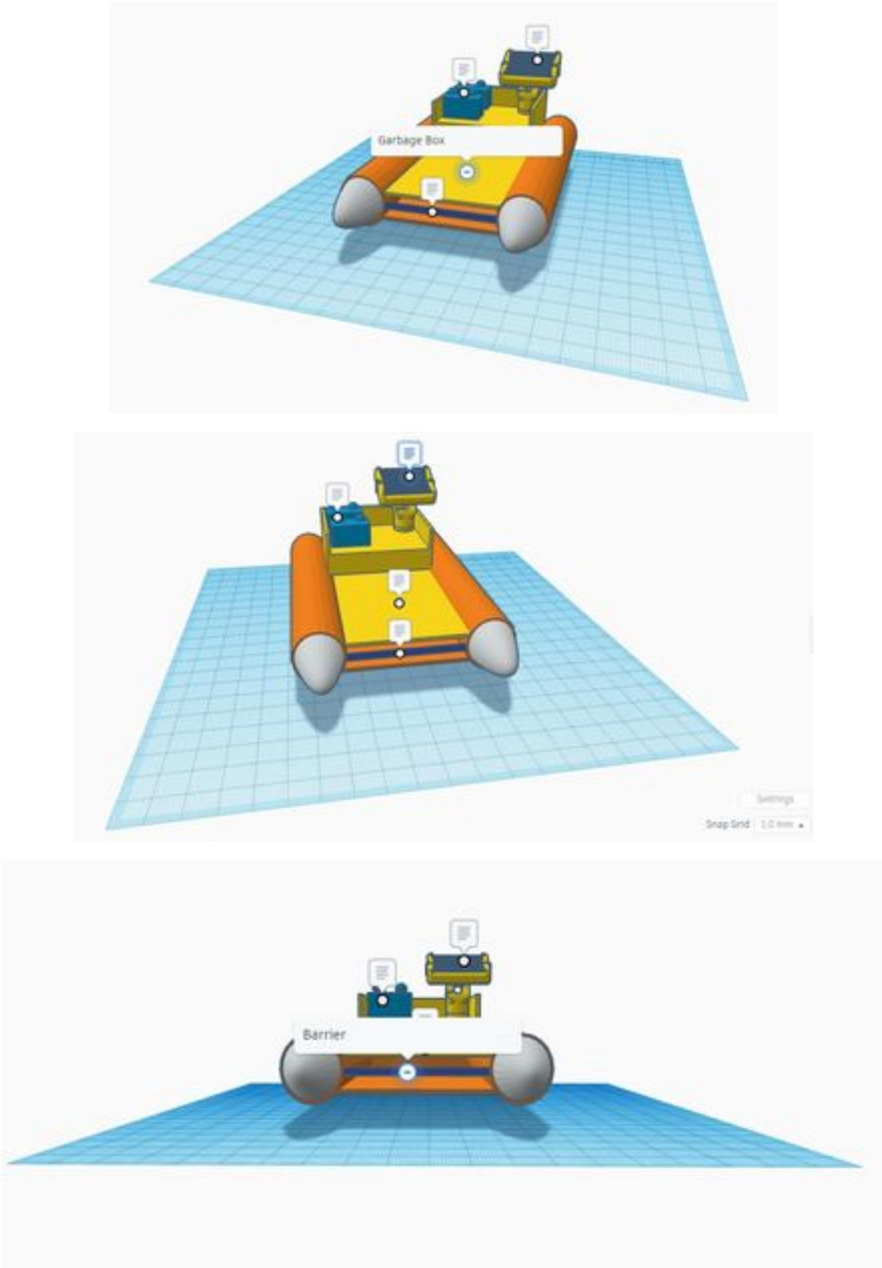

Figure 38: 3D model of Design 02

Simulation Graph for Design 2:

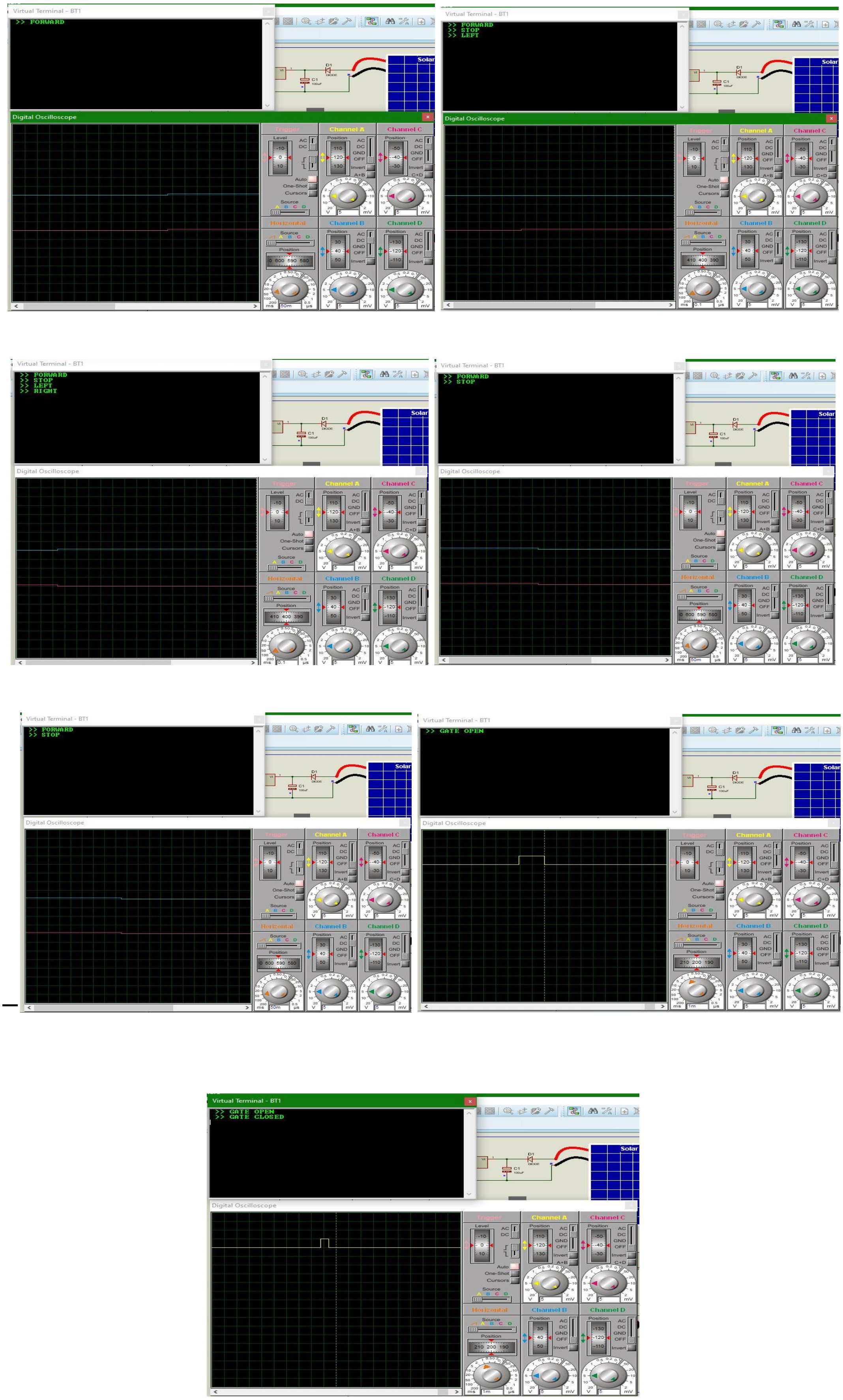

Figure 39: Simulation graph Design 2

4.2.3 Design Approach 03

The design approach illustrated below in the figure uses Arduino UNO as its processing unit. A GSM module is used to control all the activities of the robot. In this design approach we use 2 L298N motor drivers as we need three DC motors and only two motors can be connected in one motor driver. One DC motor will help to move the robot forward and backward and the other two are for front scooper and back scooper. For controlling the direction of the robot a servo motor is connected directly to the microcontroller.

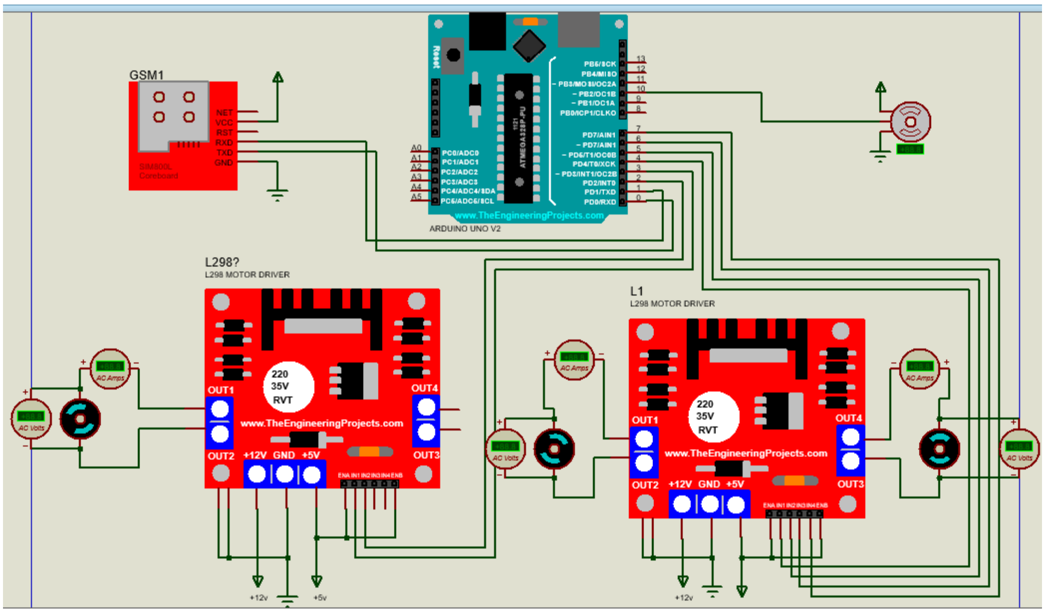

Figure 40: Schematic Diagram of Design 3

Charging Mechanism: The solar panel will charge the battery because our project is solar-powered. The battery will power the entire system after it has been charged. For charging the DC battery solar panel is used, a solar charge controller is used to regulate the voltage and current. The solar panel's positive and negative terminals should be connected to the charge controller, as well as the DC battery's positive and negative terminals.

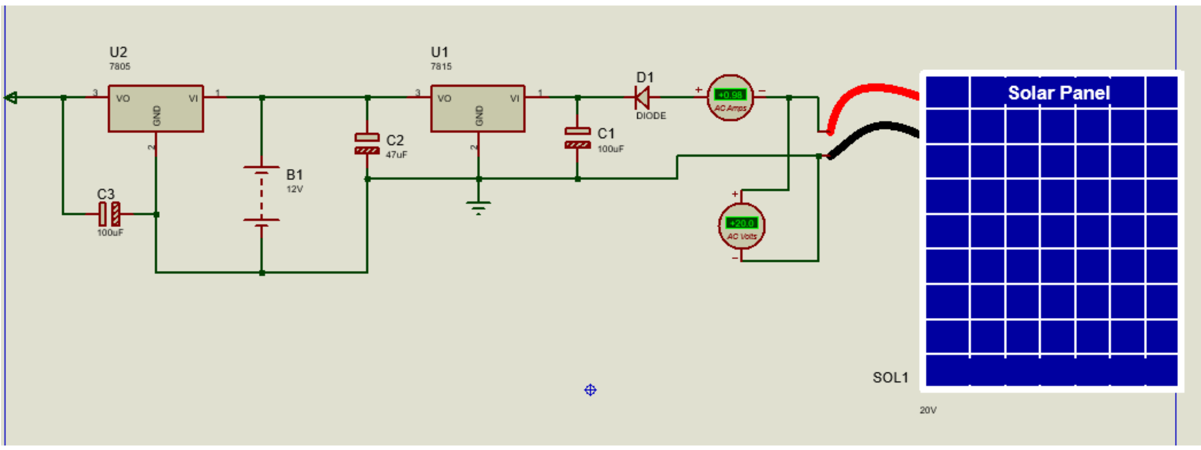

Figure 41: Schematic Diagram of charging mechanism

Control Mechanism: The robot's operation is facilitated by an Arduino Uno microcontroller, which is powered by a battery. Motor drivers are connected to the microcontroller, which enables it to control the motors. Upon receiving a command from the GSM module, the microcontroller processes the command and sends a signal through the motor drivers to the motors.

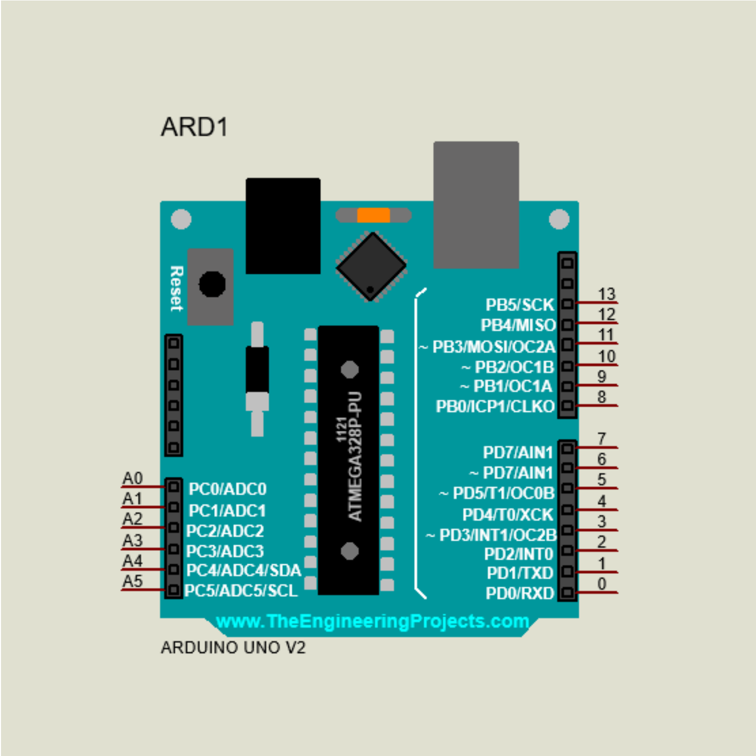

Figure 42: Schematic Diagram of microcontroller

The robot is operated using an Arduino Uno microcontroller that is powered by a battery, with the motor drivers also connected to the microcontroller. When a command is sent from the GSM module, the microcontroller processes it and sends a signal to the motors through the motor drivers, enabling movement. Essentially, the GSM module serves as the input device, while the Arduino Uno serves to interpret the command, and the motor drivers facilitate the movement of the motors.

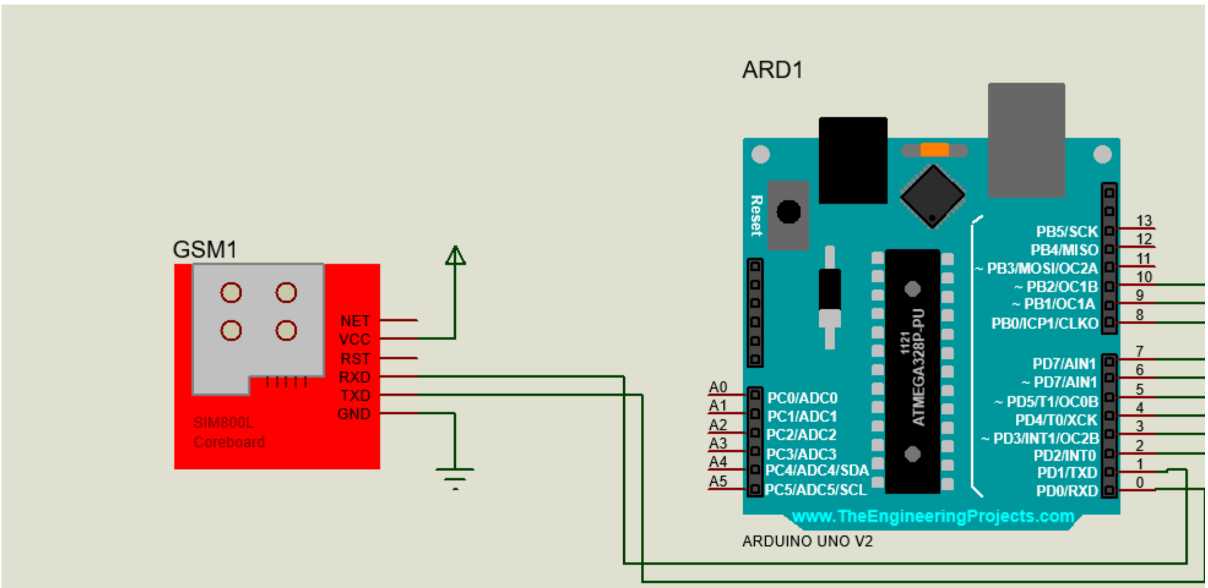

Figure 43: Schematic Diagram of microcontroller and GSM module

The figure above shows us the connection of a GSM module to a microcontroller. This will make communication with the robot to the user. Once the command is processed, the Arduino Uno sends a signal to the motor drivers to activate the motors and initiate movement. The motor drivers translate the signal into motion, causing the robot to move according to the command sent from the GSM module.

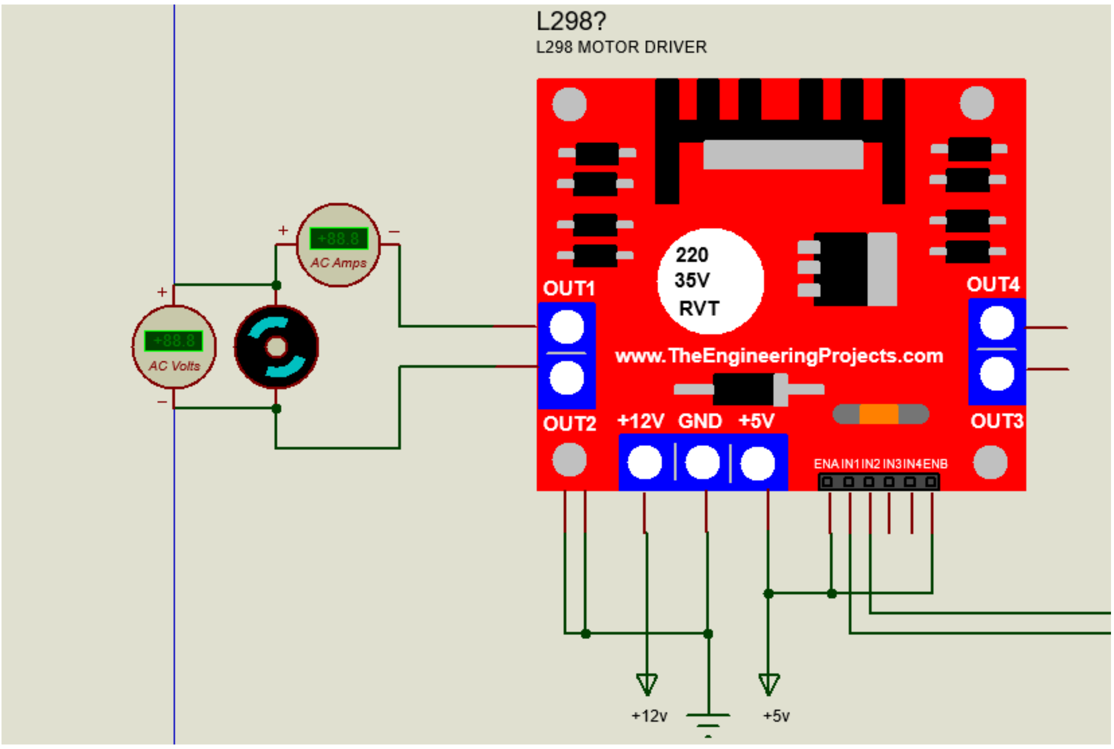

Figure 44: Schematic Diagram of motor driver and a DC motor

Here in this design one DC motor will be used to motor the robot toward the forward and backward given by the signal using the GSM module. Microcontroller will receive the signal for the operator and then run accordingly.

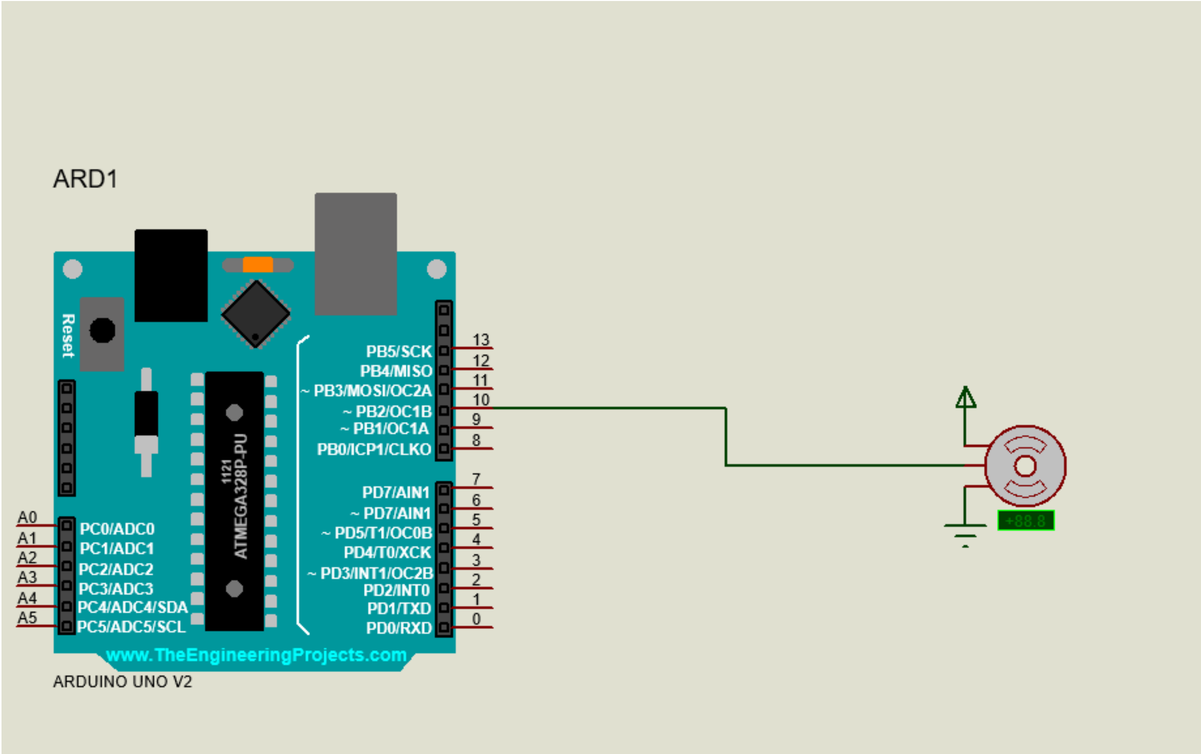

Figure 45: Schematic Diagram of microcontroller and Servo motor

Servo motor is used to give the robot its direction. The servo motor is programmed to rotate to specific angles, which can move the robot in different directions. This motor is used because of its precision and ability to rotate to specific angles.

Driving Mechanism: As previously stated, the robot is controlled using a GSM module. Even though the Proteus GSM module does not exist in Proteus, we will use a virtual terminal in this example. Here one DC motor is used to drive the robot forward and backward. Servo motor is used to give direction to the robot.

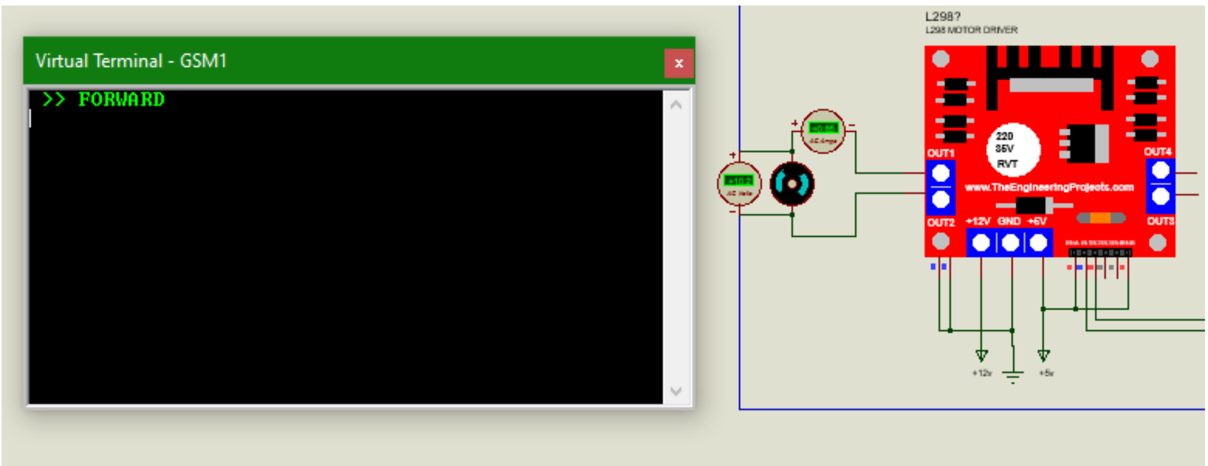

Figure 46: Schematic Diagram of design 3 with Controller (Virtual Terminal)

A virtual terminal is used to issue commands for operation. When the operator hits the 'F' button, the DC motor attached to the motor driver begins and propels the robot forward. If the operator wants to stop the robot from going ahead, the 'S' button must be hit. This disables the DC motor and prevents the robot from going ahead.

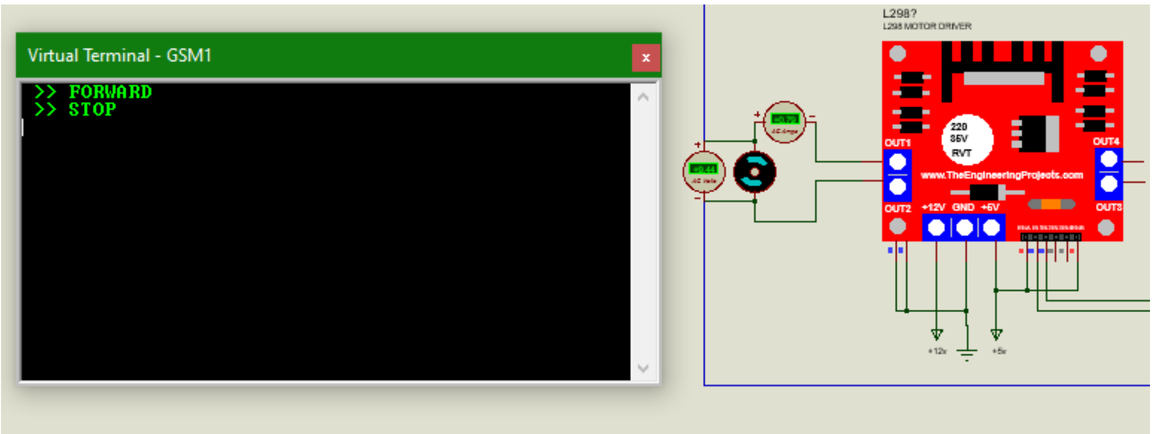

Figure 47: Schematic Diagram of design 3 with Controller (Virtual Terminal)

To move the robot backward, use the 'B' button. Users may need to move the robot backwards for cleaning, unloading garbage, or other unfavorable conditions. This backward option is being utilized for such purposes.

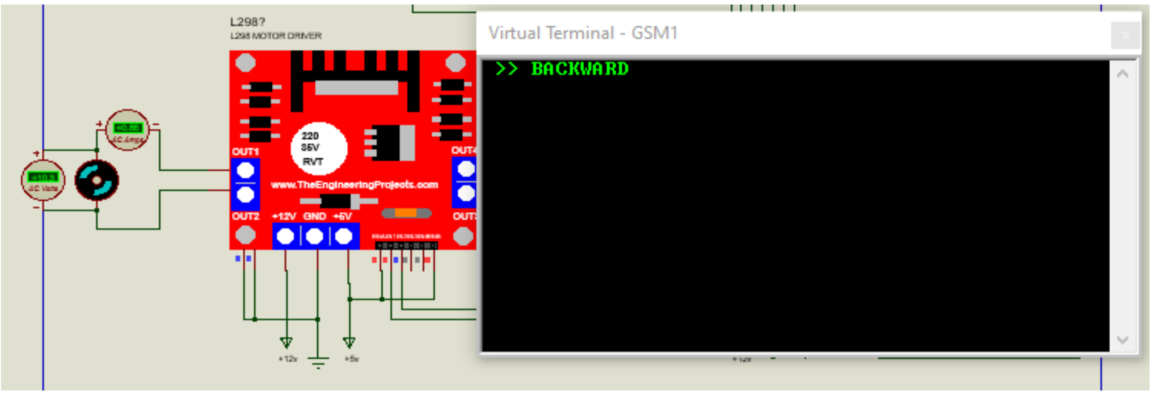

Figure 48: Schematic Diagram of design 3 with Controller (Virtual Terminal)

A servo motor is utilized to provide direction to the robot. This will give the robot a direction instruction. Using the virtual terminal keys, we can move the robot left and right.The key 'L' is being used to move the robot to the left. The key 'R' is used here to advance the robot to the right.

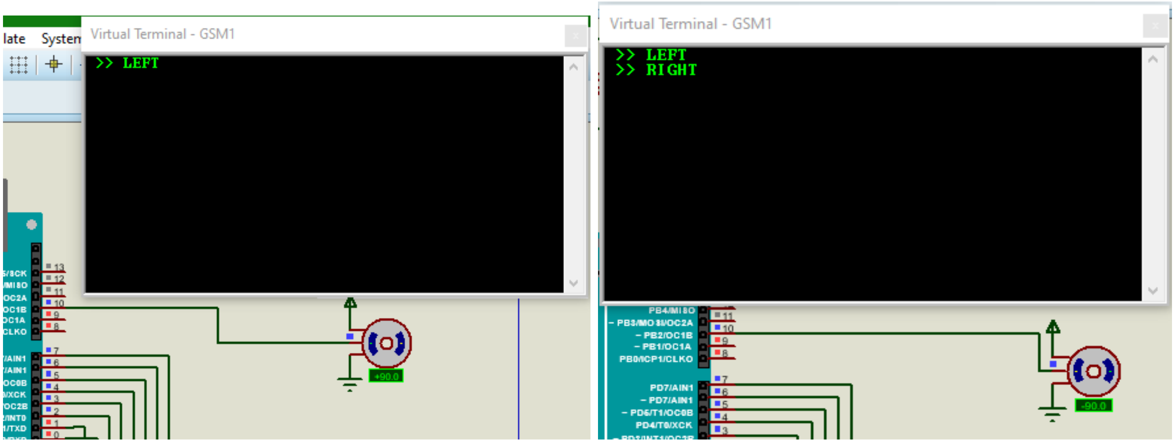

Figure 49: Schematic Diagram of design 3 with Controller (Virtual Terminal)

Trash Collection: Three scoopers are linked here to gather trash. One is in front, while the other two are to the left and right. As an example, we are using a virtual terminal for a GSM module. Despite the fact that the GSM module does not present in Proteus, when we push 1, the front scooper activates and gathers garbage; when we press 2, it stops.

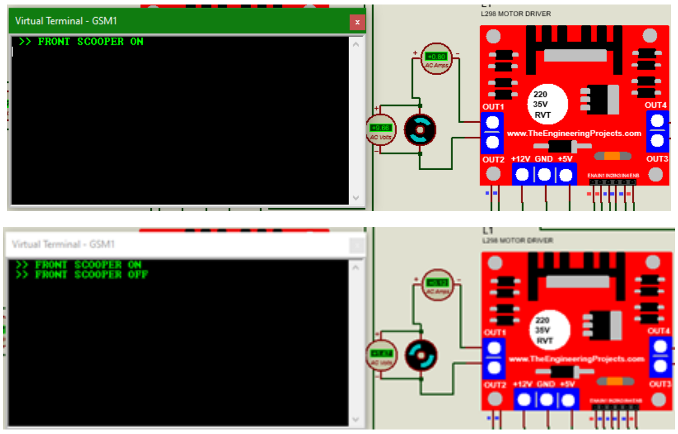

Figure 50: Schematic Diagram of trash collection system

When we hit 3, both the side scopers turn on and gather trash; when we press 4, it stops.

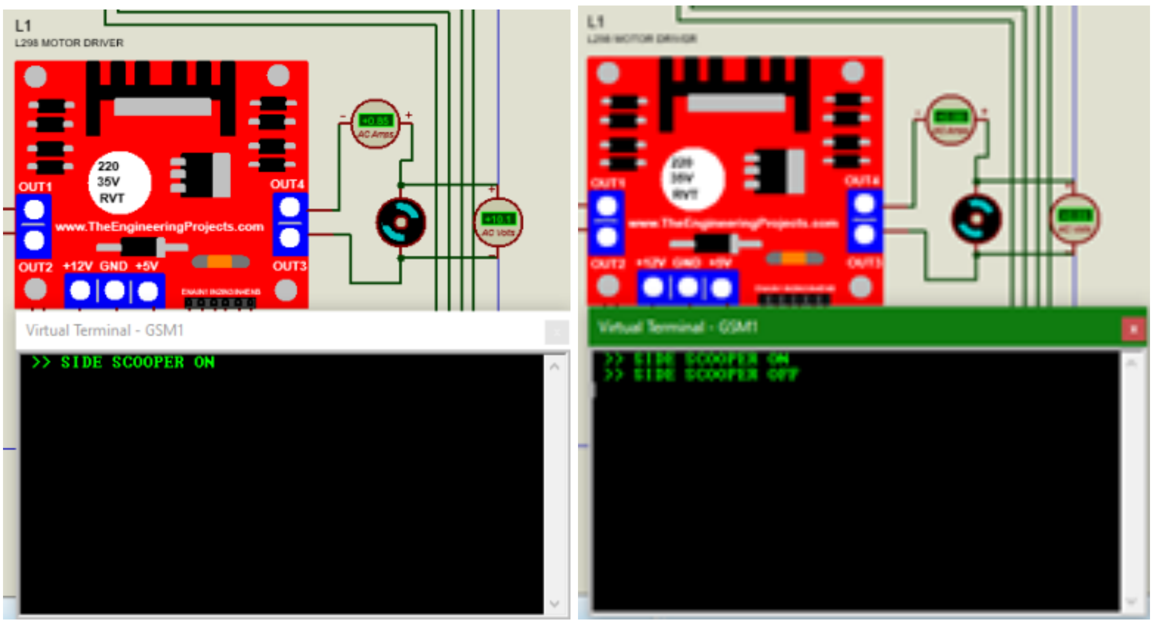

Figure 51: Schematic Diagram of trash collection system

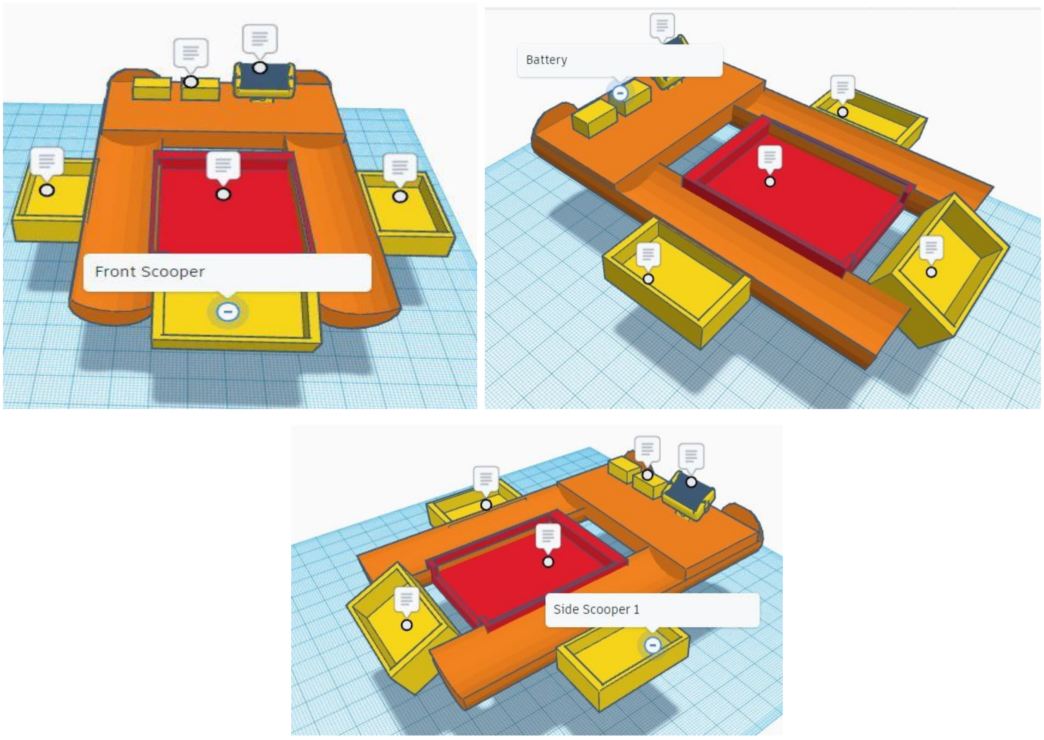

Figure 52: 3d model of design 3

Simulation Graph for Design 3:

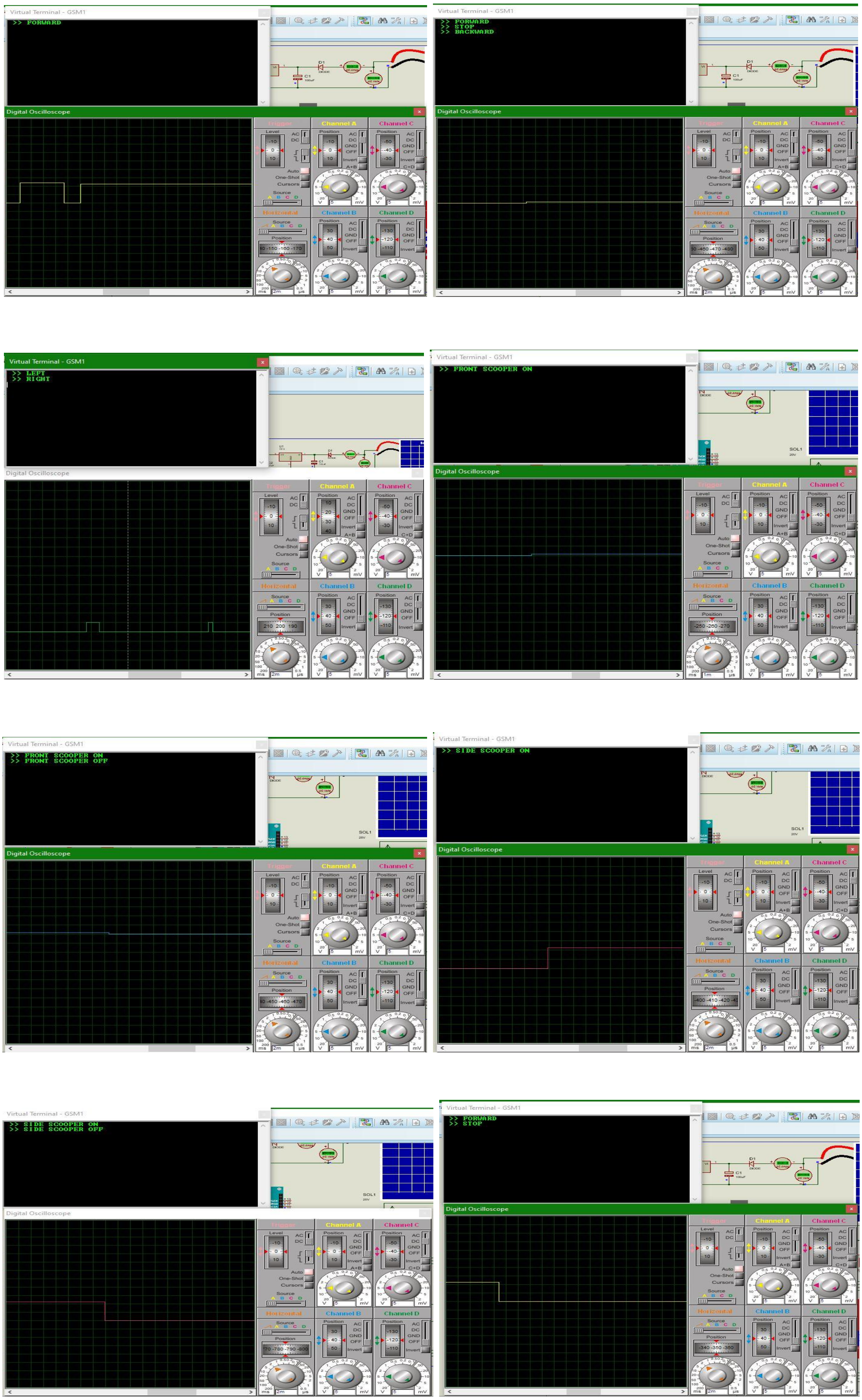

Figure 53: Simulation graph for side scooper off of Design 3

4.3 Identify optimal design approach

Power Consumption :

Table 7: Table of Power Consumption

Parameters Of assessment	**Design 1**	**Design 2**	**Design 3**
Driving mechanism	1 DC Motor : 9.218W 1 Servo Motor : 4.5W	2 DC Motors : 17.716W	1 DC Motor : 9.218W 1 Servo Motor : 4.5W
Trash collection	1 Stepper Motor: 0.36W	2 Servo Motor : 9W	2 DC Motors : 17.716W
Total	13.71W	26.716W	31.434W

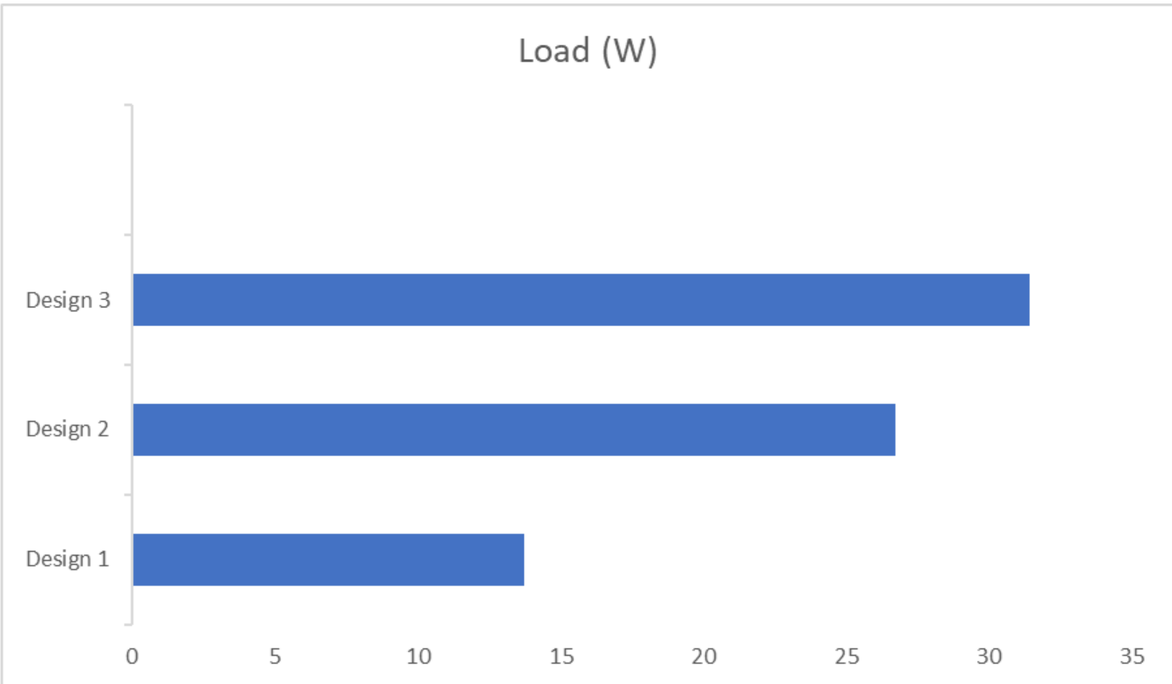

Figure 54: Power consumption graph

In the table, we can see the predicted load for Design Approaches 1, 2, and 3. In this case, Design 3 uses more power than the other designs, whereas Design 1 uses less.Here, Design 1 uses 13.71W, Design 2 uses 26.716W, and Design 3 uses 31.434W. As a result, we may conclude that Design 1 is more efficient than the other designs.

Control Mechanism:

In “Design Approach 1”,the system includes a Bluetooth module-based control mechanism for controlling the robot. An IR sensor is used to alert the user to the presence of rubbish. The user will operate the robot using the Bluetooth module and collect rubbish using the conveyor based on that signal. A microcontroller is utilized to accomplish all of these activities. Two motor drivers were utilized to control the motors. In “Design Approach 2” The robot is controlled by an Arduino Uno microcontroller. It will be connected to the battery. The motor drivers are hooked to it. When a command from the Bluetooth module is received, the device analyzes it and transmits a signal to the motor through motor drivers. In “Design Approach 3”the robot's functioning is enabled by an Arduino Uno microcontroller, which is powered by a battery. The motor drivers are linked to the microcontroller, allowing it to operate the motors. When the microcontroller receives a command from the GSM module, it analyzes the command and delivers a signal to the motors through the motor drivers.

In "Design Approach 1" and "Design Approach 2," we employ the Bluetooth module to operate the robot's driving mechanism. Nevertheless, in "Design Approach 3," we employ a GSM module to operate the robot's driving mechanism. Because the robot is so little, it will be used on lakes and other small bodies of water. Furthermore, the range of a bluetooth module is average, making it ideal for usage in small water areas and lakes. We can control the robot standing on the river's bank with this. Furthermore, in "Design Approach 3," we employ a GSM module to operate the driving mechanism, as well as an ESP32 camera to provide real-time feedback. Because the GSM module allows the robot to be operated from a distance, there may be issues with signal transmission for a variety of reasons. If there is a difficulty with signal transmission, the robot will not function.

In “Design Approach 1” we use an IR sensor. Sometimes IR sensors may be faulty. Due to errors the signal cannot be sent even after detecting the object. The microcontroller cannot communicate with the user through the bluetooth module if it cannot identify any signal from the IR sensor. Therefore, controlling the automaton will be challenging for the user. However, in design approach 2, the IR sensor is not linked to the microcontroller. The Bluetooth module will be connected straight to the microcontroller in Design Approach 2. The person can thus give the robot direct commands. Compared to designs 01 and 03, there is a lower likelihood of transmission loss.

Therefore, “Design Approach 2” is more effective at managing the robot than design 01 and design 03.

Trash Collection:

In “Design Approach 1”,a conveyor belt is linked to the stepper motor to collect rubbish. We also include an IR sensor to identify garbage. When the IR sensor provides a signal to the Arduino, the Arduino transmits signals to the motor driver, and the stepper motor begins to move down the conveyor belt. In “Design Approach 2” Using a servo motor to drive a thin foldable fence on a floating water surface cleaning robot can help enhance cleaning efficiency and effectiveness by allowing the robot to maneuver around barriers and avoid becoming tangled in dirt. In “Design Approach 3”,we gather garbage with three scoopers. One scooper is in front, while the other two are on the robot's left and right sides. On the stern of the boat, we create a garbage collecting box. These scoopers will gather rubbish and place it in the trash box.

In “Design Approach 1 and 3”, The gathered rubbish is stored in a box on top of the robot. As a result, the robot's weight grows. Because of the increased weight, more force will be required. As a result, more power will be required. However,in “Design Approach 2” a thin foldable fence will be erected in front of the garbage cage, which will be positioned beneath the deck. As soon as floating garbage enters the cage, the gate will be closed. Therefore, the weight of the robot will not increase. So, there will be no need for extra power. Moreover, because of less weight, the robot will move faster than “Design Approach 1 and 3”.

Hence, “Design Approach 2” is more suitable in terms of collecting trash than “Design Approach 1 & 3”.

Cost:

The total cost for “Design Approach 01” is seen to be approximately 17978 taka whereas for “Design Approach 02” the cost is around 15110 taka and for “Design Approach 03” the cost is around 20373 taka.

Therefore, from an economical perspective we can say that the “Design Approach 02” is more optimal than “Design Approach 01” and “Design Approach 03”

4.4 Performance evaluation of developed solution

Three factors—power consumption, control mechanism, and trash collection effectiveness—can be used to summarize the performance evaluation of the solutions that have been developed. Let's examine each component of each design strategy in more detail:

Power Consumption:

• Design Approach 1: has the lowest power consumption of the three designs, utilizing a total of 13.71W. It uses a stepper motor and a servo motor for trash collection and a DC motor and servo motor for the driving mechanism.

• Design Approach 2: It uses a total of 22.216W of power, which is more than Design Approach 1. The driving mechanism is powered by two DC motors, while the trash collecting is handled by a servo motor.

• Design Approach 3: With a total power usage of 31.434W, this design consumes the most energy of the three. For the driving mechanism, it uses one DC motor, one servo motor, and two DC motors for trash collection.

Design Approach 1 appears to be the most effective just based on power usage.

Control Mechanism:

• Design Approach 1: uses an IR sensor and a Bluetooth module-based control mechanism to detect trash. When the IR sensor malfunctions, the user controls the robot via the Bluetooth module, which is susceptible to transmission loss.

• Design Approach 2: The IR sensor is not connected to the microcontroller, but it still makes use of a Bluetooth module-based control system. By directly communicating with the robot over Bluetooth, the user lowers the possibility of transmission loss.

• Design Approach 3: Uses an ESP32 camera for real-time feedback and a GSM module-based control system. Although it enables remote control of the robot, signal transmission problems could arise.

Design Approach 2 seems to be the most effective in terms of control mechanism due to its direct user-command interface.

Trash collection:

Design Approach 1: Employs a conveyor belt and an IR sensor. The robot's weight and power requirements are increased by the storage of the collected trash in a box on top of the robot.

• Design Approach 2: To gather trash, a servo-driven, thin, foldable fence is used. The fence keeps the weight of the robot from being increased by the trash that has been collected, enhancing productivity.

• Design Approach 3: Scoopers are used to collect trash, which is then put in a box at the stern of the boat.

Due to its less weight and quicker mobility, Design Approach 2 seems to be more effective in terms of trash collection.

4.5 Conclusion

The total performance review shows that "Design Approach 2" is the best option out of the three, so to speak. In comparison to the alternative ways, it uses less electricity, has a better control system, and a better trash collection technique. It is also less expensive, making it the most inexpensive option. When deciding on the optimal solution for the intended application, it's crucial to take additional elements into account, such as durability, maintenance, and special use-case requirements.

Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction

In the previous chapter, the proposed plans were extensively compared and evaluated. Software simulations were conducted to test the circuitry and feasibility of the prototype design. Additionally, various troubleshooting options were explored to optimize the system further. A hardware prototype was developed based on the chosen optimal solution for future testing. After careful consideration, it was decided to proceed with design one, which involves creating a prototype using a regenerative braking system. This chapter offers a comprehensive overview and analysis of the selected design, summarizing its key aspects and implications.

5.2 Completion of final design

In figure 55, we created the entire circuit using proteus and that will help us to build the prototype.

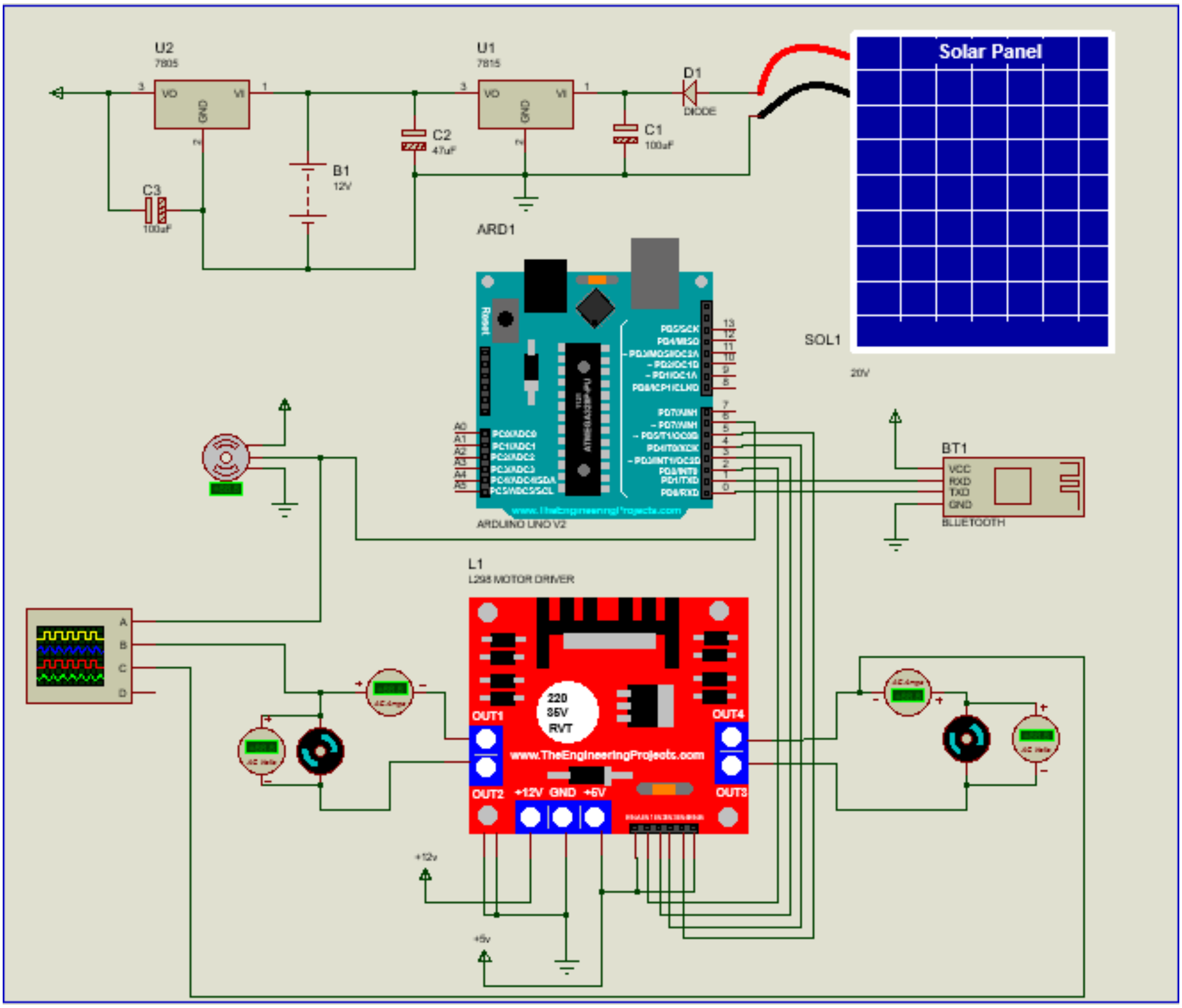

Figure 55: Simulation of the entire design process

We then went ahead and collected the crucial data regarding the prototype and other designs that were previously available on the market in order to ascertain the kind of product consumers would like.
We met with the stakeholders to obtain the guidance and information we required to create it. We also had to visit numerous places in order to create the budget and learn more about the necessary items and their costs. Before the tiny size prototype was used, we made an effort to visualize it. We built a 3D model of the prototype to put the idea into perspective and to aid in building by giving us a visual of what the final product would look like.

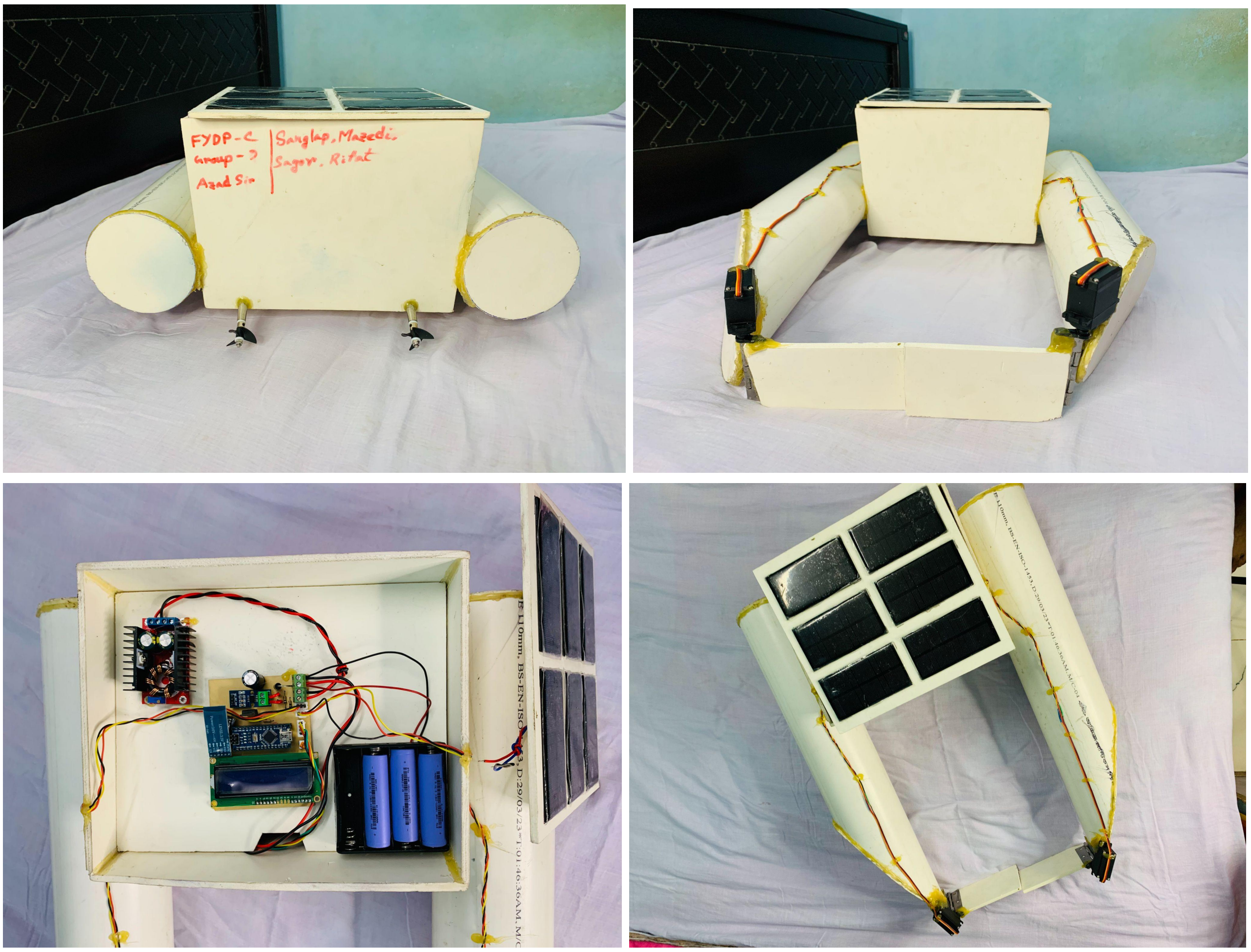

Figure 56: Prototype cleaning robot for conversion

Figure 56 shows the prototype cleaning robot.To build this robot we used different types of components.Here are the pictures and description of all components

Figure 57: HC-05 Bluetooth Module

Here, we use an HC05 to deliver commands to an Arduino Uno. We are using this module to maintain serial communication with our receiver device. We install a software named ‘Bluetooth RC Controller’ in our receiver device through which we are sending the commands to our robot to move forward, backward, left, and right.

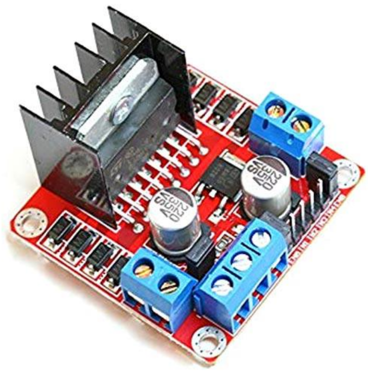

Figure 58: L298N Motor Driver

For powering our DC motors, we use the L298N high-power motor driver module. A 78M05 5V regulator and an L298 motor driver IC make up this motor driver. Here, the L298N motor driver is used to give the motors we're using the best possible power. It has direction and speed control capabilities.

Figure 59: Servo Motor

A motor type with exceptionally accurate rotational capabilities is a servo motor. Typically, this sort of motor incorporates a control circuit that provides feedback on the location of the motor shaft right now. The servo motors' exact rotation is made possible by this feedback.. Here, we will use two servo motors to make our robotic forearm. Normally these motors will be attached in front of the robot. In normal situations, the forearm will be wide open by 120°, but it can be rotated by 180° maximum. When the floating trash will enter the garbage collector box and fill the garbage box fully the forearm will be closed. When it closes the arms will return to the 0° position.

Figure 60: DC Gear Motor

An electric motor and a gearbox with several gears are the two mechanical components that make up a gear motor. The gearbox of the motor must lower its speed and increase its torque in order to execute a task at a particular speed. Gear motors will be connected to shaft propellers. Gear motors are driving the robot forward, backward, left, and right. The motor's speed can be controlled by the microcontroller. For our prototype purpose, we are using a 1000 rpm gear motor.

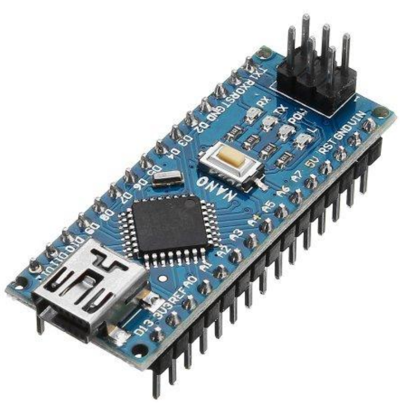

Figure 61: Arduino Nano R3

The ATmega328-based Arduino Nano (Arduino Nano 3.x) is a compact, comprehensive, and breadboard-friendly board. We are utilizing an Arduino Nano R3 to take commands and control all of the components. We use Arduino Nano for fitting in PCB boards. It has an operating voltage of 5 volts. Arduino Nano is the main control mechanism module for the robot.

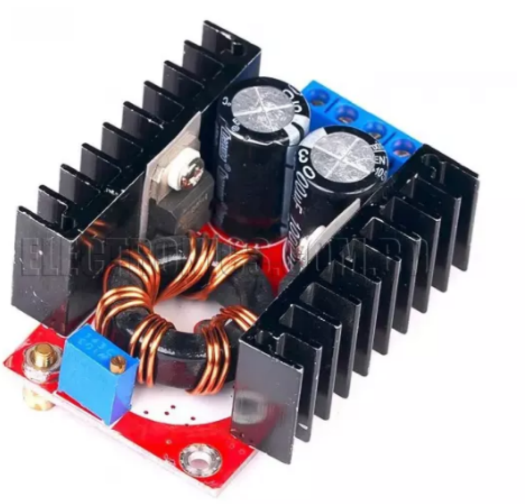

Figure 62: DC-DC Boost Converter

Here we are using “DC-DC 150W STEP-UP MODULE BOOST CONVERTER 12-32V TO 12-35V”. It is a non-isolated booster module. For stable and regulated voltage levels we use it in our prototype. The boost converter ensures that the input voltage of battery charging remains within a specified e 12V even when the input voltage fluctuates. It has 94% conversion efficiency. The boost converter can step up the required voltage to the operation that demands it.

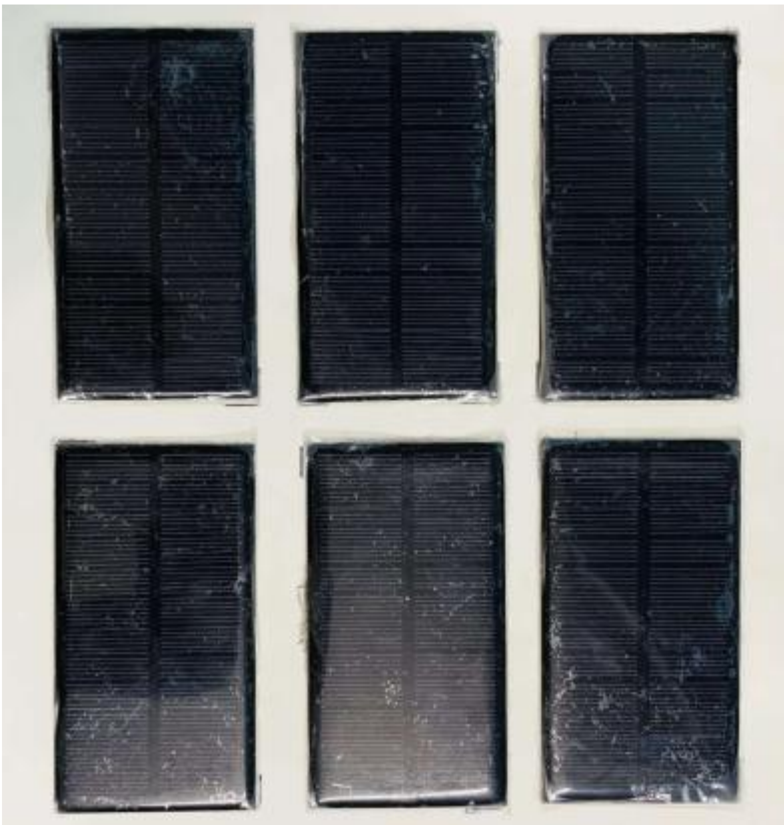

Figure 63: Solar Panel

As our robot is solar-powered that is why the solar panel is one of the most important components of our robot. For our prototype, we use 6 volts 2 watts of 6 solar panels. These panels will convert sunlight into electricity by using photovoltaic cells.

Figure 64:Shaft Propeller

The propeller shaft's job is to transfer torque between the driving axles, the transfer case, and the transmission. Two rotational axes that are not exactly in the same plane can be connected by the propeller shaft. The shaft propeller is connected to the motor. The water is moved by the propeller, drawing it behind itself (the action), and the robot is subsequently propelled forward by the ensuing pressure difference (the opposing reaction). The more thrust or forward propulsion is produced the more water that is drawn behind the propeller.

Figure 65: LCD Display

In this display we can see battery voltage and solar panel current and voltage. From here we can measure solar panel power distribution.

Figure 66: Joint Gimbal

We are using this joint gimbal for connecting the shaft propeller to the DC gear motor.

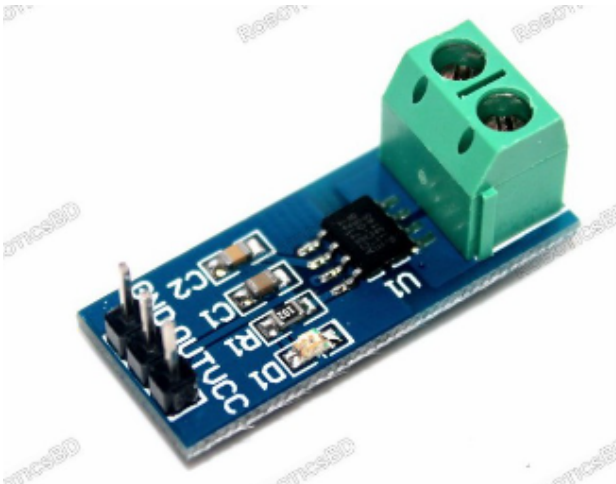

Figure 67: Current Sensor

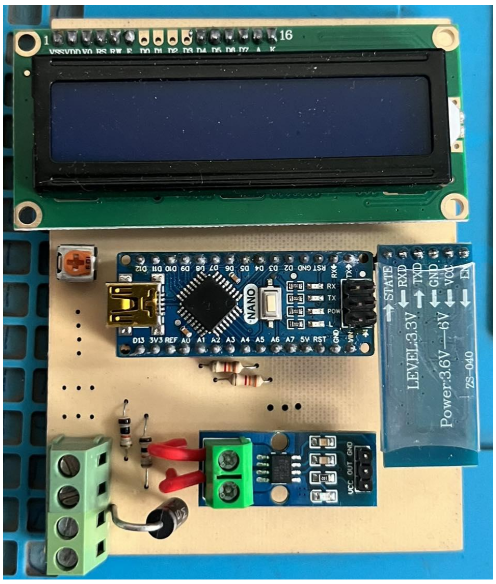

Figure 68: PCB

For organizing our components sequentially we are using PCB here. It is quite simple for us to solder the components when we use a PCB.

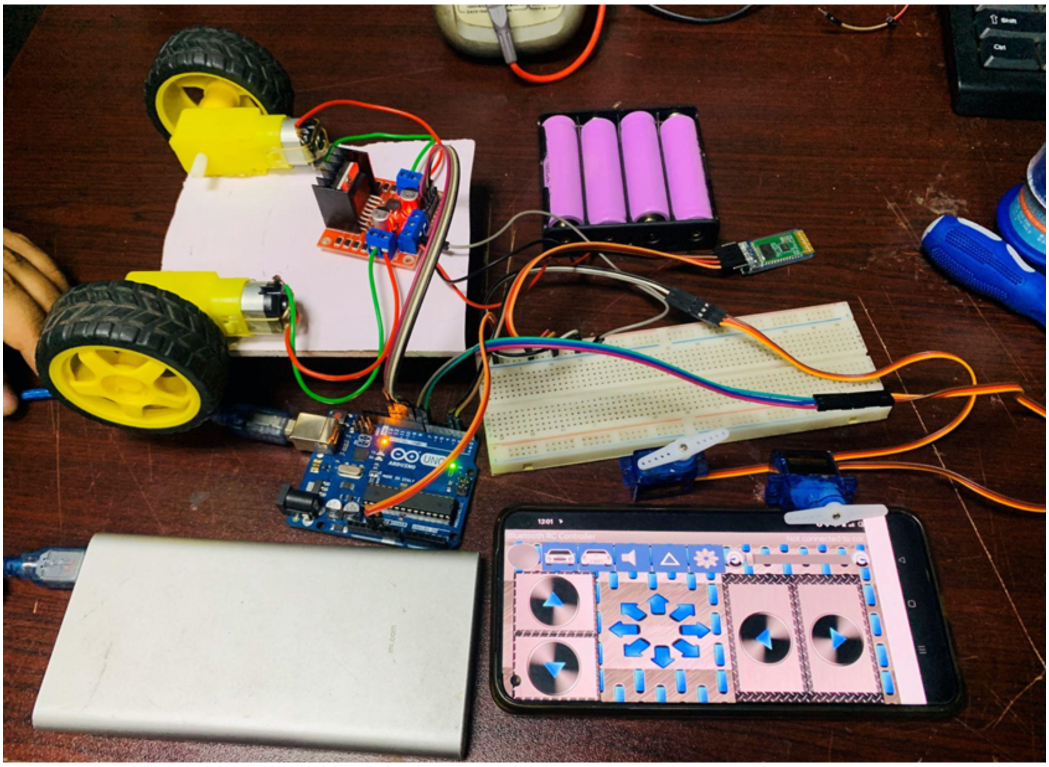
Figure69 : Electrical circuit implementation of Final Design

This is our hardware setup for our driving mechanism section, which we must now include into our main frame. We can see that all of the components are functioning properly.

5.3 Evaluate the solution to meet desired need

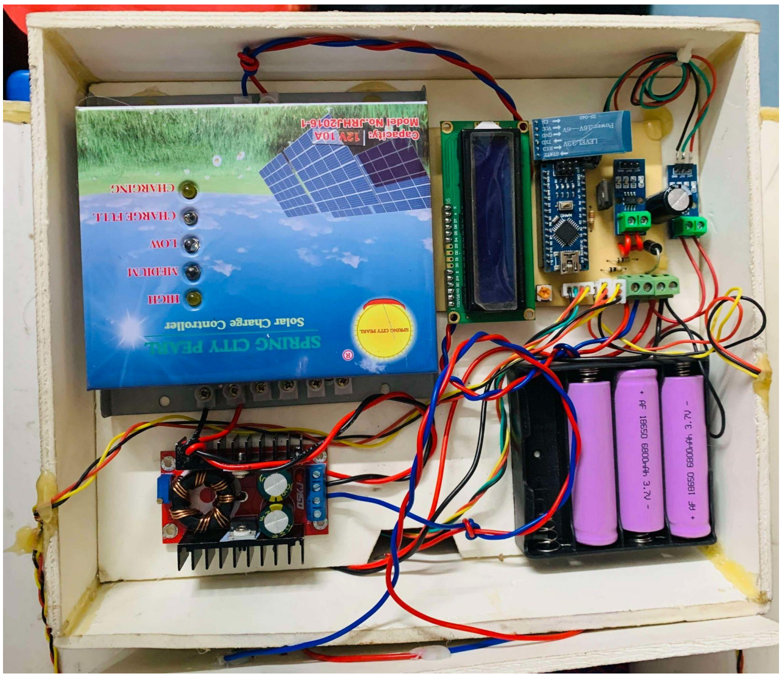

Figure70 :Electrical circuit and component box of prototype

This is the component box of the prototype. Here, we have a battery pack to charge up the device. We also have a booster module, solar charge controller and pcb board. In the pcb board we have an arduino nano, current sensor, bluetooth module HC05 and lcd display

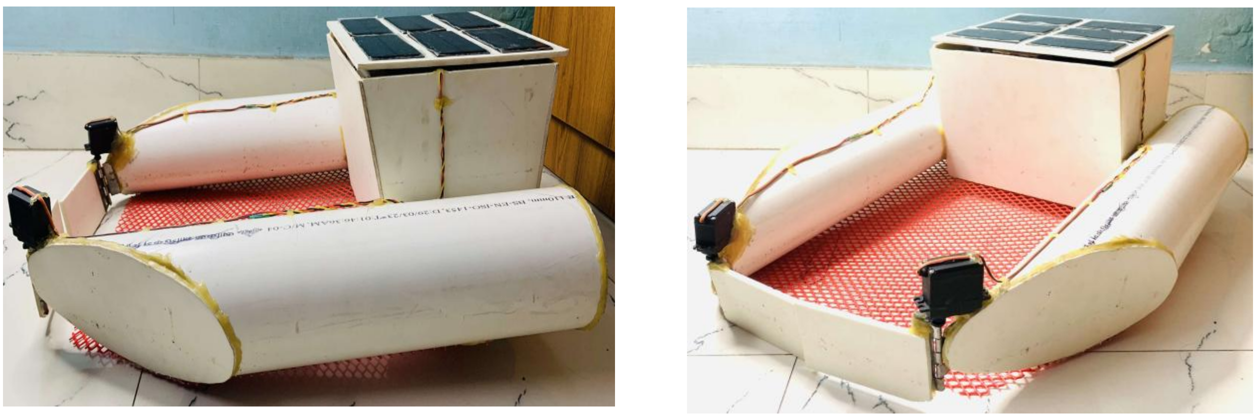

Figure71 :Final prototype

The initial trial phase of the solar-powered miniature water surface cleaning robot followed the outlined system flow diagram. In the preliminary test, the robot achieved a maximum distance of approximately 7.62 meter. Moreover, the first test could not give us accurate data as we were not running it into the water. During testing, the operation mechanism was facing a problem as solar could not provide proper voltage to the battery. This prevented the motor from generating power efficiently in lower sunlight. To optimize the performance of the water surface cleaning robot, further tests are required under varied conditions. This will allow for a more comprehensive evaluation of the regenerative cleaning system's potential when the robot operates with the necessary load and speed.

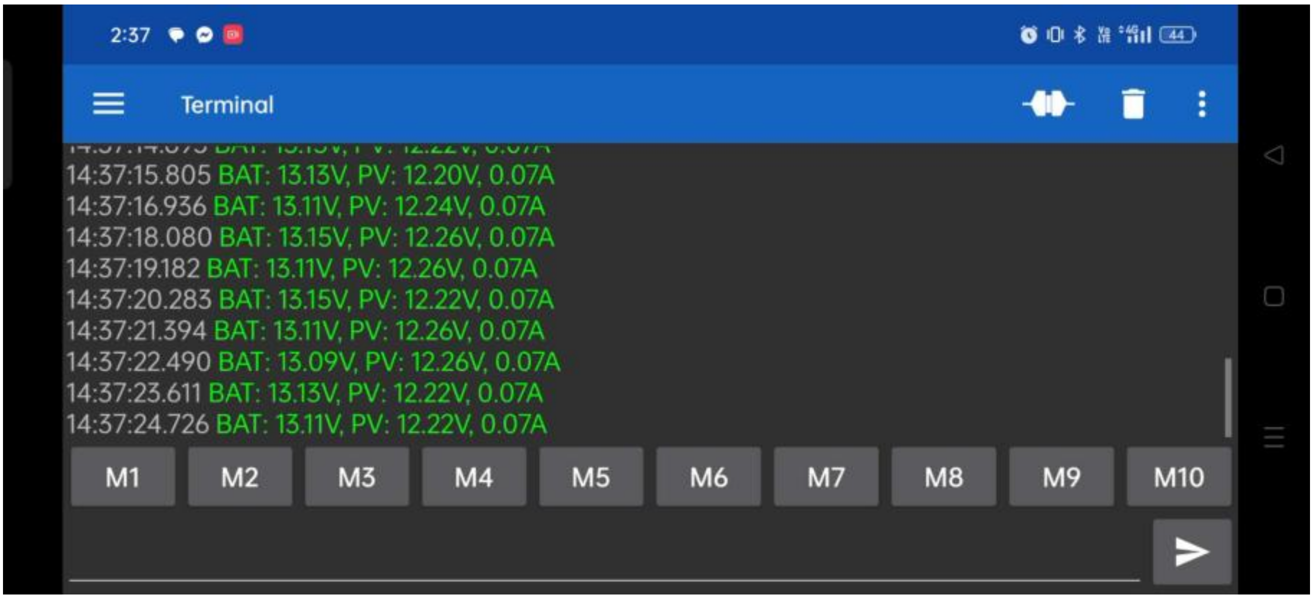

Figure72 :Controller of our prototype by Serial Bluetooth Terminal

This is the control module of the robot. Here we use a serial bluetooth terminal to control the robot. This also shows battery voltage and current and also PV voltage and current.

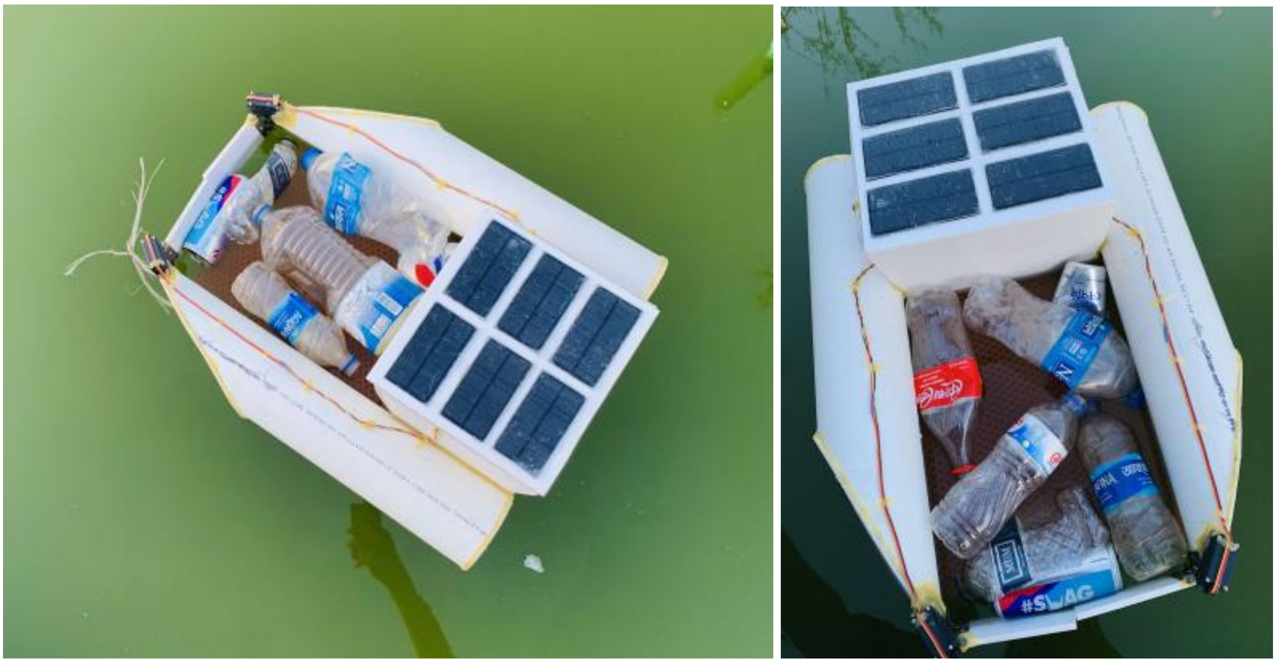

Figure73 :Testing final Prototype

We went to the countryside to test our prototype in a pond. There was floating waste in the pond. We launched the prototype into the water. At first, we checked if the prototype was functioning properly or not. Then we measured the speed of our prototype. After measuring the speed, we started to collect the trash at the pond, which was at a different distance.

5.3.1 Observation of battery voltage, PV voltage and current and PV power supply

Table 8: Table of battery voltage, PV voltage and current and PV power supply

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
2:17:32	13.58	12.22	0.07	0.8554
2:17:33	13.58	12.26	0.07	0.8582
2:17:34	13.58	12.22	0.07	0.8554
2:17:35	13.58	12.32	0.07	0.8624
2:17:36	13.58	12.32	0.07	0.8624
2:17:37	13.58	12.24	0.07	0.8568
2:17:38	13.58	12.2	0.07	0.854
2:17:39	13.58	12.24	0.07	0.8568
2:17:40	13.58	12.32	0.07	0.8624
2:17:41	13.58	12.32	0.07	0.8624
2:17:42	13.58	12.22	0.07	0.8554
2:17:43	13.58	12.28	0.07	0.8596
2:17:44	13.58	12.32	0.08	0.9856
2:17:45	13.58	12.22	0.07	0.8554
2:17:46	13.58	12.22	0.07	0.8554
2:17:47	13.58	12.24	0.07	0.8568
2:17:48	13.58	12.28	0.07	0.8596
2:17:49	13.58	12.28	0.07	0.8596

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
2:17:50	13.58	12.24	0.06	0.7344
2:17:51	13.58	12.28	0.07	0.8596
2:17:52	13.58	12.3	0.07	0.861
2:17:53	13.58	12.26	0.07	0.8582
2:17:54	13.58	12.26	0.07	0.8582
2:17:55	13.58	12.34	0.07	0.8638
2:17:56	13.58	12.24	0.07	0.8568
2:17:57	13.58	12.26	0.07	0.8582
2:17:58	13.58	12.22	0.07	0.8554
2:17:59	13.58	12.28	0.07	0.8596
2:18:00	13.58	12.24	0.07	0.8568
2:18:01	13.58	12.24	0.07	0.8568
2:18:02	13.58	12.22	0.07	0.8554
2:18:03	13.58	12.3	0.07	0.861
2:18:04	13.58	12.24	0.07	0.8568
2:18:05	13.4	12.32	0.07	0.8624
2:18:06	13.36	12.26	0.07	0.8582
2:18:07	13.38	12.32	0.07	0.8624
2:18:08	13.38	12.2	0.07	0.854
2:18:09	13.4	12.39	0.07	0.8673
2:18:10	13.4	12.24	0.06	0.7344
2:18:11	13.36	12.28	0.07	0.8596
2:18:12	13.4	12.3	0.07	0.861
2:18:13	13.4	12.22	0.07	0.8554

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
2:19:14	13.48	12.2	0.06	0.732
2:19:15	13.48	12.22	0.07	0.8554
2:19:16	13.46	12.22	0.07	0.8554
2:19:17	13.38	12.34	0.06	0.7404
2:19:18	13.48	12.75	0.08	1.02
2:19:19	13.46	13.29	0.07	0.9303
2:19:20	13.46	13.46	0.07	0.9422
2:19:21	13.46	13.46	0.06	0.8076
2:19:22	13.46	13.46	0.07	0.9422
2:19:23	13.44	13.46	0.07	0.9422
2:19:24	13.44	13.44	0.07	0.9408
2:19:25	13.44	13.44	0.07	0.9408
2:19:26	13.36	13.42	0.07	0.9394
2:19:27	13.36	13.42	0.08	1.0736
2:19:28	13.38	13.42	0.07	0.9394
2:19:29	13.38	13.4	0.07	0.938
2:19:30	13.35	13.36	0.08	1.0688
2:19:31	13.35	13.23	0.07	0.9261
2:19:32	13.36	12.61	0.07	0.8827
2:19:33	13.42	12.32	0.07	0.8624
2:19:34	13.46	12.24	0.07	0.8568
2:19:35	13.44	12.3	0.07	0.861
2:19:36	13.48	12.34	0.08	0.9872
2:19:37	13.46	12.34	0.07	0.8638

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
2:19:38	13.44	12.22	0.07	0.8554
2:19:39	13.46	12.22	0.07	0.8554
2:19:40	13.44	12.34	0.07	0.8638
2:19:41	13.46	12.34	0.07	0.8638
2:19:42	13.44	12.26	0.08	0.9808
2:19:43	13.44	12.24	0.07	0.8568
2:19:44	13.44	12.32	0.07	0.8624
2:19:45	13.54	12.22	0.07	0.8554
2:19:46	13.54	12.22	0.07	0.8554
2:19:47	13.54	12.26	0.07	0.8582
2:19:48	13.54	12.32	0.06	0.7392
2:19:49	13.54	12.32	0.07	0.8624
2:19:50	13.54	12.22	0.07	0.8554
2:19:51	13.54	12.32	0.07	0.8624
2:19:52	13.54	12.28	0.07	0.8596
2:19:53	13.54	12.28	0.07	0.8596
2:19:54	13.54	12.28	0.07	0.8596
2:19:55	13.54	12.26	0.07	0.8582
2:19:56	13.54	12.22	0.07	0.8554
2:19:57	13.54	12.26	0.07	0.8582
2:19:58	13.54	12.3	0.07	0.861
2:19:59	13.54	12.3	0.07	0.861
2:20:00	13.54	12.26	0.07	0.8582
2:20:01	13.54	12.22	0.07	0.8554

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
2:20:02	13.54	12.3	0.07	0.861
2:20:03	13.54	12.3	0.07	0.861
2:20:04	13.54	12.26	0.06	0.7356
2:20:05	13.54	12.26	0.07	0.8582
2:20:06	13.54	12.28	0.07	0.8596
2:20:07	13.54	12.24	0.07	0.8568
2:20:08	13.54	12.32	0.07	0.8624
2:20:09	13.54	12.2	0.07	0.854
2:20:10	13.54	12.26	0.07	0.8582
2:20:11	13.54	12.22	0.07	0.8554
2:20:12	13.54	12.2	0.06	0.732
2:20:13	13.54	12.24	0.07	0.8568
2:20:14	13.54	12.28	0.07	0.8596
2:20:15	13.54	12.22	0.06	0.7332
2:20:16	13.54	12.24	0.06	0.7344
2:20:17	13.54	12.2	0.06	0.732
2:20:18	13.54	12.2	0.06	0.732
2:20:19	13.54	12.22	0.06	0.7332
2:20:20	13.54	12.28	0.06	0.7368
2:20:21	13.54	12.24	0.06	0.7344
2:20:22	13.54	12.22	0.06	0.7332
2:20:23	13.54	12.22	0.06	0.7332
2:20:24	13.54	12.24	0.06	0.7344
2:20:25	13.54	12.22	0.06	0.7332

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
2:20:26	13.54	12.26	0.06	0.7356
2:20:27	13.54	12.26	0.06	0.7356
2:20:28	13.54	12.22	0.06	0.7332
2:20:29	13.54	12.26	0.06	0.7356
2:20:30	13.54	12.26	0.06	0.7356
2:20:31	13.54	12.22	0.06	0.7332
2:20:32	13.54	12.22	0.06	0.7332
2:20:33	13.54	12.2	0.06	0.732
2:20:34	13.54	12.24	0.06	0.7344
2:20:35	13.54	12.22	0.06	0.7332
2:20:36	13.54	12.24	0.06	0.7344
2:20:37	13.54	12.24	0.06	0.7344
2:20:38	13.54	12.26	0.06	0.7356
2:20:39	13.54	12.26	0.06	0.7356
2:20:40	13.54	12.22	0.06	0.7332
2:20:41	13.52	12.26	0.06	0.7356
2:20:42	13.52	12.26	0.06	0.7356
2:20:43	13.52	12.24	0.06	0.7344
2:20:44	13.52	12.26	0.06	0.7356
2:20:45	13.52	12.22	0.06	0.7332
2:20:46	13.52	12.2	0.06	0.732
2:20:47	13.52	12.22	0.06	0.7332
2:20:48	13.52	12.26	0.06	0.7356
2:20:49	13.52	12.22	0.06	0.7332

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
2:20:50	13.52	12.2	0.06	0.732
2:20:51	13.52	12.24	0.06	0.7344
2:20:52	13.52	12.22	0.06	0.7332
2:20:53	13.52	12.22	0.06	0.7332
2:20:54	13.52	12.24	0.06	0.7344
2:20:55	13.52	12.26	0.06	0.7356
2:20:56	13.52	12.22	0.06	0.7332
2:20:57	13.52	12.22	0.06	0.7332
2:20:58	13.52	12.2	0.06	0.732
2:20:59	13.52	12.24	0.06	0.7344
2:21:00	13.52	12.24	0.06	0.7344
2:21:01	13.52	12.2	0.06	0.732
2:21:02	13.52	12.24	0.06	0.7344
2:21:03	13.52	12.2	0.06	0.732
2:21:04	13.52	12.24	0.06	0.7344
2:21:05	13.52	12.24	0.06	0.7344
2:21:06	13.52	12.22	0.06	0.7332
2:21:07	13.52	12.2	0.07	0.854
2:21:08	13.52	12.2	0.06	0.732
2:21:09	13.52	12.22	0.06	0.7332
2:21:10	13.52	12.2	0.06	0.732
2:21:11	13.52	12.24	0.06	0.7344
2:21:12	13.52	12.22	0.06	0.7332
2:21:13	13.52	12.24	0.06	0.7344

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
2:21:14	13.52	12.24	0.07	0.8568
2:21:15	13.52	12.22	0.06	0.7332
2:21:16	13.52	12.2	0.06	0.732
2:21:17	13.52	12.22	0.06	0.7332
2:21:18	13.52	12.22	0.06	0.7332
2:21:19	13.52	12.24	0.07	0.8568
2:21:20	13.52	12.2	0.06	0.732
2:21:21	13.52	12.24	0.06	0.7344
2:21:22	13.52	12.2	0.06	0.732
2:21:23	13.52	12.2	0.06	0.732
2:21:24	13.52	12.24	0.06	0.7344
2:21:25	13.52	12.24	0.06	0.7344
2:21:26	13.52	12.2	0.06	0.732
2:21:27	13.52	12.24	0.06	0.7344
2:21:28	13.52	12.24	0.06	0.7344
2:21:29	13.52	12.22	0.06	0.7332
2:21:30	13.52	12.22	0.06	0.7332
2:21:31	13.52	12.24	0.06	0.7344
2:21:32	13.52	12.2	0.06	0.732
2:21:33	13.52	12.22	0.06	0.7332
2:21:34	13.52	12.2	0.06	0.732
2:21:35	13.52	12.2	0.06	0.732
2:21:36	13.52	12.2	0.06	0.732
2:21:37	13.52	12.2	0.06	0.732

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
2:21:38	13.52	12.22	0.06	0.7332
2:21:39	13.52	12.2	0.06	0.732
2:21:40	13.52	12.22	0.06	0.7332
2:21:41	13.52	12.24	0.06	0.7344
2:21:42	13.52	12.2	0.06	0.732
2:21:43	13.52	12.22	0.06	0.7332
2:21:44	13.52	12.22	0.06	0.7332
2:21:45	13.52	12.2	0.06	0.732
2:21:46	13.52	12.2	0.06	0.732
2:21:47	13.52	12.22	0.06	0.7332
2:21:48	13.52	12.2	0.06	0.732
2:21:49	13.52	12.22	0.06	0.7332
2:21:50	13.52	12.24	0.06	0.7344
2:21:51	13.52	12.22	0.06	0.7332
2:21:52	13.52	12.22	0.06	0.7332
2:21:53	13.52	12.22	0.06	0.7332
2:22:54	13.52	12.2	0.06	0.732
2:22:55	13.52	12.22	0.06	0.7332
2:22:56	13.52	12.2	0.06	0.732
2:22:57	13.52	12.22	0.06	0.7332
2:22:58	13.52	12.22	0.06	0.7332
2:22:59	13.52	12.24	0.06	0.7344
2:23:00	13.52	12.24	0.06	0.7344
2:23:01	13.52	12.22	0.07	0.8554

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
2:23:02	13.52	12.2	0.06	0.732
2:23:03	13.52	12.2	0.06	0.732
2:23:04	13.52	12.22	0.06	0.7332
2:23:05	13.52	12.2	0.06	0.732
2:23:06	13.52	12.22	0.06	0.7332
2:23:07	13.52	12.24	0.06	0.7344
2:23:08	13.52	12.22	0.06	0.7332
2:23:09	13.52	12.2	0.06	0.732
2:23:10	13.52	12.22	0.06	0.7332
2:23:12	13.52	12.2	0.06	0.732
2:23:13	13.52	12.22	0.06	0.7332
2:23:14	13.52	12.22	0.06	0.7332
2:23:15	13.52	12.24	0.06	0.7344
2:23:16	13.5	12.24	0.06	0.7344
2:23:17	13.52	12.24	0.06	0.7344
2:23:18	13.5	12.22	0.06	0.7332
2:23:19	13.5	12.24	0.06	0.7344
2:23:20	13.5	12.22	0.06	0.7332
2:23:21	13.5	12.22	0.06	0.7332
2:23:22	13.5	12.22	0.06	0.7332

The table that is presented is an example of a dataset made up of measurements of different photovoltaic (PV) system parameters, most likely a solar panel installation, that have been time-stamped. The information appears to be gathered routinely, perhaps for monitoring and analytical purposes. Columns in the table that have values are "Time," "Battery Voltage (V)," "PV Voltage (V),," "PV Current (A)," and "PV Supply Power (W)."

The data demonstrates how several factors affect the performance of the PV system by capturing how it behaves over time. When each set of measurements was taken is specified in the "Time" column. The "Battery Voltage (V)" displays the voltage level of the battery that is linked to the system and may serve as a storage device for solar energy production. The voltage produced by the solar panels is tracked in the "PV Voltage (V)" column. The amount of current generated by the panels is indicated by "PV Current (A)". Last but not least, the "PV Supply Power (W)" represents the PV system's power output, which is the sum of its voltage and current.This dataset can be used to examine the relationships between various factors, including how battery voltage, PV voltage, current, and overall power output are affected by changes in solar irradiance or environmental factors. Additionally, it can be used to evaluate the system's effectiveness and performance over time, spotting any patterns or abnormalities that might need to be addressed. The operation and upkeep of the PV system could be optimized by looking for patterns in the data, such as fluctuations in power output depending on the time of day or the weather.

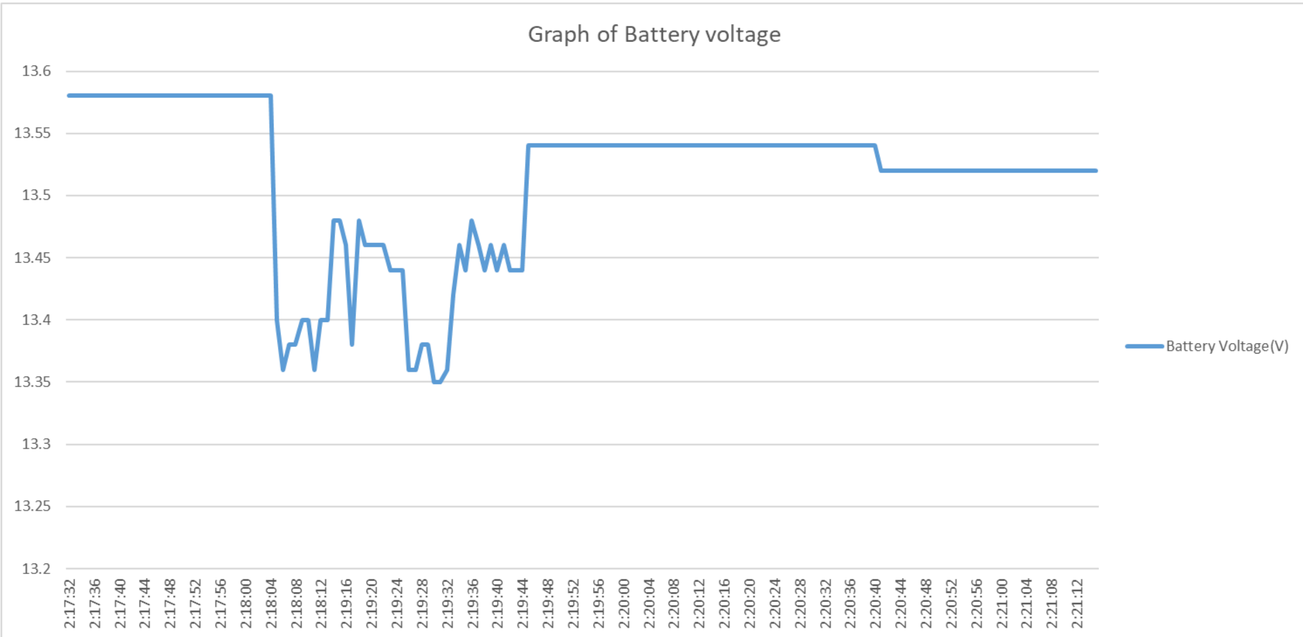

Figure74 : Graph of Battery voltage

The graph of battery voltage over time as a solar-powered water surface cleaning robot runs demonstrates a consistent voltage level of 13.58 V for an extended period of time, suggesting steady-state functioning. Occasional decreases to values such as 13.4, 13.38, and 13.35 indicate greater power consumption during more intense cleaning stages, although irregular climbs to values such as 13.48 and 13.46 may indicate reduced power needs. Voltage values are repeating, suggesting a cyclical operational pattern. Overall, the data shows the robot's capacity to sustain steady power levels while doing its cleaning duties, with variances probably due to differences in workload and solar input circumstances.

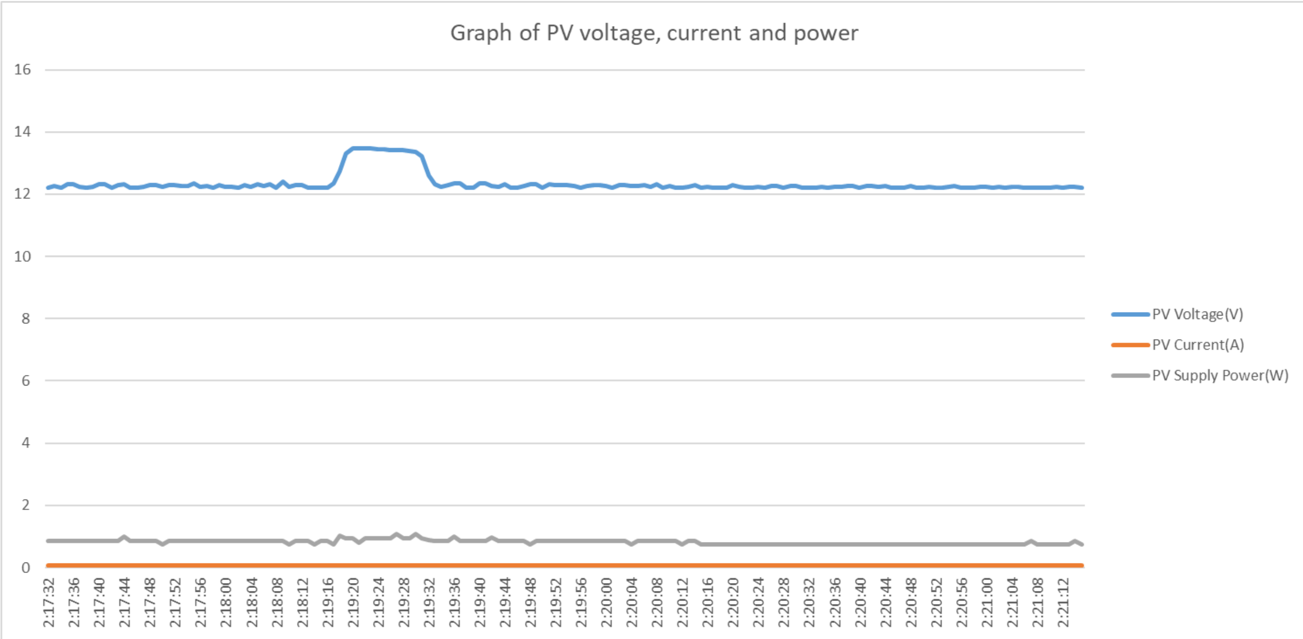

Figure75 : Graph of PV voltage, current and power

This graph shows the data how the energy consumption of the robot and the solar panels interact dynamically while the robot cleans the water's surface. The variations in PV voltage, current, and power are related to variations in solar input and the power needs of the robot, illuminating the complex interaction between solar energy generation and robot operational requirements.

5.3.2 Observation of battery voltage, PV voltage and current and PV power supply for every minute data for one hour

Table 9: Table of battery voltage, PV voltage and current and PV power supply for one hour runtime

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power (W)
2:02 PM	13.6	12.24	0.07	0.8568
2:03 PM	13.7	13.62	0.06	0.8172
2:04 PM	13.8	12.28	0.07	0.8596
2:05 PM	13.8	12.26	0.07	0.8582
2:06 PM	13.56	13.5	0.07	0.945
2:07 PM	13.54	13.23	0.07	0.9261
2:08 PM	13.74	12.26	0.07	0.8582
2:09 PM	13.62	12.38	0.07	0.8666

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power (W)
2:10 PM	13.72	12.26	0.07	0.8582
2:11 PM	13.52	12.2	0.07	0.854
2:12 PM	13.5	12.41	0.07	0.8687
2:13 PM	13.56	12.24	0.07	0.8568
2:14 PM	13.64	12.28	0.07	0.8596
2:15 PM	13.52	12.26	0.07	0.8582
2:16 PM	13.52	12.28	0.07	0.8596
2:17 PM	13.6	12.2	0.07	0.854
2:18 PM	13.58	12.28	0.08	0.9824
2:19 PM	13.48	12.2	0.07	0.854
2:20 PM	13.54	12.28	0.07	0.8596
2:21 PM	13.52	12.24	0.06	0.7344
2:22 PM	13.52	12.2	0.06	0.732
2:23 PM	13.5	12.2	0.06	0.732
2:24 PM	13.48	12.24	0.06	0.7344
2:25 PM	13.48	12.24	0.06	0.7344
2:26 PM	13.46	12.24	0.06	0.7344
2:27 PM	13.46	12.24	0.06	0.7344
2:28 PM	13.44	12.24	0.06	0.7344
2:29 PM	13.42	12.28	0.07	0.8596
2:30 PM	13.42	12.2	0.07	0.854
2:31 PM	13.4	12.21	0.07	0.8547
2:32 PM	13.38	12.21	0.07	0.8547
2:33 PM	13.36	12.24	0.06	0.7344

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power (W)
2:34 PM	13.36	12.24	0.06	0.7344
2:35 PM	13.35	12.2	0.07	0.854
2:36 PM	13.34	12.2	0.07	0.854
2:37 PM	13.33	12.26	0.07	0.8582
2:38 PM	13.13	12.24	0.07	0.8568
2:39 PM	13.25	12.26	0.07	0.8582
2:40 PM	13.23	12.22	0.07	0.8554
2:41 PM	13.09	12.26	0.07	0.8582
2:42 PM	13.03	12.28	0.07	0.8596
2:43 PM	12.85	13.29	0.08	1.0632
2:44 PM	12.99	12.2	0.07	0.854
2:45 PM	12.99	12.22	0.07	0.8554
2:46 PM	12.95	12.22	0.07	0.8554
2:47 PM	12.49	12.39	0.07	0.8673
2:48 PM	12.83	13.13	0.07	0.9191
2:49 PM	12.83	12.2	0.07	0.854
2:50 PM	12.51	12.28	0.08	0.9824
2:51 PM	12.63	12.2	0.08	0.976
2:52 PM	12.39	12.2	0.07	0.854
2:53 PM	12.34	12.41	0.09	1.1169
2:54 PM	12.36	12.24	0.07	0.8568
2:55 PM	12.22	12.28	0.07	0.8596
2:56 PM	12.08	12.28	0.07	0.8596
2:57 PM	11.9	12.24	0.07	0.8568

-

Time	Battery Voltage(V)	PV Voltage (V)	PV current(A)	PV Supply Power (W)
2:58 PM	11.6	12.2	0.07	0.854
2:59 PM	11.23	11.9	0.09	1.071
3:00 PM	11.03	12.02	0.1	1.202
3:01 PM	11.04	12.03	0.09	1.0827
3:02 PM	11.09	11.62	0.09	1.0458

The table provides a thorough overview of the PV system's operation throughout time. It emphasizes changes and patterns in the essential characteristics of the system. One indicator of the state of the energy storage component, for instance, is the Battery Voltage, which may show periods of charging or discharging. The PV Voltage and Current figures show how the solar panels and the rest of the system interact in real time as a result of variations in solar irradiation and other environmental conditions. The PV Supply Power provides a quick indicator of the system's ability to generate power and shows how adaptable it is to changing conditions.One might infer important inferences about the system's general health, effectiveness, and sensitivity to outside influences by carefully evaluating this dataset. Data patterns may reveal periods of peak power production, show how the battery reacts to various degrees of illumination, and even point out anomalies or irregularities that need to be addressed. The gathered data can also be used to improve the operation and maintenance procedures for the PV system. For instance, pinpointing time-dependent fluctuations in power production may help in planning maintenance or modifying system parameters to maximize energy absorption under ideal circumstances.

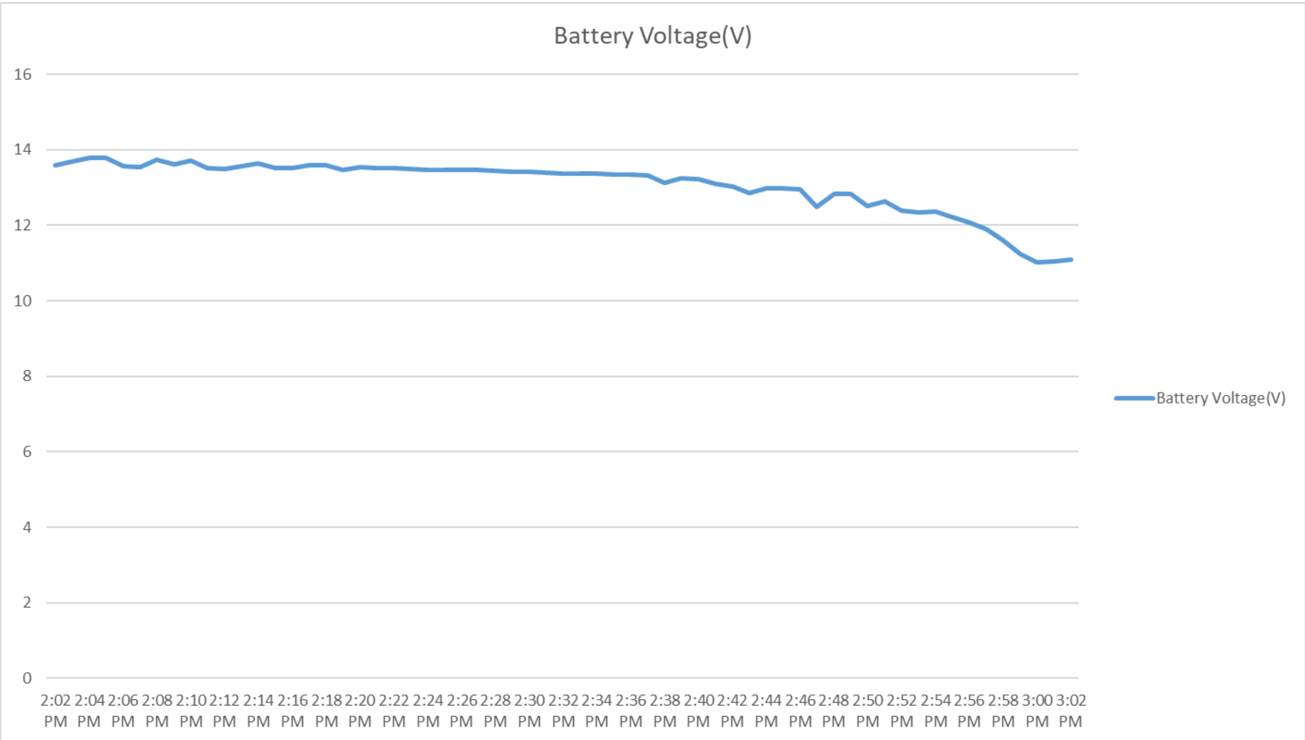

Figure76 : Graph of Battery Voltage for an hour

The battery voltage graph throughout an hour shows a pattern of fluctuations: starting at 13.6 volts, the voltage steadily drops until around the 30-minute mark, then drops more sharply until around 45 minutes, which suggests varied energy use. The voltage then partially rebounds before dropping significantly again by the hour's conclusion. These variations highlight the dynamic relationship between the robot's activity and the battery's performance since they most likely represent changes in the power requirement of the robot, which may be impacted by elements like its operational modes and solar input.

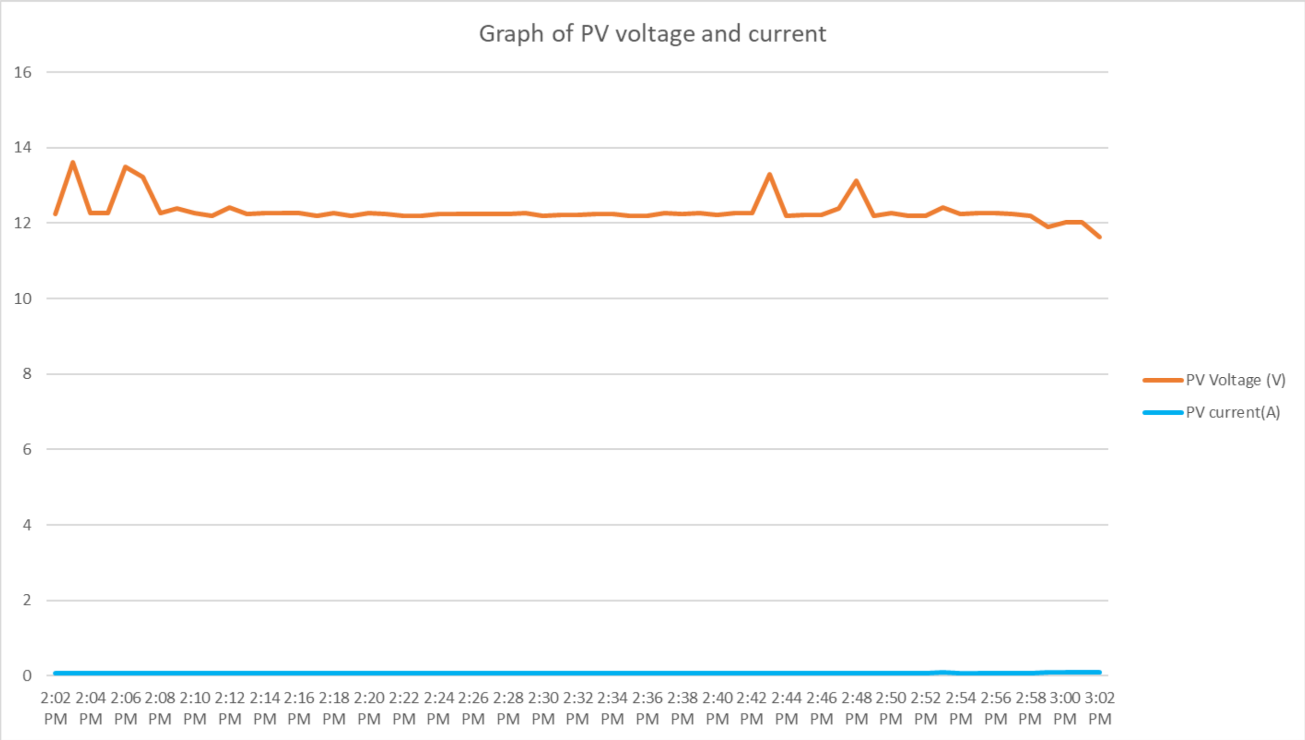

Figure77 : Graph of PV voltage and current for an hour

The graph illustrating the input of a solar panel to a solar-powered water surface cleaning robot over time shows a recurring pattern of voltage and current values. The voltage of the solar panel appears to be very steady, hovering between 12.2 and 12.41 volts, while changes in the current are mostly found between 0.06 and 0.1 amperes. This recurring pattern implies that the robot's power consumption and solar input are consistent during the measured time period, implying that it is in a stable operational condition. The robot's energy requirements appear to be largely stable based on the combination of constant voltage levels and changing current values, with sporadic small fluctuations in power demand probably caused by alterations in cleaning activities or ambient circumstances.

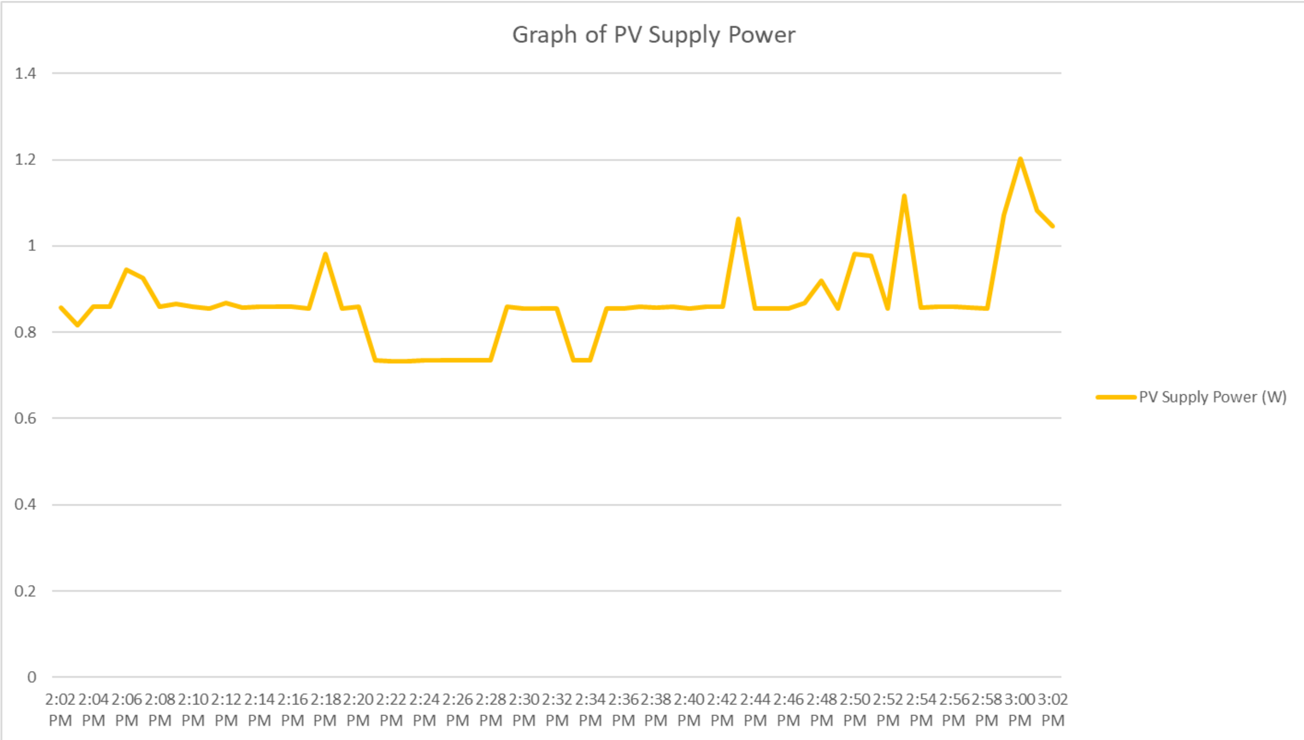

Figure78 : Graph of PV Supply Power for an hour

The graph shows the various power inputs from solar panels to a robot that cleans water surfaces using solar power. Power levels fluctuate between around 0.732 and 1.202 watts as a result of variations in solar input. Lower numbers might be the consequence of shadowing or less solar energy, whilst higher values probably correlate to ideal sunshine conditions. By influencing the energy available for its activities, these variations have an immediate influence on the robot's operating capabilities.

Table 10: Table of battery voltage, current and power, PV voltage, current and PV power supply

Time	**Battery Voltage(V)**	**Battery current(A)**	**Battery Power(W)**	**PV Voltage(V)**	**PV current(A)**	**PV Supply Power(W)**
5:26:10 PM	**12.77**	**0.45**	**5.7465**	**6.65**	**0.07**	**0.4655**
5:26:11 PM	**12.79**	**0.44**	**5.6276**	**6.65**	**0.07**	**0.4655**
5:26:12 PM	**12.77**	**0.45**	**5.7465**	**6.65**	**0.07**	**0.4655**
5:26:13 PM	**12.79**	**0.45**	**5.7555**	**6.65**	**0.06**	**0.399**
5:26:14 PM	**12.77**	**0.45**	**5.7465**	**6.65**	**0.06**	**0.399**
5:26:15 PM	**12.79**	**0.45**	**5.7555**	**6.65**	**0.07**	**0.4655**
5:26:16 PM	**12.75**	**0.44**	**5.61**	**6.65**	**0.07**	**0.4655**
5:26:18 PM	**12.77**	**0.44**	**5.6188**	**6.65**	**0.07**	**0.4655**

5:26:19 PM	**12.77**	**0.44**	**5.6188**	**6.63**	**0.07**	**0.4641**
5:26:20 PM	**12.75**	**0.45**	**5.7375**	**6.63**	**0.07**	**0.4641**
5:26:21 PM	**12.79**	**0.45**	**5.7555**	**6.63**	**0.07**	**0.4641**
5:26:22 PM	**12.77**	**0.44**	**5.6188**	**6.61**	**0.07**	**0.4627**
5:26:23 PM	**12.71**	**0.44**	**5.5924**	**6.61**	**0.07**	**0.4627**
5:26:24 PM	**12.73**	**0.45**	**5.7285**	**6.61**	**0.07**	**0.4627**
5:26:26 PM	**12.71**	**0.43**	**5.4653**	**6.59**	**0.07**	**0.4613**
5:26:27 PM	**12.77**	**0.43**	**5.4911**	**6.59**	**0.07**	**0.4613**
5:26:28 PM	**12.73**	**0.43**	**5.4739**	**6.59**	**0.06**	**0.3954**
5:26:29 PM	**12.73**	**0.44**	**5.6012**	**6.59**	**0.07**	**0.4613**
5:26:30 PM	**12.73**	**0.43**	**5.4739**	**6.59**	**0.06**	**0.3954**
5:26:31 PM	**12.73**	**0.43**	**5.4739**	**6.57**	**0.07**	**0.4599**
5:26:32 PM	**12.69**	**0.44**	**5.5836**	**6.57**	**0.07**	**0.4599**
5:26:34 PM	**12.71**	**0.43**	**5.4653**	**6.57**	**0.07**	**0.4599**
5:26:35 PM	**12.73**	**0.43**	**5.4739**	**6.57**	**0.06**	**0.3942**
5:26:36 PM	**12.73**	**0.43**	**5.4739**	**6.55**	**0.07**	**0.4585**
5:26:37 PM	**12.71**	**0.43**	**5.4653**	**6.55**	**0.07**	**0.4585**
5:26:38 PM	**12.69**	**0.43**	**5.4567**	**6.55**	**0.07**	**0.4585**
5:26:39 PM	**12.69**	**0.43**	**5.4567**	**6.55**	**0.07**	**0.4585**
5:26:40 PM	**12.71**	**0.42**	**5.3382**	**6.55**	**0.07**	**0.4585**
5:26:42 PM	**12.71**	**0.43**	**5.4653**	**6.55**	**0.07**	**0.4585**
5:26:43 PM	**12.73**	**0.43**	**5.4739**	**6.55**	**0.07**	**0.4585**
5:26:44 PM	**12.71**	**0.43**	**5.4653**	**6.55**	**0.07**	**0.4585**
5:26:45 PM	**12.71**	**0.42**	**5.3382**	**6.55**	**0.07**	**0.4585**

5:26:46 PM	**12.69**	**0.42**	**5.3298**	**6.55**	**0.07**	**0.4585**
5:26:47 PM	**12.71**	**0.42**	**5.3382**	**6.55**	**0.07**	**0.4585**
5:26:48 PM	**12.71**	**0.43**	**5.4653**	**6.55**	**0.07**	**0.4585**
5:26:50 PM	**12.69**	**0.42**	**5.3298**	**6.55**	**0.07**	**0.4585**
5:26:51 PM	**12.69**	**0.42**	**5.3298**	**6.53**	**0.07**	**0.4571**
5:26:52 PM	**12.71**	**0.42**	**5.3382**	**6.53**	**0.07**	**0.4571**
5:26:53 PM	**12.71**	**0.42**	**5.3382**	**6.53**	**0.07**	**0.4571**
5:26:54 PM	**12.69**	**0.42**	**5.3298**	**6.53**	**0.07**	**0.4571**
5:26:55 PM	**12.69**	**0.42**	**5.3298**	**6.53**	**0.07**	**0.4571**
5:26:56 PM	**12.69**	**0.42**	**5.3298**	**6.53**	**0.07**	**0.4571**
5:26:58 PM	**12.67**	**0.43**	**5.4481**	**6.53**	**0.07**	**0.4571**
5:26:59 PM	**12.69**	**0.42**	**5.3298**	**6.53**	**0.08**	**0.5224**
5:27:00 PM	**12.67**	**0.42**	**5.3214**	**6.53**	**0.06**	**0.3918**
5:27:01 PM	**12.67**	**0.42**	**5.3214**	**6.53**	**0.06**	**0.3918**
5:27:02 PM	**12.67**	**0.43**	**5.4481**	**6.53**	**0.07**	**0.4571**
5:27:03 PM	**12.65**	**0.42**	**5.313**	**6.53**	**0.07**	**0.4571**
5:27:04 PM	**12.63**	**0.42**	**5.3046**	**6.53**	**0.07**	**0.4571**
5:27:06 PM	**12.67**	**0.43**	**5.4481**	**6.53**	**0.07**	**0.4571**
5:27:07 PM	**12.65**	**0.41**	**5.1865**	**6.53**	**0.07**	**0.4571**
5:27:08 PM	**12.65**	**0.41**	**5.1865**	**6.53**	**0.07**	**0.4571**
5:27:09 PM	**12.67**	**0.42**	**5.3214**	**6.51**	**0.07**	**0.4557**
5:27:10 PM	**12.65**	**0.42**	**5.313**	**6.51**	**0.07**	**0.4557**
5:27:11 PM	**12.63**	**0.43**	**5.4309**	**6.51**	**0.07**	**0.4557**
5:27:12 PM	**12.63**	**0.43**	**5.4309**	**6.51**	**0.07**	**0.4557**

5:27:13 PM	**12.67**	**0.39**	**4.9413**	**6.51**	**0.07**	**0.4557**
5:27:15 PM	**12.73**	**0.29**	**3.6917**	**6.51**	**0.07**	**0.4557**
5:27:16 PM	**12.73**	**0.27**	**3.4371**	**6.51**	**0.07**	**0.4557**
5:27:17 PM	**12.75**	**0.28**	**3.57**	**6.51**	**0.07**	**0.4557**
5:27:18 PM	**12.67**	**0.43**	**5.4481**	**6.51**	**0.07**	**0.4557**
5:27:18 PM	**12.71**	**0.28**	**3.5588**	**6.51**	**0.08**	**0.5208**
5:27:20 PM	**12.75**	**0.27**	**3.4425**	**6.51**	**0.07**	**0.4557**
5:27:21 PM	**12.63**	**0.42**	**5.3046**	**6.51**	**0.07**	**0.4557**
5:27:22 PM	**12.71**	**0.28**	**3.5588**	**6.51**	**0.07**	**0.4557**
5:27:24 PM	**12.71**	**0.28**	**3.5588**	**6.51**	**0.07**	**0.4557**
5:27:25 PM	**12.61**	**0.46**	**5.8006**	**6.51**	**0.07**	**0.4557**
5:27:26 PM	**12.61**	**0.43**	**5.4223**	**6.51**	**0.06**	**0.3906**
5:27:27 PM	**12.59**	**0.42**	**5.2878**	**6.51**	**0.07**	**0.4557**
5:27:28 PM	**12.55**	**0.67**	**8.4085**	**6.53**	**0.06**	**0.3918**
5:27:30 PM	**12.63**	**0.42**	**5.3046**	**6.51**	**0.07**	**0.4557**
5:27:31 PM	**12.59**	**0.42**	**5.2878**	**6.51**	**0.07**	**0.4557**
5:27:32 PM	**12.57**	**0.47**	**5.9079**	**6.51**	**0.06**	**0.3906**
5:27:34 PM	**12.61**	**0.42**	**5.2962**	**6.51**	**0.07**	**0.4557**
5:27:35 PM	**12.61**	**0.41**	**5.1701**	**6.49**	**0.07**	**0.4543**
5:27:37 PM	**12.61**	**0.4**	**5.044**	**6.51**	**0.07**	**0.4557**
5:27:37 PM	**12.69**	**0.26**	**3.2994**	**6.49**	**0.07**	**0.4543**
5:27:39 PM	**12.67**	**0.27**	**3.4209**	**6.49**	**0.07**	**0.4543**
5:27:40 PM	**12.71**	**0.27**	**3.4317**	**6.49**	**0.07**	**0.4543**
5:27:41 PM	**12.69**	**0.28**	**3.5532**	**6.49**	**0.07**	**0.4543**

5:27:41 PM	**12.61**	**0.42**	**5.2962**	**6.49**	**0.07**	**0.4543**
5:27:43 PM	**12.59**	**0.42**	**5.2878**	**6.49**	**0.07**	**0.4543**
5:27:45 PM	**12.61**	**0.41**	**5.1701**	**6.49**	**0.08**	**0.5192**
5:27:45 PM	**12.65**	**0.28**	**3.542**	**6.49**	**0.07**	**0.4543**
5:27:47 PM	**12.67**	**0.28**	**3.5476**	**6.49**	**0.07**	**0.4543**
5:27:48 PM	**12.67**	**0.28**	**3.5476**	**6.49**	**0.07**	**0.4543**
5:27:48 PM	**12.57**	**0.41**	**5.1537**	**6.47**	**0.07**	**0.4529**
5:27:50 PM	**12.59**	**0.42**	**5.2878**	**6.47**	**0.08**	**0.5176**
5:27:51 PM	**12.61**	**0.41**	**5.1701**	**6.47**	**0.07**	**0.4529**
5:27:53 PM	**12.57**	**0.41**	**5.1537**	**6.47**	**0.07**	**0.4529**
5:27:54 PM	**12.59**	**0.41**	**5.1619**	**6.47**	**0.07**	**0.4529**
5:27:55 PM	**12.59**	**0.41**	**5.1619**	**6.47**	**0.08**	**0.5176**
5:27:56 PM	**12.59**	**0.41**	**5.1619**	**6.47**	**0.07**	**0.4529**
5:27:57 PM	**12.57**	**0.42**	**5.2794**	**6.47**	**0.07**	**0.4529**
5:27:58 PM	**12.55**	**0.41**	**5.1455**	**6.49**	**0.07**	**0.4543**
5:27:59 PM	**12.57**	**0.41**	**5.1537**	**6.49**	**0.07**	**0.4543**
5:28:00 PM	**12.63**	**0.27**	**3.4101**	**6.47**	**0.07**	**0.4529**
5:28:02 PM	**12.65**	**0.27**	**3.4155**	**6.47**	**0.07**	**0.4529**
5:28:03 PM	**12.65**	**0.25**	**3.1625**	**6.47**	**0.07**	**0.4529**
5:28:04 PM	**12.67**	**0.26**	**3.2942**	**6.47**	**0.08**	**0.5176**
5:28:05 PM	**12.65**	**0.27**	**3.4155**	**6.49**	**0.07**	**0.4543**
5:28:06 PM	**12.65**	**0.26**	**3.289**	**6.51**	**0.07**	**0.4557**
5:28:07 PM	**12.65**	**0.26**	**3.289**	**6.51**	**0.07**	**0.4557**
5:28:09 PM	**12.67**	**0.27**	**3.4209**	**6.53**	**0.07**	**0.4571**

5:28:10 PM	**12.63**	**0.27**	**3.4101**	**6.53**	**0.07**	**0.4571**
5:28:11 PM	**12.65**	**0.26**	**3.289**	**6.53**	**0.07**	**0.4571**
5:28:12 PM	**12.65**	**0.27**	**3.4155**	**6.53**	**0.07**	**0.4571**
5:28:13 PM	**12.65**	**0.26**	**3.289**	**6.53**	**0.07**	**0.4571**
5:28:13 PM	**12.53**	**0.41**	**5.1373**	**6.51**	**0.07**	**0.4557**
5:28:15 PM	**12.55**	**0.41**	**5.1455**	**6.51**	**0.07**	**0.4557**
5:28:17 PM	**12.55**	**0.4**	**5.02**	**6.49**	**0.07**	**0.4543**
5:28:18 PM	**12.53**	**0.41**	**5.1373**	**6.49**	**0.08**	**0.5192**
5:28:19 PM	**12.55**	**0.41**	**5.1455**	**6.49**	**0.07**	**0.4543**
5:28:19 PM	**12.71**	**0.13**	**1.6523**	**6.49**	**0.07**	**0.4543**
5:28:21 PM	**12.71**	**0.13**	**1.6523**	**6.49**	**0.07**	**0.4543**
5:28:22 PM	**12.73**	**0.14**	**1.7822**	**6.49**	**0.07**	**0.4543**
5:28:23 PM	**12.73**	**0.14**	**1.7822**	**6.49**	**0.07**	**0.4543**
5:28:25 PM	**12.73**	**0.13**	**1.6549**	**6.49**	**0.07**	**0.4543**
5:28:26 PM	**12.73**	**0.12**	**1.5276**	**6.49**	**0.07**	**0.4543**
5:28:27 PM	**12.73**	**0.12**	**1.5276**	**6.49**	**0.07**	**0.4543**
5:28:28 PM	**12.73**	**0.13**	**1.6549**	**6.49**	**0.07**	**0.4543**
5:28:29 PM	**12.73**	**0.13**	**1.6549**	**6.49**	**0.07**	**0.4543**
5:28:30 PM	**12.73**	**0.12**	**1.5276**	**6.47**	**0.07**	**0.4529**
5:28:31 PM	**12.51**	**0.42**	**5.2542**	**6.47**	**0.07**	**0.4529**
5:28:33 PM	**12.51**	**0.41**	**5.1291**	**6.47**	**0.07**	**0.4529**
5:28:34 PM	**12.51**	**0.42**	**5.2542**	**6.47**	**0.08**	**0.5176**
5:28:35 PM	**12.53**	**0.41**	**5.1373**	**6.47**	**0.07**	**0.4529**
5:28:36 PM	**12.49**	**0.41**	**5.1209**	**6.47**	**0.07**	**0.4529**

5:28:37 PM	**12.59**	**0.27**	**3.3993**	**6.47**	**0.07**	**0.4529**
5:28:38 PM	**12.59**	**0.28**	**3.5252**	**6.47**	**0.07**	**0.4529**
5:28:39 PM	**12.61**	**0.27**	**3.4047**	**6.47**	**0.07**	**0.4529**
5:28:40 PM	**12.47**	**0.41**	**5.1127**	**6.45**	**0.06**	**0.387**
5:28:42 PM	**12.47**	**0.41**	**5.1127**	**6.45**	**0.07**	**0.4515**
5:28:43 PM	**12.51**	**0.41**	**5.1291**	**6.45**	**0.07**	**0.4515**
5:28:44 PM	**12.53**	**0.41**	**5.1373**	**6.45**	**0.07**	**0.4515**
5:28:45 PM	**12.59**	**0.27**	**3.3993**	**6.45**	**0.07**	**0.4515**
5:28:46 PM	**12.59**	**0.27**	**3.3993**	**6.47**	**0.07**	**0.4529**
5:28:47 PM	**12.61**	**0.27**	**3.4047**	**6.45**	**0.07**	**0.4515**
5:28:49 PM	**12.59**	**0.26**	**3.2734**	**6.45**	**0.07**	**0.4515**
5:28:50 PM	**12.59**	**0.28**	**3.5252**	**6.45**	**0.06**	**0.387**
5:28:51 PM	**12.43**	**0.56**	**6.9608**	**6.45**	**0.07**	**0.4515**
5:28:52 PM	**12.49**	**0.42**	**5.2458**	**6.45**	**0.08**	**0.516**
5:28:53 PM	**12.49**	**0.4**	**4.996**	**6.45**	**0.07**	**0.4515**
5:28:54 PM	**12.47**	**0.4**	**4.988**	**6.45**	**0.07**	**0.4515**
5:28:55 PM	**12.47**	**0.4**	**4.988**	**6.45**	**0.06**	**0.387**
5:28:57 PM	**12.47**	**0.4**	**4.988**	**6.45**	**0.07**	**0.4515**
5:28:58 PM	**12.47**	**0.4**	**4.988**	**6.45**	**0.07**	**0.4515**
5:28:59 PM	**12.43**	**0.42**	**5.2206**	**6.45**	**0.07**	**0.4515**
5:29:00 PM	**12.45**	**0.41**	**5.1045**	**6.45**	**0.07**	**0.4515**
5:29:01 PM	**12.43**	**0.41**	**5.0963**	**6.45**	**0.07**	**0.4515**
5:29:02 PM	**12.63**	**0.13**	**1.6419**	**6.45**	**0.07**	**0.4515**
5:29:02 PM	**12.45**	**0.42**	**5.229**	**6.45**	**0.08**	**0.516**

5:29:05 PM	**12.45**	**0.41**	**5.1045**	**6.45**	**0.07**	**0.4515**
5:29:06 PM	**12.43**	**0.42**	**5.2206**	**6.45**	**0.07**	**0.4515**
5:29:07 PM	**12.43**	**0.41**	**5.0963**	**6.45**	**0.07**	**0.4515**
5:29:08 PM	**12.45**	**0.41**	**5.1045**	**6.45**	**0.07**	**0.4515**
5:29:09 PM	**12.43**	**0.41**	**5.0963**	**6.45**	**0.07**	**0.4515**
5:29:10 PM	**12.41**	**0.41**	**5.0881**	**6.45**	**0.06**	**0.387**
5:29:11 PM	**12.43**	**0.4**	**4.972**	**6.45**	**0.07**	**0.4515**
5:29:13 PM	**12.41**	**0.4**	**4.964**	**6.45**	**0.07**	**0.4515**
5:29:14 PM	**12.41**	**0.4**	**4.964**	**6.45**	**0.07**	**0.4515**
5:29:15 PM	**12.41**	**0.4**	**4.964**	**6.45**	**0.07**	**0.4515**
5:29:16 PM	**12.43**	**0.4**	**4.972**	**6.45**	**0.07**	**0.4515**
5:29:17 PM	**12.41**	**0.4**	**4.964**	**6.45**	**0.07**	**0.4515**
5:29:18 PM	**12.43**	**0.4**	**4.972**	**6.45**	**0.07**	**0.4515**
5:29:19 PM	**12.38**	**0.4**	**4.952**	**6.45**	**0.07**	**0.4515**
5:29:21 PM	**12.41**	**0.4**	**4.964**	**6.45**	**0.07**	**0.4515**
5:29:22 PM	**12.41**	**0.41**	**5.0881**	**6.45**	**0.06**	**0.387**
5:29:23 PM	**12.39**	**0.4**	**4.956**	**6.45**	**0.07**	**0.4515**
5:29:24 PM	**12.41**	**0.4**	**4.964**	**6.45**	**0.08**	**0.516**
5:29:25 PM	**12.38**	**0.4**	**4.952**	**6.45**	**0.06**	**0.387**
5:29:26 PM	**12.38**	**0.4**	**4.952**	**6.45**	**0.07**	**0.4515**
5:29:27 PM	**12.39**	**0.4**	**4.956**	**6.45**	**0.07**	**0.4515**
5:29:29 PM	**12.36**	**0.4**	**4.944**	**6.45**	**0.07**	**0.4515**
5:29:30 PM	**12.39**	**0.39**	**4.8321**	**6.45**	**0.08**	**0.516**
5:29:31 PM	**12.39**	**0.4**	**4.956**	**6.45**	**0.07**	**0.4515**

5:29:32 PM	**12.36**	**0.4**	**4.944**	**6.45**	**0.07**	**0.4515**
5:29:33 PM	**12.39**	**0.39**	**4.8321**	**6.43**	**0.07**	**0.4501**
5:29:34 PM	**12.36**	**0.39**	**4.8204**	**6.43**	**0.07**	**0.4501**
5:29:35 PM	**12.34**	**0.41**	**5.0594**	**6.43**	**0.07**	**0.4501**
5:29:36 PM	**12.53**	**0.13**	**1.6289**	**6.43**	**0.07**	**0.4501**
5:29:38 PM	**12.45**	**0.27**	**3.3615**	**6.43**	**0.07**	**0.4501**

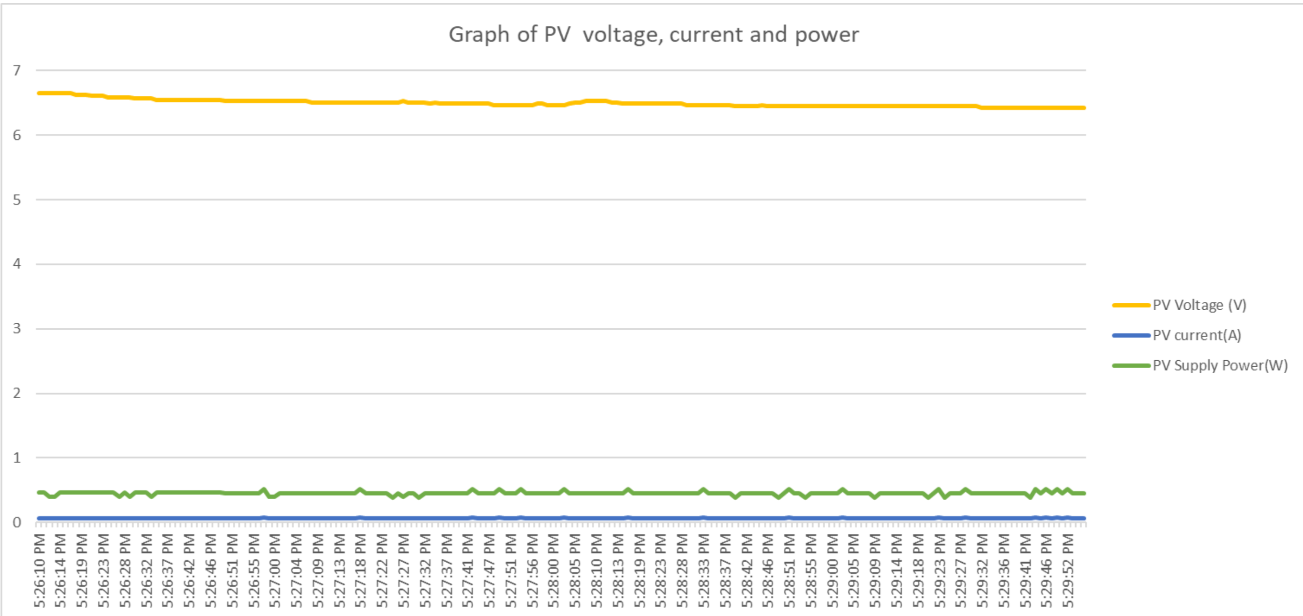

Figure79 : Graph of PV voltage, current and power

The graph represents the state of the battery while PV is continuously supplying power to the robot. The PV could not supply enough power to the robot as it was almost evening.

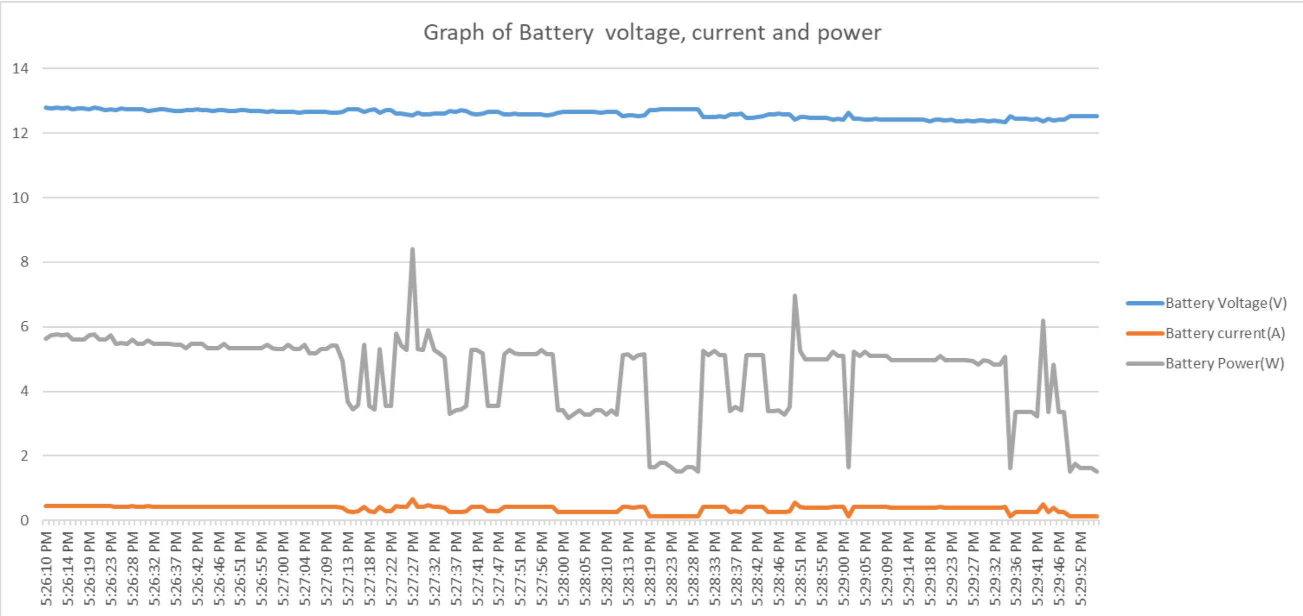

Figure80 : Graph of Battery voltage, current and power

The graph represents the state of the battery while running the robot.

Table 11: Table of battery voltage, current and power, PV voltage, current and PV power supply

Time	Battery Voltage(V)	Battery current(A)	Battery Power(W)	PV Voltage(V)	PV current(A)	PV Supply Power(W)
5:13:05 PM	10.77	0.41	4.4157	11.19	0.06	0.6714
5:13:06 PM	10.69	0.41	4.3829	10.97	0.06	0.6582
5:13:07 PM	10.65	0.41	4.3665	10.79	0.06	0.6474
5:13:09 PM	10.63	0.4	4.252	10.71	0.07	0.7497
5:13:10 PM	10.55	0.4	4.22	10.65	0.07	0.7455
5:13:11 PM	10.69	0.26	2.7794	10.75	0.07	0.7525
5:13:12 PM	10.71	0.27	2.8917	10.55	0.07	0.7385
5:13:13 PM	10.69	0.27	2.8863	10.41	0.06	0.6246
5:13:15 PM	10.67	0.27	2.8809	11.21	0.06	0.6726
5:13:15 PM	10.65	0.26	2.769	11.05	0.07	0.7735
5:13:17 PM	10.63	0.26	2.7638	10.91	0.06	0.6546

5:13:18 PM	**10.63**	**0.27**	**2.8701**	**10.63**	**0.07**	**0.7441**
5:13:19 PM	**10.63**	**0.27**	**2.8701**	**10.36**	**0.07**	**0.7252**
5:13:20 PM	**10.65**	**0.27**	**2.8755**	**11.15**	**0.06**	**0.669**
5:13:21 PM	**10.57**	**0.26**	**2.7482**	**10.85**	**0.07**	**0.7595**
5:13:22 PM	**10.53**	**0.26**	**2.7378**	**10.45**	**0.07**	**0.7315**
5:13:23 PM	**10.55**	**0.25**	**2.6375**	**11.03**	**0.07**	**0.7721**
5:13:25 PM	**10.53**	**0.26**	**2.7378**	**10.49**	**0.07**	**0.7343**
5:13:26 PM	**10.51**	**0.26**	**2.7326**	**10.97**	**0.06**	**0.6582**
5:13:27 PM	**10.47**	**0.27**	**2.8269**	**10.22**	**0.07**	**0.7154**
5:13:28 PM	**10.41**	**0.27**	**2.8107**	**10.59**	**0.06**	**0.6354**
5:13:29 PM	**10.41**	**0.26**	**2.7066**	**10.85**	**0.06**	**0.651**
5:13:30 PM	**10.45**	**0.25**	**2.6125**	**11.01**	**0.07**	**0.7707**
5:13:31 PM	**10.39**	**0.26**	**2.7014**	**11.11**	**0.07**	**0.7777**
5:13:33 PM	**10.38**	**0.26**	**2.6988**	**10.18**	**0.07**	**0.7126**
5:13:34 PM	**10.36**	**0.27**	**2.7972**	**10.22**	**0.07**	**0.7154**
5:13:35 PM	**10.34**	**0.26**	**2.6884**	**10.39**	**0.08**	**0.8312**
5:13:36 PM	**10.32**	**0.25**	**2.58**	**10.65**	**0.06**	**0.639**
5:13:37 PM	**10.3**	**0.26**	**2.678**	**10.06**	**0.07**	**0.7042**
5:13:38 PM	**10.28**	**0.25**	**2.57**	**10.53**	**0.06**	**0.6318**
5:13:39 PM	**10.06**	**0.4**	**4.024**	**10.39**	**0.07**	**0.7273**
5:13:41 PM	**10.02**	**0.39**	**3.9078**	**10.06**	**0.08**	**0.8048**
5:13:42 PM	**9.96**	**0.4**	**3.984**	**10.32**	**0.07**	**0.7224**
5:13:43 PM	**9.94**	**0.38**	**3.7772**	**10.06**	**0.07**	**0.7042**
5:13:44 PM	**9.9**	**0.37**	**3.663**	**9.98**	**0.07**	**0.6986**

5:13:45 PM	**9.86**	**0.39**	**3.8454**	**10.26**	**0.07**	**0.7182**
5:13:46 PM	**9.82**	**0.39**	**3.8298**	**10.04**	**0.08**	**0.8032**
5:13:47 PM	**9.96**	**0.26**	**2.5896**	**10.06**	**0.08**	**0.8048**
5:13:49 PM	**9.96**	**0.25**	**2.49**	**10.34**	**0.07**	**0.7238**
5:13:50 PM	**9.96**	**0.24**	**2.3904**	**10.16**	**0.07**	**0.7112**
5:13:51 PM	**9.92**	**0.24**	**2.3808**	**10.02**	**0.06**	**0.6012**
5:13:52 PM	**9.9**	**0.24**	**2.376**	**9.96**	**0.07**	**0.6972**
5:13:53 PM	**9.92**	**0.23**	**2.2816**	**10.16**	**0.07**	**0.7112**
5:13:54 PM	**9.74**	**0.4**	**3.896**	**10.38**	**0.07**	**0.7266**
5:13:56 PM	**9.68**	**0.38**	**3.6784**	**10.02**	**0.09**	**0.9018**
5:13:57 PM	**9.66**	**0.37**	**3.5742**	**9.8**	**0.06**	**0.588**
5:13:58 PM	**9.64**	**0.38**	**3.6632**	**9.96**	**0.06**	**0.5976**
5:13:59 PM	**9.62**	**0.37**	**3.5594**	**9.82**	**0.07**	**0.6874**
5:14:00 PM	**9.54**	**0.39**	**3.7206**	**10.28**	**0.07**	**0.7196**
5:14:01 PM	**9.58**	**0.38**	**3.6404**	**9.9**	**0.07**	**0.693**
5:14:02 PM	**9.64**	**0.24**	**2.3136**	**9.76**	**0.07**	**0.6832**
5:14:03 PM	**9.66**	**0.26**	**2.5116**	**10.1**	**0.07**	**0.707**
5:14:05 PM	**9.66**	**0.25**	**2.415**	**9.92**	**0.08**	**0.7936**
5:14:06 PM	**9.62**	**0.26**	**2.5012**	**9.78**	**0.07**	**0.6846**
5:14:07 PM	**9.62**	**0.26**	**2.5012**	**10.06**	**0.08**	**0.8048**
5:14:08 PM	**9.62**	**0.24**	**2.3088**	**9.76**	**0.06**	**0.5856**
5:14:09 PM	**9.62**	**0.26**	**2.5012**	**10.08**	**0.06**	**0.6048**
5:14:10 PM	**9.6**	**0.26**	**2.496**	**9.98**	**0.08**	**0.7984**
5:14:12 PM	**9.6**	**0.24**	**2.304**	**9.64**	**0.06**	**0.5784**

5:14:13 PM	**9.58**	**0.26**	**2.4908**	**10.14**	**0.07**	**0.7098**
5:14:14 PM	**9.58**	**0.25**	**2.395**	**9.9**	**0.09**	**0.891**
5:14:15 PM	**9.56**	**0.24**	**2.2944**	**9.62**	**0.06**	**0.5772**
5:14:15 PM	**9.39**	**0.36**	**3.3804**	**9.72**	**0.06**	**0.5832**
5:14:17 PM	**9.39**	**0.39**	**3.6621**	**9.48**	**0.06**	**0.5688**
5:14:18 PM	**9.35**	**0.37**	**3.4595**	**9.48**	**0.06**	**0.5688**
5:14:20 PM	**9.29**	**0.37**	**3.4373**	**10**	**0.07**	**0.7**
5:14:20 PM	**9.42**	**0.23**	**2.1666**	**9.7**	**0.07**	**0.679**
5:14:22 PM	**9.42**	**0.24**	**2.2608**	**10.36**	**0.07**	**0.7252**
5:14:23 PM	**9.42**	**0.24**	**2.2608**	**9.56**	**0.06**	**0.5736**
5:14:24 PM	**9.44**	**0.25**	**2.36**	**9.96**	**0.09**	**0.8964**
5:14:25 PM	**9.4**	**0.25**	**2.35**	**9.94**	**0.07**	**0.6958**
5:14:26 PM	**9.4**	**0.24**	**2.256**	**9.64**	**0.07**	**0.6748**
5:14:28 PM	**9.4**	**0.24**	**2.256**	**9.64**	**0.07**	**0.6748**
5:14:29 PM	**9.39**	**0.25**	**2.3475**	**9.86**	**0.06**	**0.5916**
5:14:30 PM	**9.39**	**0.24**	**2.2536**	**9.98**	**0.09**	**0.8982**
5:14:31 PM	**9.29**	**0.31**	**2.8799**	**9.13**	**0.07**	**0.6391**
5:14:32 PM	**9.33**	**0.25**	**2.3325**	**10**	**0.07**	**0.7**
5:14:33 PM	**9.35**	**0.24**	**2.244**	**10**	**0.07**	**0.7**
5:14:34 PM	**9.31**	**0.25**	**2.3275**	**10**	**0.06**	**0.6**
5:14:36 PM	**9.29**	**0.25**	**2.3225**	**9.98**	**0.07**	**0.6986**
5:14:37 PM	**9.31**	**0.26**	**2.4206**	**9.96**	**0.06**	**0.5976**
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5:14:39 PM	**9.29**	**0.24**	**2.2296**	**9.96**	**0.07**	**0.6972**

5:14:40 PM	**9.29**	**0.25**	**2.3225**	**9.94**	**0.07**	**0.6958**
5:14:41 PM	**9.27**	**0.25**	**2.3175**	**9.94**	**0.07**	**0.6958**
5:14:42 PM	**9.27**	**0.25**	**2.3175**	**9.92**	**0.07**	**0.6944**
5:14:43 PM	**9.09**	**0.36**	**3.2724**	**9.78**	**0.07**	**0.6846**
5:14:45 PM	**9.07**	**0.37**	**3.3559**	**9.76**	**0.06**	**0.5856**
5:14:46 PM	**9.07**	**0.35**	**3.1745**	**9.72**	**0.07**	**0.6804**
5:14:47 PM	**9.03**	**0.36**	**3.2508**	**9.7**	**0.06**	**0.582**
5:14:48 PM	**9.01**	**0.35**	**3.1535**	**9.68**	**0.07**	**0.6776**
5:14:49 PM	**8.97**	**0.37**	**3.3189**	**9.68**	**0.07**	**0.6776**
5:14:49 PM	**9.09**	**0.23**	**2.0907**	**9.78**	**0.07**	**0.6846**
5:14:52 PM	**9.13**	**0.24**	**2.1912**	**9.8**	**0.07**	**0.686**
5:14:53 PM	**9.11**	**0.25**	**2.2775**	**9.8**	**0.07**	**0.686**
5:14:53 PM	**8.97**	**0.36**	**3.2292**	**9.64**	**0.07**	**0.6748**
5:14:55 PM	**8.95**	**0.35**	**3.1325**	**9.62**	**0.07**	**0.6734**
5:14:56 PM	**8.93**	**0.35**	**3.1255**	**9.58**	**0.07**	**0.6706**
5:14:57 PM	**8.89**	**0.35**	**3.1115**	**9.58**	**0.08**	**0.7664**
5:14:58 PM	**8.89**	**0.36**	**3.2004**	**9.56**	**0.07**	**0.6692**
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5:15:01 PM	**8.99**	**0.23**	**2.0677**	**9.7**	**0.07**	**0.679**
5:15:02 PM	**9.01**	**0.22**	**1.9822**	**9.68**	**0.07**	**0.6776**
5:15:03 PM	**9.03**	**0.22**	**1.9866**	**9.7**	**0.08**	**0.776**
5:15:04 PM	**9.01**	**0.23**	**2.0723**	**9.68**	**0.07**	**0.6776**
5:15:05 PM	**8.99**	**0.23**	**2.0677**	**9.68**	**0.07**	**0.6776**
5:15:06 PM	**8.99**	**0.23**	**2.0677**	**9.68**	**0.07**	**0.6776**

5:15:07 PM	**8.99**	**0.23**	**2.0677**	**9.68**	**0.07**	**0.6776**
5:15:09 PM	**8.99**	**0.22**	**1.9778**	**9.66**	**0.07**	**0.6762**
5:15:10 PM	**8.99**	**0.23**	**2.0677**	**9.66**	**0.08**	**0.7728**
5:15:11 PM	**8.97**	**0.23**	**2.0631**	**9.64**	**0.07**	**0.6748**
5:15:12 PM	**8.95**	**0.24**	**2.148**	**9.64**	**0.07**	**0.6748**
5:15:13 PM	**8.95**	**0.23**	**2.0585**	**9.64**	**0.07**	**0.6748**
5:15:14 PM	**8.97**	**0.23**	**2.0631**	**9.64**	**0.07**	**0.6748**
5:15:16 PM	**8.95**	**0.23**	**2.0585**	**9.62**	**0.07**	**0.6734**
5:15:17 PM	**8.95**	**0.23**	**2.0585**	**9.62**	**0.07**	**0.6734**
5:15:18 PM	**8.95**	**0.23**	**2.0585**	**9.62**	**0.07**	**0.6734**
5:15:19 PM	**8.95**	**0.23**	**2.0585**	**9.62**	**0.07**	**0.6734**
5:15:20 PM	**8.93**	**0.22**	**1.9646**	**9.6**	**0.08**	**0.768**
5:15:21 PM	**8.91**	**0.23**	**2.0493**	**9.6**	**0.07**	**0.672**
5:15:22 PM	**8.69**	**0.37**	**3.2153**	**9.29**	**0.07**	**0.6503**
5:15:23 PM	**8.69**	**0.37**	**3.2153**	**9.39**	**0.07**	**0.6573**
5:15:25 PM	**8.71**	**0.35**	**3.0485**	**9.37**	**0.07**	**0.6559**
5:15:26 PM	**8.67**	**0.36**	**3.1212**	**9.37**	**0.07**	**0.6559**
5:15:27 PM	**8.57**	**0.37**	**3.1709**	**8.53**	**0.07**	**0.5971**
5:15:28 PM	**8.77**	**0.24**	**2.1048**	**9.44**	**0.07**	**0.6608**
5:15:29 PM	**8.79**	**0.24**	**2.1096**	**9.46**	**0.07**	**0.6622**
5:15:30 PM	**8.61**	**0.37**	**3.1857**	**9.27**	**0.08**	**0.7416**
5:15:31 PM	**8.63**	**0.35**	**3.0205**	**9.31**	**0.08**	**0.7448**
5:15:33 PM	**8.59**	**0.36**	**3.0924**	**9.27**	**0.08**	**0.7416**
5:15:34 PM	**8.59**	**0.35**	**3.0065**	**9.27**	**0.07**	**0.6489**

5:15:35 PM	**8.55**	**0.35**	**2.9925**	**9.27**	**0.07**	**0.6489**
5:15:36 PM	**8.55**	**0.36**	**3.078**	**9.25**	**0.07**	**0.6475**
5:15:37 PM	**8.57**	**0.35**	**2.9995**	**9.23**	**0.08**	**0.7384**
5:15:39 PM	**8.53**	**0.34**	**2.9002**	**9.23**	**0.08**	**0.7384**
5:15:40 PM	**8.53**	**0.36**	**3.0708**	**9.21**	**0.07**	**0.6447**
5:15:41 PM	**8.51**	**0.35**	**2.9785**	**9.19**	**0.07**	**0.6433**
5:15:42 PM	**8.49**	**0.34**	**2.8866**	**9.19**	**0.08**	**0.7352**
5:15:43 PM	**8.49**	**0.35**	**2.9715**	**9.19**	**0.08**	**0.7352**
5:15:44 PM	**8.61**	**0.23**	**1.9803**	**9.29**	**0.07**	**0.6503**
5:15:45 PM	**8.63**	**0.24**	**2.0712**	**9.31**	**0.07**	**0.6517**
5:15:45 PM	**8.43**	**0.35**	**2.9505**	**9.13**	**0.07**	**0.6391**
5:15:47 PM	**8.43**	**0.36**	**3.0348**	**9.13**	**0.07**	**0.6391**
5:15:49 PM	**8.43**	**0.35**	**2.9505**	**9.13**	**0.07**	**0.6391**
5:15:50 PM	**8.43**	**0.36**	**3.0348**	**9.11**	**0.07**	**0.6377**
5:15:51 PM	**8.38**	**0.36**	**3.0168**	**9.09**	**0.07**	**0.6363**
5:15:52 PM	**8.4**	**0.36**	**3.024**	**9.09**	**0.08**	**0.7272**
5:15:53 PM	**8.4**	**0.35**	**2.94**	**9.05**	**0.08**	**0.724**
5:15:54 PM	**8.38**	**0.35**	**2.933**	**9.07**	**0.08**	**0.7256**
5:15:54 PM	**8.49**	**0.24**	**2.0376**	**9.19**	**0.07**	**0.6433**
5:15:57 PM	**8.49**	**0.24**	**2.0376**	**9.19**	**0.08**	**0.7352**
5:15:58 PM	**8.51**	**0.25**	**2.1275**	**9.21**	**0.07**	**0.6447**
5:15:59 PM	**8.53**	**0.23**	**1.9619**	**9.21**	**0.07**	**0.6447**
5:16:00 PM	**8.36**	**0.35**	**2.926**	**9.05**	**0.07**	**0.6335**
5:16:01 PM	**8.36**	**0.35**	**2.926**	**9.03**	**0.07**	**0.6321**

5:16:03 PM	**8.34**	**0.35**	**2.919**	**8.99**	**0.07**	**0.6293**
5:16:03 PM	**8.34**	**0.35**	**2.919**	**8.99**	**0.07**	**0.6293**
5:16:05 PM	**8.3**	**0.34**	**2.822**	**8.99**	**0.07**	**0.6293**
5:16:06 PM	**8.32**	**0.35**	**2.912**	**8.97**	**0.07**	**0.6279**
5:16:07 PM	**8.3**	**0.35**	**2.905**	**8.97**	**0.07**	**0.6279**
5:16:07 PM	**8.4**	**0.23**	**1.932**	**9.09**	**0.07**	**0.6363**
5:16:09 PM	**8.43**	**0.22**	**1.8546**	**9.11**	**0.07**	**0.6377**
5:16:11 PM	**8.45**	**0.23**	**1.9435**	**9.13**	**0.07**	**0.6391**
5:16:11 PM	**8.26**	**0.35**	**2.891**	**8.95**	**0.07**	**0.6265**
5:16:13 PM	**8.24**	**0.34**	**2.8016**	**8.95**	**0.07**	**0.6265**
5:16:14 PM	**8.24**	**0.35**	**2.884**	**8.91**	**0.07**	**0.6237**
5:16:15 PM	**8.22**	**0.35**	**2.877**	**8.91**	**0.07**	**0.6237**
5:16:16 PM	**8.24**	**0.35**	**2.884**	**8.89**	**0.08**	**0.7112**
5:16:17 PM	**8.22**	**0.34**	**2.7948**	**8.87**	**0.07**	**0.6209**
5:16:18 PM	**8.18**	**0.34**	**2.7812**	**8.87**	**0.08**	**0.7096**
5:16:19 PM	**8.18**	**0.34**	**2.7812**	**8.87**	**0.07**	**0.6209**
5:16:20 PM	**7.8**	**0.63**	**4.914**	**8.51**	**0.06**	**0.5106**
5:16:22 PM	**8.1**	**0.35**	**2.835**	**8.77**	**0.08**	**0.7016**
5:16:24 PM	**8.12**	**0.35**	**2.842**	**8.79**	**0.07**	**0.6153**
5:16:24 PM	**8**	**0.4**	**3.2**	**8.61**	**0.07**	**0.6027**
5:16:27 PM	**8.06**	**0.34**	**2.7404**	**8.73**	**0.07**	**0.6111**
5:16:28 PM	**8.06**	**0.34**	**2.7404**	**8.73**	**0.07**	**0.6111**
5:16:29 PM	**8.08**	**0.34**	**2.7472**	**8.73**	**0.08**	**0.6984**
5:16:30 PM	**8.06**	**0.34**	**2.7404**	**8.71**	**0.08**	**0.6968**

5:16:31 PM	**8.06**	**0.34**	**2.7404**	**8.73**	**0.08**	**0.6984**
5:16:32 PM	**8.06**	**0.35**	**2.821**	**8.71**	**0.08**	**0.6968**
5:16:33 PM	**8.36**	**0.11**	**0.9196**	**9.07**	**0.07**	**0.6349**
5:16:35 PM	**8.41**	**0.13**	**1.0933**	**9.09**	**0.07**	**0.6363**
5:16:36 PM	**8.43**	**0.13**	**1.0959**	**8.67**	**0.06**	**0.5202**
5:16:37 PM	**8.47**	**0.12**	**1.0164**	**9.11**	**0.06**	**0.5466**
5:16:38 PM	**8.49**	**0.11**	**0.9339**	**9.13**	**0.07**	**0.6391**
5:16:39 PM	**8.49**	**0.11**	**0.9339**	**9.15**	**0.07**	**0.6405**
5:16:40 PM	**8.51**	**0.12**	**1.0212**	**9.17**	**0.06**	**0.5502**
5:16:41 PM	**8.51**	**0.12**	**1.0212**	**9.17**	**0.07**	**0.6419**
5:16:43 PM	**8.53**	**0.12**	**1.0236**	**9.19**	**0.06**	**0.5514**
5:16:44 PM	**8.53**	**0.11**	**0.9383**	**9.19**	**0.07**	**0.6433**
5:16:45 PM	**8.53**	**0.11**	**0.9383**	**9.19**	**0.07**	**0.6433**
5:16:46 PM	**8.53**	**0.12**	**1.0236**	**9.19**	**0.07**	**0.6433**
5:16:47 PM	**8.53**	**0.11**	**0.9383**	**9.19**	**0.07**	**0.6433**
5:16:49 PM	**8.53**	**0.11**	**0.9383**	**9.19**	**0.07**	**0.6433**
5:16:49 PM	**8.53**	**0.12**	**1.0236**	**9.19**	**0.07**	**0.6433**
5:16:51 PM	**8.53**	**0.11**	**0.9383**	**9.19**	**0.06**	**0.5514**
5:16:52 PM	**8.55**	**0.12**	**1.026**	**9.21**	**0.07**	**0.6447**
5:16:53 PM	**8.55**	**0.12**	**1.026**	**9.21**	**0.07**	**0.6447**
5:16:54 PM	**8.53**	**0.12**	**1.0236**	**9.21**	**0.06**	**0.5526**
5:16:55 PM	**8.53**	**0.12**	**1.0236**	**9.19**	**0.06**	**0.5514**
5:16:57 PM	**8.53**	**0.12**	**1.0236**	**9.15**	**0.06**	**0.549**
5:16:58 PM	**8.53**	**0.12**	**1.0236**	**9.07**	**0.06**	**0.5442**

5:16:59 PM	**8.53**	**0.12**	**1.0236**	**9.13**	**0.07**	**0.6391**
5:17:00 PM	**8.53**	**0.12**	**1.0236**	**9.13**	**0.06**	**0.5478**
5:17:01 PM	**8.53**	**0.13**	**1.1089**	**9.19**	**0.06**	**0.5514**
5:17:02 PM	**8.53**	**0.11**	**0.9383**	**8.61**	**0.07**	**0.6027**
5:17:03 PM	**8.51**	**0.12**	**1.0212**	**7.5**	**0.06**	**0.45**
5:17:05 PM	**8.51**	**0.12**	**1.0212**	**6.83**	**0.07**	**0.4781**
5:17:06 PM	**8.51**	**0.12**	**1.0212**	**8.95**	**0.07**	**0.6265**
5:17:07 PM	**8.51**	**0.13**	**1.1063**	**9.03**	**0.06**	**0.5418**
5:17:08 PM	**8.51**	**0.12**	**1.0212**	**8.45**	**0.07**	**0.5915**
5:17:09 PM	**8.51**	**0.13**	**1.1063**	**8.14**	**0.07**	**0.5698**
5:17:10 PM	**8.51**	**0.11**	**0.9361**	**8**	**0.07**	**0.56**
5:17:11 PM	**8.51**	**0.12**	**1.0212**	**8.02**	**0.07**	**0.5614**
5:17:13 PM	**8.51**	**0.12**	**1.0212**	**8**	**0.07**	**0.56**
5:17:14 PM	**8.51**	**0.12**	**1.0212**	**7.86**	**0.07**	**0.5502**
5:17:15 PM	**8.49**	**0.12**	**1.0188**	**7.88**	**0.07**	**0.5516**
5:17:16 PM	**8.49**	**0.12**	**1.0188**	**7.9**	**0.06**	**0.474**
5:17:17 PM	**8.49**	**0.12**	**1.0188**	**7.96**	**0.07**	**0.5572**
5:17:18 PM	**8.49**	**0.11**	**0.9339**	**8**	**0.07**	**0.56**
5:17:19 PM	**8.49**	**0.12**	**1.0188**	**8**	**0.07**	**0.56**
5:17:20 PM	**8.49**	**0.12**	**1.0188**	**8**	**0.06**	**0.48**
5:17:22 PM	**8.49**	**0.11**	**0.9339**	**8**	**0.07**	**0.56**

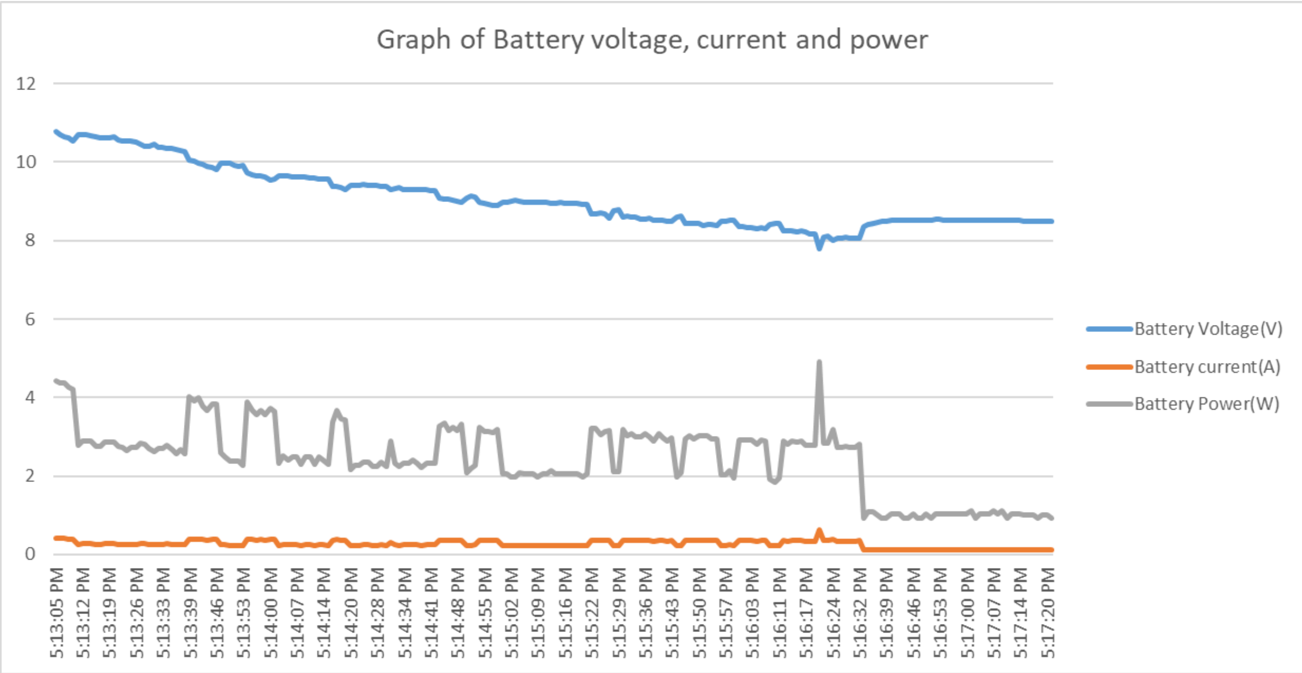

Figure81 : Graph of Battery voltage, current and power

The graph depicts the performance of a solar-powered water surface cleaning robot. Starting with varying current (0.4-0.27 A) and a steady battery voltage of roughly 10.7V, it eventually produces power variations (4.4-2.9 W). An interruption, most likely shading, is suggested in the middle by a sharp voltage-current decrease. However, a swift recovery follows, keeping a constant voltage, current, and power. This graph highlights how the robot's energy dynamics and its capacity to recover from setbacks are affected by solar input.

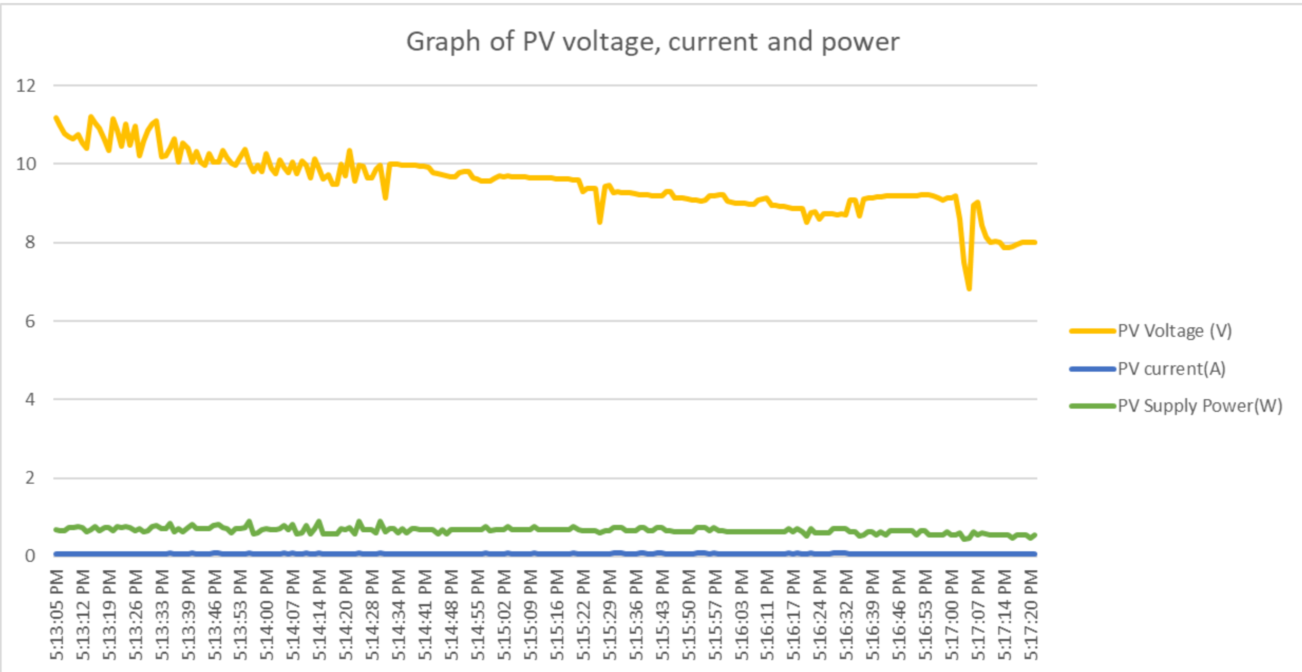

Figure82 : Graph of PV voltage, current and power

The graph depicts the performance of a solar panel that provides electricity to a water surface cleaning robot. The solar panel's output varies, with voltage levels fluctuating from 8.0V and 0.06A to 0.09A in current. As a result, power supply fluctuates between around 0.45W and 0.9W. The information illustrates how solar energy conversion is dynamic and affected by shifting environmental factors. The panel continually produces electricity to recharge the robot's battery despite variations, illuminating the solar source's variable energy input.

Table 12: Table of battery voltage, current and power, PV voltage, current and PV power supply with 1kg load.

Time	Battery Voltage(V)	Battery current(A)	Battery Power(W)	PV Voltage(V)	PV current(A)	PV Supply Power(W)
3:40:30 PM	12.88	0.56	7.5992	12.43	0.47	5.9972
3:40:31 PM	12.88	0.59	7.2128	12.76	0.47	5.9972
3:40:32 PM	12.88	0.56	7.2128	12.76	0.47	5.7868
3:40:33 PM	12.88	0.56	7.2128	12.58	0.46	5.8696
3:40:34 PM	12.88	0.56	7.2128	12.76	0.46	5.9126
3:40:35 PM	12.88	0.56	7.5697	12.58	0.47	5.9126
3:40:36 PM	12.83	0.59	7.5992	12.58	0.47	5.9972
3:40:37 PM	12.88	0.59	7.5992	12.76	0.47	5.8844
3:40:38 PM	12.88	0.59	7.1848	12.52	0.47	5.8844
3:40:39 PM	12.83	0.56	7.2128	12.52	0.47	5.7592
3:40:40 PM	12.88	0.56	7.5992	12.52	0.46	5.7904
3:40:41 PM	12.88	0.59	7.4812	12.32	0.47	5.7904
3:40:42 PM	12.68	0.59	7.1064	12.32	0.47	5.7904

3:40:43 PM	**12.69**	**0.56**	**6.34**	**12.32**	**0.47**	**6.0583**
3:40:44 PM	**12.68**	**0.50**	**6.44**	**12.89**	**0.47**	**5.9294**
3:40:45 PM	**12.88**	**0.50**	**6.345**	**12.89**	**0.46**	**5.679**
3:40:46 PM	**12.69**	**0.50**	**7.4871**	**12.62**	**0.45**	**5.679**
3:40:47 PM	**12.69**	**0.59**	**6.345**	**12.62**	**0.45**	**5.9314**
3:40:48 PM	**12.69**	**0.50**	**6.345**	**12.62**	**0.47**	**5.7105**
3:40:49 PM	**12.69**	**0.50**	**7.4871**	**12.69**	**0.45**	**5.9643**
3:40:50 PM	**12.69**	**0.59**	**6.34**	**12.69**	**0.47**	**5.7105**
3:40:51 PM	**12.68**	**0.50**	**6.345**	**12.69**	**0.45**	**5.9643**
3:40:52 PM	**12.69**	**0.50**	**6.345**	**12.69**	**0.47**	**5.661**
3:40:53 PM	**12.69**	**0.50**	**6.34**	**12.58**	**0.45**	**5.9126**
3:40:54 PM	**12.68**	**0.50**	**6.345**	**12.58**	**0.47**	**5.661**
3:40:55 PM	**12.69**	**0.50**	**6.345**	**12.58**	**0.45**	**5.661**
3:40:56 PM	**12.69**	**0.50**	**6.0864**	**12.58**	**0.45**	**5.661**
3:40:57 PM	**12.68**	**0.48**	**6.34**	**12.58**	**0.45**	**5.661**
3:40:58 PM	**12.68**	**0.50**	**6.345**	**12.58**	**0.45**	**5.9126**
3:40:59 PM	**12.69**	**0.50**	**7.5992**	**12.58**	**0.47**	**5.9972**

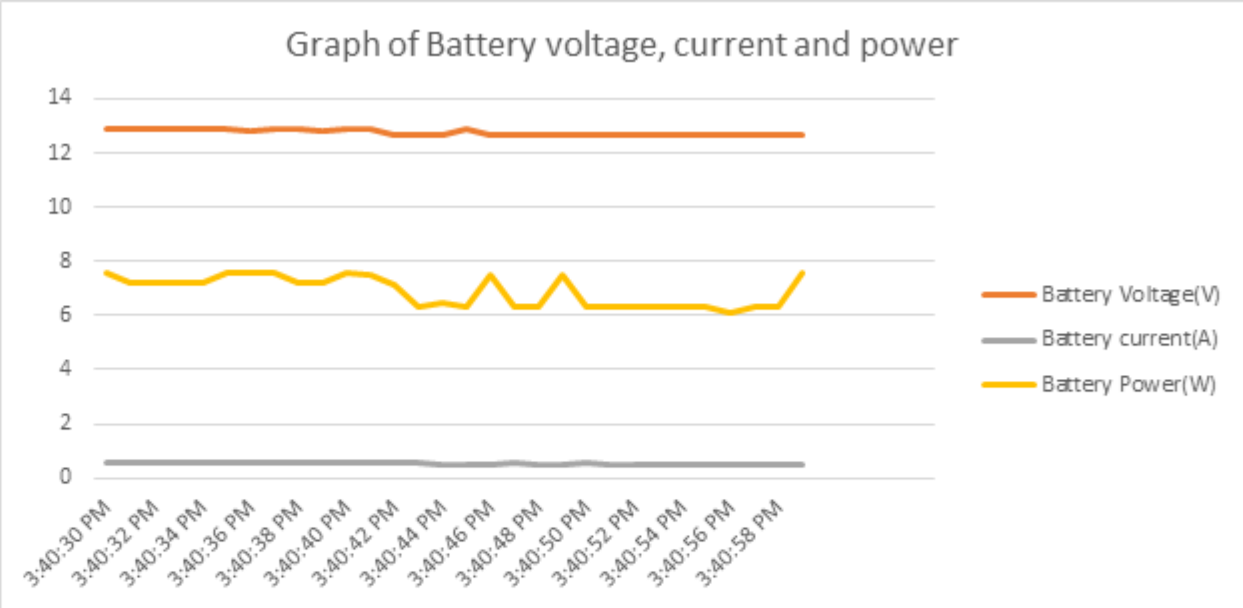

Figure83 : Graph of battery voltage, current and power with load

The data displays the effectiveness of a robot cleaning a water surface while carrying 1kg weight. While the battery voltage mostly stays at 12.88V, it can briefly drop to 12.83V or 12.68V. Battery power ranges from 6.0864 watts to 7.5992 watts, while battery current oscillates between 0.48A and 0.59A. This information shows variations in the robot's energy use, which may be useful for adjusting its activity to improve cleaning effectiveness or extend battery life.

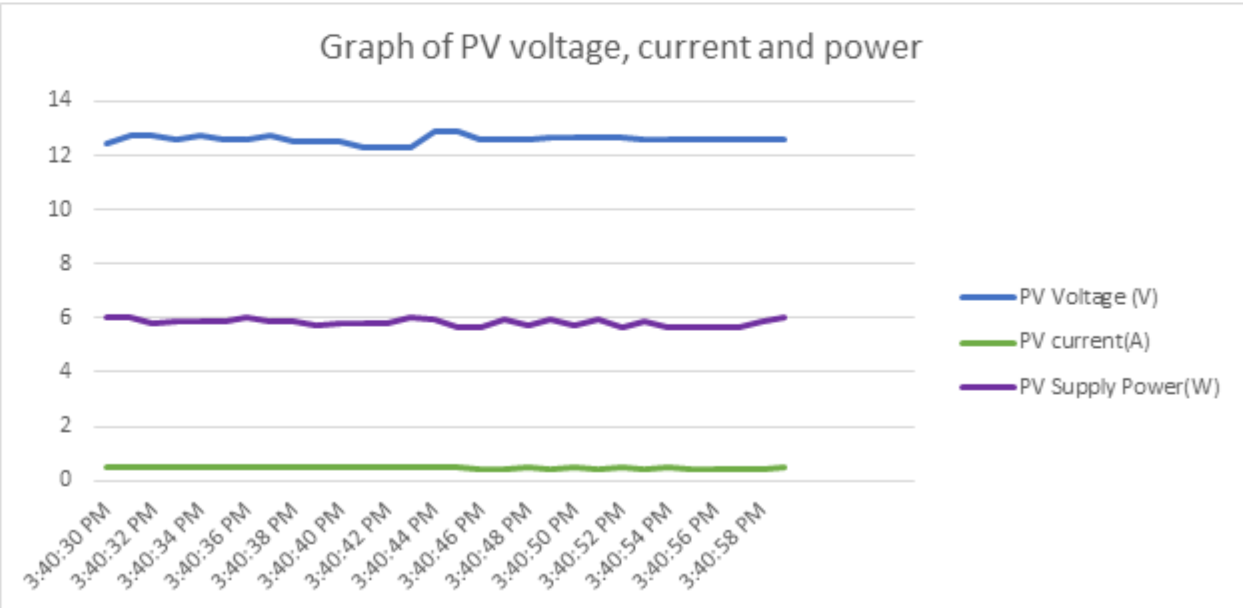

Figure84 : Graph of PV voltage, current and power with load

The data shows how a solar (PV)-powered water surface cleaning robot performs when carrying 1 kg weight. The PV voltage varies between 12.32V and 12.89V, while the PV current is essentially constant at 0.45A to 0.47A. As a result, the power output of the PV supply varies between 5.661W and 5.9972W, showing that the robot receives constant energy delivery. This information points to a consistent power supply from the PV source that supports the functioning of the robot in a variety of environmental conditions.

Table 13: Table of battery voltage, current and power, PV voltage, current and PV power supply with 2kg load

Time	Battery Voltage(V)	Battery current(A)	Battery Power (W)	PV Voltage(V)	PV current(A)	PV Supply Power(W)
3:37:30 PM	12.76	0.54	6.5076	12.38	0.47	5.8468
3:37:31 PM	12.76	0.51	6.8904	12.44	0.47	5.8468
3:37:32 PM	12.76	0.54	6.8904	12.44	0.47	5.7868
3:37:33 PM	12.76	0.54	6.8904	12.58	0.46	5.7224
3:37:34 PM	12.76	0.54	6.8904	12.44	0.46	5.9126
3:37:35 PM	12.76	0.54	6.5331	12.58	0.47	5.9126
3:37:36 PM	12.81	0.51	6.5076	12.58	0.47	5.8468
3:37:37 PM	12.76	0.51	6.5076	12.44	0.47	5.9502
3:37:38 PM	12.76	0.51	6.9174	12.66	0.47	5.9502
3:37:39 PM	12.81	0.54	6.8904	12.66	0.47	5.8236
3:37:41 PM	12.76	0.54	6.5076	12.66	0.46	5.7716
3:37:42 PM	12.76	0.51	6.4668	12.28	0.47	5.7716
3:37:43 PM	12.68	0.51	6.8526	12.28	0.47	5.7716
3:37:44 PM	12.69	0.54	6.34	12.28	0.47	6.0583
3:37:45 PM	12.68	0.50	6.38	12.89	0.47	5.9294
3:37:47 PM	12.76	0.50	6.345	12.89	0.46	5.6745

3:37:48 PM	**12.69**	**0.50**	**6.4719**	**12.61**	**0.45**	**5.6745**
3:37:49 PM	**12.69**	**0.51**	**6.345**	**12.61**	**0.45**	**5.9267**
3:37:50 PM	**12.69**	**0.50**	**6.345**	**12.61**	**0.47**	**5.7105**
3:37:51 PM	**12.69**	**0.50**	**6.4719**	**12.69**	**0.45**	**5.9643**
3:37:52 PM	**12.69**	**0.51**	**6.34**	**12.69**	**0.47**	**5.7105**
3:37:53 PM	**12.68**	**0.50**	**6.345**	**12.69**	**0.45**	**5.9643**
3:37:54 PM	**12.69**	**0.50**	**6.345**	**12.69**	**0.47**	**5.661**
3:37:55 PM	**12.69**	**0.50**	**6.34**	**12.58**	**0.45**	**5.9126**
3:37:56 PM	**12.68**	**0.50**	**6.345**	**12.58**	**0.47**	**5.661**
3:37:57 PM	**12.69**	**0.50**	**6.345**	**12.58**	**0.45**	**5.661**
3:37:58 PM	**12.69**	**0.50**	**6.0864**	**12.58**	**0.45**	**5.661**
3:37:59 PM	**12.68**	**0.48**	**6.34**	**12.58**	**0.45**	**5.661**
3:38:00 PM	**12.68**	**0.50**	**6.345**	**12.58**	**0.45**	**5.9126**
3:38:01 PM	**12.69**	**0.50**	**6.5076**	**12.58**	**0.47**	**5.8468**

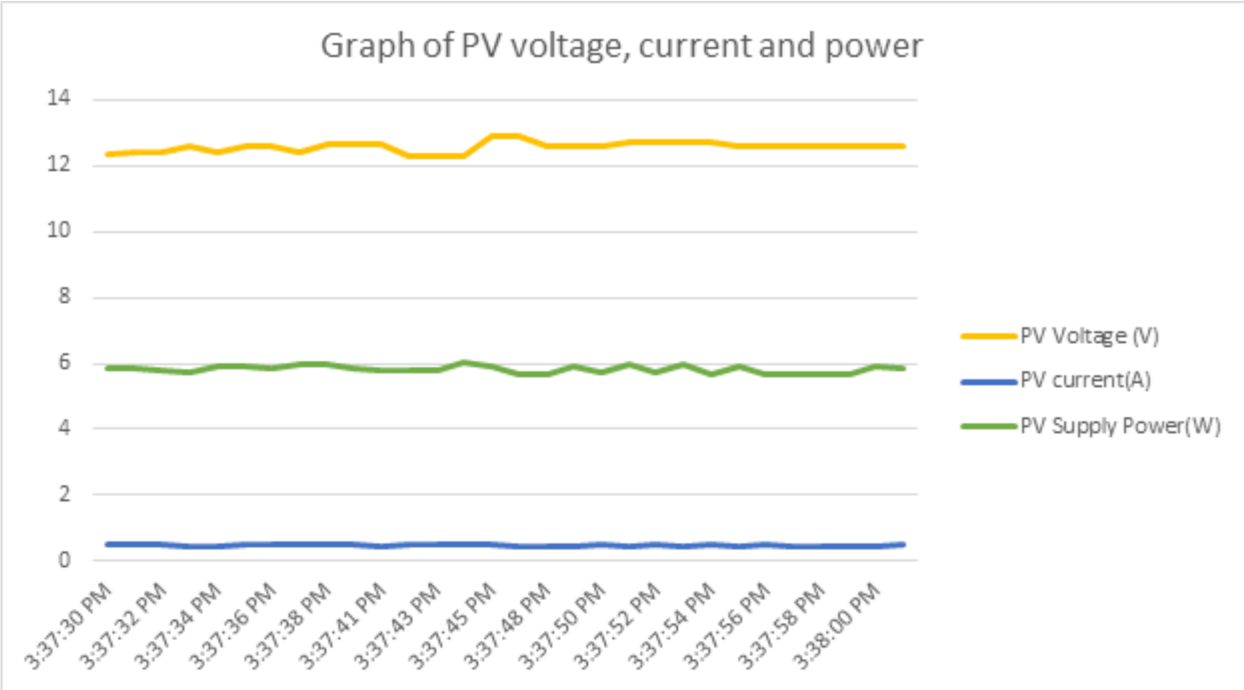

Figure85 : Graph of PV voltage, current and power with load

The data shows how a solar (PV)-powered water surface cleaning robot performs when carrying 2 kg weight. The PV voltage varies between 12.28V to 12.89V, while the PV current is essentially constant at 0.45A and 0.57A. As a result, the power output of the PV supply varies between 5.661W and 6.0583W, showing that the robot receives constant energy delivery. This information points to a consistent power supply from the PV source that supports the functioning of the robot in a variety of environmental conditions.

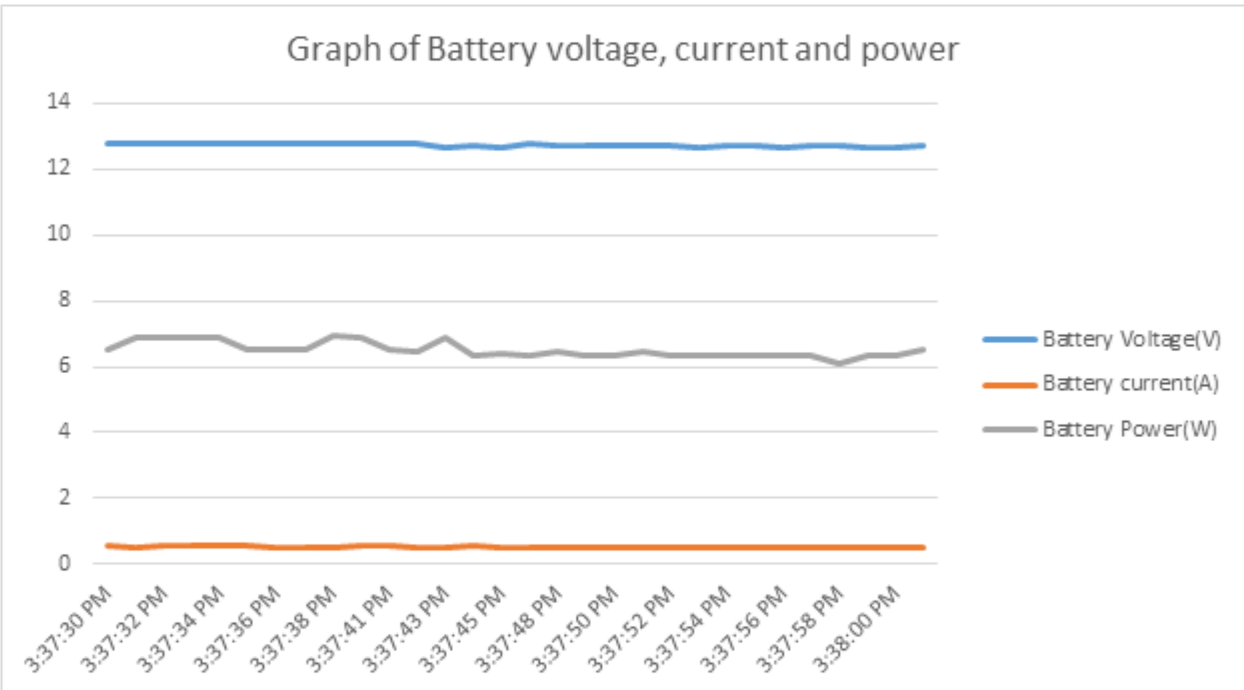

Figure86 : Graph of battery voltage, current and power with load

The data displays the effectiveness of a robot cleaning a water surface while carrying 2kg weight. While the battery voltage mostly stays at 12.89V, it can briefly drop to 12.68V to 12.81V. Battery power ranges from 6.0864W to 6.9174W, while battery current oscillates between 0.48A and 0.54A.

This information shows variations in the robot's energy use, which may be useful for adjusting its activity to improve cleaning effectiveness or extend battery life.

Table 14: Table of battery voltage, current and power, PV voltage, current and PV power supply with 3kg load

Time	Battery Voltage(V)	Battery current(A)	Battery Power(W)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
3:35:10 PM	12.698	0.52	6.0536	12.38	0.43	5.4309
3:35:11 PM	12.88	0.47	6.60296	12.63	0.43	5.4309
3:35:12 PM	12.698	0.52	6.6976	12.63	0.43	5.2836
3:35:13 PM	12.88	0.52	6.60296	12.58	0.42	5.3046
3:35:14 PM	12.698	0.52	6.6976	12.63	0.42	5.5352
3:35:15 PM	12.88	0.52	6.0207	12.58	0.44	5.1578
3:35:16 PM	12.81	0.47	5.96806	12.58	0.41	5.1783
3:35:17 PM	12.698	0.47	5.96806	12.63	0.41	5.4395
3:35:18 PM	12.698	0.47	6.6612	12.65	0.43	5.4395
3:35:19 PM	12.81	0.52	6.6976	12.65	0.43	5.313
3:35:20 PM	12.88	0.52	5.96806	12.65	0.42	5.2804
3:35:21 PM	12.698	0.47	5.96477	12.28	0.43	5.0348
3:35:22 PM	12.691	0.47	6.60036	12.28	0.41	5.0348
3:35:23 PM	12.693	0.52	5.83786	12.28	0.41	5.2849
3:35:24 PM	12.691	0.46	5.84108	12.89	0.41	5.4138

3:35:25 PM	**12.698**	**0.46**	**5.83878**	**12.89**	**0.42**	**5.71455**
3:35:26 PM	**12.693**	**0.46**	**5.96571**	**12.699**	**0.45**	**5.71455**
3:35:27 PM	**12.693**	**0.47**	**5.83878**	**12.699**	**0.45**	**5.58756**
3:35:28 PM	**12.693**	**0.46**	**5.83878**	**12.699**	**0.44**	**5.7105**
3:35:29 PM	**12.693**	**0.46**	**5.9643**	**12.69**	**0.45**	**5.4567**
3:35:30 PM	**12.69**	**0.47**	**5.83786**	**12.69**	**0.43**	**5.7105**
3:35:31 PM	**12.691**	**0.46**	**5.83878**	**12.69**	**0.45**	**5.5836**
3:35:32 PM	**12.693**	**0.46**	**5.83878**	**12.69**	**0.44**	**5.661**
3:35:33 PM	**12.693**	**0.46**	**5.83786**	**12.58**	**0.45**	**5.5352**
3:35:34 PM	**12.691**	**0.46**	**5.8374**	**12.58**	**0.44**	**5.661**
3:35:35 PM	**12.69**	**0.46**	**5.8374**	**12.58**	**0.45**	**5.661**
3:35:36 PM	**12.69**	**0.46**	**5.33022**	**12.58**	**0.45**	**5.661**
3:35:37 PM	**12.691**	**0.42**	**5.83786**	**12.58**	**0.45**	**5.661**
3:35:38 PM	**12.691**	**0.46**	**5.83878**	**12.58**	**0.45**	**5.4094**
3:35:39 PM	**12.693**	**0.46**	**6.0536**	**12.58**	**0.43**	**5.4309**

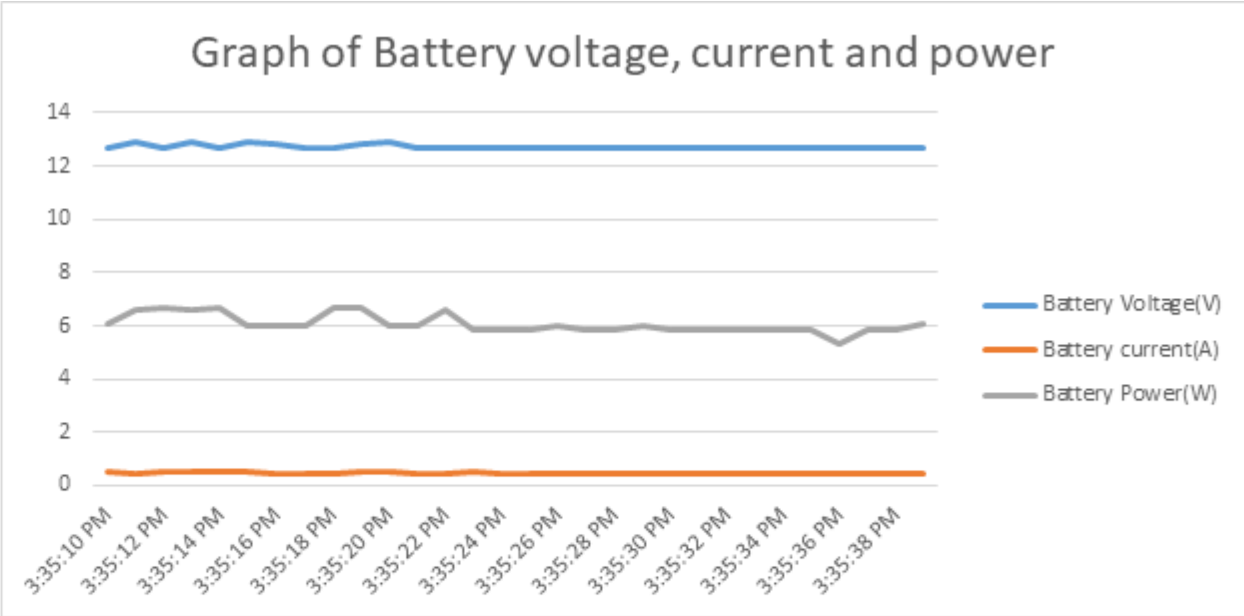

Figure87 : Graph of battery voltage, current and power with load

The data displays the effectiveness of a robot cleaning a water surface while carrying a 3kg weight. While the battery voltage mostly stays at 12.69V, it can briefly drop to 12.69V to 12.88V. Battery power ranges from 5.33022W to 6.6976W, while battery current oscillates between 0.42A and 0.52A. This information shows variations in the robot's energy use, which may be useful for adjusting its activity to improve cleaning effectiveness or extend battery life.

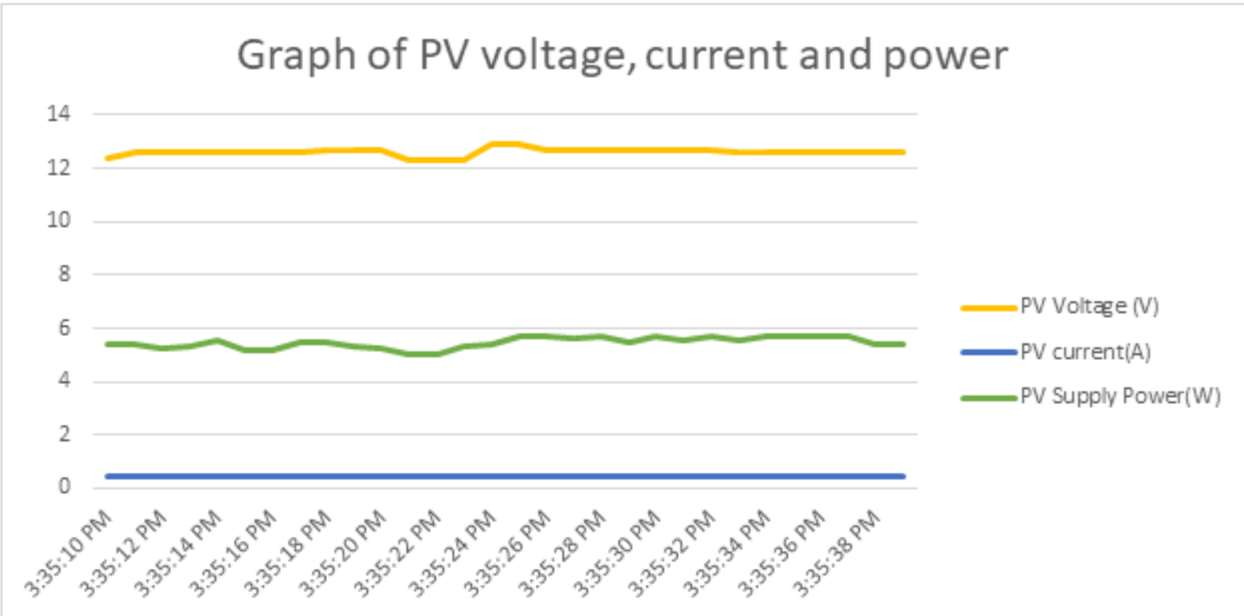

Figure88 : Graph of PV voltage, current and power with load

The data shows how a solar (PV)-powered water surface cleaning robot performs when carrying 3 kg weight. The PV voltage varies between 12.28V to 12.89V, while the PV current is essentially constant at 0.41A to 0.45A. As a result, the power output of the PV supply varies between 5.0348W and 5.71455W, showing that the robot receives constant energy delivery. This information points to a consistent power supply from the PV source that supports the functioning of the robot in a variety of environmental conditions.

Table 15: Table of battery voltage, current and power, PV voltage, current and PV power supply with 4kg load

Time	Battery Voltage(V)	Battery current(A)	Battery Power(W)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
3:33:20 PM	12.89	0.47	6.3014	12.38	0.41	5.1578
3:33:21 PM	12.86	0.49	6.0583	12.58	0.41	5.1578
3:33:22 PM	12.89	0.47	6.0442	12.58	0.41	5.1578
3:33:23 PM	12.86	0.47	6.0583	12.58	0.41	5.1578
3:33:24 PM	12.89	0.47	6.0442	12.58	0.41	5.1578
3:33:25 PM	12.86	0.47	6.2475	12.58	0.41	5.1578
3:33:26 PM	12.75	0.49	6.3161	12.58	0.41	5.1578
3:33:27 PM	12.89	0.49	6.3161	12.58	0.41	5.1865
3:33:28 PM	12.89	0.49	5.9925	12.65	0.41	5.1865
3:33:29 PM	12.75	0.47	6.0442	12.65	0.41	5.1865
3:33:30 PM	12.86	0.47	6.3161	12.65	0.41	4.961
3:33:31 PM	12.89	0.49	6.2279	12.1	0.41	4.961
3:33:32 PM	12.71	0.49	5.9831	12.1	0.41	4.961
3:33:33 PM	12.73	0.47	5.8466	12.1	0.41	5.289
3:33:34 PM	12.71	0.46	5.9294	12.9	0.41	5.289

3:33:35 PM	**12.89**	**0.46**	**5.8558**	**12.9**	**0.41**	**5.289**
3:33:36 PM	**12.73**	**0.46**	**6.2377**	**12.9**	**0.41**	**5.289**
3:33:37 PM	**12.73**	**0.49**	**5.8558**	**12.9**	**0.41**	**5.289**
3:33:38 PM	**12.73**	**0.46**	**5.8558**	**12.9**	**0.41**	**5.207**
3:33:39 PM	**12.73**	**0.46**	**6.2181**	**12.7**	**0.41**	**5.207**
3:33:40 PM	**12.69**	**0.49**	**5.8466**	**12.7**	**0.41**	**5.207**
3:33:41 PM	**12.71**	**0.46**	**5.8558**	**12.7**	**0.41**	**5.207**
3:33:42 PM	**12.73**	**0.46**	**5.8558**	**12.7**	**0.41**	**5.1578**
3:33:43 PM	**12.73**	**0.46**	**5.8466**	**12.58**	**0.41**	**5.1578**
3:33:44 PM	**12.71**	**0.46**	**5.8374**	**12.58**	**0.41**	**5.1578**
3:33:45 PM	**12.69**	**0.46**	**5.8374**	**12.58**	**0.41**	**5.1578**
3:33:46 PM	**12.69**	**0.46**	**5.3382**	**12.58**	**0.41**	**5.1578**
3:33:47 PM	**12.71**	**0.42**	**5.8466**	**12.58**	**0.41**	**5.1578**
3:33:48 PM	**12.71**	**0.46**	**5.8558**	**12.58**	**0.41**	**5.1578**
3:33:49 PM	**12.73**	**0.46**	**6.3014**	**12.58**	**0.41**	**5.1578**

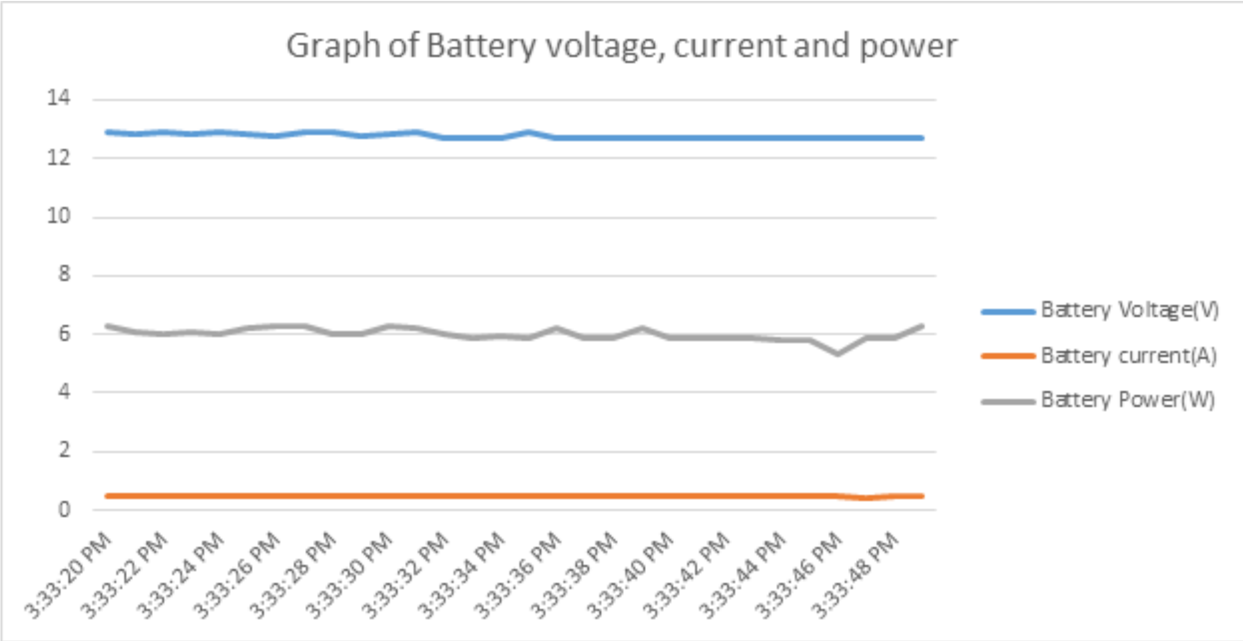

Figure89 : Graph of battery voltage, current and power with load

The data displays the effectiveness of a robot cleaning a water surface while carrying 4kg weight. While the battery voltage mostly stays at 12.88V, it can briefly drop to 12.69V or 12.89V. Battery power ranges from 5.3382W and 6.3161W, while battery current oscillates between 0.42A and 0.49A. This information shows variations in the robot's energy use, which may be useful for adjusting its activity to improve cleaning effectiveness or extend battery life.

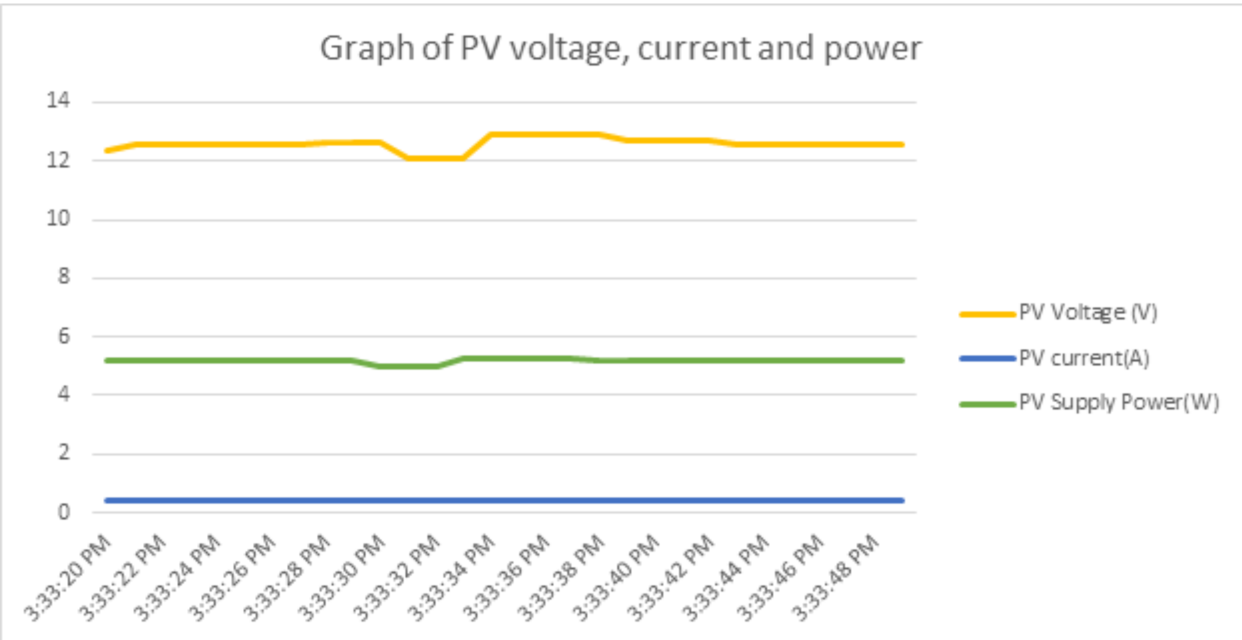

Figure90 : Graph of PV voltage, current and power with load

The data shows how a solar (PV)-powered water surface cleaning robot performs when carrying 4 kg weight. The PV voltage varies between 12.1V and 12.58V, while the PV current is essentially constant at 0.41A. As a result, the power output of the PV supply varies between 4.96W to 5.1578W, showing that the robot receives constant energy delivery. This information points to a consistent power supply from the PV source that supports the functioning of the robot in a variety of environmental conditions.

Table 16: Table of battery voltage, current and power, PV voltage, current and PV power supply with 5kg load

Time	Battery Voltage(V)	Battery current(A)	Battery Power(W)	PV Voltage (V)	PV current(A)	PV Supply Power(W)
3:32:03 PM	12.77	0.45	5.7465	12.5	0.39	4.875
3:32:04 PM	12.79	0.44	5.6276	12.5	0.39	4.875
3:32:05 PM	12.77	0.45	5.7465	12.5	0.39	5.125
3:32:06 PM	12.79	0.45	5.7555	12.5	0.41	5.125
3:32:07 PM	12.77	0.45	5.7465	12.5	0.41	4.875
3:32:07 PM	12.79	0.45	5.7555	12.5	0.39	4.875
3:32:08 PM	12.75	0.44	5.61	12.5	0.39	4.875
3:32:09 PM	12.77	0.44	5.6188	12.5	0.39	4.797
3:32:10 PM	12.77	0.44	5.6188	12.3	0.39	4.797
3:32:11 PM	12.75	0.45	5.7375	12.3	0.39	4.797
3:32:12 PM	12.79	0.45	5.7555	12.3	0.39	4.719
3:32:13 PM	12.77	0.44	5.6188	12.1	0.39	4.719
3:32:14 PM	12.71	0.44	5.5924	12.1	0.39	4.719
3:32:15 PM	12.73	0.45	5.7285	12.1	0.39	5.031
3:32:16 PM	12.71	0.43	5.4653	12.9	0.39	5.031
3:32:17 PM	12.77	0.43	5.4911	12.9	0.39	5.289

3:32:18 PM	**12.73**	**0.43**	**5.4739**	**12.9**	**0.41**	**5.031**
3:32:19 PM	**12.73**	**0.44**	**5.6012**	**12.9**	**0.39**	**5.289**
3:32:20 PM	**12.73**	**0.43**	**5.4739**	**12.9**	**0.41**	**4.953**
3:32:21 PM	**12.73**	**0.43**	**5.4739**	**12.7**	**0.39**	**4.953**
3:32:22 PM	**12.69**	**0.44**	**5.5836**	**12.7**	**0.39**	**4.953**
3:32:23 PM	**12.71**	**0.43**	**5.4653**	**12.7**	**0.39**	**5.207**
3:32:24 PM	**12.73**	**0.43**	**5.4739**	**12.7**	**0.41**	**4.875**
3:32:25 PM	**12.73**	**0.43**	**5.4739**	**12.5**	**0.39**	**4.875**
3:32:26 PM	**12.71**	**0.43**	**5.4653**	**12.5**	**0.39**	**4.875**
3:32:27 PM	**12.69**	**0.43**	**5.4567**	**12.5**	**0.39**	**4.875**
3:32:28 PM	**12.69**	**0.43**	**5.4567**	**12.5**	**0.39**	**4.875**
3:32:29 PM	**12.71**	**0.42**	**5.3382**	**12.5**	**0.39**	**4.875**
3:32:30 PM	**12.71**	**0.43**	**5.4653**	**12.5**	**0.39**	**4.875**
3:32:31 PM	**12.73**	**0.43**	**5.4739**	**12.5**	**0.39**	**4.875**

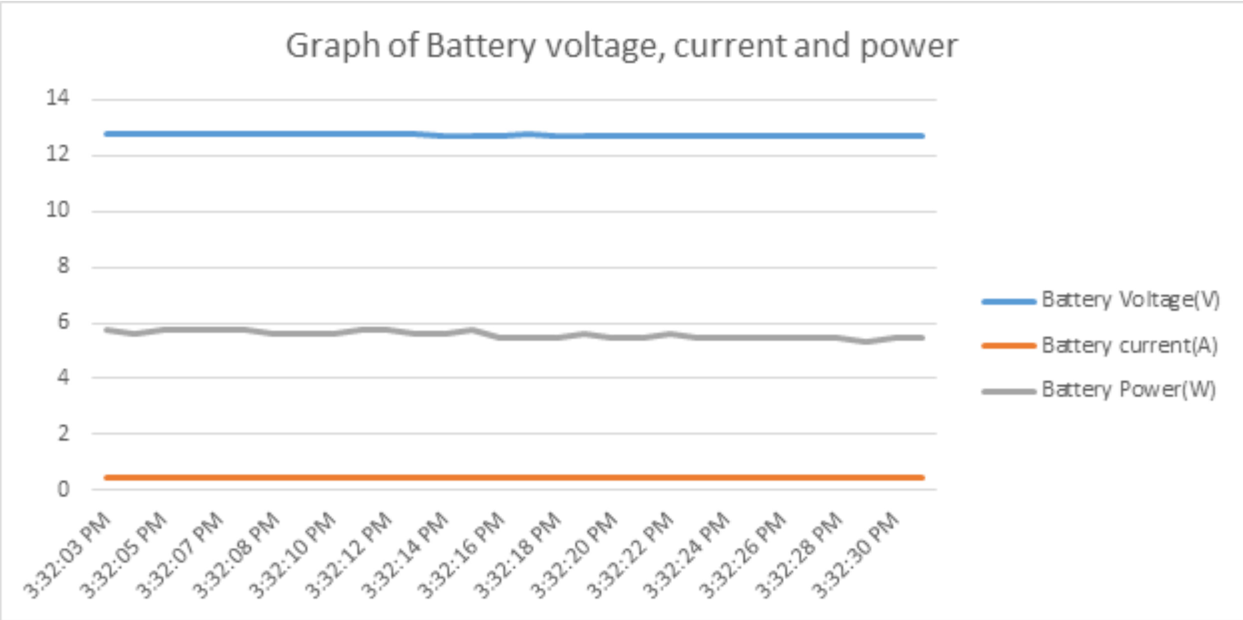

Figure91 : Graph of battery voltage, current and power with load

The data displays the effectiveness of a robot cleaning a water surface while carrying 5kg weight. While the battery voltage mostly stays at 12.73V, it can briefly drop to 12.69V or 12.79V. Battery power ranges from 5.3382W and 5.7555W, while battery current oscillates between 0.42A and 0.45A. This information shows variations in the robot's energy use, which may be useful for adjusting its activity to improve cleaning effectiveness or extend battery life.

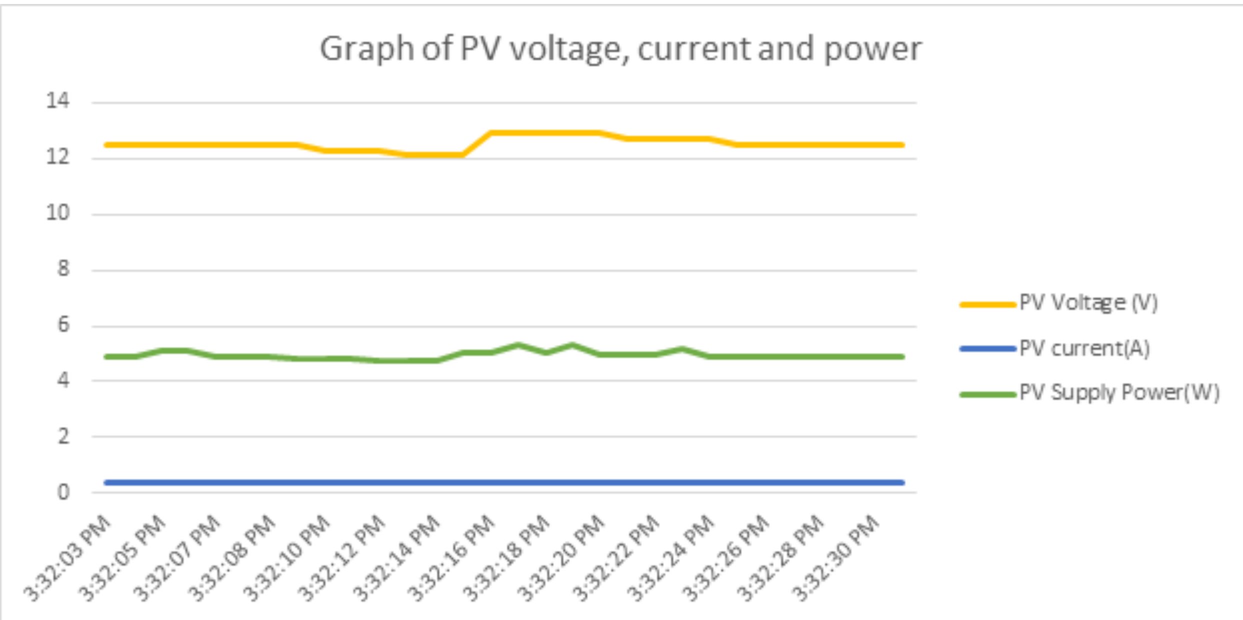

Figure92 : Graph of PV voltage, current and power with load

The data shows how a solar (PV)-powered water surface cleaning robot performs when carrying 5 kg weight. The PV voltage varies between 12.1V and 12.9V, while the PV current is essentially constant at 0.39A to 0.41A. As a result, the power output of the PV supply varies between 4.719W and 5.289W, showing that the robot receives constant energy delivery. This information points to a consistent power supply from the PV source that supports the functioning of the robot in a variety of environmental conditions.

Table 17: Table of main parameters and experimental results

Parameter	**Parameter value**
Body size	609.6 × 482.6 × 254 mm
Trash collection space	365.76 × 279.4 mm
Continuous operation time	1.5 ~ 2 h
Maximum sailing distance	7.62 m
Total number of plastic bottle collected	5 ~ 7 piece
Speed under normal wind and wave	7.9495 meters/minute

Speed:

Seconds to minutes:
23 seconds = 23 / 60 minutes ≈ 0.3833 minutes

Distance Per Minute:

Distance covered = 10 feet
Time taken = 0.3833 minutes

Rate = Distance / Time
Rate = 10 feet / 0.3833 minutes ≈ 26.11 feet/minute
Therefore, the rate is approximately 26.11 feet per minute.

To convert feet per minute to meters per minute, you can use the conversion factor:
1 foot = 0.3048 meters
So, to convert 26.11 feet per minute to meters per minute:
Rate in meters per minute = 26.11 feet/minute * 0.3048 meters/foot
Rate in meters per minute ≈ 7.9495 meters/minute
Therefore, the rate is approximately 7.9495 meters per minute.

Torque:

The torque you've mentioned (5.5 kg*cm) is already in torque units. However, the current you've provided (70 mA) needs to be converted to amperes (A) for the torque calculation.
70 mA = 0.07 A
So, to calculate the torque: Torque (τ) = Kt × I
Given that you have,
5.5 kg*cm = 0.055 Nm (since 1 Nm = 100 Ncm), and I = 0.07 A:
Torque = 0.055 Nm × 0.07 A
= 0.00385 Nm
The torque generated by the motor is approximately 0.00385 Newton-meters.

Force:

To convert the torque from newton-millimeters (Nm) to newtons using the given radius, you can use the formula: Force (F) = Torque (τ) / Radius Given:
Torque (τ) = 0.00385 Nm
Radius = 130 mm = 0.13 meters
Let's calculate the force: Force = 0.00385 Nm / 0.13 m ≈ 0.0296 N
The force exerted by the torque of 0.00385 Nm with a radius of 130 mm is approximately 0.0296 newtons.

Solar Panel Size Calculation:

Calculate the total power consumption of your load:

a. 2 x 12V DC motors:
Each motor consumes 1.2A at 12V.
Power consumption per motor = 1.2A * 12V = 14.4W
Total power consumption for both motors = 2 * 14.4W = 28.8W

b. 2 x MG996 servo motors:
Each servo motor consumes 20mA at 6V (assuming you are powering them with 6V).
Power consumption per servo = 0.02A * 6V = 0.12W
Total power consumption for both servos = 2 * 0.12W = 0.24W
Total power consumption of your load = 28.8W (motors) + 0.24W (servos) = 29.04W

Calculate the energy consumption per day, assuming our setup runs for 8 hours per day:
Energy consumption per day = 29.04W * 8 hours = 232.32 Wh (watt-hours)

Calculate the required solar panel capacity:
Assuming a solar panel efficiency of 19% (typical for many commercial solar panels):

Required solar panel capacity = (Energy consumption per day) / (Solar panel efficiency)
Required solar panel capacity = 232.32 W-h / 0.19 = 1,222.739 W-h
Therefore, the required PV panel size to drive the robot is:

$$= \frac{(W-h)}{(Peak\ Sun\ Hour * Oversize\ Factor * Dust\ Factor\ )}$$

$$= \frac{(1{,}222.739\ W-h)}{(4.5H * 0.9 * 0.9)}$$

$$\cong 335W$$

5.4 Conclusion

In conclusion, the ideal resolution successfully satisfies all defined objectives of the project's miniature water surface cleaning robot with the improvements that are required. The central control unit, battery energy management system, auxiliary battery charging mechanisms, and solar regeneration system are all operating as intended. Stakeholder requirements have also received careful consideration, and provisions have been included for prototype adaptation in response to changing demands. The objective prototype was successfully created, and it is currently undergoing extensive testing and iterative problem-solving sessions in preparation for a demonstrative showcase.

Chapter 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1 Introduction

The concept of utilizing solar-powered water surface cleaning robots carries significant implications in terms of societal, health, safety, and economic benefits. The design of an optimal solar-powered robot for this purpose can have diverse outcomes, impacting various aspects of people's lives. To ensure project sustainability, a growingly popular approach is being adopted, which involves effective management of projects, programs, organizations, businesses, and individuals involved in the production, advertising, transportation, and delivery of products and services. Throughout the project lifecycle, from strategic planning to evaluation, specific metrics and criteria need to be developed, encompassing aspects such as conceptualization, design, funding, execution, surveillance, and assessment.

6.2 Assess the impact of solution

Social and Cultural: The implementation of an efficient waste management system can have positive social and cultural impacts by reducing the amount of waste that ends up in our oceans, promoting social consciousness through education, considering cultural factors to tailor approaches, and using renewable energy sources such as solar panels to reduce our carbon footprint and promote sustainability. By addressing these factors, we can protect the environment and create a more sustainable future for generations to come.

Health: Contaminated waterways can have serious negative impacts on both public health and the environment. Water-borne diseases and skin ailments can harm stakeholders, while pollution can disrupt ecosystems and harm aquatic plants and animals. However, by implementing an effective waste management system using a machine to clean the water, we can reduce contamination, prevent the spread of diseases, and protect the aquatic habitat, promoting the health and well-being of all living beings that rely on it. This can create a healthier and more sustainable future for everyone.

Environmental protection: The robot would be designed to collect floating rubbish in waterways, reducing the amount of waste that ends up in our oceans and lakes. This could help to protect the environment and the aquatic habitat, reducing the negative impacts of pollution on ecosystems and biodiversity.

Sustainability: The use of solar panels and batteries to power the robot could promote sustainability and reduce our reliance on non-renewable sources of energy. This could help to reduce our carbon footprint and promote environmentally responsible practices.

Technological Development: The use of a microcontroller and bluetooth module to control the robot could have wider applications in the field of robotics and automation. This technology could be adapted and applied in other contexts, promoting innovation and technological development.

Improved public health: By reducing the amount of waste in our waterways, the robot could help to prevent the spread of water-borne diseases and skin ailments caused by contaminated water. This could have positive impacts on public health and well-being.

Economic benefits: The implementation of the robot could create new job opportunities in areas such as robotics, engineering, and maintenance. It could also generate cost savings for municipalities and organizations responsible for waste management, as they would no longer need to use as many resources to manually clean waterways.

Community engagement: The implementation of the robot could raise awareness about the importance of waste management and environmental protection, promoting community engagement and involvement in these issues.

Overall, the robot described has the potential to generate a wide range of positive impacts, including environmental protection, sustainability, technological development, improved public health, economic benefits, and community engagement.

6.3 Evaluate the sustainability

Sustainability evaluation by SWOT analysis:

Table 18: Table of SWOT Analysis

Strength	**Weakness**
● Zero emission from the robot. ● Having a less expensive robot. ● The maintenance cost is very low. ● Environment friendly. ● Easy mechanism and user-friendly	● As it is a miniature water cleaning robot, it can not carry more waste. ● As the robot will work on water, water may damage the electrical elements if it gets into the sealed box. ● Battery life is short and its replacement is costly.
Opportunity	**Threat**
● Reduce human suffering ● Biodiversity in the water will continue to change by cleaning the water body ● The collected waste can be recycled.	● The robot may sink by carrying extra weight. ● People may demand increased battery life.

6.4 Conclusion

The solar-powered water surface cleaning robot is an eco-friendly solution to address floating waste. With a user-friendly design and easy assembly, it efficiently removes debris from water bodies. Powered by solar energy, it minimizes pollution and reduces reliance on non-renewable sources. Its advanced navigation system ensures effective waste collection, making it suitable for daily use. The robot's long-term cost-effectiveness stems from its solar power utilization, eliminating fuel and electricity expenses. By promoting economic sustainability, this robot tackles environmental demands without compromising the ability of future generations to thrive. Its impact lies in its accessible operation, efficient cleaning, and economic viability, contributing to a cleaner and sustainable environment.

Chapter 7: Engineering Project Management. [CO11, CO14]

7.1 Introduction

The process of overseeing a project from its initiation to its completion involves the application of essential knowledge and skills to ensure adherence to relevant requirements, budgetary constraints, and timelines. From the early stages, it is crucial to clearly define the project's objectives and diligently adhere to a predetermined schedule for its development. Project management plays a vital role in formulating strategies to achieve project goals, establishing specific processes, and delivering the intended outcomes. Effective project management also involves facilitating regular communication among project participants and other stakeholders. Additionally, contingency plans must be created to address unforeseen circumstances that may arise. Successfully conducting project demonstrations within the predefined time frame is a testament to the proficiency of project management.

7.2 Define, Plan and Manage Engineering Project

FYDP - P

Design of a Solar Powered Miniature Water Surface Cleaning Robot.	START DATE	Due Date	Progress	Days
FYDP-P	25/09/2022	22/12/2022	100%	89
Task				
Problem identification	26/09/2022	29/09/2022	100%	4
Article find and discussion	30/09/2022	8/10/2022	100%	9
Different design approaches	9/10/2022	16/10/2022	100%	8
Concept note and PPT	17/10/22	2/11/2022	100%	17
Progress presentation-1	3/11/2022		100%	1
Final concept note	4/11/2022		100%	1
Research and planning the project	4/11/2022	6/11/2022	100%	3
Attributes on complex engineering	7/11/2022	9/11/2022	100%	3
Work on sustainability, ethical consideration	10/11/2022	13/11/2022	100%	4
Work on risk factors and safety consideration	14/11/2022	17/11/2022	100%	4
Working on methodology	18/11/2022	21/11/2022	100%	3
Estimating budget	22/11/2022	24/11/2022	100%	3
Research on impacts and expected outcomes	25/11/2022	28/11/2022	100%	4
Draft the project proposal	10/11/2022	9/12/2022	100%	30
Mock presentation	10/12/2022		100%	1
Work on presentation technique	11/12/2022	14/12/2022	100%	4
Project proposal presentation	15/12/2022		100%	1
Project proposal submission	22/12/2022		100%	1

Figure93 : Gantt chart for EEE400P

FYDP - D

Design of a Solar Powered Miniature Water Surface Cleaning Robot.	START DATE	Due Date	Progress	Days
FYDP-D	26/1/2023	27/4/2023	100%	102
Task				
Preparing Design process	26/1/2023	1/3/2023	100%	35
Finding specification, requirements and constraints	26/1/2023	8/2/2023	100%	14
Primary design of multiple approaches	2/2/2023	15/2/2023	100%	14
Performing simulation of the multiple design approaches	1/3/2023	29/3/2023	100%	29
Analysing optional design solution	19/2/2023	25/2/2023	100%	6
Selecting optimal design solution	29/3/2023	5/4/2023	100%	8
Selecting appropriate tools for designing	20/2/2023	26/2/2023	100%	7
Research for information,skills and materials	16/2/2023	8/3/2023	100%	21
Implementing the gained knowledge in the simulation	27/2/2023	9/3/2023	100%	13
Evaluating and submitting the simulation report	16/3/2023	22/3/2023	100%	7
Project progress presentation	2/3/2023		100%	1
Identifying ethical issues	10/3/2023	19/3/2023	100%	9
Communication with the stakeholders	2/3/2023		100%	1
Writing note,journal and preparing for the final report	19/3/2023	2/4/2023	100%	13
Preparation for the final presentation	25/4/2023		100%	1
The final presentation	27/4/23		100%	1

Figure94 : Gantt chart for EEE400D

FYDP - C

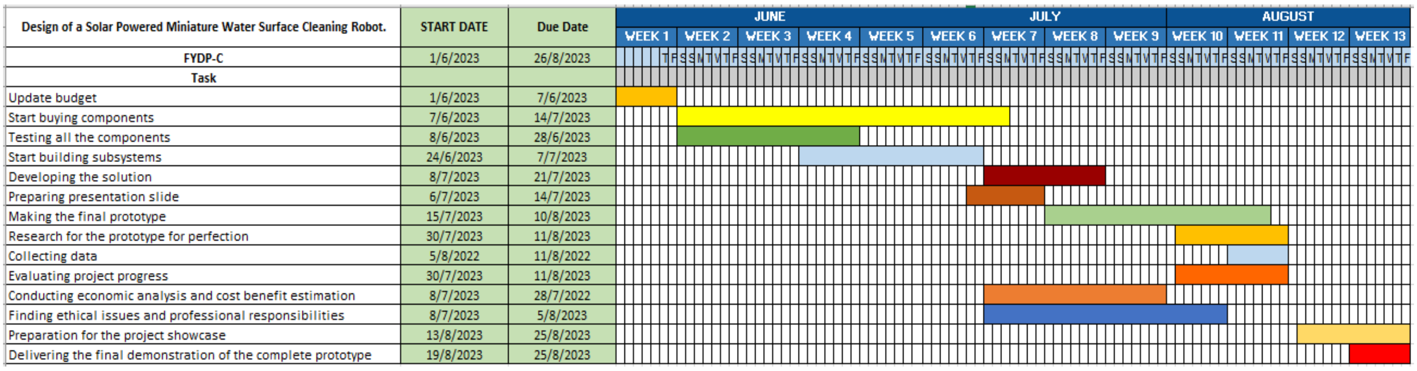

Figure95 : Gantt chart for EEE400C

7.3 Evaluate project progress

The completion status of the tasks listed in each Gantt chart for the three phases of the engineering project (FYDP - P, FYDP - D, and FYDP - C) can be analyzed to assess the project's progress. To determine whether the project is on track and finishing on time, we will take into account the actual completion dates and lengths.

FYDP-P (Project Planning Phase)

• The project's planning phase was scheduled to begin on September 26, 2022, and end on January 8, 2023.
• Based on the Gantt chart, it looks like all jobs were finished within the allotted time frames.
• The timely submission of the project proposal is evidence that the planning stage was effectively completed.

FYDP-D (Design Phase)

• The design phase was scheduled to begin on January 26, 2023, and end on April 25, 2023.
• In order to prevent delays in the succeeding phases, it is crucial to monitor the status of the ongoing activity and make sure it is finished as soon as feasible.

FYDP-C (Construction Phase)

• The building phase was scheduled to begin on June 1, 2023, and end on August 25, 2023.
• Some activities, such as "Start buying components," "Testing all components," and "Start building subsystems," are still in process and have not yet met their completion dates.
• It appears that the project is still in the planning stage, thus ongoing observation is necessary to assure a timely conclusion.

Overall Evaluation

• In the planning phase, all tasks appeared to be completed on schedule.
• In the design phase, also all tasks appeared to be completed on schedule.
• Some crucial activities are still unfinished during the construction period. To fulfill the project's total deadline, this phase must advance more quickly.

Project managers should also engage with team members and stakeholders, review and update the Gantt charts frequently, look for potential bottlenecks, and implement contingency plans as needed. The team may raise the possibility that the project will be successfully completed within the allotted time limit by remaining diligent and aggressive in project management.

7.4 Conclusion

In almost every project, encountering challenges is inevitable, and it is the responsibility of engineering project leaders to proactively tackle these issues and provide viable solutions. When problems arise, the engineering project coordinator must identify the underlying causes of these errors and utilize problem-solving techniques to steer the project back on course. Furthermore, occasional supervision from ATC panel members can ensure smooth and appropriate project management, enabling effective oversight and guidance throughout the project's lifecycle.

Chapter 8: Economical Analysis. [CO12]

8.1 Introduction

Economic analysis plays a vital role in the evaluation of any product study. Its purpose is to examine the pros and cons of the project's output, offering valuable insights into the viability and marketability of the product. While economic analysis serves various objectives, one crucial aspect is predicting and evaluating customer responses to the product. This assessment is essential for achieving profitability and understanding the overall business outcomes that can be expected.

8.2 Economic analysis

The market in Bangladesh presents a lucrative opportunity for introducing a solar-powered water surface cleaning robot. With a substantial market size and growing concern for water body cleanliness, the robot offers an environmentally friendly alternative to traditional cleaning methods. Its cost-effectiveness and superior performance make it an attractive proposition. By leveraging clean energy and employing advanced technologies, the robot can efficiently clean water surfaces while reducing labor costs. With limited competition in the eco-friendly segment, the robot has the potential to capture a significant market share. However, a comprehensive economic analysis is necessary to evaluate costs, revenue streams, and profitability for informed decision-making.

8.3 Cost benefit analysis

A cost-benefit analysis is crucial for determining the viability of a project. Economic analysis, as a component of this assessment, has its own advantages and disadvantages. The advantages include providing quantitative direction for decision-making during product development based on accurate assumptions. It is not necessary for a project to be completed at the lowest cost to be considered economically viable. The effectiveness, performance, durability, and feasibility of project components are the key factors. Precision is crucial for usability, but selecting appropriate components in terms of price and performance can be challenging due to the wide range of options available in the market. As engineers, we must carefully choose cost-efficient and effective components for the project. Each component has its pros and cons, and we have considered three approaches. While some components may be more expensive than others, we prioritize efficiency for different uses. Comparing components and approaches can provide a better understanding of the options available.

8.4 Evaluate economic and financial aspects

According to the given budget and project specifications, there is a clear opportunity to expand the market for solar-powered water surface cleaning robots in Bangladesh at a low cost. Commercially, this project is highly feasible for manufacturing in a cost-effective manner and making it accessible to the masses. Furthermore, this project stands out from conventional water surface cleaning robots currently available in the market due to their solar-powered capabilities. The use of solar energy enables the robot to operate efficiently and reduce dependency on external power sources. Moreover, the inclusion of an extra backup system significantly enhances its performance and contributes to achieving the primary objective of this project, which is effective water surface cleaning.

Budget Analysis:

Table 19: Table of Budget analysis

Component	Quantity	Link	Price (tk)
Arduino nano R3	1	https://store.roboticsbd.com/arduino-bangladesh/926-arduino-nano-gravitech-us-ft232-original-robotics-bangladesh.html	850
Arduino Bluetooth Module HC-05	1	https://store.roboticsbd.com/robotics-parts/905-arduino-bluetooth-module-hc-05-robotics-bangladesh.html	340
L298N Motor Driver	2	https://store.roboticsbd.com/motor-driver/376-l298n-h-bridge-dual-motor-driver-stepper-motor-driver-robotics-bangladesh.html	390
1000 RPM Gear Motor	2	https://www.allmartbd.com/robotics-14/12v-1000rpm-dc-gear-motor.html	1040
Shaft Propeller	2	https://www.rcgearbd.com/product/4mm-drive-shaft-l130mm-shaft-l80mm-sleeve-d36mm-propeller-fit-for-3mm-motor-shaft/	1480
Servo Motor	2	https://store.roboticsbd.com/motor/278-mg995-fully-metal-servo-motor-robotics-bangladesh.html	870
Solar Panel	1	https://www.daraz.com.bd/products/12volt-30-watt-solar-panel-poly-i125430600.html	2650
Solar Branch Cable Connector	1	https://www.daraz.com.bd/products/solar-y-branch-cable-connectorssolar-cable-parallel-adaptor-in-pair-for-solar-panecable-wire-plug-tool-kit-i242825426.html	658
	1	https://rcproductbd.com/product/mppt-solar-panel-controller-6-36v-1-25-32v-step-charging-module/	900
DC-DC booster module	1	https://www.electronics.com.bd/DC-DC-150W-Step-up-Module-Boost-Converter-12-32V-to-12-35V-150W-Step-up-Module-150W-Boost-Boost-Converter--Step-up-buck-step-up-module-price-in-online-bd-Bangladesh?fbclid=IwAR0QxIWvS3tPmlIIEj846bi4bg99BrLYiMHmQvK3JeJq4k9Y9g5Fk5IzHUM	275
3v Battery	4	https://www.electronics.com.bd/Samsung-INR21700-40T-4000mAh-35A-Li-Ion-Battery-3.6V--3.7V-INR21700-40T-INR21700-40T-4000mAh-35A-Li-Ion-18650-lithium-battery-price-in-online-BD-Bangladesh	1320
4 inch uPVC Pipe	1	https://www.oikko.com.bd/product/4-upvc-pipe-0ed1077b-080e-43a5-87c7-c6ec96720df7	850

Universal Joint Motor Shaft Coupler Connector	2	https://www.electronics.com.bd/UNIVERSAL-JOINT-MOTOR-SHAFT-COUPLER-CONNECTOR-5MM-TO-3.7MM-UNIVERSAL-JOINT-MOTOR-SHAFT-COUPLER-CONNECTOR-5MM-3.7MM-Price-in-online-BD-Bangladesh?fbclid=IwAR1yO_dQ0ObBdmJbm3FHSnoT7EZJjmHAAVkDjRGWqKQPUwivF1xPnQ0K2zY	340
Standard LCD 16x2 Display	1	https://store.roboticsbd.com/display/661-lcd-16x2-yellow-backlight-robotics-bangladesh.html?fbclid=IwAR2AMD1ZlNZ9GgB16mkT9YSKPprAuhfAHJPz6_gr_7yUNfe3cFtVLPGDLWI	240
Current Sensor	2	https://store.roboticsbd.com/sensors/555-current-sensor-acs712-30a-robotics-bangladesh.html?fbclid=IwAR1iUjpwoc_0P_HT6y1lrO5s9ZncVdHSpNe3A-r2dcxH9GK4ONKc8JV96q0	438
PCB Printing	1	Obtain From Local Market	1000
PVC Board	1	Obtain From Local Market	1400
Solar Charge Controller	1	Obtain From Local Market	250
			Total: 14391 tk

8.5 Conclusion

The long-term sustainability and success of a solar-powered water surface cleaning robot depend not only on its effectiveness and performance but also on its accessibility, which is influenced by the economic choices made for the product. To ensure the project's viability, it is essential to conduct a comprehensive analysis that considers the various compromises necessary to enhance sustainability and accessibility. Economic research should be carried out concurrently with the development of the project to thoroughly evaluate these factors and make informed decisions.

Chapter 9: Ethics and Professional Responsibilities CO13, CO2

9.1 Introduction

Due to the fact that it advances the goal of the study and aids in preventing data fabrication and distortion, ethical consideration is essential when relating to ethical principles in papers or articles. The values that are crucial to collaborative work are promoted by ethical norms since research typically requires a considerable degree of collaboration and coordination among many different users from various professions and organizations. Many of the ethical rules also help to hold researchers accountable to the general population. In order to ensure that researchers sponsored by public funds may be held accountable to the public, constitutional safeguards on research misconduct, conflicts of interest, human subject rights, and animal care and usage, for example, are crucial. The project's approval is influenced by both professional and ethical obligations.

9.2 Identify Ethical Issues and Professional Responsibility

The study of the moral applications of robotics technology is known as "robot ethics," and it is a new comprehensive approach. We currently live in a world where robots are beginning to execute duties that people are used to undertaking, such as precise medical treatments, transactions and e-commerce, and even military operations. The following terms must be kept in mind while working on this project

• **Battery Disposal:** Since almost all robots are powered by batteries, battery disposal needs to be given top consideration. Frequent use will also have an effect on battery life. The extraction and disposal processes have a number of serious negative effects on the environment. This also falls under the heading of professional responsibility

• **Automation and Employment:** Robots and artificial intelligence (AI) are likely to greatly boost productivity and, consequently, world wealth. The economy has always included efforts to increase productivity, even though the emphasis on "growth" is a more recent phenomenon. However, fewer workers are frequently required to complete the same amount of labor when productivity is increased by automation. But there might not be a total loss of employment because of the increase in available income and the possibility of higher demand as a result. Water Quality and Safety:

• **Water Quality and Safety:** The quality and safety of the water are crucial because the robot operates in bodies of water. During its cleaning process, the robot must not introduce dangerous substances or disturb aquatic life.

• **Non-Interference with Wildlife:** The robot should be made to not hurt aquatic plants and animals because it functions in natural water surroundings. Minimizing damage to wildlife habitats and preventing unintentional entanglement are ethical considerations.

9.3 Apply ethical issues and professional responsibility

• **Sustainable Design:** Designing the robot with sustainability in mind, using recyclable and ecologically friendly materials, is important. It should be designed to minimize waste and maximize energy efficiency.

• **Thorough Testing:** The robot should go through extensive testing before deployment to make sure it functions safely and effectively without endangering the environment or any wildlife.

• **Transparent Communication:** The project team must be honest with stakeholders, explaining the robot's capabilities, any potential environmental effects, and the ethical issues that have been taken into account.

• **Compliance with Regulations:** To ensure legal compliance, the team must follow pertinent environmental and safety rules pertaining to water bodies, robotics, and data privacy.

9.4 Conclusion

In conclusion, the utilization of a water surface cleaning robot can be deemed safe and effective when accompanied by appropriate ethical and professional considerations. Users must prioritize environmentally friendly cleaning solutions, maintain the robot's visibility to prevent accidents, comply with local regulations, and ensure regular maintenance and inspection. By adhering to these guidelines, users can contribute to the preservation of clean water surfaces while upholding safety standards and minimizing potential risks.

Chapter 10: Conclusion and Future Work.

10.1 Project Summary/Conclusion

Water surface cleaning robots are a type of technology that has not been adequately catered to provide efficient and effective cleaning solutions for water bodies. The stakeholders' points of view on the statement would likely be influenced by their respective interests and priorities, including technological advancement, environmental protection, and economic viability. The purpose of building a water surface cleaning robot is to automate and improve the efficiency of water cleanup efforts, thereby addressing the issue of water pollution in a sustainable and cost-effective manner. This report compares three different models for achieving the project. The report noted significant variations among the models in terms of their primary control mechanism, communication protocols, and trash collection mechanism. Based on our analysis, we have determined that Design 2 surpasses Designs 1 and 3 in terms of control ease, trash collection rate, and cost-effectiveness.

10.2 Future work

Our future work focuses on improving the project by developing the robot to work in any water bodies like rivers, oceans, etc. Furthermore, the use of image processing to differentiate the wastes as biodegradable and nonbiodegradable may also be implemented in future. This will help to protect the aquatic animals, thus maintaining a balanced ecosystem. The project can be further improved by adding a GPS and wireless communication capabilities to give information to respective authorities about the place where the wastes are being stored. The robot can be used in water quality monitoring and other applications like water sampling, testing & chemical treatment. The robot can be fitted with a camera and Transmitter and Receiver like Flysky CT6B & FS-R6B so as to enable it to be controlled from long distance. Lastly, the machines can effectively collect floating solid waste. In order to be controlled remotely, the robot can be equipped with a camera, a transmitter, and a receiver, such as the Flysky CT6B & FS-R6B. Last but not least, the equipment can efficiently gather floating solid waste.

Chapter 11: Identification of Complex Engineering Problems and Activities.

11.1: Attribute of complex engineering problem (EP)

	Attributes	Put tick (√) as appropriate
P1	Depth of knowledge required	✓
P2	Range of conflicting requirements	
P3	Depth of analysis required	✓
P4	Familiarity of issues	
P5	Extent of applicable codes	
P6	Extent of stakeholder involvement and needs	✓
P7	Interdependence	

11.2: Reasoning how the project address selected attribute (EP)

P1. Depth of knowledge required: The project requires prior knowledge of the different fields. Among them, the most important one is the floating system, the control mechanism. Here we need to learn buoyant force, how the solar system works, RC control of a motor.

P3. Depth of analysis required: To complete this project successfully, much analysis is required. For, as an illustration, we assessed the potential hazards associated with the project. We also have to calculate the risk of sinking our robot for this project. Also, we have to maintain the safety requirements. We had to ascend and provide strategies for dealing with them. Additionally, we had to research all relevant protocols, rules, and legislation for our endeavor. In order to make the project more efficient and sustainable, we also conducted an extensive analysis.

P6. Extent of stakeholder involvement and needs: The main purpose of our project is to build a robot that will collect floating trash from the water surface. We have shared some of our views with stakeholders regarding these aspects and collected some ideas from them. We had to understand their needs and consider the issues they were having. Thus, we were able to offer the ideal resolution.

11.3: Attribute of complex engineering activities (EA)

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	✓
A2	Level of interaction	✓
A3	Innovation	
A4	Consequences for society and the environment	✓
A5	Familiarity	

11.4: Reasoning how the project address selected attribute (EA)

A1. Range of resources: Our project strategy was built on the foundation of numerous study articles. There are several viewpoints on how this type of technology is used internationally. Next, we created a number of design tactics. We also looked into the cost of the equipment. Finally, we arrived at the project's ideal solution and efficient spending plan.

A2. Level of interaction: One of the most important things is getting the industry's judgment of our idea. As a result, we have had interactions with the project's stakeholders, authorities, and locals.

A4. Consequences for society and the environment: Less energy will likely be lost because our project will be powered by solar energy. Also, we will remove floating waste from the water's surface, therefore this initiative will assist keep the aquatic habitat clean.

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Appendix

The code we used for the prototype :

```
#include <LiquidCrystal.h>
#include <Servo.h>
#include <SoftwareSerial.h>
#include <Robojax_AllegroACS_Current_Sensor.h>

#define BATT_VOLT  0.0198
#define SOLAR_VOLT 0.0198

// Motor Driver Pins
const int motorPin1 = 6;
const int motorPin2 = 5;
const int motorPin3 = 4;
const int motorPin4 = 13;

// SoftwareSerial Pins for Bluetooth Module
const int bluetoothTX = 2;
const int bluetoothRX = 3;

// Servo Pins
Servo servo1;
Servo servo2;

// Analog Pins
const int solarVoltSense = A1;
const int solarAmpSense = A4;
const int batterySense = A2;
const int battAmpSense = A7;

// Last LCD update time
unsigned long lastUpdateTime = 0;

// Smooth movement parameters for servos
const int servoStepDelay = 10; // Delay in milliseconds between each step
const int servoStepSize = 1;   // Step size for smooth movement

// Define the SoftwareSerial object
SoftwareSerial bluetoothSerial(bluetoothRX, bluetoothTX); // RX, TX
// LCD Pins
LiquidCrystal lcd(12, 11, 10, 9, 8, 7);
// Current sensor
Robojax_AllegroACS_Current_Sensor sensor(2, solarAmpSense);  // 30A
Robojax_AllegroACS_Current_Sensor sensor2(0, battAmpSense);  // 5A

void setup() {
  lcd.begin(16, 2); // Initialize the LCD with 16 columns and 2 rows
  Serial.begin(9600); // Initialize hardware Serial for testing
  bluetoothSerial.begin(9600); // Initialize SoftwareSerial for Bluetooth communication
```

```
  pinMode(motorPin1, OUTPUT);
  pinMode(motorPin2, OUTPUT);
  pinMode(motorPin3, OUTPUT);
  pinMode(motorPin4, OUTPUT);
}

void loop() {
  // Read Bluetooth commands
  if (bluetoothSerial.available()) {
    char cmd = bluetoothSerial.read();
    processCommand(cmd);
  }

  // Read hardware serial commands (for testing)
  if (Serial.available()) {
    char cmd = Serial.read();
    processCommand(cmd);
  }

  // Update LCD every second
  if (millis() - lastUpdateTime >= 1000) {
    reportStatus();
    lastUpdateTime = millis();
  }
}

void motorControl(bool pin1State, bool pin2State, bool pin3State, bool pin4State) {
  digitalWrite(motorPin1, pin1State);
  digitalWrite(motorPin2, pin2State);
  digitalWrite(motorPin3, pin3State);
  digitalWrite(motorPin4, pin4State);
}

void smoothServoMove(int targetAngle1, int targetAngle2) {
  int currentAngle1 = servo1.read();
  int currentAngle2 = servo2.read();

  servo1.attach(A0); // Attach Servo1 to A0
  servo2.attach(A3); // Attach Servo2 to A3

  while (true) {
    if (currentAngle1 < targetAngle1) {
      currentAngle1 += servoStepSize;
      if (currentAngle1 > targetAngle1) currentAngle1 = targetAngle1;
    }
    else {
      currentAngle1 -= servoStepSize;
      if (currentAngle1 < targetAngle1) currentAngle1 = targetAngle1;
    }
    if (currentAngle2 < targetAngle2) {
      currentAngle2 += servoStepSize;
      if (currentAngle2 > targetAngle1) currentAngle2 = targetAngle2;
```

```
    }
    else {
      currentAngle2 -= servoStepSize;
      if (currentAngle2 < targetAngle2) currentAngle2 = targetAngle2;
    }
    servo1.write(currentAngle1);
    servo2.write(currentAngle2);
    delay(servoStepDelay);

    if (currentAngle1 == targetAngle1 && currentAngle2 == targetAngle2) break;
  }

  servo1.detach();
  servo2.detach();
}

void processCommand(char command) {
  if (command == 'F') {
    // Move forward
    motorControl(HIGH, LOW, HIGH, LOW);
  } else if (command == 'B') {
    // Move backward
    motorControl(LOW, HIGH, LOW, HIGH);
  } else if (command == 'L') {
    // Turn left
    motorControl(HIGH, LOW, LOW, LOW);
  } else if (command == 'R') {
    // Turn right
    motorControl(LOW, LOW, HIGH, LOW);
  } else if (command == 'S') {
    // Stop
    motorControl(LOW, LOW, LOW, LOW);
  } else if (command == 'O') {
    // Open servo smoothly
    smoothServoMove(1, 170);
  } else if (command == 'C') {
    // Close servo smoothly
    smoothServoMove(140, 50);
  }
}

void reportStatus() {
  float solarVoltage = analogRead(solarVoltSense) * SOLAR_VOLT;
  float solarCurrent = sensor.getCurrentAverage(200);
  float battCurrent = sensor2.getCurrentAverage(200);
  float batteryVoltage = analogRead(batterySense) * BATT_VOLT;

  String status = (String) "BAT: " + batteryVoltage + "V, ";
  status += (String) battCurrent + "A, ";
  status += (String) "PV: " + solarVoltage + "V, ";
  status += (String) solarCurrent + "A";
  bluetoothSerial.println(status);
```

```
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("PV: ");
  lcd.print(solarVoltage, 1);
  lcd.print("V ");
  lcd.print(solarCurrent, 1);
  lcd.print("A");

  lcd.setCursor(0, 1);
  lcd.print("BAT: ");
  lcd.print(batteryVoltage, 1);
  lcd.print("V ");
  lcd.print(battCurrent, 1);
  lcd.print("A");
}
```

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Project Title: Design of a Solar-Powered Miniature Water Surface Cleaning Robot.

Group: 09

Final Year Design Project (C) Summer 2023			
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Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
01.06.23 (**FYDP committee class 1**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat **Faculty member:** 1. Dr. Abu S. M. Mohsin	**1.** Discussion on what we need to accomplish in 400C and the 400C timeframe **2.** Highlighted the course outcome and Complex Engineering Problem attributes		
05.06.23 (**Group meeting 1**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeed 4. Rifat	**1.** Find relevant papers	**Task 1:** Everyone **Progress** **Task 1:** Partially completed	
07.06.23 (**Group meeting 2**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Discussion about budget	**Task 1:** Everyone **Progress** **Task 1:** Partially completed	
10.06.2023 (**ATC Meeting 1**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat **Faculty member:** 1. Prof. Dr. AKM Abdul Malek Azad 2. Prof. Dr. Touhidur Rahman	**1.** Collect partially all of the components **2.** Rewrite the gantt chart in tabular style **3.** Start writing the report and logbook	**Task 1:** Sanglap, Mazeedi. **Task 2:** Sanglap, Rifat. **Task 3:** Everyone **Progress** **Task 1:** Completed **Task 2:** Completed **Task 3:** Completed	**1.** Submit report and logbook one day before each meeting **2.** Collect the FYDP 400 C template

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12.06.23 (**Group meeting 3**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Started report writing **2.** Purchase nearly all of the components **3.** Rewrite the gantt chart in tabular style	**Task 1:** Everyone **Task 2:** Sanglap, Mazeedi **Task 3:** Sanglap, Rifat **Progress** **Task 1:** Completed **Task 2:** Completed **Task 3:** Completed	
14.06.23 (**Group meeting 4**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Started logbook **2.** Organize all of the prototype's components and start conducting tests **3.** Update report	**Task 1:** Sanglap, Sagor **Task 2:** Everyone **Task 3:** Everyone **Progress** **Task 1:** Completed **Task 2:** Completed **Task 3:** Completed	
17.06.23 (**ATC Meeting 2**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat **Faculty member:** 1. Prof. Dr. AKM Abdul Malek Azad 2. Prof. Dr. Touhidur Rahman 3. Mohammad Tushar Imran, Lecturer	**1.** Revise the project's budget **2.** Working on the subsystem such as the driving portion **3.** Include more in the project report	**Task 1:** Sanglap, Rifat. **Task 2:** Everyone **Task 3:** Everyone **Progress** **Task 1:** Completed **Task 2:** Completed **Task 3:** Completed	**1.** Put name and ID on a separate line **2.** Write ATC detail **3.** The designation of the ATC panel should be written **4.** Mention where the work was done in the report

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18.06.23 (**Group meeting 5**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.Report Editing** **(a)**Chapter1 1.Background study **(b)**Chapter1 1. Technical and Non-technical consideration and constraint in design process **(c)**Chapter1 1. Applicable compliance, standards and codes 2. Chapter 9 (Introduction) **(d)**Chapter 3 1. Software Tool Selection **(e)**Chapter 4 1. Identify optimal design approach	**Task 1:** **(a)** , **(e)** Sagor **(b)** Rifat **(c)** Sanglap **(d)** Mazeedi **Progress** **Task 1:** Completed	
19.06.23 (**Group meeting 6**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Check that all of the components are operational	**Task 1:** Everyone **Progress** **Task 1:** Completed	
20.06.23 (**Group meeting 7**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** The driving mechanism is being tested and recorded	**Task 1:** Everyone **Progress** **Task 1:** Completed	

22.06.23 (**Group meeting 8**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1. Report Writing** **(a)** Chapter 1 1. Introduction 2. Problem Statement 3. Literature Gap **(b)** Chapter 1 1. Conclusion Chapter 2 1. Introduction Chapter 3 1. Introduction 2. Conclusion **(c)**Chapter 4 1. Introduction 2. Chapter 7 Introduction 3. Conclusion **(d)** Chapter 9 1. Identify ethical issues and professional responsibility 2. Conclusion Chapter 8 1. Evaluate economic and financial aspects **2.** Updated logbook	**Task 1:** **(a)** Mazeedi **(b)** Rifat **(c)** Sanglap **(d)** Sagor **Task 2:** Mazeedi, Sanglap **Progress** **Task 1:** Completed **Task 2:** Completed	
24.06.23 (**ATC Meeting 3**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat **Faculty member:** 1. Prof. Dr. AKM Abdul Malek Azad 2. Mohammad Tushar Imran, Lecturer	**1.** Review of the logbook and provided suggestions about including some description of the report chapter in. **2.** Correct all word formats **3.** Revise budget	**Task 1:** Rifat, Sagor . **Task 2:** Mazeedi, Sanglap **Task 3:** Rifat **Progress** **Task 1:** Completed **Task 2:** Completed **Task 3:** Completed	**1.** Show the work on the prototype in the thesis lab to any ATC member **2.** Analyze the report's letter size and structure **3.** Correct the sentence structure

04.07.23 (**Group meeting 9**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.**Worked on hardware programming. **2.** Hardware test assembling all electrical components	**Task 1:** Sanglap **Task 2:** Everyone **Progress** **Task 1:** Partially completed **Task 2:** Partially completed	
05.07.23 (**Group meeting 10**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1. Report Writing** **(a)** Chapter 1 1. Rewrite Background Study 2. Objective **(b)** Chapter 2 1. Describe multiple design approach 2. Analysis of multiple design approach 3. Conclusion **(c)** Chapter 4 1. Optimization of multiple design approach **(d)** Chapter 8 1. Evaluate economic and financial aspects	**Task 1:** **(a)** Sagor **(b)** Mazeedi **(c)** Rifat **(d)** Sanglap **Progress** **Task 1:** Completed	
06.07.23 (**Group meeting 11**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Hardware test assembling all electrical components. **2.** Updated logbook	**Task 1:** Everyone **Task 2:** Mazeedi, Sagor **Progress** **Task 1:** Partially completed **Task 2:** Completed	
08.07.23 (**Group meeting 12**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** In the thesis lab, we checked the driving mechanism and recorded a video	**Task 1:** Everyone **Progress** **Task 1:** Completed	

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08.07.23 **(ATC Meeting 4)** Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat **Faculty member:** 1. Prof. Dr. AKM Abdul Malek Azad	**1.** Suggested to update the slide **2.** Update the report	**Task 1:** Rifat, Mazeedi **Task 2:** Everyone **Progress** **Task 1:** Completed **Task 2:** Completed	**1.** Chapter 5 and 6 must write something **2.** References should be corrected **3.** Add pictures on chapter 5 **4.** Add bullet points on design approach 1,2,3 **5.** Add table of content **6.** Chapter 1 need to write **7.** Keyword should be included
10.07.23 (**Group meeting 13**) Offline	**Students:** 1.Sagor 2.Sanglap 3.Mazeedi 4.Rifat **Faculty member:** 1. Mohammad Tushar Imran, Lecturer	**1.** Demonstrate the electrical sub system in front of the ATC member	**Task 1:** Everyone **Progress** **Task 1:** Completed	**1.** A 3D model of the final prototype is asked to be placed on the slide **2.** All the components are need to be shown in one slide
12.07.23 (**Group meeting 14**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Updated the progress presentation slide	**Task 1:** Mazeedi, Rifat **Progress** **Task 1:** Completed	

13.07.23 **(Progress presentation)** Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat **Faculty member:** 1.FYDP Committee members	**1.** Suggested to focus more on the hardware part of the design		**1.** Driving a motor in water is very tough so it has to be well calculated **2.** Many other things may need to be changed while working on the hardware part
14.07.23 (**Group meeting 15**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1. Report Writing** **(a)** Table of content **(b)** Chapter 11 1.Attribute of complex engineering problem (EP) 2. Reasoning how the project address selected attribute (EP) 3. Attribute of complex engineering activities (EA) 4. Reasoning how the project address selected attribute (EA) **(c)** Chapter 9 1.Introduction 2. Identify Ethical Issues and Professional Responsibility 3. Conclusion **(d)** Chapter 6 1. Introduction 2. Assess the impact of solution 3. Evaluate the sustainability 4. Conclusion **(e)** Chapter 1	**Task 1:** **(a),(f)** Mazeedi **(b),(h)** Rifat **(c),(d)** Sagor **(e),(g)** Sanglap **Task 2:** Mazeedi, Sanglap **Progress** **Task 1:** Completed **Task 2:** Completed	

		1. Systematic Overview/summary of the Proposed Project **(f)** Chapter 3 1. Select Appropriate Engineering and IT Tools **(g)** Chapter 5 1. Introduction 2. Completion of final design **(h)**Project Summary/Conclusion **2.** Updated logbook		
15.07.23 **(ATC Meeting 5)** Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat **Faculty member:** 1. Prof. Dr. AKM Abdul Malek Azad	**1.** Gantt chart has to be written in the correct way **2.** Table of figure & table need to be added **3.** Literature Gap(1.1.3) and Relevance to Current and Future Industry(1.1.4) need add reference **4.** Future work needs to be added	**Task 1:** Sanglap **Task 2:** Mazeedi **Task 3:** Sagor **Task 4:** Rifat **Progress** **Task 1:** Completed **Task 2:** Completed **Task 3:** Completed **Task 4:** Completed	**1.** Only one SWOT analysis has to be there **2.** Insist to work for prototype **3.** Keywords need to be changed accordingly **4.** Add dimension of the robot **5.** Format needs to be corrected

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23.07.23 (**Group meeting 16**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1. Report Writing** **(a)** Chapter 4 1. Performance evaluation of developed solution 2. Conclusion **(b)** Chapter 2 1. Conclusion **(c)** Chapter 7 1. Evaluate project progress 2. Gantt Chart has been corrected **(d)** Chapter 10 1. Future work	**Task 1:** **(a)** Mazeedi **(b)** Rifat **(c)** Sanglap **(d)** Sagor **Progress** **Task 1:** Completed	
24.07.23 (**Group meeting 17**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	1. Purchasing pvc sheet, pvc pipe, and solar cell	**Task 1:** Everyone **Progress** **Task 1:** Completed	

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27.07.23 (**Group meeting 18**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1. Report Writing** **(a)** Add table of figure and table **(b)** Chapter1 1. Update introduction 2. Add reference to 1.1.3 and 1.1.4 3. Update specification **(c)** Chapter 9.3 1. Apply ethical issues and professional responsibility **(d)** Chapter 8 1. Evaluate economic and financial aspects **2.** Update logbook	**Task 1:** **(a)** Sanglap **(b)** Sagor **(c)** Mazeedi **(d)** Rifat **Task 2:** Everyone **Progress** **Task 1:** Completed **Task 2:** Completed	
30.07.23 (**Group meeting 19**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Collect all components for structure **2.** Strat building structure of boat	**Task 1:** Everyone **Task 2:** Everyone **Progress** **Task 1:** Completed **Task 2:** Partially completed	
02.08.23 (**Group meeting 20**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Working on structure	**Task 1:** Everyone **Progress** **Task 1:** Partially completed	

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03.08.23 (**Group meeting 21**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1. Report Writing** **(a)** Add Solar panel data in Chapter 5 **(b)** Updated Chapter 5.2 **2.** Updated logbook	**Task 1:** **(a)** Sagor, Mazeedi **(b)** Sanglap, Rifat **Task 2:** Sagor, Mazeedi **Progress** **Task 1:** Partially completed **Task 2:** Completed	
05.08.23 **(ATC Meeting 6)** Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat **Faculty member:** 1. Prof. Dr. AKM Abdul Malek Azad	**1.** Corrections on page number 12,15,22,31,71-73,93 **2.** Correct reference numbering **3.** Connections on Keywords and Abstracts **4.** Add reference in introduction	**Task 1:** Sanglap **Task 2:** Mazeedi, Rifat **Task 3:** Sagor **Task 4:** Mazeedi **Task 5:** Rifat **Progress** **Task 1:** Completed **Task 2:** Completed **Task 3:** Completed **Task 4:** Completed **Task 5:** Completed	**1.** Prototype must be completed by next week **2.** Punctuation error needs to be corrected **3.** Poster must have to be completed by next week **4.** Take picture from all angle **5.** Take poster details from FYDP committee **6.** Table of content has to be written in the correct way
06.08.23 (**Group meeting 22**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1. Report Writing** **(a)** Chapter 5 **1.** Completion of final design **(b)** Chapter 8 **1.** Evaluate economic and financial aspects **2.** Budget analysis **(c)** Add figure and table number	**Task 1:** **(a)** Sagor, Mazeedi **(b)** Sanglap, Rifat **(c)** Mazeedi **Progress** **Task 1:** **(a)** Partially completed **(b)** Completed **(c)** Partially completed	

09.08.23 **(Group meeting 23)** Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Working on Hardware setup	**Task 1:** Everyone **Progress** **Task 1:** Partially completed	
09.08.23 **(Group meeting 24)** Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Prepare the draft poster **2.** Collect poster details from FYDP committee	**Task 1:** Everyone **Task 2:** Rifat **Progress** **Task 1:** Completed **Task 2:** Completed	
10.08.23 **(Group meeting 25)** Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Working on Hardware setup **2.** Update logbook	**Task 1:** Everyone **Task 2:** Sagor, Mazeedi **Progress** **Task 1:** Completed **Task 2:** Completed	
12.08.23 **(ATC Meeting 7)** Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat **Faculty member:** 1. Prof. Dr. AKM Abdul Malek Azad	**1.** Reviewed the logbook and provided suggestions about correcting some errors. **2.** Asked to update poster content	**Task 1:** Everyone **Task 2:** Everyone **Progress** **Task 1:** Completed **Task 2:** Completed	**1.** Alignment of table of content should be corrected **2.** Make video representation for the project showcase day **3.** Collect data for the result analysis **4.** Poster should look attractive

FYDP (C) Summer 2023 Summary of Team Log Book/ Journal

15.08.23 (**Group meeting 26**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Discussion on the type of data that we will collect. **2.** Correction on the suggestion given in ATC meeting 7	**Task 1:** Everyone **Task 2:** Everyone **Progress** **Task 1:** Completed **Task 2:** Completed	
18.08.23 (**Group meeting 27**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Testing the prototype collecting trashes from different distance **2.** Take realtime data from the prototype that we have planned in group meeting 26 **3.** Took videos of prototype testing	**Task 1:** Everyone **Task 2:** Everyone **Task 3:** Everyone **Progress** **Task 1:** Completed **Task 2:** Partially completed **Task 3:** Completed	
19.08.23 (**Group meeting 28**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1. Report Writing** **(a)** Chapter 5 **1.** Observation of battery voltage, PV voltage and current and PV power supply **2.** Observation of battery voltage, PV voltage and current and PV power supply for every minute data for one hour **2.** Updated poster **3.** Updated logbook	**Task 1:** **(a)** Mazeedi,Sanglap **Task 2:** Everyone **Task 3:** Everyone **Progress** **Task 1:** Completed **Task 2:** Completed	
20.08.23 (**Group meeting 29**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Working on a current sensor for calculating power using battery current data and fixing some issues in arduino nano **2.** Updated logbook	**Task 1:** Everyone **Task 2:** Everyone **Progress** **Task 1:** Partially completed **Task 2:** Completed	

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21.08.23 **(ATC Meeting 8)** Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat **Faculty member:** 1. Prof. Dr. AKM Abdul Malek Azad 2. Prof. Dr. Touhidur Rahman 3. Mohammad Tushar Imran, Lecturer	**1.** Add large picture of prototype **2.** Add swot analysis	**Task 1:** Everyone **Task 2:** Everyone **Progress** **Task 1:** Completed **Task 2:** Completed	
22.08.23 (**Group meeting 30**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Working on poster	**Task 1:** Everyone **Progress** **Task 1:** Completed	
24.08.23 (**Group meeting 31**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Print final poster	**Task 1:** Everyone **Progress** **Task 1:** Completed	
25.08.23 (**Group meeting 32**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Color the prototype and recheck all of the connection of prototype	**Task 1:** Everyone **Progress** **Task 1:** Completed	

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26.08.23 (**FYDP project showcase**) Offline	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat			**1.** Real life implication need some extra features **2.** Ask about production cost and how much time to make
28.08.23 (**Group meeting 33**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Working on report	**Task 1:** Everyone **Progress** **Task 1:** Completed	
30.08.23 (**Group meeting 34**) Online	**Students:** 1. Sagor 2. Sanglap 3. Mazeedi 4. Rifat	**1.** Complete the final draft report **2.** Update logbook	**Task 1:** Everyone **Task 2:** Everyone **Progress** **Task 1:** Completed **Task 2:** Completed	