A

Industrial Oriented Mini Project Report

on

"SOLAR POWERED CLEANING ROBOT"

Submitted to

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY

in partial fulfillment of the requirement for the award of degree

of

BACHELOR OF TECHNOLOGY

in

ELECTRICAL AND ELECTRONICS ENGINEERING

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JYOTHISHMATHI INSTITUTE OF TECHNOLOGY AND SCIENCE

(AUTONOMOUS)

(Approved by AICTE, New Delhi, Affiliated to JNTU, Hyderabad)

Nustulapur, Karimnagar, Telangana-505527

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

CERTIFICATE

This is to certify that the industrial-oriented mini project entitled **"SOLAR POWERED CLEANING ROBOT"** is submitted by **N. Anila (22275A0217)**, **MD. Ameer Khan (22275A0210)**, **B. Madhu (22275A0214)**, and **SD. Feroz (22275A0212)** to the Jyothishmathi Institute of Technology and Science in partial fulfillment of the requirements for the award of the degree Bachelor of Technology, during the academic years 2021–2025 is a bonafide record work carried out by us.

The result embedded in this report as not been submitted to any other University or Institute for the award of any degree.

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DECLARATION

We declare that the work which is being presented in this **Industrial Oriented Mini Project** entitled as **"SOLAR POWERED CLEANING ROBOT"** submitted towards the partial fulfilment of the requirements for the award of the degree of **Bachelor of Technology in Electrical and Electronics Engineering,** is an authentic record of our own work carried out under the supervision of **CH. SAJAN RAO,** Associate Professor, Department of Electrical and Electronics Engineering, Karimnagar.

To the best of our knowledge and belief, this project bears no resemblance with any report submitted to Jawaharlal Nehru Technological University, Hyderabad or any other university for the award of any degree or diploma.

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ABSTRACT

The solar-powered Panel cleaning robot project aims to develop an autonomous cleaning device that utilizes solar energy to enhance efficiency and sustainability in maintaining floor, solar panel cleanliness. The primary purpose of this robot is to minimize human intervention in routine floor, solar panel cleaning tasks while promoting environmentally friendly practices through the use of renewable energy sources. The robot is equipped with a dual cleaning mechanism, combining both sweeping and mopping functions to tackle different types of debris and stains. Furthermore the intuitive interface facilitates user control and programming, allowing users to set cleaning schedules according to their needs. The significance of utilizing solar power for the operation of this cleaning robot cannot be overstated. By harnessing solar energy, the robot reduces reliance on conventional electricity sources, thereby lowering operational costs and minimizing the carbon footprint associated with cleaning activities. This innovative approach not only aligns with the growing demand for sustainable technologies but also encourages users to adopt greener practices in their daily lives. The integration of solar panels into the robot's design ensures that it can recharge autonomously, making it capable of extended cleaning sessions without the need for frequent human intervention. Overall this project represents a significant step towards creating intelligent, eco-friendly solutions for everyday cleaning tasks.

INDEX

LIST OF FIGURES

LIST OF TABLES

CHAPTER-1
INTRODUCTION

1.1 Background

Solar-based energy has been gaining significant attention worldwide due to its cost-effectiveness and environmental benefits. As a renewable energy source, solar power is increasingly favored for its sustainability and ability to reduce carbon footprints compared to conventional energy methods like coal, oil, and natural gas. One of the major advantages of solar energy is that the prices of solar panels have drastically decreased in recent years, making it a more affordable option for homeowners, businesses, and governments. Additionally, solar energy does not produce harmful pollutants or greenhouse gases, further emphasizing its environmental benefits.

Solar systems generally consist of four essential components: solar panels, batteries, a charge controller unit, and a load (the device or system being powered by the solar energy). Solar panels, typically made of photovoltaic (PV) cells, convert sunlight into electricity through the photovoltaic effect. The electricity generated is stored in batteries for later use, and the charge controller ensures that the batteries are charged safely, while the load represents the electrical appliances or systems that the solar energy powers.

However, soiling, the accumulation of dirt, dust, and other particulate matter, is a significant challenge to the efficiency of solar energy systems. In regions with high levels of dust or pollution, such as deserts or urban areas with heavy traffic, solar panels can become dirty quickly, leading to a build-up of residue and dirt particles on their surface. This deposition obstructs sunlight from reaching the solar cells, effectively reducing the amount of energy that can be converted into electricity. As a result, efficiency of the solar panels declines, and the energy output becomes significantly lower than expected. If left unaddressed, the accumulation of dirt can lead to a long-term decrease in the power generation capacity of the solar panels.

The impact of soiling becomes especially noticeable in solar PV systems used in arid regions, where dust accumulation can happen more rapidly. Solar panels rely on direct sunlight irradiation, which must reach the surface of the panel to generate electricity. When dirt or dust energy available for conversion. Moreover, if debris or a residue film forms a thick layer on the surface, cleaning becomes much more difficult, leading to an even further drop in efficiency.

In order to ensure optimal performance, solar systems need to be regularly cleaned, which can sometimes be a time-consuming and costly task. Traditional cleaning methods, such as brushing with brooms or using water, are labor-intensive and require substantial resources. However, in areas with water scarcity, such as deserts, using water for cleaning is not only inefficient but also unsustainable. Moreover, manual cleaning is difficult and dangerous in harsh weather conditions, such as extreme heat or wind, and can become costly due to the need for specialized labor and transportation. Worker wages and the availability of skilled labor can fluctuate, adding another layer of uncertainty to the maintenance of solar systems.

To address these challenges, automated cleaning technologies are being explored as more effective and sustainable solutions. One promising approach is the use of robotics for solar panel cleaning. Automated systems could reduce the labor and resource costs associated with traditional cleaning methods. Yet, this solution is not without its challenges, such as the need for a stable power source for the robots and the potential for mechanical wear and tear.

This system does not require any consumables, such as water or brushes, nor does it rely on mechanical components that could wear out over time. Instead, it utilizes electrostatic waves to remove dust and dirt from the surface of solar panels, ensuring that they remain clean without causing damage to the panels themselves. This technology is still in development, but it holds the potential to keep solar panels free from dirt throughout their operating hours, maintaining maximum reflectivity and power generation without the need for human intervention.

The goal of these innovative technologies is to create an automated cleaning system that is not only more efficient but also cost-effective and environmentally friendly. Additionally, there is a growing trend to integrate smart monitoring systems with solar panel cleaning technologies. For example, an integrated mobile application could allow operators to monitor both the performance of the solar panels and the status of the cleaning process in real-time.

In conclusion, developing an automated cleaning system for solar-based collectors is crucial in addressing the problem of dirt and soiling, which significantly hampers energy production.

By reducing the need for manual intervention and minimizing the impact of environmental factors, such as dust and pollution, these innovative cleaning solutions could revolutionize the maintenance of solar energy systems, making them more reliable and efficient in the long term.

1.2 Problem Statement

There is more than enough solar radiation available around the world to satisfy the demand for solar power systems. The proportion of the sun's rays that reach the Earth's surface is enough to provide for global energy consumption 10,000 times over. On average, each square meter of land is exposed to enough sunlight to produce 1,700 kWh of power every year. Solar panels have a huge impact on our world. They can help improve the environment by reducing the need for power generation plants that harm the ecosystem. However, solar power plants require cleaning at least every three days to maintain their efficiency. The cleaning frequency generally depends on the country; for example, in the Middle East, it needs to be cleaned every day, which can be quite costly. There are various techniques for cleaning solar panels, but our idea is to design a smart solar powered robot that cleans itself automatically and remotely, ensuring a high level of efficiency without the need for frequent manual intervention.

1.3 Objectives

Following are the objectives of this project:

- To design a solar panel cleaning robot.
- To design a solar panel cleaning system that can increase the efficiency of solar panels.
- To increase the use of solar panels.
- To clean solar panels simply by using automation.
- Integrate smart features like scheduling, remote control via apps, and AI for adaptive cleaning based on floor condition.
- To minimize hazards to humans.
- Autonomous operation.
- Environmental sustainability.
- Compact and portable design.

1.4 Scope and Limitations

The scope of a solar panel cleaning robot is vast and holds significant potential for improving the efficiency and sustainability of solar power systems. As solar energy continues to grow in popularity as a clean and renewable energy source, ensuring the optimal performance of solar panels is crucial. Dust, dirt, and other residue can accumulate on the panels, reducing their efficiency by blocking sunlight. In regions with high levels of dust or pollution, this issue is even more pronounced, requiring frequent cleaning. A solar panel cleaning robot offers a practical solution by automating the cleaning process, reducing the reliance on manual labor, water, and other resources. This technology can be especially beneficial in remote or harsh environments, where traditional cleaning methods may be difficult or costly. The robot can be designed to work autonomously, utilizing advanced sensors and algorithms to detect dirt accumulation and clean the panels effectively without causing damage. By minimizing cleaning frequency, it reduces operational costs while ensuring consistent energy production from solar panels. Furthermore, this automation eliminates the potential for human injury in dangerous working conditions, such as high-altitude cleaning on large solar farms. The scope of this innovation extends to both residential and industrial applications, contributing to the broader adoption of solar energy by ensuring the long-term efficiency and sustainability of solar power systems.

Project Specification

- The solar panel cleaning system operates automatically and remotely.
- Increase the efficiency by at least 10%.

Limitations

There are some limitations of the project which are listed below:

1) These include high initial costs.
2) Challenges with maintenance and adaptability.

1.5 Project Justification

The Solar Power Panel Cleaning Robot project is justified by the growing need for efficient, cost-effective, and sustainable maintenance solutions for solar energy systems. As solar panels accumulate dirt, dust, and other debris, their energy output can drop significantly, leading to reduced efficiency and financial return Manual cleaning methods are labor-intensive, expensive, and environmentally taxing, particularly in areas facing water scarcity. A solar cleaning robot automates the cleaning process, saving on labor costs, minimizing water usage, and providing a more sustainable alternative to chemical cleaners. By maintaining optimal panel performance and reducing downtime, the robot helps increase energy production, extend the lifespan of solar installations, and lower maintenance costs. Furthermore, the scalability and automation of robotic systems make them ideal for both residential and large-scale solar farms, aligning with the growing trend toward more efficient, automated solutions in the renewable energy sector.

CHAPTER-2
COMPONENTS DISCRIPTION

2.1 Components Required

The Solar-Powered Panel Cleaning Robot has the following components:

1) Node MCU

2) L298N Motor Driver Module

3) DC Geared Motors

4) Solar panel

5) Wiper Motors

6) Jumper Wires

7) Li-ion Batteries

8) Wiper Motor

9) Soldering Kit

2.2 Node MCU (ESP8266)

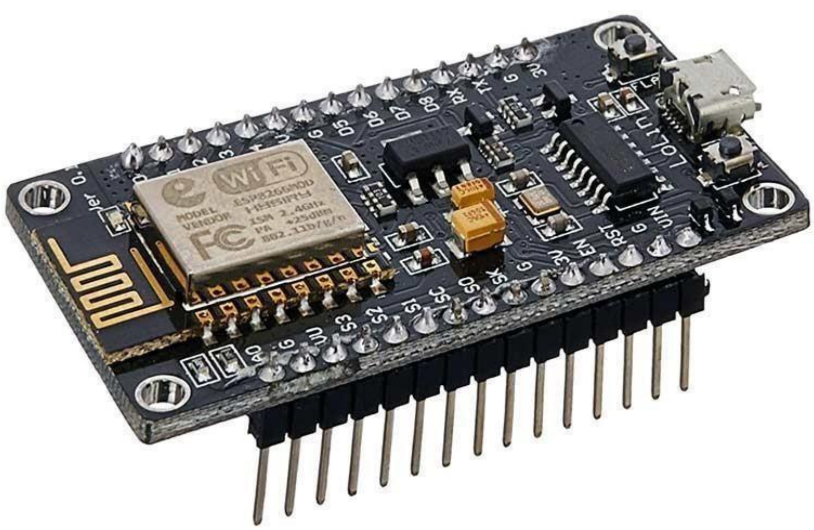


Figure 2.1: Node MCU (ESP8266)

2.2.1 Node MCU ESP (8266) Pin out

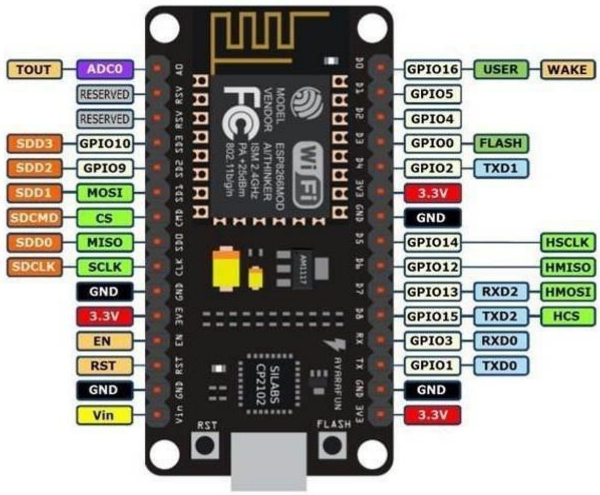


Figure 2.2.1Node MCU ESP (8266) Pin out

Node MCU is an open-source Lua-based firmware and development board specially targeted for IoT-based applications. It includes firmware that runs on the ESP8266 Wi-Fi System on Chip (SoC) provided by Espressif Systems and hardware based on the ESP-12 module.

Table.1: Node MCU Development Board Pinout Configuration

Pin Category	Name	Description
Power	Micro-USB,3.3V,GND,Vin	**Micro-USB :**Node MCU can Be powered through the USB port **3.3V:**Regulated3.3Vcanbe supplied to this pin to power the board **GND:** Ground pins **Vin:** External Power Supply
Control Pins	EN,RST	The pin and the button reset the microcontroller.

Analog Pin	A0	Used to measure analog Voltage in the range of 0-3.3V.b
GPIO Pins	GPIO 1 to GPIO 16	Node MCU has 16 general Purpose input-output pins on its board.
SPI Pins	SD1,CMD,SD0,CLK	Node MCU has four pins available for SPI Communication.
UART Pins	TXD0,RXD0,TXD2,RXD2	Node MCU has two UART interfaces,UART0(RXD0& TXD0)andUART1(RXD1& TXD1).UART1 is used to upload the Firm ware/ program.
I2C Pins		Node MCU has I2C functionality support but due to the internal functionality of these pins, you have to find which pin is I2C.

Node MCU ESP8266 Specifications & Features

- Microcontroller: Tensilica 32-bit RISC CPU Xtensa LX106
- Operating Voltage: 3.3V
- Input Voltage: 7-12V
- Digital I/O Pins (DIO): 16
- Analog Input Pins (ADC): 1
- UARTs: 1

- SPIs: 1
- I2Cs: 1
- Flash Memory: 4 MB
- SRAM: 64 KB
- Clock Speed: 80 MHz
- USB-TTL: Based on CP2102, enabling Plug and Play
- PCB Antenna
- Small-Sized Module: Fits smartly inside your IoT projects

Brief Data About Node MCU ESP (8266)

The Node MCU ESP8266 development board comes with the ESP-12E module containing the ESP8266 chip, which is powered by the Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at an adjustable clock frequency of 80MHz to 160 MHz. The Node MCU features 128 KB RAM and 4MB Flash memory to store data and programs. Its high processing power, combined with built-in Wi-Fi/Bluetooth and deep sleep operating features, makes it ideal for IoT projects.Node MCU can be powered via the Micro USB jack or the VIN pin (external supply pin).
It supportsUART, SPI,and I2C interfaces.

Programming Node MCU ESP(8266) with Arduino IDE:

The Node MCU Development Board can be easily programmed with the Arduino IDE, making it a convenient and accessible platform for developers. Programming the Node MCU using Arduino IDE typically takes just 5-10 minutes. All you need is the Arduino IDE, a USB cable, and the Node MCU board itself. For more detailed guidance, you can refer to the Getting Started Tutorial for Node MCU to set up the Arduino IDE for the Node MCU.

Uploading Your First Program
Once you have installed the Arduino IDE on your computer, follow these steps to upload a program to the Node MCU board:

1. Connect the board to the computer using the USB cable.

2. Open the Arduino IDE and select the correct board:
    - Go to Tools > Boards > Node MCU 1.0 (ESP-12E Module).
3. Select the correct Port by navigating to Tools > Port.
4. To get started with the Node MCU board, load the Blink example code:
    - Go to File > Examples > Basics > Blink.
5. Once the example code is loaded, click on the Upload button located at the top of the IDE window.
6. After the upload is complete, you should see the built-in LED of the board blinking.

Applications of Node MCU

Node MCU has a wide range of applications, especially in the fields of IoT and network projects:

- Prototyping IoT Devices: Ideal for quickly building Internet of Things (IoT) prototypes.
- Low Power Battery Operated Applications: Suitable for projects that require low energy consumption and battery operation.
- Network Projects: Great for creating network-related devices due to its Wi-Fi capabilities.
- Projects Requiring Multiple I/O Interfaces with Wi-Fi and Bluetooth Functionalities: Node MCU is versatile for complex projects requiring multiple inputs/outputs, as well as wireless communication like Wi-Fi and Bluetooth.

2.3 L298N Motor Driver Module

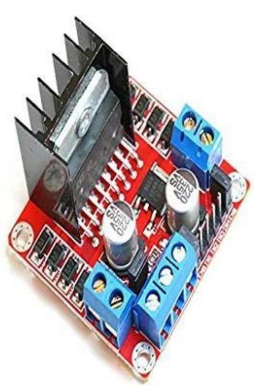


Figure 2.3: L298N Motor Driver Module

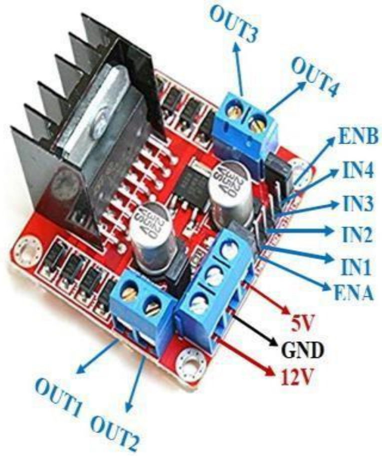


Figure 2.3.1 L298N Motor Driver Module Pinout

This **L298N Motor Driver Module** is a high power motor driver module for driving DC and Stepper Motors. This module consists of an L298 motor driver IC and a 78M05 5V regulator. **L298NModule** can control up to 4 DC motors, or 2 DC motors with directional and speed control**.**

Table.2: L298N Module Pinout Configuration

Pin Name	**Description**
IN1 &IN2	Motor A input pins. Used to control the spinning direction of Motor A
IN3 &IN4	Motor B input pins. Used to control the spinning direction of Motor B
ENA	Enables PWM signal for Motor A
ENB	Enables PWM signal for Motor B
OUT1 &OUT2	Output pins of Motor A
OUT3 &OUT4	Output pins of Motor B
12V	12V input from DC power Source

5V	Supplies power for the switching logic circuitry inside L298N IC
GND	Ground pin

L298N Module Features & Specification

1 Dual H-Bridge Driver
2 Output Current**:** Continuous Current 2A Per Channel
3 Driver Model: L298N2A
4 Driver Chip : Double H Bridge L298N
5 Motor Supply Voltage(Maximum): 46V
6 Motor Supply Current(Maximum): 2A
7 Logic Voltage: 5V
8 Driver Voltage: 5-35V
9 Driver Current: 2A
10 Logical Current: 0-36mA
11 Maximum Power(W): 25W
12 Current Sense for each motor
13 Heat sink for better performance
14 Power-On LED indicator

Applications of L298N Module

1 Drive DC motors.
2 Drive stepping motors
3 In Robotics

2.4 DC Geared Motors

A DC motor is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields.

Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current flow in part of the motor.

Figure 2.4 DC Geared Motor

DC motors were the first form of motor widely used, as they could be powered from existing direct-current lighting power distribution systems. Speed of DC motor can be controlled over a wide range using either a variable supply voltage or by changing the strength of current in field windings. Small DC motors are used in tools, toys, and appliances.

The universal motor can operate on direct current but is a light weight brushed motor used for portable power tools and appliances.

Larger DC motors are currently used in propulsion of electric vehicles elevator and hoists and in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with AC motors possible in many applications.

2.5 Solar Panel

Solar panels are devices that convert light into electricity. They are called "solar" panels because the most powerful source of light available is the sun. A solar panel is a packaged, connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system generate and supply electricity in commercial and residential applications. There are various types of panels are available like mono crystalline, polycrystalline, amorphous, and hybrid.Solar panel is placed at the top and connected to a load directly. The load may a led or a voltmeter which could be connected to get the exact voltage which depends on the intensity of light falling on the panel and the position of the tracker.

Concentrated solar photovoltaic and have optics that directly accept sunlight, so solar trackers must be angled correctly to collect energy. All concentrated solar systems have trackers because the systems do not produce energy unless directed correctly toward the sun. The solar panel is just a mere device to accept the light radiation which is purely controlled by LDR sensors and the load connected depends upon the rating of the panel used.

Key Benefits of Solar Panel:

1 Environmentally Friendly

2 Energy Independence

3 Low Maintenance

Figure 2.5 Solar Panel

Figure 2.5.1 Advanced Solar Panel

2.6 Jumper Wires

Jumper wires are simple wires that have connector pins at each end, allowing them to be used to connect two points with each other without soldering. Jumper wires are typically used with breadboards and other prototyping tools in order to make it easy to change a circuit as needed. Jumper wires typically come in three versions: male-to-male, male-to-female and female-to-female. The difference between each is in the end point of the wire. Male ends have a pin protruding and can plug into things, while female ends do not and are used to plug things into. Male-to-male jumper wires are the most common and what you likely will use the most often.When connecting two ports on a breadboard, a male-to-male wire is what you will need.

Key Benefits of Jumper Wires

- Non-Permanent Connections
- Cost-Effective

Figure 2.6 Jumper Wires

2.7 Lithium-Ion Batteries

18650 Lithium-Ion Batteries

The 18650 lithium-ion battery has several advantages, including light weight, large capacity, and no memory effect, which have made it widely popular. Many digital devices use lithium-ion batteries as their power source, despite their relatively higher price. Lithium-ion batteries offer high energy density, with their capacity being 1.5 to 2 times greater than that of a nickel-hydrogen battery of the same weight. They also have a very low self-discharge rate.

Additionally, lithium-ion batteries are more environmentally friendly compared to many older battery technologies. They do not contain highly toxic substances like cadmium or lead, which are harmful to both human health and the environment. This feature reduces the risk of contamination during disposal and recycling.

Lithium batteries are generally marked as 4.2V lithium batteries or 4.2V lithium secondary batteries, indicating that they are rechargeable. The voltage of lithium-ion batteries typically refers to 3.7V (the platform voltage), which is the typical voltage discharged during battery use. However, 4.2V refers to the voltage when the battery is fully charged. These two values are often used interchangeably, as the difference is mostly due to the manufacturer's labeling.

The common voltage of rechargeable 18650 lithium-ion batteries is 3.6V or 3.7V during use, and when fully charged, it reaches 4.2V. This difference in voltage has little to do with the power (capacity) of the battery. The mainstream capacity of 18650 batteries ranges from 1800mAh to2600mAh, with most 18650 power batteries having capacities between 2200mAh and 2600mAh.

Figure 2.7 Lithium-Ion Batteries

2.8 Wiper Motor

Windscreen wiper motor brushes play a very important role in the construction of wiper motors. The motors used in windscreen wipers are also known as Ferrite magnet type motors, as permanent magnets are used in them. These motors contain gears to control the speed of the wiper, as well as three brushes that are used based on the speed of the wiper and the motor itself.

These three brushes include a high-speed brush, a low-speed brush, and a common brush for the ground. The gear section of the wiper motor also contains a cam switch that ensures the wiper stops at the same position each time.

Figure 2.8 Wiper Motor

The armature coils in the wiper motor generate a counter-electromotive force when it is turned to control the speed of rotation of the motor.

When low-speed brush from the three Windscreen wiper motor brushes provides current into the armature coils then they generate a large counter electromotive force to slow down the speed of rotation of the wiper motor.

2.9 Soldering Kit

A Soldering Kit is a comprehensive set of tools and accessories designed for the process of soldering, which is used to join metal components by melting and fusing solder around the connection. This process is crucial in a wide range of applications, particularly in electronics, where it's used to attach components to circuit boards or repair electrical connections. In addition to electronics, soldering is used in plumbing, jewelry-making, and even crafting intricate metalwork. A standard soldering kit typically includes a soldering iron or station, solder wire, flux, and additional accessories like a stand, desoldering pump, and cleaning sponge. Advanced kits may also feature adjustable temperature settings and specialized tips for precise work.

At the heart of a soldering kit is the soldering iron, which is the main tool used for heating and melting the solder. The soldering iron has a metal tip that gets very hot when powered on, allowing it to melt solder wire, making the bond between two metals. The tip comes in various shapes and sizes for different soldering tasks, such as fine tips for precision work and wider tips for larger connections.

The kit typically includes solder wire, which is used to make the actual joint. This wire is often made from a combination of tin and lead, although lead-free options are becoming more common due to environmental and health concerns. The solder wire usually contains a flux core, which helps clean the surfaces of the metals being soldered and ensures the solder flows smoothly.

Desoldering tools are also included in many soldering kits. These tools are essential for removing excess solder or correcting mistakes. A desoldering pump creates a vacuum to suck up molten solder, while desoldering braid (or solder wick) is a braided copper wire that absorbs excess solder when heated. These tools ensure clean, precise work, especially when dealing with intricate circuits.

A soldering iron stand is a necessary accessory for safety. It allows the soldering iron to be securely placed when not in use, preventing accidental burns or damage to surfaces. The stand typically includes a cleaning sponge or pad, which is used to wipe the soldering iron tip clean of any oxidized solder or debris that could hinder performance.

In addition to these core tools, a soldering kit may include tweezers for handling small components, ensuring precise placement during soldering. Flux, a chemical cleaning agent, is often included in the kit to further clean and prepare surfaces for soldering. It helps to remove oxidation and improve the flow of solder, ensuring a stronger and more reliable electrical connection.

For safety purposes, a soldering kit usually includes protective gear, such as safety glasses to protect the eyes from solder splashes or fumes. Additionally, a heat-resistant mat is often provided to protect the work surface from the heat of the soldering iron, and wire cutters are included for trimming excess wires or leads after the soldering process is complete.

Soldering kits are widely used in various industries, particularly in electronics assembly, where they are used to assemble circuit boards and repair damaged electrical components. They are also indispensable in DIY projects, where hobbyists and engineers use them for building custom devices.

A soldering kit is an essential toolkit designed for the process of soldering, which involves joining metal components by melting and fusing solder—a metal alloy—around the connection point.

Fixing gadgets, or experimenting with new electronic designs. Whether for prototyping circuits or repairing broken devices, a soldering kit is an essential tool for anyone working with electrical connections.

Figure 2.9 Soldering Kit

Advantages of Soldering Kit

- Versatile Applications
- Cost-Effective Solution
- Enhances Reliability
- Customization of Electronics

Specifications of Soldering Kit

- Power Rating**:** Usually ranges from 20W to 60W (higher wattage heats up faster and maintains temperature better).
- Material**:** Typically made of tin (Sn) and lead (Pb) in ratios like 60/40 or lead-free solder with metal alloy

2.10 Switches

An electrical switch is a device used to control the flow of electricity in a circuit. It works by either opening or closing the circuit, allowing or preventing the flow of electric current. When the switch is in the "ON" position, the circuit is closed, and electricity can flow through the circuit, powering devices like lights, fans, and appliances. In the "OFF" position, the switch opens the circuit, stopping the flow of electricity and turning off the device.

Switches come in various types and designs, but their primary function is consistent: to control the electric current in a circuit. The simplest form of a switch is a mechanical device that moves between two states—open or closed—using a lever, button, or toggle. When the switch is "ON" or "closed," the two contacts inside the switch are connected, allowing electricity to pass through. In the "OFF" or "open" position, these contacts are separated, cutting off the current.

There are different types of switches, such as:

1. Single-pole, Single-throw (SPST): The most basic type, commonly used in homes, controls a single device from one location.
2. Double-pole, Double-throw (DPDT): This type allows switching between two circuits or changes in the direction of current flow, often used in advanced electrical systems.
3. Rocker, Push-button, and Toggle switches: These refer to the way the switch is activated—by pressing a button, flipping a toggle, or pushing a rocker.

The function of an electrical switch is crucial for safety, as it allows users to disconnect electrical devices from the power source, preventing electrical hazards or overloads. Additionally, switches can be designed to work with various voltage levels and be built for different environments, such as
outdoor or industrial applications.

Applications of Electrical Switches

- Residential: Light switches, fans, and electrical outlets.
- Industrial: Used to control large machinery and electrical systems in factories.
- Automotive: In vehicles, controlling lights, windows, and power systems.

- Electronics: Used in computers, audio equipment, and other devices for turning on/off or adjusting settings.

Figure 2.10 Switch

Figure 2.10.1 Switch

2.11 Multi meter

A multi meter is a versatile tool used to measure various electrical parameters such as voltage, current, and resistance in circuits. It is an essential device for electrical and electronic diagnostics, allowing users to check whether components are functioning properly or if a circuit has any faults. Multi meters typically offer the ability to measure AC (alternating current) and DC (direct current) voltages, the flow of current, and the resistance of components like resistors. Digital multi meters (DMMs) are the most common type, providing easy-to-read numerical values, while analog versions use a needle and dial. Multi meters are widely used by electricians, engineers, and hobbyists for troubleshooting and maintenance of electrical systems and devices.

A multi meter is a handheld electronic measuring instrument used to evaluate multiple electrical parameters such as voltage (V), current (A), and resistance (Ω). It is one of the most essential tools for anyone working with electrical circuits, providing the ability to diagnose, test, and troubleshoot electrical systems efficiently. Multi meters are used across a wide range of fields, including
electronics, electrical engineering, automotive diagnostics, and general maintenance.

Functions of a Multi meter:

1. Voltage Measurement (Volts): Multi meters can measure both AC (Alternating Current) and DC (Direct Current) voltage. This function helps users assess the electrical potential difference between two points in a circuit. For example, it can check whether the voltage supply in a battery or power source is within the desired range.
2. Current Measurement (Amps): A multi meter can measure the flow of electric current in a circuit. Depending on the settings, the multi meter can be used to measure AC current (common in household power) or DC current (found in batteries and electronic devices). For current measurements, the multi meter must be connected in series with the circuit, allowing the current to pass through it.
3. Resistance Measurement (Ohms): This function allows the multi meter to measure how much a component resists the flow of electricity. It's typically used for testing resistors, wires, or even checking for continuity in a circuit (whether the circuit is complete or broken).

Types of Multi meters:

1. Analog Multi meter**:** These are the traditional type of multi meters that use a needle and dial to display the measurement. They are less common today due to the availability of digital models, but they can still be useful for detecting small changes in the electrical values because of their continuous scale.
2. Digital Multi meter (DMM)**:** These are the most widely used type of multi meter, providing precise readings in numerical form on a digital display. Digital multi meters are preferred because they are easier to read, more accurate, and often have additional features such as auto-
ranging, which adjusts the measurement range automatically for greater accuracy.

Additional Features of Modern Multi meters:

- Diode Testing**:** This function checks if a diode is working properly, which is essential in testing components like LEDs or rectifiers.
- Continuity Testing: A common feature where the multi meter emits a sound (beep) if the circuit is continuous, making it easy to detect broken wires or faulty connections.
- Capacitance Measurement: Some advanced models can measure the capacitance of capacitors, which is useful for diagnosing issues in power supplies or other electronics.
- Temperature Measurement: Many digital multi meters have temperature sensors, allowing them to measure the temperature of a component or environment**.**

Applications of Multi meters:

- Troubleshooting Electrical Circuits**:** Multi meters are invaluable for diagnosing faults in electrical circuits. For example, a technician can use a multi meter to check if a circuit is receiving the correct voltage or if there’s an issue with the current flow or a resistor that is faulty.
- Testing Components**:** Multi meters help test components such as resistors, capacitors, diodes, transistors, and fuses to ensure they are functioning properly.
- Automotive Diagnostics**:** Multi meters are often used to check the health of a vehicle's battery, alternator, and other electrical systems, making them essential for car mechanics.

How to Use a Multi meter:

1. Voltage Measurement**:** Set the multi meter to the appropriate voltage setting (AC or DC).

   Connect the probes across the two points where you want to measure the voltage, and the digital display will show the reading.

2. Current Measurement**:** To measure current, set the multi meter to the correct current range (AC or DC). The multi meter needs to be placed in series with the circuit, meaning the current will flow through the multi meter.

3. Resistance Measurement**:** Set the multi meter to the resistance setting. Place the probes on

   either side of the component to measure its resistance. If there's no reading or the reading is infinite, the component might be faulty.

Safety Considerations :

While multi meters are designed to be safe to use, users should always take care when measuring current or voltage in high-power systems. For safety, it's essential to ensure that the multi meter is correctly set to the desired range before taking measurements to avoid damaging the instrument or causing injury. For high-voltage circuits, it's best to use a multi meter with proper insulation and safety ratings.

In summary, a multi meter is a crucial diagnostic tool for anyone involved with electrical systems. Its ability to measure and test various electrical parameters makes it indispensable for professionals and hobbyists alike. Whether used for everyday tasks like testing batteries or for complex troubleshooting, a multi meter ensures that electrical systems are functioning optimally and safely.

Advantages of Multi Meter

- Troubleshooting and Diagnostics
- Portability

Figure 2.11 Multi Meter

Figure 2.11.1 Multi meter

CHAPTER-3
METHODOLOGY

3.1 Theoretical Framework

The solar panel cleaning robot is designed to efficiently remove dirt and dust from solar panels, optimizing their ability to absorb sunlight and maximize energy production. The system consists of two main components: the cleaning robot and a brush mechanism, which is powered by a spring system. The cleaning robot moves from one panel to another, covering the entire length of each panel, while the attached brush effectively removes accumulated dirt and dust. The robot is controlled via an ESP32 Wi-Fi module, which manages its operations, movement, and communication.

One of the key design criteria for this cleaning system is its ability to clean multiple panels in a solar farm using a single robot. This approach simplifies the process compared to utilizing multiple robots working simultaneously. Although the cleaning of solar panels is essential, it is often labor-intensive and costly. This paper investigates the impact of accumulated dust on solar panel performance by conducting experiments in industrial environments with varying levels of dust accumulation. Additionally, an autonomous cleaning robot is proposed to function as an automated solution for keeping the panels clean.

The cleaning process begins with the carrier robot and cleaning robot approaching the solar panel. The cleaning robot halts its movement once it detects the panel. The carrier robot sends a signal to the cleaning robot, instructing it to travel the entire length of the panel, moving in both forward and backward directions. The robot then cleans the panel for a specified duration. After completing the cleaning process, the robot returns to the carrier robot to continue the cycle.

Once the cleaning process is complete, the robot returns to its original position near the carrier robot. This allows the system to reset and prepare for the next cycle or move on to another panel. The entire process is highly automated, reducing the need for human intervention and making it particularly effective for large solar farms. By ensuring consistent and efficient cleaning, this system maximizes the energy efficiency and lifespan of solar panels, making it an essential part of solar panel. During the cleaning process, the robot operates for a specified duration, using specialized cleaning tools or mechanisms such as soft brushes, microfiber rollers, or water jets.

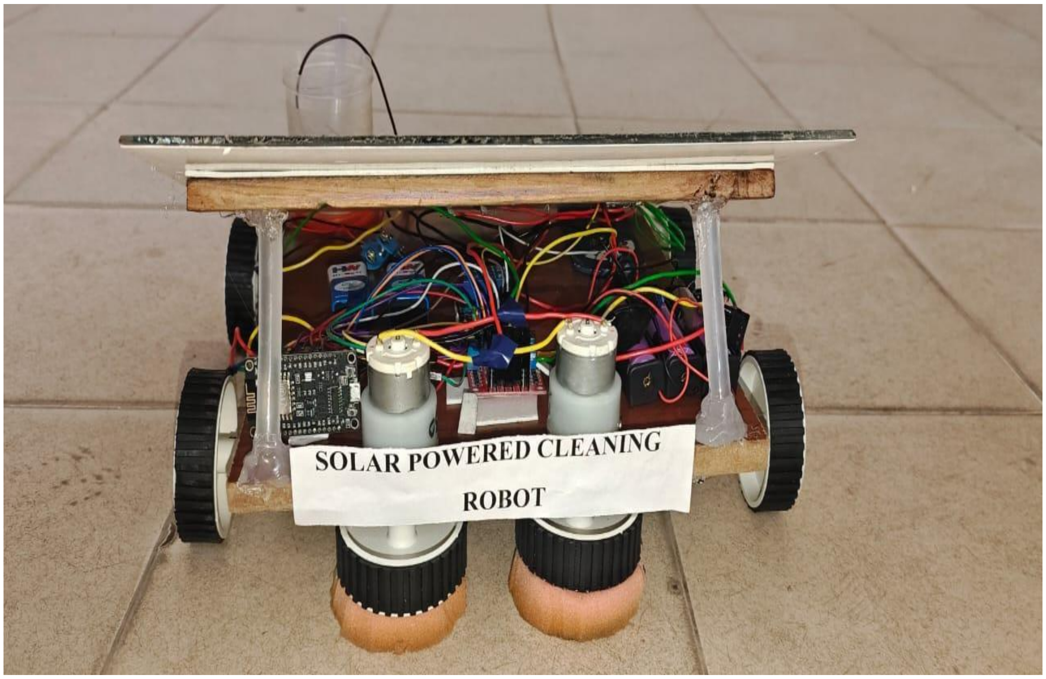


Figure 3.1 Solar Powered Cleaning Robot

The solar panel cleaning robot is designed to optimize the efficiency of solar energy generation by keeping the solar panels free from dirt, dust, and other contaminants. When solar panels are covered in dust or debris, their ability to absorb sunlight and generate electricity is significantly reduced. The cleaning robot's primary objective is to remove this accumulation of dirt, ensuring that the panels remain clean and able to absorb the maximum amount of sunlight, thus boosting their performance and efficiency.

The cleaning system consists of two essential components: the cleaning robot and a brush mechanism powered by a spring system. The robot itself is mobile, designed to move from one panel to another, covering the full length of each solar panel. The brush, which is mounted on the robot, efficiently scrubs the surface of the panel, dislodging dust and dirt particles. By continuously moving across the panel, the brush ensures that the entire surface is cleaned thoroughly. One of the standout features of this design is its use of an ESP32 Wi-Fi module, which enables wireless communication and control of the robot.

The ESP32 is responsible for managing the robot's operations, movement, and interaction with other components in the system.

This wireless connectivity makes it possible to control the robot remotely, monitor its progress, and adjust its operations if necessary, all in real-time.

An important design consideration for this cleaning system is its ability to clean multiple solar panels on a solar farm using a single robot. This approach is highly efficient, as it simplifies the process by eliminating the need for multiple robots working simultaneously. With just one robot handling the cleaning of an entire solar farm, the system is more cost-effective, reduces complexity, and can be deployed across vast areas of solar panels. However, despite the benefits of this automated system. the cleaning process itself is still considered labor-intensive and expensive, especially on large solar farms.

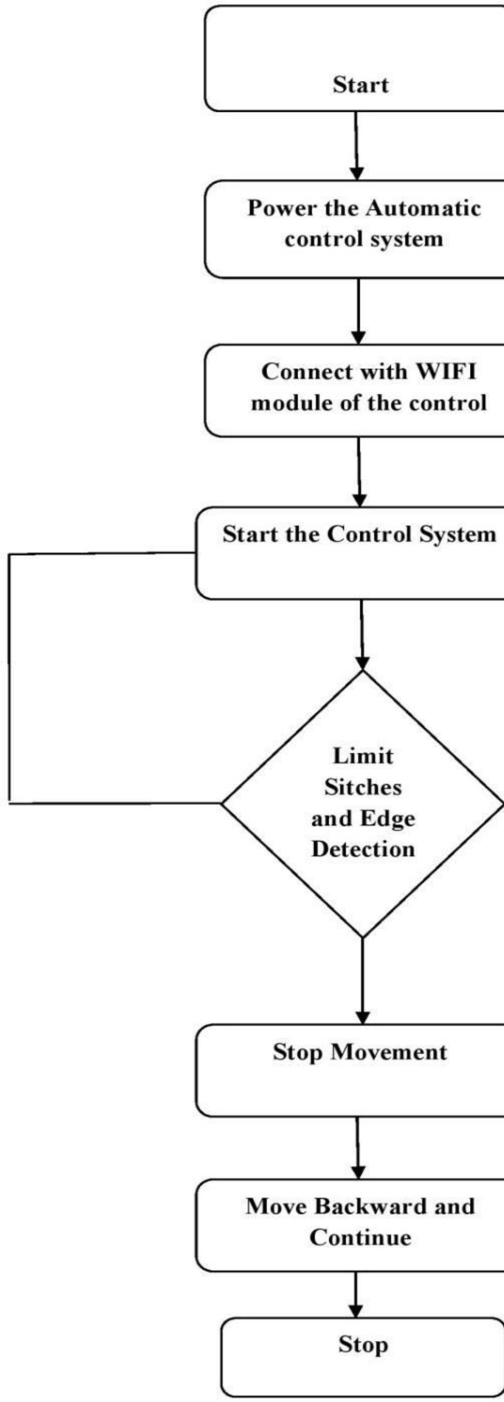
This paper explores the effects of dust accumulation on solar panel performance by conducting experiments in industrial environments with different levels of dust exposure. These experiments are designed to evaluate how various amounts of dirt and debris affect the energy output of the solar panels. Based on these findings, the paper proposes the integration of an autonomous cleaning robot that could work independently, serving as an efficient solution to maintain the cleanliness of the panels. By automating the cleaning process, this robot can reduce the need for manual labor and potentially lower the long-term operational costs associated with solar panel maintenance.

The cleaning robot is equipped with sensors that allow it to detect the solar panel's position, at which point it stops its movement. The carrier robot then sends a signal to the cleaning robot to begin its cleaning task. The cleaning robot moves across the full length of the solar panel, first in one direction (e.g.. from left to right) and then in the opposite direction (right to left). The attached brush mechanism effectively cleans the panel's surface during this back-and-forth motion. The robot is programmed to clean the panel for a specified duration to ensure that all dirt and dust are thoroughly removed.

Once the cleaning task is completed, the robot returns to the carrier robot for recharging or further instructions. This cycle continues, with the cleaning robot moving from panel to panel, ensuring that the solar farm remains clean and its panels remain efficient. The autonomous nature of the robot means that it can operate independently, eliminating the need for constant human intervention. This not only makes the cleaning process more efficient but also lowers the operational costs and time associated with manual cleaning.

During the cleaning process, the robot operates for a specified duration, using specialized cleaning tools or mechanisms such as soft brushes, microfiber rollers, or water jets.

3.2 Flow Chart



3.3 Work Plan

Developing a solar-powered cleaning robot involves a systematic and detailed process to ensure efficiency, reliability, and sustainability. The project begins with the conceptual design and requirement analysis, where the robot's core functionalities are defined. This includes determining the types of surfaces it will clean, such as floors, windows, or rooftops, the cleaning intensity needed, and environmental factors like terrain and sunlight availability. Energy requirements are estimated based on cleaning mechanisms and operation time, with plans for integrating solar panels to meet these needs. Following this, a technical feasibility study is conducted to identify the best components, such as high-efficiency solar panels, rechargeable batteries, and effective cleaning mechanisms like rotating brushes or water jets. Challenges, such as limited sunlight or uneven surfaces, are also assessed.

The next phase is detailed design and simulation, where engineers create blueprints using tools like CAD (Computer-Aided Design) to design the robot's structure, ensuring a balance between durability and lightweight construction. Electrical circuits for energy management, including solar charging and power distribution, are also designed, while software simulations test navigation algorithms, obstacle detection, and cleaning efficiency in virtual environments. With the design finalized, a prototyping and hardware assembly phase begins. A physical prototype is constructed using materials such as aluminum or ABS plastic, integrating solar panels, batteries, motors, and sensors. This prototype serves as the first functional model, combining mechanical and electrical systems for real-world testing.

Software development and integration are critical for autonomous operation. Advanced algorithms are embedded into the robot's microcontroller for tasks such as path planning, real-time obstacle avoidance, and energy optimization. Once the prototype is operational, it undergoes testing and refinement in controlled and real-world conditions. Performance metrics like cleaning efficiency, battery life, and adaptability to varying surfaces are rigorously evaluated.

Once the cleaning process is complete, the robot returns to its original position near the carrier robot. This allows the system to reset and prepare for the next cycle or move on to another panel. The entire process is highly automated, reducing the need for human intervention and making it particularly effective for large solar farms. By ensuring consistent and efficient cleaning, this system maximizes the energy efficiency and lifespan of solar panels, making it an essential part of solar panel maintenance operations.

When the prototype meets the desired standards, the focus shifts to manufacturing and scalability. This includes sourcing cost-effective materials, establishing partnerships for key components like solar panels and batteries, and implementing quality control measures. Preparations are made for mass production to ensure affordability without compromising quality. After production, the deployment and maintenance phase begins, with the final product launched into the market. User manuals, instructional videos, and customer support systems are provided to help users operate the robot efficiently. Feedback from initial users informs future updates or iterations.

Throughout the project, sustainability and market considerations remain paramount. Efforts are made to minimize the environmental footprint by using recyclable materials and maximizing energy efficiency. A cost-benefit analysis ensures competitive pricing, while marketing strategies highlight the robot's eco-friendly features to attract environmentally conscious consumers. This comprehensive and methodical approach ensures the solar-powered cleaning robot is a high-quality, innovative, and market-ready solution that meets practical needs and promotes sustainability.

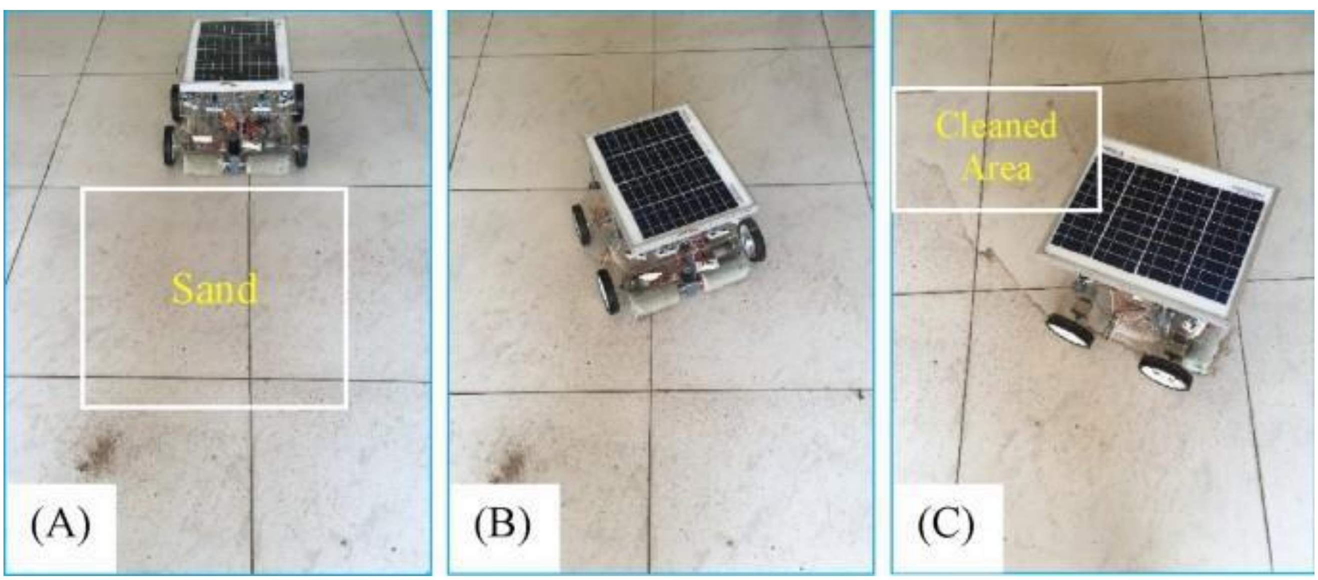


Figure 3.3 Working Operation of Solar Powered Cleaning Robot

3.4 Block Diagram

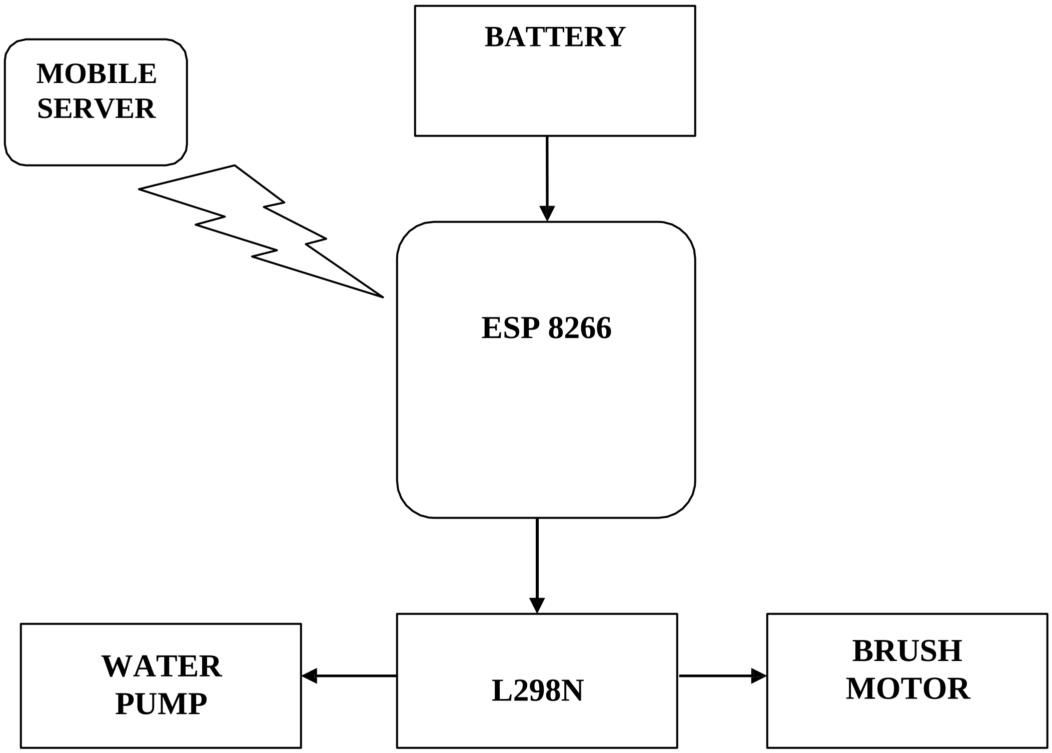


Figure 3.4 Block Diagram of Proposed Unit

Explanation of Block Diagram

The block diagram represents a solar-powered cleaning robot system that utilizes the ESP8266 microcontroller for control and connectivity. Below is an elaboration of the components and their functionality for documentation purposes:

1. ESP8266 Module:

The ESP8266 is the core of the system, serving as the processing and communication unit. It is a Wi-Fi-enabled microcontroller that allows wireless control and monitoring of the robot. It receives commands from the mobile server and processes them to operate other components, such as the motor driver and cleaning mechanisms.

2. Battery:

The system is powered by a rechargeable battery, which is typically charged using solar panels. The battery ensures consistent energy supply for all components, enabling the robot to operate in environments without a direct power source. It powers the ESP8266, water pump, and brush motor through the motor driver.

3. Mobile Server:

The mobile server communicates with the ESP8266 over a Wi-Fi connection. It provides a user interface for remotely controlling the robot. Users can send commands to start or stop the cleaning process and monitor the robot's status through a smart phone or a web application.

4. L293D Motor Driver:

The L293D is a dual H-bridge motor driver IC that controls the motors in the system. It receives control signals from the ESP8266 and manages the power delivery to the brush motor and water pump. This ensures precise and coordinated operation of the cleaning mechanisms.

5. Brush Motor:

The brush motor powers the cleaning brushes, which are responsible for scrubbing and removing dirt from surfaces. It plays a vital role in the cleaning operation by providing mechanical movement to clean effectively.

6. Water Pump:

The water pump is used for dispensing water during the cleaning process. It sprays water onto the surface to loosen dirt and stains, enhancing the cleaning efficiency. The pump is controlled via the L293D motor driver.

7. Wi-Fi Connectivity:

The ESP8266's built-in Wi-Fi module establishes a wireless connection with the mobile server, enabling real-time control and feedback. This feature allows users to remotely manage the robot and monitor its performance.This solar-powered cleaning robot integrates the ESP8266 microcontroller, a rechargeable battery, and motorized cleaning components to provide an efficient and sustainable cleaning solution. The L293D motor driver coordinates the operation of the brush motor and water pump, while the mobile server enables remote control and monitoring.

3.5 Circuit Diagram

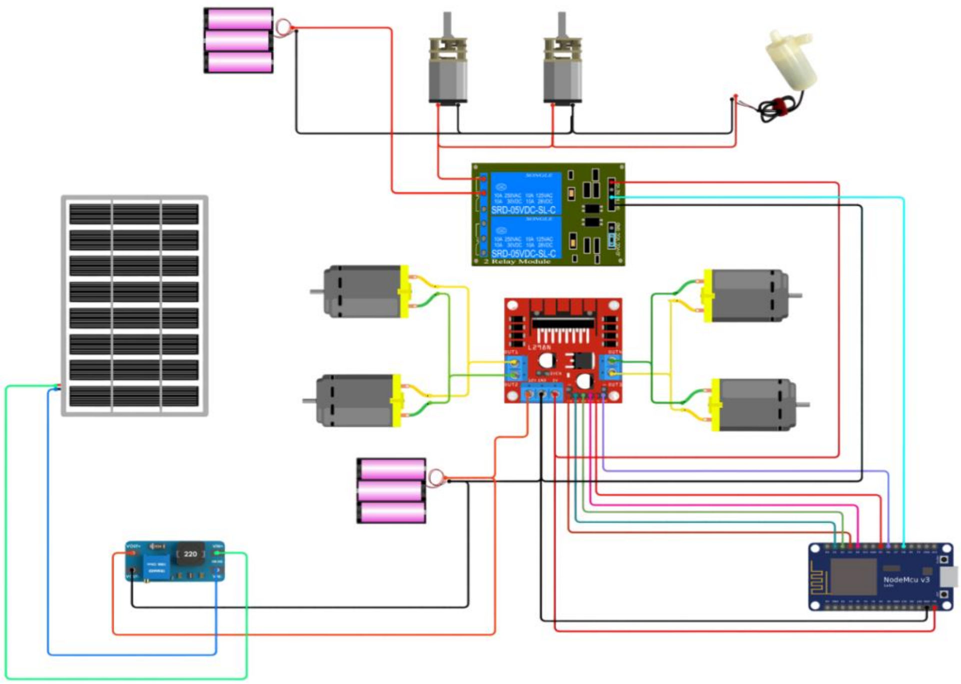


Figure 3.5 Circuit Diagram

Explanation of Circuit Diagram

This circuit diagram shows the wiring for a Node MCU-based robot with an L298N motor driver and DC motors. Below is a detailed explanation of the connections:

Components:

1. Node MCU V3: Microcontroller for controlling the robot.
2. L298N Motor Driver: Used to drive the DC motors.
3. DC Motors: Four motors for robot movement.
4. 9V Battery: Power source for the motors.
5. Wires: For connecting all components.

Connections:

L298N Motor Driver:

1. Input Pins on the L298N:
   - IN1 (Input 1): Connect to *D5* (GPIO14) of Node MCU.
   - IN2 (Input 2): Connect to *D6* (GPIO12) of Node MCU.
   - IN3 (Input 3): Connect to *D7* (GPIO13) of Node MCU.
   - IN4 (Input 4): Connect to *D8* (GPIO15) of Node MCU.

2. Motor Connections:
   - OUT1 and OUT2: Connect to the first pair of DC motors (left side motors).
   - OUT3 and OUT4: Connect to the second pair of DC motors (right side motors).

3. Power Pins:
   - +12V (VCC): Connect to the positive terminal of the 9V battery.
   - GND: Connect to the negative terminal of the 9V battery and to *GND* of the Node MCU.
   - 5V Output Pin : Supply 5V power to the Node MCU (optional if Node MCU is powered via USB).

Node MCU V3:

1. Digital Pins:
   - D5 (GPIO14): Control signal for IN1.
   - D6 (GPIO12): Control signal for IN2.
   - D7 (GPIO13): Control signal for IN3.
   - D8 (GPIO15): Control signal for IN4.

2. Power Pins:
   - VIN/3V3: Receive power from the L298N's 5V pin or an external source.
   - GND: Common ground connected to the L298N and battery.

Additional Notes:

1. Ensure the *Enable Pins (EN1 and EN2)* on the L298N are activated (jumpered or connected to PWM pins if speed control is needed).
2. Use a solar panel and a charge controller if you plan to replace the 9V battery with a solar-powered system.
3. Verify voltage levels to avoid overloading the Node MCU or the motors.

Table.3: Connection Table

Component	**Pin**	**Connection**
L298N Motor Driver	Out 1 Out 2	Left side motor terminals
z L298N Motor Driver	Out 3 Out 4	Right side motor terminals
L298N Motor Driver	IN1	Node MCU pin D5 (GPIO14)
L298N Motor Driver	IN2	Node MCU pin D6 (GPIO12)
L298N Motor Driver	IN3	Node MCU pin D7 (GPIO13)
L298N Motor Driver	IN4	Node MCU pin D8 (GPIO15)
L298N Motor Driver	+12V	Positive Terminal of 9VBattery
L298N Motor Driver	GND	Negative Terminal 9VBattery
L298N Motor Driver	5V	Optional : Power Supply to Node MCU (If Needed)
Node MCU V3	D5(GPIO14)	L298N IN1
Node MCU V3	D6(GPIO12)	L298N IN2
Node MCU V3	D7(GPIO13)	L298N IN3
Node MCU V3	D8(GPIO15)	L298N IN4
Node MCU V3	GND	Common Ground with L298N and 9V Battery
DC Motors	Motor Terminals	Connected to Out 1, Out 2, Out 3,Out 4 of L298N
9V Battery	Positive Terminal	Connected to L298N +12V

	Negative Terminal	Connected to L298N GND and Node MCU GND
-	-	-

CHAPTER-4
SOFTWARE DISCRIPTION

4.1 CODE IMPLEMENTED

```
/WiFi Robot Remote Control Mode /
#include <ESP8266WiFi.h>
#include <ESP8266WebServer.h>
#include <ArduinoOTA.h>

// Connections for drive motors
const int IN1 = D1;
const int IN2 = D2;
const int ENA = D3; // PWM control for Motor A
const int IN3 = D4;
const int IN4 = D5;
const int ENB = D6; // PWM control for Motor B

// Other peripherals
const int buzPin = D7;      // Buzzer pin
const int ledPin = D8;      // LED pin
const int wifiLedPin = D0;  // WiFi connection status LED

String command;             // Stores app command state
int SPEED = 1023;           // Default speed (0 - 1023)
int speed_Coeff = 3;        // Speed coefficient for turning

ESP8266WebServer server(80); // Web server on port 80

// WiFi configuration
```

```
const char* sta_ssid = "Your_SSID";       // Replace with your SSID
const char* sta_password = "Your_PASSWORD"; // Replace with your WiFi password
IPAddress staticIP(192, 168, 1, 100);    // Static IP address
IPAddress gateway(192, 168, 1, 1);       // Gateway
IPAddress subnet(255, 255, 255, 0);      // Subnet mask
IPAddress dns1(8, 8, 8, 8);              // Primary DNS
IPAddress dns2(8, 8, 4, 4);              // Secondary DNS

void setup() {
  Serial.begin(115200);
  Serial.println("\n*WiFi Robot Remote Control Mode*");
  Serial.println("--------------------------------------");

  // Pin configurations
  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  pinMode(ENA, OUTPUT);
  pinMode(IN3, OUTPUT);
  pinMode(IN4, OUTPUT);
  pinMode(ENB, OUTPUT);
  pinMode(buzPin, OUTPUT);
  pinMode(ledPin, OUTPUT);
  pinMode(wifiLedPin, OUTPUT);

  // Initial states stopMotors();
  digitalWrite(buzPin, LOW);
  digitalWrite(ledPin, LOW);
  digitalWrite(wifiLedPin, HIGH);

  setupWiFi();
  setupWebServer();
```

```
  ArduinoOTA.begin(); // Enable OTA firmware updates
}

void loop() {
  ArduinoOTA.handle();
  server.handleClient();
}

// WiFi setup function with static IP
void setupWiFi() {
  WiFi.config(staticIP, gateway, subnet, dns1, dns2);
  WiFi.mode(WIFI_STA);
  WiFi.begin(sta_ssid, sta_password);

  Serial.print("Connecting to WiFi: ");
  Serial.println(sta_ssid);

  unsigned long startAttempt = millis();
  while (WiFi.status() != WL_CONNECTED && millis() - startAttempt < 10000) {
    delay(500);
    Serial.print(".");
  }

  if (WiFi.status() == WL_CONNECTED) {
    Serial.println("\nConnected in STA mode with Static IP");
    Serial.print("Static IP Address: ");
    Serial.println(WiFi.localIP());
    digitalWrite(wifiLedPin, LOW); // WiFi connected
  } else {
    Serial.println("\nFailed to connect to WiFi. Check credentials.");
    while (true); // Halt here if unable to connect
  }
```

```
}

// Web server setup function void
setupWebServer() { server.on("/",
HTTP_handleRoot);
  server.onNotFound(HTTP_handleRoot);
  server.begin();
}

// HTTP request handler
void HTTP_handleRoot() {
  if (server.hasArg("State")) { command =
    server.arg("State"); Serial.println("Command
    received: " + command);
    processCommand();
  }
  server.send(200, "text/html", "Command received");
}

// Process commands
void processCommand() {
  if (command == "F") forward();
  else if (command == "B") backward();
  else if (command == "R") turnRight();
  else if (command == "L") turnLeft();
  else if (command == "S") stopMotors();
  else if (command == "V") beepHorn();
  else if (command == "W") turnLightOn();
  else if (command == "w") turnLightOff();
  else if (command >= "0" && command <= "9") SPEED = map(command[0] - '0', 0, 9, 330, 1023);
}
```

```
// Motor control functions
void forward() {
digitalWrite(IN1, HIGH);
digitalWrite(IN2, LOW);
  analogWrite(ENA, SPEED);

  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
  analogWrite(ENB, SPEED);
}

void backward() {
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  analogWrite(ENA, SPEED);

  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
  analogWrite(ENB, SPEED);
}

void turnRight() {
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  analogWrite(ENA, SPEED);

  digitalWrite(IN3, LOW);
  digitalWrite(IN4, HIGH);
  analogWrite(ENB, SPEED);
}

void turnLeft() {
```

```
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, HIGH);
  analogWrite(ENA, SPEED);

  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
  analogWrite(ENB, SPEED);
}

void stopMotors() {
  digitalWrite(IN1, LOW);
  digitalWrite(IN2, LOW);
  analogWrite(ENA, 0);

  digitalWrite(IN3,  LOW);
  digitalWrite(IN4,  LOW);
  analogWrite(ENB, 0);
}

// Peripheral control functions
void beepHorn() {
digitalWrite(buzPin, HIGH);
delay(150);
  digitalWrite(buzPin, LOW);
}

void turnLightOn() {
  digitalWrite(ledPin, HIGH);
}

void turnLightOff() {
  digitalWrite(ledPin, LOW);
```

}

Description of Software Program

This Arduino program allows remote control of a WiFi-based robot using an ESP8266 module. Below is a detailed explanation of its key features:

Features:

1. WiFi Connectivity :
   - The robot connects to a WiFi network using the ESP8266 module.
   - A static IP is assigned to ensure consistent access without needing to check for a dynamically assigned IP.
2. Remote Commands :
   - The robot receives commands via HTTP requests through a simple web server hosted on the ESP8266.
3. Motor Control :
   - Uses two drive motors controlled via PWM signals for smooth motion.
   - Implements functions for:
     - Moving forward (forward()).
     - Moving backward (backward()).
     - Turning left (turnLeft()).
     - Turning right (turnRight()).
     - Stopping (stopMotors()).
4. Peripheral Control :
   - Buzzer (beepHorn()): Short beeps for alerts.
   - LED lights:
     - Control via turnLightOn() and turnLightOff().
5. OTA Updates :

Supports Over-The-Air (OTA) updates using the ArduinoOTA library, allowing firmware updates without physical connection.

6. Web Server :
   - Handles HTTP requests:
     - Commands are sent as URL parameters (State).
     - Processes specific commands such as F, B, L, R, S, and others.
7. Speed Control :
   - Robot speed can be adjusted dynamically via commands (e.g., 0-9 to set a speed level between 330 and 1023).

Command List:

Command	Action
F	Move Forward
B	Move Backward
L	Turn Left
R	Turn Right
S	Stop Motors
V	Beep the horn
W	Turn LED on
W	Turn LED off
0-9	Adjust Speed

Setup Steps:

1. Replace "Your_SSID" and "Your_PASSWORD" with your WiFi credentials.
2. Flash the code to the ESP8266 module.
3. Ensure all connections are made according to the pin assignments.
4. Use a browser or HTTP client to send commands to the robot's IP address.

Pin Assignments:

- Motor A**:** IN1, IN2 (D1, D2), ENA (D3)

- Motor B**:** IN3, IN4 (D4, D5), ENB (D6)
- Buzzer: buzPin (D7)
- LED: ledPin (D8)
- WiFi Indicator LED: wifiLedPin (D0)

This program offers a foundation for further enhancements, such as integrating additional sensors

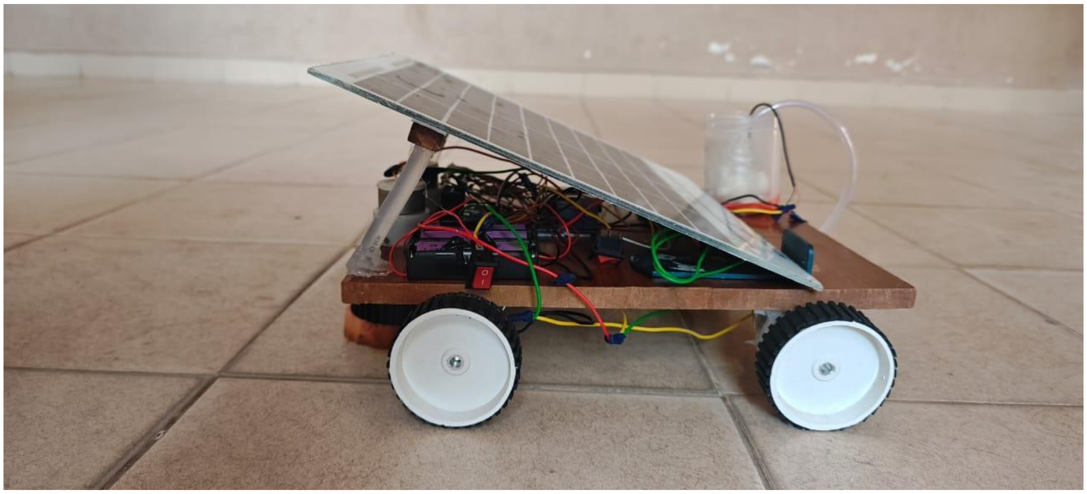
(e.g., ultrasonic for obstacle detection) or adding a more advanced web interface.

CHAPTER-5

RESULT AND DISCUSSION

5.1 RESULT

The result of a solar-powered cleaning robot is a self-sustaining and efficient cleaning system that combines renewable energy with automation to deliver effective and eco-friendly cleaning solutions. Powered by solar energy through integrated photovoltaic panels, these robots minimize reliance on traditional electricity sources, making them highly sustainable and cost-effective. Their design typically includes intelligent navigation systems, enabling them to clean various surfaces, such as floors, windows, or solar panels, with precision and minimal human intervention. The use of solar power allows for extended operation during daylight hours, and many models incorporate energy storage systems to function during low-light conditions or nighttime. This innovation results in significant energy savings, reduced environmental impact, and a versatile cleaning solution adaptable to residential, commercial, and industrial applications. Despite challenges like reduced efficiency in areas with limited sunlight and the initial cost of solar technology, the overall performance of solar- powered cleaning robots highlights their potential as a forward-looking solution for sustainable cleaning practices.



5.2 Discussion

The discussion around solar-powered cleaning robots highlights their role as a sustainable and efficient solution for modern cleaning needs. By leveraging solar energy, these robots reduce reliance on traditional power sources, making them eco-friendly and cost-effective. Equipped with advanced sensors and navigation systems, they deliver precise cleaning for various surfaces, including floors and solar panels, with minimal human effort. However, challenges such as reduced efficiency in low-sunlight areas, high initial costs, and the need for maintenance limit widespread adoption. Despite these hurdles, ongoing advancements in energy storage and solar technology continue to enhance their feasibility, positioning them as a promising innovation for sustainable automation.

CHAPTER-6
FUTURE SCOPE AND CONCLUSION

6.1 Future Scope

The future of solar-powered cleaning robots is expensive, with significant potential for innovation and integration into various industries. As advancements in solar technology make photovoltaic cells more efficient and affordable, these robots will become increasingly viable for wide spread use in both urban and rural environments. Integration with artificial intelligence and IoT (Internet of Things) could enable these robots to work autonomously with real-time adaptability, improving their efficiency in diverse applications such as residential cleaning, large-scale industrial maintenance, and solar farm upkeep. Energy storage innovations, like next-generation batteries or capacitors, will further enhance their usability by enabling operations during low-light or nighttime conditions. Additionally, the development of modular robots capable of performing multiple functions such as cleaning, inspecting, and minor repairs will expand their applications and economic appeal. These advancements will position solar-powered cleaning robots as key players in sustainable automation solutions for a wide range of industries.

6.2 Conclusion

Solar-powered cleaning robots represent a significant step forward in the pursuit of sustainable and efficient automation technologies. By leveraging renewable energy, these robots reduce reliance on conventional power sources, minimize energy costs, and contribute to environmental sustainability. They have demonstrated their utility in various sectors, including residential, commercial, and industrial applications, offering precision and reliability with minimal human intervention. However, current challenges, such as dependency on sunlight, high initial costs, and maintenance requirements, must be addressed for broader adoption. Despite these limitations, their environmental and economic benefits underscore their potential as a viable solution for future cleaning needs.

6.3 Recommendation

To maximize the potential of solar-powered cleaning robots, several strategic recommendations can be made. Manufacturers should focus on enhancing the efficiency and durability of solar panels and energy storage systems to improve performance across different environmental conditions. Research and development efforts should prioritize integrating advanced technologies, such as AI, IoT, and machine learning, to enable smarter and more adaptive operations. Additionally, reducing production costs through economies of scale and innovative manufacturing processes can make these robots more accessible to a wider audience. Governments and organizations could promote their adoption by providing incentives, such as subsidies or tax benefits, for renewable technology investments. Public awareness campaigns highlighting the environmental and economic advantages of solar-powered robots can also encourage their integration into everyday cleaning solutions.

6.4 References

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