REPORT OF INDIVIDUAL DESIGN PROJECT

INTAKE 39

IOT BASED SMART WINDOW

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ABSTRACT

The IoT Based Smart Window is an innovative solution introduced to bring a new awakening to the conventional window through its new functionalities based on the use of Internet of Things (IoT). This innovative solution enables users to manage their indoor environment offering remarkable levels of convenience, automation and connectivity. The Smart Window is equipped with a rain sensor that detects precipitation and thereby automatically closes to prevent the ingress of water indoors, safeguarding against adverse weather conditions. With an ESP32 board and a stepper motor, the Smart Window ensures precise and reliable window opening and closing mechanisms, ensuring smooth operation and efficient energy utilization. The operation of the window can be controlled effortlessly using the dedicated mobile application, that provides convenient access and management of the window from any location with internet connectivity. The Window also enables scheduled operation through the utilization of a Real -Time Clock (RTC) module which empowers users to program the window to close at predetermined times, enhancing comfort of the user. Moreover, the incorporation of a GSM module enables the Smart Window to send necessary SMS notifications to users, keeping them informed about critical events such as widow operations, thereby enhancing safety and peace of mind. Overall, the IoT-based Smart Window offers enhanced safety, convenience, energy efficiency, and peace of mind, marking a significant advancement in window management for modern living spaces.

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CHAPTER 1: INTRODUCTION

In today's era of rapid technological advancement, the integration of Internet of Things (IoT) technology into everyday objects has revolutionized the way we interact with our environment. Our project focuses on harnessing this potential by introducing an IoT-based Smart Window system. The Smart Window combines various sensors, actuators and communication modules to create a versatile and automated solution for managing window operations.

The primary objective of this project is to enhance user convenience and efficiency while addressing common challenges associated with traditional window management. By leveraging IoT capabilities, our Smart Window offers a range of features that redefine the concept of window functionality.

At the heart of the Smart Window system lies its ability to intelligently sense and respond to environmental stimuli. A precision rain sensor, meticulously calibrated to detect even the slightest precipitation, serves as the frontline defense against inclement weather. Upon detecting rain, the Smart Window promptly initiates automated closure, safeguarding interiors from water ingress and minimizing the risk of property damage. This proactive response not only enhances occupant comfort but also preserves the structural integrity of buildings, particularly in regions prone to frequent rainfall or storms.

Complementing its reactive capabilities, the Smart Window empowers users with unprecedented control and flexibility through a dedicated mobile application. Taking advantage of the widespread availability of smartphones, the application provides a user-friendly interface for controlling window functions remotely. This includes opening and closing the windows. By offering this functionality, users can easily personalize their indoor environment to suit their preferences, significantly enhancing comfort and convenience. The mobile application puts the power of window management directly into the hands of users, regardless of their physical location.

Beyond real-time control, the Smart Window introduces a new dimension of automation through its integration with a Real-Time Clock (RTC) module. By harnessing the precision of time-based scheduling, users can program the Smart Window to execute predefined actions at specified intervals, seamlessly aligning window operations with daily routines. This allows the user to set the window to automatically close at nightfall for enhanced security and prevent mosquitoes entering the household, the RTC functionality enhances the adaptability and efficiency of the Smart Window, optimizing both comfort and resource utilization.

In addition to its proactive and user-centric features, the Smart Window ensures continuous engagement and awareness through its robust notification system. Leveraging a GSM module for wireless communication, the Smart Window is capable of sending SMS alerts to users, providing timely updates on significant events such as rain detection, scheduled operations, or system anomalies. This proactive communication not only keeps users informed of the Smart Window's status but also fosters a sense of trust and confidence in its reliability and performance.

In the implementation of the Smart Window system, a range of sophisticated hardware components has been meticulously selected and integrated to ensure optimal performance and reliability. Key components include the rain sensor, which serves as the primary detection mechanism for inclement weather conditions, triggering automated window closure to prevent water ingress. Additionally, the system incorporates a Real-Time Clock (RTC) module to facilitate scheduled window operations, enabling users to program opening and closing times according to their preferences. The GSM module plays a crucial role in providing seamless communication capabilities, allowing the Smart Window to send timely SMS notifications to users regarding important events. A stepper motor and a rack and pinion mechanism, enables precise control over window movement, ensuring secure closure. Furthermore, the Smart Window utilizes an ESP32 board to establish Wi-Fi connectivity, enabling seamless communication with the user's smartphone and facilitating remote control and monitoring of window operations.

All in all, the Smart Window seamlessly integrates advanced IoT technology with traditional window functionalities, offering unparalleled convenience and peace of mind. This innovative solution enhances user comfort, promotes energy efficiency, and simplifies daily routines, making it an indispensable addition to modern living spaces.

CHAPTER 2: PRODUCT SURVEY

2.1: EXISTING PRODUCTS

2.1.1: THERMOCHROMIC WINDOWS

Thermochromic windows are a type of smart window technology that dynamically adjusts its transparency based on changes in temperature. These windows offer several advantages and applications, making them an increasingly popular choice in various industries.

1. **How Thermochromic Windows Work**: Thermochromic windows contain materials that undergo a reversible phase transition in response to temperature changes. Typically, these materials are microcapsules or coatings containing thermochromic pigments or dyes. When the temperature rises above a certain threshold, the material absorbs heat energy, causing it to undergo a color change or transition from translucent to transparent. Conversely, when the temperature decreases, the material returns to its original state, blocking light and heat transmission.

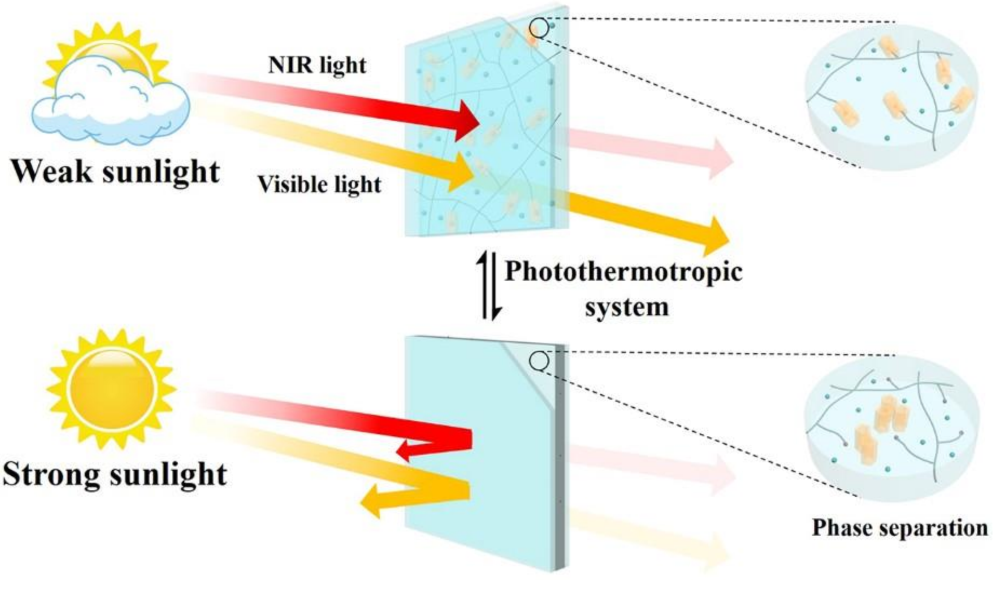


Fig 2.1.1 Thermochromic windows

2. **Applications of Thermochromic Windows**:
    - Residential Buildings: Thermochromic windows can be used in homes and apartments to improve energy efficiency, enhance comfort, and provide privacy without the need for curtains or blinds.

- Commercial Buildings: In commercial settings, thermochromic windows can help reduce energy consumption, optimize daylighting, and create comfortable work environments for occupants, contributing to productivity and well-being.
- Automotive Industry: Thermochromic materials are also used in automotive windows to regulate cabin temperature, reduce glare, and enhance driving comfort for passengers.
- Greenhouses: Thermochromic films or coatings can be applied to greenhouse glazing to control light transmission and optimize growing conditions for plants, improving crop yields and reducing energy costs.
- Specialty Applications: Thermochromic materials are utilized in various specialty applications, such as smart textiles, packaging, signage, and temperature-sensitive labels.

2.1.2: MOTORIZED BLINDS

Fig 2.1.2 Motorized Blinds

Motorized blinds and shades have become a sought-after choice for homeowners seeking an upgrade in convenience, energy efficiency, and home automation. Offering seamless control at the touch of a button or through a smartphone app, these window treatments bring unparalleled convenience to daily life. Whether you’re adjusting them to let in the morning sunlight or closing them for privacy at night, the ability to operate blinds and shades remotely is a game-changer.

Beyond convenience, motorized blinds and shades contribute to energy efficiency by allowing for precise control over sunlight and heat gain. With the ability to program them to open and close at specific times, you can optimize natural lighting and temperature regulation throughout the day, reducing reliance on artificial lighting and HVAC systems. This not only saves energy but also lowers utility costs over time.

2.1.3: PHOTOCHROMIC WINDOWS

Photochromic windows operate through a fascinating process rooted in photochromism, wherein exposure to ultraviolet (UV) light triggers a reversible chemical reaction within a specialized organic compound, the photochromic material. This reaction induces a molecular transformation, altering the material's structure and consequently its optical properties, resulting in darkening or tinting of the window. This darkening effect, visible to the human eye, occurs as the molecules absorb and scatter more light, reducing the passage of visible light through the window. Importantly, when UV light exposure diminishes, the molecular structure of the photochromic material begins to revert to its original state, gradually clearing the window. This reversibility enables photochromic windows to dynamically adapt to changing light conditions, automatically providing occupants with a comfortable indoor environment while minimizing the need for manual intervention or external controls. Overall, photochromic windows offer a passive and energy-efficient solution for controlling light transmission and glare in buildings, leveraging the unique properties of photochromic materials to enhance both functionality and sustainability.

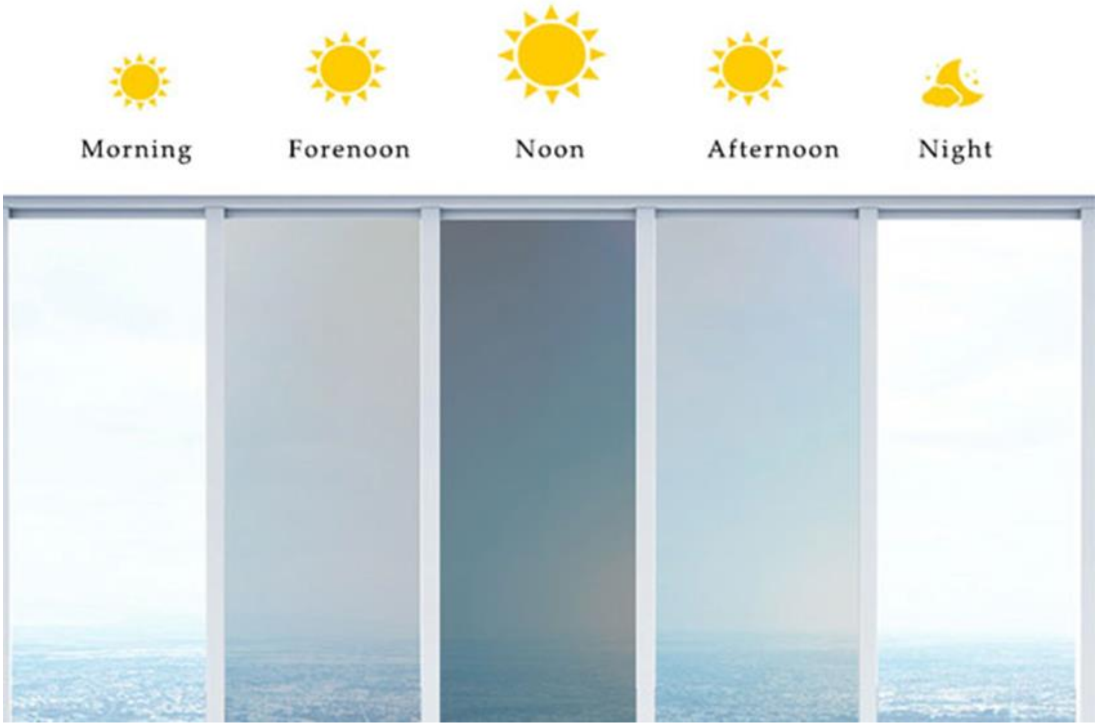


Fig 2.1.3 Photochromic Windows

2.2: MAIN DRAWBACKS OF EXISTING PRODUCTS

PRODUCT NAME	DRAWBACKS
1. Thermochromic Windows	• Limited temperature control • Lack of user control • Initial cost and installation
2. Motorized Blinds	• High cost • Quite complex • Dependence on power
3. Photochromic Windows	• Partial darkening • Quite costly • Temperature sensitivity

Table 1: Major drawbacks of existing products

CHAPTER 3: OBJECTIVES AND AIM

3.1 AIM

To design and develop an IoT-based smart window system that enhances convenience, security, and energy efficiency through automated operation and remote-control capabilities.

3.2 OBJECTIVES

- Develop a rain sensing mechanism for automatic window closure.
- Create a user-friendly environment using Blynk for remote control.
- Implement scheduling functionality using an RTC module.
- Implement a notification system to notify user.
- Prioritize safety features and reliability mechanisms.

CHAPTER 4: METHODOLOGY

4.1: IOT BASED SMART WINDOW

The IOT based smart window is an automated device that aim to make household operations easier with its features which include rain detection, mobile control, scheduled operation, notification system and error dentification. This new system provides a more efficient and advanced solution. The features can be further described as below;

- **Rain Sensing Capability**: A rain sensor is employed to detect precipitation and this sends out a signal to the ESP32 board and in turn the window automatically closes to prevent water from entering indoors.
- **Mobile Application Control**: The ESP32 board is used to connect the window to the smart phone using Wi-Fi. Users have the flexibility to remotely open and close the window using a dedicated mobile application, providing convenience and control from anywhere.
- **Scheduled Operation**: The window incorporates a Real-Time Clock (RTC) module, allowing users to schedule automatic opening and closing times according to their preferences and routines.
- **SMS Notifications**: A GSM module is utilized to send SMS notifications to users, alerting them of important events such as rain detection, scheduled operations, or system malfunctions.
- **Error identification**: A limit switch is installed on the window panel so that it can be detected if the window does not close and the user can be notified. This gives the user more trust in the product.

4.2: HARDWARE IMPLEMENTATION AND COMPONENTS USED

4.2.1: ESP32 DEVELOPMENT BOARD

The ESP32 board serves as the central control unit in our IoT-based Smart Window project. It facilitates seamless communication between various components, such as the rain sensor, GSM module, and stepper motor. Additionally, the ESP32 enables connectivity to the internet, allowing users to remotely control the window via a mobile application.

The ESP32 Dev Kit is a versatile development board based on the ESP32 microcontroller. It offers a comprehensive set of features and peripherals, making it ideal for a wide range of IoT applications, including our Smart Window project. The ESP32 Dev Kit includes built-in Wi-Fi and Bluetooth connectivity, allowing seamless integration into IoT networks and enabling remote communication and control. Its dual-core processor provides ample computing power for handling complex tasks and real-time operations. The board also features a rich selection of GPIO pins, analog-to-digital converters (ADCs), and serial interfaces, offering flexibility for interfacing with sensors, actuators, and other peripherals. With robust hardware capabilities and extensive software support, the ESP32 Dev Kit serves as the cornerstone of our Smart Window system, empowering us to create a reliable and feature-rich IoT solution. Below are some features of this board.

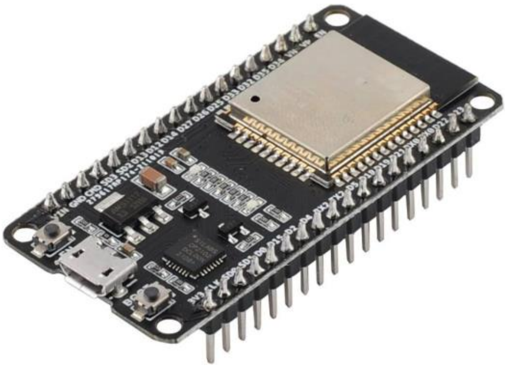


Fig 4.2.1 ESP32 Development Board

- **Versatile I/O Pins:** The ESP32 Dev Kit boasts a variety of digital and analog I/O pins, facilitating easy interfacing with sensors, actuators, and peripherals.

- **Wi-Fi and Bluetooth Connectivity:** With built-in Wi-Fi and Bluetooth capabilities, the ESP32 Dev Kit enables seamless connectivity to wireless networks and devices, essential for IoT applications.

- **Low Power Consumption:** Designed for efficiency, the ESP32 Dev Kit consumes minimal power, making it suitable for battery-powered and energy-efficient projects.

- **Security Features:** Equipped with Secure Boot, Flash Encryption, and Cryptographic Hardware Acceleration, the ESP32 Dev Kit ensures robust security for IoT deployments, safeguarding against threats.

- **Programming Language and IDE:** Developers can program the ESP32 Dev Kit using familiar languages such as C and C++, with support for popular development environments like the Arduino IDE and the Espressif IoT Development Framework (ESP-IDF), streamlining the development process.

- **OTA Updates:** Support for Over-the-Air (OTA) updates allows developers to remotely update device firmware, ensuring scalability and flexibility in managing IoT deployments.

- **Dual-Core Processor:** The dual-core processor architecture enhances multitasking capabilities, enabling efficient execution of tasks and optimal resource utilization.

- **Analog-to-Digital Converter (ADC):** High-resolution ADCs enable accurate measurement and conversion of analog signals from sensors, enhancing precision in data acquisition.

- **Touch Sensing:** Integrated touch sensing capabilities enable the development of touch-sensitive interfaces, enhancing user interaction in IoT applications.

- **USB Connectivity:** The ESP32 Dev Kit features USB connectivity, allowing for easy programming and debugging via USB-to-serial communication.

- **Analog-to-Digital Converter (ADC):** High-resolution ADCs facilitate precise measurement and conversion of analog signals, enabling accurate sensor data acquisition for various applications.

- **Integrated Flash Memory:** Featuring integrated flash memory, the ESP32 Dev Kit offers ample storage space for firmware, configuration data, and other resources, simplifying deployment and storage management.

- **Peripheral Interfaces:** The ESP32 Dev Kit supports a range of peripheral interfaces, including SPI, I2C, UART, and PWM, providing flexibility for interfacing with a wide variety of sensors, displays, and actuators.

The ESP32 boasts versatile communication capabilities, featuring built-in Wi-Fi and Bluetooth connectivity for seamless internet access, data exchange, and wireless control. Its dual-mode operation enables simultaneous operation in both Wi-Fi and Bluetooth modes, facilitating diverse communication scenarios. Additionally, support for mesh networking protocols like ESP-Mesh allows devices to form self-healing mesh networks for distributed communication. With Over-the-Air (OTA) updates and hardware-accelerated cryptographic operations, the ESP32 ensures secure and efficient communication in IoT deployments, making it a preferred choice for a wide range of applications.

- **Specifications of ESP32 Development Board**

The ESP32 Dev Kit boasts a powerful dual-core Xtensa LX6 microprocessor, operating at frequencies of up to 240 MHz, providing ample processing power for a variety of applications. With built-in Wi-Fi (802.11 b/g/n) and Bluetooth (v4.2 BR/EDR and BLE) capabilities, the Dev Kit enables seamless wireless connectivity and communication. It offers 520 KB of SRAM and supports up to 16 MB of external SPI Flash memory, providing sufficient storage for firmware and data.

The board features a range of peripheral interfaces, including SPI, I2C, UART, ADC, DAC, and PWM, facilitating interfacing with various sensors, actuators, and peripherals. With a wide input voltage range of 5V to 12V DC and USB-powered operation support, the ESP32 Dev Kit offers flexibility in power supply options. Its compact form factor and integrated components, such as the on-board USB-to-serial converter and integrated antennas, contribute to its ease of use and versatility.

Additionally, the Dev Kit supports Over-the-Air (OTA) updates, secure boot, flash encryption, and hardware-accelerated cryptographic operations, ensuring enhanced security and firmware management capabilities. Overall, the ESP32 Dev Kit provides a robust and feature-rich platform for developing IoT and embedded projects.

4.2.2: RAIN SENSOR (FC-37)

The FC-37 rain sensor module is a widely used device for detecting rainfall in various applications. Its simple design and reliable functionality make it popular among hobbyists, students, and professionals alike.

The sensitivity of the FC-37 rain sensor module can be adjusted using an onboard potentiometer. This allows users to fine-tune the sensor's response to different rainfall intensities and environmental conditions. Additionally, the module often includes a digital output pin that provides a signal when rainfall is detected, making it easy to interface with microcontrollers or other electronic devices.

The FC-37 rain sensor module is typically used in weather monitoring systems, automatic watering systems, and smart home automation projects. It provides a simple and cost-effective solution for detecting rainfall and triggering appropriate actions based on weather conditions.

- **Working principle of rain sensor**

The FC-37 rain sensor module operates on the principle of conductivity. It consists of two conductive traces or pads on the sensor board, typically arranged in a parallel configuration. When raindrops fall onto the sensor surface, they create a conductive path between these two pads, effectively bridging the gap between them.

This bridging of the gap between the conductive pads allows electrical current to flow between them. The module includes circuitry to measure the conductivity or resistance between the pads. When rain is detected, the conductivity between the pads increases, leading to a decrease in resistance. This change in resistance is then detected by the module's circuitry.

By monitoring the change in resistance, the FC-37 rain sensor module can determine when rainfall occurs. This change in resistance is typically converted into a voltage signal or a digital output, indicating the presence of rain.

The sensitivity of the FC-37 rain sensor module can be adjusted using an onboard potentiometer. This allows users to fine-tune the sensor's response to different rainfall intensities and environmental conditions. By adjusting the sensitivity, users can control the threshold at which the module detects rainfall, making it suitable for various applications and climates.

Overall, the working principle of the FC-37 rain sensor module relies on the conductivity of water to detect rainfall and trigger appropriate actions based on weather conditions.

Fig 4.2.2 Rain Sensor

- **Features**
  - **Simple Design:** The FC-37 rain sensor module features a compact and straightforward design, making it easy to use and integrate into various projects.
  - **Conductive Sensing:** Utilizing a conductive sensing mechanism, the module detects rainfall when raindrops create a conductive path between two conductive pads on the sensor board.
  - **Adjustable Sensitivity:** Users can fine-tune the sensitivity of the module using an onboard potentiometer, allowing customization of its response to different rainfall intensities and environmental conditions.

- **Digital Output:** Many FC-37 modules include a digital output pin that provides a signal when rainfall is detected, simplifying interfacing with microcontrollers or other electronic devices.
- **Operating Voltage:** The FC-37 rain sensor module typically operates with a voltage supply in the range of 3.3V to 5V DC, making it compatible with most microcontroller systems.
- **Low Cost:** Affordable and widely available, the FC-37 rain sensor module offers a cost-effective solution for detecting rainfall in various projects and applications.

4.2.3: REAL TIME CLOCK MODULE (DS3231)

Maxim Integrated's DS3231 is a real-time clock module that is very accurate and reliable, loved by hobbyists and professionals alike. It provides timekeeping that is highly precise in this module. It has an integrated TCXO and a built-in temperature sensor that renders accurate timekeeping in fluctuating environmental conditions. In addition, it is interfaced with I2C, which makes it easy to be applied to various projects, ranging from data loggers to alarm clocks, and many more time-sensitive applications. The DS3231 is also equipped with several additional features, including battery backup and even alarms, which make it almost the perfect choice for many kinds of timekeeping applications.

The DS3231 RTC module from Maxim Integrated comes with several featured specifications and allows you to do some great things in timekeeping applications. Here are some of its major features and specifications:

- **Features:**

    • **High Accuracy: The** DS3231 uses a temperature-compensated crystal oscillator (TCXO) to achieve highly accurate timekeeping with typical accuracy of ±2 ppm (parts per million) from 0°C to +40°C.

    • **Internal Digital Temperature Sensor:** It is fitted with an internal digital temperature sensor that measures temperature with an accuracy of ±3°C.

    • **Temperature Compensation:** The DS3231 compensates its timekeeping frequency according to temperature readings from the internal sensor, thus ensuring accurate timekeeping over wide temperature ranges.

    • **I2C Serial Interface:** It is easily interfaced with other microcontrollers or devices through the Inters-Integrated Circuit (I2C) serial interface, which makes the integration with different projects very easy.

• **Backup Battery Input**: This unit has an internal backup battery input, together with automatic switching to battery power in the case of main power loss, which allows for continued operation of timekeeping.

• **Programmable Time-Of-Day Alarms:** The unit can have up to two programmable time-of-day alarms with repeat functions, so the user can program alarms according to specific time or date.

• **Square Wave Output:** The DS3231 outputs square waves at several frequencies, such as 1Hz, 1.024kHz, 4.096kHz, or 8.192kHz, which makes it very handy for applications, for example, in clock generation or periodic triggering of events.

• **Low Power:** The DS3231 operates with typical operating current consumption of just 200uA, so it is usable for battery-based applications, which require low power consumption.

• **Compact Size:** The DS3231 is available in miniature packages like SOIC and DFN, so it is available for space-constrained applications.

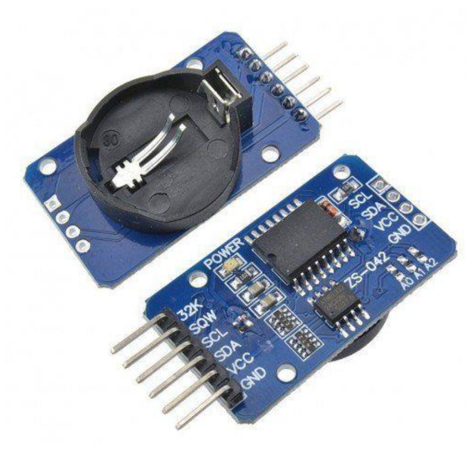


Fig 4.2.3 RTC Module

- **Specifications:**

• Power Supply Voltage: 2.3V to 5.5V
• Power Operating Temperature Range: -40°C to +85°C
• Operating Life: 2 years, at 23°C with input to the backup battery terminal and the internal digital temperature sensor
• Output Pulse Width: 14µS max
• Power Consumption: Low — typically < 200uA — (depending upon the time format and alarming)

- **Working principle of DS3231:**

1. **Timekeeping Accuracy**:
    - The DS3231 maintains hours, minutes, seconds, day, month, and year information.
    - It compensates for leap years and months with fewer than 31 days.
    - A temperature-compensated crystal oscillator (TCXO) ensures accurate timekeeping.
2. **Battery Backup**:
    - Unlike the Arduino’s internal clock, the DS3231 runs on a battery.
    - Even during power loss or reprogramming, it continues tracking time.
    - A typical CR2032 3V battery can power it for over a year.
3. **I2C Communication**:
    - The DS3231 communicates via I2C (Inter-Integrated Circuit) protocol.
    - It requires minimal connections: VCC, GND, SDA (data), and SCL (clock).
    - Compatible with both 3.3V and 5V microcontrollers.
4. **Programming**:
    - Use libraries (e.g., Henning Karlsen’s DS3231 library) to program the module.
    - Set date, time, and day of the week using simple commands in your code.

4.2.4: GSM MODULE (SIM800L)

The SIM800L GSM module is one of the most popular choices for adding GSM/GPRS communication capabilities to microcontroller-based projects. It can be used to connect devices to a network, enabling functions such as sending and receiving SMS messages and making/receiving calls and accessing the internet over GPRS. The module is compact in size, very user-friendly, and operates over a wide range of voltages, making it applicable to a wide variety of uses. It communicates with the microcontroller via the UART interface and is configured and controlled with the help of AT commands. Due to its low power consumption and robust performance, the SIM800L module is used in a wide variety of applications, including those related to IoT, tracking systems, and security systems.

Fig 4.2.4 GSM Module

- **Specifications:**

    Interface Type: TTL UART
    Baud Rate: Adaptive (default), Support 2400-115200
    Input Supply Voltage: 5V DC
    Power Interface: 2.54mm Pin Header/Micro USB
    Antenna Interface: ASMA, IPX
    Voice Interface: 3.5mm

- **Features:**

  - Network support: Quad-Band 850/900/1800/1900 MHz – works on GSM networks in all countries across the world.
  - TTL serial interface compatible with 3.3V and 5V MCU
  - The small size is suitable for all kinds of sleeve belt types and embedded.
  - playing card slot, convenient change mobile phone card. Can side reserve replacement cell phone bayonet into the box.
  - using the IPX interface can arbitrarily change the antenna. The default PCB antenna greatly reduces: use the of space.

- **Pin Description:**

  - **5v:** Power interface Power the module CONNECT TO DC 5v
  - **GND:** Connect to GND
  - **VDD:** If the development board's TTL level is 5V (Example: UNO, Mega, Nano), then supply 5V. If it is 3.3V (Example: NodeMCU), then supply 3.3V
  - **SIM_TXD:** SIM module Transmitter
  - **SIM_RXD:** SIM module Receiver
  - **GND:** If this pin is unused, keep open
  - **RST:** RST the module, if this pin is unused, keep open

4.2.5: STEPPER MOTOR (17HS4401)

The 17HS4401 stepper motor is a commonly used stepper motor in various applications, especially in CNC machines, 3D printers, and robotic systems.

- **Features**
  - **NEMA 17 Standard:** The 17HS4401 stepper motor conforms to the NEMA 17 standard, which specifies its dimensions and mounting hole pattern. This standardization allows for easy integration into various systems.
  - **Bipolar Configuration:** This stepper motor operates in a bipolar configuration, meaning it has two coils that require a bipolar stepper motor driver for control. This configuration offers precise control over the motor's movement.
  - **High Torque:** The 17HS4401 stepper motor provides high torque relative to its size, making it suitable for applications requiring precise and powerful motion.
  - **Step Angle:** It typically has a step angle of 1.8 degrees per step. This means that the motor rotates 1.8 degrees with each step when energized appropriately.
  - **Rated Voltage and Current:** The rated voltage and current of the 17HS4401 motor vary depending on the specific model and manufacturer. However, common ratings include a voltage range of 2V to 4V and a current range of 1A to 2A per phase.
  - **Shaft Diameter and Length**: The shaft diameter is typically 5mm, and the shaft length varies depending on the manufacturer. This shaft size is compatible with various couplings and pulleys used in mechanical systems.
  - **High Precision:** It offers high precision and repeatability in motion control applications, making it suitable for tasks that require accurate positioning and smooth movement.
  - **Low Noise and Vibration:** The 17HS4401 stepper motor operates with low noise and vibration levels, contributing to quieter and smoother operation in machinery.

- **Temperature Range:** It can operate within a wide temperature range, typically between -20°C to +50°C, making it suitable for use in various environmental conditions.

Fig 4.2.5 Stepper motor

- **Working principle of stepper motor**

The 17HS4401 stepper motor operates on the principle of electromagnetic induction to achieve controlled and precise movement. It consists of two coils wound around a central rotor, which is typically a permanent magnet or contains a magnetized core. When an electric current passes through these coils, they generate magnetic fields. The rotor interacts with these magnetic fields, causing it to align itself in discrete steps with the magnetic field generated by the coils. Each step corresponds to a specific angle of rotation, typically 1.8 degrees for the 17HS4401 motor. To rotate the motor continuously or move it to a specific position, the coils are energized in a specific sequence. This sequencing of coil energization is managed by a control circuit, which can range from simple switches to complex microcontroller-based driver circuits. By controlling the sequence and timing of coil energization, the motor can be accurately positioned, making it suitable for applications requiring precise control and positioning, such as robotics, CNC machines, and 3D printers.

- **Specifications**

  - Operating Voltage: 12VDC
  - Step Angle: 1.80°
  - Length: 34mm
  - Current: 1.30A
  - Resistance/Phase: 2.4ohm
  - Holding Torque: 28Ncm
  - Detent Torque: 1.6Ncm
  - Winding Type: Bipolar

4.2.6: STEPPER MOTOR DRIVER (DRV8825)

The DRV8825 is a robust stepper motor driver module designed for precise motion control in applications like 3D printers and CNC machines. With its high current capability of up to 2.5A per coil, it can efficiently drive stepper motors with demanding power requirements. The module supports micro-stepping allowing for smoother movement and finer resolution. Its adjustable current limit feature enables users to tailor the motor current to specific requirements. Additionally, built-in overtemperature protection ensures safe operation by preventing overheating. Compatible with both 3.3V and 5V logic levels, the DRV8825 offers versatility and ease of integration with various control systems. Overall, it provides reliable and precise motor control, making it a popular choice among hobbyists and professionals alike.

The DRV8825 is a popular stepper motor driver module commonly used in 3D printers, CNC machines, and other motion control applications. Here's an overview of its features and how it works:

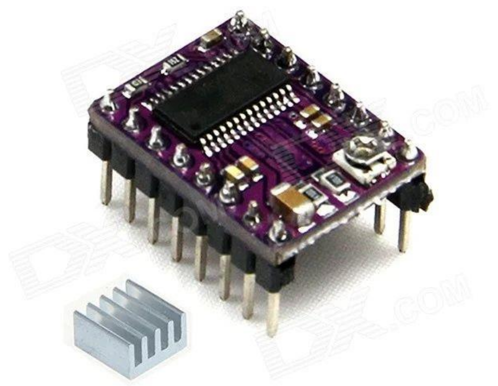


Fig 4.2.6 Stepper Motor Driver

- **Features**

1. **High Current Capability:** The DRV8825 is capable of driving stepper motors with high current requirements, typically up to 2.5A per coil.

2. **Micro-stepping:** It supports micro-stepping, allowing for smoother motion and finer resolution compared to full-step operation. Micro-stepping divides each full step into smaller steps, typically ranging from 1/2 to 1/32 of a full step.

3. **Adjustable Current Limit:** The driver module includes a potentiometer for adjusting the current limit, enabling users to set the appropriate motor current based on the motor's specifications and application requirements.

4. **Overtemperature Protection:** It features built-in overtemperature protection, which helps prevent damage to the driver module and the connected stepper motor in case of overheating.

5. **Built-in Translator:** The DRV8825 integrates a stepper motor translator, which simplifies the control interface between the driver module and the microcontroller or other control electronics.

6. **Compatible with 3.3V and 5V Logic Levels:** The driver module is compatible with both 3.3V and 5V logic levels, making it versatile and compatible with a wide range of microcontrollers and control systems.

- **Working principle of DRV8825**

  - **Step Generation:** The DRV8825 generates step pulses based on the signals received from the control electronics, such as a microcontroller. These step pulses determine the direction and step size of the connected stepper motor.
  - **Micro-stepping Control:** By controlling the timing and amplitude of the current supplied to the stepper motor coils, the DRV8825 achieves micro-stepping. This allows for smoother motion and higher resolution compared to traditional full-step operation.
  - **Thermal Management:** The DRV8825 includes thermal protection mechanisms to monitor the temperature of the driver module. If the temperature exceeds a certain threshold, the driver reduces the current supplied to the motor to prevent overheating.

- **Pin Descirption**

  1**. VCC**: This pin is used to supply power to the internal logic of the DRV8825. It typically requires a voltage between 3.3V and 5V.

  2. **GND:** The ground pin serves as the reference point for all other voltages on the module.

  3. **VMOT:** This pin is used to supply power to the stepper motor. It typically requires a higher voltage than the logic voltage (VCC), often in the range of 8V to 35V, depending on the motor's specifications.

4. **STEP:** The STEP pin is used to input step pulses to the DRV8825, which control the movement of the stepper motor. Each pulse corresponds to a single step of the motor.

5. **DIR:** The DIR (direction) pin determines the direction of rotation of the stepper motor. A logic high or low signal on this pin controls the direction of movement.

6. **MODE0, MODE1, MODE2:** These pins are used to set the micro-stepping mode of the DRV8825. By configuring these pins to different logic levels (high or low), users can select various micro-stepping resolutions, such as full-step, half-step, quarter-step, etc.

7. **RESET:** The RESET pin is used to reset the driver module, typically to its default settings. Pulling this pin low resets the internal state of the DRV8825.

8. **FAULT:** The FAULT pin is an output pin that indicates any fault conditions detected by the DRV8825, such as overtemperature or overcurrent conditions.

9. **MS1, MS2, MS3:** These pins are alternative options for setting the micro-stepping mode, similar to MODE0, MODE1, and MODE2.

10. **GND:** This pin is connected to the ground of the sense resistors used to set the current limit of the stepper motor.

4.2.7: BUCK CONVERTER

The LM2596S module is compact and easy to use, making it suitable for various electronic projects and applications. It typically consists of a small printed circuit board (PCB) with surface-mount components, including the LM2596S voltage regulator IC, input and output capacitors, an inductor, and an adjustable potentiometer for voltage regulation. The module may also include input and output terminals or pins for easy connection to external power sources and loads.

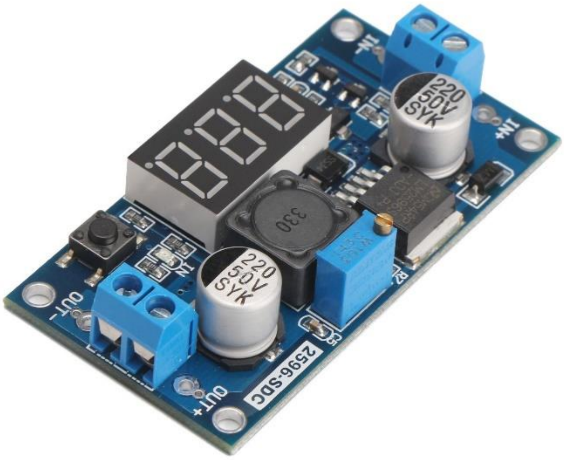


Fig 4.2.7 Buck Converter

- **Features:**

1. **Wide Input Voltage Range:** The LM2596S can accept input voltages from 3V to 40V, allowing it to be used with a variety of power sources, including batteries, solar panels, and AC adapters.

2. **Adjustable Output Voltage:** It provides an adjustable output voltage ranging from 1.5V to 35V, which can be precisely set using the onboard potentiometer. This flexibility makes it suitable for powering a wide range of electronic devices and components.

3. **High Output Current Capacity:** With a maximum output current of 3A, the LM2596S can deliver sufficient power to drive moderate to high-current loads, such as motors, LEDs, and microcontrollers.

4. **High Efficiency:** The module offers high efficiency, typically around 80% to 90%, depending on input voltage, output voltage, and load conditions. This efficiency helps

minimize power loss and heat generation, ensuring reliable operation and extending battery life in portable applications.

5. **Protection Features:** The LM2596S includes built-in protection features to enhance the reliability and safety of the module and connected devices. These features may include overcurrent protection (OCP), thermal shutdown, and input reverse polarity protection.

6. **Compact Design:** With its compact size and minimal external component requirements, the LM2596S module is easy to integrate into various projects and applications with limited space constraints.

7. **Easy to Use:** The module requires minimal external components for operation, making it easy to use even for beginners or hobbyists with basic electronics knowledge.

8. **Versatile Applications: The** LM2596S buck converter module is commonly used in DIY electronics projects, battery-powered devices, automotive electronics, LED lighting systems, and other applications requiring efficient voltage conversion and regulation.

4.2.8: 12V 5A POWER SUPPLY

A metal casing power pack rated at 12V and 5A is a robust power supply unit designed to deliver a maximum output of 12 volts with a current of up to 5 amperes. This voltage acts as the electrical potential difference, akin to water pressure in a pipe, while the amperage represents the rate of electric charge flow through a circuit. Encased in metal, these units are chosen for their durability, efficient heat dissipation, and ability to shield against electromagnetic interference.

Fig 4.2.8 Power Supply

Typically, such power packs are utilized to power various electronic devices like LED light strips, small motors, and sensors, among others, which have low power requirements. It's crucial to ensure that the power needs of any intended device align with or fall below the power pack's capabilities to prevent potential damage to either the device or the power supply. In essence, a 12V 5A metal casing power pack is a reliable source of electrical power suited for low-power electronics, housed in a sturdy metal enclosure, with careful matching of power requirements to avoid any mishaps.

4.3: WORKING PRINCIPLE

4.3.1: WORKING PROCEDURE

In this design I have used a gear rack and pinion for the movement of the window using the stepper motor, which enables for precise movement of the window.

- The system consists of three units:
    1. Rain Detection Unit
    2. Automated Closure Unit
    3. Fixed Time Closure Unit
    4. Notification Unit

The Rain Detection Unit:

This unit is made of a rain sensor, the ESP32 board, motor driver and the stepper motor. When it rains the rain sensor detects moisture and sends an input signal into the ESP32 board that is programmed to close the window at moments that it rains. When raindrops make contact with the sensor's surface, altering its conductivity, the sensor promptly relays a signal to the microcontroller. This signal serves as a prompt for the window system to activate, swiftly closing the window to prevent water ingress into the interior space.

The Automated Closure Unit:

By utilizing the microcontroller, ESP32 board, programmed to communicate with the Blynk app via Wi-Fi or cellular connectivity. Real-time status updates and notifications provided by the Blynk app keep users informed of any changes in window status or operation, enhancing usability and peace of mind. In essence, the automated closure unit using the Blynk app epitomizes the seamless integration of technology and user-centric design. All the user has to do this use the blynk app on the smartphone to open or close the window according his liking.

The Fixed Time Closure Unit:

The window closing at a fixed time is facilitated by the integration of a real-time clock (RTC) module, such as the DS3231, with the microcontroller within the smart window system. This RTC module accurately keeps track of time independent of external factors, ensuring precise timing for scheduled events. Through programming, the microcontroller is configured to receive time updates from the RTC module and execute the closing command when the specified time, such as 4 pm, is reached. This process enables the window to close automatically at the predetermined time each day, enhancing convenience, energy efficiency, and security within the home or building.

The Notification Unit:

Notifications are sent through the GSM module, specifically the SIM800L module, which enables communication via SMS or calls. Integrated with the microcontroller within the smart window system, the GSM module is programmed to send notifications to the user's mobile phone when certain events occur, such as the window closing due to rain or reaching a specified time, such as 4 pm.

When triggered, the microcontroller sends a signal to the GSM module, instructing it to initiate communication with the user's mobile phone. Depending on the programming logic, the GSM module sends a pre-defined SMS message containing relevant information about the event.

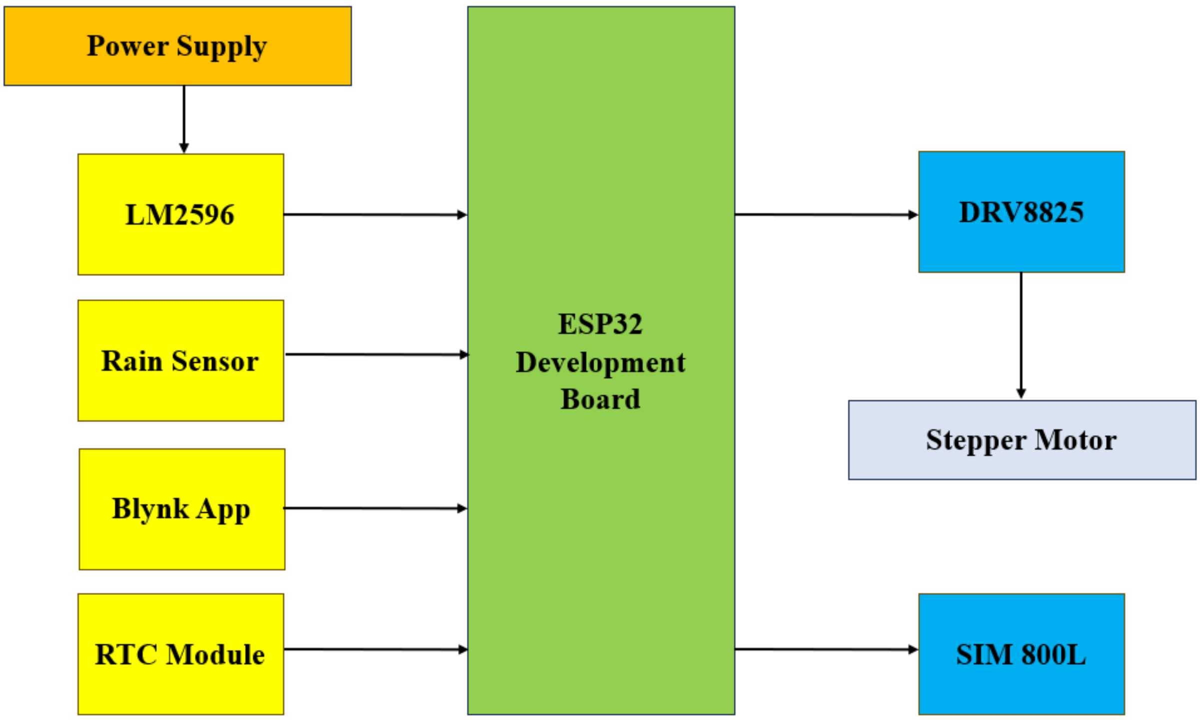
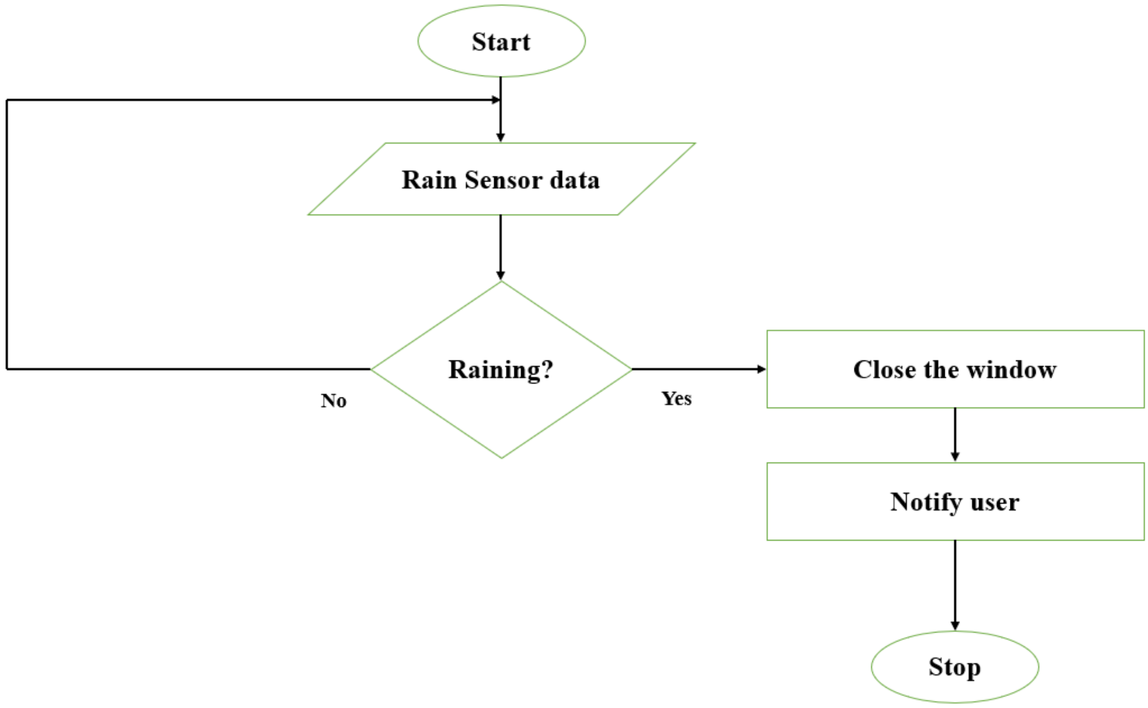


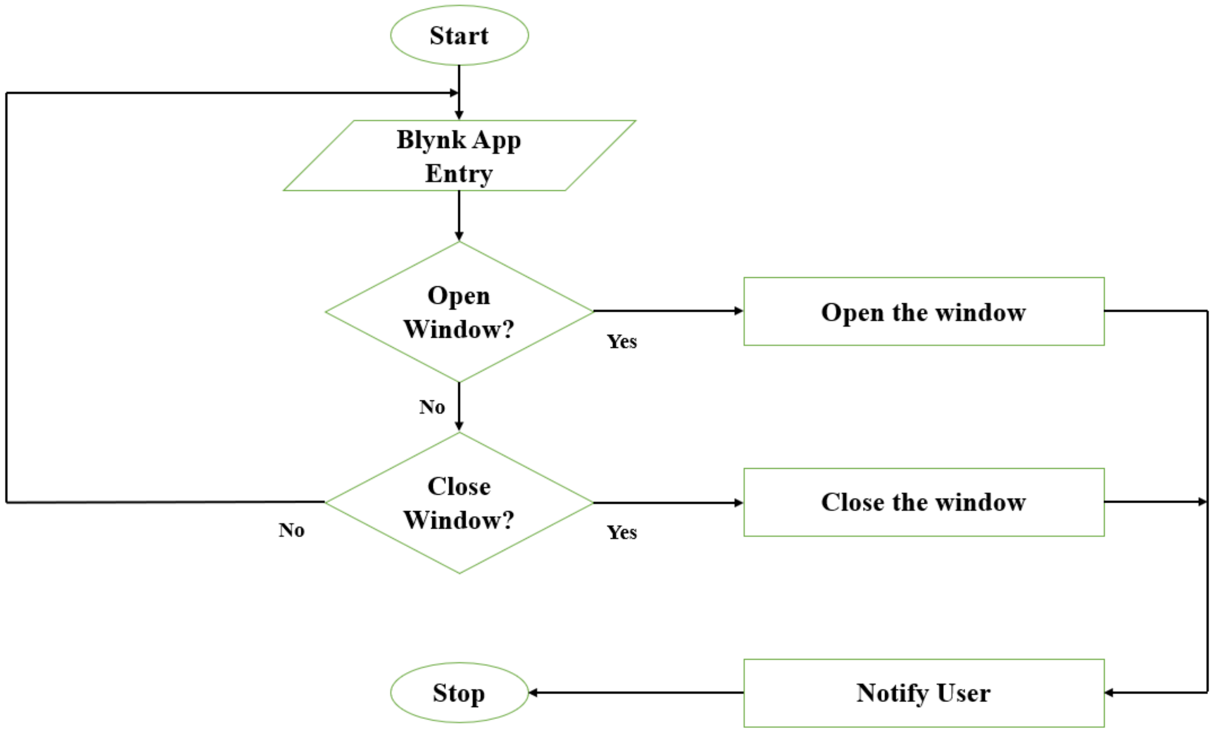
Fig 4.3.1 Layout of the smart window

4.3.2: FLOWCHART

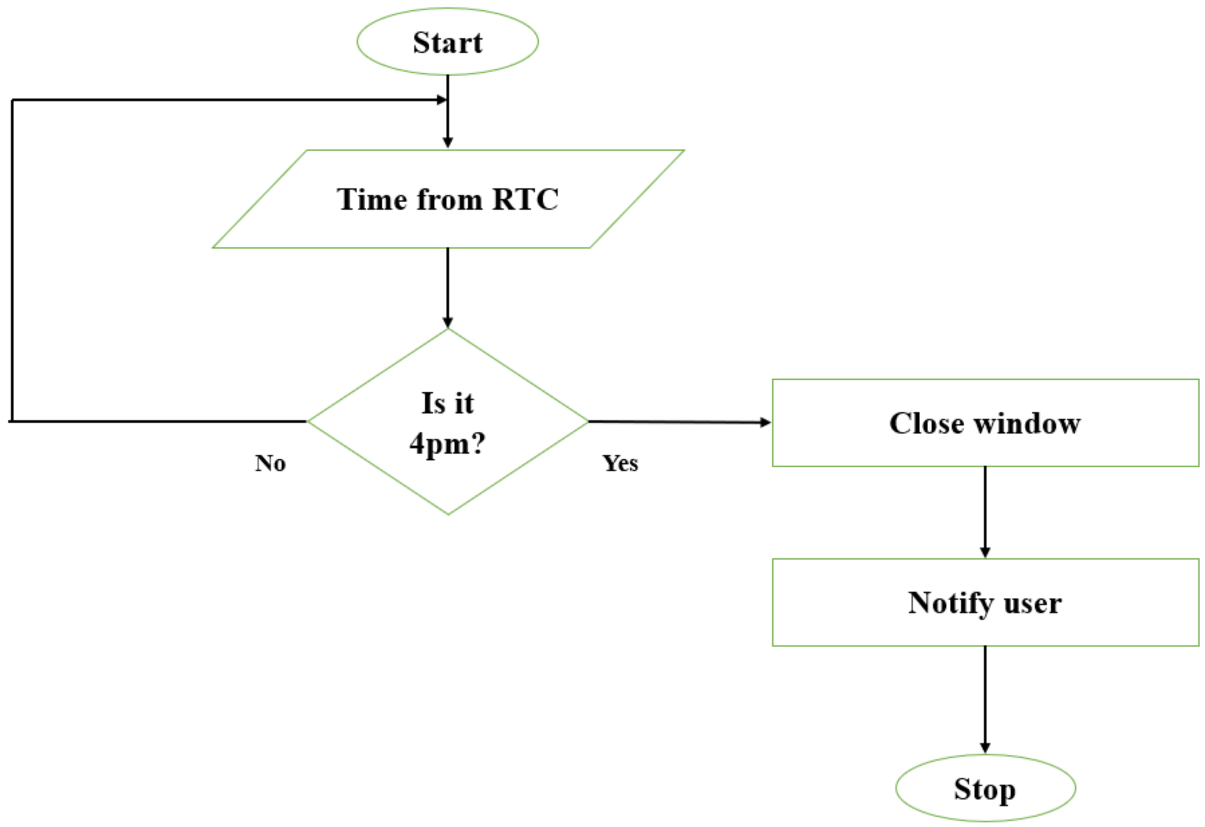
- **Rain Detection Unit**



- **Automated Closure Unit**



- **Fixed Time Closure Unit**



4.3.3: CIRCUIT DEVELOPMENTS

- DRV8825, Stepper motor and LM2596 not included.
- The stepper motor driver DRV8825 has 4 connections to the stepper motor and ENABLE, STEP, FLT and GND pins of the DRV8825 are connected to D19, D18, VIN and GND pins of the ESP32 board. Also, the RST and SLP pins of the DRV8825 are shorted.
- A 12V power is supplied to the stepper motor through the DRV8825. Power is supplied through VMOT and GND pins of the driver.
- The voltage is step down to 5V using the LM2596 to supply power to the SIM800L GSM module. And the TXD and RXD pins of the GSM module are connected to TX2 ad RX2 pins of the ESP32 board.
- The SCL, SDA, VCC and GND pins of the RTC module are connected to the D22, D21, 3V3 and GND pins of the ESP32 board.
- The VCC, GND, A0 pins of the rain sensor are connected to the 3V3, GND, D12 pins of the ESP32 board.

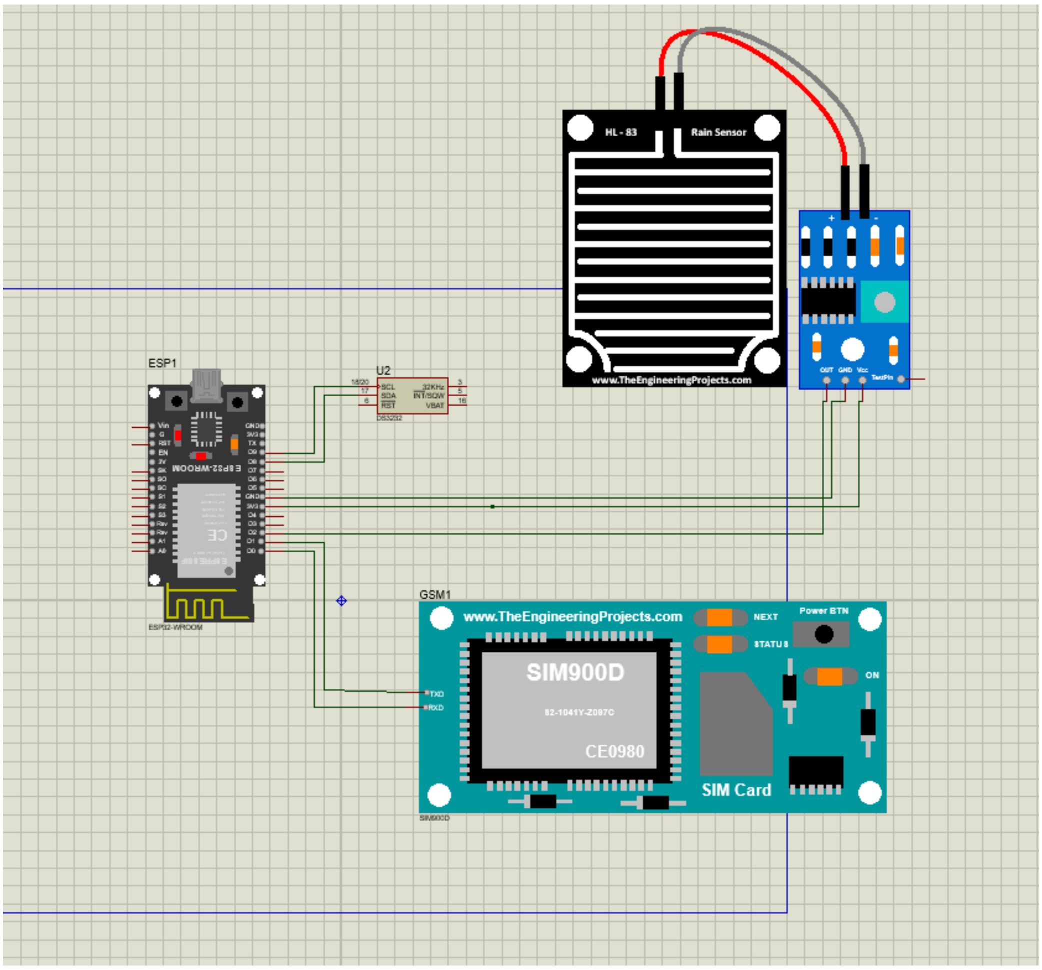


Fig 4.3.3 Proteus Simulation

4.3.4: ARDUINO CODE

Code is provided in Annexture 1

4.4: COST ANALYSIS

ITEM	COST
Circuit components	7000
Soldering Iron 40W	1500
Soldering wire lead	300
Power Supply	1200
Gear rack and pinion	6000
Net Total	10000
Cost of the product considering only circuit components and miscellaneous costs related to the product	8500
Estimated market price	15000-20000

CHAPTER 5: FINAL OUTCOME AND DISCUSSION

5.1: FINAL OUTCOME

I was able to finish the project as I proposed in my project proposal. The following figures show the final prototype;

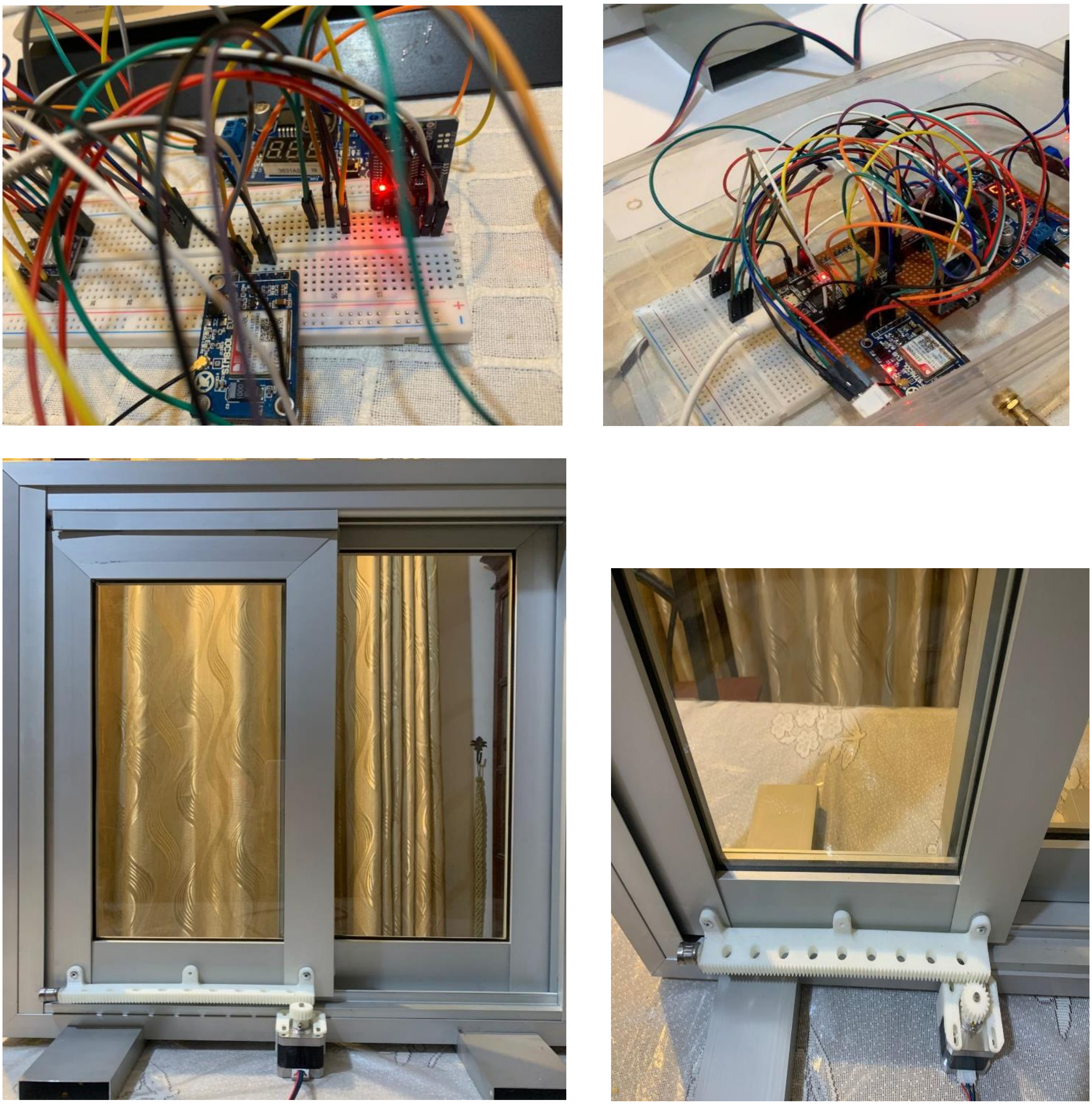


Fig 5.1 Final Circuit and Design

5.2: DISCUSSION

The IoT-based smart window project showcases multiple technologies to automate window operations based on environmental conditions, user commands, and scheduled timings. At the heart of the system lies the ESP32 microcontroller, which takes inputs from a rain sensor, RTC module, Blynk app and controls a stepper motor to open or close the window. The ESP32’s built-in Wi-Fi capability allows seamless connectivity with the Blynk app, enabling users to remotely control and monitor the window through a user-friendly interface. This remote - control feature is further enhanced by the Blynk app’s virtual pins, which facilitate smooth communication between the user and the hardware.

A critical component of the system is the rain sensor, which automatically closes the window when it detects rain, thus protecting the interior from water damage. This real-time responsiveness is essential for the system’s reliability and underscores the practical benefits of such an automated setup. The RTC module (DS3231) adds another layer of functionality by allowing the window to close at predetermined times, such as at night or during specific hours when the user is not at home. The DS3231’s high accuracy ensures that these scheduled operations are carried out reliably, enhancing the system's security features.

The inclusion of a GSM module that sends SMS notifications for various actions like window movements and rain detection keeps users informed about the window’s status even when they are not actively monitoring the system. This communication layer adds a significant security benefit, ensuring users are always aware of the state of their window. The stepper motor, combined with a gear rack and pinion mechanism, efficiently converts rotational motion into the linear motion needed to open and close the window. This setup ensures precise control and smooth operation, crucial for the system's functionality. The motor driver connected to the ESP32 ensures that the motor receives the correct power and signals for operation.

Despite the project's successes, several challenges must be addressed. Managing the power requirements of various components, particularly the stepper motor, is critical to avoid interruptions in operation. Ensuring a stable power supply, possibly through voltage regulators or dedicated power sources for the motor, is essential. Signal interference from the GSM module is another potential issue, which can be mitigated through proper shielding and spatial separation of components.

Overall, the IoT-based smart window project successfully demonstrates the potential of IoT solutions in enhancing home automation through a practical and user-friendly system.

5.3: ENCOUNTED PROBLEMS AND IMPLEMENTED SOLUTIONS

The development of the IoT-based smart window project involved tackling several technical and integration challenges. One of the significant challenges was ensuring a stable power supply to all components, particularly the stepper motor, which has high power demands. Inconsistent power could lead to interruptions in operation or potential damage to the components. To address this, a dedicated power supply for the stepper motor was used, and a buck converter was used to power the ESP32.

I had to ensure the system could handle real-world conditions, such as sensor malfunctions, communication failures, and power outages, was crucial for maintaining continuous operation. Redundant sensors and fail-safes were incorporated into the system design. For instance, a manual override switch was added, allowing users to operate the window manually if the system failed.

Achieving precise control over the stepper motor’s movements was challenging, especially given the need for smooth and reliable opening and closing of the window. Fine-tuning the motor driver settings and implementing micro-stepping techniques improved the precision of the stepper motor control. The gear rack and pinion mechanism were carefully calibrated to ensure smooth linear motion, and limit switches were added to define the window’s fully open and fully closed positions, preventing over-driving.

Through addressing these challenges with targeted solutions, the smart window system was enhanced for robustness, reliability, and user satisfaction. These improvements not only solved immediate issues but also laid the groundwork for future enhancements and scalability of the system.

5.4: LIMITATIONS

The system's reliance on Wi-Fi for communication with the Blynk app means that its remote control and monitoring capabilities are contingent upon a stable internet connection. Any disruptions in Wi-Fi connectivity can hinder the user's ability to operate the window remotely, thereby limiting the system's usability during internet outages.

The effectiveness of the GSM module for sending SMS notifications is dependent on the availability and strength of the GSM network. In areas with poor network coverage or during network outages, there can be significant delays or failures in delivering notifications, compromising the system's ability to inform users promptly.

During an outage, the window cannot be operated automatically, and if the backup is not well-maintained, the system could fail during critical times.

The system currently uses a rain sensor for environmental detection. However, it does not account for other environmental factors like strong winds, extreme temperatures, or humidity, which could also necessitate closing the window for safety or energy efficiency.

IoT devices are susceptible to security vulnerabilities. The smart window system could be a target for hacking if not properly secured.

5.5: KNOWLEDGE GAINED

An understanding of integrating various IoT components was developed. This includes interfacing sensors (rain sensor, RTC module), actuators (stepper motor), communication modules (GSM), and controllers (ESP32), learning to ensure these components work together. Programming the ESP32 microcontroller using Arduino IDE provided practical skills in embedded systems programming. Writing and debugging code to read sensor data, control actuators, and manage communications via Wi-Fi and GSM broadened expertise in programming for embedded systems.
Using the Blynk platform for remote control and monitoring of the window system facilitated learning about mobile app integration with IoT devices. This involved setting up the Blynk app, and managing virtual pins for communication between the app and the microcontroller.

Managing power requirements for different components, especially high-power devices like stepper motors, taught valuable lessons in power distribution and regulation. Implementing solutions such as dedicated power supplies and voltage regulators helped ensure stable and reliable operation.

Integrating the stepper motor with a gear rack and pinion mechanism provided insights into mechanical design and control systems. Learning to convert rotational motion to linear motion effectively and ensuring precise control over the motor’s movements was an essential part of the project.

The project allowed for the practical application of theoretical concepts learned in coursework. Concepts from electronics, programming, network communication, and mechanical engineering were put into practice, reinforcing their real-world applications.

CHAPTER 6: CONCLUSIONS AND FUTURE WORKS

6.1: CONCLUSION

The IoT-based smart window project represents a significant achievement in integrating diverse technologies to create a functional and user-friendly automated window system. Through the development process, extensive knowledge was gained in areas such as IoT system integration, microcontroller programming, real-time systems, and mobile application interaction. The project not only showcased the practical applications of theoretical concepts but also highlighted the importance of power management, communication protocols, and mechanical design. Despite facing challenges such as ensuring stable power supply, mitigating signal interference, and achieving synchronization, the solutions implemented demonstrated problem-solving skills and technical ingenuity. The project also underscored the critical importance of security considerations in IoT systems and provided valuable experience in project management and teamwork. In conclusion, the successful completion of this project has provided a solid foundation in both the technical and practical aspects of IoT development and we could develop it further to improve the project beyond this level.

6.2: FUTURE WORKS

In the future many steps could be taken to make this device even better. Incorporating a reliable battery backup system would ensure the smart window operates during power outages. This enhancement would involve selecting an appropriate battery, integrating a charging circuit, and ensuring seamless switching between mains power and battery power.

Expanding the system to include more environmental sensors, such as temperature, humidity, wind speed, and air quality sensors, can provide comprehensive control over the window’s operation. These sensors can enhance the system's capability to create an optimal indoor environment by responding to various external conditions.

Implementing advanced security measures, such as end-to-end encryption for data transmission, regular firmware updates, and secure boot mechanisms, can protect the system from unauthorized access and potential cyber threats.

Enhancing the user interface of the Blynk app to provide more detailed status updates, historical data, and predictive analytics can improve user experience. Offering customization options for notifications and control settings would also be beneficial.

CHAPTER 7: ANNEXTURE

7.1: ARDUINO CODE

```
#define BLYNK_TEMPLATE_ID "TMPL6bD2KEXTs"
#define BLYNK_TEMPLATE_NAME "Motor"
#define BLYNK_AUTH_TOKEN "llygsdgSIVl1QGE-T_EAcK2pLmizNi8u"

#define BLYNK_PRINT Serial

#include <WiFi.h>
#include <Wire.h>
#include <RTClib.h>
#include <SoftwareSerial.h>
#include <BlynkSimpleEsp32.h>

char auth[] = BLYNK_AUTH_TOKEN;  // Replace "YourAuthToken" with your
Blynk authentication token
char ssid[] = "Siyol-4G3D4D0D";   // Replace "YourWiFiSSID" with your WiFi SSID
char pass[] = "leoBoy123";  // Replace "YourWiFiPassword" with your WiFi
password

#define RAIN_SENSOR_PIN 12
#define EN_PIN   19 // Enable
#define STEP_PIN  18 // Step
#define DIR_PIN   4  // Direction
#define SIM800_TX_PIN 17
#define SIM800_RX_PIN 16
```

```
BlynkTimer timer;
RTC_DS3231 rtc;


void setup() {
  Serial.begin(9600);

  if (!rtc.begin()) {
    Serial.println("Couldn't find RTC");
  }

  if (rtc.lostPower()) {
    rtc.adjust(DateTime(F(_DATE), F(TIME_)));
  }

  pinMode(RAIN_SENSOR_PIN, INPUT);
  pinMode(EN_PIN, OUTPUT);
  digitalWrite(EN_PIN, HIGH); // Deactivate driver (LOW active)

  pinMode(DIR_PIN, OUTPUT);
  digitalWrite(DIR_PIN, LOW); // Set the direction pin to low

  pinMode(STEP_PIN, OUTPUT);
  digitalWrite(STEP_PIN, LOW); // Set the step pin to low
  digitalWrite(EN_PIN, LOW);
  pinMode (V1, OUTPUT);
```

```
  pinMode (V2, OUTPUT);
  Blynk.begin(auth, ssid, pass);
}

int flag = 0;
void loop() {
  int isRaining = digitalRead(RAIN_SENSOR_PIN);

  if (isRaining == LOW && flag == 0) {
    rotateMotor(875, 0, 1100);
    Serial.println("Its Raining");
    sendSMS("Window closed due to rain!"); // Rotate clockwise to close the window
    flag = 1;
    delay(10000);
  } else if (isRaining == HIGH && flag == 1) {
    flag = 0;
  }

  DateTime now = rtc.now();
  if (now.hour() == 13 && now.minute() == 40 && now.second() == 0) {
    // Rotate the motor clockwise
    rotateMotor(875, 0, 1100);
    sendSMS("Window closed as scheduled!");
    delay(1000); // Adjust as needed
  }
  delay(100);
  Blynk.run();
```

```
  timer.run();
}

// Function to rotate the motor
void rotateMotor(int steps, bool direction, int speed) {
  // Set the motor direction
  digitalWrite(DIR_PIN, direction);

  // Step the motor
  for (int i = 0; i < steps; i++) {
    digitalWrite(STEP_PIN, HIGH);
    delayMicroseconds(speed);
    digitalWrite(STEP_PIN, LOW);
    delayMicroseconds(speed);
  }
}

SoftwareSerial serialSIM800(SIM800_TX_PIN,SIM800_RX_PIN);
void sendSMS(String message) {
  serialSIM800.begin(9600);
  delay(1000);

  Serial.println("Setup Complete!");
  Serial.println("Sending SMS...");

  //Set SMS format to ASCII
  serialSIM800.write("AT+CMGF=1\r\n");
```

```
  delay(1000);

  //Send new SMS command and message number
  serialSIM800.write("AT+CMGS=\"+94771143079\"\r\n");
  delay(1000);

  //Send SMS content
  serialSIM800.print(message);
  delay(1000);

  //Send Ctrl+Z / ESC to denote SMS message is complete
  serialSIM800.write((char)26);
  delay(1000);

  Serial.println("SMS Sent!");
}

// Blynk app button to move the motor clockwise
// Blynk app button to move the motor clockwise
BLYNK_WRITE(V1) {
  int buttonState = param.asInt();
  if (buttonState == 1) { // If button is pressed
    rotateMotor(925, 1, 1100); // Rotate clockwise
    sendSMS("Window opened!");
    digitalWrite(EN_PIN, LOW);

     // Activate driver
```

```
  }
}

// Blynk app button to move the motor counterclockwise
BLYNK_WRITE(V2) {
  int buttonState = param.asInt();
  if (buttonState == 1) { // If button is pressed
    rotateMotor(875, 0, 1100); // Rotate counterclockwise
    sendSMS("Window closed!");
    digitalWrite(EN_PIN, LOW);
     // Activate driver
  }
}
```

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