Automatic Window Operator

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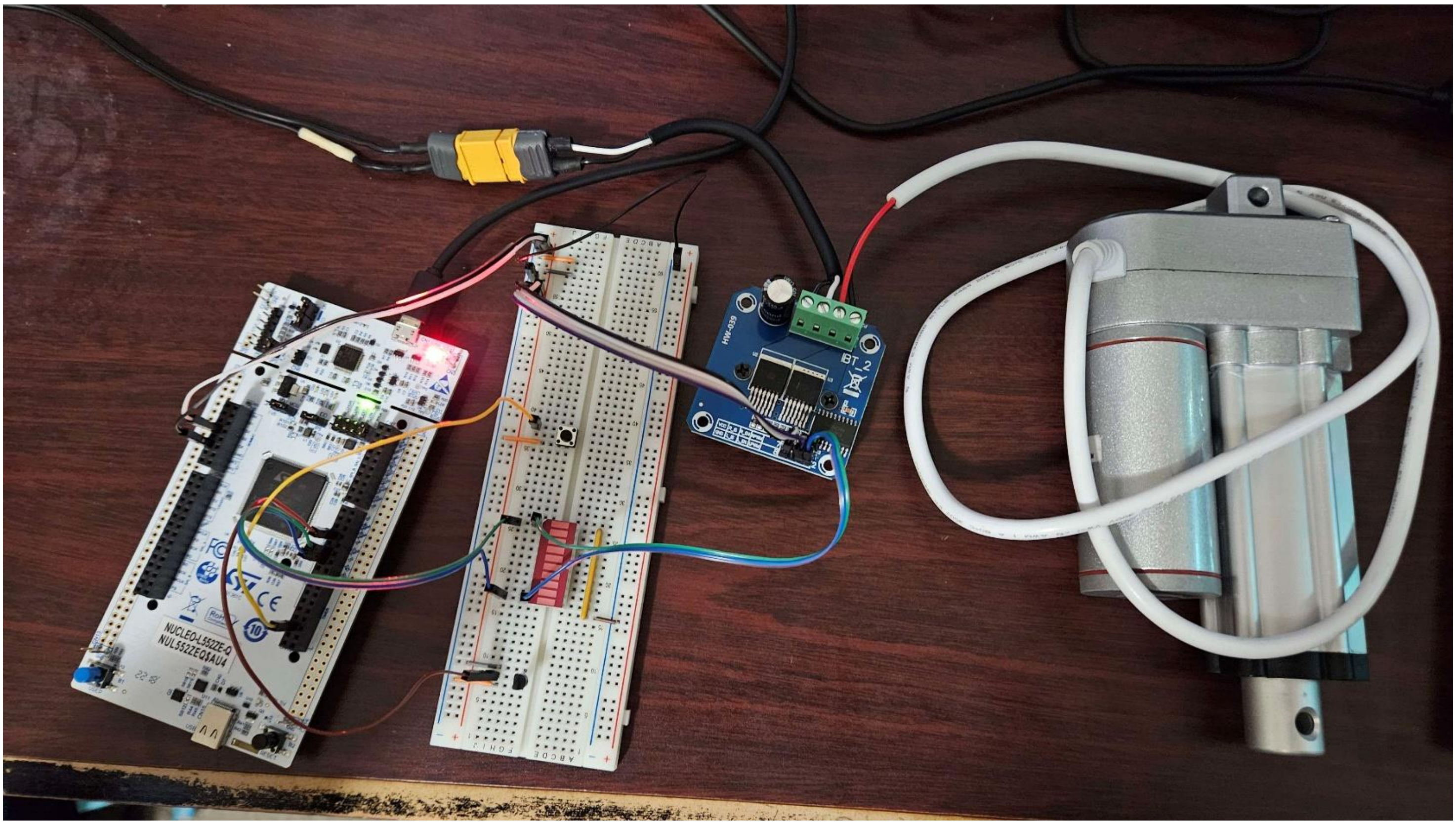


Abstract

The "Automatic Window Operator" project proposes a novel solution to enhance safety, comfort, and convenience in residential and commercial settings through automated window operations. Leveraging advanced sensor technologies and cyber components, the system intelligently adjusts window openings based on ambient light levels, ensuring optimal ventilation and climate control. By integrating physical components such as photoresistors, relays, and linear actuators with cyber components like STM32 CubeIDE and Finite State Machine logic, the project showcases the capabilities of automated systems in real-world applications. Through MATLAB simulations and rigorous testing, the system demonstrates its reliability, scalability, and potential for integration with IoT platforms. The project not only addresses immediate needs for efficient window management but also lays the foundation for future advancements in home automation and smart building technologies.

1. Introduction

In the ever-evolving landscape of modern living, the pursuit of safety, comfort, and convenience has become paramount. Innovations in technology continually seek to streamline and automate various facets of our daily lives. Among these advancements, the management of windows in residential and commercial environments stands as a critical focus area. The "Automatic Window Operator" project emerges as a pioneering solution to address this need, offering a sophisticated system designed to intelligently adjust window openings in response to ambient light levels. Windows plays a vital role in regulating indoor environments, providing natural light, ventilation, and climate control. However, manual control of window operations can prove cumbersome and inefficient, particularly in environments where changing light conditions necessitate frequent adjustments. In both residential and commercial settings, the demand for efficient window management solutions has never been greater.The Automatic Window Operator project seeks to meet this demand by offering a robust system that autonomously controls window operations based on real-time light intensity readings. In this updated iteration of the project, significant enhancements have been made, including the adoption of thermistors for light sensing and H-bridges for actuation. These changes reflect a commitment to leveraging the latest advancements in sensor and actuator technologies to deliver a more efficient and reliable solution.

This report provides a comprehensive overview of the Automatic Window Operator project, detailing its objectives, system architecture, implementation plan, simulation results, and future enhancements. Through meticulous design, development, and testing processes, the project aims not only to demonstrate the feasibility and practicality of automated window management systems but also to pave the way for future innovations in home automation and smart building technologies, automated window management systems.

2. System Architecture

The Automatic Window Operator system comprises both physical and cyber components seamlessly integrated to enable automated window operations based on ambient light levels. The architecture remains robust, ensuring functionality, reliability, and scalability across various environments, including residential homes, commercial buildings, and smart home automation setups.

2.1. Physical and Cyber Components

***Physical Components**:*

Thermistors: Serve as the primary sensors for detecting ambient light levels and converting them into corresponding voltage signals.

H-Bridges: Replace relays in the system architecture to facilitate the control of linear actuators. H-bridges are used to manage the direction and speed of the actuators, allowing for precise adjustment of window positions.

Power Supply: Provides the necessary power for the entire system's operation, ensuring consistent and reliable performance.

Linear Actuators: Mechanisms responsible for physically opening and closing the window in response to control signals from the H-Bridges.

***Cyber Components**:*

STM32 CubeIDE: Integrated Development Environment (IDE) used for programming the microcontroller, facilitating efficient code development, and debugging.

Finite State Machine (FSM): Logic implemented in software to govern the behavior of the system based on predefined states and transitions.

2.2. System Workflow

Data Acquisition: The photoresistor continuously monitors ambient light levels and generates a corresponding voltage signal.

Signal Processing: The microcontroller, programmed using STM32 CubeIDE, processes the voltage signal from the photoresistor.

Decision Making: Based on the processed data, the FSM logic determines the appropriate action to be taken (i.e., open or close the window).

Actuation: The microcontroller sends control signals to the relay, which in turn activates the linear actuator to adjust the window position accordingly.

Feedback Loop: The system may incorporate feedback mechanisms to verify the successful execution of the desired action and ensure system reliability.

The physical and cyber components of the system communicate seamlessly to achieve synchronized window operations. The STM32 microcontroller serves as the central processing unit, orchestrating the flow of information between the various components. Communication between the microcontroller and peripheral devices such as the photoresistor, relay, and linear actuator is facilitated through GPIO (General Purpose Input/Output) pins and appropriate communication protocols (Visualization shown in Figure 1).

2.3. Scalability and Flexibility

The system architecture is designed to be scalable, allowing for easy integration of additional sensors, actuators, or control mechanisms as needed. Moreover, the modular nature of the architecture enables flexibility in adapting the system to different environments and applications, ranging from small-scale residential installations to large-scale commercial deployments. The robust and versatile system architecture of the Automatic Window Operator project lays the foundation for efficient, reliable, and intelligent window management. By seamlessly integrating physical and cyber components, the system demonstrates the potential of automated systems to enhance safety, comfort, and convenience in various settings, paving the way for future advancements in home automation and smart building technologies.

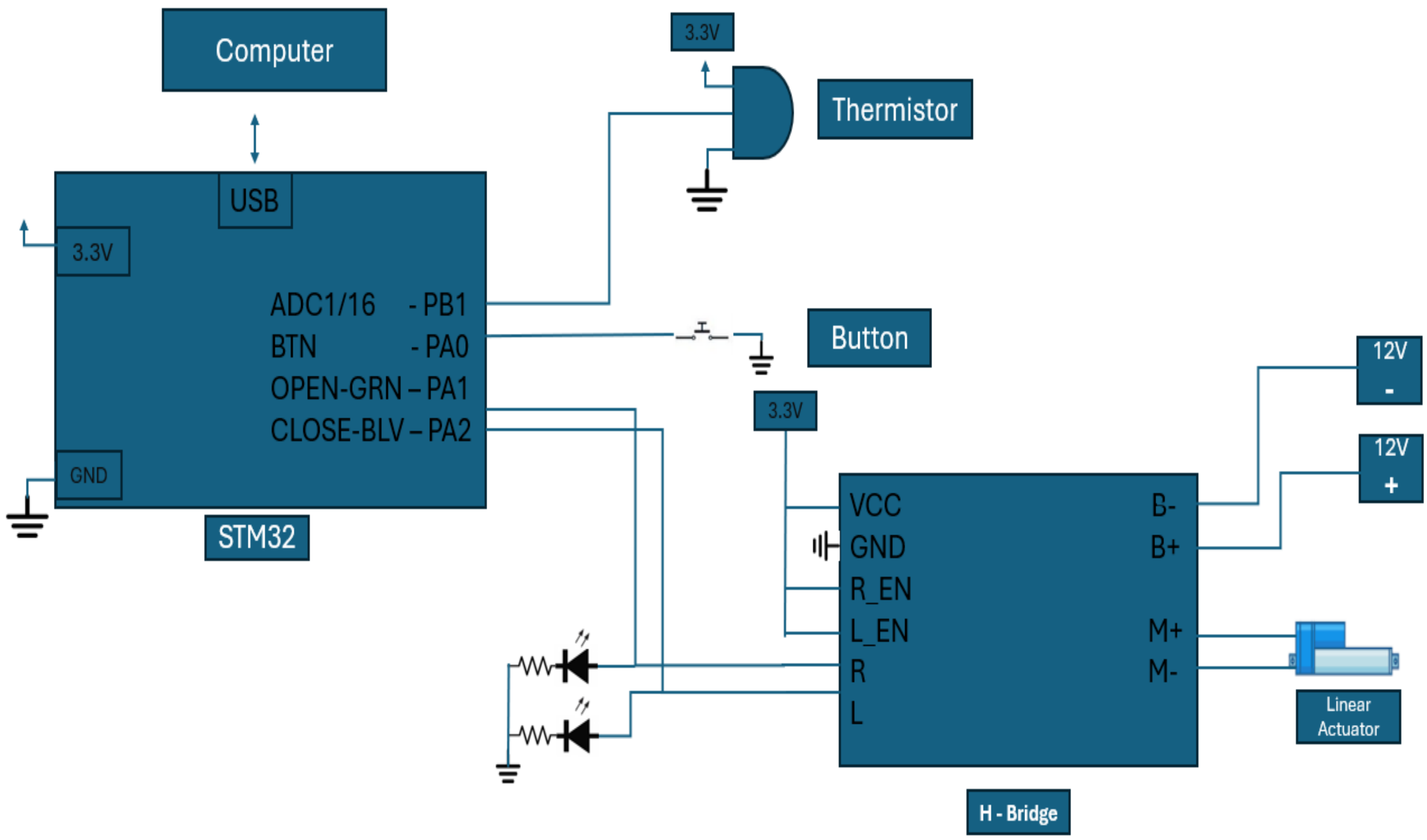


Figure 1. Physical Components Connections.

2.4. System design

The system design of the Automatic Window Operator project embodies a meticulous approach aimed at creating an efficient, robust, and user-centric solution for automated window management. Leveraging a combination of hardware and software components, the design ensures seamless integration, scalability, and adaptability to diverse environments and applications.

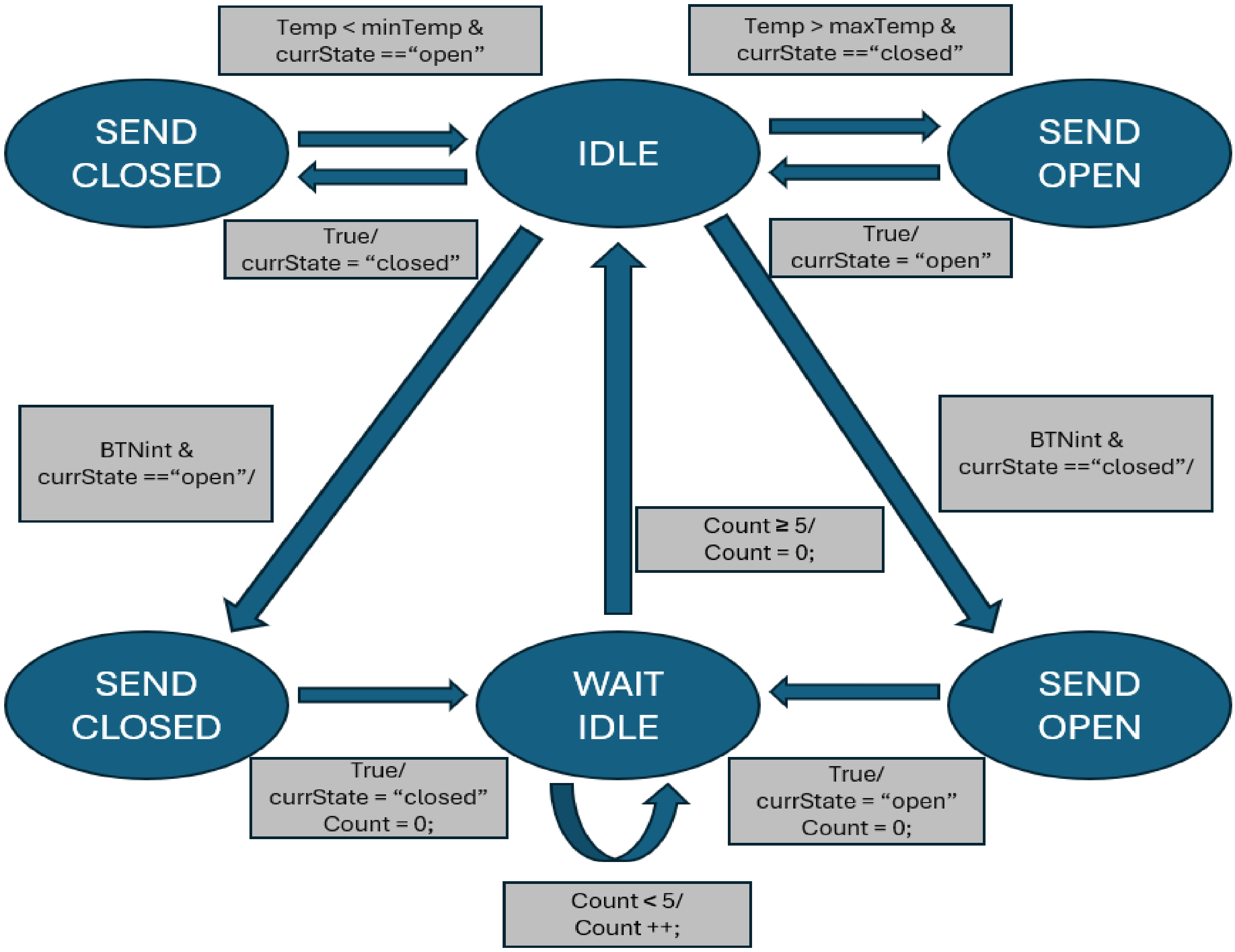


Figure 4. System design used for our project.

3.1. Implementation Plan

The successful completion of the Automatic Window Operator project relies on a well-crafted implementation plan that ensures the smooth integration of hardware and software components, rigorous testing, and iterative refinement. This plan consists of a series of well-defined steps that aim to turn conceptual ideas into tangible results, driving the project toward its goals of improved safety, comfort, and convenience in various environments.

The foundational step in the implementation process involves the acquisition and assembly of physical components essential for the operation of the Automatic Window Operator system. This entails sourcing components such as photoresistors, relays, power supplies, and linear actuators, followed by their meticulous assembly according to predefined design specifications and wiring diagrams. The assembly process demands precision and attention to detail to ensure seamless integration and optimal functionality of the hardware components.

With the hardware components in place, the focus shifts to the development of software modules essential for interfacing with and controlling the system. Leveraging the STM32 CubeIDE as the primary development environment, firmware is meticulously crafted to facilitate communication with hardware components. This encompasses the development of code modules for reading data from the photoresistor, controlling the relay and linear actuator, and implementing Finite State Machine (FSM) logic to govern system behavior. The software development phase demands a methodical approach, encompassing code writing, debugging, and testing to ensure robustness and compatibility with hardware components.

Upon completion of software development, the hardware and software components are seamlessly integrated to form the complete Automatic Window Operator system. This phase involves initial testing to validate basic functionality, including sensor readings, actuator control, and communication between components. Comprehensive testing is subsequently conducted under varied lighting conditions to evaluate the system's responsiveness, accuracy, and reliability. Any discrepancies or issues encountered during testing are meticulously addressed through iterative refinement of hardware and software components, ensuring the system's readiness for deployment.

Following successful integration and testing, the focus shifts towards optimization and calibration to fine-tune system parameters and ensure optimal performance. This entails refining threshold values for light intensity and actuator response times to optimize system functionality. Sensors and actuators are meticulously calibrated to ensure consistency and reliability across diverse environments. Additionally, feedback mechanisms are implemented to monitor system behavior and performance, facilitating ongoing optimization and refinement.

In conclusion, the implementation plan serves as a roadmap for transforming the vision of the Automatic Window Operator project into a tangible reality. Through meticulous hardware assembly, software development, integration, testing, optimization, and validation efforts, the project endeavors to deliver innovative solutions that enhance safety, comfort, and convenience in diverse environments, while laying the foundation for future advancements in automation technologies.

4.1. Simulation Part

For the simulation of the Automatic Window Operator system, MATLAB/Simulink was employed, utilizing the Hsu block to emulate the system's dynamic behavior. The Hsu block was configured to simulate the main jump and flow conditions, capturing interactions between hardware components and environmental inputs. Additionally, outputs generated during the simulation were saved for further analysis. Incorporating a Finite State Machine (FSM) block into the simulation framework enabled control of the system's behavior. Programmed with specific logic, the FSM block governed state transitions based on predefined conditions. If the system state is 0 and the ambient light level exceeds 50 lumens (the specified minimum threshold), or if the state is 1 and the light level falls below 100 lumens (the predetermined maximum threshold), the state transitions to 1; otherwise, the state remains at 0 (shown in Figure 2).

```
% evaluate ell
if ((q == 0) && (L >= Lmin)) || ((q == 1) && (L <= Lmin))
    ell = 1; % report jump
else
    ell = 0; % report jump
end
```

Figure 2. FSM and algorithm.

The simulation utilized a repeating sequence block to generate input, representing environmental conditions encountered during operation. The repeating sequence block ensured the cyclical nature of environmental changes, facilitating comprehensive testing of the system's response under varied conditions. The FSM block served as the control mechanism, orchestrating the interaction between the input sequence and the Hsu block. Dictating state transitions based on predefined logic, the FSM block-controlled system components are represented by the Hsu block. This integration allowed the emulation of real-world scenarios and the evaluation of system performance under different conditions.

Within the simulation framework, the Hsu block emulated relay functionality, translating control signals from the FSM block into corresponding actions on the simulated window actuator. This abstraction facilitated the simulation of the physical actuation of the window based on control logic implemented in the FSM block.

In summary, the simulation framework, comprising the sub-block, FSM block, and input generation mechanism, provided a robust platform for testing and validating the Automatic Window Operator system. By accurately modeling system components and interactions, the simulation facilitated a comprehensive analysis of system behavior under various environmental conditions, informing the design and optimization of real-world implementation.

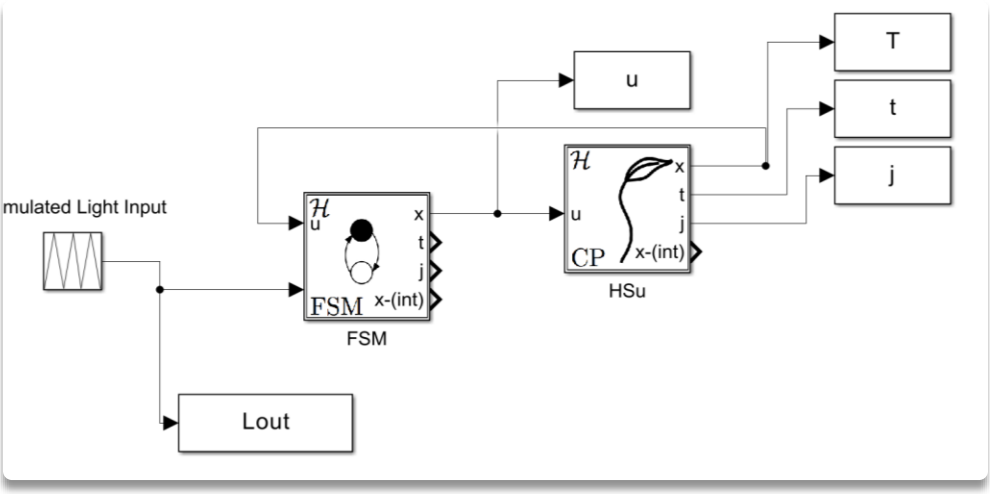


Figure 3. The simulation system for Automated Window Operator

5. Implementation

The successful implementation of the Automatic Window Operator project involves a systematic process encompassing hardware assembly, software development, integration, testing, and optimization. Each phase is crucial for transforming the conceptual design into a functional and reliable system ready for real-world deployment.

5.1 Hardware implementation

The hardware assembly phase begins with the acquisition of all necessary components, including thermistors, H-bridges, linear actuators, and power supplies. Following predefined design specifications and wiring diagrams, the components are meticulously assembled to form the physical infrastructure of the system. Attention to detail is paramount to ensure proper connections, alignment, and installation of components.

Thermistor Installation: Thermistors are strategically positioned to capture ambient light levels effectively while minimizing interference from external sources. Careful calibration ensures accurate sensing and consistent performance across different environments.

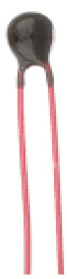
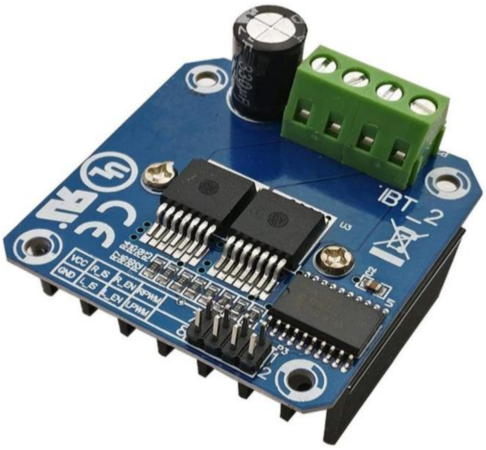


Figure 4. Thermistor

H-Bridge Integration: H-Bridges are interfaced with the microcontroller and linear actuators to enable precise control of window movements. Proper configuration and testing of H-Bridge parameters, such as PWM frequency and duty cycle, are conducted to optimize motor control and minimize power consumption.



- Input Voltage: 6 ~ 27Vdc.
- Driver: Dual BTS7960 H Bridge Configuration.
- Peak current: 43-Amp.
- PWM capability of up to 25 kHz.
- Control Input Level: 3.3~5V.
- Control Mode: PWM or level
- Working Duty Cycle: 0 ~100%.
- Over-voltage Lock Out.
- Under-voltage Shut Down.
- Board Size (LxWxH): 50mm x 50mm x 43mm.
- Weight: ~66g.

Figure 5. H-Bridge with features.

Linear Actuator Setup: Linear actuators are installed near window mechanisms, ensuring smooth and reliable operation. Stroke length, force output, and speed settings are adjusted to achieve desired window movements while maintaining structural integrity and safety.

- Standard Travels start at 148mm and go up to 5763mm.
- Loads from a few grams to 440 Newtons (200 lbs.)
- Slide can be fitted with several different types of motors.
- Come standard with a mechanical limit switch built into the end of travel on both ends.
- Speeds range up to 10 meters per second.
- Stepper or servo motor options are available.

Figure 6. Linear Actuator and features.

Power Supply Connection: The power supply unit is connected to all components, providing the necessary voltage and current levels for operation. Voltage regulators and protective circuits may be implemented to safeguard against overvoltage, overcurrent, and short circuits.

- World Wide Input Voltage 100-240VAC 50/60Hz OVP, OCP, SCP Protection (OVP: Over Voltage output Protection. OCP: Over Current output Protection. SCP: Short Circuit output Protection) Tested Units. In Great Working Condition. UpBright 30 days Refund. 24 Months Exchange.
- UpBright New Input AC 100-240V Output DC 12V Wired Power Supply Adapter Converts Compatible with WindyNation Linear Actuator DC Motor Control LIN-SPSU-12 12VDC 3A - 5A 3 - 5 Amp Switching Power Supply Cord Cable PS Battery Charger Mains PSU

Figure 7. Power Supply Connection and some features.

With the components outlined above and referencing the hardware diagram we previously provided, we successfully constructed the physical system for our Automatic Window Operator project. Each component was meticulously positioned and configured to ensure optimal functionality, safety, and longevity.

5.2. Software implementation

In parallel with hardware assembly, software development plays a critical role in realizing the functionality of the Automatic Window Operator project. The firmware for the STM32 microcontroller is developed to interface with hardware components, process sensor data, and control window operations based on predefined logic.

Microcontroller Firmware: The provided code implements the core functionality of the system within the main loop of the microcontroller firmware. This firmware is responsible for reading temperature data from the thermistors, monitoring the system state, and issuing control signals to adjust window positions accordingly.

Sensor Data Processing: The firmware utilizes the ADC module of the microcontroller to sample analog signals from the thermistors and convert them into digital values. These values are then processed to calculate temperature readings in both Celsius and Fahrenheit scales.

Window Control Logic: Based on temperature readings and predefined thresholds, the firmware issues control signals to adjust window positions using the H-Bridge motor drivers. The openWindow() and closeWindow() functions are called to activate the linear actuators and move the windows accordingly.

UART Communication: The firmware also establishes UART communication to enable real-time monitoring of system status and interaction with external devices. UART functions are implemented to transmit temperature data and receive commands from external sources.

By integrating the provided code snippets with the hardware components and operational logic, the software component of the Automatic Window Operator project ensures seamless coordination and control of window operations based on ambient temperature conditions. This integration facilitates the realization of a fully functional and autonomous window automation system, ready for deployment in residential and commercial environments.

5.3. Implemented project

Here we attach the ready project (link)

6. Conclusion

In conclusion, the Automatic Window Operator project represents a significant advancement in the realm of automated window management, offering a solution that enhances safety, comfort, and convenience in both residential and commercial settings. Through the integration of advanced sensor technologies and cyber components, the system intelligently adjusts window operations based on ambient light levels, optimizing ventilation and climate control.

The project's systematic approach, from conceptualization to implementation, has resulted in a robust and reliable system architecture. Meticulous hardware assembly, software development, integration, testing, and optimization processes have been employed to ensure functionality and reliability. Moreover, simulation using MATLAB/Simulink has provided valuable insights into the system's behavior under various environmental conditions, informing design decisions and optimizations. The scalability and flexibility of the system architecture allow for easy integration into different environments and applications, ranging from small-scale residential setups to large-scale commercial deployments. Furthermore, ongoing monitoring, maintenance, and iteration ensure the system's adaptability to evolving needs and advancements in automation technologies.

Overall, the Automatic Window Operator project exemplifies the convergence of hardware and software technologies to address real-world challenges effectively. By delivering innovative solutions for efficient window management, the project sets a precedent for future advancements in home automation and smart building systems, ultimately contributing to safer, more comfortable, and more sustainable living environments.

REFERENCES

1. Team Wavelength. Thermistor Basics.

2. Amazon.com.

3. Handsontec.BTS7960 Motor Driver Datasheet.

4. Hackaday.io. Window Opener Project.

5. Arduino Forum.