Automatic Window and Blind Regulator

ECE 445 DESIGN DOCUMENT - SPRING 2024

Project # 72

Austin Chong, Mahdi Almosa, Marco Oyarzun

Professor: Arne Filflet
TA: Douglas Yu

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1. Introduction

1.1 Problem

The optimal sleep environment varies considerably among individuals, with distinctions such as a preference for a cooler room or a warmer setting during the transition into slumber. The diversity extends to the waking experience, ranging from individuals who value the invigorating touch of natural sunlight to those who favor a more subdued awakening environment. Beyond temperature considerations, personal preferences encompass auditory and olfactory experiences, adding layers of complexity to the task of creating an ideal sleep and wake environment. Some individuals derive comfort from the rhythmic patter of raindrops outside their window as they venture into the realm of dreams, while others find solace in inhaling fresh, invigorating air upon waking. These nuanced preferences contribute to the intricate challenge of tailoring the sleep and wake experience for each unique individual.

However, the practical realization of these preferences encounters constraints, particularly in the management of ventilation and exposure to external elements. Leaving a window ajar indefinitely raises legitimate concerns regarding safety, security, and energy efficiency. Additionally, unpredictable weather conditions, noise disturbances, and the potential intrusion of pests underscore the impracticality of relying solely on manual adjustments. In response to these challenges, the development of an automatic window and blind regulator emerges as a promising solution. This sophisticated system seeks to harmonize the diverse preferences of individuals by autonomously adjusting window openings and blind positions based on predetermined user settings and real-time environmental conditions. The integration of intelligent sensors and responsive controls aims to strike an equilibrium between personalized comfort and practical considerations, ensuring a secure, safe, and energy-efficient approach to crafting an optimal sleep and wake environment.

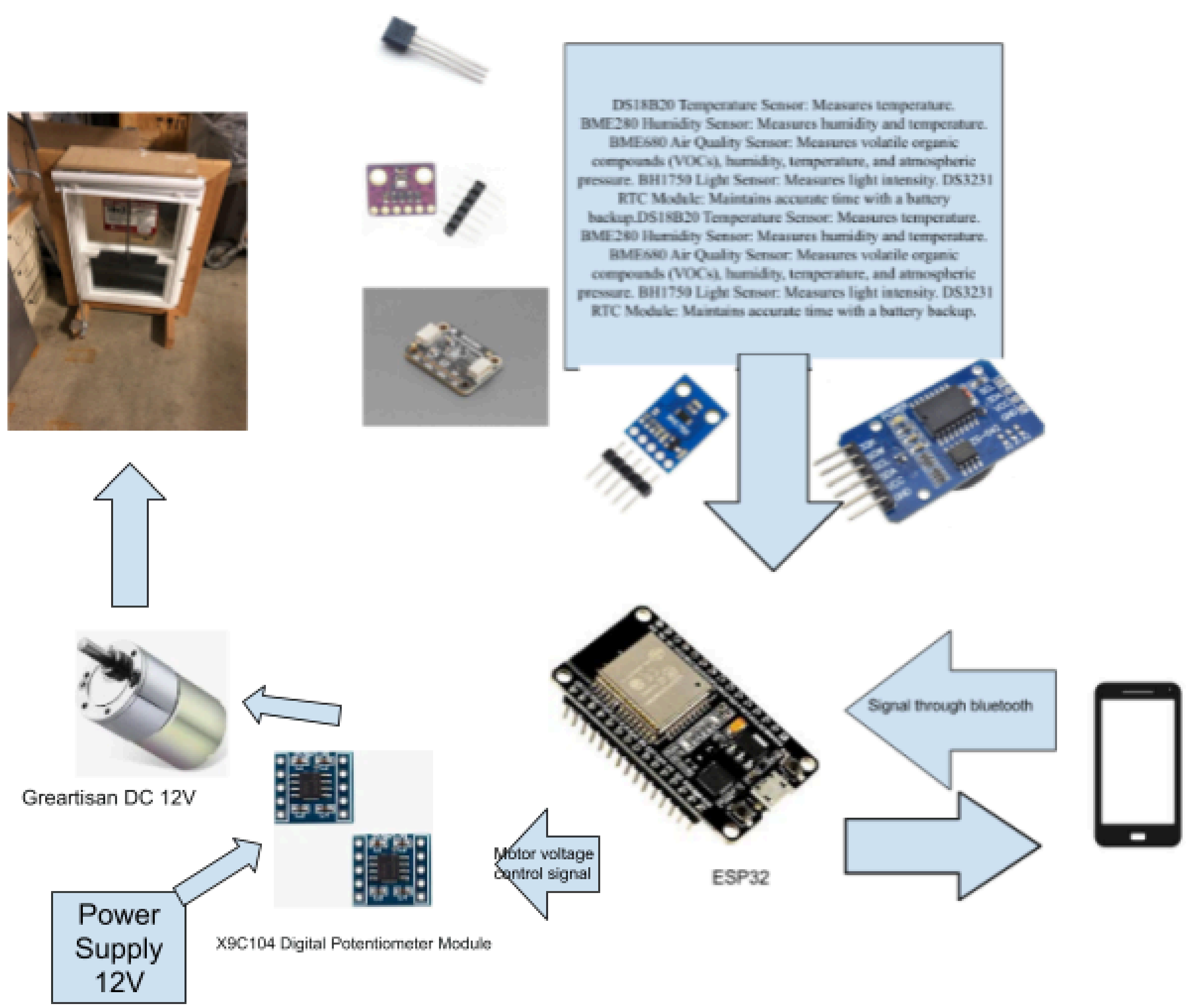
1.2 Solution

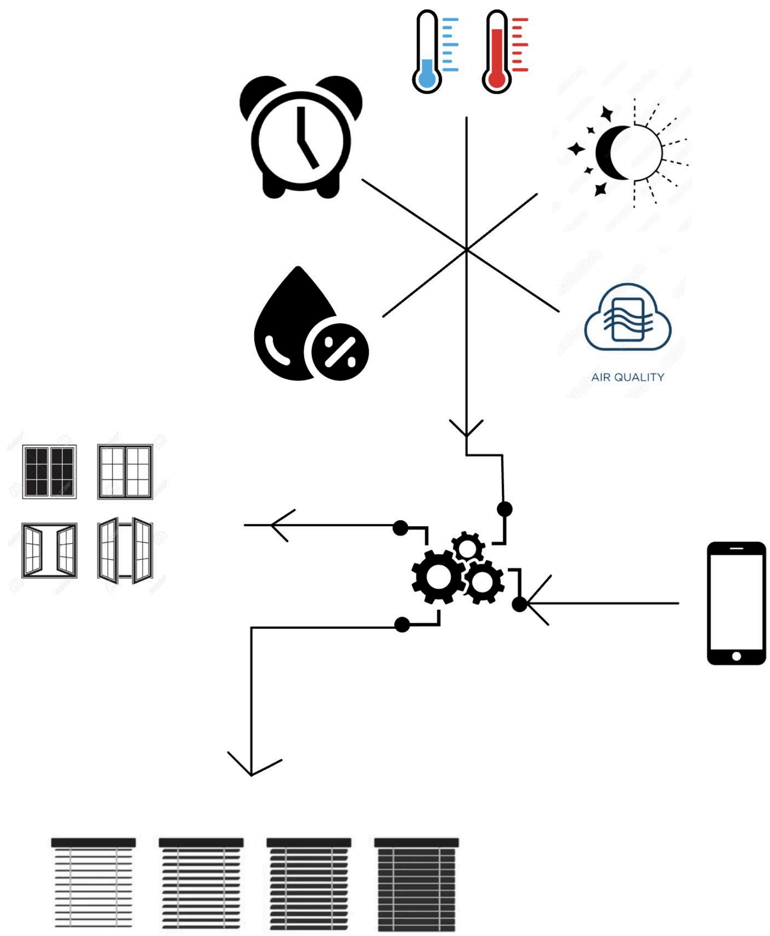
Our proposed solution involves the development of a comprehensive automated window and blind regulation system designed to respond to diverse indoor and outdoor environmental conditions. Users will have the flexibility to customize settings based on factors such as temperature, humidity, air quality, and available sunlight. This system employs an array of sensors to continuously monitor the indoor environment, comparing data with real-time outdoor weather conditions sourced from an online weather forecast.

Utilizing user-defined preferences, the integrated motors within the system will dynamically adjust the window and blind positions, ensuring alignment with the desired ambient conditions. By employing this solution, individuals can intricately tailor the atmosphere within their living spaces without compromising on safety. This automated system mitigates concerns related to the need for constant manual adjustments, offering users a seamless and personalized control over their home environment.

1.3 Visual Aid

Physical window to be managed by the system





Conceptual diagram of system

1.4 High-level requirements

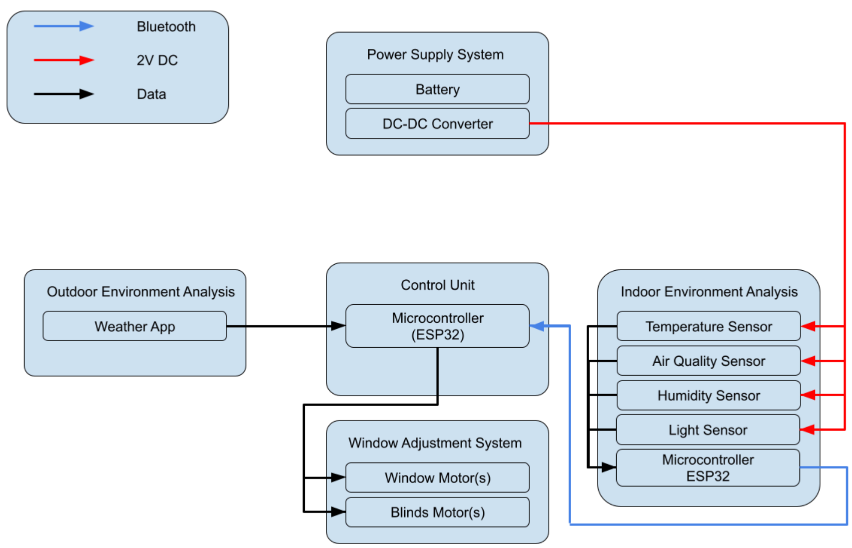
1.4.1 - The windows and blinds need to be able to close/open upon request. These need to have the minimum strength of 10 pounds of force as this is the weight of an average window. This should be done automatically instead of manually via motors and signals from the microcontroller.

1.4.2 - The windows and blinds need to have sensors that detect if the temperature is between 60 degrees to 80 degrees fahrenheit. If not, the windows would change accordingly depending on how the indoor temperature differs from the outdoor temperature.

1.4.3 - The windows and blinds should be able to correctly adjust at full extension of both closed and open. This full extension should be at minimum 2 feet for the windows to be fully closed or opened, as the blinds should be at least 4 feet.

2. Design

2.1 Block Diagram



2.2 Subsystem Overview and Requirements

2.2.1 Power Supply System - The power system is designed to supply energy to the entire window and blind regulator setup. It will handle various DC power levels, with the ability to adjust between 1 to 12 volts as required by each component. The system will be powered by a combination of batteries and a mains power supply. Depending on the needs of each subsystem, the voltage will be either stepped up or stepped down by a set of voltage regulators. These regulators ensure that every part of the system receives the right amount of power. The power management is smart enough to switch between the battery and mains power, ensuring there's always a consistent supply without any interruption to the operation. This ensures that all parts of the system work properly, with stable power delivery that matches their specifications.

Requirements	Verification
• Monitoring system power supply	• Regulate output terminals of the power supply that feeds the sensors and the ESP32. Measure and record the voltage to ensure it falls within the specified operating range for each component. The ESP32 typically operates at 3.3V, whereas sensors may vary in their voltage requirements. • Apply a variable load to simulate different operating conditions and verify that the voltage remains stable within the acceptable tolerance range, which is often ±5% of the nominal voltage. • Implement a test sequence where the load is rapidly switched between different values. Observe the power supply's response using an oscilloscope connected across the power lines to the sensors and the ESP32. The goal is to ensure that the

	power supply can handle transient changes without significant voltage spike. ● Ensure the measurements and sensors are functioning properly and are integrated all across and that the power requirement to have a clear reading for all parts is met.
● Control system power supply	● Achieve fast control over the actuating system which will be moving the blinds and windows, and integrating the ESP32 controller with the power supply connected to the motors. ● Try multiple controls and environments to ensure that the control signals sent from the controller are producing the sufficient voltages that can move the blinds and the windows and are within the ratings of the motors used. ● Apply some external noise or pressure to the blinds and the windows to observe the effect of obstacles on the motor and the measurement system response in accordance and ensure a safety mechanism for voltage to stabilize and not increase.

2.2.2 Indoor Environment Analysis - Using various sensors, this subsystem will record data about the environment inside the home and send it to the main microcontroller in the control unit through a different microcontroller via bluetooth.

Requirements	Verification
● Sensor readings will be sent to a secondary microcontroller on a PCB that is separated from the window unit.	● Multiple settings will be tested to ensure clear communication between sensors and the microcontroller. ● Sensors will have a range in which the data carried will be acceptable, and data outside such ranges will send an alarm signal through the PCB to indicate failure. ● A priority in sensor changes will be set and the user interface will be updated according to the sensed conditions.
● Sensor data will be accurate to the conditions within the home.	● Calibration tests can be run by changing the temperature and air quality near the unit. ● This unit must be placed relatively far from the window to avoid being influenced by outdoor conditions.
● Secondary microcontroller will send sensor data to the primary microcontroller in the control unit.	● Bluetooth connection must be maintained at all times. ● This can be ensured by testing how far the unit can be taken away from the window

2.2.3 Outdoor Environment Analysis

This subsystem will retrieve data from the internet containing information about outdoor conditions (temperature, humidity, etc.). It will then send this information to the control unit. Using the public Open-Meteo API, the system will be able to download CSV data of the current as well as future weather conditions.

Requirements	Verification
• The system will be able to access accurate weather data from the Open-Meteo API.	• Ensure that the API connection works correctly. • Ensure that the data has been retrieved correctly. • Ensure that the data is locally accurate.
• The system will convert the data into a format that the control unit is capable of interpreting.	• Compare with data from indoor analysis system to ensure that the format of the data allows the microcontroller to effectively compare environments. • Test on a computer to make sure that the format is consistent.
• The system will successfully send the data to the main microcontroller.	• Information can be sent back to a computer to make sure that the correct data is being transferred. • This can be tested using the microcontroller

2.2.4 Control Unit - This subsystem will contain the main microcontroller which will be responsible for receiving signals from the indoor and outdoor analysis units to determine how to adjust the window and blinds separately. It will consist of an ESP32 microcontroller with various inputs and outputs connecting to the other subsystems. First, it will receive signals from the indoor and outdoor environment analysis units via I2C inputs. It will use these signals to execute logic that will determine whether or not to adjust the window or blinds. It will then send signals to the window adjustment subsystem accordingly. For example, if the inside of the home has become full of smoke from cooking, the microcontroller will receive this data from the air quality sensor and determine that the window must be opened. Likewise, if the sun has set, then the microcontroller will send the window unit a signal to close the blinds.

Requirements	Verification
• Subsystem will successfully communicate with the microcontroller in the indoor analysis unit.	• First, the bluetooth connection must be established. • Data received by the control unit must be correct and properly formatted for logical computation.
• Subsystem will properly execute logic based on inputs received from other subsystems.	• First, the data from the indoor and outdoor analysis subsystems must be in the correct form • Once this is ensured, the logic in the microcontroller must be correctly executed. • This can be ensured by testing under different ambient conditions.
• Unit will send correct signals to the	• Ensure that the window and blinds are

window adjustment system based on outputs from logic sequence.	opening or closing when they should be based on the logic

2.2.5 Window Adjustment

This subsystem assumes the crucial role of manually regulating the positioning of windows and blinds within the designated space. Its operational mechanism involves the integration of motors affixed to specific components of both the windows and blinds, facilitating precise control over their individual movements. These motors receive signals from the central control unit, which acts as the orchestrator for orchestrating adjustments. The coordination between the control unit and the motors ensures a synchronized and efficient response to user commands, allowing for seamless manual adjustments in the positioning of windows and blinds as needed.

Requirements	Verification
● The system should enable precise manual adjustments of both windows and blinds through the integrated motors.	● The system can go up and down 4 feet in length to accommodate the blinds. This would also suffice for the windows since they are less in length. ● Manual adjustments would be dynamic where the windows and blinds would be stationary upon manual movement. ● Changes in manual adjustment would not affect the functionality in terms of length.
● Motors should reliably receive signals from the control unit for consistent	● Ensure that the temperature of the system is high/low enough, 60-90

and responsive adjustments	degrees, where the window changes accordingly ● Ensure that the window closes upon sensing outside detections. Also reacting to the weather reports on the internet. ● The blinds respond to the time of day of the internet. This is communicated with through the signal of the PCB.

2.3 Tolerance Analysis

An aspect of the Automatic Window/Blind Regulator that would pose a risk would be if the device has enough force to close the window correctly and successfully. Utilizing the equation Force = Mass * Acceleration, and Acceleration being equal to either negative or positive gravity (depending on opening or closing the blinds/windows), we need to calculate both the force needed for the blinds and the window:

*F = m (weight of the window/blinds) * a (negative/positive gravity)*

Given this relation, we found that the average window mass is about 5 pounds and the average blind weight is 340 grams. We are now able to calculate the estimated force needed to open/close the windows and blinds:

5 pounds = 2267.96 grams = 2.26796 kilograms

a = g = 9.8 m/s^2

*F (window) = (2.25696 kilograms) * (+/- 9.8 m/s^2)*

F (window) = +/- 22.118208 Newtons

*F (blinds) = (0.340 kilograms) * (+/- 9.8 m/s^2)*

F (blinds) = +/- 3.332 Newtons

From these calculations the negative/positive forces indicate whether the current state of the mechanism needs to be pulled down or up. Thus, we can conclude that the design needs to have at least the force of +22.118208 Newtons of force since this is the greater of the two values. This force problem may pose a risk for the blind regulator as well since some blinds have a pull-down mechanism in order to regulate the blinds.

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor

The total cost of labor for all engineers involved can be calculated using the following formula:

($/hour) x 3 engineers x hours to complete = TOTAL

In order to estimate an hourly wage per engineer, the average starting salaries of a University of Illinois ECE grad will be used. (as provided by the course website) These are $87,769 and $109,176 for electrical engineering and computer engineering students, respectively. Given that the three engineers involved are electrical engineering students, the $109,176 will not be used. Assuming 40 hour work weeks for 50 weeks in the year, the hourly compensation for each engineer will be approximately $44. Lastly, a 16-week semester at (approximately) 10 hours per week will give us a final value of **$21,120.**

3.2.2 Parts

Description	Manufacturer	Qty	Cost
ESP32-C3-WROOM-02-N4	Espressif Systems	4	$3.80
Sensor Digital 0C-50C 8TDFN	Analog Devices	1	$3.66
Air Quality Gas Sensor VOC/NO	Sensiron	1	$8.96
Tin Can Step Motor	Nippon Pulse America	2	$60.00

Stepper Motor Hybrid Bipolar 12V	Adafruit Industries	1	$14.00
Tax + Shipping			$8.79
Total			**$99.19**

3.2.3 Total

The total cost of the project will be the sum of the labor costs and the cost of all the parts, equalling a final cost value of **$21,219.19.**

3.2 Schedule

Week	**Task**	**Person**
2/19	Design Document	Everyone
	Design Review Presentation	Everyone
2/26	Order Parts needed	Marco
	Reflect on Design Review. Assemble Power Supply Subsystem.	Austin
	PCB Review. Evaluate sensors and feasibility of Indoor Environment Subsystem.	Mahdi
3/4	PCB Work	Everyone
	Teamwork Evaluation	Everyone
	Order and evaluate remaining parts needed after evaluation.	Mahdi
3/11	SPRING BREAK	N/A
3/18	PCB Rework. Control unit management for outdoor temperature analysis.	Marco

	Assembly with motors. Need to check feasibility of strength as it can satisfy the High-Level Requirements.	Mahdi/Austin
3/25	Fully assemble prototype hardware. Assess if temperature detection and sensors are feasible.	Mahdi/Austin
	Fully code PCB and software. Assess if bluetooth connectivity is feasible.	Marco
	Individual Progress Reports	Everyone
4/1	Combine and fully assemble the prototype. Evaluate feasibility and order new parts if needed.	Everyone
4/8	Finalize Demonstration	Everyone
	Final Papers	Everyone
4/15	Demo	Everyone
	Evaluation	Everyone

4. Ethics and Safety

4.1.1 This project will need to retain the same level of security as that of a normal window. This requires a safety feature that can shut the window in order to prevent burglaries or other forms of danger.

4.1.2 The window also poses a risk to the user under dangerous weather conditions (air quality, extreme temperatures and weather) and must be shut in accordance with these conditions to prevent danger to the user or home.

4.1.3 To ensure safety of users, the opening and closing of the system will start and accelerate gradually to allow users some window for making sure that operation will not result in any incidents.

4.1.4 A mapping will be used to feedback where the position of the windows and blinds are currently at. In this way, the motors will be responding accordingly, and if with certain voltage, no changes occur, the user will be notified, and the system power system will shut down to insure that the other parts and system do not get damaged and if the user or kids are around the system, no will happen.

4.1.5 Any unusual readings will be sent to the user interface, and the system will have a sequential closing mechanism, to ensure safe operation.

4.1.6 The system will have minimum and maximum temperature of operations to ensure that the user faulty control will not result in inhumane living conditions.

References

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