ECE 445

Angling Blinds: Design Document

Team 20

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1) Introduction

1.1) Problem and Solution Overview

As working from home has become more popularized, people have become more accustomed to sitting in their rooms all day. However, many workers may not be getting consistent sunlight from their windows while being preoccupied with work and neglecting to angle their blinds accordingly. Several studies have proven that natural sunlight provides measurable health benefits, including boosting Vitamin D, improving sleep, etc. [1], and for people to get consistent levels of sunlight, it is crucial to frequently adjust their blinds throughout the day. However, this frequent action is often forgotten.

We propose building blinds that adjust the angles based on the desired level of brightness of the user using a pulley that pulls on the strings of the blind. This would be done using a photo sensor to detect how much sunlight exists outside and another sensor to detect how much sunlight is coming into the room. With the data from these sensors, the device will adjust the blinds based on the current brightness level where the desired brightness level may vary throughout the day. The behavior of the device based on these two factors will be adjusted through an application, which can cater to the specific needs of the user. This would mean that the user does not have to constantly adjust the blinds to get their desired brightness and they will get consistent sunlight.

1.2) Visual Aid

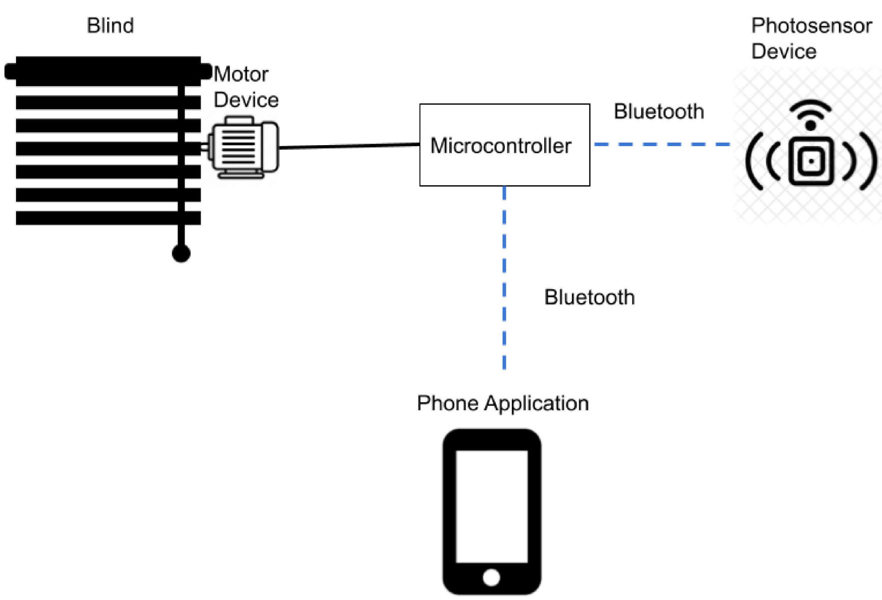

Figure 1. Visual aid

1.3) High-Level Requirement List

1. The blinds adjust to achieve a target brightness $\pm$ 200 lux.
2. The battery for the photo sensor devices must be able to last at least three months.
3. The blinds begin to adjust to the desired brightness within five seconds of the user inputting a value.
4. The blinds should finish adjusting within thirty seconds of starting.

2) Design

2.1) Block Diagram

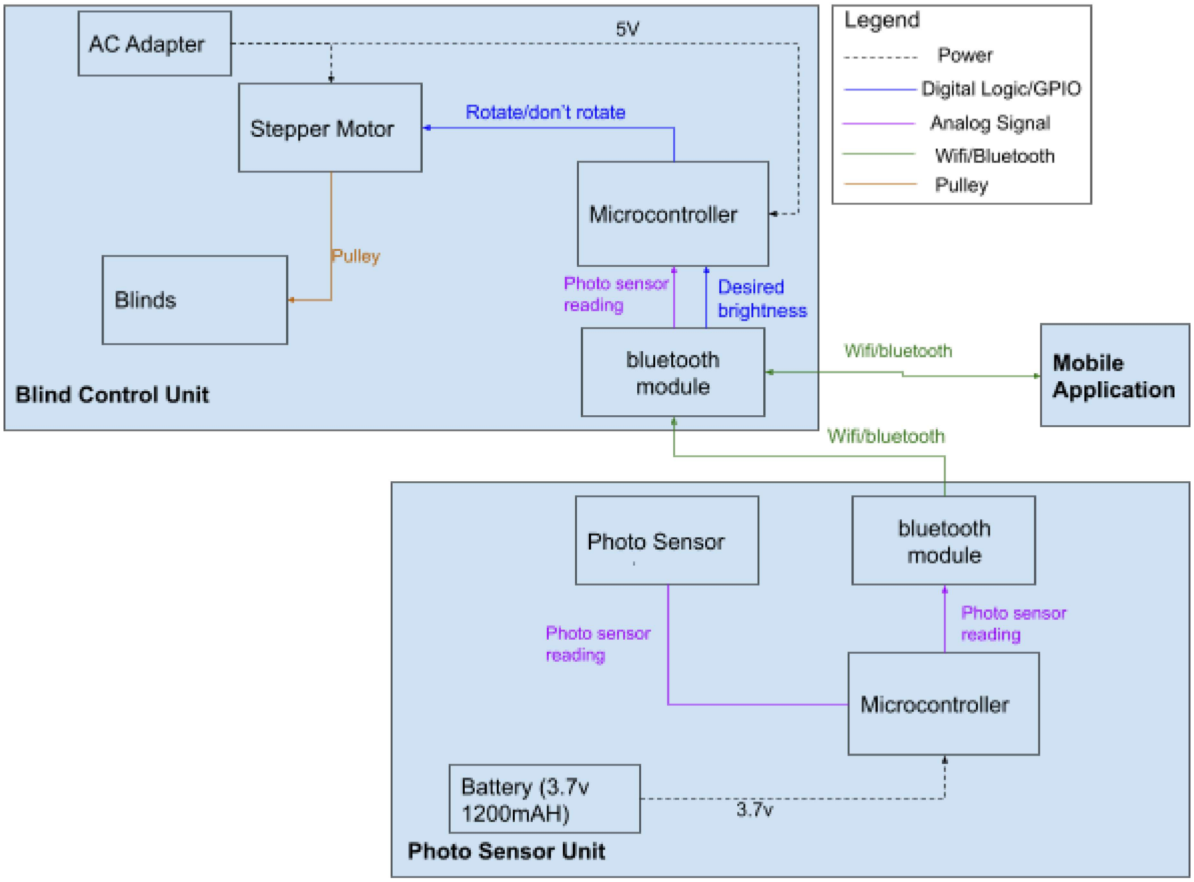

Figure 2: Block Diagram

As shown in Figure 2, our overall design consists of three subsystems with two of them being implemented with a physical component and one software based. The Photo Sensor Units record the brightness of the environment and send this information to the Blind Control Unit via Bluetooth. The mobile application receives input from the user containing desired brightness information and relays it to the Bluetooth module in the Blind Control Unit. From there, the Bluetooth module will send the desired brightness to the Microcontroller. When the reading is outside of the $\pm$ 200 lux range of the target brightness, the stepper motor will begin adjusting the angles within five seconds and finish adjusting in thirty seconds. The Blind Control Unit is responsible for turning the stepper motor in the right orientation to match the target brightness of the user. The stepper motor should finish adjusting the angles within thirty seconds and the photo sensor readings of the inside should match the target brightness at the end. The Photo Sensor Units will be powered by a 3.7V battery that is expected to last at least three months.

2.2) Physical Design

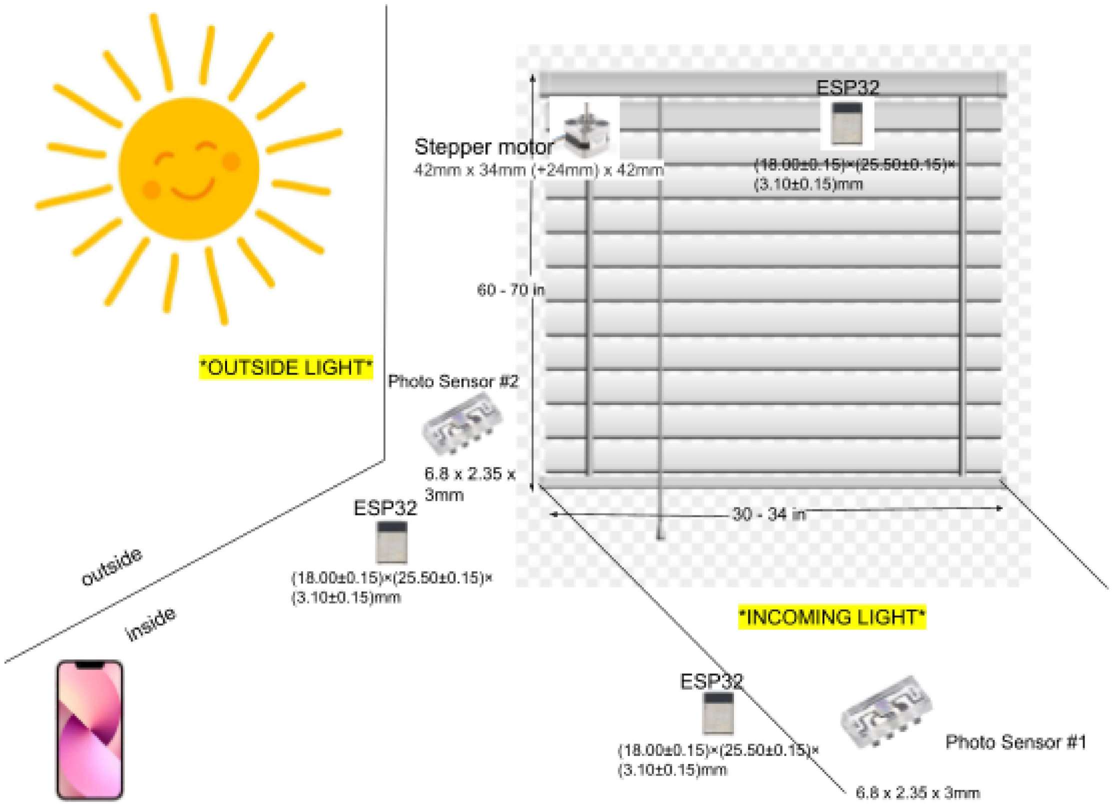

Figure 3: Physical Design

Photo sensor #1 is the photo sensor reading the amount of light inside the room. Photo sensor #2 is the photo sensor reading the amount of light outside of the room. Thus, photo sensor #1 is well inside the room while photo sensor #2 is between the sun outside and the blinds but still inside the room.The stepper motor is attached to the strings of the blinds to adjust the angles and all of these components communicate with each other through the ESP32 microcontrollers. The stepper motor, the photo sensors, and the ESP32 microcontrollers are all small and won't be visually distracting to look at from the user's perspective.

2.3) Flow Chart

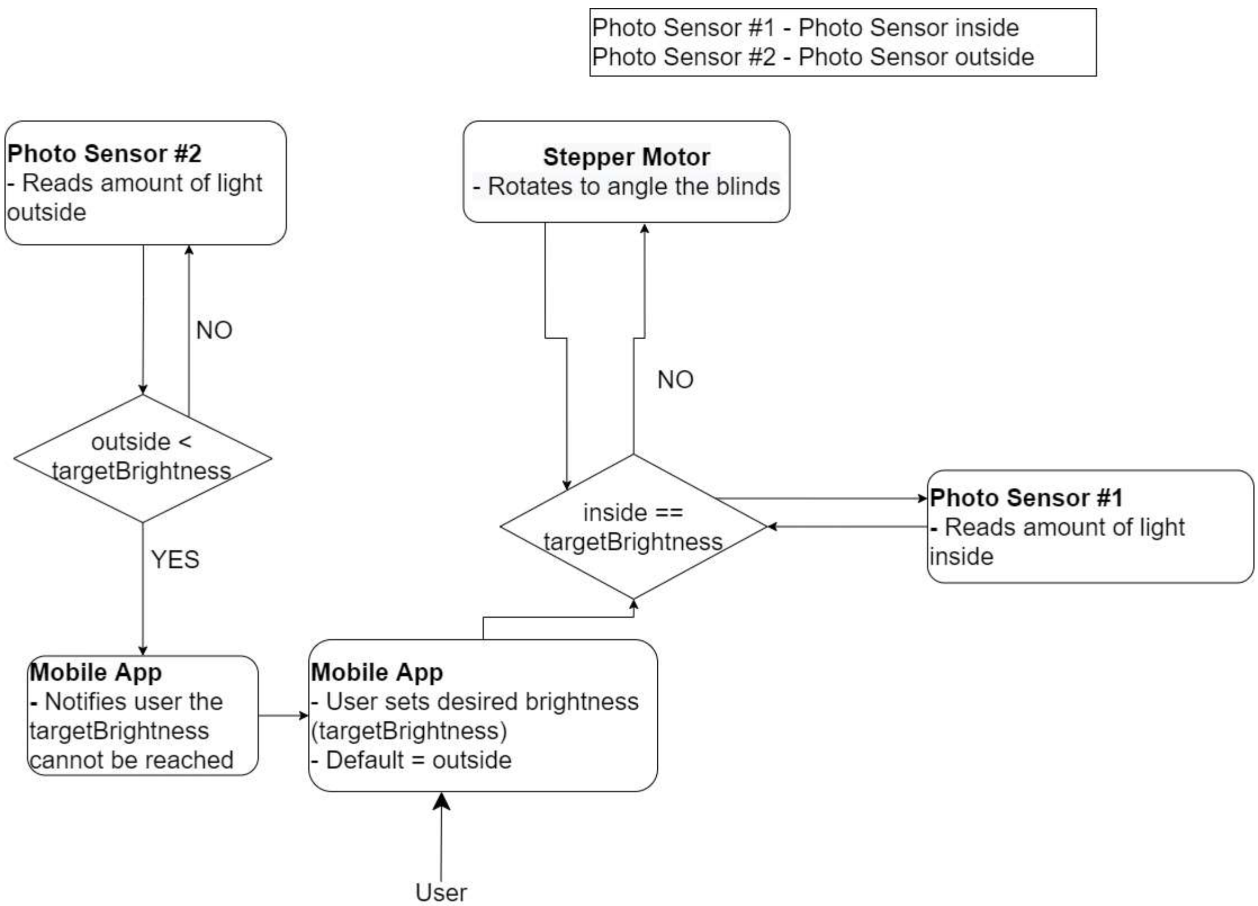

Figure 4: Flowchart

As seen in Figure 4, when a user sets their desired brightness (targetBrightness) in the mobile app, we compare to see if the amount of light inside (inside) is read by photo sensor #1. If the inside brightness is not the same as targetBrightness, then the stepper motor rotates to angle the blinds until the inside brightness that photo sensor #1 reads the same amount of light. At the same time, photo sensor #2 is constantly reading the amount of light outside (outside). If outside is less than targetBrightness, then we must notify the user that targetBrightness cannot be reached. Which then the user must re-enter their desired brightness or the default will be the brightness outside.

2.4) Subsystem Overview

2.4.1) Blind Control Unit

The blind control unit will determine whether to adjust the blinds and then adjust them. The subsystem includes a stepper motor, motor driver, and an ESP32-WROOM-32D microcontroller. The stepper motor will rotate the strings controlling the blinds as told by the microcontroller, adjusting the angles. We decided to go with a stepper motor because of this project requiring a high position accuracy and reliability while also not needing to have a high top speed [2]. We also settled on the ESP32-WROOM-32D for the microcontroller for all the physical subsystems because of the built-in Bluetooth module that conveniently connects to other Bluetooth-based devices [3]. This subsystem will be programmed through USB using a CP2102 USB to UART Bridge to receive light sensor data via Bluetooth transceiver module and will control the motor based on the light sensor (Subsystem #2) and time data received [5]. Ideally, the device will adjust the angles of the blinds so the room can have the desired brightness level of a user throughout the day given through the application subsystem, where this level may vary as the day progresses. The microcontroller would take all of this data (the desired brightness level from the application unit and the photo sensor readings from the photo sensor unit) and determine whether the motor should rotate or not rotate. And if the outside photo sensor reading is greater than the desired brightness, then the microcontroller communicates this to the application. The stepper motor and the microcontroller would be powered by an AC adapter.

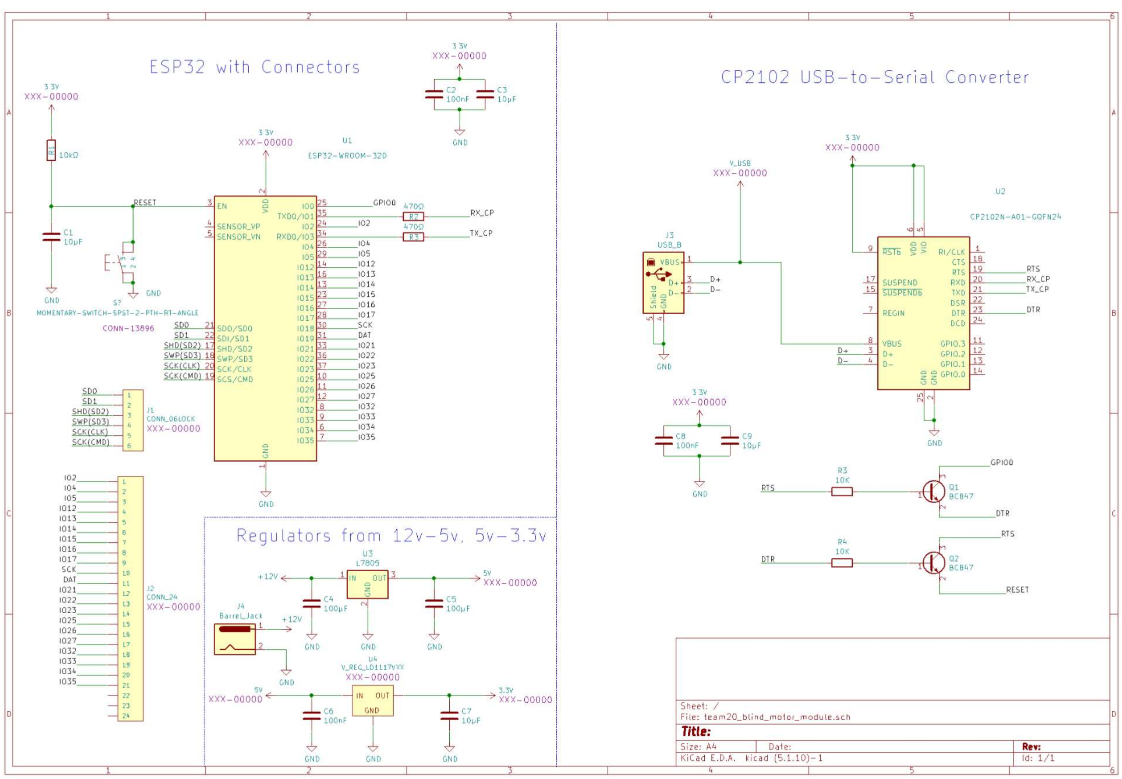

Figure 5: Motor unit schematic

2.4.2) Photo Sensor Unit

The photo sensor unit consists of a photo sensor, a microcontroller, and a battery. There will be two of these units spread out across the room. The microcontroller in this subsystem is also programmed in a CP2102 USB to UART Bridge. These devices are connected to the blind control unit (Subsystem #1) via the Bluetooth module in the ESP32 WROOM 32D microcontroller. The first photo sensor will be well within the room to abstain from the general brightness of the room itself to make sure that the desired amount of sunlight is entering the room. The second photo sensor will read the output from the outside window to record the maximum brightness so that the user knows the maximum sunlight that can be brought inside the room. Both of these readings would be sent via Bluetooth through the microcontroller to the blind unit. To ensure accurate brightness readings, the VEML7700 ambient light sensor was chosen due to its high ambient light range from 0 to 120,000 lux [5]. This unit is powered by a 3.7V 1200mAH battery.

The photo sensor unit contributes to the overall design because of how the blinds adjust based on the photo sensor readings from this unit. These units are crucial in monitoring the room and the brightness outside so that the blinds can adjust when necessary. This unit will interact with the motor device through Bluetooth, sending photo sensor information in quick intervals to the microcontroller of the blind unit to ensure consistent updated communication.

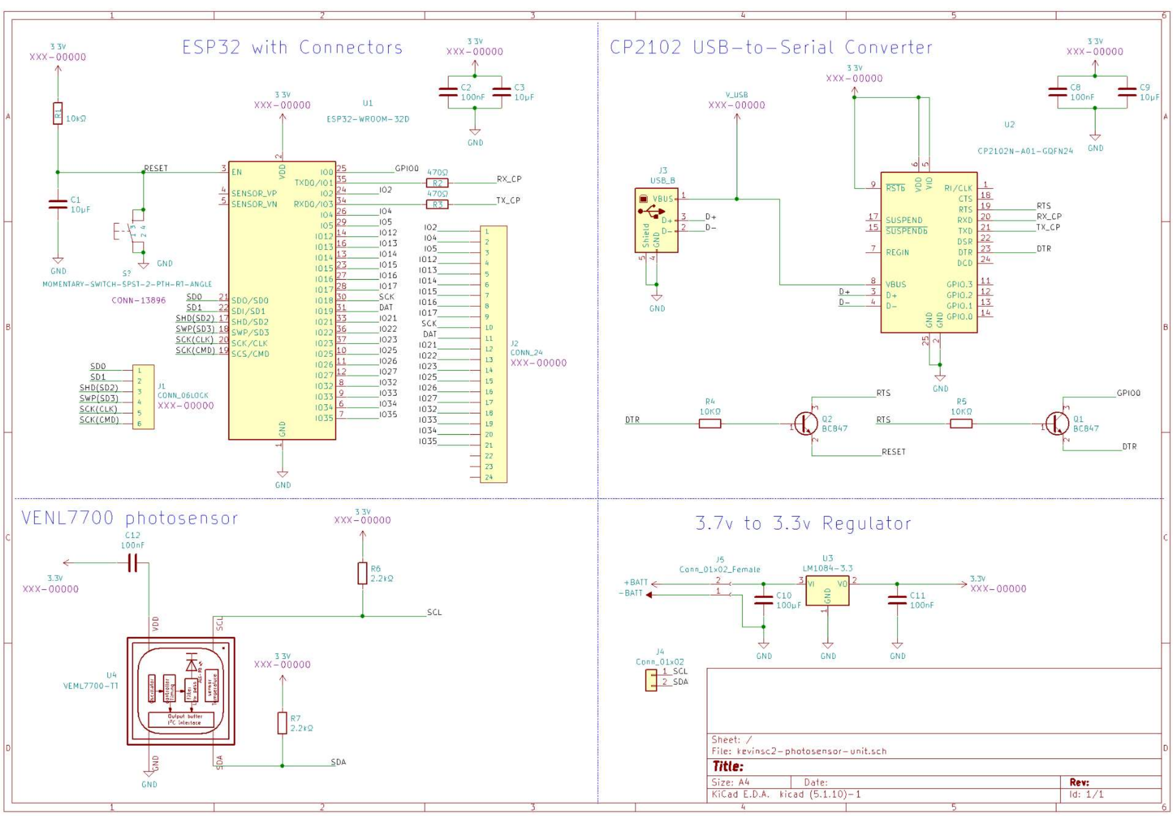

Figure 6: Photo sensor unit schematic

2.4.3) Mobile Application Unit

We will have a mobile application that sets a brightness level manually and this allows the blind system to operate accordingly. Through Bluetooth, the app will receive the photo sensor readings of how much light is outside. It would let the user know and have a scale of how much light they would like inside. When the user adjusts how much light they would like inside, the app would send this information through Bluetooth to the microcontroller in the blind control unit.

Additionally, the application will support a scheduling utility that determines the working hours of the blind system. We would also like a recommendation algorithm incorporated into the application and suggest brightness levels for users depending on the time of the day if time permits.

The user mainly interacts with this subsystem.

2.4) Requirements and Verification

2.4.1 Blind Control Unit RV Table

Requirements	Verification
1. The stepper motor rotating adjusts the angles of the blinds in each orientation. 2. The motor stops before rotating beyond the set maximum total number of steps and under the set minimum total number of total steps to prevent damage to the blinds. 3. The motor starts moving within 3 seconds of the photo sensor reading inside brightness being outside of the target brightness $\pm\ 200$ lux range.	1. Verification Process for Item 1: a. Have the stepper motor rotate to the right and this adjusts the angles towards closing one way. b. Have the stepper motor rotate to the left and this adjusts the angles towards closing the other way. 2. Verification Process for Item 2: a. Have the blinds in a fully open orientation b. The microcontroller tells the motor to rotate to the left continuously. c. The motor should stop at the set maximum total number of steps. d. The microcontroller tells the motor to rotate to the right continuously e. The motor should stop at the set minimum total number of steps. 3. Verification Process for Item 3: a. Set the target Brightness X where X is greater or less than 200 lux than the reading of the inside photo sensor b. Start a timer c. Wait for the blinds to start adjusting and stop the timer d. Verify if the time recorded is less than 3 seconds .

2.4.2 Photo sensor Unit RV table

Requirements	Verification
1. The microcontroller can report the photo sensor output. 2. The photo sensor must be able to accurately read the brightness of the area with a bound of $\pm$200 lux 3. This unit must communicate to the blind control unit at slowest in 0.5 second intervals through Bluetooth. .	1. Verification Process of Item 1: a. Cover the photo sensor. b. The Microcontroller should report 0 lux $\pm$200 lux. c. Uncover the photo sensor. d. The Microcontroller should report not 0 assuming it is not completely dark in the room. 2. Verification Process of Item 2: a. Have both photo sensor units right next to each other b. Obtain the lux reading of both photo sensor units c. Check if they are within 200 lux of each other 3. Verification Process of Item 3: a. Have the photo sensor unit send a print message to the blind control unit b. Look at the time duration between each print message sent to the blind control unit c. Verify if the duration is less or equal to 0.5 seconds

2.4.3: Mobile App Unit RV Table

Requirements	Verification
1. The desired brightness set by the user is communicated properly to the Blind Control Unit's microcontroller. 2. The user sees the maximum brightness outside as read by the photo sensor outside through the application. 3. If there is not enough light outside to match the desired brightness level, the application lets the user know through a text (ex. "There is not enough light outside). 4. The user schedules the desired brightness at a certain time and the application communicates to the microcontroller in the blind unit at that time $\pm$ 1 second.	1. Verification Process for Item 1: a. Set the brightness to no light in the app. b. The microcontroller prints the value coming from the application as 0 lux c. Set the brightness to 10,000 lux d. The microcontroller prints 10,000 lux 2. Verification Process for Item 2: a. Manually send the 3 different brightness measurements at different times in the day (brightest, middle, darkest) from the microcontroller of the photo sensor unit. b. The app should return the same value as the maximum brightness outside. 3. Verification Process for Item 3: a. Set the desired brightness at the darkest setting at the peak of the day (12 pm - 3 pm) b. The text should not show up. c. Set the desired brightness as a higher lux value than the maximum brightness around 4 pm and around evening (past 9 pm) the application should have the text "There is not enough light outside". 4. Verification Process for Item 4: a. Schedule the desired brightness at time X for no light. b. The microcontroller prints out the 0 lux as the target brightness. c. Measure the time it took for the microcontroller to print the 0 lux since X

2.4.4: Power Unit RV Table

Requirements	**Verification**
1. The voltage regulator for the AC adapter must provide 5V ± 1 at 50 mAh for the ESP32. 2. The battery outputs a voltage of 3.7V $\pm\ 0.1$ at 50 mAh. 3. The voltage regulator for the battery must provide 3.3V ± 1 at 50 mAh.	1. Verification Process for Item 1: a. Attach a 5 Ω resistor as a load. b. Supply regulator with the power brick. c. Measure the current through the resistor with an oscilloscope d. Ensure the output voltage is between 4.9V and 5.1V. 2. Verification Process for Item 2: a. Attach a 5 Ω resistor as a load. b. Measure the current through the resistor with an oscilloscope. c. Ensure the output voltage is between 3.6V and 3.8V. 3. Verification Process for Item 3: a. Attach a 5 Ω resistor as a load. b. Supply regulator with the power brick. c. Measure the current through the resistor with an oscilloscope. d. Ensure the output voltage is between 3.2V and 3.4V.

2.5) Tolerance Analysis

A critical component of our project is the stepper motor's control logic of controlling the blinds. The stepper motor must adjust the blind to reach fully open and closed as much as possible without exceeding the boundary and damaging the blinds. To achieve the requirements of this control logic, we decided to take advantage of the stepper motor's characteristics and provide an initial state of the stepper motor and the blind subsystem.

First of all, we need to calculate the full range of motion from blinds being completely closed at one angle to completely closed at the opposite angle. A fully open blind lies in the median angle in between. (Visuals shown below)

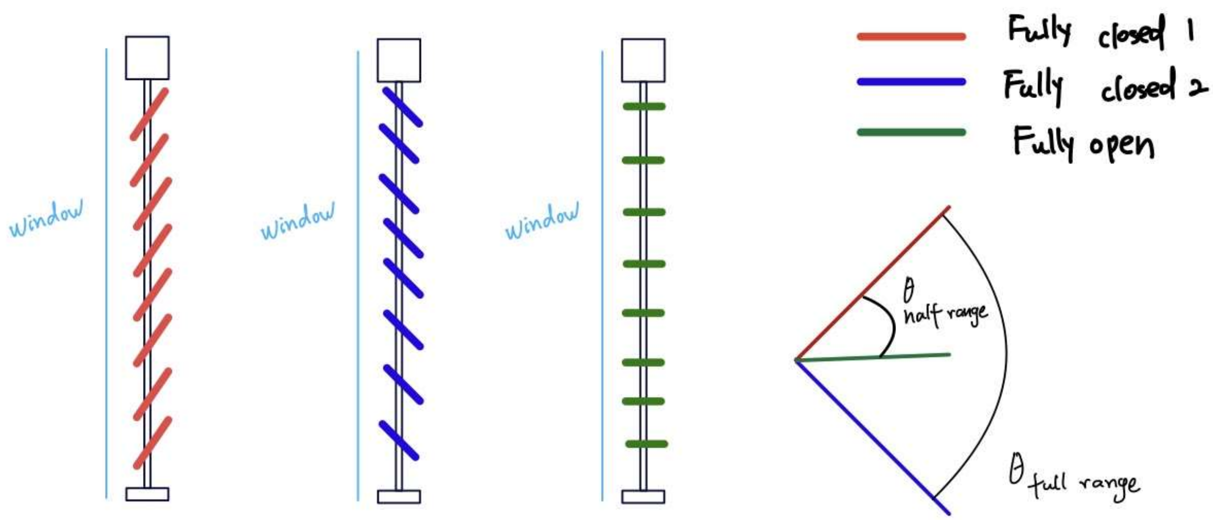

Figure 7. Blinds motion

Assuming a full range motion of the blinds $\theta_{full\ range}$ is approximately 4 revolutions using the rod, then with the stepper motor that we picked having 200 steps per revolution and 1.8 degree step angle as stated by its datasheet [6], we are able to calculate the exact steps needed to achieve a full range of motion and this number can be easily incorporated into the software.

$$4 * 200 = 800\ steps$$

To prevent the stepper motor from damaging the blinds, we should always initialize the blinds to a starting position to be fully closed (denoted using red color in the figure above), so we know exactly where the boundary is. For example, half of the full range of motion, 400 steps, is needed going from a fully closed to a fully open orientation, and vice versa where 400 steps is required from a fully open to fully closed orientation.

3) Cost Analysis

3.1) Cost Analysis

Labor:

(45/hour) x 2.5 x (60 hours to complete) = $6750/member x 3 members = $20250 for the entire project

Parts:

Name	Quantity	Price
Blinds	1	17.59
ESP32-Wroom-32d(4MB)	3	13.5(4.50ea)
Big Easy Driver	1	19.95
Stepper Motor with Cable	1	15.95
L7805 regulator	1	0.95
LD1117 regulator	1	1.95
LM1084 regulator	2	6.1(3.05ea)
BC847 transistor	6	1.26(0.21ea)
CP2102	3	5.73(1.91ea)
0475890001 connector	3	2.46(0.82ea)
2011-2X12G00RB header	3	3.06(1.02ea)
51125-06-0200-01 header	3	0.81(0.27ea)
VEML7700	2	4.26(2.13ea)
10kΩ resistor	9	3.33(0.37ea)
470Ω resistor	6	2.70(0.30ea)

2.2kΩ resistor	4	1.48(0.37ea)
10μF capacitor	12	3.36(0.28ea)
100nF capacitor	11	3.30(0.30ea)
100μF capacitor	8	3.08(0.28ea)
3.7V batteries	2	9.95 ea
JST connector (female)	2	0.75 ea
12V power adapter	1	9.00 ea

Total: $115.92 with the most expensive option of the ones listed

Sum:

$20345.25 (so far)

3.2) Schedule

Week	**Task**	**Members**
9/27	Finish design document	All
	PCB Schematic	Kevin and Kevin
10/4	Finish PCB Design	Kevin Yu and Chaehee
	Order parts	All
10/11	Teamwork Evaluation 1	All
	Start on application	Kevin Choi + Chaehee
	Start assembling Photo Sensor Unit	Kevin and Kevin
10/18	Finish creating application	All
	Continue assembling Photo Sensor unit	All
10/25	Finish Assemble Photo sensor Unit	Kevin and Kevin
	Start assembling Blinds Unit	All
11/1	Finish assemble Blinds Unit	All
	Connecting all of the units	All
11/8	Testing the system	All
	Prepare mock demo	All
11/15	Mock Demo with TA	All
	FIx anything/change according to feedback	All
11/22	Fall break	
	Fix more anything/change according to feedback	All
	Start final paper	All

11/29	Demonstration	All
	Mock presentation	All
	Continue working on the final paper	All
12/6	Presentation	All
	Finish final paper	All
	Final paper due	All

4) Ethics and Safety

This project has potential ethics and safety issues that may conflict with the IEEE Code of Ethics, namely the safety and privacy of the user [7]. For instance, the user could get their finger, hair, etc. stuck in the motor area. As a preventative measure, our implementation of the stepper motor is designed to be turning at a low speed to ensure user safety in a potential case of physically interacting with the motor. We would also install the motor so that it is out of reach for small children.

The user must be okay with an automated system opening and closing their blinds as this can be a privacy issue. As the designers for this project, it is important to be transparent about the potential privacy issues of the project and to address ways to ensure the privacy of a sure. As the user will be controlling the behavior of the motor as it controls the blinds through the application, the user must understand the possibility of their space being seen as a result of the system adjusting the brightness level of their space. The mobile application will also have a manual setting where the user will be able to fully control the orientation of the blinds to respect the user's privacy.

We will accept and apply honest criticisms of the product we produce as well as credit the proper contributions of others. As stated by the IEEE Code of Ethics, we will respect every person and not discriminate regardless of their race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression [7]. We will also not engage in harassment and avoid causing injuries to others, property of others, reputation, or employment through any form of abuse or malicious actions [7].

References

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[5] High Accuracy Ambient Light Sensor With I2C Interface. Vishay Semiconductors. (n.d.). Retrieved September 30, 2021, from https://www.vishay.com/docs/84286/veml7700.pdf.

[6] Sparkfun. (n.d.). Stepper Motor With Cable Datasheet. Retrieved October 4, 2021, from https://www.sparkfun.com/datasheets/Robotics/SM-42BYG011-25.pdf.

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