Design Document

Smart Home Conditioning System

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Introduction

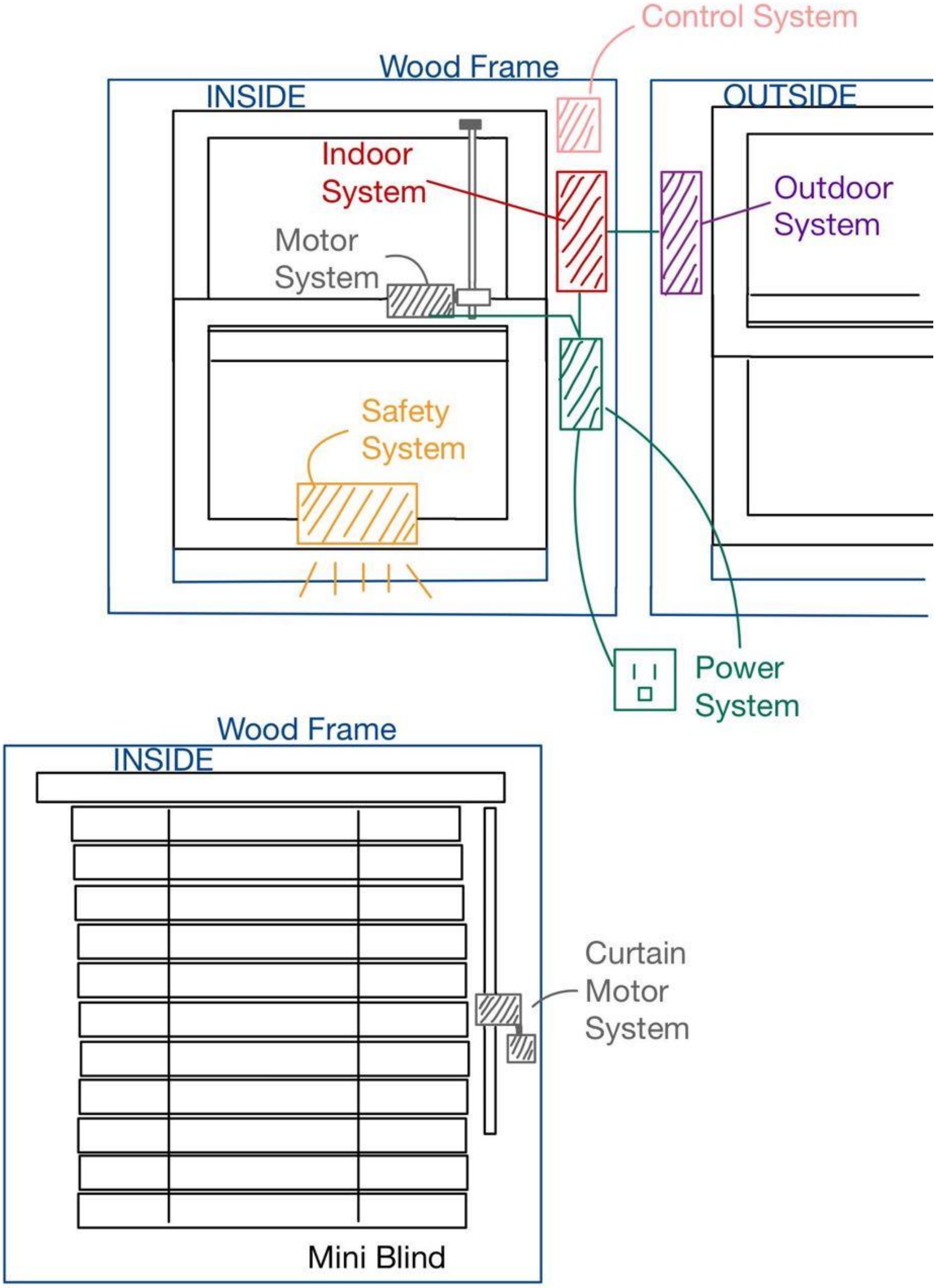
1.1 Problem

The windows and blinds, which enable the exchange of air, light, and sound, are essential pieces of furniture that maintain the comfortable environment of a house. For people with physical disabilities who often stay at home for a long time, to maintain their mental health, it is particularly important to keep their home in exchange for fresh air and receive mild sunshine which will help them build a connection with nature and the outside world. However, for people with physical disabilities, it might be inconvenient for them to open the windows and blinds when it's a pleasant day outside or to close them when it rains, fogs, smokes, or when it is too noisy or shiny outside. Therefore, we aim to design a Smart Home Conditioning System that automatically keeps the house in exchange for fresh air and mild sunshine on pleasant days and blocks the unpleasant weather outside for people with disabilities.

1.2 Solution

The Smart Home Conditioning System consists of sensors to detect humidity, temperature, brightness, air quality, and noise levels, and two motors to open/close the window and the blind. The sensor module consists of two subsystems: indoor and outdoor. For the outdoor subsystem, we will have the rain sensor, humidity sensor, and PM2.5 sensor to determine whether it rains, fogs, or smokes outside. For the indoor subsystem, we will have the brightness sensor and noise sensor to measure brightness and noise level. Additionally, we will also have two temperature sensors to measure indoor and outdoor temperatures. When the indoor temperature is lower than a preset value, and the outdoor temperature is high, the microcontroller will tell the motor to open the window. When the indoor temperature is higher than a preset value, and the outdoor temperature is low, the microcontroller will also tell the motor to open the window. In the case when the outdoor temperature is not within a preset range, when it rains, fogs, or smokes, or when it is too shiny or noisy outside, the microcontroller will tell the motors to close the window or the blind. Besides, we will have a linear encoder for the motor to know whether the window and blind are closed or opened. To address potential safety problems, we will employ an IR sensor to detect whether there are any obstacles such as hands or pets between the window and the frame. Overall, this Smart Home Conditioning System consists of a sensor module with indoor and outdoor subsystems, a safety module with an IR sensor, a linear encoder, a microcontroller, and a motor module with a window motor and a blind motor.

1.3 Visual Aid



1.4 High-level requirements list

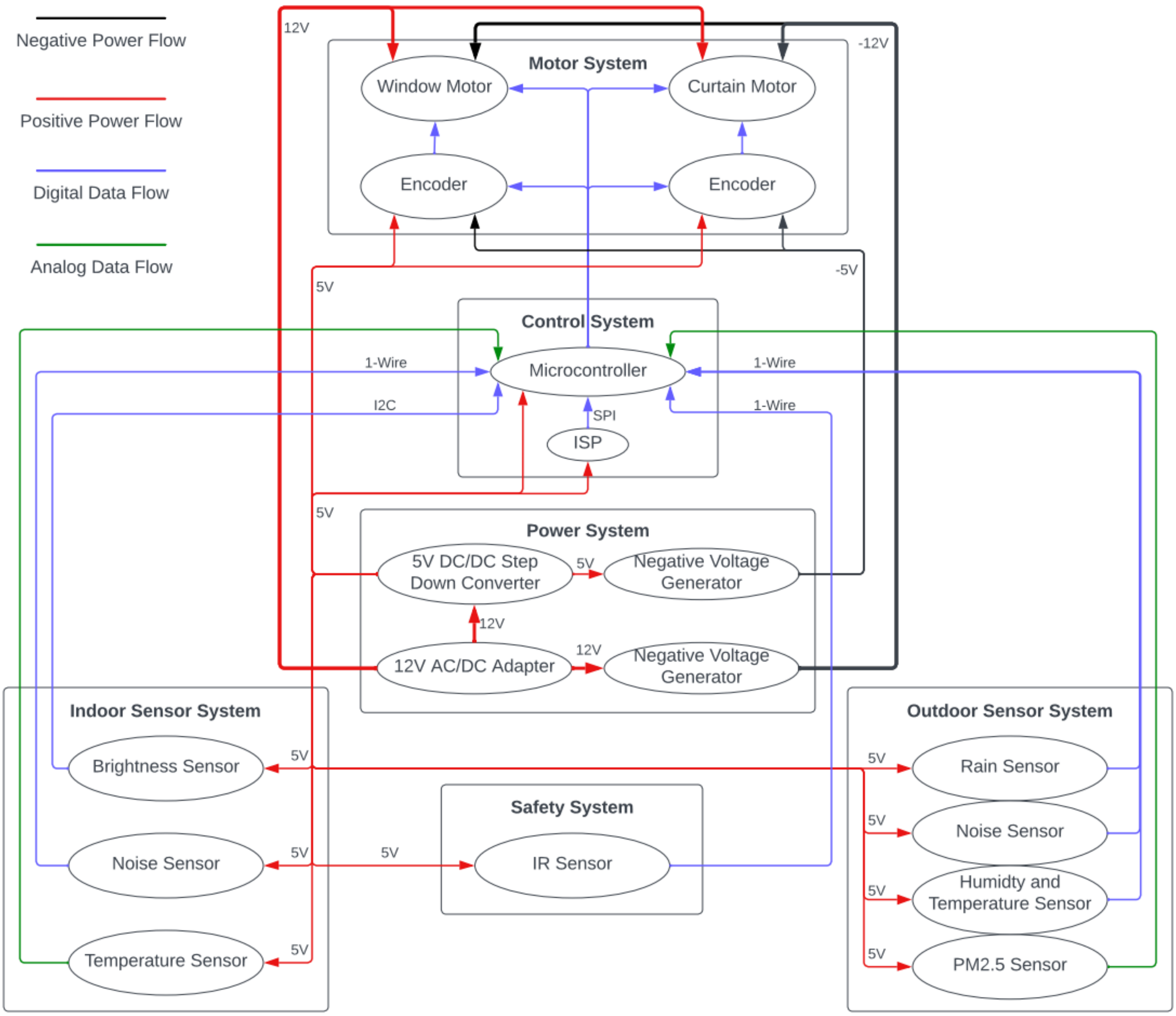
1. The window will close when the relative humidity outside is larger than 70 %; when it is raining outside; when the PM2.5 concentration outside is larger than 300 μg/m³; when the noise is larger than 70 dB; when the indoor temperature stays between 23 ℃ and 25.5 ℃ while the outdoor temperature is lower than 21 ℃ or higher than 27.5 ℃. In other cases, the window will remain open.

2. To ensure the privacy of our design, we want to check the brightness outside. The blinds will be closed whenever the brightness level falls below 10 lux, indicating it's night outside. In this case, the inside view will be separate from the outside. Otherwise, The blind will be left open.

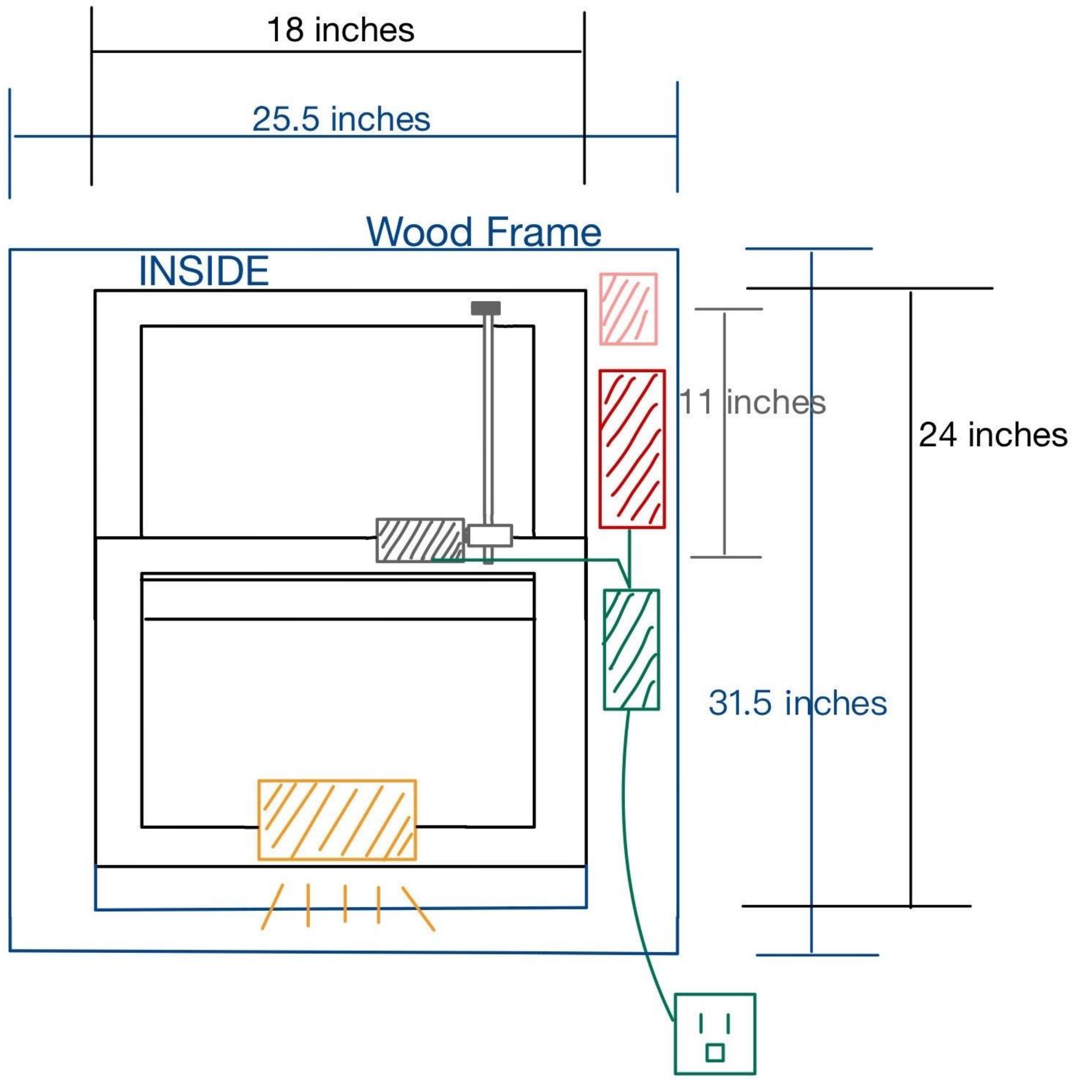
3. Safety is an essential consideration of our design. Therefore, the safety module should respond within 0.5 seconds when any obstacles appear within 10cm of the window. We also want to detect rain and noise levels every 30 seconds, indoor and outdoor humidity and temperature every 5 minutes, and brightness and dust level every 30 minutes.

Design

2.1 Block Diagram

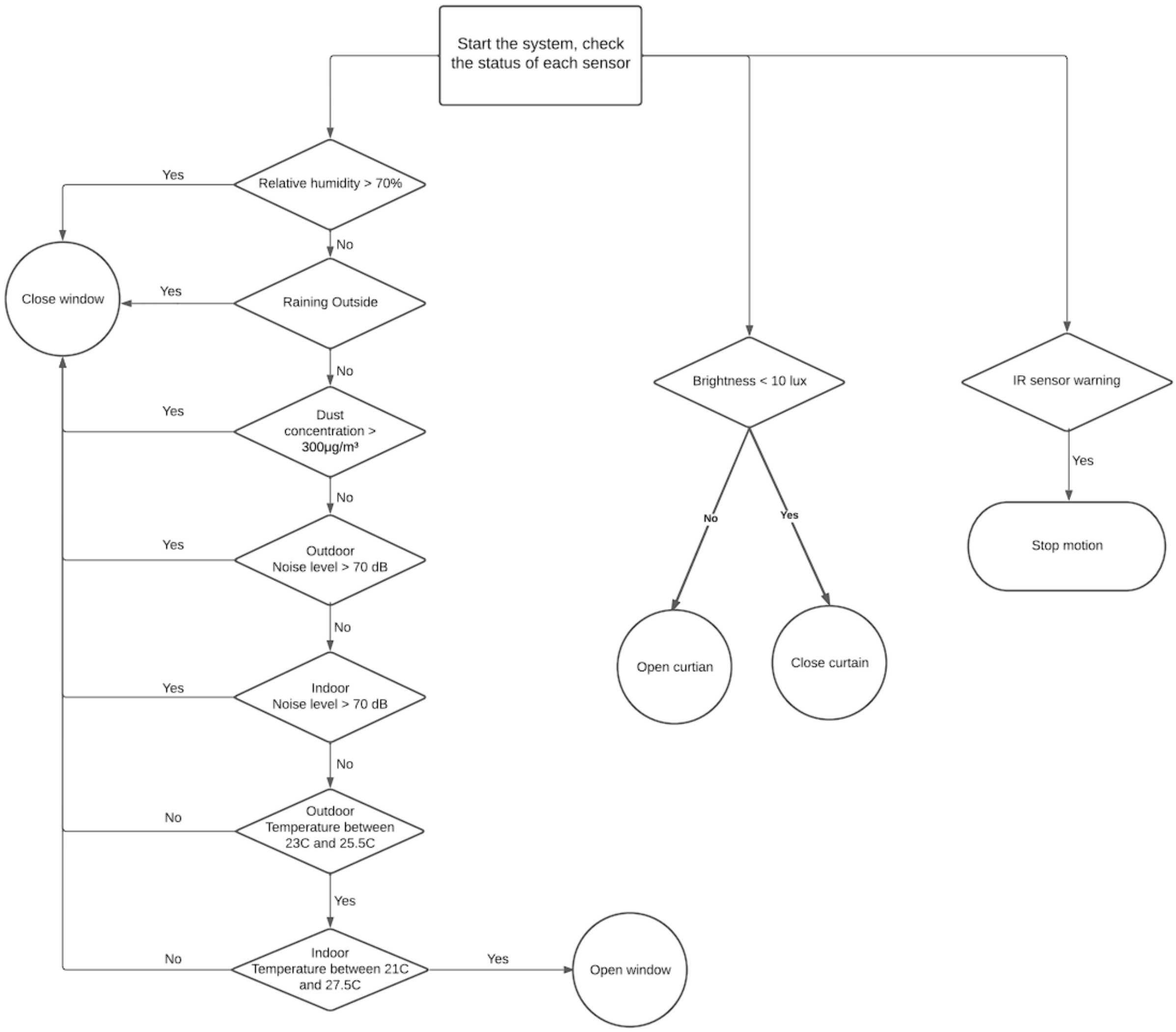


2.2 Physical Design



Our design for the Smart Home Conditioning System would build on a vertically pull window, which has a frame size of 18*24 inches. The wood frame around the window has a dimension of 25.5*31.5 inches, and most of our design would be located on the wood frame. To be specific, the control system, the indoor sensor system, and the power system would all be attached to the right side of the wood frame. The control system consists of our PCB design and microcontroller, the indoor sensor system consists of the temperature sensor, brightness sensor, and noise sensor, and the power system consists of an AC-DC Converter and a DC-DC Step Down Converter. The motor system will install on the top of the underneath window, which will also be attached with a straight and long screw that will install on the top of the above window. The safety system consists of an IR sensor, which will be located at the bottom of the underneath window. The outdoor system consists of a rain sensor, humidity sensor, PM2.5 sensor, and temperature sensor. The outdoor system would install on the right side of the wood frame, but it would locate outside of the wood frame. The blind system would have a mini blind installed on the top of the wood frame, and the motor would be attached to the spinning stick that opens/closes the blind.

2.3 High-Level Flow chart



2.4 Subsystems Overview

Power Subsystem: Support the power needed by the motors to perform the opening and closing of the window and blind. The power system should be able to supply power to all the motors, sensors, and microcontrollers we are using in this project. With the wall adapter that converts the voltage from alternating current (AC) to direct current (DC) 12V voltage and a DC-DC Step Down (buck) regulator to convert the 12V DC to 5V DC, it will be able to successfully power up the system.

Requirements	**Verification**
The system must provide stable 12 ± 0.5V DC, 2 Amp power to motor system and DC-DC converter	- Connect the Converter to the wall and use Voltmeters and Ammeters in the ECE 445 lab to measure the output voltage of the Converter, verify the reading is between 11.5 and 12.5 V - After 5 minutes, measure the output voltage and check it is still in the range of 11.5 - 12.5 V
The system must provide stable 5 ± 0.5V DC power to the sensors and microcontroller in this project	- Connect the Converter to the 12V power supply and use Voltmeters and Ammeters in the ECE 445 lab to measure the output voltage of the Converter, verify the reading is between 4.5 and 5.5 V - After 5 minutes, measure the output voltage and check it is still in the range of 4.5 - 5.5 V
The system must provide stable -12 ± 0.5 V DC and -5 ± 0.5 V DC power to the motor system	- Connect the negative power converter to the two converters above, connect wires to positive and negative power rail and ground. - Connect the wires to Voltmeters and measure the output voltage of the converter - When connected to the 12V DC output power converter, verify the readings are +(11.5 to 12.5)V and -(12.5 to 11.5) V from the two power rails - When connecting to the 5V DC output power converter, verify the readings are +(4.5 to 5.5)V and -(5.5 to 4.5)V from the two power rail - After 5 minutes, measure the output voltage which should be the same compare to the reading 5 minutes ago

1. AC-DC Converter

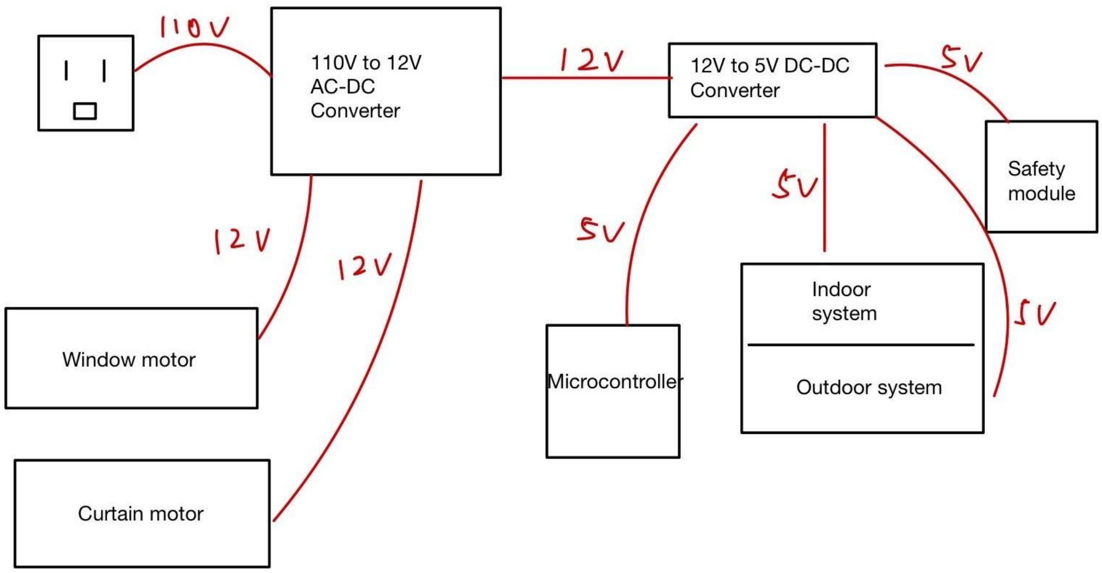
For our AC-DC Converter, we will use a 110V AC to 12V DC converter by inShareplus. The AC-DC Converter accepts AC voltage from 100V to 240V, which can satisfy our need for the design. The Converter pack also includes a 5.5/2.1mm DC Female Barrel Connector, which would be convenient for the connection with the motor. The AC-DC Converter will also connect to the DC-DC Converter to provide 5V DC voltage, which will be useful for most of the components in our design. The maximum wattage is 24 watts, which would be enough to supply the power of each component.

Input Voltage	AC 100-240V
Input Frequency Range	50/60Hz
Output Voltage	DC 12V
Output Current	2Amp
Output Voltage	24Watt
Wire Length	20 Awg, 100cm long at the outlet end

2. DC-DC Step-Down Converter

The DC-DC Converter will convert 12V DC voltage from the AC-DC converter to 5V DC voltage. In our design, we choose the 12V to 5V Converter by DROK. This component has a range of advantages, and to be specific: the converter has a conversion efficiency of over 95% percent; the converter has an aluminum case with strong protection and heat resistance; the converter has low heat generation. The DC-DC Converter will provide the power supply for most of the components, such as the microcontroller, the indoor & outdoor sensor, and the safety module. The selected DC-DC converter can provide an output current of up to 3A, which will be enough for our design.

Input Voltage	12V DC
Output Voltage	DC 5V
Output Current	3Amp
Output Voltage	15Watt



Control Subsystem: Consists of the microcontroller that reads in and processes the data from the sensors and then decides the action of the motors for the window and blind. The microcontrollers should provide enough consideration of the current weather and generate decisive signals to other motors. The microcontrollers should also respond fast to data from sensors within 0.5 seconds.

Requirements	Verification
Could read in I2C data passed in from brightness sensor, and 1-wire data passed in from noise, rain, IR, humidity, and temp sensors. And analog data passed in from the P.M. 2.5 and temperature sensor.	- Simulate input signals for different pins: noise, rain, IR, humidity, and temp sensors can generate high/low signals, thus we can create high/low input to see if Microcontrollers work. - Check the microcontroller can print out the I2C data input coming from the brightness sensor on the monitor. - Simulate analogy data input for P.M. 2.5 and temperature sensor.
Respond within 0.5 seconds to the different input signals, especially for IR sensors	- Simulate input signals and use the oscilloscope to measure the time for the Microcontrollers to respond - Provide the low/high signal for the assigned IR data reading pin measures the microcontroller response time, verify it is

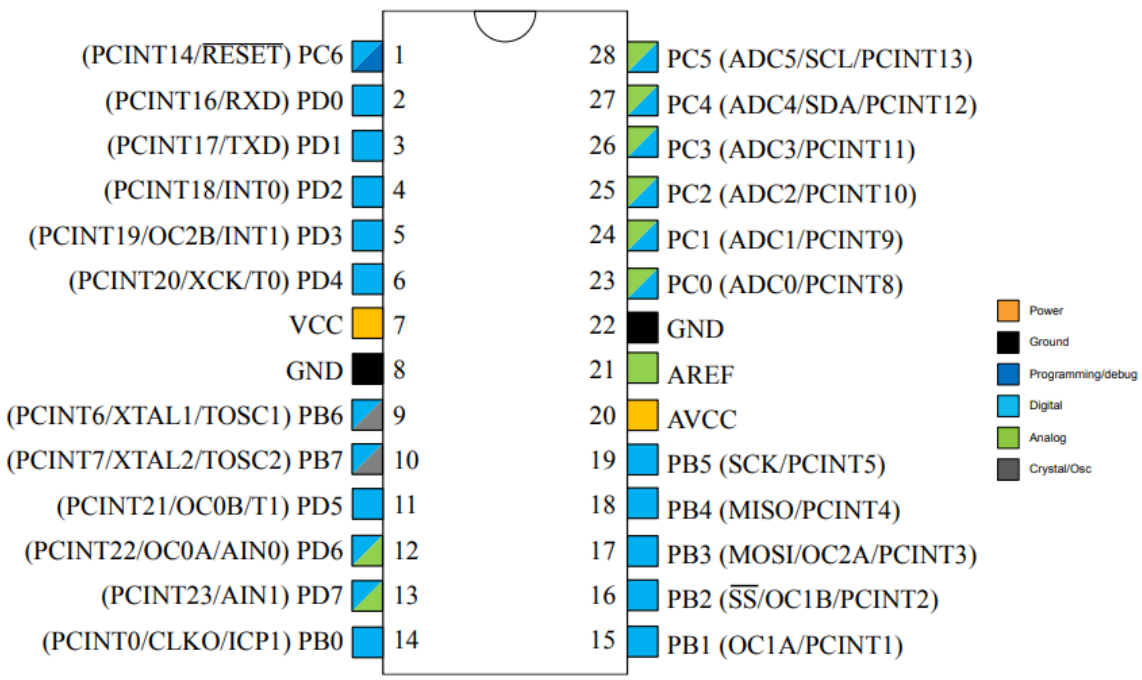
	less than 0.5 seconds
Microcontrollers should detect the environment in various time frames (detailed in high-level requirements) and check whether we need to change the status	- Use an oscilloscope to check whether the Microcontollers could process the data every 30 seconds / 5 minutes / 30 minutes: check if there is output to the motor when we change the testing environment after 30 seconds / 5 minutes / 30 minutes - Check if the Microcontroller would constantly read data for 30 seconds in a 1-minute duration: we will keep providing high readings to the Microcontroller for 30 seconds check if the motor position changes

We will choose Atmega328P-PU as our microcontroller, which is the Atmega328 series produced by MICROCHIP. This low-power CMOS 8-bit microcontroller is based on the AVR Enhanced RISC architecture, and it has 23 programmable I/O lines and 28 pins on the chip. The 23 programmable I/O lines have 6 PWM-capable pins and 6 analog input pins. Atmega328P-PU has 32 KB of Program Memory Size and 2KB of RAM Memory Size, including 1KB of Electrically Erasable Programmable Read-Only Memory. The operation frequency of Atmega328P-PU is 20MHz, which means that it can calculate 20 million times in 1 second in ideal conditions. With this powerful performance, the microcontroller only requires a supply voltage of 1.8V to 5.5V, which can be satisfied by the power supply by the DC-DC Converter.

In our design, the Atmega328P-PU will be used as the center of the design, and it will connect with our PCB to process the status of different sensors and motors. The data and signals will be sent to the PCB board when the threshold is met or the data is changed, and the PCB will pass the signal to the microcontroller for further analysis. The microcontroller in this step will consider the current environment and preset conditions, which will be combined to decide whether we need to open or close the window or blind. After processing, the microcontroller will send instructions to the motors, and with the encoder embedded in the motors, the microcontroller can achieve precise commands to the motor. The motor will then rotate to open/close the window or blind, which will be precisely restricted by the encoder and microcontroller.

The microcontroller will also handle the safety module, and since safety is the priority in our design, the microcontroller should always respond to the safety module before other operations. During the opening/closing, the microcontroller will always process simultaneously with the safety module and send out instructions to the motors immediately when unusual signals are received from the safety module.

Supply Voltage	1.8V - 5.5V
No. of Pins	28
No. of Programmable Pins	23
Active Mode Current	0.2mA
Program Memory Size	32KB
RAM Memory Size	2KB
Operating Frequency Max	20MHz
Interfaces	I2C, SPI, UART



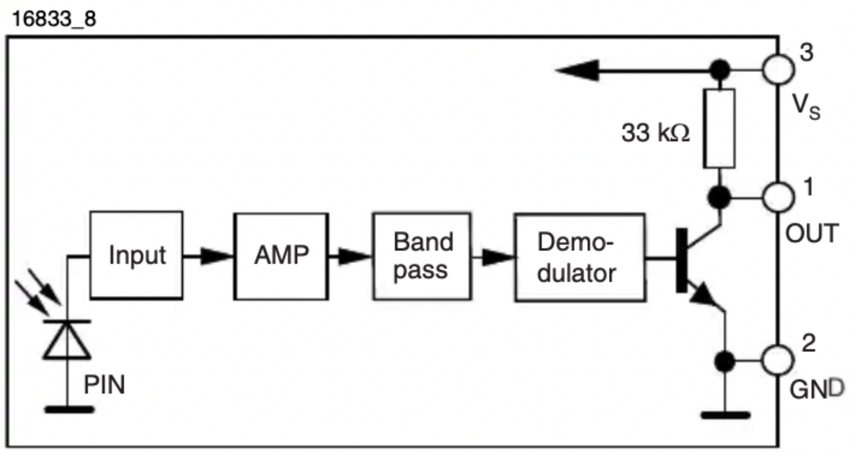
Safety Subsystem: This subsystem is a crucial part of our design as it prevents potential safety issues from happening. Consists of linear encoders and one IR sensor, which will tell the microcontrollers if something is near the windows, and pauses the window motor. Prevent users from getting injured when the window is opening or closing. The safety system requires the motor to stop within 0.5 seconds, and the IR sensor that detects obstacles should also be accurate when any obstacles appear within 10cm of the window.

Requirements	**Verification**
Able to detect any obstacles appear within 10 cm of the window	- Place the book within 10 cm of the window frame and verify the sensor captures the abnormal behavior and sends a signal to the microcontroller
The IR sensor should respond and send the signal within 0.5ms to avoid safety problem	- Use an oscilloscope to check the response time for IR sensor and the time for the microcontroller to receive it, verify it is within 0.5ms

IR Sensor:

We will be putting IR sensors on the bottom window frame to prevent people from getting hurt in the process of closing the window. The TSSP4038 sensor we selected is a compact infrared detector module. And provide an active low output in response to infrared bursts at 940 nm, which results in a quick response time, allowing it to detect changes in its environment rapidly. With its rapid detection capabilities, the TSSP4038 sensor can quickly send back the data to the microcontroller for potential safety hazards, allowing for faster response times and ultimately reducing the risk of accidents.

Pins	Connection
1	Out
2	GND
3	Vs (2.5V-5.5V DC)



Motor Subsystem: Giving direction by the microcontroller and powered by the power module the window motor and the blind motor will perform the close or open action, achieving the goal of our design to build a healthier indoor environment. Consist of a window motor and a blind motor. When informed by the microcontroller and powered by the power system it should be able to fully open and close the window and blinds.

Requirements	**Verification**
Window should be steadily opened within 30 seconds	- Attach a piece of paper to the motor and check if the motor spins with a constant Angular velocity: use a timer to see how many cycles the motor spins within 30 seconds. - Used an object with a similar mass as the window to see whether the motor can lift the object steadily - Use the timer to see whether the motor spins enough cycles within 30 seconds
Blinds should be steadily opened within 30 seconds	- Attach a piece of paper on the motor and check if the motor spins with a constant Angular velocity: use a timer to see how many cycles the motor spins within 30 seconds. - Attach the motor to the blinds rotation rod to see whether the motor can open the blinds steadily - Use the timer to see whether the motor performs enough rotations within 30 seconds
Encoder should precisely	- Attached a piece of paper on the motor

control the spin of the motor	and check if the motor spins the desired cycles - Used the timer to measure the time it takes to perform the rotation and check with the preset speed

1. Window Motor:

   We will place two motors on the top of the top window frame and attach them to a spiral iron Rod fixed on the top frame of the lower window. The motor will then rotate either clockwise or counterclockwise to pull up and down the window, depending on the decision made by the microcontroller. Given the weight for the whole window is 8lb and aiming to be able to lift the window up in roughly 30 seconds, we are choosing the motor that is powered by 12V DV, with 20 RPM and a rated current of 0.6A.

Pins	Connection
1(red)	Motor Power +(12V DC)
2(black)	Encoder Power -
3(yellow)	Signal feedback
4(green)	Signal feedback
5(blue)	Encoder Power +
6(white)	Motor Power -

2. Blind Motor:

   We will be placing the motor on the side and attaching it to the blinds' rotation rod. The motor will then rotate either clockwise or counterclockwise to change the blind position, blocking the strong sunlight. Because the blinds' rotation is lighter than the window, the motor we chose previously will be able to support enough torque. With the ability to rotate more than 720 degrees, this motor will also be able to change the blinds' position fully. Additionally, with the encoder in place, the motor will be able to lock its position and keep the blinds in their intended position.

Pins	Connection

1(red)	Motor Power +(12V DC)
2(black)	Encoder Power -
3(yellow)	Signal feedback
4(green)	Signal feedback
5(blue)	Encoder Power +
6(white)	Motor Power -

Outdoor Sensor Subsystem: This module is powered by the power system and it will measure the rain, fog, smoke, and temperature of the outside environment. It will send back the collected data to the microcontrollers which will then decide if the data had exceeded the preset value. The outdoor sensor subsystem will help the microcontroller to determine if the window needs to be closed when the humidity sensor detects > 70% relative humidity; when the PM2.5 sensor detects > 300 μg/m³ dust concentration; when the rain sensor detects raindrops; or when the noise sensor detects noise level exceeding 70 dB. The outdoor sensor subsystem will also provide the outside temperature to the microcontroller for further analysis.

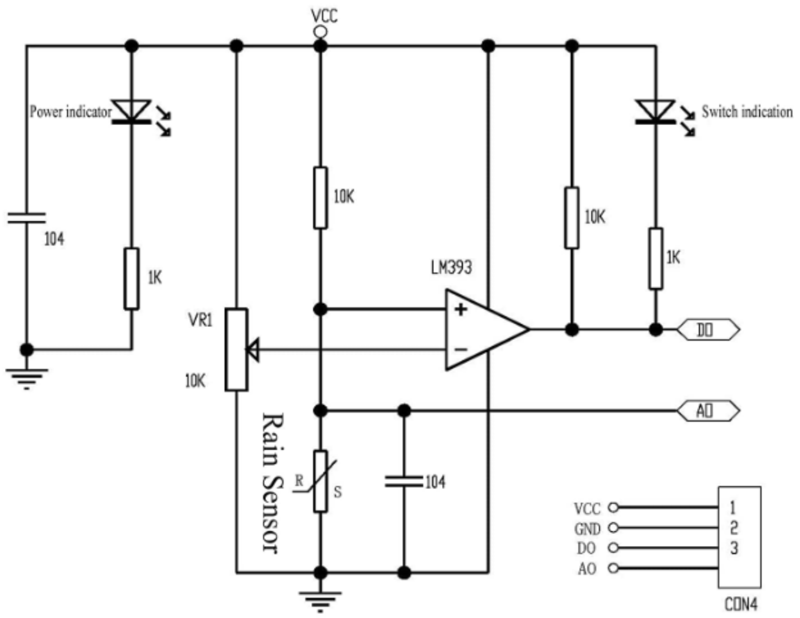
Requirements	**Verification**
Sensor should be able to work steadily under the 5V DC Power supply	- Connect the sensors to the 5V power supply and ground, and use the oscilloscope to check if the sensor is giving output - After 5 minutes, check again to see if the sensors are still able to give out the data output
Sensors should be able to respond within corresponding time to the pre-set threshold correctly	- Rain sensor: Verify the sensor will correctly signal the microcontroller when it rains outside - Add 4 - 5 drops of water on the raindrop board and check the switch indicator, repeat the process for 20 times - P.M 2.5 sensor: Verify the sensor will correctly signal when the environment around has 300 μg/m³ or higher dust concentration - Create 3 environments each with around

	250 µg/m³, 300 µg/m³, 350 µg/m³ dust concentration, then measure the accurate dust concentration with another PM2.5 sensor with known high accuracy, and finally compare that to the data collected by the PM2.5 sensor we want to test. - Humidity sensor: Verify the sensor will correctly signal when the humidity of the environment around is 70% or higher - Create 3 environments each with around 50%, 70%, and 90% relative humidity, then measure the accurate relative humidity with another humidity sensor with known high accuracy, finally compare that to the data collected by the humidity sensor we want to test. - Noise sensor: Verify the sensor will correctly signal when the environment around is exceeding 70dB - Create 3 environments each with around 50dB, 70 dB, and 90dB, then measure the accurate decibel with another noise sensor with known high accuracy, and finally compare that to the data collected by the noise sensor we want to test

1. Rain Sensor:

   We need a rain sensor on the right side of the outside wood frame to detect if it is rainy outside so that the microcontroller can tell the window motor to close the window when it is raining. Therefore, we choose the LM393 because it has a large raindrop board that is separate from the control board which makes wiring convenient. It also contains a potentiometer to adjust the sensitivity. LM393's control board can send DO TTL digital output to the microcontroller, where high DO output indicates no rain while low DO output indicates rain. LM393's control board can also send AO analog output to the AD port of the microcontroller to detect drops in the above rainfall size. We want it to accurately detect rainfall in the case of light rain (80%) and heavy rain (90%).

Pins	Connection
1	VCC (3 - 5V DC)
2	GND
3	Digital Signal Output
4	Analog Signal Output



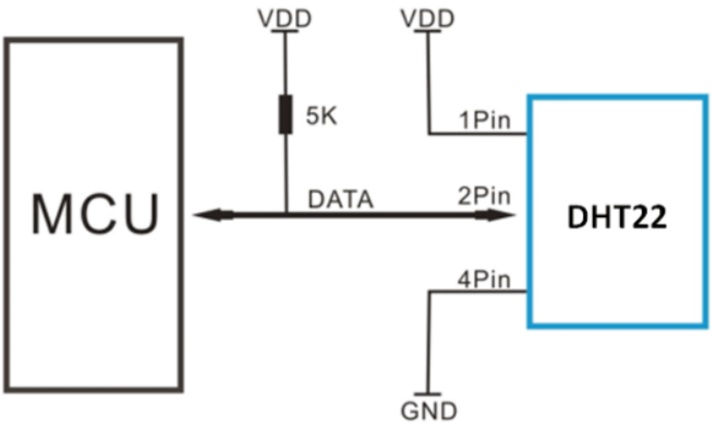
2. Temperature and Humidity Sensor:

   We need a temperature sensor on the right side of the outside wood frame to detect the outside temperature for the microcontroller to analyze the overall temperature.

   We also need a humidity sensor on the right side of the outside wood frame to detect if it is foggy outside by measuring the relative humidity, so that the microcontroller can tell the window motor to close the window when relative humidity > 70%.

   Therefore, we choose the DHT22 because it consists of a humidity sensor and a thermistor, and can both measure temperature in degree celsius and humidity in relative humidity. Its accuracy can go up to ±0.5 ℃ and ±2% RH and exhibit excellent long-term stability. DHT22 sends a digital signal from its data pin to the microcontroller in the format of “8-bit integral RH data+8 bit decimal RH data+8 bit integral T data+8 bit decimal T data”.

Pins	Connection
1	VDD (3.3 - 6V DC)
2	Serial Data Interface
3	N/C
4	GND



3. PM2.5 Sensor:

   We need a PM2.5 sensor on the right side of the outside wood frame to detect if it is smoking outside by measuring the dust concentration, so that the microcontroller can tell the window motor to close the window when dust concentration > 300 μg/m³. Therefore, we choose the KS0196 which performs well in detecting delicate particles. KS0196 sends analog signals to the microcontroller with an output voltage linear to the dust density, so there is no need to make calculations. We want it to accurately measure dust concentration with the accuracy of ±30 μg/m³.

Pins	Connection
1	VCC (3 - 5V DC)
2	GND
3	LED --- MCU IO (module driving pin)
4	OUT --- MCU IO (analog output)

4. Noise Sensor:

   We need a noise sensor on the right side of the inside wood frame to detect if the environment is too noisy by measuring decibels, so that the microcontroller can tell the window motor to close the window the indoor noise level > 70 dB. Therefore, we choose DAOKI which enables users to set a threshold. When the threshold is reached, it will send a DO output to the microcontroller. What's more, DAOKI also has a potentiometer for sensitivity adjustment. We want it to accurately measure the noise level with the accuracy of ±5 dB.

Pins	Connection
1	VCC (4V - 6V DC)
2	GND
3	Digital Signal Output (1 s and 0 s + v)

Indoor Sensor Subsystem: This module is powered by the power system and it will measure the noise level, brightness, and temperature of the indoor living space. Data will be sent back to the control Subsystem to decide if the data had exceeded the preset value. The indoor sensor subsystem will help the microcontroller to determine if the window needs to be closed when the noise sensor detects a value exceeding 70 dB or if the blinds need to be closed when the brightness sensor detects a value below 10 lux. The indoor sensor subsystem will also provide the inside temperature to the microcontroller for further analysis.

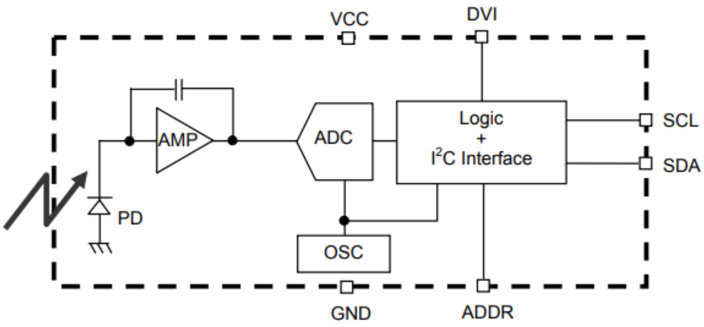
Requirements	**Verification**
Sensor should be able to work steadily under the 5V DC Power supply	- Connect the sensors to the 5V power supply and ground, and use the oscilloscope to check if the sensor is giving output - After 5 minutes, check again to see if the sensors are still able to give out the data output
Sensors should be able to respond within corresponding time to the pre-set threshold correctly	- Brightness sensor: Verify the sensor will correctly signal the microcontroller when the outside environment is below 10 lux - Place the brightness sensor in the environment of a cloudy outdoor, sunny indoor, typical office, and sunny outdoor with no direct sun, and compare the data

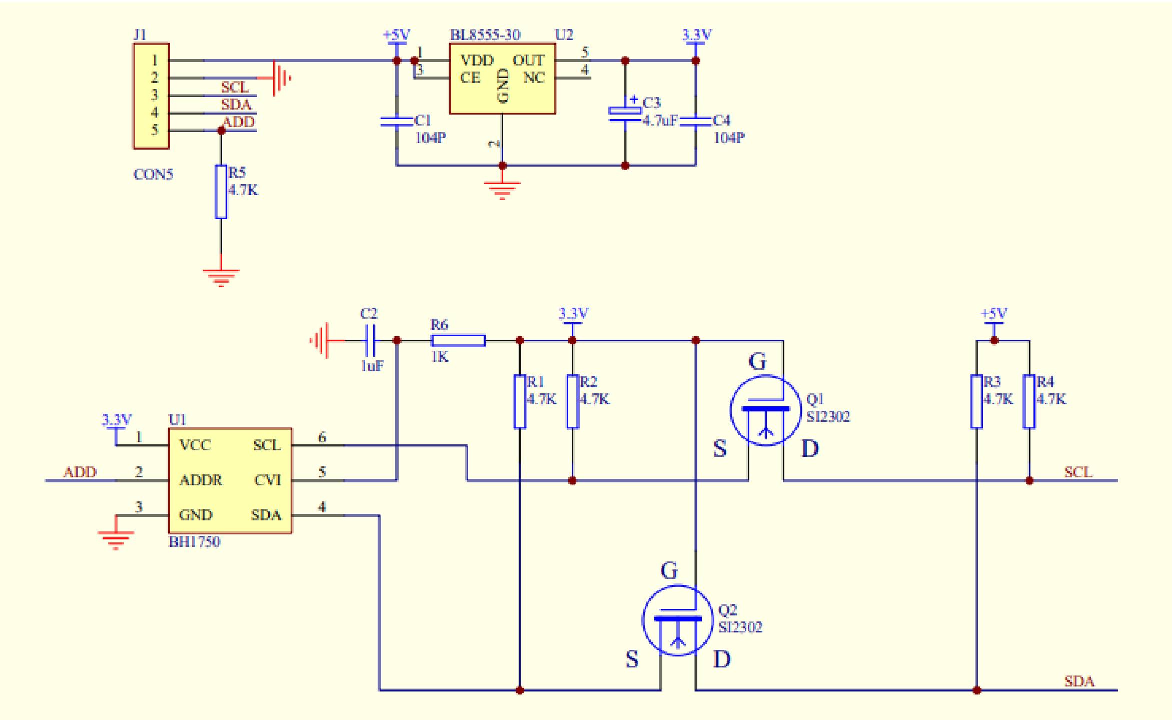
	collected by the brightness sensor to the standard light level chart (Iluminance–Recommended Light Level, n.d.) - Noise sensor: Verify the sensor will correctly signal when the environment around is exceeding 70 dB - Create 3 environments each with around 50 dB, 70 dB, and 90 dB, then measure the accurate decibel with another noise sensor with known high accuracy, and finally compare that to the data collected by the noise sensor we want to test

5. Brightness Sensor:

   We need a brightness sensor on the right side of the inside wood frame to detect if the indoor environment is too shiny by measuring the level of illuminance, so that the microcontroller can tell the blind motor to close the blind when illuminance < 10 lux. Therefore, we choose the BH1750 which has a wide range and high resolution (1 - 65535 lux). It also shows little dependency on light sources and little influence by infrared. BH1750 sends digital signals to the microcontroller directly in lux, so there is no need to make calculations. We want it to accurately measure the brightness level with the accuracy of ±1 lux.

Pins	Connection
1	VCC (3 - 5V DC)
2	GND
3	SCL
4	Serial Data Interface
5	ADD





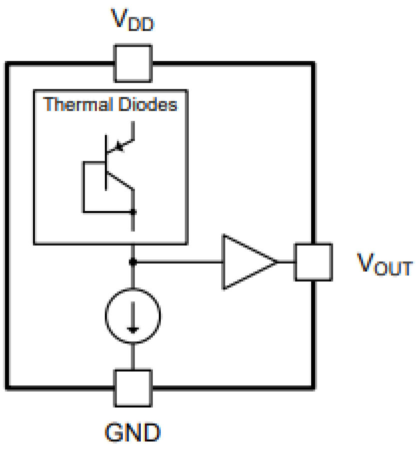
6. Noise Sensor:

   We need a noise sensor on the right side of the inside wood frame to detect if the environment is too noisy by measuring decibels, so that the microcontroller can tell the window motor to close the window the indoor noise level > 70 dB. Therefore, we choose DAOKI which enables users to set a threshold. When the threshold is reached, it will send a DO output to the microcontroller. What's more, DAOKI also has a potentiometer for sensitivity adjustment. We want it to accurately measure the noise level with the accuracy of ±5 dB.

Pins	Connection
1	VCC (4V - 6V DC)
2	GND
3	Digital Signal Output (1 s and 0 s + v)

7. Temperature Sensor:
   We need a temperature sensor on the right side of the inside wood frame to detect the inside temperature for the microcontroller to analyze the overall temperature. Therefore, we choose the TMP235 because it has a high accuracy of ±0.5 ℃ from a wide range of 0 °C to +70 °C. TMP235 sends analog signals to the microcontroller with an output voltage proportional to temperature, so there is no need to make calculations.

Pins	Connection
1	VDD (2.3V - 5.5V DC)
2	Analog Signal Output
3	GND



2.5 Tolerance Analysis

In our design, there are three main aspects that require deep consideration for the tolerance analysis.

The first aspect is the power and capability of each component. In our power system, the 110V AC power will transfer into 12V DC and 5V DC as the power supply, and thus the converter would be important in our design to ensure that the maximum current will not exceed the limits. If the current exceeds the limit for converters, the design may lead to serious danger. In this case, we need to calculate the power needed for each sensor and motors, and decided if our choice of the converter is safe to use.

For the DC-DC Converter, the maximum current is 3A. For the components that are supplied by 5V DC power, the total current needed is:

0.2mA(microcontroller) + 5mA(IR Sensor) + 0.4mA(Rain Sensor) + 2.5mA(Temperature and Humidity Sensor) + 20mA(PM2.5 Sensor) + 0.2mA(Brightness Sensor) + 0.4mA(Noise Sensor) + 0.012mA(Temperature Sensor) = 29mA = 0.03A, which is far lower than the maximum current of the Converter. Thus, the DC-DC converter will be safe to use.

For the AC-DC Converter, the maximum current is 2A. For the components that are supplied by 12V DC, the total current needed is:

0.03A(DC-DC Converter) + 2*0.6A(motor) = 1.23A, which is lower than the maximum current of the AC-DC Converter. Thus, the AC-DC converter will be safe to use.

The second aspect is the torque by the motor, and we need to make sure that our choice of motor can lift the window and spins the stick on the blind. For this aspect, we also need to consider the case in which the motor is not spinning at the maximum torque, and we need to leave some room to ensure the success of our design.

The force needed to lift the window in our design is $F = ma = 3.63kg * (9.8)\ m/s^2 = 36.162N$, and to make sure that we can close/open the window within 30 seconds, we need more force $F = ma = 3.63kg * (0.5)\ m/s2 = 1.82N$. Thus, the total force needed is 38N. The motor we choose has a radius of 2.7cm, which is 0.027m. In this case, the torque needed is 38N * 0.027m = 1.026Nm.

With consideration for the energy lost, we will choose the motor with at least 3Nm to ensure the success of our design. The motor we choose has 5.4Nm, which is much higher than our need. Thus the motor will be safe to use.

The last aspect is the response time of our systems.

For our safety system, we want the time it takes for the IR sensor to react and the microcontroller to respond when any obstacles appear within 10cm of the window to be within 0.5 seconds for safety considerations. The IR sensor we chose can respond in 5 ms for ranges from 10 cm to 2m. What's more, the microcontroller can respond within 2 ms. Therefore, the safety system can satisfy our requirements.

For the rain sensor, we want it to detect the environment every 30 seconds, and based on the datasheet, the rain sensor can complete measurement in 5 seconds, and it can provide constant output that indicates rain for over 30 seconds. Thus, the rain sensor can fulfill our needs.

For the indoor temperature sensor, we want it to detect the environment's temperature every 5 minutes, and based on the datasheet for the temperature sensor, it can achieve a measurement time within 2 seconds. Thus, the selection of the temperature sensor can fulfill our needs.

For the sunlight sensor, we want it to detect the brightness every 30 minutes, and with the datasheet, the brightness can be measured from the sunlight sensor within 120 ms. Thus, the selection of the sunlight sensor can fulfill our needs.

For the P.M 2.5 sensor, we want it to detect the environment every 30 minutes, and based on the datasheet for the dust sensor, it can achieve a measurement time within 1 second. Thus, the selection of the P.M 2.5 sensor can fulfill our needs.

For the humidity and temperature sensor, we want the sensors to detect the environment's temperature every 5 minutes and humidity every 30 minutes. Based on the datasheet for the humidity and temperature sensor, it can achieve a measurement time for temperature and humidity within 2 seconds. Thus, the selection of the humidity and temperature sensor can fulfill our needs.

For the noise sensor, we want it to constantly detect the environment, and based on the datasheet for the sound sensor, it supports real-time data output. Thus, the selection of the sound sensor can fulfill our needs.

Cost and Schedule

3.1 Cost Analysis

1. **Labor:**

Assume the hourly salary for a newly employed Engineer is $45/hr and assume an average workload for this project is 10 hrs per person per week. With a total of 16 weeks of work this semester, the total labor cost would be

$45 × 10 hrs/week × 16 weeks × 3 people = $21600.

2. **Parts:**

Description	Manufacturer	Part #	Quantity	Cost($)
Motor System				
Motor	Fafeicy	Fafeicyogdbg2c9up-03	3	16.13 x 3
Power System				
110V AC - 12V DC Converter	inShareplus	ISP-NW-PS-12V-WP-UL-24W	1	8.89
12V DC - 5V DC Step Down Converter	DROK	090600AFA	1	12.99
Negative Power Converter	YWBL-WH	14dhe9wf7p-05	2	10.79 x 2
Control System				
Microcontroller (2pc)	Microchip Technology	ATMEGA328-PU	1	25.99
PCB	PCBway		1	30
Safety System				
IR Sensor	Vishay	TSSP4038	1	1.30
Indoor/Outdoor Sensor System				
humidity and temperature sensor	Aideepen	DHT22	1	10.35
PM 2.5 sensor	Keyestudio	Ks0196	1	10.00
sound sensor (set of 5)	Daoki	TS-US-115-CA	1	6.29
Temperature Sensor (analog)	Texas Instruments	TMP235A2DBZR	2	0.402 x 2
sunlight sensor	DFRobor	BH1750	1	4.5
rain sensor (set of 3)	HiLetgo	LM393	1	6.49
Other				
blinds	Lumino		1	9.97
Total:			**$ 197.54**	

Grand Total (Labor + Parts):	$ 21797.64

3.2 Schedule:

Time table

Week	Task	Member
2/20 - 2/26	Design document; Select desired sensors and components; Specify detailed expectation for design;	All Members
2/27 - 3/5	Buy sensors and motors, and test whether the sensors and motors are functional	Shuning Zhang Zhaonan Shi
	Buy microcontroller and test whether the microcontroller fixes into our design	Zhaonan Shi Haoen Li
	Start PCB design, work on the component and contact with machine shop	All Members
3/6 - 3/12	investigate motor and encoder, program motor and test with the window	Shuning Zhang
	PCB assembly and test the functionality	Zhaonan Shi Haoen Li
3/13 - 3/ 19	Spring Break	All Members
	Finish any leftover job from previous week	
3/20 - 3/26	Implement rain drop sensor and sunlight sensor with microcontroller and program basic induction for these sensors	Haoen Li
	Contact machine shop and install the motor and blind on the window	Shuning Zhang Zhaonan Shi
	Programming of the motors and encoder	Zhaonan Shi
	Install the Safety module	Shuning Zhang Haoen Li
3/27 - 4/2	Link indoor sensors to the	Shuning Zhang

	microcontroller and connect to the PCB board; Test and debug the indoor system	Zhaonan Shi
	Link outdoor sensors to the microcontroller and connect to the PCB board; Test and debug the outdoor system	Haoen Li Zhaonan Shi
4/3- 4/9	Test out exact location on the window frame for better measurement of the inside sensor module; Test and debug the indoor system for finalization	Shuning Zhang Zhaonan Shi
	Test out exact location on the window frame for better measurement of the outside sensor module; Test and debug the outdoor system for finalization	Haoen Li Zhaonan Shi
	Connecting indoor sensors with outdoor sensors	All members
	Assemble all components, test the coordination of each components	
4/10 - 4/16	Finalized design, debug and test the design; prepare for the demo	All members
4/17 - 4/30	Mock Demo Final Demo Start writing Final Paper and Presentation	All Members
5/1 -5/3	Finalize Final Paper and Final Presentation	All Members

Ethics and Safety

Our design will only render limited Ethics problems, as we mainly focus on the mechanism and functionality. Based on the IEEE Code of Ethics, we, as a group, need to “hold the highest standards of integrity, responsible behavior, and ethical conduct in professional activities" (IEEE, 2023). To be specific, we need to "hold paramount the safety, health, and welfare of the public" (IEEE, 2023). This guideline emphasizes that we should always place safety in the first place and ensure that anyone who uses our design will be safe and pleasant. We should also "seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest, and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others" (IEEE, 2023). We need to keep promoting better design and listen to others' suggestions since they may have more professional consideration. At the same time, we must "maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations" (IEEE, 2023). Only after we equipped ourselves with professional skills will we make the knowledge into practice, and this will make sure that we won't damage and hurt the equipment, labs, students, and even ourselves.

Besides ethics problems, our design may involve many safety concerns and we need to make sure that we eliminate those safety problems to a minimal degree. For our motor system, we must make sure that the closing/opening of windows stops immediately when some obstacles appear. This includes human arms, human hands, pets, and other objects like books, phones, and computers. The IR sensors should respond fast to ensure that the motor stops, and the encoder on the motor should also be precise to make sure that the motor stops when the windows or blinds are fully open or closed. The power system should also be taken into serious consideration, since the electricity may lead to a severe fire risk and shorted risk. In addition, the components should be well protected: no matter the outdoor system or the indoor system, the components should be protected with shields and tapes, which can ensure that the design won't be affected by unexpected damage like weather and unintended touch.

In conclusion, we will follow the IEEE Code of Ethics and eliminate any safety problems to protect the ECE 445 lab environment, professors and TAs, students, and ourselves. We will work together and meet frequently to improve the design, and we will keep our Ethics and safety standards so that we can present the best side of our design.

Safety Document

Since the design involves the human interfaces, sensors, and AC adapter, it is possible that the design may lead to severe safety issues. Thus, the safety document would be necessary to address unsafe situations. In our design, the IR sensor would be used to detect any unusual obstacles, and when obstacles appear, the motor would stop within 1 second to make sure that the window or blind will not hurt the user.

The sensor unit placed outside is susceptible to potentially hazardous weather conditions, which could result in a short circuit and cause significant damage to the window unit, home, or even result in injury to the user. Such outcomes would deviate from the intended purpose of this project. Thus we will ensure the components are properly installed and well insulated and shielded.

As for the AC adapter, our design will provide the necessary protection to the adapter, and for example, insulation Tape would be employed to fully cover the wires. While our design can minimize the potential risks, it is important that users should still avoid any unsafe behaviors.

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