ECE 445 Senior Design Lab Project Proposal: Smart Curtains

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1 Introduction

This section will set up the problem we are trying to tackle and the general solution we came up with.

1.1 Problem

Alarm clocks are a shocking way to wake up in the morning, and often times can be ineffective when used on their own for extra early mornings.

1.2 Solution

We want to make LED-assisted smart curtains that automatically open in the morning to complement a user's alarm set on their smart phone. The curtains will open at a certain time in the morning based on user preference, should be able to sync up with a smart phone's alarm by connecting via WiFi, and will activate LEDs that are installed around the user's window to simulate sunlight in case it is not bright enough outside.

1.3 Visual Aid

A visual depiction of our smart curtain system can be found below. The black button in the top right would be used by the user to interface with the processor. Depending on the input this button could assist the user with setting up the WiFi connection, toggle modes of the device to control if it should react to the connected phone's alarm or not, perform a hard restart on the device, or much more.

The blue light on our system represents the photodetector used to read the brightness in the room. This sensor reading will control the LEDs represented by the Christmas lights wrapped around the window.

The green and red buttons would be used for the user to open or close the blinds without requiring a connection to WiFi, or without the user's alarm having to be set.

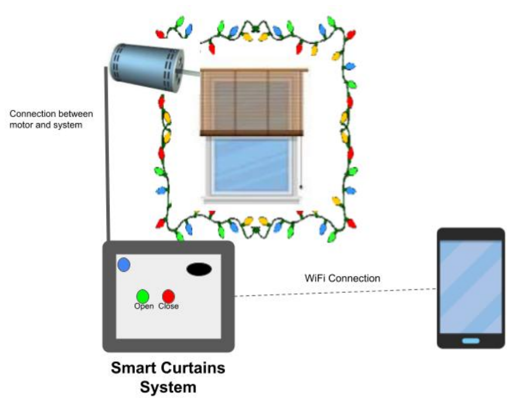

Figure 1: Visual representation of Smart Curtains.

1.4 High-Level Requirements

- Able to reliably open and close curtains accurately with apple homekit.
- Successfully connect to the user's smartphone via WiFi and set the opening or closing time of the curtain system from the user's iPhone.
- Our LED strip effectively reacts and illuminates a room in the case where opening the blinds does not provide sufficient light from outside.

2 Design

2.1 Block Diagram

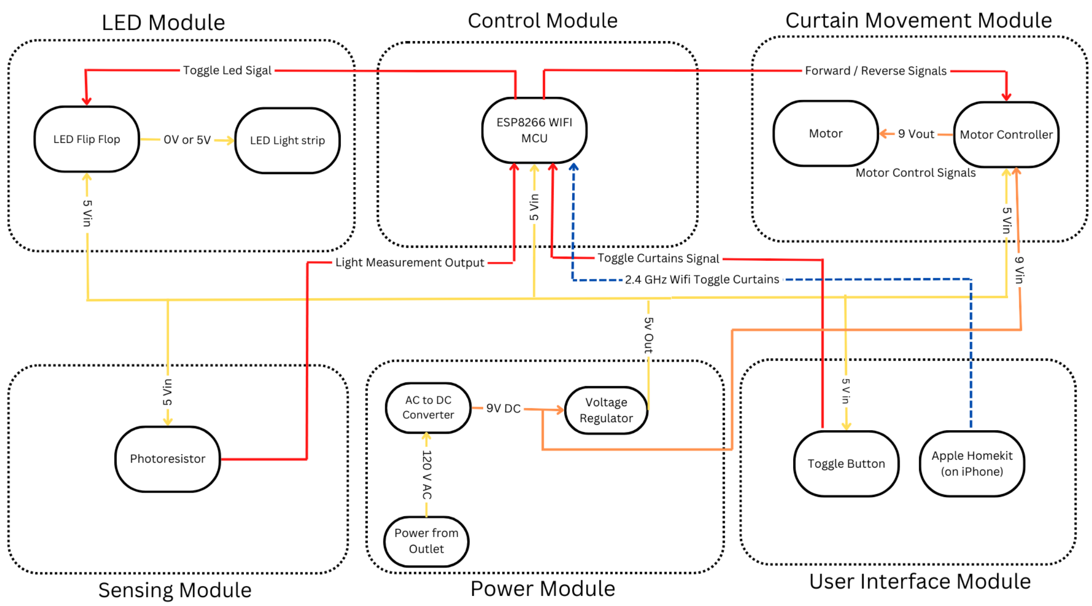

Figure 2: Block diagram representation of Smart Curtains.

2.2 Subsystem Overview

2.2.1 Curtain Movement Subsystem

For the movement of the curtain itself, we will connect a motor to a modified roller curtains mechanism to raise and lower the curtain. The curtains will be modified so that the gear that controls the turning of the curtain rod will be rotated by our motor. A gear will be attached to the motor's output shaft, which rotates as the motor runs, transmitting rotational force to the gear on the curtains. The gear on the motor shaft will be designed and 3D printed with teeth that engage the teeth on a curtains gear, which in turn drives the rod connected to the curtains. This results in the curtains being raised and lowered by the bidirectional rotation of our motor.

Parts

- Motor and Motor Controller
- PVC Pipe
- Curtain sheet

2.2.2 Brightness Monitoring Subsystem

In the case that the curtains open up and there isn't a sufficient amount of light entering through the window, we will utilize a photoresistor to measure the ambient light intensity around our device. The intensity reading will be used by the microcontroller to determine whether the room needs additional light by turning on the LEDs. For applying additional light to the room, we will mount an LED strip onto a curtain rod and turn them on only if there isn't enough light entering the room through the window.

Parts

- Photodiode
- LED Strip

2.2.3 Processing Subsystem

Our microcontroller is connected to our WiFi module (ESP8266) and will receive open and close signals over the WiFi using Apple HomeKit, which the microcontroller will then process. The microcontroller will then send signals to the motor controller to open and close the Curtains. The microcontroller also will receive the measurement of the lighting in the room from the photoresistor, and will potentially send signals to the LED strip to activate it if there is not enough light. In addition, we will have a physical button for manually changing the microcontrollers open and close state of the curtains.

Parts

- ESP8266
- Button

2.2.4 Power Subsystem

In order to power the Microprocessor, motor, and other components of the system we will draw 120 V AC from the wall, which will be converted to 9 V DC using an AC to DC converter. We will then use a LM2596S-5 to step down the voltage to 5 V DC, the needed voltage for most of our components.

2.3 Subsystem Requirements

2.3.1 Curtain Movement Subsystem

1. The motor should be able to open and close the curtain in a reasonable amount of time $\sim$ 10 secs.
2. The motors should spin just the right amount to have the length of the curtain (72") be rolled/unrolled within ± 0.5 inch of its full length

2.3.2 Brightness Monitoring Subsystem

1. The light sensors must be able to read the light intensity through the window within a bound of 100 lumens.
2. The LEDs must possess enough healthy lighting to make up for darkness inside the room. This light level should be greater than 650 lumens.

2.3.3 Processing Subsystem

1. Even if the iPhone is in sleep mode during an alarm, the PCB WiFi-chip should still receive a trigger from the phone alarm within $\sim$ 1 sec and move its curtains accordingly.
2. The PCB should handle manual button presses appropriately (i.e depending on the current state of the PCB, the button should trigger either a close command or open command).
3. For every significant change of sensed light levels from inside the room, the PCB should accurately receive data from the light sensors and dim/brighten the LED strip accordingly within $\sim$ 1 sec.

2.3.4 Power Subsystem

1. The system should have protection against overvoltage, overcurrent, undervoltage, and undercurrent
2. The Power Subsystem must be able to supply at least 500mA to the rest of the system continuously at 9V ±0.1V and at 5V ±0.1V after the voltage step down.

2.4 Tolerance Analysis

The part of our system that we are most worried about overheating or causing issues regarding tolerance is our motor control system due to the amount of current required to drive our motor. To fix this issue we had to choose a motor driver that provides extra safety and was designed to support our required current while minimizing heat generation. We chose to use the MAX14872 IC since it can support a wide voltage range from 4.5 - 36V, handle up to 2.5A peak current, as well as provide a variety of other benefits discussed below [2].

The MAX14872 device offers safety features built into the integrated circuit such as overcurrent condition checking, current regulation using a sense resistor, and thermal shutdown [2]. We may monitor these failure cases by observing a FAULT signal generated by the device. These features ensure that our system functions within safe operating points, and disables our motors in the case of a short or improper circuit design to avoid unnecessary damage. We can choose our desired maximum current output by increasing or decreasing the value of a sense resistor connected between the COM and GND pins. According to the documentation [2] for the MAX14872, we can set our maximum motor current using the equation:

$$I_{MAX} = 0.1V/R_{SENSE} \tag{1}$$

The documentation [2] also recommends choosing our sense resistor to have a value such that the voltage at COM relative to ground due to the current flowing through the sense resistor stays within ±250mV. This means we must choose a resistance such that:

$$|I_{SENSE} * R_{SENSE}| < 250mV \tag{2}$$

To control the current supplied to the motor we will use an external pulse-width modulation circuit. This controlled signal will be supplied into the FWD or REV pins of the MAX14872 device. We will experimentally decide what motor current will be ideal for our implementation, and with this current we will directly calculate the corresponding ideal sense resistance.

The schematic for our motor controller implementation is shown in the image below. The MAX14872 IC can be seen on the right side of the circuit. The left side of the circuit is our implementation of a PWM regulator using a precision timer IC, specifically Texas Instrument's NE555D [4], which closely resembles the circuit shown on a website [3]. This can be controlled using the potentiometer to increase or decrease the duty cycle of the signal the MAX14872 receives, thus increasing or decreasing output motor current.

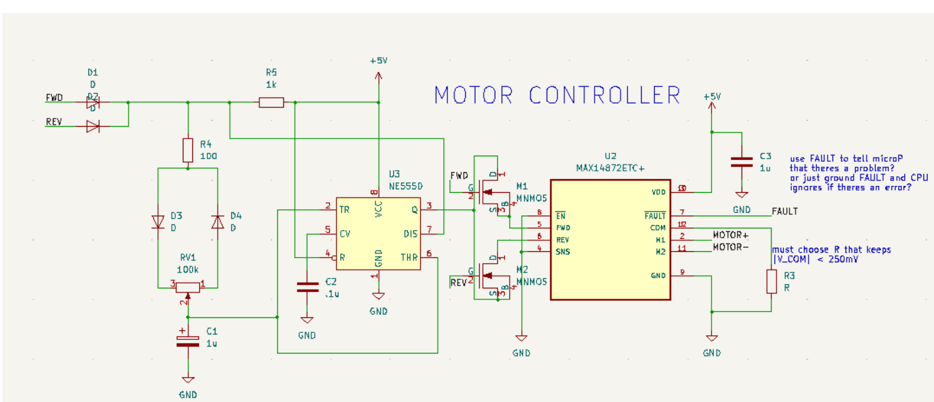

Figure 3: Circuit schematic of the motor controller.

3 Ethics & Safety

In considering the ethics and safety of our project, our group will look to adhere to the IEEE code of ethics during the design and creating process [1]. In reviewing our design, there are a few potential safety concerns that we will have to address. Firstly, automated window blinds systems may pose a risk of electric shock if not properly installed or maintained. Things such as exposed wire or improper grounding could lead to this safety hazard. Another potential risk is the risk of entrapment of fingers or other body parts getting caught in the moving parts of the automated window blinds. To mitigate these risks, we will work to make sure there are no exposed wires or improper wiring in our design, use plastic casing to make sure nothing can get stuck in the motor subsystem, and install the motor subsystem out of reach of everyday movement to avoid potential hazards.

In reviewing our design, there are also a few ethical concerns that we will have to address. Firstly, automated window blinds systems may raise privacy concerns for the users. If used non cautiously, the automated blinds could be opened at times that the user would not want leading to a potential privacy violation. Also, automated window blinds systems may pose security risks if they are vulnerable to hacking or other forms of cyber attack which could lead to unwarranted use. Our team will make these potential concerns transparent to the user and work to mitigate them as much as possible with our design and creation of the system.

As stated in the IEEE code of ethics, we will treat all people we engage with fairly and with respect no matter their race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression. We will be open to and seek honest criticism, and acknowledge and accept any mistakes made along the way, prioritizing the safety, health, and welfare of everyone involved.

References

[1] "IEEE Code of Ethics." IEEE, www.ieee.org/about/corporate/governance/p7-8.html.

[2] Maxim Integrated, "Compact 4.5V to 36V Full-Bridge DC Motor Drivers", MAX14870/MAX14872, Jun. 2017

[3] Nawazi, Farwah. "DC Motor Speed Control PWM Circuit." Circuits DIY, 24 Aug. 2022, www.circuits-diy.com/dc-motor-speed-control-pwm-circuit/.

[4] Texas Instruments, "xx555 Precision Timers", NE555D, Sep. 2014