AUTO SUN VISOR
FINAL REPORT

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Abstract

This report includes the design, progress, and result of the auto sun visor designed by group 4. The auto sun visor provides a better choice between the expense of photochromic glasses and the manual adjustment of sun visors or wearing sunglasses. It contains two motors to change the position and angle of the shading board based on the direction of the sun relative to the vehicle. This paper will also introduce the requirements, verification, estimated cost, and future consideration of this visor system.

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1. Introduction

1.1 Problem

As drivers go through urban areas or blocks on sunny days, it's common practice to use sun visors when sunlight interferes with visibility. However, the frequent turns encountered in such environments can make sunlight seem erratic. Attempting to adjust the sun visor while driving the vehicle can lead to brief periods of distraction and reduced visibility, which is not only unsafe but increases the risk of accidents, including potential collisions with pedestrians. According to data from the National Highway Traffic Safety Administration, sun glare contributes to approximately 9,000 traffic accidents annually in the United States [1]. This statistic shows the need for drivers to exercise caution and seek alternative solutions to manage sunshine interruption while driving, especially in densely populated areas where the risk of accidents is heightened. Polarized sunglasses can reduce sun glare in certain areas. However, drivers who already need prescription glasses would need either to customize prescription sunglasses or add another polarized filter on their own glasses, which can be inconvenient. Moreover, wearing sunglasses while driving could potentially lead to accidents due to reduced visibility under certain conditions. Also, this era's technology allows electrochromic glasses, which could be the most ideal choice to respond to sun glare if it is not that expensive.

1.2 Solution

An auto-adjustable sun visor that is powered by vehicle electricity and reacts to the direction of the sun relative to the vehicle can be a safe choice for drivers to avoid manually modifying the visor position. Our solution seeks to provide a compromise between the expense of photochromic glasses and the manual adjustment of sun visors or wearing sunglasses. This project has two hardware parts, the first part is the robotic arm holding the visor, and the second part is the sensor system. We will install sensors surrounding the vehicle body to determine the sun's position relative to the cars, then take the sensors' input into our algorithm to decide the rotation of our robotic arm to let the visor block the sunlight accordingly under the reaction time that won't let people's eyes be exposed under sunlight.

2 Design

2.1 Physical Design

As in Figure 1, these three views only show the mechanical part for the robotic arm that consisted with two stepper motors and one linear actuator to form two revolutional joints and one prismatic joint. Accordingly, this mechanism design lets the sun visor board contain enough degree of freedom that it can appear in any location the driver needs. For the left-side view in Figure 1, we start to have the 17mm stepper motor1 connected to the vehicle ceiling, a steel pipe connected with motor1 's shaft to link to the rear of another stepper motor2 with 14mm dimension, and the motor's shaft directly connected with a converter linked to the linear actuator, then the linear actuator's extension rod is directly connected with a light weighted visor. The motor1 is mainly in charge of rotating the visor left and right, and the motor2 works to adjust the angle of the visor front and back, then the linear actuator helps the motor go up and down. The reason we do not use the classic design for vehicle sun visors is that flipping the visor could harm/bother the driver under an unaware automotive situation, so our design makes the visor "slide" down to help cover the sun glare that will not affect the head position of the driver.

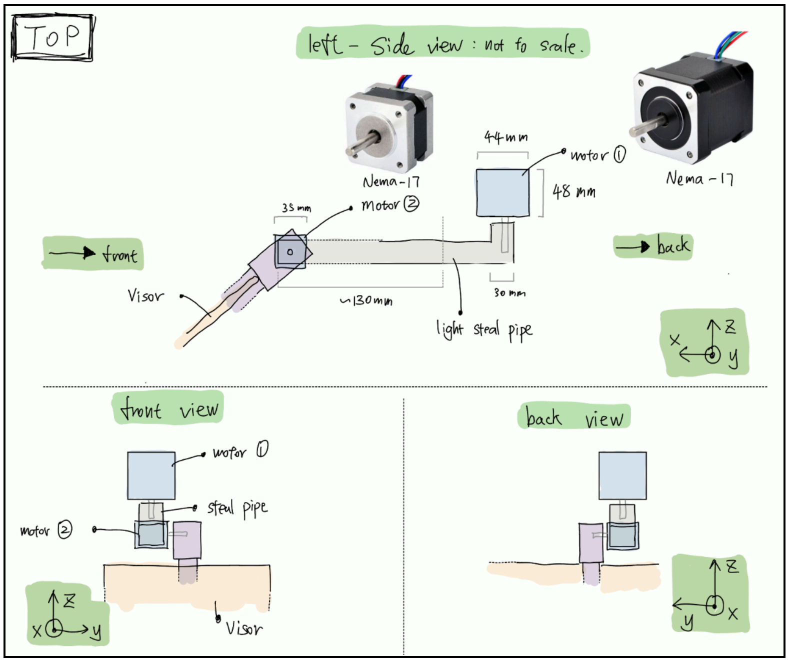

Figure 1: Visor Handler Mechanics

For light sensor installation, we need to make sure to find the position of the sun, so first we can imagine the driver's cab as a rectangular box, as shown in Figure 2, and the different angles' light rotation needs to be taken into account. So we need a sensor face on top of the car, and also sides of the car. Also because it is rectangular, the light sometimes will not cover all its longer side, as shown in the left light rectangular example, so we need to install two sensors for the longer side.

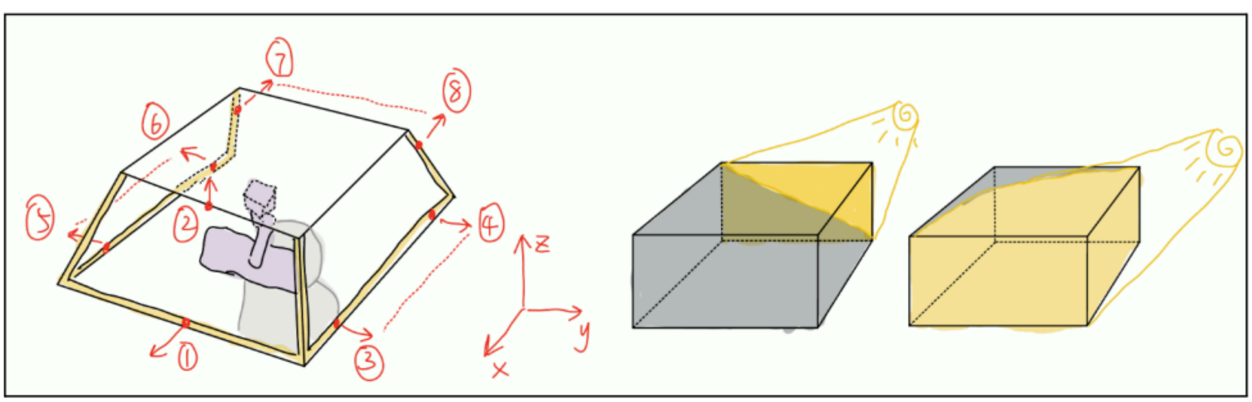

Figure 2: Sensor installation design

Figure 3: Frame used in Demo

2.2 High-Level Requirement List

- A 12v DC power should be able to supply the entire system, while a backup power supply connects to the remaining systems within 3 seconds if the vehicle's power source fails, ensuring the visor returns to its original position when DC power is cut off.
- The microcontroller needs to provide a proper visor angle to cover the sunshine based on the light sensor input.
- The light sensor must be able to identify different levels of light intensity (1 lux to 50,000 lux) as data input and correctly input the data into the MCU unit within 1 second.
- The motor should be capable of moving the shading board to the correct position within 1 second after receiving a move command.

2.3 Block Diagram

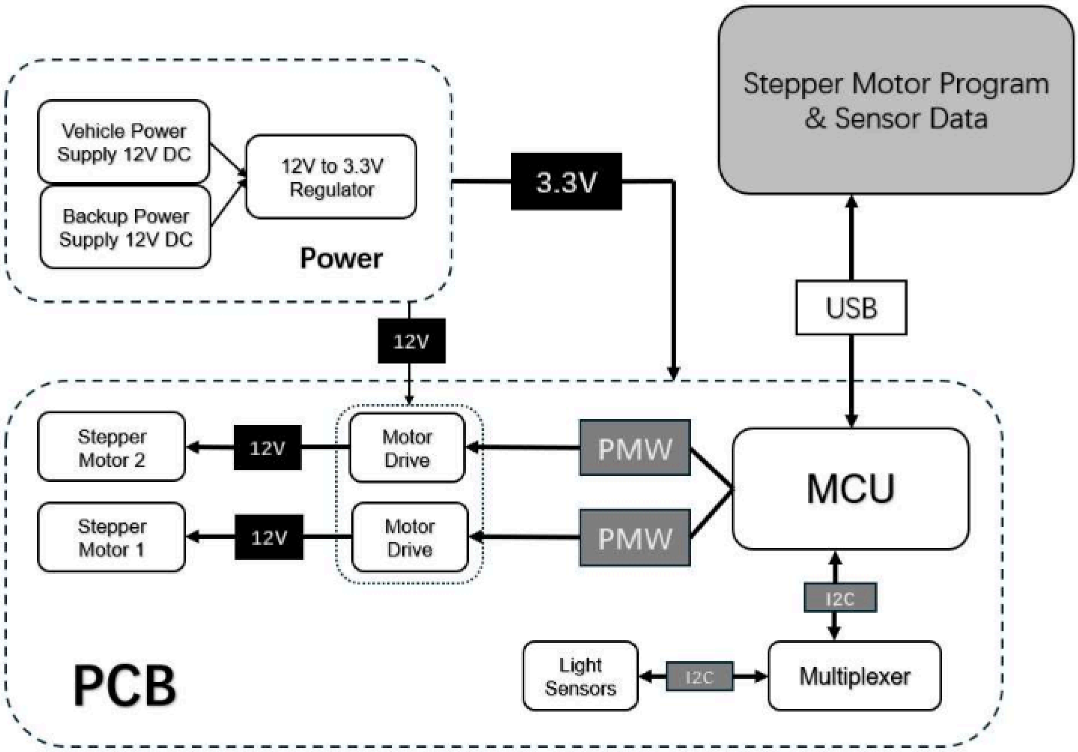

Figure 4: Block Diagram

2.4 Subsystem Overview

Power Subsystem: This is a straightforward power system to supply all the rest of the subsystem.

Sensor Subsystem: A total of 8 light sensors will receive light intensity information, enabling the control system to determine how the visor should rotate. These sensors will be placed at different positions at the front of the vehicle window to facilitate the determination of the visor's optimal position.

Microcontroller Subsystem: The control system receives information from all the light sensors and converts it into a packet that is transmitted via a data cable to the motor, enabling the motor to adjust the control arm according to the instructions received.

Motor Subsystem: The motor system comprises three motors, a steel pipe, and a visor. The main motor is responsible for controlling the steel pipe, while the remaining two motors facilitate the rotation and movement of the visor.

2.4.1 Power Subsystem

Drivers must manage two scenarios with the visor: engaged mode and closing mode. In engaged mode, activated by a light sensor, the visor rotates to shield the driver from the sun. This mode receives a steady 12V power supply from the car, enabling the visor to rotate. In contrast, closing mode occurs either when the visor is not required or when the car's engine is turned off. During this mode, a MOSFET is used to select the power source, primarily the car engine's power. If activated, closing mode draws on the battery's power to assist in returning the visor to its original position using the motor. To let the microcontroller know if we switched the power source, we used an LED to send a signal to one of our light sensors and the data is used in the code to start the power off condition.

2.4.2 Sensor Subsystem

The TSL2591 module allows us to measure light intensity in lux. Since our microcontroller has a limited number of two I2C buses, we incorporated the TCA9548A I2C extension multiplexer. By connecting all sensors to the multiplexer and utilizing its built-in library, we can efficiently gather readings from each sensor. We have installed seven light sensors around the car's frame to enhance accuracy. For demonstration purposes, we simulate sunlight using an intense flashlight that emits approximately 50,000 lux. By varying the light angles, we collect sensor data and apply a straightforward algorithm to pinpoint the location of the light source. Based on this information, the motor is adjusted to optimally block the incoming light.

2.4.3 Microcontroller Subsystem

We use ESP32-S3-WROOM-1 as our microcontroller. It is powered by 3.3V from the power subsystem. This part should take the light intensity from sensors as input and transfer it into the microcontroller. Also, the microcontroller generates PWM to the motor unit to control the motor subsystem. The output of the sensor chip should be lux thus our receiving microcontroller should be able to read in lux, and our programing algorithm should be also in lux units to reflect in the real-world simulation.

2.4.4 Motor Subsystem

We utilize two motors to adjust the visor's vertical and horizontal movements. The A4988 motor driver is employed to manage the motor coils effectively, while the AccelMotor library facilitates the coding for motor control. During testing, we encountered challenges, including the breakdown of three stepper motors. This experience taught us that manually adjusting the motors while they are powered can disrupt the coils and damage the gears. The AccelMotor library has proven invaluable in ensuring smooth and precisely controlled motor movements. However, we occasionally face issues with the power supply; the expected 12V sometimes drops to 11.3V due to wire resistance and other practical physics challenges.

2.5 Software Design

Instead of using the initial software as we mentioned in the proposal, we hard code the position of the visor based on the seven light sensors. For each light sensor, there are three different positions for it depending on the different levels of light intensity. Although doing so prevents the visor from calculating the position it should reach based on real-time data, with about 20 hardcoded positions, our project still accomplishes its function.

2.6 Subsystem Diagrams & Schematics

Our subsystem schematics and board designs are in Appendix B.

2.7 Tolerance Analysis

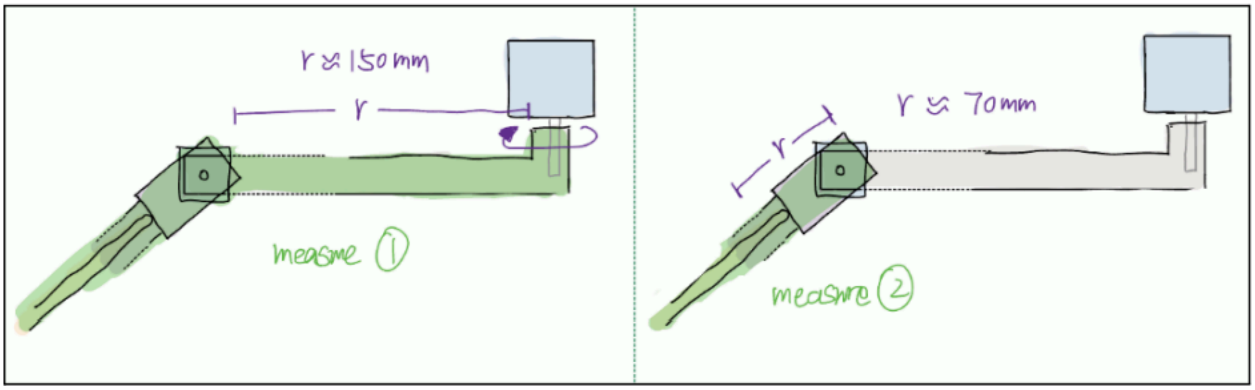

Figure 5: Torque Analysis

After discussing with the machine shop, we found a potential issue is that the motor may not have enough torque to be able to hold the weight and rotate. To measure tolerance, we can divide it into two separate measurements for the two main stepper motors. As shown in Figure 5 measure 1, the motor1 (torque = 59N·cm) is holding the rest of the whole system's weight: steel pipe (mass = 0.2N), visor (mass = 0.1N), motor2 (mass = 3.6N, torque = 59N·cm). The calculated measured torque will be defined as T_1. In measure 2, motor 2 is only needed to hold the pole and visor, and we define this torque as T_2. To calculator the torque resulting by the weight, use T = F*r*sinθ, for sinθ = 1 always since the initiative angle made by the arm and pivot is 90° in both cases:

$$T_1 = (0.2+0.1+3.6) \times 15 \times 1 = 58.5 \text{ N·cm}$$

$$T_2 = 0.1 \times 15 \times 1 = 1.5 \text{ N·cm}$$

As the calculated data shows T_1 is just at the edge of the tolerance of motor1 and T_2 is within the torque of motor2.

3. Design Verification

3.1 Power Subsystem

The two motors require a stable 12V voltage supply. The remaining subsystems need a 3.3V voltage supply. The regulator allows 3.3V voltage output. At the same time, the power supply should be able to switch from the car providing power to backup power based on the light intensity.

The following procedure was followed to verify the above requirement:

1. Power on all systems.
2. Measure the current and voltage of every branch and item to check whether they match with the rated voltages.
3. Shut down the car providing power and repeat step 2.

3.2 Sensor Subsystem

The light sensors need to detect light intensity changes within 1s.

The following procedure was followed to verify the above requirement:

1. Power up the light sensor and connect it to the computer.
2. Try covering by hand or shining a lamp onto the sensor to experiment with the light levels
3. Check the data from the backend and make sure the lux output is valid.
4. Repeat step 2 and measure response time. Ensure the sensor takes less than 1s to give feedback.

Sensor	1	2	3	4	5	6	7	8
Covered[lux]	10.91	9.21	5.35	7.25	9.66	8.40	6.32	3.25
Normal [lux]	127.23	130.74	127.49	128.31	127.19	127.87	128.42	126.63

Table 1: Light Sensors Testing Data

All the sensors respond to the light intensity change within 1s.

3.3 Microcontroller Subsystem

The microcontroller needs to receive the digital signal from the sensor unit continuously. It should send orders to the motor with a given light intensity from the sensor unit. The microcontroller should be able to process input lux and send order with 2s (motor should begin to move after light data change)

The following procedure was followed to verify the above requirement:

1. Power up sensor and pcb board
2. Connect sensor and pcb together
3. Connect motor with pcb board and send simple
4. Send order to make the motor move
5. Change the light source and measure how long it takes to move the motor

Because the requirements for the microcontroller is the ultimate goal of our project, we test it after all the other subsystems are finished. It is hard to provide quantitative data to prove that we meet the requirements but the demonstration of our project shows that those requirements are achieved.

3.4 Motor Subsystem

The motors need to react to the order from the control unit within 2s and change to different angles with the given order from the control system.

The following procedure was followed to verify the above requirement:

1. Power up the motors and use example tests to make sure motors work.
2. Test the motor with the movement code and check whether the motor reaches the right connection.
3. Recording the time that motors needed to reach the right position.

We finished those testing when the motors arrived and added them to the car frame. The demonstration and the printed information in the Serial Monitor proves that the motor received the right orders and reached the position.

4. Costs

The cost of buying parts is $342.60. The labor cost is $32,760. The total cost is $33102.60.

4.1 Parts Costs

Table 2 Parts Costs

Part	Manufacturer	Retail Cost ($)	Quantity	Actual Cost ($)
Light Sensor TSL2591	AMS	6.26	10	62.6
10 Pairs DC Power Jack Plug	Daykit	7.99	1	7.99
Regulator	Taxas Instruments	6.13	5	30.65

LM2596S-3.3				
Battery	Energizer	12.99	1	12.99
P-Channel MOSFET IRF9540NPBF-ND	Infineon Technologies	1.26	5	6.3
DC 12V 3A Power Adapter	LeTaoXing	17.98	1	17.98
Battery Holder	Jex Electronics	8.75	2	17.5
Resistor Pack	Chanzon	8.99	1	8.99
Capacitor Pack	Interstellar Electronic	14.90	1	14.9
DIODE SCHOTTKY 1N5822	STMicroelectronics	0.34	20	6.78
33uH Inductor MLZ2012M330WT D25	TDK Corporation	0.11	20	2.24
22nF Capacitor	TDK Corporation	0.13	20	2.66
0.1uF Capacitor	YAGEO	0.06	20	1.26
500ohm Resistor	Vishay Dale	1.75	10	17.47
Multiplexer TCA9548A	Adafruit	6.95	2	13.90
Stepper Motor Driver A4988	WWZMDiB	6.99	1	6.99
100uF Capacitor EEE-FK1C101P	Panasonic Electronic Components	0.26	10	2.57
220uF Capacitor EEE-FK1C221XP	Panasonic Electronic Components	0.35	10	3.50
680uF Capacitor EEE-FK1C681P	Panasonic Electronic Components	0.54	10	5.44
Button Switch	SCHURTER Inc.	0.25	10	2.50
Female Pin Headers	Ronmee Industrial Corp.	23.89	1	23.89
Male Pin Headers	CHANZON	7.99	1	7.99
LED LS R976-NR-1-0-20-R 18	ams-OSRAM USA INC.	0.13	20	2.66
Buck Converter	Valefod	13.99	1	13.99
Microcontroller ESP32-S3-WROO M-1	Espressif Systems	3.48	6	20.88
Nema-17 Stepper Motor 17HS19-2004S1	STEPPER ONLINE	13.99	2	27.98
Total				**342.60**

4.2 Labor Costs

The salary for one team member is \$40 per hour. We worked on the project for 21 hours per week for 13 weeks. Therefore, the labor cost of one team member is $\$40 \times 21hr \times 13 = \$10,920$. The total labor cost of three team members is $\$10920 \times 3 = \$32,760$.

5. Conclusion

5.1 Accomplishments

Our project successfully achieved all the functionality stated in the design. The visor is able to automatically cover sunlight according to light intensity from light sensors, movement orders from the ESP32, and correct execution of motor orders. The power supply allows the entire system to operate normally, and the backup power supply also enables the visor to return to its original position after the main power is turned off, which solves the basic safety concerns of the project. The demonstration of the project proves that the visor can cover sunlight within a few seconds. The accomplishment of the project is closely related to the success of each subsystem.

5.2 Uncertainties

The final design differed from the initial design in a few aspects. The final design used a different motor model. This was due to a misjudgment of the weight of the visor and linear actuator in the initial design. After obtaining the car frame, we found that the motor could not bear the weight of the visor and was unable to move correctly. Therefore, we updated our tolerance analysis and purchased a new motor based on the calculations. Additionally, the PCB design was also modified due to some oversights. During the initial testing of the PCB, the power regulator section often overheated and smoked. We did some research and found that we had underestimated the heat generated from 12V to 3.3V. A more reasonable design would be 12V to 5V and then 5V to 3.3V in practice, which could reduce the overheating phenomenon.

When connecting the PCB, we should also leave more space and use thicker wires to improve heat dissipation.

5.3 Ethical considerations

The project tries to follow the IEEE and ACM Code of Ethics [10]. Before we put the project into real use, there are a few issues that need to be resolved. First, the current demo frame is provided by the machine shop, while our original design idea was for this to be an in-vehicle upgrade. Normally, all wires should be hidden under the car body. This would prevent the connection between the light sensor and the PCB from being easily interfered with by external factors (collisions, scrapes). However, due to time and cost constraints, we were unable to truly experiment with this idea.

Secondly, before actually using the auto sun visor, we should conduct multiple experiments and tests to ensure that the visor's direction, speed, and functionality will not interfere with actual driving. Since our original intention was to eliminate the safety hazards caused by sun glare, we should pay particular attention to other potential hazards that the automatic car sun visor may bring. This should include simulated tests as well as actual vehicle tests. We can only truly put it into use after ensuring that the driver will not be interfered with by it.

5.4 Future work

There are many aspects of the project that can be further improved. One point for further extension of the project could be to add an extra solar energy subsystem on the visor and a rechargeable battery. In this case, the entire system could use solar energy to provide part of the power. This would also allow users to avoid frequently replacing batteries by themselves.

Another available option is to add more light sensors and use more complex algorithms to ensure accuracy of the visor movement and achieve smoother tracking. We believe this enhancement could solve the issue of our visors not being fast enough.

References

[1] Nowell Law Firm (2024) The hidden dangers of car accidents caused by Sun Glare: Law blog, Nowell Law Firm. Available at: https://www.nowelllawfirm.com/the-hidden-dangers-of-car-accidents-caused-by-sun-glare/#:~:text=According%20to%20the%20National%20Highway,the%20first%20being%20slick%20roads. (Accessed: 20 February 2024).

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Appendix A Requirement and Verification Table

Power Unit R&V Table

Requirements	Verification
Be able to provide 11.5V to 12.5V power supply to make all the subsystems work.	- Power the whole system - Measure the current and voltage of every branch and item to check whether they match with the rated currents and voltages. - Shut down the car providing power and measure the magnitude at every branch and item to check whether backup power works successfully.
Be able to switch from car providing power to back up power if needed.	

Motor Unit R&V Table

Requirements	Verifications
Be able to react to the order from control unit within 2s.	- Power up the motors and ensure each motor works well (just the basic check whether motors work) - Connect with the PCB board. Use the backend to send orders. Make sure the motor can move. - Connect the PCB with the sensor and check our programming. - Measure the time took for motor to start to move after light source changed is within 2s.
Be able to change to different angle with given order from control system.	

Sensor Unit R&V Table

Requirements	Verifications
Be able to detect light intensity changes within 1s	- Power up the light sensor and connect it to the backend. - Try covering by hand or shining a lamp onto the sensor to experiment with the light levels. - Check the data from the backend and make sure the lux output is valid. - Repeat step 2 and measure response time. Ensure the sensor takes less than 1s to give feedback.

Microcontroller Unit R&V Table

<table>
<tr><th>Requirements</th><th>Verifications</th></tr>
<tr><td>Be able to receive digital signal from sensor unit continuously.</td><td rowspan="3">- Power up sensor and PCB board and connect sensor and PCB together.
- Waving hand on the sensor and printing out the input of PCB at the backend.
- Connect the motor with the PCB board and send a simple order to make the motor move.
- Change the light source and measure how long it takes to move the motor
- To check whether the program is correct, use the model frame and specific light source. Then verify the board is in the correct position.</td></tr>
<tr><td>Be able to send order to motor with given light intensity from sensor unit.</td></tr>
<tr><td>Be able to process input lux and send order with 2s (motor should begin to move after light data change).</td></tr>
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Appendix B PCB Board Design & Schematics Design

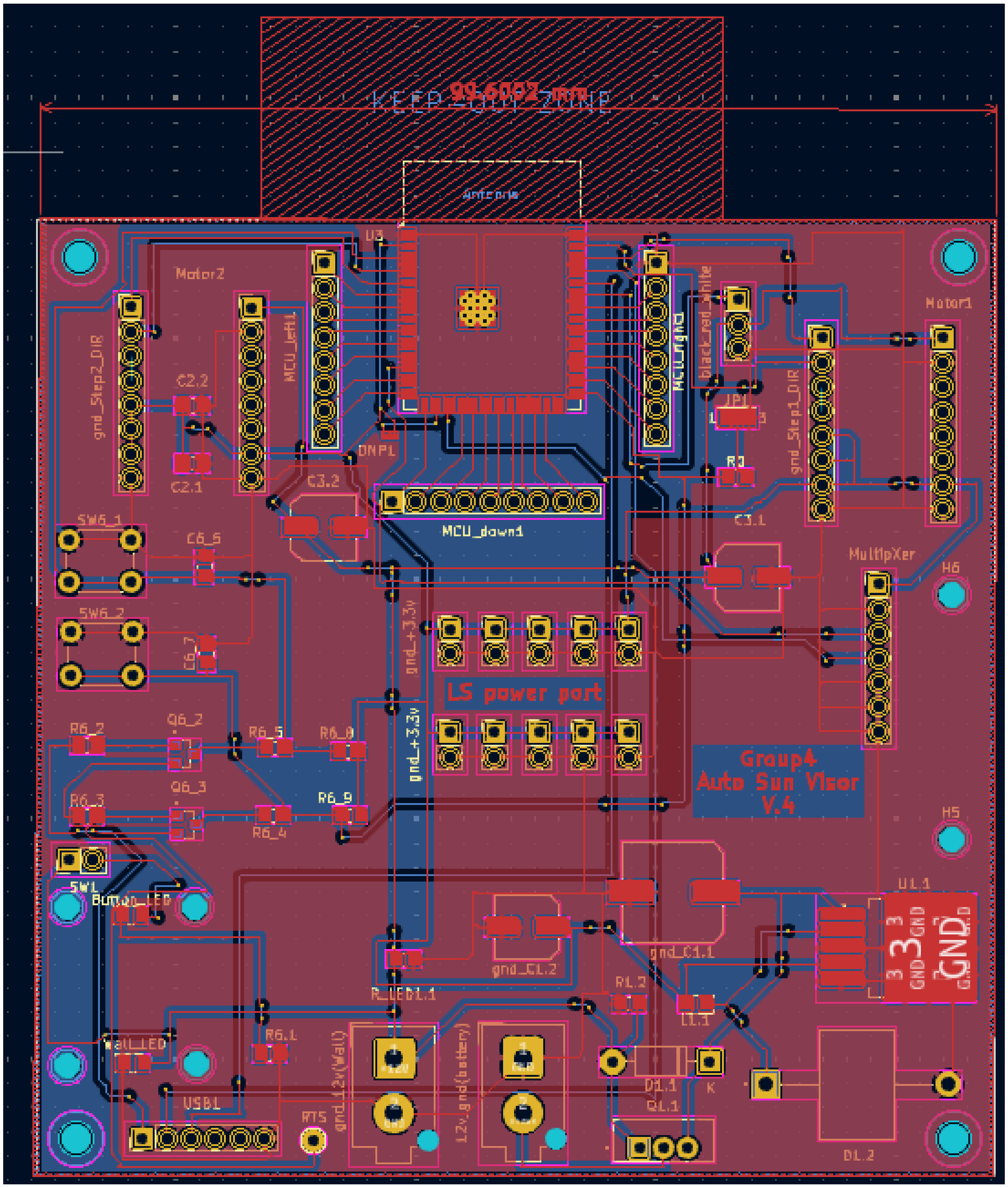

Figure 6. PCB Board Design

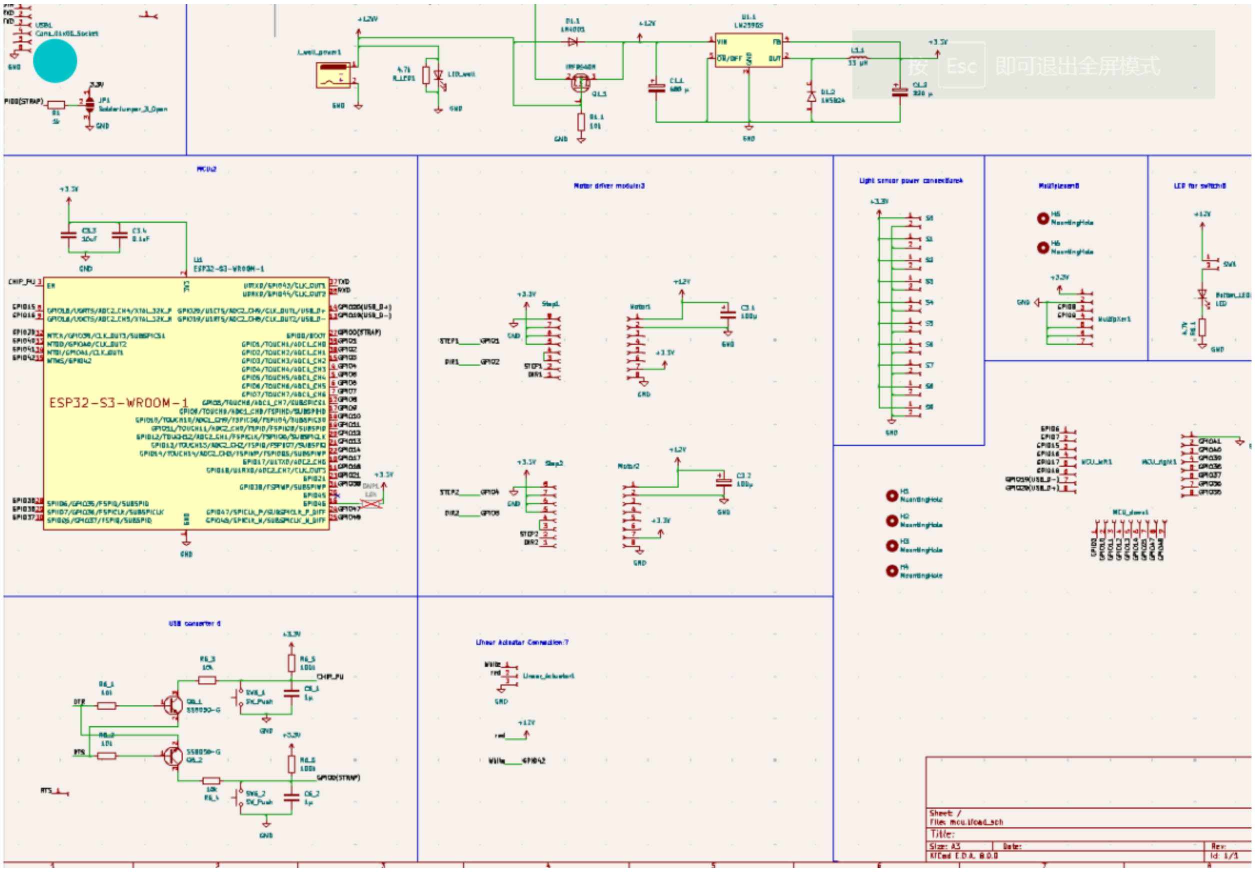

Figure 7. PCB Schematics

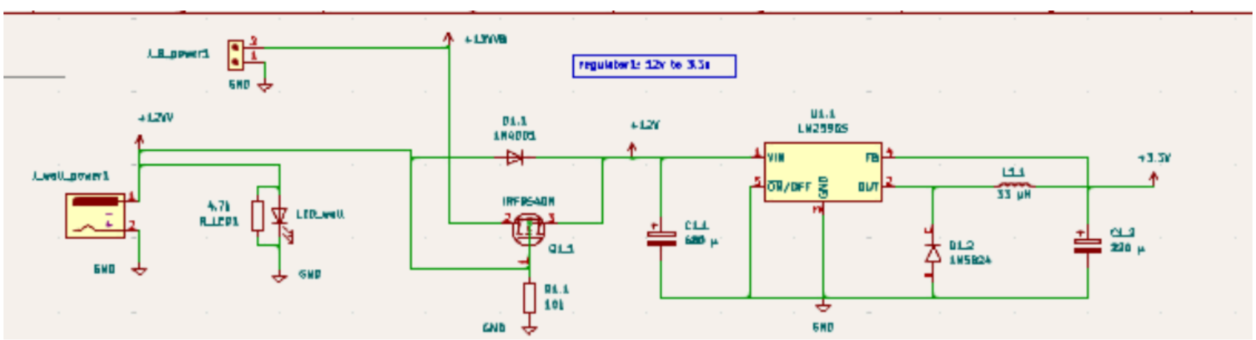

Figure 8. Power Subsystem

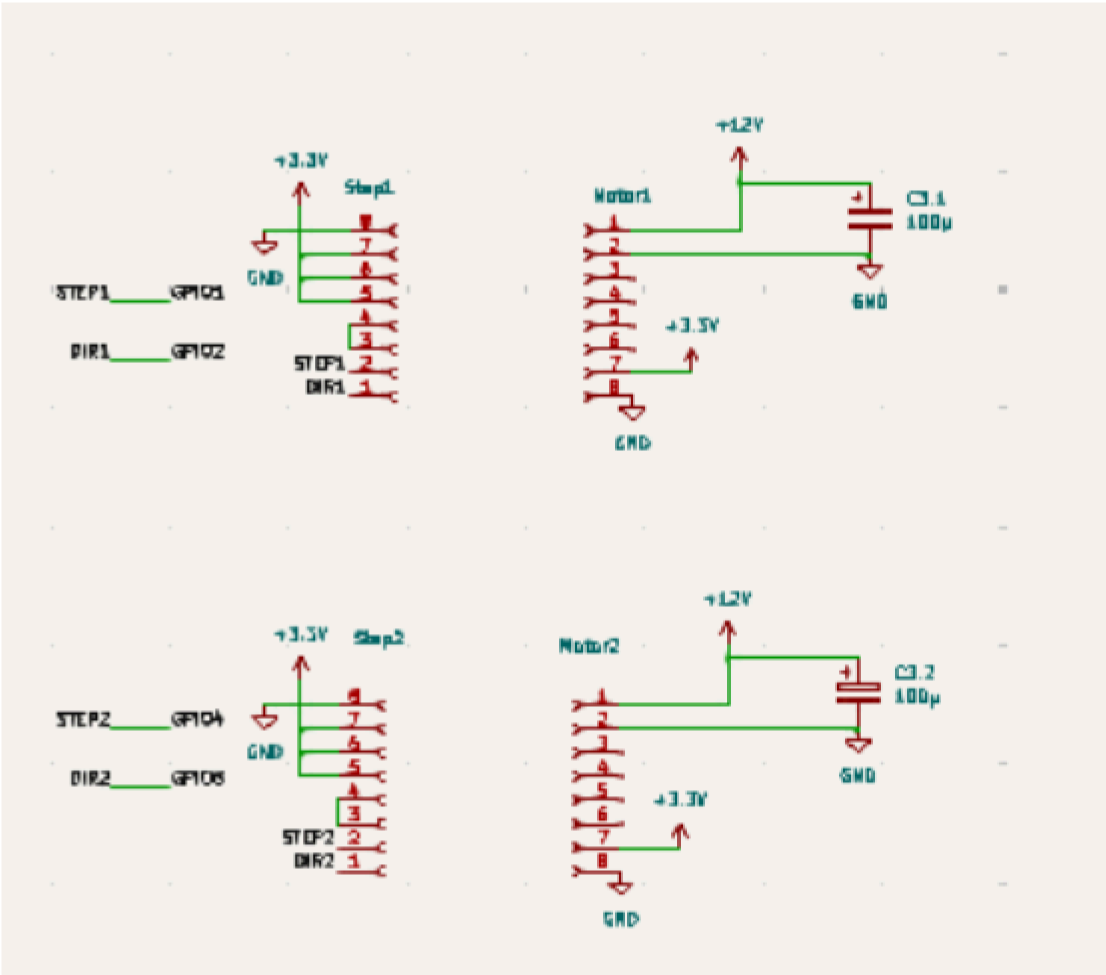

Figure 9. Motor Subsystem

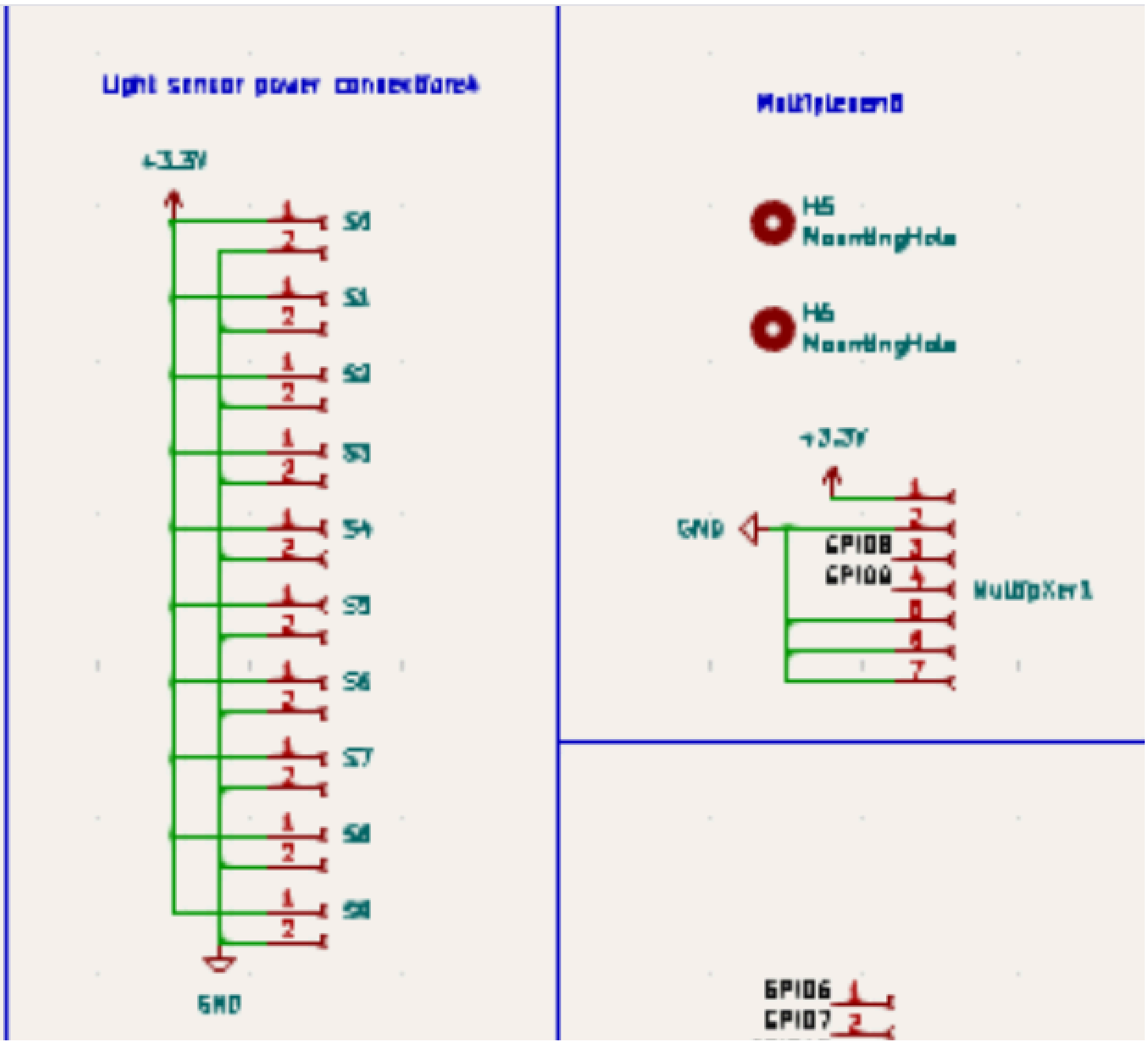

Figure 10. Sensor Subsystem

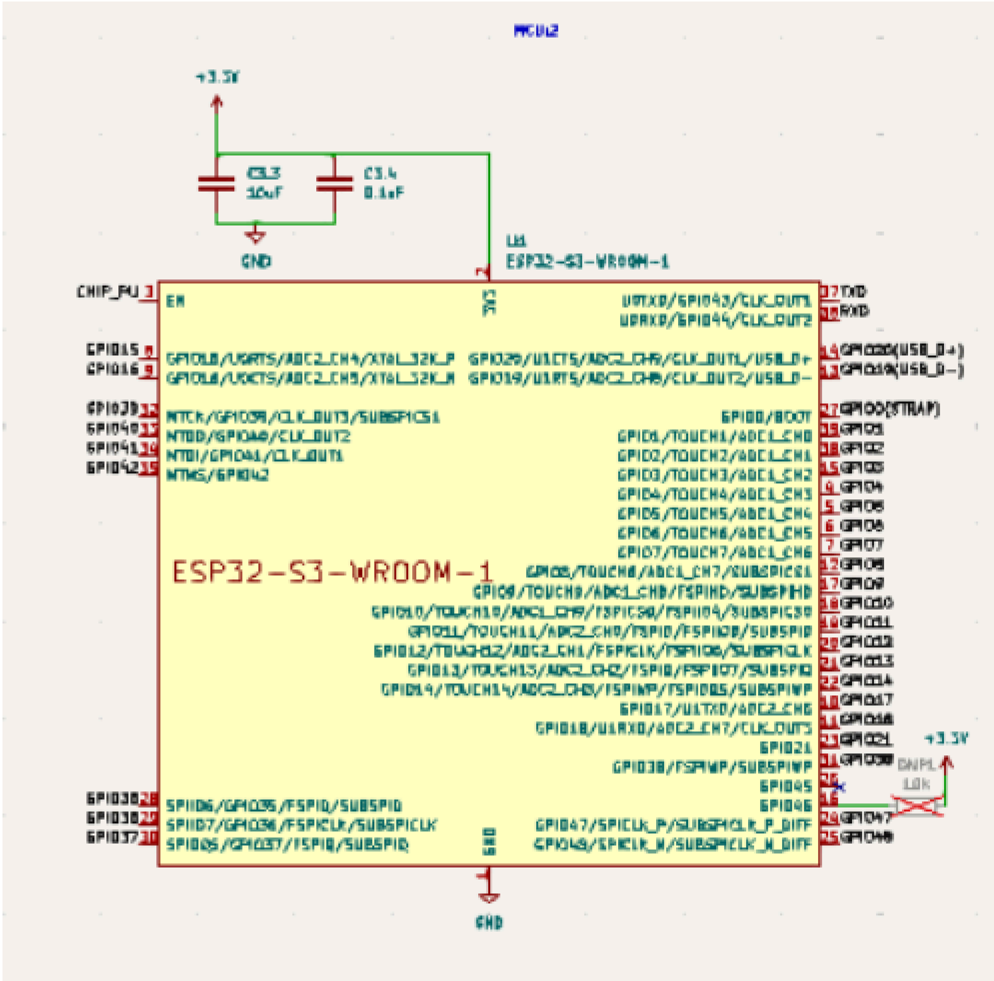

Figure 11. Microcontroller Subsystem