Executive Summary

The state of the current bus system in low-income communities calls for an upgrade. In urban-suburban areas such as Troy, NY, many of the bus signs are simply a pole sticking out of the ground with just its designated bus numbers on a sign. This conveys little information and provides almost no comfort for regular bus-riders, which comprise 10% of all Americans. Therefore, our team opted to design a product that would provide comfort to mind and body.

After acquiring some insight from locals and a city planner, we brainstormed some solutions to the problem at hand. Ultimately, we came up with 6 subsystems that when integrated, would create a product that provides real-time information and advanced shading. Additionally, this can be accomplished with a significantly lower budget. The 6 subsystems include: the sun tracking shade mechanism, the sun tracking shade control system, the LED real-time display, the solar power supply circuit, the cooling system, and last but not least, the housing. Each of these subsystems are integrated with at least one of the others. Each subsystem had a unique set of target specifications. This required intense planning and designing. The solar panels would supply power to the battery, which then gives power to the LED display, the cooling system, and the sun tracking circuit. Real-time bus locations are obtained from the CDTA website and displayed with LEDs. The cooling system automatically activates upon reaching a certain temperature within the housing. The sun tracking circuit utilized photoresistors to compare lux differences and activate the motor for the mechanism of the sun tracking shade. After testing, some modifications were required. As a result, all were able to meet their corresponding requirements.

Much of this report focuses on the design process. Each step of the process is thoroughly discussed among the team. Due to limited resources, our prototype in this report has omitted some of the functions that we plan to implement in the final design. However, most of its functionalities are fully operational. The estimated cost of our final completed product is just under 800$.

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Revision History

Table 1 - Revisions

Version	Date	Name	Reason for Changes
1.0	8/13/23		Initial document.
2.0	8/17/23		FInal Draft

1 Introduction

The origins of this project stem from a critical urban infrastructure gap observed in many areas: the absence of shelters and reliable real-time information at bus stops. This issue has long plagued commuters, particularly those in low-income communities, leading to discomfort, uncertainty, and inefficient transportation experiences. Addressing this challenge is essential for enhancing urban mobility and ensuring equitable access to public transportation.

Most of the end users of this product are low-income groups who are heavily rely on public transport, On this basis, the problems addressed can be summarized into the following two types:

- Lack of Shelter: Many bus stops lack proper shelters, exposing commuters to adverse weather conditions, which can deter people from using public transportation.
- Inaccurate Information: Limited access to real-time bus arrival information leads to uncertainty and longer waiting times, negatively impacting user experience.

For a comprehensive breakdown of these end users' needs and requirements, please refer to Appendix B: Customer Requirements Analysis.

The pursuit of the Sun Tracking Shelter and Real-Time Information Display System is fully justified by its potential to solve and improve critical issues related to urban transportation:

- Enhanced commuter experience: By providing shelter from the elements and accurate real-time bus information, this project directly addresses the pain points of waiting at bus stops, thereby significantly enhancing the quality of commuters' journeys.
- Increased public transport usage: Improving the overall experience for low-income commuters can result in higher ridership, subsequently reducing traffic congestion, air pollution, and promoting sustainable urban mobility.
- Equitable access: This project aligns with social equity goals by ensuring that all members of the community have equal access to reliable and comfortable public transportation facilities.

This report will encompass various essential facets. It will initiate by outlining the team's set objectives and delineating the project's scope. Then, it will proceed to undertake an extensive examination of existing technologies. Following this, the process of concept selection and evolution will be expounded. Subsequently, the working principle for each subsystem will be discussed, leading to an exploration of the comprehensive prototype testing and the consequent data accumulation process. In conclusion, the report will explain the achieved results, deliberate on feasibility, and assess the project's overall value.

2 Project Objectives & Scope

2.1 Mission Statement

Our mission is to design a cheap and self-sufficient alternative to the modern bus stop, redefining where transportation systems can support and benefit the modern member of society. We aim to minimize the time required for manufacturing and installing bus stops to allow for easy integration into the local community, providing safety, information, and a great place for advertising local businesses.

2.2 Customer Requirements

To develop our project idea, it was necessary to gather data on the current state of bus transportation and the opinions of those who use them. Two methods were employed to gather information: an interview conducted with a city planner and surveys around nearby bus stops in the Troy vicinity.

The interview was held with Mr. Stephen Maples, a city planner with the local capital district committee. Mr. Maples provided valuable insight and recommendations on the overall design and direction of the project. Some notable suggestions he made when discussing points of the project include:

- Overall product design
- Examples of existing infrastructure
- Big picture connection between disciplines

Mr. Maples also brought up a number of different considerations that were not initially included during the start of the product design, including:

- Complete integration cost
- Product scalability
- Vagrancy deterrence

In addition to an expert opinion, surveys were conducted around nearby bus stops to collect information and gauge public opinion from bus riders. From the survey responses, some points that were often brought up in discussions include:

- Types of people who use public transit
- Frequency of use
- Opinions on the current state of transportation
- Potential points of improvement

- Safety

Taking all of the data collected into consideration, the customer needs can be grouped into the following categories:
- User comfort
- Quality of life
- Safety
- Accessibility
- Cost
- Time

2.3 Technical Specifications

Using these customer needs categories as a guideline, the customer requirements and specifications were written and revised to the following table below.

Table 2 - Final version of combined customer requirements organized by priority

Customer Requirement	Technical Specification	Target Value / Range of Values	Priority
Construction	Time and cost	< $1000 < 1 week to build	1
Updated, relevant, digestible information	Accuracy and simplicity	Constantly updating information relevant for the day Can be read by most age groups	2
Power	Efficiency	Use solar energy as a source of power System can run for ≥ 1 hour on battery	3
Shelter	Size	Cast shadow length ≥ 6 ft. Roof length ≥ 6 ft.	4
Safety	Shape, weight, and material	Have rounded edges Support ≥ 150 lbs.	5

		Weighs < 30 lbs	
Temperature	Temperature	Operational temperatures range of 0 - 50 °C Fans run at ~ 50 °C to lower system temperature	6
Implementation	Time and cost	< $1000 ~ 1 day to implement	7
Maintenance	Time and cost	~ $1000 ~ 15 min. maintenance	8

3 Assessment of Relevant Existing Technologies

This section designates the process taken in investigating other shelter products and designs that could inspire concepts detailed later in this report. Here, six designs are detailed and discussed.

La Sombrita:

Figure 1: La Sombrita bus stop design in Los Angeles built by the Los Angeles Department of Transportation (LADOT)

Figure 1 above demonstrates the recent la sombrita bus shelter design that found criticism upon its arrival. This open design provided shade during the day and lighting during the night to provide safety to social and environmental hazards. The premise of design was to protect those who were discouraged from utilizing public transportation due to safety concerns. It is useful for providing protection against the harsh sunlight of southern california, the primary weather concern of the area. LADOT claims each installment of this model costs only $10,000 as opposed to the typical $50,000 of more standard designs (Carpenter). These space-efficient models are attached to pre-existing signs, allowing for easy installation.

Brasco:

Figure 2: Axle Retreat bus stop design by Brasco

As an approach to “micro shelter solution”, the axle retreat bus stop design, shown in Figure 2, is a more traditional design of a bus stop, while still adhering to the size restrictions that many current bus stops face. This model features seating, solar powered lighting, and protection against the weather. Brasco also offers schedule holders, light activation sensors, and customizability in color and materials for this design.

Handi-hut:

Handi-hut believes the importance of bus shelters lies in their ability to provide decor to an area, attracting people to use public transport, and function as a station for advertising. They have seven core beliefs that lie in quality, fulfilling a purpose, good location, cleanliness, visibility, low maintenance, and comfortability. In quality, they mean a stop that has good longevity and design. Fulfilling a purpose and good location lie hand in hand, requiring popular stops that can fit the local population and businesses. Visibility is a belief that stops require the ability to see incoming transit, bus or metro. Low maintenance articulates resistance to corrosion, weather, and other forms of failure. Comfortability was tied in with security, allowing lighting and seating to all stops.

Figure 3: Handi-hut's Barrington Design

Figure 4: Handi-hut's 3 series design

The designs shown above in figures 3 and 4 show two of Handi-hut's smaller designs. Each one comes with additions of signage, lighting, USB charging ports, heaters, and seating/leaning Rails. USB charging ports, heaters (in the form of infrared heating), and leaning rails offered new insights into possible concepts that could be included in the design discussed in this paper.

Shelter Store:

Shelter store offers similar core beliefs as handi-hut, and recognizes vandalism as a potential hazard of shelter design. As such, they design models that discourage vandalism, are corrosion-proof, and allow for easy disassembly and maintenance in cases of damage. They also recognize that shelters are key to their environment, and should blend in accordingly. This is why they offer eleven basic models, ranging from $1,700 (BDS Bus Shelter in figure 5) to $40,000 (Bespoke Timber Shelter in figure 6). Each of their models offer dryness, visibility/ease of access, lighting, seating, and security.

Figure 5: Shelter store's BDS Bus Shelter Design

Figure 6: Shelter Store's Bespoke Timber Bus Shelter Design

Conclusion:

For the scope of our project, it is not practical to design an entire shelter with walls and a roof. Ultimately, the decision was made to design a product similar to La Sombrita. While keeping its simplicity, more functions were added and heavily cut down on the costs associated with the modern transportation shelters.

4 Professional and Societal Considerations

Our team applied the engineering design process to produce solutions that meet the specified needs with consideration for the topics found in Table 4 - Engineering Solutions Impact.

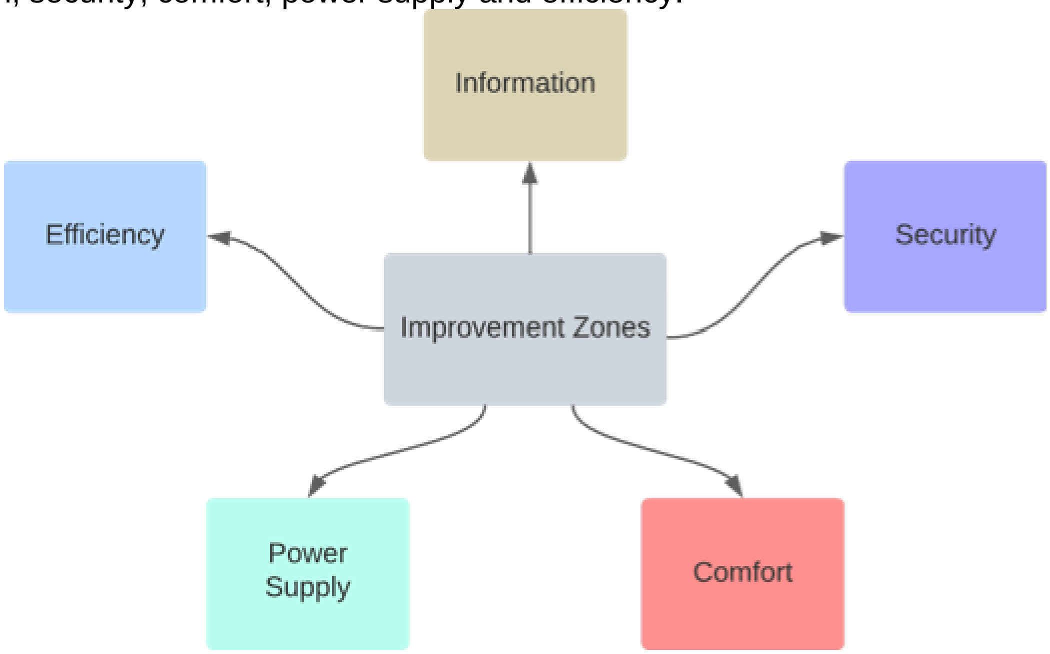
Table 3 - Engineering Solutions Impact

Area of Impact	Impact	Description of Impact
Public Health and Safety	Yes	Slight positive impact as it provides moderate sheltering, lighting, and encourages use of transport systems, increasing ability of local residents to seek medical attention if needed
Global	No	Slight positive impact as it is designed to fit any postable system but information display cannot accommodate symbol-based languages
Cultural	Yes	Slight negative impact as it can’t accommodate local methods of transport that have little dependence on scheduled systems
Societal	Yes	Positive impact as system is accessible, adjustable in both height and components, allows for advertising of local businesses, targets low-income developments, and encourages public transport
Environmental	Yes	Slight positive impact as it uses renewable energy to reduce local waste and encourages public transport to reduce carbon waste
Economic	Yes	Positive impact as it is cheaper to produce and implement than most transit shelters, and is easily installable. By providing a station for advertising, local business can be boosted as well as creating a source of revenue for the bus stop

Generally speaking, the design of this product basically has a positive impact on the aspects mentioned in the above table. The reason for this is that the prototypes of the product basically exist all over the world, and people have a high degree of acceptance for it. The purpose of this project is to improve the product and enhance the user experience. While improving products, cost reduction is also a major purpose, so it has a positive impact from the perspective of end users and product buyers.

5 System Concept Development and Selection

The initial stages of the concept generation phase are figuring out what could be done to improve these bus stops. 5 improvement zones were decided on to tackle: information, security, comfort, power supply and efficiency.



Mindmap 1- Improvement Zone Branching

With this, tables that delve into more specificity were generated:

Table 4- Concept Selection Matrices - Efficiency & Power

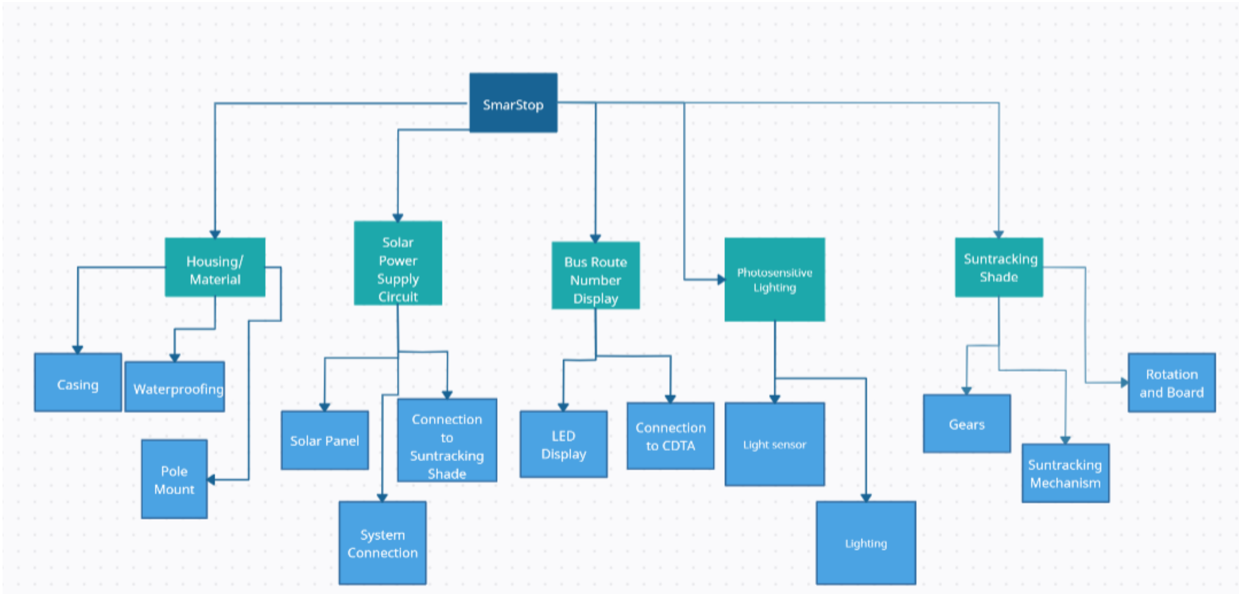
Criteria	Video Display	LED Display	Route Display	Pressure Sensing Occupancy	Check-in App	Pay Ahead App	Paystation At Stop	Solar	Wind	Mainline
Cost	-1	1	1	-1	0	0	0	-1	0	-1
Adoptability	1	1	1	0	-1	-1	0	N/A		
Accessibility	1	1	1	-1	0	-1	0			
Durability	-1	1	1	0	0	0	0	-1	-1	1
Size	0	0	0	-1	0	0	0	1	-1	1
Feasibility	-1	0	0	-1	-1	-1	0	1	-1	-1
Creativity	-1	0	1	1	0	-1	-1	1	1	-1
Necessity	0	0	1	0	0	1	1	N/A		

Team Opinion	-1	1	0	0	-1	-1	0	1	0	-1
Total	-3	5	6	-3	-3	-4	0	2	-2	-2
Rank	4	2	1	4	4	5	3	1	2	2

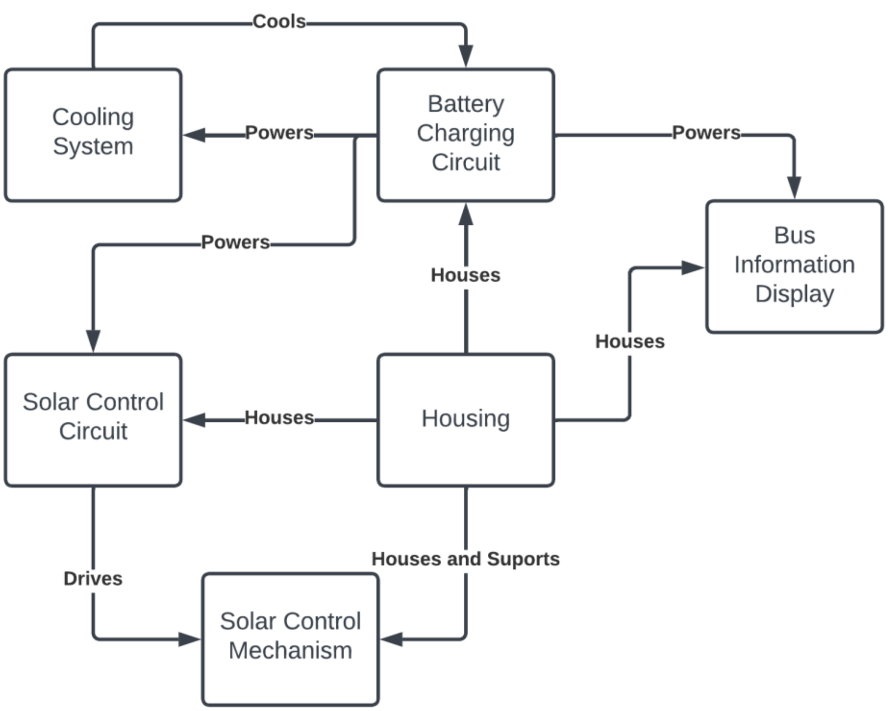
Table 5 - Concept Selection Matrices - Security & Comfort

Criteria	*Blue Light System*	*Emergency Phone*	*Photo-Sensitive Lighting*	*Static Seating*	*Retractable Seating*	*Weatherproof Enclosure*	*Sun Following Shade*	*Passive Heating*
Cost	*1*	*1*	*1*	*1*	*0*	*-1*	*-1*	*0*
Adoptability	*0*	*0*	*1*	*0*	*0*	*1*	*1*	*1*
Accessibility	*1*	*0*	*1*	*0*	*0*	*1*	*1*	*1*
Durability	*1*	*0*	*0*	*1*	*0*	*1*	*-1*	*-1*
Size	*1*	*1*	*1*	*-1*	*1*	*-1*	*0*	*-1*
Feasibility	*-1*	*-1*	*1*	*1*	*1*	*-1*	*-1*	*1*
Creativity	*0*	*0*	*0*	*-1*	*1*	*-1*	*1*	*1*
Necessity	*0*	*0*	*1*	*1*	*1*	*0*	*-1*	*1*
Team Opinion	*0*	*0*	*1*	*-1*	*1*	*-1*	*1*	*1*
Total	*3*	*1*	*7*	*1*	*5*	*-2*	*0*	*4*
Rank	*4*	*5*	*1*	*5*	*2*	*7*	*6*	*3*

Considering feasibility and necessity, the following subsystems were selected: Housing, solar power supply, bus route number display, photosensitive lighting and sun tracking shade.



Mindmap 2 - Subsystem Generation



Mindmap 3 - Subsystem Integration

After some more thoughtful planning, the sun tracking shade was split into a mechanical subsystem and an electrical subsystem. The photosensitive lighting was replaced by the cooling system as well, as we found it was more necessary for the safety of our design. Mindmap 3 shows the integration of each subsystem and how they work with each other.

6 Subsystem Analysis and Design

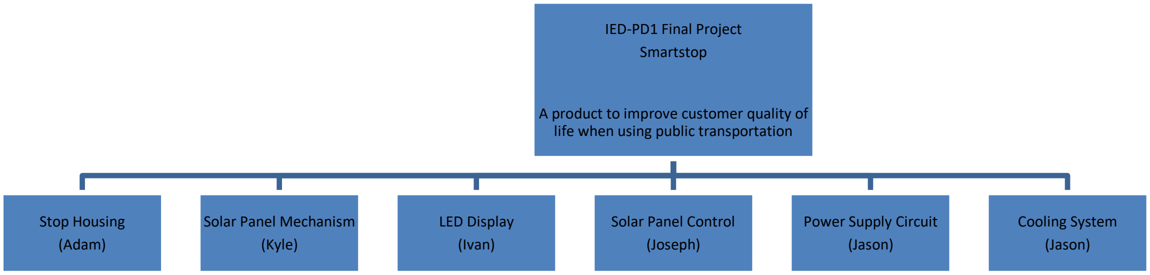


Figure 7 - Subsystem Diagram

6.1 Stop Housing

The goal of the housing subsystem was to provide a safe, secure design that can protect from external and environmental hazards to protect sensitive internal components, be easily manufactured and installed to reduce costs of implementation, and provide a neutral and versatile design that allows for the design to be used worldwide without insulting any local cultures or practices, as well as allowing for adaptability to local environments.

While the prototype of this design is shown to be wooden, the final design will be made from 7075 aluminum with a thinner paneling to enhance the housing's ability to prevent rain damage to the system, as well as enabling mass production of the simple design.

Figure 6.1.1 and 6.1.2 show four systems of the housing, the first being represented by the back panel which provides venting that allows the cooling system of the smartstop to maintain optimal temperature conditions in the system. The left panel allows for placement of the LED display, which would be expanded or contracted to accommodate local bus routes. The top panel allows for movement of the shaft controlling the sun shade and solar powered systems. Finally, a door with a small slot can be observed to the right of Figure 6.1.2, which provides security to the system from the general public using a general locking system that is up to the discretion of the customer.

The testing specifications of the prototype of the housing was to withstand over 150 lbs of compression, or the weight of an average adult. During demonstration, the prototype was shown to withstand at least 200 lbs of compression, and has yet to be loaded until failure. The strength of the system is dependent on the perpendicular area of minimum area associated with the housing, it is important that the maximum stress incident on the system does not overcome the yield stress, in this case the stress at which plastic deformation occurs, of the material in the design, be it wood or aluminum. Due to the greatly increased modulus of 7075 aluminum compared to wood, the cross sectional area for this is greatly reduced.

In the NX design, the smallest cross sectional area is associated with the venting system and is 21.75 square inches. Assuming a uniform distribution and the weakest type of wood having failure at compression perpendicular to the wood grain of 300 psi [1], this model could hold 6525 lbf, which is equivalent to about 203 lbs. However, since this is likely an oak based prototype, with yield strength of roughly 1000 psi [1], this system could hold about 676 lbs under the stated conditions. Aluminum 7075, with a yield stress of 73000 psi, could accommodate 49000 lbs under these conditions and design.

Figure 8 - Prototype Design of Stop Housing

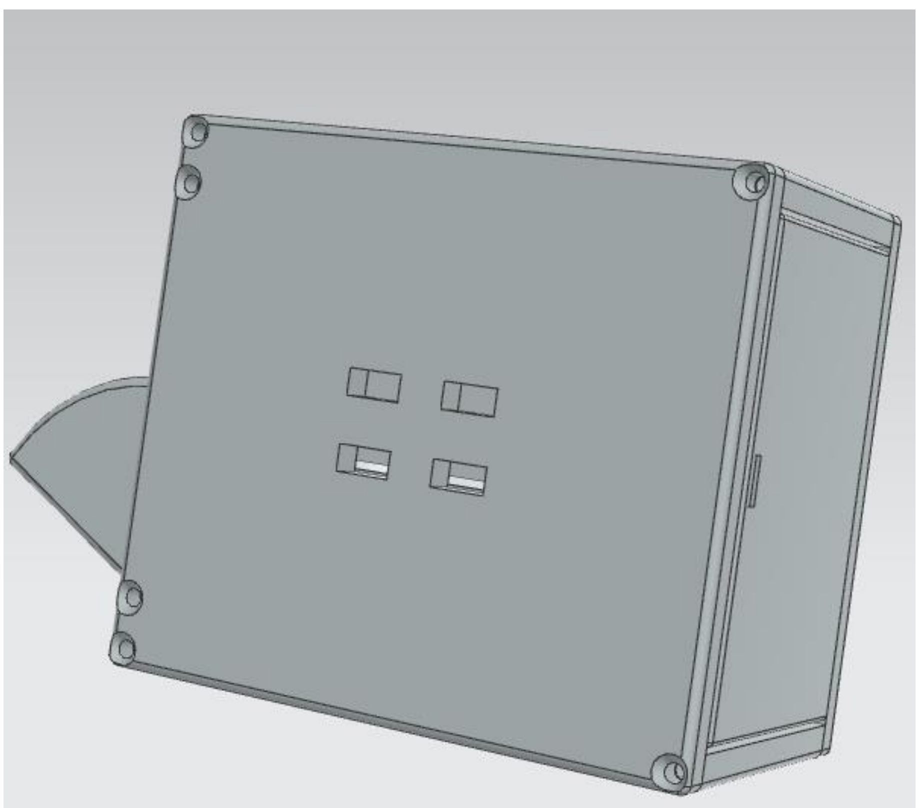


Figure 9 - Current CAD Design of Mass Produced Final Design

Below in figure 6.1.3 is the initial sketch for the housing design, including details of how each subsystem is incorporated into the housing through space allocation. An Important distinction between this and the current NX design are the holders for the metal belts that are meant to firmly attach to the pole.

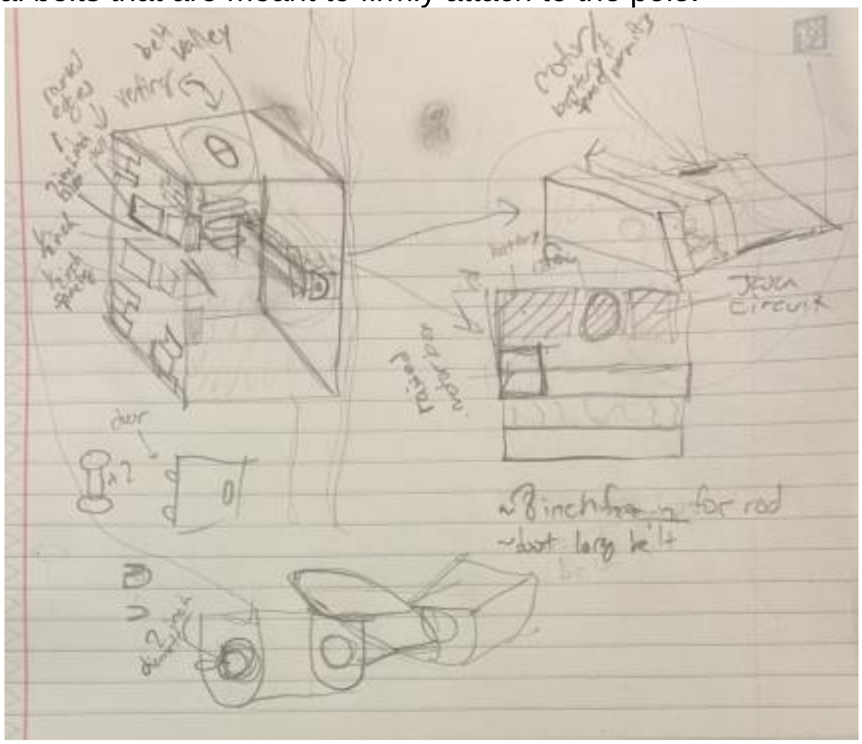
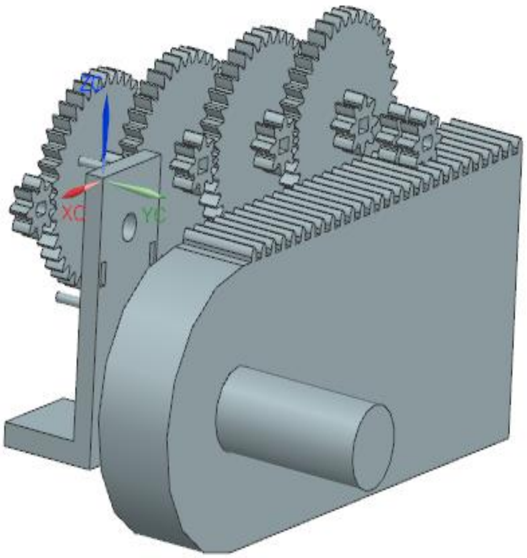
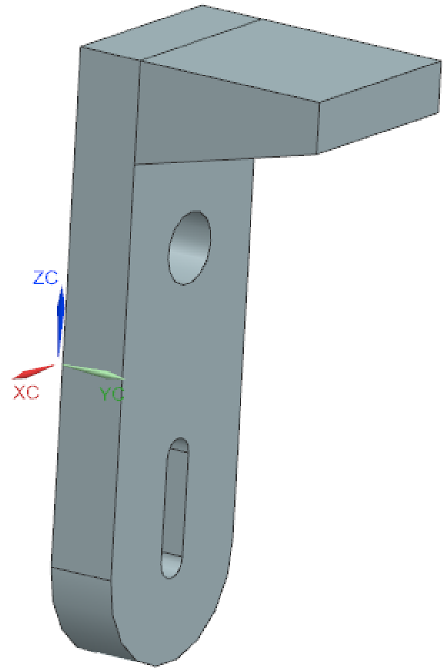


Figure 10 - Initial Sketched Design of Housing

6.2 Solar Panel Mechanism

The goal of the solar panel shades is to provide shelter while also taking in energy from the sun. Therefore, while having the ability of sun-tracking, some limitations regarding its speed and maximum angles were implemented. This will be explained in further detail with the components of the mechanism. The sun-tracking shade mechanism consists of these components: the shade panel, the rotating shaft, the slider, the gears, and the motor.





Left Figure 11 - CAD Model of Gear Train and Slider
Right Figure 12 - CAD Model of Sun Shade Shaft

6.2.1 Overview and Initial Concept Design

The initial concept was to simply directly attach gears to the shade panel. As the motor rotates the gears, the panel will rotate as well. However this would require additional housing, and the pressure on the pin connecting the gears would be too high.

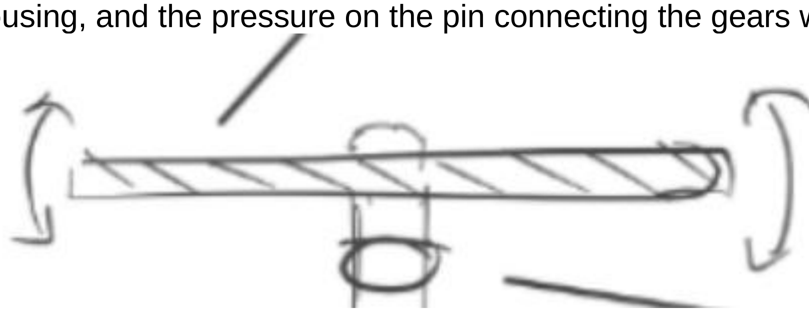


Figure 13 - Early Concept Drawing of Sun Shade

Therefore, instead of just the panel rotating, the whole shaft rotates about the top of the box instead. This would require something that is pinned to the shaft and moves within the box. With this, all that is left is a gear system to control the speed of the rotation.

6.2.2 Components

In this section, the design of the major components will be explained.

6.2.2.1 Motor Holder

To keep the motor steady and in place while operating, a motor holder was needed. There were 3 holes on the motor that could be taken advantage of.

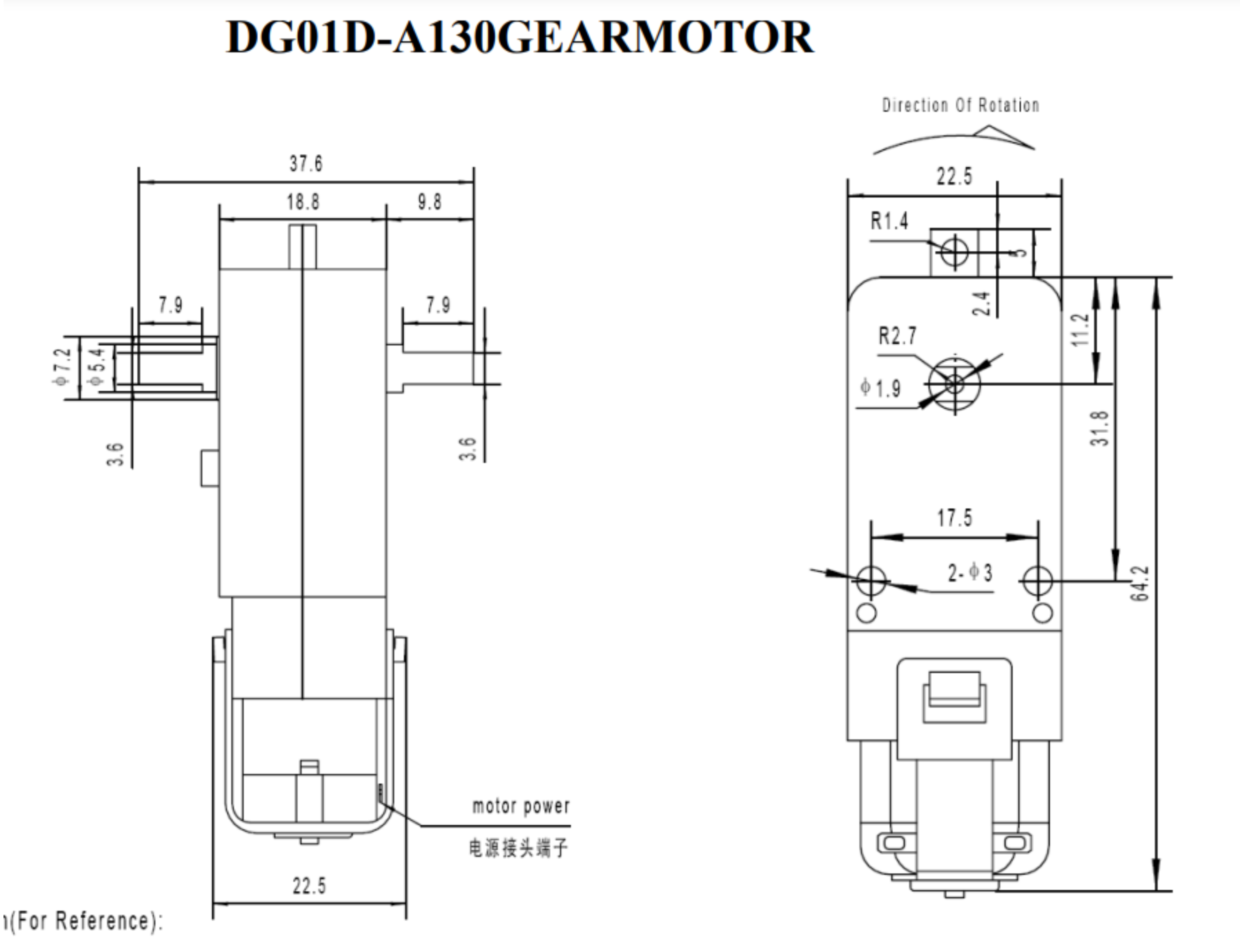


Figure 14 - Schematics of Motor Used

With the schematics, a design could be made:

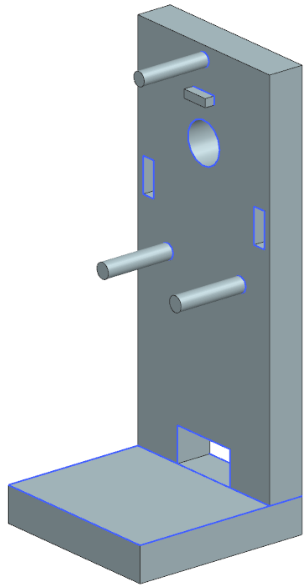


Figure 15 - CAD Model of Motor Container

The dimensions were determined by the motor schematics, converted from millimeters to inches. Additional holes on the sides were added to run a zip tie through to prevent slipping. Another hole on the bottom gives room for wiring. This design was straightforward and was the first component of this system to be 3D printed. It fits the motor tightly and smoothly. It is strong and can withstand at least 20N of force without breaking. There was no evident need of the zip tie, however one was strapped around the motor to be safe.

Figure 16 - Motor Holder Holding the Motor

6.2.2.2 Rotating Shaft and Shade Panel

This was the first component to be tackled as this is the deciding factor of the angle of the shade panel. This would also determine the size of the housing for the product. The shaft would be pinned on the top of the box and rotate about that pin. The bottom of the pin is loosely connected to a slider that causes the shaft to rotate. The shaft holds the weight of the shade panel. Therefore, the shaft must be long enough so it can rotate with minimal force from the slider, but also short enough to keep the size of the housing down.

Ultimately, 13.5 inches in total length was decided to be sufficient. This would leave 6 inches from the shade panel to the pin at the top of the box, 6 inches from the pin to the connection with the slider, and an extra 1.5 inches to prevent the slider from slipping off.

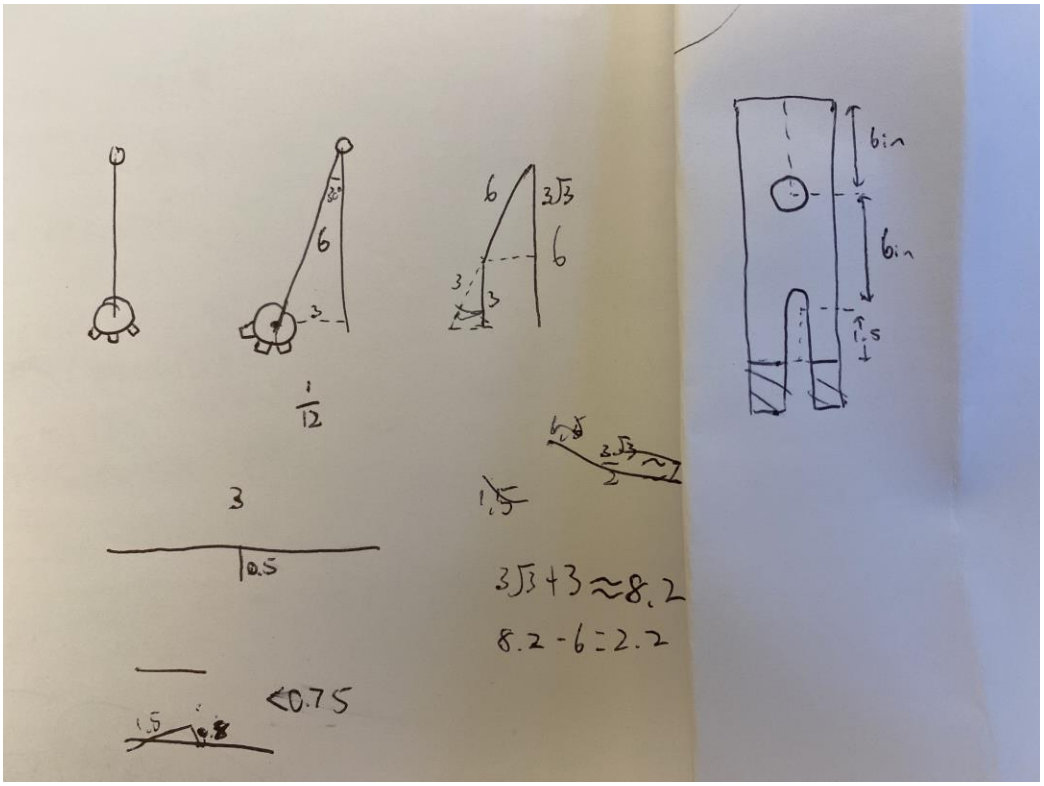


Figure 17 - Angle Design/Calculations and Dimension Design

As shown on Figure 17, the final design of the shaft is the rightmost sketch. the left portion calculates the maximum width that the shaft would take up in its maximum span. (NOTE: The gear shown in the sketch is part of an abandoned design where the gear would be locked with the gear rack on the slider).

The shade panel is attached on top of the rotating shaft. This is a very straightforward component as it is a rectangular panel with dimensions of 8”x20”.

Originally, both components were to be 3D printed; however, due to their size and simplicity, it was decided that wood is the best option for a prototype.

6.2.2.3 Slider

The slider is what allows the shaft to rotate. It is also the medium of rotational and translational motion for this mechanism subsystem. In simple terms, the slider is a block with a pin that sticks out. This pin is locked between the small space on the bottom of the shaft. It is measured that for every inch the slider moves, the shaft would rotate 10 degrees. To meet the requirement of a 60-degree rotation span of the shaft, the slider would be ideally 6 inches. An additional 0.2 inches were added to ensure its functional operation. For the slider to move, a gear tread was designed accordingly to the gears (this will be further explained in 6.2.2.4).

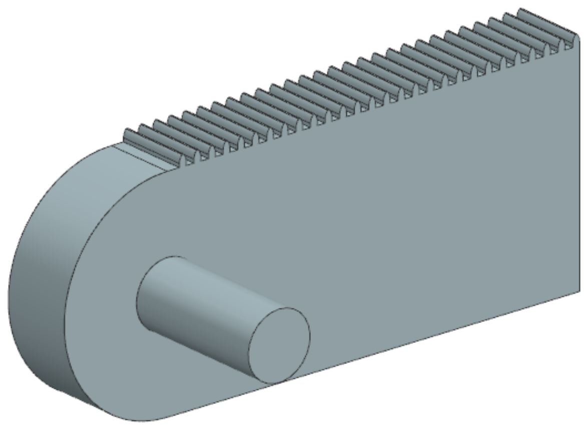


Figure 18 - CAD Model of Slider

6.2.2.4 Gears and Gear Holder

The gears were perhaps the most challenging to design within the subsystem. There were many things to consider, including the gear ratios, the gear radii, the tread depth, etc.

Assistance was obtained through a gear simulator: geargenerator.com. This helped visualize the required gear ratio and total number of gears required to obtain the desired final rotational speed.

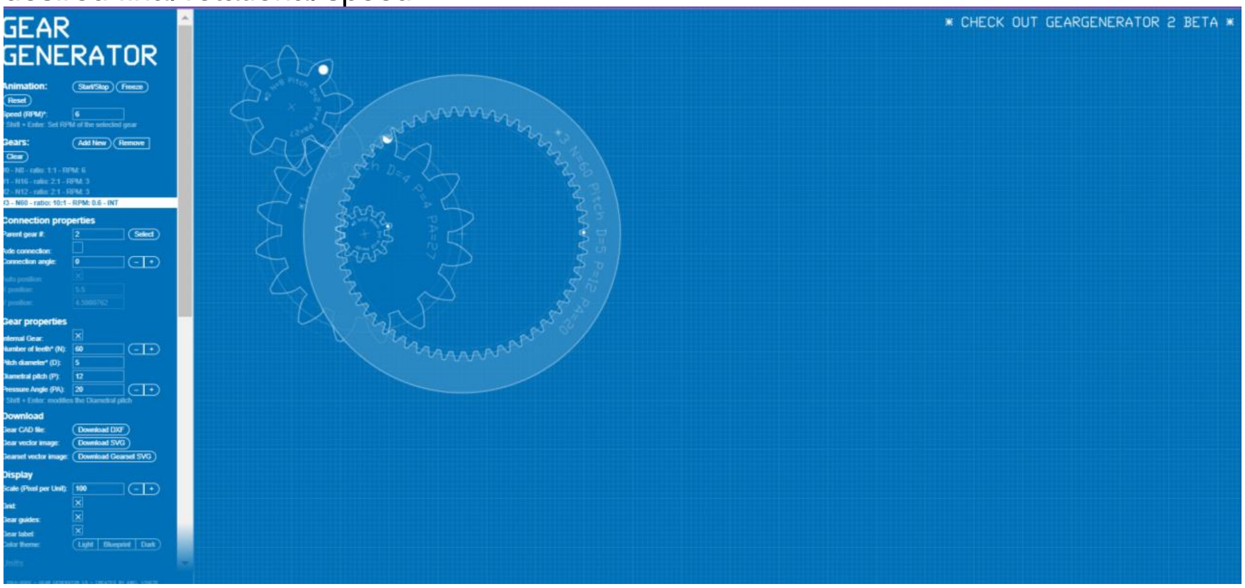
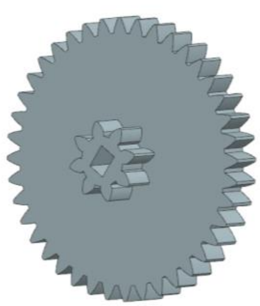


Figure 19 - Screenshot of Gear Simulator

Although the website provided CAD file generation for the needed gears, the gears in the prototype were completely self-designed. The website provided helpful insight and understanding of gears, but they were simply guidelines toward the design. In total 7 gears were printed: 3 ‘small’ gears, and 4 ‘large’ gears. The ‘small’ gears are simple 8-tooth spur gears with a hole in the center. The ‘large’ gears are 40-tooth united with 8-tooth gears concentrically. The smaller pitch radius is 0.25”, while the larger pitch radius is 1”.

Left Figure 20 - CAD Model of 40-tooth Gear
Right Figure 21 - CAD Model of 8-tooth Gear

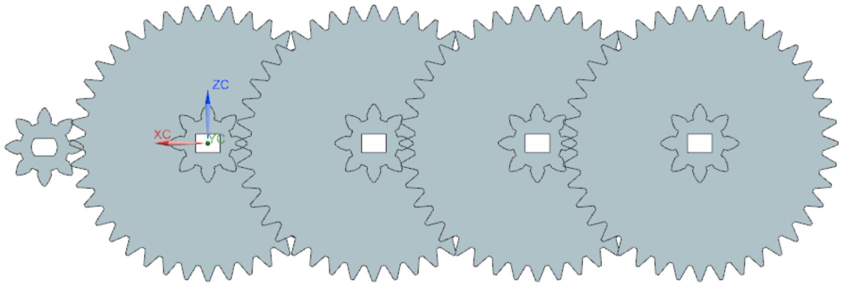


Figure 22 - CAD Model of Assembly Gear Train

The 8 tooth gear is attached to the motor, the large gears follow in succession. One pin goes through each of the large gears. The pin that goes through the final gear also has two of the small gears to drive the slider. The dimensions of the gear rack on the slider are determined by the pitch radius of the small gear.

The gear holder is a rectangular structure to hold the gears in place. It has spacings for pins to go through according to the pitch radii of the gears.

6.2.3 Calculations

Shaft and Panel Analysis:

Assuming the shaft is pinned perfectly with no errors. The mass of the panel is 2.5kg, the mass of the shaft is 2kg. All of the weight is held up by the pin that rests on top of the box, which is 45N. The moment created by the panel is 25N * 0.1m =2.5Nm. To counter this, the bottom of the shaft meets a force of 14.28N at 0.18m from the pin. Additionally, at the maximum angle of 30 degrees, with the center of mass roughly 4 inches above the pin a moment of 45N*0.1m*cos(30)=22.5Nm, the counter moment at the bottom of the shaft requires a force of 22.5Nm/0.19m=12N. Assuming the friction constant of wood is roughly 0.5, the net force of the pin is sqrt((0.5*14.28)^2+12^2)=14N.

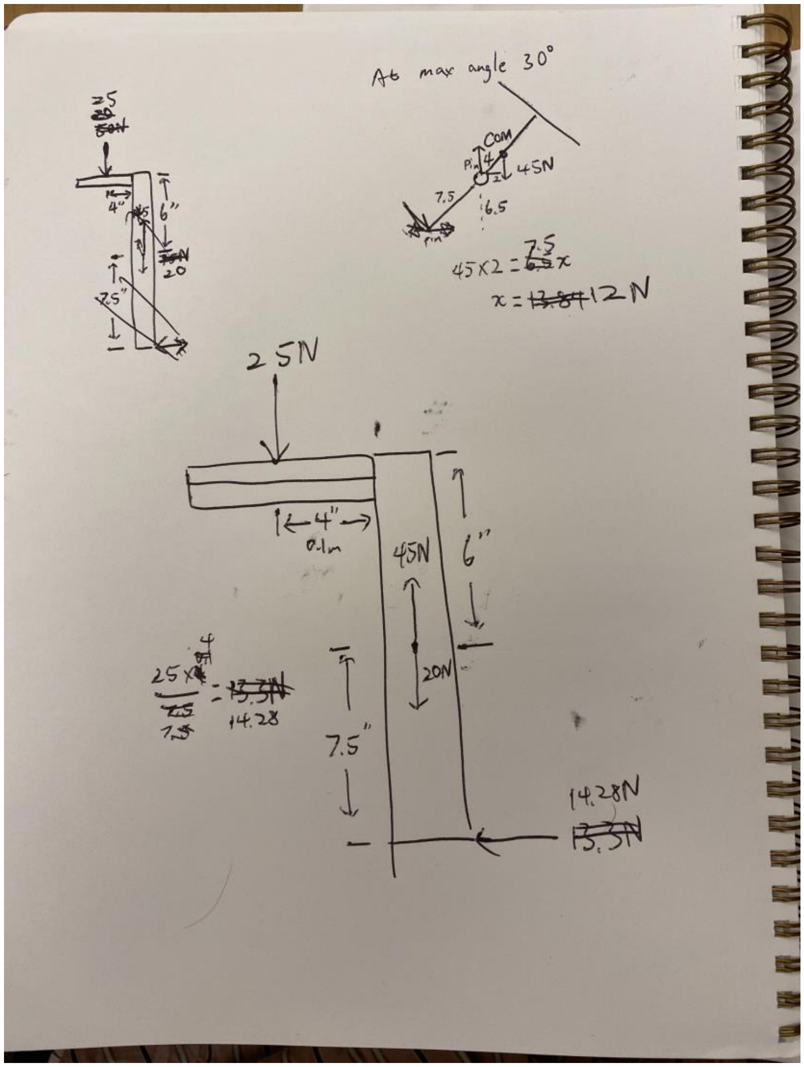


Figure 23 - Math Calulcations for Gears and Shaft

Gear Analysis:

The motor speed at 5V with load was tested to be 80 rpm. The pitch radius of the small gear being 0.25 inches, its circumference is 1.57. With the shaft rotating 1 degree for each 0.1 inch the slider travels, the slider should travel at 0.2 inches per minute. Therefore the final gear should rotate at a speed of 0.2/1.57=0.127 rpm. With 40 teeth on the large gears and 8 on the small gears, the gear ratio of each interaction is 1/5. 4 of these make a total gear ratio of 1/625, causing the final gear to rotate at a speed of 80/625=0.128 rpm. Considering friction between the gears, the final rotation speed would be slightly lower than 0.127 rpm.

6.2.4 Modifications

Due to the limited accuracy of 3D printers, the pins for the gears were printed too thick. As it was only slightly over specifications, some filing on each face of the pins would suffice.

The slider was designed to have its pin sticking out on one side, however this would require more space for the box. In order to make our system more compact, the pin was sawed off along with the unnecessary edge. The pin was then reattached to the center of the slider via hot glue.

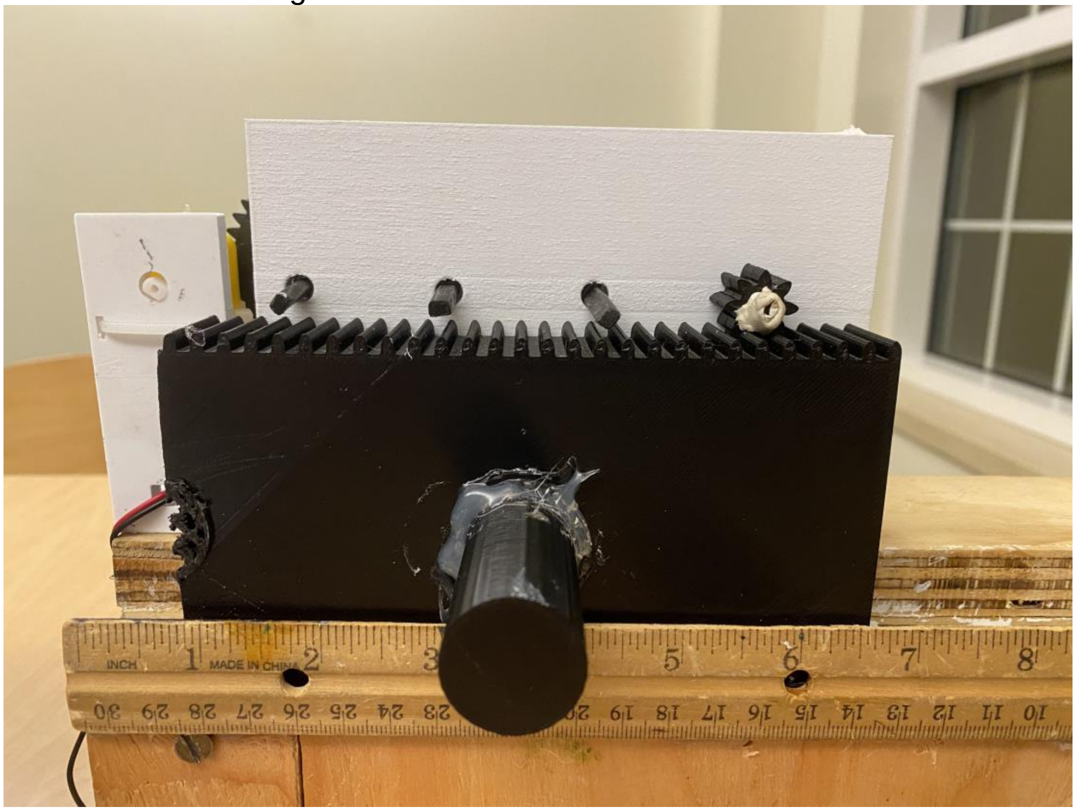


Figure 24 - Modified Slider

6.3 LED Display

6.3.1 Overview

The goal of the LED display subsystem is to provide a physical, visual interface that would provide information that is accurate, relevant, and digestible while also being easily expandable if more information is to be added to the display.

6.3.2 Initial Design

For the initial design of the LED display, the basic process consisted of four major steps:

1. Pulling information from the computer
2. Storing the information externally to be fed to our LEDs
3. Translating the information to be fed into the LEDs
4. Outputting the translated information to the LEDs

Using the materials available, the following components were used in the initial design:

1. **Raspberry Pi Pico**
   The Raspberry Pi Pico is a microcontroller that controls the LED display functionality as well as stores the initial data that will be fed into the LED displays.

In addition, the Raspberry Pi Pico also stores code that updates the information being displayed automatically during a timed event, such as when a minute has passed or when the bus arrival time reaches zero minutes.

Figure 25 - Raspberry Pi Pico

2. **Registers**

Registers are used to store the initial data stored on the Raspberry Pi Pico. Data can be sent to registers from the Pico using two methods, in parallel or in serial.

Data that is sent in parallel is much faster than being sent in serial, as the bits that compromise the data are loaded simultaneously into the register. This however came with the trade-off of requiring more pins on the Pico to be allocated to a single external chip, meaning that there would be fewer LEDs we could work with for the display. To be able to demonstrate the expandability of the subsystem, the data will have to be loaded serially, meaning that the bits that compromise the data are sent one by one through only a single pin on the Pico. By sending the data serially, more pins are available which allows us to scale up the number of the LEDs for the display if desired. To accomplish this goal, the following register down below was used.

Figure 26 - CD4015BE CMOS Dual 4-Stage Shift Register

3. **Decoders**

Decoders are used to translate the information held in the register into an output that will correctly format the 7-segment display. The following chip was used as a decoder.

Figure 27 - CD4543BE CMOS BCD-to-Seven-Segment-Latch/Decoder/Driver For Liquid-Crystal Displays

4. **7-segment display**
   The 7-segment display is used to display the information stored in the register after it has been translated by the decoder. Using a combination of 4-digit and 2-digit seven-segment displays, any bus route and bus arrival time could be displayed. The following LED displays were used


Left Figure 28 - ATA8041AB LED Digits
Right Figure 29 - CL5621AH 0.56" Seven Segment Numeric LED Display

Figure 30 - Initial Component Flowchart

6.3.3 Final Design

During the initial construction of the LED display, it became clear that the circuitry of the system was complex and required a significant amount of space for wiring. This was an issue as there would not be much room in the product's housing to allow for the LED display subsystem to fit.

To address the issue, we significantly simplified the LED display design by switching to a new 7-segment display as shown below.

Figure 31 - TM1637 4-Digit 7-Segment Display

The TM1637 simplified the design by reducing the number of pins needed for wiring, compressing the LED display circuitry enough so that it can integrate into our product housing. The tradeoff for simpler wiring resulted in the removal of registers and decoders from the design. However, their functionality could be implemented via code which can be loaded onto the Pico.

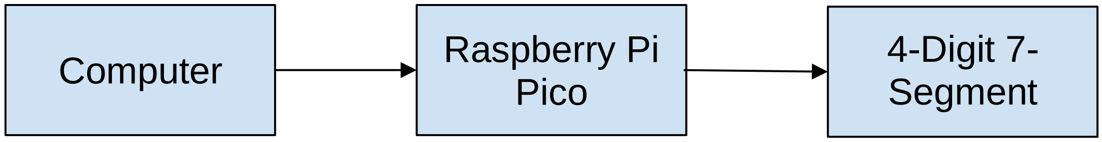


Figure 32 - Final Component Flowchart

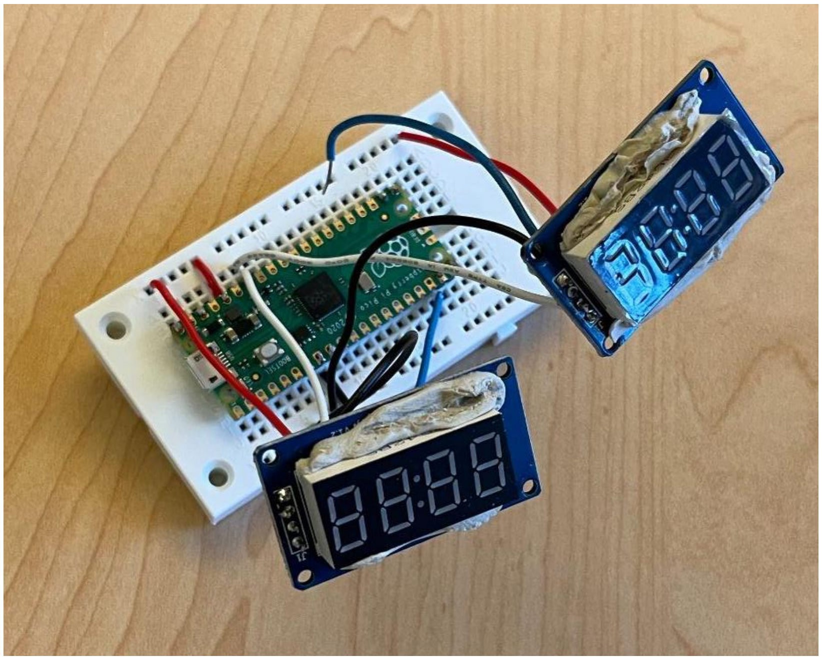


Figure 33 - Final LED Display Circuit

6.4 Solar Panel Control

6.4.1 Overview

For the Sun-Tracking Shade mechanism to function, a control circuit was needed to drive the motor.

6.4.2 Design

Initial designs utilized a schmitt trigger configuration, much like that described in section 6.6. This proved faulty, as the motor's direction would oscillate wildly at smaller lux differences, due to the hysteresis present in a schmitt trigger, as seen below

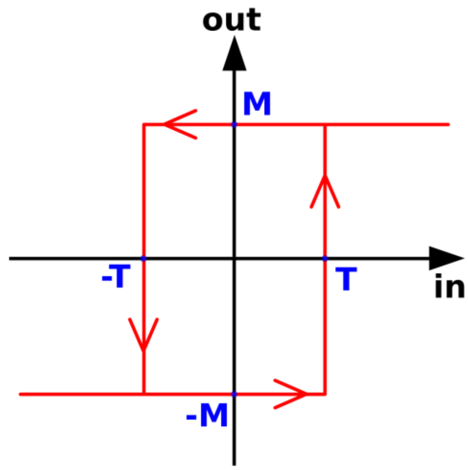


Figure 34 - Hysteresis Plot of a Schmitt Trigger

This design was swapped for a simple comparator configuration, with both light-dependent resistors combined in a voltage divider configuration, such that an increase in light on one without an increase in light on the other would instantly trigger a change in direction.

Below is the circuit diagram for the subsystem, prepared in LTSpice:

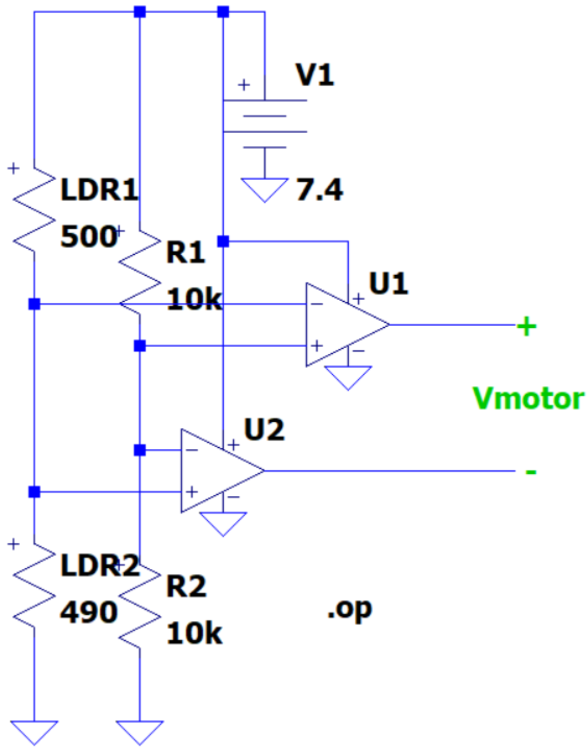


Figure 35 - Diagram of Control Circuit

Note that the motor driver is not shown here, as it is irrelevant to the control functions of the circuit.

6.4.3 Simulation

When the LDR values are set to those shown in the schematic (490ohms and 500 ohms), simulating lux levels approximate to those of direct sunlight (~50,000), the simulation outputs a Vmotor voltage of +7.4v. When the values are switched, the simulation outputs a value of -7.4v. For any two lux levels so long as they disagree in the slightest, there will be a difference in output. Only when the lux levels are exactly the same does Vmotor equal zero.

6.4.4 Implementation and Results

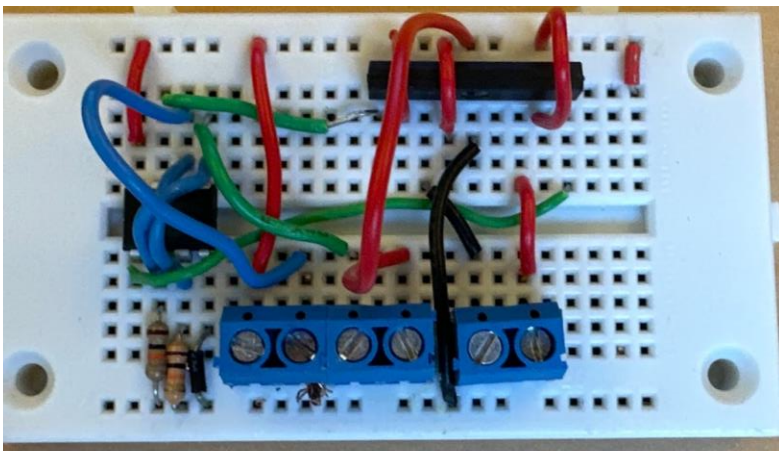


Figure 36 - Working Implementation of Circuit

For the final implementation, the only difference from the initial design is the inclusion of the motor controller. Here, the voltage signal to control the motor is sent into the motor driver, an MC1741. This chip simply applies the voltage to the motor, while drawing current directly from the source instead of through the comparator, as the comparator is unable to output enough current to drive the motor at the desired speed. The blue screw terminals seen at the bottom of the board are where the LDRs (left 2) and the motor (right of black wire) connect to the circuit. These terminals were chosen as they allowed for easy connecting and disconnecting during the process of fully integrating the final design, while simultaneously being strong enough to hold the wires in place if tension were applied to them. The results of testing the circuit were exact to those of the simulation; The motor would change direction if the levels of lux on the sensors disagreed even slightly, and the motor was successfully able to draw enough current to run at the speed required by the mechanism.

6.5 Power Supply Circuit

6.5.1 Overview

From an environmental protection standpoint, the entire product's power supply system is fueled by solar energy. Excess electricity generated from solar energy during the day is stored in rechargeable batteries for utilization by other subsystems at night. This self-contained power supply system transforms each bus station into a more independent entity, thereby significantly reducing the expenses associated with planning power supply circuits and energy consumption.

6.5.2 Design

The energy supply circuit is generally divided into three parts, solar panel, voltage regulator, and rechargeable battery.

The solar panel is two 6v small solar panels connected in series to provide an output voltage that is stable at 12~14v during the day. In the realistic model, two sets of such solar panels connected in series are placed in parallel on the shelter to increase the output current, thus improving the charging efficiency. The power rate of a group of solar panels is 1 watt, and the output current can be stabilized at 320mA through parallel connection.

$$P = VI$$ **Equation 1**

$$I = \frac{P}{V} = \frac{1W}{6V} = 0.167A$$ **Equation 2**

The maximum voltage of a single rechargeable battery is 3.7v, and the maximum capacity is 2000mAh. The rechargeable battery pack used in the model connects two such lithium cells in series for charging and power supply. Since the output voltage of the solar panel is 12~14v, which is much higher than the safe charging voltage of the rechargeable battery. In order to ensure the normal operation of the charging circuit and the safe use of the product, the voltage regulator is used to reduce the output voltage of the solar panel.

The circuit design of the voltage regulator mainly revolves around the LM337. (Due to limited materials, LM317 cannot be used. However, LM337 and LM317 work similarly, and the same effect can be achieved by reversing the positive and negative terminals of the input port.)

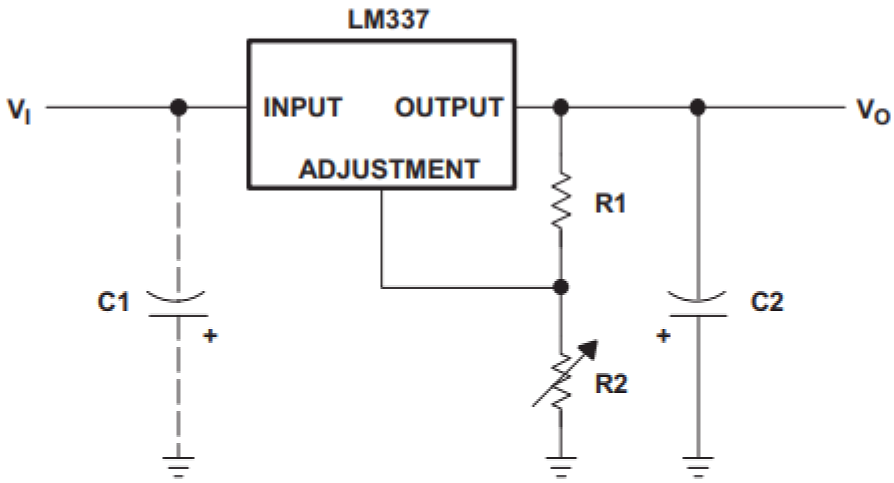


Figure 37 - The circuit diagram for the LM337

$$R2 = R1\left(\frac{V_O}{-1.25} - 1\right)$$

where V_O is the output in volts.

Equation 3: Calculating the output voltage of LM337

R1=1900 ohms, R2=10k ohms

Vo=-1.25(1+10000/1900)=-7.83v

Since the positive and negative terminals were reversed, the output voltage become +7.83v.

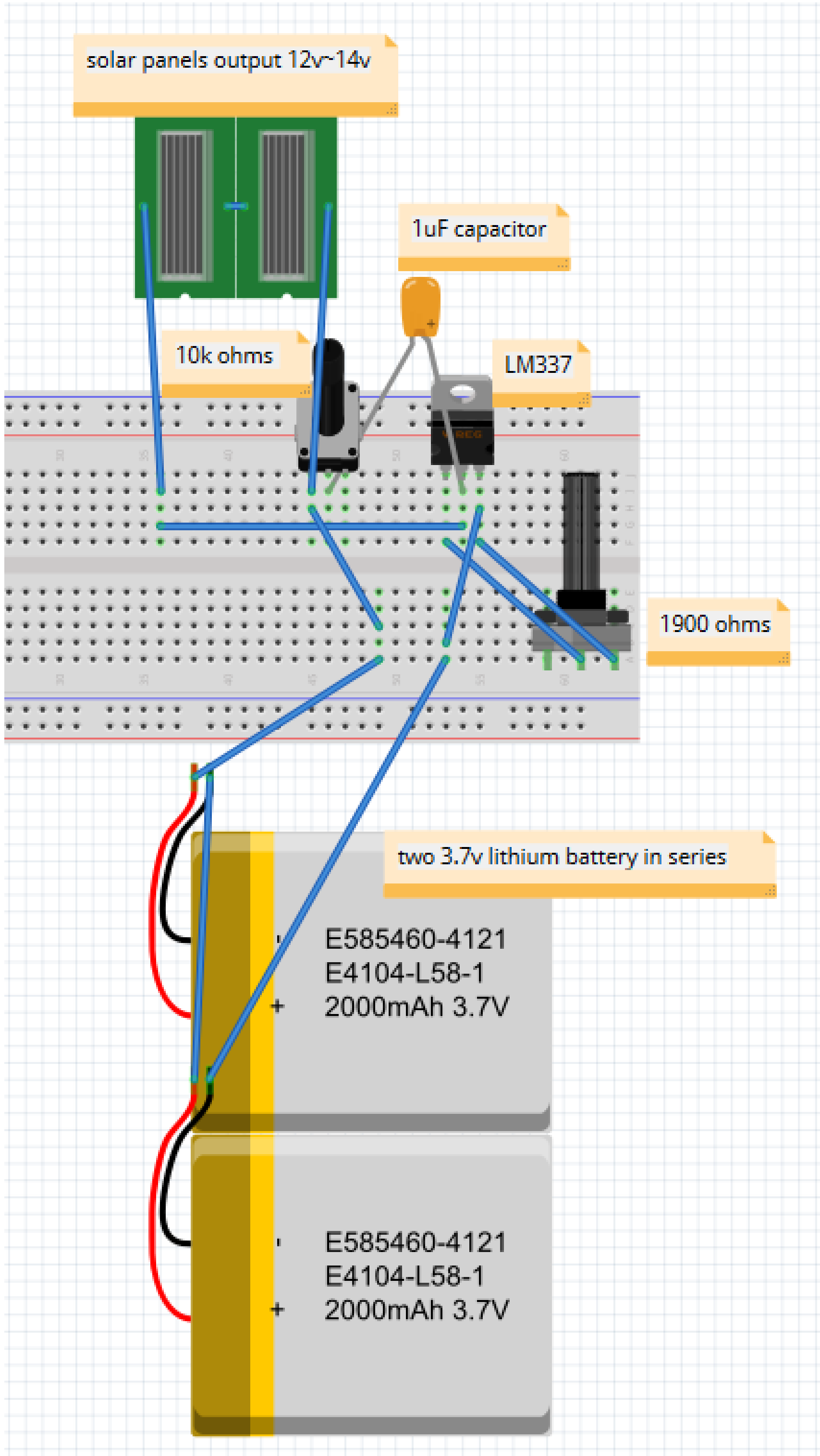


Figure 38 - The power supply circuit by Fritzing

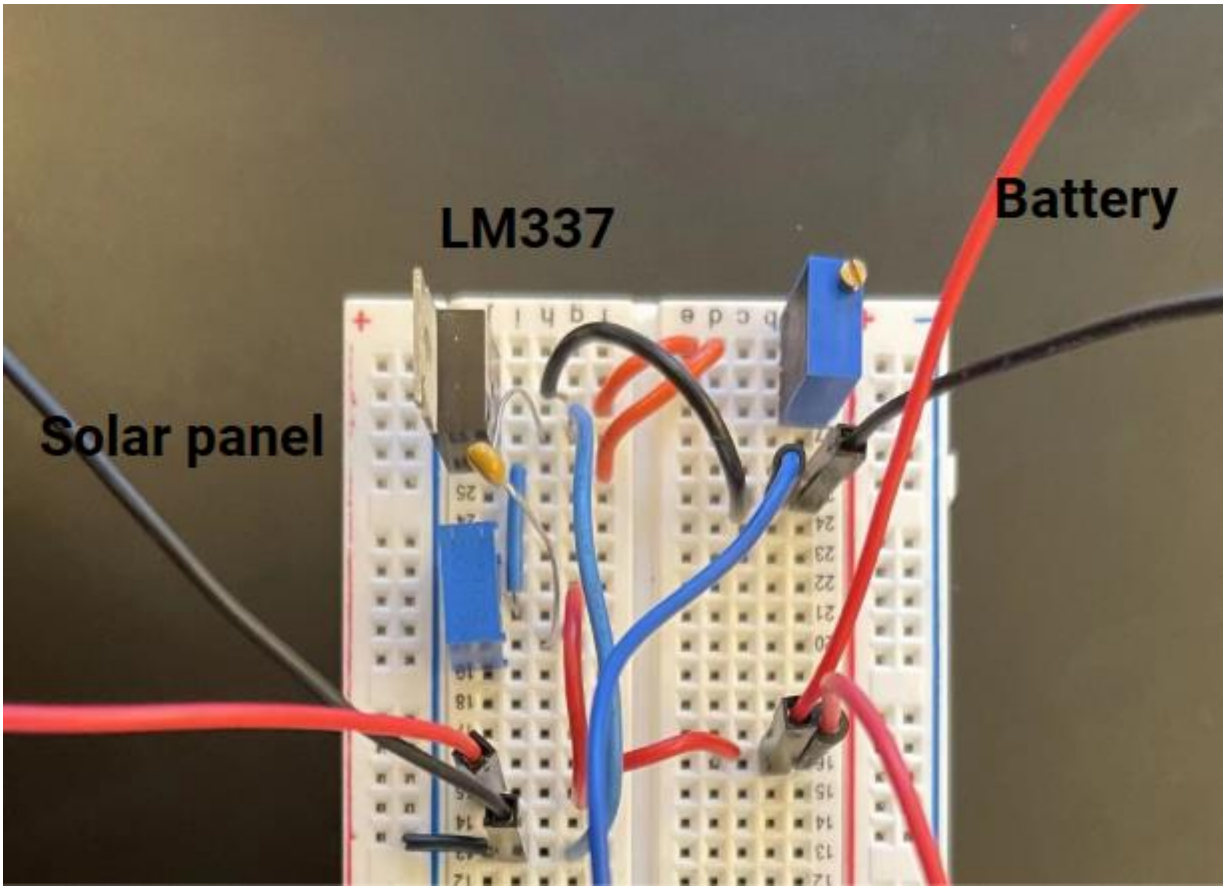


Figure 39 - The Picture of Real Circuit

6.5.3 Basic information about the material

Figure 40 - The shape of LM337

Device	Pins	L (mm)	W (mm)	T (um)	B (mm)
LM337	3	532	34.1	700	9.6

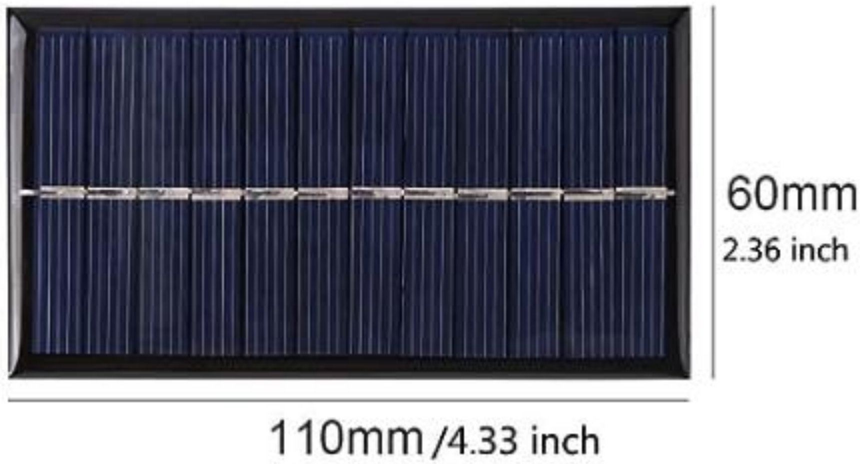


Figure 41 - Single Solar Panel Size Picture

Figure 42 - Single rechargeable battery picture

Product Dimensions	1.36 x 2.2 x 0.42 inches

Item Weight	1.94 ounces

6.5.4 Simulation of the circuit

Since there is no LM337 model in the simulation software, LM317 is used for simulation here. As mentioned before, LM337 and LM317 are similar modules, so the changed simulation results are valid.

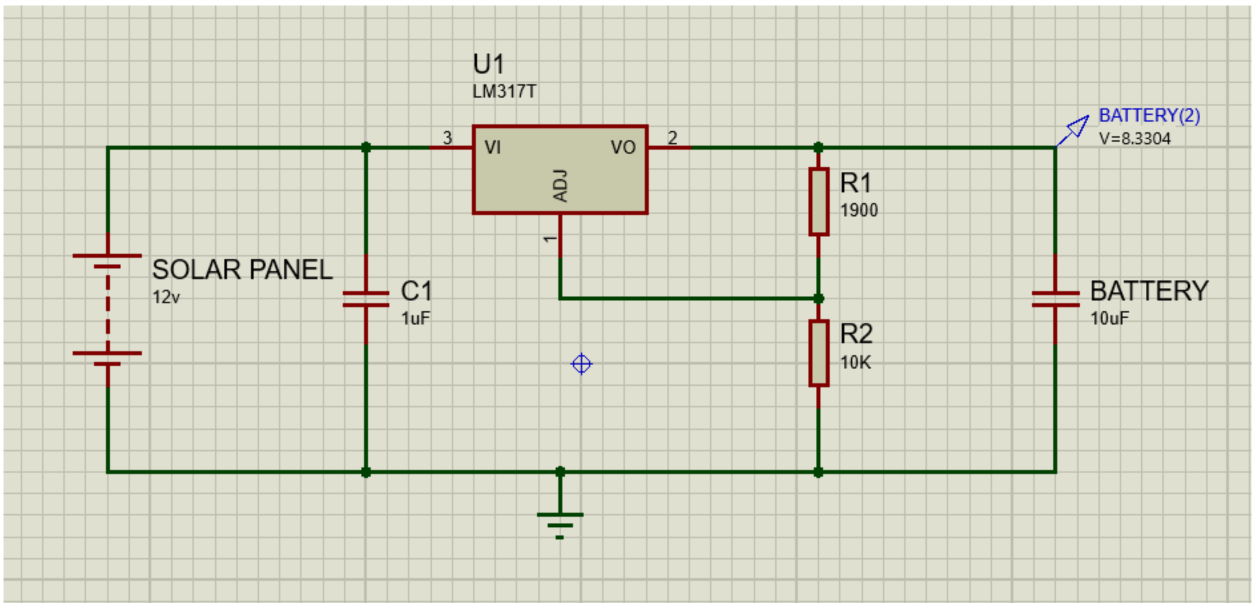


Figure 43 - Simulation of entire circuit

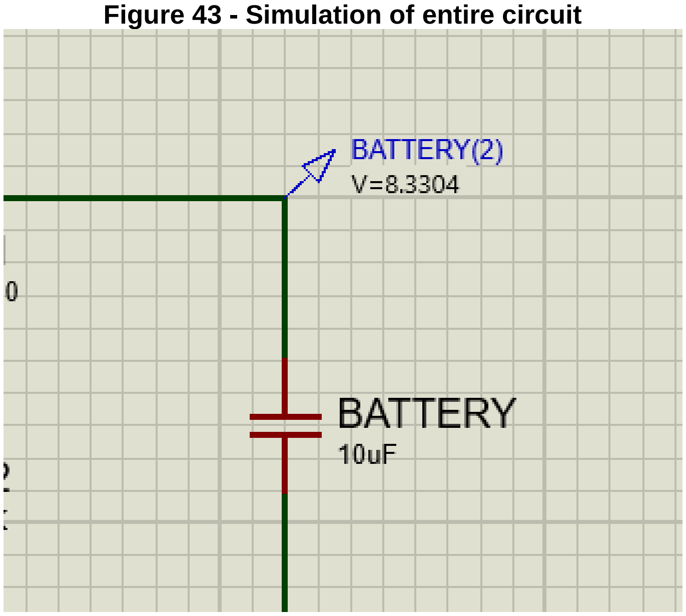


Figure 44 - The simulation result of the circuit

Due to the slight difference and influence of analog modules and input voltage, the simulation results and calculation results are slightly different, but within an acceptable range. Simulation results were found to be valid.

6.6 Cooling System

6.6.1 Overview

Because the motor and battery will release a lot of heat energy when they are working, especially in high temperature environment. The temperature in the housing will increase significantly. To ensure that other subsystems in the housing can work within a safe temperature range, a cooling system is essential.

6.6.2 Design

The cooling system is mainly composed of a thermistor, a comparator, and an electric fan. The thermistor will be attached to the battery pack and motor to accurately and timely sense their temperature. The thermistor used in this product is 10k ohms at room temperature. Its resistance decreases with increasing temperature.

The reason for using LTC1541 is that there is a Schmitt trigger inside, which can be used as a comparator to set the temperature range where the fan starts to work. After many tests, when the temperature around the thermistor is 50 degrees Celsius, its resistance is about 500 ohms. So compare a 500 ohm resistor to a thermistor. When the temperature is higher than 50 degrees Celsius, its resistance is lower than 500 ohms, and the fan starts to work after the input comparison of LTC1541.

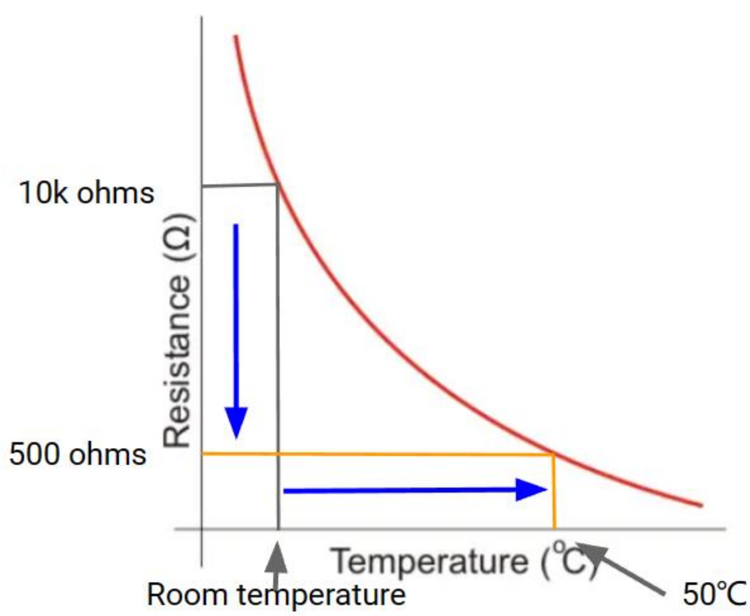


Figure 45 - The relation between the resistanc and temperature of thermistor

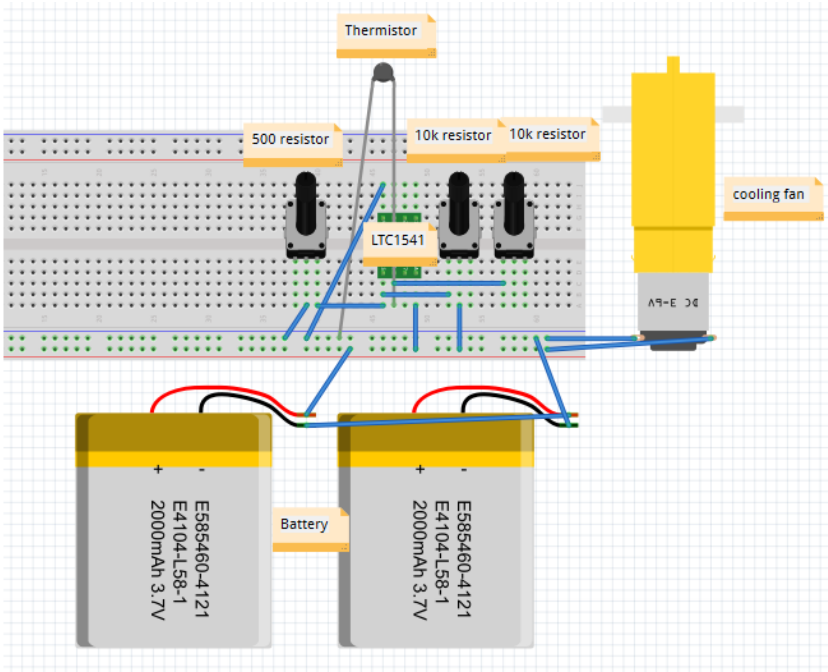


Figure 46 - The circuit diagram by Fritzing

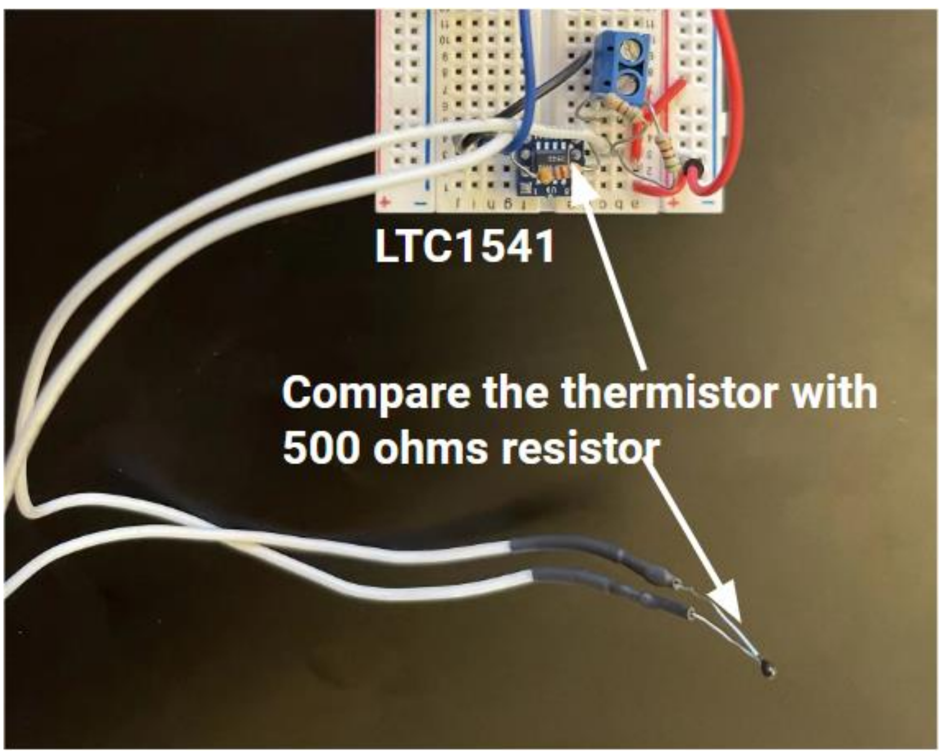


Figure 47 - The real circuit of cooling system

6.6.3 Basic information of the material

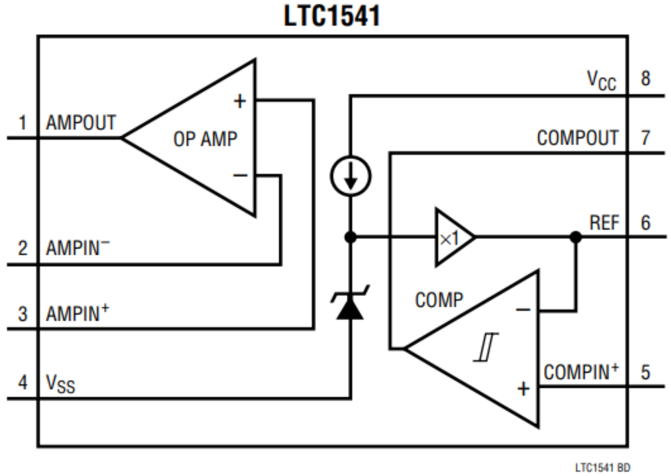


Figure 48 - the diagram of LTC1541
8-Lead Plastic DFN (3mm × 3mm)

In the cooling system circuit, Pin 6 and Pin 5 will be compared as two input. After comparing, if the input voltage of Pin 6 is less than that of Pin 5, Pin 7 will output Vcc. Otherwise, it will out a zero voltage, which means that the fan will not work.

Figure 49 - The fan used in the circuit

Maximum Rotational Speed	3000 RPM
Product Dimensions	4.71"L x 1"W x 4.71"H

Figure 50 - The thermistor used in the circuit

6.6.4 Simulation

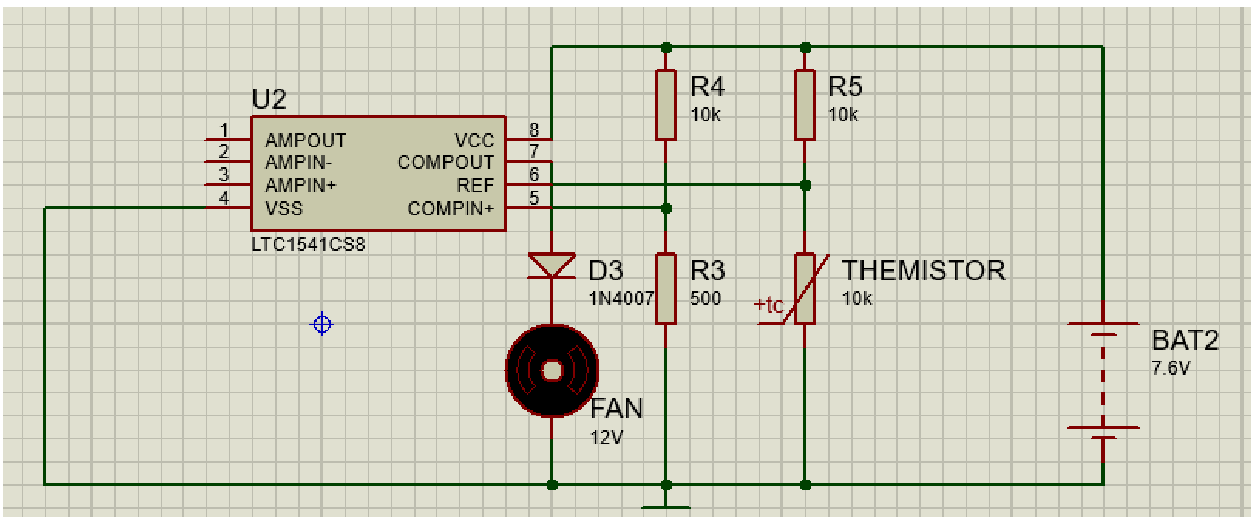


Figure 51 - Simulation for the cooling system

The simulation results met expectations, but the actual demonstration was not successful. This failure will be analyzed and explained later, and a corresponding improvement plan will be given.

7 Results and Discussion

7.1 Results

Overall, the results of the final design were within expectation and even surpassed some of the initial specifications we had initially set out. One of the biggest technical accomplishments to come from the final design was full integration between each member's subsystem. Some other noteworthy accomplishment include:

- Housing subsystem supporting more weight than expected
- Power circuit subsystem storing energy from solar panels and fully charging batteries
- Power circuit subsystem configured correctly to power multiple subsystems, including LED display system, cooling system, solar panel control subsystem, and solar panel mechanism subsystem
- Solar panel control subsystem correctly adjusting angle of solar panel mechanism subsystem to be perpendicular with angle of incoming light

Each subsystem performed testing according to the following testing criteria

7.1.1 Stop Housing

The housing subsystem had the following testing criteria:

- Be able to support the weight of an average adult persion: ~ 150 lbs.

The housing subsystem had the following testing procedure:

- Have a person sit and stand on product housing for 5 seconds to put model in a state of compression
- Record the weight the person standing on the housing and any observable effects on the housing subsystem
- Repeat with using people with different weights
    - 117.51 lbs
    - 132 lbs
    - 160 lbs
    - 200 lbs

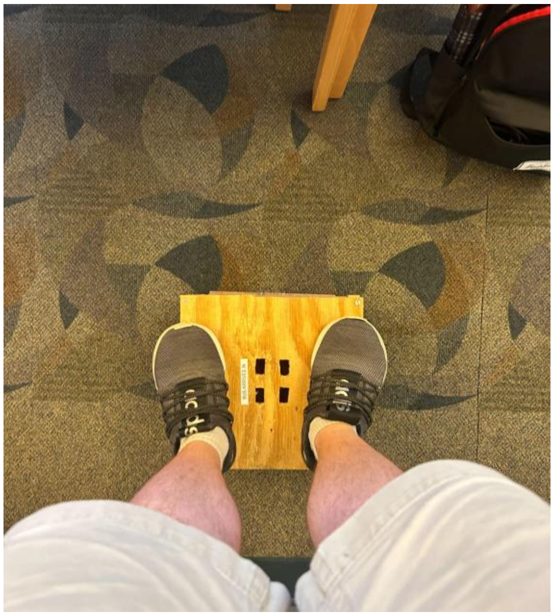


Figure 52 - 117.51 lbs Housing Model Test

7.1.2 Solar Panel Mechanism

The solar panel mechanism subsystem had the following testing criteria:

- Rotate a maximum angle on either side should be 30 degrees
- Maximum rotation speed should be 2 degrees per minute

The solar panel mechanism subsystem had the following testing procedure:
- Move slider to its maximum ranges and use protractor to measure shaft angle
- Set timer for 5 minutes and measure the change in shaft angle after elapsed time

7.1.3 LED Display
The LED display subsystem had the following testing criteria:
- Display numbers and letters
- Decrement timer by 1 after one minute

The LED display mechanism subsystem had the following testing procedure:
- Wire one LED display to test if it turns on
- Start a timer and wait one minute to see if displayed number decremented by 1
- Repeat test with each individual LED display
- Wire all LED displays and run two timers concurrently

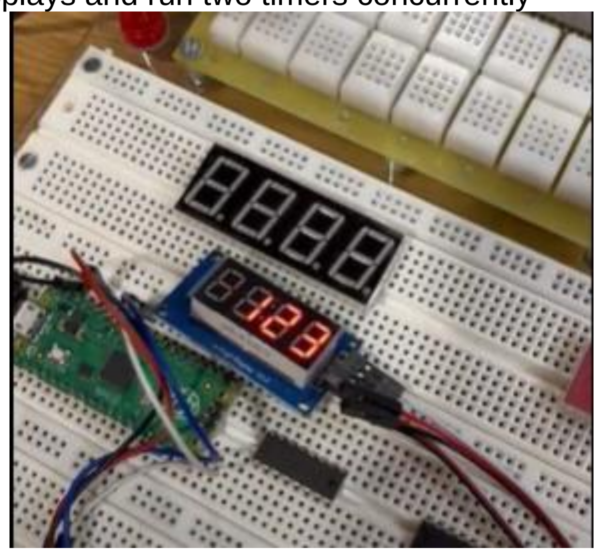


Figure 53 - Individual LED Display Test

7.1.4 Soar Panel Control
The solar panel control subsystem had the following testing criteria:
- Motor activates and turns if the difference in lux on two sides of the product is more than ~5%

The solar panel control mechanism subsystem had the following testing procedure:
- Shine a light at 95 lux on one side and 100 lux on the other side of the product
- Observe to see if motor rotates in correct direction
- Measure light’s lux value using luxometer to check circuit works as expected

7.1.5 Power Supply Circuit
The power supply circuit subsystem had the following testing criteria:
- Solar panel charge two 3.7V in-series batteries in roughly 10 hours

The solar panel control mechanism subsystem had the following testing procedure:

- Measure the battery voltage at a particular time
- Wait a set amount of time and measure the new battery voltage
- Calculate the amount of time to fully charge the batteries using collected data points

Left Figure 54 - Battery Starting Voltage
Right Figure 55 - Battery Ending Voltage After 40 Minutes

7.1.5.1 Calculations

Maximum battery capacity $= 3.7 \times 2 = 7.4$
Change in voltage after 40 minutes $= 6.929V - 6.891V = 0.039V$
Difference between startign voltage and maximum voltage $= 7.4V - 6.891V = 0.509V$
Time needed to full charge battery $= \frac{0.509V}{0.039V} = 13.05 \times 40 = 522.05\, mins = 8.7\, hours$
Battery charge time is within the expected 10 hours needed.

7.1.6 Cooling System

The cooling subsystem had the following testing criteria:

- When the subsystem reaches 50°C or higher, fans would turn on to lower temperature
- After temperature has been lower to below 50°C, fans will stop running

The cooling subsystem hsd the following testing procedure:

- Using a heat gun, blow warm air onto the sensor to raise temperature to 50°C. Temperature will be measured using a infrared temperature reader.
- Once temperature reach ~50°C, observe the fan to see if it turns on and stop applying heat using gun
- Repeat test for consistency

While we had meet our target specifications, improvements could still be made to the product. Among them being:

- Building the product housing ou of 7075 aluminium instead of wood for better durable and environment resistance
- Replacing the solar panel mechanism with lighter material such as plastic to reduce energy consumption and ease load on motor from solar panel control subsystem
- Increase the number of LED displays to present more information

7.2 *Significant Technical Accomplishments*

The overall completion of the entire project is within an acceptable range. There are two relatively failure points: component damage caused by the application of new technologies and insufficient stability of a subsystem lead to demonstration failure. When the entire project is nearing completion, all subsystems are assembled. Due to errors in prior communication and understanding, the LED screen could not fit perfectly into the hole on the housing. In order to ensure the consideration of the aesthetics and safety of the project, the zero-time modification plan is to shorten the existing pins and fuse the lines behind the LED screen. Out of a total of 4 LED screens, 2 were completely corrected. The remaining two happened to not work after being connected back into the circuit. After testing it was found that the cause of this could be destroying the LED circuit board while fusing the circuit. Although there are two LEDs that don't work, the remaining two perfectly present the function of this subsystem. Overall, this is a worthwhile trade-off. The point to note next time is to be more careful when operating some destructive tools. At the same time, spare components should be prepared for replacement.

The second point of failure is that the stability of the cooling subsystem is not up to standard. When testing a single circuit in the laboratory, the whole system works well. But when this system is connected to other systems, due to slight changes in the circuit, the entire circuit does not achieve the expected rendering effect. In the case that no error is found in the entire circuit logic, it is initially judged as the result of unstable circuit connection. This is also a trade-off point for this project. Due to the construction cost of the whole project, the microcontroller is not used, which greatly simplifies the circuit and also improves the budget. After considering that all expected functions can be completed with existing chips and the end users are low-income groups, the microcontroller solution was rejected. From a learning point of view, this is a good trade-off. It is undeniable that the microcontroller allows the designer to not think too much when designing the circuit, but to focus on the debugging of the code. In the long run, this behavior does not improve the designer's knowledge base or use of related skills. From the perspective of actual products, if the designer has more time to burn the circuit, the stability problem of the system can be solved. At the same time, the cost of products targeting low-income groups will be significantly reduced. Although this will take a lot of time and effort, it will be a very beneficial solution if this product is mass-produced.

8 Conclusions

Overall, everyone on the team was able to learn valuable lessons from this project. This was a project that required commitment from each member. This is the first time for many to work on a project while having little to no knowledge of other members' parts. There were many other challenges along the way, but ultimately, we were able to produce a product that operates smoothly.

The prototype performed quite well overall, meeting all subsystem specifications. The housing was able to withstand at least 200lb, and the shade panel could cover a total of 60 degrees while sun-tracking at a safe speed of 2 degrees/min. The solar panel could change its direction whenever it reaches a lux difference of less than 5%. The displays showed accurate timings and can adjust when special events occur. The cooling system activates upon reaching 50°C. Finally, the battery can charge from the solar panels and distribute voltage across the system.

Our next step is to create a prototype out of its designed material, instead of 3D printed material and wood. This would require some metal working and more advanced design for each of the subsystems. Moving forward, it would certainly be interesting to see a design that is even more compact than what is currently present.

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10 Appendix A: Selection of Team Project

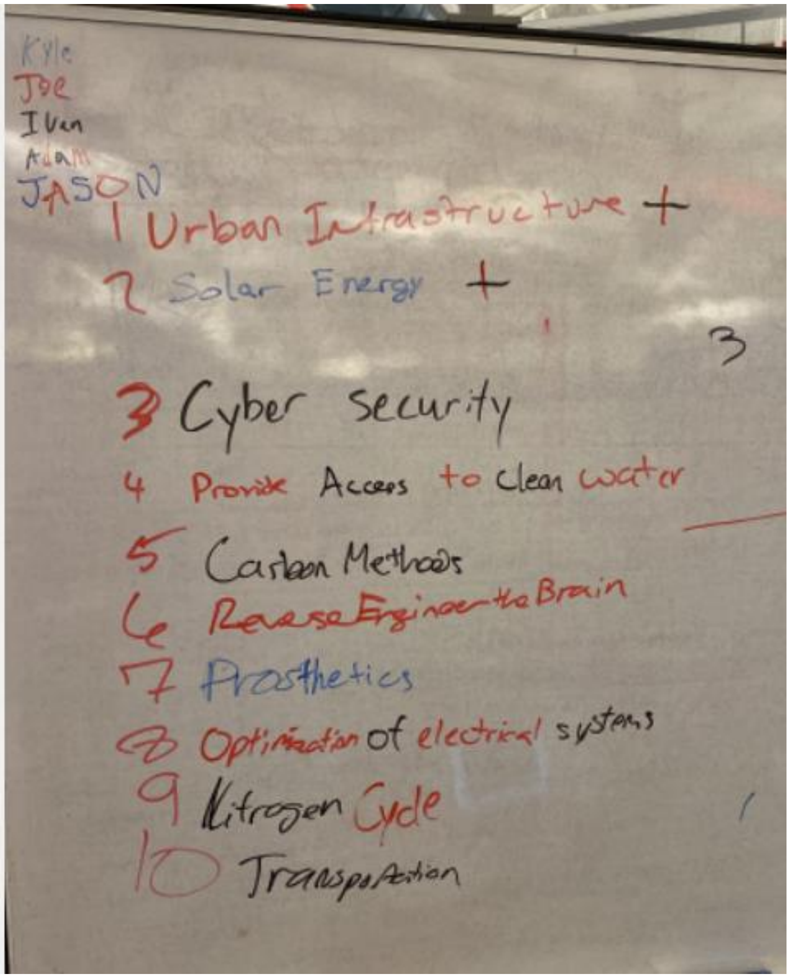

Figure 57 - Possible project concepts

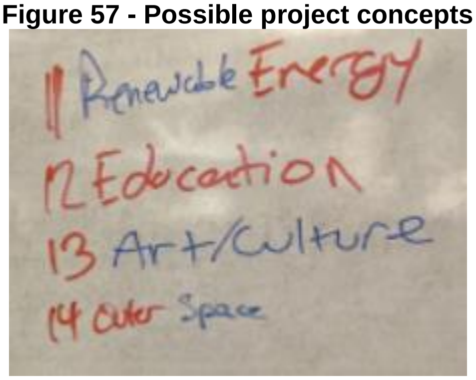

Figure 58 - Possible project concepts (cont.)

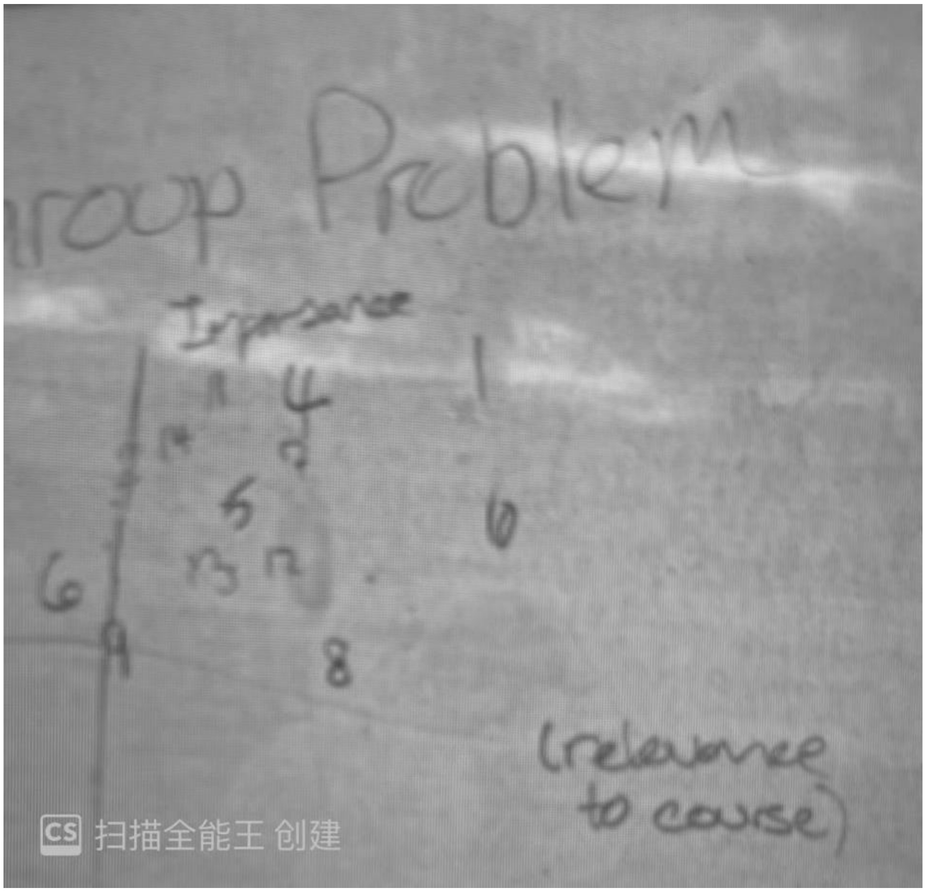

Figure 59 - The selection chart: Importance vs Relevance

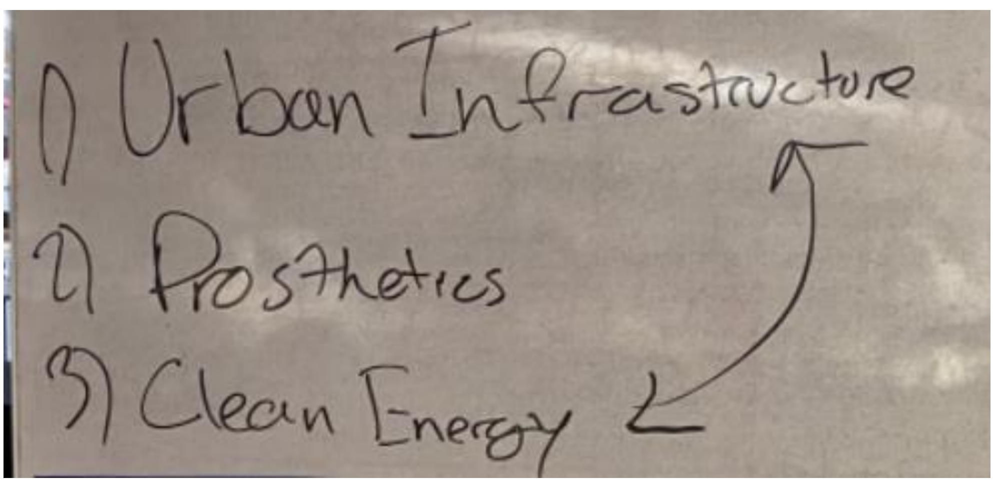

Figure 60 - Three final concept of the project

The initial idea was to take a monorail and apply it to RPI's campus to replace the shuttle. After discussion, it is found that a rapid automated rail transit system cannot be realized with the existing time and knowledge reserves. And by analyzing the terrain of RPI, the form of shuttle is more suitable than rail transit.

After discussion, the bus as the earliest and largest public transportation system was considered as a more suitable project subject. This theme can be transformed on the existing basis, and the starting point of the transformation is very low while the degree of freedom is large, which makes this the optimal choice. The bus platform obviously has many obvious deficiencies when compared with existing buses. This is also the entry point of the whole project. Combining the three selected themes, 1 and 2 are very suitable and easy to combine. In the end, based on designers' own experience and field interviews, improving the sun blocking shelter and turning the entire product into a solar drive became the goal of the entire project.

11 Appendix B: Customer Requirements and Technical Specifications

As stated in the Customer Requirements section, our main target customers are the following:

- Local residents
- Transit riders
- Urban planners/engineers

As local residents and transit riders share very similar customer needs and requirements, the two customer groups were combined and treated as one group when creating the following customer needs and requirements tables below.

Table 6 - Interpreted customer needs table for local residents and transit riders

Customer: Local Residents / Transit Riders		
Question / Prompt	Customer Statement	Interpreted Need
Typical Uses	Waiting for a bus	Located on bus route
	What bus is coming	Displays information
Dislikes	No shelter	Protection against weather Climate control
	No light at night	Time controlled light source
	No safety	Emergency system
	Limited/outdated information	Modifiable information display
Suggested Improvements	Overhead shelter that moves to block the sun	Dynamic sun shelter
	Ability to call for help	Blue light system
	Have live information be displayed	Digital info display with organized interface/legend

Table 7 - Customer requirement and specifications for local residents and transit riders

Customer Requirement	Technical Specification	
	Metric	Target Value / Range of Values
Shelter	Size and space	Within ~15 ft. around bus stop
Night Visibility	Presence of light	20 - 50 lumens
Safety	Criminal activity	Little to none
Updated, Digestible Information	Accuracy and simplicity of information	At a minimum have information regarding bus time and route Bus information should be relevant for the day Easily digestible by most age groups
Temperature	Temperature	Environment temperature range of 60 - 76 °F
Easily Accessible	Age and disabilities	All ages Wheelchair accessible

Table 8 - Interpreted customer needs table for urban planners and engineers

Customer: Local Residents / Transit Riders		
Question / Prompt	Customer Statement	Interpreted Need
Typical Uses	Proving a space for bus riders to wait	Identifiable place for riders to wait
Dislikes	High maintenance and cost	Easy to maintain and relatively cheap to build
	Complex implementation	Easy to install
	Not customer friendly	Customer-centric design
	Aviod vagrancy	Space must be safe and discourage “camping”
	Poor construction	Must be long lasting and easily repairable
Suggested Improvements	Overhead shelter that moves to block the sun	Dynamic sun shelter
	Ability to call for help	Blue light system
	Have live information be displayed	Digital info display with organized interface/legend

Table 9 - Customer requirements and specifications for urban planners and engineers

Customer Requirement	Technical Specification	
	Metric	Target Value / Range of Values
Maintenance	Cost and time	~$1000 < 15 min. maintenance
Implementation	Cost and time	~$1000 < 1 day to implement
Construction	Cost and time	~$1000 1 week to build
Safety	Criminal activity	Little to none
Easily Accessible	Age and disabilities	All ages Wheelchair accessible
Easy Customer Interface	Age and disabilities	All ages
Seating	Number of customers and weight	3 - 5 person capacity Support 100 - 250 lbs.
Temperature	Temperature	Environment temperature range of 60 - 76 °F
Visibility	Clarity and presence of light	Able to see the bus stop from ~2 street blocks 20 - 50 lumens

Table 10 - Initial draft of combined customer requirements organized by priority

Customer Requirement	Technical Specification	Target Value / Range of Values	Priority
Safety	Criminal activity	Little to none	1
Construction	Time and cost	< $1000 < 1 week to build	2
Updated, relevant, digestible information	Accuracy and simplicity	Constantly updating information relevant for the day Can be read by most age groups	3
Visibility, especially at night	Lighting	20 - 50 lumens	4
Implementation	Time and cost	< $1000 ~ 1 day to implement	5
Shelter from the elements	Size and space	~15 ft. around bus stop	6
Accessibility for the handicapped and disabled	Age and disabilities	All ages and wheelchair accessible	7
Maintenance	Time and cost	~ $1000 ~ 15 min. maintenance	8
Temperature	Temperature	Environmental temperature range of 60 - 76 °F	9
Seating	Size, space, and number of customers	Fits within 15 ft. around bus stop 3 - 5 people capacity Support 100 - 250 lbs.	10

For the final version of the combined customer requirements table, refer to Table 2 in the Customer Requirements section.

12 Appendix C: Gantt Chart

Table 11 - Gantt Chart

Smart Stop	Status	Owne	Start	End	18-Jul-23	22-Jul-23	26-Jul-23	30-Jul-23	3-Aug-23	7-Aug-23	11-Aug-23
Solar Power Supply	100%	Jason	7/11/2023	8/11/2023							
Circuit Design	100%	Jason	7/11/2023	7/21/2023							
Materials Acquisition	100%	Jason	7/15/2023	7/28/2023							
Simulation	100%	Jason	7/24/2023	7/28/2023							
Circuit Construction	100%	Jason	7/31/2023	8/4/2023							
Testing and Troubleshooting	100%	Jason	8/2/2023	8/11/2023							
Photosensitive Light	100%	Joe	7/11/2023	7/31/2023							
Circuit Design	100%	Joe	7/11/2023	7/14/2023							
Materials Acquisition	100%	Joe	7/14/2023	7/21/2023							
Simulation	100%	Joe	7/14/2023	7/21/2023							
Circuit Construction	100%	Joe	7/24/2023	7/26/2023							
Testing and Troubleshooting	100%	Joe	7/26/2023	7/31/2023							
Housing	100%	Adam	7/11/2023	8/11/2023							
Materials Selection	100%	Adam	7/11/2023	7/17/2023							
Materials Acquisition	100%	Adam	7/17/2023	7/24/2023							
Design	100%	Adam	7/17/2023	7/24/2023							
Construction	100%	Adam	7/24/2023	7/31/2023							
Weatherproofing	100%	Adam	7/31/2023	8/7/2023							
Testing and Troubleshooting	100%	Adam	8/6/2023	8/11/2023							
Route Number Display	100%	Ivan	7/11/2023	7/31/2023							
Circuit Design	100%	Ivan	7/11/2023	7/14/2023							
Write Code	100%	Ivan	7/14/2023	7/17/2023							
Materials Acquisition	100%	Ivan	7/14/2023	7/21/2023							
Simulation	100%	Ivan	7/17/2023	7/24/2023							
Circuit Construction	100%	Ivan	7/24/2023	7/26/2023							
Testing and Troubleshooting	100%	Ivan	7/26/2023	7/31/2023							
Sun Tracking Shade	100%	Kyle	7/11/2023	8/4/2023							
Design	100%	Kyle	7/11/2023	7/18/2023							
Simulation	100%	Kyle	7/18/2023	7/20/2023							
Materials Acquisition	100%	Kyle	7/18/2023	7/25/2023							
Circuit Design	100%	Joe	7/11/2023	7/18/2023							
Circuit Construction	100%	Joe	7/22/2023	7/25/2023							
Construction	100%	Kyle	7/25/2023	7/28/2023							
Testing and Troubleshooting	100%	Kyle	7/28/2023	8/4/2023							

13 Appendix D: Expense Report

Table 12 - Project Expenses

Item	Quantity	Unit Price	Subtotal	Shipping
Aluminum 7075 for Housing and Hardware	53.3	$5.20	$277.16	$160
Aluminum 6063 for Solar Mast Mechanism	10	$1.37	$13.67	$30
Solar Panel	2	$69.00	$138.00	$30
LM337 Linear Voltage Regulator	1	$0.47	$0.47	$0.20
24 AWG Copper Wire - 1 Foot	15	$0.42	$6.30	$30
Misc. Resistors	6	$0.01	$0.04	$0.01
3.7v Li-Ion Battery	2	$5.50	$11.00	$2
Gearmotor	1	$9.90	$9.90	$2
Misc. Sensors	3	$0.10	$0.30	$0.20
Misc. Ics	3	$1.30	$3.90	$0.20
Raspberry Pi W	1	$6.00	$6.00	$1
LED Display	4	$17.00	$68.00	$6
Total			$796.74	

14 Appendix E: Team Members and Their Contributions

14.1 Ivan Chen

Responsible for the design and implementation of the LED display of the Smartstop.

Design of the subsystem included:

- Formatting of information to be displayed
- Selection of information to be displayed
- Overall layout of the LED display.

Implementation of the design included:

- Selection and acquisition of electronic parts needed to build the subsystem
- Writing code to program electronic part functionality
- Subsystem wiring and testing

In addition, assisted with testing with other subsystems such as the power supply circuit and stop housing subsystem.

14.2 Kyle Fairfield

Responsible for the sun-tracking shade mechanism subsystem. Spent a lot of time in the IED shop, Forge and processes shop for the shade mechanism and housing subsystems.

14.3 Adam Leicester

In charge of the housing system for general body and wood work of prototypes. Facilitated group meetings and coordinated material analysis for mechanical designs.

14.4 Jason Zhai

1. Responsible for the design and implementation of energy supply systems and cooling systems. Work as an assistant to help with final product assembly.

14.5 Joseph Zito

Responsible for design and implementation of sun-tracking shade control circuit. Provided large amounts of advice and design consultation for other electrical subsystems, functioned as chief electrical engineer. Together with Jason fully integrated all subsystems, through wiring, soldering, adhering, and adjusting.

15 Appendix F: Statement of Work

This project aims to design a cheap and self-sufficient product that can be attached to existing modern bus stop. We aim to design a product with minimal time and cost requirements for manufacturing while also allowing for easy integration. The product serves to improve the quality of life of local communities by providing safety, information, and a great place for advertising local businesses.

16 Appendix G: Professional Development - Lessons Learned

One thing that our team did very well is communication. We hold weekly meetings to keep everyone up to date on progress. As we reached deeper into the semester, many of us got increasingly busy with school work. However, everyone on the team made an effort to contribute. If anything went wrong, members would notify the rest of the team in a timely manner. Any sketches or important graphs and tables were well documented.

There weren't any major problems within the team. Unfortunately, it was difficult at times to have the full team present in meetings due to schedule conflicts and health issues. Although we manage to finish every milestone on schedule, it is noticeably more stressful as deadlines close in. This would require some improvement in time and project management.

17 Appendix H: Software / Technology Used

17.1 Collaboration Among Team Members

- Cisco WebEx Teams and Meetings

17.2 Subsystem Design

This list would include software and other tools used for modeling and analytics.

- Siemens NX
- Solidworks
- Fusion 360
- AutoCAD
- LTspice – for schematics and simulation
- Fritzing – note that Fritzing's "pictorial views" are not acceptable as schematics.

17.3 Programming

- Thonny Python Integrated Development Environment (IDE)
- Raspberry Pi Pico IDE

17.4 Subsystem Testing/Simulation/Emulation

- Siemens NX
- Solidworks
- Fusion 360
- AutoCAD
- LTspice – for analog circuits
- LogicWorks – for digital circuits
- AppyPie
- Digilent Waveforms
- TinkerCAD – note that TinkerCAD pictorial views are not an acceptable alternative to schematics
- MATLAB

18 Appendix I: User Manual

This product is a fully automated bus stop based on solar energy, and there is no place for end users to operate. The current automation functions are the sun tracking system and the automatic body cooling system after overheating. Please look forward to the development of the follow-up system.

Below are some safety instructions in effect when you enter the working area of a bus stop.

Do not block or forcibly change the running track of the solar visor.

Do not spill liquid into the cabinet.

Do not destroy the door on the cabinet and open it without authorization.

(Built-in complex circuit, there is a risk of electric shock if opened without authorization.)

Do not block or remove the cover of the cabinet exhaust port.

2.