Design Realization Phase for a Project to Develop an Improved Method of Waking to Help Users Get Out of Bed and Feel Refreshed in the Morning

To: Aayush Mathur

25 April 2024

Team Members

Aadit Kumar (kumar605@purdue.edu)

Gabe Kurfman (gkurfman@purdue.edu)

Cecilia Kutheis (ckutheis@purdue.edu)

Colin Levitt (cjlevitt@purdue.edu)

ME 263 Lab 216

Executive Summary

Purpose: This report shares Team 5's development of a problem, primary concept, bill of materials and assembly analysis, benchmarks and performance analysis, and overall conclusions for the design realization phase of the ME263 project, which focuses on helping consumers wake up and get out of bed in the morning.

Conclusion: The team has selected the "Sunriser" blinds opener to be the primary solution concept (See Figure E.1). After developing the assembly process for the Sunriser, the team found that the device is relatively simple to produce and assemble and will likely sell 36,000 units per year to the market of college students.

Process: After making adjustments to the problem definition, the team brainstormed concepts and ultimately selected the "Sunriser", a device that opens the user blinds and plays audio at the user's specified waking time. The concept was further developed and improved throughout this phase. After finalizing the design, the team wrote a Bill of Materials and used a process flow diagram to ensure the assembly process was effective and efficient. Detail drawings and CAD models of the concept were created. Several analyses of the concept were performed surrounding tolerance stack ups, benchmarks, and overall performance. Overall conclusions were drawn and recommendations for the future of the project were presented.

Discussion: The most important engineering specifications to be met include the following qualitative and quantitative requirements: Must wake user from sleep at least 95% of the time, must cost less than $120 per unit for the consumer, must last more than 2000 use cycles, must allow adjustable settings, and must be nondisruptive. Each of these specifications are met by the Sunriser.

Since the Sunriser include a visual and auditory stimulus and encourages the user to physically get out of bed and walk to the window to turn off the alarm, it is very likely to wake the user. Financial analysis on the Sunriser projected that after 15 quarters of selling 9,000 units per quarter at a retail price of $120, the net worth present value will be about $455,000. Preliminary testing shows that the Sunriser is durable and reliable, lasting several use cycles during its prototype development, so it is projected to last more than 2000 use cycles.

The Sunriser features three buttons that allow the user to adjust the hour and time that the alarm sounds and the volume of the alarm. Each of these settings is important for the user to adjust the device to best wake them according to their sleeping habits. The Sunriser meets the nondisruptive requirement because it utilizes natural light for waking and customizable alarm volume. Users that wake easily can wake up to natural light and a quieter alarm, while users that have a more difficult time waking can wake up to natural light and a higher volume alarm, which each of these circumstances offering minimal disruption (unlike loud sounds and abrupt physical stimulants, which other waking devices utility.

The final design is characterized by a single unit to be clamped to a windowsill featuring an OLED time and message display screen, three buttons for adjusting settings, an audio speaker, and the blinds tassel pulley and clips. The device's body and tassel clips for the prototype are custom manufactured 3D-printed PLA plastic, however, for mass production, injection molding technique will be used. The electronic and hardware components for the device are purchased in bulk from suppliers. The final unit is made up of the electronic assembly, the clamp assembly, and the tassel assembly.

When the consumers uses the Sunriser, they will adjust the screws in the clamp so that it fits securely over their windowsill. They can use the clips to secure the pully to their blinds and plug the device into a wall outlet. To set the clock time, the user will first select the leftmost button to enter the time setting mode, and then use the center and rightmost buttons to adjust the current time in hours and minutes, respectively. Then, the user can follow a similar process to set the "alarm time" when the device will activate and pull the blinds open. Once the desired alarm time is reached and the device activates, the user can push the rightmost button to stop the alarm and retract the pulley.

Overall, the Sunriser meets eat of the key criteria to develop a better waking device for college students. Most notably, the Sunriser offers reliability, affordability, and durability in addition to configurability and non-disruptiveness. Each of these characteristics working together provides a solution to the problem college students face every day of waking up and getting out of bed in the morning.

Figure E.1: CAD Model of the Sunriser

Table of Contents

Section 1: Introduction

Over 90% of adolescents have trouble waking up, leading to problems throughout the day, such as sleep inertia (Amaral et al., 2014). Team 5 is not the first to attempt a solution to sleep-waking difficulty; there is a large market dedicated to assisting in waking people through vibration, light, and sound. However, waking difficulty persists: In the team's survey with a sample size of 68, 57.3% of respondents found at least some difficulty waking in the morning. Therefore, the team is attempting to combat this with a new design. Additionally, the disruptive solutions, yet widely used for their reliability (like the alarm clock), are linked with adverse health outcomes such as strokes and heart attacks (Kim, 2023). Therefore, the goal is to generate a solution that is effective and non-disruptive. This will help consumers wake up rested and refreshed and arrive at their daily responsibilities promptly and without hassle.

This report will cover the specifics of the design realization of the Sunriser. It will initially go through the development of the problem definition and then update the final design based on the problem definition. Afterwards, the concept generation and selection will discuss the process behind selecting the Sunriser as the primary design. The operational description will review the Sunriser's operation. Afterwards, the bill of materials for the design will be presented, along with a review of the material and fabrication processes being used. Technical CAD drawings will enable a user to visualize the Sunriser in detail. The assembly method will then be detailed, along with tolerance stack-ups of essential fittings of the design. Then, the Sunriser will be compared to the most relevant products (benchmarks) that exist in the sleep-waking space, and the performance of the Sunriser will be compared to that of its competitors.

Section 2: Problem Definition Development

To establish grounds for solving this problem, the team had to decide if enough people experienced the problem and if the potential market size was large enough. Since the issue focuses on adolescents' sleep and waking habits, the team found research that indicates adolescents have issues waking up. A Portuguese study found that 90.6% of adolescents report having difficulty waking up (Amaral et al., 2014). Applying this percentage to the team's target audience of American adolescents implies that nearly 38 million people face issues waking up in the morning. Therefore, the problem at hand is very broad and affects millions of people, which confirms the need to solve it.

Additionally, the standard electronic alarm clock does not solve the various problems adolescents face when waking up and getting out of bed in the morning, it is the closest product currently on the market, so it’s market trends can be used to predict market growth overall for waking devices. According to Business Research Insights, the market for alarm clocks was estimated to be $182.6 million in 2022 and is projected to reach $273.64 million by 2031 (*Electronic alarm clock market size*).

The team additionally created and shared a survey that received 68 responses. Questions discussed the difficulty consumers face when waking up, the frequency of this difficulty, and the methods used to wake up. From this survey, the team found that most users had difficulty waking between 2-5 times per week (Figure 1.1), and the largest group experienced "some difficulty". From this, it was found that a solution must have multiple modes configured for the days when users don't have difficulty waking up. It was also asked what methods customers use to wake up in the mornings (Figure 1.2).

Interestingly, 16% of respondents say that loud sounds always wake them up, while only 9% say the same of bright light. However, a higher percentage of respondents claim that bright light wakes them up sometimes or most of the time. It was also found that consumers are worried about disturbing their roommate's sleep, so this must also be considered when designing a solution.

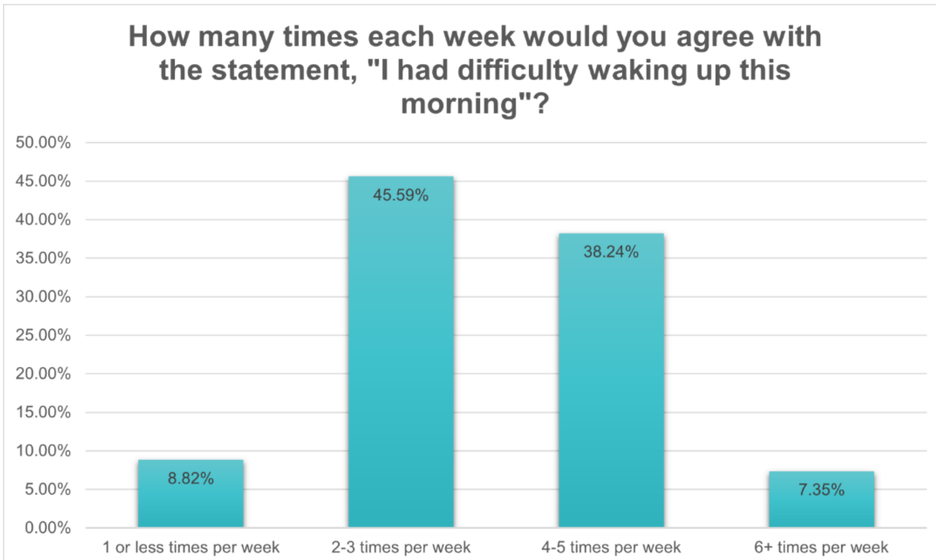


Figure 1.1: Frequent Difficulty Waking Up Survey

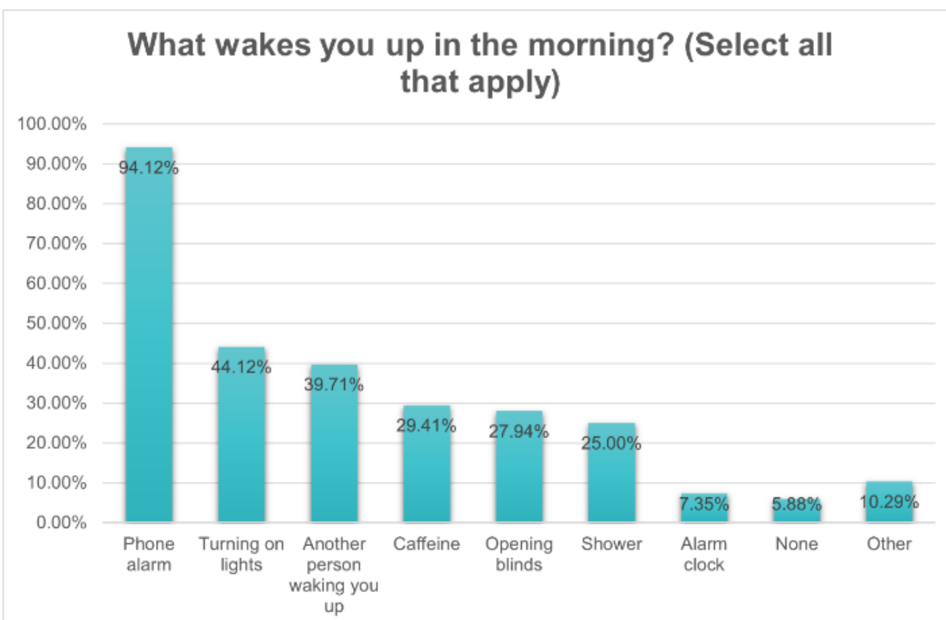


Figure 1.2: Waking Method Survey

Some of the free responses suggested that physical activity helped make them feel more awake. Thus, a potential solution to the problem of waking up in the morning could be to create a device that kickstarts or signals a chemical response in the body. This suggests that a device that encourages a biological response, like physically getting out of bed, could help the user get out of bed and stay awake.

From this research, the team derived several customer requirements for the product, most importantly: reduces sleep inertia, reliably and effectively wakes the user and is affordable.

Section 3: Problem Definition

The team's problem statement is as follows: "Research shows that the majority of adolescents (90.6%) report having difficulty waking up (Amaral et al., 2014), which prolongs a phenomenon known as sleep inertia. The team aims to design and implement a device to reduce sleep inertia, making waking up easier."

Consumer and market research provided vital information about the necessary qualitative and quantitative characteristics the solution must fulfil to successfully solve the problem of waking difficulty and be well-received by consumers. The requirements are as follows:

Quantitative Requirements

- Must wake user from sleep at least 95% of the time
- Must cost less than $120 per unit for the consumer
- Must cost less than $30 per unit to produce
- Must be capable of, at least, one configuration change per week
- Must survive a drop height greater than four (4) feet
- Must occupy less than 180 cubic inches of space

- Must weigh less than four (4) pounds
- Must consumer less than two (2) watts of power
- Must have a minimum fillet radius greater than 0.05 inches
- Must have no free-standing choking hazards with a diameter less than one (1) inches
- Must last more than 2000 use cycles
- Must contain no substance concentrations above the EPA standard
- Must take less than 20 minutes to install and set up
- Must require less than two (2) total parts
- Must have no greater than three (3) protruding buttons
- Must be built using more than 50% recyclable components
- Must require no more than five (5) tools to assemble
- Effective range of ten (10) ft radius

Qualitative Requirements

- Must allow adjustable settings
- Must not wake any roommate
- Must not degrade upon exposure to disinfectant
- Must not greatly increase chance of heart disease
- Must be designed with neutral colors
- Must be manufactured in the USA
- Must be wheelchair accessible

Section 4: Concept Generation and Selection

For the Concept Generation and Selection phase, the team first conducted functional decomposition (Fig 4.1) for the required solution. The main function was that it needed to wake a user up. The subfunctions identified were that it needed to have a user interface, could emit auditory and visual stimulus, and it also needed to be able to be installed near the bed.

To complete the decision matrix, the team compiled a list of design requirements, ranked them from least (1) to most important (5), and compared them against the datum and team sketches. The Phillips Smart Sleep was selected as the datum as it performed well against earlier established benchmarks. Additionally, the target market was narrowed to college students. When ranking the importance of design requirements, the team considered the goal of effectively waking the user. The most important requirement is that the device dependably wakes the consumer. Additionally, the solution must be affordable, long-lasting, and easy to install, as college students tend to be price-sensitive and tend to live in semi-temporary housing (on a yearly basis).

Design concept sketches were then gathered using brainstorming. A Decision matrix was created in which design alternatives were specified. A datum was selected, and critical customer requirements were listed. The design options were then compared against the datum. The advantages and disadvantages of the design options were then considered, with possible reworks.

The concepts that were considered were the "Light Switcher" (a device that flips a light switch on and off), the "Sheet Puller" (a device that pulls the sheets off the bed), the "Directional Lamp" (a device that shines bright light directed at the user's face), and the "Blinds Puller" (a device that opens the user's blinds).

After scoring and weighing each sketch's results, the Blinds Puller sketch scored better than the datum and better than the other sketches (see Figure 4.2). In particular, the Blinds Puller performed well in the highly weighed, affordable, durable, and dependable design requirements. Additionally, it was on par with the benchmark (The Philips SmartSleep) on most other design requirements and was worse than the benchmark, which was only on two relatively low-weighed benchmarks – low power and ease of installation. The Benchmark that was second in place, the Directional Lamp, had issues with Portability and didn't improve much on the Benchmark- most of the scores were equal to the Benchmark (the only improvements were on affordability and Durability). Thus, the Blinds Puller improved on the Directional lamp in the categories of Dependability and Portability. Therefore, the Blinds Puller was pushed to the decision matrix's forefront and was ultimately chosen as the final design.

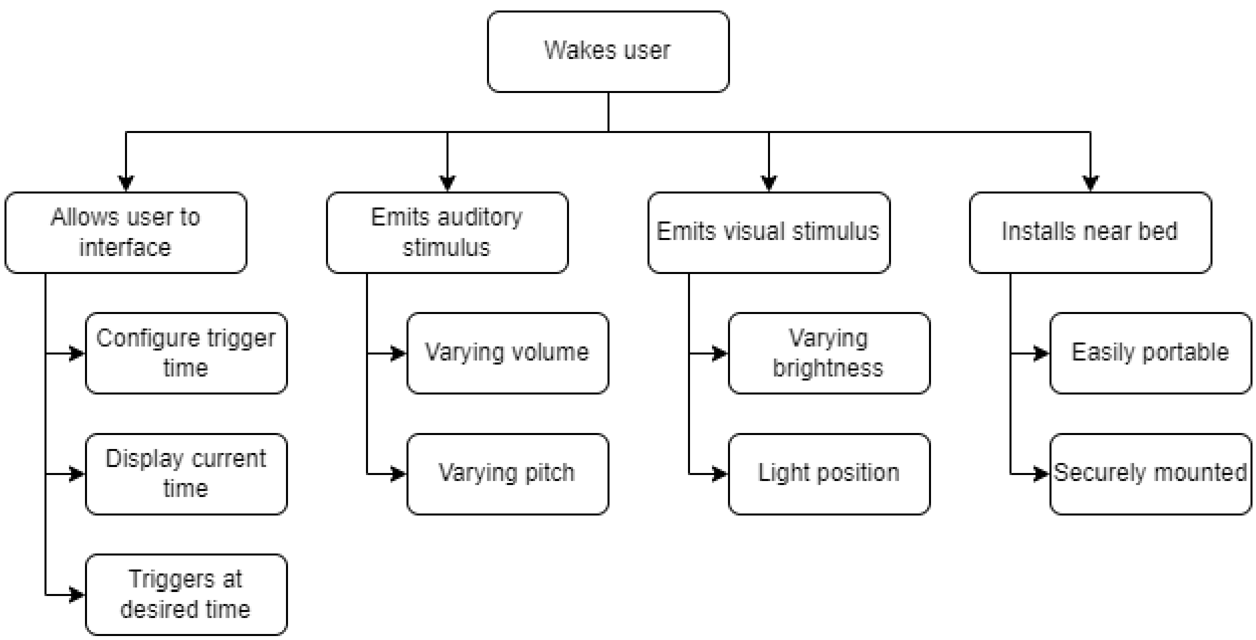


Figure 4.1. Functional Decomposition

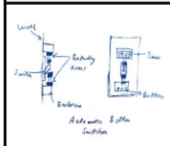
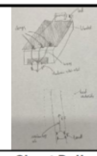
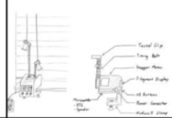
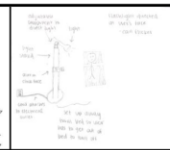
		Concepts				Datum
						
Design Requirements	**Weights**	**Light Switcher**	**Sheet Puller**	**Blinds Puller**	**Directional Lamp**	**Philips SmartSleep**
Affordable	4	1	1	1	1	0
Low maintenance	3	0	-1	0	0	0
Configurable	2	-1	0	0	0	0
Durable	3	1	1	1	1	0
Dependably wakes customer	5	1	2	1	0	0
Portable	3	1	-2	1	-1	0
Non-disruptive	3	-1	1	0	0	0
Low Power	2	-1	-2	-1	0	0
Stand-alone	2	0	0	0	0	0
Impervious to household cleaners	1	0	0	0	0	0
Safe for children	2	0	-2	-1	0	0
Sustainably Sourced	1	-1	0	0	0	0
Good Aesthetics	3	0	0	0	0	0
Recyclable	1	0	0	0	0	0
Ethical	3	0	0	0	0	0
Long-lasting	4	0	-1	0	0	0
Non-Toxic Materials Used	1	0	0	0	0	0
Easy to install	3	-2	-2	-1	0	0
Accessible	4	0	1	0	0	0
	Total +	4	6	4	2	0
	Total -	-6	-10	-3	-1	0
	Overall Total	-2	-4	1	1	0
	Weighted Total	**1**	**-3**	**8**	**4**	**0**

Figure 4.2. Decision Matrix

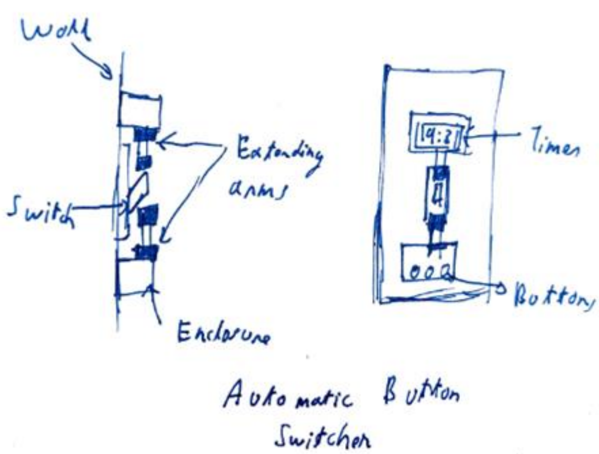


Figure 4.3. Light Switcher

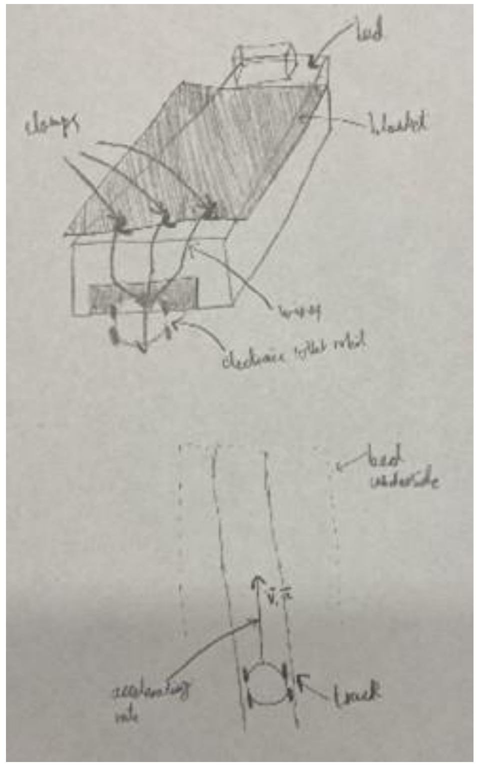


Figure 4.4 Sheet Puller

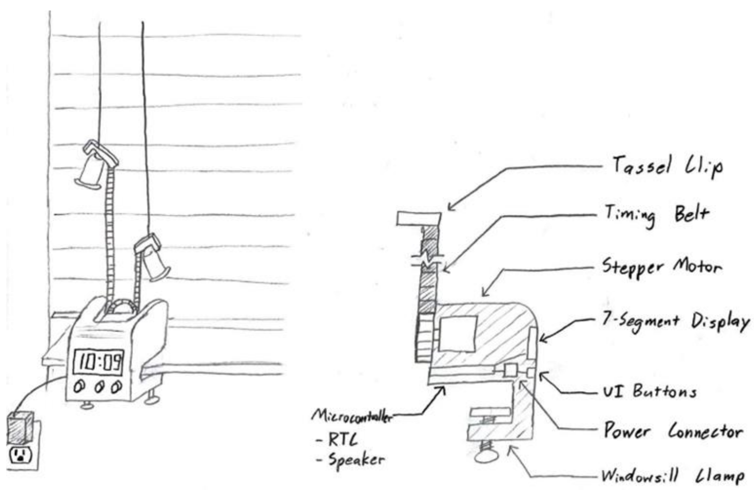


Figure 4.5 Blinds Puller

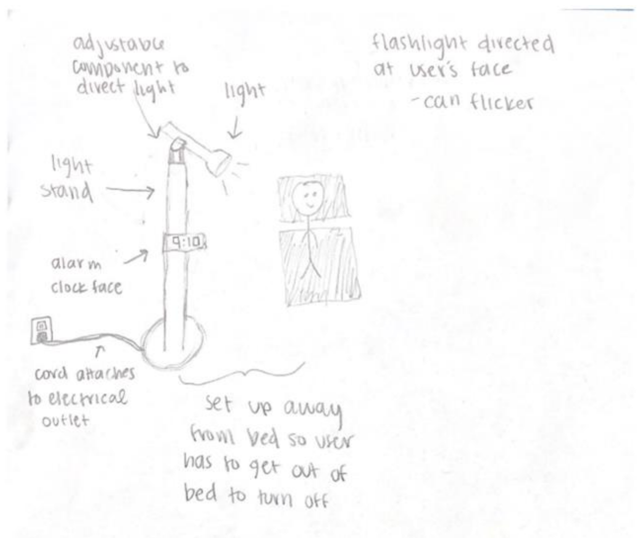


Figure 4.6 Directional Lamp

Section 5: Operational Description

The chosen concept for this project is an automatic window shade opener called the Sunriser (Figure 5.1). This device utilizes an electronic timer to pull open the user's blinds and expose them to natural sunlight in the morning. This idea is built on the team's research which shows natural light assists in comfortable waking.

Figure 5.1: Sunriser CAD model

From the end-user's perspective, the design is a single unit that can be clamped to a bedroom windowsill (Figure 5.2). It has a long belt that threads through the device and up to the blinds tassel. The user can program the trigger time and other settings from the interface buttons and display them on the front of the device. When the appropriate time is reached, a motor will pull the belt, which will open the blinds and expose the room to natural sunlight. To use this device, the user needs to plug the system into wall power and attach the tassel clips, adjusting the position as needed based on the length of blinds.

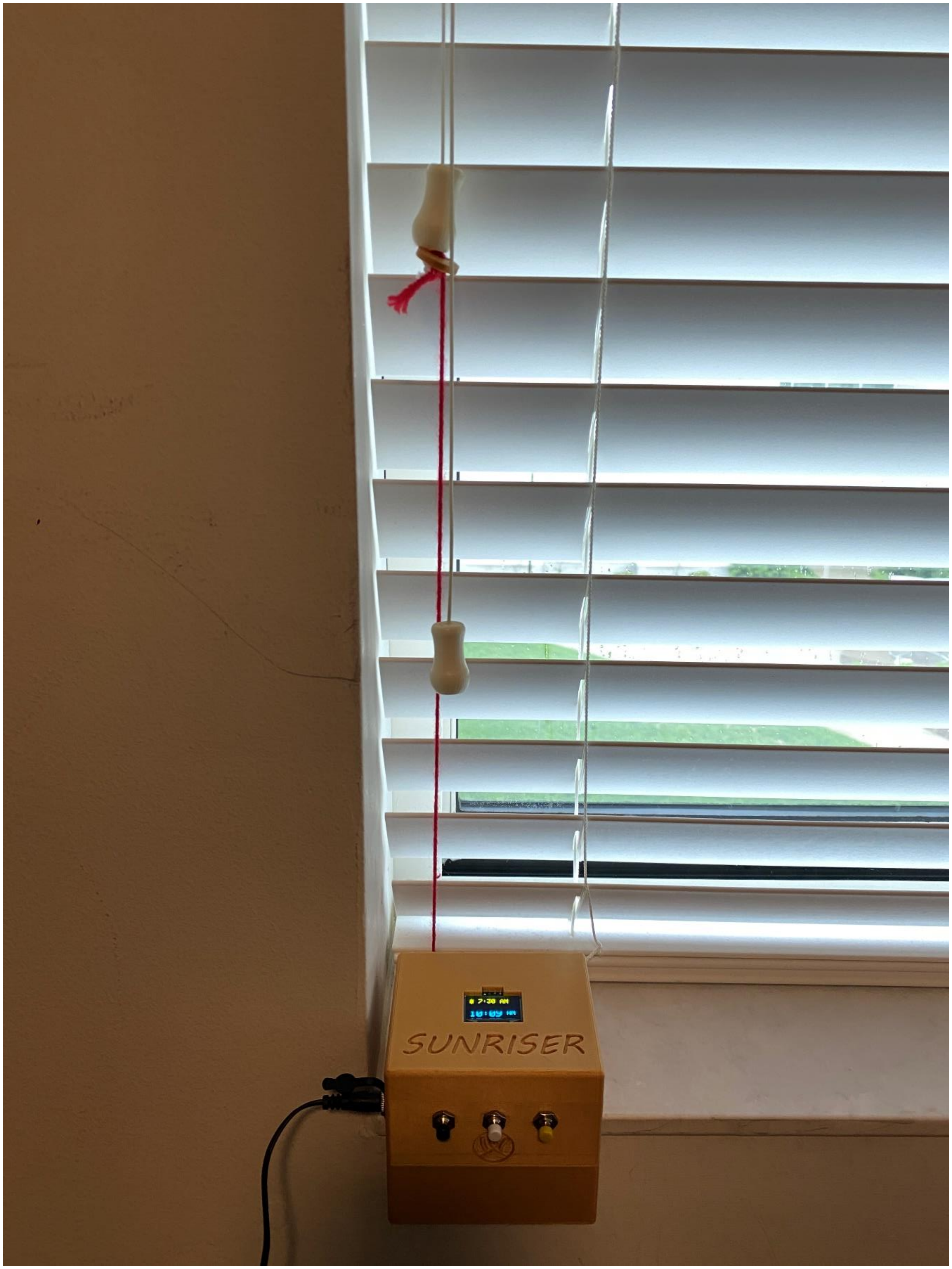


Figure 5.2: Installed mock-up

This concept adequately addresses several subfunctions. This includes both varying brightness as the blinds open and varying volume/pitch through the speaker. The device is also configurable as its buttons can be used to switch between modes and set timer and blind length. The OLED display also displays the time and the time set simultaneously to minimize confusion. The design is also easily portable due to its small size and can be securely mounted via a clamp to most windowsills. The user maintenance is minimal as the product comes pre-assembled and will not need to be opened or any components replaced for the operating life of the product. As well as this, the installation is also as simple as the user affixing the device to the windowsill and setting the pulling length needed for opening the blind. This is also all addressed in the user manual that comes with the device and will be a simple and stepwise process.

The only function that this device lacks is light positioning. In some senses this is irrelevant as the window light will likely encompass the entire room. However, it must be noted that this could negatively impact any roommates' sleep patterns. Other downsides to this design are that it only works for Venetian styles of window shades and only works if the user wants to wake up when the sun has already risen. However, this concept adequately addresses the problem statement and should be an appealing product to consumers.

Section 6: Bill of Materials, Material & Fabrication Review

The team generated a Bill of Materials (BOM) for prototype and production units to tabulate the required materials and costs for this chosen design.

To generate the prototype BOM (Figure 6.1), McMaster Carr and Amazon were used to determine the costs of necessary components. Parts that required custom manufacturing were estimated in their cost of 3D-printed PLA plastic. Part/Item number, part name, and quantity were assigned to each component according to purpose and purchase location.

Most components remained constant between the prototype and production BOM (Figure 7.2). However, since 3D printing is not feasible on a mass scale, injection molding was used to make the custom parts. These injection molding costs were approximated using online research.

Unit processing costs, estimated at $0.50, are only applied to in-house custom parts. Likewise, assembly costs were calculated based on the estimated time taken for assembly multiplied by the given $60 hourly rate.

Line total cost was calculated by multiplying unit cost by quantity and adding assembly and unit processing costs for each item. The sum of all line total costs provided the total cost to manufacture a product. In conclusion, the total purchased parts costs comes to $16.38, the total custom manufactured part cost comes to $4.00, and the total assembly costs comes to $9.00. This sums up to a total cost of $29.38 with the total purchased parts costing $16.38, the total custom manafactured parts at $4.00 and the total assembly cost at $9.00.

Item No.	Part No.	Part Name	Units	Qty	Material / Description	Source	Catalog No.	Unit Cost ($)	Unit Processing Cost ($)	Assembly Cost ($)	Line Total Cost ($)
00	A00	Final Assembly	-	1	Final Assembly of product	-	-	$ -	$ -	$ 2.00	$ 2.00
01	A01	Tassel Assembly	-	1	Assemble clips to belt	-	-	$ -	$ -	$ 1.00	$ 1.00
02	A02	Clamp Assembly	-	1	Assemble clamps to body	-	-	$ -	$ -	$ 2.00	$ 2.00
03	A03	Electronic Assembly	-	1	Assemble PCB components	-	-	$ -	$ -	$ 4.00	$ 4.00
04	M01	Belt Pulley	pcs	1	Acetal	McMaster	3563N11	$ 1.06	$ -	$ -	$ 1.06
05	M02	Belt	ft	2.08	Neoprene	McMaster	7959K25	$ 0.51	$ -	$ -	$ 1.06
06	M03	1/4"-20 Thumb Screw	pcs	2	Steel	McMaster	91746A413	$ 0.56	$ -	$ -	$ 1.12
07	M04	1/4"-20 Hex Nut	pcs	2	Steel	McMaster	95462A029	$ 0.01	$ -	$ -	$ 0.02
08	C01	Tassel Clip	pcs	2	ABS	Injection Mold	-	$ 0.70	$ 1.00	$ -	$ 3.40
09	C02	Clamp Tip	pcs	1	ABS	Injection Mold	-	$ 0.70	$ 1.00	$ -	$ 1.70
10	C03	Clock Body	pcs	1	ABS	Injection Mold	-	$ 0.70	$ 1.00	$ -	$ 1.70
11	E01	DC Gearbox Motor	pcs	1	Plastic	Amazon	hcMVdl6	$ 1.84	$ -	$ -	$ 1.84
12	E02	DC Motor Driver	pcs	1	Silicon PCB	Amazon	7nAri3b	$ 2.15	$ -	$ -	$ 2.15
13	E03	Power Jack Socket	pcs	1	Insulated copper	Amazon	d1kZHkO	$ 0.45	$ -	$ -	$ 0.45
14	E04	5V Regulator	pcs	1	Silicon PCB	Amazon	7Ne7FsA	$ 0.20	$ -	$ -	$ 0.20
15	E05	Arduino Nano	pcs	1	Silicon PCB	Amazon	cFrxFiZ	$ 1.12	$ -	$ -	$ 1.12
16	E06	RTC	pcs	1	Silicon PCB	Amazon	i1g2S6m	$ 1.80	$ -	$ -	$ 1.80
17	E07	Buzzer	pcs	1	Silicon PCB	Amazon	6piUOaU	$ 0.17	$ -	$ -	$ 0.17
18	E08	OLED Display	pcs	1	Silicon PCB	Amazon	7JUTC85	$ 0.75	$ -	$ -	$ 0.75
19	E09	UI Button	pcs	3	Plastic	Amazon	ia39XPU	$ 0.21	$ -	$ -	$ 0.62
20	E10	Breadboard	pcs	1	Plastic	Amazon	g2WzkSe	$ 0.37	$ -	$ -	$ 0.37
21	E11	Wire	pcs	20	Insulated copper	Amazon	8uBQNsf	$ 0.04	$ -	$ -	$ 0.83
										Total Purchased Parts	$ 16.38
										Total Custom Manufactured Parts	$ 4.00
										Total Assembly Cost	$ 9.00
										Total Cost	$ 29.38

Part Number Key
A = Assembly
M = Mechanical
C = Custom Part
E = Electronic

Unit Cost Reductions	
Mass Production Factor	4
McMaster Carr Factor	10

Figure 6.1: Production BOM

Section 7: Drawings

Figure 7.1 shows the assembly drawing and part explosion for the Sunriser. See Appendix A for additional detail drawing of the individual parts in the assembly.

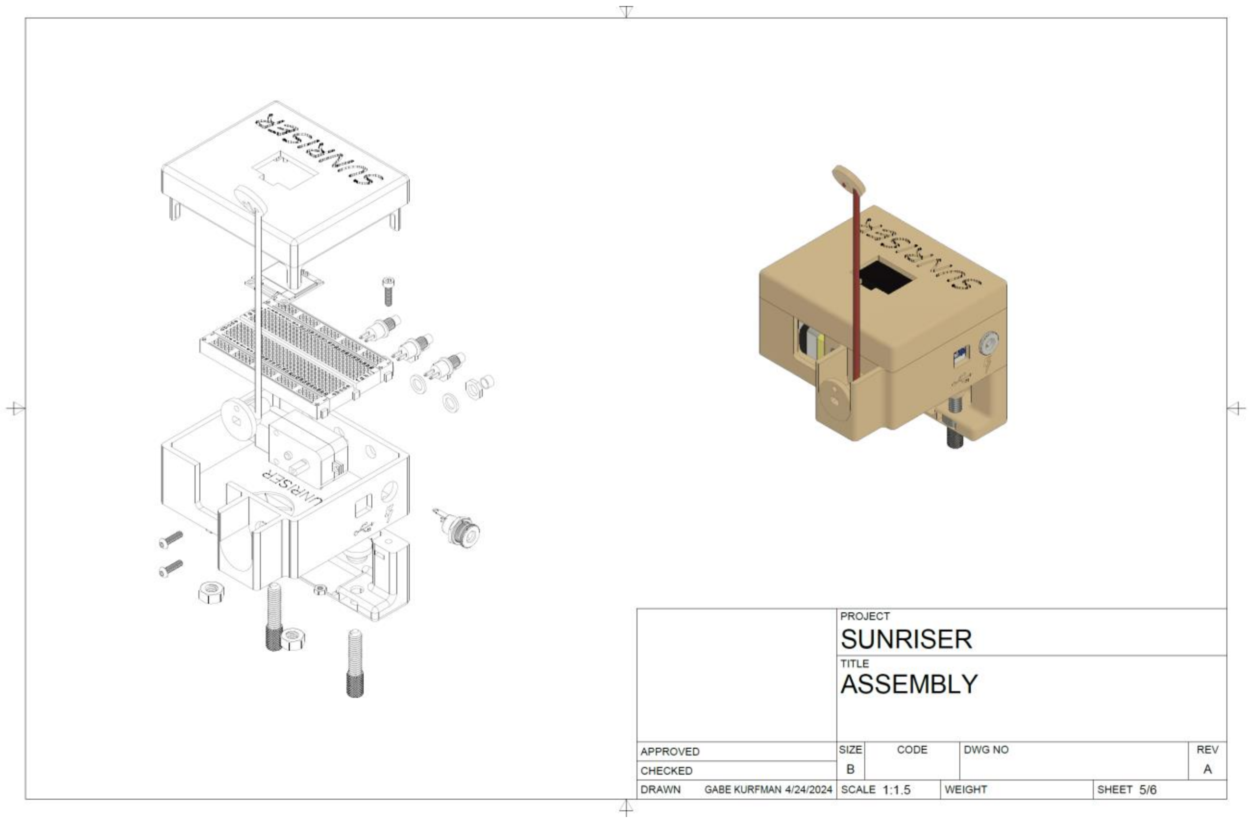


Figure 7.1: Sunriser Assembly Drawing

Section 8: Assembly Analysis and Tolerance Discussion

The assembly process is completed as follows:

1. **Lay out all hardware**

Spread out all parts over the work space and sort according to their step in the assembly process.

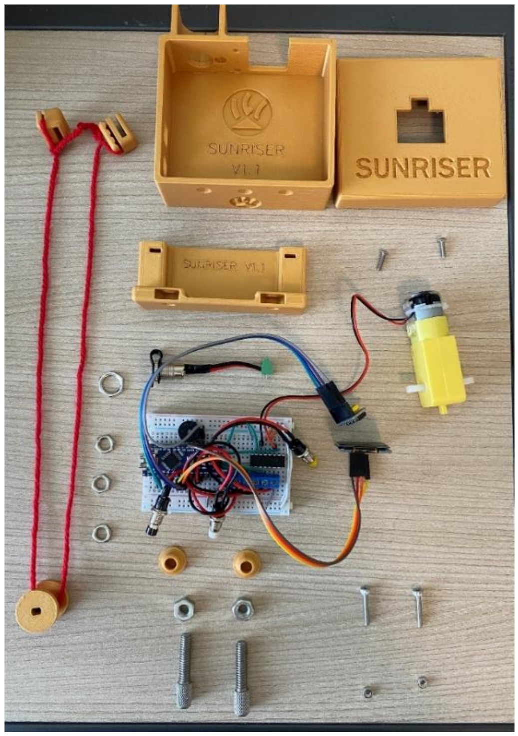


Figure 8.1: Lay out all hardware

2. **Insert imbedded nuts**

Push in the two M3 and two ¼” nuts into their respective slots in the clamp body.

Figure 8.2: Insert embedded nuts

3. Fasten clamp thumbscrews

Screw in the two ¼" thumbscrews into the nuts and place the clamp tips at the ends.

Figure 8.3: Fasten clamp thumbscrews

4. Attach body and clamp assembly

Use two M3 screws to fasten the clamp assembly to the main Sunriser body.

Figure 8.4: Attach body and clamp assermbly

5. **Assemble electronics**

Place the Arduino Nano, buzzer, H-bridge, and switch terminals onto the breadboard as shown. Also connect the DC motor, OLED display, and RTC via wires.

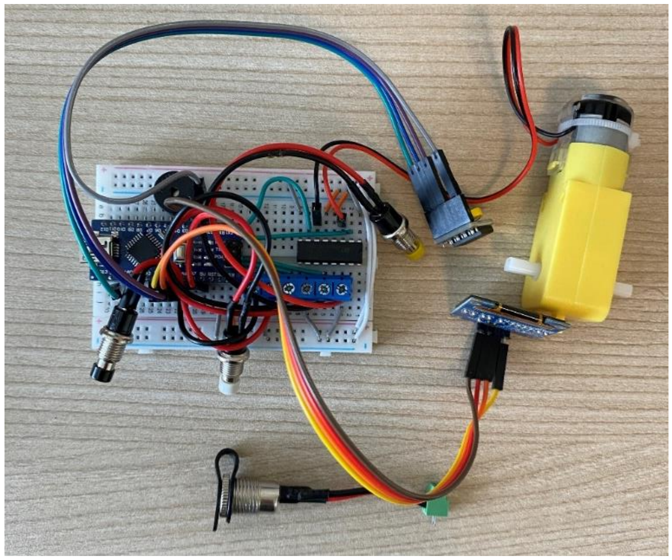


Figure 8.5: Assemble electronics

6. **Insert electronics into body**

Place the electronics assembly into the main Sunriser body, ensuring that the motor is placed as shown. Leave the OLED display free-floating.

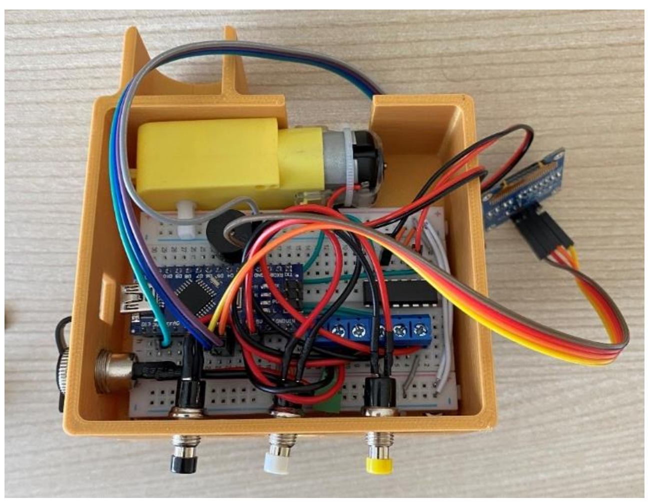


Figure 8.6: Insert electronics into body

7. Secure buttons and power plug to body with nuts

Use the three M6.7 nuts to fasten the buttons to the main Sunriser button.

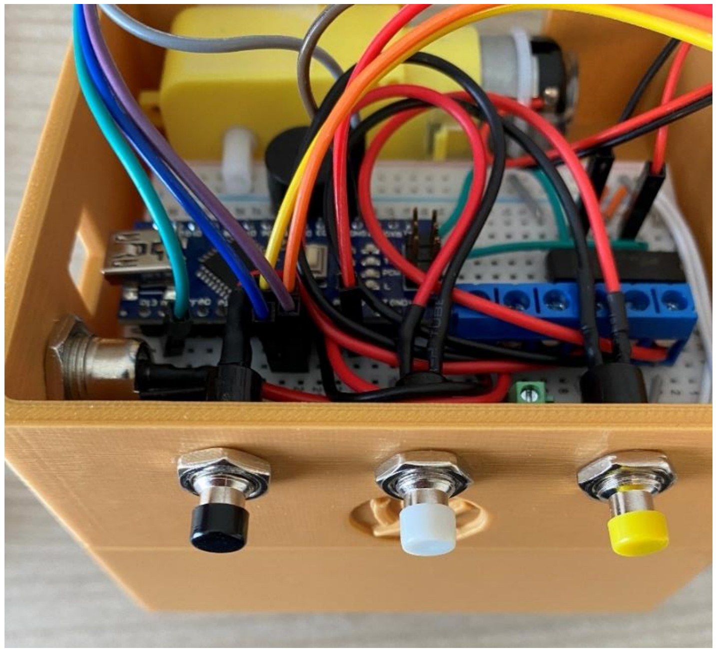


Figure 8.7: Secure buttons and power plug to body with nuts

8. Secure motor to body with screws

Use two M3 screws to secure the DC motor to the main Sunriser body.

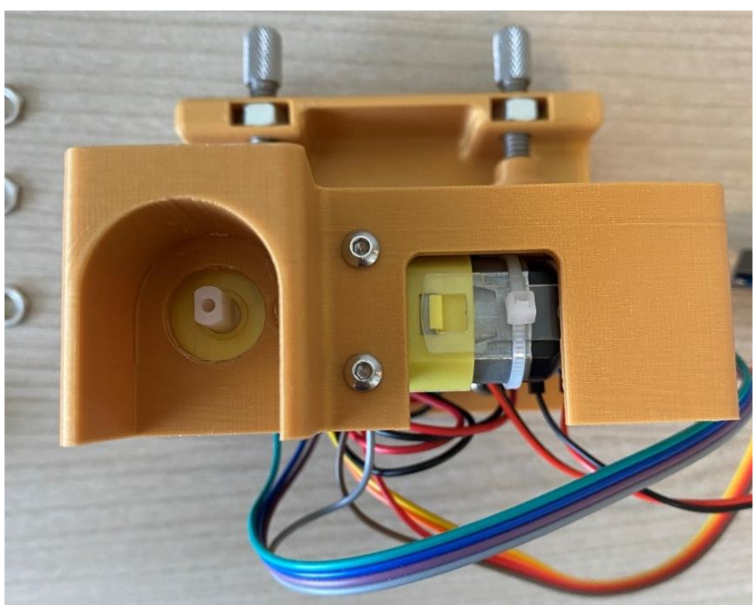


Figure 8.8: Secure motor to body with screws

9. Wrap belt around pulley

Tie one end of the belt to the pulley and the opposite end to the tassel clip.

Figure 8.9: Wrap belt around pulley

10. Attach belt pulley to motor shaft

Friction-fit the belt and pulley assembly onto the motor shaft.

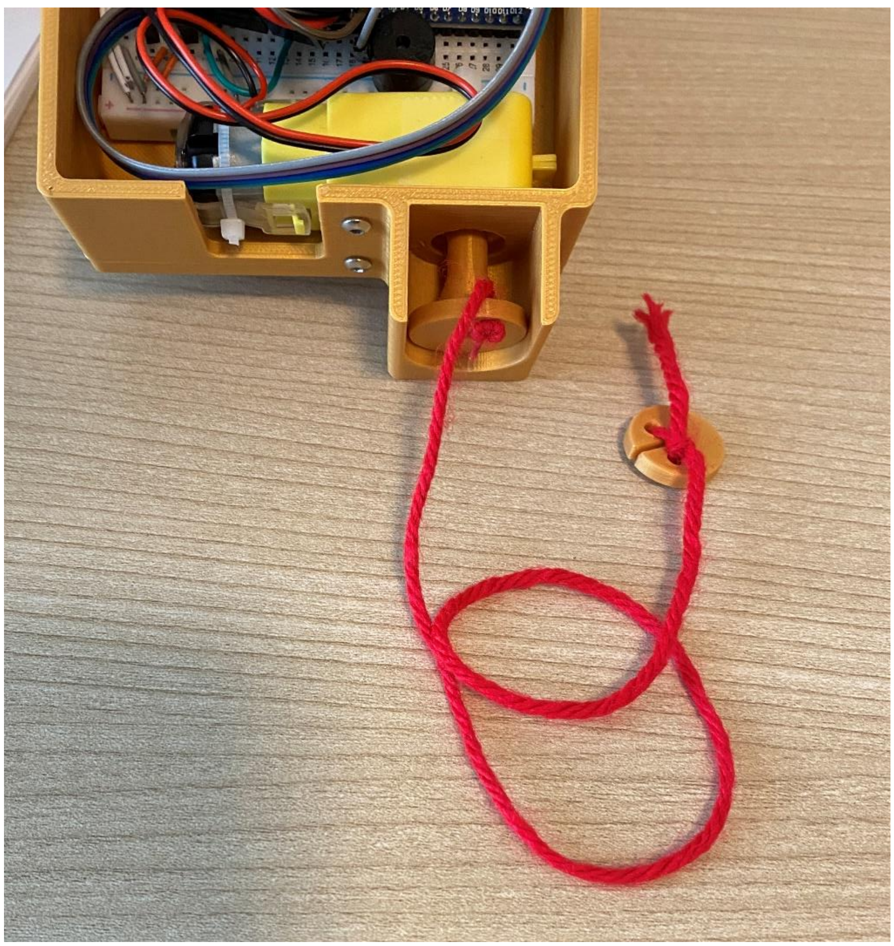


Figure 8.10: Attach belt pulley to motor shaft

11. Fix OLED screen to lid

Press the OLED into the slot into the lid and secure with a single strip of Scotch tape.

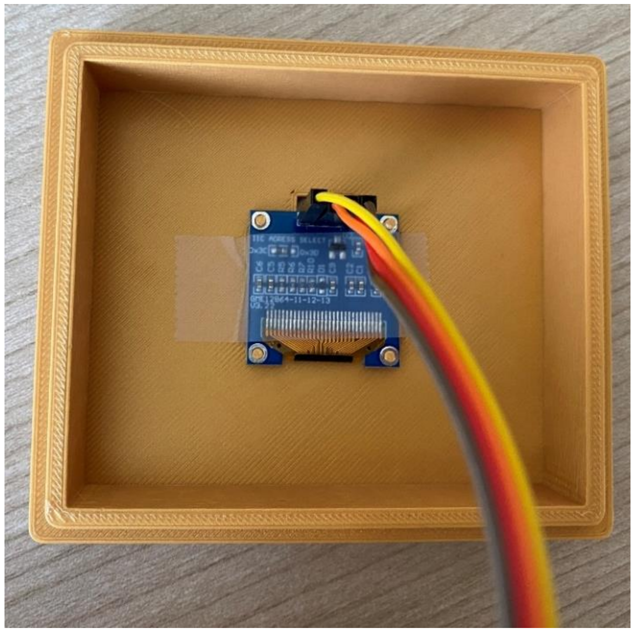


Figure 8.11: Fix OLED screen to lid

12. Attach lid onto body

Slide the lid onto the top of the main Sunriser body, where it will fit snugly.

Figure 8.12: Attach lid onto body

13. Clamp to windowsill (end customer)

Use the thumbscrews to clamp the Sunriser against the windowsill.

Figure 8.13: Clamp to windowsill (end customer)

14. Adjust tassel clip length and plug in (end customer)

Re-tie the belt lengths for the specific set of blinds and attach the power cord to the barrel jack on the left side of the Sunriser.

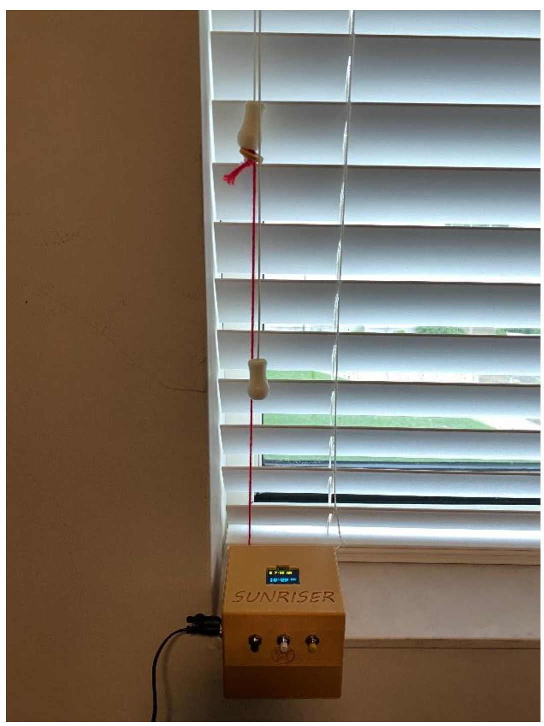


Figure 8.14: Adjust tassel clip length and plug in (end customer)

This assembly process meets all engineering requirements pertaining to assembly. The entire device takes 7-10 minutes to build, and 2 minutes to install and set up. This is far less than 20 minute engineering requirement. It also requires only three (3) tools for the manufacturer to assemble (Allen wrench, combination wrench, tweezers) and one (1) tool for the user to assemble (Allen wrench), less than the maximum of five (5).

Tolerance stack-ups were performed for a variety of critical parameters for the final design. The parameters selected were the M3 slot fit nut, the thumb screw, the pulley slot and the clamp nut, the locations of these can be seen in figures 8 below. The M3 nut and the pully slot both fit even in worst case analysis, while 99.8% of the thumb screws and 99.6% of the clamp nuts fit. This means most parts will be usable and parts would need to substantially decrease in quality to cause waste. The team considered searching for lower quality and cheaper parts to reduce costs, however, most components are custom 3D printed and would be more expensive to purchase by other means. By continuing to use the high-quality current parts, the team minimizes waste and maintains ethical and environmental obligations.

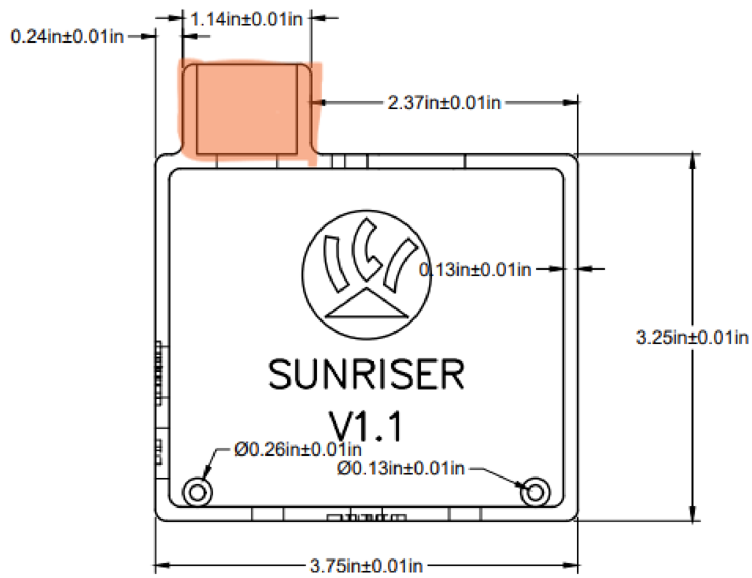


Figure 8.1: Pulley Slot (Orange) Schematic

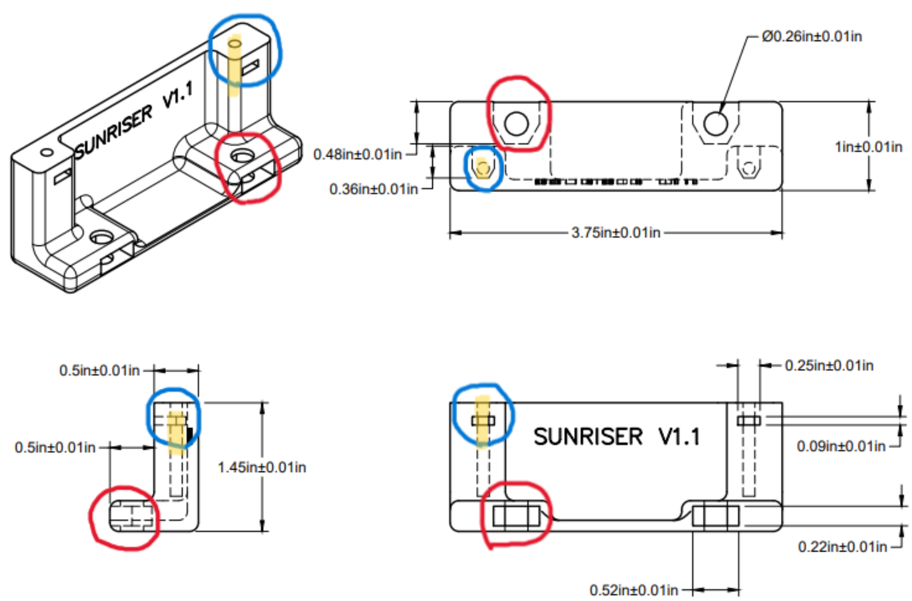


Figure 8.2: Thumb Screw (Yellow), Slot Nut (Blue) and Clamp Screw (Red) Schematic

Section 9: Benchmarks and Performance Analysis

Benchmark and performance analysis was done of the Sunriser to determine how it compares to competitors and if engineering requirements are met. Figure 9.1 displays the comparison of requirements met by current solutions for waking – Clocky and the Phillips SmartSleep. Clocky is an alarm clock that rolls away from the user, so the user has to physically get out of bed to turn off the alarm. The Phillips SmartSleep is an alarm clock that increases light brightness levels over time, emulating a sunrise, to wake the user. The Sunriser outperformed each of these products in nearly every requirement. The main drawback of Clocky is that it is too disruptive and puts the user at risk of hurting themselves. The main drawback of the Phillips SmartSleep is that it may not be disruptive enough and it is very expensive.

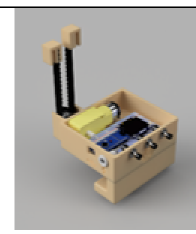
Customer Requirement	 Clocky	 Philips SmartSleep	 Sunriser
Low Cost	$40	$180	$120
Low maintenance	Yes – battery powered	Yes – plugs into wall socket	Yes – plugs into wall socket
Configurable	Yes – time to alarm	Yes – time to alarm, brightness of light, sounds	Yes – time to alarm
Durable	Yes – according to customer reviews	No – fragile screen	Yes – strong exterior material
Dependably wakes customer	Yes – auditory stimulus, requires customer to get out of bed	No – light does not dependably wake all consumers	Yes – requires customer to get out of bed
Portable	Yes 3.94" x 1.97"	Yes 8.8" x 8.6" x 4.7"	Yes 5.5" x 5.5"
Non-disruptive	No – loud alarm, strikes into furniture and potentially the user	Yes – gradual sound volume and light brightness increase	Yes – natural light and moderate sound volume

Figure 9.1: Benchmark Analysis

For the performance analysis modelling, it was decided to tackle four problems: the force of the clamp required to keep the device stable on the windowsill, specifications for the spring used in the button, the torque of the pulley, and the time required for the blinds to be opened as a function of torque.

1) **Force of clamp required to keep the device stable on the windowsill.**

One necessary system to model in the product is the force required from the clamp to the windowsill so that the device will stay clamped to the windowsill and will not tip, even as the device is in motion and opening blinds. The force calculated to keep the device stable was 30 pounds. See figure 9.2.1 for assumptions and calculations. The calculated force can also provide information about the necessary strength if the user to securely clamp the device to the windowsill.

Force can be written as a function of tension from the string pulls (T), the length between the contact point and left end of the device body (L1), the coefficient of friction (M), and the height of the windowsill (L2). See Figures 9.2.2, 9.2.3, 9.2.4 and 9.2.5 for graphs representing the force as a function of each of the variables.

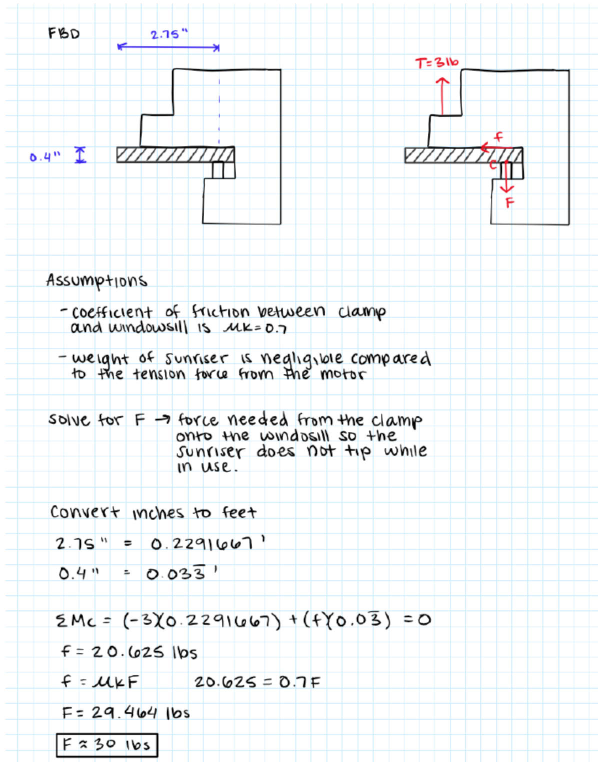


Fig 9.2.1 Calculations for force required to keep the clamp stable.

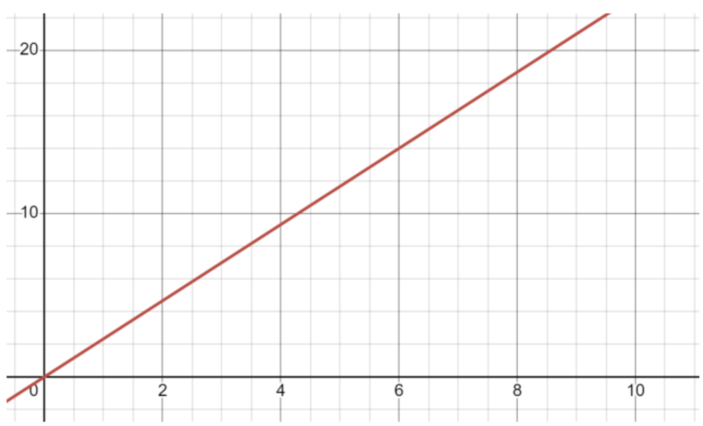


Fig 9.2.2 Force as a function of Tension

Fig 9.2.3 Force as a function of L_2

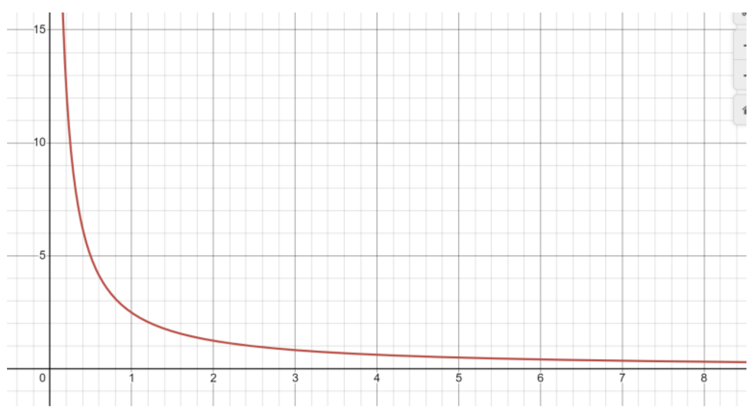


Fig 9.2.4 Force as a function of M

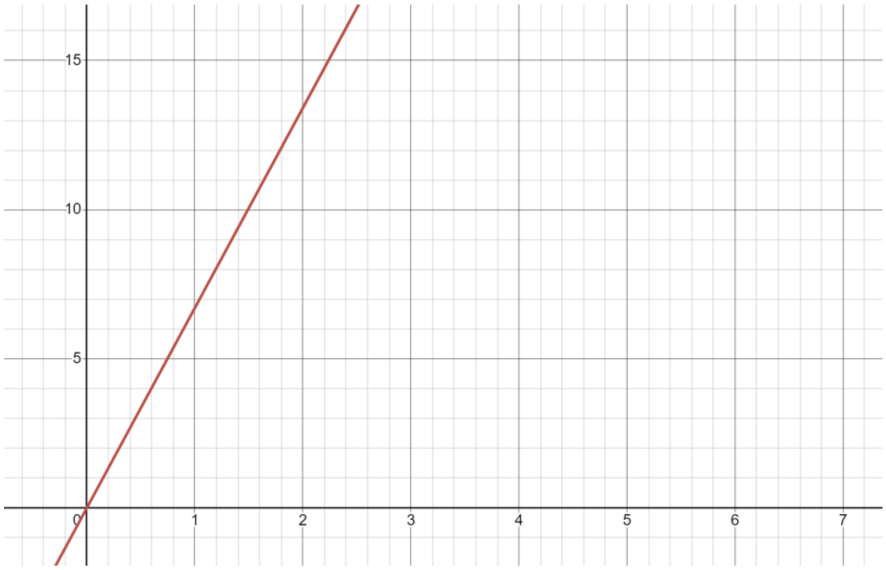


Fig 9.2.5 Force as a function of L_1

2) The specifications for the spring used in the button.

The analysis showed that the spring used for the buttons should be 2mm long, have a diameter of 6 mm or less, and have a spring constant of 2850 N/m.

Cummins recommends a force of 5.7 Newtons for a button pushed less than once every two minutes. As calculated in Figure 9.3, this force is directly related to the spring constant. Considering the button's diameter of 6mm, the spring must be of equal or lesser diameter. The button can be inserted up to 2mm when pressed, indicating that the spring's length can be a maximum of 2 mm.

The source (Cummins) also states that 7.4 is the limit for Force expected by the user that can be applied, resulting in a spring constant of 3700 N/m. While 2850 N/m is ideal, anything within the range of 2850 to 3700 is usable. One of the critical limitations of this assumptions used was that, in general, springs are commonly made larger than the size required for this button. Thus, finding a spring of this size that fit the needed specifications was challenging. See Figure 9.3 for further calculations.

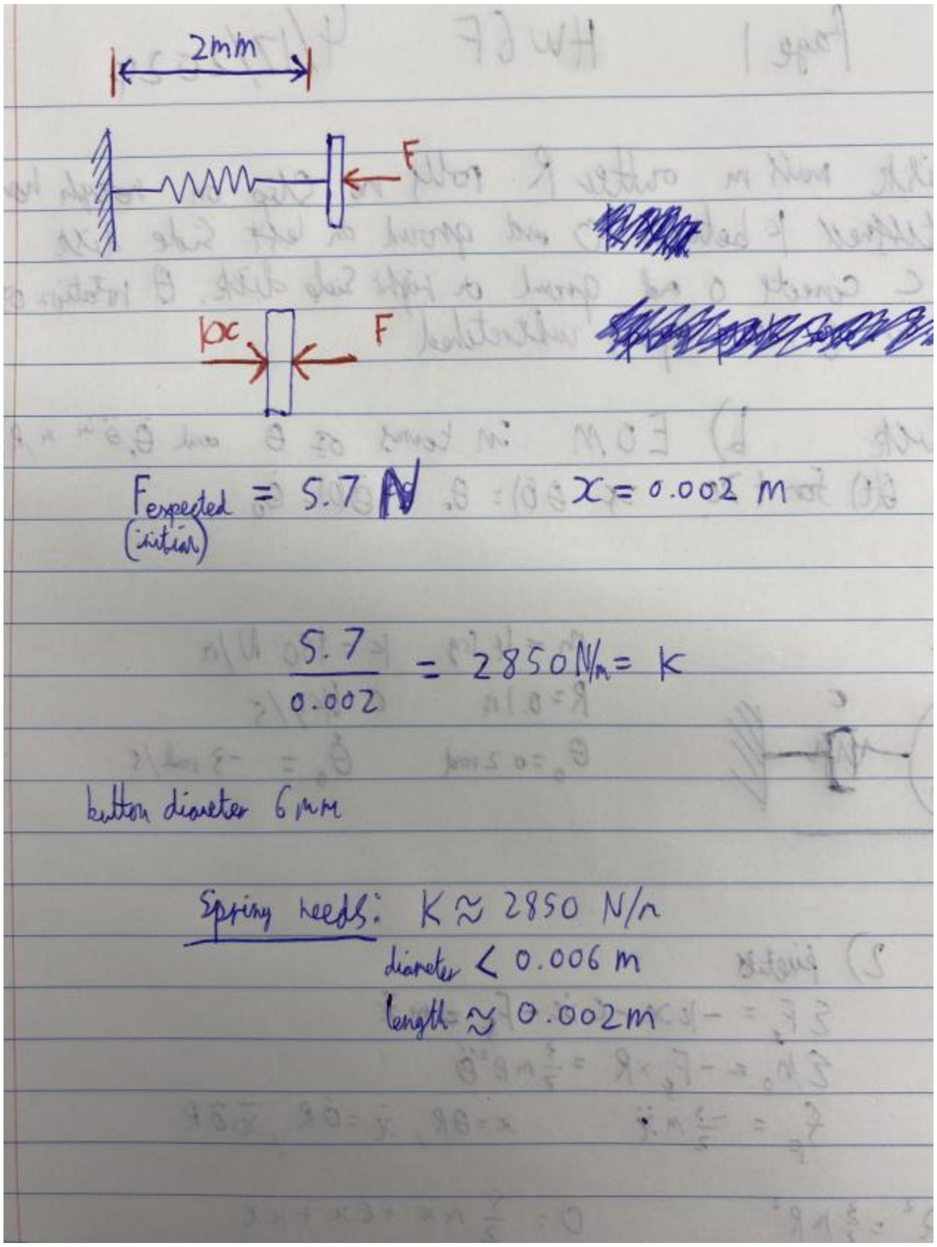


Fig 9.3: Modelling for the spring force in the adjustable buttons

3) The Torque of the pulley.

Based on the analysis, it was concluded that the chosen motor is adequate to pull open the blinds.

The Sunriser operates by using a DC motor to pull a belt attached to the blinds tassel. By applying the motor torque through a pulley, a force is generated that pulls down the blinds. Below is a free body diagram showing the forces in action in the model (Figure 9.4.1).

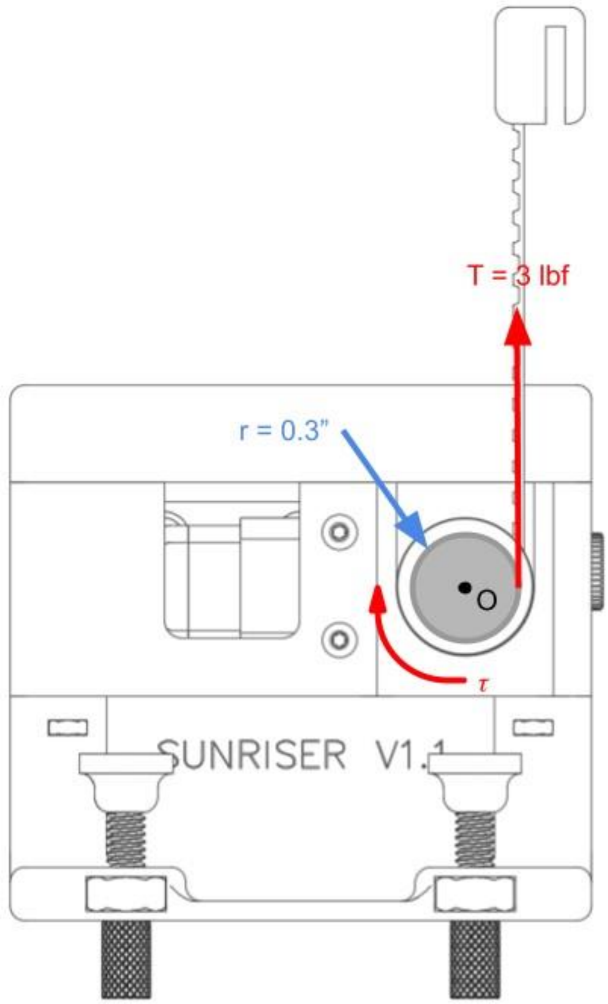


Figure 9.4.1: FBD for torque of pulley

Assumptions:

- The tension on the belt required to pull down the tassel is a constant 3.0 lbf
- Friction between the pulley and frame is negligible
- The effective radius of the pulley remains constant as the belt wraps around

The minimum τ required to generate the tension, used the summation of moments equation.

$$\sum M_O = T * r - \tau_{min} = 0$$

$$\sum M_O = 3 * 0.3 - \tau_{min} = 0$$

$$\tau_{min} = 0.9 \text{ in·lbf}$$

This equation can also be plotted varying the values of T and r, as shown in Figure 9.4.2.

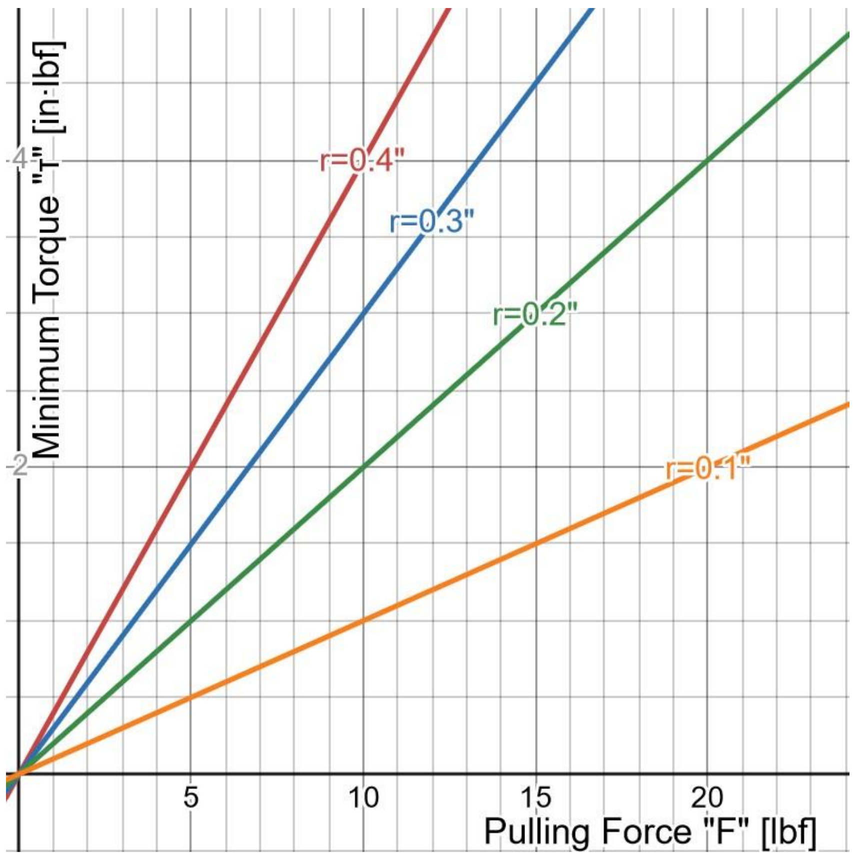


Figure 9.4.2: Minium Torque vs. Pulling Force

From this calculation, it was determined that the concept can easily meet the engineering requirements. The rated torque of the chosen DC motor is 0.15 Nm – 0.6 Nm, or 1.32 in-lbf – 5.31

in-lbf (Figure 9.4.3). This will easily create a moment in the clockwise direction, inducing an angular acceleration and pulling down the blinds tassel.

TECHNICAL DETAILS

- Rated Voltage: 3~6V
- Continuous No-Load Current: 150mA +/- 10%
- Min. Operating Speed (3V): 90+/- 10% RPM
- Min. Operating Speed (6V): 200+/- 10% RPM
- Torque: 0.15Nm ~0.60Nm
- Stall Torque (6V): 0.8kg.cm
- Gear Ratio: 1:48
- Body Dimensions: 70 x 22 x 18mm
- Wires Length: 200mm & 28 AWG
- Weight: 30.6g

Product Weight: 30.6g / 1.1oz

Figure 9.4.3: Motor specifications

This simple model has some shortcomings. The most prevalent is the assumption that the effective radius of the pulley remains constant as the belt wraps around. In practice, the belt has a thickness and will increase the radius as it is pulled. To improve the model, the radius could be made a function instead of a constant that increases with time.

The thickness of the belt is 1/8". The radius as a function of number of wraps would then be:

$$r = 0.3 + 0.125w$$

To convert from number of wraps to distance pulled, use:

$$D_{wrap} = 2\pi r$$

$$D_{total} = \sum_{x=0}^{w} 2\pi * (0.3 + 0.125x) \approx 0.39w^2 + 2.28w + 1.88$$

This has been simulated in Figure 9.4.4.

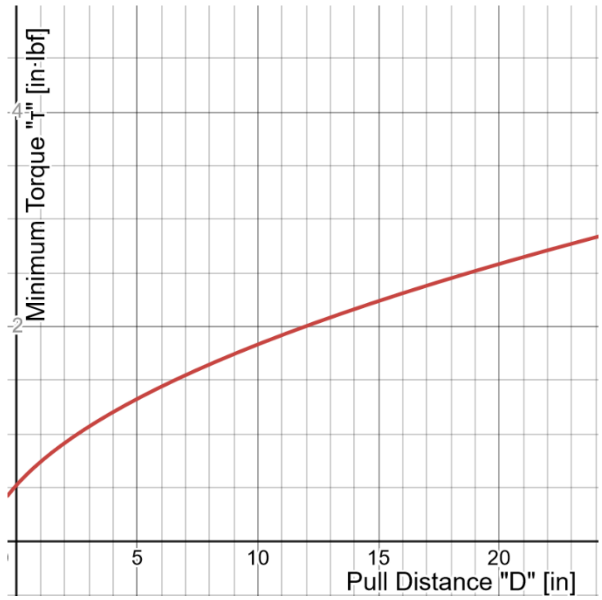


Figure 9.4.4: Minimum Torque vs. Pull Distance

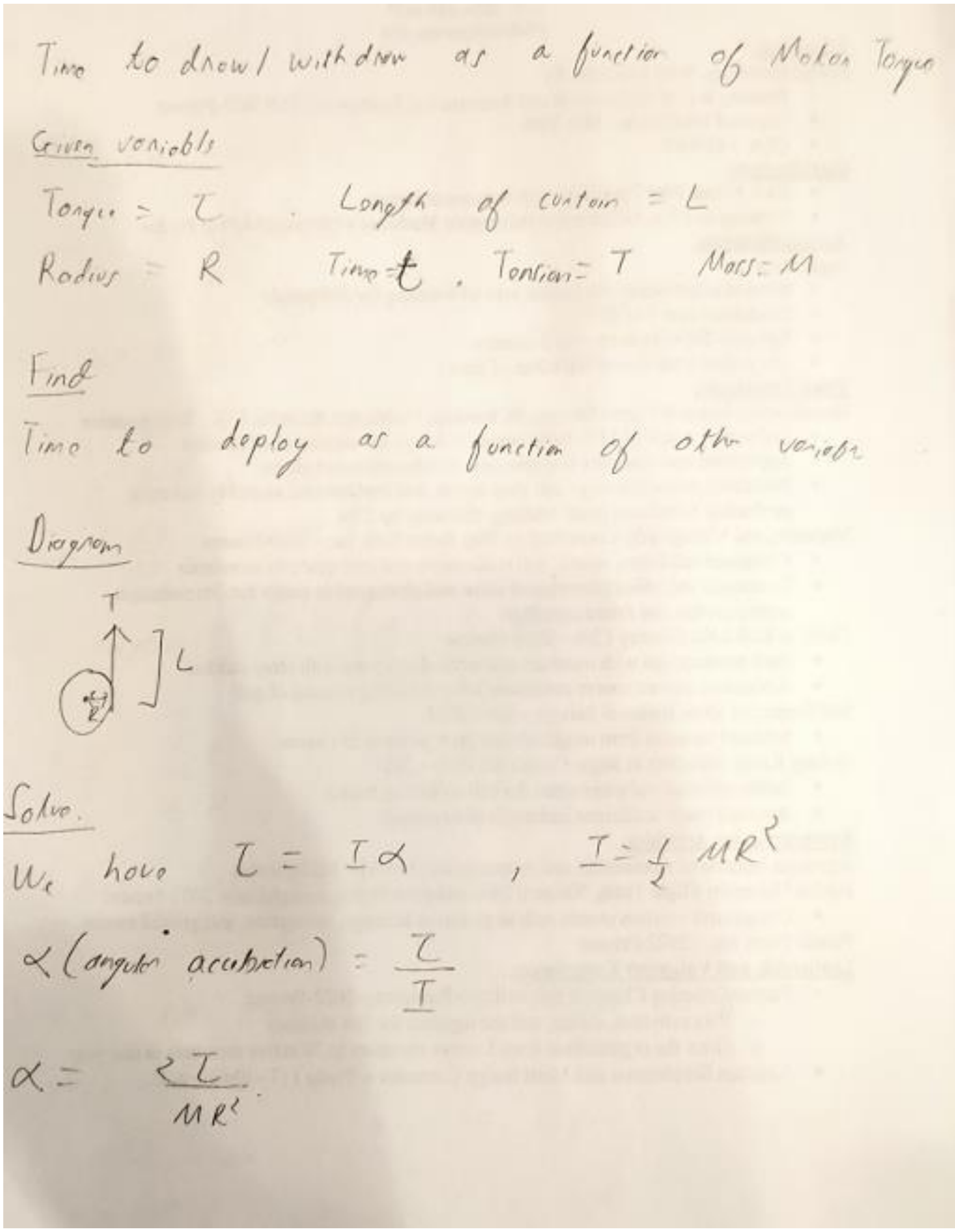
4) Time to deploy as a function of torque.

This model was designed to relate the time to deploy to the motor's torque. This relation is given by t = (0.225 / torque) ^ 0.5.

The model that was developed served to determine the time to deploy based on the parameters that could be controlled (namely, length, torque, Mass and Radius).

The sketches, sketches and derivations are listed in the detail in figures 9.5.1.1, 9.5.1.2, and 9.5.1.3. The assumptions for this model are that an ideal pulley, a uniform mass distribution, no slipping, constant torque, no external forces, a linear relationship between torque and angular velocity.

Looking at the model, time is directly proportional to most factors (mass, length and radius). However, it is inversely proportional to torque. It can also be seen that the time to deploy can be under 2 seconds. With the current configuration, the time to deploy is approximately 0.43 seconds. This is an appropriate time for the current requirements. However, future requirements might change the factors.



Time to draw/withdraw as a function of Motor Torque

Given variables

Torque = τ , Length of curtain = L

Radius = R Time = t , Tension = T Mass = M

Find

Time to deploy as a function of other variables

Diagram

Solve.

We have $\tau = I\alpha$, $I = \frac{1}{2}MR^2$

α (angular acceleration) = $\frac{\tau}{I}$

$\alpha = \frac{2\tau}{MR^2}$.

Fig 9.5.1.1 Calculations for time to deploy as a function of variables (page 1)

(2)

But $\alpha = \frac{d\omega}{dt}$

Therefore, $\omega = \int \frac{2\tau}{MR^2}\, dt$

(Released from Rest)

$$\omega = \frac{2\tau}{MR^2}\, t$$

Now, velocity at a point $= \omega(R)$

$$V = \frac{2\tau}{MR}\, t$$

But, $\frac{ds}{dt} = v$

Which implies, $S = \int \frac{2\tau}{MR}\, t\, dt$

$$S = \frac{\tau t^2}{MR}, \quad \text{but}, \quad S = L$$

$$t = \left[\frac{L\, MR}{\tau}\right]^{\frac{1}{2}}$$

Thus, the time to deploy depends on the Mass, Radius, mass.

$R = 0.3$ inch $\tau = 1.2$ lbf

Mass $= 0.5$ pounds $L = 1.5$ inch

Fig 9.5.1.2 Calculations for time to deploy as a function of variables (page 2)

3

Thus, we got the following as the relation of t (Keeping only 1 constant variable)

$$t = \left[L^{0.125}\right]^{\frac{1}{2}}$$ — (1) Time as a function of length

$$t = \left[\frac{1}{\tau}^{0.25}\right]^{\frac{1}{2}}$$ — (2) Time as a function of torque

$$t = \left[M^{0.375}\right]^{\frac{1}{2}}$$ — (3) Time as a function of mass

$$t = \left[R^{0.625}\right]^{\frac{1}{2}}$$ — (4) Time as a function of Radius

Fig 9.5.1.3 Calculations for time to deploy as a function of variables (page 3)

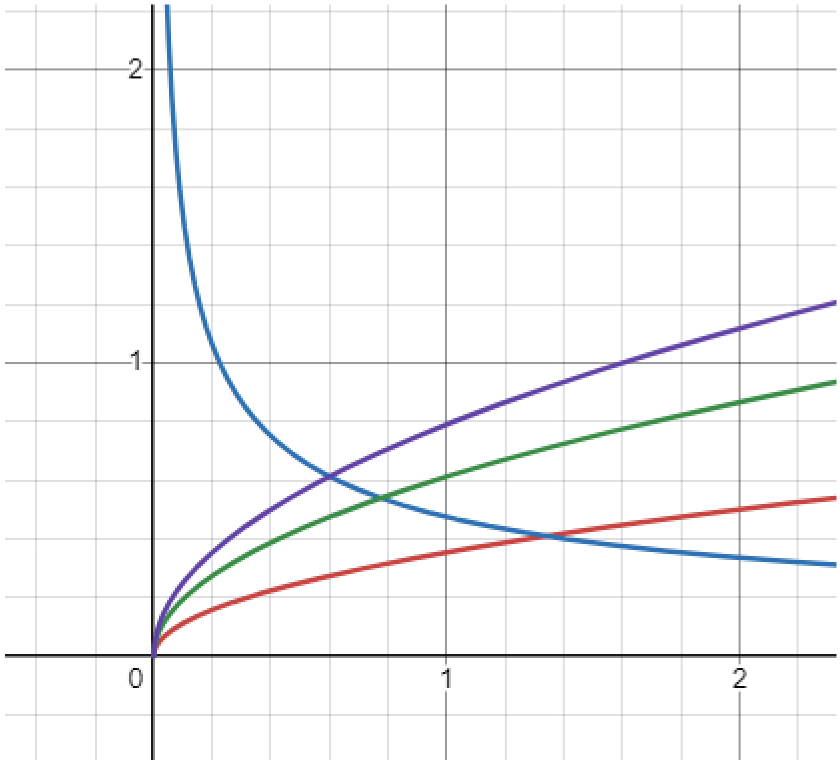


Fig 9.5.2 Results of plotting time to deploy as a function of variables

Table 9.5.1 Key to results of plotting time to deploy as a function of variables

Variable Being Varied (X Axis)	**Y Axis**	**Color**
Length (inch)	Time (s)	Red
Torque (lb -inch)	Time (s)	Blue
Mass (pound)	Time (s)	Green
Radius (inch)	Time (s)	Purple

Section 10: Conclusion

Within this phase of the project, the team finalized the design and ensured the product met all the constraints needed. This included finalizing the assembly process steps. From this the team found full assembly to take between 7 to 10 minutes and installation/setup to take approximately 2 minutes. Both manufacturing took three tools and installation only took one. Surprising the team, both the time taken, and the number of tools needed were under the desired 20-minute time limit and 5 tool limits respectively listed under the problem definition. This is beneficial to both manufacturers and consumers who will be able to assemble and install the design cheaper and faster than the team had originally anticipated. The only tool needed for installation is an Alan key, one of the simplest tools, which can be cheaply made and provided in the box for a minimal price increase to allow for laymen consumers to self-install the design. This will improve the design's usability for all groups, especially the target group of college students that may have limited experience with setting up and installing products. The prior designs' exposed circuitry was remedied with a lid that displays the team's logo and increases the safety, aesthetics and durability of the product. The team used various models and tolerance stack-ups to ensure minimization of waste and maximize the products' efficiency and usability in all circumstances and by all types of consumers. Through this the team learned that the critical parameters of the design all fit by comfortable margins and under 0.5% of all parts will be unusable and wasted.

We have four future recommendations. The first one is based on the fact that the current design only works with blinds that can be pulled up and down. It is suggested adding adapters to the Sunriser that allow users to switch out one type of blinds for another, thus allowing users multiple choices. Secondly, some windows might not have ledges to attach to. Thus, adding adhesives to the bottom of the sunriser, would enable it to be more versatile. It was also realized that the buttons needed to be more apparent in their functioning and that one would need to know their functions beforehand. Thus, it is recommended to label buttons/ adding a user manual. Fourth, the design works so that the user loses the ability to open/close blinds themselves. It would be beneficial to add a setting that reduces the tension on the string, allowing users to open/close the blinds themselves.

Section 11: References

O, A. (2014). Sleep patterns and insomnia among Portuguese adolescents: A cross-sectional study. Atencion primaria. https://pubmed.ncbi.nlm.nih.gov/25476060/

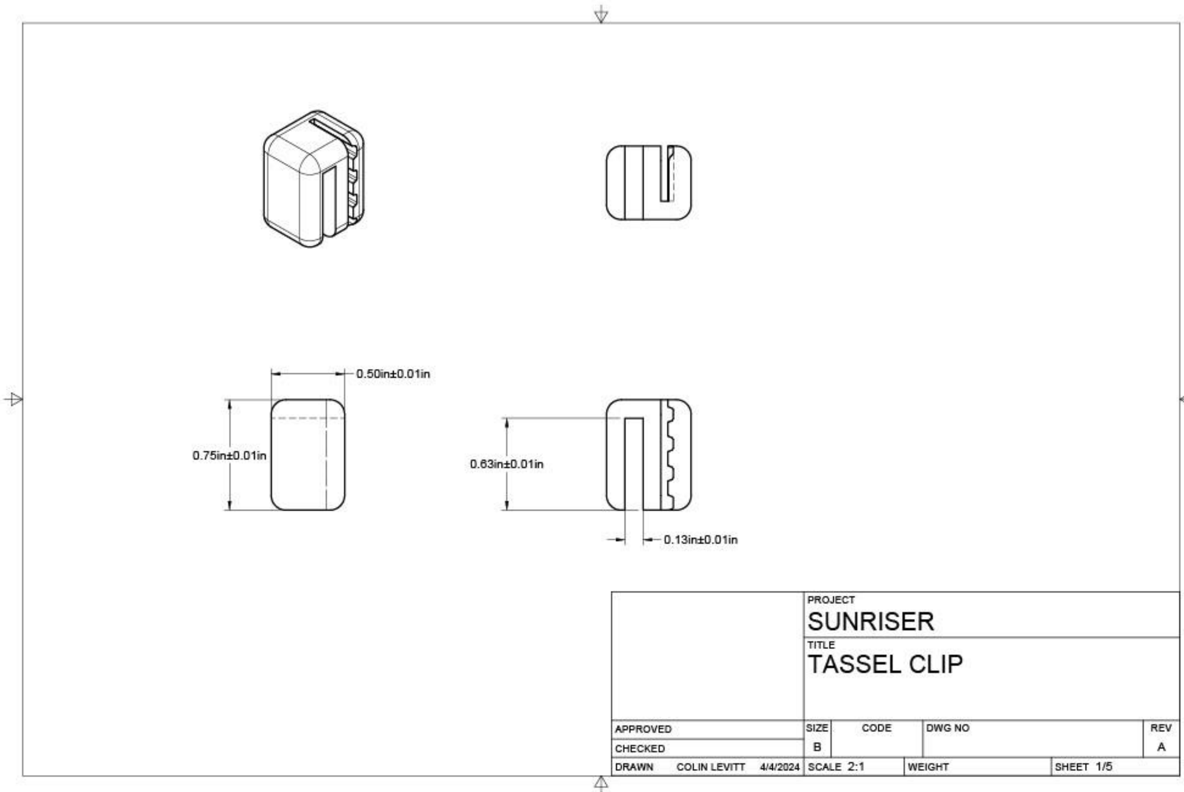
Yeonsu , K. (2023, December 22). Is your morning alarm putting your heart at risk?. Healthy Balance. https://blog.uvahealth.com/2023/12/22/morning-alarm-heart-risk/#:~:text=The%20alarming%20part%20%E2%80%93%20Kim%20found,on%20your%20heart%20and%20veins.

Electronic alarm clock market size. Electronic Alarm Clock Market Size - Forecast To 2031. (n.d.). https://www.businessresearchinsights.com/market-reports/electronic-alarm-clock-market-100374#:~:text=The%20global%20electronic%20alarm%20clock,4.6%25%20during%20the%20forecast%20period.

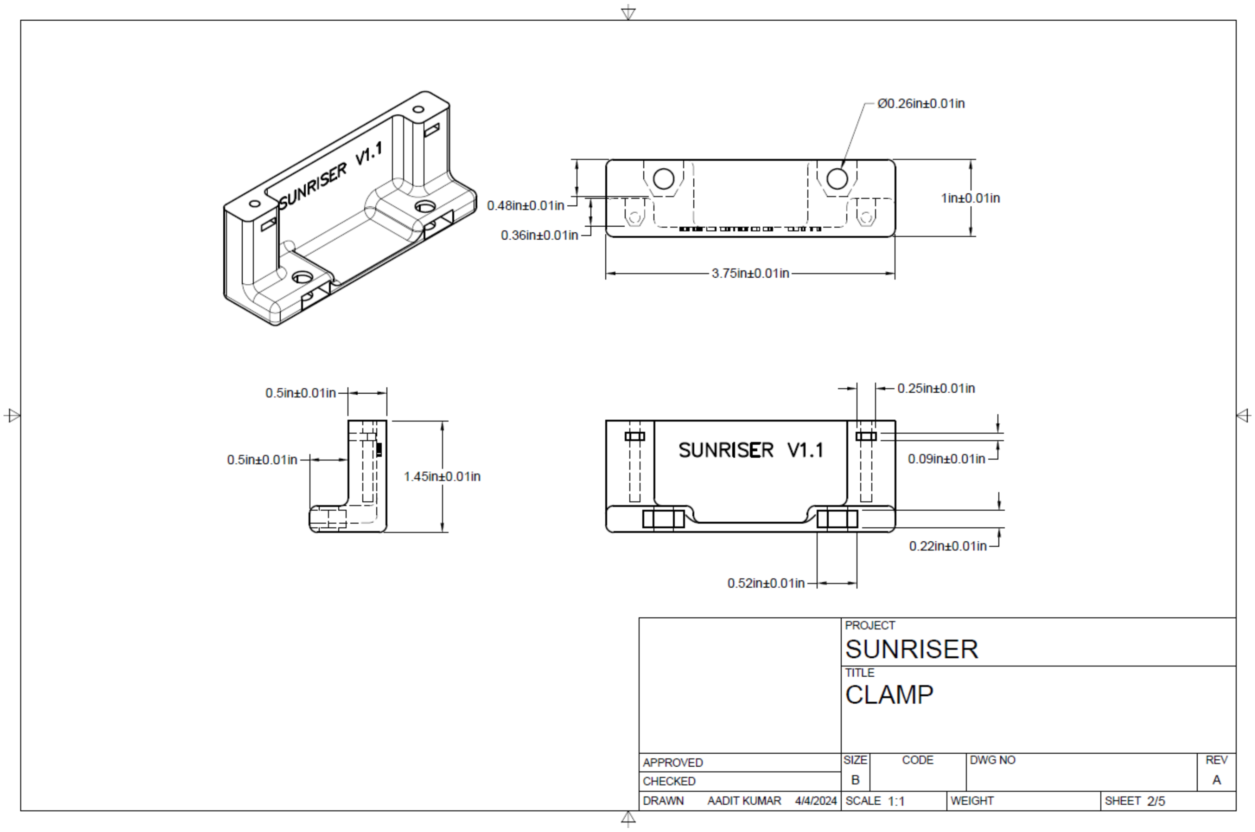
Cummins. "Spring Force for Physical Push Buttons." *User Experience Stack Exchange*, 1 Nov. 1967, ux.stackexchange.com/questions/142478/spring-force-for-physical-push-buttons.

Section 12: Appendix

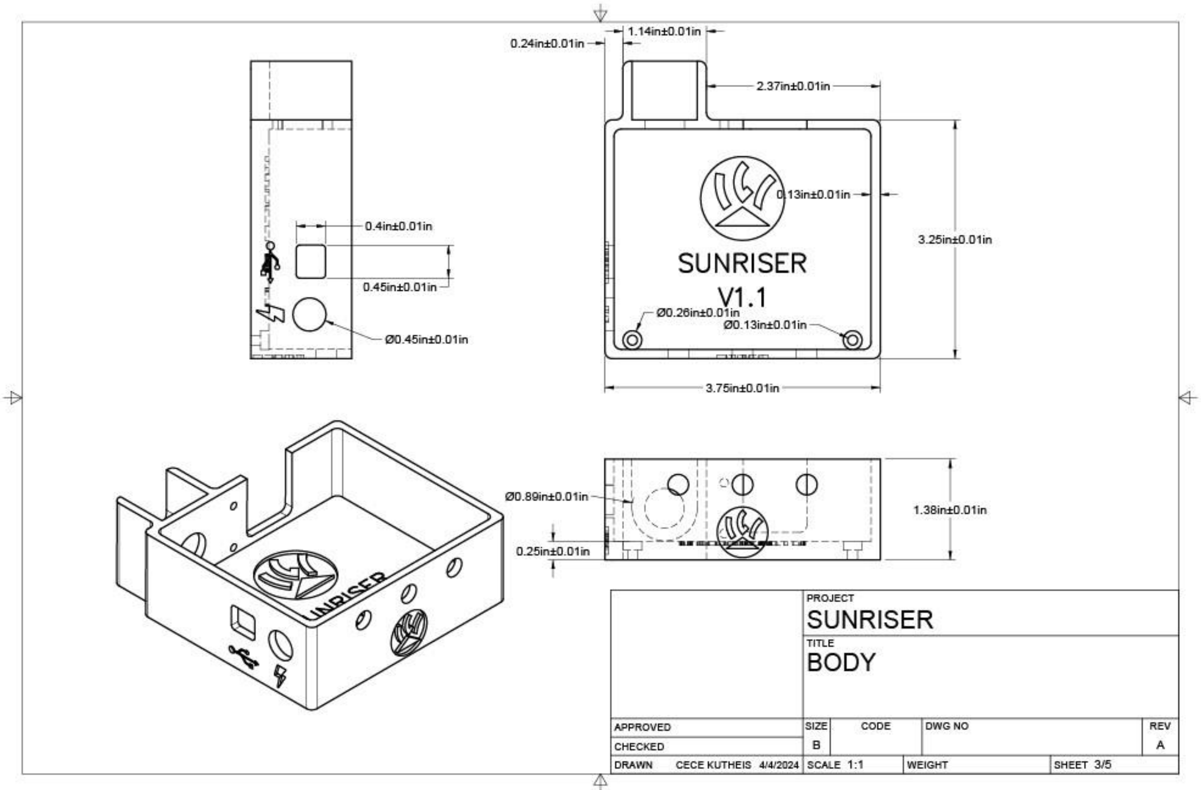
Appendix A: Detail drawings of the Sunriser assembly



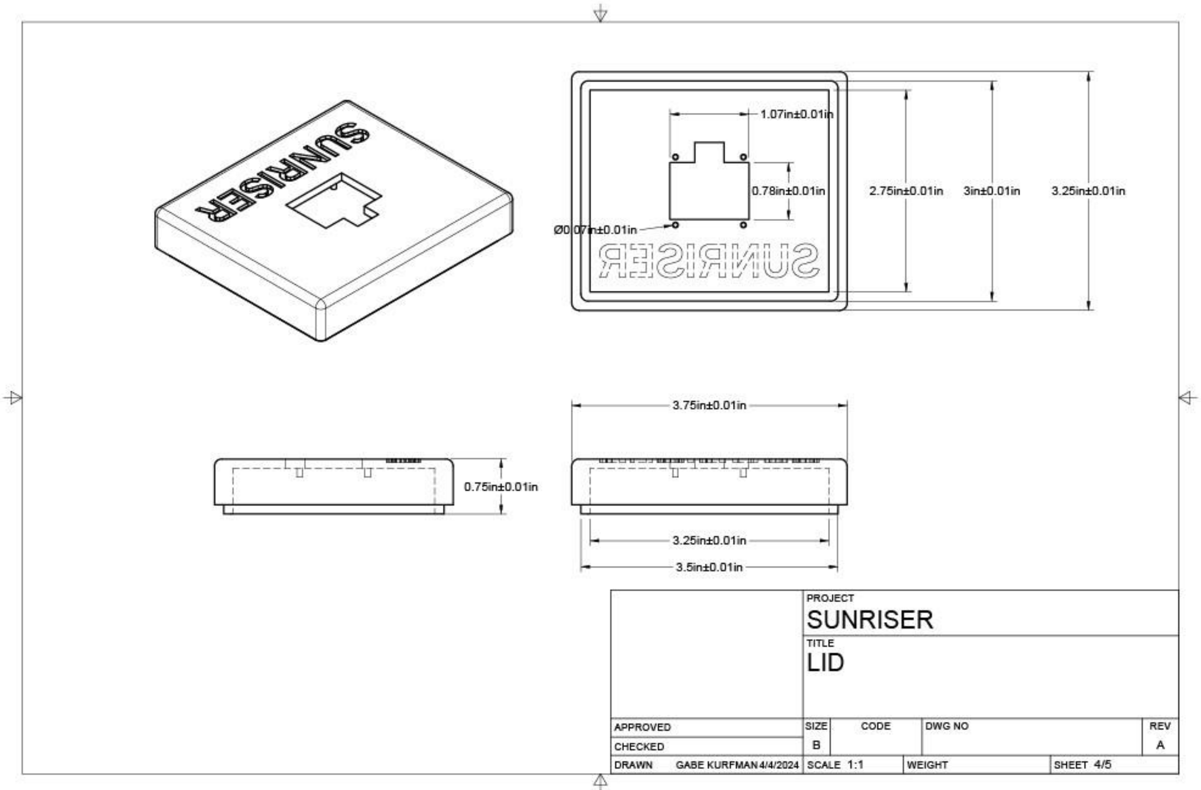
A1: Tassel Clip Detail Drawing



A2: Clamp Detail Drawing



A3: Body Detail Drawing



A4: Lid Detail Drawing