

University of Nevada, Reno

Solar Sensing Blinds

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Abstract

Indoor heating and cooling costs are a major expenditure globally and windows provide one of the most significant sources of inefficiency in the average building. Blinding Sun Systems set out to counteract this growing problem by researching, designing, and prototyping a device that could be used to retrofit existing window blinds and automate them as to optimize the amount of solar radiation being allowed to pass through at any time. Blinding Sun Systems analyzed the smart home market in order to predict the feasibility of introducing such a product, theorized design concepts, created CAD modeling of those concepts, conducted engineering analyses to determine if the product would function as designed, designed experiments to test the effectiveness of the product, and synthesized all of these elements together to present a prototype model of their solar sensing blinds product.

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Introduction

The problem that team 13A is trying to solve is that of autonomous house blinds. These blinds will either allow or block sunlight from entering a home. Currently, if a homeowner is experiencing too much or too little sunlight, they must engage the blinds manually. Blinds are also left to a singular position if homeowners leave the premises, which may contribute to energy loss. Homeowners leaving blinds in a singular position while sleeping may experience a loss of productivity due to the inability for blinds to react to a homeowner's sleep schedule.

The United States Department of Energy suggests that heat gain can be reduced as much as 45% by having reflective blinds shut on a window exposed to direct sunlight [1]. Aside from just keeping out the sunlight, passive solar can also be utilized with autonomous blinds. Blinds that can properly deflect sunlight into a light colored ceiling will greatly increase the amount of natural light available with a negligible increase to heat gain [1]. Another facet of the autonomous blind problem is the loss of productivity due to oversleeping or a lack of a regimented sleep schedule. Sunlight acts as a zeitgeber for the sleep cycle and depending on what kind of sleep chronotype someone has, more or less exposure to sunlight throughout the day can impact the sleep cycle [2].

A study done on urban Brazilians show that sedentary habits can increase Vitamin D deficiency. "The major source of vitamin D is the endogenous cutaneous synthesis from sunlight, around 90%" [3]. Window blinds being at an un-optimized position lower the sunlight a person can receive in an urban setting. Vitamin D deficiency can lead to a

lower absorption rate, increased cancer rates, hypertension, Type 2 diabetes, and autoimmune diseases.

Literature and Patent Review

Patent Review

Scope of Search

This technical search is focused on the following:

1. Solar tracking methods
 2. Blind micro-adjustments in relation to the position of the sun
 3. Varying ways to adjust different types of blinds in a more efficient manner
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Search History

Keywords Used:

- Sun Tracking
 - Blind Actuator
 - Window Blinds
 - Solar Sensor
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Summary of Results

There are pre-existing patents that are already in effect that utilize several of the features of the solar blinds concepts, which include solar sun trackers (many of which are used in solar tracking applications for solar energy). Additionally, there is a patent for an actuator that is directly hooked into the blinds and can be controlled remotely.

The literature search showed that consumers are most welcoming towards products that have automatic systems with continuous feedback. It is most effective for blind systems such as this to fully integrate a building and connect to blinds remotely, but it is much more complicated and expensive to integrate.

Ratings

Documents were rated using the following codes:

1 = Document is directly related to area of interest

2 = Document is categorically related to area of interest

3 = Document references for other reasons

Patent Overview

Table 1: Table of Patents which will be reviewed in further detail below.

Aspect	Patent Number	Applicant	Class	Rating
Sun Tracking Sensor	US20150136944A1	Avraham Segev	G01S 3/768	1
Light Sensing, Battery Powered, Blind Actuator	US5495153A	Douglas R. Domel, Winston G. Walker	Y02B80/50	1
Attachment to Window Blinds	US07411324	George Georgopoulos	E06B9/307	2
Self-calibrating <i>solar</i> position sensor	US20160091298	Lonnie Curt Maxey	F24J 2/38	1

Load control system having energy savings mode	US9013059B2	Lutron Electronics	E06B9/68	2
Dual-mode automatic window covering system responsive to AC-induced flicker in ambient illumination	US5598000A	Pradeep Papat	E06B9/68	2
Translucent solar cell and manufacturing method thereof	US20090151783A1	NexPower Tech Corp	H01L31/186	2

Patent Details

Aspect	Patent Number	Applicant	Class	Rating
Sun Tracking Sensor	US20150136944A1	Avraham Segev	G01S 3/768	1

Title: Sunlight tracking sensor and system

Comments: This sun tracking solar sensor comprises of a cylindrical base, a rotating post, two pairs of light sensors, and a gyroscopic mechanism. This sensor has both a rotating base which allows it to track the sun east to west, as well as the gyroscopic mechanism on top of the post allowing it to track light intensity based on the sun's position in the sky. A sensor of this nature is simple, relatively cheap, and would solve a major design obstacle in the implementation of solar sensing blinds. However, the nature of this sensor may introduce complications when integrating it with a small housing confined to the gap between standard blinds and a window. This type of sensor would also potentially be able to solve the issue of tracking the sun in a variety of seasons, where it sits at different points

in the sky. The ability to discern seasonal change based on the positioning of a gyroscopic sensor could also indicate to the system when letting light in is desirable and also when it is not.

Aspect	Patent Number	Applicant	Class	Rating
Light Sensing, Battery Powered, Blind Actuator	US5495153A	Douglas R. Domel, Winston G. Walker	Y02B80/50	1

Title: Head rail-mounted mini-blind actuator for vertical blinds and pleated shades

Comments: This patent describes an actuator which attaches to the top of a blind system and in response to a signal, adjusts the blinds. The signal type is not entirely specified, but two options for signals given in the patent is either a user-generated remote controlled input or an automated solar-sensing input. The sensors signal is read by a simple circuit within the housing of the device which activates a motor. The motor, powered by a DC battery, is able to turn clockwise and counterclockwise, which gives it the ability to turn the blinds in either direction. The entire mechanism is attached the top of a set of blinds, around the existing rod used to adjust the blinds.

Aspect	Patent Number	Applicant	Class	Rating
Attachment to Window Blinds	US07411324	George Georgopoulos	E06B9/307	2

Title: Tilt wand attachment for window blinds

Comments: The tilt wand attachment is an attachment that allows easier installation of the rod that turns horizontally oriented blinds that turn longitudinally. The attachments designated by the patent consist of a hook, and gear assembly that connects to the worm shaft that moves along the horizontal length of the housing for the horizontally oriented blinds. These parts are difficult to install, and can cause the installer to have to build, take apart, and rebuild components. The invention detailed involves a single assembly that connects with the worm shaft with a hook assembly all as one, and then features a separate assembly that connects to the rod from one end and the hook assembly from the other.

Aspect	Patent Number	Applicant	Class	Rating
Self-calibrating <i>solar</i> position sensor	US20160091298	Lonnie Curt Maxey	F24J 2/38	1

Title: Self-Calibrating *Solar* Position Sensor

Comments: This sun tracking solar sensor comprises of a cylindrical base, two position sensing diodes, and a block program to track the position of the sun. The two diodes measure both intensity and position therefore reading different voltages back to the block diagram. The data collected is then validated through recent centroid data and stored intensity data. In this manner, the system can use data being inputted from the four photodiode method employed in sun pointers to determine the position and intensity of the sun. This is one route that team 13A could apply to our design. The use of a constantly running program might prove to drain more energy than the solar panel can produce. This would produce failure into the system so the team would have to ensure a sufficient power supply for this patent to be valid for our design.

Aspect	Patent Number	Applicant	Class	Rating
Device and Method for Blind Control and Automation	US20170362888A1	Jalousier Ou	E06B9/322	1

Title: Device and Method for Blind Control and Automation

Comments: This is the patent of the current competitor of Blinding Sun Systems, Flip Flic. When creating the prototype, it will be critical to ensure that the claims of Blinding Sun System's device is clearly distinguishable from those of the competitor product. The patent describes itself as a device for blind automation to optimize heating, cooling, and natural light. This patent also references prior art that could be helpful to the development of Blinding Sun System's Prototype as well.

Aspect	Patent Number	Applicant	Class	Rating
Load control system having energy savings mode	US9013059B2	Lutron Electronics	E06B9/68	2

Title: Self-Calibrating *Solar* Position Sensor

Comments: The load control system with energy savings modes is a full-building system that integrates several smart technologies. The goal is for the house to remain connected - in that there are sensing capabilities for lighting in the home, temperature, and controls in place to increase the temperature from external load sources, or to modify window configurations to allow extra natural light to enter the building. The methodology behind this is to maximize energy savings via heating and cooling of the home and this is in some

ways directly related, but more so categorically related to the product being designed by Blinding Sun Systems. The team hopes to deliver energy savings via only one modular piece attached to the blinds to moderate temperature within the home to lead to energy savings.

Aspect	Patent Number	Applicant	Class	Rating
Dual-mode automatic window covering system responsive to AC-induced flicker in ambient illumination	US5598000A	Pradeep Papat	E06B9/68	2

Title: Dual-mode automatic window covering system responsive to AC-induced flicker in ambient illumination

Comments: This patent describes a blind automation system that is dependent on natural and artificial light readings. When the system detects artificial lighting, it turns to mode specifications to determine if it should open or close the blinds. If a room should be heated in colder outdoor weather, the blinds will open. If a room should be cooled in warmer weather, it closes the blinds to keep out the sun's energy. This system is similar to Blinding Sun Systems solution in how it treats temperature readings. However, Team 13's solution does not incorporate artificial lighting into the solution because it was determined that ambient lighting levels are at comfortable levels most of the day even with blinds completely closed.

Aspect	Patent Number	Applicant	Class	Rating
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Translucent solar cell and manufacturing method thereof	US20090151783A1	NexPower Tech Corp	H01L31/186	2
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Title: Translucent solar cell and manufacturing method thereof

Comments: This patent outlines not only what comprises a translucent solar cell, but also manufacturing methods to create one. A claim that Blinding Sun Systems makes is that the use of its blind system will allow for more natural light to enter a space. If this automated blind system is to be taken to market a solar cell attachment for the window that does not block natural light or heat energy to the system would be ideal. The inclusion of manufacturing methodology would allow Blind Sun System a starting point if translucent solar cells are not immediately available for purchasing.

Literature Review

Title: A daylight optimized simulation-based shading controller for venetian blinds

Author(s): Angelina Katsifaraki, Bruno Bueno, Tilmann E. Kuhn

Journal: Building and environment

Rating (same system as patent rating): 2

Summary: This article explains the use of a new controller for typical venetian blinds with the purpose of maximizing daylight and glare control. This system is controlled by an algorithm. If users are present, visual comfort (direct sun and radiation) are priority. When no users are present, energy efficiency is prioritized. There are initial inputs into the system such as weather, global location, and indoor air temperature. Constant time step monitoring

dictates to the controller what angle the blinds should be at for optimized comfort or energy efficiency.

Comments: While the concept of solar monitoring is not a novel idea, it is clear that this particular algorithm provides one of the more efficient and effective systems tested to date. The entire system is run off of a computer. This will be a significant challenge when attempting to monitor current conditions while not overloading a processor inside of our proposed housing. As a constantly monitoring system will be 'overbuilt' and very expensive, it is unlikely that our design will include this level of monitoring.

Title: Automated blinds with light feedback to increase occupant satisfaction and energy saving

Author(s): B.W. Meerbeek, C. de Bakker, Y.A.W. de Kort, E.J. van Loenen, T. Bergman

Journal: Building and Environment

Rating: 1

Summary: This article goes over an experiment that tracked how individuals reacted to automated window blinds in an office based on the system interface. The experiment not only tracked user satisfaction but also the number of corrections they made to the blinds via manual input. The results showed that the more expressive an interface the blinds system had, the higher user satisfaction was, and the less corrections were made to the blinds. These results suggest that an expressive interface increases a user's trust and acceptance of an automated system.

Comments: This could be very useful information as Team 13A moves into a potential interface. This study seems to suggest an increase in trust in a product, where if Team 13A chooses to take the product to market, could give us an edge. It could also give us some potential heading if we chose to design a more mechanical interface.

Title: Lighting energy savings in offices using different control systems and their real consumption

Author(s): B. Roisin, M. Bodart, A. Deneeyer, P. D'Herdt

Journal: Energy and Buildings

Rating: 2

Summary: This article explains the use of a DAYSIM simulation for the purpose of maximizing daylight when necessary and reducing energy consumption. The main focus of the article is to quantify the actual experienced savings when limiting artificial light through the use of occupancy sensors and light dimmers. The paper goes on to say that with lighting control systems in place, they could calculate savings based off of the preset light switch on and light switch off. This experiment was conducted for an entire year in an office building in Europe. They found that the best saving potential was 61% of the annual power consumption in a south facing office in Athens. The worst case is a north-orientated office in Stockholm for which the potential gain was still 45%.

Comments: This paper goes takes an in depth analysis of occupational sensors and dimmers. For the purpose of our project, we will be changing the supply of light via the

sun and not the supply of artificial light via light bulbs. Therefore, the same principles apply to our project. One serious issue with the papers experiment as it relates to our project is that our project will not be able to integrate an occupancy sensor. This will result in a lower power savings yield.

Title: Evaluating visual comfort and performance of three natural lighting systems for deep office buildings in highly luminous climates

Authors: C. Ochoa, I. Capeluto

Journal: Building and Environment

Rating: 2

Comments: The research in this paper provides both a qualitative and quantitative approach to figuring out whether natural lighting in an office where natural light could be abundant, but is under-utilized, can lead to improvements in energy savings and general productivity. Research in favor not only of the hard data of natural lighting cost versus the cost of artificial lighting, but also an examination of productivity and mood, can become even better selling points for a blind automation product than just cost savings alone.

Summary: A study of done in Israel, which has an abundance of passive lighting potential due to the reflective nature of its deserts and cities. Three different configurations of window coverings were analyzed: no window covering, a horizontal light shelf, and an anidolic concentrator. The office space was also retrofitted with office furniture with a

more reflective finish. The data collected is both qualitative in terms of comfort levels and evaluations, and quantitative analysis of reflectivity and illuminance.

Title: Influence of window size on the energy balance of low energy houses

Author(s): Mari-Louise Persson, Arne Roos, Maria Wall

Journal: Science Direct

Rating: 3

Summary: Typical passive solar heating involves large windows on the South end of a building, with small windows in the North. This is to allow maximum heat into the home from the South and minimum heat to escape through the North. This occurs because of the low thermal insulation of windows, and a lot of heat may be lost to the windows. The study came to a conclusion that although typical thinking has considered significant heat loss through the small, north facing windows, this is not quite true in practice. From the results, it may be more beneficial to maintain larger windows in the North to allow extra light into the home. The tests were conducted in Gothenburg, Sweden, and part of the author's conclusion was that while window size in the north is not as significant of a factor to consider, the most important factor within the system was the thermal insulation throughout the home. It is necessary to use well insulated walls and smart e-windows.

Comments: Considering thermal insulation as a primary means of maintaining habitable environments, it is important to consider how that would affect our project. Although thermal insulation is not directly related to our product, obviously it is something that

should be gone over when promoting the product. The marketing for the product may also provide education for the user in stating ideas about how south facing windows are the most important because they receive the most sunlight, and how upgrading windows to more eco-friendly options may really help individuals save on energy in the future.

Title: Environmental retrofit: building integrated passive cooling in housing

Author(s): Schiano-Phan, Rosa

Journal: Architectural Research Quarterly; Cambridge

Rating: 2

Summary: It is often easy to forget, living in the western United States that not every building worldwide has an air conditioning unit working at full capacity to keep it comfortable. In this article, Rosa Schiano-Phan discusses the increasing need for residential cooling in many southern European countries. Areas that have been historically temperate, but due to climate change, are now increasing in average temperatures. Introducing air conditioning units into residential buildings in these cities would be expensive, inefficient, and counter-productive because it would only increase the changes occurring in the climate. Schiano-Phan proposes a passive cooling technique to implement into residential areas being affected such as Sevilla, Spain. The systems she discusses are known as modular porous ceramic evaporators, a passive cooling system that if the technology is further developed and implemented, could cut a huge hole in southern Europe's energy consumption.

Comments: Passive cooling and heating are incredibly important concepts that are not discussed enough in conversations of climate change and the energy crisis. Blinding Sun Systems is interested in a future that is as smart and efficient in heating and cooling as possible. The blind system being developed utilizes the sun's warmth specifically. However, there are numerous passive energy systems that can be put in place to effectively cool/heat a home. These systems take advantage of pressure differences, changes in temperature, wind patterns, humidity levels, etc. to make a living space more comfortable.

Title: Impacts of climate change on building heating and cooling energy patterns in California

Author(s): Peng Xu, Yu Joe Huang, Norman Miller, Nicole Schlegel, Pengyuan Shena

Journal: Energy; Oxford

Rating: 3

Summary: Climate change has started to raise the average temperature in California, and as a result the energy consumption of cooling costs has started to rise. The study extrapolates energy trends that have appeared and estimates that energy consumptions for cooling will increase roughly 25%-50% over the next hundred years. This in turn will increase carbon emissions contributing to climate change negatively and further accelerating the process.

Comments: While Blinding Sun System's product will only passively adjust temperatures in a room by a few degrees it is a renewable product. While it isn't the solution to the

problem of climate change, it could help lower overall emissions due to heating and cooling by reducing heating and cooling needs. The focus of the product is to be a self-sufficient energy saver that can be a part of the renewable market. This could also serve as an avenue to emphasize with regards to marketing.

Product Design Specifications

This document defines the project requirement specifications for the Solar Sensing Blinds, which function as the design inputs of the project as an origin for traceability throughout the project. Additionally, this document provides defining guidance on identifying project design specifications.

Intended Use: To automatically open and close house/office blinds, such that energy costs are noticeably reduced. Product should have minimal installation and an extremely long life independent of the end user.

Intended User: Homeowners/Home Developers/Offices

Intended Use Environment: Room temperature and standard humidity. The sensor should also operate with the varying temperatures of the window it is installed on.

Table 2: Full table of Project Requirement Specifications for prototype Solar Sensing Blinds.

PRS	Category	Requirement
13.PRS.1.1	1	Total cost to the consumer should be less than \$40 as a similar product exists at this price point. Total manufacturing cost should be \$25 or less.
13.PRS.1.2	1	Product should be modular in nature, as to not obstruct the window but still control the blinds.
13.PRS.2.1	2	Product will have to work at a variety of humidity levels.
13.PRS.3.1	3	Product should house circuitry and mechanical components should fit within a housing of no more than 30 cubic inches.
13.PRS.3.2	3	Product should be able to detect when calibration is necessary and self-calibrate.
13.PRS.3.3	3	Product should be able to clear stored data automatically.

13.PRS.3.4	3	Product will be wired from main system to a photocell configuration on a window.
13.PRS.3.5	3	Product will feature buttons that may turn the blinds manually.
13.PRS.4.1	4	Product should perform in standard office or home environments.
13.PRS.5.1	5	The motor used should be wear resistant.
13.PRS.5.2	5	Sensor used should be able to handle glass temperatures on the current natural hottest day globally.
13.PRS.5.3	5	System should be protected from condensation via an enclosed casing that won't allow moisture to contact electrical components.
13.PRS.6.1	6	Program should run the system independently.
13.PRS.8.1	8	Product should include a manual with warnings, instructions, installation procedure, and recycling instructions. Warnings should include, but are not limited to: warnings about disassembly, improper use of manual override, and potential damage that could be caused to existing blind system in case of failure. Instructions should include, but are not limited to: how to properly handle the device.
13.PRS.9.1	9	Product should be single installation and operable for long-term use.
13.PRS.9.2	9	Product should include instructions for a single, secure installation and for selecting and cleaning the installation area as to prevent possible malfunctions.
13.PRS.10.1	10	Product must have the ability to function continuously with the use of a solar panel.
13.PRS.11.1	11	System powered by a battery solar panel; electrical safety requirements should be met.
13.PRS.11.1	11	System casing should have no sharp edges.
13.PRS.12.1	12	Product should follow the safety regulations of all relevant US agencies

Functional Decomposition

Preliminary designs for the team's solution to the problem of developing solar sensing blinds focused primarily on the aspects of how to engage blinds in a manner that was both monetarily beneficial for the user as well as convenient for user to implement. Autonomy is key in the varying designs formulated by Team 13. Blinding Sun Systems aims to have a device that performs the primary functions of adjusting blinds based on the positioning of the sun to increase energy efficiency, have the ability to incorporate both user defined programs and a manual user override, and modularity to allow for its use on varying types of blinds. The design also incorporates the utilization of a program featuring logic that will control the blinds sun-tracking capabilities, as well as some user inputted options.

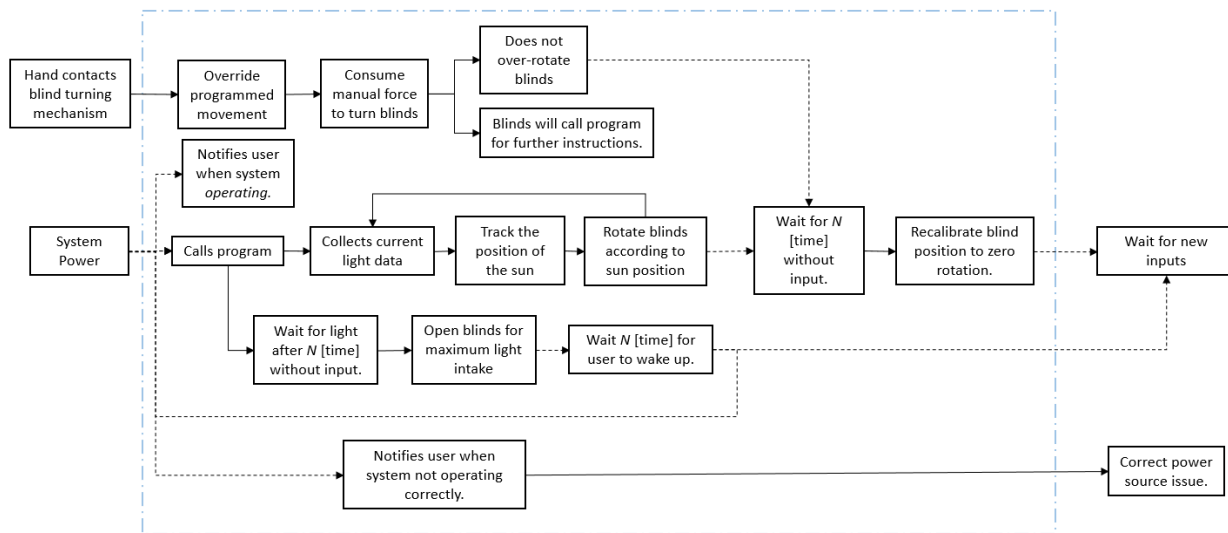


Fig. 1: Functional Decomposition created by Team 13 that outlines the functional modes for solar sensing blinds.

Marketing

Market Analysis

The smart home industry has been increasing gradually throughout the technological age of the 21st century. According to P&S Market Research, the smart home industry is expected to grow at a CAGR of 14% by 2023 [P&S Market Research, website]. Figure 1 contains data displaying the growth of the smart home market since 2013, and includes projections up to 2023.

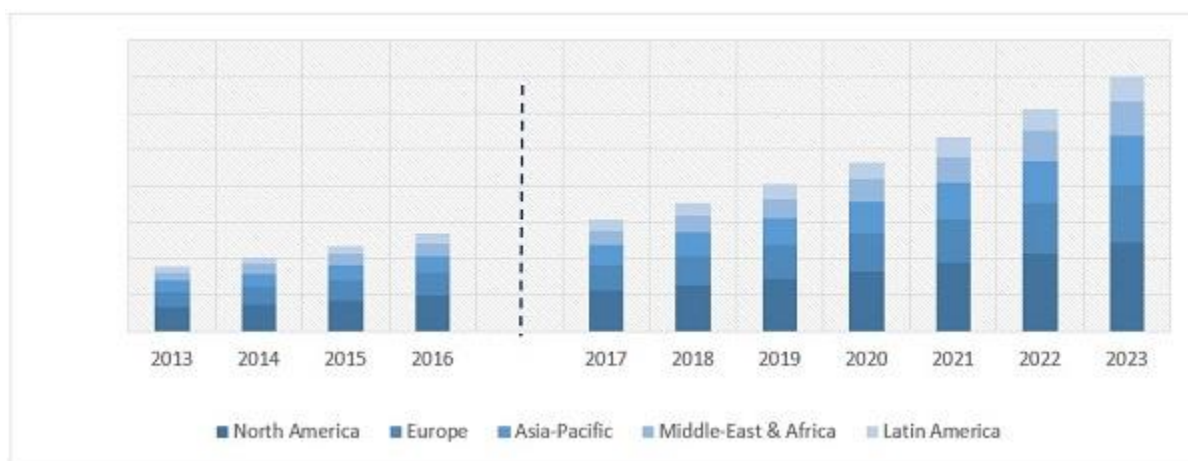


Fig. 2: A stacked bar graph that displays the growth and projected growth of the smart home market from 2013 to 2023 [P&S Market Research, website].

A primary driving factor for the increase in the smart home market is the increasing availability and accessibility to use smart home devices. Along with this, many smart home products such as smart thermostats, and automated lighting systems can save significant amounts of money for consumer energy bills.

An article from Business Insider, *The US smart home market has been struggling - here's how and why the market will take off*, discusses the current status of the smart home and how it can break through to reach a mass market.

Many of the smart home barriers include high production costs, long device replacement cycles, and the lack of accessibility to use multiple smart home devices seamlessly. Currently, most smart home devices require remote control from a separate application, however these devices cannot all be controlled via the same application, and this in turn decreases consumer ease of use. Mentioned in the report from Business Insider, the smart home market is in the adoption phase where some consumers are acting as early adopters for the industry. Business Insider also mentioned that “the largest barrier [to the smart home market] is technological fragmentation.” [Greenough, 2017].

The target market that Blinding Sun Systems seeks to tap into is for individuals seeking lower budget, smart home appliances. The system will attempt to break the barrier between several different devices and applications, by allowing everything to be controlled through the device. The device will feature buttons for manual movement of the blinds, as well as features to track the sun and move according to the sun's position in the sky.

The team expects to be able to take over the majority of the smart blind market assuming the primary competitor, continues to behave in the way in which they have for several months now - that is without providing updates or releasing their product to their crowdfunded backers. Additionally, our product will feature several of the same primary functions at about half of the price, allowing for much greater long-term potential.

Blinding Sun Systems has created a budget system for different scales of manufacturing. From a home grown operation the cost per unit is about \$16.20 with a \$200 development cost. This means that nine units must be sold for breakeven to occur. If manufacturing were scaled to a larger size, then two options are apparent. First, a good 3D printer must be purchased for roughly \$6000 dollars and filament must be bought to supply it. At this scale neglecting labor 237 units must be sold for break even. The second option is to do injection molding. The mold would be \$15,000 dollars and the plastic to supply it. For this to be profitable 540 units must be sold neglecting labor. Due to the steep cost of the larger scale manufacturing methods, Blinding Sun Systems has no plans to increase production scale at this time.

Competitive Analysis

Solar sensing and tracking blinds are a product that is newly under development, but has not reached market quite yet. A startup company named FlipFlic has been selling their product on Indiegogo and Kickstarter and has crowdfunded over \$200,000, but has yet to ship out their product to customers. As recent as February, the founder of the company, Ksenia Vinogradova, released a new update. The update stated that firmware development was holding up production. During this delay, FlipFlic has recently revised the motor and mechanics of the system. The first units are still 6 months out. Following the first manufactured units, the Beta testing can begin. There is a likely year long wait before kick starter and Indiegogo backers will see products. Furthermore, there have been many comments on these pages of requests for refunds due to delays and lack of updates.

FlipFlic is a company that is manufacturing a modular device that can be attached to current horizontal or vertical blind systems, and is featured as a smart home technology. The device is small, and is connected directly to the blinds, replacing the typical spin rod. It features an app that can set open and closing schedules based on time, sunlight levels, and temperature differences. The device is powered by a solar panel, and can also be recharged via micro-USB. Currently, FlipFlic controls the market for smart window blinds, although has not very highly penetrated the market for blind owners in general, and this may be due to their high price point of \$89 per unit (including solar panel) [Vinogradova, 2016].

Hunter Douglas is a company that produces blinds, shades, and various other window fixtures. They sell a product that can motorize blinds and shades via both a controller, and an app. The app feature can connect to all blinds installed in the house at a touch of a button and even operate the shades while away from home via a mobile device. The shades are battery operated. When the batteries die on each and every shade, it has to be replaced. Over time, this can be a very costly form of automatic shading systems. Hunter Douglas does not appear to have penetrated the market very deeply outside of the products that they sell. Furthermore, the price point is not listed as each home has a different path of integration.

MySmartBlinds is another kick starter funded company that plans to integrate a smart home hub device such as Alexa. They are also planning on selling their own house hub that will strictly focus strictly on the blind operations of the entire house. The device is installed inside the existing blinds and consists of a motor, a battery, and a manual switch. The company claims that the battery will work for up to 6 months before needing

to be recharged depending on the usage. The company is currently in its first round of beta testing with 50 backers. Once this testing is complete, they will pursue a second round of testing and then open the doors for public sale. The hub to control the motor and battery costs \$80. This is required if the consumer purchases one blind or ten. For \$150, the customer receives one hub unit, one solar panel, and one automation kit. Additionally, MySmartBlinds is also pursuing integrated blinds to sell as a unit. For \$250 the customer receives blinds with the following available sizes: Width 21"-74" Height 24"-120". Overall, the price for automation units costs about \$100 per unit. The cost of the integrated blind is approximately \$200 per unit.

SWOT Analysis

Table 3: Solar Sensing Blinds SWOT Analysis

Strengths	Weaknesses
One time installation and then no further maintenance required	No phone application integration capabilities.
Simple, physical interface located directly on the unit for ease of use.	No device synchronization. Each unit works independently based on location, local conditions, and overrides.
System easily transferable in the event of changing home or office space.	Unable to adjust corded pulley blinds.
Opportunities	Threats
Low cost allows for more customers that would not normally be able to enter the smart home market to partake.	Lack of phone application integration could dissuade more tech savvy buyers that intend to link all of their devices.

Cheaper unit cost allows for a quicker return of investment.	Cheap unit cost combined with a lack of need for regular replacement severely limits returning customer base.
Simple design allows for ease of transition to mass production.	Passive energy savings per month are only a few dollars at best, customers could not notice seeing the product as nonfunctional

Porter's 5 Force Model

A Porter's 5 Force Model for the home smart-blind market is shown below in Fig. 2. Within this market Blinding Sun Systems has determined that suppliers have very low power. The components used in the Solar Sensing Blinds, are very simple from a manufacturing standpoint. There's a vast selection of companies who produce the required motor, plastic, circuit boards, wiring, sensors, etc. that will be used in the product. The large supplier base and the simplicity of the parts allows the suppliers to be easily switched/replaced and heavily drives down their power. The buyers in this market tend to be financially well off and generally have other smart-home devices. Buyer power has been identified as moderate. There is a quickly growing customer base, but as a convenience product, potential customers do not need to purchase products if they do not want to. The threat of new entry was determined to be high. The market is rather open currently. Two of the main, identified competitors, FlipFlic and Hunter Douglas, have not brought their product to shelves. This means the field is wide open for new competitors to enter and have a large potential market share. The simplicity of the product is also a danger that contributes to the high threat of entry. In addition to the above stated threats, there is no well-known, trusted name currently in this market. A company with a reputable name could likely take a huge market share if they were to enter. In regards to

substitution, the largest threat comes from users opting away from luxury and convenience, thus choosing to control their blinds manually. Other threat of substitution comes from potential customers opting for curtains in their home.

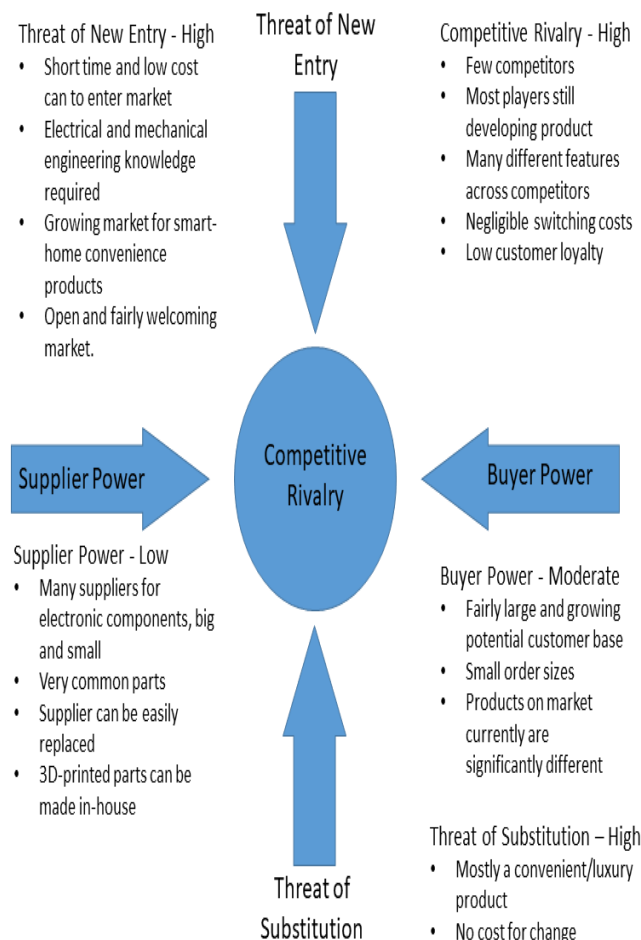


Fig. 3: A Porter's 5 Force Model which shows characteristics of the current smart-blind technology market.

Competitor SWOT Analysis

A SWOT analysis was performed to evaluate two other players in the smart-blinds market. Competitors that will be analyzed include FlipFlic and Hunter Douglas,

who are both competitors that manufacture smart blinds systems. The SWOT analysis for FlipFlic and Hunter Douglas can be found in Table 2 and Table 3 respectively.

Table 4: FlipFlic SWOT Analysis

Strengths	Weaknesses
Mobile application integration	No physical control of the blinds without mobile application.
Models fitting for vertical and horizontal type blinds.	Price point.
Synchronization with other FlipFlic devices.	Not compatible to all blind devices

Opportunities	Threats
Integration with raising and lowering blinds.	Uncertain market outlook.
Increasing compatibility.	High initial setup cost.
Potential to increase energy savings.	No hold on market because no deliverables yet.

Table 5: Hunter Douglas SWOT Analysis

Strengths	Weaknesses
Mobile application integration	Battery powered
Models fitting for all Hunter Douglas products	No physical control of the blinds without mobile application.
Synchronization with other Powerview devices	Not compatible to all blind devices

Opportunities	Threats
Integration with raising and lowering blinds.	Uncertain market outlook.

Increasing compatibility.	High initial setup cost including purchasing of blinds
Potential to increase energy savings via alternative sources of power.	No hold on market because product is only compatible to products from same company.
	Universality of product.

FlipFlic is a competitor that sells a small device that attaches to the blinds directly and is controlled via sun position, or manual control via smartphone application. While the device can be controlled through a smartphone, there is no ability for the user to control the blinds manually, nor is there a method for users to raise/lower the blinds remotely. Overall, the FlipFlic has strong market potential, although their slow development and very high price may prevent much success for the company.

Hunter Douglas is a competitor that produces blinds, shades, a remote control and smartphone application as an entire integrated system. This device much like FlipFlic, does not have a manual user interface for their blinds. However, there is the option to remotely raise and lower blinds even while not home using a mobile device that connects to the web. Overall, Hunter Douglas has a fair market potential. Their cohesive systems allow for seamless integration into a house, but in order to use the app feature the blinds installed in the house must be Hunter Douglas blinds or shades. Because of this, the existing market of blinds and shades are not currently reachable for Hunter Douglas.

Market Survey

The purpose of marketing surveys and results analysis often lies not only in aiding the decision process for developing a product, but also in understanding the

demographics of who our product appeals to. In the case of most marketing surveys some significant demographics questions would be asked to understand what age groups, genders, income levels, etc. are most interested in a product. For this course, it is safe to assume that a majority of the people who took the survey are within the ages of 20-30, currently non-homeowners (but likely future homeowners), and male. This is important to note because of how this sample and their opinions may differ from our true market. One significant differentiation could exist in the age group of the people who the automatic solar blinds system appeals to. Specifically, since our demographic group is entirely made up of college students, it is unlikely that there is large expendable amounts of revenue to spend on this product. Because this product is a convenience item, for many it is not justifiable to spend money on non-essential items. Furthermore, since most college students are not in a permanent residence, there might be hesitation to enter the home improvement market.

Question Breakdown

Note: A full list of the exact questions asked during the survey and their results is displayed in Appendix D.

The first question of our survey asked the potential customer about the means by which their blinds are opened. Because of the fact that our current designs are all designed for wand-operated blind systems, it was important to understand the statistics of people who would even be able to use the product. From the survey data, 53% of the takers have a pulley operated system in their homes, the second most selected answer

being wands with 41%. With such split responses, it is up to the group to determine whether the design should be changed to appeal to more potential customers.

The second question of the survey attempted to learn of customers would prefer a system that attaches to the current blind adjustment system or one that completely replaces the existing system. The results for this inquiry returned rather inconclusive. The most popular response was to replace the existing blind adjustment system altogether with 39%. However, this is hardly unanimous with customers electing to keep the existing system and customers not having a preference just behind at 35% and 27% respectively.

The third question dealt with interest to include an LED to be used as an indicator for the system. The options given were to have it on during motion, to have it on while powered, only for it to turn on if the system was malfunctioning, or no indicator light necessary. Once again, while the most popular answer was for the light only to be on if the system was malfunctioning, the answers got 25%, 19%, 31%, and 25% respectively which is not exactly unanimous. It's clear most people would like some sort of indicator for feedback, but the use of this indicator will be mostly up to the design team.

The fourth survey question involved a potential design addition the team has discussed, which would be the addition of a solar panel which would be used to power the device. Potential customers were asked about how important it would be to them to include a solar panel as part of the design. The most popular answer choice was selected by voters who felt this feature would be "Somewhat Important," with "Very Important"

coming in second place. In total, 61 of the 75 survey-takers said adding a solar panel would at least be a somewhat important feature for them.

The fifth question asked the survey takers the importance of four potential modes of operation that the system could have. The results of this question proved to be rather evenly spread across the board. However, the most votes for a function was shown to be the energy saving function. This result is congruent with team 13's initial assessment of the product being marketed as an energy saving device. 40 of the 72 individuals rated this energy saving mode as the most important function that the device could serve. The second and third most important function proved to be the custom user defined setting and the wake up and/or night time mode respectively.

The sixth question proved to yield a definitive answer. The question asked "How often would you like the blinds to make an adjustment?" 33 votes or 44% of the survey population agreed that making an adjustment 20 or more minute intervals would be sufficient to effectively track the constant changing elevation of the sun throughout the day. The other survey answers seemed to agree that a longer time interval between changes would be sufficient. This is backed by the second and third most popular answers being 15 and 10 minute intervals. The demographic group of this survey likely have more realistic expectations for battery longevity than that of everyday people who might not realize that the more often there is an adjustment in the blind system, the more watt draw, and therefore the quicker the battery is depleted.

The seventh question dealt with the manual override option. The options were either pushing a button, twisting the rod, or not having a manual override option. Not

surprisingly, all the mechanical engineers did not trust the electrical system and only 2 voters thought that there should not be a manual override option. The primary answer for override option was overwhelmingly pressing a button at over 57%. This is clearly a majority of the votes, however, team 13 might have to redesign the system to account for this feature. One idea might be to place buttons on the outside of the system to allow for this feature.

The eighth question was likeliness of using the product. This may be the most important question for this product actually seeing the market. 82% of voters said that they could see themselves using this product. This is an enormous majority and one that realizes that there is in fact a market for this product. The other 18% of the voters said they could not see themselves using the product. The most common reasons were “I never adjust my blinds” to “Don’t have a need for a product of this design”.

Finally, the ninth question dealt with price of the product. The options were \$25 or less, \$26-\$50, \$51-75, and \$76 and up. The answer with the most response was the \$26-\$50 option. This answer might not be entirely indicative of a true market interpretation because as stated above, the survey population is made up of college students. This might suggest that a higher price point could be feasible. However, competitor products are already at this higher price point, and as such, it would not make sense for the price point of the product to be equivalent to that of a competitor strictly from a market standpoint.

Engineering Analysis

Overall Analysis

Although Blinding Sun Systems did not select two explicit designs to analyze, there were components of each concept that varied but would not be influenced by engineering calculations. The only required comparison of analysis between two different designs is in regards to the power source, whether or not we are using a solar panel to charge a battery or replaceable, disposable batteries to power the system.

There were several facets of the solar sensing blinds system that were considered when analyzing the engineering requirements of the system, including the power source requirements. Additional engineering models that were analyzed include the axial force on the blind system from the device, the required torque output to turn blinds, and the power requirement to operate the device. It is also worth estimating the final cost of the device in order to meet the specifications set forth in the PDS. The results of the engineering analysis are shown in Table 1 below.

Table 6: Estimated calculation results determined based on potentially usable components.

Estimated Axial Weight of Unit	0.8lb = 3.5N
Estimated Motor Torque Required	4.5N-mm
Estimated Power Usage	870.92 mWh consumed, 972 mWh gained

Force Analysis

A force analysis was conducted on the electrical unit which will be attached to the window. The weight of all parts: two or four sensors, a circuit board, and ABS Plastic for a housing, was determined to be roughly half a pound. The direct weight changes based on the circuit board used and the dimensions of plastic that are used. An average of multiple analysis was used to determine the weight to be half a pound. In order to achieve a strong cohesion to the window, Blinding Sun Systems plans to have the friction force equal or greater than two pounds. This will act as a factor of safety for the electrical housing.

When choosing the light sensor, three main criteria were determined: power draw, cost per unit, and sensing range. The sensor chosen was SFH 3711 by OSRAM Opto Semiconductors. The sensor was chosen as the cost per unit is \$0.21, the sensing range is designed for sunlight and closely matches the human eye. The power draw of light sensors within similar specifications was the same within 5 μ A. The sensor chosen runs for 4807.69 days at constant maximum draw. While not the maximum possible, the price of the sensor and the designation of solar light detection make this the best possible sensor. Table 2 shows its specifications.

Table 7: Specifications of Ambient Light Sensor SFH 3711

SFH 3711 Ambient Light Sensor			
Cost per Unit	Operating Time*	Peak Wavelength	Operating Temperature

\$0.21	4807.69 days	570 nm	-40 C to +85 C
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**Operating time is based on powering a single sensor.*

Power Analysis

During the determination of the power required to operate the system and the battery capacity needed to power the system, it was discovered that utilizing a non-rechargeable batteries was not a sufficient means of powering the device. A standard 9V battery only has a capacity of roughly 500mAh, while a reasonable static power requirement to power a motor is roughly 15mA. This means that during a typical daylight cycle of around 9 hours, the motor would draw over a quarter of the available battery life. This would be impractical for a device that is intended to be a low maintenance, cost effective method to making slight adjustments to blinds, so this revelation effectively ruled out the idea of utilizing non-rechargeable batteries. Instead, a rechargeable battery in conjunction with a solar cell was used to perform the power analysis.

The battery used for the power analysis was the 6V 4500mAh Panasonic LC-R064R5P and the Ixolar SLMD480H12L 6.06V 18mA solar cell. The relevant specifications of these components are included below in Table 3 and Table 4.

Table 8: Specifications of Rechargeable Battery Panasonic LC-R064R5P

Panasonic LC-R064R5P			
Cost per Unit	Voltage	Current Capacity	Dimensions

\$14.75	6V	4500mAh	71.0mm x 49.0mm x 103.2mm
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Table 9: Specifications of Solar Cell Ixolar SLMD480H12L

Ixolar SLMD480H12L			
Cost per Unit	Voltage	Current	Dimensions
\$7.64	6.06V	18mA	22.00mm x 35.00mm x 2.00mm

Under the assumptions that there would be 9 hours of daylight available in a standard day and the motor would only be operational for 180s worth of adjustments per day, the net power gained by using four sensors continuously, a motor during daylight hours, and a solar cell during daylight hours the net power gained over the time period would be 101.28 mWh left over after powering the system at 870.92 mWh during that time span. Below in Table 5.

Table 10: Power Requirements of each component. The negative value for the solar cell represents power gained by the system.

Power Consumption				
1 x Sensor	4 x Sensor	Motor (Static)	Motor (Loaded)	Solar Cell
4.68 mWh	18.72 mWh	810 mWh	42 mWh	-972 mWh
Total:				-101.28 mWh

Project Management

Project Overview

Blinding Sun Systems aims to create a gadget that will retrofit and automate pre-existing window blinds to improve energy efficiency and increase consumer convenience. The device will actuate a small motor, which will fit to a removable, modular attachment that can either manually rotate horizontal slat blinds or manually operate pulley system blinds to adjust their angle relative to the sun. A small solar panel will power the device in order to both minimize cost and maximize potential energy savings. The device will be programmable to either heat or cool a space depending on the desired outcome and will also include a manual override option.

The final deliverable that Blinding Sun Systems aims to achieve for the completion of the project is the production of a single, fully functioning prototype model. The prototype model will be able to track the relative position of the sun and adjust the angle of the blinds to optimize heating or cooling accordingly. A prototype for the tracking program using the Arduino program and C language will also be developed to demonstrate the functionality of the physical prototype. The team will also develop a procedure and manual detailing the setup, calibration, operation, maintenance, and disposal of said device.

Project Milestones

In order to achieve the goal of creating a functioning prototype as outlined above, Blinding Sun Systems will have to meet strict deadlines and outcomes throughout the

next month and a half. The essential tasks Team 13 will need to complete are as follows: the production of a CAD model in SolidWorks of both the motor attachment, modular adapter, and adhesive solar panel module, the sourcing and purchasing of required materials to build the prototype, the final fabrication of the components into the physical prototype, development of software, and the construction of a testing rig for demonstration. The SolidWorks assembly model will be developed with the three components mentioned above and will be laid out in a drawing format with a complete bill of materials. This bill of materials will then be used to acquire the motor, sensors, solar panel, battery, and other components needed for the final design. Then, the assembly will be manufactured in a 3D printed casing of ABS plastic and the components will be fastened inside. Software will be developed to utilize photocells inside the solar panel housing with varying resistances to pinpoint the location of the sun and then adjust the blind angle relative to that position. Finally, the project will have to be demonstrated at the University of Nevada's Innovation Day, so a testing rig consisting of a window and blinds must be constructed in order to model the performance of the device.

Gantt Chart

The Gantt chart was developed with feasibility for successful project completion in mind. Because of this, some things within the final design may be considered more of "stretch goals" and were not implicitly considered for the Gantt chart and for the prototype. For example, implementation of different user defined settings and complete universality between all blind types has been considered as stretch goals, that may be

investigated dependent on the progress the team makes. The realistic Gantt chart is shown in Figure 1.

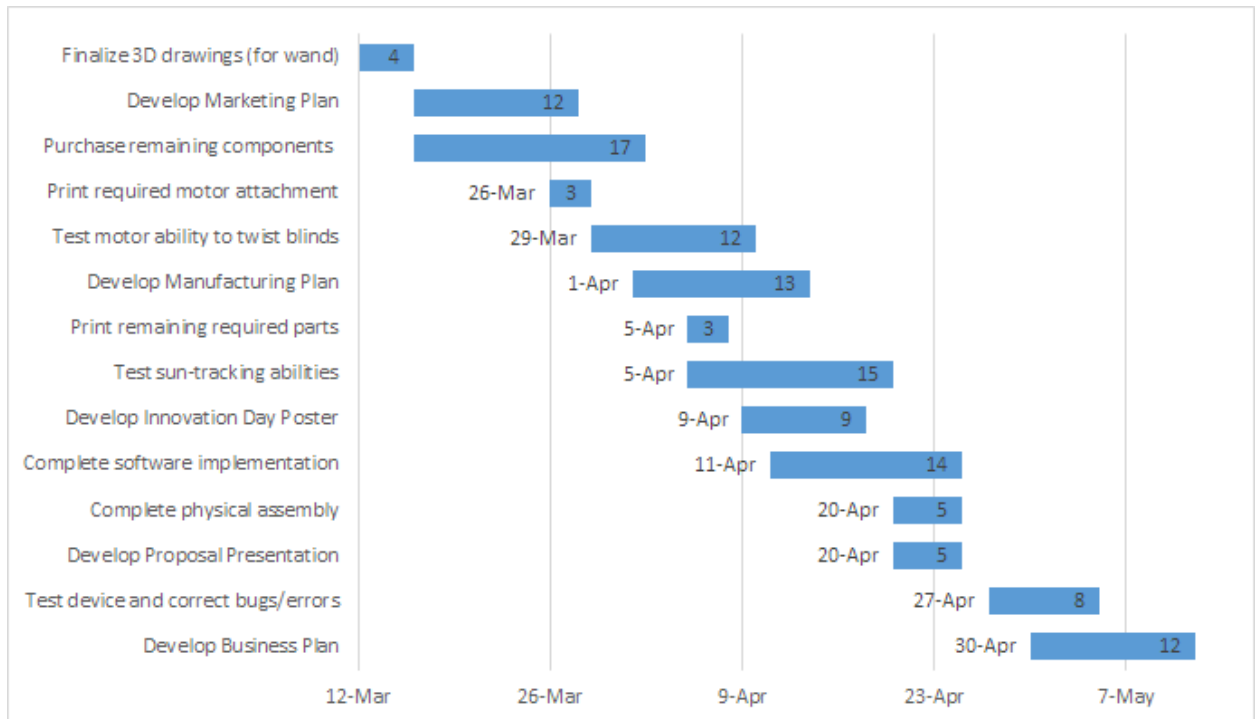


Fig. 4: Gantt chart Team 13 has developed to ensure tasks are being completed to complete development of the product. Dates indicated are required start dates for each task.

Additionally, the team decided that it would be a smart idea to delegate a “Task Manager” to each task that is in the Gantt chart. The manager is in charge of ensuring progress and completion of their task with the rest of the team, as well as managing progress for tasks at team meetings. Enabling each member to have a managerial role will better allow the team to focus on smaller chunks, ultimately putting out higher quality

work, and ensuring everyone is accountable. The list of tasks with corresponding managers is shown in Table 1.

Table 11: Displays all tasks, start and due dates, duration, and the assigned Task Manager.

Task	Start Date	Due Date	Duration [days]	Task Manager
Finalize 3D drawings (for wand)	12-Mar	16-Mar	4	Alex P.
Develop Marketing Plan	16-Mar	28-Mar	12	Alex B.
Purchase remaining components	16-Mar	2-Apr	17	Alex P./Mark M.
Print required motor attachment	26-Mar	29-Mar	3	Jeff H.
Test motor ability to twist blinds	29-Mar	10-Apr	12	Mark M.
Develop Manufacturing Plan	1-Apr	14-Apr	13	Jeff H.
Print remaining required parts	5-Apr	8-Apr	3	Mark M.
Test sun-tracking abilities	5-Apr	20-Apr	15	Alex P./Alex B.
Develop Innovation Day Poster	9-Apr	18-Apr	9	Jens C.
Complete software implementation	11-Apr	25-Apr	14	Alex P.
Complete physical assembly	20-Apr	25-Apr	5	Jeff H.

Develop Proposal Presentation	20-Apr	25-Apr	5	Jens C.
Test device and correct bugs/errors	27-Apr	5-May	8	Jens C.
Develop Business Plan	30-Apr	12-May	12	Alex B.

Schedule Management Plan

Blinding Sun Systems has developed a comprehensive Gantt chart, shown above, that will be used in order to track progress on the project. The Gantt chart outlines individual tasks as well as the timeframe in which the team expects to complete them. Every individual task outlined within the Gantt chart has been assigned a team member to be the task manager. Each task manager is not necessarily required to complete more work within the task they are assigned, but they are expected to manage the task's progress, keep teammates informed in regards to due dates, lead team meetings regarding the task, and ultimately take responsibility for the completion of the task. Tracking progress for the project will prove a simple task when the project is split into smaller sub-tasks each with a different team member responsible for tracking the progress of it. In order to keep progressing along with the Gantt chart, the team will hold weekly meetings to work on tasks, delegate responsibilities, and complete assignments. By using the Gantt chart and weekly meetings to track progress, the team expects to progress efficiently through the end of the project

Cost Management Plan

Currently Blinding Sun Systems' product has an annual return of about ten dollars. We are planning to take it to market at a price point of forty dollars. For this reason, the maximum budget for each unit is twenty dollars. It is assumed that this would be even lower in large scale manufacturing. To manage the cost, team 13A plans on making all parts and casings out of ABS plastic, utilizing 3D printing. This will be done using university resources to accomplish the printing at the lowest price possible. All motor and sensor components, accounting for about a dollar of production costs cannot be found for a lower cost, will be bought from a third party. A solar cell will also be purchased, and will be the most expensive single unit, exact pricing isn't available as a decision hasn't been decided on. The main focus will be streamlining production and verifying part drawings well ahead of time. If time must be spent constantly remaking parts it could become a source of unnecessary waste. The main focus will be verifying correct parts in SolidWorks for proper mating requirements and trying to plan ahead for any shrinking or warping that may occur during printing.

Risk Management Plan

The most pressing risks that Blinding Sun Systems will face will be both the physical development and programming of the sun tracking system. This portion of the project presents the biggest unknown to the group, as no one has a large amount of programming experience. In order to combat this, Blinding Sun Systems will continually track the progress of the sun tracking mechanism at each weekly team meeting. Additionally, Team 13 decided to allow one of the largest blocks of time (April 5th to the 15th) for verifying the sun tracking programming and design.

Another significant risk that Blinding Sun Systems will have to consider will be part ordering and shipping times. The team has already encountered complications with this risk in the previous Proof of Concept phase, and will take the necessary steps to plan ahead and limit this risk for the remainder of the project. Right now, ordering is planned for April 2nd, which allows for a two week window prior to the beginning of the final assembly task. Team 13 will have all components and vendors selected well before the part ordering deadline as well for maximum preparedness.

Critical Path

The critical path of tasks necessary for the successful completion of the project consists of several components. As indicated by the Gantt chart, timely ordering and 3D printing of design specified parts will dominate the next two weeks agenda. There is also testing of the motor capabilities and then, the overall prototype and coding testing will follow. Testing sun tracking abilities and user controls will consume the first half of April. However, if there are issues with completing the project, the critical path will slip into the second half of April. This slip would set back the complete physical assembly as well as compromising the deliverables team 13A promised. To prevent this and other foreseeable slips, the risk management plan will be used to determine the course of action. The most important part of the risk management plan is simply to have one in existence. Team 13A will implore aggressive task delegations and schedule frequent team meetings to monitor the progress of each small task and gauge the overall progress of the final deliverable. From this, Team 13A can make educated decisions in respect to the risk management plan which in turn will prevent slipping into other phases of the project.

Test Plan

The focus of Team 13A's proof of concept was intended to show that an automated blind system could save money on electricity costs in regards to heating and cooling. The team focused on proving this via experimentation in a controlled environment. As the timeframe of the test was set to be late February, a test on the basis of heating was derived. The room used for testing was based on its position as a West facing window and its lack of environmental obstruction. The system utilizes four temperature sensors to record data at different positions within the room and all vents to the HVAC system have been covered. The team changed the blinds position daily based on a randomly generated order as to eliminate bias. It was determined through engineering analysis that the solar sensing blinds must be able to raise the temperature of a room by about a seven degrees Fahrenheit from a control setting in order to generate significant savings on energy cost. The expected result show a favorable trend, but as data acquisition isn't complete no technical results can be drawn. The trend of data shows that the blind system will consistently save money on energy costs.

Fabrication, Assembly, Test Procedures

Fabrication

The fabrication process for this proof of concept mainly entailed purchasing the materials consisting of the Arduino R3 breadboard, the jumper wires, and the software to program and run the system. We had serious setbacks as far as purchasing goes. The

delay of materials led to less accurate data being collected with the poor equipment from our Arduino kit. Due to this delay, Team 13A started the project by collecting data using DHT11's which have a narrow range of $0-50^{\circ}\text{C}\pm 2^{\circ}\text{C}$. A sensor was placed just behind the blinds, and the other sensor was placed outside of the sun range on an interior room wall. The data from the DHT11's had an insufficient measuring range for the outside environmental data we were trying to collect. However, we did receive our DHT22 sensors on Monday Feb 26. We started collecting data with these sensors the same day and were able to expand upon the readings due to the sensor capabilities. The DHT22's have a range of $-40^{\circ}\text{C}-125^{\circ}\text{C}$ with an overall accuracy of 2%. With the increase in temperature reading capability, the team was able to swap out the existing two DHT11's and replace them with DHT22's.

We also added one sensor immediately outside the window and one sensor inside the room on the other end of the room. With three DHT22 sensors reading inside the room and one DHT22 sensor reading directly outside the house, the team feels confident that all data acquired from this setup will provide the most useful readings to prove that a change in blind orientation will determine the energy input into the system (the room). The team is also considering ambient light as a potential source of energy savings. Two photo-resistor sensors PC11's were added to the project on Feb 28. The photoresistors take into account the ambient light in the room. If the lumen readings of the sensors is high enough, the necessity of an overhead or artificial light is not needed. This will theoretically also result in an energy savings in the form of a 60W light bulb. Typically, the cost of running a typical 60W incandescent light bulb for a single hour at the national average price of \$0.12 per kilowatt hour only comes out to a cost of \$0.0072 [2]. This

will most likely yield insignificant energy savings but the team felt it was necessary to conduct the experiment before assuming the overall impact of light cost.

Test Procedures

The test procedures were established as a team. The goal was to create as near to a closed environmental system as feasibly possible. The specifications were as follows. The ventilation provided to the room via the conditioning vent was turned off and sealed shut with press sheet wrap and then taped shut for added security. This ensures that any heat in the form of humidity and temperature was added to the room through the window via the sun. The thermal radiative and the convective heat was measured with a total of four DHT22 sensors. The culmination of both the DHT22's and the PC11's data is to measure the watt hours of energy input into a room each day. The start of each testing day was in the evening when all light data for the day had been collected. Immediately after one test stops, the blind orientation was changed, and the experiment would start anew running throughout the night. The orientation of the blinds was randomized on a per day basis to prevent any bias from entering the data. Data points were collected every five seconds on all four DHT sensors and two PC11 sensors. The team has made a total of three major revisions to the testing layout of the room in order to collect the most useful and accurate data possible. Complete testing procedures can be found in the Lab Testing Procedure portion of this Test plan document.

Bill of Materials

Actual Bill of Materials

The proof of concept described in the test plan for Team 13A required few materials. This is due to the simplicity of the physical setup involved in the designed test. Included below is the actual bill of materials, which includes the items purchased and used by Team 13A to execute the test plan for the proof of concept. When referring below, it is clear to see that a majority of the setup and execution of the test will be the coding and circuitry, without a physical design or test.

Table 12: Actual bill of materials which includes information on the items purchased and used by Team 13A for the proof of concept.

#	Name:	Retailer:	Producer:	Item Price:	Quantity:	Shipping:	Total:	Notes:
1	Arduino Kit	Amazon	Elegoo	\$34.99	1	\$0	\$34.99	Includes breadboard, Arduino, resistors, and photoresistors used in proof of concept.
2	DHT22 Temperature Humidity Sensor	Amazon	Gowoops	\$10.00	2	\$0	\$20.00	
3	Jumper Wires - 12 Inches	Amazon	SIM&NAT	\$7.49	1	\$0	\$7.49	
Total					4	\$0	\$62.48	

As-Built Bill of Materials

Along with the actual bill of materials, the team has also developed an as-built bill of materials. The as-built BOM shown in Table 2 below shows what components were

used in experimentation for the proof of concept, and if it were to be replicated, or considered for mass scale, only the displayed parts are necessary.

Table 13: As-built BOM includes only the components used to perform the Proof of Concept.

#	Short Name:	Retailer:	Producer:	Item Price:	Quantity:	Shipping:	Total:
1	Arduino	Amazon	Elegoo	\$10.90	1	\$0	\$10.90
2	DHT22 Temperature Humidity Sensor	Amazon	Gowoops	\$10.00	2	\$0	\$20.00
3	Jumper Wires - 12 Inches	Amazon	SIM&NAT	\$7.49	1	\$0	\$7.49
4	400-Point Breadboard	Amazon	microtivity	\$3.99	1	\$0	\$3.99
5	Photoresistor (Pack of 20)	Amazon	SUNKEE	\$1.97	1	\$0	\$1.97
6	1k Resistors (Pack of 10)	Amazon	E-Projects	\$5.73	1	\$0	\$5.73
Total					7	\$0	\$50.08

There is clear distinctions that can be identified when comparing the actual bill of materials and the as-built bill of materials. Most notably, the as-built bill of materials includes a savings of \$12.40. This is due to the exclusion of a full Arduino kit and simply purchasing the Arduino and individual parts required to conduct the testing. As seen above, the 400-point breadboard, two photoresistors, and two 1k Ω resistors come included in the purchased Arduino kit, but can be purchased separately for less. If this experiment was to be recreated, the use of the As-built materials in table 2 would be used.

Ethical and Safety Concerns

There are no relevant ethical or safety concerns to account for with the design of this experiment. While the prototype will introduce some safety concerns when it is fitted with a motor and automated, the experiment only utilizes hand adjustments of blinds along with an experimental set up on an Arduino-style Uno 3 clone, which is both powered by and exports data to a computer. The final prototype will also use a small solar panel and battery, which comes with ethical concerns of proper waste disposal and management, but those will not be present for the Proof of Concept experiment design.

Test Methodology

Testing Factors and Variable Control

In order to prove the efficacy of our sun tracking blind system, Team 13 decided to designate blind angle as the independent control variable of the experiment in order to analyze its effect on the dependent variables of room temperature and ambient light level. Blind angle was the clear choice for the independent variable of the Proof of Concept experiment design because Blinding Sun System's future product aims to increase cost efficiency through constant adjustments in blind angle relative to the sun's position. Since the sun's orbit is a force of nature that cannot be controlled, though it can be very well predicted, minor adjustments in the blinds is the best way to control the experiment.

Temperature was chosen as our primary dependent variable for the experiment because the team hypothesized that energy cost savings would be most directly correlated

to the disparity between outdoor and indoor temperature levels. Changing the temperature of a room by even a single degree can have as much as a 3% to 5% decrease in heating or cooling costs for an individual room [1]. Our secondary factor in this experiment that Team 13 will be tracking is the ambient light levels present in a room and comparing those to the ambient light levels present outside of the blinds enclosure. Utilization of natural light has become a mainstream design choice in many homes to decrease the need for artificial light, which uses energy. However, the cost of running a typical 60W incandescent light bulb for a single hour at the national average price of \$0.12 per kilowatt hour only comes out to a cost of about \$0.0072 [2]. Team 13 would still like to analyze this effect to see if it can have a reasonable overall impact on cost savings like controlling strictly for temperature would. Since windows are one of the least insulated places in an average home and most vulnerable to heat exchange, Blinding Sun Systems currently hypothesizes that the effect of increasing the ambient light to decrease overall energy cost will not provide a significant enough effect on cost to prioritize the effect over controlling for temperature. Team 13 decided that the effect would still be significant enough to measure and account for in the actual experiment.

The levels of treatment the experiment is designed to use are blind angles of 0° (completely closed, parallel to the window), intermediate angles of 30° , 45° , 135° , and 90° (completely open, perpendicular to the window). Both the parallel and perpendicular states of the blinds will provide a majority of the control data of the experiment, essentially analyzing the effect of allowing minimal energy through and maximum energy through the blinds. The intermediate angles of 30° , 45° , 90° , and 135° were chosen to provide a variety of measurements between the rigid confines of completely

open and completely closed in order to see if it is justifiable to consider adjusting blinds at increments other than the baseline to begin with.

The major external factors that Team 13 has to account for in the Proof of Concept will consist of the variability and complications introduced by weather. Since weather is variable and unable to be controlled for, all the data collected for temperature and light will be collected at multiple points throughout the room and window. For temperature, a sensor directly outside the window corroborated with local weather data will provide a baseline for the data. Then, other sensors placed directly inside the window and throughout the room in different locations as well as the indoor thermostat will be compared relative to the outdoor temperature to observe any increase in efficiency. For light, a similar process will occur with sensors in between the blinds and window compared to both the readings observed by the sensor in the room with only natural light and the sensor when exposed to artificial light as well.

Experimental Design and Development

Since the hypothesis of the experiment is that energy costs will decrease if blind angle is controlled primarily due to temperature, the Team decided to design the experiment to have mainly a fixed angle approach, both for ease of data collection and the ability to analyze the window of time when the sun is at a favorable angle to the blinds compared to when it is at a less favorable angle. One day will be used to consistently adjust blind angle in increments of 20 minutes, which will be similar to the prototype's adjustment frequency, while the rest of the test days will be used to observe

the blinds set at a fixed, predetermined angle. It should be noted that since Team 13A will be manually adjusting these blinds, there is likely to be some small angle approximation error. Again, the attempt here is to keep the blinds perfectly parallel to the sun allowing maximum heat transfer to occur.

For the Proof of Concept experiment, Team 13 conducted an initial test of the experiment using two DHT11 temperature sensors while awaiting the arrival of better DHT22 sensors. This initial test made it clear that the DHT22 sensor with a smaller margin of error and larger operable temperature range would be much better suited to collecting reliable data. In addition, the team revised the sensor layout in the room, with the addition of two more sensors to collect data in other parts of the room. To analyze the data collected in the final test, Team 13A has decided to utilize Microsoft Excel since the limited amount of factors involved in the experiment do not call for an extensive design of experiment in a more complex program. The differences between the outdoor temperature, temperature directly inside the window, and temperatures throughout the room will be taken and compared to the cost of changing the temperature in the closed room of fixed area by those differences. Essentially, the data will focus on how many watt hours of energy are required to produce the same effect as a regimented schedule for the control of the blinds.

Engineering Analysis

The analysis will be focused on feasibility within the system. Specifically, calculation will focus on how much energy is required to raise the temperature of the

room and how much the blind system needs to cut energy wise in order to be profitable to a significant degree.

Assumptions

1. The room we are using has a west facing window with unobstructed access to sunlight
2. The dimensions of the room will not account for items in the room, it will be treated as only full of air.
3. All energy change will be treated as from the blind system, and will be focused on solar radiation, and not on ambient temperature change from the walls of the room.
4. Energy calculations will include no fluctuations in power cost per time of day.
5. The system will act as a closed system where only temperature inputs are from the sun.
6. House height is considered constant.
7. Total system refers to an entire house with a centralized HVAC system and a solar sensing blind on each window.
8. When referring to room or test room fractionalized power output from the HVAC system and a single window system.

Theoretical

Air Density= $\rho_{\text{Air}}=1.225 \text{ kgm}^3$

Specific Heat Capacity of Air= $CP=1.005 \text{ KJkg}^*K$

$$\text{Volume of test room} = V = 2.8956\text{m} \times 3.048\text{m} \times 2.4622\text{m} = 21.73 \text{ m}^3$$

$$\text{Power Consumption of Heater} = P = 3250 \text{ Whr} = 11700 \text{ KJ}$$

The following equations will be used to calculate how much energy must be used to raise the temperature of the air in our test room

$$\text{Mass of Air} = M_{\text{Air}} = \rho_{\text{Air}} * V = 1.225 \text{ kgm}^3 * 21.73 \text{ m}^3 = 26.62 \text{ kg}$$

$$\text{Energy Need} = E = M_{\text{Air}} * C_P * \Delta T = 26.62 \text{ kg} * 1.005 \text{ KJkg}^* \text{K} * \text{K} = 26.75 \text{ KJ}^{\circ}\text{C} = 7.43 \text{ W-hr}^{\circ}\text{C}$$

$$\text{Total Square Feet of House} = 1344 \text{ ft}^2 \quad \text{Test Room Square Feet} = 95 \text{ ft}^2$$

$$\text{Test Room Percentage of Total Area} = 7.1\%$$

$$\text{Fractional Power Consumption} = 11700 \text{ KJ} * 7.1\% = 830.7 \text{ KJ} = 0.23075 \text{ kWh}$$

The next equations will calculate the cost of changing the temperature of the air in the test room by a single degree Celsius

$$\text{Energy Cost of Total System} = [4] 9.12 \text{ cents per kWh} * 3.25 \text{ kWh} = 29.64 \text{ cents/hr}$$

$$\text{Energy Cost of Room} = 9.12 \text{ cents per kWh} * 0.23075 \text{ kWh} = 2.10 \text{ cents/hr}$$

$$\text{Time} = 0.52 \text{ min}^{\circ}\text{C} = 0.29 \text{ min}^{\circ}\text{F}$$

$$\text{Cost per Time of Total System} = 0.25 \text{ cents}^{\circ}\text{C} = 0.14 \text{ cents}^{\circ}\text{F}$$

$$\text{Cost per Time of Room} = 0.0182 \text{ cents}^{\circ}\text{C} = 0.0102 \text{ cents}^{\circ}\text{F}$$

Blinding Sun Systems means to have this product help consumers save a significant amount of money on a full home system. Significant savings will be defined here as forty dollars per year.

Cost Savings per Day = \$40365 days=10.96 centsday=0.46 centsshr

As the blinds will only be able to operate during sunlight they must output double the value as sunlight will only be available about twelve hours a day.

Temperature Change Needed for total system=0.46

centsshr0.14 cents°F*2=6.57 °Fhr=3.68 °Chr

As Team 13A is only testing a single room so the amount needed will be based on the percentage of total volume.

Temperature Change Needed for Room=0.46 centsshr0.0102 cents°F *2*7.1%=6.40

°Fhr= 3.59 °Chr

The solar sensing blinds must be capable of heating the test room by 6.40 degrees Fahrenheit from a control point, or heating an entire home by 6.57 degrees Fahrenheit from a control point, in order to generate significant savings.

Lab Test Procedure

Assembly and Disassembly

Assembly of the proof of concept test environment considered window location, selection, and sensor placement. The base assembly to conduct the proof of concept

required the placement of three to four temperature sensors throughout a room, connected with an Arduino to gather data dynamically reported to an excel document on a computer.

The team was limited to what windows may be used as some of the required criteria were: easily accessible at all times of the day, not directly obstructed, South, East, or West facing (per the direction of the sun's rays are most visible from these three directions throughout the day based on geography of Reno), and in a fairly isolated room (without many other inputs such as a fan blowing throughout the day or a lot of bodies close to the sensors, potentially distorting data). As a result, the team decided that we shall use Jens C.'s home to conduct the testing, as he has an unobstructed West facing window that was in a room that would not be accessed frequently.

There were three significant data points that were determined to be necessary to evaluate the effectiveness of the sun to heat a room under different blind configurations. These were the points where the sensors would be placed which were (a) on the outside of the blinds, so direct sunlight may reach it inside the room, (b) outside of the room to evaluate the outside temperature for day-to-day variation, (c) inside the middle of the room to evaluate how the room temperature is affected, not under direct sunlight. Two sensors were placed throughout the room, not being hit with direct sunlight.

Disassembly after testing will require the removal of the sensors throughout the room and the disconnection from the Arduino.

Operation

Operation of the test setup requires the knowledge of the custom developed Arduino code, and a macro-enabled spreadsheet that allows data to be read directly from an Arduino and outputted to the spreadsheet [3]. With the spreadsheet, data collection is fully autonomous and quite easy. All that is necessary is the proper connection of the four temperature sensors and two photodiode sensors. With the code uploaded to the Arduino, all that is needed to be done is to connect the spreadsheet with the Arduino, and data is dynamically outputted to this spreadsheet.

Test Sequence and Procedure

There were five different blind configurations that were considered to evaluate the most effective mode of heating/cooling of a room from the sun. These configurations were with the blinds at 0°, 30°, 45°, 90°, and 135° (all angles in degrees are in reference to the blinds at 0° being closed in the downwards facing position). Each of these blind angles were to be tested twice and in randomized order in order to attempt to eliminate bias, especially with the weather. Additionally, one point was added in which the team would adjust the blinds in 20 minute intervals throughout the day to match the angle of the sun, allowing maximum sunlight in. A random test sequence was generated by using Excel's "RAND()" feature, and then ordering in ascending order. The test sequence would thus be conducted across 11 days and was in the order shown in Table 3. Data on each day was analyzed from sunup to sunset, ranging from about 6:00am to 6:00pm.

Table 14: Randomized test order of the six different configurations.

Test Number	Blind Position (°)	Day	Date
1	135	Friday	23-Feb
2	90	Saturday	24-Feb
3	30	Sunday	25-Feb
4	Closed	Monday	26-Feb
5	45	Tuesday	27-Feb
6	Closed	Wednesday	28-Feb
7	135	Thursday	1-Mar
8	45	Friday	2-Mar
9	90	Saturday	3-Mar
10	20 minute intervals	Sunday	4-Mar
11	30	Monday	5-Mar

Expected Outcomes

It is expected that the test results will show that in general, open blinds will cause more heating of the home than closed blinds. More specifically, the test in which the blinds are adjusted to follow the sun in 20 minute intervals should maximize the temperature increase and energy savings in the home, although to what degree it increases the temperature is uncertain. If we find that the angle of the blinds is not very significant, then we may be able to maintain the blinds as statically opened or closed in the prototype. The team is also expecting the significance of the photodiode to be marginal for reasons stated above. Furthermore, the experiment with the most human error comes from the 20 min interval experiment. Since the team has to change the blinds by hand, the angle is approximated.

Proof of Concept

In Fig. 5 below, the two most extreme levels of the test were compared, the 30 minute interval test and the test with the blinds completely closed for the duration of the day. These graphs show that, despite the outside temperature being higher on the day with the closed blind testing, the day with the interval testing exhibited indoor temperatures 2-3°C higher. This proves that optimizing blind angle compared to ignoring the movement of the blinds can improve indoor heating abilities during the winter. However, other effects may have had an impact on the temperature readings throughout the room, such as conduction and convection effecting the temperature of the wall sensor or the positioning of sensors and higher or lower altitudes in the room. Additionally, further testing with varied weather conditions throughout the year would be needed to get a better overall picture of the savings potential of solar sensing blinds.

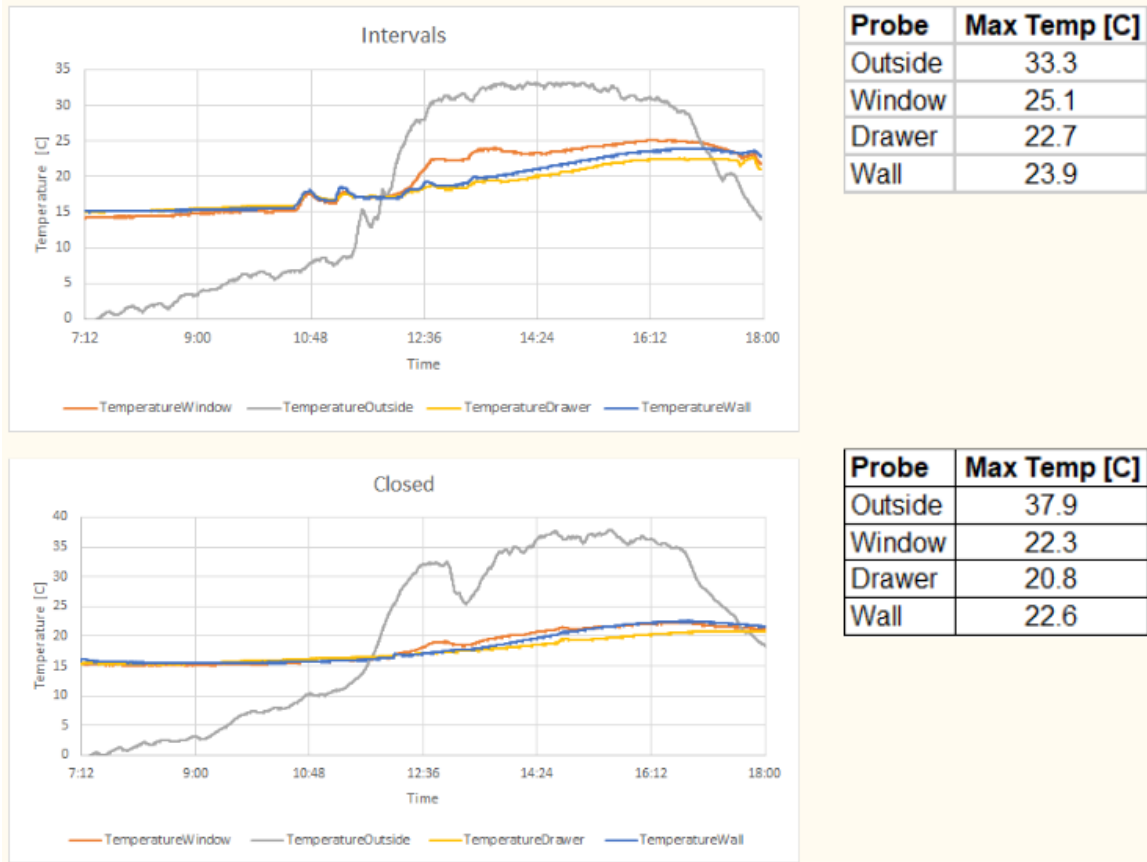


Fig. 5: Graphs of the temperature throughout the testing day for both the interval testing (top) and the closed testing (bottom), each accompanied by tables with the peak values from each sensor.

The next graph, Fig. 6, demonstrates that despite the day with interval testing being the median temperature over the various tests, consistently higher temperatures were observed on average when blind angle was not only accounted for, but actively adjusted throughout the day. This also raises a question of whether a product of this nature could be effective during warmer months, since it was determined that ambient light levels were fairly constant and negligible compared to the differing tests and that on the closed blind days the temperature was always cooler.

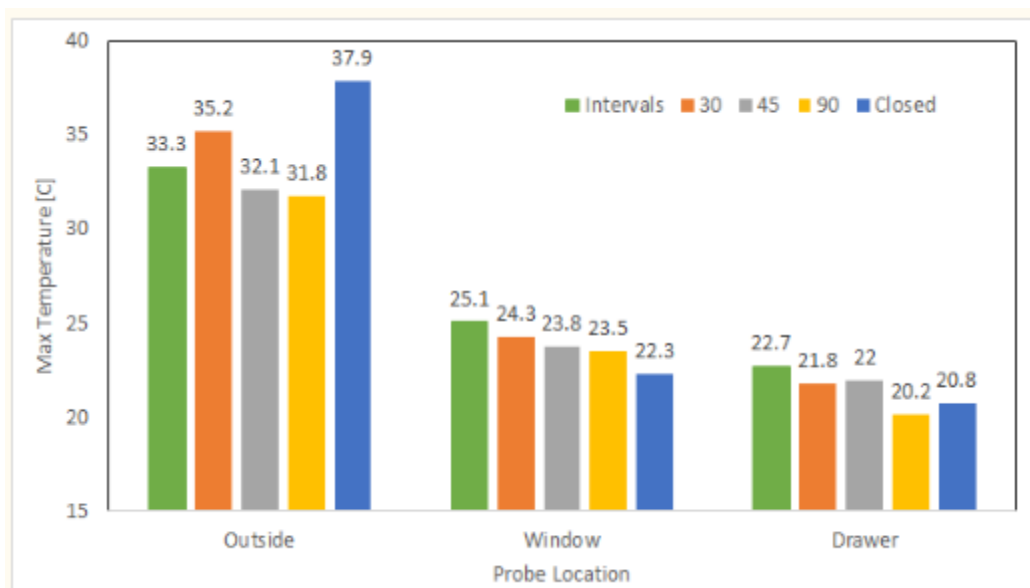


Fig. 6: Max temperature readings outside, directly inside the window, and at the drawer for the interval, 30°, 45°, 90°, and closed positions. The wall sensor was omitted due to inconsistencies from the effects of conduction and convection.

An approximated annual return of investment was calculated using the test results and then extrapolated over the span of the year to give an estimate of cost savings. At an average temperature difference of 2.73°C and maximum temperature difference of 5°C between the interval and constant position tests, an energy usage of 0.020 kilowatt hour per hour was determined mathematically. From the data collected and the Nevada rate for electricity at \$0.0912 per kilowatt hour, an annual return of roughly \$9.00 per year was obtained. It is worth mentioning that this was only a test of the products ability to heat a space, more testing to observe the products ability to cool a space would be needed to confirm this figure or provide a more accurate estimation.

Manufacturing Plan

Product Overview

Blinding Sun Systems is making Solar Sensing Blinds. This is an aftermarket product that will attach to the turning mechanism of window blinds. The device is made of two separate housings. One holding a solar panel and sensors, and the other holding the motor, batteries, and circuit board. The device uses solar data collected by photocells attached to the window of the system to calculate the optimum angle for heating and cooling, without sacrificing light levels. The system then turns the blinds via a small motor to match the calculated angle. Solar Sensing Blinds are powered by a solar panel that is attached to the window with the photocells. The housing that attaches to the blinds also has a manual override joystick, allowing for opening a closing at desired times.

Flow Diagrams

The primary process that would be enacted to mass produce Blinding Sun Systems' Solar Sensing Blind device would be injection molding. Injection molding would be utilized due to its ability to precision form complex geometries, easy replicability, and low material cost after the high initial investment required for tooling. Injection molded parts would include the outer plastic housing, the motor hook cap, the motor base holder, the solar panel housing, and the photocell dome housing. Polypropylene would be a good choice of material due to its low price point, easy workability, versatility, and resistance to repeated cyclic fatigue in non-load bearing applications. Fig. 1 in Appendix B details the specific processes that would be used to produce detail part BSS-P-001. A similar process

will be adapted for detail parts BSS-P-002, BSS-P-003, BSS-P-004, which are all listed below in Table 1 in Appendix A.

Outside of the injection molding of the very specific plastic pieces, the rest of the materials, such as printed circuit boards, photocells, motor, solar panel, battery and wiring would be ordered from outside vendors in bulk and introduced to the process in the final assembly stage. Manufacture would be very limited for these off the shelf components, with the main focus being on connections through clips and interference fits, adhesion, and soldering.

Manufacturing Risk Management

Likely the biggest manufacturing challenge that Blinding Sun Systems would face in mass production would be in regards to the up-front costs. 3D printers may be utilized short term and in prototyping, but as sales begin to increase, plastic injection molding equipment and space would be required to produce the custom plastic parts that we require for our product(s). Fortunately, developing all of our own plastic parts (instead of purchasing OTS parts) will yield strong, long-term savings for manufacturing. To protect ourselves from failure, we would need to ensure that we have the support for our product before we invest hundreds of thousands of dollars in the mass manufacture of our products. Part of our risk management plan would be to begin initial development with 3D printing technologies. 3D printing has the ability to produce all the required parts fairly inexpensively - at least in the short term (up to 1 year to produce about 2,500 parts). At this point, Blinding Sun Systems would have easily broken even (without significant

compensation), and would be able to provide an initial investment on injection molding technology.

Prior to this, to ensure that the investment can make provide the required returns, marketing would ramp up to increase sales and justify the purchase of injection molding technology and mass production of Solar Sensing Blinds. At this point, manufacturing costs would decrease to approximately \$16-\$18 per unit, compared with about \$20-\$24 per unit.

Conclusion

While much further work would be required to bring a solar sensing blinds device to market as speculated in this thesis, much of the groundwork is covered and provided for in the text above. Initial iterations of the device in physical form and coding functionality helped to not only visualize how this solution to the problem of energy inefficiency in homes could function, but also how it could be greatly improved with further investment and commercialization. Blinding Sun Systems also proved that a blind automation device could provide a cost savings of roughly \$9.00 per year to the consumer in addition to being a novelty smart home automation product that could conveniently turn a typically ignored part of the home into a source of savings. With a further optimized product and future integration into an entire smart home system, this figure could even to increase and be used in applications such as affixing solar panels to blinds to generate electricity for homes.

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Appendices

Appendix A – Hazard Identification

PURPOSE

This document provides a framework of identifying potential hazards of the Solar Sensing Blinds. Hazards will be considered under normal, anticipated conditions and failure modes.

PRODUCT USE DESCRIPTIONS

Intended Use

To automatically open and close house/office blinds, such that energy costs are noticeably reduced. Product should have minimal installation and an extremely long life independent of the end user.

Intended User

Homeowners/Home Developers/Offices

Intended Use Environment

Room temperature and standard humidity. The sensor should also operate with the varying temperatures of the window it is installed on.

HAZARD IDENTIFICATION

HID	D/P/S	Category	Failure Mode	Hazardous Situation
13.HID.1.1	D	1	Failure to sufficiently warn user of hazard.	Manual interference (hand in blinds)
13.HID.1.2	D	1	Failure to properly instruct user on proper installation.	Over-rotation of blinds
13.HID.1.3	D	1	Failure to properly instruct user on proper installation.	Rotation in wrong direction
13.HID.2.1	P	2	Failure to properly wire circuit and/or inform the user of when to dispose of the battery.	Battery failure
13.HID.4.1	D	4	Failure to properly house components and/or inform the user of proper use of the device during inclement weather.	Open window – rain damage to electrical components inside plastic housing
13.HID.4.2	D	4	Failure to provide a secure mounting mechanism.	Open window – wind may dislodge device from mount.
13.HID.6.1	D	6	Failure to properly enclose housing and warn user of hazards present upon opening the housing.	Pinch hazard from moving parts within housing
13.HID.7.1	D	7	Failure to properly wire circuit.	Electrical current output
13.HID.8.1	D	8	Failure to sufficiently warn user of hazard.	Potential choking hazard on small components.

13.HID.8.2	D	8	Failure to sufficiently protect solar panel within housing.	Solar panel glass shattering
13.HID.11.1	D	11	Failure to properly program device data system.	Conflicts between historical data and sun-tracking data.
13.HID.13.1	D	13	Failure to properly instruct user on proper cleaning techniques.	Solar Cell damage due to improper cleaning.
13.HID.19.1	D	19	Failure to inform user of proper disposal method.	Battery disposal
13.HID.21.1	D	21	Failure to warn user about improper manual control of blinds.	User control of blinds may damage device motor
13.HID.21.2	D	21	Failure to adequately inform user of proper device handling techniques.	User damage caused to blinds may damage device.
13.HID.21.3	D	21	Failure to properly instruct user on where to place sun tracking mechanism.	Improper rotation on blinds
13.HID.25.1	D	25	Failure to properly inform user of potential consequences of this product on existing blind systems.	Connections with blinds may cause damage

(D - Design, P – Production, S – Supplier)

Appendix B – Product Design Specifications

PURPOSE

This document defines the project requirement specifications for the Solar Sensing Blinds, which function as the design inputs of the project as an origin for traceability throughout the project. Additionally, this document provides defining guidance on identifying project design specifications.

PRODUCT USE DESCRIPTIONS

Intended Use

To automatically open and close house/office blinds, such that energy costs are noticeably reduced. Product should have minimal installation and an extremely long life independent of the end user.

Intended User

Homeowners/Home Developers/Offices

Intended Use Environment

Room temperature and standard humidity. The sensor should also operate with the varying temperatures of the window it is installed on.

PROJECT REQUIREMENT SPECIFICATIONS

PRS	Category	Requirement
13.PRS.1.1	1	Total cost to the consumer should be less than \$40 as a similar product exists at this price point. Total manufacturing cost should be \$25 or less.
13.PRS.1.2	1	Product should be modular in nature, as to not obstruct the window but still control the blinds.
13.PRS.2.1	2	Product will have to work at a variety of humidity levels.
13.PRS.3.1	3	Product should house circuitry and mechanical components should fit within a housing of no more than 30 cubic inches.
13.PRS.3.2	3	Product should be able to detect when calibration is necessary and self-calibrate.
13.PRS.3.3	3	Product should be able to clear stored data automatically.
13.PRS.3.4	3	Product will be wired from main system to a photocell configuration on a window.
13.PRS.3.5	3	Product will feature buttons that may turn the blinds manually.
13.PRS.4.1	4	Product should perform in standard office or home environments.
13.PRS.5.1	5	The motor used should be wear resistant.
13.PRS.5.2	5	Sensor used should be able to handle glass temperatures on the current natural hottest day globally.
13.PRS.5.3	5	System should be protected from condensation via an enclosed casing that won't allow moisture to contact electrical components.
13.PRS.6.1	6	Program should run the system independently.
13.PRS.8.1	8	Product should include a manual with warnings, instructions, installation procedure, and recycling instructions. Warnings should include, but are not limited to: warnings about disassembly, improper use of manual override, and potential damage that could be caused to existing blind system in case

		of failure. Instructions should include, but are not limited to: how to properly handle the device.
13.PRS.9.1	9	Product should be single installation and operable for long-term use.
13.PRS.9.2	9	Product should include instructions for a single, secure installation and for selecting and cleaning the installation area as to prevent possible malfunctions.
13.PRS.10.1	10	Product must have the ability to function continuously with the use of a solar panel.
13.PRS.11.1	11	System powered by a battery solar panel; electrical safety requirements should be met.
13.PRS.11.1	11	System casing should have no sharp edges.
13.PRS.12.1	12	Product should follow the safety regulations of all relevant US agencies

Appendix C – Initial Models and Concepts

DESIGN CONCEPT A - ALEX POLES

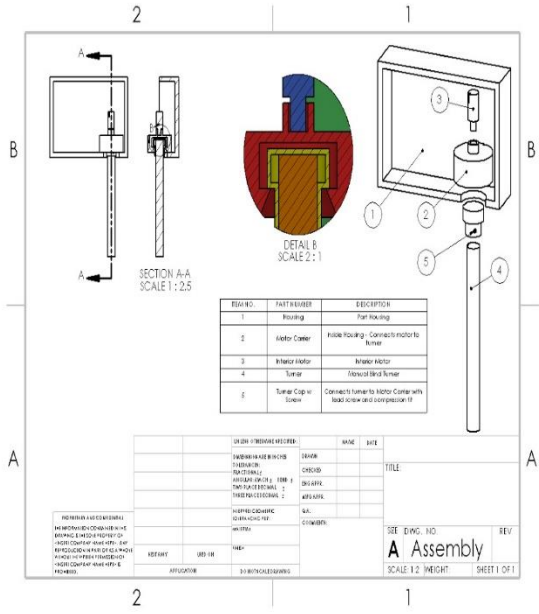


Fig. 1: Design concept A by Alex Poles featuring a motor connected to cap that holds the user’s already owned turner in place. The design will also attach a hook to the motor which will drive the movement of the blinds.

DESIGN CONCEPT B - MARK MARTINEZ

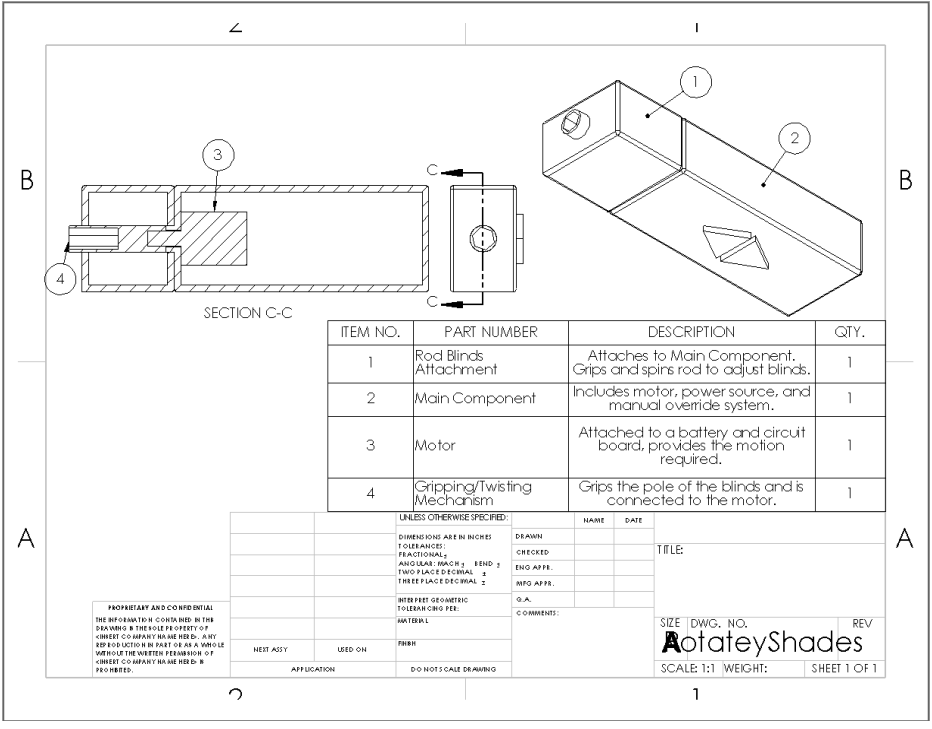


Fig. 2A: Housing and mechanical components designed by Mark Martinez in design B for blind systems that utilize a rod.

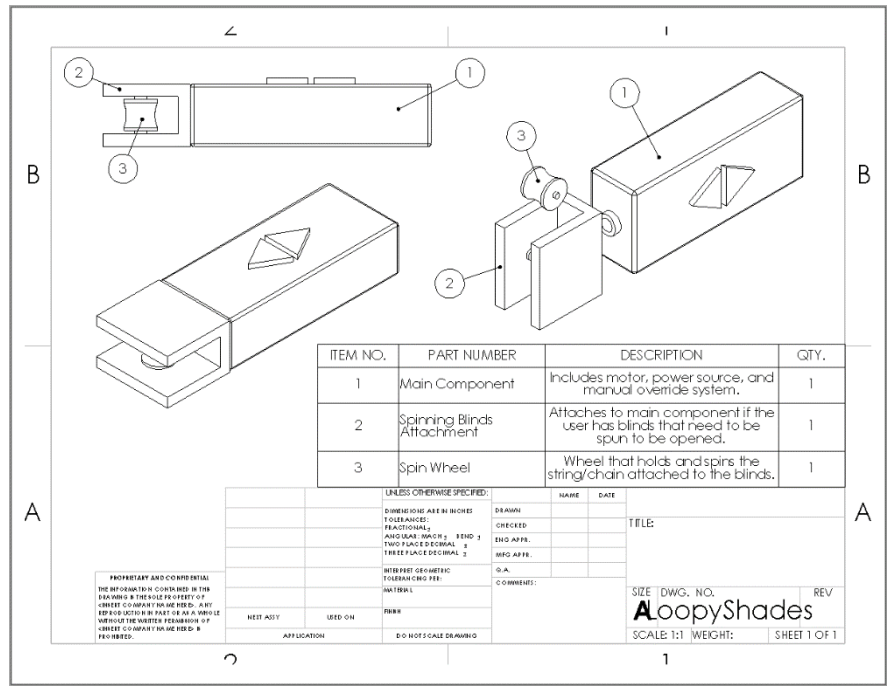


Fig. 2B: Housing and mechanical components designed by Mark Martinez in design B for blind systems that utilize a pulley system.

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Pseudo-Code:
IF Up directional manual override button is pressed
    Motor on clockwise
ELSEIF Down directional manual override button is pressed
    Motor on counterclockwise
ELSE Read light sensor
    For A lot of light
        If Blinds are open
            "Close Blinds" Motor on counterclockwise
        If Blinds are closed
            Do nothing
    For A medium amount of light
        If Blinds are open
            Do nothing
        If Blinds are closed
            "Open Blinds" Motor on clockwise
    For no light
        If Blinds are open
            "Close Blinds" Motor on counterclockwise
        If Blinds are closed
            Do nothing
End
    
```

Fig. 2C: Pseudocode designed by Mark Martinez depicting some basic functions for the blind system.

DESIGN CONCEPT C - ALEX BAGLIONE

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Motor w/ Hook	The motor used to power blind adjustment.	1
2	Motor/Rod Connector	Pin connector fastening the motor to the rod.	1
3	Manual Rod	Rod allowing for manual override of blinds.	1
4	Pin	Pin fastener.	1

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DATE: 10/21/2011
 DRAWN BY: A. BAGLIONE
 CHECKED BY: M. MARTINEZ
 APPROVED BY: M. MARTINEZ

SCALE: 1:8 WEIGHT: SHEET 1 OF 1


```
for "light sensor input" range x1:xmax
  if "change in light sensor input" < 1 minute
    no action
  elseif
    engage motor

if manual rod turns
  for time= 1 hour
    disengage motor
elseif
  turn motor on

if "light sensor input" < x1
  no action
if "light sensor input" = xmax
  blind angle = 90 degrees
elseif
  adjust blind angle x degrees

for time >= 1 hour
  if "light sensor input" <= xmin
    close blinds
    power device off
```

Fig. 3C: Rough pseudo code idea by Alex Baglione for design concept C

DESIGN CONCEPT D - JEFFERY HOKE


```
Sensor = 0
While system on
Value = sensor
Sensor_1 = light value of sensor 1
Sensor_2 = light value of sensor 2
Sensor_3 = light value of sensor 3
Sensor_4 = light value of sensor 4
Sensor = (Sensor_1+Sensor_2+Sensor_3+Sensor_4)/4
If sensor > value
Motor run proportional control positive
Else if sensor < value
Motor run proportional control negative
Else
Reset to closed position
End
If motor change > 1
End while
Else continue while
End
```

Fig. 4C: Pseudo code developed for Design D by Jeff Hoke

DESIGN CONCEPT E - JENS CHRISTIANSEN

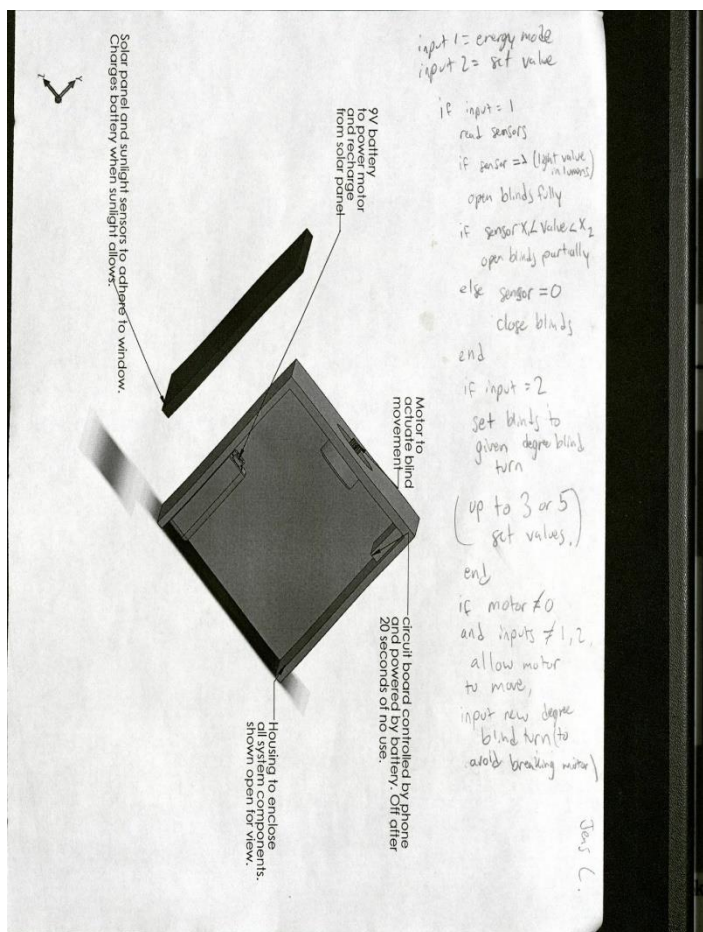


Fig. 5: Housing and mechanical components designed by Jens Christiansen in design E feature a motor connected directly to the user's already owned turning rod. The design will also attach a hook to the motor which will drive the movement of the blinds.

Appendix D – Formal Decision Making Process

1. DECISION MATRIX

Table 1: The formal decision matrix the team used to quantify the final design concept that should be utilized. The Top row indicates the weight apportioned to each category. The values in green indicate the summed score of each sub-function. Only two sub-functions were compared for each category.

		Weight:	3	1	2	3	0	1	4	5	
		Criteria:	Ease	Manufacturability	Inexpensiveness	Marketability	Survey Weight	Survey Results	Consumer Ease of Use	Likeability	
Manual Override	Buttons	Alex P.	3	1	5	3	5	5.7	3	1	
		Mark M.	3	3	3	3	3	5.7	5	3	
		Jeff H.	1	1	3	5	3	5.7	5	3	
		Jens C.	3	1	3	1	3	5.7	5	1	
		Alex B.	3	3	5	5	5	5.7	3	3	
			7.6	1.8	3.8	3.8	3.8	5.7	4.2	2.6	
	Built in Rod	Alex P.	1	5	5	3	5	4	5	5	80.1
		Mark M.	3	3	3	3	3	4	5	3	
		Jeff H.	5	5	3	3	3	4	5	3	
		Jens C.	5	3	3	5	3	4	3	5	
Alex B.		3	3	3	1	5	4	5	3		
		4.2	3.8	3.4	3	3.8	4	4.6	3.8		
Amount of Solar Sensors	2	Alex P.	5	0	5	0	0	15.2	18.4	19	84.8
		Mark M.	3	0	3	0	0	0	0	3	
		Jeff H.	5	0	3	0	0	0	0	1	
		Jens C.	3	0	5	0	0	0	0	3	
		Alex B.	3	0	3	0	0	0	0	1	
			3.8	0	3.8	0	0	0	0	1.8	
	4	Alex P.	1	0	5	0	0	0	0	9	28.0
		Mark M.	3	0	3	0	0	0	0	3	
		Jeff H.	1	0	3	0	0	0	0	5	
		Jens C.	3	0	3	0	0	0	0	5	
Alex B.		3	0	3	0	0	0	0	5		
		2.2	0	3.4	0	0	0	0	4.6		
Operation Notification	LED During Motion Only	Alex P.	5	0	0	5	5	2.6	0	5	36.4
		Mark M.	5	0	0	5	5	2.6	0	3	
		Jeff H.	1	0	0	3	5	2.6	0	3	
		Jens C.	3	0	0	3	5	2.6	0	5	
		Alex B.	3	0	0	5	3	2.6	0	5	
			3.4	0	0	4.2	4.6	2.6	0	4.6	
	LED always on	Alex P.	10.2	0	0	12.6	0	12.0	0	23	57.8
		Mark M.	5	0	0	3	5	1.8	0	3	
		Jeff H.	3	0	0	3	5	1.8	0	1	
		Jens C.	5	0	0	3	5	1.8	0	3	
Alex B.		5	0	0	3	5	1.8	0	3		
		4.6	0	0	3	4.6	1.8	0	1.8		
Battery Life Notification	Blinds Auto Close	Alex P.	1	0	0	9	0	8.3	0	9	40.1
		Mark M.	3	0	0	5	0	0	0	3	
		Jeff H.	1	0	0	5	0	0	0	3	
		Jens C.	1	0	0	1	0	0	0	1	
		Alex B.	3	0	0	3	0	0	0	3	
			1.8	0	0	3	0	3.4	0	2.6	
	LED color change	Alex P.	5.4	0	0	9	0	13.6	0	13	41
		Mark M.	5	0	0	3	0	0	0	3	
		Jeff H.	1	0	0	3	0	0	0	1	
		Jens C.	5	0	0	5	0	0	0	5	
Alex B.		5	0	0	5	0	0	0	5		
		3.8	0	0	3.8	0	3.8	3.4	3.4		
Attachment Method	Attach Housing to Hook at Top	Alex P.	11.4	0	0	11.4	0	15.2	17	55	
		Mark M.	5	3	0	5	3	5.3	3	5	
		Jeff H.	5	1	0	3	5	5.3	1	3	
		Jens C.	5	5	0	3	3	5.3	5	5	
		Alex B.	3	3	0	5	5	5.3	1	3	
			4.6	3	0	4.2	4.2	5.3	2.6	4.2	
	Attach at Bottom of Rod	Alex P.	13.8	3	0	12.6	0	22.3	10.4	21	83.06
		Mark M.	3	5	0	3	5	4.1	3	1	
		Jeff H.	1	1	0	3	3	4.1	3	3	
		Jens C.	3	5	0	5	5	4.1	5	3	
Alex B.		1	1	0	1	3	4.1	5	3		
		1.8	3	0	2.6	4.2	4.1	4.2	2.6		
Device Calibration	Only calibrate at Install	Alex P.	3.4	3	0	7.8	0	17.2	16.8	11	63.22
		Mark M.	3	0	0	3	0	0	0	1	
		Jeff H.	5	0	0	3	0	0	0	3	
		Jens C.	5	0	0	5	0	0	0	1	
		Alex B.	3	0	0	1	0	0	0	1	
			3.8	0	0	3.4	0	0	0	1.4	
	Nightly Recalibrate	Alex P.	11.4	0	0	10.2	0	0	0	7	28.6
		Mark M.	1	0	0	3	0	0	0	5	
		Jeff H.	1	0	0	3	0	0	0	5	
		Jens C.	1	0	0	3	0	0	0	1	
Alex B.		5	0	0	3	0	0	0	5		
		1.8	0	0	3	0	0	0	4.2		
Motor Adjustment Frequency	>15	Alex P.	5.4	0	3	5	5	4.4	0	21	35.4
		Mark M.	0	0	3	3	5	4.4	0	3	
		Jeff H.	0	0	3	3	5	4.4	0	1	
		Jens C.	0	0	3	3	5	4.4	0	5	
		Alex B.	0	0	3	3	5	4.4	0	3	
			0	0	3	3	5	4.4	0	3.4	
	<15	Alex P.	0	0	6	9	0	22.0	0	17	54
		Mark M.	0	0	1	3	5	5.6	0	1	
		Jeff H.	0	0	1	3	5	5.6	0	3	
		Jens C.	0	0	1	5	5	5.6	0	1	
Alex B.		0	0	1	3	5	5.6	0	3		
		0	0	1	3.4	5	5.6	0	2.6		
		0	0	2	10.2	0	28.0	0	13	53.2	

2. MARKET SURVEY RESULTS

How are the blinds at YOUR living space adjusted?

Answered: 75 Skipped: 0

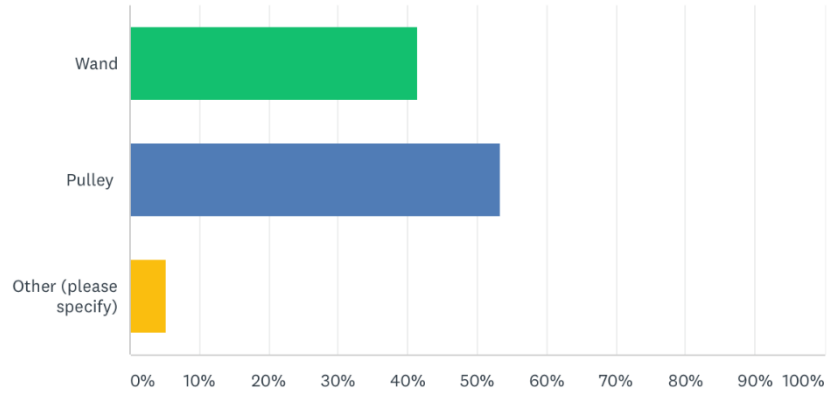


Fig. 1: Survey question 1.

Would you like this product to attach to an existing blind adjustment system or replace the blind adjustment system altogether?

Answered: 75 Skipped: 0

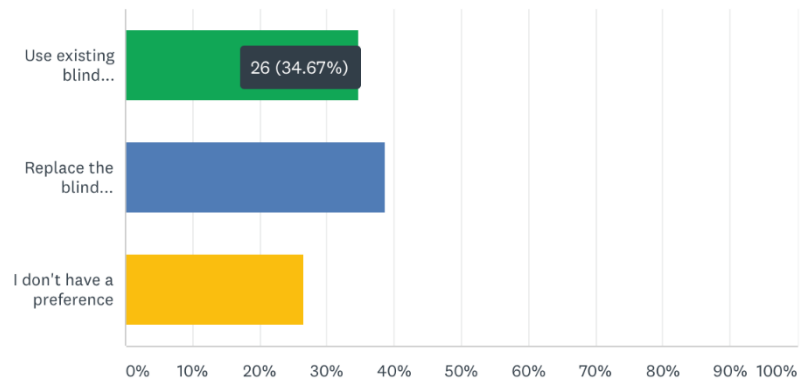


Fig. 2: Survey question 2.

If there were an LED indicator light, when would you prefer that it be lit?

Answered: 75 Skipped: 0

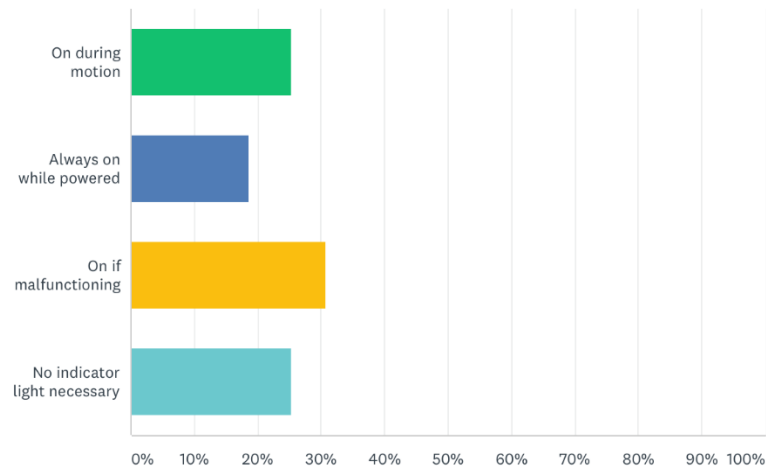


Fig. 3: Survey question 3

IF we have the time, we would like to power this device via solar energy instead of a battery. How important would this feature be to you?

Answered: 75 Skipped: 0

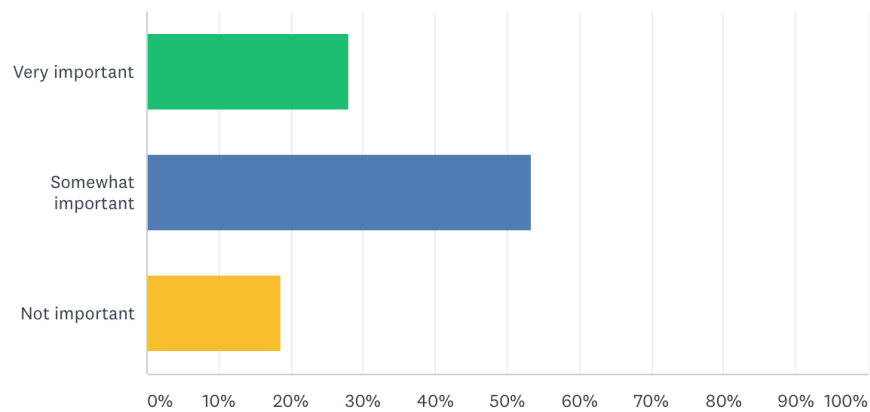


Fig. 4: Survey question 4

Please rank the following potential modes of operation by importance (1=most, 4=least):

Answered: 75 Skipped: 0

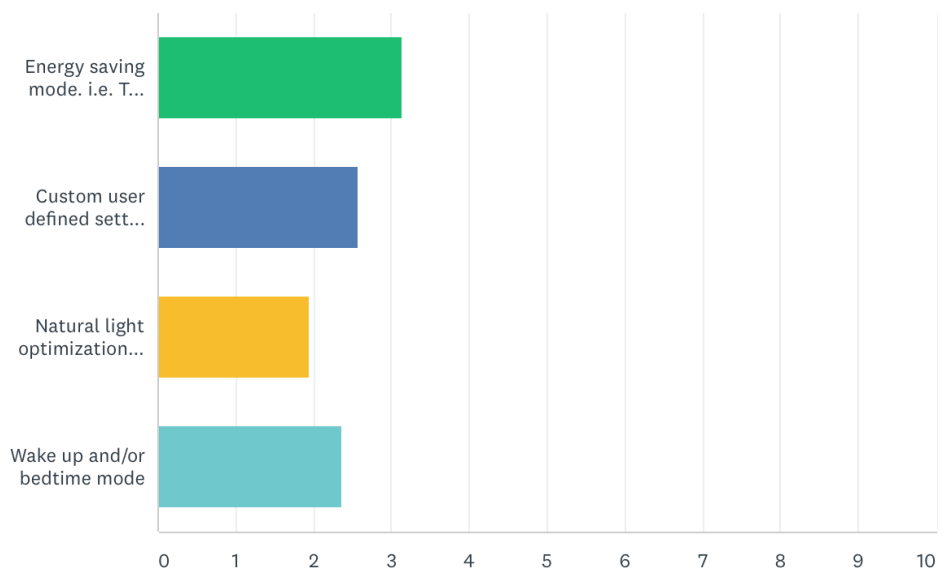


Fig. 5: Survey question 5

How often would you like the blinds to make an adjustment?

Answered: 75 Skipped: 0

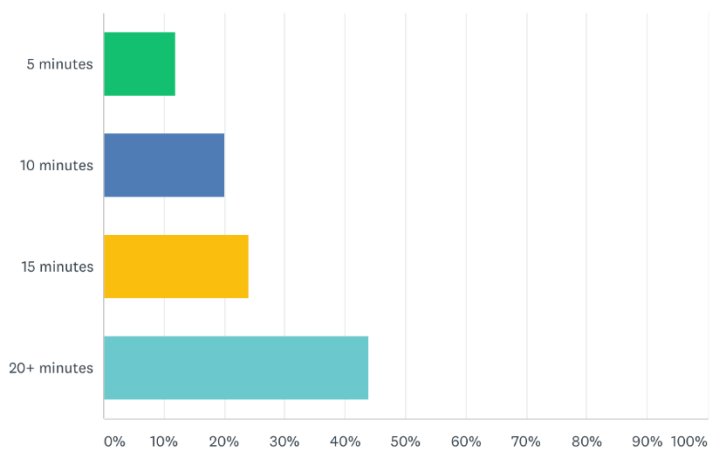


Fig. 6: Survey question 6

For the manual override option, would you prefer:

Answered: 75 Skipped: 0

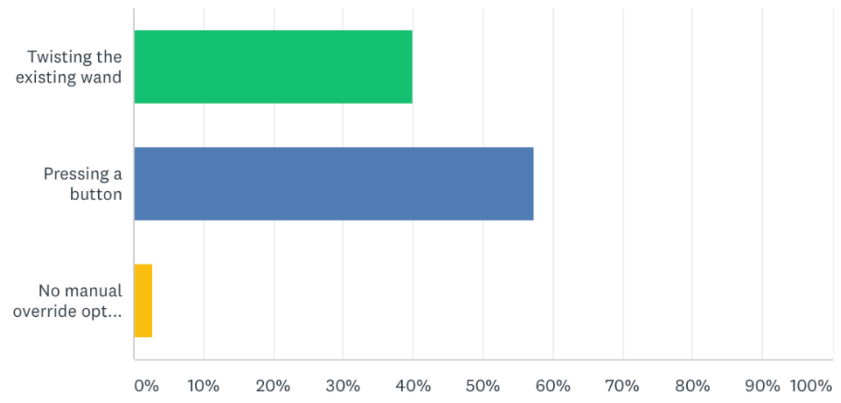


Fig. 7: Survey question 7

Based on your current understanding, could you see yourself using this product?

Answered: 75 Skipped: 0

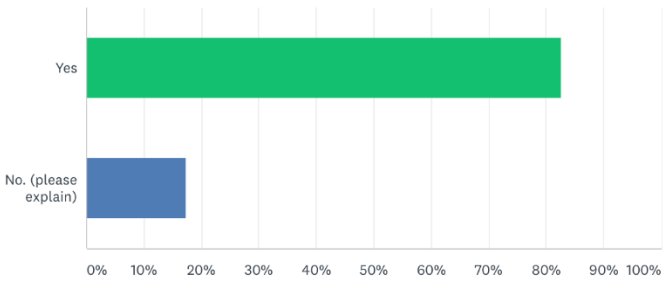


Fig. 8: Survey question 8

What price range would you expect to pay for this product?

Answered: 75 Skipped: 0

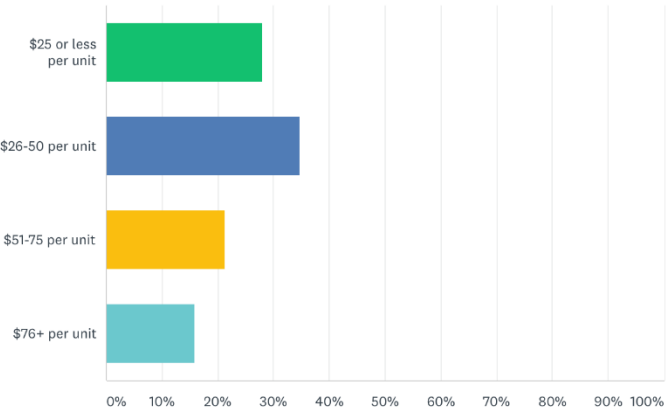


Fig. 9: Survey question 9

3. SELECTED DESIGN BASED ON DECISION MATRIX

Table 2: A summary of the results that were determined from the decision matrix shown in Table 4 above. The items in bold indicate the “winner” of the category.

Manual Override	Buttons	80.1
	Built in Rod	84.8
Amount of Solar	2	28.0
	4	36.4
Operation Notification	LED During Motion Only	57.8
	LED always on	40.1
Battery Life Notification	Blinds Auto Close	41.0
	LED color change	55.0
Attachment Method	Attach Housing to Hook at Top	83.1
	Attach at Bottom of Rod	63.2
Device Calibration	Only calibrate at Install	28.6
	Nightly Recalibrate	35.4
Motor Adjustment	>15	54.0
	<15	53.2

4. FORMAL ENGINEERING ANALYSIS

Table 3: Estimated calculation results determined based on potentially usable components.

Estimated Axial Weight of Unit	0.8lb = 3.5N
Estimated Motor Torque Required	4.5N-mm
Estimated Power Usage	870.92 mWh consumed, 972 mWh gained

Table 4: Specifications of Ambient Light Sensor SFH 3711

SFH 3711 Ambient Light Sensor			
Cost per Unit	Operating Time*	Peak Wavelength	Operating Temperature
\$0.21	4807.69 days	570 nm	-40 C to +85 C

Table 5: Specifications of Rechargeable Battery Panasonic LC-R064R5P

Panasonic LC-R064R5P			
Cost per Unit	Voltage	Current Capacity	Dimensions
\$14.75	6V	4500mAh	71.0mm x 49.0mm x 103.2mm

Table 6: Specifications of Solar Cell Ixolar SLMD480H12L\

Ixolar SLMD480H12L			
Cost per Unit	Voltage	Current	Dimensions
\$7.64	6.06V	18mA	22.00mm x 35.00mm x 2.00mm

Table 7: Power Requirements of each component. The negative value for the solar cell represents power gained by the system.

Power Consumption				
1 x Sensor	4 x Sensor	Motor (Static)	Motor (Loaded)	Solar Cell
4.68 mWh	18.72 mWh	810 mWh	42 mWh	-972 mWh
Total:				-101.28 mWh

Axial Weight of device:

Givens:

Table 8: Given values for blind attachment device component weight.

Battery Weight, W_b [lb]	0.1
Motor Weight, W_m [lb]	0.2

Other Weight, W_o [lb]	0.5
--------------------------	-----

$$W_T = W_B + W_M + W_O = 0.8 \text{ lb}$$

$$[0.8 \text{ lb}] * [0.454 \text{ kg/lb}] * [9.81 \text{ ms}^2] = 3.5 \text{ N}$$

Required Torque to Rotate Blinds:

Assume that low torque required to twist blinds.

$$\text{Approximate } T_{\text{Req}} = 1 \text{ lb-mm} = 4.5 \text{ N-mm}$$

Weight of Electrical System:

Givens:

Circuit Board dimensions: 4X6 cm

Table 9: Given values for sensor and circuit housing device component weight.

Sensor Weight, W_s [lb]	0.0022
Circuit Board Weight, W_c [lb]	0.15
ABS Weight Density, D_{ABS} [lb/in ³]	0.0387

$$W_{\text{ABS}} = D_{\text{ABS}} * L * W * T = 0.0387 * 1.75 * 2.5 * 1.25 = 0.212 \text{ lb}$$

$$W_T = W_{\text{ABS}} + 4 * W_s + W_c = 0.37 \text{ lb}$$

Power of Electrical System

Assumptions:

Light is available 9 hours per day

The motor will adjust for 5s in increments of 15 minutes for the above 9 hour period.

Givens:

Battery: Panasonic LC-R064R5P Rechargeable

Solar Cell: Ixolar SLMD480H12L

Table 10: Given values for component electrical properties

Battery Capacity, C_B [mAh]	4500
Battery Voltage V_B [V]	6
Solar Cell Current, I_c [mA]	18
Solar Cell Voltage V_c [V]	6.06
Static Draw of Motor I_M [mA]	15
Load Draw of Motor I_{ML} [mA]	140
Draw of Sensor, I_s [μ A]	39

Power Consumption and Addition of Various Components:

$$P=IV$$

Power Draw of Single Light Sensor: $(39\mu A * 1 \text{ sensor}) * 1000 \mu A * 5V = .195mW$

Power Draw of Four Light Sensors : $(39\mu A * 4 \text{ sensors}) * 1000 \mu A * 5V = .78mW$

Static Power Draw of Motor: $(15mA * 1 \text{ motor}) * 6V = 90mW$

Loaded Power Draw of Motor: $(140mA * 1 \text{ motor}) * 6V = 840mW$

Power Addition of Solar Panel: $(18mA * 1 \text{ motor}) * 6V = 108mW$

Net Power Consumption Per Day:

$$P_{consumed} * \text{operational time} - P_{gained} * \text{operational time} = P_{Net}$$

$.78mW * 24 \text{ hours} + 90mW * 9 \text{ hours} + 840 mW * 180s * 1 h3600s - 108mW * 9 \text{ hours} = -101.28mWh$

Operational Time on Battery Life Only:

$$(CB/(I_s * n)) = t$$

Single Sensor Operating Time = $4500 \text{ mAh} / 39 \mu A * 1000 \mu A / 1 \text{ mA} * 1 \text{ day} * 24 \text{ h} = 4807.69 \text{ days}$

Four Parallel Sensors Operating Time = $4500 \text{ mAh} / 4 \text{ sensors} * 39 \mu A * 1000 \mu A / 1 \text{ mA} * 1 \text{ day} * 24 \text{ h} = 1201.92 \text{ days}$

$$(CB/IM) + (CB/IML) * Mf = t$$

Appendix E – Risk Analysis and Management Plan

RISK ANALYSIS

Engineering Risk Element							High Risk	Subtotal	Risk Assessment
Chapter	Technology	Environmental Impact	Resources Availability	Safety	Quality Requirements	Manufacturing Complexity			
Requirements and Specifications	0	0	2	0	1	0	≥7	3	Standard
System Design	5	1	0	0	4	3	≥13	13	High Risk
Engineering Design Review	1	0	0	0	4	2	≥10	7	Standard
Procurement and Implementation	2	1	1	1	1	2	≥19	8	Standard
Testing and Validation	0	0	1	0	3	0	≥7	4	Standard
Release to Operations	2	3	2	4	3	1	≥19	15	Standard
Final Documentation	0	1	0	0	5	0	≥7	6	Standard
Project Risk Elements							High Risk	Subtotal	Risk Assessment
Schedule	Interfaces	Experience or Capability	Project Funding	Public Impact	Project Reporting Requirements	Project Cost			
2	1	3	1	1	1	1	≥22	10	Standard

Fig. 1: The risk analysis performed by Team #13. A 1-5 scale of assessing risk was utilized at various stages of the project and a high risk criterion was calculated by using the formula $3n+1$, with n being the number of categories scored above a zero.

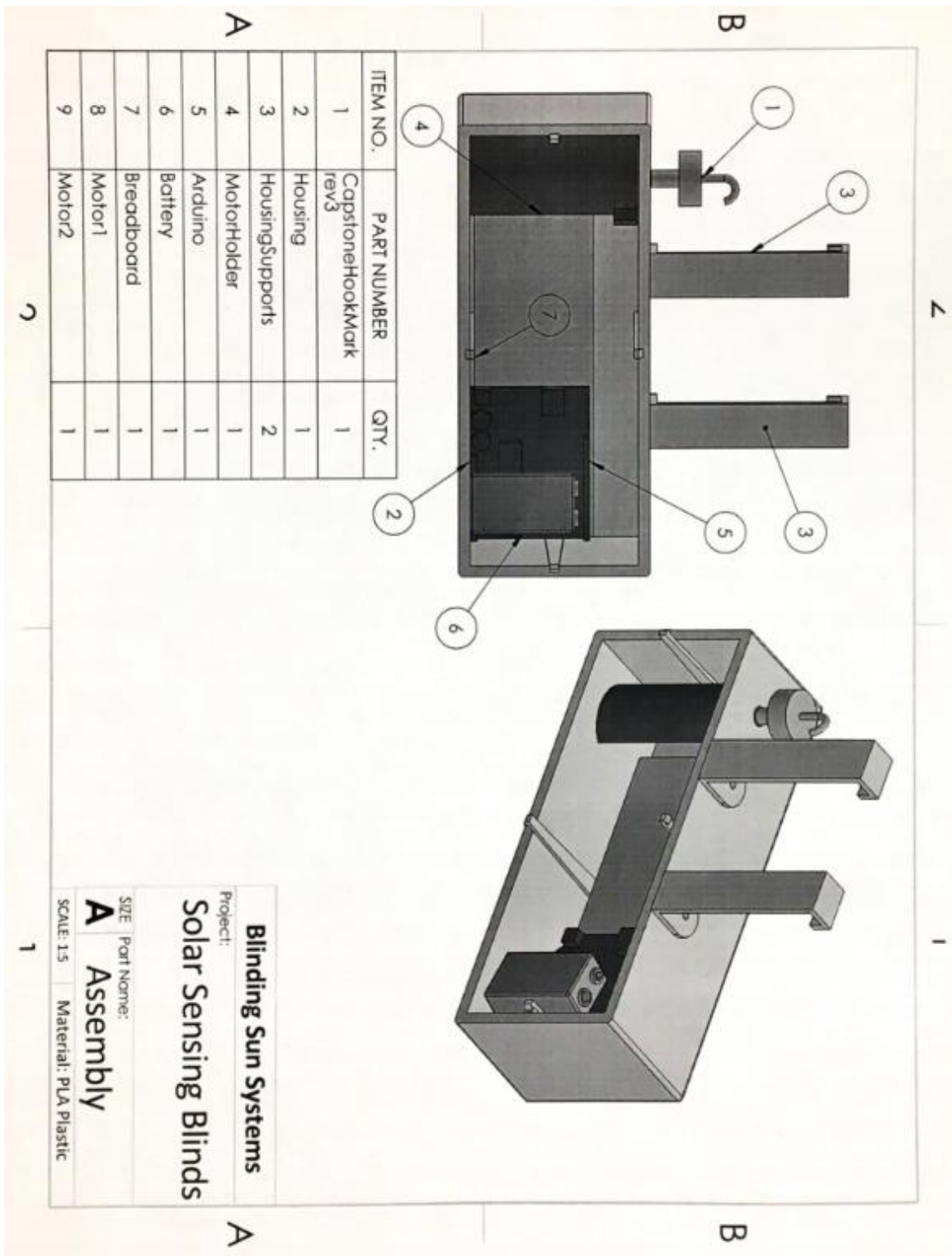
RISK MANAGEMENT PLAN

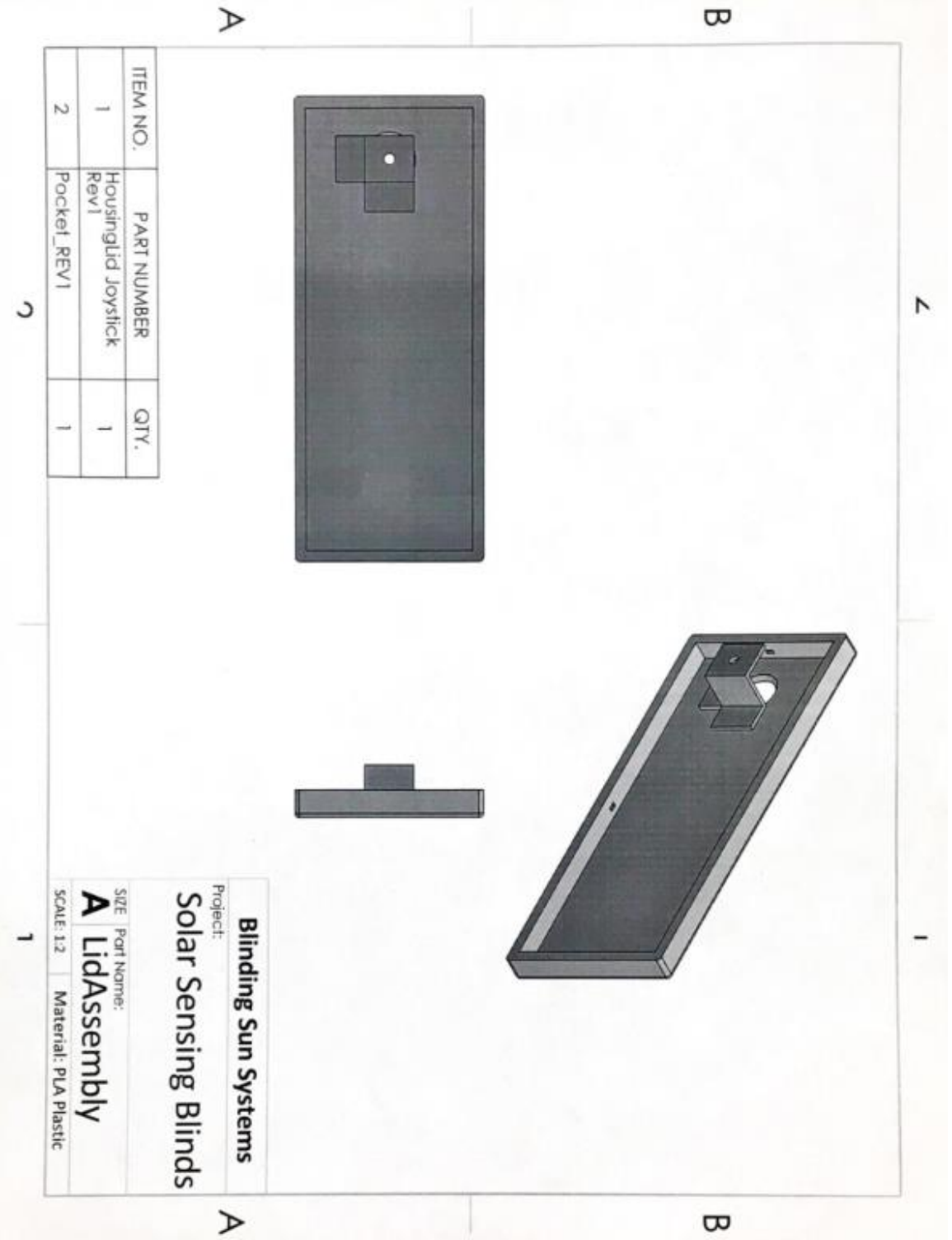
Table 1: The risk management plan performed by Team 13. This plan will be referred to for any future risks that the team will face when continuing the design. The risk items listed below were agreed upon as the most likely sources of risk for the project yet to be completed.

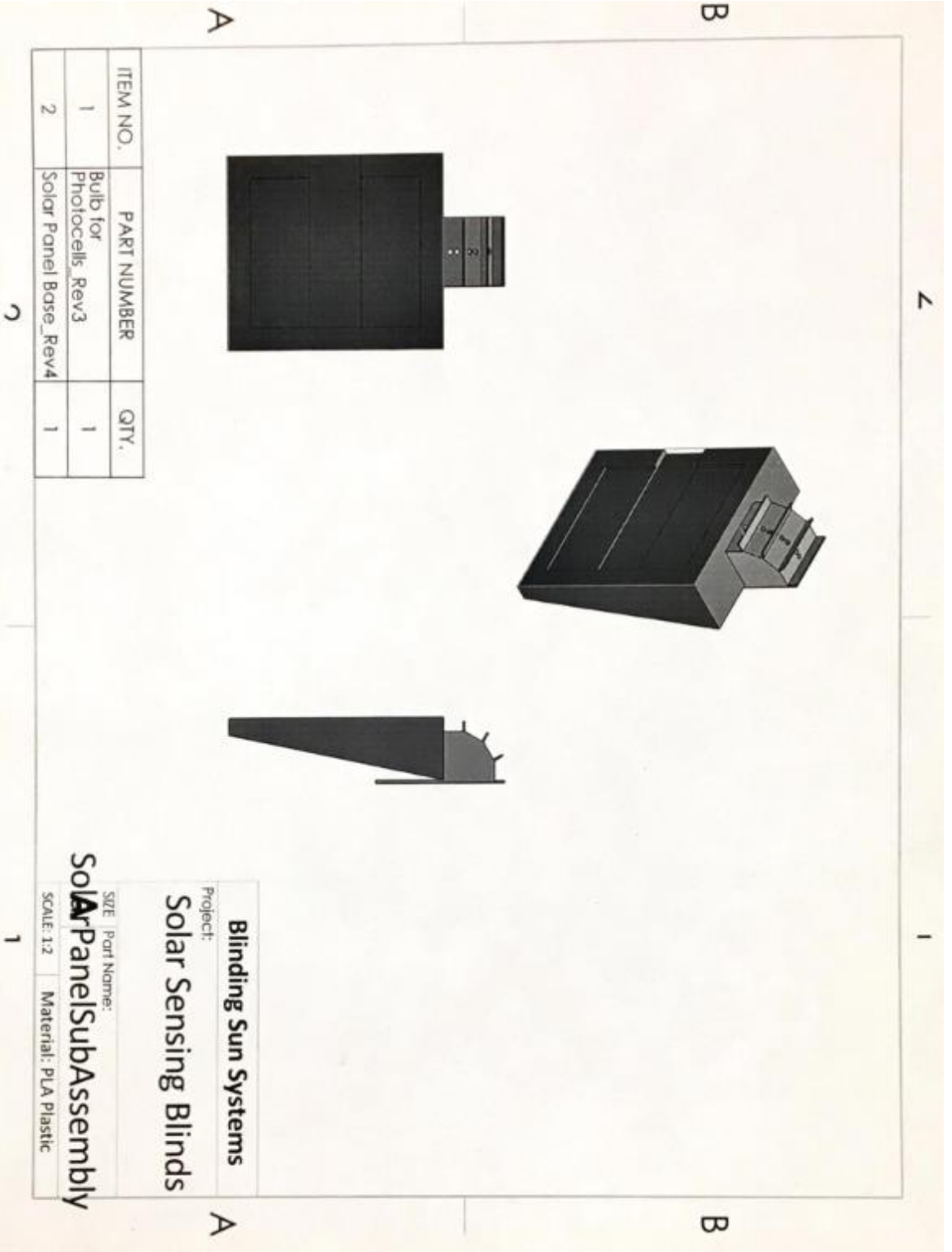
Risk Item	Risk Management Technique
Cost to manufacture	To reduce the cost of production the team will find the cheapest materials that adhere to the stability risk item below.
Ease of Installation	This risk is mitigated by having the product attach to the existing blind without any difficult or tedious steps.
Stability	The team will utilize materials with a safety factor of at least 1.5 for all components experiencing forces.
Ease of Manufacturing	Simplify all components requiring machining and limit the amount of material machining required
Practicality	Continually monitor the ratio of cost to risk and ensure that it is acceptable for all team members before proceeding

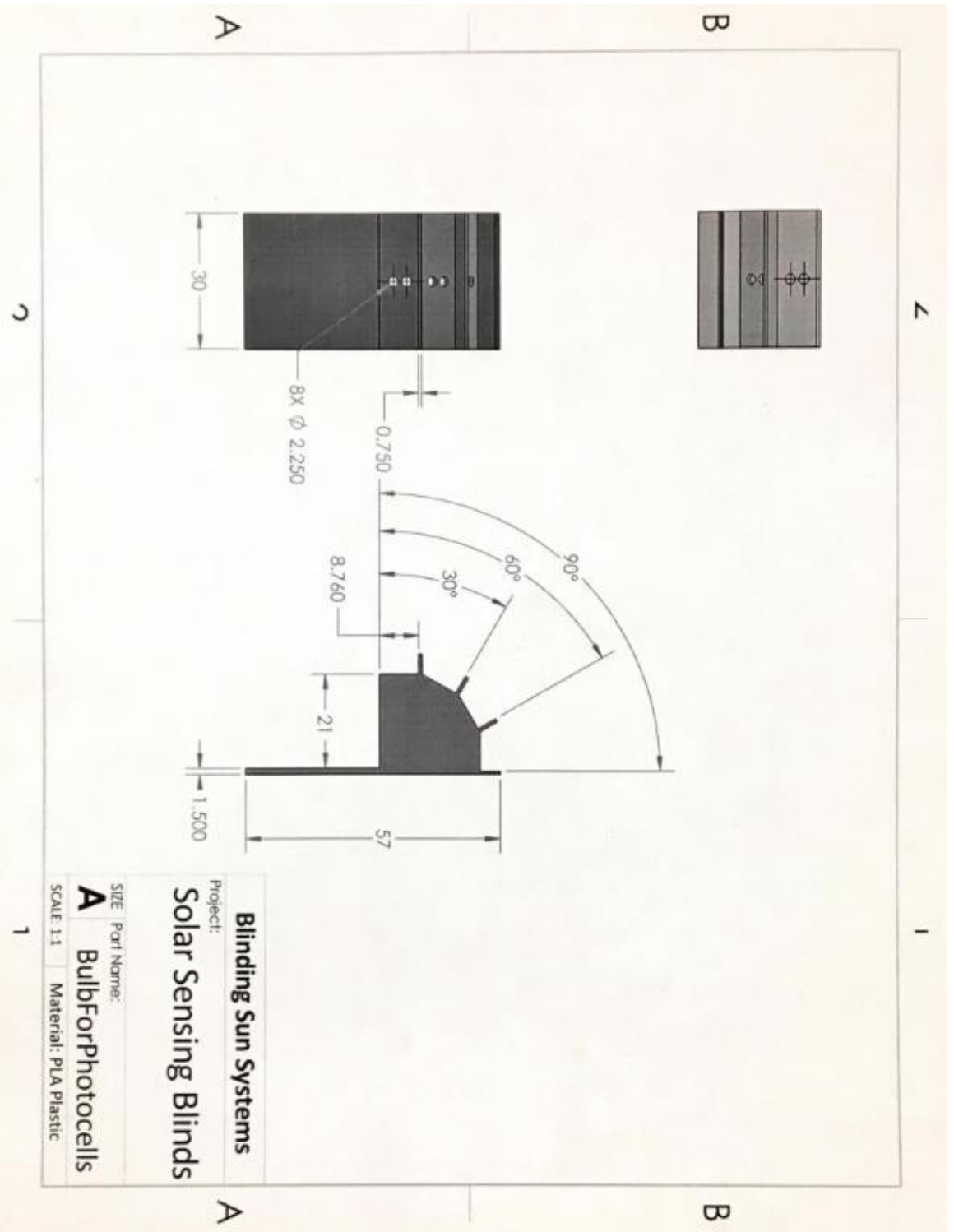
Energy Source	To control the risk of premature battery failure, the team is planning on implementing a recharge source. The backup plan is to increase the number or size of the existing battery
Coding	The team is willing to retain all coding difficulties that may arise. To ensure product usefulness, accepting this risk is required.

Appendix F – Released Product Design Drawings









2

1

B

B

A

A

2

1

Appendix G – Manufacturing Plan

Table 1: Parts list for the prototype model of Blinding Sun Systems’ device. All parts manufactured by Blinding Sun Systems have BSS part numbers and would be injection molded if brought to production. The other parts present would be consolidated with the use of printed circuit boards or changed to suit the needs of mass production.

Item No.	Manufacturer	Part No.	Part Name	Description	Quantity	Total Cost	Notes
1	Blinding Sun Systems	BSS-P-001	Plastic Housing	Outer case PLA 3D printed housing for components. Includes snap hook opening and closing system.	1	\$13.62	
2	Elegoo	28BYJ-48	Stepper Motor	5V DC Stepper Motor 4 Phase 100 Hz	1	\$1.89	
3	Blinding Sun Systems	BSS-P-002	Motor Cap with Hook	PLA 3D printed connector for motor attachment to blind system	1	\$0.26	
4	Blinding Sun Systems	BSS-P-003	Motor Base Holder	PLA 3D printed connector to fix motor base to plastic housing	1	\$0.83	
5	Energizer	NH22NBP	Battery	9V 175mAh Nickel-Metal Hydride Battery	2	\$14.78	
6	Seeed Technology	1597-1417-ND	Solar Panel	0.5W 55X70mm Solar Panel	1	\$1.95	
7	Adafruit	1528-2141-ND	Photocell	Photocell that changes resistance based on light exposure	4	\$3.80	
8	Elegoo	EL-CP-002	Circuit board	400 tie-points breadboard	1	\$3.33	Component would be replaced with PCB in commercialization.

9	SIM&NAT	EA-DW40P-A-03M=120_F	Wiring	Jumper wire to connect components in the prototyping phase.	N/A	\$7.49	Wiring acquired in bulk, would be able to create 50+ prototypes. Component would be replaced with PCB in commercialization.
10	Blinding Sun Systems	BSS-P-004	Photocell Housing	Hemispherical PLA 3D printed housing for solar tracking components.	1	\$0.48	
11	Elegoo	EL-KIT-003	Stepper Motor Driver Board	Integrates stepper motor with Arduino microcontroller	1	\$1.06	Component would be replaced with PCB in commercialization.
12	Elegoo	EL-CB-001	Arduino Uno	Arduino Uno R3 clone microcontroller by Elegoo.	1	\$16.38	Component would be replaced with PCB in commercialization.
13	Elegoo	EL-KIT-003	Power Supply Module	Regulates power from Arduino to stepper motor	1	\$0.95	Component would be replaced with PCB in commercialization.
14	Blinding Sun Systems	BSS-P-005	Housing Hooks	Affixes housing to blinds	2	\$0.83	
15	Blinding Sun Systems	BSS-P-006	Housing Lid	Contains all components in housing and provides opening for joystick	1	\$3.70	
16	Blinding Sun Systems	BSS-P-007	Joystick Pocket	Holds Joystick in place	1	\$0.31	
16	Blinding Sun Systems	BSS-P-008	Solar Panel Housing	Houses the solar panel and attaches to Photocell Housing	1	\$3.22	
17	SZYTF	KY-023	Joystick	Used for manual control of blinds.	1	\$0.52	

18	Mouser Electronics	FMP100JR-52-12K	1K Ohm Resistor	Reference resistor for Photocell to gauge value off of	4	\$0.34	
----	--------------------	-----------------	-----------------	--	---	--------	--

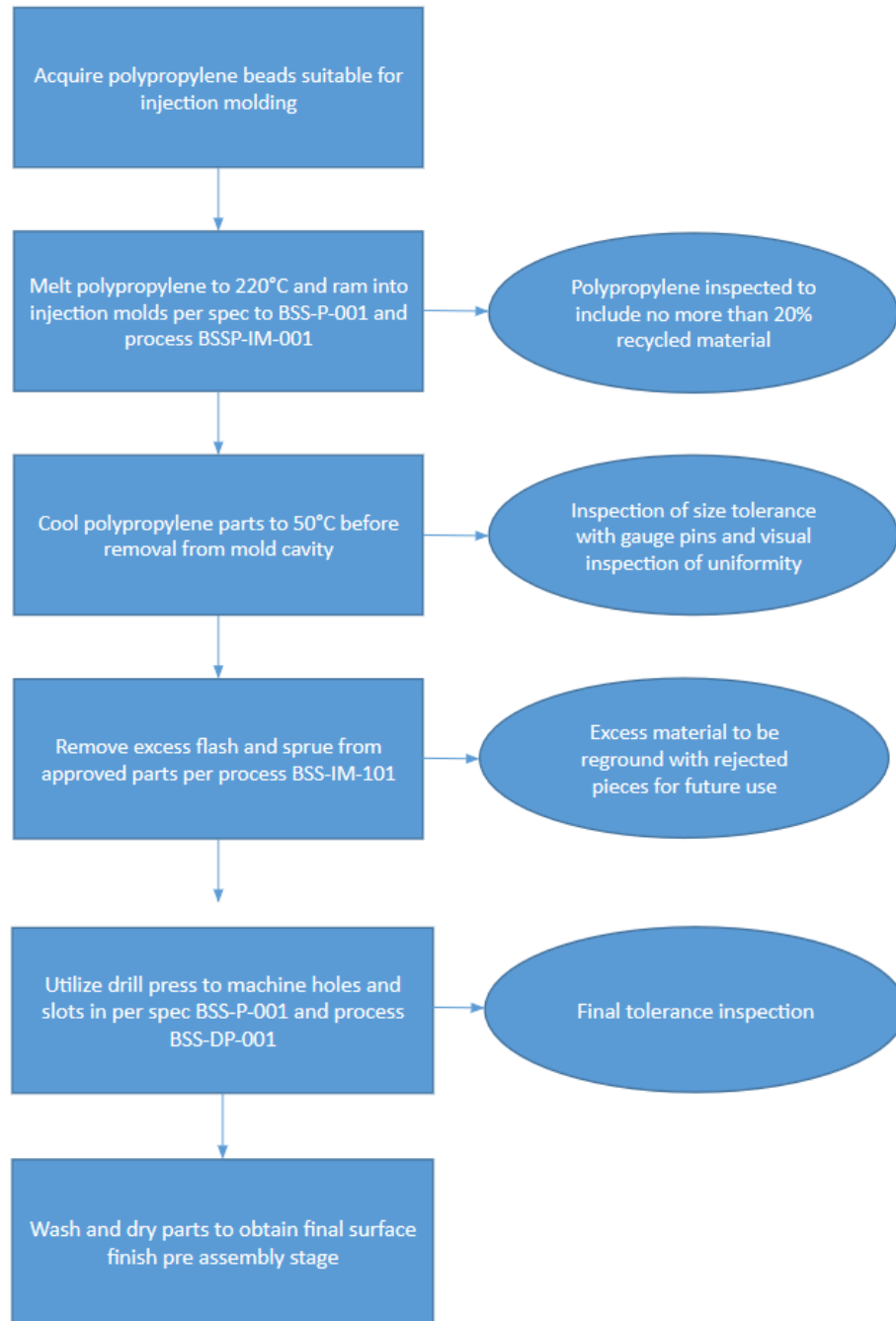


Fig. 1: Process description for injection molding of part BSS-P-001. Similar procedure to be used for BSS-P-002, BSS-P-003, and BSS-P-004

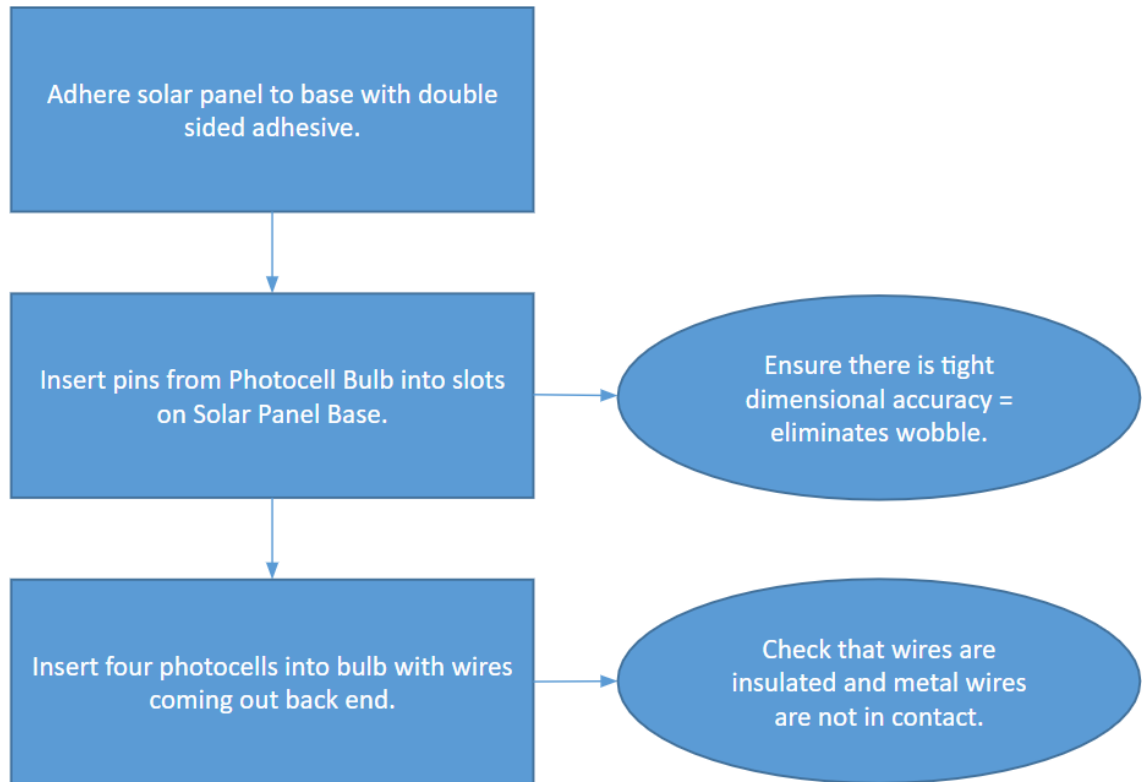


Fig. 2: Solar Panel, Solar Panel base, Photocell Bulb Sub-assembly

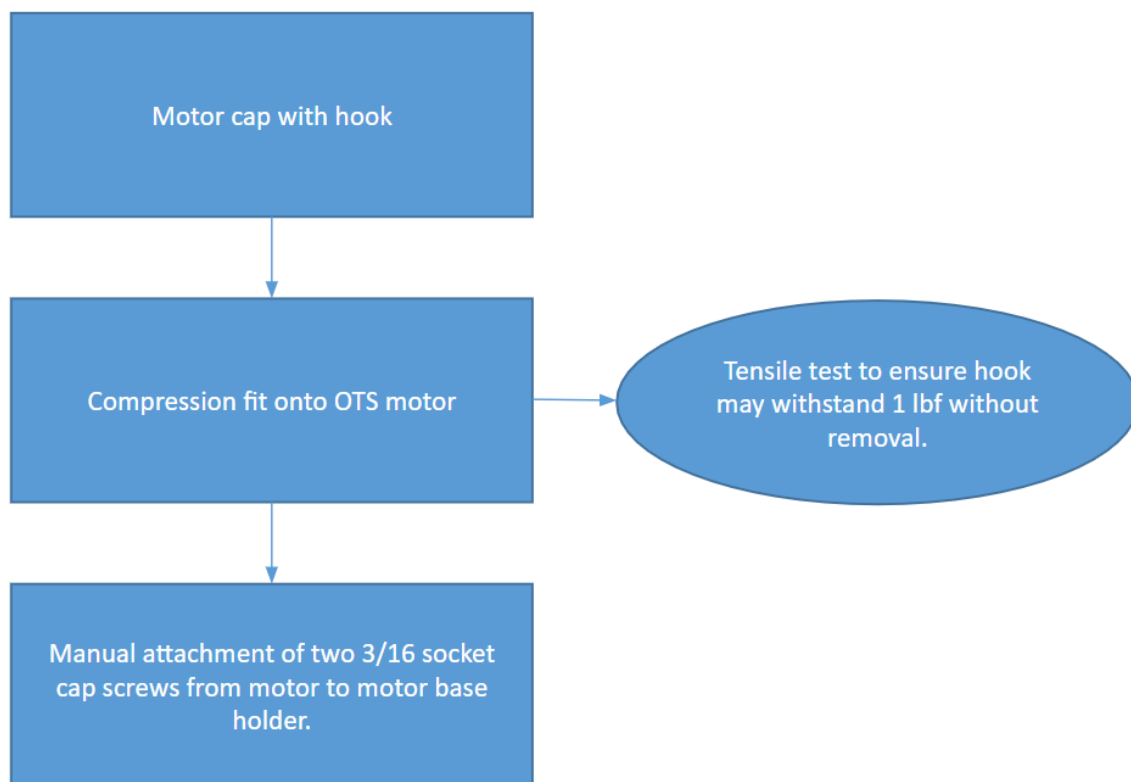


Fig. 3: Motor Cap with Hook, Motor, and Motor Base Holder Sub-assembly

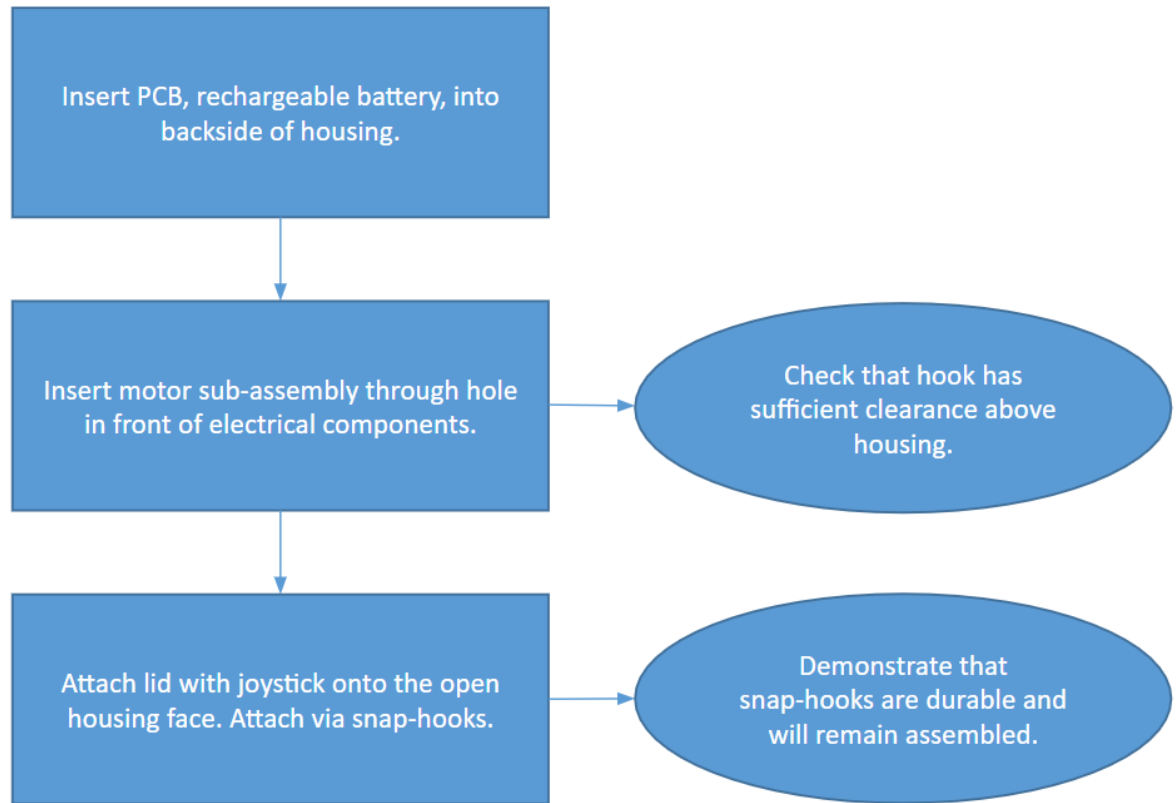



Fig. 4: Housing, Motor Sub-assembly, electrical components Assembly

Appendix H - Design Control Matrix

Document:		Team13A-Doc019-RevA		Solar Sensing Blinds			
Date:		May 7, 2018		Design Control Trace Matrix			
Phase I - Design Inputs			Phase II - Design Output	Phase III - V&V		Comments	
Requirement ID	Requirement Description	Applicable Standards	Design Specification	Verification	Validation		Item Closure (Y/N)
13.PRS.1.1	Cost of manufacturing should be less than \$42.	N/A	Design features 3D printed plastic and cheap electrical equipment. As seen in Prototype BOM.	Yes	13.VVR.1	No	Prototype cost \$61.63 according to Doc013 BOM, but cost would be reduced significantly to under \$42 in commercialization with the use of a PCB and injection molding.
13.PRS.1.2	Product should be modular and accommodate for multiple different blind types.	N/A	Modular attachment for pulley blind assembly will be included in future Product Design Drawings.	Yes	13.VVR.2	No	For simplicity, prototype was made for only a single style of blinds.
13.PRS.2.1	Product will function in varying humidity levels.	IEC 60085:1984, IEC 60664-1:1992, IEC 60664-3:1992	Wires will be properly insulated and protected by the housing. As seen in Item No. 9 in Prototype BOM.	Yes	13.VVR.4	Yes	
13.PRS.3.1	Size of housing for electrical and mechanical components must be less than or equal to 30 cubic in.	N/A	As-Built final design is 53in^3 to accommodate for extra components for prototype.	Yes	13.VVR.5	No	Prototype didn't use custom parts (i.e. Arduino, Bread Board, Jumper Cables, etc. in Doc013 BOM) and was forced to be larger to accommodate that.
13.PRS.3.2	Product should be able to detect when calibration is necessary and self-calibrate.	N/A	Motor will feature rotation sensor; Item No. 10 in Prototype BOM.	Yes	13.VVR.6	No	Unable to incorporate recalibration into the code. Insufficient equipment/information to accurately set a motor reference position. Motor Spec Sheet 28BYJ-48 in Appendix H.
13.PRS.3.3	Device should be able to sufficiently manage data (receive, store, clear).	N/A	Device will be properly programmed using Arduino interface and C language.	Yes	13.VVR.7	Yes	
13.PRS.3.4	Product will be wired from main system to a photocell configuration on a window for sun-tracking capabilities.	N/A	Thin wire will run from blind assembly to sensor assembly. Design Drawing No. 4.	Yes	13.VVR.8	Yes	
13.PRS.3.5	Product will feature ability to turn the blinds manually.	N/A	Buttons will be implemented and attached to circuitry. Design Drawing No. 1.	Yes	13.VVR.9	Yes	Feature was implemented with joystick rather than buttons for sake of simplicity in the coding. Joystick datasheet KY-023 in Appendix H.

13.PRS.3.6	Product should contain switch that allows for heating/cooling functions.	N/A	Switch may be implemented and attached to circuitry. Will be implemented in future Product Design Drawing.	Yes	13.VVR.10	No	Joystick press featured a switch between heating and cooling mode but no ability to provide feedback to the user. Mode was removed from testing. As seen in the code in Appendix I
13.PRS.4.1	Product should perform in standard office or home environments.	N/A	Prototype BOM contains typical components used indoors.	Yes	13.VVR.11	Yes	
13.PRS.5.1	The motor used should be wear resistant and able to withstand cyclical loading on an interval basis.	CPSC 15.(a)2, CPSC 15.(b)3	Will be no friction at motor interface.	Yes	13.VVR.12	Yes	
13.PRS.5.2	Sensor used should be able to handle glass temperatures on the current natural hottest day globally.	N/A	Sensors may typically operate within range 40C - 85C. Prototype BOM Item No. 7.	Yes	13.VVR.13	Yes	
13.PRS.5.3	System should be protected from condensation via an enclosed casing that won't allow moisture to contact electrical components.	N/A	Plastic housing will enclose electrical components. Design Drawing No. 1.	Yes	13.VVR.14	Yes	
13.PRS.6.1	Program should run system independently.	N/A	Program will always run while on.	Yes	13.VVR.15	Yes	
13.PRS.8.1	Label should include proper disposal procedure (Rechargeable Battery and Solar Panel).	IEEE 1145-1990	Product will feature a warning with disposal procedures on the label.	Yes	13.VVR.16	Yes	No label on prototype. This information was recorded in User Manual.
13.PRS.8.2	Product should contain sufficient warnings and installation procedure.	CPSC 7.(a)1-2	Product will come with detailed instruction manual.	Yes	13.VVR.17	Yes	
13.PRS.9.1	Product should only require one initial installation and remain functional for an extended period of time.	N/A	Product may be installed and function indefinitely.	Yes	13.VVR.18	Yes	Issue with motor power draw detailed in 13.VVR.21. Device does only require a single installation.
13.PRS.9.2	Product should include instructions for a single, secure installation and for selecting and cleaning the installation area as to prevent possible malfunctions.	N/A	Information will be included in the enclosed manual.	Yes	13.VVR.19	Yes	
13.PRS.10.1	Single, secure installation with motor attachment and sensor placement phases.	N/A	An adhesive backing on the sensor housing in conjunction with a modular blind attachment connected to the motor.	Yes	13.VVR.20	Yes	

13.PRS.10.2	Product must have the ability to function continuously with the use of a solar panel.	N/A	Solar panel implementation will ensure this. Item No. 6 in Prototype BOM.	Yes	13.VVR.21	Yes	Stepper motor was unable to continuously function with battery power. The voltage draw was too high and caused a steep decline in motor power.
13.PRS.11.1	System powered by a battery solar panel, electrical safety requirements should be met.	IEC 60335-1:1991, IEC 61000-3-3:1994	All electrical components must be acceptable for use. Listed in Prototype BOM Item No. 5 - 9.	Yes	13.VVR.22	Yes	
13.PRS.11.2	System casing should have no exposed sharp edges.	CPSC 7.(a)1-2	Rounded edges of housing. Incorporated in Design Drawing No. 1.	Yes	13.VVR.23	Yes	
13.PRS.12.1	Product should follow the safety regulations of all relevant US agencies	CPSC 7.(a)1-2	All product components must be acceptable for use. Components outlined in Prototype BOM.	Yes	13.VVR.24	Yes	

Appendix I – Verification and Validation Report

Verification

Team 13A had Jens Christiansen and Jeff Hoke validate the information as they did not design or redesign any parts of the prototype during the design phase. All documentation was given to the members. Any and all problems are addressed below.

13.PRS.1.2 - Product should be universal to multiple blind types.

Prototype drawings Doc017 show that only blinds using a twist rod are supported. Any other blind type was not designed for. -Jeff Hoke

The team did this for the simplicity of the prototype. Different attachments had early designs but were scrapped for prototyping. The team would design these attachments before releasing the product in the market.

13.PRS.3.1 - Size of housing for electrical and mechanical components must be less than or equal to 30 cubic in.

Prototype drawings Doc017 show dimensions of 195mm width by 75mm length by 60mm depth => 7.68 in. width by 2.95 in. length by 2.36 in. depth = 53.47 cubic in.. - Jens Christiansen

The team was forced to make the prototype larger so as to accommodate a breadboard for wiring. In a final product a PCB will be used and the original parameters should hold true.

13.PRS.3.2 - Device should be able to self-calibrate.

Self calibration is not mentioned or functional in any documents or coding. - Jens Christiansen

The team would have no way to show the calibration at innovation day. The programming for it was put on hold to focus on more vital components.

13.PRS.3.6 - Product should contain switch that allows for either cooling or heating functions.

There is no switch designed on the housing Doc017. - Jeff Hoke

The team did not include the switch as a focus on a single mode for presentation purposes sent a clearer message. The final design should have this, and the code already exists.

13.PRS.8.1 - Label should include proper disposal procedure (Rechargeable Battery and Solar Panel).

There is no label that was designed. - Jeff Hoke

The team moved this to the user manual and never updated the DCTM. This is an oversight by the team.

Validation

13.VVR.1

13.PRS.1.1 - Cost of manufacturing should be less than \$42.

Prototype cost \$61.63 according to BOM Doc013, but price can be dropped to under \$42 if a PCB were to be utilized.

13.VVR.2

13.PRS.1.2 - Product should be universal to multiple blind types.

Product is compatible with multiple configurations but not compatible with universal blind types. This is due to the motor attachment as seen in Doc017. If more attachments were designed this could be rectified.

13.VVR.4

13.PRS.2.1 - Product will have to function in varying humidity levels.

All product materials were spec'd to have no problems with humidity. See Appendix H

13.VVR.5

13.PRS.3.1 - Size of housing for electrical and mechanical components must be less than or equal to 30 cubic in.

It does not. *70mm width by 30mm length by 15mm depth => 2.76 in. width by 1.18 in. length by .60 in. depth = 34.54 cubic in.* As seen in Doc017. This would be rectified by use of PCB and a small redesign.

13.VVR.6

13.PRS.3.2 - Device should be able to self-calibrate.

It does not. This was excluded for simplicity.

13.VVR.7

13.PRS.3.3 - Device should be able to sufficiently manage data (recieve, store, clear).

Device accurately does this. All data storage is managed correctly. See Appendix I.

13.VVR.8

13.PRS.3.4 - Product will consist of main system wired to solar sensor on window.

Product has a main housing that interfaces with the blinds. The system is the wired to a solar panel and photocells that adhere to the window. See Figure _____ (Pic from innovation day)

13.VVR.9

13.PRS.3.5 - Product will feature interface that will turn the blinds per the user's preference.

Product does this. A joystick is used as the interface. As indicated by the KY-023 spec sheet in Appendix H.

13.VVR.10

13.PRS.3.6 - Product should contain switch that allows for either cooling or heating functions.

Product does not have a switch, but two different programs can be run to simulate a switch. See Doc017 for details.

13.VVR.11

13.PRS.4.1 - Product should perform in standard indoor environments.

Product does this. All parts were selected to meet this criteria. See Appendix H for details.

13.VVR.12

13.PRS.5.1 - Motor should sufficiently resist wear.

Not enough long term testing to be validated. No fatigue or stress tests were performed.

Motor is assumed to fit this criteria. Spec Sheet 28BYJ-48 in Appendix H contains motor performance.

13.VVR.13

13.PRS.5.2 - Sensor should be able to handle window temperatures based on the hottest recorded temperature.

Sensors were specifically picked to both resist extremely hot and cold environments. See Appendix H

13.VVR.14

13.PRS.5.3 - System should be properly housed to protect from condensation.

Housing protects against any naturally forming moisture. See housing design in Doc017
As-Built prototype drawings

13.VVR.15

13.PRS.6.1 - Program should run system independently.

Product does this. No program errors or failures were witnessed at any point in final testing. Program located in Appendix I.

13.VVR.16

13.PRS.8.1 - Label should include proper disposal procedure (Rechargeable Battery and Solar Panel).

No Label exists, but proper disposal procedure is included in the user manual. See Appendix J.

13.VVR.17

13.PRS.8.2 - Product should contain sufficient warnings and installation procedure.

Product has no warnings or labels. This is included in the manual. See Appendix J.

13.VVR.18

13.PRS.9.1 - Product should only require one initial installation and remain functional for an extended period of time.

Product doesn't completely do this. Single installation occurs, but two batteries were used during verification testing and one failed due to high power draw of stepper motor.

Excluding power failure, device was successful. Solar panel requires more testing.

13.VVR.19

13.PRS.9.2 - Product should include information on proper installation location and unit/area cleaning procedures.

Product does this, this is done in the manual. See Appendix J.

13.VVR.20

13.PRS.10.1 - Single, secure installation with motor attachment and sensor placement phases.

Product does this. Manual details how this should be done. See Appendix J.

13.VVR.21

13.PRS.10.2 - Product must have the ability to function continuously for at least one year without battery replacement.

Two batteries were used during verification testing and one failed due to high power draw stepper motor. Excluding power failure, device was successful.

13.VVR.22

13.PRS.11.1 - Device should meet all electrical safety requirements.

Device does this, all relevant electrical safety considerations were accounted for.

Electrical components spec sheets located in Appendix H.

13.VVR.23

13.PRS.11.2 - System should have no exposed sharp edges.

Device does this. All casings were designed with smooth edges. See parts in Doc017.

13.VVR.24

13.PRS.11.3 - Product should be compliant with all relevant safety organizations.

Device does this, all relevant safety considerations were accounted for. See Doc013 BOM and Appendix H for details on individual components.

Appendix J – Component Specification Sheets

JOYSTICK MODULE



Description

Lots of robotic projects need a joystick. This module offers an affordable solution to that. The Joystick module is similar to analog joysticks found in gamepads. It is made by mounting two potentiometers at a 90 degrees angle. The potentiometers are connected to a short stick centered by springs.

This module produces an output of around 2.5V from X and Y when it is in resting position. Moving the joystick will cause the output to vary from 0v to 5V depending on its direction. If you connect this module to a microcontroller, you can expect to read a value of around 512 in its resting position (expect small variations due to tiny imprecisions of the springs and mechanism) When you move the joystick you should see the values change from 0 to 1023 depending on its position.

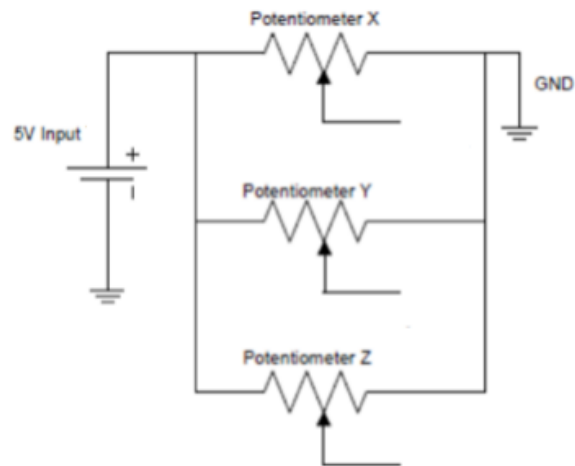
Specifications

- Directional movements are simply two potentiometers - one for each axis
- Compatible with Arduino interface
- The biaxial XY Joystick Module KY-023 applies ARDUINO
- Dimensions: 1.57 in x 1.02 in x 1.26 in (4.0 cm x 2.6 cm x 3.2 cm)
- 5 Pin
- Color: Black

Pin Configuration

1. GND: ground
2. +5V: 5V DC
3. VRx: voltage proportional to x position
4. VRy: voltage proportional to y position
5. SW: switch pushbutton

Schematic Diagram

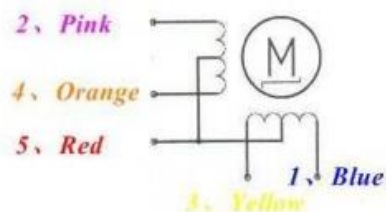


28BYJ-48 – 5V Stepper Motor

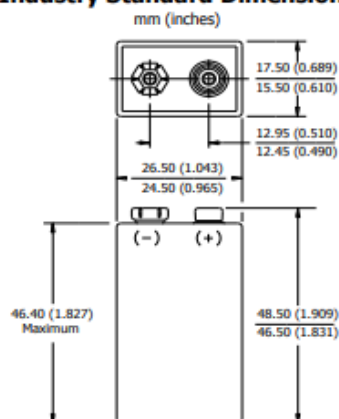
The 28BYJ-48 is a small stepper motor suitable for a large range of applications.



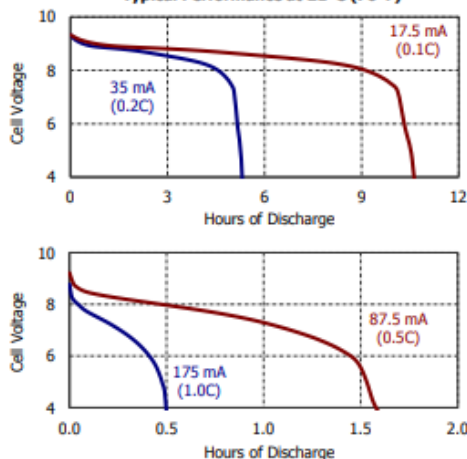
Rated voltage :	5VDC
Number of Phase	4
Speed Variation Ratio	1/64
Stride Angle	5.625°/64
Frequency	100Hz
DC resistance	50Ω±7%(25°C)
Idle In-traction Frequency	> 600Hz
Idle Out-traction Frequency	> 1000Hz
In-traction Torque	>34.3mN.m(120Hz)
Self-positioning Torque	>34.3mN.m
Friction torque	600-1200 gf.cm
Pull in torque	300 gf.cm
Insulated resistance	>10MΩ(500V)
Insulated electricity power	600VAC/1mA/1s
Insulation grade	A
Rise in Temperature	<40K(120Hz)
Noise	<35dB(120Hz,No load,10cm)
Model	28BYJ-48 – 5V



ENERGIZER NH22-175 (HR22)

9V**Industry Standard Dimensions****Discharge Characteristics**

Typical Performance at 21°C (70°F)

**Specifications**

Classification:	Rechargeable
Chemical System:	Nickel-Metal Hydride (NiMH)
Designation:	ANSI-7.2H5
Nominal Voltage:	8.4 Volts
Rated Capacity:	175 mAh* at 21°C (70°F)
Typical Weight:	42.0 grams (1.5 oz.)
Typical Volume:	22.0 cubic centimeters (1.3 cubic inch)
Terminals:	Snap
Jacket:	Plastic

* Based on 35 mA (0.2C rate) continuous discharge to 1.0 volts.

Internal Resistance:

The internal resistance of the cell varies with state of charge, as follows:

Cell Charged	Cell 1/2 Discharged
1000 milliohms	1500 milliohms
(tolerance of ±20% applies to above values)	

AC Impedance (no load):

The impedance of the charged cell varies with frequency, as follows:

Frequency (Hz)	Impedance (milliohms) (charged cell)
1000	950

Above values based on AC current set at 1.0 ampere.
Value tolerances are ±20%.**Operating and Storage Temperatures:**

To maintain maximum performance, observe the following general guidelines regarding environmental conditions:

Charge:	0°C to 40°C (32°F to 104°F)
Discharge:	0°C to 50°C (32°F to 122°F)
Storage:	-20°C to 30°C (-4°F to 86°F)
Humidity:	65±20%

NOTE: Operating at extreme temperatures, will significantly impact battery cycle life.**Important Notice**This data sheet contains typical information specific to products manufactured at the time of its publication.
Contents herein do not constitute a warranty and are for reference only.



0.5W Solar Panel 55x70

SKU 313070004



IN STOCK 20 Available

- 1 +

ADD TO CART

Description

Best-sellers

Technical Details

Questions and Answers

View History

Description

Many people like solar energy because it is simple, clean and renewable. Especially when you are building outdoor projects, solar energy is one of the best solutions for power supply. Depending on the project you are going to build, there are many different sizes of solar panel to choose. If you are looking for a portable solar panel, why not look at this small solar panel that we are going to introduce today-----0.5W Solar Panel 55x77.

0.5W Solar Panel 55x77 is monocrystalline silicon solar panel, which is the main trend in the future. Comparing to polycrystalline silicon solar panel and thin-film solar panel, monocrystalline silicon solar panel performs higher conversion rate that up to 17%. The surface is covered by fine resin which makes it waterproof, together with a very sturdy back, it is really suitable for outdoor environment.

Depending on light intensity, the typical open circuit voltage is 5V. If you take it to a summer day with bright sunshine and no cloud in the sky, the peak OC voltage can be up to 10V. Because the voltage range is relatively wide, if you are going to use boards that require narrow range of input voltage, such as Lipo Rider, to prevent any damage, please check whether the OC voltage is acceptable for the board before any connection.

To begin with, we recommend you to choose some of the solar panel compatible board produced by Seeed such as [Seeeduino microcontroller series](#), [Lipo Rider charging board series](#) and [Xbee Carrier WSN products series](#). Since a 2mm JST connector is attached to the panel, it is perfect to team up with the boards that recommended above.

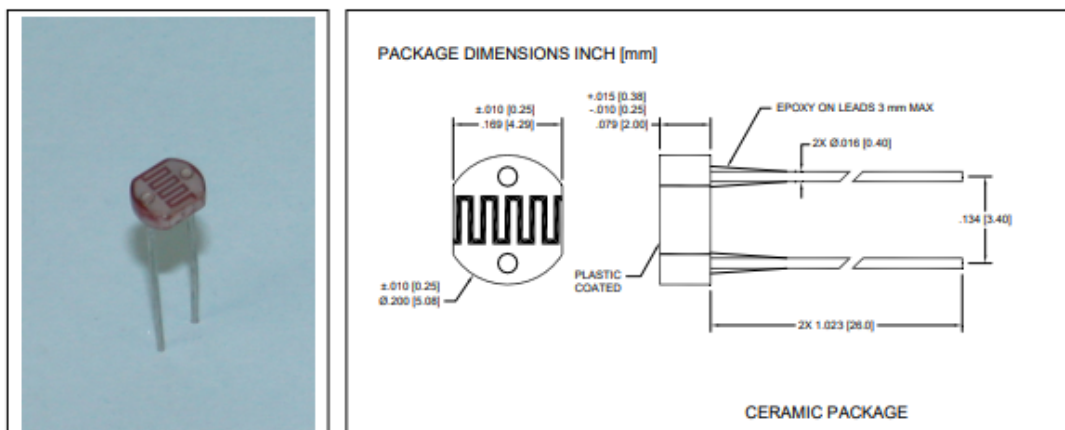
Despite all the good features, it is really a very cheap solar panel among solar panel kits. Again, if you are looking for portable solar panels for sale, 0.5W Solar Panel 55x77 is the best choice!

Features

- Dimensions: 70x55x3(±0.2) mm
- Typical voltage: 5.5V
- Typical current: 100mA
- Open-circuit voltage: 8.2 V
- Maximum load voltage: 6.4V



CdS Photoconductive Photocells PDV-P8001



FEATURES

- Visible light response
- Sintered construction
- Low cost

DESCRIPTION

The **PDV-P8001** are (CdS), Photoconductive photocells designed to sense light from 400 to 700 nm. These light dependent resistors are available in a wide range of resistance values. They're packaged in a two leaded plastic-coated ceramic header.

APPLICATIONS

- Camera exposure
- Shutter controls
- Night light Controls

ABSOLUTE MAXIMUM RATING (TA)= 23°C UNLESS OTHERWISE NOTED

SYMBOL	PARAMETER	MIN	MAX	UNITS
V _{pk}	Applied Voltage		150	V
P _{d Avo/st}	Continuous Power Dissipation		100	mW/°C
T _O	Operating and Storage Temperature	-30	+75	°C
T _S	Soldering Temperature*		+260	°C

* 0.200 inch from base for 3 seconds with heat sink.

ELECTRO-OPTICAL CHARACTERISTICS RATING (TA)= 23°C UNLESS OTHERWISE NOTED

SYMBOL	CHARACTERISTIC	TEST CONDITIONS	MIN	TYP	MAX	UNITS
R _D	Dark Resistance	After 10 sec. @ 10 Lux @ 2856 °K	0.2			MΩ
R _I	Illuminated Resistance	10 Lux @ 2856 °K	3		11	KΩ
S	Sensitivity	$\frac{\text{LOG}(R_{100})-\text{LOG}(R_{10})^{**}}{\text{LOG}(E_{100})-\text{LOG}(E_{10})^{***}}$		0.6		Ω/Lux
λ _{range}	Spectral Application Range	Flooded	400		700	nm
λ _{peak}	Spectral Application Range	Flooded		520		nm
t _r	Rise Time	10 Lux @ 2856 °K		55		ms
T _f	Fall Time	After 10 Lux @ 2856 °K		20		ms

**R100, R10: cell resistances at 100 Lux and 10 Lux at 2856 °K respectively .

***E100, E10: luminances at 100 Lux and 10 Lux 2856 °K respectively.

Information in this technical datasheet is believed to be correct and reliable. However, no responsibility is assumed for possible inaccuracies or omission. Specifications are subject to change without notice.

REV 3/30/06

Appendix K – Arduino Code

```

#include <Stepper.h>
#include <elapsedMillis.h>
#include <RunningAverage.h>

#define OverrideWaitTime 5000 //interval in ms - 1 hour = 3,600,
000
#define MoveWaitTime 20000 //inverval in ms - 30 min = 1,800,000

#define HALFSTEP 8

#define motorPin1 8 // IN1 on the ULN2003 driver 1
#define motorPin2 9 // IN2 on the ULN2003 driver 1
#define motorPin3 10 // IN3 on the ULN2003 driver 1
#define motorPin4 11 // IN4 on the ULN2003 driver 1

//Motor Initalization
const int stepsPerRevolution = 1000; //This is TEMPORARY. For
FASTER TESTING PURPOSES ONLY.
// initialize the stepper library on pins 8 through 11:
Stepper myStepper(stepsPerRevolution, 8, 10, 9, 11);

//=====

//Photocell Initialization

int photocellPin_1 = 0;
int photocellPin_2 = 1;
int photocellPin_3 = 3;
int photocellPin_4 = 4;

int photocellReading_1;
int photocellReading_2;
int photocellReading_3;
int photocellReading_4;

RunningAverage ph1(10); //how many points are being averaged ->
should be ~5minutes of data

```

```
RunningAverage ph2(10);
RunningAverage ph3(10);
RunningAverage ph4(10);

//=====

//JoystickInitialization

int Y_pin = 5; //analog pin connected to Y directional output
for manual override
const int SW_pin = 3; //digital pin connected to switch output
(call this fake darkness sensing)

//=====

int ledPin = 5;
byte leds = 0;

void setup() {

    //Switch setup
    pinMode(SW_pin, INPUT);
    digitalWrite(SW_pin, HIGH);
    pinMode(ledPin, OUTPUT);
    digitalWrite(ledPin, 1);

    ph1.clear(); ph2.clear(); ph3.clear(); ph4.clear(); //clears
all running averages

    // initialize the serial port:
    Serial.begin(9600);
}

void loop() {

    int photo_1 = analogRead(photocellPin_1);
```

```

int photo_2 = analogRead(photocellPin_2);
int photo_3 = analogRead(photocellPin_3);
int photo_4 = analogRead(photocellPin_4);

int Y_dir = analogRead(Y_pin);
int Switch = digitalRead(SW_pin);

elapsedMillis motorMoveTimer;

if (Y_dir <= 200 || Y_dir >= 800)
{
  override();
}

/*else if (Switch == 0) {
  digitalWrite(ledPin, 0);
  coolingmode();
}*/

else {

  suntracking();

  /* Covert to a new function - void solarsensing();
  * statements will all include light reading values and
  comparisons.
  * dictate where motor should move to.
  * This part will be fairly complex with several else if
  statements.
  *
  * Incorporate elapsedMillis and a new timer (motorMoveTimer)
  to ensure movement
  * only may occur every 30 minutes.
  * Timing will be less significant for innovation day.
  * Maybe only 30 seconds(?)
  */
}

```

```
delay(1000); //how often is data being collected? -> Should be
>= 10seconds

}

void override() {

    int Y_dir = analogRead(Y_pin);
    int Switch = digitalRead(SW_pin);
    elapsedMillis overrideTimer;

    /* Convert while loop to execute while it is bright outside.
    * Add if statement -
    *   if (joystick > 800) - move up
    *   else if (joystick < 200) - move down
    */

    while (Switch == 1){
        Serial.println(overrideTimer);
        int Y_dir = analogRead(Y_pin);
        int Switch = digitalRead(SW_pin);

        if (Y_dir < 200){

            myStepper.setSpeed(30);
            myStepper.step(stepsPerRevolution);
        }
        else if (Y_dir > 800){

            myStepper.setSpeed(30);
            myStepper.step(-1*stepsPerRevolution);
        }

        Serial.print("Joystick: "); Serial.println(Y_dir);
        Serial.print("Switch: "); Serial.println(Switch);

    /* Convert to:
```

```

* if (average of photocells < 100(?) ) - Nightly calibration -
initialize motor.
* This part might be hard and need to be removed. ):
*/

if( Switch == LOW && overrideTimer > OverrideWaitTime) {
  Serial.println("Initialize Motor and Wait for Sunlight");
  return;
}
}
}

void suntracking() {

  int photo_1 = analogRead(photocellPin_1);
  int photo_2 = analogRead(photocellPin_2);
  int photo_3 = analogRead(photocellPin_3);
  int photo_4 = analogRead(photocellPin_4);

  /* photo_1 = 90deg, vertical cell
  * photo_2 = 60deg
  * photo_3 = 30deg
  * photo_4 = 0deg, horizontal cell
  */
  static elapsedMillis motorMoveTimer;
  Serial.println(motorMoveTimer);

  ph1.addValue(photo_1);
  ph2.addValue(photo_2);
  ph3.addValue(photo_3);
  ph4.addValue(photo_4);

  float ph1A = ph1.getAverage();
  float ph2A = ph2.getAverage();
  float ph3A = ph3.getAverage();
  float ph4A = ph4.getAverage();

```

```

Serial.print("Photo 1 Average: "); Serial.println(ph1A,1);
Serial.print("Photo 2 Average: "); Serial.println(ph2A,1);
Serial.print("Photo 3 Average: "); Serial.println(ph3A,1);
Serial.print("Photo 4 Average: "); Serial.println(ph4A,1);
Serial.println("=====");

if (motorMoveTimer > MoveWaitTime) {

  if (ph1A > ph2A && ph1A > ph3A && ph1A > ph4A) {

    Serial.println("Photocell 1 MAX");
    myStepper.setSpeed(30);
    myStepper.step(21*stepsPerRevolution);
    motorMoveTimer = 0;
    ph1.clear(); ph2.clear(); ph3.clear(); ph4.clear(); //clears
all running averages

  }

  if (ph2A > ph1A && ph2A > ph3A && ph2A > ph4A) {

    Serial.println("Photocell 2 MAX");
    myStepper.setSpeed(30);
    myStepper.step(18*stepsPerRevolution);
    motorMoveTimer = 0;
    ph1.clear(); ph2.clear(); ph3.clear(); ph4.clear(); //clears
all running averages

  }

  if (ph3A > ph2A && ph3A > ph1A && ph3A > ph4A) {

    Serial.println("Photocell 3 MAX");
    myStepper.setSpeed(30);
    myStepper.step(15*stepsPerRevolution);
    motorMoveTimer = 0;
    ph1.clear(); ph2.clear(); ph3.clear(); ph4.clear(); //clears
all running averages

  }
}

```

```
if (ph4A > ph1A && ph4A > ph3A && ph4A > ph2A) {

    Serial.println("Photocell 4 MAX");
    myStepper.setSpeed(30);
    myStepper.step(12*stepsPerRevolution);
    motorMoveTimer = 0;
    ph1.clear(); ph2.clear(); ph3.clear(); ph4.clear(); //clears
all running averages
}

}

}

/*void coolingmode(){

    int Switch = digitalRead(SW_pin);
    while (Switch == 1){
    int Switch = digitalRead(SW_pin);

    if (Switch == 0) {
        digitalWrite(ledPin,1);
        return;
    }
}
}*/
```

Appendix L – User Manual



Solar Sensing Blinds User Manual



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Introduction

Thank you for your investment in Blinding Sun Systems. Before beginning installation please read all instructions and warning labels.

This product is designed to regularly adjust the angle of your homes blinds to optimize heating or cooling depending on your need. This preprogrammed product will lower the overall cost of heating and cooling your home while allowing appreciable levels of sunlight into the home for passive lighting. The product is meant to fit most blind fixtures that operate via twist rods. The simple one time installation and quick program process should take less than five minutes and once installed, expect little to no maintenance.

We expect our product will fully satisfy your window blind needs. If there is ever any reason to contact us please do so at support@blindingsunsystems.com.

Device Installation

- 1.** Pick a location on the window to place solar panel. This location should be free from obstruction due to trees, buildings, or other impairments.
- 2.** Thoroughly clean window surface where solar panel module will be applied.
Allow surface to dry.
- 3.** Peel protective tape from solar panel module and firmly press adhesive against window. Apply uniform pressure for one minute. Allow adhesive to dry for at least two hours.
- 4.** Slide motor hook into blind turning mechanism while the window blinds are completely closed with the blinds tilted up. This will establish the starting position for your blinds every morning.
- 5.** Affix main housing onto blinds by sliding the two hooks into the gap over the existing blinds.
- 6.** Turn on main housing and apply desired settings.
- 7.** You're done! Let Solar Sensing Blinds do its job keeping your blinds at the ideal angle!

Device Operation

Heating Mode: When the device is in heating mode*, proper operation will be indicated by automatic adjustment of the blinds in thirty minute intervals. Upon initiation of tracking program, the blinds will fully open. The blinds will then track the sun, directing light towards ground until midday. Then, the blinds will adjust to direct light upwards into the ceiling, until the blinds close at the end of the day cycle.

Cooling Mode: When the device is in cooling mode*, a blue LED will light up to indicate that cooling mode is active. The blinds in this mode will remain fairly closed and direct some light into the ceiling to create ambient lighting

To switch between heating and cooling, press the joystick in once. A blue LED will be lit when the device is in Cooling Mode and the LED will not light up when the device is in Heating Mode.

Manual Mode: If the blinds are adjusted manually via the joystick, the blinds will stay in that position until the end of day. The blinds will be ready for further manual adjustment, until automatic tracking the next day.

Device Disposal

Reduce, reuse, recycle.

Blinding Sun Systems encourages its consumers to properly dispose/recycle unwanted batteries and end-of-life products in accordance to federal, state, and local regulations.

WEEE - Waste Electrical and Electronic Equipment accounts for roughly 10% of all waste in the world.

To obtain information about disposing unwanted, end-of-life products please contact your local waste disposal provider.

Product Safety Information

IMPORTANT SAFETY INSTRUCTIONS

1. **SAVE THESE INSTRUCTIONS**
— This manual contains important safety and operating instructions.
2. **CAUTION** - To reduce risk of injury:
 - A) Do not open case to replace rechargeable battery.
 - B) Do not attach motor hook to blinds without housing hooks securely fastened.
 - C) Keep out of the reach of children.
3. Do not expose product to excessive wind, rain, or snow.
4. Do not attempt to hang objects off of the unit.
5. To reduce risk of damage to motor, do not forcefully twist blinds while in operation.
6. If unit is inoperable or appears to be damaged, do not use and refer to the maintenance instructions below.

MAINTENANCE INSTRUCTIONS

Do not attempt to disassemble the unit. To send in for repair at Blinding Sun Systems, contact:

support@blindingsunsystems.com