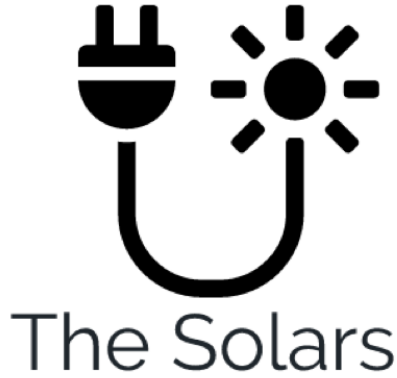
Marine Solar Charger – Final Report



DESIGN REPORT SUBMITTED BY: THE SOLARS

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We certify that the narrative, diagrams, figures, tables, calculations and analysis in this report are our own work.

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MECHANICAL ENGINEERING DEPARTMENT
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THE UNIVERSITY OF TEXAS AT TYLER

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Executive Summary

The goal for team “The Solars” is to provide an alternative energy source for kayakers who need to charge their batteries for loads such as fish finders, lights and cell phones. The purpose of this project is to design an automated solar tracking system that optimizes the charging process of kayaker’s on-board batteries. Most fishermen will drain their electrical equipment when they are taking a longer fishing or recreational trip. It is suggested that kayakers use the solar tracking system to charge the electrical equipment because it increases the efficiency of the charging process.

The team designed and built a portable solar powered system to charge commonly used batteries for sit-on-top kayaks during marine activities. A printed circuit board was created to achieve the proper solar charging along with a visual display and buttons to deactivate the charge controller for safety purposes during maintenance. The mechanical system was designed using spur gears to rotate the solar panel and a linear actuator to respond to the solar tracking system. This will optimize the amount of sun that the panel will receive to charge the battery as quickly as possible during peak sun hours. The system was tested and confirmed to charge the battery in the allotted time frame. This report outlines the process for the design and build of the solar tracking and charging system.

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Nomenclature

Table 1 Nomenclature

Unit name	Acronym
Pounds	Lbs.
Inches	in
Newtons	N
Pascal	Pa
Volts	V
Watt	W
Amperes	A
Seconds	S
Hours	h
Mass-Pound	lbm/lbmass
Pound-Force	lbf
Pounds / Square Inch	psi
1000 Pounds / Square Inch	ksi

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I. Introduction / Background and Project / Problem Description

1. Background

Austin Canoe & Kayak is a small, family-owned outdoors store. The merchandise includes all sorts of fishing accessories and different types of kayaks. It was later purchased in 2005 by two brothers who since then decided to branch out. With only one store in existence back then, located in Austin, ACK has now expanded and has four locations and an online planform. The new Texas locations are in San Marcos, San Antonio, Houston and Spring. Since then, they have become an award-winning paddle sport specialty store that is always coming up with new ideas to bring in new potential clients and keep it interesting for the already existing.

ACK hosts events like outdoor expos which are also known as “Demo Days”. This is where they rent off private locations in each city and they bring in new and improved accessories and kayaks for all the people that attend to be able to see and experience. A trip often spoken about at this event is The Devil’s River. The river is located in southwest Texas and part of the Rio Grande. It is considered one of the most hostile environments for human and domestic animal populations. The length of the river is about 94 miles, surrounded by a harsh landscape and private properties. As a result, this makes the river one of the most visited attractions for kayakers and adventure sports enthusiasts. The journey of the river takes a regular kayaker around 3 to 4 days from start to finish.

2. Problem Description

As mentioned earlier, since most of the land surrounding the river is privately owned or harsh, it leaves kayakers to face many obstacles. It was specifically pointed out by our sponsor, regarding the environment and how the voyagers recharge their electronic devices. There are no electrical plugs to set up when camping, making all the electrical equipment aboard hard to maintain a

charged status. The project was designed to solve this issue by taking advantage of solar energy since it is affordable, efficient, and a convenient way to charge the electrical equipment. Another natural source of energy that could be taken into consideration would be hydropower but due to the complexities of hydropower, solar energy is the most fitting.

Austin Canoe and Kayak (ACK) is trying to develop a charging system that would be most helpful to kayakers to charge their electrical devices without any outside assistance. Some of those devices include fish finders, LED lights, GPS and other gadgets. The goal is to design a universal solar panel mount and box system including a solar panel that can charge a battery during fishing trips. The system should fit on all types of sit on top kayaks with an easy method to assemble and disassemble.

II. Requirements, Specifications, and Constraints

1. Requirements

1.1. Design Requirements

The initial design requirements by the sponsor are listed below.

Table 2 Design requirements provided by the sponsor

№	Design Requirements provided by sponsor
1	Universal for watercrafts
2	Portable
3	Solar Panel to charge a marine battery
4	Ability to monitor the battery and charging status
5	Target customers: Fishermen

The initial requirements provided a base for the project; however, more insight was required by the team from a typical user therefore a customer survey was conducted.

1.2. Customer Survey

With the evidence provided by the sponsor and program, the group decided to research additional legitimate material to gain reasonable data in order to appropriately work with the information provided and received. The survey was conducted on Yahoo answers and four Facebook groups. The purpose of the survey was to better understand consumer needs. The set of questions was posted, and the results are provided below.

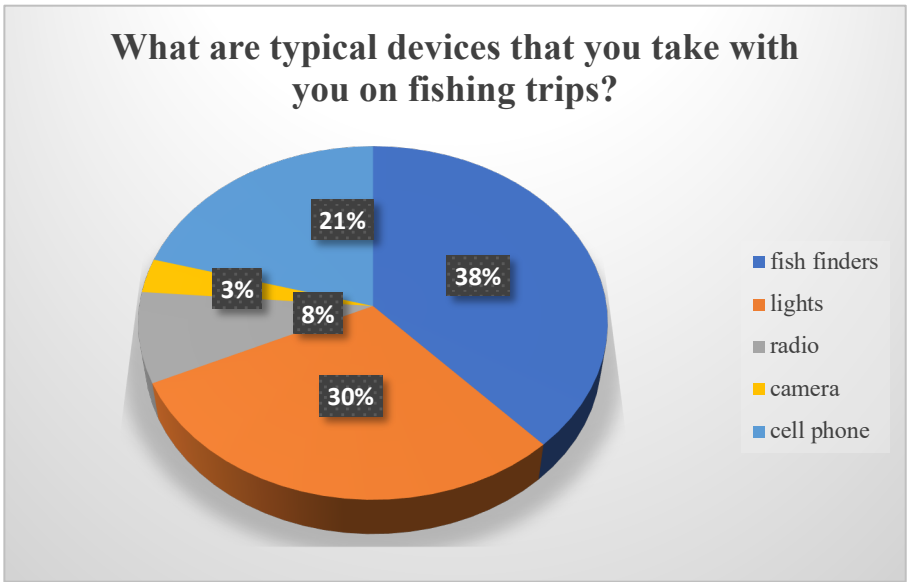


Figure 1 Survey Result 1. Typical Devices on trips

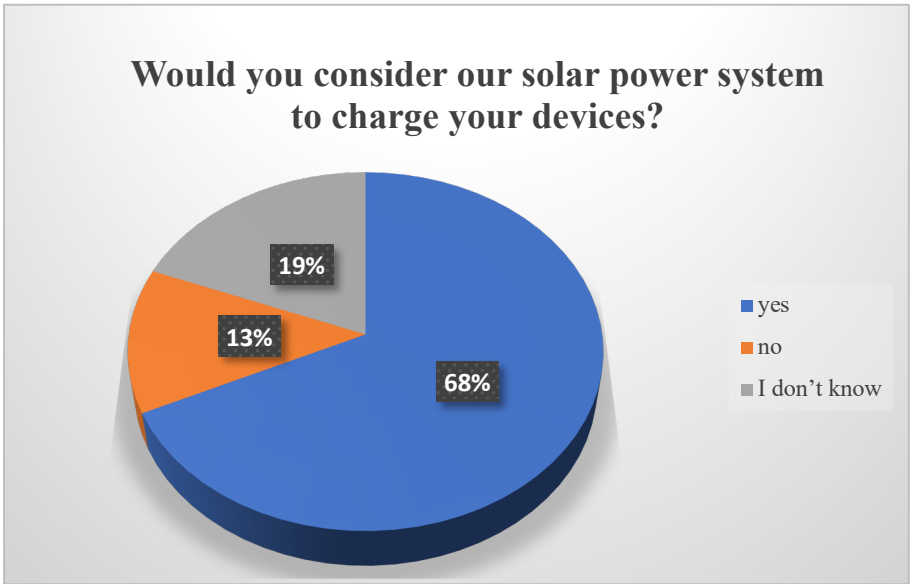


Figure 2 Survey Result 2. Use of Solar Power

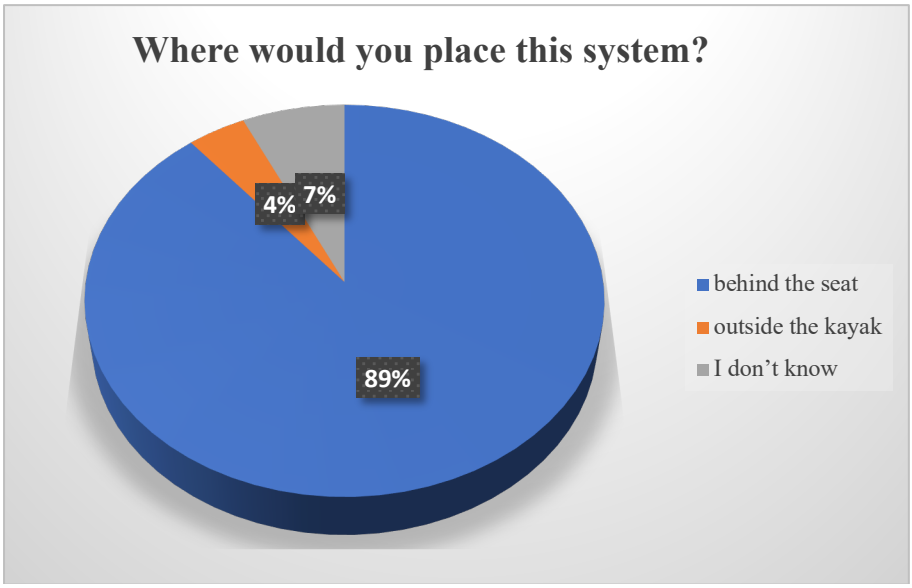


Figure 3 Survey Result 3. Location of the system

More than 40 responses were reviewed and analyzed and later implied in the calculations for the solar panel size. Also, the group confirmed the best spot to place the system is behind the seat, since some of the early ideas were to place the system outside of the kayak.

2. Specifications

The table below provides a list of specifications that were achieved in the final product. Austin Canoe and Kayak was requested to provide insight and discussion points on the specifications provided. The specifications have been agreed upon by both parties, and The Solars are presenting the information in this document for the design of the prototype.

Table 3 Specifications

Specification	Required/ Optional	Value/limit YES/NO	Units	Acceptance Test or Method
"Sit-on-top" kayak	Required	NO		
Lightweight system	Required	30	lb. max	Weight scale
Solar Panel				
Voltage (DC)	Required	12	V	Oscilloscope/multimeter to verify the power output
Max Power	Required	50	W	Multimeter
Operating Voltage	Required	18.5	V	Oscilloscope/multimeter to verify the current output
Operating current	Required	2.7	A	Oscilloscope/multimeter to verify the current output
Estimated Weight	Required	10	lbs.	Weight scale
Estimated Dimensions	Required	26.5x20x0.08	in	
Ingress protection	Required	IP65		Water and dust resistant – depth of up to 1m for 30 mins
Controller				
Max Charging current	Required	4.2	A	Oscilloscope/multimeter to verify the current output
Output Voltage	Required	12	V (output)	Oscilloscope/multimeter to verify the power output
Ingress protection	Required	IP65		Water and dust resistant - depth of up to 1m for 30 mins
Display	Required	YES		LED Display and LED indicators for charge status and manual adjustment of panel
Universal mounts	Required	YES	kg, Pa, N	Digital simulation of stress/strength test analysis
Mount to track	Required	0.875	in	Calipers to measure inside the distance of the track
Adjustable Width	Required	18 - 34	in	Using measuring device to determine the distances between tracks

3. Constraints

Table 4 below shows the factor and constraints that affects the making process of the project. The project constraints include both the internal and external challenges that are listed in the table.

Table 4 Constraints

Factor	Constraints
Users have no available space on the tracks for the device and would have to install new tracks. If a cooler is behind the seat of the user, then tracks would need to be installed on the cooler	Limited Space
The battery for the solar tracking system needs to be replaced or recharged	Time
The continuous movement of the kayak in different directions may affect solar tracking	Quality
The heavy load on the battery may drain the power quickly	Scope
The solar panel might not work on a rainy or cloudy day	Quality
Splashes of water might affect the electrical components	Safety
The system might come in the way while fishing	Quality
In case of component failure, replacements need professional skills	Scope
The system might be heavy for some fishermen	Safety
The system might not be able to withstand the force of fast-moving and high tides current	Quality
The initial investment in the system might be expensive for some kayakers	Cost
The system might take up a lot of space in the kayak, which could result in people not investing in it	Scope
Maintenance of the combined system will be costly	Cost
Project deadline	Time

III. List of Relevant Standards Used

The system must incorporate some safety rules and regulations such as:

1. **SAE-J378: Marine Propulsion Wiring System**

The SAE Recommended Practice covers requirements for all marine inboard engine wiring, wiring assemblies, wiring components, and wiring connectors connected to microprocessors associated with the operation of the propulsion system, operating at 50 V or less. (SAE International, 2018)

2. **IEC 61427: Secondary Cells for Solar Photovoltaic Energy Systems**

IEC 61427-1:2013 is part of a series that gives general information relating to the requirements for the secondary batteries used in photovoltaic energy systems (PVES) and to the typical methods of test used for the verification of battery performances. This part deals with cells and batteries

used in photovoltaic off-grid applications. This standard is applicable to all types of secondary batteries. (International Electrotechnical Commission, 2013)

3. IP65: Waterproof and Dustproof Ingress Protection

IP means Ingress Protection, 6 solid protection, and 5 liquid protection. As defined in international standard IEC 60529, IP65 classifies the degrees of protection provided against the intrusion of solid objects (including body parts like hands and fingers), dust, accidental contact, and water in electrical enclosures. The standard aims to provide users with more detailed information than vague marketing terms such as “water-resistant”. (Geneva: International Electrotechnical Commision, 2011)

IV. Final Design Details and Considerations

The final design of the system was selected to make the device compact, portable and capable of charging electrical appliances through solar energy. The design was selected taking into consideration different parameters and suggestions provided by the sponsor as well as the advisor. The design was divided into mechanical and electrical subsystems and a 3D model was created using multiple CAD drawing software to make full and subsystem assemblies. Below is the 3D representation of the final system.

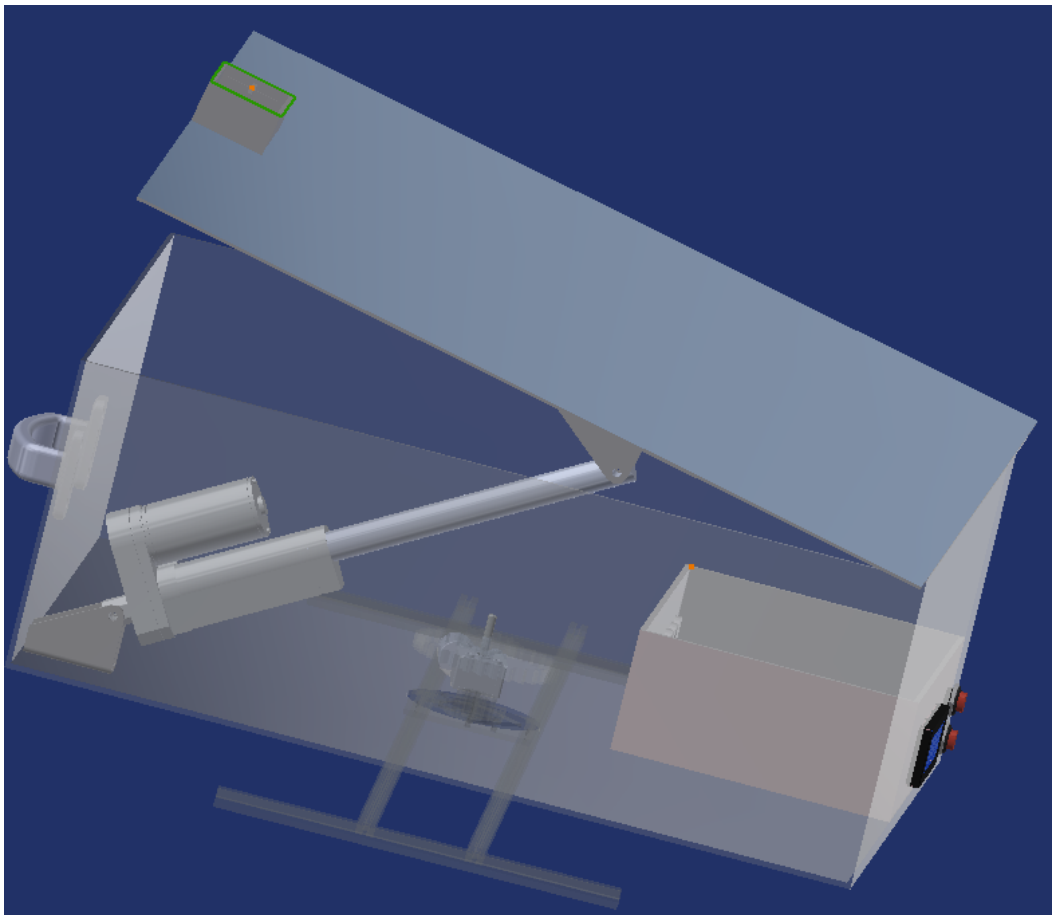


Figure 4 Full system 3D drawing

A visual representation of the full system on a kayak is shown below.

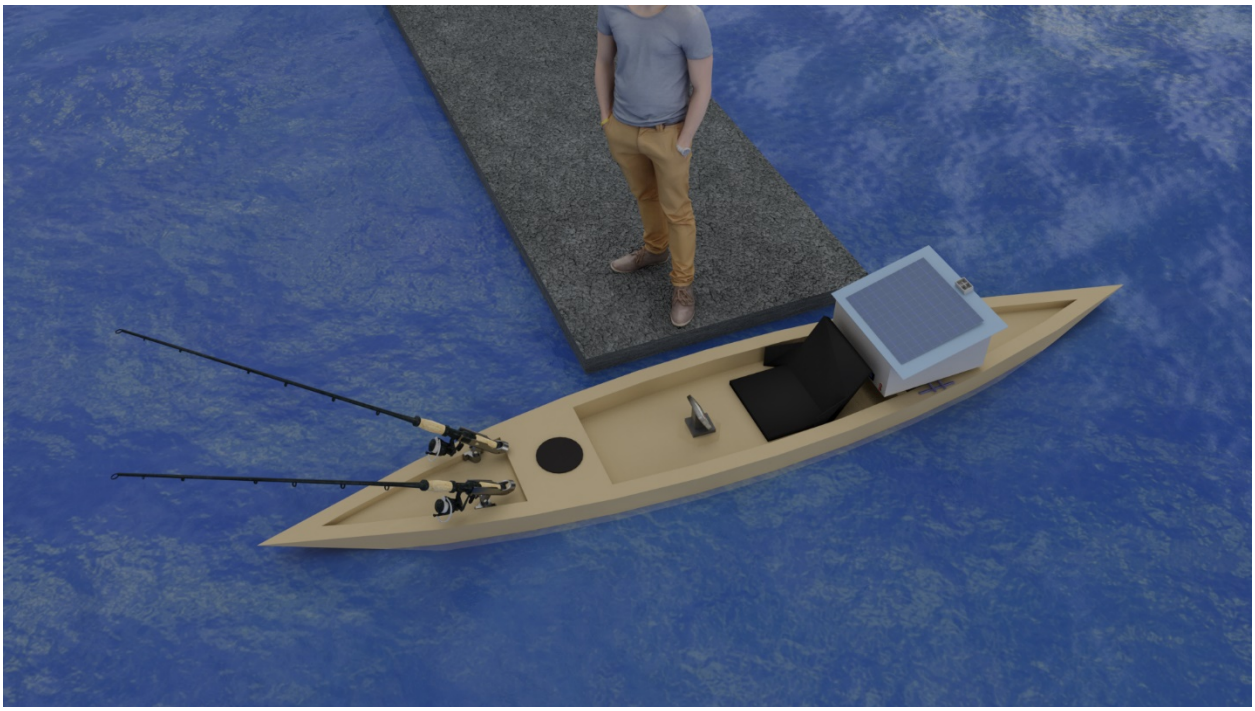


Figure 5 Full System Rendering

1. Mechanical Design

The mechanical design of the system consists of three major components: an actuator, a motor and gears. The components were added to rotate the box and adjust the angle required by the solar panel for maximum efficiency. An adjustable mount was added to the system to make it compatible with all kinds of sit-on-top kayaks. Moreover, the device would mostly be near water, so the device was designed to be water resistant. The components are listed below.

1.1. Mount Subsystem

The components of the mounting system consist of two aluminum bars, the lazy Susan (turning table), and gear support. The mounts measure 33.00” × 1.60” ×1.00”. The slides provide adjustability of the mounting system for kayaks to be properly positioned on the frame. The mounts slide into the existing grooves in the kayak, the screws are securely tightened to lock the position of the mount on the kayak frames. The adjustment slides make it possible for a universal fit for all

sit-on-top kayaks. The system is stabilized by four main features. The bars which structurally supports the system and stabilize it in moving water. The central plate which provides rigidity to the box. Additionally, the lazy Susan (turning table), and the gear support which allow full rotation to the box without any interference.

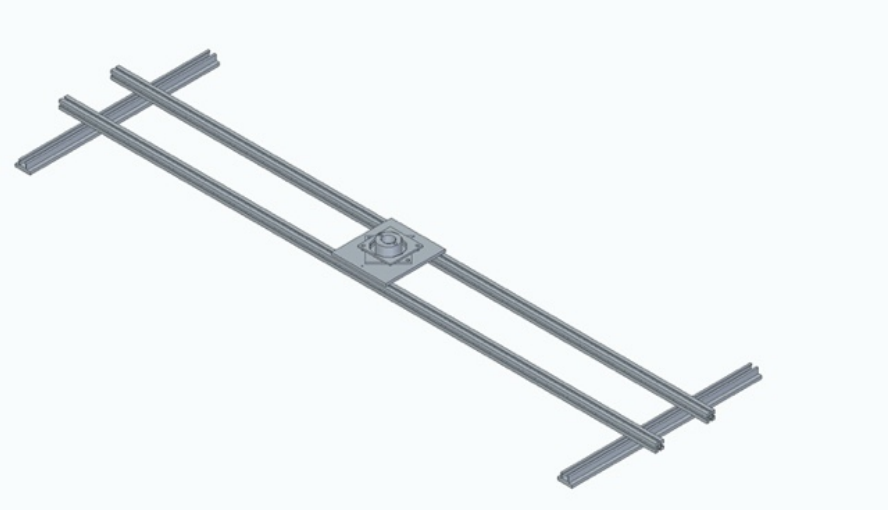


Figure 6 Mount subsystem

1.1.1. Motor

The second component in the mount subsystem is a 12V DC worm gear motor. The operational speed is 10 rpm. The motor 24 watts of power to operate. Based on system load, the torque required is 1.517 lbf *ft to rotate the box. To make the device IP 65, a motor holder made of Acrylic with a dimension of 3.649” X 2.647” was made to protect the motor for any water damage. Both the motor and motor holder will be secured to the base of the box using screws.

For specifications refer to Parts Listing.

1.1.2. Gears

The third component of the mount subsystem system is the spur gears. They were chosen based on the calculations done in equations 3 and 5, the torque required by the box was 1.517 lbf*ft, so gears of gear ratio 1:3 were designed, the smaller gear was 1 inch in diameter and has 12 teeth and the pinion was 3 inch in diameter and has 36 teeth which reduces the torque to 0.505 lbf*ft. ($\frac{\tau_{out}}{\tau_{in}} = \frac{D_{big}}{D_{small}}$). The gear and the pinion were 3D printed for this project based on the design.

For specifications refer to Parts Listing.

1.2. Box Subsystem

1.2.1 Box

The box is made of Acrylic sheets. Two Acrylic sheets of 24" x 24 x .125 were purchase from a supplier (home depot). A templet was used to provide a precision to cut a sheet. A waterjet was used to cut each side of the box. To deburr the edge, the team filed them using sandpaper. The material was washed, cleaned, and aired dry for a day. Next, all sides of the Acrylic sheet were assemble using C clamps to hold them together. Heavy duty water resistance glue was used to join all sides of the box. A box measures 22.1 wide ×20 in depth×8 high inches was a final product that will encompass all the electrical components, the actuator, motor, and the gears. This housing ensures protection against direct contact with water.

1.2.2 Actuator

The last component of the mechanical system is a 12 V DC linear actuator with a 10 in stroke. The actuator comes with mount Brackets for a maximum lift. The actuator will be mounted to the bracket which will be attached to the base and the lid of the box. The actuator does all the elevation and the extension of the lid and solar panel to maximize its efficiency. In addition, the actuator can extend and retract to from 10.4" to 16.4".

For specifications refer to Parts Listing.

2. Electrical Design

Electrical design consists of a custom charge controller. The controller implements digital control using Arduino Nano, LCD display and automatic solar tracking operation. It follows pulse width modulation battery charging algorithm to improve battery life. Current design is for 12V marine-grade lead-acid batteries, mostly used by fishermen, but there`s room for improvement. Electronic protection that is implemented in the design, can prevent damage against incorrect wiring or system faults. For more information about system protection please refer to Electrical Failures section.

2.1. Main Functions

The load connected to the system is a marine-grade battery that will supply power to the consumer electronics such as fish finders, LED lights mounted on kayak, cellphones and other small electronic devices used by the fishermen. The system has its own load: the solar tracking system, which consists of a linear actuator and a DC Motor to provide angular and rotational motion to the system to track sunlight intensity as it is described thoroughly in Mechanical design above.

Main functions of the custom controller:

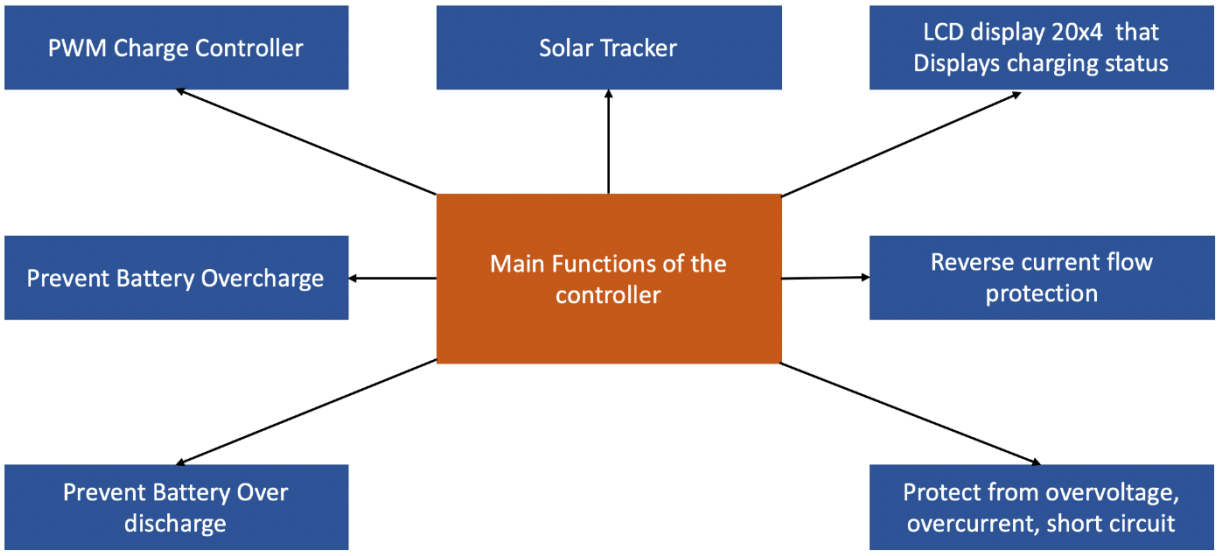


Figure 7 Main functions of the controller

2.2. Design Details

Electrical design started with analyzing battery charging cycles. The Flow Charts of Software was the first step in the design. The code follows the flowcharts and it integrates controller part as well as tracker. The code is written in Arduino Software (IDE) and uploaded to the board.

For the full code please refer to Appendix H.

2.2.1. Charge controller schematic

The circuit below is simulated on *NI Multisim*® software.

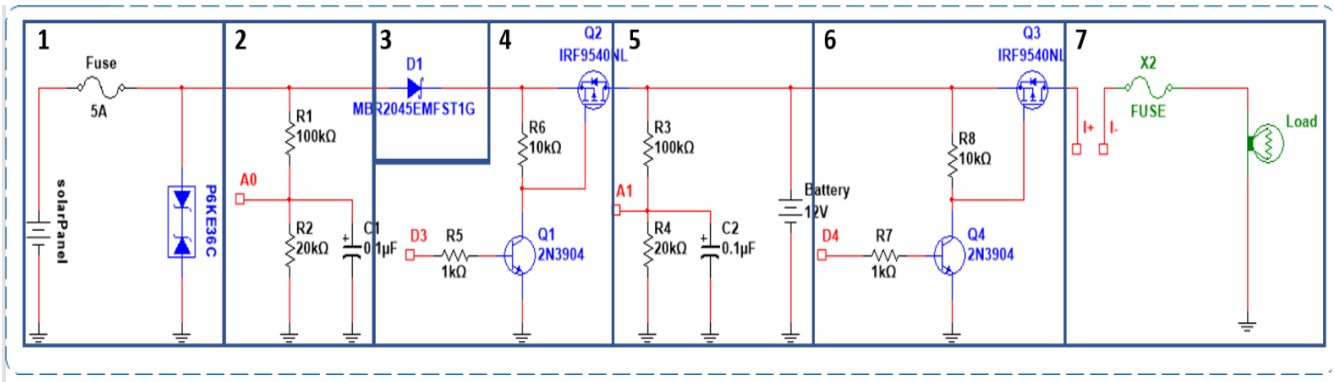


Figure 8 Charge Controller Circuit Diagram

The schematic explanation is below:

Part 1: Input of the system. Power is supplied by solar panel. Fuse and TVS (Transient-voltage-suppression) diode protect against high current coming from the source.

Part 2: Voltage Sensor. Resistors R1 and R2 protect Arduino analog input pin A0 from high voltage:

$$V_o = \left(\frac{R_2}{R_1 + R_2}\right) V_{in} = \frac{20k}{120k} V_{in} \qquad \textit{Eq. 1}$$

If maximum voltage limit for Arduino analog input (A0) is 5V, then maximum value for the input voltage should not be greater than 30V.

Part 3: Power diode MBR2045 is used for reverse polarity and reverse current flow protection. Power diode is meant for handling large amounts of current.

Part 4: To charge the battery controller gives a fixed frequency PWM signal to the MOSFET (frequency of the signal is 490.20 Hz). Duty cycle 0-100% is adjusted by the error signal. The Arduino output pin D3 control the base of NPN transistor Q1 which in turns controls the gate of the MOSFET transistor Q2 responsible for allowing the current to flow from the solar panel to the battery.

Part 5: Battery. Another voltage divider connected to pin A1 of the Arduino in order to measure voltage of the battery.

$$V_{A1} = \left(\frac{R_4}{R_3 + R_4}\right) V_{bat} = \frac{20k}{120k} V_{bat} \qquad \textit{Eq. 2}$$

Part 6: Is the output load control circuit. The Arduino output pin D6 control the base of NPN transistor Q4 which in turns controls the gate of the MOSFET transistor Q3 to control the current flow from battery to the load. Whenever D6 is low (0V), the base of Q4 will be high and the

MOSFET Q3 will be passing the current. When D6 switches to high (5V), the MOSFET will be open circuit and the current flow will be blocked.

Part 7: Load system. Fuse protects from overcurrent. I+ and I- are inputs of the Hall Effect Current Sensor, ACS712. The ACS712 20A was used for this project to mininize power loss of the target current circuit. The current sensor is used for measuring load current in order to calculate the load power and energy.

Once initial design of charge controller was tested in the lab, final design using proper terminals was done in *Autodesk Eagle®*. Below is board blueprint.

For full schematic refer to Appendix G.

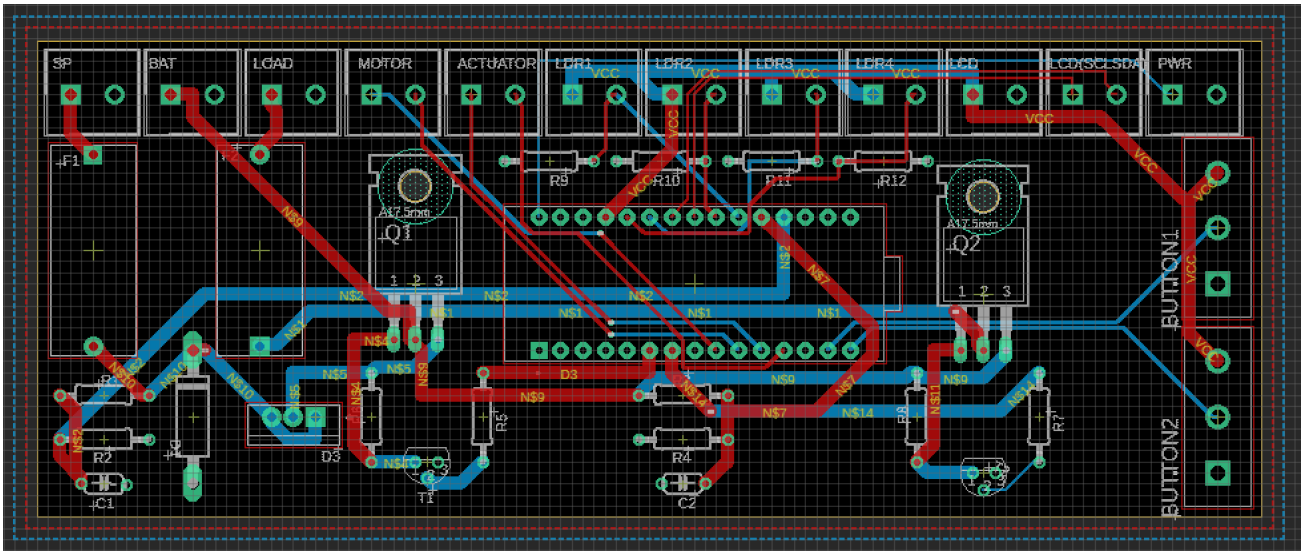


Figure 9 PCB design

2.2.2. Solar tracker

The custom solar tracking system is built to maximize solar panel performance. Four photoresistors are installed on top border of the solar panel to indicate the direction of sunlight to the microcontroller.

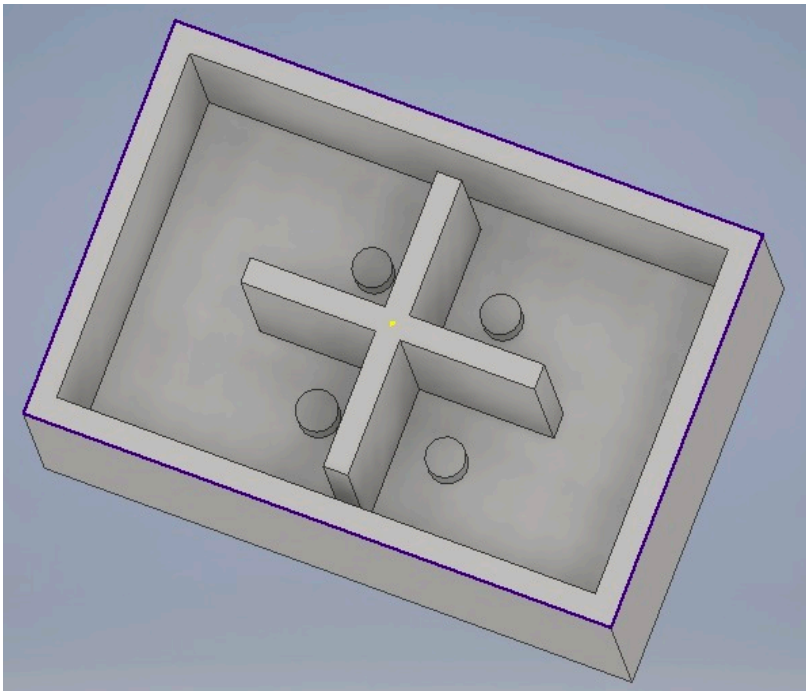


Figure 10 Solar Tracker

The photoresistors are connected through the circuit to the linear actuator and motor. When the resistance of the top two combined photoresistors is higher/lower than the bottom two, the controller communicates with the actuator to cause expansion or retraction. The H-bridge is used to reverse the polarity of the Firgelli actuator. This adjusts the solar panel angle in the vertical direction. The movement halts once the light intensity is balanced on both photoresistors by 10%, and no access current is generated in the circuit.

Similarly, two photoresistors connected on the right/left side of the solar panel have a similar application as that of a linear actuator but are connected to 12V DC motor installed in the box and connected via a spur gear system.

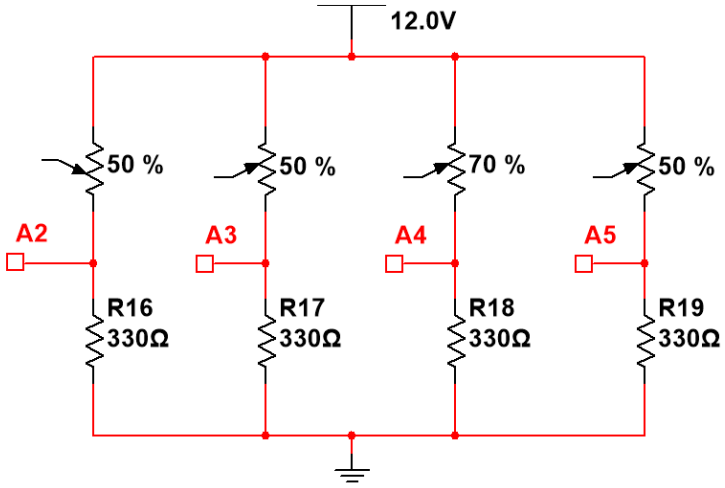


Figure 11 Dual Axis Photoresistor (Light Dependent Resistor) Circuit

To increase the current of Arduino from 40mA (Arduino Official Store, 2019) to 2A, a DC motor driver is used. The function of a L298N Motor Drive Controller is to take a low current signal and turn it into a higher current signal that can drive 2 DC motors. It also serves as a power supply for the Arduino Nano, making the system self-sufficient. Another purpose of the motor driver is a H-bridge, that helps reverse the direction of the current in the motor in order to perform backward and forward rotations. Any fluctuations in one of the photoresistors' resistance will cause a rotational movement of the box towards incident light intensity, exposing the solar panel to the extreme light intensity to maximize the output current.

2.3. Prototypes

Electrical system has a total of three prototypes:

First prototype was done on a solderless breadboard with other components and jumper wires. It was tested in the lab using two power supplies as solar panel and battery, while still perfecting the design. Oscilloscope and multimeter were used to read values. The first prototype was not designed for higher currents, hence could only be used in controlled lab environment.

Second prototype was soldered on the protoboard with proper wire gauges in order to support higher current going through. Solar panel rated current is 2.92A (RNG International Inc., n.d.), the wires used in the design were rated for 5A. It was tested with power supply as solar panel and a 12V battery, proving to be fully functional.

Third and final prototype was a printed circuit board. Printed circuit boards are widely used by professionals and are a more permanent design. The printed circuit board was designed using *Autodesk Eagle*® software and manufactured by JLCPCB company. The PCB was tested with a 50W solar panel and a 12V battery. For experiment results please refer to Final Actual Results section.

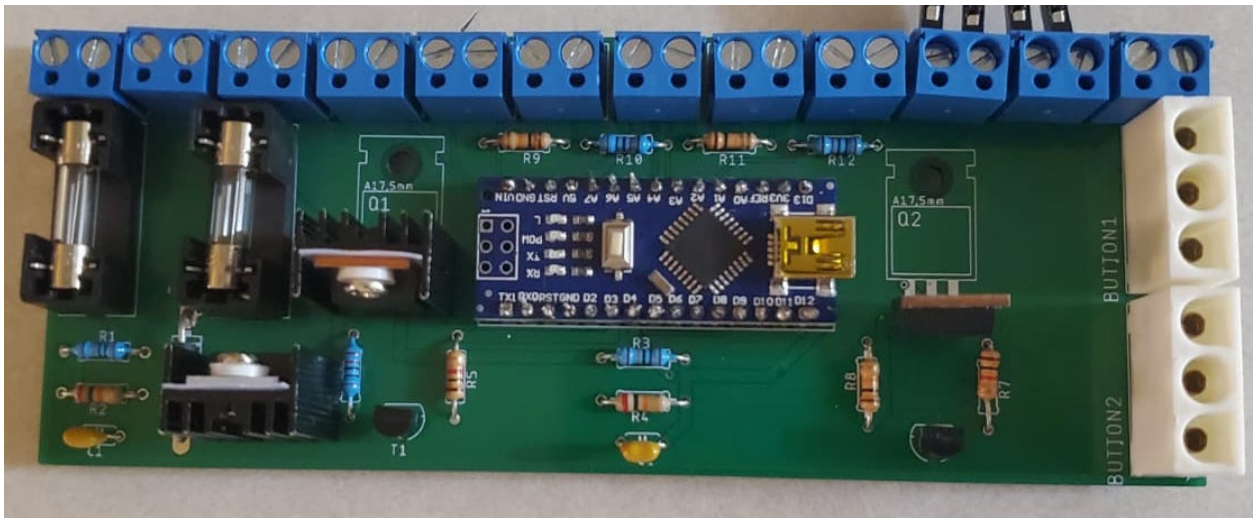


Figure 12 Custom charge controller PCB

List of specifications was developed according to third prototype and does not apply to the first two prototypes.

Table 5 Specifications of the controller

GENERAL Characteristics	
Layers	2
Dimensions	5.511” x 2.126”
Thickness	1.125”
Color	Green
Surface Finish	LeadFree HASL-RoHS
Copper Weight	1
Gold Fingers	No
ELECTRICAL	
Rated Voltage	12V
Maximum Current	5A
Maximum Load Current	5A
Open Circuit Voltage	15V-25V

2.4. Charge Controller Case

The charge controller case is made from an acrylic material, which is held together by a clear silicon material. The silicon is placed all over the edges of each face of the case excluding the lip, which was not included in the image for that reason. The lid itself is screwed on with four screws at each corner. The holes are made for all the cables that will run out of the system and these holes, while taking up some space from the cables themselves, will also be covered with J-B WELD Marine Weld. The case is rated IP 65, water and dust resistant, so even when the lid of the box is open, water and dust particles cannot harm the controller. The printed circuit board of the controller and connectors are inside the case.

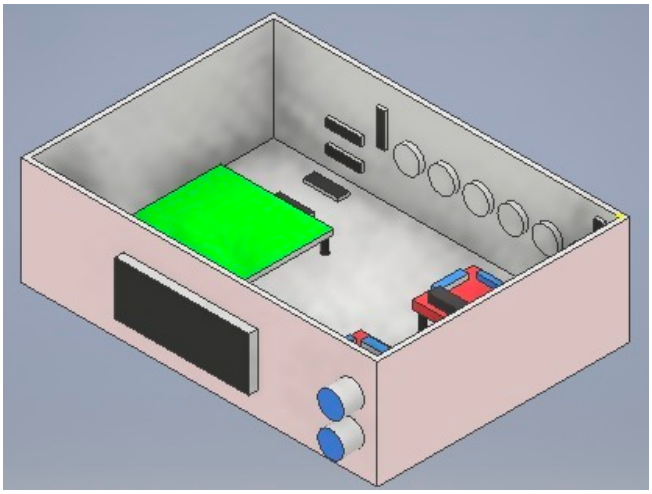


Figure 13 Charge controller case

The LCD display, power, and tracker buttons are placed on the sides of the case. The LCD can display 20 characters per line with 4 lines total. The LCD is programmed to display the voltages of the solar panel and the battery, charging status of the battery, as well as the on/off status of the solar tracker. Once the controller is initialized, the display will show the values. Icons are assigned for easier interaction with the user.

Table 6 Charger icon specification

Icon	Description
	Icon displayed next to solar panel voltage
	Icon displayed next to battery voltage
Bulk	The charger is in Bulk stage
Float	The charger is in Float stage
12V	Voltage

2.5. Considerations

As mentioned above, the system is designed for a 12V lead-acid battery. Further expansion to other battery types and voltage ratings will make it more universal. This could be implemented by writing separate sections in the code for different types of batteries. In order to let the controller know what kind of battery is connected, few switches or push buttons could be added on the side

of the case. User would push the assigned button for their battery type. Furthermore, the interface could be automated with only 3 buttons that could navigate through options on the LCD display.

V. Final System and Subsystems' Level Black Boxes and Functional Diagrams

1. Full System Black Box

In engineering, a black box is a device, system or object which can be viewed in terms of its inputs and outputs without any knowledge of its internal workings. The diagram below shows full system inputs and outputs.



Figure 14 Full system black box

2. Subsystems Black Boxes

The mechanical design of the system has two subsystems. The first part is the mount, which is attached to the kayak, and the second part is the box, which includes the solar panel and electrical components inside of it.

2.1. The Mount Subsystem

The mount includes two major components. The first component is two adjustable bars of 33 inches in length that is attached at the bottom of the box and the frame of the kayak. The second component of the mount is the plate, rotating table, and the supporting gear mechanism connecting to the gear inside the box.

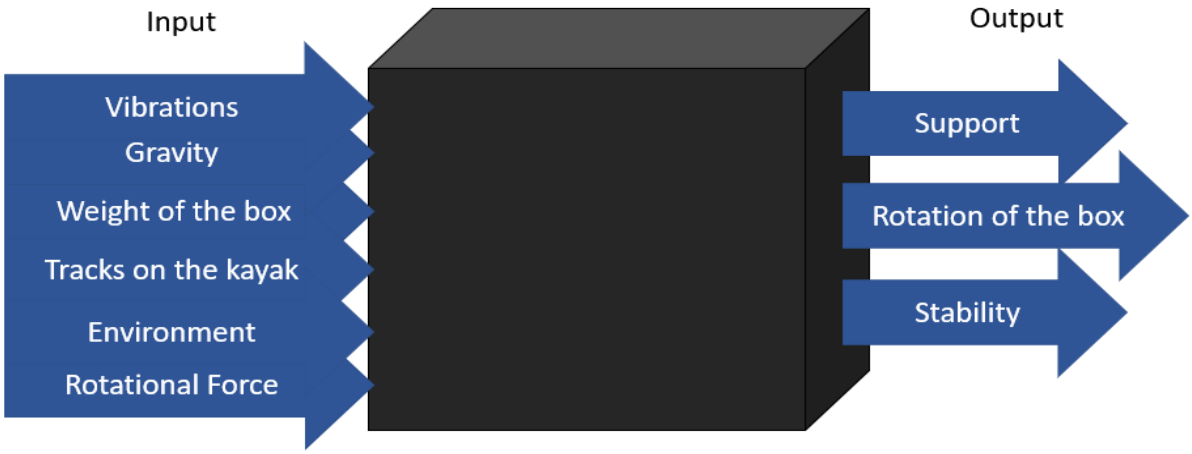


Figure 15 Mount system black box

2.2. The Box Subsystem

The box consists of a linear actuator connected with a hinge system to the top part of the box. Actuator will allow the lid to elevate at an angle and adjust automatically to reduce the angle of incidence between the incoming sunlight and photovoltaic panel. In addition, light intensity will be measured by 4 photoresistors deployed at the top of the box lid.

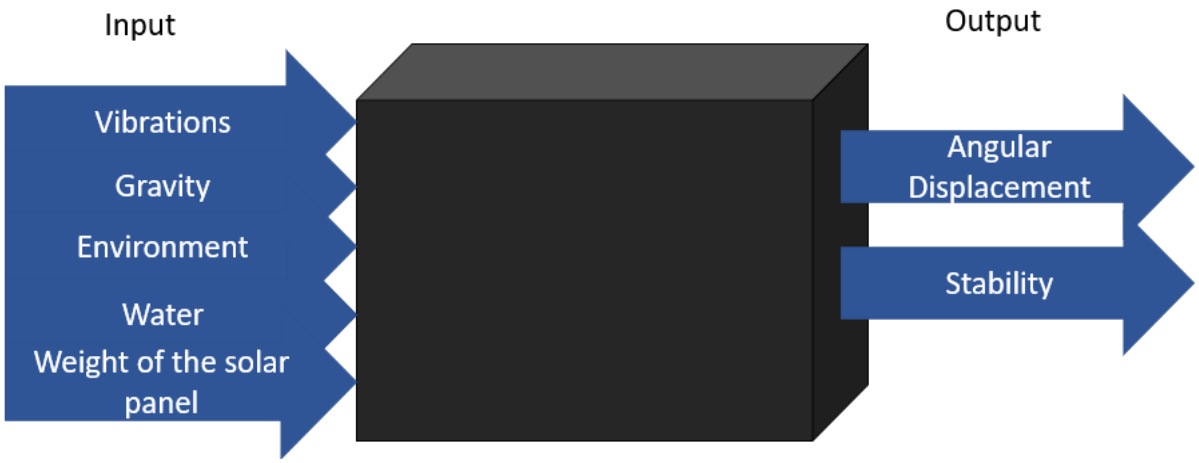


Figure 16 Box system black box

A circuit designed to operate the actuator (as discussed thoroughly in electrical design) also included. As the current fluctuates in the system, the actuator will adjust. Even more than that, a 12V DC motor along with two gears were added to rotate the box system for solar tracking. The smaller gear attached to the motor, whereas the bigger gear takes the load of the box and rotates it accordingly through the feedback signals provided by the controllers.

2.3. The Charge Controller Subsystem

Main purpose of the charge controller is to convert solar power into electrical energy. The solar power system intended for marine purposes, so making the case water resistant is critical to the project. Another main function of the controller includes the protection of the system from abnormal conditions. Described more in detail in the Failure Mode analysis section of the report.

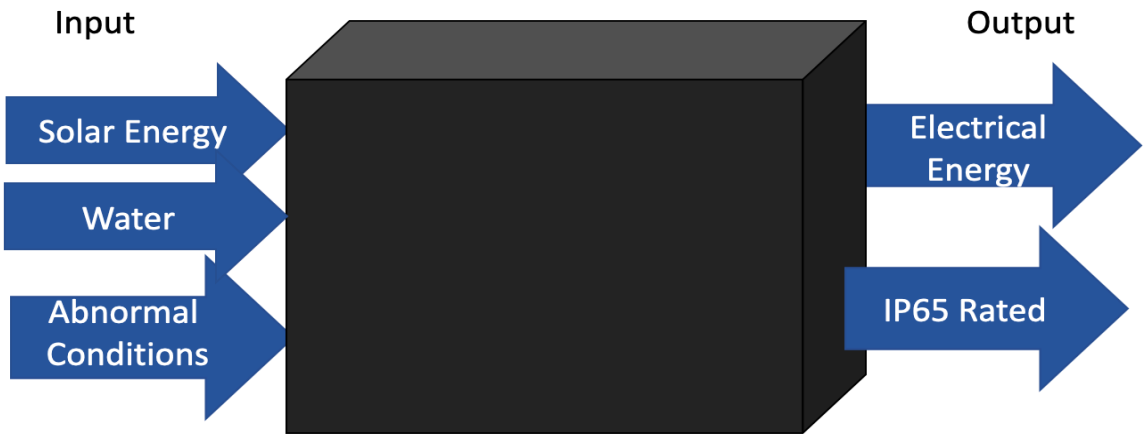


Figure 17 Charge controller black box

2.4. The Solar Tracker Subsystem

The custom controller not only serves as a charge controller, but also a solar tracker. Main purpose is to reach the desired position to achieve maximum sunlight.

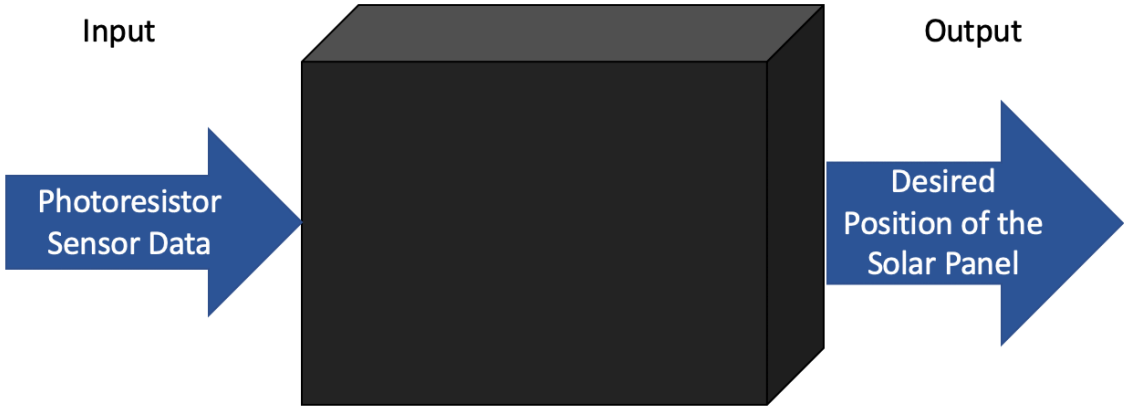


Figure 18 Solar tracker black box

3. Functional Diagrams

3.1. Power Distribution

The diagram below shows power distribution for the entire system. Red arrows indicate power, and black indicates control. Values of voltages are nominal, because real values will fluctuate within a range of ±2V from nominal value.

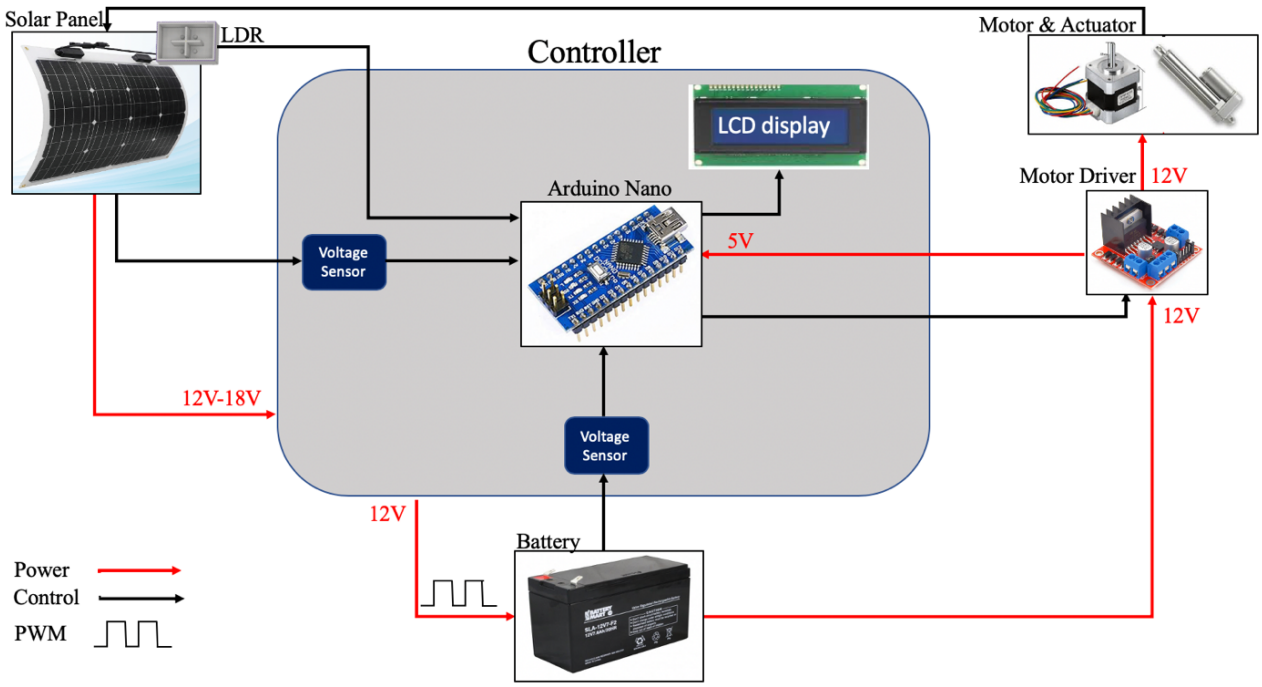


Figure 19 Power flow diagram

The load connected to the system is a marine-grade battery, that will supply power to the consumer electronics such as fish finders, LED lights mounted on a kayak, cell phones and other small electronic devices used by the fishermen. The system has its own load: the solar tracking system, which consists of a linear actuator, and a DC Motor to provide angular and rotational motion to the system to track sunlight intensity as described thoroughly in Mechanical design above.

3.2. Solar Tracker

The solar tracker consists of four photoresistors that determine the most optimal position for the solar panel based on the position of the sun. As the sun rises and sets, the actuator will adjust the angle of the solar panel. As the user rotates their kayak, the motor will rotate the system so that it is always facing the sun.

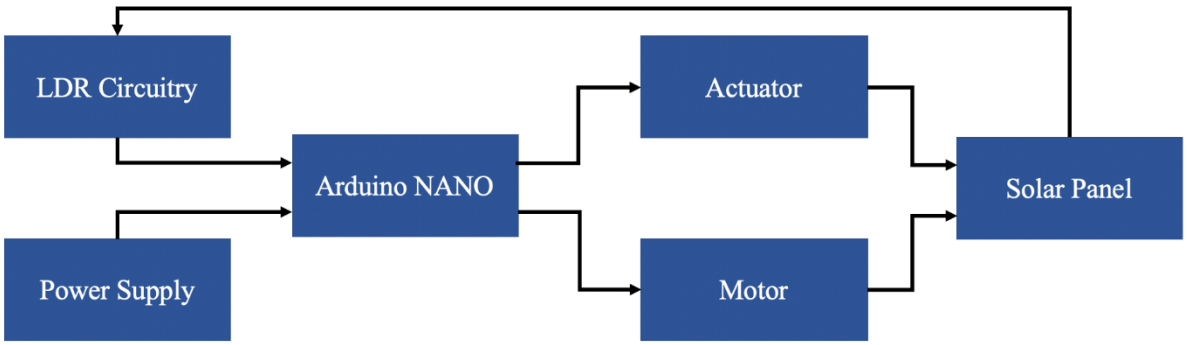


Figure 20 Solar Tracker Block Diagram

VI. Final Design Calculation Results and Selection Reasoning for All Parts

1. Final Design Calculations

1.1. Solar Panel

The first factor to know when calculating the size of the solar panel was how much energy customers consumed on a daily basis. The conducted survey helped the team to determine typical devices kayakers use on their trips. Manuals and data sheets helped establish how much power the mentioned devices consumed.

A solar insolation map helped estimate the number of hours of direct sunlight per day in a local region. Number of hours is affected by factors like the time of the year and the weather on a day. For testing purposes, only the average number was considered.

Once those two numbers were determined, the solar panel size was calculated by dividing the average consumption of power (watt hour/day) by the number of hours of direct sunlight. In

addition, a safety factor of 20% was used to estimate the correct size of the solar panel. For full calculations, please refer to Appendix I, equation 13.

1.2. Mechanical Calculations

Calculations were done in order to ensure the proper functioning of the device. for maximum efficiency, a motor, gears and an actuator were used in the system to rotate and elevate the system. The total weight of the system was 18.22 lbs., the force exerted on the mounts was 18.22 lbf. To calculate the force, the mass of the system and acceleration due to gravity was used.

$$Force\ extered\ on\ the\ gear\ (F) = mass\ of\ the\ system * g$$

Based on the calculations, a motor was selected that would provide torque needed for the rotation of the box. The torque required for the box to rotate was 1.517 lb. ft. To calculate the torque the force and the radius of the gear were used.

$$\tau = F * r$$

Similarly, the gears were 1- inch and 3-inch and the number of teeth on the smaller gear were 12 and on the bigger gear 36. The gear ratio was 1:3, which reduces the speed of the bigger gear by three times which is 3.34 RPM and reduces the torque to 0.505 lb. ft. To calculate the output torque the diameters of the gears were used along with the input torque

$$\frac{\boldsymbol{\tau_{out}}}{\boldsymbol{\tau_{in}}} = \frac{\boldsymbol{D_{big}}}{\boldsymbol{D_{small}}}$$

Lastly, an actuator was installed at a 30° angle to elevate the lid of the box where the solar panel is attached to provide maximum efficiency while the device is in use. The required force exerted on the actuator was 5 lbf.

*Force exerted on the actuator= weight of the lid (including the solar panel) *g*

Below are the results obtained from the calculations and the detailed calculations are shown in Appendix I. Also, *Autodesk Inventor*® was used to run the stress analysis on the 3D model of the system and the values of the results of the simulations are explained below along with other specifications.

Table 7 Results

Specification	Calculated Value
Force exerted on the mount	18.22lbf
Torque	1.517 lb. Ft
Speed	3.34 RPM
Force exerted on the actuator	5lbf
Optimum angle required	30 °
Yield strength (Aluminum 1061)	44961.7 psi
Weight	7.91 lbmass
Von Mises Stress	1.652
Safety Factor	15 ul

Even though the image depicted shows deflection, it is only part of the software illustrating possible deflection. It is so small that it can be neglected running at 1.2e-4 in. only considering we add something more than its limit weight which is 400 lbs. This value is nowhere near the weight that the box will apply running at 30 lbs., so no deflection will be made. We can refer to the values under the Final Simulations Testing Results and Actual Final Actual Testing Results title block.

1.3. Voltage Sensor

The voltage sensors are used to define the voltages of the solar panel and the battery. The voltage of the solar panel can go up to 22.6V (RNG International Inc., n.d.) and the voltage of the battery can go up to 15V, which is higher than Arduino Nano nominal input voltage of 5V (Arduino Official Store, 2019). In order to protect the microcontroller, two voltage divider circuits are used. Resistor's values needed are calculated according to the highest input voltage with a safety factor. For calibration calculations refer to Appendix I, equation 14.

2. Parts Selection

2.1. Solar Panel

There are 3 types of solar panels on the market. Monocrystalline, polycrystalline and amorphous (flexible). In order to determine the best type for our design, the team considered factors like efficiency, cost, safety, weight and durability. Polycrystalline panels were excluded first because of lower silicon purity, which makes them not quite as efficient as the others. Monocrystalline panels are heavier and more expensive in comparison to flexible panels. Since weight is critical in the design and flexible is about three times lighter than the first option, the team decided to go for amorphous.

For specifications refer to Parts Listing.

2.2. Material for the Mount

Aluminum was chosen to make the mount because of its non- conductive, lightweight and non-corrosive material properties. The mount's length is 33" and the adjustment slides are added to reposition the mount on the kayak according to the frames on the kayak, which makes it universal for all sit on top kayaks.

For specifications refer to Parts Listing.

2.3. Material for the Box

One of the requirements for the design was to make the system lightweight and as a result, a compatible material was required. Aluminum and Acrylic were the two choices suitable for this project, but due to the feasibility of acrylic, it was chosen to make the box.

For specifications refer to Parts Listing.

2.4. Material for the Gear

Selection for the gear was done keeping in mind that the team needed to keep everything under an economic level. Since the gears are located inside the box system, and the system is secured by the means of silicon which protects it from water. So, there will be no need to have any exclusive material. Hence, a 3D printed material was selected because it is lightweight.

For specifications refer to Parts Listing.

2.5. Controller Case

The selection of the case material was simple. To cut cost leftover material from the box system was used. An interesting part of the polycarbonate system as well is that it is clear. Having a see-through system is beneficial because it allows any user to see how every system inside of it functions. In case of malfunction, it would be easy to see the problem.

2.6 Connectors

The MC4 connectors are used to connect the solar panel to the controller. These connectors are IP67 rated and sized at 10 gauge for a 30A rating. The control wires are 16 gauge that include the connection from the photoresistors to the controller. These 8 wires will be joined as one common cable that connects into the charge controller case and sealed so no water can enter the case.

For specifications refer to Parts Listing.

2.7. LCD display with I2C module

The 20x04 LCD can display twenty characters in each of the four rows. The I2C module is used to reduce the number of wires connected to the Arduino from nine to four.

For specifications refer to Parts Listing.

2.8 Printed Circuit Board

Previous prototype for the controller was soldered on protoboard. Even though it was fully functional, the team decided to go with printed circuit board instead, since it`s more permanent design. The PCB has no wires connected on the outside and more convenient layout in comparison with the protoboard.

For specifications refer to Parts Listing.

VII. List of Risks Involved and Failure Mode Analysis

1. Mechanical Failures

Mechanical Failure mode analysis is a risk management tool to identify and assess the causes and effects of potential failures in a system. It will prevent failure from happening again by evaluating the effectiveness of the mechanical and the electrical system. Some of the mechanical failure components were actuator, motor malfunction, and gear wear. The table below describes some of the problems causing the failure, and its solution.

Table 8 List of Mechanical Failures

Problem	Solution
Actuator malfunction	IP 65 rated, code
Motor malfunction	Check wire connections and fuse
Gear wear	Lubrication, replacement

More specific and precise details of failures and its solutions are discussed in the User Manual in the Appendix M. The table above depicts the problem along with its solution.

2. Electrical Failures

Table 9 Protection System of Charge Controller

Problem	Solution
Reverse Polarity & Reverse Current Flow	Power diode MBR2045 (can handle large amount of current)
Overcharge & Deep Discharge	Code
Overcurrent & Overload	2 fuses
Overvoltage (Lightning)	TVS diode (P6KE36CA)

Power diode MBR2045 can handle immense amounts of current. It is used for protection against the reverse current flow as well as reverse polarity. Some of the electrical failures include preventing battery overcharge and over-discharge. Battery overcharge occurs when the charge controller keeps providing energy coming from the solar panel even if the battery is fully charged, permanently damaging it. A section of the charge cycle code is implemented to prevent this failure. Over-discharge occurs when the battery is low and dragging power from electrical loads. Section load control helps the system to avoid this problem.

The general purpose of fuses is to protect against higher currents. The solar panel used in the design has a maximum current of 2.92A (RNG International Inc., n.d.), so closest to this value 5A rated fuse is used in the design. Natural events like lightning and storms can occur and cause very severe overvoltage. To protect against events like that, a bidirectional TVS diode is used.

VIII. Final Testing Results

Due to COVID-19, some of testing could not be completed. Subsystems were tested separately, but not the full system. For actual testing results please refer to Final Actual Testing Results section. The plan for testing is below.

Test Plans

The prototyping phase of the project requires that the system be broken down into subsystems in order to ensure that the full system will be functioning as designed. The four subsystems in this project include the charge controller, the rotational gear drive system, the actuator angle adjustment system, and the solar tracking system. By testing each individual subsystem, it will ensure that the components are properly functioning, the electronic components are connected and secured, and the programming algorithms are correct. Once this is complete, the subsystems can be combined to create the full assembly. The mechanical and electrical testing procedures for each subsystem are described below.

The following flow chart shows the overall system divided into subsystems.

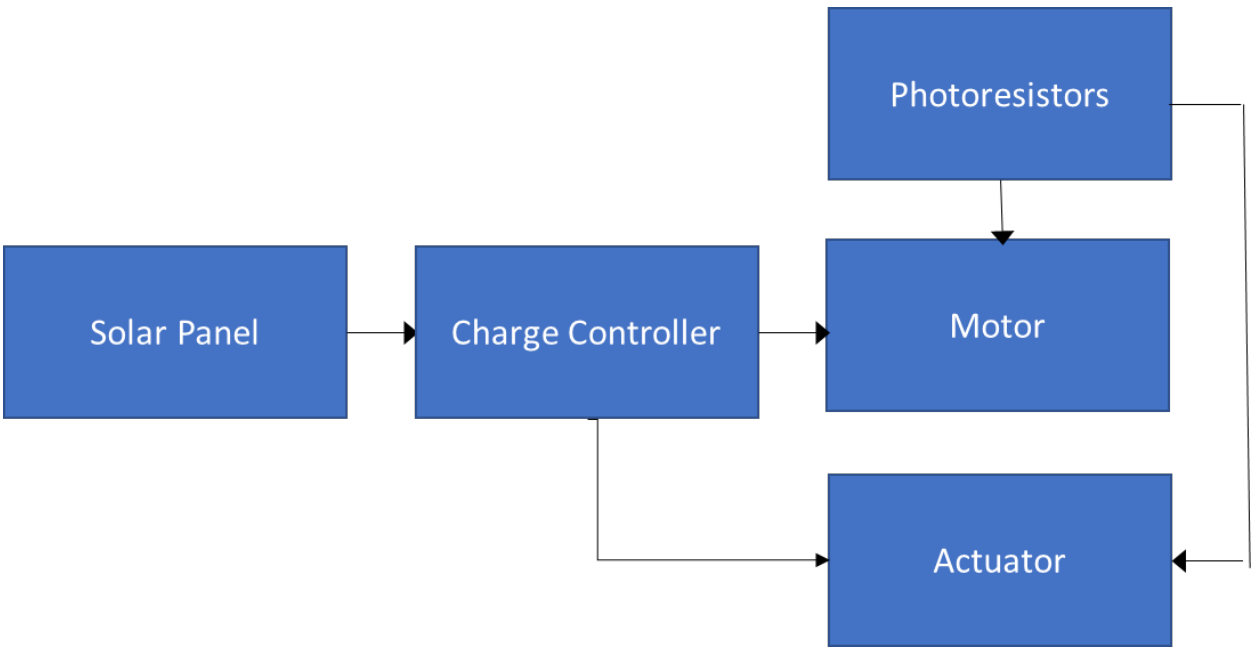


Figure 21 Overall System Flow Chart

I. Charge Controller

1.1. Mechanical

The cables for the charger will be already purchased as waterproof the only ideal way to verify if the cables are indeed waterproof, they will be submerged underwater. They will be left there for two to three minutes, brought back up then time to dry out and connect back to the charger and verify if they still work. Same thing will apply to the case with all the research done there is several companies that offer testing, and, in their specifications, they simply state that all devices are put through; mild to high pressures of water and submerged under water. The case will be held in place while a water pressure gun will blast it full pressure. This will last about two to three minutes as well, after the case dries out then it will be turned on and verified if it works. One could also submerge the control underwater as well for two to three minutes and then later try to run it. Several videos on YouTube did so, as well as companies such as ATS (Applied Testing Service), MW (Minnesota Wire), just to name a few.

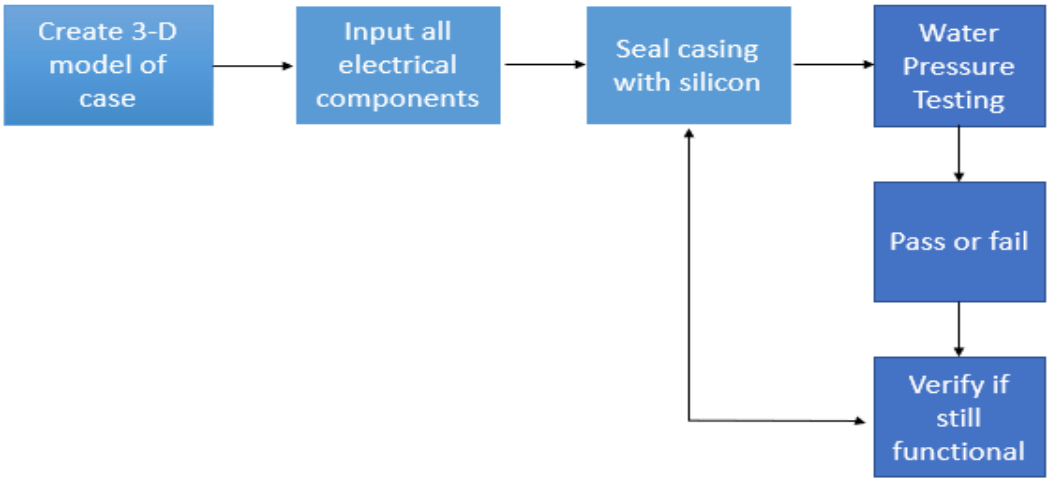


Figure 22 Charge Controller Test Flow Chart

1.2. Electrical

The purpose of testing the charge controller is to verify that all the components are functioning properly before the solar panel is connected. The circuit will be connected to a DC power supply in a controlled lab environment. This allows for a simulation of a solar panel with lower currents to safely test the electronics. 1A of current will be initially supplied in 0.3A increments up to 4.2A, which would simulate a solar panel under full sun conditions. The output voltage, current, power and efficiency of the circuit design will be determined during this test using a multimeter and oscilloscope.

The test will also include a confirmation of the battery voltage transitions between the different cycles of charging. A power source will be connected to the battery voltage sensor input to simulate the status of the battery and charge mode.

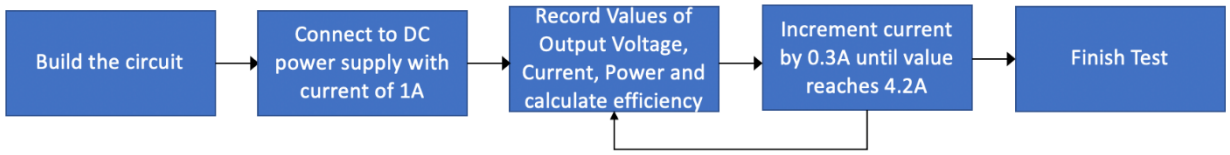


Figure 23 Charge Controller Test Plan

II. Motor-Gear system.

2.1. Mechanical

A full-scale 3D model of the gears will be made and to check if they rotate according to the feedback provided by the photoresistors. The prototype gear will be made and subjected to different size of loads, starting from 5 lbs. until the system fails to check if the gear can withstand

the subjected load. In case of load failure, measures will be taken to solve the problem. After the components are connected, a test run will be applied by exposing the photoresistors to the light, which will send signals to the motor to rotate the gears and turntable. As a result, the system will pass or fail the mechanical test. An IP65 rated protection case will be made to protect the motor from the water exposure which may damage its electrical components. To seal the protection box for the motor a waterproof silicon coding will be applied on the case and IP65 testing procedures will be followed.

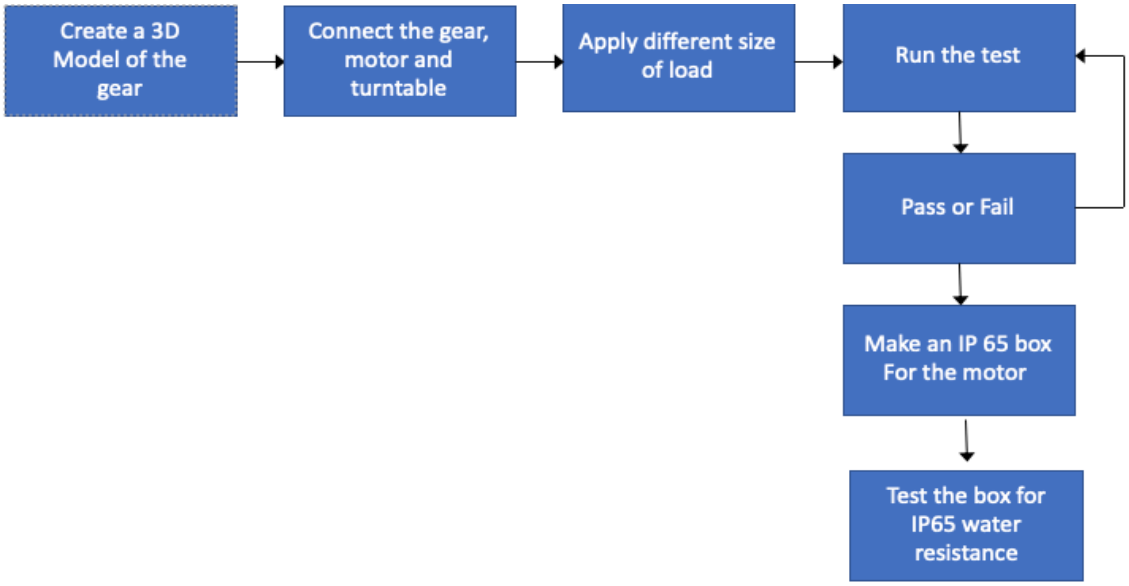


Figure 24 Mech Motor-Gear Test Flow Chart

2.2. Electrical

To control the speed and direction of the motor, the Pulse Width Modulation (PWM) pins on the microcontroller and an H-Bridge motor driver. The testing of the motor will consist of rotating the motor in both directions at various speeds so that the motor can be calibrated to the necessary torque required by the gears to rotate the box. Two pins are used to control the rotation of the motor, while the speed is adjusted from the PWM pin.

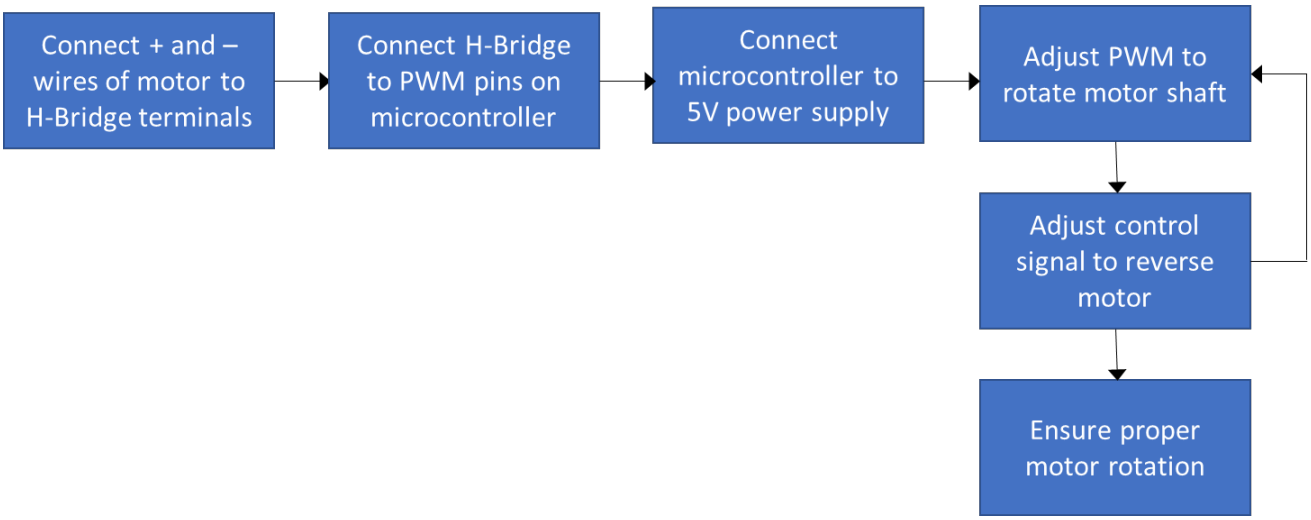


Figure 25 Elec Motor Test Flow Chart

III. Actuator

3.1. Mechanical

The actuator will be mechanically tested after connecting it to the system, like the simulation. The actuator will be checked for its durability and stability in the system, that will be used to determine the life. Also, it will be tested cursory for water resistance; provided, the actuator is already IP66 as mentioned by the manufacturer.

The actuator can operate under 35lbs of dynamic load and 200lbs of static load, given the maximum load on the actuator do not go beyond 15lbs in the most severe conditions and high winds. The life of the actuator can be predicted as infinite.

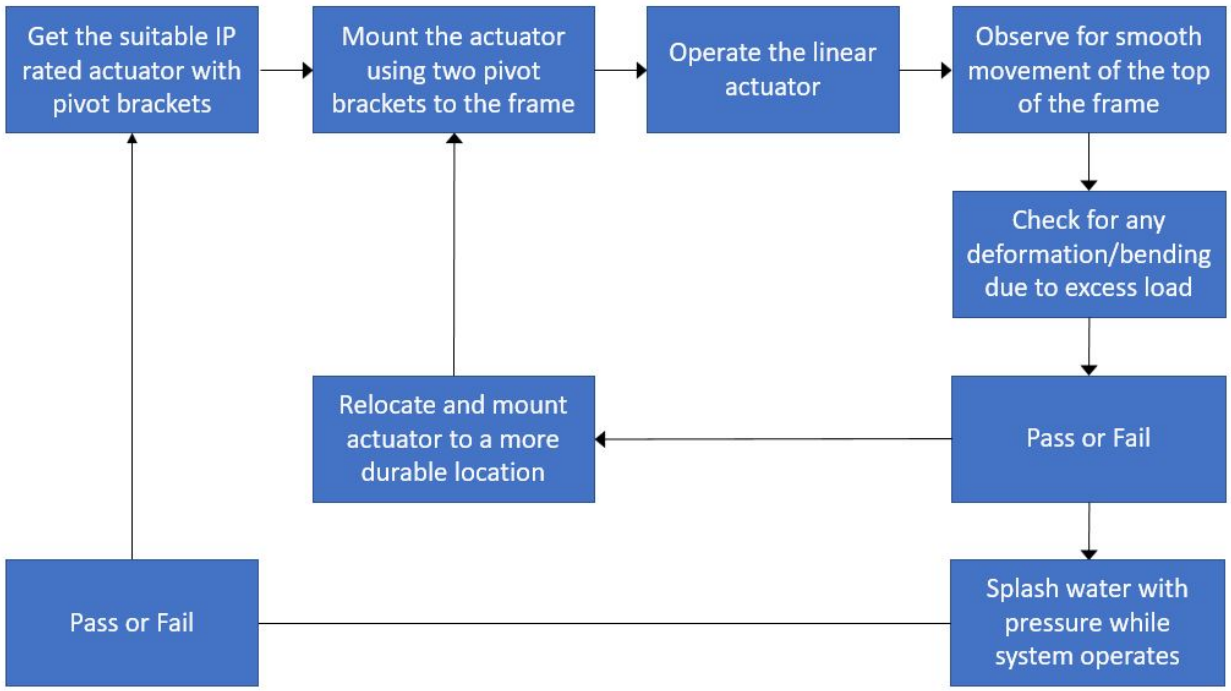


Figure 26 Mech Actuator Test Flow Chart

3.2. Electrical

The actuator will be electrically tested by using an H-Bridge to control the direction of current flow. Depending on the direction of current, the direction of the actuator arm can be controlled. Calibration is required on the PWM circuit and the amount of extension or retraction is necessary to raise and lower the solar panel. By adjusting the amount of time, the actuator is receiving current, the displacement can be determined. For hold conditions, the current will be monitored using an oscilloscope at various positions of the actuator.

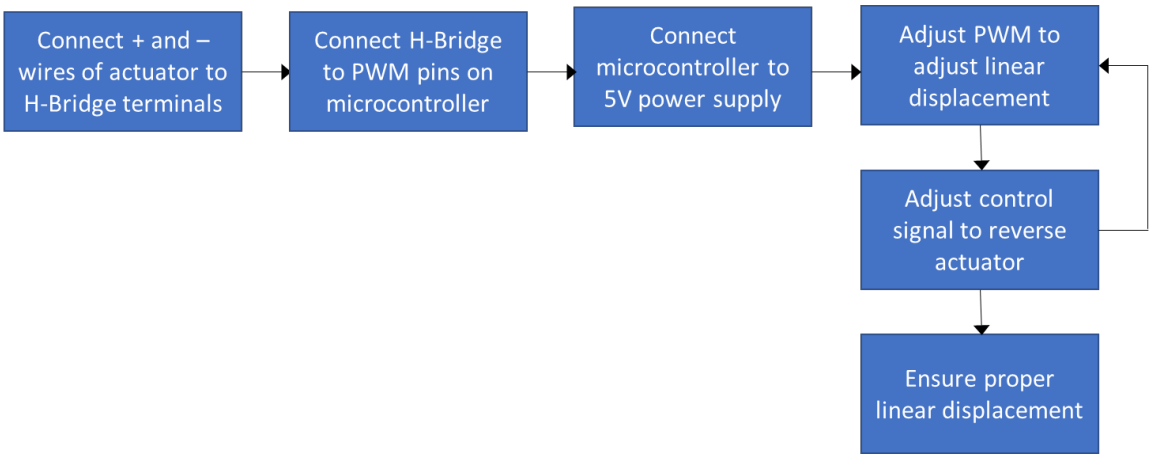


Figure 27 Elec Actuator Test Flow Chart

IV. Solar Tracker

4.1. Mechanical

The wires of the photoresistors will be made IP65 by using an electrical tape to protect it from water damages and short circuits. In order to pass testing and achieve an IP65 rating, fixtures must be able to withstand water projected by a 0.25-inch nozzle. To achieve satisfactory results, this test must be run for a minimum of fifteen minutes, with the water source placed three yards from the fixture. Additionally, the water pressure must be 30 kPa with a water volume of 3.3 gallons per minute.

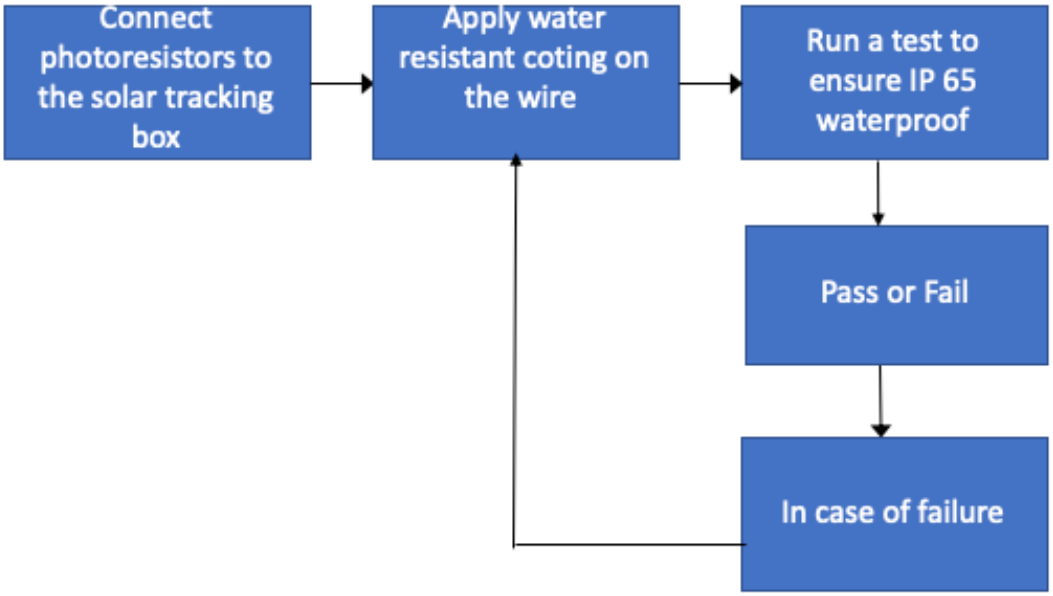


Figure 28 Mech Solar Tracking Test Flow Chart

4.2. Electrical

The electrical testing of the solar tracking system requires four photoresistors. The goal of the test is to determine the resistance values for each photoresistor under sunny and shaded outdoor environments. The difference in resistance under sunny and shaded conditions can be determined to provide a threshold value that can be used to rotate or angle the solar panel until the opposite photoresistor resistance values are within a tolerance of 10%.

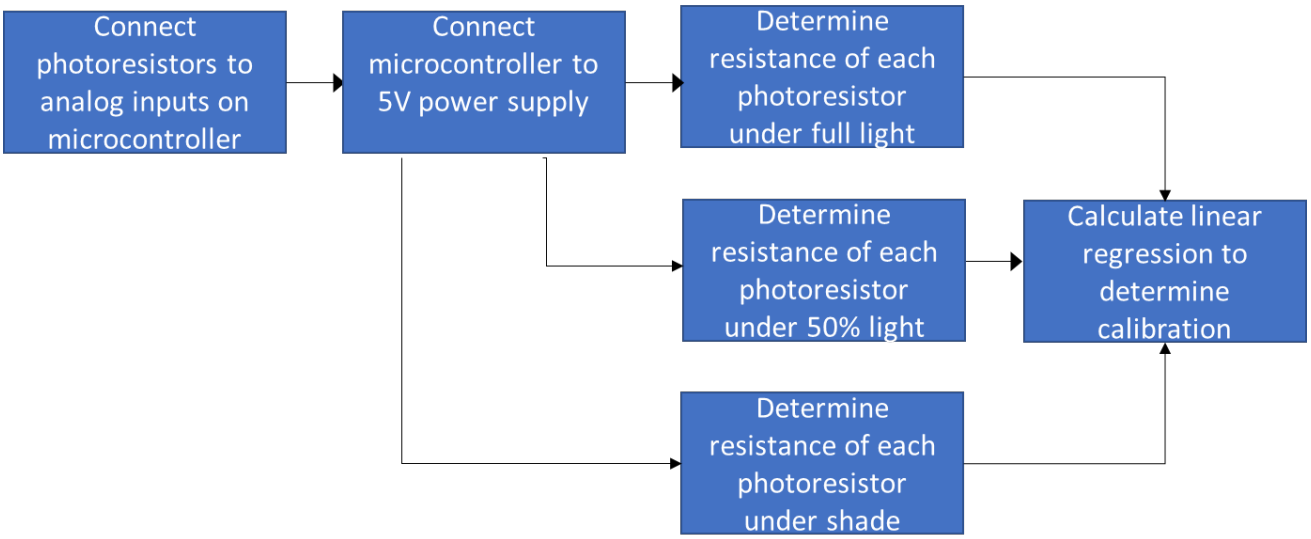


Figure 29 Elec Solar Tracking Test Flow Chart

V. Combined System.

5.1. Mechanical

After the custom manufacturing of the mechanical components, i.e. box, mount system and the frame, it will be weighed to make sure that the weight of the system remains under 30 lbs. The components are all tested separately for IP 65 ratings to make sure the components are not damaged by splashes of water. In order to pass testing and achieve an IP65 rating, fixtures must be able to withstand water projected by a 0.25-inch nozzle. To achieve satisfactory results, this test must be run for a minimum of fifteen minutes, with the water source placed three yards from the fixture. Additionally, the water pressure must be 30 kPa with a water volume of 3.3 gallons per minute.

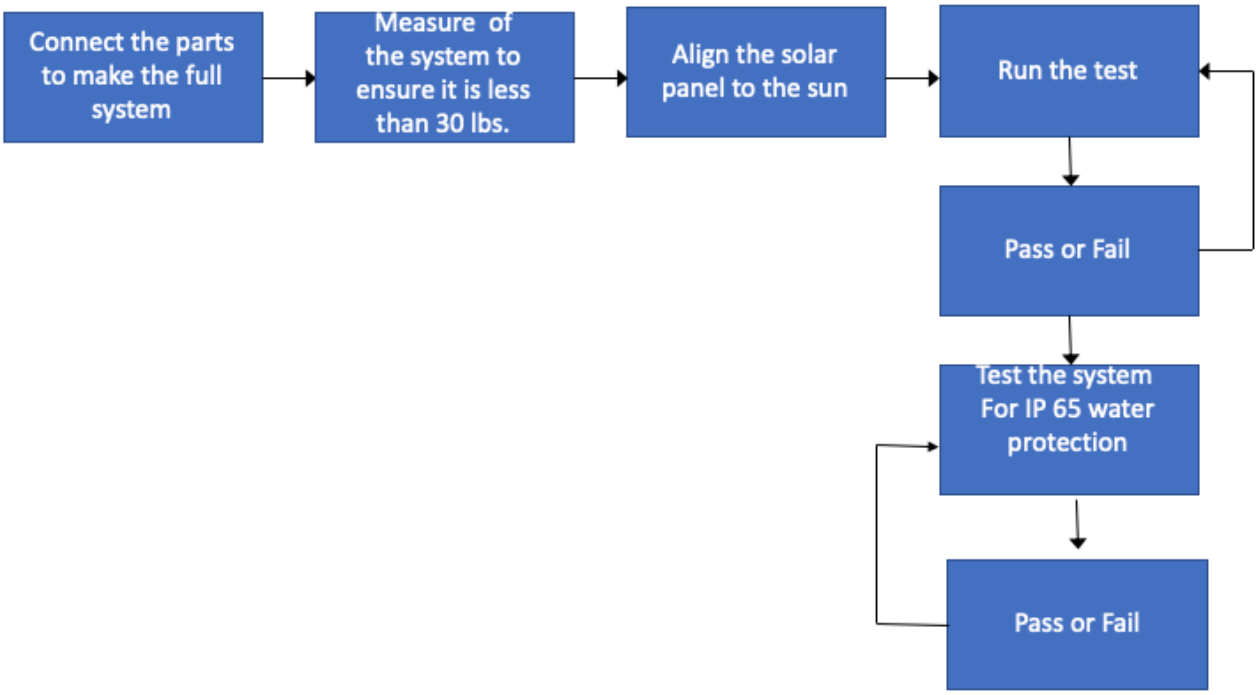


Figure 30 Mech Combined System Test Flow Chart

5.2. Electrical

Once the electrical subsystems have been tested and verified, there will be three stages of combining. The first is to integrate the motor and actuator with the solar tracker. The photoresistors will be mounted to a piece of cardboard and individually covered. The response of the motor and actuator will be tested to ensure proper movement.

The second stage is to integrate the tracking system with motor and actuator to the charge controller circuit. This will be tested still using a DC power supply in a lab and light conditions simulated with a lamp. This test will determine that the charge controller is becoming more efficient as it tracks the light.

The final stage is to include the solar panel with the charge controller to verify that the entire electrical system is functioning together. A 10Ah battery will be connected to the full system

and the voltage will be monitored to determine the charge time and proper transitions of the controller charge modes.

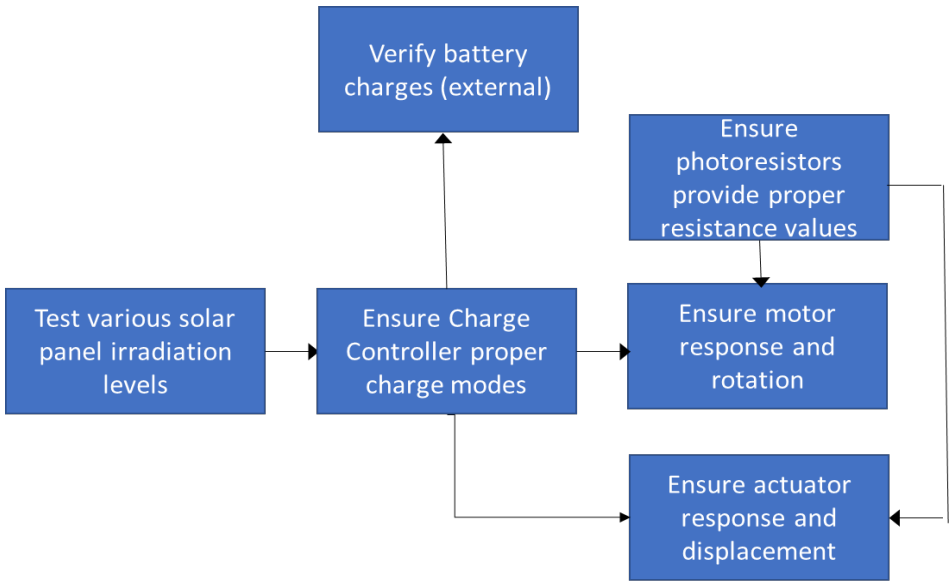


Figure 31 Elec Combined System Test Flow Chart

IX. Final Simulations Testing Results and Final Actual Testing Results

1. Simulation Results

The final simulation testing was done in *Autodesk Inventor*® and the results are explained below.

To obtain the following values, *Inventor*® was used to be able to run the stress analysis attachment. The material selected for the mounting system was Aluminum 1061 giving us a yield strength of 44961.7 psi. The whole mounting system itself weighed 7.91 lbmass. Having a Von Mises Stress of 1.652. Even though the image depicted shows deflection it is just part of the software illustrating possible deflection, it is so small it can be neglected running at 0.00012 in.

and only considering we add something more than its limit weight which is 400 lbs. Which is nowhere near the weight the box will apply running at 30 lbs., so no deflection will be made. Also, this gives us the safety factor of 15 ul.

Table 10 General Properties

Name	Aluminum 6061	
General	Mass Density	0.0975437 lbmass/in^3
	Yield Strength	39885.4 psi
	Ultimate Tensile Strength	44961.7 psi
Stress	Young's Modulus	9993.1 ksi
	Poisson's Ratio	0.33 ul
	Shear Modulus	3756.8 ksi

The material selected for the mounting system was aluminum giving us a yield strength of 44961.7 psi giving us a very strong stiffness of a very much needed solid material. Presenting us with the opportunity of being to hold a large mass.

Table 11 Material Properties

Name	**Minimum**	**Maximum**
Volume	81.1184 in^3	
Mass	7.91259 lbmass	
Von Mises Stress	0 ksi	1.23673 ksi
1st Principal Stress	-0.267862 ksi	1.72503 ksi
3rd Principal Stress	-0.727997 ksi	0.371331 ksi

The mounting system itself weighed in at 7.91 lbmass giving us the lightweight the system requires. Like all Von Mises Stress (as pictured below) on all metals giving is a small yield point for such brittle material, but with the small system and light weight there is no worry for the system breaking apart.

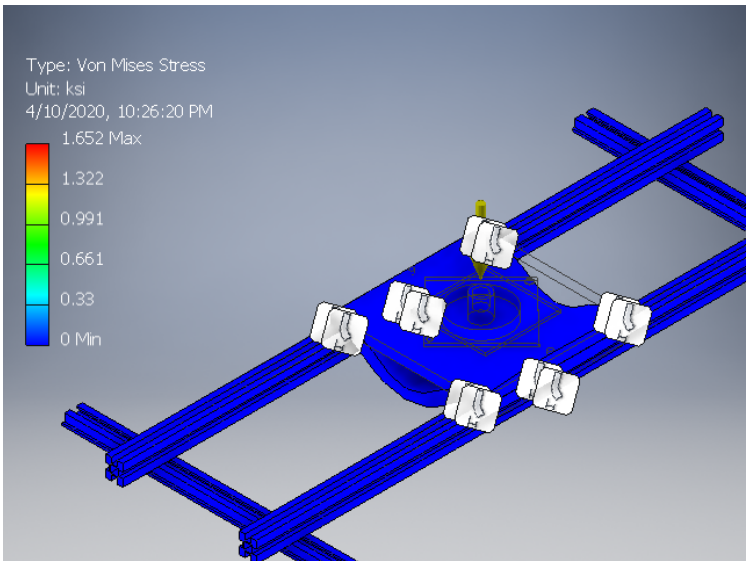


Figure 32 Mounts Von Mises Stress

Even though the image above shows deflection it is just part of the software illustrating possible deflection. When there is no deflection, ever so small that it does not need to be considered which can be illustrated in the system report. Also, this gives us the safety factor of 15 ul.

Table 12 Safety Factor

Displacement	0 in	0.000120187 in
Safety Factor	15 ul	15 ul

2. Final Actual Results

2.1. Charge Controller

Charge controller test was conducted by connecting the PCB to the 50W rated solar panel and a 12V lead acid battery. Battery charging time and status were closely monitored.

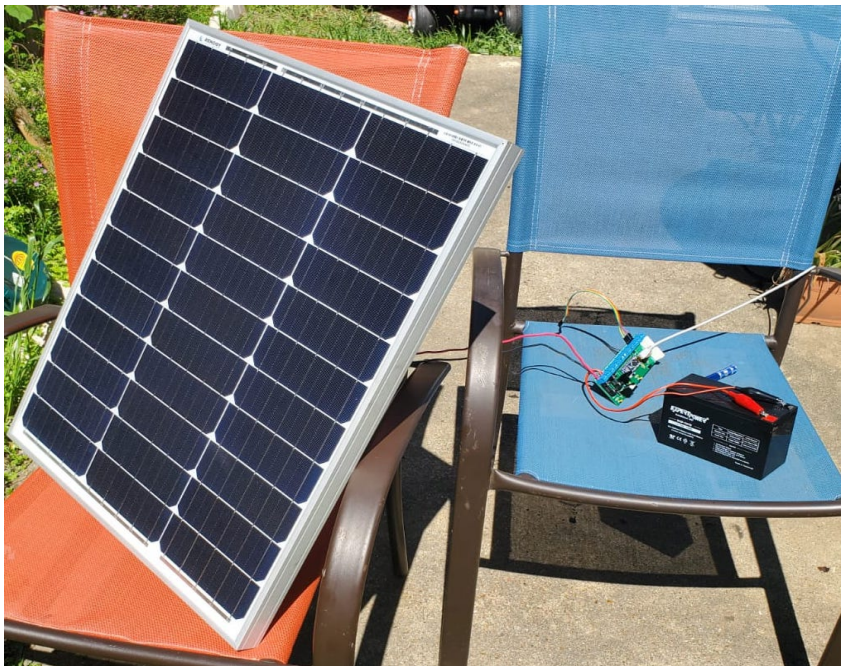


Figure 33 Charge controller testing

The figure below the change in battery voltage over time:

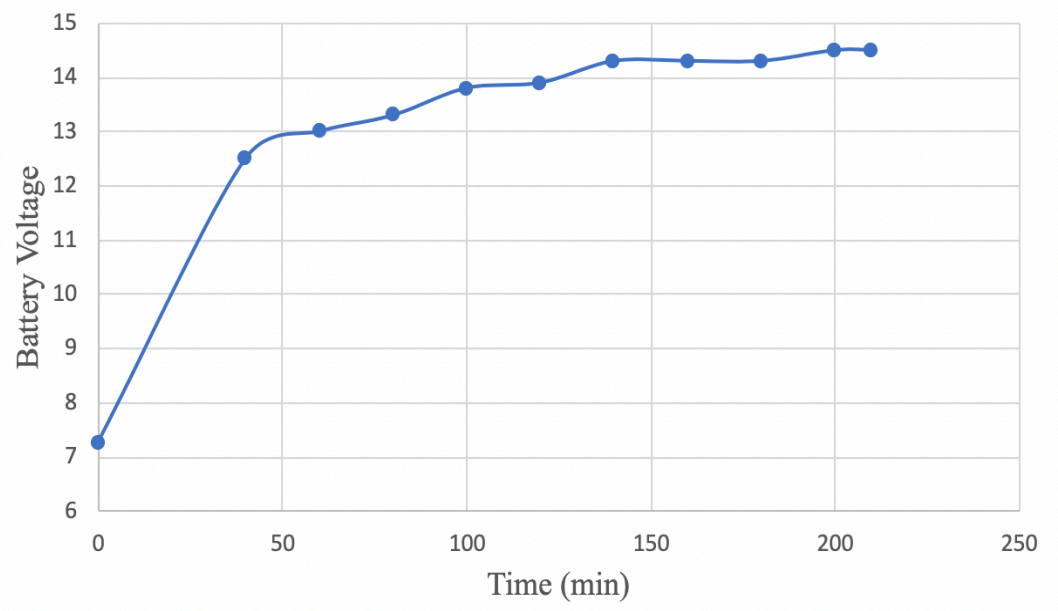


Figure 34 Battery charge time graph

The total charge time was 220 min under ideal solar conditions. First charging cycle, Bulk mode started at the beginning of the test and continued until 50 minutes. It got battery voltage up to 12.5V and then switched to Absorption mode. Float mode continued until 140 minutes, getting

battery voltage up to 14.3V. Float mode starts at 140 minutes and continues until the battery is fully charged at 14.5V.

2.2. IP65

Due to the unfortunate pandemic the only test that was able to be physically conducted was the testing of the charge controller case. In order to pass testing and achieve an IP65 rating, fixtures must be able to withstand water projected by a 0.25-inch nozzle. To achieve satisfactory results, this test must be run for a minimum of fifteen minutes, with the water source placed three yards from the fixture. Additionally, the water pressure must be 30 kPa with a water volume of 3.3 gallons per minute.

2.3. Mechanical subsystem

Mechanical subsystem testing includes testing of the motor, gears and actuator. The motor and actuator were able to rotate the box and elevate the lid of the box to 30°. Picture below shows the testing:

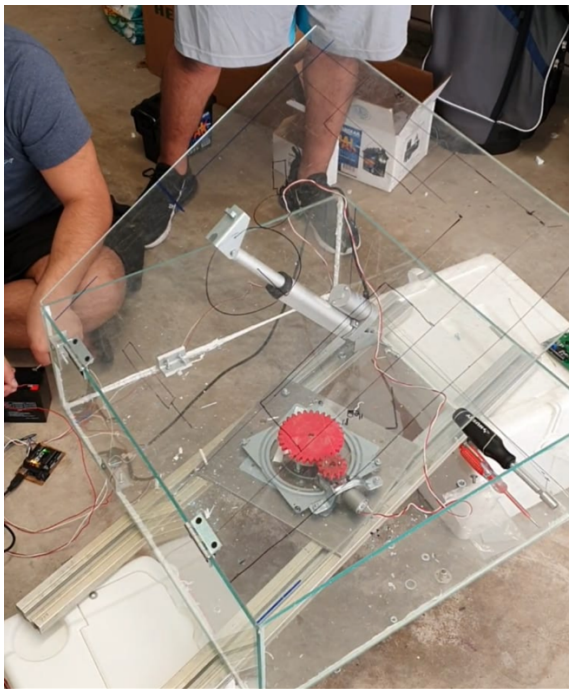


Figure 35 Mechanical testing

X. BOM and Detailed Actual Budget

1. Bill of Materials

Table below includes the bill of materials for final prototype.

Table 14 Bill of Materials

№	Name	Qty	Unit Price	Total Price	Description
1.	Acrylic sheet	3	$40	$120.00	Acrylic 24 x36 x0.124
2.	Solar Panel (RNG-50DB-H-BC)	1	$95.99	$95.99	26.5x20x0.08 in 2.87 lbs.
3.	Linear actuator (FA-35-12-6-P)	1	$35	$35	Aluminum 16 in Extended 10 in Retracted
4.	12V DC Motor	1	$20	$20	Steel 3 x1.3 x1
5.	Box Handle (5186A5)	1	$24.45	$24.45	Stainless Steel 8” width
6.	3D Printer filament	1	$19.79	$19.79	PLA
7.	Flex Seal	1	$12.34	$12.34	
8.	Lead acid battery	1	$20.79	$20.79	Lead
9.	Handle Screws	2	$1	$1.99	Steel
10.	Power Button	1	$6.49	$6.49	Plastic
11.	Brackets	4	$2.5	$10	Steel
12.	Hinges	4	$2.5	$10	Steel
13.	Linkage	1	$5	$5	Brass
14.	Arduino Nano	1	$8.59	$8.59	

Table 13 Bill of Materials continued on the next page

№	Name	Qty	Unit Price	Total Price	Description
15.	Custom PCB	5	$29.65	$29.65	Manufactured by JLCPCB
16.	P-Channel MOSFET	2	$0.95	$1.90	IRF9540
17.	Power Diode	1	$1.24	$1.24	MBR 2045
18.	Buck Converter	1	$1.77	$1.77	MP1584
19.	TVS Diode	1	$0.42	$0.42	P6KE36CA
20.	BJT (2N3904)	2	$0.44	$0.88	2N3904
21.	100kΩ Resistor	2	$0.1	$0.2	Carbon Film
22.	20kΩ Resistor	2	$0.1	$0.2	Carbon Film
23.	10kΩ Resistor	6	$0.1	0.6	Carbon Film
24.	1kΩ Resistor	2	$0.1	$0.2	Carbon Film
25.	0.1µF Capacitor	2	$0.4	$0.8	Ceramic
26.	LCD Display	1	$14.59	$14.59	20x04
27.	Wires	1	$1.95	$1.95	12 AWG, 16 AWG
28.	Fuse holder	2	$0.62	$1.24	
29.	Fuses	4	$0.36	$1.44	Fast Blow 5amp rating
30.	Screw Terminals	14	$0.42	$5.85	2 pins
31.	Button Terminals	3	$0.78	$2.34	Plastic

Table 15 Bill of Materials continued on the next page

№	Name	Qty	Unit Price	Total Price	Description
32.	Photoresistor	4	$0.95	$3.80	GL5528
33.	Heatsink	3	$1.48	$4.44	Uxcell 20x
34.	Push Button	1	$0.11	$0.11	
	Total (not including tax)			**$464.05**	

2. Detailed Actual Budget

2.1. Electrical

Detailed actual budget includes cost for 3 prototypes, as well as spare components. They were purchased in case of accidents during testing like overheating of a MOSFET or blowing the fuse. List of full components purchased is below:

Table 17 Detailed Actual Budget for electrical components

№	Name	Qty	Unit cost	Total Cost	Description
1.	Arduino Nano	2	$8.59	$17.18	
2.	Breadboard	1	$7.29	$7.29	Used in prototype 1
3.	Protoboard	1	$3.00	$3.00	Used in prototype 2
4.	Printed circuit board	5	$29.65	$29.65	Final prototype
5.	P-Channel MOSFET	6	$0.95	$5.70	IRF9540
6.	Power Diode	2	$1.40	$2.80	MBR 2045
7.	Buck Converter	1	$5.09	$5.09	MP1584
8.	TVS Diode	2	$0.39	$0.78	P6KE36CA
9.	BJT (2N3904)	4	$0.75	$3.00	2N3904
10.	100kΩ Resistor	4	$0.20	$0.80	Carbon Film
11.	20kΩ Resistor	4	$0.20	$0.80	Carbon Film
12.	10kΩ Resistor	8	$0.20	$1.60	Carbon Film
13.	1kΩ Resistor	4	$0.20	$0.80	Carbon Film
14.	0.1µF Capacitor	4	$0.50	$2.00	Ceramic
15.	LCD Display	1	$12.99	$12.99	20x04
16.	Wires	1	$1.95	$1.95	12 AWG, 16 AWG

Table 16 Detailed Actual Budget for electrical components continued on the next page

№	Name	Qty	Unit cost	Total Cost	Description
17.	Fuse holder	2	$0.62	$1.24	
18.	Fuses	5	$0.36	$1.80	Fast Blow 5amp rating
19.	Screw Terminals	14	$0.42	$5.88	2 pins
20.	Button Terminals	3	$0.78	$2.34	Plastic
21.	Photoresistor	8	$0.95	$7.60	GL5528
22.	Heatsink	3	$2.00	$6.00	Uxcell 20x
23.	Push Button	1	$0.11	$0.11	
24.	Alligator Clips	4	$0.75	$3.00	Used for testing
25.	Battery	1	$20.79	$20.79	Used for testing
26.	Current Sensor	1	$9.99	$9.99	Used for testing
27.	Motor Driver	2	$8.89	$17.78	L298N
	Total (not including tax)			**$171.96**	

2.2 Mechanical

The mechanical design had two prototypes. Both of them had the same mounts, the materials for the mount was salvaged from our team members manufacturing company and the other parts were donated to us by our sponsor ACK. The material used for the box for the first prototype were also salvaged from ACK, but for final prototype the Acrylic sheet were purchased through the university.

Table 18 Detailed budget for mechanical components

№	Name	Qty	Unit Price	Total Price	Description
1	Acrylic sheet	3	$40	$120.00	Acrylic 24 36 x0.124
2	Solar Panel (RNG-50DB-H-BC)	1	$95.99	$95.99	26.5x20x0.08 in 2.87bs.
3	Linear actuator (FA-35-12-6-P)	1	$35	$35	Aluminum 16 in Extended 10 in Retracted
4	12V DC Motor	2	$20	$40	Steel 3 x1.3 x1
5	Box Handle (5186A5)	1	$24.45	$24.45	Stainless Steel 8” width
6	3D Printer filament	2	$19.79	$39.58	PLA

7	Flex Seal	1	$12.34	$12.34	
8	Handle Screws	2	$1	$1.99	Steel
9	Power Button	1	$6.49	$6.49	Plastic
10	brackets	4	$2.5	$10	Steel
11	Hinges	4	$2.5	$10	Steel
12	Linkage	2	$5	$10	Brass
	Total (not including tax)			**405.84**	

XI. Economic Feasibility (Cost of Prototype vs. Mass Production Cost)

According to Statista approximately sixteen million people went for kayaking trips in the United States in 2018. (statista, n.d.) People like to spend time outdoors with family and friends and they might not always have a source of power to charge their electrical appliances when they are out. If they do have a system, it`s heavy and takes up a lot of space. Our product gives them the freedom to charge their electrical appliances anywhere they go using solar power, its lightweight and is easily portable.

The cost to manufacture a single unit was $464, while the recommended price to sell a single unit would be $1000. Since the unit was a prototype model, the cost to manufacture was a lot higher, if mass-produced the cost of a unit could be reduced to $250. Giving a return on investment of $750 per unit I.e. a margin of 300%.

The market for solar chargers has been constantly increasing over the years but is still not crowded. The product has novelty and if promoted, could cover the target audience not only the kayakers but also campers and other adventure seekers. This device is portable, lightweight and waterproof, making it a useful product for outdoors. The table in the Appendix C shows the cost breakdown for the mass production.

XII. Flow Charts of Software

1. Charge Controller

In order to construct the flow chart of the charge controller, the charging algorithm of the battery needed to be understood. Batteries have 3 stages of charging: bulk, absorption and float.

Ideal Charging Procedure:

During **Bulk** mode a fixed maximum amount of current is fed into the battery until it reaches the set voltage. After that **Absorption** mode turns on, where PWM begins to hold constant voltage and current goes down to safe levels. Otherwise the battery might overheat or over-gas. At **Float** mode the battery is fully charged.

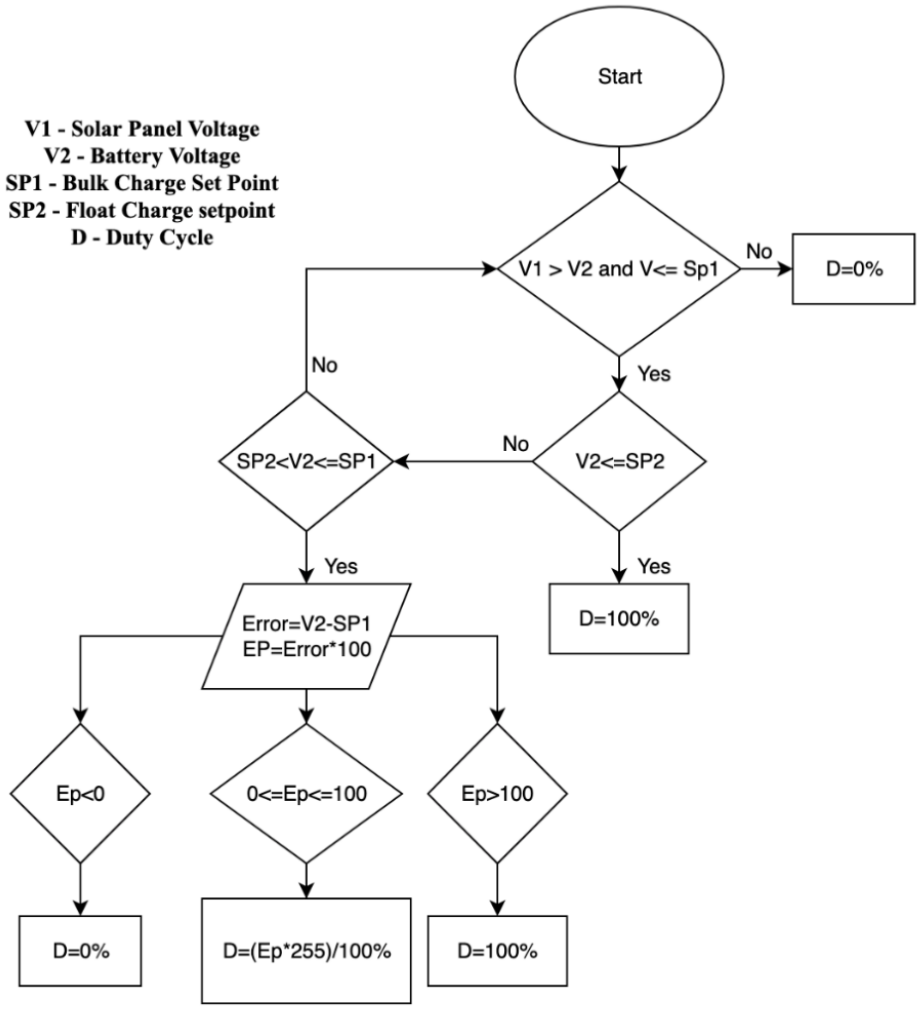


Figure 36 Charging Algorithm

Arduino Nano reads both panel and battery voltages and then decides how to charge the battery. Amount of charging current is concluded from the difference between battery voltage and setpoint voltage. Then it sends a PWM signal to solar panel side p-MOSFET. The frequency of pin-3 PWM signal is 490.2Hz. The duty cycle is adjusted by the error signal.

2. Solar Tracker

The dual-axis tracking system is used to track the sun. A flowchart is done to show the logic of the code that is saved in Arduino Nano Microcomputer. Code starts by reading values from photoresistors, compares the readings from LDR1 and LDR2 that are connected on the left and

right side of the solar panel and then decides what action to take: move panel left or right using DC Motor. Once values of LDR1 and LDR2 are equal, code proceeds to do the same with LDR3 and LDR4. All 4 photoresistors are not checked simultaneously in order to prevent confusion of the computer. Once LDR3 and LDR4 have equal values system halts for 15 min and repeats the loop.

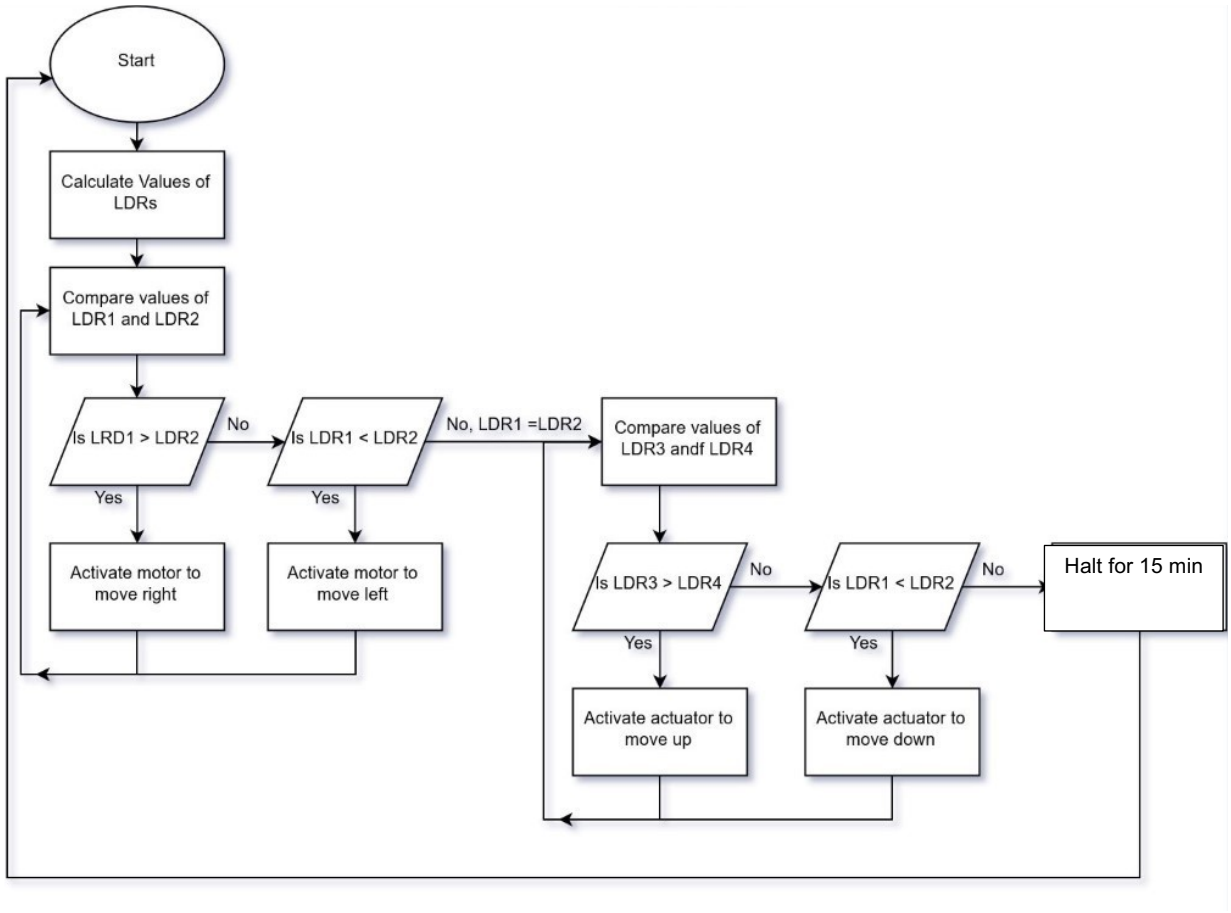


Figure 37 Solar Tracker Flowchart

XIII. Final Acceptance Criteria

Table 19 Final Acceptance Criteria

Spec/Requirement	Validation Method	Acceptance
"Sit on top" kayak		
Lightweight system	Weight Scale	30 lbs. maximum
Mount Subsystem		
Able to hold weight of the box	Digital simulation of stress/strength test analysis	The system must pass this spec to be accepted
Universal mount	Testing on a kayak	The system must fit onto kayak to be accepted
Gears at the center of the box	Taking Measurements	Confirming that gears are at the center of the box
The system easily disassembled	Testing on a kayak	The system must pass this spec to be accepted
Box Subsystem		
Actuator able to hold the lid	Digital simulation of stress/strength test analysis	The system must pass this spec to be accepted
Actuator able to lift the lid to 30°	Digital simulation of stress/strength test analysis	The system must pass this spec to be accepted
Able to access inside the box	Testing on a kayak	The system must pass this spec to be accepted
Charge Controller		
Must be able to charge the battery	Multimeter to verify voltage output	The battery is fully charged at the end of the experiment
Must be able to recognize 3 different stages of charging	Oscilloscope to check duty cycle(lab)/Serial Monitor(prototype)	The system changes duty cycles with different voltages of the battery to be accepted
Must be able to prevent battery overcharge	Code/ Serial Monitor(prototype)	The system must stop charging after the battery is full to be accepted
Must be able to protect the circuit against abnormal conditions	Electrical components for protection	The system must pass this spec to be accepted
IP65 rated case	IP65 testing	The system must pass this spec to be accepted
Ability to monitor charging progress	Able to see results on the prototype	The system must pass this spec to be accepted

XIV. Discussion

The results and observations were made and based on existing concepts that are proven to be crucial to those who partake in such an outdoor sport. A survey was disseminated amongst individuals who desire improvements that would make their sport more enjoyable. After gathering the data, it was determined which of the features were most important. The results from this data allowed a systematic concept to evolve into a design that could be achieved while improving the device within a given budget.

The most important step would be the selection of the material that would be most suitable for a carrying system for the solar panel. In the first draft, materials were chosen that would withstand the environment under which they would be used for. The materials included: polycarbonate, pure aluminum, and Styrofoam. Several trials of Finite Element Analysis (FEA) were used on the materials to determine if there were any stress riser and their performance under loads. This analysis leads to clear polycarbonate material being chosen. It was selected because of its lightweight qualities, translucency, and low cost. The selection of polycarbonate material allowed the box system to be the most ideal concept. The box system was a sound selection for the polycarbonate material. The polycarbonate allows viewing of its electrical components in the event of any problems, an addition to extra room for miscellaneous items. In comparison, the polycarbonate measures 22.1 x 20 x 8 (in) and weighs 5.975 (lbm) more than fifty percent less than pure aluminum which weighs 13.436 (lbm). The other consideration was that of Styrofoam. The Styrofoam design was designed with very thin aluminum reinforcements. This designed was a contender because of its buoyancy and low cost. After the analysis and the test trail, it was determined that after adding the solar panel the aluminum borders had become brittle. The breakdown of material caused deflection and deformation in the design. The tests resulted in the

selection of the polycarbonate due to lightweight, portability, and its ability to connect with the faces of the box system by using silicon to make it waterproof. The same approach was used for the mounting system. This design considered two materials, aluminum, and steel. One of the advantages of using steel or aluminum is that they are readily available and cost-effective. Minimizing waste and using scrap parts was another opportunity to cut the cost. A comparison of their weight was done. The aluminum weighted 7.913 lbm and the steel weighted 23.00 lbm. The selection of the aluminum was made for maximum portability and availability.

Other considerations were made for solar panel, gears, charge controller, motor, and even the linear actuator. Extensive calculations were done to verify which would be the most suited for a specific scenario. It was discovered that the 50W solar panel would be the best fit for this system. This decision was made because of the power equipment. The motor, charge controller, fish finders, GPS, LED lights, and other frequently used electrical components. A device using less than 50W would not generate enough energy to power simultaneously. A higher amount of energy would be violating good design principles. The linear actuator devices required the most accurate calculations. This device is very intricate in detail. Devices of such detail have mechanisms that require precision. The precision and accuracy of these calculations are found in the appendix. Utilizing the sun was another attempt at cutting the cost. Calculating the maximum sunlight reciprocated from the sun would maximize the power created by the solar panel. This study concludes that between 10:00 – 4:00 pm CST is the ideal time to charge the solar panel if the panel is in the optimal position (30 degrees). Solid Edge was also used in the calculations. The functionality in the software included that of a pinion and gear set that would yield 12 and 36 teeth respectively, generating a force of 43.409 lbf and a safety factor of 4.7. A 3D printer was also utilized for prototypes as opposed to actual components for cost-effectiveness. Another design

criterion was that of a customized charge controller. To meet the requested criteria a controller was added and integrated a Pulse Width Modulation charging algorithm with auto charge setpoint. According to the battery voltage and a solar tracker to have optimum charging power. The main part of the controller was a custom-made Printed Circuit Board. It contained an LCD display to show the power usage and a waterproof case. The experimental analysis recorded the charge time that has been tested with a 50W solar panel and a 12 V lead-acid battery. Under perfect weather conditions, total test time was around 220 min, the controller was proven to change charging modes with time.

A redesigned system must have key components that will make it feasible to undertake such an endeavor. Every great design has a blueprint that is based on an existing device. The results and observations were made and based on existing concepts that are proven to be crucial to those who would benefit. This survey was disseminated amongst individuals who desire improvements that would make their sport more enjoyable. After gathering the data, it was determined which of the features were most important. The results from this data allowed a systematic concept to evolve into a design that could be achieved while improving the device within a budget.

XV. Recommendations

There are several recommendations for future work that could be implemented into this project. The first would be to replace the PWM charge controller with a Maximum Power Point Tracking (MPPT). This has a higher efficiency than the PWM because it monitors both the input and output current and voltages. The second would be to include additional IP65 rated compartments within the box system for storage of tools and additional accessories if troubleshooting is needed while on a kayaking trip. This is applicable because of the several day

journeys out on the water and campgrounds in remote locations. The third recommendation would be to implement multiple types of natural energy into the system, including wind and hydroelectric to further reduce the charge time required. Finally, the size of the solar panel can be interchangeable based on a user's needs. If they only desire to charge their cell phone, for example, a smaller panel could be used. The system in this project is optimal for a full load of multiple devices at the same time. The panel size, thus entire system dimensions, could be reduced to optimize for the specific devices needed.

XVI. Conclusion

Research shows that several concepts are readily available for rechanging a potable or solar battery. Charging a battery is a convenience regardless if it is portable or solar. It is advantageous to have such a convenience. Currently, the charging system is at a disadvantage because it is not universal. Limitations make it impossible to use the battery with other brands. In this dynamic society, the consumer is no longer loyal to a brand. This limitation is further complicated by being kayak specific. The proposed design would allow mounting in any position and on a track of any size. This design concept was the most favorable consideration because of the flexibility that it provides. Further development was necessary to prove the design. To undertake this initial study, Finite Element Analysis (FEA) was used. The analysis was set-up to simulate harsh conditions. The environmental conditions tested are heavy winds, storms, dust particles and water. FEA provides the ability to analyze how forces of nature push materials to their tensile limits. The data generated allows a comparison to be done to choose the most viable material. The use of FEA made complex calculations with ease and accuracy. Some calculations brought ideas to life in a short period and made the ideas favorable in saving time and money.

Another concept that needed further development was of greater importance, the electric component. Electrical components can be small but deadly. One of the greatest responsibilities of an engineer to design a safe and functional product. Due to the nature of this development assistance was sought from key professors. The professors were able to assist in the coordination of student to company representatives for additional knowledge regarding correction and validation of the design. The IP65 rated test was performed with light pressurized water. The trials were conducted several times for validation. The charge controller needed to pass without allowing any water penetration. A complete system would be analyzed on a traveling kayak and under the worse-case scenarios. It was presumed that the worse- case presented was that of a flipping kayak. This case could study how the design would function under flipping conditions. It would be considered a viable system if it passed the necessary evaluation test and continued to function when the kayak returns to its original orientation. The final prototype incorporated the tested components. This design was fully functional, lightweight and a portable system. The most beneficial factors considered were precision, detail, and specifications provided in the prototypes.

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Appendices Content

Appendix A. Copy of Poster

The University of Texas at TYLER

HEC 6: The Solars

Electrical & Mechanical Engineering

Marine Solar Charger

Team Members: Dana Bekmaganova, Prakash Jha, Kieran Kapila, Rudy Marban, Hicham Matraka
Sponsor: Austin Canoe & Kayak
Advisor: Aws Al-Shalash

Abstract

When fishermen go on extended fishing or recreational trips, they use 12VDC batteries to charge various loads such as: fish finders, LED lights and cellular devices. The main objective for the team is to provide an alternative source of power in the form of a solar battery charger for kayakers who need to recharge their 12VDC batteries. The design incorporates many different features, including an automated solar tracking system that helps optimize the time to charge the battery, a custom charge controller and a universal mount that can be used on different kayaks.

Design Requirements

- Solar panel to charge a marine battery
- "Sit on top" kayak
- Portable
- Lightweight (30 lb. max)
- Ability to monitor the charging status
- IP65 Standard

System Overview

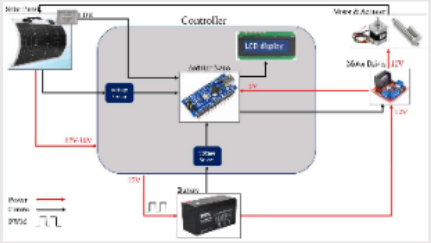


Figure 1: Power Flow Diagram

The heart of the controller is an Arduino Nano. The microcontroller senses voltages of both the battery and solar panel, then decides how to charge the battery based on the proper charging cycles. The tracker receives readings from four photoresistors mounted on the lid and rotates the box left/right and lid up/down until it finds the optimal position facing the sun.

Component Breakdown

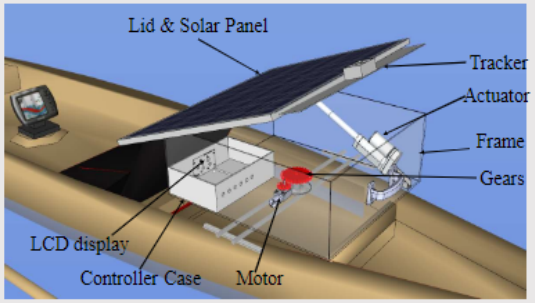


Figure 2: Model of System

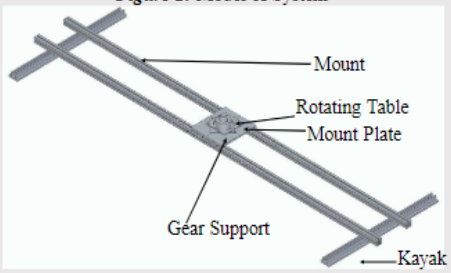


Figure 3: Mounting System Breakdown

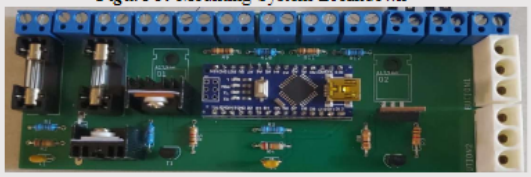


Figure 4: Custom Controller

Figure 2 is the model of full system including all the electrical components. *Figure 3* is the breakdown of the mounting system that will be attached to the kayak. *Figure 4* illustrates custom-made PCB that integrates solar charge controller and solar tracker.

Experimental Analysis

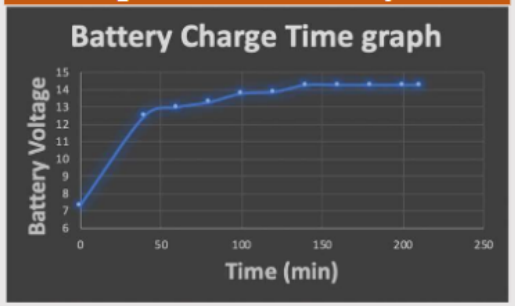


Figure 5: Charge time

- The figure above shows the results of the battery testing. The 12V lead acid battery was charged by a 50W Solar Panel using the custom charge controller. The total charge time was 220 min under ideal solar conditions.
- Tests were done on the motor and the actuator to verify the results obtained from the calculations. The torque required by the system i.e. 3.037 lbf*ft was provided by the motor. The force required to lift the lid of the box (3.87 lbf) was provided by the actuator.
- IP testing was done to fulfill the design requirement of IP65 rating.

Conclusion

After combining the mechanical and electrical components to form the full system, tests were conducted to verify that it was functional and met all the design requirements. A 3D model of the system was made using CAD software and was subjected to different stresses. The data was generated to estimate the durability of the system. As a result, the final prototype proved to be fully functional, light weight and portable system. In addition, the acknowledgement of precision, detail, and specification in our prototype were noted to be the most beneficial factors to take into consideration.

1 of 1

Figure A-1 Poster

Appendix B. Sign-off Sheet

The University of Texas at TYLER
COLLEGE OF ENGINEERING

Department of Mechanical Engineering
Phone: +1.903.566.7003
Fax: +1.903.566.7148
Uttyler.edu/engineering

Senior Design Project II

MENG 4216 / EENG 4315

Project Marine Solar Charger Delivery and Acceptance

Senior design team The Solars, from UT-Tyler College of Engineering, has worked with a sponsor: Austin Kayak and Canoe to design and build a Marine Solar Charger as part of the senior students' academic work during the academic year of 2019-2020. This document includes the sign-off list and Shaun Gregory`s final approval of the outcome of Marine Solar Charger delivered by The Solars, based on the previously set and mutually approved scope and specifications of the project. An authorized signature indicates this approval.

Table 1: Sponsor Sign OFF list for Deliverables of the Senior Project Marine Solar Charger

Item No.	Description of Deliverable	Comments:	Sponsor Sign Off: Authorized Initials
Marine Solar Charger	Marine grade battery charger		SG
Solar Panel	50W Solar Panel		SG
Charge Controller	12V Output		SG
Universal Mount	Mount to a kayak with extendable tracks	The glass look makes the product look clean	SG
Solar Tracker	Automatic solar tracker	This shows the group going above what was asked in the beginning of this project	SG
Production Model Documentation	Technical Documentation		SG
B.O.M.	Bill of Materials	great use of what you had	SG
I.O.M.	Installation and Operations Manual	11	SG

CAD drawings	Includes assembly and manufacturing drawings	The Cad. design was very clean and functionable	SG
Electrical Schematic	Electrical Layout		SG
Testing	Testing of system		SG
Charge Controller Output	Adjust input voltage and battery voltage sensor voltages to ensure 12V output		SG
Solar Tracker	Light will be monitored and adjustments to the actuator and motor will be analyzed		SG
Water resistant case	IP65 standards will be tested on the empty cases in water and determining any leakage		SG

The video I received was great. It showed the team was able to complete the concept that was laid out for them on day one. I'm impressed with the teams ability to adjust and overcome any obstacles they faced along the way. Thank you for allowing me to be part of this great team and great project.

The following signatures indicate that Shaun Gregory approves of the completion of this project and deliverables stated above which included all sponsor changes from original design and any consequent changes in the project, as mutually approved by all signing parties. Also indicated is the acknowledgement by Shaun Gregory of reception of the final product of the project.

For UT-Tyler Mechanical Engineering: Dr. Nael Barakat// Dr. Andres Garcia, etc…

Date

For Austin Canoe and Kayak: Shaun Gregory *Store Manager*

4-27-20

Date

For UT-Tyler Mechanical Engineering: Professor Aws Al-Shalash

Date

For the Senior Project Students' Team: Kieran Kapila *Team Captain*	04/26/20 Date
For the Senior Project Students' Team: Dana Bekmaganova *Team Captain*	04/26/20 Date
For the Senior Project Students' Team: Prakash Jha	04/26/20 Date
For the Senior Project Students' Team: Rudy Marban	04/26/20 Date
For the Senior Project Students' Team: Hicham Matraka	04/26/20 Date

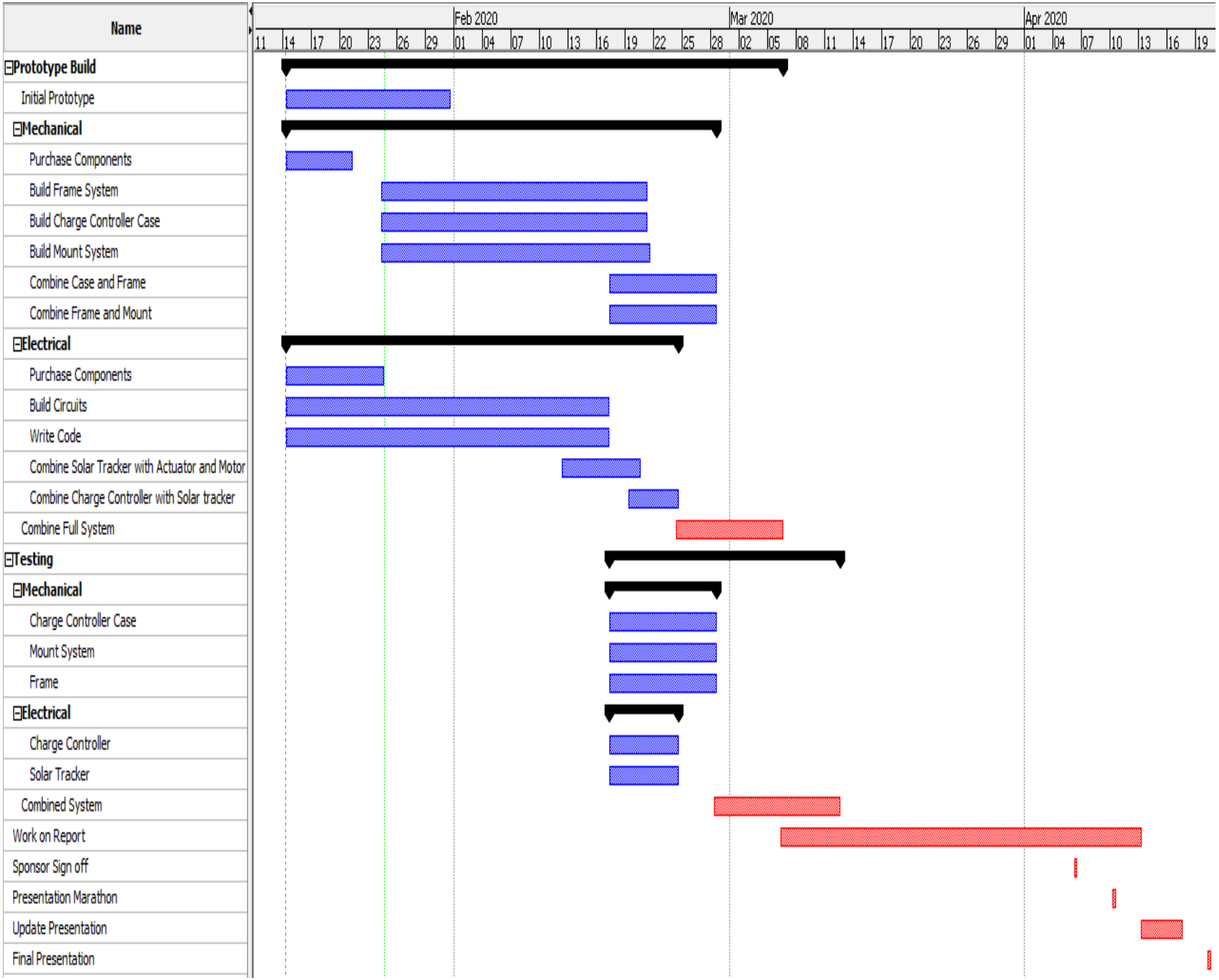
Appendix C. Economic Feasibility (Cost of Prototype vs. Mass Production Cost)

The cost of prototype from the bill of material was $ 464 but if the product is mass produced the unit cost is reduced considerably. The prices of major components like acrylic sheet, solar panel, linear actuator and the motor and other electrical components can be reduced if bought directly from the manufacturer. below is the table of unit cost and cost per unit in bulk ordering (i.e. 1000 piece) and the savings achieved. $214 were saved through bulk ordering and so the mass production cost per unit was $250 in total.

Table C-1 Mass Production Cost

No.	Material	Qty	Unit cost	Bulk price per unit	Savings
1.	Acrylic sheet	3	$40	$20	$60
2.	Solar panel	1	$95.99	$45	$50.99
3.	Linear actuator	1	$ 35	$ 20	$15
4.	Motor	1	$ 20	$ 10	$10
5.	Lead acid battery	1	$20.79	$12	$8.79
6.	Custom PCB	5	$5.93	$2	$3.93
7.	Box handle	1	$24.45	$10	$14.45
8.	Handle Screws	2	$1	$0.40	$1.20
9.	Power Button	1	$6.49	$2	$4.49
10.	Brackets	4	$2.5	$1	$6
11.	Hinges	4	$2.5	$1	$6
12.	Linkage	1	$5	$2	$3
13.	Flex seal	1	$12.34	$ 7	$5.34
14.	LCD display	1	$14.59	$5	$9.59
15.	Electrical components	53	$12.29	$6	$15
	Total				**$214**

Appendix D. Timelines and Milestones with Dates


Name
Feb 2020
Mar 2020
Apr 2020
11 14 17 20 23 26 29 01 04 07 10 13 16 19 22 25 28 02 05 08 11 14 17 20 23 26 29 01 04 07 10 13 16 19
Prototype Build
Initial Prototype
Mechanical
Purchase Components
Build Frame System
Build Charge Controller Case
Build Mount System
Combine Case and Frame
Combine Frame and Mount
Electrical
Purchase Components
Build Circuits
Write Code
Combine Solar Tracker with Actuator and Motor
Combine Charge Controller with Solar tracker
Combine Full System
Testing
Mechanical
Charge Controller Case
Mount System
Frame
Electrical
Charge Controller
Solar Tracker
Combined System
Work on Report
Sponsor Sign off
Presentation Marathon
Update Presentation
Final Presentation

Appendix E. ARCI chart

Table E-1 Responsibility assignment matrix

Tasks	Dana Bekmaganova	Prakash Jha	Kieran Kapila	Rudy Marban	Hicham Matraka
Prototype/Manufacturing					
Box	**I**	**A**	**I**	**C**	**R**
Mounts	**I**	**RC**	**I**	**R**	**AR**
Controller Case	**C**	**I**	**C**	**AR**	**I**
Charge Controller	**AR**	**I**	**C**	**I**	**I**
Tracker installation	**C**	**C**	**AR**	**I**	**C**
Code	**R**	**I**	**AR**	**I**	**I**
Testing					
Charge Controller	**AR**	**I**	**C**	**I**	**I**
FEA	**I**	**R**	**C**	**AR**	**C**
IP65	**I**	**R**	**A**	**R**	**C**
Documentation					
Budget	**R**	**AR**	**I**	**I**	**I**
Failure Mode Analysis	**R**	**C**	**C**	**I**	**AR**
Final Assembly Drawings	**I**	**I**	**C**	**A**	**R**
Final Manufacturing Drawings	**I**	**C**	**I**	**R**	**AR**
User Manual	**A**	**R**	**C**	**C**	**R**
Final Report	**ARCI**	**ARCI**	**ARCI**	**ARCI**	**ARCI**

Table E-2 Key roles

A	**Accountable**
R	**Responsible**
C	**Consulted**
I	**Informed**

Appendix F. Mechanical Drawings

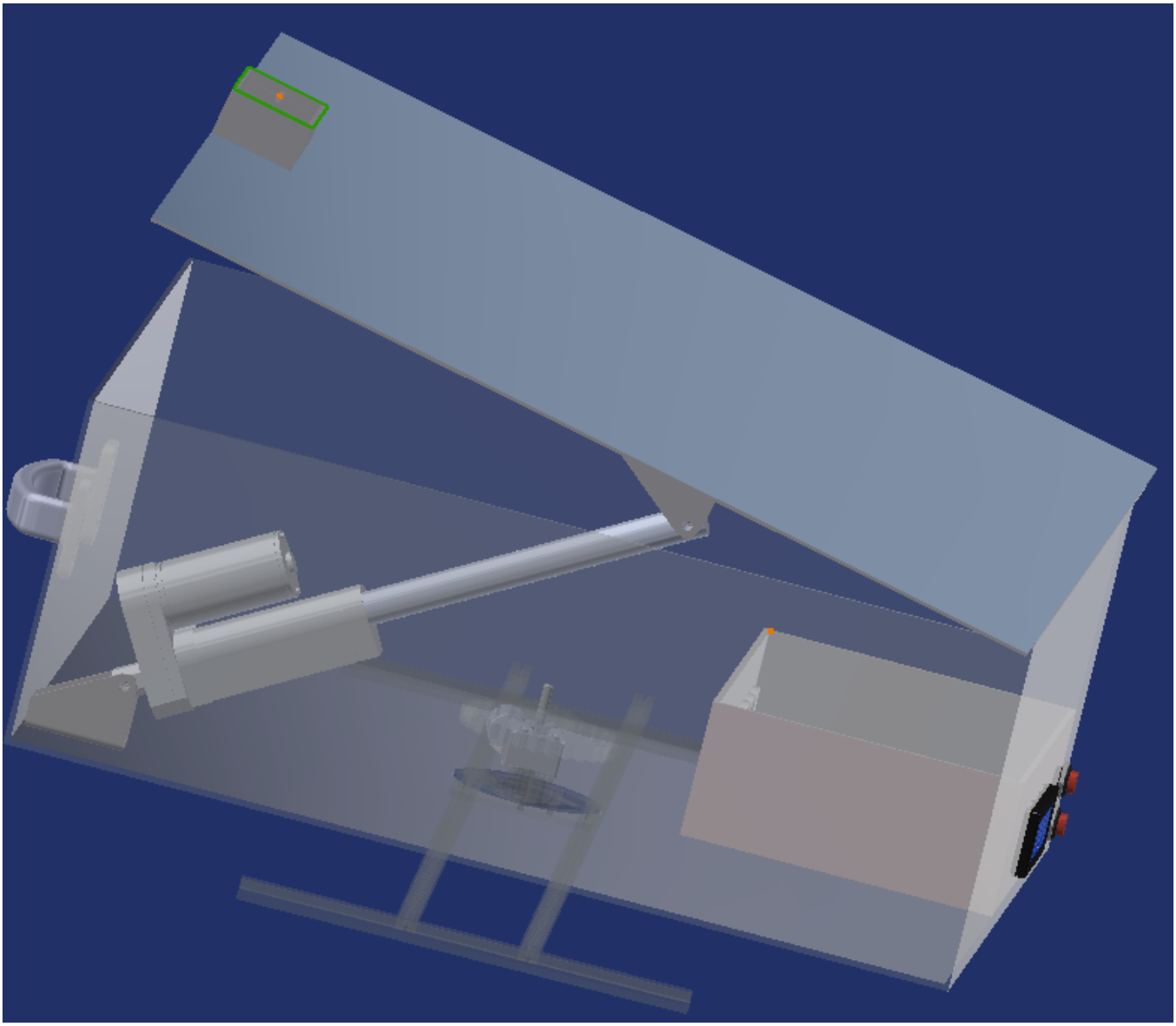


Figure F-1 Full system 3D drawing

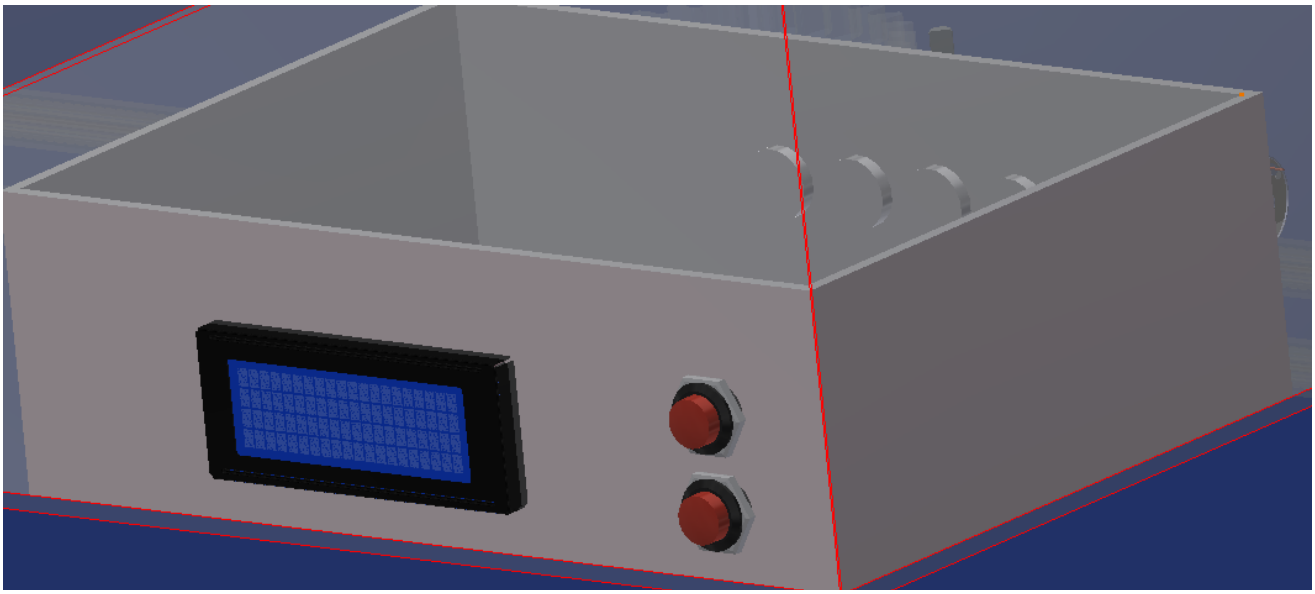
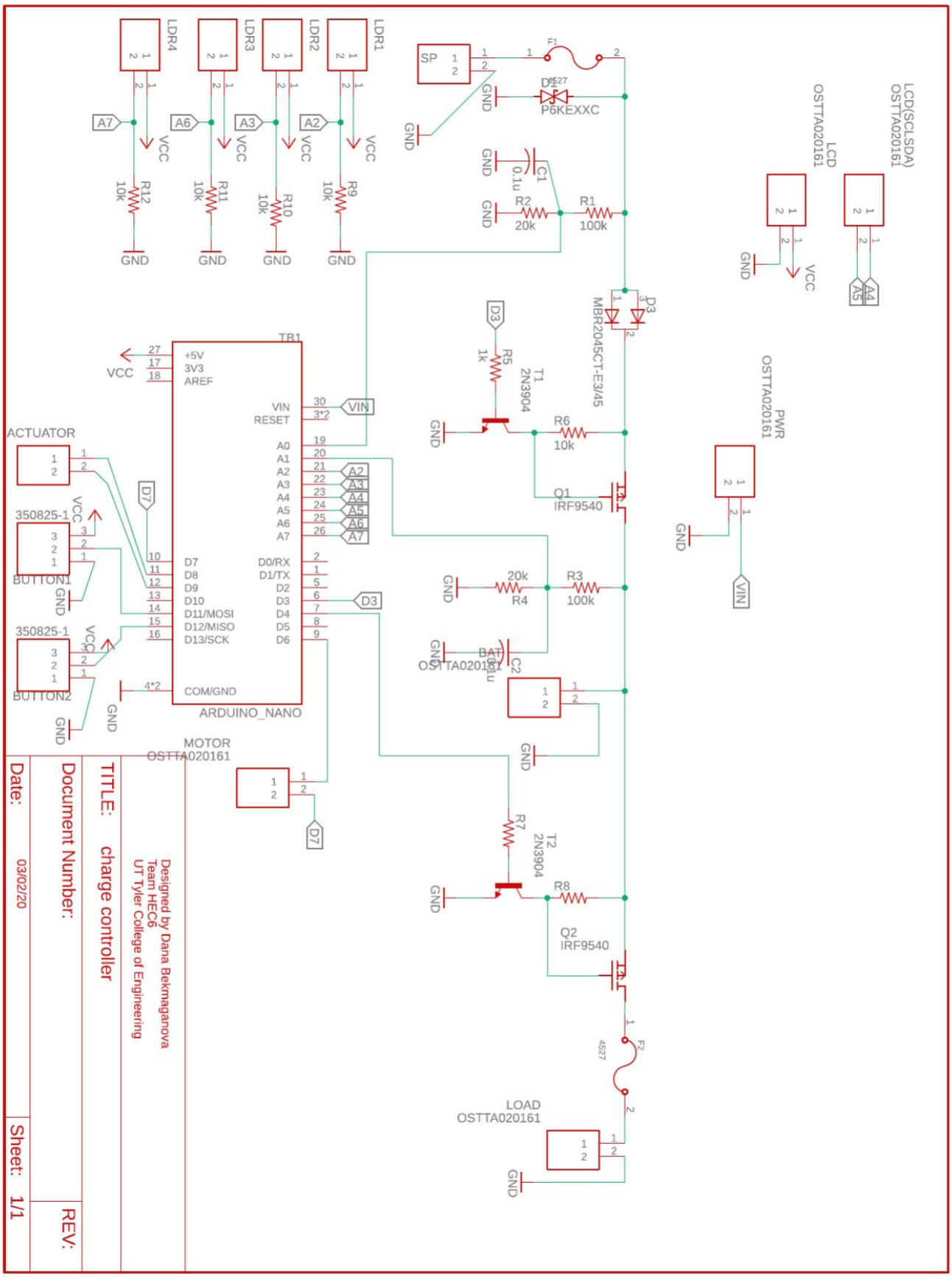


Figure F-2 Controller case 3D drawing

Appendix G. Electric Circuits Diagrams

Below is diagram for PCB design.


LDR4
LDR3
LDR2
LDR1
A7
A6
A3
A2
VCC
R12 10k
R11 10k
R10 10k
R9 10k
GND
SP
F1
D4
P6KEXXC
C1 0.1u
R2 20k
R1 100k
LCD(SCLSDA)
OSTTA020161
LCD
OSTTA020161
A4
A5
D3
MBR2045CT-E3/45
R5 1k
T1 2N3904
R6 10k
Q1 IRF9540
PWR
OSTTA020161
VIN
TB1
+5V
3V3
AREF
RESET
A0
A1
A2
A3
A4
A5
A6
A7
D7
D8
D9
D10
D11/MOSI
D12/MISO
D13/SCK
D0/RX
D1/TX
D2
D3
D4
D5
D6
COM/GND
ARDUINO_NANO
ACTUATOR
350825-1
BUTTON1
BUTTON2
R4 20k
R3 100k
BAT
OSTTA020161
C2 0.1u
MOTOR
OSTTA020161
R7
T2 2N3904
R8
Q2 IRF9540
F2
4527
LOAD
OSTTA020161
Designed by Dana Bekmaganova
Team HEC6
UT Tyler College of Engineering
TITLE: charge controller
Document Number:
REV:
Date: 03/02/20
Sheet: 1/1

Appendix H. Any Code or Program Listing

```
// ARDUINO SOLAR CONTROLLER

#include <Wire.h>
#include <LiquidCrystal_I2C.h> //library for LCD screen
#define SOL_ADC A0     // Solar panel side voltage divider is connected to pin A0
#define BAT_ADC A1     // Battery side voltage divider is connected to pin A1
#define AVG_NUM 10     // number of iterations of the adc routine to average the adc readings
#define BAT_MIN 10.5  // minimum battery voltage for 12V system
#define BAT_MAX 14.5  // maximum battery voltage for 12V system
#define BULK_CH_SP 12.5 // bulk charge set point for sealed lead acid battery
#define FLOAT_CH_SP 14.3  //float charge set point for lead acid battery
#define LVD 11.5          //Low voltage disconnect setting for a 12V system
#define PWM_PIN 3         // pin-3 is used to control the charging MOSFET //the default
frequency is 490.20Hz
#define LOAD_PIN 2        // pin-2 is used to control the load

//initialize motor driver inputs
int in1Mot = 6; //Declaring the pins where in1 in2 from the driver are wired
int in2Mot = 7; //here they are wired with D9 and D8 from Arduino
int in1Act = 8;
int in2Act = 9;
int in3Act = 10;
int in4Act = 11;
int buttonTracker = 12;
int buttonCharger = 13; //

//initialize photoresistors
int pResistorL = A2;
int pResistorR = A3;
int pResistorT = A6;
int pResistorB = A7;

//initialize values for debugging

int valueLT;
int valueRT;
int valueLB;
int valueRB;

//DECLARATION OF ALL BIT MAP ARRAY FOR FONTS//

byte solar[8] = //icon for solar panel
{
  0b11111,0b10101,0b11111,0b10101,0b11111,0b10101,0b11111,0b00000
```

```
};
byte battery[8] =  //icon for battery
{
 0b01110,0b11011,0b10001,0b10001,0b10001,0b10001,0b10001,0b11111
};

byte charge[8] = // icon for battery charge
{
 0b01010,0b11111,0b10001,0b10001,0b10001,0b01110,0b00100,0b00100,
};
byte not_charge[8]=
{
 0b00000,0b10001,0b01010,0b00100,0b01010,0b10001,0b00000,0b00000,
};

//DECLARATION OF ALL GLOBAL VARIABLES//
float solar_volt=0;
float bat_volt=0;
float system_volt=0;
float bulk_charge_sp=0;
float float_charge_sp=0;
float charge_status=0;
float load_status=0;
float error=0;
float Ep=0;
int duty =0;
float lvd;
float msec=0;
float last_msec=0;
float elasped_msec=0;
float elasped_time=0;
float ampSecs = 0;
float ampHours=0;
float watts=0;
float wattSecs = 0;
float wattHours=0;

// Set the pins on the I2C chip used for LCD connections:
//                    addr, en,rw,rs,d4,d5,d6,d7,bl,blpol
LiquidCrystal_I2C lcd(0x27, 2, 1, 0, 4, 5, 6, 7, 3, POSITIVE);  // Set the LCD I2C address
//************************************************** MAIN PROGRAM
START **********************************************
void setup()
{

Serial.begin(9600);
```

```
pinMode(PWM_PIN,OUTPUT);
pinMode(LOAD_PIN,OUTPUT);
digitalWrite(PWM_PIN,LOW);  // default value of pwm duty cycle
digitalWrite(LOAD_PIN,LOW);  // default load state is OFF
lcd.begin(20,4);   // initialize the lcd for 20 chars 4 lines, turn on backlight
lcd.backlight(); // finish with backlight on
lcd.createChar(1,solar);
lcd.createChar(2, battery);
//lcd.createChar(3, energy);
lcd.createChar(6,charge);
lcd.createChar(7,not_charge);
lcd.clear();

//setup the pin inputs on the arduino for solar tracker
 pinMode(in1Mot, OUTPUT); //Declaring the pin modes, they're outputs
 pinMode(in2Mot, OUTPUT);
 pinMode(in1Act, OUTPUT); //Declaring the pin modes, they're outputs
 pinMode(in2Act, OUTPUT);
 Serial.begin(9600);
 pinMode(pResistorL, INPUT);
 pinMode(pResistorR, INPUT);
 pinMode(pResistorT, INPUT);
 pinMode(pResistorB, INPUT);

}

void loop()

{
read_data();            // read different sensors data from analog pin of arduino
system_voltage();       // detect the system voltage according to battery voltage
setpoint();      // decide the charge set point according to system voltage
charge_cycle();         // pwm charging of battery
load_control();         //control the load
print_data();           // print in serial monitor
lcd_display();          // lcd display

//read resistance values from photoresistors. based from 0-1024.
valueTL = analogRead(pResistorL);
valueTR = analogRead(pResistorR);
valueBL = analogRead(pResistorT);
valueBR = analogRead(pResistorB);

//debug statements showing the values of the photoresistors
Serial.println("Left: " + (String)valueTL);
Serial.println("Right: " + (String)valueTR);
```

```
Serial.println("Top: " + (String)valueBR);
Serial.println("Bottom: " + (String)valueBL);

//delay to visualize debug data
delay(500);

  //compare the values of the photoresistors to eachother to determine movement for rotation
  if(valueTR + valueBR - valueTL + valueBL > 75)
    Serial.println("Turn Right");
    TurnMotorRight();
    delay(100);
    TurnOFFMot();
  }

  if(valueTL + valueBL - valueTR + valueBR > 75)
  {
    Serial.println("Turn Left");
    TurnMotorLeft();
     delay(100);
    TurnOFFMot();
  }

//compare the values of the photoresistors to eachother to determine movement for actuation
    if(valueTL + valueTR - valueBR + valueBL > 75)
  {
    Serial.println("Extend");
    Retract();
    delay(100);
    TurnOFFAct();
  }

  if(valueBL + valueBR - valueTR + valueTL> 75)
  {
    Serial.println("Retract");
    Extend();
     delay(100);
    TurnOFFAct();
  }

 }
//********************************** PROGRAM END************************


// READS AND AVERAGES THE ANALOG INPUTS (SOLAR VOLTAGE, BATTERY
VOLTAGE)//
```

```
int read_adc(int adc_parameter)
{
  int sum = 0;
  int sample ;
  for (int i=0; i<AVG_NUM; i++)
  {                                  // loop through reading raw adc values AVG_NUM number of times
    sample = analogRead(adc_parameter);    // read the input pin
    sum += sample;                       // store sum for averaging
    delayMicroseconds(50);              // pauses for 50 microseconds
  }
  return(sum / AVG_NUM);               // divide sum by AVG_NUM to get average and return it
}

//READ THE DATA//
 void read_data(void)
 {
    //5V = ADC value 1024 => 1 ADC value = (5/1024)Volt= 0.0048828Volt
    // Vout=Vin*R2/(R1+R2) => Vin = Vout*(R1+R2)/R2   R1=100 and R2=20
     solar_volt = read_adc(SOL_ADC)*0.02928;
     bat_volt   = read_adc(BAT_ADC)*0.02928;
     //load_current = (read_adc(CURRENT_ADC)*.0488 -25);
  }
//PRINT DATA IN SERIAL MONITOR//
  void print_data(void)
  {
    delay(100);
    Serial.print("Solar Panel Voltage: ");
    Serial.print(solar_volt);
    Serial.println("V");
    Serial.print("Battery Voltage: ");
    Serial.print(bat_volt);
    Serial.println("V");
    Serial.print("System Voltage: ");
    Serial.print(system_volt);
    Serial.println("V");
    Serial.print("Charge Set Point:");
    Serial.println(bulk_charge_sp);
    Serial.print("Duty Cycle :");
    if (charge_status==1)
    {
    Serial.println("99%");
    Serial.println("BULK CHARGING");
    }
    else if (charge_status==2)
    {
    Serial.print(Ep);
```

```
   Serial.println("%");
   Serial.println("FLOAT CHARGING");
   }
   else
   {
   Serial.println("0%");
   Serial.println("NOT CHARGING");
   }
   if(load_status==1)
   {
    Serial.println("LOAD IS CONNECTED");
   }
   else
   {
Serial.println("LOAD IS DISCONNECTED");
   }
Serial.println("**************************");
 }
//SYSTEM VOLTAGE AUTO DETECT //
void system_voltage(void)
{
  if ((bat_volt >BAT_MIN) && (bat_volt < BAT_MAX))
  {
     system_volt = 12;
  }
  else if ((bat_volt > BAT_MIN/2 ) && (bat_volt < BAT_MAX/2))
  {
    system_volt=6;
  }
}
//CHARGE SET POINT //

void setpoint(void)
{
  if(system_volt ==12)
  {
     bulk_charge_sp = BULK_CH_SP-0.030 ;
     float_charge_sp=FLOAT_CH_SP-0.030 ;
     lvd =LVD;
  }
else if(system_volt ==6)
  {
bulk_charge_sp = (BULK_CH_SP/2)-(0.015) ;
float_charge_sp= (FLOAT_CH_SP/2)-(0.015) ;
lvd=LVD/2;
  }
```

```
}
//PWM CHARGE CYCLE @500 HZ //
void charge_cycle(void)
{
 if (solar_volt > bat_volt && bat_volt <= bulk_charge_sp)
  {
 if (bat_volt <= float_charge_sp) // charging start
  {
 charge_status = 1; // indicate the charger is in BULK mode
 duty= 252.45;
 analogWrite(PWM_PIN,duty); // 99 % duty cycle // rapid charging
  }
else if (bat_volt >float_charge_sp && bat_volt <= bulk_charge_sp)
  {
charge_status = 2; // indicate the charger is in FLOAT mode
error  = (bulk_charge_sp - bat_volt);      // duty cycle reduced when the battery voltage
approaches the charge set point
Ep= error *100 ; //Ep= error* Kp // Assume  Kp=100
      if(Ep < 0)
       {
        Ep=0;
       }
      else if(Ep>100)
       {
        Ep=100;
       }
      else if(Ep>0 && Ep <=100) // regulating
       {
         duty = (Ep*255)/100;
       }
       analogWrite(PWM_PIN,duty);
  }
 }
  else
  {
  charge_status=0;  // indicate the charger is OFF
  duty=0;
  analogWrite(PWM_PIN,duty);
  }
}
//LOAD CONTROL//

void load_control()
{
 if (solar_volt < 5  ) // load will on when night
{
```

```
  if(bat_volt >lvd)   // check if battery is healthy
  {
  load_status=1;
  digitalWrite(LOAD_PIN, HIGH); // load is ON
  }
  else if(bat_volt < lvd)
  {
    load_status=0;
   digitalWrite(LOAD_PIN, LOW); //load is OFF
  }
 }
 else // load will off during day
 {
   load_status=0;
   digitalWrite(LOAD_PIN, LOW);
 }
}

//movement functions for motor
void TurnMotorLeft(){
  digitalWrite(in1Mot, HIGH);
  digitalWrite(in2Mot, LOW);
 // Serial.println("turn 1");
 // analogWrite(ConA,10);
}

void TurnOFFMot(){
  digitalWrite(in1Mot, LOW);
  digitalWrite(in2Mot, LOW);
//  analogWrite(ConA,0);
}

void TurnMotorRight(){
  digitalWrite(in1Mot, LOW);
  digitalWrite(in2Mot, HIGH);
  //Serial.println("turn 2");
//  analogWrite(ConA,250);
//
}

//movement functions for actuator
void Extend(){
  digitalWrite(in1Act, HIGH);
  digitalWrite(in2Act, LOW);
}
```

```
void Retract(){
  digitalWrite(in1Act, LOW);
  digitalWrite(in2Act, HIGH);
}

void TurnOFFAct(){
   digitalWrite(in1Act, LOW);
  digitalWrite(in2Act, LOW);
}


// LCD DISPLAY//
void lcd_display()
{
 lcd.setCursor(0, 0);
 lcd.write(1);
 lcd.setCursor(2, 0);
 lcd.print(solar_volt);
 lcd.print("V");
 lcd.setCursor(14, 0);
 lcd.write(5);
 lcd.setCursor(16, 0);
 lcd.setCursor(0,1);
 lcd.write(2);
 lcd.setCursor(2, 1);
 lcd.print(bat_volt);
 lcd.print("V");
 lcd.setCursor(14, 1);
 lcd.write(2);
 if((charge_status==1) | (charge_status== 2))
 {
 lcd.write(6);
 }
 else
 {
 lcd.write(7);
 }
 lcd.setCursor(0,2);
 lcd.write(3);
 }
```

Appendix I. Detailed Design Calculations, Formulae Derivations, and Software Extra Analysis Output (e.g. FEA pictures)

1. **Force exerted on the gear.**

From the design of the system, the two forces exerted on the gears are due to the weight of the box and gravity. The calculation below addresses the amount of load the gears will withhold to rotate the system.

$$Force\ extered\ on\ the\ gear\ (F) = mass\ of\ the\ system * g$$

$$F = 18.22\ lb * \frac{32.174\ ft}{s^2} \qquad \textit{Eq. 3}$$

$$\therefore F = 18.22\ lbf$$

2. Torque produced by the box.

$$\tau = F * r$$

$$\tau = 18.22\ lbf * 0.0833\ ft \qquad \textit{Eq. 4}$$

$$\therefore \tau = 1.517\ lbf * ft$$

To calculate the torque produced by box, the force exerted on the gears and the radius of the gears are to be known. Since the diameter of the driven gear is 3 inches, the radius of the driver gear is 1 in. (1in = 0.0833ft)

To find the correct motor for the system, the torque required by the gear system to rotate the box was calculated, it was then equated with output torque and input torque with the size of the gear.

$$\frac{\boldsymbol{\tau_{out}}}{\boldsymbol{\tau_{in}}} = \frac{\boldsymbol{D_{big}}}{\boldsymbol{D_{small}}} \qquad \textit{Eq. 5}$$

$$\frac{1.517\ lbf * ft}{\tau_{in}} = \frac{3}{1}$$
$$\therefore \tau_{in} = 0.0506\ lbf * ft$$

To calculate power consumption for the motor, power of the motor was multiplied with the number of hours the motor would be used for (since the motor is only used for 0.08 hours). Refer to Parts Listing for specifications.

*Watthour=Power*number of hours the motor is used (0.08)*

Watthour=24*0.08 *Eq. 6*

$$\therefore Power\ consumption\ of\ the\ motor = 1.92\ Wh$$

3. Gear Calculation

Following the design, two gears of 1 in and 3 in in diameter were added to the system. The bigger gear is attached right below the box and is rotated via the smaller gear, that is connected to the motor and causes the rotation of the box. The smaller gear has 12 teeth and the bigger gear has 36 teeth. The speed of the smaller gear is 10 RPM and so to calculate the speed of the bigger gear.

$$\frac{N_1}{N_2} = \frac{\omega_2}{\omega_1}$$
$$\omega_2 = \frac{N_1}{N_2} * \omega_1$$
$$\omega_2 = \frac{12}{36} * 10$$
$$\therefore \omega_2 = 3.34\ RPM$$

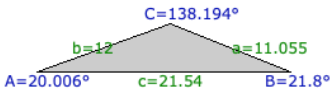
Eq. 7

4. Actuator Position Calculation

The figure below is the 3d drawing of the universal mount system, with gears, motors and turntable compiled to make one unit.

To calculate the position of actuator inside the box, calculations were done.

Calculates b, ∠A, and ∠C based on given a, c, and ∠B.



$$b = \sqrt{(a^2 + c^2 - 2ac \cdot \cos(B)}$$

$$= 21.54066 = 4\sqrt{29}$$

$$\angle A = \arccos\left(\frac{b^2 + c^2 - a^2}{2bc}\right)$$

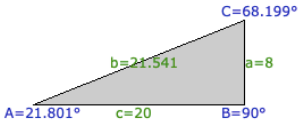
$$= 21.801°$$

Eq. 8

$$\angle C = \arccos\left(\frac{b^2 + a^2 - c^2}{2ba}\right)$$

$$= 68.199° \text{ "}$$

Calculates a, ∠C, and ∠A based on given b, c, and ∠B.



$$\angle C = 180° - \arccos\left((c \cdot \sin(B))/B\right)$$

$$= 138.194°$$

Eq. 9

$$\angle A = 180° - B - C = 20.006°$$

$$a = (b \cdot \sin(A))/(\sin(A)) = 11.0546$$

Calculates a, ∠C, and ∠A based on given b, c, and ∠B.

$$\angle C = 180° - \arcsin\left(\frac{c \cdot \sin(B)}{b}\right) = 112.89°$$

$$\angle A = 180° - B - C = 37.11°$$

$$A = \frac{b \cdot \sin(A)}{\sin(B)} = 7.2408$$

Eq. 10

From the calculations above, the actuator was placed at an angle of 37.105°, 10 inches from the center at the top right corner of the box to elevate the lid of the box at an angle of 30°, as required by the system.

5. Linear Actuator Power Consumption.

The performance graph below was taken from the Firgelli actuator instruction manual in order to help our calculations. The actuator used is denoted as FA-35-12-X-P on the graph (Blue legend).

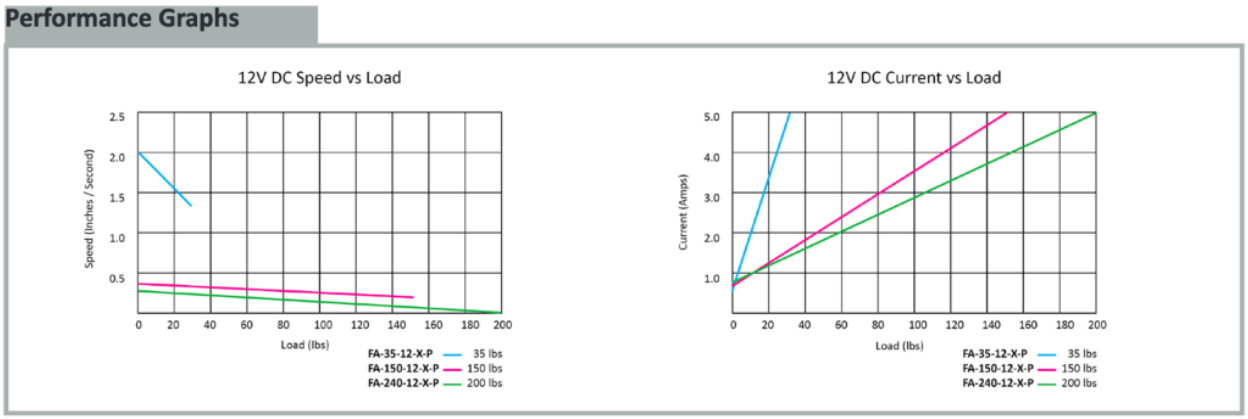


Figure 38 Actuator Performance Curve

The weight of the load is approximately 5 lb. (Solar panel & Lid). From the graphs, speed of the actuator is 1.9 in/sec and the current required is 2A. The tracker will be on for 6 hours a day, tracking sun position every 15 mins. The tracker activates every 15 min for 10 seconds, which is 4 times within an hour. Since the tracker is on for about 6 hours a day, the total number of times actuator is activated is 24, With safety factor it is considered 25 times.

To calculate power consumption for the actuator, the power of the actuator is multiplied with the number of hours the actuator would be used for (since the actuator is only used for 0.08 hours).

Watthour=Power*number of hours the actuator is used (0.08)

Watthour=24*0.08 *Eq. 11*

$$\therefore \textbf{Power consumption of the actuator} = \mathbf{1.92\ Wh}$$

6. Force exerted on the actuator

To calculate the force exerted on the actuator to elevate the lid along with the solar panel, the weight of the lid along with the weight of the solar panel was multiplied by the acceleration due to gravity.

*Force exerted on the actuator= weight of the lid (including the solar panel) *g* *Eq. 12*

$$F = 5\ lbs * \frac{32.174\ ft}{s^2}$$

$$\therefore F=5\ lbf$$

7. Solar Panel Calculation

Table I-1 Maximum load power calculation

Appliance	Avg Current Draw (amps)	Nominal Voltage (V)	Watts (I*V)	Average Daily Power Use (hours/day)	Average Consumption (Watthours/day)
Fish Finder	0.30	12	3.60	8.00	28.80
LED Lights	2 x Spotlight 350mA (each) 1x Flood light 750 mA	12	17.4	6.00	104.4
Battery Charger	2.00	5	10.00	4.00	40.00
Cell Phone			3.68	6.00	22.08
Actuator	2.00	12	24.00	0.08	0.72
Motor	2.00	12	24.00	0.03	1.92
				TOTAL	**197.92**

Value for average power draw of a cell phone is taken from (Lawrence Berkeley National Laboratory, 2019).

$$Number\ of\ Wh\ used\ per\ day \approx 197.92\ Wh$$

$$Number\ of\ hours\ of\ direct\ sunlight\ per\ day = 5h$$

$$Minimum\ Watts\ required = \frac{194.32\ Wh/day}{5\ h/day} = 39.58\ Wh * 20\% = 47.50 \approx 50W \quad \text{Eq. 13}$$

With the safety factor of 20% a 50W solar panel was needed.

8. Sensor Calibration

$$ADC\ count\ for\ 5V = 1024$$

$$1\ ADC = \frac{5}{1024} V = 0.00488 \quad \text{Eq. 14}$$

$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$

$$V_{in} = \frac{120k}{20k} V_{out}$$

$$V_{in} = (ADC\ count) * 0.00488 * \frac{120}{20} V$$

$$V_{in} = (ADC\ count) * 0.02928$$

9. FEA Full Report

Table I-2 Physical

Material	Generic
Density	0.0361273 lbmass/in^3
Mass	2.93059 lbmass
Area	780.977 in^2
Volume	81.1184 in^3
Center of Gravity	x=3.74496 in y=0.422583 in z=15.8515 in

Static Analysis:1

Table I-3 General objective and settings

Design Objective	Single Point
Study Type	Static Analysis
Last Modification Date	4/10/2020, 9:57 PM
Detect and Eliminate Rigid Body Modes	No

Table I-4 Mesh settings

Avg. Element Size (fraction of model diameter)	0.1
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	Yes

Table I-5 Material(s)

Name	Aluminum 6061	
General	Mass Density	0.0975437 lbmass/in^3
	Yield Strength	39885.4 psi
	Ultimate Tensile Strength	44961.7 psi
Stress	Young's Modulus	9993.1 ksi
	Poisson's Ratio	0.33 ul
	Shear Modulus	3756.8 ksi
Part Name(s)	New Mounting System	

Table I-6 Operating conditions

Load Type	Force
Magnitude	322.000 lbforce
Vector X	0.000 lbforce
Vector Y	-322.000 lbforce
Vector Z	0.000 lbforce

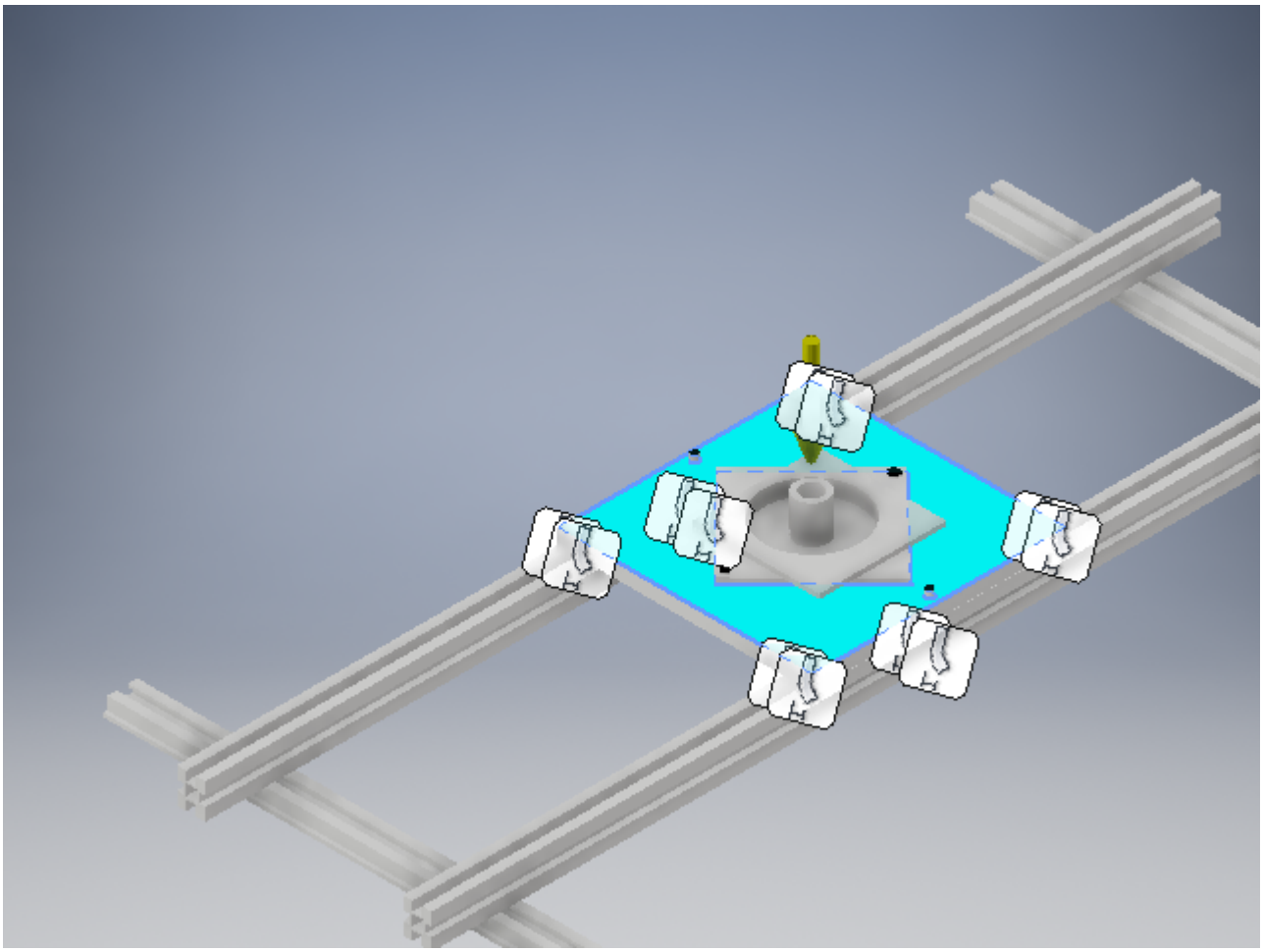


Figure I-1 Selected Constraints

Table I-7 Fixed Constraint 1

Constraint Type	Fixed Constraint

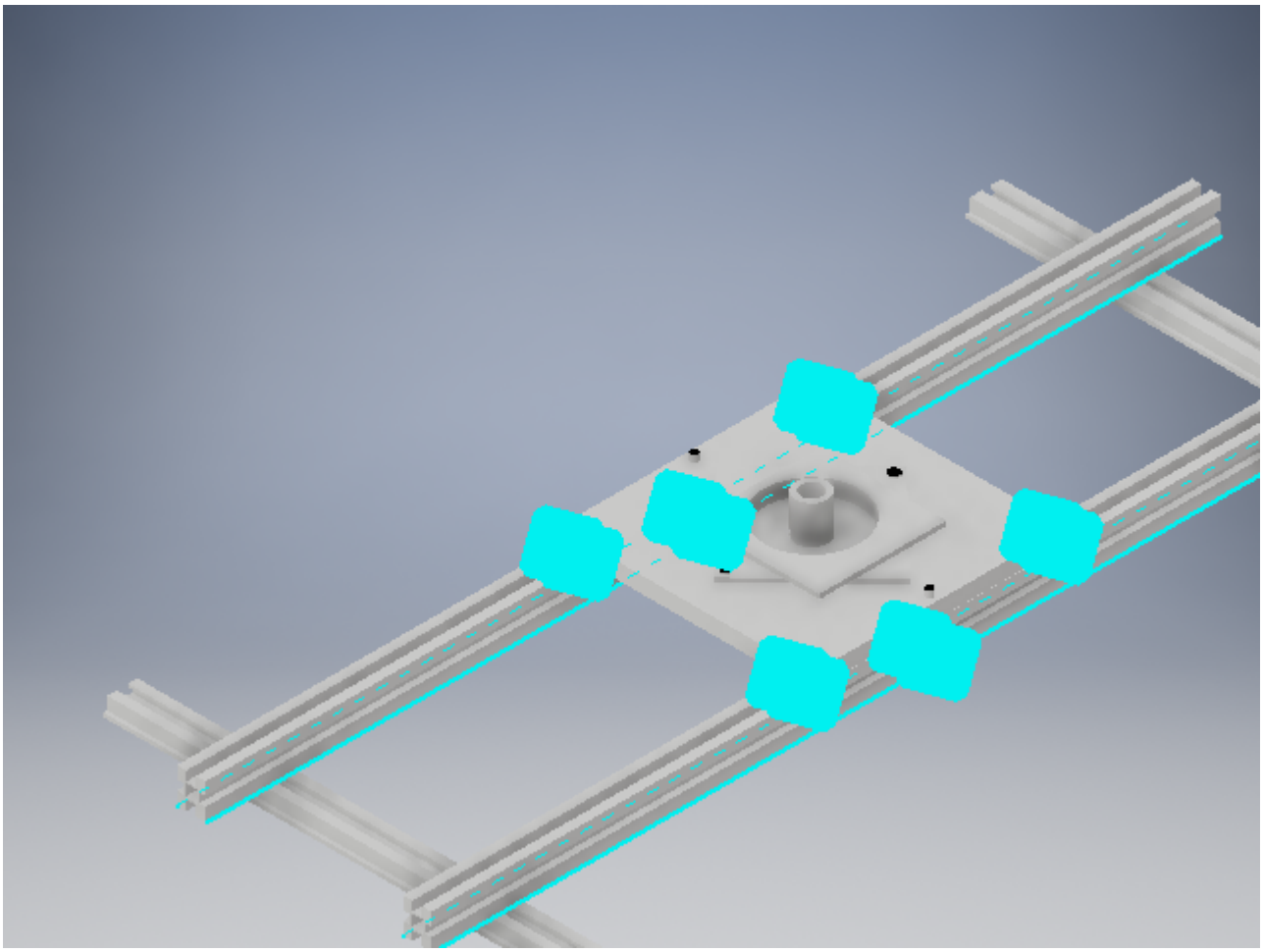


Figure I-2 Selected Constraints Outline

Table I-8 Reaction Force and Moment on Constraints

Constraint Name	Reaction Force		Reaction Moment	
	Magnitude	Component (X,Y,Z)	Magnitude	Component (X,Y,Z)
Fixed Constraint:1	322 lbforce	0 lbforce	0.170458 lbforce ft	0 lbforce ft
		322 lbforce		0 lbforce ft
		0 lbforce		-0.170458 lbforce ft

Table I-9 Result Summary

Name	Minimum	Maximum
Volume	78.7355 in^3	
Mass	22.3293 lbmass	
Von Mises Stress	0 ksi	1.65225 ksi
1st Principal Stress	-0.238298 ksi	2.27886 ksi

3rd Principal Stress	-0.953763 ksi	0.491472 ksi
Displacement	0 in	0.000120187 in
Safety Factor	15 ul	15 ul

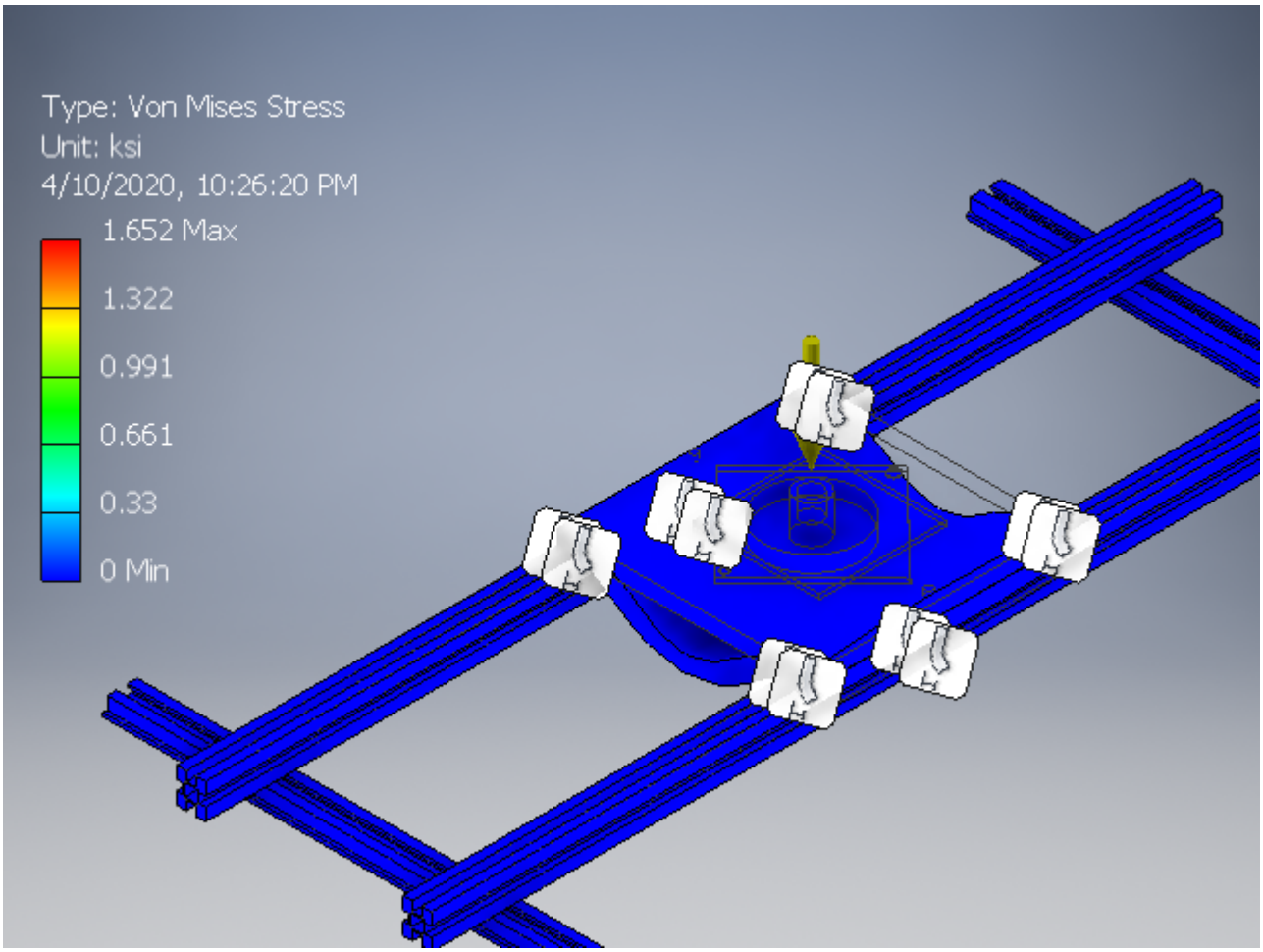


Figure I-3 Von Mises Stress

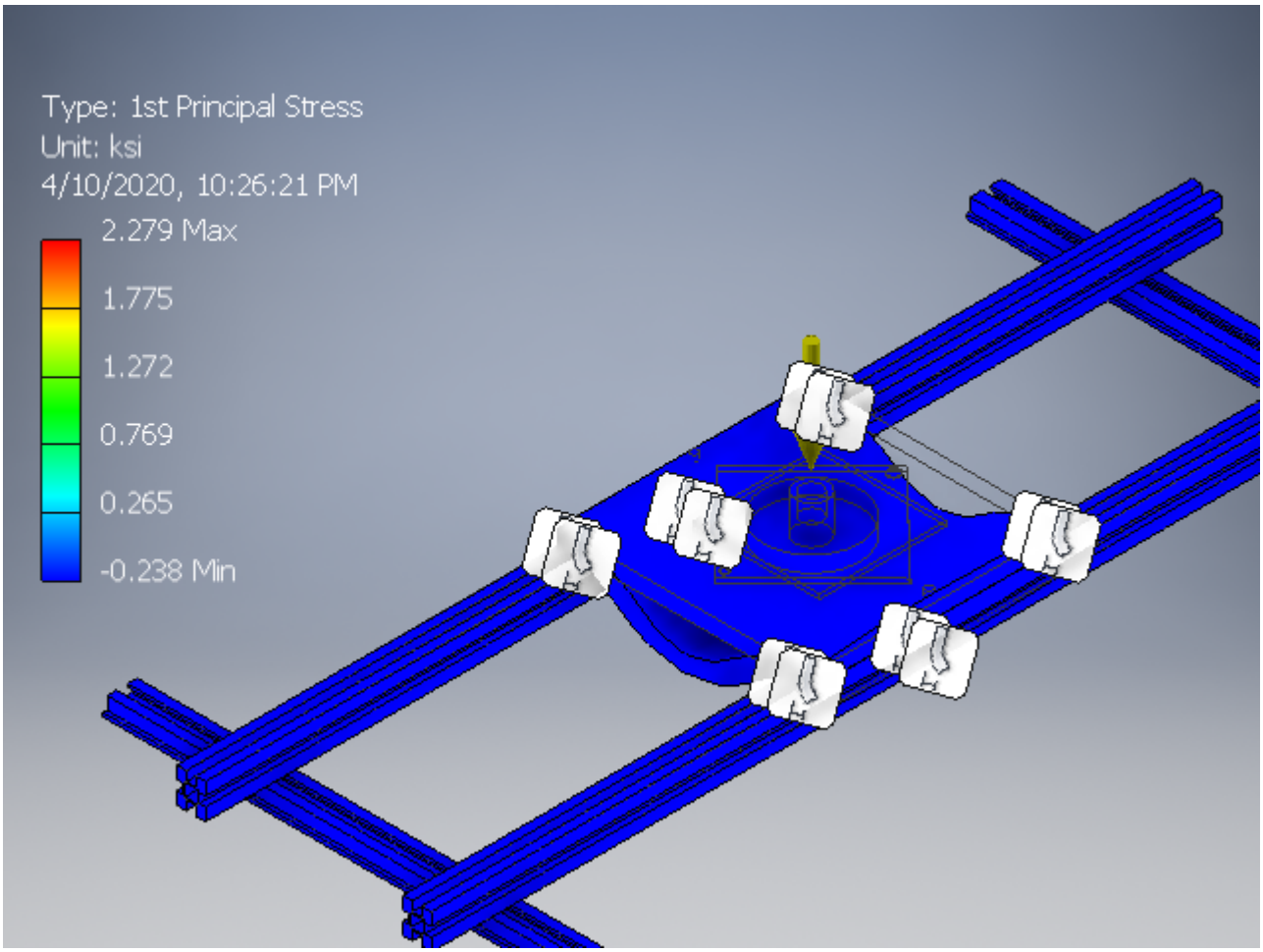


Figure I-4 1st Principal Stress

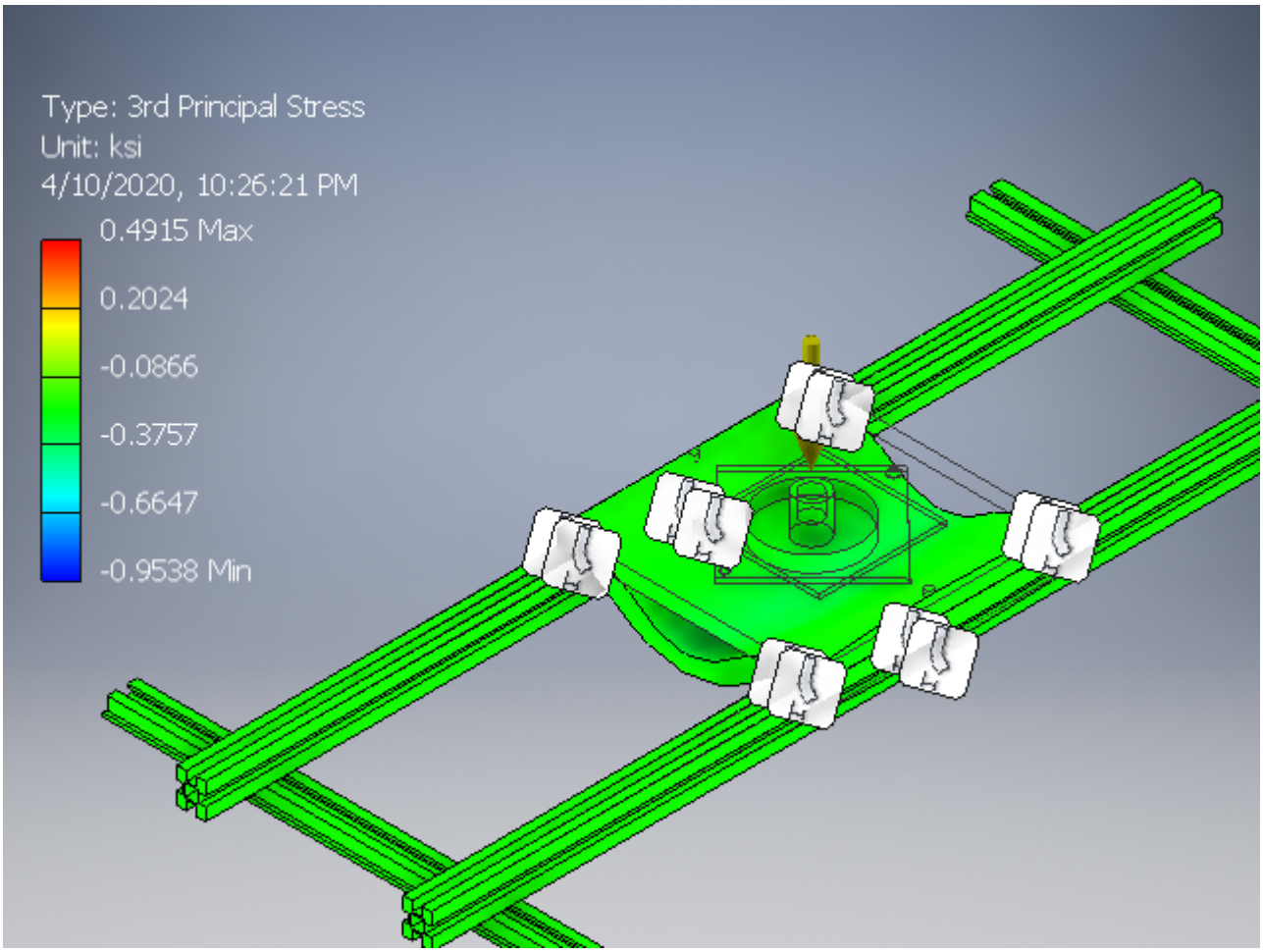


Figure I-5 3rd Principal Stress

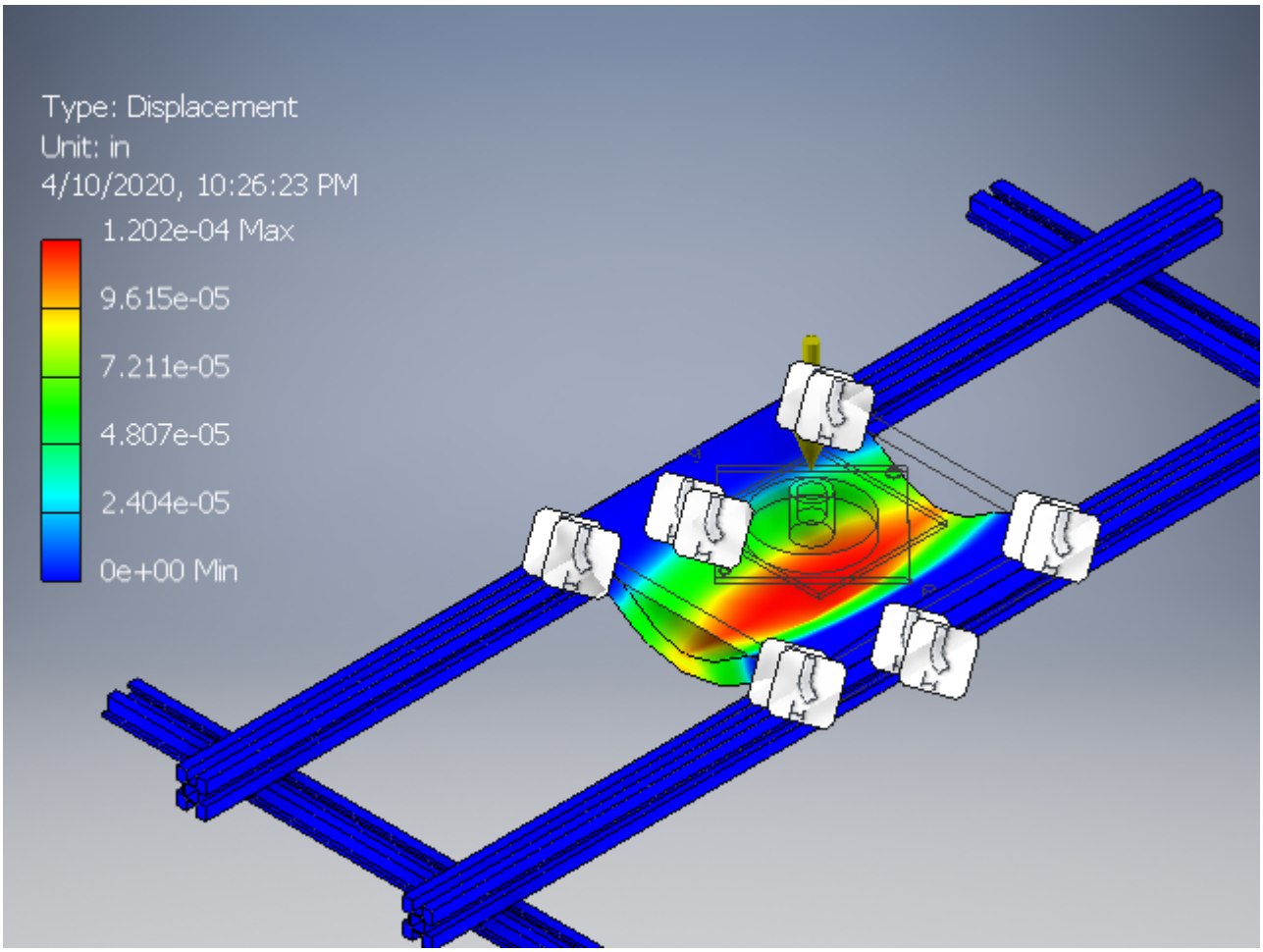


Figure I-6 Displacement

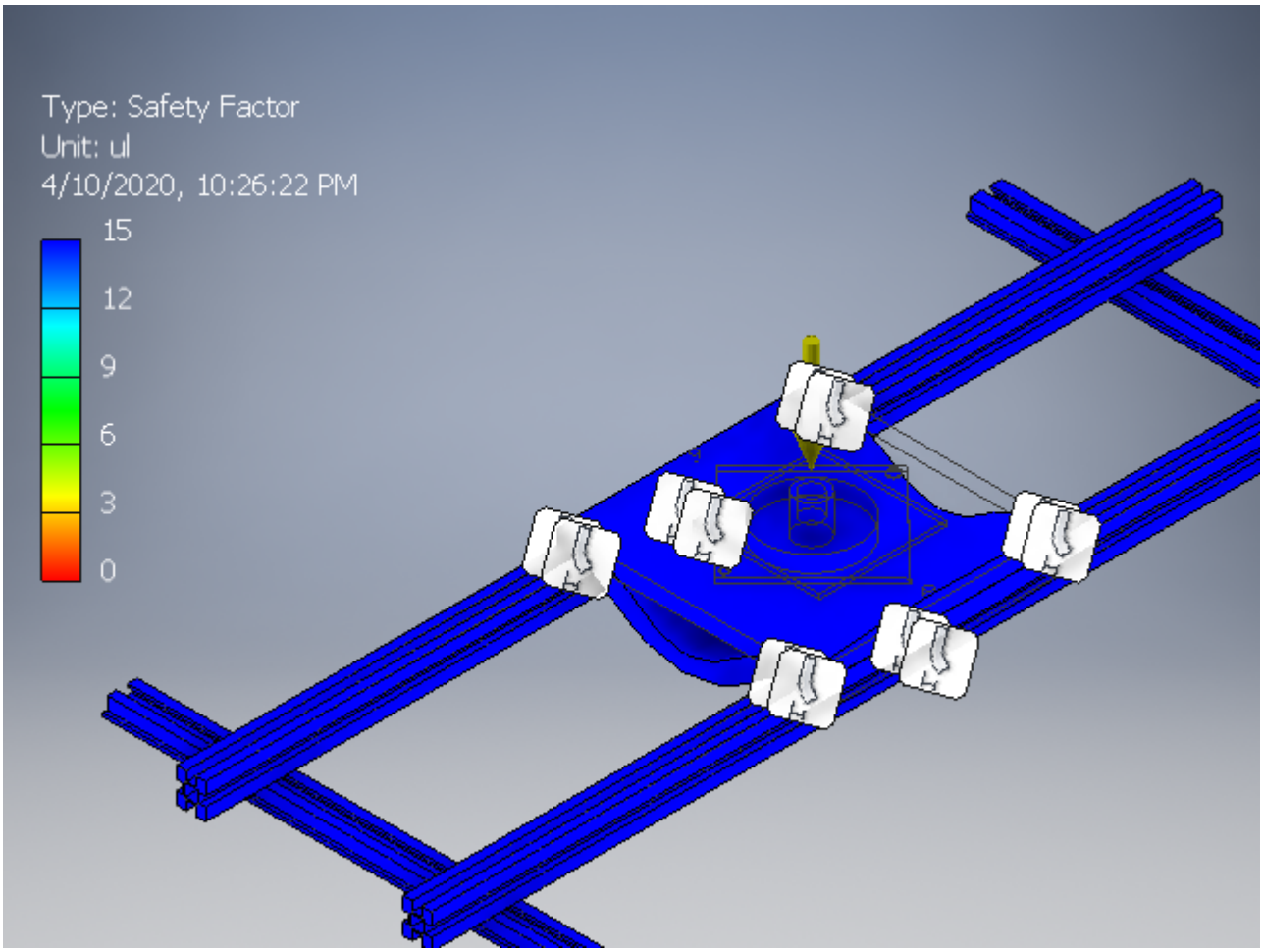


Figure I-7 Safety Factor

Appendix J. Design of Experiments, Experimental Procedures, and Results (Test Plans)

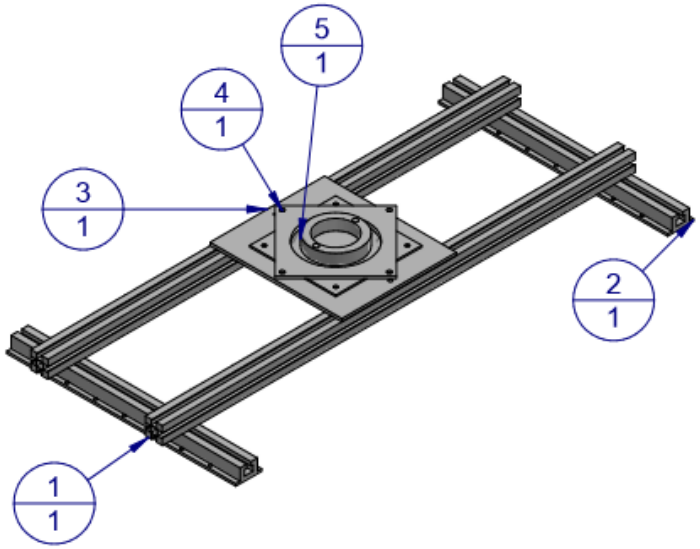
The system went through few iterations. List is below

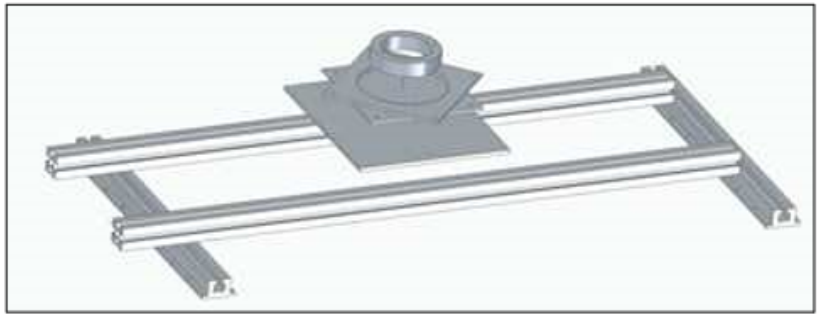
Table J-1 Design Iterations

No.	Modification	Initial design	Final design	Comments
1	Material	Aluminum	Acrylic	To reduce weight
2	Dimension	24*21.3*1.2	20*22.1*8	Easy installation of components
3	Gear and motor	Outside the box	Inside the box	Protection from water and dust
4	Weight	Approx. 30 lbs.	18.22 lbs.	User friendly
5	Mount	3 separate adjustable plates	2 adjustable bars	Easy adjustment of the mount

Appendix K. Final Assembly Drawings

NOTES:
1. DO NOT SCALE DRAWING
2. ALL DIMENSIONS IN INCHES
3. SURFACES TO BE 16 √
4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES

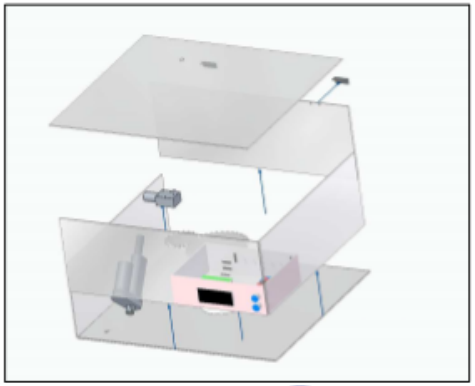




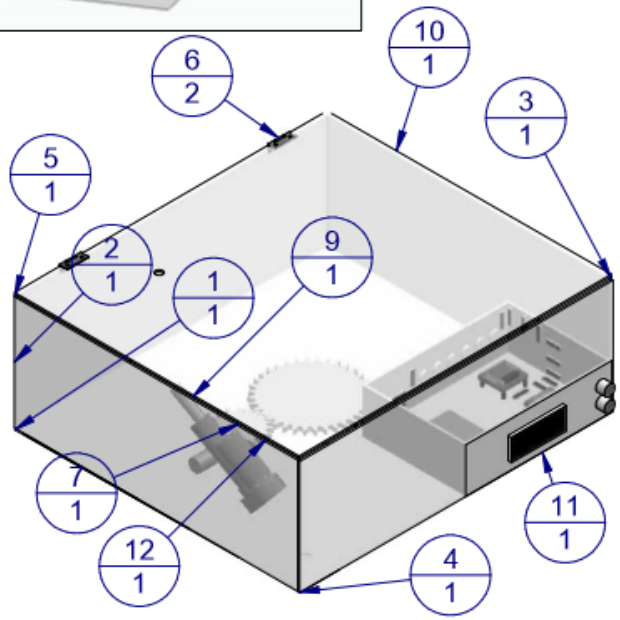
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2	framekayak	hmatraka	1
3	plate	hmatraka	1
4	lazysusan table	hmatraka	1
5	gearsupport	hmatraka	1

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.X ±0.1 .XX ±0.05 .XXX ±0.005 .XXXX ±0.0005 ANGLE ±1.0°	SCALE: NTS	DWN BY: HM	
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	TITLE: EXPLODE VIEW		
	MATERIAL: ALUMINUM		DWG# EXPLODE

NOTES:
1. DO NOT SCALE DRAWING
2. ALL DIMENSIONS IN INCHES
3. SURFACES TO BE 16 √
4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES

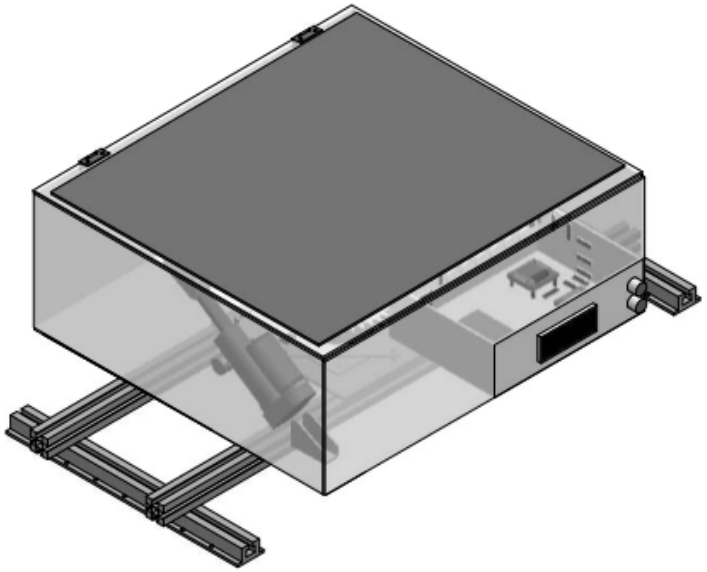


Item Number	File Name (no extension)	Author	Quantity
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2*	INFRONT	hmatraka	1
3	BACK	hmatraka	1
4	RIGHT	hmatraka	1
5	LEFT	hmatraka	1
6	Asm1	hmatraka	2
7*	motor	hmatraka	1
8*	semilarge linear actuator		1
9*	rod - Copy	hmatraka	1
10	TOPBOX	hmatraka	1
11*	Updated Wiring Template (Controller)	hmatraka	1
12*	Assem200gear	hmatraka	1



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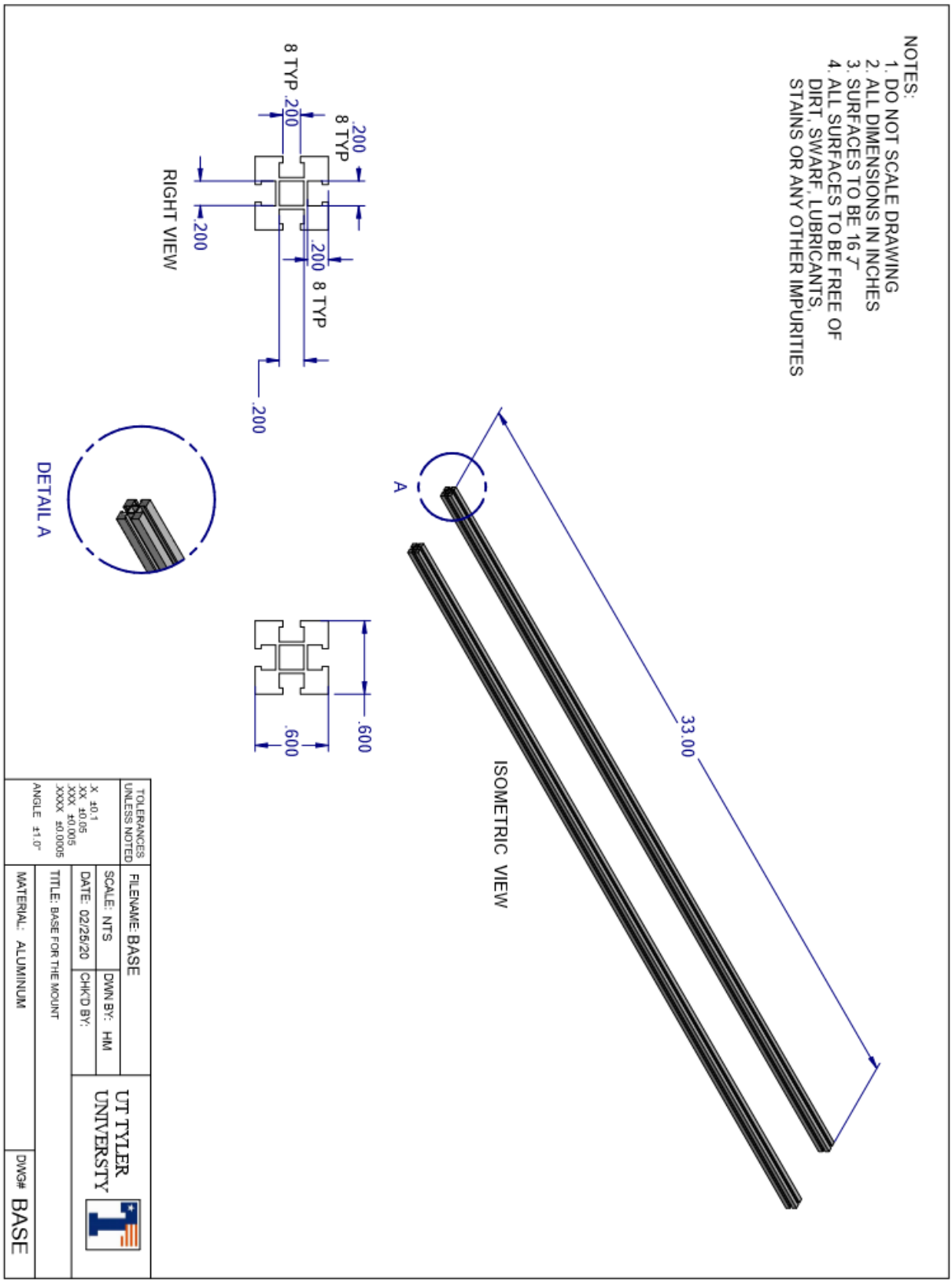
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1. DO NOT SCALE DRAWING
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3. SURFACES TO BE 16 √
4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES



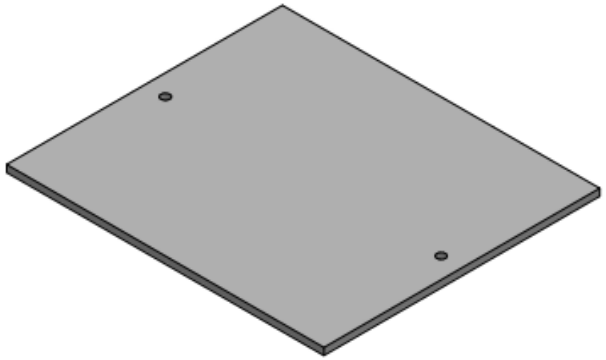


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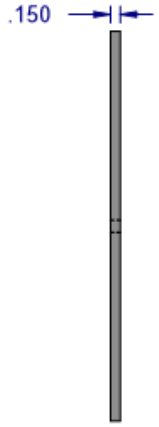
Appendix L. Final Manufacturing Drawings (Detailed 2D Layout)



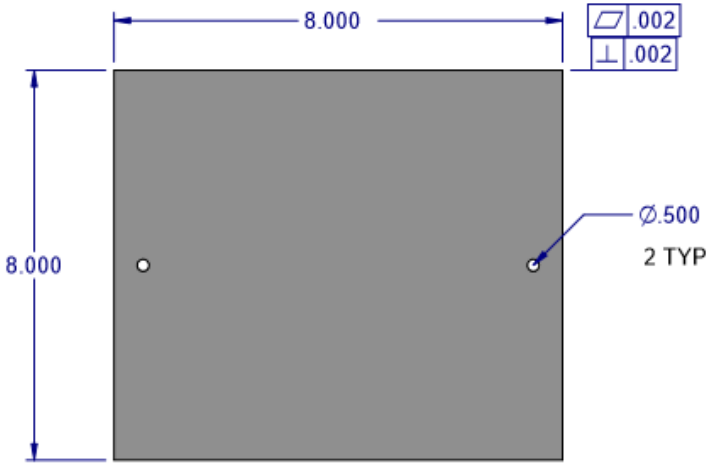
NOTES:
1. DO NOT SCALE DRAWING
2. ALL DIMENSIONS IN INCHES
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4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES



ISOMETRIC VIEW

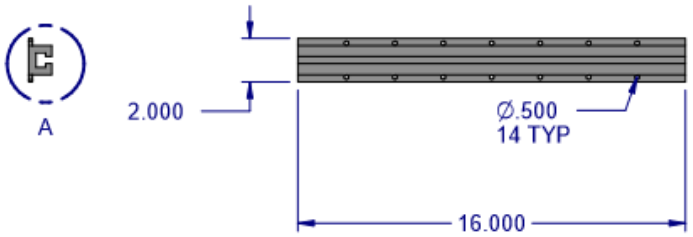


RIGHT VIEW



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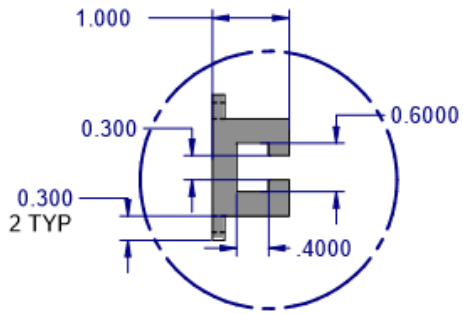
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1. DO NOT SCALE DRAWING
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ISOMETRIC VIEW



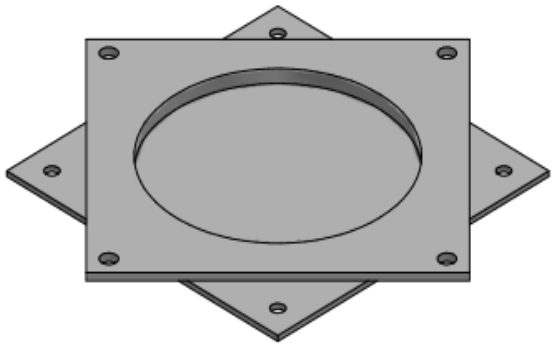
DETAIL A



RIGHT VIEW

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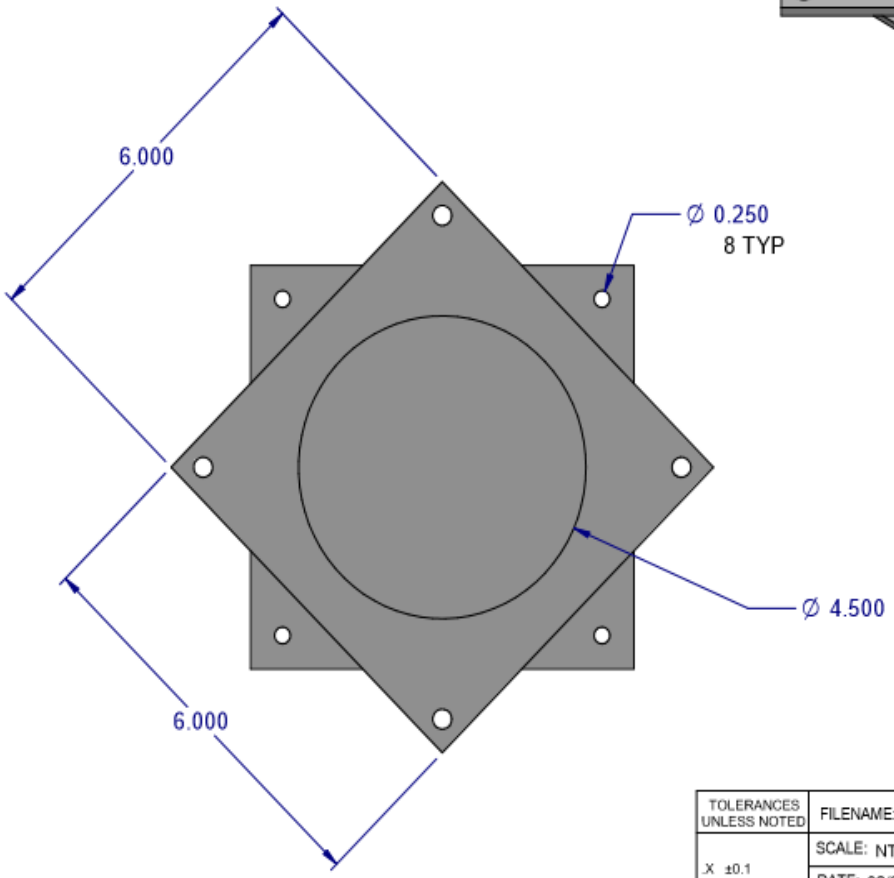
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2. ALL DIMENSIONS IN INCHES
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4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES



ISOMETRIC VIEW

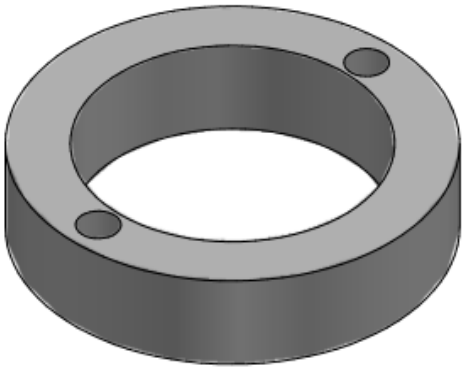


RIGHT VIEW

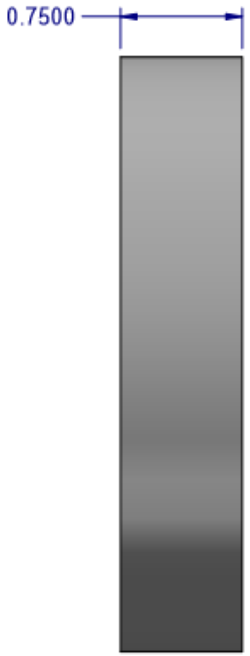


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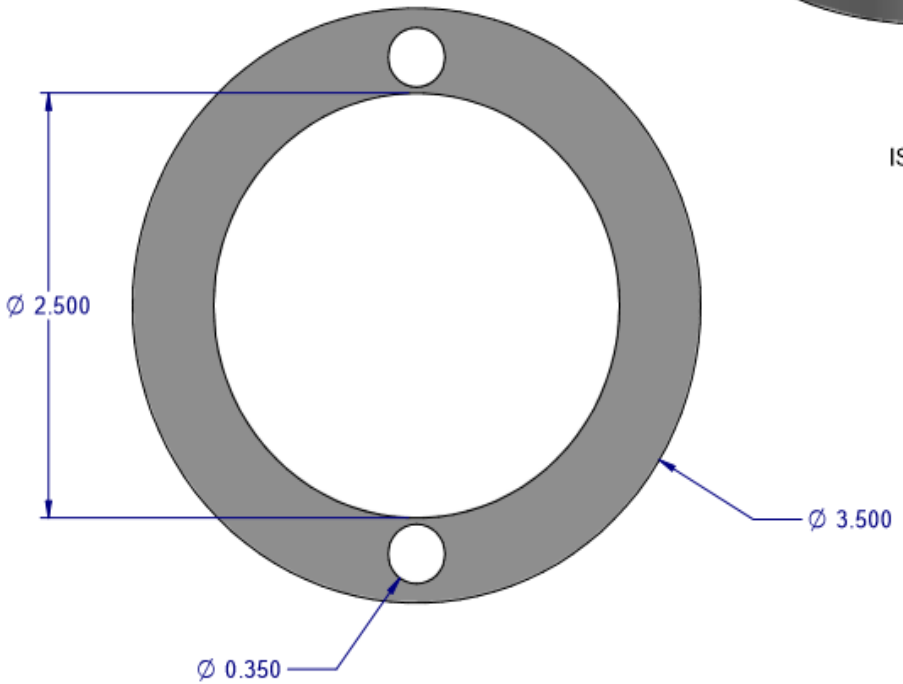
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1. DO NOT SCALE DRAWING
2. ALL DIMENSIONS IN INCHES
3. SURFACES TO BE 16 $\sqrt{}$
4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES



ISOMETRIC VIEW

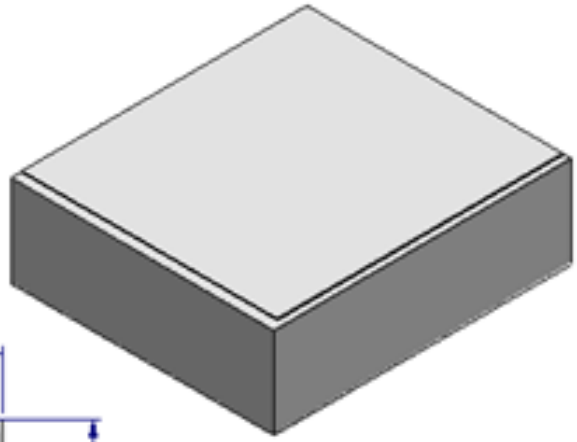


RIGHT VIEW

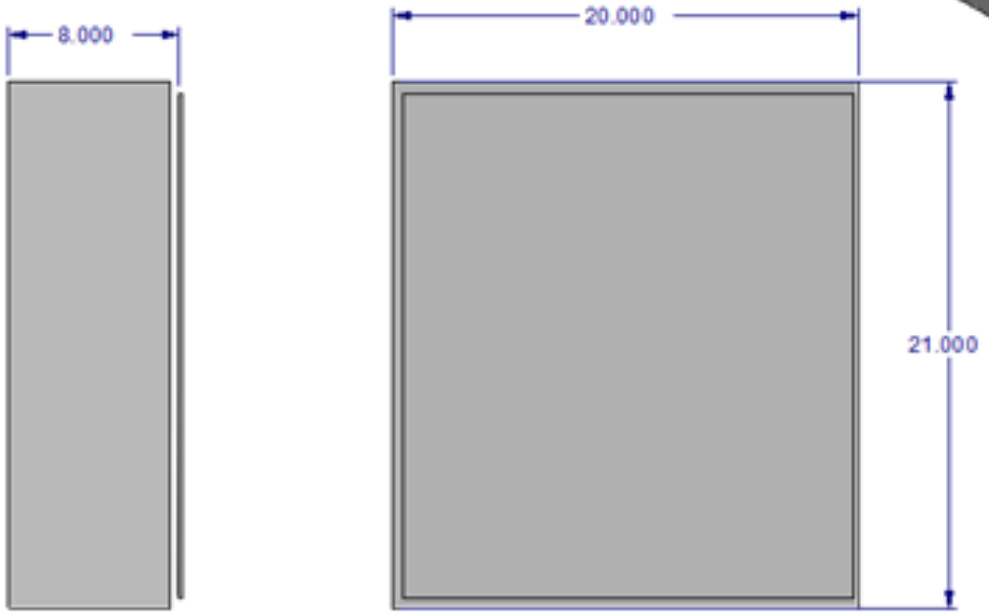


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	DATE: 02/25/20	CHK'D BY:	
	TITLE: GEAR SUPPORT		
	MATERIAL: ALUMINUM		DWG# GEARSUPPORT

NOTES:
1. DO NOT SCALE DRAWING
2. ALL DIMENSIONS IN INCHES
3. SURFACES TO BE 16 7"
4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES



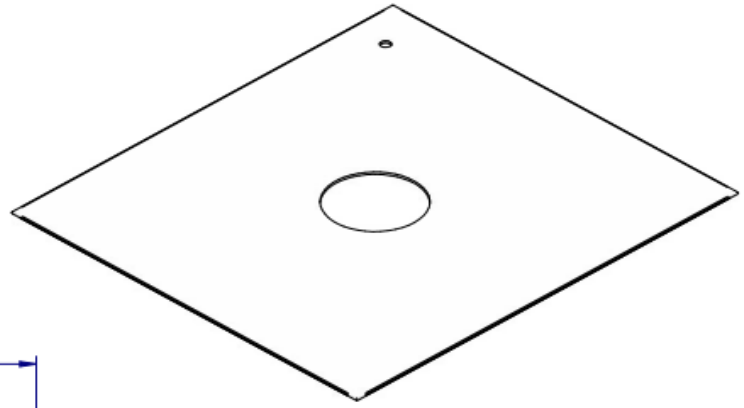
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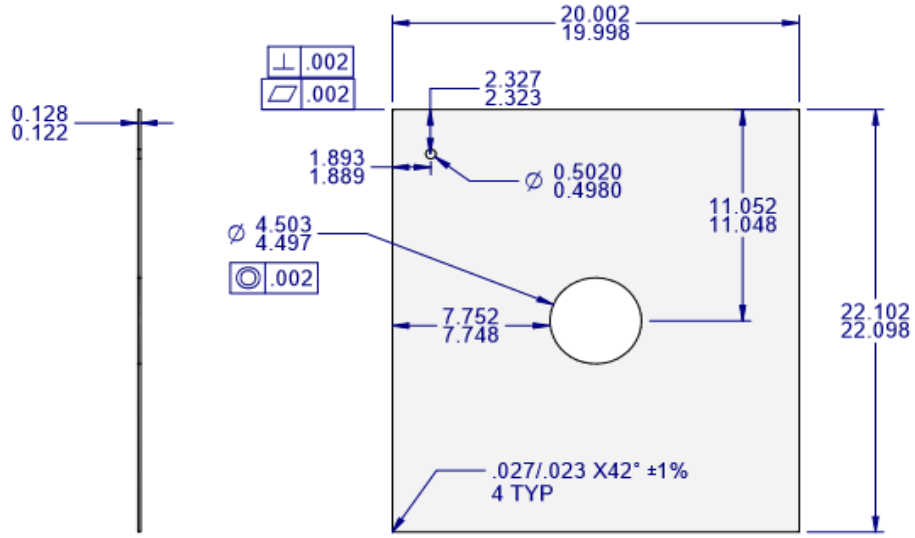
RIGHT VIEW

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	TITLE: BOX		
	MATERIAL: ALUMINUM		DWG# BOX

NOTES:
1. DO NOT SCALE DRAWING
2. ALL DIMENSIONS IN INCHES
3. SURFACES TO BE 16 √
4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES



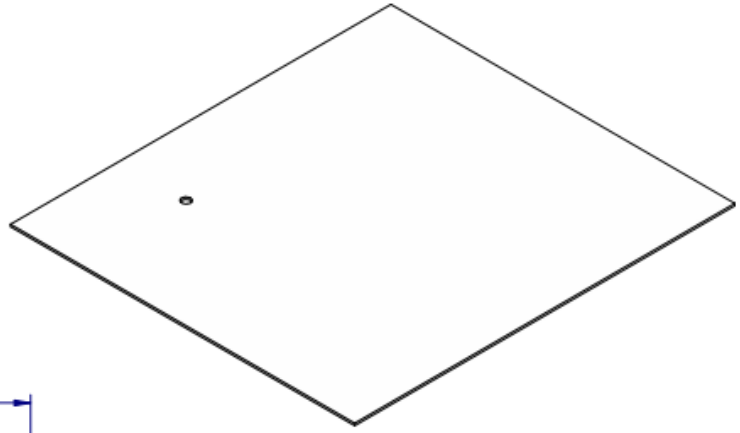
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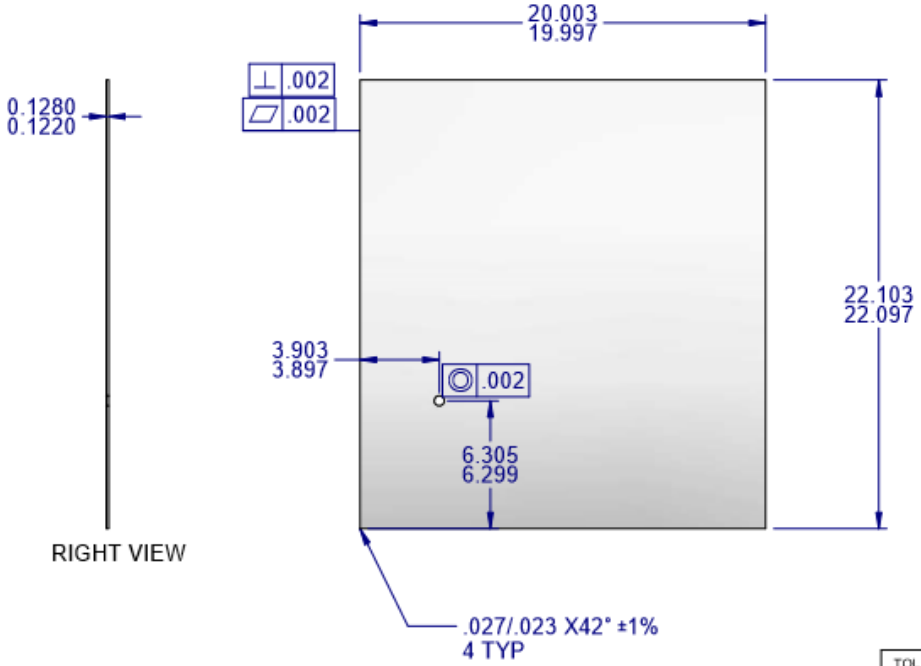
RIGHT VIEW

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	DATE: 02/25/20	CHK'D BY:	
	TITLE: BOTTOM		
	MATERIAL: ARCYLIC	DWG# BOTTOM	

NOTES:
1. DO NOT SCALE DRAWING
2. ALL DIMENSIONS IN INCHES
3. SURFACES TO BE 16 $\sqrt{}$
4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES

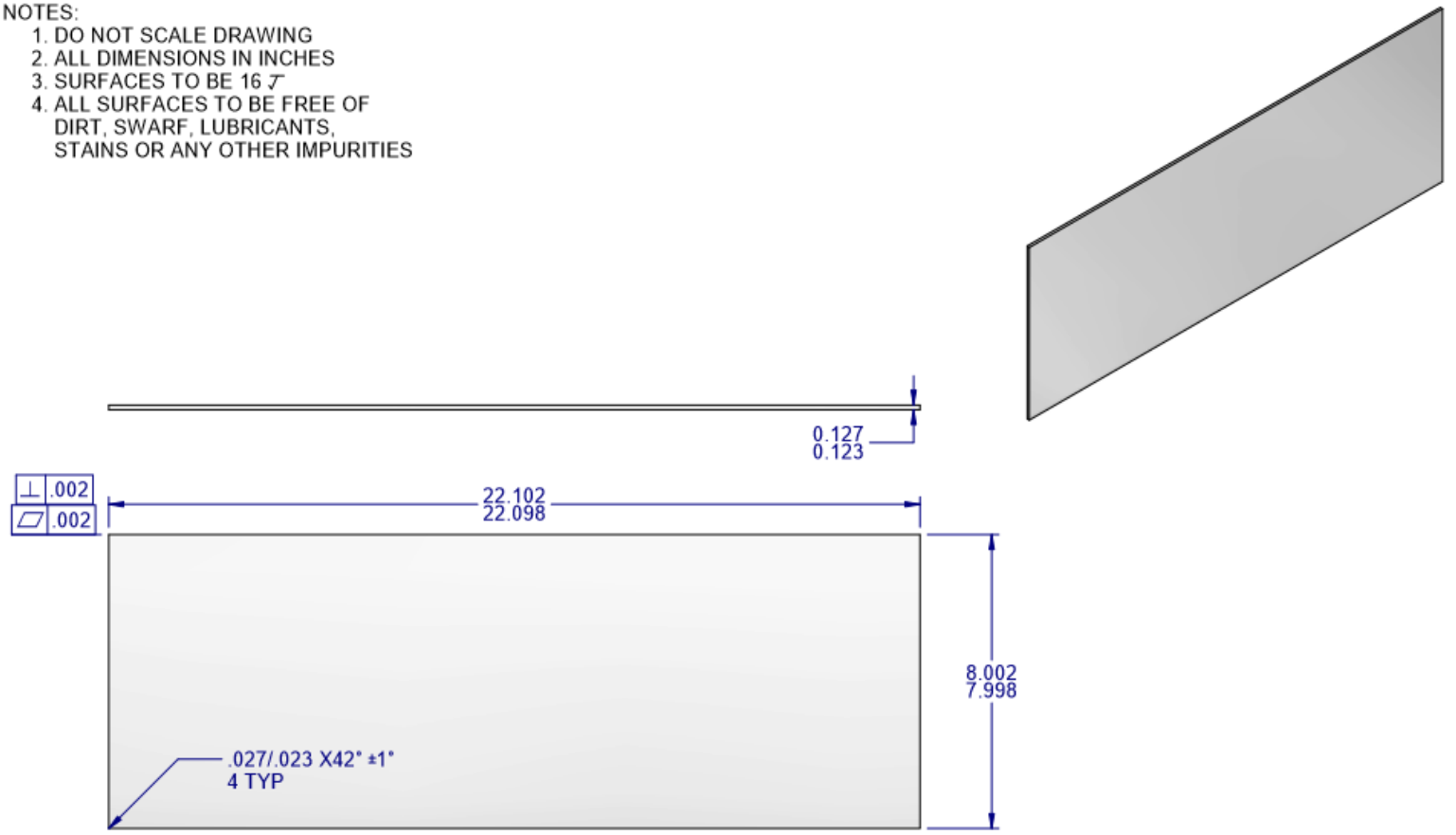


ISOMETRIC VIEW



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	TITLE: LID OF BOX		
	MATERIAL: ARCYLIC		DWG# LID

NOTES:
1. DO NOT SCALE DRAWING
2. ALL DIMENSIONS IN INCHES
3. SURFACES TO BE 16 $\mathcal{T}$
4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES



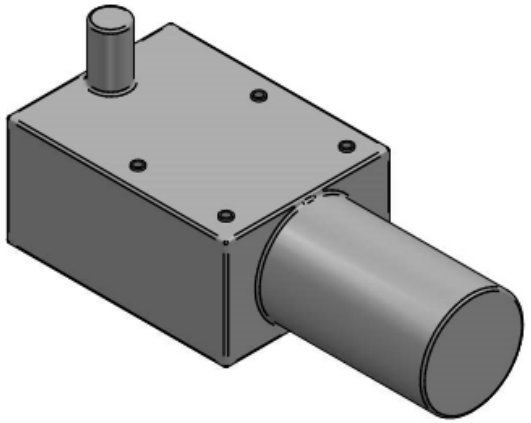
RIGHT VIEW

QUANTITY 2 PIECES

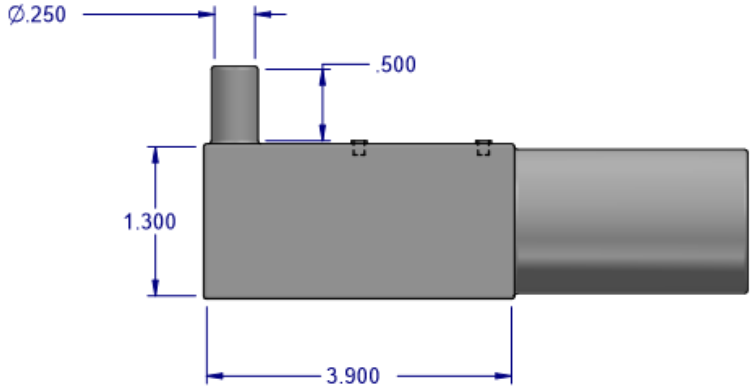
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	TITLE: ILEFT AND RIGHT SIDE		
	MATERIAL: ARCYLIC	DWG# left right	

NOTES:
1. DO NOT SCALE DRAWING
2. ALL DIMENSIONS IN INCHES
3. SURFACES TO BE 16 $\sqrt{}$
4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES

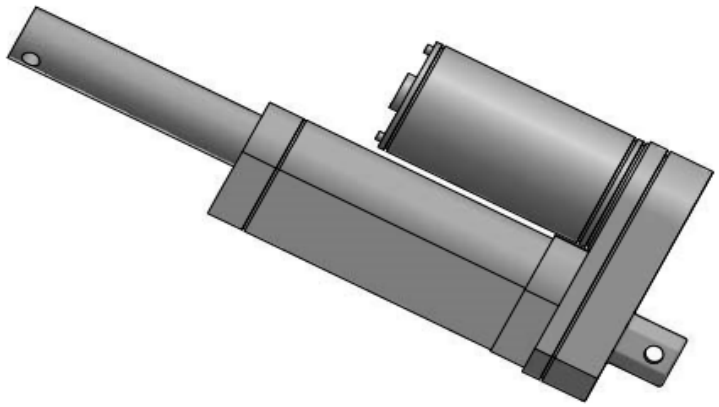


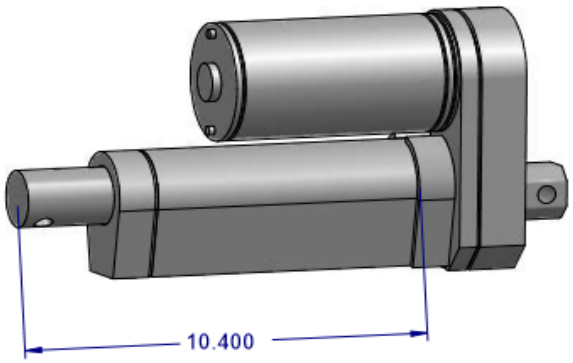
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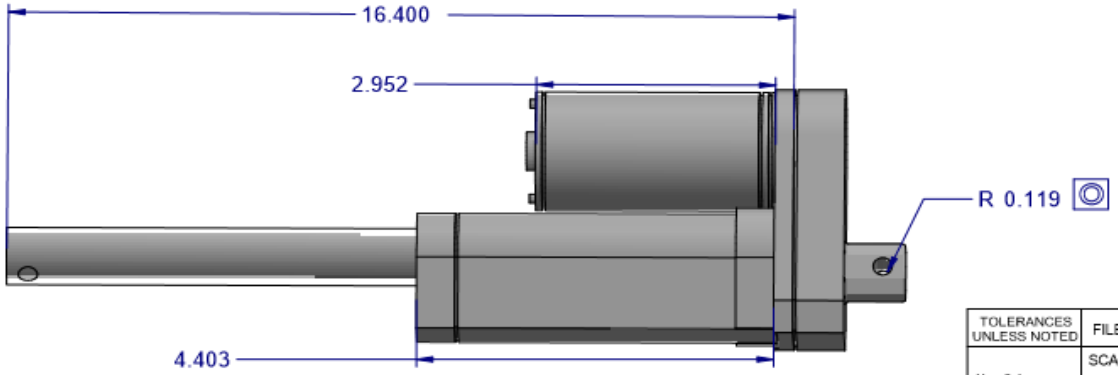


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	DATE: 02/25/20	CHK'D BY:	
	TITLE: Motor		
	MATERIAL: STEEL		DWG# MOTOR

NOTES:
1. DO NOT SCALE DRAWING
2. ALL DIMENSIONS IN INCHES
3. SURFACES TO BE 16 $\sqrt{}$
4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES

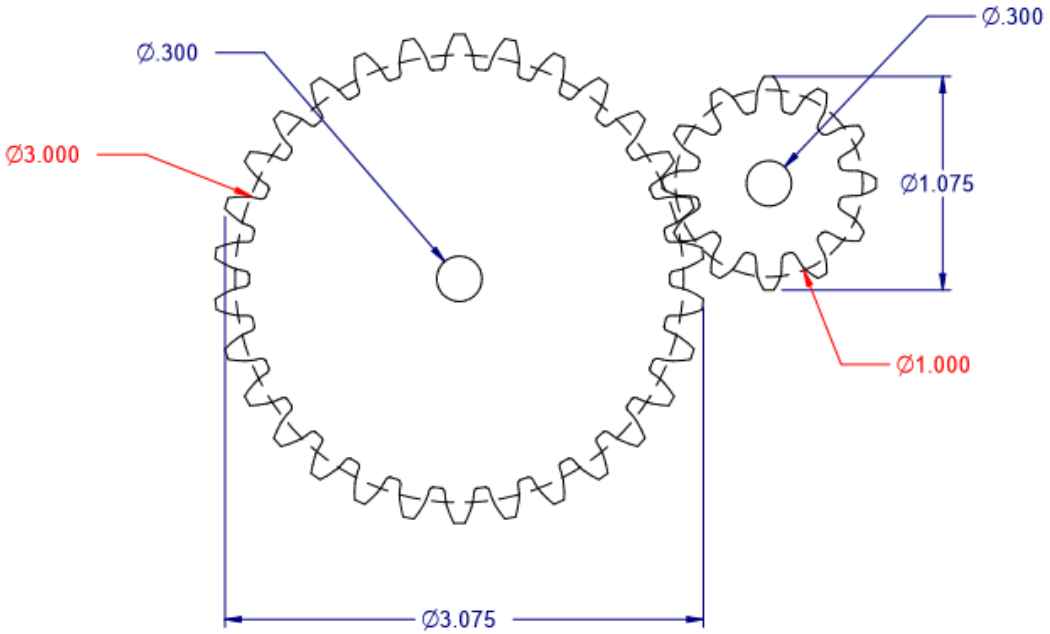






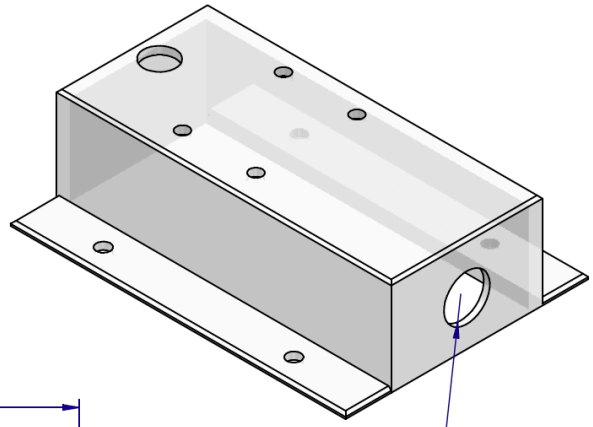
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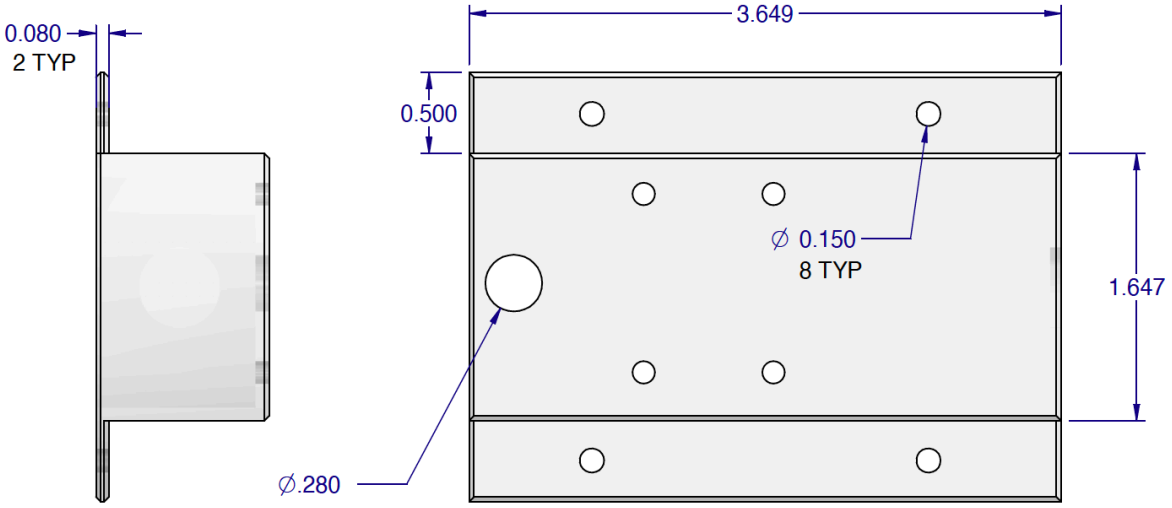
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4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES



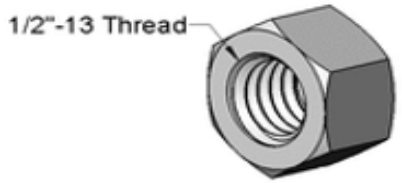
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	TITLE: SPUR GEAR		
	MATERIAL: ALUMINUM	DWG# Gear	

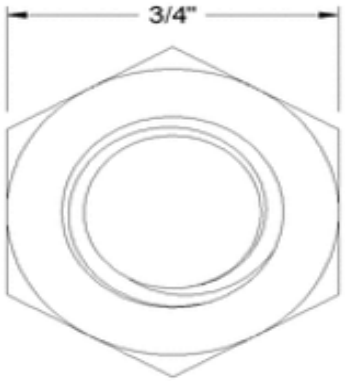
NOTES:
1. DO NOT SCALE DRAWING
2. ALL DIMENSIONS IN INCHES
3. SURFACES TO BE 16 √
4. ALL SURFACES TO BE FREE OF DIRT, SWARF, LUBRICANTS, STAINS OR ANY OTHER IMPURITIES





TOLERANCES UNLESS NOTED	FILENAME: MOTOR HOLDER		UT TYLER UNIVERSTY
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	MATERIAL: ACRYLIC		DWG# MHOLDER







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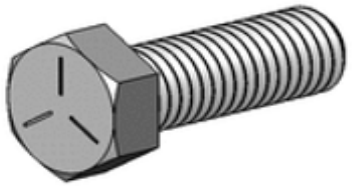
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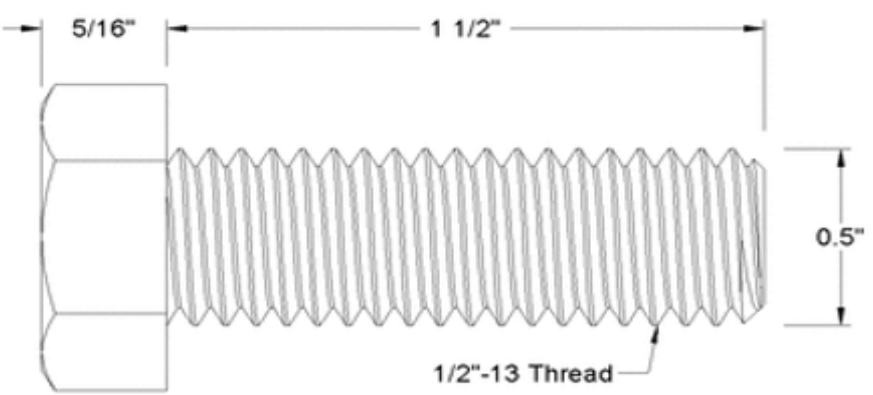
Information in this drawing is provided for reference only.

PART NUMBER **95462A033**

Hex Nut







McMASTER-CARR CAD

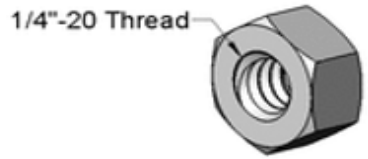
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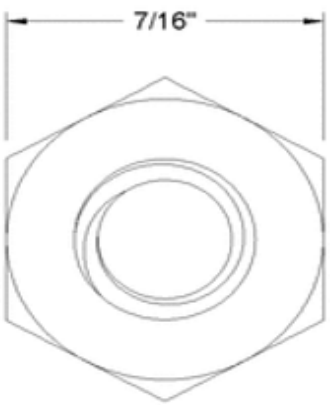
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Information in this drawing is provided for reference only.

PART NUMBER **92965A716**

Medium-Strength Steel
Cap Screw -Grade 5







McMASTER-CARR CAD

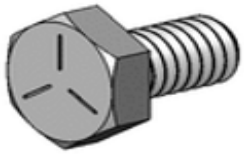
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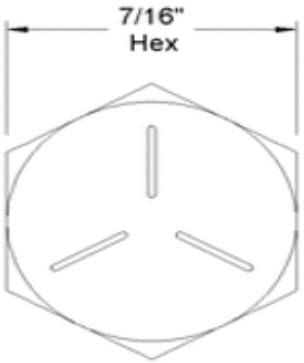
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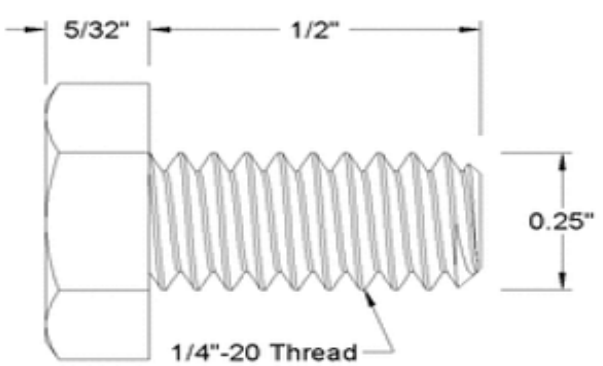
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PART NUMBER **95462A029**

Hex Nut







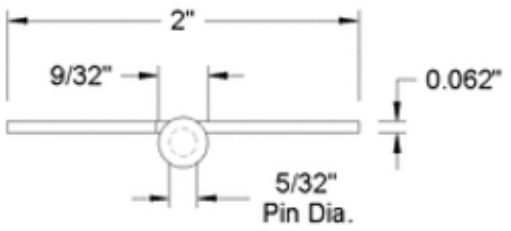
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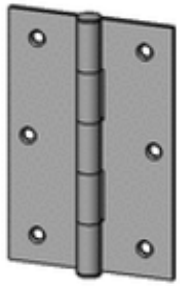
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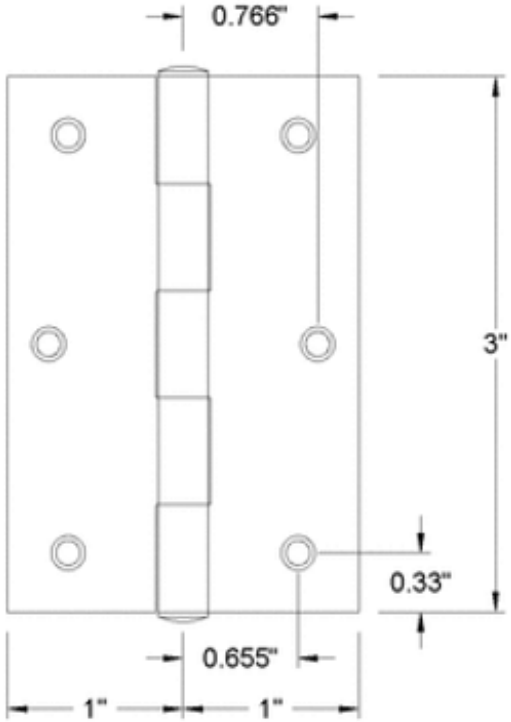
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Information in this drawing is provided for reference only.

PART NUMBER **92965A537**

Medium-Strength Steel
Cap Screw -Grade 5







Hinge uses #7 screws.

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PART NUMBER 1598A18

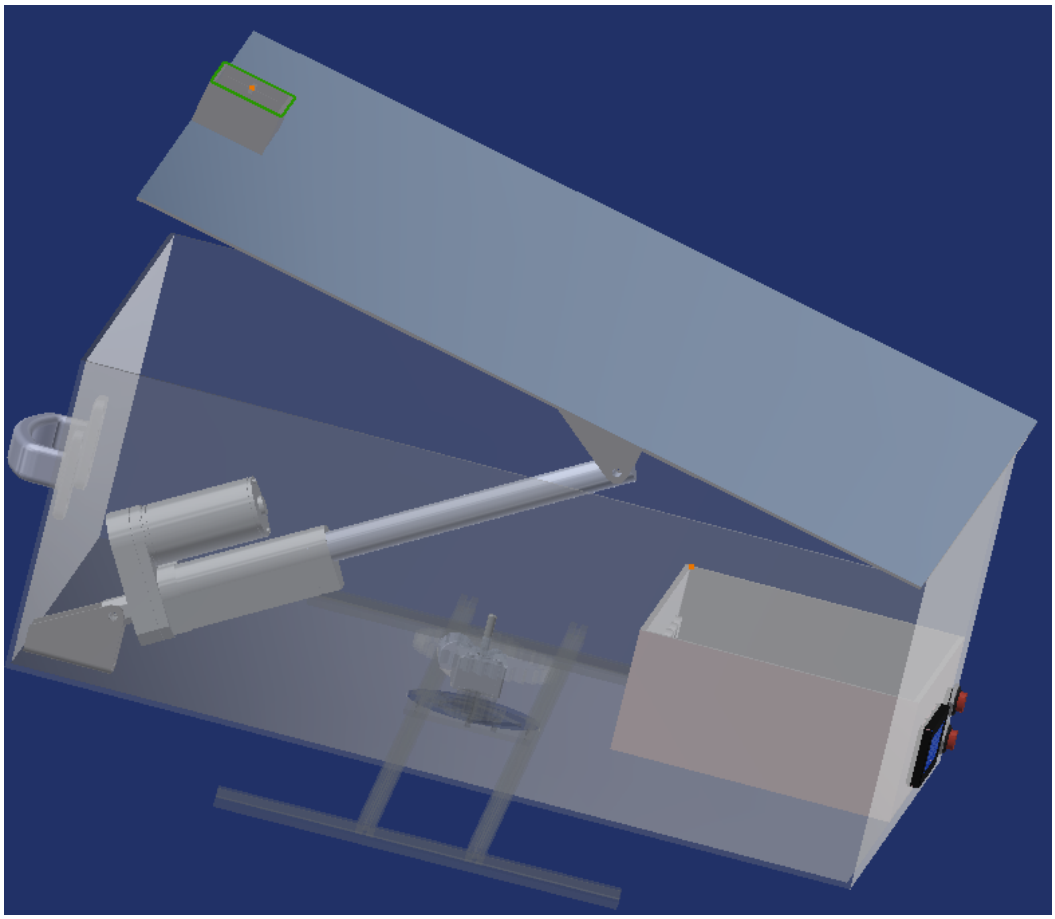
Mortise-Mount Hinge with Nonstandard Mounting Hole Pattern

Appendix M. User Manual – Operations, Safety, and Parts Listing

The University of Texas at TYLER™

Marine Solar Charger User Manual

Designed and manufactured by The Solars:
Dana Bekmaganova
Prakash Jha
Kieran Kapila
Rudy Marban
Hicham Matraka



Thank you for the purchase of the portable solar charger system! With the purchase of this system now those long kayak trips will become a lot less of a hassle without having to worry about conserving battery in all your electronic devices.

This system was made with the thought of make it long lasting as possible, several components being water resistant (IP 65). Considering this advancement, this manual will break down some of the mechanical and electrical components to give you the costumer a better understanding of all the parts that make a specific component in this system.

Please keep manual in a safe place, retuning back to it for reference will be needed in case of needed repairs

1. Safety

**Safety instructions**

Please read this safety information carefully

Be aware of the following three symbols throughout the user manual:

**Warning!**

Failing to follow these instructions can cause accidents resulting in serious personal injury.

**Recommendations**

Failing to follow these instructions can result in the actuator suffering damage or being ruined.

**Additional information**

Usage tips or additional information that is important in connection with the use of the actuator. Furthermore, ensure that all staff who are to connect, mount, or use the actuator are in possession of the necessary information and that they have access to this user manual.

Before you start mounting/dismounting, ensure that the following points are observed:

- The system is not in operation
- The actuator and motor are free from load that could be released during this work

Before you put the actuator, motor, and gear into operation, check the following:

- The actuator, motor and gear are correctly mounted.
- The equipment can be freely moved no interference
- The actuator and motor are connected to a mains electricity supply/transformer with the correct voltage.
- Ensure that the voltage applied matches to the voltage specified
- Ensure that the connection bolts are secured safely.

Before you use the charge controller, ensure that the following points are observed:

- There are no user serviceable parts inside the controller. Please do not disassemble or attempt to repair it.
- The solar cell model and battery must be disconnected before mount and wire the controller.
- Wearing eye protection glasses when you mount the battery.
- Use insulated tools, do not place any metal near the battery to avoid risk of short circuit.
- Virtual connection point and corroded wire may overheat to melt the wire, burn surrounding materials, or even cause fire. Ensure tight connection and use cable clamps to secure cables and prevent them from swaying in mobile applications.
- The battery that is intended to be charged is rated 12V
- The battery is properly connected

2.4. Mounting guidelines

2.4.1. Actuator

- The mounting pins must have the correct dimension.
- The bolts and nuts must be made of a high-quality steel.
- Bolts and nuts must be protected so there is no risk for them to fall out.
- Do not use a torque that is too high when mounting the bolts.

2.4.2. Motor

- The motor must be fix to the base of the box
- Should be ip 65
- Cable must be clear for any interference
- Shaft must fit the gear exactly to the gear

2.4.3. Gear

- Gear and pinion teeth are match exactly

2.4.4. Wiring



Caution: For secure installation, must follow below connect sequence: battery first, then the photovoltaic panel.



Caution: The solar module(s) high voltage output can cause severe shock and injury. Be careful operation when installing solar wiring.



Loose power connections and/or corroded wires may result in resistive connections that melt wire insulation, burn surrounding materials, or even cause fire. Ensure tight connections and use cable clamps to secure cables and prevent them from swaying in mobile applications.

2.5. Troubleshooting

2.5.1. Actuator

Table M-1 Actuator troubleshooting

Symptom	Cause	Action
Motor runs but spindle does not move	Gearing system or spindle damaged	Contact manufacture
No motor sound or movement of piston rod	• Not properly connected • Fuse burned • Cable damage	• Check power supply connection • Check fuse • Check cable
Excessive power	Overload in application	Reduce the load
Actuator can't lift load	Insufficient power	Check power supply

2.5.2. Motor

Table M-2 Motor troubleshooting

Symptom	Cause	Action
Motor does not run	Manufacturing defect	Contact manufacture
No motor sound or movement	• Not properly connected • Fuse burned • Cable damage	• Check power supply connection • Check fuse • Check cable
Excessive power	• Overload in application • Insufficient power	• Reduce the load • Check power supply
Shaft to small	Gear diameter is big	Make a mechanism support to connect the shaft and gear

2.5.3. Gear

Table M-3 Gears troubleshooting

Symptom	Cause	Action

Wear	Wear on tooth surface	Change the gear
Cavitation or corrosion	By force and friction	Lubrication
Plastic deformation	Overload force and heat	Reduce the load
crack	Fatigue	Change gear

2.5.4. Charge controller

Table apx M-4 Charge controller troubleshooting

Symptom	Cause	Action
LCD display and indictor are off after power on	Battery has seriously low voltage or disconnected	Please change the battery. Check the battery connection is correct and tight or not
Soon after charged, the battery power status showing full	Charging over voltage or current	Check the maximum charging current match with battery maximum charging current or not. Revise the charging voltage when necessary
Tracker stops even though switch is on	Battery over discharge	The controller cut off the output automatically and recovers when fully charged

2.6. Maintenance

- The actuator, motor, and gear must be cleaned at regular intervals to remove dust and dirt and inspected for mechanical damages or wear.
- Inspect the three components attachment that they are going to function correctly.
- Pre-grease each component in order to limit damage due to friction and environment.
- Inspect the electrical part of the actuator and motor for any water damage.

3. Parts Listing

1. Solar Panel



Figure M-1 Solar Panel

Specifications:

Table M-1 Specifications of the Solar Panel

TYPE	DESCRIPTION
Electrical Data	
Maximum Power at STC*	50 W
Optimum Operating Voltage (Vmp)	18.5 V
Optimum Operating Current (Imp)	2.71 A
Open Circuit Voltage (Voc)	22.6 V
Short Circuit Current (Isc)	2.92 A
Cell Efficiency	21.0%
Mechanical Data	
Solar Cell Type	Monocrystalline (5.92x2.04 in)
Number of Cells	32 (4 x 8)
Dimensions	26.5 x 20.0x 0.08 in
Weight	2.87 lbs.
Connectors	MC4 Connectors
IP Rating	IP 68

2. Aluminum Frame



Figure M-2 Aluminum Frame

Specifications:

Table M-2 Specifications of the Frame

TYPE	DESCRIPTION
Height	36 in
Length	36 in
Thickness	0.019 in
Weight	2.348 lbs.
Manufacturer	Home Depot
Part#	10001195035

3. Mount bracket

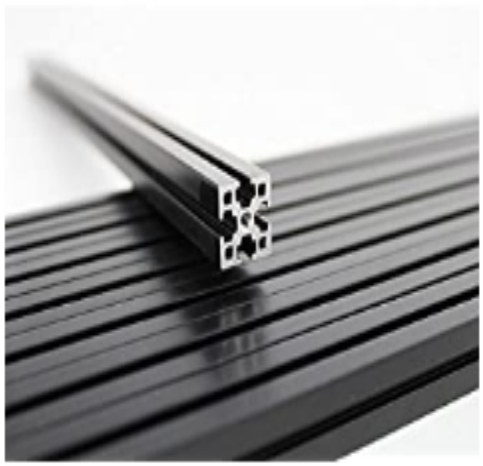


Figure M-3 Mount Bracket

Specifications:

Table M-3 Specifications of the Mount Bracket

TYPE	DESCRIPTION
Product Height	.600 in
Product Length	39.400 in
Product thickness	.600 in
Product weight	10.4 ounces
Quantity	2
Manufacture	Home Depot
Part#	103251

4. Turning table



Figure M-4 Turning Table

Specifications:

Table M-4 Specifications of the Turning Table

TYPE	DESCRIPTION
Material	Metal
Length	6 in
Width	6 in
Weight	400 lbs.
Quantity	1
Manufacture	Home Depot
Part#	998538

Screw Set	8

5. Frame Material



Figure M-5 Frame Material

Specifications:

Table M-5 Specifications of the Frame

TYPE	DESCRIPTION
Material	Acrylic
Product Height	24.00 in
Product Length	24.00 in
Product thickness	0.125 in
Product weight	2.7 LB
Quantity	2
Manufacture	Home Depot
Model #	2424-1-C

6. Gear and pinion

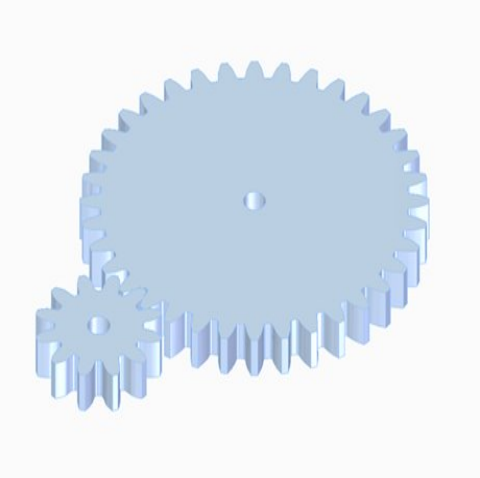


Figure M-6 Gear and Pinion

Specifications:

Table M-6 Specifications of the Gear and Pinion

	Pinion	Gear
General Characteristics		
Number of teeth	12	36
Mounting Hole Diameter	0.300 in	0.300 in
Face Width	0.400 in	0.400 in
Power	737.562 ft-lbf/s	
Speed	6000.000 deg/s	
Strength Validation		
Allowable Bending Stress	70.706 ksi	47.165 ksi
Safety Factor in Bending	4.7	3.33
Allowable Pitting Stress	148.085 ksi	148.085 ksi
Safety Factor in Pitting	1.35	1.51

7. Actuator



Figure M-7 Actuator

Specifications:

Table apx M-7 Specifications of the Actuator

TYPE	DESCRIPTION
Material	Aluminum and Steel
Brand Name	Homend
Ean	0615200920562
Input Voltage	12 V
Input Current	3 Amp
Load Capacity	225.00 lbs.
Quantity	1
Manufacture	Amazon
Part#	GR9863
Stroke Length	6 in
Retracted length	10.4 in
Extended Length	16.4 in
Mounting Bracket	2
Screw Set	2
Travel speed	0.39 inches/sec
Maximum current draw	3A

8. Motor



Figure M-8 Motor

Specifications:

Table M-8 Specifications of the Motor

TYPE	DESCRIPTION
Material	Metal
Brand Name	High Torque Turbo
Rated Torque	1.808 lbf*ft
Rated Voltage	12 V
Load Speed	5 RPM
Shaft Diameter	0.25 IN
Quantity	1
Manufacture	Amazon
Part#	Yosooo2367
Screw Set	4
Rated Current	2 A
power	24 watts
Motor Size	4.72×1.41×1 inch

9. MC4 Connectors



Figure M-9 MC4 connectors

Specifications:

Table M-9 Specifications of the MC4 Connectors

TYPE	DESCRIPTION
Rated Current	30 A
Wiring Size Range	12 AWG
Contact Material	Silver Plated Copper
Temperature	-40°F to +194°
Protection Class	IP67

10. Nuts

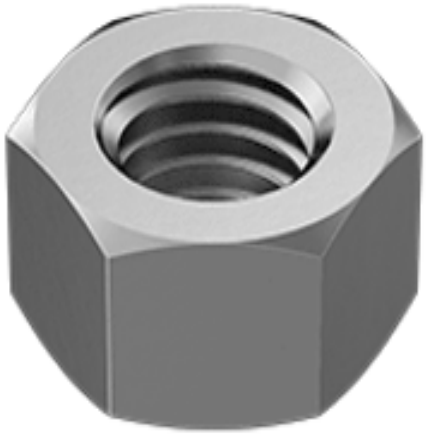


Figure M-10 Nut type 1

Specifications:

Table M-10 Specifications of the Nut type 1

TYPE	DESCRIPTION
Nut Type	Hex
Height	7/16 IN
Width	3 / 4 IN
Thread	1 / 2 –13 IN
Thread Type	UNC
Quantity	100
Manufacture	McMaster
Part#	95462A033

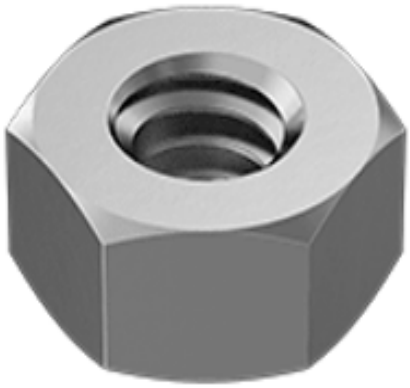


Figure M-11 Nut type 2

Specifications:

Table M-11 Specifications of the Nut type 2

TYPE	DESCRIPTION
Nut Type	Hex
Height	7/32N
Width	7/16 IN
Thread	1/ 4-20 IN
Thread Type	UNC
Quantity	100
Manufacture	McMaster
Part#	95462A029

11. Bolts

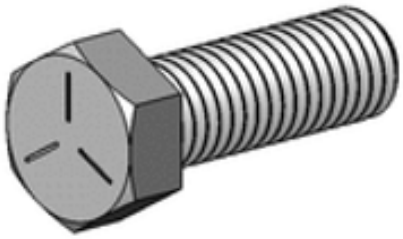


Figure M-12 Bolt type 1

Specifications:

Table M-12 Specifications of the Bolt type 1

TYPE	DESCRIPTION
Head Type	Hex
Height	5/16 IN
Width	3/ 4 IN
Length	1 1/ 2 IN
Thread	1/ 2 –13 IN
Thread Type	UNC
Threading	Fully Threaded
Manufacture	McMaster
Part#	9296A716

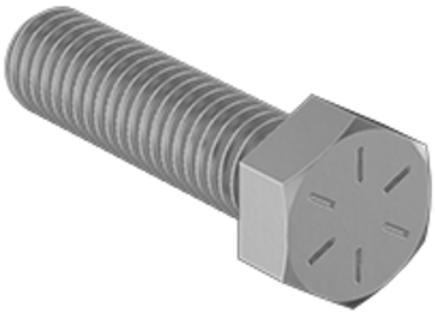


Figure M-13 Bolt type 2

Specifications:

Table M-13 Specifications of the Bolt type 2

TYPE	DESCRIPTION
Head Type	Hex
Height	11/32 IN
Width	3/ 4 IN
Length	3 IN
Thread	1/ 2 –13 IN
Thread Type	UNC
Threading	Fully Threaded
Manufacture	McMaster

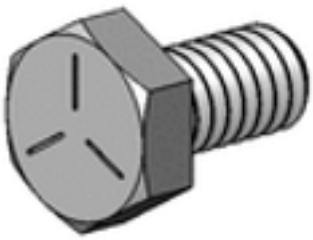


Figure M-14 Bolt type 3

Specifications:

Table M-14 Specifications of the Bolt type 3

TYPE	DESCRIPTION
Nut Type	Hex
Height	7/16 IN
Width	3 / 4 IN
Thread	1 / 2 –13 IN
Thread Type	UNC
Quantity	100
Manufacture	McMaster
Part#	9296A537

12. Hinges

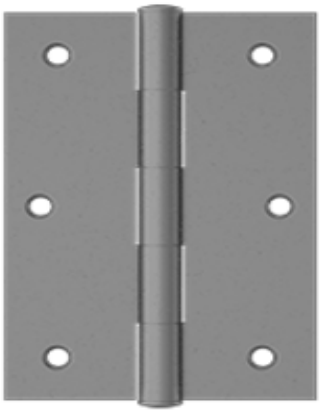


Figure M-15 Hinges

Specifications:

Table M-15 Specifications of the Hinges

TYPE	DESCRIPTION
Head Type	Butt
Door Leaf Height Width	 3 IN 1 IN
Frame Leaf Heugh Width	 3 IN 1 IN
Leaf Thickness	0.062 IN
Range of Motion	270 IN
Pin Diameter	5/32 IN
Manufacture	McMaster
Part#	1598A18

13. Custom PCB

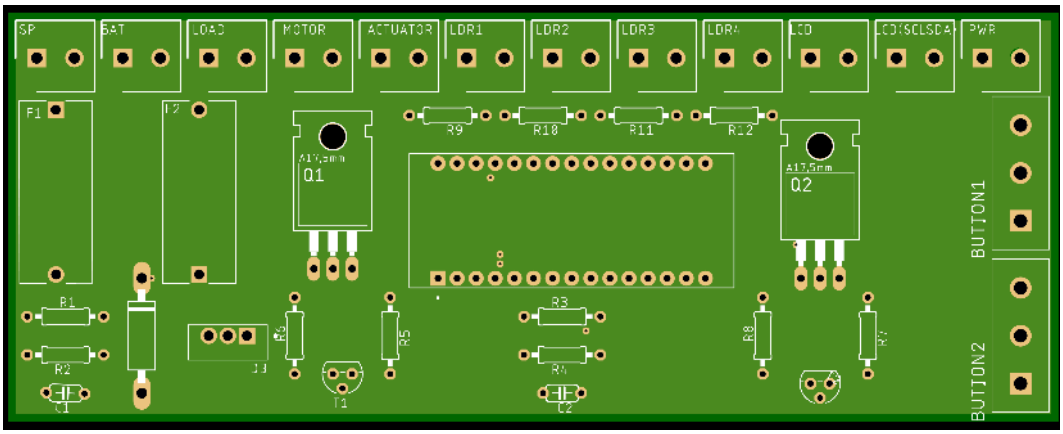


Figure M-16 Custom PCB

Specifications:

Table M-16 Specifications of the Custom PCB

GENERAL Characteristics	
Layers	2
Dimensions	5.511” x 2.126”
Thickness	1.125”
Color	Green
Surface Finish	LeadFree HASL-RoHS
Copper Weight	1
Gold Fingers	No
ELECTRICAL	
Rated Voltage	12V
Maximum Current	5A
Maximum Load Current	5A
Open Circuit Voltage	15V-25V

Custom PCB includes a solar charge controller with Solar Tracker that is controlled by Arduino Nano. Gerber files are included in the appendix. PCB contains several components mounted on it:

14. Terminal Block 2P Wire to Board



Figure M-17 Terminal Block

Specifications:

Table M-17 Specifications of the Terminal Block

TYPE	DESCRIPTION
Quantity	12
Category	Wire to Board
Manufacturer	On Shore Technology Inc.
Series	ED120/DS
Pitch	0.200”
Current	15A
Voltage	300V
Wire Gauge	14-22 AWG
Mounting Type	Through Hole
Color	Blue
Operating Temperature	~30°C~105°C
Housing Material	Polyamide (PA), Nylon
Contact Material - Plating	Brass
Clamp Material - Plating	Steel, Stainless
Torque - Screw	0.5 Nm (4.4 Lb-In)
Screw Thread	M3

15. “3 Position Header Connector”



Figure M-18 Button Terminal

Specifications:

Table M-18 Specifications of the Button Terminal

TYPE	DESCRIPTION
Quantity	2
Categories	Rectangular Connectors - Headers, Receptacles, Female Sockets
Manufacturer	TE Connectivity AMP Connectors
Series	Universal MATE-N-LOK
Connector Type	Header
Contact Type	Female Socket
Style	Board to Cable/Wire
Number of Positions	3
Pitch - Mating	0.250"
Mounting Type	Through Hole
Termination	Solder
Insulation Color	White
Insulation Height	0.550"
Contact Length - Post	0.155"
Insulation Material	Polyamide (PA), Nylon

16. Fuse Holder



Figure M-19 Fuse Holder

Specifications:

Table M-19 Specifications of the Fuse Holder

TYPE	DESCRIPTION
Quantity	2
Categories	Circuit Protection-Fuse holders
Manufacturer	Keystone Electronics
Mounting Type	Through Hole
Fuse Size	0.197” x 0.787”
Current Rating (Amps)	5A
Voltage	250V
Contact Material	Brass
Contact Finish	Tin

17. Fuse



Figure M-20 Fuse

Specifications:

Table apx M-20 Specifications of the Fuse

TYPE	DESCRIPTION
Quantity	2
Manufacturer	Littelfuse Inc.
Series	217
Fuse Type	Cartridge, Glass
Current Rating (Amps)	5A
Voltage Rating	250V
Response Time	Fast Blow
Melting I^2t	42.795
Operating Temperature	-55°C ~ 125°C
Size / Dimension	0.205" Dia x 0.787" L

18. MOSFET



Figure M-21 MOSFET

Specifications:

Table M-21 Specifications of the MOSFET

TYPE	DESCRIPTION
Quantity	2
Manufacturer	Vishay Siliconix
Part Number	IRF9540
FET Type	P-Channel
Drain to Source Voltage (Vdss)	100V
Current - Continuous Drain (Id) @ 25°C	19A (Tc)
Power Dissipation (Max)	150W (Tc)
Operating Temperature	-55°C ~ 175°C (TJ)
Mounting Type	Through Hole

19. BJT



Figure M-22 BJT

Specifications:

Table apx M-22 Specifications of the BJT

TYPE	DESCRIPTION
Quantity	2
Manufacturer	ON Semiconductor
Part Number	2N3904
Transistor Type	NPN
Current - Collector (Ic) (Max)	200mA
Vce Saturation (Max) @ Ib, Ic	300mV @ 5mA, 50mA
Frequency - Transition	300MHz
Operating Temperature	-55°C ~ 150°C (TJ)
Mounting Type	Through Hole

20. TVS Diode

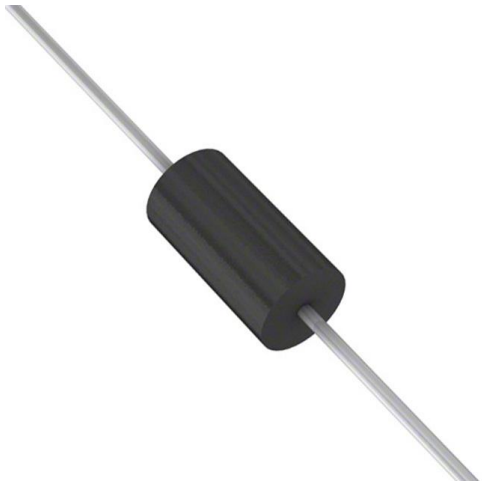


Figure M-23 TVS Diode

Specifications:

Table M-23 Specifications of the TVS diode

TYPE	DESCRIPTION
Quantity	1
Manufacturer	Littelfuse Inc.
Series	P6KE
Type	Zener
Bidirectional Channels	1
Power - Peak Pulse	600W
Current - Peak Pulse (10/1000µs)	12.2A
Operating Temperature	-55°C ~ 175°C (TJ)
Mounting Type	Through Hole

21. Power Diode

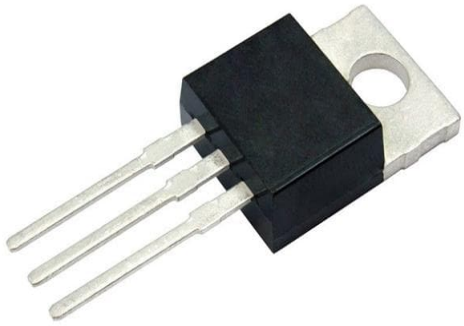


Figure M-24 Power Diode

Specifications:

Table M-24 Specifications of the Power Diode

TYPE	DESCRIPTION
Quantity	1
Manufacturer	Vishay Semiconductors
Type	Schottky Rectifiers
Configuration	Dual Common Cathode
If - Forward Current	10 A
Vf - Forward Voltage	0.84 V
Technology	Si
Operating Temperature	-65°C ~ 150°C (TJ)
Mounting Type	Through Hole

22. Resistors

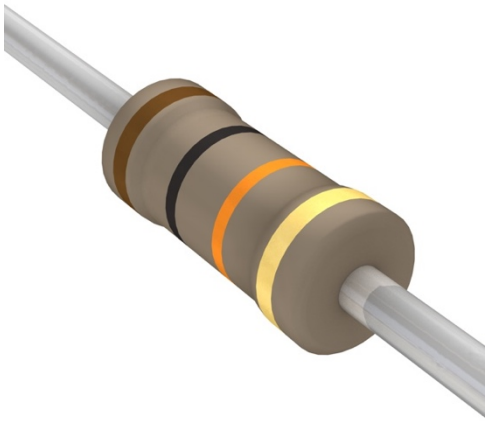


Figure M-25 Resistors

Specifications:

Table M-25 Specifications of the Resistors

TYPE	DESCRIPTION
Quantity	2 x 100kΩ
	2 x 20kΩ
	6 x 10kΩ
	2 x 1kΩ
Manufacturer	Yageo
Tolerance	±5%
Power (Watts)	0.25W, 1/4W
Composition	Carbon Film
Size / Dimension	0.094" Dia x 0.248" L
Operating Temperature	-55°C ~ 155°C (TJ)
Mounting Type	Through Hole

23. Capacitors



Figure M-26 Capacitors

Specifications:

Table M-26 Specifications of the Capacitors

TYPE	DESCRIPTION
Quantity	2
Manufacturer	Vishay BC Components
Tolerance	±10%
Voltage - Rated	200V
Size / Dimension	0.197" L x 0.126" W
Height - Seated (Max)	0.299"
Operating Temperature	-55°C ~ 175°C (TJ)
Mounting Type	Through Hole

24. Photoresistors



Figure M-27 Photoresistors

Specifications:

Table M-27 Specifications of the Photoresistors

TYPE	DESCRIPTION
Quantity	4
Manufacturer	Adafruit Industries LLC
Cell Resistance (Min) @ Dark	200 kOhms @ 10s
Mounting Type	Through Hole

25. LCD display

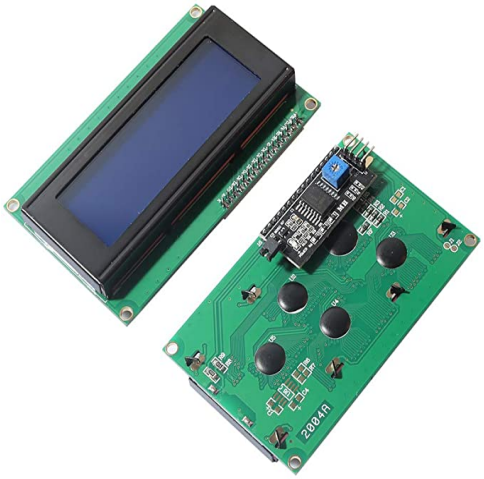


Figure M-28 LCD Display

Specifications:

Table M-28 Specifications of the LCD display

TYPE	DESCRIPTION
Display	4 lines x 20 characters
LCD Controller	HD44780
Contrast Adjust	Potentiometer
Backlight Adjust	Jumper
Default Address	0x27 for PCF8574T chip
Working Voltage	5V
Package Dimensions	7 x 5.5 x 1.3 in
Weight	3.2 ounces

Replacement Order Form

REPLACEMENT ORDER FORM

		Send filled out form to pjha@patriots.uttyler.edu	
Date			
Ordered by			
Quantity			
Billing Information		**Shipping Information**	
Name		*Name*	
Company Name		*Company Name*	
Address		*Address*	
City		*City*	
State		*State*	
Zipcode		*Zipcode*	
Phone		*Phone*	
E-mail		*E-mail*	
Payment Method			
		Subtotal	
Credit Card Type		Sales Tax	
Credit Card Number		Shipping	
CCV		**Total**	
		THANK YOU FOR USING OUR PRODUCT	
Signature		*THE SOLARS*	