PORTABLE SOLAR TRACKING STATION

Final Presentation

Group 11

Engineer Students

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Introduction

- Present Energy Crisis
- Alternative of Energy Sources
- Global Warming
- Carbon Footprint
- Environmental Issue

Objectives

- Efficient solar tracking for optimal energy output to reduce the use of additional solar panels
- Significant waste reduction due to use of renewable energy
- Reliable operation through non-ideal weather conditions such as rain or clouds
- Long term reliability of alternative energy
- Charge systems up to 24 volts to provide 420 watts of power
- Increase overall cost-effectiveness
- Provide mobility, wider range of motion, and high power

Reasons of Motivation

- Clean alternative way of energy source
- Use Fewer Resources
- Removal of the limitations of stationary panels
- Increased versatility
- Convenient alternative to charging electric devices up to 24 volts
- Easy energy accessibility device

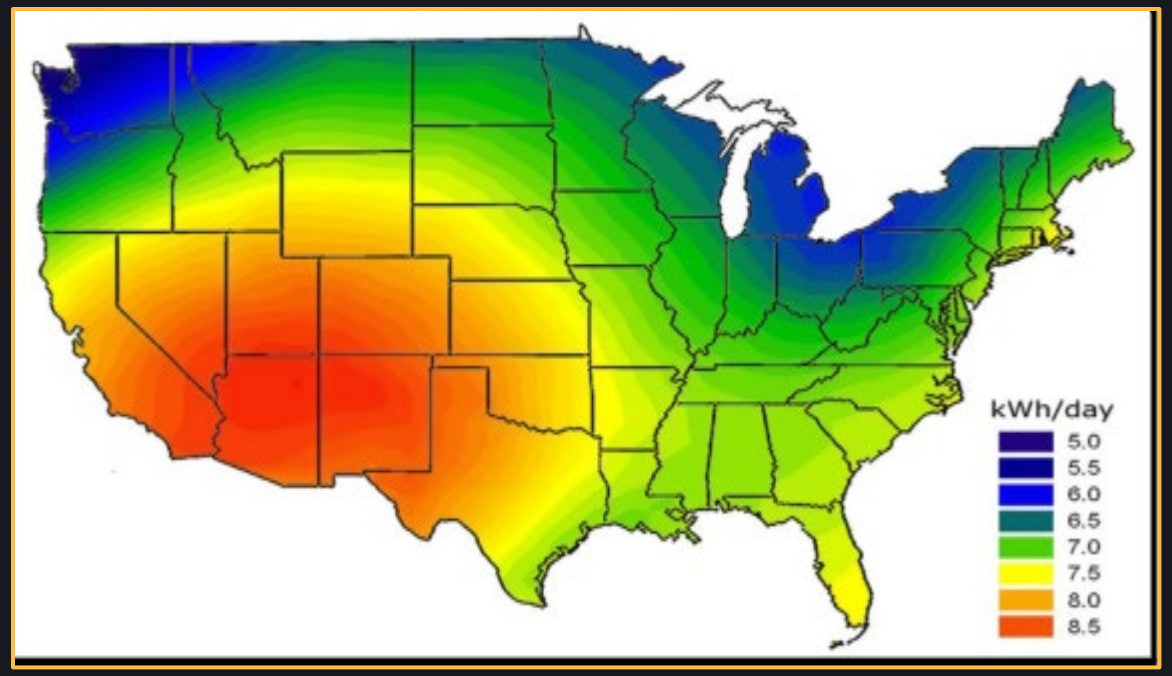
Economic Impact

- Overall, Solar Panels are becoming less costly over time
- They allow for energy independence, as opposed to being tied down to a power grid.
- Fewer resources used means less impact cost and manufacturing
- Over time Solar Panels will pay for themselves

TRACKING SYSTEM	FIXED SYSTEM
Higher Initial Cost	Less Initial Cost
Generates More Electricity	Generates Less Electricity
Higher Maintenance Cost	Less Maintenance Cost
Require More Electricity to Operate Different Mechanism	Consume Less Electricity to Operate
Require More Parts to Operate	Less Parts to Operate

U.S. Solar Radiation Effects

- In any part of the United States, there is plenty of opportunity to harness solar power
- Orlando, FL has an average annual solar radiation value of 5.64 kWh/m2/day
- Having Solar panels in a area with higher solar radiation area will increase the out of electricity



Overall Functionality

- Dual Axis Movement
- Portable Structure (Light Frame)
- Equipped with Wheels for Easy Movability
- 5V, 12V, and 24V Output
- Stand with Junction Box
  - Touchscreen User Interface
- Manual Control
- Automatic Mode
- Parked Mode

Overall Functionality - Cont.

- Photoresistors detect sunlight
- Dual axis motors powered by the solar panels
- Use of a dual axis system to allow for more motion of range
- Two 24 volt panels in Parallel to allow for 24 volt system to generate 420 watts
- Step down converter configuration system used to charger electric systems less than 24 volts if needed.

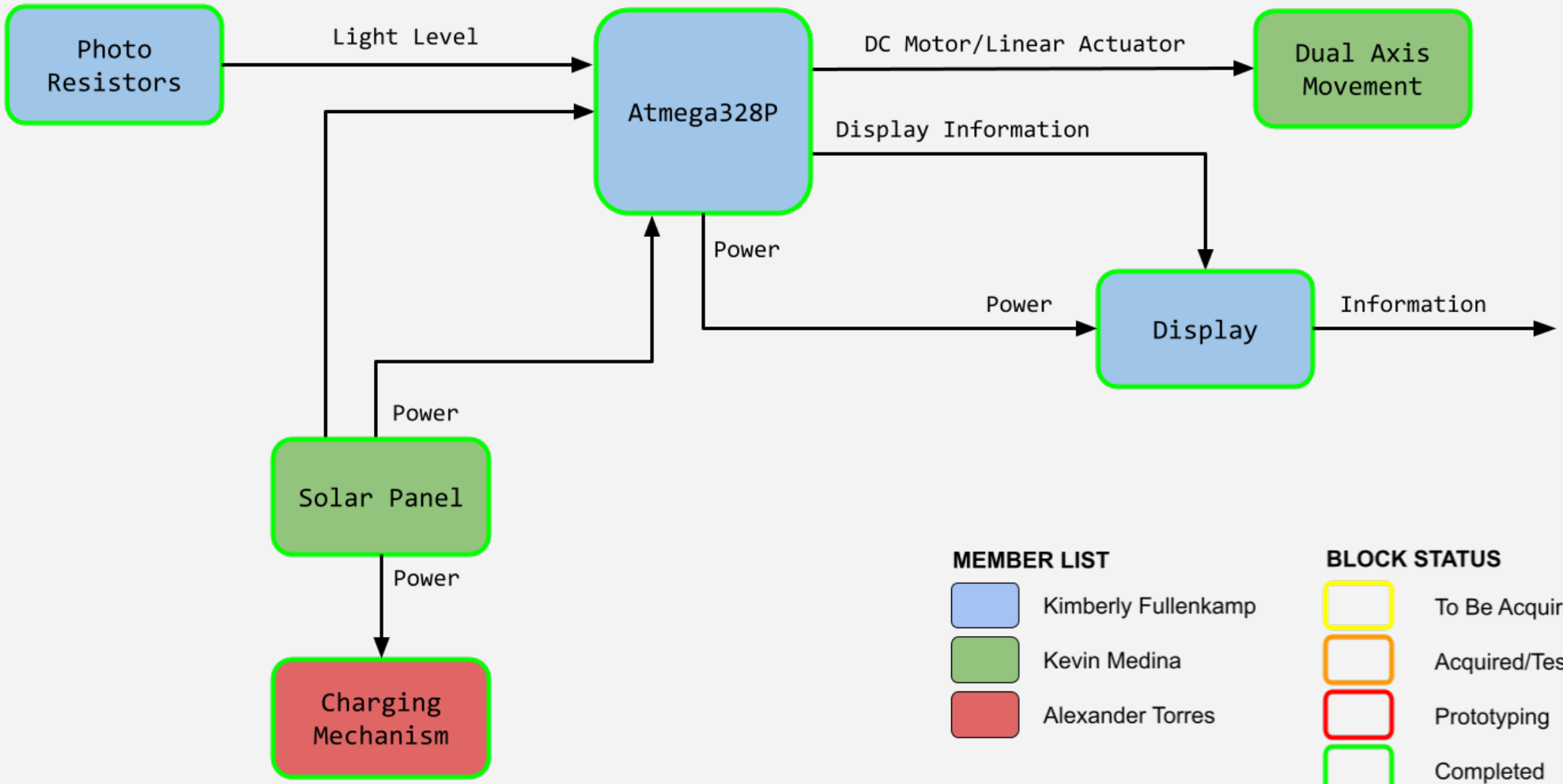
Design Specifications

Component	Specification	Purpose
Photovoltaic Cell	200 watts/24 volts	Primary energy source
Linear Actuator 300mm stroke	12 volts	Vertical motion
Linear Actuator 1m stroke	12 volts	Horizontal motion
Photosensor	>500 ohms	Tracking
Inverter	24 volts DC to 120 volts AC	Secondary power function
Solar Charger Housing	NEMA 3	Protection
Controller	ATmega328P (5V)	Tracking/Display
Full bridge rectifier	Single phase 1kV	Reverse polarity protection
DC-DC step down converters	(36-80) volts to 5/12/24 volts	Voltage regulation

Design Specifications - Demonstrable

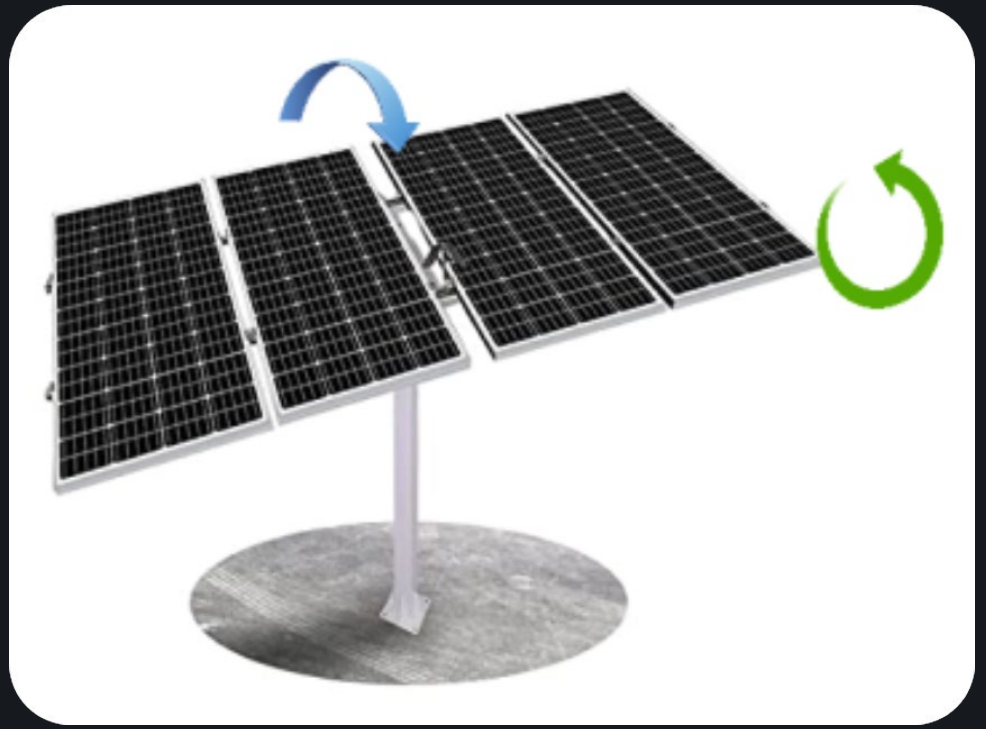
Requirement Specification	Description
Degrees of Motion (Vertical)	> 15°
Degrees of Motion (Horizontal)	> 80 °
Time to Track Sun (From Any Starting Position)	< 5 minutes

Block Diagram



Similar Technologies

- This technology is not new, there are different setups
- This is the solar tracker from Eco-worthy.
- Provides sufficient power and voltage, which is dependant on the solar panels and their configurations respectively.
- Provides dual axis maneuverability
- Lacks portability as this is a stationary mounted design



Similar Technologies - Cont.

- This is the solar tracker from Eco-flow
- Provides dual axis maneuverability
- Provides portability
- Lacks power. Each panel provides only 60 watts.

Our Unique Design Properties

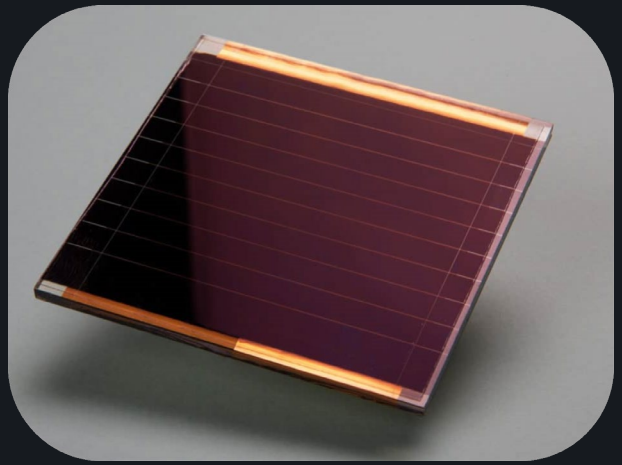
- 420 watts of power and 24 volts in a parallel configuration.
- Dual axis maneuverability
- Portability with easy setup
- Durability
- Stable DC outputs
- Water resistance
- Power even under non-ideal atmospheric conditions.
- Upgradable

24V Monocrystalline Silicon Photovoltaic Cells

- Less costly the 48V panels by a factor of 30
- Same size and weight of 12 volt panels, use of 24V panels means fewer resources
- More versatile as they can be easily scalable down to 5 volt systems or up to 600V systems
- The Newpowa 24V solar panel provides the best power density compared to other brands by an average of 6%
- Can function up 85 degrees Celsius before there is a depletion in its operation
- Temperature coefficient -.38%/Celsius.
- Silicon is a significantly safer material, unlike photovoltaics made from Cadmium, or Gallium.
- Power density of 1kW/m^2

Other Photovoltaic Cells

- Polycrystalline cells
  - Known for their blue appearance are designed with melded silicon fragments
  - More durable but are <19% efficient and 20-35 year lifespan
- Perovskite cells
  - Offer efficiencies >26%
  - Not available for purchase



24 Volt Inverter

- An inverter that will convert 24 DC to 120 AC
- Will be used as a secondary function powered by a 24 volt panel
- Can handle up to 600 watts of continuous power
- Can handle up to 900 watts of surge power
- Compared to other inverters, it has half the volume and mass
- Significantly less costly by a factor of 4

Other Inverters

- Vevor 24VDC to 120VAC pure sine wave
  - Handles 3 kW continuous power and 6kW surge power, but is 4 times the cost and 2 times the mass of the chosen inverter.
- AIMS 24VDC to 120VAC pure sine wave
  - Handles 5kW of continuous power, but is 6 times the cost and 2.5 times the mass of the chosen inverter

Inverter Comparison

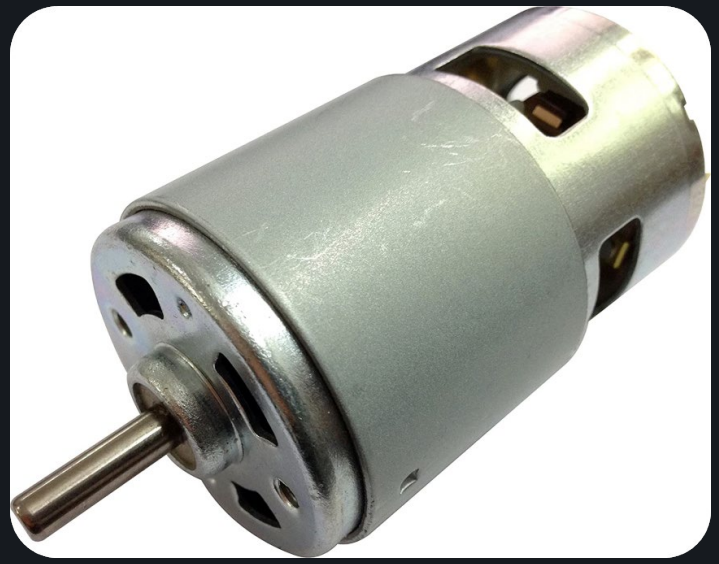
	Generic 600 watt	Vevor 3 kW	AIMS 5 kW
Volume	9.45x6.7x3.7 "	13.78 x 7.87 x 5.91 "	16.95X 7.95X 6.10"
Weight	5.25 lbs	15 lbs	20 lbs
Cost	$77	$257	689
Continuous power	600 watts	3 kW	5 kW
Surge power	1.2 kW	6 kW	10 kW

Linear Actuator

- 30/100 centimeter reaches respectively
- 25% duty cycle
- Can move 1500/900 newtons respectively
- Water resistant
- Their function will be to control the vertical axis and horizontal axis of the solar tracker

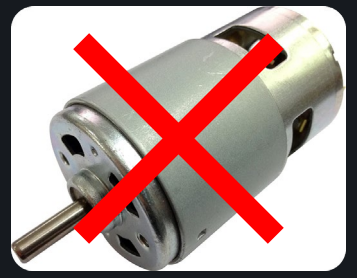
Other Motors

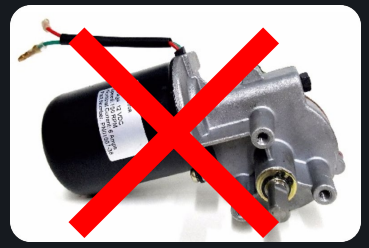
- 12 volt DC motor
  - Offers full rotation
  - Lacks the capability of moving a large unit
- Servo motor
  - Offers dual axis movement
  - Lacks the capability of moving a large unit



Motor Comparison

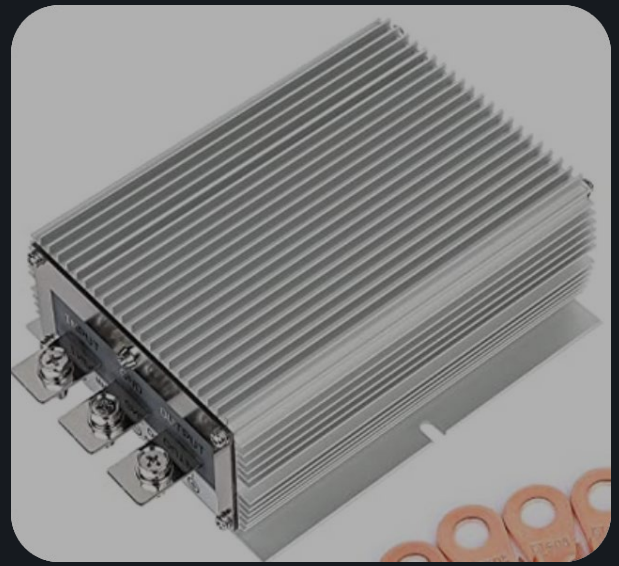
	Linear Actuator	12V DC Motor	12V Servo Motor
Cost	$42/$111	$20	$22
Force	1500/900 Newtons	.13 Newtons	6 Newtons
Duty cycle	25%	100%	100%
Water resistant	yes	no	no





Voltage Regulator

- Because the solar panels are subject to high voltage and voltage variations, the use of several regulators will be implemented
- Tobsun's (36-80) volt to 5/12/24 volt step down converter has a 99% efficiency.
- Can handle 120/600/960 watts of power
- Powerful, lightweight and non-invasive
- Dimensions: 5.91 x 5.12 x 1.97 in
- Weight: ~16.2 ounces
- Operating temperature: 85° C
- Provides complete stable DC output
- Each linear actuator will use a 12 volt converter
- The inverter will use a 24 volt converter
- The PCB will use the 5 volt converter

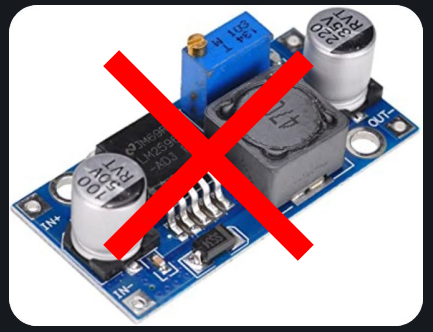


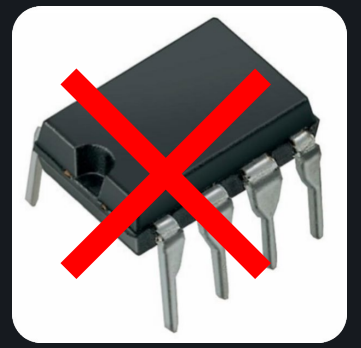
Other Voltage Regulators

- Buck converter
  - Can vary input and output voltage ranging from 0-60 volts
  - Inaccurate as it does not offer the desired output voltage
- Linear integrated circuit
  - 99% accurate
  - Limited to only 60 watts.

Voltage Regulator Comparison

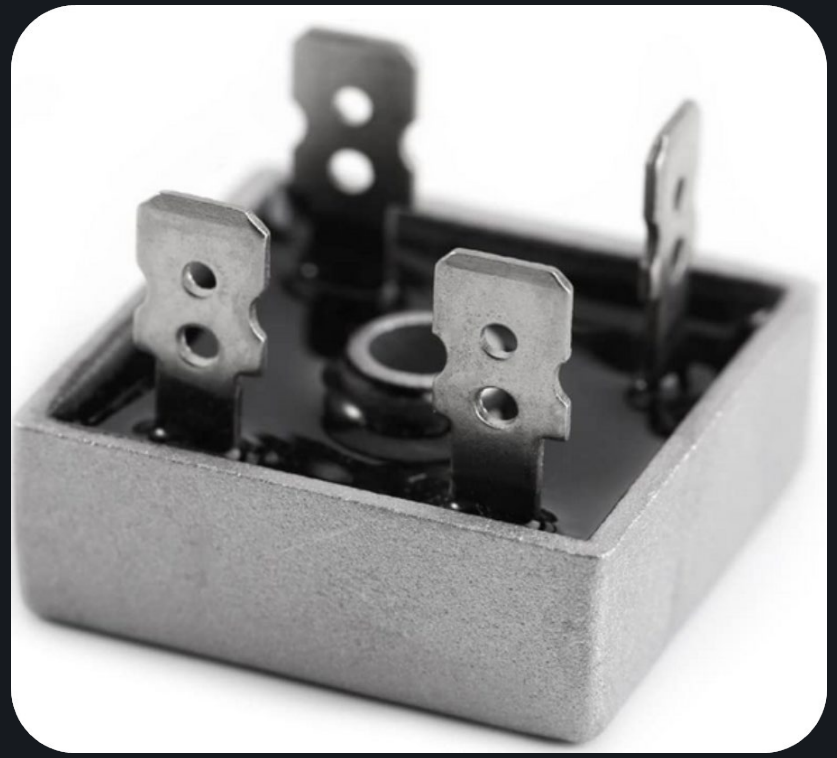
	Tobsun 12/24	Buck Converter	Linear Integrated Circuit
Cost	$95	$35	$1
Power	600/800 watts	100 watts	60 watts
Volume	5.91 x 5.12 x 1.97 "	2.25 x 1.35 "	.25 x .35 "
Weight	1 lbs	.15 lbs	.05 lbs
Water resistant	Yes	No	No





Rectifier

- KBPC5010 is a full bridge rectifier that will provide reverse polarity protection to its components
- Forward drop activation voltage of only 0.51V
- Maximum operating voltage: 1kV
- Maximum surge current: 0.5kA
- Maximum operating temperature: 150° C
- Dimensions: 1x1x.88 in
    - Very small

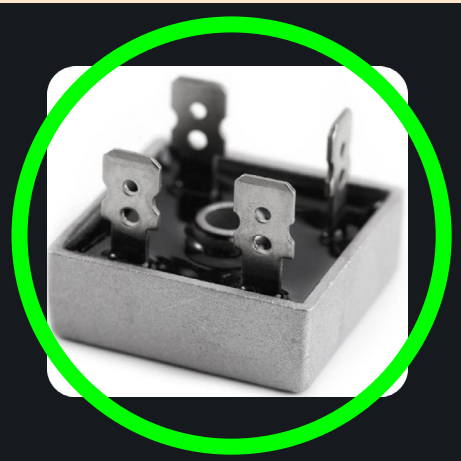


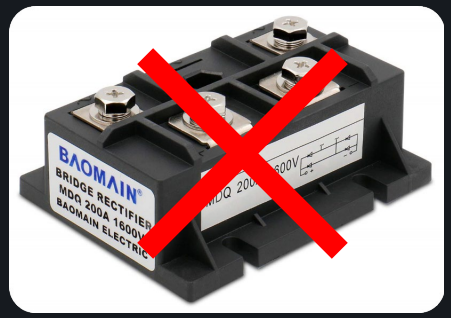
Other Rectifiers

- MDQ
  - Can handle 100 amps and 1.6kV
  - 5x the size of the chosen rectifier
  - 5x the cost of the chosen rectifier
- MDS
  - Can handle 500 amps and 1.6kV
  - 10x the size of the chosen rectifier
  - 12x the cost of the chosen rectifier

Rectifier Comparison

	KBPC5010	MDQ	MDS
Cost	$2	$10	$60
Volume	1 x 1 x .88 "	2.6 x 1.5 x .75 "	6.34 x 4.12 x 1.15 "
Current	50 amps	100 amps	500 amps
Voltage	1 kV	1.2 kV	1.6kV
Forward drop	.51 volts	.51 volts	.51 volts





Vertical Linear Actuator Weight Calculations

- Calculations used to justify vertical motor to prevent overexertion of the vertical linear motor
- Maximum force on the linear actuator: $F = m*a*\cos(\theta)$
- m = total mass of the solar panels = 30 kg
- a = acceleration due to gravity = 9.8 meters/second^2
- θ = angle with respect to the horizontal axis = 0
- At 0 degrees is the greatest amount of force = 294 Newtons against a rated 1500 Newton motor
- Friction is negated because there are no sliding of components

Horizontal Linear Actuator Weight Calculations

- Calculations used to justify horizontal motor to prevent overexertion of the horizontal linear motor
- The maximum force on the linear actuator: F = m*a*f
- m = total mass of the solar panels = 50 kg
- a = acceleration due to gravity = 9.8 meters/second^2
- f = coefficient of kinetic friction as tracker is rotating at the nose using material similar to teflon = 0.15
- Total force required to push the tracker = 44 newtons against a 900 newtons linear motor

Vertical Linear Actuator Current Calculations

- Calculations used to justify vertical motor to prevent overcurrent of the vertical linear motor which is rated to be 3 amps
- The maximum power on the linear actuator: m*a*d/t = v*i
- m=total mass of the solar panels=30 kg
- a=acceleration due to gravity=9.8 meters/second^2
- d=distance the actuator travels=.31 meters
- v=electric potential=12 volts
- t=time for full extension/retraction=53.5 seconds
- i=minimum current required to move the panels=.14 amps
- During times of operation, the current was measured to be .42 amps
- Only 5.04 watts of power are consumed for 53.5 seconds, the duration of the motor movement

Horizontal Linear Actuator Current Calculations

- Calculations used to justify vertical motor to prevent overcurrent of the horizontal linear motor which is rated to be 3 amps
- The maximum power on the linear actuator: m*a*d/t = v*i
- m=total mass of the tracker=50 kg
- a=acceleration due to gravity=9.8 meters/second^2
- d=distance the actuator travels=1 meter
- v=electric potential=12 volts
- t=time for full extension/retraction=100 seconds
- i=minimum current required to move the panels=.245 amps
- During times of operation, the current was measured to be .435 amps
- Only 5.22 watts of power are consumed for 100 seconds, the during of the motor movement

Vertical and Horizontal Range of Motion Calculations (1st and 2nd Demonstrable)

- The rest angle of the tracker based on the panel lengths and retracted linear actuator was calculated to be 14.36 degrees vertically.
- At maximum actuator extension, the maximum angle achieved was calculated to be 36.42 degrees vertically.
- Based on the tracker support lengths, the maximum horizontal angle achieved was calculated to be 87.56 degrees.
- As a result, the ideal calculated angles closely corresponded to the angles that were measured for demonstration
- For the State of Florida sun angles vary from 38 degrees to 86 degrees from the horizon throughout a 365 day calendar year making this solar tracker design ideal as the solar panels will always be nearly perpendicular with the sun

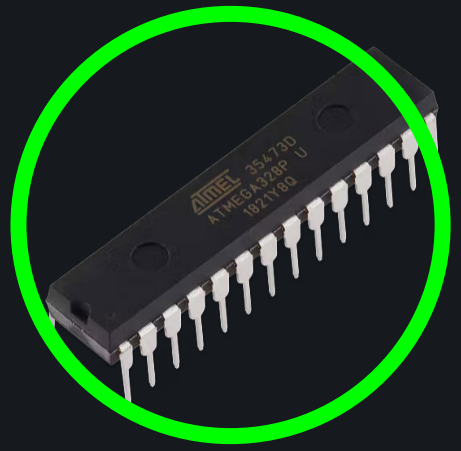
Mechanical Structure

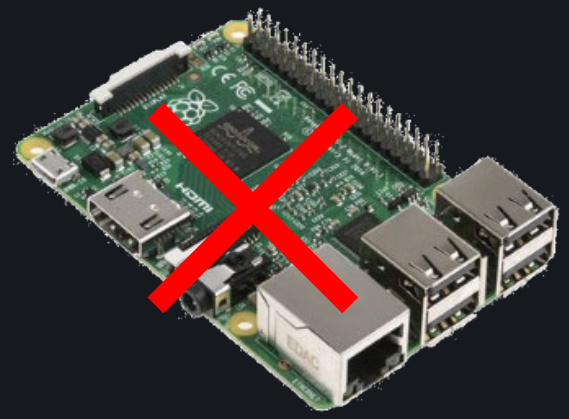
- Main structure is comprised primarily of 6061 aluminum for the exterior
- Interior panel support will be comprised of 455 annealed steel
- Design for this solar tracker will be custom
- 6061 Tensile strength: 124 Mpa
- Density: 2.7 g/cm^3, Lightweight
- 455 Tensile strength: 1413 Mpa

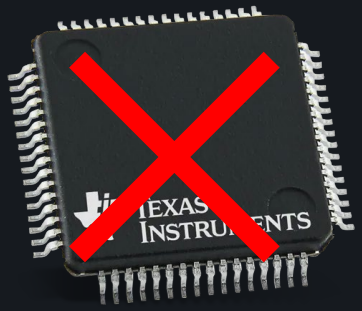
PCB AND SOFTWARE

Microcontroller Comparison

	Atmega328p	Raspberry Pi	MSP430
Clock Speed	16MHz	1.5GHz	16MHz
Flash Memory	32KB	32GB	16KB
GPIO Pins	20	26	14







Atmega328p - Microcontroller

Manufacturer	ATMEL
Price	$5.95
Digital Pins	14
Analog Pins	6
Clock Speed	20MHz
Input Voltage	5V

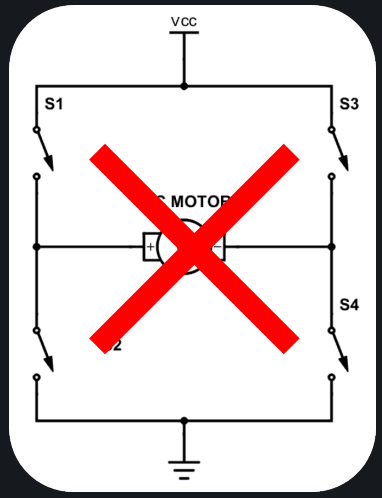
- Simple design flow from Arduino Dev board to final PCB
  - Bootloader preprogrammed
- Large number of pins for I/O
- Utilized 28-pin IC Socket for PCB Mount
  - Allows for simple testing and troubleshooting
- Component Alternatives:
  - Raspberry Pi
  - MSP430

Motor/Linear Actuator Control Considerations

- Three major control options
  - Stand-alone H-bridge circuit
    - Primitive and functional
    - Lacks PWM control by itself
  - Songle SRD Relays
    - Functional and simple implementation
    - Uses too many pins as each motor/linear actuator would require two relays each for each direction of movement
  - L293D Motor Driver IC
    - Simple implementation of IC and has built in PWM control if needed

Motor Control Comparison

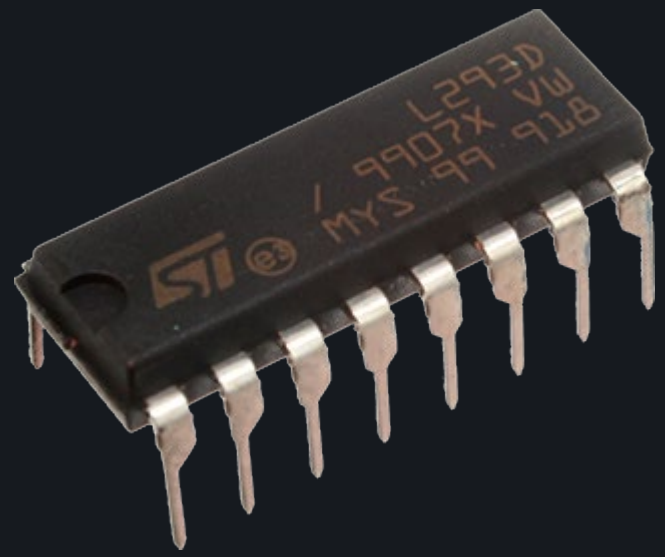
	L293D	Songle SRD Relays	H-bridge Circuit
Bi-directional Control	YES	YES	YES
Speed Control	YES	NO	NO
Pin Requirement (To Control 2 Motors)	4	6	4



Motor Driver - L293D

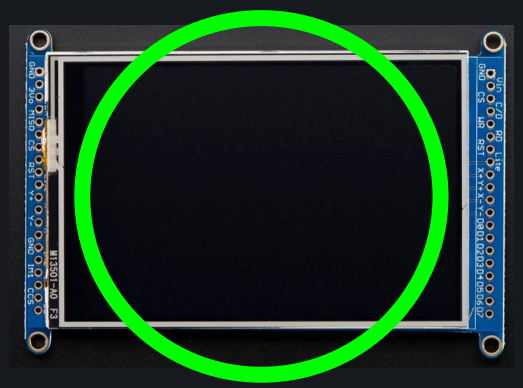
- One chip utilized in project for mechanical control of Linear Actuator
- Contains two full H-bridges in each
- PWM input per driver for speed control
- Mounted with 16-pin DIP IC Socket
  - allows for easy replacement in case of damage
  - eliminates risk of damage from soldering

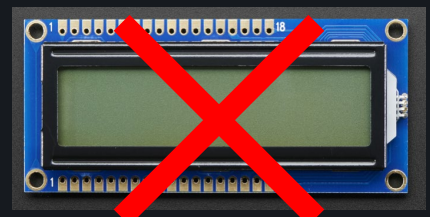
Manufacturer	Texas Instruments
Price	$4.50
Output Devices Supported	2
Working Voltage	5V



User Interface/Control Comparison

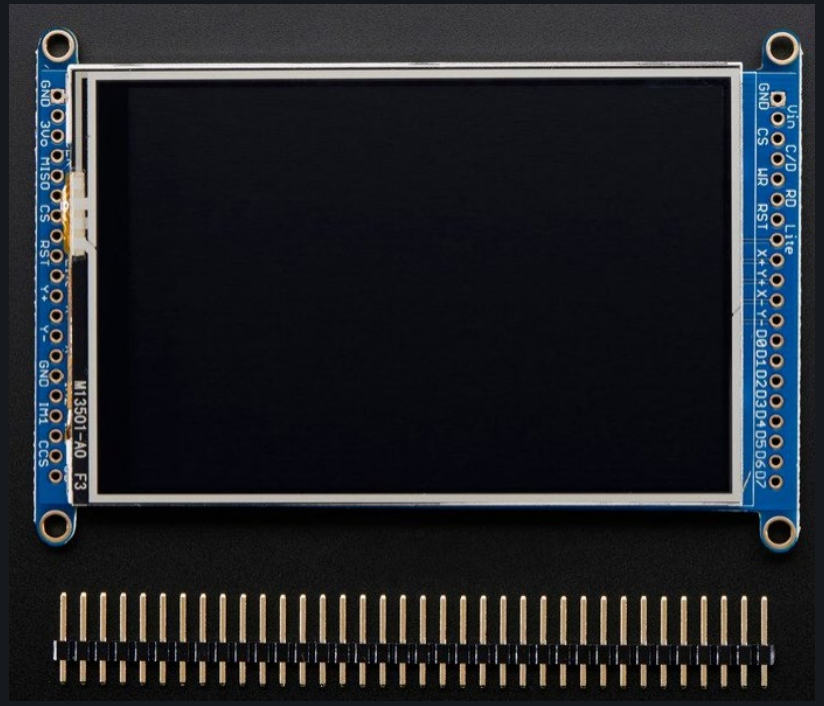
	HX8357	Grayscale 1.5" 128x128 OLED	RGB LCD 16x2
Screen Size	320x480 pixels	128x128 pixels	16x2 pixels
Touchscreen	YES	NO	NO
Pin Requirement	9	4	9





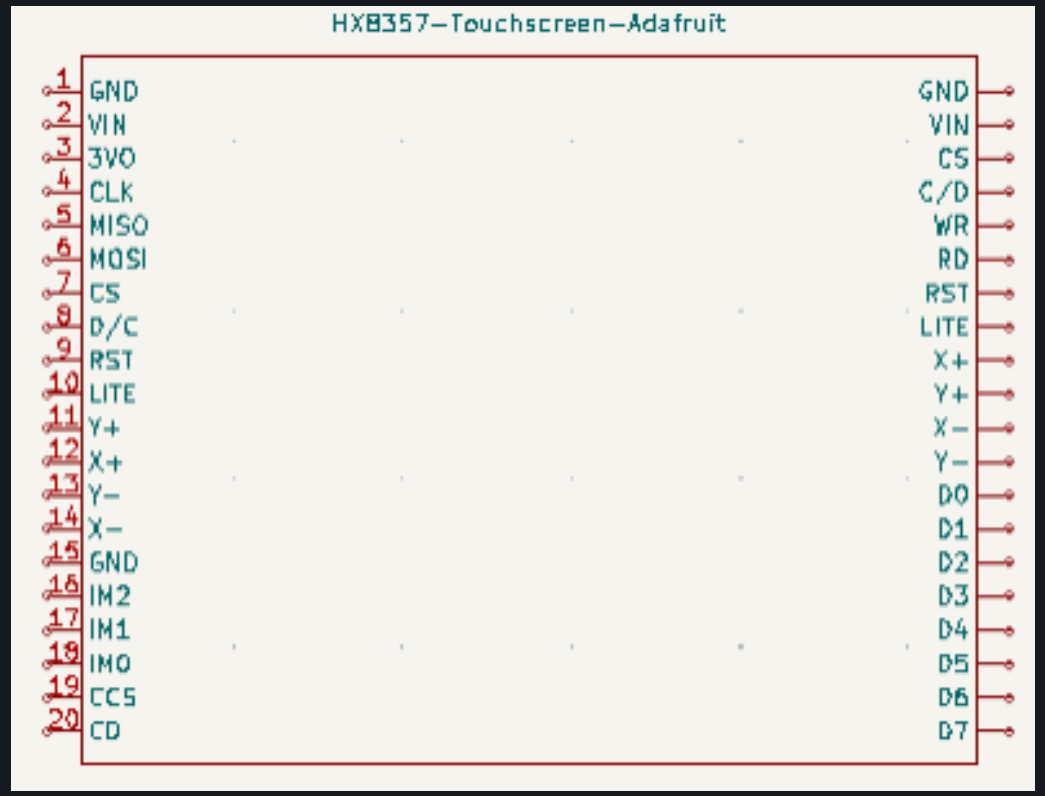
3.5" Touchscreen - HX8357

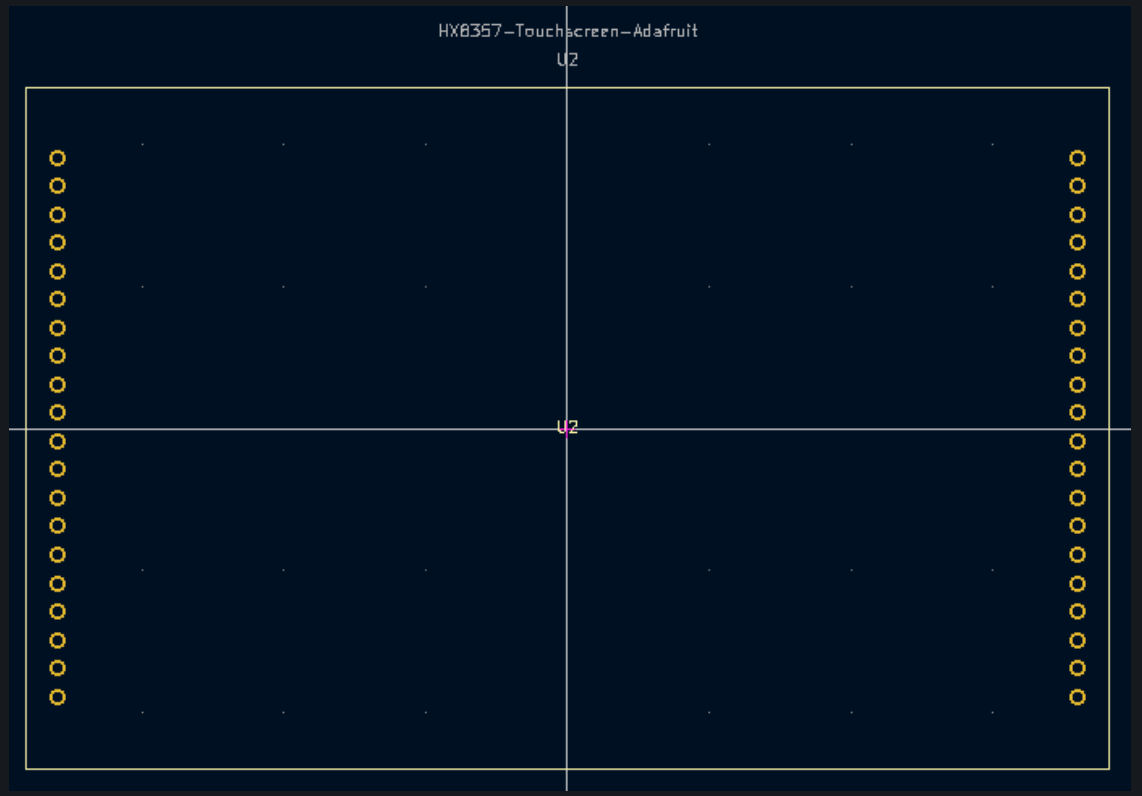
- Bright, Full Color
- Two Modes
  - SPI w/8 Pins (+4 for Touch Capabilities)
  - 8-bit w/12 Pins (+4 for Touch Capabilities)
  - SPI mode chosen due to fewer pin usage
- Built-in Controller with RAM buffering for reduced load on microcontroller
- Developed Custom Schematic Symbol and Component Footprint for PCB integration



Manufacturer	Himax
Price	$39.95
Resolution	320x480 pixels
Working Voltage	3.3V or 5V

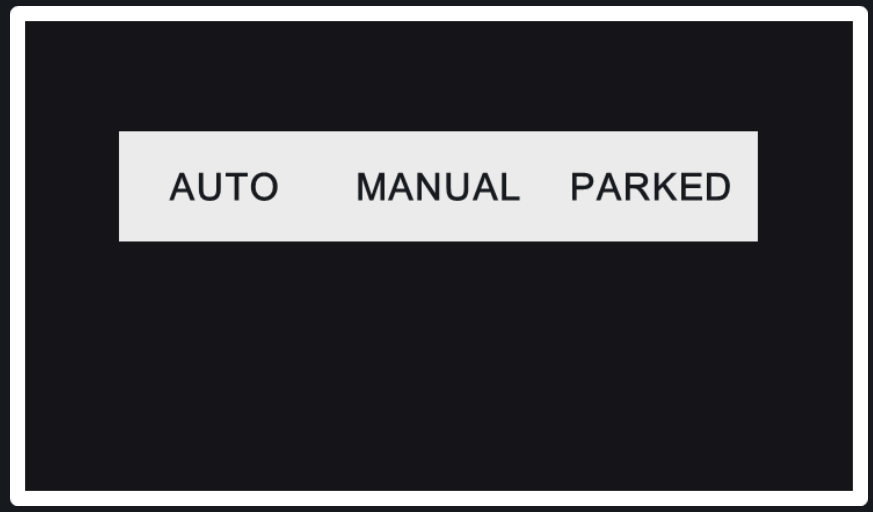
Custom Schematic Symbol and Footprint



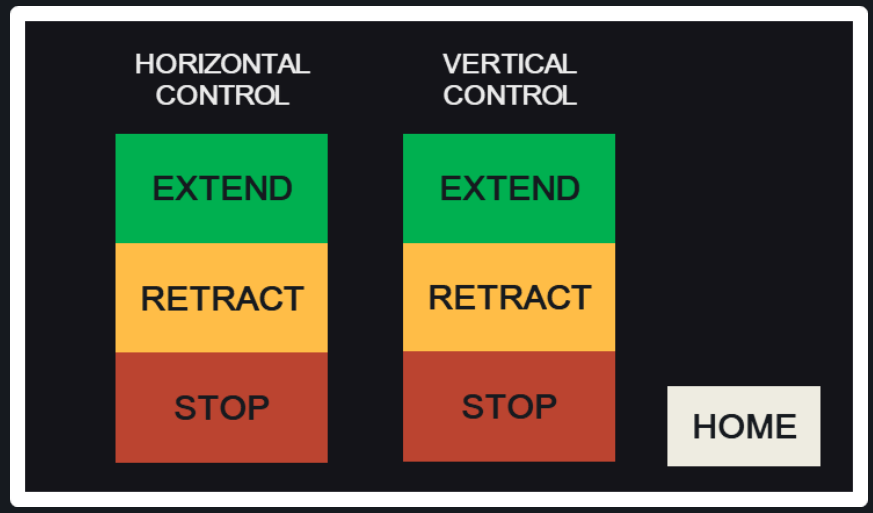


GUI/ User Controls

- Three Modes
  - Automatic
  - Manual
  - Parked
- Simple and Readable Design for easy consumer usage
- Stretch goal to show voltage production over time with live updating graph not achieved

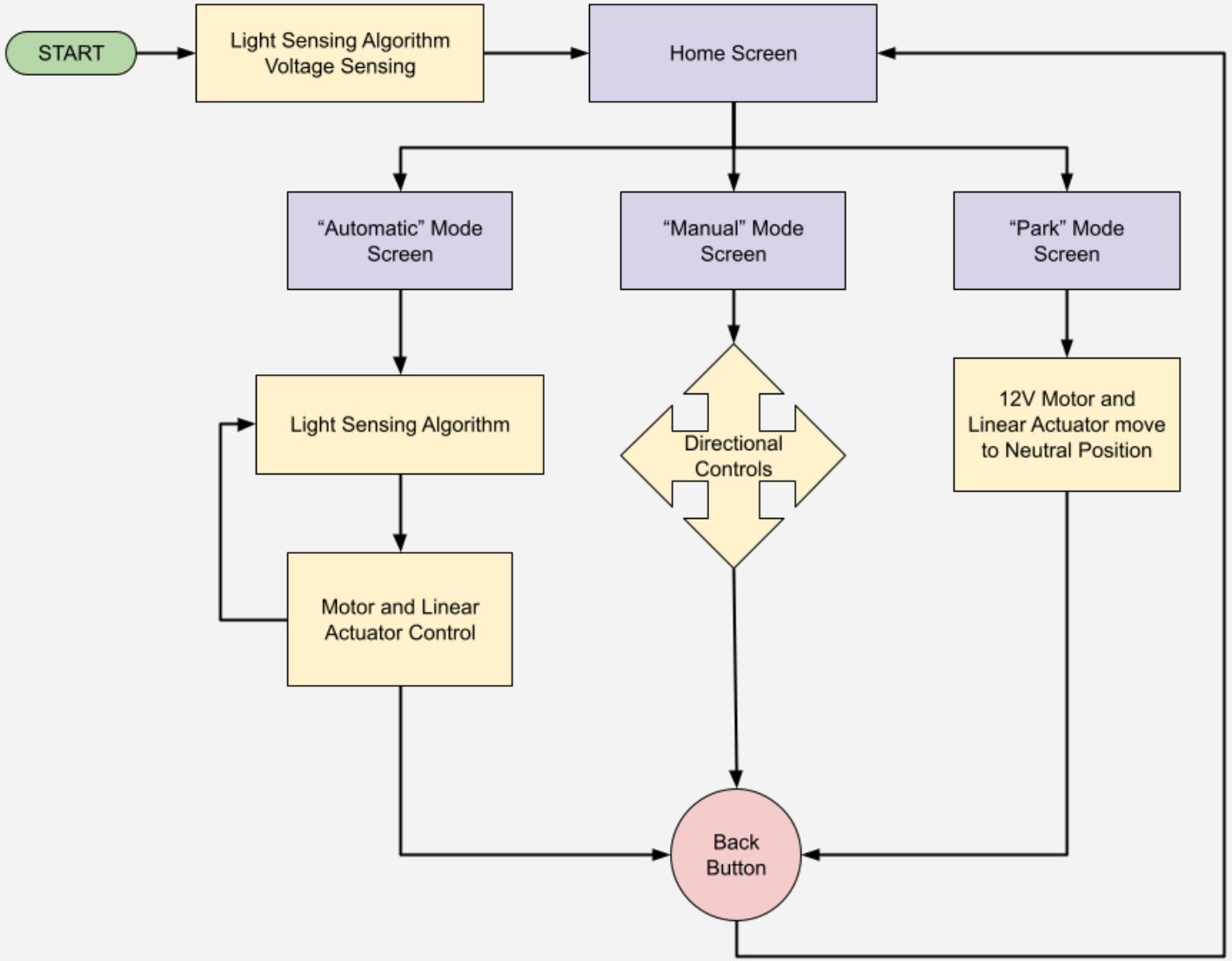


Home Screen



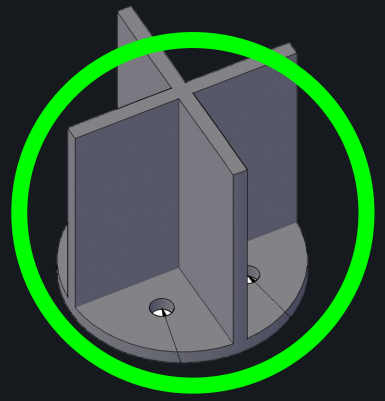
Manual Control Screen

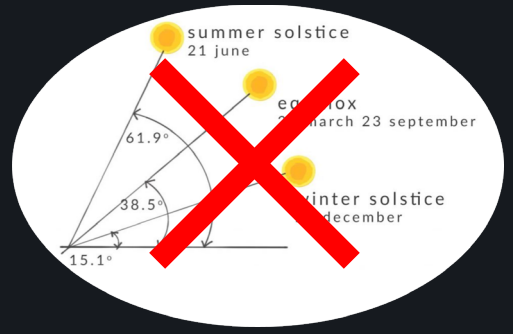
Software Flowchart



Solar Tracking Comparison

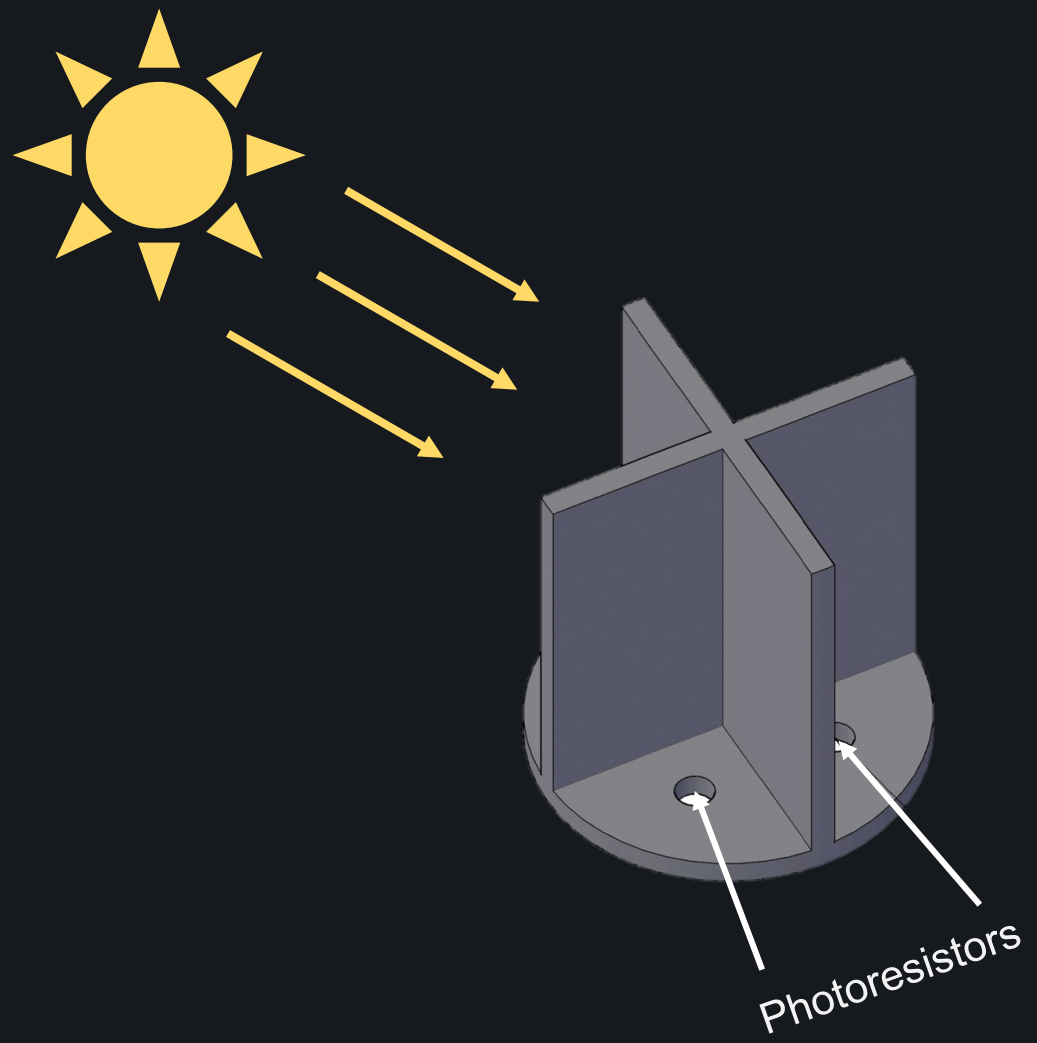
	LDR Housing	Time of Day	Parabolic Mirror
Pros	• Can track sun throughout the year without altering code	• Technically simple to implement	• Very little movement necessary • Cheap large scale since mirror can be cheaper than solar panels
Cons	• Technically demanding to integrate hardware sensors and code	• Must have lengthy code to accommodate for solar position changes throughout seasons	• Expensive small scale • Lack of knowledge of photonics



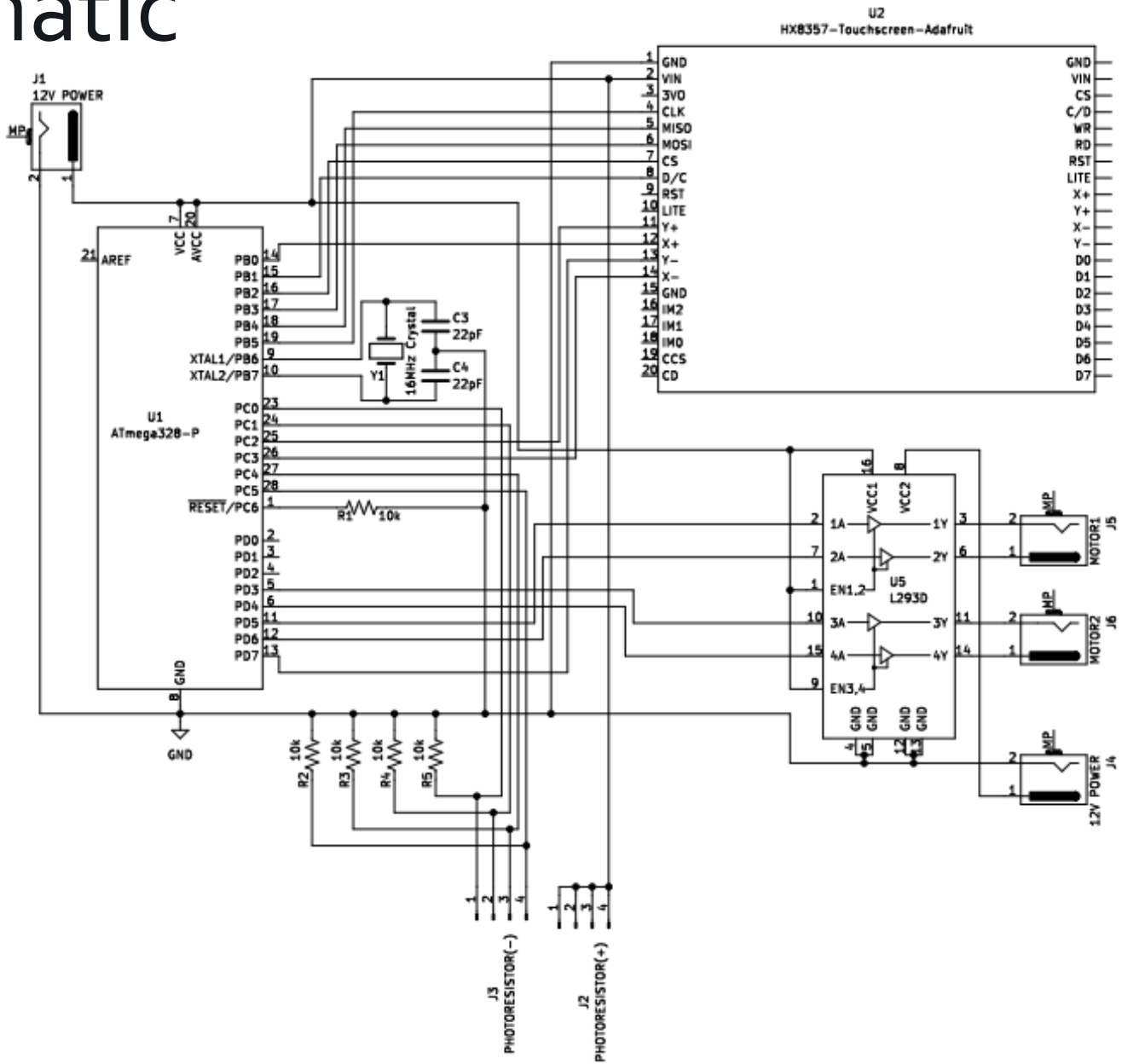


Light Direction Sensing

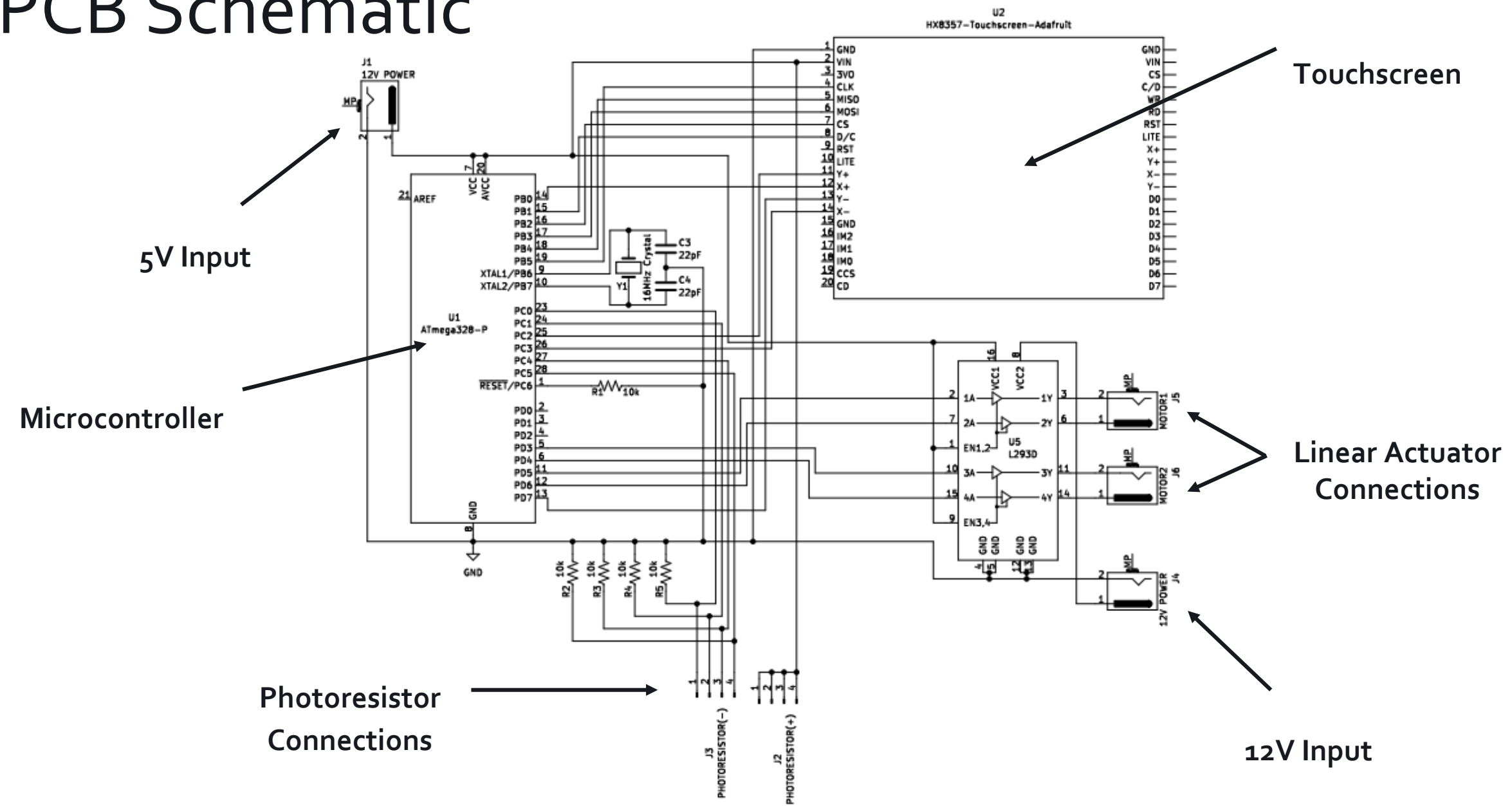
- Light received from all directions
  - Depends on x number of photoresistors cast in shadow
- Final fabrication by 3D print
- Chosen for simple design structure frequent usage in smaller scale solar tracking structures
- Design allows for simple testing with bread/proto-board and photoresistors
- Alternatives
  - Basic programing to point panel in general direction of sun by time of day, pre-programmed path



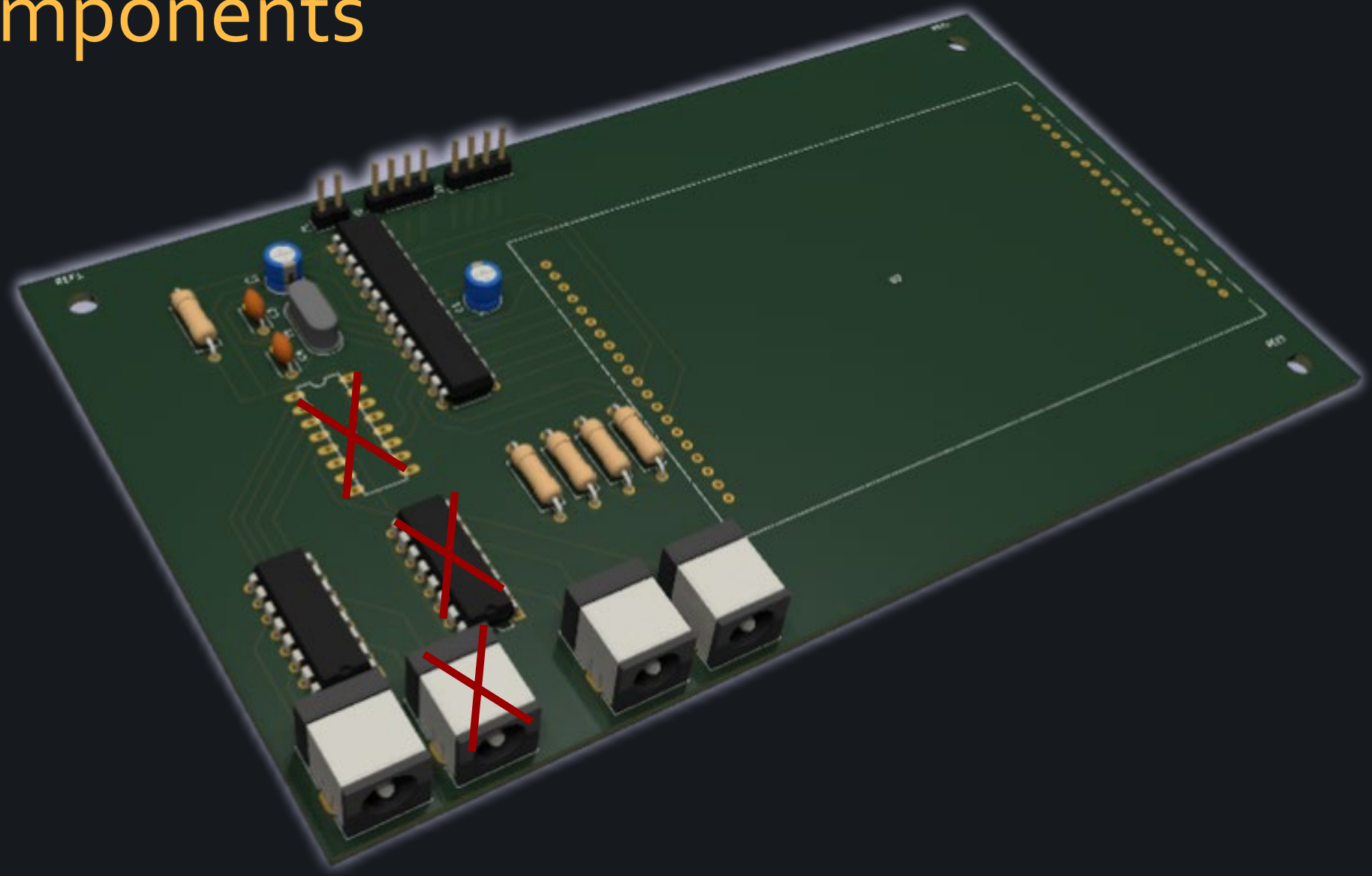
PCB Schematic



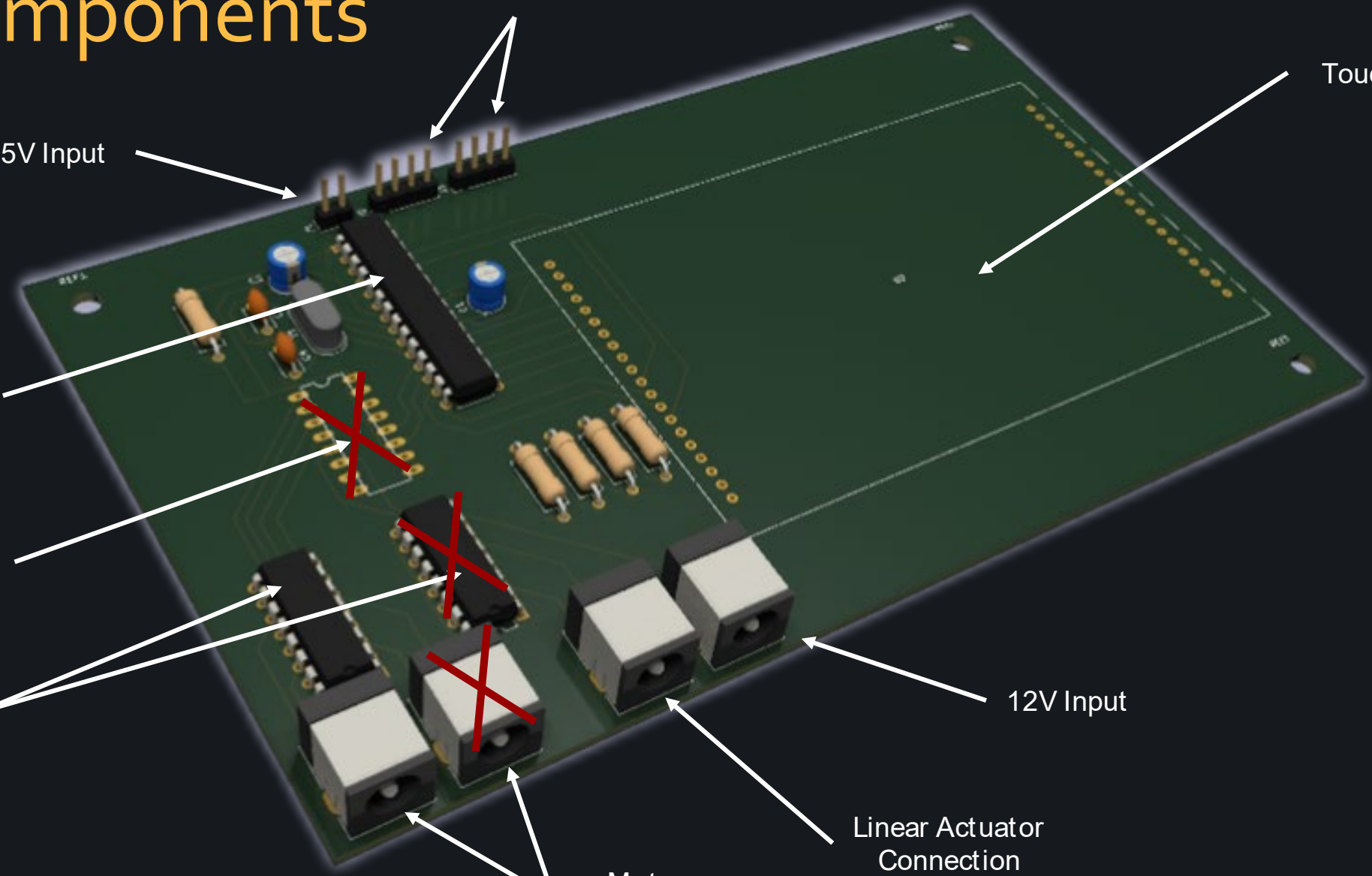
PCB Schematic



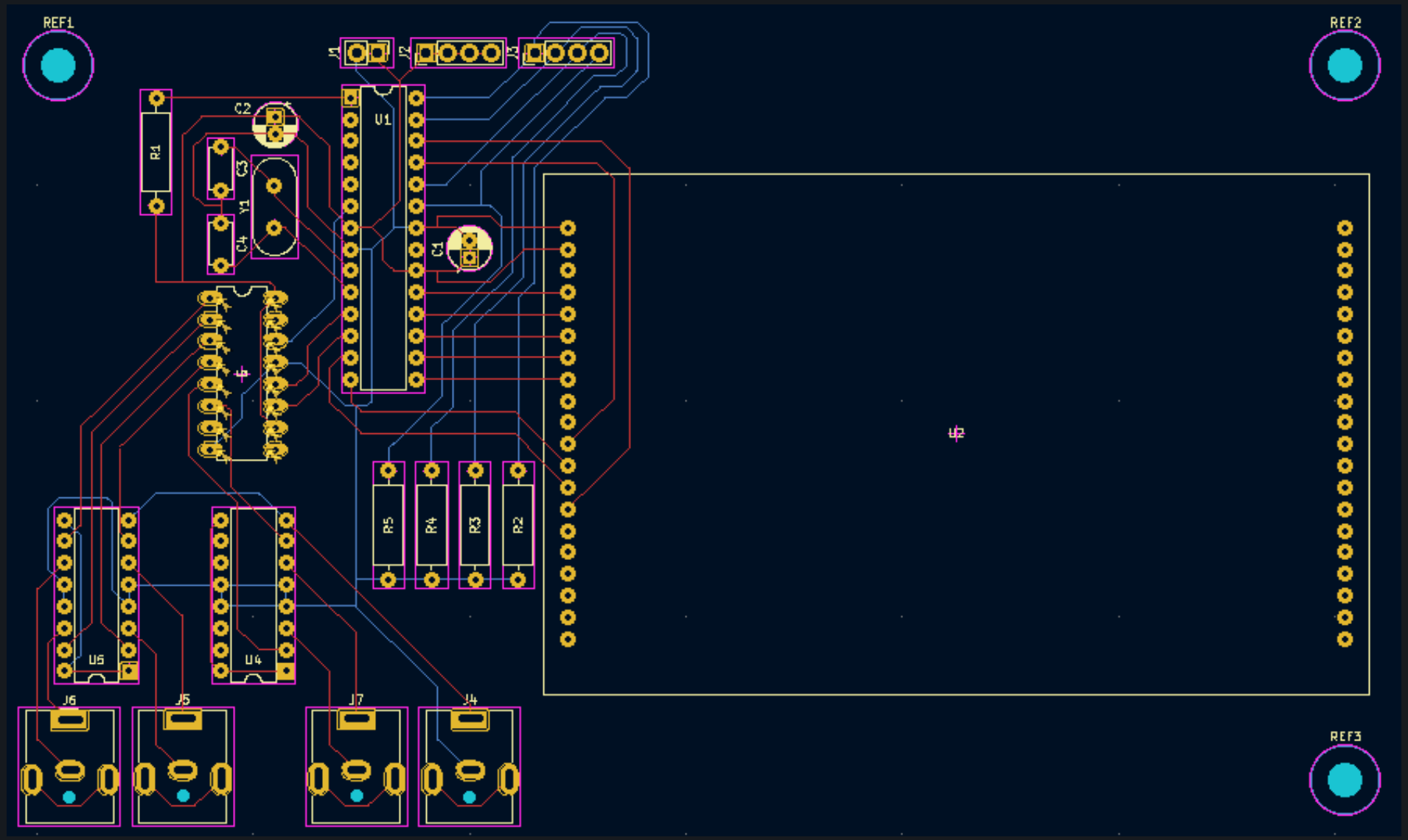
PCB Components



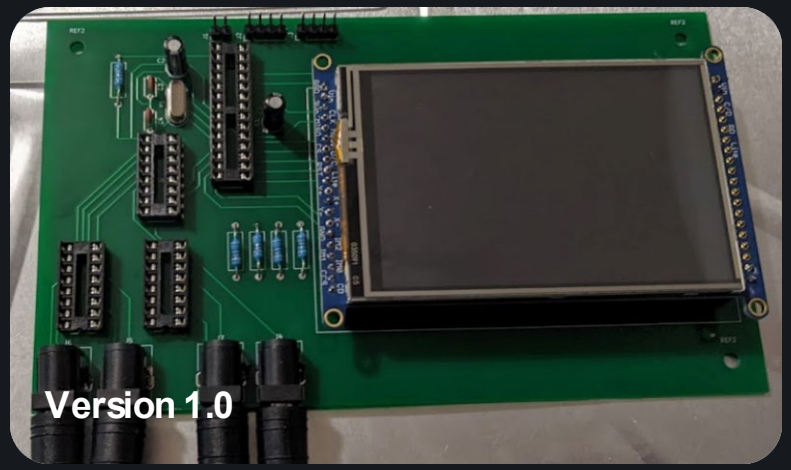
PCB Components

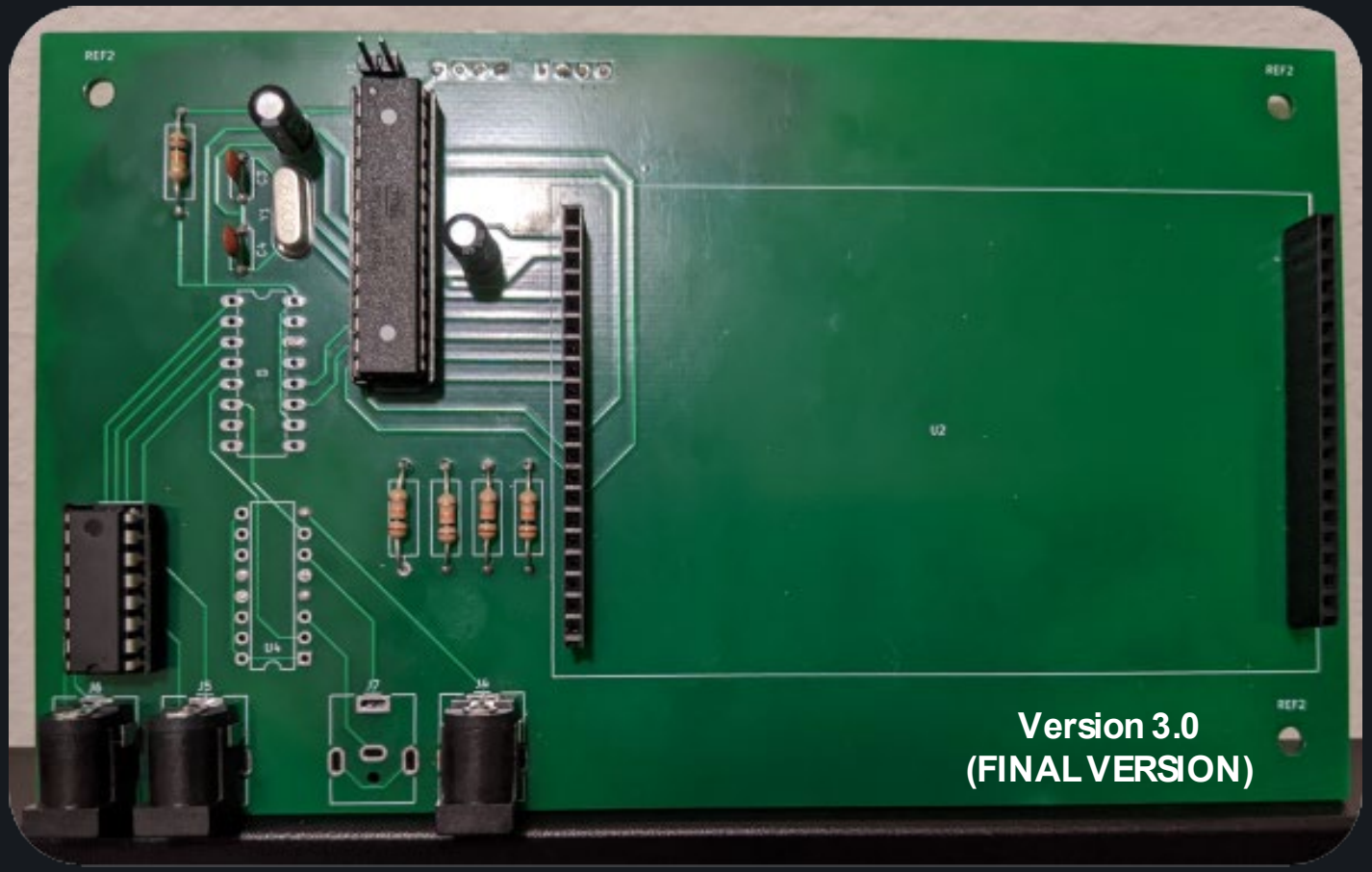


PCB Connections



PCB Versions



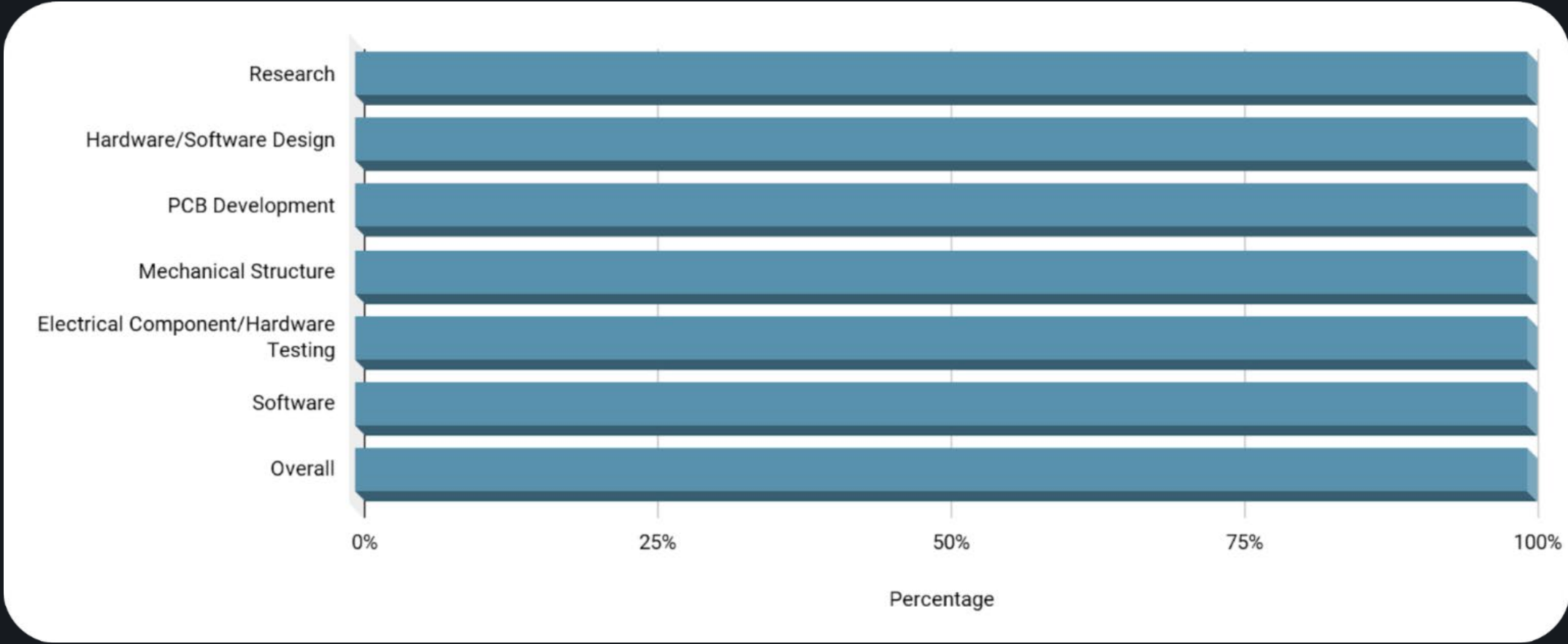


ADMINISTRATION

Budget and Financing

Part Number	Description	Vendor	Unit Price	Quantity	Total Price
B07DPHY2YJ	Solar Panel (200W/24V)	Newpowa	$179.99	2	$359.98
A000066	Arduino Uno Rev 3 Microcontroller	Amazon	$21.99	1	$21.99
EP1210	12V Lithium-iron Phosphate Battery	ExpertPower	$99.99	1	$99.99
N/A	PCB	TBA		1	$50
RBP60024B1	DC to AC Inverter	WZRELB	$73	1	$73
TBAAM-TGF12V300-T-1	Linear actuator	ECO-WORTHY	$33.99	2	$67.98
2183-4742-ND	DC motor	DigiKey	$24.95	2	$49.90
485-161	Photoresistor (LDR)	Adafruit	$.95	4	$3.80
EA120-12V	24V to 12V DC converter	EPBOWPT	$12.98	3	$38.94
B07MQ65HLB	Full bridge rectifier	Bridgold	$.89	6	$5.34
HXD8357D	3.5" TFT 320x480 + Touchscreen Breakout Board w/MicroSD Socket	Adafruit	$39.95	1	$39.95
N/A	Zulkit Junction Box ABS Plastic Dustproof Waterproof IP65 Electrical Box	Zulkit	$27.89	1	$27.89
TOTAL					**$ 931.82**

Progress


Research
Hardware/Software Design
PCB Development
Mechanical Structure
Electrical Component/Hardware Testing
Software
Overall
0%
25%
50%
75%
100%
Percentage

Challenges

- Overheating of the motor driver
- Damaging the microcontroller and touchscreen during testing
- Short circuiting motors and converters during run phase
- Dealing with weather conditions such as rain and cloudy
- Insufficient power using the 12 volt DC motor
- Safely reducing the unstable high solar panel voltage into stable desired voltage. Solar panels operating voltage is actually much lower than the output voltage. Additionally, it is subject to variation.
- Understanding the limitations of a DC-DC converters. There can only be 1 load for 1 converter. They cannot be placed in series. Additionally, they can only be placed in parallel with dramatic modifications.
- The structure buckling under the weight of the solar panels. Positioning of the motors and solar panels were critical during the design phase
- Choosing the most suitable/ cost effective material for structuring and compartmentalizing. 6061 aluminum boasts high tensile strength in addition with corrosion resistance, and versatile to work
- Transport limitations due a large system
- Travel time solar tracker storage location

Work Distribution

	PCB	Software/GUI	Mechanical Structures	Electrical Structures	LDR Sensor Housing	Junction Box Stand
Kim Fullenkamp	X	X				
Alexander Torres					X	X
Kevin Medina			X	X		

QUESTIONS?