Sharing Solar: A PV Sculpture Project

Group 10
Carolyn Cressman, *Electrical Engineering*
Carla Majluf, *Computer Engineering*
Jose Jerez, *Electrical Engineering*
Ruben Vazquez, *Computer Engineering*

*Sponsored by OUC

Motivation

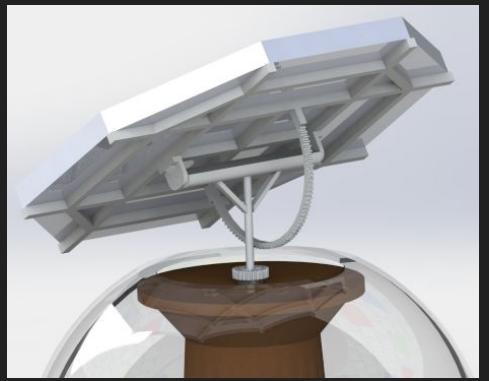
Motivation

- OUC sponsored project to create an artistic sculpture to educate the public about solar energy through the collaborative work of electrical, mechanical, and art students.
- Project Requirements for Full Scale sculpture

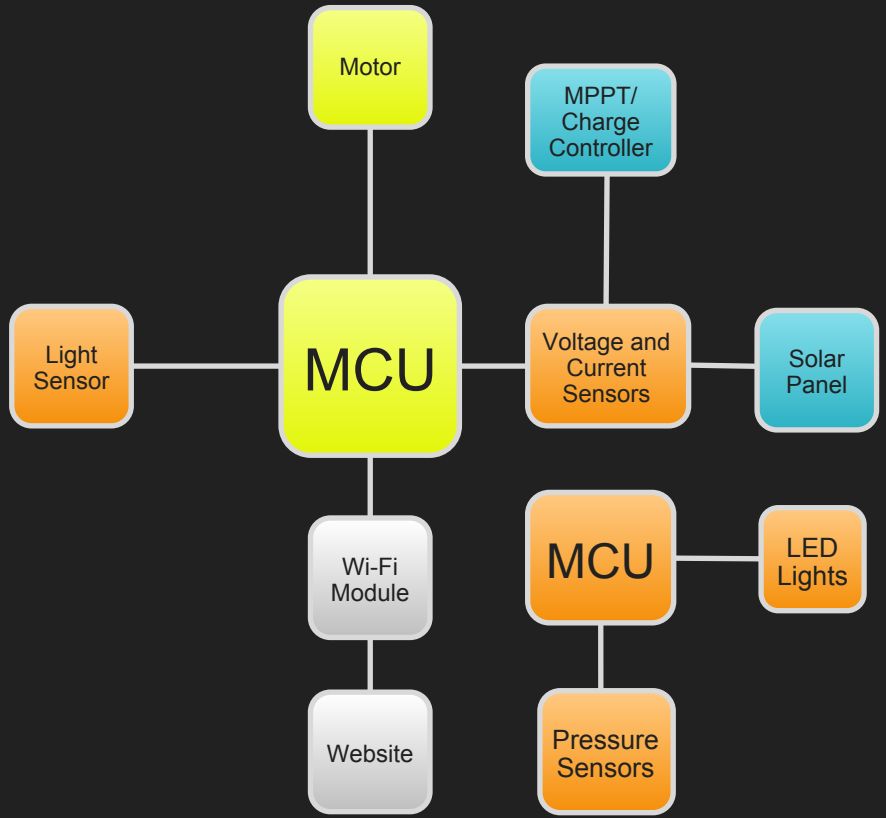
Requirement	Full Scale
Power	850 kWh/year
Size	8’ dia x 15’ h
Budget	$75,000

Goals and Objectives

- Create a small scale proof of concept model
  - Measure and display the solar panel power production on web app
  - Build circuitry to regulate solar panel voltage and charge battery
  - Control position of solar panel to match the position of the sun
  - Design interactive feature to incorporate in full scale sculpture using lights and sensors
  - Two axis solar tracking device.

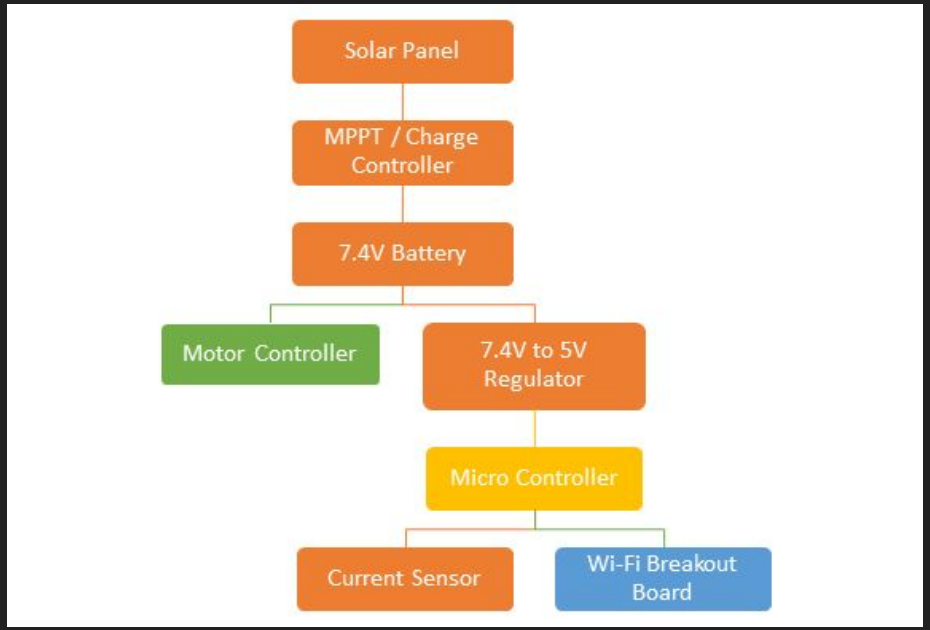


Block diagram

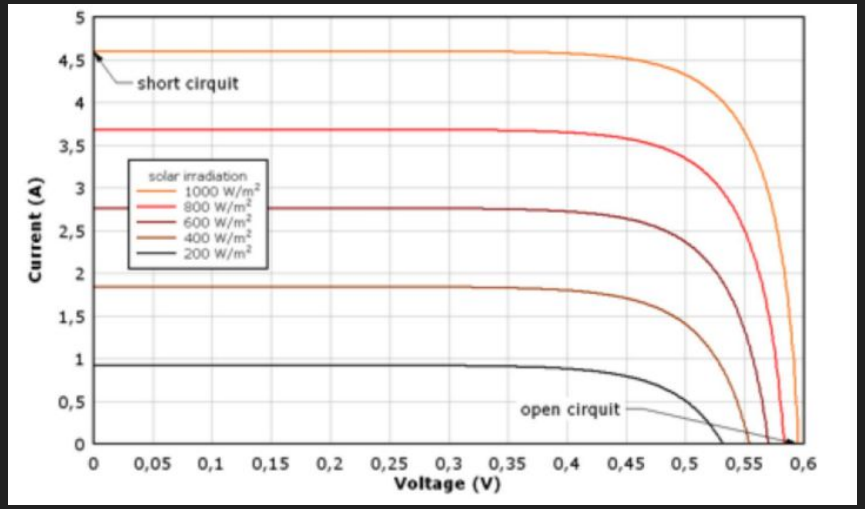


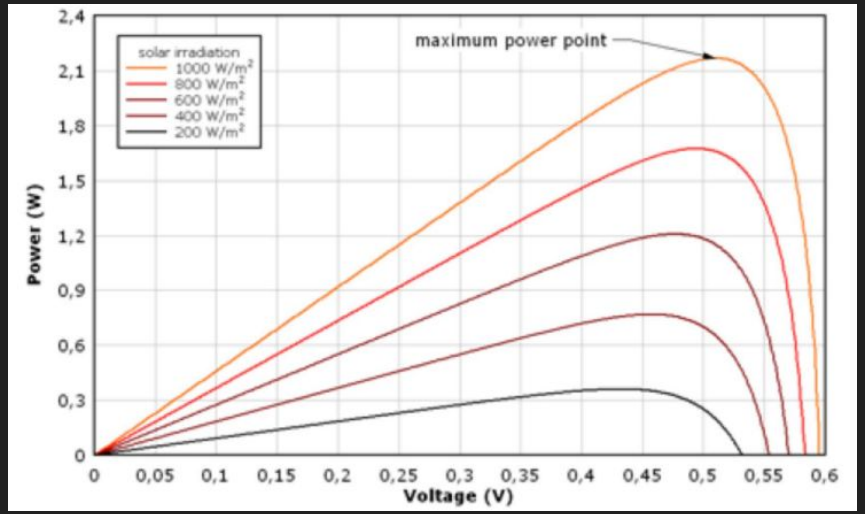
Carolyn Cressman • Sensors and Interactive system • Secondary for Jose	Jose Jerez • Power system • Secondary for Carolyn
Carla Majluf • Wireless communication system • Secondary for Ruben	Ruben Vazquez • Motion (solar tracking) system • Secondary for Carla

Power Subsystem



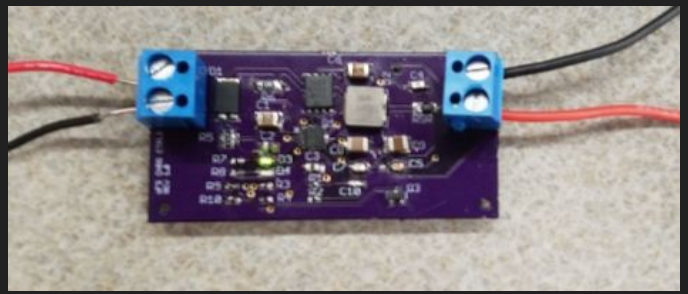
Maximum Power Point Tracking (MPPT)

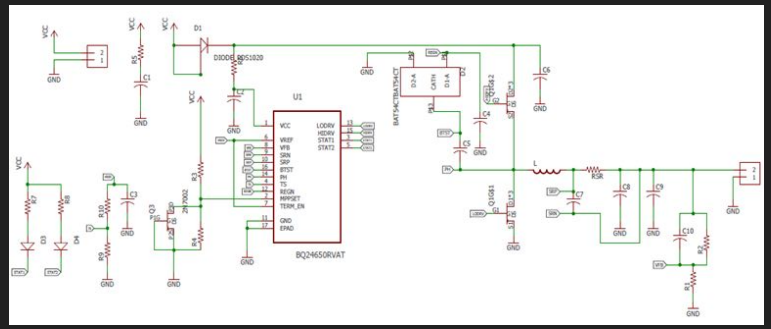


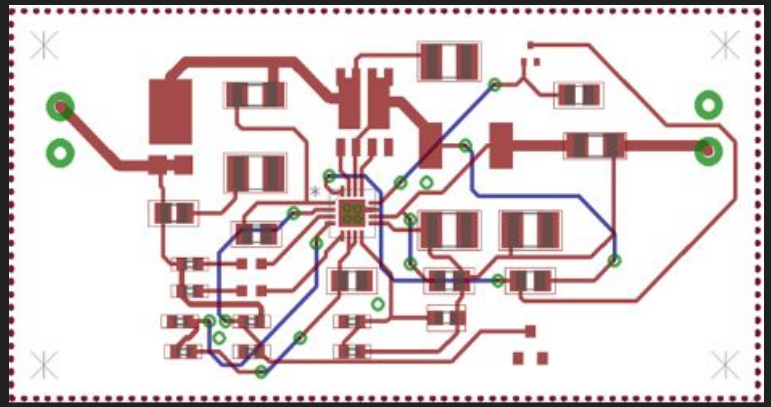


Maximum Power Point Tracking (MPPT)

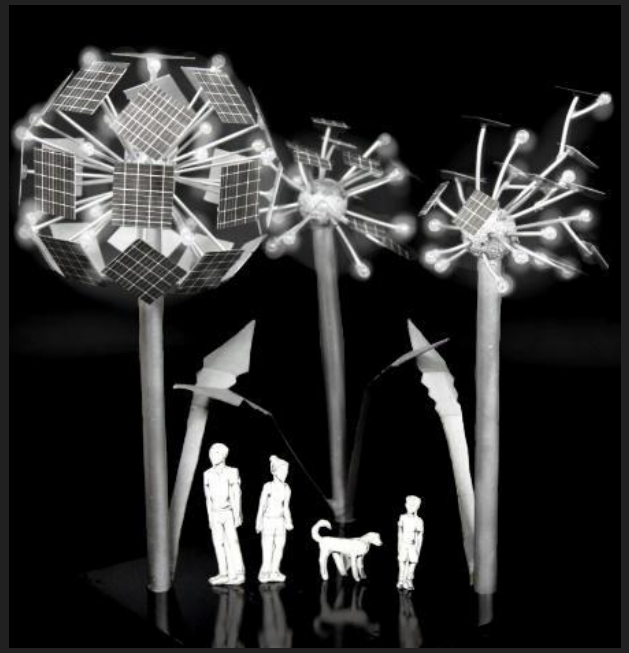
- TI BQ24650 Solar Charge Controller
  - Synchronous Solar Charge Controller
  - Provides wide range of input voltage regulation (5-28 V) with variable charge current
  - High efficiency synchronous buck controller
  - Battery overcharge protection
  - Only available in VQFN package i.e., hard to solder onto board

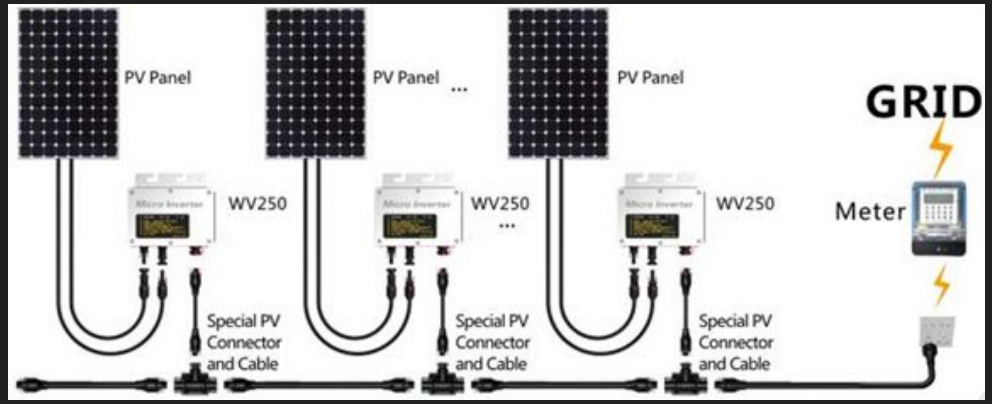






Power Subsystem



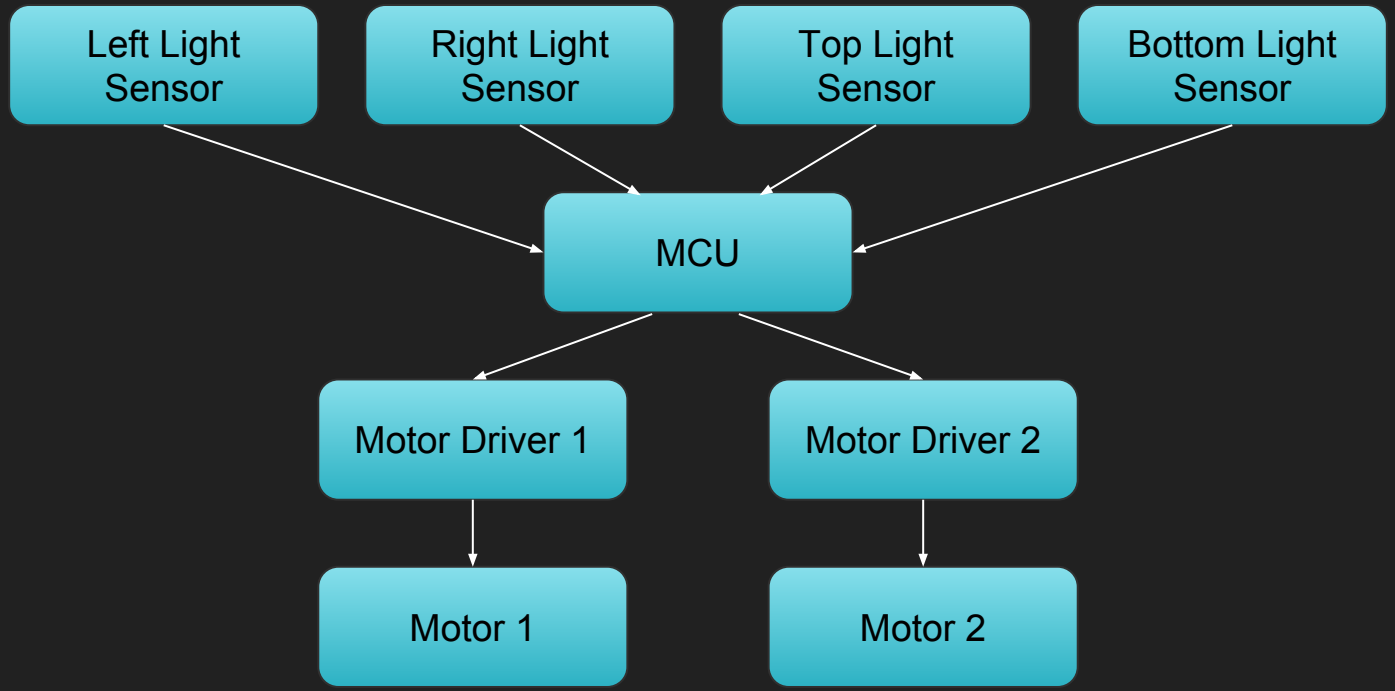


Microinverter system vs. Central inverter system

System Size

Direction	kWh/y From 50W Panels			Total
	90 Degrees	45 Degrees	0 Degrees	
S (180)	43	72		
SE (135)	44	69		
E (90)	39	60		
NE (45)	27	46		
N (0)	18	38		
NW (315)	25	44		
W (270)	37	57		
SW (225)	43	67		
Total	**276**	**453**	**68**	**797**

Motion Subsystem



Motion Subsystem

- Purpose
  - To track the movement of the sun to maximize power output.

- Major components
  - Light sensors - Provides input to microcontroller on light intensity
  - Motors - Controls the movement of the structure.
  - MCU - Processes data from light sensors to determine motor movement.

Motion Subsystem - MCU Selection

	Arduino Uno	SAM D21 Breakout
Cost	$24.95	$24.95
Operating Voltage (Volts)	1.8 - 5.5	1.62 - 3.63
Flash Memory (kB)	32	256
# of Digital Pins	15	24
# of Analog Pins	8	14
Package	DIP	TQFP

Motion Subsystem - MCU

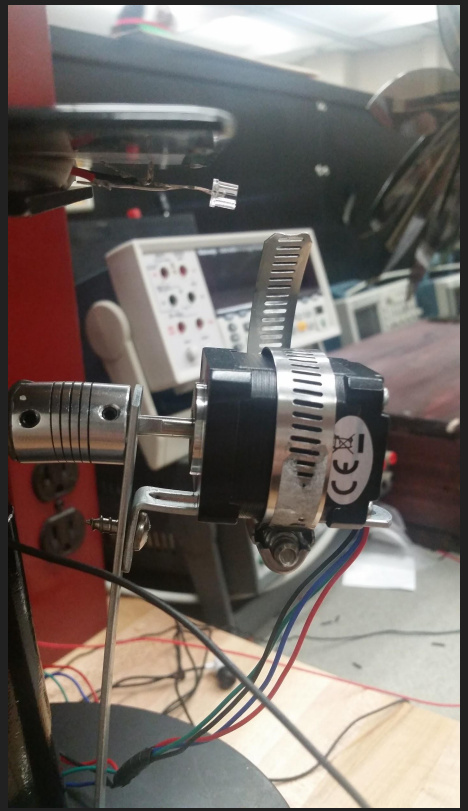
- SAMD21 Dev Breakout Board
  - 32-bit ARM Cortex-M0+ processor
  - 6 Analog Pins - Receiving data from light sensors
  - 14 Digital Pins - Sending signals to motor drivers
  - SPI Header - Interfacing with WiFi module

Motion Subsystem - Motor Selection

	324 Adafruit Nema 17	Nema 14 14HS17-0504S	Inventables 25253-01 Nema 17
Operating Voltage (Volts)	12	7.5	2.8
Degrees per Revolution	1.8	1.8	1.8
# of Leads	4	4	4
Amps (Amps per Phase)	0.35	0.5	1.68
Holding Torque (Ounce-Force Inches per Phase)	28	32.6	62
Weight (kg)	0.22	0.22	0.35

Motion Subsystem - Motor

- NEMA 14 14HS17-0504S Stepper Motor
  - Open-loop control motor
  - Operates from 7.5 V
  - Low current per phase
  - Very fine movement

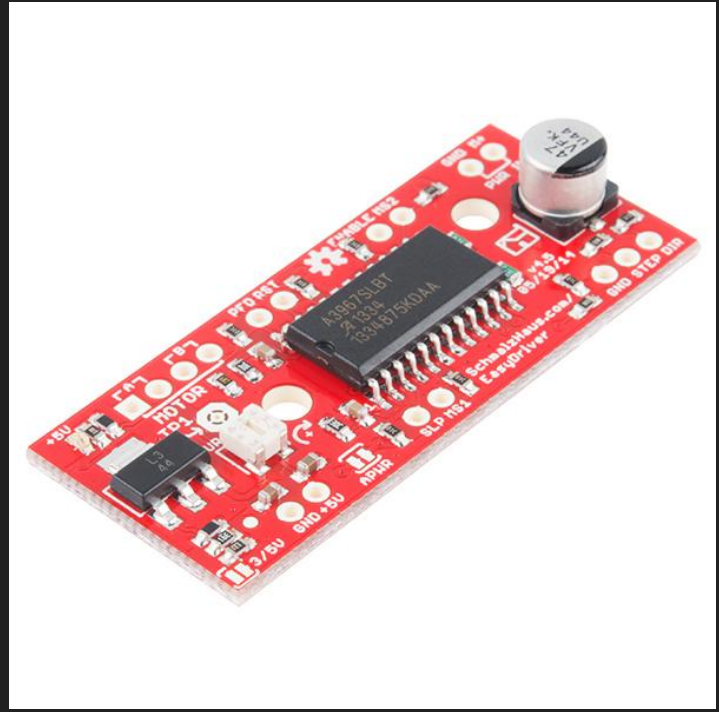


Motion Subsystem - Motor Driver Selection

	Texas Instruments L293D	Sparkfun ROB -12779	Allegro A4988
Cost	$1.58	$17.95	$5.95
Operating Voltage (Volts)	Up to 36	0 - 30	8 - 35
Output current (Amperes)	600	± 0.750	1
Operating Temperature (Celsius)	0 - 70	-20 - 85	-20 - 85

Motion Subsystem - Motor Driver

- Sparkfun ROB - 12779 Stepper Motor Driver
  - Motor driver for proper coil sequencing
  - Input voltage between 6 V and 30 V
  - Onboard potentiometer for current control
  - Microstepping resolution up to ⅛ step



Motion Subsystem - Light Sensor Selection

Electrical Characteristic	Photodiode	Phototransistor	Photoconductor	CdS Photocell
Wavelength (μm)	0.2 – 2.0	0.4 – 1.1	2-15	0.4-0.7
Performance-to-cost ratio	Good	Excellent	Fair	Excellent
Sensitivity	Very Good	Very Good	Very Good	Very Good
Linearity	Excellent	Good	Good	Good
Dynamic Range	Excellent	Very Good	Good	Good
Stability	Very Good	Good	Fair	Poor
Cost	Low	Very Low	High	Very Low
Ruggedness	Excellent	Excellent	Good	Excellent
Size	Small	Small	Small	Small

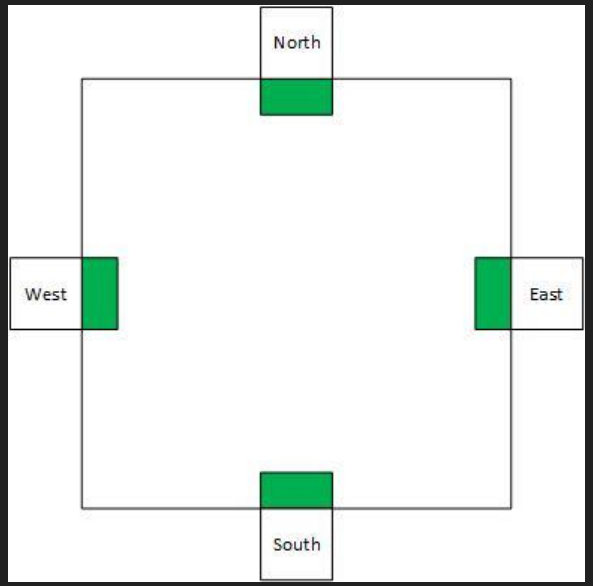
Characteristics	TI OPT3001	Adafruit 2831	Jameco 373001
Type	Phototransistor	Phototransistor	Phototransistor
Wavelength (ηm)	460 - 655	480 - 1050	500 - 1200
Supply Range (Nom V)	1.6 – 3.6	3 - 15	0.3 - 5
Collector Current	2 – 3.5 μA	50 - 70 μA	0.6 – 2.0 mA
Max Temperature (°C)	85	90	85
Packaging	SON	Through Hole	Through Hole
Price	$2.77	$0.95	$0.35

Motion Subsystem - Light Sensor

- Adafruit 2831 Phototransistor
  - RoHS compliant
  - 3 - 15 V operating voltage
  - Through-hole

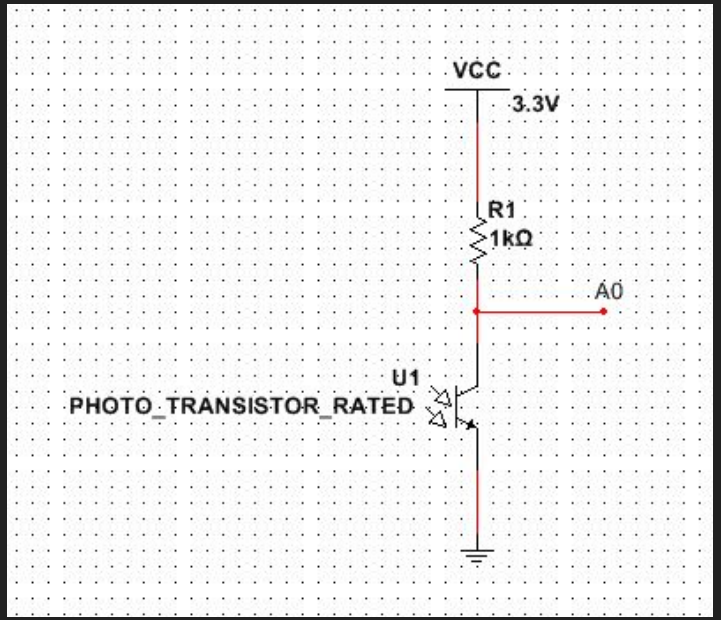
Motion Subsystem - Sensor Layout

- Phototransistors are placed in all compass directions
- West and East sensors control panning motion
- North and South sensors control tilting motion

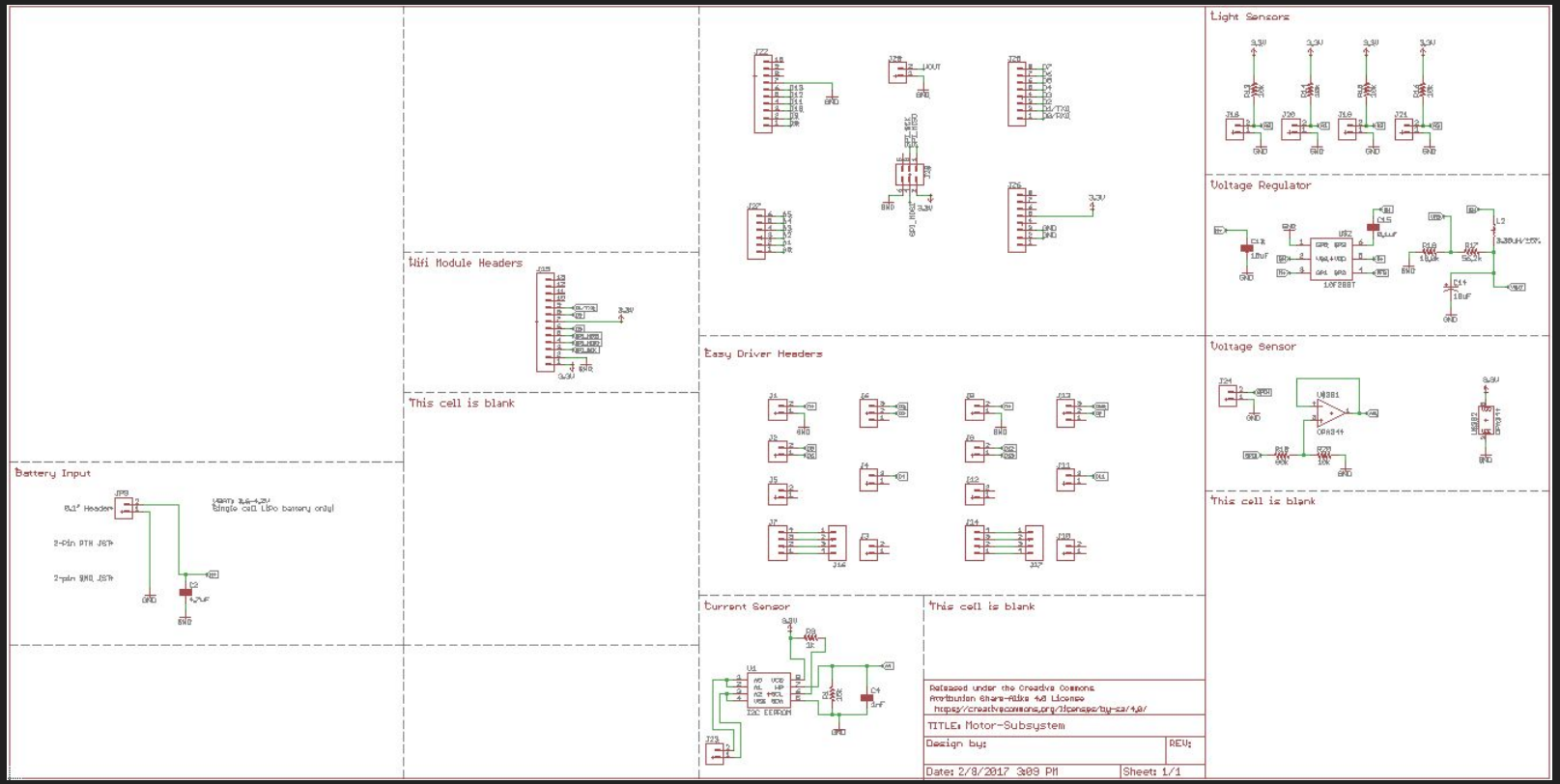


Motion Subsystem - Sensor Circuit Design

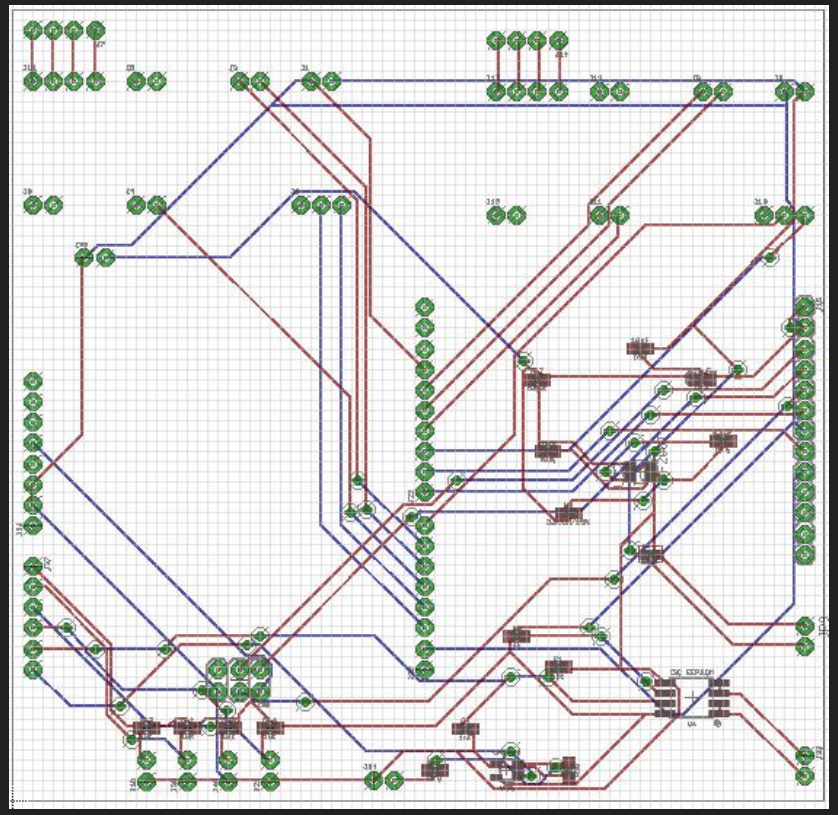
- Powered by 3.3 V from MCU
- Lower reading at A0 correlates to higher light intensity
- 1 kOhm resistor is used for outside conditions



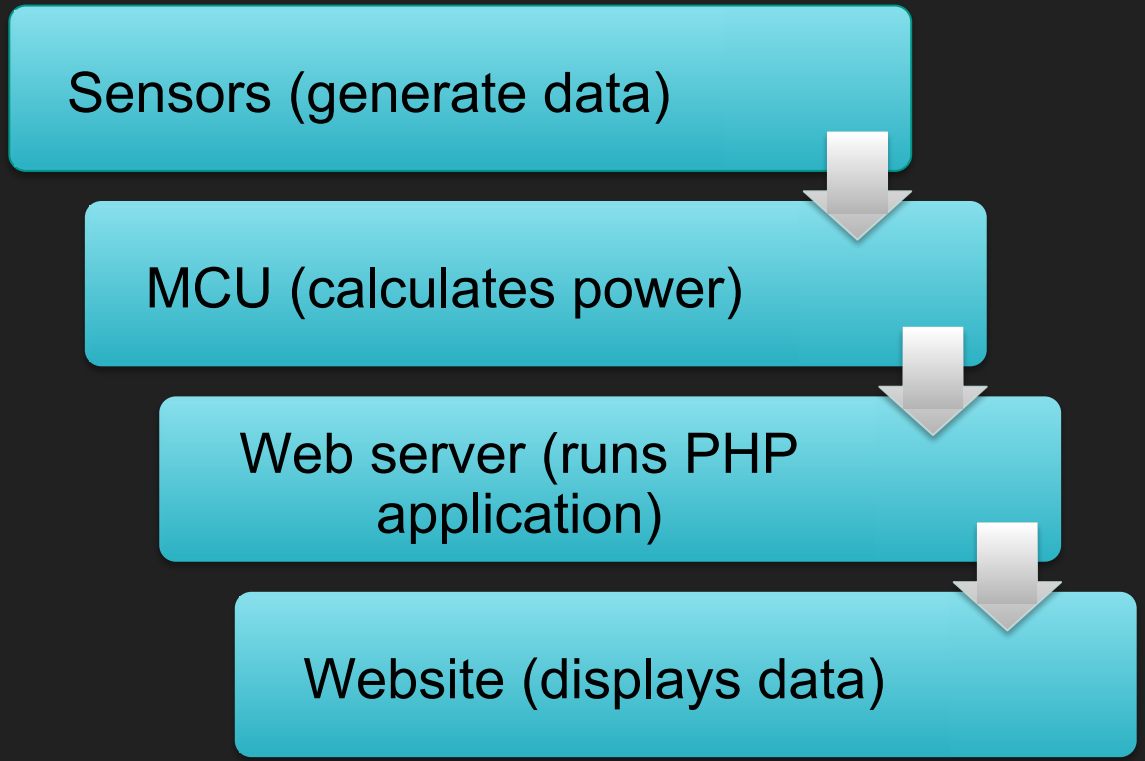
Motion Subsystem - Schematic



Motion Subsystem - Board

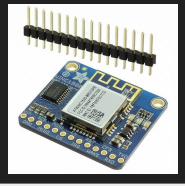


Wireless Communication Subsystem



Wireless Communication Subsystem

Wi-Fi module selection

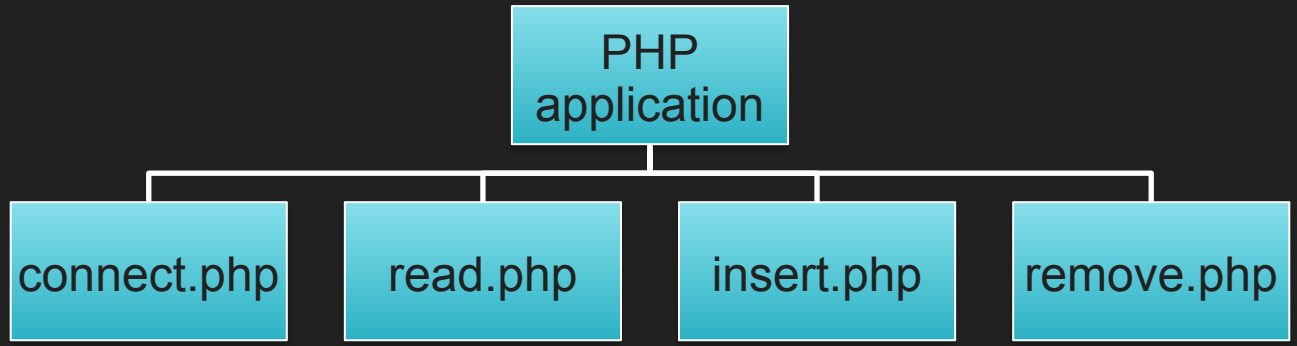


	Atmel ATSAMW25	Adafruit ATWINC1500 Breakout
Cost	$23.70	$24.95
Operating Voltage	2.7 – 3.6 V	3.0 – 4.2 V
Dimensions	34 x 15 mm	22 x 15 mm
Wi-Fi SoC	WINC1510B	WINC1500B
Host	Embedded SAMD21	External MCU
TCP/UDP, DNS, HTTP/HTTPS, TLS	Yes	Yes
CryptoAuthentication	Yes	No

Wireless Communication Subsystem

Web server

- Amazon AWS Free-tier.
- Allows one EC2 instance to run continuously.
- Provides 10 GB of storage.
- Runs PHP application and holds database.



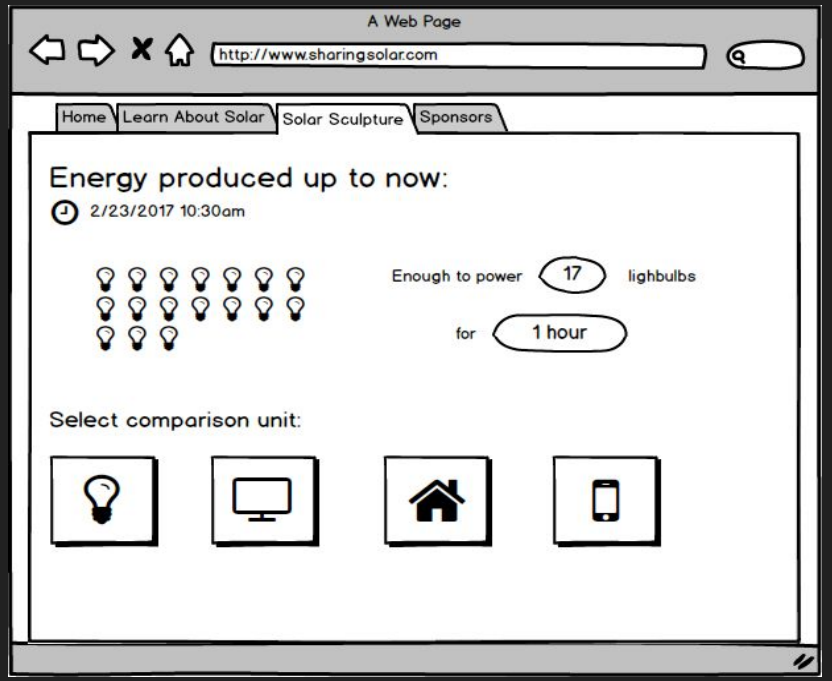
Wireless Communication Subsystem

Website

- Displays energy produced by the sculpture.
- ISOTYPE design to maximize public understanding.
- Provides every-day measures of power.
- Interactive and animated.

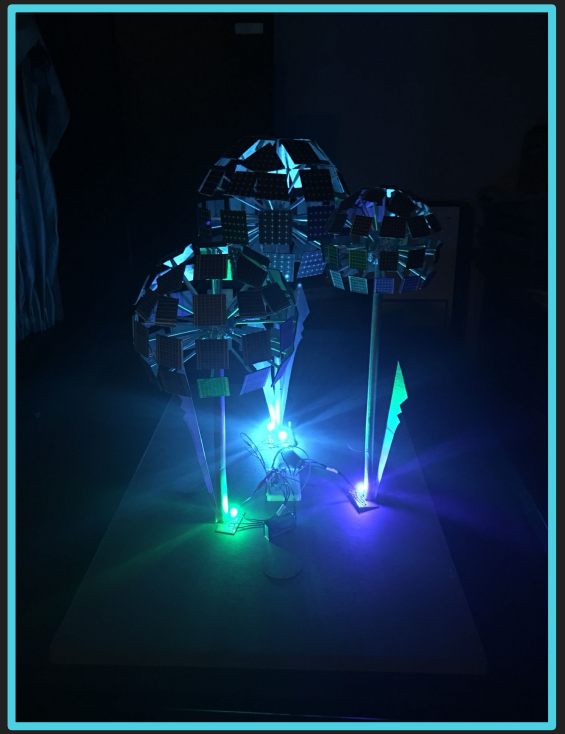
Other educational features:

- Solar panel calculator app
- Articles
- Test your knowledge quiz game



Interactive Feature Subsystem - Overview

- Purpose:
  - Engage the people of Lake Nona community
- Needs:
  - Flexibility
  - Easy to scale
  - Easy to add to
  - Interactive/Fun
  - Add interest to the sculpture at night
- Current Design
  - Four pressure sensitive tiles representing the colors red, blue, yellow, and white
  - LED lights on the structure will change color with tile activation
  - Multiple tile activation achieves in between colors (such as orange and purple)



Interactive Feature Subsystem - Sensor

- Need: Sensor to activate lights when tile is stepped on
- Researched and compared 3 types of sensors

Type of Sensor	Pros	Cons
Contact Switch	• Low cost • Easy to implement	• Fair lifetime • Acts like a switch
Force Sensitive Resistor (FSR)	• Good lifetime • Easy to implement • Dependence on force allows for more interactivity	• High cost
Proximity Sensor	• Low cost • Best lifetime • Dependence on distance allows for better interactivity	• Difficult to place in an unobstructed location

Price: $6.95

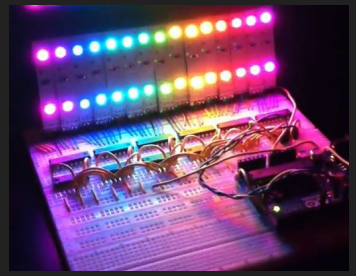
Size: 0.5”

Manufacturer: VersaPoint Technologies

Seller: Sparkfun

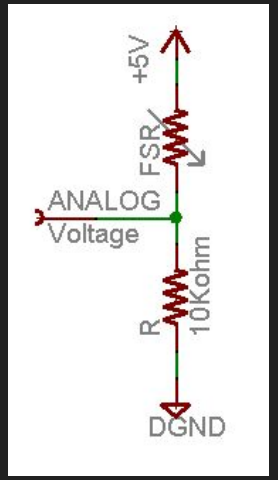
Interactive Feature Subsystem - Other Material

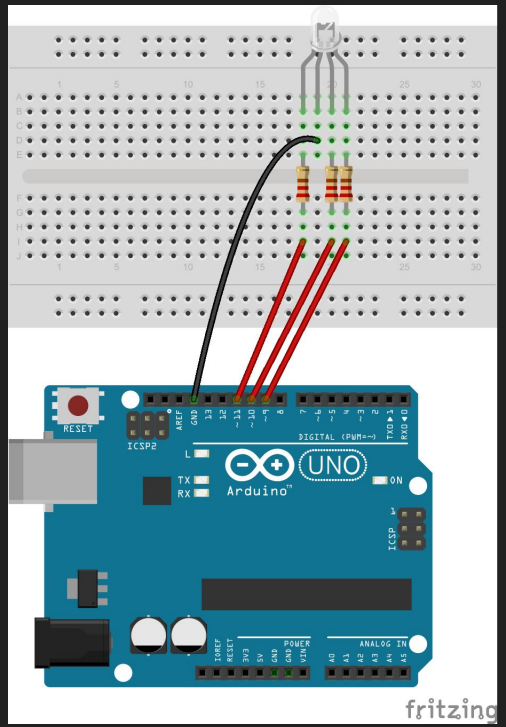
- RGB LEDs
  - Price: $8.96 for 100 LEDs
  - Allows for programmable color change
  - Allows for in between colors
- Arduino Uno
  - Price: $17
  - Included PWM without purchasing additional parts/boards
  - PWM allows for color fade rather than abrupt change
  - Built in features can cover any additions to the interactive portion of the design
  - Why two microcontrollers?
    - Want 1/8 scale model and prototype to be as independent as possible
    - Need model electronics to be flexible and changeable



Interactive Feature Subsystem - Overall Circuit

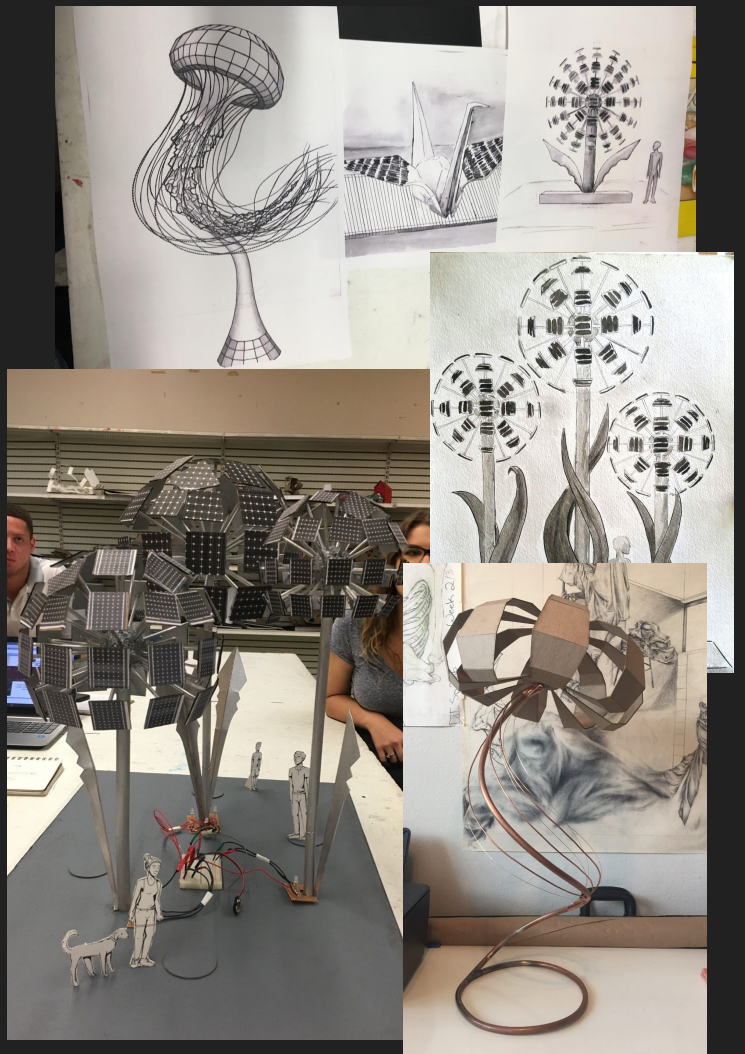
- The FSRs will be connected to the analog pins of the Arduino Uno
  - Gives a signal to the Arduino representing that tile has been activated
- The RGB LEDs will be connected to the PWM pins on the Arduino Uno
  - Allow for different intensities from 0 to 255 on each color (Red, Green, Blue) pin
  - Creates different hues of colors which can be connected to the measure of force on the tiles





Changes This Semester

- OUC and Tavistock removed the 2 axis solar tracking from large sculpture
- Expressed a want for motion but with little to no maintenance (no motors)
- Artists created about 50 concepts and we are now focusing on two
- Our sponsor/client have new critiques and additions every week
- Attend a meeting twice a week

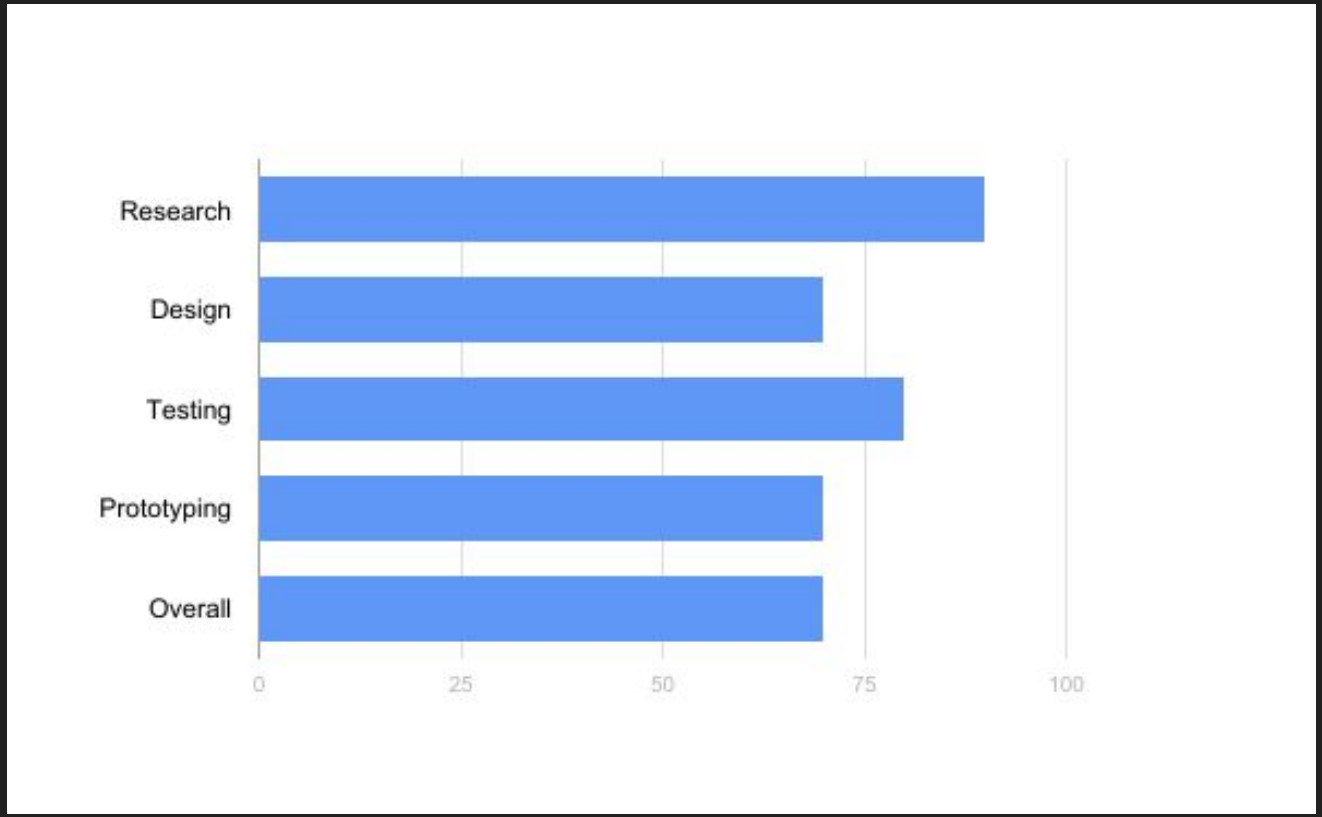


Administrative Content

Budget

Item	Subsystem	Unit Price	Quantity	Total Price
Phototransistor	Motion	$0.95	10	$9.50
Wi-Fi board	Wi-Fi comm.	$24.95	1	$24.95
Current sensor	Power	$2.15	5	$10.75
Batteries	Power	$42.95	1	$42.95
Arduino Uno	Interactive	$17.00	1	$17.00
Charge controller	Power	$5.49	3	$16.47
SAMD21 Dev board	Motion/Wi-Fi comm.	$24.95	1	$24.95
Stepper motor driver	Motion	$14.95	2	$29.90
Stepper motor	Motion	$11.58	2	$23.16
Pressure sensor	Interactive	$6.95	4	$27.80
Other electrical components	Power/All	-	-	$48.89
			TOTAL	$276.32

Progress



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