Sun Tracking Solar Panel

Design Document

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Team 4

Daniel Bullock (djb6@illinois.edu)

Rohan Gore (rohanvg2@illinois.edu)

Tyler Newlin (tylerjn2@illinois.edu)

TA: Amr Ghoname

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1 Introduction

1.1 Problem

Stationary solar panels do not produce the maximum amount of energy possible at all hours of daylight. Setting up stationary solar panels requires finding an optimum tilt as well as an angle to face the average position of the sun in the sky. Calculation of these angles depends on the latitude and longitude at the panel's location.

1.2 Solution

Our solution to maximize energy production is for a sun tracking solar panel. The panel will move to face all directions to be perpendicular with the sun. It will use photoresistors behind the solar panel which will try to minimize the light in their view, sending movement data to server motors to move the panel, until completely shaded when the panel is perpendicular with the sun. Calculations are not required; the user just has to position it roughly facing where the sun will rise in the morning for first-time setup. Our panel will also send power data directly to a webapp, so the user can see how much power is being generated and used by the panel during the course of a day.

1.3 Visual Aid

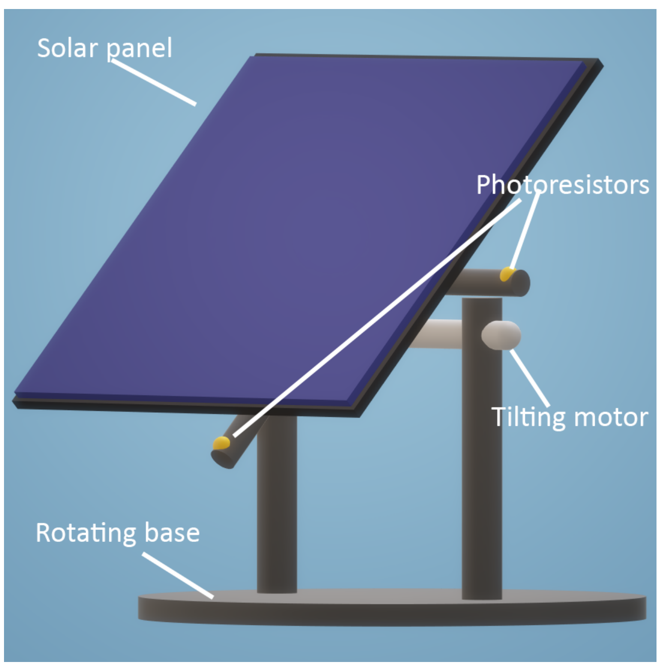

Figure 1. Model of Sun Tracking Solar Panel

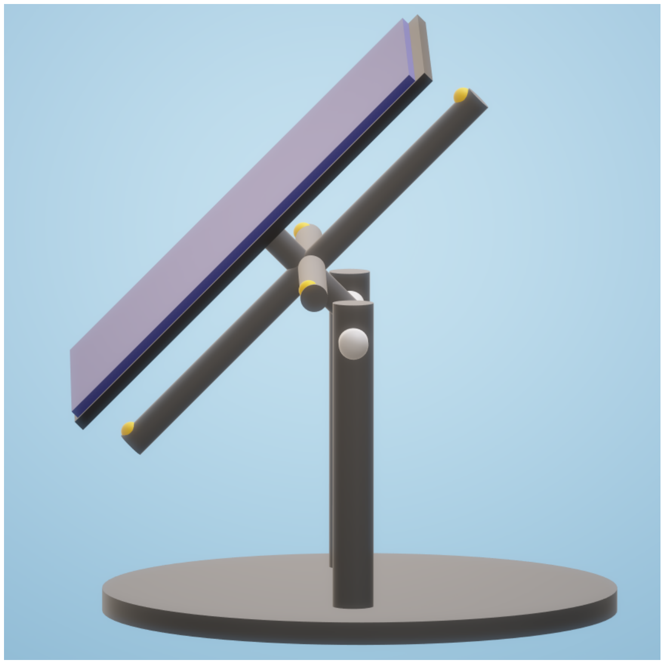

Figure 2. Side View of Model of Sun Tracking Solar Panel

1.4 High Level Requirements:

- The panel must utilize the photoresistors to be perpendicular +/-10° to the sun at all hours of the day to maximize energy production. It must perform a 180° tilt at nighttime to reset it for the morning.
- The panel must generate and store power in a battery used to power its functions, while still producing at least 15% more net power than a stationary solar panel.
- The panel must send a stream of data including the power generation and efficiency to a webapp which will display live graphs and data.

2 Design

2.1 Block Diagram

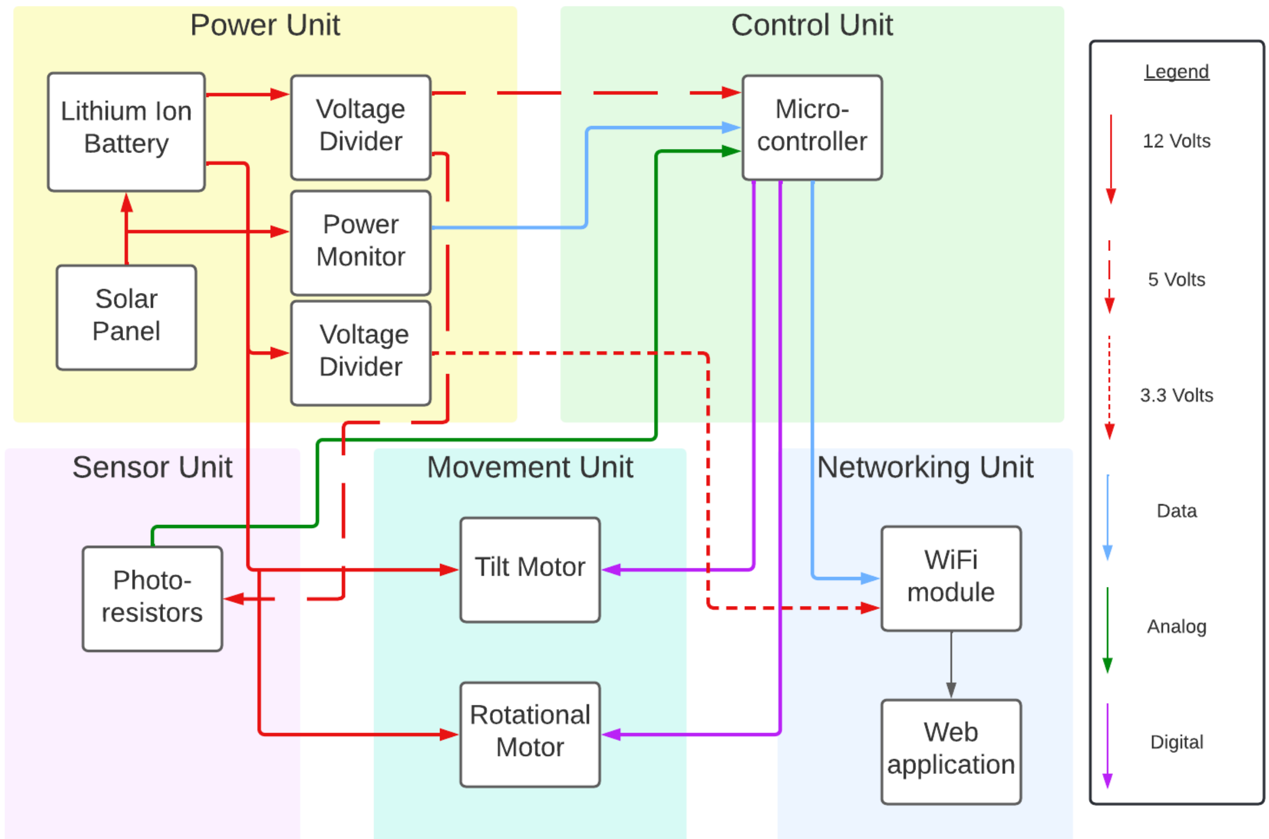

Figure 3. Block Diagram

2.2 Power Unit

2.2.1 Battery

The 12 V battery will power the motors, microcontroller, and photoresistors. The solar panel will charge the battery while the battery powers the rest of the system.

Requirement: Power Converter converts battery voltage to appropriate voltages for controller, photoresistors, and motors.

Requirements	Verification
1. The battery will receive and store power from the solar panel, and send it to the rest of the components. It must supply >500 mAH of charge at 12V +/-5%.	1. Connect a fully charged battery to the system a. Discharge battery at 100mA. b. Use a voltmeter to ensure the voltage remains within the 12V threshold.

2.2.2 Power Converter

The power converter will create the required voltages for our circuit to operate, 5V for the microcontroller and 3.3 V for the wifi module. It will draw the power from the battery. The power converter will also power the photoresistors.

Requirements	Verification
1. Provides 5 V +/- 5% and 3.3 V +/- 5% from a 12 V source with currents from 0-590mA.	1. Connect the input to a 12 V source and draw 590 mA. a. Measure the voltage output using a multimeter to ensure it is within 5 V +/- 5% or 3.3 +/-5%.

2.2.3 Solar Panel

The solar panel will be the power source for the battery which will power the whole system. It will create enough power to power the system while still producing excess energy.

Requirements	Verification
1. Outputs 350-590 mA between 12 and 18 V in direct sunlight.	1. Put the solar panel outside in direct sunlight. a. Measure the current using a multimeter.

2.2.3 Power Monitor

The power monitor chip will take in voltage and current from the solar panel, which will then be sent to the microcontroller for logging power.

Requirements	Verification
1. Power monitor chip accurately depicts voltage and current.	1. Measure the voltage and current across the solar panel using a multimeter. a. Verify that voltage and current is within +/-5% of the chip’s output.

2.3 Control Unit

2.3.1 Microcontroller

The microcontroller will take data from the photoresistors and calculate which motors will need to move and what direction, then outputs this data to the movement unit to move the solar panel to the correct angle. Sends power generated data to the WiFi module.

Requirements	Verification
1. The microcontroller will use the photoresistor values to tell the motors where to turn the solar panel.	1. Verify that the resistance of the photoresistors matches the direction the solar panel is moved i. Use multimeter to record the values of the photoresistors b. Observe that the solar panel moves in the correct direction c. Check that the values of the photoresistors are +/- 5% of each other
2. The power generated by the solar panel will be recorded by the microcontroller, and sent to the WiFi module.	2. Discharge a battery connected to the microcontroller. a. Verify the power input coming through the microcontroller data. b. Verify the data comes through in the web application.

2.4 Sensor Unit

2.4.1 Photoresistors

Changes resistance based on the position of the solar panel and sends this data to the microcontroller.

Requirements	Verification
1. Horizontal photoresistors resistance changes as rotational motor rotates the base 2. Vertical photoresistors resistance changes as the tilt motor tilts the panels	1. Record the resistance of the photoresistors with the microcontroller. a. Ensure that the values of the photoresistors correspond to the direction the solar panel is moving.

2.5 Movement Unit

The movement unit contains the motors required to move the solar panel to the correct position. The movement unit receives the correct position from the microcontroller.

2.5.1 Rotational Motor

This motor will rotate the base of the panel to maintain the optimal position during the day.

Requirements	Verification
1. The motor must move within +/-2° of the value given by the microcontroller.	1. Send an input angle from the microcontroller. a. Measure the rotation of the motor using a protractor to ensure it is within +/-2°.

2.5.2 Tilt Motor

This motor will tilt the solar panel to ensure the panel maintains the optimal angle towards the sun.

Requirements	Verification
1. The motor must move within +/-2° of the value given by the microcontroller.	1. Send an input angle from the microcontroller. a. Measure the rotation of the motor using a protractor to ensure it is within +/-2°.

2.6 Networking Unit

2.6.1 WiFi Module

Will connect to WiFi to communicate power generated data from the microcontroller to the web application.

Requirements	Verification
1. The module must be able to interface with the microcontroller and send data to the web application.	1. Send a number of watts to the WiFi module from the microcontroller. a. Send the data from the WiFi module to the web application. Verify the web application receives the data.

2.6.2 Web Application

The web application will receive data from the system via the WiFi module. It will show live graphs and data of the power consumed and generated by the panel system.

Requirements	Verification
1. The web application must display live data and visualizations of the power consumed and generated by the panel.	1. Send random power signals to the microcontroller over the course of a few minutes. a. Verify the web application receives the data and graphs it over time.

2.8 Circuit Schematics

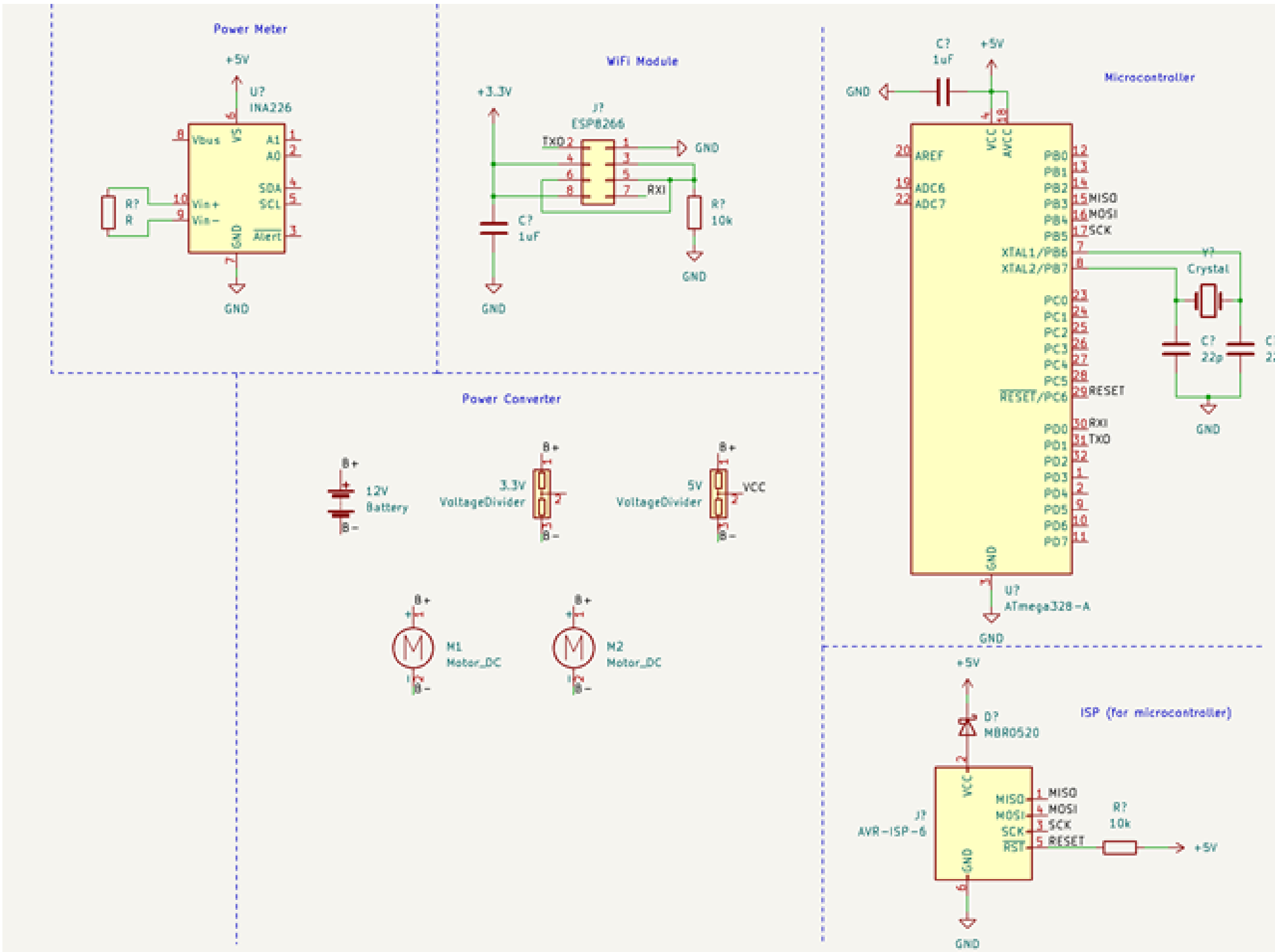

Figure 4. Circuit Schematic

2.7 Tolerance Analysis

The greatest challenge to the successful completion of this project is the energy cost to power the controller and motors. The energy cost may exceed the power produced by the solar panels, resulting in an energy drain. To prevent this we have to choose a large enough panel and a battery with enough capacity to consistently power the electronics in the system. Also, the pole, the panel and photoresistor array will require a short enough length to avoid overloading the motor. We will either need to find a motor with sufficient torque and holding power or greatly minimize the distance between the photoresistors and the panel.

Month	Solar Radiation (kWh / m^2 / day)
January	3.02
February	3.69
March	4.57
April	5.77
May	5.91
June	6.52
July	6.52
August	6.22
September	5.66
October	4.29
November	3.24
December	2.40
Annual	4.82

Figure 5: Theoretical Fixed Axis Daily kWh in Champaign, IL

$$0.535m \ * \ 0.555m = 0.296925\, m^2 * \ 4.82\, kWh/m^2/day = 1.4311785\, kWh/day$$

Month	Solar Radiation (kWh / m^2 / day)
January	4.55
February	5.29
March	6.18
April	7.64
May	7.88
June	9.01
July	8.89
August	8.26
September	7.74
October	6.04
November	4.96
December	3.67
Annual	**6.68**

Figure 6: Theoretical 2 Axis Tracking Daily kWh in Champaign, IL

$$0.535m \; * \; 0.555m = 0.296925\, m^2 * \; 6.68\, kWh/m^2/day = 1.983459\, kWh/day$$

$$1.983459\, kWh/day \; - \; 1.4311785\, kWh/day \; = \; 0.5522805\, kWh/day$$

For our project to be successful the system will have to theoretically consume less than 0.55 kWh/day.

Assuming we run the motors from sunrise to sunset everyday(roughly 7 hours of sunlight on average).

$$12\, V \; * \; .250A \; * \; 1kW/1000W \; * \; 7\, hours/day \; * \; 2\, motors \; = \; 0.042\, kWh/day$$

$$0.5522805 \; - \; 0.042 \; = \; 0.5102805\, kWh/day$$

Even with other electronics consuming small amounts of power, the system should be more efficient than a stationary panel.

3 Cost Analysis and Schedule

3.1 Cost Analysis

3.1.1 Labor

A University of Illinois graduate makes on average $105,879 [0]. With 2080 working hours in a year that makes the hourly wage $50.90/hr. We each plan to spend at least 10 hours working on this project a week and with 9 weeks left before the project demo that makes $50.90/hr * 10 hrs/week * 3 people * 9 weeks = $13,743 in labor costs.

3.1.2 Parts

Part	Cost	Bulk Cost	Quantity
50W 22V Solar Panel	$0.00	NA	1
WiFi Module - ESP8266 (4MB Flash)	$7.50	NA	1
Photoresistors - Adafruit	$0.95	$0.86	10
Adafruit METRO ATMEGA328 Microcontroller	$17.50	NA	1
BP3-12-T1 12 V 3AH Lead Acid Battery	$28.79	NA	1
MG16B-030-AB-00 Gear Motor	$36.65	NA	2
INA226AIDGST Power Monitor	$4.25	NA	1
Total Cost	**$138.94**		

3.2 Schedule

	Daniel	Rohan	Tyler
2/21	Design Doc/PCB	Design doc/PCB	Design doc/PCB
2/28	Order parts	Test/simulate PCB	Finalize PCB
3/7	Talk to machine shop	Test/simulate PCB	Research programming microcontroller
3/14	Start web app	Test PCB	Program microcontroller
3/21	Work on integrating web app with microcontroller	Make PCB revision	Test PCB with microcontroller
3/28	Combine modules	Combine modules	Combine modules
4/4	Final assembly	Final assembly	Final assembly
4/11	Testing	Testing	Testing
4/18	Mock demo	Mock demo	Mock demo
4/25	Demonstration	Demonstration	Demonstration
5/2	Presentation and final paper	Presentation and final paper	Presentation and final paper

4 Ethics and Safety

Section 1.1 of the IEEE Code of Ethics states: “to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment” [2]. This relates to our project because we will be working with lithium ion batteries and electrical power. We will uphold Section 1.1 of the Code of Ethics and make sure to follow safety procedures with our battery. Also, we will keep in mind the sometimes questionable ethics of solar panels. Polysilicon, a key component of solar panels, has a lot of poor environmental and labor practices where it is mined [3]. Also, the recycling of solar panels limits their ideal use for environmental sustainability [4].

References

[1] “Data Portal,” *Engineering Career Services*. [Online]. Available: https://ecs.engineering.illinois.edu/data-portal/. [Accessed: 24-Feb-2022].

[2] “IEEE code of Ethics,” *IEEE*. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 24-Feb-2022].

[3] J. Gudmundsen, 2020 Jason Hayes | March 25, and 2020 Jack McHugh | December 18, “There are ethical concerns surrounding solar energy,” *Mackinac Center*. [Online]. Available: https://www.mackinac.org/the-ethical-concerns-surrounding-solar-energy. [Accessed: 24-Feb-2022].

[4] V. Taylor, “The complicated ethics of solar power,” *Mic*, 26-Oct-2021. [Online]. Available: https://www.mic.com/impact/solar-power-ethics-sustainability/amp. [Accessed: 24-Feb-2022].