Designing a Self Powered Solar Tracking Device

Eng 100 Section 420 Final Project Report

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Team Frozen Grapes

Christina Sheckler
Rishab Lanka
Hypatia Magyar
Sasha Bacon

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Prepared for :

Dr. Erik Hildinger, Lecturer IV in Technical Communication

Zhaohui Zhong, Associate Professor: Electrical Engineering and Computer Science

ABSTRACT

The authors were tasked to design and test a self-powered and free-standing solar panel device capable of tracking the brightest point in the sky using servo motors across 2 axes. Using bluetooth, the device should send ambient temperature, sun position, and irradiance data received by the device to a computer. We completed 4 preliminary labs to learn the necessary skills to build this device. Our design solution was a structure made out of two main parts, the platform and the base. The platform holds a solar panel and photoresistors. The photoresistors read voltage from the light source. The device works by moving in the direction of the photoresistor of highest voltage reading until the solar panel faces the sun. In the lab, we tested the physical structure, single axis tracking, double axis tracking, and bluetooth data transmission. These tests were successful. We successfully designed the device according to the constraints given. If given more time, we would replace any tape used in the device with more permanent adhesive and color code and shorten the wires to decrease confusion.

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INTRODUCTION

The objective of the final project of engineering 100 section 420 is to build a self-powered device that can track the sun as it moves across the sky. The project is subject to the following requirements. The device must be self-powered by a solar cell with battery storage. This allows the solar cell to charge the battery so the battery can power the device if there is not enough light. The device must be able to find the sun even if the device is initially pointed away. The device must be able to wirelessly report data, including ambient temperature, sun position, and irradiance, by Bluetooth at regular time intervals. The device must be portable and freestanding. The device's height, width, and weight must be minimized.

As an optional challenge, the average power used for tracking should be minimized. The device must be constructed from the following materials - solar cell, Li-ion battery, maximum power point tracker (MPPT)/Li charging controller, microcontroller (Redboard), Bluetooth serial module (HC-05), timer circuit, optical sensors, servos, resistors, switches, LEDs, breadboard, wire, soldering equipment, materials for mechanical assembly.

BACKGROUND/METHODOLOGY

The goal of this project was to build a self-powered device that can track the sun as it moves across the sky. Over the course of 4 labs, we learned the skills necessary to complete this task.

Tracking Irradiance

To make the solar tracker able to track the sun even if initially pointed away requires the ability to program the software to track irradiance, which we did in Lab 4 on the topic of power management with solar cells.

Circuit Diagram

To draw the diagram of the solar tracker requires the ability to read and create an electrical circuit diagram, which we did in Lab 1 on the topic of circuits.

Servo Tracking

To make servo move the solar panel requires the ability to program the software to manipulate the servo, which we did in Lab 3 on the topic of power management with solar cells

Maximum Power Point Tracker (MPPT)

To provide the proper charge profile for the lithium battery requires the ability to integrate the Maximum Power Point Tracker (MPPT) into the solar circuit, which we did in Lab 3 on the topic of power management with solar power.

Soldering

To make the solar tracker have strong electrical connections requires the ability to solder, which we did in Lab 4 on the topic of power management with solar power.

Battery

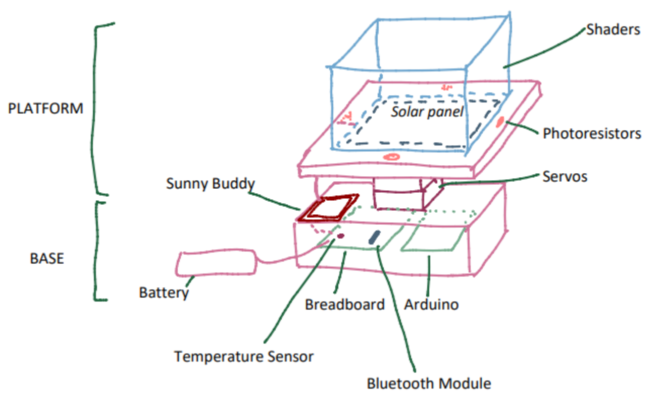
To power the solar circuit requires the ability to integrate the Li-Ion Battery into the solar circuit, which we did in Lab 4 on the topic of power management with solar power.

DESIGN DESCRIPTION

The device (Figure 1) is made out of two main parts, the platform and the base. The platform holds a solar panel and photoresistors. The photoresistors read voltage from the light source, and the device works by moving in the direction of the photoresistor of highest voltage reading until the solar panel faces the sun.

The platform is made out of a thin wood panel with four photoresistors along its edges. A solar panel is glued to the middle of the panel and four opaque shades separate the solar panel and the photoresistors. This placement causes the shades to cast shadows on some of the photoresistors, exaggerating the differences in readings between them. From this the code can clearly identify the photoresistor with the highest reading. Two servos are attached to the platform, one that tilts the platform and one that turns it. The two opposite photoresistors along the width of the platform correspond to the turn axis and the two opposite photoresistors along the length of platform correspond to the tilt axis. The code starts with the turn dimension, moving the turn servo one degree in the direction of the highest photoresistor on the turn axis. This repeats until the two turn photoresistors have similar voltages, and then the code moves on to the tilt axis and does the same movement with tilting instead of turning. Once both axes are about equal in voltage, the solar panel will be facing the brightest point in the sky. The turn servo can’t rotate past a certain point, so to account for this an edge case code sends the turn servo forward or back 180 degrees and flips the tilt servo to the opposite side.

The base is made out of two wooden panels and four plastic pillars. The panels and pillars make a hollow box that fits an Arduino, breadboard, and battery. A Sunny buddy is a small device that optimizes power output from a solar panel to a battery. A Sunny buddy is secured on top of the base and connects to the solar panel and the breadboard. The breadboard connects to the battery as well, allowing the solar panel to charge the battery and the battery to power the solar panel. The breadboard also connects a bluetooth module, a temperature sensor, and the Arduino to power. The bluetooth module sends the reading from the temperature sensor, position, and irradiance data wirelessly to our computer.



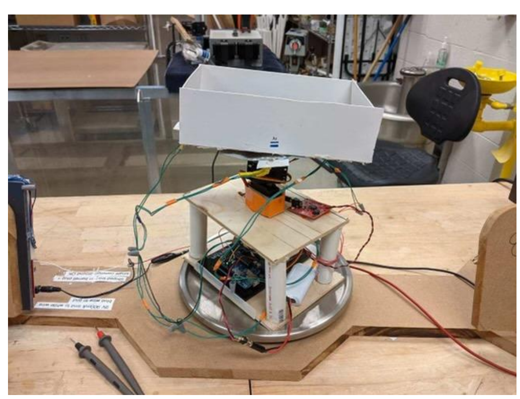


Figure 1 : Diagram of the structure of device and photograph of device

RESULTS OF TESTING

Below is a discussion of the results of testing. The device as a whole was very light and compact. It has a base with dimensions 15.7 x 10.8 cm, and a height of 29.5 cm. The deceive weighed 932.8 grams without the battery and 1027.1 grams with the battery. The solar panel discharged the battery at an irradiance less than 400, powered the device without discharging or charging the battery at an irradiance of 400, and charged the battery at an irradiance greater than 400. To test the device's ability to track the sun, we used a "mock sky". This is a machine that powers multiple light bulbs equidistant from each other in a semicircular arc. It turns on the light bulb on one end and then progressively powers the next light bulb while turning off the previous bulb, making a moving light source.

Link to Video of Device Tracking the Sun

Below is a link that shows the device successfully tracking the sun in the mock sky while reporting bluetooth data.

https://photos.app.goo.gl/2E8XKYGiXFMiZBP76

Testing the Physical Structure

The efficiency and strength of the styrofoam platform was tested by observing it on the servos while the code ran and a light was shining on the photoresistors. Upon testing, we discovered while functional, it was not optimal. The styrofoam was wobbly and too large. After 3 labs, the team decided a wood platform would be more efficient. The efficiency and strength of the wood platform was tested by observing it on the servos while the code ran and the device was under the mock sky. This test was successful; the platform was lightweight, compact, and strong.

Testing Single Axis Tracking

Single axis tracking was tested with the styrofoam prototype platform. The platform was not yet connected to the servos, so a lamp was used to test the photoresistors' ability to track. This test was successful.

Testing Double Axis Tracking

The device should be able to track the sun as it moves along the semicircular sky. The device should also be able to track the sun left to right, perpendicular to the semicircle. To do this, the device must move in two axes. To test double axis tracking, we initially shined a lamp light on one side of the photoresistors to see how the device would react. Initially, the device was very jerky and could not track the light very well. Upon conferring with our GSI, we discovered that the code contained two serious errors. The code integrated the turn and tilt axis tracking instead of having them track one after the other. Second, it assumed both servos tilted insead of one tilting and one turning. After editing the code, we tested the servo again by shining a light on one side of the photoresistors. The device worked much better, however, the servos were jerky. We discovered that it was because the servo movement was being interrupted by the Bluetooth code's print statements. Upon correcting this error, we tested double axis tracking by shining a light on both sides of the photoresistors, then by putting it under the mock sky, and the tests were successful.

Testing Bluetooth Data Transmission

Bluetooth was tested by implementing the bluetooth code into the device code and seeing if the data was successfully wirelessly reported. Upon the first test of Bluetooth, the values did not display. This error was corrected by changing the entrance statement for our bluetooth function to something less specific. Upon the second test of Bluetooth, we saw that the device stuttered and jerked as it moved. We discovered this was because the Bluetooth was taking too long to run and interrupting the servos' movement. To correct this error, we made the Bluetooth run less and print less characters. Upon the third test of Bluetooth, the Bluetooth was successful. As shown in Figure 2, the data reported back T, Pos x, Pos y, and Irr. T is the temperature in Celsius. Pos x is the angle of the tilt servo. Pos y is the angle of the turn servo. Irr is the irradiance measured.

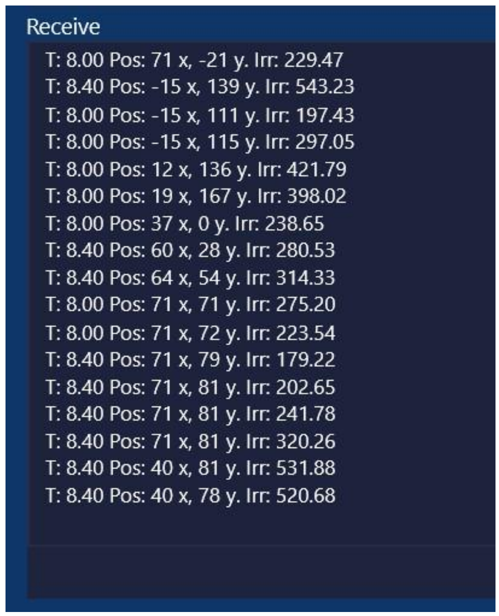


Figure 2 : Bluetooth data reported back, including : temperature in celsius (T), position x - the tilt position measured from the normal angle of the servo (Pos : x), position y - the value is the turn position of the servo (Pos y), and irradiance measured (Irr)

Solar Battery Discharge/Dissipation

For this test we measured the current coming from the battery at irradiances of 170, 400, 460, and 500 W/m^2 by connecting an ammeter in series with the battery. Irradiance is a measure of power/area, the intensity of the light. We found where the battery was discharging and charging. At an irradiance of 170 (the irradiance of the mock sky) the battery was discharging. At an irradiance of 400, the battery was discharging. At an irradiance of 460, the current was 0, meaning the solar panel produced just enough power to power the system. At an irradiance of 500, the battery was charging (Table 1).

Table 1: Current from battery to solar panel

Irradiance	Current(A) from battery to solar panel
170	0.0851
400	0.0145
460	0.0000
500	-0.0154

CONCLUSIONS

Our team was successful in designing and building a self-powered device that could track the sun as it moves across the sky. Throughout the process, we learned about tracking irradiance, drawing circuit diagrams, programming servos, MPPTs, soldering, and integrating batteries into solar powered systems. Reflecting on our design, the strongest part was the wood platform design. This was very effective at keeping the solar panel in place, and was a minimal height and weight.

The weakest part of our design was the wiring and tape in the device. The wires were messy and tangled. The tape within the device made the device flimsy long term. To improve the device, we would color code the wires and make them shorter, and screw in parts of the device that were taped. If we made those specific changes, we would expect the device to have a more professional appearance and to be sturdier.

Reflecting on the design changes we made, our initial code was a midpoint method-like code. After talking to John Getsoian and our GSI Anand Asokan, we came up with a better method: using shadows to obstruct the light. Also, our initial plan for the platform was to use styrofoam because it was lightweight. Upon further testing, we found that it was not durable and too large for our solar powered device. Furthermore, the weight distribution of the original cardboard shades on the styrofoam made the solar powered device unstable. To fix this problem, we replaced the styrofoam with a thin wood material. We also used new shades made out of a hard card that were smaller and more securely in place, as the previous shades were too tall and blocked the light reaching the sensor while also being flimsy.