Solar Tracker

By

Team Sunflower

Caroline Collins

Daniel Erickson

John Keane

Juliana Rodich

Prepared For

Dr. Zhaohui Zhong, Electrical Engineering and Computer Science Department, University of Michigan

Dr. Erik Hildinger, Technical Communications Department, University of Michigan

Dates of Project: 22 February 2021 to 12 April 2021

Date Report Submitted: 25 April 2021

ABSTRACT

We were tasked to build a device which actively angles a solar panel towards the sun to maximize power generation. The device was required to track the sun across the full range of the sky, wirelessly report environmental condition data, power itself using a solar panel and rechargeable battery, and occupy minimal height and weight. Four introductory labs were completed in order to learn the skills necessary to complete this project. Throughout the eight week project, the solar tracker device was designed, built, and tested weekly during the given lab time. The device was successfully completed on time, met all given design constraints, and passed all performance tests.

TABLE OF CONTENTS

INTRODUCTION

The objective of this project was to build a self-powered solar tracking device which has the ability to track the sun and position a solar panel to the optimal location to take in the most light. The solar panel was required to charge a lithium phosphate rechargeable battery using energy from the sun, and the battery is required to provide power for the electronic components of the solar tracker. In addition, the solar tracker needs to be able to wirelessly report environmental condition data via Bluetooth. The solar tracker should be portable and freestanding with minimal height and weight.

BACKGROUND AND METHODOLOGY

Over the course of the first four lab meetings, we learned the skills necessary for the completion of a solar tracker with the given design constraints. These labs introduced basic circuit design and construction, the function of solar cells, battery and solar cell power integration, and the use of Arduino microcontrollers.

Circuit Design and Solar Cells

To complete the final solar tracker, knowledge of circuit construction and solar cells was necessary. This design constraint required wiring electrical components into a breadboard. This was learned in Lab 1, where we were tasked with translating schematic circuit diagrams into physical circuits and testing different components of these circuits for their voltage and current. The design constraints also required knowledge of the function of a solar cell, which was discussed in Lab 2. In Lab 2, a circuit with a solar cell and resistor was built, and current and voltage were measured through various resistances and irradiances to determine the resistance and irradiance conditions for maximum power generation. This lab provided important background information on solar cells and basic circuit construction which was necessary for the completion of the solar tracker.

Battery and Solar Cell Power Integration

The solar tracker was required to receive power from a lithium phosphate battery and a solar cell. During ideal lighting conditions, the solar cell needs to power the device and charge the battery, and when the sun does not provide enough irradiance, the battery needs to power the electronic components. This design constraint requires knowledge of how to integrate a battery into a solar cell circuit. In lab 3, a lithium phosphate rechargeable battery was connected into a circuit with a solar cell and load resistor, and load voltage and battery current were measured for different load resistance and irradiance values. These data were used to determine what irradiance and load resistances would allow the solar cell to charge the battery. This circuit was the foundation of the battery integration circuit of the final solar tracker.

Reading Sensors with Arduino Microcontroller

The solar tracker was required to angle itself perpendicular to a detected light source as well as report ambient temperature data while running. These skills were developed in Lab 4, where an Arduino microcontroller, a temperature sensor, and two photoresistors were used to create a temperature sensor circuit and a light detection circuit. The temperature sensor circuit used a temperature sensor and a microcontroller to report the temperature of the sensor to the serial monitor of the Arduino program on a computer. This circuit was used in the final solar tracker to report ambient temperature. The light detection circuit contained two photoresistors, an Arduino microcontroller, and a cardboard light blocker. The irradiance data from the photoresistors was reported to a computer, which determined which side of the blocker the light was on and wrote ‘right’ to the serial monitor when there was more irradiance on the right side of the circuit and wrote ‘left’ to the serial monitor when there was more irradiance on the left side of the circuit. This circuit design was modified for the final solar tracker, but the simple light detection circuit became the foundation of the sun detection system used in the final product.

Technical and Programming Skills

The solar tracker was required to track the full span of the sky with 360 degrees range of motion. This design constraint required the movement of two servo motors across two different axes that the solar panel was mounted to for full range of motion. The code written in the Arduino program causes the servo motors to move in the direction of the photoresistor with the most light detected. The Arduino programming skills were learned in a combination of lab 4, where code was written to output the results of the temperature sensor circuit and the light detection circuit, and engineering homework using the Sparkfun Inventor's Kit. The solar tracker also required permanent wiring, which was achieved using soldering. This skill was developed during a tutorial in the lab and was implemented on the wiring of the photoresistors on the final device.

DESIGN DESCRIPTION

The solar tracker is composed of six important components that comprise two main categories. The wooden base, servo motors, and solar panel mount create the structure of the solar tracker and the photoresistors, Arduino microcontroller, and power integration circuit make up the electronic components. The photoresistors and solar panel are attached to the solar panel mount, which is attached to the servo motors, which in turn are attached to the base which houses the electronics. The Arduino microcontroller takes in the sensor inputs from the photoresistors and moves the servo motors in response to lighting changes. The solar cell powers the device while exposed to the sun, and the battery provides backup power in the absence of light. The fully assembled solar tracker is shown in Figure 1 below.

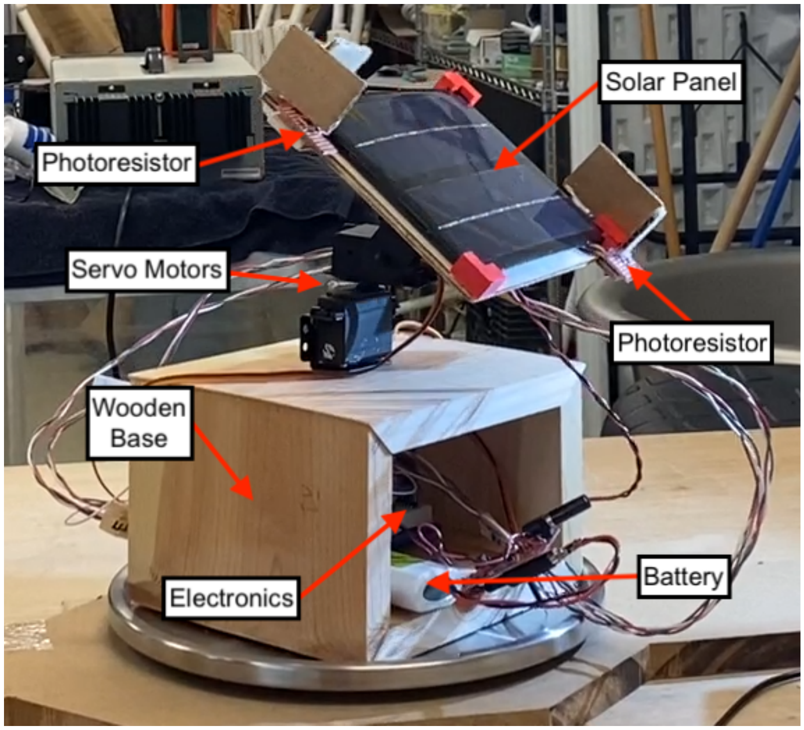

Figure 1: This figure shows the solar tracker with the major components labeled.

Base

The base was constructed from a sheet of three-quarter-inch plywood. The four sides were cut out with a 45º beveled edge and attached together with wood glue. This base serves as a solid foundation for the rest of the assembly and provides a protected housing for the electronics.

Servo Motors

Two 180º hobbyist servo motors were attached to the base using an aluminum mount; both of these components were provided as part of a kit during lab time. These motors operate at 6V and are controlled using the built-in Arduino Servo library on the Arduino microcontroller. One servo motor was attached parallel to the ground and controlled horizontal rotation, and the other was attached perpendicular to the ground and controlled vertical rotation.

Solar Panel Mount

A custom mount for the solar panel was constructed from quarter-inch plywood and custom 3D printed plastic corners. The corners were attached to the wooden panel with wood glue. They also had detachable caps which fit over the solar panel, which allowed for easy installation of the panel without obstruction of the solar cells. The solar panel mount also contained small protrusions for mounting the photoresistor sensors.

Photoresistor Sensors

Four photoresistor sensors were attached to the solar panel mount and separated by cardboard barriers. The sensors were soldered onto small circuit boards, which were then hot glued onto the solar panel mount. This configuration allowed the Arduino microcontroller to determine the angle of the light source and move the servo motors accordingly.

Power Integration Circuit

A lithium phosphate battery was integrated with the electronics and solar panel to store extra solar power for use during poor lighting conditions. The battery was connected with a barrel plug to a small power integration circuit, which also connected the solar panel and Arduino microcontroller in parallel. This system enabled the solar cell to power the electronics and charge the battery during ideal lighting conditions and then activate the battery during poor lighting conditions. The system also allowed the Arduino microcontroller to receive a steady 6V supply of power so that the system would remain functional at all times.

Arduino Microcontroller

An Arduino microcontroller, which is a small computer used in robotics applications, collected all data from the various sensors and controlled the position of the two servo motors. The Arduino received a 6V power supply from the power integration circuit and then output a 5V supply to the sensors. The power circuitry was greatly simplified by relying on the Arduino's built-in power management system for the sensors. The Arduino also was connected to an HC-05 Bluetooth module, which broadcast environmental data to a computer.

TEST RESULTS

This project required multiple rounds of testing to ensure each individual component of the design worked properly before integrating everything together. We tested single axis tracking, dual axis tracking, bluetooth data reporting, and battery dissipation. Successful testing in all of these categories ensured all design criteria were met

Successful Single Axis Tracking

Single axis tracking was tested by having two photoresistors wired to a breadboard separated by a piece of cardboard. A lamp was shone on either side of the cardboard, and the Arduino successfully moved the servo motor in the direction of the light and stopped it when perpendicular to the light

Successful Dual Axis Tracking

The solar tracker was tested for dual axis tracking by using the mock sun device which contains several LED lights that illuminate over time in an arc shape to mimic the path of the sun. The mock sun device with the solar tracker placed beneath is shown in Figure 2 below. The panel was placed in the mock sun device and then rotated before turning on the mock sun device. The solar tracker was expected to find the light at the beginning of the cycle and follow the light as it moves in an arc. The solar tracker successfully tracked two complete cycles of the light in the mock sun system and passed the dual axis test.

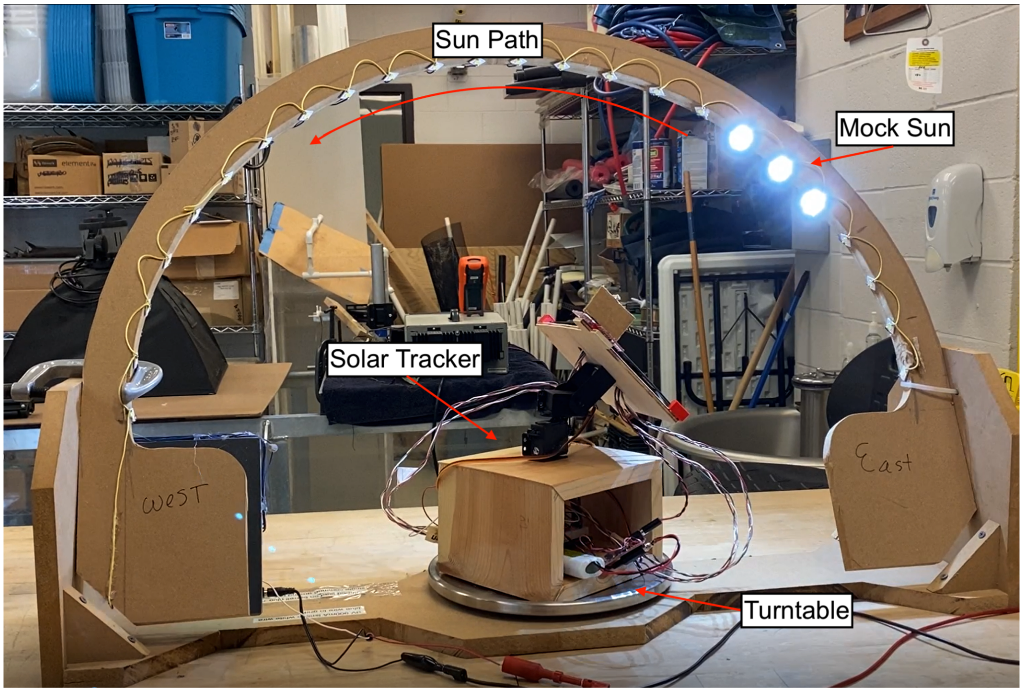

Figure 2: This image shows the solar tracker being tested for dual axis tracking ability in the mock sun device. The lights move over time from the right side of the device to the left side of the device and reset to the right side of the device eventually.

Successful Bluetooth Data Reporting

The data reporting via Bluetooth was tested while the device was placed in the mock sun system. The Bluetooth system successfully wirelessly reported the sun position angle relative to the panel, the ambient temperature, the current irradiance reaching the panel, and the current time of operation every five seconds.

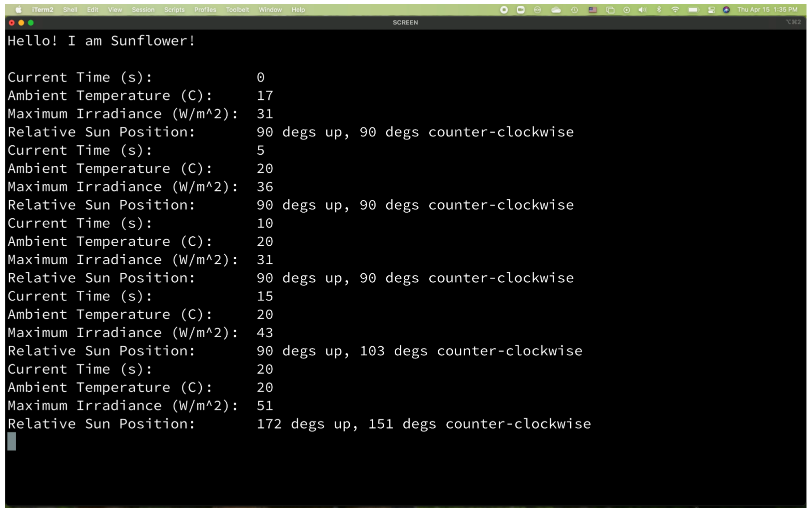

Figure 3: Serial terminal displaying bluetooth output from Arduino bluetooth module during a test.t Every five seconds, the ambient temperature, sun position, and irradiance are reported. The Maximum Irradiance label on the computer is mislabeled and actually represents the current irradiance on the solar tracker.

Successful Battery Discharging

The battery discharge was also tested while the solar tracker was placed inside the mock sun system. The servo motors, microcontroller, and all other electronic components were only powered by both the panel and battery, and the device was not connected to an external power source during the test. The mock sun does not produce enough power for the solar tracker and there was no other power source, so the solar tracker was clearly receiving power from the battery. Although there was not enough time to ensure that the panel could properly charge the battery in a test with higher irradiance, based on our tests and conclusions from Lab 3, we are confident that the battery will charge with enough irradiance.

CONCLUSION

After completing all testing and utilizing all available time, we reviewed the device to note our accomplishments and design strengths and weaknesses. Additionally, we critiqued the design and discussed possible future changes to the device to improve functionality.

Achievements

Overall, our team successfully completed the construction of the solar tracker, and the solar tracker met all major requirements for the project. Throughout the labs and construction of the project, our group learned many technical skills including how to construct circuits, how to solder, how to measure and track voltage, power, and current, and how to use a microcontroller. Our team also developed many non-technical skills such as teamwork, communication, and planning as a result of working in a group.

Design Changes

During the course of the project, we changed several components of our design. The solar panel mount was originally planned to be entirely 3D printed as one piece, but instead we used wood for the panel and 3D printed corner pieces to hold the panel in place. This change was made because it was not possible to 3D print such a large piece with the printers that were available.

We also made a major change to our microcontroller code. We originally relied on the Arduino Software Serial library for bluetooth transmission, but this library interfered with our ability to upload code to the Arduino. After significant troubleshooting, the Arduino was reset and the software was rewritten to use the built in Serial library. This library utilizes the hardware serial controller on the Arduino and therefore does not hinder communication. While some flexibility was lost in this transition, all critical components still worked as intended and so the change was deemed beneficial.

Design Strengths

One of the strengths of the design is that the mount and base are well constructed and sturdy which allows the device to be portable and mobile. Another strength of the device is the accurate and efficient tracking ability. The solar tracker is accurately able to detect a light source from any direction when the tracker is in its initial position and the panel is parallel to the ground. This prevents the tracker from scanning for a light source and wasting energy. The device will also quickly and accurately rotate to face the light source, and if no light source is found, the device will rotate to its initial position and will be able to track a light source from any direction again.

Design Weaknesses

One design weakness of the device is the lack of neatness in the wiring. Although electrical components functioned properly, the wiring was not organized well, and it can be difficult to determine which parts of the circuit are connected. Another design weakness is that the servo had a dead zone in one area, and this caused the solar tracker to shake when it reached a specific position.

Design Critiques

One design critique was that the reset function of our device was not perfected and occasionally the device would not reset fast enough to track the sun for the second cycle or would reset just before the sun had completed a cycle. The device was programmed to reset the servos to a neutral position parallel to the ground after five seconds of minimal irradiance detected by the photoresistors. The solar tracker can track the light at any angle as long as it starts in a neutral position, so the solar panel needs to reset to neutral after the light source disappears at the end of a day cycle. Unfortunately, the irradiance threshold value and time to reset was not perfected, and if there was more time, our group would attempt to optimize the irradiance threshold value and time to reset to reduce errors.

Another change we would make in the future would be to create our own servo motor mounting assembly. In our final design we used a hobbyist servo motor kit which we received during the lab time, but the connection to the horizontal servo motor was weak and deteriorated over time. This caused performance issues and stuttering during the final testing.

Appendix A

This link goes to our team's GitHub repository which contains all of our source code for the Arduino microcontroller. In the repository is the Arduino sketch file and a file called README with more information about the code. Please contact one of the authors if you have an issue accessing the repository.

https://github.com/derickson2402/Engr100-Solar-Tracker

Appendix B

The following link goes to a video in Google Drive which demonstrates the two axis tracking ability of the device in the mock sun system. Please contact one of the authors if you have an issue accessing the video.

https://drive.google.com/file/d/1TMwCJCDU8XBB-Pi7SxMaHpwk7iwLLQxL/view?usp=sharing