ELEC 327 Final Project Report
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Light-Tracking Solar Array

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Initial Design Concept:

The goal of this project was to design and implement a light-tracking solar array system that maximized energy harvested by rotating a mounted solar panel towards the direction of highest light intensity. Unlike conventional static-mounted solar panels, this system would use light sensors and servo motors to dynamically adjust the panel's orientation in two degrees of freedom (yaw and pitch), improving its efficiency across varying lighting conditions. LEDs may also be included to visually indicate the intensity of light captured by the sensors. A battery may be used to power the system such that, with the aid of the solar panel, the system is able to power itself.

The system would be built around a MSPM0+ microcontroller (specifically the Texas Instruments MSPM0G3507xPM in 64 LQFP package configuration) that reads analog signals from an array of light sensors positioned radially around the panel. By comparing these light intensity inputs, the microcontroller determines the direction of maximum illumination and uses servo motors to adjust the solar panel orientation accordingly.

Initial Projected Component List:

- Photoresistors
    - Positioned in two arrays of four radially on the solar panel to detect light intensity in different directions.
    - Their resistance changes with light intensity, enabling a voltage divider to be used to provide varying voltage readings to Analogue to Digital Conversion (ADC) pins that can be used to gauge light intensity.
- LED indicators
    - Positioned to correspond with each sensor, with higher light intensity corresponding to brighter LED.
- Servo Motors (FS5103R)
    - Enables movement in two axes, giving the panel flexibility to track both horizontal and vertical changes in lighting.
    - Controlled by PWM signals from the microcontroller
- Microcontroller
    - Interfaces all the individual components and handles collecting sensor data and processing which light source has the highest intensity.

Printed Circuit Board (PCB) Schematic and Layout:

The schematic in Figure 1 and layout in Figure 2 reflects our final PCB design, created in KiCad.

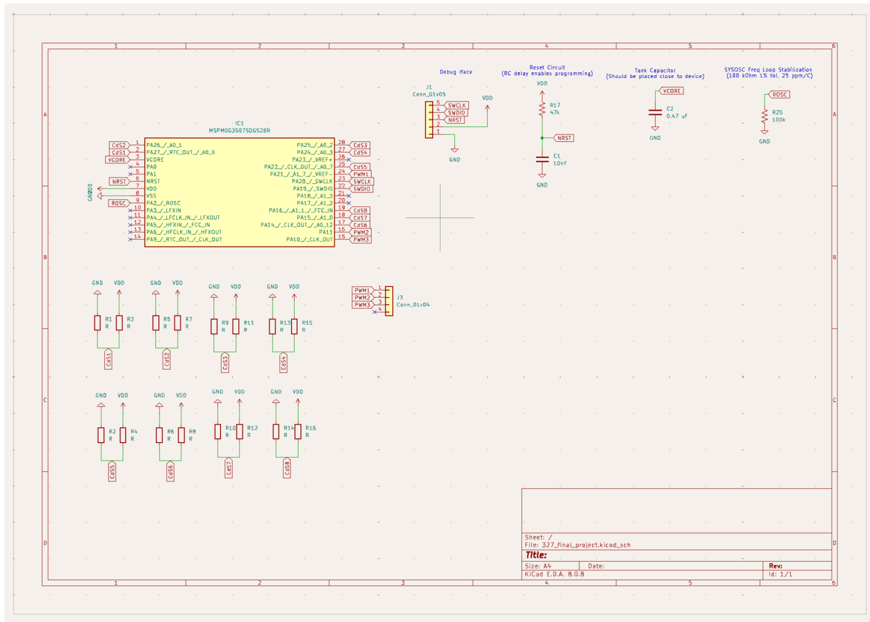

Figure 1: Schematic of PCB Design

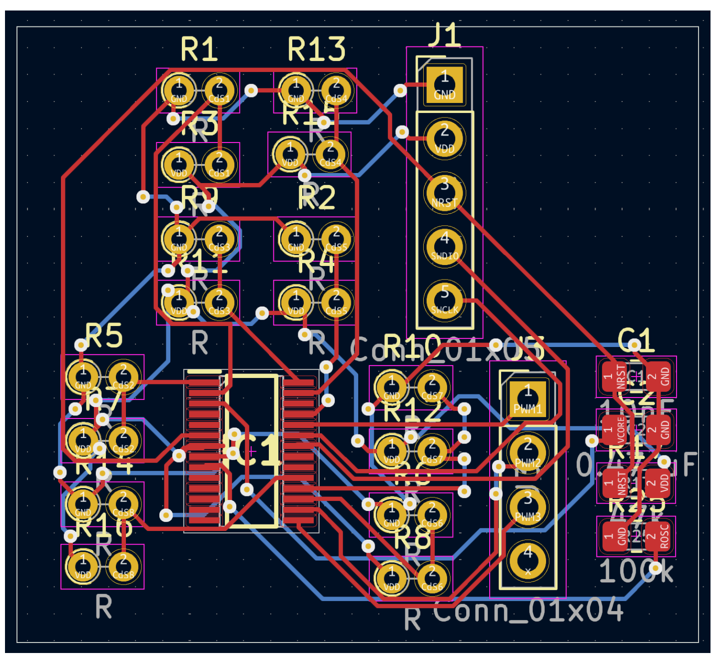

Figure 2: Wired PCB design

3D Printed Parts Designed Using CAD (Fusion 360)

Below is an image showing the custom designed parts for the project (Figure 3)

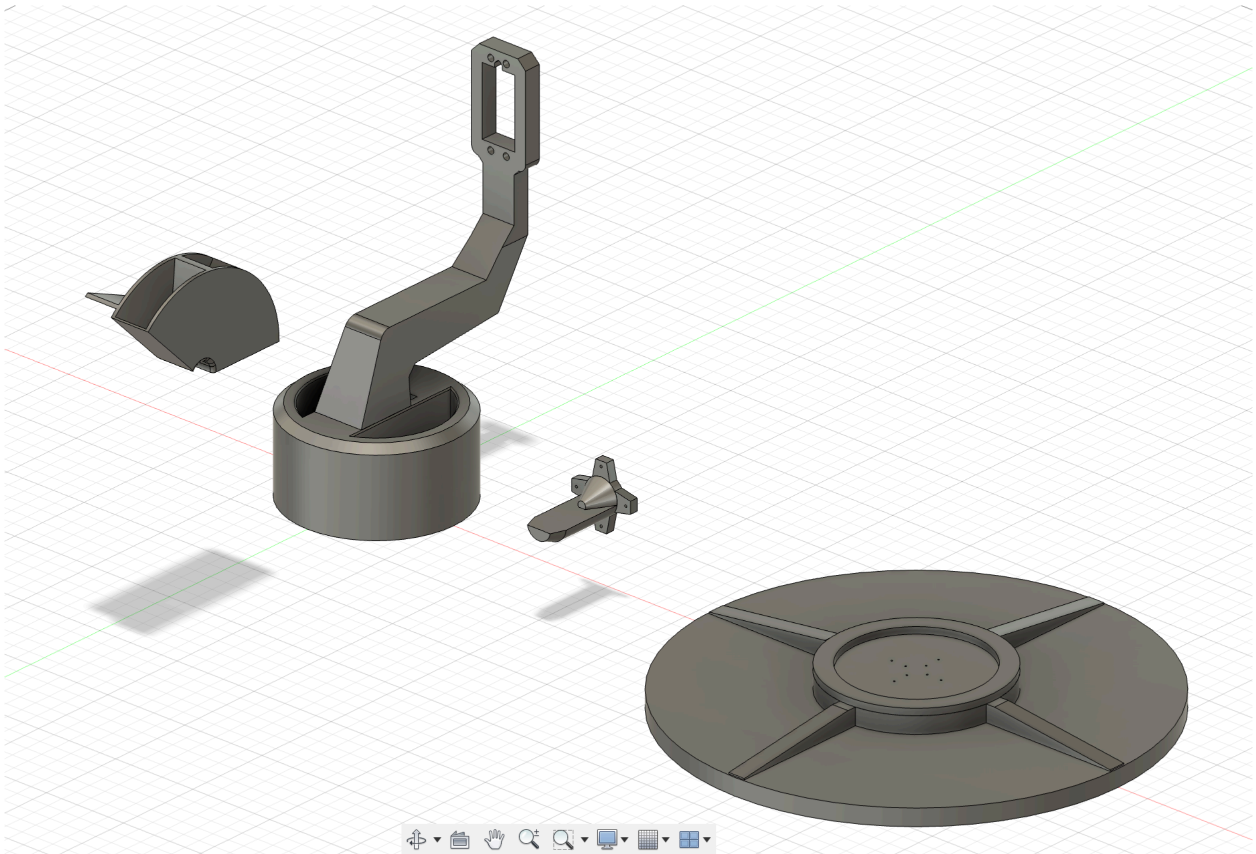

Figure 3: From Left to Right - Sensor Array Mount, Arm, Servo Attachment, Base

Actual Physical Implementation & Differences From Concept:

Our final achieved physical implementation accomplishes most of our original design goals. The specific components of the original concept are discussed below.

Overall function:

The overall tracking function of the project works as initially conceptualised. The system is able to rotate to the closest light source detected and maintain the panel's normal vector within about a 25 degree angle to the true direction of highest light intensity. This was successfully achieved using 2 arrays of photocells that act as light intensity sensors when used in a voltage divider and read by the microcontroller's ADC input pins. Two servos running on 3.3V and being controlled by PWM generated by timers on the microcontroller allow for yaw and pitch of the panel so that it is able to orient its normal vector in any direction in 3D space.

Photocell Implementation and ADC Functionality:
Each photoresistor and pull-down resistor form a voltage divider with one end being 3.3 V, the other end being ground, and the middle connects back in the ADC pin of the microcontroller. Based on using 3.3V, the pull-down resistor was chosen to be 2.2kΩ.

For each photoresistor, the changes in voltage value are reflected back into the microcontroller as a digital integer, where a lower number means more light detected by the photoresistor and a greater number means less light detected by the photoresistor.

The microcontroller comes with two 12-bit 4-Msps ADCs, so the ADC conversion of photoresistor cell voltages was done through the internal ADC of the microcontroller. Based on the datasheet, 8 pins were initially chosen that correspond to different ADC pins on the microcontroller, where each photoresistor is attached to a separate ADC pin. Through changing the ADC system configuration to sequence, multiple ADC conversions across different ADC pins were functional at the same time. Each photoresistor cell was converted back into its own variable that stores the digital value and updates every time a resampling occurs based on the servo movement.

However, there was trouble with doing ADC conversions across both ADC0 and ADC1. As a result, using only ADC0 allowed us to convert a maximum of 6 photoresistor cells back into the microcontroller. This resulted in using 3 photoresistors per array instead of the originally planned 4 photoresistors per array. While using only 3 sensors per array still allows relatively precise tracking, it is not as precise as the original planned array of 4 as it no longer allows for proper “gradient descent” towards the light source direction. Instead, to mitigate this issue as much as possible, the angle of light exposure of the center sensor was made significantly narrower so that it acts as a sort of stop signal sensor to indicate when to stop rotation.

Servo Control
The control of the servos was successfully implemented by adapting logic used in Lab6 and the midterm project to produce PWM systems using timers and the compare/capture functionality.

The servos themselves required a PWM signal period of 20 ms, with a pulse width between 500 to 2500 us to control the rotation direction and speed. To produce a compliant PWM signal that would work on our 16 bit timer/comparators, our timers had to the system clock but pre-scaled by a factor of 2. The resultant clock was then further divided by 8 to get a final clock frequency of 4MHz. The compare/capture registers were then set appropriately in the main function based on this frequency to provide PWM signals between 500 to 2500 us.

Use of PCB
There were issues with integrating the PCB for use. The IC we used was the MSPM0G3507xDGS28R. During testing and debugging phases, we repeatedly found that we faced DAP connection errors, likely due to the fact that the IC incorrectly soldered onto the PCB.

Using an oscilloscope to probe VDD on the PCB, we were able to see that the voltage was stable at the pad of the IC, but noisy when we probed the leg. This issue could be because there was not enough solder to create a stable connection, leading to increased contact resistance and an intermittent electrical path. This would cause the voltage at the leg to fluctuate under load or due to slight physical disturbances, directly impacting the IC's ability to maintain stable operation and communicate effectively with the debugger. Unfortunately, due to time constraints, we were unable to fully resolve this soldering issue before the submission deadline.

Self-Powering Ability

Unfortunately, due to persistent issues with PCB integration and time constraints, we were unable to integrate the panel’s power output into the circuit. Instead our final design used the 3.3V power pins and the ground pins on the Launchpad to power both the servos as well as serving as the Vdd of our photo cell voltage dividers.

LED Visual Indicators For Light Intensity

Unfortunately, due to time constraints, certain features needed to be omitted so as to complete the project on time. This functionality was deemed non-critical to the core function of tracking. As such it was not included in the final design.

Evaluation & Improvements

Our main potential avenues for improvement are the features that we were unable to implement in time. We had already bought a battery and a charging circuit that would have enabled us to utilize the panel’s output to supply power to our system.

Overall the project achieved its primary goal, which was to demonstrate that the microcontroller is successfully able to control a moving system that tracks sources of high light intensity. All tracking and movement related design goals initially laid out were met.