Chapter 6

Sustainability and Renewable Energy

6.1 Introduction

The Sustainability and Renewable Energy field addresses global technological challenges balancing societal needs with environmental and economic tradeoffs. Topics addressed include energy conservation through more efficient electronic systems, intelligent energy management through smart grid approaches, and renewable technologies including solar PV, wind, and wave for energy generation and distribution. Students pursuing the Sustainability and Renewable Energy track will engage in leadership development and demonstrate their leadership through community service related to sustainability. It is recommended that the leadership service take place as part of an international experience.

6.2 Section Overview

In lab you have done a number of activities dealing with the various electrical and computer engineering tracks here at OSU. However, many problems you'll deal with in the future will involve multiple electrical engineering disciplines. This week's lab involves using photovoltaic cells (sometimes known as solar cells), which encompasses two of the tracks you have covered before: Materials & Devices and Energy Systems. Ideas from these two tracks are combined to use a green form of energy and relates to the new Sustainability and Renewable Energy track.

The completion of this project will result in an efficient Solar Cell Positioning unit. The Tiny26 will rotate a motor with a solar cell attached to it. We will be reading the voltage of the solar cell using the ADC (Analog-to-Digital Converter) in the Tiny26, and storing that data. Then, the motor will rotate back to the point where the voltage from the solar cell was highest (where it is converting the most energy).

6.3 Objectives

In this section, the following items will be covered:

1. The Engineering Method
2. Solar Energy and the integration into electronics
3. Analyzing efficiency tradeoffs

6.4 Materials

1. ECE 111 Kit
2. Photovoltaic cell
3. Tiny26 Microcontroller (tiny26.1)
4. Solar Tracker code from the ECE 111 Repository for the Tiny26

6.5 How Light is Affected by the Angle

The amount of light and heat energy received at a point on the globe is directly affected by the angle the sun's rays strike the earth. This angle is affected by location, time of day, and season because the Earth is constantly orbiting around the sun and revolving upon its tilted axis. As shown in Figure 6.1, the reason that the poles are colder and have greater fluctuating day lengths than the rest of the earth is because the sunlight is spread over a greater area in those regions, and because the light also has to go through twice as much atmosphere, further dissipating the rays and reflecting more of the energy back into space.

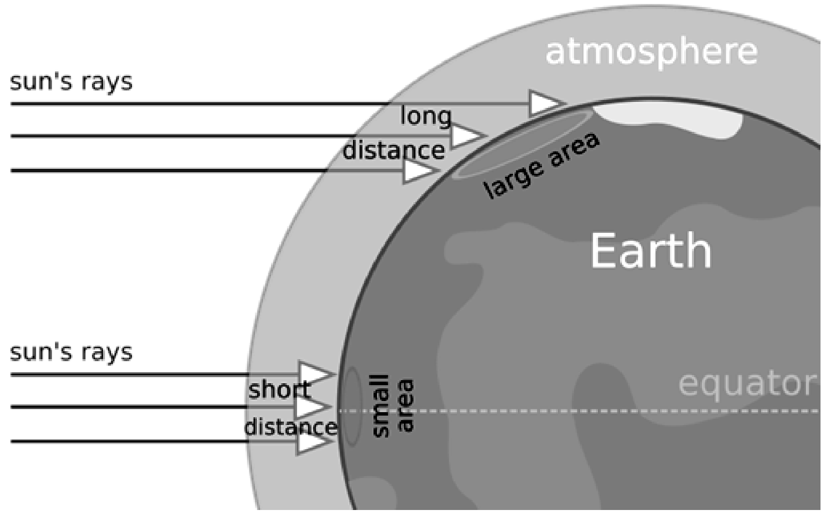

Figure 6.1: Sun's Rays hitting the Earth

6.6 Photovoltaic Cells

A photovoltaic (PV) cell is a device that converts light directly into electricity. Many photovoltaic cells are made of silcon, which is a type of semiconductor. The energy from the light knocks electrons loose, allowing them to flow freely. This flow of electrons is a current, and by placing metal contacts on the top and bottom of the PV cell, we can draw that current off to use externally. For example, the current can power a calculator. Understanding PV cells is important, because alternative energy is a rapidly expanding field of engineering.

6.7 Modeling Concepts

The concept of the sun's rays hitting the earth at different angles can be simplified and modeled in lab using a photovoltaic cell and directed light source as shown below in Figure 6.2, and mathematics can support it. This is important, because while everything must start as a concept, for it to be accepted and proven, engineers rely heavily upon mathematics and physics to support their ideas.

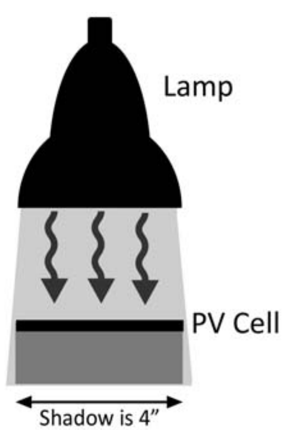

Figure 6.2: Flat PV Cell

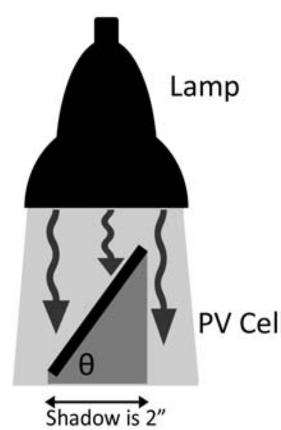

Figure 6.3: Angled PV Cell

6.7.1 Mathematical Support

$$Shadowwidth = SolarCellWidth \times cos(\theta)$$

Basic trigonometry shows us that the cosine of a 60^o angle is 0.5, whereas the cosine of 90^o is 0. Therefore, with a lamp beam of approximately 4 inch width directly hitting a 4 inch wide PV cell as shown in Figure 6.2, there will be maximum voltage output, because the most light is hitting it. The PV cell is at a 0^o angle with the ground, and therefore the cosine is 1. In Figure 6.3, the PV cell is at a 60^o angle with the ground, and therefore the cosine is 0.5, meaning that only half the amount of light is hitting the PV cell, and therefore the voltage output will be less as well.

6.7.2 Experimental Support

Now that there is mathematical support of the concept, there needs to be observational support as well through experimentation. For this, you will need some way of measuring angles (protractor). You need to measure the voltages produced by the PV cell at no less than 7 different points between 0^o and 90^o, zero being what is shown in Figure 6.2. Then graph these points on Figure 6.4 and analyze the resulting line.

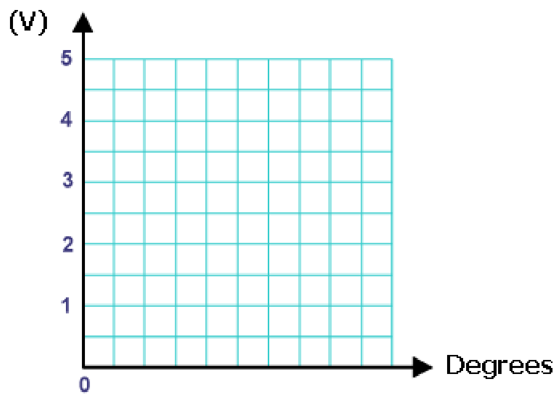

Figure 6.4: Voltage Output vs. Degrees

Distance between Lamp and PV Cell (at 0^o): ____________________

6.8 Characterization

To characterize the solar cell there are a few tests that need to be completed. We will be finding the open circuit voltage and short circuit current.

1. Using the DMM, hook up each of the leads to the points on the solar cell. Turn the DMM knob to the ”20 volt” setting. Then place the solar cell by the window and then in a darker area. Record each individual voltage below.

   Sunlight Voltage____________________**V** **Dark Voltage**____________________**V**

2. Following the same procedure as above except now turn the DMM knob to the ”2mA” setting. Record both results below.

   Sunlight Current____________________**A** **Dark Current**____________________**A**

6.9 Assembly of Tracking Device

In this part of the lab, the goal is to create a light tracker using the servo motor circuit you built in a previous lab in conjunction with a photovoltaic cell. You need to attach the PV cell to the servo so that the PV cell can still rotate approximately 180 degrees when placed below one of the lab lamps. After the PV cell is attached to the motor, you need to program the Tiny26. This code will turn the circuit into a light tracker. Basically, the PV cell will periodically scan the surrounding light area by rotating and recording the voltages at each point. Then, it will go to the point at which the voltage was highest, and stay there until the solar cell isn't receiving enough light. This way, the device will always find the strongest light source and can be the most efficient in its energy conversion.

To assemble the solar tracking device, a GM-8 motor along with a motor adaptor will be required. The code has been provided in the code repository. The schematic is in Figure 6.5 *(Hint: We will be using the same motor driver as in the Energy Systems Lab).*

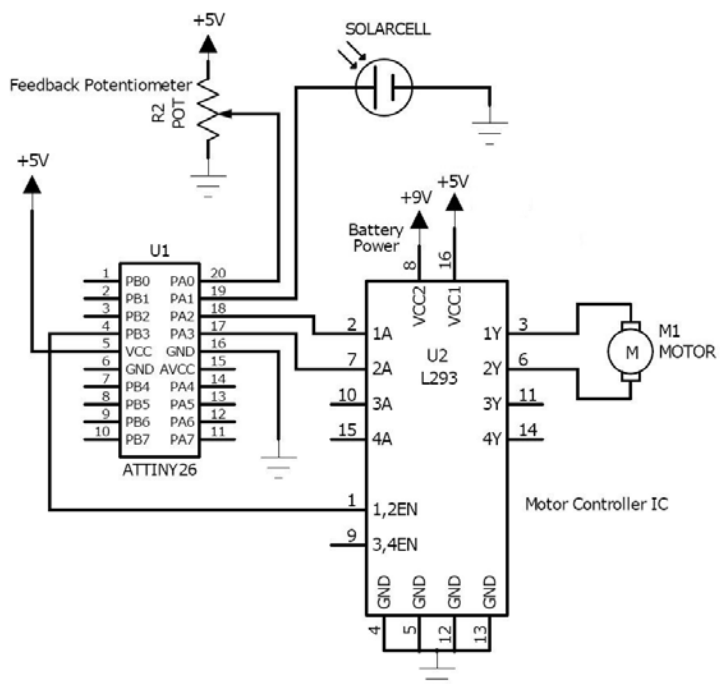

Figure 6.5: Schematic of Light Tracking Device

Mounting the Photovoltaic Cell to the motor

1. Place the 1 inch bolt through the hole on the protoboard.
2. Set the protoboard and bolt against the hub of the motor so the protoboard is resting on the side of the circle that has been cut flat and the bolt is resting in the slot on the face of the hub.
3. Put the nut on the end of the bolt and slowly tighten the bolt while holding the nut with a pair of pliers. *(Hint: This might work better with two people.)*
4. Make sure you tighten the bolt just enough to make a snug connection, but not so much that the bolt isn't flat against the hub.
5. The protoboard mounted to the hub is shown in Figure **??**.

6. Mount the solar cell onto the protoboard with hot glue. Make sure not to cover up the mounting bolt on the protoboard.
7. Wait for the glue to dry before running the motor or moving the system around.

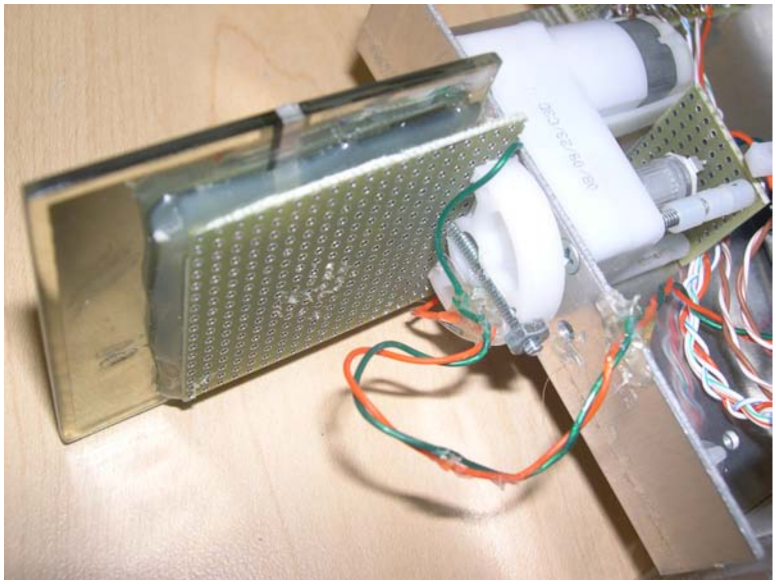

Figure 6.6: Completed Solar Servo

6.10 Study Questions

1. Name at least 3 places you've seen solar cells/power in everyday life.

2. Explain in your own words why the voltages generated during lab created that kind of curve when graphed. Theoretically, it should be close in shape to a bell curve. What are some potential reasons why the graph isn't perfectly smooth?

3. Transparent electronics is something that has been developed here at OSU. One use they are being developed for is the creation of clear solar panels that can be used as windows. Using what you have learned from this lab about photovoltaic cells and light angles, discuss the pros and cons of using this new technology on skylights versus windows on the sides of buildings. Which one would be more efficient at energy conversion, and why?