Designing a Solar Tracker and Water Overflow System for a Solar Water Heater

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Abstract

Conventional solar panels are often used in solar water heating systems. These solar panels have a fixed position and do not always face the sun, which makes the panels less efficient and causes their energy output to vary widely throughout the day. In order to keep the panels facing the sun, we designed and paritally built a solar tracking component that adjusts the angle of a solar panel to follow the sun. The solar tracking system includes two light dependent resistors (LDRs), which are photo-resistors that decrease in resistance when exposed to stronger light. The outputs from the two LDRs mounted next to the solar panel drive a servo motor to adjust the angle of a solar panel. Water collectors in the solar water heating system are prone to overflow so we also designed and built a water overow detector. The water overflow system uses two electrical leads attached near the top of the water collector to detect when the water is in danger of overflowing and then sound a buzzer. Due to time constraints we did not build the solar tracker. To test the system when completed we will measure the accuracy in degrees from the sun and the lag time of the tracker. We will also test the difference in solar panel efficiency when using the tracker. The water overflow system we built functioned perfectly 100% of the time.

1 Introduction

Due to increased dependence on quickly depleting fossil fuels, new energy sources are being used now more than ever. Solar energy is one such popular alternative energy source. Common utilization of solar energy falls into two categories: active and passive solar systems. Passive solar technology does not involve the use of mechanical systems while active solar technology does. In this project we are designing components to add on to a simple solar powered water heating system that uses active solar technology.

The solar powered water heating system we are designing for is built from inexpensive, easily attainable parts and involves simple circuitry, which makes it well suited for use in the home. The system can be separated into two main components: the solar panel with the tracker and the water heating with external water collector. Solar panels produce the most electricity with strong, direct sunlight and are not being used to their full potential if installed stationary. The solar tracker component in the project adjusts the tilt angle of the panel to maximize the sunlight it receives. The water heating section consists of a water overflow detector for use with an actual water heater. The overflow system sets off a buzzer when the water level in the heated water container is two centimeters below the rim. The complete system efficiently heats and stores water using energy from the sun.

2 Background

2.1 Solar Tracking System

Solar panels need to be facing the sun to perform optimally. When facing the sun, the angle of incidence between the sun's rays and each cell in the solar panel is about 90 degrees. If the panel is tilted off to either side and the angle is far from 90 degrees then some cells will not receive maximum light and not output as much electricity. Our solar tracking system rotates the panel to maintain the angle of incidence needed for optimal electricity output.

The direction in which the motor in the tracker rotates is towards the side of the solar panel that is receiving a higher amount of light. Light dependent resistors (LDRs) decrease their resistance when exposed to light. When LDRs are used in solar trackers they are most often placed on each end of the panel to determine which end is receiving more light. The voltage from each LDR is compared and the difference is outputted to turn the motor in the direction of the LDR with more light. Solar trackers using LDRs, such as the solar tracker we designed, are less complex than many others, such as those that use microcontrollers, but are one of the most efficient types of solar trackers, getting a 30% increase over solar panels without a tracker in past studies. [1] There are many other types of solar trackers on the market, such as more complex dual axis solar trackers that tilt in two directions. While these trackers might seem far superior to a single axis tracker, they are actually only more efficient by a small percentage.

A servo motor is another common component found in solar trackers. A servo consists of a potentiometer attached to control circuits that regulate the servo motor shaft. The motor can turn a total of 180 degrees which allows the solar panel to rotate in a full semicircle. The speed at which the motor turns is regulated by Pulse Coded Modulation. The frequency of the input AC square signal changes the angle of the output shaft. [2] If the duration of the positive pulseis more than 1.5 milliseconds the servo will turn to the right and if the duration is less than 1.5 milliseconds it will turn to the left. When the duration is exactly 1.5 milliseconds the servo will remain stationary. (See Figure 1). In our case, this signal is determined by the voltage difference from the two LDRs. This type of motor is perfect for this application because it adjusts the angle of the solar panel very precisely.

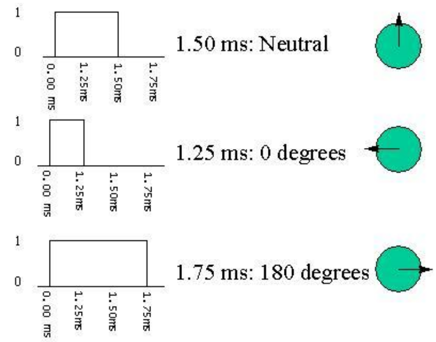

Figure 1: Servo movement based on frequency of AC square signal input. [2]

2.2 Water Overflow System

Solar water heating systems often have an external water collector of some sort. Since the water trickles out slowly as it is heated these heaters are typically left turned on unsupervised. A simple design for a water overflow detector involves the use of two leads at the desired overflow water level. The leads are connected to a circuit that powers a buzzer or other warning device. When the water level rises to meet the leads the circuit is completed. This system depends on the electrolytes and salts in tap water for conductivity. Distilled water, for example, will not complete the circuit. This system will most commonly be used with tap water for cooking or bathing among other uses.

3 Designing the Systems

3.1 Solar Tracking System Design Process

The goal of the solar tracker was to adjust the servo motor so that the solar panel was always perpendicular to the sun. In order to achieve this adjustment we first determined the suns position relative to the solar panel. We obtained this data using LDRs mounted to each side of the solar panel. The two LDRs are connected to a potentiometer inside our Futaba micro servo motor with one side of the resistor leading to mounting pin 1 of the potentiometer and the other end leading to pin 2, as shown in Figure 2.

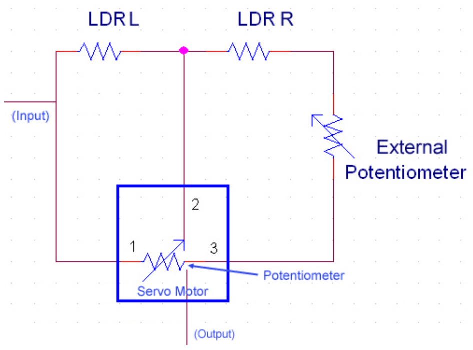

Figure 2: Circuit for LDR attached to potentiometers in the Futaba servo.

This potentiometer is wired to the control circuits which tell the motor which way to turn. The motor turns its output shaft with a series of gears. Servos require an AC voltage to work, specifically square pulses. The 555 timer circuit provided this square pulse voltage. Servos are normally controlled by the length of the positive half of the square pulse, in this case a high voltage frequency of 1.5 ms. The low voltage supplied is 18.5 ms. The potentiometer is also wired as one of the resistors, allowing for resistance to be tweaked in order obtain the exact frequency values. (See Figure 3)

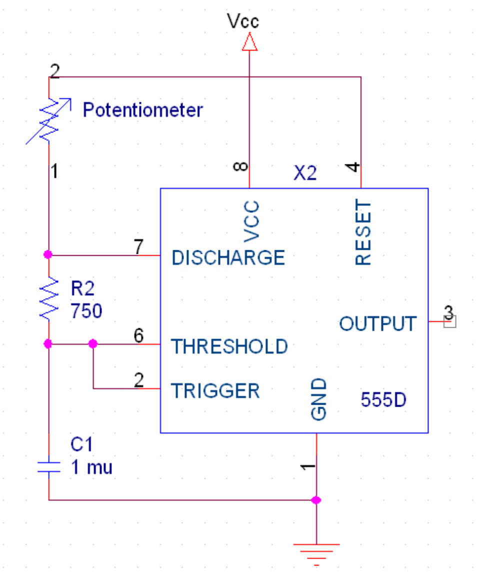

Figure 3: Circuit for solar tracker using 555 timer.

3.2 Water Overflow System Design Process

The basic function of the water overflow system is sounding a buzzer when the water level in the collection container reaches a certain point. We used a 555 timer circuit which converts DC voltage into AC voltage for use with the buzzer. The 555 timer circuit is a very common IC that can change a DC input into a square AC output. The duration of the positive signal is determined by Equation 1 and the duration of the negative signal is determined by Equation 2. R_1 and R_2 are the resistance values of the two resistors in the circuit seen in Figure 4. C is the capacitance in microfarads of the capacitor in the circuit.

$$T_1 = .693\,(R_1 + R_2)\,C \tag{1}$$

$$T_2 = .693\,(R_2)\,C \tag{2}$$

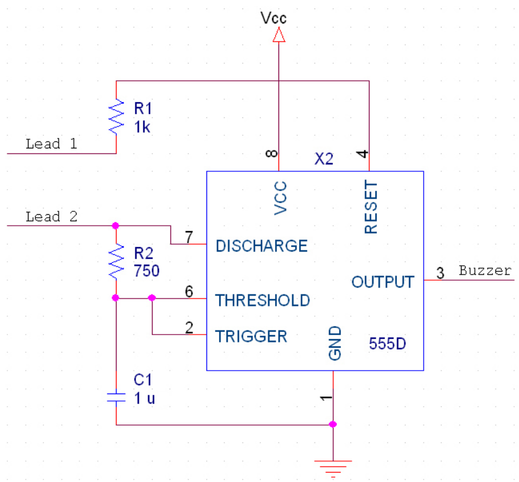

Figure 4: Circuit for water overflow system.

This circuit was left open with two leads secured near the top of the water collector. Once the water hits the leads, the circuit is completed because the water conducts the electricity, and the buzzer sounds. This design is very versatile, because the buzzer can be replaced with any type of mechanism that accepts square pulse AC signals.

3.3 Future Testing

Due to time constraints we were not able to fully assemble the solar tracker. Once we do build the system, we will test its accuracy using a variety of measurements. Testing the solar tracking system consists of checking if the solar tracker is aligning the solar panel perfectly with the light source. Once the tracker is settled on a position, we will use a protractor to note the difference between the angle the solar panel is facing and the actual angle of the light source. We will test the system by moving the light source at different speeds and for different distances. To adjust the solar tracker it is necessary to measure the varying resistance output from the LDRs. We took the measurements for this component by securing an LDR near the bottom of a PVC pipe sealed at both ends. At the other end of the pipe was a LED light source that was moved towards the LDR in increments of 3 centimeters. (See Figure 5)

LDR Resistance Variance	
Distance	Resistance Across LDR
15cm	110 K
12cm	95.3 K
9cm	87.4 K
6cm	62.3 K
3cm	45.8 K
0cm	25.7 K

Figure 5: Resistance across LDR as LED light source is moved closer in increments of 3 cm.

We will also calculate the lag time of the solar tracker by timing how long it takes for the solar tracker to adjust the solar panel each time the light source changes position. We will start the timer as soon as the light source begins to move, and stop it when the solar panel settles. We will be careful to keep the distance and speed with which the light is moved as consistent as possible.

In order to calculate the success rate of the water overow system, we performed trials where we overflowed the water container and observed whether or not the buzzer sounded.

4 Results and Discussion

We implemented a successful water overflow system and properly designed a solar tracker. The buzzer for the water overow system was successful in every trial, sounding the buzzer once the water covered both leads, as shown in Figure 6.

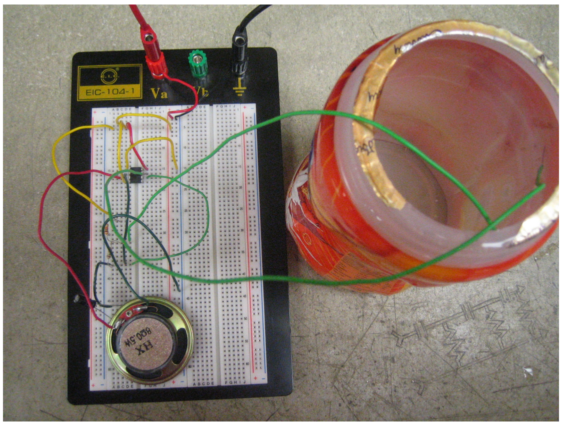

Figure 6: Water Overflow Detector

One of the result metrics that will be determined is the average amount of lag time in seconds. We expect the lag time to be fairly short and almost negligible in a real life situation with the sun, which moves across the sky at a much slower rate. Additionally, we will take the average of the values for the angle error. We expect these values to be significantly improved from those that would be obtained using a stationary panel. The angle error will influence the last measurement, the solar panel efficiency. We expect that the solar panel mounted on the tracker will produce more electricity throughout the day as opposed to the same solar panel mounted in a stationary position.

5 Conclusion

The original goal of this research project was to contribute to the use of solar energy as an alternative energy source by improving upon existing solar water heating systems. Our improvements consisted of creating a system to control water overflow and designing a tracker to maximize absorption of solar energy. These improvements were successful since the water overflow system consistently sounded a buzzer when a water collector was near overflowing. Possible options for improving the design in the future include designing a dual-axis tracker which will rotate the solar panel in the x and y axes. Additionally, we would like to improve the water overflow system to remove the need for human interaction. The design we created for the solar tracker should improve the efficiency of solar panels greatly when used in solar water heating systems. Together, the solar tracker and water overflow system are successful accessory components to solar water heaters.

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