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Course Project Report

Course: EE 712 Embedded System Design

Project Group No: 15

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Project Title: Dual axis solar tracking system using light dependent resistors

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Abstract

This project discusses about an effective way how the solar panels can be oriented using LDRs for maximum output. The sun provides us with its energy all year around, as it move around a stationary solar panel will have lower efficiency. This project aims to track the sun's position using LDRs so that the solar panel's platform always points to the sun. This project uses a tiva c microcontroller for its operation, with four LDRs and two micro servo motors.

Programming of the microcontroller device is done in the manner that the LDR sensor, in accordance with the detection of the sun rays, will provide direction to the servo motor that in which way the solar panel platform is going to revolve. Although solar tracking using date, time and location can be done leading to a more sturdy platform design, this project explores the conditions where solar tracking information cannot be obtained easily, like in case of a mobile platform.

Contents

1. Introduction

Today, where we heavily depend on non-renewable energy resources have led to the depletion of these resources and also resulting in heavy amounts of pollution. This compels us to look for other renewable energy resources for the benefit of the environment. One of these resources is solar energy, which is gaining popularity today as it is abundantly available and would never run out.

The project objective is to build a dual axis solar tracking system which tracks the sun's position using four LDRs and signals the servo motors such that the solar panel platform is pointing to the sun's direction. The LDRs as the name suggests varies its resistance as the light falling on it varies. This variation leads to variable current through the LDR, using this variable current an algorithm can be written by which the rotation of two servo motors can be obtained.

1.1 Problem Statement

As the sun changes its direction the efficiency of a stationary solar panel decreases because the sun's rays are not falling on the solar panels perpendicularly. Although the sun can be tracked using geographical data, date and time, doing so would be difficult in remote platforms and places where geographical data cannot be obtained. A solar tracking system can change its orientation according to the sun's position throughout the day.

1.2 Block Diagram

Block diagram is shown in FIG 1.

2. Literature Survey

Following are the types of solar tracking systems:

2.1 Single axis solar tracking system

This method is actually used for solar trackers aimed to be used in tracking the sun in only one direction. i.e, only to track the angle of tilt. A single linear actuator is used, such as a motor to drive the panel. This way, the solar panel is always oriented, normally to sun irradiation but along a single axis. A set of two LDRs on opposite sides of the solar panel may be used to measure the intensity of the solar irradiation by measuring the voltage drop across them.

2.2 Dual axis solar tracking system

This method is mainly designed for the localities outside the tropics or areas beyond 10 °C of the Equator. In this technique, both angles of azimuth and angle of tilt of the solar tracker is used. Using this technique we can track the sun throughout the year. For these two actuators, motors are usually used. When the voltage drop on all the four LDRs is equal then the panel experiences the maximum solar irradiation and therefore the motor stops. This ensures the solar panel is at right angles with sunlight at all times.

2.3 Passive solar tracking

This technology involves trackers that determine the sun's position by means of a pressure imbalance created at two ends of the tracker. This imbalance is caused by solar heat creating gas pressure on a low boiling point compressed gas fluid that is driven to one side or the other which then moves the structure.

2.4 Active solar tracking

This technique involves the continuous and constant monitoring of the sun's position throughout daytime and when the tracker is subjected to darkness it stops or sleeps according to its design. This can be done using light sensitive sensors, such as photo resistors(LDRs) whose voltage outputs are into a microcontroller which then drives actuators (motors) to adjust the solar position.

3. System Overview

This section aims to paint a broad sketch of what the system will consist of and how each of the subsystems will function. The circuit consists of four LDRs, four 1 K**Ω** resistors, two micro servo motors and a TIVA C board.

3.1 LDR

LDR (Light Dependent Resistor) as the name states it is a special type of resistor that works on the photoconductivity principle that means that resistance changes according to the intensity of light. Its resistance decreases with an increase in the intensity of light. In this project this is used as a light sensor.

Whenever the light on its photoconductive material falls it absorbs its energy and the electrons of that photoconductive material that is in the valence band get excited and go to the conduction band and thus increases the conductivity as per the increase in light intensity. Also, the energy in incident light should be greater than the bandgap energy so that the electrons from the valence band get excited and go to the conduction band.

3.2 Servo Motor SG90

Servo Motor SG90 is a tiny and lightweight servo motor with high output power. Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller.

To make this motor rotate, we have to power the motor with +5V using the Red and Brown wire and send PWM signals to the Orange colour wire. Hence we need something that could generate PWM signals to make this motor work, in this project it is a TIVA C Microcontroller.

PWM signals produced should have a frequency of 50Hz (FIG 2), that is the PWM period should be 20ms. Out of which the On-Time can vary from 1ms to 2ms. So when the on-time is 1ms the motor will be at 0° and when 1.5ms the motor will be 90°, similarly when it is 2ms it will be 180°. So, by varying the on-time from 1ms to 2ms the motor can be controlled from 0° to 180°

3.3 TM4C123GH6PM Microcontroller

The TM4C123GH6PM microcontroller (FIG 3) is designed around an ARM Cortex-M processor core. We need multichannel ADC for sampling the LDR values, and PWM generator for generating PWM signals to control the servo motors.

The TM4C123GH6PM microcontroller contains two identical Analog-to-Digital Converter modules. These two modules, ADC0 and ADC1, share the same 12 analog input channels (FIG 4).

The TM4C123GH6PM microcontroller contains two PWM modules, each with four PWM generator blocks and a control block, for a total of 16 PWM outputs. The control block determines the polarity of the PWM signals, and which signals are passed through to the pins. Each PWM generator block produces two PWM signals that share the same timer and frequency.The output signals, pwmA' and pwmB', of the PWM generation blocks are managed by the output control block before being passed to the device pins as MnPWM0 and MnPWM1 or MnPWM2 and MnPWM3, and so on.

The servo motors runs on +5V power supply but the TM4C123GH6PM microcontroller can only provide +3.3V. Therefore a TIva C Series LaunchPad BoosterPack XL Interface is used such that +5V can be generated for the proper operation of the servo motor.

3.4 Software Interface

Code Composer Studio software is an integrated development environment (IDE) that supports TI's microcontroller and embedded processor portfolios. Code Composer Studio software comprises a suite of tools used to develop and debug embedded applications. The software includes an optimizing C/C++ compiler, source code editor, project build environment, debugger, profiler and many other features. The intuitive IDE provides a single-user interface that takes you through each step of the application development flow. This software was used for the relative ease of coding in C programming language, and availability of various tutorials provided by WEL Lab IITB website.

4. Project Implementation

We initially tested LDRs(LDR0, LDR1, LDR2, LDR 3) using single ended ADC interfacing and 1 KΩ resistor in the following configuration (FIG 5).

Similarly the servo motors(SV0, SV1) were tested using the PWM generator of the microcontroller (FIG 6). These tests were performed using the bread board. After bread boarding the tests, Code Composer Studio was used to code the algorithm.

As the TM4C123GH6PM microcontroller has two 12 bit ADCs, the maximum value obtained by the ADC is 4095. The pins used for ADC operation are shown in Table 1, and pins for PWM outputs are shown in Table 2.

4.1 LDR Orientation

As the LDR gives the same values approximately, thus a structure for shadow must be provided such that only one or two LDR have light incident directly. The structure of the model for LDR is as shown in (Fig 7).

4.2 Operation

LDRs are used as the main light sensors. Two servo motors are fixed to the structure that holds the solar panel. The program for TIVA C is uploaded to the microcontroller. The working of the project is as follows.

1) LDRs sense the amount of sunlight falling on them. Four LDRs are divided into top, bottom, left and right.

2) For east — west tracking, the analog values from two top LDRs and two bottom LDRs are compared and if the top set of LDRs receive more light, the vertical servo will move in that direction.

3) If the bottom LDRs receive more light, the servo moves in that direction,

4) For angular deflection of the solar panel, the analog values from two left LDRs and two right LDRs are compared. If the left set of LDRs receive more light than the right set, the horizontal servo will move in that direction.

5) If the right set of LDRs receive more light, the servo moves in that direction.

5. Testing and Evaluation

For choice of the resistor we tested the LDRs with 3 different resistors, 560 Ω, 1 KΩ, 10 KΩ. We measured the voltages for different environment lightings. Table 3 elaborates the same.

We tested our board at multiple stages.

1) First we tested each LDR using 10 KΩ resistor using Port E pins using +5V supply. Even if LDR was in an ambient light environment the value that comes is 4095, in a very dark environment it varies between 0 and 500.
2) We tested the servo motors separately using PWM generators in the microcontroller, according to datasheet of the SG90 servo motor, it operates on 50 Hz PWM signal, so it was generated using the microcontroller and the exact values for exact rotation was found out using hit and trial method.
3) Once the servo was working, we started to control the servo using the difference of two LDRs.

6. Experiments

The sampling frequency of the ADC module was kept at 10 Hz, so that an appropriate amount of sample can be taken per second for the algorithm. For azimuth rotation of the model, right(top and bottom) and left(top and bottom) LDRs values are compared and according to the bigger values the model is rotated in that direction. And for the tilt rotation top(right and left) and bottom (right and left) LDRs values are compared and according to the bigger values the model is rotated in that direction.

6.1 3D-printing of the parts and model

The model was printed in SINE Lab, we are very thankful to their generosity to print out the design. The 3D model is shown in FIG 8. The actual photos of the model are shown in FIG 9.

7. Conclusions

This project has presented a means of controlling a sun tracking array with an embedded microcontroller system. Specifically, it demonstrates a working software solution for maximizing solar panel output by positioning a solar array at the point of maximum light intensity. This project presents a method of searching for and tracking the sun using light sensors. While the project has limitations, particularly in hardware areas, this provides an opportunity for expansion of the current project in future years.

References

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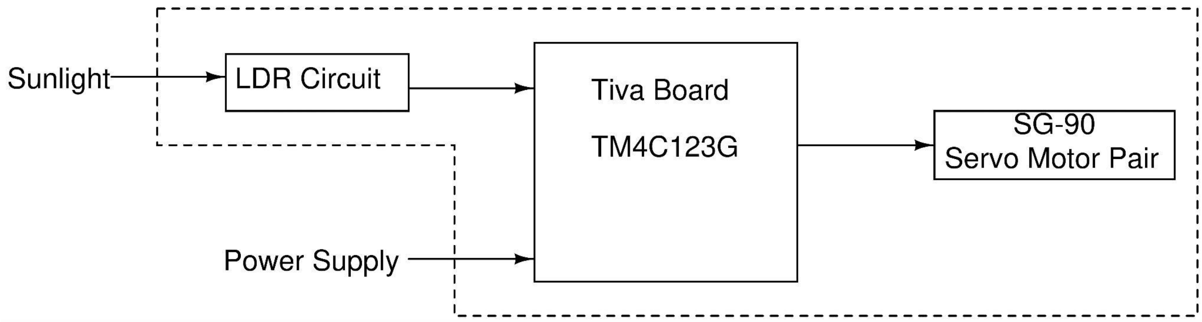


FIG 1: Block Diagram

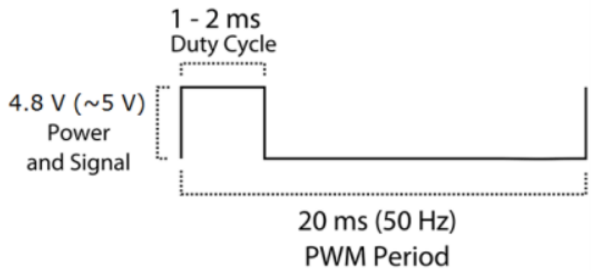


FIG 2: PWM for servo motor SG-90

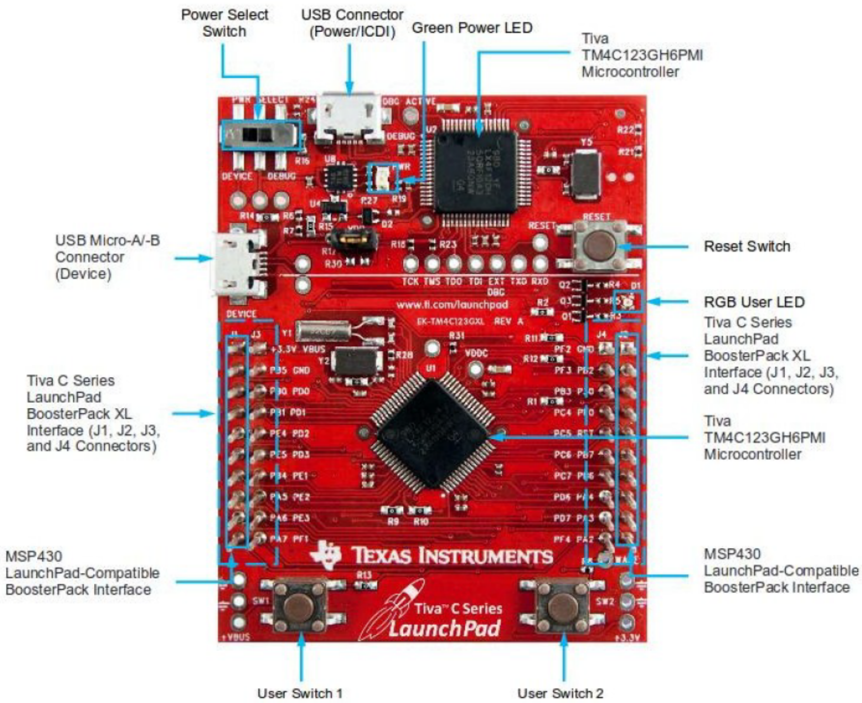


FIG 3: TM4C123GH6PM microcontroller

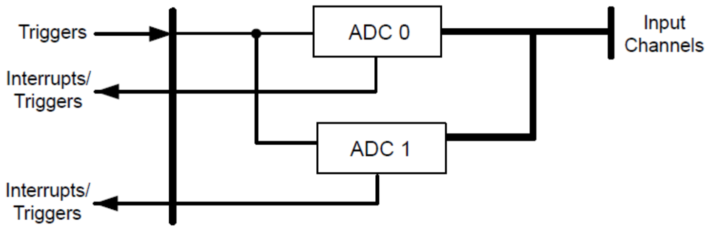


FIG 4: ADC module block diagram of TM4C123GH6PM microcontroller.

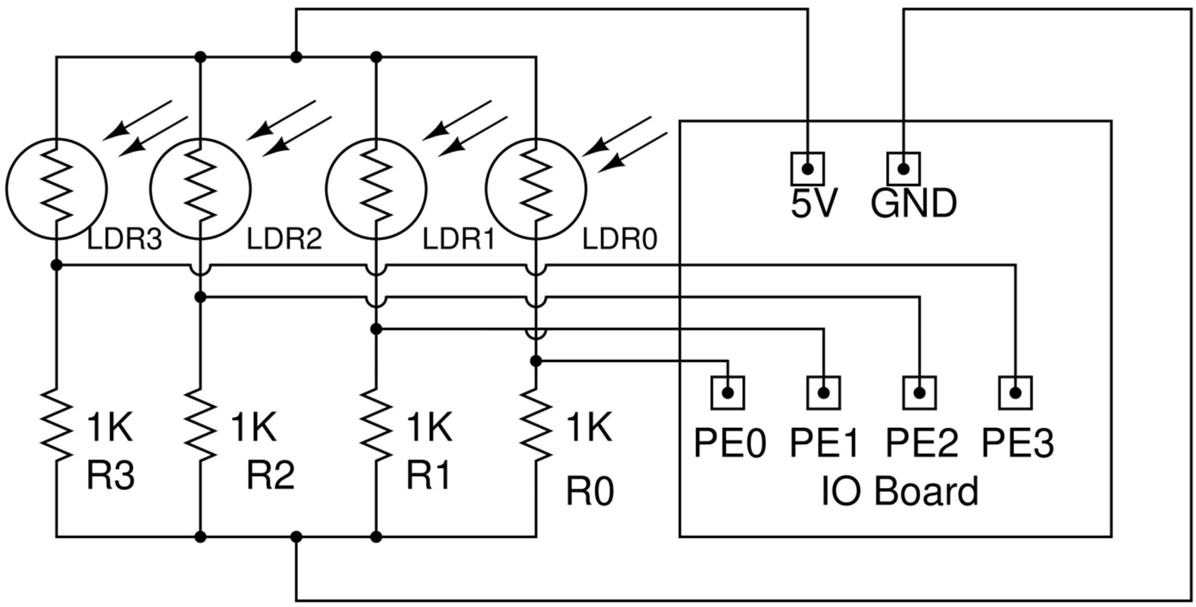


FIG 5: LDR interfacing with TIVA C board.

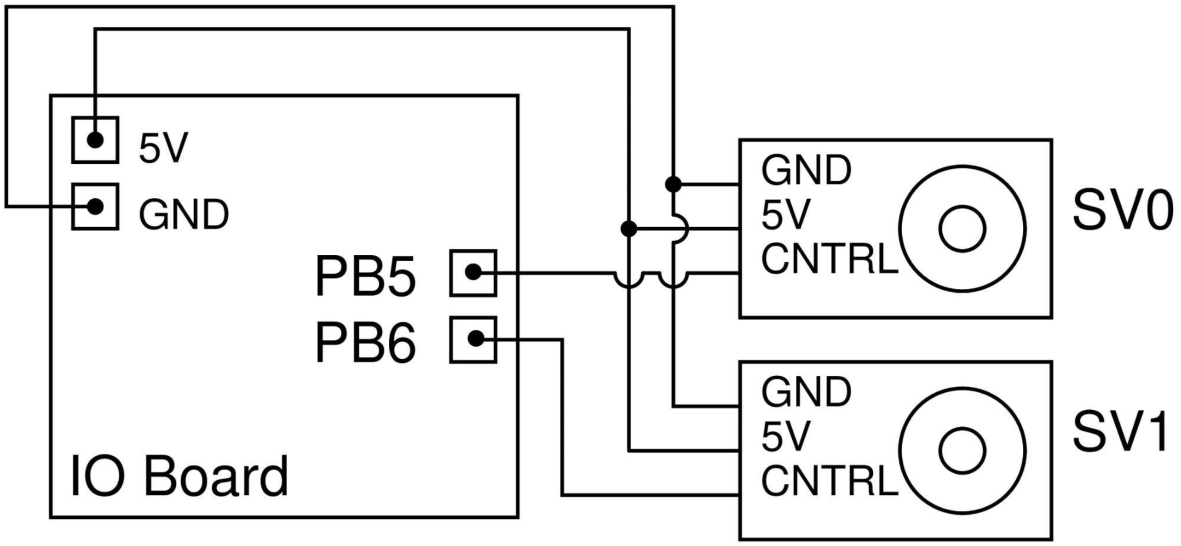
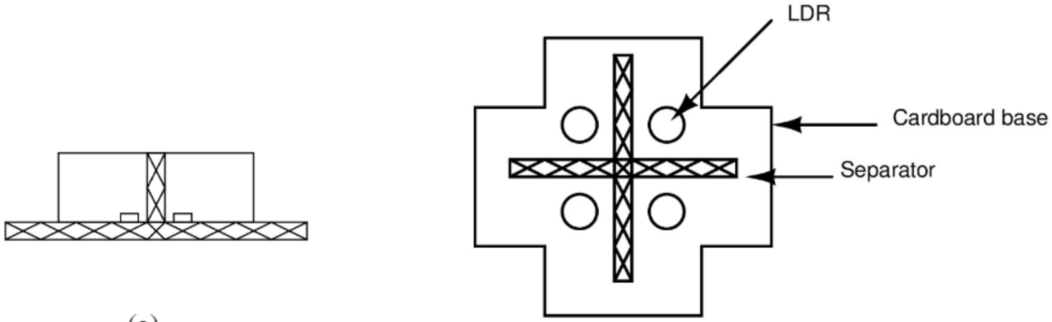


FIG 6: Servo Motor interfacing with TM4C123GH6PM microcontroller.



(a)

(b)

Fig 7: (a) Side view (b) Top view of the shadow structure for the LDR circuit.

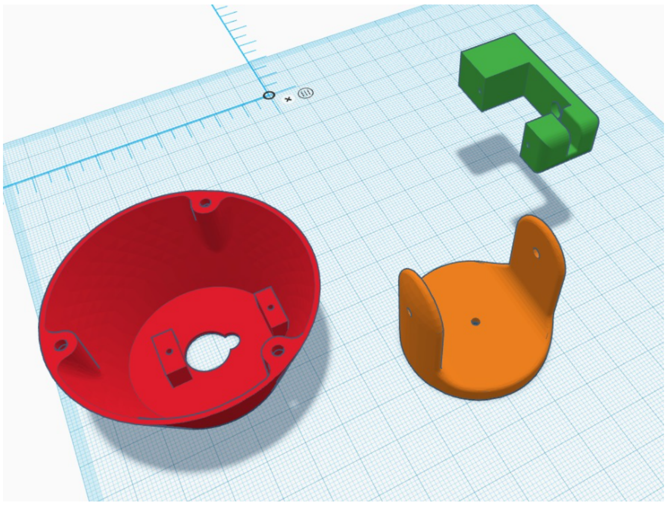


FIG 8: Model used for 3D printing.

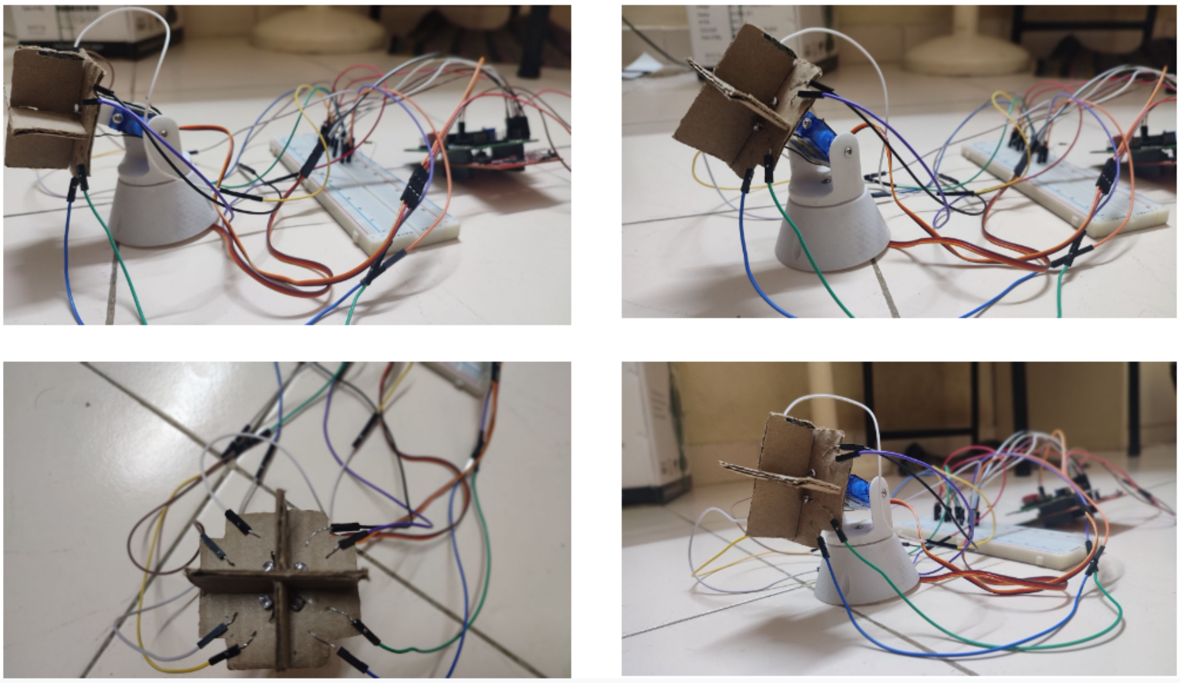


FIG 9 : Actual photos of the model.

S. No.	Pin Name	Pin no.	Pin Mux	Remark
1	AIN3	6	PE0	Analog-to-digital converter input 3.
2	AIN2	7	PE1	Analog-to-digital converter input 2.
3	AIN1	8	PE2	Analog-to-digital converter input 1.
4	AIN0	9	PE3	Analog-to-digital converter input 0.

Table 1: Pin assignment for ADC.

S.No.	Pin No.	Pin Mux	PWM Module	PWM Generator	PIN Name
1	57	PB5	Module 0	Generator 1	M0PWM3
2	1	PB6	Module 0	Generator 0	M0PWM0

Table 2: Pin assignment for PWM.

Resistor Value(Ω)	Ambient Light (V)	Very Bright Environment (V)	Dark Environment (V)
560	1.20	4.50	0.08
1000	1.80	4.70	0.10
10,000	3.50	4.80	1.10

Table 3: Observations for LDRs using different resistor values in series.