Shedding Light on Light Dependent Resistors: An Experiment on the Effects of Luminosity on Photoresistor Behavior

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Abstract: Light Dependent Resistors (LDR), also referred to as photoresistors, are light-sensitive passive electronic components that possess varied resistance based on the intensity of incident light. This behavior makes photoresistors convenient for detecting the presence or absence of light, and may also be used to measure light intensity. The experiment's primary objective is to investigate the relationship between light intensity and photoresistor resistance. The experiment also aims to validate the expected behavior of photoresistors by comparing the experimental results with established knowledge and to explore the applications of photoresistors in different fields. This experiment comprises two parts. The first part was designed to focus on analyzing the relationship between light intensity and photoresistor resistance. This part involved measuring five different levels of luminosity from a light source and exposing a photoresistor to these different luminous levels. A multimeter was used to measure the current passing through the photoresistor as it was subjected to different luminous intensities. The second part involved utilizing an Arduino microcontroller to simulate an application of photoresistors by turning on a light-emitting diode (LED) in the case that light is obstructed from the photoresistor. The results gathered from this experiment were consistent with the expected behavior of photoresistors in which resistance increased as a result of decreasing luminosity. Such a simple component is relied upon by many different applications in varying fields. Photoresistors are found in automobiles, security systems, medical devices, and consumer electronics. The experimental results provided key insights into the behavior of photoresistors as a result of exposure to different light intensities. This experiment also verified the established principles of photoresistor behavior as well as its numerous applications, gaining a deeper appreciation and understanding of this technology.

Key Words: Photoresistors; Light sensing; Arduino; Ohm's law; Electronics

1. INTRODUCTION

1.1 Background

In 1873, Willoughby Smith, a cable engineer, discovered the concept of Photoconductivity, the change of conductivity with the presence of light. It started with an observation of Selenium used in telegraph wires for long-distance communication. During the day, information sent through was more unstable and varied, causing concern over the wire's reliability. Upon inspection, Smith realized that Selenium wires, even in underwater lines, were subject to change from the light above (ITI, 2019). From this discovery, came the creation of the first photoresistor, also known as the Light Dependent Resistor (LDR), a type of photodetector that uses semiconductors and photons to adjust electrical resistance within a circuit. The device works by using specific materials such as lead sulfide, lead selenide, indium antimonide, cadmium sulfide and cadmium selenide on its surface as a means for photons or light particles to land (EE Power, n.d.). Once light hits the photoresistor's surface, the free electrons present are excited, induce charge, and move to the conduction band, increasing the conductivity of the device (Ngonzi & Kamya, 2022). Considering the inverse relationship between conductivity and resistance, it can be inferred that when light hits the surface of the photoresistor, it decreases in resistance (US EPA, 2024). Thus, the highest resistance is achieved in dark conditions and the lowest resistance in brighter conditions.

Since then, photoresistors have developed into intrinsic and extrinsic types, and have been adapted for different wavelengths of light (EE Power, n.d.). These developments have played a major role in the present applications of this product, as seen in solar-powered devices, automatic lights, and light-sensitive alarms.

1.2 Objectives

With that said, understanding this relationship is crucial in enabling these technologies to occur and improve in the future. Thus, this experiment aims to do the following:

a) To investigate the relationship between light intensity and photoresistor resistance
b) To validate the expected behavior of photoresistors
c) To explore the applications of photoresistors in different fields.

1.3 Scope and Limitations

In order to achieve these, the experiment's setup utilized, most notably, one Cadmium sulfide (Cds) photoresistor and one Multimeter (VOM) to track current and resistance levels. To track light, one five-level built-in mobile phone flashlight unit was used, and measured with one lumen meter. As for possible limitations, considering there were outside light sources during this experiment, it is possible that the photoresistor may have picked up these lumens. However, the researchers find these precise measurements to be negligible due to the large scale of values.

2. METHODOLOGY

This study's primary objective is to investigate the relationship between light intensity and photoresistor resistance. The study also aims to accomplish two other objectives which are to validate the expected behavior of photoresistors by comparing the experimental results with established knowledge of photoresistor behavior and to explore the applications of photoresistors in different fields.

These objectives are to be accomplished by the two parts that comprise this experiment. The first part of this experiment will focus on observing photoresistor resistance by subjecting the photoresistor to varying intensities of luminosity. The second part will utilize an Arduino microcontroller to demonstrate the application of photoresistors.

2.1 Materials

The materials utilized in this experiment include:

1) *9-volt battery.* The battery was connected to a circuit together with the photoresistor to be able to record current compared to solely recording resistance. The 9 volts in the circuit was sufficient to record considerable values of current.

2) *Arduino Uno.* The microcontroller was utilized to demonstrate the application of photoresistors by reading its analog signals and incorporating them in a program to turn an LED on. The program was uploaded to the microcontroller using the Arduino IDE.

3) *Breadboard.* Used for integrating and connecting the various components in the circuit.

4) *Connection wires.* Breadboard jumper wires and alligator clips were used to connect the various components together, including the battery, to the circuit.

5) *Digital multimeter.* This device was utilized to read the current passing through the photoresistor circuit.

6) *Light emitting diode.* Used to demonstrate the action done by the Arduino as luminosity received by the photoresistor changes.

7) *Light source.* The researchers originally intended to use an incandescent light bulb connected to a rheostat and a 3-volt battery as the light source for this experiment. The rheostat was to be utilized to alter the luminous output of the light source. However, the highest luminosity outputted by this setup was approximately 180 lux. This setup did not provide the researchers with enough opportunity to record notable changes in the current of the photoresistor circuit. Instead, the researchers opted to utilize a smartphone containing a built-in flashlight unit with five varying levels of luminous intensity as the light source with 970 lux as the highest recorded luminosity.

8) *Lumen meter.* A PASPORT High Sensitivity Light Sensor connected to a desktop was utilized for the first part of this experiment. The researchers utilized this device in accompaniment with the PASCO Capstone software to record luminosity (lux) values.

9) *Photoresistor.* The main focus of this experiment is to subject the photoresistor to varying levels of luminous intensity and observe the changes in its resistance.

10) *Resistors.* The experiment used a 1K ohm resistor for the photoresistor and a 220 ohm resistor for the LED.

2.2 Foundational Theory

The working principle behind light-dependent resistors can be distilled to their resistivity being a function of incident light. Hence, its resistance changes depending on the amount of light that it is exposed to. However, this experiment records the current flowing through the circuit with a photoresistor and a given voltage source rather than solely recording the photoresistor's resistance. Measuring current serves a practical use as most applications that use photoresistors integrate the component into a circuit that performs functions depending on the amount of current flowing through the circuit. With this information, meaningful data regarding resistance can still be obtained due to the fundamental theory that governs this experiment, Ohm's Law.

Ohm's law simply states that the electric current across a conductor is directly proportional to the potential difference across two points. Hence, three mathematical equations that represent this relationship can be obtained by introducing the proportionality constant, resistance.

$$V = IR \qquad \text{(Eq. 1)}$$

$$I = \frac{V}{R} \qquad \text{(Eq. 2)}$$

$$R = \frac{V}{I} \qquad \text{(Eq. 3)}$$

where:

V = potential difference

I = electric current

R = resistance

2.3 Experimental Design

The experiment comprises two distinct parts, each with two different configurations:

1) *Luminosity and resistance.* Measure the current flowing through the circuit as the photoresistor is exposed to five levels of luminosity.

2) *Arduino application.* Demonstrate an action that can be performed through light sensing. In this experiment, the microcontroller turns on a light-emitting diode in the absence of light absorption by the photoresistor.

2.4 Expectations and Assumptions

Expectations. A trend of increasing current and decreasing resistance is to be an expected outcome in response to incremental increases in luminosity. Additionally, the Arduino microcontroller is expected to be able to read analog signals from the photoresistor and perform an action once signal values fall under or go above a certain threshold.

Assumptions. It is assumed that the recorded data may contain some degree of uncertainty or variability due to environmental and technical influences. Such potential limitations include the accuracy of photoresistor measurements, considering factors such as sensor sensitivity variations, light fluctuations in the laboratory, and circuit noise.

2.5 Experimental Procedure

In the first part of the experiment, a circuit was designed and setup to focus on measuring the current flow. This involved setting up the photoresistor and multimeter in series. A schematic diagram of the circuit is shown in Figs. 1 and 2 and an image of the final circuit can be seen in Fig. 3.

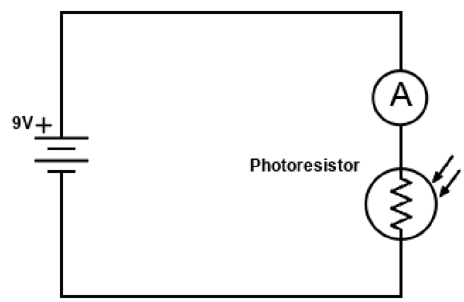

Fig. 1. Schematic for the first part of the experiment

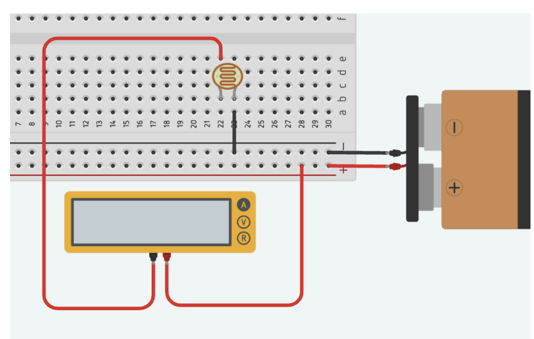

Fig. 2. Circuit diagram for the first part of the experiment

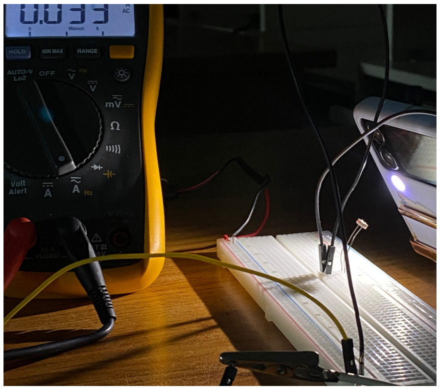

Fig. 3. Final circuit for current measurements

Once the circuit was built, the researchers proceeded to measure the five varying levels of luminosity outputted by the built-in flashlight unit of the smartphone at a set distance of 6cm. This was also the same distance the flashlight was placed away from the photoresistor. Luminosity was measured using the PASPORT High Sensitivity Light Sensor, as shown in Fig. 4., and its values were outputted through the PASCO Capstone software, seen in Fig. 5.

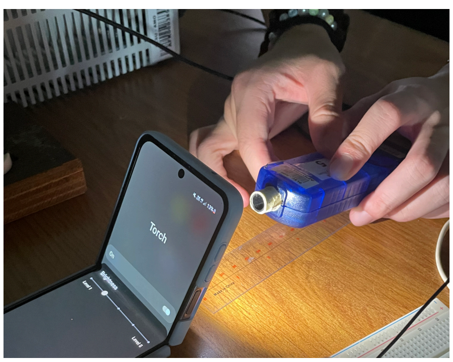

Fig. 4. Luminosity measurements using a light sensor

Fig. 5. Luminosity readings from the Capstone software

After, measuring the luminosity levels, the researchers exposed the photoresistor to the five levels of luminosity. As the photoresistor is exposed to each luminous level, the current outputted by the multimeter is recorded into the spreadsheet corresponding to its luminosity. The following procedure is shown in Fig. 6.

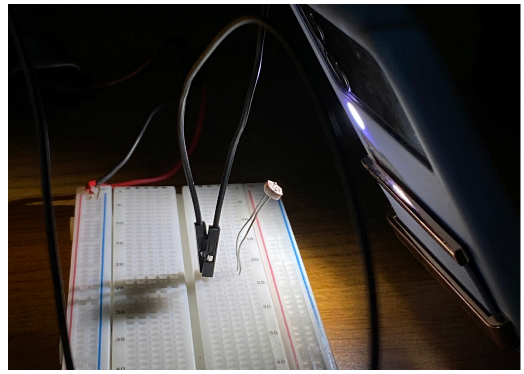

Fig. 6. Photoresistor exposed to flashlight

In the second part of the experiment, a circuit was assembled to demonstrate the practical application of photoresistors as a light sensing device. This involved setting up the photoresistor with an Arduino microcontroller and an LED. A schematic diagram of this setup is shown in Figs. 7 and 8, and an image of the final circuit can be seen in Fig. 9.

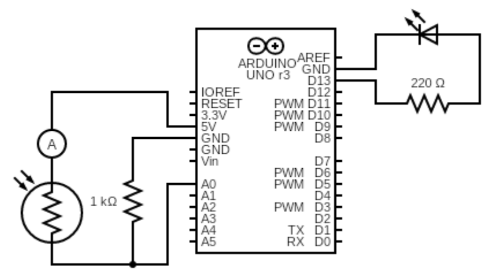

Fig. 7. Schematic of the second part of the experiment

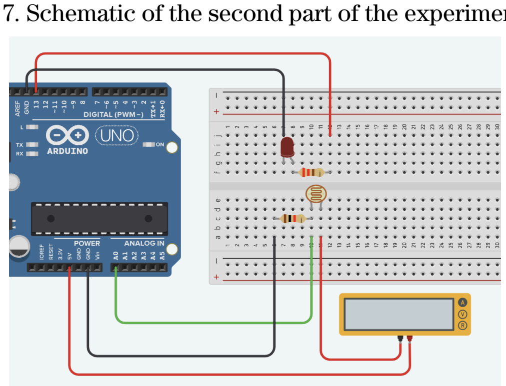

Fig. 8. Circuit diagram for the second part of the experiment

Once the circuit was assembled, the Arduino program was uploaded to the microcontroller (Murillo, 2024). To demonstrate a practical application of a photoresistor as a light-sensing device, the microcontroller is programmed to send a digital signal to the LED if the photoresistor fails to detect a certain amount of light. This failure to detect a minimum light value may come as a result of many factors, such as the obstruction of light or simply being placed in a dark environment. The researchers opted to simply obstruct the light from the photoresistor by covering it with a hand. In this scenario, the LED just represents a myriad of actions that can be substituted in its place, such as turning on a buzzer, rotating a servo motor, or even running a DC motor. The program flowchart is shown in Fig. 9, and Fig. 10 shows the researchers testing the circuit.

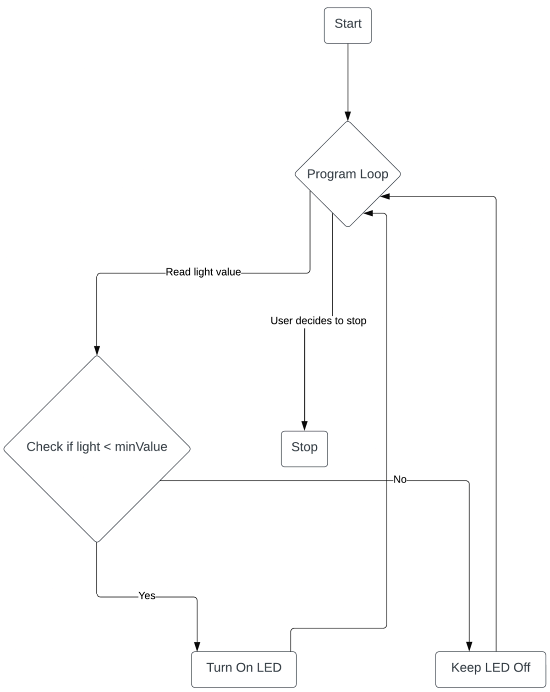

Fig. 9. Flowchart for Arduino program (Murillo, 2024)

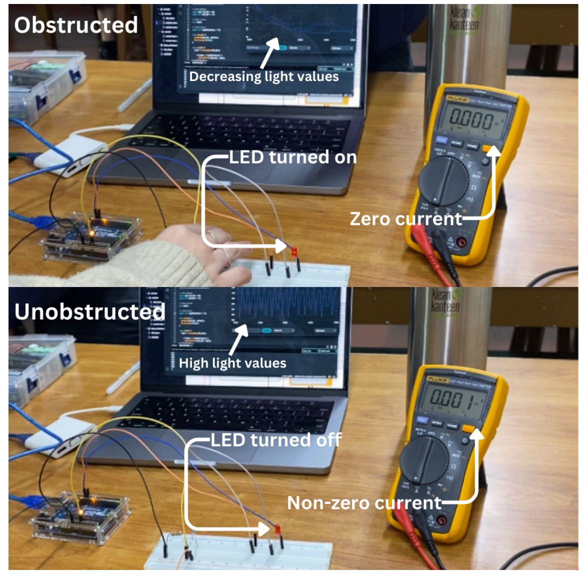

Fig. 10. Demonstration of Arduino circuit

3. RESULTS AND DISCUSSION

During the experiment, the recorded voltage of the voltage source, a standard 9-volt battery, is 7.58V. Listed below are the tables and figures showing the results made in the experiment.

Table 1. Recorded voltage

EMF	Recorded
9	7.58

Table 2. Values for Luminosity, Current, and Resistance

Luminosity (LUX)	Current (A)	Resistance (OHMS)
185.85	0.028	270.71
281.98	0.031	244.51
487.06	0.035	216.57
775.45	0.038	199.47
967.71	0.041	184.88

The tables show the value of current and resistance as luminosity changes. The current increases as luminosity increases. Hence, it appears that they are directly proportional, and resistance decreases for they have an inverse relationship.

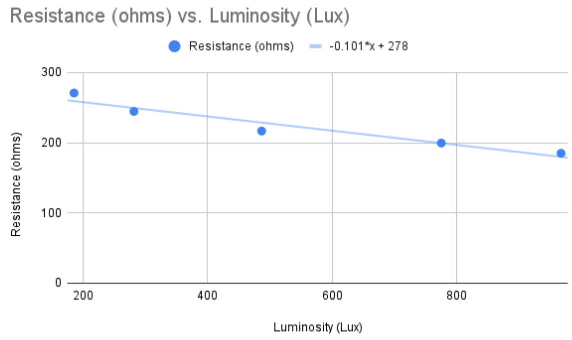

Fig. 11. Analyzing the relationship between Luminosity and Photoresistor Resistance

Figure 11 shows the negative correlation of the values of the resistance and luminosity. As the luminosity increases, the resistance decreases.

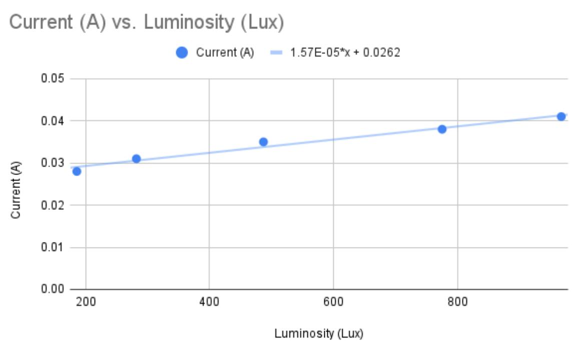

Fig. 12. Analyzing the relationship between Current and Luminosity.

Figure 12 shows the relationship between current and luminosity. It can be observed that the two variables have a positive correlation between their values.

3.2 DISCUSSION

Through the first experiment, the researchers observed the relationship of luminosity with resistance in a photoresistor. The relationship between luminosity (lux) and resistance (ohms) shows a negative correlation as it is related to the current (A) values measured in the experiment. This was observed as the researchers increased the luminosity, which in turn led to an observed increase in current. In correlation to this, the increase in current can be explained by Ohm's Law, found in section 2.2. Specifically, equation 3, states that resistance and current are inversely proportional as long as the voltage remains constant. Hence, it is found that current increases due to a decrease in the resistance of the photoresistor. Therefore, in the context of a photoresistor, resistance increases as luminosity decreases. This means that the photoresistor allows more current to flow through it as the incident light intensity increases and restricts current as luminosity decreases. These findings appear to be consistent with established knowledge of the behavior of photoresistors, as noted in several references (An et al., 2021; *Photoresistors - an Overview | ScienceDirect Topics*, n.d.; Keim, R., n.d.).

In the second experiment, the researchers demonstrate an application of photoresistors in which the obstruction of light can be utilized to perform a programmed action. As the Arduino microcontroller detects significantly less light, a digital signal is sent to the LED port, which causes the LED to turn on. Although this may appear as a simplistic demonstration, the LED can represent any electronic load such as, but not limited to, a DC motor, a piezo buzzer, an actuator, and a relay controller. In a journal article about photoresistors, Sawle (2021) explains that these light-dependent resistors act as light-sensitive switches, regulating current flow on the intensity of the light it receives. These devices find applications in solar-powered devices, automatic lights, and light-sensitive alarms, where they detect changes in light levels. Moreover, photoresistors are utilized in audio compressors as indicated by Keim, R. (n.d.). In these devices, a light source worked to control signal gain. This setup smooths changes in volume, making the sound more even. When an audio signal is detected to exceed a set threshold, the light source adjusts to change the resistance of the photoresistor, regulating the current flow.

4. CONCLUSIONS

In conclusion, this research experiment delved into the relationship between light intensity and photoresistor resistance. By meticulously analyzing the behavior of photoresistors under varying luminous conditions, the study revealed a negative correlation between luminosity and resistance, consistent with the principles of Ohm's law. As the luminosity increased, resistance decreased, allowing for greater current flow through a photoresistor. These findings underscore the fundamental role of photoresistors as light-sensitive components, serving as switches that regulate current flow based on incident light intensity. The versatility and reliability of photoresistors make them indispensable in modern technology, facilitating efficient energy management. Through this experiment, the researchers not only validated established principles but also gained a deeper understanding of the behavior and applications of photoresistors. This study serves as a foundation for further exploration and innovation in utilizing photoresistors across many technological domains. Ultimately, it contributes to advancing our comprehension of light-dependent electronic components and their integration into cutting-edge technologies, fostering progress and innovation in the field of electronics.

5. ACKNOWLEDGMENTS

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