THE OPTICAL MEASUREMENT SUSCEPTIBILITY OF THE PHOTODIODE AND LDR LIGHT SENSORS

Mehmet Ali ÖZÇELİK
Gaziantep University, Technical Science, Department Electric and Energy
ozcelik@gantep.edu.tr

ABSTRACT: Electrical parameters such as current, voltage and resistance are produced by the light-sensitive sensor elements depending on the light. Therefore, optically sensitive sensors are widely used in light measurement and light control systems. LDR (A Light Dependent Resistor) and Photodiode, which are widely used in light detection systems, have been discussed in the study, they have been exposed to different lighting values in an indoor environment. Their electrical reaction values have been measured and susceptibility analysis has been conducted. In the light of the findings obtained, it has been seen that with 9.44 standard deviation rate photodiode has shown more light sensitivity than LDR.

Key words: LDR, Photodiode, Light Intensity, Lux-meter, Photo-Current

1. INTRODUCTION

In most public indoor areas, offices, living areas, factories, the light is used during the day time, but it is known that most of the time the energy consumed for illumination is more than necessary [1]-[2].That is why, it is essential that the light intensity of the environment is measured and controlled to save energy [3]-[5]. In light control and measurement systems various sensors such as phototransistors, photodiode, LDR, and photocells are used [6]-[9]. Although these sensors' reactions to the light is varying, usually these variations come as parameters such as resistance, current, and voltage. The variation of electrical values that light sensors produce depending on light intensity determines the sensor sensitivity and it is essential for light control and especially for light measurement devices [10]. In general, the brighter the light; the lower resistance, the upper current or voltage, but the relationship between electrical parameters and lux for a light sensors is not the same. While some sensors show a linear variation to light, some others do not show the same trend. These numerical values produced by the sensors depending on the light are input values of control systems such as microcontrollers. As a result of mathematical calculations, these numerical values produce an illumination information value at the output of the system or they adjust the lighting level of an illumination system. That is why, the selection of these sensors in light measurement systems and control systems is an essential issue.

LDR and photodiode sensors (BPW34) are the most commonly used optical sensors in light measurement and control systems. In this research, these sensors' electrical values in an indoor environment depending on varying light intensity have been measured, their characteristic curves have been obtained, and analysis of sensitivity has been conducted.

*Corresponding Author: ozcelik@gantep.edu.tr

1.1. LDR

LDR is defined as a light-dependent resistor, and cadmium sulphide (CdS) is known or photo-resistance. It is also called a photoconductor. In LDRs, resistance is inversely proportional to light change. LDRs have low resistance in the light, and they have high resistance in the dark. They are used in street lighting control devices, light alarm circuits, lighting control, cameras and optical measuring systems.

The basic structure of an LDR is shown in Figure 1.

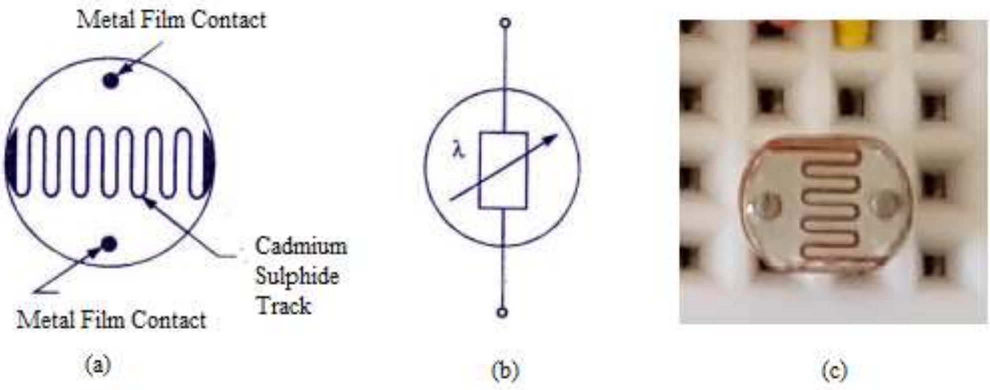

Figure 1. The Basic Structure of an LDR (a) Symbol (b) Picture (c)

The zig-zag track in Figure 1 shows cadmium sulphide or cadmium selenide. The metal films at the top and bottom are connected to terminal points. To achieve the focusing of the light that is coming to the LDR, the top side is covered with transparent glass. When there is no light, the mega-ohm values show resistant. Once the light falls on the optoelectronic circuit elements, the resistance decreases hence the conductivity of the material increases. The resistance value in this case (<1 kΩ) . LDR is a cost-effective and handy circuit element. In order for it to operate there is no need for high power and voltage.

LDR's are cheap and are readily available in many sizes and shapes. Practical LDRs are available in a variety of sizes and package styles, the most popular size having a face diameter of roughly 10 mm. They need very small power and voltage for its operation [11]-[12].

1.2. Photodiode

A photodiode is a semiconductor device which converts light into current. When the photons of light are absorbed by the photodiode, they begin to produce current. The current is very small if there is no light. Photodiodes are contain optical filters, built-in lenses, and they have large or small surface areas [13].

The BPW34 used in this research is a PIN photodiode with high speed and high radiant-sensitive miniature, flat, top view, clear plastic package. It is sensitive to visible and near infrared radiation [14]. The image and symbol of photodiode can be seen in Fig. 2.

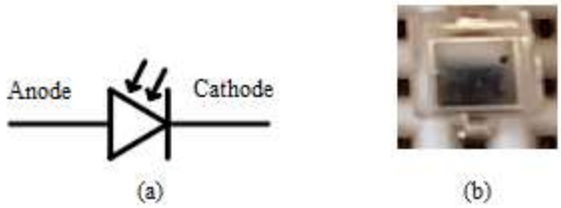

Figure 2. The Symbol (a) and Picture (b) of the Photodiode

Photodiodes are used in consumer electronics devices such as compact disc players, smoke detectors, and the receivers for infrared remote control devices used to control equipment from televisions to air conditioners. For many applications either photodiodes or photoconductors may be used. Photodiodes are often used for accurate measurement of light intensity in science and industry or to respond to light levels, as in switching on street lighting after dark.

The rest of the paper is structured as follows: in the methodology part, information about the experimental mechanism has been provided. In the Results and Findings part, in relation with light intensity, the values measured from LDR and photodiode have been provided. In the conclusion part, an assessment has been made in line with the results obtained.

2. METHODS

The experimental mechanism set up to analyse the optical sensitivity of the Photodiode and LDR sensors will be examined.

2.1. Experimental Set-up

The experimental setup used in this paper included a 5 V DC (Direct Current) power supply, Dimmer which is used to lower or upper the brightness of a halogen lamp, 100 Ω resistance, LDR sensor, BPW34 photodiode sensor, Multi-meter and for the indoor environment lighting measurement DT-8809A professional light meters (Max. range 400,000 lux, Resolution 0.1 lux, Accuracy ±%5) have been utilized, The experimental set-up is shown in Figure 3.

Figure 3. The System Used for Observing the Output Currents of LDR and Photodiode under Different Lighting Levels and DC Power

3. RESULTS AND FINDINGS

In the experiment, two cases are considered to compare both LDR and Photodiode lighting sensors. In the first one:

3.1. The Analysis of LDR under Changing Light

The LDR is connected to 5V, 100 Ω resistor is connected to ground. In an indoor ambient, light intensity on LDR is increased by 10 lux from 0(dark) up to 150(bright) lux. The current values at the output have been measured by digital multi-meter as it is seen in Figure 4.

Generally, in microcontrollers +5 V is used, therefore this voltage value has been applied.

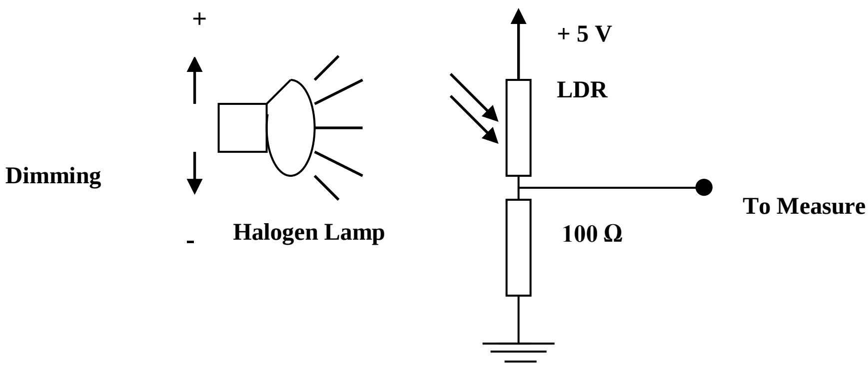

Figure 4. Different Lighting Values Applied on LDR

In Figure 5, LDR's current variation curve in relation with the lighting values increasing from 0 to 150 lux is shown.

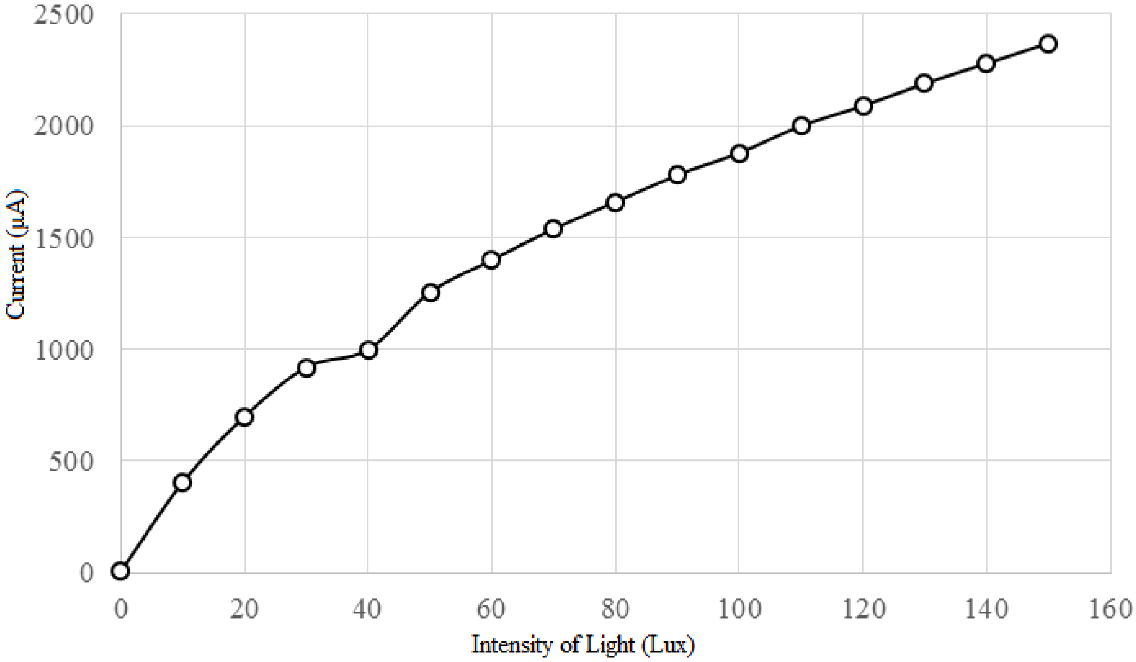

Figure 5. LDR's Current Response to the Light Change

When Figure 5 is examined, it is seen that as the light intensity increases, the current change increases exponentially and that at about 40 lux the current change is less. In line with the light intensity, the current values read from multi-meter have been given in Table 1.

Table 1. LDR's Current Response in Relation with Intensity of Illumination

Intensity of Illumination (Lux)	**Current Response of LDR (μA)**
0	7.25
10	406
20	700
30	921
40	1000
50	1256
60	1400
70	1540
80	1660
90	1780
100	1880
110	2000

120	2090
130	2190
140	2280
150	2370
Maximum	2370
Minimum	7.25
Mean	1411.26
Standard Deviation	774.31
COV (Covariance (%))	54.86
SSE (the sum of the squared errors)	22580.25
MSE (the mean squared error)	1411.26
RMSE (The root-mean-square deviation)	37.56

It is seen in Table I that the standard deviation value stands at 774,31. RMSE value is 37,56.

3.1. The Analysis of Photodiode under Changing Illumination

In Figure 4, when photodiode is connected in inverse bias in place of LDR, Figure 6 is formed. Similarly, when light intensity values from 0' (dark) to 150 (dark) lux are applied to photodiode, the curve in Figure 7 comes about.

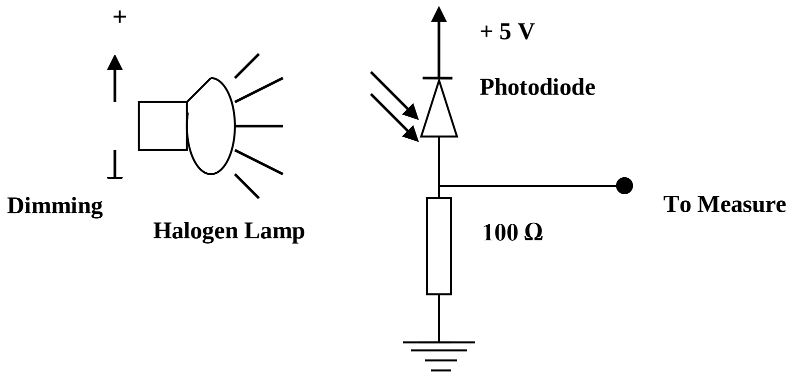

Figure 6. Different Lighting Values Being Applied on LDR

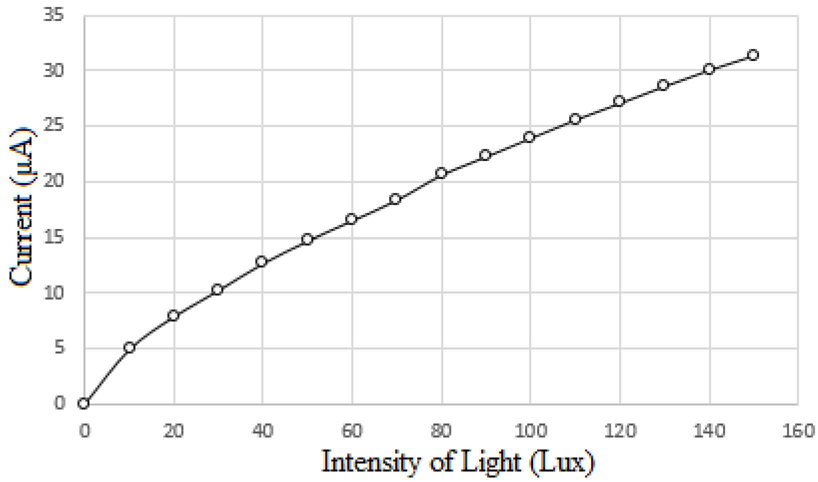

Figure 7. Photodiode's Current Response to the Intensity of Light

In relation with the light intensity values applied to Fig. 6, the measured current values have been given in Table 2.

Table 2. Photodiode's Current Response to Intensity of Illumination

Intensity of Illumination (Lux)	**Current Response of Photodiode (µA)**
0	0
10	4.91
20	7.88
30	10.26
40	12.7
50	14.71
60	16.52
70	18.38
80	20.63
90	22.29
100	23.97
110	25.62
120	27.12
130	28.66
140	30.11
150	31.41
Maximum	31.41
Minimum	0
Mean	18.44
Standard Deviation	9.44
COV (Covariance (%))	51.19

SSE (the sum of the squared errors)	295.17
MSE (the mean squared error)	18.44
RMSE (The root-mean-square deviation)	4.29

As it is seen in Table II, the Standard Deviation value stands at 9.44 the root-mean square deviation (RMSE) value is 4.29.

Taking into consideration the findings obtained from the two experiments, it is seen that photodiode's change to light is more linear. The current changes are near constant with 10 lux increase. However, in LDR, the current changes are more varying and far from constant.

4. CONCLUSION

In this research, the current values of the LDR and Photodiode, which are used quite commonly in light control and measurement systems, in the same ambient temperature (28 °C) and voltage (+5V) under changing light intensity have been examined and a sensitivity analysis has been carried out. When the changes obtained are examined, it is seen that both sensors respond to the light exponentially, but while the LDR standard deviation value stands at 774.3, that of photodiode stands at 9.44. Together with the other statistical data, it can be said that the electrical responses of photodiode in relation with lighting shows a better variation profile in terms of sensitivity and precision.

Author Note: This article was presented as oral paper at the International Energy and Engineering Conference 2016 (UEMK 2016)

REFERENCES

[1] Ghassan M.S., Hashimah I., Debnath N. Optimal Light Power Consumption Using LDR Sensor. IEEE International Symposium on Robotics and Intelligent Sensors 2015; 144-148.

[2] Ozcelik M.A. Light Sensor Control for Energy Saving in DC Grid Smart LED Lighting System Based on PV System. J Optoelectron Adv M 2016; 18(5-6): 468-474.

[3] Juan F.D.P, Bajo J., Rodriguez S., Villarubia G., Corchado J.M. Intelligent system for lighting control in smart cities, Inform Sciences 2016; 372:241–255.

[4] Toufiq I., Afshari S., Sandipan M. An Experimental Survey of Feedback Control Methodologies for Advanced Lighting Systems, Energ Buildings 2016; 130: 600–612.

[5] Gentile N., Laike T., Dubois M.C. Lighting Control Systems in Individual Officies Rooms at High Latitude : Measurements of Electricity Savings and Occupants' Satisfaction, Sol Energy 2016; 127:113-123.

[6] Fathabadi H. Comparative Study between Two Novel Sensorless and Sensor Based Dual-Axis Solar Trackers, Sol Energy 2016; 138:67–76.

[7] Wang X., Duan N., Chen H., Campbell J.C. InGaAs–InP Photodiodes with High Responsivity and High Saturation Power, IEEE Photonic Tech L 2007; 19(16): 1272-1274.

[8] Coskun A., Sevil H.E., Ozdemir S. Cost Effective Localization in Distributed Sensory Networks, Eng Appl Artif Intel 2011, 24: 232–237.

[9] Lau K.T., Baldwin S. O'Toole M. A Low-Cost Optical Sensing Device Based on Paired Emitter-Detector Light Emitting Diodes, Anal Chim Acta 2006; 557:111–116.

[10] Williams D. Design a Lux-meter using a Light Dependent Resistor, http://www.allaboutcircuits.com/projects/design-a-luxmeter, 2015.

[11] Laskar S., Bordoloi S. Microcontroller-based instrumention system for measurement of refractive index of liquid using bare, tapered and bent fibre as sensor, IET Optoelectron 2013; 7(6):117-124.

[12] Bachani M, Qureshi U.M, Shaikh F.S. Performance Analysis of Proximity and Light Sensors for Smart Parking. Procedia Comput Sci 2016; 83:385-392.

[13] Zhang P., Xiupu Z., Rong Z. Design of broad band and high-output power uni-traveling-carrier photodiodes, Opt Commun 2016; 365:194–207.

[14] Vishay Semiconductors. BPW34, Document Number 81521, http://www.vishay.com/docs/81521/bpw34.pdf, 2016.