Karaelmas Fen ve Mühendislik Dergisi
Journal home page: http://fbd.beun.edu.tr

Research Article
Received / Geliş tarihi : 04.01.2017
Accepted / Kabul tarihi : 24.04.2017

The Analysis of the Optical Measurement Sensitivity of the Phototransistor and LDR Sensors

Fototransistör ve LDR Sensörün Optik Ölçüm Hassasiyetinin İncelenmesi

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Abstract

The light sensitive circuit elements, in line with the changes in the amount of light, produce electrical values such as current, voltage and resistance change. Thus, these elements are being used in light measurement, light control and light detection systems. In this research, the Phototransistor and LDR (light dependent resistor), which are commonly used in light detection systems, have been exposed to different lighting values in an indoor environment. Their electrical reaction values have been measured and sensitivity analysis has been conducted. In the light of the findings obtained, it has been seen that with 134.23 standard deviation rate Phototransistor has shown more light sensitivity than LDR.

Keywords: LDR sensor, Light intensity, Lux-meter, Photo-current, Phototransistor

Öz

Işığa duyarlı devre elemanları, ışık miktarındaki değişime bağlı olarak akım, gerilim ve direnç değişimi gibi elektriksel değerler üretirler. Bu sayede bu elemanlar ışık ölçüm, ışık kontrol, ışık algılama sistemlerinde kullanılırlar. Bu çalışmada ışık algılama sistemlerinde yaygın kullanıma sahip Fototransistör ve LDR (ışığa bağlı direnç) kapalı ortamda değişken ışık değerlerine maruz bırakılarak elektriksel cevap değerleri ölçülmüş hassasiyet analizi yapılmıştır, elde edilen değerler göz önünde bulundurulduğunda fototransistör 134.23 standart sapma değeri ile LDR den yüksek ışığa duyarlılık gösterdiği belirlenmiştir.

Anahtar Kelimeler: LDR sensör, Işık yoğunluğu, Luxmetre, Foto akım, Fototransistör

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 (Ghassan 2015, Ozcelik 2016).That is why, it is essential that the light intensity of the environment is measured and controlled to save energy (Juan 2016, Toufiq 2016, Gentile 2016). In light control and measurement systems various sensors such as phototransistors, photodiode, LDR and photocells are used (Fathabadi 2016, Kamran 2011, Coskun 2006, Lau 2006). 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 (Singh 2014). 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 phototransistor sensors are the most commonly used optical sensors in light measurement and control systems. However, in the literature there is not much research involving the experimental comparison of these

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two elements in an indoor environment. 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.

1.1. Light Dependent Resistor (LDR)

LDR is a light dependent resistor and it shows a inversely proportional resistance change depending on the light it is exposed. LDRs are produced from light-sensitive substances such as CdS (Cadmium Sulphide), CdSe Cadmium Selenide), germanium, silicium. LDRs are mostly used in lighting control, measuring system, road illumination control, anti-robbery alarm systems, and etc.

Figure 1 shows the layout of LDR.

The zig-zag trend 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 (Yuwaldi 2017). 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 (Latha, 2013).

1.2. Phototransistor

Phototransistors are semi-conductor circuit elements that convert light into current. When they are exposed to light, the resistance between collector and emitter decreases. In order for phototransistors to produce current, it is enough that light falls on base lead. For this reason, they are used in light control and measuring systems (Kostoy 2011).

In this study BP 103-5 (as shown in Figure 2) phototransistor that is of "high speed" and "radiant sensitive, miniature, flat, top view, clear plastic package" have been used. (Osram 2016).

Phototransistors are light sensitive; photo-bipolar transistors are a popular kind of phototransistors which, by being placed in a transparent case enables light to reach the base-collector. It was first invented by Dr.John N. Shive in 1948. Phototransistors could be used as photodiodes as well. This is possible when the emitter is not connected with the base and collector leads are utilized. Phototransistors could be distinguished from other transistors by the magnifier they have on them (Kostoy 2011).

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 phototransistor have been provided. In the conclusion part, an assessment has been made in line with the results obtained.

2. Material and Method

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

2.1. Experimental Set-up

The experimental setup used in this paper included a 5 V DC power supply, Dimmer which is used to lower or upper the brightness of a halogen lamp, 100 Ω resistance, LDR sensor, phototransistor 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.

3. Result and Discussion

In the experiment, two cases are considered to compare LDR and Phototransistor 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

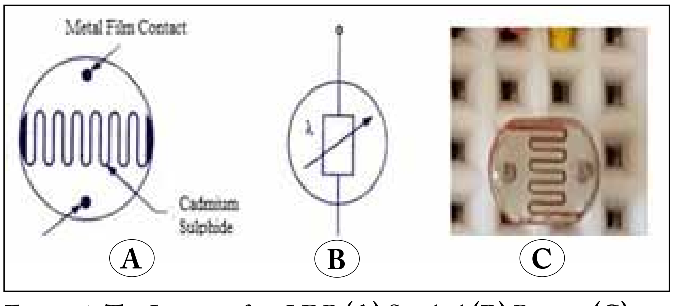

Figure 1. The Layout of an LDR **(A)** Symbol **(B)** Picture **(C)**.

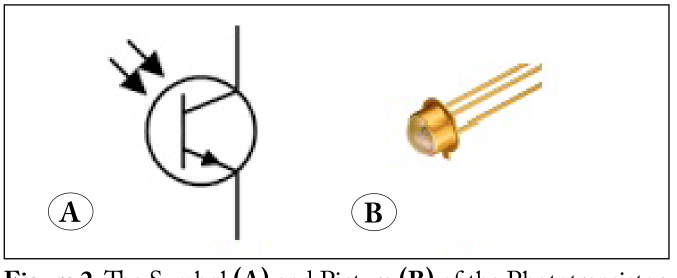

Figure 2. The Symbol **(A)** and Picture **(B)** of the Phototransistor

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.

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

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. The root-mean square deviation (RMSE) value is 37.56.

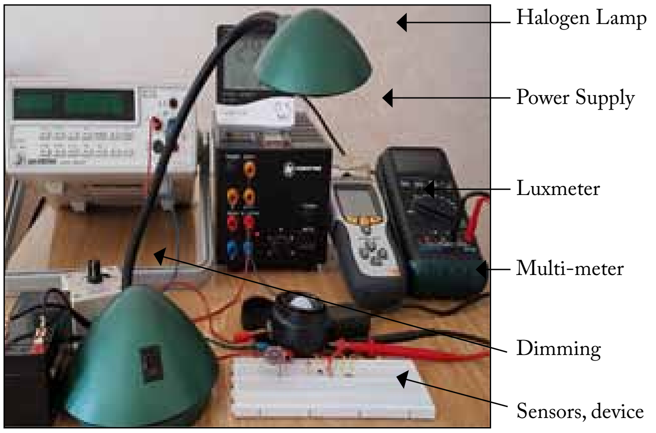

Figure 3. The system used for observing the output currents of LDR and phototransistor under different lighting levels and dc power.

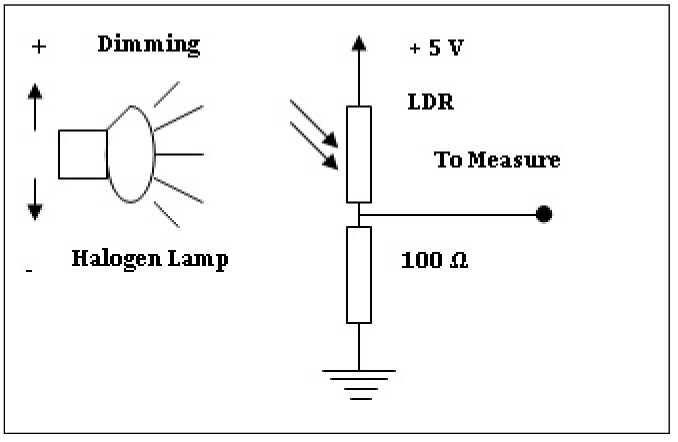

Figure 4. Different lighting values applied on LDR.

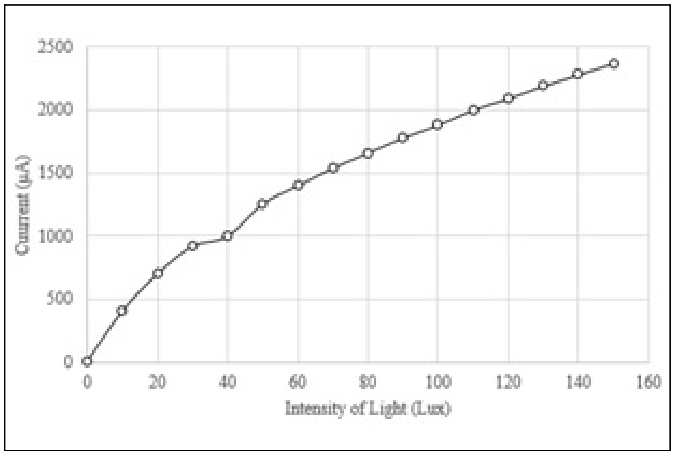

Figure 5. LDR's current response to the light change.

3.2. The Analysis of Phototransistor under Changing Illumination

In Figure 4, when the phototransistor 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 phototransistor, the curve in Figure 7 comes about.

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

Table 2. Phototransistor's current response to intensity of illumination.

Intensity of Illumination (Lux)	Current Response of Phototransistor (μA)
0	0.5
10	63
20	105.78
30	141
40	174.42
50	202.13
60	231.36
70	258.14
80	284.37
90	309.36
100	333.45
110	358
120	380.35
130	403.72
140	425.33
150	445.15
Maximum	445.15
Minimum	0.5
Mean	257.53
Standard Deviation	134.23
COV (Covariance (%))	52.176
SSE (the sum of the squared errors)	4116.06
MSE (the mean squared error)	257.253
RMSE (The root-mean-square deviation)	16.039

As it is seen in Table II, the Standard Deviation value stands at 134.23 and the root-mean square deviation (RMSE) value is 16.039.

Taking into consideration the findings obtained from the two experiments, it is seen that phototransistor'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 Phototransistor, 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 phototransistor's stands at 134.23. Together with the other statistical data, it can be said that the electrical responses of the phototransistor in relation

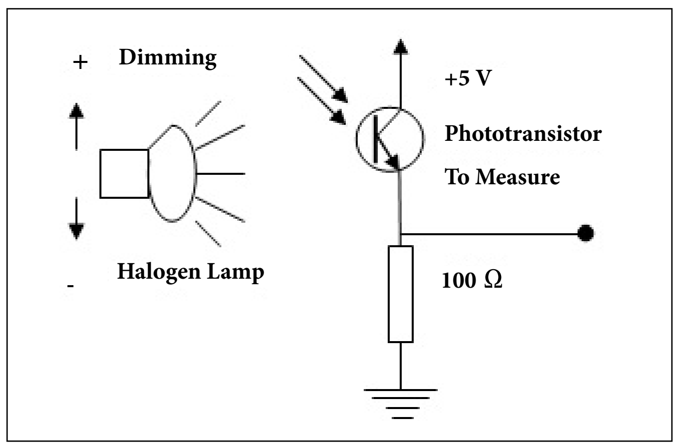

Figure 6. Different lighting values being applied on the phototransistor.

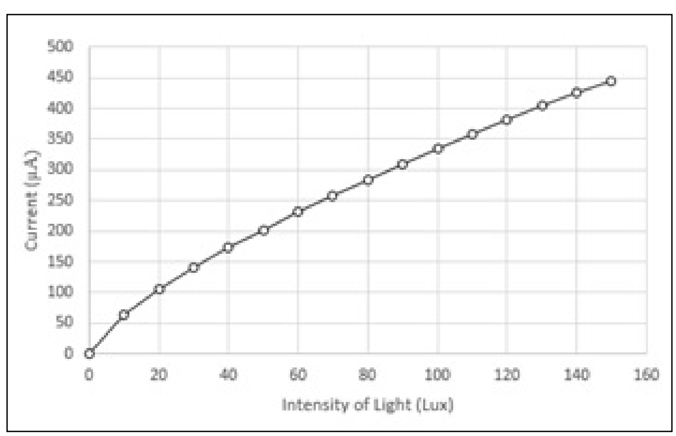

Figure 7. Phototransistor's current response to the intensity of light.

with lighting shows a better variation profile in terms of sensitivity and precision. In light measurement electronic systems, the consistency of the electrical values produced in relation with the illumination variations is essential. In the light of the light-based electrical values obtained from LDR and phototransistors, it seen that using phototransistors in illumination measurement device is going to give more consistent values.

5. References

Coskun, A., Sevil H.E., Ozdemir S. 2011. Cost Effective Localization in Distributed Sensory Networks. *Eng. Appl. of Artificial Int.,* 24:232–237.

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

Gentile, N., Laike, T., Dubois, M.C. 2016. Lighting Control Systems in Individual Officies Rooms at High Latitude: Measurements of Electricity Savings and Occupants' Satisfaction, *Solar En.,* 127:113-123.

Ghassan, M.S., Hashimah, I., Debnath, N., Nadya A. 2015. Optimal Light Power Consumption Using LSDR Sensor. *2015 IEEE Int. Symposium on Rob. and Int. Sensors (IEEE IRIS2015)*, 144-148.

Juan, F.D.P., Bajo, J., Rodriguez, S., Villarubia, G., Corchado, J.M. 2016. *Int. sys. for lighting cont. in smart cities. Inf. Sci.,*372 :241–255.

Kamran, A., Khokhar, A.Z. 2011. Rahman F., High responsivity silicon MOS phototransistors. *Sens.and Act. A*, 172:434-439.

Kostov, P., Hornstein, K.S., Zimmermann, H. 2011. Phototransistors for CMOS Optoelectronic Integrated Circuits. *Sen. and Act.,*172:140-147.

Lau, K.T., Baldwin, S., O'Toole, M. 2006. A Low-Cost Optical Sensing Device Based on Paired Emitter-Detector Light Emitting Diodes. *An. Ch. Acta.* 557:111–116.

Latha, P., 2013. Simulation of PLC based Smart Street Lighting Control using LDR, *Int. Jour. of Latest Trends in Eng. and Techn.,*2 (4): 113-121.

Osram, 2016. Phototransistor BP 103-5.

Ozcelik, M.A. 2016. Light Sensor Control for Energy Saving in DC Grid Smart LED Lighting System Based on PV System. *Jour. of Optoelect. Adv. Mat.,* 18(5-6):468-474.

Singh, S.P., Sathya P. 2014. Measurement of the illuminance using a Signal Conditioning Circuit. *Int.Journ. of Eng. Sciences & Research Tech.*, 3(5):574-578.

Toufiq, I., Afshari, S., Sandipan, M. 2016. An Experimental Survey of Feedback Control Methodologies for Advanced Lighting Systems. *En.Build.*, 130:600–612.

Yuwaldi, A., Ikhsan, M. 2017. Dual-axis sun tracker sensor based on tetrahedron geometry. *Automat.Construct.*, 73:175–183 .