Navigation Physics: Journal of Physics Education
Vol. 7, No. 2, December 2025
E-ISSN: 2722-5593

Analysis of the Precision, Accuracy, and Variability of the GL5506 LDR Sensor as a Low-Cost Luxmeter

Heriansyah [1], Fades Br.Gultom [1]
[1] Diploma-III Program in Science Laboratory,
Faculty of Mathematics and Natural Sciences, University of Bengkulu, Bengkulu, Indonesia

Abstract

The LDR (Light Dependent Resistor) sensor is inexpensive component that has been used as an alternative light intensity monitoring system, however its performance can be vary significantly because of large manufacturing variability. This study evaluates the performance of four GL5506 LDR sensors (S1-S4) as Arduino based luxmeter by considering lux-prediction accuracy, ADC-Signal stability, and sensor characteristic differences using a two-way ANOVA analysis. Light levels of intensity were measured from 10% to 100%, and turned the signals from the Arduino's ADC into lux values by exponential regression model. Accuracy was evaluated using MAE, RMSE, and R^2*. While stability, was assessed through standard deviation and the coefficient of variation (%CV). The results showed that all sensors had dominant lux-ADC relationship (*R^2 *over 0.997), but there are big differences in their actual accuracy. S1 and S2 had the lowest error, S4 is the most stable with a %CV of 0.32%, and S3 has the largest error, with an MAE of 41.92. The ANOVA results show that both the light level and the sensor unit have a big effect on the ADC values (*$p < 0.001$*), but the light error only depends on the sensor unit, not the light level (*$p > 0.05$*). These results suggest that each LDR should be calibrated on its own to get the most accurate light measurements.*

Keywords: *Light Dependent Resistor, Light Intensity, Luxmeter, Arduino, Accuracy*

Corresponding Author:
Heriansyah
Diploma-III Program in Science Laboratory, Faculty of Mathematics and Natural Sciences, University of Bengkulu, Bengkulu, Indonesia
Jl. WR. Supratman, Kandang Limun, Kec. Muara Bangka Hulu, Sumatera, Bengkulu 38371
Email: heriansyah@unib.ac.id

1. INTRODUCTION

A luxmeter is an instrument for measuring light intensity and that is commonly used in various fields such as interior design, education, occupational health, and agriculture (Heindri et al., 2022; Hashemifar et al., 2024). In practice, commercial luxmeters generally have high accuracy, but are relatively expensive. This makes commercial luxmeters less flexible for education purposes or small-scale use. This condition has encouraged the development of more economical alternative devices and provide reliable illuminance measurements, especially for practical needs in vocational education laboratories that require simple but standardized instruments.

The Light Dependent Resistor (LDR) is one of the low-cost light sensors that has been widely integrated with microcontrollers (Setya et al., 2019; Marinho et al., 2019; Wardhana et al., 2022; Yusof, 2024). The working principle of the LDR sensor is its ability to detect changes in light intensity through changes in resistance. Through this principle, the integration with microcontroller systems becomes easier to implement. However, the optoelectronic characteristics of LDRs are influenced the composition of CdS material composition, semiconductor film thickness, and production conditions. Consequently, the resistance response to changes in light intensity in LDRs non-generic. The difference in light resistance and dark resistance among LDR types in the GL55xx series shows that calibration cannot be performed uniformly; but must be adjusted to the type characteristics of each sensor used

(CDIL, n.d.). Inaccurate calibration can produce in significant illumination deviations in certain measurement ranges.

Although the use LDRs is quite common in microcontroller-based light sensing systems, there are still challenges in their application. This is due to heterogeneity of sensor performance. Differences in manufacturer tolerance can cause variations in resistance between LDR types and units of the same type. These differences may affect the accuracy of calibration models, measurement stability, and consistency of LDR sensors. In addition, previous studies have generally focused on the accuracy of a single LDR unit calibrated against a standard luxmeter, without comparing multiple units of the same type. Furthermore, the lack of analysis that integrated metrological parameters such as MAE, RMSE, R^2, and analysis of variance (ANOVA) has limited understanding of LDR reliability as a luxmeter alternative.

Based on this situation, this study aims to bridge the existing gap by conducting an in-depth analysis of the accuracy, precision, and variation of the GL5506 LDR sensor through controlled light measurements using a variable light source. The exponential regression method was used for calibration, accompanied by model performance assessment and statistical testing between sensor units. This research is expected to provide deeper insights into the performance of LDR sensors that function as an alternative to luxmeters, thereby opening up the possibility of developing a more stable and reliable LDR sensor-based luxmeter system.

2. METHODS

This study applied an experimental method with controlled lighting to assess the accuracy, precision, and fluctuation of the GL5506 LDR sensor. Four GL5506 LDR units (S1-S4) were connected to an Arduino Uno microcontroller through a 10kΩ voltage divider circuit. The test was conducted using a 12-watt smart lamp with a maximum brightness level of 1300 lm. Other tools, such as a 20 x 4 LCD, were used to display the measurement results directly. The luxmeter circuit equipped with four LDR sensors can be seen in Figure 1.

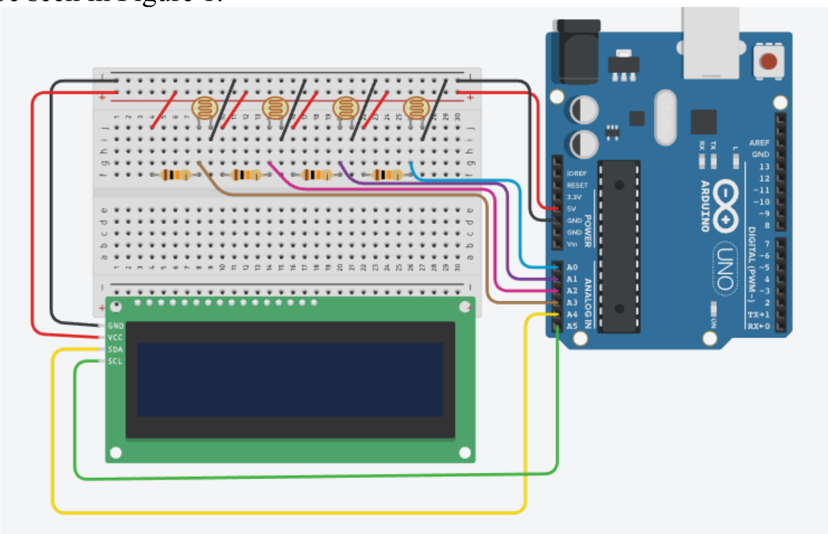

Figure 1. LDR Sensor Testing Circuit with Arduino

The experiment was carried out with intensity variations ranging from 10% to 100% within a controlled dark environment. The test was repeated three times for all sensors. Meanwhile, the reference luxmeter used a commercial luxmeter with the brand GM1030C. The testing took place within a test box that measured 70 × 50 × 50 cm³, and the distance maintained between the light source and the sensor was set at 57 cm.

During the experiment, ADC values were obtained from all four sensors and three repetitions. In addition, reference lux values were also averaged from repetitions for each intensity level. The ADC value is then converted into a light value using an exponential regression model with formula (1).

$$Lux = Ae^{B.ADC} \quad (1)$$

Lux refers to the unit of measurement for light intensity, while ADC indicates the value of the analog-to-digital converter. Parameters A and B are determined through a linear regression process. The performance of this calibration model is determined by utilizing the coefficient of determination (R2), Mean Absolute Error (MAE), and Root Mean Square Error (RMSE), which compare the predicted lux value with the reference lux value. The accuracy of the system is assessed based on the standard deviation and coefficient of variation (%CV) for ADC data from each sensor at various illumination levels. Variations between sensor units are analyzed using two-way analysis of variance (ANOVA) related to ADC values and lux errors. This step aims to find significant differences between sensors and illumination levels.

3. RESULT AND DISCUSSION

An evaluation of the performance of four GL5506 series LDR sensors (S1-S4) was conducted to evaluate the accuracy of the applied exponential regression model. Exponential regression models are commonly applied in the calibration process of Arduino-based LDR sensors (Wardhana et al., 2022; Kusuma et al., 2023). This preference arises from non-linear nature of LDRs. The ADC valued were collected from the four LDR sensors across different level of illumination, with the ADC data shown in Table 1.

Table 1. ADC Measurements of Four LDR Units at Various Light-Intensity Levels

Tingkat Cahaya	Nilai Lux Referensi (Lux)	ADC S1	ADC S2	ADC S3	ADC S4
10%	141,00 ± 1,73	333,00 ± 2,65	264,00 ± 2,65	341,00 ± 2,00	411,00 ±3,00
20%	219,00 ± 6,00	404,00 ± 1,00	321,67 ± 0,58	412,00 ± 7,00	486,33 ± 5,03
30%	283,67 ± 3,79	450,33 ± 3,21	357,67 ± 2,08	454,33 ± 0,58	529,33 ± 0,58
40%	344,00 ± 1,00	485,33 ± 2,08	389,33 ± 3,21	491,67 ± 1,53	564,67 ± 1,53
50%	408,33 ± 3,06	520,67 ± 1,53	419,33 ± 4,51	525,33 ± 3,21	594,33 ± 1,15
60%	475,00 ± 3,61	549,00 ± 0,00	445,00 ± 1,73	556,00 ± 1,00	623,33 ± 0,58
70%	549,67 ± 0,58	569,00 ± 10,44	469,00 ± 4,00	584,33 ± 2,08	646,67 ± 1,53
80%	607,00 ± 1,00	595,33 ± 2,08	486,33 ± 3,06	600,33 ± 2,08	663,67 ± 1,53
90%	620,67 ± 7,23	599,67 ± 2,89	489,67 ± 1,53	605,33 ± 1,53	667,67 ± 1,15
100%	630,33 ± 5,77	602,33 ± 3,21	492,33 ± 2,52	608,00 ± 2,52	670,00 ± 1,87

The experimental findings concerning all sensor units, there was a consistent increase in ADC values as the light intensity increases from 10% to 100%. These values correspond to the voltage measured across the voltage divider, thus the increase in ADC readings from S1–S4 verifies a standard and valid photoconductive response. At every illumination level, there were differences in ADC values for each LDR sensor units. The S4 showed the highest ADC value, whereas the S2 showed the lowest. These differences indicate the high variability in LDR manufacturing. Differences in the production process can cause dimensional differences that affect device performance (Olu-Lawal et al., 2024). Even small defferences in sensor dimensions can affect the characteristics of the LDR. According to Kusuma et al. (2023 different LDR sensor sizes will provide different readings, where a 10 mm size provides a higher light intensity reading than a 5 mm LDR size.

The standard deviation derived from three repetitions indicates the stability of sensor readings. The reference luxmeter shows deviations between 0.58 and 7.23 lux. This indicates variations in light intensity originating from the smartbulb. These variations may be triggered by Pulse Width Modulation (PWM) in the lamp, which causes rapid light flickering (Shah et al., 2025). On the LDR sensor, the lowest deviation was recorded on S4 with a range of 0.58-1.87 lux. S1 showed greater deviation than the other units, especially at a lighting level of 70%. Low deviation on LDR units generally reflects conditions with low noise levels, indicating that fluctuations in the ADC do not originate from the circuit but from the nature of the sensor itself.

The LDR sensor does not provide consistent ADC values at specific lux levels, indicating that the response between each unit is not uniform. This reinforces the reason for avoiding a single calibration model for all sensors. Individual unit calibration is mandatory to ensure the accuracy of alternative LDR sensor based luxmeters.

An evaluation of absolute accuracy for the four sensors was conducted by analyzing MAE, RMSE, and R^2 values. Table 2 show a comparison of the accuracy evaluation for S1–S4. Based on the obtained data, S1 has excellent accuracy, as indicated by an MAE of 7.98 lux and an RMSE of 9.20 lux. This values are the lowest among all units. In contrast, S3 shows poor accuracy with an MAE of 41.92 lux and an RMSE of 45.94 lux.

Table 2. Comparison of MAE, RMSE, and R^2 Across LDR Units

Unit LDR	MAE (lux)	RMSE (lux)	R^2
S1	7,98	9,20	0,9979
S2	9,06	10,38	0,9982
S3	41,92	45,94	0,9990
S4	12,88	14,37	0,9998

The coefficient of determination (R^2) shows high values for all LDR units This indicates that the exponential regression model effectively describing the relationship between lux and ADC values. However, even a high R^2 value, it does not mean that the absolute accuracy is better, as observed with S3 unit. This may occur because there are other influencing factors, such as sample size and standard error, which affect the efficiency of the regression model.

The standard deviation (SD) and coefficient of variation (%CV) parameters of the ADC output on the four LDR sensors assess signal stability, interference, and sensor reading consistency. Table 3 presents data on the SD and %CV of the four sensors. The %CV values for all sensors range from 0.32 to 0.63%. This indicates that the relative variation of the ADC signal is very small, which indicates that the noise in the readings is also minimal. S4 shows the most stable sensor performance with an SD of 1.87 and a %CV of 0.32%. The high level of stability in this sensor indicates good consistency in response to changes in light. S1 shows the highest SD even though the %KV is 0.57%, which explains that S1 has greater reading fluctuations compared to the other units.

Table 3. Comparison of SD and %CV Across LDR Units

Unit LDR	SD	%KV
S1	2,91	0,57
S2	2,59	0,63
S3	2,45	0,47
S4	1,87	0,32

A two-way ANOVA analysis without replication was performed to examine the variation in ADC signals caused by variations in light levels and differences in sensor units (Table 4). The results showed that the F value obtained for light levels was 725.06, which exceeded the critical F value of 2.25. This indicates that changes in light levels have a very significant impact on ADC values. Meanwhile, for sensor units, the calculated F value reached 1191.54, far exceeding the critical F value of 2.96. This confirms that the differences between sensor units are very significant.

Table 4. ANOVA of ADC Values Across Illumination Levels and Sensor Units

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Level	275302,7	9	30589,19	725,062	8,28E-30	2,250131
Unit Sensor	150807,2	3	50269,05	1191,538	8,68E-29	2,960351
Error	1139,086	27	42,18837			
Total	427248,9	39				

Furthermore, ANOVA analysis was also applied to lux error, which is the difference between the lux value predicted through regression and the reference lux (Table 5). The analysis results show that the F value produced at the illumination level is 0.82, which is lower than the critical F value of 2.25

(p>0.05). This indicates that the illumination level does not have a significant effect on the error of the predicted lux value. However, for the sensor unit, the F value obtained is 27.83, which is much higher than the critical F value (2.96). This shows that differences in sensors result in significant errors. This can be seen in S3, which shows a much larger error than other units. Variability in the manufacturing process is the main source of absolute errors experienced by LDR sensors.

Table 5. ANOVA of Lux Error Across Illumination Levels and Sensor Units

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Level	1205,602	9	133,9558	0,817848	0,604839	2,250131
Unit Sensor	13676,12	3	4558,707	27,83254	2,05E-08	2,960351
Error	4422,344	27	163,7905			
Total	19304,07	39				

Based on the two ANOVA analyses conducted, the information obtained shows that the ADC response is significantly affected by light intensity. This is in accordance with the working principle of LDR. The variation between sensor units is statistically significant for ADC values and lux errors. Light intensity does not affect lux errors, due to the stable exponential regression model. Lux error is influenced by sensor differences, so the accuracy of the luxmeter will be affected by the quality of the sensor unit. Variability between sensor units clearly affects the ability of the LDR sensor as an intensity measuring device. Individual calibration systems must be carried out in the development of LDR sensor-based illumination measuring devices to improve measurement accuracy.

4. CONCLUSION

This study shows that all LDR sensors have a very strong lux–ADC relationship ($R^2 > 0.997$), so that an exponential regression model is appropriate for mapping their photoconductive response. However, the accuracy of lux predictions differs significantly between units, with S1 and S2 showing the lowest errors, S4 having the best reading stability (KV 0.32%), and S3 producing the largest errors, indicating high manufacturing variability. The excellent ADC stability across all sensors (KV < 1%) confirms that the performance differences are not caused by noise, but by the inherent characteristics of the sensors. ANOVA confirms that light intensity and sensor unit significantly affect the ADC value, while lux error is mainly influenced by differences in sensor units and is not related to the illumination level. Therefore, each LDR sensor requires individual calibration because the use of a single regression model cannot be applied universally. Overall, LDRs have the potential to be used as low-cost luxmeters, but accurate implementation depends on the selection of stable sensors, per-unit calibration processes, and good measurement control.

ACKNOWLEDGMENTS

The authors express their sincere gratitude to the Faculty of Mathematics and Natural Sciences, University of Bengkulu, for funding this research through the Development Grant Scheme under Contract No. 4536/UN30.12/HK/2025..

REFERENCES

Heindri, N., Dewi, O.C., and Ismoyo, A.D., (2022), Lighting system evaluations of working space in educational building, Universitas Indonesia. IOP Conference Series: Earth and Environmental Science, 998 012029

Hashemifar, Z., Sanjarian, F., Naghdi, B.H., and Mehrafarin, A., (2024), Varying levels of natural light intensity affect the phyto-biochemical compounds, antioxidant indices and genes involved in the monoterpene biosynthetic pathway of Origanum majorana L. BMC Plant Biol. 24(1).

Setya, W., Ramadhana, A., Putri, H.R., Santoso, A., Malik, A., and Chusni, M.M., (2019), Design and development of measurement of measuring light resistance using Light Dependent Resistance (LDR) sensors. Journal of Physics: Conference Series, 1402 044102

Marinho, F., Carvalho, C.M., Apolinario, F.R., and Paulucci, L., (2019), Measuring light with light-dependent resistors: an easy approach for optics experiments, 40 035801

Wardhana, I., Isnaini, V. A., Wirman, R. P., Novitasari, N., & Gunawan, O. I. (2022). Rancang Bangun Lux Meter Real Time Berbasis Internet of Things. Jurnal Fisika Flux: Jurnal Ilmiah Fisika FMIPA Universitas Lambung Mangkurat, 19(1), 43-49.

Yusof, I. M., & Zin, R. M. (2024). IoT Based Light Intensity Measurement Devices for Indoor Monitoring. Evolution in Electrical and Electronic Engineering, 5(1), 221-229.

CDIL., (n.d.), GL55 Series Photoresistor datasheet, [online]. Availabel: https://www.micros.com.pl/mediaserver/info-orrgl5549.pdf

Olu-lawal, K. A., Olajiga, O. K., Ani, E. C., Adeleke, A. K., & Montero, D. J. P. (2024). The role of precision metrology in enhancing manufacturing quality: a comprehensive review. https://doi.org/10.51594/estj.v5i3.868

Kusuma, A., Saputra, H., Muharzi, Sandi, T., (2023). Analisis Perbandingan Performa Sensor Light Dependent Resistor (LDR) pada Ukuran 5mm dan 10mm dalam Pengukuran Intensitas Cahaya. Dalam: Seminar Nasional Teknik Elektro. Conference: Seminar Nasional Teknik Elektro (SNTE) 2023. Magelang: 10 Agustus 2023 Hal. 175-180

Shah, A., Ashwith,R., Robinson, D., Raj, G., Shetty, R. 2025. Controlling the Intensity of a Bulb Based on Surrounding Light Using Arduino and LDR. International Journal of Advanced Research in Science, Communication and Technology, 5 (1)

BIOGRAPHIES OF AUTHORS

Heriansyah is a lecturer in the Diploma-III Science Laboratory Technology Program, Faculty of Mathematics and Natural Sciences, University of Bengkulu, Bengkulu City, Indonesia. His research focuses on physics, materials physics, and physical instrumentation. He can be contacted at:
heriansyah@unib.ac.id

Fades Br. Gultom is a lecturer in the Diploma-III Science Laboratory Technology Program, Faculty of Mathematics and Natural Sciences, University of Bengkulu, Bengkulu City, Indonesia. His research focuses on physics and Geophysics. He can be contacted at:
fadesgultom@unib.ac.id