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EFFECT OF SENSOR GAP, LIGHT INTENSITY, AND TEMPERATURE ON PERFORMANCE OF OPTOCOUPLER

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Abstract: *Previous studies have utilized optocouplers that consist of Light Emitting Diode (LED) and photodiode or phototransistor pairs. However, these studies did not investigate how changes in the gap between the LED and photodiode would affect the output of the photodiode sensor. Therefore, this study aimed to explore the effects of physical factors such as changes in sensor gap, light intensity, and temperature on the output of the photodiode sensor in an optocoupler. The results showed that the increase in the gap between the LED and photodiode was directly proportional to the increase in the photodiode output, which consisted of various segments depending on the type of photodiode used. However, the output of the photodiode sensor decreased with an increase in light intensity due to destructive interference between the LED light waves and the ambient light waves that illuminated them. The study also found that the photodiode output did not significantly change with variations close to the room temperature.*

Keywords: *Optocoupler, Sensor gap, Light intensity, Temperature.*

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Introduction

An optocoupler, also known as an optoisolator, is an electronic component that is used to isolate two circuits from each other while allowing signal transfer between them. It consists of a light-emitting diode (LED) and a photosensitive detector (such as a photodiode or a phototransistor) packaged together in a single device. The two parts are separated by a transparent barrier.

When an electric current flows through the LED, it emits light that is detected by the photosensitive detector on the other side of the barrier. The amount of current flowing through the LED controls the amount of light emitted, which in turn controls the current flowing through the photosensitive detector. This allows electrical signals to be transmitted between the two circuits without any direct electrical connection. Due to how they operate, optocouplers are widely used in applications where electrical isolation is required for safety, protection, and noise reduction.

Several previous studies (Sesa, Farhamsah, & Lasman, 2016; Sesa et al., 2020; Sesa, Labania, Darwis, Ismail, & Ulum, 2021; Sesa, Ulum, Farhamsa, & Samsul, 2018; Sesa et al., 2023) have utilized self-produced optocouplers in their final project, but they did not consider physical factors such gap of LED and photodiode, ambient light intensity, and temperature. Although Sesa *et al* research identified light's impact on those optocouplers, ambient light's influence was not deeply explored (Sesa et al., 2020). Moreover, no research has been found to examine the effect of varying the gap between LED and phototransistors on the optocoupler's output.

This paper aims to investigate the impact of various physical factors, including changing the LED and photodiode gap, the variation of ambient light intensity, and the temperature differences, on the photodiode's output in those optocouplers. The study utilizes two types of photodiodes: ordinary photodiodes and infrared photodiodes. The findings demonstrate that the two photodiodes exhibit different output behaviors.

Literature review

Optocouplers are electronic components that use light to transmit signals between two isolated circuits (Figure 1). They are used in a variety of applications where electrical isolation is required, such as power supply switching (Bizon, Sofron, Raducu, & Oproescu, 2010; Panov & Jovanovic, 2004; Shi, Lu, Chen, & Feng, 2014), industrial control systems (Chen, Zhang, & Liu, 2016; Sergei, Bohdan, & Viktoriya, 2019), audio equipment (Crisan, 2014; Eichas & Zölzer, 2016), medical devices (Majid, Yusro, Yuliatmojo, & Siregar, 2021; Sun, Zhu, Ma, Xing, & Wang, 2019), and automotive systems (Dimitrov, Collier, & Cruden, 2019; Wu, Liu, Wang, Su, & Yue, 2021).

There are four variations of optocouplers, each with a distinct photosensitive component but the same LED as shown in Figure 2. The photodiode or phototransistor and photo-Darlington are commonly used in direct current (DC) circuits, while the photo-SCR and photo-TRIAC are typically used for regulating alternating current (AC) circuits. The phototransistor optocoupler contains a transistor that could be either PNP or NPN. On the other hand, the photo-Darlington optocoupler includes two transistors, with one controlling the other, resulting in a high-gain transistor.

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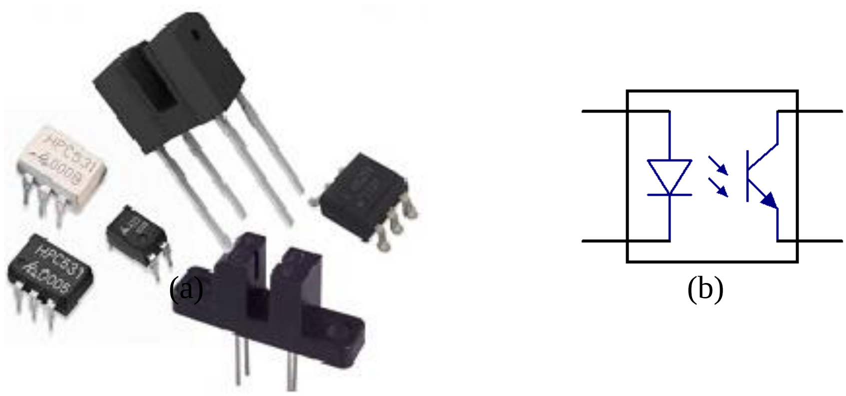

Figure 1: (a) Some examples of optocouplers and (b) symbol of an optocoupler (Suprianto, 2015)

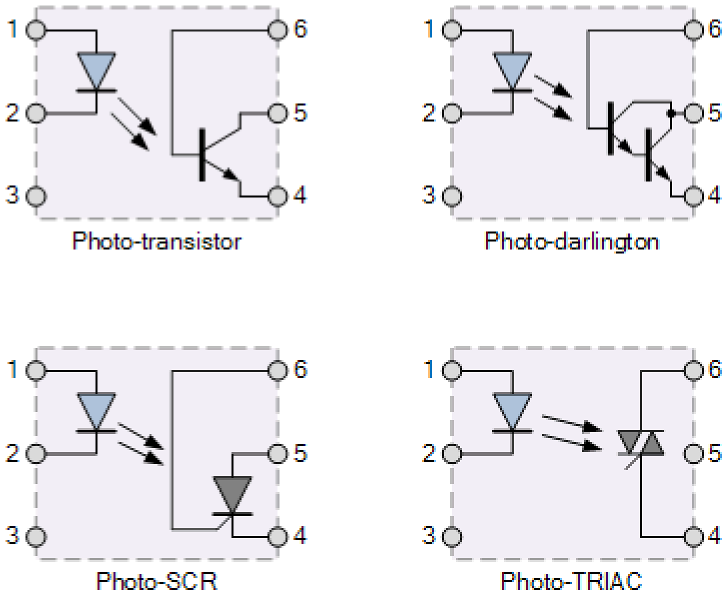

Figure 2: The four types of optocouplers based on the application of different photosensitive components (Electrical-Technology, 2012-2023).

Based on the light source used, optocouplers are categorized into two types: ordinary optocouplers and infrared optocouplers. Ordinary optocouplers use visible light to transmit signals between the LED and the photodetector (Kasap, 2012). These optocouplers are often used in low-frequency applications and have a relatively slow response time compared to their infrared counterparts. They are also more susceptible to ambient light interference, which can cause errors in the output signal. Infrared optocouplers, on the other hand, use infrared light to transmit signals (Sesa et al., 2020). This type of optocoupler is preferred in high-frequency applications because they have a faster response time and are less susceptible to interference from ambient light. Infrared optocouplers also have a longer transmission distance than ordinary optocouplers. Another advantage of infrared optocouplers is their ability to operate at higher temperatures. The infrared light used in these optocouplers has a longer wavelength than visible light, which allows it to penetrate materials better. This property makes infrared optocouplers suitable for harsh environments where temperature and humidity vary widely.

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Several studies have explored the influence of physical factors, such as radiation and extreme temperatures, on optocoupler performance. Abd El-Basit *et al* researched the impact of extreme environmental conditions, specifically temperature fluctuations ranging from -175 ºC to 100 ºC (Abd El-Basit, Hassan, Kamh, & Soliman, 2017). The results revealed that the collector current of the phototransistor of the optocoupler exhibited temperature dependence that followed a Gaussian distribution. In another case, the study investigated the performance of multiple quantum well LEDs and photodiodes in detecting and emitting light at temperatures up to 800 K. The findings suggest that it is possible to integrate a pair of specific LEDs to create high-temperature optocouplers that can be utilized as galvanic isolation, replacing the need for bulky isolation transformers in high-density power modules (Sabbar et al., 2022). Moreover, several studies have examined the ability of optocouplers to withstand radiation (Brelski & Hiemstra, 2015; Miyahira & Johnston, 2002; Reed, Marshall, & Label, 2004), including exposure to various types of radiation such as gamma rays, particles, and ions.

Materials And Methods

Materials

A set of instruments was built to examine the impact of three physical parameters on the performance of a self-produced optocoupler, namely altering the gap between the LED and photodiode, varying the ambient light intensity, and differentiating the ambient temperature on the optocoupler. The block diagram of this instrument is shown in Figure 3. The instrumentation consists of two main parts, namely the mechanical system and the electronic system. The mechanical system consists of a box with dimensions of 40 cm x 40 cm x 40 cm (Figure 4) and a spacer for gap variation (Figure 5).

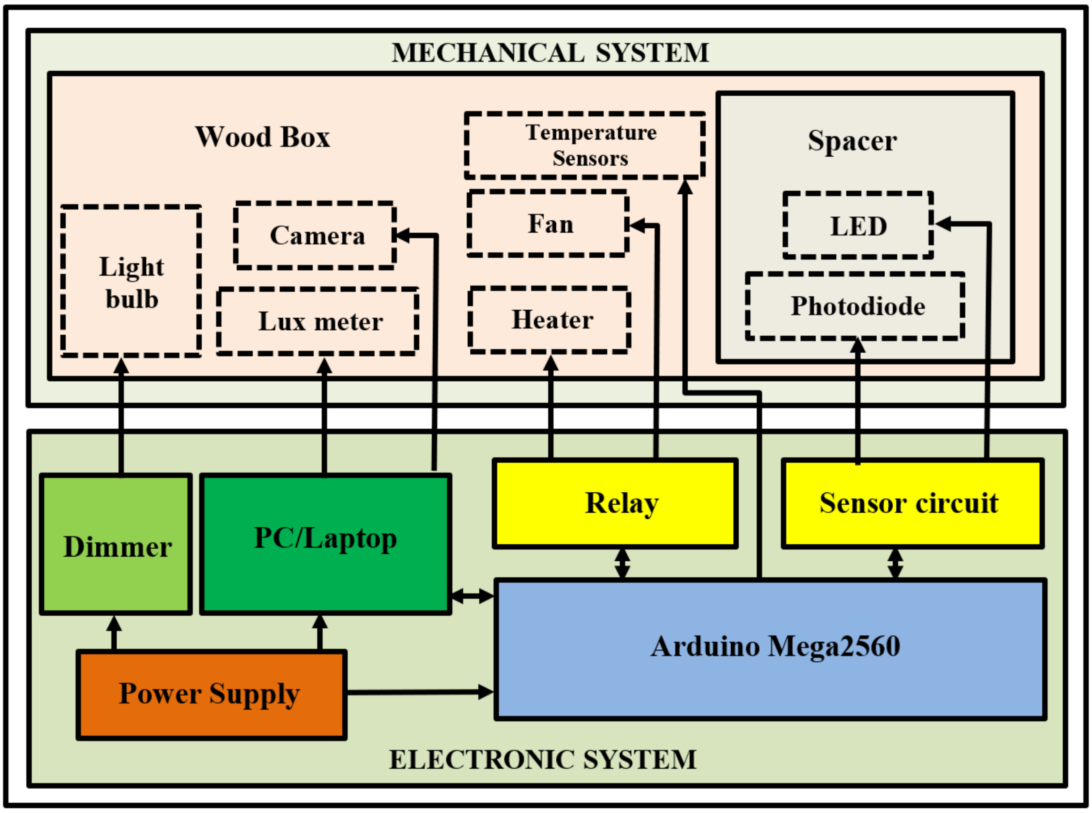

Figure 3: Block diagram of the testing instrument for optocoupler

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Figure 4: The instrument for testing the effect of the three physical parameters on the output of the photodiode of the self-produced optocoupler.

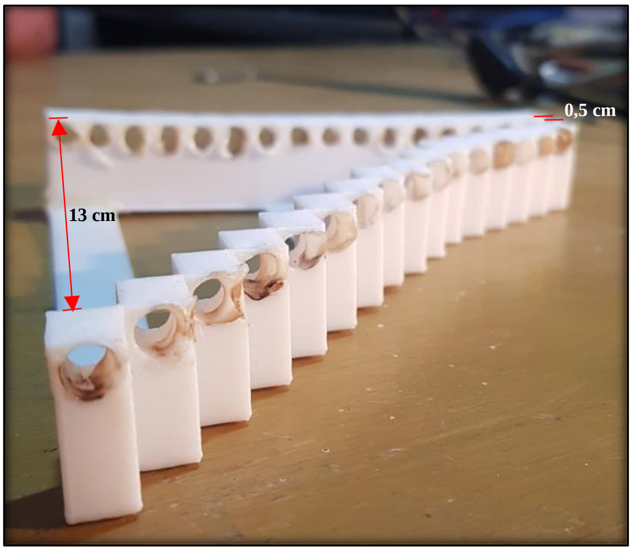

Figure 5: Spacer for gap variation treatment

The interior of the box was lined with aluminum foil to maintain its condition and prevent it from being influenced by the surrounding environment (Figure 6). On the other hand, the electronic system consists of an Arduino Mega2560 connected to a heater, fan, optocoupler circuit, and temperature sensors that used 4 pieces of LM35. The temperature sensors are placed in each side of the box wall (Figure 7). Additionally, there is a PC/Laptop to control the camera, lux meter, and programming of the Arduino Mega2560 in this system. The self-produced optocoupler that is used in this instrument was constructed by using both ordinary and infrared-based LED and photodiode components with a size of 5 mm. The sensor circuit for the self-produced optocoupler used in this instrument is shown in Figure 8.

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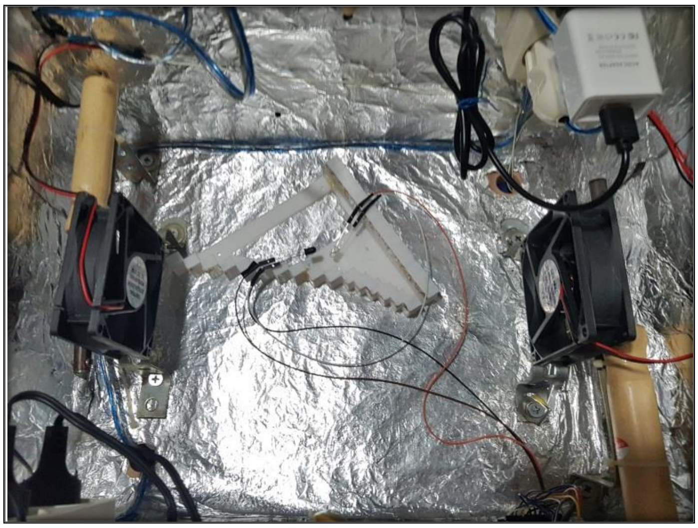

Figure 6: The interior of the instrument box is sealed with aluminum foil.

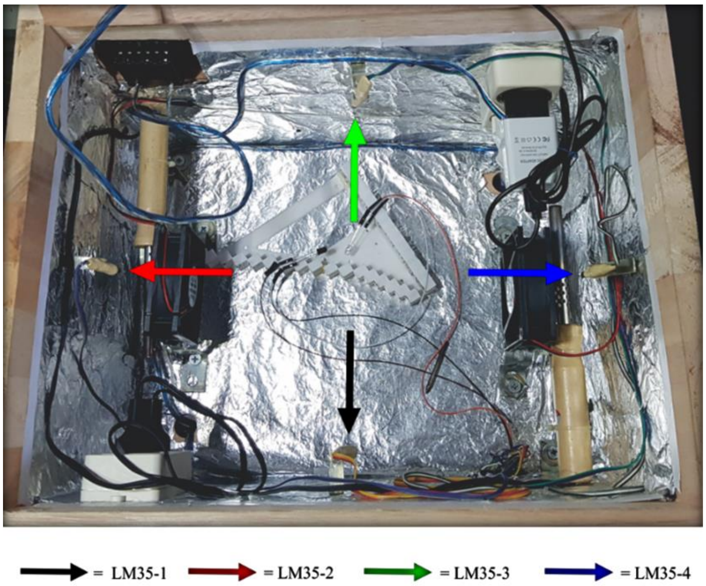

Figure 7: The four temperature sensors are placed in four-sides of the box wall

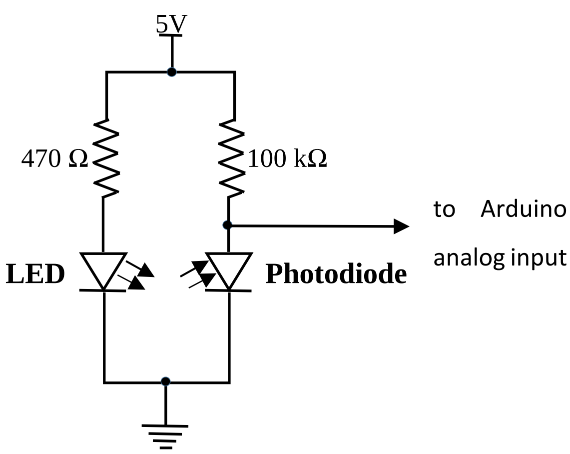

Figure 8: The optocoupler circuit used in the instrument.

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Methods

Effect of variation of the gap between the LED and photodiode

The measurement of the optocoupler output voltage for the variation of the gap between the LED and photodiode was conducted by installing the LED and photodiode facing each other in the circuit with a spacer. The measurement started with a gap of 0.5 cm. For each gap, the voltage was measured 10 times and then averaged. The same treatment was repeated for gaps of 1 cm, 1.5 cm, 2 cm, 2.5 cm, 4 cm, 6 cm, 8 cm, 10 cm, and 13 cm.

Effect of variation of light intensity

Regarding the observation of the effect of light intensity, the variation of light intensity inside the instrument box was conducted by adjusting the dimmer connected to the light bulb on the instrument box cover (Figure 9). The value of light intensity could be observed through the infrared camera attached to the lit of instrument box. The optocoupler output voltage measurement was carried out with a variation of intensities of 500 lux, 1000 lux, 1500 lux, 2000 lux, and 2500 lux. The measurement was conducted for gaps of 0.5 cm, 6 cm, and 13 cm.

Effect of ambient temperature differences

Meanwhile, the measurement of the optocoupler output voltage for the variation of temperature was conducted at temperatures that close to the room temperature, which was 30°C, 40°C, and 50°C. This measurement was also conducted for gaps of 0.5 cm, 6 cm, and 13 cm.

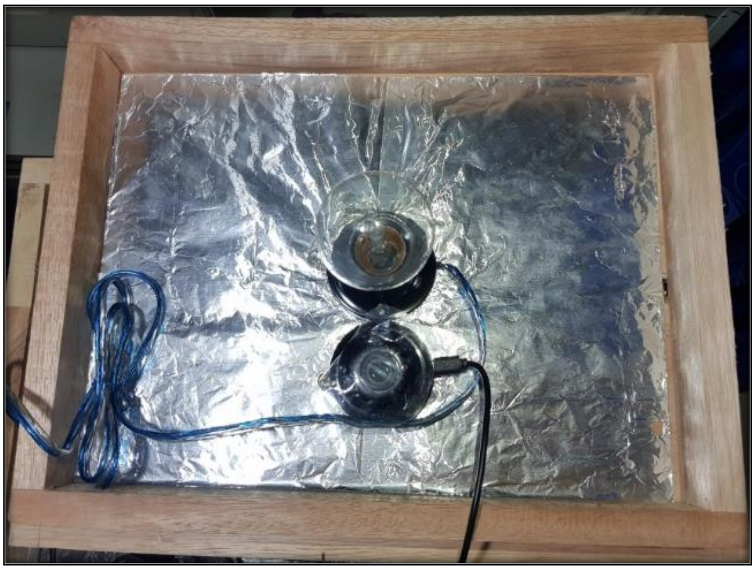

Figure 9: The light bulb and infra camera under the lit of the instrument box

Results and discussions

Effect of variation of the gap between the LED and photodiode

Figure 10 shows that the output of the photodiode tends to increase with the gap between the LED and the photodiode. For infrared photodiode, at the gap of 0.5 cm - 2 cm, the output of the photodiode tends to increase with a gradual slope. However, when the gap is higher than 2 cm, the output of the photodiode increases with a steeper slope as the gap changes. In essence, the output of a standard photodiode consists of two segments of slope on the graph. The first segment is present at small gaps between the LED and the photodiode (0.5 cm - 2.5 cm), where

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the increase in output is more significant with respect to the gap and has a steeper slope. The second segment occurs at longer gaps, where the increase in output with respect to the gap tends to be smaller compared to the first segment and has a gentler slope.

The two measurement graphs show a contrasting behavior between the output of a regular photodiode and an infrared photodiode with respect to the LED and photodiode gap variation. First, at the starting point, the value of the regular photodiode is already high while the infrared photodiode is still low, almost close to zero. Second, the behavior of the output of these two photodiodes is different, where the increase in output of the infrared photodiode with respect to the gap changes starts with a gentle slope and then becomes steep. On the other hand, the output of the ordinary photodiode starts with a steep slope at short gaps and becomes gentler at greater gaps.

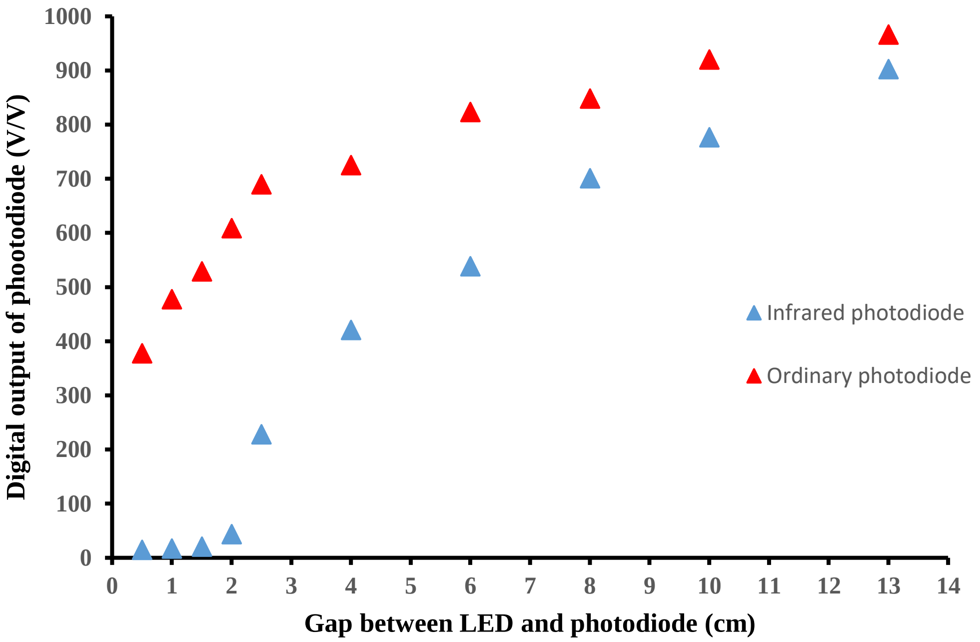

Figure 10: The output of the ordinary optocoupler (red triangle) and infrared optocoupler (blue triangle) due to the variation of gap between the LED and photodiode.

Effect of variation of light intensity

In Figure 11(a), the output of the infrared photodiode tends to decrease as the light intensity increases at all gaps. At gap of 6 cm and 13 cm, the photodiode output experiences a significant decrease compared to a gap of 0.5 cm. This indicates that at the gap of 6 cm and 13 cm, there is a wide space where the LED light waves will interfere with the light waves from the lamp. The light beam provided by the LED (transmitter) horizontally to the photodiode receiver interacts with the light beam from the incandescent lamp vertically. The decrease in the photodiode output with increasing intensity indicates that the interference becomes more destructive, which will have an impact on both the quantity and quality of light received by the photodiode. For a gap of 0.5 cm, there is a narrow space, and the amount of interfering light is not significant, so the amount and quality of light received by the photodiode are still high. The same phenomenon is observed in the behavior of the output of the regular photodiode in response to changes in intensity (Figure 11(b)).

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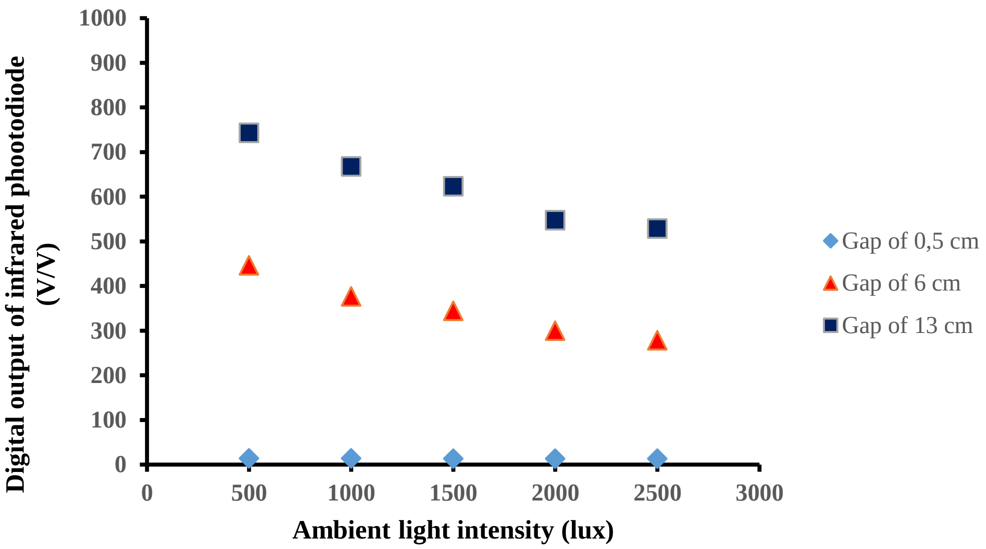
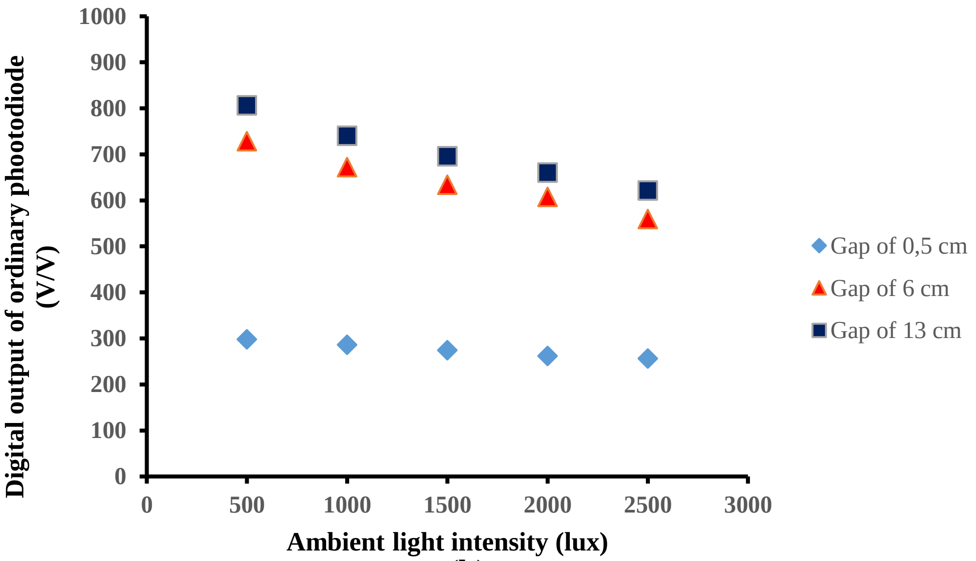


(a)



(b)

Figure 11: The optocoupler output under light intensity variation where (a) infrared photodiode and (b) Ordinary photodiode.

Effect of ambient temperature differences

Figures 12 demonstrate that both the output of the infrared photodiode and the ordinary photodiode tend to increase with temperature changes, but the increase is very small for all gaps. The slope of the data distribution at all three gaps is very small (almost 0). This phenomenon indicates that the temperature changes made have not significantly affected the output changes of both photodiodes. The figure also shows that output of the photodiode is dependent on the gap between LED and photo diode where the smaller the gap, the higher the digital output of the photodiode.

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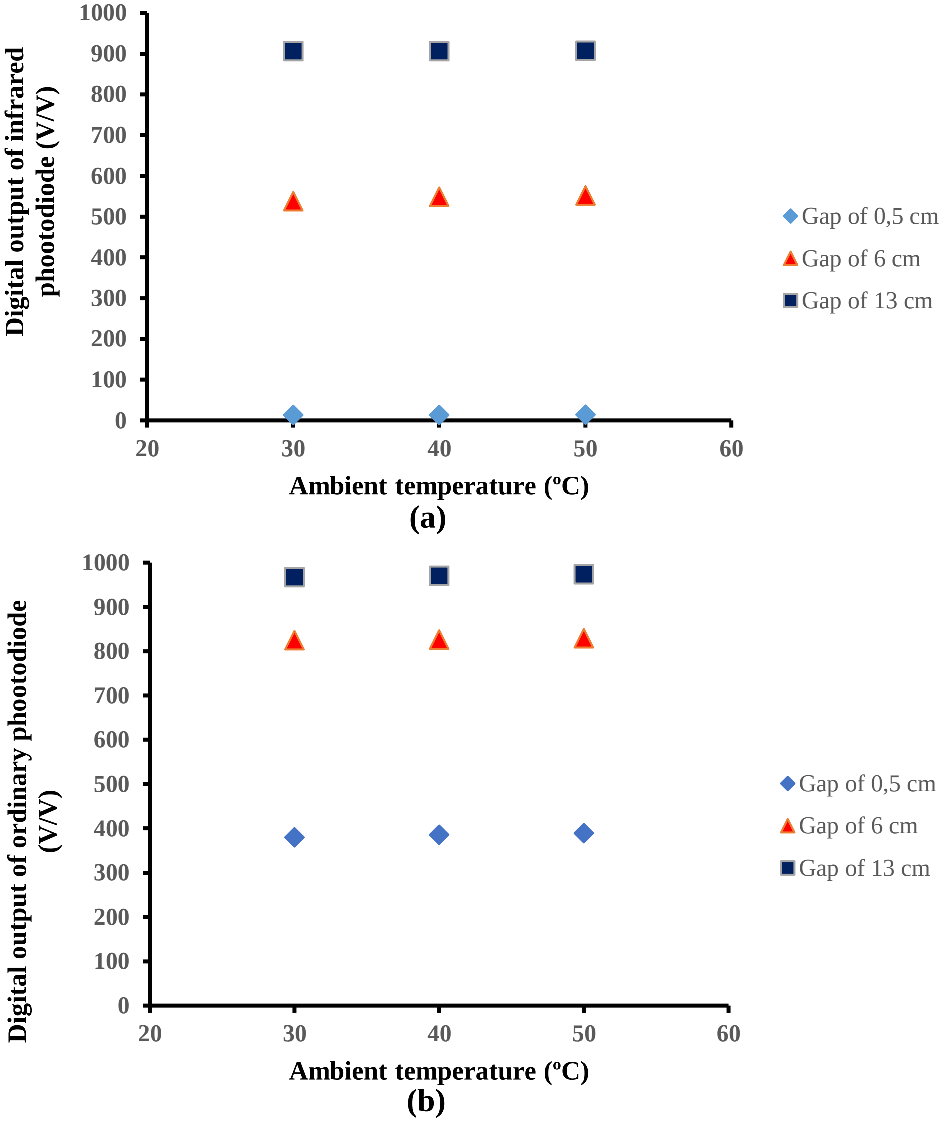

Figure 12: The optocoupler output under temperature variation where (a) infrared photodiode and (b) Ordinary photodiode.

Conclusions

The investigation of the impact of various physical factors, including changing the LED and photodiode gap, the variation of ambient light intensity, and the temperature differences, on the photodiode's output have been done. The increase in the gap between the LED and the photodiode is directly proportional to the increase in the output of the photodiode, which consists of various segments depending on the type of photodiode. On the other hand, the output of the photodiode is inversely proportional to the increase in light intensity. The output tends to decrease with increasing intensity, indicating the occurrence of destructive interference between the LED light waves and the lamp light waves. Additionally, the output of the photodiode did not significantly change with the temperature changes applied in this study.

Reccomendation

Based on the investigation of temperature effect that conducted only on three temperature values, we recommend continuing the research on the wide range of temperature differences to show entire picture of temperature effect on both ordinary and infrared optocouplers.

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References
Abd El-Basit, W., Hassan, W., Kamh, S., & Soliman, F. (2017). Operation of Optocouplers Under the Influence of Extreme Environmental Conditions. *Journal of Nanoelectronics and Optoelectronics, 12*(1), 33-41.

Bizon, N., Sofron, E., Raducu, M., & Oproescu, M. (2010). Nonlinear control for buck switching power supplies using opto-couplers in the stabilization feedback loop. *Optoelectronics and Advanced Materials-Rapid Communications, 4*(June 2010), 788-794.

Brelski, J., & Hiemstra, D. (2015). *Predicting optocoupler life with radiation damage in various circuits.* Paper presented at the 2015 IEEE radiation effects data workshop (REDW).

Chen, R., Zhang, Y., & Liu, J. (2016). *Design of remote industrial control system based on STM32.* Paper presented at the Industrial IoT Technologies and Applications: International Conference, Industrial IoT 2016, GuangZhou, China, March 25-26, 2016, Revised Selected Papers.

Crisan, N. (2014). High Linearity Analog Optocouplers-Applications Inside the RF Shielded Enclosures. *Acta Technica Napocensis, 55*(1), 10.

Dimitrov, B., Collier, G., & Cruden, A. (2019). Design and experimental verification of voltage measurement circuits based on linear optocouplers with galvanic isolation for battery management systems. *World Electric Vehicle Journal, 10*(4), 59.

Eichas, F., & Zölzer, U. (2016). *Modeling of an optocoupler-based audio dynamic range control circuit.* Paper presented at the Novel Optical Systems Design and Optimization XIX.

Electrical-Technology. (2012-2023). What is an Optocoupler or Opto-isolator – Working And Applications. *Electrical Technology.* Retrieved from https://www.electricaltechnology.org/2022/09/optocoupler-opto-isolator.html Accessed on 23 March 2023

Kasap, S. O. (2012). Optoelectronics and photonics: principles and practices. 2nd. In: Pearson.

Majid, S., Yusro, M., Yuliatmojo, P., & Siregar, K. (2021). *Web-based intravenous fluid monitoring.* Paper presented at the IOP Conference Series: Materials Science and Engineering.

Miyahira, T., & Johnston, A. (2002). Trends in optocoupler radiation degradation. *IEEE Transactions on Nuclear Science, 49*(6), 2868-2873.

Panov, Y., & Jovanovic, M. (2004, 22-26 Feb. 2004). *Small-signal analysis and control design of isolated power supplies with optocoupler feedback.* Paper presented at the Nineteenth Annual IEEE Applied Power Electronics Conference and Exposition, 2004. APEC '04.

Reed, R. A., Marshall, P. W., & Label, K. A. (2004). Space radiation effects in optocouplers. *International journal of high speed electronics and systems, 14*(02), 401-417.

Sabbar, A., Madhusoodhanan, S., Tran, H., Dong, B., Wang, J., Mantooth, A., . . . Chen, Z. (2022). Design and optimization of high temperature optocouplers as galvanic isolation. *Scientific Reports, 12*(1), 2228. doi:10.1038/s41598-021-04145-3

Sergei, P., Bohdan, S., & Viktoriya, U. (2019). *Features of using optoelectronic alignment amplifiers in industrial control systems.* Paper presented at the 2019 IEEE 8th International Conference on Advanced Optoelectronics and Lasers (CAOL).

Sesa, E., Farhamsah, D., & Lasman, R. (2016). Rancang Bangun Alat Ukur Curah Hujan, Temperatur, dan Kelembaban Udara dengan Media Penyimpan Dalam SD Card. *Gravitasi, 15*(2).

Volume: 8 Issues: 55 Special Issue [August, 2023] pp. 273 - 284
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DOI: 10.55573/JISED.085527

Sesa, E., Feriyono, A., Djamal, M., Musa, M., Ulum, M., & Farhamsa, D. (2020). *The design and implementation of an instrument for converting angular velocity to linear velocity based on arduino atmega 2560.* Paper presented at the Journal of Physics: Conference Series.

Sesa, E., Labania, H., Darwis, D., Ismail, M., & Ulum, M. (2021). *Design and implementation of an Arduino-based instrument for parabolic motion.* Paper presented at the Journal of Physics: Conference Series.

Sesa, E., Ulum, M. S., Farhamsa, D., & Samsul, S. (2018). Penentu Kecepatan Dan Percepatan Benda Berbasis Mikrokontroler Arduino Pada Percobaan Benda Menggelinding Pada Bidang Miring. *Natural Science: Journal of Science and Technology, 7*(2).

Sesa, E., Zulfahri, Z., Murfuatin, Y., Musa, M. D. T., Nismayanti, A., Badaruddin, B., & Ulum, M. S. (2023). *The Arduino-based instrument for energy conservation law.* Paper presented at the AIP Conference Proceedings.

Shi, Z., Lu, Y., Chen, Y., & Feng, J. (2014, 6-8 Aug. 2014). *The real-time fault diagnosis of optocoupler in switching mode power supply.* Paper presented at the 2014 10th International Conference on Reliability, Maintainability and Safety (ICRMS).

Sun, F., Zhu, W., Ma, G., Xing, K., & Wang, L. (2019). *Design of Cleaning Module based on CAN*. Paper presented at the Proceedings of the 4th International Conference on Biomedical Signal and Image Processing, Chengdu, China. https://doi.org/10.1145/3354031.3354053

Suprianto. (2015). Pengertian Optocoupler dan Prinsip Kerjanya. Retrieved from https://blog.unnes.ac.id/antosupri/pengertian-optocoupler-dan-prinsip-kerjanya/ Accessed on 12 March 2023

Wau, C., Liu, J., Wang, L., Su, Y., & Yue, J. (2021). An Online Proactive CTR Monitoring Method for Optocoupler in Automotive Auxiliary Converter. *IEEE Transactions on Instrumentation and Measurement, 70*, 1-13.