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Development of Forehead Electrooculogram (EOG) Measurement Device using Plastic Optical Fibre

Muhammad Khaizuran Kamarul Baharin[1], Wan Suhaimizan Wan Zaki[1]*

[1]Department of Electronic Engineering, Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author Designation

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Abstract: This paper is carried out for the purpose of developing forehead electrooculogram (EOG) measurement to analyse and monitor the EOG signal that responds to eye movement stimulation. The corneo-retinal standing potential, which exists between the front and the rear of the human eye, can be measured using the EOG technique. Normally, pairs of surface electrodes are typically placed either above and below the eye or to the left and right of the eye which often causes discomfort to the user. Using plastic optical fibre (POF) offers many advantages with respect to the surface electrode such as high flexibility, low cost and ease to handle. This paper shows the process of detection of EOG signals which used red LED as a light source that transmitted to the skin via POF. The blinking of eye movement causes a shift in pressure, which causes a sudden rise in light intensity detected by the photodiode. The transimpedance amplifier is used to convert the photodiode current to voltage and amplify the signals. Next, the signals were connected to NodeMCU for data collection then the data were exported to the Blynk application for data analysis. Through the Internet of Things (IoT) platform, EOG signals can be analysed and monitored online by the medical practitioner and this system can be used as an online tool for EOG assessment.

Keywords: Electrooculogram, Plastic Optical Fibre, Blynk Application

1. Introduction

Electrooculogram (EOG) is a signal that measures the potential difference between the retina and the cornea [1]. The primary applications of EOG are ophthalmological diagnosis and eye movement recording. Besides, EOG analyses can be used to identify states similar to fatigue in microsleep detection [2]. Typically, surface electrodes are used for EOG signals measurement by placing the electrode at four positions around the eyes (above, below, left, and right). However, the electrodes

**Corresponding author: mizan@uthm.edu.my*
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around the eyes often cause discomfort to the user. To simplify and improve user convenience, this research proposed a new method to acquire EOG signals by using plastic optical fibre. The plastic optical fibre offers many advantages with respect to the surface electrode such as high flexibility, low cost and ease to handle [3]. Some study shows that the EOG signal can be measured on the forehead through headbands, hats, or glasses [4]-[5]. In this study, EOG signals will be monitored on the forehead by using an optical device. The optical device is used as a method to measure changes in the muscle activity on the forehead using Infra-Red (IR) LED light source which can penetrate the tissue. This light reaches the surface of the muscle and the amount of transmitted light that returns to the surface of the head is then measured by the photodiode, which can be used to calculate changes in the muscle activity during eye movement stimulation.

In most prior EOG-based HCI investigations, electrodes were implanted so that one was above and below the eye (left or right) to detect vertical eye movement, and one was put to monitor horizontal eye movement at the left and right of the outer canthi. The vertical and horizontal channels each had their own positive electrode, which was situated above the eye. The vertical channel's negative electrode was placed above the positive electrode while the horizontal channel's negative electrode was positioned over the other eye.

Optical fiber is commonly employed in medical applications in hospitals. Optical fibre transmission uses electromagnetic radiation ranges of 850 nm, 1310 nm, and 1550 nm in a variety of applications [6]. The optical fibre is a waveguide used for transmitting light. Plastic Optical Fiber, (POF), typically uses polymethyl methacrylate (PMMA), a general-purpose resin as the core material, and fluorinated polymers for the cladding material. In large-diameter fibers, the core, which promotes light transmission, makes up 96 percent of the cross-section. The cross-section of POF is generally divisible into four called the core, cladding, buffer, and jacket [7].

The objective of this study is to develop an optical device for monitoring the EOG signal on the forehead using plastic optical fibre, to design LED light source and photodiode circuit for light intensity measurement for forehead EOG measurement, and to analyse and monitor the EOG signal that responds to the eye movement stimulation. Besides, this study is focused on several scopes such as the measurement is based on the light intensity changes at the photodiode due to the change of electrical activity on the muscle signal at the forehead, the response data of the sensor will be sent to NodeMCU using IoT application, The muscle activities are limited to eye movement stimulation only, and the response of the EOG signals will be analysed offline using Blynk application.

2. Materials and Methods

2.1 Block Diagram

The muscle signal at the forehead may be affected by the eye movement stimulus, thus a change in EOG signals. The process of detection of EOG signals was sensed by the IR LED light source before transmitting the output signal to the photodiode via Plastic Optical Fiber (POF). The transimpedance amplifier is used to convert the photodiode current to voltage and amplify the signals. Next, the signals are connected to NodeMCU for data collection storage and process using the IOT application. Then, the stored data will be exported to the Blynk application on a mobile phone for data analysis. The block diagram of the project is shown in Figure 1.

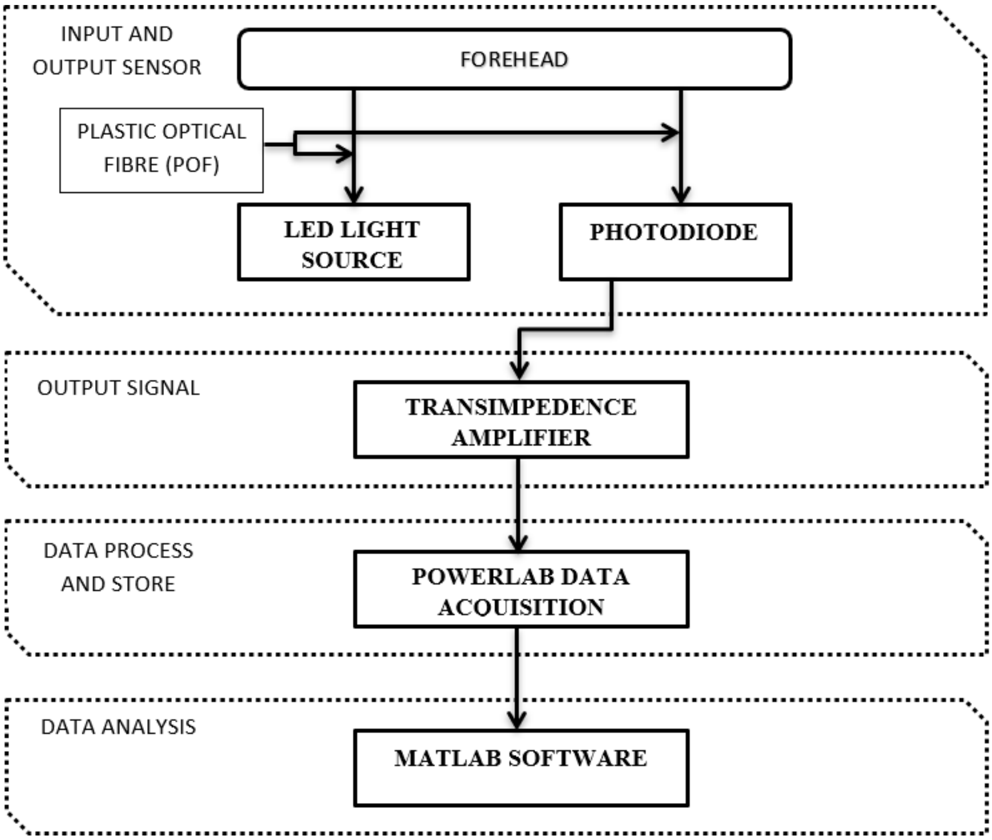

Figure 1: Example of presenting data using a figure

2.2 Red LED Transmitter circuit

The transmitter circuit was constructed by four red light LEDs which are responsible for the input signal in the initial phase of the project before the signal penetrates the forehead through POF and is powered by 3.3V from the power supply module MB-V2. The four 1k ohm potentiometer was used as a variable resistor to control the light intensity of each LED. The circuit design can be seen in Figure 2.

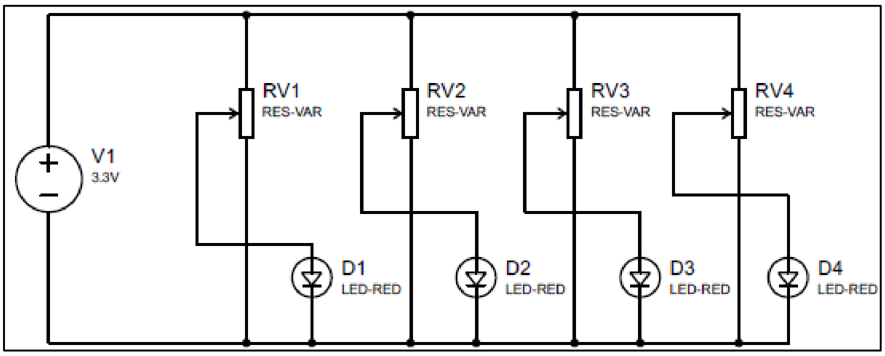

Figure 2: Circuit diagram of the transmitter circuit

2.3 Photodiode Receiver Circuit

The photodiode receiver was constructed with SFH250 photodiode receiver as the main component to receive the light intensity from the forehead through POF. In order to convert the current from the photodiode to the voltage output, the LM358 was used as an operational amplifier which was powered by a 5V power supply module before being transferred to NodeMcu ESP8266 module Wi-Fi via the 16-channel analog multiplexer module. The circuit design can be seen in Figure 3.

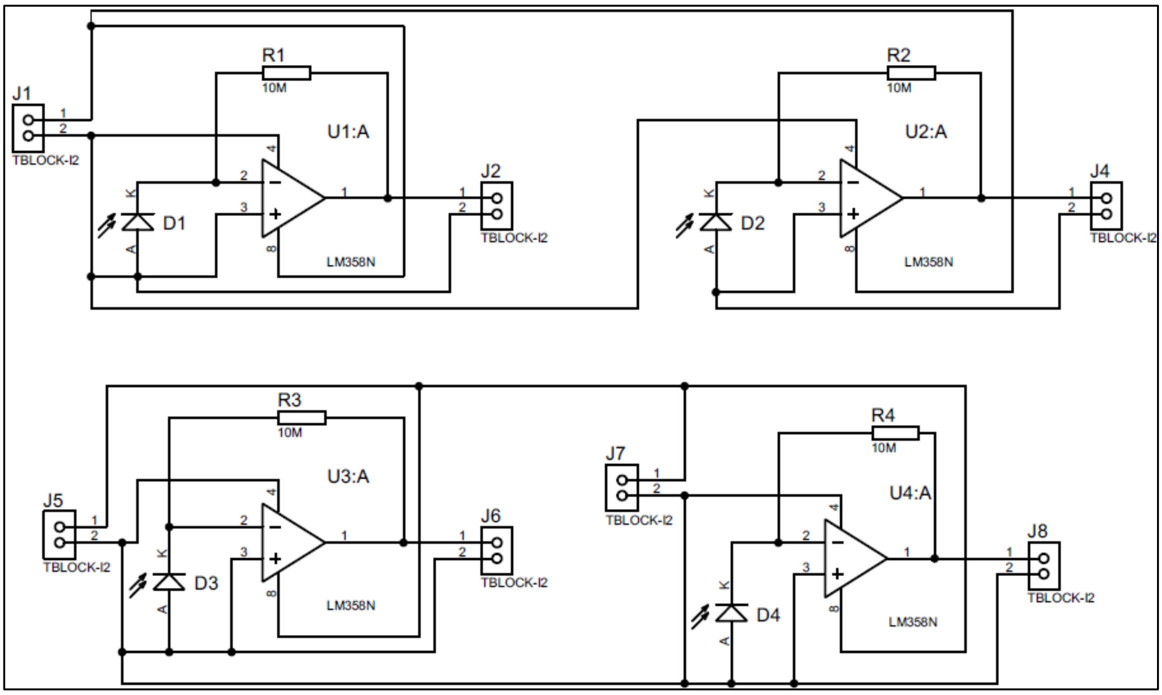

Figure 3: Circuit diagram of the photodiode receiver circuit

2.4 Plastic Optical Fibre (POF) as a Sensor

The POF was the integral component of this project where it acts as a sensor that received the light from the red LED before sending it through to the forehead to penetrate the skin and then send it back to the photodiode receiver. The one-meter-long POF was cut at a 45-degree angle at end of the tip where it touches the human skin to reflect the light that passes through it as in Figure 4.

Figure 4: The design of POF surface 45 degree

3. Results and Discussion

This section focuses on the result and analysis of the EOG measurement on the volunteer's forehead. Besides, this chapter also the specifics of the tasks accomplished, and the tasks are defined and discussed to be completed.

3.1 Calibration

According to the findings, the light intensity diminishes with increasing of resistance, going from 2.5V to 0.7V as it is bright to dimmer. When the light is brighter, the optical reaction will be more sensitive. As a result, for the transmitter circuit, the resistance is set to 350Ω, which corresponds to 2.4V as shown in Figure 5.

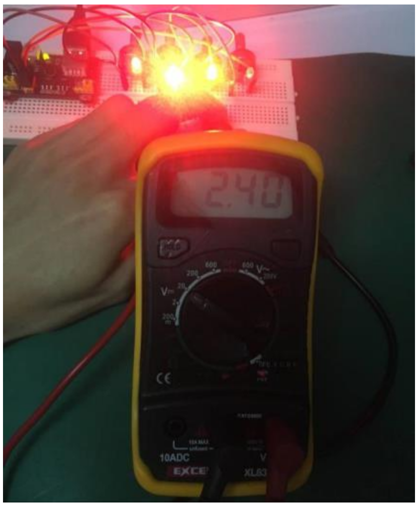

Figure 5: Red LED voltage reading

3.2 POF Placement

To test its effectiveness, the POF was placed on the volunteer's forehead which is above and below the level of the eye and on both sides of each eye. Figure 6 demonstrates the POF placement on the human forehead.

Figure 6: Placement of POF

When the placement of POF was done, the experiment begins with the full setup as shown in Figure 7. This figure shows how the real-time connection between the transmitter circuit and receiver circuit interconnects together via POF to read the EOG signals from the volunteer.

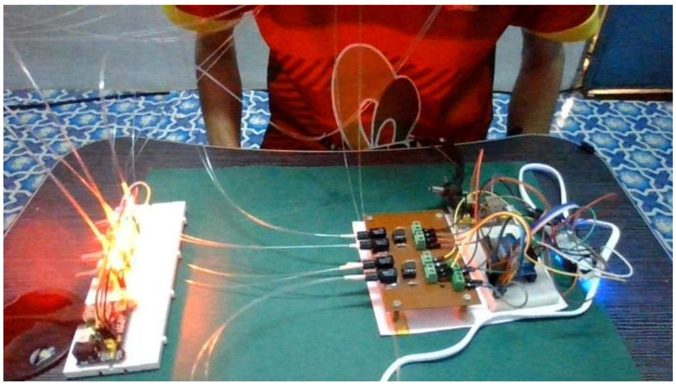

Figure 7: Full setup of the project

3.3 Blynk Application

Based on results from the Blynk application in Figure 8, it shows that there is no output reading. Despite being well prepared the result was unsatisfied due to a lack of red-light intensity and spectrum frequency which in this case was very critical to get the reading of the EOG signals. The red light that travels through POF was not bright enough or specifically below 850nm in term of its light spectrum.

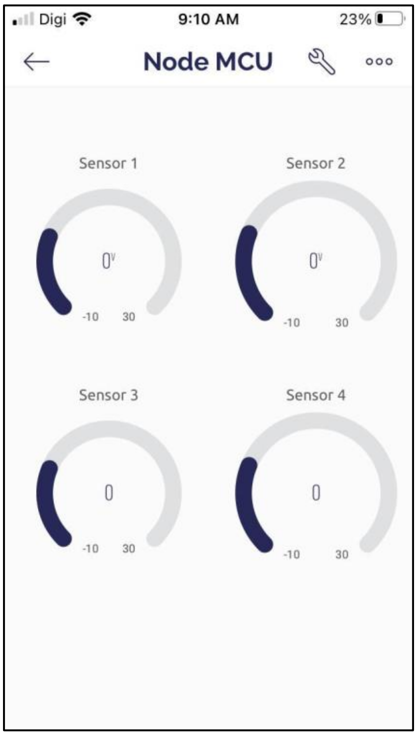

Figure 8: Data from the Blynk application

3.4 Measurement from Photodiode Receiver

In order to further examine the POF signal on the volunteer, voltage values from the multimeter were collected. Based on the result, here is how the table goes during all six phases of volunteer eye movement.

As seen in Table 1, the applied pressure measurement reveals that when the eyelid moves under pressure the voltage drop. and reflected light is steady when no external pressure is applied to the forehead to cause eyelid movement. Blinking causes a shift in pressure, which causes a sudden rise in light intensity. Even though the value is too small and almost null but there is still in fact that the POF can be used as a pathway between the signal. Figure 9 shows the linear graph based on Table 1.

Table 1: Reading from photoreceiver against the phase of eye movement

Phase	Measurement (mV)			
	Sensor 1	Sensor 2	Sensor 3	Sensor 4
Eyes close/looking straight	4.8	4.6	5.3	4.1
Looking right	4.6	5.1	4.7	4.0
Looking left	5.1	4.6	4.5	4.1
Looking up	4.5	4.3	4.3	4.5
Looking Down	4.4	4.3	4.5	4.3
Blinking	4.7	4.7	4.6	4.6

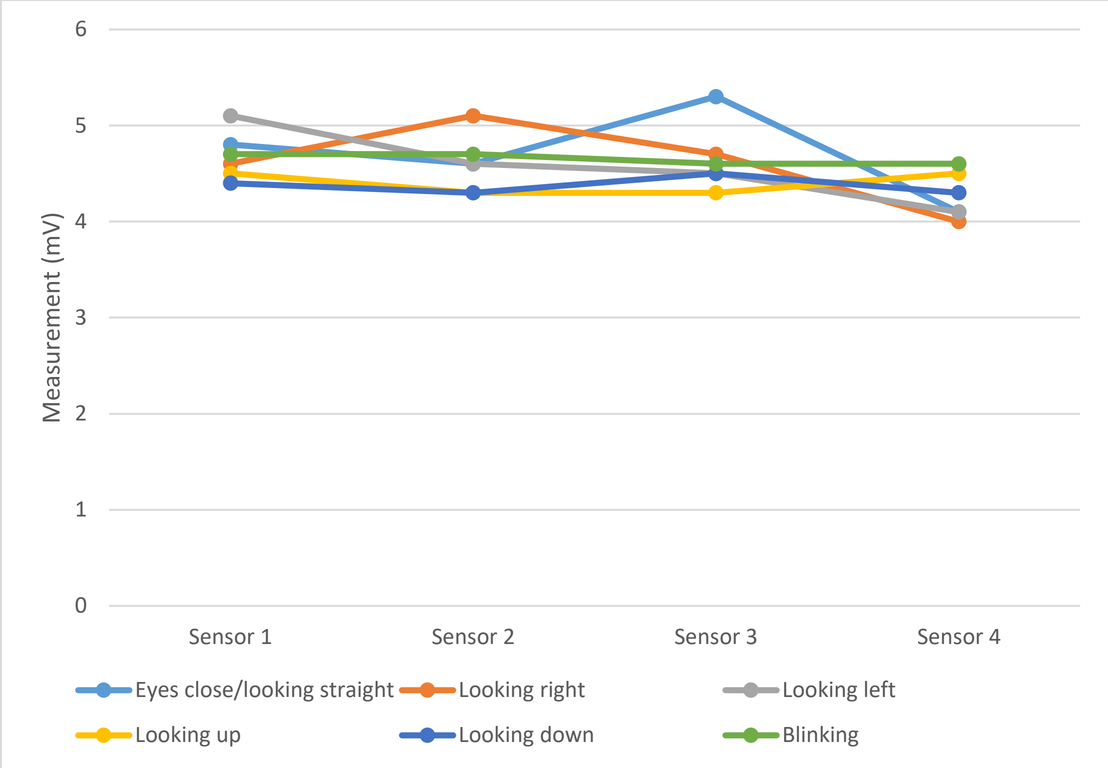

Figure 9: Linear graph based on table 1

4. Conclusion

In this study, a simultaneous design technique for a forehead EOG and eye movement stimulation was put forth. To detect light intensity, a photodiode circuit and LED light source were successfully created. The findings demonstrate that the resistance affects the light intensity. The voltage will rise when the resistance of the transmitter circuit is reduced, boosting the brightness of the light. Even though the light spectrum intensity did not reach as expected the result is still gained from the multimeter reading. The volunteer forehead experiment demonstrates that as the eyelid raises, the voltage of the photoreceiver sensors increases. For additional study, the movement readings may be transmitted to the PowerLab data acquisition for data collection storage and process. Then, the stored data will be exported to Matlab for data analysis. This technology will eventually be used to examine EOG measurements with applied pressure. This project requires careful attention to the cutting of the fibre tips in order to produce results that are more dependable. Because the fibre utilised in this research has a very small diameter, specific instruments like power microscopes must be employed in the lab to optimize fibre cutting.

Acknowledgement

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