

RESEARCH PAPER

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Design of an Electrooculography Equipped with Digital Neck Angle Elevation Gauge

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ABSTRACT Human eye health problems due to uncontrolled use of gadgets can cause eye fatigue. However, medical devices for diagnosing the electrical activity of the eye muscles have received less attention. This study designed a tool that can monitor the electrical eye muscles (EOG) equipped with a neck angle elevation meter, to see if there is a difference in signal when someone is working in front of a computer screen at a certain angle elevation. This study designed an EOG module consisting of an instrument amplifier, a pre amplifier circuit, a high pass filter, a low pass filter, a summing amplifier, and a notch filter. In this study, the lead points are at the vertical point and the horizontal point of the eye using disposable electrodes. The frequency of the signal used is 0.5-30 Hz. The output results were compared with KandH as a standard tool. In this study, the results obtained the smallest error on the vertical channel of -1.35622% and on the horizontal channel of -4.32745%. For conditioning carried out on respondents, all respondents experienced a decrease in amplitude with an elevation of the neck angle of 60°. Thus, it can be concluded that the elevation of the neck angle affects the electrical power of the eye muscles. For further development, an alarm or eye fatigue indicator can be added.

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I. INTRODUCTION

The development of medical devices in the field of diagnostics, especially for monitoring the electrical power of the eye muscles, is still underdeveloped. Even though the use of gadgets to support human activities is increasingly massive, especially in this pandemic era. Globally nearly 60 million people had CVS in 2007; each year it is estimated that one million sufferers increase. More than 243 million people in the United States work using computers every day, an estimated 90% experience symptoms of eye fatigue[1]. The intensity of exposure received by workers and students who stare at the monitor screen at this time is longer than usual[2].

Several researchers have conducted research on fatigue detection in various methods and parameters on vision. Sutarno and Rossi Passarella have conducted research on the detection of eye fatigue for computer users using image processing methods and research was also conducted in 2018 by Alla Phani C. Reddy et al, on the detection of eye muscle tension using the Raspberry-pi-based image processing method. The advantage of this prototype tool is that it is simple and easy to carry everywhere, but it has a weakness when it detects different mappings of a person's face and is less effective when in low light[3] [4][5]. Chaofeng L et al, have conducted research on monitoring eye fatigue using Flexible Piezoelectric, which is attached to the upper edge of the eye, the advantage of this tool is that the Piezoelectric sensor is very thin and small so that the edge of the eye is not

disturbed by foreign objects, but the sensor used is difficult to find. market [6]. Next is testing of features for fatigue detection in EOG which has been carried out by Andrea Nemcova et al, about a feature extraction method from EOG signals to detect eye fatigue in a person, this study still uses data acquisition which is relatively expensive [7]. Research by R. Billones et al, regarding the recognition of fatigue and eye muscle tension using the EOG signal recording method equipped with a distance from the monitor, but in this method the researcher only uses eye movement signal parameters only when the respondent is reading and the acquisition data used is quite expensive [8].

Based on the things that have been mentioned in previous research, it is important to develop a system that can monitor EOG signal activities. Based on previous research using image processing that is less effective in dark conditions and requires a camera with a good sensor and is quite expensive in the market, Ultrathin Piezoelectric[9][10] used is still rarely found in the market, and still uses a data acquisition module that is classified as have an expensive price, then the purpose of this study is to develop a module that can tap the electrical activity of the eye muscles using materials on the market. This module is expected to be able to monitor the electrical activity of the eye muscles in vertical and horizontal eye movements. EOG signal[11] can be monitored directly on computer. The purpose of the study is to develop a module that can tap the electrical activity of the eye muscles using

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materials on the market. This module is expected to be able to monitor the electrical activity of the eye muscles in vertical and horizontal eye movements. EOG signal[12] can be monitored directly on computer.

This article is composed of chapter I containing the problem and introduction to chapter II containing research tools and methodologies regarding the components used and data collection. chapter III contains the results of the research. Chapter IV contains the results of a discussion about the advantages and disadvantages of the module designed by the author. Finally, chapter V contains an analysis of the research results obtained.

II. MATERIALS AND METHODS

A. Experimental Setup

This research was conducted on 3 respondents who were sitting working in front of the computer. The distance between the respondent and the computer varies according to the angle given. Respondents are normal people without eye disorders. Tapping is done at two points, namely the vertical channel and the horizontal channel. Respondents were treated with different neck angle elevations (0°, 30°, 60°) using an accelerometer sensor, then measured their eye muscle signal leads using electrooculography. Data were collected for 30 minutes and recorded in the initial 5 minutes and the final 10 minutes for each neck elevation angle measurement.

1) Materials and Tool

This study uses electrooculography to detect biosignals of eye muscle activity. This circuit consists of an instrumentation amplifier circuit using the AD620[13], a high pass filter circuit using the CA3240N IC[14], a low pass filter circuit using the CA3240N IC, and an adder circuit consisting of a summation amplifier circuit using the CA3140N IC and a voltage divider circuit, the Atmega328 microcontroller as sensor data processing. Oscilloscope with digital storage (Textronic, DPO2012, Taiwan) for retrieving test point data on analog circuits.

2) Experiment

In this study, the data taken were EOG signals from three subjects conditioned with different neck angle elevation (0°, 30°, 60°) for 30 minutes. After the signal is recorded and stored, 10 minutes of the initial tapping signal and the last 10 minutes of the tapping signal are sampled to compare whether there is a change in the frequency of the two data. The method used is Fast Fourier Transform (FFT)[15]. After processing the FFT on the two data, the data is presented in tabular form

B. The Block Diagram

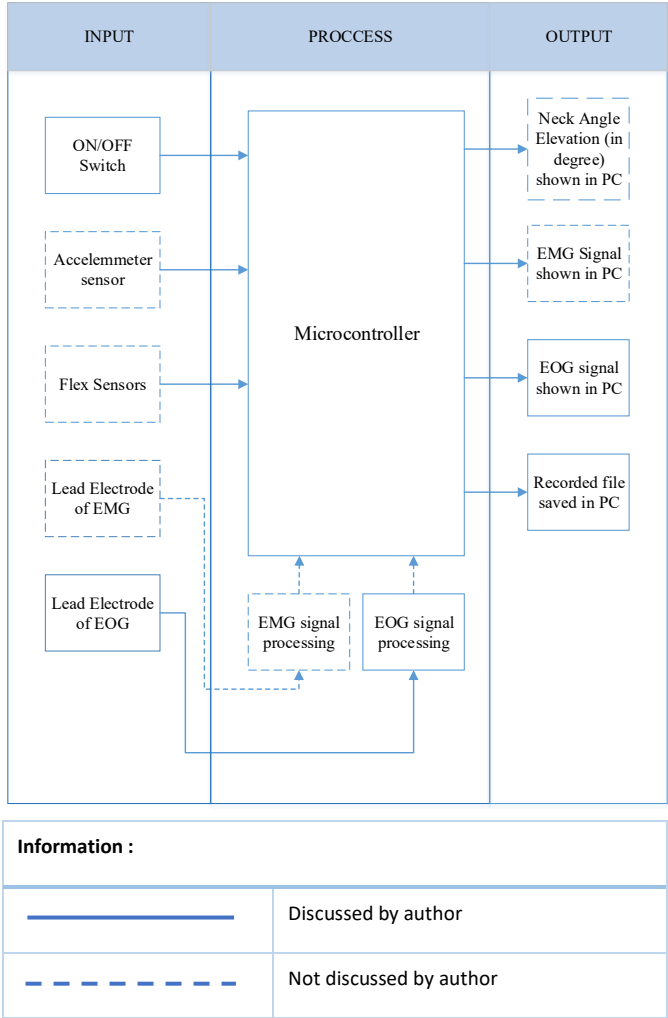


FIGURE 1. The diagram block of the Reasearch

In this study the block diagram is shown in FIGURE 1. When the on switch is pressed, the initializer, accelerometer circuit block and flex sensor as neck angle elevation sensor and EOG circuit[16] block are active. The EOG circuit block detects biosignals from the electrical activity of the eye muscles. Biosignal from eye muscle activity is processed in a arduino microcontroller, which will be displayed on a PC to see the difference in signal shape between neck angle elevation less than 0°, 30°, and 60°.

C. The Flowchart

The Arduino program is built based on the flowchart as shown in FIGURE 2. When the ON button is pressed, the tool starts to initialize. The EOG signal is tapped through the electrodes into the EOG circuit. Through instrumentation and filters, the signal passes through the Arduino as an ADC so that the signal can be displayed on the PC. When the tapping starts, the signal is displayed and when the "Save"

button is pressed, the signal will be saved on the PC, the recording is complete

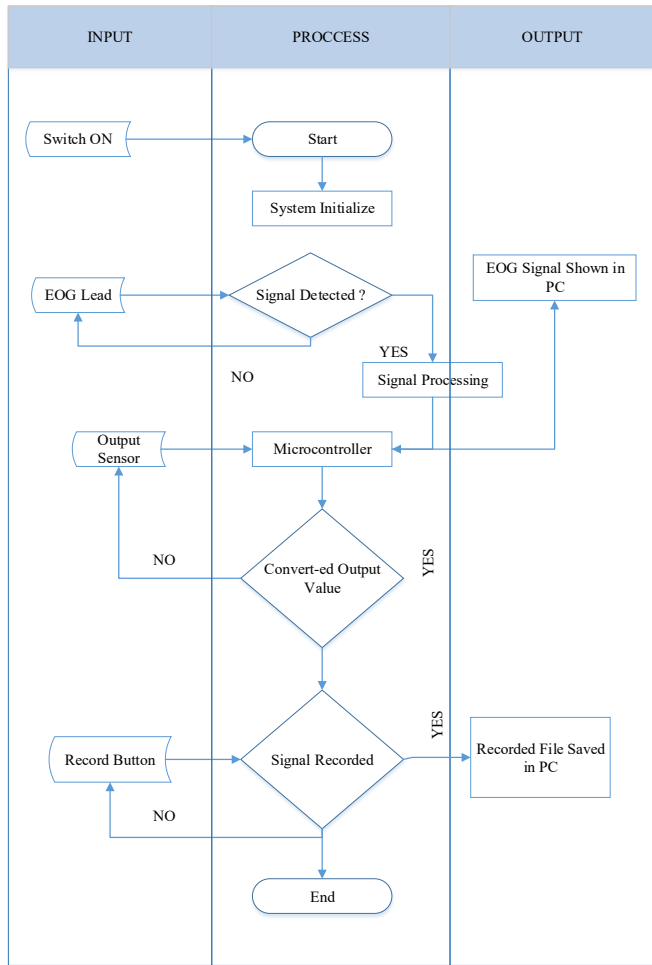


FIGURE 2. The Flowchart of the Arduino Program

D) Analog Circuit

1) Instrumentation Amplifier Circuit

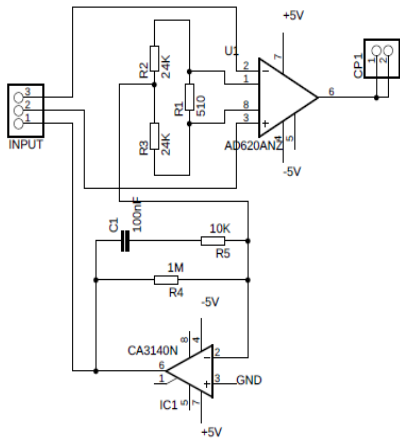


FIGURE 3. Instrumentation Amplifier Circuit

The instrumentation circuit[17][18] as shown as [FIGURE 3](#). used is Analog Devices is AD620A. However, it is found that for a gain of 991, $R_G = 49.9$. A gain of 100 with $R_G = 499\Omega$ (510Ω). $G = 1 + (49.4\text{ k}\Omega/R_G)$ is selected[19].

2) High Pass Filter Circuit

The High Pass Filter[20] as shown in [FIGURE 4](#). is a filter that passes high frequencies and suppresses the amplitude of frequencies lower than the cut-off frequency. The noisy muscle electrical signal that has been obtained from the instrumentation amplifier circuit will be filtered on a high pass filter circuit to pass frequencies above 0.5 Hz.

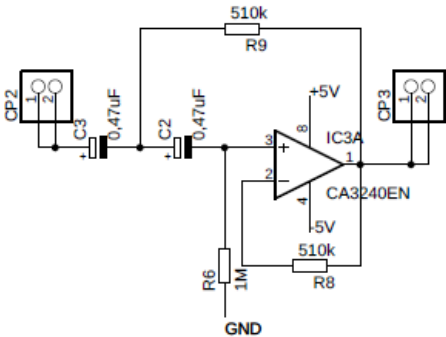


FIGURE 4. High Pass Filter Circuit

3) Low Pass Filter Circuit

The low pass filter[21] as shown in [FIGURE 5](#). is a filter that functions to suppress frequencies above the cut-off frequency and pass frequencies below the cut-off frequency. In the low pass filter circuit, it is used to filter signals with frequencies above 30 Hz so that signals below 30 Hz will be passed.

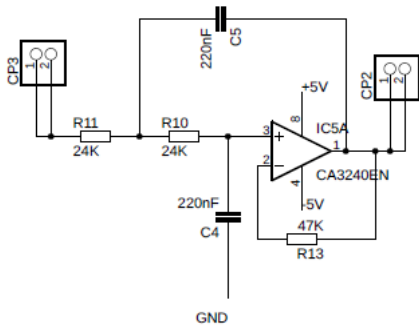


FIGURE 5. Low Pass Filter Circuit

4) Low Gain Amplifier Circuit

The low gain amplifier as shown in [FIGURE 6](#). is an amplifier block that serves to amplify the weak signal coming out of the filter block to a certain extent. This is a

low gain amplifier with a gain of 2. The low gain amplifier is designed to avoid saturation of operational amps.

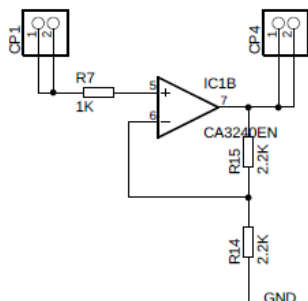


FIGURE 6. Low Gain Amplifier Circuit

5) Summing Amplifier Circuit

The adder circuit as shown in FIGURE 7. is a circuit that serves to increase the dc offset of the EOG signal. In this module the adder circuit consists of a summing amplifier circuit and a voltage divider circuit. The summing amplifier circuit serves to 'add' the DC voltage coming from the voltage divider circuit and the EMG signal pulse from the LPF circuit. The output of the LPF circuit and the voltage divider is connected to pin 3 of the CA3140N IC as a positive input after each output is assembled with a resistor of the same value. The adder circuit serves to facilitate analog to digital communication between the EOG module circuit and the microcontroller so that the EOG signal can be converted into digital and displayed on a PC.

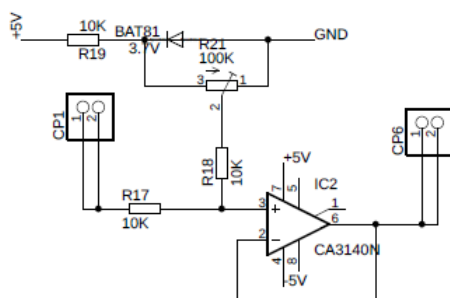


FIGURE 7. Summing Amplifier Circuit

6) Notch Filter Circuit

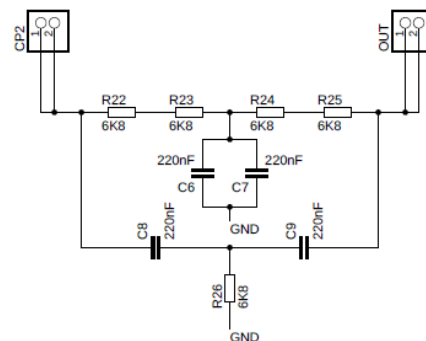


FIGURE 8. Notch Filter Circuit

The adder circuit as shown in FIGURE 8. is a circuit that functions to hold or not pass a certain frequency range, namely between the lower cut off frequency and the upper cut off frequency[22]. The application of this circuit is used to eliminate unwanted frequencies, for example in the circuit there is a noise signal at a frequency of 50-60 Hz from the power grid, so to remove the noise, a Notch Filter circuit can be used to eliminate the noise signal.

III. RESULT

1) EOG Design

The modules as shown in FIGURE 7. which have been planned and then designed, here are the results of the module design in this study. This module consists of a power supply block, an EOG circuit, an Arduino UNO[23][24], a signal input block, and an EMG circuit. This study was combined with the EMG study, but the discussion on EMG is presented in a different thesis.



FIGURE 9. Overall Module

2) The Listing Program For arduino

```
void setup() {
  Serial.begin(9600);
}

void loop() {
  eog1= analogRead(eogvertical);
  eog2= analogRead(eoghorizontal);
  emg= analogRead(emg);
```

The baute rate is set to 9600, then the analog output of the EOG circuit is read and converted to digital. The reading result is initialized in the EOG variable.

3) Measurement

A. Measurement on High Pass Filter

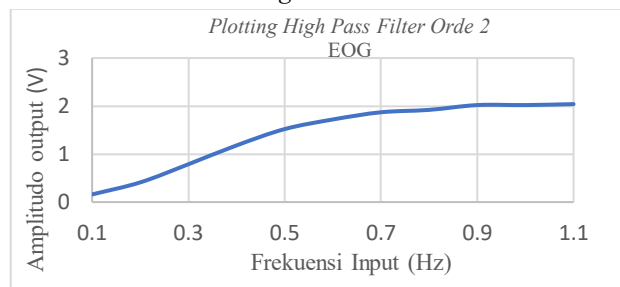


FIGURE 10. HPF Circuit Plotting Graph

The HPF circuit measurement result is indicating that the circuit running properly. Because it can banned the lower frequency of 0.5 Hz. The more input frequency value, the output of voltage become bigger.

B. Measurement on Low Pass Filter

The result of plotting Low Pass Filter were shown in FIGURE 11. Shown graphic output voltage of circuit. The LPF circuit measurement result indicate that the circuit works according to design. Banned the upper frequency of input and pass the lower frequency of input.

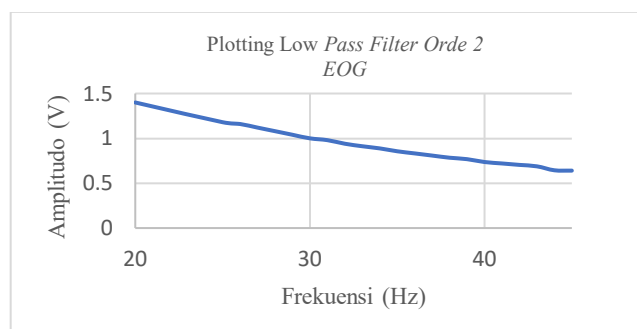


FIGURE 11. LPF Circuit Plotting Graph

C. Measurement on respondents

- Measurement on EOG Vertikal Channel

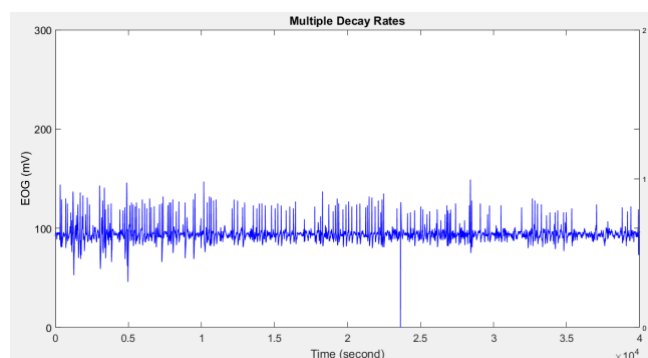


FIGURE 12. Vertikal EOG signal (0°)

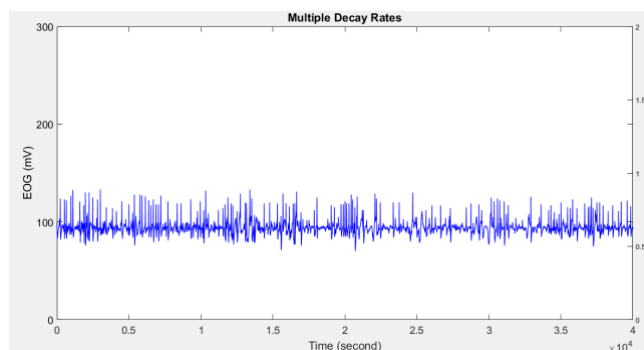


FIGURE 13. Vertikal EOG signal (30°)

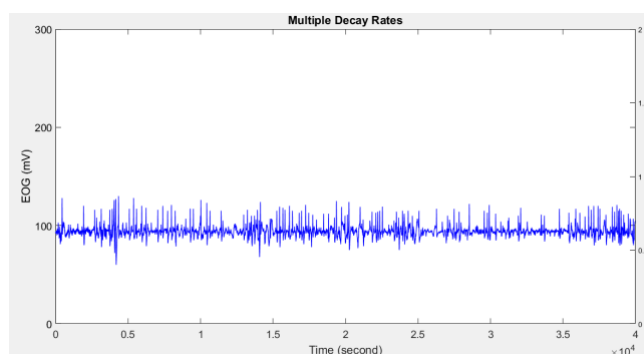


FIGURE 14. Vertikal EOG signal (60°)

Respondents were conditioned to bend at different angles of the neck for five minutes. An image of the EOG signal from this activity is recorded and shown in FIGURE 12-14. Recording starts when the required respondent's EOG signal appears on the computer screen.

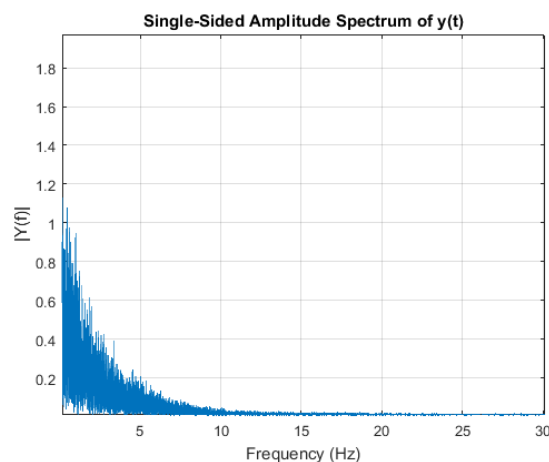


FIGURE 15. FFT first respondent with Vertikal EOG signal (0°)

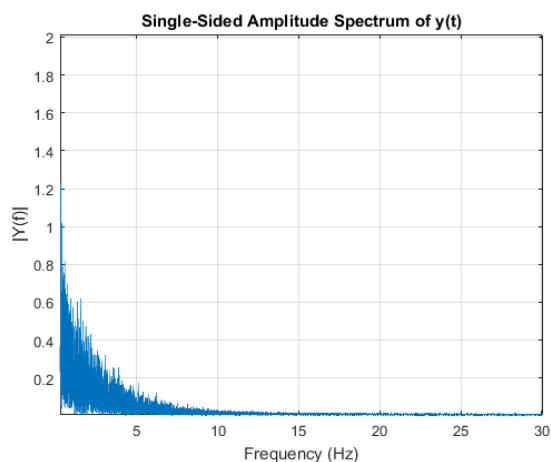


FIGURE 16. FFT first respondent with Vertikal EOG signal (30°)

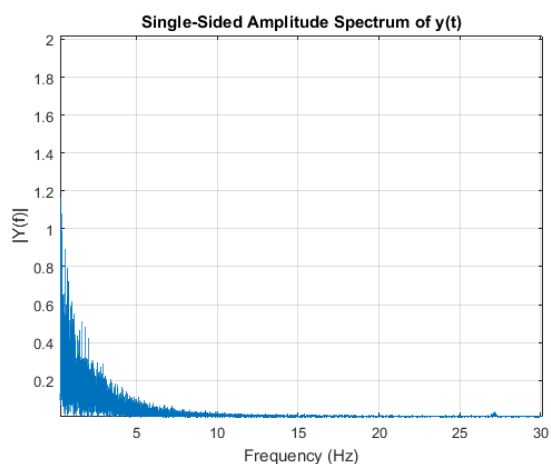


FIGURE 17. FFT first respondent with Vertikal EOG signal (60°)

■ Measurement on EOG Horizontal Channel

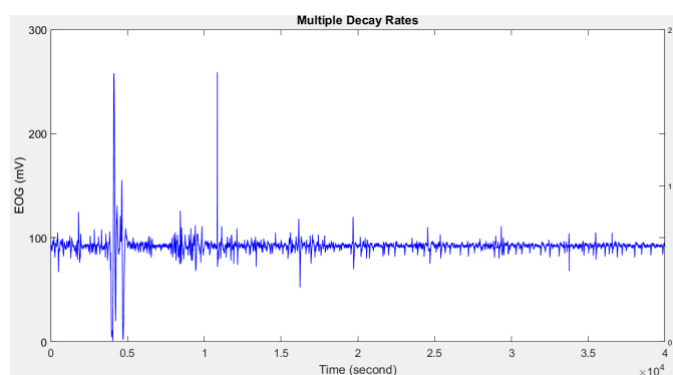


FIGURE 22. Horizontal EOG signal (0°)

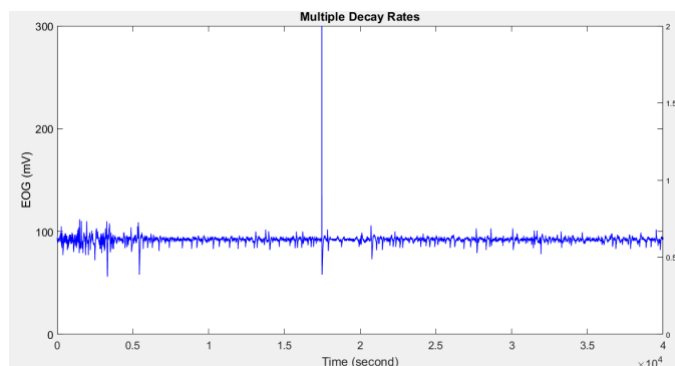


FIGURE 23. Horizontal EOG signal (30°)

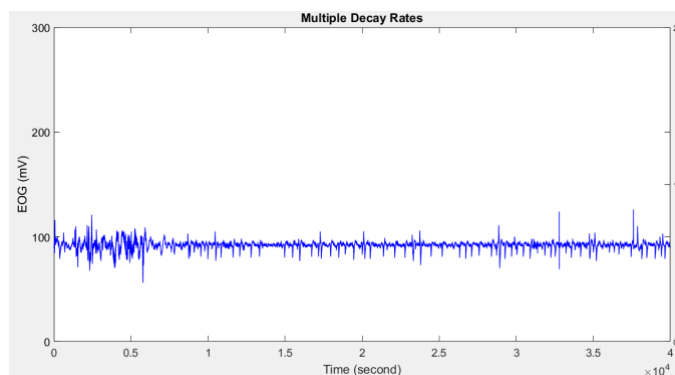


FIGURE 24. Horizontal EOG signal (60°)

From FIGURE 22 - 24, it is the same as the vertical channel, that is, there is no significant difference in amplitude for each increase in the angle of neck flexion. From the results of the Horizontal EOG Channel FFT[25], it was found that the change in amplitude was visible but the difference was less clear as the degree of neck flexor increased. For more detailed results, see Table VI which shows the average power frequency value.

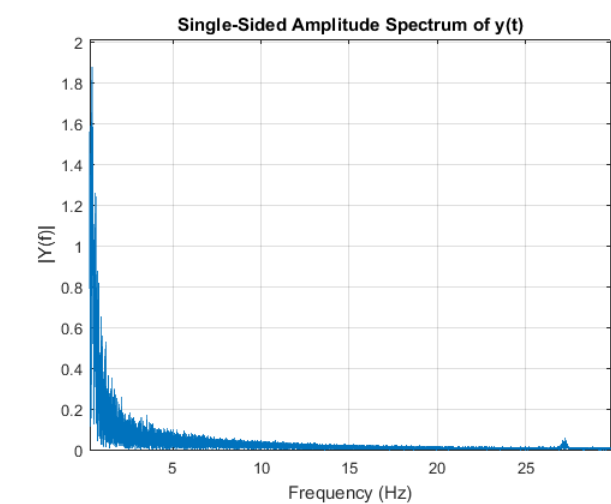


FIGURE. 25. FFT on Horizontal EOG signal (0°)

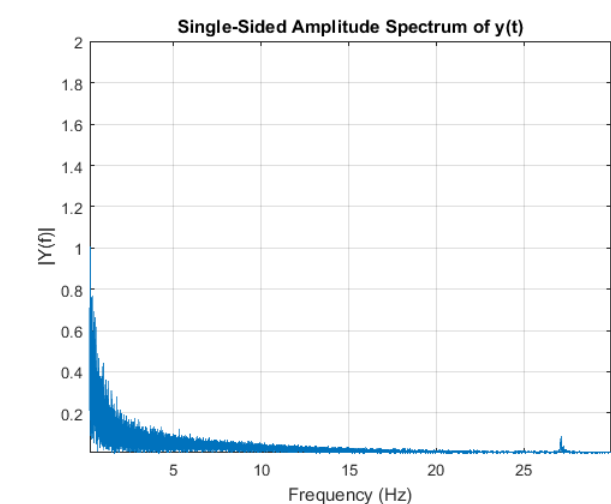


FIGURE. 26. FFT on Horizontal EOG signal (30°)

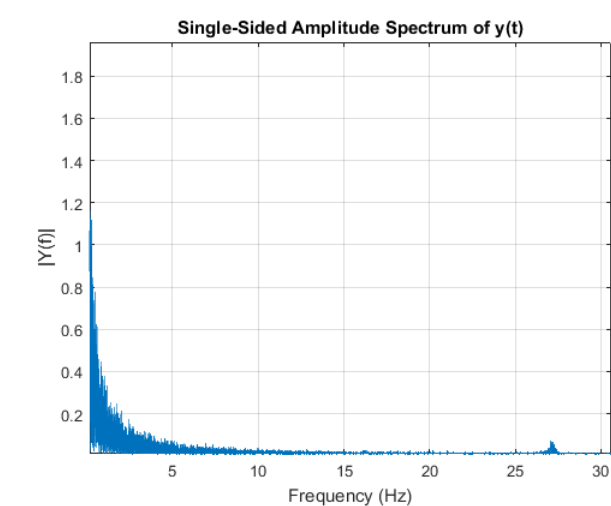


FIGURE. 27. FFT on Horizontal EOG signal (60°)

TABLE I. MEASUREMENT VERTICAL CHANNEL OF MEAN POWER FREQUENCY ON RESPONDENT

Respon- dent	Dura- tion	Mean Power Frequency (Hz)		
		0°	30°	60°
1	5 minutes	0.038927	0.034139	0.032203
2	5 minutes	0.036132	0.034259	0.029054
3	5 minutes	0.037667	0.035408	0.033261
Mean		0.037575	0.034602	0.031506
Error		3.472311 %	-1.35622%	2.164395%

Stdev		0.0014	0.000701	0.002188
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TABLE II. MEASUREMENT HORIZONTAL CHANNEL OF MEAN POWER FREQUENCY ON RESPONDENT

Respon- dent	Dura- tion	Mean Power Frequency (Hz)		
		0°	30°	60°
1	5 minutes	0.028814	0.027195	0.026536
2	5 minutes	0.037355	0.033409	0.028298
3	5 minutes	0.032489	0.032110	0.028219
Mean		0.032886	0.030905	0.027684
Error		-14.132%	-13.641%	-4.32745%

Stdev		0.004284	0.003278	0.000995
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From the FFT results from both Vertical and Horizontal channels, it can be seen that the mean power frequency value

is shown in **Table I**, from these results the average value decreases as the neck flexor degree increases. This can be evidence that the built EOG module successfully shows the difference in eye muscle signal based on the subsequent increase in flexor extension.

IV. Discussion

Respondents are conditioned by the relative distance from the screen. Respondents were conditioned to look at the screen with a neck elevation of 0° 30° 60°. In 5 minutes. After taking data with respondents, it can be seen that the greater the angle of elevation, the smaller the amplitude of the EOG signal. It can also be seen that a similar change occurs in the mean power frequency. This shows that the greater the elevation of the neck angle, the smaller the amplitude when the eyes tend to lean closer to the screen. The greater the elevation angle, the closer the eye and the screen are, the longer the muscle will be burdened. In this study, the results obtained the smallest error on the vertical channel of -1.35622% and on the horizontal channel of -4.32745%.

The following are the results of measurements on respondents with different conditioning, respondents were asked to bend over with an elevation of the neck angle of 30°, then respondents were asked to read an article for 30 minutes. And see the difference in the EOG signal in the first 10 minutes and the last 10 minutes. It can be seen that the EOG signal difference in the first 10 minutes and the last 10 minutes, the amplitude in the last 10 minutes is not smaller than the first 10 minutes. This shows that the eye muscles have changed slightly in the last 10 minutes, which indicates that time affects the load received by the muscles. If this condition is received by the eye continuously, in a long time it can have a negative impact on eye health.

V. Conclusion

The purpose of this study to find the difference amplitude of EOG signal in different condition. From the research that has been done, it can be seen that the EOG signal on the Vertical and Horizontal channels requires a magnification of 44x calculation for each channel to be tapped and processed. The difference in amplitude does not occur when someone looks at a certain angle for a short time, but the difference in amplitude looks significant when someone looks at the screen with an interval of 30 minutes. Like activities in front of a computer or laptop in general. Eye work is more difficult when the exposure time is longer. Mean Power Frequency in male respondents aged 20-23 years with normal eye conditions and not having the habit of playing games or doing activities in front of the computer for more than 2-4 hours per day. In this study, the results obtained the smallest error on the vertical channel of -1.35622% and on the horizontal channel of -4.32745%. However, the suggestion from the researcher is to add an alarm to this tool, and extract more features from the EOG signal. The researcher hopes that this module will be useful for helping ophthalmologists to diagnose eye fatigue.

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ATTACHMENT

Link of EAGLE Circuit and Program

<https://drive.google.com/drive/folders/13MpZF0gMaHOb9QAnnLb-Zwig2Ww8BpuW?usp=sharing>