Design and Experiment of Electrooculogram (EOG) System and Its Application to Control Mobile Robot

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Abstract. In this paper, we design and investigate a biological signal detection of eye movements (Electrooculogram). To detect a signal of Electrooculogram (EOG) used 4 instrument amplifier process; differential instrumentation amplifier, High Pass Filter (HPF) with 3 stage filters, Low Pass Filter (LPF) with 3 stage filters and Level Shifter circuit. The total of amplifying is 1000 times of gain, with frequency range 0.5-30 Hz. IC OP-Amp OP07 was used for all amplifying process. EOG signal will be read as analog input for Arduino microprocessor, and will interfaced with serial communication to PC Monitor using Processing® software. The result of this research show a differences value of eye movements. Differences signal of EOG have been applied to navigation control of the mobile robot. In this research, all communication process using Bluetooth HC-05.

1. Introduction

Biological signal detection system had been researched by scientists almost around the world. Mostly, everyone make biological signal detection system to help disabled or weak human like an elder (e.g., [1]-[3]), and health detection (e.g., [4]-[5]). Biological signal detection system we know like ElectroMyoGram (EMG), ElectroCardioGram (ECG), ElectroOculoGram (EOG), and ElectroEnchepaloGram (EEG). The biological signal detection system usually used to make command and control which called Human Machine Interface (HMI) or Brain Machine Interface (BMI). In robotic usually, make the EOG system to control a Wheel Chair (e.g., [6]-[9]), Arm Robot (e.g., [10]-[13]), Mobile Robot (e.g., [14]-[15]), and other (e.g., [16]-[17]).

When eye going moving side by side, it will be product a little signal. To read a little potential differences of eye movement, we use detector called EOG system. EOG detect a signal from eye movement with measuring a potential differences between cornea and retina, the differences will be processed to be control command (e.g., [19]-[20]). In literature, EOG signal have a differential potential between 50-3500 μV of Amplitude, and frequency range 100 Hz (e.g., [6],[18]-[20]).

In this paper, we make and simulate a new design of Low Cost EOG system. Basic signal characteristic of EOG signal which will be analyze such as gain of amplified signal and bode plot frequency analysis. The proposed design of EOG system will be experimentally demonstrated. Then we will prototyping an EOG system to control mobile robot.

The paper is organized as follows. In section 2, the details of the proposed general system design of EOG and its application. In section 3, describe hardware design of EOG and its application in detail. In Section 4, algorithm processing and control system described the system will be work. Finally, in Section 5, the concluding remarks are given.

2. System Design

In this research, we build own Low Cost EOG scheme as figure 1. We need some electrode to stick on our eye muscle to get eye movement signal. Then, amplifier will amplify eye movement signal in order can be read by computer using an ADC. We use ADC from Arduino board to convert analog data to digital data. The EOG signal data which can be classified will implemented to program for navigation of Arduino Mobile Robot via Bluetooth.

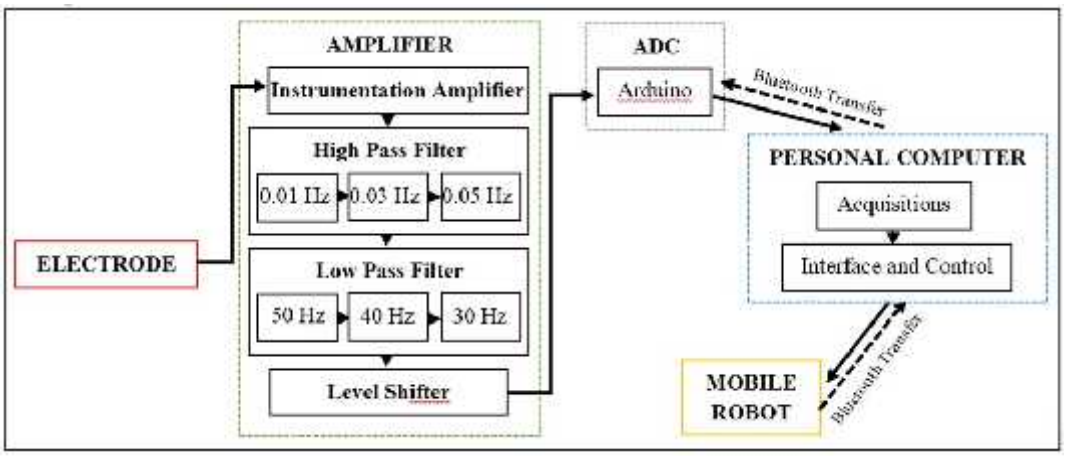


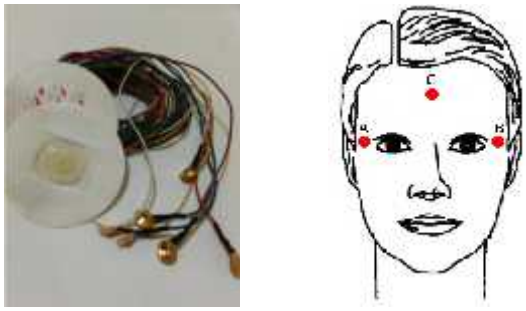
Figure 1. EOG scheme to navigate mobile robot.

3. Hardware Design

In this section, will described how EOG system will be works and its application hardware (mobile robot). The system have been show at figure previously (see figure 1). And below was a descriptions of hardware design;

3.1 Electrodes

Electrode used to detect and get eye movement signal from our biological eye muscle. The electrodes as figure 2a will be stick on some point around eye muscle that show at following the figure;



(a) (b)

Figure 2. (a) Electrode cap, (b) Electrodes sign

In figure 2b, point A (stick on right side eye) and point B (stick on left side eye) as an input, and point C (stick on forehead) as a ground of the circuit electrodes system.

3.2 Amplifier

Eye movement have a very little signal (50-3500 μV), to make it readable by ADC of Arduino Board need an amplifier circuit. To build an amplifier circuit need IC Op-Amp OP07 component to amplifying process. Power for IC Op-Amp OP07 used 12 volt battery. Non-Inverting Amplifier circuit we used for amplifier system show as figure 3. And to determine the gain of the amplifier following at equation (1).

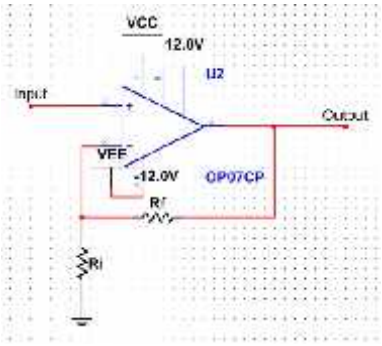


Figure 3. Non-Inverting Amplifier

$$G = 1 + \frac{R_f}{R_i} \quad (1)$$

The EOG circuit system in this research will amplify 1000 times of gain from eye movement signal nature with 3 steps (present in following subsection). The EOG circuit system divided by 4 part, they are; Instrumentation Amplifier, High Pass Filter (HPF), Low Pass Filter (LPF) and Level Shifter. The circuit concept as figure 4;

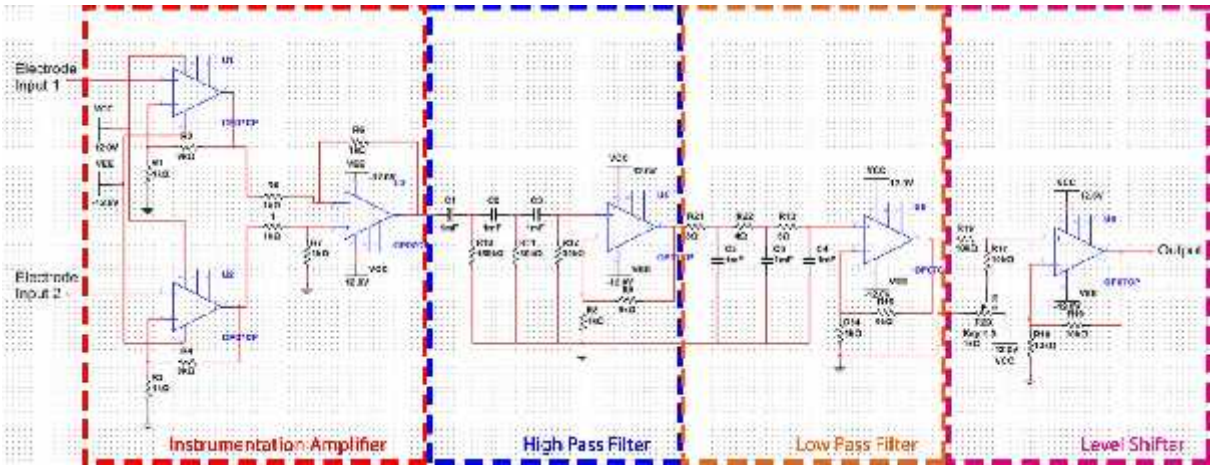


Figure 4. EOG circuit system

The range of frequency of EOG monitoring system is 0.05 Hz – 30 Hz. So that, the cut-off frequency of HPF is 0.05 Hz, and LPF at 30 Hz. To determine cut-off frequency for HPF and LPF circuit, can be get from;

$$f = \frac{1}{2\pi} \quad (2)$$

And more descriptions about the part of amplifier, described below:

3.2.1 Instrumentation Amplifier. This part is the basic of Non-Inverting amplifier with 10 times of gain from the eye movement signal nature. Consist by 2 input from electrode which have been present at figure 2b (point A and B). After the both electrode has been amplified, the system will entered to

subtractor circuit. The function of subtractor circuit is to detect the potential difference of the both input signal.

3.2.2 High Pass Filter (*HPF*). The waveform of the signal from Instrumentation Amplifier still mix with noisy signal. So that, need filter circuit to block the noisy signal to get better characteristic of the signal. HPF used to release the signal which have higher frequency than cut off (block the low frequency). In this research, we make 3 stage of HPF which will block under 0.01 Hz, 0.03 Hz and 0.05 Hz of frequency. This circuit we design gradually in order to get the best signal result. After that, the signal will be amplify a potential become 10 times of gain with Non Inverting Amplifier. To confirm frequency value from the HPF circuit has been analyze using Bode Plotter. The bode plotter show that at 0.05 Hz position can be look the vertical line in figure 5, and has 39.396 dB.

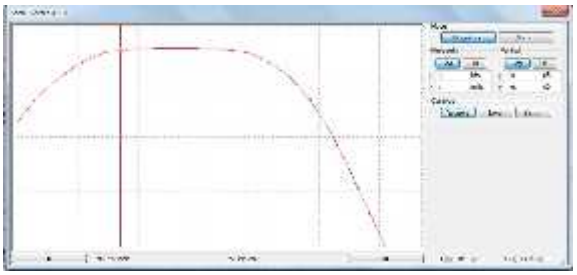


Figure 5. Bode plotter for HPF

3.2.3 Low Pass Filter (*LPF*). LPF is the active filter which can release the signal which have lower frequency than cut off (block the high frequency). LPF in this system make 3 stage and will block upper 30 Hz, 40 Hz and 50 Hz of frequency. This circuit will amplify the signal potential become 10 times of gain. Bode plotter used to confirm frequency value from LPF circuit. And the bode plotter show that at 30 Hz position can be look the vertical line at figure 6, and has 27.702 dB.

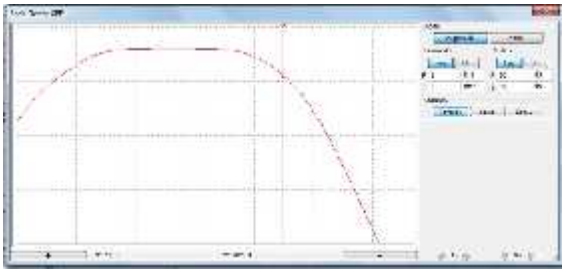


Figure 6. Bode plotter for LPF

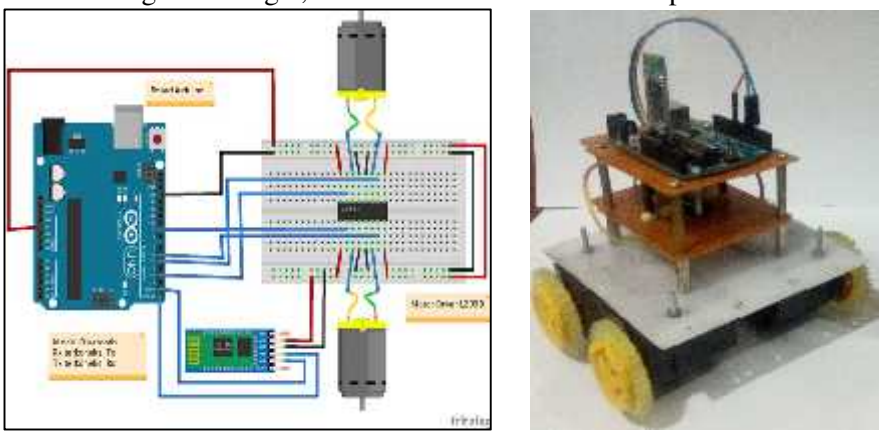
3.2.4 Level Shifter. This part was based Non Inverting Amplifier, but without gain. Level shifter used just to bring up the signal because of Arduino ADC can't be read negative potential difference. In other word, level shifter used to up or down the signal at oscilloscope.

3.3 Analog Input on Arduino (*ADC of EOG*)

Arduino is a microcontroller board system that have internal ADC facility. ADC used to convert Analog data to Digital data of potential difference. We used ADC from Arduino board because easily to operate. This ADC will connected with Amplifier circuit. After the signal of eye movement processed from amplifier, value of potential difference will be read by Arduino board. Data of the signal will be transferred to Personal Computer (PC), then the data will be process for signal classify in PC via Bluetooth.

3.4 Mobile Robot

Mobile robot in this system consist; Motor driver, motor DC, Arduino board and Bluetooth HC-05 as figure 7. In this part, Arduino board microcontroller will control the Mobile Robot. Mobile robot will move suitable the serial algorithm logic, and the mobile robot will be operated via Bluetooth HC-05.

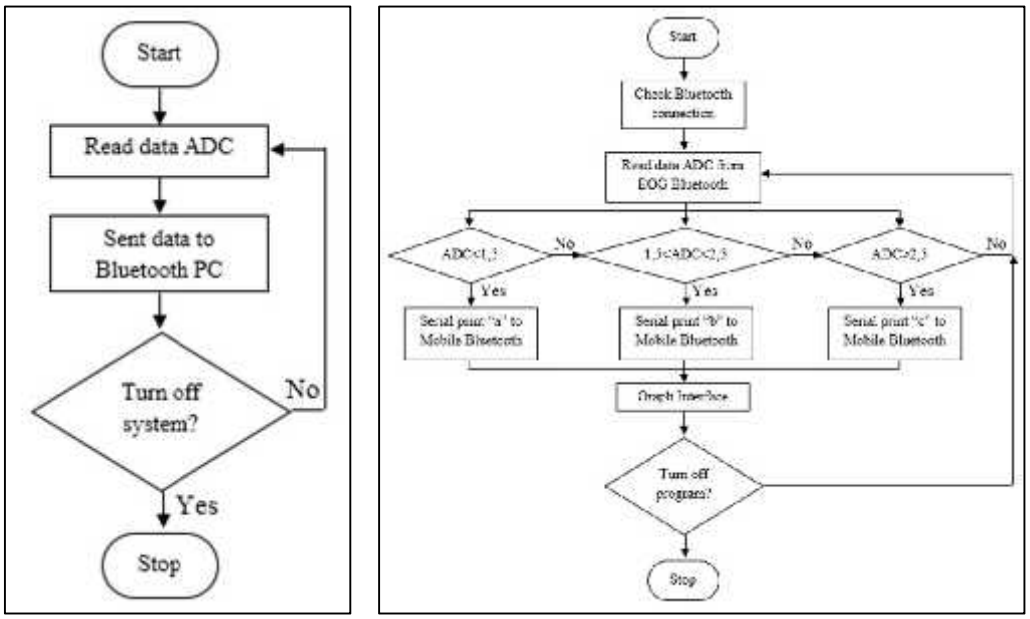


(a) (b)

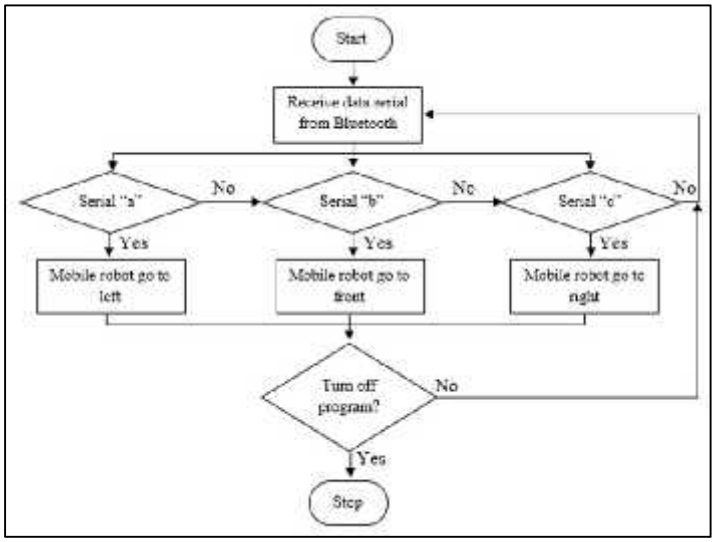
Figure 7. (a) Mobile robot schematic, (b) Realization of Mobile Robot

4. Algorithm Processing and Control System

In this research, the program for microcontroller type by using IDE Arduino software, and the program for computer type by using Processing® software. First, the program will transmitted EOG signal to computer as figure 8a. The program can receive, interface, classify, and send serial data command as figure 8b. Last, the program can receive serial data and navigate the mobile robot as figure 8c.



(a) (b)



(c)

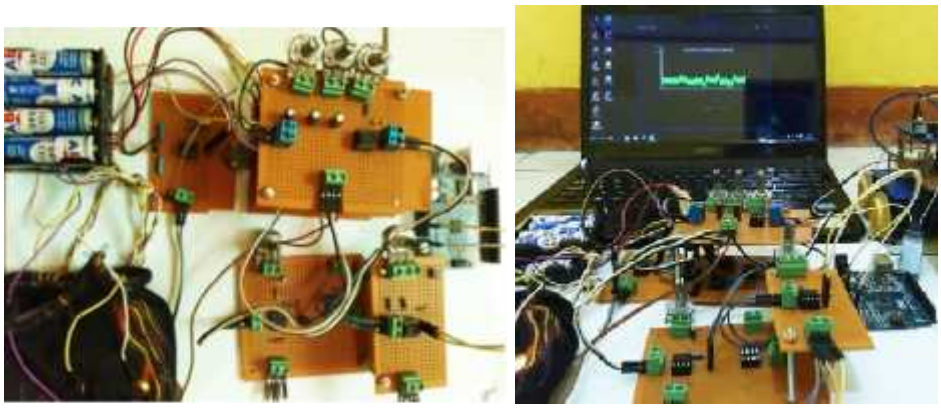
Figure 8. Chart of the program, (a) For microcontroller of EOG system amplifier, (b) For personal computer, (c) For microcontroller of Mobile Robot

And below is the logic algorithm for eye movement data and serial to navigate the Mobile Robot as table 1;

Table 1. Eye movement data and serial to navigate Mobile Robot

Eye movement	Range of ADC read (volt)	Serial data	Navigation	Motor LeftA	Motor LeftB	Motor RightA	Motor RightB
Left	0 – 1.5	a	left	HIGH	LOW	LOW	HIGH
Front	1.5 – 2.5	b	front	LOW	HIGH	LOW	HIGH
Right	2.5 – 3.5	c	right	LOW	HIGH	HIGH	LOW

5. Result

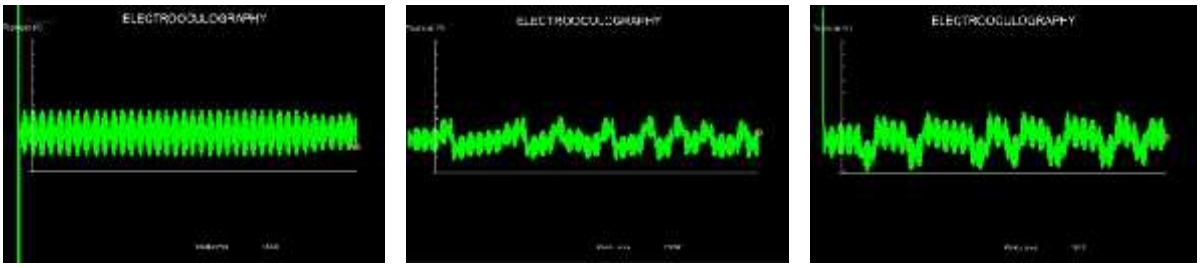


(a) (b)

Figure 9. (a) EOG circuit, (b) EOG system

Figure 9 show the realization of EOG circuit and system. To get differences condition from EOG circuit, we investigate an acquisition data to analyze of the EOG signal. Analyze have been investigated to some people with doing eye movement to the right, to the left and looking front. Amplitude result of potential difference from ADC can be classified while eye doing moving. The amplitude of potential differences eye movement, we get; when eye just looking at front the amplitude

1.5 – 2.5 volt, when eye looking at right the amplitude 2.5 – 3.5 volt, and when eye looking at left the amplitude 0 – 1.5 volt. Below, show the time series graph of potential differences;



(a) (b) (c)

Figure 10. Graph result of eye movement, (a) Looking front, (b) Looking right, (c) Looking left

Following the figure 10 has been show that; when the eye look at front or at normal condition waveform has harmonic oscillation without fluctuation (see figure 10a), when the eye look to the right waveform sways upward (see figure 10b) and when the eye look to the left waveform sways downward (see figure 10c).

After the data can be classified, we implemented the data to the program for navigation of Mobile Robot. When eye looking to the right Mobile Robot will move to the right, when eye looking to the left Mobile Robot will move to the left, and when eye looking front Mobile Robot will move to the front. The algorithm of the program; when eye do a movement, ADC data will send to computer. Then the data will processed in computer become data serial. Finally data serial will sent to control navigation of Mobile Robot based microcontroller. All communication data serial between EOG (ADC microcontroller), computer and Mobile Robot microcontroller sent via Bluetooth.

6. Conclusion

In this paper, the EOG circuit system divided by 4 part are Instrumentation Amplifier, High Pass Filter (HPF), Low Pass Filter (LPF) and Level Shifter. The EOG circuit system will gain 1000 times from eye movement signal nature. And the frequency range of EOG monitoring system is 0.05 Hz – 30 Hz. We get that the system of EOG signal can be classified when eye movement looking at front, left and right. The data which can be classified implemented to program for navigation of Mobile Robot. When eye do a movement, ADC data will send to computer. Then the data will processed in computer become data serial. Finally data serial will sent to control navigation of Mobile Robot based microcontroller. All communicated serial data sent via Bluetooth.

7. Acknowledgment

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