

DESIGN AND IMPLEMENTATION OF EOG ACQUISITION CIRCUIT

Jane Phoebe Achieng Ogenga^a, Waweru Njeri^a, Joseph Muguro^a, Peterson Nyaga^b, Michael Gichane^b

^aCenter for Robotics and Biomedical Engineering, Dedan Kimathi University of Technology, Private Bag-10143 Nyeri, Kenya,

^bMechatronic Engineering, Dedan Kimathi University of Technology, Private Bag-10143 Nyeri, Kenya,

*E-mail: phoebeachiengaj@gmail.com

Keywords: Electrooculogram, electrodes, neurological disorders

ABSTRACT

Individuals with serious neurological abnormalities have restricted bodily motions, except for their eyes in most cases. This makes the individuals to depend on an assistant. Electromyogram (EMG), Electrooculogram (EOG), and other bioelectric signals can be utilized by these individuals to interact with the outside world without an assistant. This paper presents a design of an Electrooculogram (EOG) signal data acquisition (DAQ) system. Cascaded amplification stages and a band pass filter were used. EOG data was successfully acquired using the presented system. This can be used to acquire EOG data for different application

INTRODUCTION

Communication is crucial for human interaction with society in our daily activities. As the number of people with disabilities rises, rehabilitative tools are needed to help these people communicate with the outside world. Severe neuromuscular problems make it difficult for sufferers to lead fulfilling lives. It is crucial to find an alternative to voice and hand gestures for communicating if you want to improve these people's quality of life.

The user's behaviors and cognitive processes can be retrieved from the eye, which can be thought of as a rich source of information. Several techniques, including scleral search coils[1], electrooculography (EOG) [2]–[6], infrared oculography [7]–[9] and image-based methods, can be used to detect eye movement and blinking. The EOG-based techniques are comparatively more practical, economical, and non-invasive. Applications for the EOG signal include estimating sleepiness levels to prevent accidents, assisting in communication via a virtual mouse, electric power wheelchair, keyboard control, industrial assistance robot, or neuroprostheses, and diagnosing eye conditions [10].

EOG Signal Processing built on LabVIEW was created by Lydia et al [11]. Electrodes made of Ag/AgCl were utilized for signal acquisition. Two channels and four Commands were employed. Huang *et al.* created a system that utilized electro-oculography (EOG) signals to control a wheelchair by identifying a specific sort of eye movement (blink)[12]. For EOG acquisition, a single vertical channel with three wet electrodes was used. The system's sampling frequency was 250 Hz. using a differential method, noise from the 50 Hz power line and DC level was eliminated. Several features were retrieved, including the peak value of the sub-segment and the blink time. The system produced 13 distinct commands. These signals were processed using a thresholding method.

In [13], a combined EOG and EMG circuit for differentiating intentional and unintentional eye blinks. For EOG, a threshold was applied on the duration while for EMG the threshold was applied

on the amplitude. Mulan et al. created a wireless HCI gadget based on EOG [14]. For EOG acquisition, two channels with five wet electrodes were used. The system's sampling frequency was 250 Hz. There were eight different commands produced. To categorize the EOG signals, this system used a wireless acquisition device and a thresholding algorithm.

A novel wearable forehead EOG measurement system for HCI was created in [15]. Electrooculograms (EOG) are acquired using Ag/AgCl electrodes. It sampled at a rate of 256 Hz. The thresholding algorithm was used to process these signals after that.

METHODS

Data acquisition circuit

The circuit in Figure 1 was designed using three amplification stages and one filtering stage. The sampling frequency of the circuit was 192 Hz with an overall gain of 95.55Db. In overall, data was collected from six randomly selected subjects, between the ages of 23-28 years for 520s each.

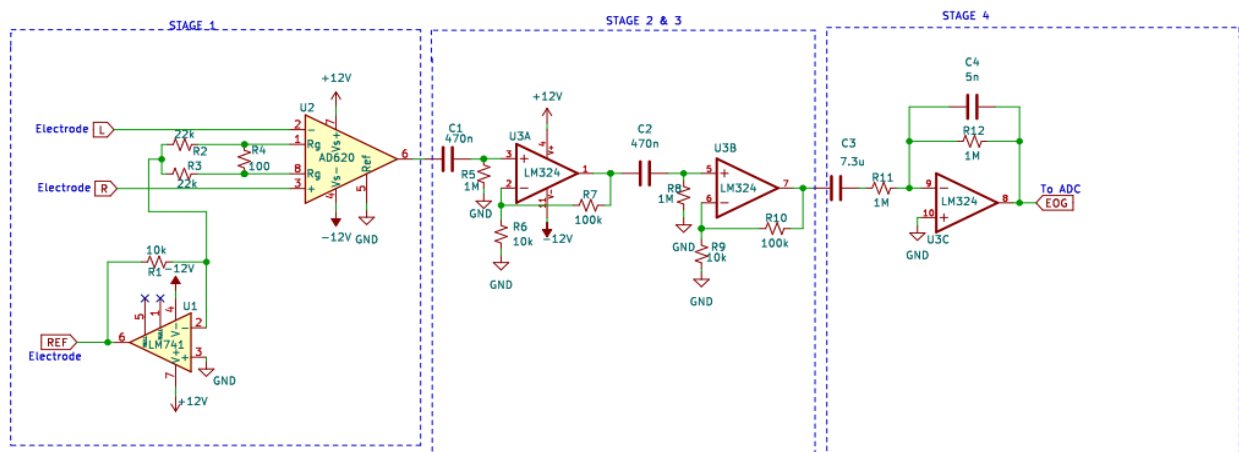


Figure 1: Data Acquisition Circuit

Electrode placement

Using a single channel, horizontal in this case, signals from saccadic eye movement can be collected. Using three electrodes, placed as in Figure 2, the horizontal eye signals were acquired.



Figure 2: Electrode placement

The horizontal eye signals were acquired by placing the electrodes between the outer canthi of both the left and right eye and the hairline as well as the forehead for referencing. The skin preparation involved wiping the skin with alcoholic pads and drying with cotton gauze or leaving it to dry. The electrodes used were the silver/silver Chloride (Ag/AgCl) electrodes because of their

clear transmission of surface bio-potentials and high accuracy. To improve sensor-skin conductivity and reduce impedance, the sensors in the electrodes we gelled before use.

Instrumentation amplifier

The instrumentation amplifier AD620 is employed in the first stage of the circuit because it can amplify the weak EOG signals from the electrodes. The signals from the electrodes were fed to AD620 which has a high ability to suppress the common mode signal from the electrodes. Depending on the value of the gain resistor, R_4 , the amplifier's gain can be adjusted. In this case, $100\ \Omega$ was chosen to give a gain of 53.89dB calculated as in (1):

$$A = \frac{49.4k\Omega}{R_4} + 1 \quad (1)$$

$$A = \frac{49.4k\Omega}{100\Omega} + 1 = 495 = 53.89dB$$

For the subject's safety, the reference electrode was connected to the output pin of the LM324 amplifier of the reference circuit. The common mode signal rejected by the instrumentation amplifier is picked up by the Driven Right Leg (DRL) circuit through the inverting voltage buffer and the reference probe. The reference electrode thus reduces this common mode voltage by negating the signal.

Non-Inverting Amplifier

The signal from the instrumentation amplifier was fed into two cascaded non-inverting operational amplifiers (LM324) for more amplification thus increasing the amplitude but keeping the output signal in phase with the input signal. From figure 2, resistors of value $R_6 = R_9 = 10k\Omega$, $R_7 = R_{10} = 100k\Omega$. The gain of each stage was 20.83 dB and is given by (2):

$$A_V = 1 + \frac{R_7}{R_6} = 1 + \frac{R_{10}}{R_9} \quad (2)$$

$$A_V = 1 + \frac{100k}{10k} = 11 = 20.83dB$$

Band-Pass Filter

To eliminate EMG, intrinsic, and power line noise, an active band-pass filter with a gain of 1 was used. The cutoff frequency was calculated as in (3):

$$f_i = \frac{1}{2\pi R_i C_i} \quad (3)$$

Lower cut-off: $f_L = 0.02\text{Hz}$, $R_{11} = 1\text{M}\Omega$, $C_2 = 7.3\mu\text{F}$

Upper cut-off: $f_H = 30\text{Hz}$, $R_{12} = 1\text{M}\Omega$, $C_4 = 5\text{nF}$

The signal from the bandpass filter output was passed through an Arduino Uno ADC to MATLAB. The Arduino microcontroller converts the analog signals to digital signals and then sends them to MATLAB through a USB cable via serial communication with the computer.

The signal was further filtered digitally in MATLAB using the moving average filter. This assists in the removal of noise from the signal while retaining the sharp steep response with important information about the signal. The filter response is given by equation (4):

$$y(n) = \frac{1}{M} \sum_{i=0}^{M-1} x[n + i] \tag{4}$$

M, n, x, and y represent the window size, current sampling point, raw signal, and processed signal respectively

Control system

To have a standard and defined instruction system for all the subjects, a moving dot was displayed on a laptop screen approximately 1 meter away from the subject as in Figure 3. The dot would randomly appear either to the right or left. The subject was instructed to move their eyes to the direction of the dot appearance and back to the center.

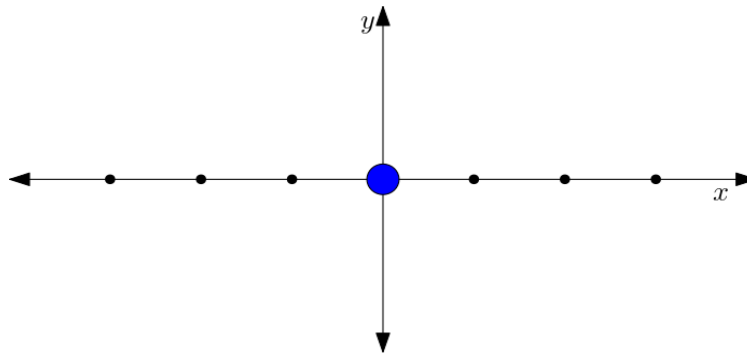


Figure 3: Control layout

RESULTS

The data collected from the DAQ in figure 1 involved three eye activities. Eye movement from the center to the right and back, from the center to the left and back, and no eye movement (eye stays at the center) as in Figure 4. The EOG signal collected coincided with the control signal but with a slight delay owing to the subject’s time to respond to the direction that the dot appeared.

The signal from the left and right eye movements have two pulses with an amplitude Vpp of 30mv and inverted behaviors i.e. the signal from the left eye movement and back to the center has a positive pulse followed by a negative pulse while the signal from the right back to center in the inverse.

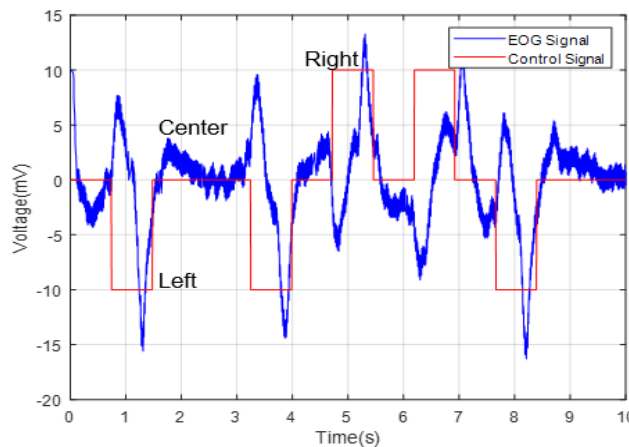


Figure 4: EOG signal and control signal

Filtering of this signal using a moving average filter with a window length of 15 samples achieved a signal as in Figure 5. The window length of MAF was settled upon trial and error and ensured the conservation of the important aspect of the signal. Compared to commercially available DAQ, this design is easy to implement and it is relatively cheap as it can be done with components readily available from the lab. It however, due to its nature, introduces more noise to the signal. The noise can successfully be eliminated through digital filtering to acquire a usable signal.

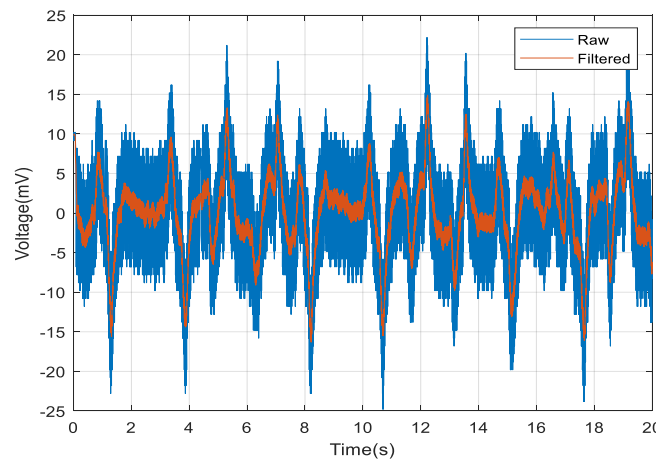


Figure 5: Raw and filtered EOG Signal using MAF

CONCLUSION

The designed DAQ use used to successfully collect EOG signals from horizontal eye movement. The system's sampling frequency was low compared to other ready-made DAQs in the market. This makes the system more affordable as it can be easily made in the lab. Despite the low sampling frequency, the system was able to collect quality data on the eye movement that contained the required information and had a distinction between the two eye activities. The system can be used to collect both horizontal and Vertical EOG signals that can be used for automation and control of any devices as desired. In this case, the system will be used in the control of the wheelchair as the work progresses.

ACKNOWLEDGEMENT

This work was supported by the Kenya Education Network (KENET) award of the Research and Innovation Grant in Engineering 2022/2023.

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