Integrated EOG and EMG Front-End for Differentiating Intentional and Unintentional Blinks

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Abstract—**Electrooculography (EOG) is beneficial in many human interface systems when the signals are measured, amplified and filtered to produce a signal from movement of eyes by which appliances can be controlled. Some patients who are disabled by paralysis can only control their eyes; therefore, these EOG and electromyography (EMG) signals become one of the few ways they can interact with the surrounding environment. The signals gathered from blinking intentionally and unintentionally, need to be distinguished in order for the system to work correctly. By integrating duration and amplitude data from both EOG and EMG signals simultaneously from three electrodes, an efficient algorithm is proposed to distinguish the two classes of blinking: intentional and unintentional.**

I. Introduction

The main objective of this project is to create an electrical system that can differentiate when the user intentionally blinks versus when he or she unintentionally blinks with the use of electromyography (EMG) and electrooculography (EOG). An electromyogram is a record of the electrical potential from muscle cells. With electrodes attached above and below the eye, an electrical potential is recorded from the orbicularis oculi and levator palpebrae when the patient blinks. An electrooculogram is a record of the electrical potential dipole created by the difference in the electrical potential of the cornea in relation to the retina of the eye. Electrodes are placed around the eye to observe this dipole. Typically, the absolute position of the eye is not measured due to the number of noise sources dominating the potential measured. EMG signal amplitudes range from approximately 0.001 to 100 millivolts with a frequency range of 50 to 3000 Hertz. EOG signal amplitudes range from approximately 0.001 to 0.3 millivolts with a frequency range of 0.1 to 10 Hertz [5]. These ranges are the foundation of our design for filtering and amplifying the signals separately for analysis and use.

Previous work has explored the characteristics of intentional and unintentional blinks. Research by Kaneko [1] demonstrated an ability to isolate the two blink classes using independent electrodes for EMG and EOG signal collection. Our proposed configuration uses three electrodes to record both signals simultaneously. With this configuration, preliminary results appear positive to discern blinking classes with a simple threshold based upon threshold and duration of the events.

II. Build

Fig. 1 shows our schematic for the EMG and EOG bandpass filters along with their respective gain stages and

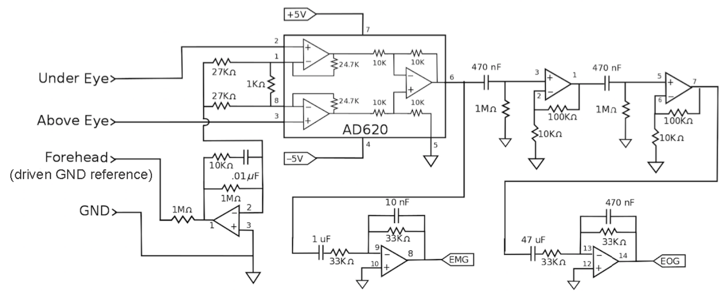

Figure 1: EMG and EOG Circuit.

an instrumentational amplifier (AD620). The bandpass filter for the EMG signal amplifier in our circuit has cutoff frequencies at 50 Hz and 4.8 kHz, putting us in the frequency range of EMG signals. The upper limit of 4.8 kHz was chosen to align with commonly available synthetic capacitors and resistors while also being the closest frequency to the top of the EMG frequency range.

For the EOG bandpass filter, the resistor and capacitor values were chosen for -3 decibel cutoff frequencies at 0.1 Hz and 10 Hz.

For the operational amplifiers, multiple LM324 integrated circuits (ICs) were utilized to provide a driven ground to the forehead, gain stages, and bandpass filters. The LM7660 voltage inverter provided a negative voltage supply for LM324 bipolar operation.

Due to the small signals associated with the EOG, three amplifier stages were implemented to maximize the dynamic range of the signal for measurement on a 0 to 5V input range. Two non-inverting op-amp gain stages are cascaded with the AD620 gain of 50. A total gain of 6,050 was provided with this configuration.

For testing, the AD620 was placed on a small circuit board mounted to the head. The wires were kept short (approximately 8 inches) to reduce the impact of electromagnetic interference.

For EOG and EMG signals, one electrode was placed above and below the eye. The third electrode on the forehead provided a driven ground reference. This arrangement of electrodes is similar to configurations commonly reported by researchers, such as Kaneko [1], when trying to detect EOG signals. When someone looks up or down, the electrodes will propagate electrical potential changes related to dipole pose modifications. Vertical movements were the focus of the measurements due to the greater amplitudes observed compared to the lateral motion for horizontally placed electrodes.

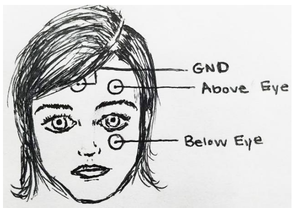

Figure 2: Electrode Placement.

III. Results

After testing each gain stage sequentially, we did a frequency sweep to find where the half power, or -3db point occurs with the hardware setup. We found that the EMG circuit has cutoff points at approximately 70 Hz and 4.3 kHz. We found that the EOG circuit has cutoff points at approximately 2 Hz and 11 Hz.

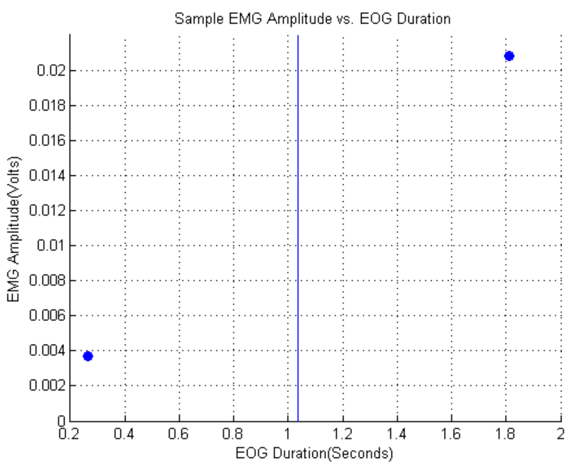

Figure 3: Sample Data Average of EMG Amplitude VS. EOG Duration differentiating Intentional from Unintentional blinks

Based upon example waveforms, a threshold was developed that is applied to the duration of the EOG and amplitude of the EMG. An initial qualitative assessment was obtained based upon an independent threshold in both the EOG and EMG components.

IV. Conclusion

The EOG and EMG signals play a crucial role in how people with paralysis can communicate. Differentiating between voluntary and involuntary blinking can make the difference for a patient to communicate effectively and accurately. An apparatus was discussed that qualitatively appears to produce results consistent with reports by Kaneko [1], which allude to a feasibility of pursuing a simple threshold based classifier of intentional and unintentional blinking. While our initial proposal is for a simple logical AND operation between a threshold on EOG and EMG, a second option being considered is a threshold based upon the linear combination of EOG and EMG to better isolate the classes. Future work is anticipated to quantify the performance of the proposed approach with a human study.

Theoretically, a bandwidth for our EMG and EOG circuits was designed for 50 and 3000 Hz, and 0.1 and 10 Hz, respectively, but component availability and tolerance of the capacitors and resistors generated a slightly different set of bandwidths. Even though the realized bandwidth was more limited than initially planned, the design appeared to have similar characteristics to those reported by Kaneko [1] and was from a preliminary qualitative assessment effective at discrimination so the simplistic design was maintained. The use of the same electrodes for EMG versus EOG has led to a contamination of the signal by EOG related potentials, but for the purpose proposed, it does not appear to be significant enough to impact results. If so, a higher order filter could be applied to the EMG signal to reduce further. Future work will explore the impact of different filter approaches by applying post-processed higher order digital filters.

References

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