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Electrooculography Signal Processing Using National Instruments LabVIEW

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Electrooculography Signal Processing Using National Instruments LabVIEW

by

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A Thesis

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This thesis is accepted and approved in partial fulfillment of the requirements for the Master of Engineering

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ABSTRACT:

Many people with physical disabilities have difficulty performing tasks that require directional discrimination. This research paper develops new ways to allow such people to operate mechanical devices without much physical mobility. The process takes Electrooculography signals from the motion of the eyes, analyzes and modifies these signals for specific operations using National Instruments LabVIEW, and then translates these signals into mechanical motions for the controller's benefit.

For this paper, electrodes were placed to read vertical (up-down) and horizontal (left-right) eye movements, as well as blinks. These signals were sent to a biopotential amplifier (or bioamplifier) and the output of that was sent to LabVIEW for analysis and modification. The modified signal was then sent to an Arduino microcontroller, used to transmit instructions corresponding to the different directional movements. A receiving device takes these instructions and sends them to another Arduino microcontroller, which then executes the motion corresponding to that instruction.

Eyes	→	Bioamplifier	→	National Instruments LabVIEW	→	Transmitter	→	Receiver	→	Device

Figure 1: Basic Framework of the Project

INTRODUCTION:

The eye forms a dipole between the cornea and the retina, and the resulting voltage difference causes electrical signals to be generated with the movement of the eyes. These signals are called Electrooculography (EOG) signals and are useful in many medical and bioelectronics applications. To acquire these signals, electrodes are placed around the eyes, and then amplified using a bioamplifier, to make them observable to the researcher. Depending on the placement of the electrodes, the voltage signals fluctuate in response to the direction of the eyes' movements.
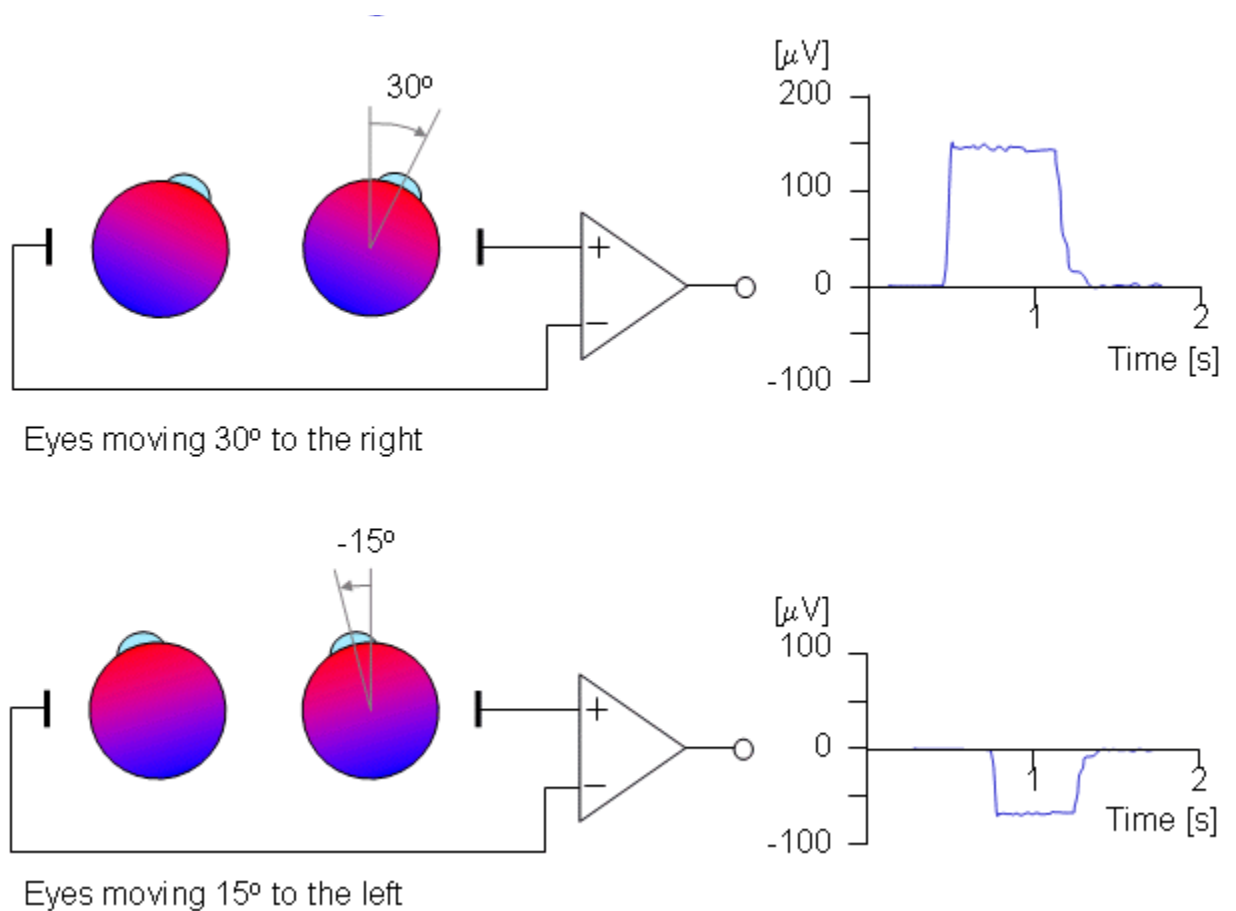

Figure 2: Differential Voltage Response to right-left Movement of the Eyes

APPROACH:

1. Biopotential amplifier Circuit

A basic biopotential amplifier circuit was used, and it can be adjusted to have a wide range of bioelectronics application. A biopotential amplifier is used to decrease the noise and increase the amplitude of signals from the body. This circuit used one (1) AD620 instrumentation amplifier and two (2) LM741 operational amplifiers.
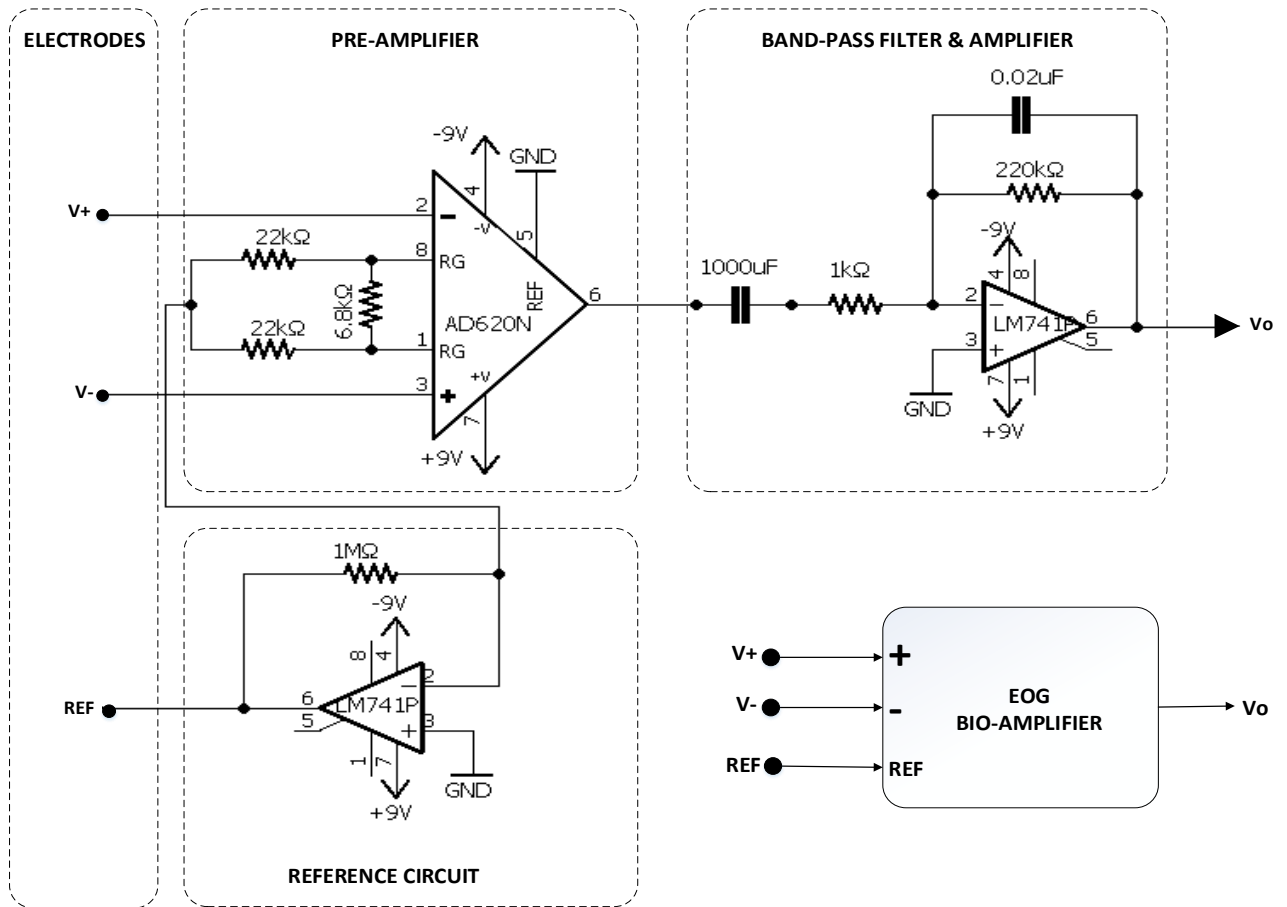

Figure 3: Bioamplifier Circuit Design

- Electrodes: the system has three probes; two differential probes placed across the location where the signal is to be measured, and one used as a reference

point. Two pairs of differential probes were used; one pair placed vertically across the right eye to measure up and down movements, and another pair placed horizontally across the face to measure left and right movements.
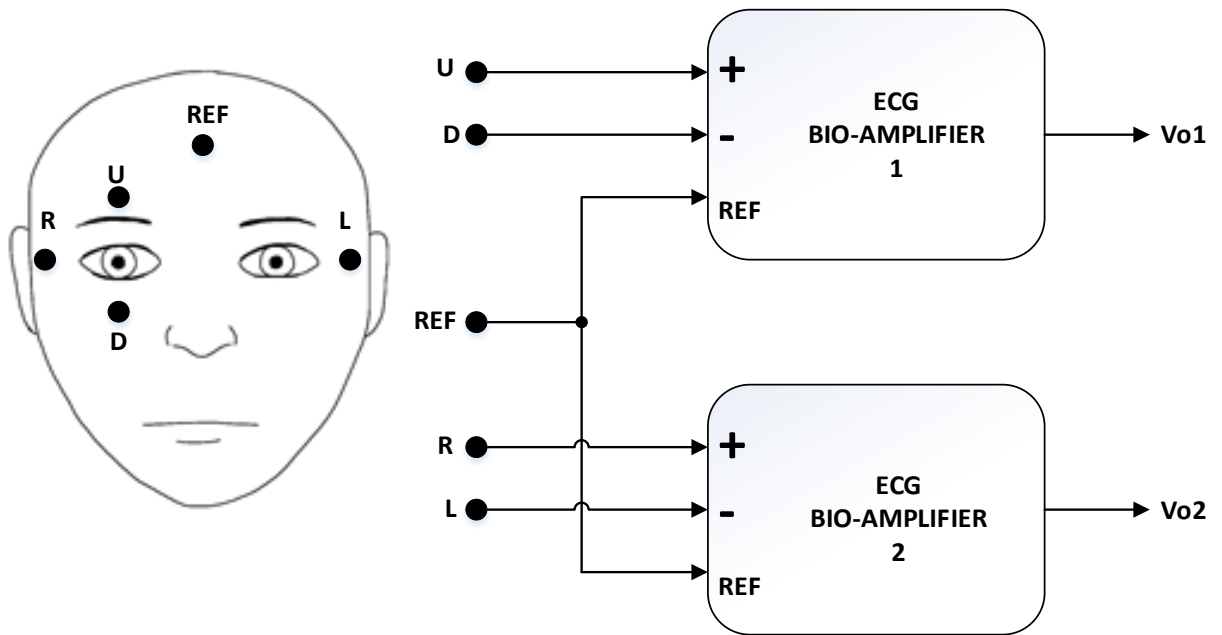

Figure 4: Electrode Placement

- Pre-amplifier: the signals form the probes were sent to a pre-amplifier, to eliminate the common-mode signal (noise) and amplify the differential signal. The AD620 instrumentation amplifier has a low common-mode gain, used to remove common-mode signals, and an adjustable differential gain, controlled by the value of RG

$$G_1 = 1 + \frac{49.4 \times 10^3}{RG}$$

RG was chosen to be 6.8kΩ

$$G_1 = 1 + \frac{49.4 \times 10^3}{6.8 \times 10^3} = 8.26$$

- Reference circuit: This is a basic Driven-Right-Leg circuit used in Electrocardiogram (ECG). It improves patient safety and reduces interference. The forehead (or the neck) was used in this application in place of the right leg. The forehead was connected to the output of an auxiliary amplifier, instead of ground. Common-mode voltage was gotten by averaging the 22kΩ resistors, and fed back to the reference probe. The reference circuit provided negative feedback to reduce the common-node voltage.

- Band-pass filter and amplifier: Electrooculography signals typically fall within the frequency range of 0.1Hz – 10Hz. A high-pass filter is necessary to eliminate low frequencies noise caused by factors like head movements, electrode placement and electrode-skin contact. A low-pass filter is necessary to remove the 50/60Hz power line frequency and prevent aliasing. A bandwidth of 0.16Hz – 9.7 Hz was chosen.

$$f_i = \frac{1}{2\pi R_i C_i}$$

Lower cut-off: $f_L = 0.16$Hz, $R_L = 1$kΩ, $C_L = 1000\mu F$

Upper cut-off: $f_H = 9.7$Hz, $R_H = 820$kΩ, $C_H = 0.02\mu F$

The band-pass filter had a gain

$$G_2 = \frac{R_H}{R_L} = \frac{820k\Omega}{1k\Omega} = 820$$

Total gain, $G = G_1 \times G_2 = 8.26 \times 820 = 6773.2$
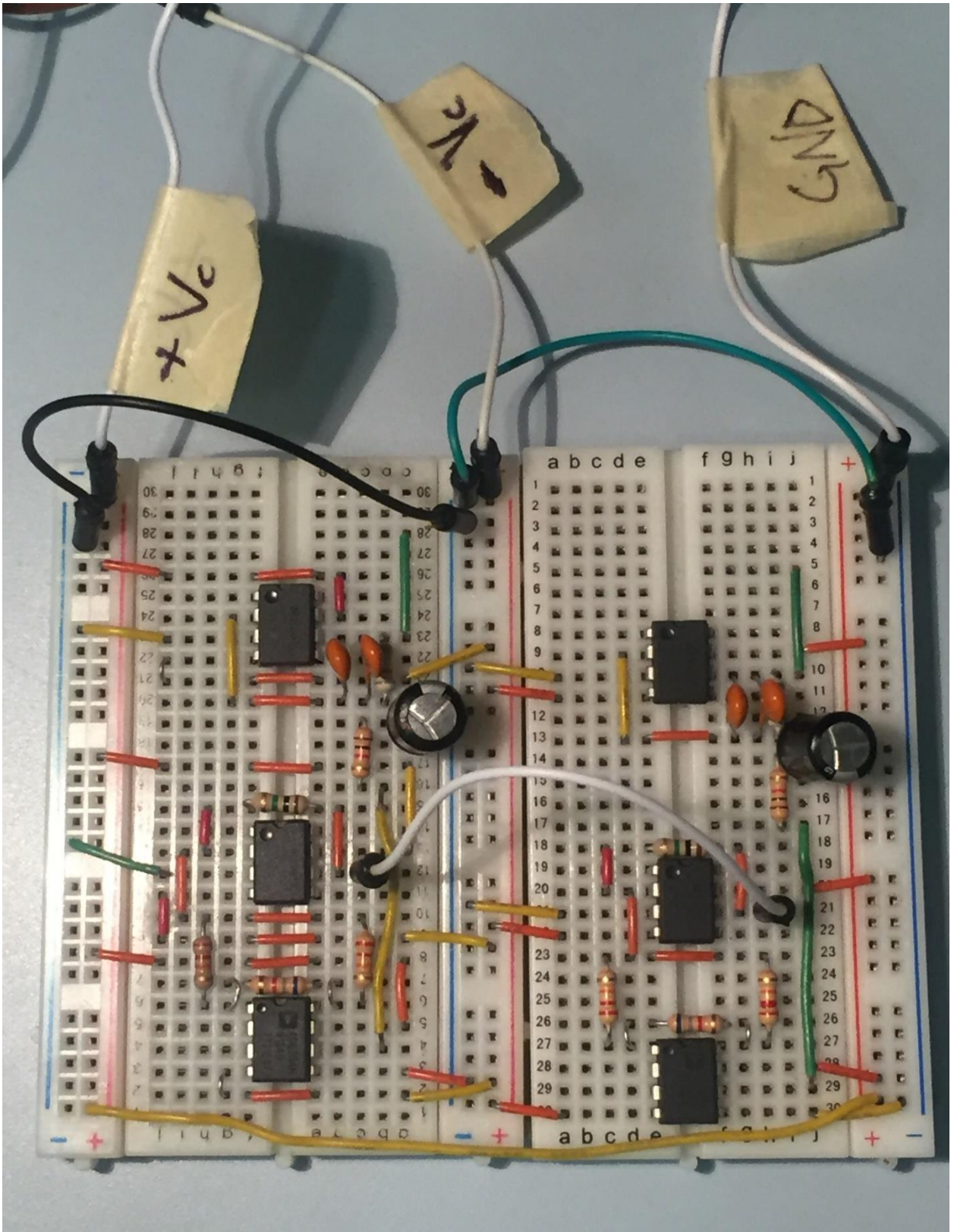
Figure 5: Bioamplifier Circuits

2. Output Voltage Signals
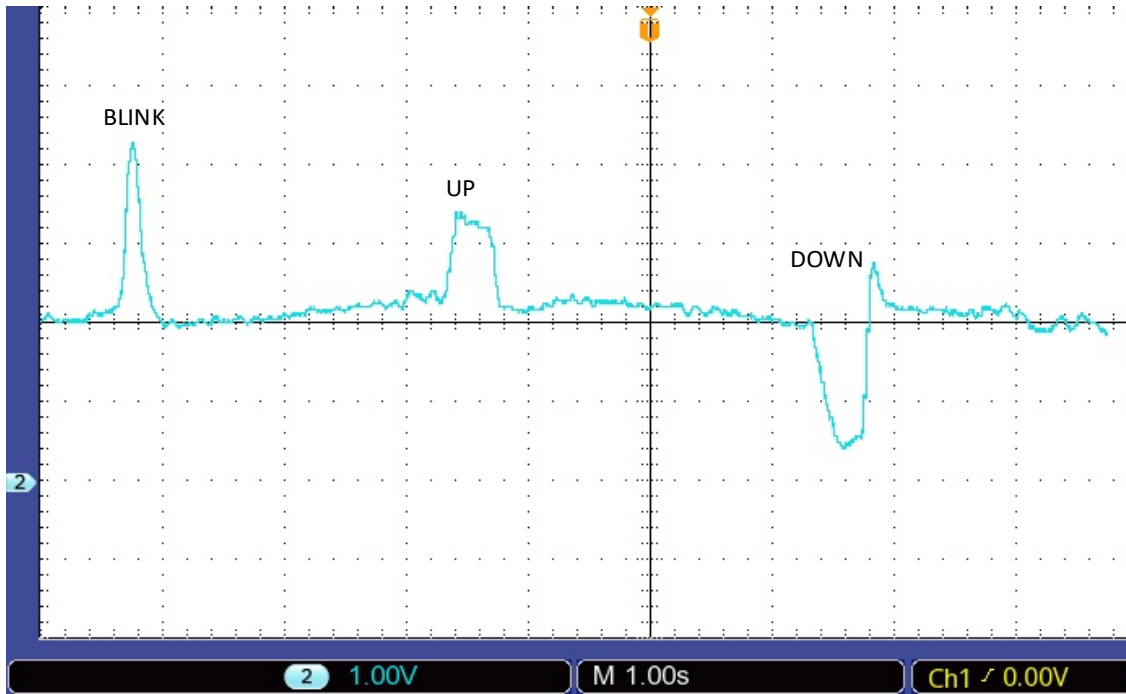

Figure 6: Vo1; blink, up, and down
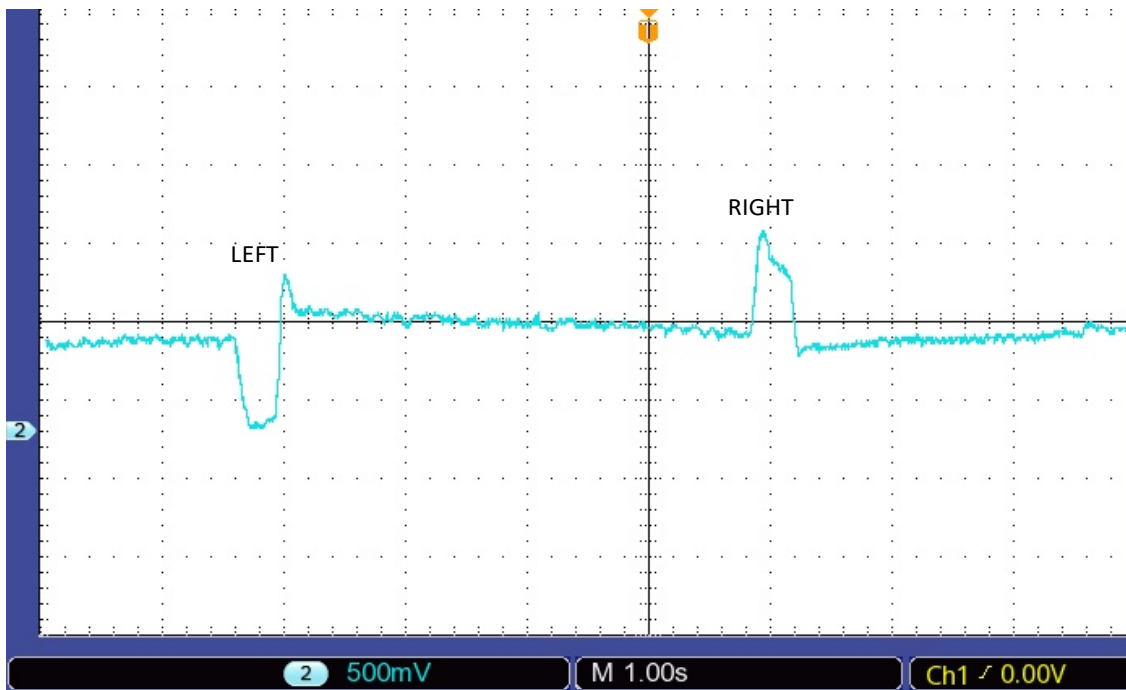
Figure 7: Vo2; left and right

3. LabVIEW Schematic

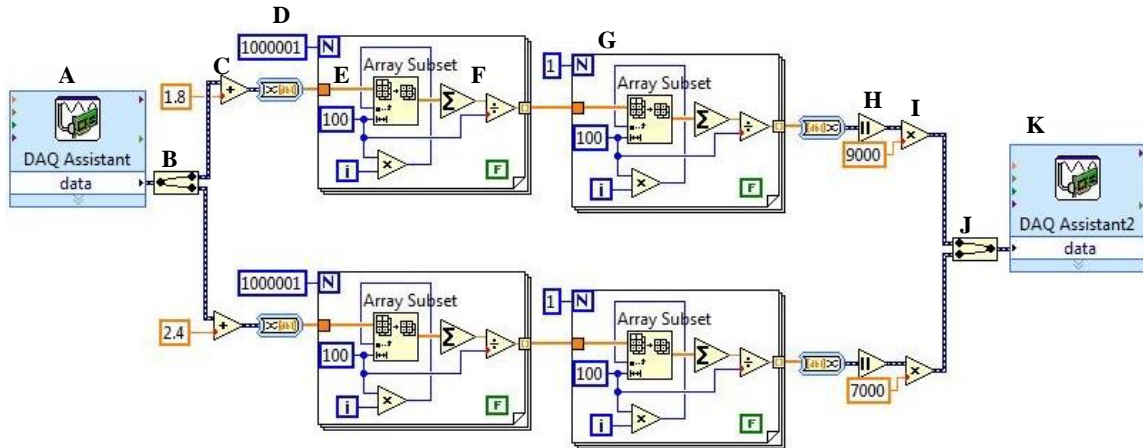Figure 8: LabVIEW Circuit

A) Voltage signals, Vo1 and Vo2, from the bioamplifier were read using the National Instruments Data Acquisition (DAQ) device. The DAQ device was represented by a DAQ Assistant on the LabVIEW circuit. Two input channels were created for Vo1 and Vo2, and the Acquisition Mode was set to read 1 sample on demand.
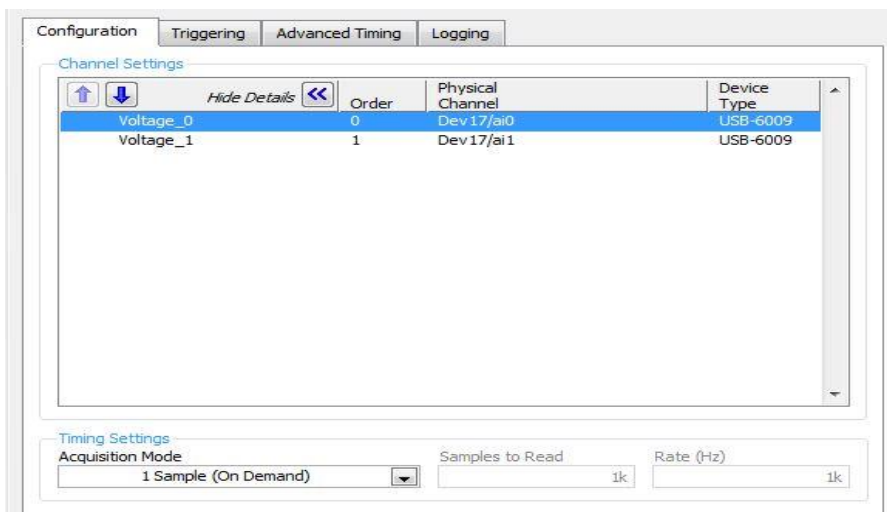
Figure 9: Input DAQ Assistant Settings

B) The different voltage signals were separated using the Split Signals function, to be modified separately.

C) 1.8 was added to Vo1, and 2.4 was added to Vo2, to give entirely positive waveforms, since Arduino does not read negative signals.

D) The positive signals were filtered through a smoothing filter. The smoothing filter was initiate with a For Loop.

E) The samples were divided into groups of 100 sample points each, and the average of each of these groups was derived. The Array Subset function was indexed with a counter multiplied by the length of each subset (100), producing indexes 0, 100, 200…

F) The values of the 100 samples in each subset was summed and divided by 100, to give the average value.

G) The smoothed signals were then sent thorough a second filter, to further reduce the noise.

H) The final signals were passed through an Absolute Value function, to eliminate any possible negative values.

I) The final Vo1 and Vo2 were amplified for readability, by multiplying the signals by 9000 and 7000 respectively.

J) The signals were merged into a single input using the Merge Signals function.

K) The output was written to the DAQ device using the DAQ assistant.

L) Two output channels were created for the modified Vo1 and Vo2 outputs.

DAQ Assistant 2 (from Figure 8) was set to read 1 sample on demand.
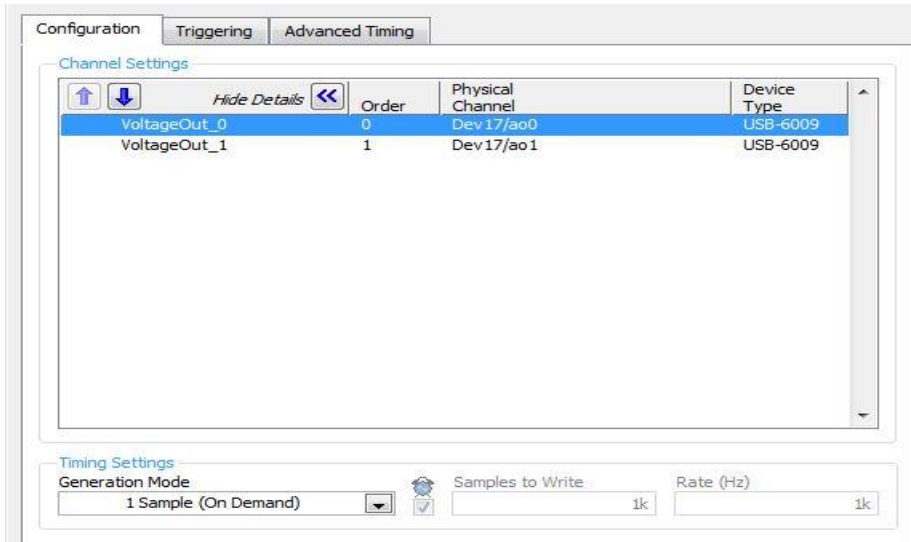

Figure 10: Output DAQ Assistant Settings

4. Transmitter Schematic

The transmitter design contained an Arduino UNO microcontroller, a DAQ device, and an RF 433MHz transmitter module. The electrodes connected to the eyes measured the differential voltages from the eye movements. These voltage signals were amplified by the biopotential amplifier to give Vo1 and Vo2, which were then read by the DAQ device to be modified using LabVIEW. The LabVIEW voltage outputs were sent through the DAQ device to the analog input of the Arduino UNO microcontroller. The Arduino UNO instructed the RF transmitter module to send out a signal, depending on the amplitude of the analog input signal.

The Arduino analog input can read a signal range of 0V-5V, which maps to Serial values of 0-1024 in the Arduino code. Vo1 and Vo2 were connected to two analog

input pins, and an upper and a lower threshold value, corresponding to the voltage inputs were selected for each pin.

For Vo1: If the voltage value was greater than the upper threshold U1, the transmitter sent out a "1" signal, corresponding to an "up" movement. If the voltage value was less than the lower threshold L1, the transmitter sent out a "2", corresponding to a "down" movement. If the voltage value was between the upper and the lower threshold values, no signal was sent.

For Vo2: If the voltage value was greater than the upper threshold U2, the transmitter sent out a "3" signal, corresponding to a "right" movement. If the voltage value was less than the lower threshold L2, the transmitter sent out a "4", corresponding to a "left" movement. If the voltage value was between the upper and the lower threshold values, no signal was sent.
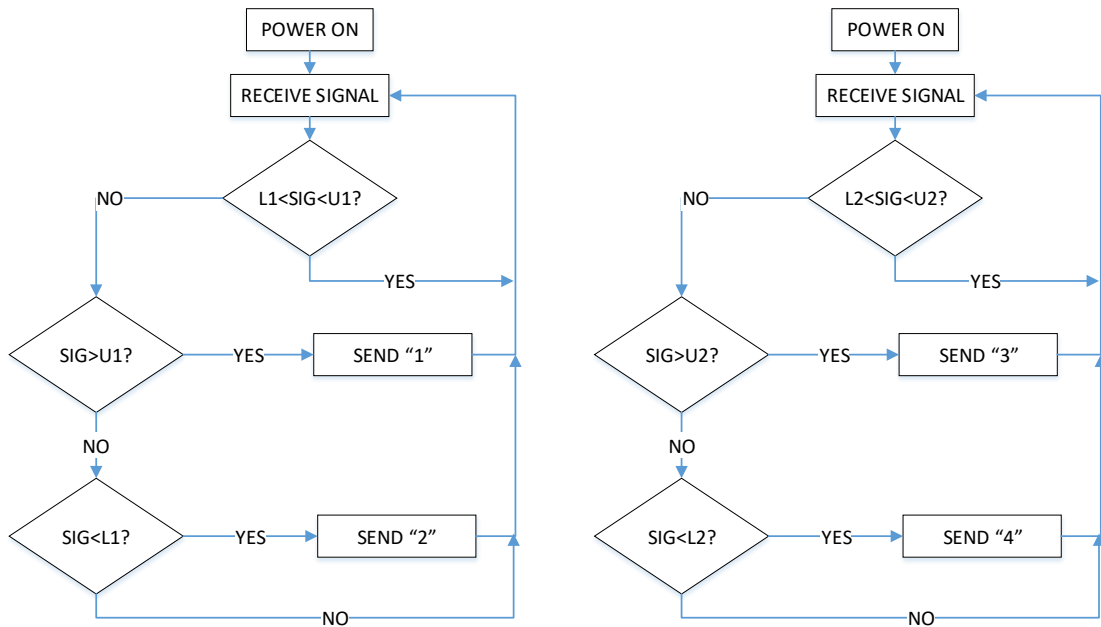
Figure 11: Transmitter Schematic

5. Receiver Schematic

The receiver design was placed on a toy car. It contained an Arduino Pro Mini microcontroller, an RF 433MHz receiver module, and an L298N motor driver.

Figure 12: Receiver Schematic
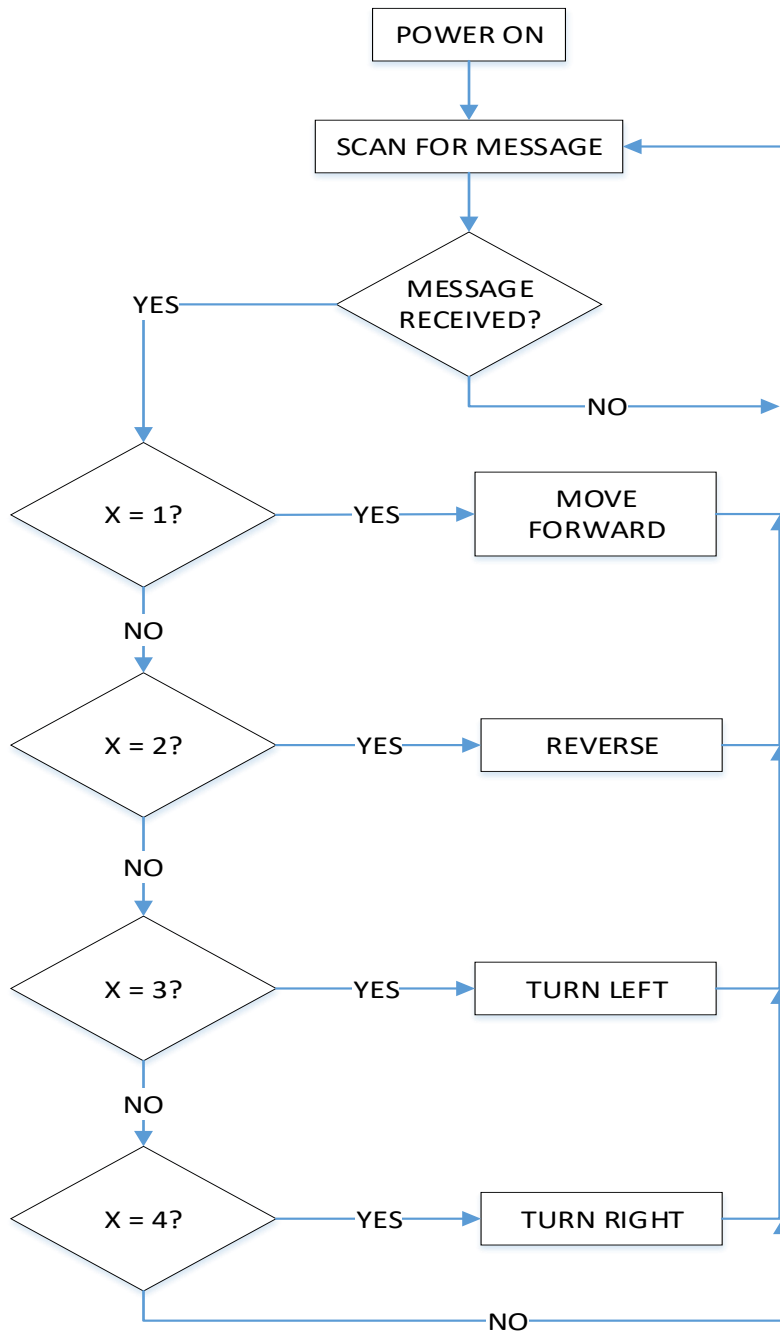
CONCLUSION:

The prototype successfully enabled a toy car to be controlled remotely using EOG signals. In the future, the project could be modified to have a wide variety of applications including wheelchair mobility. The project can also be modified to use bio-signals from other parts of the body. This device will hopefully improve accessibility for people who are physically-disabled.

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Clinton Nwanedo was born in Lagos, Nigeria to Barr. Ethelbert and Dr. Joan Nwanedo.

Education

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Software: SolidWorks, Eagle, Cadence, Verilog HDL, LabVIEW, OVS (One Virtual Source), OFM (Oil Field Manager), WellView

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Electrical/Industrial Engineering Intern

ExxonMobil, Lagos, Nigeria   Summer 2014

Petroleum Engineering/Analytics Intern