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Scaled Electric Wheelchair Controlled By Electro-Oculographic Signals

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ABSTRACT:
The electrooculographic signals or EOG are widely used to develop robotic equipment to serve people who have partially or totally lost the functionality of one or several members of their body due to neurodegenerative diseases such as Amyotrophic Lateral Sclerosis or serious accidents. These signals are applied in the control of robotic arms, serious games, robotic wheelchairs, among others. Also, these signals require specialized electronic circuits for amplification and filtering, in addition to requiring a microcontroller for processing them.

This paper presents the results of the development of a prototype of an elctrooculography for the movement of a wheelchair scale, the design of data acquisition, the transmission system via Bluetooth and control of the wheelchair with eye movement is presented. The data acquisition is performed using gel electrodes for EOG, a signal conditioning system and the characterization of this, also presents the data transmission system via Bluetooth and the power stage.

Keywords: Electro oculography, bio signals, dipole, control

INTRODUCTION

Electrooculographic (EOG) signals are widely used to develop robotic equipment to serve people who have partially or totally lost the functionality of one or several members of their body due to neurodegenerative diseases such as amyotrophic lateral sclerosis (ALS) or serious accidents [1,2]. Such signals are applied in the control of robotic arms, serious games, electric wheelchairs, among others [3,4]. Also, these signals require specialized electronic circuits for amplification and filtering, in addition to requiring a microcontroller for processing them.

This paper describes the development of a prototype to control a scaled wheelchair through EOG signals (Ramli et al., 2015). The prototype has an electronic circuit for amplification and

filtering of the EOG signal, which comes from 3 electrodes located on the forehead of a person (Li et al., 2018). Then, the signal is passed to an Arduino UNO microcontroller to verify the magnitude of the signal and make a decision based on whether it has exceeded the decision thresholds. The decision is sent via Bluethoot to another Arduino UNO microcontroller that controls the scaled wheelchair to move forward or backward.

The objective of this research is the characterization of the electrical signals coming from the movement of the eyes, to control the movement of a scaled wheelchair. This research is important because it proposes a solution to the mobility problems of people with disabilities.

MATERIALS AND METHODS

This section presents the description of the processes of sensing, filtering and data acquisition of the EOG signals. The flow chart of the data acquisition algorithm, signal processing and transmission of the control signal is also presented, as well as the flow chart of the control signal reception algorithm and the respective control action.

2.1. EOG signals:

It can be said that EOG signals are the potential difference generated by the retina and the cornea, forming a dipole in which the retina corresponds to the negative pole and the cornea to the positive pole (see figure 1) (Aungsakul et al., 2012). When saccadic eye movements are performed we can achieve a rapid change in the magnitude and polarity of the potential difference between the retina and the cornea (Mehra et al., 2021). Therefore, it is easy to analyze the eye movements from the EOG signals, it should be noted that the eye movements can go from the central part to the right, left, up or down.

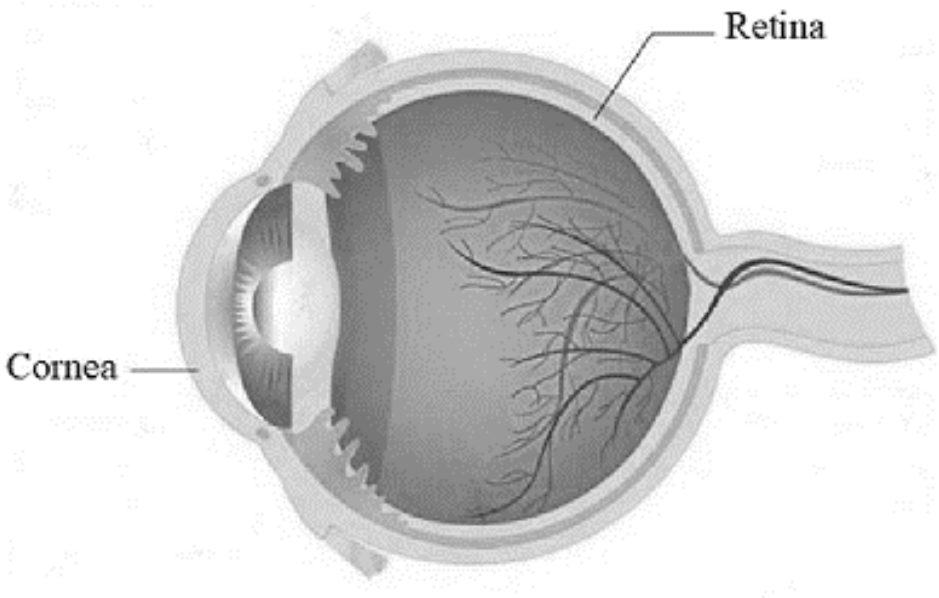


Figure 1. Cornea-retina dipole (Horacio, 2014).

These movements are captured through electrodes placed on the right and left temple, to capture the horizontal movement, and two electrodes above the eyebrow and on the lower part of the eye, to capture the vertical movements (Lv et al., 2018). Finally, a reference electrode is placed

in the centre of the forehead. On the other hand, the amplitude of the EOG signals generated oscillates between 5 uμV and 20 uV with frequencies between 0 Hz and 30 Hz. Figure 2 shows an ideal EOG signal (Sharma et al., 2020).

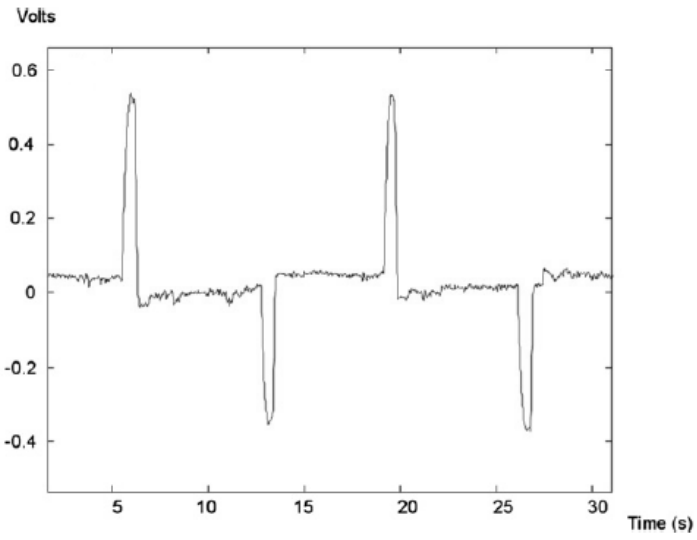


Figure 2. Ideal EOG signal for vertical movements (Horacio, 2014).

2.2. EOG signal conditioning circuit:

The EOG signal conditioning circuit consists of 3 stages:

2.2.1. Amplification stage:

In this stage the EOG signals coming from the electrodes are amplified approximately 225.5 times according to their magnitude. This gain is configurable through the gain resistor called RG, which in this case is 220 ohms. Figure 3 shows the schematic diagram of an AD620 instrumentation amplifier and the gain formula can be seen in equation number (1).

$$G = \frac{49.4\ K\Omega}{R_G} + 1 \quad (1)$$

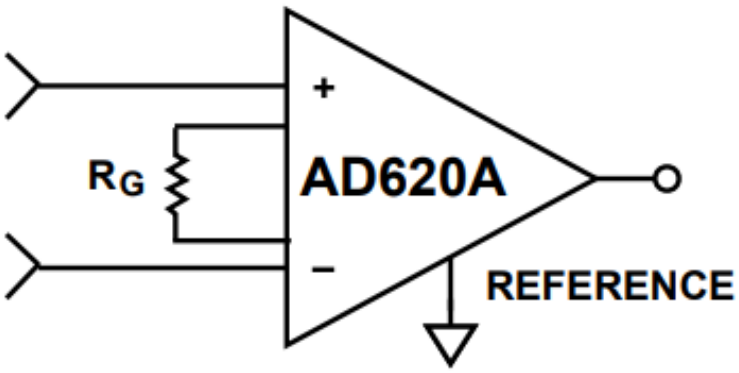


Figure 3. AD620 Schematic Diagram (Mohammadi Fathabad & Shahri, 2021).

Figure 4 shows the schematic diagram of the instrumentation amplifier in the configuration specified by the supplier. The resistors R1 and R2 act as impedance coupling, that is, they improve the acquisition of the EOG signal as they have a magnitude of 1 MΩ each.

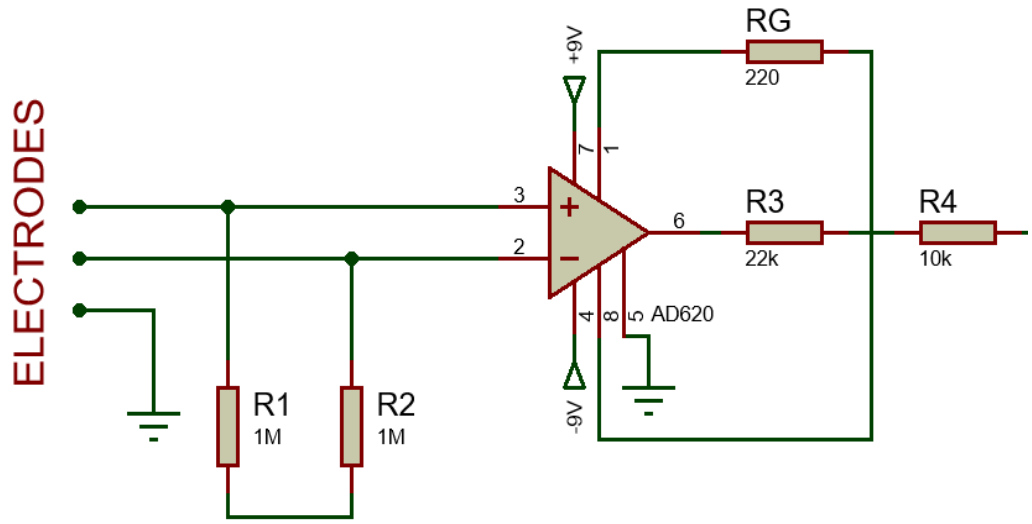


Figure 4. Implemented circuit

2.2.2. Filtering stage - Low pass:

In this stage, the frequency components that exceed 30 Hz of the amplified signal are attenuated, taking into account that theoretically the bandwidth of the EOG signals is in the range of 0 Hz and 30 Hz. Likewise, this is also done in order to minimize false positives if the signal exceeds the decision thresholds programmed on the Arduino UNO board, which will be explained later.

Figure 5 shows the schematic diagram of the implemented circuit (Barea et al., 2012).

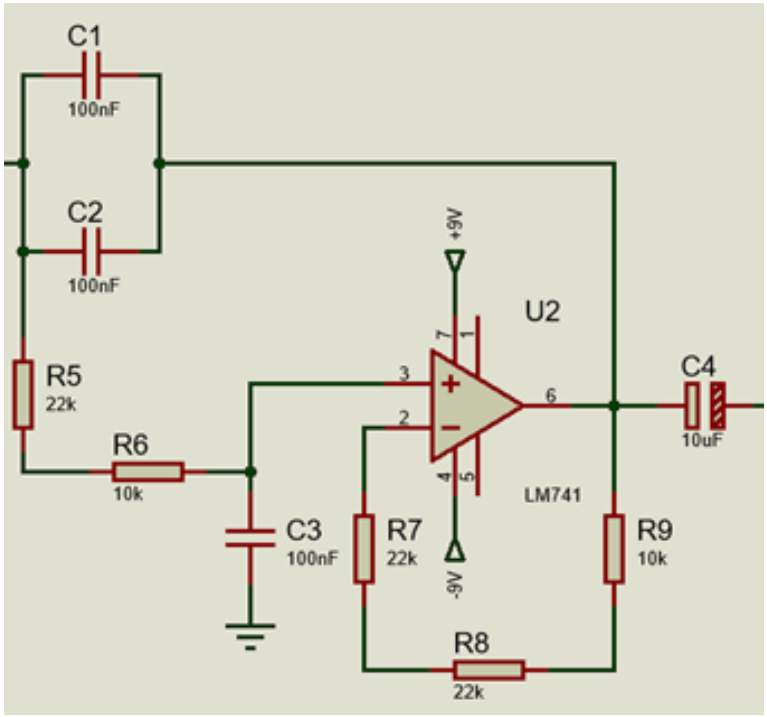


Figure 5. Low Pass Filter

2.2.3. Filtering stage - high pass:

Finally, in this stage the frequency components lower than 0.5 Hz are attenuated. In addition, a first order RC passive low-pass filter with a cutoff frequency of approximately 15 Hz is implemented. Figure 6 shows the schematic diagram of the implemented circuit and the analog connection port on the Arduino UNO board.

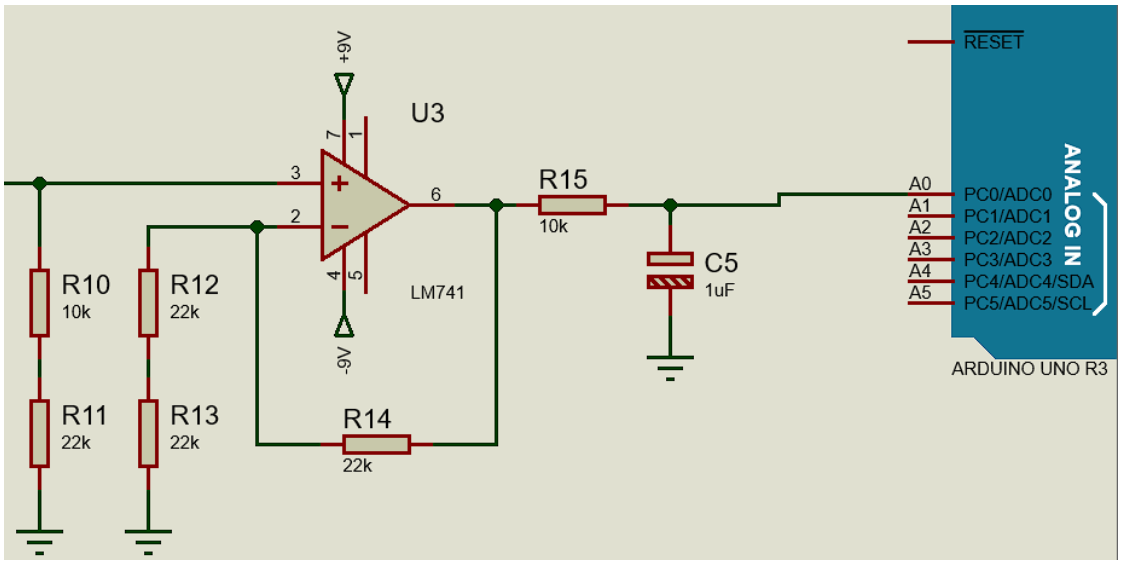


Figure 6. High-pass filter, RC passive filter and connection to Arduino UNO

2.3. Bluetooth communication:

In this project we use communication through HC-05 bluetooth modules. With this, it is possible toseparate the acquisition and conditioning of the EOG signal and the control of the robotic wheelchair. The HC-05 bluetooth modules can be configured as Master or Slave. In the present project we use 2bluetooth modules of the mentioned reference configuring them as: Master in the part of acquisition ofthe EOG signal and Slave in the part of control of the wheelchair to scale. Figures 7 and 8 show theconnection between the Master and Slave bluetooth modules and the Arduino UNO board respectively.

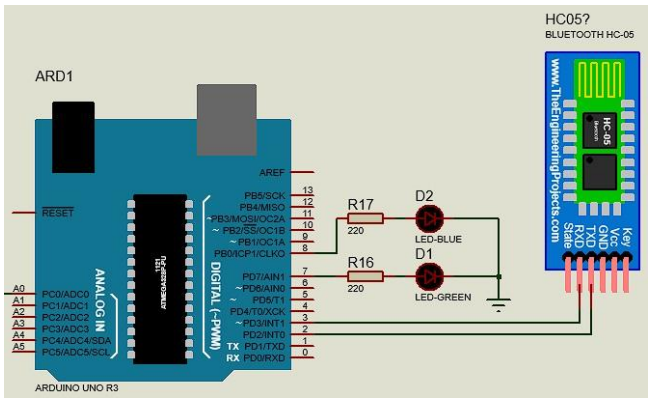


Figure 7. Connection bluetooth Master module

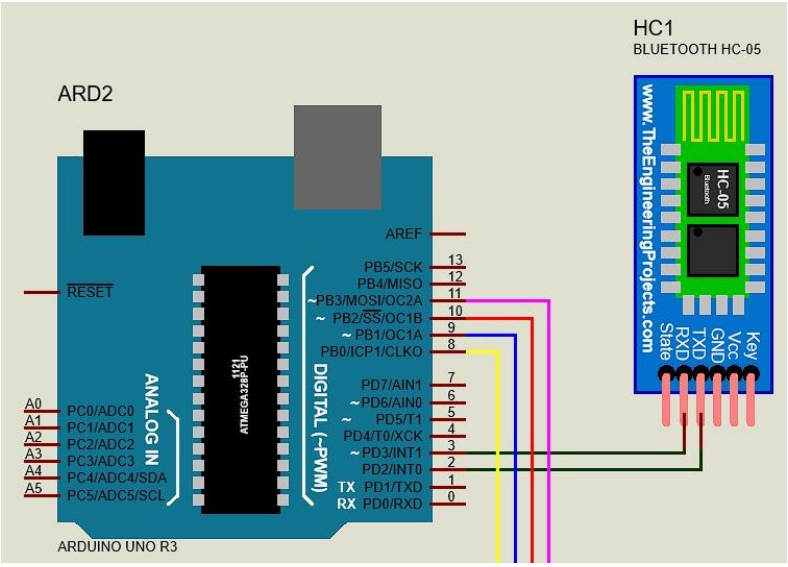


Figure 8. Bluetooth Slave Module Connection

It is important to note that the State and Key ports are not connected, and the VCC and GND ports are connected to 5V and GND of the Arduino UNO board respectively.

2.4. Power supply:

To feed electrically to the circuit of amplification and filtering of electro-oculographic signals, it is necessary a dual source of ±9 Volts, for which, it is made use of two batteries of this voltage connectedas it is observed in figure 9.

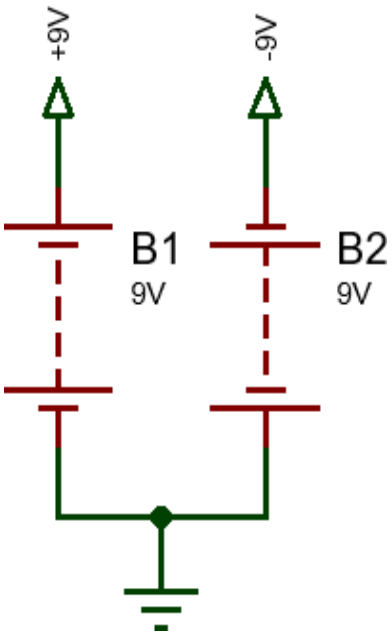


Figure 9. Dual voltage source 9 Volts.

2.5. Control of the wheelchair to scale:

To control the movement of the wheelchair (forward or backward), the L293B reference integrated circuit is used, which allows to control up to 2 DC motors, serving as an interface between the control and information processing part (Arduino UNO board) and the actuators (9V DC motors).

The above-mentioned integrated circuit supports 4 inputs, so the direction of rotation of each motor can be manipulated separately. In addition, there is the possibility of enabling or disabling the operation of each motor thanks to the EN1 and EN2 ports present in the L293B. To carry out this action, simply apply a logic 1 (approximately 5 Volts) or a logic 0 (approximately 0 Volts) to each port to enable or disable respectively. In this project, these ports remain enabled, since the wheelchair is constantly receiving control signals.

Figure 10 shows the connection scheme implemented in this prototype.

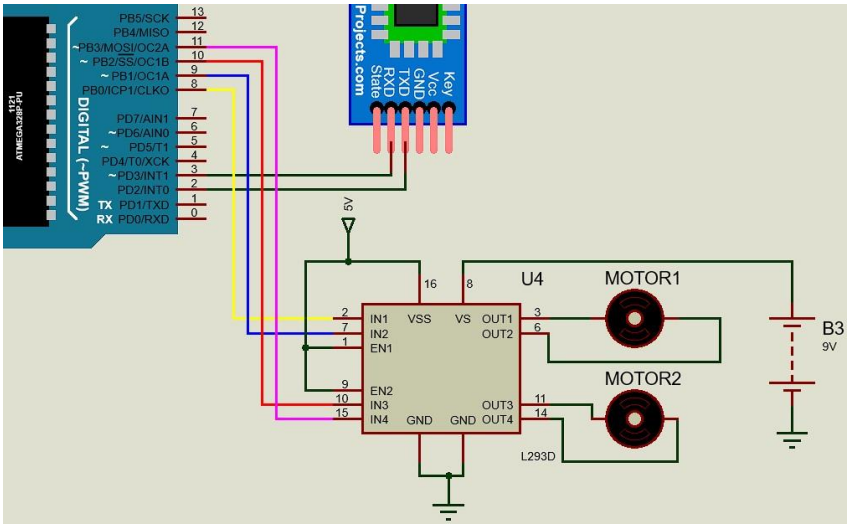


Figure 10. L293B IC and Arduino UNO Connection

Also, the 3D design of the electric wheelchair was made to scale in the CAD software Fusion 360. Thedesign can be seen in figure 11.

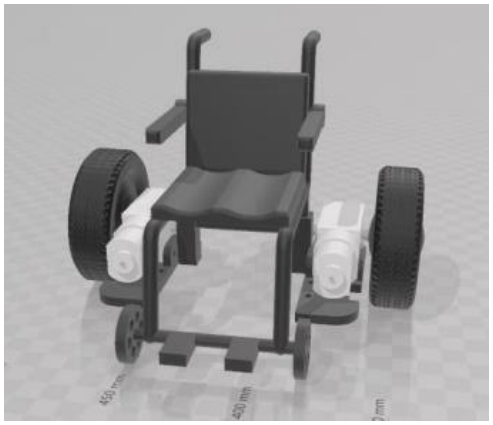


Figure 11. 3D Design of scaled electric wheelchair

2.6. EOG signal processing:

The EOG signal processing is done with an Arduino UNO development board. On this board, the analogvalue of the EOG signal is captured and averaged with 20 samples. This averaging serves as a basis for finding the peaks in the EOG signal generated by saccadic eye movements by asking if the magnitude of the EOG signal exceeds the averaged value beyond the upper or lower threshold. Depending on the threshold reached, the program will send a value via the Bluetooth module to the control circuit of the scaled power chair. Figure 12 shows the flowchart of the program developed on the above mentioned board.

On the other hand, the movement control of the scaled electric wheelchair depends on the value receivedthrough the Bluetooth module, which indicates whether the chair moves forward or backward. Figure 13 shows the flowchart of the algorithm developed on the Arduino UNO board.

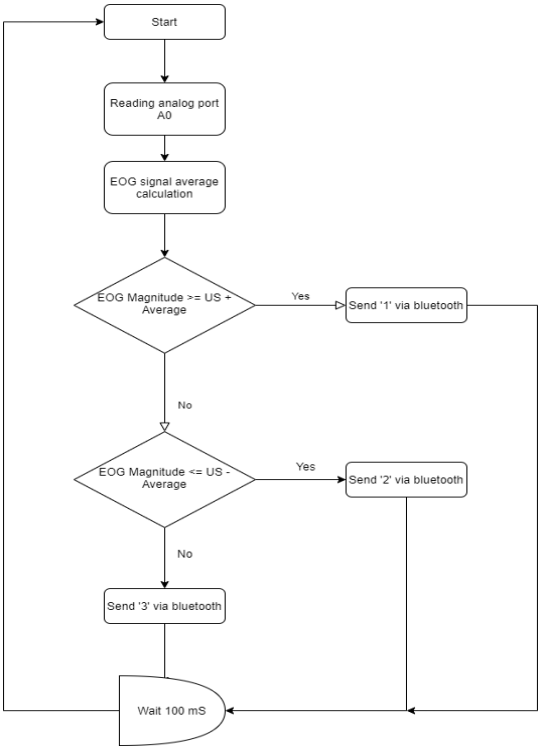


Figure 12. EOG signal processing flow diagram.

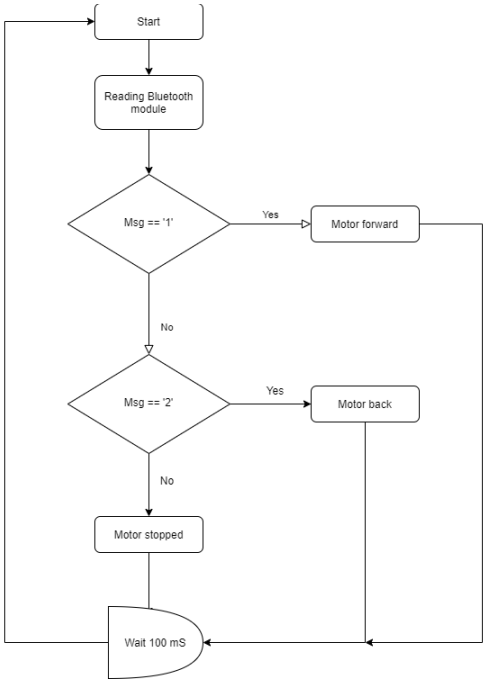


Figure 13. Scaled electric wheelchair control flow diagram.

3. Results:

3.1. Circuit implementation and EOG signal visualization

First, the implementation of the amplification and filtering circuits of the EOG signal can be seen in Figure 14. The AD620 amplifier takes directly the signals coming from the electrodes, amplifies the potential difference and its output is connected to a low-pass filter of 30 Hz and this signal then passesto a high-pass filter of 0.5 Hz. On the other hand, the control circuit of the scaled electric wheelchair can be seen in Figure 15.

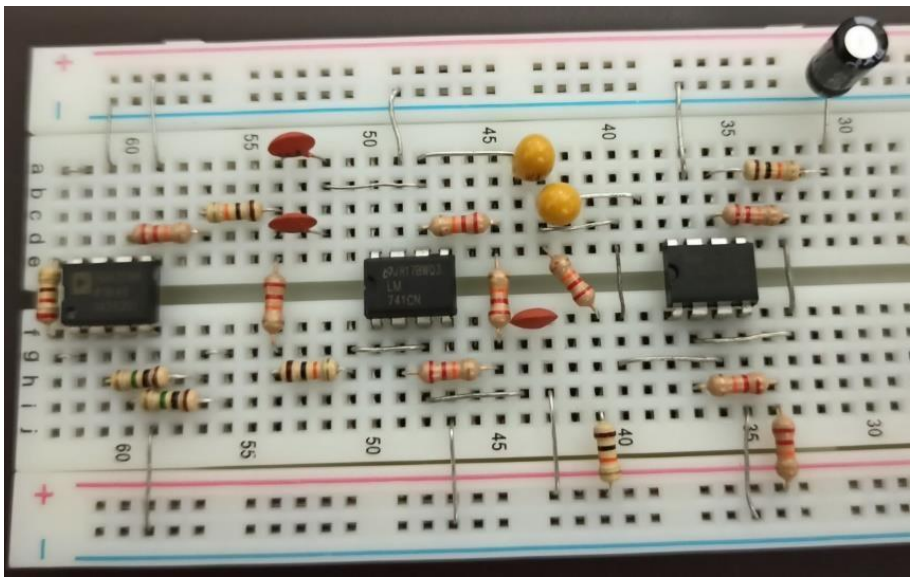


Figure 14. EOG signal amplification and filtering circuit implementation.

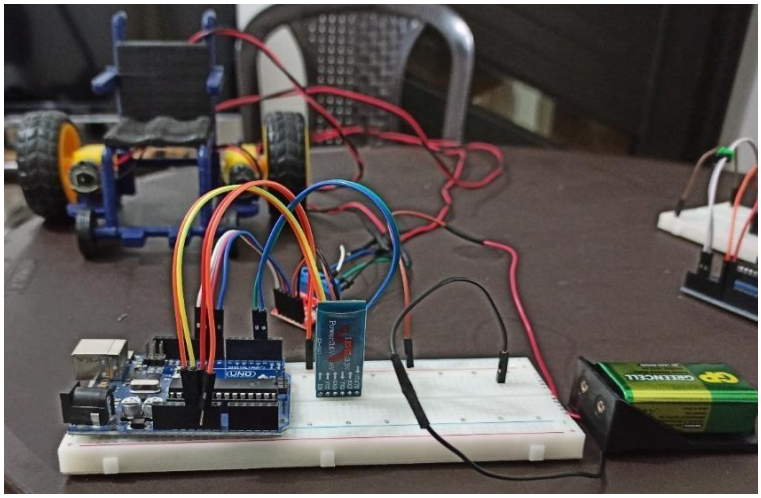


Figure 15. Implementation of a scaled electric wheelchair controlcircuit.

The saccadic movements captured by the amplification and filtering circuit and the Arduino UNO boardcan be seen in Figure 16. In this figure, the blue line corresponds to the EOG signal and the red line corresponds to the average of the EOG signal. Between the second 1765 and 1865 you can see how theblue line generates from bottom to top and then from top to bottom. These peaks are generated by saccadic movements of the eyes. In addition, it is verified that the captured signal follows the pattern ofan ideal EOG signal as can be seen in figure 2.

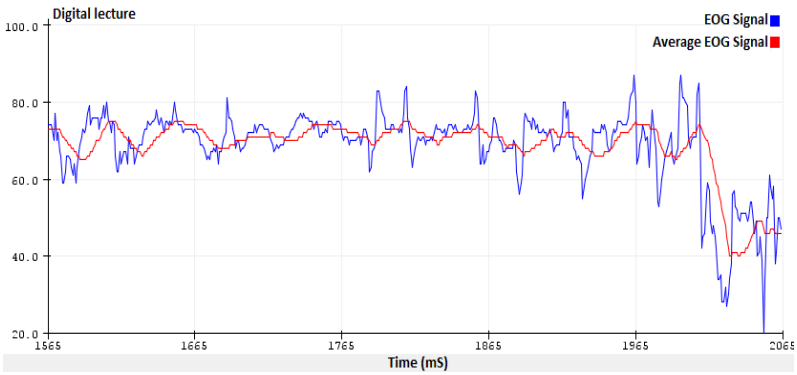


Figure 16. EOG signal graph and average EOG signal graph

3.2. Validation

The developed prototype was tested on a population of 20 healthy people, which includes men and women between 16 and 62 years old. A confusion matrix represented in Table 1 is constructed in orderto find the percentage of success according to the movement made by the person with the eyes. That is,if the person moves his/her eyes to the right, the chair must make a forward movement and vice versa. Each person made 5 movements to the right and 5 movements to the left. In other words, 200 eye movements were made and the percentage obtained was recorded in the table according to the movementmade by the chair.

The confusion matrix is as follows:

Table 1. Confusion matrix prototype electric wheelchair controlled by EOG signals.

Eye Movement / Chair Movement	Go to	Back	Accuracy
Right	62%	38%	
Left	33.5%	66.5%	
Accuracy			64.25%

4. Conclusions.

The implementation of the prototype described in this work allowed understanding the generation and reading of biosignals, especially electrooculographic signals. Likewise, the design of amplification andfiltering circuits of noisy signals as the one mentioned above with low-cost devices, broadens the possibilities of designing cheap systems that meet the needs of people with motor deficiencies caused by neurodegenerative diseases or accidents.

The accuracy of the present prototype, although relatively high, can be improved with the addition ofreconfigurable hardware devices and the implementation of easily mounted electrodes on people's heads.

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