An Electrooculogram Based Virtual Instrumentation System

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Abstract - This paper presents the design and development of a low cost, flexible system, dedicated to electro-oculographic applications. This virtual instrumentation system is based on the electrical signal generated by the human eye, which is amplified, filtered and then gathered by a National Instruments data acquisition board. A LabVIEW application was implemented in order to detect eyes movement directions and the blinking. The obtained signal has a low noise level and the algorithm permits to use it in a lot of biomedical applications like those of assistive communication for people with disabilities.

Keywords – Electrooculography, eye movement, amplification, filtering, virtual instrumentation system

1. INTRODUCTION

In order to put a diagnostic, physicians are based more and more on electronic systems that monitor, register and give the parameters needed to the clinic examination. Moreover, in present, the focus is put on practical applications for acquisition, processing and analysis of bio-signals both in medical purpose (cardiac, muscular, neurologic diseases) and also for real time monitoring of the patients or to rehabilitate the handicapped persons.

Electrooculography is a technique for measuring the resting potential of the eye, and the resulting signal is called Electrooculogram (EOG) [1]. This signal shows certain patterns for each kind of eye movement (left, right, up, down, blink). These signal patterns can be recognized, and then, the acquired signals can be used for controlling external devices, such as virtual keyboards, powered wheelchairs, movable arms and robots. The electro-oculographic signal is one of the most useful biomedical signals. [2]

The eye movement is controlled by a group of 6 muscles, relatively small sized. Four of the muscles of the eye globe control the movement in the directions of the 4 cardinal points, namely: up, down, left, right and the other two muscles control the adjustments involved in counterworking the movement of the head. When these muscles exercise different tensions, a couple is applied to the eye globe, causing the rotation movement almost pure, with just approximately a millimeter of translation. Eye muscles are illustrated in figure 1. [3]

Measuring the movements of human eye using an electro-oculographic method is based on the electric dipole character of the eye.

Taking into account that the retina is more negative than the cornea, between them there is a difference of potential (resting potential) that may vary between 0.4-1mV. The movement of the eye globe causes changes in the direction of the vector corresponding to the electric dipole and the occurrence of a measurable electric signal, signal with amplitudes within the interval 5-20µV and frequencies between 0-100 Hz [4][5]. The measurement of those changes needs the placement of five electrodes on subject’s face according to figure 2: HR-Horizontal Right, HL-Horizontal Left, VU- Vertical Up, VD- Vertical Down and GND-ground.

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Eight directional eye movements (up, down, right, left, up-right, up-left, down-right, and down-left) like in figure 3 are the basic eye movements, particularly the first four directions [6].

Electrooculography has wide range of applications like those of: human computer interfaces [7][8][9][10], dedicated wheelchair control [11][12], mouse control [13], rehabilitation, driving simulation, fatigue detection, human activity recognition [14], patient monitoring, marketing research, eye typing and many more [1].

Within this paper focus was on elaborating an as simple as possible solution for the acquisition and processing of the electrooculographic signal (EOG), as well as choosing the conditioning circuits, so as the useful signal to be enough amplified, as clear as possible, noiseless and very stable in fluctuant operation conditions.

The acquired signal can be easily interpreted by using virtual instrumentation techniques that completes the range of solutions and applications in the field [15][16].

2. SYSTEM DESCRIPTION

In figure 4 the block diagram of the implemented biomedical system is presented. The conditioning of EOG signal (power supply, amplification and filtering) is done entirely analogical and the acquisition and analysis of the EOG signal are done using elements specific to virtual instrumentation.

The final choice of components for signal conditioning was done depending on their specifications, in the same time being tested several alternatives and the final selection was done depending on the clarity of the useful signal obtained after amplification and filtering.

2.1. Power supply circuit

The system is powered (figure 5) through a galvanic insulation against the power outlet, this being necessary both for electro-safety reasons and for reasons of electromagnetic compatibility. Galvanic insulation in this case is done by a DC-DC convertor of type DCP022415DU. A stabilized voltage of +/-5V was obtained by means of two voltage regulators of type 7805, for the voltage of +5V and respectively 7905, for the voltage -5V.

2.2. Signal conditioning circuits

The EOG signal is picked-up at the skin level by means of five surface electrodes Ag/AgCl, which includes also an electrolyte gel to reduce skin impedance. The acquired signal is then transmitted to an instrumentation amplifier of type INA118P. First stage of signal conditioning is illustrated in figure 6.

According to relation (1) the gain (G) of the instrumentation amplifier is set on 500, by means of a resistance of 100Ω.
\[ G = 1 + \frac{50k\Omega}{R_i} \]  

(1)

The output voltage can be calculated with (2):

\[ V_{out} = G \cdot (V_{IN}^+ - V_{IN}^-) \]  

(2)

In order to protect the instrumentation amplifier against electrostatic discharges there were used ESD diodes of PESD5V0S1BA type, and for patient’s protection the electrodes were connected to the instrumentation amplifier by means of a resistance of 100 kΩ. Also, best results have been obtained by connecting the reference electrode as close possible to 5th pin of the instrumentation amplifier, this being also the analogical ground of the circuit.

Another change to the first stage of signal conditioning was the addition of some capacitors of 100nF to the power supply pins of the amplifier, for a better filtering and implicitly for reducing the common mode noise.

In second stage of signal conditioning the 50Hz component is eliminated. The main cause for producing 50Hz noise is represented by person’s head to which the electrodes are attached, this acting like an antenna, forming a capacity between the fluorescent light present in the room and patient's head, the air being considered as dielectric. Similar interferences may be induced by electric and electronic devices present near the investigated person.

In order to eliminate the component of 50Hz frequency a notch filter was used, this practically blocking the 50Hz frequency in order to avoid its effect on the sensitivity of the electrodes. The practical implementation of the notch filter is presented in figure 7. It was chosen a notch filter in “T”, RC type with a very high Q factor, from 0.3 which is usually, to a value of over 50, this having a top of band very abrupt, in order to assure, as that is possible, that only the 50 Hz frequency is eliminated.

\[ f_0 = \frac{1}{2\pi R_1 C_1} \]  

(3)

\[ R_1 = R_2 = 2R_3 \]  

(4)

\[ C_1 = C_2 = \frac{C_3 + C_4}{2} \]  

(5)

It was experimentally proved that in the case of using polyester film capacitors, the filter cut-off frequency was different from 50Hz and due to the too big oscillation of this type of capacitors the visualization of useful signal was not possible. This problem was solved by replacing the polyester capacitors with ceramic capacitors. In the same time it was needed to add another capacitor of 1nF due to the oscillations produced at filter output. Also, the follower from the filter output has the role to reduce output resistance.

For a better filtering of the power supply signal there were added two capacitors of 100nF and the integrated circuit with two operational amplifiers of type LM358N initially used was replaced with an integrated circuit of type TL082. The last one has a reduced level of noise at output, experimentally proved due to the field effect transistors of type JFET, different from the bipolar transistors used at LM358N.

Third stage of signal conditioning represents the selection of frequency range needed to identify the variations of corneal-retinal potential in order to identify the movements of eye globe. Although the useful highest frequency of the recorded signal at eye level is 32Hz, much better results were obtained with a low pass filter at 16Hz, when the unwanted noise was eliminated. This filtering stage may be viewed in figure 8.

Fig. 8. Third stage of signal conditioning

The fourth and last stage of signal conditioning, is used to eliminate the DC component and to amplify the output signal in order to be centered around the value of 0V (figure 9). A problem encountered was the fact that both capacitors are charging simultaneously, the system entering in saturation, problem solved by the introduction of a 33kΩ resistor.

Fig. 9. Last stage of signal conditioning
2.3. EOG signal acquisition

The proposed system was initially put on a test board (figure 10) and each stage of the signal conditioning (including power supply) was implemented in Proteus ISIS and tested using a digital oscilloscope, on a human subject like in figure 11. In this manner it was possible to make changes for the improvement of the optimal operation of the designed circuit.

After reaching the final system configuration, the electronic circuit was designed in Proteus ARES, and then transposed on a printed circuit board. This circuit was then connected to NI-MyDaq from National Instruments like in figure 12. The signals acquisition was made on two AI channels, one for horizontal and the other for the vertical direction. The EOG signals were acquired and processed in a LabVIEW application.

The front panel from figure 13 contains the following elements: two recording elements (Waveform chart type) for simultaneous, real time monitoring of signals on vertical and on horizontal directions as well as two graphic elements (Waveform graph type) for viewing the evolution of signals on the whole running of the program. Also on the front panel are placed logical type elements that will indicate (one or two lighted) any of the eight eye movement directions as well as the action of “blinking” of monitored person.

There were recorded EOG signals in the following cases: forward-up (figure 14.a), forward-down (figure 14.b), forward-left (figure 14.c) and forward-right (figure 14.d), and blinks figure 14.e).

It is to be mentioned the fact that prior to each set of measurements it is needed a software calibration. This calibration is done for the four main directions of (up, down, left, right) as well as a series of blinks in the purpose of setting the thresholds, those being different depending on the user, the placement of the electrodes and not last on the electrode-skin contact.
3. CONCLUSIONS

An EOG-based virtual instrumentation system was designed and implemented. The aim of the proposed system is to identify and indicate the eight directions of eye movements as well as blinking. The signals waveforms were displayed on the front panel of the LabVIEW application and they may be recorded in real time and shown afterwards.

The signal conditioning was done entirely hardware and the part of its analysis was done software.

This system is very useful being possible to use it both in the clinic area of interest for certain ophthalmologic investigations as well in different applications of command and control especially for the disabled persons.

As directions of further work it may be considered the implementation of the system with SMD components, making the acquisition of data by means of a microcontroller; to create a software application specialized only on the acquisition and analysis of EOG signal, control of certain activities and/or apparatus for the disabled people and last but not least the integration in an ophthalmologic diagnosis system.

REFERENCES

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