A Novel Topology for Design and Development of Wireless Electro-oculogram Biopotential Amplifer

P. Swami, T. Gandhi, S.S. Ray, S. Anand

Abstract— This paper illustrates a novel topology for the conditioning of electro-oculogram signals. The system is composed of a second order amplification chain and assures stability, speed and accuracy. The proposed configuration has been developed in order to make signal acquisition of biological signals such as electro-oculogram simpler and robust with low cost. The filters between the pre-amplification and the amplification stages eliminate the out-of-band frequencies before amplification. This reduces the possibility of interferences from high frequency noises and maximizes the dynamic power consumption. The presented topology holds clinical and rehabilitative control applications.

Index Terms— Elctro-oculogram (EOG), Corneal-retinal potential (CRP), Signal conditioning, Biopotential amplifier, Instrumentation amplifier, Embedded system, Ophthalmoscopy.

1 Introduction

The eye movements have attracted many researchers in the past. A seminal review of major types of eye movements [1] illustrates the advantages and the disadvantages of various types of eye movement detection methods. To list a few, magnetic field search coil technique [2], Video Oculography (VOG) system and Infrared Oculography (IROG) are some of the commonly used eye movements' detection systems [3]. However since the electro-oculography (EOG) provides an effective, low cost and non-invasive method for detection of full range of eye movements it has been a frequently used system in ophthalmoscopy. It is commonly used in for the diagnosis and prognosis of several diseases such as best's disease [4] and multiple sclerosis [5]. Besides the clinical applications of EOG, it has been the theme of research for development of assistive technologies by human-machine interface [6, 7].

The electro-oculogram is the measure of potential between the cornea and the retina of the eye called the corneal-retinal potential (CRP). This potential is generated due to the hyperpolarization and depolarization of retinal cells. During the process the cornea establishes a relatively positive potential with respect to the retina. Information about the changing position and the speed of the eye movement can be acquired by the placement of electrodes around the eyes. The EOG is acquired using a bi-channel electrode placement system, namely horizontal and vertical channels. The strength of the EOG signal varies from 10- 30mV [8] with frequencies in the DC-10Hz band [9].

The recording of the EOG has been associated with several problems [10]. In addition to EOG signal produced from the eyeball rotation and movements it is also affected by different sources of artifacts like head movements, electro-encephalogram (EEG) signals, electrode placement, etc. Hence, it becomes necessary to develop an amplifier which eliminates the shifting resting potentials arising due to these artifacts and simultaneously avoid saturation. Most of the commercially available EOG amplifiers are costly and uses intricate design. Hence, the development of dedicated topology for the maximization of overall circuit performance in a cost effective manner has been the motive behind this study. Additionally, this system follows the trend of integrating real-time embedded systems with wireless transmission for diagnostics [11, 12], making it more practicable to implement on newer and smaller platforms.

2 Methodology

2.1 Design of Biopotential Amplifier

Two channels EOG amplifier was developed for the acquisition of horizontal and vertical eye movement signals. For the electrode placement scheme as shown in Fig. 1, the positive horizontal channel electrode (H1) was placed on the right canthus of the right eye and the negative horizontal channel electrode (H2) was placed on the left canthus of the left eye. And the positive vertical channel electrode (V1) was placed 2cm above the cornea and the negative vertical channel electrode (V2) was placed 1cm

- *Piyush Swami is presently pursuing M.Tech in Biomedical Engineering from the Dept. of Biotechnology & Medical Engineering, National Institute of Technology Rourkela, Orissa, India. E-mail: piyushswami@yahoo.com.*
- *Tapan Gandhi is an INSPIRE faculty with the Dept. of Science and Technology, Govt. of India and is currently a Post-doctoral Research fellow in the Dept. of Brain and Cognitive Sciences, MIT, USA.*
- *S. S. Ray is assistant professor with the Dept. of Biotechnology & Medical Engineering, National Institute of Technology Rourkela, Orissa, India.*
- *Sneh Anand is professor with the Centre for Biomedical Engineering, IITD and AIIMS, New Delhi, India.*

below the cornea of the eye. The common reference signal was taken from the reference electrode (R) placed on the forehead.

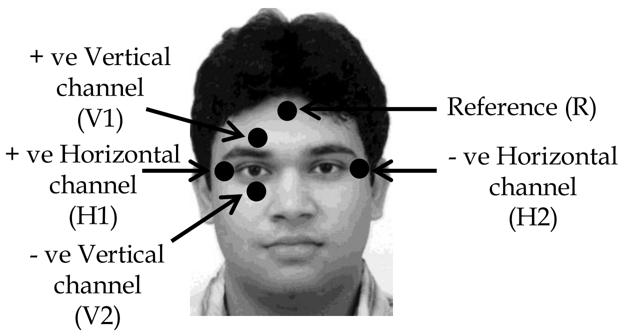

Fig 1. Electrode placement scheme used in the study.

The methodology for the designing of EOG biopotential amplifier has been explained in Fig. 2. For the study, instrument amplifier IC AD620 having an adjustable gain was used. Initially, out-of-band frequencies were removed by band pass filtering in the cutoff range between same that of the useful EOG signal range i.e., 0.1-30Hz. The pre-amplification stage followed another instrumentation amplifier with the adjustable gain maintained between 0-500. Further, suppression of the low frequency components was done by implementation of 10Hz low pass filter. Since, all the circuitry used DC sources and the frequencies above the 10Hz were rejected so the role of ambient noises due to 50Hz power line interference was neglected. The analog output available was digitized by using analog-to-digital converter IC ADC0804 and its output was provided to the input of the encoder IC HT640. The parallel digitized data was hence converted to serial data and feed to the ASK Transmitter module TX 01 433MHz. The ASK Receiver module RX 02 was kept at the receiver end for the reception of the serial data. This serial data was decoded to its parallel form by the use of decoder IC HT648. The analog signal was recovered to its original form by use of digital-to-analog converter IC DAC0800.

2.2 Subjects

The experiment was conducted on 8 healthy right handed subjects (4 F, 4 M) of age between 20-26 years (with mean age= 22.25 years). Before each experiment, the subject was asked to comfortably sit on a chair in a relaxed position with eyes closed while the electrodes were placed according to the illustrated scheme.

2.3 Experiment paradigm and data acquisation

Typically, the EOG signal consists of eye movements in the vertical, horizontal, diagonal directions and blinks. The blink can be involuntary blink having amplitude around 50mV or a voluntary forced blink with amplitude of 500mV approximately [8]. The experimental tasks involved the execution of various combinations of eye movements by each subject. The eye movement combinations used for the present study are as follows:

1. Continuous Right (R) and Left (L) eye movements for 5sec.
2. Right (R) and Left (L) eye movements for 10sec followed by central eye-gaze or hold for 10sec followed by Up (U) and Down (D) eye movements.
3. Continuous forced blinks and normal blinks.
4. Right (R) – Up (U) and Left (L) – Down (D) diagonal eye movements each with 5sec hold.

The output of the EOG amplifier was feed into the NI USB 6008 DAQ card. The signals were then visualized on the computer screen after the creation of sub vi in the LabVIEW software. The screen shots of the images seen while the acquisition of the EOG signals during the execution of different tasks

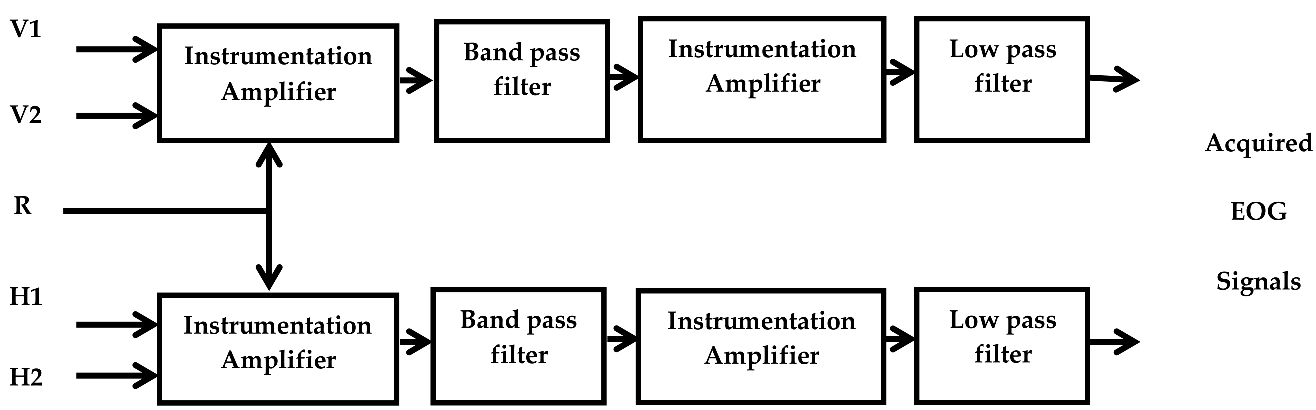

Fig 2. Methodology for design of EOG amplifier.

by a subject has been shown in the results.

3 Results and Discussion

The red lines in the figures shows the signal acquired from the horizontal (H) channel and the black lines show the signal acquired from the vertical (V) channels. The Fig. 3 shows the R-L eye movements executed by the subject for 5sec. The phenomenon involved behind this resultant is that during the straight ahead eye-gaze, equilibrium is established in the eye dipole and EOG output is zero. While when the eye-gaze is shifted to right, the positive potential is picked up with respect to the second electrode and similarly, the reverse is resultant when the eye-gaze is shifted to left. The visualization of the acquired signals on the computer screen confirmed the occurrence of well-defined EOG peaks.

The Fig. 4 shows the resultant when the subject executed R-L eye movements for 10sec followed by 10sec central eye-gaze followed by U-D eye movements for 10sec. It is evident from the observation that the U movements produces positive peaks while the D movements produces negative peaks.

The Fig. 5 which shows the continuous forced and normal blinks clearly indicates that the two blinks are segregated due to production of positive potentials with different amplitude.

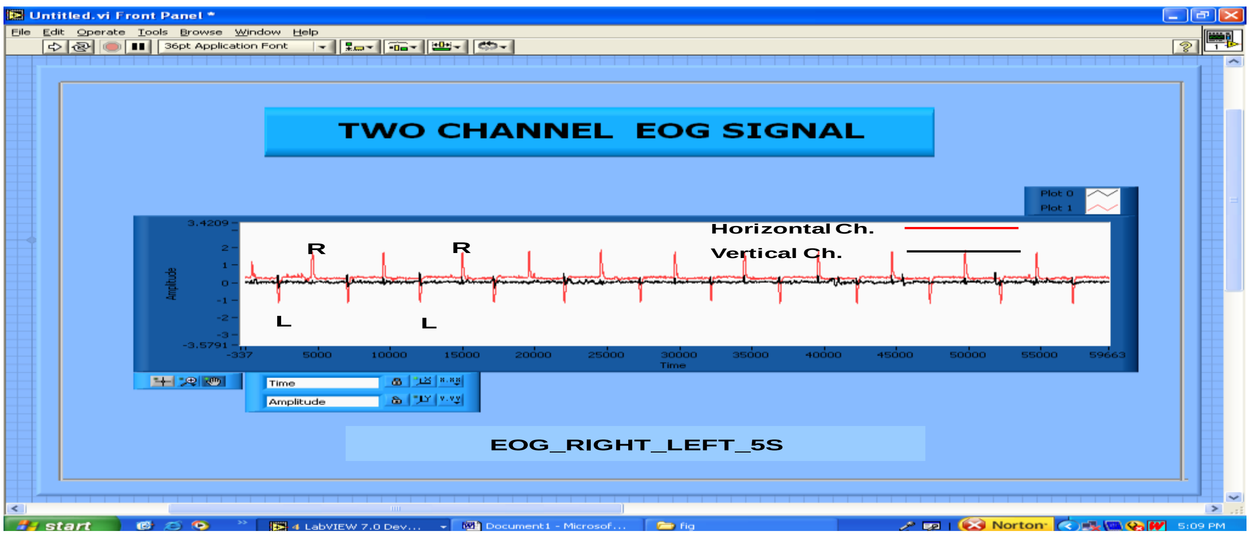

Fig 3. Continuous Right (R) and Left (L) eye movements for 5sec.

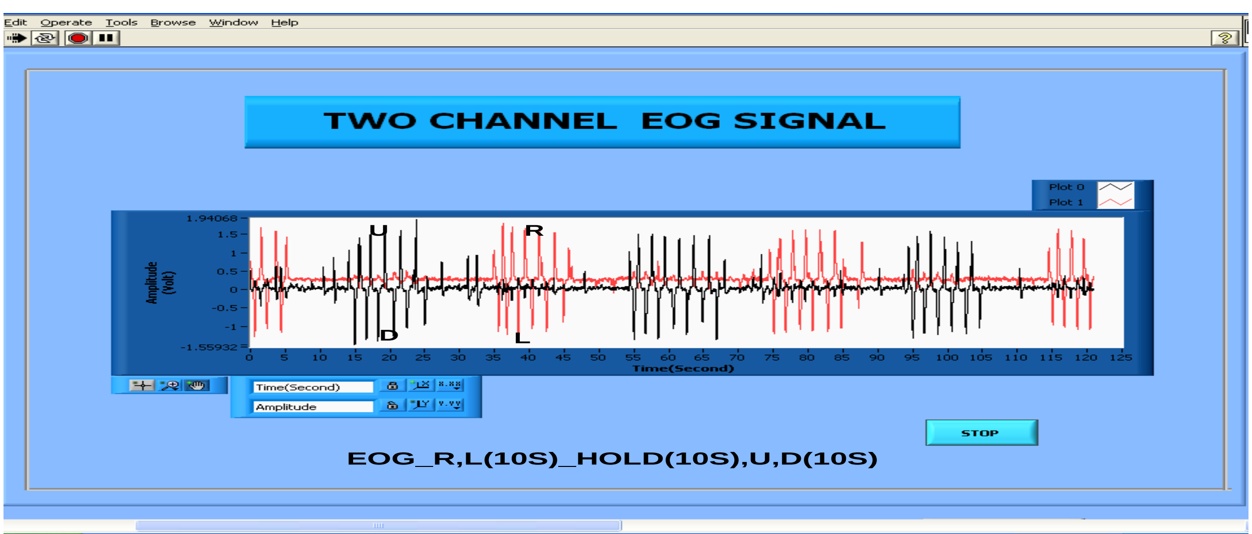

Fig 4. Methodology for design of EOG amplifier.

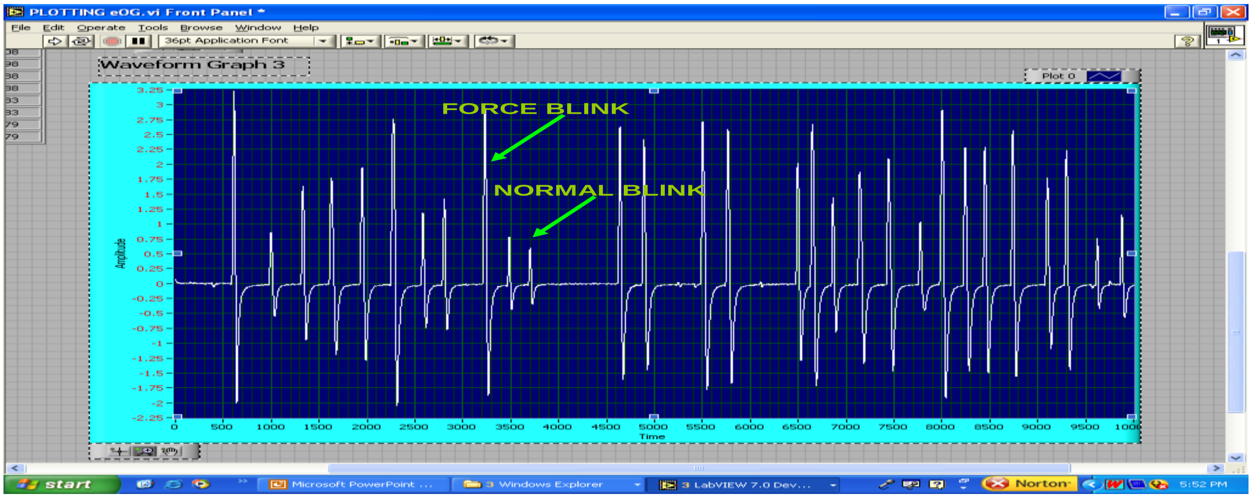

Fig 5. Continuous forced and normal blinks.

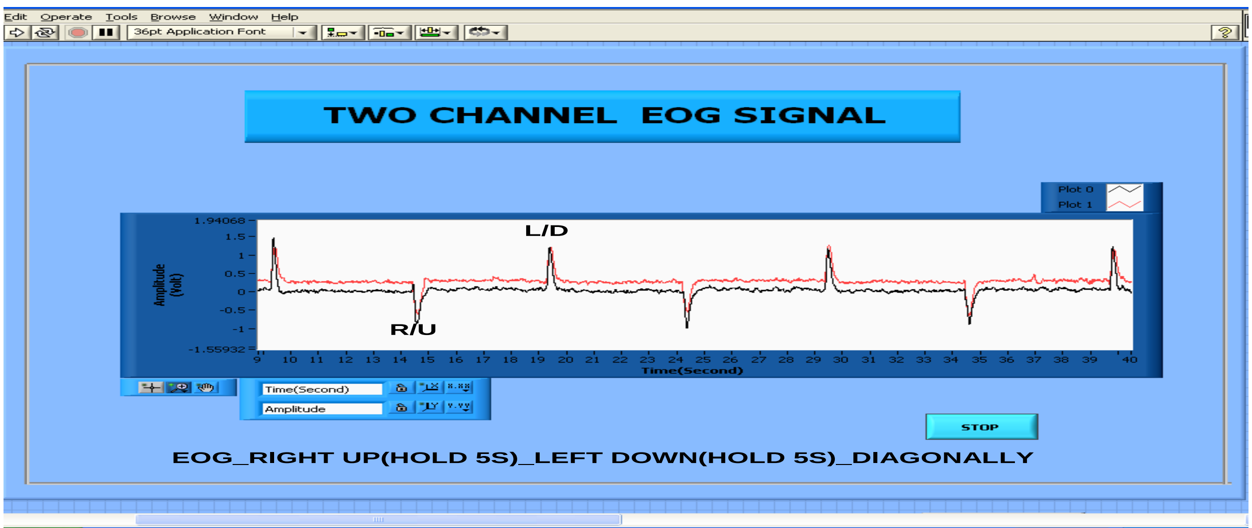

Fig 6. Right (R) – Up (U) and Left (L) – Down (D) diagonal eye movements each with 5sec hold.

The Fig. 6 showing the R-U and L-D diagonal eye movements each with 5sec hold shows the production of another interesting result with different combination of eye movements. This resultant demonstrates that even further combinations of eye movements could be made which could holds grounds for the development of intelligent assistive technology based upon implementation of classification algorithms on the EOG signals [8, 13, 14].

4 Conclusion

The purpose of the present study was to develop a cost effective and accurate EOG amplifier. The novel part of this device is its processing speed, size and low power consumption (just ±9V DC power supply). The wireless module further makes it ideal for the real time implementation. More sophisticated

signal processing and parameter setting can further improve the accuracy, speed and usability. This system could be comprehensively applied for the development of systems requiring real time EOG signals as primary input. Additionally the pivot research topology can be used as a model for the development of other biopotential amplifiers.

Acknowledgment

The authors would like to Mr. Rajesh Parashar, CBME, IITD for his assistance during the hardware development.

REFERENCES

[1] L. Young, “Methods and designs: survey of eyemovement recording methods,” *Behav Res Methods Ins*, vol. 7(5), pp. 397-429, 1975.

[2] H. Kasper and B. J. M. Hess, “Magnetic search coil system for linear detection of three-dimentional angular movements”, *IEEE Trans Biomed Engg*, vol 38(5), pp. 466-475, 1991.

[3] J. J. Gu, M. Meng, A. Cook, and M. G. Faulkner, “A Study of natural eye movement Detection and Ocular Implant movement control using processed EOG signals”, *IEEE Procc Int Conf on Robotics and Automation*, vol. 2, pp. 1555-1560, July 2003.

[4] A. Pinckers, M. H. M. Cuypers, and A. L. Aandekerk, “The EOG in Best's disease and dominant cystoid macular dystrophy (DCMD),” *Ophthalmic Genetics*, vol. 17(3), pp. 103-108, 1996.

[5] M. P. Espada, J. I. de Diego Sastre, and M. J. de Sarriá Lucas, “EOG findings in patients with multiple sclerosis,” *Acta Otorrinolaringol Esp*, vol. 47(1), pp. 29-31, 1996

[6] R. Barea, L. Boquete, J.M. Rodríguez-Ascariz, S. Ortega, and E. Lopez, “Sensory System for Implementing a Human—Computer Interface Based on Electrooculography,” *Sensors*, vol. 11(1), pp. 310-328, Dec 2010

[7] M. Hashimoto, K. Takahashi, and M. Shimada, “Wheelchair control using an EOG- and EMG-based gesture interface”, *IEEE Proc. Advanced Intelligent Mechatronics*, pp. 1212-1217, Sep 2009.

[8] T. Gandhi, M. Trikha, J. Santhosh, and S. Anand, “Development of an expert multitask gadget controlled by voluntary eye movements,” *Expert Syst. with Applications*, vol. 37, pp. 4204-4211, 2010.

[9] S. R. Choudhury, S. Venkataramanan, H. B. Nemade, and J. S. Sahambi, “Design and Development of a Novel EOG Biopotential Amplifier,” *J Bioelectromagnatism*, 2004.

[10] R. J. K. Jacob, “Eye movement-based human-computer interaction techniques: Toward non-command interfaces,” Human Computer Interaction Lab. Naval Research Lab. Washington, D.C.

[11] Y. H. Nam, Z. Halm, Y. J. Chee, and K. S. Park, “Development of sensing diagnosis system integrating digital telemetry for medicine,” *Proc. 20th Annu. Znt. Conf. IEEE Eng. Med. Biol.Soc.*, vol. 20, pp. 1170–1173, 1998.

[12] S. Kondra, C. Yew, F. Ahmed, and U. G. Hofmann, “Prototype of a patient monitoring device based on an embedded RISC/DSP system,” *Proc. 39th Ann. Cong, German Society Biomed. Eng*, Nuremberg, Sep 2005.

[13] R. Barea, L. Boquete, S. Ortega, E. Lopez, and J.M. Rodríguez-Ascariz, “EOG-based eye movements codification for human computer interaction”, *Expert Syst. with Applications*, vol. 39(3), pp. 2677-2683, Feb 2012.

[14] T. Gandhi, M. Trikha, J. Santhosh, and S. Anand, “VHDL based Electro Oculogram Signal Classification”, *IEEE Proc. Int. Conf. Advanced Computing and Comm*, pp. 153-158, Dec 2007.