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Two Electrode ECG And EOG System For Monitoring Applications

Pema Wangmo, Goli Ramyavani, Kaustubh Shivkumar Iyer, Karthik Raj V

Abstract*: *Heart and Eye are two vital organs in the human system. By knowing the Electrocardiogram (ECG) and Electro-oculogram (EOG), one will be able to tell the stability of the heart and eye respectively. In this project, we have developed a circuit to pick the ECG and EOG signal using two wet electrodes. Here no reference electrode is used. EOG and ECG signals have been acquired from ten healthy subjects. The ECG signal is obtained from two positions, namely wrist and arm position respectively. The picked-up biomedical signal is recorded and heart rate information is extracted from ECG signal using the biomedical workbench. The result found to be promising and acquired stable EOG and ECG signal from the subjects. The total gain required for the arm position is higher than the wrist position for the ECG signal. The total gain necessary for the EOG signal is higher than the ECG signal since the ECG signal is in the range of millivolts whereas EOG signal in the range Fig. 2 Complete circuit design ***of microvolts. This two-electrode system is stable, cost-effective and portable while still maintaining high common-mode rejection ratio (CMRR).***

Index Terms*: *Biomedical Workbench, Electrocardiogram, Electro-oculogram, Signal.

I. INTRODUCTION

Electrocardiogram (ECG) and Electro-oculogram (EOG) are low-frequency biomedical signals acquired from the humans using either wet electrode or dry electrode. ECG gives an idea about the electrical activity of heart muscle and EOG gives an idea about the eyeball movements. The clinical bandwidth of the ECG signal is from 0.05 to 125 Hz, whereas the monitoring bandwidth is from 0.5 to 50 Hz [1]. The clinical bandwidth of the horizontal channel of EOG is from 2 to 16 Hz [2]. A lot of research activities has been conducted in acquiring the ECG and EOG signals using different types of electrodes [3]-[5]. Some of the researchers have worked in acquiring the ECG signals using two electrodes [6]-[8]. ECG can also be acquired from the arm region [7], [8]. This work mainly designed to reduce the number of electrodes from three to two for extracting ECG information (from the arm region and wrist region) and for picking the EOG signal. By eliminating the need for a reference electrode, the circuit uses two electrodes to pick the ECG and EOG signal while maintaining a high common-mode rejection ratio here.

II. MATERIALS AND METHODS

A. Block Diagram

Fig. 1 shows the block diagram of the implemented system. For acquiring the ECG and EOG signal, gel electrode is used. As shown in Fig. 2, two electrodes are used in which electrode 1 is the positive terminal and electrode 2 is the negative terminal. The signal acquired using the electrodes are then given to an instrumentation amplifier having a gain of 100. An instrumentation amplifier is mainly used because it helps to maintain high CMRR (common-mode rejection ratio), which is an important factor in acquiring accurate ECG and EOG signal without the need of reference electrode. The signal from instrumentation amplifier is then given to second-order Butterworth high pass filter having a gain of 1.586. The high pass filter has a cut-off frequency of 2 Hz. The signal then goes through fourth-order Butterworth low pass filter having a gain of 2.515. The cut-off frequency of low pass filter used for acquiring ECG signal is 40 Hz whereas for EOG signal we use cut-off frequency of 13 Hz. After that, the signal is given to notch filter having a cut off frequency of 50 Hz. Notch filter helps in eliminating the power line interference from the signal of interest. To further increase the amplitude of the signal, a non-inverting amplifier is used. The gain of non-inverting amplifier used for acquiring ECG is 11 and that for EOG is 57. Finally using NI ELVIS, we acquire the biomedical signal and is recorded with the help of biomedical workbench. The value of different resistor of LPF and non-inverting amplifier used for acquiring ECG and EOG is shown in Table 1. The complete circuit design is given in Fig. 2.

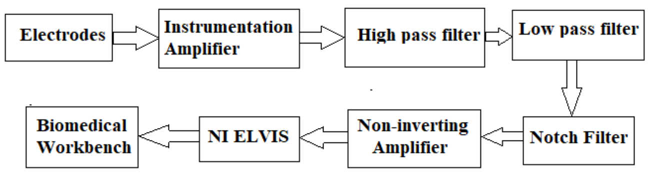

Fig. 1 Block diagram of the implemented system

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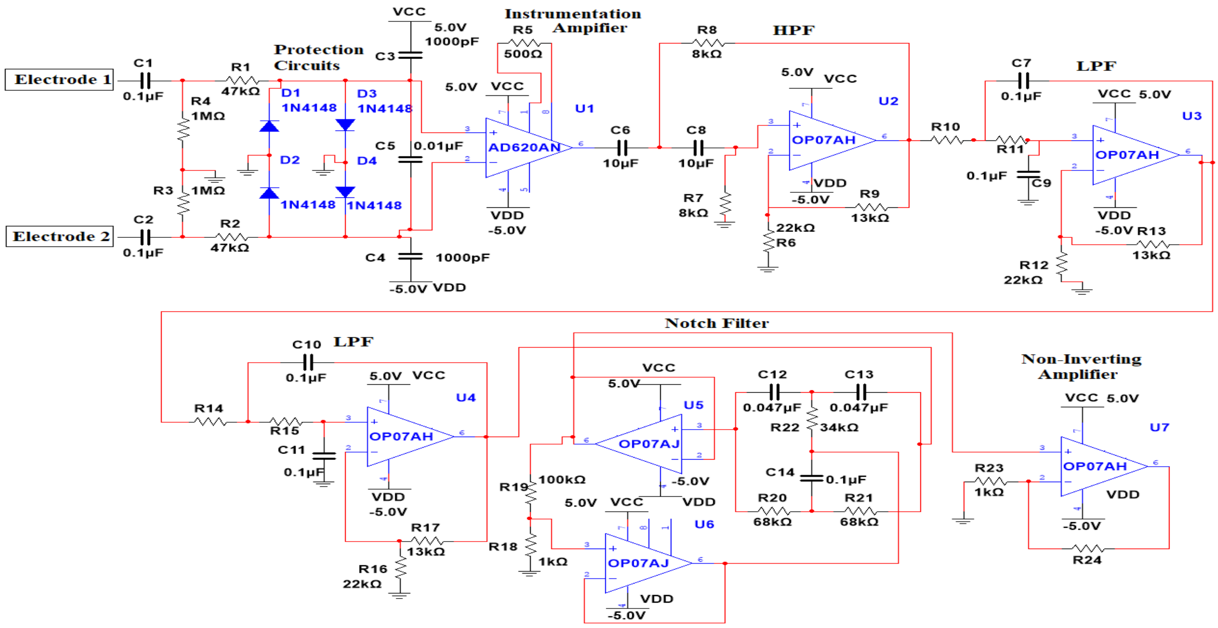

Table 1 Values of R_{10}, R_{11}, R_{14} and R_{15} for second order LPF circuit and R_{24} for non-inverting amplifier

Waveform	R_{10}, R_{11}, R_{14}, R_{15}	R_{24}	Cut-off Frequency for LPF
EOG	122 kΩ	56 kΩ	13 Hz
ECG	39 kΩ	10 kΩ	40 Hz

B. NI-ELVIS and Biomedical Workbench

The National Instruments Educational Laboratory Virtual Instrumentation Suite (NI-ELVIS) is used for acquiring the signal from the non-inverting amplifier and transfers it to LABVIEW Biomedical workbench. The ECG signal is then recorded using bio-signal logger of LABVIEW Biomedical workbench as indicated using Fig. 3 (A). For the calculation of heart rate in the ECG signal, we used ECG feature extractor as mentioned using Fig. 3 (B).

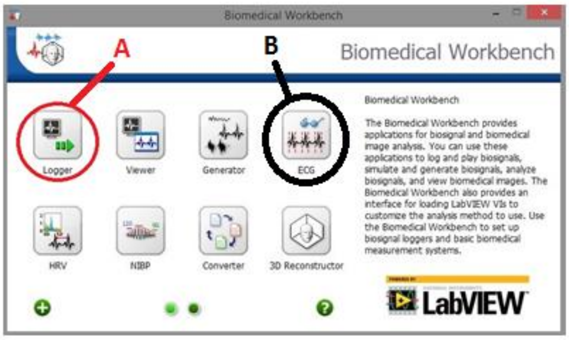

Fig. 3 Biomedical Workbench home console

C. Electrode Placement and Subject Positioning

For acquiring ECG from the wrist, we place the positive electrode (electrode 1 as shown in Fig. 2) on the left-hand wrist and the negative electrode (electrode 2 as shown in Fig. 2) on the right-hand wrist which is shown in Fig. 4 (A). Before acquiring single-arm ECG, the subject is made to relax as even a small movement can affect the result. The subject is made to sit properly for the acquisition of single-arm ECG. For the single-arm ECG, negative electrode (electrode 2 as shown in Fig. 2) is positioned 2 cm below the armpit on the right side of the left arm and the positive electrode (electrode 1 as shown in Fig. 2) is placed diametrically opposite on the left side of the left arm which is shown in Fig. 4 (B) [9]. While acquiring the EOG signal, the subject is made to sit properly, then the electrode is placed as shown in Fig. 5. The positive electrode (electrode 1 as shown in Fig. 2) is placed on the left side of the left eye and the negative electrode (electrode 2 as shown in Fig. 2) is placed on the right side of the right eye.

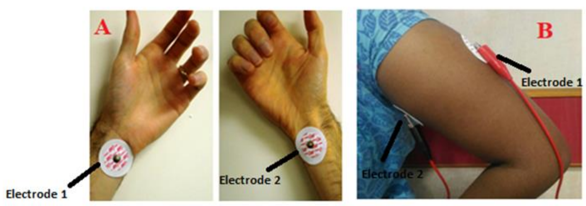

Fig. 4 Electrode positioning for acquiring ECG

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Fig. 5 Electrode placement for acquiring EOG

III. RESULT

Fig. 6 shows the ECG output of subject 1 from the arm region (left arm). Fig. 7 shows the ECG output of subject 2 from the wrist region.

Fig. 6 Single arm ECG output of subject 1

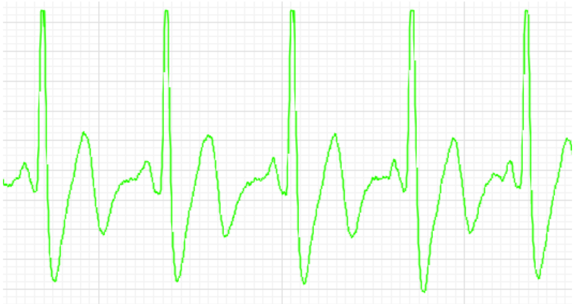

Fig. 7 Wrist ECG output of subject 1

Fig. 8 shows the EOG signal of the subject 1 when the subject moves the eye towards the left direction from the centre initially and back to the centre whereas Fig. 9 shows the EOG signal when the subject moves the eye towards the right direction from the centre initially and back to the centre.

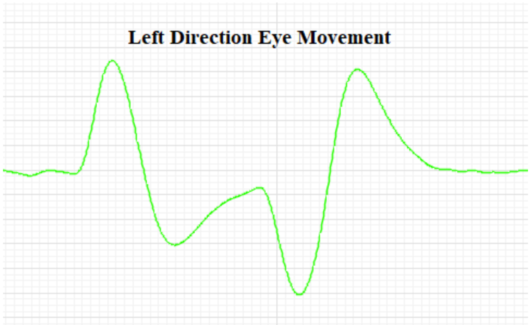

Fig. 8 EOG Left direction Output of subject 1

Fig. 9 EOG Right direction Output of subject 1

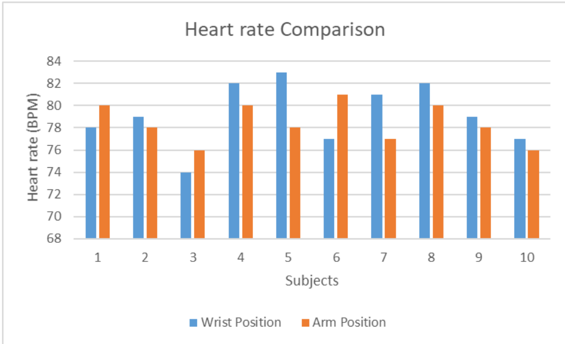

Fig. 10 Heart rate comparison bar graph

Fig. 10 shows the heart rate comparison between the arm position and wrist position bar graph.

IV. DISCUSSION

Using the two-electrode system, we can acquire a clean and noise-free ECG signal and EOG signal from human subjects. EOG and ECG signal have been taken from ten healthy subjects. Here we used two different positions for acquiring the ECG waveform, which is wrist and arm. Precise placement of the electrode is very important to acquire an accurate ECG waveform. The amplitude of the ECG signal obtained from the wrist position is higher than that of the arm position. This amplitude difference can be seen in Fig. 7 and 8. Therefore, while acquiring the ECG from the left arm, more gain has to be provided compared to the wrist position [9], [10]. The normal heart rate varies from 60 to 90 beats per minute (BPM). In Fig. 11, all ten healthy subject's heart rate falls on the normal range. Here the bandwidth considered for ECG is 2 Hz to 40 Hz and that of EOG is 2 to 13 Hz. The final non-inverting amplifier gain for EOG signal should be more compared to the ECG signal since the ECG signal is in the range of millivolts and EOG signal is in the range of microvolts [1], [2], [5].

V. CONCLUSION

This paper deals with the design of a two-electrode ECG and EOG system for monitoring applications. ECG and EOG signals have been acquired from 10 subjects successfully. The ECG signal is successfully acquired from the wrist and arm position for ten subjects and their heart rate have been found out using the biomedical workbench. The picked-up EOG signal can be used for applications such as designing a device for quadriplegia

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patients calling the nurse using EOG signals in which less electrodes are used in the face region enhancing the comfortability factor. With this study, two-electrode system for monitoring applications is cost-effective, affordable and portable.

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AUTHORS PROFILE

Pema Wangmo has completed her higher secondary education from Motithang Higher Secondary School, Thimphu, Bhutan in 2015 and got King Jigme Khesar Namgyal Wangchuck certificate for topping the school in the year 2010, 2011 and 2014. Currently under the scholarship from the government of Bhutan she is pursuing B. Tech Biomedical Engineering at SRM Institute of Science and Technology. She got the award certificate for topping the biomedical engineering department for the year 2016 and 2017. Her field of interest is in biomedical instrumentation and medical electronics. She is currently doing research on how to acquire ECG from finger and to make a portable health machine.

G Ramyavani is a fourth year B. Tech Biomedical Engineering student at SRM Institute of Science and Technology, Chennai, India. She has completed her higher secondary education with biology, physics, and chemistry as her subjects form Narayana College, Nellore district, Andhra Pradesh in the year 2015. She has completed her 10th standard from Ratnam public school, Nellore dirstrict, Andhra Pradesh in the year 2013.She has participated in various extra-curricular activities. She is interested in biomedical instrumentation and she is currently doing research on how to acquire bio signals like ECG from various part of the human body and analyze the accuracy of it.

Kaustubh Shivkumar Iyer is a fourth year B. Tech Biomedical Engineering student from the year of 2016 to 2020 studying at the prestigious institute, SRM Institute of Science and Technology, Kattankulatur, Chennai. He is a very hard working student and along with academics, he participates in various extra-curricular activities. He has got Certificate of Appreciation from Career Development Center, SRM Institute of Science and Technology during an extempore speech competition held during soft skills course in first year. Other awards that he has achieved are Certificate of Appreciation for delivering a guest lecture on communication skills at Tech-A-Mania startup and Certificate of Participation for completing Young Leadership Program at Tech-A-Mania. He also works as an event organizer at Tech-A-Mania.

Karthik Raj V was working as Assistant Professor in the Department of Biomedical Engineering, SRM Institute of Science and Technology. He has received M.E degree in Medical Electronics from College of Engineering, Anna University in 2011 and B. Tech in Biomedical Engineering from Sahrdaya College of Engineering and Technology, Calicut University in 2008. His research area focus is on medical instrumentation and medical electronics. He has been studying the processing of bio-signals like ECG, EOG, and EMG for certain applications, for example, a helping device for disabled patients using EOG signal. Testing of different dry electrodes which can pick up the bio-signals without the use of gels and single arm single lead ECG system are some of his works recently published. Studying the acquisition sites for bio signals is another exciting work which he is currently doing for the point of care technology applications.

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