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A Versatile Cost Effective Biosignal Acquisition System

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Abstract---

Biosignal acquisition is the basis for diagnosis systems and understanding of the electrophysiology of the body. Bioelectric signals arise from the changes in the potential across the cell membrane of excitable cells. These are of low frequency and very low voltage and are often plagued with external interferences. Hence an ideal acquisition system should provide high overall gain, high selectivity for the biosignal and high common mode rejection ratio (CMRR) with ease of use and applicability. This paper presents a feasible, low cost, general purpose biosignal acquisition system which can be used to acquire and record biosignals in a computer using commercially available Data Acquisition (DAQ) device. The purpose of the system is to reduce the complexity and to improve the ease of acquiring biosignals. The uniqueness of the system is that it allows frequency and gain adjustability thus allowing the acquisition of a number of biosignals using a compact unit. The main circuit consists of differential preamplifier, multi stage filter and final amplifier stage. Acquisition examples are in the form of ElectroOculogram (EOG) and Electrocardiogram (ECG) using NI USB-6009 DAQ device.

Keyword- Biosignal, CMRR, DAQ, NI USB-6009.

1. Introduction

Biochemical processes in the cell molecular level lead to separation of charges across the cell membrane thus creating electric fields within the cells and tissues. Some cells in the body are excitable and produce Action Potentials (AP) in response to stimulation resulting in current loops in the surrounding volume conductor and spreads to the whole body independent of the source. These Biopotentials are specific to a particular tissue or organ and has a unique waveform that provides information of the function. Measurements of these Biopotentials provide an insight into the activity of the organ thus helping in the diagnosis of the pathological conditions [3].

Biopotentials are of small amplitude (10µV to several mV) and low frequency range (DC to several hundred Hz). Electrodes placed on the surface of the body transduce the ionic current to electric current in the lead wire. An electrolytic gel is used to improve the conduction between the skin and electrode surface. Silver-Silver Chloride electrodes are commonly used in biopotential pickup as it has a low junction potential, low intrinsic noise and very low external interferences [2]. Biopotentials being low level signals need high amplification to be measured reliably and are often imposed with interferences (both biological and environmental) making their acquisition complex. These interferences include baseline drifts, motion artefacts, power line interferences and radiated electromagnetic energy [1]. Choice of electrodes, electrode site, amplifier and filter circuitry and measurement practices determine the reliability and quality of biopotential measurement. Patient safety needs to be ensured by providing isolation between the acquisition system and patient in case of systems power from AC mains.

2. The Proposed Biosignal Acquisition System

The primary function of any biosignal acquisition system is to recover the low level analog signals corrupted with noise and external disturbances. The proposed system is designed to reliably pick up the surface potentials and condition it adequately before digitising using a recording device in order to obtain the highest resolution and maximal effective number of bits (ENOB) thus preserving the signal information [2]. Fig.1 illustrates the complete acquisition system with the inputs of the preamplifier coupled to RC poles in order to effectively cancel out the noise induced in the

lead wires due to the electromagnetic interferences and load (a display or recording device) connected to the output [1].

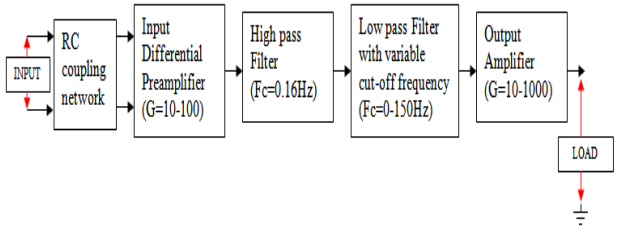

Fig. 1. Block Diagram of the Biosignal Acquisition System

2.1. Instrumentation Amplifier Using AD620

The Differential Amplifiers are commonly used in biopotential measurement as they cancel out the common mode signals (external interferences) to a greater extent when compared to single ended amplifier. It amplifies the difference in potential between the two electrodes connected to its input with reference to a third ground. The biopotential vary in their magnitude over the surface of the body and hence are amplified whereas the typical common mode signal such as 50Hz power line interference is eliminated [4]. The AD620 is a low cost instrumentation amplifier which provides a differential gain of 10-1000 set with a single external resistor Rg (calculated using the equation 1). It provides low current noise, high input impedance and a high CMRR (Common mode rejection ratio) of 130dB, which meets the biopotential amplifier requirements. The AD620 does not saturate for DC input voltages or electrode offset voltages of up to 200mV [8].The electrode offsets are caused due to induced electromagnetic interference between the lead wires or due to the movement of the electrodes. The power supply to AD620 is reduced to 5V in order to reduce the wave form distortions.

$$Rg = 49.4k\Omega / (G-1) \quad (1)$$

2.2. Active filters with tuneable cut-off frequency (Fc)

Filtering and limiting the bandwidth of the biopotential is essential in eliminating the interferences and to amplify the signal of choice in the latter stages. A first order high pass filter of cut-off frequency of 0.16Hz is implemented after the instrumentation amplifier stage in order to reduce the low frequency biopotential (0.1-0.7Hz) that remain in the signal after the differential pickup [4]. The high pass filter consists of a single pole with critical frequency given by $fc = 1 / (2\pi RC)$. The signal is band limited using a 6th order Bessel lowpass filter which provides roll-off of 60dB/decade and produces greatest rejection outside the frequency band of interest [6]. The multistage filter is designed with contact capacitances such that the filter cut off can be varied by varying selective resistors. Trim pots are used in this case to vary the resistance precisely, thus achieving the selected cut off. The Bessel filter is chosen in this case since it reduces phase distortions that are inevitable in Butterworth and Chebyshev filters responses and preserves the waveform of the signal which is essential in case biopotentials for accurate interpretation of the underlying physiological processes [5]. The Damping Factor (DF) of the filter determines the response characteristics the filter exhibits. It is determined by the negative feedback resistors ratio [7]. The damping factor depends on the order of the filter for a particular response. For the 6th order Bessel filter the damping factor and the other filter parameters are taken from the Bessel filter design table and the each second order stage is designed using MFB (Multiple Feedback) filter configuration. The 50Hz notch filter is not used to in this system since it causes distortion of the biosignals and affects the features of the waveform [4]. The system is powered by a pair of 9V batteries to effectively reduce the power line interferences.

2.3. Final Stage Output Amplifier

The Final stage amplifier is a non-inverting amplifier using a single operational amplifier LM741.The Gain Bandwidth Product (GBP) is high enough for desirable gain in the bandwidth required and hence a single op-amp is used to provide the output gain [9]. The classic offset nulling network is used to nullify undesired offset voltages and the opamp has overload protection in the output and hence can drive common display and recording devices without any compromise in performance.

3. Features

The System provides a simple design for single channel acquisition of a vast range of Biopotentials and eliminates interferences to a great extent. It is highly flexible with adjustable amplifier gain and variable cut-off frequency of low pass filter unit. The system has been designed to be portable, easy to interface with display and recording systems and offers easy installation. The system is cost effective as it consists of low priced elements available commercially. The DC offset potentials arising from the interferences in

the lead wires are blocked in the input stage thus avoiding input saturation.

4. Results and Discussion

The proposed Biopotential acquisition system is designed using NI Circuit Design Suite. The circuit was implemented as a Printed circuit board (shown in fig.2) and the performance was tested for the acquisition of electrooculogram (EOG) and electrocardiogram (ECG) biosignals which is discussed below. Determining the optimal position of electrode placement was found by trial and error method until a satisfactory signal is obtained.

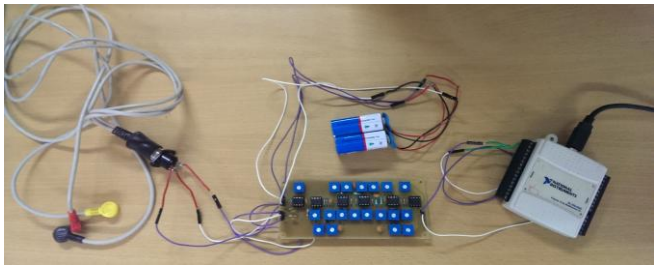

Fig.2. Biosignal Acquisition System

4.1. EOG Acquisition

EOG signals are generated by the electric potentials developed by the movement of the eyeballs with in the skull. The EOG potentials can be picked up by placing electrodes above and below the eyeball or across them. The signal is of low amplitude (10-100µV) and has low frequency (DC-30Hz) [3]. Hence the overall gain of the system is adjusted to 10000 and frequency is set to 30Hz by varying the corresponding variable resistors. The electrode positions are chosen as shown in the fig 3.a) and the signal viewed in the Digital storage oscilloscope is shown in fig 3.a).

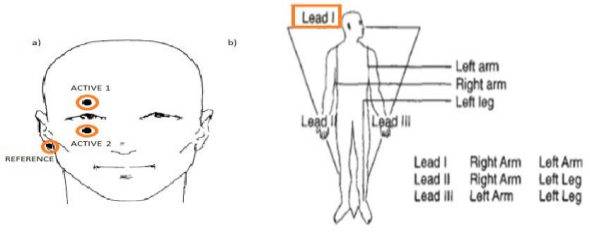

Fig.3. a) EOG and b) ECG Electrode placement (Marked in Red)

4.2. ECG Acquisition and Recording using NI USB-6009

ECG signal is generated by the cardiac smooth muscle contraction and the activity of which on the surface of the body reflects the underlying heart activity. The ECG signal has amplitude of 1-5mV and 0.05-150Hz frequency [3]. The clinically accepted lead I electrode arrangement is used for ECG acquisition (shown in fig 4.b)). The system gain for the ECG acquisition is adjusted to 1000 and frequency is set to 100Hz. The ECG signals thus obtained are recorded in a PC using NI USB-6009 DAQ (Data Acquisition) system and NI LabVIEW software as shown in fig 4.b)

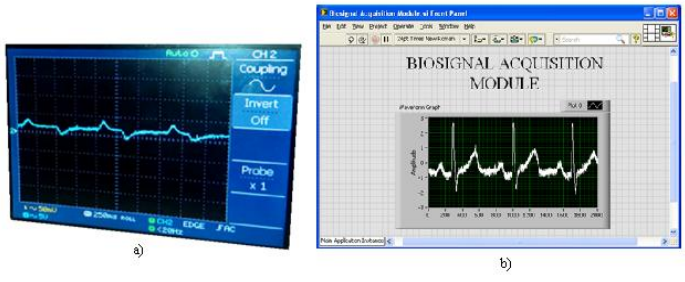

Fig.4.a) EOG and b) ECG signals acquired using the designed module

5. Conclusion

The designed acquisition system is a single channel system which offers increased portability while reducing the number of biosignals analysed simultaneously. The system can be effectively used to observe biosignals within the range of 0.16-150 Hz and record them using any commercially available DAQ systems. Better results can be obtained by using specific electrodes for various biosignal acquisitions (e.g. Gold coated electrodes for EEG recording) and shielding the device. The system was used to acquire and record ECG signal in a computer using NI USB-6009 DAQ and NI LabVIEW. The recorded signal was used to perform heart rate variability calculations in LabVIEW and results were compared with ECG data files downloaded from PHYSIO NET. The results were found to be matching satisfactorily, thus justifying the use of the designed system for biosignal analysis purposes. Our future plan is to improve the design to maximally reduce the noise interferences, increase the frequency variability range and to design a DAQ device to make the system a complete acquisition and recording system.

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