DESIGN OF SINGLE CHANNEL PORTABLE EEG SIGNAL ACQUISITION SYSTEM FOR BRAIN COMPUTER INTERFACE APPLICATION

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ABSTRACT

In this paper designing of a battery operated portable single channel electroencephalography (EEG) signal acquisition system is presented. The advancement in the field of hardware and signal processing tools made possible the utilization of brain waves for the communication between humans and computers. The work presented in this paper can be said as a part of bigger task, whose purpose is to classify EEG signals belonging to a varied set of mental activities in a real time Brain Computer Interface (BCI). Keeping in mind the end goal is to research the possibility of utilizing diverse mental tasks as a wide correspondence channel in the middle of individuals and PCs. This work deals with EEG based BCI, intent on the designing of portable EEG signal acquisition system. The EEG signal acquisition system with a cut off frequency band of 1-100 Hz is designed by the use of integrated circuits such as low power instrumentation amplifier INA128P, high gain operational amplifiers LM358P. Initially the amplified EEG signals are digitized and transmitted to a PC by a data acquisition module NI DAQ (SCXI-1302). These transmitted signals are then viewed and stored in the LAB VIEW environment. From a varied set of experimental observation it can be said that the system can be implemented in the acquisition of EEG signals and can stores the data to a PC efficiently and the system would be of advantage to the use of EEG signal acquisition or even BCI application by adapting signal processing tools.

KEYWORDS

EEG, BCI, amplifier, data acquisition system.

1. INTRODUCTION

The brain computer interface (BCI) can be depicted as a communication system which is to interact with an external contrivance and can be controlled by the brain activity. In the recent years a large community of researchers around the world has been exhibiting a great interest to the conception of direct interface between the human brain and an artificial system. It detects patterns in brain activity and translates them into commands and given as an input the external device. The main motive of the BCI-based applications system has been to provide communication and controls for those users who have lost their ability to communicate naturally. In a BCI, signals from the brain are acquired and processed to extract categorical features and relegate to reflect the utilizer's intent. These features are then translated into commands to operate a contrivance [1]. The conception of controlling machines not by manual operation, but by mere cerebrating (i.e., the brain activity of human subjects) has fascinated humankind since ever, and researchers working at the crossroads of computer science, neurosciences, and biomedical engineering have commenced to develop the first prototypes of BCI over the last decade [2] [3].
Since Hans Berger reported about electroencephalography (EEG) in 1929, a lot of research work on it has been done by various researchers around the world [4]. EEG commonly known as brain

waves represents the electrical activity of the brain and can be obtained from the various locations of the scalp [5]-[6]. Depending on the various position of the brain there are five major brain waves distinguished by their different frequency ranges. These frequency bands are varies from low to high respectively and can be distinguished as alpha (α), theta (θ), beta (β), delta (δ), and gamma (γ) [7].

Due to the invention of CMOS (Complementary Metal oxide Semiconductor) to the field of technology, EEG acquisition system were started designing and fabricated by using the CMOS IC (integrated Circuit) technology [8] [9], which make the system compact and reliable.

Since 90's so many researchers have been developing various EEG acquisition systems with different sensor and can be recorded using fully computerized systems [10]. The new generation EEG machines are equipped with many signal processing tools, delicate and accurate measurement electrodes, and enough memory for very long-term recordings. EEG machines may be integrated with other neuroimaging systems such as functional magnetic resonance imaging (fMRI) for the advancement in the field of medical technology and will help in the clinical applications [11].

2. System Design

2.1. EEG Signal Conditioning Circuit

Signal conditioning unit has been designed to amplify the EEG signal for further processing. EEG signal picked up using electrodes have a magnitude of around (5–500µV). The signal is also confined in the range of (1–100 Hz), as the information about EEG signals lies in this range. An active high pass filter and an active low pass filter have been designed in this cut off frequency range. For removing the 50 Hz power line interference, a notch filter has been designed for better performance. After designing of the all filter circuit, a post amplifier for further amplification of the EEG signal and a voltage adder circuit has been designed for keeping the signal in positive domain. Figure 1, shows the basic block diagram of the designed EEG signal acquisition system which is mainly the collected composition of scalp electrodes, instrumentation amplifier, active high pass and low pass filter, notch filter, post amplifier and voltage adder, DAQ card and the computer display and storage.

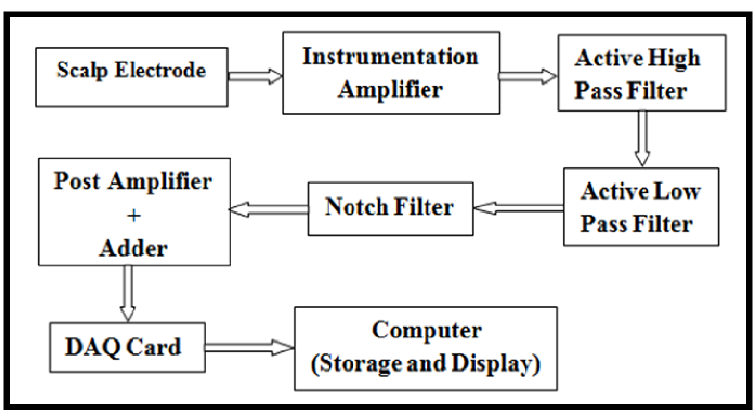

Figure 1. Block Diagram of Designed EEG Signal Acquisition System

A Third order Butterworth filter has been implemented in the designing of the active high pass and active low pass filter circuit. The frequency response of the Butterworth filter estimate capacity is additionally regularly alluded to as "maximally flat" (no ripples) response on the grounds that the pass band is intended to have a frequency response which is as level as numerically conceivable from 0 (zero) Hz (DC) until the cut-off frequency at (-3dB) with no ripples [12] [13].

2.2. THE INSTRUMENTATION AMPLIFIER

The instrumentation amplifier is acting as a front end for the designed EEG signal acquisition system. The schematic diagram is available in [14].The Burr–Brown INA 128P has been selected for implementation in the designing of the EEG acquisition circuit after a set of experimental performance with some other instrumentation amplifier ICs. The integrated single supply instrumentation amplifier is designed based on a typical customized three op-amp approach. It is a high precision, low power general purpose amplifier. It has various beneficial features which makes the INA 128P idyllic for the battery power-driven medical applications, those are like low offset voltage 50µV max, low drift 0.5µV/max, low input bias current 5nA max, high CMRR (Common Mode Rejection Ratio) 120db min, inputs protected to 40V, wide supply range: 2.25V to 18V.

The gain of the amplifier is controlled by a 10kΩ POT (potentiometer) single external resistor. The gain of the particular instrumentation amplifier can be calculated by:

$$[G = 1 + 50K\Omega/RG] \quad (1)$$

Where, RG is the external resistor. Here, RG = 10 kΩ POT. Hence, the gain of the amplifier is set with 26db.

2.3. ACTIVE HIGH PASS BUTTERWORTH FILTER

The acquired raw EEG signal is overlapped with low frequency noises, to overcome from these noises a proper high pass filter has to be designed. Here the active high pass filter is designed with the cut off frequency of 1 Hz. This is also help in removing the baseline drifting, which is created by low frequency noise. Figure 2, shows the circuit diagram of high pass Butterworth filter. The cut off frequency is calculated by:

$$[\text{Cut off frequency (fc)} = 1/2\pi RC] \quad (2)$$

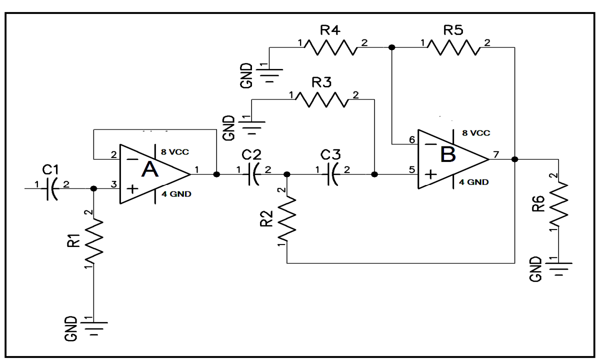

Figure 2. Active High Pass Butterworth Filter Circuit\
Here, R1, R2, R3 = 15.9kΩ, R4, R5 = 27kΩ, R6 = 10kΩ and C1, C2, C3 = 10µF. Hence, (fc) = 1.0097 Hz.

2.4. Active Low Pass Butterworth Filter

The acquired raw EEG signal is overlapped with high frequency noises, to overcome from these noises a proper low pass filter has to be designed. Here the active low pass filter is designed with the cut off frequency of 100 Hz. The cut of frequency is calculated by using the Equation 2. Figure 3, shows the circuit diagram of active low pass Butterworth filter.

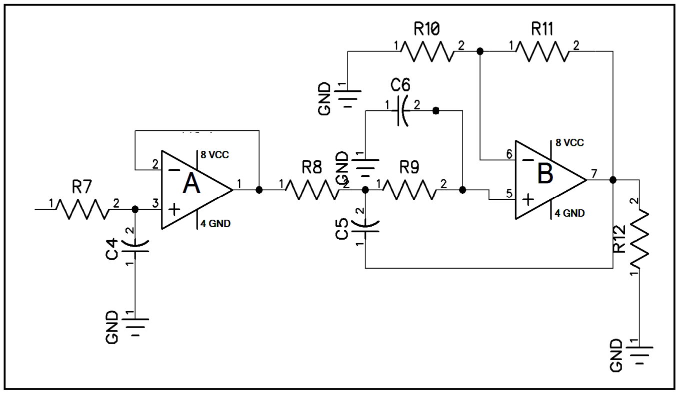

Figure 3. Active Low Pass Butterworth Filter Circuit

Here, R7, R8, R9 = 15.9kΩ, R10, R11 = 27kΩ, R12 = 10kΩ and C1, C2, C3 = 0.1μF. Hence, (fc) = 100.097 Hz.

2.5. Notch Filter

A major source of interference of EEG is the electric power system. Besides providing power to the electroencephalograph itself power lines are connected to the other pieces of equipment and appliances present nearby. Implementing of the perfect 50 Hz hardware notch filter is very hard to make because the perfect matching of resistance and capacitances is almost hard to find.

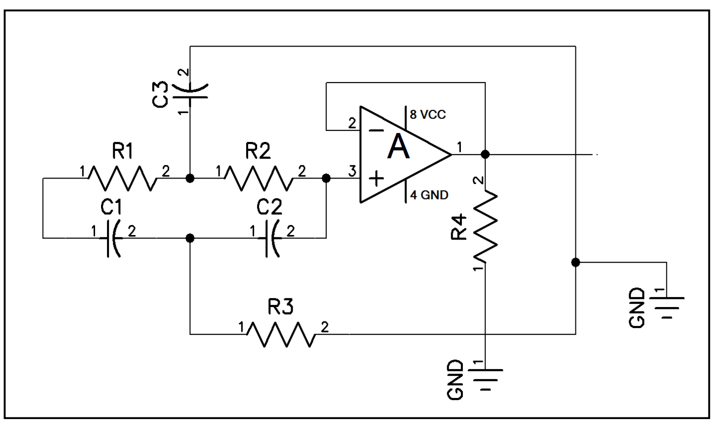

Figure 4, shows the circuit diagram of 50 Hz notch filter.

Here, R1, R2 = 320kΩ, R3 = 150kΩ and C1, C2 = .01μF and C3 = .022 μF. Using Equation 2, it has been found that, (fc) = 49.735 Hz.

2.6. POTS AMPLIFIER AND VOLTAGE ADDER

A post amplifier circuit has been designed to provide some additional gain to the circuit. It is a non – inverting amplifier and will capable of amplifying the signal to 1 – 1000 times of the filtered EEG signal. The gain of the non – inverting amplifier can be calculated by using Equation 3:

$$[G = 1 + Rf/Rin] \quad (3)$$

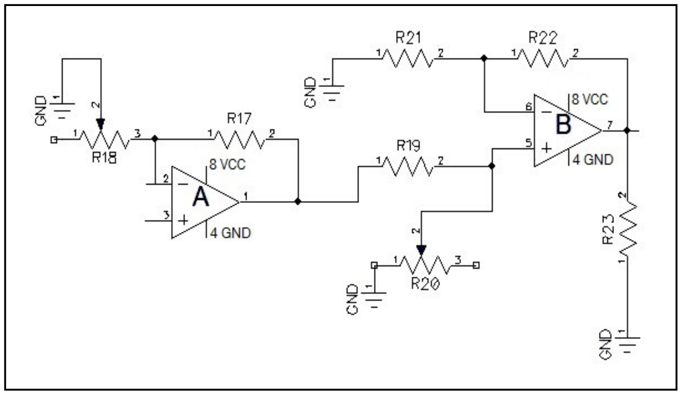

Figure 5. Pots Amplifier and Voltage Adder Circuit

Here, Rf= R17 = 10kΩ and R18 = 0.26kΩ. Hence the gain is adjusted as, Gain = 39.46 db.

The EEG information is presently prepared to be digitized in the wake of finishing the methodology of separating and intensification of the raw EEG information by utilizing the designed hardware. The data acquisition card obliges the signal is to be encased totally in the positive voltage area. The DC voltage that the signal will be added to is supplied by the voltage divider framed with two 10kΩ and 15kΩ resistor. Alternate resistors set the increase of the enhancer to be one and are much bigger than the resistors in the voltage divider so they don't impact the voltage division.

Here, R19 = 10kΩ and R20 = 15kΩ and V= 5V. Hence, according to the voltage divider rule the output voltage of the summing amplifier is that, the EEG signal is transposed by = (5*10)/ (10+15)=2V.

3. EEG SIGNAL ACQUISITION AND RESULTS

After designing the complete EEG acquisition system and implementing it to PCB (printed circuit board) the next step is to acquisition of the EEG signal. Data acquisition has been done by using the NI DAQ in LAB VIEW environment and displayed in the computer. For the EEG data acquisition, electrodes are to be placed on the frontal region and the positions are Fp1, Fp2. For the single channel data acquisition process, positive electrode is placed on the Fp2 position, reference electrode is placed on the Fp1 position and negative electrode is placed on A1 (earlobe) position. The positions are determined according to the international 10-20 electrode system [5]. Figure 6, shows the different position of electrodes on scalp according to the 10-20 electrode system.

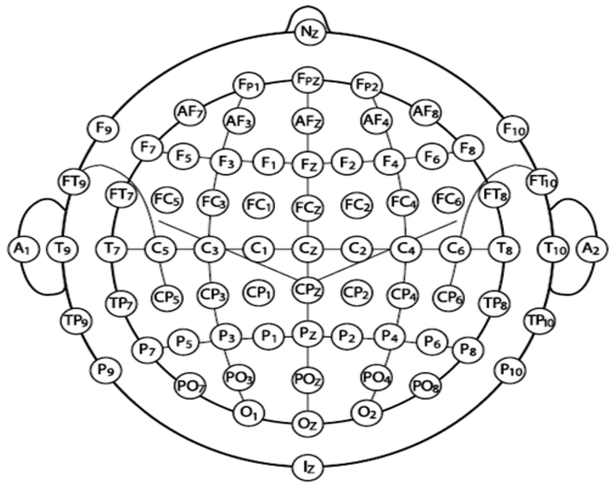

Figure 6. 10-20 Electrode Position System

Electrodes are working as transducer, which are commonly of direct contact type and converting the ionic flows from the body through an electrolyte into electron current and therefore an electric potential able to measure by the front end of the EEG signal acquisition system. EEG electrodes are available as gold plated, tin plated, EEG cap, and disposable electrode [15].

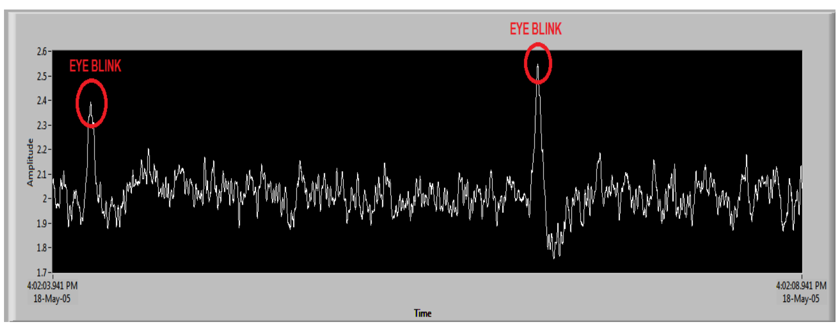

Figure 7. EEG Signal Pattern during Eyes Open

For the experimental purpose we have decided mainly two states to collect the EEG signal that is Eyes Open and Eyes Closed state. Two high amplitude peaks are showing in the Figure 7, which are the eye blink signal formed during the signal acquisition at the eyes open state. After the acquisition of the signal in LAB VIEW, the output voltages were collected for further processing of the signal. Figure 7 and Figure 8, shows the EEG signal pattern of eyes open and eyes closed state which have acquired from a healthy subject. For the experimental purpose data acquisition has been done form several subjects. But for the further processing we have chosen only two subjects data. Data was acquiring for maximum of 2 minutes in 500 samples per second.

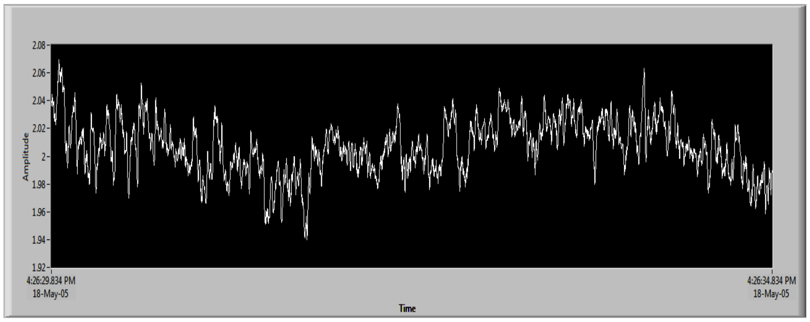

Figure 8. EEG Signal Pattern during Eyes Closed

4. CONCLUSION

In this paper, a portable single channel EEG signal acquisition system for the brain computer interface application is proposed. The EEG signal acquisition system has been trying to designed cost – effective due to the future use in the brain computer interfacing (BCI) system. For the development of a real time BCI application, the use of signal processing is always essential. From the experimental observation it can said that the designed system can be implement for the EEG signal acquisition and storage of data to a PC efficiently. For further use of the system in case of BCI application, the different signal processing tools like feature extraction by using FFT (Fast Fourier Transform) or Wavelet Analysis and for training of the EEG data set Neural Network or SVM (Sample Vector Machine) can be used.

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