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Fundamentals of Electroencephalogram(EEG) and Data Acquisition: A Prospective Review

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Abstract—*Nowadays, technological growth is very fast. Especially in biomedical data acquisition and analysis is a very fast growing domain. This paper presents a proposed system for acquiring Electroencephalogram (EEG) signal for further processing like to automate system and to develop biomedical data acquisition and processing systems. This paper describes EEG signal acquisition which collects the signals from brain and pre-processing them then send to the desktop computer using microcontroller a varied set of mental activities in a real time Brain Computer Interface (BCI). EEG signal acquisition system is effective in measuring audio event-related potential, measuring visual event-related potential, and rapid serial visual presentation.*

1. INTRODUCTION

Electroencephalography (EEG) has been extensively utilized in automation and data acquisition [1] and biomedical data analysis [2] technology. EEG signal is an electrical signal generated by brain. In automation, the brain computer interface (BCI) can be depicted as a communication system which is interact with an external device and can be controlled by the brain activity for the betterment of imparted people. In last few years the researchers around the world has been exhibiting a great interest to the conception of direct interface between the brain and an artificial system. It detects patterns in brain activity and translates them into commands and given as an input to the external device [3].In biomedical EEG is use for seizure disorders (such as epilepsy [2]), a head injury, a brain tumor, memory problems, sleep disorders etc.

For EEG signal acquiring different types of electrodes are used like wet electrode, dry electrode [4], Self-Adhesive and Capacitive Carbon Nanotube-Based Electrode [5], Comb-Shaped Dry Electrode [6], etc. EEG electrodes are shown in figure.1 and figure.2. For continuous long term monitoring based on EEG, wet electrode, which might result in skin irritation, in contrast, the dry electrode is less impacted by the skin irritation for long-term monitoring. If we have more hair on scalp then we can use Self-Adhesive and Capacitive Carbon Nanotube-Based electrode, it is elastic, highly conductive, self-adhesive, and capable of making conformal contact with hairy scalp [5]. Also we can use Comb-Shaped Dry Electrode for hairy scalp.

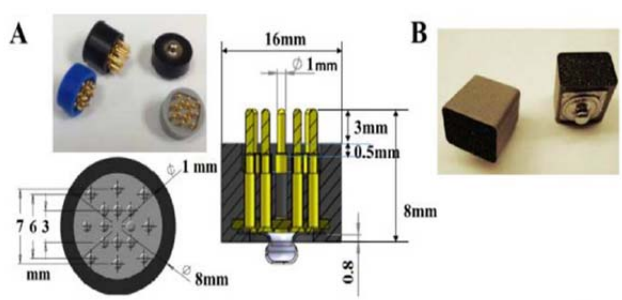

Fig. 1 (A) Dry EEG spring-loaded sensors with dimension specifications[4], (B) Dry foam-based EEG sensor[4]

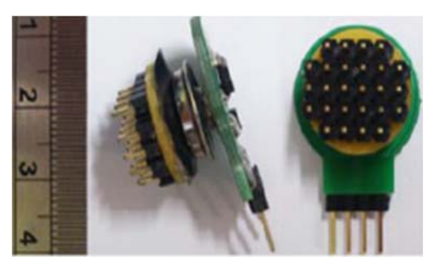

Fig. 2: Comb-shaped dry electrode [6].

EEG signal have different potential, generally there are four wave, which is alpha, beta, theta, and delta. The EEG waveforms are varied by the position of electrode placements on scalp of human.

Alpha waves have a frequency between 7.5 and 13Hz. The alpha waves produced when a person is in a conscious, relaxed state with eyes closed. The amplitude of the alpha wave is largest and can be best recorded at parietal and frontal regions of the brain.

Beta waves have the frequency range of 14-30Hz and sometimes it has frequency high as 50Hz for intense activity. Beta waves are occurring when people have fever, sick and anxious with open eyes.

Theta waves have large amplitude, low frequency range of 3.5-7.5Hz. Theta wave is abnormal in alert adults but seen during sleep, and small children. Theta waves measured mainly in the parietal and temporal region of scalp.

Delta waves are the largest amplitudes and the lowest frequency which is less than 3.5Hz. It is normal wave for less than one year old and in adults in deep sleep. This wave can occur solely within the cortex, it is independent of the brain activities in lower regions of the brain. [7]

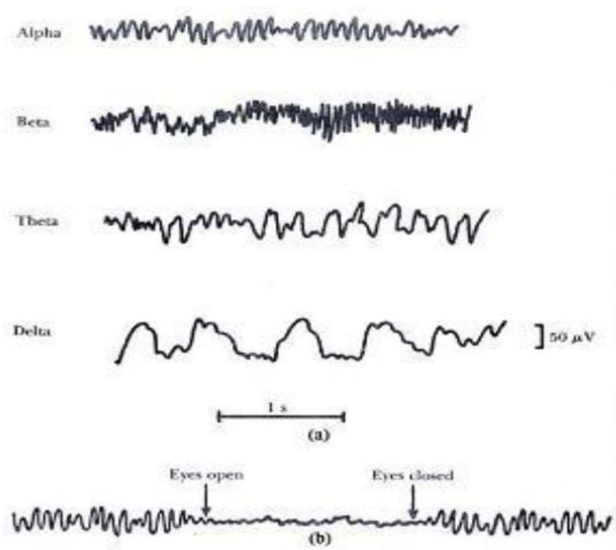

Fig. 3: EEG signal [7] a) normal EEG signal, (b) change in alpha rhythm by an asynchronous discharge when opens eyes.

2. EXISTING METHODS FOR EEG ACQUISITION

In EEG Acquisition system circuit is the most important for acquiring data. Design and Implementation of a Wearable, Wireless EEG Recording System [9], in this paper EEG acquisition circuit is developed using voltage follower, instrumentation amplifier, DC restorator, band pass filter and drive right leg circuit. This system design is effective with high common-mode rejection ratio (CMRR).

Low-cost Circuit Design of EEG Signal Acquisition for the Brain-computer Interface System [3] in this paper, a single-channel low-cost circuit of EEG acquisition for the BCI system is developed. The circuit is designed with protection circuit, instrumentation amplifier, common mode rejection (CMR) circuit, gain adjustable amplifiers and filters. Lei Zhang et.el shows the experimental results of circuit is effective with good performance; it is very suitable for the online BCI system.

Cost-Effective EEG Signal Acquisition and Recording System [10], in this system designed using an amplifier, filter and an opto-isolator. The acquired EEG signal is amplified using instrumentation amplifier which has low noise, high gain accuracy, low gain temperature coefficient and high linearity for use in high resolution data acquisition systems. The output of the instrumentation amplifier is then passed to a low pass Butterworth filter. The amplified output is then passed through an opto-isolator. The opto-isolator is used for short optical transmission path to transfer an electronic signal between a transmitter and a receiver, while keeping them electrically isolated. Opto-isolator is convert electrical signal to a light beam, transferred, and then converted back to an electrical signal, there is no need for electrical connection between the source and destination circuits.

Design and Implementation of an On-Chip Patient-Specific Closed-Loop Seizure Onset and Termination Detection System [12] is a multichannel EEG acquisition system. Chen Zhang et.el is reviewed for seizure detection and suppression algorithm and system which comprise electroencephalography (EEG) data acquisition, feature extraction, classification, and stimulation. Support vector machine substantiated in power, area, patient specificity, latency, and classification accuracy for long-term monitoring of patients with training seizure patterns. Dual-detector architecture comprises two area-efficient linear support vector machine classifiers along with a weight-and-average algorithm for high sensitivity and good specificity. The system is verified using CHB-MIT EEG database which achieves high sensitivity and specificity of 95.1% and 96.2%, respectively, with latency of 1 s. It also attains seizure onset and termination detection delay of 2.98 and 3.82 s, respectively.

A 1.83 J/Classification, 8-Channel, Patient-Specific Epileptic Seizure Classification SoC Using a Non-Linear Support Vector Machine [11], in this paper Muhammad Awais Bin Altaf et.el an eight-channel patient EEG acquisition is implemented. This system integrates a feature extraction (FE) engine, patient specific hardware-efficient NLSVM classification engine, 96 KB SRAM for EEG data storage and low-noise, high dynamic range readout circuits. The FE engine utilizes time division multiplexing (TDM)-BPF architecture to achieve on-chip integration of the NLSVM classification engine with minimum area and energy consumption. The NLSVM classifier exploits the linearization to achieve energy consumption of 0.39 J/operation and reduces the area by 28.2% compared to conventional log-linear Gaussian basis function (LL-GBF) implementation.

3. SYSTEM DESIGN

In EEG Acquisition, Signal is acquire from electrode placed on scalp. The Signal is amplified and digitized using Instrumentation amplifier, Active High Pass Filter, Active Low Pass Filter, Notch Filter and Adder circuit. Signal from Scalp electrode have amplitude of range 5-500μV and frequency range of 1-100Hz. For this cut off frequency, An Active High Pass Filter and an Active Low Pass Filter have been designed. A notch filter has also been designed for more accurate signal acquiring. After getting signal, a post amplifier and voltage adder circuit use for amplification and digitization of the signal. Basic block diagram of EEG Acquisition system is shown in Figure. 4.

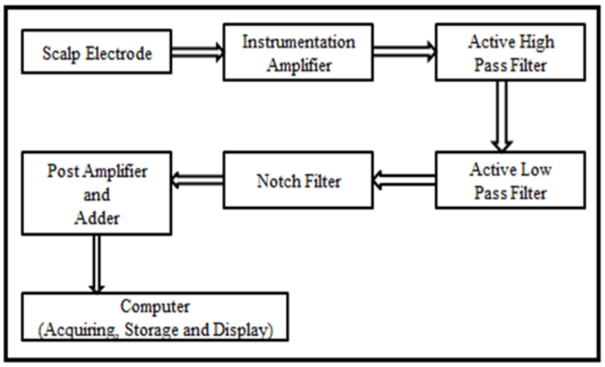

Fig. 4: Block diagram of EEG acquisition system

The single supply instrumentation amplifier is designed based on three op-amp approach. It has low power, high precision general purpose amplifier. It has various features like low offset voltage 50µV max, low drift 0.5µV/max, low input bias current 5nA max, high Common Mode Rejection Ratio (CMRR) 120db min, inputs protected to 40V, supply voltage range: 2.25V to 18V.

The acquired EEG signal is distorted with low frequency noises, to remove these noises a proper high pass filter has to be used with the cut off frequency of 1 Hz. It is also remove the baseline drifting, which is created by low frequency noise. Also, the acquired EEG signal is overlapped with high frequency noises, to remove these noises a low pass filter has to be designed with the cut off frequency of 100 Hz. The acquired signal is also contain some interference by electric power system, for remove these notch filter is used.

Design of Single Channel Portable EEG Signal Acquisition System for Brain Computer Interface Application[8], in this paper Amlan Jyoti Bhagawati et. el describe circuits of instrumentation amplifier, active high pass butter worth filter, active low pass butter worth filter, notch filter and post amplifier and voltage adder. Figure.5 shows simulation circuit diagram of combination of this circuit in LT-Spice Software and the result of this circuit is shown in fig 6. Fig 6 shows that the input signal is sinusoidal and output signal is digital signal.

Electrodes are working as EEG sensor, which are converting the ionic flows from the body into electron current and therefore an electric potential able to measure with the EEG signal acquisition system. EEG signal acquisition system is measuring audio event-related potential, measuring visual event-related potential, and rapid serial visual presentation for further application development in automation as well as in biomedical.

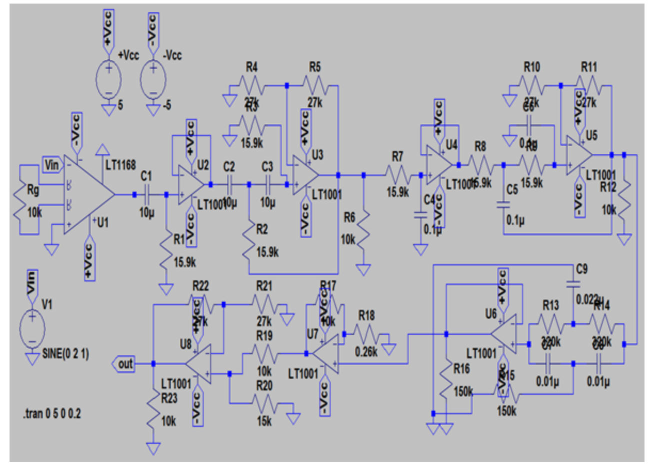

Fig. 5: Circuit diagram of EEG acquisition system in LT-Spice

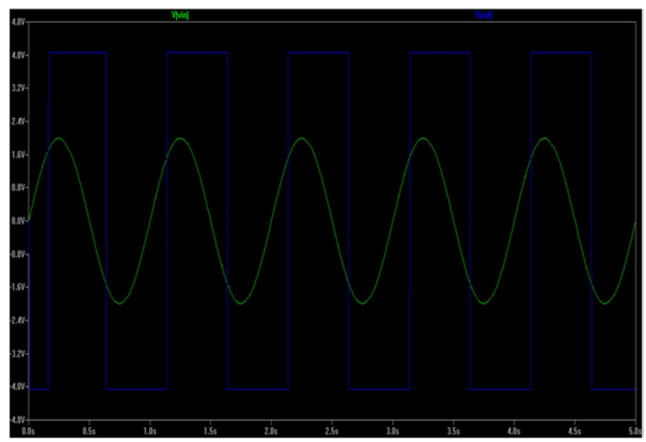

Fig. 6: Simulation signal for EEG acquisition system in LT-Spice

4. CONCLUSION

In this paper, a single channel EEG signal acquisition system for the development of further applications is proposed. The system can be implemented for the EEG signal acquisition and storage of data to a PC. For further use of the system in to automate system and to develop biomedical systems application, training of the EEG data set with Artificial Neural Network, Linear Support Vector Machine(LSVM), Non-linear SVM or log-linear Gaussian basis function (LL-GBF) can be used.

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