Design of Active EEG Electrodes for BCI Applications

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Abstract— **Brain–computer interface (BCI) is an equipment and programming correspondences framework that allows brain signal alone to control computers or outside gadgets.**
The aim of this project is to develop an economical and portable BCI system which could be used for various applications like patient assistance systems , military applications and various other clinical requirements with least usage of commercially available hardware's and software's. The overview of the various steps involved in the BCI cycle are – Measurement of brain signals, classification of the received data, feedback to the user and the effect of feedback on brain activity In this action we will get to apperceive the analytical accomplishment of the BCI cycle, the present issues and advanced results. However, we shall develop a vision on how recently obtained results may contribute to the neural representation of perceived stimuli, intended actions and emotions.In this paper compact active EEG electrodes for constant observation of brain waves is exhibited. Fundamental advancement in the undertaking is the improvement of high performance dry active electrodes, which are much better than the wet electrodes. This device was constructed with simple and digitally integrated circuits. The outcomes acquired demonstrates that, the devices performs comparatively or way superior to the ordinary EEG frameworks. The noninvasive Steady State Visual Evoked Potential (SSVEP) method is used for this purpose

Keywords—BCI; EEG; active EEG electrode;Instrumentational amplifiers; SSVEP

I. INTRODUCTION

BRAIN–COMPUTER interfaces (BCIs) have been a region of exceptional study both as an intends to restore paralyzed patients and to just enlarge the standard material, mechanical client interfaces universal today. A brain–computer interface (BCI), or a brain–machine interface (BMI), is a direct correspondence pathway between the Brain and an outside gadget. Basically, BCI, likewise named Brain–Machine Interface (BMI) when utilizing intrusive EEG, allows by method for Electroencephalogram (EEG) to convey (for e.g. word) and control outer gadgets, for instance a wheelchair or a bionic arm.

The prompt objective of BCI examination is to give correspondences abilities to seriously incapacitated individuals who are completely deadened or 'secured' by neurological neuromuscular issue, for example, amyotrophic sidelong sclerosis, cerebrum stem stroke, or spinal rope damage. Brain-computer interface has attracted much attention recently, triggered by new scientific progress in understanding brain function and by impressive applications. It is a moderately youthful research field which has seen a developing enthusiasm with related number of publications throughout the most recent decades.

The characteristic highlight of a BCI is that it doesn't rely on upon the brain's typical yield pathways of fringe nerves and muscles. Two fundamental prerequisites are met for a communication channel between the brain and the PC: 1) highlights that are valuable to recognize a few sorts of cerebrum state; 2) techniques for the identification and arrangement of such highlights executed progressively in real time. Different methods are presently accessible to screen brain capacity and function, e.g., electroencephalography (EEG), magneto encephalography, useful magnetic resonance imaging, and position emanation tomography. The recent three strategies are actually requesting and costly. At present, EEG is the ideal decision for BCI usage.

Fig 1 represents the basic block diagram of BRAIN COMPUTER INTERFACE SYSTEM. Each block is explained as follows:

Active EEG electrodes - Signals are exceptionally weak signals that need extraordinary treatments to be taken care of accurately. The quality of the deliberate signals is more often than not between 1 µV and 99 mV alongside the scalp impedance and different clamors. Keeping in mind the end goal to get such signals as explained and presenting them on advanced arrangements, suitable amplifiers ought to be utilized.

The EEG estimation electrodes are typically made of gold or silver chloride. The gold electrodes are successful in measuring electroencephalogram, electromyography or electrocardiography motions too. Be that as it may, these terminals ended up being more powerful when the EEG frequencies were underneath 0.1 Hz.
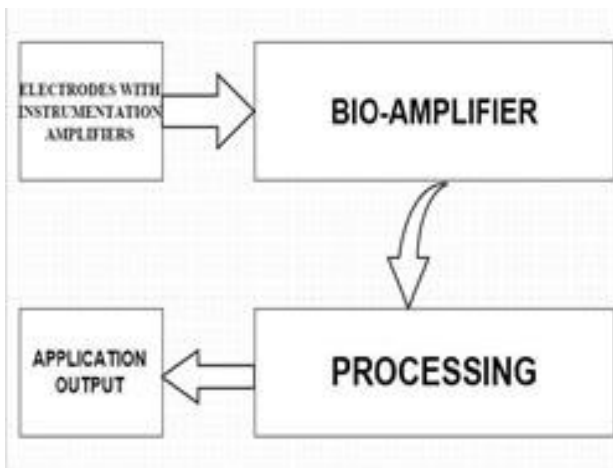
Fig 1.Basic block diagram

Bio-amplifier - The other piece of the BCI equipment is the natural signal amplifier. It is one of the imperative parts of physiological recording and investigation in which the brain signals are exceptionally feeble and it is utilized to amplify them in case of passive electrodes.
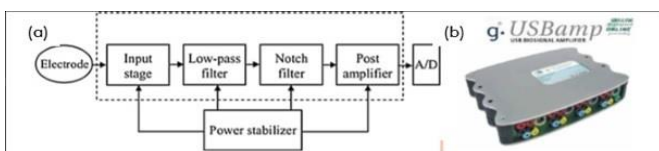

Fig 2 Basic block diagram of bio-amplifier [13]

As can be seen in Fig 2, signals caught by electrodes are enhanced through handling the info stage segment to expel the conceivable noise created from electrode skin interfaces. The signal is additionally gone through two channels which are Low-pass filter and Notch filter. As it would turn out, the signal is first amplified.

Fig 2 shows g.USBamp bio-amplifier. This gadget has 16 info channels, which are associated over programming controllable changes to the inner amplifier stages and hostile to associating channels before the signals are digitized with sixteen 24 Bit ADCs. The gadget is likewise outfitted with digital to analog converters (DAC) empowering the era of diverse signs like sinusoidal waves, which can be sent to the inputs of the intensifiers for framework testing and alignment. The digitized signs are gone to a computerized sign processor (DSP) for further processing. The DSP performs an over-sampling of the bio-signal information, band pass filtering, Notch filtering to stifle the power line interference and figures bipolar deductions. These processing stages dispense with undesirable clamor from the signal, which serves to guarantee precise and dependable grouping. At that point the preprocessed information are sent to a

controller which transmits the information through USB to the computer.

This device is principally focused for natural electrical signal estimations in the recurrence range up to 150 Hz. The gadget is named Bio Amp taking into account its primary function. Due to distinctive adequacy of different bio-signals, e.g. ECG has abundancy around 1.1 mV, EEG around 99 µV; it is suitable to change signal additionally relying upon the sort of measured signal. Change of addition serves to keep up stronger signal in characterized yield voltage range and weaker signals, for example, EEG are extended to entire voltage range. Regularly the gadget operating voltage is supplied from USB. Yields simple signal and is in the range of 0 – 3V. Then again, the gadget may be supplied from outer DC force source associated by means of 2.5 mm power jack connector. At the point when outside force source is associated, supply from USB is naturally exchanged off and yield simple sign is in extent from 0 V to 5 V. More extensive voltage extent permits estimation of signals with higher increase without abundancy cut-off. 3 electrodes can be connected to the Bio-amplifier i.e. one from the DRL, next from the reference and finally from the signal electrode placed either in O1, O2 or Oz region.

Processing – Analog to digital conversion (ADC) is done using Arduino board. Real time signal recording and investigation is overseen on distinctive Operating Systems including windows and Linux and also Mac OS. C++, Lab VIEW (National Instruments Corp., Austin, TX, USA) and MATLAB (The Math Works Inc., Natick, USA) are generally utilized as programming dialects. C++ executions have the focal points that no basic programming package is required when the product ought to be circulated, and permit an exceptionally adaptable framework plan. The MATLAB preparing motor is based upon very upgraded lattice operations, permitting high handling velocity. Such a preparing pace is exceptionally hard to acknowledge with self-composed C code.

The patterns utilized as a part of BCIs are described by specific highlights or properties. For example, amplitudes and frequencies are crucial highlights of sensorimotor rhythms and SSVEPs. The terminating rate of individual neurons is an imperative highlight of intrusive BCIs utilizing intracortical recordings. The highlight extraction calculations of a BCI calculate these highlights. Highlight extraction can be seen as another venture in setting up the signals to encourage the ensuing and last signal preparing stage, identification and classification. Recognition and characterization of cerebrum is the core task. The client inspires certain mind designs by performing mental errands as per mental methodologies, and the BCI identifies

Application-BCI is intriguing range to analysts on the grounds that it can take care of numerous issues which appear to be outlandish. The key focus of BCI applications is to change over the client's expectation or musings to an activity in outer gadget or PC and control to these gadgets.

Numerous uses of BCI concerned on patients experience the ill effects of scatters of cognizance (DOC). These patients are not able to make correspondence with their around world. By utilizing BCI, these patients can control a

Special Issue - 2015

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
ICESMART-2015 Conference Proceedings

few gadgets to perform essential and critical employments they require without assisting like moving with wheelchair, getting something for eating or drinking by utilizing automated legs or arms controlled by mind. BCI advancements are utilized to restore the vision to blinds by associating an outside cam with mind.

Applications on gadget control exclude patients just, but rather additionally sound clients like whose needs to perform numerous occupations in the meantime like jumpers, space travellers and drivers where they keep their hands on swimming, work gear and the controlling wheel. Rabie et al. built up a BCI based framework that can help impaired persons to utilize the web through their brains just.

II. ELECTRODES

There are various types of electrodes used for BCI namely passive, active, non-contact electrodes. There was a survey done on electrodes which were used in the existing BCI systems which are explained as follows:

M. A. Lopez-Gordo, D. Sanchez-Morillo [1] In this review they explain about the Electroencephalography (EEG) developed which in the second decade of the 20th century as a procedure for recording the neurophysiological reaction. From that point forward, there has been little variety in the physical standards that manage the sign obtaining tests, generally called anodes. At present, new advances in innovation which has brought new sudden fields of uses separated from the clinical, for which new perspectives, for example, ease of use and without gel operation are first request needs. Because of new advances in materials and incorporated electronic frameworks innovations, another era of dry electrodes has been produced to satisfy the need. In this original copy, they audit current ways to deal with dry EEG electrodes for clinical and different applications, including data about estimation systems and assessment reports. They presume that, despite the fact that an expansive and non-homogeneous assorted qualities methodologies has been assessed without an accord in strategies and framework, their shows are not far from those got with wet non active electrodes, which are viewed as the highest level, consequently empowering the previous to be a valuable apparatus in an assortment of novel applications.

Abhishek B, Abhishek [2] In this paper a low power and minimal EEG with element electrodes as shown in Fig 3 for steady seeing of brain waves is shown. Major headway in the endeavor is the change of tip top dry active anodes, which are more practical and wearable than the routine wet terminals. The contraption was developed with discrete low power straightforward and modernized facilitated circuits given by Texas Instruments, in perspective of too less power usage. The results got shows that, the contraption performs similar or by a long shot better than the conventional EEG framework.
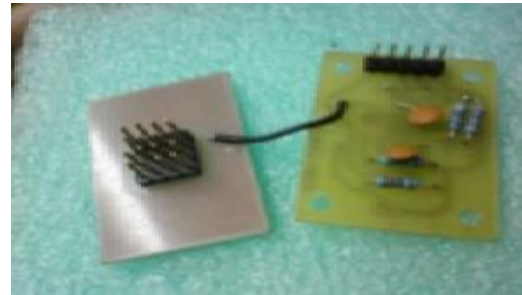

Fig 3 Low power portable EEG for continuous monitoring with active electrodes [2]

Yu Mike Chi, Yu-Te Wang, Yijun Wang [3].Here contactless and dry electroencephalographic (EEG) electrodes, which doesn't require gel to be pasted on the scalp to make the electrode sit on the scalp to acquire the EEG signals, have been considered as an empowering agent of pragmatic, certifiable, brain–computer interface (BCI) stages. This study contrasts wet cathodes with dry and through hair, noncontact terminals inside an unfaltering state visual evoked potential (SSVEP) BCI ideal model. The development of a dry contact terminal, emphasizing fingered contact posts and dynamic buffering hardware is exhibited. Also, the advancement of another, contactless, capacitive terminal that uses an exclusively coordinated, high-impedance front-end is shown. Tests which were made offline was tested on few subjects shows the signal quality from the diverse terminals and show that obtaining of little plentifulness, SSVEP signs is conceivable, indeed, even through hair utilizing the new contactless electrode (sensor). Trails which were made online represents that the data exchange rate (ITR) with the dry anodes is similar to that of wet terminals, totally without the requirement for gel or other conductive media. Also, information from the noncontact terminal, working on the highest point of hair, demonstrate a most extreme ITR in abundance of 19 bits/min at 100% exactness (versus 29.2 bits/min for wet cathodes and 34.4 bits/min for dry terminals), a level that has never been exhibited previously. The consequences of these investigations demonstrate that both dry and noncontact cathodes, with further advancement, may turn into a reasonable device for both future portable BCI and general EEG application. There are several EEG systems are available that are suited for BCI applications. These range from high-end systems like Gtec to lower cost, simpler systems like Emotive, etc.

Fig 4 illustrates different types of electrodes as explained in the survey papers.

Fig 4 Different types of electrodes [14]

Fig 5 shows Gtec electrodes and one of the earliest electrodes were from Gtec

Fig 5 Gtec electrodes [15]

A high resolution multichannel EEG system : Emotiv EPOC which is intended for research applications which gives access to array of EEG information utilizing the Test bench programming and SDK. It uses sequential sampling method and a single ADC, at a rate of 129 SPS.In this system it includes Emotiv EPOC along with 14 EEG channels and 2 references. It uses the international 10-20 electrode location system shown as follows: O2, P8, T8, FC6, F4, F8, AF4 AF3, F7, F3, FC5, T7, P7, O1, with DRL references in the P4 or P3 positions

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Fig 6 Emotive EEG headset [16]

V. ACTIVE EEG ELECTRODE

A. Technical Background

The zone of bio-potential estimation has dependably been a region of exploration in the field of therapeutic gadgets. There have been a ton of papers on expanding the sign to commotion proportion of bio-potential estimations like ECG, EEG, and EMG. Out of these signs EEG is of most reduced voltage in the scope of 1 to 49μV and recurrence extending from 0.5 to 69Hz. Subsequently its extremely hard to get brain waves contrasted with the ECG and EMG signals.

Versatile remote EEG has as of now been produced, however they utilize the traditional wet electrode idea of obtaining the signal. At the same time this is not in the slightest degree practical, in the event that we need to incorporate the gadget with other compact gadgets like PDAs or portable workstation and so on. It's exceptionally bothering for a single person to wear the wet terminal EEG on for quite a while. Therefore to take care of this issue we have turned out with a thought of active anodes.

Wet and dry EEG electrodes are available in Florida research instruments. It includes 16 channel EEG electrodes, arm or leg band , reusable electrodes and several disposable elctrodes in its package.

Brain products have used accurate and fast electrodes in the active electrodes. CapTrak is a light, hand-held scanner furnished with two incorporated cameras and an instinctive, simple to-utilize programming for quick terminal confinement. The framework comes prepared to use out of the case, with a preconfigured PC. CapTrak is good with the actiCAP terminal tops as well as backings all actiCHamp frameworks and is hence the must-have anode confinement framework when working with Brain Products dynamic anodes.

The electronics of the active EEG electrodes includes the Instrumentation amplifier, resistors and capacitors. The proposed solution for developing dry active EEG electrodes was to embed Instrumentation amplifiers along with the gold platted copper electrodes that is normally used for acquiring bio-potential signals like ECG, EEG. In the conventional electrodes, the signal was acquired after scalp preparations, which needed experienced professionals to apply the conductive gel on to the scalp to improve conductivity, hence signal to noise ratio. But it is very uncomfortable for the individual to wear the EEG system for a long time with this conductive gel on scalp. Thus our solution for this problem was to develop an Active electrode, which has amplifiers embedded in it. This provides in place amplification of brain waves hence improves the signal to noise ratio. As the amplifier is used here, hence the signal acquired will be more immune to attenuation and noise interference. Thus high quality shielded cables are not very much necessary as compared to conventional EEG system.

Instrumentation amplifier - An instrumentation (or instrumentational) amplifier is a kind of differential enhancer that has been furnished with information cushion intensifiers, which kill the requirement for data impedance coordinating and subsequently make the amplifier especially suitable for utilization in estimation and test gear. Extra qualities incorporate low DC counterbalance, low float, low clamor, high open-circle increase, high regular mode dismissal degree, and high enter impedances. Instrumentation enhancers are utilized where incredible precision and steadiness of the circuit both short and long haul are needed.

Despite the fact that the instrumentation enhancer is generally indicated schematically indistinguishable to a standard operational intensifier (operation amp), the electronic instrumentation amp is quite often inside made out of 3 operation amps. These are orchestrated so there is one operation amp to cushion every data (+,−), and one to create the coveted yield with sufficient impedance coordinating for the capacitor.

Special Issue - 2015

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
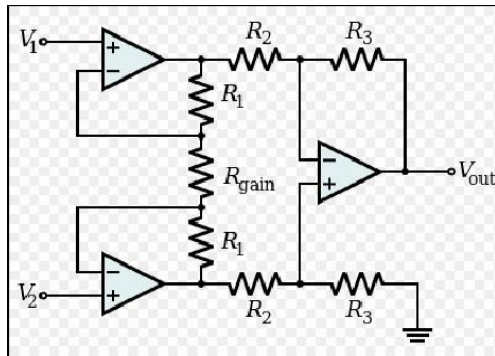**ICESMART-2015 Conference Proceedings**

Fig 7 Instrumentation amplifier [17]

The Instrumentation amplifier which is placed in the electrode has the following advantages which make the active electrode much better than the passive electrodes and with a very low noise which is reduced at the analog front-end.
● LOW OFFSET VOLTAGE
● LOW DRIFT
● LOW INPUT BIAS CURRENT
● HIGH COMMON-MODE REJECTION
● INPUT OVER-VOLTAGE PROTECTION
● WIDE SUPPLY RANGE
● LOW QUIESCENT CURRENT
● 8-PIN PLASTIC AND SOL-16

Applications of Ina114

● BRIDGE AMPLIFIER
● THERMOCOUPLE AMPLIFIER
● RTD SENSOR AMPLIFIER
● MEDICAL INSTRUMENTATION
● DATA ACQUISITION

Resistors are used to set the Gain for the instrumentation amplifier and a couple of decoupling capacitors are also used. Since the diameter of the active electrode is to be maintained around 13mm, thus the number of components is reduced in such a way that it serves the purpose. Fig 6 shows Gtec electrodes and one of the earliest electrodes were from Gtec.

VI. COMPARISION

Table 1 shows the comparative study of passive and active electrodes.

Table 1 Passive and active electrodes

PASSIVE ELECTRODE	ACTIVE ELECTRODE
Does not contain any circuitry	Contains active circuitry
Time consuming part of the circuit is to montage the electrodes on the scalp using the gel	Gel is not required thus not a time consuming process.
It needs wet contact with the scalp.	These are dry electrodes thus there is no wet contact with the scalp
Signal contains noise	Signal contains less noise as it is amplified

VII. CONCLUSION

Active electrodes are being built and tested. This paper presents the novel method of designing the active electrode. It is mainly focused on reducing the area of the active eeg electrode. There is a wide application end to the BCI system:

• Helps the neck down paralysed patients to be independent
• Brain painting
• Extra limb for a healthy human being to control many things
• Military applications
• Clinical applications

Special Issue - 2015

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
ICESMART-2015 Conference Proceedings

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