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Brain Controlled Robotic Vehicle

Authors
Sukrut Ubale, Siddharth Telang, Ranjeet Dargude
Department of Electronics Engineering, Pad. Dr. D.Y.P.I.E.T., University of Pune
Sant Tukaram Nagar, Pimpri,Pune - 411018
Emails:, *sukrutubale22@gmail.com*, *siddharth.telang910@gmail.com*
dranjeet1122@gmail.com

Abstract
Independent mobility is core to being able to perform activities of daily living by oneself. A large number of people who are not comfortable with conventional interfaces, due to various machine dysfunctions, like wiring problems, control inefficiency, etc. The non–invasive brain– computer interfaces (BCIs) offer a promising solution to these problems. The electrical activity of the brain can be monitored in real– time using an array of electrodes, which are placed on the scalp in a process known as Electroencephalography (EEG). In order to bypass the peripheral nervous system, we need to find some reliable correlates in the brain signals that can be mapped to the intention to perform specific actions. Our brain generates different types of signals, having their respective frequency and amplitude. We can control any device by decoding, processing these signals and digitalizing them, which may further be used as actuating commands. The EEG electrodes provide a medium to acquire the Brain Signals. These signals have very low frequency and amplitude (in Hz and µV respectively). For signal conditioning, we design a series of high gain amplifiers and specific filters. The signal can further be digitized can converted into actuating commands.
Keywords—*EEG, brain computer interface, electrodes, fire bird V robot.*

I. INTRODUCTION

The need of new communication channels was strongly felt for the disabled people, who can't move their muscles, can't communicate with the outside world, so that they can also be able to lead an independent life. Thus, the idea is why not to use one's brain to control one's own environment. It is now a proven fact in medical sciences that the blockage of neural pathway between the cognitive part of brain (the signal generator) and the part which has to respond causes paralyses. Though the signals are being generated in most of the cases but somehow or the other are not communicated properly because of disorder[4]. The human brain is always active. The brain controls the different activities of the body. The brain functions can be monitored by observing the electrical signals generated in the neurons. This signal is called electroencephalogram (EEG) signal. The signal can be extracted using electrodes and can be viewed using a voltmeter, oscilloscope or on a computer screen. The EEG signal can be recorded and the phenomenon is known as electroencephalography [5]. The EEG signal can be used to investigate the condition of a human brain and the overall health of the person. These signals are roughly less than 100 µV and 100 Hz and can be measured with electrodes placed on the scalp, noninvasively. The signals can further be amplified and filtered. The analog signal is digitized by ADC's and transmitted and received by xbee protocol. In receiver section we have a robotic vehicle which converts the received signals into actuating commands like Motion, Camera Pod Control and Distance measurement.

II. EEG ACQUISITION

An electroencephalogram (EEG) is a test that measures and records the electrical activity of your brain. EEG measures voltage fluctuations resulting from ionic current flows within the brain. Special sensors (electrodes) are attached to the head and hooked by wires to a computer. The computer records your brain's electrical activity on the screen or on paper as wavy lines. Certain conditions, such as seizures, can be seen by the changes in the normal pattern of the brain's electrical activity.

A. Wired Acquisition

Review Electrodes are used to obtain the EEG signals from the scalp of the human brain. The EEG recording electrodes and their proper function are crucial for acquiring high quality data. For multi-channel recordings with a large number of electrodes, electrode caps are often used. Commonly used scalp electrodes consist of Ag–AgCl disks, less than 3 mm in diameter, with long flexible leads that can be plugged into an amplifier.

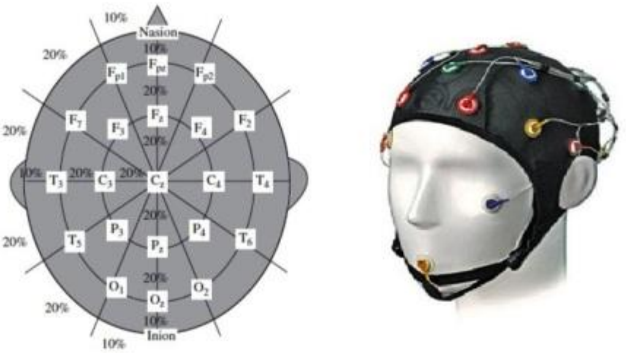

Fig. 1. Conventional 10 - 20 EEG electrode position for the placement of 21 electrodes

Silver chloride (AgCl) is preferred for common neurophysiologic applications. Because Ag is a slightly soluble salt, AgCl quickly saturates and comes to equilibrium. Therefore, Ag is a good metal for metallic skin-surface electrodes. The International Federation of Societies for Electroencephalography and Clinical Neuro-physiology has recommended the conventional electrode setting (also called 10–20) for 21 electrodes (excluding the earlobe electrodes), as depicted in Fig. 1. The "10" and "20" refer to the fact that the actual distances between adjacent electrodes are either 10% or 20% of the total front-back or right-left distance of the skull [5]. For setting a larger number of electrodes using the above conventional system, the rest of the electrodes are placed in between the above electrodes with equidistance between them. For example, C1 is placed between C3 and Cz. Fig. 2 represents a larger setting for 75 electrodes including the reference electrodes based on the guidelines by the American EEG Society. Extra electrodes are sometimes used for the measurement of EOG, ECG, and EMG of the eyelid and eye surrounding muscles. In some applications such as ERP (Event-Related Potentials) analysis and brain computer interfacing a single channel may be used. In such applications, however, the position of the corresponding electrode has to be well determined [6]. For example, C3 and C4 can be used to record the right and left finger movement related signals respectively for brain–computer interfacing (BCI) applications. Also F3, F4, P3 and P4 can be used for recording the ERP P300 signals. In another similar setting, called the Maudsley electrode positioning system, the conventional 10–20 system has been modified to capture better the signals from epileptic foci in epileptic seizure recordings. The only difference between this system and the 10–20 conventional system is that the outer electrodes are slightly lowered to enable better capturing of the required signals. The advantage of this system over the conventional one is that it provides a more extensive coverage of the lower part of the cerebral convexity [5]. Since EEG signal represents voltage difference between two electrodes, one or more electrodes have to be set as reference so that the output voltage can be measured with respect to that reference point. There are various systems of taking reference, most common being the linked ears, which is an average of the voltage of the electrodes attached to either earlobes or mastoids.

B. Wireless Acquisition

The wireless-transmission unit consisted of a wireless module and a micro-controller. It used a Bluetooth module to send the acquired EEG signals to a custom real-time DSP unit described below or a Bluetooth-enable cell phone which was used as a real- time signal-processing unit. The dimension of the wireless transmission circuit was 40 x 25 mm2. Figure 2 shows a picture of the integrated 4- channel wireless EEG system. A reference and a ground channels were also included in the system (not shown). The integrated circuitry can be embedded into a headband, NCTU BCI-headband. The power-consumption of the NCTU BCI-headband is very low (a 1100 mAh Li-ion battery can last over 33 hours).

Fig. 2. A picture of the wearable & wireless EEG system, NCTU BCI-headband. It comprises 4- or 8-channel snap-on electrode holders (plus a reference and a ground channels), miniature bio-amplifier, a bandpass filter, an ADC and a Bluetooth module. All channels were referred to the left mastoid [6].

NeuroSky mindset: The easy to apply EEG device, that is wearable like regular headphones. It has one dry sensor that can be placed on the forehead, left side (approximately equal to Fp1 in the 10-20 system, figure 3). And 3 dry sensors on the left ear, for reference. It has a microchip which pre-process the EEG signal, and transmits that data via bluetooth. The output data is presented in table 5.1. The processing algorithms are not an open protocol, but it does a FFT on the signal which gives the band powers. However, these powers are scaled and filtered and thus only relative to each other (NeuroSky, 2010) [6]. Also, the mindset have speakers, like a headset, and a microphone, so it can be used for multiple tasks.

Fig.3. NeuroSky Mindwave EEG Headset

III. BRAIN COMPUTER INTERFACE

The electrical activity of the brain can be monitored in real– time using an array of electrodes, which are placed on the scalp in a process known as electroencephalography (EEG). In order to bypass the peripheral nervous system, we need to find some reliable correlates in the brain signals that can be mapped to the intention to perform specific actions. A Brain-Computer Interface (BCI) is a system that acquires and analyzes neural signals with the goal of creating a communication channel directly between the brain and the computer. Such a channel potentially has multiple uses [5].

- Bioengineering applications: Assist devices for disabled people.
- Human subject monitoring: Sleep disorders, neurological diseases, attention monitoring, and/or overall ―mental state.
- Neuroscience research: Real-time methods for correlating observable behavior with recorded signals.
- Man – Machine Interaction: Interface devices between human and computers, machines, etc.

The common structure of a Brain Computer Interface is the following:

- Signal acquisition: the eeg signals are obtained from the brain through invasive or non-invasive methods (for example, electrodes). After, the signal is amplified and sampled.
- Signal pre-processing: once the signals are acquired, it is necessary to clean them.
- Signal classification: once the signals are cleaned, they will be processed and

classified to find out which kind of mental task the subject is performing.

Computer interaction: once the signals are classified, they will be used by an appropriate algorithm for the development of a certain application [5].

A. Implementation of BCI

Cerebral electric activity is recorded via the electroencephalogram (EEG): electrodes, attached to the scalp, measure the electric signals of the brain. These signals are amplified and transmitted to the computer, which transforms them into device control commands. The crucial requirement for the successful functioning of the BCI is that the electric activity on the scalp surface already reflects motor intentions, i.e., the neural correlate of preparation for hand or foot movements

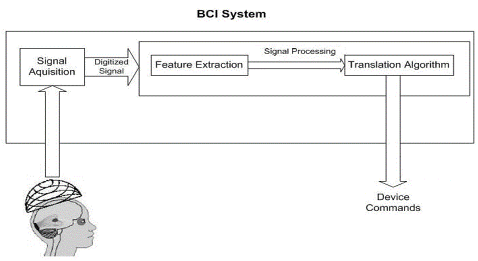

Fig.4. BCI Block Diagram.

The BCI detects the motor-related EEG changes and uses this information, [1] for example, to perform a choice between two alternatives, the detection of the preparation to move the left hand leads to the choice of the first, whereas the right hand intention would lead to the second alternative. By this means it is possible to operate devices which are connected to the computer.

IV. SYSTEM DESIGN

The proposed system design is shown in figure 5. In EEG acquisition system, preamplifier is the most crucial part. EEG signals recorded from the human brain by the placement of electrodes on the surface of the scalp are very small (on the order of a few microvolt's).

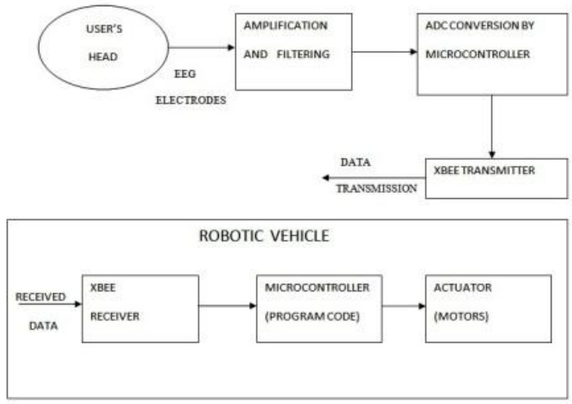

Fig 5. Proposed system design.

Hence, an amplification module is required to amplify these small potentials to an acceptable level. Further, due to the small amplitude, these signals are very susceptible to any interference introduced through body, amplifier, measurement cables and magnetically induction as described in. Moreover, the DC voltage owing to the polarization of electrodes and the noise caused by power supply are also serious in bio-potential measurements. So a signal conditioning circuit is required which is capable of filtering certain high and low frequency components of the input while allowing only the signal in the desired bandwidth to pass. An actual preamplifier should include these parts discussed above, and it is also the foremost unit in an EEG recording system for a purified true EEG signal converted into a digital form. This digitized signal is to be used for further processing to obtain the actuating commands.

A. Signal Acquisition

The EEG electrodes pick up the low amplitude, low frequency Brain Signals. These electrodes can be in a cap like, Band or Headset. The 10-20 electrode cap is the most used one [3]. Figure 6 shows various stages in signal acquisition.

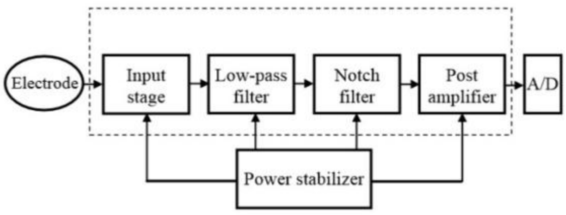

Fig 6. Stages in signal acquisition

The EEG signals are in magnitude of micro-volts. Proper amplification of these signals is required to bring them to such a potential so that they can be processed further. [3] Using Precision Instrumentation Amplifiers the above target can be achieved. High pass filters with a cut-off frequency of usually less than 0.5 Hz are used to remove the disturbing very low frequency components such as those of breathing. On the other hand, high-frequency noise is mitigated by using low pass filters with a cut-off frequency of approximately 50–70 Hz. Notch filters with a null frequency of 50 Hz are often necessary to ensure perfect rejection of the strong 50 Hz power supply . The amplified and filtered signals are analog in form. To be understandable by the Micro-controller, digitizing must be done. ADC conversion is done by either Op-Amp and variable potentiometers or by the inbuilt ADC of the microcontroller.

B. Signal Transmission

The digitized signal is coded by the microcontroller and transmitted by XBee module. XBee modules are embedded solutions providing wireless end-point connectivity to devices. These modules use the IEEE 802.15.4 networking protocol for fast point-to-multipoint or peer-to-peer networking. They are designed for high-throughput applications requiring low latency and predictable communication timing. As per the module used, the range varies from 300 ft to 40 miles.

C. Receiver Section

The receiver section consists of a Robotic Vehicle, having XBee receiver module interfaced. In this project we are using the FireBird V Robot by NEX Robotics. The block diagram of Firebird V is shown in shown in Fig.7

Fire Bird V ATMEGA2560 technical specification

Microcontroller:

Atmel ATMEGA2560 as Master microcontroller (AVR architecture based Microcontroller)

Atmel ATMEGA8 as Slave microcontroller (AVR architecture based Microcontroller)

Sensors:

Three white line sensors (extendable to 7)

Five Sharp GP2Y0A02YK IR range sensor (One in default configuration)

Eight analog IR proximity sensors

Two position encoders (extendable to four)

Battery voltage sensing

Current Sensing (Optional)

Five MaxBotix Ultrasonic Range Sensors (Optional)

Indicators:

2 x 16 Characters LCD

Buzzer and Indicator LEDs

Fig 7. Fire Bird V Robot

Control:

Autonomous Control

PC as Master and Robot as Slave in wired or wireless mode

Communication:

USB Communication

Wired RS232 (serial) communication

Wireless ZigBee Communication (2.4GHZ) (if XBee wireless module is installed)

Wi-Fi communication (if Wi-Fi module is installed)

Bluetooth communication (if Bluetooth wireless module is installed)

Simplex infrared communication (From infrared remote to robot)

Dimensions:

Diameter: 16cm

Height: 8.5cm

Weight: 1100gms

Power:

9.6V Nickel Metal Hydride (NiMH) battery pack and external Auxiliary power from battery charger.

On Board Battery monitoring and intelligent battery charger.

Battery Life:

2 Hours, while motors are operational at 75% of time

Locomotion:

Two DC geared motors in differential drive configuration and caster wheel at front as support

Top Speed: 24 cm / second

Wheel Diameter: 51mm

Position encoder: 30 pulses per revolution

Position encoder resolution: 5.44 mm

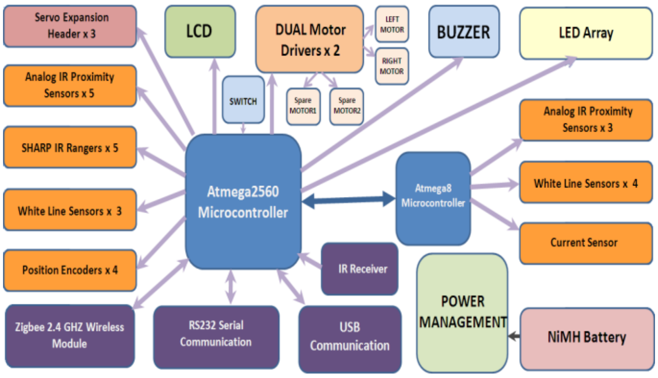

Fig 8. Block Diagram of FireBird V Robot

V. CONCLUSION

Small-signal amplification is always a difficult problem in the field of circuit system design. The presented amplifier module proposes a way for pre-processing EEG signals. More contents about DSPs, electrode optimization, system control and data transmission etc. need to be better discussed in the next stage, and it is believed that all of them will be employed in the BCI system. According to the performance test, the preamplifier described in this paper has great common-mode rejection ratio (CMRR) profiting from the highly symmetrical design of the input stage. The main flaw of this module lies in the noise introduced through the body, measurement cables and the amplifier itself without shielding. To improve this preamplifier, there are several approaches, such as modifying the low-pass filter design, adopting shielding measures. A notch filter can be used to eliminate the 50 Hz power supply noise. The device is used to acquire data for different activities with different subjects. In further stages this data will be analyzed using particular processing software. for example MATLAB, EEGLAB, BCI2000 etc. In this project we wll be using the robotic research platfom FireBird V Robot, having ir sensors, lcd, buzzer, white line sensors, position and shaft encoders, servo pod and XBee module inerfaced; easy to program and run.

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