Prosthetic Arm and Arm Strap and Control for Paralysed People and Arm Amputees

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***Abstract*— This paper focuses on the design of a prosthetic arm (a forearm robotic arm as well as a complete robotic arm) using switches and thoughts to control them. Switch control is done by embedding switches and toggling them accordingly. The key of thought control lies in the mapping of the EEG signal of the subject to the 2D cursor through signal processing to achieve the objective. We designed low cost and reliable devices for switch control as well as thought control. The advantages of the design are (i) cost prohibitive and reliability (ii) attains a high-resolution EEG signal after transmission for signal processing. (iii) its universal usability irrespective of their age and social status.**

***Key words*—Bionic arm, thought control, EEG, 2D.**

I. Introduction

India stands second in terms of population next to China with a count of 120 million people. Out of them 21 million are physically disabled which mostly include limb amputees, paralysis patients etc. This is one of the major problems our country is facing. According to the Indian census, the disability rate (number of disabled per I lakh population) of the country as a whole turns out to be 2130. It is a pity that at least 20 percent of people living below the poverty line have some kind of disability. So there is a need of device which is of low cost and can be accessed by all classes of people and help them lead a self-dependent life.

Brain Computer Interface (BCI) is a direct interface connecting human brain to a computer. BCI techniques are broadly divided into invasive and non-invasive techniques. Non-invasive BCI is a rapidly growing field where there is a lot of progress being done in research. Nowadays, non-invasive BCI techniques are constantly dragging people's attention over invasive BCI techniques. The reason behind this is, over decades it's been believed that invasive methods with electrodes planted in the brain alone could restore people with more complex disabilities. These include providing control over a robotic arm for limb amputees, navigating the wheel chair for paralyzed, Spondylitis victims etc. But, with the demonstration of 2D and 3D cursor control using electroencephalography (EEG) , a non – invasive BCI technique, pulled up the attention of the researchers all over the world, giving them a hope on the efficiency of the tool.

There are various non-invasive BCI techniques such as EEG, Electro-Oculography (ECoG) etc. EEG technique uses an electrode cap that is placed on the user's scalp for the acquisition of the EEG signal, which relates the scalp potential differences to various complex actions. Classification of the EEG signal has been made into several bands like alpha, beta, delta, theta and mu suppression, each corresponding to various states of being like relaxing, ranging over 8-14 Hz; concentrating, ranging over 13-30 Hz; deep sleep, from 0-4 Hz; meditating from 4-8 Hz; moving your hands or legs or just by imagining these motor actions respectively. As it is being non-invasive in nature, it has an advantage over traditional BMI, not being hazardous to health. With the advent of technology the EEG acquisition devices are made more compact, handy and wireless.

This paper is divided into 3 phases.
Phase1:-A switch controlled Robotic forearm, where input to the arm is driven from switches.
Phase2:-A thought controlled Robotic forearm, where input to the arm are EEG signals.
Phase3:- An EEG Acquisition Device for A Thought Controlled Robotic Arm (complete arm).

II. Problem Statement

Arms play an important role in day to day life of every individual. Even the basic needs like brushing, bathing, writing, typing, feasting to playing games etc., become Herculean tasks without arms. It is these arms that make us different from other animals. Soldiers, who have lost their arms in war, limb amputees and paralysed people, who lost their control over limbs, are cursed for the rest of their lives, finding it difficult to meet their daily needs. The disabled needs an escort throughout, which is practically impossible. The two major problems which we are concerned about are

Problem-1
Amputees and paralysed people, who lost their control over limbs, are unable to meet their daily activities.

Problem-2
People who have lost their arms completely suffer for their entire life.

III. Related Works

The paper cited in [2] presents how to control a cursor in 2D using EEG based brain computer interface. The movements of the cursor on the computer screen are controlled based on the EEG scalp potentials. The EEG signal is mapped from the user head to the 2D cursor control. The horizontal motion is based on the mu beta rhythm and vertical motion is based on P300 potential respectively. The user can move the cursor horizontally to the right just by imagining his right hand motion and the same way the left hand motion imagination is mapped to move the cursor left. The user can move the cursor vertically upwards by focusing on one of the three UP buttons on the monitor and similarly downwards by focusing on the either of the three DOWN buttons.

The study cited in [3] focus on the target selection of BCI 2D cursor using hybrid feature. As in most of the applications, 2D cursor control is used as a sequential control, which involves cursor control and target selection. The paper focuses on the latter, the target selection of the cursor using a hybrid feature from P300 potential and motor imagery. It has got an advantage of better performance compared to others, especially in case of subjects with poor performance.

IV. System Design

Phase-1 A switch controlled Robotic forearm, where input to the arm is controlled by switches.

Description

The Prosthetic forearm is made of lighter materials and plastics.It is placed over the forearm as shown in Fig.1a. It works based on the rotation of servo motor which is attached in between thumb finger and the remaining four fingers. The high-torque standard servo we used can rotate approximately 180 degrees. This servo is interfaced with an Arduino development board. Two switches are embedded so as to control the arm. A Peizo sensor which works on the pressure variations is attached to the front portion of the index finger.

Fig.1a. Prosthetic arm with a servo motor placed on forearm.

Working

Two Push button switches (switch-1 and switch-2) which are controlled by the user are placed on his foot wares. The switches which are connected on the left side and right side are used to start and reset the rotation of the servo respectively. In the prototype of prosthetic arm, the thumb is the only area which is flexible and remaining fingers are fixed. It is controlled by the servo motor by rotating it from the initial position to the required position till it reaches the object. The amount of rotation is based on the size of the object. When the switch on the left side is turned ON, the servo motor stars running as a result the thumb starts running and the moment it comes in contact with the object, it moves along with the thumb. This causes a slight displacement in the object's position to the extreme end where peizo sensor is placed. So a pressure is exerted on the sensor and it is given a threshold value (say 10).The input from the sensor is fed back to the microcontroller and the motor is stopped there by halting the thumb movement. Now the arm is able to hold any object.

When the switch on the right side is turned ON the motor rotates in the opposite direction and comes back to the original position. The working of the entire setup is shown in Fig.1b.

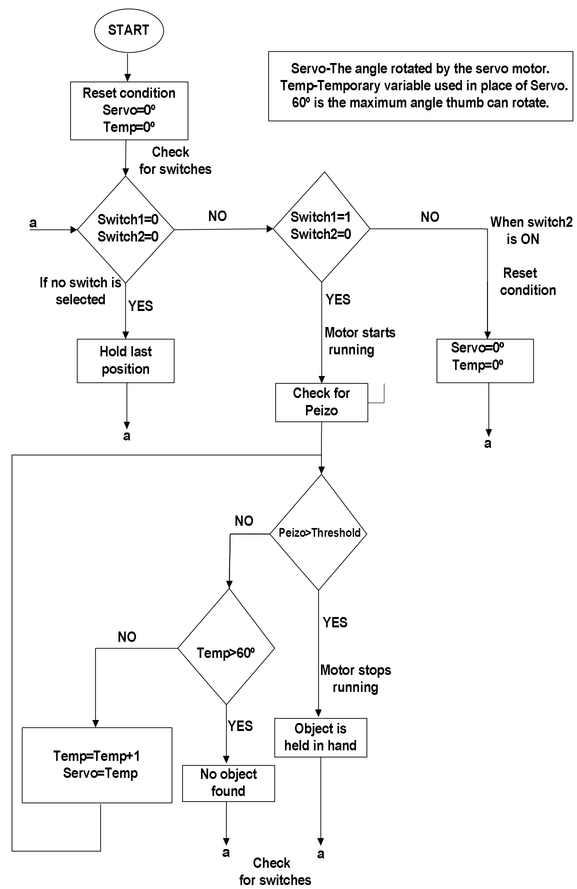

Fig.1b.Algorithm Flow chart of Phase -1.

Phase2:- A thought controlled Robotic forearm, where input to the arm are EEG signals.

This system is brodly divided into three blocks as shown in Fig.1, EEG signal acquisition, signal transmission and signal processing, each aiming at acquisition of the EEG signal from user scalp. EEG scalp potentials are amplified, digitized and transmitted to a PC that processes to map them to a 2D cursor control.

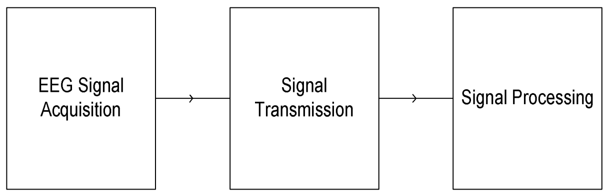

Fig.1. Schematic Outlining Various Stages Involved

EEG Signal Acquisition

This stage primarily targets at the careful extraction of the EEG signal from the user scalp. It is made up of different blocks such as instrumentation amplifier, operational amplifier, high pass, low pass and notch filters. The purpose of the instrumentation amplifier is to extract the EEG signal. The extracted EEG signal is passed through the operational amplifier block for proper amplification, as shown in Fig.2. It is then, passed through the high pass, low pass and notch filters. The high pass filter, removes the noise in the signal. Low pass filter extracts the signal frequencies of interest. As DC power supplies are used, one common problem to encounter is the 60 Hz power line signal. This 60 Hz power line signal will distort the EEG scalp potentials. Integration of a notch filter will filter out this undesirable power line signal.

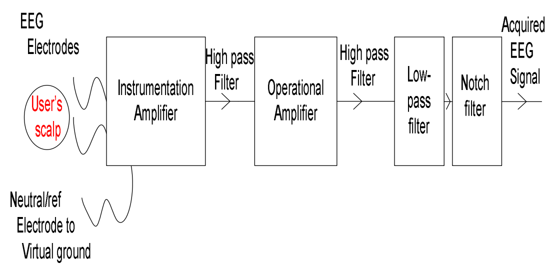

Fig.2.Schematic outlining various stages involved in signal acquisition stage.

Signal Transmission

This stage focuses on the transmission of the acquired EEG signal to a PC. It consists of 12-bit A/D converter for digitizing the EEG signal. The ATMega 644 microcontroller is used for UART transmission. This microcontroller is having a 10-bit A/D converter peripheral, which cannot be used because of lesser resolutions. That is the reason we are using an external 12-bit A/D converter. The FTDI USB RS232 is an opto-coupler used for electrical isolation to prevent electrical hazards during the transmission of the digitized EEG signal to a PC as shown in Fig.3. It is also used for converting the RS232 signals to USB signals so that this setup can be interfaced to a laptop or PC.

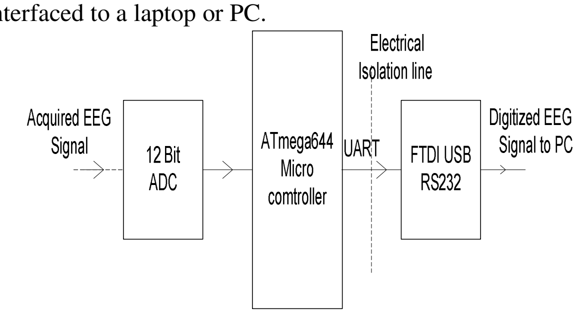

Fig.3.Schematic outlining various stages involved in signal transmission.

Signal Processing

In this stage, the EEG signal gets processed in the MATLAB and is used for controlling a 2D cursor on the GUI as shown in Fig .4.

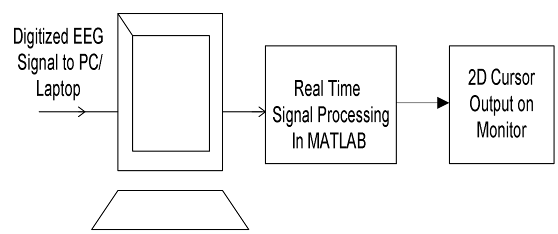

Fig.4.Stages involved in EEG signal processing for cursor control.

Phase3:- An EEG Acquisition Device for A Thought Controlled Robotic Arm .
This phase is identical to Phase-2 with the forearm replaced by a complete arm. More servo motors are used to increase the degrees of freedom of the arm there by increasing the ways in which the arm can move.

IV. Experiment

The simulation of the EEG amplifier in phase2 is done using Multisim Simulation tool. The EEG Amplifier, shown in Fig.5 is designed based on the circuit shown in [1]. It consists of an instrumentation amplifier, operational amplifier and a voltage follower with a virtual ground set up. The gain of instrumentation amplifier is given by G = (49.4kohm/Rg) + 1. It is calibrated to have a gain of about 23 (using Rg = R1). The gain of the operational amplifier, used for post amplification purpose, is given by (-R2/R1). It is designed to have a gain of around 65 (using R2 and R3). Thus the overall circuit gain is about 1500, approximately. Two First Order high pass filters are integrated; one each after instrumentation amplifier and operational Amplifier (OP-AMP). A first order low pass filter is integrated along with the operational amplifier.

We have used AD620 as an instrumentation amplifier; it is used for pre amplification purpose, with a nominal gain of about 23. This stage of amplification is mainly aimed at the EEG signal extraction, whose value ranges in microvolts, without being distorted. The instrumentation amplifier provides high input impedance to the EEG electrodes. The idea behind infinite input impedance is to assure zero attenuation of EEG signal across electrodes. The voltage follower along with a virtual ground set up with CA3140 collectively known as virtual ground. Virtual ground is

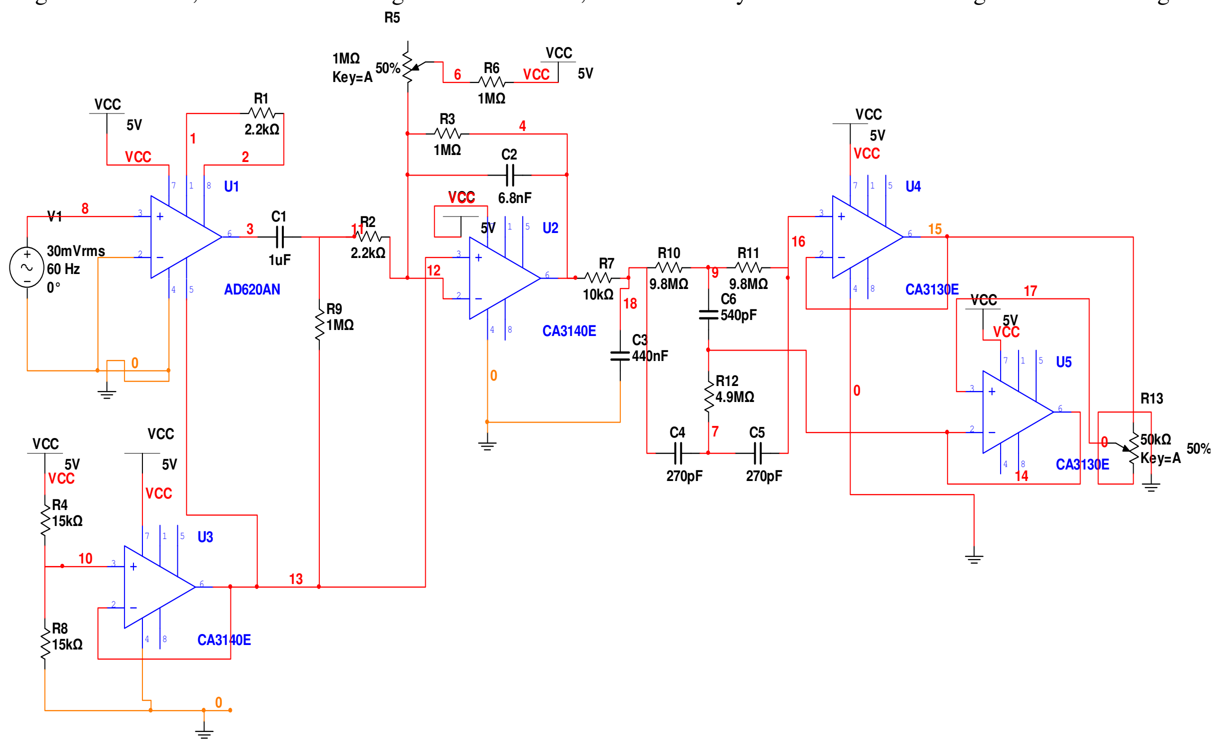

Fig.5.Schematic of the circuit simulated in the Multisim.

coupled with the instrumentation amplifier to provide a DC offset. Virtual grounds are used to cope up with the problem of dual power supplies. The DC offset provided by the virtual ground to the pre amplification stage is treated as the reference with respect to which the single power supply is seen as a dual power supply.

CA3140 is used as an OP-AMP, for post amplification purposes, with an approximate gain of around 65. This stage of amplification is aimed at maximum gain. A high pass filter is coupled in between pre and post amplification stages and another is coupled after post amplification stage, both with a cut-off 0.13 Hz. Each of these high pass filters prevents the low frequency noise being carried to the later stage. EEG signals of interest range to a maximum of 48 Hz. A low pass filter with a bandwidth of 48 Hz is integrated along with the OP-AMP to extract the frequencies of interest.

The next part of the simulation involves the Proteus simulation tool for building and testing the microcontroller part of the system as show in Fig. 3. The circuit shown in the Fig.8 is the simulation schematics of the microcontroller for ADC conversion and UART transmission. ATmega 644 is the microcontroller used. It is a 8-bit Atmel Microcontroller with 64K Bytes In-System Programmable Flash and 10-bit ADC. For simulation purpose, we used the internal A/D peripheral block instead of an external 12-bit ADC. The input sine wave is given through analog pin A1 and expected output is taken through digital pin D1. The digital output is verified through the Oscilloscope, which is connected to the microcontroller as shown in the Fig. 6.

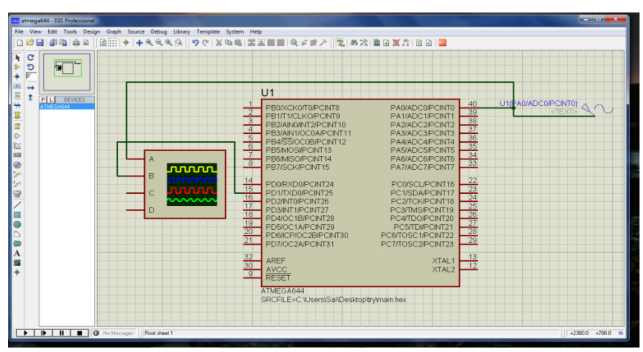

Fig.6.shcematic of the circuit simulated for UART transmssion.

V. Results

After a series of trails with the prosthethic arm used in phase1,we could finally make the arm hold the objects.The prosthetic arm holding an arm is shown in the figure(7)

The bode plots of the amplifier setup in phase2 are shown in figures 8a and 8b. These plots show the frequency response of the circuit in Fig.5, with its lower cut-off, 4Hz and upper cut-off, 48Hz. Frequencies in between lower and upper cut-off refer to the pass band of the amplifier. Frequencies outside the pass band got a gain less than one third of the maximum gain, 1500, of the amplifier. A maximum gain of about 1500 is observed for central frequencies of the pass band. Figure 8a shows the plot without the notch filter. The small lobe on the right side of the bode plot in Fig. 8b, refers to the 60Hz notch of the notch filter.

Fig.7. Arm holding an object and circuit setup

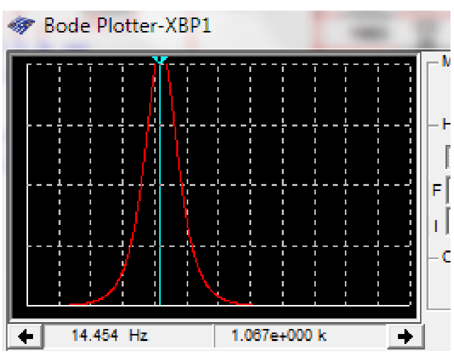

Fig.8a. Frequency response of the amplifier, without notch filter.

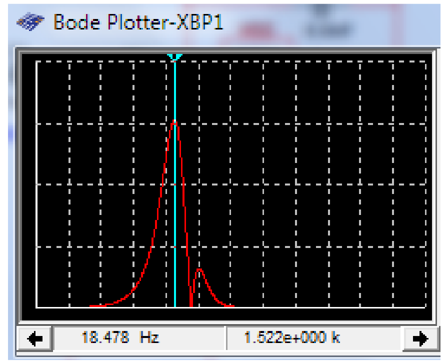

Fig.8b. Frequency response of the amplifier, with the notch filter.

The waveforms (1) and (2) shown in Fig.9a are the input and output waveforms of the first stage of amplification in the circuit shown earlier in Fig. 5. For an input signal (1) of a frequency well within the pass band of the amplifier, the output signal after first stage of amplification is observed to have a gain of about 23. This output waveform is observed with a dc offset of 2.5 volts. The (3) and (4) output waveforms shown in Fig. 9b are the input and output waveforms of the post amplification stage of the same circuit. For an input waveform (3) within the pass band frequency along with a DC offset, the post amplification stage is observed to have a gain of around 65. This output waveform is observed with a dc offset of 2.5 volts. The overall circuit gain is around 1500 approximately.

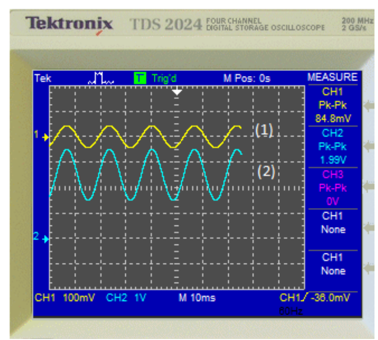

Fig. 9a. Output waveform after first stage of amplification.

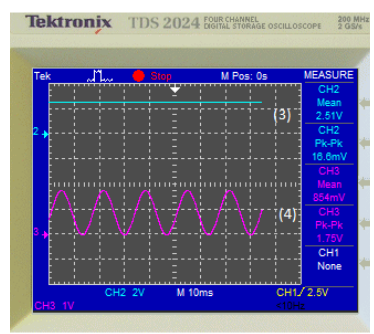

Fig. 9b. Output waveform after second stage of amplification.

The resulting waveform of the UART transmission simulation using the ATmega microcontroller in Proteus is shown in the Fig. 10. This is the 10-bit digital data output of the ADC module inside the microcontroller.

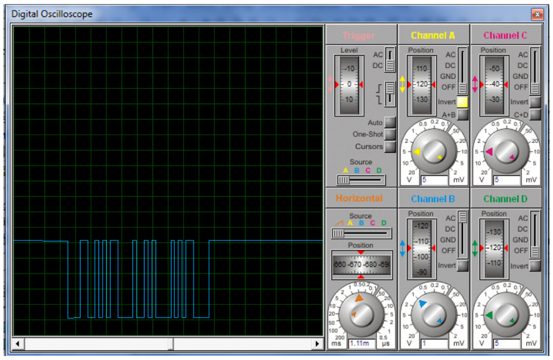

Fig.10.Output waveform of the UART Transmission.

VI. Conclusion

This paper explains about hardware implementation of the switch control and EEG acquisition setup. Phase2 and Phase3 is done in three stages which is experimented and the obtained results are also explained. The cost of the entire setup is around $60(Phase-1:$10,Phase-2:$20,Phase-3:$30), which is very cheap compared to the existing devices. A single channel amplifier is used to extract the EEG signals. The signals are generated to control a bionic arm, which is still under construction.

VII. FUTURE WORKS

1)Interfacing RF module in Phase1.

2)Thought Controlled wheel chair with EEG Acquisition setup

3)Placing few more servo motors to increase the degress of freedom of the arm in Phase-3

VIII. Acknowledgment

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