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EEG Radio Telemetry

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ABSTRACT
EEG (Electroencephalograph) is the recording of brain electrical activity. It has numerous diagnostic and research application in the study of brain. The main objective of the project is to build a telemetry system for EEG. Multichannel EEG instrumentation can be prohibitively expensive for research purpose. The purpose of the study is to design and implement a cost effective Arduino-based EEG amplifier system and transmit the EEG through radio transceiver. The project consists of two phases. The first phase consists of designing the EEG amplifier using IC INA118 due to its cost efficiency and Medical applications. The second phase is designing a telemetry system using radio frequency waves which would transmit and receive up to one kilometer. ARDUINO MEGA 2560 is used for analog to digital conversions. Thus EEG digitalized output can be transmitted wirelessly.

I. INTRODUCTION

This tells that EEG is the recording of the electrical activity of brain. It is a bio potential product and if properly recorded can prove very useful in diagnostic as well as research applications. Such application may include brain-machine interface, cognitive studies, sleep research and detection of certain conditions such as Epilepsy, Parkinson disease etc. Neurons are electrically charged by membrane transport proteins that pump ions across their membranes. When the wave of ions reaches the electrodes on the scalp, they can push or pull electrons on the metal of the electrodes. push or pull difference measured as voltage across time is measured. The recording of this potential is called Electroencephalogram. The frequency range of EEG is 0.4HZ to 50HZ.

"Improvement of EEG signal acquisition: An electrical aspect at the front end.(Department of Technical Sciences, The NCO Academy, 10100 Balikesir, Turkey)"- EEG electrode principles and main points of electronic noise reduction methods in EEG signal acquisition front end are discussed, and some suggestions for improving signal acquisition are presented.

"EEG signals and wireless transfer of EEG signals(Md Belal Bin Heyat, Shaguftah, Yassir. M. Hasan,et.al)"-
Electroencephalogram data transmitted through radio signals and no wires were used.

"Wireless Transmission of Real Time Electrocardiogram (ECG) Signals through Radio Frequency (RF)
Waves.(D.Sridhar raja Asst. Professor, Bharath University)"-
Radio frequency waves are used for transmitting the eeg signal acquired and the range of transmission is about 300 m.

"Biomedical signal transceivers. (Reza Fazel-Rezai, Noah Root, Ahmed Rabbi,"- Basic design of the biomedical transceivers and some of the design issues.

"Design of single channel portable EEG signal acquisition system for brain computer interface application. (Amlan Jyothi Bhagawati and Riku Chutia, et.al)"- Design of EEG signal acquisition device for brain computer interface.

II. USES OF EEG

1) CLINICAL USE

- Distinguish epileptic and non-epileptic seizures, syncope (fainting) , and sub-cortical movement disorders.
- To serve as an adjunct test of brain death.
- To determine whether to use anti-epileptic medications.

2) RESEARCH USE

- Cognitive science, cognitive psychology, neuro-linguistics and psycho physiological research.

III. RECORDINGS OF EEG

Various challenges are faced during the recording of EEG which complicates the design of the amplifier as these signals produce noise from external sources such as power lines and noise that is originating from the body.EEG recording systems consists of i)electrodes and conductive gel.
ii)amplifiers with filters
iii)A/D converter.
iv)recording device.
For accurate interpretation of EEG ,it is important to obtain a low noise signal free from artifacts and other factors that affect the performance of the amplifier circuit impedance, offset voltage and noise contribution due to electrode skin interface.
The amplifier design is described in the paper includes an instrumentation amplifier INA118 , band pass filter with low pass filter with cut off frequency of 33Hz and high pass filter with cut off frequency of 0.5Hz for noise reduction and non-inverting amplifier for increasing gain of the amplifier.

IV. DESIGN CONSIDERATIONS

A .Effects of interference

Interference can be caused due to several sources in an instrumentation amplifier. It may be due to the current through the body, currents into the amplifier, currents through moment cable and magnetically induced interference between the amplifier and the cellular phones. Interference can be produced by the capacitance between the subject through power line and the earth. This causes interference currents flow through the body which can be picked up by the bio potential electrode . Interference can also cause by capacitance between the common amplifier and the power supply. Finally interference may also be caused due to other signals like ECG and EMG.

B. Amplifier requirements

An instrumentation amplifier is usually used for the recording of all bioelectric signals including EEG, ECG, EMG . It is a version of differential amplifier with certain special requirements
(1 Fixed differential gain
(2)High input impedance
(3)low output impedance
(4)high gain
(5)High common mode rejection ratio(CMRR)
(6)Low differential noise
(7)minimum input voltage(1μV)
(8)output voltage(0-4V)
(8)common mode input range(>200 mV)
(9)banwidth(1-50 Hz)
The major requirement of instrumentation amplifier used for biomedical application is to acquire tiny signals with larger common mode and dc voltage. Unity gain differential could limit the common mode range of the amplifier which causes the input to saturate with signal induced from external power lines. Hence there is a need to increase common mode range of the amplifier design.

V. BLOCK DIAGRAM

The components of the system can be seen in the block diagram shown in figure 1.1.

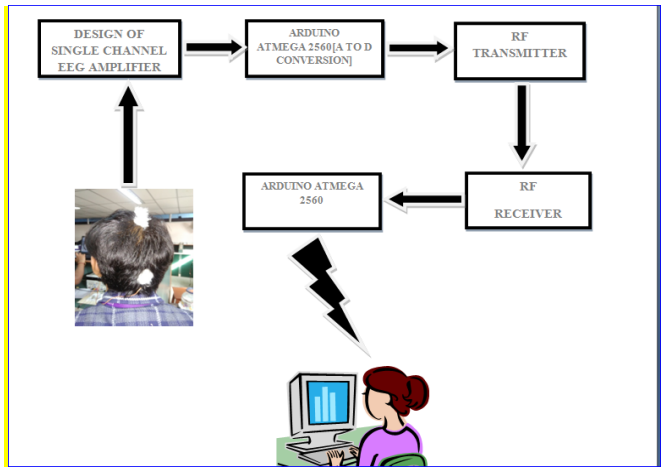

Figure 1.1. General Block Diagram

The overall process is shown in the form of block diagram in figure 1.1. The EEG activity is picked up with the help of scalp electrodes that is placed on the patient's scalp. This signal has to be amplified for removing the noise present in it. The signal is given to Arduino which does the process of analog to digital conversion. This is given to RF transmitter which transmits it to the receiver. On the receiver side, another Arduino is used and the final digitalized output is viewed on a computer or PC.

VI. DESIGN OF THE SYSTEM

The overall design of amplifier is shown in figure 1.2.

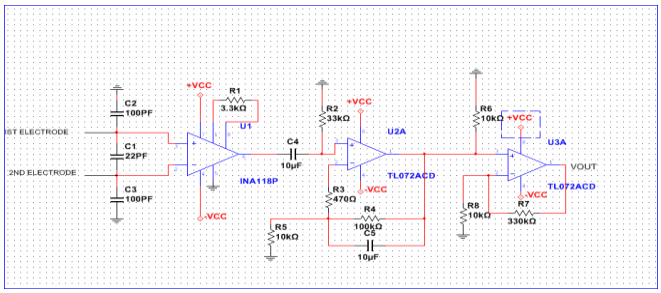

Figure 1.2. Overall Design of the Amplifier

The design of the amplifier consists of three stages:

- Instrumentation amplifier
- Band pass filter
- Non-inverting amplifier

A. INTRUMENTATION AMPLIFIER

The instrumentation amplifier is acting as a front end for the designed EEG signal acquisition system. The schematic diagram is available in figure4.2. The INA 118P 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. It is a high precision, low-power, general purpose instrumentation amplifier offering excellent accuracy. The device is versatile, 3 op-amp design and small size make it ideal for a wide range of applications. It has a low offset voltage (50µV), drift (0.5µV/℃), and high common mode rejection (110 db at G=100 db). It operates with power supplies as low as ± 1.35 V to ± 18 V, and quiescent current is only 350µV.The gain of the particular instrumentation amplifier can be calculated by:

[G = 1+ 50K_/RG]

Where, RG is the external resistor. Here, RG = 3.3 K. Hence, the gain of the amplifier is set with 16.

The simplified schematic of the instrumentation amplifier

INA 118 with 3 op-amp design is given in figure 1.3.

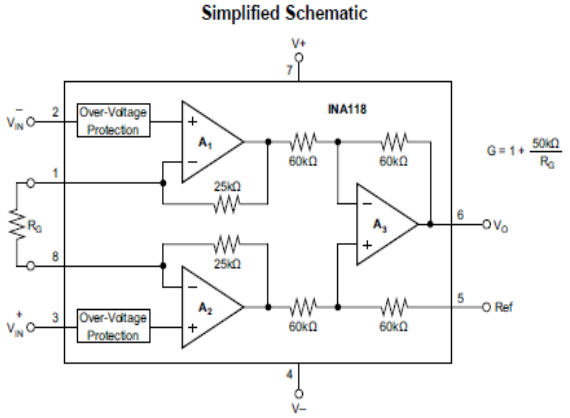

Figure 1.3. Schematic of INA 118

B. BAND PASS FILTER

The acquired raw EEG signal is consists of both low frequency noises as well as high frequency noises. In order to overcome from these noises a proper band pass filter has to be designed. It consists of both high pass filter and low pass filter .The TL072 low noise JFET- input operational amplifier is used for the design of band pass filter because of its low power consumption, low noise and its main usage in medical applications. The high pass filter is designed with a cutoff frequency of 0.5 Hz which helps in removing the baseline drifting, which is created by low frequency noise.

The low pass filter with cutoff frequency of 33 Hz to remove any high frequency noises. The gain of this stage is set as 11. The cutoff frequency is calculated by:

$$F_c=1 / 2\Pi RC$$

The gain is calculated as :

$$Gain=1+R_f /R_{in} =1+100K /10K$$
$$=11.$$

Hence, the gain of this stage is set with 11.

C. NON-INVERTING AMPLIFIER

A amplifier is said to be non-inverting if the input signal is given to the non-inverting input and output is directly given to the inverting input. This circuit is added for post amplification purpose and to reduce the noise of the acquired EEG signal. 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 34 times of the filtered EEG signal. The gain of the non – inverting amplifier can be calculated by using equation:

$$G = 1+ R_f / R_{in}$$

D. ANALOG TO DIGITAL CONVERSION AND EEG ACQUISITION

After designing the complete EEG amplifier system and implementing it to PCB (printed circuit board), the next step is acquisition of the EEG signal. ARDUINO mega 2560 is used for analog into digital conversion and data acquisition has been done by interfacing Lab VIEW with ARDUINO MEGA 2560. For the EEG data acquisition, electrodes are to be placed on the central region(C_z), occipital region(O_z), and ear lobe(A_1 or A_2). For the single channel data acquisition process, positive electrode is placed on the occipital (O_Z) position, reference electrode is placed (A_1 or A_2) position and negative electrode on the central (C_z) position. The positions are determined according to the international 10-20 electrode system.

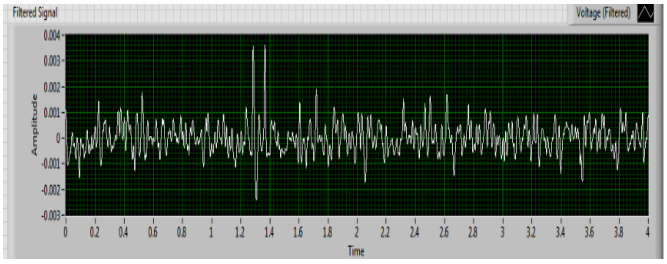

Figure 1.4. EEG Signal Acquisition

Figure 1.5 shows the testing of the amplifier.

Figure 1.5. During Acquisition

VII. RADIO TRANSCIEVER

A. RADIO FREQUENCY MODULE

A wireless radio frequency (RF) module is a small electronic device used to transmit and receive radio signals between two devices. RF modules are the medium of choice in many applications because it does not require the line of sight. Wireless transmission can be done by using 433MHz RF transmitter and receiver modules. In these modules digital data is represented by different amplitude of the carrier wave ,hence this modulation is known as Amplitude shift keying(ASK). Radio Frequency (RF) transmission is more strong and reliable than Infrared (IR) transmission due to following reasons:

- Radio Frequency signals can travel longer distances than Infrared.
- Only line of sight communication is possible through Infrared while radio frequency signals can be transmitted even when there is obstacles.
- Infrared signals will get interfered by other IR sources but signals on one frequency band in RF will not interfered by other frequency RF signals

RF TRANSMITTER

Figure 1.5. Transmitter

An RF transmitter module is a small PCB sub-assembly capable of transmitting a wave and modulating that wave . Transmitter modules are usually implemented alongside a micro controller which will provide data to the module which can be transmitted. Some of its features are:

1. Product Model: MX-FS-03V
2. Launch Distance: 20-200 meters (different voltage, different results)
3. Operating voltage:3.5-12V
4. Dimensions : 19*19mm
5. Operating mode : AM
6. Transferrate : less than 10kbps
7. Transmitting power : 25Mw
8. Transmitting frequency : 315MHz
9. An external antenna : 25cm ordinary multi-core or single-core line
10. Pin out from left to right: (DATA; VCC; GND)

B. RF RECIEVER

An RF receiver module receives the modulated RF signal, and demodulates it.

Figure 1.6. Reciever

Some of the features of the reciever are :

1. Product Model: MX-05V
2. Operating voltage: DC5V
3. Quiescent Current: 4mA
4. transmitting velocity: <9.6 kbps
5. Receiving frequency:315Mhz
6. Receiver sensitivity:-105DB
7. Size: 30 * 14 * 7mm

VIII. ARDUINO

Arduino is an open source, computer software and hardware company that designs and manufactures microcontroller kits for building interactive objects and digital devices.

It is such a board that contains

1. Microcontroller,
2. Typical an 8-bit AVR such as the Atmega8, Atmega168, Atmega328, Atmega1280, and Atmega2560
3. Plus power supplies, crystal oscillator female headers to interface with various peripheral boards.
4. Analog and digital pins.

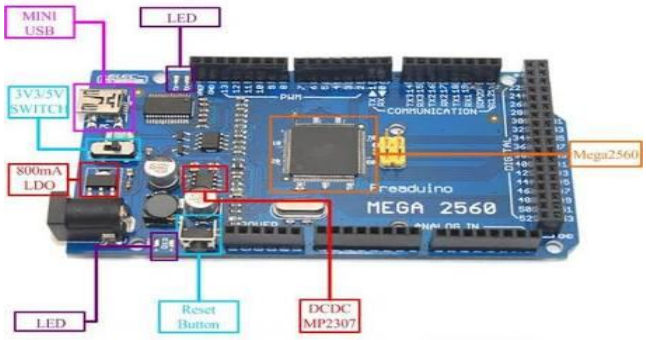

Figure 1.7. Arduino Mega 2560

A. ARDUINO TO TRANSMITTER

VCC – 5V

DATA – D12 PIN OF ARDUINO

GROUND - GROUND

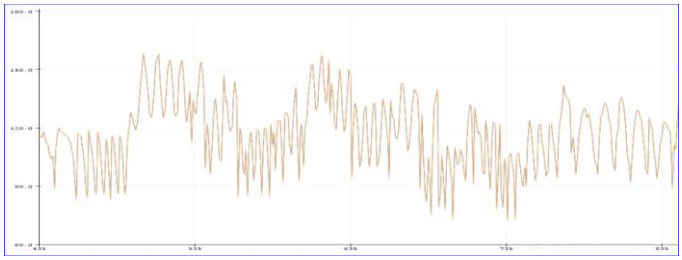

Figure 1.8. EEG Signal at the Transmitter

B. ARDUINO TO RECIEVER

VCC – 5V OR 3V
DATA – D11 PIN OF ARDUINO
GROUND – GROUND

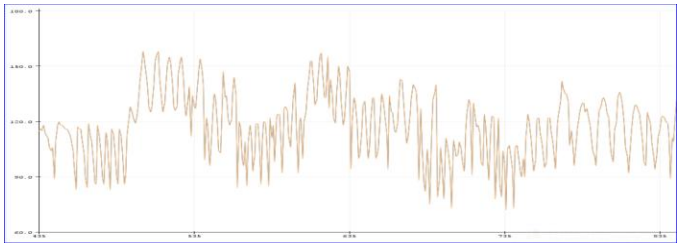

Figure 1.9. EEG Signal At The Reciever

IX.CONCLUSION AND FUTURE WORK

In this project, scalp electrodes are used to obtain the real time EEG signal from the human body. Signal is collected with the help of instrumentation amplifier(INA118). It is used to amplify so that desired gain can be achieved signal is transmitted through (RF) wave at 2.4GHz.Range of transmission is around one kilometer that means the receiver can receive the signal within this range. Further, we can use 2 active electrodes or 8 active electrodes to get more accurate results. By using RF transmitter with more range of transmission, we can transmit EEG signal at desired distance. Output can be interfaced with the computer for automatic recording and interpretation. Thus, with the help of this system, we can transmit other biological signals like ECG and EMG.

The transmission can be carried out by using other technologies such as

- Zigbee
- Bluetooth
- Internet of things
- GSM modem
- Wi-Fi
- Wireless router
- Optical wireless communication

In future, the project can be developed by implementing this design in a cap like structure for recording of EEG for patients with epilepsy. This cap can be worn by them at any time. The EEG signal thus picked up after A to D conversion is sent wirelessly to the doctor's phone or computer. When the seizure like activity is detected, an alarm rings in the phone.

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