Design of an ElectroEncephaloGram (EEG) Amplification Circuit for Neonates

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***Abstract*—The overall objective of this paper is to design a module for Electroencephalogram (EEG) amplification for the neonates.EEG refers to the recording of the electrical activity of the brain. EEG can be recorded from the human brain by the placement of the electrodes on the surface of the scalp but the signals produced by the brain are in the order of micro volts. Moreover, noise and artifacts in the circuit induced by motion, cables etc. does not allow for accurate analysis of the EEG signals. This calls for proper amplification and filtering of the signals. The circuit is built with an instrumentation amplifier, low pass filters, high pass filters and operational amplifiers. The amplified and filtered EEG waveform is of great significance as it allows doctors to study and analyze brain activity of the neonates and help diagnose brain disorders at an early stage itself. The circuit for EEG amplification and signal processing was successfully simulated on Multisim and verified with the necessary hardware components.**

***Index Terms*—Amplification, Electroencephalogram, Instrumentation amplifier, Neonates**

I. INTRODUCTION

According to National Commission on Macroeconomics and Health in 2014, nearly 20% of India's population suffers from brain disorders. EEG acquisition and analysis, of neonates, will help understand their brain functions at an early stage, diagnose abnormalities and find techniques that will help in early diagnosis and treatment of disorders and further increase the scope for research and development in the medical domain. The Electroencephalogram is the recording of the electrical activity of the brain. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain. Diagnostic applications generally focus on the spectral content of EEG, that is, the type of neural oscillations that can be observed in EEG signals [1]-[3].

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The EEG frequency ranges are classified as:
1) Delta: It has a frequency of 3 Hz or below.
2) Theta: It has a frequency of 3.5 to 7.5 Hz and is classified as "slow" activity. It is generally present in children up to 13 years and in sleep but abnormal in awake adults.
3) Alpha: It has a frequency between 7.5 and 13 Hz
4) Beta: It has a frequency of 14 and greater Hz.
In new-borns, the predominant waves are delta waves of frequency 0.5-2Hz. The signals obtained from the electrode leads are about 1μV to 100μV range which are of very low amplitude range and hence are very difficult to analyze these signals. They have to be appropriately amplified so as to perform analysis. Hence the gain of the amplifier should be around 5000 to 10,000 to get an amplified wave for EEG analysis.
In neonates (infant in the first 28 days after birth) the clinical examination of cerebral function is often difficult to perform. An incubator, monitoring equipment, ventilator and indwelling lines may interfere with proper observation of the neonate. Many children need medication with effects on the central or peripheral nervous system such as sedatives and neuromuscular blocking agents which hamper examination. Clinical phenomena, in particular epileptic manifestations, are often subtle and may easily escape notice to the observing eye. The EEG has proven to be an efficient adjunct to clinical assessment of cerebral function in neonates[4]. Furthermore, the EEG has prognostic value and is a reliable instrument in decisions on continuation of therapy in the neonatal intensive care unit. Continuous monitoring of cerebral function is possible as well, in particular now most recordings are digitally stored.

This paper could help cure a child with brain disorders at an early stage and if possible the child would also be able to lead a healthy life in the years to come. In this paper we will show the design of EEG Amplifier and artifacts in EEG in Section II and Section III, the result and conclusion of the paper in Section VI and Section VII.

II. EEG AMPLIFIER REQUIREMENTS

Electrical signals produced by the brain are in the order of micro volts. They have to be magnified so that the voltage changes can be given sufficient power to be graphically displayed either on paper or on a computer screen and made compatible with devices such as displays, recorders, or A/D converters. The

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amplifier used for the amplification of neonatal EEG should reject superimposed noise and interference signals, and ensure protection from damages through voltage and current surges for the patient and the electronic equipment. The EEG signals to be monitored should not be influenced in any way by the amplifier. The measured signal should not be distorted. The amplifier should provide the best possible separation of signal and interferences. It also has to offer protection of the patient from electric shock. The amplifier itself has to be protected against damages that might result from high input voltages as they occur during the application of defibrillators or electrosurgical instrumentation.

An amplifier multiplies an input voltage by a factor usually lying in the range of up to 10,000. The amplification factor is referred to as gain and may be expressed as Vout/ Vin. The measurement of the potential difference between pairs of electrodes is performed by means of a differential amplifier. This differential or balanced amplifier subtracts one signal's voltage, relative to the same reference electrode, from another signal, relative to the same reference, and amplifies the difference signal. The ability of the amplifier to suppress voltages common to both electrodes, i.e. varying together over time, is called the common mode rejection[5]. An example is the noise from a 50 or 60 Hz line current. The inputs will pick up 50 or 60 Hz noise even if not connected directly to ground, because of capacitance between the body and nearby line current. Fortunately, this noise voltage is very similar on parts of the body that are close together; that is, the power line noise is a common mode signal.

An instrumentation amplifier is a type of differential amplifier, which eliminates the need for input impedance matching and thus makes the amplifier particularly suitable for use in measurement.

In order to satisfy the above mentioned recording consideration it is found that instrumentation amplifier is the best fit for EEG signals because of very low DC offset, low drift, low noise, very high open-loop gain, very high common-mode rejection ratio, and very high input impedances.

The amplification and signal conditioning circuit designed in this paper makes use of AD620 (instrumentation amplifier) because of its characteristics as specified in Table I.

III. ARTIFACTS IN EEG

Analysis of EEG signals from neonates is a difficult task due to its very low amplitude (1μV to 100μV) and its susceptibility to noise from the below mentioned artifacts:

- 50/60 Hz power line noise
- impedance fluctuation
- cable movements
- broken wire contacts

The amplification and signal conditioning circuit designed in this paper can be used to solve these problems with the help of suitable amplifiers, buffers and filters implemented in the circuit.

IV. METHODOLOGY

The amplification is done in three stages, along with necessary filtering stages. EEG is measured as a differential input signal between two points. The instrumentation amplifier AD620 is the first stage and acts like the pre-amplification stage. The reason for using an instrumentation amplifier as a pre-amplifier is that it has very high CMRR, low offset voltage and low drift. AD620 has a high CMRR of 110dB. The next two stages of amplification are done after the signal passes through a high pass filter and low pass filter with calculated cutoff frequencies of 0.16 Hz and 50 Hz respectively. The high pass filter is ideally used to remove dc offset and the low pass filter eliminates the power line interference.

V. SYSTEM DESIGN

An Instrumentation amplifier is used in the preamplifier stage. EEG of neonates has delta waves as the predominant waves with 100uV amplitude and frequency 0.5-2 Hz. The gain of instrumentation amplifier is set low at 16 V/V to prevent the amplification of noise signals and dc offset picked up by EEG electrodes. Instrumentation amplifier is followed by a passive 2nd order Butterworth High Pass Filter with a cut off frequency of 0.16Hz to remove dc offset introduced by skin and the amplifier. This filter output is given to OP37 which is used as an amplifier with a gain of 101V/V. Finally an active 2nd order Butterworth Low Pass filter with a cut-off frequency of 50Hz is used which allows all the brain waves to pass through and eliminates noise that might be introduced from the power line and also provides a gain of 11V/V.

Therefore, the gain of all three stages combined is 17776V/V (16*101*11).

- Instrumentation amplifier design:
  $G_D = 1 + 49.4\ k\Omega / R_G$
  For gain=16 V/V, R_G=3.3KΩ
- Design of High Pass Filter:
  f=1/2∏RC=0.16Hz
  C=1μF, R=1MΩ
- 2nd Stage Amplifier Design:
  Gain= 1 + R2/R1=101 V/V
  R2=100KΩ, R1=1KΩ
- Design of Low pass Filter:
  f=1/2∏RC=50Hz
  C=1μF, R= 3.18kΩ
- 3rd Stage Amplifier Design:
  Gain=1+R2/R1=11 V/V
  R2=10KΩ, R1=1KΩ

VI. RESULT

The circuit for EEG amplification and signal conditioning was successfully simulated on Multisim. The circuit simulated on Multisim is shown in the Fig. 2.

The circuit was also tested using a delta wave EEG simulator, (as the EEG signals from neonates will consist of predominantly delta waves) and the result obtained was in accordance to the simulated result obtained on Multisim. The amplified and filtered waves obtained upon simulation and by practically testing the circuit using EEG simulator are shown in Fig. 4 and Fig. 5 respectively.

VII. CONCLUSION

This paper began in an attempt to alleviate the difficulties faced by doctors at hospitals while recording the EEG signals from neonates. Acquiring and amplifying the signals was a difficult task. Noise in the circuit induced by movements, cables etc. did not allow for accurate analysis of the EEG signals. The amplification and signal conditioning circuit designed in this paper could help solve these problems by providing a solution for amplification and filtering of signals. EEG acquisition and analysis of neonates will help understand their brain activity at an early stage and diagnose abnormalities. This can be extrapolated to automatically identifying the nervous disorder by studying the traits and patterns of the EEG waveform. This will prove to be a major breakthrough in the field of medicine and research that will help in early diagnosis and treatment of brain disorders like epilepsy. This can greatly ease the pain of individuals, reduce mortality rate and pave way for a healthy and happy world.

ACKNOWLEDGMENT

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TABLE I

INSTRUMENTATION AMPLIFIER - AD620 CHARACTERISTICS

CHARACTERISTICS	VALUE
Low offset voltage	50µV max
Low input bias current	1nA max
Input impedance	10 G Ω
Common-mode rejection	110dB min
Low drift	0.6µV/°C max
Input voltage noise	0.28 µV p-p Noise (0.1 Hz to 40 Hz)

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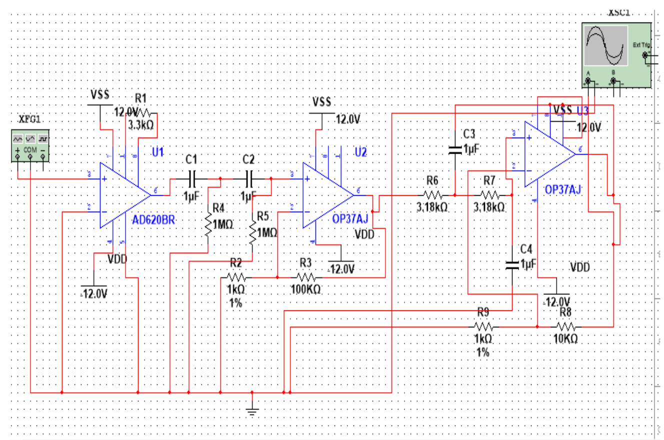

Fig. 2. Circuit simulated on Multisim software.

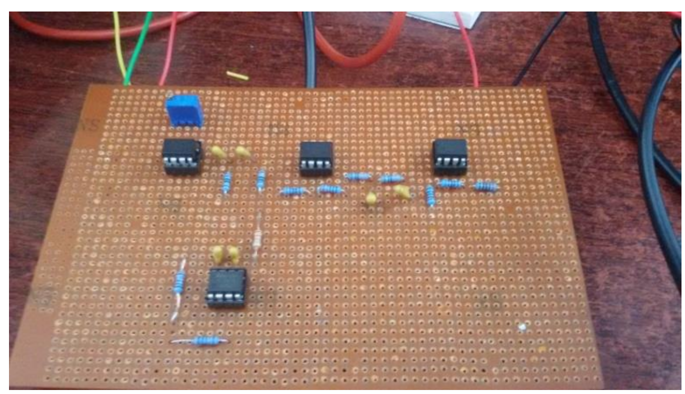

Fig. 3. Circuit soldered on perf board for the purpose of testing the designed circuit in laboratory with input from EEG simulator.

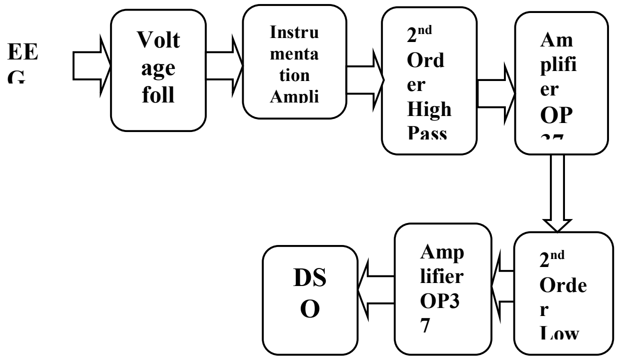

Fig. 1. Block diagram of Amplification and signal conditioning circuit

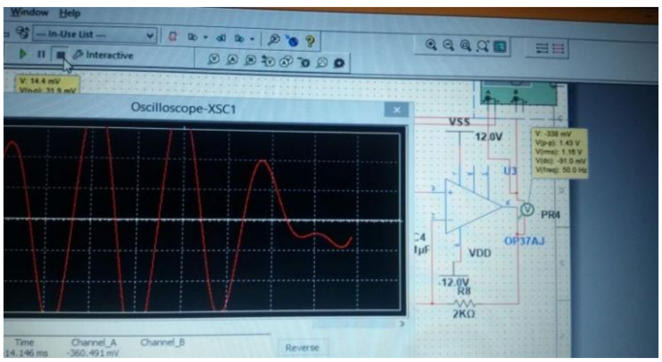

Fig. 4. Output of the Circuit simulated on Multisim, for EEG equivalent sine wave

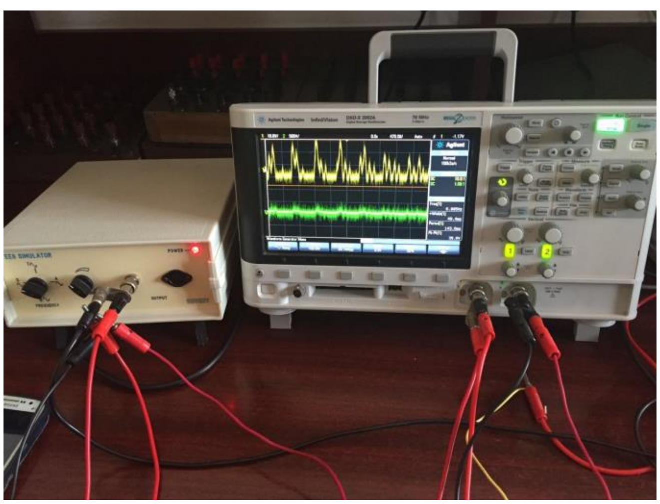

Fig. 5. Amplified EEG obtained on the DSO, on giving input through an EEG Simulator.