DEVELOPMENT OF AN EEG AMPLIFIER FOR REAL – TIME ACQUISITION

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ȝSTRACT

Electroencephalography (EEG) are primarily use for diagnosis, detect and localize cerebral brain ;ions, aid in the studying of epilepsy, diagnosing mental disorders, assist in diagnosing sleep patterns and lowing observation and analysis of brain responses to sensory stimuli. To date, advance researchers have veloped system that use EEG signals to decipher thoughts so that a person can communicate by means of ain activity alone. The purpose of this project is to develop an EEG amplifier that forms part of an EEG signal quisition system with the intention to form a basis for EEG research. The hardware includes amplifications d filtering circuit and a personal computer (PC) while the software allows to store the recorded EEG data in al-time.

EYWORDS

:G amplifier, EEG activity, Real-time

INTRODUCTION

EEG is the neurophysiologic measurement of the electrical activity of the brain by recording from :ctrodes placed on the scalp, or in the special cases on the cortex. The resulting traces are known as an EEG. iis device is used to assess brain damage, epilepsy and other problems. In some jurisdictions it is used to assess ain death. EEG can also be used in conjunction with other types of brain imaging. The objective of the project to develop small signal amplifier circuit to acquiring EEG signals. Filtering circuit is added in to ensure that : standard range of low and high electroencephalography (EEG) frequencies from 0.1 – 70 Hz is recorded thout attenuation. The circuit is then interfaced to a PC using LABVIEW software, NI Datalogger.

EEG DATA ACQUISITION SYSTEM

l EEG Signals

The amplitude of the EEG I can reach up to 10 mV when measured on the brain and approximately 10 100 μV when measured on the scalp [1]. EEG signals are acquired via a noninvasive method, by placing :ctrodes on the scalp. The 10-20 system of electrode placement is a method used to describe the location of scalp electrodes. The system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex[2]. The chosen area for the electrode placement is Fp1 and Fp2. The scalp electrodes are placed after preparing the scalp area by light abrasion and application of a conductive gel to reduce impedance.

EEG activity can be broken down into 4 distinct frequency bands; beta activity (> 13 Hz), alpha activity (8 Hz-13 Hz), theta activity (4 Hz-7 Hz) and delta activity (< 4 Hz).Beta activity is a normal activity present when the eyes are open or closed. It tends to be seen in the channels recorded from the centre or front of the head. Alpha activity is also a normal activity when present in waking adults. It is mainly seen in the channels recorded from the back of the head. It is fairly symmetrical and has amplitude of 40 μV to 100 μV. It is only seen when the eyes are closed and should disappear or reduce in amplitude when the eyes are open [3].

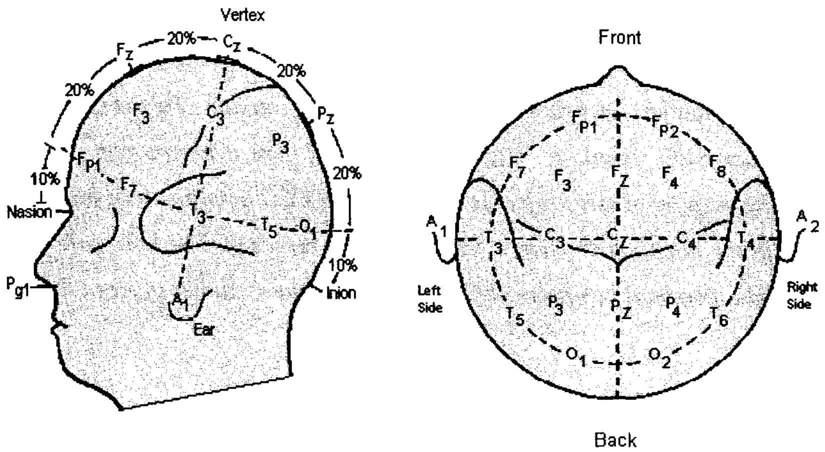


Fig. 1. The International 10-20 electrode placement system
(Source : http://faculty.washington.edu./chudler/1020.html

(a)

(b)

Fig. 2. EEG activities (a) beta activity, (b) alpha activity.
(Source: [4])

2.2 Electrodes

A small round nickel-silver alloy plate, reusable electrodes are used. The skin must first be scrubbed using NuPREP™ prepping gel. A small amount of conductive paste, Ten20 EEG™, area applied onto the electrodes before placing them on their respective locations. This will establish skin contact. This type of electrodes is clinically being used due to its size, 0.5cm, which allows it to be placed on the scalp of a patient without having to shave off some of their hair. The electrodes can be cleaned by soaking it in lukewarm water for a few minutes.

Fig.3. EEG electrode placement training

2.3 Amplifiers

The electrodes are connected to the protection circuit which serves two purposes: first, it protects the circuitry from electrostatic discharge (ESD) and second it protects the user from failing circuitry. The amplification system consists of two-stage amplification where the first stage is the operational amplifier and the second stage is the instrumentation amplifier. The first stage consists of INA114AP as instrumentation amplifier and the second stage consist of LM741C operational amplifier. IC component INA114AP is a Burr-Brown instrumentation amplifier that has low noise, low input bias current, low offset voltage and low power making it well suited for medical application such as ECG and noninvasive blood pressure monitors [4]. The gain is computed using this equation:

$$G = 1 + \frac{50k\Omega}{R_G} \quad (1)$$

R_G was chosen 51Ω, 1% tolerance, so the gain achieves approximately 1,000. This was done gradually starting at a lower gain. The two analog inputs, positive and negative electrodes, are connected to input pins of INA114AP respectively. Each of the signals from the two electrodes is then fed into the instrumentation amplifier. The output from instrumentation amplifiers is fed into a LM741C operational amplifier. Reasons for having the instrumentation amplifier are first it provides very high input impedance that compensates for any impedance imbalance between the source electrodes. Secondly, the instrumentation amplifier provides electrical isolation between the circuit and the human body to prevent lateral current effect from the electronics circuits. The second stage amplifier is designed to produce a high gain of 10. Thus, the overall output voltage from this amplification circuit is kept to a range of 0.5-1V. The third electrode is connected between Fp1 and Fp2 on the forehead of the patient to reduce common-mode signals i.e., 50Hz mains hum. The third electrode has its signal connected to the ground of the amplifier circuit. This ground signal is necessary to prevent saturation in the instrumentation amplifier circuit. The amplifier circuit operates on ± 15V supply.

2.4 Filter

The EEG signal can be easily drowned by noise generating from the small muscle movements (electromyogram, EMG), power lines (50Hz), fluorescent lights, AM/FM radio broadcasts, computer clock oscillators, laboratory equipment, cellular phones[5]. Noisy signal causes inaccurate output when digitized and eventually produces distorted output signals that are impossible to be analyzed or interpreted. These noises are generated from various sources such as contact between the electrodes and body surface, muscle movements, internal noise from the wires and amplifier circuits, and external noise from the environment. Shielding provided by the casing is one of the methods used to reduce the noise. Filters are used to reduce the noise and to maximize the signal-to-ratio (SNR).

An EEG signal falls in the frequency range 0.1 – 70 Hz, considering the above problem, a bandpass filter is built to filter off the high and very low frequency components. Besides, in order to remove the 50-Hz power line interference, a High Q notch filter is used. Normal passive bandpass filter using large value capacitors and inductors is not suitable for the EEG signal in low band frequencies. Instead of using the passive filter, the active filter is used incorporating the operational amplifiers, resistors and capacitors, thus eliminates the inductor component. Moreover, passive filter using appropriate inductors and capacitors is more cumbersome to be configured compared to the active filter. A bandpass filter is a combination of a low pass filter and a high pass filter. It is built by two LM741C operational amplifier IC, two resistors and two capacitors.

2.5 DAQ card

The amplified and filtered EEG signal is transferred to a computer. This is done by using a four channel National Instruments data acquisition board, NI cRIO-9215 with 16-bit resolution capability. Included with the board is the NI-DAQ software. This software is specifically designed to quickly install devices and begin data measurement. This easy-to-use software integrates the full functionality of DAQ hardware to LabVIEW®. These windows based software are used to display the digitized data in time-series format, as would be obtained on an oscilloscope.

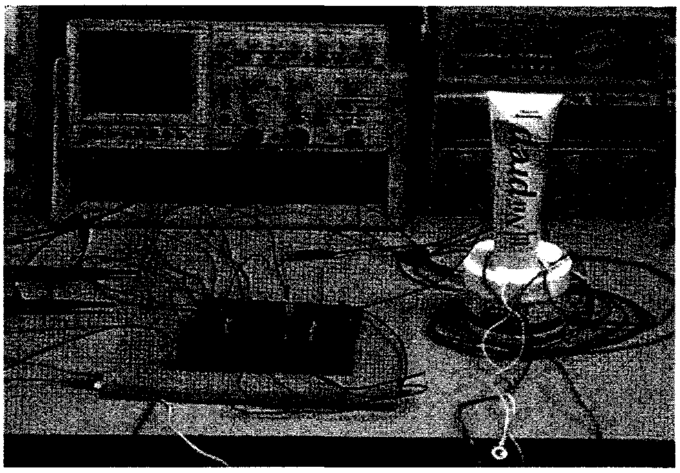


Fig. 4. Experiment setup; the hardware circuit and the scalp preparation kit

3. RESULTS & DISCUSSIONS

3.1 Results

The EEG amplifier was first simulated in Multisim 8. The development of the circuit is tested with a gain of 10 and with input 1V. From there gain is increased according to Table 1, up to 1,000. Fig shows the result of the instrumentation amplifier. The development of the circuit was continued on a breadboard and the circuit was tested. Starting at gain 50, clipping occurred.

Fig. 5. EEG amplification unit with scalp electrodes

Table. 1 Resistor values for the desired gain[5]

DESIRED GAIN	R_G (Ω)	NEAREST 1% R_G (Ω)
1	No Connection	No Connection
2	50.00k	49.9k
5	12.50k	12.4k
10	5.556k	5.62k
20	2.632k	2.61k
50	1.02k	1.02k
100	505.1	511
200	251.3	249
500	100.2	100
1000	50.05	49.9
2000	25.01	24.9
5000	10.00	10
10000	5.001	4.99

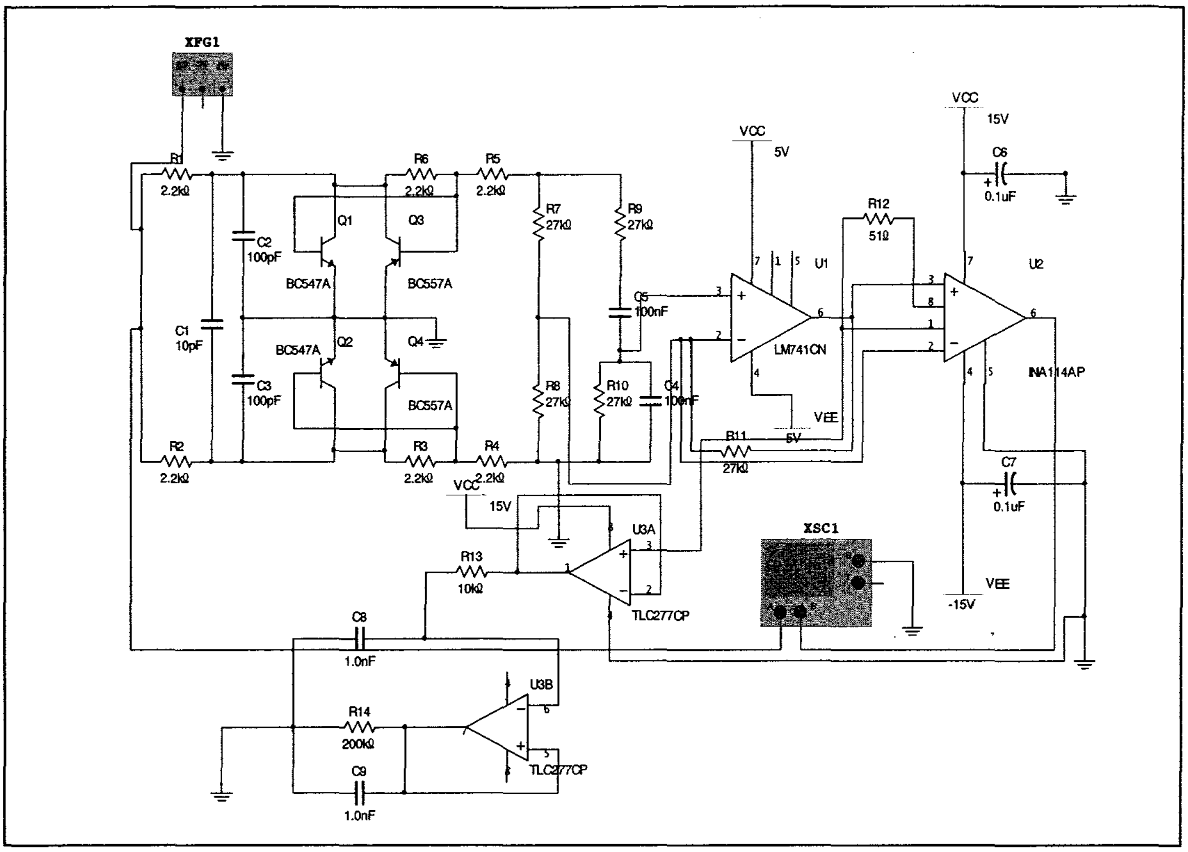
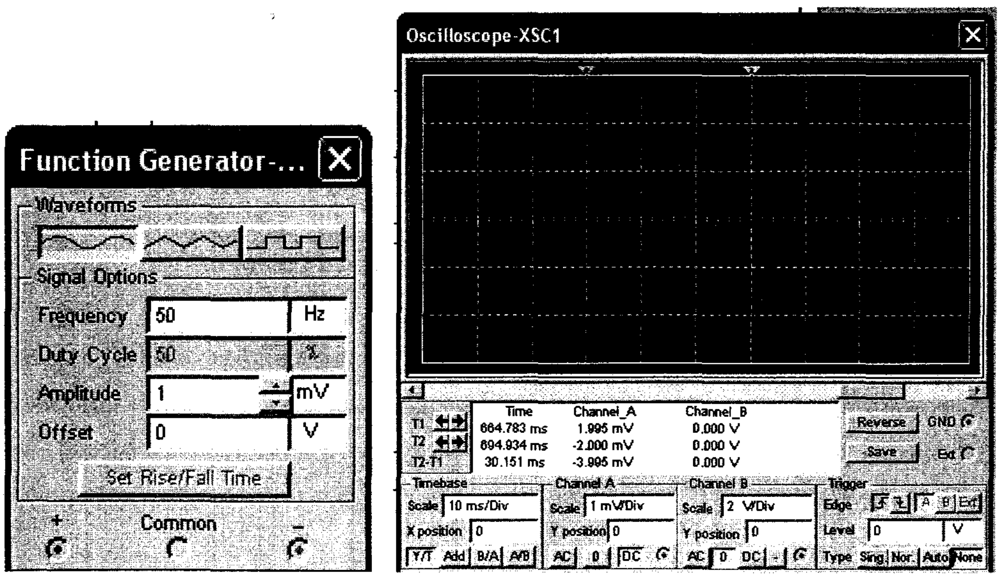
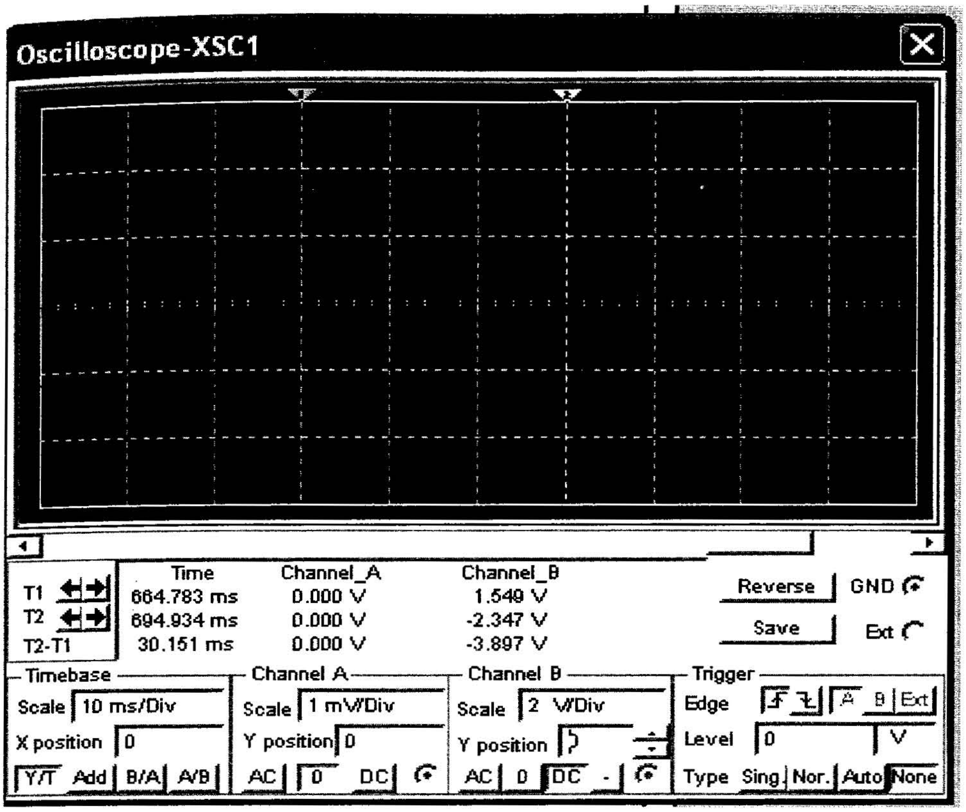


Fig. 6. Signal waveform generated on the ECG Monitor



(a)



(b)

Fig. 7. Simulation result of the amplifier (a) Input 1mV, (b) Output 1.5V

3.2 Discussion

The work focus was mainly on the study of EEG signals and the front end of the amplifier. The amplifier circuit may work at a certain gain before clipping occurs. The SNR for the circuit is inadequate to allow any EEG signal to be captured. The close proximity of the circuit to the computer used in recording the signal may have also contributed to the circuit non-performance. The filter design has to be more in depth and precaution steps for the experiment setup must be followed very closely.

4. CONCLUSION

An EEG amplifier for a real time acquisition has been designed and developed. In spite of the result, a basis for an EEG research has been setup with the knowledge of clinical (EEG electrode placement and patient handling) and biomedical engineering.

REFERENCES

[1] D. Prutchi and M. Norris, *Design and development of medical electronic and instrumentation: a practical perspective of the design, construction and test of material devices*. Hoboken, New Jersey: John Wiley & Sons, Inc., 2004.

[2] J. D. Bronzino, *The Biomedical Engineering Handbook*, vol. II, 2nd ed. Boca Raton, Florida: CRC Press, 2000.

[3] C. M. Epstein, *Introduction to EEG and evoked potentials*: J, B Lippincott Company, 1983.

[4] J. D. Enderle, S. M. Blanchard, and J. D. Bronzino, *Introduction to Biomedical Engineering*. San Diego: Academic Press, 2000.

[5] "INA11AP online datasheet."

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Here we would like to take this opportunity to thank UNIC, KUTKM for funding the project **PJP/2005/FKEKK(14)-S105**. To Mr. Lee from Radicare and the nurses and neurologist at Hospital Melaka, Ayer Keroh, we would like to convey our gratitude for their patience and understanding. Also, a sincere appreciation goes to the Dean of FKEKK, Prof. Abdul Hamid Bin Hamidon and Puan Fauziyah Sallehuddin for their support in setting up the biomedical research workspace in Digit 1 Laboratory.

REFERENCES

[1] D. Prutchi and M. Norris, *Design and development of medical electronic and instrumentation: a practical perspective of the design, construction and test of material devices*. Hoboken, New Jersey: John Wiley & Sons, Inc., 2004.

[2] J. D. Bronzino, *The Biomedical Engineering Handbook*, vol. II, 2nd ed. Boca Raton, Florida: CRC Press, 2000.

[3] C. M. Epstein, *Introduction to EEG and evoked potentials*: J, B Lippincott Company, 1983.

[4] J. D. Enderle, S. M. Blanchard, and J. D. Bronzino, *Introduction to Biomedical Engineering*. San Diego: Academic Press, 2000.

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