Brainwaves

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Introduction

The goal of this project was to build a working Electroencephalograph. Electroencephalography, EEG, is a method of measuring brainwaves by detecting minute amounts of electrical activity on the scalp. EEG measures the activity of large groups of neurons and cannot detect what a person is thinking.

Purpose

The purpose of this project was to build and test an inexpensive EEG device. The device is based on the modularEEG circuit (Buttlar, Hansmann, & Robinson, 2005) from the openEEG project. It could be used as a brain-computer interface for paralyzed people and people with muscle disorders. For example, levels of relaxation could be used to control a simple typing interface to allow paralyzed people to communicate.

Hypothesis

Relaxation of different levels will be monitored with active electrodes and analyzed by a computer program. The data will be used for a simple brain-computer interface controlled by relaxing or concentrating.

Background

Electroencephalography (EEG) signals in humans were discovered in 1924 by Hans Berger (Nunez & Srinivasan, 2007). In the 1930s, scientists started finding medical uses for EEG, such as diagnosing and later studying epilepsy. EEG is now used to test for specific mental disorders. For example, abnormal activity in the Alpha band can be used to detect a coma (Boggs, 2009). EEG signals have been categorized into different frequency bands:

- **Alpha band** waves are 8 to 13 Hertz. Waves in this band normally signify relaxation and closing of the eyes. They are measurable at the back of the head.

- **Beta band** waves are the second most prominent and can be anywhere from 13 to 30 Hertz. They signify mental activity and concentration.
- **Theta band** waves are 4 to 7 Hertz and are mostly seen when the brain is drowsy or idle.
- **Delta band** waves are 1 to 4 Hertz and are usually seen during certain stages of sleep.
- **Gamma band** waves are 30 Hertz and above. Waves in the Gamma band are associated with some cognitive and motor functions.

Procedure

Materials	
1. 2 INA114 instrumentation amplifiers ("INA114 Precision Instrumentation Amplifier datasheet", n.d.) 2. Assorted operational amplifiers 3. Capacitors, resistors, wires and transistors of different types 4. Arduino micro controller ("The Arduino microcontroller platform website", n.d.)	5. Laptop with oscilloscope and graphing software 6. Silver chloride disc electrodes 7. Ten20™ conductive electrode paste and Nuprep™ abrasive skin prepping gel 8. Breadboards 9. Battery 10. Voltage regulator 11. DC-DC converter

Building Procedure	Measuring Procedure
1. Order parts. 2. Create breadboard diagram. 3. Place parts on breadboard according to diagram. 4. Test with a calibration signal. 5. Adapt and test various software solutions to visualize the signals.	1. Connect power. 2. Start monitoring software. 3. Rub skin prep gel on scalp. 4. Apply conductive paste to scalp. 5. Apply conductive paste to electrodes. 6. Put electrodes on scalp. 7. Secure electrode cables with a headband. 8. Capture oscilloscope traces.

Challenges and Solutions

It is challenging to detect EEG signals from the significant amount of noise caused by the 60 Hertz oscillation of the AC electrical system. The EEG signal is about 200 microvolts peak-to-peak, much smaller than the 60 Hertz noise. The body also acts as an antenna and picks up more noise. The system and laptop computer also must be powered by batteries to isolate the circuit from AC power noise.

The first stage of the EEG device amplifies only the difference between two points on the head. The brainwaves on different parts of the head will be different, but the noise will be the same. The second and third stages amplify and filter the signal. The filter does not filter out power noise because 60 Hertz hum is close in frequency to the EEG signals. It is hard to get rid of the hum without getting rid of the signal. The three stages achieve a minimum gain of 1,152 and a maximum gain of 19,200.

Electrodes

There are three main types of electrodes that are used to capture the electrical signals from the scalp:

- **Active electrodes** use a circuit near the electrode to pick up the signal and drive it down the cable to reduce signal loss. Active electrodes do not require any conductive paste or gel; this makes them easier to use.
- **Saline electrodes** use saline solution to conduct electricity from the scalp. These are easier to clean up after than paste electrodes, but they do not conduct as well.
- **Paste electrodes** use a conductive and often sticky paste to get better electrical contact with the skin. These are the most commonly used electrodes in medical applications.

All three types of electrodes were tested:

1. The first tests were conducted with a pair of active electrodes following a design used by Peters (2007). They consisted of a small circuit board and a gold pin array to make contact

through the hair. But, there was a problem in the circuit that caused it to amplify the signal and not just help it along, causing the amplifiers to be over-driven.

2. Next, saline electrodes were made with a silver quarter in the bottom of a bottle cap and a sponge filled with saline solution stuck in the cap. But, when tested, the electrodes could only pick up noise. It was not as bad as the active electrodes because there was no amplification. The problem was that the saline solution was too resistive so the signal could not get through.
3. Lastly, using silver chloride disk electrodes, Ten20™ conductive paste and Nuprep™ abrasive skin prep gel, the EEG signal could be detected. It was then just a matter of finding a suitable electrode placement on the scalp and increasing the amplification.

Results

Brainwaves were recorded using paste electrodes located on the back of the head. Alpha waves were clearly recorded when eyes were closed. Occasionally, when math problems were being done, Beta waves were recorded. On rare occasions, during relaxation, Theta waves were recorded. Signals were fairly uniform in size. Waves also did not appear immediately after eyes were closed, or any other action was performed. So far, Alpha waves have only been recorded when eyes are closed and not when the mind is relaxed but the eyes are open. The person's head also has to be kept still during measurement or changes in electrode contact affect the signal.

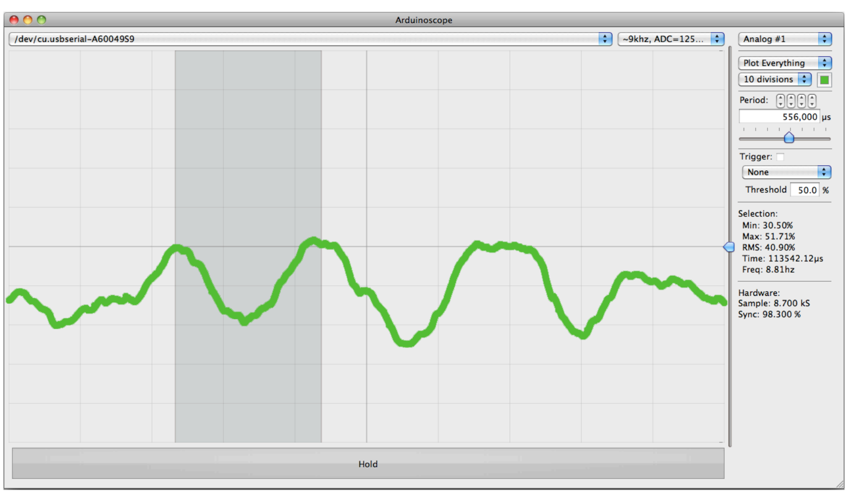

Figure 1.

An oscilloscope trace of the EEG output showing Alpha band waves. The frequency of the highlighted wave is 8.8 Hertz.

Future Improvements

I am writing new software that uses a fast Fourier transform (Weisstein, n.d.). This transforms the time domain into the frequency domain, allowing visualizations of the levels of different frequencies. With the transform data, the software could measure the level of alpha waves and use periods of relaxation and concentration to, for example, allow a person to communicate by selecting letters in a menu.

I also want to troubleshoot the active electrodes and possibly rebuild them. The conductive paste is impractical for a brain-computer interface.

Conclusion

In the end, the EEG software in this project was not accurate enough to measure the slight changes in brain activity required for a brain-computer interface.

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