Neuro-transmitter (EEG) Interface System

Project Proposal

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I. INTRODUCTION

1.1 Statement of Purpose

The purpose of this project is to reduce the cost of and improve the efficiency of current Electroencephalography(EEG) systems. The current market for EEG systems is in high demand both in neurological research and the medical industry. Today's devices on the market require that one carries around a laptop in order to record data. We will augment the fidelity of the device's capabilities. We will rid the necessity to carry a laptop and along with using a cheaper device design, we will make our device more mobile and more cost-efficient thus creating a very viable product in the EEG market.

1.2 Objectives

1.2.1 Goals

- Create a fully functional EEG that logs time-stamped data on an SD card
- Keep within a budget of $500
- Guarantee a medical quality device
- Meet the ethical requirements and quality of data for research

1.2.2 Functions

- Op-amps with 10,000 gain to accurately detect and differentiate between voltages produced by brain waves
- Bandpass filtering to remove unwanted frequency noise from the environment, facial muscles, and from subconscious controls
- Analog to digital converter that also timestamps and stores the digitized information
- LED display to verify sensors are making the correct contact by measuring their impedances

1.2.3 Benefits

- Making EEG mobile for novel neuroscience research
- Having a modular design to fit multiple high-grade sensing devices
- They will be able to tell in the field that the sensors are making good contact with research participant's head
- Circuitry involved will be light and packaged for unrestricted movement

1.2.4 Features

- SD card to store 256MB of memory which translates to 20+ hours worth of research data in an easy to read text format
- Power supply that lasts 5 hours
- We have dual color LEDs that tell us if the sensors are applied properly (impedances are less that 20 kΩ
- All sensors will pass through the same amplification component

II. Design

2.1 Block Diagrams

Overall EEG Block Diagram:

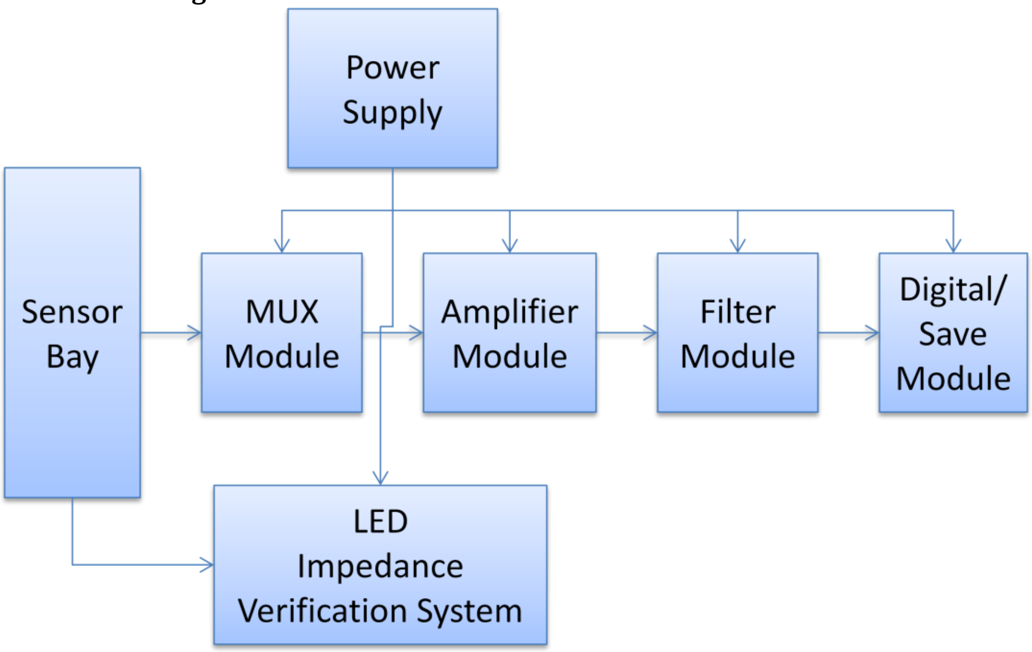

Figure 1. Overall summary layout.

Overall Summary:

The large-scale block diagram describes the connection between the sensors in the headgear(listed here as "sensor bay") and our physical device encased in an acrylic box measuring 6"x6"x6" that is transparent and connects to the hip of the headgear user. The amplifier module will take in the signals from the sensors and amplify them in order to properly filter out the noise components from the signal. From the amplifier module, a filter module will remove the noise from each signal and leave the resulting data signal information that we need to store in the SD card. Both the amplifier and filter modules will take place on a PCB board. After filtering out the noise from each sensor, the individual sensor signals will be fed into a MUX module that allows the Digital/Save Module to store the data by signal. The SD card and Arduino memory module will organize the signal information by sensor channel.

Power Supply:

The basic design of our power supply will be contained in an acrylic box. The overall power supply will consist of three AA batteries that consist of ~4.2-4.8V range. We will implement a set of LEDs that emit light and notify user when chips are receiving too much (over-voltage) or too little (under-voltage) voltage. A separate MOSFET reverse voltage protection circuit will serve to measure the voltage fed into the circuit and act as a controller, lighting the LED and breaking the circuit to the chips at abnormal voltage readings. The power supply will also serve as the voltage necessary to power the Arduino processor.

MUX Module:

The MUX module will take input from the sensor bay and one output to the amplification component. The block will go through the sensor inputs one at a time and connect the output to the amplification component. The purpose of this block is to reduce the amount of circuitry involved to amplify and filter all 13 sensor's signals.

Amplifier Module: The amplifier module will take its inputs from the 13 sensors in the head cap, and will send its outputs to the Filter module. It will consist of an operational amplifier that will take in voltages between 20-200 micro-volts and output voltages from 0.02-2.00 voltages. It will primarily be composed of resistors and an operational amplifier designed to give 10,000 gain for the range of input voltages. This amplification will be done to ensure the ADC can properly differentiate between the types of voltage values to convert. This will specifically be a non-inverting output.

Filter Module:

The filter model will consist of a 2nd order band pass filter circuit that will remove signals with frequencies above 50 Hz and below 0.16 Hz, while minimizing any reduction in the signal amplitude of those frequencies that are between the two. It will take inputs from the amplifier module and send its outputs to the MUX module. It will primarily be composed of a high pass filter in series with a low pass filter that will be composed of resistors, capacitors, and operational amplifiers.

Digital/Save Module (Memory module):

The memory module will consist of three devices, an A/D converter, the Arduino board, and a 256 MB SD card. It will also consist of a DeMUX that will take its inputs from the output of the A/D converter and send the output to the Arduino board to one of the 13 different output lines that correspond to the 13 sensors used.. The DeMUX will be synchronized with the MUX so the sensor currently selected will be passed through amplification, filtering, A/D conversion, and then get put on the specific sensor signal channel on the Arduino to get stored on the SD card. The Arduino attaches a timestamp to each signal and stores the signal in the memory card. This data would be accessible from the memory card by means of a USB cable connection from a computer to the Arduino board.

LED Impedance Verification System:

The LED Impedance Verification System will consist of 14 LEDs and a small current source. We will send a small known current through the first lead of each sensor to the second lead and read the voltage across the terminal. With that we can calculate the impedance. The ideal impedance would be less than 20 kilo-ohms. Our LED array will display if the contacts are properly applied. If the impedance on a sensor is more than 20 kOhms, or improperly applied, the LED corresponding to the sensor will not display a color and stay off. If the impedance on a sensor is less than 20 kOhms, or properly applied, the LED corresponding to the sensor will display green. The system in itself will provide a visual to show the user if each sensor is correctly applied.

SD Card Memory Feedback Diagram:

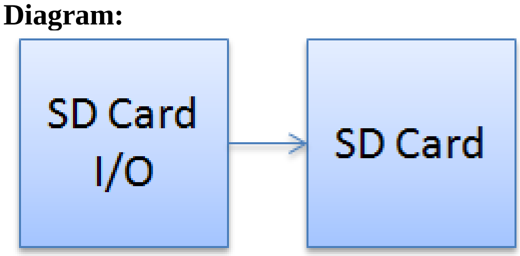

Figure 2. Memory Storage Block Diagram

Overall Summary:

In the 6"x6"x6" acrylic box, there will be an opening for the user to insert and remove the 256MB SD card. Within the box, there is a separate compartment for the SD card reader, allowing users access to insert and remove the SD card. The output from the eight filtering channels will be fed into the

Arduino board(represented here as SD Card I/O Module) that will timestamp the signals and store them on to a 256MB SD card.

SD Card I/O:

Our I/O device for the sensor signals will be amplified and filtered, and then each of the eight channels will go into the Arduino board, where each signal is timestamped and stored on to the 64GB SD card.

SD Card:

This is a standard 256 MB SD card that will hold roughly one hour's worth of sensor data. The user would be able to unlock this data by means of the Arduino SDCardLibrary, and a USB connection from the Arduino board to the computer.

2.2 Performance Requirements

In addition to the performance requirements listed in the block descriptions, these are the other performance parameters of each block.

1. The MUX mobile performance requirement is to be able to switch between the 13 sensor inputs and output the one needed to go through amplification at the time. Thus it takes inputs from the sensor bay and sends its one output to the amplifier module.
2. The gain of the amplification step will need to be 10,000 to have detectable voltage values at the A/D conversion stage. So it takes inputs from the MUX, amplifies, and sends the output to the filtering module.
3. The central frequency of the filter will need to be 2.828 Hz. This is calculated by (Highpass frequency x Lowpass frequency)^(1/2). Thus (50 Hz x 0.16Hz)^(1/2) = 2.828 Hz. This will remove the amplified noise and interfering signals and leave only those amplified signals with frequencies we care about. Thus the filtering module takes inputs from the amplifier module and sends its output to the Digital/Save module.
4. The Digital/Save Module (Memory module) must be able to convert the data from all 13 sensors to digital signals and then timestamp and store the data on an SD card. This will be done using an A/D converter that takes its input from the filtering module and sends its output to the DeMUX. The DeMUX will take its input from the A/D converter and select the correct sensor channel to into the Arduino. The Arduino will then write all the sensor data onto an SD card.
5. LED impedance verification system take its inputs from the sensor bay and outputs to LED's to verify that the sensors are properly attached to the head. The performance requirement is that if the impedance value at a specific sensor is less than 20k ohms then the corresponding LED for that sensor will lights up. If the impedance is higher than 20k ohms then the LED does not light up.
6. Our power supply will consist of three AA batteries (~4.2-4.8V). We will have a set of LEDs that emit light and notify the user when chips are receiving too much (over-voltage) or too little (under-voltage) voltage. A separate MOSFET reverse voltage protection circuit will serve to measure the voltage fed into the circuit and act as a controller. It will light the LED and break the circuit at abnormal voltage readings. The power supply will also serve as the voltage necessary to power the Arduino processor.

III. VERIFICATION

3.1 Testing Procedures

1. To test the Arduino and SD card, to ensure that the channel data receives timestamps for every cycle. We will correct any changes by accessing the SDCardLibrary and can be programmed using the diskio.c file within the Arduino software. The timestamp sampling frequency will vary with testing from 64Hz-128Hz.
2. In order to test the EEG circuit power supply, we will link a multimeter in parallel to the input and output terminals of the three AA powerpack. This will measure how much current our circuit draws, which can be tested on a sensor-by-sensor basis.
3. The individual sensor test will be done in two methods: the LED ohmic testing (described in part 4) and the signal reading testing(described in 7).
4. LED impedance verification testing: To test the LED array circuit, we must apply two different impedances on each sensor that corresponds to the LEDs in the array and send in a known current (1uA). The circuit is designed that if the impedance is under 20k-Ohms, the LED will light up. The LEDs which are in parallel to the impedance source, will light up based on their turn-on voltages which correspond to the voltage over the impedance. We will first apply an open circuit and see if the LED is unlit. Then we will apply a wire with a very minimal resistance to see if the LED changes to green.
5. Amplifier and Filter testing: To test the amplifier stage we will input the low and high end of the voltages values we expect to at the input and measure the output voltage and current. The output voltage will be used to verify the correct gain occurred which would be 10,000. To test the filtering circuit we would apply voltages signals with 0.1 Hz, 25 Hz, and 60 Hz. Correct filter performance will give an output signal with approximately the same magnitude as the input signal for the 25 Hz test. The 0.1 Hz and 60 Hz should give near zero magnitude for the output signal.
6. MUX module testing: We will test the chip separately with a multimeter and a signal generator. We will make sure that each pin works and that the chip generates the correct outputs.
7. All sensor testing will be done with free sensors provided by the Electronic shop located on the 2nd floor of Everitt Laboratory. These sensors will generate voltage readings akin to the sensors on the head gear, yet will prevent damaging the one set of headgear sensors, if our sensor circuit shorts in the process. The individual sensor readings will be tested while linked to the amplifier/filter module scheme. The output readings will be measured and recorded on an oscilloscope.

3.2 Tolerance Analysis

For our tolerance testing, the signal amplification and filtering modules must achieve a high precision low noise filter so that we do not corrupt our data with noise and commit it to memory. Our tests will be checking for a 10,000 voltage gain, no current saturation, and keeping the bandpass filter transition band and loss in signal amplitude in the pass-band to a minimum to preserve the signal from 0.16Hz to 50Hz. Specifically we will be performing simulations using Simulink to measure gain, and output current and to fine tune the resistor values making up the amplifier component. Also, we will be using Simulink to simulate the specific frequencies that the pass band occurs at for different types of filters (Butterworth, Chebychev, etc), as-well as showing the sensitivity to attenuation in the pass-band for these filters. Based on power consumption, the cost, and the effectiveness of different filter types, we will decide which the final filter to use for our system. The passband needs to be at the correct frequencies. We will adjust the order of the filtering system based on the need to reduce noise.

IV. COST AND SCHEDULE

4.1 Cost Analysis

4.1.1 Labor

Name	Hourly Rate	Total Hours Invested	Total=(Hourly Rate)*2.5*(Total Hours)
Kevin Armstrong	$35.00	150	$13,125
John Burton	$35.00	150	$13,125
Alex Lostumbo	$35.00	150	$13,125

4.1.2 Cost

Item	Quantity	Cost(USD)
Batteries	4	10.00
A/D Converter	1	40.46
LEDs	16	6.72
MUXs	3	4.82
256MB SD Card	1	6.64
Capacitors, Resistors, Inductors		24.00
Arduino DEV-11229	1	59.95
Op-Amp chip	36	43.20
Acrylic sheet 24"x24"x1/8"	1	22.33
Soft. Developer tools	1	90.00
PCB Board	1	30.00

4.1.3 Grand Total

Section	Total
Labor	$39,375.00
Parts	$338.12
Total	$39,713.10

4.2 Schedule

Week	Task	Responsibility
9/16	Turn in proposal	John
	Research LED circuit, get Arduino	Kevin
	Research amplifier/filter circuits	Alex
9/23	Pull up datasheet for Amplifier/Filter circuit	John
	Conduct PSPICE simulation	John, Alex, Kevin
	Write out code for storing channel data to SD card	Kevin
	Design Review	Alex
9/30	Research power supply structure	Alex
	Order parts for power supply, amplifier/filter circuits	John
	Look into PCB board, order LED parts	Kevin
10/7	Build and wire LED circuit	Kevin
	Build control box	Alex
	Layout PCB board design	John
10/14	Assemble the amplifier and filter circuits	John
	Program channel inputs and test for tolerance in Arduino	Kevin
	Prepare documentation for Mock up demo	Alex
10/21	Prepare for Individual Progress reports; go-over journals	Kevin, Alex, John
	Tolerance analysis	Alex
	Update final paper, presentation	Kevin
10/28	Verification of specs	John
	Update final paper	Kevin
	Update presentation	Alex
11/4	Mock-up Demo	Kevin, Alex, John
	Fix remaining issues	John
	Completion of Modules	Alex

11/11	Check memory data is compatible with software	Kevin
	Edit final paper	John
	Edit presentation	Alex
11/18	Thanksgiving break	Kevin
	Thanksgiving break	Alex
	Thanksgiving break	John
11/25	Finish final draft of paper	Kevin
	Finish final draft of presentation	Alex
	Practice demo	John
12/2	Demo	Kevin, John, Alex
12/9	Presentations	Kevin
	Final Paper	John
	Check In Supplies	Alex

V. ENGINEERING ETHICS

5.1 Ethics Discussion

"to accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment."

Our group is working toward creating a safe and affordable EEG that would be conducive with current health and safety standards. Our final device depends on the safety of the individual, since the data itself is useless without the individual trusting our device.

The ramifications imposed by this medical device must be upheld to a specific set of standards. To satisfy these standards, our group will meet with a special medical advisory board (called the Human Subject Committee) located on Green street in Champaign, IL. This medical advisory board works with the Institutional Review Board, the ethics review board for the University of Illinois.

Our project will ensure the participant's safety and guarantee accurate and useful data for the researcher.