Portable stimulator for BCI system

Project Proposal

Group Member: Siyuan Wu, Randy Lefkowitz, Bonnie Chen

TA: Ryan May

February 6, 2013
# Table of Contents

## Introduction
- Purpose ........................................................................................................................................ 3  
- Goals ........................................................................................................................................ 3  
- Benefits ...................................................................................................................................... 3  
- Features ..................................................................................................................................... 3  
- Functions .................................................................................................................................. 4  

## Design
- Block Diagrams ..................................................................................................................... 5  
- Block Descriptions .................................................................................................................. 6  

## Performance/Requirements and Verifications
- Testing Procedures .................................................................................................................. 8  
- Tolerance Analysis .................................................................................................................... 9  

## Cost and Schedule
- Labor ......................................................................................................................................... 10  
- Parts ......................................................................................................................................... 10  
- Schedule .................................................................................................................................. 11  

I. Introduction
Brain Computer Interfaces (BCI) based on Electroencephalography (EEG) allow for the monitoring and analysis of ongoing brain activity in real time. The signals measured by this technology can be used to control user interfaces without the requirement of the human motor system. This technology can benefit those with paralysis and other severe disabilities. As of now, the majority of BCI systems are currently large and immobile, and therefore impractical for use in everyday life outside of a lab. There are several components to a BCI system such as data acquisition, a classification system, as well as stimulation, all of which must be made portable to create a portable BCI. To address this problem, we would like to focus on making a portable stimulator that can interact, through wifi, with the BCIs that are monitoring brain activity. The stimulator will consist of flickering LEDs at predefined frequencies, with attention to luminescence (we don’t want our LEDs to blind the user so it must be at the right intensity for each user) as well as controls to adjust the frequencies while maintaining signals timing. Our design goals are to make the stimulation for the BCI and EEG portable and be integrated wirelessly so that users are not confined to just a lab setting and that the system could be tested and used in different environments.

Purpose
Most brain computer interfaces (BCI) are limited to laboratory settings. We would like to make a BCI stimulator based on electroencephalography (EEG) that is portable, and therefore useful in real world applications. This could be a great advancement in allowing people with paralysis to communicate without any type of movement.

Goals
- Design circuit with optimal settings for a glasses-mounted stimulator
- Usable in everyday life
- Wireless communication with control panel
- Painless to user’s eyes

Benefits
- Portable
- Lightweight
- Operable from a distance
- Simple real-time controls

Features
- Wireless controls
- Variable frequency
- Variable duty cycle
Functions
● 5 LEDs (per eye) flashing at varying frequencies
● Wireless communication between controller and computer
● Frequency variable between 1 and 100 Hz
● Duty cycle variable from 10 to 90%
II. Design
Block Diagrams

The Overall BCI system
Block Descriptions

**Overall Summary:**
A microcontroller will be receiving data from a PC wirelessly. The Microcontroller will control the LED Array through the corresponding program we run on PC. The program will be able to set the frequency and duty cycle of the each LEDs. The LED array will be placed on glasses and powered by batteries for portability.

**PC:**
The PC will load the program which can control the frequency and duty cycle of the LED array. This will include input from the user to change the frequency of each LED on PC and have the resulting information be transmitted to the microcontroller instantaneously through the wireless components. It will be directly connected to the wireless transmitter.

**Wireless Transmitter:**
The wireless transmitter will be used to send serial data to the microcontroller that controls the LED array. The wireless component we choose to use is the Xbee module. This may include another microcontroller to mount the transmitter properly. It will connect the PC to the wireless receiver.

**Wireless Receiver:**
The wireless receiver will receive and interpret the multiple packets of serial data sent from the transmitter, and translate them into a signal for the microcontroller to work with in outputting the correct frequency. The receiver will transmit data from the transmitter to the microcontroller.

**Microcontroller:**
The microcontroller used for the stimulator will be the Arduino 2560 (MEGA). It is the primary control of the module. The controller input will be serial data from the wireless receiver and will output the frequencies chosen and set by the user through the program to the correct LEDs through the PWM pins, which can also control the luminosity of the LEDs. It will be powered by a 9V source.

**Power:**
All portable components in the stimulator will require power from this module. The wireless receiver, microcontroller and LEDs will be powered by a 9V battery which is connected to the rest of the components through a Battery snap connector.

**LED Array:**
The LED array will consists of 5 pairs of LEDs, one for each eye. Each set can be controlled by the microcontroller. The array will have 10 RGB Clear Common Cathode LEDs no bigger than 5mm to allow for easy mounting onto a wearable frame and adjustments in luminosity and light color. The LEDs are powered by 3.2 V in which limiting resistors will be used to protect the
LED’s from burning out. The LEDs will be connected directly to the microcontroller, and will output to the user’s eyes.

*User:*
When the user is looking at a certain LED with a certain blinking frequency, information about the output brainwave signal from the user will be retrieved by the EEG/BCI system and will determine which LED the user is looking at. Because this portion is handled solely by the EEG and BCI, we will not be testing this portion while testing the stimulator.
III. Performance / Requirements and Verification

**PC:**
The PC program controlling the Microcontroller must have the proper code and setup of the wireless components in order for any data to be transmitted. This will require proper debugging and code formatting to ensure no bug in the program itself will affect the hardware. We will first design the code that can transmit and set-up the wireless communication, to verify that this will not affect the data being sent to the microcontroller. Then we will design the code that will be adjusting the frequencies of each pair of LEDs, this may be designed in a separate model or in the same code as the wireless set-up, depending on which form of wireless communication we use.

**Wireless Transmitter/Receiver:**
The Wireless communication must be able to handle multiple packets of serial data on the transmitting and receiving end. We will verify this capability by sending a series of on/off signals through PC module into the transmitter, and confirming that the same signals are being read out through the receiver into the microcontroller.

**Microcontroller:**
Since each pair of LEDs has to be controlled with a different signal, so with 5 LED per pair, there will need to be at least 5 control signals being output from the microcontroller. We will verify that each signal coming from each PWM pin is capable of operating at the correct frequency with the microcontroller alone by using an oscilloscope to monitor the signal waveforms and frequencies being output, in which we will program into the microcontroller during testing.

**Power:**
The power given off by the batteries must supply sufficient energy to all the portable components which are connected through the microcontroller. We will test the power source by using a multimeter for the batteries, wireless receiver, microcontroller and resistors in series with the LEDs, making sure the correct voltage is being provided to the microcontroller and its subsidiaries.

**LED Array:**
The LED array must show correct operation with the microcontroller as well as be modified to the correct luminosity in order to minimized user discomfort. The frequency of the LEDs will be tested by an oscilloscope. We will test LED intensity with a photodetector, if necessary, ensuring that each LED is at the right luminance.
**Tolerance Analysis**

Our design of the LED array must be precise with the duty cycle and frequency of the LEDs, because all the data gathered by the BCI and EEG system is in real time. The input (in this case, the rate of the blinking lights displayed in front of the user) must be exact in order for proper monitoring of the brain’s response.

One way the duty cycle and frequency can be affected by other parts of the circuit is by the wireless transmission of our controls from the computer. Thus, extensive testing and analysis of the tolerance of the frequency and duty cycle that is affected by the information transmitted by bluetooth in real time must be accounted for in our design of the stimulator.

Also because the final output of our stimulator system is into the user’s eyes, we must preserve the comfort and visual perception of the user, meaning that the LED array must account for not only precise frequencies and duty cycle output, but also safe operating limits for various users such that no discomfort or harm will be done onto the user’s vision through the use of the blinking lights. This will require proper testing and research on operating limits that are safe for long periods of exposure to blinking lights to the human eye.
### IV. Cost and Schedule

**Cost:**

<table>
<thead>
<tr>
<th>Name</th>
<th>Hour Rate</th>
<th>Total Hour Invested</th>
<th>Total = Hourly Rate x 2.5 x Total Hours Invested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siyuan Wu</td>
<td>$35</td>
<td>150</td>
<td>$13,125</td>
</tr>
<tr>
<td>Bonnie Chen</td>
<td>$35</td>
<td>150</td>
<td>$13,125</td>
</tr>
<tr>
<td>Randy Lefkowitz</td>
<td>$35</td>
<td>150</td>
<td>$13,125</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$105</strong></td>
<td><strong>450</strong></td>
<td><strong>$39,375</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per Unit</th>
<th>Quantity</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEDs</td>
<td>$0.50</td>
<td>20</td>
<td>$10</td>
</tr>
<tr>
<td>XBee RF Module</td>
<td>$30</td>
<td>1</td>
<td>$30</td>
</tr>
<tr>
<td>Wireless Shield</td>
<td>$30</td>
<td>2</td>
<td>$60</td>
</tr>
<tr>
<td>9V Battery</td>
<td>$2.5</td>
<td>5</td>
<td>$10</td>
</tr>
<tr>
<td>Battery Snap</td>
<td>$0.10</td>
<td>1-2</td>
<td>$0.20</td>
</tr>
<tr>
<td>Arduino MEGA 2560</td>
<td>$39</td>
<td>1</td>
<td>$39</td>
</tr>
<tr>
<td>Glasses Mounting Frame*</td>
<td>$0</td>
<td>1</td>
<td>$0</td>
</tr>
<tr>
<td>PCB*</td>
<td>$0</td>
<td>2</td>
<td>$0</td>
</tr>
<tr>
<td>Resistors*</td>
<td>$0</td>
<td>10</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>$102.10</strong></td>
<td><strong>44</strong></td>
<td><strong>$149.20</strong></td>
</tr>
</tbody>
</table>

*UIUC Senior Design Lab resources
<table>
<thead>
<tr>
<th>Component</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parts</td>
<td>$149.20</td>
</tr>
<tr>
<td>Labor</td>
<td>$39,375</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$39,524.20</strong></td>
</tr>
</tbody>
</table>

**Schedule:**

<table>
<thead>
<tr>
<th>Week</th>
<th>Task</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/05</td>
<td>Hand in proposal</td>
<td>Siyuan</td>
</tr>
<tr>
<td></td>
<td>Order XBee transmitter and Wireless shield; start designing wireless module</td>
<td>Randy</td>
</tr>
<tr>
<td></td>
<td>Order LEDs and microcontroller; write microcontroller code to control frequencies</td>
<td>Bonnie</td>
</tr>
<tr>
<td>2/12</td>
<td>Write mock design review</td>
<td>Siyuan</td>
</tr>
<tr>
<td></td>
<td>Integrate wireless components into microcontroller code</td>
<td>Randy</td>
</tr>
<tr>
<td></td>
<td>Find safe operating limit values for frequency of LEDs, integrate into Arduino code</td>
<td>Bonnie</td>
</tr>
<tr>
<td>2/19</td>
<td>Finalize Design Review</td>
<td>Siyuan</td>
</tr>
<tr>
<td></td>
<td>Test and debug entire stimulator circuit</td>
<td>Randy</td>
</tr>
<tr>
<td></td>
<td>Design and order mounting frame</td>
<td>Bonnie</td>
</tr>
<tr>
<td>2/26</td>
<td>Turn in Design Review</td>
<td>Siyuan</td>
</tr>
<tr>
<td></td>
<td>Continue debugging stimulator</td>
<td>Randy</td>
</tr>
<tr>
<td></td>
<td>Create and order PCB for stimulator</td>
<td>Bonnie</td>
</tr>
<tr>
<td>3/05</td>
<td>Replace breadboard with PCB</td>
<td>Siyuan</td>
</tr>
<tr>
<td></td>
<td>Debug new issues from PCB insertion</td>
<td>Randy</td>
</tr>
<tr>
<td></td>
<td>Test stimulator in lab with EEG system</td>
<td>Bonnie</td>
</tr>
<tr>
<td>3/12</td>
<td>Test full BCI outside of lab</td>
<td>Siyuan</td>
</tr>
<tr>
<td>Date</td>
<td>Task Description</td>
<td>Person</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Fix issues created by external stimuli</td>
<td>Randy</td>
<td></td>
</tr>
<tr>
<td>Debug BCI</td>
<td>Bonnie</td>
<td></td>
</tr>
<tr>
<td>3/19</td>
<td>SPRING BREAK</td>
<td>Siyuan</td>
</tr>
<tr>
<td>SPRING BREAK</td>
<td>Randy</td>
<td></td>
</tr>
<tr>
<td>SPRING BREAK</td>
<td>Bonnie</td>
<td></td>
</tr>
<tr>
<td>3/26</td>
<td>Fix remaining issues</td>
<td>Siyuan</td>
</tr>
<tr>
<td>Fix remaining issues</td>
<td>Randy</td>
<td></td>
</tr>
<tr>
<td>Finish up Mock Demo</td>
<td>Bonnie</td>
<td></td>
</tr>
<tr>
<td>4/02</td>
<td>Start final paper</td>
<td>Siyuan</td>
</tr>
<tr>
<td>Start working on presentation</td>
<td>Randy</td>
<td></td>
</tr>
<tr>
<td>Finalize testing of stimulator</td>
<td>Bonnie</td>
<td></td>
</tr>
<tr>
<td>4/09</td>
<td>Continue working on final presentation</td>
<td>Siyuan</td>
</tr>
<tr>
<td>Final testing with BCI and EEG</td>
<td>Randy</td>
<td></td>
</tr>
<tr>
<td>Continue writing paper</td>
<td>Bonnie</td>
<td></td>
</tr>
<tr>
<td>4/16</td>
<td>Continue working on presentation</td>
<td>Siyuan</td>
</tr>
<tr>
<td>Continue working on final report</td>
<td>Randy</td>
<td></td>
</tr>
<tr>
<td>Continue working on final report</td>
<td>Bonnie</td>
<td></td>
</tr>
<tr>
<td>4/23</td>
<td>Finish up Final Demo for Presentation</td>
<td>Siyuan</td>
</tr>
<tr>
<td>Finish up Final Presentation</td>
<td>Randy</td>
<td></td>
</tr>
<tr>
<td>Finish up Final Paper</td>
<td>Bonnie</td>
<td></td>
</tr>
<tr>
<td>4/30</td>
<td>Final presentation and turn in final report</td>
<td>Siyuan</td>
</tr>
<tr>
<td>Final presentation and turn in final report</td>
<td>Randy</td>
<td></td>
</tr>
<tr>
<td>Final presentation and turn in final report</td>
<td>Bonnie</td>
<td></td>
</tr>
</tbody>
</table>