60 Hertz Electromagnetic Field Detector/Interface System

UIUC ECE 445, Spring 2012 – Team #13
3 Segments of this Presentation

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Introduction

Background, Objectives & Initial Design Thoughts
Background

Mr. Jamie Norton came up to us with a unique project requiring us to build a user friendly device which would have applications in neuroscience.

Working with a different department and the potential for further research is what attracted us most to this project.
Project Objectives

What was required?

• A 60-Hertz electromagnetic radiation detection device
• Greater Sensitivity, Portability, and user-friendliness than previous designs
• Integrated Haptic Feedback

Why do we need it?

• To detect ambient noise that decreases SNR of EEG Machines
• It has potential research applications in Brain-Machine interfacing and the development of new senses
Features

- Static 3-axis coil configuration for detection of all polarizations
- Detection of electromagnetic radiation between 55 and 65 Hertz
- Haptic feedback user interface
- Compact, portable design
- Filter with in-built amplifier and rectifier to reduce number of parts used.
After a few brainstorming sessions amongst ourselves, meetings with Jamie and consulting with professors, we came up with the following block diagram which we stuck with to the end.
Engineering Process

Final Design Choices, Justification, Hardware development
After finalizing the block diagram we went on to design each module and develop the necessary hardware for it.

The next few slides will discuss each individual design choice.
Antenna’s

- Coils hand-wrapped around ferrite cores
- Wooden stoppers to preserve shape
- Counting Error → More turns than expected
  - Adjustment in filter gain
Filter Design

- Two-pole active band-pass filter
- Center Frequency: 60Hz
- A single Supply Design
- 3 dB Bandwidth: 10Hz
- Power Supply: 6V
- Desired Gain: 200 V/V
Actual Filter Circuit
Software (Input)

• Intensity detection routine
  – Sampling over ~2 periods (34ms)
  – Vector sum of maximum intensities from each channel
Software (Output)

- **Driving micro-transducer array**
  - Number of high digital outputs corresponds to intensity of field

- **Saturation Handling**
  - Single coil saturates $\rightarrow$ Feedback unit pulses
Micro-transducer Array

- Driven by BJT array
  - Controlled by Arduino outputs
- Mounted on self-made wristband
  - Vinyl band with mounted project box
- Four above wrist, four below
- Low Resolution, High Intuitiveness
  - Sense of touch
  - Mapping
User Interface Picture

- Interweaved rubber and tape for vibration damping
- Velcro for adjustable size

- Disconnecting, 8 conductor cable for ease of use
Final Project Analysis

Tests, Successes, Challenges, Ethical considerations and Recommendations
Putting it all together
Test Procedures

Antenna
- The detection coils were placed in a Helmholtz coil generating a constant 60 Hertz magnetic field. The induced response was measured using an oscilloscope.

Filter
- Each channel was swept with 60 Hertz waveforms to characterize the gain. The frequency was also varied around 60 Hertz to characterize the bandwidth.
A graph Showing Voltage Induced vs Magnetic Field for each coil separately.
Filter tests and results

• Adjustment in filter gain
• Testing using proto-board before PCB
• Lack of exact required resistances → pass-band offset to one side
  • Increased bandwidth in design
• Diode nonlinearities
  • Converted to single-supply
### Filter tests and results

<table>
<thead>
<tr>
<th>Channel#1</th>
<th>Channel#2</th>
<th>Channel#3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vin (mV)</td>
<td>Vout (Vm)</td>
<td>Vin (mV)</td>
</tr>
<tr>
<td>0</td>
<td>1.313</td>
<td>120</td>
</tr>
<tr>
<td>1</td>
<td>2.813</td>
<td>171.9</td>
</tr>
<tr>
<td>2</td>
<td>3.75</td>
<td>453</td>
</tr>
<tr>
<td>3</td>
<td>4.188</td>
<td>581</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>793.8</td>
</tr>
<tr>
<td>5</td>
<td>6.375</td>
<td>850</td>
</tr>
<tr>
<td>10</td>
<td>11.72</td>
<td>1766</td>
</tr>
<tr>
<td>15</td>
<td>16.09</td>
<td>2250</td>
</tr>
<tr>
<td>20</td>
<td>23.75</td>
<td>2480</td>
</tr>
<tr>
<td>30</td>
<td>32.19</td>
<td>2770</td>
</tr>
<tr>
<td>40</td>
<td>43.75</td>
<td>2970</td>
</tr>
<tr>
<td>50</td>
<td>54</td>
<td>3130</td>
</tr>
<tr>
<td>60</td>
<td>62.5</td>
<td>3270</td>
</tr>
<tr>
<td>70</td>
<td>75.62</td>
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</tr>
<tr>
<td>75</td>
<td>78.75</td>
<td>3450</td>
</tr>
<tr>
<td>80</td>
<td>80</td>
<td>3470</td>
</tr>
</tbody>
</table>

Table showing filter test results at 60 Hz. See where it saturates. We noticed that no significant gain was observed outside a 10 Hz window.

- Gain 1: 163.7
- Gain 2: 175.3
- Gain 3: 140.2
## Test Procedures

<table>
<thead>
<tr>
<th>Microcontroller</th>
<th>Haptic Feedback</th>
<th>Power Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The robustness of the code was tested by outputting serial data regarding the detected amplitudes to a computer, and comparing with the input waveform.</td>
<td>• The feedback array contained in the wristband was tested by driving each individual BJT on at a time using the Arduino.</td>
<td>• The batteries worked properly, only concern is as the 6V source for the op-amps slowly falls in voltage value, the output offset falls with it, and the Arduino code constant for the offset must be adjusted.</td>
</tr>
</tbody>
</table>
As the table shows, the system can detect magnetic field strengths from around 0.01 uT to around 10 uT.
Ethical Considerations

We commit ourselves to abide by the ethical code laid down by the IEEE. A few considerations specific to our project are:

» Safety concern - if this device is used in areas of high radiation density. We ensured that currents do not exceed normal levels.
» No Ghost Hunting!
» Being honest to our clients – No false promises, and keeping the cost in mind.
Recommendations for future work

Tunable Filter
More compact case
Different user-interface
Larger size array using better transducers
Wireless communication sensor & feedback
From All of us

Thank You!

All peer reviewers
Everyone at the parts shop
Prof. Doug Jones
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Mr. Jamie Norton
Prof. Paul Scott Carney