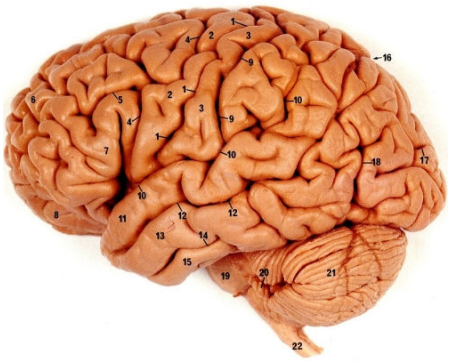
P08050 Remote EEG Sensing

Team Guide:
Dr. Daniel Phillips

Customer:
Daniel Pontillo
Dr. Fei Hu

Team Members:
Dan Pontillo
Ankit Bhutani
Jonathan Finamore
John Frye
Zach McGarvey



Project goal:

Interfacing an EEG acquisition system with a Wireless Mesh Network

Justification:

In standard EEG systems, noise and artifacts are generated by the movement of wires. The elimination of wiring from the analog system helps to alleviate this problem.

This project is a proof-of-concept design directed towards the eventual development of a wire-free EEG system wherein each electrode is a miniature self-contained microprocessor node in wireless mesh network.

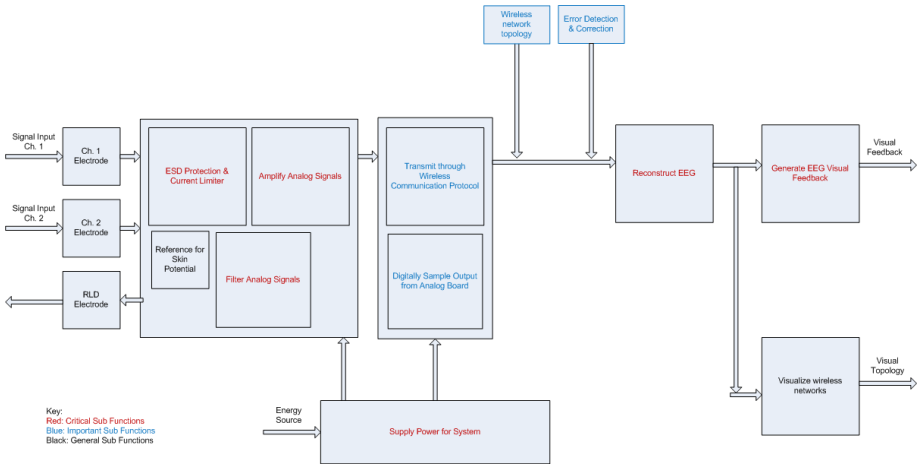
Customer Requirements

- Needs to acquire sufficiently accurate digital representation of an EEG signal
- Needs to transmit output wirelessly to a base station
- Needs to be scalable for multiple channels
- Needs to operate for at least 24 hours of continuous use on a mobile power source
- Needs to avoid using live mains due to safety considerations
- Needs to allow base station user to control and configure network
- Needs to display visual representation of acquired data
- Needs to cost less than $500.00 per unit to manufacture

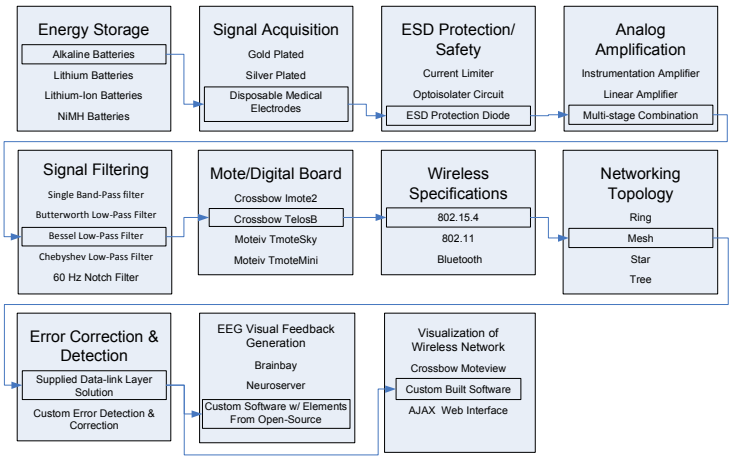
Implementation

- Analog amplification and filtering of the EEG signal using custom designed hardware
- Digital sampling of analog signal and encapsulation of data using TelosB mote
- Transmission of data over wireless mesh network using TinyOS platform
- Receipt and visualization of EEG data at base station PC using custom software application

Functional Diagram



Chosen Concept



Design Revisions

- Revisions to analog design
  - Switched to low power voltage regulator
  - Added Zener diode at output to protect ADC
  - Used Zener diode for ESD protection in place of transistor network
- Revisions to software design
  - Assigned highest priority to sampling thread
  - Added sample buffer

Integration Procedure

- Independently verify functionality of analog and digital systems
- Verify desired operation of combined system
- Mount analog circuit and mote in modified COTS enclosure

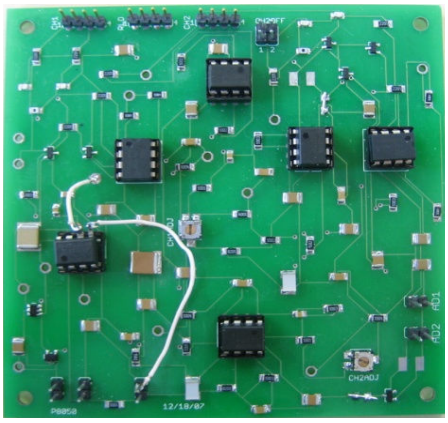
Budget

- Total Cost: $230
  - Analog board: $125
  - Digital Mote: $70
  - Electrodes & Miscellaneous: $35
- Final cost is 46% of projected $500 per unit budget

Tests Performed

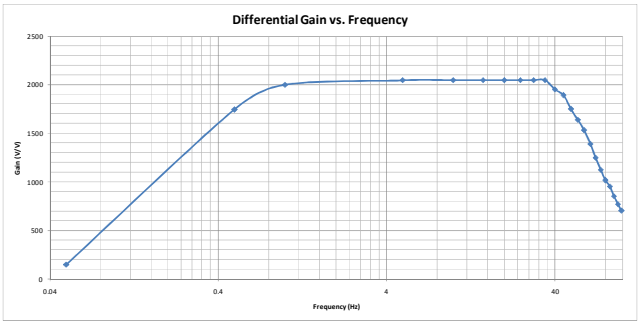
- Square-Wave Calibration Test
- Anti-Aliasing High-Filter Test
- Low Filter Test
- Common Mode Rejection Ratio (CMRR) Test
- Power Consumption
- Simulated EEG Waveform Test
- Digital Frequency Verification
- Amplitude Range Verification
- Wireless Transmission Reliability Test
- Software Functionality Test
- Multihop Verification
- Scalability Test

Results – Analog Board



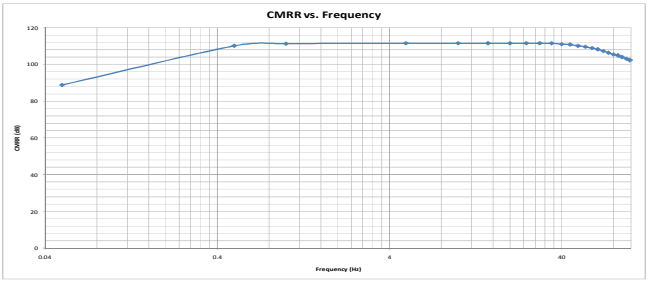
- Two Channel EEG signal acquisition and processing system successfully designed.
- Surface mount components used for the design
- Single supply, low power battery operation successfully implemented

Results – Analog Board



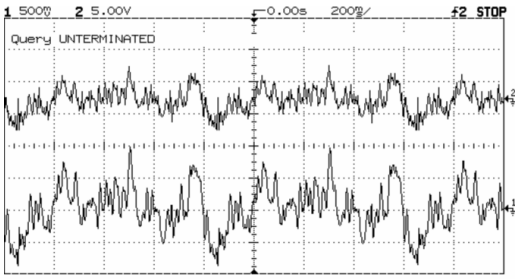
- The designed differential gain is attained and constant throughout the pass band
- The -3dB cutoff frequencies are within specified limits
- The gain can be adjusted from 1000V/V to 7000V/V at the adjustable gain stage to suit individual user needs

Results – Analog Board



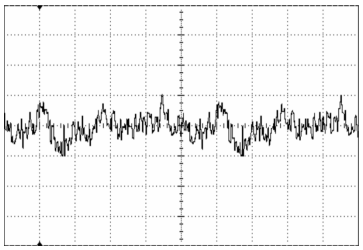
- The CMRR meets the IFCN standards of 110dB per channel
- The use of the right leg driver greatly increased the CMRR with minimal additional power consumption

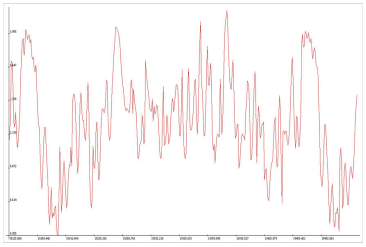
Results – Analog board



- Clinical EEG data is modeled in MATLAB and applied as an input
- The gain and frequency response of the output is as expected

Results – Digital Output





- A simulated EEG input of magnitude 100uV is applied to the amplifier input. The processed signal is wirelessly transmitted to the base PC and reconstructed.

Results – Power Consumption

Input Signal Amplitude (uV)	Voltage Applied (V)	Current Drawn (mA)	Power (mW)
1	6.327	5.504	34.82
10	6.327	5.507	34.84
100	6.327	5.515	34.89
500	6.327	5.960	37.71
1000	6.327	8.210	51.94

- Power consumption of the analog board is observed to increase as input magnitude increases
- Worst case analog board power consumption is 52mW
- Worst case digital board power consumption is 82mW
- Total consumption is 134mW, which is well below the 150mW specifiation

Design Strengths and Weaknesses

- Strengths
  - Modularity
  - Availability of Components
- Weaknesses
  - Digital and analog components using different power supply magnitudes
  - Lack of an automatic gain adjustment circuit in the analog board
  - Mote characteristics sub-optimal

Future Development

- Miniaturization of digital and analog boards for use as subdural implants.
- Superior quality digital board – faster processor – more RAM
- Automatic gain adjustment on analog board
- Uniform supply voltage for digital and analog boards
- Improvements to physical design
- Improvements to graphical user interface
- Active electrodes

Questions & Comments