Brain Modulator

Background

Neurological disorders such as epilepsy can severely disrupt a person's life robbing them of their livelihood. Epilepsy is characterized by having recurrent seizures, a synchronized abnormal activity of the brain. Status epilepticus, seizures that continue for 30 minutes or more cause 20,000 to 40,000 deaths in the United States each year. Dr. Besio has developed a method using his unique concentric ring electrodes to noninvasively (on the scalp surface) apply electrical stimulation to control seizures. The current prototype of the device is bulky, fragile, and is not easy to use or suitable for sharing with other researchers.

The objective of this project is to design and prototype a stand-alone Bio-Neuro Device for Brain Modulation that can be used by Dr. Besio and other researchers for neuro-modulation and monitoring. The final deliverables will be detailed design drawings, electronic schematics and layouts, materials list, interconnect diagram, control algorithms, and prototype.

Previous Progress:
The previous Capstone Team made great progress on our research system. However, there are still some aspects of the research system that need readdressing.

Functional specification:
For the Brain Modulator device it is necessary to develop an integrated system that will measure the skin-to-electrode impedance, apply stimulation, acquire and process data (electroencephalography (EEG) or other signals). The Brain Modulator must be a portable device capable of functioning for up to four hours of continuous use.

In order of priority

<u>Multiplexer</u> (last year's team nearly finalized this)
The multiplexer must be capable of switching the electrodes between the impedance meter, stimulator, and biosignal amplifier and will be controlled manually through a graphical user interface to determine which electrodes it will connect to what other subsystem. It must also be capable of software control via a controlling device during operation such as recording, stimulation, or impedance measuring. Must be able to connect the stimulator to any electrode of the three or any combination of the three electrodes.

<u>Analog-to-digital converter</u>
Twenty-four bit ADC capable of at least 2000 samples per second per channel for a minimum of 6 channels. (Not a multiplexed ADC.) We are considering the ADS1298 TI Low-power 8Ch 24 bit Analog Front End.

<u>Monitor</u>
The device should have a display for showing the skin-to-electrode impedances and selectable channels of biosignals (6 at a time).

Data storage (This can be to a laptop.)
Storage should be to some nonvolatile memory device. Minimum storage of 8 Ch at 4000 S/s at 24 bit for one hour is necessary, preferably up to four hours.

Biosignal amplifier (assemble and test)
Gain 100, bandpass 0.5 Hz to 30 Hz, 100 Hz, 300 Hz via a jumper or electronically selected. CMRR 100 dB, low noise (less than 500 nV RMS at 100 Hz)

Impedance meter (A prototype design was built and needs to be completed)
An alternating current such as a sine wave at 30 and 300 Hz should be applied through known resistors to the electrodes. The voltage measured across the resistors is proportional to the skin-to-electrode impedance. An automated process for determining the skin-to-electrode impedance that can be activated manually or via a software-controlled input must be developed. The impedance range should be from 500Ω to 100 KΩ. If the impedance is greater than 100 KΩ a "over range" message should be displayed. The impedance should be measured between each element of the electrodes and the reference as well as between each element of the electrodes. (If possible, the system should be able to measure skin-to-electrode impedance between stimulation pulses. To do so may mean increasing the skin-to-electrode signal beyond 30 Hz.)

Stimulator (The software interface is working now the hardware must be built)
The constant current stimulator should be capable of applying a single or series of monophasic or biphasic pulses. The frequency of the pulses must range from 0 Hz to 1000 Hz in 10 Hz increments. The frequency may change within a stimulation sequence (for example, start at 100 Hz, change to 200 Hz, and end with 500 Hz). The current must be adjustable from 0.1 mA to 200 mA in 0.02 mA increments. The stimulation pulse width should vary from 60 µs to 10 ms in 10 µs increments. The duration of the stimulation will be variable from 15 seconds to 5 minutes. The stimulator should be activated both manually and automatically via a software interface. The stimulation pattern must be programmable via a graphic user interface. Wave shapes other than just pulses would be a plus.

Digital signal processing
The seizure detection and source localization algorithms have not been finalized yet so several will be tested and possibly developed with hardware for speed.

Miscellaneous
All integrated subsystems must be capable of being programmed via a PC, all with the same interface USB or serial. The system should fit in one small box no larger than 24"x12"x6". The system should run on batteries for at least 4 hours.

Required skills: Dr. Besio needs a diverse team to accomplish the objective of this project.

1. Electronics and microcontrollers
2. Analog signal processing (Circuit design applications)
3. Digital signal processing (Matlab, Java, Visual C, or C/C++)
4. FPGA, VHDL