Bio-Nuero Device for Brain Modulation

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 eptilepticus, seizures that continue for 30 minutes or more cause 20,000 to 40,000 deaths in the United States each year. Dr. Walter Besio, of our department, (http://www.ele.uri.edu/faculty/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 or clinicians.

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, other researchers, and clinicians for neuro-modulation and monitoring. The final deliverables will be detailed design drawings, materials list, circuit design, interconnect diagram, control algorithms, and prototype.

Functional specifications:

For the Brain Modulator device it is necessary to develop an integrated system that will measure the impedance of 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 8 hours of continuous use.

In order of priority:

<u>Multiplexer</u>
The multiplexer has two functions. Function #1, it must be capable of switching the electrodes between the impedance meter, stimulator, and biosignal amplifier. Function #2, it must be capable of shorting all three elements of each tripolar concentric ring electrode or opening them for every-other data sample.

Function #1: The multiplexer must 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.

Function #2: The multiplexer must receive information about the data acquisition sampling rate and which electrodes are to be used. It will then calculate the switching rate to generate two separate data streams, one for the three elements of each electrode shorted and the other keeping the three elements of each electrode independent. The signals will then be applied to the biosignal amplifier. When the three elements are kept independent they will be applied to two instrumentation amplifiers taking two differences and when they are shorted the multiplexer must apply the single input to a single instrumentation amplifier and apply a reference signal to the other input of the instrumentation amplifier.

Analog-to-digital converter
Twenty-four bit (16 bit minimum) ADC capable of at least 2000 samples per second per channel for a minimum of 32 channels.

Monitor
The device should have a display for showing the skin-to-electrode impedances and selectable channels of biosignals (8 at a time).

Data storage
Storage should be to some nonvolatile memory device.

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

Impedance meter
An alternating current such as a sine wave at 30 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. (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 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. 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 0.5 mA to 200 mA in 0.5 mA 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.

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. A modular design is necessary to accommodate using 3 to 128 electrodes. The system should fit in one small box no larger than 24”x12”x4”. The system should run on batteries. The digital to analog converters should be 24 bit.

Required skills in the Engineering Team: Dr. Besio and Dr. Sendag need a diverse team of Electrical and Computer Engineers to accomplish the objectives of this project. Expertise in the following areas is required:

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

For further information and response to any questions, please contact the 2 faculty members below:

Walter G Besio: besio@ele.uri.edu
http://www.ele.uri.edu/faculty/besio/

Resit Sendag:
sendag@ele.uri.edu