Implantable Sensor for Longitudinal Recording of Spontaneous and Voluntary-Evoked EMG and NAP in Untethered Animals

Rebecca A. Bercich, Zhi Wang, Kevin L. Seburn, and Pedro P. Irazoqui, *Member, IEEE*

MYOELECTRIC (EMG) and nerve action potential (NAP) recordings are often used to diagnose patients with neuromuscular diseases and disorders. The study of peripheral neuropathy, motoneuron disease, and muscular dystrophy can be improved through the use of animal models that present similar phenotypic signs such as gradual denervation of muscle and axonal death. For example, a decline in motor performance and persistent denervation and reinnervation of muscle can be seen in the Tg.SOD1G93A mouse strain, which is a model for amyotrophic lateral sclerosis (ALS). To improve the face validity of these models, and to better characterize the progression and proper treatment of these diseases, researchers require a means of longitudinally recording spontaneous and voluntary-evoked aberrant muscle and nerve activity[1]. At present EMG and NAP data is most often gathered from anesthetized animals and is stimulus-evoked. However, in order to accurately characterize disorders of central motor control it is necessary to retrieve this data from awake, untethered animals. Towards this end a wirelessly powered, chronically-implantable device has been developed that is capable of both harvesting electromagnetic energy from radio frequency (RF) waves and simultaneously transmitting recorded data in real-time using a wireless telemetry link.

Sensor operation is delegated using a 32-bit ARM Cortex-M0 microcontroller and is configured to transmit using a Gaussian frequency shift keying (GFSK) modulation scheme. The microcontroller is programmed such that its on-board analog to digital converter (ADC) samples at a rate of 5kHz with 8-bit resolution. Wireless data transmission is achieved via an ultra-low-power RF transceiver and 2.4GHz ceramic antenna which communicates with an external receiver board connected to a PC for continuous data demodulation, visualization, and storage. Recorded data is adjustably bandpass filtered and amplified on-chip with typical bandwidth and gain being 1Hz to 1kHz and 46dB, respectively. The sensor has an average current consumption of 3.06mA and an average power consumption of 5.81mW.

The device is integrated on a 6-layer printed circuit board (PCB) measuring 6.5mm x 11.5mm x 2mm. This platform is capable of accommodating various electrode sizes and configurations depending on the type of signal being targeted and desired specificity. For example, input terminals can accommodate fine wire, needle, or concentric electrodes for focalized EMG or single fiber action potential recording in a manner similar to clinical practices[2]. Alternatively, a separate board with planar electrode contacts connected to the main device by flexible wires can be used to record compound muscle action potential from the surface of the muscle. Power is harvested from a nearby antenna radiating at or close to 915MHz (elected for the favorable compromise between necessary harvesting antenna dimensions and degree of tissue attenuation[3]). Radiation frequency may be adjusted slightly to accommodate changes in resonance in the ceramic power scavenging antenna.

Initial animal trials have been performed in which the device is placed subcutaneously within the fascia above the gluteus maximus of a mouse. The device was successfully powered using a wideband horn source antenna with a power output of 30dBm (1W). Functionality and validity of the sensor's wireless telemetry link was simultaneously confirmed during the animal trials. Efforts are ongoing to improve the efficiency and robustness of the power harvesting link and ultimately increase the volume of space in which the device can receive adequate levels of power to operate. This will be advantageous when recording from multiple devices in awake, untethered animals within their housing or testing environments.

References

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R. A. Bercich is with the Biomedical Engineering Department, Purdue University, West Lafayette, IN 47906 USA (phone: (765)496-1439 fax: (765)494-1193 e-mail: rbercich@purdue.edu).

G. Z. Wang is with the Electrical Engineering Department, Purdue University, West Lafayette, IN 47906 USA (e-mail: grant.z.wang@gmail.com).

K. L. Seburn is with The Jackson Laboratory, Bar Harbor, ME 04609 USA (e-mail: kevin.seburn@jax.org).

P. P. Irazoqui is with the Electrical Engineering and Biomedical Engineering Departments, Purdue University, West Lafayette, IN 47906 USA (e-mail: pip@purdue.edu).