PROJECT DESCRIPTION

Title: *A Lightweight Bidirectional Wireless Neural Recording and Control Microsystem*

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Funding Source: NIH *Work Began: 01/01/2006*

Project Goals:

The primary goal of this project is to collect biological information from freely flying songbirds, and specifically from the Zebra Finch. To understand the role of experience in modifying the brain, songbirds are one of the best models to study due to the fact that the male specie can learn his father's song by a process of imitation which is independent of genetic ties between the birds (S. Overduin, 2003). To collect the biological data, extracellular neural activity sensed by electrodes implanted in the host's forebrain, should be processed and transmitted out over a wireless link to a remote receiver by a lightweight, low-power, and long-range transceiver capable of both sending and receiving data and power.

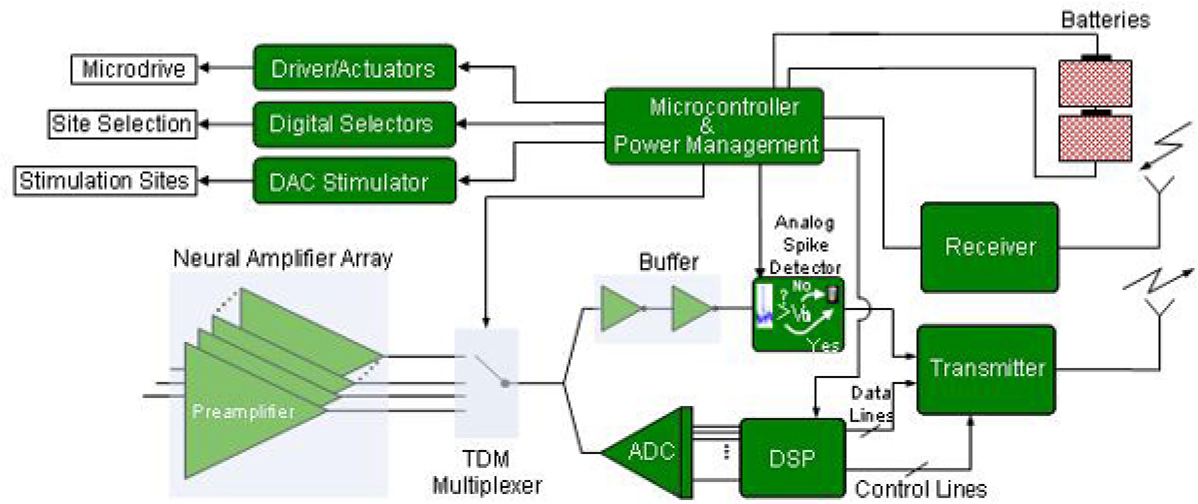

Figure 1: Block diagram of a generic bi-directional wireless multichannel bio-telemetric microsystem.

Approach and Methodology:

The architecture of this wireless microsystem (Figure 1) provides several input channels for sensed signals, such as neural biopotentials, that are amplified, multiplexed, and transmitted out through a wireless link. It also provides several output channels to deliver electrical signals to either actuators, such as a microdrive, or to other components such as stimulating electrodes. As a consequence of running on batteries, two key challenges needed to be addressed are low-power dissipation to maximize the lifetime and light weight (including the batteries). Aiming at engineering a complete system (front-end, signal conditioner, data modulator, wireless link, receiver ...), at design phase, there are many unknown interrelated parameters only known by testing the entire system; a high-level system simulation can give first-order information about the parameters, and therefore, in the first phase of design, a high-level Simulink model of the complete system was developed. Second phase of the project was employing the model in designing the hybrid 15-Channel prototype version of the system. The third phase consists of integrating the hybrid components on a single die to further reduce the power, size, and weight.

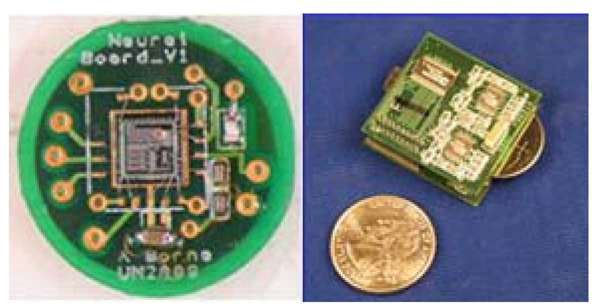

Figure 2: (Left) Single-chip, wireless, biotelemetry microsystem (Weighs <1g, Volume <1cm^3). (Right) The hybrid, multichannel, biotelemetry microsystem.

Role in Supporting the Strategic Plan and Testbeds:

The system developed in this project could be used in a variety of applications that need low-power, long-range, and lightweight sensors, including those intended for biological signal acquisition from untethered biological hosts. This project directly supports both WIMS testbeds.

Results and Accomplishments:

Various hybrid multichannel systems are developed and employed in characterizing the system performance metrics, e.g., SNR, transmission range and channels' crosstalk; specifically a lightweight (6.7g without batteries), low power (3.7mA from a 3V battery, operates up to 24Hrs from a Panasonic CR_2032), small size (30 × 30 × 8mm^3), multichannel (up to 15-Ch, tested for 7-Ch) prototype system was designed and assembled (Figure 2 Right); it has shown successful operation in *in vitro* tests and *in vivo* experiments on Zebra Finches and Guinea Pigs. In third phase of the project, a single-chip, wireless, biotelemetry microsystem, NC_V1 (Figure 2 Left) is developed and has been characterized through *in vitro* experiments. This is a 3-Ch system with transmission range of 10ft, weight of 1g (including the batteries), volume of < 1cm^3, and lasts for 25hrs. NC_V1 has shown successful results in recording neural signals from Femur of Cockroaches and *in vivo* experiments on motor cortex of Long Evans Rats (Figure 4).

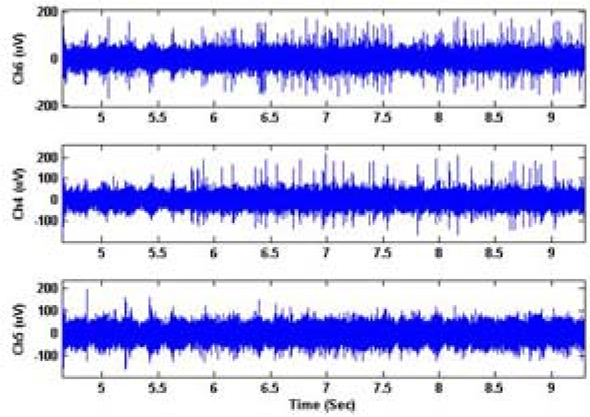

Figure 4: Multichannel recording from Motor Cortex of Long Evans Rats.

Currently, another single-chip, wireless, biotelemetry microsystem, NC_V2, is under design which will extend the number of channels to 16 and further reduces power and improves transmission range.

Relevance to Other Work:

Many academic research groups are working toward developing wireless microsystems to transmit physiological data from untethered biological hosts; also recently the wireless biotelemetry systems can be found in market through companies like AphaOmega, Neuralynx, and TBSI; a common characteristic of these commercial off-the-shelf biotelemetry microsystems is their prohibitive size and weight which makes them unattractive for the application of the project presented here. This work aims at further improving the performance metrics and reducing the size and weight of such microsystems by integrating all the components on a single die.

Plans for the Coming Year:

During the next year, we will develop the next generation of standalone, single-chip, biotelemetry transceivers to achieve further improvements in performance.

Expected Milestones and Dates:

- Design and fabrication of a hybrid 15-Channel system prototype *(Completed)*
- *In vitro* and *in vivo* tests of the above prototype *(Completed)*
- Design of a 3-Channel integrated microsystem and submission to MOSIS *(Completed)*
- *In vitro* and *in vivo* tests of the above 3-Channel microsystem *(Completed)*
- Design of a 16-Channel, single-chip, wireless biotelemetry microsystem (11/15/2009)
- *In vitro,* and *in vivo* tests of the 16-Ch biotelemetry device (02/15/2010)

Expected Contributions, Deliverables, and Company Benefits:

- Develop lightweight, low-power, long-range, wireless microsystems for biopotential recording in untethered biological hosts
- Develop ultra-low-power, bidirectional transceivers

References and Recent Publications:

1. A. Borna, T. Marzullob, G. Gage, and K. Najafi "A Small, Light-Weight, Low- Power, Multichannel Wireless Neural Recording Microsystem," *The 31st Annual International IEEE EMBS Conference,* September 2009.
2. J. A. Gregory, A. Borna, S. Roy, X. Wang, B. Lewandowski, M. Schmidt, and K. Najafi, "Low-Cost Wireless Neural Recording System and Software," *The 31st Annual International IEEE EMBS Conference,* September 2009.
3. P. Mohseni, K. Najafi, S. J. Eliades, and X. Wang, "Wireless Multichannel Biopotential Recording Using an Integrated FM Telemetry Circuit," *IEEE Trans. on Neural Systems and Rehabilitation Engineering,* (see also *IEEE Trans. on Rehabilitation Engineering*), vol. 13, issue 3, pp. 263–271, September 2005.