Peripheral Nerve Interface System For Controlling and Sensing in Artificial Limbs

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Abstract

The MMRO is developing an interface to a peripheral nerve to be used to control the joints of an artificial limb, and to stimulate the appropriate neurons with signals from sensors on the prosthetic. The interface will consist of a slanted Bed of Nails (BON) similar to the concept of Branner[1] and Dhillon [2]. It will contain a hermetically sealed integrated circuit in the "Bed" which is connected to a Battery Powered Repeater (BPR) by a thin flexible cable. The BPR communicates via a 400MHz radio channel with the Prosthetic Control Unit (PCU) in the prosthetic. The BON contains 128 solid iridium needle electrodes of various lengths. The system allows Bidirectional communication and can be programmed to stimulate or sense on any electrode. The system is capable of simultaneously sending 90 commands/sec to each of the electrodes on six different BONs.

1 Introduction

There are about 1.5 million leg amputees in the United States from Diabetes and many thousands of amputees from the war. Artificial limbs are continuously improving. However there is a need for a peripheral nerve interface to permit the patient to obtain touch and proprioceptive feeling, and to directly control the movement of the prosthetic. In the work by Dhillon et al. [2], they demonstrated the ability of the patient to detect touch and proprioceptive signals by stimulating neurons in the peripheral nerve, and they could also detect spikes on individual neurons indicating that the patient wanted movement at a specific joint. The nerve is very fragile and should not be kept from freely moving relative to other muscles and nerves. This means that the BON must be small and light weight, and attached to the nerve. Also the BON needles are randomly connected to the different neurons in the peripheral nerve. Not knowing in advance which needles need to be stimulating or sensing requires that each needle be programmable as to whether it be a stimulating or sensing needle.

1.1 System Components and Equipment:

The interface will consist of three components:

(1) A slanted Bed of Nails [1][2] (BON) containing a hermetically sealed integrated circuit and 128 needle electrodes. The circuit will allow any electrode to be used as a sensing electrode or as a stimulating electrode. The bed of the BON will contain the integrated circuit and will be about 5mm x 10mm x 2mm thick. The BON will be mounted on the peripheral nerve close to the neuroma. From the BON there will be a thin flexible cable containing about 5 wires that is connected to the Battery Powered Repeater (BPR).

(2) The BPR contains a battery, a 125kHz magnetic field pickup coil, a circuit for charging the battery, an interface to the cable coming from the BON, a bidirectional 400 MHz radio transceiver, and an antenna. The BFR will have bidirectional radio communication with the Prosthetic Control Unit (PCU) mounted in the prosthetic. The dimensions of the BPR will be determined by the location on the stump. The initial BPR will be about 25mm wide, 50mm long and 7mm thick.

(3) The PCU will contain an antenna, a transceiver, interface microprocessor, wired outputs to actuators and wired inputs to sensors. It will either contain a battery or use the power from the prosthetic battery.

Additional equipment in the form of a notebook computer and a charger will be used to program the Interface and charge the BPR. The communication system will allow up to six interfaces to operate simultaneously at a speed of 90 commands per electrode per second. Additional interfaces can be operated by reducing the number of commands per electrode per second.

2 Methods

2.1 Stimulating and Sensing parameters:

Each pulse generator will be capable of being programmed between 5uA and 2mA in 3.3% steps. The pulse width will be programmable between 10uSec and 1000uSec in 3.3% steps., and the rate will be programmable between 1 and 200 PPS in 3.3% steps.
Bursts on time, and Burst off time individually: 0.1Sec to 10 seconds in 3.3% steps,
Rising and falling slopes will also be included.
Pulses fixed relative to frame edge.

2.2 Programmable Sensing parameters:

1.0 uV to 100 mV in 3.3% steps.
High pass frequency cut off at 1kHz, 3kHz and 10kHz
Low pass frequency cut off 0.1 HZ, 1Hz, 10Hz

Data reduction:
Window circuits:
Rectify and integrate

Oscilloscope mode (Streaming) 30000 samples per second with three channels simultaneously

Amplifier locked off for 5 ms just prior to start of stimulation pulse

4 Discussion and Conclusions

The communication system will use TDMA to save battery power. Many details have yet to be worked out. Most of the circuitry that we will be using were generated in other projects. There is concern that the BON will not be able to maintain a stable connection to the peripheral nerve. Apparently such problems have come up in other labs. We are hoping that the thinness and flexibility of our connecting lead will provide stability.

References

[1] Branner A, Stein R, Normann R, Selective Stimulation of Cat Sciatic Nerve Using an Array of Varying Length Microelectrodes. The American Physiological Society, 2001
[2] Dhillon G, Lawrence S, Hutchison D, Horch K, Residual Function in Peripheral Nerve Stumps of Amputees: Implications of Neural Control of Artificial Limbs. The Journal of Hand Surgery.

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