CAPITel: Design and Implementation of a wireless 6 channel EMG measurement system for permanent *in vivo* use: *in vitro* results

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Poster number: IFESS27

Introduction

Currently, intelligent prostheses use electrodes applied to the skin or within the prosthesis socket to measure muscle contractions (ElectroMyoGraph or EMG) to control the prosthesis' movements. Bad contact leads to signal issues and control problems. These limitations are slowing developments and are affecting the transition from an on/off style of control to graded control with complex gesture detection. These prostheses integrate multiple signals into one control unit, and require increasingly accurate EMG.

The Implant

We have developed an implant capable of recording signals from 6 electrode arrays sutured directly onto the muscle belly for a higher signal to noise ratio (SNR).

The implant uses 1wire as the optimal communication method through a metal feedthrough socket in the stump *(Figure 1)*. With 1wire, bidirectional communication and power is possible using only one wire.

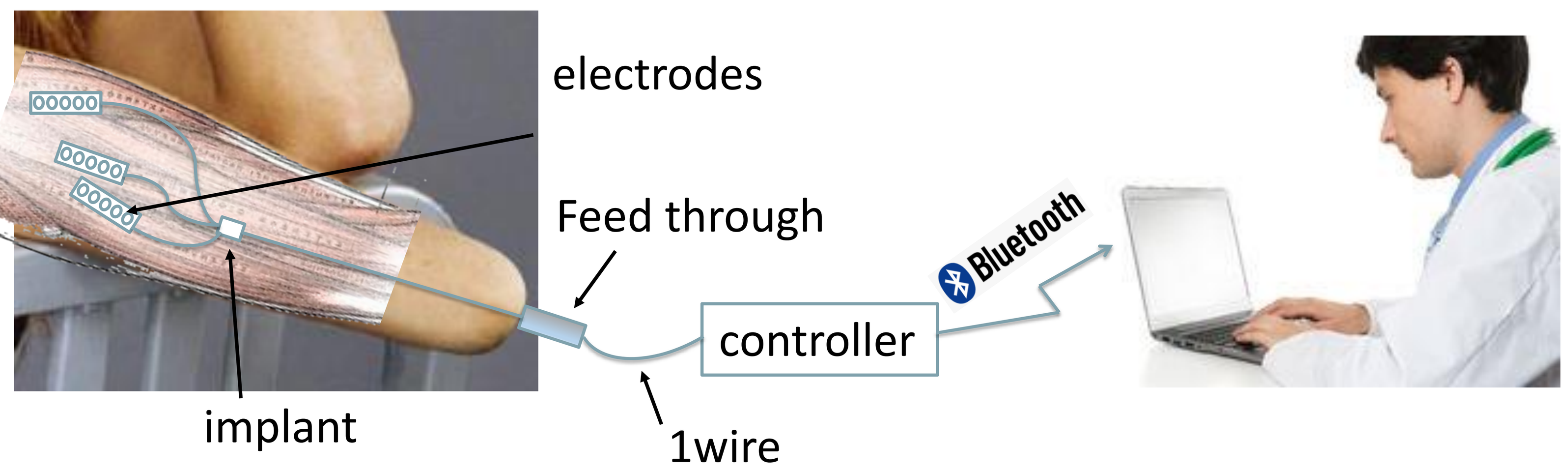

Figure 1: the CAPITel system. The implant will reside in vivo *and measure 6 channels of electrode arrays. The data is then sent through 1wire to a controller, in turn providing two-way wireless communication with a computer.*

Each analog input channel has 16 bit resolution, measured at 2 KHz per channel, using the ADS1298 (Texas Instruments, USA) Analog to Digital Converter (ADC). The implant had PCB dimensions 19.33 x 14.37 x 2.5 mm, suitably sized for housing in a ceramic implantable package.

With 6 channels of EMG we have created a platform for multiple signal integration. Multiple inputs per channel allow the use of electrode arrays (Figure 2), which enable determining the optimal electrode distance for future standard bipolar electrodes.

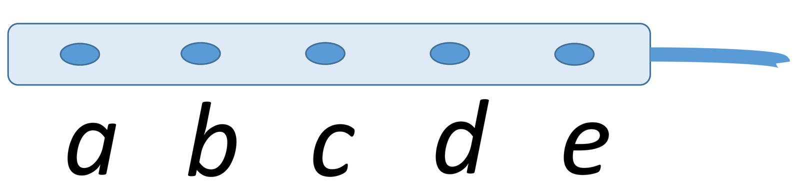

Figure 2: muscle electrode array with individually addressable electrodes

A multiplexing array (ADG2188, Analog Devices, USA) made it possible to measure any combination of the electrode array connections by an ADC.

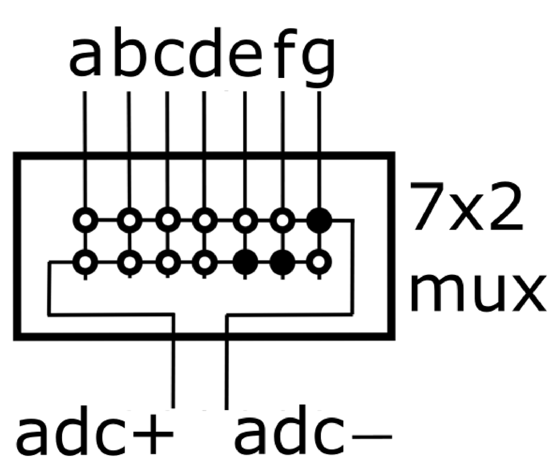

Figure 3: multiplexer

The Control Unit

For bench tests, the implant has a wired connection to a control unit, itself connected wirelessly to a PC. The control unit communicates bidirectionally with the implant using 1 wire to receive envelope data (rectified and averaged data at 31 Hz), send configuration commands, and provide power through one wire. The control unit can also read raw measurement data from the implant at 2 KHz through a direct connection

Validation method

A sinewave with frequencies between 20 and 1000 Hz and an RMS amplitude of 25 mV was applied as a test signal on channel 1, with all other inputs shorted and floating. The data that was received wirelessly on the laptop was analysed in MATLAB.

Preliminary Results

The frequency response shows a band pass characteristic with -3dB frequencies of 20 and 500 Hz.

The noise floor of the system was better than -59 dB, resulting in an effective resolution of 9.5 bits. The noise had a mean RMS of 18.78±12 μV.

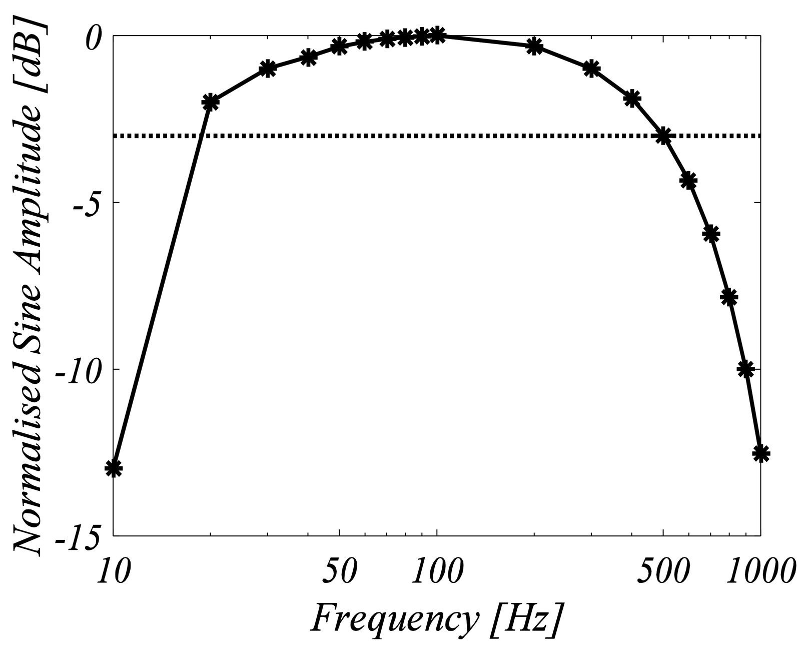

Figure 4: Frequency characteristic

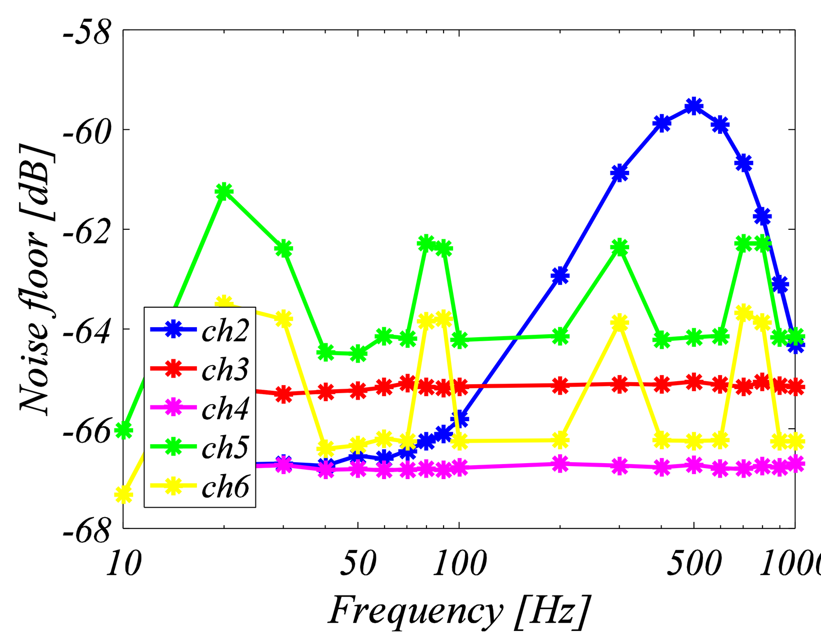

Figure 5: Noise floor

Discussion

The preliminary results look very promising, with 6 channels of simultaneous input, a choice out of 7 inputs per channel, and a noise floor better than -59 dB. A high SNR and multiple input channels increase the data processing capabilities of a smart prosthesis.

The implant [1] that is most comparable to CAPITel had one 8 bit ADC channel, and achieved a SNR of 30-52 dB.

1wire is a very robust method to transmit power and enable bidirectional communication. Future versions of the implant will also use inductive power and communication.

Conclusion

A novel implant with multiple channels and a superior signal to noise ratio has been developed and validated. Raw data at 6x 2KHz and envelope data at 6x31 Hz was sent wirelessly and stored on a computer. The dimensions are suitable for implantation. CAPITel provides an excellent basis for future improvements in myoelectric control of prostheses.

[1] Pasquina et al, "First-in-man demonstration of a fully implanted myoelectric sensors system to control an advanced electromechanical prosthetic hand." J Neurosci Methods (2015) **244**: 85-93.