Low-cost, open source bioelectric signal acquisition system

Enzo Mastinu, *Student Member, IEEE,* Max Ortiz-Catalan, *Member, IEEE,* and Bo Håkansson

***Abstract*— Bioelectric potentials provide an intuitive source of control in human-machine interfaces. In this work an open source low-cost system for bioelectric signals acquisition and processing was developed. A single module can acquire up to 8 differential or single-ended channels, and several modules can be daisy-chained together. Opto-isolated USB communication was included in the design to interface safely with a personal computer. Embedded digital processing was used for float conversion and filtering. The high-level software was implemented as a complementary part of BioPatRec, an existing open source project. Source files for the PCB, firmware, and high-level software are available online (GitHub: ADS_BP). This integration provides a low-cost, open source and complete system for research on intuitive myoelectric control.**

I. Introduction

Human-machine interfacing via bioelectric signals has been historically pursued for rehabilitation and research purposes [1], as well entrainment in recent years. Commercially available bioelectric acquisition systems are costly, bulky, and often restricted to operating only with the manufacturer's software. Open source projects have tried to oppose this trend, but most of the time the related hardware and software is not openly available for further development.

In this study, a versatile, portable and low-cost bioelectric signal acquisition device has been developed and made freely available as an open source project. It includes the board design, as well as the microcontroller unit (MCU) firmware and Matlab routines needed to acquire data on a PC. The cost evaluation of this system is below $100 USD. Functional and power consumption tests revealed its potential for portable bioelectric acquisition, in USB mode, as well as in WiFi and Bluetooth. Test results and all related materials are available on GitHub from March 2016 [2].

II. System Architecture & Details

The system is divided into three parts: 1) the Analog Front-End (AFE) and optically isolated communication in a dedicated PCB, 2) the MCU and its embedded software for signal acquisition and processing, and 3) computer software for control and communication of a personal computer (PC). We selected a low-cost MCU developing platform: the Tiva LaunchPad (Texas Instruments, USA). The Tiva LaunchPad has a double 20 pin connectors that allows stacking expansion boards (booster packs), thus allowing sharing of power lines, GPIOs and peripherals. The board was designed (52x65 mm) containing the AFE and isolated communication interface which takes advantages of this stackable architecture (Fig. 1);

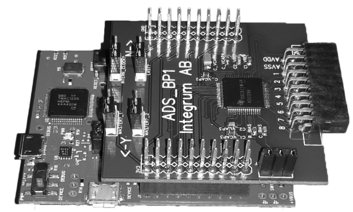

Figure 1. ADS_BP stacked on top of a Tiva LaunchPad.

more than one can be connected in parallel easily expanding the number of channels. The ADS1299 (Texas Instruments, USA) was selected as the AFE due to its low cost and previous performance benchmarking [3]. A single ADS1299 provides 8 simultaneous bipolar channels with a resolution of 24 bits, making it suitable for EMG/EEG/ECG applications. An Opto-isolated USB port was included in the board to provide a safe user interface (>25 kV/μs). The firmware was written in two consequent versions. In the first version the MCU only reads the raw bytes packages and forwards them to an external back-end. In the second one, the MCU applies digital signal processing (DSP) with float conversions and filtering (Fig. 2). Efforts were also spent on the high-level software, all necessary routines to use the device proposed here are provided in the BioPatRec release FRA [4] (March 2016).

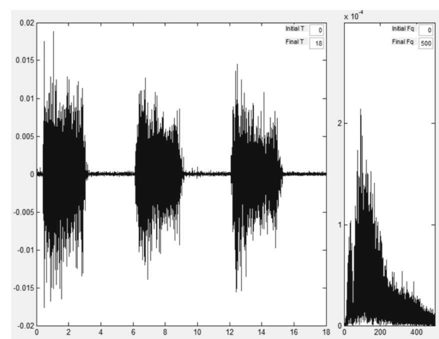

Figure 2. Sample of recordings using BioPatRec.

Acknowledgment

The authors thank the Swedish Research Council (Vetenskapsrådet), VINNOVA, Integrum AB and Chalmers University of Technology.

References

[1] D. Farina, N. Jiang, H. Rehbaum, A. Holobar, B. Graimann, H. Dietl, and O. C. Aszmann, "The extraction of neural information from the surface EMG for the control of upper-limb prostheses: Emerging avenues and challenges," *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 22, no. 4, pp. 797–809, 2014.

[2] E. Mastinu and M. Ortiz-Catalan, "ADS_BP." [Online]. Available: https://github.com/biopatrec/ADS_BP.

[3] E. Mastinu, M. Ortiz-catalan, and B. Håkansson, "Analog Front-Ends comparison in the way of a portable , low-power and low-cost EMG controller based on Pattern Recognition," *EMBC 2015*, pp. 2111–2114, 2015.

[4] M. Ortiz-Catalan, R. Brånemark, and B. Håkansson, "BioPatRec: A modular research platform for the control of artificial limbs based on pattern recognition algorithms.," *Source Code Biol. Med.*, vol. 8, p. 11, 2013.

Research supported by Integrum AB and Chalmers University (CTH).

E. Mastinu and B. Håkansson are with the Dept. of Signals and System, Chalmers University of Technology (CTH), Gothenburg, Sweden (e-mail: enzo@chalmers.se, boh@chalmers.se).

M. Ortiz-Catalan is with the CTH, the Centre for Advance Reconstruction of Extremities (C.A.R.E.), Sahlgrenska University Hospital (SUH), and Integrum AB (e-mail: maxo@chalmers.se).