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TEN ACTIVE ELECTRODE LINEAR ARRAY FOR WIRELESS SURFACE ELECTROMYOGRAPHY

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SUMMARY

The interest of the researchers in linear electrode arrays for surface electromyography is increasing. In addition to performing the task of the traditional bipolar electrodes, they allow the study of the innervation zone location and the assessment of the muscle fiber conduction velocity. The cost of equipment like these is high, and it is attractive to build a wireless version. So, a wireless linear array of ten active electrodes for surface electromyography was developed in Bioengineering and Biomechanics Laboratory/Federal University of Goiás. Preliminary tests had shown that the desired specifications are in accordance with the standards described in the literature.

INTRODUCTION

A promising research field in surface electromyography (s-EMG) is the linear arrays of electrodes. Applications are many for electromyography and can even be used for in-depth study of some neuromuscular diseases, such as polyneuropathies, myasthenia and myopathies [1].

Using a multichannel electrode array, we can also obtain the decomposition of s-EMG signals, estimation of conduction velocity of muscle fibers, location of areas of innervation (the motor points) among other applications [2]. As an example, Figure 1 shows simple differential s-EMG signals of an array of eight electrodes.

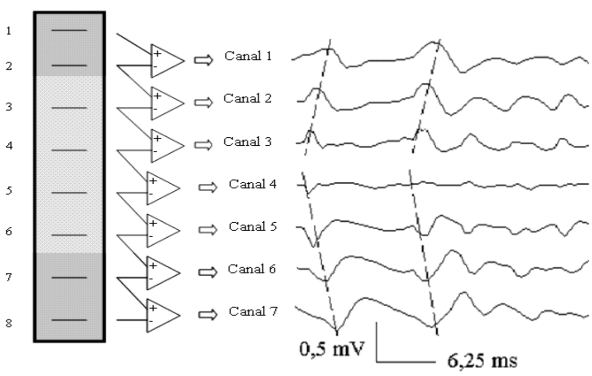

Figure 1: Propagating potential in the short head biceps brachialis muscle (elbow flexion to 90°; linear array of eight electrodes of silver of 10 mm length and 1 mm diameter, 10 mm distance between electrodes in bipolar configuration). Dotted lines illustrate the propagation of action potentials of the motor units. The innervation zone is in the region of the channel number 4 [2].

One of the problems faced when using surface electrodes is the interference due to the movement of the cables [3]. Therefore, the use of an array of surface electrodes capable of transmitting captured wireless signals is interesting, not only by the reduction of the artifacts, but also by the comfort and freedom given to patients during data acquisition.

In Brazil we found multichannel wireless s-EMG electrodes or wired s-EMG linear electrodes array [2], but there is no wireless linear electrode array yet. Furthermore, wireless multichannel electrodes have high commercial cost, even without the linear array configuration.

Aiming to overcome these limitations, a linear array of ten wireless active high-resolution electrodes for real time acquisition of EMG-S is in the final stages of development in Biomechanics and Bioengineering Laboratory, Federal University of Goiás. This article describes the topology, functionality and motivation for this circuit, and the difficulties encountered so far.

METHODS

It was developed so far a system consisting of ten active electrodes, which provide nine channels of EMG-S in single differential configuration. Each electrode is a bar made of silver (99.99% purity) with 1 mm width and 10 mm length, inter-electrode spacing of 10 mm.

The signal amplification is done by instrumentation amplifiers and operational amplifiers. The signal is received by a high resolution Analog/Digital (A/D) converter, and sent in digital format to a microcontroller, responsible for organizing the data acquired. This data is transmitted wirelessly to a computer through a Bluetooth module via serial communication, and represented as waveforms on a program developed in Labview.

In Figure 2 is shown the block diagram of the system. It is expected that in the final testing of the project, the electrode array meets the following requirements:
- Low cost compared to similar equipment on the market;
- High resolution (16 bits), high sample rate (10000 samples per second) and a high common mode rejection ratio (CMRR);

- Meet the standards for safe use of medical equipment;
- Possess an interface for easy interaction with any computers and smartphones via Bluetooth;
- Enable research in several areas (biomechanics, athlete's signal acquisition, underwater s-EMG, animals, among other possibilities);
- Powered by only one high-capacity lithium-ion battery, (3.7 V, 2400 mAh).

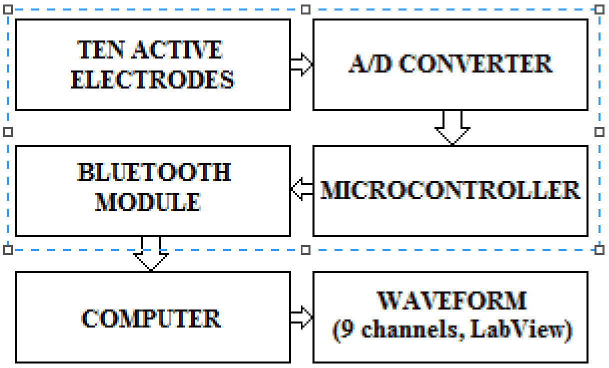

Figure 2: Block diagram of the linear electrode array: the developed hardware is in a package containing ten electrodes, analog / digital converter, microcontroller and Bluetooth module.

RESULTS AND DISCUSSION

The amplifier circuit was quite simple to build, but requires a lot of caution when collecting the signal. Since the system does not have a filter to eliminate noise generated by the electrical grid it is possible to find components of 60 Hz in the signal. Since this is a range of frequencies present in the signal of EMG-S, it was decided not to use notch filters to eliminate this component, as it is likely to be eliminated through properly positioning of the reference electrode. Thus, the signal was maintained with the highest possible quality.

The conversion and transmission circuit was more demanding. It requires a minimum sampling rate of 1000 samples per second per channel, since the S-EMG signal has information relevant around 500 Hz [4]. It was proposed to have a high resolution acquisition (16 bits, 10000 samples per second per channel).

Thus, there is the need for a high transmission rate: 9 channels, with at least 20 bits per channel (16 data bits, three bits of channel information, one start bit) to at least 1000 samples per second, which generates a need for a transmission rate of at least 180 Kbits/s. Considering acquiring at 10000 samples per second, it was necessary a transfer rate of 1.8Mbits/s to support the application's needs.

The circuit built so far, according to the assumptions above, should also be as small as possible, in order to be compact and comfortable to wear during measurements. This led us to choose the PIC24FV32KA304-I/PT, together with two analog/digital converters ADS1278 (resolution up to 24 bits, up to 144,000 samples per second, 8-channel, Delta Sigma architecture), INA114 instrumentation amplifiers (single power supply, rail to rail, very high CMRR) and operational amplifiers OPA344 (single power supply, variable reference). The chips of the amplifiers and the microcontroller have been inserted into a SMD version board to occupy the smallest possible space.

To meet the demanding signal transmission speed requirement, it was necessary to use a WT12 Bluetooth module (Bluetooth 2.0 + Enhanced Data Rate with actual speed up to 3 Mbits/s) [5].

CONCLUSIONS

Performing bench testing, it was verified that the desired gain was obtained with a clean signal and noise free - including at 60 Hz. The tests were done by applying sine waves (with frequencies between 1 and 500 Hz and 1mV of amplitude) at the input of the circuit and checking the output initially with an oscilloscope, and later on the developed software.

Nevertheless, using a microcontroller, it is possible to improve the developed software so we can set via computer the desired characteristics at real time during the acquisition. For example, will be possible to disable eight channels and use the array as a single electrode, or raise/lower the sampling rate, customizing the acquisition according to the needs. The software still deserves a carefully review to fully achieve the developed hardware's potential.

Therefore, the proposed system, in final stage of development, demonstrated, so far, good quality and will especially contribute in scientific research, with applications in biomechanics, motor control and s-EMG fields in Brazil. There are also applications beyond scientific research: its customization capabilities also allow medical applications, control at distance, and hospital instrumentation.

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