Multichannel EMG acquisition system for arm and forearm signal detection

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Multichannel EMG Acquisition System for Arm and Forearm Signal Detection

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Abstract— **The aim of this article is to design a multi-channel electromyographic (EMG) signal acquisition system, using the fewest electronic components to avoid noise as much as possible. This is accomplished by means of an electrodes array for differential acquisition and two references to reduce array's area and noise. It consists of a 16-channel acquisition system connected through a microcontroller USB interface for storage. Each single acquisition channel consists of a buffer, a pre-amplifier and filters; providing a low cost acquisition stage as well as a low noise system and retaining all the information that can be found at a frequency of 50 Hz, due to non-use of a notch filter. Making it possible to measure specific movements of the arm and forearm at the same time.**

Key words—**EMG, signal acquisition, multichannel, electrodes array.**

I. INTRODUCTION

A. Electromyography

Electromyographic signals (EMGs) are electric potentials generated by the action of different motor units during a muscle contraction. The amplitude of this signals go from 50 μV to 20-30 mV. The amplitude of this biopotentials is proportional to the intensity of the contraction [1]. EMGs are detected in a frequency range between 20-450 Hz [2].

In clinical neurophysiology, EMG is used to determine anatomical properties of the underlying muscular tissue, like the location of innervation zones or fiber lengths [3], but also to analyze neurological properties like the conduction velocity of single motor unit action potentials [4].

To improve EMG based predictions of muscle activation and force, it is important to reduce unwanted variability, so real muscle activity is best represented in the acquired signal. Previous research has contributed to optimization of technical aspects, instrumentation [5-9] and appropriate filtering techniques [2,10].

A decrease in EMG variability, resulting in an improvement of EMG based force estimation quality, can be obtained when using multiple bipolar electrodes spatially distributed [10,11]. However, only limited experimental evidence exists on how EMG is affected by sensor configuration properties [12].

B. EMG standards

According with the International Society of Electrophysiological Kinesiology[13], the minimum specifications for EMG signals are:

- Input impedance:
  - $>10^{10}\Omega$ en DC y $>10^{8}\Omega$ a 100 Hz
- Amplification gain:
  - 200 – 100.000 ± 10% on discrete increments
- Gain nonlinearity:
  - ≤ ± 2.5%
- Gain stability:
  - Variation should be 5%/year
- CMRR:
  - > 90dB

II. METHOD

Design in figure 1 for EMGs acquisition system is proposed. The pre-amplifier consists of 2 buffers for differential amplification system, and a first-order high-pass passive filter with a 0.05 Hz frequency to link the electrode-skin interface.

Fig. 1. Proposed EMG acquisition system.

Instrumentation amplifiers used are two INA128 due to its high CMRR, 120 dB, with a gain of 100 and 10.

The filters consist in a high pass active filter with the configuration of an integrator with feedback that goes to the INA128 reference input in order to reduce the offset voltage.

The other is a low pass active filter with a second order Sallen-key configuration to restrict the frequency band to 450 Hz. The signal output was measured with an oscilloscope.

Figure 2 shows the multichannel acquisition system proposed. The multichannel consist in 16 blocks of a single channel acquisition system in which output signals are driven to a 16-input high-speed multiplexor with a microcontroller unit; the multiplexor outputs are then connected to an 16-bits / 8-channel ADC, in order to transform the voltage values into a digital signal. This signal will be connected to the microcontroller as the USB interface for storage.

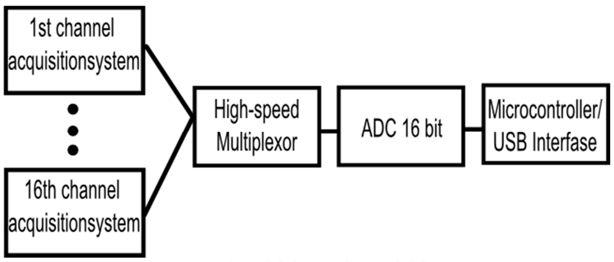

Fig. 2. Proposed multichannel acquisition system.

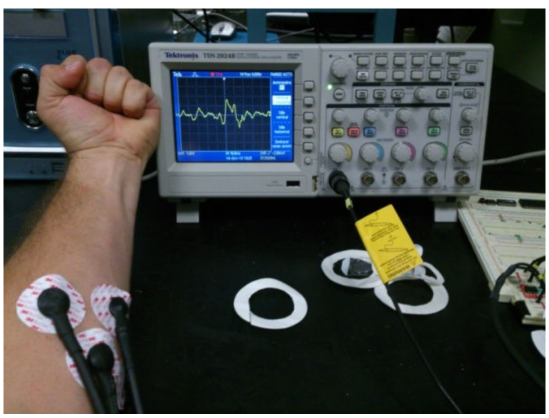

Fig. 3. Electrodes and EMG shown at the oscilloscope.

The system was powered by two 9V rechargeable batteries to supply the amplifiers with ±9V. The electrodes used were disposable surface electrocardiographic (EKG) 3M Red Dot Electrodes, using a differential acquisition array and two nearby references in order to obtain less noise or unwanted information and reduce acquisition area.

Fig. 4. Electrodes array.

The system was built on a cooper board in order to reduce noise and obtain a high CMRR. The system then is built on a cooper board but with surface elements to reduce the acquisition system size and reduce even more the noise.

III. Results

Figure 5 shows the signal of the muscle in low-strength contraction. Figure 6 is the signal of a high-strength contraction at the same muscle. An absent contraction shows no signal. Output voltage with a 1110 gain from the INA128 with a 2 Vpp, depending of the muscle and contraction strength. The noise was reduced by removing the amount of circuits connected as well as the notch filter, that wasn't use because important information can be found in that range of frequency. The noise was also reduced with the array configuration of electrodes that makes smaller the acquisition area. They were connected in differential configuration along the targeted muscle, with two more electrodes as reference electrodes connected nearby the acquisition electrodes. All these adjustments produce less-noisy signals due to the restriction of the area at the measured muscle.

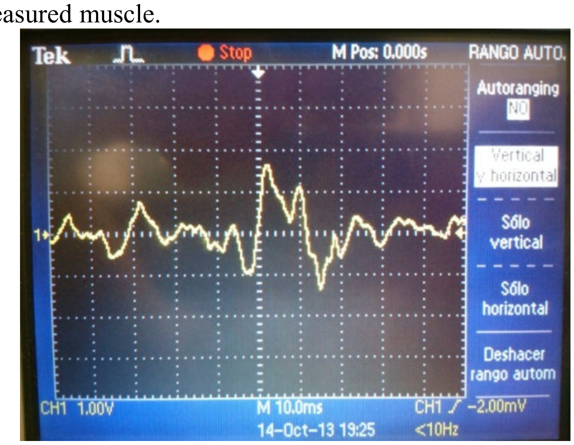

Fig. 5. Low contraction.

Fig. 6. High contraction.

Figure 7 shows the circuit on board. In order to measure the differential gain one of the entrance of the amplifier was connected to ground, while the other one was connected to 7.1 mVrms. The output voltage measured of the system was 7.91Vrms, obtaining a differential gain of: Δd=1112. To measure the common gain we connect the same voltage of 707 mVrms to both entrances, obtaining an output voltage of 11.5mVrms. The common gain obtained was: Δcm=.015. Therefor calculating the CMRR: $CMRR = 20log\left(\frac{\Delta d}{\Delta mc}\right)$, obtaining a calculated CMRR of 97dB.

Figure 8 and 9 shows the entrance and output of the amplifier, while figure 10 is the last circuit design using surface elements.

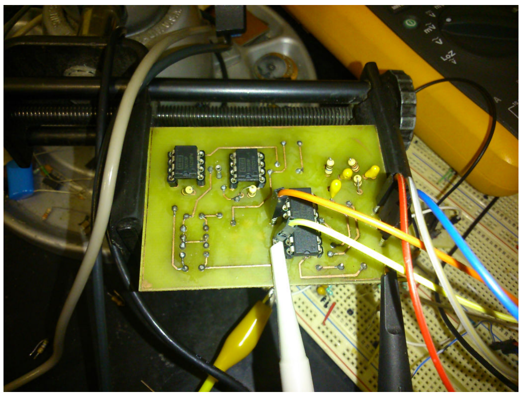

Fig. 7. Board circuit of the EMG acquisition system

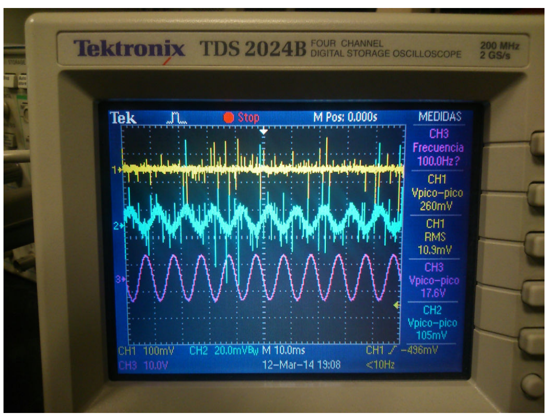

Fig. 8. The yellow signal shows the entrance connected to the ground, the blue signal is the 7.1mVrms entrance, the pink signal is the output of the amplifier in differential gain

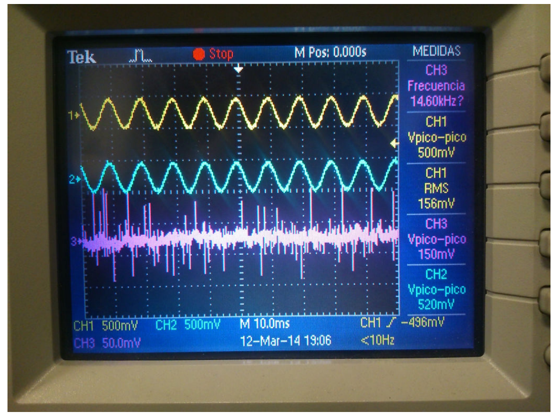

Fig. 9. The yellow and blue signal are the entrance of the amplifier. The pink signal is the output of the common gain

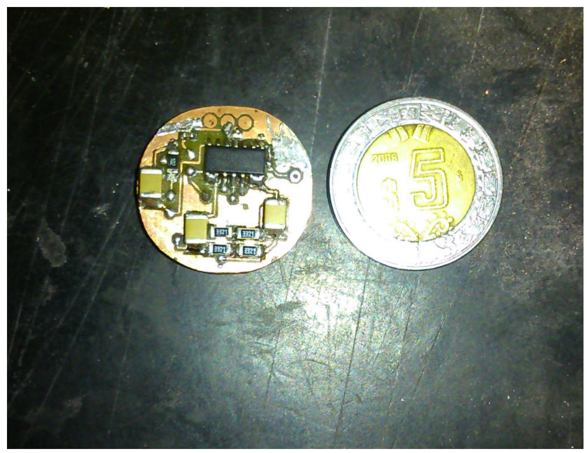

Fig. 10. Final design of the EMG acquisition system using surface elements

IV. Discussion and Conclusion

The proposed design for the acquisition system reduces the amount of electronic devices needed, so costs and noise are improve within the system. A future work will be to acquire the signals from a multichannel electrode array, using a multiplexor with a microcontroller connected to a PC to store data. Electrodes array reduce a lot the detection area, therefor, the unwanted signals that interfere with the acquisition.

In spite the circuit was tested on breadboard, there was no noise interference. The system was built into a printed circuit, to reduce even more the noise that can result from the use of a breadboard, the CMRR is between the standards rate established, this value will be increased with the board circuit using surface elements. The circuit was built but the measure of the CMRR ant the other standards will be done in the near future. The electrodes array will be improved as well, making them smaller, so the acquisition area will be more concentrated and more precise. The configuration of 2 nearby references helped reduce the noise usually introduced by connecting a faraway reference, which include noise and other muscle movements.

The multichannel is the last stage in the acquisition system providing the opportunity to visualize the information of one movement around the whole arm or forearm; obtaining and storing this information through the USB interface in order to process and analyze them in further stages.

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