TECHNICAL UNIVERSITY OF THE NORTH

ENGINEERING FACULTY IN APPLIED SCIENCE

MECHATRONIC ENGINEERING

"ACQUISITION AND CONDITIONING SYSTEM OF ELECTROMYOGRAPHIC SIGNALS FOR A ROBOTIC ANKLE"

SCIENTIFIC ARTICLE

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IBARRA – ECUADOR

2015

"Acquisition And Conditioning System Of Electromyographic Signals For A Robotic Ankle"

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Abstract— **The use of electromyography (EMG) to control robotic myoelectric prosthesis represents the highest degree of rehabilitation for amputees [1] [2] [3] [4]; Several groups of researchers throughout the world have made inroads in the field of electromyography applying in many areas such as: neurophysiological and medical research, rehabilitation, ergonomics, sports and science of movement, among others [5]. This research aims: 1st To design and implement all the necessary circuitry to acquire and condition the EMG signal safely of certain muscles of lower limbs, specifically muscles remnants of a transtibial amputation and 2nd To Test the system based on amplitude analysis and frequency spectrum of the surface electromyographic signal (SEMG) acquired and conditioned by the system. For the design and implementation of all circuits that make up the system is premised the use of cheap electronic components available in the environment; contributing to endogenous technological development of the country.**

Keywords— *Surface electromyography; Myoelectric signal; Electromyography; Acquisition and Conditioning; Detection circuit; Muscle potential; Bioelectric signals; rehabilitation; prosthesis; Electromyographic system*

I. INTRODUCTION

Worldwide, it's estimated that over one billion people live with some kind of disability, a number that represents about 15% of the world population [6]; this number is higher than previous estimates published by the World Health Organization (WHO) in the World report on disability in 1970. At the national level according to the Consejo Nacional de Igualdad de Discapacidades del Ecuador (CONADIS), approximately 397233 people with disabilities and approximately 193905 people have some kind of physical disability in the country. 4620 people have physical disabilities in Imbabura [7].

Framed within the field of electromyography, investigations such as: EMG signal analysis [8] [9], detection circuits [9] [10] [11] [12] [13] [14], control prosthesis, [15] [16] [17] [18] [19] rehabilitation systems [20] [21] [22], human - machine interfaces [2] [23], myoelectric medical studies [24] [25] [26] [27], among others; they demonstrate the usefulness of electromyography for the study and development of systems and devices for people with disabilities. In recent years, the number of investigations related to EMG is increasing [28], specifically in the development of electromyographic technology as devices for the acquisition and conditioning of EMG signals.

The design and construction of a system for the acquisition and conditioning of surface electromyographic signals, built with inexpensive electronic components available in Ecuador, allows to innovate and to contribute in the technological area of the nation, using the EMG system in the development of active myoelectric prostheses which represent an integral solution for people with disabilities, eliminating any kind of social discrimination and especially a work discrimination that exists today, due to the limitation of passive prosthesis (cosmetic) to perform complex tasks at work.

II. METHODOLOGY

Generated the idea of the Technical University of North about research projects oriented to the society, framed within the policies of state [29] [30]; in order to refine and structure this idea is set a problem, which allows to divide this macro project on several projects with specific focus, one of these subdivisions represents the current investigation. Having established the objectives, rationale, reach and limitations the next point is the construction of theoretical framework, therefore is necessary to obtain, review and collect information related to issues such as electromyography, EMG systems, EMG devices, myoelectric robotic prostheses, EMG interfaces, surface electromyography, muscular electrical activity; information acquired mainly from literature sources, scientific publications and thesis developed .

The selection of SEMG electrode is based in the review of scientific publications from sources such as the Journal of Electromyography and Kinesiology about studies of medical-clinical approach of EMG, also the Institute of Electrical and Electronics Engineering (IEEE) and especially Publisher Springer's publications. They contain electrical and electronic technical specifications on the use of electromyography electrodes. These sources provide information about the level of application of the electrode; the electrodes are analyzed

commercially available global and in national level, suppliers' websites of medical devices and materials are consulted.

For the acquisition stage must be compared and selected an instrumentation operational amplifier (OA) available nationally; the review of data sheets allows to develop this stage since all manufacturers recommend protection circuits for the patient and circuits to eliminate unwanted signals.

The filters design is based in the selection of a general purpose operational amplifier available nationally, then the answers to all types of existing analog filters (Bode plots generated in Matlab 2014b) are analyzed. With the kind of response and order of filters selected, the filters are designed based on the required cutting rate, using formulas and equations available; manufacturers' manuals of integrated circuits operational amplifiers available are used.

For the full wave rectification and the smooth of the EMG signal, scientific publications available on the network must be analyzed related to the design of full-wave precision rectifiers; authorship of these publications is related primarily to manufacturers of integrated circuits.

All circuits that belong to the stages of acquisition and signal conditioning are simulated using the Multisim 13.0 computer software. The use of virtual sources provided by Multisim 13.0 can simulate interferences that affects such systems once already implemented; based on these components, the signal filtered is checked. Analyzing the input graphic (potential SEMG with interference) and output graphic (DC voltage output), the operation of amplify, rectified and smoothed of the signal can be verified.

The Ultiboard 13.0 computer software of National Instruments is used for the construction of the printed circuit boards of all stages of the system, the footprint of each electronic component is selected, the necessary pathways are routed and system's PCB board is built.

Before testing the system built, muscles for the data collection are selected, therefore the theoretical framework must be used, taking into account recommendations provided by the SENIAM Project [31], analyzing the muscles involved in the movement of the ankle and establishing criteria for this selection. It defines the procedure for data logging, this procedure is divided in three stages: an initial stage (skin preparation, location and placement of electrodes), a register stage (Clinical test for measure the maximum voluntary contraction of every muscle) and a processing stage performed in LabVIEW 2014 (Functions implemented in the software and hardware elements used). Finally the results are presented and analyzed graphically and textually based on tables with the main characteristics of the waveform obtained in each record, also the records of the designed system's records and the Muscle sensor V3 records [32] are compared.

III. ELECTROMYOGRAPHY

A. Definition

Electromyography studies muscle function through the acquisition of the electrical signal generated by muscles [33].

The process of generating a muscular movement starts when the brain sends a series of electrical impulses (instructions) through neurons, these special cells are responsible of sending and receiving these impulses through the central and peripheral nervous system; in this process, a neuron has the function of sending and receiving electrical impulses from the spine to muscle fibers [34]. The assembly formed by a motor neuron in the ventral horn of the spinal cord, its axon and muscle fibers innervating axons are known as a motor unit (see Fig. 1) [35] [36].
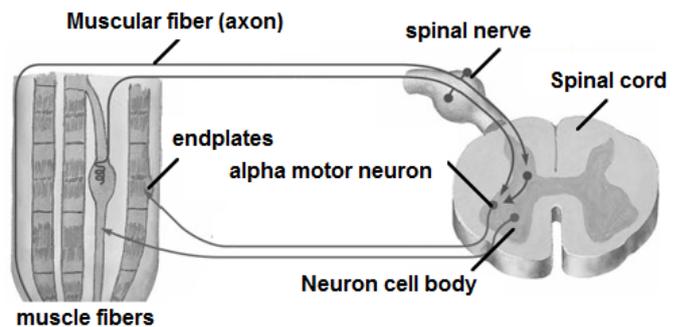
Fig. 1. Motor unit. [28]

In surface electromyography because multiple muscle fibers are innervated by a single motor neuron, the neuron is active, activating simultaneously to several muscle fibers [28]; the sum of all these individual potential generates an action potential in the motor unit (MUAP), the algebraic sum of these action potentials are considered as the SEMG signal from the set of muscle fibers constituting a specific muscle (see Fig. 2) [33].
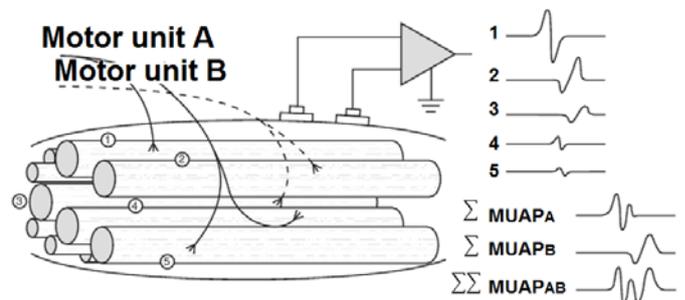
Fig. 2. MUAP algebraic addition (surface electromyography) [28]

B. Characterization of SEMG signal

Studies and recorded data allow to characterize these signals according to the anatomical and physiological properties of the muscle and the characteristics of the

instrumentation used to detect it and watch it [33]; this research establish the following statements:

- The amplitude of SEMG signal isn't equal to the physical level of the patients [33] [37].

- The amount of force or strain that a muscle can apply depends on the length at rest of it [38].

- The amount of force of a muscle is affected by the speed and type of contraction (isometric, isotopic, isokinetic concentric and eccentric) [35] [39].

- The waveform of the action potential depends of the orientation of the electrode relative to the muscle fibers [33].

- Peak amplitude range - peak within the range of 0, 01 [mv] - 5 [mv] [28] [33] [39].

- Frequency within the range of 1 [Hz] - 300 [Hz] (see Fig. 3) [33] [39].
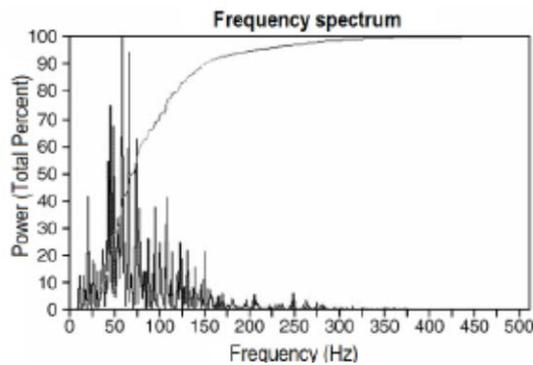
Fig. 3. Frequency spectrum of an electromyographic signal. [102]

C. Factors affecting the SEMG signal

Within muscular level and instrumentation used in the detection circuit level, there are several factors that characterize and influence the SEMG signal specifically in the peak to peak amplitude and frequency:

- The firing rate of the MUAP [33] [39].

- The number of motor units [33] [39].

- Synchronization of activation of motor units [39].

- The driving speed of muscle fibers [39].

- The orientation and distribution of muscle fibers on the motor units [28] [39].

- The diameter of muscle fibers [39].

- The number of motor units within the detection zone of the electrode surface relative to the muscle fibers [33] [39].

- Materials and preparation of electrodes [31] [39].

- The location of the electrode [28] [31] [39].

- The orientation of the detection electrodes relative to the axis of muscle fibers [39].

- Ambient noise [40].

- Transducer noise [40] [41] [42].

- Cross talk (EMG signal of nearby muscles) [33] [40] [43].

D. Surface electrodes

The elements able to acquire muscle bioelectrical signal and transfer to the electronic device able to acquire and condition the input signal to obtain an output signal are known as "electrodes" [43]. Noninvasive electrodes are used in SEMG applied directly to the skin and lead to obtain the sum of the action potentials of motor units which are activated in muscle movement [44] [45].

IV. SEMG SISTEM DESIGN

The SEMG system has all the stages shown below (see Fig. 4); all these stages ensure acquisition of muscle electrical signal and the quality of the output signal with all the protections required to use this system on a person.
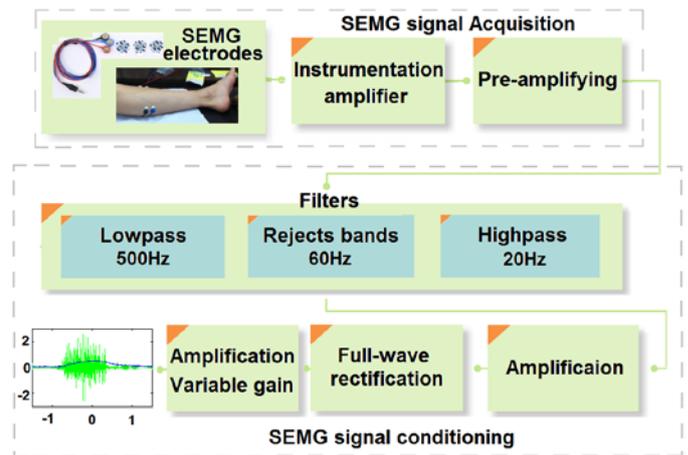
Fig. 4. SEMG System block diagram

The electrodes represent the starting point to design the acquisition and conditioning system of EMG signals, selected a particular type electrode the stages of amplification and filters are designed; checking several previous studies [46] [47] [48] [49] [50] [51] for the system, the non-invasive passive Ag / AgCl and gelled adhesives electrodes are used (see Fig. 5), selected by the study of suppliers and manufacturers at global and national level [52] [53] [54] [55] [56] [57] [58].

Fig. 5. DORMO SX - 30 ECG electrode. [54]

The cables used to the connection between the electrodes and wires instrumentation amplifier are the electrodes used in the "Muscle Sensor v3" (see Fig. 6) [32]; this wire has three subdivisions: an inverter electrode, an non-inverting electrode connected to the instrumentation operational amplifier

terminals with the same denominations, also it as one subdivision to the reference electrode.

Fig. 6. Wire used in the SEMG system. [59]

The use of an instrumentation amplifier to acquire electromyographic signal [60] [61] [62] [63] [64] [65] [66] requires the fulfillment of certain essential characteristics [39] such as high input impedance [GΩ], high gain (200-100000), a ratio of common mode rejection (CMRR) greater than 90 [dB] frequency response within the range of an EMG signal (1 [Hz] - 3000 [Hz]), polarization current less than 50 [nA], low isolation [μA] and noise less than 5 [μV] RMS.

The AD620 instrumentation amplifier manufactured by Analog Devices [67] is an instrumentation amplifier inexpensive of high precision that requires only a resistor to set the gain from 1 to 10000. For dual operation it requires a minimum supply voltage ± 2, 3 [V] and maximum ± 18 [V] also a low current (maximum supply current of 1, 3 [V]). This OA is ideal for precision data acquisition because it has a high accuracy of 40 [ppm] maximum nonlinear gain, low offset voltage maximum 50 [mV] and offset drift of 0, 6 [μV/°C] max. The high ratio of common mode rejection, low noise, low input bias current and low power allows use in medical applications such as ECG, EMG, monitors non-invasive blood pressure, etc.

Using a resistance of 4,4 [kΩ] inserted between the terminals 1 and 8 of AD620 a gain of about 12 times the original signal is obtained based on the formula given by the manufacturer [67].

For the acquisition of bioelectric signals the manufacturer recommends a circuit for medical monitoring of ECG signals [11] [67] [68]; this circuit is adapted for use in EMG (see Fig. 7), therefore the location of the electrodes is changed: the electrode located in the right leg (reference electrode) is placed in a joint due to minimal presence of muscles in said area, the remaining two electrodes placed on the patient's arms are placed on the muscle being studied. The aim of this feedback loop is to provide stability to the system and to avoid unbalance current offset attenuating noise problems and common mode voltages at the differential input of the instrumentation amplifier, also to add an adequate protection by creating an active ground isolated land electrical circuit to protect the patient from potential damage [11].
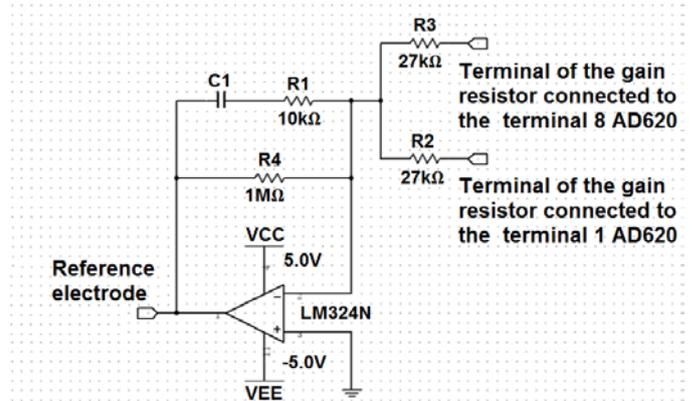
Fig. 7. Right leg circuit used in EMG.

Using a general purpose operational amplifier LM324N [69] in integrating configuration connected between the output terminal and the reference terminal AD620 (see Fig. 8) allows an AC coupling with which the AC signal, the signal of direct current (DC) and common mode noise present is rejected [70][71].
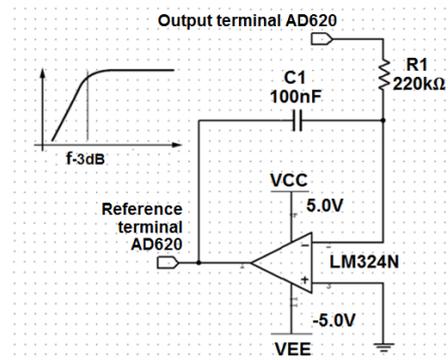
Fig. 8. AC coupling circuit.

In the acquisition stage is included a circuit to eliminate interference caused by devices that generate and transmit radio frequency energy (RF) (see Fig. 9) [71].
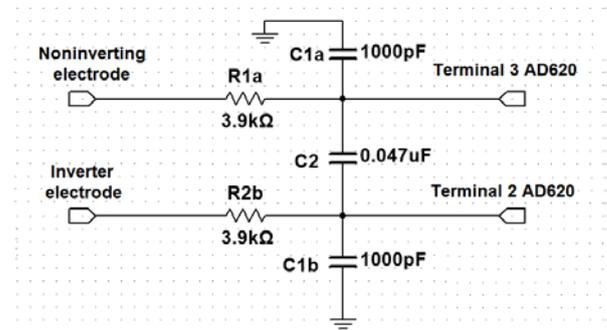
Fig. 9. Radio frequency roll-off filter.

In general, mainly monolithic operational amplifiers have referenced to one terminal or both power supplies that need to be decoupled with respect to the reference terminal; whereby a

bypass capacitor connected between each terminal and the reference supply circuit (see Fig. 10) is added.
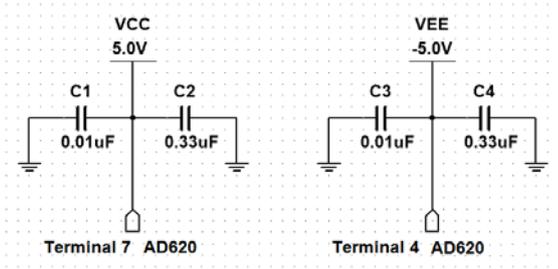
Fig. 10. Bypass capacitors.

To complete the acquisition stage, the output signal of the AD620 is amplified using a LM324N operational amplifier in inverting configuration with a gain of about 11 times the source signal (see Fig. 11).
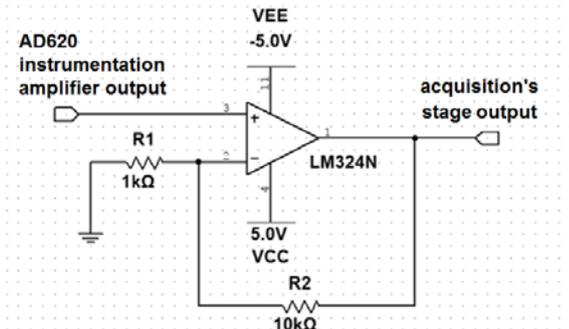
Fig. 11. Non-inverting operational amplifier.

The conditioning stage of the signal is divided in two main parts: filtering and rectification. To make all circuits used in this stage the operational amplifier (OA) of general purpose LM324N is used, which has a sufficient bandwidth within the frequency range of an EMG signal, low supply current, low noise and input voltage; using for the filter design formulas given in [72] [73] [74].

For filtering the signal, Butterworth filters with Sallen - Key topology are used, due they provide a flat response amplitude in the pass band also the higher the filter order, the greater the flattening [73] [74].

The typical frequency range of a surface electromyographic signal is mostly between 1 [Hz] - 300 [Hz] [39]. However, such signals reach up to a frequency of 500 [Hz] (see Fig. 3); in addition signals captured from 1 [Hz] and 20 [Hz] are due to factors affecting the EMG signal as the size and orientation of the electrode, electrode – electrolyte interface, ambient noise, DC values, among others. To limit the output frequency to 20 [Hz] to 500 [Hz] one band pass filter placed in series a low pass filter (see Fig. 12) and a high pass filter (see Fig. 13) of 6th order each station is designed with a slope of -60 [dB] / decade; for 6th filter order required is placed in series three 2nd order filters, obtaining the required order.
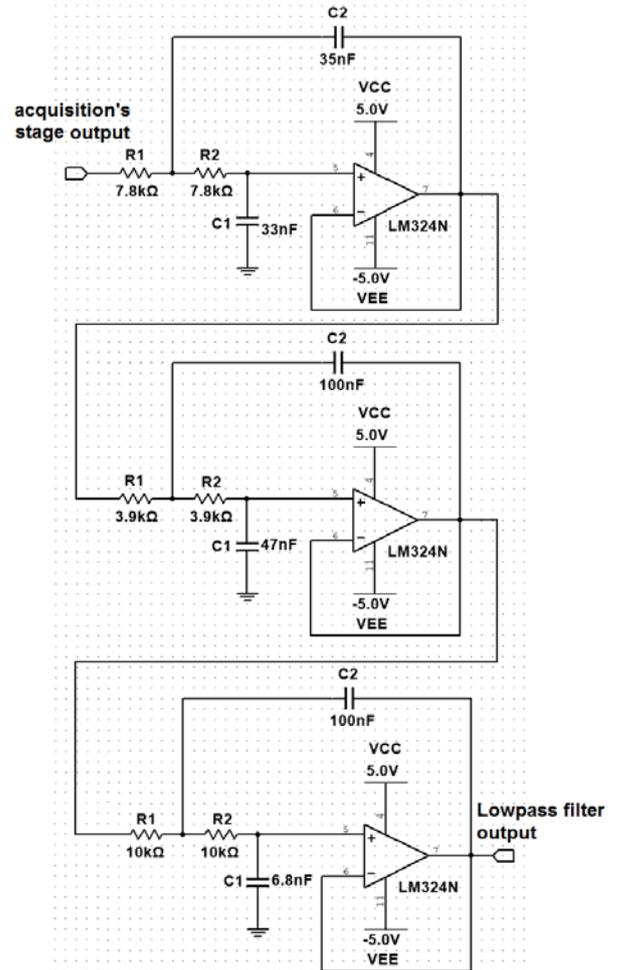
Fig. 12. Sixth order low pass Butterworth filter with unity gain.
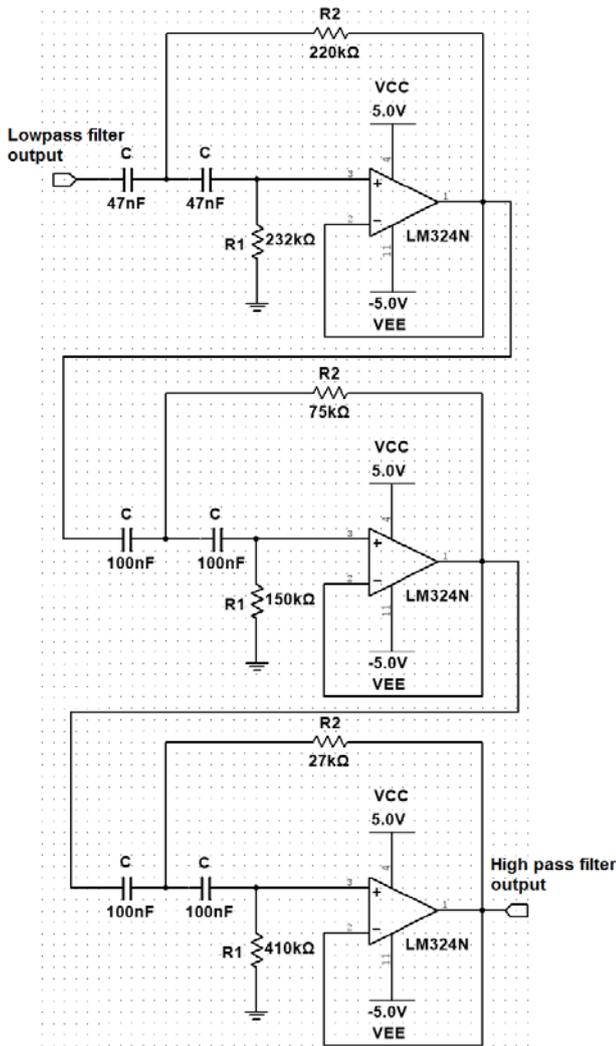
Fig. 13. Sixth order High pass Butterworth filter with unity gain.

To remove unwanted signals of 60 [Hz] generated by devices of alternating current (AC) is designed by cascading two filters rejects band made up each by a filter rejects bands with Sallen – Key topology (active filter Twin - T) [74] with a gain of approximately twice the original signal (see Fig. 14).
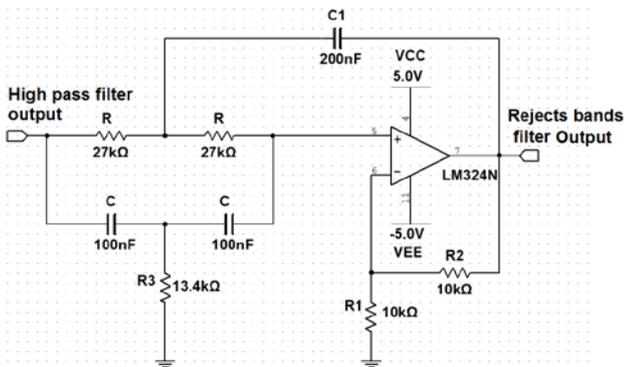
Fig. 14. Filter rejects bands Twin-T of second order.

The fourth order filter removes a percentage of approximately 77, 78% of the signals of 60 [Hz] [11].

The graph (see Fig. 15) has the amplitude and phase response of all filters designed.
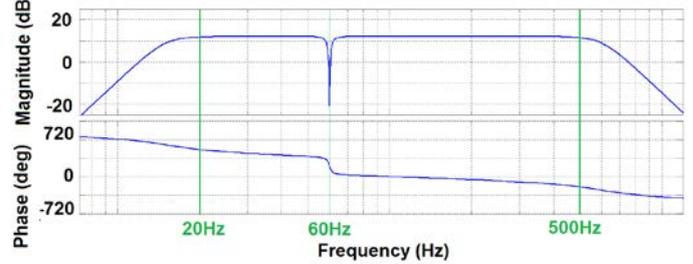
Fig. 15. Amplitude and phase response acquired in Matlab based on the transfer function of all filters designed for the system.

Once the surface electromyographic signal has been fully filtered, a new signal amplification is performed; for this purpose a non-inverting operational amplifier with a gain of about 11 times the original signal it's used (see Fig. 11).

With the original surface electromyographic signal acquired and filtered, the next step is the rectification. For signal rectification the 1N4148 high speed diodes are used [75], these diodes are used for high speed switching applications in a full-wave rectification (see Fig. 16) [76] [77] that obtains an average DC signal of the AC signal.
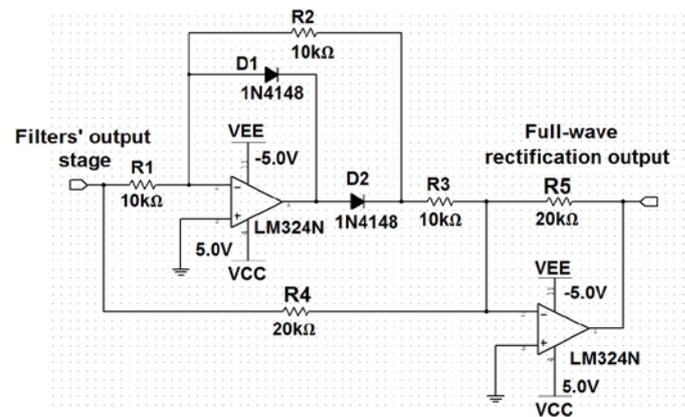
Fig. 16. Precision full wave rectifier

The electromyographic signal requires a "smoothing" to finally have a fully DC signal, an operational amplifier in an integrating configuration is used which works just like an low pass inverter filter of first order; using the characteristic of charging and discharging of a capacitor may perform this signal smoothing (see Fig. 17).
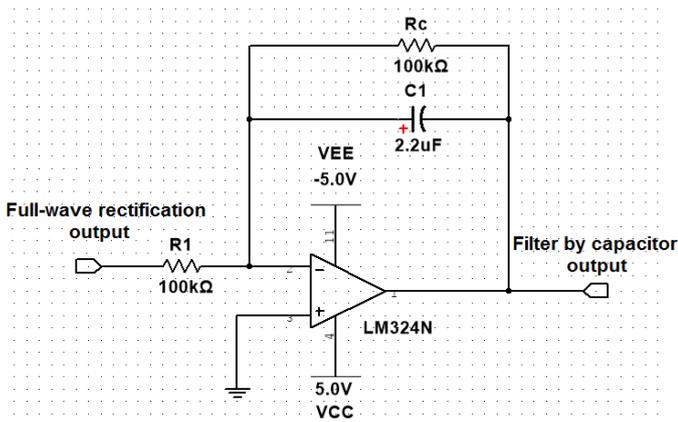
Fig. 17. First order low pass inverter filter (smoothing SEMG signal rectified).

To conclude the rectification stage of SEMG signal, the average EMG signal proportional to the rectified DC signal is amplified; therefore a non-inverting operational amplifier with variable gain set between 1 and 5, 25 is used (see Fig. 18).
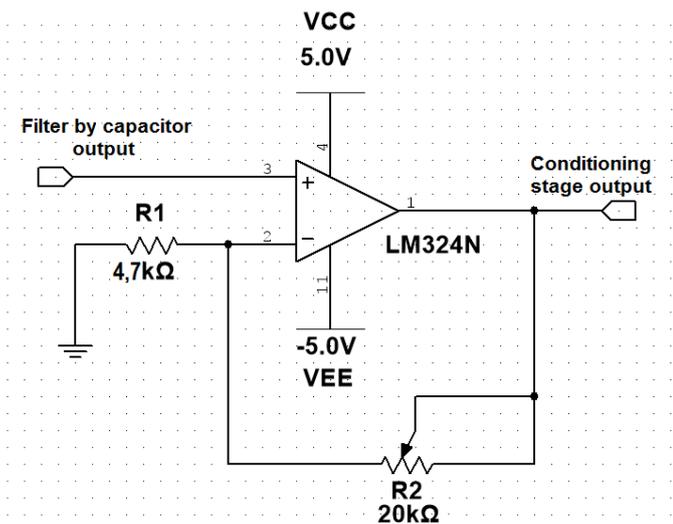
Fig. 18. Non-inverting amplifier in rectification stage.

The graph (see Fig. 19) has the simulation of the complete system operation using as input an EMG signal generated by a data table [78].
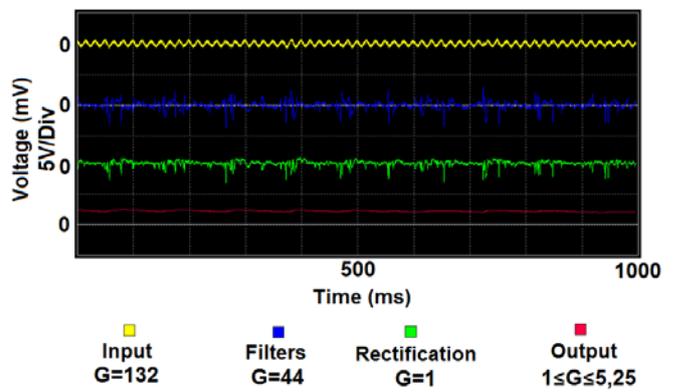
Fig. 19. Potentials generated at specific points of complete system simulation.

V. EXPERIMENTAL TESTS, RESULTS AND SEMG SYSTEM IMPLEMENTATION

There are a number of methods to process a detect an EMG signal and decompose it into a set of signals, most are used for comprehensive analysis of EMG signal [79] [80] [81] [82] [83] [84] [85] [86] [87] [88] [89] for a specific motor unit (medical applications), but the use of these methods to validate the current SEMG system is tedious and long lasting; therefore, to validate the system are used the amplitude analysis and frequency spectrum analysis given by fast Fourier transform [90].

A. Experimental tests

For the muscles' selection to record data must take into consideration all the muscles involved in the movement allowed by the ankle (dorsiflexion and plantar flexion) [91] [92] [93] and based on reviewing previous studies [31] [91] [94] [95] [96] [97] [98] [99], three suitable muscles are determined: (a) lateral gastrocnemius, (b) medial gastrocnemius and (c) tibialis anterior (see Fig. 20).
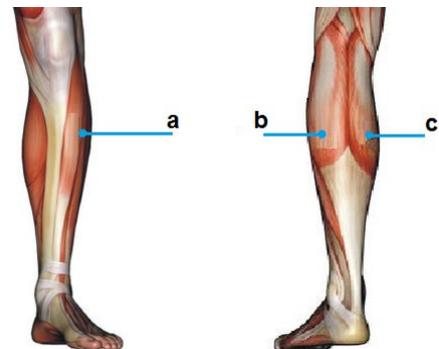
Fig. 20. Selected muscles to record data.

The procedure for acquiring the signal [100] using electronic instruments already determined (NI MyRIO and oscilloscope BK Precision 2534) is divided into three stages: an initial stage, a register stage and processing stage.

The initial stage involves preparing the patient's skin and the placement of the electrodes:

- Shave the skin area where the electrodes will be applied.
- Cleaning the skin with alcohol to reduce the layer of dry skin or dead cells and eliminate the sweat in areas of muscle for registration.

Using published guidelines [31] [35] [101] are determined the proper location of the bipolar electrodes and the location of the reference electrode (far to the registration area and an electrically neutral tissue location) for the three selected muscles; with a inter electrode distance of approximately 20 [mm] (see Fig. 21) [31].
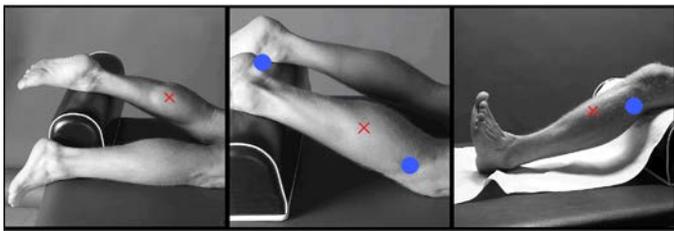
Fig. 21. Electrodes' location for the selected muscle [31].

The registration stage of EMG signal involves to obtain the maximum voluntary muscle contraction in each study; to reach this aim a specific clinical procedure is used to obtain this contraction [5] [31].

The registration of the muscle electrical activity that is produced with maximum voluntary contraction (see Fig. 22) allows to normalize waveform obtained respect to this particular muscle contraction and patient. Generally to register the signal are performed three isometric maximum contractions of 6 seconds, with a rest interval between each one; so it's possible to analyze an average of the three samples to normalize the signal [100].

Fig. 22. Preliminary tests of SEMG system.

The processing stage involves the amplitude analysis and frequency analysis of the SEMG signal. The analysis of the signal's amplitude involves a rectification and smoothing of the signal thereby a proportional value of the maximum muscle contraction is obtained; to the analysis of the signal's frequency is applied the rapid Fourier transform and a smoothed signal whereby the frequency spectrum for the EMG signal recorded is obtained.

B. Results

The table (see Table 1) has recorded data extracted from the amplitude analysis and frequency analysis given by the interface programmed and designed in LabVIEW 2014 during experimental tests for the three selected muscles.

Comparison between the main features of the selected muscles' SEMG signals			
Characteristic	Medial gastrocnemius	Lateral gastrocnemius	Tibialis anterior
Peak to Peak	1,635 [mv]	1,026 [mv]	1,313 [mv]
Maximum positive peak	0,758 [mv]	0,501 [mv]	0,620 [mv]
Maximum negative peak	-0,877 [mv]	-0,525 [mv]	-0,692 [mv]
Maximum frequency	517,32 [Hz]	325,77 [Hz]	343,92 [Hz]
Minimum frequency	12,30 [Hz]	35,54 [Hz]	12,40 [Hz]

Table 1. Comparison of SEMG signals' characteristics.

Based on the table above (see Table 1) provides that the medial gastrocnemius muscle has a greater potential EMG, it's also one of the muscles involved mainly doing movements in the ankle; so then the results are presented in this muscle (see Fig. 23) (see Fig. 24) (see Fig. 25) (see Fig. 26) (see Table 2) (see Table 3) (see Table 4) (see Table 5); based on these figures and tables is possible to analyze and determine the results obtained by recording and processing of the SEMG signals match the data established by previous research [28] [33] [39] [102].
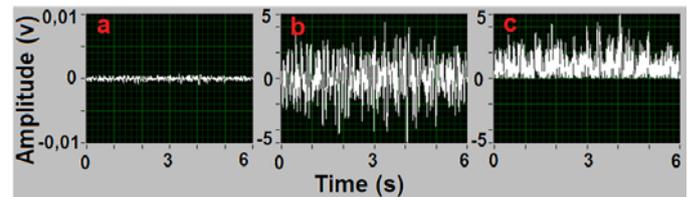
Fig. 23. Processing of the SEMG signal recorded in the medial gastrocnemius muscle.
(a) Average SEMG signal.
(b) SEMG signal amplified and filtered by hardware.
(c) SEMG signal rectified by LabVIEW.

Characteristics of average SEMG signal from the medial gastrocnemius muscle.	
Characteristic	Value
Peak to Peak	1,63545 [mv]
Maximum positive peak	0,758035 [mv]
Maximum negative peak	-0,87741 [mv]

Table 2. Characteristics of average SEMG signal from the medial gastrocnemius muscle.

SEMG signal's characteristics amplified and filtered from the medial gastrocnemius muscle	
Characteristic	Value
Average cycle	0,0241498 [v]
RMS cycle	1,54282 [v]
Peak to Peak	9,49867 [v]
Maximum positive peak	4,40267 [v]
Maximum negative peak	-5,096 [v]
RMS	1,41889 [v]

Table 3. SEMG signal's characteristics amplified and filtered of the medial gastrocnemius muscle.

Fig. 24. SEMG signal's amplitude analysis recorded in the medial gastrocnemius muscle.
(a) Rectified signal smoothed by filtering.
(b) RMS value of the signal.

Characteristics of SEMG signal rectified and smoothed from the medial gastrocnemius muscle	
Characteristic	Value
Maximum peak	1,80598 [v]
DC average	1,08935 [v]
RMS	1,12595 [v]

Table 4. Characteristics of SEMG signal rectified and smoothed from the medial gastrocnemius Muscle.

Fig. 25. SEMG signal's frequency analysis from the medial gastrocnemius muscle.
(a) Frequency spectrum using fast Fourier transform.
(b) Smooth of the frequency spectrum by filtering.

Frequency spectrum's characteristics of the SEMG signal from medial gastrocnemius	
Characteristic	Value
Maximum frequency	517,32 [Hz]
Maximum amplitude	3,65578 [v]
Minimum frequency	12,307 [Hz]
Minimum amplitude	0,154788 [v]

Table 5. Frequency spectrum's characteristics of the SEMG signal from medial gastrocnemius.

Fig. 26. SEMG signal's spectrogram from the medial gastrocnemius muscle.

Using the medial gastrocnemius muscle, the rectified signal of the designed and built system is compared with the output of the Muscle sensor v3 [32] (see Fig. 27) (see Fig. 28) (see Table 6).

Fig. 27. Rectified output signal with minimum gain proportional to the muscle contraction.
(a) SEMG system designed and built.
(b) Muscle sensor v3.
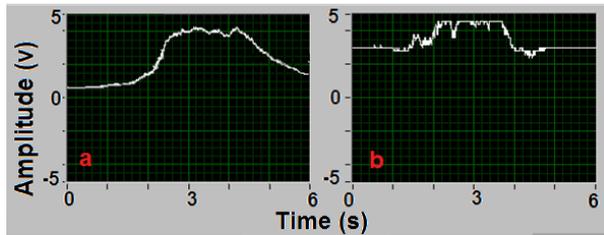
Fig. 28. Rectified output signal with maximum gain proportional to the muscle contraction.
(a) SEMG system designed and built.
(b) Muscle sensor v3.

Comparison between the main features of the SEMG signals of selected muscles			
Characteris-tic	SEMG system designed and built		Muscle sensor v3	
	Minimum gain	Maximum gain	Minimum gain	Maximum gain
Peak to Peak	0,86 [v]	2,11 [v]	1,47 [v]	5,98 [v]
Maximum positive peak	1,69 [v]	4,29 [v]	2,16 [v]	3,12 [v]
Maximum negative peak	0,43 [v]	0,45 [v]	0,69 [v]	2,86 [v]

Table 6. Comparison of the main features of the SEMG signals of selected muscles.

C. Implementation

For the implementation and verification of the system an electronic card Arduino DUE programmed with Simulink is used, with the output potential of the SEMG system a servo motor and a RGB LED are controlled; i.e. for a given muscle contraction a number of degrees of movement in the servomotor is obtained and a change of brightness - color in the RGB LED is obtained (see Fig. 29) (see Fig. 30)
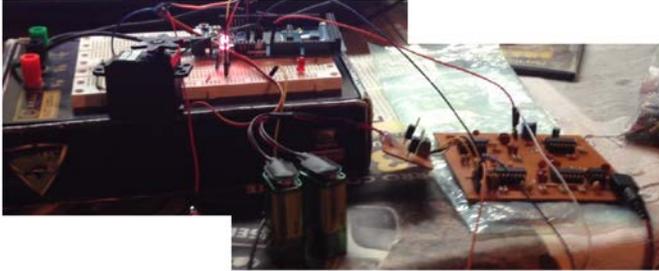
Fig. 29. SEMG System Implementation
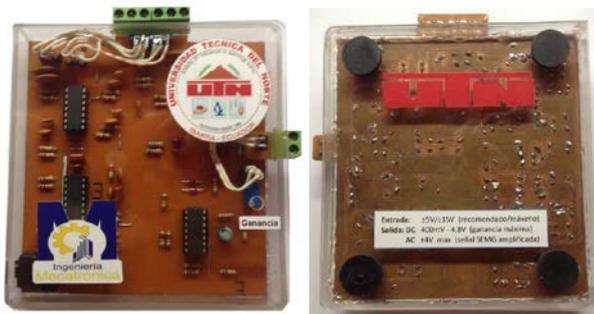
Fig. 30. System for the acquisition and conditioning of electromyographic signals.

VI. CONCLUSIONS

The system for acquisition and conditioning of surface electromyographic signals designed, built and tested has a low manufacturing cost, about 70% less than the cheapest device on the market.

The inclusion of protection circuits in the acquisition stage of the SEMG signal provides all the warranties needed for the use of the system on anyone.

Compared with the Muscle sensor v3, the SEMG system designed and built not only can be used to control elements of direct current, also can be used as an electromyograph, since it has an output with pure filtered EMG signal.

The selection of an instrumentation amplifier for the initial stage of acquisition of the EMG signal requires several points to consider, one of the main features for the selection is the CMRR; the higher the value of the CMRR of the amplifier, the better the cancellation of unwanted signals common between the two input terminals, so that interference to 60 [Hz] would be completely bypassed by eliminating the need to implement a rejects bands filter of 60 [Hz].

To the design filters of the system is determined that the best response applicable in SEMG systems is presented by the Butterworth filter type due its flat slope and close to the cutoff frequency fall; the use of higher order filters requires the use of filters of first and second order connected in series, however the circuits shouldn't be the same due the use of commercial values doesn't allow, the design of filters with accurate frequency cutting, while the station of filters connected in series advance, compensation is required in the cutoff frequency.

The system must be calibrated for use in a given patient due a potential EMG vary for each person; therefore it's difficult to have a system output potential within a standard range.

Rectifying the signal in addition to the average rectification used, it can be performed using an envelope detector circuit, which provides a wider range of system output; however, the use of this circuit deteriorates the proportional operation of muscle contraction and the DC output signal muscles tested.

VII. FUTURE RESEARCH

The SEMG system built, it can create a database with records of potential EMG of Ecuadorian people of different age and sex to set a starting point to a future develop control systems for prosthetic or other device where a SEMG signal can be used as an input variable.

For future improvements to the current SEMG system, it can use analog elements with highest quality, since the present system started with the premise of being a functional system of low cost, thus built with electronic components of lower quality.

Field of endogenous production of reusable electrodes is still unexplored, future research work would enhance the use of electromyographic devices in many applications.

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