PROTOTYPE OF A THIGH BAND FOR THE CAPTURE AND CONDITIONING THE EMG SIGNAL OF THE LOWER EXTREMITIES

Danny Jácome, Luz Tobar

Career of Engineering in Mechatronics, FICA, Técnica Del Norte University, Av. 17 de Julio, Ibarra, Ecuador

drjacome@utn.edu.ec, lmtobarsubia@utn.edu.ec

Overview. *This research specifies the development of a prototype of a thigh band for conditioning and transmission wirelessly of signals EMG to the PC, observing the behavior of signals from the muscles being studied.*

Currently there are prostheses myoelectric which help people to facilitate the mobility of the affected part function. Electronic boards responsible for the reading of the signals coming from the muscles of interest can be found at the time of the capture of signals EMG.

A problem comes at the capturing the moment of gathering data with conventional cards, since cables must be connected to the person and at the same time to a display of these signals also to be in constant surveillance to check that cables won´t be disconnected, in this way so the functionality of these cards results uncomfortable, for this reason this research is aimed to improve the EMG signal conditioning card conducted at the Técnica del Norte University by Franklin Cadena Meneses, by implementing superficial assemblase circuits and replacing wires with wireless communication, thus having just full prototype in a single circuit to observe these signals and thus implement prosthesis controlled by muscles.

Key words

Surface Electromyography, XBee, electrodes of stainless steel prosthesis, electromyography signals, baud.

Abstract. This present paper details the development of a prototype band thigh for conditioning and transmission of EMG signals wirelessly to the PC, observing the behavior of the signals from the muscles of study.

Currently there myoelectric prosthesis which help people to facilitate the mobility function of the affected part. At the time of capturing EMG signals you can be found electronic charge cards perform reading signals from the muscles of interest.

One drawback is presented at the time of data collection conventional cards, because they must be connected with cables to the person and these in turn to display of those signals and also be in constant vigilance to check that the cables do not are disconnected, so the functionality of these cards is uncomfortable, for that reason this work is to improve the card conditioning EMG signals conducted at the technique of the Técnica del Norte University by Franklin Cadena Meneses, implementing surface mount replacing wireless communication cables and circuits, thus having the complete prototype in a single circuit to observe these signals and thus implement the muscles controlled prostheses.

Keywords

Surface electromyography, XBee, stainless steel electrodes, prosthesis, electromyographic signals, baud.

1.INTRODUCTION

The progress of technology in different fields such as: medicine, control, automation of processes, physical therapy among others, has made it possible to merge all of these, despite their differences in the type of applications that each one plays, the technology goes by the hand in these fields for example medicine and Mechatronics.

Signals myoelectric which are produced by the body at the moment of relaxing or contracting a muscle, have been discovered many years ago which was called electromyography (EMG), these signals allow to analyze the behavior of the muscles, when performing any movement, as well as to control several elements such as the myoelectric prostheses, which are driven by this type of signals.

This project aims at the construction of a band of thigh prototype for the capture, conditioning and wireless transmission of EMG signals of lower extremities, and the improvement of the interaction at the time of working with these signals.

2. STATE OF THE ART

Today, the most of the research's on electromyography had been the studying the of EMG signals in the upper extremities using communication cables to watch the signal being studied, there are few studies about a free interaction at the moment of collecting the data of the myoelectric signals in the thigh muscles.

All research carried out in Ecuador had been using communication cables in the moment of the signals visualization whether on an oscilloscope or a computer.

In previous research carried out at the Técnica del Norte University were used cables which do not allow the person to have a free movement when tests are performed. Most are focused on makings a card to connect: electrodes, data cables, batteries, voltage etc. but not a device containing all, and allows better interaction when performing this type of studies.

3. METHODOLOGY

3.1 PROJECT REQUIREMENTS

Methods, techniques, and proper procedures on the type of wireless communication being used, as well as the type of EMG electrodes for best results in prolonged support in documents about wireless electromyography.

The EMG signal conditioning is based on: pre amplification of the EMG signal, protection of the patient, integration circuit, pass band circuit filter of the EMG signal, filter to eliminate interference from equipment AC, final amplification of the filtered EMG signal, rectifier circuit, and envelope circuit detector.

Electrodes for the project are silver chloride silver and stainless steel, he is the comparison between the two types, and thus to choose the best sensor for the operation of the prototype.

3.2 SELECTION OF THE BEST ELECTRODE

The project analyzes the best electrode for good results in extended use, and so have a sensor that can be used without worry about its use. Here is a comparison with electrodes that stand out most in the field of biomedicine these are: Silver/silver chloride electrode (Ag / AgCl) and dry electrode of stainless steel (Table 1).

Features	**(Ag / AgCl)**	**Stainless steel**
Contact with the skin impedance	Low	Low
Wear the adhesive	High wear	It has no adhesive, so it does not it wear
Wear of the gel	High wear	It does not contain gel
Cost	Under	Under
Durability	Low	High
Time of use	Under	High

TABLE 1 SELECTION OF BEST ELECTRODE

A superiority of the superficial electrode of stainless steel can be seen in Table 1. It accomplishes the requirements of the project. The electrode chosen for this project is the stainless steel, due to their scarcity, it was decided to build them according to the standards of the SENIAM.

3.3 CONSTRUCTION OF STAINLESS STEEL ELECTRODE

This type of electrodes (Fig. 1). Were chosen because they are on low cost and also the material with which they are produced can be found very easily in the middle.

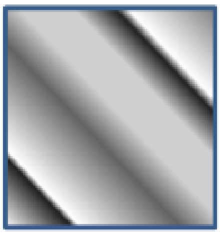

Fig. 1. Stainless steel. [15]

These electrodes are capable of EMG signal, also does not require medical supervision at the time of the placement on the muscle.

The rectangles were cut 1.6 cm x 1.3 cm out from a sheet of stainless steel. We sand and clean well the conductive side which would be in contact with the skin**,** while the other side was welded snap electrodes of silver chloride of silver which is also stainless steel, all this was mounted on the band to have a better fit (Fig. 2),

Fig. 2. Band with electrodes (inverter and inverter not)

3.4 WIRELESS COMMUNICATION SYSTEM

To select the module that is used should make the analysis of resources offered by this type of wireless communication (Table 2).

Features	Bluetooth HC-05	XBee S1
Data transmission	2.1 Mbps (max). [32]	250 kbps. [29]
Range	External line of sight 10 m. inside 5 m. [32]	Exterior view Interior 120 m. 40 m. line [29]
Applications	Home Automation, projects	Home automation, projects, industry. [31]
Modes of operation	Few	Several modes of operation. [31]
Power consumption	50mA	45mA

TABLE 2 FEATURES OF THE COMPONENTS OF WIRELESS COMMUNICATION

Communication S1 XBEE module was that most stood out in the analysis. This model will be the one used in the prototype.

3.5 SELECTION OF THE MICROCONTROLLER TO DIGITIZE THE EMG SIGNAL

When selecting the microcontroller of the project an analysis takes places in the resources offered by each range of PIC microcontrollers from Microchip (Table 3).

Features	Middle range	High range
Number of instructions	35 instructions	77 instructions
Bit length	12- and 14-bit	16-bit
Stack	8 levels	32 levels
A/d converter	10-bit a/d converter	10-bit a/d converter
Clock frequency	Up to 20 Mhz	Up to 48 Mhz
Interruptions	An interrupt vector	2 interrupt vectors
PIN	up to 64 14	up to 64 14

TABLE 3 CHARACTERISTICS OF THE MICROCONTROLLERS [21].

The high-end family of PIC18FXXX microcontrollers were those who stood out in this research. Due to its greater capacity of processing, cost availability and application.

Continuing with the analysis should define what family of microcontroller to use, the most outstanding are PIC18F4550 and PIC18F2550, both possess similar characteristics what differ from the other is: the number of pins, inputs and outputs, the PIC 18F2550 is smaller than the 18F4550. Therefore microcontroller to use is the PIC18F2550, since the objective is that the prototype would be as small and light as possible.

3.6 THE SIGNAL CONDITIONING

The signal conditioning system uses the following steps.

a) Stage of pre amplification
b) Band pass filter 20 [Hz] 500 [Hz] of fourth-order Butterworth
c) Notch Filter of 60 [Hz] with width of band 2 [Hz].
d) Stage of final amplification.
e) Rectifier in full wave of precision.
f) Envelope detector.

3.7 SYSTEM POWER

To obtain outputs for both the PIC supply voltage, packaging card and wireless communication. An integrated LM7805 is used to keep the positive voltage of 5v that the PIC, needs to work it occupies also the integrated LM7905 to maintain - 5v voltage for conditioning card (Fig. 3).

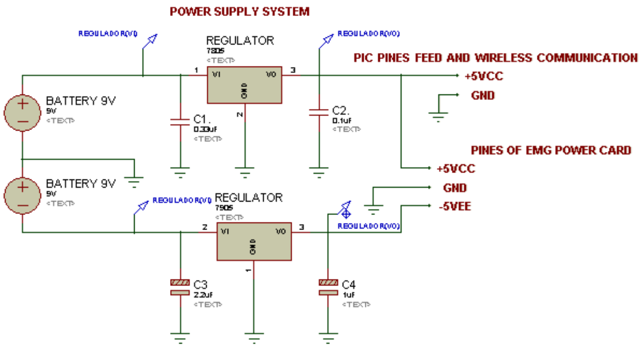

Fig. 3. Final stage of power design of prototype

3.8 BLOCK DIAGRAM OF THE SYSTEM

The next fig. 4 it corresponds to the block diagram of the whole system that sends EMG signals wirelessly to the PC.

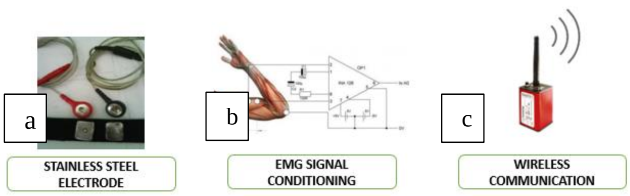

Fig. 4 block diagram of the system. (a) Electrodes of stainless steel, b) the EMG, c) wireless communication signal conditioning

In Fig. 4 (a) the EMG sensor get the signals coming from the muscles involved, these electrodes were designed of stainless steel.

Fig. 4 (b) it is the system of conditioning of the signal that is composed of filters and operational amplifiers and instrumentation.

Fig 4 (c) it is the stage of discretization and sending the EMG signal to the computer wirelessly, this stage works with high speed for data transmission, a sampling according to study signal time must also take. In this case the signal is in the range of 20 Hz - 500 Hz. By requiring a minimum sampling frequency of 1 kHz to be able to reconstruct the signal on your computer.

3.9 Digitization of the EMG signal

Flowchart (Fig. 5) stage of digitization are signals with sampling time.

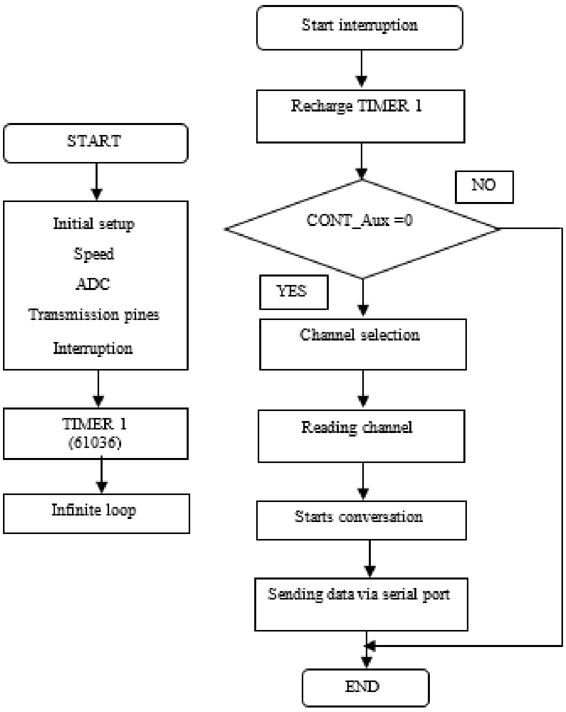

Fig. 5. Flow diagram

Once configured all necessary parameters of the microcontroller we enter the interruption which through the already established time must repeat the cycle whit the following instructions; counter equals zero, identifies the corresponding channel to be digitized, and begins the conversion to be then sent via the serial port.

3.10 Muestreo de la señal

A good processing allows us to reconstruct the analog signal, retrieve important information and dispose part of the noise [39].

If the sampling period is measured in seconds, then the sampling frequency is expressed in Hertzs. In Fig. 6 you can see that; to sample the EMG signal at constant times, TM (sampling time) must be greater than RS (reading and sending data).

$$T_M > RS \qquad (1)$$

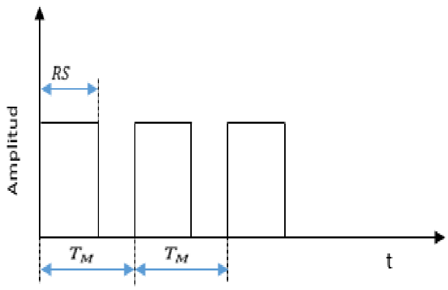

Fig. 6. Time TM increased to RS

$$RS = t_L + t_C + t_E \qquad (2)$$

Where the letters stand for:

t_L = Reading time

t_C = Conversion time

t_E = Sending time

$$T_M = \text{Sampling time} \qquad (3)$$

Oscillator for the project is 20 MHz, and a conversion of the ADC clock is selected 16 Tosc, from to ensure a minimum conversion time 0.7µs that suggests the technical data sheet of the PIC.

For not the losing the data, it is performed with an outage type TIMER 1, in a time of sampling suitable to the EMG signal.

Before knowing what value you should load TIMER 1 the first thing to do is to know how long it takes the PIC to make the reading, conversion and sent the data. A Settled led that lights up when you start the process and that shuts off when the process is finished as a checker (Fig. 7).

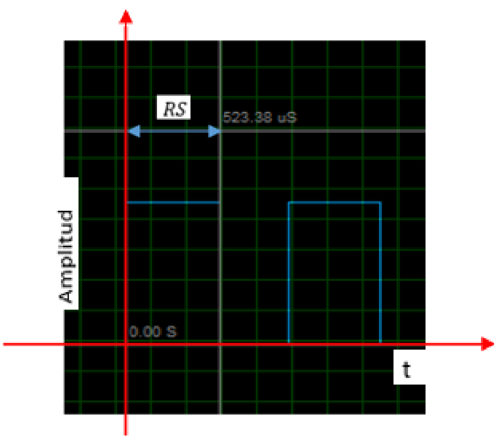

Fig. 7. Acquisition time and sending data

The Fig. 7 displays the time that it takes to acquire, convert and send the data. This time is 523.38 µs. With the data of Fig. 7 we proceed to calculate the value loaded onto the TIMER 1 to obtain a sampling time of 900µs that is greater than RS.

In Fig. 8 you can see the simulation of sampling time= $900\mu s$.

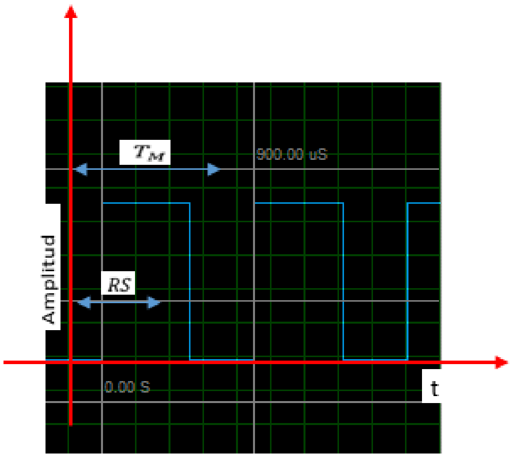

Fig. 8. Time of sampling TM 900$\boldsymbol{\mu s}$

The frequency of sampling of our signal is applied (equation 4):

$$F_M = \frac{1}{T_M} = \frac{1}{900\mu s} = 1.1Khz \qquad (4)$$

Visualization on the oscilloscope for the verification of the PIC that is sending the data in the calculated time. TM= $900\mu s$. Each grid represents 500 μs (Fig. 9).

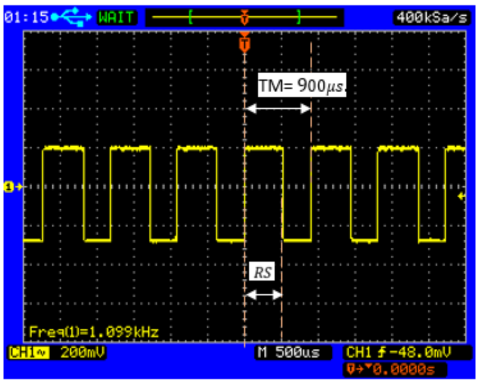

Fig. 9. Oscilloscope displays

3.11 DISPLAY OF THE SIGNAL INTERFACE

At the stage of data visualization the software used is LabVIEW version 2014. EMG signals produced during contraction or relaxation is displayed in the environment.

The user can view the data in real time and have the option of recording the data whenever you create convenient (Fig. 10).

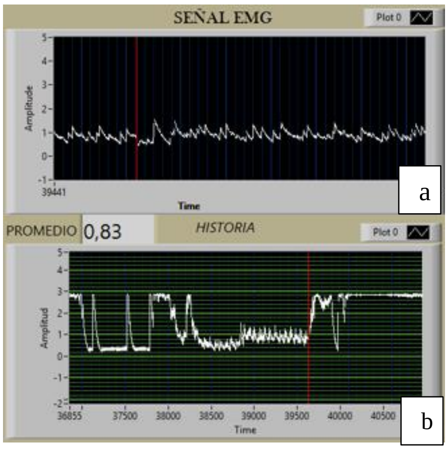

Fig. 10. Display of the EMG signal. (a) Signal in real time, b) Signal in one longer

The program also has a second panel, where you can visualize the previously recorded signal and thus appreciate the behaviour of the muscle during previous sessions (Fig. 11).

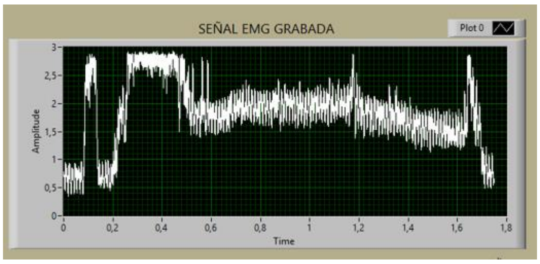

Fig. 11 Visualization of the EMG signal recorded in a given time

4.RESULTS AND DISCUSSIONS

The tests of comparison of electrodes were made in the arm Biceps muscles. This test was carried out with the thigh band prototype in both cases.

Movements: rest, flexion and extension, two movements in flexion and one in extension, the Protocol used was: cleaning of the area with alcohol and location of the electrodes according to the SEMIAN parameters.

Here is shown the signal acquired in LabVIEW (Fig. 12 to) and the same signal (Fig. oscilloscope (12 b), in order to check that they signal generated is the same without affecting the pattern of this signal.

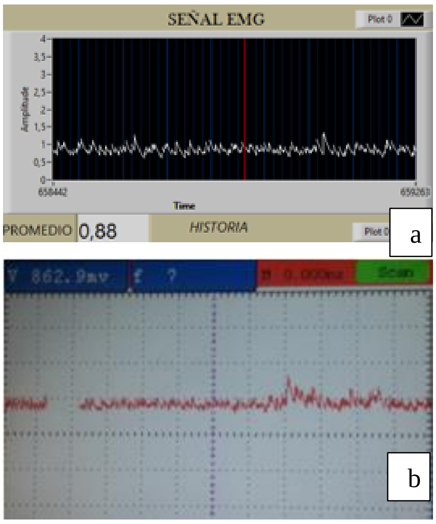

Fig. 12 Amplitudes of the thigh muscles. (a) Signal in LabVIEW, b) Signal on the oscilloscope

In Fig. 13 it can be seen that the two electrodes respond similarly when performing the same contraction in the muscle, the difference between the two is that stainless steel electrode wears more gradually than the disposable electrode Ag/AgCl.

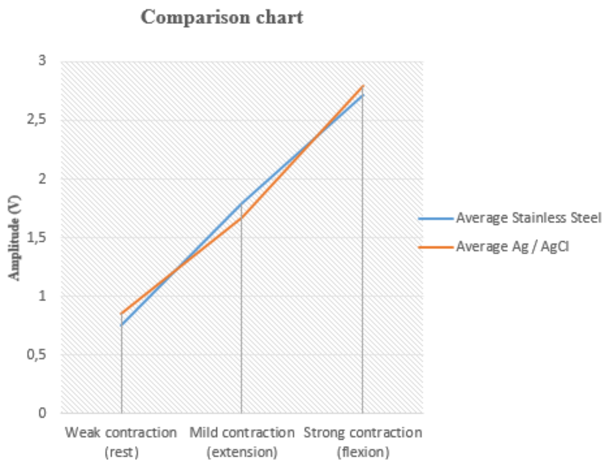

Fig. 1 3 Comparison of the two electrodes

This comparison is based with the typical disposable electrodes against electrodes of stainless steel, in order to check the response and verify the operation. The best result was obtained by the electrodes of stainless steel, which have more durability and are less expensive.

In the following fig. 14 the values of variation in terms of breadth of thigh muscles are observed: straight femoral, vast medium and vast side obtained with the thigh band prototype.

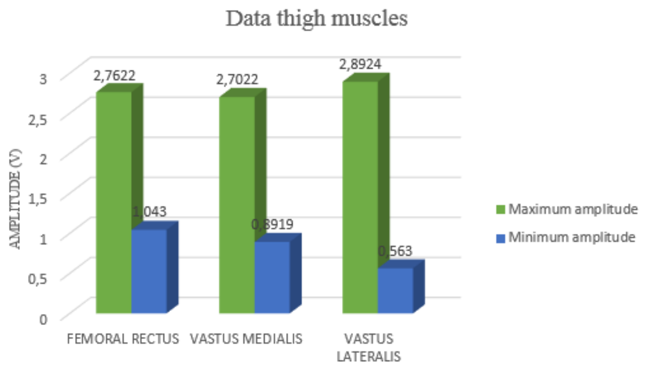

Fig. 14. Reading data

The possible improvements that can increase the prototype are:

A USB storage data system to be able to collect data whenever you want without having to deal with wireless communication.

To improve the resolution and signal sampling time the EMG must occupy a DSPIC.

5.Conclusions

In the selection of the best electrode electrodes of stainless steel were built according to the standards of the SENIAM for size and the ideal shape of the electrode, comparing them with the disposable electrodes silver / silver chloride, choosing as material for electrode stainless steel.

About the ideal location of the electrodes of the SENIAM standards were followed to acquire a signal with a low noise level.

In the design of the packaging and wireless transmission the system was is aimed to work with elements of surface mount and get so the device is as small as possible, we designed an electronic card of double layer that contains all the necessary elements for conditioning and signal wireless transmission.

The tests allowed us to observe the signals coming from the thigh muscles which directly influence the movements of flexion and extension of the knee, we also could watch the behavior of these muscles when the patient was walking or running.

6. REFERENCES

[1] «Consejo Nacional de Igualdad de Discapacidades,» Consejo Nacional de Igualdad de Discapacidades, [En línea]. Available: http://www.consejodiscapacidades.gob.ec/estadisticas/.

[2] F. C. Ricapa, «Desarrollo de un sistema para la evaluación de la actividad muscular mediante electrodos de superficie,» LIMA, 2013.

[3] S. N. d. P. y. Desarrollo, Plan Nacional para el Buen Vivir 2013-2017, Quito, 2013.

[4] D. L. D. Soto, «Desarrollo histórico y fundamentos teóricos de la electromiografía como medio diagnóstico,» 2008. [En línea].

[5] E. Criswell, Cram's introduction to surface electromyography, Second ed., United States: Jones & Bartlett Publishers, LLC., 2011.

[6] U. D. ALCALÁ, «Instrumentación Biomédica».

[7] G. d. I. Biomédica, «DALCAME,» 2015. [En línea].

[8] J. S. G. V. C. D. O. O. F. Cadena, *Acquisition and Conditioning of Electromyographic Signals for Prosthetic Legs,* Ibarra, 2015.

[9] L. B. M. G. Juan Enrique Argüelles Morales, «DISEÑO Y CONSTRUCCIÓN DE,» MÉXICO, D.F., 2011.

[10] D. A. Navarro, «Monitor EMG con conexión,» Barcelona, 2008.

[11] D. A. Navarro, «Monitor EMG con conexión,» 2008.

[12] R. R. Pendenza, SISTEMA MUSCULAR EN EJERCICIO.

[13] J. D. B. JOHN D. ENDERLE, INTRODUCTION TO BIOMEDICAL ENGINEERING, 2012.

[14] J. D. Enderle and J. D. Bronzino, Introduction to biomedical engineering, Third ed., United States: Elsevier Inc., 2012.

[15] I. A. C. González, «DISEÑO Y CONSTRUCCIÓN DE UN SISTEMA PARA LA DETECCIÓN DE SEÑALES ELECTROMIOGRÁFICAS,» Mérida, Yucatán, 2010.

[16] I. H. N. J. John Wiley & Sons, ENCYCLOPEDIA OF MEDICAL DEVICES AND INSTRUMENTATION, Segunda Edición ed., Canada, 2006.

[17] SENIAM, «Surface Electromyography for the Non-Invasive Assessment of Muscles,» 2015. [En línea]. Available: http://www.seniam.org/. [Último acceso: 06 Enero 2015].

[18] M. F.Cadena, «TARJETA DE ACONDICIONAMIENTO PARA PRÓTESIS DE RODILLA ACCIONADA POR SEÑALES ELECTROMIOGRÁFICAS,» Ibarra, 2015.

[19] J. C. V. Ferreira, MICROCONTROLADORES Motorola-Freescale, México: Alfaomega, 2008.

[20] I. C. M. Ing. Gonzalo Tejera, «Funcionamiento de microcontroladores,» 2003.

[21] I. G. COLLAGUAZO, Sistemas con Microcontroladores.

[22] M. Technology, *PIC18F2455/2550/4455/4550 Data Sheet,* 2006.

[23] J. C. Plaza, «Sistema inalámbrico y multicanal para monitorización de señales biológicas en tiempo real,» 2010.

[25] R. C. Quesada, «Digitalizador de señales de banda base compleja utilizando el TMS320VC5416 DSK,» Costa Rica, 2008.

[28] J. P. Dignani, «ANÁLISIS DEL PROTOCOLO ZIGBEE,» 2011.

[29] D. R. F. Javier Martín Moreno, «Protocolo ZigBee (IEEE 802.15.4),» 2007.

[30] J. P. Dignani, *ANÁLISIS DEL PROTOCOLO ZIGBEE,* 2011.

[31] A. Oyarce, «XBEE Series 1.,» Santiago, Chile, 2010.

[32] P. G. S. Juan Pablo Sevilla Martín, *COMUNICACIÓN ENTRE DISPOSITIVOS BLUETOOTH,* 2006.

[39] J. A. R. y. C. S. Forgach, *Un complemento al teorema de Nyquist,* 2010.