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DESIGN AND FABRICATE EMG ANALYSIS SYSTEM

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GRADUATION THESIS

DESIGN AND FABRICATE EMG ANALYSIS SYSTEM

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ABSTRACT

EMG is a bioelectrical signal produced by muscle activity. EMG has a lot of advantages for applying in control field. Nowadays, there are many research using the EMG signal to control the robot arm and peripheral devices. However, acquisition of EMG signal have some challenges… In this research, our group focus on designing and fabricating the EMG acquisition system in real time.

EMG acquisition system circuit including ADS1293 communicate with Raspberry 3 via SPI protocol. This circuit using electrodes for collecting signal from surface skin. The collected signal is processed, analyzed on acquisition system circuit and displayed on the computer.

During the research, our group successfully fabricate the EMG acquisition system with low cost and compact size. The signal is collected accurately which represent the full characteristic of muscle activity, the results of this research show the EMG acquisition system could be response particularly the acquisition, processing and analysis.

This project opens opportunity to the development and application of EMG signals in the technical control field. It can become one of the most widely used scientific fields in the future.

ACKNOWLEDGEMENT

We sincerely thank the lecturers of the department of mechatronics of high quality training who have continuously encouraged us and also provided precious knowledge. Without it, we could not complete our project.

We would like to express my special thanks to Dr.Bui Ha Duc who supported us a lot for doing this study and we explored so many new things.

The group is looking forward to receiving feedback, instructions of lecturers to revise and improve the project better.

My group sincerely thanks!

Ho Chi Minh City, *July 2018*

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List of Abbreviations

EMG - Electromyogram
SEMG – Surface Electromyogram
MUAP - Motor Unit Action Potential
MUAPT - Motor Unit Action Potential Trains
CMRR - Common Mode Rejection Ratio
ADC - Analog to Digital Converter
ECG - Electrocardiogram
EMI - Electromagnetic Interference
INA - Instrumentation Amplifier
SDM - Sigma-Delta Modulator
PCB - Printed circuit board
RPi3 - Raspberry Pi 3
SPI - Serial peripheral interface
SCLK, SCK - Serial Clock
MOSI - Master Output Slave Input
MISO - Master Input Slave Output
SS - Slave Select
CS - Chip Select
CSB - Chip Select Bar
DRDYB - Data Ready Bar
CPOL - Clock polarity
CPHA - Clock phase
HTTP - Hypertext Transfer Protocol
FTP - File Transfer Protocol
SMTP - Simple Mail Transfer Protocol
POP - Post Office Protocol
URL - Uniform Resource Locator
JS - Java Script
CSV - Comma Separated Values
DPS - Data Points

Chapter I: INTRODUCTION

1.1. Motivation

Electromyogram (EMG) is bioelectrical signal produced by motor control neuron that transmit signal for active muscle cells, this electric affected by level of muscle activities. This signal appears before moving of muscle in about 150ms. That is a big advantage. If the EMG signal is utilized effectively, it could significantly enhance the robustness of control system. There were several groups have researched and applied EMG signal into control some devices. For example, Myo Gesture Control Armband is researched and manufactured by Thalmic Labs. The EMG signal can be applied to some devices such as a computer game, digital pointer controller for zoom in on your slides and touch-free.

However, acquisition of EMG signal have some challenges. First, cost of parts and devices is very expensive. Second, it is not easily to find in Vietnam. Usually, we must order this from abroad. Third, some devices are big or oversized. So, it is unsuitable for portable system. Four, the collected signal is easily noised by external factors. This require the acquisition system have to perfect and work correctly. And finally, some parts is unsuitable for technical control.

To overcome these challenge, our team aims to design a compact, reliable device for acquiring and analyzing EMG signal. This devices will be affordable, compactly, easy to use and has capability to work in the real-time.

In this project, our team will use embedded circuit Raspberry Pi 3 to control an Analog Front End for Biopotential Measurements ADS1293. Interface SPI is used for transmit and receive data between Raspberry and ADS1293. Additions, we use wireless connection to push the collected data onto Cloud and draw plot real-time on Web.

1.2. Project objectives

- Determine technical requirements of EMG signal acquisition system.
- Design and fabricate EMG signal acquisition system circuit.
- Collect and analyze the EMG signal.
- Transmit and store the signal from Raspberry to the computer via wireless.

- Apply the signal to control software on the computer.

1.3. Scope of research

The scope of this project is focus on designing and fabricating the hardware. Then, we apply the EMG signal which is collected to process and analyze in EMG acquisition system. We use the filters which integrated in system to eliminate the unwanted noise. Next, we process data and display on Web by plot. We have already demoed on the presenter application.

1.4. Thesis organization

This thesis will have 6 chapters.

In chapter 1, we will present the EMG, the generation of EMG signal, processing the signal and factors affecting the EMG signal.

In chapter 2, we will learn about the EMG, the generation of EMG and EMG signal. EMG has many benefits and applications and we can apply it for technical control, …

In chapter 3, we use the ADS1293 and the Raspberry Pi 3 to fabricate the EMG acquisition system circuit. This circuit collected signal by ADS1293 and RPI3 via SPI protocol and send it to computer via wireless for program.

In chapter 4, we will do some experiment for collecting the EMG signal from the forearm. This chapter provide us the characteristic of the EMG signal

In chapter 5, will have the experiment results which have done in chapter 4. The results on the circuit show quality of collected EMG signal. We will finger out how to collect EMG signal without ambient noise

In chapter 6, will show research results and research directions.

Chapter II: LITARETURE REVIEW

1.5. Theory of EMG

1.5.1. Definition

Electromyography (EMG) [1] is an experimental technique concerned with the development, recording and analysis of myoelectric signals. Myoelectric signals are formed by physiological variations in the state of muscle fiber membranes.

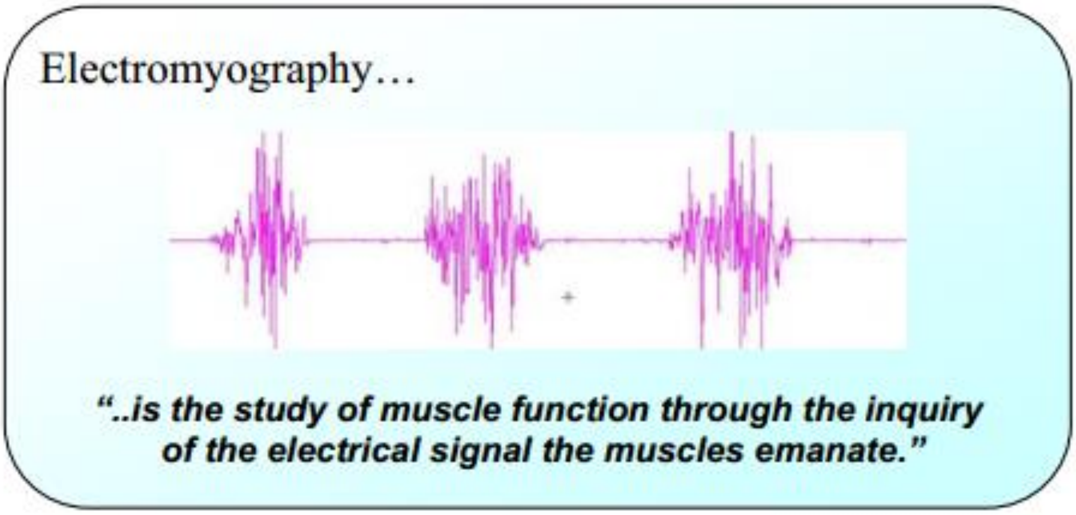

Figure 1. EMG Signal

EMG measurement is a medical technique which evaluate and record the electrical activity produced by skeletal muscles. EMG is performed using an instrument called an electromyograph to produce a record called an electromyogram. An electromyograph detects the electric potential generated by muscle cells when these cells are electrically or neurologically activated. The signals can be analyzed to detect medical abnormalities, activation level, or recruitment order, or to analyze the biomechanics of human or animal movement.

Surface EMG (SEMG): A technique in which electrodes are placed on (not into) the skin overlying a muscle to detect the electrical activity of the muscle.

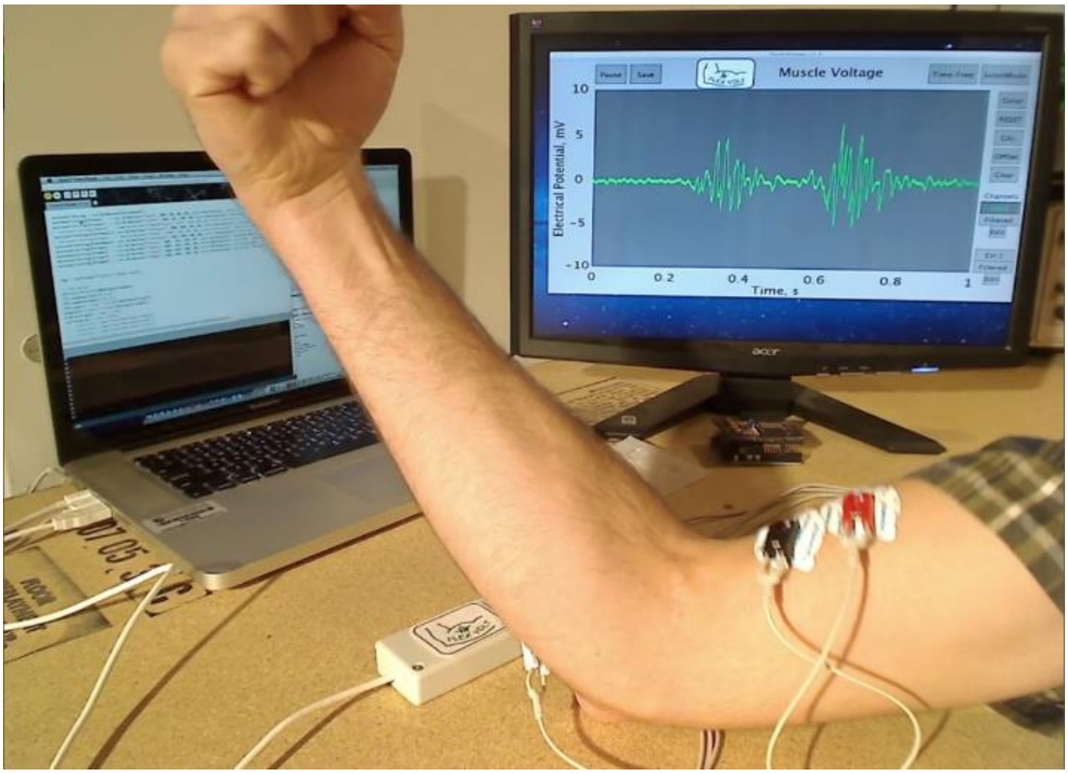

Figure 2.Surface EMG

Surface EMG (SEMG) has some attractive features. Most notably, it does not involve piercing the skin and does not hurt. However, the American Association of Electro diagnostic Medicine notes that: "There is in fact almost no literature to support the use of SEMG in the clinical diagnosis and management of nerve or muscle disease". Still, the SEMG may prove of value in the future in helping to monitor the progression of disorders of nerves and muscles.

1.5.2. Medical uses

EMG testing has a variety of clinical and biomedical applications. EMG is used as a diagnostics tool for identifying neuromuscular diseases, or as a research tool for studying kinesiology, and disorders of motor control. EMG signals are sometimes used to guide botulinum toxin or phenol injections into muscles. EMG signals are also used as a control signal for prosthetic devices such as prosthetic hands, arms, and lower limbs.

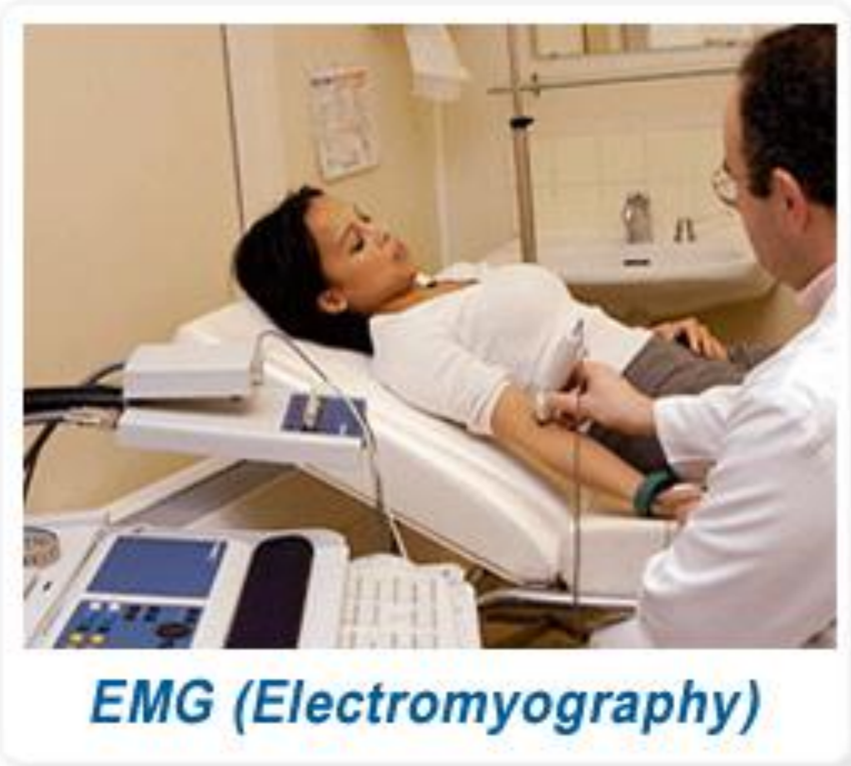

Figure 3. Medical benefits of EMG

EMG then an acceleromyograph may be used for neuromuscular monitoring in general anesthesia with neuromuscular-blocking drugs, in order to avoid Postoperative Residua Curarization (PORC).

1.5.3. Typical benefits

The use of EMG starts with the basic question: "What are the muscles doing?"

Typical benefits are:

- EMG allows to directly "look" into the muscle
- It allows measurement of muscular performance
- Helps in decision making both before/after surgery
- Documents treatment and training regimes
- Helps patients to "find" and train their muscles
- Allows analysis to improve sports activities
- Detects muscle response in ergonomic studies

1.5.4. EMG signal

1.5.4.1. Definition

EMG signal is the electrical expression caused by neuromuscular activation during muscular contraction, depicting the current detected at the specific location that is produced by the ionic flow across muscle fiber membranes and transmitted through intervening tissues.

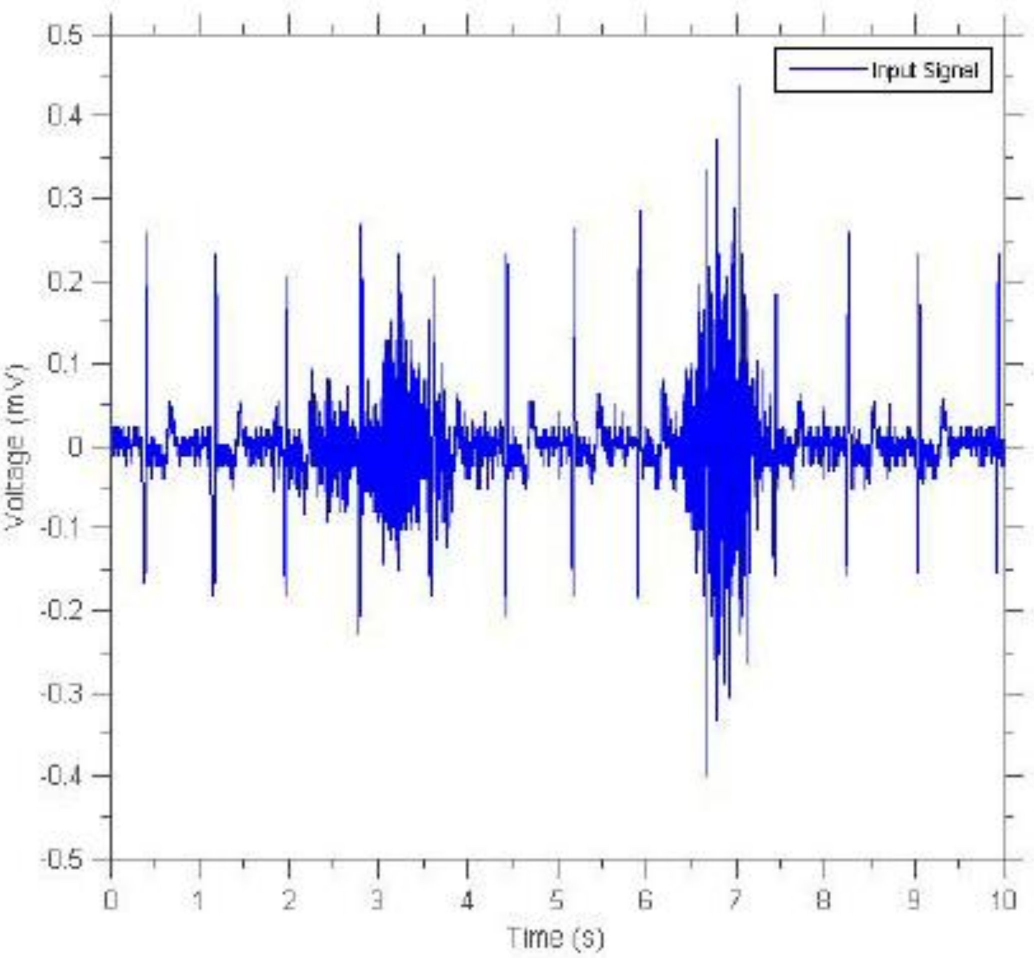

Figure 4. EMG Signal

1.5.4.2. The motor unit

The motor unit is the most elementary functional unit of a muscle, generating a motor unit action potential (MUAP) when activated. Repeated continuous activation of motor units generates motor unit action potential trains (MUAPT) that are superimposed to form the EMG signal.

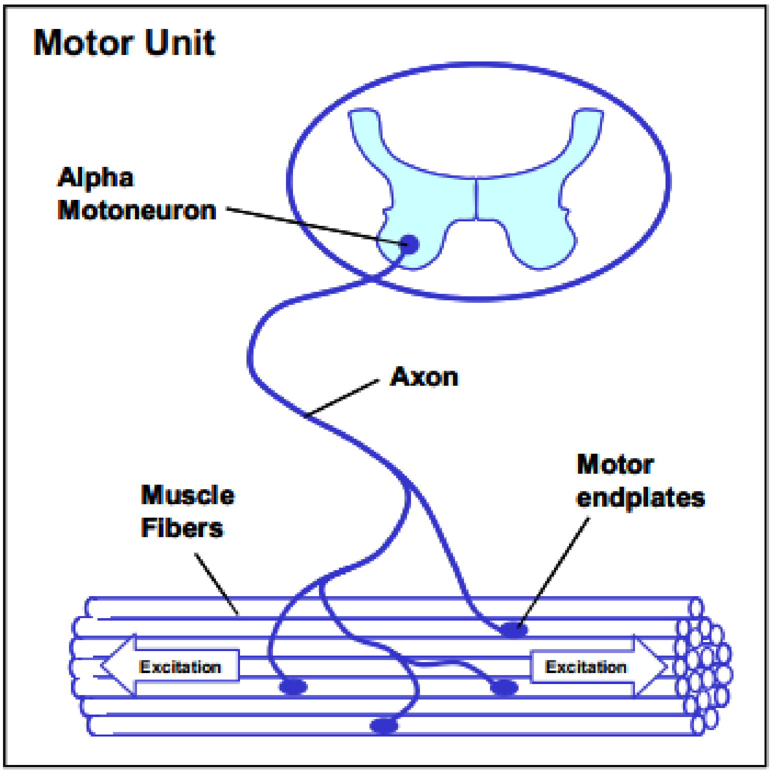

Figure 5. Motor unit

1.5.4.3. The generation of the EMG signal

The excitability of muscle fibers through neural control represents a major factor in muscle physiology. This phenomenon can be explained by a model of a semi-permeable membrane describing the electrical properties of the sarcolemna. An ionic difference between the inner and outer spaces of a muscle cell forms a resting potential at the muscle fiber membrane (approximately -80 to -90 mV when not contracted). This causes a membrane Depolarization which is immediately restored by backward exchange of ions within the active ion pump mechanism, the Repolarization [1]:

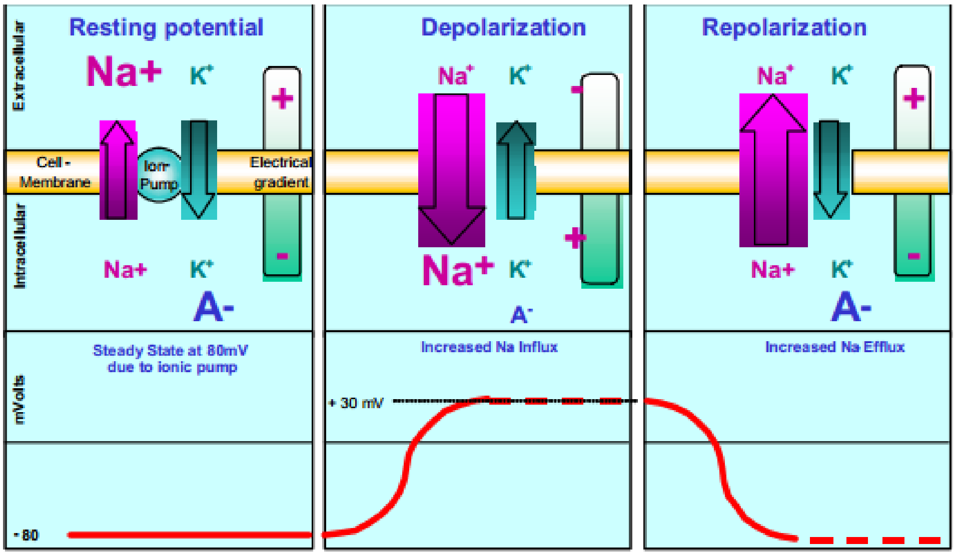

Figure 6. Schematic illustration of depolarization/repolarization

If a certain threshold level is exceeded within the Na+ influx, the depolarization of the membrane causes an Action potential to quickly change from – 80 mV up to + 30 mV. It is a monopolar electrical burst that is immediately restored by the repolarization phase and followed by an After Hyperpolarization period of the membrane.

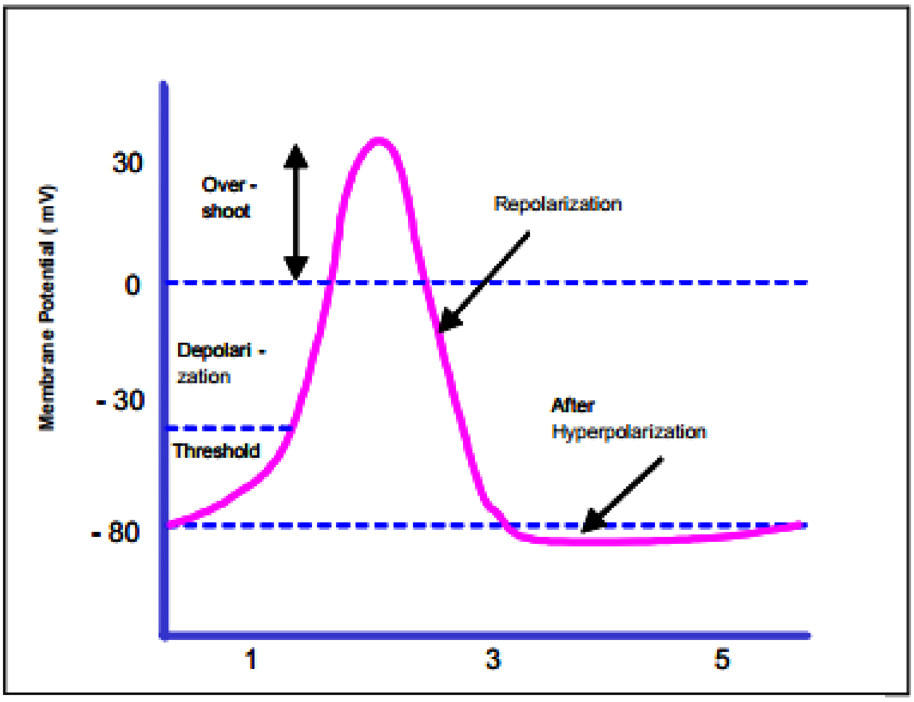

Figure 7.The action potential.

1.5.4.4. The "raw" EMG signal

An unfiltered (exception: amplifier bandpass) and unprocessed signal detecting the superposed MUAPs is called a raw EMG Signal [1]. In the example given below, a raw surface EMG recording (sEMG) was done for three static contractions of the biceps brachii muscle:

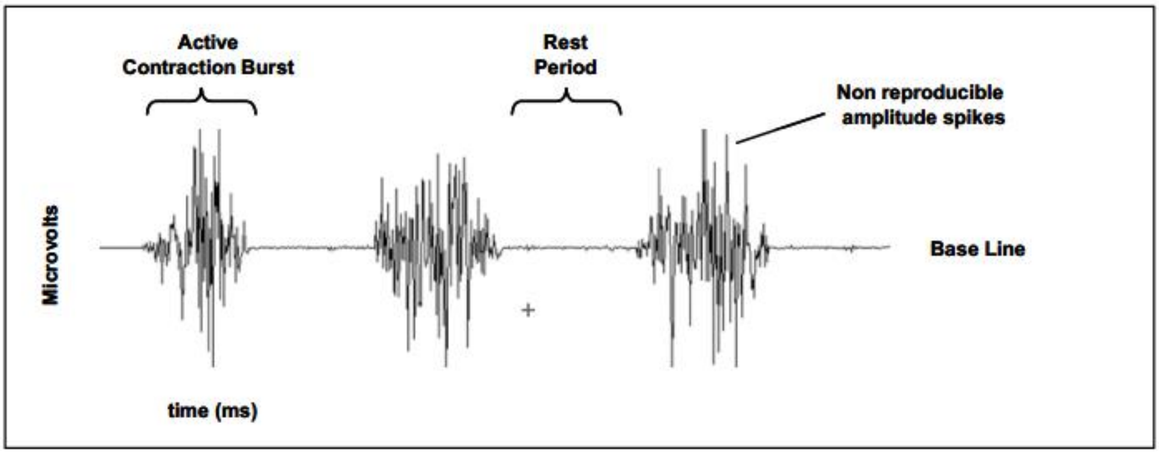

Figure 8. The "Raw" EMG Signal

Raw sEMG can range between +/- 5000 microvolts (athletes!) and typically the frequency contents ranges between 6 and 500 Hz, showing most frequency power between ~ 20 and 150 Hz.

1.5.5. EMG Amplification

1.5.5.1. EMG – Amplifiers

EMG-amplifiers [1] act as differential amplifiers and their main purpose is the ability to reject or eliminate artifacts. The differential amplification detects the potential differences between the electrodes and cancels external interferences out. Typically external noise signals reach both electrodes with no phase shift. The "Common Mode Rejection Ratio" (CMRR) represents the relationship between differential and common mode gain and is therefore a criteria for the quality of the chosen amplification technique. The CMRR should be as high as possible because the elimination of interfering signals plays a major role in quality. A value >95dB is regarded as acceptable (11, SENIAM, ISEK).

State of the art concepts prefer the use of EMG pre-amplifiers. These miniaturized amplifiers are typically built in the cables or positioned on top of the electrodes (Active electrodes). The main idea of using small EMG pre-amplifiers located near the detection site is early pick up of the signal, amplification, (e.g. 500 gain) and transmission on a low Ohm level that is less sensitive to (cable) movement artifacts.

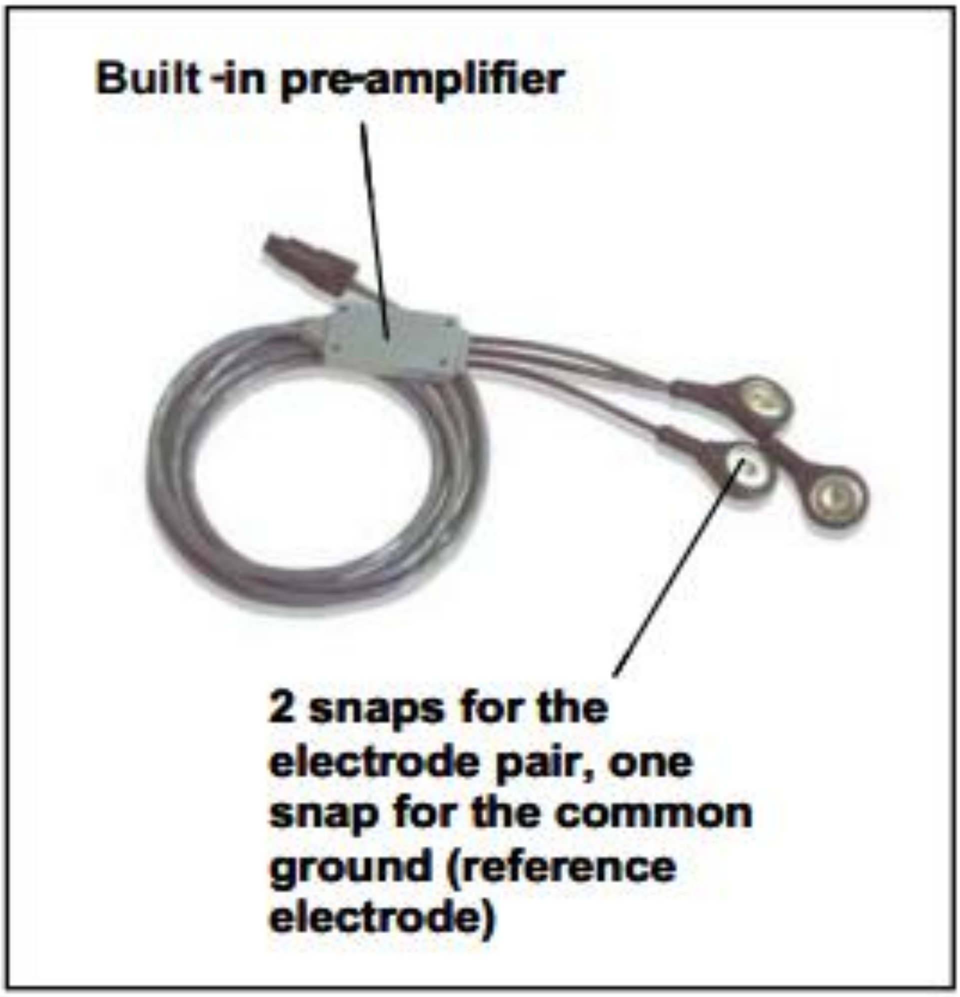

Figure 9. Electrode leads with cable built-in preamplifiers

An EMG signal that has not been amplified has typical charges between a few microvolt and 2-3 millivolt when reading on the skin. The signal is generally amplified by a factor of at least 500 (e.g. when using preamplifiers) to 1000 (passive cable units). The frequency range of an EMG amplifier (bandpass settings) should start from 10 Hz high-pass and go up to 500 Hz low-pass.

1.5.5.2. A/D Sampling Rate

Sampling a signal at a frequency which is too low results in aliasing effects. For EMG almost all of the signal power is located between 10 and 250 Hz and scientific recommendations (SENIAM, ISEK) require an amplifier band setting of 10 to 500 Hz. This would result in a sampling frequency of at least 1000 Hz (double band of EMG) or even 1500 Hz to avoid signal loss.

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