

## Pre-Amplification Technique for Capturing and Conditioning of Electromyogram Signal off the surface of the muscle



Engineering

KEYWORDS:

Shashwat V Vyas

M.E.Student, Department of E &amp; C, Venus International College of Technology, Gandhinagar

Bhargav Makodia

Assistant Professor, Department of E &amp; C, Venus International College of Technology, Gandhinagar

### ABSTRACT

*The actual hardware implementation of the exoskeleton begins with the design and development of the first stage that is required to detect the Electro\_Myo\_Gram signal off the muscles followed by the second stage that will cleanse the raw Electro\_Myo\_Gram signal making it useful and clear enough to be worked upon for defining decision making algorithm that will make the mechanical system make movements based on the Electro\_Myo\_Gram signal detected.*

### I. INTRODUCTION

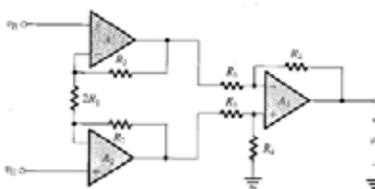
The first stage designed as part of this thesis comprises of a sensor, an amplifier and a filter. We begin with sensor that will detect the Electro\_Myo\_Gram signal off the muscle. The pursuit of finalizing a sensor presented itself with a decision of making a choice between a sensor that can be just fixed over the skin to detect the signaling right underneath it within the muscle or a sensor that can be inserted right into the skin through to the muscle off which the signal is to be detected and captured. Taking into consideration the underlying objective of this thesis of designing a technological aid that is helpful to stroke survivors, a care is emphasized on making the system as comfortable to the end user as much as possible and also making it's fixture over user's hands or the upper limbs easy and free of any clumsiness, the sensors that can be placed right over the skin surface are chosen. This choice has two advantages, being surface based sensor, no need to insert anything within the skin relieving the user off the pain that they would have to undergo if the insertion based sensor was to be used and second the assistant who would aid the user in wearing or putting over the system for use will have comfort in applying sensor and assembling the set-up hence eliminating need of any medically trained professional for using the insertion type sensor which would have lead to cost rise and constraints. The sensor used for the thesis is: "The Raxon PE Foam / 43 x 45 mm/ Solid Gel surface sensors"<sup>[3]</sup> for its easy availability and low cost.

### II. IMPLEMENTATION

The sensors selected for capturing Electro\_Myo\_Gram signal off surface are placed on the Bicep muscle, right over the Muscle Belly (the Muscle Central Portion).<sup>[3]</sup> The distance kept between both the mono-polar sensors is about 20 mm to cover the most optimum area under the muscle which will generate the useable Electro\_Myo\_Gram signal.<sup>[3]</sup> The next important characteristic of a sensor that is to be taken care of is it either being, mono-polar, bi-polar, tri-polar or multi-polar. In my thesis, a mono-polar sensor is used and again the reason being it's low cost compared to its other polarity counterparts.<sup>[3]</sup> The next part comprising first stage is an amplifier which naturally generates a question of what has an amplifier to do with a detecting stage. The answer for the above generated question lies in the natural characteristics and properties of Electro\_Myo\_Gram signal, the most prominent being highly random and asymmetrical frequency components and the amplitude level being in range of millivolt range which poses a serious challenge in making it useful enough to dictate the mechanical parts of the system in performing desired movements. To first eliminate the constraint of low level amplitude, an amplifier is

designed which effectively amplifies the amplitude levels making signal ready to be put to second phase that will take care of eliminating the frequency based constraints. The amplification is undertaken using a differential amplifier as best result of an Electro\_Myo\_Gram signal can be obtained from two nearby points off a muscle. More specifically an instrumentation amplifier implemented using three Operational Amplifiers OP-07 ICs is used to pre amplify the Electro\_Myo\_Gram signal.<sup>[2]</sup>

### III. INSTRUMENTATION AMPLIFIER



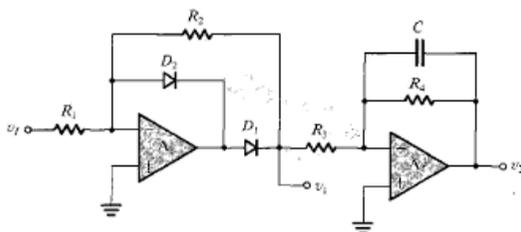
**Fig 4.1** The Instrumentation Amplifier circuit diagram implemented using tri-Op-Amps<sup>[1]</sup>.

This above mentioned figure depicts the 3 Op-Amps connection in an instrumentation amplifier designed and implemented for pre-amplification of an Electro\_Myo\_Gram signal captured using surface electrodes off the muscle under consideration. The instrumentation amplifier is designed in such a way that the gain of the amplification is 201, that is, the input signal is amplified 200 times its actual raw value. This circuit above is a mixture of two circuits, a voltage follower and a differential amplifier. The first stage is the voltage follower circuit which is amalgamated to a differential amplifier circuit. The voltage follower circuit has three resistances, the values of which are taken as  $R_2 = 100 \text{ K}\Omega$  and the value of  $R_1 = 1 \text{ K}\Omega$ . The input to the voltage follower is the raw Electro\_Myo\_Gram signal which is passed over to the following differential amplifier that generates the first conditioned (amplification) signal from the muscle contraction and relaxation. The use of differential amplifier is further justified in order to eliminate the common mode disturbance that humans possess over their skin surface. The common mode disturbance is the capacitive or the inductive coupling of 50 Hz sinusoidal, called the Ambient Noise caused by electromagnetically effecting devices like power lines of the central A/C Power Supply that we get via the outlets on the walls having working frequency of 50 Hz or 60 Hz depending on the country and their specifications of the power supply available<sup>[2]</sup>. Thus the output of the instrumentation amplifier is the first stage of the complete pre-amplification stage for capturing Electro\_Myo\_Gram signal off the skin surface. The next stage that follows the instrumentation amplification is the high pass filter which

is placed in there to remove the offset DC voltage which is present at end of the amplification stage due to the difference in the impedance value and chemical reactions taking place at the skin-surface electrode interface. This offset DC is amplified along with the Electro\_Myo\_Gram signal and is removed using a high pass filter which is designed to have a cut-off frequency of approximately 10 Hz – 15 Hz. [2] The High Pass Filter here is an active filter designed using a 1 MΩ resistance, a matching capacitor value (approximately value: 10 kpF) and OP-07 IC. The amplification gain of the active filter has been kept unity. [1] The Averaging technique is being used to select necessary components of the raw Electro\_Myo\_Gram signal to make it suitable for directing the mechanical system.

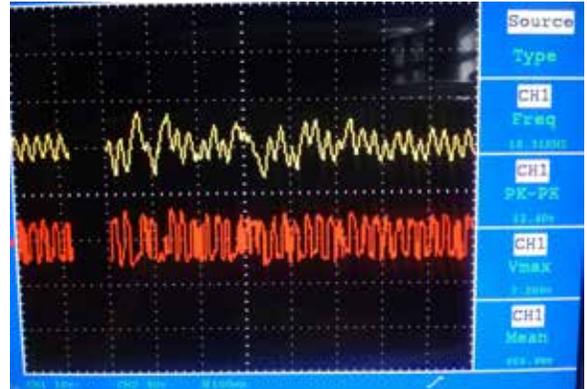
**IV. AVERAGING**

Averaging is a simple mathematical calculation to analyze set of available signal values, its varying variables but collecting scores of averages of smaller sub-sets of the complete pool of data available to us. Thus the whole of the bunch of signal is divided into smaller sub-divisions and average of each division is calculated. The flow of the technique goes as, on dividing the available pool of quantity into smaller sections, we calculate average of the values thus available. Now we move one data bit at a time to the right forming a new set. We continually move creating different sets and calculating average of each of this set. The advantage of this technique is its use with a time series which aides in smoothing out the short duration fluctuations, a challenge that is highest in a bio-medical signal, in case of this thesis, an Electro\_Myo\_Gram signal. It exemplifies a Low Pass Filter. The other advantage is its simplicity which doesn't involve complex mathematical calculations. This simple and straight forward signal processing technique has been deployed in the thesis with a precision Op-Amp based rectifier followed by a Low Pass Filter. Following is the deployed Precision Op-Amp based rectifier which has been implemented using OP-07 IC and 1N4148 Diodes which are suitable for precision rectification of signals like, Electro\_Myo\_Gram signal. The use of an Op Amp has an advantage of high input impedance and the circuit under design being an active circuit, an active rectifier. [1] The rectifier implementation in thesis is carried out by using two 1N 4148 diodes and same valued resistors which makes it a rectified negative output. This recommendation is taken into consideration from Micro-Electronics, Sedra & Smith [1]. The intention of using a precision rectifier lies in the fact that the regular diodes are fired up by higher value currents than which is generated by Electro\_Myo\_Gram signal. This challenge is answered using 1N4148 ( $D_1 = D_2$ ) that are fired upon lesser current values than regular diodes. The values of resistors selected are  $R_1 = R_2 = 4K7$ . The next part of the Averaging Implementation is a Low Pass Filter. Again the implementation guidance under consideration is present in Sedra & Smith [1]. It's as follows:



**Fig 4.2** Precision Rectifier circuit followed by a Low Pass Filter diagram implemented using Op-Amp [1]

The above shown circuit diagram is implemented using a Low Pass Filter arrangement designed using a OP-07 Op-Amp and resistor values chosen as  $R_3 = 100\text{ K}$  and  $R_4 = 1\text{ M-Ohm}$  with  $C = 10\text{ nF}$ . The choice of particular values in the combined above arrangement has been made to get a useful signal off the challenge posing Electro\_Myo\_Gram signal. [3]



**Fig 4.3** The DSO output of a comparison between the output of Averaging Circuitry and instrumentation amplifier implemented using Op-Amp.

The above both the figures represent the output of the Instrumentation Amplifier and that of a comparison between the outputs of an Instrumentation Amplifier and the output of the Averaging Circuitry. It's clear that the output of the instrumentation amplifier shows a flexed muscle signal which is a mixture of many frequency components and its amplitude is too very small and not very distinct enough to be able to use for controlling the mechanical system. But after it has been fed to the Averaging Circuitry, we can see the envelope developed that shows reasonably clear enough to be used to control the mechanical system after being fed to the Schmitt Trigger Circuitry. The final part that follows the averaging circuitry is the decision making electronics and this will generate decisive signals to control and direct the mechanical system. This part of the signal conditioning stage comprises of a comparator circuitry that will differentiate between two prominently different signals to direct the mechanical system to perform flexion. The mechanical system performing flexion will help the user to undergo the same physical movement using upper limb (the hand) i.e. with the mechanical system making a movement from the elbow, the hand clasped in the mechanical system will follow suit. Repetition of this activity will help the user get accustomed to the regular hand movements that had been restricted following a stroke or any possible Spinal or a Brain Injury. The decisive circuitry proposed is a Schmitt Trigger implementation using an Op-Amp to decide two prominent signal levels which will direct the mechanical system to perform the up and the down movement from the elbow onwards.

The advantage of using a Schmitt Trigger is its ability to convert an analog signal to a square wave or pulse making it absolutely perfect candidate to be used by a Controller, in this thesis a perfect clientele incoming signal to an Arduino Uno which will generate the controlling signal based on the algorithm of identifying the signal level and accordingly generating motor control signal that will aid the mechanical system in making the desired movements.

**4.4 Schmitt Trigger**

The fundamental of a Schmitt Trigger circuit working lies in its voltage threshold deciding capability based on simple voltage division and its ability of holding output even in the absence of an input incoming signal. Depending upon the output signal

available at the end of the Averaging Circuitry, the optimal and distinctively different threshold levels of voltage are decided that will on being fed to the waiting Arduino Unit will direct the movement of the mechanical system.

## REFERENCE

- [1] Adel S. Sedra, Kenneth C. Smith. Microelectronic Circuits; 5th Edn; Oxford University Press, New York, 2004 | [2] Dr. Scott Day, "Important Factors in Surface EMG Measurement", Bortec Biomedical Limited, [www.bortec.ca](http://www.bortec.ca). | [3] Hermie J. Hermens, Bart Freriks, Catherine Disselhorst-Klug, Gunter Rau, "Development of recommendations for SEMG sensor and sensor placement procedures", Elsevier, Journal of Electromyography and Kinesiology 10 (2000),361-374.