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Design and Development of EMG Controlled Prosthetics Limb

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Abstract

Arm amputees are people who have lost their upper limb due to accident, trauma or any disease affecting the limbs. Such people cannot perform functions which require using the hand, not even routine activities in day-to-day life such as holding the objects, moving them, eating and all the like functions. Broadly speaking, these people are not self-sufficient, but they do have an opening to look forward to. The muscles in the remaining part of the arm function in a normal way, enabling the electromyogram (EMG) signals from them to be used in limb replacement techniques. One such solution would be a Myoelectric Prosthetic Arm, which uses the EMG signals from the patient and controls movement of the prosthetic arm. The advantage of this technique is that the signal will be acquired from the patient's body and after suitable processing it is used as a control input to drive motors which are coupled to the prosthetic arm. So, the arm can be worn by amputees and the control mechanism will be initiated by their own EMG signals.

Keywords: EMG Singal , Prosthetics Limb, EMG Siganal Processing

1. INTRODUCTION

Prosthesis is basically an artificial device which replaces a part or organ of the body. A Prosthetic arm replaces an upper limb which might have been amputated due to several reasons. Prosthetic arms are being widely used, especially in countries such as Russia and United States where limb replacement techniques are growing. National limb loss Information center given the amputation statistics in that there are approximately 1.7 million people living with limb loss in United States [1]. A Myoelectric Prosthetic Arm, as the name suggests, is a prosthetic arm which uses myoelectric (EMG) signals for control. This is possible due to the fact that the neuro-muscular system of amputees remains intact even after amputation. The residual signals are made use of and it is sufficient enough to control the movement of the arm after suitable processing [9]. Actuators such as motors are used to replace the role which muscles play by providing force for movement of the arm. Myoelectric prosthetic arm stands out from externally powered arms which depend on external power for controlling the arm, Though an amputee is dependent on the prosthetic arm, it is his/her own myoelectric signals which run the arm, which is a confidence-boosting aspect of the myoelectric prosthetic arm.

2. EMG - SIGNAL PROCESSING

Electromyographm signals measures electrical activity of the muscle fiber at contraction and relaxation phase. These myoelectric signals are recorded by two methods which are invasive and noninvasive. In invasive method, needle electrodes are used to measure the EMG signal. But noninvasive is often preferred, because it is directly placed above the skin surface without inserting the electrode into patient body. There are many factors affecting the EMG signal such as motion artifacts, electrode misplacement and noise interpolation. In order to obtain more information, Signal processing is done over EMG signals such as filtering, rectification, baseline drifting and

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threshold leveling. EMG signal processing block diagram is shown in figure1.b. EMG signals for shoulder rotational movement, are acquired from muscles of the shoulder using three pre-gelled surface electrodes.. Two electrodes are placed in the shoulder acromial part of central deltoid muscle and Clavicular part of central deltoid (anterior fibers) [2][3] which shown in figure 1.a. Ground electrode is placed on the other hand for effective grounding. EMG signals are picked by surface electrode .But the picked signal has amplitude in micro Volts. So preamplifier is necessary to amplify the micro level EMG Signal (10µV) into milli voltage (mV). From the electrode, EMG signal is fed into Preamplifier. Instrumentation Amplifier INA 128P with high CMRR (120 dB), high input impedance, Gain is fixed as 1000 as per equation 1 to do the amplification process [4][5][11].

$$G = 1 + \left(\frac{50K}{Rg}\right) \tag{1}$$

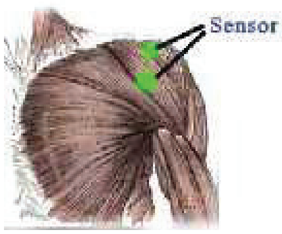

Figure 1(a)

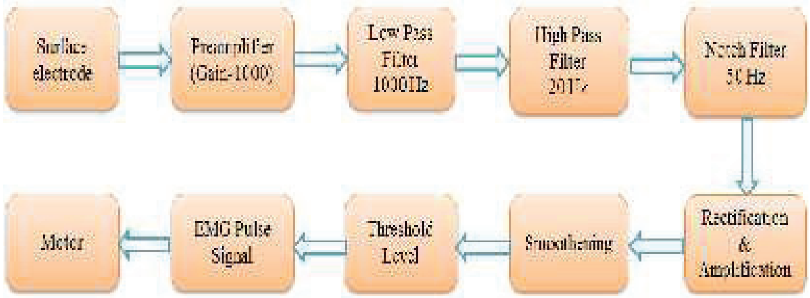

Figure 1 (b)

Figure 1 (a) location of EMG Sensor. (b)Block Diagram of EMG Signal Processing

The remaining blocks of EMG signal processing are described as follows:

2.1 LOW PASS FILTER

In order to eliminate the high frequency signal (above 1000 Hz), the output of the preamplifier is fed into low pass filter. To design an effective filter, comparison is done with various filter topologies such as Butterworth, Chebyshev, Bessel, Gaussian. Gain response, phase delay, and Group delay parameters are taken for filter response analysis. Comparison is done by filter pro software and simulation results are shown in figure 2 and figure 3

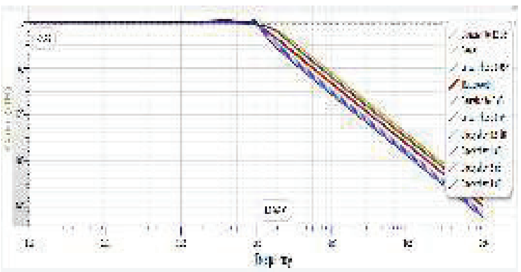

Figure.2 Gain (dB) response for various filters

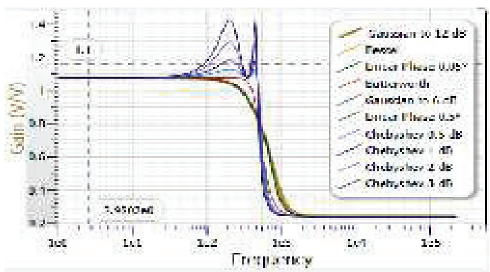

Figure 3. Gain (V_0/v) response for various filters

From the above comparison, Butterworth filter has no ripple at pass band frequency. This flat response is more suitable for our effective low pass filter. When filter order increases, signal gets sharp response at Stop band. For 80 dB Stop band attenuation [4][5], fourth order Butterworth filter has been designed
The transfer function for the fourth order low pass filter is shown in equation 2.

$$H(S) = \frac{1}{(S^2+1.8478\,S+1)(S^2+0.7654\,S+1)} \tag{2}$$

Output signal of low pass filter is digitalized with NI DAQ system and signals stored as text and excel Format for future process.

2.2. HIGH PASS FILTER AND NOTCH FILTER:

The stored EMG signals are processed by labview simulation software. The acquired EMG signals are filtered by high pass filter with cutoff frequency 20 Hz to remove motion artifacts and external noise. Fourth order Butterworth high pass filter has been selected for 80dB stop band attenuation [4][5]. When considering muscle contraction, dominant EMG signals frequency between 20 Hz – 500 Hz should be used [7]. The EMG signals suffer from noise corruption due to the 50 Hz power-line interference (50 Hz in India, 60 Hz in Western countries). A notch filter which eliminates 50 Hz frequency component is used, a band stop filter with cut-off frequencies 48 Hz and 52 Hz could be used for the same [5]. The effect of notch filtering is not prominently reflected in the EMG signal but it can be perceived in the disappearance of the peak at 50 Hz from the FFT Spectrum of the raw signal is shown in figure .7.

2.3 RECTIFICATION AND AMPLIFICATION

After notch-filtering, the signal needs to be rectified. The purpose of rectification is to remove the negative components of the signal. Removing the negative components implies that the negative amplitude is made positive by squaring the entire signal. As expected, the amplitude value also gets squared in this step. Furthermore, if the amplitude is less than 1, squaring would push the amplitude away from 1 towards 0, making the value to decrease. In order to boost the amplitude of the signal to a reasonable range, amplification is done. A constant value is multiplied to the signal, thereby boosting the amplitude of the entire signal by that value. The end product of this processing step is a positive signal (without negative components) with amplitude in the desired range, (around 0 to 4 V).

2.4 SMOOTHENING

The signal in hand after the first few processing steps still resembles an EMG signal, looking at the contraction and relaxation phases of the signal, the prominent change being the conversion of negative components to positive ones after rectification. As mentioned earlier, the contraction phase of the signal is of maximum interest, it has to be extracted from the rest of the signal. This is done by passing the signal through a low-pass filter which detects only the envelope of the signal. Moving average filter is applied with a half-width of 50. The result of smoothening is a signal with blunt peaks exactly at the contraction phases.

2.5 BASELINE DRIFT ELIMINATION

The acquired EMG signal has baseline drift which is a common phenomenon in signal acquisition. Baseline drift is a condition where the zero potential line of the signal is shifted towards positive or negative side away from the zero value. This could be eliminated by subtracting the averaged version of the signal from the original signal. The technique adopted in our case is that we subtract the drift value directly from the signal. For example, if the baseline of the raw signal is shifted from the zero value by 2 units, the value 2 is subtracted from the signal for baseline drift elimination. The value which is to be subtracted from the signal is controlled by a user-control in the front panel of Labview.

2.6 THRESHOLDING AND AMPLIFICATION

After baseline drift elimination, the signal is ready to be converted into a pulsed signal, with each pulse corresponding to contraction phase of the EMG. A threshold level is set, around 0.5 to 2 V, and the result after thresholding is a pulsed signal with amplitude of the pulse at 1V. Next, we amplify the voltage from 1V to 5V because our aim is to obtain a 5V pulse output. As before, amplification is done by multiplying a constant value to the signal, in this case, the value is 5.

3. SIGNAL ACQUISITION AND SIMULATION OUTPUT

3.1. SIGNAL ACQUISITION

The acquired EMG signals are stored in excel and text formats which will be used in offline analysis. The signal acquisition is done for 10 seconds with a sampling rate of 1 kHz. Each recording has 10,000 samples. The uniform number of samples in the recorded data ensures that data from all trials could be processed using the same processing techniques. In different recordings, duration and frequency of contraction are different, and those different variations of EMG signal are taken into account for processing. The signal acquisition is also tried for different subjects to overcome subjective variations. The entire signal processing is performed using NI Labview 8.0. The input to the signal processing process is the text file containing the EMG data and it is processed using labview technique which is shown in figure 4. Raw EMG Signal is retrieved from the stored data file and the output of the waveform is shown in figure 5. FFT spectrum of raw EMG signal is shown in figure 6. This EMG signal is filtered by Notch filter and disappearence of 50 Hz peak is shown in figure 7. After then output of Notch Filtered signal is fed into rectifier, in order to eliminate the negative components of the signal . Rectified signal is shown in figure 8. The Rectified signal has amplified for voltage level (0-5V).

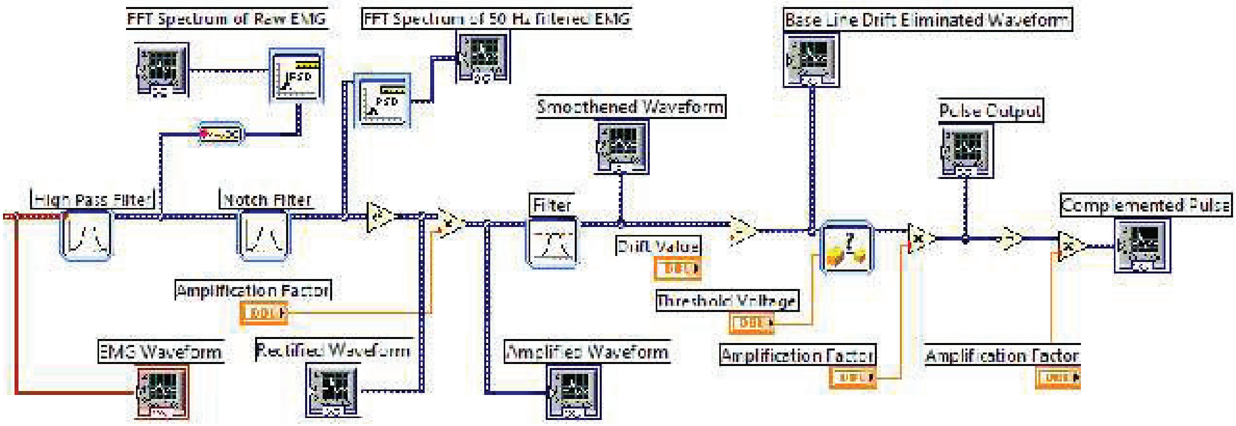

Figure 4. Labview Block diagram for EMG Signal Processing

To get maximum contraction phase , Amplified signal is smoothened by moving average filter and filtered output signal is shown in figure 9. Baseline drift elimination signal is shown in figure 10 and coresponding pulse and complemented pulse signal is shown in figure 11 and figure 12 respectively.

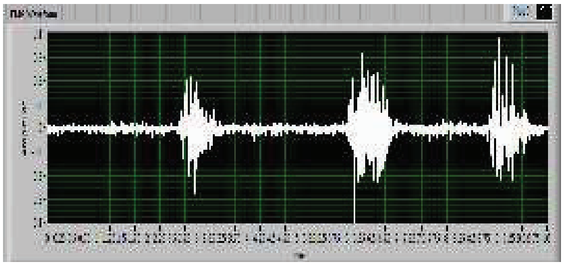

Figure. 5. Raw EMG Signal

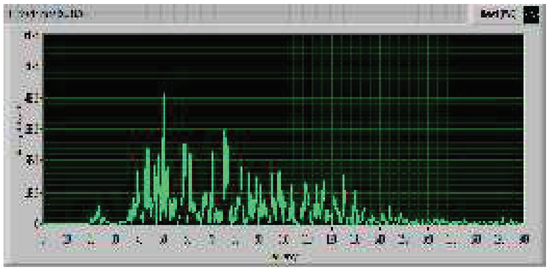

Figure. 6. FFT Spectrum Analysis of EMG signal

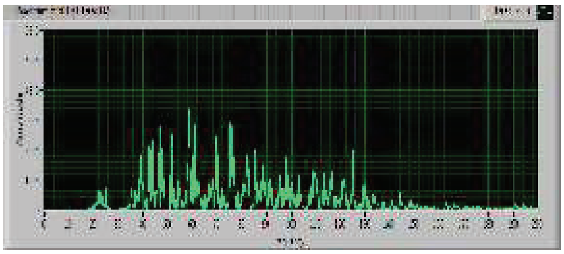

Figure 7. 50 Hz Notch output Signal

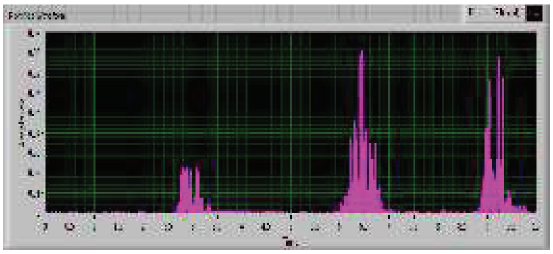

Figure 8 Rectified EMG Signal

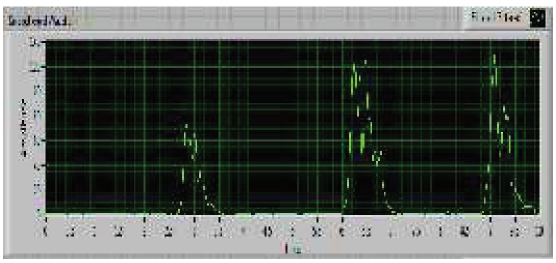

Figure 9. Smoothening output Signal

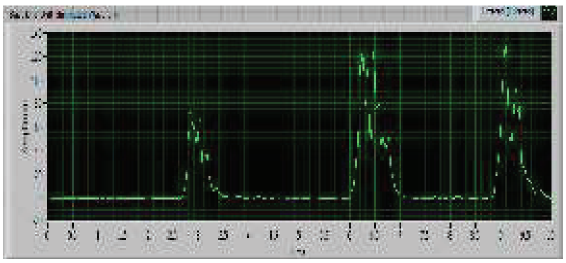

Figure 10. Baseline drift Elimination

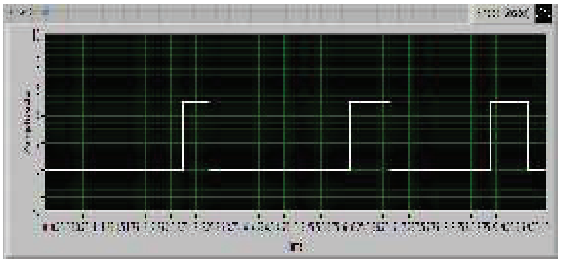

Figure11. Pulse Output Signal

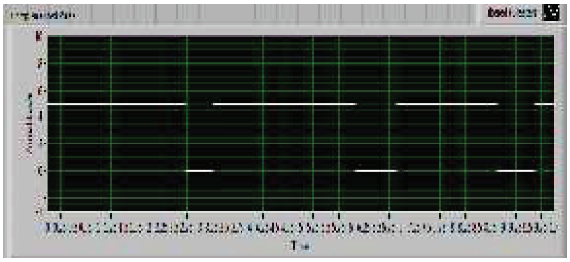

Figure 12. Complemented Pulse Output signal

4. CONCLUSION

In this study, EMG signal is successfully extracted from the subject and the acquired EMG signal has two parts: relaxation phase and contraction phase. The contraction phase is what we are interested in for proceeding with the work. In order to control the motor rotation using the EMG signal, the contraction phase is made use of, for which it has to be processed suitably to result in a pulse output whenever the muscle is contracted. The steps involved in processing are those which convert the EMG signal into pulsed output for each contraction. The final output is a pulsed signal where each pulse corresponds to muscle contraction. When considering prosthetics limb, more degree of freedom is required. So our future work extends to signal classification such as K-means algorithm and support vector machine.

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