Electromyogram (EMG)

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Abstract - Electromyography signal carries valuable information regarding the nerve system. So the aim of this paper is to give brief information about EMG signal detection technique in voluntary muscle movement of human being. In this paper, method is applied to analyze EMG signal with detection, processing and application.

I. INTRODUCTION

Electromyography (EMG) is a technique for evaluating and recording the electrical activity produced by skeletal muscles. EMG is performed using a process of study called an electromyography, to produce a record called an electromyogram. An electromyography detects the electrical potential generated by muscle cells when these cells are electrically or neurologically activated.

The first documented experiments dealing with EMG started with Francesco Redi’s works in 1666. Redi discovered a highly specialized muscle of the electric ray fish generated electricity. In 1792, a publication entitled ‘Commentary on the Force of Electricity on Muscular Motion’ appeared, written by Luigi Galvani, in which the author demonstrated that electricity could initiate muscle contractions. After some decades, in 1849, Emilde Bois-Reymond discovered that it was also possible to record electrical activity during a voluntary muscle contraction. The first actual recording of this activity was made by Marey in 1890, who also introduced the term electromyography. Hardyck and his researchers were the first (1966) practitioners to use EMG. In the early 1980, Cram and Steger introduced a clinical method for scanning a variety of muscles using an EMG sensing device.

There are two kinds of EMG in widespread use: surface EMG and intramuscular (needle and fine-wire) EMG. To perform intramuscular EMG, a needle electrode is inserted through the skin into the muscle tissue. A trained professional (such as a neurologist, physiatrist, or physical therapist) observes the electrical activity while inserting the electrode. The insertion activity provides valuable information about the state of the muscle. Normal muscles at rest make certain, normal electrical signals when the needle is inserted into them. Then the electrical activity when the muscle is at rest is studied. Abnormal spontaneous activity might indicate some nerve and/or muscle damage. Then the patient is asked to contract the muscle smoothly. The shape, size, and frequency of the resulting motor unit potentials are judged. Then the electrode is retracted a few millimeters, and again the activity is analyzed until at least 10–20 units have been collected. Each electrode track gives only a very local picture of the activity of the whole muscle. Because skeletal muscles differ in the inner structure, the electrode has to be placed at various locations to obtain an accurate study.

Intramuscular EMG may be considered too invasive or unnecessary in some cases. Instead, a surface electrode may be used to monitor the general picture of muscle activation, as opposed to the activity of only a few fibers as observed using an intramuscular EMG. This technique is used in a number of settings; for example, in the physiotherapy clinic, muscle activation is monitored using surface EMG and patients have an auditory or visual stimulus to help them know when they are activating the muscle. A motor unit is defined as one motor neuron and all of the muscle fibers it innervates. When a motor unit fires, the impulse (called an action potential) is carried down the motor neuron to the muscle. The area where the nerve contacts the muscle is called the neuromuscular junction, or the motor end plate. After the action potential is transmitted across the neuromuscular junction, an action potential is elicited in all of the innervated muscle fibers of that particular motor unit. The sum of all this electrical activity is known as a motor unit action potential.

This electrophysiological activity from multiple motor units is the signal typically evaluated during an EMG.
II. EMG SIGNAL PROCESSING

There are four basic signal processes in EMG. Each of them has got its own value and function.

1) Amplification:

EMG signal has a very low amplitude. Hence amplifier is used for amplification purpose. The gain of amplifier needs to be high for amplification. The amplifier used is instrumentation amplifier. The signals captured are given to instrumentation amplifier. After amplification, signals are given to filter. This amplifier has a high input impedance to limit the attenuation from electrode-skin interference.

2) Filtering:

EMG is actually a composite of many signals, as well as some noise. These voltages also rise and fall at various rates or frequencies, forming a frequency spectrum. Circuits filter the composite signal and eliminate unwanted and meaningless electrical noise like movement artifact. Because most EMG exists in a frequency range between 20 and 200 Hz, and because movement artifacts have frequencies less than 10 Hz, that is the cutoff frequency frequently employed in "high-pass" filters.

3) Rectification:

As the raw signal is biphasic, its mean value is zero. The rectifier allows current flow in only one direction, and so "flips" the signal's negative content across the zero axes, making the whole signal positive.

4) Signal Processing:

For EMG signal processing, following softwares are used

1) MATLAB  2) Arduino

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins. These pins are used for interfacing external components. The program is loaded in arduino through computer using USB.

MATLAB is used for programming purpose. It is also used for simulation in earlier stages.

III. EMG SENSOR DESIGN

EMG acquisition system consists of 1) Instrumentation amplifier

2) Filter
3) Rectifier
4) Very low pass filter
5) Sample and hold circuit

A) Instrumentation Amplifier:

For EMG sensor design, instrumentation amplifier is used for amplification purpose. The captured muscle is given to two buffer amplifiers then their outputs are given to another opamp. The total construction is called as instrumentation amplifier.

The signals captured from muscle have very low amplitude. These signals need to be amplified for easy analysis.

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<tr>
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</tr>
<tr>
<td>Opamp</td>
<td>IC 741</td>
<td>3</td>
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</table>
B) Filter:
The band pass filter input is the output of the instrumentation amplifier. It’s used to eliminate the unwanted frequency component that is outside the typical SEMG signal frequency range 20-500Hz. High-pass filtering is used to remove movement artifacts and DC components and low pass filtering is desirable to remove high frequency content above 500Hz to avoid signal aliasing.

Fig3. Band pass filter

C) Rectifier:
Rectifier is used for rectification of filter output. The signal at the output of filter is biphasic, having zero mean value. So the signal needs to be shifted at single side, say positive side of x axis. This function is performed by rectifier.

Fig4. Rectifier

<table>
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<tr>
<td></td>
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<td>Opamp</td>
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<td>Opamp</td>
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</table>
D) Very low pass filter:
The very low pass filter is used for removal of unwanted signals from the output of rectifier. It is the combination of two low pass filters together called as very low pass filter.

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</tbody>
</table>

E) Sample and hold circuit:
Sample and hold circuit plays an important role when it comes to sampling and holding the signal. Sampling is nothing but the conversion of continuous time signal to discrete time signal. It holds the circuit for better analysis.

The control wave is provided to sample and hold to decide sampling rate.
MATLAB is used for programming the signal taken from arduino. MATLAB performs some operation useful for easy signal analysis such as fft.

MATLAB Code :

```
emg = load('emg_healthy.txt');
figure(1)
plot(emg(:,1), emg(:,2))
xlabel('Time'); ylabel('EMG'); title('EMG SIGNAL'); %EMG MUSCLE SIGNAL
grid
rec_emg = abs(emg);
figure(2)
plot(rec_emg(:,1), rec_emg(:,2))
xlabel('Time'); ylabel('EMG'); title('Full Wave Rectifier'); %RECTIFICATION
grid
Fs=4000;
pi=3.142;
T=1/Fs;
L=length(emg);
%t=(0:L-1)*T;
Y=fft(emg(:,2));
P2=abs(Y/L);
P1=P2(1:fix(L/2)+1);
P1(2:end-1)=2*pi(2:end-1);
f=Fs*(0:(L/2))/L;
figure(3)
plot(f,P1)
xlabel('Frequency'); ylabel('Intersity');title('FFT of EMG');%FFT grid
fnqy=Fs/2;
Fc=3;
O=4;
[B,A]=butter(O,Fc*2/Fs,'low');
RMS=filtfilt(B,A,rec_emg);
figure(4)
plot(rec_emg(:,1),rec_emg(:,2),'b') %BUTTERWORTH FILTER OUTPUT
hold on
plot(emg(:,1),RMS(:,2),'R','linewidth',2)
xlabel('Time'); ylabel('EMG'); title('RAW EMG');
legend('Rectified EMG','RMS EMG') %OUTPUT
```

**F) Arduino:**

Arduino is a user friendly hardware with its own software. It is used for programming purposes. Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output(I/O) pins. These pins are used for interfacing external components. The program is loaded in arduino through computer using USB.

Signal captured from arduino is in column form. The signal is then given to MATLAB for further processing. Following code is used for storing data in text file when muscle is stretched.

```
//Serial printer for the EMG sensor
//This code is for printing the EMG value on the //serial monitor.

int x;
void setup()
{
  Serial.begin(9600);
}

void loop()
{
  Serial.println(analogRead(x));
}
```

**G) MATLAB :**
IV. CONCLUSIONS

- EMG is crucial for detection of disorders related to muscle.
- It helps doctors to find and cure the disorder.
- EMG can be used for some other applications also like motor controlling, robotic hands, etc.

REFERENCES


[4] Carlo J. De Luca a, b, L. Donald Gilmore b, Mikhail Kaznetsov b, Serge H. Roy b ‘Filtering the surface EMG signal: Movement artifact and baseline noise contamination.’


TABLES:

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List of signals:

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AUTHORS

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