

Electromyogram (EMG)

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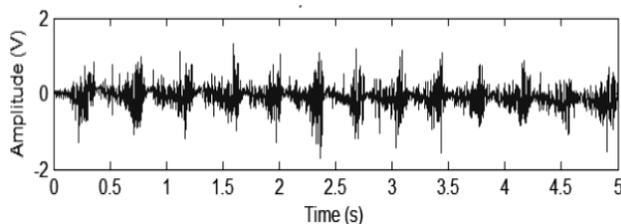
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Abstract- Electromyography signal carries valuable information regarding the nerve system. So the aim of this paper is to give brief information about EMG signal detection technique in voluntary muscle movement of human being. In this paper, method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



Signal 1: sample EMG

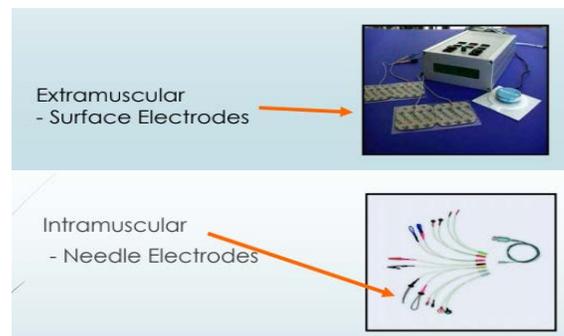
The first documented experiments dealing with EMG started with *Francesco Redi's* works in 1666. Redi discovered a highly specialized muscle of the electric ray fish generated electricity. In 1792, a publication entitled 'Commentary on the Force of Electricity on Muscular Motion' appeared, written by *Luigi Galvani*, in which the author demonstrated that electricity could initiate muscle contractions. After some decades, in 1849, *Emildu 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.



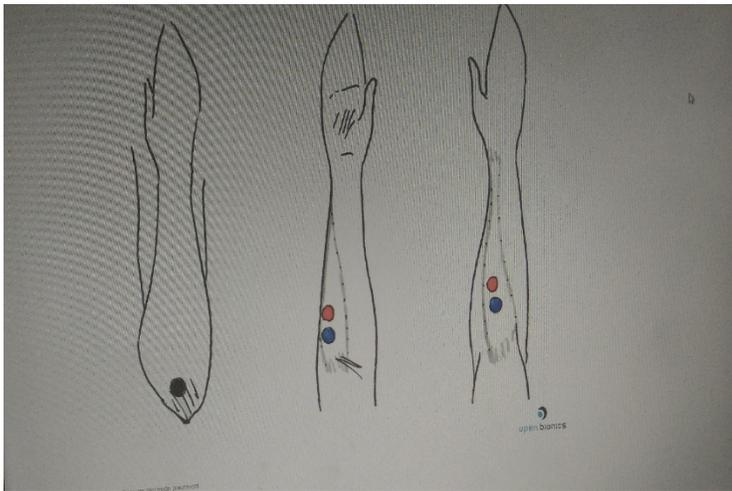


Fig1. Electrode types and placing

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:

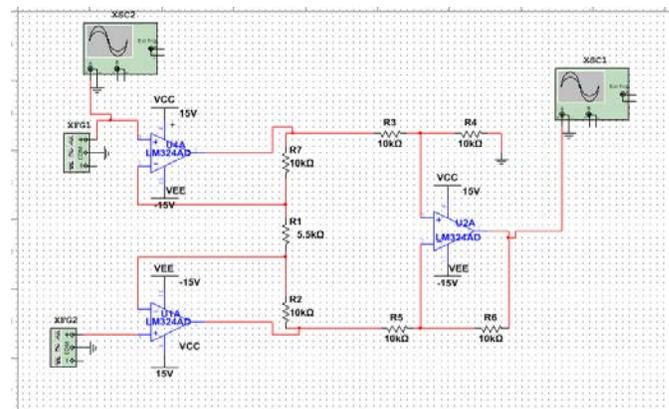


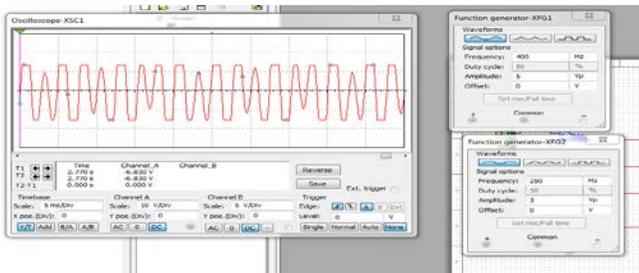
Fig2. Instrumentation amplifier

An instrumentation amplifier is a type of differential amplifier that has been outfitted with input buffer amplifiers, which eliminate the need for input impedance matching and thus make the amplifier particularly suitable for use in measurement and test equipment. Although the instrumentation amplifier is usually shown schematically identical to a standard operational amplifier (op-amp), the electronic instrumentation amp is almost always internally composed of 3 op-amps. These are arranged so that there is one opamp to buffer each input (+,-), and one to produce the desired output with adequate impedance matching for the function.

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.

Components	Rating	Quantity
Resistors	10k	6
	5.5k	1
Opamp	IC 741	3



Signal 2: Amplifier output

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.

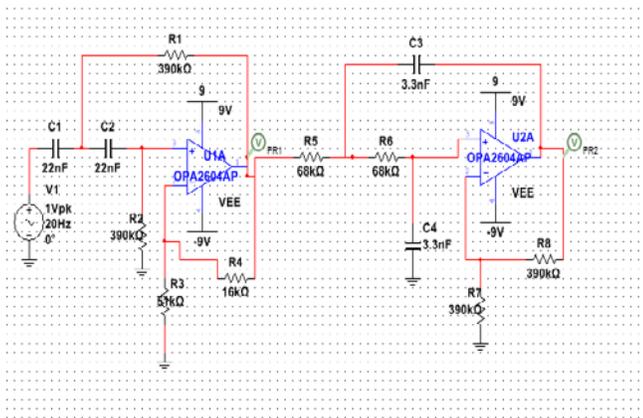
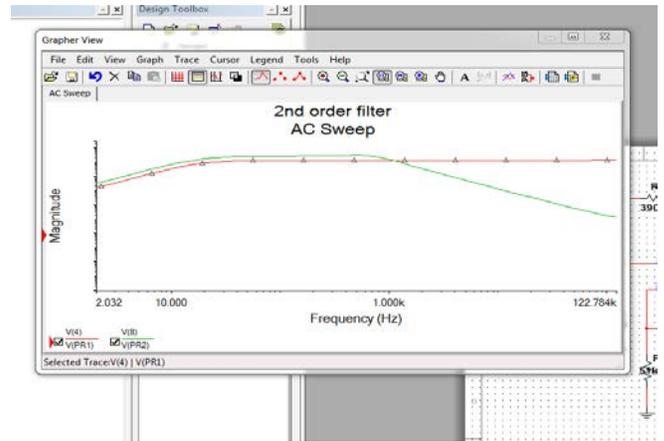


Fig3. Band pass filter

Components	Rating	Quantity
Resistors	390k	4
	51k	1
	16k	1
Capacitors	68nF	2
	22nF	2
	3.3nF	2
Opamp	IC 741	2



Signal 3: 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.

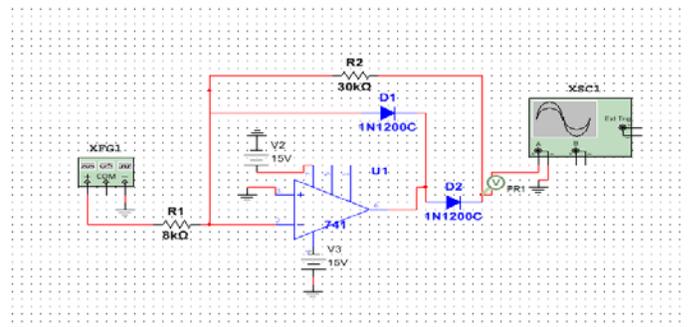
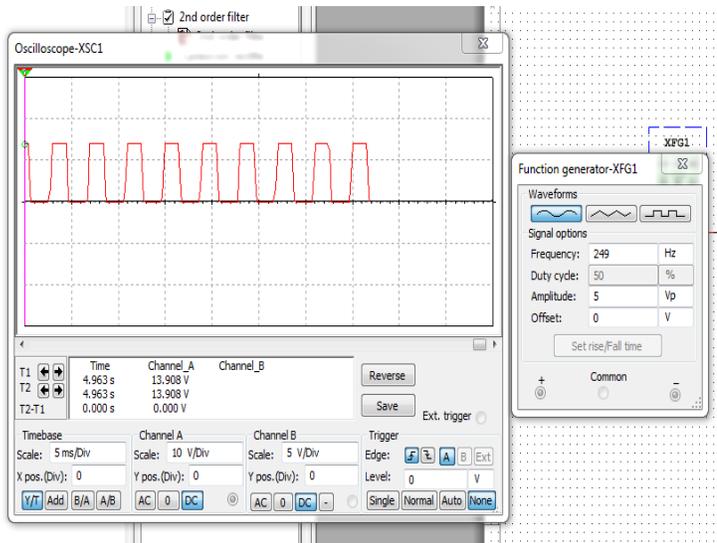


Fig4. Rectifier

Components	Rating	Quantity
Resistor	8k	1
	30k	1
Diode	1N1200C	2
Opamp	IC 741	1



Signal 4: Rectifier output

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.

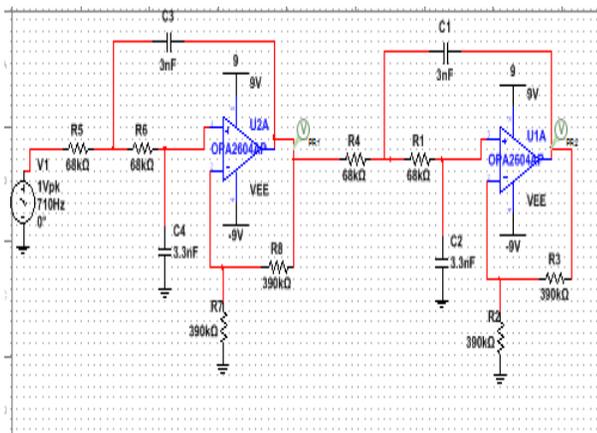
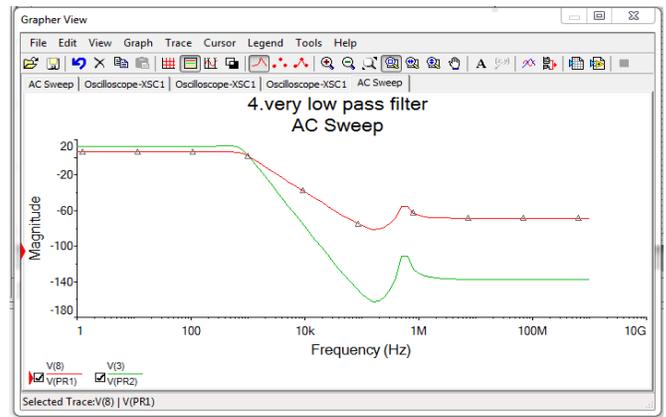


Fig5. Very low pass filter

Components	Rating	Quantity
Resistor	68k	4
	390k	4
capacitor	3nF	2
	3.3nF	2
Opamp	IC 741	2



Signal 5: Very low pass filter

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.

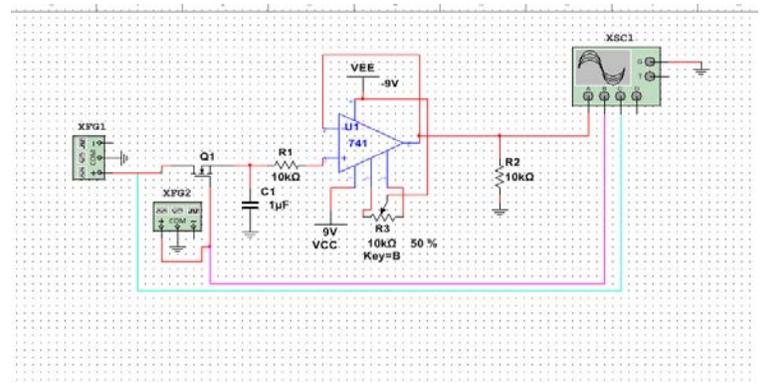
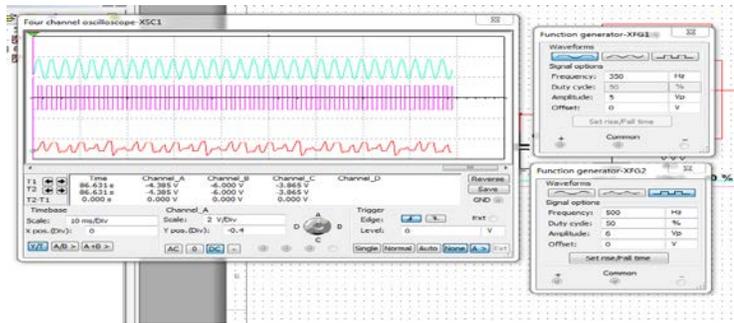


Fig6. Sample and hold circuit

Componen	Rating	Quantit
Resistor	10k	2
Capacitor	1 uF	1
Opamp	IC 741	1



Signal 6: sample and hold output

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('Intensity');title('FFT of EMG');%FFT
grid
fnqy=Fs/2;
Fc=3;
O=4;
[B,A]=butter(O,Fc*2/Fs,'low');
RMS=filter(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.

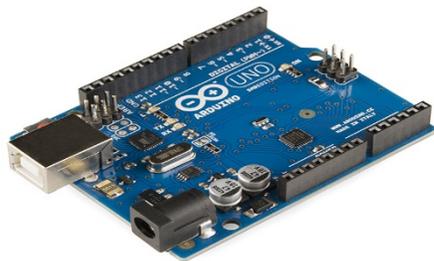


Fig7. Arduino board

Arduino code:

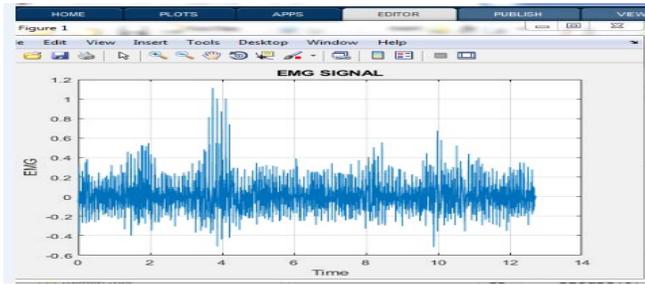
```

//Serial printer for the EMG sensor
//This code is for printing the EMG value on the
//serial monitor.
//
//© Au Robots 8.4.2017

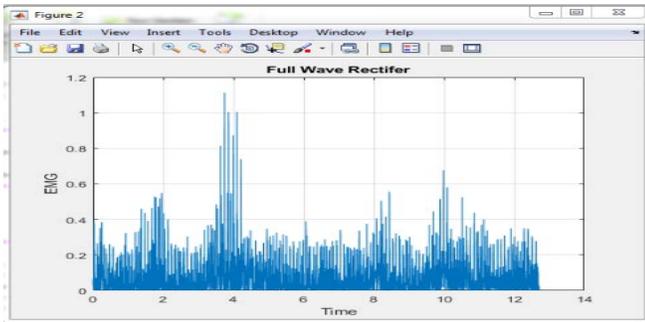
int x;
void setup()
{
Serial.begin(9600);
}

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

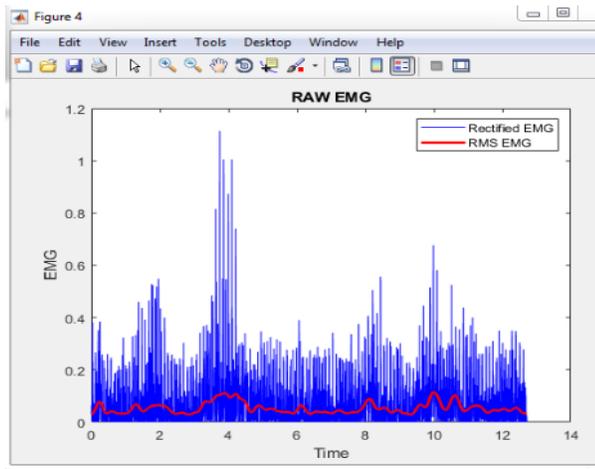
G) MATLAB :



Signal 7: Raw EMG signal

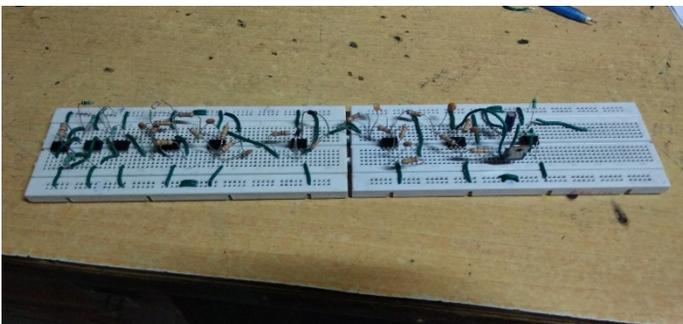


Signal 8: Rectified EMG signal



Signal 9: Filtered and ff transformed EMG

hardware model



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.

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List of signals:

Signal 1	Sample emg
Signal 2	Aamplifier output
Signal 3	Bandpass filter
Signal 4	Rectifier output
Signal 5	Very low pass filter
Signal 6	Sample and hold
Signal 7	Raw EMG
Signal 8	Rectified EMG
Signal 9	Filtered and ff transformed

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