EDL Group #3 Final Report
- Surface Electromyograph System

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INTRODUCTION

The EMG signal measures electrical currents generated in muscles during its contraction, representing neuromuscular activities. A motor unit (MUS) consists of all muscle fibers innervated by one motor neuron. When the motor neuron discharges, all fibers in the MU respond by producing an action potential (AP) and the recorded signal is called a motor unit action potential (MUAP). This signal is normally a function of time and space and is describable in terms of its amplitude, frequency and phase. The equipment to acquire and analyse this signals is known as EMG sensor. We must first understand the origin these signals, and hence we need to discuss the physiology of muscle movement control. An electrode is used to convert the muscle signal into an external electrical voltage. Processing is done on this signal sensed by electrode to get a useful signal.

PHYSIOLOGY

The human body as a whole is electrically neutral. But in the resting state, a nerve cell membrane is polarized due to differences in the concentrations and ionic composition across the plasma membrane. A potential difference exists between the intra-cellular and extracellular fluids of the cell. In response to a stimulus from the neuron, a muscle fibre depolarizes as the signal propagates along its surface and the fibre twitches. This depolarization, accompanied by a movement of ions, generates an electric field near each muscle fibre. An EMG signal is the train of Motor Unit Action Potential (MUAP) showing the muscle response to neural stimulation. The EMG signal decomposition studies performed with indwelling sensors have proved to be fruitful for physiological and clinical investigations. However, indwelling sensors cause discomfort, are risky and need a practitioner. Hence it would be preferable to be able to decompose the EMG signal detected from a surface sensor. However for those muscles that are not in contact with the skin, the needle sensor remains the only viable option. The purpose of this EDL project was to design a surface EMG sensor.

Nature of Signal

Studies have shown that amplitude of EMG signal is stochastic in nature and can be represented by Gaussian distribution. The amplitude of the signal can range from 0 to 10 mV (pk-pk). The required frequency range is limited to 0 to 500 Hz, with the dominant energy being in the 50-200 Hz range.

The amplitude and time and frequency domain properties of the sEMG signal are dependent on factors such as (Gerdle et al., 1999):

• timing and intensity of muscle contraction
• distance of the electrode from the active muscle area
• properties of the overlying
• electrode and amplifier properties
• quality of contact between the electrode and the skin

The actual detected signal is corrupted by various noise sources as described in the next section

Noise

Ambient noise*:* Ambient noise is generated by electromagnetic radiations from various electromagnetic devices in surroundings. Among these of main concern is 50/60 Hz noise arising due to power sources

Electrode-skin interface noise: DC voltage potential is caused by differences in the impedance between the skin and the electrode sensor, and from oxidative and reductive chemical reactions taking place in the contact region between the electrode and the conductive gel. AC Voltage Potential is generated by factors such as fluctuations in impedance between the conductive transducer and the skin.

Motion artifacts *:* Motion artifacts arise from the interface between the detection surface of the electrode and the skin, and from movement of the cable connecting the electrode to the amplifier.

Cross talk *:* Crosstalk from neighbouring muscle's signal also affects the observed EMG signals

Uses of EMG Signals

EMG Signals are used in Muscle contraction, activation & Nerve conduction studies. These help to determine any neurological or muscular abnormalities. Since different abnormalities produce different characteristic signals doctors can diagnose the disease by observing them.

Recent trends are not only to analyse these signals but also differentiate and decompose them depending on their specific patterns so that they can be used as control signals for communication and co-ordination by paralysed people.

Initial Proposal

We propose to make a Surface EMG Device. We plan to focus on signals in the

mV range and frequency between 25- 500 Hz. This development process will involve

1. **Detection method** – The signal detected depends on size of electrodes, position where they are placed, their orientation, etc.

2. **Electrical Signal Acquisition** – Signals detected by surface electrodes need to be sent to main circuit for amplification. But this adds noise and hence there is need for isolation.

3. **Signal Amplification & Conditioning**– Given the small range of EMG signal voltages MUAP signals need to be amplified preferably by differential instrumentation amplifiers. Further since we are interested only in particular band of frequency, filtering needs to be done. This also helps in reducing unwanted noise signals

The main design focus areas identified are -

1. **Faithful Signal Reproduction-** for the requirement of qualitative signal analysis, appropriate signal amplification and conditioning is important. MUAP signal waveforms are not smooth and firing times are sporadic thus appropriate circuit design is essential for proper analysis.

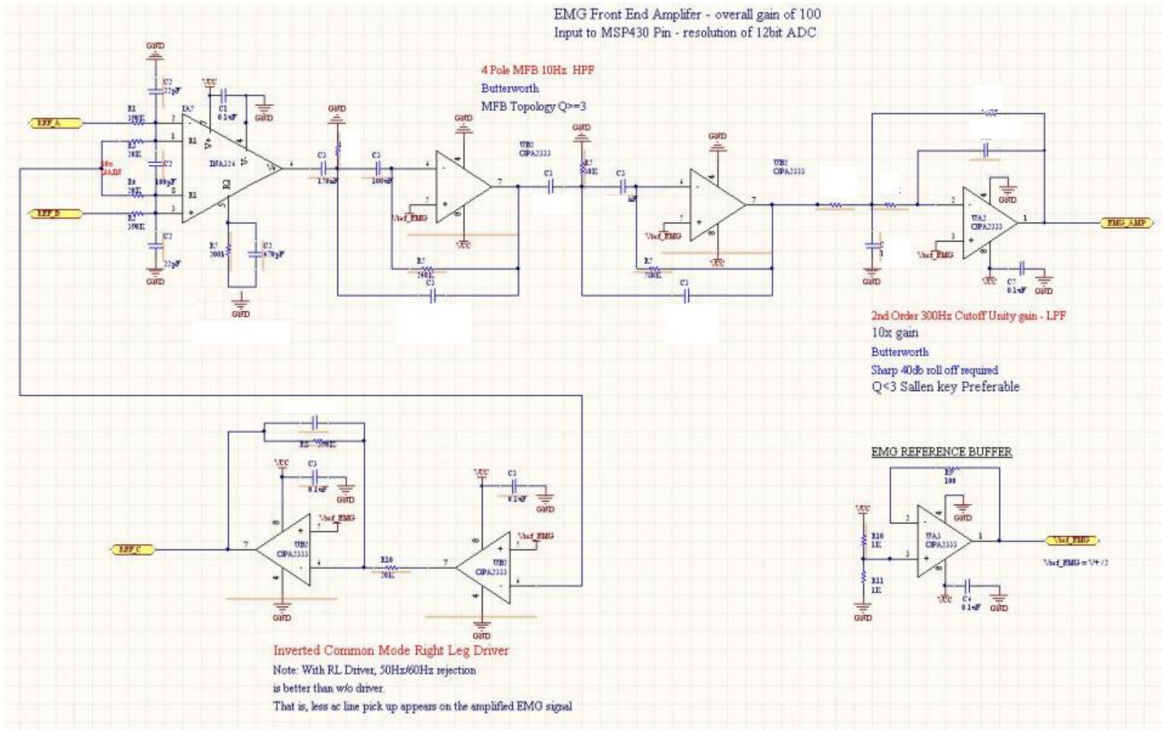
2. **Reliability-** surface EMG is used to detect neural and muscular disorders by clinicians. Given this important diagnostic function, the instrument should provide accurate readings whenever used.

3. **Noise Reduction** – Since the power of the required signals is low in surface electromyography, low noise circuit designs are essential

4. **Biomed Safety Standards** – Given the human application of the system appropriate isolation and safety features need to be incorporate

Project Description

Circuit



EMG Signal Characteristics

1. The amplitude of EMG signals depends on the size of muscle, activation and placement of electrodes. Signals can range form few tens of uV to 50mV. We will be focusing on larger muscle groups in the 0 to 50mV MUAP range.

2. The Ag-AgCl half cell in the surface electrodes introduces an offset voltage of ~ 200mV. Thus the instrumentation amplifier requires a CMRR ratio of more than 80dB

3. Most of the signal power is present in the frequency range of ~ 50Hz to 500 Hz. Unwanted noise components include, DC voltage offset, mains 50 Hz interference, noise due to motion artefacts and circuit components.

Surface Electrodes and Connectors

Two types of surface electrodes are commonly in use:

- Dry electrodes in direct contact with the skin
- Gelled electrodes using an electrolytic gel as a chemical interface between the skin and the metallic part of the electrode

We decided to go for second type of electrode because the gel (mostly Ag/AgCl) helps to reduce the electrode-skin ac impedance improving conductivity of skin by providing reversible chloride exchange interface.
Impedance can be further reduced by cleaning the skin of dead cells and dust that increase impedance.

Increase in contact area helps to decrease impedance and hence a use a easily and cheaply available ECG electrodes was undertaken. The main problem is that a larger area increases the chances of electrode catching MUAP signals of neighbouring muscles.

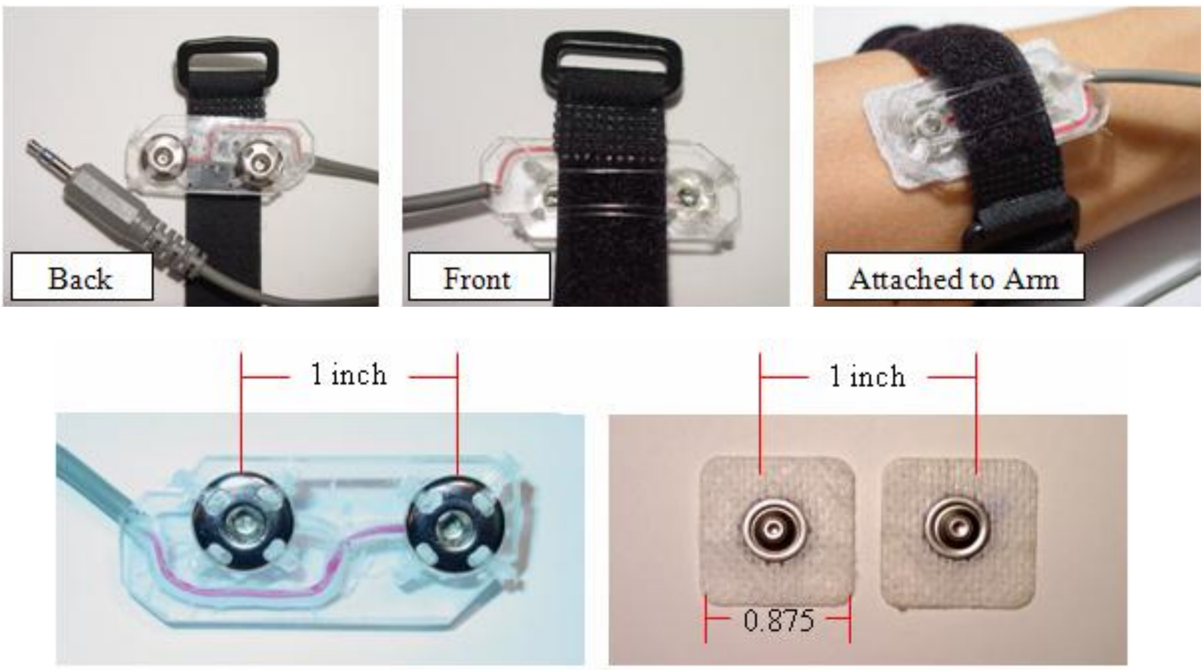


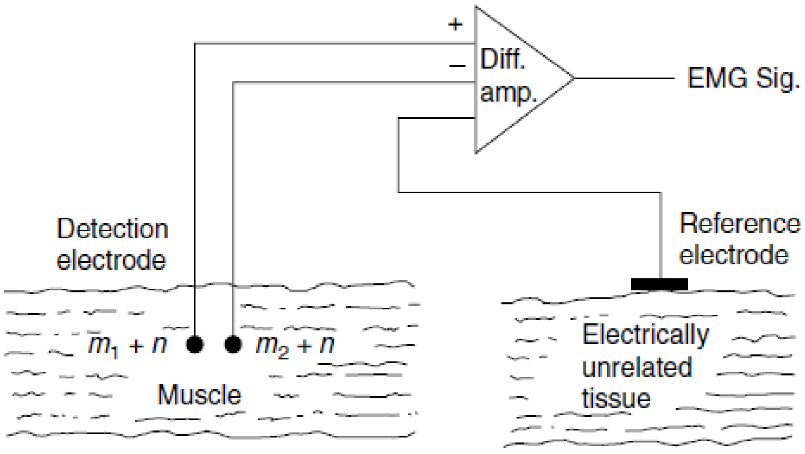
Fig6: Planned Connector Design

ELECTRODE Configuration

Electrode attached to active muscle tissue is called an active electrode while that attached to neutral muscle tissue is called reference elctrode
Signals can be detected from electrode arranged in two configurations either
Monopolar:
With one active electrode and other reference electrode
This has more noise as it detects all electrical signals in the vicinity

Bipolar:
Two active electrodes and one reference electrode are used
Noise signals are similar due to same vicinity and assuming similar carrier path
EMG signals are different due to spatial variations
Hence differential amplification with good SNR gives good signal representation. Noise which is common is eliminated and signals that are different are amplified

We are using a Bipolar configuration as shown in figure



(b)

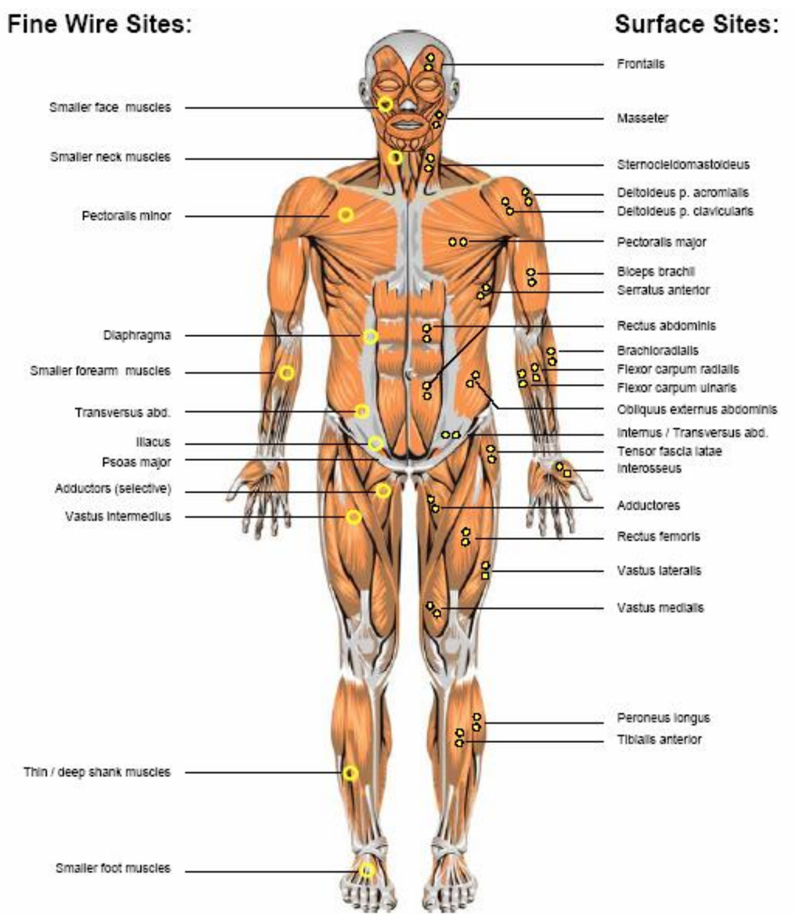
Electode Placement needs to be accurate. Electrodes should be

Along the axis of muscle fibre

In the center bulgy part

Very near to each other

Reference electrode on non-active tissue preferably bony joint



SIGNAL CONDITIONING

1. Instrumentation amplifier

We are using the low cost INA128PA Instrumentation Amplifier(IA) from Texas Instruments. This amplifier meets CMRR and offset specifications. It has a low input bias current, this is important for accurate amplification in the IA topology

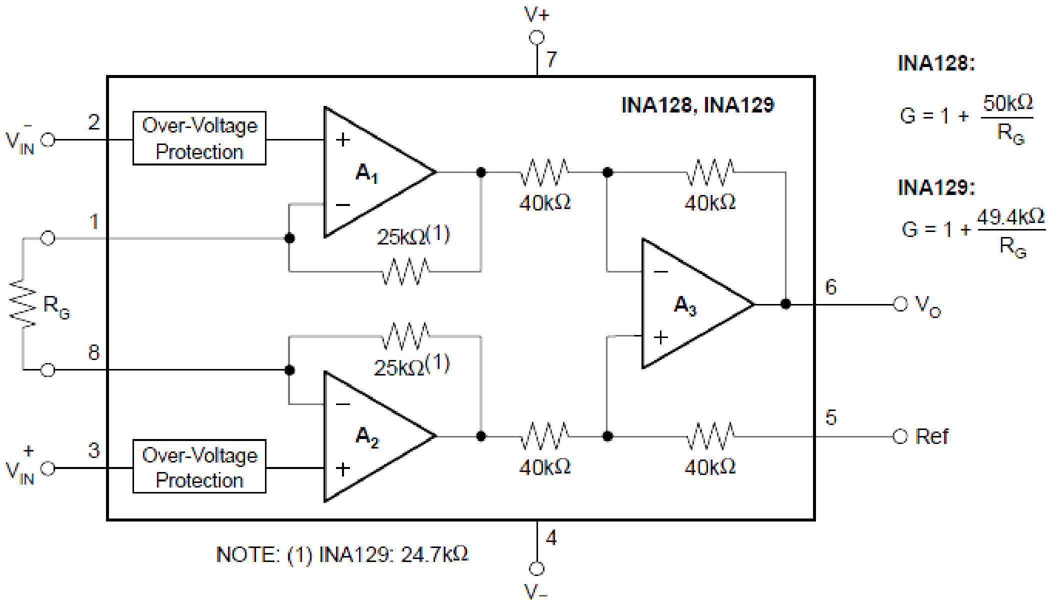


Fig2: Internal Circuit of INA128PA Instrumentation Amplifier

Key Operational Parameters of INA128PA

CMRR: 110dB

Amplifies differential signal by a factor of $10^{5.5}$ compared to common mode signal

Input impedance: 10 Gohms

Relative drop of signal Vin/Vs = $R_{in}/(R_{in}+R_{source})$ is less due to higher input impedance Rin

Input bias current: ±2nA

Doesn't draw much current from electrode site.

(#proper path needs to be provided to ground from them else bias current flows into the INA giving a voltage=Rin*Ibias which is significantly large)

Valid Power Supply: ±2.25V to ±18V

Over-Voltage protection at inputs, can withstand voltages upto 40V

Circuit Implementation

1. The IC requires +Vcc, GND, -Vcc voltage sources. Presently we are using ±9V. Any power source above 3 V may be used during operation subject to nature of muscle output. For larger muscles saturation may result due to high gain.

2. Path for input bias current to flow is given by connecting input to ground by a very high resistance. Without a bias current path, the inputs would float to a potential which exceeds the common-mode range, and the input amplifiers saturate.

3. The value of Rgain has to be appropriate. Also to provide input signal for Right Leg Driving (Body Reference) circuit both the resistances that make up Rgain have to be equal.

2. BAND PASS Filter

For the filter requirement we have used the Sallen Key filter topology and a Chebychev filter type. The design includes a low-pass filter of cut-off 500Hz and high-pass filter of 25Hz.

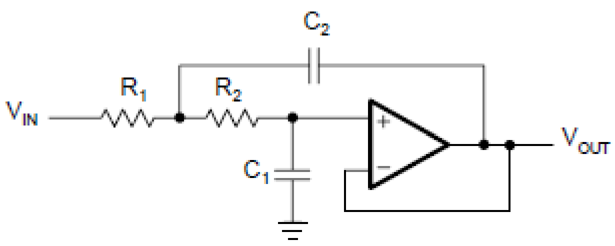


Fig3: Low-pass Stage

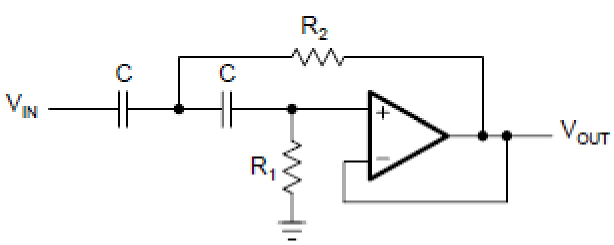


Fig4: High-pass Stage

Two implementations of each are cascade for 4th order implementation. The final low-pass band-pass cascade is a band pass filter block with 25-500 Hz pass band

To determine appropriate R and C values we have used an online filter design applet. By taking the nearest values available in the lab, we have used Octave program to find the frequency response of filter designed as cascade of 4 stages 2 each of low-pass and high-pass.

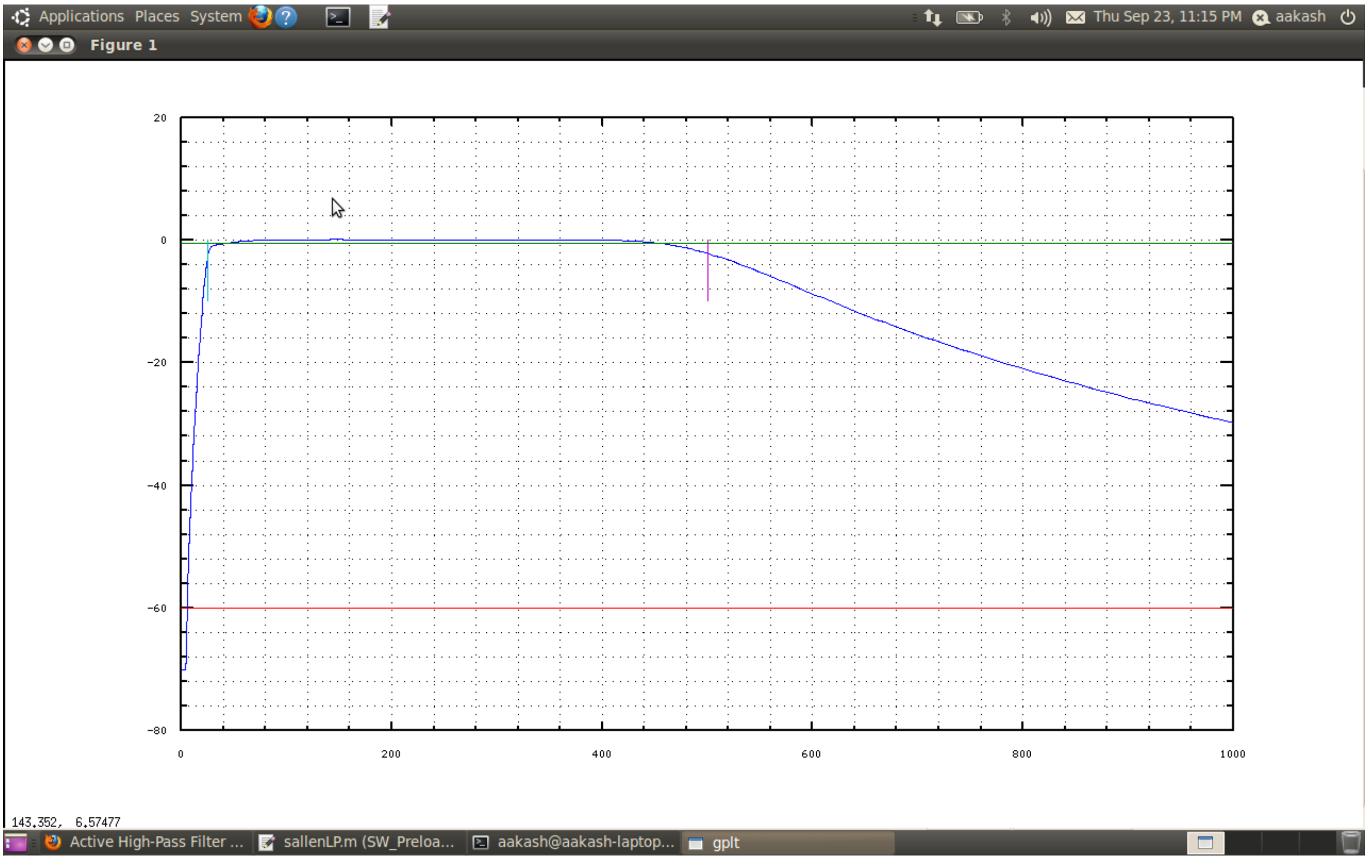
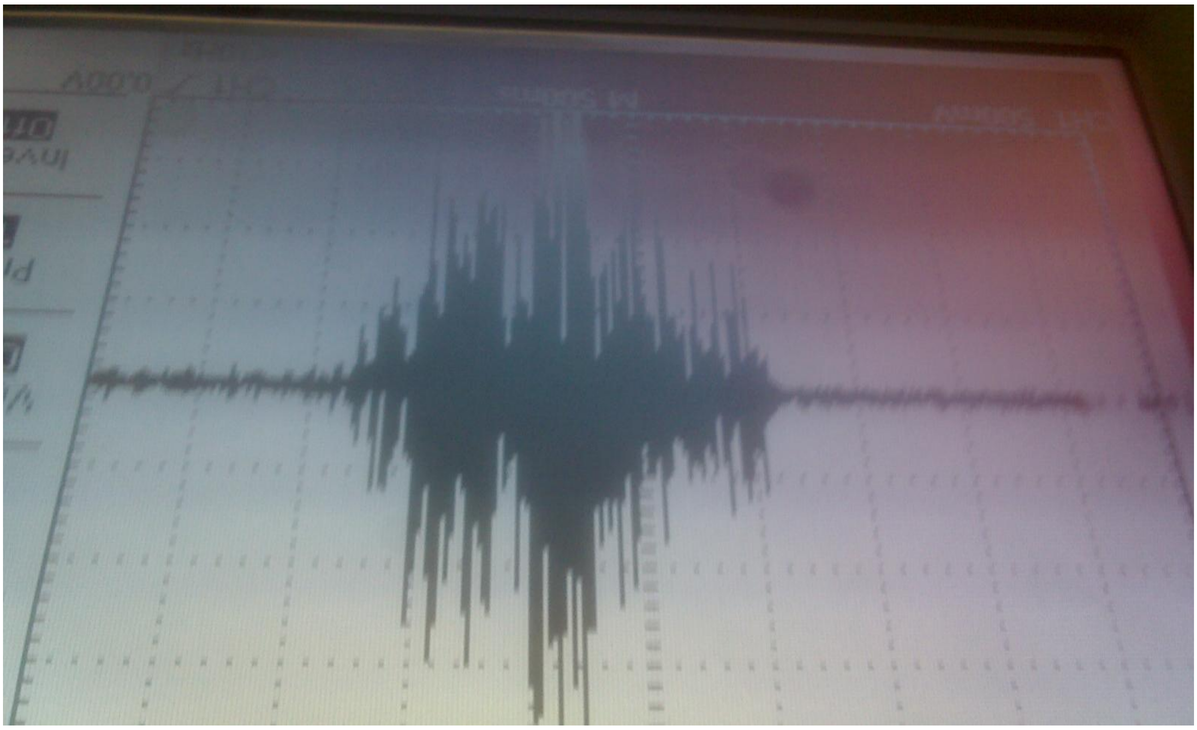
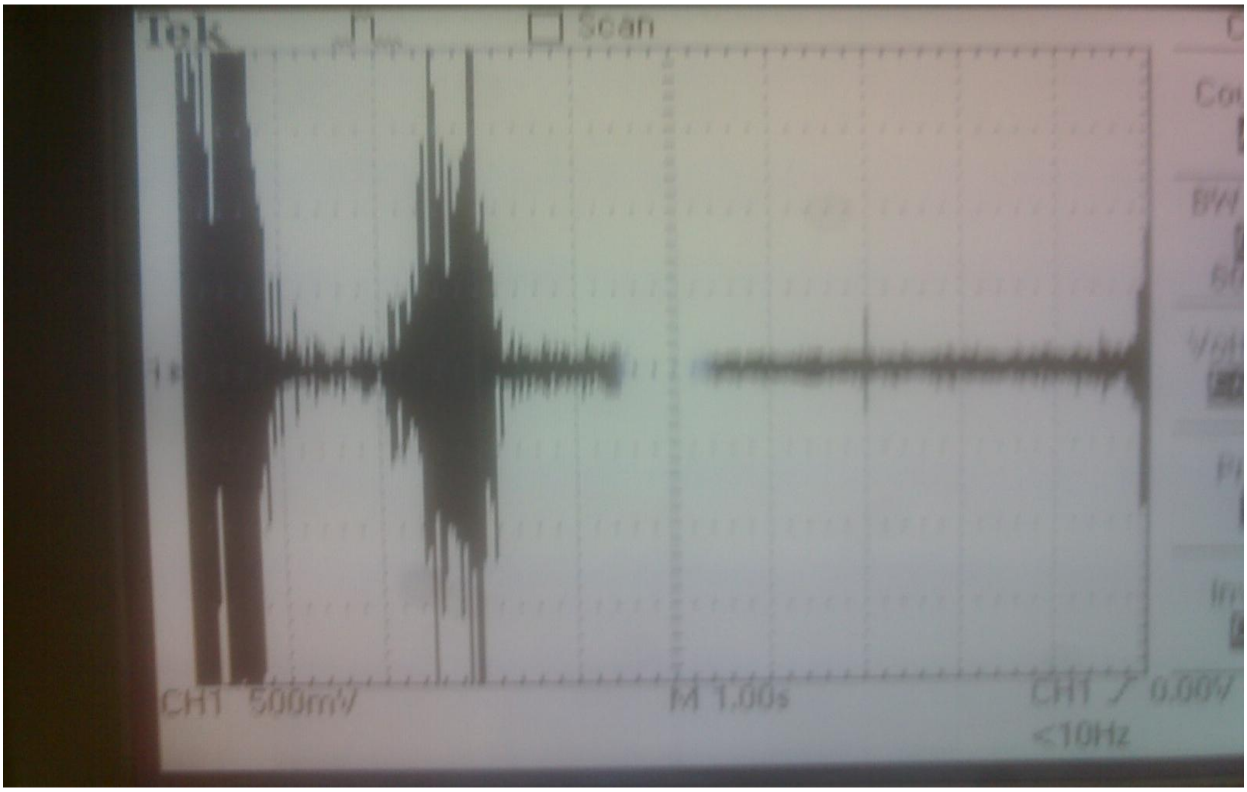


Fig5: Frequency Response of Band Pass Filter

Some output Signals Obtained on the DSO





Due to Successive muscle movements

Scope for Further Work:

For specific control applications and communication one can digitise the acquired EMG signal

If the specific muscle characteristics are known than using signal processing methods muscle movements can be isolated for control of remote robotic objects.