UNSW SYDNEY | Australia's Global University

ENGG1000 Session 2018 Biomedical Engineering Technical Stream

Lecture 2: Practical EMGs

Outline of the technical lectures

Week	**Topic**
3	Nerves and Muscles
4	Function of the Hand, Practical Issues of EMGs
5	Prosthetics in reality, Materials, **Quiz 1**
6	Industry Perspective, Workshop safety
9	**Quiz 2**

Quiz 1

Date: Thursday March 29 (Week 5)

Time: 3pm. You will have your normal lecture at 2pm from the guest lecturer, Dr Tim Scott. Then a ten-minute break, followed by the quiz. There will be a small lecture at the end of the quiz.

Location: M032 (Normal Lecture Room)

What you need to bring: Laptop, tablet or Mobile phone that is FULLY CHARGED and can open Moodle. Laptop is preferable.

Quiz 1

Type: Multiple Choice, facilitated via **Moodle.**

Number of Questions: 15

Time Limit: 30 minutes

Content: All lecture content from Week 3 (Nerves and Muscles) and Week 4 (Function of the hand, Practical EMGs)

Weighting: 10% of your final grade.

Quiz 1

Rules

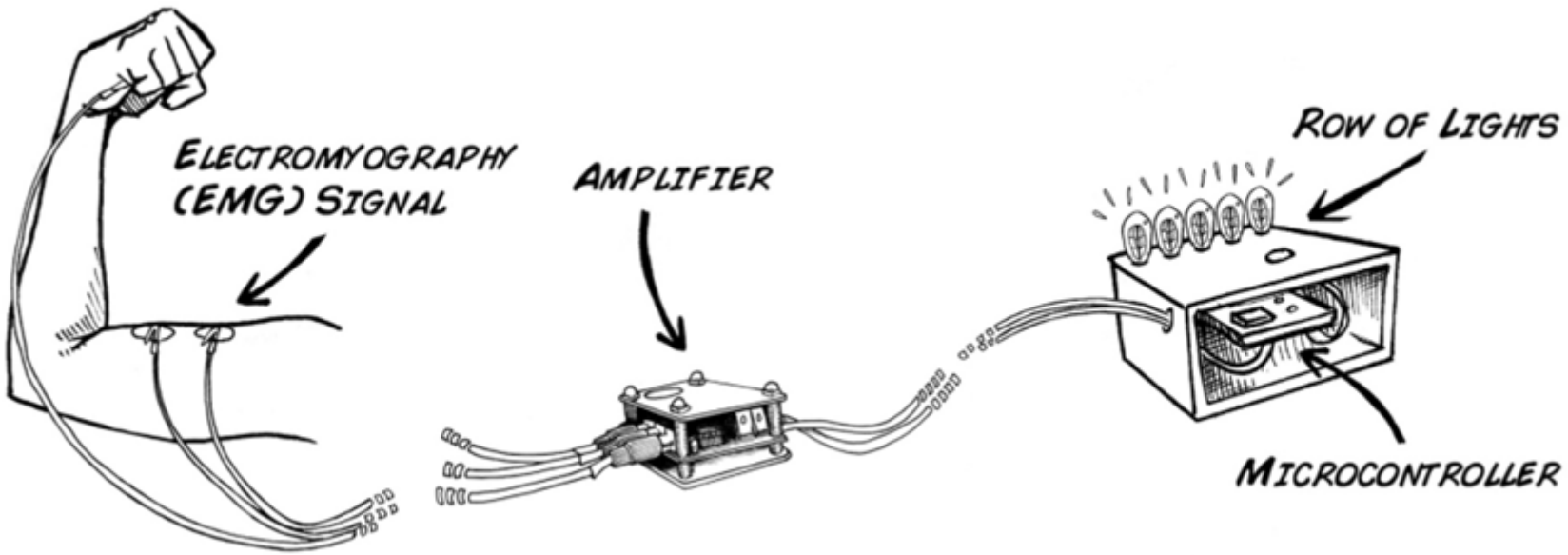
- This is a **closed book** examination. No notebooks, lecture notes, or other resources can be accessed during this quiz.
- Quiz will be locked by a password, that you will receive in class. Therefore, you must attend this class to complete the quiz.
- Only 1 tab to be open in your browser window.
- Your device must not be used to access any other information.
- Quiz will be supervised.
- At the completion of the quiz, shutdown your device and wait silently and patiently until the time has elapsed.

Aim of technical lectures

- Understand physiology behind EMGs
- **Understand practical issues around obtaining an EMG**
- Introduce hand gripping mechanics
- Get insight into real-world prosthetic design
- Gain biomedical industry perspective on engineering design

Context of Biomedical Technical Stream: Electromyography and Prosthetics

EMG is the technique for evaluating and recording electrical activity of skeletal muscle.



What we learnt last week

CELLS

NERVE CELLS

RESTING MEMBRANE POTENTIAL

ACTION POTENTIAL PROPAGATION

ACTION POTENTIALS

MUSCLE CELLS

MUSCLE CELL CONTRACTION

Aims of today's lecture

- History of EMG
- What EMG can be used for
- Measurement of an action potential - review (single cell)
- Measurement of an action potential in reality

Keep an eye out for Mike’s Mistakes...

This photo

will be used to highlight areas that you should check if your EMG is poor or non functional.

History of EMG

https://wonderopolis.org/wonder/are-eels-really-electric

History of EMG

- 1666: Francesco Redi documents that electric ray fish has muscles that generate electricity.
- 1773: Walsh demonstrates that muscle tissues of eel fish can generate spark of electricity.
- 1792: Galvani showed electricity could initiate muscle contractions
- 1838: Matteucci used a galvanometer to demonstrate electric potential between frog nerve and muscle.
- 1849: Dubois-Raymond discovered that it was possible to record electrical activity during muscle contraction.
- 1900s: Magnitude of energy associated with muscle contraction was due to recruitment of individual muscle fibres, rather than size of neural impulse.
- 1920s: Gasser and Newcomer showed EMG on a CRT oscilloscope.
  - Nobel Prize in 1944

EMG can be used for many purposes.

- Diagnosing neuromuscular disorders
- Studying kinesiology
- Controlling prostheses

http://www.todaysmedicaldevelopments.com/article/deka-arm-system-prosthetic-emg-electrodes-51214/

How to obtain an electromyograph? Just like measuring any voltage….

Demonstration

Can this work for EMG?

https://www.quora.com/What-is-an-ammeter-voltmeter-and-multimeter-How-are-they-different-from-each-other

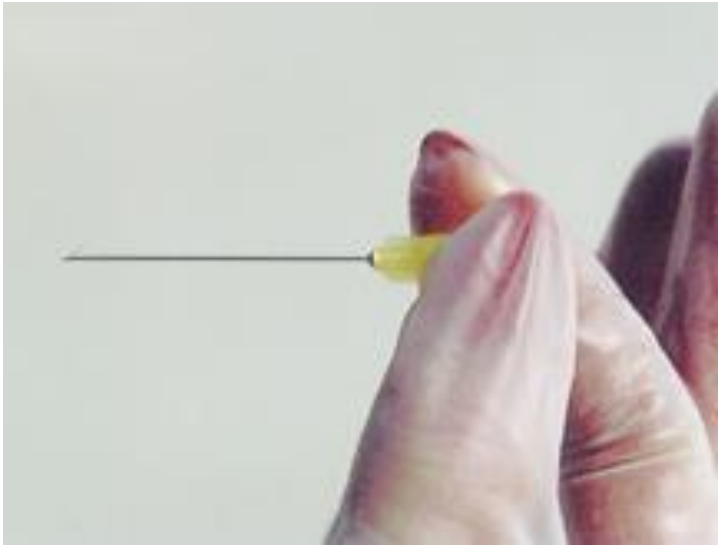
Can we measure action potential of a single cell?

- Micrometer scale - need very tiny probes to get in this space
- Vision: How do you identify the muscle cell? How do you make sure one probe is inside the cell
- When you probe the cell, can you do so without breaking the membrane?
- This is possible - called Patch Clamping

How can measure EMGs in a practical way?

What electrodes can you use?

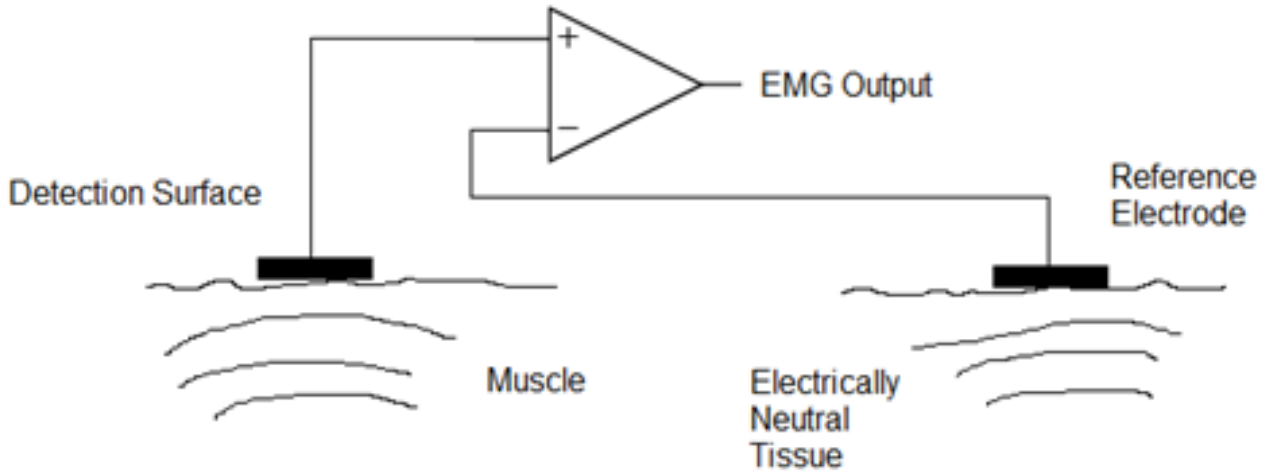
Surface Electrodes



Invasive Electrodes

Surface Electrodes

Surface EMG (sEMG) - Monopolar Configuration



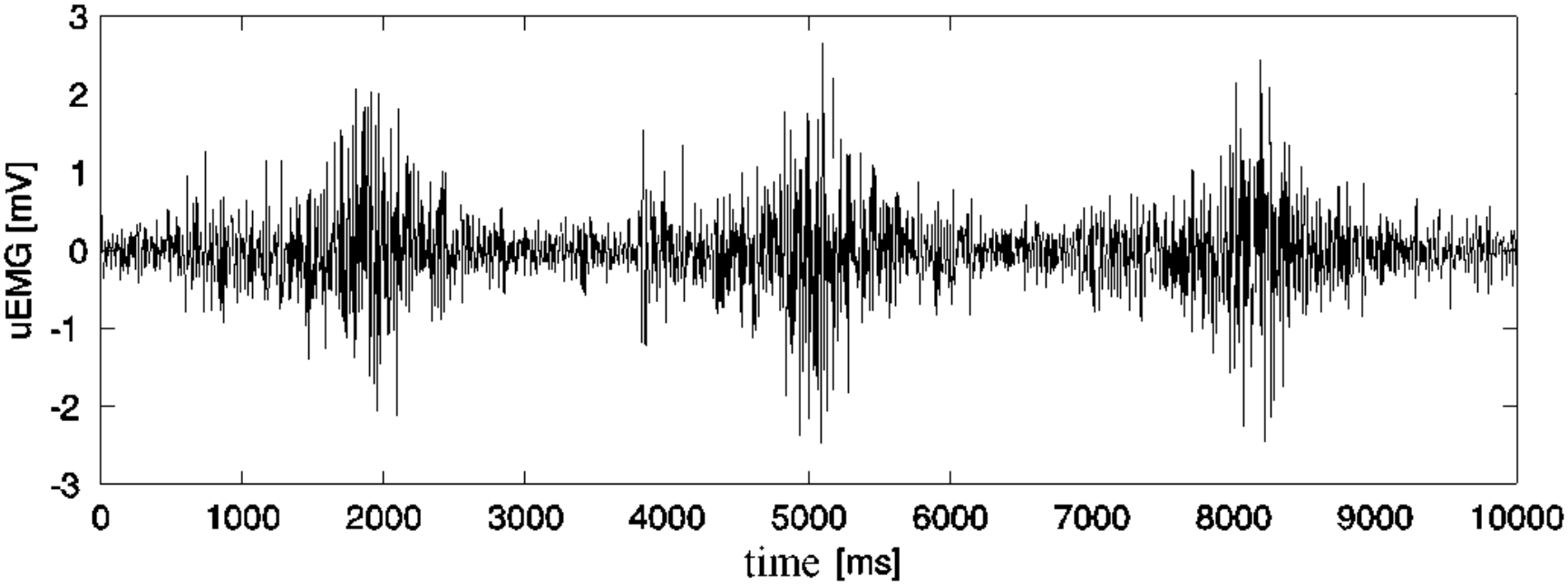
Detection surface: Total charge is sum of all action potentials (APs) under the electrode + sum of all resting membrane potentials.

Reference surface: Charge is the sum of all resting membrane potentials in this area.

Assuming that the RMPs in both areas are roughly the same, subtracting one signal from the other and amplifying should just give the action potentials in this region.

Therefore, at rest, EMG output should be zero! Ideally...

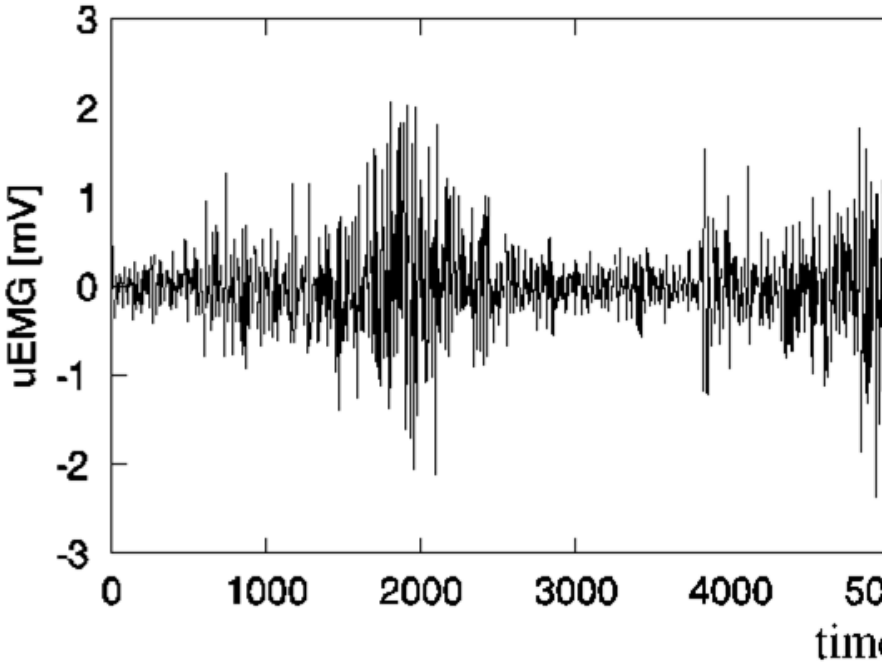
A typical EMG signal (after post processing)



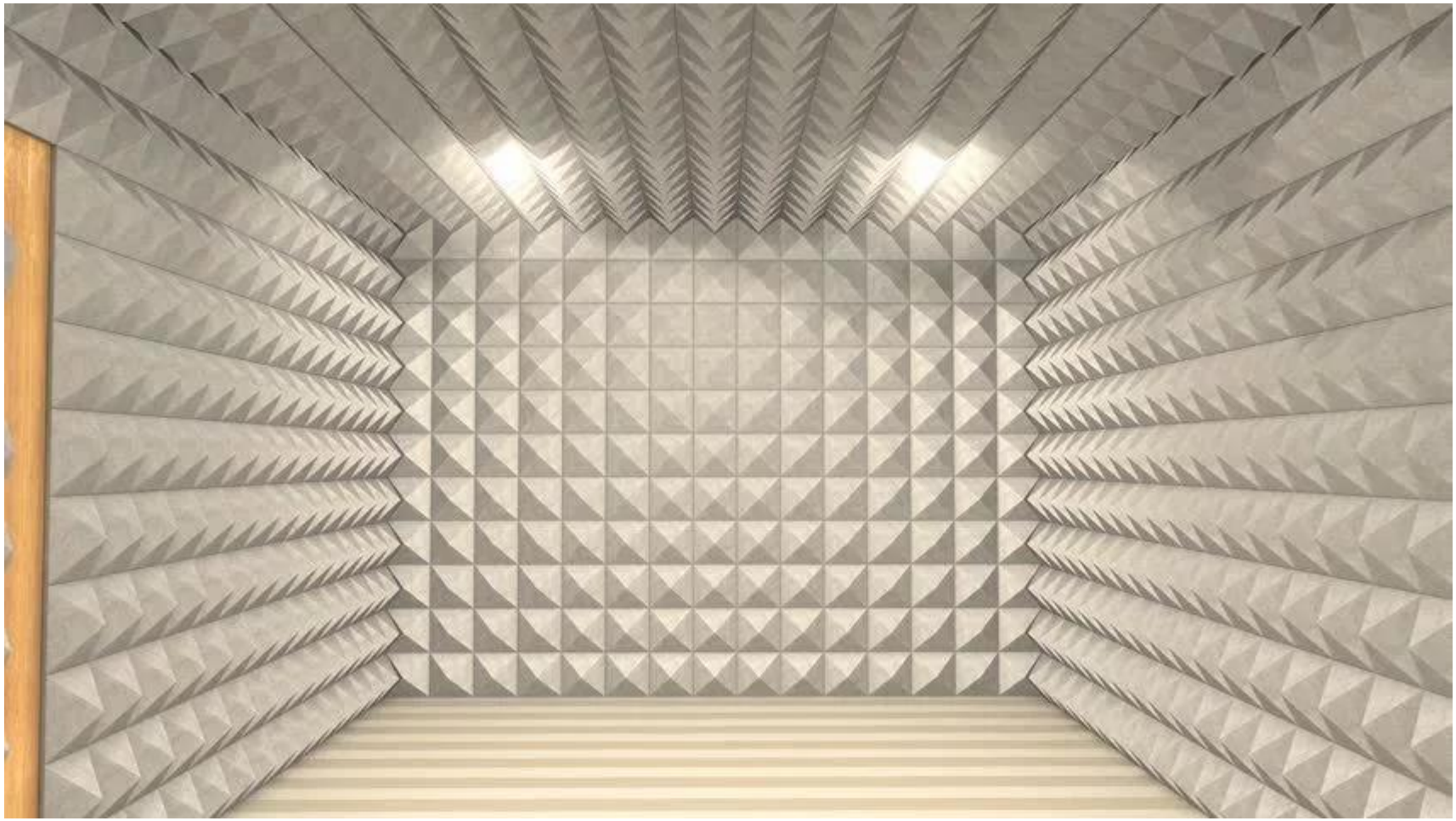
(your raw signal will not look this good!!!)

A typical EMG signal (after post processing)

- Low amplitude
  - High Impedance
  - Can reduce impedance
  - Can amplify signal (electricals)
- Noise
  - Poor signal acquisition and conditioning
  - Some can be removed in post-processing (filters - electricals)
  - Other noise can be removed through better EMG acquisition.



Impedance

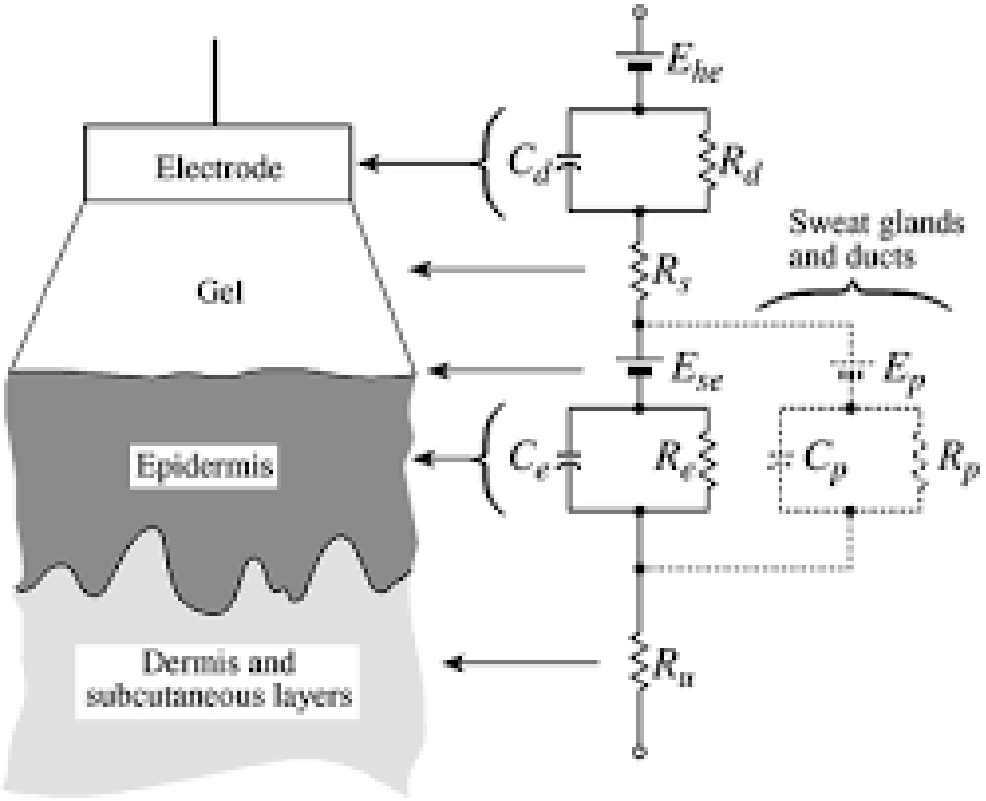


Impedance

“the effective resistance of an electric circuit or component to alternating current, arising from the combined effects of ohmic resistance and reactance.”

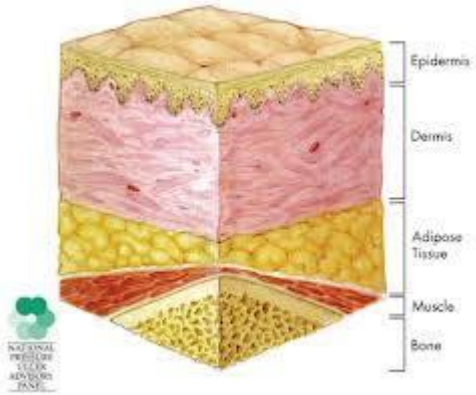
The reduction in amplitude across a range of frequencies of an electric signal.

Skin Impedance - Ultrasound example



http://soundlab.cs.princeton.edu/learning/tutorials/sensors/node10.html

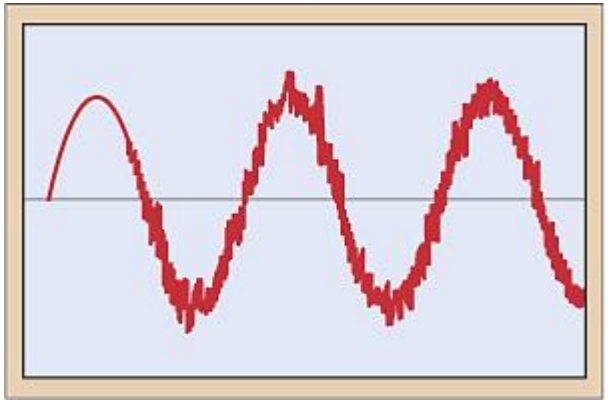
What contributes to high impedance?



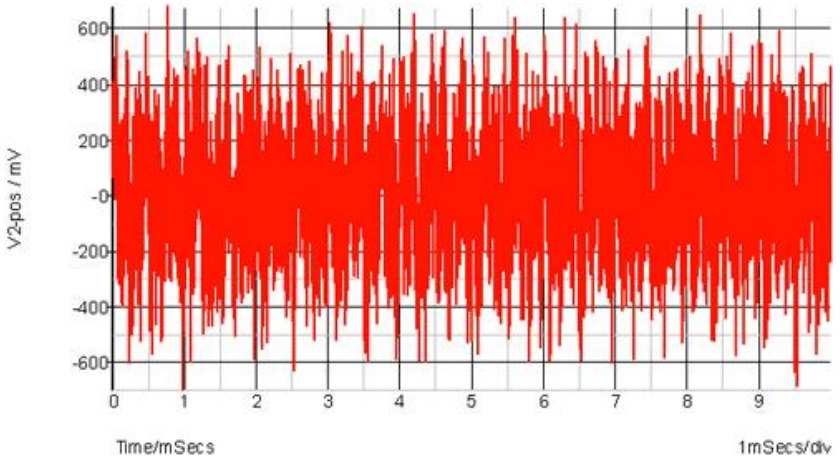
Choose a muscle close to the skin surface

Noise (electrical noise)

"Noise, or interference, can be defined as undesirable electrical signals, which distort or interfere with an original (or desired) signal. Noise could be transient (temporary) or constant"



Low noise



High Noise

https://www.analogictips.com/tips-electrical-noise-reduction/

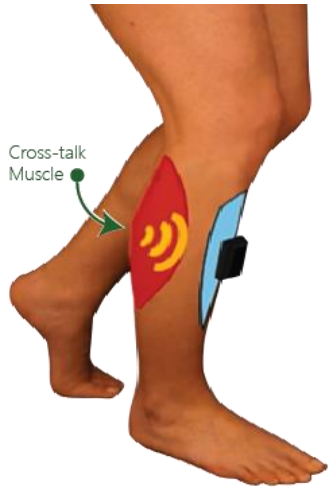
http://www.ecmweb.com/content/ask-experts-9

https://www.eetimes.com/document.asp?doc_id=1274125

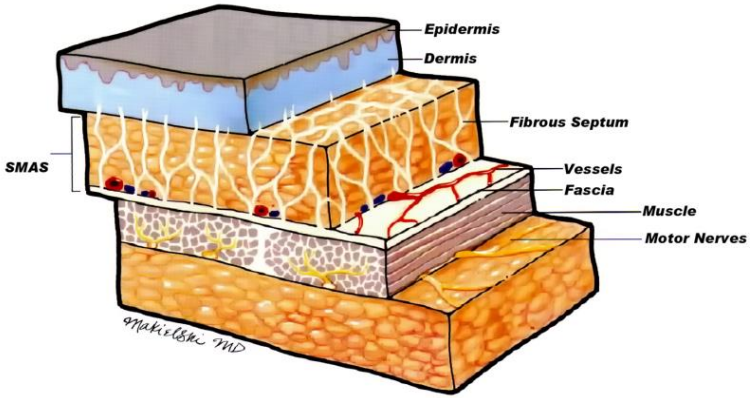
Sources of noise in sEMG

Movement Artefact (1-10Hz)

Electromagnetic Sources (50-60Hz)



Cross-talk



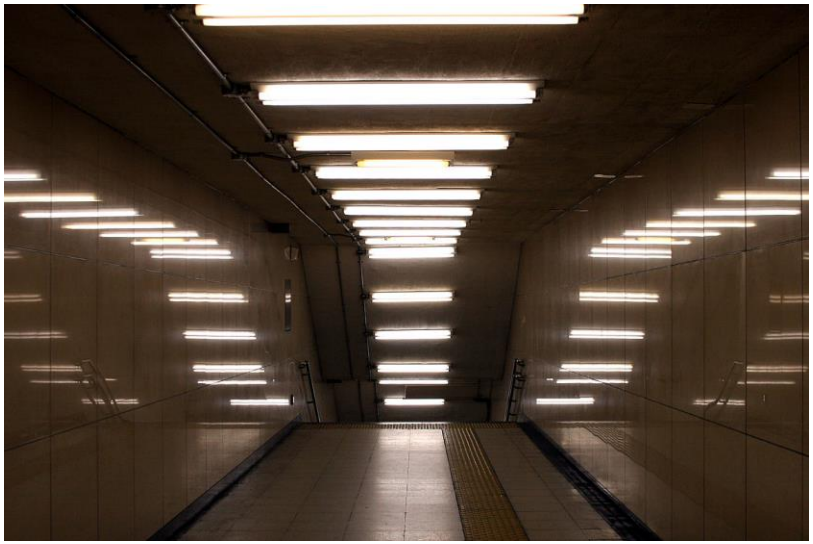
Internal noise

Choudhary et al. Sensors (Basel). 2013 Sep; 13(9): 12431–12466

Movement artefact

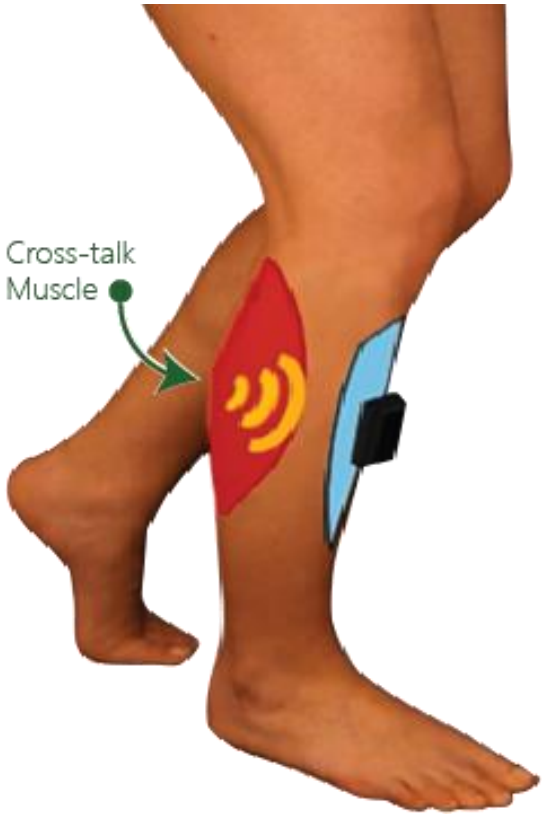
- Low frequency noise
- 1-10Hz
- Minimise arm movements during EMG
- Can be removed using signal processing - filtering (electrical engineering!)

Electromagnetic noise



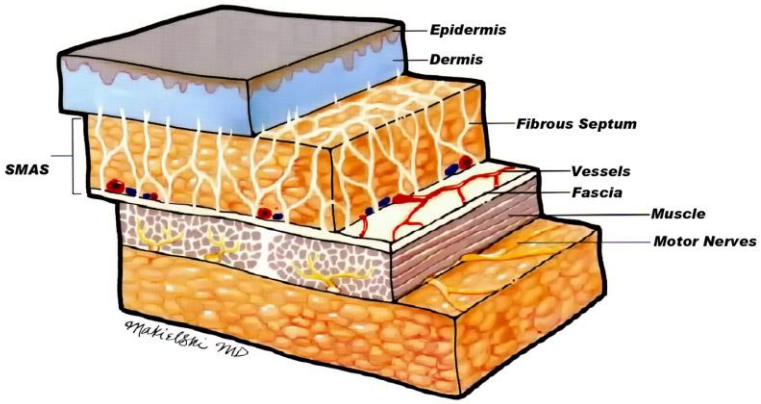
- High frequency noise (50-60Hz)
- Our bodies act as antennas. Skin surface constantly bombarded with sources of electromagnetic radiation.
- Wires and exposed electronics can also pick up noise.
- Amplitude can be 1-3x greater than that of the EMG
  - SERIOUS ISSUE!!
- During EMG, stay away from fluorescent lights, AC power cables
- Can be removed via filtering
- Consider using shielding cables and/or a shielded enclosure.

Cross Talk



- Undesirable EMG from another muscle not monitored.
- Cannot be removed via filtering - why?
  - Similar frequency characteristics and amplitude as desired EMG
- Bipolar > monopolar configuration (more on this later)
  - Keep bipolar electrodes close together
- Increases with distance between muscle and electrode
  - Avoid choosing a muscle that is surrounded by fatty tissue

Internal Noise



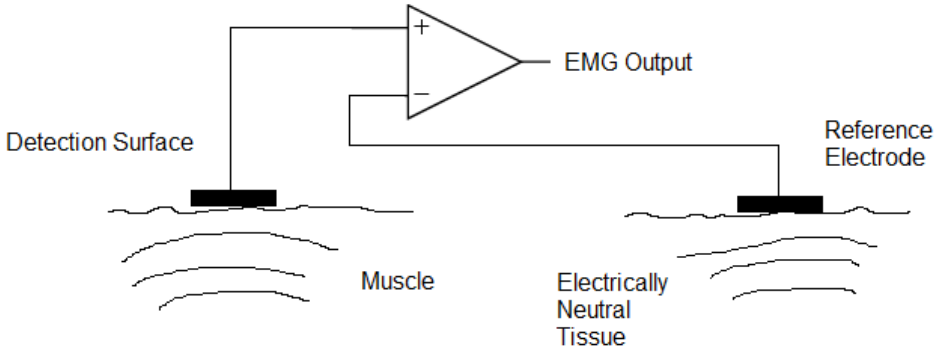
- Other biological and other anatomical factors and activity
- e.g. changes in membrane potential in other nearby cells
- Cannot be removed with filtering
- Consider electrode placement (same as in cross talk)

Other sources of noise

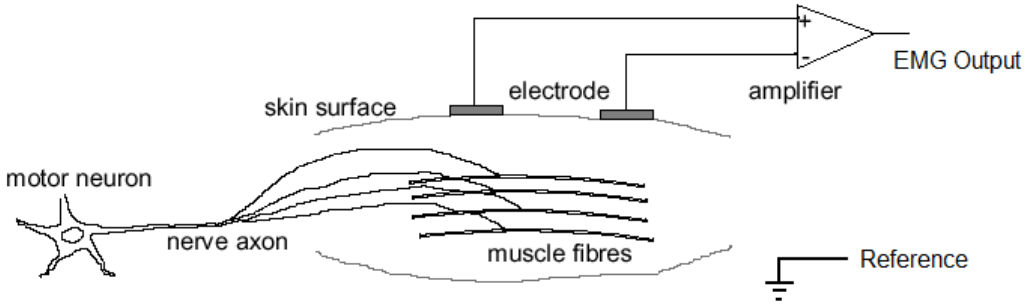
- Instability of signal
  - EMGs are unstable.
  - numbers of active motor units, motor firing rate and mechanical interaction between muscle fibers all affect behaviour of EMG signal
  - Not much you can do about this
- Electrocardiogram (ECG) artefacts
  - If performing EMG close to the trunk, the contraction of the cardiac muscles can be a source of cross talk.
  - Choose a muscle away from the torso!

Monopolar vs Bipolar – Getting rid of the noise

Monopolar

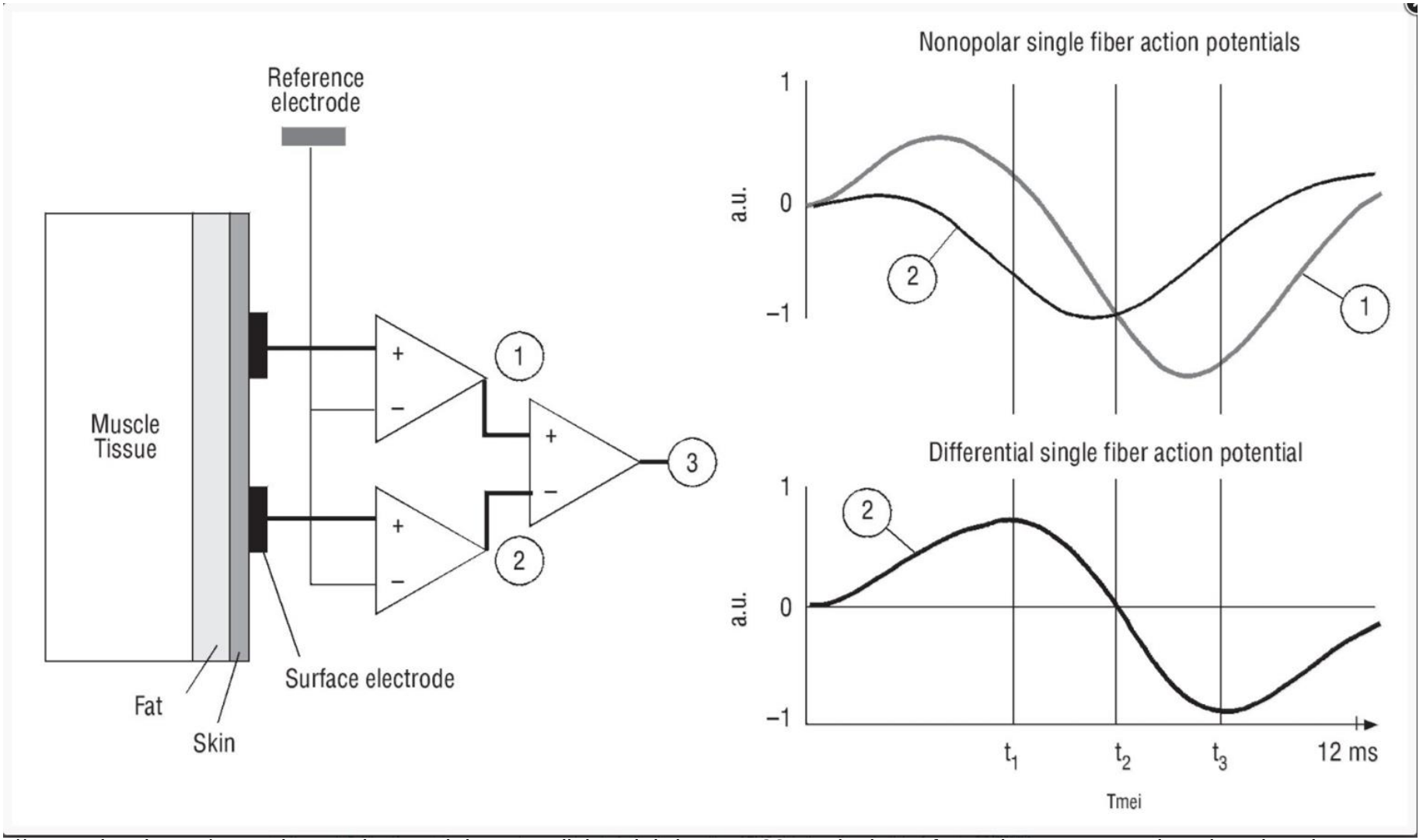


Bipolar



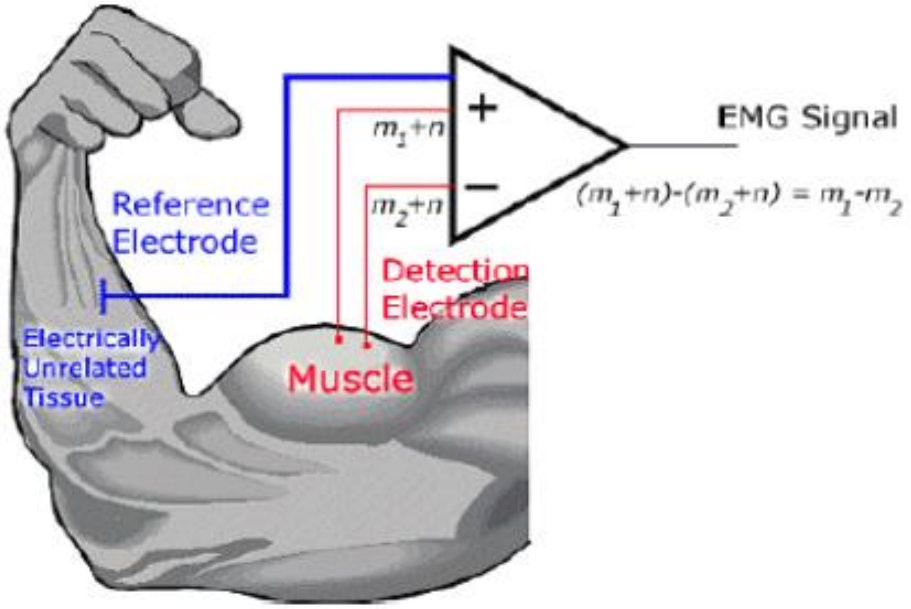
https://www.nrsign.com/monopolar-vs-bipolar-emg-readings/

Bipolar configuration



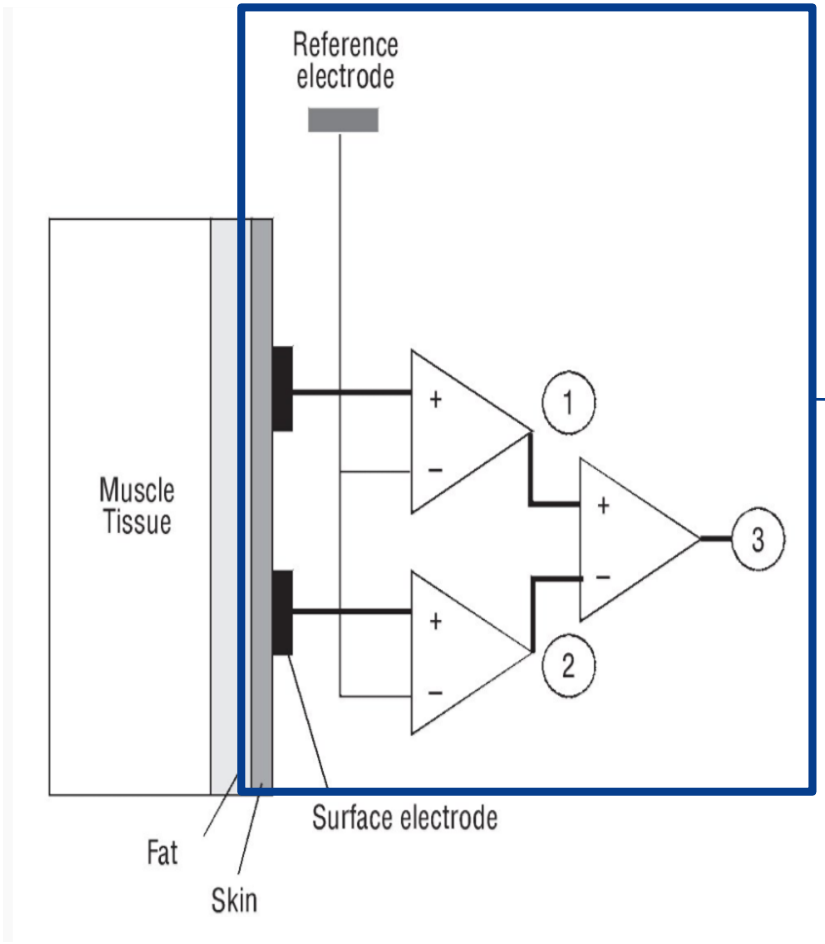
http://www.elsevier.es/es-revista-revista-andaluza-medicina-del-deporte-284-articulo-surface-electromyography-why-when-how-X1888754611201253

Monopolar vs Bipolar – Getting rid of the noise



https://www.delsys.com/Attachments_pdf/WP_SEMGintro.pdf

A note about amplifiers



Instrumentation amplifier

http://www.elsevier.es/es-revista-revista-andaluza-medicina-del-deporte-284-articulo-surface-electromyography-why-when-how-X1888754611201253

A note about amplifiers

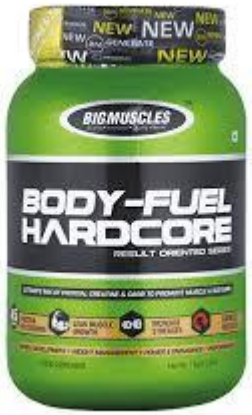
- Many types of amplifiers used in DIY electronics - these will be discussed in the electrical engineering technical stream.
- The type of amplifier that you choose will affect your EMG performance.
- Each of the following types will amplify a difference between signals.

- Op-amp: very inexpensive. High input impedance.
- Differential amplifier: Good for amplifying the difference between signals. A little more expensive than an op-amp. Higher input impedance than op amp.
- Instrumentation amplifier: Very good for amplifying the difference between extremely small signals. More expensive than an op amp (10x the price). Highest input impedance.

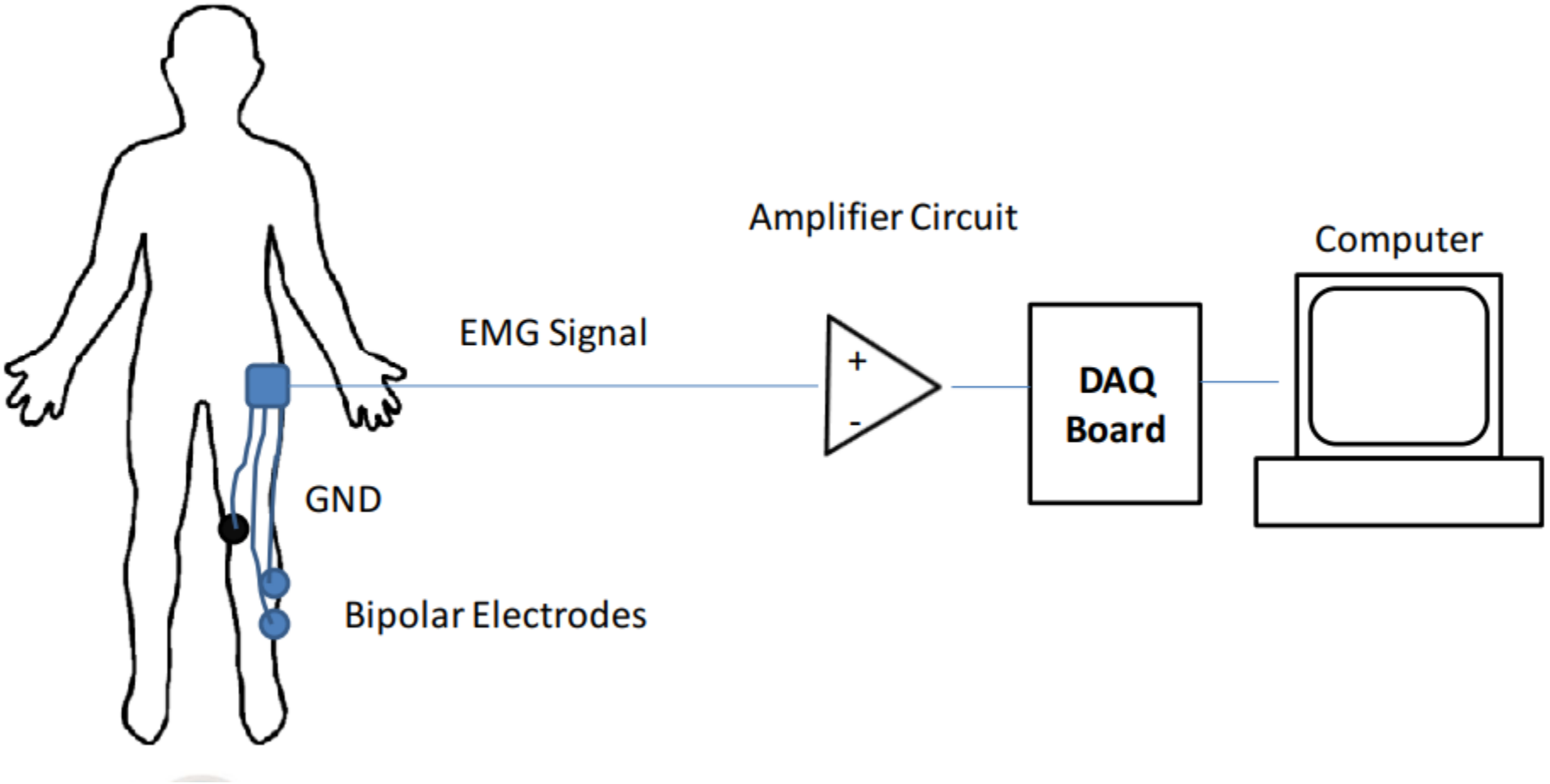
http://www.elsevier.es/es-revista-revista-andaluza-medicina-del-deporte-284-articulo-surface-electromyography-why-when-how-X1888754611201253

EMG magnitude is not a measure of force

- EMGs are not a measure of force.
- Amplitude of the voltage signal is not a measure of force, effort or muscle resting length.
- It is a measure of the number of muscle fibres undergoing an action potential propagation



Acquiring an Electromyograph



Summary

- History of EMGs
- What EMGs are used for
- Practical EMGs
  - Types of electrodes
  - Impedance
  - Noise
  - Electrode configuration (monopolar vs bipolar)
- A note about amplifiers
- A note about sEMG magnitude

Don’t forget about Mike’s Mistakes!