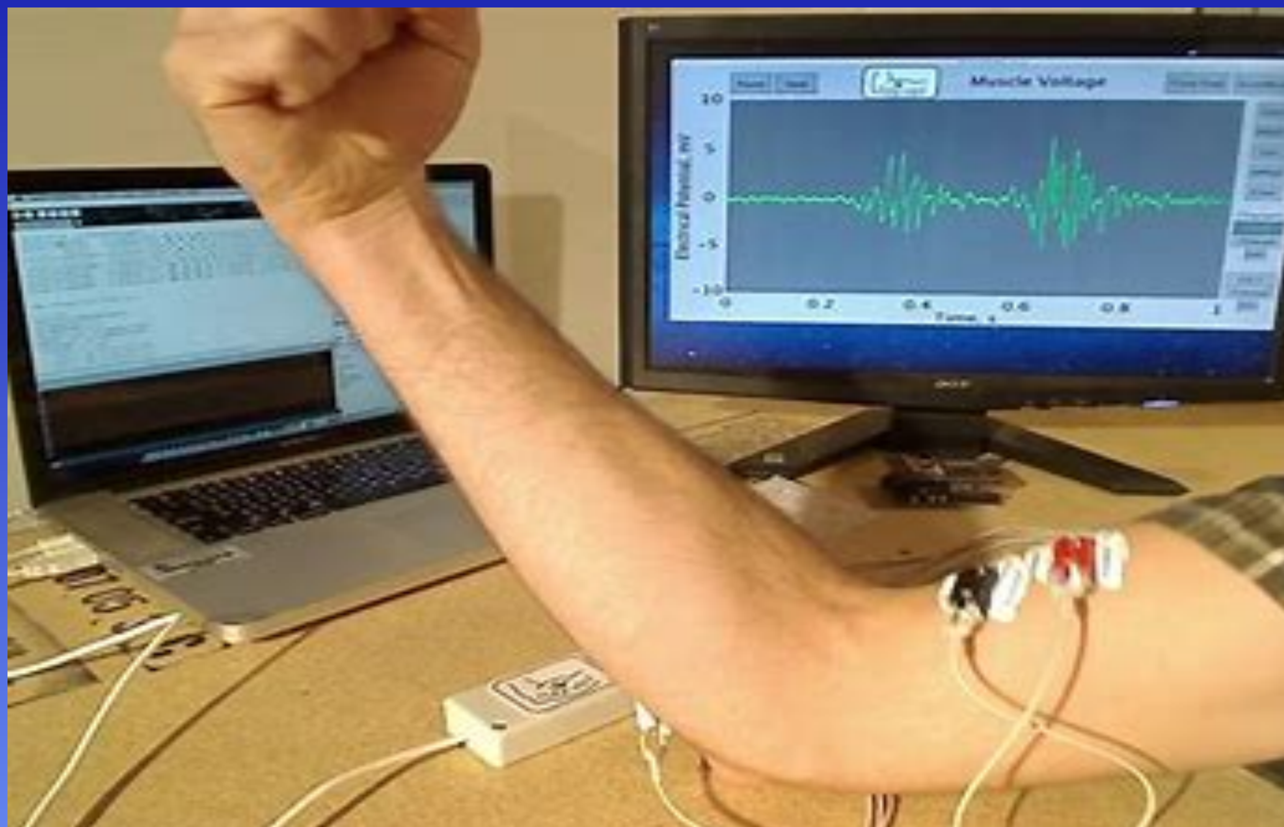
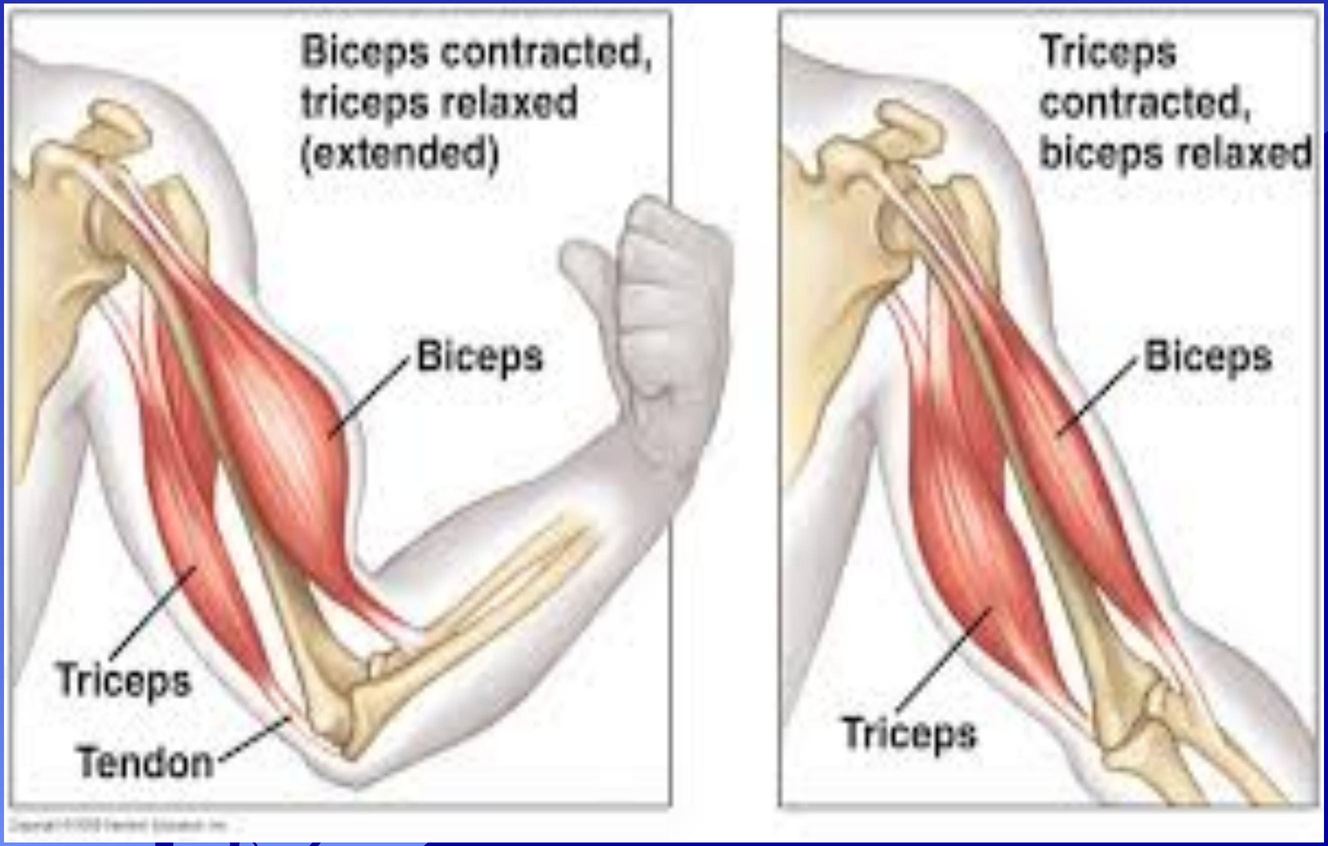
Electromyography (EMG)



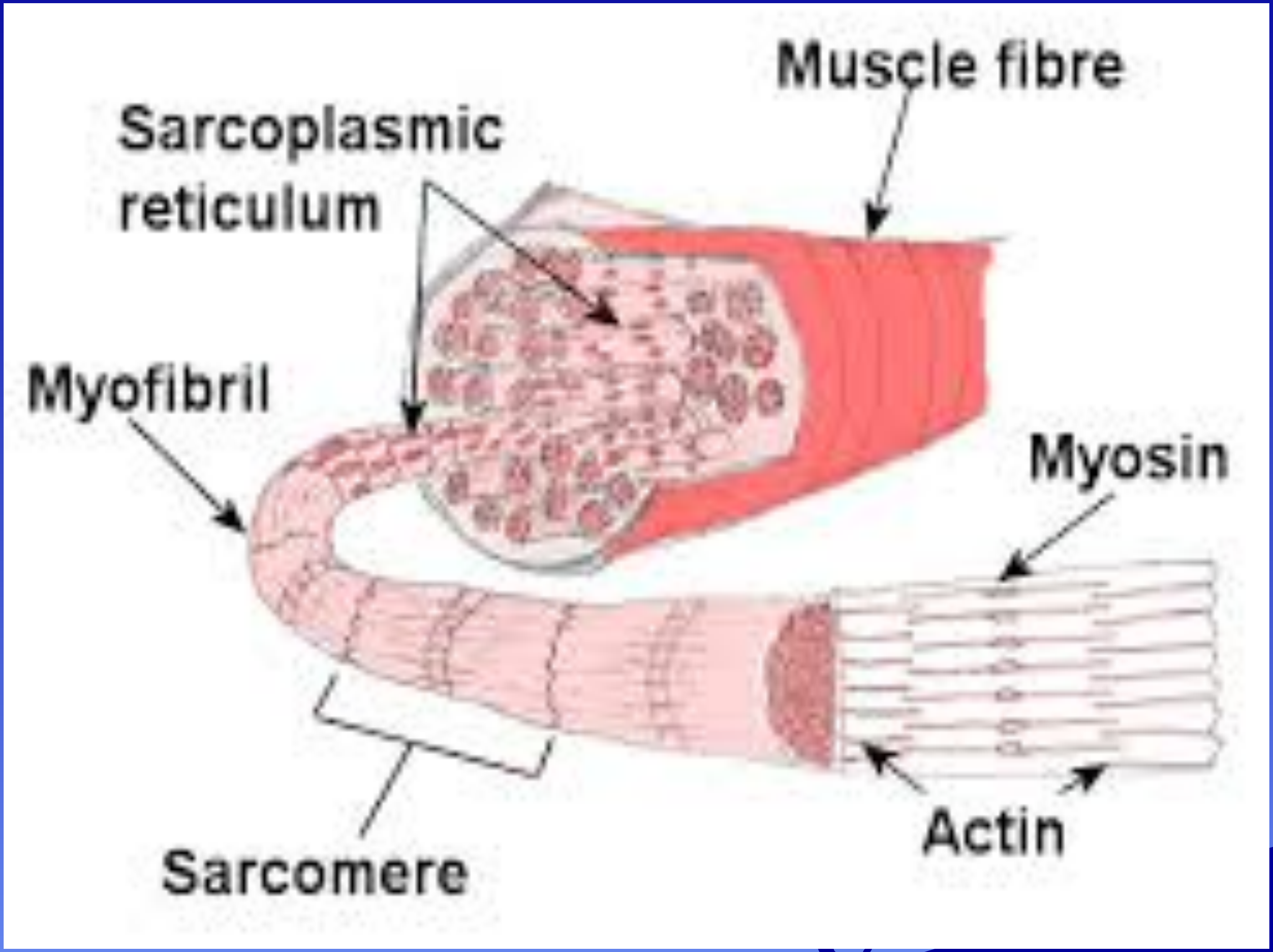
EMG



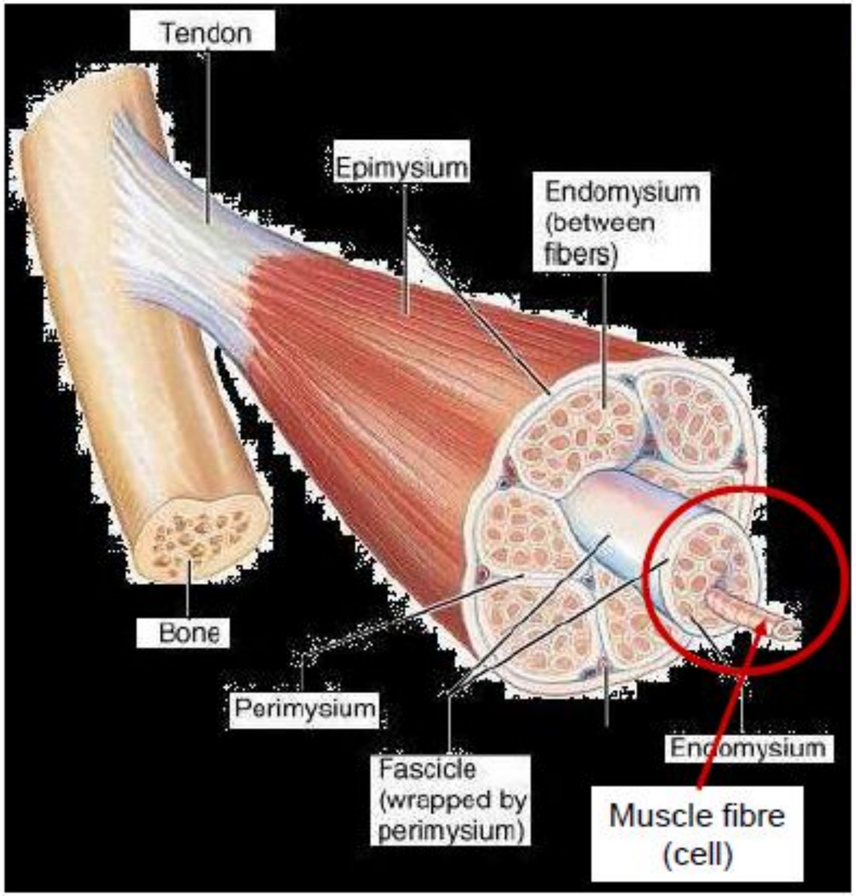
Biceps contracted, triceps relaxed (extended)
Biceps
Triceps
Tendon
Triceps contracted, biceps relaxed
Biceps
Triceps

Physiological Basis

- **Muscle contraction due to a change in the relative sliding of thread-like molecules or filaments**
  - **Actin and Myosin**
- **Filament sliding triggered by electrical phenomenon (Action Potential, AP)**
- **The recording of muscle APs is called electromyography. The record is known as an <u>electromyogram</u>**


Muscle fibre
Sarcoplasmic
reticulum
Myofibril
Myosin
Actin
Sarcomere

Skeletal Muscle Organization



Muscle consist of:

- Muscle fascicles (bundles of muscle fibres)
- Muscle fascicles are wrapped by perimysium
- Muscle fascicles consist of
  - Muscle fibres (muscle cell)
  - Muscle fibres are wrapped by endomysium

The Muscle Fibre is what contracts

What can be learned from an EMG?

- Time course of muscle contraction
- Contraction force
- Coordination of several muscles in a movement sequence
    - These parameters are derived from the amplitude, frequency, and change of these over time of the EMG signal

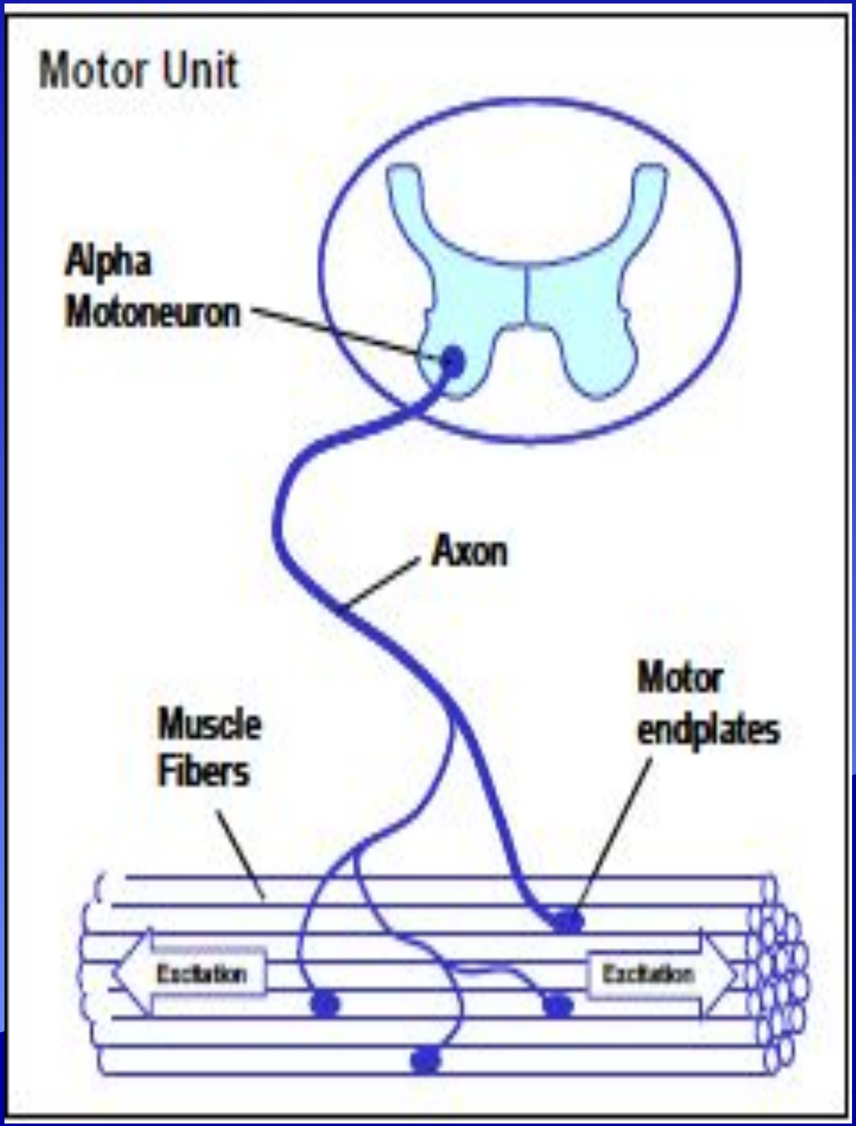
- <u>Field of Ergonomics</u>: from the EMG conclusions about muscle strain and the occurrence of muscular fatigue can be derived as well

The Motor Unit

The motor unit (MU) is a part of the neuromuscular system that contains

- an anterior horn cell, its axon,
- all of the muscle fibers (MFs) that it innervates neuromuscular junction.

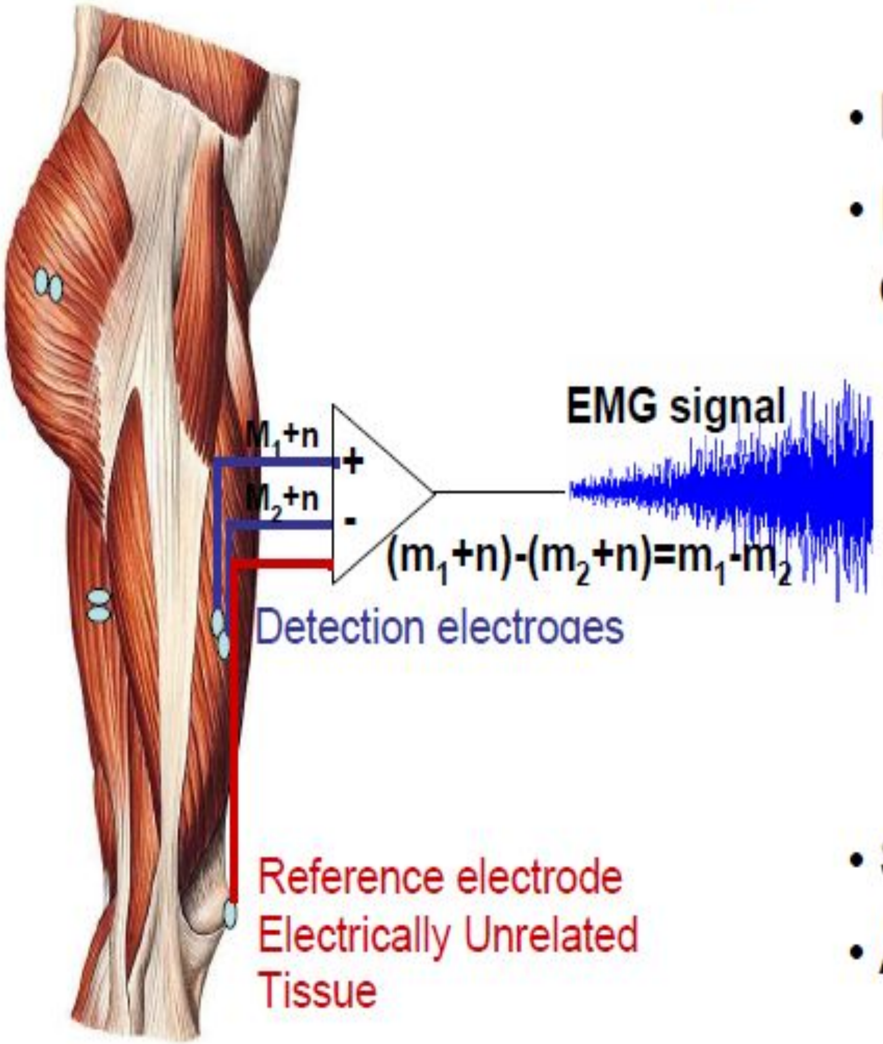
The term units outlines the behavior, that all muscle fibers of a given motor unit act **“as one” within the innervation process**



Motor Unit Action Potential

- Typically, each motorneuron innervates several hundred muscle fibers
- Motor Unit Action Potential (MUAP) = summed electrical activity of all muscle fibers activated within the motor unit
- Muscle force increased through <u>higher recruitment</u> and increased <u>rate coding</u>

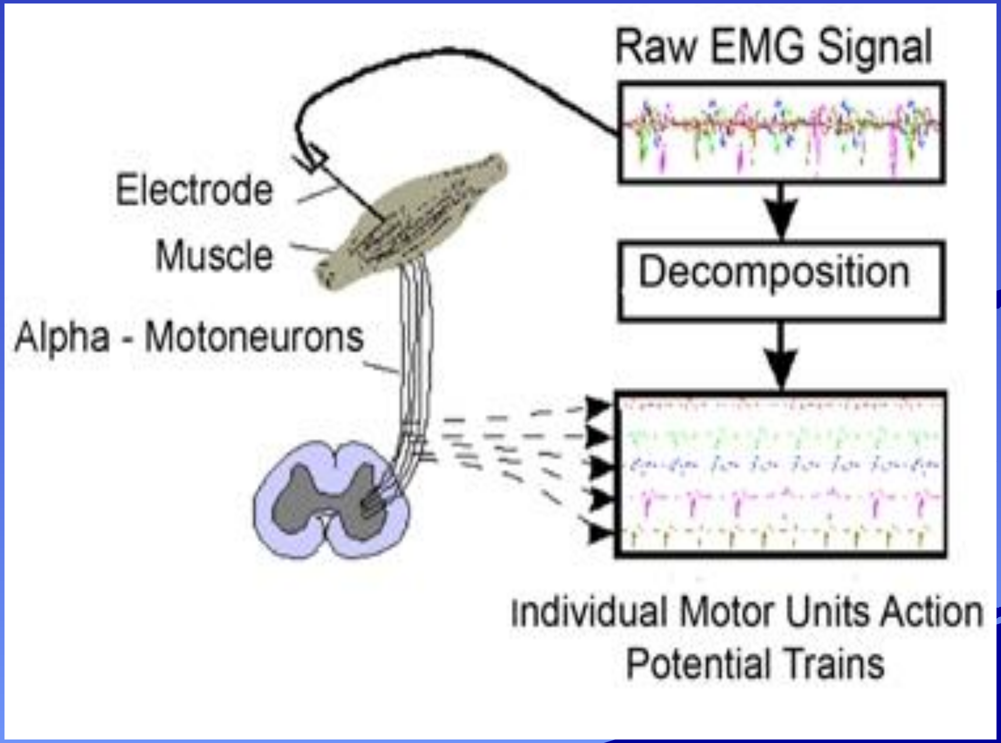
EMG-signal capture



- Differential amplifier
- Input from two different points of the muscle
  - –Close (usually 1-2cm)
  - –Electrode alignment with the direction of muscle fibres → Increased probability of detecting same signal
- Subtracts the two inputs
- Amplifies the difference

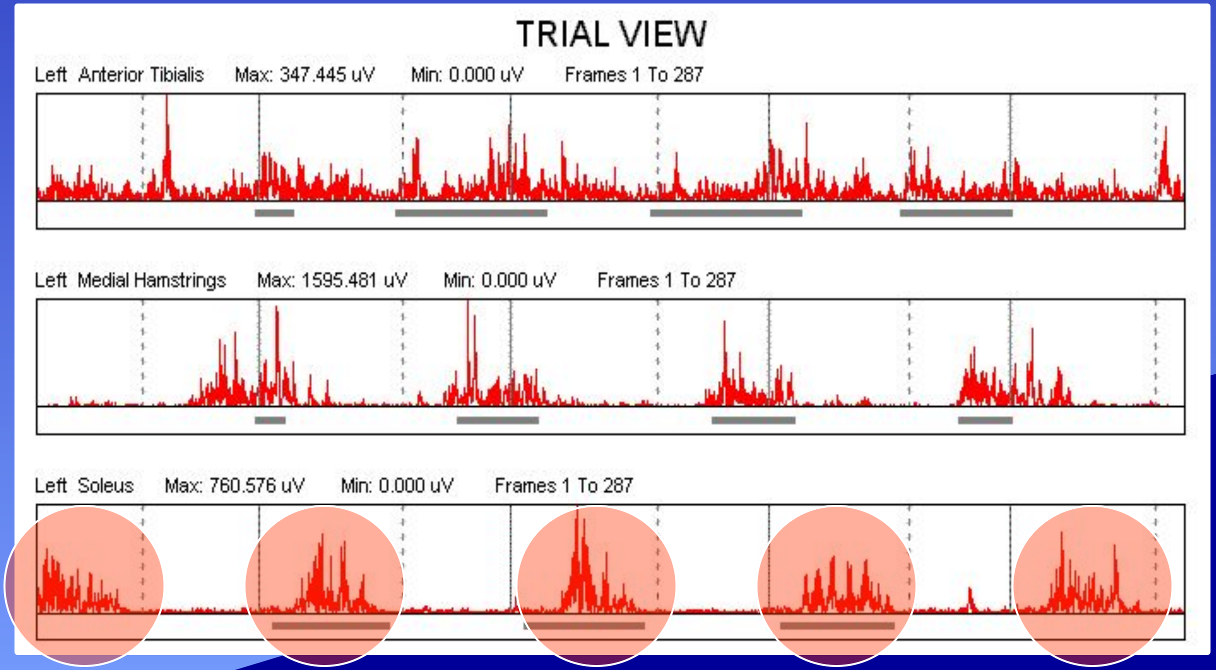
Physiological Basis of EMG

"The technique of electromyography is based on the phenomenon of electromechanical coupling in muscle"



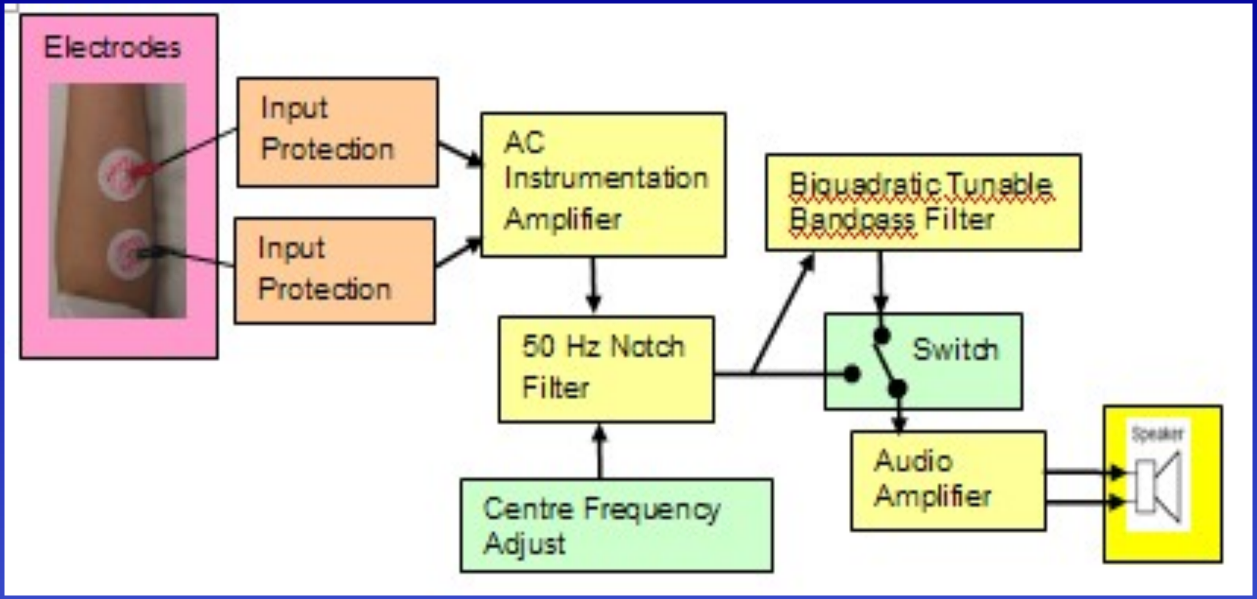
Physiological Basis of EMG
Recording Methodology

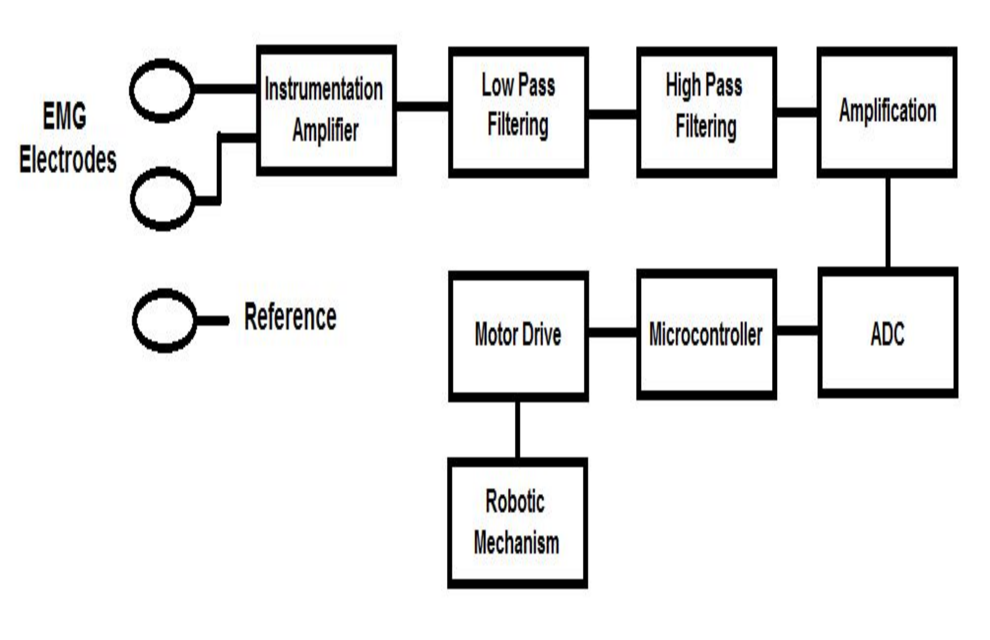
- Sweep of AP similar to a wave
- Height of wave and the density of the wave can be recorded
- Represented graphically electromyogram

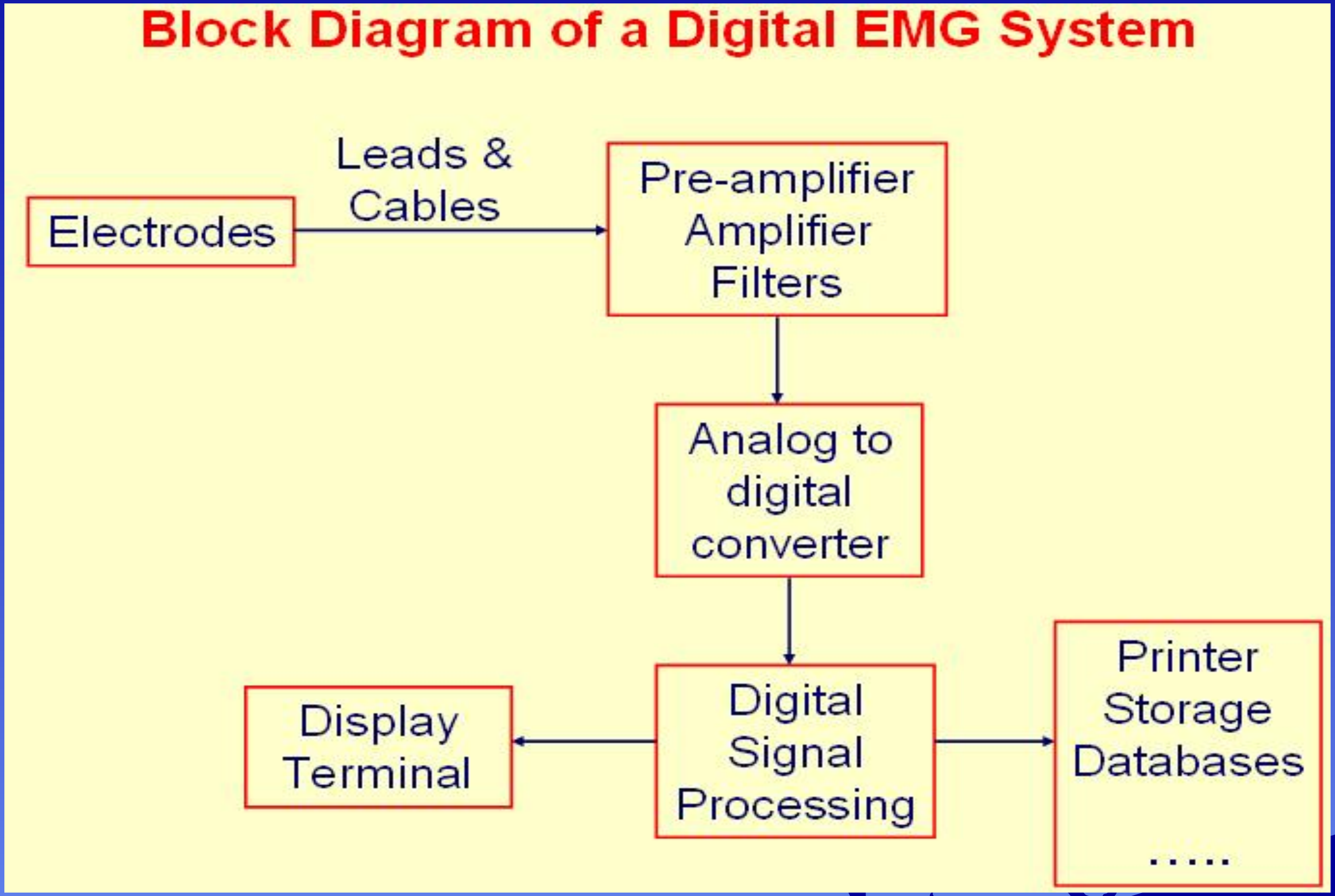


EMG frequency

- Frequency range of muscle - <u>slow twitch motor units</u>
- 75-125 Hz
- <u>Fast twitch motor units</u>
- 125 - 250 Hz


Electrodes
Input Protection
Input Protection
AC Instrumentation Amplifier
50 Hz Notch Filter
Centre Frequency Adjust
Biquadratic Tunable Bandpass Filter
Switch
Audio Amplifier


EMG Electrodes
Reference
Instrumentation Amplifier
Low Pass Filtering
High Pass Filtering
Amplification
ADC
Microcontroller
Motor Drive
Robotic Mechanism


Block Diagram of a Digital EMG System
Electrodes
Leads &
Cables
Pre-amplifier
Amplifier
Filters
Analog to
digital
converter
Digital
Signal
Processing
Display
Terminal
Printer
Storage
Databases
…..

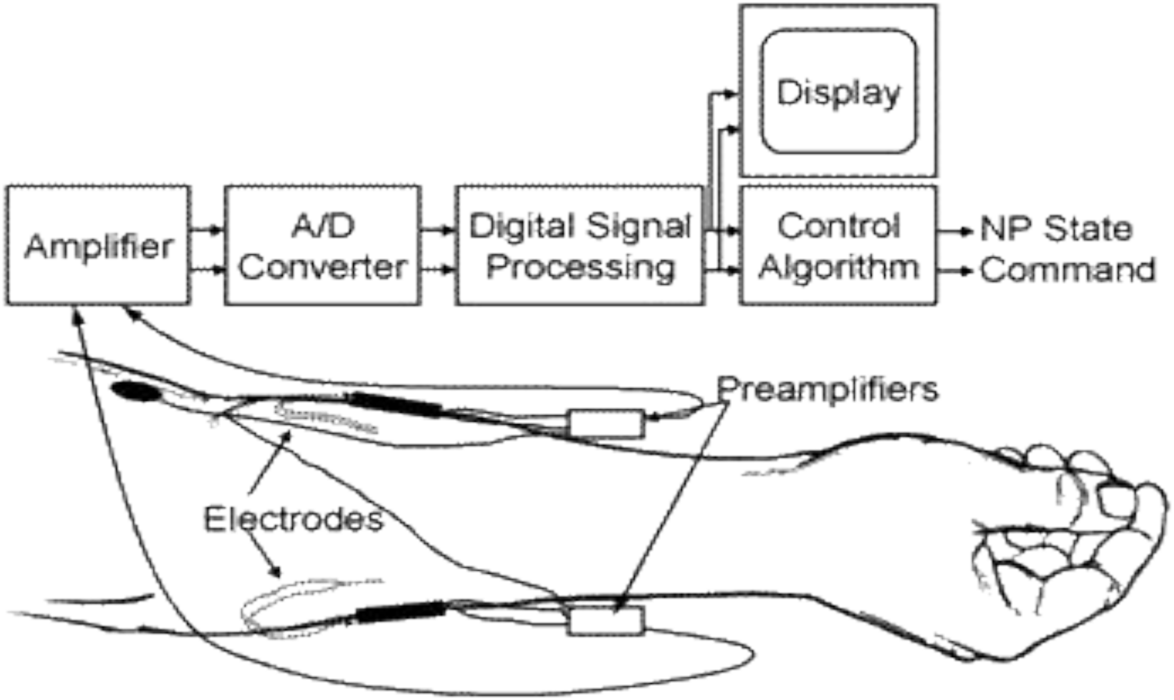
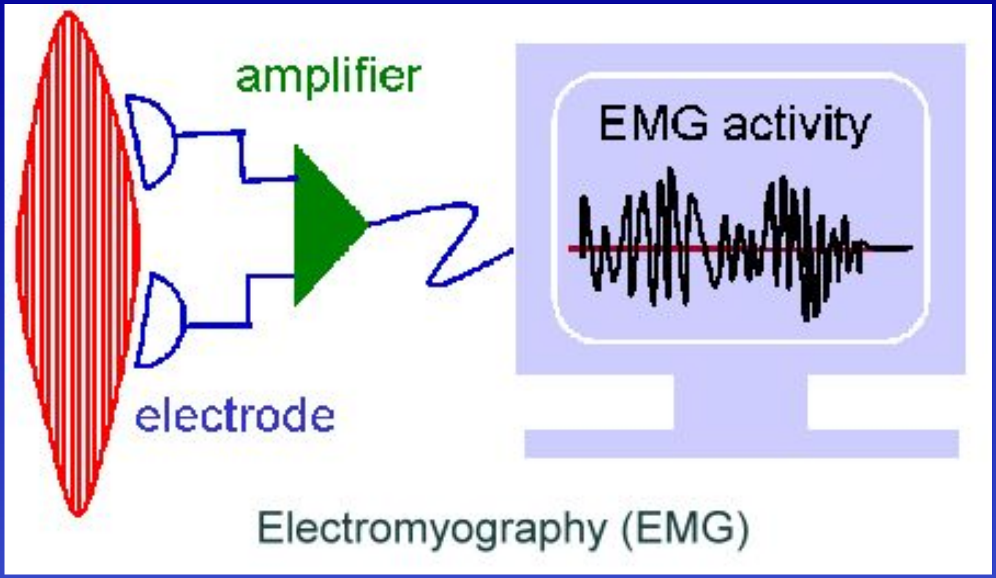


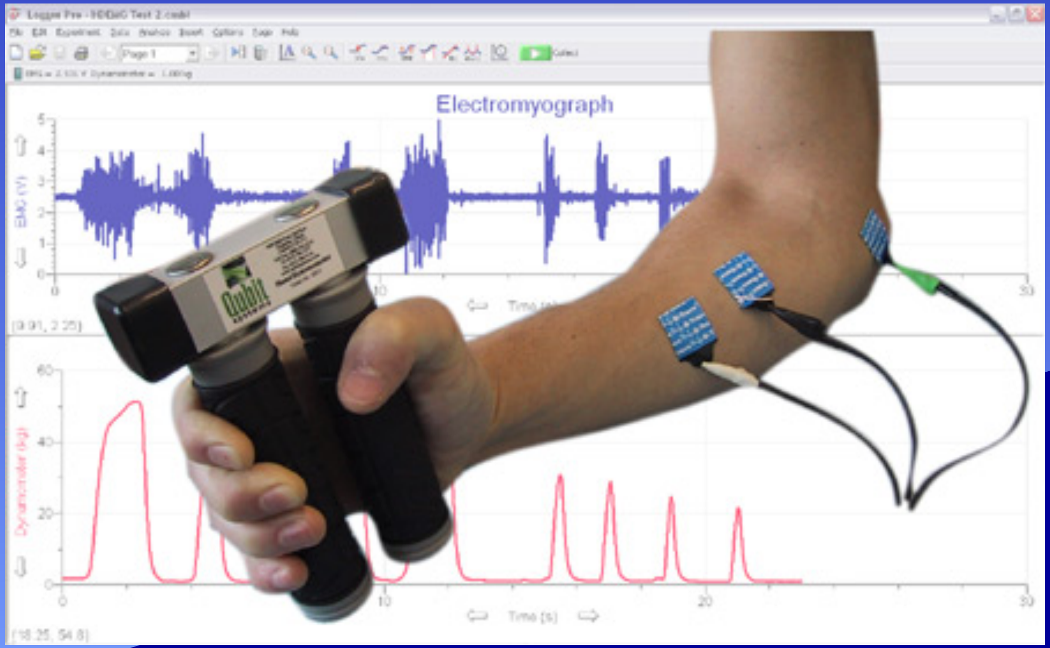
Figure 2.
Block diagram of experimental setup.

EMG Amplitude vs Muscle Contraction Intensity

- Amplitude increases with increased contraction intensity

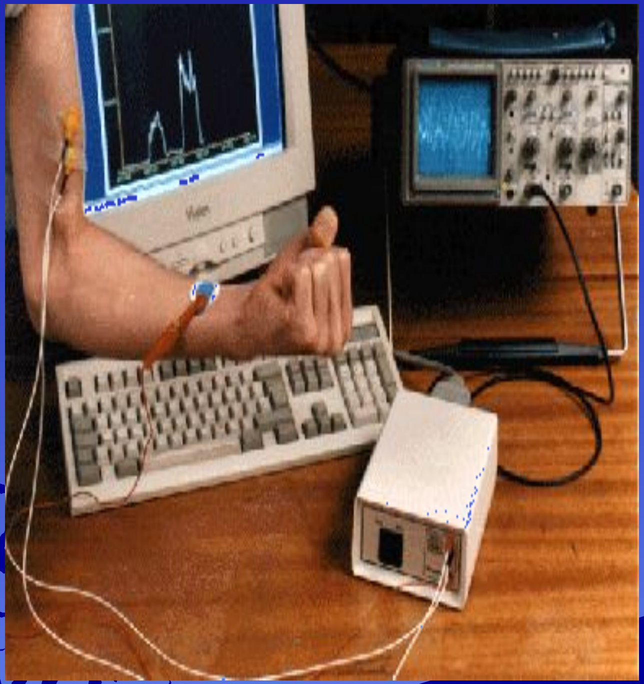
- Non-linear relationship between EMG amplitude and contraction intensity


amplifier
EMG activity
electrode
Electromyography (EMG)


Electromyograph

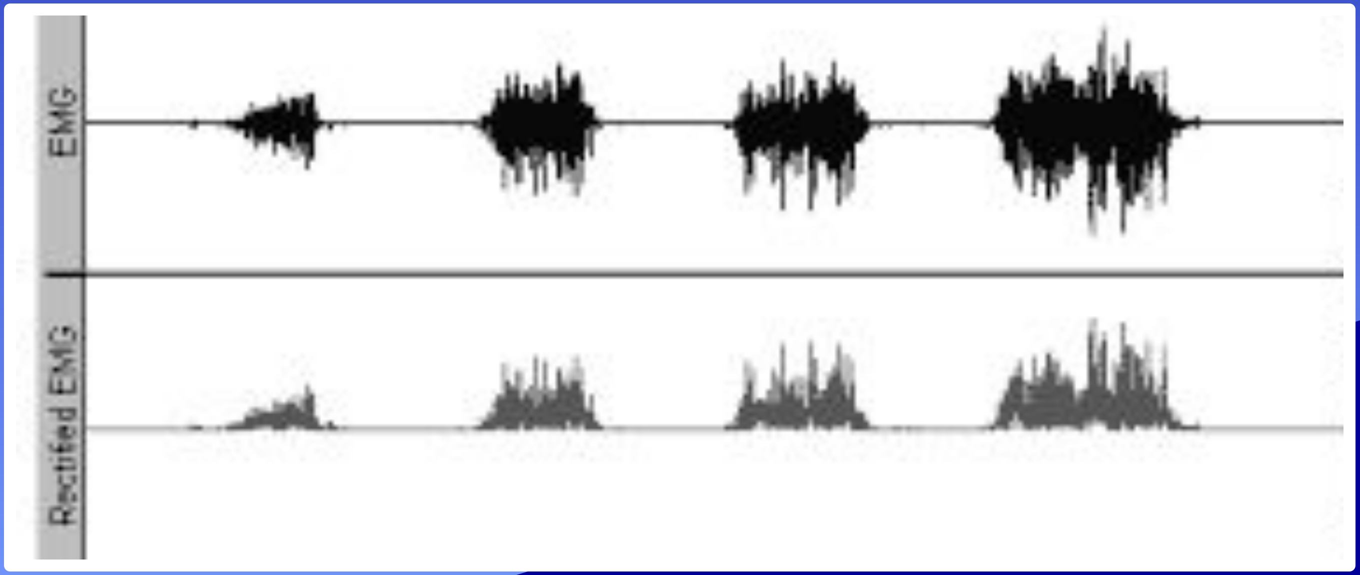
Recording Methodology *(continued)*

- **Electrical potential difference measured between two points bipolar electrode configuration used**
- **Bipolar Electrode Types**
  - **Fine Wire**
  - **Needle**
  - **Surface**
    - **Most common, less invasive**
    - **Silver-silver chloride electrodes**
- **Electrode Placement**
  - **Overlying the muscle of interest in the direction of predominant fiber direction**
  - **Subject is GROUNDED by placing an electrode in an inactive region of body**



Average Rectified Amplitude

- EMG contains a varying negative, positive alternative current (AC) signal
- Rectified = all negative values converted to positive values (absolute value)



Most usual EMG parameters in biomechanics or physiology

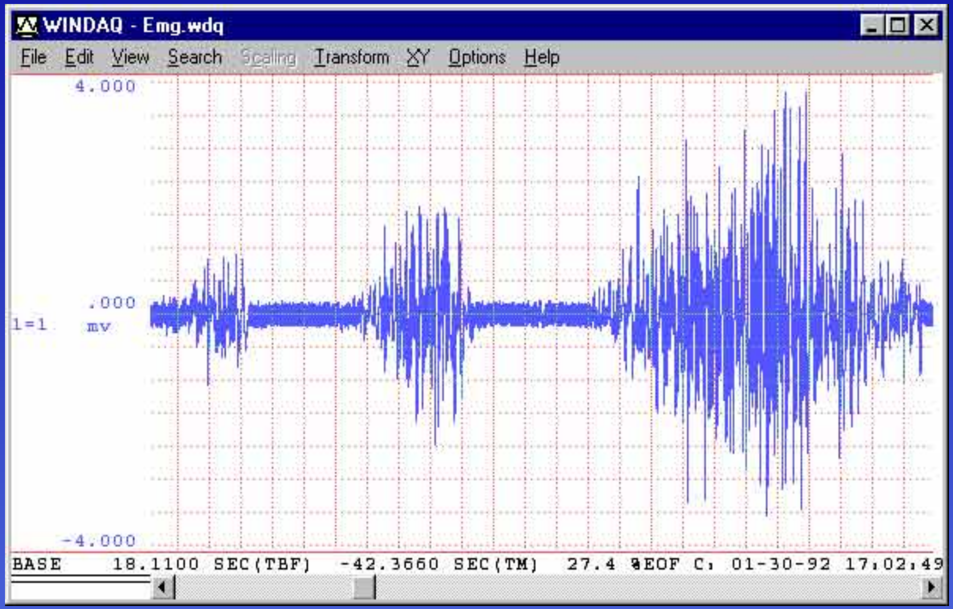
Time domain:

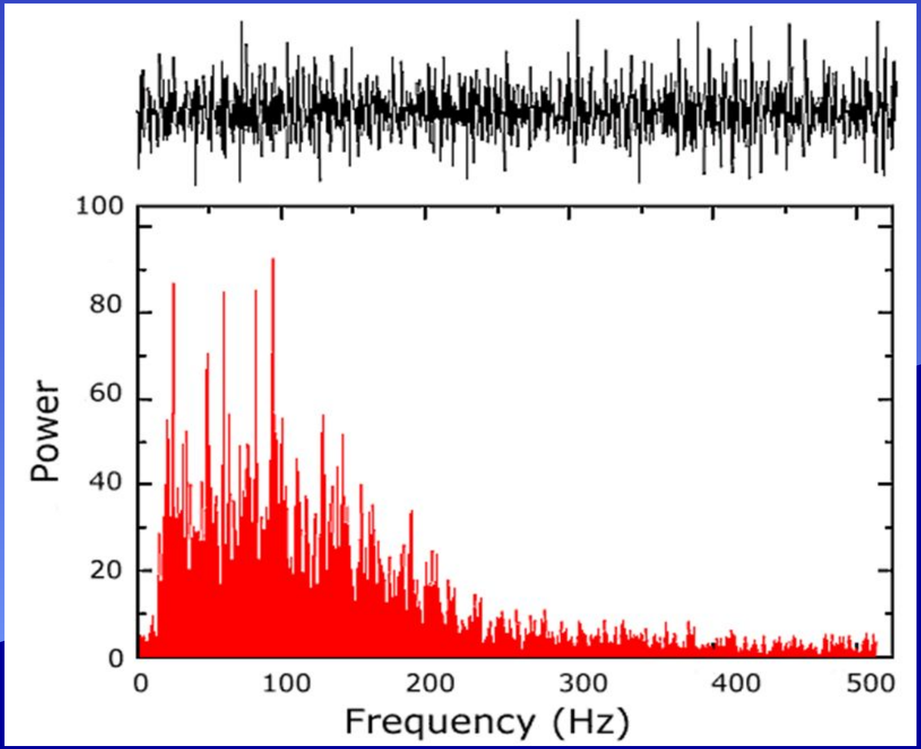
- RMS
- Average of the rectified EMG

Frequency domain:

- FFT Analysis (spectral analysis)
  - Power Density
  - Mean power frequency
  - Median power frequency

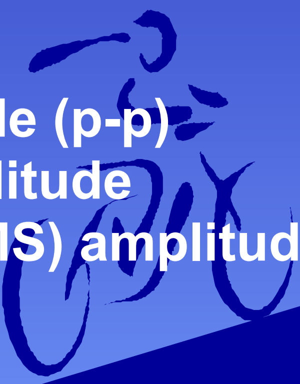
EMG & FFT


WINDAQ - Emg.wdq
File Edit View Search Scaling Transform XY Options Help
4.000
.000
1=1
mv
-4.000
BASE 18.1100 SEC(TBF) -42.3660 SEC(TM) 27.4 %EOF C: 01-30-92 17:02:49


Power
100
80
60
40
20
0
0
100
200
300
400
500
Frequency (Hz)

Analyzing the EMG Signal

- Amplitude & Frequency
- More MU → more spikes and turns in signal
- Change in firing rate → change in frequency
- Major variables:
  - » peak-to-peak amplitude (p-p)
  - » average rectified amplitude
  - » root-mean-square (RMS) amplitude
  - » linear envelope
  - » integrated EMG



Other Variables

- RMS: Does not require rectification
- Linear Envelope: computed by passing a low-pass filter (3-50 Hz) through the full wave rectified signal
- Integrated EMG: sums the total activity over a period of time (area under the curve)

Potential Use of sEMG

Usual normalisation: To capture the signal during an isometric maximal voluntary contraction.

- Compare the contribution of a specific muscle across subjects during static or dynamic contractions

- Compare the relative contribution of various muscles across subjects during static or dynamic contractions.

- Determine when the muscle contraction begins and ends (from raw rectified signal).

- sEMG can be useful as an input signal to the system which can **control devices** such as keyboard, mouse or computer.

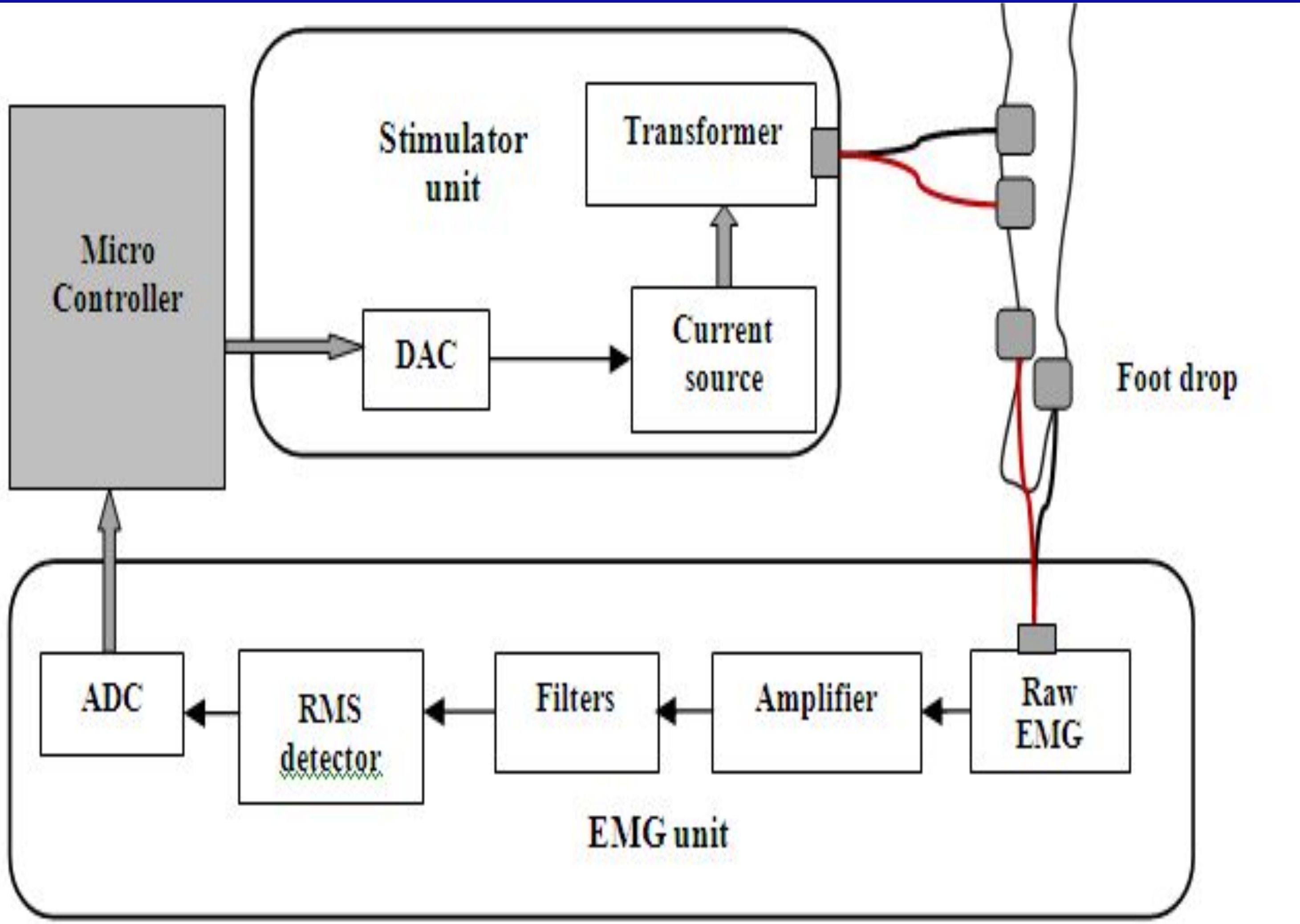
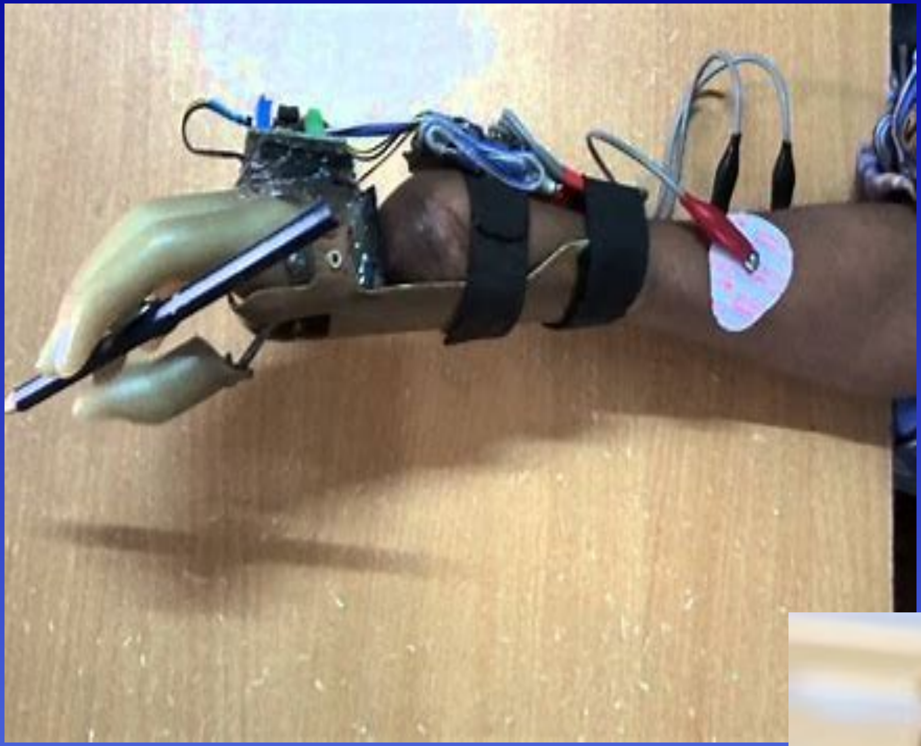


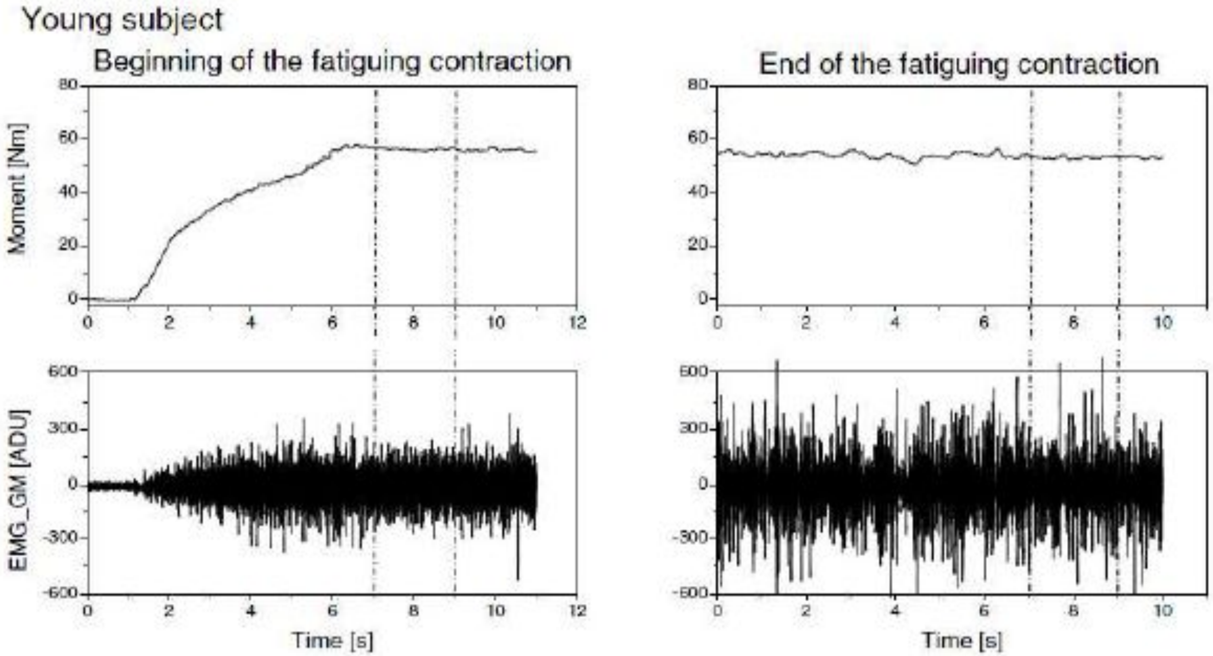
Figure 3.25: Block diagram of EMG-controlled FES system for foot drop.



Use of sEMG

"The strength of sEMG is a good measure of the strength of contraction of muscle". *(Arjunan et al. 2007)*

Not always true: For example



Electrooculography (EOG/E.O.G.)

- EOG is a technique for measuring the corneo-retinal standing potential that exists between the front and the back of the human eye.

- The resulting signal is called the electrooculogram.

- Primary applications are in ophthalmological diagnosis and in recording eye movements.

- To measure eye movement, pairs of electrodes are typically placed either above and below the eye or to the left and right of the eye.

- If the eye moves from center position toward one of the two electrodes, this electrode "sees" the positive side of the retina and the opposite electrode "sees" the negative side of the retina.

- Consequently, a potential difference occurs between the electrodes.

- Assuming that the resting potential is constant, the recorded potential is a measure of the eye's position.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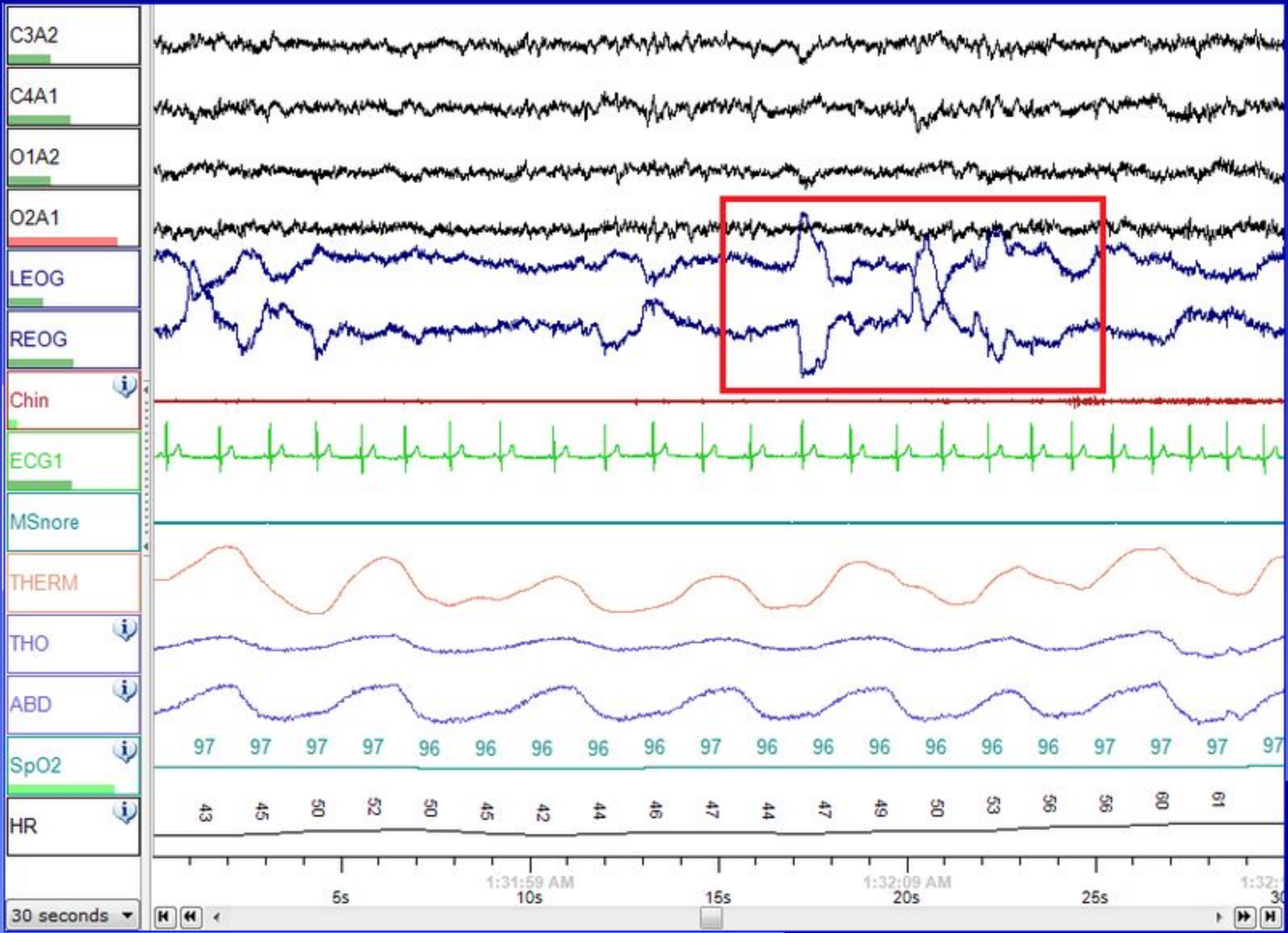
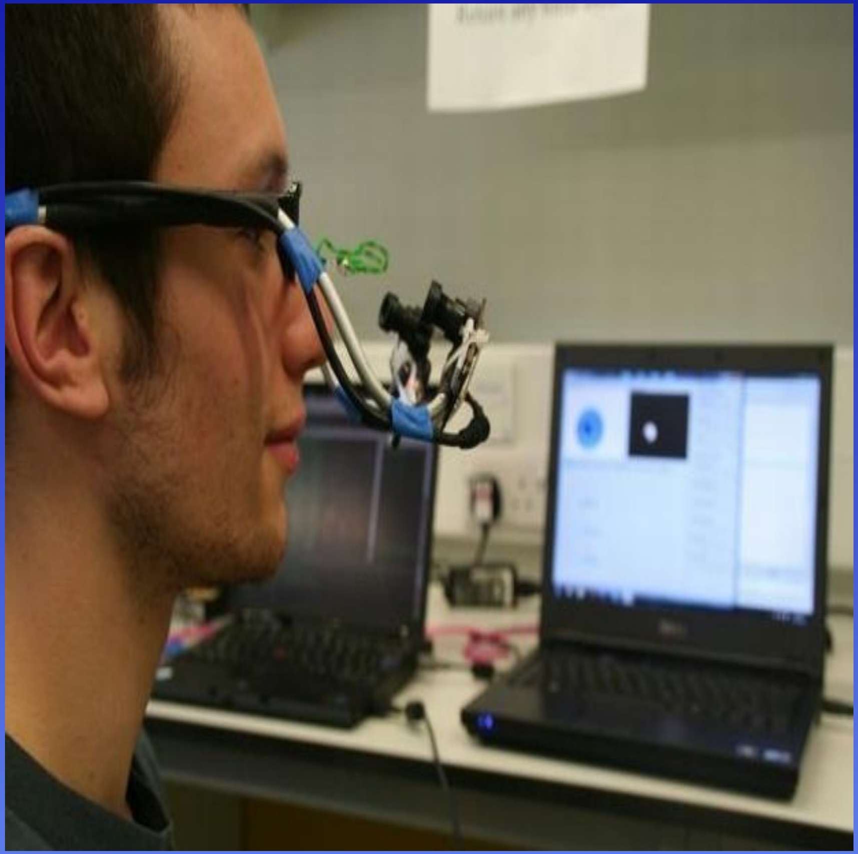
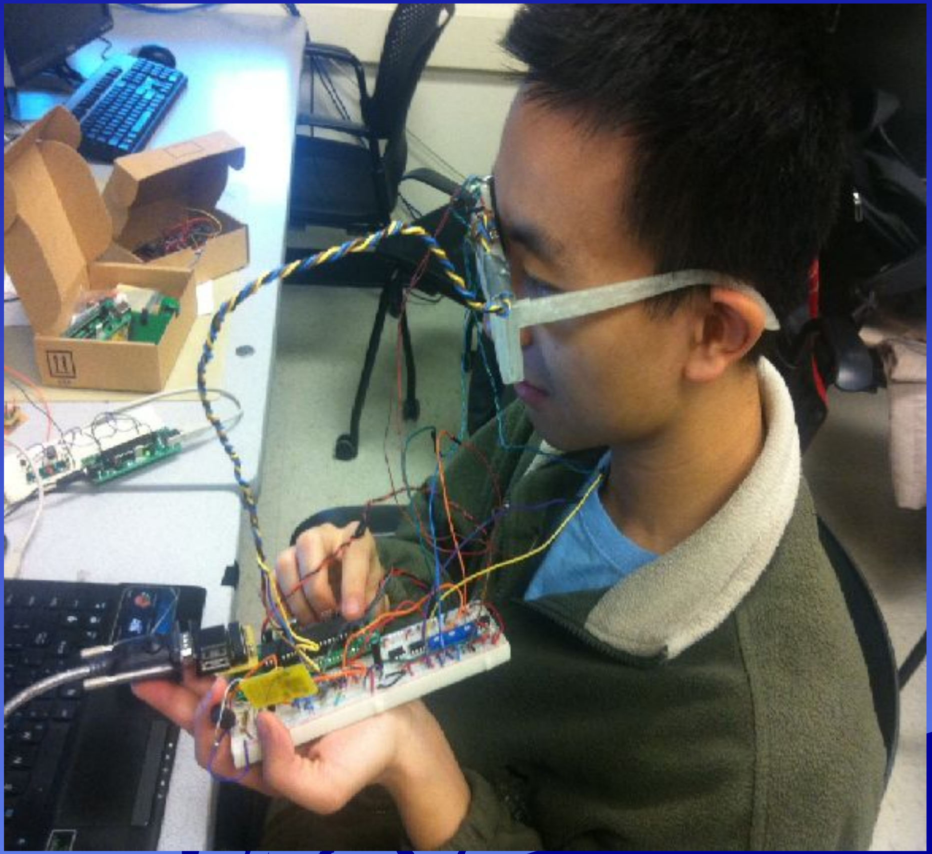
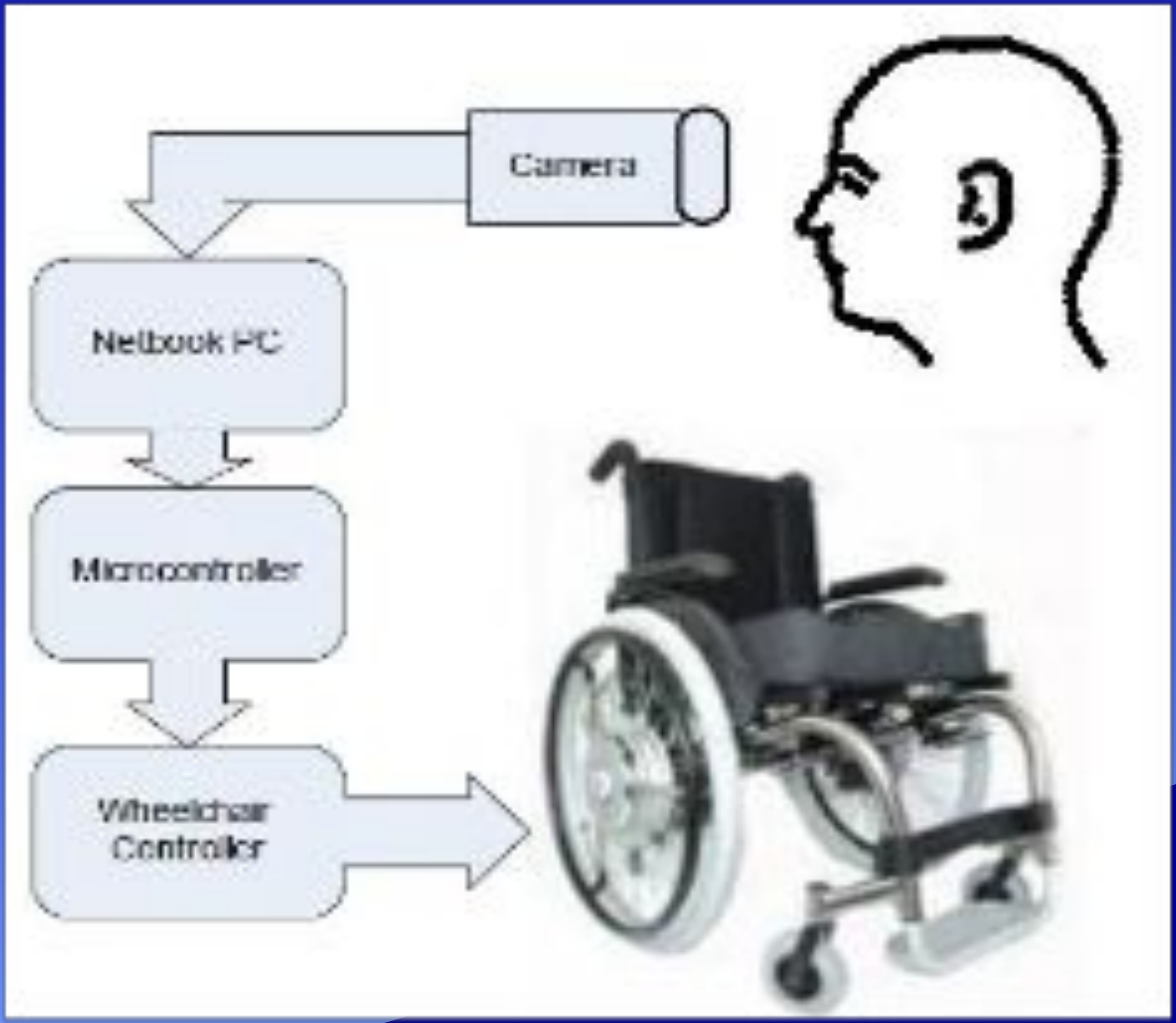

C3A2
C4A1
O1A2
O2A1
LEOG
REOG
Chin
ECG1
MSnore
THERM
THO
ABD
SpO2
HR
97 97 97 97 96 96 96 96 96 97 96 96 96 96 96 96 97 97 97 97
43 45 50 52 50 45 42 44 46 47 44 47 49 50 53 56 56 60 61
1:31:59 AM
1:32:09 AM
5s
10s
15s
20s
25s
30 seconds

Eye controlled Mouse Movement





Eye controlled wheelchair



Electroretinography (ERG)

- **Electroretinography** measures the electrical responses of various cell types in the retina, including the photoreceptors, inner retinal cells & the ganglion cells.

- Electrodes are usually placed on the cornea and the skin near the eye.

- During a recording, the eyes are exposed to standardized stimuli and the resulting signal is displayed.

- Signals are very small, and typically are measured in microvolts or nanovolts.

- The ERG is composed of electrical potentials contributed by different cell types within the retina, and the stimulus conditions (flash or pattern stimulus) can elicit stronger response from certain components.

- Clinically used mainly by ophthalmologists, the ERG is used for the diagnosis of various retinal diseases.

Retinal implant

- The implant is meant to partially restore useful vision to people who have lost their vision due to degenerative eye conditions such as retinitis pigmentosa or macular degeneration.

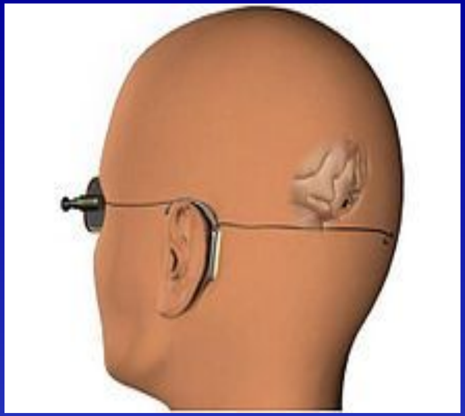
- Retinal implants provide the user with low resolution images by electrically stimulating surviving retinal cells.

- Such images may be sufficient for restoring specific visual abilities, such as light perception and object recognition.

A visual prosthesis, **often referred to as a bionic eye, is an experimental visual device intended to restore functional vision in those suffering from partial or total blindness.**

Many devices have been developed, usually modeled on the *cochlear implant* or bionic ear devices, a type of *neural prosthesis* in use since the mid-1980s.

Visual Cortical Implant



- Dr. Mohamad Sawan, Professor at the Ecole Polytechnique de Montreal, has been working on a visual prosthesis to be implanted into the visual cortex.

- The basic principle: consists of stimulating the visual cortex by implanting a silicon microchip on a network of electrodes, made of biocompatible materials, wherein each electrode injects a stimulating electrical current in order to provoke a series of luminous points to appear (an array of pixels) in the field of vision of the blind person.

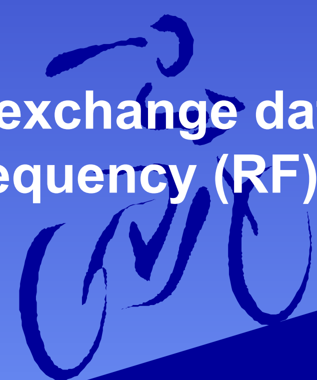
- This system is composed of two distinct parts: the implant and an external controller.

- The implant is lodged in the visual cortex and wirelessly receives data and energy from the external controller.

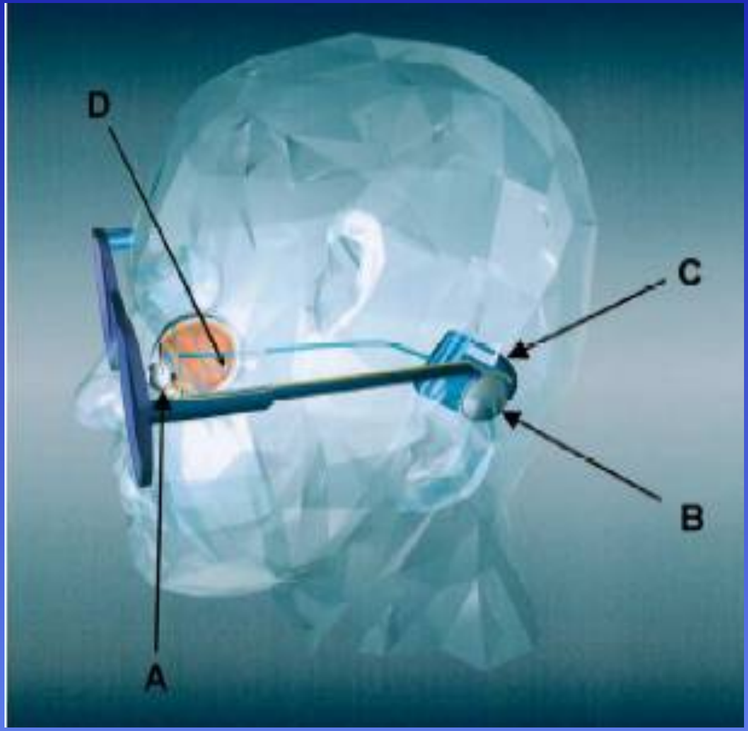
- It contains all the circuits necessary to generate the electrical stimuli and to monitor the changing *microelectrode/biological tissue interface.*

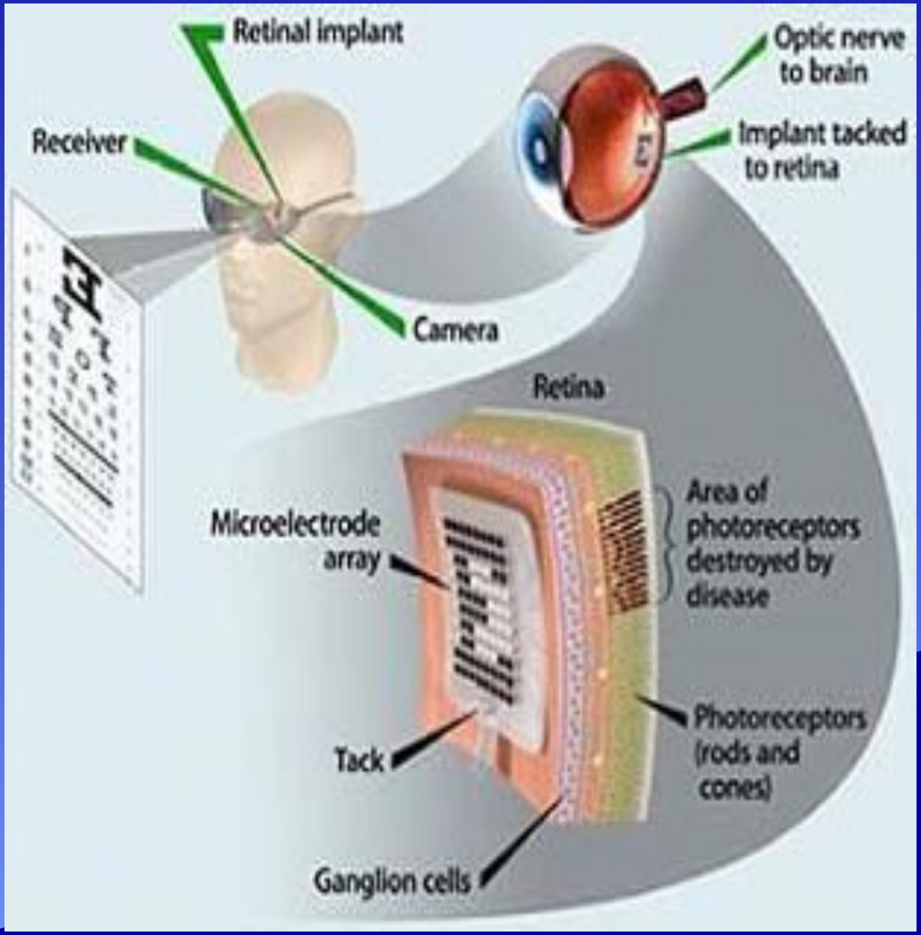
- The battery-operated outer controller consists of a micro-camera, which captures images, as well as a processor and a command generator, which process the imaging data to translate the captured images and generate and manage the electrical stimulation process.

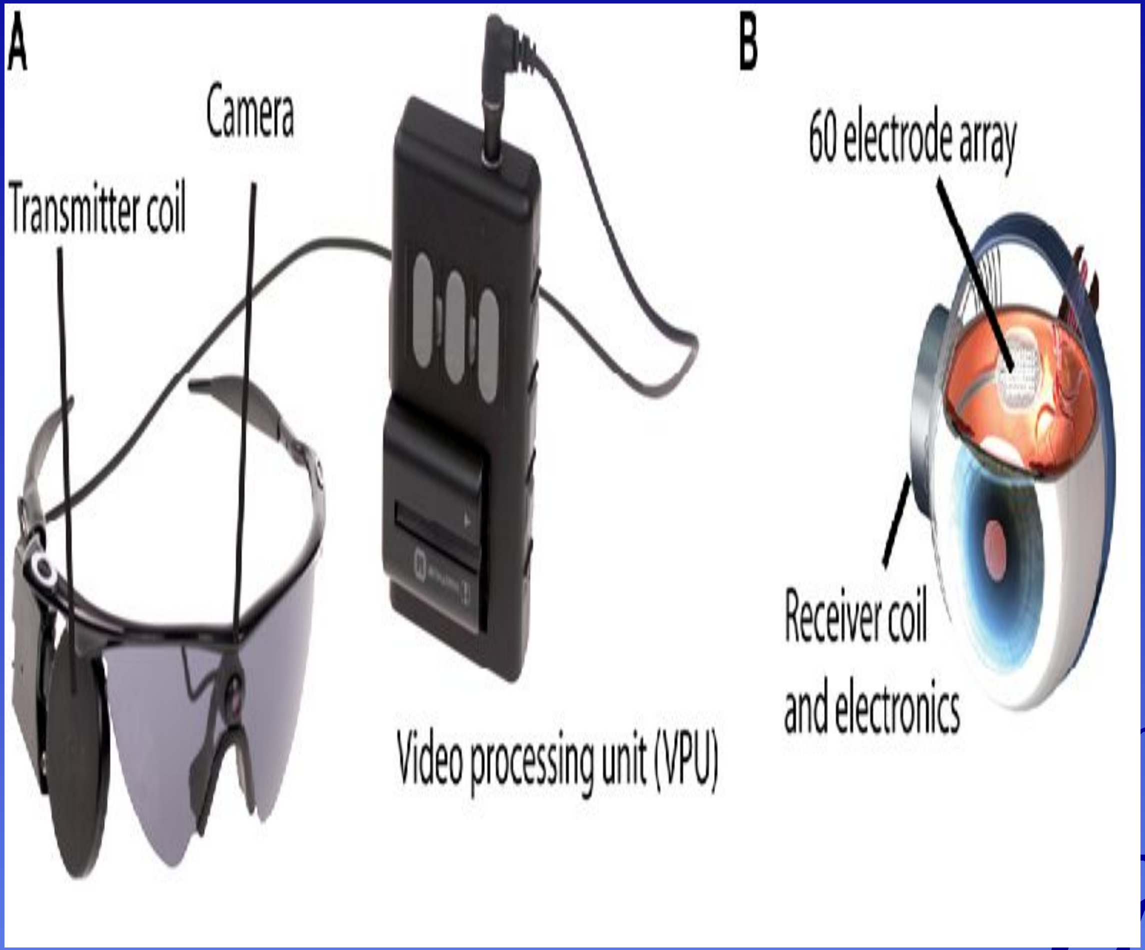
- The external controller and the implant exchange data in both directions by a transcutaneous radio frequency (RF) link, which also powers the implant.



Retinal Prosthesis






A
Camera
Transmitter coil
Video processing unit (VPU)
B
60 electrode array
Receiver coil
and electronics

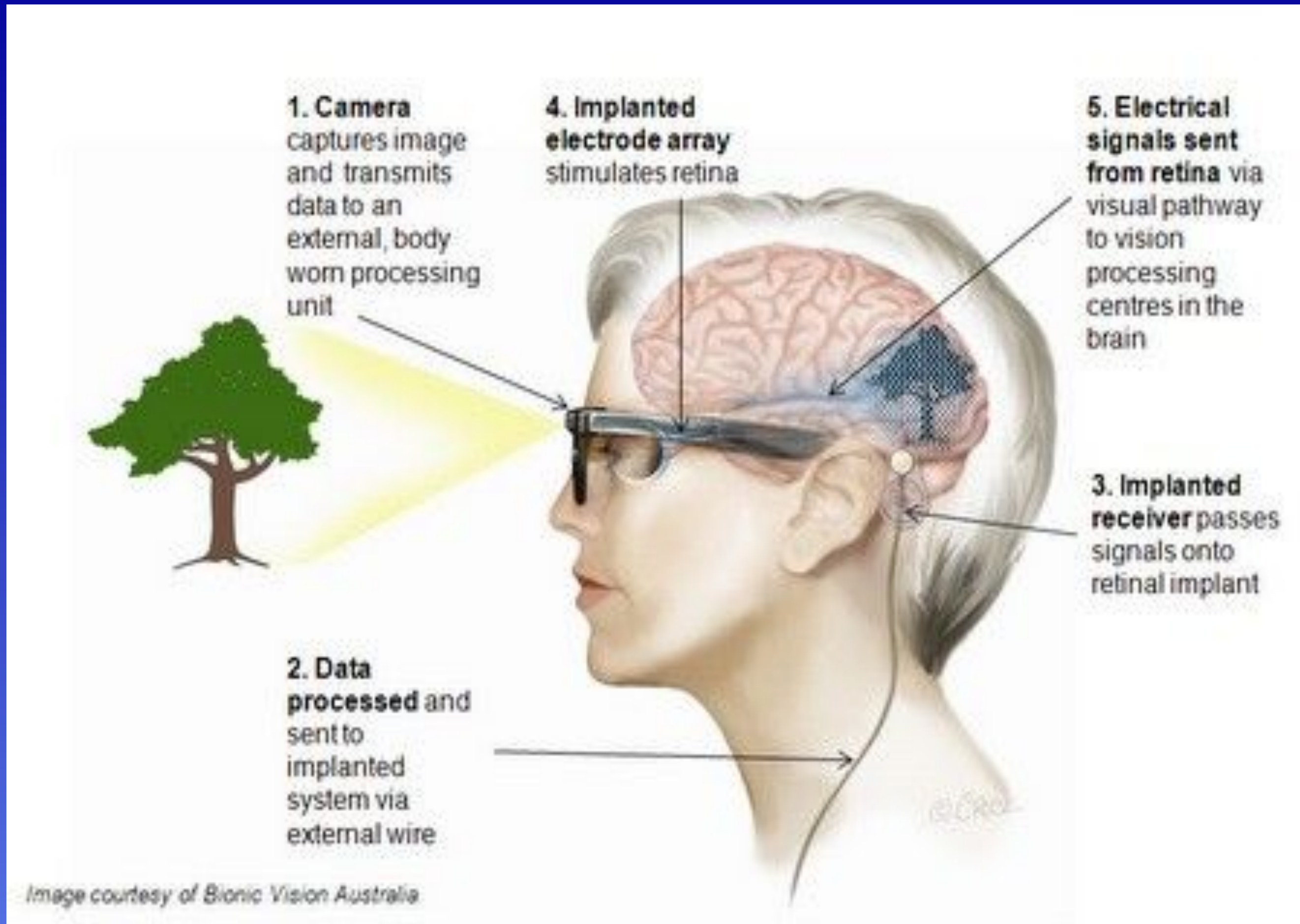
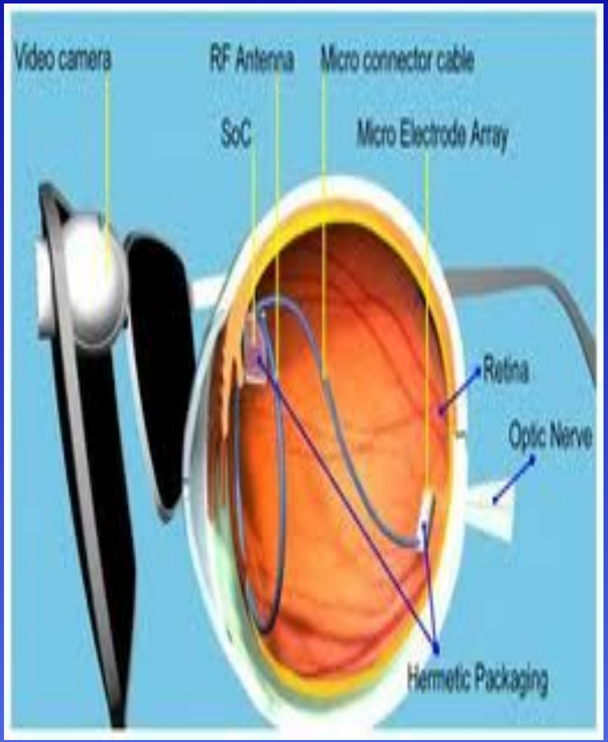
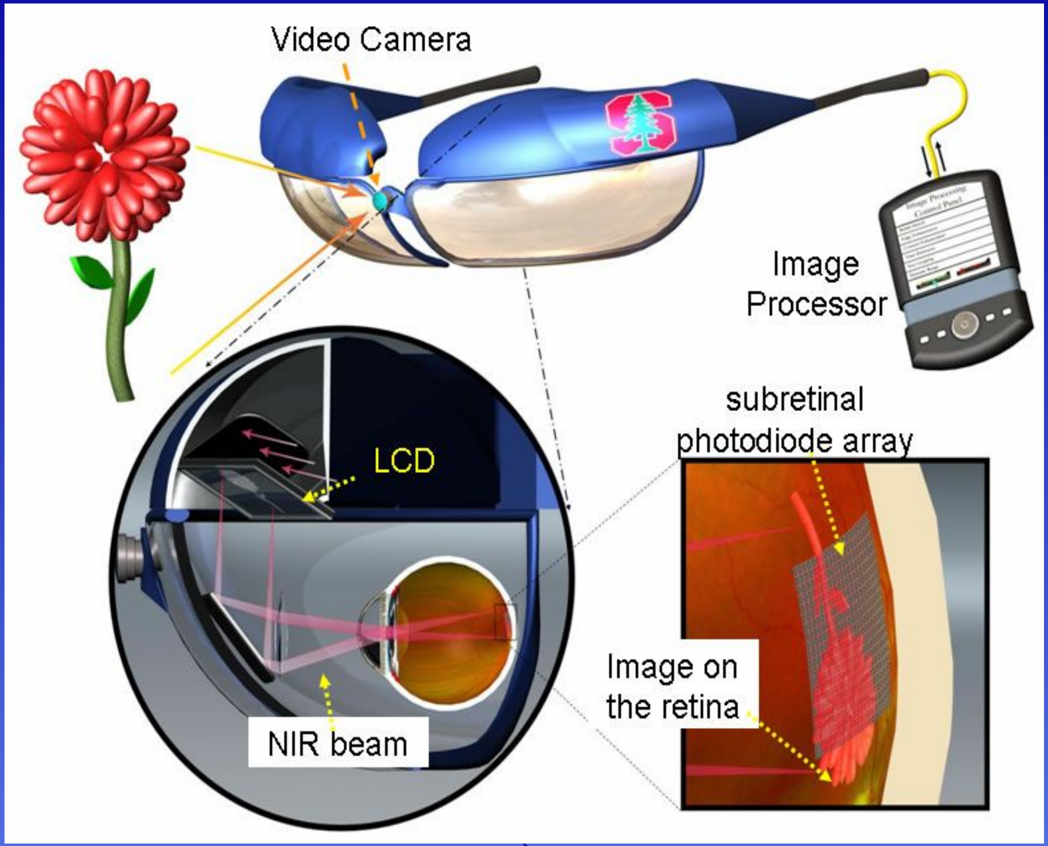


Image courtesy of Bionic Vision Australia


Video camera
RF Antenna
Micro connector cable
SoC
Micro Electrode Array
Retina
Optic Nerve
Hermetic Packaging


Video Camera
Image
Processor
subretinal
photodiode array
LCD
Image on
the retina
NIR beam

THANK YOU FOR YOUR ATTENTION