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Electronic Instrumentation

Chapter 6

Introduction to Biomedical Instrumentation

Chapter 6. Introduction to Biomedical Instrumentation

- Introduction
- Biopotentials and their measurement.
- Measurement of Blood Pressure and Sound
- Measurement of Flow and Volume of Blood
- Examples of Non-invasive Tests using ultrasound and Photon Radiation (excluding Imaging)

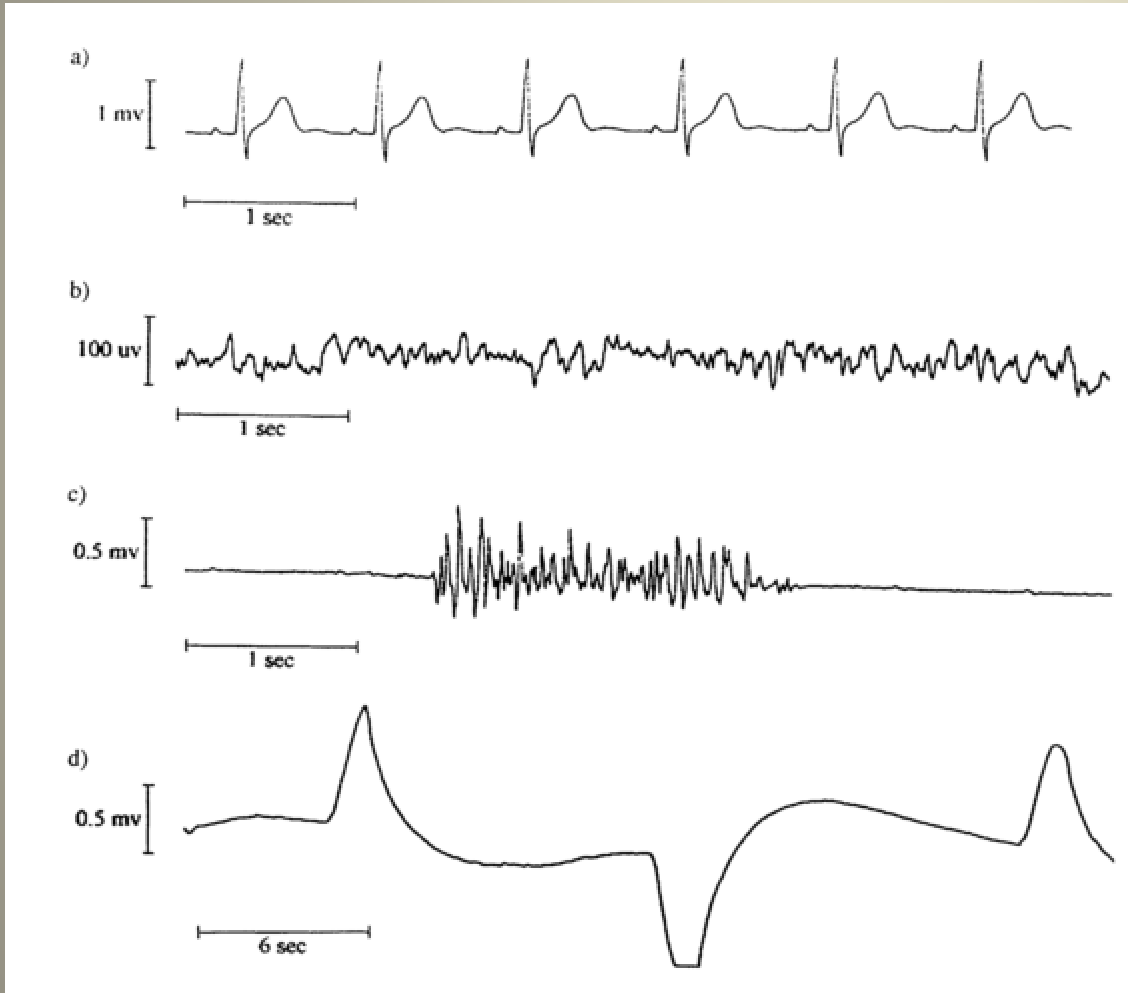
Introduction

- In this chapter we will introduce the principles associated to some measurements of interest in the biomedical Field.
- We will focus mainly on non-invasive techniques, as those are closer to the contents already covered in previous chapters.
- Medical Imaging systems are deliberately omitted as they are presented in other courses and the systems and signal processing strategies involved are far from this course’s objectives.
- IMPORTANT: This chapter presents only SOME of the typical medical instrumentation systems currently under use. It is not our objective to cover ALL the sensors and instrumentation systems currently being used, and the enumeration that follows isn’t by any means complete.

Biopotentials and their Measurements

- Biopotentials are electric fields associated to the electrochemical activity of a certain class of cells and give information of the activity of the organs they are part of.
- These potentials are given names according to their sources: Electrocardiogram (ECG or EKG, heart), Electroencephalogram (EEG, brain), Electromyogram (EMG, muscles) or Electrooculogram (EOG , eye).
- Measurement of biopotentials are nowadays critical in medical diagnostic as these electrical signals from the body can provide vital clues as to normal or pathological functions of the organs.

Biopotentials. Examples



ECG: Normal Sinus Rhythm

EEG: Normal Patient

EMG: Biceps flexion

EOG: Eye movement

Biopotentials. Characteristics

- Small amplitude signals (10 μV to 10 mV)
- Low frequency range.
- Difficult acquisition:
  - Presence of Biological Interference (electrode motion, skin,…)
  - Noise from environmental sources (power line, radiation from other equipment)

Source	Amplitude (mV)	BW (Hz)	Measurement error source	Amplifier Design	Aditional Features
ECG	1-5	0.05-100	Motion Artifact Powerline 50/60 Hz	Moderate Gain, BW, noise, CMRR,input Z	Safety, Isolation, Defibrillation protection
EEG	0.001-0.01	0.5-40	Johnson noise Powerline 50/60 Hz	High gain, very low noise	Safety, Isolation, low electrode-skin resistance
EMG	1-20	20-2000	Powerline 50/60 Hz	Higher BW	Post acquisition data processing
EOG	0.01-0.1	DC-10	Skin potential motion	DC and low frequency drift	Artifact Reduction, electrode-skin potential

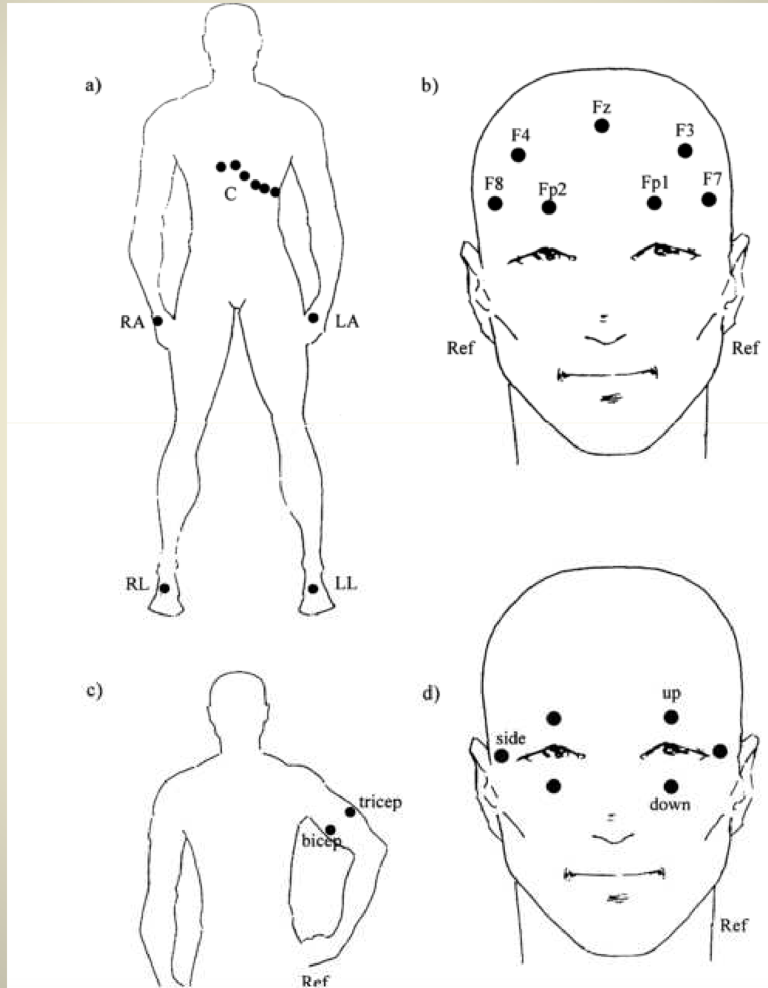
Biopotentials. Measurement.

- Electrode placement
- Electrodes for signal acquisition
  - Silver-silver chloride Electrodes
  - Gold Electrodes
  - Conductive polymer Electrodes
  - …
- Amplifier
  - Instrumentation Amplifier with high CMRR
  - Defibrillation protection (ECG)
  - Electrical Interference reduction
  - Electrical Isolation
  - Artifact Reduction

Electrode placement

ECG

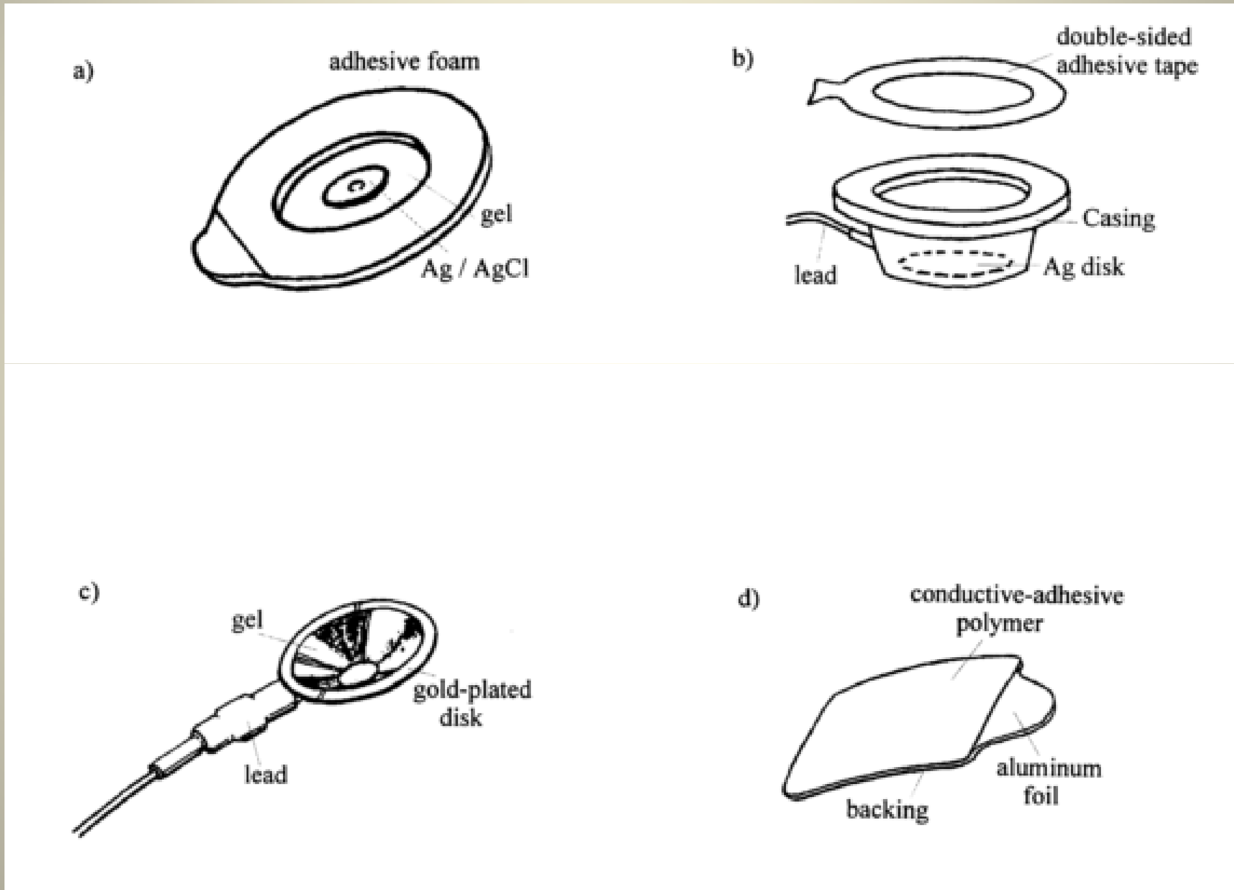
EEG



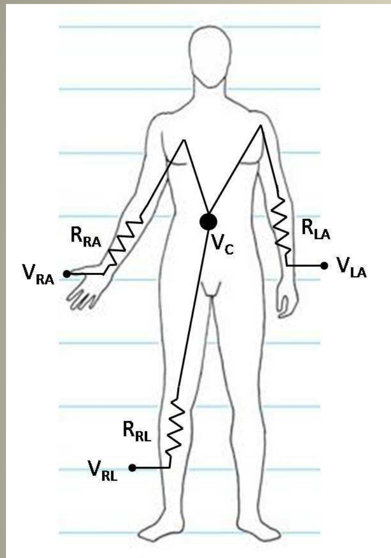
EMG

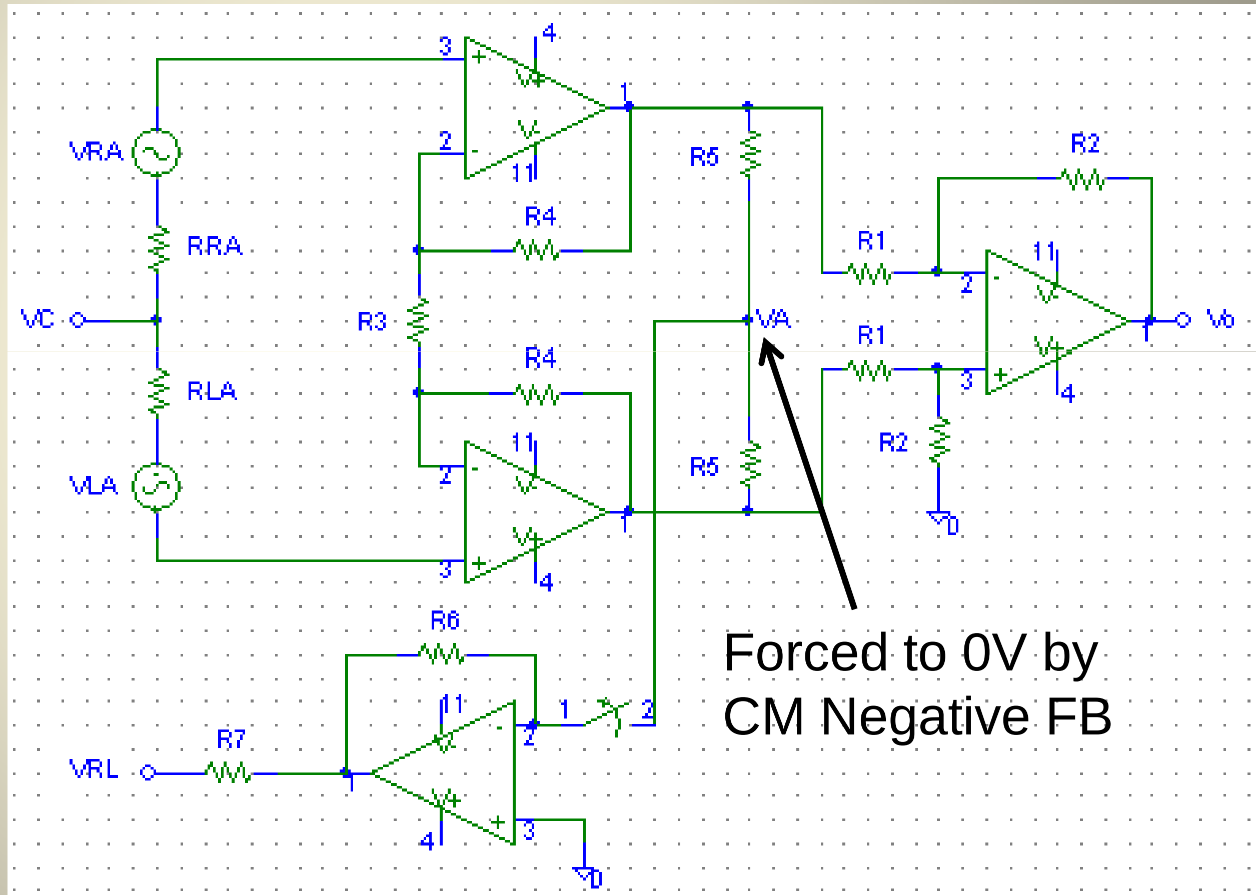
EOG

Electrode Types



ECG Measurement





Simplified schematic of a driven-leg ECG amplifier

Measurement of Blood Pressure and Sound

- Determining blood pressure is a standard clinical measurement.
  - Direct Measurements (invasive): Use of catheters (both liquid-filled or with a pressure sensor in the tip)
  - Indirect systems (non-invasive): Sphygmanometer, ultrasonic, tonometry.
- Heart Sounds: Gives information about the functional integrity of the heart. These sounds are associated to the acceleration or deceleration of blood (variations in pressure) in the different heart vessels.

Direct Measurements

- Types:
  - Extravascular sensors (A catheter couples a flush solution through a disposable pressure sensor to the sensing port).
  - Intravascular sensors: Different solutions for catheter-tip sensors: strain gauges, or even fiber optic.
- Requirements
  - Bandwidth
  - Range
  - …

Indirect Measurements

- Types:
    - Sphygmomanometer: Inflatable cuff for blood vessel occlusion (typical, manual method).
    - Ultrasonic: Use of a transcutaneous doppler sensor that detects the motion of the blodd-vessel walls in various states of occlusion.
    - Tonometry: Typically used to measure the intra-ocular pressure using a force-balance technique (pressure needed to flatten a specific optically determined area)

Heart Sounds

- Heart sounds give a valuable information about the functional integrity of the heart and even more can be obtained through comparison with the ECG.
  - Auscultation: Use of stethoscopes to couple the sounds from the chest wall to the human ear. Sounds must be interpreted by the physician.
  - Phonocardiography: Recording of the heart sounds and murmurs that eliminates the subjective interpretation of the sounds.

Typical Diagnostic Problem

Interest on the acquisition of O_2 and other nutrients in the cells (Difficult)

Use instead (second-class measurement) →

Blood flow and changes in blood volume (correlates with former). Also Difficult.

Use instead (Third-class measurement) ↓

Blood Pressure (correlates with blood flow)

← Use instead (Fourth-class measurement)

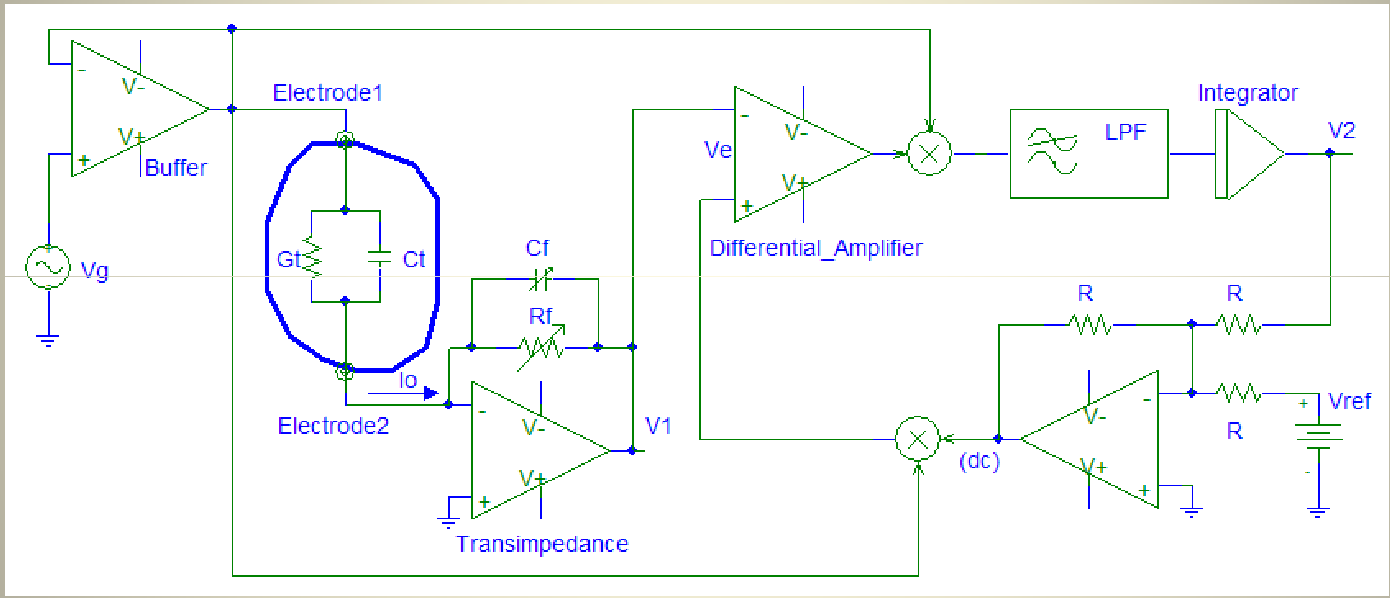
ECG (correlates with blood pressure)

Measurement of Flow and Volume of Blood

- Electromagnetic flowmeters
- Ultrasonic flowmeters
- Thermal-convection velocity sensors
- Plethysmography
  - Chamber Plethysmography
  - Electrical Impedance Plethysmography
  - Photoplethysmography (Lab Project #3)

Example

- Impedance plethysmography in monitoring the breathing of newborns



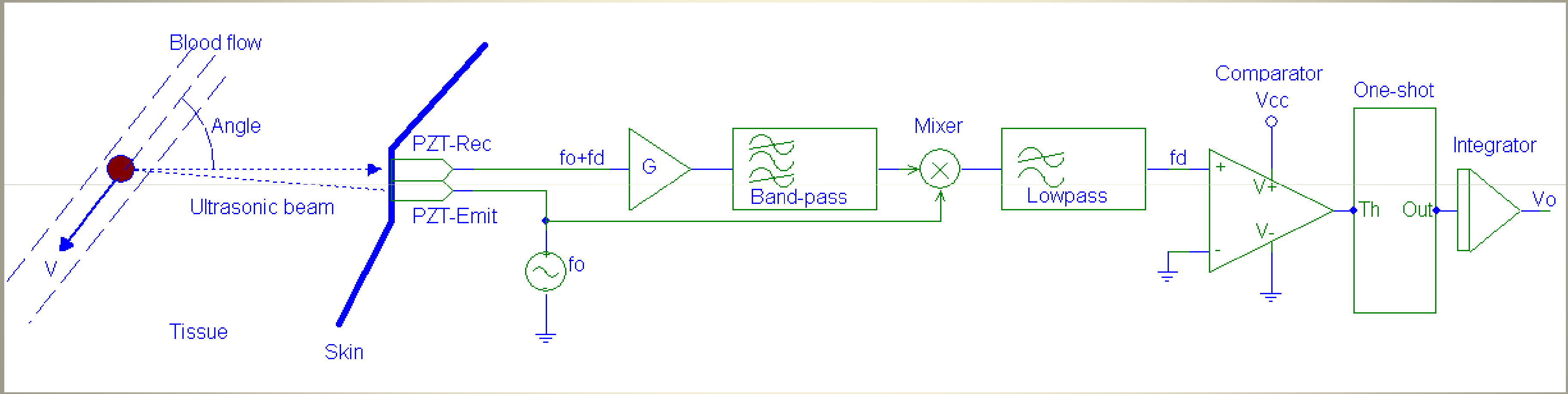
The breast volume is proportional to the conductivity measurement Gt made by an excitation voltage Vg across two electrodes and the corresponding current reading Io conditioned with a transimpedance amplifier.

Non-invasive Tests using ultrasound.

- As we have seen ultrasound techniques are widely applied in biomedical instrumentation, best associated with its ability to image internal structures of the body. However is also well suited for applications where the phase and frequency of the reflected sound is used to measure other parameters:
  - Doppler velocimetry
  - No-Touch ocular pulse measurement
  - Glucose concentration
  - ……

Example

- Ultrasonic Doppler system for blood flow measurements



$$f_D = f_0 \frac{2V\cos(\theta)}{c}$$

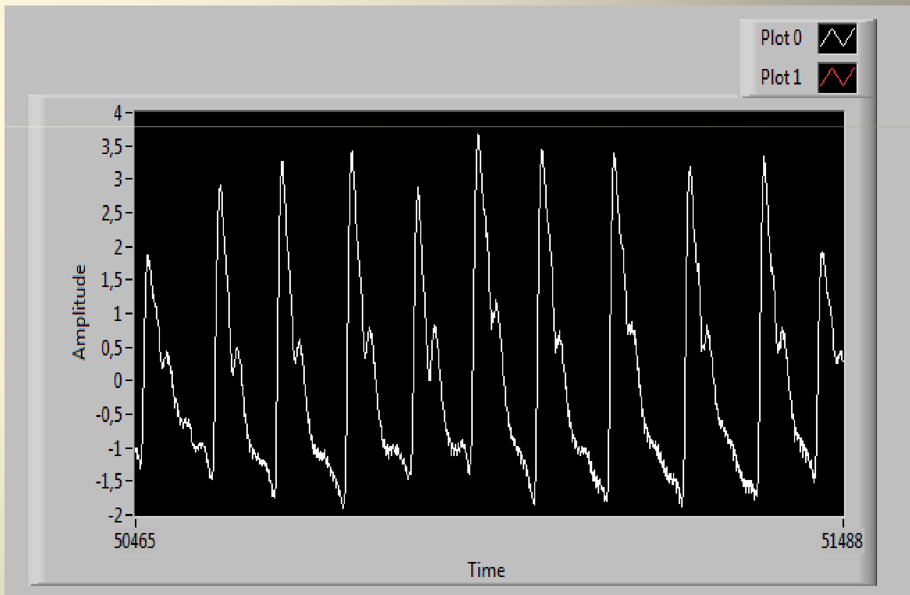
Non-invasive Tests using Photon Radiation

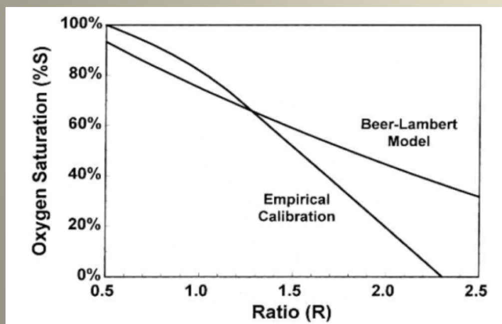
- Photon radiation (between Microwaves to gamma radiation) are of great use in medical imaging systems (X –rays, PET, ODT, …) However, reflected, absorbed and scattered photons can give further information:
  - Bone density analysis (X-rays)
  - Tissue fluorescence
  - Interferometry to measure nanometer displacements of body surfaces
  - Laser Doppler velocimetry
  - IR spectroscopy
  - Pulse oxymetry
  - …

Example

- Pulse Oximetry

- Use of two wavelengths
- Heart beat Rate and Oxygen Saturation Provided





$$R = \frac{\log\left(I_{AC}(\lambda_1)\right)}{\log\left(I_{AC}(\lambda_2)\right)}$$

Summary

- In this module we have introduced the principles associated to some measurements of interest in the biomedical Field.
- Biopotentials are a primary source for vital information as to normal or pathological functions of the organs. They measurement involved high CMRR instrumentation amplifiers as well as noise/interference reduction techniques.
- Blood Pressure and Blood flow are also magnitudes that give a lot of information for medical diagnosis. The invasive nature of some of these techniques put some problems in their utilization (use of second class or third class measurements)
- Ultrasound and photon radiation are also or great use in medical diagnosis besides their imaging applications.