

# Design your own bioimpedance meter

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<https://clabio.tec.br/>

REALIZAÇÃO



APOIO



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núcleo de Ingeniería biomédica

PATROCÍNIO



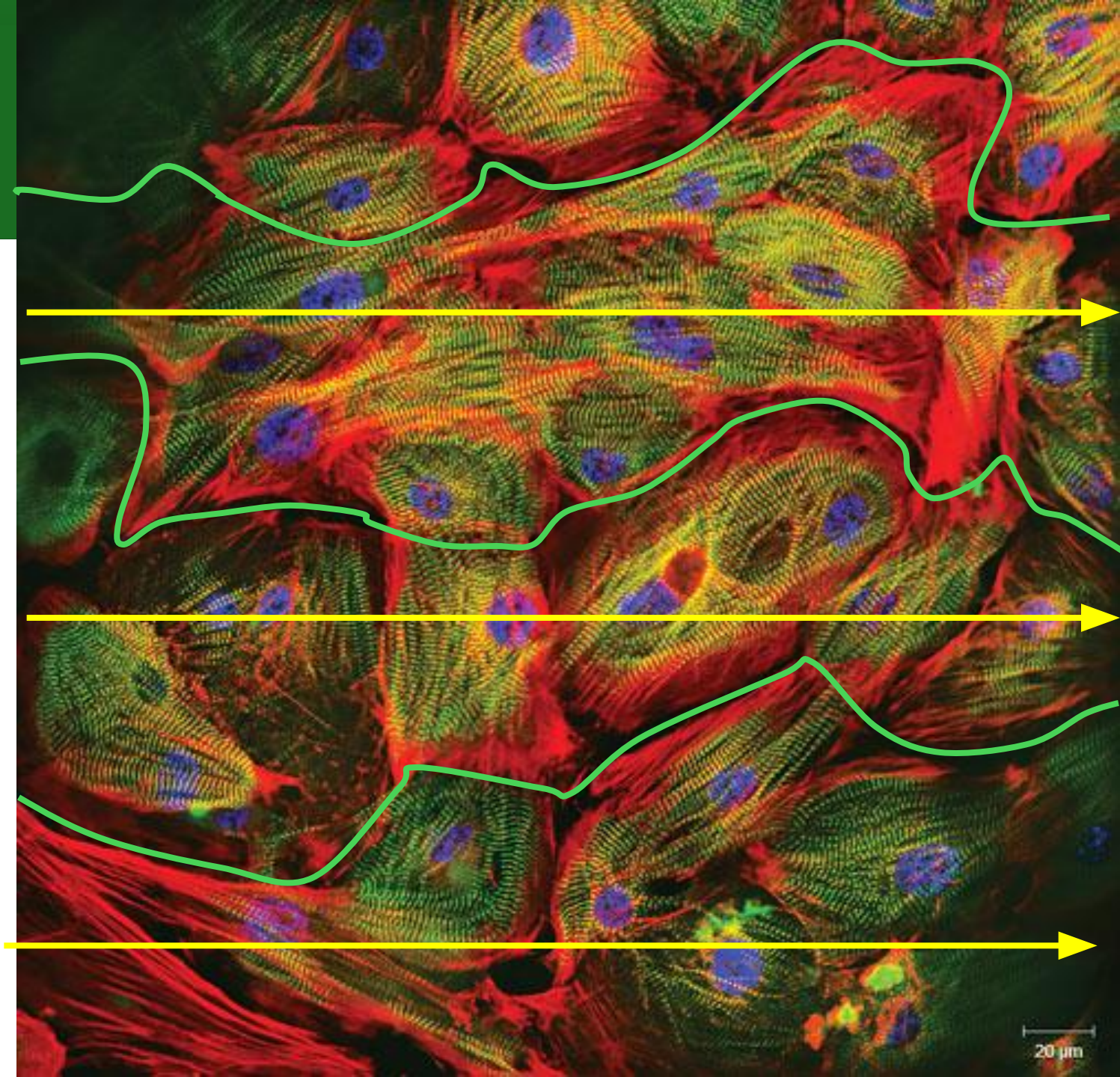
IFMBE



ABEE-SC



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# CONTENTS



## □ Choosing your application

- ✓ Frequency range; Measuring sensor

## □ Is it a real time monitoring/analysis?

- ✓ Yes; No

## □ Do we need modulus and phase?

- ✓ Discrete elements; Integrated elements

## □ Is calibration important?

- ✓ By firmware; By hardware

## □ Are you collecting in-vivo data?

- ✓ Safe; Isolation techniques

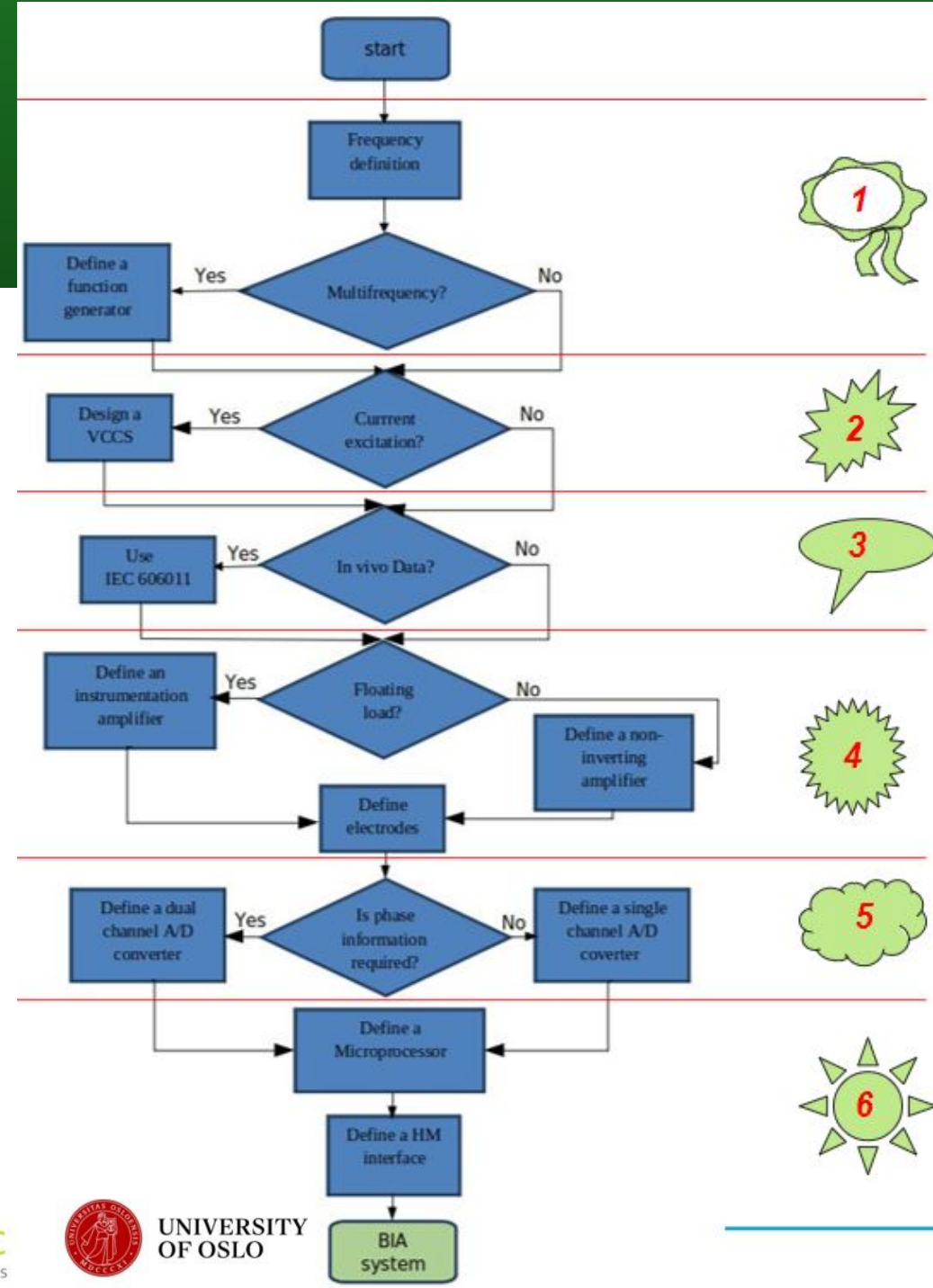
## □ Does size and portability matter?

- ✓ In loco collection; Power consumption



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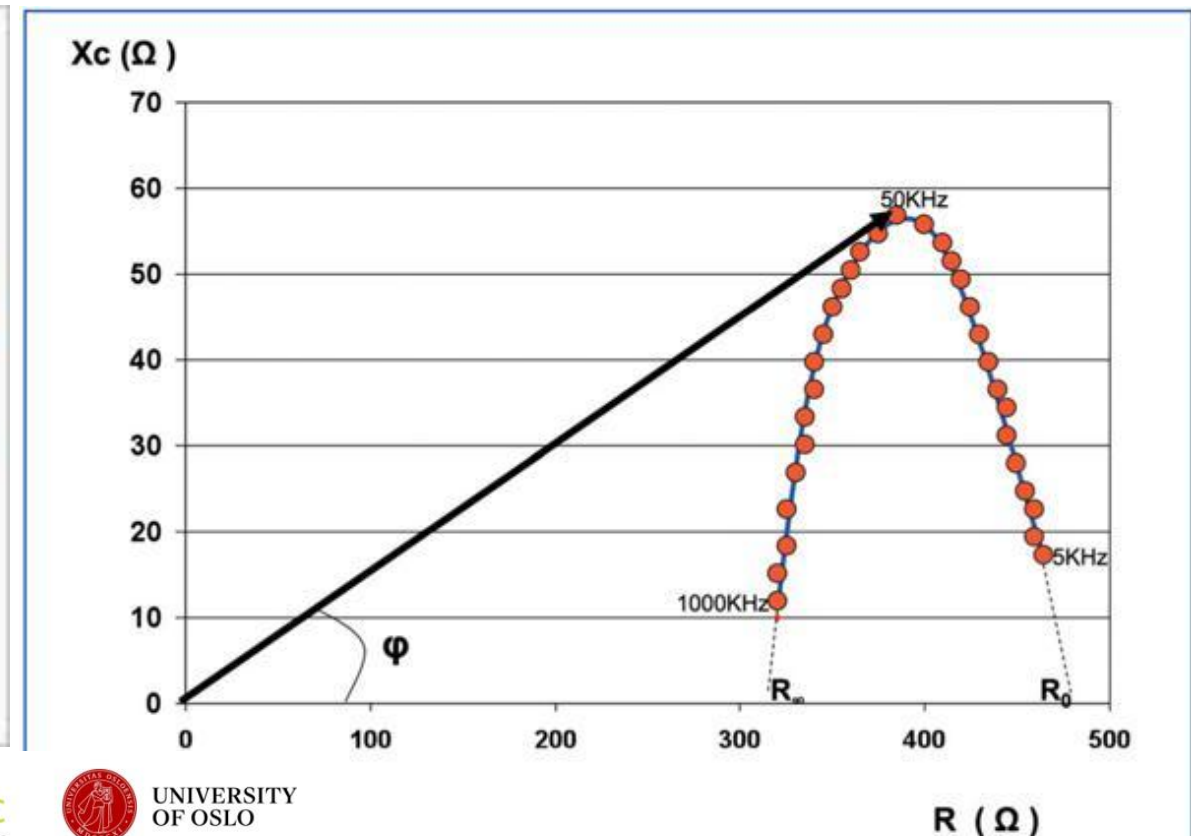
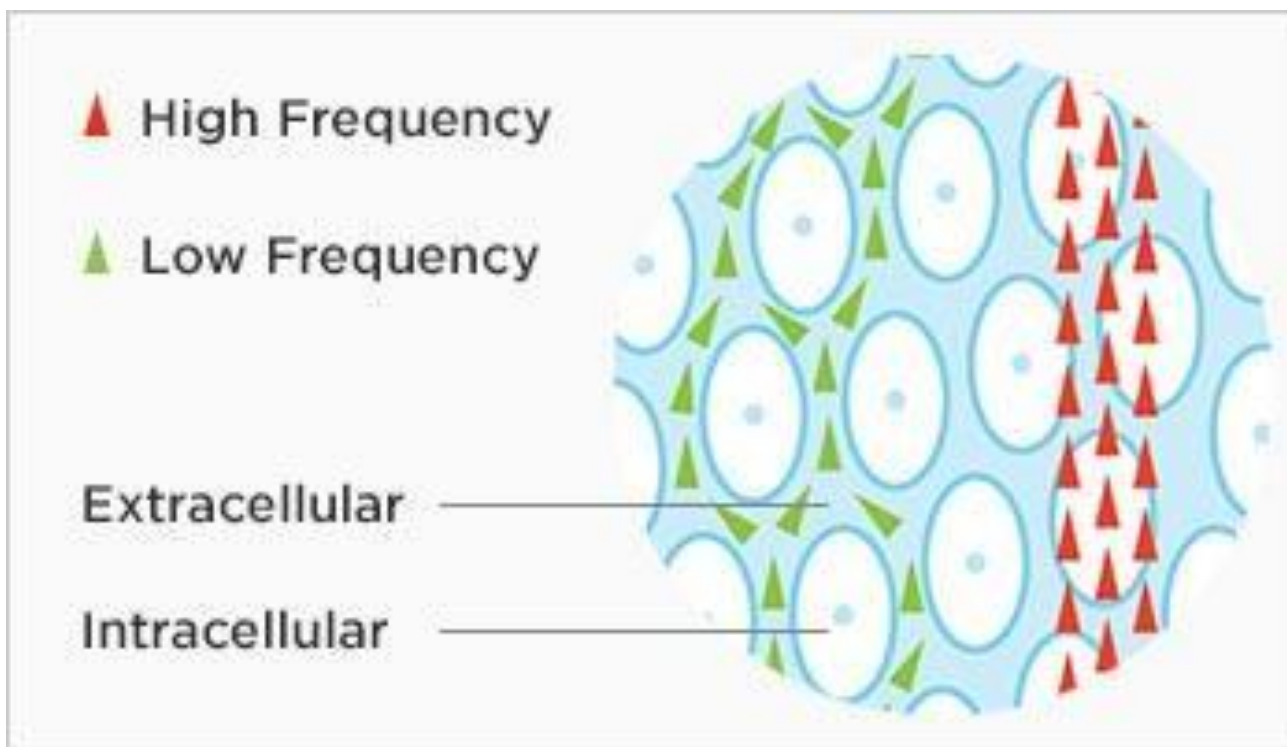
# Bioimpedance meter



# Choosing your application

## Bioimpedance meter

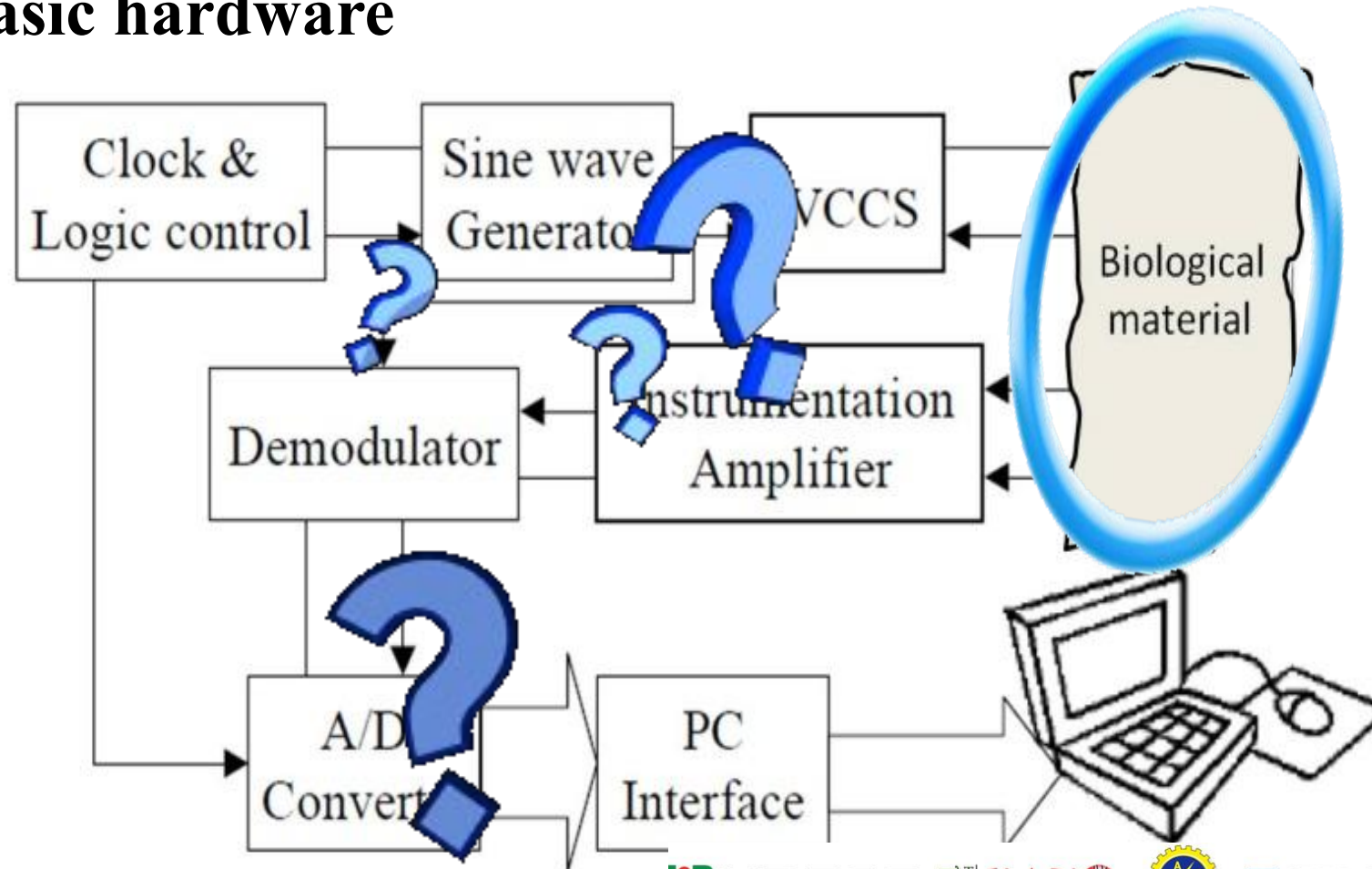
### Why impedance spectra?



# Choosing your application

## Bioimpedance Meter

### Basic hardware



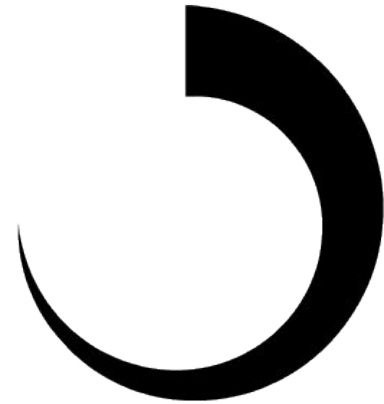
# Choosing your application

## Bioimpedance Meter



### □ Medicine / Biology / Industry?

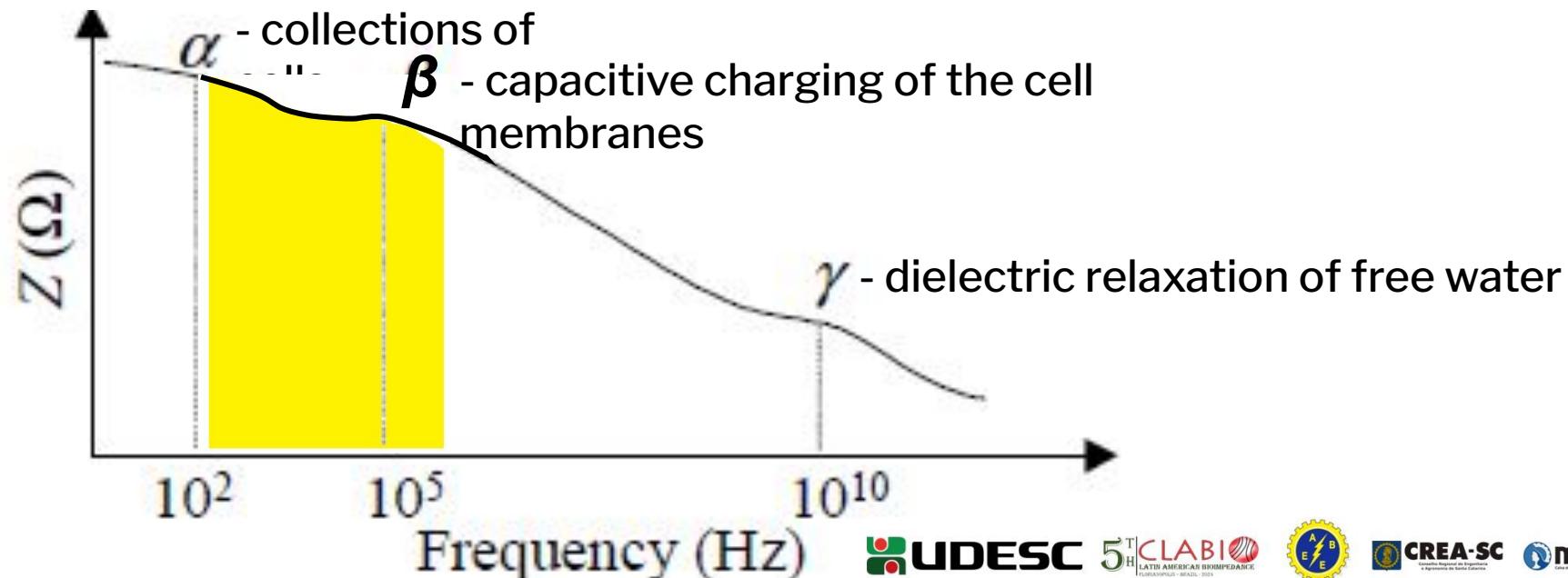
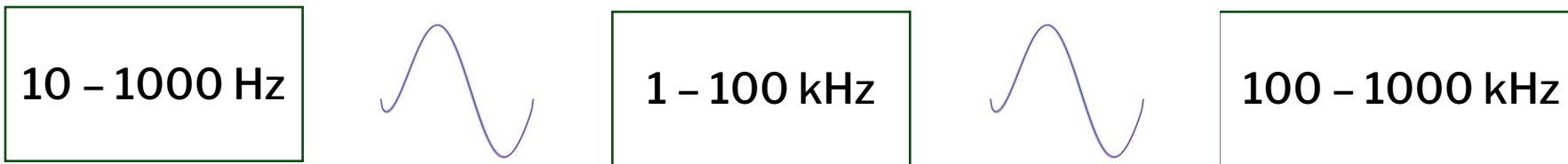
- ✓ Skin water content
- ✓ Body composition (training, nutrition)
- ✓ Impedance Cardiography (ICG)
- ✓ Cardiac Output monitoring
- ✓ Ablation monitoring
- ✓ Blood volume
- ✓ CO<sub>2</sub> catheter transducer
- ✓ Bacteria detection
- ✓ Tissue characterization
- ✓ Quality of milk
- ✓ Beef maturation
- ✓ Lung ventilation monitoring
- ✓ Preterm labour prognosis
- ✓ Cancer diagnosis



# Choosing your application

## Bioimpedance Meter

### □ Frequency range?

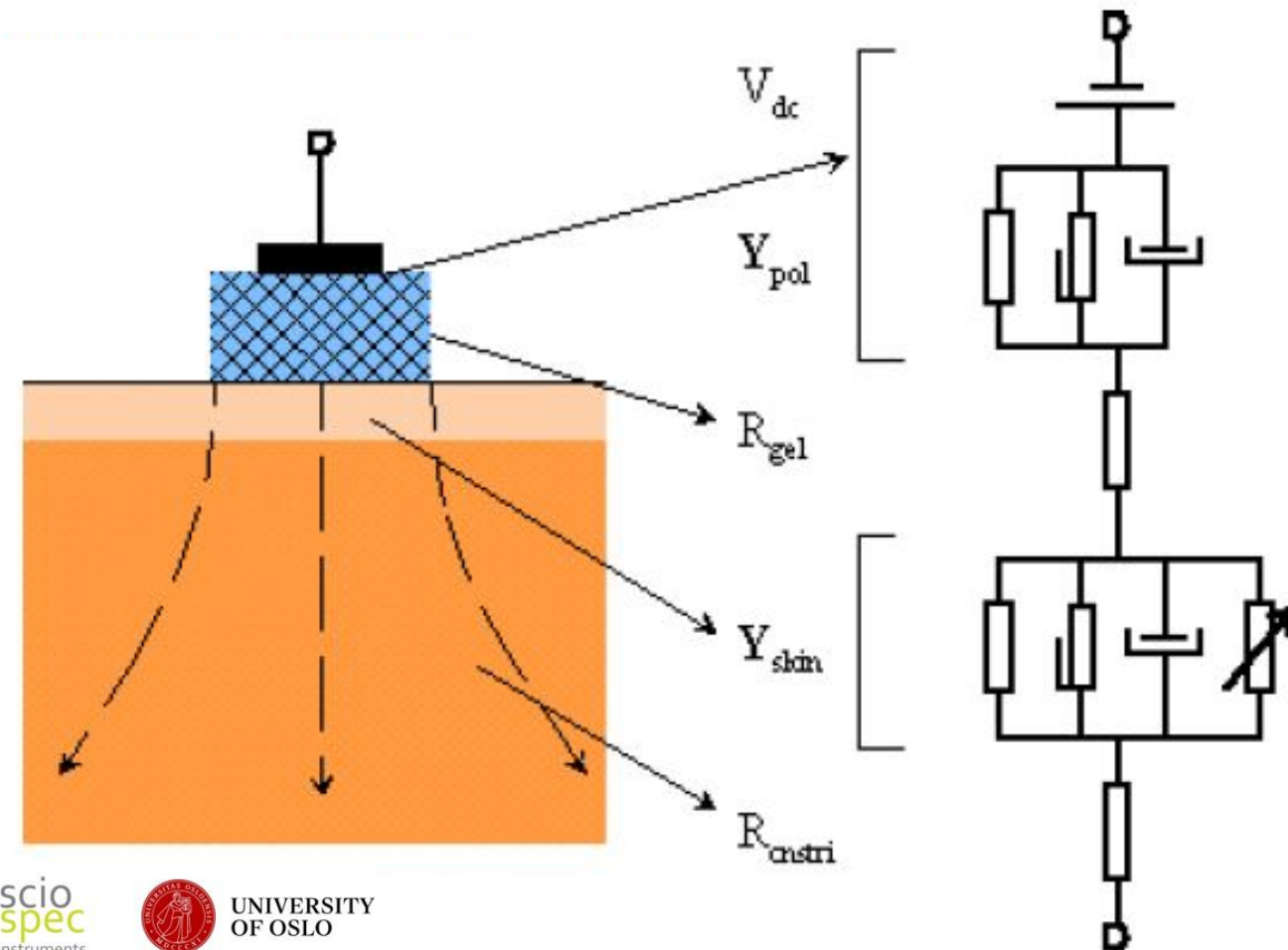


# Choosing your application

## Bioimpedance Meter

### □ Measuring sensor type?

- Electrode polarization is an important issue in IS

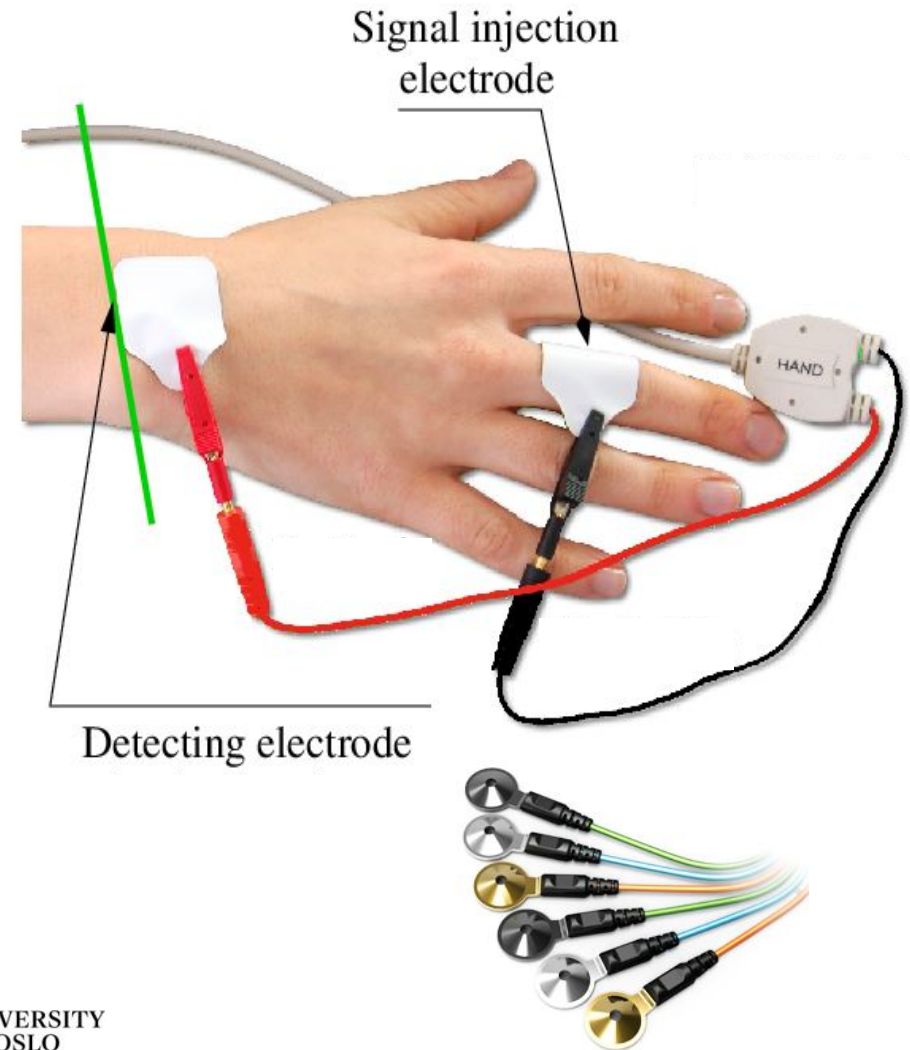




### □ Measuring sensor type?

□ Electrode polarization is an important issue in IS

- ✓ Biosignal electrodes
- ✓ Metal electrodes
- ✓ Single electrode
- ✓ Needle electrode
- ✓ Array of electrodes
- ✓ Impedance probe

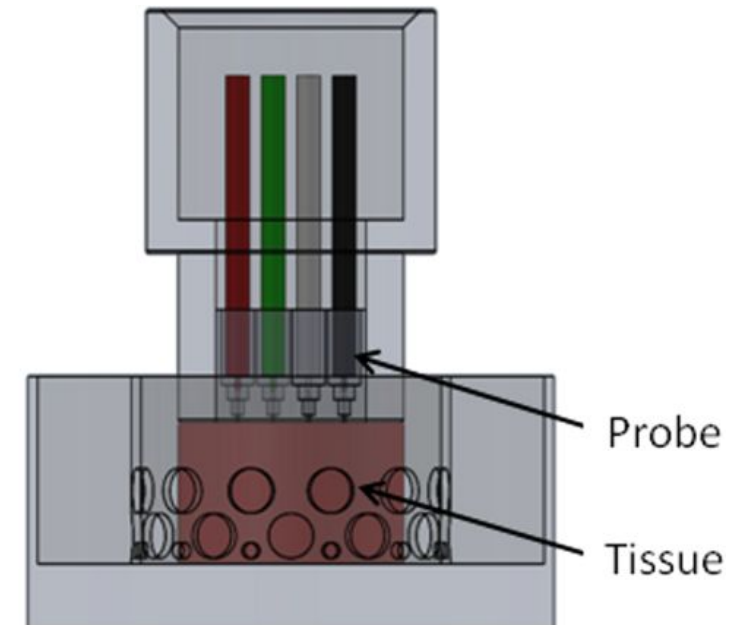
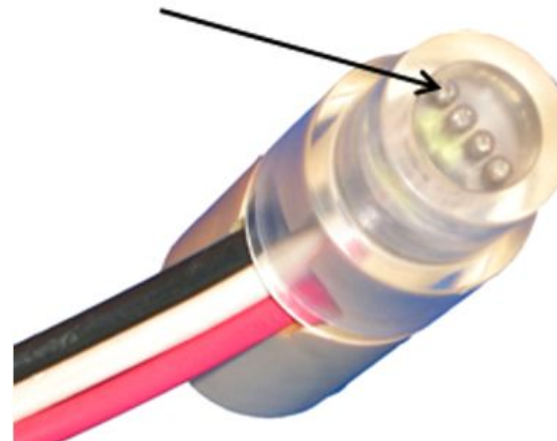


### □ Measuring sensor type?

□ Electrode polarization is an important issue in IS

- ✓ Biosignal electrodes
- ✓ Metal electrodes
- ✓ Single electrode
- ✓ Needle electrode
- ✓ Array of electrodes
- ✓ Impedance probe

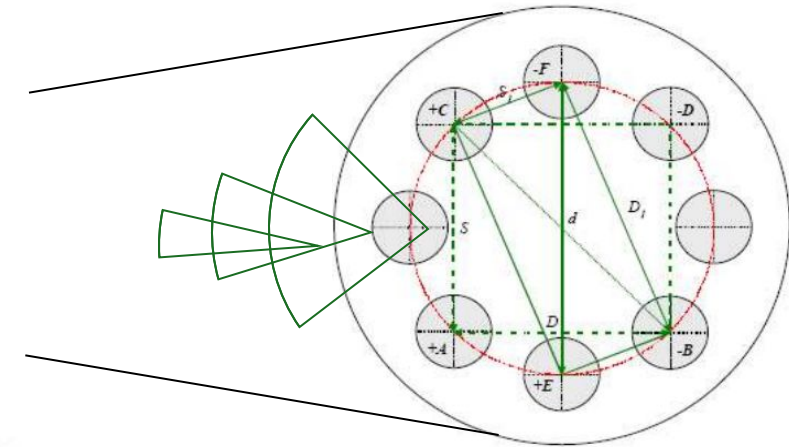
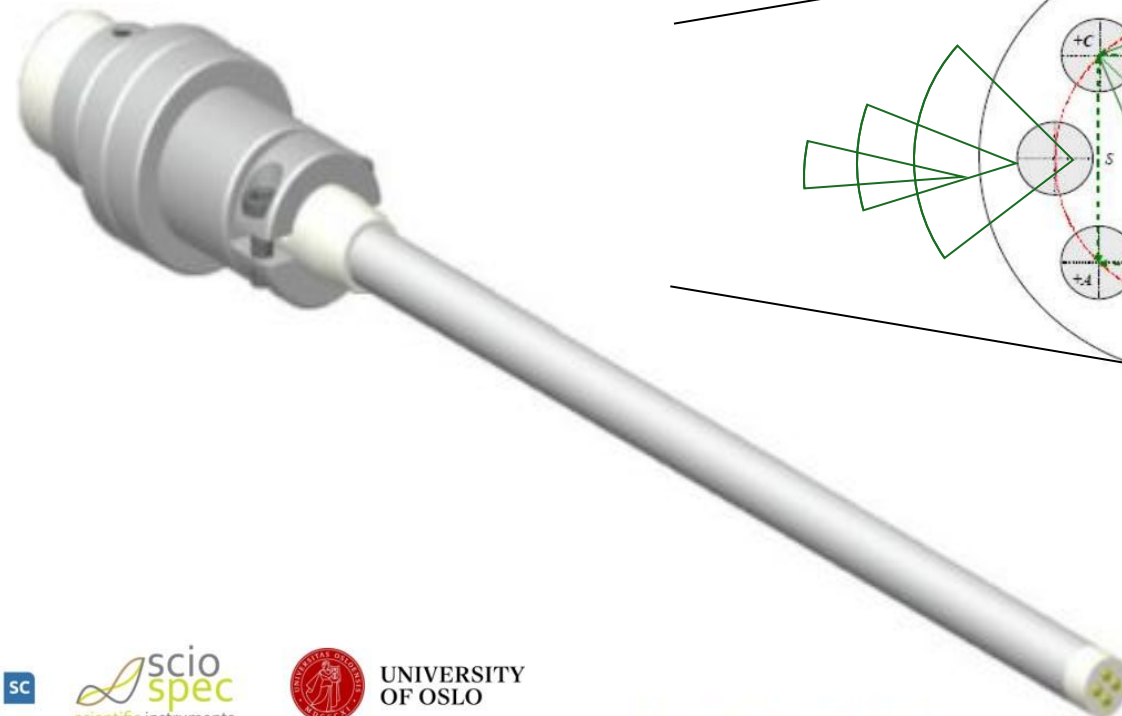
Bioimpedance Electrodes



### □ Measuring sensor type?

□ Electrode polarization is an important issue in IS

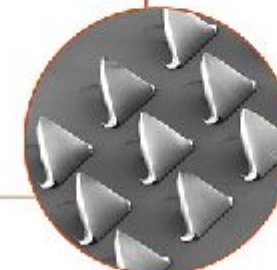
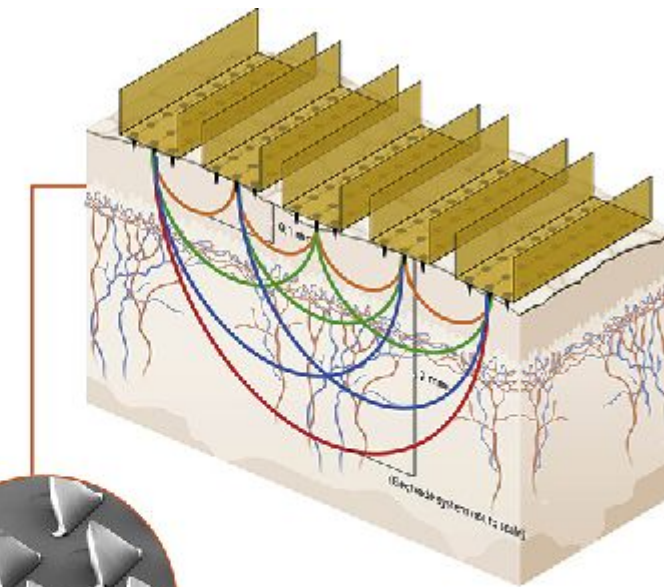
- ✓ Biosignal electrodes
- ✓ Metal electrodes
- ✓ Single electrode
- ✓ Needle electrode
- ✓ Array of electrodes
- ✓ Impedance probe



### □ Measuring sensor type?

□ Electrode polarization is an important issue in IS

- ✓ Biosignal electrodes
- ✓ Metal electrodes
- ✓ Single electrode
- ✓ Needle electrode
- ✓ Array of electrodes
- ✓ Impedance probe

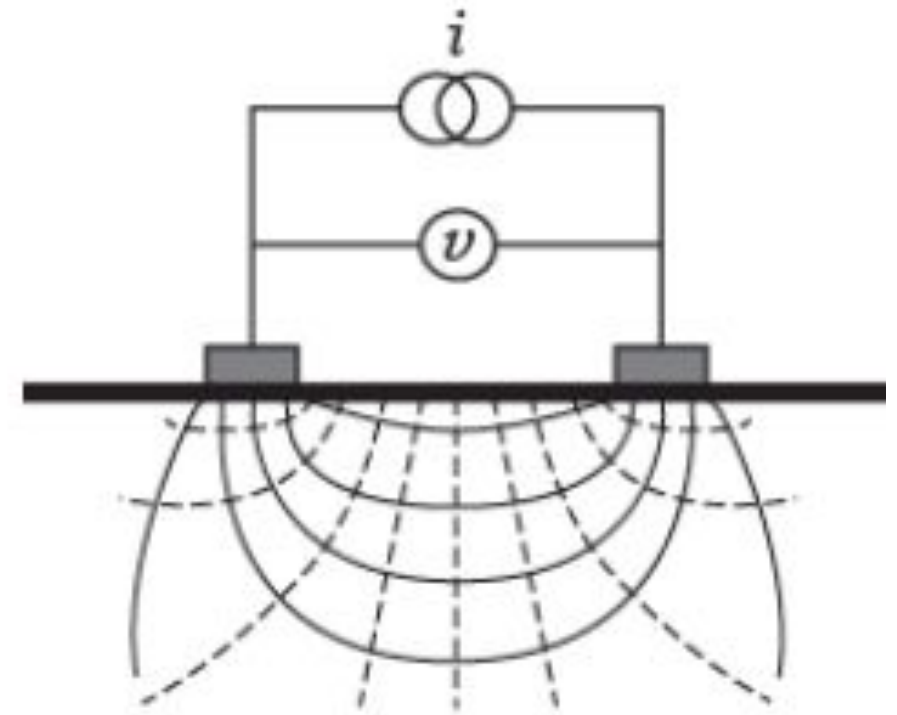
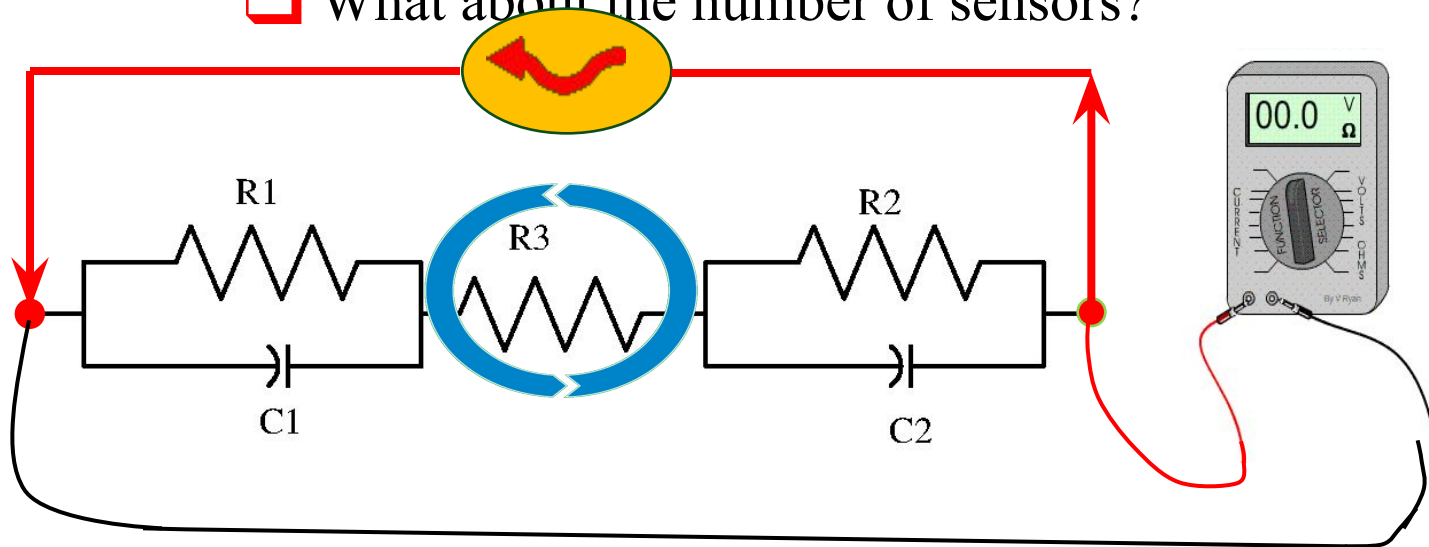


# Choosing your application

## Bioimpedance Meter

### □ Measuring sensor type?

### □ What about the number of sensors?

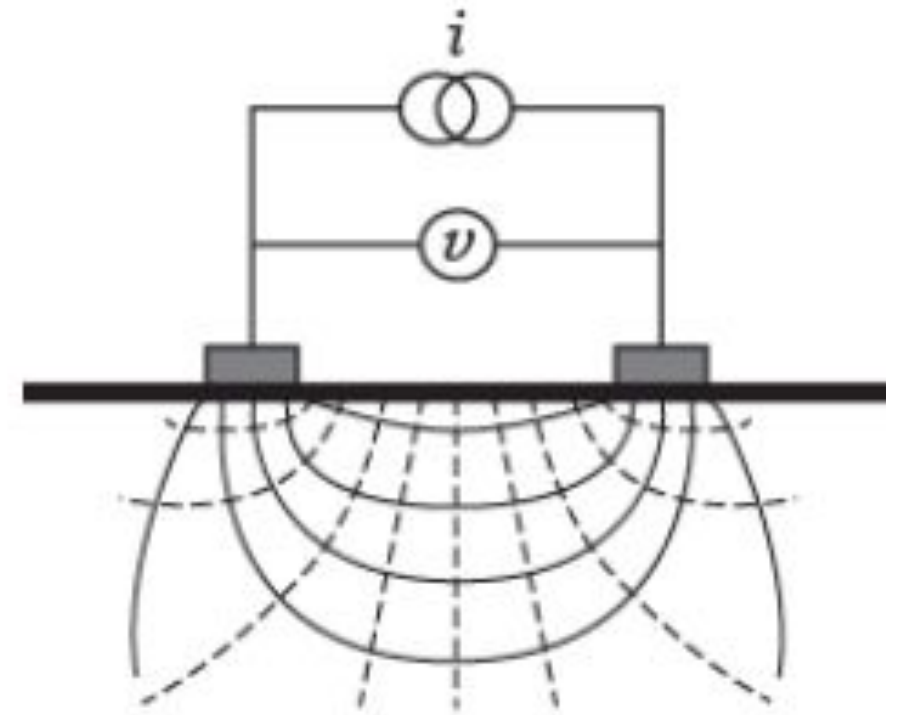
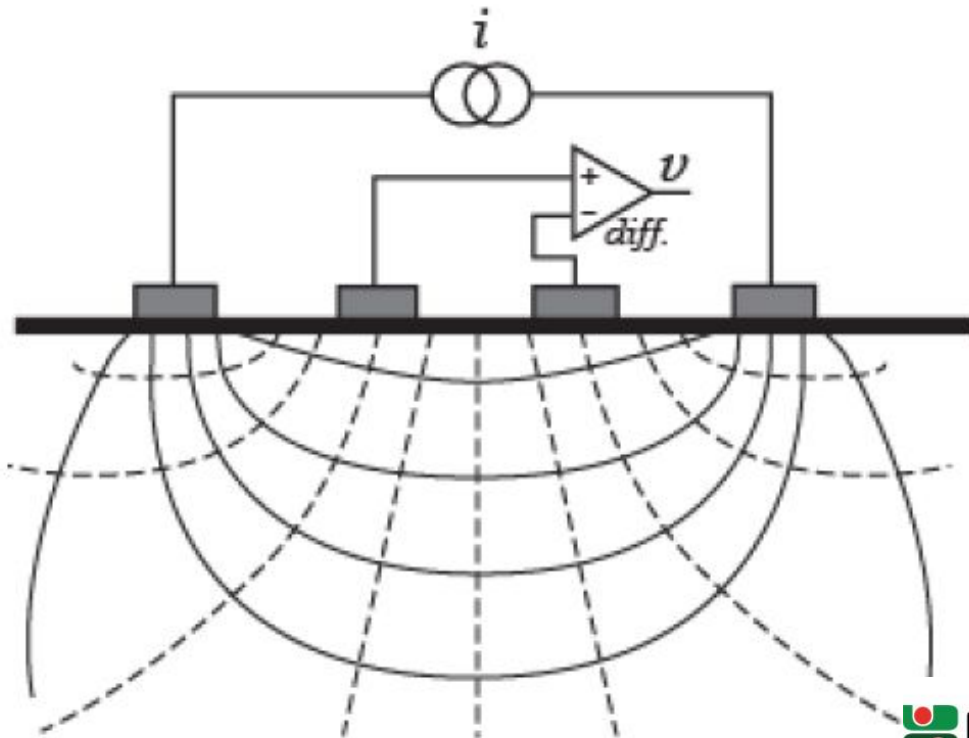


# Choosing your application

## Bioimpedance Meter

Measuring sensor type?

What about the number of sensors?

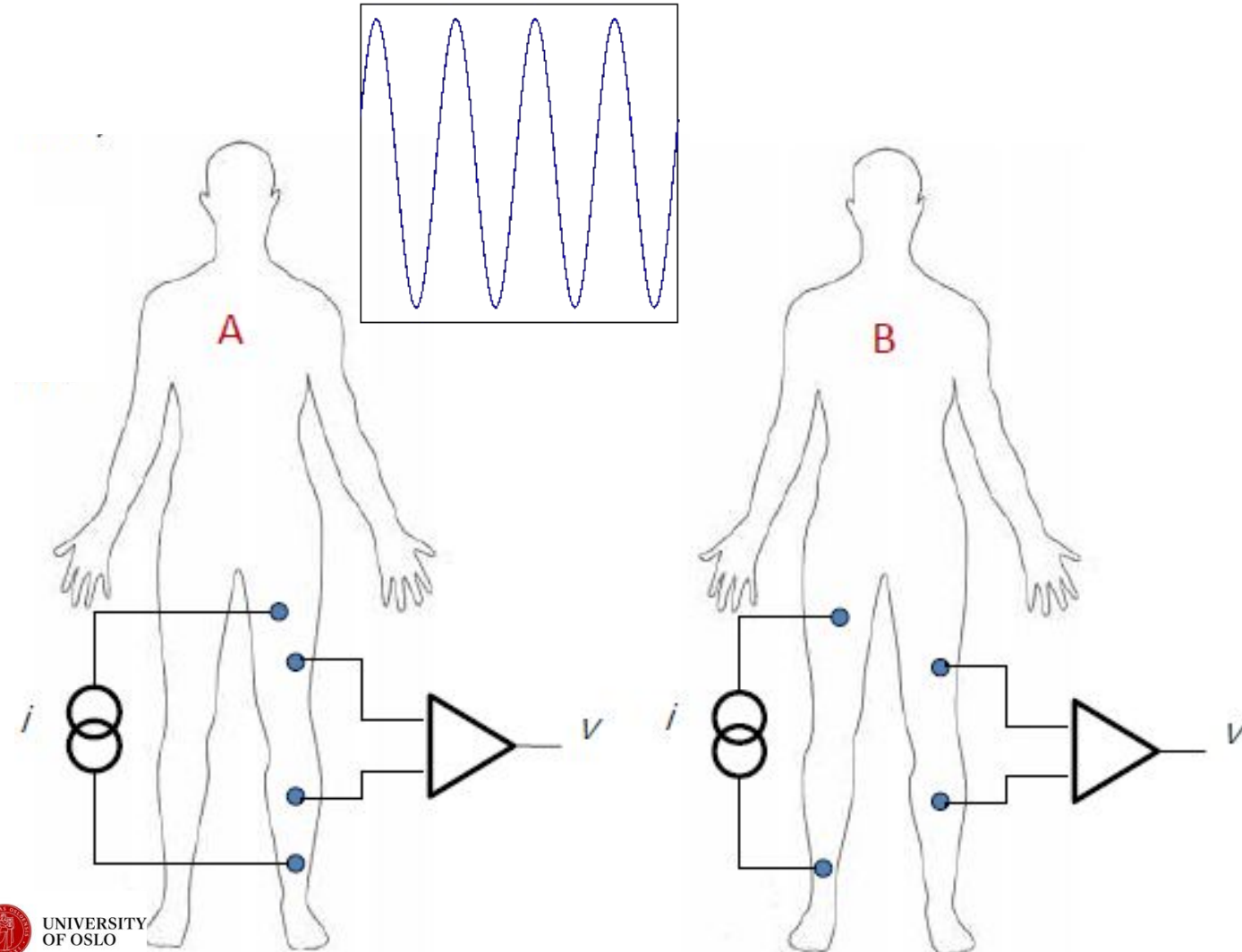
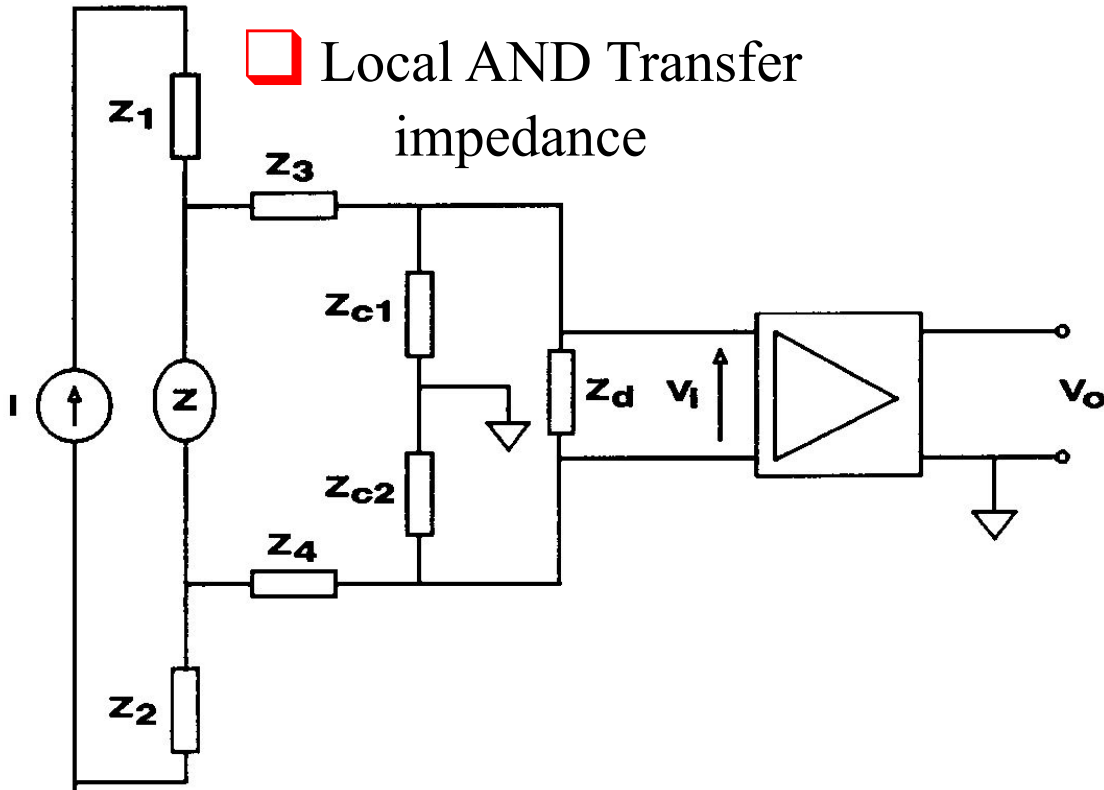


# Choosing your application

## Bioimpedance Meter

### Measuring sensor type?

Local AND Transfer impedance



# Real time monitoring/analysis

## Bioimpedance Meter



## DAQ / Prototype

### ✓ Why?

- Easy to use
- Low cost for simple applications
- Low circuitry complexity
- Trustable
- Development kit



# Real time monitoring/analysis

## Bioimpedance Meter



### DAQ / Prototype



### ✓ ADuCM350 (2014)

#### Measurement capability

Impedance measurements  
Current measurements  
Amperometry  
Voltammetry  
Voltage measurements  
Potentiometry

#### Analog hardware accelerators

- Autonomous analog front-end (AFE) controller
- Direct digital synthesizer (DDS)/arbitrary waveform generator
- Receive filters
- **US 299.00**

#### Analog performance

160 kSPS, 16-bit, precision analog-to-digital converter (ADC)  
High precision voltage reference  
Ultra Low Leakage Configurable Switch Matrix  
12-bit digital-to-analog converter (DAC)

## DAQ / Prototype

### ✓ AFE4300 (2013)

- Segmental-BIA using multi-channels
- Multi-frequency impedance measurement
- 6-Bit, 1 MSamples/s Sine-Wave Generation DAC
- 247.5- $\mu$ Arms,  $\pm 20\%$  Excitation Source
- 2-electrode measurement
- ADC of 16 Bits @ 860 Samples/s
- U\$ 232.71

# Real time monitoring/analysis

# Bioimpedance Meter

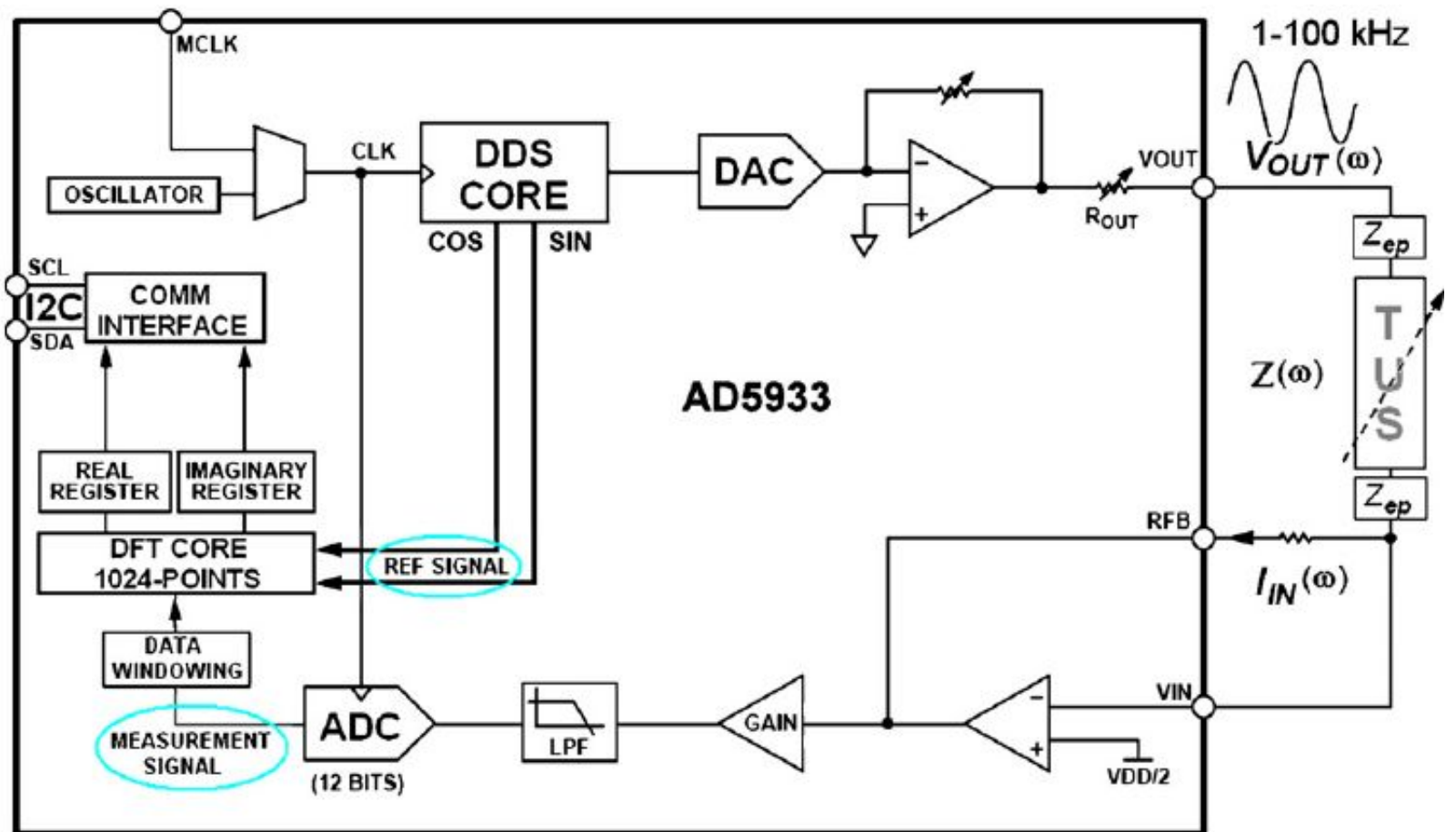


## DAQ / Prototype

✓ AD5933 (original)



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# Real time monitoring/analysis

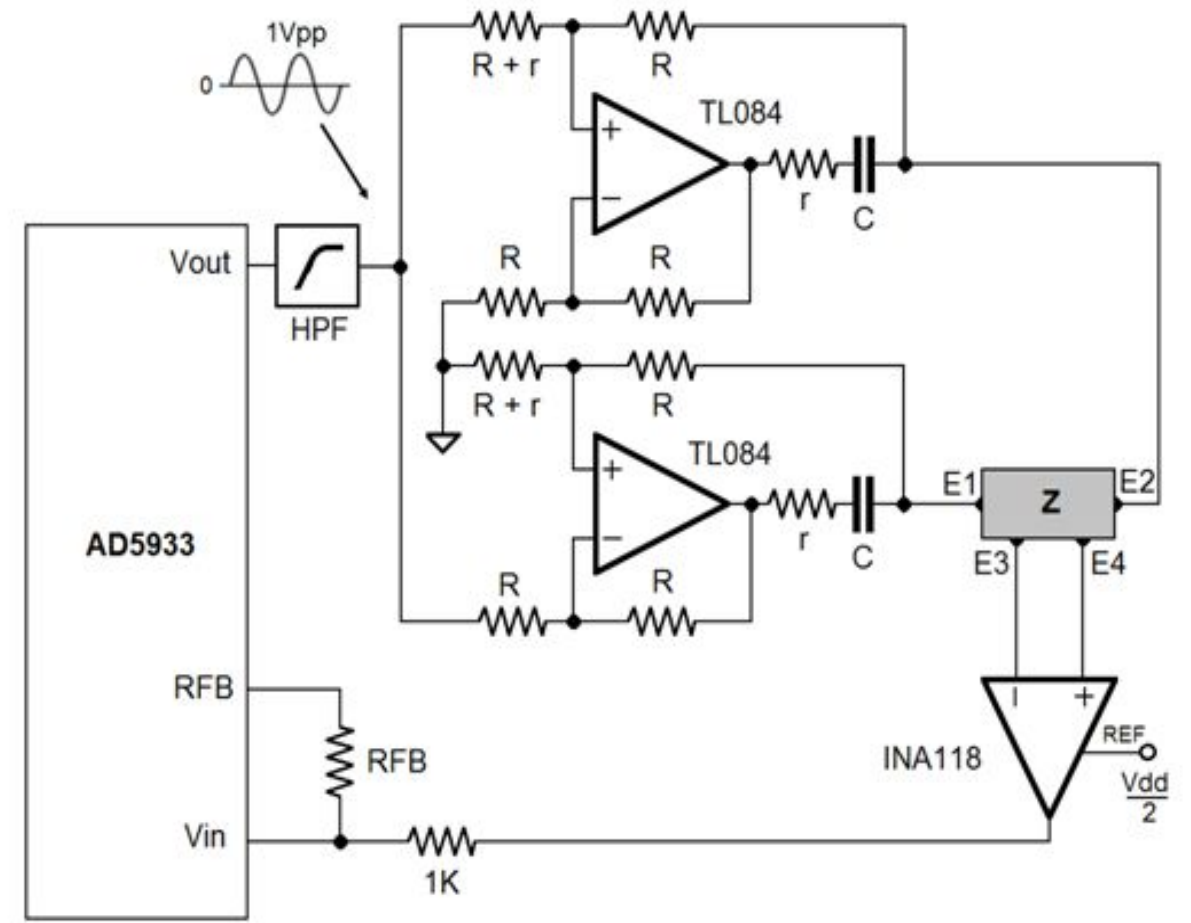
# Bioimpedance Meter



## DAQ / Prototype

✓ AD5933 converted to 4-electrode

- Limited to 500 kHz
- RFB resistor needed
- 2005
- US\$ 60.77



# Building your device

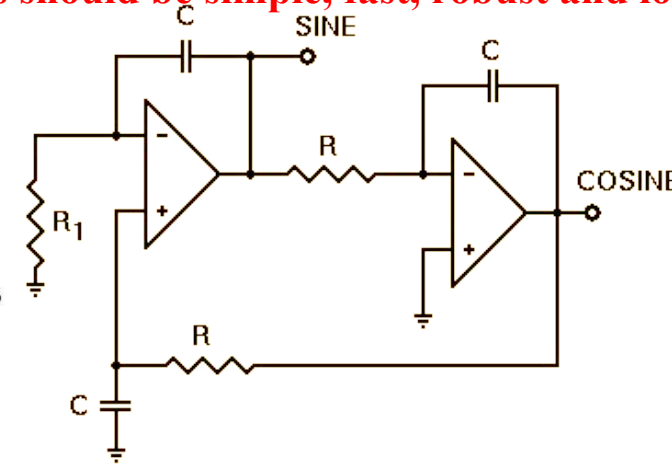
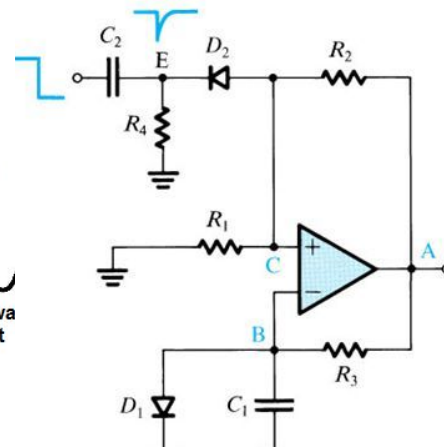
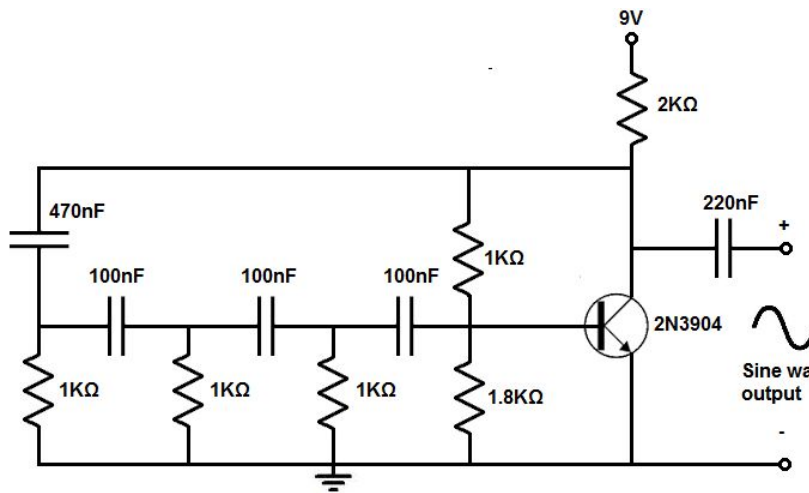
## Bioimpedance Meter



DAQ / Prototype

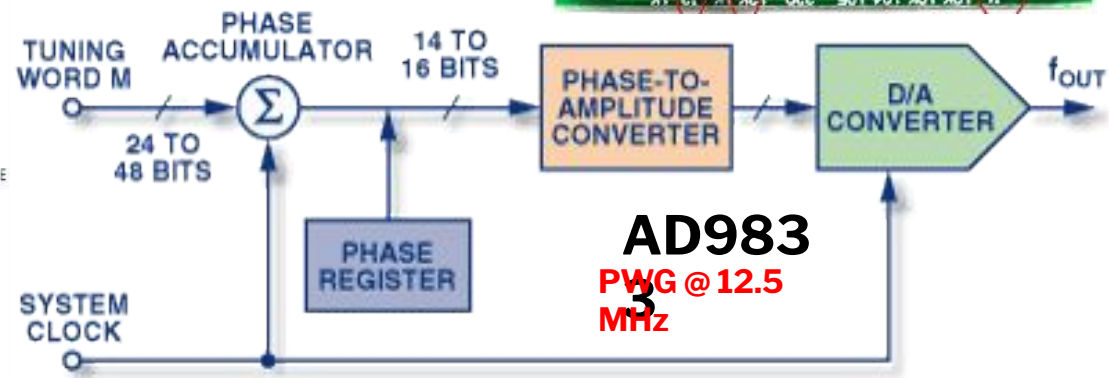
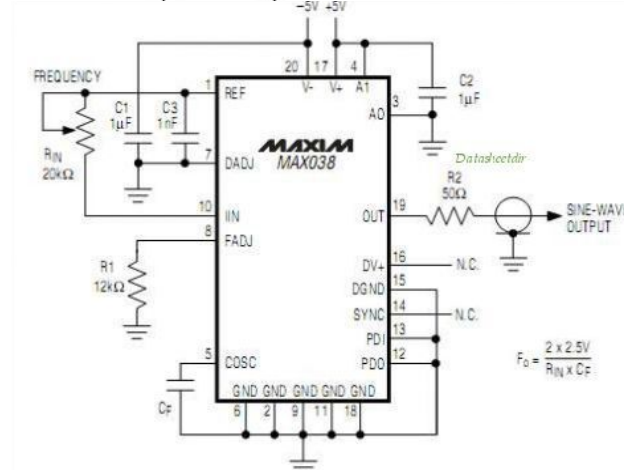
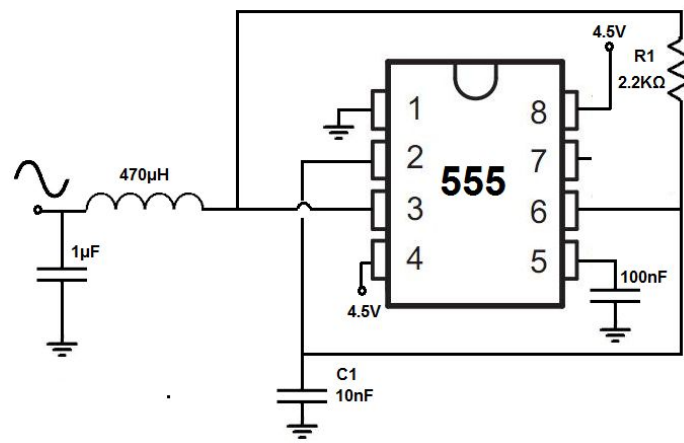
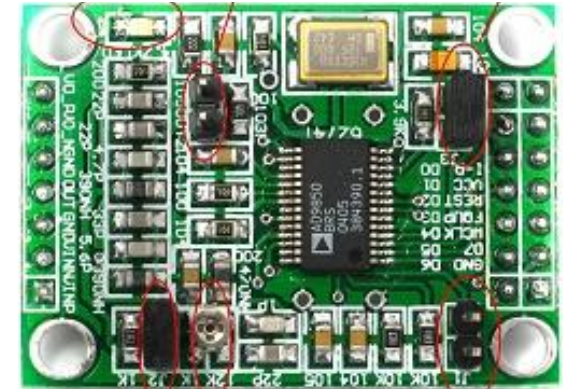


Generators should be simple, fast, robust and low SNR



AD9850

DDS @ 125 MHz



AD9833

PWG @ 12.5 MHz

## DAQ / Prototype – designing VCCS

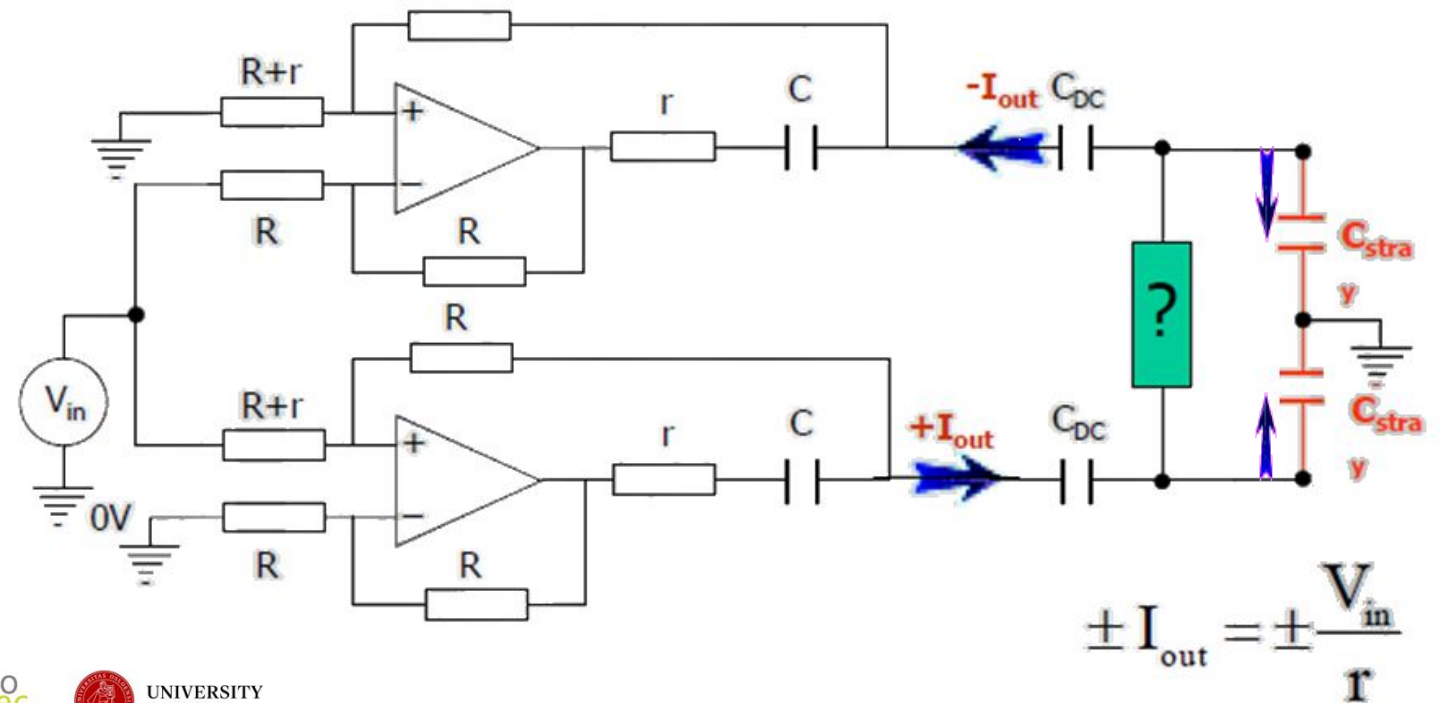
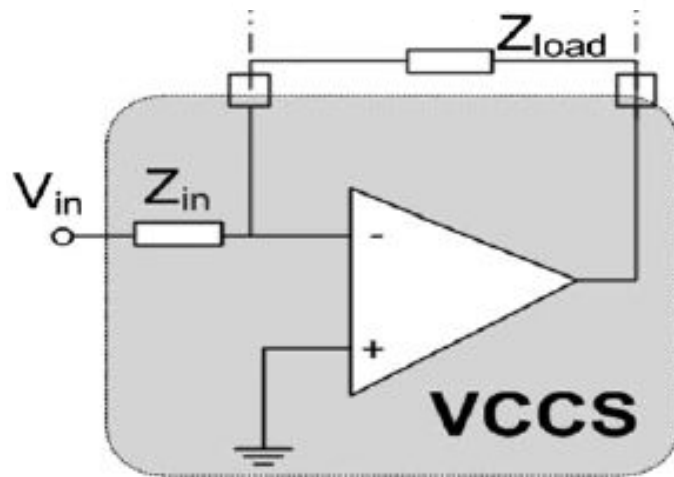
- A - Simple or Modified
- B – Modified with optimization
- C – Modified + Lead-Lag compensation
- D – Mirrored Modified
- E – Modified differential (or “*Bridge*”)
- F – Modified + buffer in the positive feedback
- G - Modified + buffer in the negative feedback
- H – Modified compensated + external Opamps
- I – Modified + GIC
- J – Modified + NIC
- K – Modified + current buffer

# Building your device

## Bioimpedance Meter

### DAQ / Prototype – designing VCCS

✓ Single channel OR Multichannel?



# Building your device

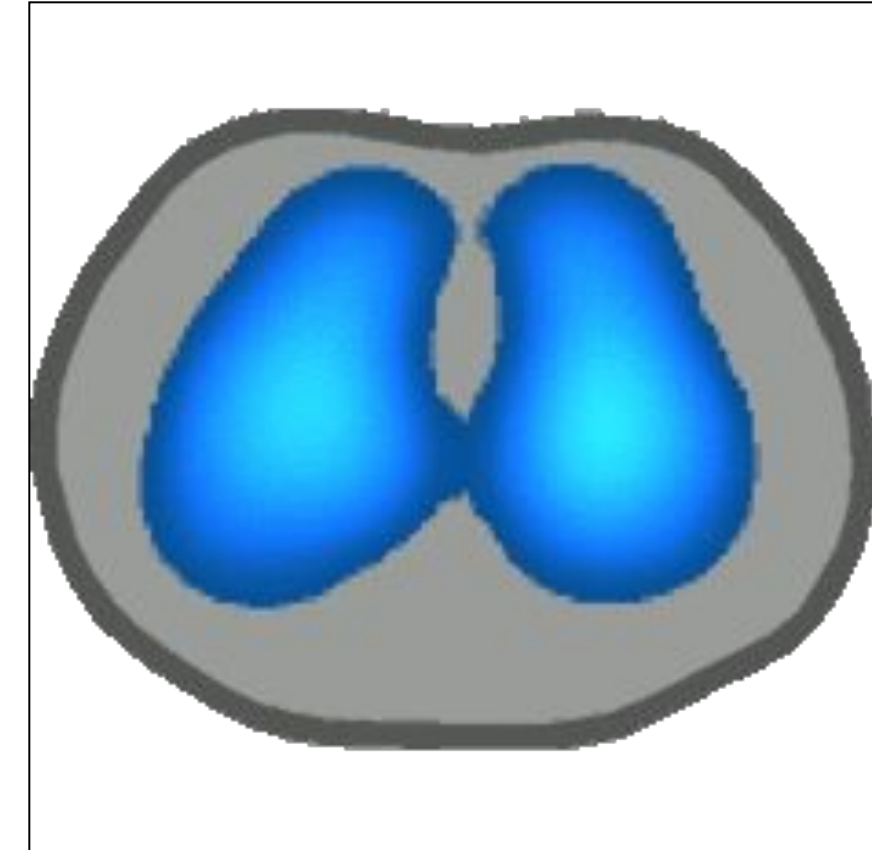
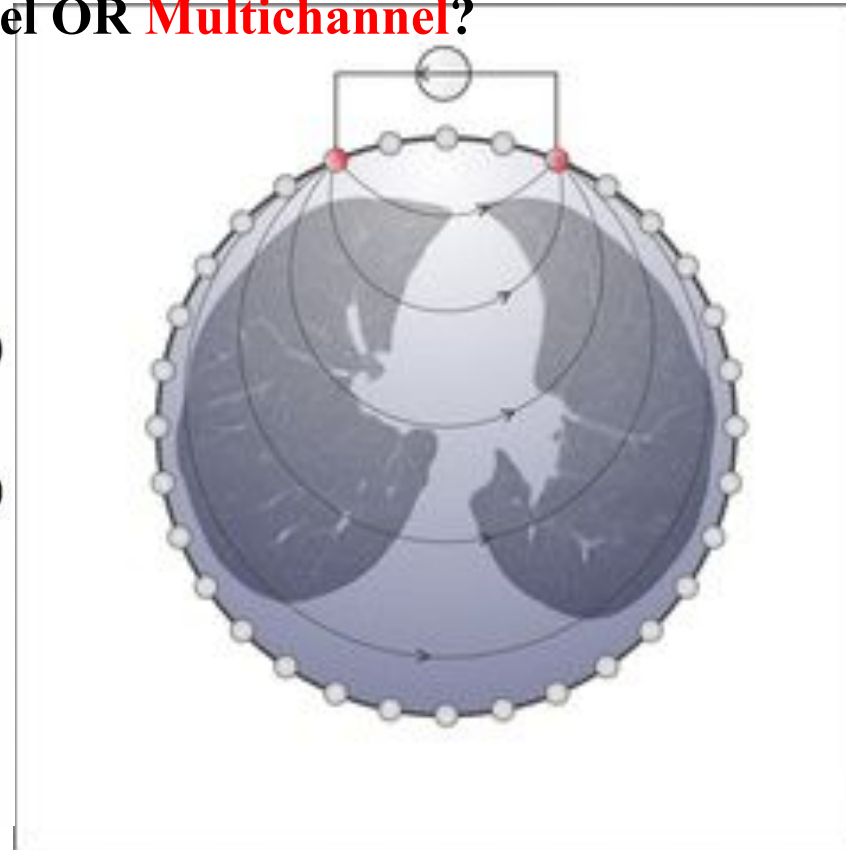
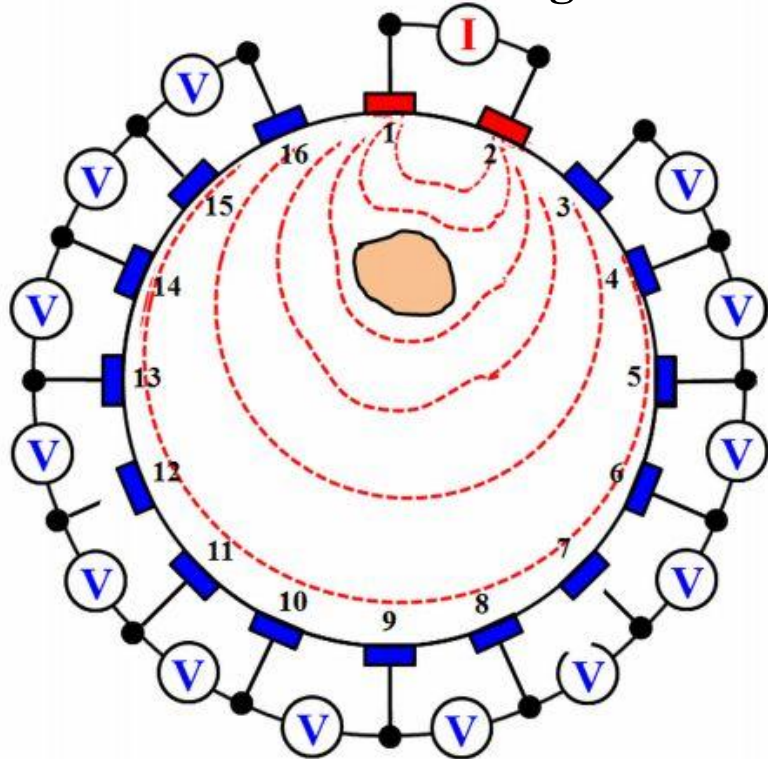
## Bioimpedance Meter



### DAQ / Prototype – vCCS



✓ Single channel OR Multichannel?





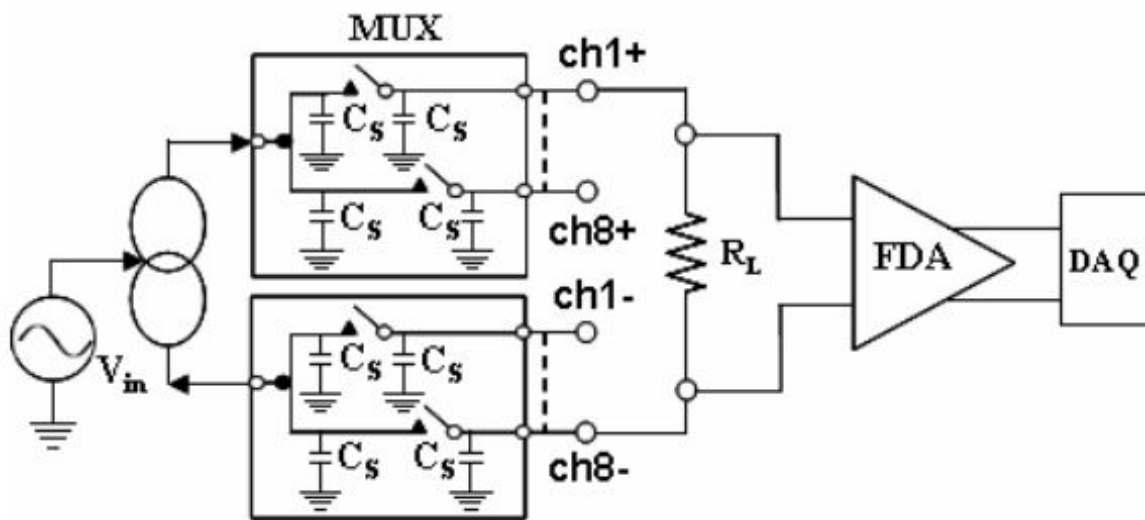
# Building your device

## Bioimpedance Meter

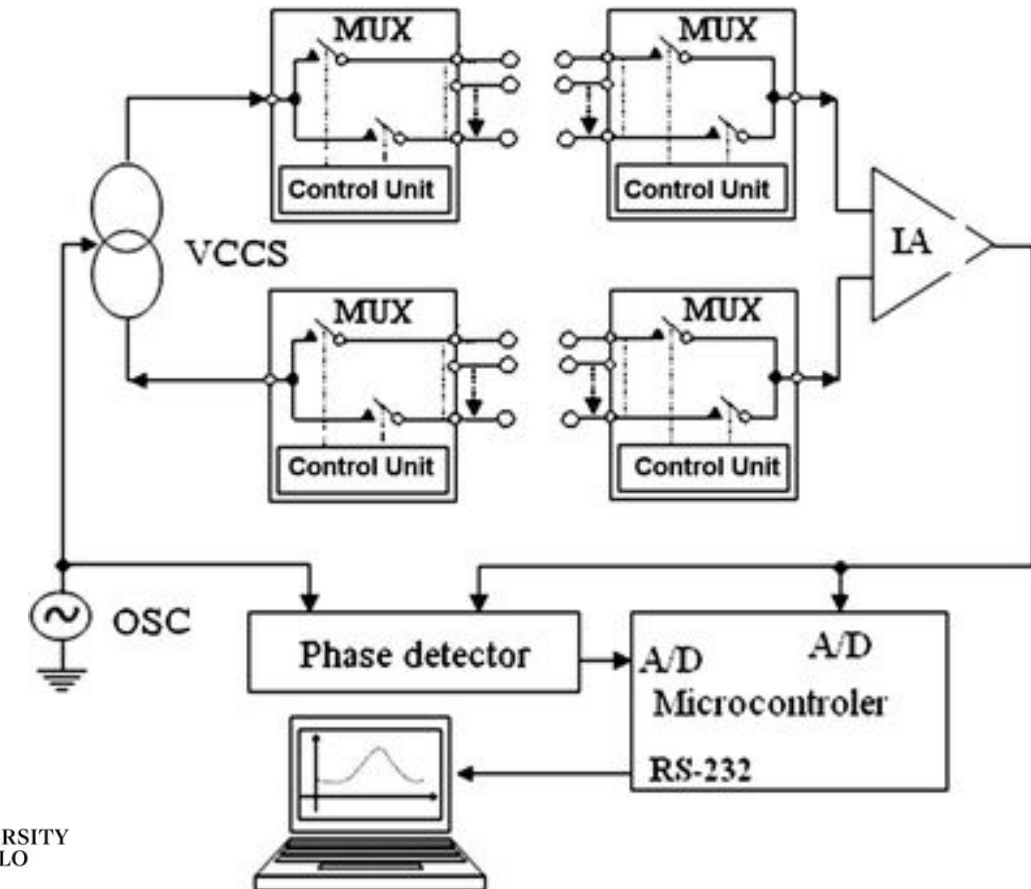


### DAQ / Prototype – designing VCCS

✓ Single channel OR Multichannel?



OR



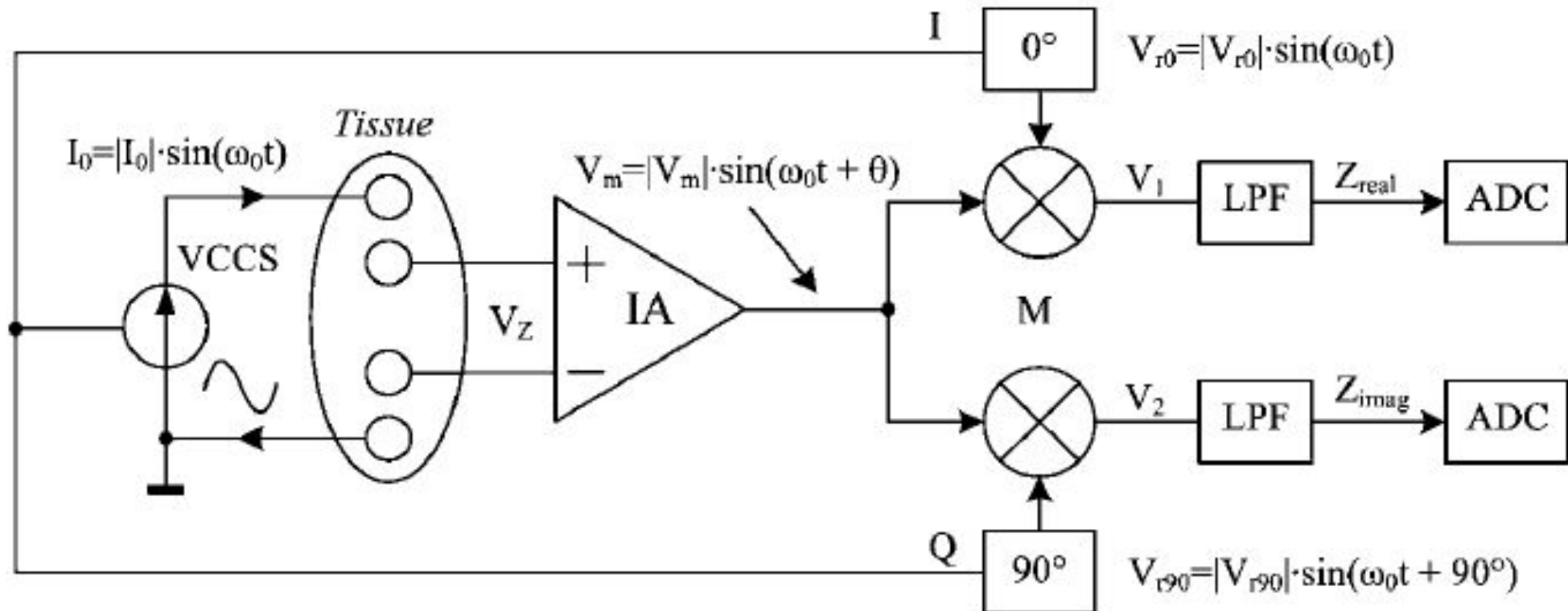
# Building your device

## Bioimpedance Meter



### Demodulator

✓ Hardware solution



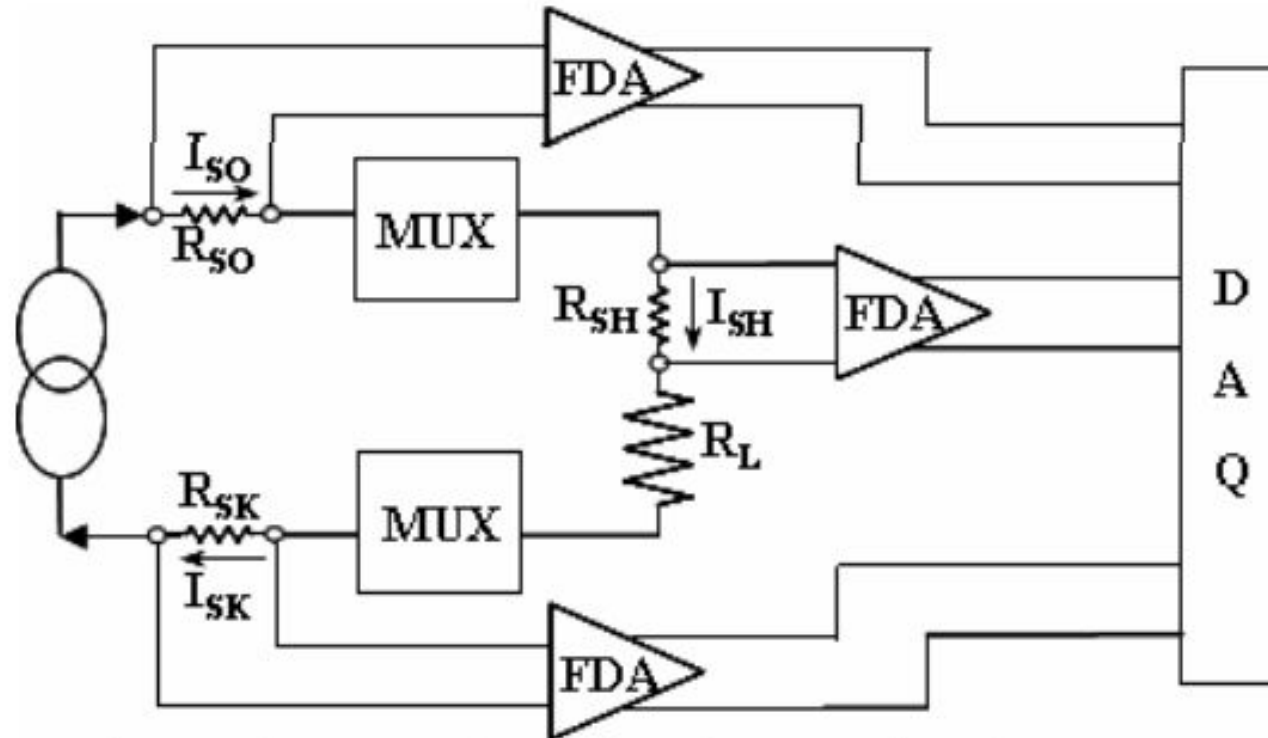
# Building your device

## Bioimpedance Meter



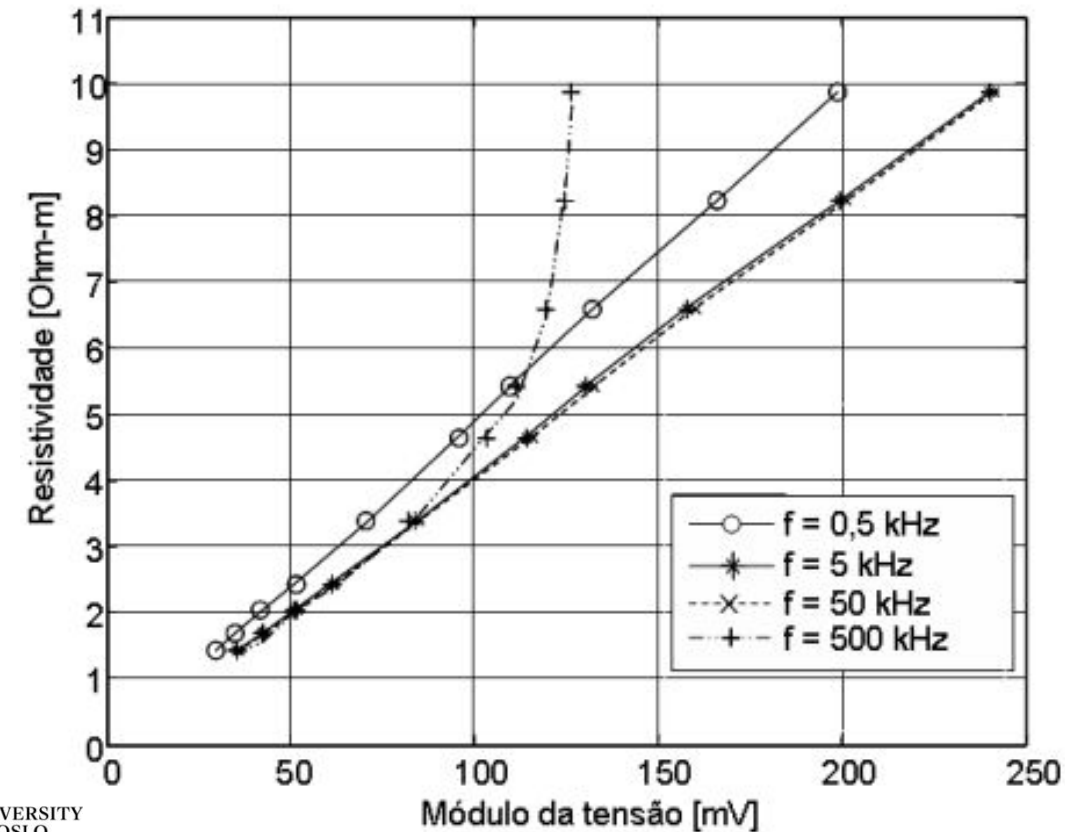
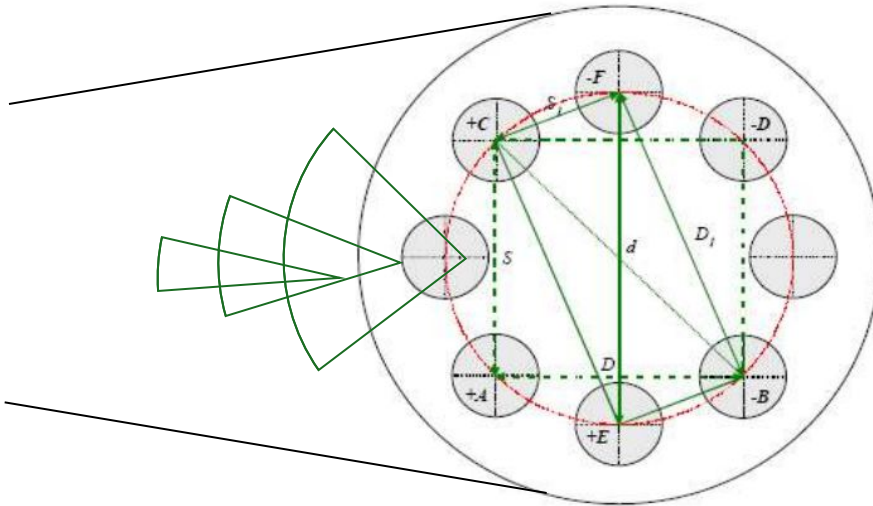
### Measuring current

✓ Software solution



## Saline solutions

✓ Why?

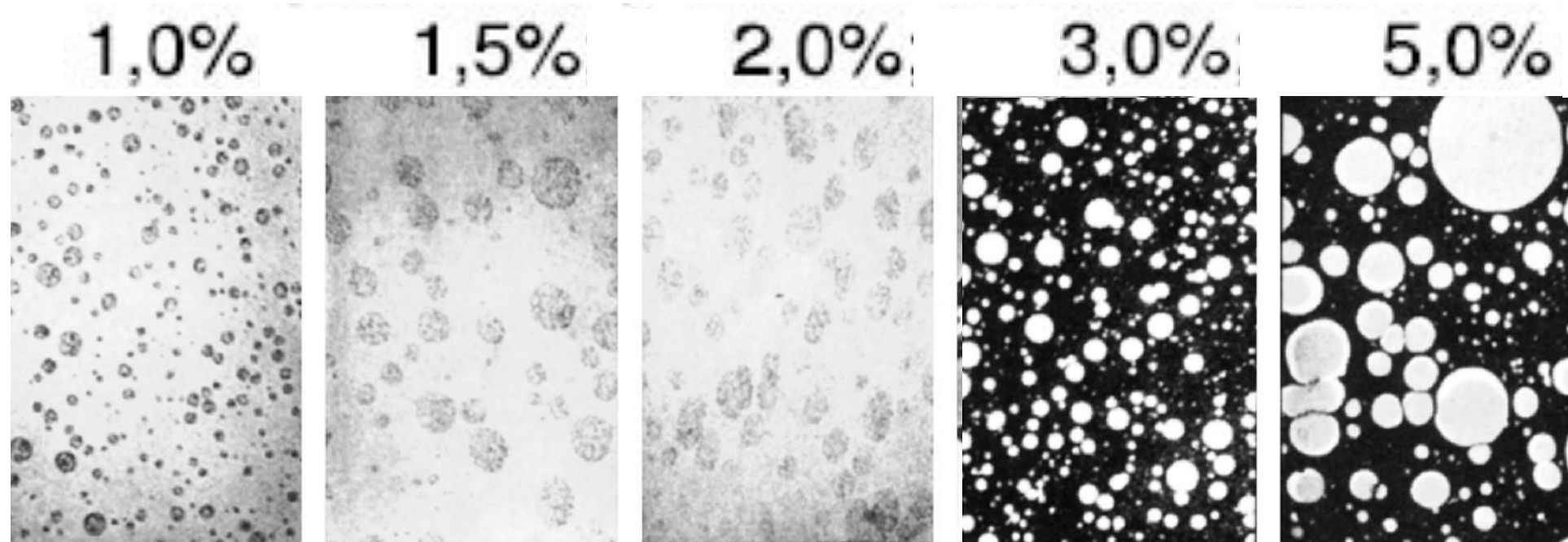


# Building your device

## Bioimpedance Meter



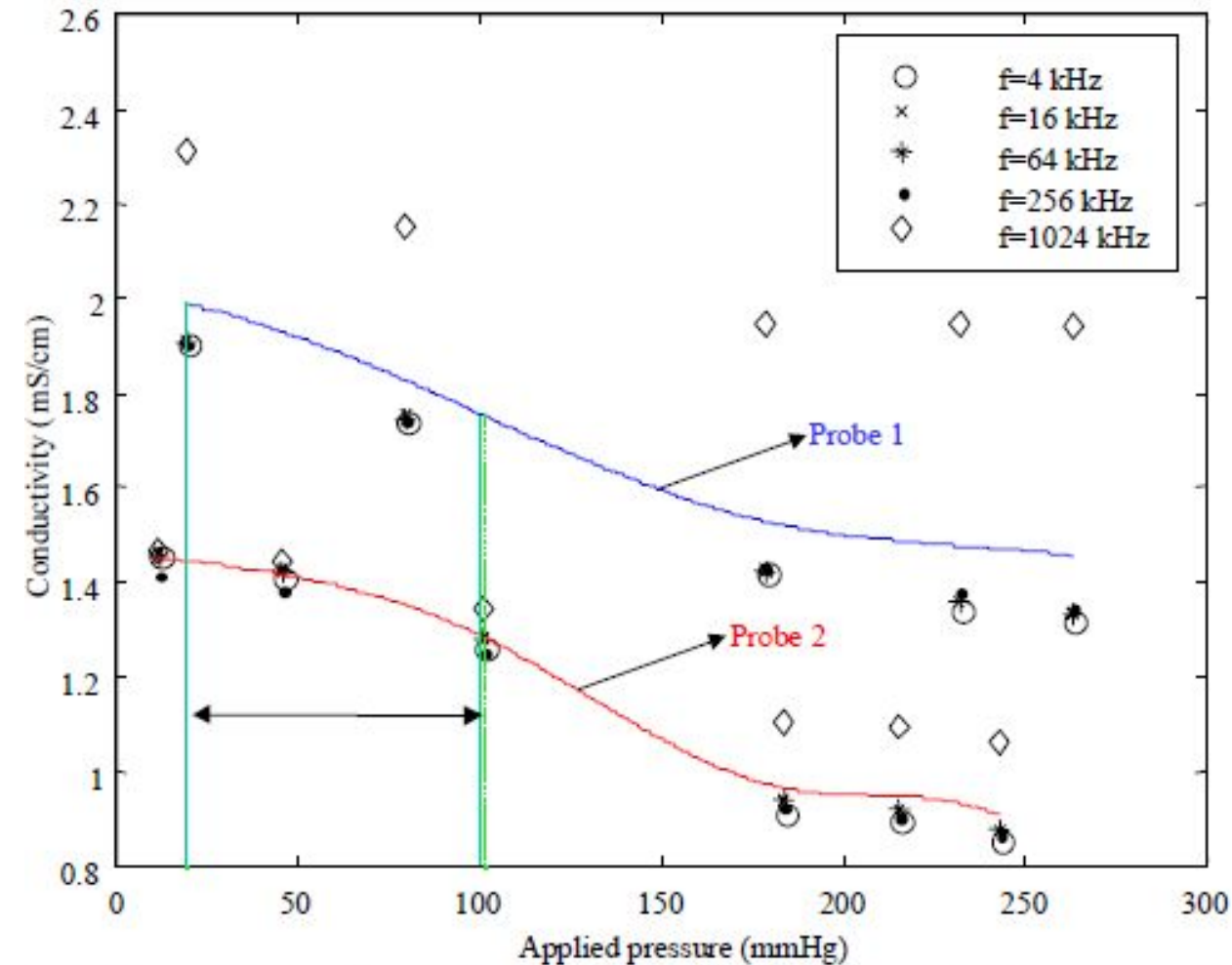
### □ Agar-gel phantoms



# Building your device

## Bioimpedance Meter

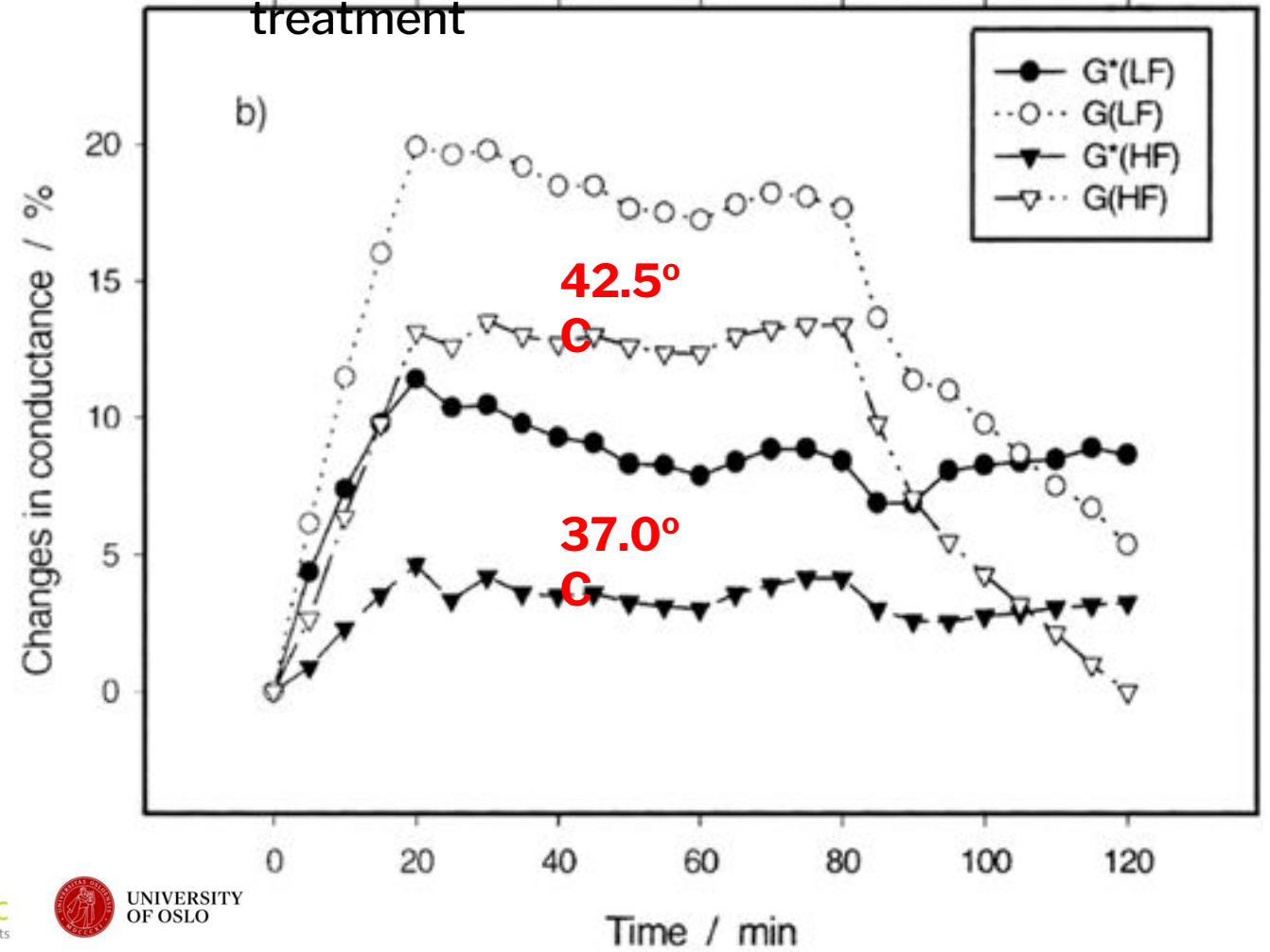
Be aware of applied pressure when working with impedance probe



### Temperature effects

This the measured relative changes in conductance  $G(LF)$  at 100 Hz (open circles) and  $G(HF)$  at 3 MHz (open triangles).

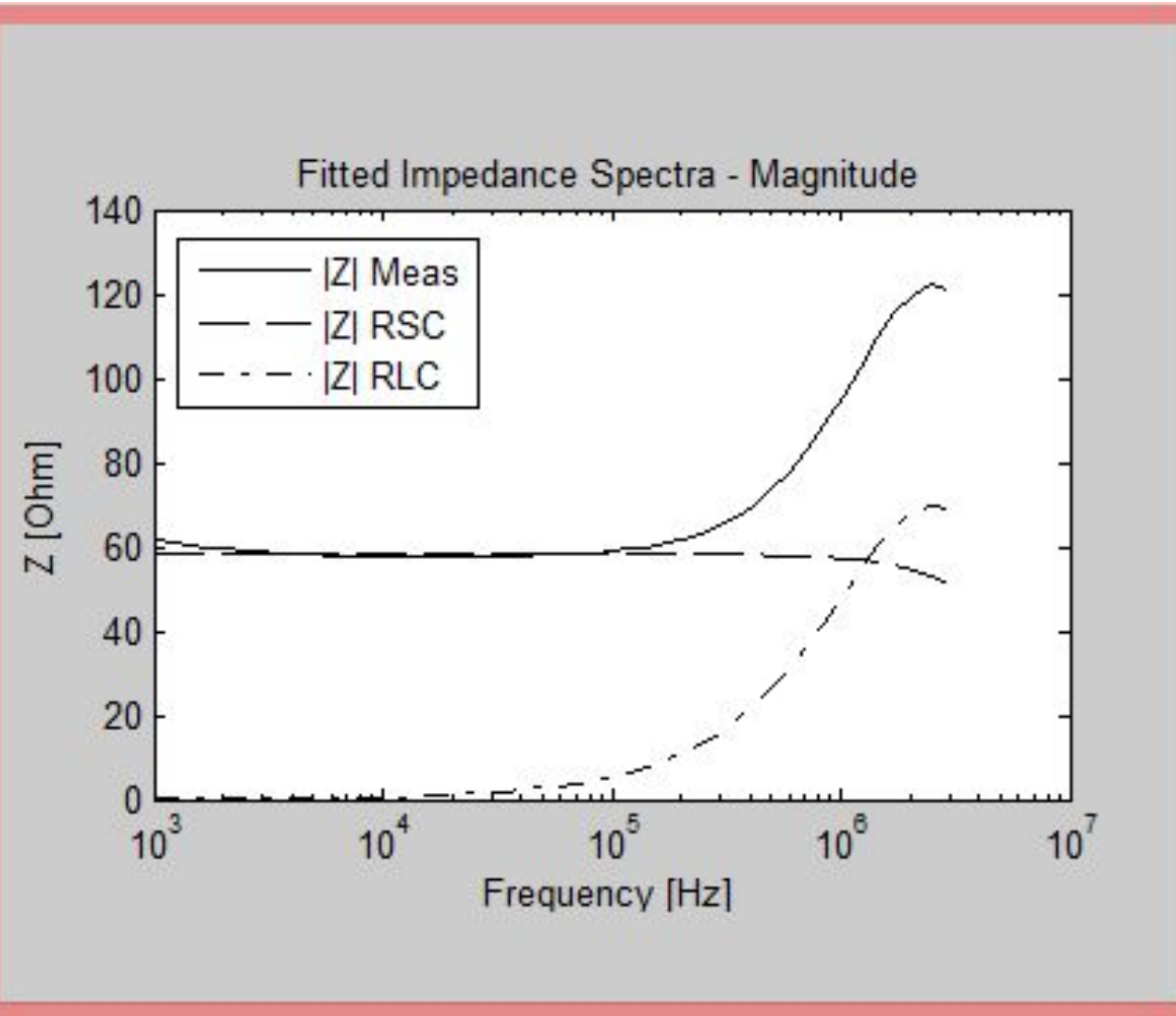
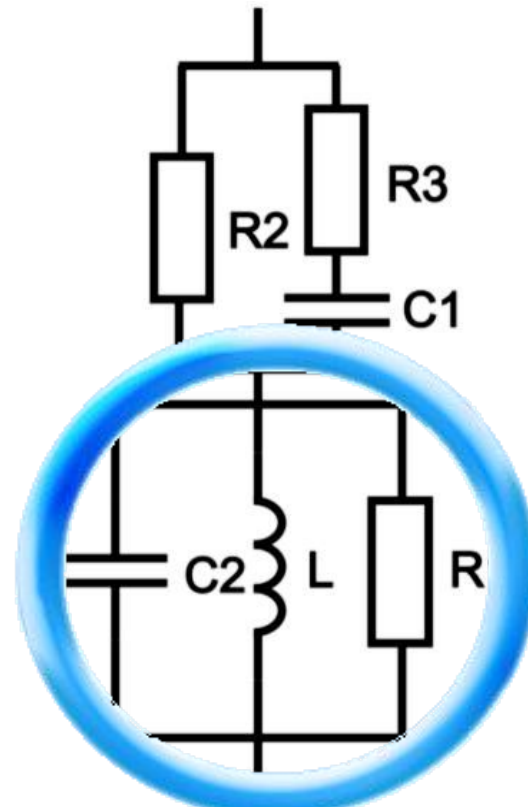
Skeletal muscle during hyperthermic treatment



# Building your device

## Bioimpedance Meter

### Parasite effects to ground





### ➤ IEC 60601-1

- According to the IEC601 regulations, the maximum direct current, i.e. current at zero frequency, must be less than  $10 \mu A_{rms}$  and less than  $100 \mu A_{rms}$  at 1 kHz. It also establishes the maximum root-mean-square current for frequencies above 1 kHz, and the maximum current cannot exceed  $10 mA_{rms}$ .

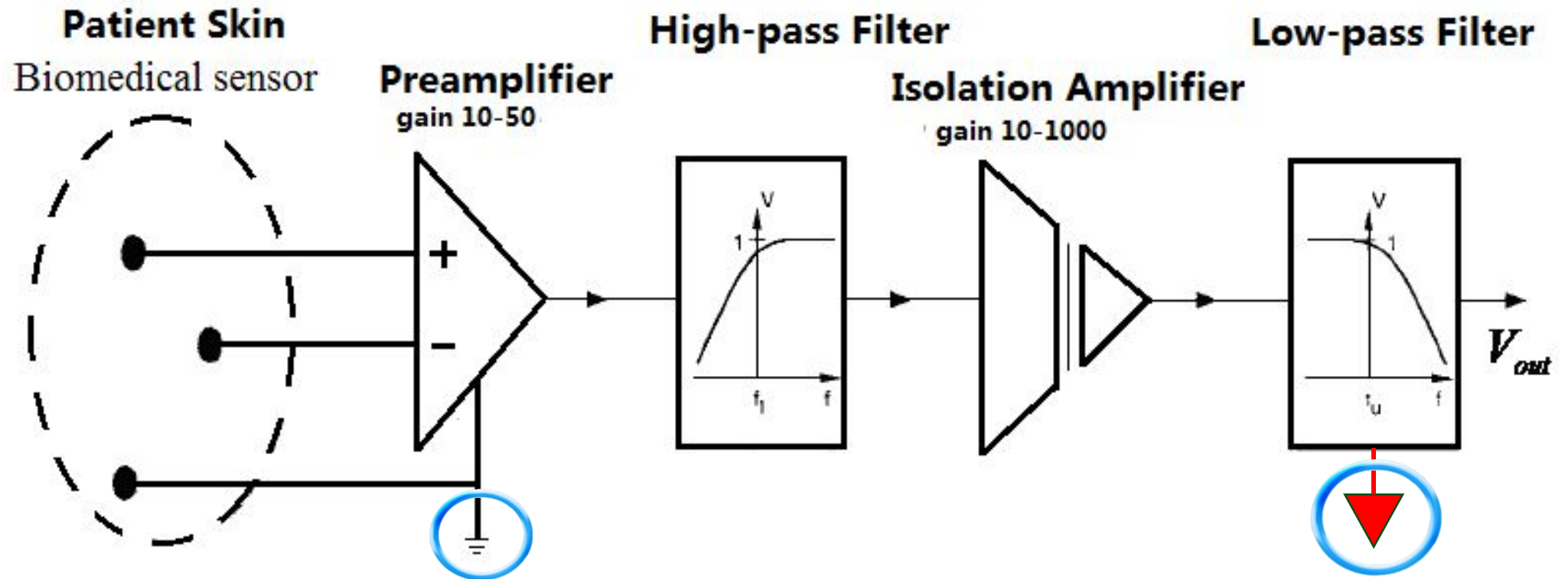
$$I_{max}(f) = 9 \times 10^{-8} \cdot f + 10^{-5} [A_{rms}]$$

# Building your device

## Bioimpedance Meter



### □ Isolating system

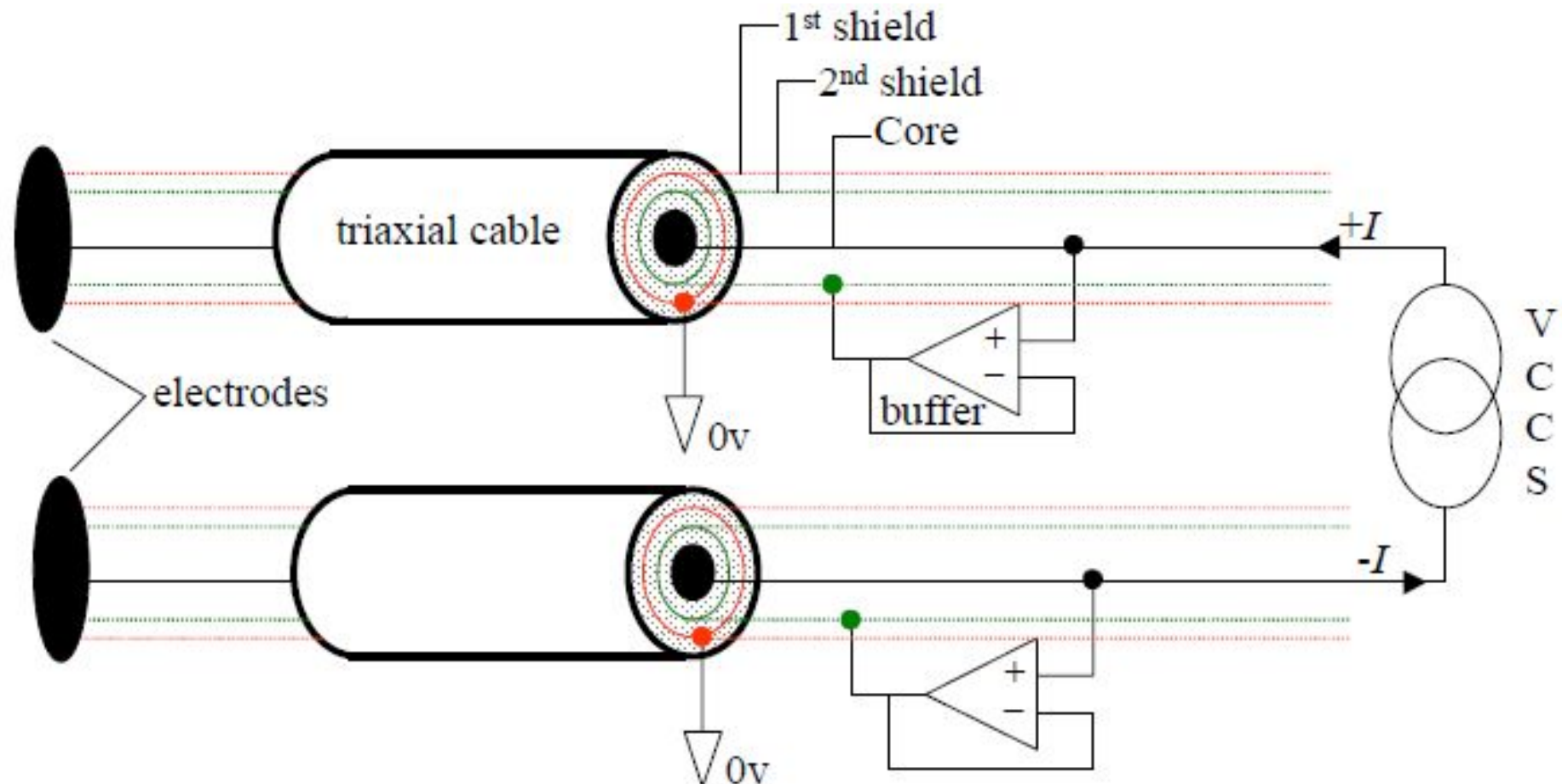


# Building your device

## Bioimpedance Meter



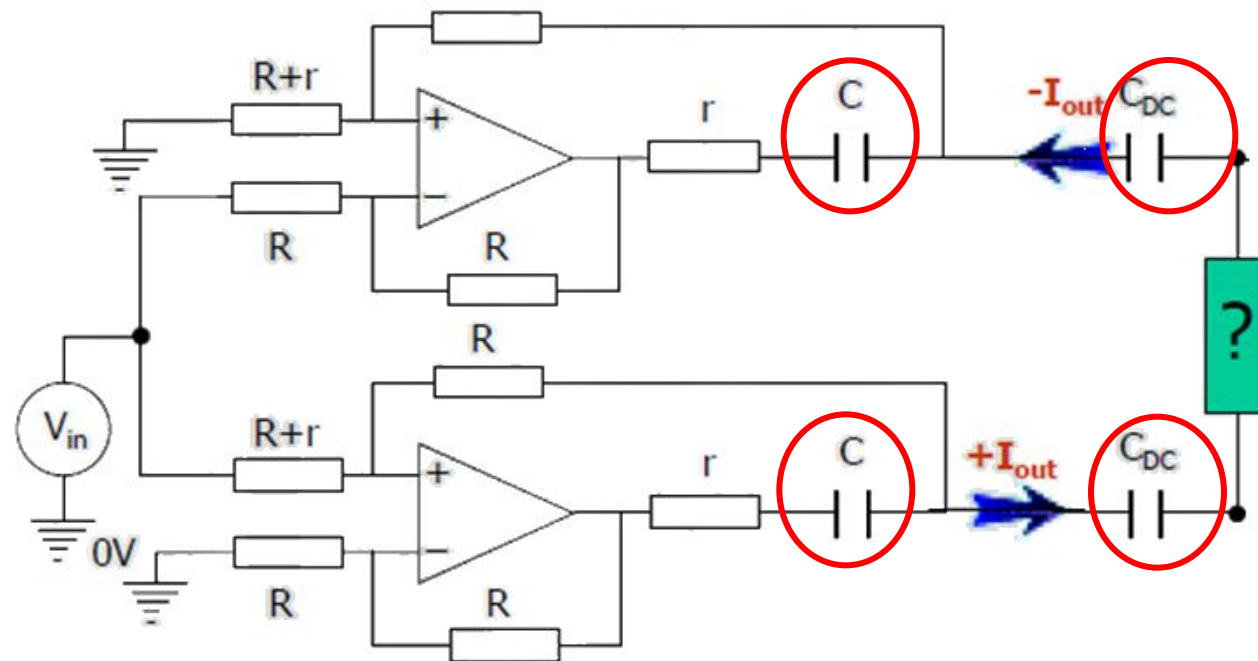
### Guard shield



# Building your device

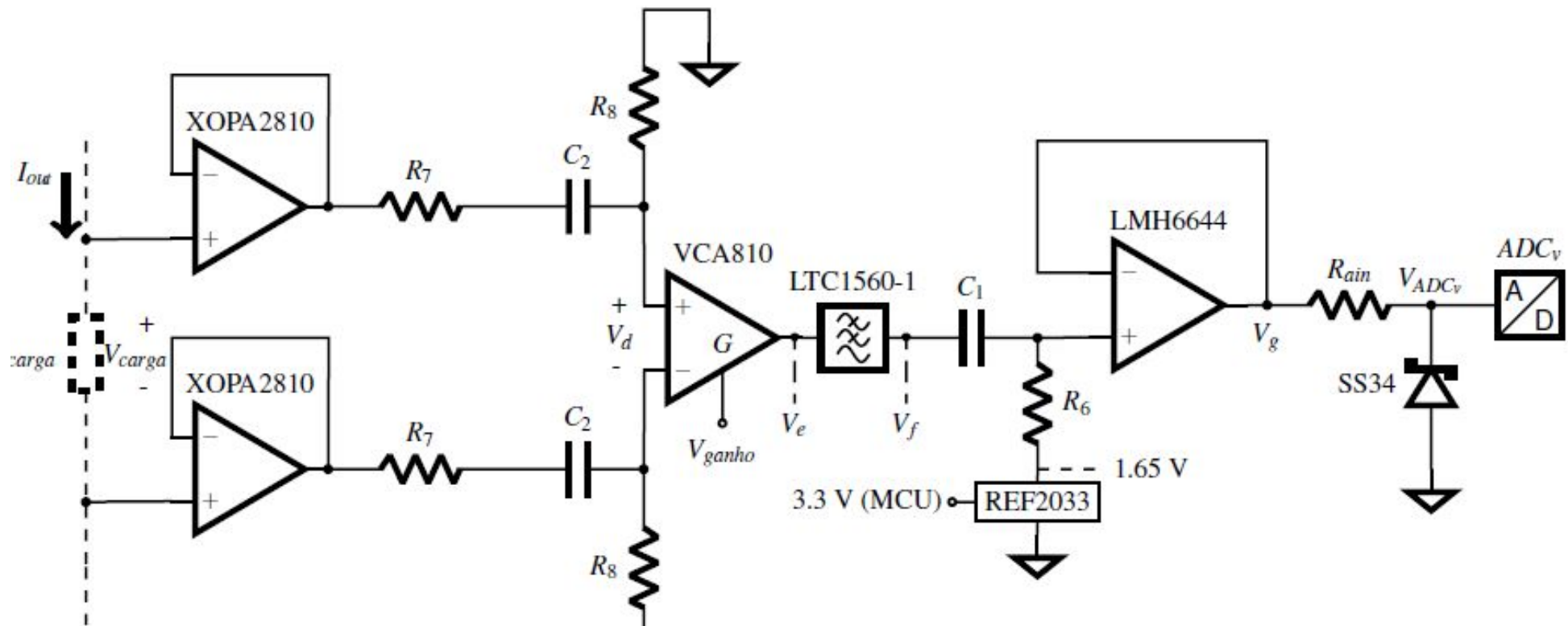
## Bioimpedance Meter

### Blocking filters



$$\pm I_{out} = \pm \frac{V_{in}}{r}$$

### Isolation and protection : measuring system



- There are many variables which **MUST** be monitored in order to have a good Bioimpedance meter;
- Make the Bioimpedance meter as **simple** as possible;
- **Microelectronic** current source for bioimpedance will be the key;
- Active electrodes **SHOULD** be used, especially in multifrequency applications;
- Temperature and applied pressure **MUST** be measured for data calibration if impedance probe is used;
- Huge data base is **needed** for a more realistic tissue characterization;

# End of part 01

## Bioimpedance Meter



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REALIZAÇÃO



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