ELECTIVE COURSE S6b-S8b
ELECTRONIC SYSTEMS FOR SENSORS

Design project

Design of a signal conditionner

PROJECTS

1. *Linear Variable Differential Transformer (LVDT)*
2. *Photoplethysmographic sensor (PPG)*
3. *Electrocardiogram-Electromyogram (ECG/EMG)*
4. *Electrical Impedance Spectroscopy (EIS)*

GROUPS

- *Project groups of 4-5 students.*
- *Make groups*

  https://docs.google.com/spreadsheets/d/1jG2lCris9GgGGdKWz7DQZVMgyiD3Ul3fMIYuKIeCu6E/edit?usp=sharing
- *Project assigned randomly.*
- *Exchanges are possible.*

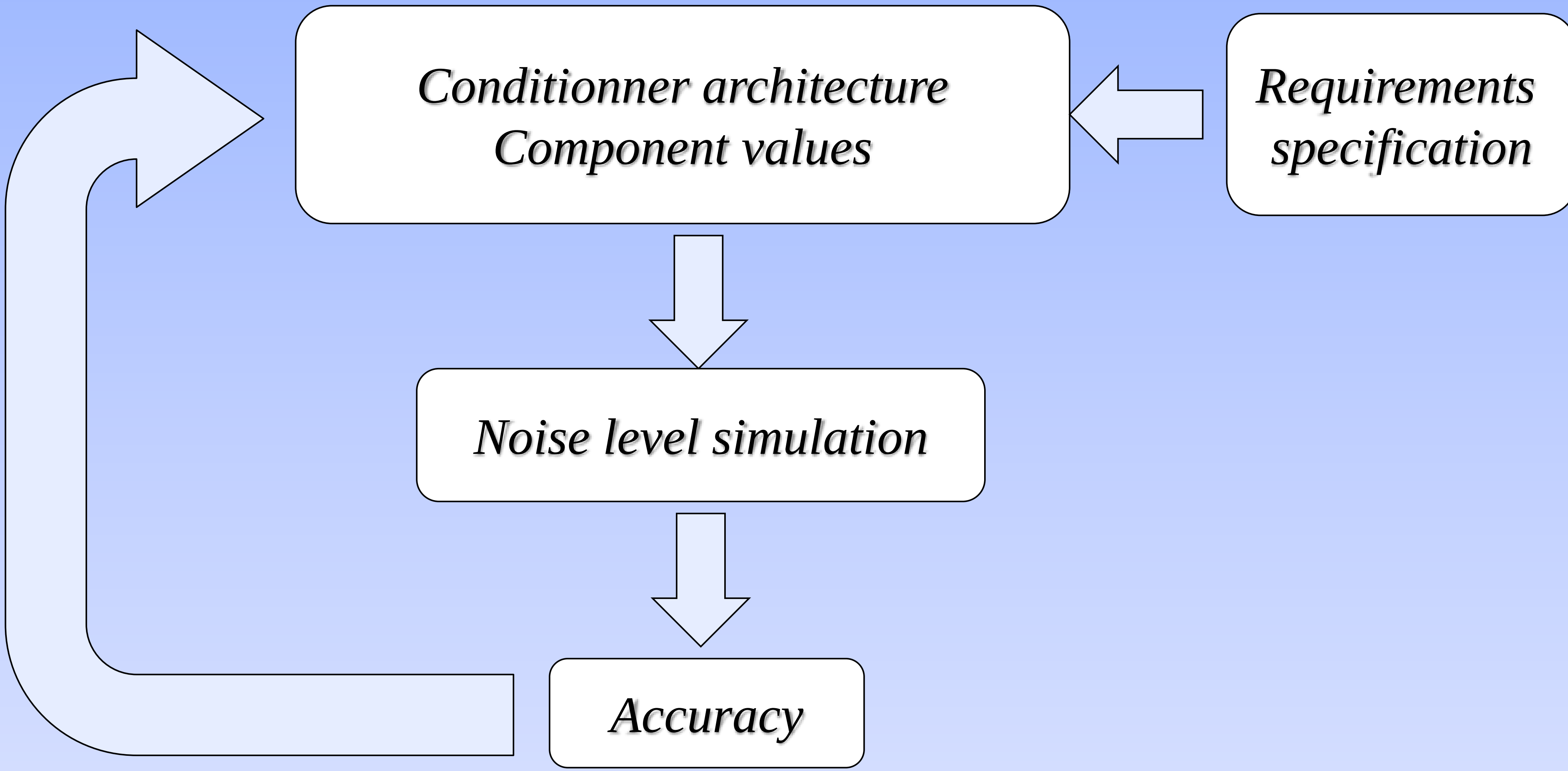
OBJECTIVES

- *Design a signal conditionner for a given sensor, following a list of specifications.*
- *Include sensor electrical model.*
- *Validate the design using simulation.*
- *Take extrinsic/intrinsic noise into account.*
- *Mitigate the effect of noise, using filtering or synchronous detection.*
- *Dual/Single supply circuit → Arduino*

TOOLS

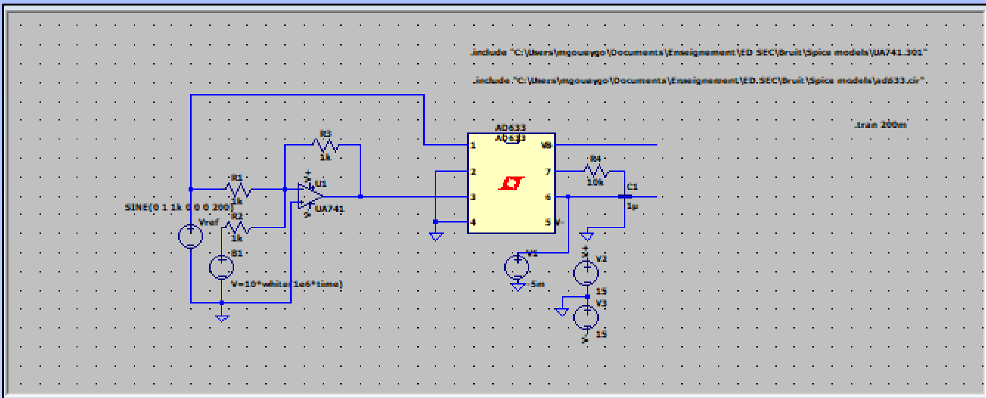
- *Biblio references available on Moodle.*
- *Hints for sensor model in LTSpice.*
- *Utilize (all) electronic functions.*
- *Use Moodle forum for consultation.*
- *A few face-to-face sessions are scheduled.*

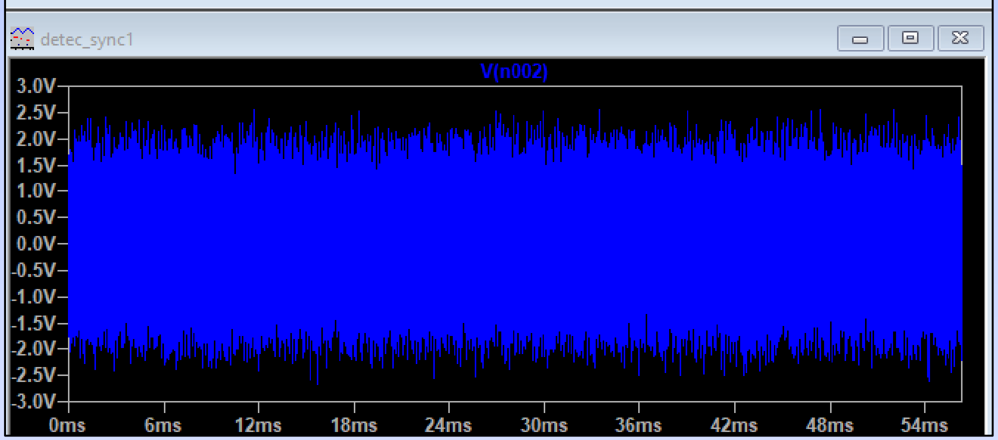
PROCEDURE


Conditionner architecture
Component values
Requirements specification
Noise level simulation
Accuracy

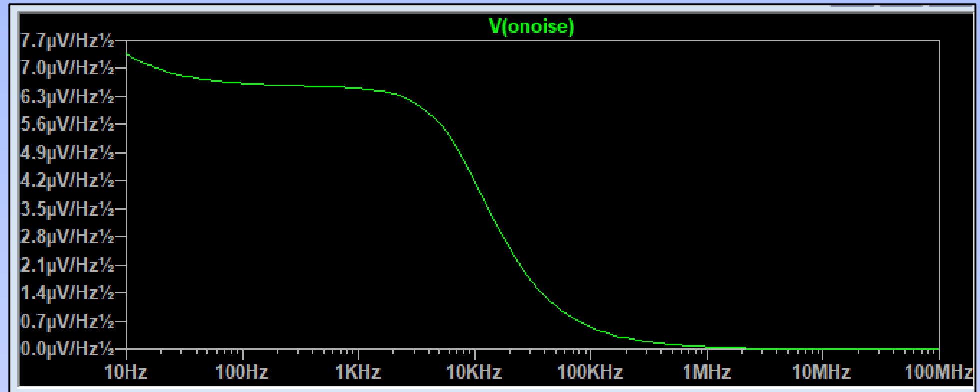
NOISE EVALUATION IN LTSpice

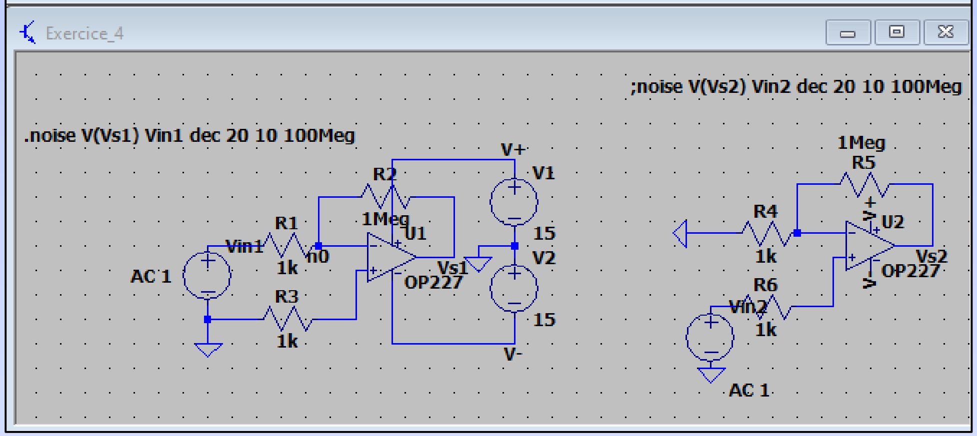
Transient simulation mode





Noise simulation mode





Marc GOUEYGOU

DELIVERABLES

D1 : well-argued schematic of the conditionner

- D1.1 : general schematic.
- D1.2 : schematic with parameters & component values.

D2 : LTSpice simulation

- D2.1 : Validation per block.
- D2.2 : Global validation.

D3 : Conditionner development

- D3.1 : Validation per block.
- D3.2 : Global validation.
- D3.3 : improved design
- D3.4 : single supply operation

PROJECT DEFENSE

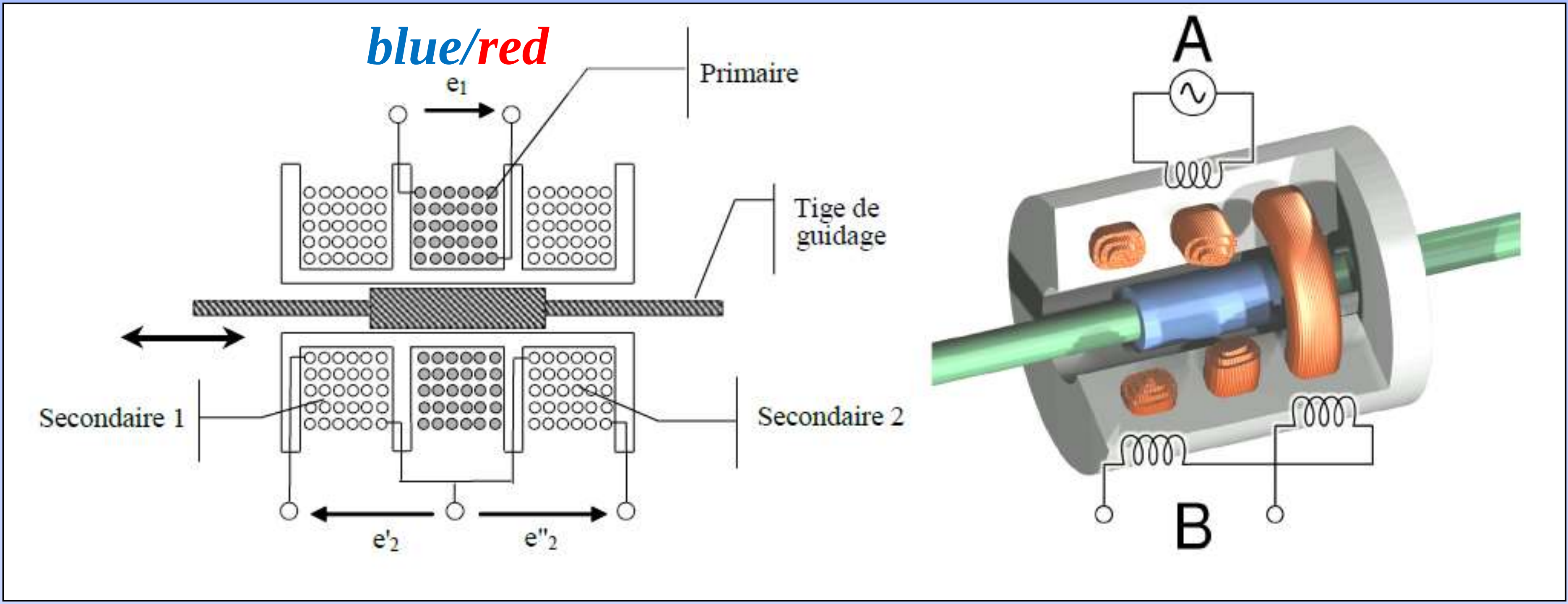
- Friday 06/28 15h30-17h30
- 12h30-14h00 : get prepared
- Presentation = slides+simulation+prototype
- All group members must speak!

PROJECTS

1. ***Linear Variable Differential Transformer (LVDT)***

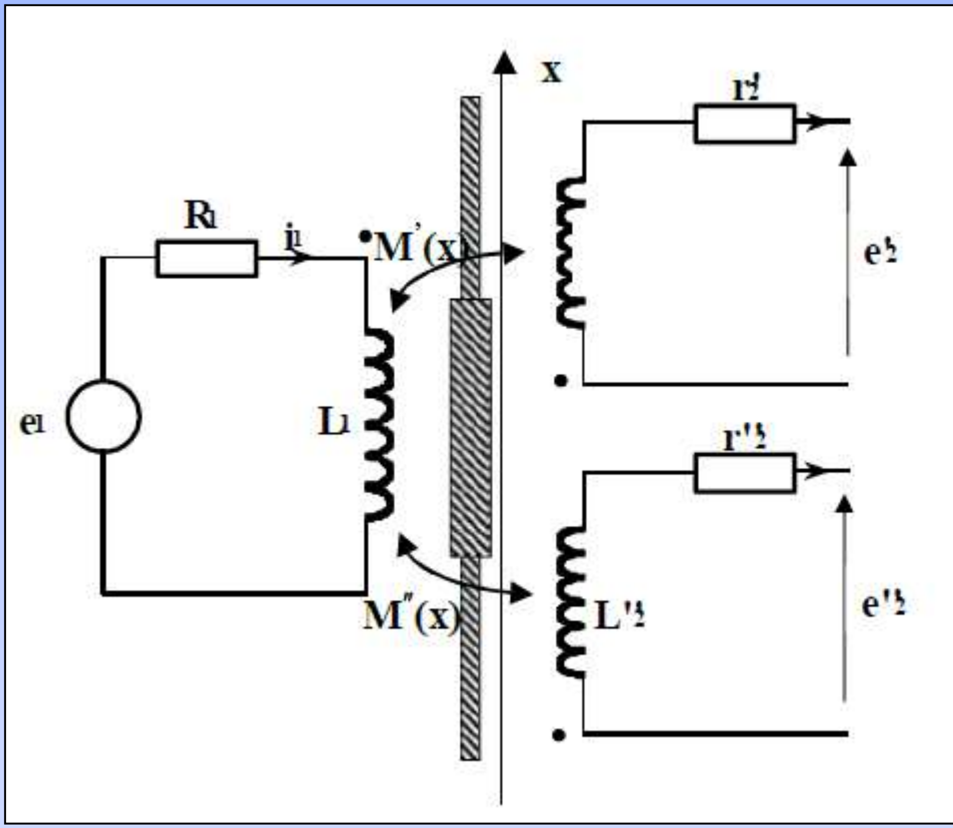
2. *Capteur photopléthysmographique (PPG)*

LVDT



green/yellow/white

EQUATIONS



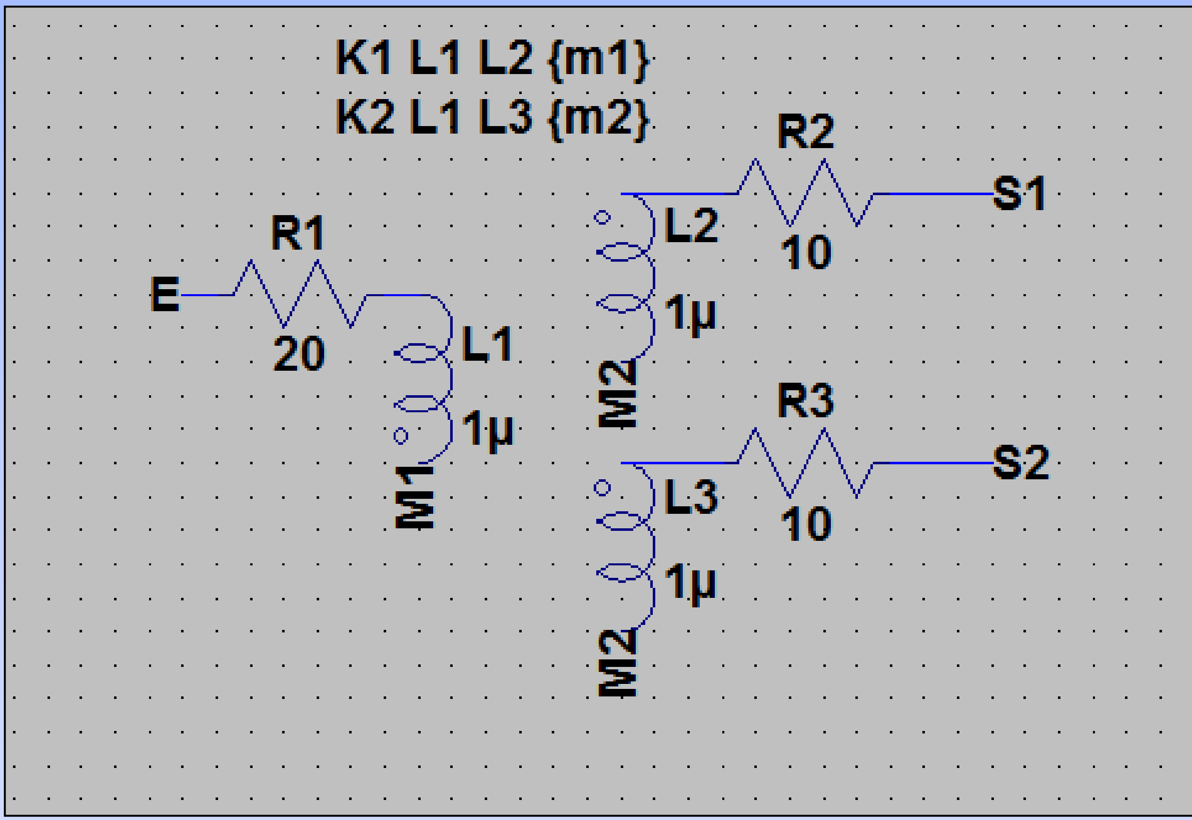
$$
\begin{cases}
e_1 = (R_1 + j\omega L_1) i_1 \\
e'_2 = -j\omega M'(x) i_1 = -j\omega \dfrac{M'(x)}{R_1 + j\omega L_1} e_1 \\
e''_2 = -j\omega M''(x) i_1 = -j\omega \dfrac{M''(x)}{R_1 + j\omega L_1} e_1
\end{cases}
$$

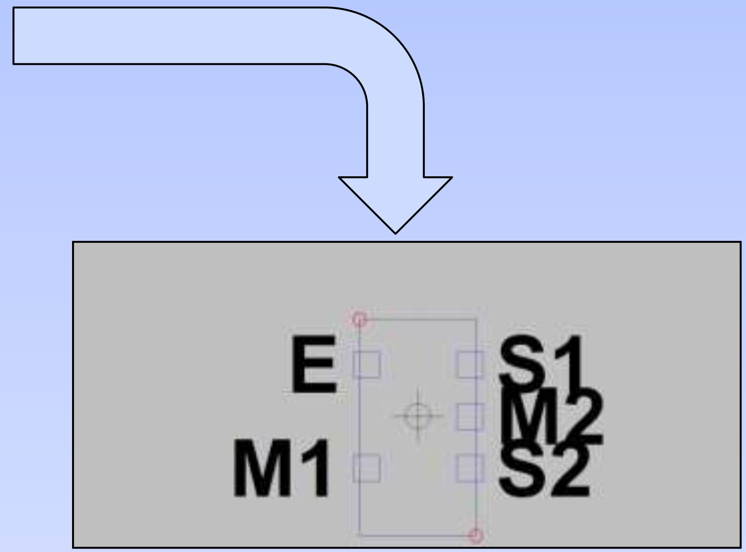
$$
\begin{cases}
M'(x) = m(0) + ax + bx^2 + o(x^3) \\
M''(x) = m(0) - ax + bx^2 + o(x^3)
\end{cases}
$$

$$
e'_2 - e''_2 = -j\omega \frac{M'(x) - M''(x)}{R_1 + j\omega L_1} e_1
$$

$$
= j\omega \frac{2ax}{R_1 + j\omega L_1} e_1 \underset{\omega >> R_1/L_1}{\cong} \frac{2ae_1}{L_1} x
$$

LVDT sensor modeling





OBJECTIVE

LVDT

Solartron AX/0.5/S

CONDITIONNER
???

ARDUINO
ADC

Measure linear displacement
from -2,5 to +2,5mm
with a 10 µm accuracy

PROCEDURE

-2,5 mm 0 +2,5 mm

x

0V $V_{out,max}=?$

V_{out}

CONDITIONNER
???

0V 5V

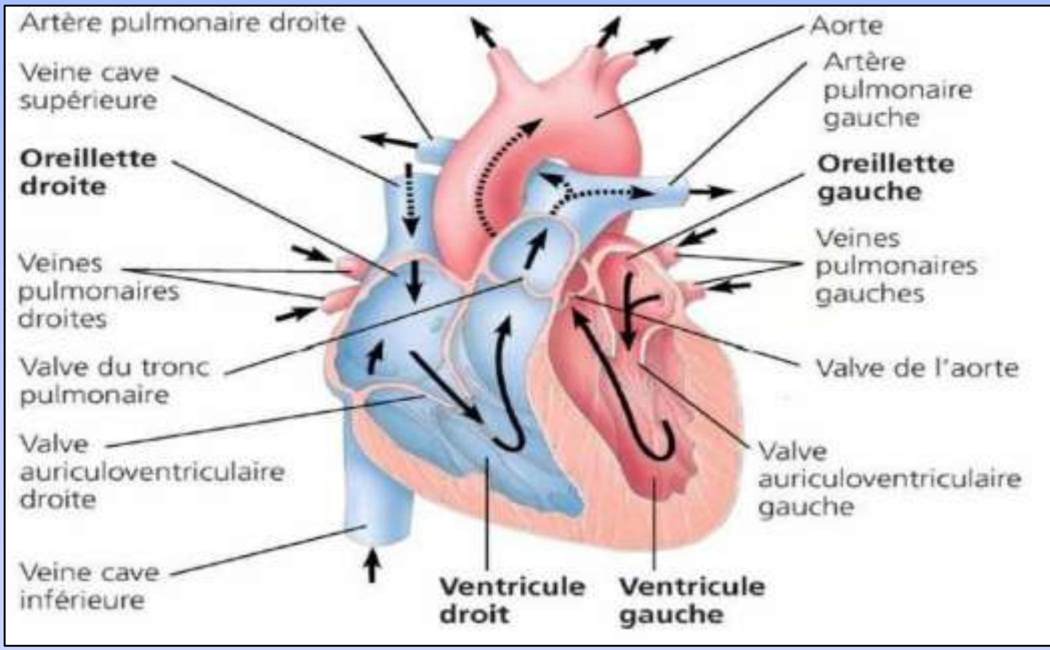
$V_{in,ADC}$

NOISE

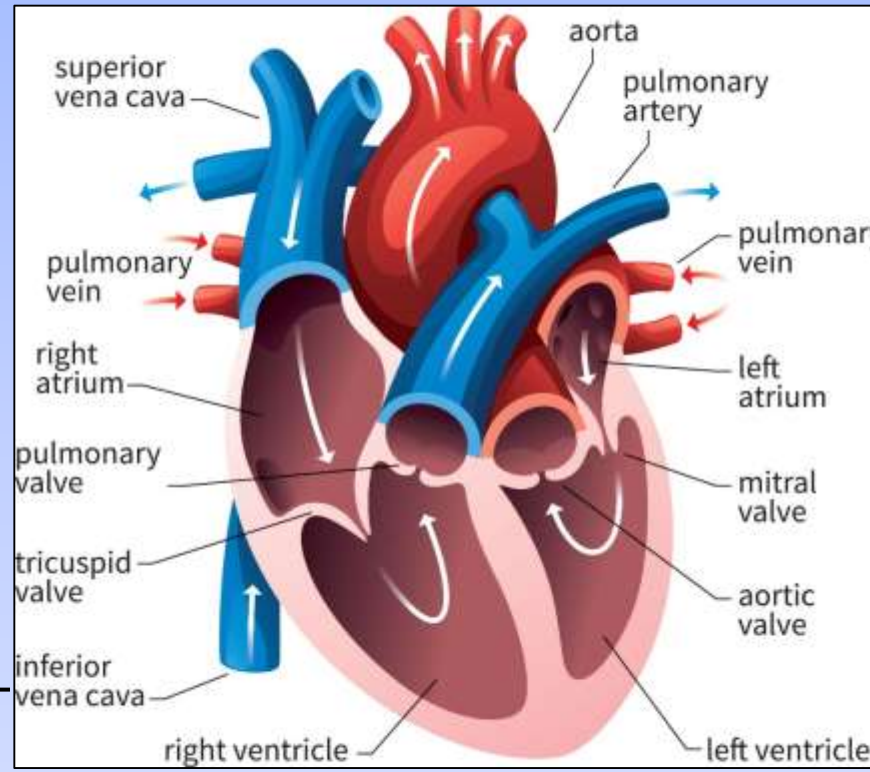
PROJECTS

1. *Linear Variable Differential Transformer (LVDT)*
2. ***Photoplethysmographic sensor (PPG)***
3. *Accéléromètre MEMS*
4. *Capteur photo-acoustique*

HEART ANATOMY

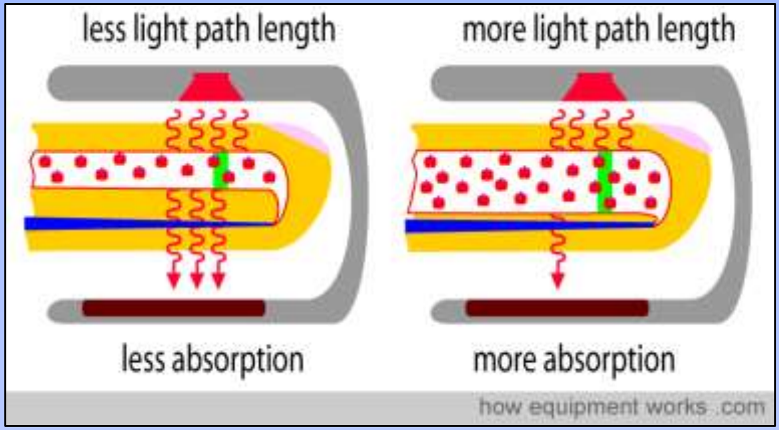


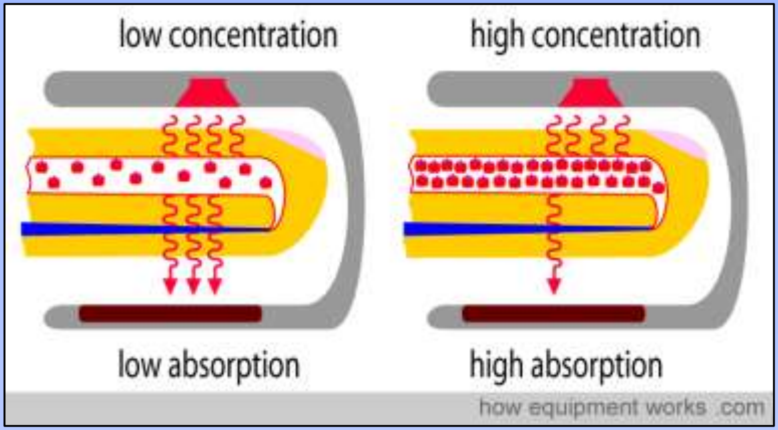
https://www.researchgate.net/figure/Lanatomie-du-coeur-13_fig3_328006263



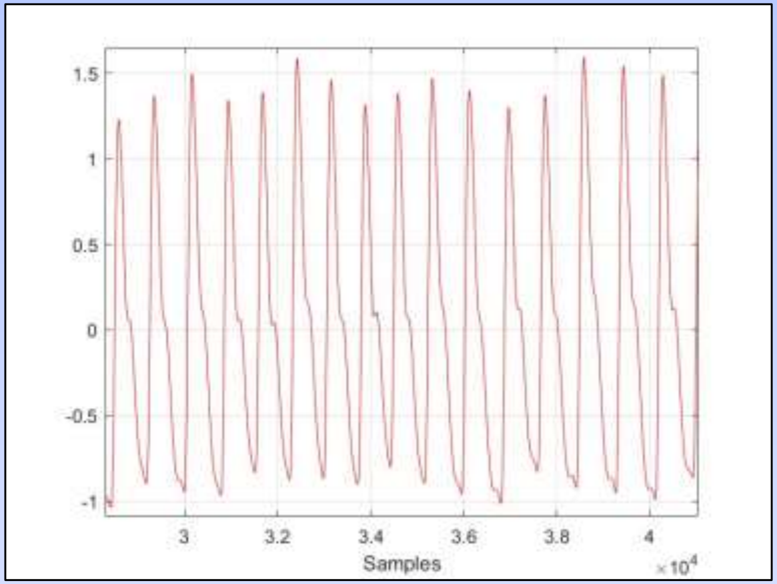
https://www.cardofmich.com/anatomy-human-heart-fun-facts/

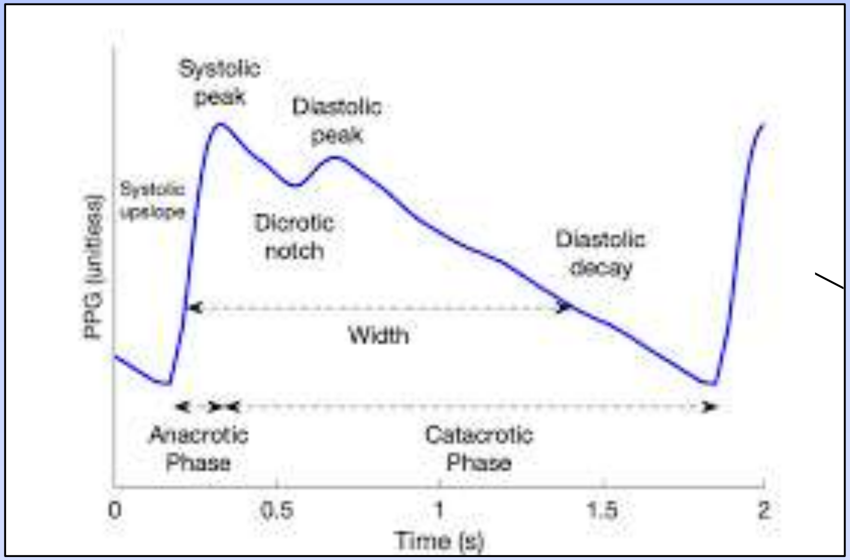
PPG





Pulse signal





https://peterhcharlton.github.io/publication/ppg_sig_proc_chapter/

PULSE OXIMETRY

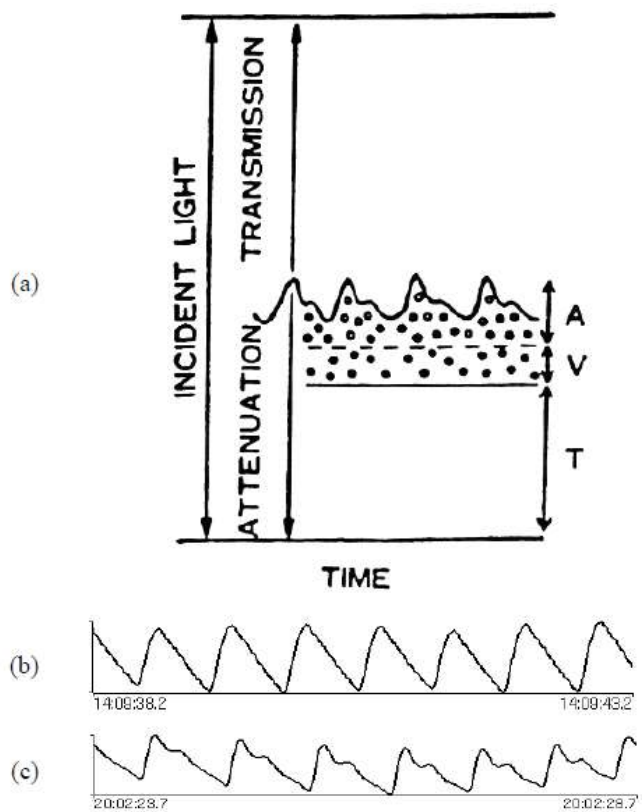


Figure 35: (a) Transmission of light through the finger when the attenuation of light is caused by arterial blood (A), venous blood (V) and tissues (T). (b) and (c) show typical pulsatile signals detected in the intensity of detected light when light is shone through a finger.

Beer-Lambert law

$$I = I_0 e^{-c\varepsilon(\lambda)d}$$

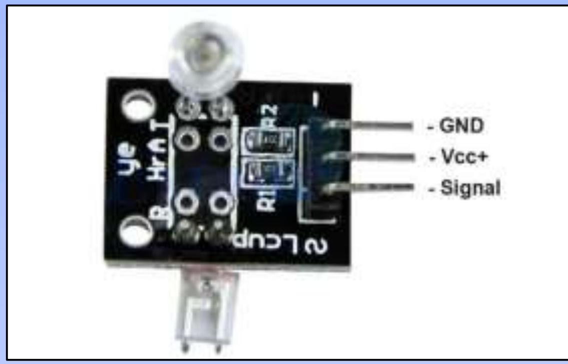
AC<<DC

Caucasian skin type (location finger tip):

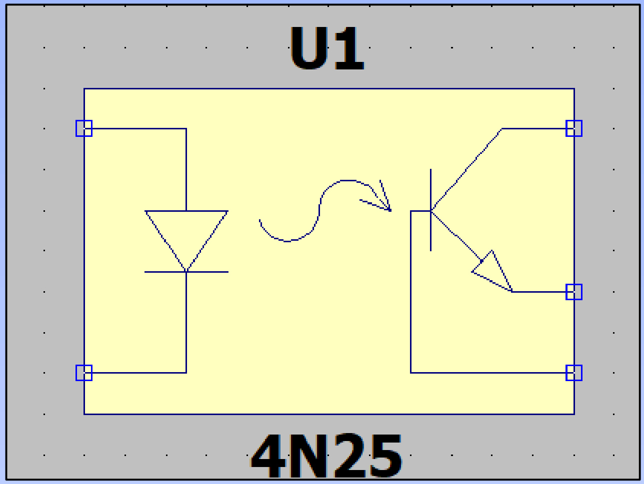
- detected AC: 80 nA$_{\text{(pk-pk)}}$
- detected DC offset: 1680 nA
- AC/DC – ratio: 4.8 %

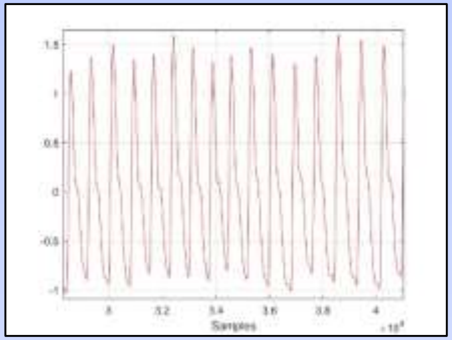
PPG SENSOR

KY-039

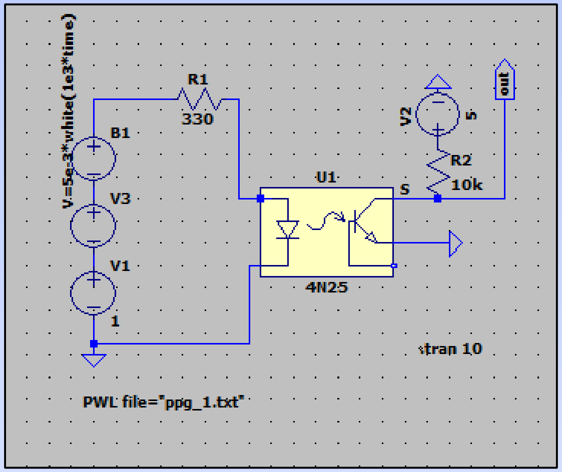


⇔





PWL file



OBJECTIVE

PPG sensor

CONDITIONNER
???

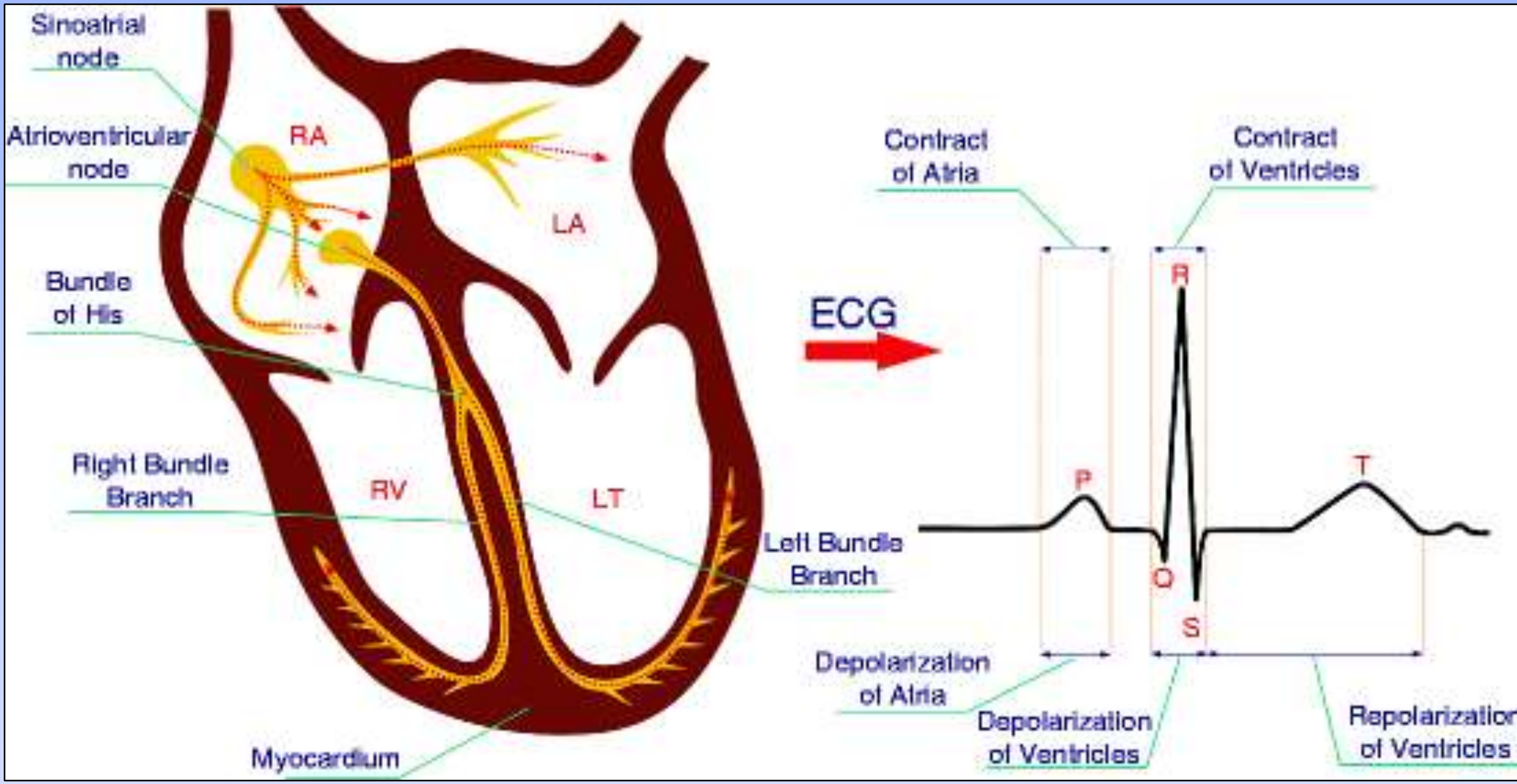
Arduino ADC

Visualize pulse signal with SNR > 20 dB

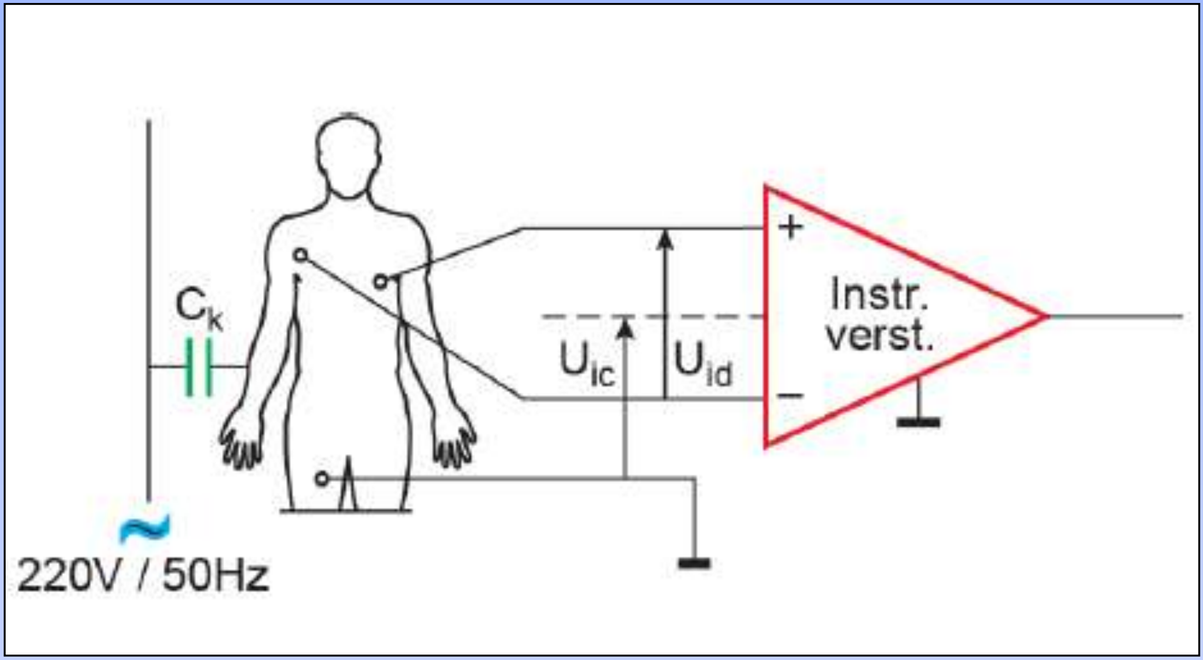
PROJECTS

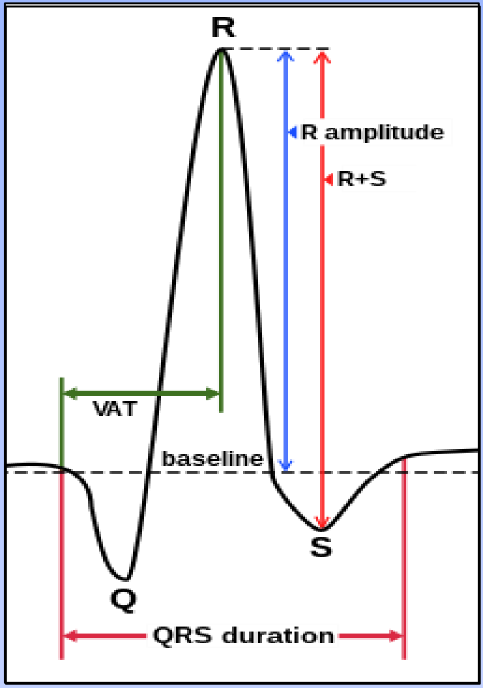
1. *Linear Variable Differential Transformer (LVDT)*
2. *Photoplethysmographic sensor (PPG)*
3. ***Electrocardio-Electromyogram (ECG/EMG)***
4. *Electrical Impedance Spectroscopy (EIS)*

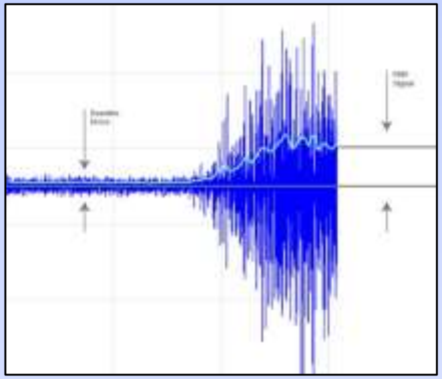
CARDIAC ELECTRICAL ACTIVITY



ECG/EMG





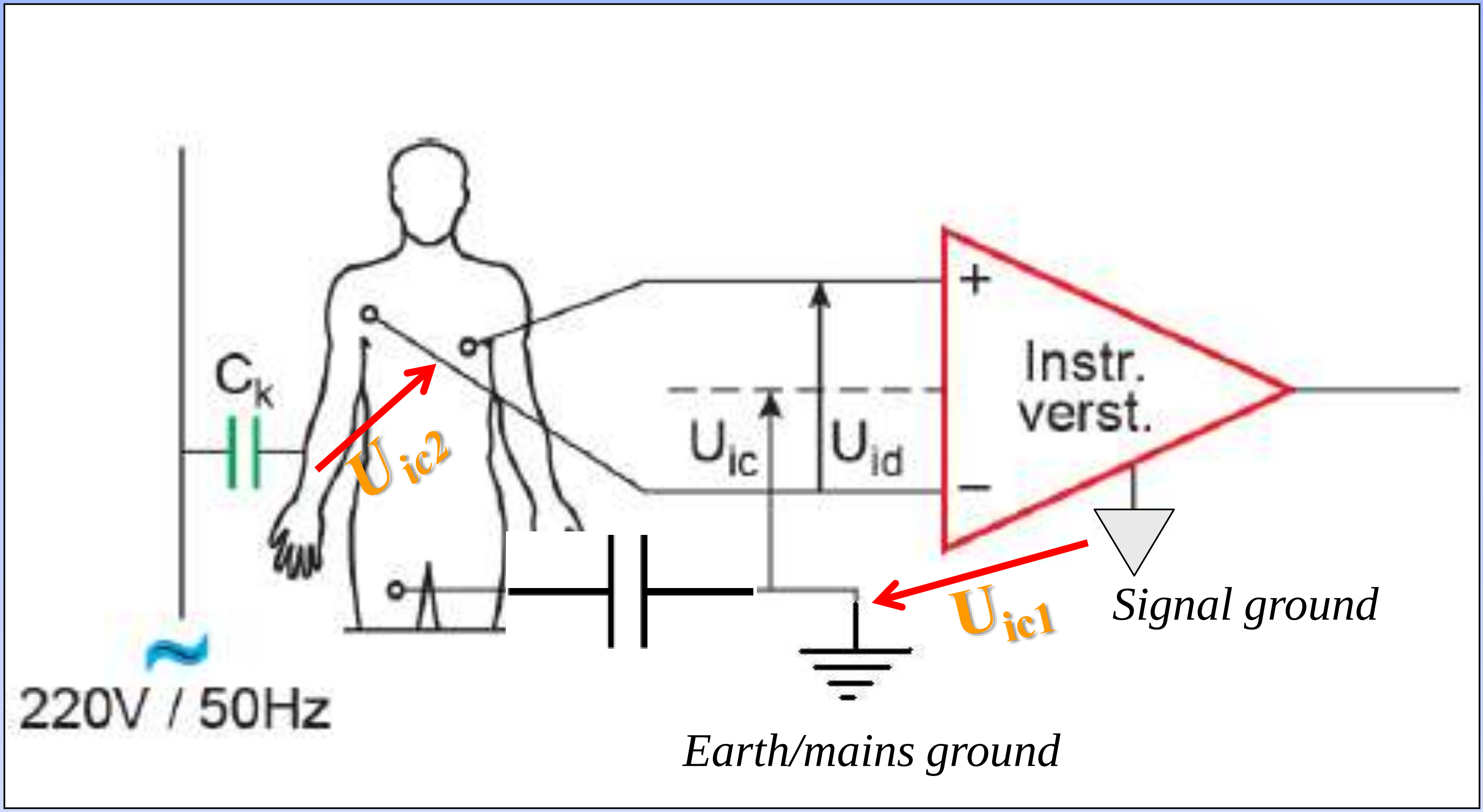


ECG $U_{id} \sim 10\mu V - 1mV$
$DC - 200Hz$

Mains $U_{ic} \sim 1mV$
$50Hz$

EMG $U_{id} \sim \ 100mV\ max$
$200 - 2000\ Hz$

COMMON MODE NOISE



ECG/EMG ELECTRODE

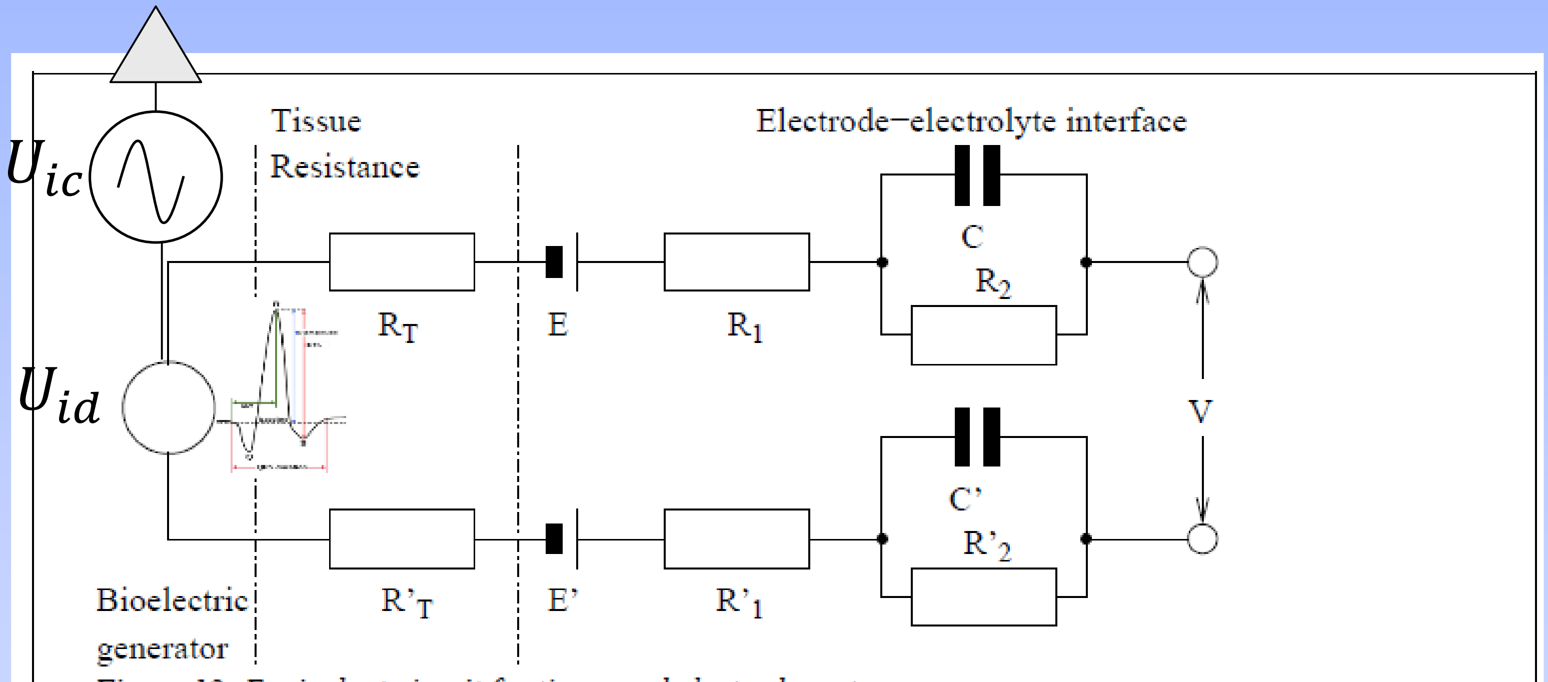
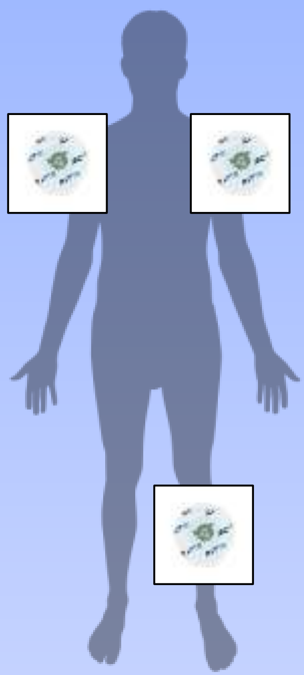


Figure 12: Equivalent circuit for tissue and electrode system

From Neil Towsend, Lecture Notes on Medical Electronics, U. Oxford, 2001

OBJECTIVE



CONDITIONNER
???

Arduino ADC

Visualize QRS complex with SNR > 12 dB

PROJECTS

1. *Linear Variable Differential Transformer (LVDT)*
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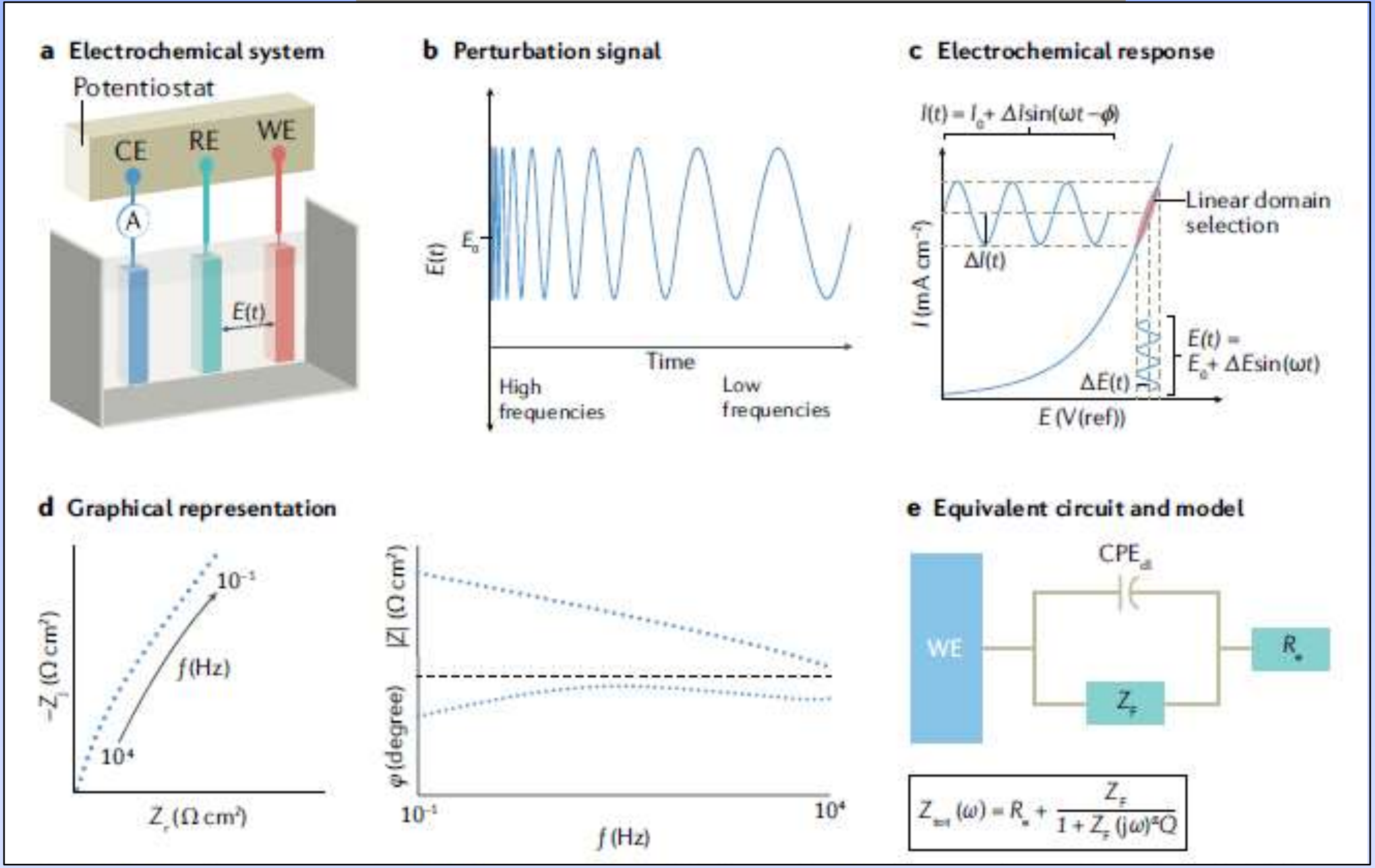
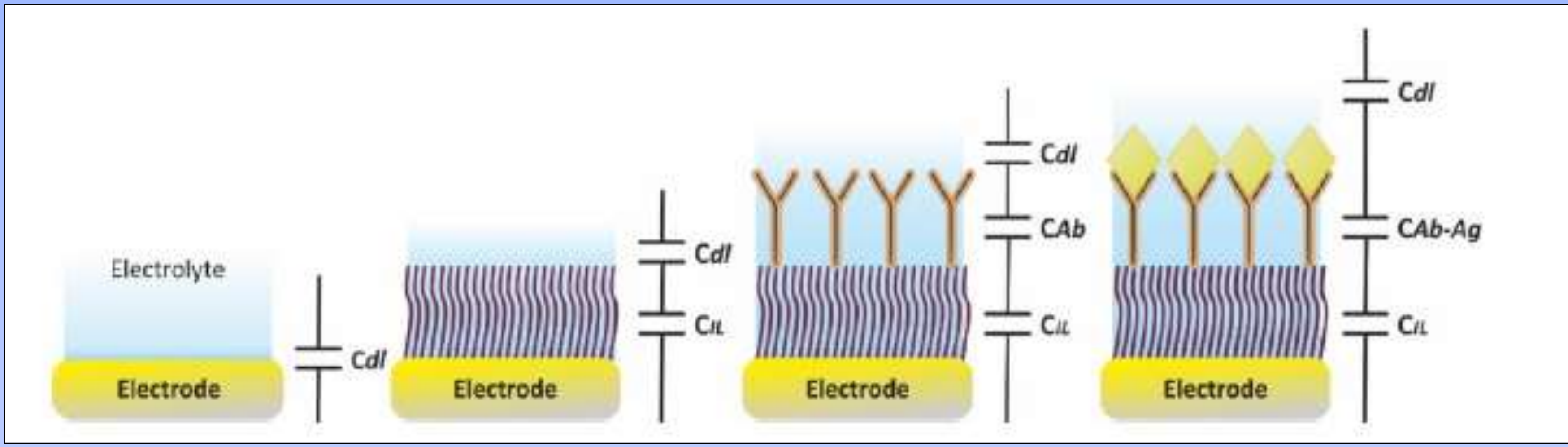
4. ***Electrical Impedance Spectroscopy (EIS)***

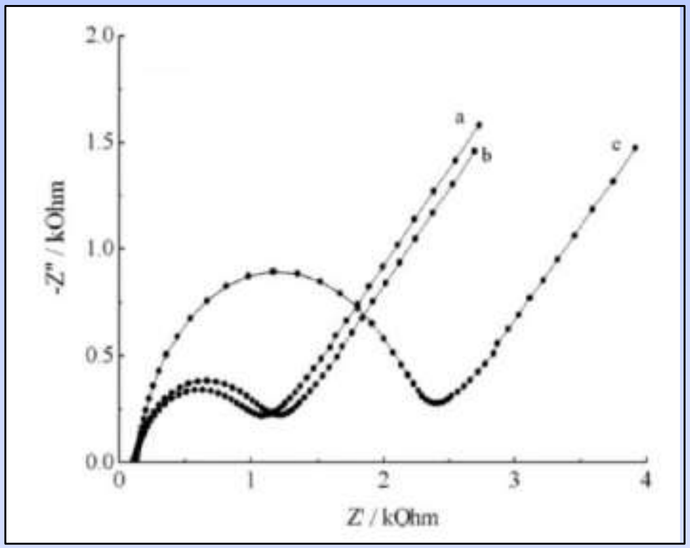
ELECTRICAL IMPEDANCE SPECTROSCOPY

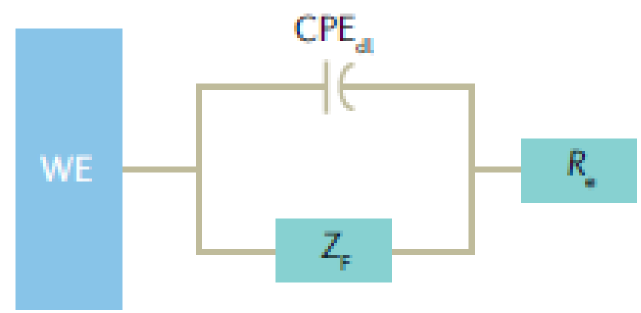


From Nature Reviews
https://doi.org/10.1038/s43586-021-00039-w

BIO-IMPEDANCE SENSOR



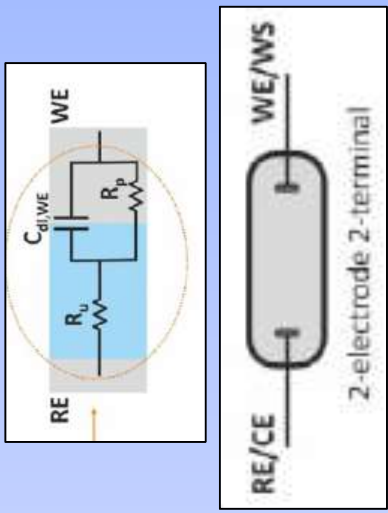




$$Z_{tot}(\omega) = R_s + \frac{Z_F}{1 + Z_F (j\omega)^n Q}$$

From ACS Meas. Sci.
https://pubs.acs.org/doi/10.1021/acsmeasuresciau.2c00070?ref=PDF

OBJECTIVE



CONDITIONNER
???

Arduino
ADC

Estimate impedance with 1% accuracy in the range 10Hz-1MHz

WHAT'S UP NEXT?

- *Homework #2 due this Sunday.*
- *Finalize groups*

  https://docs.google.com/spreadsheets/d/1jG2lCris9GgGGdKWz7DQZVMgyiD3Ul3fMIYuKIeCu6E/edit?usp=sharing

- *Read through biblio ressources.*