European Training Network on Electromagnetic Risks in Medical Technology

Deliverable: D.5.4– ETERNITY NWE2

Start date of the project: 1st March 2021

Duration: 48 months

Deliverable: summary Progress Report

This document aims to provide an overview of ETERNITY's second Network Wide Event

D.5.4 – ETERNITY NWE2

Due date of deliverable: M20
Organization name of the lead contractor for this deliverable: PLUX
Main author(s): PLUX -TU/e
Validated by: Tu/e and KU Leuven
Version number: FINAL
Submission Date: 31.10.2022

Type:	Report
Dissemination Level:	Public

Revision history

Revision	Date	Description	Author (Organization)
V0.1	07/10/22	Table of content + complete draft of the deliverable	PLUX
V0.2	14/10/22	Peer- review of the deliverable	TU/e and KU Leuven

This project has received funding from the European Union's EU Framework Programme for Research and Innovation Horizon 2020 under Grant Agreement No. 955.816.

Acronyms

EC	European Commission
PO	Project Officer European Commission
CA	Consortium Agreement
GA	Grant Agreement
DoA	Description of the Action
PCDP	Personal Career development plan
NWE	Network Wide Event
SB	Supervisory Board
MT	Management Team
PM	Project manager
RC	Recruiting Committee
NWE	Network Wide Event

Beneficiaries' short names

TU/e	Technische Universiteit Eindhoven
UT	Universiteit Twente
PMS	Philips Medical System Nederland B.V.
KUL	Katholieke Universiteit Leuven
UPC	Universitat Politècnica de Catalunya
IDNEO	Idneo Technologies SAU
PLUX	Plux -Wireless Biosignals S.A.

Partner Organizations' short names

PMC	Plasmacure
UMCU	Universitair Medisch Centrum Utrecht
EUF	Eurofins
BARCO	Barco
FCT	Faculdade de Ciências e Tecnologia
MST	Medisch Spectrum Centrum
ASEPEYO	Asepeyo hospital

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Table of Contents

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1. ETERNITY NWE2

The ETERNITY NWE2 took place in Lisbon, Portugal from the 26th to the 29th of September 2022.

The event was successful for the high number of attendees and their active participation indicated a great interest in the topics faced.

1.1. First day: Mid-Term check review meeting + lecture

On the first day, the project coordinator did an update on the project and took the opportunity to launch the official Eternity movie where the ESR's speak about the project.

The current 13 ESR's made a presentation about their work, more precisely what they already did in these last months and many topics were discussed in detail between the Beneficiaries and the Partner Organisations.

After lunch, Prof. Mireya Fernandez from UPC - Universitat Politècnica de Catalunya gave an invited talk on the subject of Bioelectric Signals. Prof. Mireya Fernandez gave an overview of the types and acquisition of electrical biosignals and made considerations about EMC problems that can be found when dealing with biosignals processing. After this session, the consortium visited the installations of one partner organization, FCT - NOVA School of Science and Technology and visited Cristo Rei.

The day ended up with a social event dinner where was performed the traditional Portuguese music, Fado.

1.2. Second day: Meeting Day with conclusions on 1st day + lecture

During the second day, the SB-MT meeting and ESR Council meetings took place separately in the morning. Both meetings were confidential and therefore their contents are not shared in this public deliverable. After these meetings, the consortium visited the premises of PLUX.

In the afternoon, Prof. Hugo Silva from PLUX held a lecture on Entrepreneurship in Biosignals. In this talk, Prof. Hugo Silva shared his knowledge on the creation of a new company and the product giving one real case and he learned about innovation, creative thinking, and market trends in a company. After this session, the ESR's gathered in groups for the first time during this event to discuss what they learned from the previous talk and to continue their previous work from the last NWE, with a slot for Immersive Training, related to Ideas and Solutions.

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The day finished with the sunset on a boat trip on the Tagus River with the best views of Lisbon's illuminated sights.

1.3. Third day: Lecture + "*S/T training*" and "*Immersive Training*"

The third day started with an invited talk on the subject "Machine Learning applied to Biosignals" held by Prof. Hugo Gamboa from FCT. The speaker gave an overview of the machine learning algorithms that are most frequently used for biosignals applications and processing. After this session, there was another slot for the ESR's to continue their previous work from the day before. After lunch, there was another session from PLUX devices Architecture, held by Filipe Silva and Renato Costa from PLUX, followed by a hands-on session related to PLUX devices. In the session, the speakers introduced one of the PLUX products' architecture, explained the different product versions, the low-cost biosignal acquisition platform and finally, the possible EMC obstacles found during the initial phase of product development.

1.4. Fourth day: "*S/T training*" and "Immersive training"– part 2

The last day started with a session by Prof.Hugo Silva "Current and Emerging applications". In this session, the speaker gave an insight into the entrepreneurial forming of technological applications and interaction between companies and customers. After this session, the ESR's continued their Immersive Training, which resulted in one presentation of each group presented by the ESR's. The day ended up with the analysis and feedback from Anne Roch' from Tu/e and Hugo Silva.

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2. Annex 1 (4-day event agendas)

ETERNITY's Network Wide Event II, Lisbon, September 26th – 29th

AGENDA

26th September

Time (GMT+1)	
09:00 – 09:10	Update on Project Development (Project Coordinator)
09:10 – 09:20	ETERNITY movie official launch + promoting ETERNITY (P.Coordinator + All)
09:20 – 10:20	ESR's 1-5 PPTs (10 min ppt + 5min Q&A)
10:20 – 10:40	Coffee Break
10:40 – 11:40	ESR's 6-9 PPTs (10 min ppt + 5min Q&A)
11:40 – 12:55	ESR's 10-14 PPTs (10 min ppt + 5min Q&A)
12:55– 14:30	Lunch
14:30 – 15:30	Invited Talk: Bioelectric Signals, Mireya Fernandez
15:30 – 18:00	Visit to FCT
19:15 – 20:45	Official Dinner

27th September – For the ESR's

Time (GMT+1)	
9:00 - 12:30	ESR's council / Representative vote Visit to PLUX
12:30 – 14:00	Lunch
14:00 – 15:15	Entrepreneurship in Biosignals, Hugo Silva
15:15 – 15:45	Coffee Break
15:45 – 16:45	Immersive Training (Ideas and Solutions)
18:00 – 20:00	Boat trip on Tagus River

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27th September – For Beneficiaries

Time (GMT+1)	
9:00 – 9:10	Status on PO's recommendations (Project Coordinator)
9:10 – 9:15	Ongoing deliverables and end of 2022 (Project Coordinator)
9:15 – 9:25	Next coming deliverables - M24 - (Project Coordinator)
9:25 – 9:35	Financial aspects (Project Coordinator)
9:35 – 10:20	Short PPT on each ESR's activity showing project progress (Beneficiaries)
10:20 – 10:30	Break
10:30 – 10:40	UPC status (without ESRs' representative)
10:40 – 11:00	Status on PCDPs -D.7.8 "Progress report of PCDP to Supervisory Board 1" (Beneficiaries with new and update PCDPs)
11:00 – 11:15	Update on secondments (Project Coordinator)
11:15 – 11:30	NWE3 in Barcelona (UPC)+ A.O.B.
11:30 – 12:30	Visit to PLUX
12:30 – 14:00	Lunch
14:00 – 15:15	Entrepreneurship in Biosignals, Hugo Silva
15:15 – 15:45	Coffee Break
15:45 – 16:45	Immersive Training (Ideas and Solutions)
18:00 – 20:00	Boat trip on Tagus River

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28th September

Time (GMT+1)	
10:00 – 11:15	Invited Talk: Machine Learning applied to Biosignals, Hugo Gamboa
11:15 – 11:30	Coffee break
11:30 – 12:30	Immersive Training (Ideas and Solutions)
12:30 – 14:00	Lunch
14:00 – 15:15	PLUX devices Architecture, Filipe Silva and Renato Costa
15:15 – 15:45	Coffee break
15:45 – 17:45	Hands-on PLUX Devices

29th September

Time (GMT+1)	
10:00 – 11:15	Current and Emerging applications, Hugo Silva
11:15 – 11:30	Coffee break
11:30 – 12:30	Immersive Training (Ideas and Solutions)
12:30 – 14:00	Lunch
14:00 – 15:00	Immersive Training (Ideas and Solutions) - Presentation Preparation
15:00 – 15:15	Coffee break
15:15 – 16:15	Presentations

(The coffee breaks between the sessions and the official dinner mentioned in the agenda as well as social events will be covered by ETERNITY central budget).

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3. Annex 2 (first day's presentations)

This project has received funding from the European Union's EU Framework Programme for Research and Innovation Horizon 2020 under Grant Agreement No. 955.816.

Grup de Compatibilitat Electromagnètica
UNIVERSITAT POLITÈCNICA DE CATALUNYA

Mireya Fernández Chimeno
GCEM-UPC

Bioelectrical signals

from cell to amplifier

eTERNITY
European Training Network
on Electromagnetic Risks
in Medical Technology

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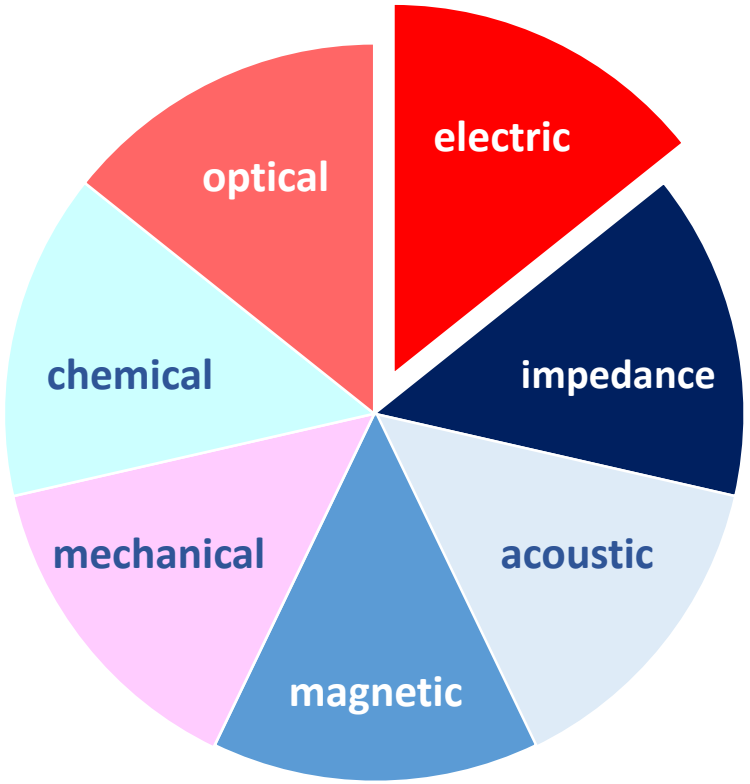
Biomedical signals

What is a biomedical signal?

A signal is a phenomena that conveys information. Biomedical signals are signals for extracting information of a biologic system

What types of biomedical signals are there?

BIO



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Biomedical signals

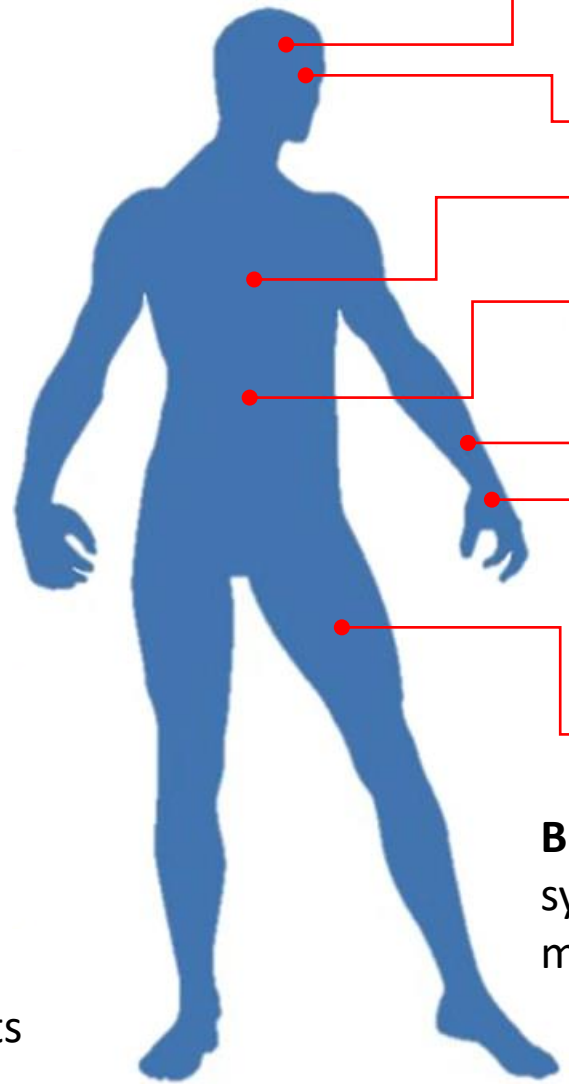
Bioelectric: ECG, EMG, EEG, EOG, EGG, ENG, ERG, GSR…

Bioimpedance: Body composition, blood volumen, blood distribition, endocrine activity, ANS activity, tissue status (detection of tumors, scars..)

Biomechanical: motion, displacement, pressure, flow,..

Biomagnetic: weak magneic fieldsgenerated by some organs as brain, heart and lungs: MEG, MNG, MRG, MCG, MMG, MOG

Bioacustic: Biomedical phenomena that create acoustic noise



EEG, EP, MEG

EOG, ERG, MOG, MRG

ECG, MCG

EGG

ENG, MNG

GSR

EMG, MMG

Biochemical: Result of chemical measurements of living tissues

Biooptical: Result of optical functions of the biological system, occurring naturally or induced by the measurement.

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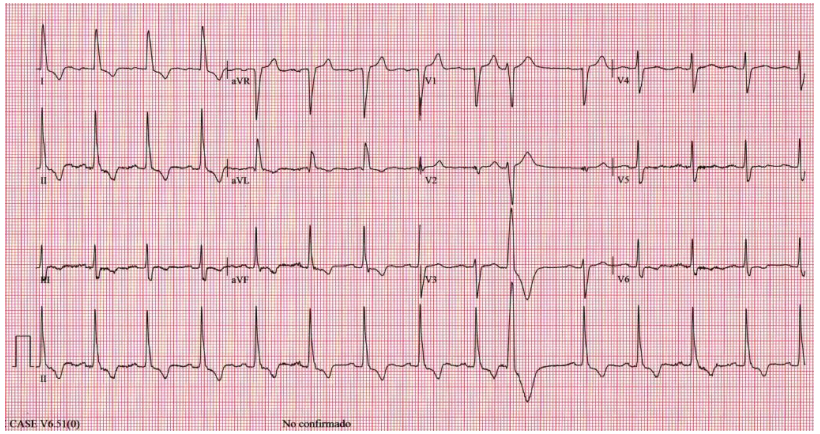
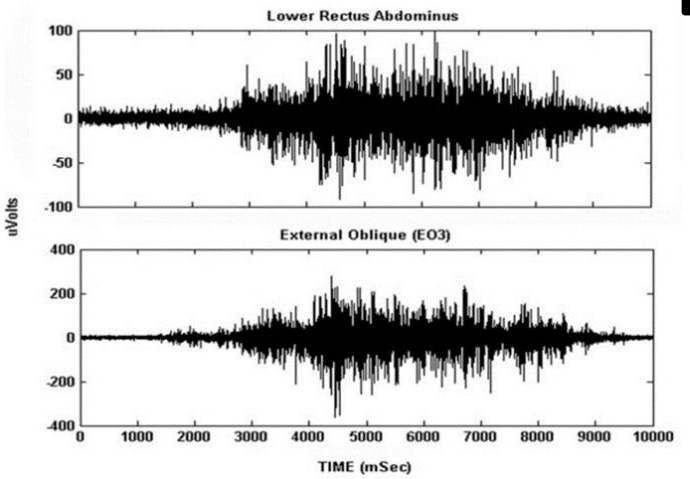
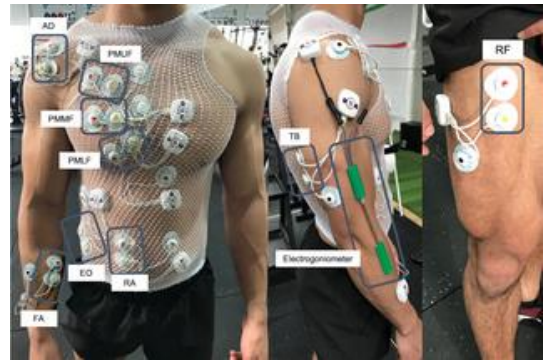
Bioelectric signals

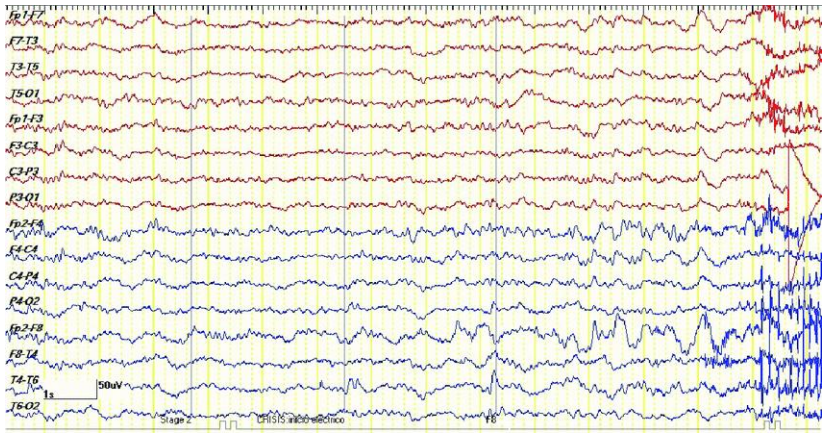
ECG



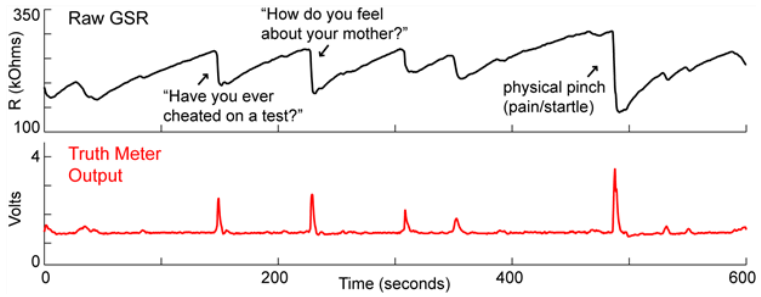
EMG

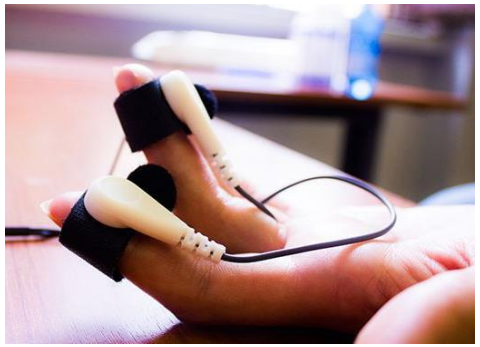






EEG





GSR

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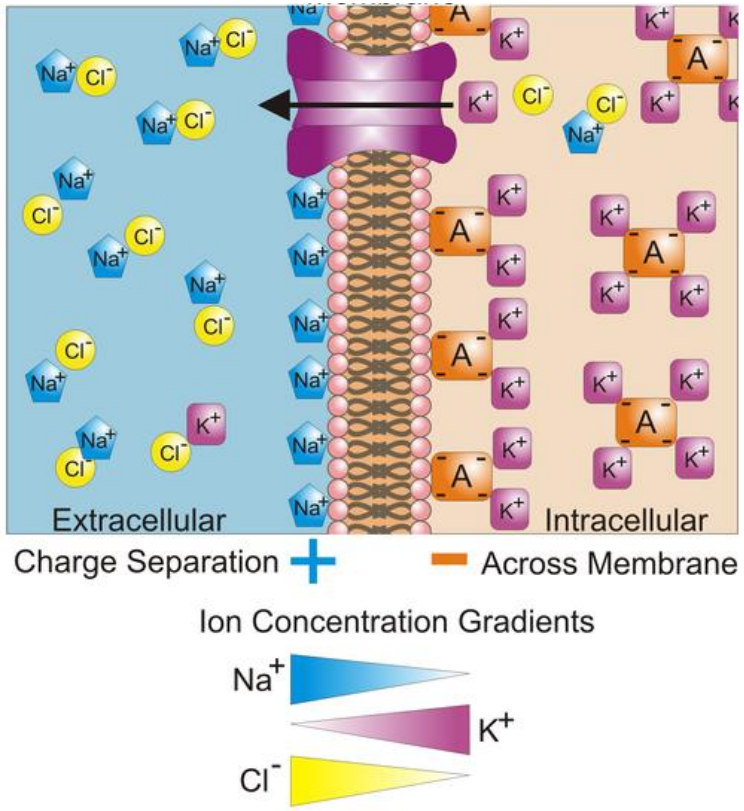
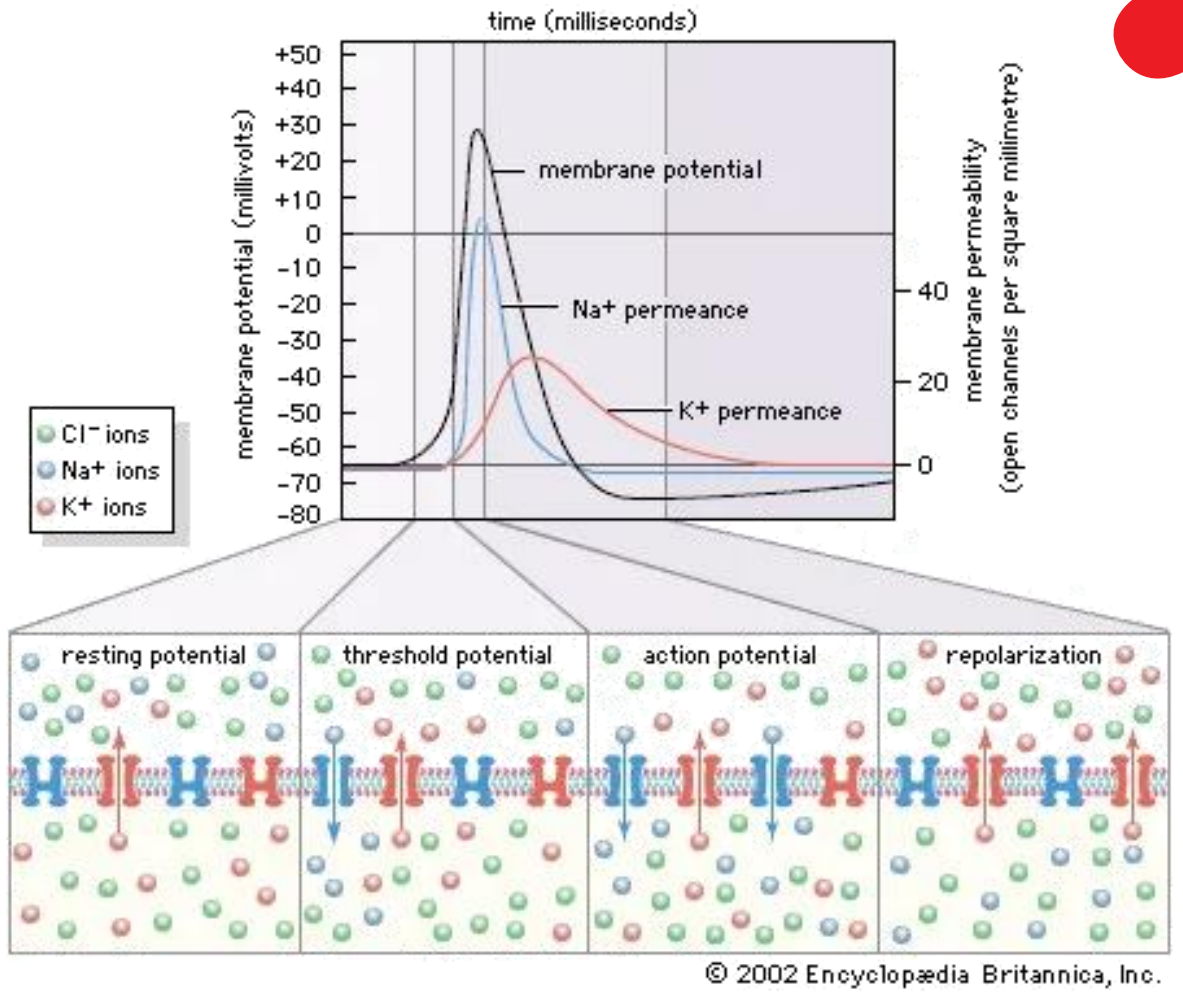
Origin of bioelectric signals





Action Potentials

The action potential, the brief (about one millisecond) reversal of electric polarization of the membrane of a nerve cell (neuron) or muscle cell. In the neuron an action potential produces the nerve impulse, and in the muscle cell it produces the contraction required for all movement.

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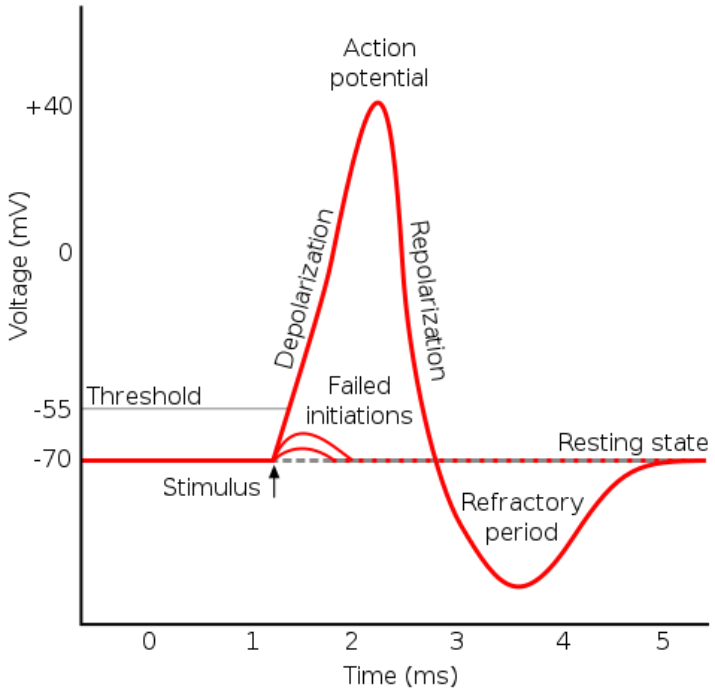
Origin of bioelectric signals



Every action potential is followed by a **refractory period**. This period can be further divided into:

the **absolute refractory period** which occurs once the sodium channels close after an AP. Sodium channels then enter an inactive state during which they cannot be reopened, regardless of the membrane potential.

the **relative refractory period** which occurs when sodium channels slowly come out of the inactivation. During this period the neuron can be excited with stimuli stronger than the one normally needed to initiate an AP.

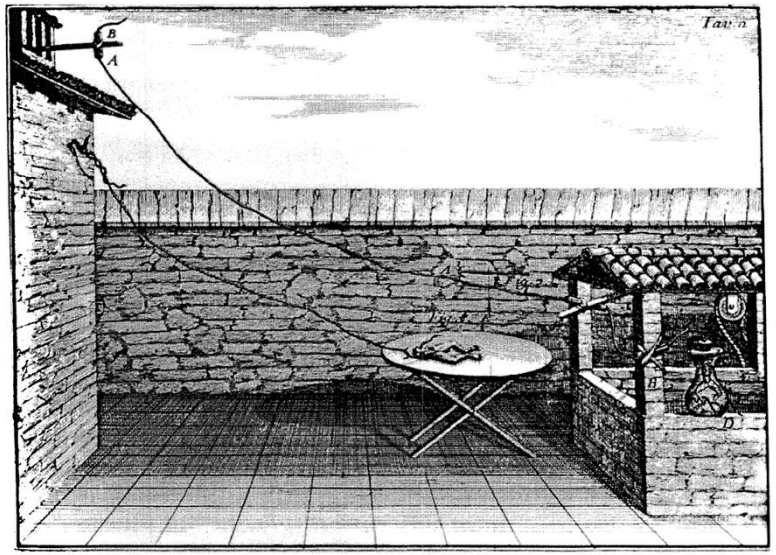
Action potentials are propagated along the axons of neurons via local currents. Local currents induce depolarization of the adjacent axonal membrane and where this reaches a threshold, further action potentials are generated. The areas of the membrane that have recently depolarized will not depolarize again due to the refractory period.

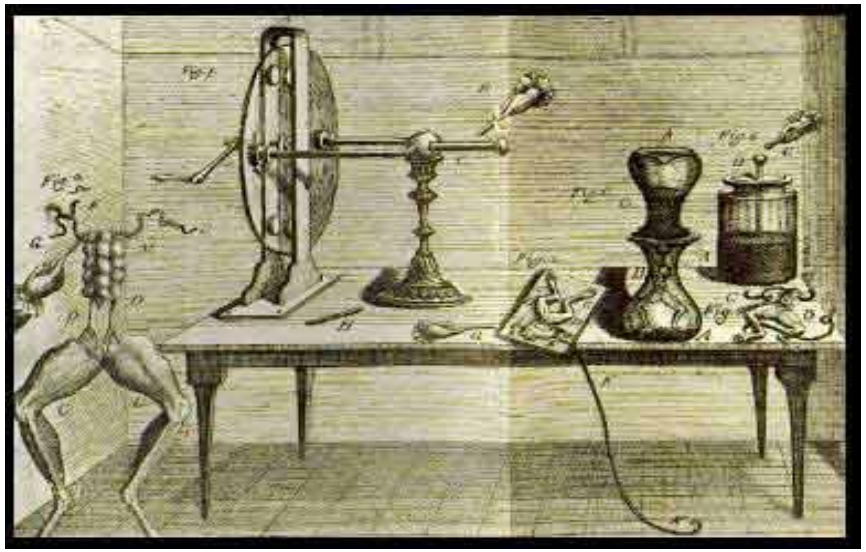
→ the action potential will only travel in one direction.

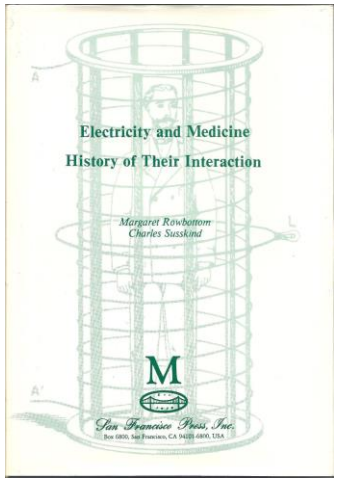
The Beginnings

Until the 17th century: muscular activity was due to the production of "animal spirits“ and the nerves were empty like pipes.

* 1718 Newton proposes solid nerves and wave propagation by vibrations.
* 1781 Fontana proposes full nerves and transmission by electrical impulses
* 1780-1790 Galvani and Volta demonstrate the existence of bioelectric potentials and muscle stimulation.







Luigi Galvani. “animal electricity” 1780

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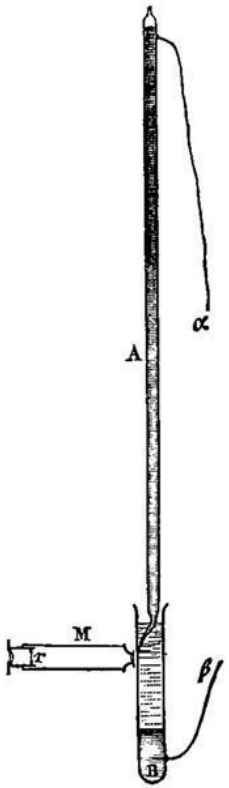
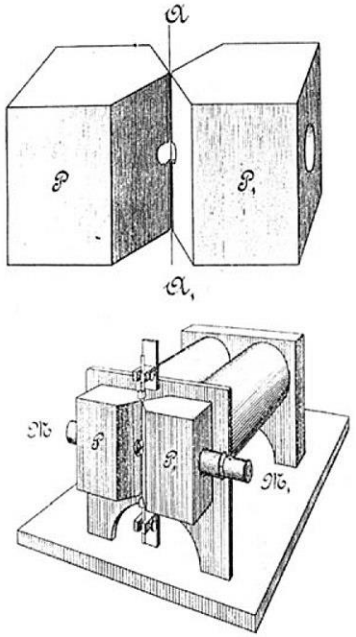
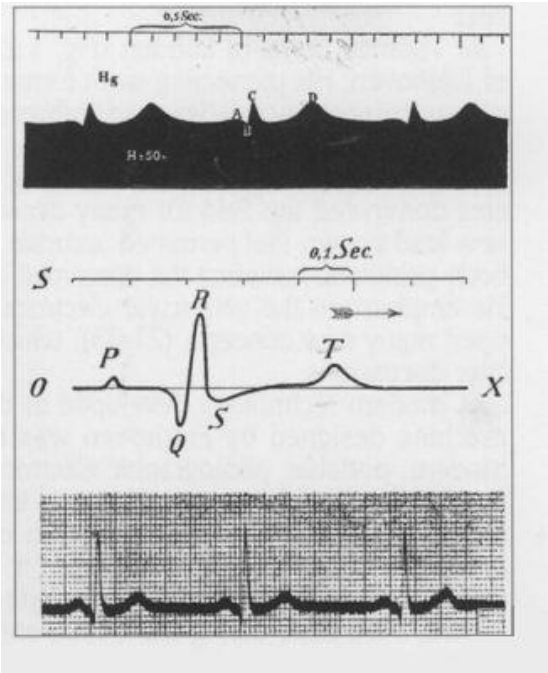
The Beginnings

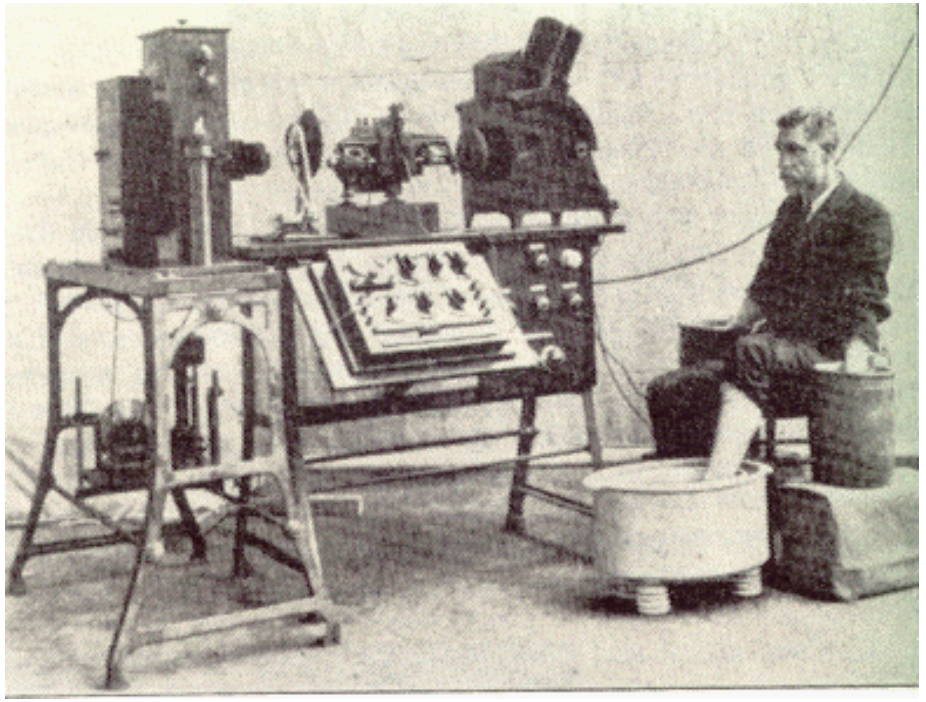
First biopotentials recording:

1873: Lippmann : mercury electrometer
1876: Waller: human ECG
1901: Einthoven: ECG+ Filament Galvanometer
1925: Berger EEG





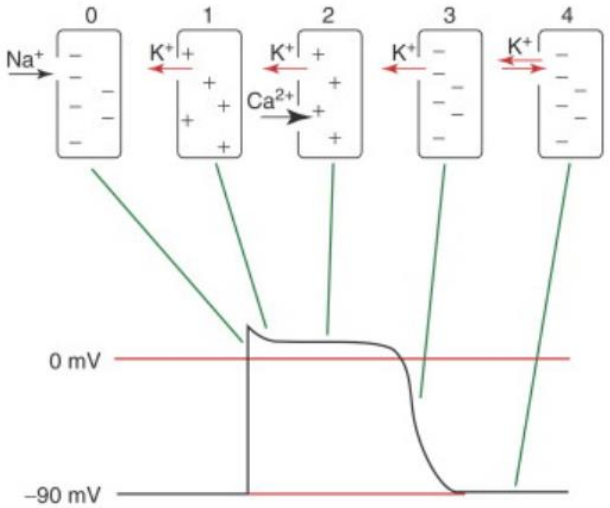


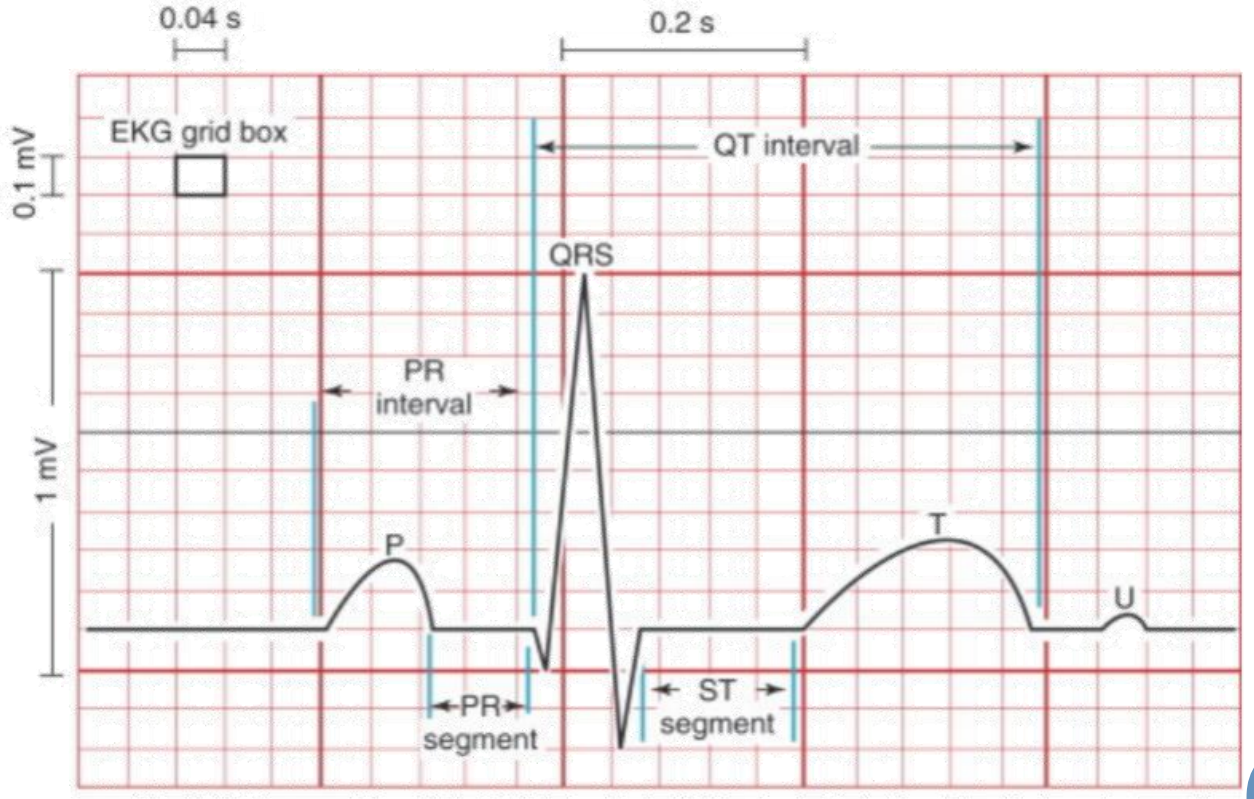


First Commercial Electrocardiograph, Einthoven, 1912

The ECG

The depolarization and repolarization of heart cells uses electrically charged ions that enter back and forth heart cell membranes in a synchronized sequence to create the AP. As ions are electrically charged, the propagation of the AP engenders the propagation of an electrical current. The electrocardiogram (ECG or also EKG) is a non-invasive test that captures an electrical tracing of these currents using electrodes attached to the surface of the body, producing a graph of voltage over time.





Mireya Fernández Chimeno
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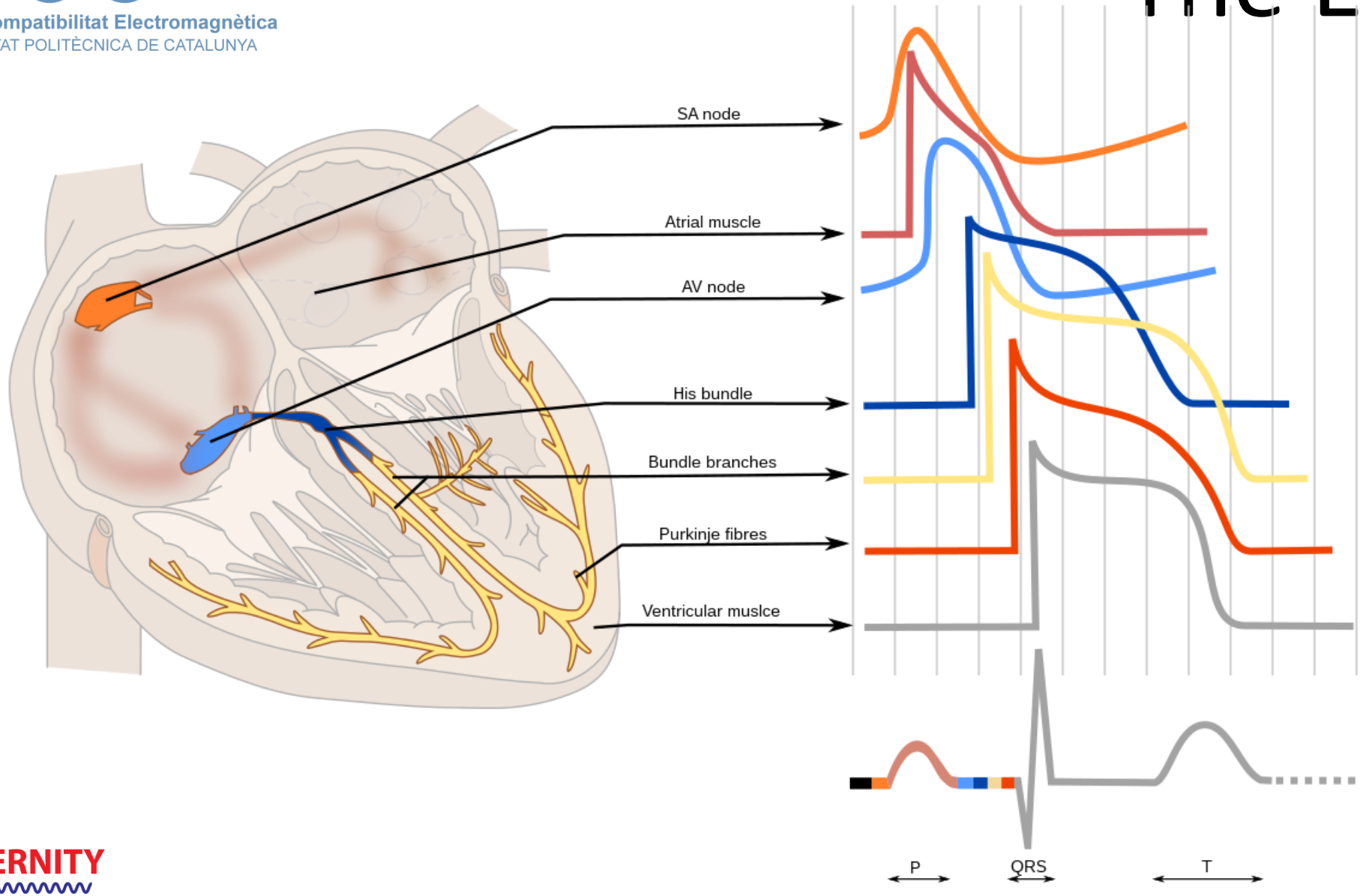
The ECG



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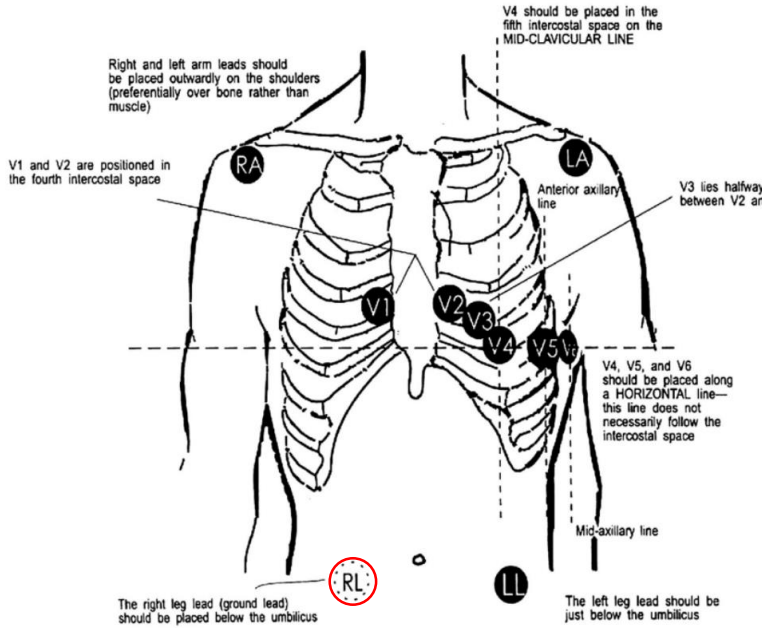
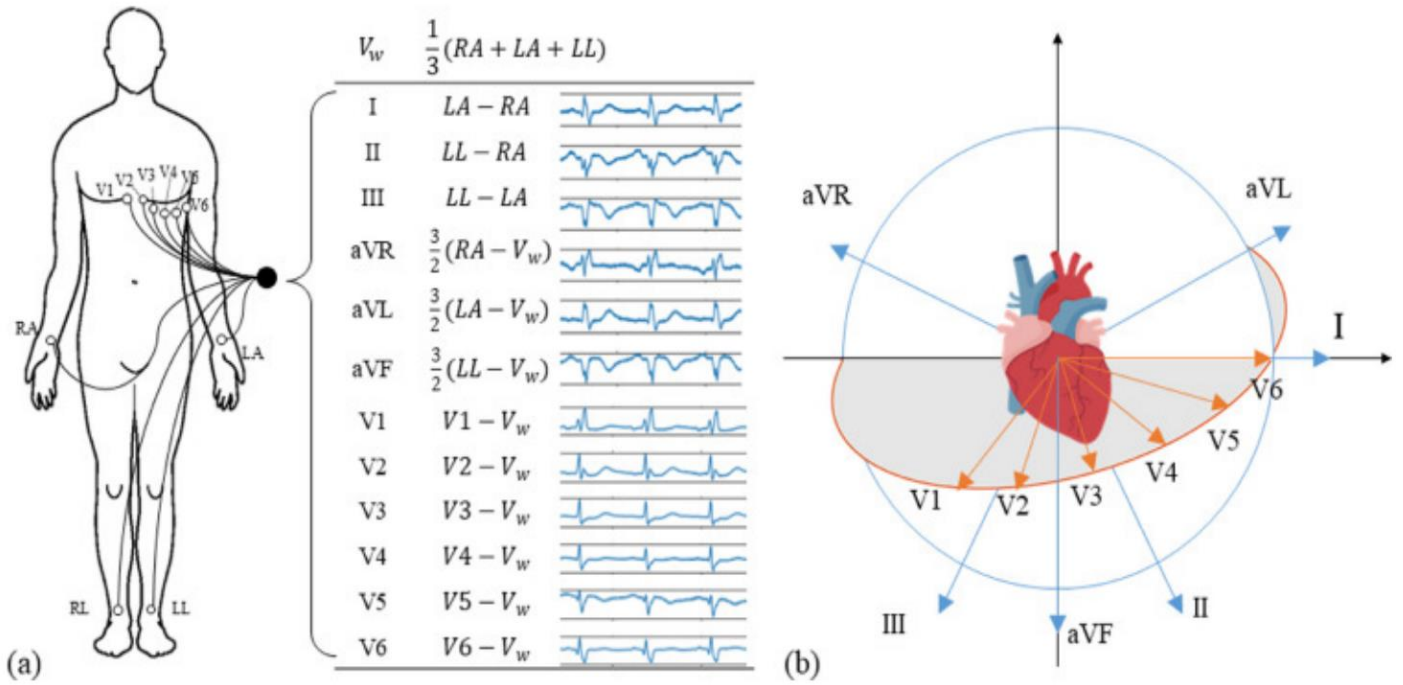
The ECG

The 12-lead ECG, The Gold Standard

The 12-lead ECG is a combination of **Einthoven's, Wilson's and Goldenberg's ECG developments** and, as such, captures the electrical activity of the heart from 12 different angles using 10 electrodes, traditionally with the patient lying down, and has become the gold standard in clinical settings.





Standard placement of the 10 electrodes for the 12-lead ECG, here the limb electrodes are placed at proximal locations (Harder, 2015)

(a) 12-lead ECG electrode positioning with lead representation
(b) 3D model of vectors captured in the 12-lead ECG (Yao et al., 2020).

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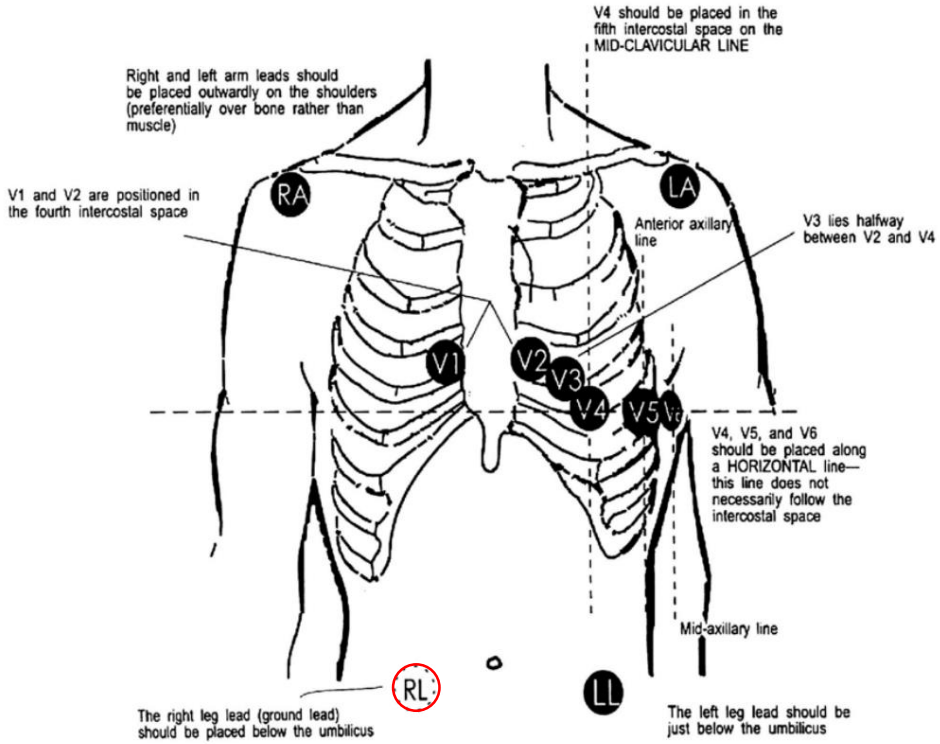
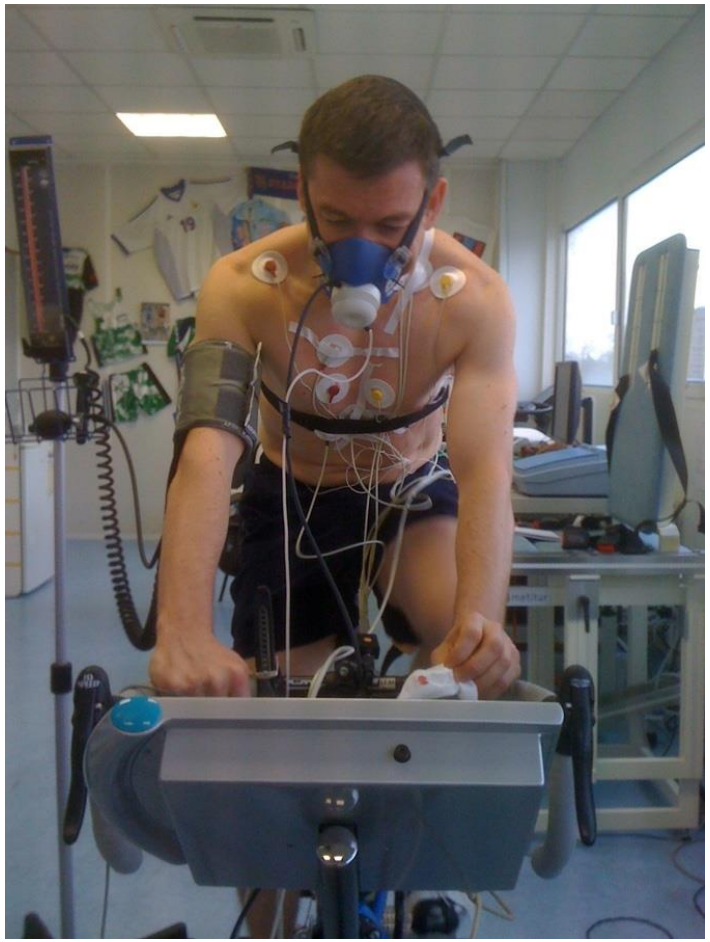
The ECG

The 12-lead ECG, The stress ECG





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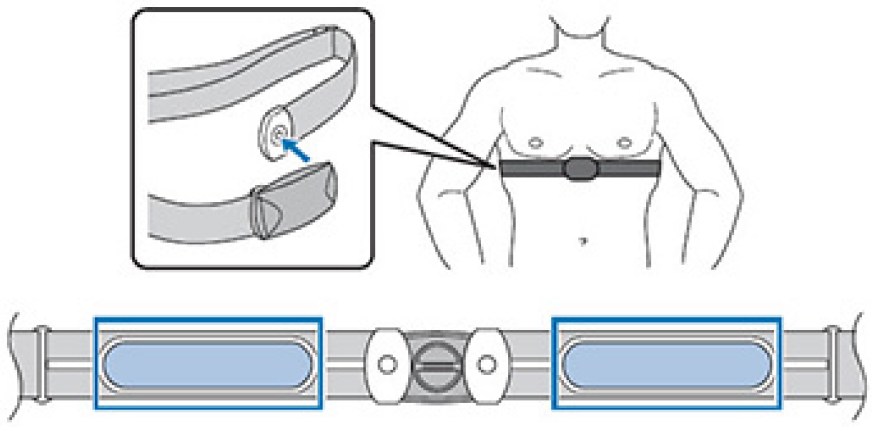
The ECG

Single Lead ECG

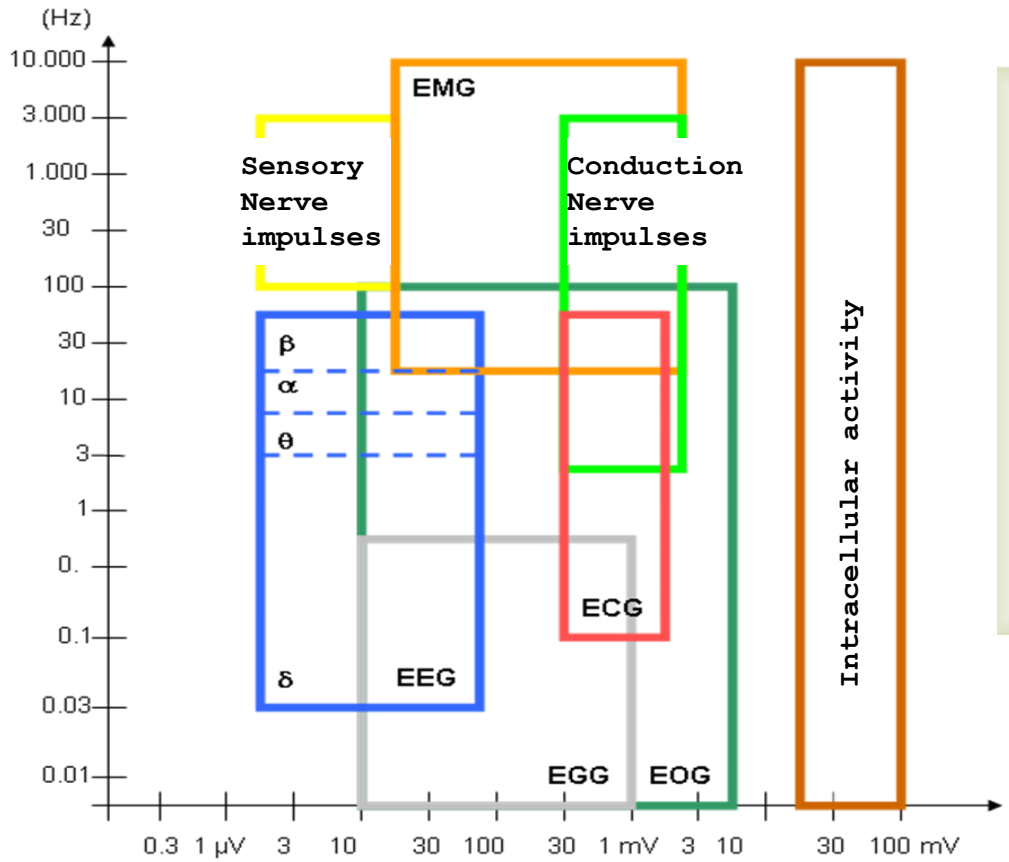
The vast majority of ECG-based wearable devices are single lead systems consisting of two electrodes without using a third earthing reference electrode. Whereas for the detection of a variety of cardiac pathologies such as ischemia multi lead ECG is required, single lead ECG is able to efficiently detect HR and thus HRV.

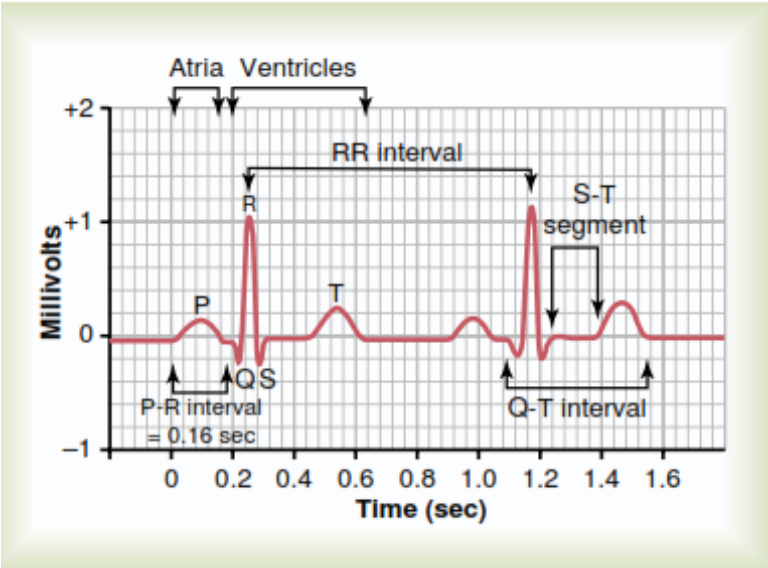


Chest-based strap electrodes (Epsom, 2015).

How can we measure a biopotential ?

We need to know the signals characteristics



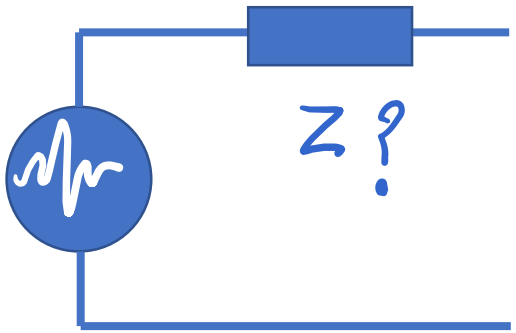


Amplitude:

- QRS 0.5 mV - 3 mV
- P wave 0.1 mV – 0.3 mV
- T wave 0.2 mV – 0.3 mV

Duration

- QRS 70 ms - 100 ms
- PR interval ≈160 ms
- QT interval ≈ 350 ms
- RR Interval 500 ms - 1200 ms
- ECG BW: 0.05 to 40 Hz



WEBSTER, J. G. Medical Instrumentation: Application And Design. 3rd. ed. John Wiley, 1998

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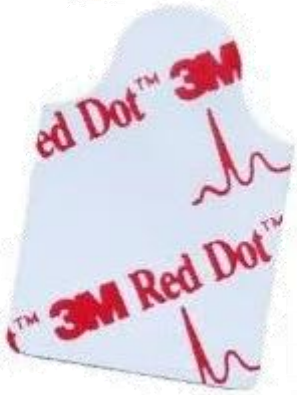
How can we measure the ECG?

The electrodes

When we want to measure a biopotential, we need to put some electrodes in contact with the skin. The electrodes are the transducers between the ionic currents inside the body and the electrical currents that goes to the measurement system.





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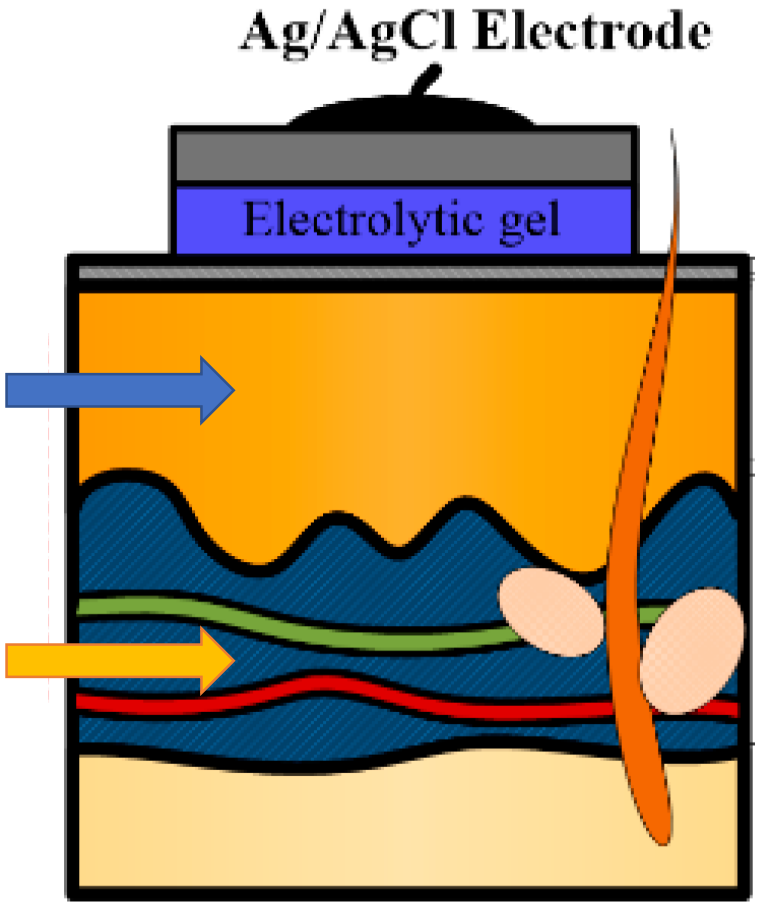
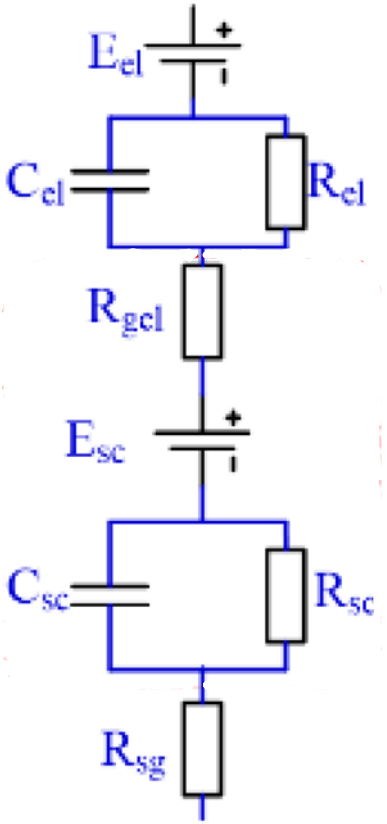
How can we measure the ECG?

The electrodes

Stratum corneum (epidermis)

Dermis

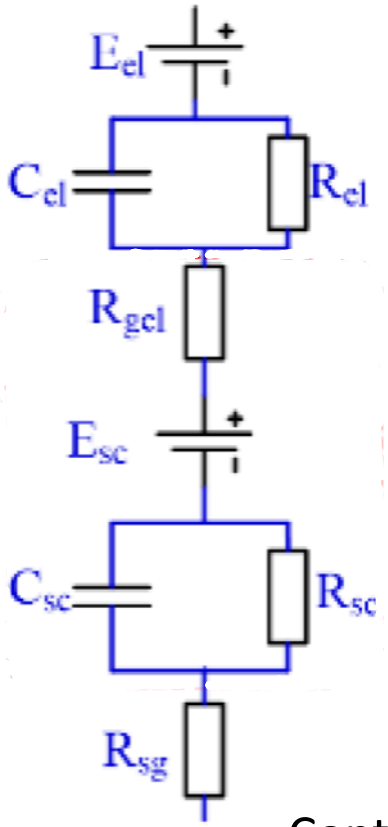




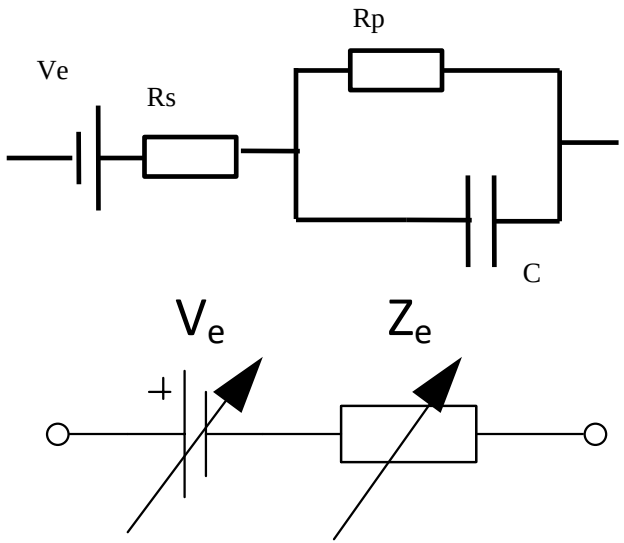
E_{el}: Electrode potential
E_{sc}: Skin potencial
R i C Equivalent resistance and capacitance for electrodes, gel, and Skin

How can we measure the ECG?

The electrodes



Simplified model



Ve: contact potential Rs: series resistance
Rp: parallel resistance C: parallel capacitance

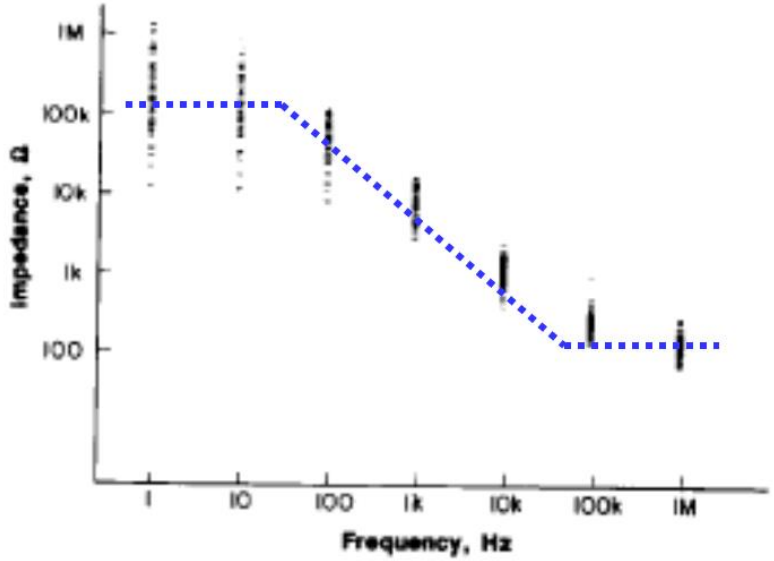
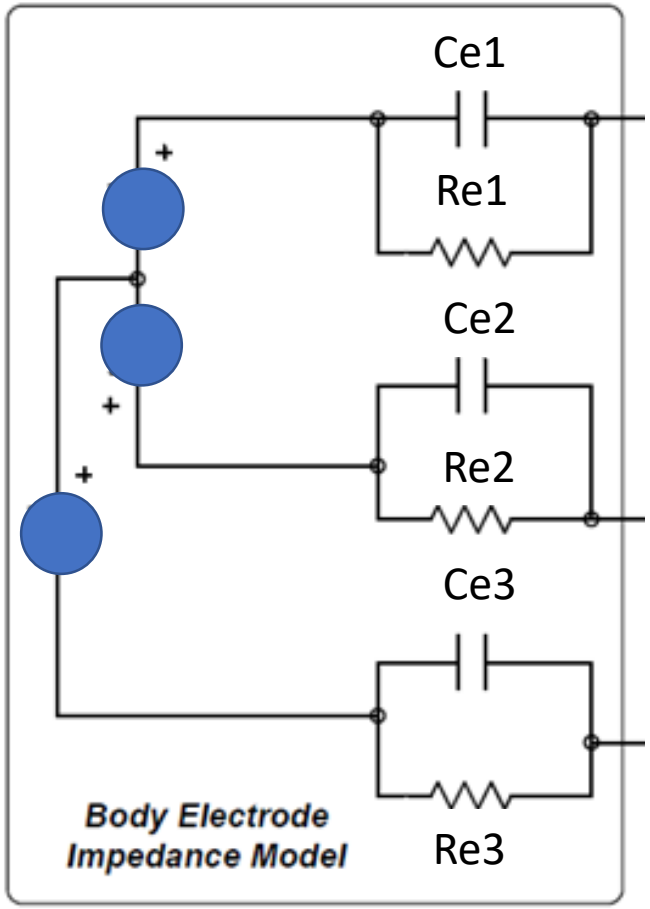


Fig. 4. Impedance versus frequency for all data. High-frequency impedance is about 100 Ω, whereas low-frequency impedance varies from 10 kΩ to 1 MΩ.

J.G. Webster, "*Medical instrumentation: application and design. 2nd ed*",Houghton Mifflin, Boston, U.S., 1992

Contact potential and electrode impedance depend on the contact and skin condition. They can have slow variations along a measurement (**base line drift**) or rapid changes associated with motion (**motion artifacts**)

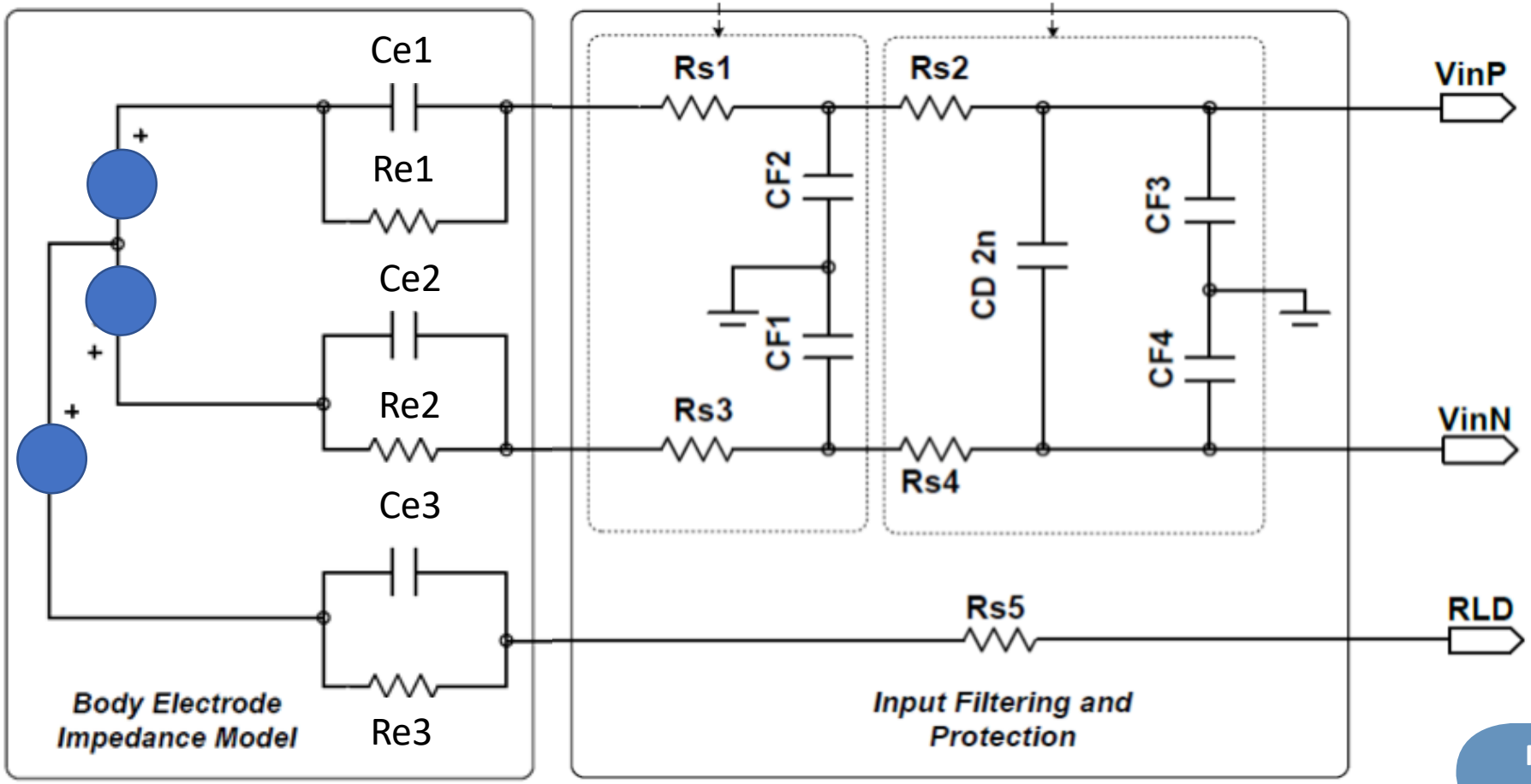
How can we measure the ECG?



Diferential signal with common mode

How can we measure the ECG?

$$fc = \frac{1}{2\pi\sqrt{R_{s1}R_{s2}C_{F1}C_{F2}}} \qquad f_D = \frac{1}{2\pi(R_{s1} + R_{s2} + R_{s3} + R_{s4}) \cdot C_D}$$



$$f_D \geq 10 \cdot f_{ECG}$$

$$f_D \leq \frac{f_c}{10}$$

Diferential signal with common mode

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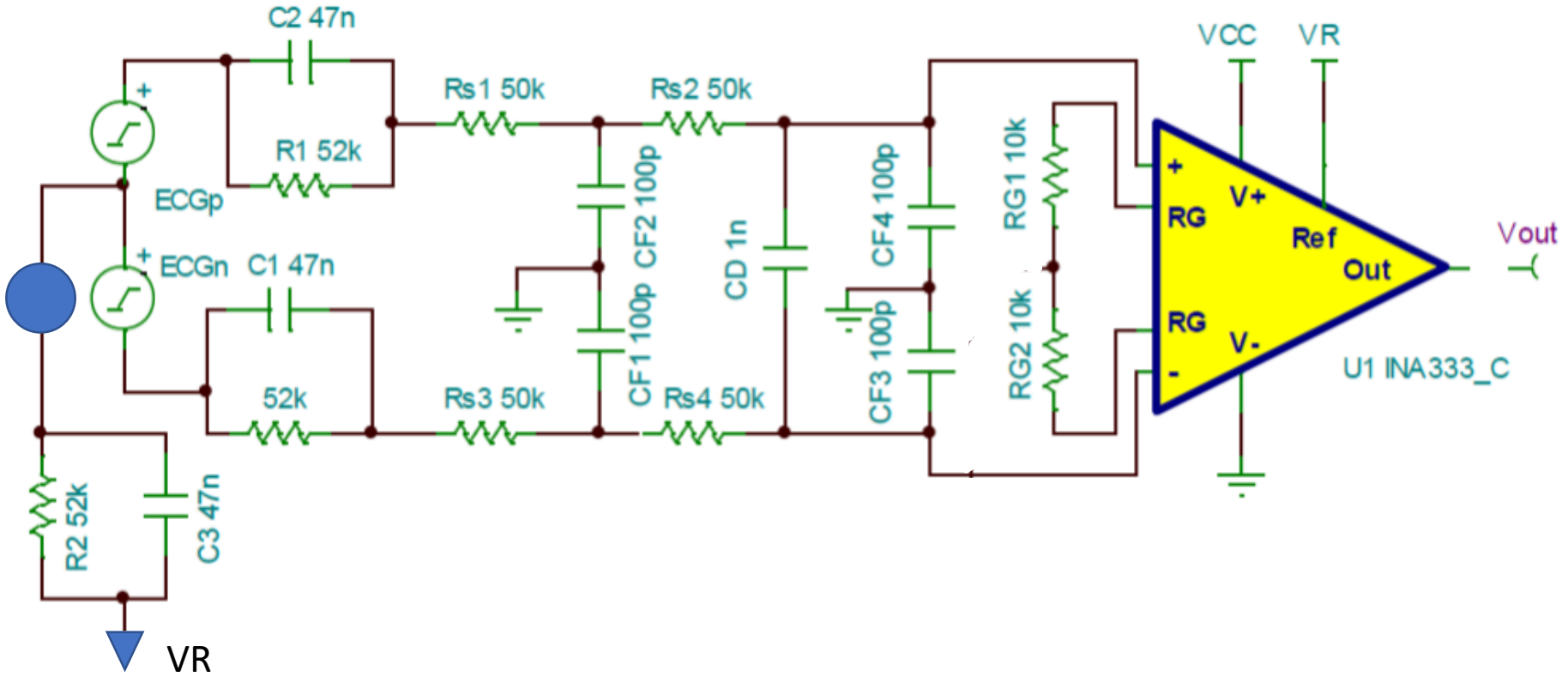
How can we measure the ECG?



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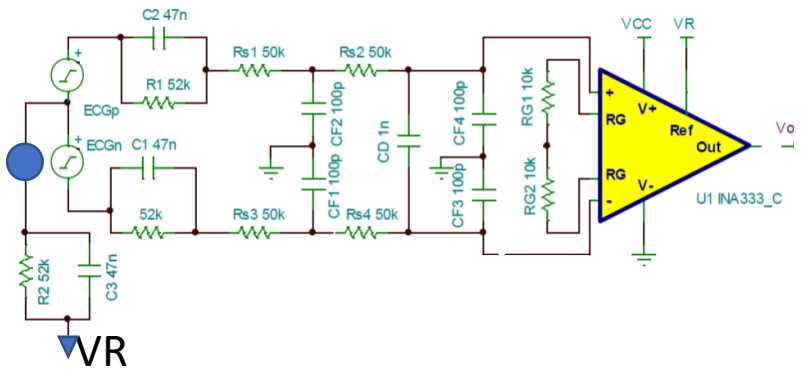
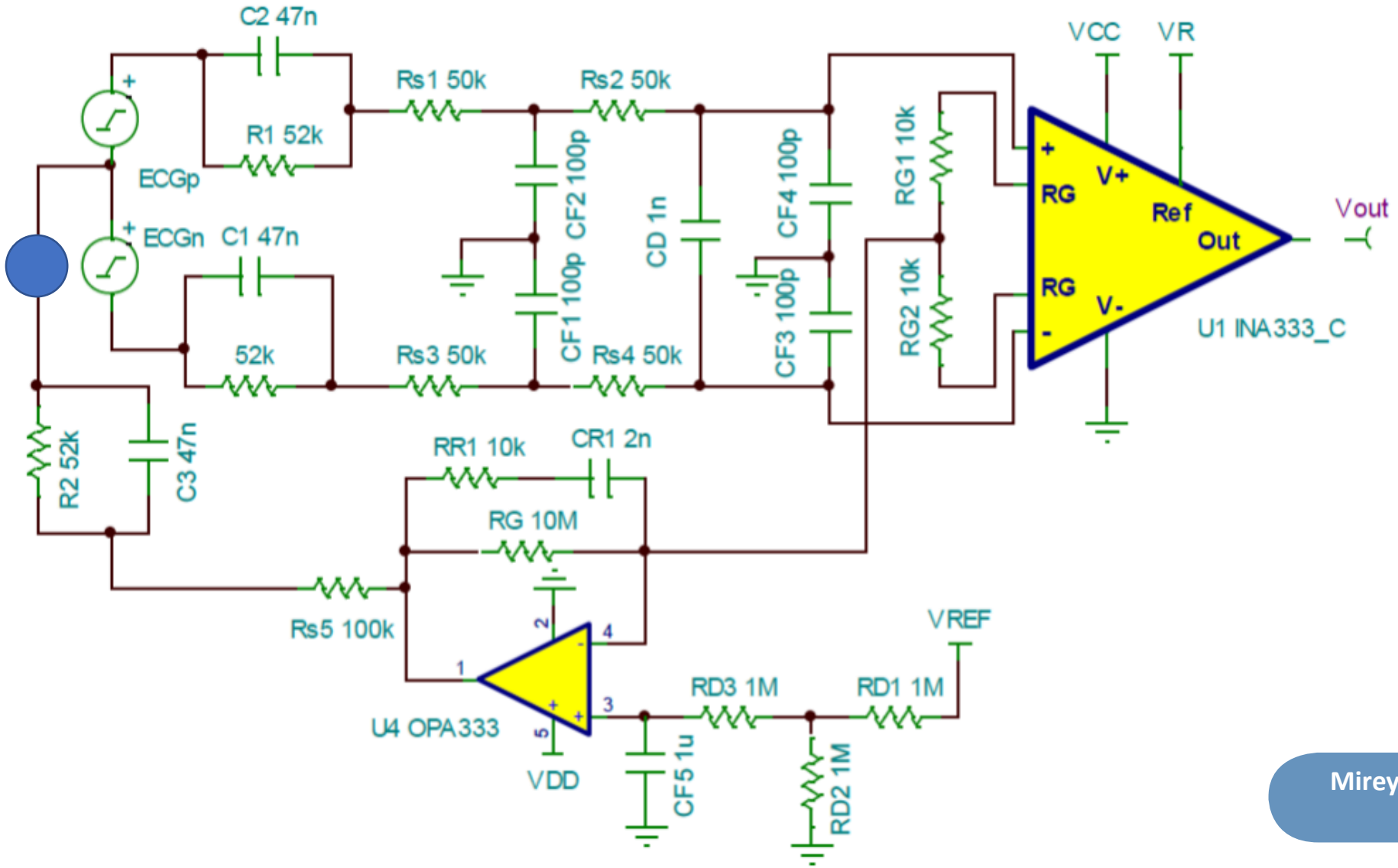
How can we measure the ECG?



Selection Considerations for the Instrumentation Amplifier ECG Front End

Requirement	Benefit
High Input Impedance	Minimizing this reduces input loading on sensor, minimizes input current offsets on input resistors
Input Current Noise	Minimizing this reduces the amount of current noise that becomes converted to voltage noise on input resistors
Voltage Noise	Minimizing this improves the overall signal to noise ratio
CMRR vs. Frequency	Maximizing this reduces the amount of input offset changes due to 50/60Hz common noise coupling on the inputs
Resistive Gain Matching	Maximizing this improves the total unadjusted system error
Voltage Offset Drift	Minimizing this reduces the amount that the total unadjusted error changes at the output of the INA
Single Supply Operation	Designing a single supply amplifier simplifies the system supply requirements; usually correlates with a lower power architecture
Low Power	Enables use in power-sensitive or battery monitoring applications
Input Type	Using Differential Input Structure can improve common mode noise rejection
Output Type	Using Differential Output Structure can improve common mode noise rejection at ADC inputs as well as potentially reduce / relax signal conditioning circuitry

How can we measure the ECG?



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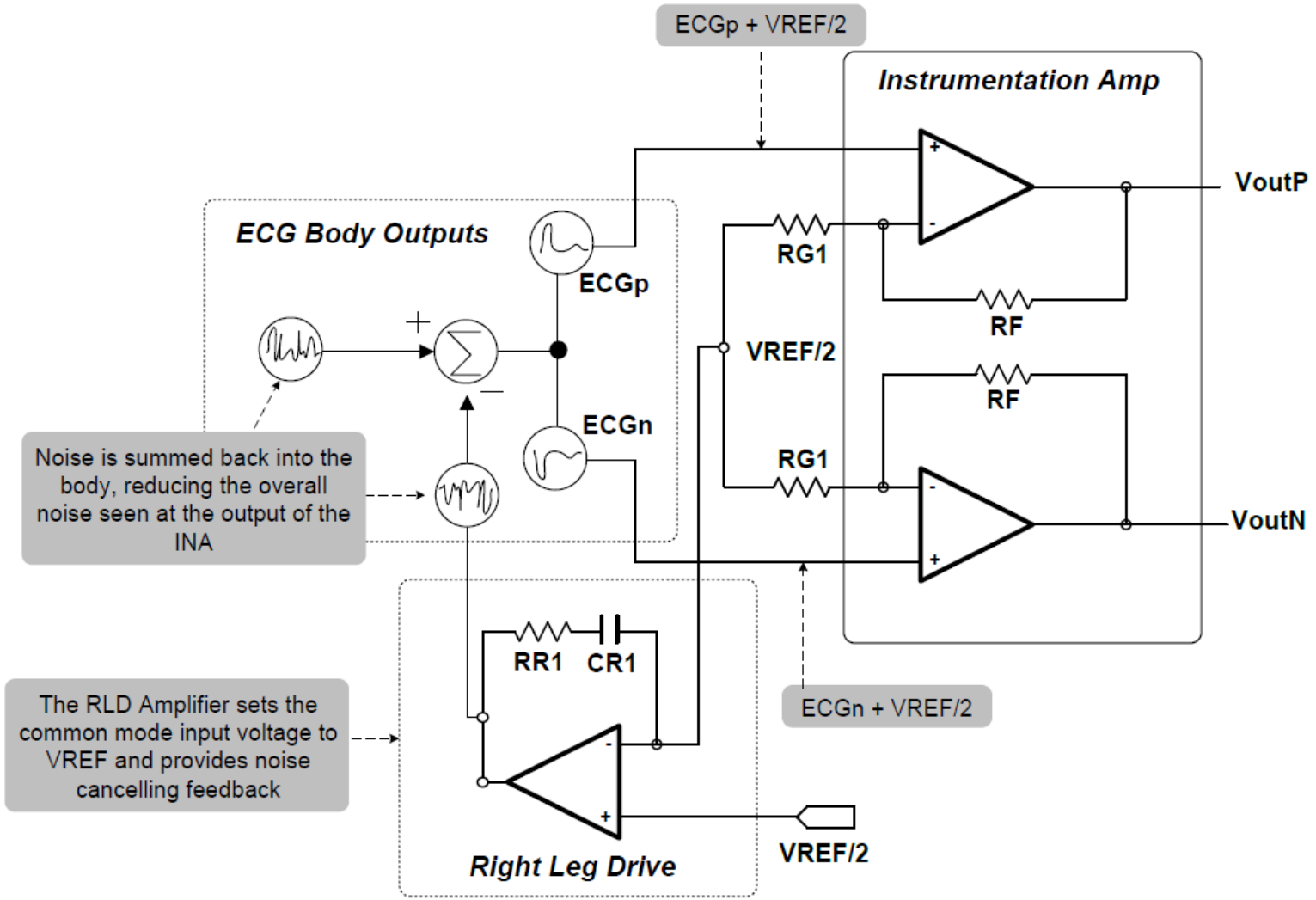

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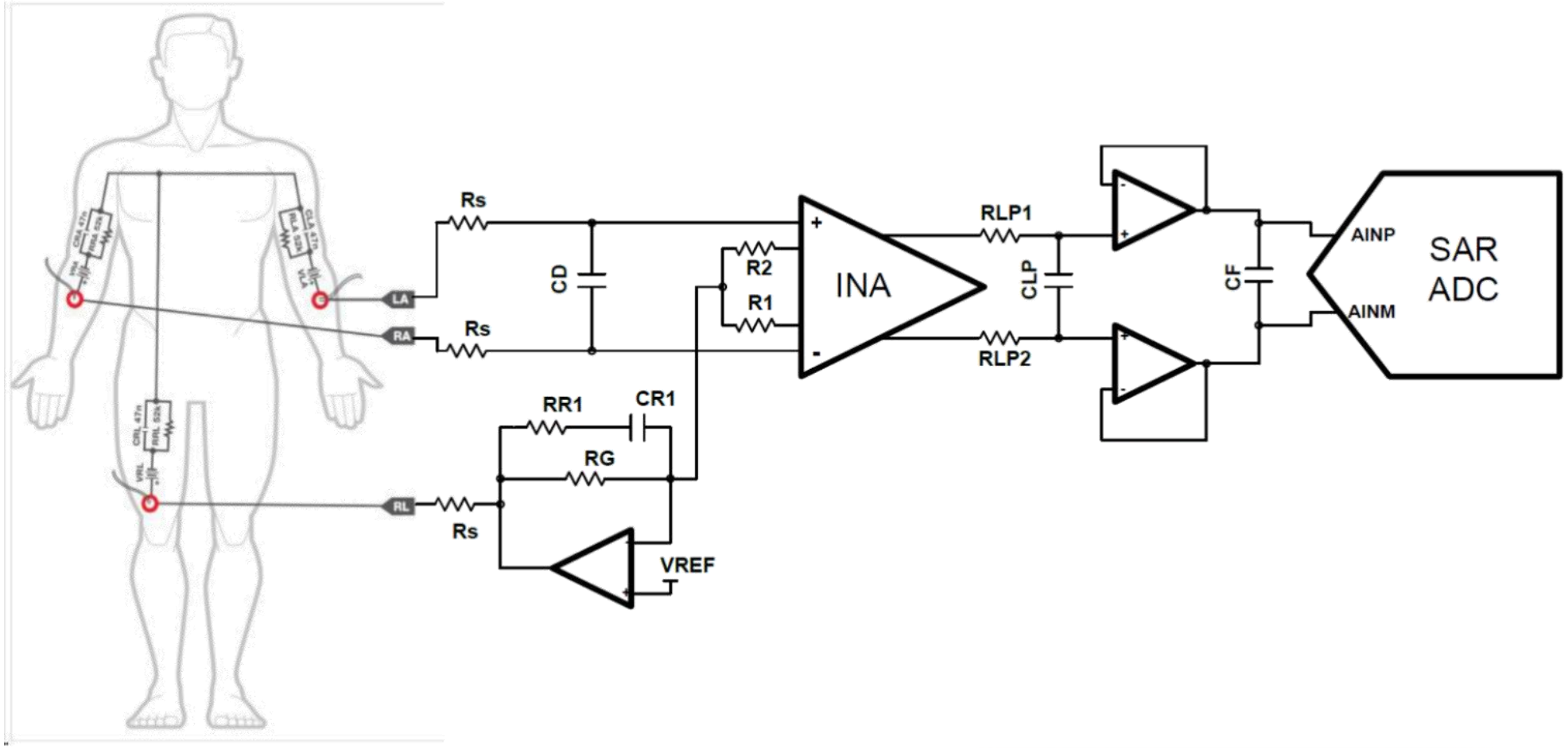

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How can we measure the ECG?