Patient monitoring 101: Part-2

Understanding ECG basics and lead derivation

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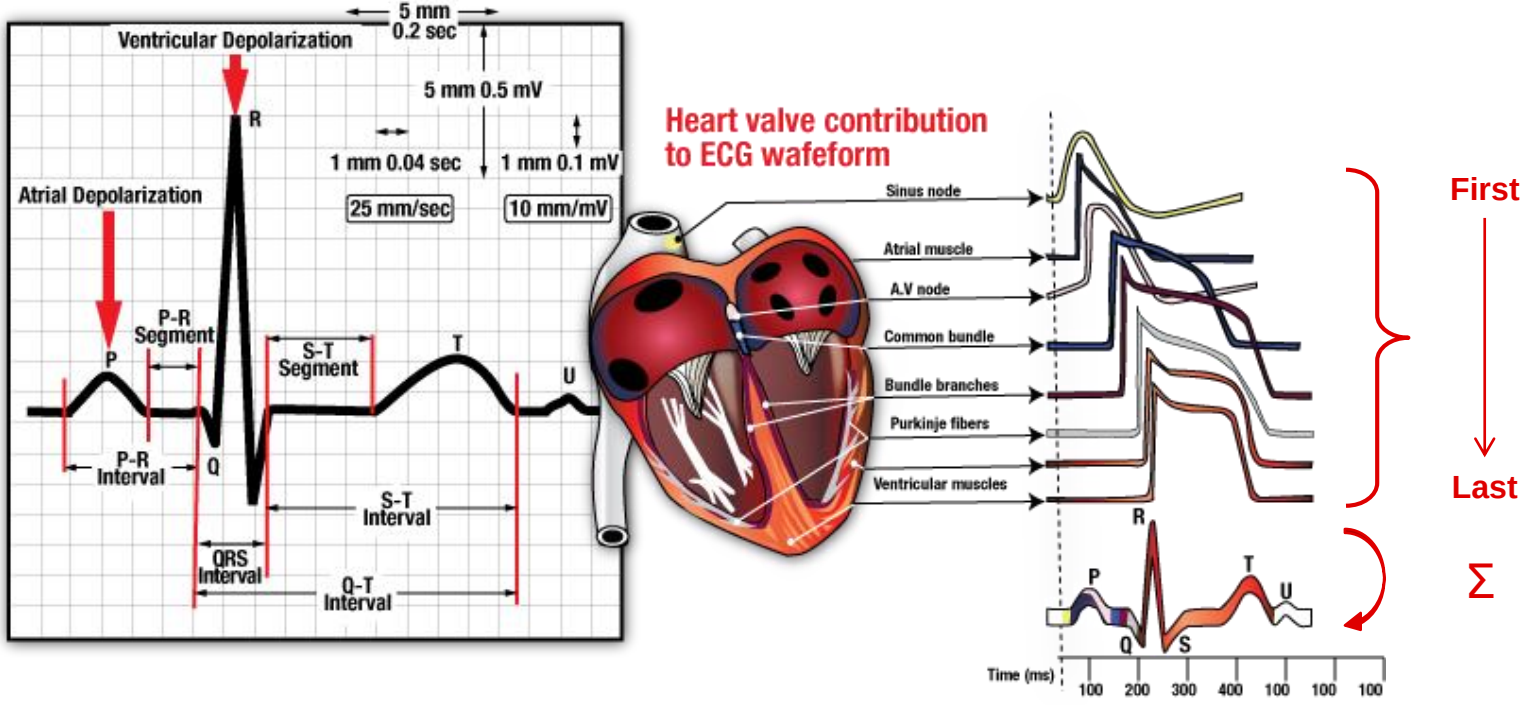
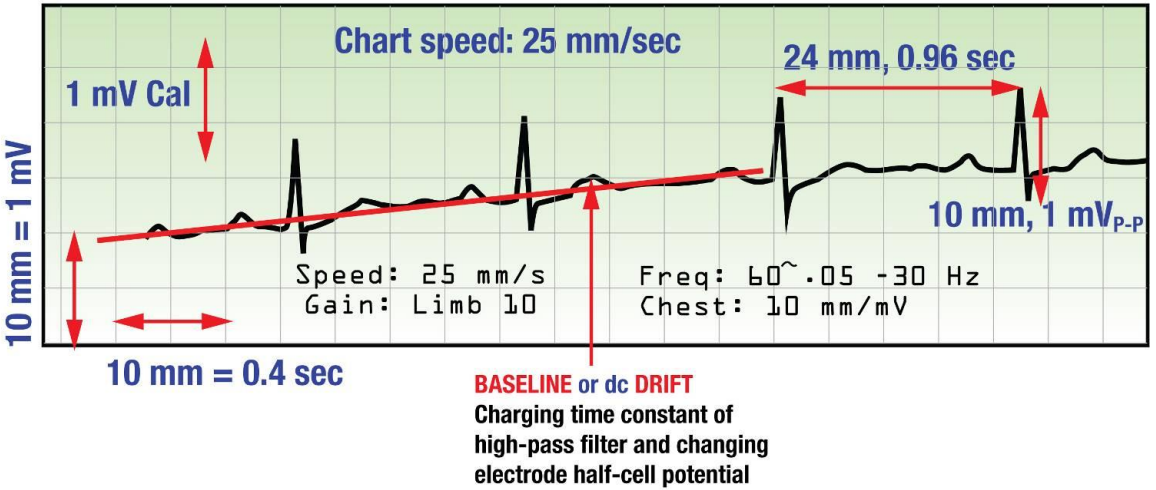
What is ECG?

The electrocardiogram (ECG) is a measure of electrical activity of the heart



ECG characteristics

Time domain

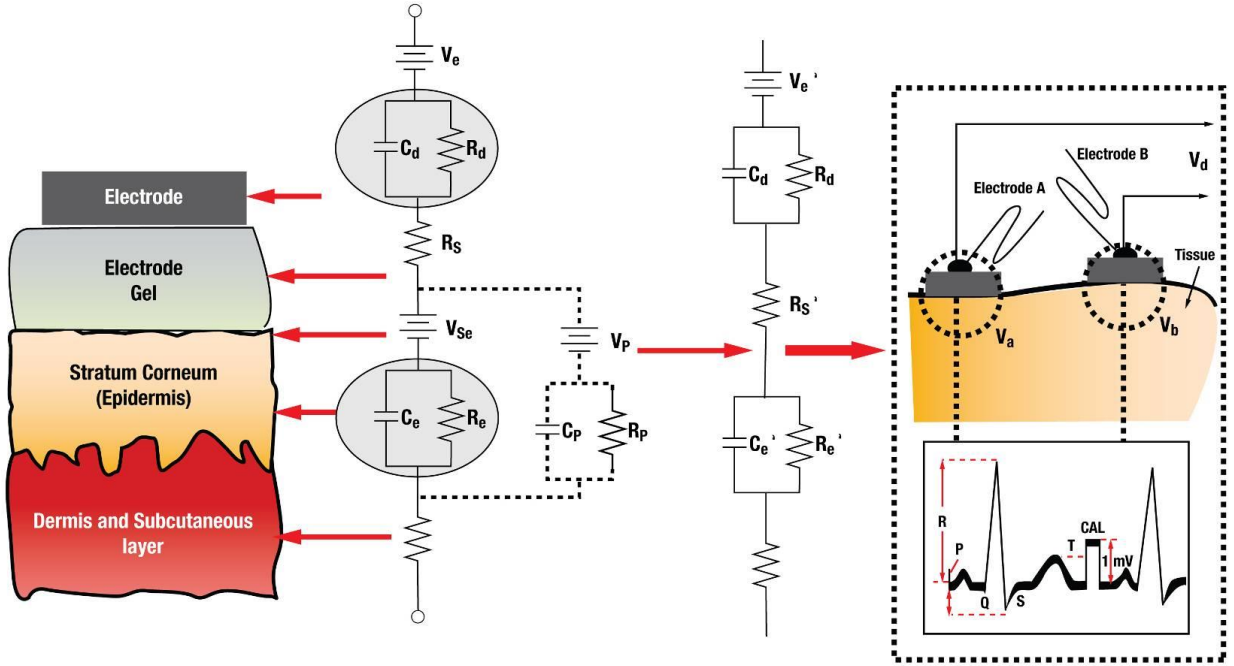


24 mm x 1 sec / 25mm = 0.96 sec / beat => 1 / 0.96 sec = 1.04 bps

62 BPM at rest

ECG characteristics

Electrode offset



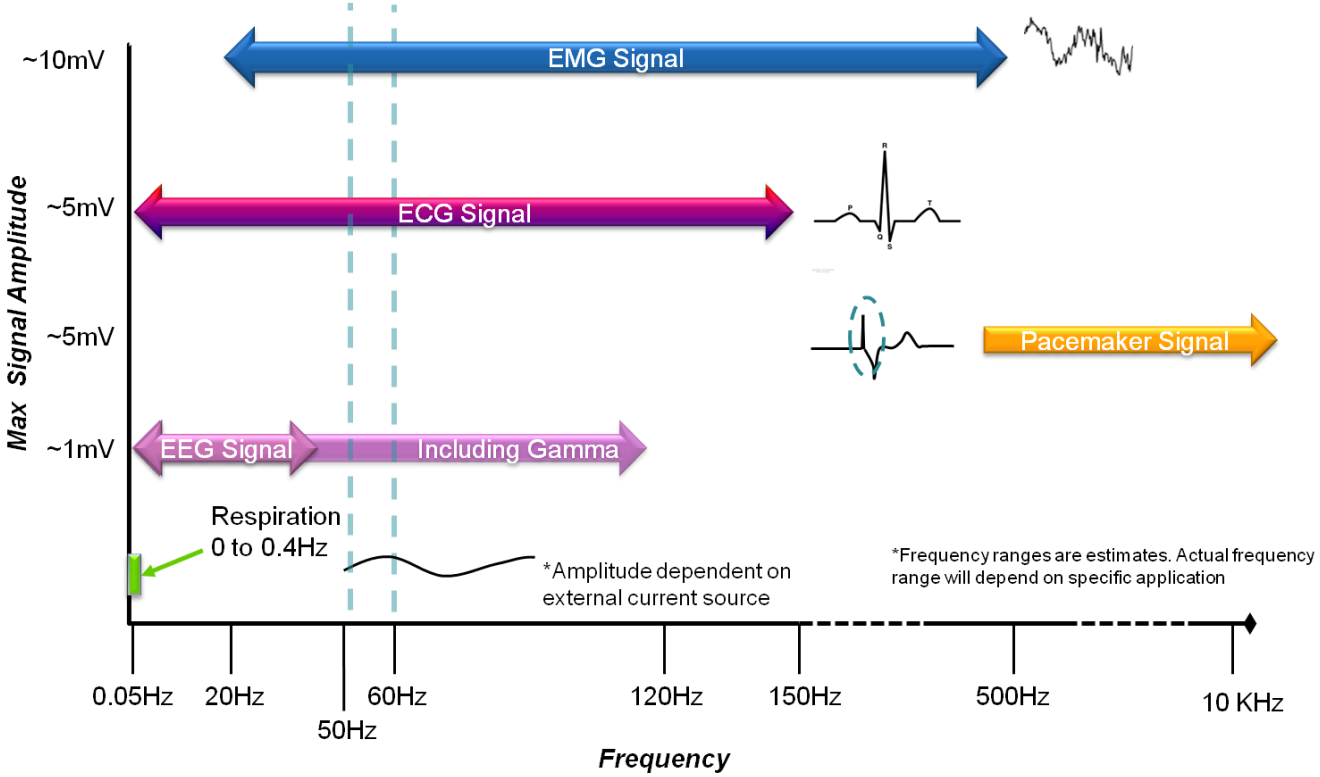
Differential offset

$V_d = V_a - V_b$

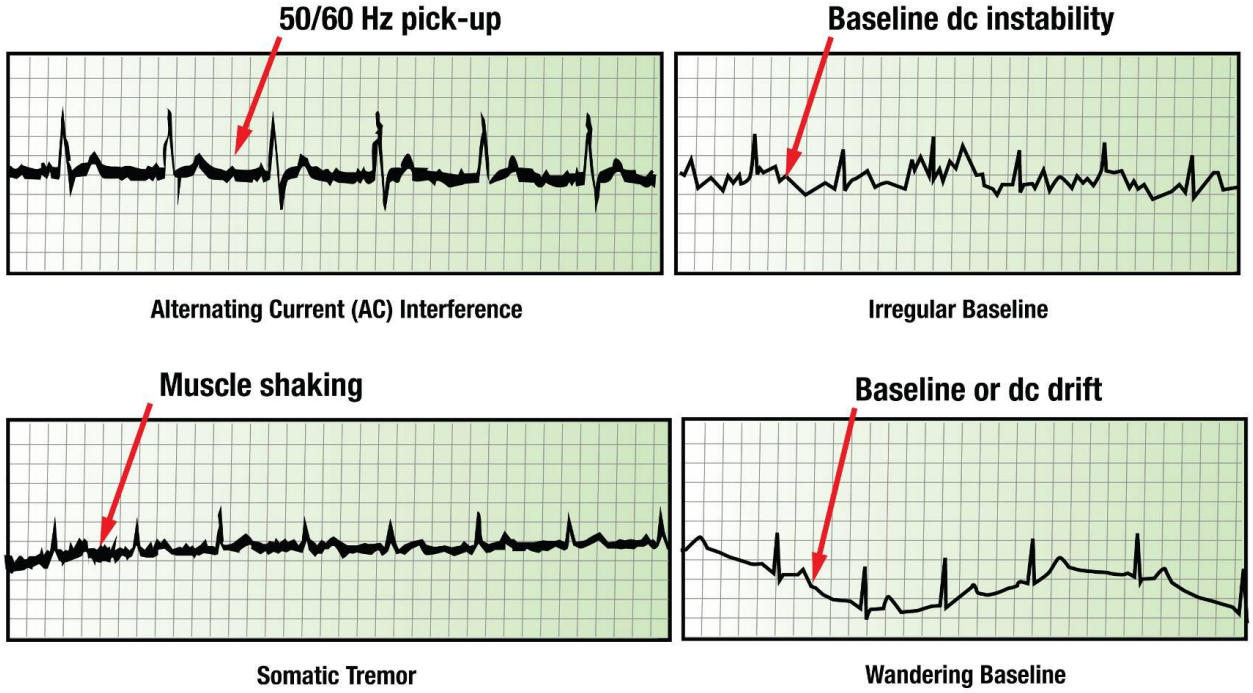
Electrical characteristics include a **DYNAMIC** resistance, capacitance and offset voltage

ECG characteristics

Frequency domain

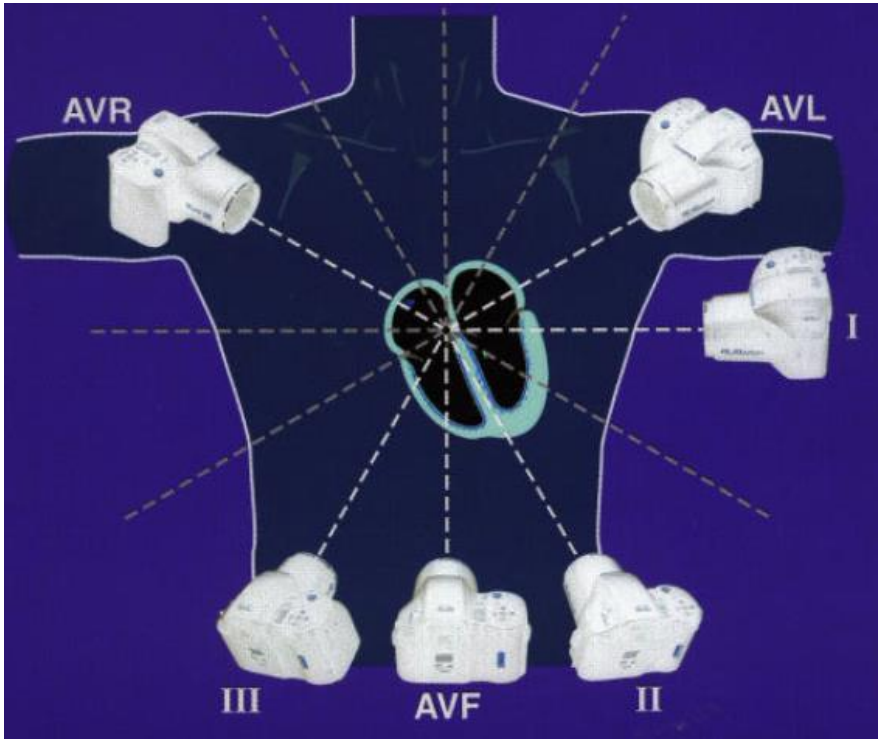


Challenges in measuring ECG



Lead derivation

Why so many leads?



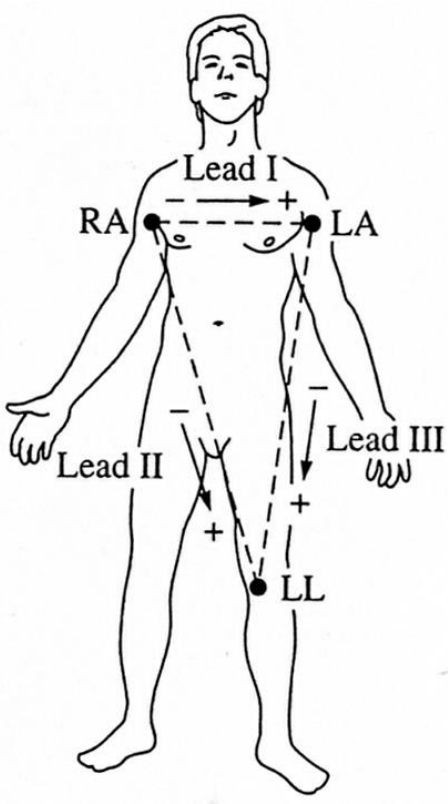
- A ***lead*** is the voltage difference between 2 ***electrodes.***
- Each lead in the ECG provides ***unique*** information about the heart's activity.
- Multiple angles give a better ***picture*** of the ECG output.

Lead derivation

Lead	Electrode Formula	Measured or Calculated	Calculation Formula
Primary Limb Leads			
Augmented Leads			
Chest Leads			

Lead derivation

ECG Einthoven triangle



3 Body **electrodes**,
3 Derived **leads** = I, II, III

Lead I $= V_{LA} - V_{RA}$
Lead II $= V_{LL} - V_{RA}$
Lead III $= V_{LL} - V_{LA}$

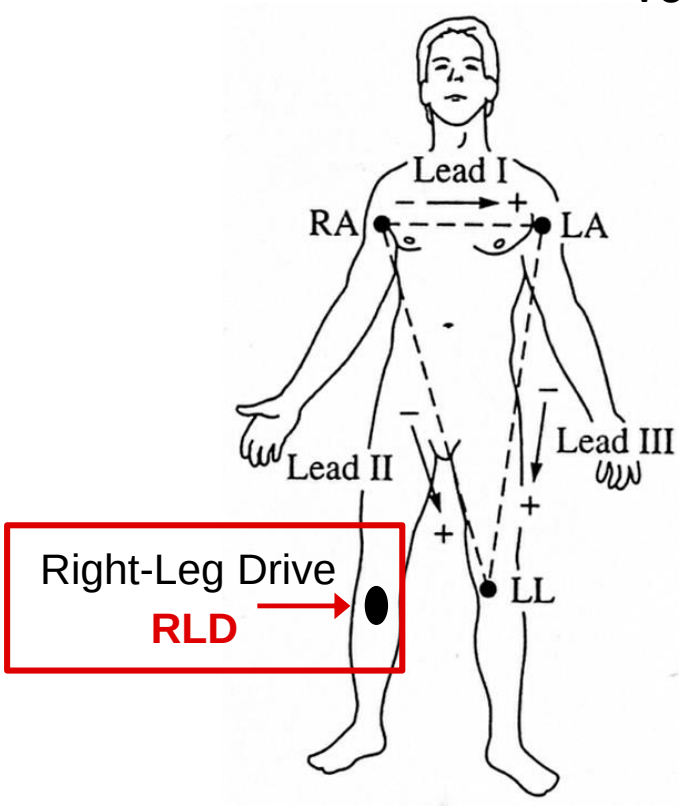
Einthoven's Law

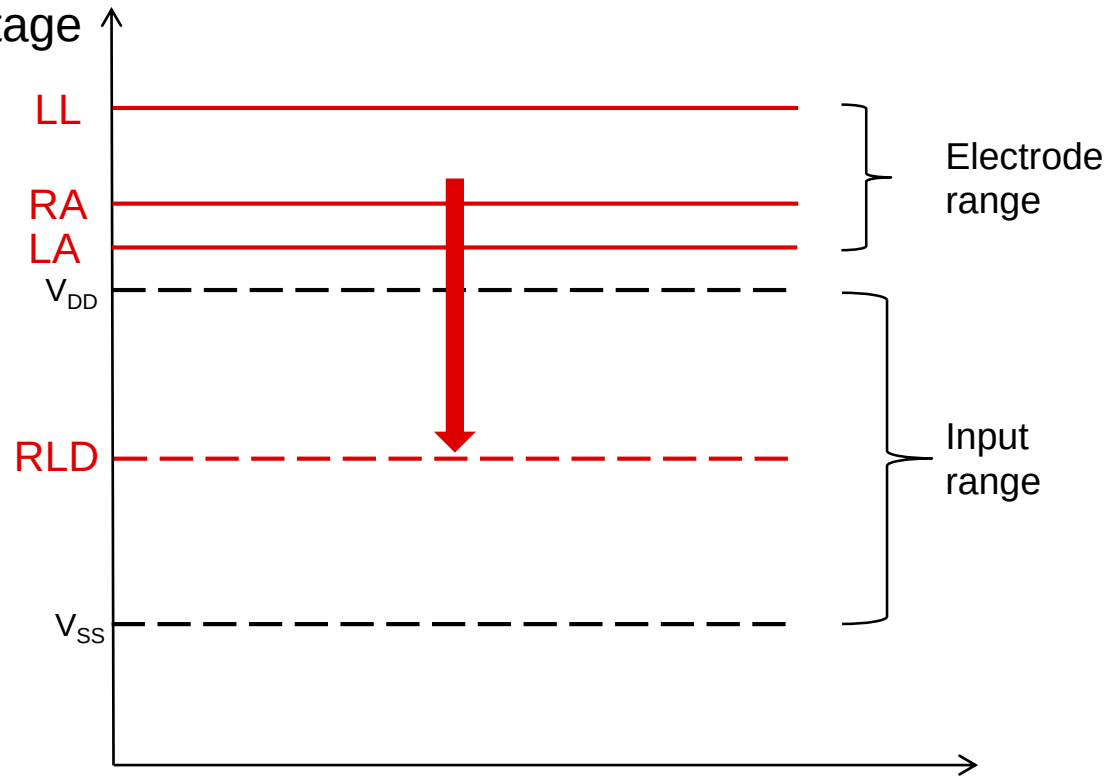
In an electrocardiogram, the potential of Lead II at any given instant is equal to the ***sum*** of the potentials in Lead I and III.

i.e. Lead II = Lead I + Lead III

Lead derivation

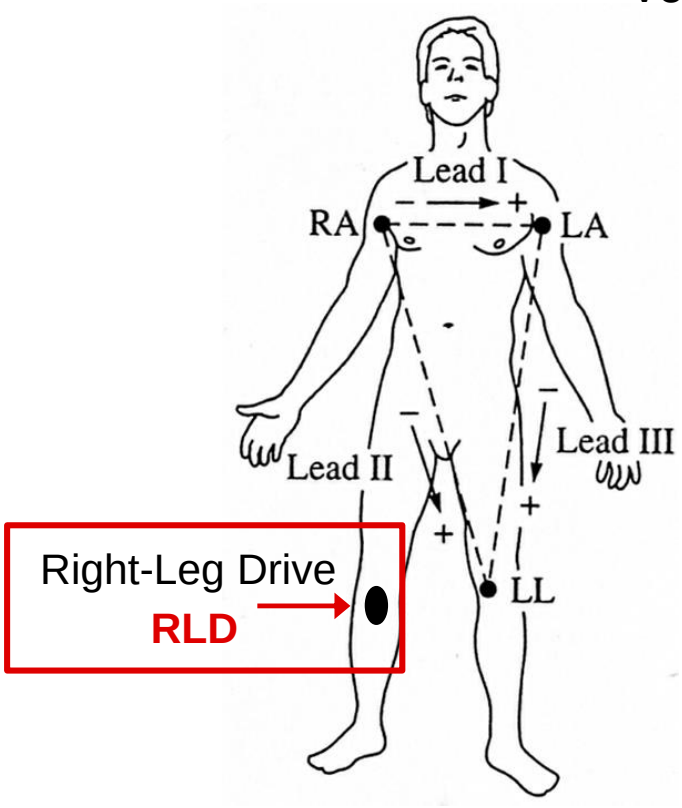
RLD electrode

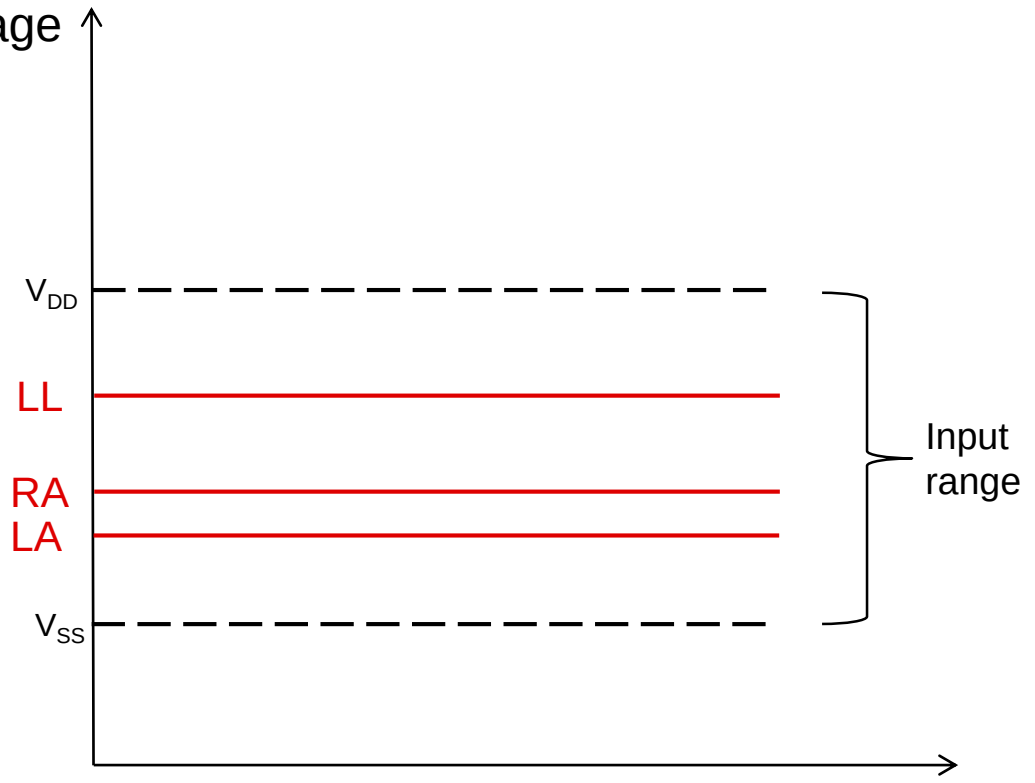




Lead derivation

RLD electrode



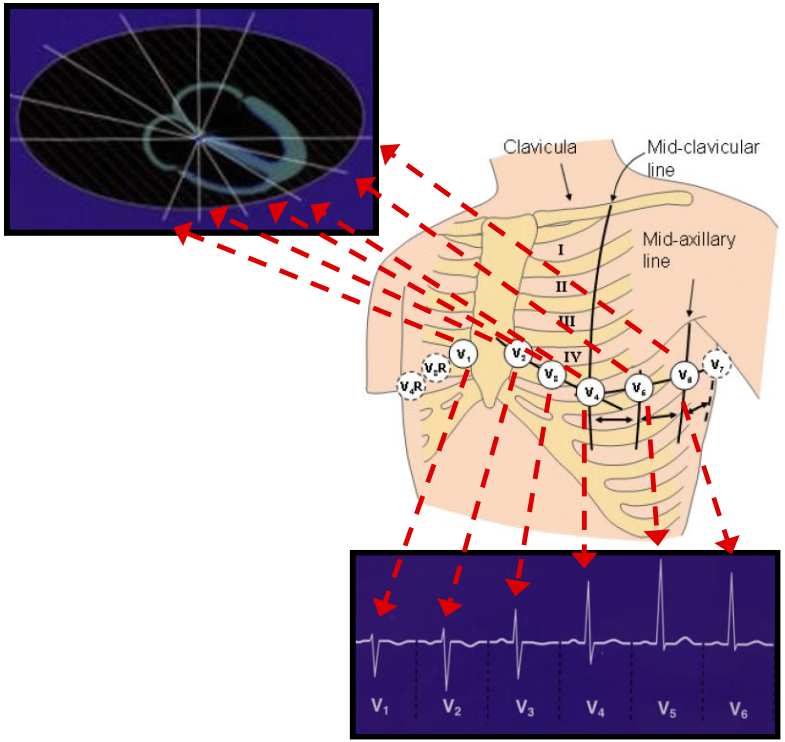


Lead derivation

Lead	Electrode Formula	Measured or Calculated	Calculation Formula
Primary Limb Leads			
I	LA - RA	Both	Lead II - Lead III
II	LL - RA	Both	Lead I + Lead III
III	LL - LA	Both	Lead II - Lead I
Augmented Leads			
Chest Leads			

Lead derivation

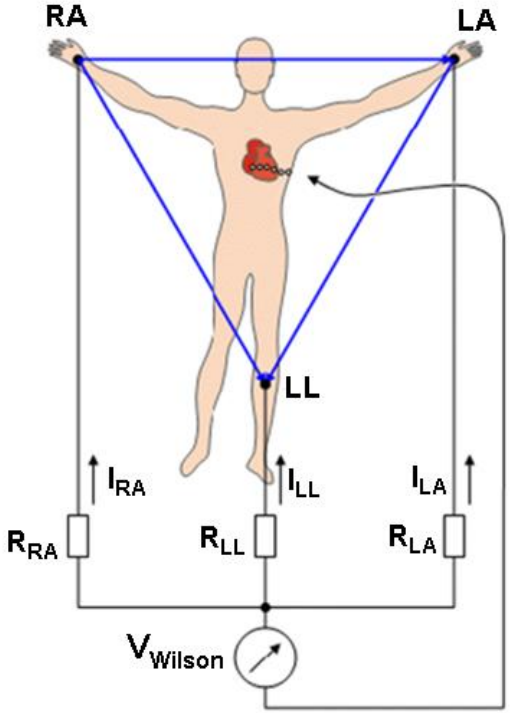
Chest leads



- Chest leads provide information about the heart's ventricles at multiple cross-sectional angles
- Each has a unique ECG signature
- Enhanced pattern recognition

Lead derivation

Wilson Central Terminal (WCT)

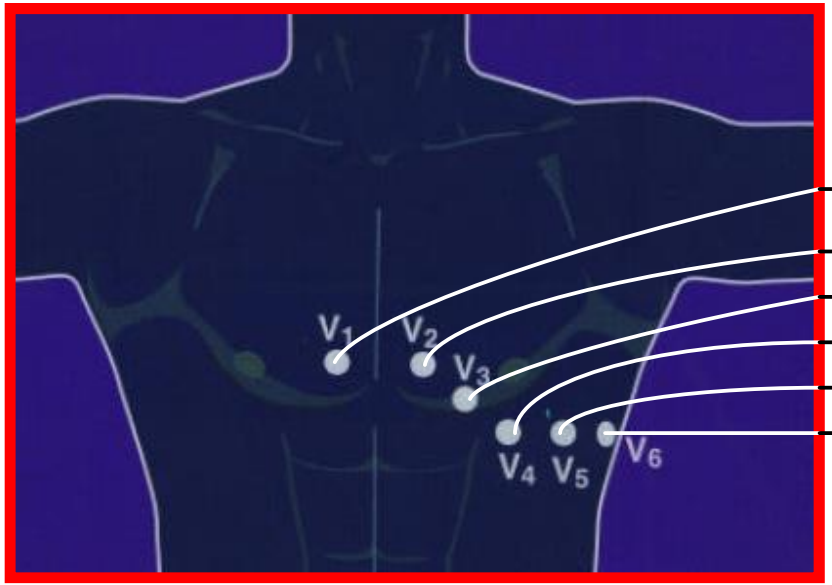


- The **WCT** provides chest lead reference at center of Einthoven triangle.
- Assuming $R_{RA} = R_{LA} = R_{LL}$:

$$V_{Wilson} = \frac{RA + LA + LL}{3}$$

Lead derivation

Chest leads

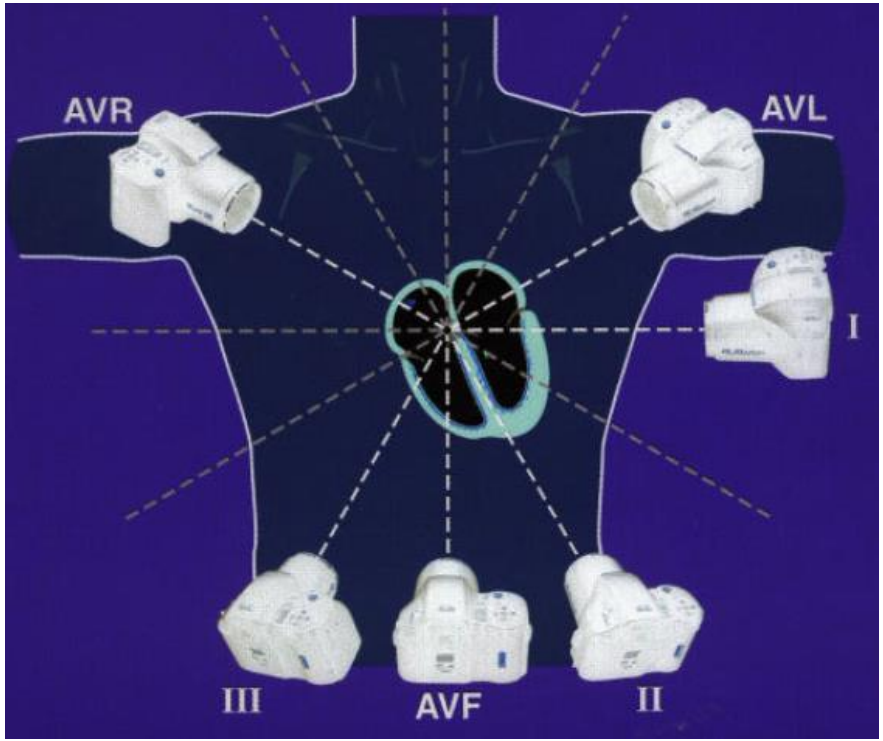


Lead derivation

Lead	Electrode Formula	Measured or Calculated	Calculation Formula
Primary Limb Leads			
I	LA - RA	Both	Lead II - Lead III
II	LL - RA	Both	Lead I + Lead III
III	LL - LA	Both	Lead II - Lead I
Augmented Leads			
Chest Leads			
V1	V1 - WCT	Measured	-
V2	V2 - WCT	Measured	-
V3	V3 - WCT	Measured	-
V4	V4 - WCT	Measured	-
V5	V5 - WCT	Measured	-
V6	V6 - WCT	Measured	-

Lead derivation

Augmented leads



- Augmented leads provide enhanced vector information to determine the heart's electrical axis.
- **aVR, aVL, aVF** are derived via midpoint of 2 limbs with respect to 3rd limb
- For example:

$$aVR = RA - \left(\frac{LA + LL}{2} \right)$$

Lead derivation

Lead	Electrode Formula	Measured or Calculated	Calculation Formula
Primary Limb Leads			
I	LA - RA	Both	Lead II - Lead III
II	LL - RA	Both	Lead I + Lead III
III	LL - LA	Both	Lead II - Lead I
Augmented Leads			
aVR	RA - (LL + LA)/2	Both	−(Lead I + Lead II)/2
aVL	LA - (LL + RA)/2	Both	(Lead I - Lead III)/2
aVF	LL - (LA + RA)/2	Both	(Lead II + Lead III)/2
Chest Leads			
V1	V1 - WCT	Measured	-
V2	V2 - WCT	Measured	-
V3	V3 - WCT	Measured	-
V4	V4 - WCT	Measured	-
V5	V5 - WCT	Measured	-
V6	V6 - WCT	Measured	-

ECG leads and ADC channels

Number of Leads	Leads Used	Number of ADC Channels
1	Lead I	1
3	Lead I, Lead II, Lead III	2
6	Lead I, Lead II, Lead III, aVR, aVL, aVF	2
12	Lead I, Lead II, Lead III, aVR, aVL, aVF, V1 – V6	8