German University in Cairo
Faculty of Media Engineering and Technology
Spring 2020

CSEN 1099 – Introduction to Biomedical Engineering

Problem Set #3 – Solution

Question 1

Determine how to place limb and augmented limb leads to obtain ECG recordings at a medical angle of:

a) +180° b) +270° c) +30°

Answer:

a) +ve electrode: RA, -ve electrode: LA.

b) +270° medical angle = -270° mathematical angle = +90
+ve electrode = (1/2)(RA + LA), -ve electrode = LL

c) +30 medical angle = -30 mathematical angle → opposite of the aVL lead
+ve electrode = (1/2) (RA + LL), -ve electrode = LA

Question 2

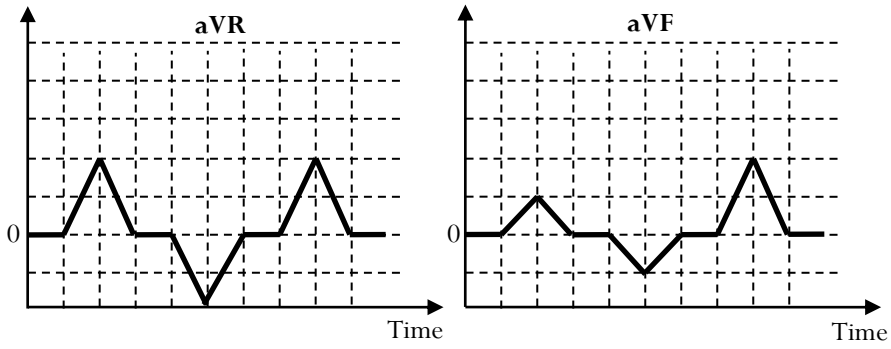
In a rare case, a patient has his heart oriented towards the right side instead of the left side. Determine how to change the placement of the 12-lead system to get the corresponding ECG recordings.

Answer:

Reverse all electrode positions and use RL instead of the LL.

Question 3

Consider the following ECG recorded on lead aVR (medical angle -150°) and aVF (medical angle +90°). From the figures, compute the recorded ECG on lead I (medical angle 0°).



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Answer:

$$aV_R = RA - \frac{1}{2}(LA + LL) \quad (1)$$

$$aV_F = LL - \frac{1}{2}(RA + LA) \quad (2)$$

$$Lead\ I = LA - RA$$

$$From\ (2),\ LL = aV_F + \frac{1}{2}(RA + LA)$$

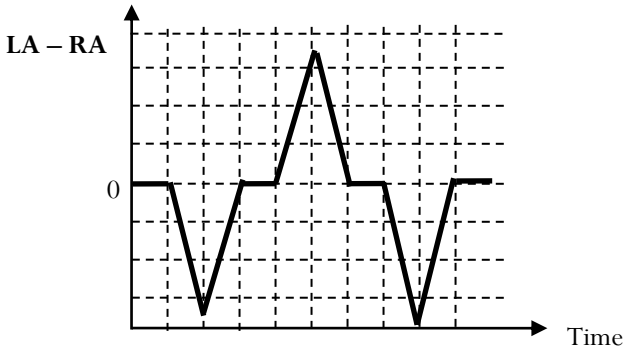
Substitute in (1)

$$aV_R = RA - \frac{1}{2}LA - \frac{1}{2}aV_F - \frac{1}{4}(RA + LA)$$

$$= \frac{3}{4}RA - \frac{3}{4}LA - \frac{1}{2}aV_F$$

$$\therefore RA - LA = \frac{4}{3}\left(aV_R + \frac{1}{2}aV_F\right)$$

$$\therefore LA - RA = -\frac{4}{3}\left(aV_R + \frac{1}{2}aV_F\right)$$



Question 4

Explain what will happen to the heart and the recorded ECG in each of the following cases:

i – The pacemaker cells in the Sinoatrial node do not depolarize.

ii – The pacemaker cells in the Sinoatrial node depolarize but the Atrium does not contract.

iii – The pacemaker cells in the Sinoatrial node depolarize and the Atrium contracts but the ventricles do not contract.

Answer:

i – The atria and ventricles will not contract and the ECG will be equal to 0

ii – Same as i

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iii – The atrium will contract and then relax but the ventricles will not. The ECG will show the p-wave and the repolarization of the atria only without QRS or T waves.

Question 5

Write the pseudocode of an algorithm that can be used to detect QRS waves that correspond to premature ventricular contractions explained in lecture.

Answer:

- Apply the QRS detection algorithm to detect the R waves
- Take a window before each QRS wave and extract the signal recorded (which is supposed to be the P-wave)
- Compute the average of the extracted signals
- For each extracted signal, compute the difference between this signal and the computed average using mean-square-error
- When the difference is large, this would indicate the absence of a P-wave which represents the premature ventricular contraction case

Question 6

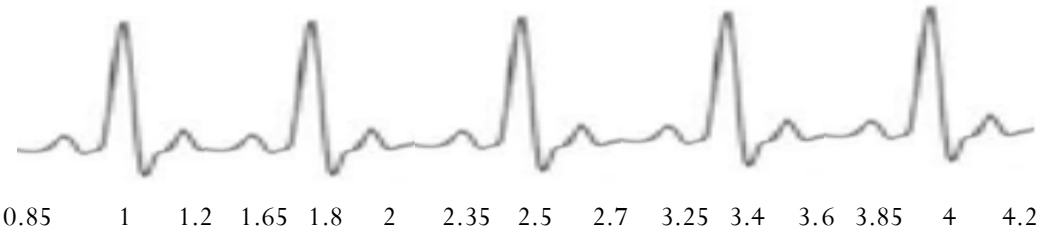
Consider an ECG signal with R waves occurring at 1 sec, 1.8 sec, 2.5 sec, 3.4 sec and 4 sec. Assume that the durations of the P-wave is 0.1 sec, QRS-complex is 0.1 sec and T-wave is 0.15 sec.

i – Draw the corresponding ECG signals showing the exact timing of each wave.

ii – Draw the RR interval plot of the ECG signal. Find the heart rate in beats per minute (bpm).

Answer:

i-



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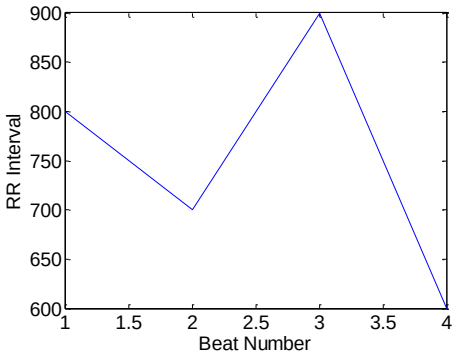
ii- Excluding the first beat:



Average RR Interval = (900+800+700+600)/4 = 750 ms

Beats/second = 1000/750 = 1.232 beats/second → 80 bpm