Final Project – Biomedical Engineering

1. **Removing signals from muscle movement:**

   Download the ECG signal from the web at: http://bme.elektro.dtu.dk/31610/data/data4/ecg.mat

   The signal has been sampled with a frequency of 500 Hz and the values in the variable ecg are directly in volts. The amplification factor on the electrode signals is 500. (Variable name EKG1)

   Plot the signal measured at the leads with the proper units on the axis. Zoom in on just one period of the signal.

   The person under measurement will often move a bit, which gives rise to a low-frequency signal from the muscles. This will overlap the ECG signal and make it more difficult to study its details. The downloaded signal also includes such muscle signals. Remove them by Fourier transforming the signal ecg, set frequencies below 0.5 Hz to zero, and then make an inverse Fourier transform. Plot the new signal ecg1 and note the differences to the original signal. Make sure that you filter has a real impulse response by making an inverse Fourier transform of the transfer function.

2. **Removing 50 Hz interference:**

   Often the ECG is contaminated with 50 Hz noise from the power outlet, which overlaps the ECG. This interference should be removed. Design a filter for removing 50 Hz noise as a Notch filter with a zero at 50 Hz. A Notch filter is an all-pass filter with a zero at one given frequency.

   Apply the filter to the signal and generate a new signal ecg2. Plot the new signal and note the difference.

3. **Increasing the signal-to-noise ratio:**

   The ECG signal is also contaminated with noise. The amount of noise is proportional to the measurement bandwidth. A higher bandwidth will give more noise in the signals, and limiting the bandwidth can obscure details in the ECG. Try to find a compromise on the cut-off frequency, where the shape of the ECG signal is preserved and the noise reduced. Try different choices and plot and comment on the results.

   Make a plot of one period of the new filtered signal ecg3 and identify as many intervals in the ECG as you can.

4. **Finding the heart rate using autocorrelation:**

   The heart rate can be found from the autocorrelation function of the signal. This is done be finding the first local maximum after the global maximum at tau = 0 in the autocorrelation function. Make a procedure for doing this automatically and use it on the processed signal ecg3 or ecg2 and on the unprocessed ECG signal ecg. Limit your search interval for the maximum to the possible range for the heart rate. Does your program find the right pulse rate? Document your program with plots of the autocorrelation functions found.

5. **Finding the QRS complex:**

   Detects QRS complex in an ECG signal based on Pan Tompkins algorithm. The Pan–Tompkins algorithm applies a series of filters to highlight the frequency content of this rapid heart depolarization and removes the background noise. Then, it squares the signal to amplify the QRS contribution, which makes identifying the QRS complex more straightforward. Make a procedure for doing this automatically and use it on the processed signal ecg3 or ecg2 and on the unprocessed ECG signal ecg.

6. **Make a survey about various heart diseases diagnosed from the waves of ECG signals. Support your survey with Figures as possible.**

ECG background

The cardiac cycle involves a sequential contraction of the atria and the ventricles. The combined electrical activity of the different myocardial cells produce electrical currents that spread through the body fluids. These currents are so large that they produce detectable potential differences between different sites on the body surface. The signal recorded as the difference between two potentials on the body surface is called an "ECG lead". The ECG signal used in this exercise has been measured by placing five ECG electrodes on the arms and legs of a volunteer. The Lead I signal is recorded as the potential difference between the left and right arms, and Lead III is recording the potential difference between the left foot and the left arm. The fifth electrode is a ground (GND) electrode attached to the right leg (see fig. 1).

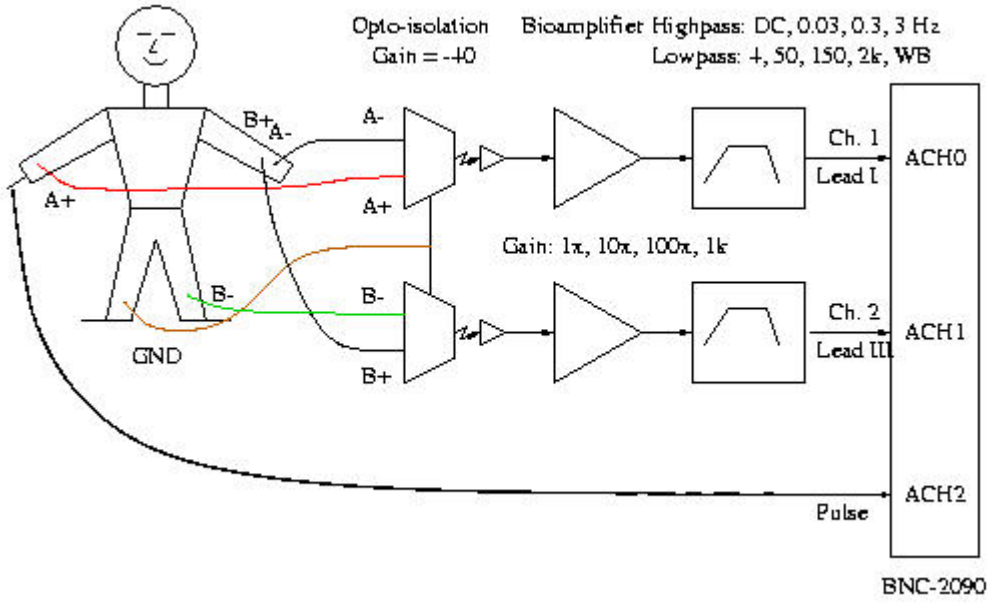

Fig. 1 *System diagram for a dual lead ECG recording (lead I + III) and a simultaneous recording of the pulse signal in a finger.*

The regular pattern of peaks produced by the heart repeats for each heartbeat (see fig. 2). This pattern of potential peaks is called the electrocardiogram or ECG. The initial small peak, the P-wave, marks the contraction of the atria. The larger peaks following the P-wave, the QRS complex, is a superposition of atrial relaxation and ventricular contraction. The electrical potentials arising from atrial relaxation is, however, much smaller than the potentials arising from ventricular contraction. The QRS complex is, thus, often taken to simply mark ventricular contraction. After the QRS complex follows the T-wave associated with ventricular relaxation.

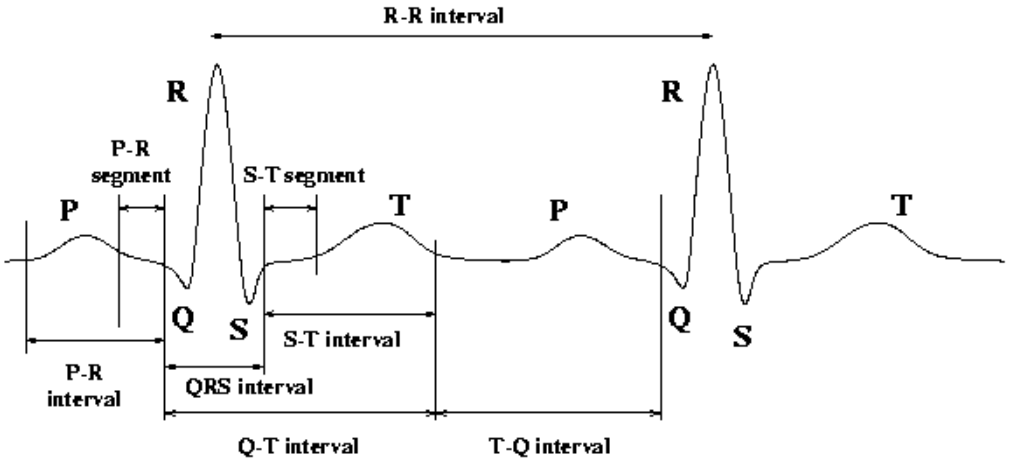

Fig. 2. *Definition of waves, segments and intervals in the normal ECG waveform.*

The Heart Rate and Rhythm

Determination of the heart rate and rhythm. Normally, the heart of an adult is depolarized 60 to 90 times per minute. A depolarization rate lower than this is called sinus bradycardia, while one that is higher is called sinus tachycardia. The heart rate of the normal newborn is much higher than that of an adult. The heart rate can be calculated by dividing the R-R interval into 60. This number is denoted BPM (Beats Per Minute).

The Duration of the Complexes and Intervals

After determining the heart rate and rhythm, the clinician should measure the duration of the waves and intervals on the electrocardiogram.

The P wave: The duration of the P wave is measured from the beginning of the P wave to the end. In normal adults, this period is usually less than 0.12 second; in neonates, it is less than 0.08 second. This is the time interval required for the wave of depolarization to spread through the atria and to reach the atrioventricular node. The amplitude of the P waves of the normal adult is less than 0.25 mV in the extremity leads and smaller than this in children.

The PR interval: The PR interval represents the amount of time required for the depolarization process to spread from its origin in the sinus node, through the atria, to and through the atrioventricular node (where the impulses are delayed), down the bundle branches and their sub-branches (including the Purkinje fibers), and to the ventricular muscle. It is measured from the beginning of the P wave to the beginning of the QRS complex. In reality, this interval should be called the PQ interval, but convention holds that it is called the PR interval. When there is no Q wave, the measurement is made from the beginning of the P wave to the beginning of the R wave. The difference between the intervals as measured to the beginning of the Q wave, and as measured to the R wave, is usually about 0.02 second but may be as much as 0.04 second. The PR interval is less than 0.20 second in the normal adult and much less than this in normal children.

The duration of the QRS complex: The duration of the QRS complex represents the amount of time required for the depolarization of the ventricular musculature. It is measured from the beginning of the Q wave to the end of the S wave. In normal adults, the QRS duration is usually 0.10 second or less and in children, it is usually less than 0.08 second. When the QRS duration is greater than 0.10 second in adults, it is proper to consider the presence of some type of ventricular conduction defect.

QRS amplitude: The normal QRS voltage may be as small as 0.5 - 0.7 mV, but it is usually greater than this. It is generally accepted that the QRS voltage is definitely small, when it measures 0.4 mV or less in all the extremity leads. When this occurs, it is wise to consider certain abnormalities as possible causes.

The duration of the ST segment: The duration of the ST segment represents the amount of time during which the ventricular musculature is depolarized. The depolarization process ends with the end of the QRS complex, and the repolarization begins with, or before, the beginning of the T wave. In some patients, the repolarization process begins during the ST segment. The ST segment duration is determined by measuring the interval of time from the end of the S wave to the beginning of the T wave. In practice, a prolonged ST segment is identified by detecting a prolonged QT interval, while the duration of the T wave remains normal.

The QT interval: The QT interval represents the amount of time required for depolarization of the ventricles, plus the amount of time during which the ventricles are excited (ST segment), plus the amount of time required for their repolarization (T wave). This interval represents the duration of electrical systole, which is different from the duration of mechanical systole. The QT interval is measured from the beginning of the Q wave of the QRS complex to the end of the T wave. The duration of the QT interval varies with age, gender, and heart rate. It should not exceed 0.40 second, when the heart rate of an adult is 70 depolarizations per minute.

The duration of the T wave: The T wave is produced by the repolarization process. The duration of the T wave is measured from the beginning of the wave to the end. The repolarization process undoubtedly begins before the T wave and is sometimes quite visible as a displaced ST segment, which is referred to as "early repolarization." Although the duration of the normal T wave has been studied, and tables have been constructed using the data, the actual measurement is rarely performed in practice.

The magnitude of the T wave: The area encompassed by the T wave may be a little smaller or a little larger than that encompassed by the QRS complex; it is usually about two-thirds that of the latter. Characteristically, the upstroke of the normal T wave is less steep than the downstroke.

The TQ interval. The TQ interval is measured from the end of the T wave to the beginning of the next Q wave. During this period the ventricles are polarized and waiting for the stimulation that initiates depolarization.

Submission regulations:

Groups	Individual or maximum 2 students per group
Submission Deadline	May 11th 2023
Submission Email	bio.2023.handouts@gmail.com
Submission Files	Soft Copy of: - MATLAB (.m files) - PDF Report with clear screen shots of the results and your comments Hard copy of the report on the discussion day. Discussion dates will be set later.
Submission notes	- Copied codes and reports will be graded ZERO. - Please write "Biomedical project" in the title of the mail and write your names in the body of the email.