**Khulna University of Engineering and Technology.**

**Course no:** BME 3112

**Course name:** Biomedical Signal Analysis.

**Project name:** Detection of R wave and measurement of heart rate from those R wave.

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**Introduction:**

**Butterworth low-pass filter:**

A Butterworth low-pass filter is a type of electronic filter designed to allow low-frequency signals to pass through while attenuating higher-frequency signals. It is named after the British engineer Stephen Butterworth, who first described the filter's characteristics in the 1930s.

The Butterworth filter is a type of infinite impulse response (IIR) filter, meaning it has feedback in its transfer function. It is characterized by its maximally flat frequency response in the passband, which means that the magnitude response of the filter is as flat as possible within the desired passband.

The transfer function of a Butterworth low-pass filter is given by the following equation:

H(s) = 1 / (1 + (s / wc)^n)

Where:

* H(s) represents the transfer function.
* s is the complex frequency variable.
* Wc is the cutoff frequency, which determines the point at which the filter starts attenuating the signal.
* n is the order of the filter, which determines the sharpness of the roll-off beyond the cutoff frequency.

The cutoff frequency wc is typically defined as the frequency at which the magnitude response of the filter is reduced by 3 dB (approximately 70.7% of the passband gain). The order of the filter, represented by the parameter n, determines the rate at which the filter attenuates the frequencies beyond the cutoff. A higher order results in a steeper roll-off but may introduce more phase distortion.

**Butterworth low-pass filter:**

A Butterworth high-pass filter is another type of electronic filter that allows high-frequency signals to pass through while attenuating lower-frequency signals. It is the complement of the Butterworth low-pass filter, and together they form a set of basic filter designs known as Butterworth filters.

The transfer function of a Butterworth high-pass filter is derived from the low-pass filter transfer function by a process known as frequency transformation. The transfer function of a Butterworth high-pass filter can be expressed as:

H(s) = (s / wc)^n / (1 + (s / wc)^n)

In this equation:

* H(s) represents the transfer function.
* s is the complex frequency variable.
* Wc is the cutoff frequency, which determines the point at which the filter starts allowing high-frequency signals to pass.
* n is the order of the filter, determining the sharpness of the roll-off below the cutoff frequency.

Similar to the Butterworth low-pass filter, the cutoff frequency wc is typically defined as the frequency at which the magnitude response of the filter is reduced by 3 dB. The order of the filter, represented by the parameter n, affects the steepness of the roll-off. A higher order results in a sharper roll-off but may introduce more phase distortion.

The Butterworth high-pass filter attenuates frequencies below the cutoff frequency while allowing higher frequencies to pass through. The magnitude response of the filter is maximally flat in the stopband, meaning that it has a uniform attenuation for frequencies below the cutoff. However, like the Butterworth low-pass filter, it has a relatively wide transition band and a slower roll-off compared to other filter designs.

**R WAVE OF ECG SIGNAL:**

The R wave is a prominent feature of an electrocardiogram (ECG) signal, which is a graphical representation of the electrical activity of the heart. The ECG signal provides important information about the heart's rhythm and function.

The largest wave in an electrocardiogram (ECG) signal is the R wave. The R wave represents the depolarization of the ventricles, specifically the left and right ventricles, during each cardiac cycle. It is part of the QRS complex, which includes the Q wave, R wave, and S wave. It is typically the tallest and most prominent wave in the ECG signal. Its amplitude can vary depending on factors such as the position of the ECG electrodes, the position of the heart within the chest, and the individual's cardiac health.

While the R wave is typically the largest wave in a normal ECG, there can be variations and abnormalities in the ECG waveform depending on the individual's heart condition.

The R wave is one of the upward deflections observed in the ECG waveform. It corresponds to the depolarization of the ventricles of the heart. During the normal cardiac cycle, the depolarization wave spreads through the heart, causing the contraction of the ventricles and subsequent ejection of blood.

In a standard 12-lead ECG, the R wave is typically observed as a positive deflection in leads that are positioned over the chest. The amplitude and shape of the R wave can vary depending on factors such as the individual's age, heart rate, and overall cardiac health.

The R wave is commonly used to measure the duration between consecutive heartbeats, known as the R-R interval. This interval provides information about the heart rate and rhythm, and abnormalities in the R-R interval can indicate various cardiac conditions.

It's important to note that the R wave is just one component of the ECG waveform, which also includes other deflections such as the P wave, Q wave, S wave, and T wave. Each of these components represents different electrical events that occur during the cardiac cycle.

Interpreting an ECG requires a comprehensive understanding of the various waveforms and their relationships to each other. It is typically done by healthcare professionals, such as cardiologists or specialized technicians, who can identify abnormal patterns and diagnose cardiac conditions based on the ECG findings.

**HEART RATE MEASUREMENT:**

Heart rate measurement is the process of determining the number of times the heart beats per minute. It provides valuable information about the cardiovascular health and function of an individual.

**FORMULA OF HEART RATE CALCULATION:**

Heart Rate (BPM) = (Number of Beats\*60) / Time

**Methodology:** The basic steps of our project are

end

start

Apply high pass and low pass to filter the ecg signal

Use findpeaks function to detect the peaks of the signal

If, pks>

threshold

yes

no

No peaks detected

The peaks are detected as R wave

Calculate , Total num of beats = R wave.

Heart rate= (Total num of beats /T)\*60.

Print heart rate and detected R waves

High pass and low pass filter design

Load the ECG signal

Load the ECG signal

**Result:**

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**Figure:** Filtered ECG signal and magnitude response of low pass and high pass filter.



**Figure:** detected R wave and heart rate measurement.

In first graph we can see that the graph is about two different noisy ECG signal and filtered signal. And next graph is the magnitude response of lowpass and highpass fiter.

From third graph we can say that in our project, we have detected 14 R wave in 10 seconds in our first ECG signal and measured heart rate is 84 bpm.

In 2nd ECG signal 12 R wave are detected in 5 seconds and the heart rate in 144 bpm.

In first signal we can say that it is a normal heart rate and in next heart rate there is some problem in this ECG signal. We can detect it as supraventricular tachycardia.