

## APPENDIX B - ECG DATA FILTERING

An ECG signal is made up of several sources. Recording is done using electrodes on the skin, which capture more than just the electrical activity of the heart. The primary electrical components captured are signals from the myocardium, muscles, skin-electrode interface and external interference.

The most common frequencies of important components on the ECG are:

Heart rate: 0.67 - 5 Hz (which equates to: 40 - 300 bpm)

P wave: 0.67 - 5 Hz

QRS: 10 - 30 Hz

T wave: 1 - 7 Hz

Meanwhile, the common frequencies of the medical apparatus and noise on the ECG are:

Muscle movement: 5 - 50 Hz

Respiration: 0.12 - 0.5 Hz (eg, 8 - 30 bpm)

Power line interference: 50 or 60 Hz

Other electrical: typically > 10 Hz (derived from muscle stimulators, strong magnetic fields and pacemakers with impedance monitoring)

When filtering out any biomedical signal, care must be taken not to alter the desired information in any way.

A big concern is how the QRS complex influences the filter's output; for the filter, it often represents a big unwanted boost. The possible distortion caused by the filter must be carefully quantified.

Filtering on an ECG, in principle, can be done in two steps, that is, with the application of 2 filters: a high-pass filter and a low-pass filter. The high-pass filter removes low-frequency signals (that is, only the highest frequencies can pass), and the low-pass filters remove high-frequency signals. High-pass and low-pass filters together are known as a band-pass filter, literally allowing only a certain frequency band to pass.

All filters introduce distortion into the resulting output signal. This distortion can be in amplitude or phase. Filters found in heart monitors need to be real-time and therefore cannot tolerate delays. Because of this, the filter output exhibits non-linear characteristics due to its shorter required delays. Basically, they distort different frequencies, causing phase distortion. If filters were applied during post-processing, where real-time output of the signal is unnecessary, the design of these filters can be linear, which minimizes phase distortion.

Low-pass filters on the ECG are used to remove high frequency muscle noise and especially electrical line interference noise. Analog low-pass filtering has a noticeable effect on the QRS complex, epsilon, and J waves, but does not alter the repolarization signals.

High-pass filters remove low-frequency components such as motion noise, breathing variation, and baseline wobble. Unlike low-pass filters, analog high-pass filters do not attenuate the signal too much. However, analog high-pass filters suffer from the phase shift that affects the first 5 to 10 harmonics of the signal. This means that a 0.5 Hz high-pass filter, which is a lower frequency than that produced by the myocardium, can still affect frequencies up to 5 Hz. To reduce this effect, a higher order filter is used, where frequencies near and above the cutoff frequency have virtually no attenuation.