Université de Liège

Bachelor in Engineering - 3rd year

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Applied digital signal processing

Homework 2

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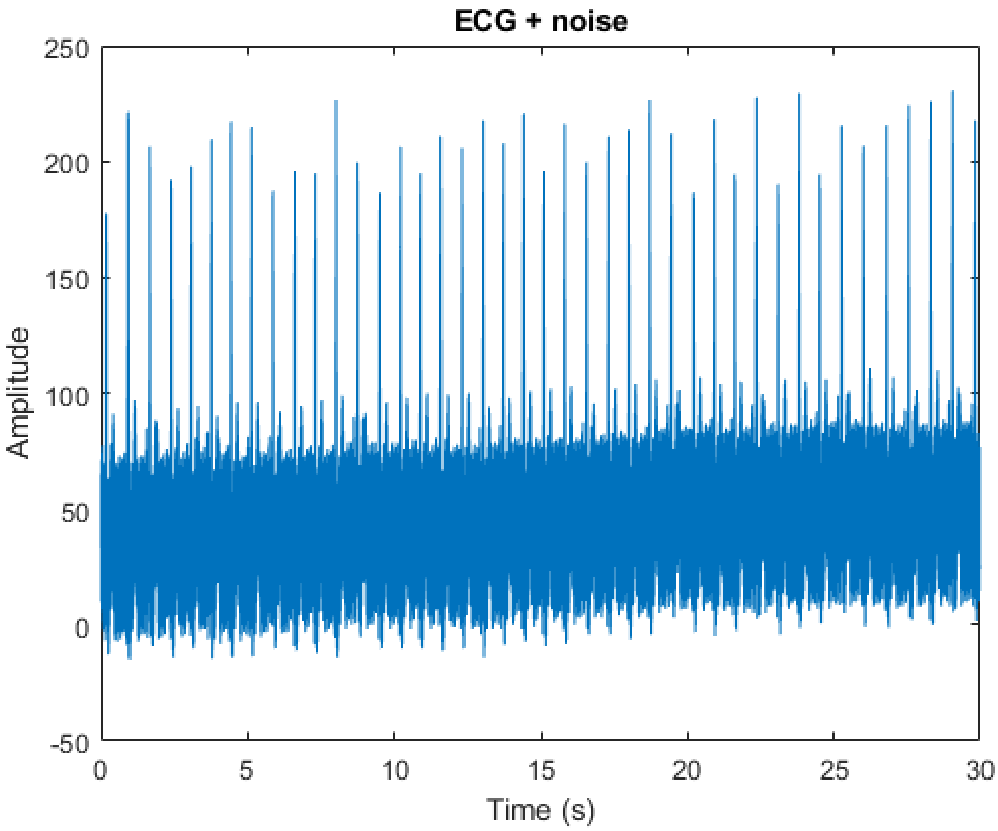
1 Noise elimination

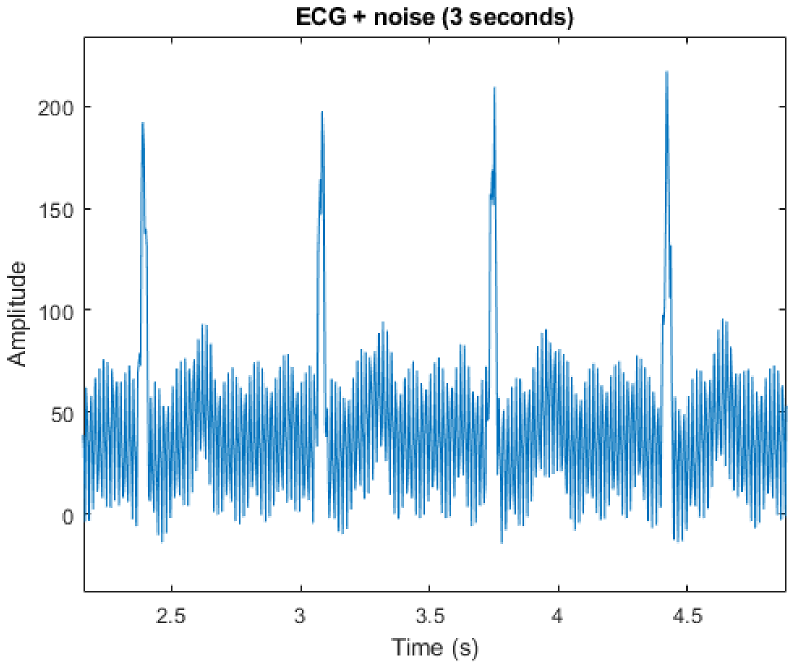
1.a

Knowing the sampling frequency F_s, we easily compute the sampling period $T_s = \frac{1}{F_s}$ and the ending time $T_{max} = (N-1) * T_s$ of the noise-corrupted electrocardiogram signal where $N = 7500$ is the length of the signal. We can then plot the signal entirely :



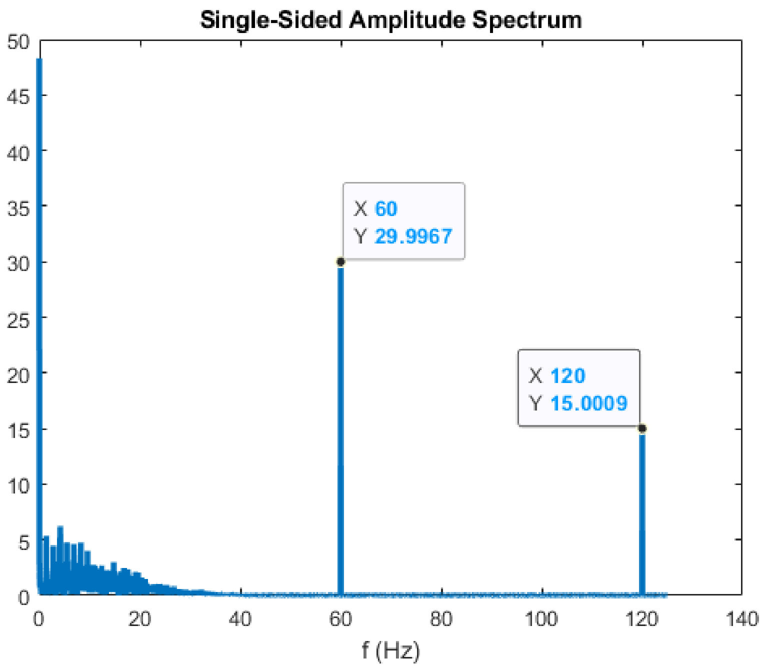
1.b

Since the signal is long and very dense, we plot it between 2 and 5 seconds to have a better observation of the noise (see graph below).



1.c

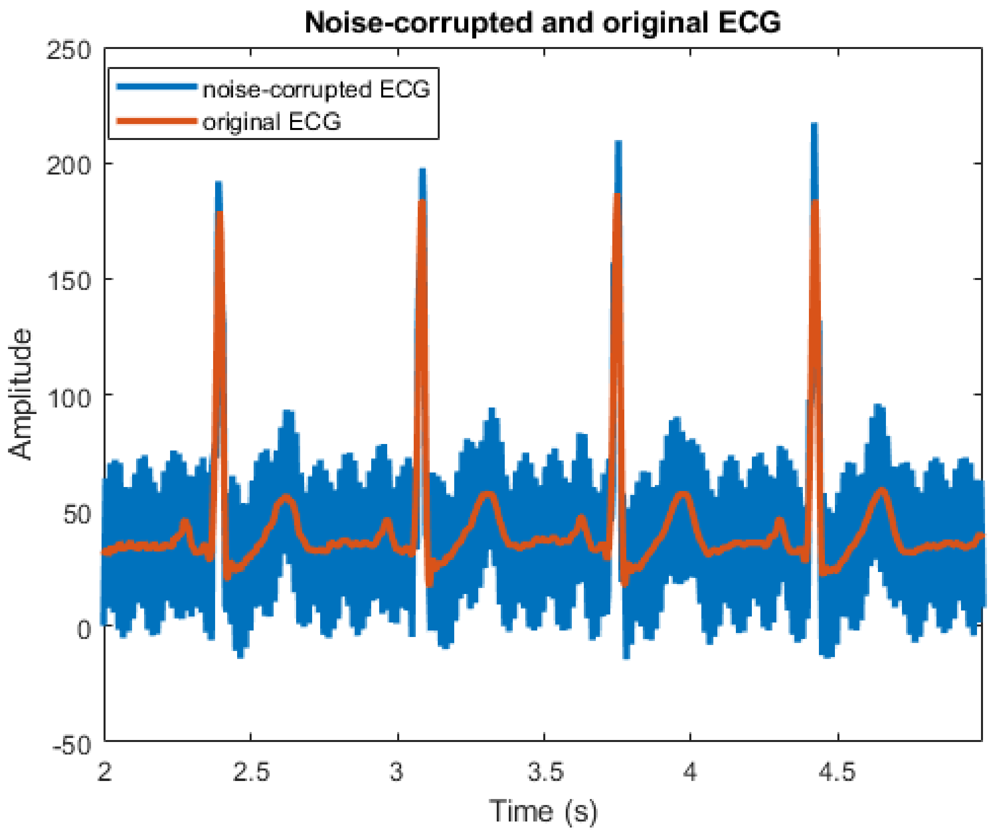
We plot the single-sided magnitude spectrum of the electrocardiogram signal (see graph below) thanks to the fft Matlab function that allows transformation of the signal from time domain to the frequency domain and thanks to manipulations afterwards.



1.d

We can easily spot the two noise frequencies on the figure right above because they correspond to the two rightmost peaks : we have the main noise frequency 60 Hz and its harmonic 120 Hz.

1.e



1.f

To eliminate the noise we need two cascaded Notch filters, one for each noise frequency. We filter the noise-corrupted electrocardiogram signal with a first Notch filter that filters out the 60 Hz noise frequency. However, the output of this filter is still corrupted (because there's a second noise frequency). The output is thus put into a second Notch filter that filters out the 120 Hz noise frequency. We then obtain the noise-free signal that we plotted 3 seconds of *(in orange)* in section **1.e** right above.
We built the first filter in Matlab the way it's shown in *Figure 1* below. We built the second filter in a similar way.

Thanks to the *fvtool* Matlab function we can analyze the filters we designed. In *Figure 2* (first filter) and *Figure 3* (second filter) below, we can see both the magnitude response *(in blue)* and phase response *(in orange)* of each filter.
By analyzing the magnitude and phase responses, we can see that the first Notch filter rejects the 60 Hz ($\sim= 0.48\pi$ rad/sample) frequency and the second Notch filter rejects the

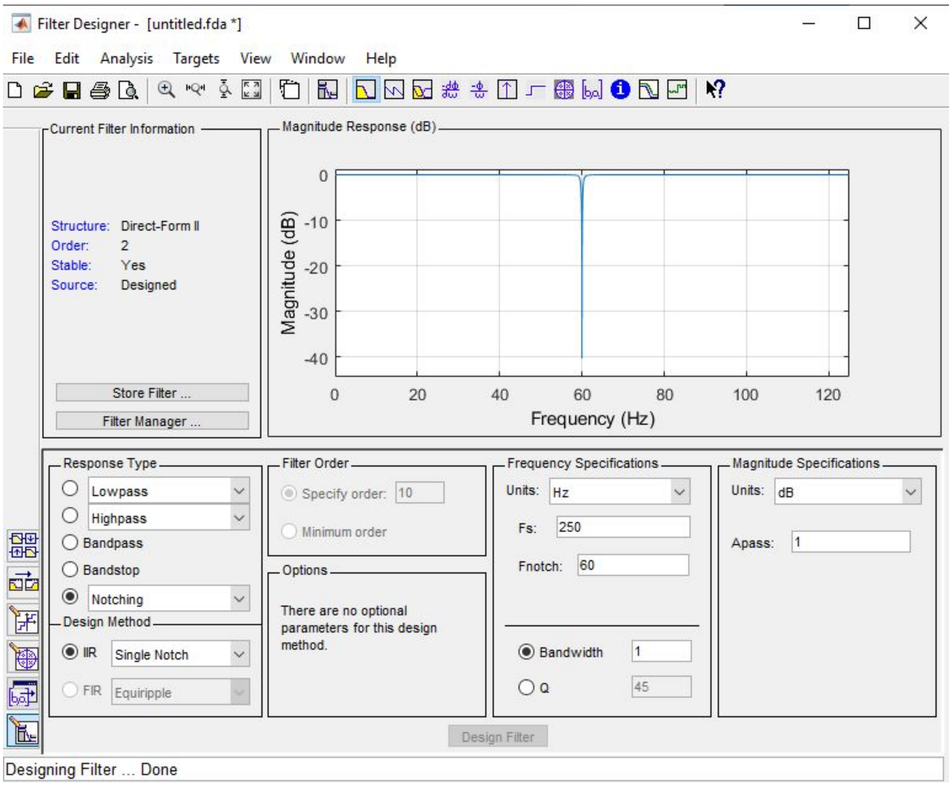


FIGURE 1 – Designing 60 Hz Notch filter

120 Hz ($\sim= 0.96\pi$ rad/sample) frequency.
We can also see that for each filter, the phase response is constant everywhere except at rejection band.

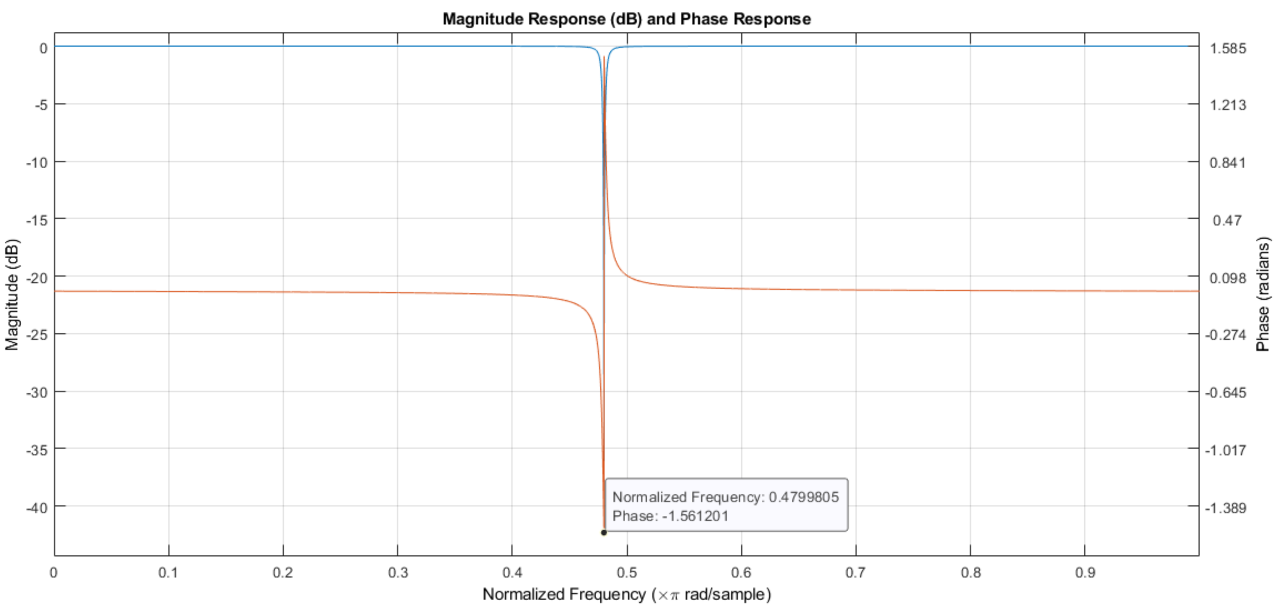


FIGURE 2 – Magnitude (blue) and phase (orange) responses of first Notch filter

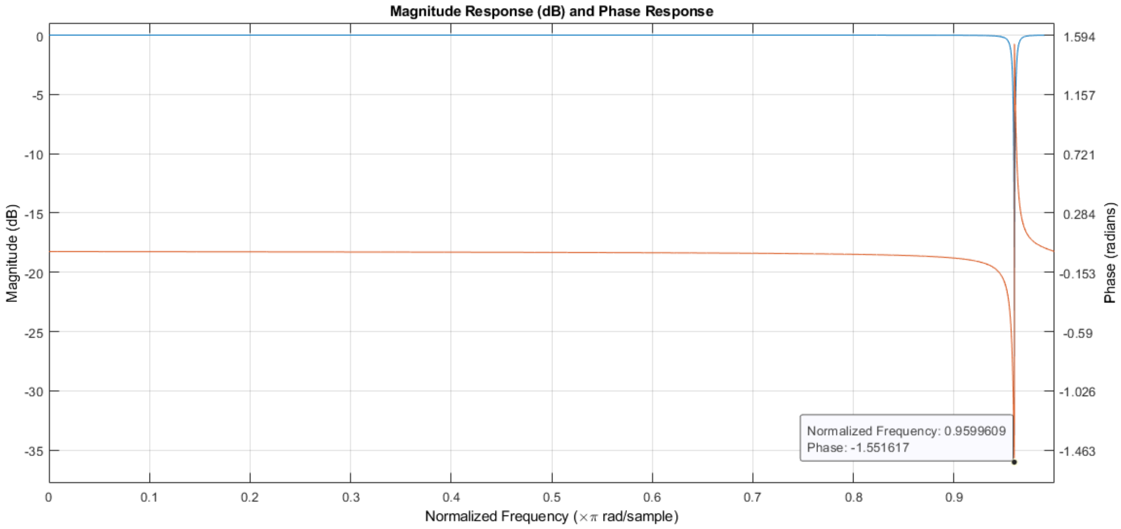


FIGURE 3 – Magnitude (blue) and phase (orange) responses of second Notch filter