# Programming Exercise 3 - IIR Filters

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**Digital Biomarkers**

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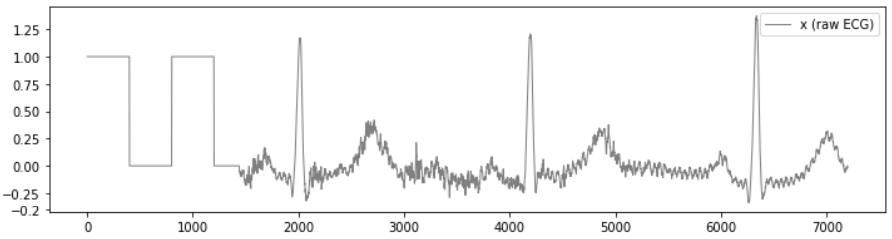
|---|---|
| Python script template: | `L3-IIR-Filters-ecg-Template.py` |
| Data set: | `SECG3_FILT_HP51_3CH_20S_FS2400HZ.csv` |
| | `SECG3_RAW_3CH_20S_FS2400HZ.csv` |
| Data source: | https://lmlib.ch |




The provided template code applies an IIR filter parametrized by the coefficients $a$ and $b$ to an input signal $x$, which is a real ECG signal with a trailing synthetic rectangular signal (see figure above). In the current template, the dummy setting $a = b = [1]$ is applied which has no filtering effect.

## Programming Exercise 3-1: Low-Pass Filter (Butterworth)

A common class of IIR filters are the *Butterworth filters*. Butterworth is a filter design method defining rules on how to choose coefficients $a$'s and $b$'s for lowpass, high-pass, bandpass, and other filter types.

Start with the first ecg signal. To activate the first signal in the Python template, set the if-clause for `"ECG SIGNAL 1"` to `True`.

*Tasks:*

a) Complete the code in Cell (2) for a 4th order low-pass Butterworth filter with a cut-off frequency of $f_c = 20\,\text{Hz}$. Check the online manual[1] for `scipy.signals.iirfilter(..., ftype="butter")` or `scipy.signals.butter(...)` which will provide the filter coefficients for you. Verify that the cut-off frequency in the frequency response in Cell (3) matches your expectations.

*Note:* According to the definition of the cut-off frequency, we expect a amplitude dumping of $-3\,\text{dB}$ ($= 0.707$) at frequency $f_c$.) Cell (4) will show the resulting, filtered signal.

b) Do you observe a phase shift (delay) in the filtered QRS waves?

c) By what factor is QRS amplitude reduced?

[1] `scipy.signalshttps://docs.scipy.org/doc/scipy/reference/signal.html`

### Programming Exercise 3-2: Symmetric Filters

As you might have observed in the previous task, IIR filters usually delay (and distort) the signals. A common way to compensate for such delays and signal distortions is to apply the same IIR filter twice, once in forward direction and once in reverse direction. In this way, the delays cancel and distortions compensate.

a) Check the manual for `scipy.signals.filtfilt(...)` and complete the code in Cell (2). Verify the result also on the synthetic test signal sequence.

b) By what factor is QRS amplitude reduced?

### Programming Exercise 3-3: Notch Filters

Notch filters suppress a narrow frequency band. They are often use to cancel 50 Hz noise in recordings.

a) Work with test signal `ECG SIGNAL 2` which is showing strong 50 Hz interferences. Check the manual for `scipy.signals.iirnotch(...)` and modify the code in Cell (2) accordingly. Verify the result also on the synthetic test signal sequence.

b) By what factor is QRS amplitude reduced?