

Chapter 3

Frequency-domain Filtering for Removal of Artifacts

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Contents

- Frequency-domain filters
- Applications:
 - Removal of artifacts in the ECG

Frequency-domain filters

- Removal of HF noise: Butterworth LPF
- Removal of LF noise: Butterworth HPF
- Removal of periodic artifacts: Notch and comb filters

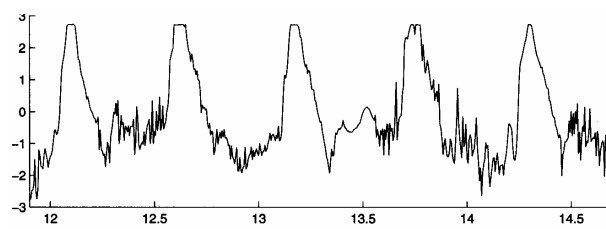
Problem:

- Propose a frequency-domain technique to remove HF noise with minimal loss of signal components in the specified pass-band.

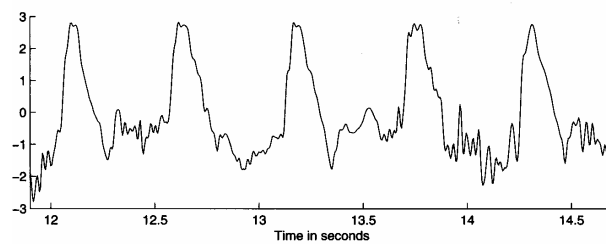
Solution

- Butterworth lowpass filters

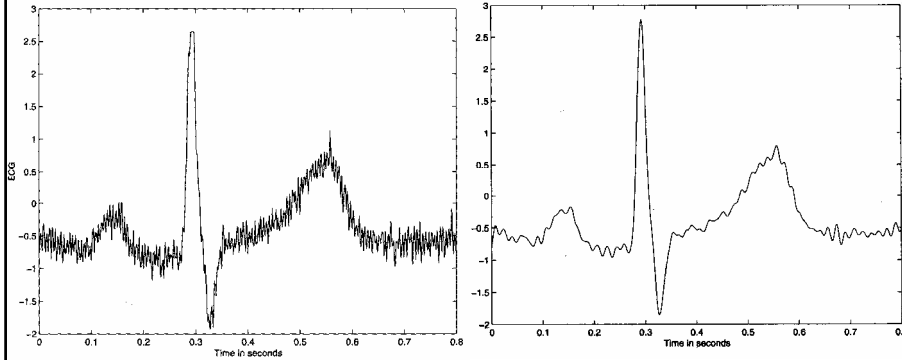
Butterworth lowpass filter



$f_c = 40$ Hz
 $f_s = 200$ Hz
 $N = 4$



Butterworth lowpass filter



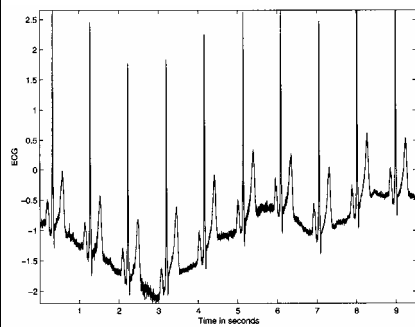
$N = 8$
Butterworth LP filter
 $f_c = 70$ Hz

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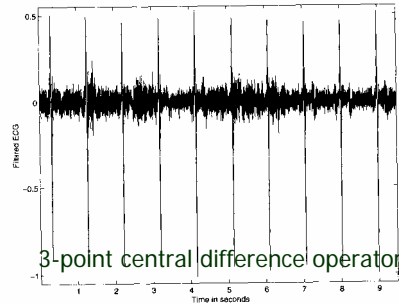
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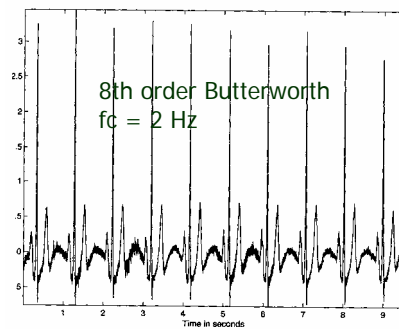
Highpass filter



Original ECG



3-point central difference operator



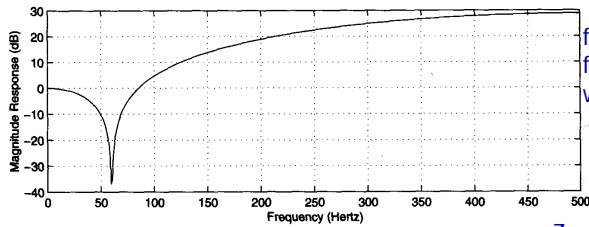
8th order Butterworth
 $f_c = 2$ Hz

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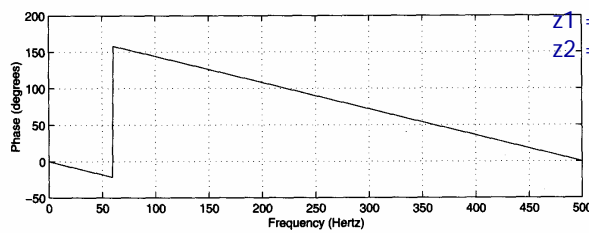
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Notch Filter

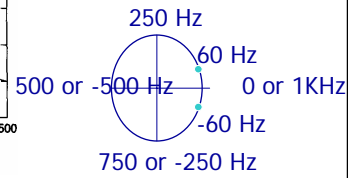


$f_0 = 60 \text{ Hz}$
 $f_s = 1000 \text{ Hz}$
 $\omega_0 = \pm (60/1000) 2\pi$
 $= \pm 0.377 \text{ radians} =$
 $= \pm 21.6 \text{ degrees}$



Zero locations $\cos(\omega_0) + j\sin(\omega_0)$

$z_1 = .92977 + j.36812$
 $z_2 = .92977 - j.36812$



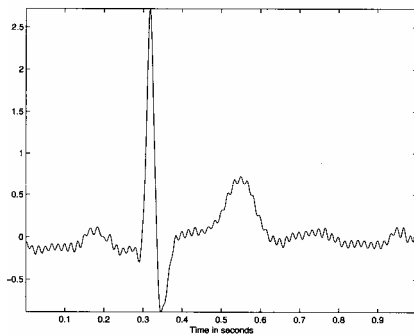
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60 Hz interference

Signal w/ 60Hz noise



Noise removed w/ notch filter

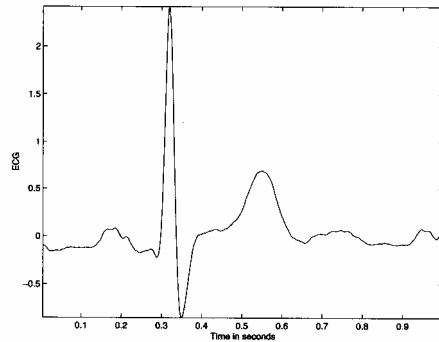


Figure 3.44 ECG signal with 60 Hz interference.

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Comb Filters

<http://www.mathworks.com/company/newsletters/digest/september99/spttool/>

Google'da comb filter matlab yazin.