# DIGITAL SIGNAL PROCESSING LAB (BECE301P)

Due Date: 3-3-2025 Lab Slot:L35+L36
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**Objective:**

To use MATLAB for spectral analysis of signals.

**Task Questions:**

Filter the noisy ECG signal in the file ecg_hfn.dat (See also the file ecg_hfn.m; fs = 1, 000 Hz.) using the following filters with the specified characteristics;

1) Four different Butterworth low pass with the following characteristics:
   (a) Order 2. cutoff frequency 10 Hz
   (b) Order 4. cutoff frequency 20 Hz
   (c) Order 6. cutoff frequency 40 Hz
   (d) Order 8. cutoff frequency 70 Hz

2) Chebyshev filter (Both Type-1 and Type-2) with the order range 2-8 and cutoff frequencies range 5 to 100 Hz.

Solution:

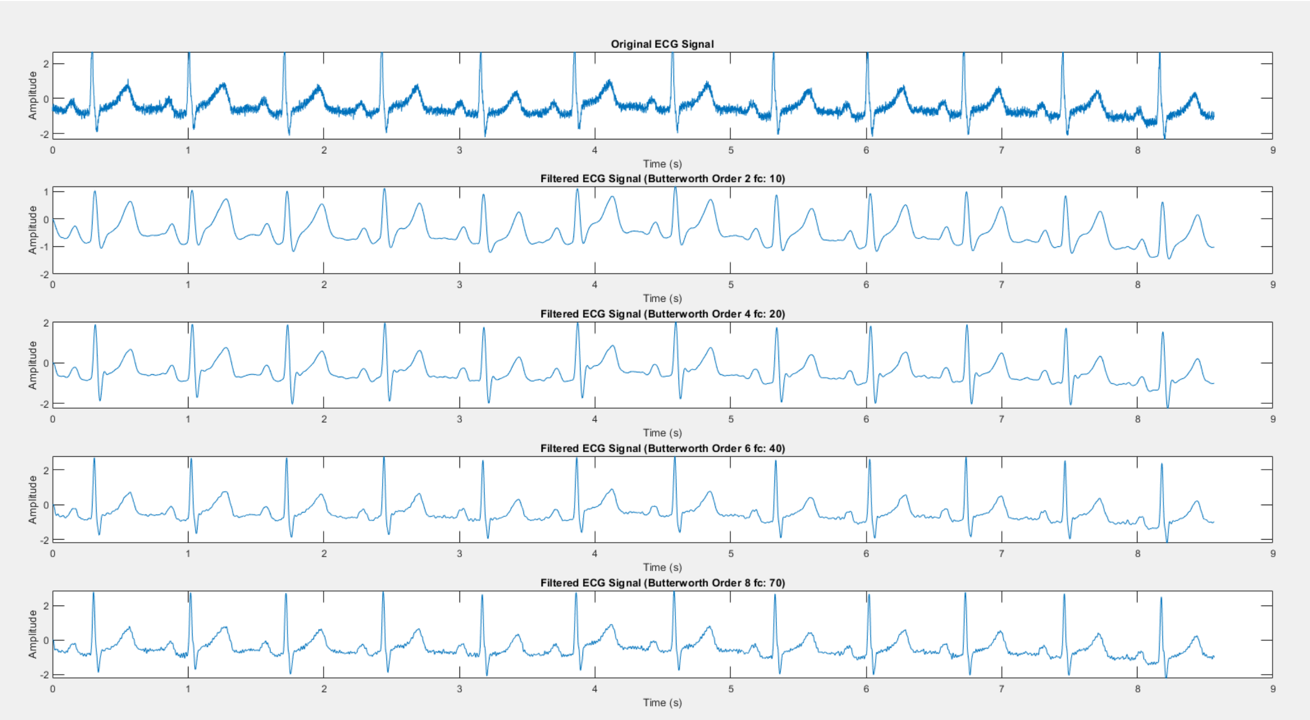
Code:

```
% Load ECG signal
clc
clear
close all
ecg_signal = load('ecg_hfn.data.txt');
fs = 1000;  % Sampling frequency in Hz
t = (0:length(ecg_signal)-1)/fs;  % Time vector

% Butterworth filters
butter_orders = [2, 4, 6, 8];
butter_cutoffs = [10, 20, 40, 70];
figure;
subplot(5, 1, 1);
plot(t, ecg_signal);
title('Original ECG Signal');
xlabel('Time (s)'); ylabel('Amplitude');
for i = 1:length(butter_orders)
    [b, a] = butter(butter_orders(i), butter_cutoffs(i)/(fs/2), 'low');
    filtered_signal = filter(b, a, ecg_signal);

    subplot(5, 1, i+1);
    plot(t, filtered_signal);
```

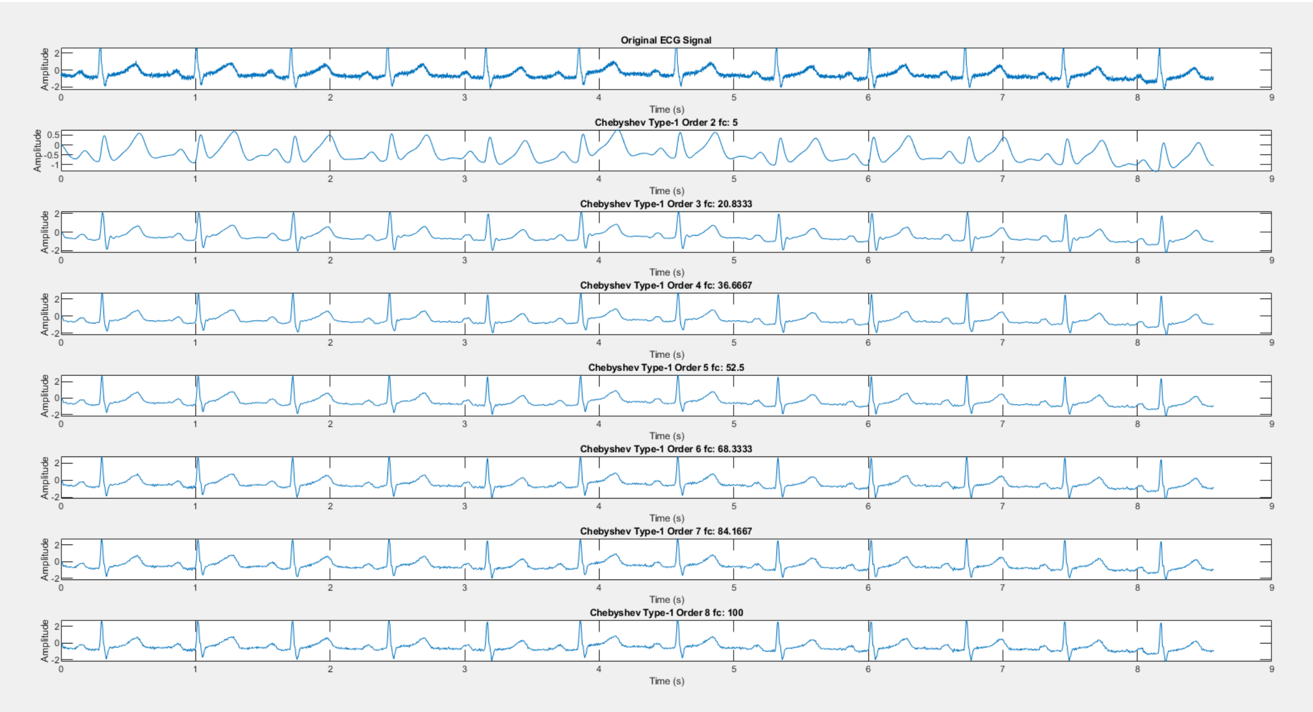
```
    title(['Filtered ECG Signal (Butterworth Order ', num2str(butter_orders(i)),
')']);
    xlabel('Time (s)'); ylabel('Amplitude');
end

% Chebyshev Type-1 and Type-2 filters
cheby_orders = 2:1:8;
cheby_cutoffs = linspace(5,100,7);
figure;
subplot(8, 1, 1);
plot(t, ecg_signal);
title('Original ECG Signal');
xlabel('Time (s)'); ylabel('Amplitude');
for i = 1:length(cheby_orders)
    [b1, a1] = cheby1(cheby_orders(i), 0.5, cheby_cutoffs(i)/(fs/2), 'low');

    filtered_signal1 = filter(b1, a1, ecg_signal);


    subplot(8, 1, i+1);
    plot(t, filtered_signal1);
    title(['Chebyshev Type-1 Order ', num2str(cheby_orders(i))]);
    xlabel('Time (s)'); ylabel('Amplitude');


end
cheby_orders = 2:1:8;
cheby_cutoffs = linspace(5,100,7);
figure;
subplot(8, 1, 1);
plot(t, ecg_signal);
title('Original ECG Signal');
xlabel('Time (s)'); ylabel('Amplitude');
for i = 1:length(cheby_orders)

    [b2, a2] = cheby2(cheby_orders(i), 20, cheby_cutoffs(i)/(fs/2), 'low');

    filtered_signal2 = filter(b2, a2, ecg_signal);


    subplot(8, 1, i+1);
    plot(t, filtered_signal2);
    title(['Chebyshev Type-2 Order ', num2str(cheby_orders(i))]);
    xlabel('Time (s)'); ylabel('Amplitude');
end
```

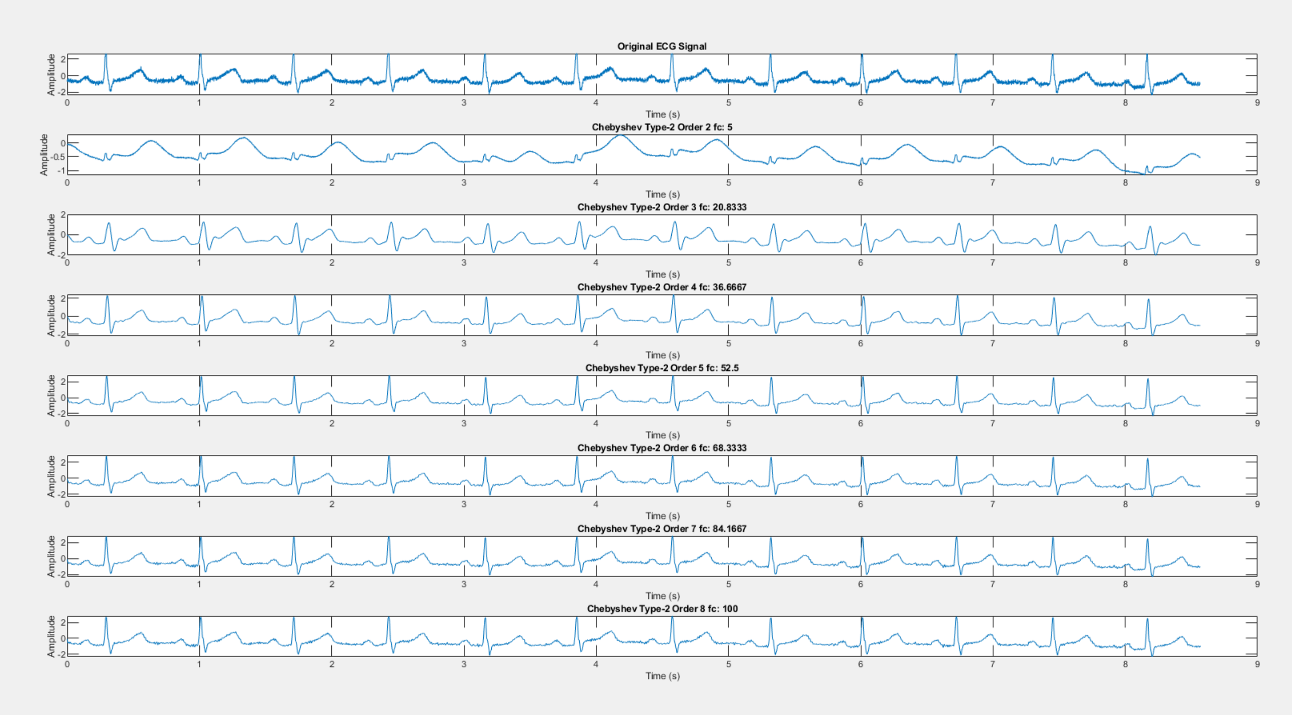
OUTPUT:

1)


Original ECG Signal
Filtered ECG Signal (Butterworth Order 2 fc: 10)
Filtered ECG Signal (Butterworth Order 4 fc: 20)
Filtered ECG Signal (Butterworth Order 6 fc: 40)
Filtered ECG Signal (Butterworth Order 8 fc: 70)
Amplitude
Time (s)

2)


Original ECG Signal
Chebyshev Type-1 Order 2 fc: 5
Chebyshev Type-1 Order 3 fc: 20.8333
Chebyshev Type-1 Order 4 fc: 36.6667
Chebyshev Type-1 Order 5 fc: 52.5
Chebyshev Type-1 Order 6 fc: 68.3333
Chebyshev Type-1 Order 7 fc: 84.1667
Chebyshev Type-1 Order 8 fc: 100
Amplitude
Time (s)




## Inferences:

i) Increasing the cutoff frequency allows more high-frequency components to pass through, preserving finer details in the ECG waveform. Lower-order filters (e.g., 10 Hz, Order 2) smooth the signal more aggressively, effectively reducing noise but also attenuating some ECG features. In contrast, higher-order filters (e.g., 70 Hz, Order 8) retain more signal details while minimizing noise, though they may introduce slight high-frequency artifacts. Overall, using higher-order filters with higher cutoff frequencies improves the trade-off between noise reduction and signal fidelity.

ii)
A. **Chebyshev Type-1 filters** have a flat passband but introduce ripple in the stopband. As the filter order increases, they provide better noise suppression and sharper roll-off. However, the stopband ripple becomes more pronounced, particularly at higher cutoff frequencies. Lower-order filters allow more noise, whereas higher-order filters enhance performance at the cost of increased stopband ripple.

B. **Chebyshev Type-2 filters** feature a flat stopband with ripple in the passband. Increasing the filter order reduces passband ripple, leading to better signal preservation. However, at higher cutoff frequencies, the ripple effect in the passband becomes more noticeable. These filters excel in stopband attenuation, making them ideal for applications where minimizing stopband noise is more critical than slight distortions in the passband.