MAWLANA BHASHANI SCIENCE AND TECHNOLOGY UNIVERSITY

SANTOSH, TANGAIL-1902

DEPARTMENT OF INFORMATION AND COMMUNICATION TECHNOLOGY

Lab Report

Lab Report No : 06

Lab Report on **:** Design and analysis of Butterworth IIR digital filters using MATLAB.

Course Title **:** Digital Signal Processing Lab

Course Code **:** ICT-3206

Submitted By	Submitted To
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Introduction:

IIR digital filters are widely used due to their sharp frequency response with lower filter order. Butterworth filters are especially popular because of their maximally flat magnitude response in the passband. The bilinear transformation technique is commonly used to convert analog filters into digital form. This experiment demonstrates the design of Butterworth low-pass and high-pass filters using MATLAB.

Objective:

- To design a digital filter using bilinear transformation.
- To design a Butterworth low-pass filter.
- To design a Butterworth high-pass filter and analyze its response.

Theory:

- **Butterworth filter** provides a smooth and flat passband response.
- **Bilinear transformation** maps the analog frequency axis to the digital frequency axis.
- The frequency response of a digital filter is analyzed using magnitude and phase plots.

MATLAB Code:

Program 1: Filter Design Using Bilinear Transformation

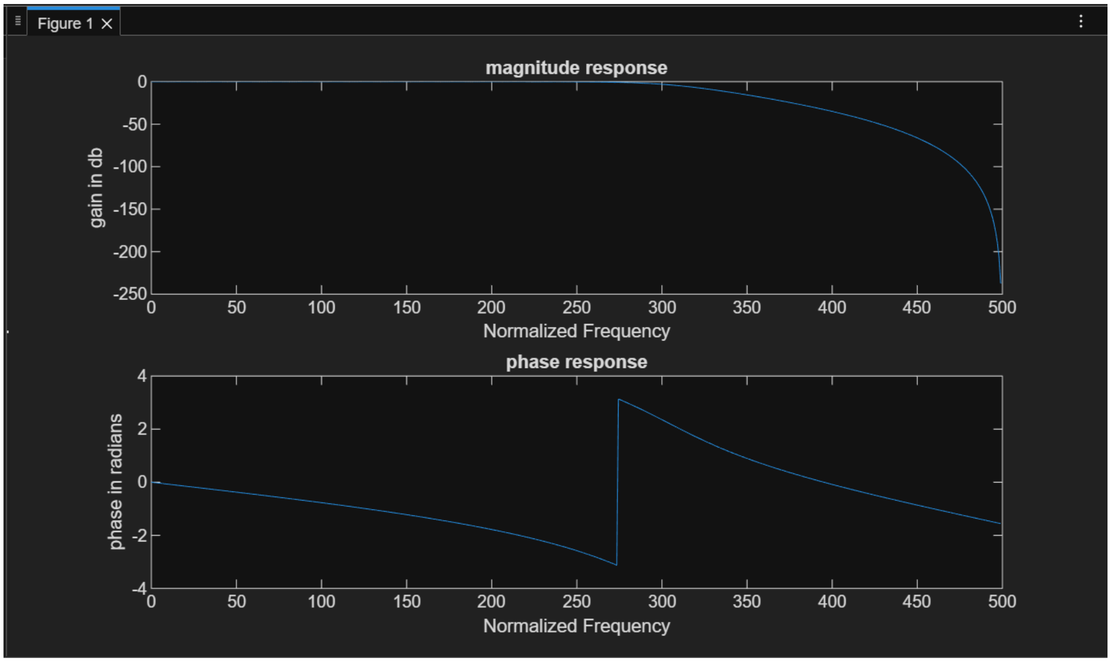
```
clc;
clear all;
close all;
fs = 1000;        % sampling frequency
fn = fs/2;
fc = 300;         % cutoff frequency
n = 5;
[z,p,k] = butter(n, fc/fn);
b = k*poly(z);    % zeros
a = poly(p);      % poles

[h, om] = freqz(b, a, 512, fs);

subplot(2,1,1);
plot(om, 20*log10(abs(h)));
xlabel('Normalized Frequency');
ylabel('gain in db');
title('magnitude response');

subplot(2,1,2);
plot(om, angle(h));
xlabel('Normalized Frequency');
ylabel('phase in radians');
title('phase response');
```

Output:



Program 2: Butterworth Low-Pass Filter Design

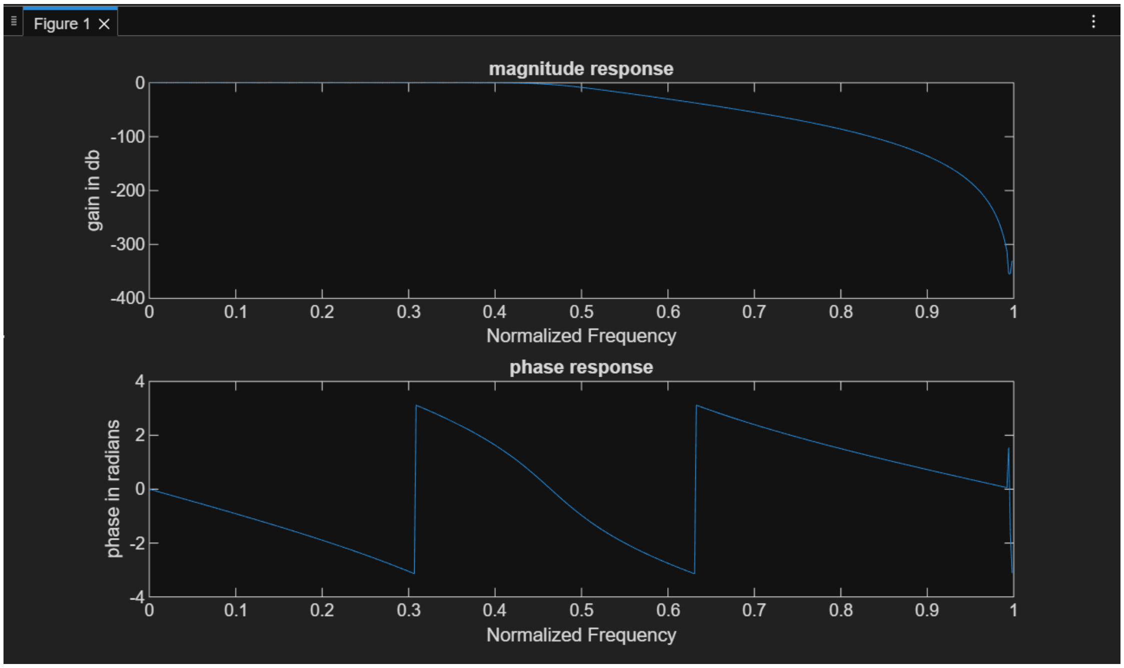
```
clc;
clear all;
close all;
alphas = 30;     % pass band attenuation in dB
alphap = 0.5;    % stop band attenuation in dB
fpass = 1000;    % pass band frequency in Hz
fstop = 1500;    % stop band frequency in Hz
fsam  = 5000;    % sampling frequency in Hz
wp = 2*fpass/fsam;
ws = 2*fstop/fsam;   % pass band and stop band frequencies
[n, wn] = buttord(wp, ws, alphap, alphas);
[b, a] = butter(n, wn);

[h, w] = freqz(b, a);

subplot(2,1,1);
plot(w/pi, 20*log10(abs(h)));
xlabel('Normalized Frequency');
ylabel('gain in db');
title('magnitude response');

subplot(2,1,2);
plot(w/pi, angle(h));
xlabel('Normalized Frequency');
ylabel('phase in radians');
title('phase response');
```

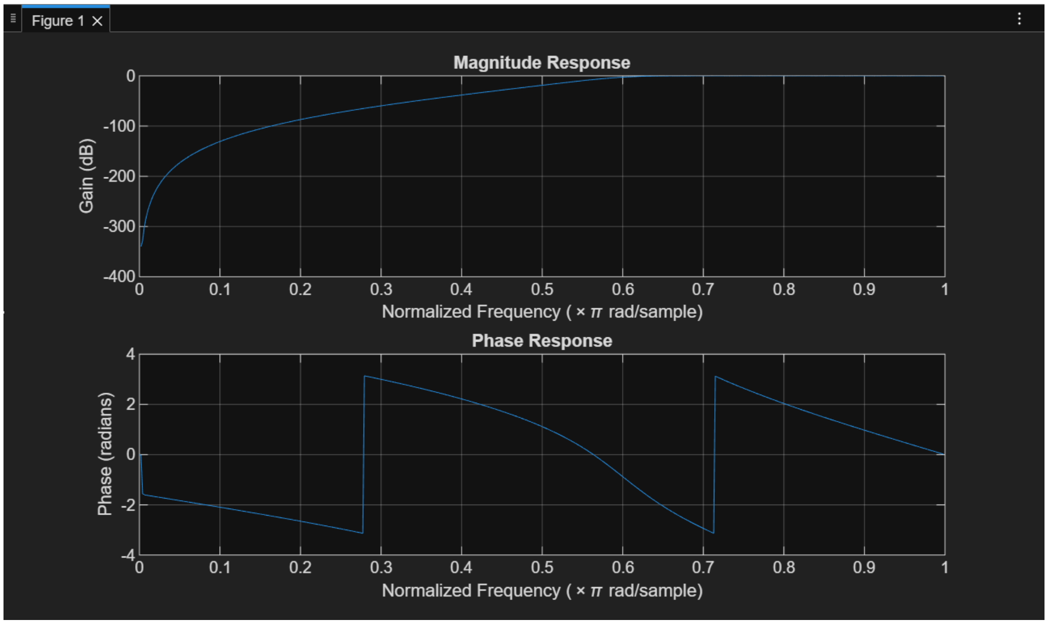
Output:



Program 3: Butterworth High-Pass Filter Design

```
% Butterworth High-Pass Filter Design
clc;
clear;
close all;
alphap = 5;      % Passband attenuation in dB
alphas = 50;     % Stopband attenuation in dB
fp = 1050;       % Passband frequency (Hz)
fs = 600;        % Stopband frequency (Hz)
fsam = 3500;     % Sampling frequency (Hz)
wp = fp / (fsam/2);
ws = fs / (fsam/2);
[n, wn] = buttord(wp, ws, alphap, alphas);
[b, a] = butter(n, wn, 'high');
[h, w] = freqz(b, a, 512);
subplot(2,1,1)
plot(w/pi, 20*log10(abs(h)))
grid on
xlabel('Normalized Frequency (\times\pi rad/sample)')
ylabel('Gain (dB)')
title('Magnitude Response')
subplot(2,1,2)
plot(w/pi, angle(h))
grid on
xlabel('Normalized Frequency (\times\pi rad/sample)')
ylabel('Phase (radians)')
title('Phase Response')
```

Output:



Result:

- Butterworth low-pass and high-pass filters were designed successfully.
- Magnitude and phase responses matched theoretical expectations.

Conclusion:

This experiment demonstrated the design of IIR Butterworth filters using bilinear transformation. The frequency responses confirmed the effectiveness of Butterworth filters in digital signal processing.