Experiment 9

GROUP No. : 6

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Aim: Design and implementation of IIR filter to meet given specifications using Butterworth filter .

Software : OCTAVE

Theory: An IIR filter of order N can be described mathematically as a linear time invariant system with it's output y[n] at time n given by the convolution of the input signals x[n] with the filter's impulse response h[n] as follow :

Butterworth filter   Chebychev filter

Elliptic filter   Besrel filter

Algorithm:

Step 1: Get/Read the pass band frequency of LPF to 'fp'.

Step 2: Get/Read the stop band frequency of LPF to 'fs'.

Step 3: Get/Read the pass band ripple of LPF to 'rp'.

Step 4: Get/Read the stop band ripple of LPF to 'rs'.

Step 5: Get/Read the sampling frequency to 'f'.

Step 6: Normalize the pass band and stop band frequencies using

wp = 2 * fp / f;

ws = 2 * fs / f;

Step 7: Determine the order 'n' of the filter using Butterworth design.

[n, wc] = buttord(wp, ws, rp, rs);

Step 8: Make sure that the order of the filter is always odd.

```
if rem(n, 2) ~= 0
   n1 = n;
   n = n - 1;
else
```

n1 = n + 1;

end

Step : 9 Determine the coefficients 'b' of digital LPF using butterworth (butter function) .
Step : 10 Determine the frequency response of low pass filter 'H' using the coefficients 'b'.
Step : 11 Determine the magnitude of H in dB and store it in 'mag'.
Step : 12 Determine the phase of H and store it in 'phase'.
Step : 13 Plot the Graphs of 'mag' and 'phase'.
Step : 14 Repeat the steps 10 to 14 for HPF, BPF & BSF.

Program:

```
clc;
clear all;
close all;
pkg load signal;

fp = input('Enter the passband frequency  :');
fs = input('Enter the stopband frequency :');
rp = input('Enter the pass band ripple frequency :');
rs = input('Enter the stop band ripple frequency :');
f = input('Enter the sampling frequency :');

wp = 2*fp/f;
ws = 2*fs/f;
figure(1);
[n,wc]=buttord(wp,ws,rp,rs);
[b,a]=butter(n,wc,'low');
disp('Numerator coefficients');b
disp('denominator coefficients');a
[y,t] = impz(b,a,60);
subplot(3,1,1);
stem(t,y);
xlabel('Time Index n');
ylabel('Amplitude');
title('Impulse response of Butter worth low pass filter');

%Low Pass Filter
[b,a]=butter(n,wc,'low');
w =0:0.01:pi;
[h,om]= freqz(b,a,w);
m = 20*log10(abs(h));
```

```
an = angle(h);
subplot(3,1,2);
plot(om/pi,m);
xlabel('Normalized frequency');
ylabel('gain in dB');
title('Magnitude response(LPF)');
subplot(3,1,3);
plot(om/pi,an);
xlabel('Normalized frequency');
ylabel('gain in dB');
title('frequency response(LPF)');

%High Pass Filter

[b,a]=butter(n,wc,'high');
figure(2);

disp('Numerator coefficients');b
disp('denominator coefficients');a
[y,t] = impz(b,a,60);

subplot(3,1,1);
stem(t,y);
xlabel('Time Index n');
ylabel('Amplitude');
title('Impulse response of Butter worth high pass filter');

w =0:0.01:pi;
[h,om]= freqz(b,a,w);
m = 20*log10(abs(h));
an = angle(h);
subplot(3,1,2);
plot(om/pi,m);
xlabel('Normalized frequency');
ylabel('gain in dB');
title('Magnitude response(HPF)');
subplot(3,1,3);
plot(om/pi,an);
xlabel('Normalized frequency');
ylabel('gain in dB');
title('frequency response(HPF)');
figure(3);
%Band Pass Filter
wn=[wp,ws];
```

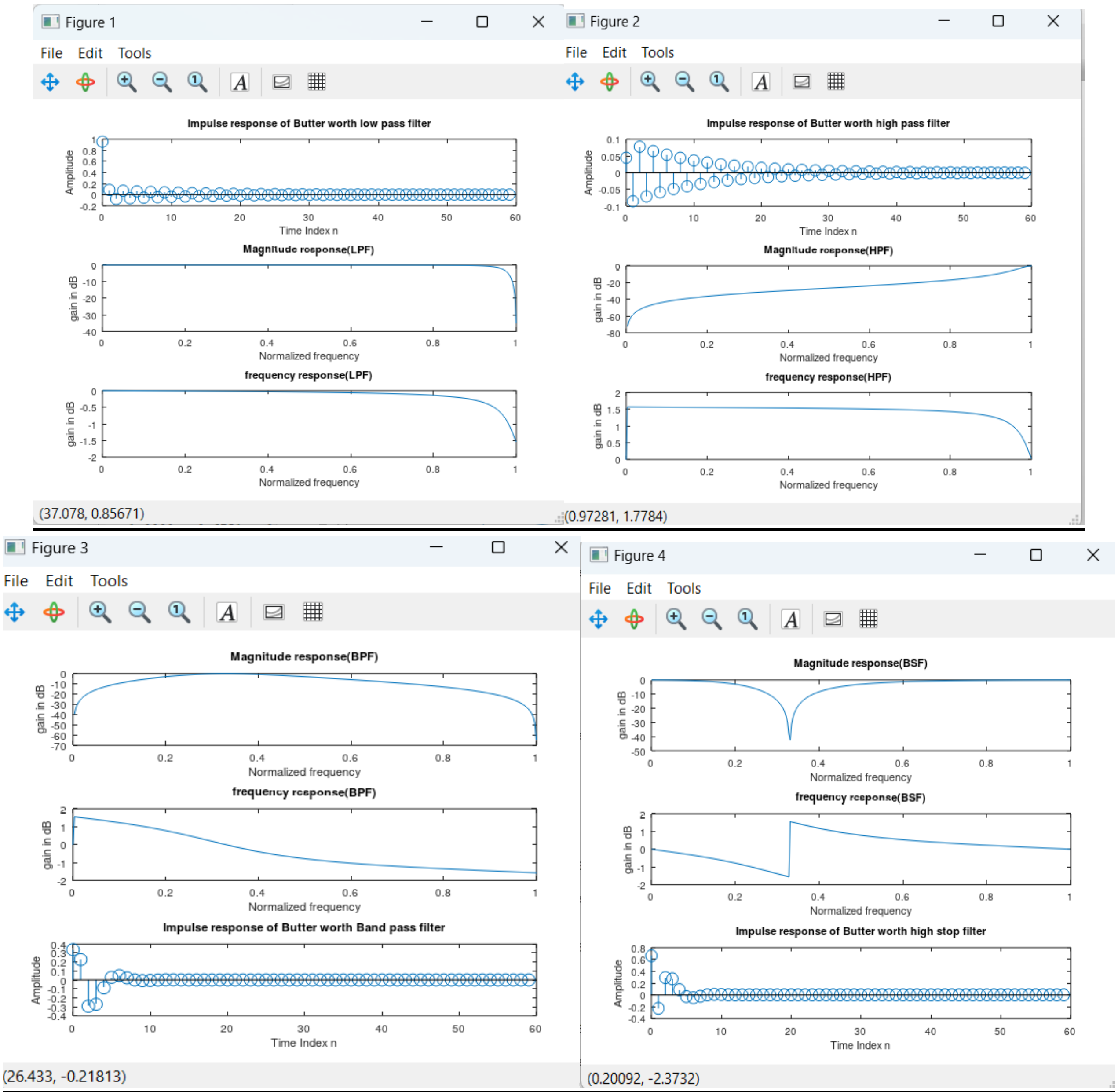
```
[b,a]=butter(n,wn,'pass');
w =0:0.01:pi;
[h,om]= freqz(b,a,w);
m = 20*log10(abs(h));
an = angle(h);
subplot(3,1,1);
plot(om/pi,m);
xlabel('Normalized frequency');
ylabel('gain in dB');
title('Magnitude response(BPF)');
subplot(3,1,2);
plot(om/pi,an);
xlabel('Normalized frequency');
ylabel('gain in dB');
title('frequency response(BPF)');

disp('Numerator coefficients');b
disp('denominator coefficients');a
[y,t] = impz(b,a,60);

subplot(3,1,3);
stem(t,y);
xlabel('Time Index n');
ylabel('Amplitude');
title('Impulse response of Butter worth Band pass filter');

figure(4);
%Band Stop Filter
wn=[wp,ws];
[b,a]=butter(n,wn,'stop');
w =0:0.01:pi;
[h,om]= freqz(b,a,w);
m = 20*log10(abs(h));
an = angle(h);
subplot(3,1,1);
plot(om/pi,m);
xlabel('Normalized frequency');
ylabel('gain in dB');
title('Magnitude response(BSF)');
subplot(3,1,2);
plot(om/pi,an);
xlabel('Normalized frequency');
ylabel('gain in dB');
title('frequency response(BSF)');
```

```
disp('Numerator coefficients');b
disp('denominator coefficients');a
[y,t] = impz(b,a,60);
subplot(3,1,3);
stem(t,y);
xlabel('Time Index n');
ylabel('Amplitude');
title('Impulse response of Butter worth high stop filter');
```

Input:

Fp=200; fs =500; Sampling frequency=2000;passband ripple=0.001, stop band Ripple=0.005

OUTPUT:



Command Window

```
Enter the passband frequency  :200
Enter the stopband frequency :500
Enter the pass band ripple frequency :0.001
Enter the stop band ripple frequency :0.005
Enter the sampling frequency :2000
Numerator coefficients
b =

   0.9554   0.9554

denominator coefficients
a =

   1.0000   0.9108

Numerator coefficients
b =

   0.044620  -0.044620

denominator coefficients
a =

   1.0000   0.9108

Numerator coefficients
b =

   0.3375         0   -0.3375

denominator coefficients
a =

   1.0000  -0.6751   0.3249

Numerator coefficients
b =

   0.6625  -0.6751   0.6625

denominator coefficients
a =

   1.0000  -0.6751   0.3249

>> 
```