Hacettepe University

Department of Electrical and Electronics Engineering

ELE 409 Digital Signal Proccessing Laboratory

EXPERIMENT 4 – IIR FILTER

PRELIMINARY WORK

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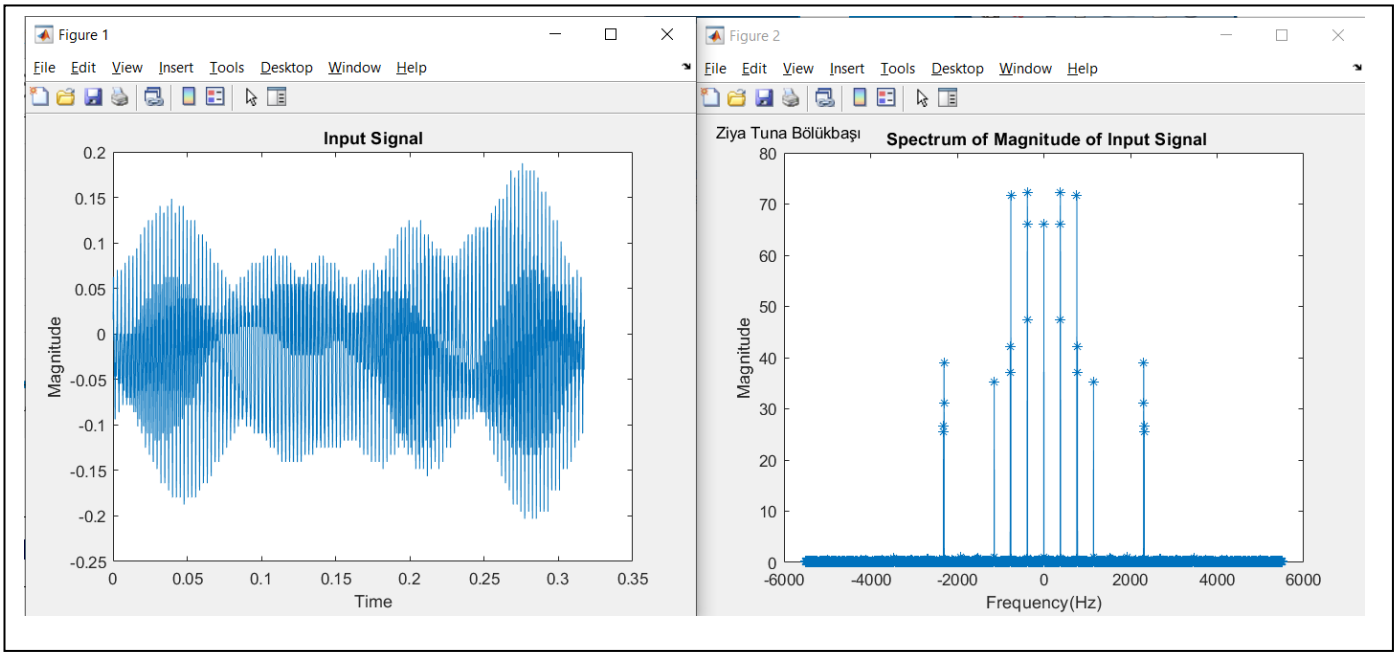
1)

Matlab Code

```
clc;
clear all;
close all;
[x_input,fs]=audioread('C:\Users\Tuna\OneDrive - hacettepe.edu.tr\Masaüstü\dersler\2022
1.dönem\dsplab\pre-exp4\sound4.wav');
fft_of_x=fft(x_input)
fftshift_of_x=fftshift(abs(fft_of_x));
length_fftx=length(fftshift_of_x);
length_x=length(x_input);
range_of_frequency=-fs/2:fs/length_fftx:fs/2-fs/length_fftx;
time=[1:length_x]/fs;
figure;
plot(time,x_input);
title('Input Signal');
xlabel('Time');
ylabel('Magnitude');
figure;
plot(range_of_frequency,fftshift_of_x,'-*');
title(' Spectrum of Magnitude of Input Signal');
xlabel('Frequency(Hz)')
ylabel('Magnitude')
gtext('Ziya Tuna Bölükbaşı')
peak_values_of_x=mypeakfinder(x_input,5,fs);
function y=mypeakfinder(x,P,Fs)
fft_of_x=fft(x)
fftshift_of_x=fftshift(abs(fft_of_x));
length_fftx=length(fftshift_of_x);
range_of_frequency=-Fs/2:Fs/length_fftx:Fs/2-Fs/length_fftx;
sort_fftx=sortrows(fftshift_of_x,-1);
for k=2:2:2*P
    y(k/2)=sort_fftx(k)
    for i=1:length(fftshift_of_x)
        if fftshift_of_x(i)==y(k/2)
            sort_fftx1(k)=i;
        end
    end
    y(k/2)=range_of_frequency(sort_fftx1(k));
end
end
```



Top 5 peak values frequencies(Hz):

381.1500	762.3000	378.0000	384.3000	774.9000

3)The first peak value is 381.15 Hz.

wp=end of the passband

ws= beginning of stopband

wp ve ws values are found by looking at the ratio of the frequency value.Nyquist frequency value is accepted as 1 and frequency value we want is proportioned accordingly.

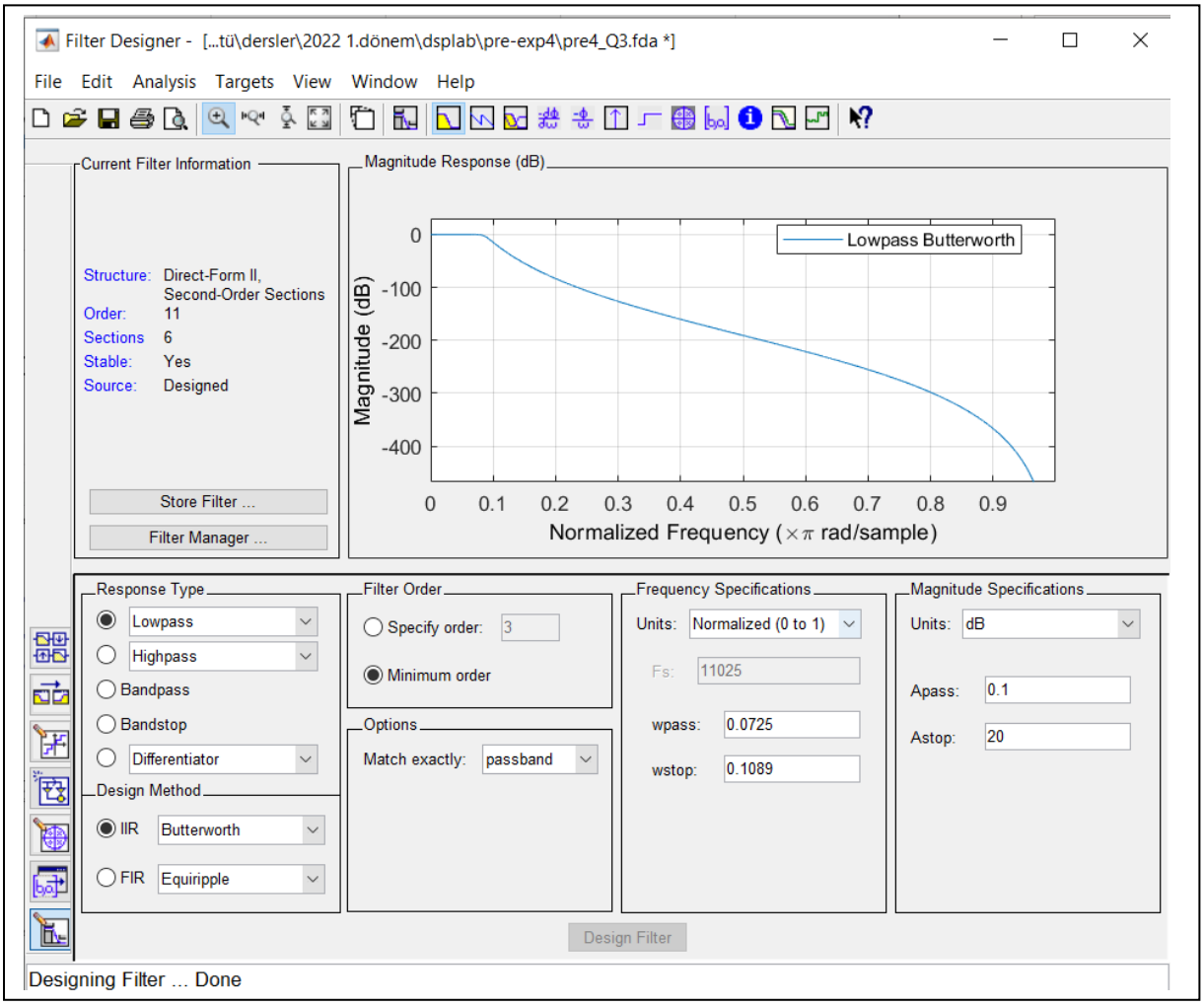
So, sample frequency is 11025 Hz and Nyquist frequency is 5512.5.

Frequency I want for wp is 400Hz.So wp is 0.0725.Frequency I want for ws is 600 Hz.So ws is 0.1089

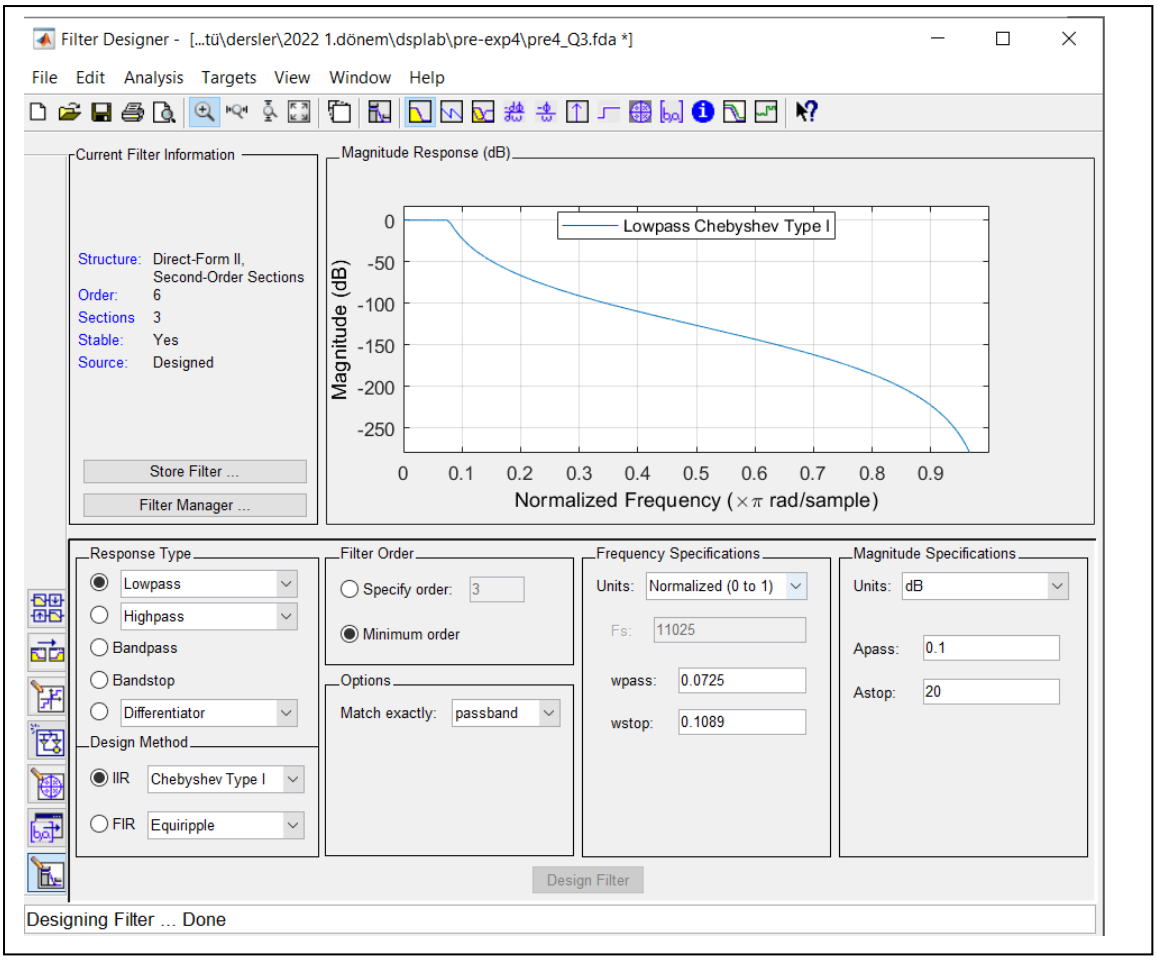
wp=0.0725 ws=0.1089 Rp=0.1 Rs=20

4)

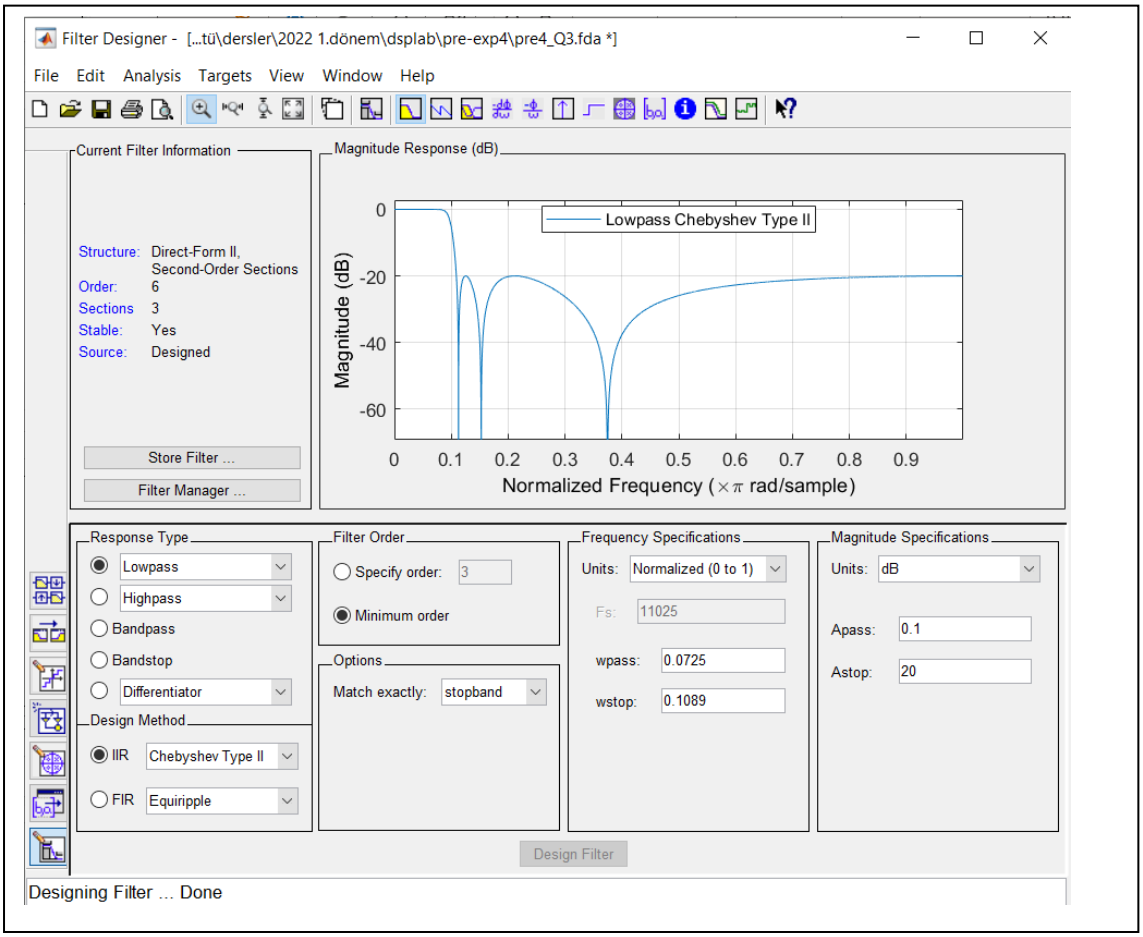
Butterworth Filter Low Pass:



Chebyshev Type 1 Low Pass Filter:



Chebyshev Type 2 Filter Low Pass:



5)

Matlab Code

```
clc;
clear all;
close all;
[x_input,fs]=audioread('C:\Users\Tuna\OneDrive - hacettepe.edu.tr\Masaüstü\dersler\2022
1.dönem\dsplab\pre-exp4\sound4.wav');
F=400;
Fs=11025;
[y,x]=butter(11,F/(Fs/2));
filtered_xinput=filter(y,x,x_input);
length_x=length(x_input);
time=[1:length_x]/fs;
figure;
plot(time,x_input);
title('Original Input Signal');
xlabel('Time(sec)');
ylabel('Magnitude');
figure;
subplot(2,1,1)
plot(time,filtered_xinput);
fft_of_fx=fft(filtered_xinput)
fftshift_of_fx=fftshift(abs(fft_of_fx));
length_fftfx=length(fftshift_of_fx);
length_x=length(x_input);
range_of_frequency=-fs/2:fs/length_fftfx:fs/2-fs/length_fftfx;
title('Filtered of Input Signal by Butterworth Filter');
xlabel('Time(sec)');
ylabel('Magnitude');
subplot(2,1,2)
stem(range_of_frequency,fftshift_of_fx,'-*');
title('Magnitude Response of Filtered Signal by Butterworth Filter');
xlabel('Frequency(Hz)');
ylabel('Magnitude');
gtext('Ziya Tuna Bölükbaşı');
figure;
subplot(2,1,1)
F=400;
Fs=11025;
[y,x]=cheby1(6,0.1,F/(Fs/2));
filtered_xinput=filter(y,x,x_input);
plot(time,filtered_xinput);
title('Filtered of Input Signal by Chebyshev Type-I Filter');
xlabel('Time(sec)');
ylabel('Magnitude');
fft_of_fx=fft(filtered_xinput)
fftshift_of_fx=fftshift(abs(fft_of_fx));
length_fftfx=length(fftshift_of_fx);
length_x=length(x_input);
range_of_frequency=-fs/2:fs/length_fftfx:fs/2-fs/length_fftfx;
subplot(2,1,2)
plot(range_of_frequency,fftshift_of_fx,'-*');
title('Magnitude Response of Filtered Signal by Chebyshev Type-I Filter');
xlabel('Frequency(Hz)');
ylabel('Magnitude');
gtext('Ziya Tuna Bölükbaşı');
figure;
subplot(2,1,1)
F=600;
Fs=11025;
[y,x]=cheby2(6,20,F/(Fs/2));
filtered_xinput=filter(y,x,x_input);
plot(time,filtered_xinput);
fft_of_fx=fft(filtered_xinput)
fftshift_of_fx=fftshift(abs(fft_of_fx));
length_fftfx=length(fftshift_of_fx);
length_x=length(x_input);
range_of_frequency=-fs/2:fs/length_fftfx:fs/2-fs/length_fftfx;
title('Filtered of Input Signal by Chebyshev Type-II Filter');
xlabel('Time(sec)');
ylabel('Magnitude');
subplot(2,1,2)
plot(range_of_frequency,fftshift_of_fx,'-*');
title('Magnitude Response of Filtered Signal by Chebyshev Type-II Filter');
xlabel('Frequency(Hz)');
ylabel('Magnitude');
gtext('Ziya Tuna Bölükbaşı');
```

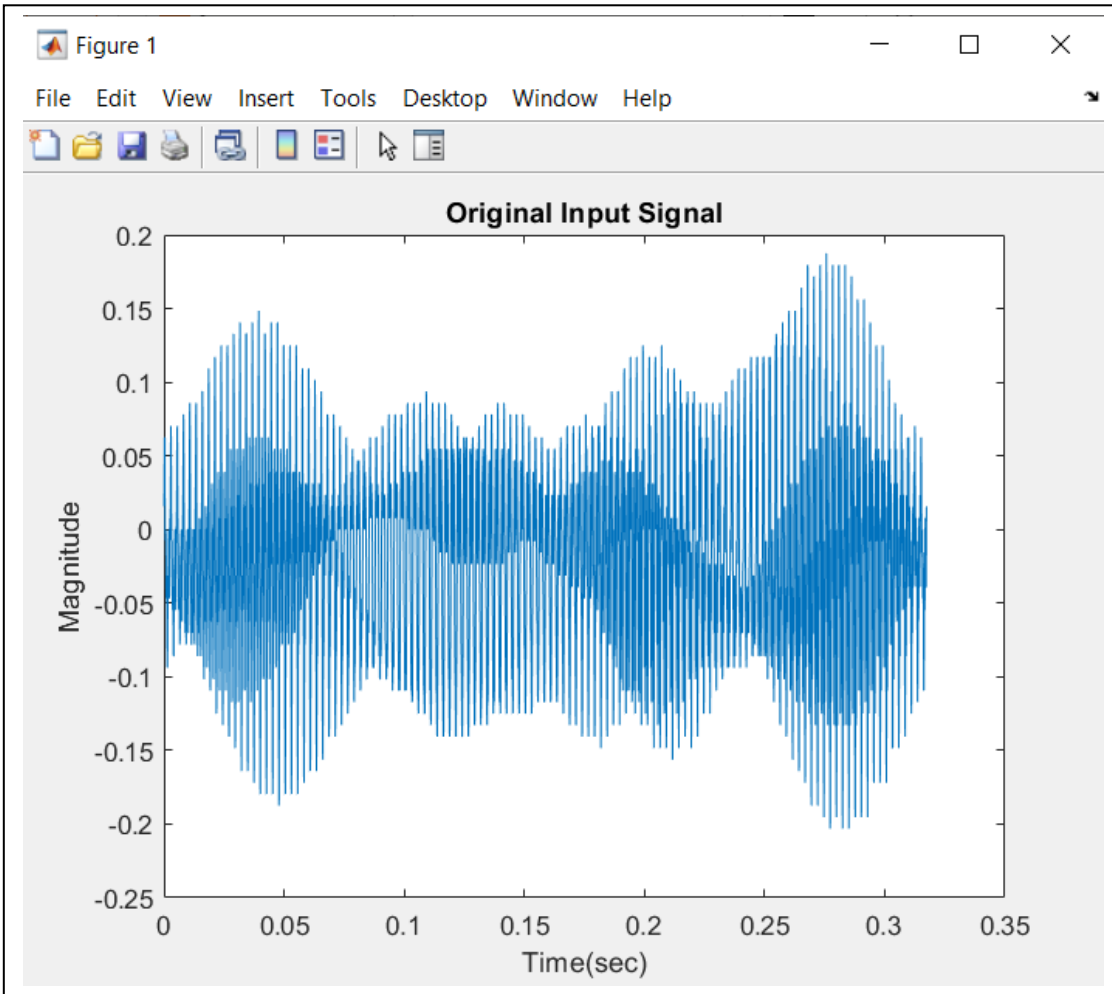


Figure 1
File Edit View Insert Tools Desktop Window Help
Original Input Signal
Magnitude
Time(sec)
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

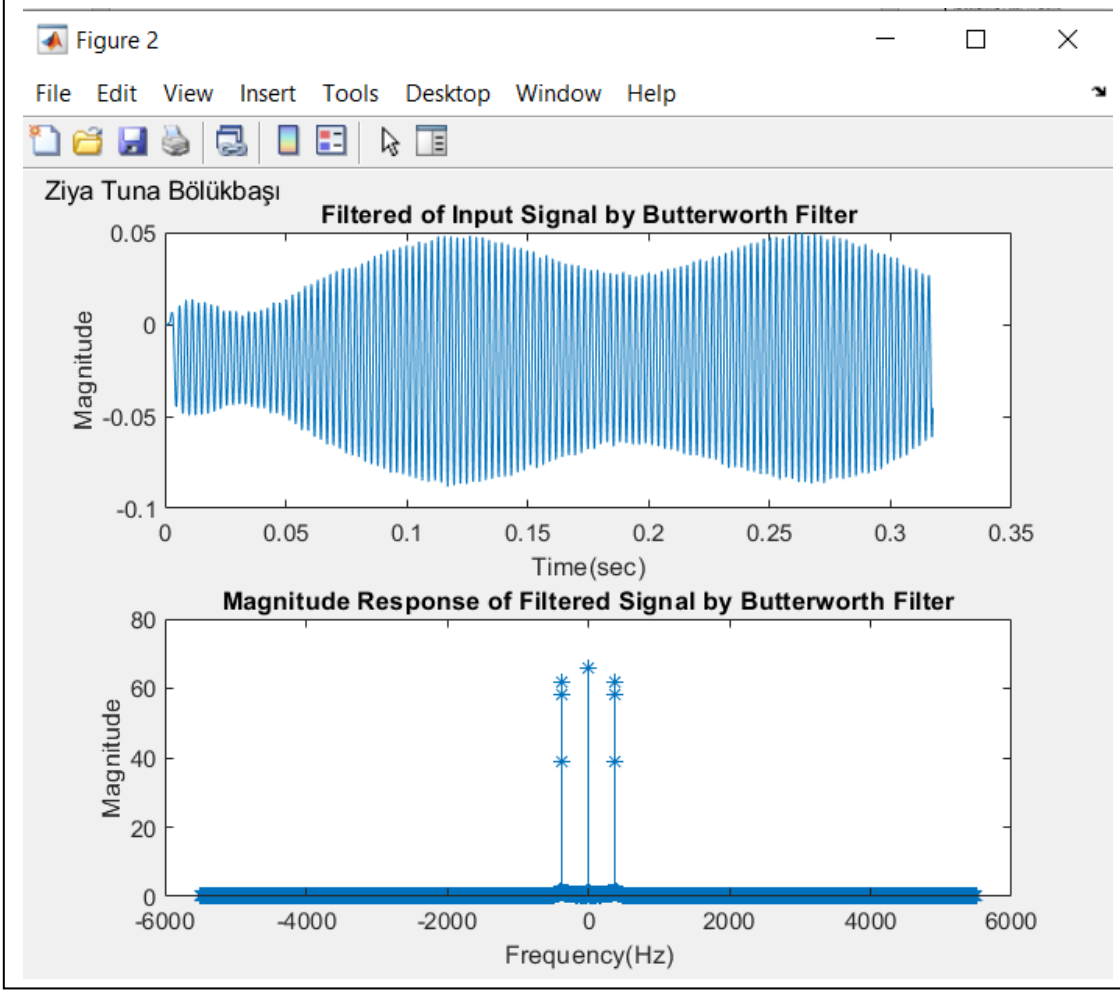


Figure 2
File Edit View Insert Tools Desktop Window Help
Ziya Tuna Bölükbaşı
Filtered of Input Signal by Butterworth Filter
Magnitude
Time(sec)
0.05
0
-0.05
-0.1
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Magnitude Response of Filtered Signal by Butterworth Filter
Magnitude
Frequency(Hz)
80
60
40
20
0
-6000
-4000
-2000
0
2000
4000
6000

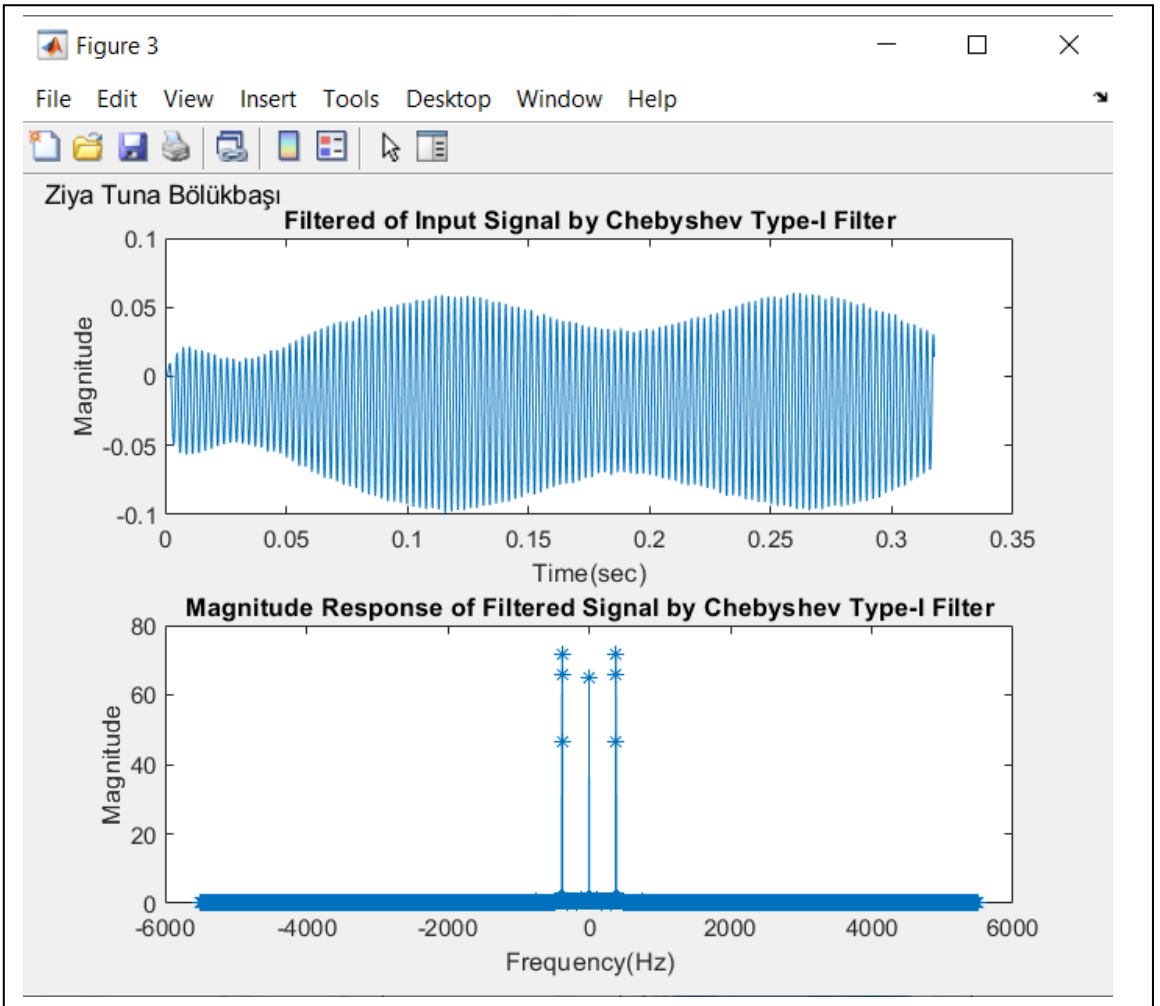


Figure 3
File Edit View Insert Tools Desktop Window Help
Ziya Tuna Bölükbaşı
Filtered of Input Signal by Chebyshev Type-I Filter
Magnitude
Time(sec)
Magnitude Response of Filtered Signal by Chebyshev Type-I Filter
Magnitude
Frequency(Hz)

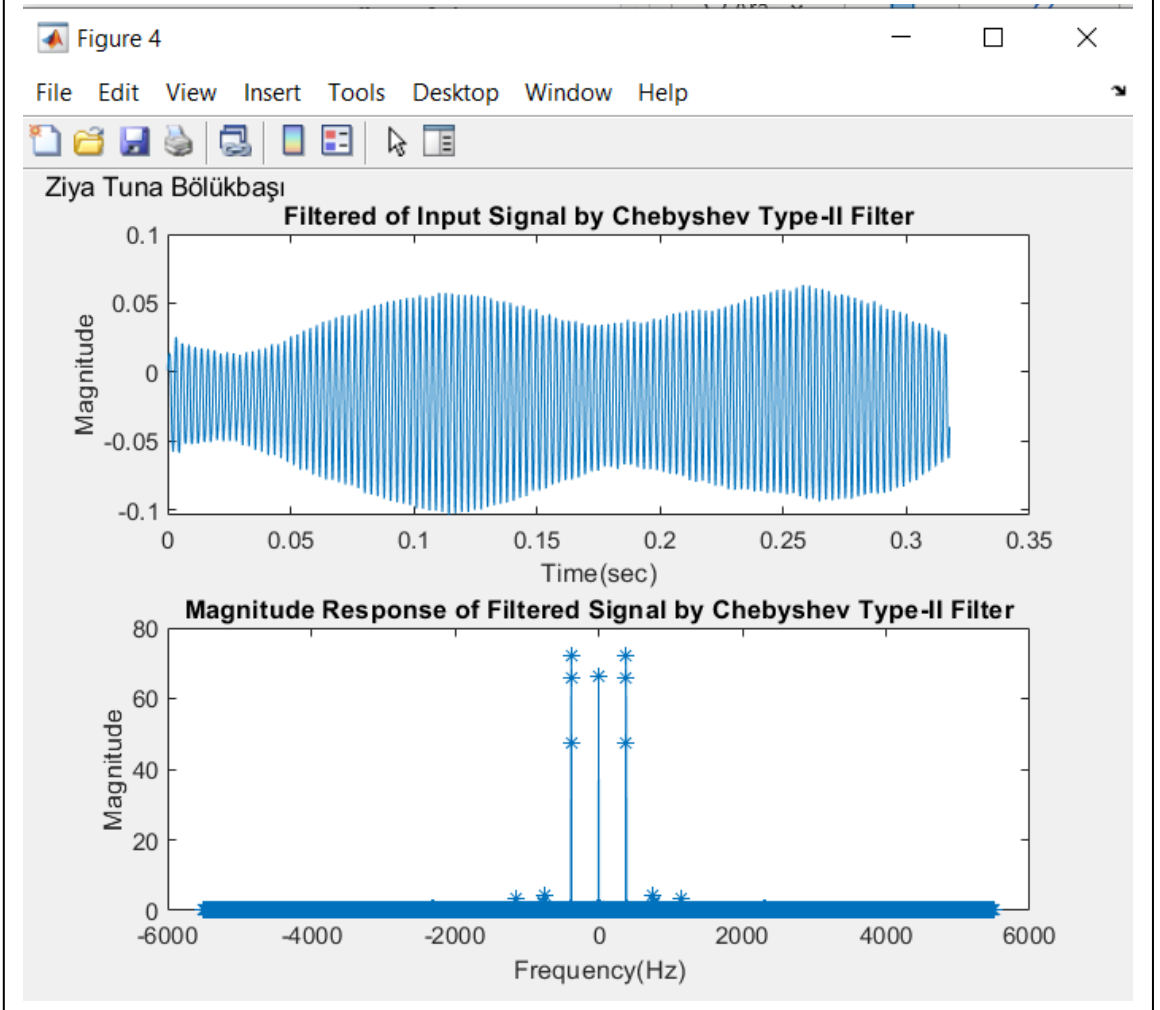


Figure 4
File Edit View Insert Tools Desktop Window Help
Ziya Tuna Bölükbaşı
Filtered of Input Signal by Chebyshev Type-II Filter
Magnitude
Time(sec)
Magnitude Response of Filtered Signal by Chebyshev Type-II Filter
Magnitude
Frequency(Hz)

When we use the Butterworth and Chebyshev type-1 filter, we get a signal much closer to the desired output. However, in the Chebyshev type-2 filter, the attenuation is lower and fluctuations occur in the regions close to the cut-off frequency.

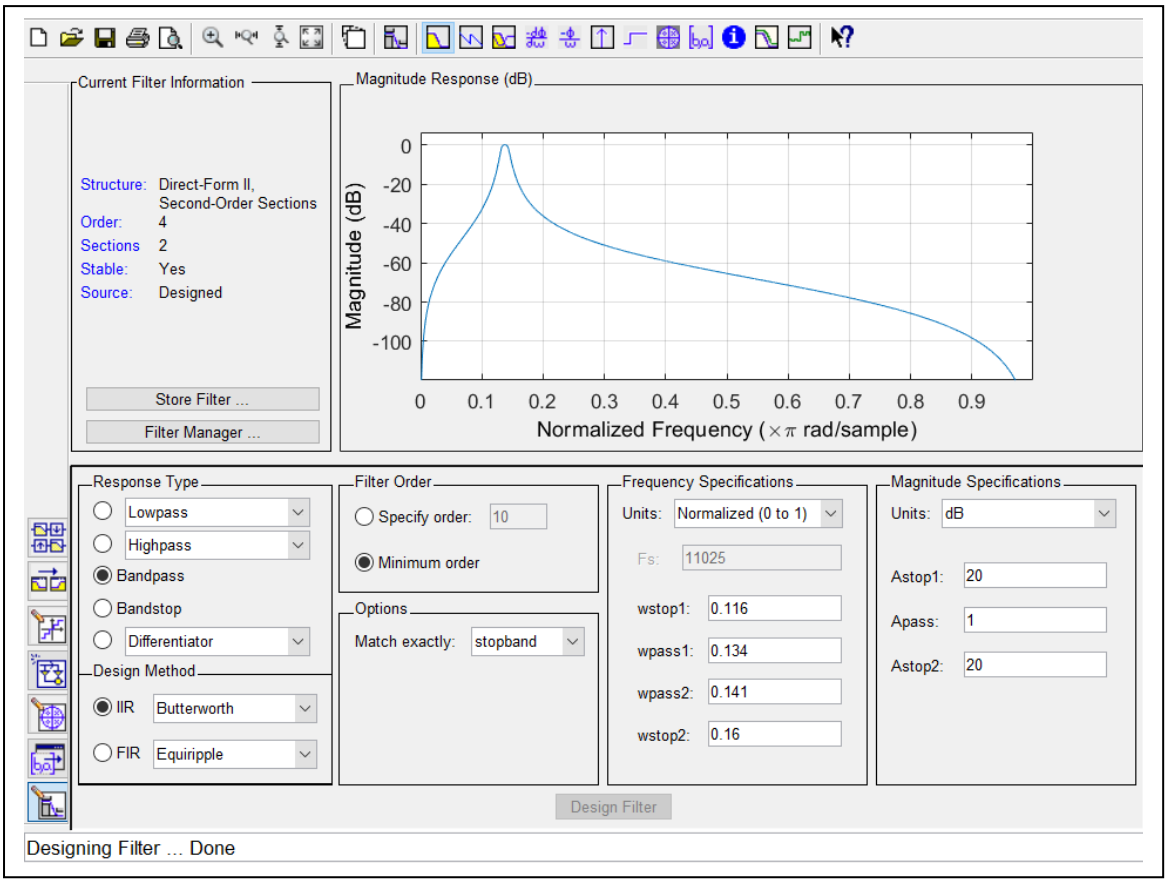
6)The second dominant peak value is 762.3 Hz

Rp=0.1 Rs1=20 Rs2=20

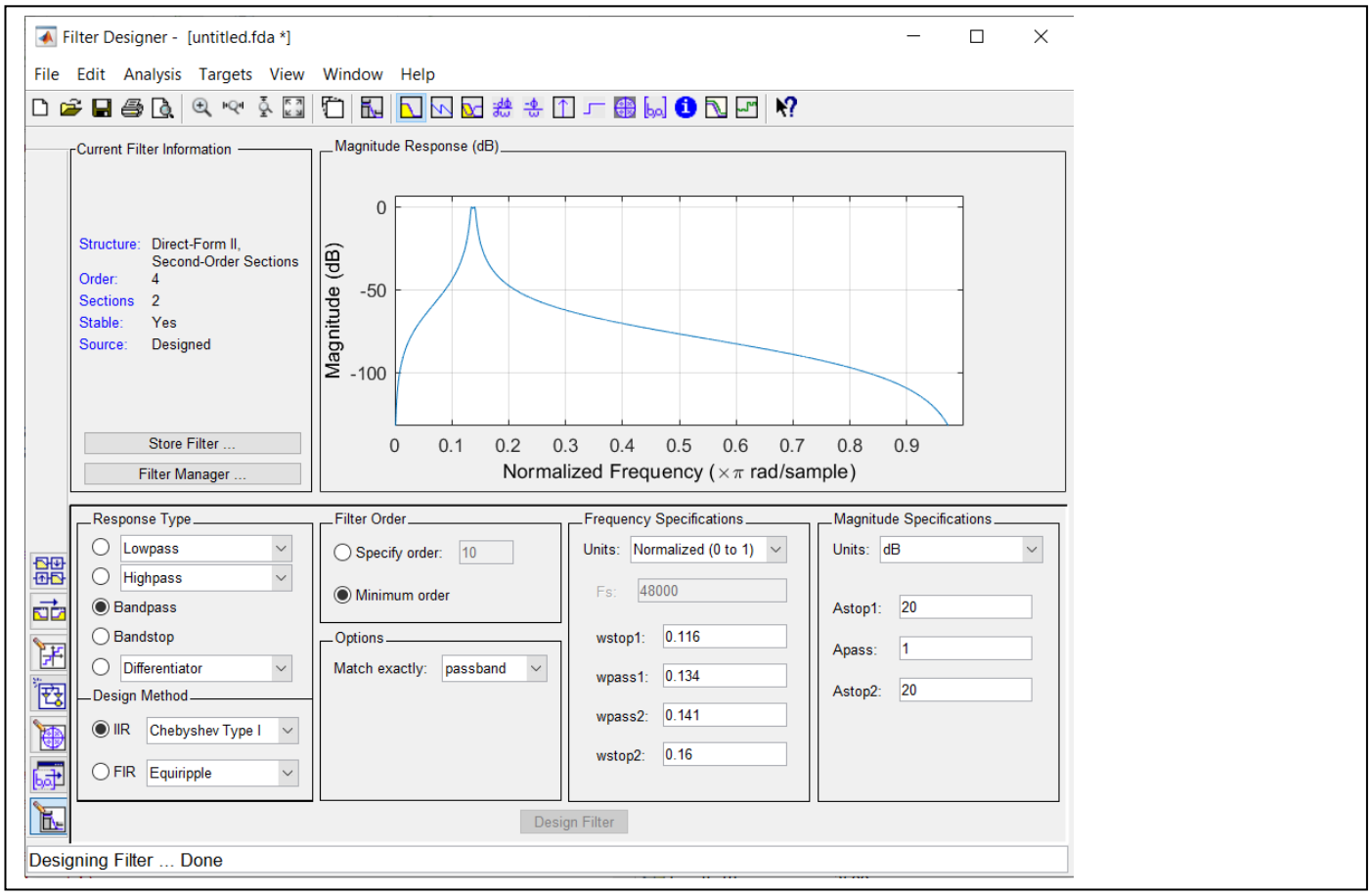
wstop1=0.116 wpass1=0.134 wpass2=0.141 wstop2=0.16

7)

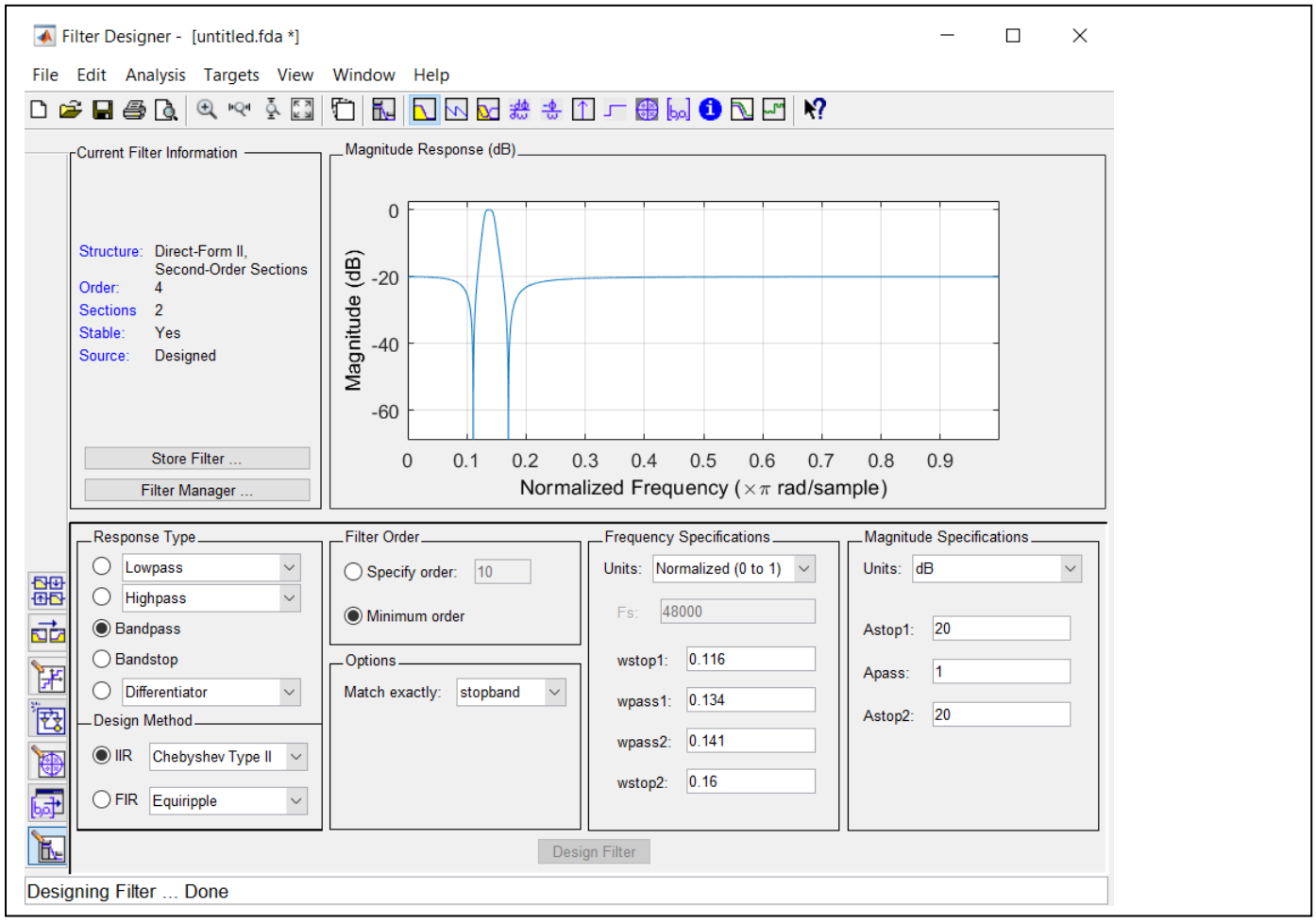
Butterworth Band Pass Filter



Chebyshev Type 1 Band Pass Filter:



Chebyshev Type 2 Band Pass Filter:



8)Matlab Code

```
clc;
clear all;
close all;
[x_input,fs]=audioread('C:\Users\Tuna\OneDrive - hacettepe.edu.tr\Masaüstü\dersler\2022 1.dönem\dsplab\pre-exp4\sound4.wav');
Fs=11025;
figure;
length_x=length(x_input);
time=[1:length_x]/fs;
plot(time,x_input);
title('Original Input Signal');
xlabel('Time(sec)');
ylabel('Magnitude');
%butter
[y,x]=butter(4,[740,780]/(Fs/2),'bandpass');%(order,fc/fs/2,'bandpass')
filtered_xinput=filter(y,x,x_input);
figure;
subplot(2,1,1)
plot(time,filtered_xinput);
fft_of_fx=fft(filtered_xinput)
fftshift_of_fx=fftshift(abs(fft_of_fx));
length_fftfx=length(fftshift_of_fx);
length_x=length(x_input);
range_of_frequency=-fs/2:fs/length_fftfx:fs/2-fs/length_fftfx;
title('Filtered of Input Signal by Butterworth Filter');
xlabel('Time(sec)');
ylabel('Magnitude');
subplot(2,1,2)
stem(range_of_frequency,fftshift_of_fx,'-*');
title('Magnitude Response of Filtered Signal by Butterworth Filter');
xlabel('Frequency(Hz)');
ylabel('Magnitude');
gtext('Ziya Tuna Bölükbaşı');
%chebs1
[y,x]=cheby1(4,0.1,[740,780]/(Fs/2));%(order,ripple-Apass,Fc/fs/2)
filtered_xinput=filter(y,x,x_input);
length_x=length(x_input);
time=[1:length_x]/fs;
figure;
subplot(2,1,1)
plot(time,filtered_xinput);
fft_of_fx=fft(filtered_xinput)
fftshift_of_fx=fftshift(abs(fft_of_fx));
length_fftfx=length(fftshift_of_fx);
length_x=length(x_input);
range_of_frequency=-fs/2:fs/length_fftfx:fs/2-fs/length_fftfx;
title('Filtered of Input Signal by Chebyshev-I Filter');
xlabel('Time(sec)');
ylabel('Magnitude');
subplot(2,1,2)
stem(range_of_frequency,fftshift_of_fx,'-*');
title('Magnitude Response of Filtered Signal by Chebyshev-I Filter');
xlabel('Frequency(Hz)');
ylabel('Magnitude');
gtext('Ziya Tuna Bölükbaşı');
%chebs2
[y,x]=cheby2(4,20,[740,780]/(Fs/2)); %(order,Astop,Fc/fs/2)
filtered_xinput=filter(y,x,x_input);
length_x=length(x_input);
time=[1:length_x]/fs;
figure;
subplot(2,1,1)
plot(time,filtered_xinput);
fft_of_fx=fft(filtered_xinput)
fftshift_of_fx=fftshift(abs(fft_of_fx));
length_fftfx=length(fftshift_of_fx);
length_x=length(x_input);
range_of_frequency=-fs/2:fs/length_fftfx:fs/2-fs/length_fftfx;
title('Filtered of Input Signal by Chebyshev-II Filter');
xlabel('Time(sec)');
ylabel('Magnitude');
subplot(2,1,2)
stem(range_of_frequency,fftshift_of_fx,'-*');
title('Magnitude Response of Filtered Signal by Chebyshev-II Filter');
xlabel('Frequency(Hz)');
ylabel('Magnitude');
gtext('Ziya Tuna Bölükbaşı');
```

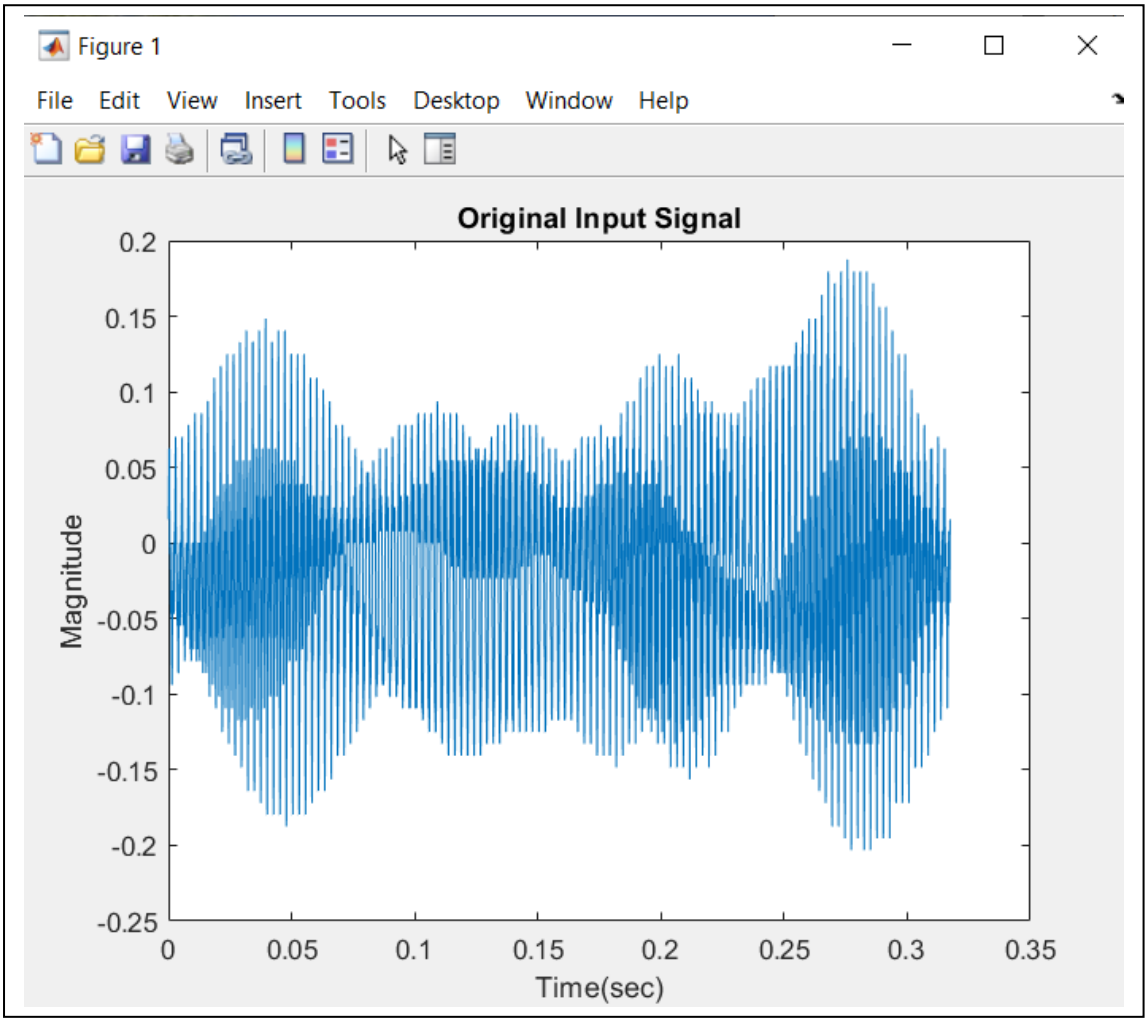


Figure 1
File Edit View Insert Tools Desktop Window Help
Original Input Signal
Magnitude
Time(sec)
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35

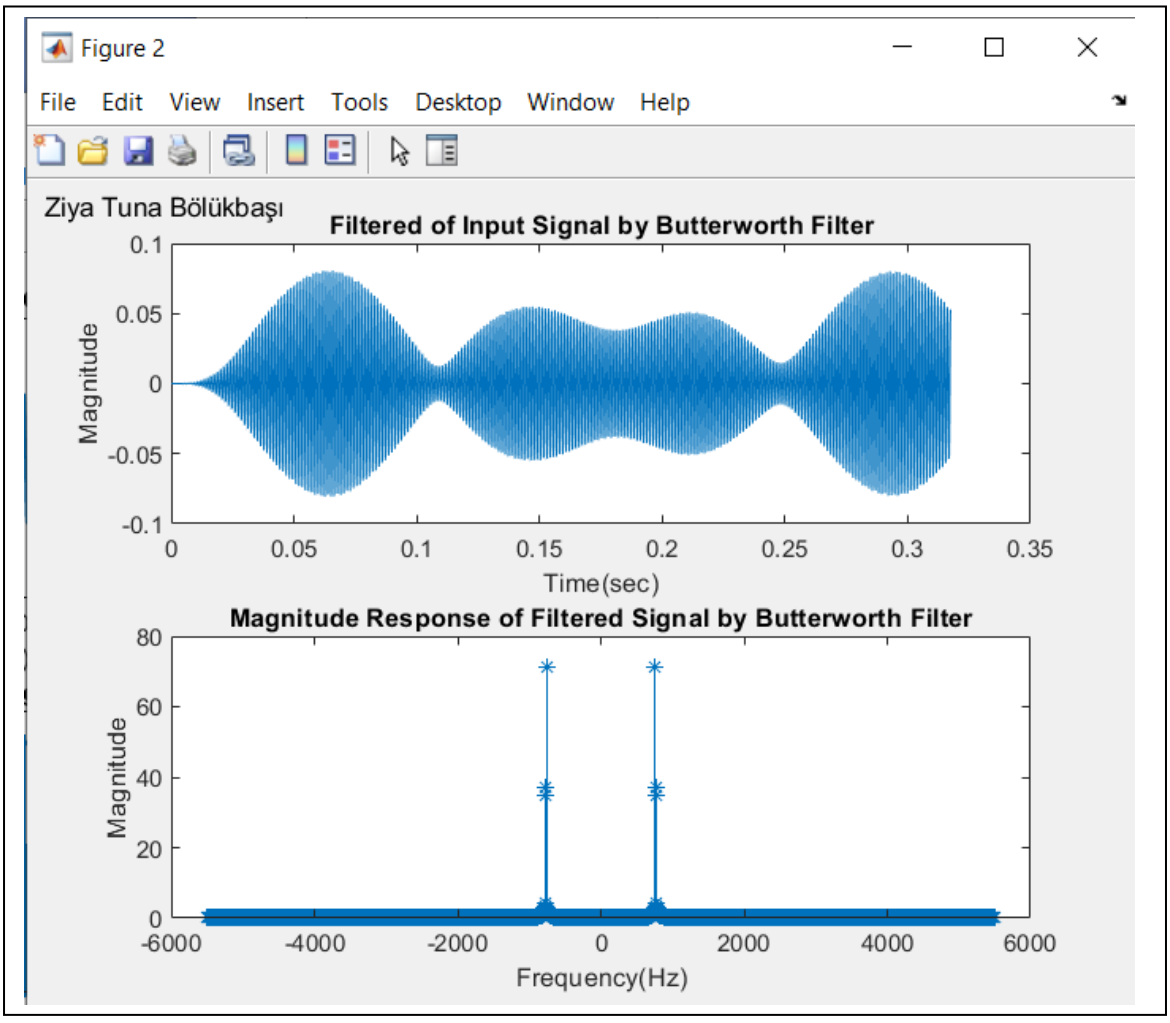


Figure 2
File Edit View Insert Tools Desktop Window Help
Ziya Tuna Bölükbaşı
Filtered of Input Signal by Butterworth Filter
Magnitude
Time(sec)
0.1
0.05
0
-0.05
-0.1
0 0.05 0.1 0.15 0.2 0.25 0.3 0.35
Magnitude Response of Filtered Signal by Butterworth Filter
Magnitude
Frequency(Hz)
80
60
40
20
0
-6000 -4000 -2000 0 2000 4000 6000

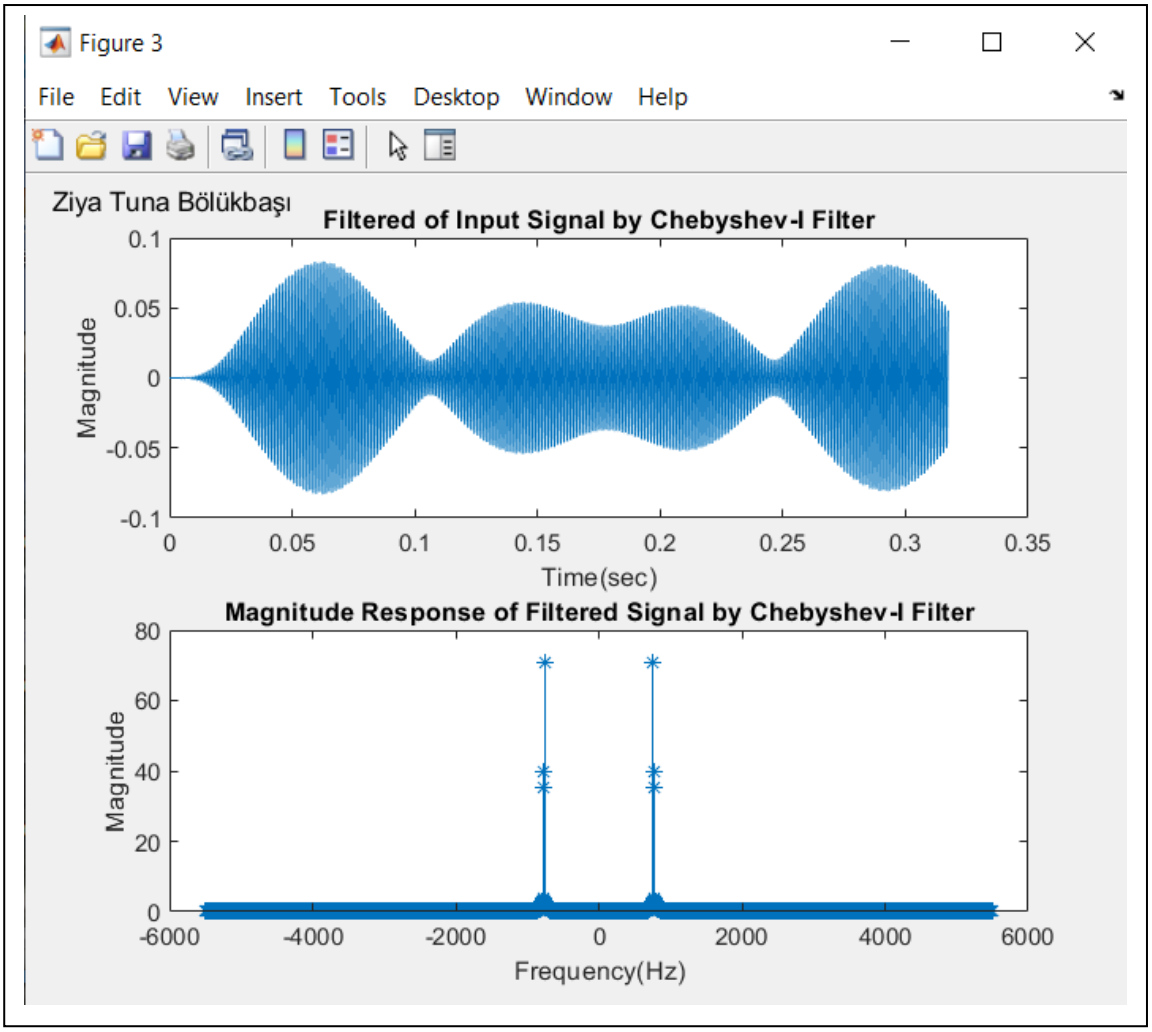


Figure 3
File Edit View Insert Tools Desktop Window Help
Ziya Tuna Bölükbaşı
Filtered of Input Signal by Chebyshev-I Filter
Magnitude
Time(sec)
Magnitude Response of Filtered Signal by Chebyshev-I Filter
Magnitude
Frequency(Hz)

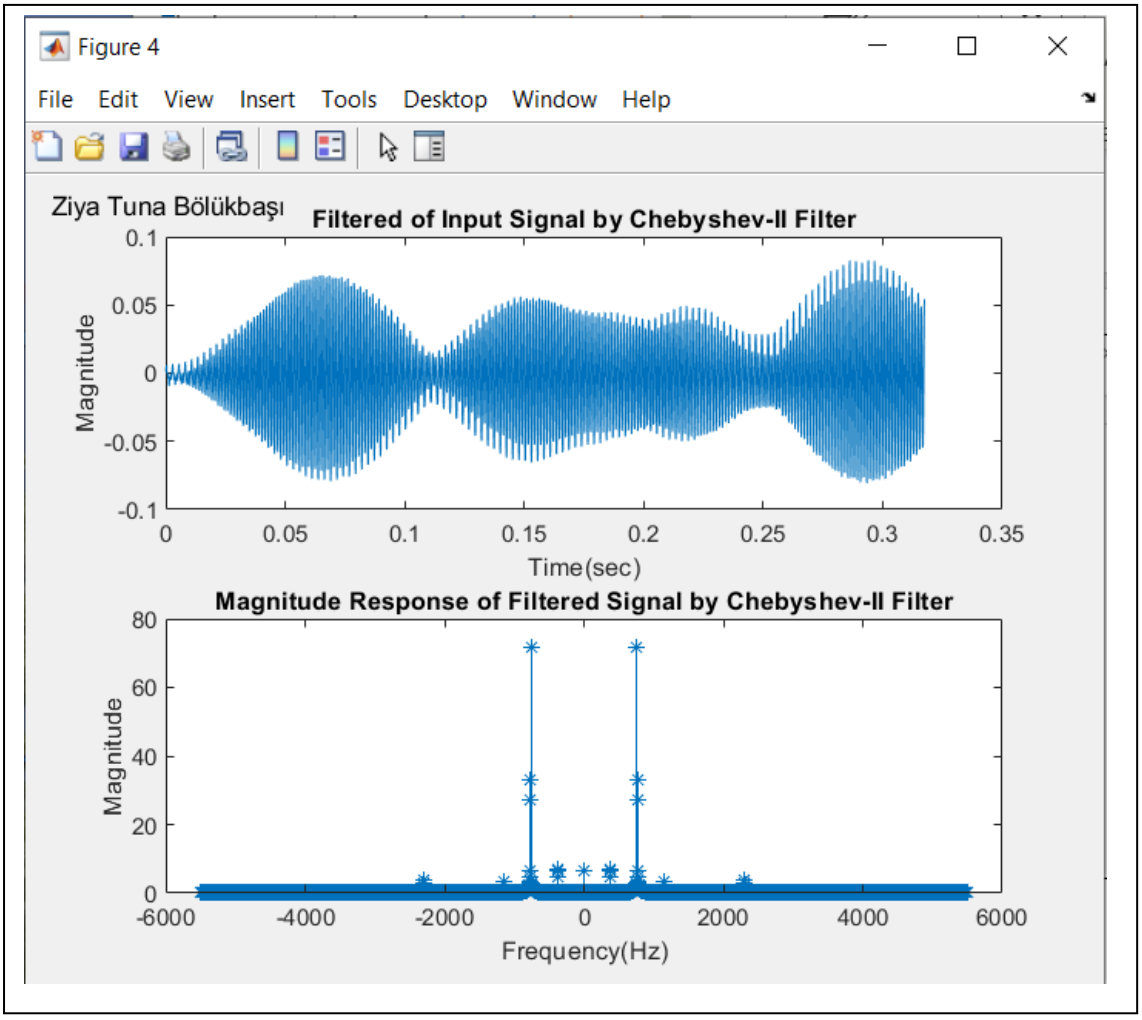


Figure 4
File Edit View Insert Tools Desktop Window Help
Ziya Tuna Bölükbaşı
Filtered of Input Signal by Chebyshev-II Filter
Magnitude
Time(sec)
Magnitude Response of Filtered Signal by Chebyshev-II Filter
Magnitude
Frequency(Hz)

Frequency of the output signal is 762.3 Hz. Butterworth Bandpass and Chebyshev-I Bandpass outputs are almost same.But Chebyshev-II Bandpass output has some ripples.

9) I can say that chebyshev-I filter does not provide meaningful filtering compared to other filters, butterworth filter provides meaningful filtering in all cases and chebyshev-II filter is more suitable for bandpass filter. I think chebyshev-II filter is the best filter.

10)Matlab Code

```
clc;
clear all;
close all;
[x_input,fs]=audioread('C:\Users\Tuna\OneDrive - hacettepe.edu.tr\Masaüstü\dersler\2022 1.dönem\dsplab\pre-
exp4\bana.wav');
Fs=11025;
%x_input
sound(x_input)
length_x=length(x_input);
time=[1:length_x]/fs;
figure;
plot(time,x_input);
title('Original x input Signal');
xlabel('Time(sec)');
ylabel('Magnitude');
fft_of_x=fft(x_input)
fftshift_of_x=fftshift(abs(fft_of_x));
length_fftx=length(fftshift_of_x);
range_of_frequency=-fs/2:fs/length_fftx:fs/2-fs/length_fftx;
figure;
plot(range_of_frequency,fftshift_of_x,'-*');
title(' Spectrum of Magnitude of Input Signal');
xlabel('Frequency(Hz)')
ylabel('Magnitude')
gtext('Ziya Tuna Bölükbaşı')
%butterworth
Fc=2000
[y,x]=butter(11,Fc/(Fs/2));
filtered_xinput=filter(y,x,x_input);
figure;
subplot(2,1,1)
plot(time,filtered_xinput);
fft_of_fx=fft(filtered_xinput)
fftshift_of_fx=fftshift(abs(fft_of_fx));
length_fftfx=length(fftshift_of_fx);
range_of_frequency=-fs/2:fs/length_fftfx:fs/2-fs/length_fftfx;
title('Filtered of Input Signal by Butterworth Filter');
xlabel('Time(sec)');
ylabel('Magnitude');
subplot(2,1,2)
stem(range_of_frequency,fftshift_of_fx,'-*');
title('Magnitude Response of Filtered Signal by Butterworth Filter');
xlabel('Frequency(Hz)');
ylabel('Magnitude');
gtext('Ziya Tuna Bölükbaşı');
sound(filtered_xinput)
%chebyshev-I
figure;
subplot(2,1,1)
Fc=2000;
Fs=11025;
[y,x]=cheby1(6,0.1,Fc/(Fs/2));
filtered_xinput=filter(y,x,x_input);
plot(time,filtered_xinput);
title('Filtered of Input Signal by Chebyshev Type-I Filter');
xlabel('Time(sec)');
ylabel('Magnitude');
fft_of_fx=fft(filtered_xinput)
fftshift_of_fx=fftshift(abs(fft_of_fx));
length_fftfx=length(fftshift_of_fx);
range_of_frequency=-fs/2:fs/length_fftfx:fs/2-fs/length_fftfx;
subplot(2,1,2)
plot(range_of_frequency,fftshift_of_fx,'-*');
title('Magnitude Response of Filtered Signal by Chebyshev Type-I Filter');
xlabel('Frequency(Hz)');
ylabel('Magnitude');
gtext('Ziya Tuna Bölükbaşı');
sound(filtered_xinput)
%chebyshev-II
figure;
subplot(2,1,1)
Fc=2000;
Fs=11025;
[y,x]=cheby2(6,20,Fc/(Fs/2));
filtered_xinput=filter(y,x,x_input);
plot(time,filtered_xinput);
fft_of_fx=fft(filtered_xinput)
fftshift_of_fx=fftshift(abs(fft_of_fx));
length_fftfx=length(fftshift_of_fx);
range_of_frequency=-fs/2:fs/length_fftfx:fs/2-fs/length_fftfx;
title('Filtered of Input Signal by Chebyshev Type-II Filter');
xlabel('Time(sec)');
ylabel('Magnitude');
subplot(2,1,2)
plot(range_of_frequency,fftshift_of_fx,'-*');
title('Magnitude Response of Filtered Signal by Chebyshev Type-II Filter');
xlabel('Frequency(Hz)');
ylabel('Magnitude');
gtext('Ziya Tuna Bölükbaşı');
sound(filtered_xinput)
```

I filtered the original signal with three of this filter . I listened both the original signal and other filtered signals.As for me the more understandable and the cleanest signal I listened between three signals is the signal filtered by Chebyshev-II Filter.