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DSP Project 2

```
clear all; close all; clc
load('projIB.mat')
```

Filters

```
Ny = fs/2;
Wp = 2500/Ny;
Ws = 4000/Ny;
Rp = 40-37;
Rs = 55+40;
Rpl = 10^(-Rp/20);
Rsl = 10^(-Rs/20);

[N,Wn] = buttord(Wp, Ws, Rp, Rs);
[B,A] = butter(N,Wn);
[z,p,k] = butter(N,Wn);
[s,g] = zp2sos(z,p,k);
[H,W] = freqz(s);
hb1 = dfilt.df1(B,A);
hb2 = dfilt.df2(B,A);
hb3 = dfilt.df2sos(s,g);
hb4 = dfilt.df2tsos(s,g);

[N1,Wp1] = ellipord(Wp, Ws, Rp, Rs);
[B1,A1] = ellip(3*N1,Rp,Rs,Wp1);
[z1,p1,k1] = ellip(3*N1,Rp,Rs,Wp1);
[s1,g1] = zp2sos(z1,p1,k1);
[H1,W1] = freqz(s1);
he1 = dfilt.df1(B1,A1);
he2 = dfilt.df2(B1,A1);
he3 = dfilt.df2sos(s1,g1);
he4 = dfilt.df2tsos(s1,g1);

[N2,Wp2] = cheb1ord(Wp,Ws,Rp,Rs);
[B2,A2] = cheby1(N2,Rp,Wp2);
[H2,W2] = freqz(B2,A2);
[N3,Ws1] = cheb2ord(Wp,Ws,Rp,Rs);
[B3,A3] = cheby2(N3,Rs,Ws1);
```

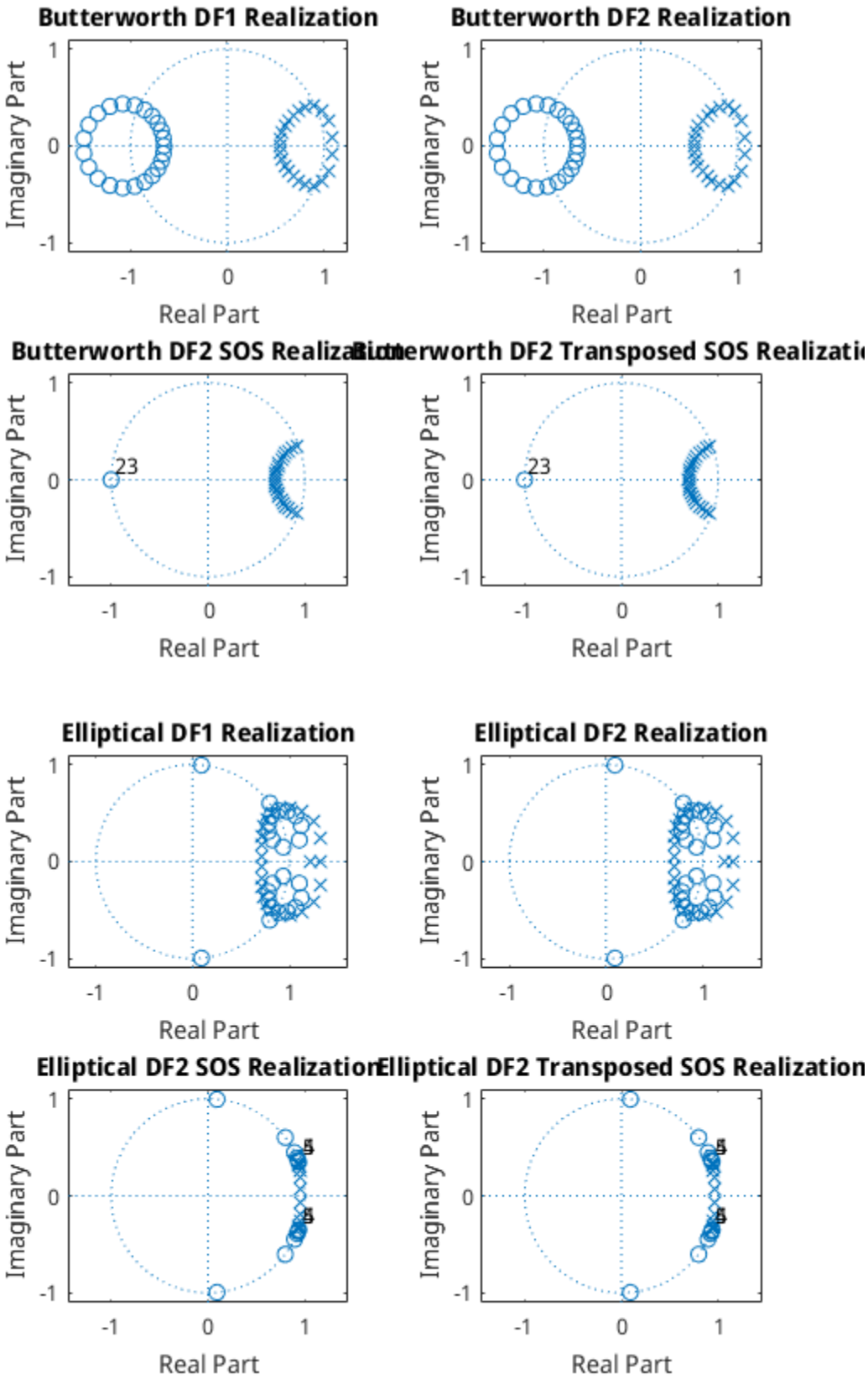
```
[H3,W3] = freqz(B3,A3);
[N4,fo,mo,w] = firpmord([Wp*Ny Ws*Ny],[1 0],[Rpl Rsl],fs);
B4 = firpm(N4,fo,mo,w);
[H4,W4] = freqz(B4,1);
[N5,Wn2,bta,filtype] = kaiserord([Wp*Ny Ws*Ny],[1 0],[Rpl Rsl],fs);
B5 = fir1(N5, Wn2, filtype, kaiser(N5+1,bta), 'noscale');
[H5,W5] = freqz(B5,1);
```

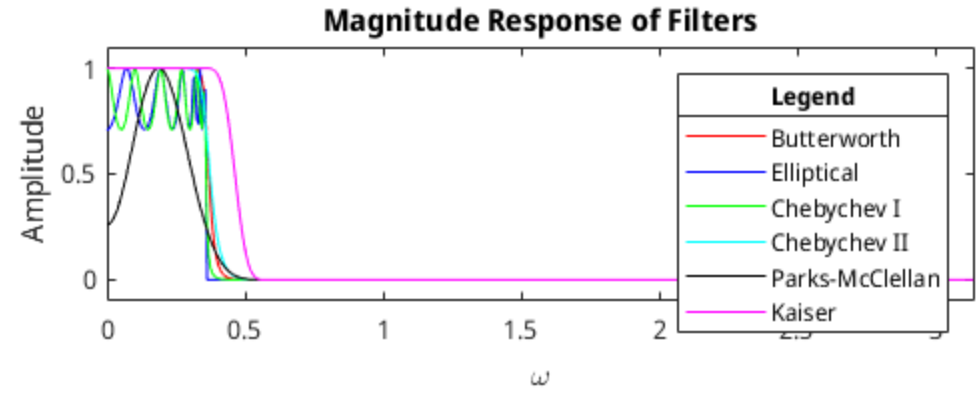
Plots

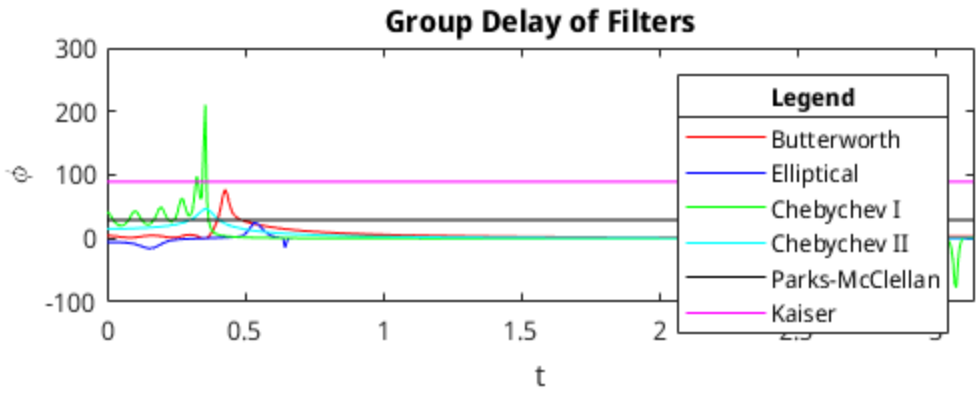
```
figure
subplot(2,2,1)
zplane(hb1.Numerator,hb1.Denominator)
title('Butterworth DF1 Realization')
subplot(2,2,2)
zplane(hb2.Numerator,hb2.Denominator)
title('Butterworth DF2 Realization')
subplot(2,2,3)
[zz,pp] = hb3.zpk;
zplane(zz,pp)
title('Butterworth DF2 SOS Realization')
subplot(2,2,4)
[zz1,pp1] = hb4.zpk;
zplane(zz1,pp1)
title('Butterworth DF2 Transposed SOS Realization')

figure
subplot(2,2,1)
zplane(he1.Numerator,he1.Denominator)
title('Elliptical DF1 Realization')
subplot(2,2,2)
zplane(he2.Numerator,he2.Denominator)
title('Elliptical DF2 Realization')
subplot(2,2,3)
[zz2,pp2] = he3.zpk;
zplane(zz2,pp2)
title('Elliptical DF2 SOS Realization')
subplot(2,2,4)
[zz3,pp3] = he4.zpk;
zplane(zz3,pp3)
title('Elliptical DF2 Transposed SOS Realization')

figure
subplot(2,1,1)
plot(W,abs(H/max(H)),'r')
hold on
plot(W1,abs(H1/max(H1)),'b')
hold on
plot(W2,abs(H2/max(H2)),'g')
hold on
plot(W3,abs(H3/max(H3)),'c')
hold on
plot(W4,abs(H4/max(H4)),'k')
```

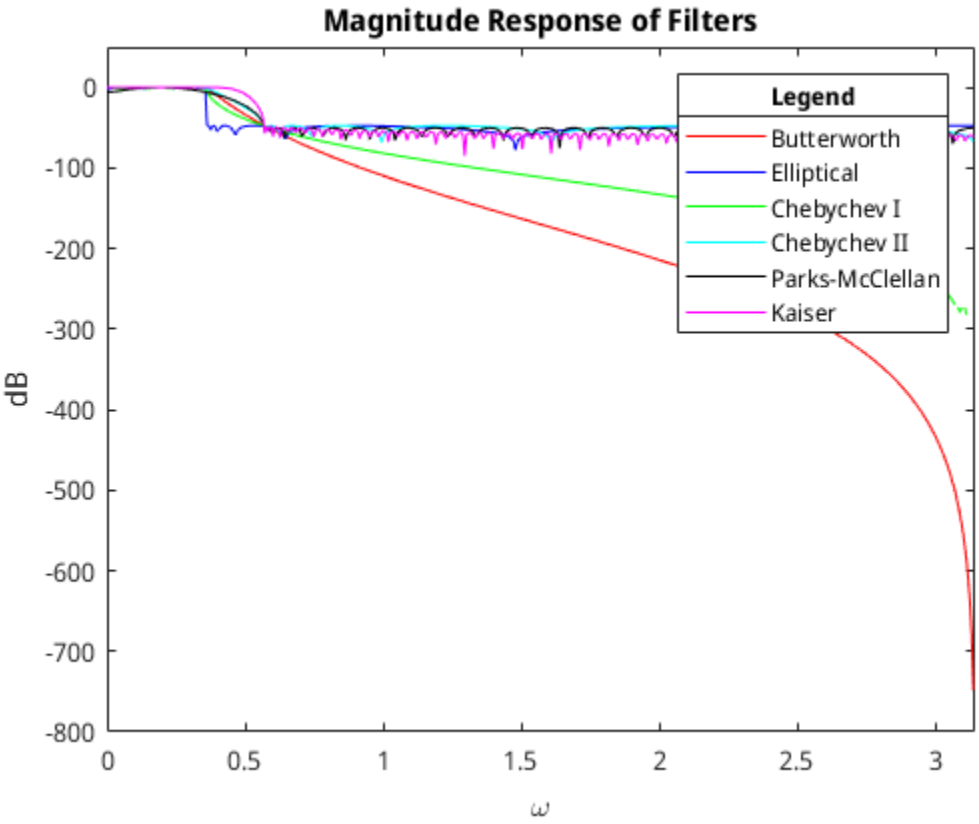
```
hold on
plot(W5,abs(H5/max(H5)),'m')
axis([0 pi -0.1 1.1])
title('Magnitude Response of Filters')
xlabel('\omega')
ylabel('Amplitude')
lgd = legend('Butterworth','Elliptical','Chebychev I','Chebychev
 II','Parks-McClellan','Kaiser');
title(lgd,'Legend')
subplot(2,1,2)
plot(W,grpdelay(B,A,length(W)),'r')
hold on
plot(W1,grpdelay(B1,A1,length(W1)),'b')
hold on
plot(W2,grpdelay(B2,A2,length(W2)),'g')
hold on
plot(W3,grpdelay(B3,A3,length(W3)),'c')
hold on
plot(W4,grpdelay(B4,1,length(W4)),'k')
hold on
plot(W5,grpdelay(B5,1,length(W5)),'m')
axis([0 pi ylim])
title('Group Delay of Filters')
xlabel('t')
ylabel('\phi')
lgd = legend('Butterworth','Elliptical','Chebychev I','Chebychev
 II','Parks-McClellan','Kaiser');
title(lgd,'Legend')

figure
plot(W,10*log10(abs(H/max(H))),'r')
hold on
plot(W1,10*log10(abs(H1/max(H1))),'b')
hold on
plot(W2,10*log10(abs(H2/max(H2))),'g')
hold on
plot(W3,10*log10(abs(H3/max(H3))),'c')
hold on
plot(W4,10*log10(abs(H4/max(H4))),'k')
hold on
plot(W5,10*log10(abs(H5/max(H5))),'m')
axis([0 pi -800 50])
title('Magnitude Response of Filters')
xlabel('\omega')
ylabel('dB')
lgd = legend('Butterworth','Elliptical','Chebychev I','Chebychev
 II','Parks-McClellan','Kaiser');
title(lgd,'Legend')

figure
subplot(2,1,1)
stem(filter(hb4,[1 zeros(1,99)]),'r')
title('Impulse Response for Butterworth Filter')
xlabel('Sample')
```

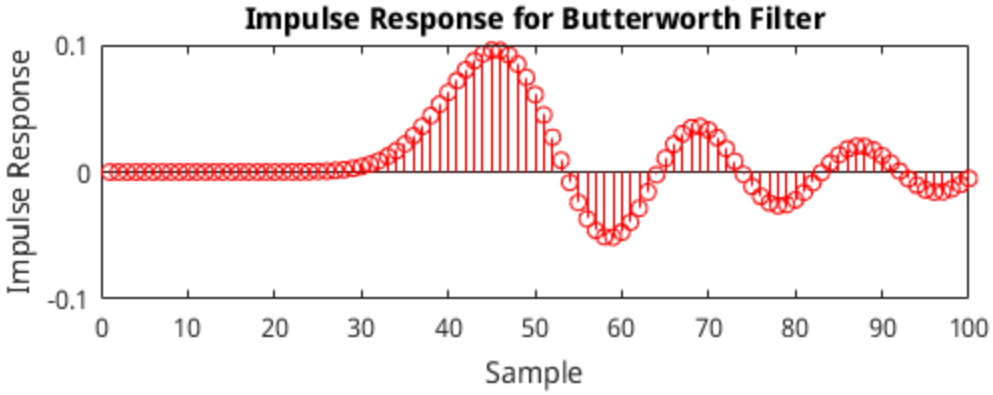
```
ylabel('Impulse Response')
subplot(2,1,2)
zplane(z,p)
title('Pole-Zero Plot for Butterworth Filter')

figure
subplot(2,1,1)
stem(filter(he4,[1 zeros(1,99)]),'b')
title('Impulse Response for Elliptical Filter')
xlabel('Sample')
ylabel('Impulse Response')
subplot(2,1,2)
zplane(z1,p1)
title('Pole-Zero Plot for Elliptical Filter')

figure
subplot(2,1,1)
stem(filter(B2,A2,[1 zeros(1,99)]),'g')
title('Impulse Response for Chebychev I Filter')
xlabel('Sample')
ylabel('Impulse Response')
subplot(2,1,2)
zplane(B2,A2)
title('Pole-Zero Plot for Chebychev I Filter')

figure
subplot(2,1,1)
stem(filter(B3,A3,[1 zeros(1,99)]),'c')
title('Impulse Response for Chebychev II Filter')
xlabel('Sample')
ylabel('Impulse Response')
subplot(2,1,2)
zplane(B3,A3)
title('Pole-Zero Plot for Chebychev II Filter')

figure
subplot(2,1,1)
stem(filter(B4,1,[1 zeros(1,99)]),'k')
title('Impulse Response for Parks-McClellan Filter')
xlabel('Sample')
ylabel('Impulse Response')
subplot(2,1,2)
zplane(B4)
title('Pole-Zero Plot for Parks-McClellan Filter')

figure
subplot(2,1,1)
stem(filter(B5,1,[1 zeros(1,99)]),'m')
title('Impulse Response for Kaiser Filter')
xlabel('Sample')
ylabel('Impulse Response')
subplot(2,1,2)
zplane(B5)
title('Pole-Zero Plot for Kaiser Filter')
```

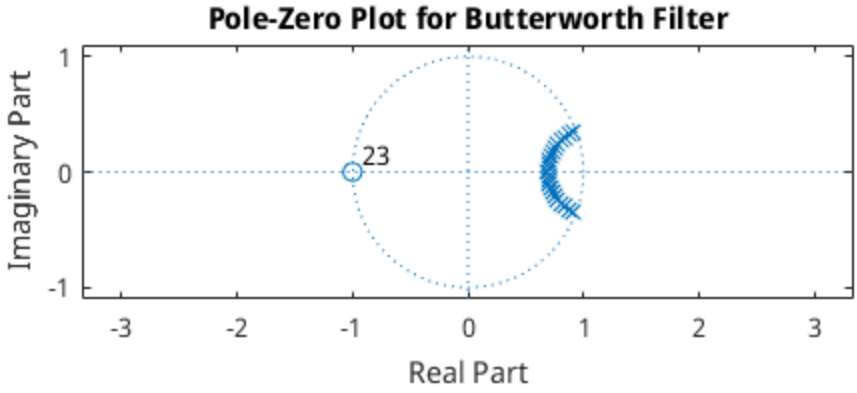

Butterworth DF1 Realization
Butterworth DF2 Realization
Butterworth DF2 SOS Realization
Butterworth DF2 Transposed SOS Realizati
Elliptical DF1 Realization
Elliptical DF2 Realization
Elliptical DF2 SOS Realization
Elliptical DF2 Transposed SOS Realization
Imaginary Part
Real Part
1
0
-1
23
5

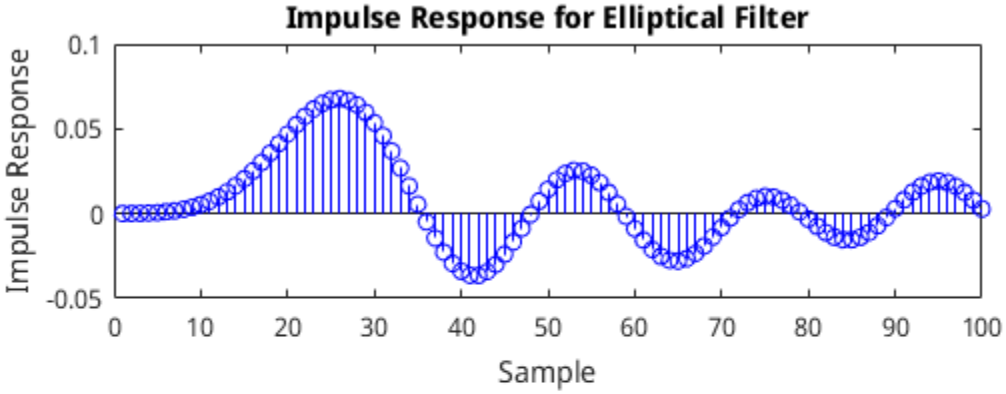

Magnitude Response of Filters
Amplitude
ω
Legend
Butterworth
Elliptical
Chebychev I
Chebychev II
Parks-McClellan
Kaiser

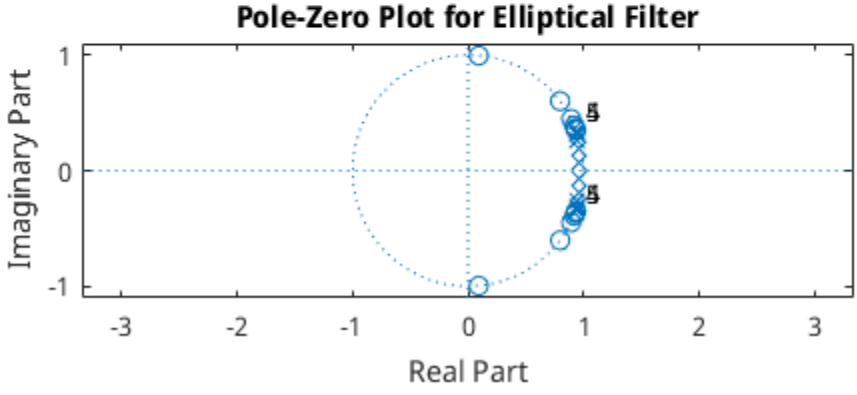

Group Delay of Filters
Φ
t
Legend
Butterworth
Elliptical
Chebychev I
Chebychev II
Parks-McClellan
Kaiser

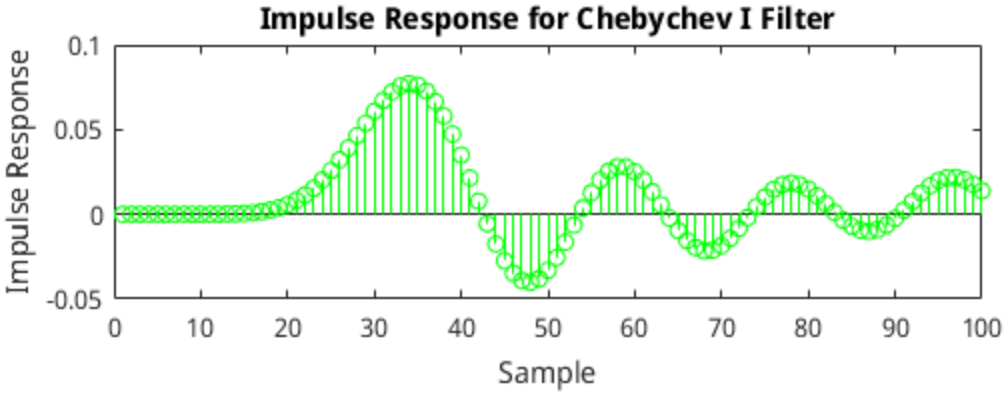

Magnitude Response of Filters
dB
ω
Legend
Butterworth
Elliptical
Chebychev I
Chebychev II
Parks-McClellan
Kaiser

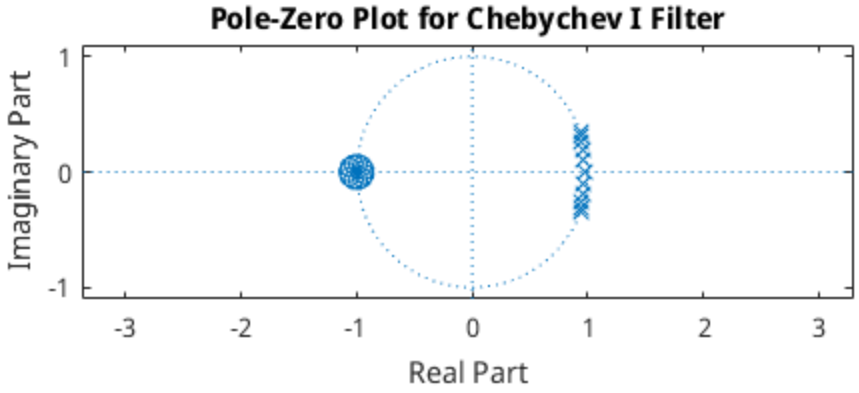

Impulse Response for Butterworth Filter
Impulse Response
0.1
0
-0.1
0
10
20
30
40
50
60
70
80
90
100
Sample

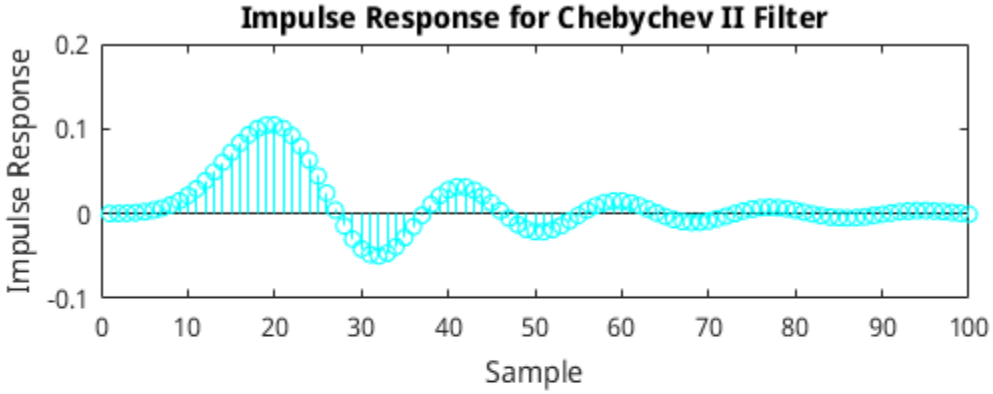

Pole-Zero Plot for Butterworth Filter
Imaginary Part
1
0
-1
23
-3
-2
-1
0
1
2
3
Real Part

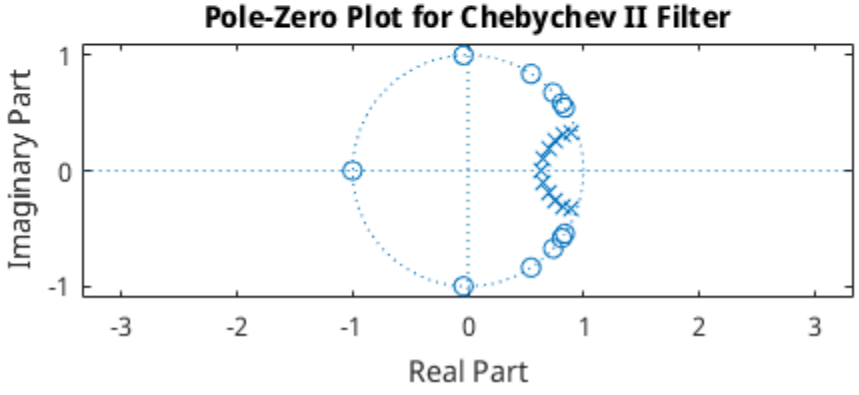

Impulse Response for Elliptical Filter
Impulse Response
0.1
0.05
0
-0.05
0
10
20
30
40
50
60
70
80
90
100
Sample

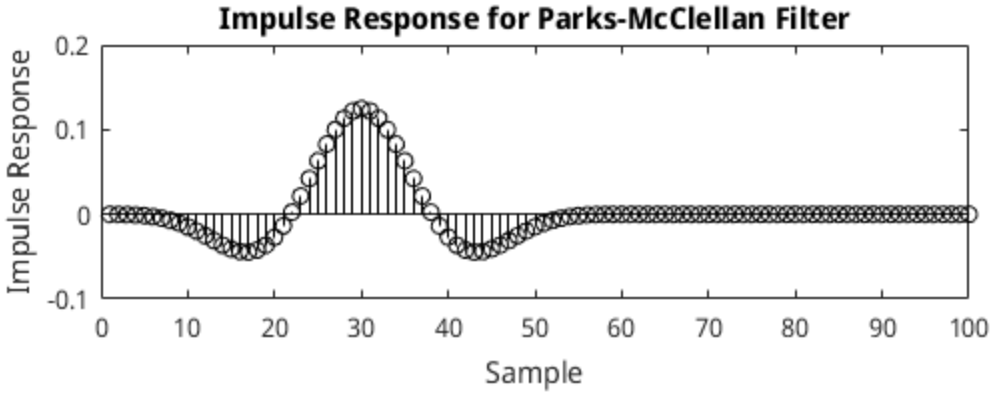

Pole-Zero Plot for Elliptical Filter
Imaginary Part
1
0
-1
5
5
-3
-2
-1
0
1
2
3
Real Part

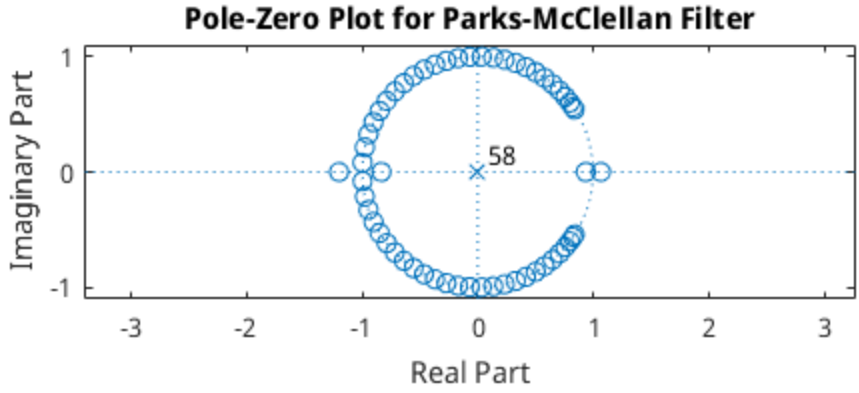

Impulse Response for Chebychev I Filter
Impulse Response
Sample
0.1
0.05
0
-0.05
0
10
20
30
40
50
60
70
80
90
100

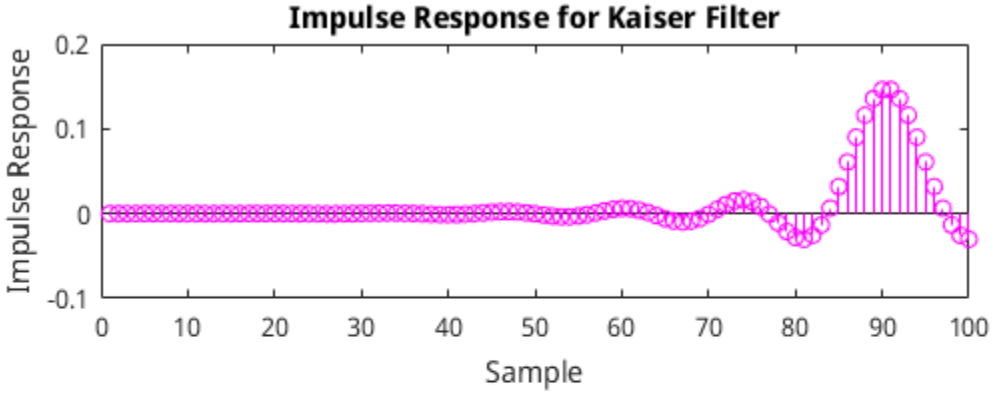

Pole-Zero Plot for Chebychev I Filter
Imaginary Part
Real Part
1
0
-1
-3
-2
-1
0
1
2
3

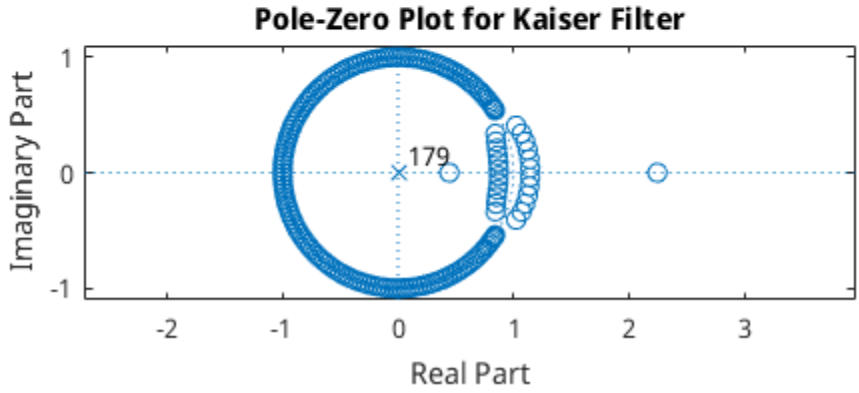

Impulse Response for Chebychev II Filter
Impulse Response
Sample
0.2
0.1
0
-0.1
0
10
20
30
40
50
60
70
80
90
100


Pole-Zero Plot for Chebychev II Filter
Imaginary Part
Real Part
1
0
-1
-3
-2
-1
0
1
2
3


Impulse Response for Parks-McClellan Filter
Impulse Response
Sample


Pole-Zero Plot for Parks-McClellan Filter
Imaginary Part
Real Part
58


Impulse Response for Kaiser Filter
Impulse Response
Sample


Pole-Zero Plot for Kaiser Filter
Imaginary Part
Real Part
179

Sounds

```
% original
soundsc(noisy,fs)
waitforbuttonpress

% Butter
soundsc(filter(hb4,noisy),fs)
waitforbuttonpress

% Ellip
soundsc(filter(he4,noisy),fs)
waitforbuttonpress

% Cheby1
soundsc(filter(B2,A2,noisy),fs)
waitforbuttonpress

% Cheby2
soundsc(filter(B3,A3,noisy),fs)
waitforbuttonpress

% Parks McClellan
soundsc(filter(B4,1,noisy),fs)
waitforbuttonpress

% Kaiser
soundsc(filter(B5,1,noisy),fs)
```

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