Digital Signal Processing
MATLAB HW2 - q3

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Professor: Dr. Sheikhzadeh Author: Maryam Barazande - 9723016 E-mail: maryambarazande7@gmail.com University: Amirkabir University of Technology

Clear recent data

```
clear; close all; clc;
```

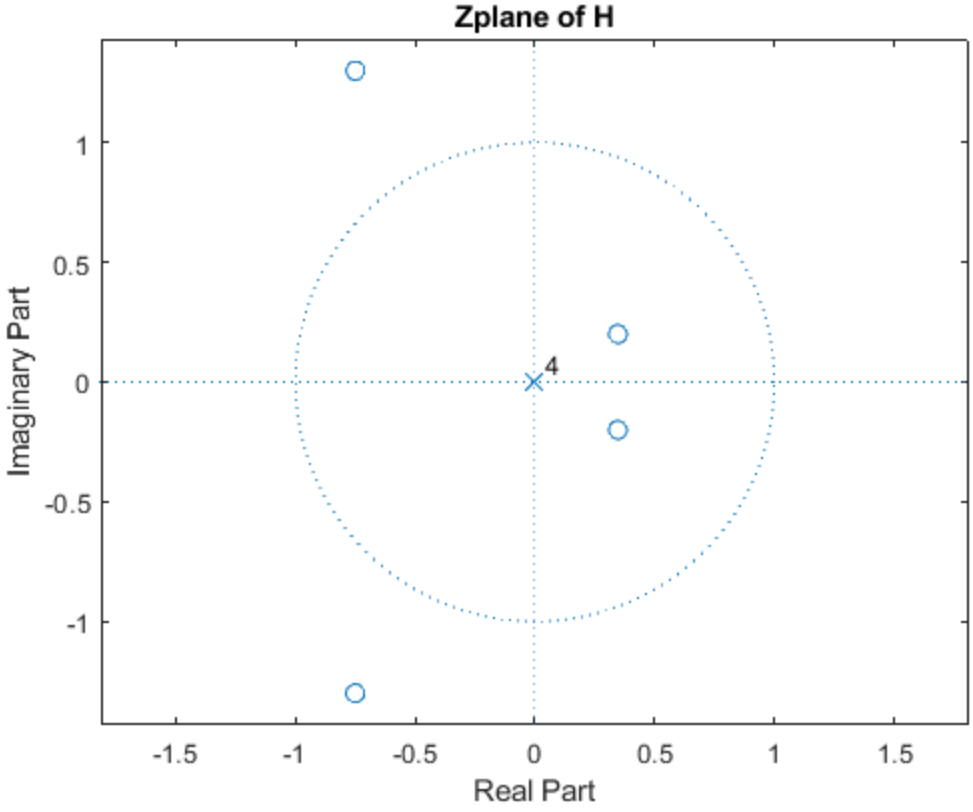
Transform Analysis of Linear Time-Invariant Systems

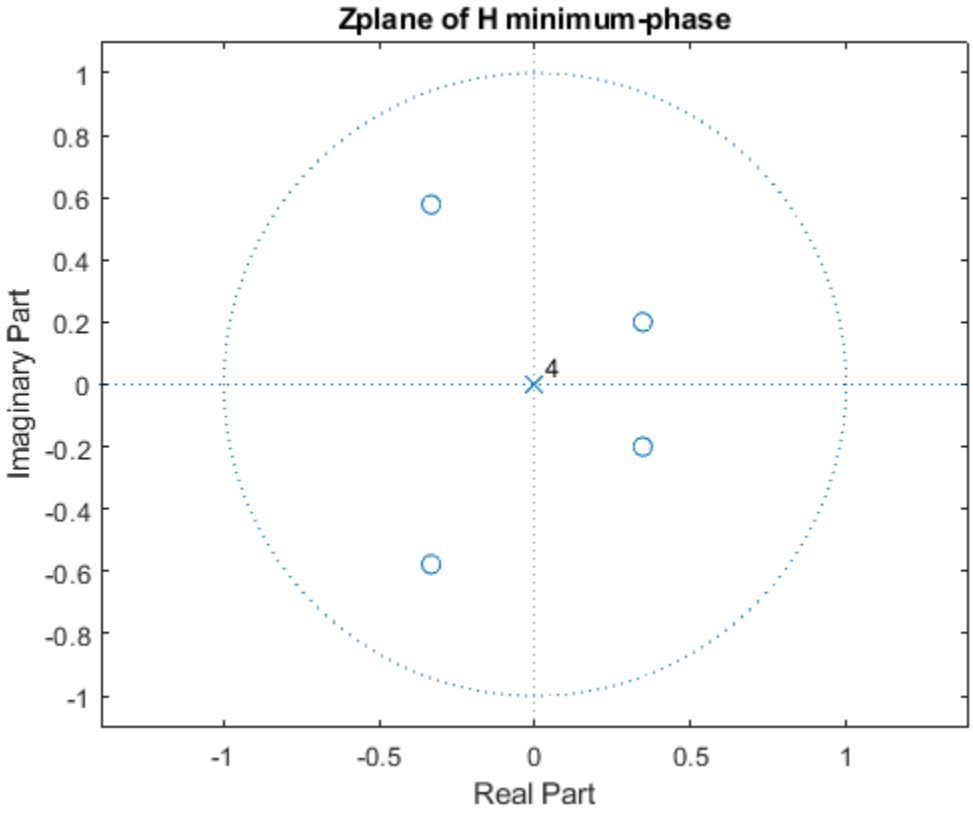
PART 1

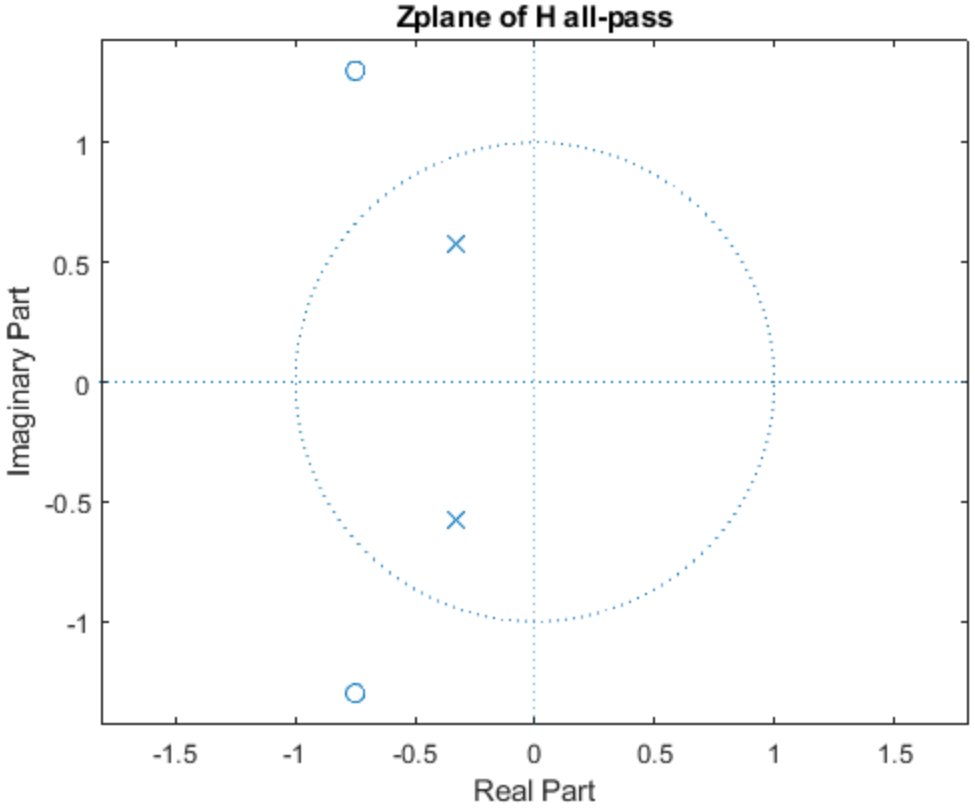
```
%%%%%%%%%%%%%%%%%%%%%%%%% a %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
z1 = conv([1, -0.4*exp(1j*pi/6)], [1, -0.4*exp(-1j*pi/6)]);
z2 = conv([1, -1.5*exp(1j*2*pi/3)], [1, -1.5*exp(-1j*2*pi/3)]);
H = conv(z1,z2);
figure(1);
zplane(H,1);
title("Zplane of H");

% Minimum Phase
z1m = conv([1, -0.4*exp(1j*pi/6)],[1, -0.4*exp(-1j*pi/6)]);
z2m = conv([1, (-2/3)*exp(1j*2*pi/3)],[1, -(2/3)*exp(-1j*2*pi/3)]);
H_MP = (1.5)^2 * conv(z1m, z2m);
figure(2)
zplane(H_MP,1);
title("Zplane of H minimum-phase");

% All Pass
z1a = conv([(-2/3)*exp(1j*2*pi/3),1],[-(2/3)*exp(-1j*2*pi/3), 1]);
p1a = z2m;
figure(3)
zplane(z1a,p1a);
title("Zplane of H all-pass");

%%%%%%%%%%%%%%%%%%%%%%%%% b %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
[h,w] = freqz(H,1);
```

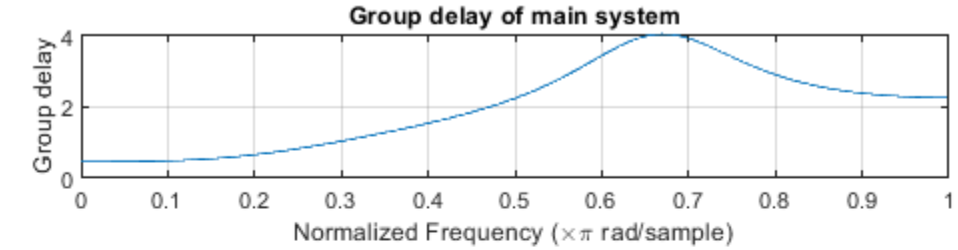
```
phaseDH = phase(h);
groupDH = grpdelay(H,1);            % group delay in main system

groupDmin = grpdelay(H_MP,1);       % group delay in minimum phase
 system
[hm,wm] = freqz(H_MP,1);
phaseDmin = phase(hm);



groupDall = grpdelay(z1a,p1a);      % group delay in all pass system
[ha,wa] = freqz(z1a,p1a);
phaseDall = phase(ha);


% Plot group delays
figure(4);
subplot(3,1,1);
plot(w/pi,groupDH);
title("Group delay of main system");
xlabel 'Normalized Frequency (\times\pi rad/sample)';
ylabel ('Group delay');
grid;
subplot(3,1,2);
plot(w/pi,groupDmin);
title("Group delay of minimum phase system");
xlabel 'Normalized Frequency (\times\pi rad/sample)';
ylabel ('Group delay');
grid;
subplot(3,1,3);
plot(w/pi,groupDall);
title("Group delay of all pass system");
xlabel 'Normalized Frequency (\times\pi rad/sample)';
ylabel ('Group delay');
grid;

% Plot phase
figure(5);
subplot(3,1,1);
plot(w/pi,phaseDH);
title("Phase of main system");
xlabel 'Normalized Frequency (\times\pi rad/sample)';
ylabel ('Phase');
grid;
subplot(3,1,2);
plot(w/pi,phaseDmin);
title("Phase of minimum phase system");
xlabel 'Normalized Frequency (\times\pi rad/sample)';
ylabel ('Phase');
grid;
subplot(3,1,3);
plot(w/pi,phaseDall);
title("Phase delay of all pass system");
xlabel 'Normalized Frequency (\times\pi rad/sample)';
```

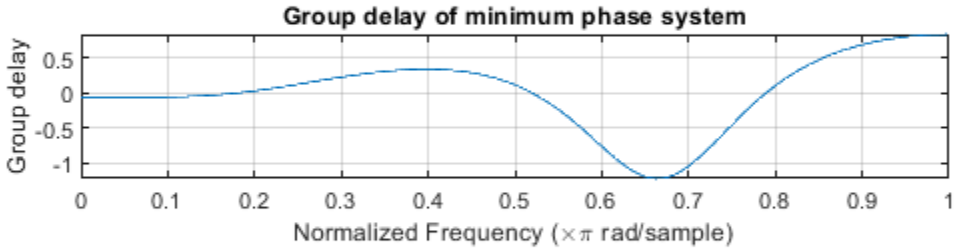
```
ylabel ('Phase');
grid;

% relation between groupdelay
gd_min_all = groupDmin + groupDall;
figure(6);
subplot(2,1,1);
plot(w/pi,groupDH);
title("Group delay of main system");
xlabel 'Normalized Frequency (\times\pi rad/sample)';
ylabel ('Group delay');
grid;
subplot(2,1,2);
plot(w/pi,gd_min_all,'r');
title("Group delay of min phase system + all pass system");
xlabel 'Normalized Frequency (\times\pi rad/sample)';
ylabel ('Group delay');
grid;

% relation between phase
pd_min_all = phaseDmin + phaseDall;
figure(7);
subplot(2,1,1);
plot(w/pi,phaseDH);
title("Phase of main system");
xlabel 'Normalized Frequency (\times\pi rad/sample)';
ylabel ('Phase');
grid;
subplot(2,1,2);
plot(w/pi,pd_min_all,'r');
title("Phase of min phase system + all pass system");
xlabel 'Normalized Frequency (\times\pi rad/sample)';
ylabel ('Phase');
grid;
```

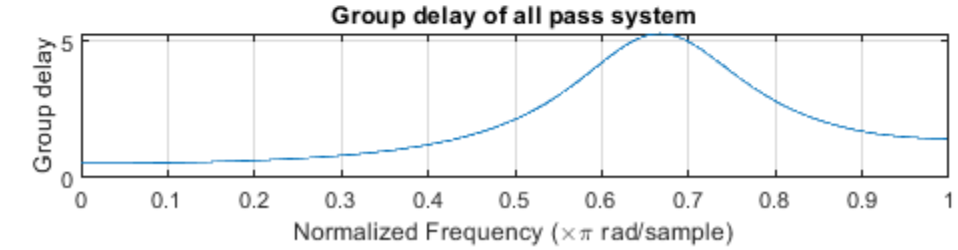

Zplane of H
Imaginary Part
Real Part
1
0.5
0
-0.5
-1
-1.5
-1
-0.5
0
0.5
1
1.5
4

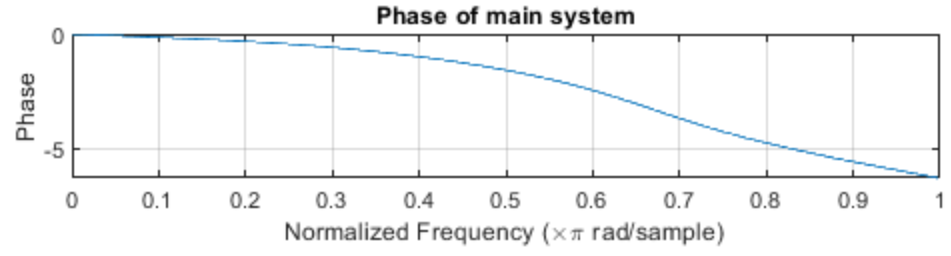

Zplane of H minimum-phase
Imaginary Part
Real Part
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.5
0
0.5
1
4

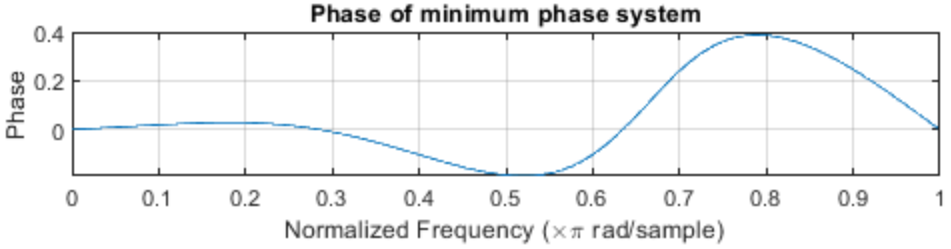

Zplane of H all-pass
Imaginary Part
Real Part
1
0.5
0
-0.5
-1
-1.5
-1
-0.5
0
0.5
1
1.5

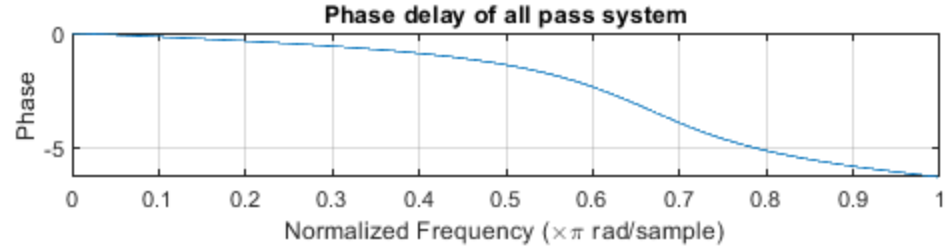

Group delay of main system
Group delay
Normalized Frequency (×π rad/sample)
0
2
4
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

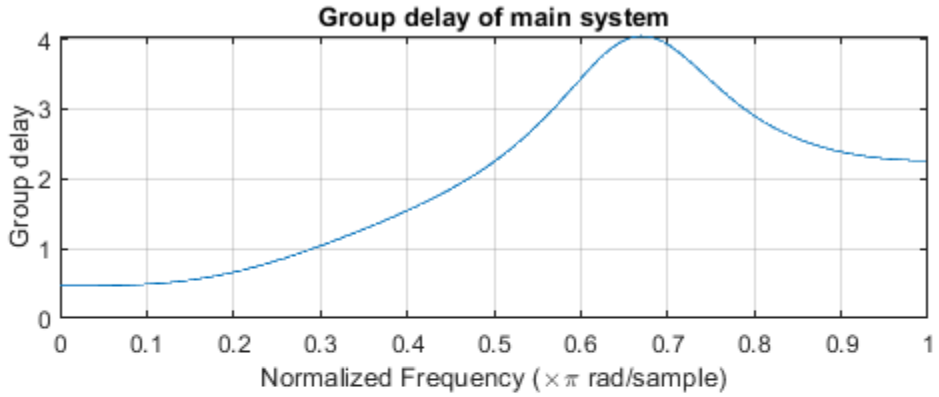

Group delay of minimum phase system
Group delay
Normalized Frequency (×π rad/sample)
0.5
0
-0.5
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

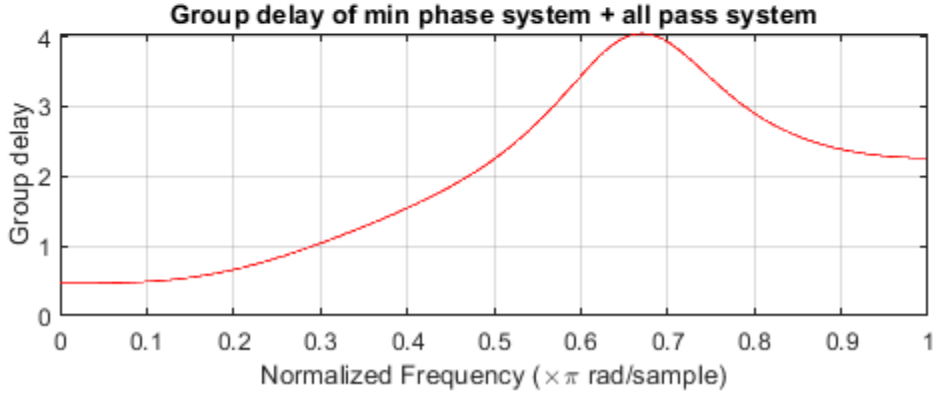

Group delay of all pass system
Group delay
Normalized Frequency (×π rad/sample)
0
5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

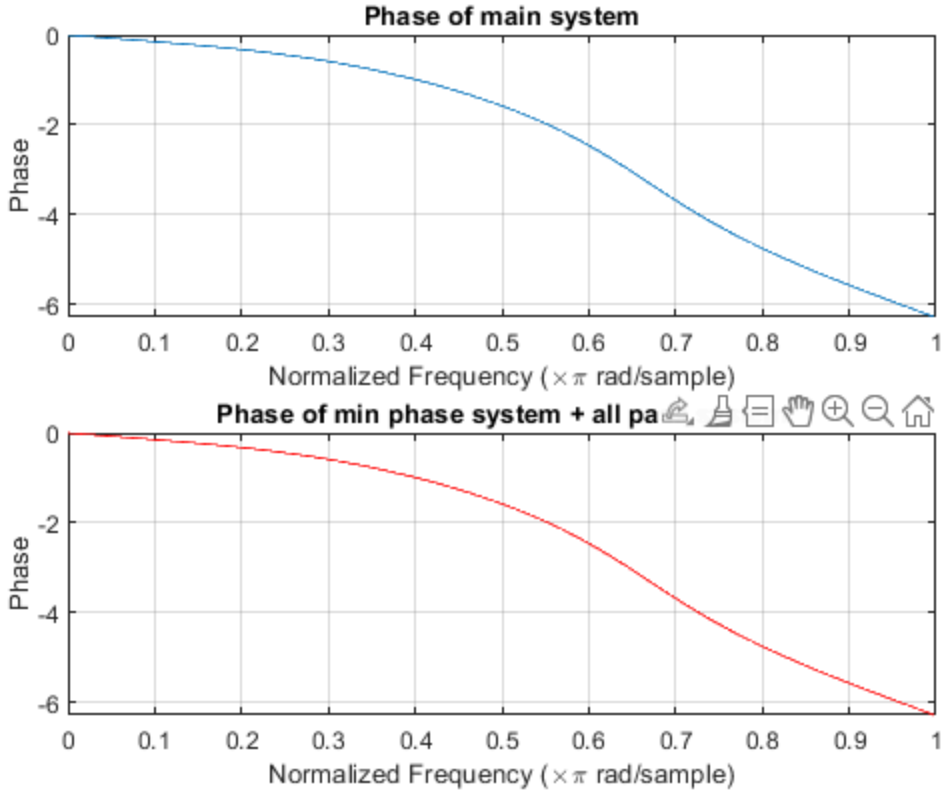

Phase of main system
Phase
0
-5
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (×π rad/sample)


Phase of minimum phase system
Phase
0.4
0.2
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (×π rad/sample)


Phase delay of all pass system
Phase
0
-5
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (×π rad/sample)


Group delay of main system
Group delay
4
3
2
1
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (×π rad/sample)

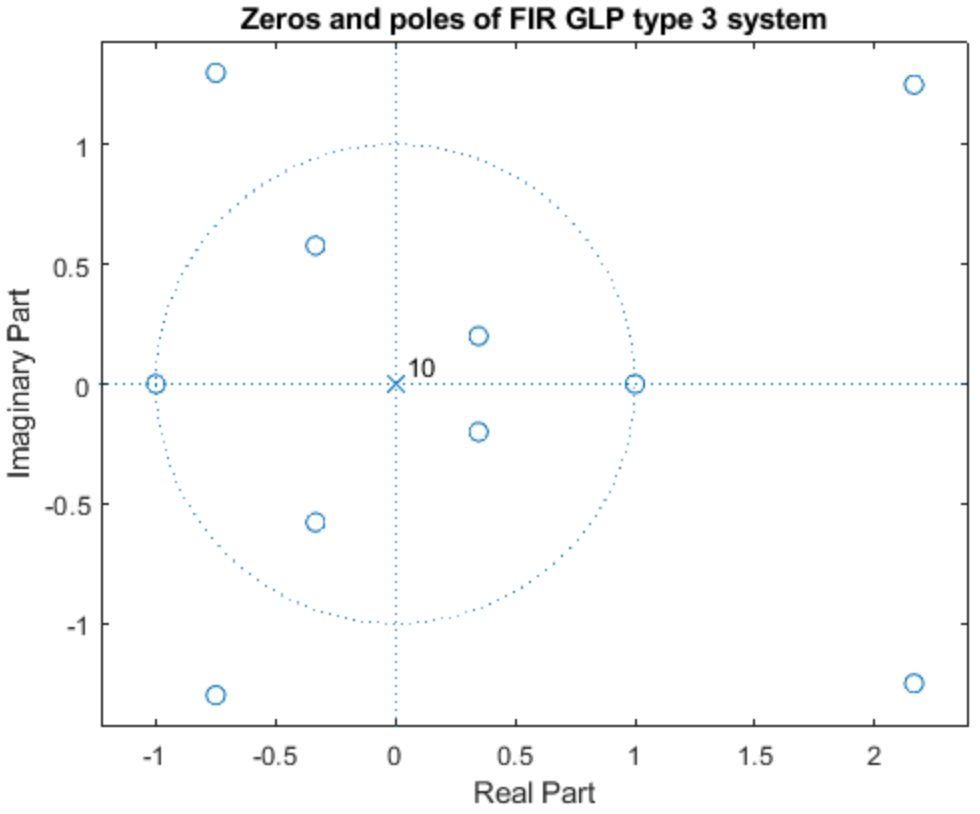

Group delay of min phase system + all pass system
Group delay
4
3
2
1
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (×π rad/sample)

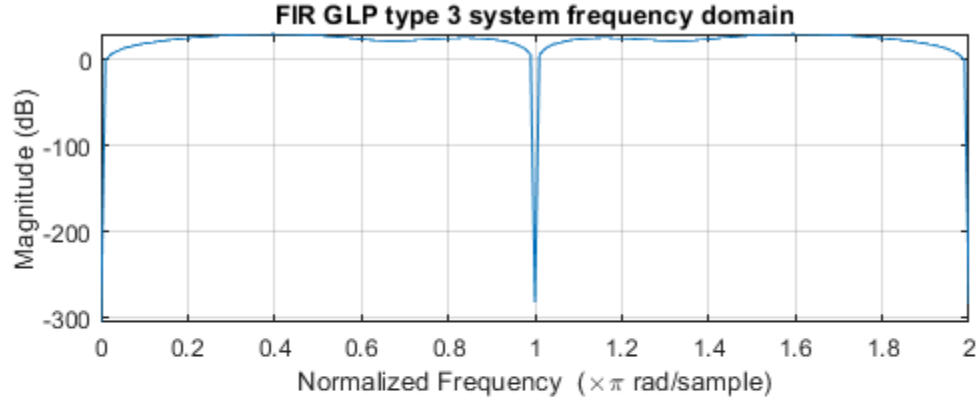


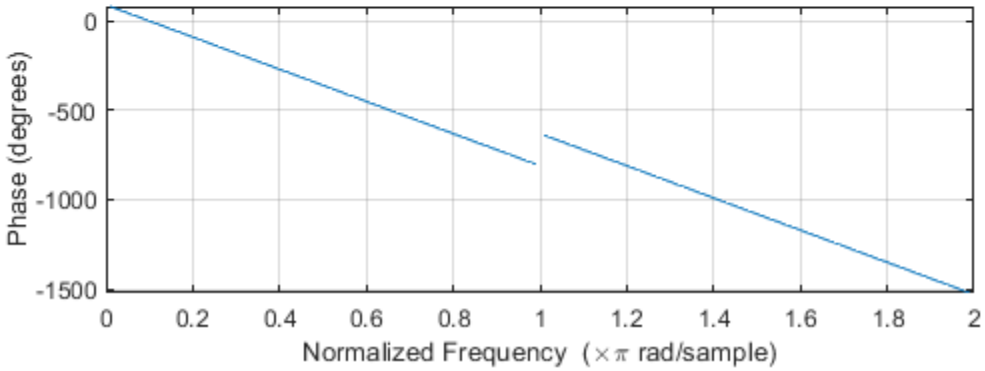
PART 2

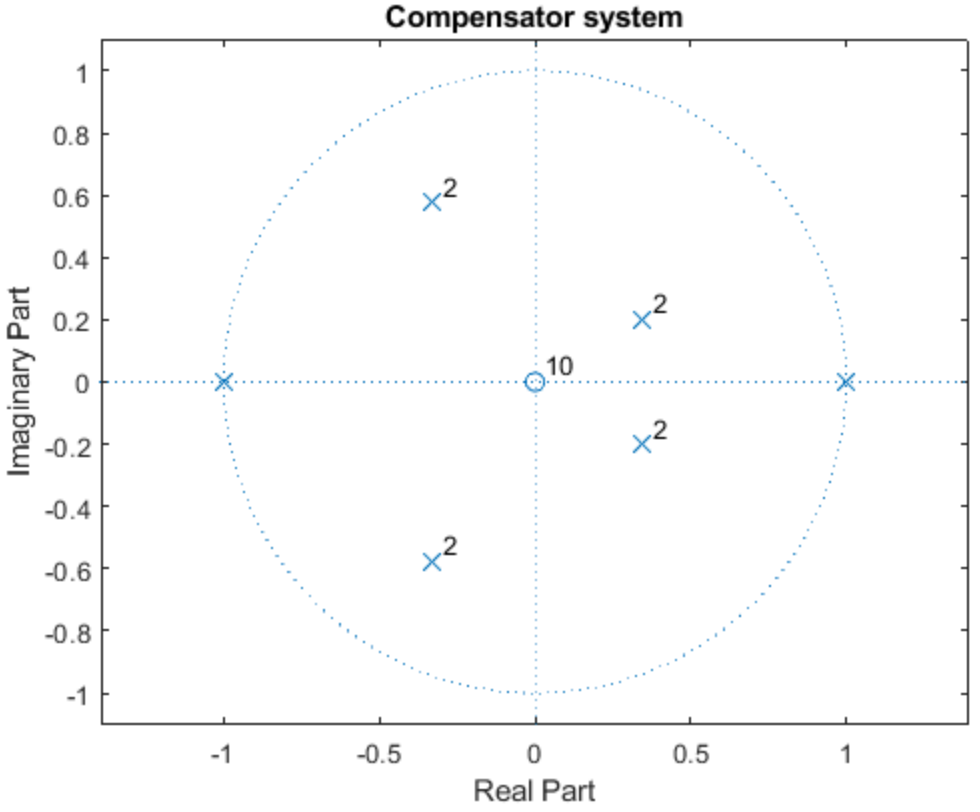
```
%%%%%%%%%%%%%%%%%%%%%%%%%% a %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% a)FIR GLP type 3 System
b31 = conv([1,1],[1,-1]);
b32 = conv([1, -(2/3)*exp(1j*2*pi/3)], [1, -(2/3)*exp(-1j*2*pi/3)]);
b33 = conv([1, -(2.5)*exp(1j*pi/6)], [1, -(2.5)*exp(-1j*pi/6)]);
H3 = conv(conv(b31,b32),conv(b33,H));

figure(8);
zplane(H3,1);
title('Zeros and poles of FIR GLP type 3 system');

figure(9);
freqz(H3,1,0:pi/100:2*pi);
title('FIR GLP type 3 system frequency domain');


% Min-Max-Uc Decomposition
z1=0.4*exp(pi*1j/6);
z2=1.5*exp(pi*1j*2/3);
z3=conj(z1);
z4=conj(z2);
z5=1;
p1=0.99
```

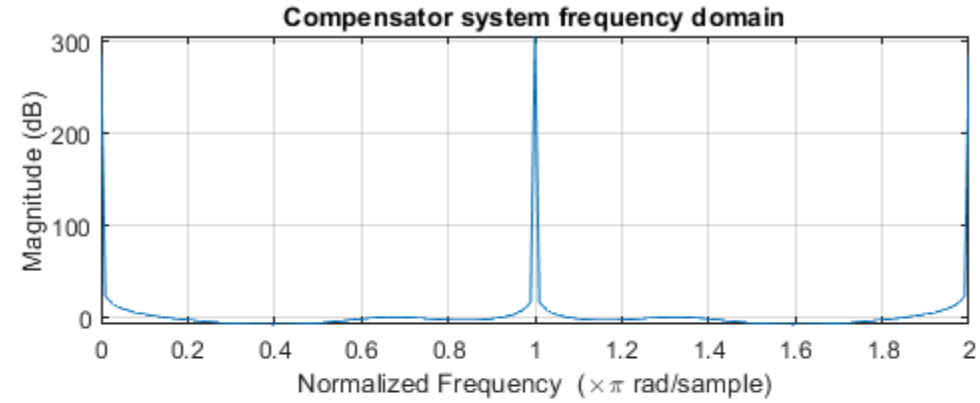
```
z6=-1;
p2=-0.99
z7=0.4^(-1)*exp(pi*1i/6);
z8=0.4^(-1)*exp(-pi*1j/6);
z9=1.5^(-1)*exp(pi*1j*2/3);
z10=1.5^(-1)*exp(-pi*1j*2/3);

a_Hc = poly([z1,z1,z3,z3,z5,z6,z9,z9,z10,z10]);

% Hm = HC*H(Z) => |Hm|=1
b_Hm = poly([z1,z1,z3,z3,z9,z9,z10,z10,z5,z6,z2,z4,z7,z8] );
a_Hm = poly([z1,z1,z3,z3,p1,p2,z9,z9,z10,z10,z1,z3,z9,z10]);

figure(10);
zplane(1,a_Hc);
title('Compensator system');

figure(11);
freqz(1,a_Hc,0:pi/100:2*pi);
title('Compensator system frequency domain');

figure(12);
zplane(b_Hm,a_Hm);
title('Hc.H(Z)');

figure(12);
freqz(b_Hm,a_Hm,0:pi/100:2*pi);
title('Hc.H(Z) frequency domain');


p1 =

    0.9900


p2 =

   -0.9900
```

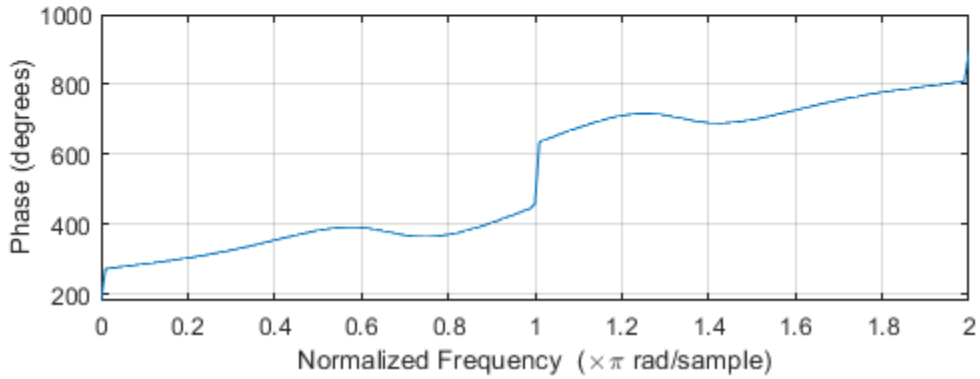

Zeros and poles of FIR GLP type 3 system
Imaginary Part
Real Part
10
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1
1.5
2

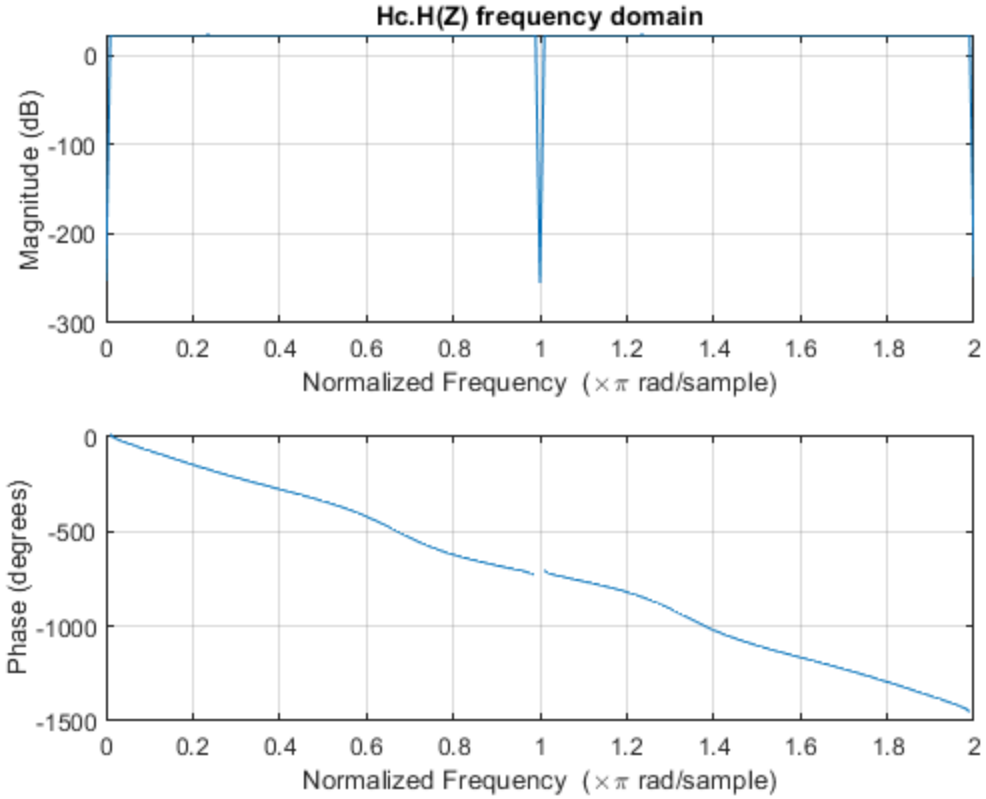

FIR GLP type 3 system frequency domain
Magnitude (dB)
Normalized Frequency (×π rad/sample)
0
-100
-200
-300
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


Phase (degrees)
Normalized Frequency (×π rad/sample)
0
-500
-1000
-1500
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


Compensator system
Imaginary Part
Real Part
2
2
2
2
10
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.5
0
0.5
1


Compensator system frequency domain
Magnitude (dB)
Normalized Frequency (×π rad/sample)
300
200
100
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


Phase (degrees)
Normalized Frequency (×π rad/sample)
1000
800
600
400
200
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2



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