电子科技大学格拉斯哥学院
Glasgow College UESTC

标 准 实 验 报 告
Lab Report

（实验）课程名称：信号与系统
(LAB) Course Name：Signals and Systems

电子科技大学教务处制表

Lab Report 8

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Location：UESTC, ChengDu, SiChuan Province, China
Date： June 20, 2018

1. **Laboratory name：** Signals and Systems
2. **Project name：** Represent signals using MATLAB
3. **Lab hours：** 2
4. **Theoretical background：**

1. The basic concepts of signals and systems arise in a variety of contexts, from engineering design to financial analysis. In this lab1, you will learn how to represent, manipulate, and analyze basic signals and systems in MATLAB.

2. Some basic MATLAB commands for representing signals include: zeros, ones, cos, sin, exp, real, imag, abs, angle, linspace, plot, stem, subplot, xlabel, ylabel, title.

3. Some useful commands in Symbolic Math Toolbox are as: zeros, ones, cos, sin, exp, real, imag, abs, anglelinspace, plot, stem, subplot, xlabel, ylabel, title. Symbolic Math Toolbox: sym, subs, ezplot, Conv, filter, fft, fftshift, freqz, freqs, filter, residue, lsim.

5. **Objective：**

1. Make pole-zero plot for CT and DT system.
2. Understand the pole location's influence on the frequency response of a system.

Description：

The following exercises are from the book "John R.Buck, Michael M. Daniel, Andrew C. Singer. Computer Exploration in Signals and Systems —— Using MATLAB."

1. Make pole-zero plot using MATLAB. 9.1 (a)(c) 10.1(a)(b)
2. Obtain the frequency response of a second-order system. 9.2 (a)(b)

Required instruments：

Computer, MATLAB.

6. **Procedures, Analysis of Lab data & result and Conclusion：**

MATLAB codes and results for the exercises:

■ 9.1 Tutorial: Making Continuous-Time Pole-Zero Diagrams

In this tutorial you will learn how to display the poles and zeros of a rational system function $H(s)$ in a pole-zero diagram. The poles and zeros of a rational system function can be computed using the function `roots`. For example, for the LTI system with system function

$$H(s) = \frac{s-1}{s^2+3s+2}, \tag{9.3}$$

the poles and zeros can be computed by executing

```
>> b = [1 -1];
>> a = [1 3 2];
>> zs = roots(b)
zs =
     1
>> ps = roots(a)
ps =
    -2
    -1
```

A simple pole-zero plot can be made by placing an 'x' at each pole location and an 'o' at each zero location in the complex s-plane, i.e.,

```
>> plot(real(zs),imag(zs),'o');
>> hold on
>> plot(real(ps),imag(ps),'x');
>> grid
>> axis([-3 3 -3 3]);
```

The function `grid` places a grid on the plot and `axis` sets the range of the axes on the plot.

(a). Each of the following system functions corresponds to a stable LTI system. Use `roots` to find the poles and zeros of each system function and make an appropriately labeled pole-zero diagram using `plot` as shown above.

(i) $H(s) = \dfrac{s+5}{s^2+2s+3}$

(ii) $H(s) = \dfrac{2s^2+5s+12}{s^2+2s+10}$

(iii) $H(s) = \dfrac{2s^2+5s+12}{(s^2+2s+10)(s+2)}$

Several different signals can have the same rational expression for their Laplace transform while having different regions of convergence. For example the causal and anticausal LTI systems with impulse responses

$$h_c(t) = e^{-\alpha t}u(t), \qquad h_{ac}(t) = -e^{-\alpha t}u(-t),$$

have a rational system function with the same numerator and denominator polynomials,

$$H_c(s) = \frac{1}{s+\alpha}, \ \Re e(s) > -\alpha,$$
$$H_{ac}(s) = \frac{1}{s+\alpha}, \ \Re e(s) < -\alpha.$$

However, they have different system functions, since their regions of convergence are different.

(c). For the causal LTI system whose input and output satisfy the following differential equation

$$\frac{dy(t)}{dt} - 3y(t) = \frac{d^2x(t)}{dt^2} + 2\frac{dx(t)}{dt} + 5x(t),$$

find the poles and zeros of the system and make an appropriately labeled pole-zero diagram.

The code:

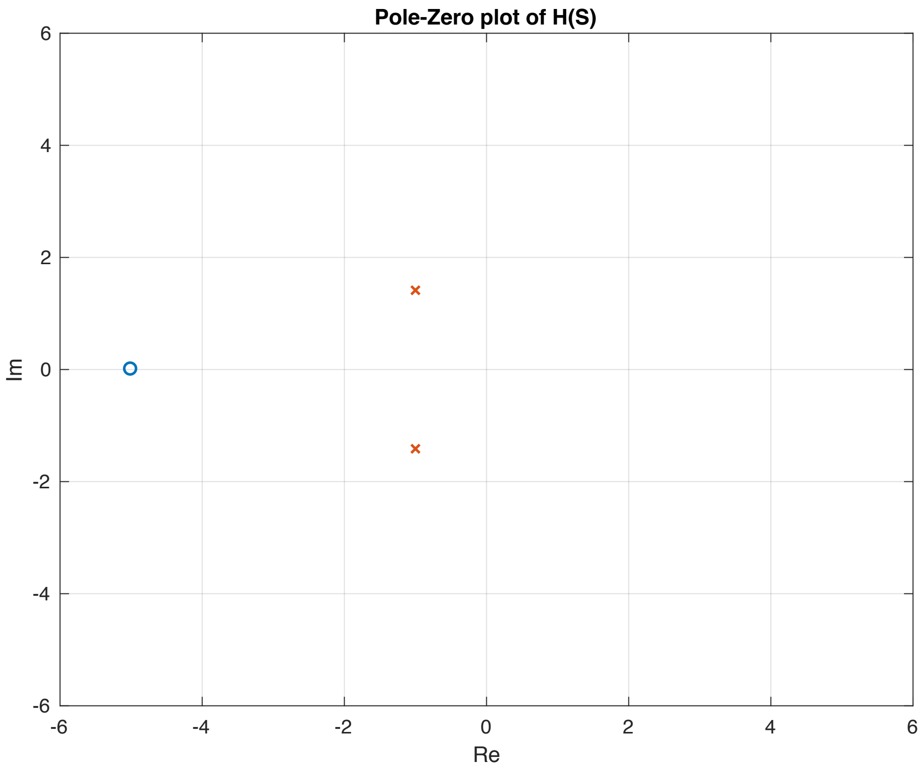
```
%Name: Matlab: Signals and Systems Lab 8th
%Auther: Changgang Zheng
%Student Number UESTC:2016200302027
%Student Number UoG:2289258z
%Institution: Glasgow College UESCT

function solve_plot(up, down)
    zero = roots(up);
    pole = roots(down);
    figure;
    plot(real(zero),imag(zero),'o','LineWidth',1.3);
    hold on;
    plot(real(pole),imag(pole),'x','LineWidth',1.3);
    axis([-6 6 -6 6]);

    %set(gca,'XTick',-4:0.5:4);
    %set(gca,'YTick',-5:2:5);
    grid on;
end


%Name: Matlab: Signals and Systems Lab 8th
%Auther: Changgang Zheng
%Student Number UESTC:2016200302027
%Student Number UoG:2289258z
%Institution: Glasgow College UESCT
%Question: 9.1 (a)(c)

function  problem_1st
    %% Problem a -(i)
    up = [1 5];
    down = [1 2 3];
    solve_plot(up,down);
    title('Pole-Zero plot of H(S)');
    xlabel('Re');
    ylabel('Im');
    %% Problem a -(ii)
    up = [2 5 12];
    down = [1 2 10];
    solve_plot(up,down);
    title('Pole-Zero plot of H(S)');
    xlabel('Re');
    ylabel('Im');
    %% Problem a -(iii)
    up = [2 5 12];
    down = [1 4 14 20];
    solve_plot(up,down);
    title('Pole-Zero plot of H(S)');
    xlabel('Re');
    ylabel('Im');
    %% Problem c
    up = [1 2 5];
    down = [1 -3];
    solve_plot(up,down);
    title('Pole-Zero plot of H(S)');
    xlabel('Re');
    ylabel('Im');
```

The result:

Answer for problem (a):

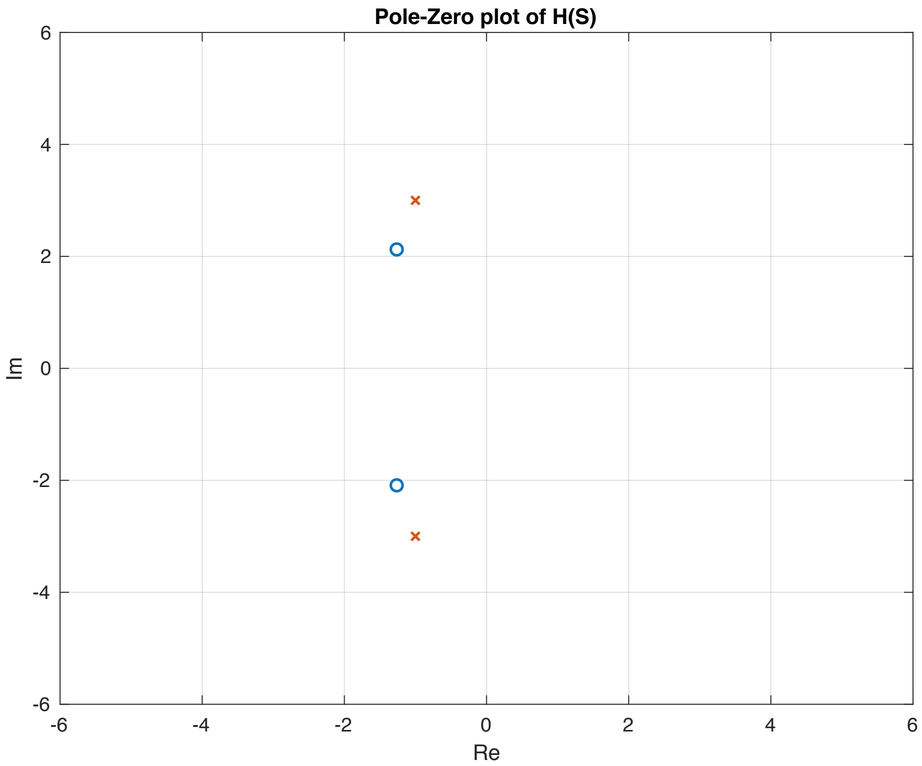
Cession (i):

The plot of the result:



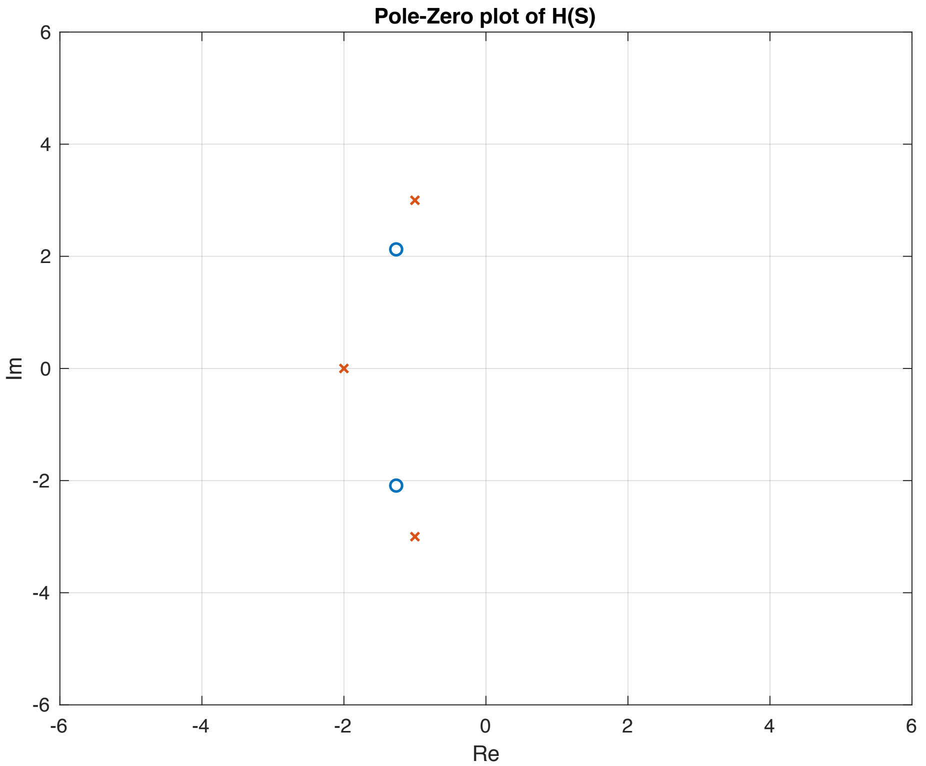
Cession (ii):

The plot of the result:



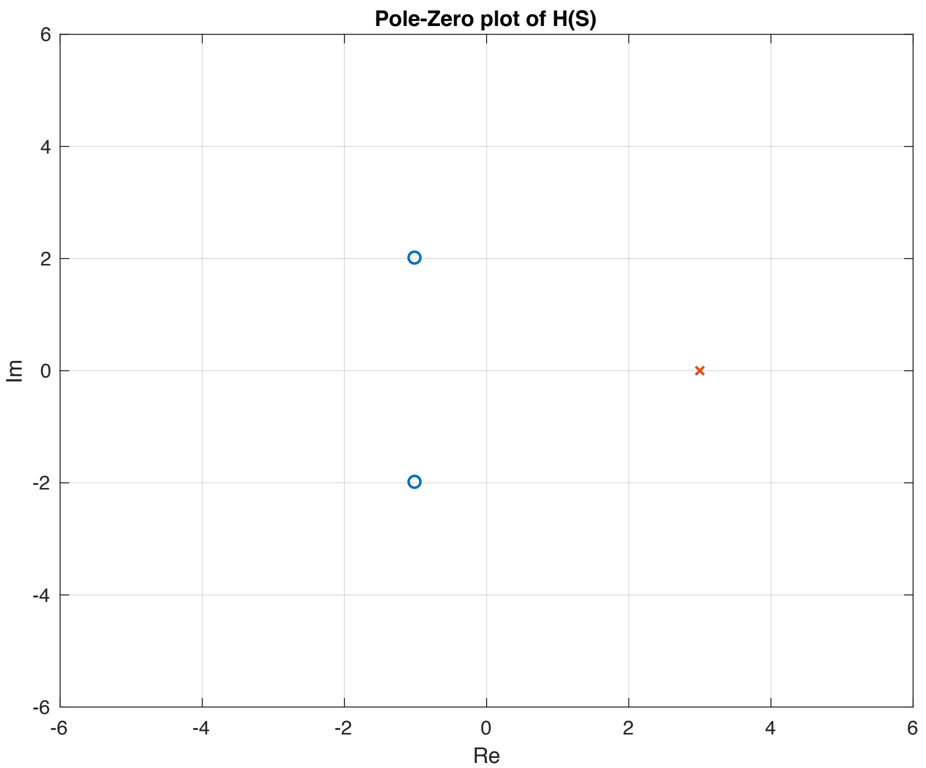
Cession (iii):

The plot of the result:



Answer for problem (c):

The plot of the result:



$$H(s) = \frac{Y(s)}{X(s)} = \frac{s^2 + 2s + 5}{s - 3}$$

After we use the root to get the zeros and poles, we can plot it and the result is like above.

Summary and comments：

I used the MATLAB to solve some problems such as creating and processing signals as well as plotting them. I also gained more impression of the concept of MATLAB and how it could be used in processing of the signals and systems.

In this problem, I have learned that I can use the ‘root’ function to solve the equations. By doing this, we can get the poles (the denominator equation) and zeros (the numerator equation) and use function ‘plot’ to plot them out.

Besides, I also review the Laplace Transfer and understand how to get the system function H(s) from the LCCDE. For instance, do the LT Transfer before doing the transpose. After we get the system function, we can plot the pole-zero plot and know the property of the system.

■ 10.1 Tutorial: Making Discrete-Time Pole-Zero Diagrams

In this tutorial you will learn how to display the poles and zeros of a discrete-time rational system function $H(z)$ in a pole-zero diagram. The poles and zeros of a rational system function can be computed using `roots` as shown in Tutorial 9.1. The function `roots` requires the coefficient vector to be in descending order of the independent variable. For example, consider the LTI system with system function

$$H(z) = \frac{z^2 - z}{z^2 + 3z + 2}. \tag{10.3}$$

The poles and zeros can be computed by executing

```
>> b = [1 -1 0];
>> a = [1 3 2];
>> zs = roots(b)
zs =
      0
      1
>> ps = roots(a)
ps =
     -2
     -1
```

It is often desirable to write discrete-time system functions in terms of increasing order of z^{-1}. The coefficients of these polynomials are easily obtained from the linear constant-coefficient difference equation and are also in the form that `filter` or `freqz` requires. However, if the numerator and denominator polynomials do not have the same order, some poles or zeros at $z = 0$ may be overlooked. For example, Eq. (10.3), could be rewritten as

$$H(z) = \frac{1 - z^{-1}}{1 + 3z^{-1} + 2z^{-2}}. \tag{10.4}$$

If you were to obtain the coefficients from Eq. (10.4), you would get the following

```
>> b = [1 -1];
>> a = [1 3 2];
>> zs = roots(b)
zs =
      1
>> ps = roots(a)
ps =
     -2
     -1
```

Note that the zero at $z = 0$ does not appear here. In order to find the complete set of poles and zeros when working with a system function in terms of z^{-1}, you must append zeros to the coefficient vector for the lower-order polynomial such that the coefficient vectors are the same length.

For the exercises in this chapter, you will need the M-file **dpzplot.m**, which is in the Computer Explorations Toolbox. For convenience, the M-file is also listed below. The function **dpzplot(b,a)** plots the poles and zeros of discrete-time systems. The inputs to **dpzplot** are in the same format as **filter**, and **dpzplot** will automatically append an appropriate number of zeros to **a** or to **b** if the numerator and denominator polynomials are not of the same order. Also, **dpzplot** will include the unit circle in the plot as well as an indication of the number of poles or zeros at the origin — if there are more than one.

(a). Use **dpzplot** to plot the poles and zeros for $H(z)$ in Eq. (10.3).

(b). Use **dpzplot** to plot the poles and zeros for a filter which satisfies the difference equation

$$y[n] + y[n-1] + 0.5y[n-2] = x[n].$$

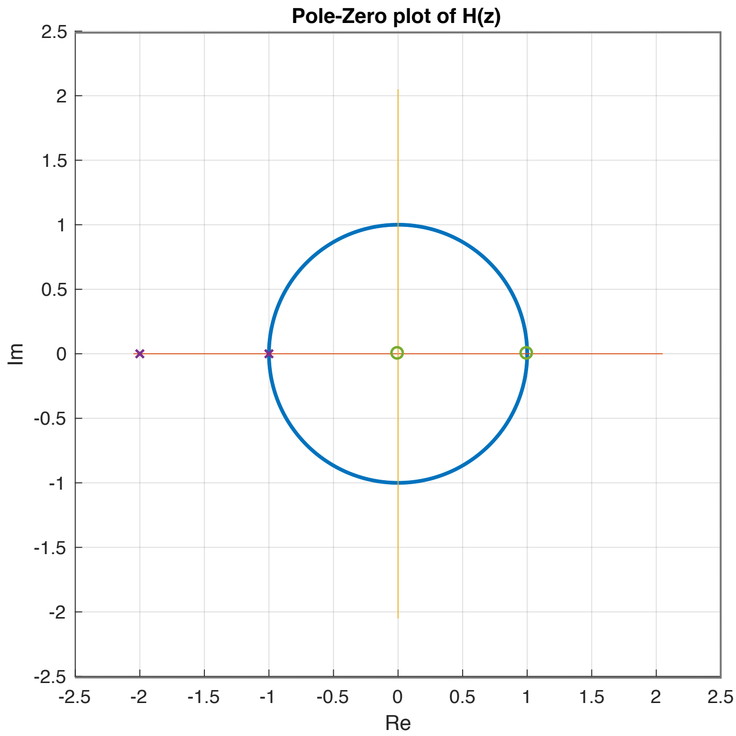
The code:

```
%Name: Matlab: Signals and Systems Lab 8th
%Auther: Changgang Zheng
%Student Number UESTC:2016200302027
%Student Number UoG:2289258z
%Institution: Glasgow College UESCT
%Question: 10.1(a)(b)


function  problem_2nd

    %% Problem a
    zero = [1 -1 0];
    pole = [1 3 2];
    figure;
    dpzplot(zero,pole);
    title('Pole-Zero plot of H(z)');
    xlabel('Re');
    ylabel('Im');
    %% Problem b
    zero = 1;
    pole = [1 1 0.5];
    figure;
    dpzplot(zero,pole);
    title('Pole-Zero plot of H(z)');
    xlabel('Re');
    ylabel('Im');
```

The result:

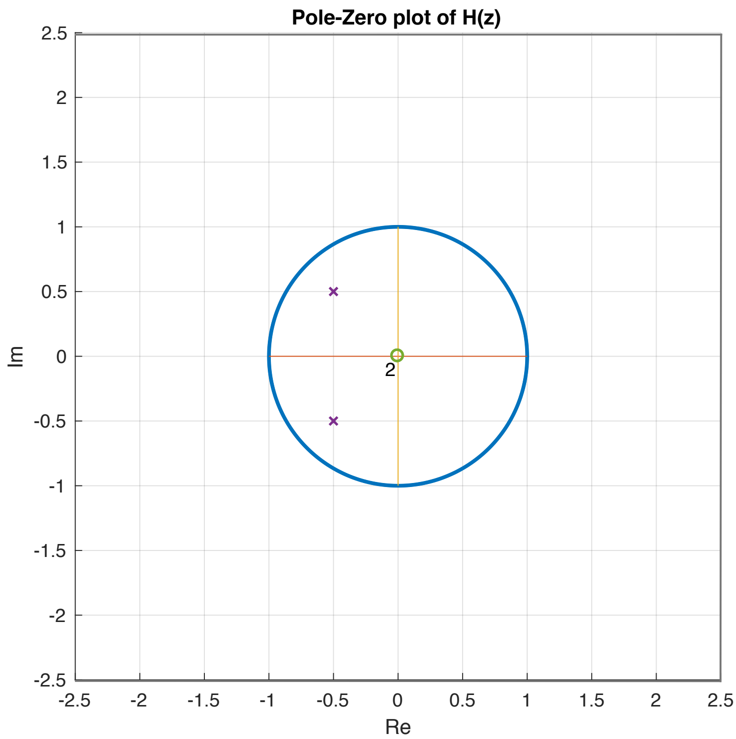
Answer for problem (a):

The plot of the result:



Answer for problem (b):

The plot of the result:



Summary and comments：

I used the MATLAB to solve some problems such as creating and processing signals as well as plotting them. I also gained more impression of the concept of MATLAB and how it could be used in processing of the signals and systems.

In this problem, I have reviewed something about the Z Transfer. For instance, how to calculate the H(z). Besides, I also learn how to use MATLAB to calculate the zeros and poles and plot the pole-zero plot by suing the function 'dpzplot'.

Moreover, compare with using Laplace Transfer to process continuous signal, the discrete signal need to use the Z Transfer.

■ 9.2 Pole Locations for Second-Order Systems

In these problems, you will examine the pole locations for second-order systems of the form

$$H(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}. \tag{9.4}$$

The values of the damping ratio ζ and undamped natural frequency ω_n specify the locations of the poles, and consequently the behavior of this system. Exercise 6.1 explored the relationship between the time-domain and the frequency-domain behavior of this system. In this exercise, you will see how the locations of the poles affect the frequency response.

Basic Problems

In these problems, you will examine the pole locations and frequency responses for four different choices of ζ while ω_n remains fixed at 1.

(a). Define $H_1(s)$ through $H_4(s)$ to be the system functions that result from fixing $\omega_n = 1$ in Eq. (9.4) while ζ is 0, 1/4, 1, and 2, respectively. Define **a1** through **a4** to be the coefficient vectors for the denominators of $H_1(s)$ through $H_4(s)$. Find and plot the locations of the poles for each of these systems.

(b). Define **omega=[-5:0.1:5]** to be the frequencies at which you will compute the frequency responses of the four systems. Use **freqs** to compute and plot $|H(j\omega)|$ for each of the four systems you defined in Part (a). How are the frequency responses for $\zeta < 1$ qualitatively different from those for $\zeta \geq 1$? Can you explain how the pole locations for the systems cause this difference? Also, can you argue geometrically why $H(j\omega)|_{\omega=0}$ is the same for all four systems?

The code:

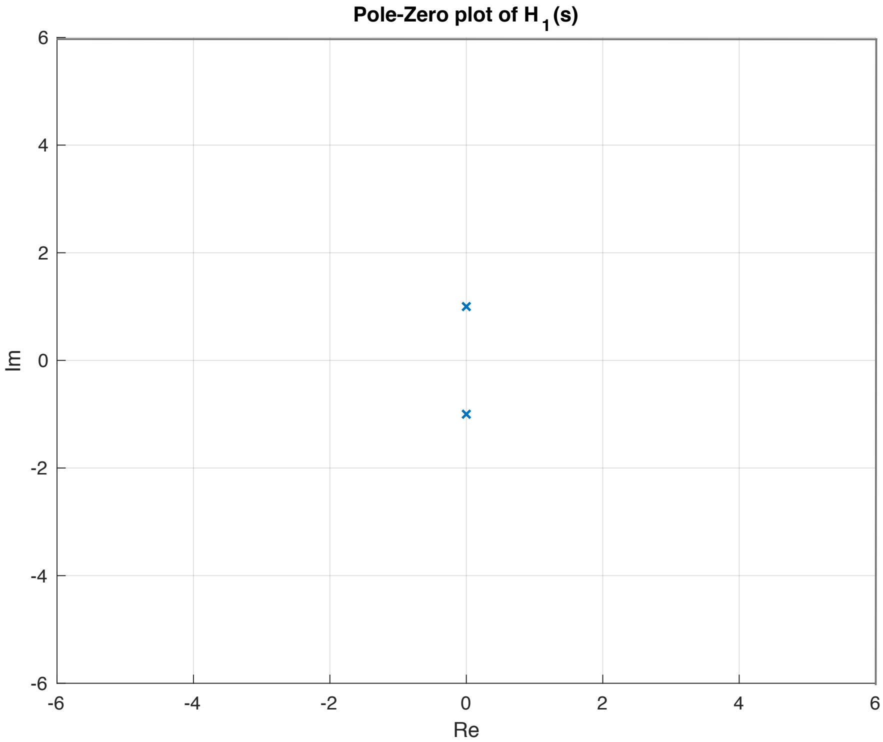
```
%Name: Matlab: Signals and Systems Lab 8th
%Auther: Changgang Zheng
%Student Number UESTC:2016200302027
%Student Number UoG:2289258z
%Institution: Glasgow College UESCT
%Question: 9.2 (a)(b)


function  problem_3rd

    %% Problem a
    zero = 1;
    a1 = [1 0 1];
    a2 = [1 0.5 1];
    a3 = [1 2 1];
    a4 = [1 4 1];
    solve_plot(zero,a1);
    title('Pole-Zero plot of H_1(s)');
    xlabel('Re');
    ylabel('Im');
    solve_plot(zero,a2);
```

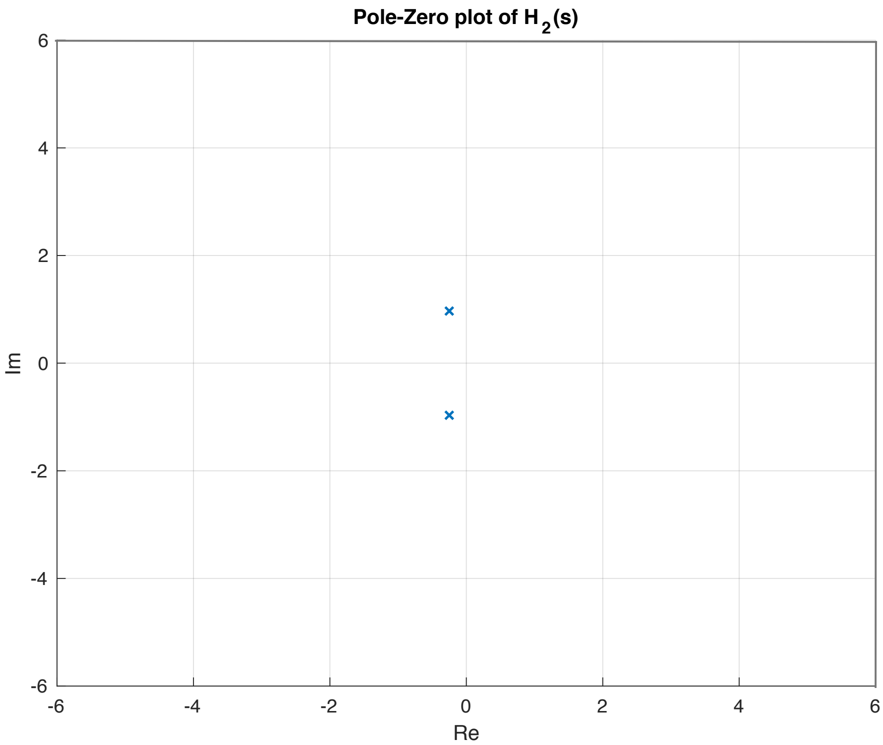
```
title('Pole-Zero plot of H_2(s)');
xlabel('Re');
ylabel('Im');
solve_plot(zero,a3);
title('Pole-Zero plot of H_3(s)');
xlabel('Re');
ylabel('Im');
solve_plot(zero,a4);
title('Pole-Zero plot of H_4(s)');
xlabel('Re');
ylabel('Im');

figure;
solve_plot_tog(zero,a1);
solve_plot_tog(zero,a2);
solve_plot_tog(zero,a3);
solve_plot_tog(zero,a4);
title('Pole-Zero plot of H_1(s) to H_2(s)');
xlabel('Re');
ylabel('Im');
legend('H_1(s)','H_2(s)','H_3(s)','H_4(s)')
%% Problem a
omega = -5:0.1:5;
H1 = freqs(zero,a1,omega);
H2 = freqs(zero,a2,omega);
H3 = freqs(zero,a3,omega);
H4 = freqs(zero,a4,omega);
figure;
subplot(221);
plot(omega,abs(H1));xlabel('w');ylabel('|H_1(jw)|');title('|H_1(jw)|');
set(gca,'XTick',-5:2.5:5);
%set(gca,'YTick',-5:2:5);
grid;
subplot(222);
plot(omega,abs(H2));xlabel('w');ylabel('|H_2(jw)|');title('|H_2(jw)|');
set(gca,'XTick',-5:2.5:5);
%set(gca,'YTick',-5:2:5);
grid;
subplot(223);
plot(omega,abs(H3));xlabel('w');ylabel('|H_3(jw)|');title('|H_3(jw)|');
set(gca,'XTick',-5:2.5:5);
%set(gca,'YTick',-5:2:5);
grid;
subplot(224);
plot(omega,abs(H4));xlabel('w');ylabel('|H_4(jw)|');title('|H_4(jw)|');
set(gca,'XTick',-5:2.5:5);
%set(gca,'YTick',-5:2:5);
grid;
```

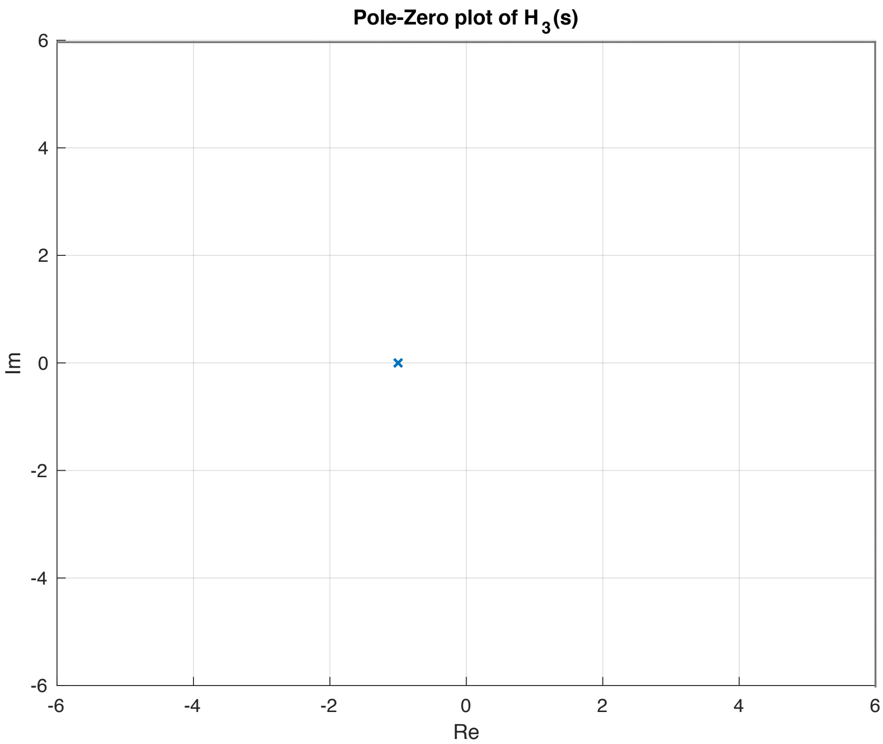
The result:

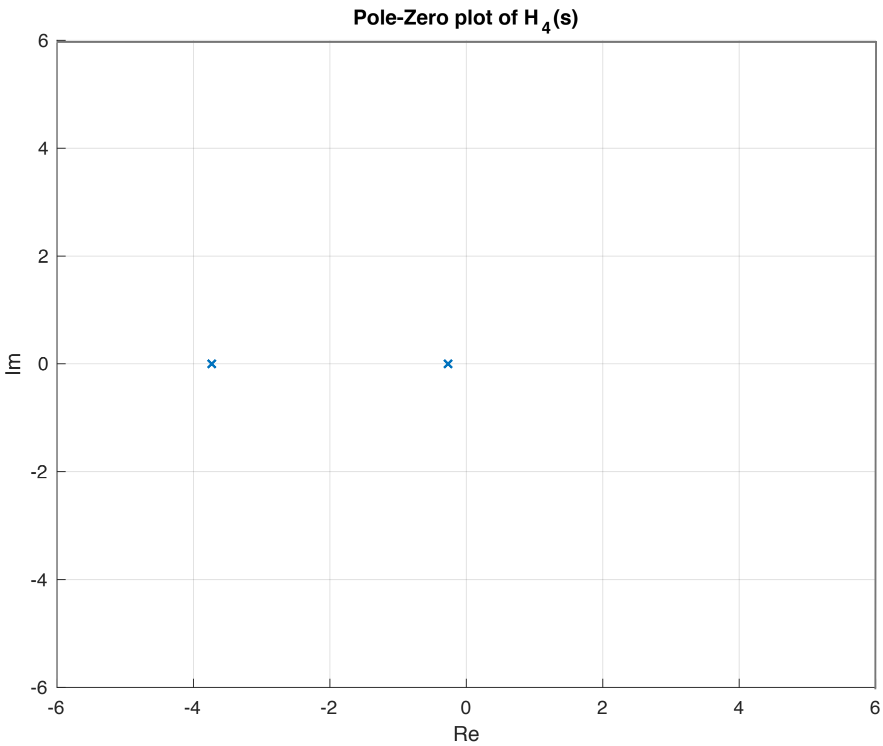
Answer for problem (a):

The plot of the result:

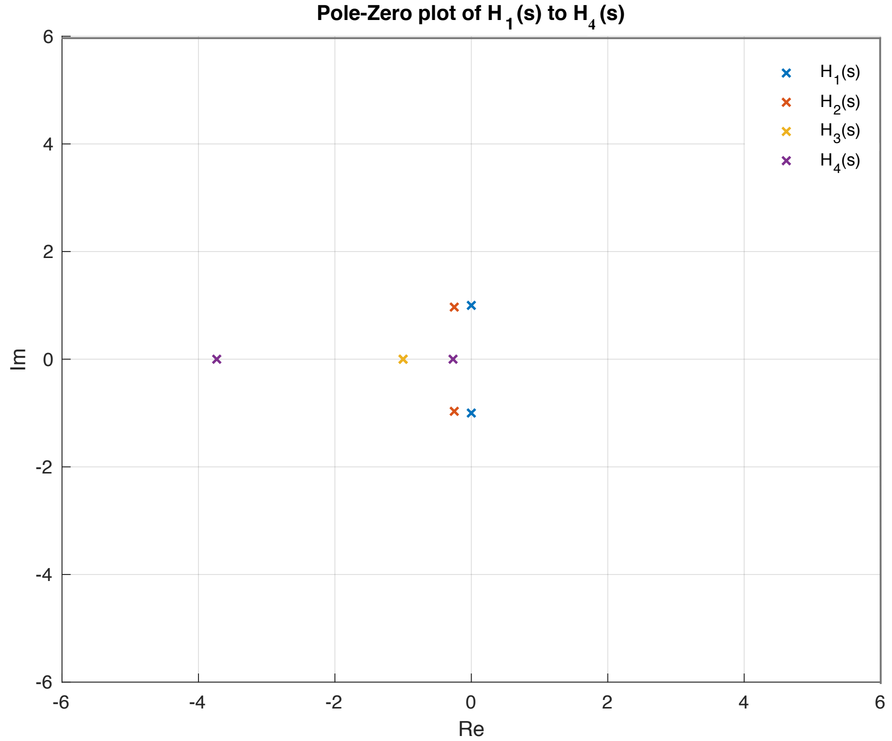





Pole-Zero plot of H 3 (s)
Im
Re
6
4
2
0
-2
-4
-6
-6
-4
-2
0
2
4
6

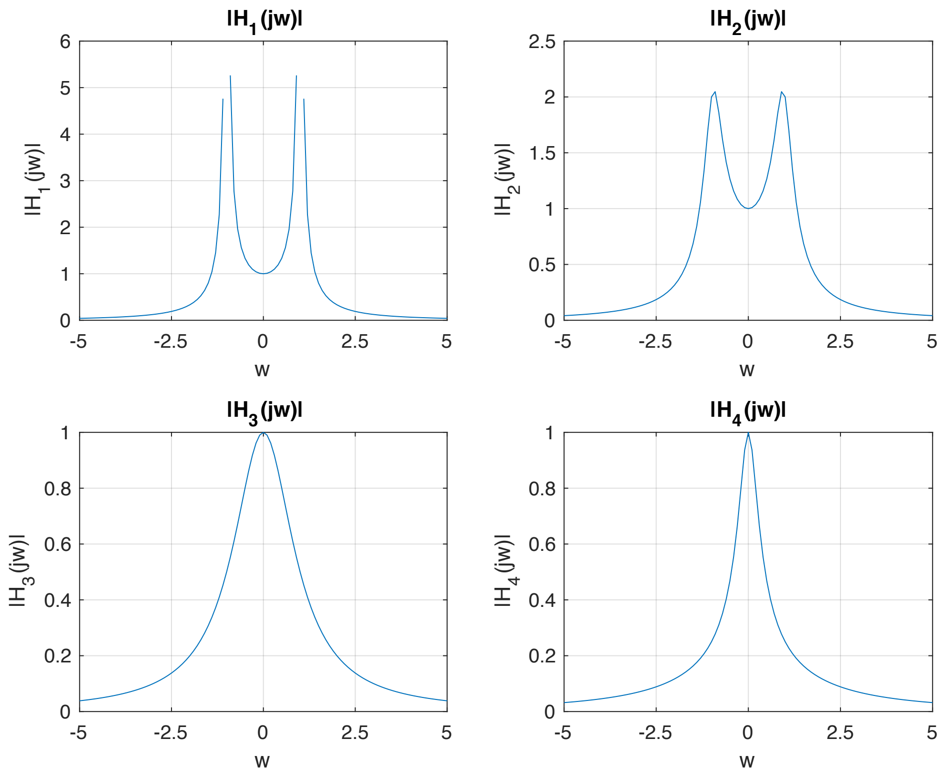

Pole-Zero plot of H 4 (s)
Im
Re
6
4
2
0
-2
-4
-6
-6
-4
-2
0
2
4
6

If we plot the result in a single graph, it is much easier for us to see the trend. The follow graph is the plot of the result:



Answer for problem (b):

The plot of the result:



$$H(s) = \frac{Y(s)}{X(s)} = \frac{w_n^2}{s^2 + 2\zeta w_n s + w_n^2}$$

If we want to calculate the poles:

$$s^2 + 2\zeta w_n s + w_n^2 = 0$$

For $\zeta < 1$, the result of the poles is **complex** as $4\zeta^2 w_n^2 - 4w_n^2 < 0$. From the graph, we can see that the maximum magnitude of the frequency response appears at around w=1 and the magnitude of the frequency response decreases as w increases.

For $\zeta \geq 1$, the result of the poles is **real** as $4\zeta^2 w_n^2 - 4w_n^2 > 0$. From the graph, we can see that the maximum magnitude of the frequency response appears at around w=0 and the bandwidth of the frequency response decreases as w increases.

The reason why the frequency response $|H(s)| = 1$ at all $s = 0$ for all the graph is that when $s = j0$, $H(j0) = \frac{w_n^2}{j0^2 + 2\zeta w_n j0 + w_n^2} = 1.$ Besides, we can also know that $H(j0)$ is the same for all four systems as the products of the distances of the poles from $(0,0j)$ are the same.

Summary and comments：

I used the MATLAB to solve some problems such as creating and processing signals as well as plotting them.

I gained more impression of the concept of MATLAB and how it could be used in getting frequency response of the system.

In this problem, I have practiced to use the 'root' function to solve the equations. By doing this, we can get the poles (the denominator equation) and zeros (the numerator equation) and use function 'plot' to plot them out (pole-zero plot).

I also review the Laplace Transfer and understand how to get the system function H(s) from the LCCDE. After we get the system function and plot the pole-zero plot, we can know the property of the system.

Besides, I also analyze the system function. By doing so, we could understand why the frequency response is like that and what it would be like if we change some parameter of the H(s).

Suggestion for this lab：

It is already great! I have the answer I could check if my work is stay on track, as I have the answer.

Score：

Instructor：