# LAB 3: Standard 2nd Order System Identification

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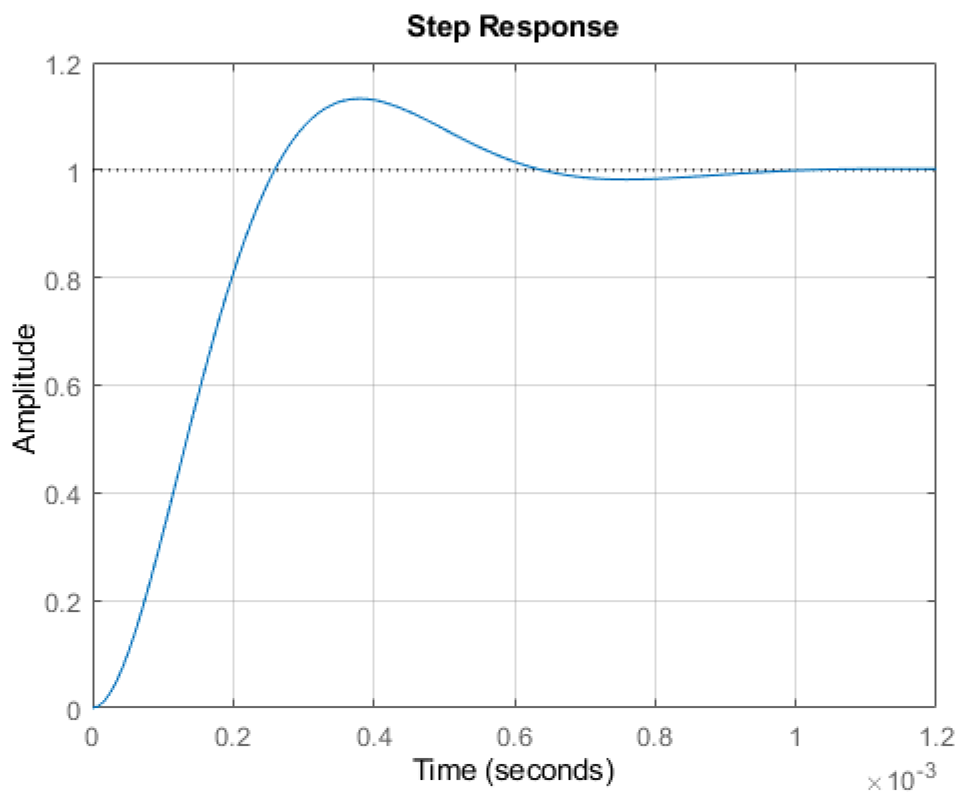
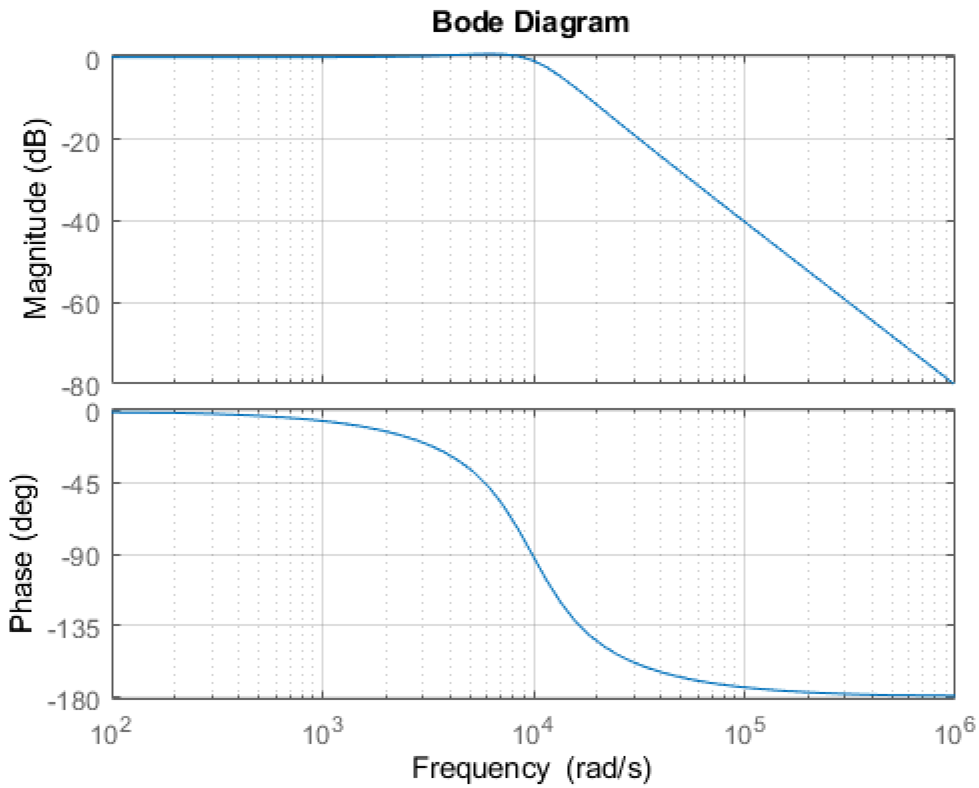
# Part A

```
L=(47*10^(-3))
C=(0.22*10^(-6))
R=500


Tftop=[1/(L*C)];
s=zpk('s');
Tfbot=(s^2+(R/L)*s+(1/(C*L)));

Tf=Tftop/Tfbot
figure(1);
step(Tf)
grid on;
figure(2);
bode(Tf);
grid on;

% Part D

% The issue with the step response graph is that it is underdamped.
 You can
% solve this by adding lossy elements into the circuit in order to
 damp the
% response more effectively. This can also be accomplished using
 feedback
% phase shift.
```

```
L =

    0.0470
```

```
C =

   2.2000e-07


R =

   500


Tf =

           9.6712e+07
  ----------------------------
  (s^2 + 1.064e04s + 9.671e07)

Continuous-time zero/pole/gain model.
```

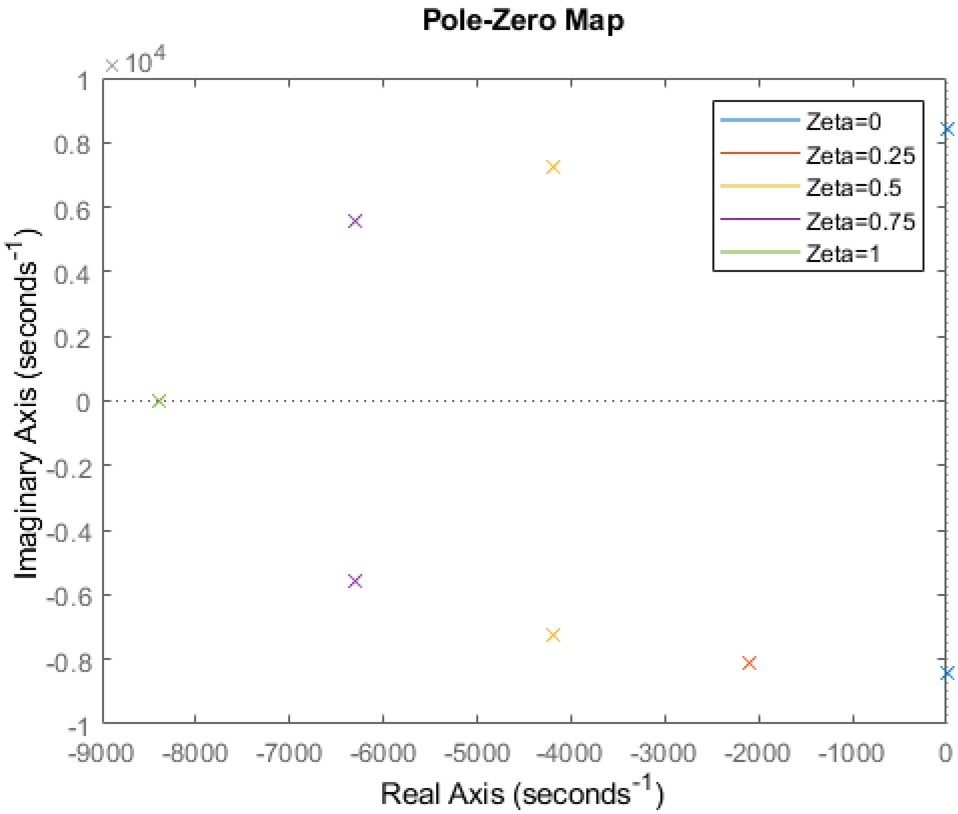


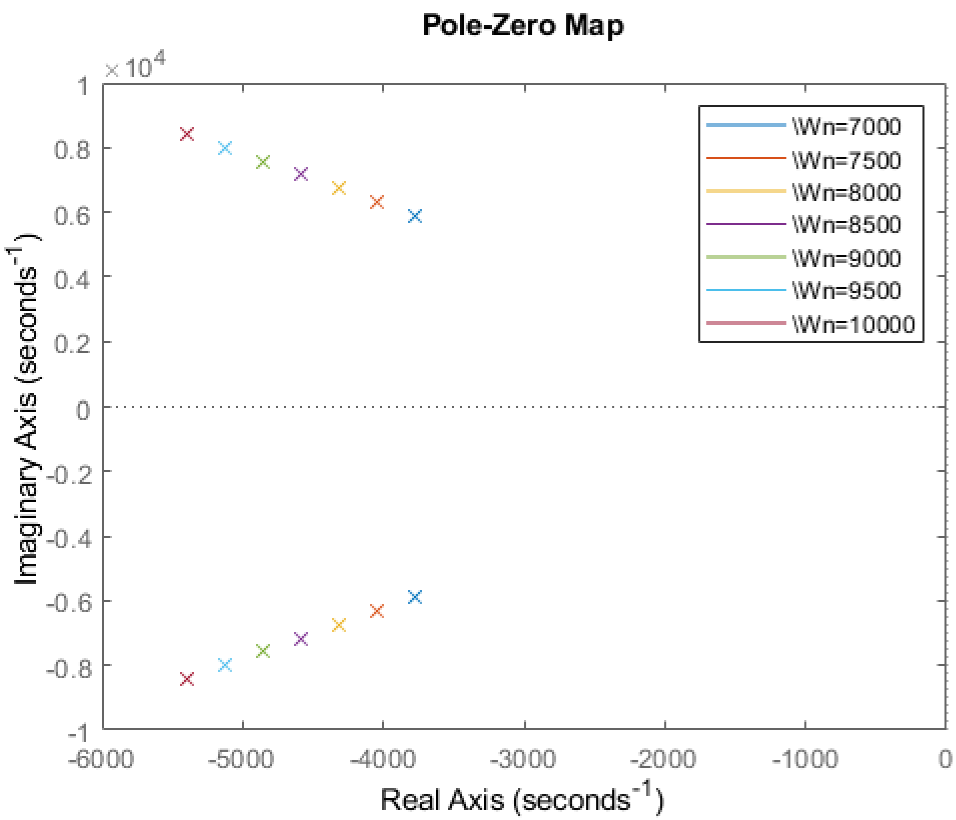



# Effect of Damping Ratio & Natural Frequency of the Pole Locations

```
[poles, ~]=pzmap(Tf);

figure (3);
grid on;
zeta=0:0.25:1;
Labels = 'Zeta=' + string(zeta);
for i = 1:length(zeta)
    Wn=8400;
    Tftop=(Wn^2);
    Tfbot=(s^2+(2*zeta(i)*Wn)*s+(Wn^2));
    Tf(i)=Tftop/Tfbot;
    hold on
    pzmap(Tf(i));

    legend(Labels);


end
hold off

figure(4);
```

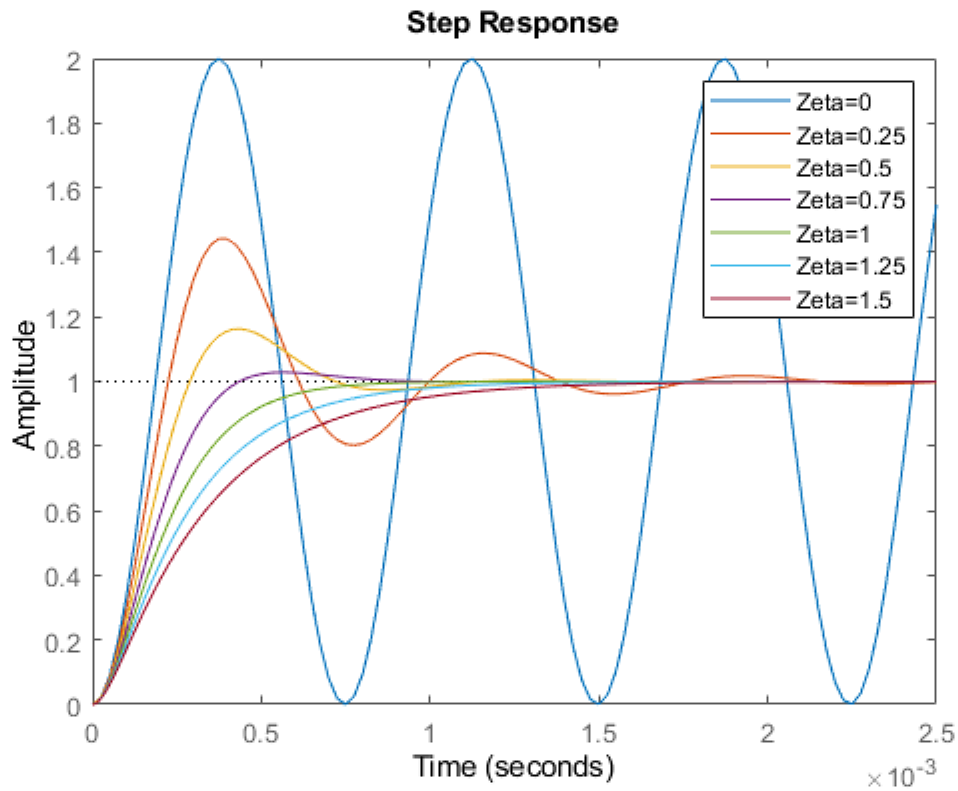
```
Wn=7000:500:10000;
zeta=.54
 Labels = '\Wn=' + string(Wn);
 hold on;
for i=1:length(Wn)

    Tftop=(Wn(i)^2);
    Tfbot=(s^2+(2*zeta*Wn(i))*s+(Wn(i)^2));
    Tf=Tftop/Tfbot;

    pzmap(Tf)
    legend(Labels);

end
hold off

% Analysis for Part B (part b and c)

% The effect of damping ratio on location of poles: as damping ratio
 gets
% larger, the pole's real and complex values get larger. The poles are
% increasing at a decreasing rate.

%The effect of natural frequency on location of poles: As natural
 frequency
%increases, the pole's real and complex values are approaching zero.


zeta =

    0.5400
```

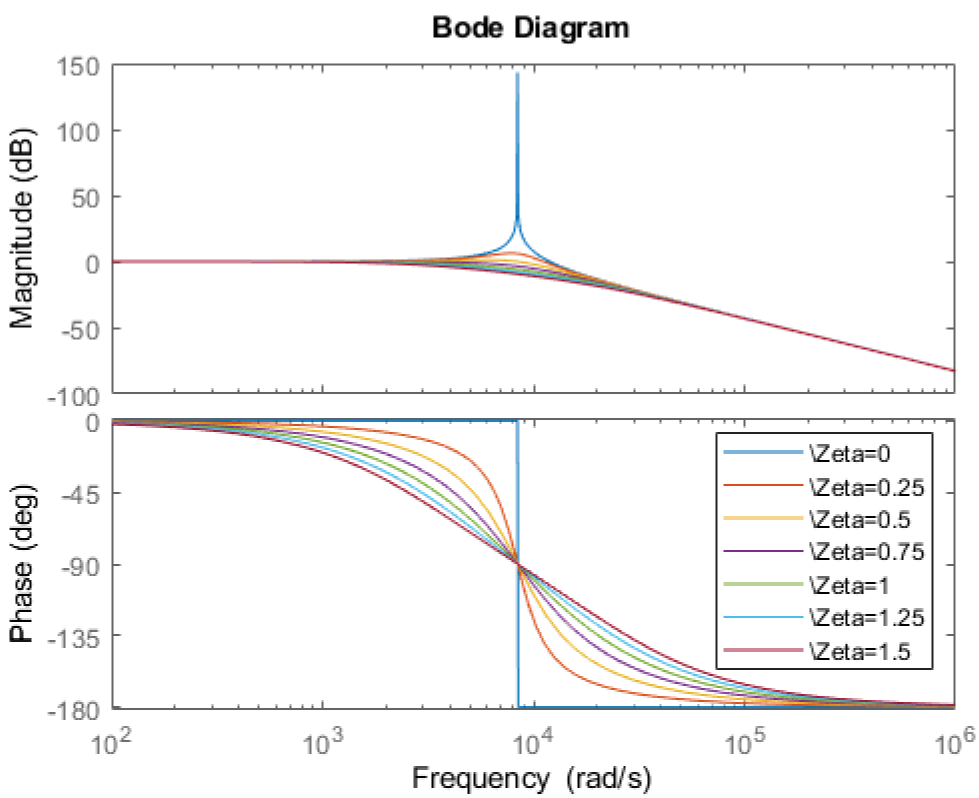

Pole-Zero Map
×10^4
Imaginary Axis (seconds^-1)
Real Axis (seconds^-1)
Zeta=0
Zeta=0.25
Zeta=0.5
Zeta=0.75
Zeta=1
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-9000
-8000
-7000
-6000
-5000
-4000
-3000
-2000
-1000
0


Pole-Zero Map
×10^4
Imaginary Axis (seconds^-1)
Real Axis (seconds^-1)
\Wn=7000
\Wn=7500
\Wn=8000
\Wn=8500
\Wn=9000
\Wn=9500
\Wn=10000
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-6000
-5000
-4000
-3000
-2000
-1000
0

# Part C: Effect of Pole Location on Step and Frequency Response

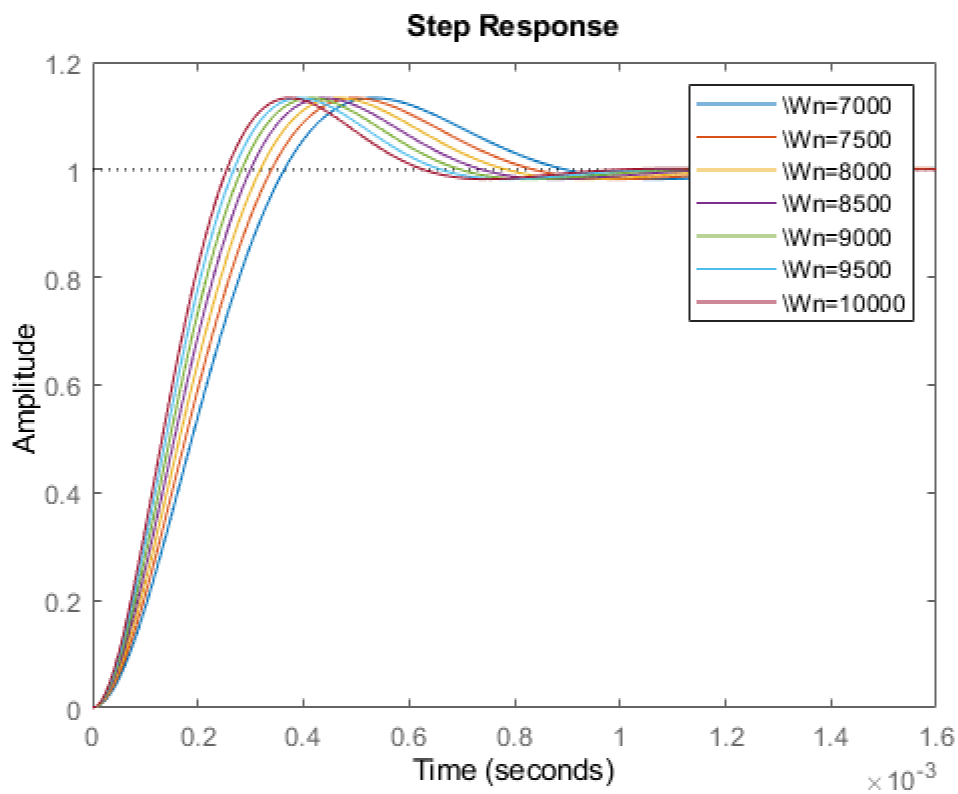
```
figure (5);
grid on;
zeta=0:0.25:1.5;
Labels = 'Zeta=' + string(zeta);
for i = 1:length(zeta)
    Wn=8400;
    Tftop=(Wn^2);
    Tfbot=(s^2+(2*zeta(i)*Wn)*s+(Wn^2));
    Tf(i)=Tftop/Tfbot;
    hold on
    step(Tf(i),0.0025);

    legend(Labels);
end
hold off
% As damping ratio increases, the system goes from undamped to
 overdamped.
% The Overshoot percentage starts to decrease and the settling time
% decreases up to the point that zeta=1 and then it starts to increase
% again.
figure (6);
grid on;
zeta=0:0.25:1.5;
 Labels = '\Zeta=' + string(zeta);
for i = 1:length(zeta)
    Wn=8400;
    Tftop=(Wn^2);
    Tfbot=(s^2+(2*zeta(i)*Wn)*s+(Wn^2));
    Tf(i)=Tftop/Tfbot;
    hold on
  bode(Tf(i));

    legend(Labels);


end
hold off

% Damping ratio on frequency response: As damping ratio increases,
 there is
% a decrease in the maximum magnitude. The real component of the pole
% increase. This will smooth the phase response and prevent the
 vertical
% discontuinity when zeta=0;
```


Step Response
Amplitude
Time (seconds)
× 10^-3
Zeta=0
Zeta=0.25
Zeta=0.5
Zeta=0.75
Zeta=1
Zeta=1.25
Zeta=1.5

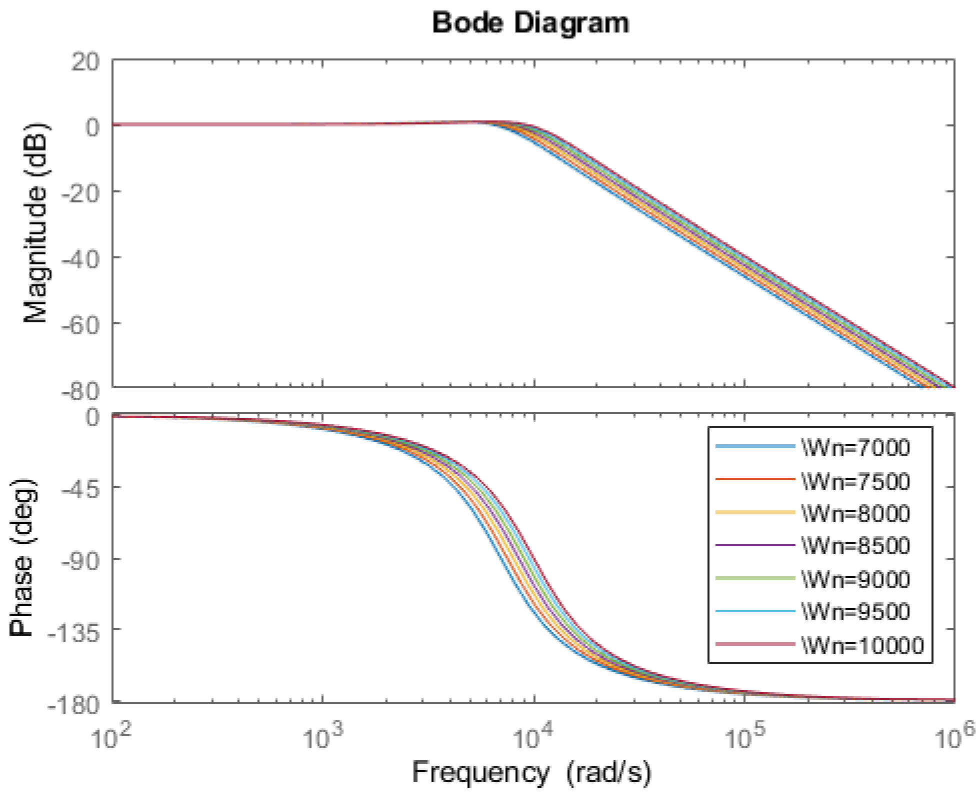

Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/s)
\Zeta=0
\Zeta=0.25
\Zeta=0.5
\Zeta=0.75
\Zeta=1
\Zeta=1.25
\Zeta=1.5

```
figure(7);
Wn=7000:500:10000;
zeta=.54
 Labels = '\Wn=' + string(Wn);
 hold on;
for i=1:length(Wn)

    Tftop=(Wn(i)^2);
    Tfbot=(s^2+(2*zeta*Wn(i))*s+(Wn(i)^2));
    Tf=Tftop/Tfbot;

   step(Tf)
    legend(Labels);

end
hold off
%Effect of natural frequencies on step responses: As you increase the
%natural frequency there is a linear delay of the maximum amplitude in
 the
%step response. All of the responses are underdamped.
figure(8);
Wn=7000:500:10000;
zeta=.54
 Labels = '\Wn=' + string(Wn);
 hold on;
for i=1:length(Wn)

    Tftop=(Wn(i)^2);
    Tfbot=(s^2+(2*zeta*Wn(i))*s+(Wn(i)^2));
    Tf=Tftop/Tfbot;

    bode(Tf)
    legend(Labels);

end
hold off

%  Effect of natural frequency on frequency response: At low
 frequencies,
%  all of the responses have the same amplitude. At high frequencies
 an
%  increase in wn causes a subsequent increase in amplitude. For
 Phase, the
%  responses are all close to zero for low frequencies and as
 frequency
%  increases the phase starts to deviate


zeta =

    0.5400


zeta =
```

```
0.5400
```



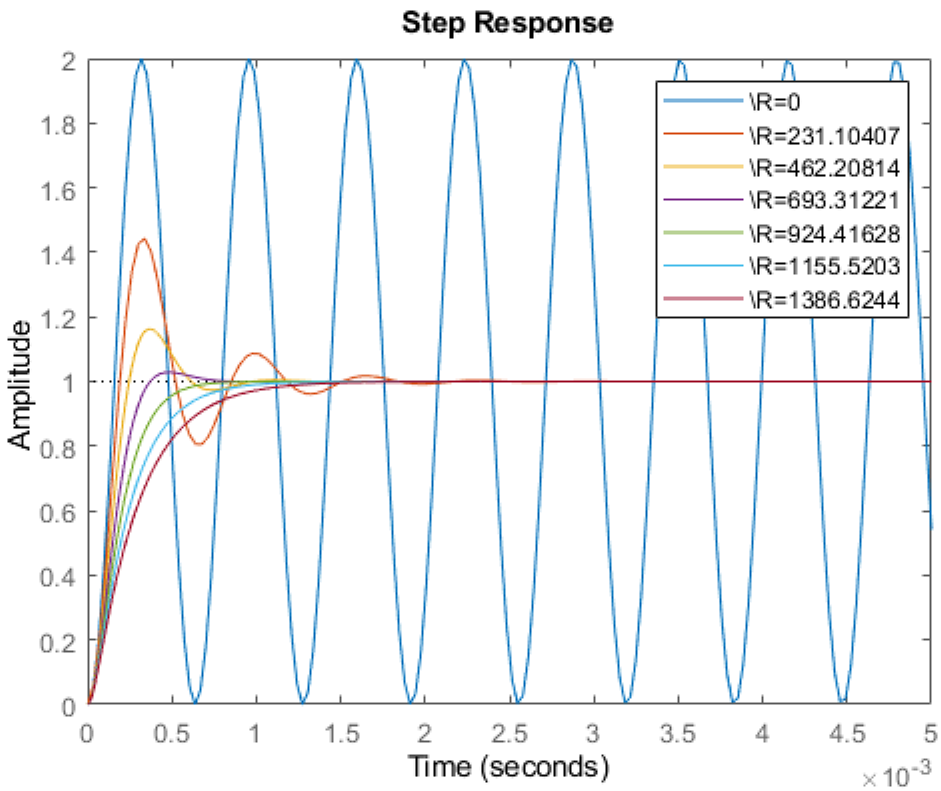
Step Response
Amplitude
Time (seconds)
$\times 10^{-3}$
\Wn=7000
\Wn=7500
\Wn=8000
\Wn=8500
\Wn=9000
\Wn=9500
\Wn=10000




# Part C part e

```
L=(47*10^(-3))
C=(0.22*10^(-6))
s=tf('s');

figure(9);

zeta=0:0.25:1.5;
hold on;
for i = 1:length(zeta)
    R(i)=(2*zeta(i)*L)*(1/sqrt(L*C));
    Tftop=(1/(L*C));
    Tfbot(i)=(s^2+(R(i)/L)*s+(1/(C*L)));
    Tf(i)=Tftop/Tfbot(i);
    hold on;
    figure(9)
    step(Tf(i), 0.005);


    Labels = '\R=' + string(R);
    legend(Labels)

end
hold off;
```

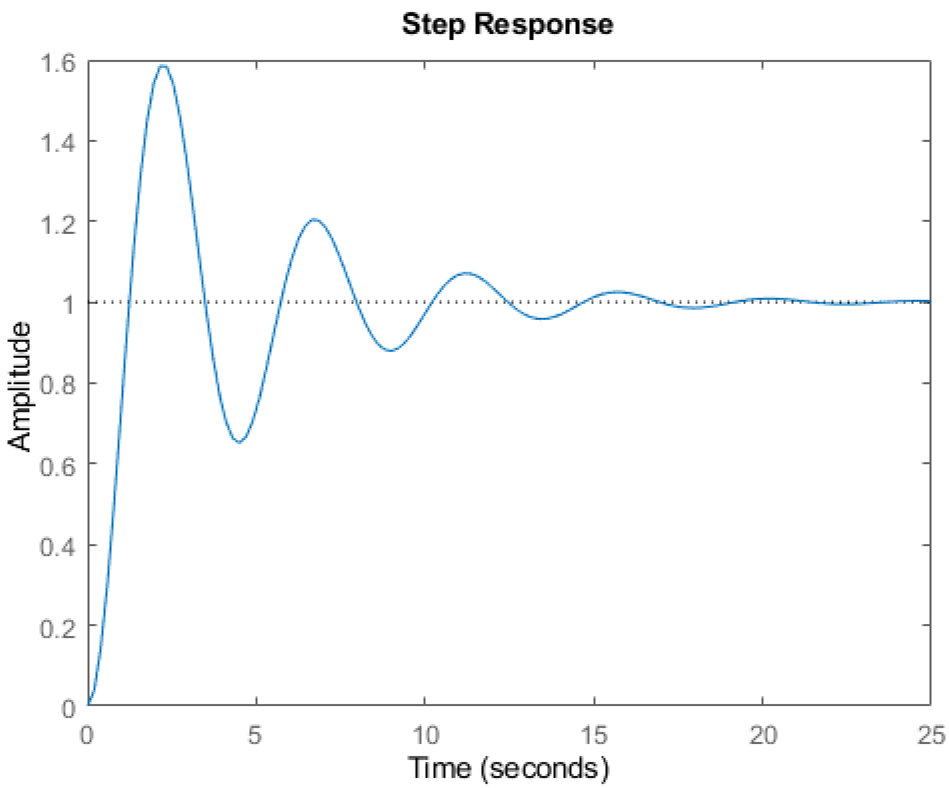
```
% Underdamped: R= Between 231-693 ohms
% Overdamped: R=1155+
% Undamped: R=0-231 ohms
% Critically damped: R=924

% Zeta is used, R is calculated using a range of zeta values, that way
% "guess and check" is not the method used to find resistance values.
% Underdamped, overdamped, and undamped was found by graph
 characteristics
% such as OS percentage. Critically damped does not have any visually
% unique characterisitcs, we looked for repeated poles on the real
 axis in
% order to find where it was critically damped. The resistance overall
 is
% changing the zeta value or damping frequency, which has an effect on
 step
% response. The resistance amd damping frequency have a direct
 relationship
% so as R increases, so does zeta and the step response will change as
 was
% analyzed previouslly in this lab.


L =

    0.0470


C =

   2.2000e-07
```




```
pos=((1.59-1)/1)*100
zeta=(-log(pos/100))/sqrt(pi^2+log(pos/100)^2)
Ts=17
wn=4/(Ts*zeta)

s=tf('s');
G=(wn^2)/((s^2)+(2*wn*zeta*s)+(wn^2))
figure(11)
step(G)
num=(wn^2);
den=[1,2*wn*zeta,wn^2];
% State Space
[A,B,C,d]=tf2ss(num, den)

%{
Measured normalized heading, measured by hand then verify with matlab
 the
response from the heading.
Solved with system, found the settling time.
Problem was that the ship was swinging back and forth (it will
 eventully
stabilize) and we do not know how the ship responds to input. From
 that
swinging, we were given a normalized step response from which we were
 able
```

```
to determine a transfer function for the ships motion. We saw that
 given
very little information, we were able to accurately model the ships
behavior and get very close to perfectly modeling the ship's step
 response
graph.
%}


pos =

   59.0000


zeta =

    0.1656


Ts =

    17


wn =

    1.4206


G =

          2.018
  ----------------------
  s^2 + 0.4706 s + 2.018

Continuous-time transfer function.


A =

   -0.4706   -2.0181
    1.0000         0


B =

     1
     0


C =

         0    2.0181
```

```
d =

     0
```




# Conclusion

```
%{
The lab began by examining the transfer function of a simple RLC
 circuit.
We plotted and analyzed its step and frequency responses,
revealing an underdamped system. We then explored how damping ratio
 and
natural frequency influence pole locations. After plotting poles on
 the
s-plane for the continuous-time transfer function, we created a for
 loop
to vary the damping ratio within a specified range. Similarly, we used
another for loop to vary the natural frequency and plotted the
 results.
Analysis showed that increasing damping ratio leads to larger real and
complex pole values. Regarding the natural frequency's effect on pole
location, we observed that as it increased, pole magnitudes approached
zero.
%}
```

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