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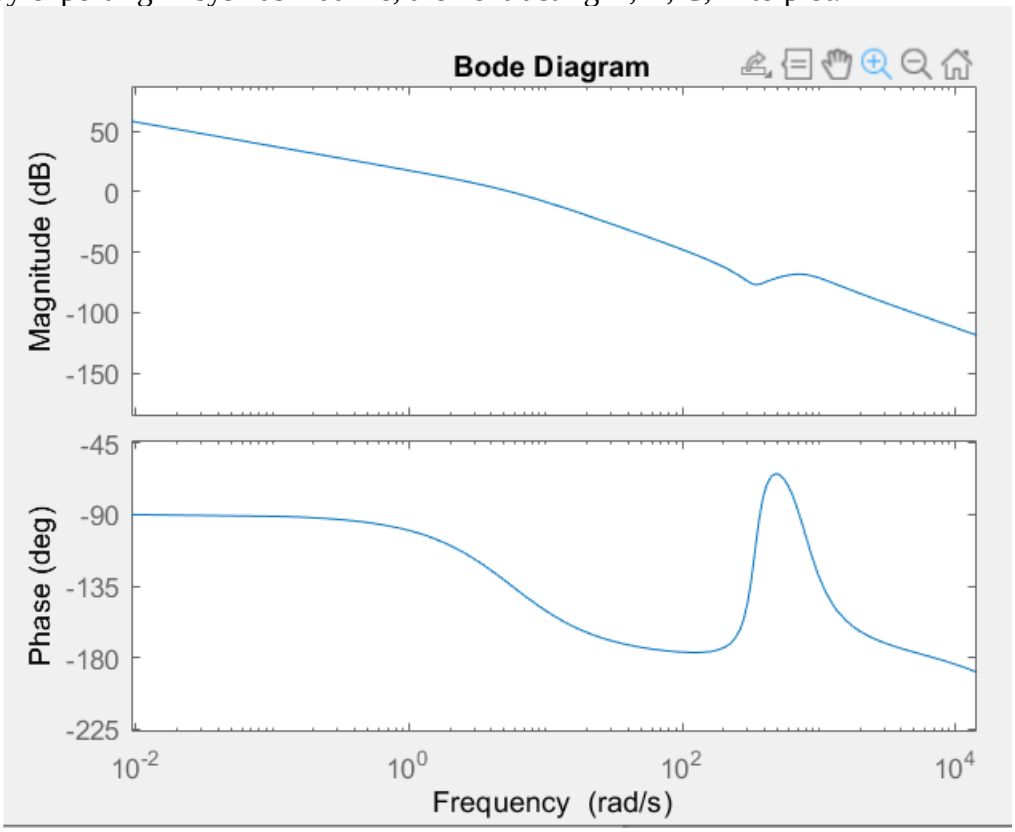
MECH421 Lab 3

1. I obtain this by exporting linsys1 as mat file, then extracting A, B, C, D to plot.



2.
We can use lead lag compensator to satisfy phase margin and cross over frequency requirements. I picked 75 deg as initial pick for phase margin, since it's a decent bit above 60 deg. I picked 10000 rad/s as cross over frequency as it's reasonably high. We can use these two numbers to solve for alpha and T.

$$C(s) = K\frac{1+\alpha Ts}{1+Ts}$$

$$\alpha = \frac{1+\sin(\phi_m)}{1-\sin(\phi_m)}$$

$$T = \frac{1}{\sqrt{\alpha}\omega_m}$$

K is the offset that will shift gain plot such that cross over frequency will become approximately 10000 rad/s. I picked K = 35000.

Cascading integrator will make steady state error equals zero.

$$\frac{K_i + s}{s} \qquad K_i = \omega_c / 10$$

The resulting controller is:

```
leadlag =

  26.59 s + 35000
  ---------------
  1.317e-05 s + 1

Continuous-time transfer function.

>> integrator

integrator =

  s + 1000
  --------
     s

Continuous-time transfer function.

>> controller

controller =

  26.59 s^2 + 6.159e04 s + 3.5e07
  -------------------------------
         1.317e-05 s^2 + s
```

3.

L(s) = C(s)P(s)

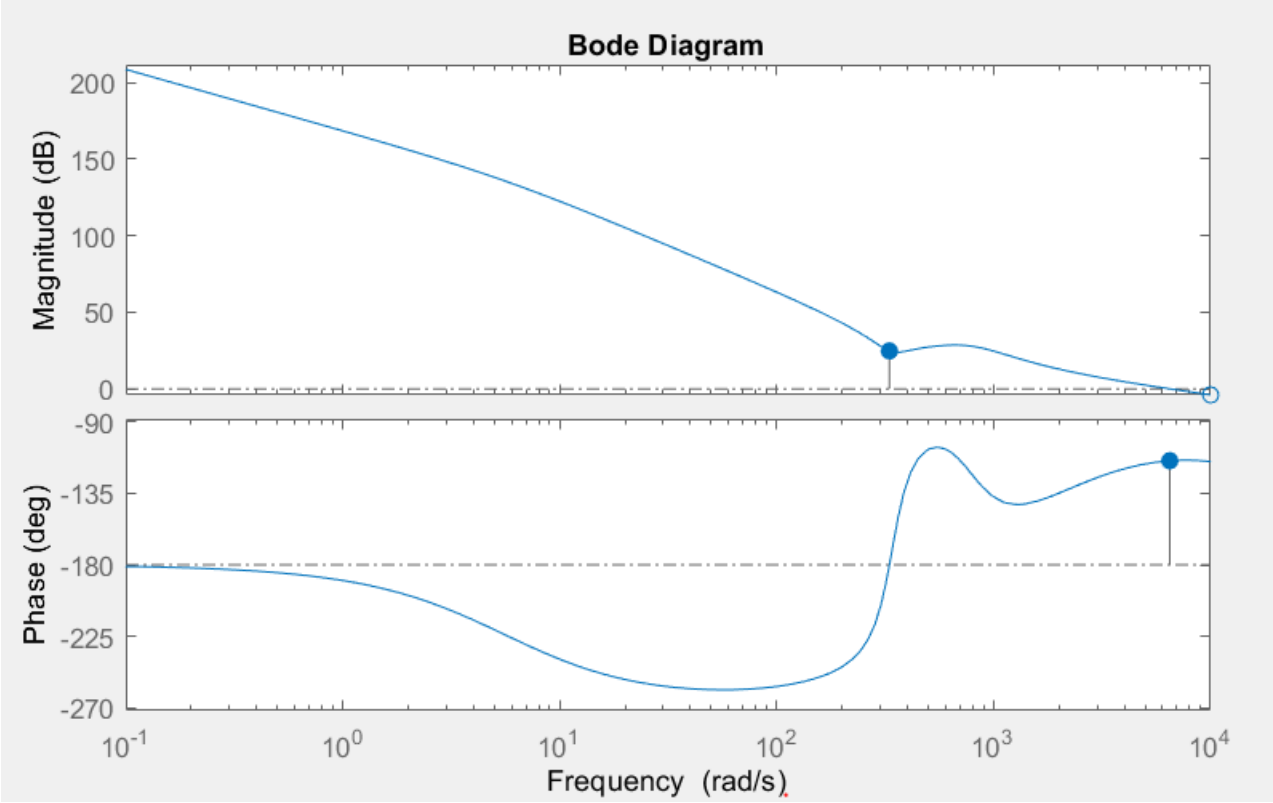
Since P(s) is a state space model, L(s) is too. We can convert L(s) to transfer function like shown below.

```
>> [n,d]=ss2tf(system.A, system.B,system.C,system.D)
```

```
>> Ls = tf(n,d)

Ls =

            -2.745e16 s^6 + 1.546e27 s^5 + 1.373e31 s^4 + 2.689e34 s^3 + 1.763e37 s^2 + 4.46e39 s + 1.53e42
  ----------------------------------------------------------------------------------------------------------------------
  s^10 + 2.087e07 s^9 + 5.087e13 s^8 + 7.254e18 s^7 + 2.903e23 s^6 + 1.819e27 s^5 + 1.226e30 s^4 + 1.007e33 s^3
                                                                                                  + 5.678e33 s^2
```

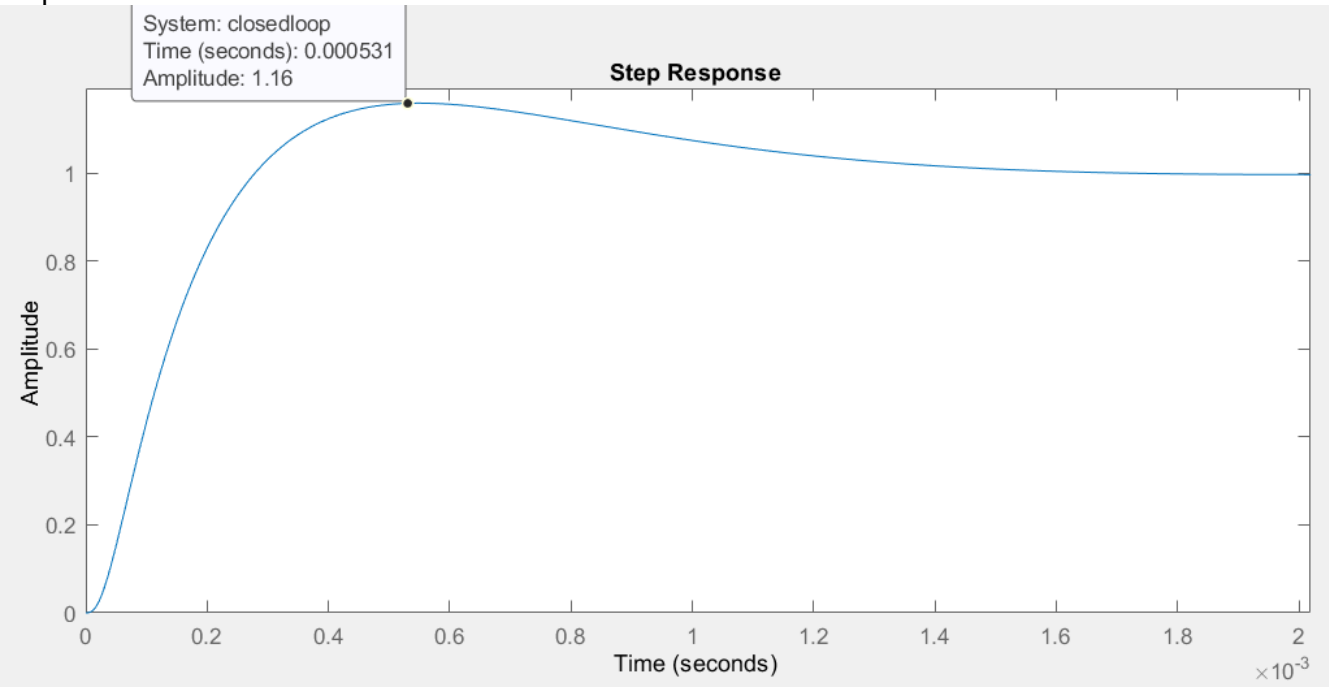


System: system
Phase Margin (deg): 65.5
Delay Margin (sec): 0.000176
At frequency (rad/s): 6.48e+03
Closed loop stable? Yes

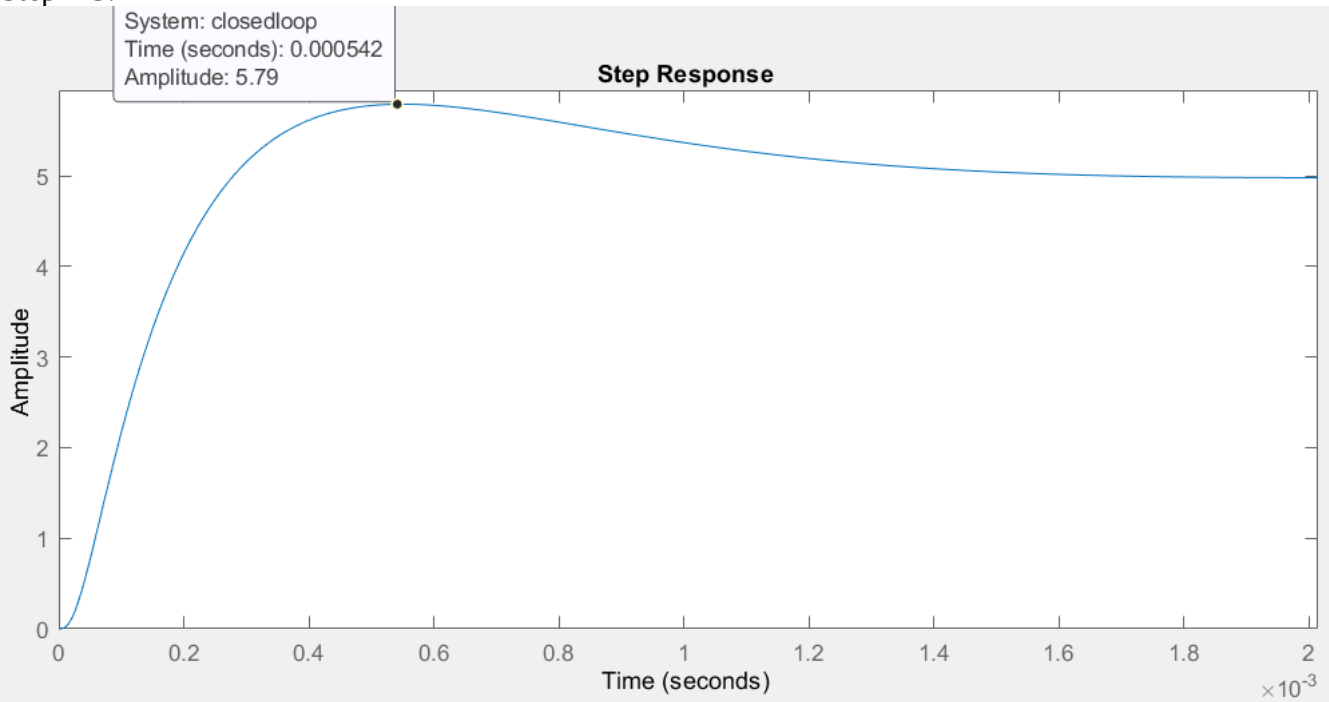
We can see that phase margin of 65.5 deg is more than 60 deg requirement. Cross over frequency is 6480 rad/s which is reasonably high. Therefore, requirements are achieved.

4.

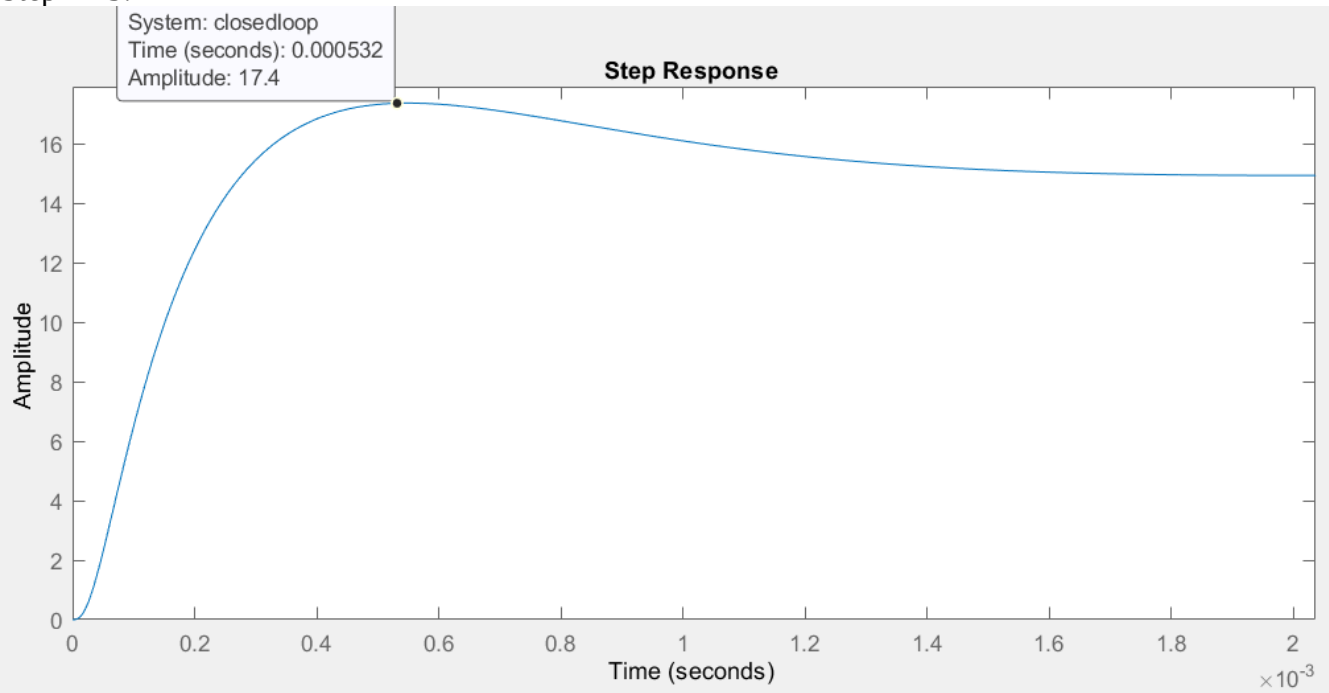
Step = 1:



Step = 5:



Step = 15:



For all:
Rise time: 1.9176e-04 s
Overshoot: 14.6209%
Amplitude is linearly proportional to input size, with no other changes observed.

Appendix: MATLAB code

```
% q1
load('q1.mat'); % exported from model linearizer
a = LinearAnalysisToolProject.Plots.Variables.Value.A;
b = LinearAnalysisToolProject.Plots.Variables.Value.B;
c = LinearAnalysisToolProject.Plots.Variables.Value.C;
d = LinearAnalysisToolProject.Plots.Variables.Value.D;
system = ss(a,b,c,d);
plot = bodeplot(system);
plot.showCharacteristic('AllStabilityMargins');
p = getoptions(plot);
p.PhaseMatching = 'on';
p.PhaseMatchingFreq = .1;
p.PhaseMatchingValue = -90;
setoptions(plot,p);
% q2
w = 10000;
phi = 75; % deg
phi = phi * pi/180;
a = (1+sin(phi))/(1-sin(phi));
t = 1/(sqrt(a)*w);
K = 35000; % trial and error
Ki = w/10;
integrator = tf([1 Ki], [1 0]); % integrator
leadlag = tf([K*a*t K], [t 1]); % lead lag compensator
controller = leadlag*integrator;
system = controller*system;
% q3
plot = bodeplot(system);
plot.showCharacteristic('AllStabilityMargins');
p = getoptions(plot);
p.PhaseMatching = 'on';
p.PhaseMatchingFreq = .1;
p.PhaseMatchingValue = -90;
setoptions(plot,p);
setoptions(plot,'Xlim',[0.1,10000]);
% q4
closedloop = system/(1+system); % black's formula
step(closedloop);
opt = stepDataOptions('StepAmplitude',5);
step(closedloop, opt);
opt = stepDataOptions('StepAmplitude',15);
step(closedloop, opt);
info = stepinfo(closedloop);
```