Engineering 446

Control Systems Laboratory

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Lab Assignment #4 The Effect of Controller Gain on open- and closed-loop responses in Frequency Domain

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Introduction

The ultimate goal of this laboratory assignment is much like that of the previous assignment which allowed the user to get acquainted with a feel for the affect of the controller again on some vital system characteristics. The difference here is that we are working in Frequency domain and not time domain. As such, it is important to be familiarized with systems not only in the time domain but also within the frequency domain. The specific plant being used in this laboratory assignment will be a third order system plant and the function is as follows:

:

$$G_p(s) = \frac{K_p {\omega_n}^2 (s+1)}{(\tau s + 1)(s^2 + 2\zeta\omega_n s + {\omega_n}^2)}$$

Specific values for the variables will vary throughout the lab. A real world example of this application would be the position control associated with a DC motor with time delay in the position sensor.

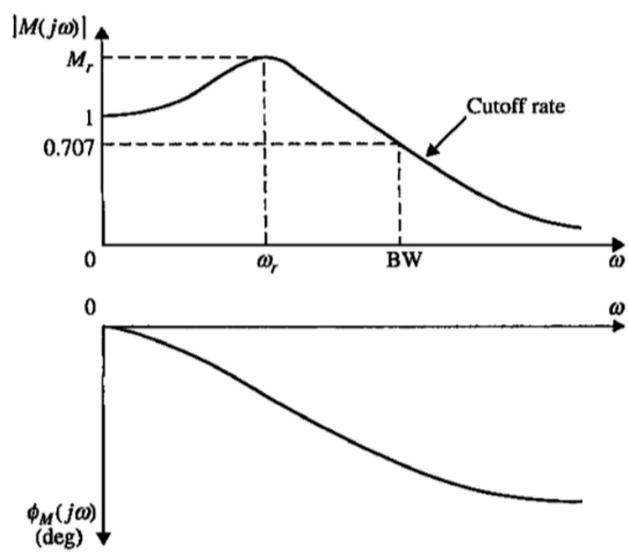
Problem Definition

The goal of this laboratory assignment is to plot the unit step responses of the open loops system for the range of controller again values that are given; 0.2, 0.5, 1 and 10. The controller has a gain equivalent to, K_c, in the upstream direction of the plant in a system with no feedback or otherwise known as open loop. The loop around the system will then be closed with a unit negative feedback line in order to obtain the unit step response of the closed loop system for the range of controller games indicated previously. Matlab control system toolbox commands such as tf and step will be implemented instead of using Simulink. After the plots are generated for the given controller gains; the values of the following staff response characteristics of both the open and close loop systems of those simulated staff response data can be determined; a legend will be included to indicate these points.

Explanation of the experiments

The goal of the experimentation portion of this laboratory assignment is to understand the sample code provided, then to be able to replicate it and understand all the functions/modules. When using frequency-domain methods it is important to define a set of specifications for the system. It is necessary to understand important system functions that are frequently used in practice. Resonant Peak value, Resonant frequency and bandwidth. The plot below shows the frequency-domain analysis of a typical gain-phase characteristics of a control system which has feedback.

Frequency-Domain Analysis



For the range of controller gain given in the laboratory assignment the user is required to obtain the frequency response characteristics of the system; bandwidth, peak resonance, and the resonance frequency. This is achieved by means of obtaining a bode plot for the open and closed loop systems. The curves obtained are used to find the characteristics.

Models/Calculations/ Simulation Results

Open Loop

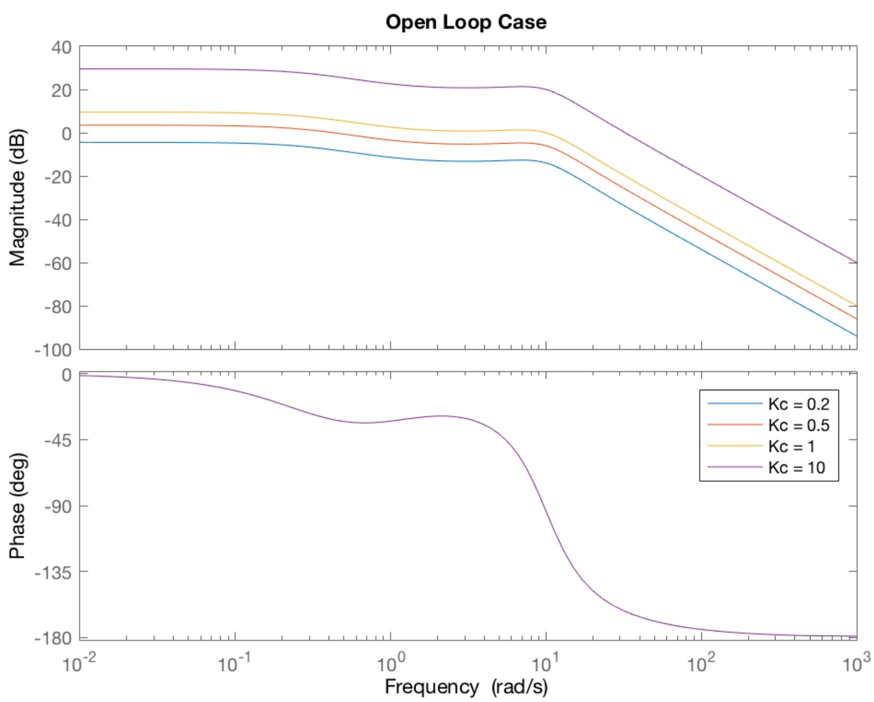
	Kc = 0.2	Kc = 0.5	Kc = 1	Kc = 10
Bandwidth	0.3776	0.3776	1.4277	0.3776
Peak Res.	0.6000	3.5218	9.5424	29.5424
Res. Frequ.	0	0	0	0

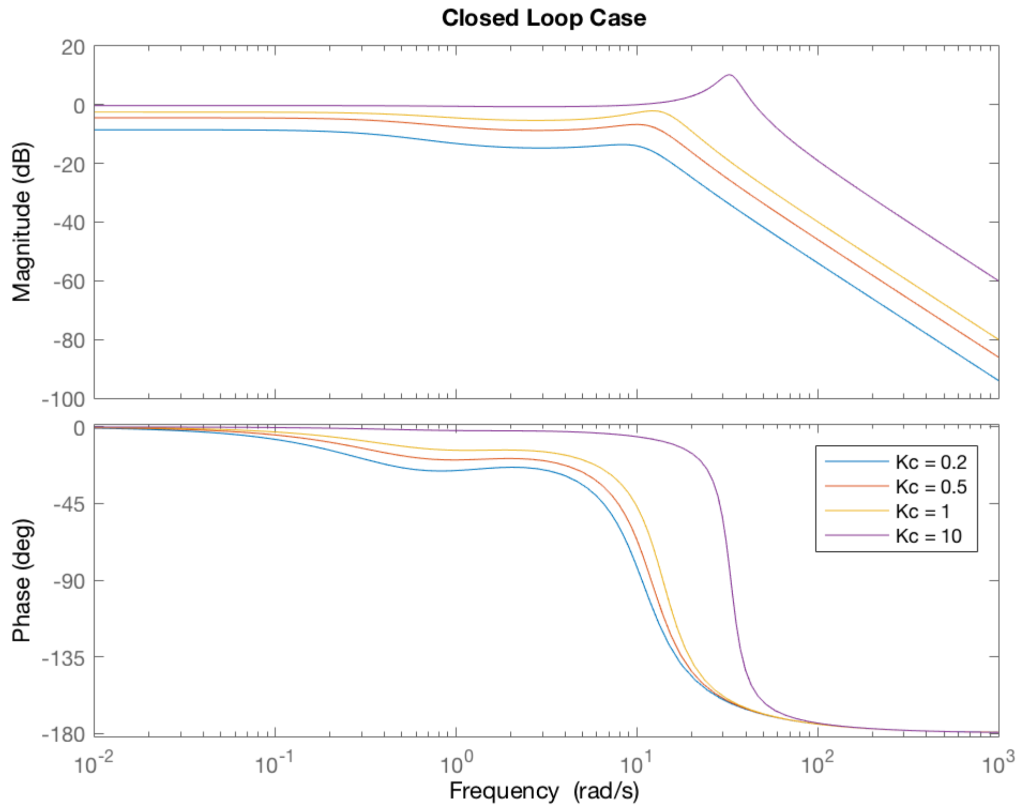
Step Response w/ feedback

	Kc = 0.2	Kc = 0.5	Kc = 1	Kc = 10
Bandwidth	0.5810	0.9440	17.0096	49.7724
Peak Res.	0.3750	0.6000	0.7500	0.9677
Res. Frequ.	0	0	0	0

```
% LAB 4 Code
% Farnam Adelkhani (915815724)

clear; % Clear all variables.
Kp = 3;
tau = 3;
zeta = 0.5;
wn = 10;
Kc = [.2; .5; 1; 10]

s = tf('s')
Gp = Kp * wn^2 * (s + 1) / (tau *s +1) / (s^2 + 2* zeta * wn *s +wn^2)

% ******* OPEN LOOP Case *******
figure
hold % Hold plotting.
for n = 1:4
Gs = Gp * Kc(n);
bode(Gs); % Draw Bode plots.
disp(['********** Open Loop Kc = ', num2str(Kc(n)), ' **********'])

BW = bandwidth(Gs) %bandwidth
DCGain = dcgain(Gs) %dcgain
DCGaindB = 20 * log10(DCGain) % Convert to dB, log10=log
[MaxGain, MaxFreq] = getPeakGain(Gs) %getPeakGain
```

```
MaxGaindB = 20 * log10(MaxGain) % Gain is not in dB; convert to dB.
end
hold % Release the plots.

title('Open Loop Case')
legend('Kc = 0.2', 'Kc = 0.5', 'Kc = 1', 'Kc = 10', 'location', 'northeast')

% ******* CLOSED LOOP *******
figure
hold
for n = 1:4
Gs = feedback(Gp * Kc(n), 1);
bode(Gs)
disp(['********** Closed Loop Kc = ', num2str(Kc(n)), ' **********'])
BW = bandwidth(Gs)
DCGain = dcgain(Gs)
DCGaindB = 20 * log10(DCGain)
[MaxGain, MaxFreq] = getPeakGain(Gs)
MaxGaindB = 20 * log10(MaxGain)
end
hold
title('Closed Loop Case')
legend('Kc = 0.2', 'Kc = 0.5', 'Kc = 1', 'Kc = 10', 'location', 'northeast')
```





Closed Loop Case
20
0
-20
-40
-60
-80
-100
Magnitude (dB)
0
-45
-90
-135
-180
Phase (deg)
Kc = 0.2
Kc = 0.5
Kc = 1
Kc = 10
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Frequency (rad/s)

Conclusions

Matlab is a powerful tool for simplifying calculations that require the user to find the output characteristics of sets of plots of information, outputted to tabular form in the matlab command window. For this particular experiment the variables are first established, then the open loop case is setup where the bode plot are plotted. The system characteristics are then defined by shorter names that are fed to the system output. By overlapping the plots, trends in the information can be exposed. We can that as the value for K_c increased, the peak for the closed loop case is significantly reduced. It is important to remember to convert between units when the gain is not in the necessary units of dB. This is achieved by using the following command: MaxGaindB = 20*log10(MaxGain), remembering that log10, in matlab, really just means log.

List of References

"Simulink Basics Tutorial", SFSU 446 Laboratory manual book. Provided by University.