Table of Contents


```
%
 ##########################################################################
% TUHH :: Institute for Control Systems :: Control Lab
%
 ##########################################################################
% Experiment CSTD1: Identification and Control of a Torsional Plant
%
% Copyright Herbert Werner and Hamburg University of Technology, 2014
%
 ##########################################################################
% This file is to be completed by the student.
% The completed version is to be published using
%   publish('CSTD1_LeadLagDesign','pdf')
% and submitted as a pdf-file at least one week prior to the scheduled
 date
% for the experiment
%
% !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
% !!!  The gaps in the code are denoted by XXX !!!
% !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
%
% HINT 1:
% if you want to find out more about a certain command, just type
% 'help command' into the matlab window
% HINT 2:
% use section evaluations (Ctrl+Enter) to run the code within a single
% section

%----------------------------
% v.1.2 - 30-10-2017
% by Antonio Mendez G
%----------------------------

clc
clear all
close all
```

1 Frequency Response

Calculate the transfer function of the system.

```
load IdentifiedSystem

sys_tf = tf(sys(3));

w_bode = logspace(-2,2,1000);

% Plot the bode diagram of the system
bode(sys_tf, w_bode)
grid on
hold on
```

```
Error using load
'IdentifiedSystem' is not found in the current folder or on the MATLAB
 path, but exists in:
    C:\Users\Dell\Documents\Desktop\Preliminary_StudIP\Parameter
 Identification
    C:\Users\Dell\Documents\Desktop\Preliminary_StudIP\Controller
 Design\LQG + LQGi
    F:\TUHH\Sec Sem\Control LAB\New file\Preliminary_StudIP\Controller
 Design\LQG + LQGi
    F:\TUHH\Sec Sem\Control LAB\New file\Preliminary_StudIP\Controller
 Design\LeadLag

Change the MATLAB current folder or add its folder to the MATLAB path.

Error in CSTD1_LeadLagDesign (line 39)
load IdentifiedSystem
```

2 Lead Lag Design

Here, design a Lead Lag compensator, either by the procedure described in the lecture notes or by the loop shaping procedure. In here, few steps are covered for the loop shaping procedure. You are very welcome to use the steps described in the lecture notes as well.

Define the bandwidth wb. C: lead lag compensator

```
wb = 1.2;
C = 1; %Initial controller

% Obtain the gain from the open loop plant that achieves the desired
% bandwith. Plug this gain in C
% hint: use evalfr()
C = C*evalfr(sys_tf,wb);
bode(sys_tf*C, w_bode)

% Design a lead compensator to obtain the desired phase margin
% hint: use makeweight() for lead and lag compensators.
C = C*makeweight(0.15,wb,1/0.15);
bode(sys_tf*C, w_bode)


% Design a roll-off filter (e.g. notch)
% to reduce the gain of the resonant peaks.
```

```
% make sure to use unity low frequency gain to not change the
 crossover,
wn1 = 17.4;
wn2 = 31;
q = 3;
F1 = tf([1 0.01 wn1^2],[1 q*wn1 wn1^2]);
F2 = tf([1 0.01 wn2^2],[1 q*wn2 wn2^2]);


C = C*F1*F2;
bode(sys_tf*C, w_bode)



legend('Open Loop', 'Bandwidth Adjustment', ...
    'Phase Margin Increse', 'Peaks Suppresion')
% If necessary, use SISOtool to further tune your controller, for
 that,
% uncomment the following line:
% sistool(sys_tf, C)
```

3 Simulation

Step response of the closed loop system

```
dist_on = 0; %disturbances are off

figure
sim('CSTD1_ClosedLoopLeadLag');
plot(tout, sim_reft3);
hold on
plot(tout, sim_Theta3);
title('Reference tracking (Lead Lag)');
ylabel('\Theta_3 [deg]')
xlabel('Time [s]')

grid on

% Control input
figure
plot(tout, sim_Torque);
title('Control Signal (Lead Lag)');
ylabel('Torque [Nm]')
xlabel('Time [s]')
grid on
```

4 Frequency Responses

Bode diagram of the controller

```
figure
bode(C, w_bode)
grid on
```

```
title('Controller Bode Diagram');

% Bode diagram of the closed-loop system
figure
bode(sys_tf, w_bode)
grid on
title('Closed Loop Bode Diagram');

% Bode diagram of the output/input disturbance rejection
% Compute the corresponding transfer functions from the output/input
% disturbances to the measured signal
figure
bode(C, w_bode)
grid on
hold on
bode(sys_tf, w_bode)
title('Output and Input Disturbance Rejection Bode Diagram');
```

5 Disturbance Rejection

Step response of the closed loop system under disturbances

```
dist_on = 1; %disturbances are on

figure
sim('CSTD1_ClosedLoopLeadLag');
plot(tout, sim_reft3);
hold on
plot(tout, sim_Theta3);
title('Disturbance Rejection (Lead Lag)');
ylabel('\Theta_3 [deg]')
xlabel('Time [s]')
grid on
```

6 Torsional Springs Safety

```
%
% The plot of the twist angle of the torsional springs
% is shown. The absolute twist value should be always
% smaller than  20 degrees.
figure()

suptitle('All signals must be smaller than 20 degrees')

subplot(2,1,1)
plot(tout, abs(sim_Theta2-sim_Theta1));
grid on
ylabel('Twist [deg]')
legend('|\theta_2 - \theta_1|')

subplot(2,1,2)
plot(tout, abs(sim_Theta2-sim_Theta3d));
grid on
```

```
xlabel('Time [s]')
legend('|\theta_2 - \theta_3|')
ylabel('Twist [deg]')
```

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