ELEC ENG 3CL4: Introduction to Control Systems Lab 5: Phase Lead-Lag Compensator Design Using Root Locus (Experiments)

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Objective

To design a phase lead-lag compensator for a marginally-stable servomotor using the root locus method, and to examine the frequency domain properties of the design.

Assessment

This laboratory is conducted in groups of no more than two students. The students are required to attend their assigned lab section. The assessment of this lab will occur based on your pre-lab design report, in-lab design and experiment activities, and a final lab report. Each group is required to submit their pre-lab report electronically through the course webpage by 12:01pm on the day of the lab. Pre-labs submitted after 12:01pm but before 2:30pm will be subject to a penalty of 50%. No marks will be awarded to pre-labs submitted after 2:30pm. You will earn a maximum of 100 marks from Lab 5 activities. Lab 5 will contribute to a maximum of 25% of your total lab grade for this course. The components of the assessment are:

- Pre-lab root locus based phase lead-lag control design and evaluation **(30 marks)**;
- In-lab design and experiment activities **(45 marks)**;
- Final laboratory report **(25 marks)**.

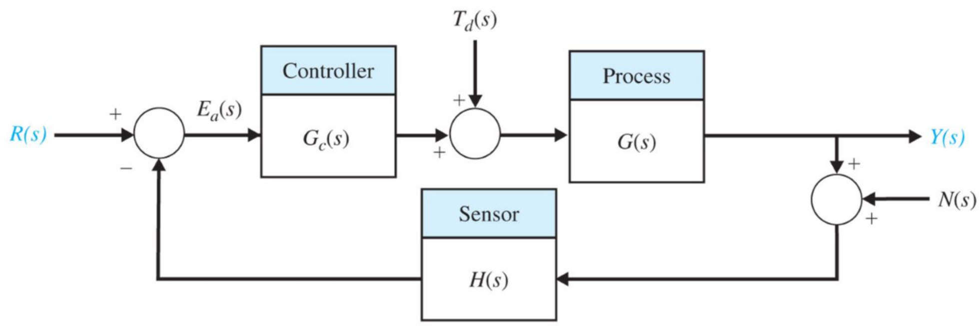

Figure 1: A feedback control system. We will focus on the case in which $H(s) = 1$. (Figure 10.1 of Dorf and Bishop, *Modern Control Systems*, 11th edition, Prentice Hall, 2008.)

1 Design of a Lead-Lag Compensator for the Quanser Servomotor

In this section we will design a lead-lag compensator for the model of the Quanser servomotor. You should use the values of A and τ_m that you identified in Lab. 2. and you should retrieve the lead compensator that you designed for the Quanser motor in the experimental part of Lab. 4. (Note that both the plant and the compensator that you will design are different from those in the pre-lab.)

In the experimental part of Lab. 4 you designed a lead compensator for the Quanser servo motor to achieve a 20% overshoot and a 2% settling time of 0.5 sec. In this lab, we would like to achieve similar characteristics in the transient response, but we would like to reduce the steady state error due to a step disturbance by a factor of 10.

For the design part of the lab, you must perform the following tasks:

i) Using a procedure similar to that in the pre-lab exercise, but using the model for the Quanser plant, the lead compensator for the experimental part of Lab. 4, and the design specifications in this section, design a lead-lag controller for the Quanser model. **(15 marks)**

ii) Verify your design by performing Matlab calculations analogous to those outlined in the pre-lab. **(10 marks)**

2 Experiment: Implementation of Your Lead-Lag Compensator

We will now implement the controller that you have just designed on the Quanser servomotor.

i) Download the simulink file `qube_servo2_EE3CL4_Lab5.slx` from Avenue-to-Learn, and open it. Open Quanser Interactive Labs, and proceed to the "Servo Workspace" as described in Lab. 1.

ii) Note that the frequency of the input signal has been reduced from previous labs.

iii) Make sure that the amplitude of the disturbance signal is set to zero.

iv) Enter the coefficients of the numerator polynomial and the denominator polynomial for the lead controller that you designed for the model of the Quanser servomotor in the experimental part of Lab. 4.

v) Run the simulation and measure the peak overshoot and the 2% settling time.

vi) Stop the experiment, and close Quanser Interactive Labs.

vii) Enter the coefficients of the numerator and denominator polynomials for the lead-lag controller that you designed for the model of the Quanser servo motor in Section 1 of this lab.

viii) Relaunch Quanser Interactive Labs.

ix) Run the simulation and measure the peak overshoot and the 2% settling time.

x) Compare these measurements to those for the case of the lead controller and discuss whether or not your lead-lag controller has achieved the performance specifications that are related to the input-output transient performance. **(20 marks)**

xi) Stop the experiment, and close Quanser Interactive Labs.

xii) Set the amplitude of the disturbance signal to $\tau_d = 0.1745$.

xiii) Enter the coefficients from the lead controller that you designed in the experimental part of Lab. 4.

xiv) Relaunch Quanser Interactive Labs.

xv) Run the simulation and measure the steady-state error due to the disturbance. Since the disturbance is positive and essentially constant, it is easier to interpret this error in the "step up" phase of the square wave.

xvi) Stop the experiment, and close Quanser Interactive labs.

xvii) Enter the coefficients from the lead-lag controller that you designed in Section 1 of this lab.

xviii) Relaunch Quanser Interactive Labs.

xix) Run the simulation and measure the steady-state error due to the disturbance.

xx) Compare this measurement to that for the lead controller, and discuss whether or not your lead-lag controller has achieved the performance specifications related to the steady-state response to a step disturbance. **(20 marks)**

xxi) Stop the experiment, and close Quanser Interactive Labs.

xxii) Set the amplitude of the disturbance to zero.

xxiii) Change the input signal to a triangle wave with an amplitude of 2.0769, which corresponds to an angle of $135°$. Leave the frequency unchanged.

xxiv) Relaunch Quanser Interactive Labs.

xxv) Run experiments to show the behaviour of both the lead compensated closed loop and the lead-lag compensated closed loop when the input is this triangular wave.

xxvi) Use those experiments to measure the steady state error due to a ramp input for each of the controller designs.

xxvii) Compare these steady-state errors. To what extent do your observations align with the insight developed from the linearized models in the pre-lab. **(5 marks)**

3 Laboratory Report (25 marks)

Each group must submit an electronic report through Avenue to Learn due by midnight one week from the day of the lab. For example if your lab is on Monday, your report would be due by next Monday at midnight. Reports that are late up to 24 hours will receive a penalty of 50%. No marks will be awarded to reports that are more than 24 hours late. The report should be formatted in a single-column, using single-spaced text and the Times New Roman 12 or equivalent font. The group members should clearly state their individual contributions to the report in a statement in the beginning of the report. The laboratory report must include the design calculations and plots of the results of the experiments, followed with a brief analysis of these results. You must measure the values of the settling time, the percentage overshoot in the step response, the steady-state error due to the disturbance, and the steady-state error to the ramp input from the experiments. You should compare the measurements you obtain for the lead and lead-lag controller designs. You should compare those measurements to each other, and to the predictions made by the theory. You should discuss any potential discrepancies between the experimental and theoretical results.