Department of Electrical Engineering, Automation and Control

31300 Linear control theory 1

Autumn 2021

Exercises week 10 - draft version

This is the last exercise.

Description of dynamic system:

In this exercise, the question is related to the electro-mechanical control system from Exercise no. 4 (from the first report) will be used.

Questions:

1. Write the open-loop transfer function $G_{\text{open}}(s) = G(s)H(s)$ for the electro-mechanical system used in Exercise no. 4. The parameters used in the first report are also used here for the 3 working points. Analyze $G_{\text{open}}(s)$, calculate e.g. system poles, zeros, gain, type, damping, the undamped frequency, etc. for the 3 work points.

   In the following questions, only $x0 = 0.003m$ is used as the linearization point.

2. It is now desired that the system be used in closed loop using a feedback controller. Based on the analysis of the open-loop system $G_{\text{open}}(s)$, formulate realistic requirements for the closed-loop system. These requirements can be given in both the time domain as well as in the frequency domain.

3. Let's use a feedback controller where the position of the system (mass) is applied in the feedback (i.e. with $H(s)$). Explain the effect on the closed-loop performance by using standard controllers (P, PI, P-lead and PI-lead).

   Discuss (but do not design controllers here) why it is difficult to achieve reasonable performance when using standard controllers (P, PI, P-lead and PI-lead).

4. In order to obtain a reasonable control of the system, an internal control loop is introduced. Here, the velocity is feedback using a velocity sensor with gain H_{vel}. The velocity controller is given as a constant gain K_{vel} in the feedforward part of the system, see e.g. Exercise no. 9 for a description. Write down the open-loop system including an internal velocity feedback loop. Explain how it will be possible to change the damping of the open-loop system using this velocity feedback.

   Hint: It is a good idea to do the calculation of the open-loop transfer function including a velocity feedback loop by considering the open-loop block diagram for the system. It is also possible to explain how such an internal velocity feedback loop can be applied for a change of the damping. See also Exercise no. 9 for inspiration.

In the following, use $H_{vel} = 1000$.

5. Calculate K_{vel} so that the open-loop system gets a reasonable damping.
6. Design a P regulator so that a reasonable phase margin is obtained. Consider the steady state error (closed loop) when using this controller. Show by simulation that the closed-loop system behaves in accordance with the design. Also show that the control signal is appropriate.
7. Examine how good the designed controller is in terms of robustness. One of the parameters that can be difficult to determine is the damping constant $D1$ in the mechanical part of the system. Analyze both the open-loop and closed-loop system when $D1$ increases (not more than a factor 5 - 10) and when $D1$ is completely removed. The analysis can easily be done in the frequency domain but can also be done in the time domain. Discuss the result.
8. Design a PI controller with the internal velocity feedback designed above. Show by simulation that the closed-loop system behaves in accordance with the design. Also show that the control signal is appropriate.

Report no. 2:

General info:

This report deals with the above exercise. The report must be prepared by a maximum of 3 students.

Deadline for the report: The report must be submitted at DTU Learn no later than December 5, 2021. Please also handle in a hard copy to me.

Report size: It is strongly recommended that the report no. 2 is not too long.

Report contents:

Page 1: The front page must contain course name and number, report number, date, student names and study numbers as well as signatures.

The following pages: Answers to the above 8 questions.