Lab 9

Stability Analysis in the Frequency Domain

Objective

The lab aims to teach the students to determine system stability and stability margins using Nyquist diagram and Bode diagram.

Background Materials

Lecture notes for the course Control Theory 1, Theme 7. Frequency Response Analysis, pp. 17 – 36.

Tasks

Part I: Stability Analysis using Nyquist Diagram

Task 1

Consider the feedback control system shown in Figure 1. The values of the parameters are $T_1 = 0.06$ s, $T_2 = 0.03$ s, $a_0 = 0.01\ \text{s}^2$, $a_1 = 0.25$ s, $c_0 = 0.04\ \text{s}^2$, and $c_1 = 0.29$ s. Using MATLAB, analyze the stability of the closed-loop system for $k = 2$, $k = 4$, and $k = 6$.

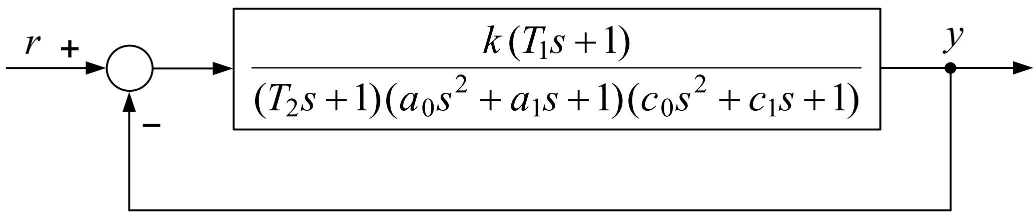

Figure 1 Block diagram of the control system for Task 1.

Task 2

Consider the control system in Figure 2. Apply the Nyquist criterion to investigate the stability of the control system. To verify the result obtained, plot the closed-loop system step response.

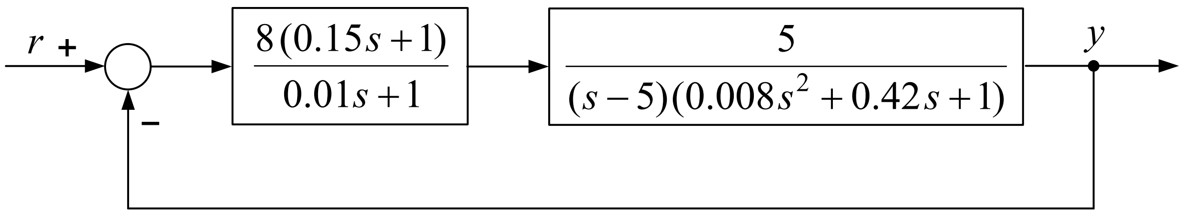

Figure 2 Block diagram of the control system for Task 2.

Task 3

Block diagram of the feedback control system is shown in Figure 1. The values of the parameters are $k_2 = 2\ \mathrm{s}^{-1}$, $T = 0.01\ \mathrm{s}$, $c_0 = 0.0004\ \mathrm{s}^2$, and $c_1 = 0.008\ \mathrm{s}$.

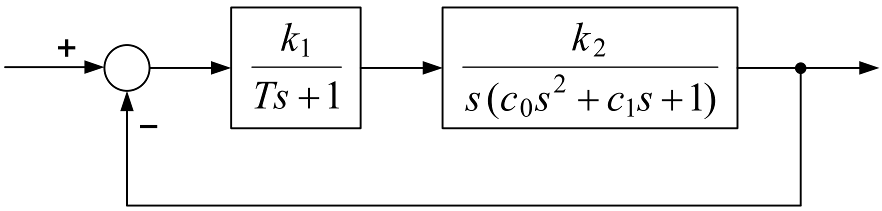

Figure 3 Block diagram of the control system for Task 3.

(a) Using the Nyquist criterion, determine the stability of the control system for $k_1 = 5$ and $k_1 = 20$.

(b) Determine the value of the gain k_1 for which the control system is marginally stable.

Task 4

A unity feedback control system has a loop transfer function

$$L(s) = \frac{10(0.4s+1)}{s(s-1)(0.02s+1)(0.002s^2+0.09s+1)}.$$

Apply the Nyquist criterion to analyze the stability of the control system. To verify the obtained result, plot the closed-loop system step response.

Task 5

A unity feedback control system has a loop transfer function

$$W(s) = \frac{8}{2s^2+3s+1} e^{-\tau s}.$$

Using the Nyquist criterion, determine the stability of the control system for the following values of the time delay: $\tau = 0.2$ s, $\tau = 0.4$ s, $\tau = 0.8$ s, $\tau = 1.6$ s, and $\tau = 3.2$ s.

Task 6

Block diagram of the temperature control system is shown in Figure 4. The values of the parameters are $k_1 = 8\ \%/^\circ\mathrm{C}$, $k_2 = 0.5\ ^\circ\mathrm{C}/\%$, $T_1 = 20$ s, $T_2 = 25$ s, $c_0 = 4200\ \mathrm{s}^2$, and $c_1 = 180$ s. Find the gain margin and the phase margin for the control system from the Nyquist diagram.

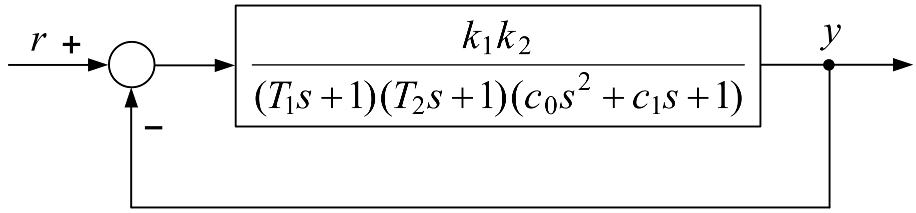

Figure 4 Block diagram of the control system for Task 6.

Part II: Stability Analysis using Bode Diagram

Task 7

Consider the position control system shown in Figure 5. The values of the parameters are $k_2 = 2\ \mathrm{s}^{-1}$, $T_1 = 0.1$ s, $T_2 = 0.01$ s, $T_3 = 0.02$ s, and $T_4 = 0.25$ s. Using the MATLAB function `bode`, analyze the stability of the closed-loop system for $k_1 = 25$ and $k_1 = 250$. To verify the result obtained, plot the closed-loop system step response.

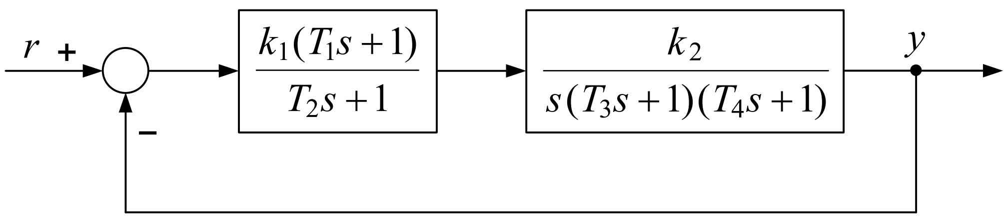

Figure 5 Block diagram of the control system for Task 7.

Task 8

Consider the control system examined in Task 7.

(a) Using the MATLAB function `margin`, find the gain margin and the phase margin when $k_1 = 25$.

(b) Determine the value of the gain k_1 for which the control system is marginally stable.

Task 9

Consider the control system in Figure 6. The values of the parameters are $k_1 = 5\ \text{Nm}/(\text{rad/s})$, $T_1 = 0.06\ \text{s}$, $c_0 = 0.00005\ \text{s}^2$, $c_1 = 0.01\ \text{s}$, $J = 0.1\ \text{kgm}^2$.

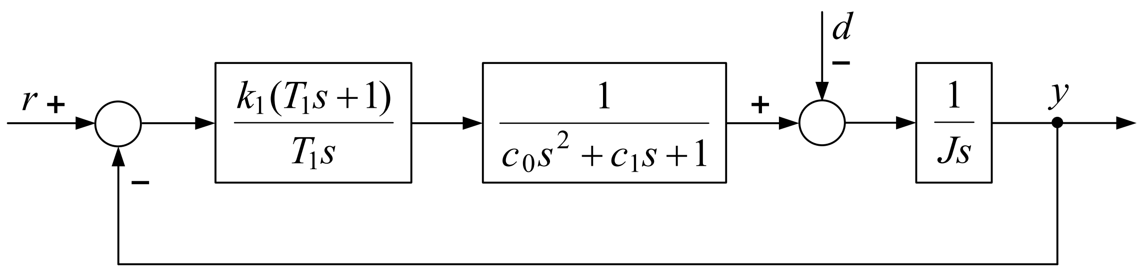

Figure 6 Block diagram of the control system for Task 9.

(a) Using the MATLAB function `bode`, determine the stability of the control system.

(b) Using the MATLAB function `margin`, find the gain and phase margins.

(c) Determine the value of the gain k_1 for which the control system is marginally stable.

Task 10

A unity feedback control system has a loop transfer function

$$L(s) = \frac{k}{(0.1s+1)(s^2+s+2)}.$$

Select a gain k so that the phase margin is approximately 30°.

Report Content

The lab report should contain the following:

- The objective of the lab.
- Formulation of the tasks.
- Results, MATLAB script-files, and obtained plots.
- Discussion of the obtained results.
- Conclusion.