

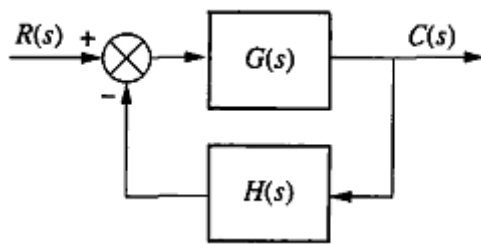
XMUT315 Control Systems Engineering

Laboratory 2: Stability and Time Domain Analysis

Due Date: Ask the XMUT co-teacher on how to submit the report.

A. Stability Analysis

- Given a negative feedback system as shown in the Figure 1 below, perform the following tasks.



$$G(s) = \frac{K}{s(s+2)^2} \quad \text{and} \quad H(s) = 1$$

Figure 1: Block diagram and transfer functions of a negative feedback system

- Determine the equivalent transfer function of the negative feedback system. [5 marks]
- Using MATLAB, find two values of gain that will yield closed-loop overdamped response. [5 marks]
- Repeat part (b) for underdamped response. [5 marks]
- For (b) and (c) cases, plot in MATLAB on one graph the time domain response of the system. [5 marks]
- Using Simulink, plot the step response of the system at each value of gain calculated to yield overdamped, underdamped, critically damped, and marginally stable responses. [10 marks]
- Plot the step responses in Simulink for two values of gain, K , above that calculated to yield marginal stability. [5 marks]
- At the output of the negative feedback system, cascade the system with the following transfer function of a compensator.

$$G_1(s) = \frac{1}{s^2 + 4}$$

Determine the overall transfer function equation of the system with the compensator. Set the gain, K , at a value that calculated for marginal stability and plot the step response in Simulink. Repeat for K calculated to yield plot just above marginal stability that leads to unstable system. [10 marks]

- h. From your plots, discuss the conditions that lead to unstable responses and discuss the effect of gain upon the nature of the step response of a closed-loop system. [5 marks]

B. Time Response Analysis

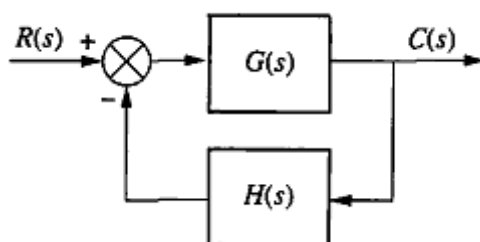
2. Given the transfer function of a control system below, perform the following tasks.

$$G(s) = \frac{b}{s^2 + as + b}$$

- Evaluate percent overshoot, settling time, peak time, and rise time for the following values: $a = 4$ and $b = 25$. Also, plot the poles in MATLAB. [10 marks]
- Calculate the values of a and b so that the imaginary part of the poles remains the same, but the real part is increased two times over that of (a), and repeat (a). [5 marks]
- Calculate the values of a and b so that the imaginary part of the poles remains the same, but the real part is decreased 1/2 time over that of (a), and repeat (a). [5 marks]
- Using Simulink, set up the systems. Using the Simulink's LTI Viewer, plot the step response of each of the three transfer functions on a single graph. Also, record the values of percent overshoot, settling time, peak time, and rise time for each step response. [10 marks]
- Make a table of calculated and experimental values of percent overshoot, settling time, peak time, rise time, and pole location. [5 marks]
- Discuss the effects of pole location upon the time response for both first- and second-order systems. Discuss any discrepancies between your calculated and experimental values. [2.5 marks]

C. Steady-State Analysis

3. For the negative feedback system of Figure 2 given below, perform the following tasks.



$$G(s) = \frac{K(s + 6)}{(s + 4)(s + 7)(s + 9)(s + 12)}$$

$$H(s) = 1$$

Figure 2: Block diagram and transfer functions of a negative feedback system

- a. Calculate the steady-state error in terms of K for the following inputs: $5u(t)$, $5tu(t)$, and $5t^2(t)$. [5 marks]
- b. Using Simulink, plot on one graph the error signal of the system for an input of $5u(t)$ and $K = 50, 500, 1000$, and 5000 . Repeat for inputs of $5tu(t)$ and $5t^2u(t)$. [5 marks]
- c. Use your Simulink plots to compare the expected steady-state errors to those calculated. Explain the reasons for any discrepancies. [2.5 marks]

Marking Schedule

Student No : _____

Student Name : _____

No	Description	Mark	Your Mark	Remarks
A	Stability Analysis			
1a.	Transfer function of negative feedback system.	5		
1b.	Two values of gain for closed-loop overdamped response.	5		
1c.	Two values of gain for closed-loop underdamped response.	5		
1d.	Time-domain response plot of system in MATLAB for cases (b) and (c).	5		
1e.	Step-response plot of system in Simulink for overdamped, underdamped, critically damped and marginally stable responses.	10		
1f.	Step response plot for two values of gain (K) for marginal stability.	5		
1g.	Transfer function of the system with compensator and step response plots for at marginal stability and for just above marginal stability.	10		
1h.	Discussion of condition for unstable response and effect of gain on step response of closed-loop system.	5		
B	Time Response Analysis			
2a.	Evaluation of $\%OS$, T_s , T_p , and T_r for $a = 4$ and $b = 15$ and plot of the poles.	10		
2b.	Calculation of a and values when imaginary part of the poles is the same and real part is increased 2 times of (a).	5		
2c.	Calculation of a and values when imaginary part of the poles is the same and real part is decreased 1/2 times of (a).	5		

2d.	Plot step response of the systems in (a), (b) and (c) in Simulink and values of %OS, T_s , T_p , and T_s for each step response.	10		
2e.	Table of calculated and experimental values of %OS, T_s , T_p , and T_s for each step response.	5		
2f.	Discussion of the effect of pole location in time response of first- and second-order systems and discrepancy between calculated and experimental values.	2.5		
C	Steady-state Analysis			
3a.	Steady-state error in terms of K for inputs $tu(t)$, $5tu(t)$, and $5t^2(t)$.	5		
3b.	Plot of graph of error signal of the system for inputs $tu(t)$, $5tu(t)$, and $5t^2(t)$.	5		
3c.	Comparison of steady-state errors of simulation results with calculated ones. Explanation for differences.	2.5		
	Total	100		

Comments