IIT Bombay
Systems and Control Engineering
Intelligent Feedback and Control

SC 645 | ***Assignment 3*** | Maximum Marks: 10

Deadline
Date: 08.03.24, 11.59pm

Instructions:

- Submit the answers to this assignment on or before the deadline at 11:59 p.m. on 9.03.2024. This is a strict deadline, and no request for any extension will be entertained.
- All the results and the associated observations/analysis must be compiled in a single pdf file. This pdf and the associated code must also be submitted in a single zip folder on moodle on the relevant submission link.
  Label this folder in the form: FirstName_RollNumber_AS03.
- Please preserve the code and the report till the end of this semester.
- Assumptions made, if any, must be clearly stated and must be justified.
- After the end of each question, the numbers to the right, in square brackets, indicate marks allotted to it.

1. Consider a feedback control system of an RLC circuit as follows,

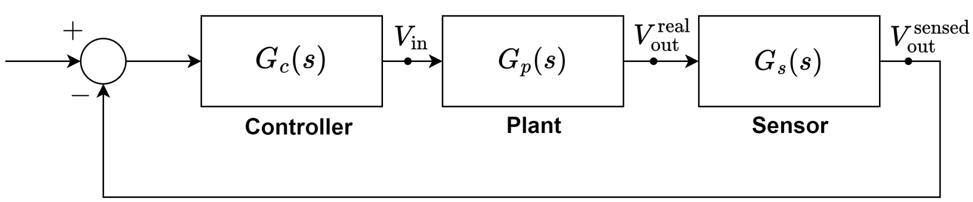

Figure 1: Feedback control system

$$G_c(s) = 1 \quad ; \quad G_p(s) = \frac{1}{LC \cdot s^2 + RC \cdot s + 1} \quad ; \quad G_s(s) = K(T)e^{-st_d}$$

- The gain $K(T)$ of the sensor transfer function $G_s(s)$ varies with the ambient temperature T as follows, (Here, T_0 is a sensor parameter that is known already)

$$K(T) = \left(1 + \frac{T}{T_0}\right)$$

- There is also a delay of t_d seconds to get the sensed output voltage.

If the system parameters are given by,

$$R = 1 \quad ; \quad L = 12.25 \quad ; \quad C = 0.075 \quad ; \quad t_d = 0.05 \quad ; \quad T_0 = 5$$

The following questions **must be answered only** via supporting arguments on the basis of associated MATLAB simulation plots (either Bode/Nyquist). No claims based on any analytical approximations must be made to answer the questions below.
(Hint: Use the different margins of stability for reasoning)

- Suppose the system in Figure 1 is designed for operation at an ambient temperature $T = 0$. Is the overall closed-loop system stable at this temperature?
- In which of the following set of ambient temperatures $\{0.5, 1, 1.25\}$ does the system possess the best stability margin? (compare in terms of gain margins)
- Do you think it is reasonable to conclude that increasing operating ambient temperatures tend to push the closed-loop feedback control system in Figure 1 toward instability? Provide supporting arguments based on appropriate analysis from MATLAB simulation plots.
- Suppose the sensor malfunctions and consequently adds delay in sensing the plant's real output voltage,

$$G_s(s) = K(T)e^{-st_d} \longrightarrow G_s(s) = K(T)e^{-s(t_d+\Delta t_d)}$$

  - What is the maximum delay Δt_d that can be accommodated, after which the feedback control system fails if it has to operate at $T = 0$?
  - What is the trend in the maximum delay that can be accommodated that you observe as a function of operating ambient temperature?

[05]

2. Consider the control system shown in Figure 2. The system is controlled by a PID controller for a second-order plant G(s) given by:

$$G(s) = \frac{1}{s^2 + 3.6s + 9} \tag{1}$$

It is assumed that the Reference input is normally held constant, and the response characteristics to the disturbances are very important to the system.

Note: This question requires both analytical calculations and MATLAB simulations.

Question 2 continues on the next page…

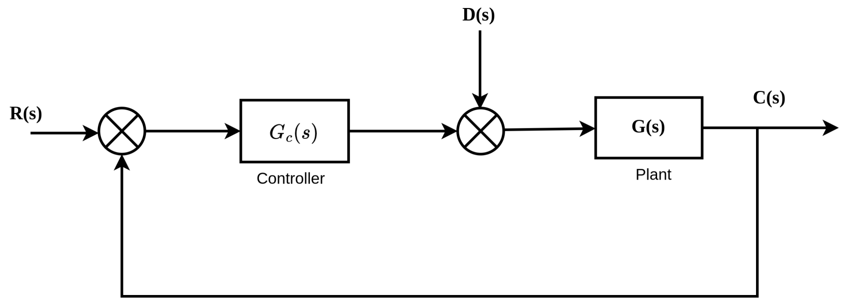

Figure 2: Plant Control System

- Design a PID controller such that the response to any step disturbances will be damped out quickly (in 2 to 3 sec in terms of 2% settling time). **Hint:** Choose the configuration of closed-loop poles such that there is a pair of dominant closed-loop poles.
- Tune the PID controller using the ZN method and the PID auto-tuner block of MATLAB. Compare the response of both controllers for unit-step reference input.
- Obtain the response to unit-step and unit-ramp disturbance input, and based on the observations:
  - Comment on the stability of the system.
  - Effect of the disturbance on the system response and how it can be reduced.

[05]