BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
Second Semester 2021-2022
Mid Semester Exam (Open book)
Industrial Instrumentation and Control (INSTR F343)

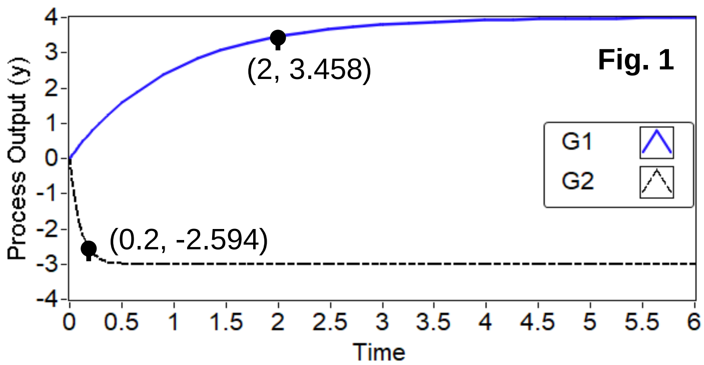
Time:*90 Minutes* ***Max Marks:*** *90* ***Date:***14.03.2022*

Note: *This question paper has 5 questions. Assume and clearly specify any missing data suitably. Marks are indicated against each question. Unless otherwise specified, assume final control element and measurement element transfer functions as unity.*

Question 1: A system G(s) is modeled as, $G_P(s) = G_1(s) + G_2(s)$, where $G_1(s)$ and $G_2(s)$ are first-order transfer functions. The individual unit step response of these systems, i.e. G_1 and G_2, are shown in Fig. 1. Consider time units in seconds. [18]

(A) Find the transfer functions $G_1(s)$, $G_2(s)$, and overall transfer function $G_P(s)$ and show it in the time constant form.

(B) Design a controller using direct synthesis approach using an appropriate closed-loop response with λ = 0.5 seconds and zero steady state error for constant setpoint. Express the controller in the form $G_c(s) = K_C\left(1 + \frac{1}{\tau_I s} + \tau_D s\right)$.



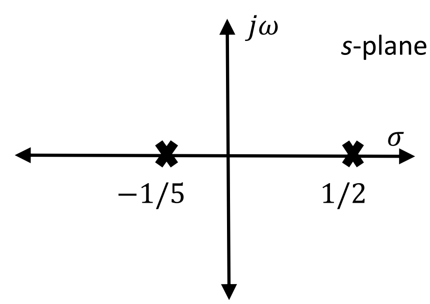


Fig. 2

Question 2: A second order system having a pole-zero map as shown in Fig. 2. Design an IMC based feedback controller $G_c(s)$ in the form $G_c(s) = \left(K_P + \frac{K_I}{s} + K_D s\right)$ for this system with a λ value of unity. [18]

Question 3: Consider a transfer function G(s), where time constant values are in minutes,

$$G(s) = \frac{4(1 - 2s)}{(20s + 1)(5s + 1)(s + 1)(0.1s + 1)}$$

(A) Find an approximate second order plus dead time model $\tilde{G}(s)$ using "Skogestad's Half rule" for the above mentioned $G(s)$.

(B) Find the Tyres-Luyben based K_P, K_I and K_D settings for controlling the system using the approximate transfer function. Use Pade's first order approximation for approximating dead-time. [18]

Question 4(*i*): A first order process $G_1(s)$ when subjected to a unit step input applied at t = 0 seconds, shows the deviation in process variable as shown in Fig. 3. Design and draw an electronic analog PI controller for this process using op-amps, having proportional gain, $K_C = 8\frac{(\tau_P + 0.5\theta)}{K_P(1 + 0.5\theta)}$ V/V and, $\tau_I = \tau_P$ seconds, where K_P is the process static gain, τ_P is the process time constant, and θ is the dead-time. Assume that a capacitor of 20 μF is available. Consider time units in seconds. [9]

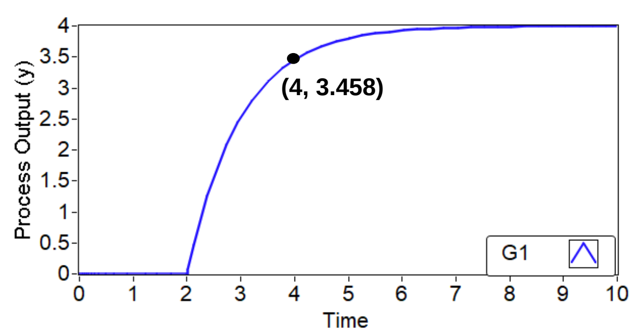


Fig. 3

Question 4(*ii*): A relay auto-tuner is used on a process. It was observed that the process output (y) and control input (u) to process are oscillating, as shown in Fig. 4. Find the settings for of K_P and K_I for this process using Z-N suggested gains for PI controller. [9]

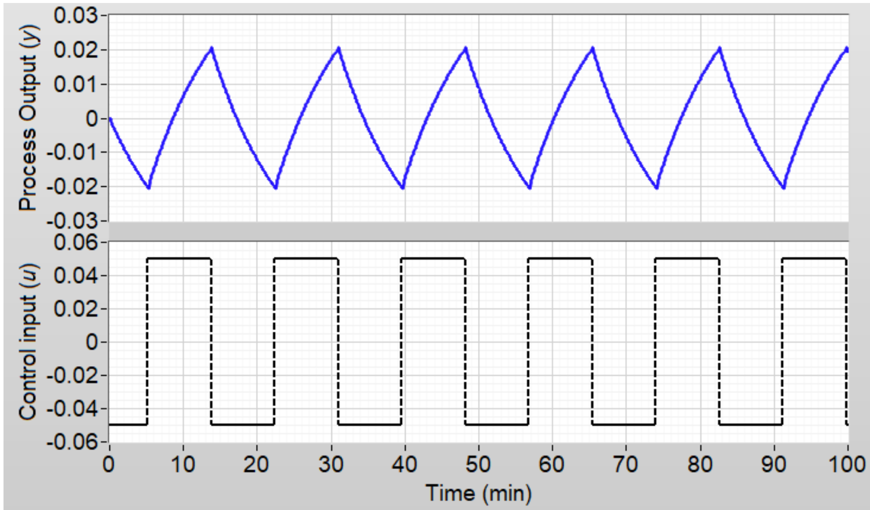
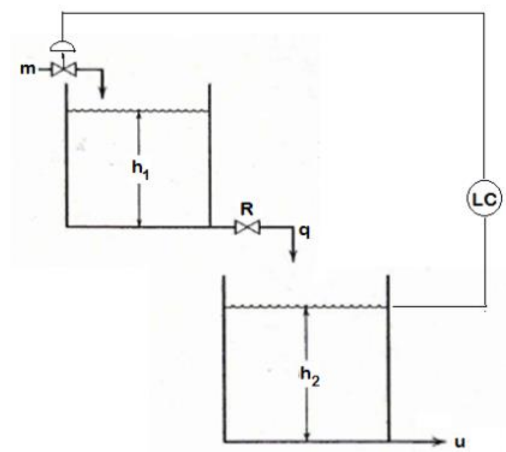


Fig. 4

Question 5: For a non-interacting two tank system, inflow 'm' to upper tank is the manipulated variable, outflow of the upper tank is going to lower tank through a pipe having linear resistance (R = 2 sec/m^2), the outflow of tank 2 i.e. 'u' is through a pipe having no resistance and acts as a disturbance. Level controller (PD type with K_C = 2 and T_d =2 sec) put on the lower tank is changing 'm' through a control valve (First order system with all characterizing parameters unity) in inflow line of tank 1. Areas of upper and lower tanks are 1 m^2 and 2 m^2 respectively, heights of upper and lower tanks are h_1 and h_2 respectively. [18]

(A) Derive the expression of $H_2(s)$ in terms of $M(s)$ and $U(s)$.
(B) Draw the closed-loop block diagram putting transfer function in each block, assuming the transfer function of level measuring element is unity.
(C) Find the expression for error in terms of the setpoint and load changes.
(D) Find the static error for a unit step disturbance and unit step change in setpoint.



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