

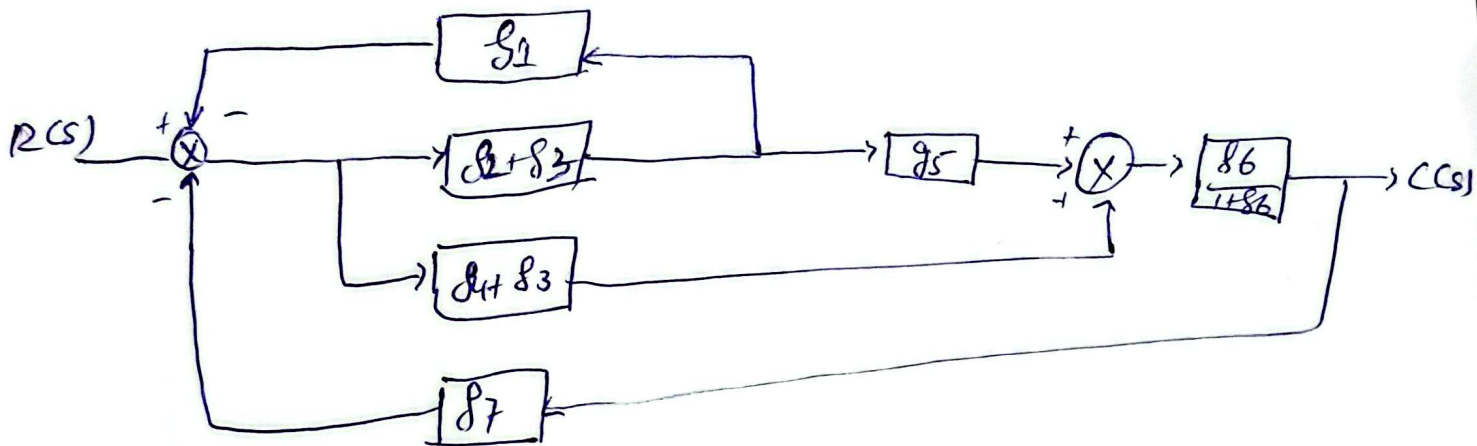
Assignment # 2

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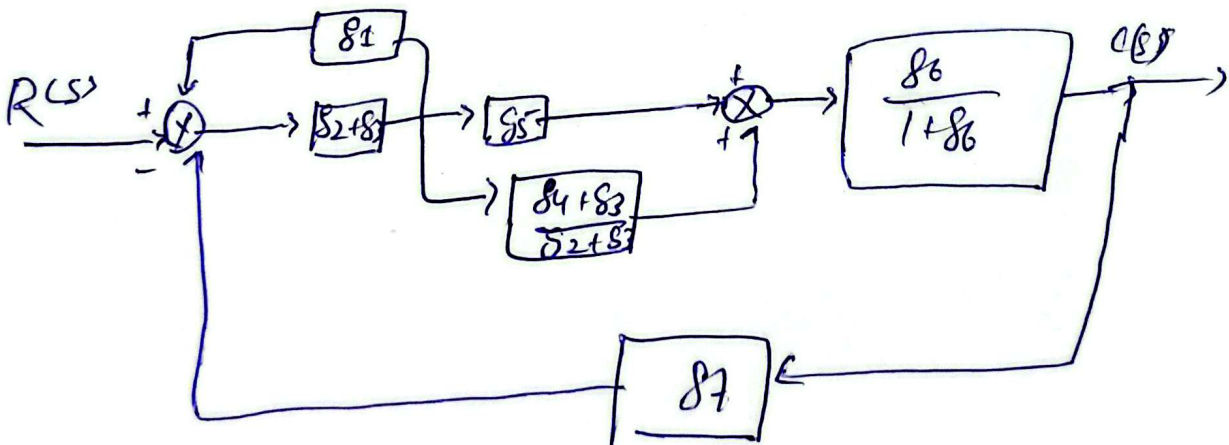
Question # 1

Solutions:-

Step 1:- split s_3 and combine s_2 and s_4
Also use s_6 and apply feedback formula:-

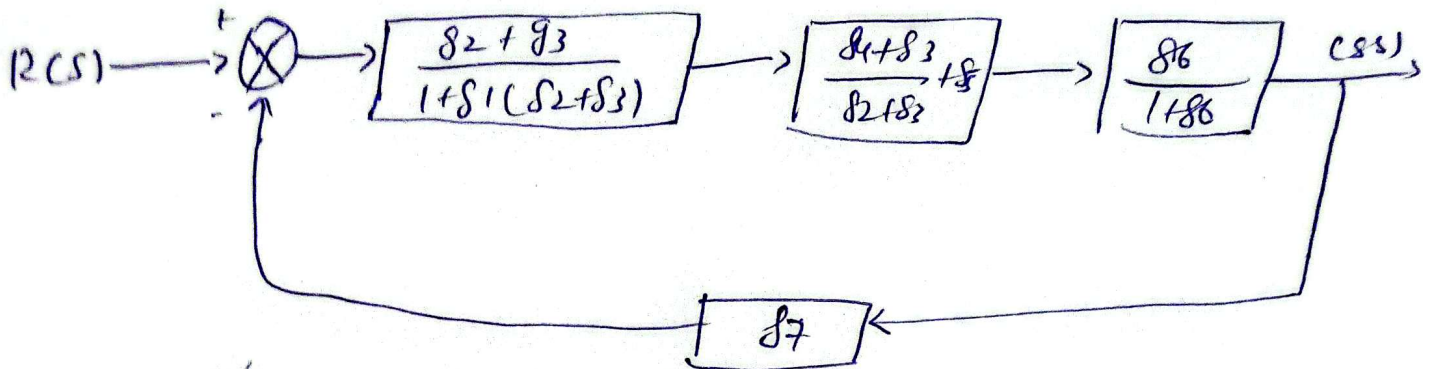


Step 2:- push $s_2 + s_3$ to left past the pickoff point-



Step 3:-

using the feedback formula of combining parallel blocks.



Step 4:-

multiplying the blocks of forward path and applying feedback formula

$$C(s) = \frac{s_6 s_4 + s_6 s_3 + s_6 s_5 s_2}{1 + s_6 + s_2 s_1 + s_2 s_2 + s_7 s_6 s_4 + s_7 s_6 s_3 + s_7 s_5 s_6 s_3 + s_7 s_6 s_5 s_2 + s_6 s_3 s_1 + s_6 s_2 s_1}$$

Ans

Rise time

$$T_r = \frac{\pi - \phi}{\omega_d}$$

$$T_r = 0.03150 \text{ s}$$

$$\therefore \omega_d = \omega_n \sqrt{1 - \xi^2} = 6464.89 \text{ rad/s}$$

$$\therefore \phi = \tan^{-1} \frac{\xi}{\sqrt{1 - \xi^2}} = 0.848 \text{ rad}$$

settling time

$$T_s = \frac{4}{\xi \omega_n} = \frac{4}{(0.58)(85.73)}$$

$$T_s = 0.0804 \text{ s}$$

Question 11-3 :-

Solution :-

Step # 01 :-

Identify the forward PATH:-

$$P1 = g2 g3 g4$$

Step # 02 :-

Identify all individual loops

$$L_a = -1 ; \quad L_b = -g2 g3 g4 ; \quad L_c = -g3 g4$$

$$L_d = -g4$$

Step # 03 :-

Non-touching loops:-

$$L_a L_c ; L_a L_d$$

Step # 04 :-

compute Δ

$$\Delta = 1 - (-1 - g2 g3 g4 - g3 g4 - g4) + (g3 g4 + g4)$$

$$\Delta = 2 + 2g4 + 2g3 g4 + g2 g3 g4$$

Step # 05 :-

compute Δ_I

$$\Delta_I = 1$$

$$\zeta = ?$$

$$\text{Let } M = \frac{4.05}{100} \text{ then}$$

$$\ln M = \frac{-\zeta \pi}{\sqrt{1-\zeta^2}}$$

$$\zeta = \frac{-\ln M}{\sqrt{\pi^2 + (\ln M)^2}}$$

(B)

$$OS = 10\% \quad \& \quad T_P = 5s$$

$$1) \text{ overshoot } \rightarrow M \Rightarrow M = 0.10$$

$$2) \text{ damping ratio } \zeta = \frac{-\ln(0.10)}{\pi^2 + (\ln 0.10)^2} = 0.5915$$

$$3) \text{ Damped natural frequency } \omega_d = \frac{\pi}{T_P} = \frac{\pi}{5} = 0.628 \text{ rad/sec}$$

$$4) \text{ Natural frequency } \omega_n = \frac{\omega_d}{\sqrt{1-\zeta^2}} = 0.7750 \text{ rad/sec}$$

$$5) \text{ poles } s_1 s_2 = -\zeta \omega_n \pm j \omega_d = -0.4605 \pm j 0.628 (\text{rad/sec})$$

$$6) T_P = 5; \quad T_r = 3.507s; \quad T_s = 8.686s$$

7) The system is stable, underdamped with 10%, 0.5, moderate oscillation of slow settling response.

Step II obs:-

mason's gain formula:-

$$T(s) = \frac{C(s)}{R(s)} = \frac{P_1 D_1}{\Delta} = \frac{g_1 g_2 g_3 g_4}{2 + 2g_4 + 2g_3 g_4 + g_2 g_3 g_4}$$

Step 7:-

Loop Instructions.

In this system each feedback loop affects the overall transfer function by changing Δ is mason's gain formula

- i) Touching loop directly influence the poles, damping and stability of system
- ii) Non-touching loops add positive product terms to parameters changing.
- iii) Local loops adjust local gains & improve damping.

Question ~~11~~ 4

Solution ~~11~~

(A)

Relationship:-

$$G(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} \quad (\text{damping ratio})$$

$$\text{percent overshoot} \rightarrow \%OS = 100e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$$

(B)

$$T_p = 55$$

Step 3:- finding damping ratio

$$\%OS = 100e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$$

$$0.10 = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}} = \sqrt{\zeta} = 0.591$$

step 2:-

find the natural frequency-

$$T_p = \frac{\pi}{\omega_n \sqrt{1 - \zeta^2}} = \frac{\pi}{T_p \sqrt{1 - \zeta^2}}$$

$$\omega_n = 0.779 \text{ rad/sec}$$

$$\omega_d = \omega_n \sqrt{1 - \zeta^2} = 0.628 \text{ rad/sec}$$

step 3:- find pole location

$$s_{1,2} = -\zeta \omega_n \pm j \omega_d$$

$$s_{1,2} = -0.46 \pm j 0.63$$

step 4:-

→ poles lie in the left half-plane
→ stable system

- Real part (-0.46) → rate of decay
- Imaginary part (0.63) → oscillation frequency.
- Results in 10% overshoot, $T_p = 5.5$ smooth settling (~8s)