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***Abstract*—This manual is an introduction to control systems based on GATE problems.Links to sample Python codes are available in the text.**

Download python codes using

1 STABILITY

1.1 Second order System

1.1. The Block diagram of a system is illustrated in the figure shown, where $X(s)$ is the input and $Y(s)$ is the output. Draw the equivalent signal flow graph.

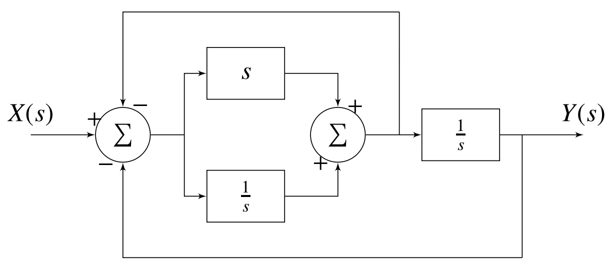

Fig. 1.1.1: signal flow block diagram

Solution: Signal flow graph of given above block diagram is

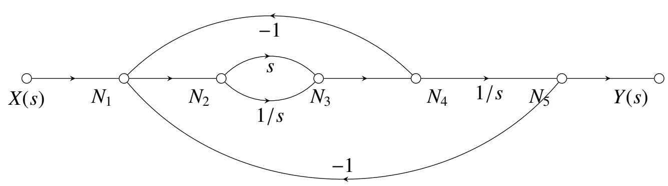

Fig. 1.1.2: signal flow graph

1.2. Draw all the forward paths and compute the respective gains. **Solution:** Here,

$$P_1 = \frac{s}{s} = 1 \tag{1.2.1}$$

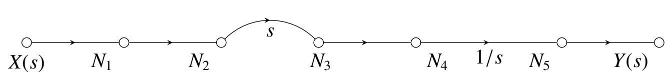

Fig. 1.2.3: P_1

$$P_2 = (1/s)(1/s) = 1/s^2 \tag{1.2.2}$$

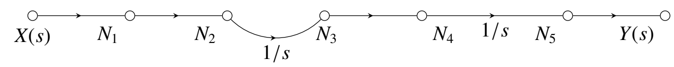

Fig. 1.2.4: P_2

1.3. Draw the loops and calculate the respective gains.
Solution:

$$L_1 = (-1)(s) = -s \tag{1.3.1}$$

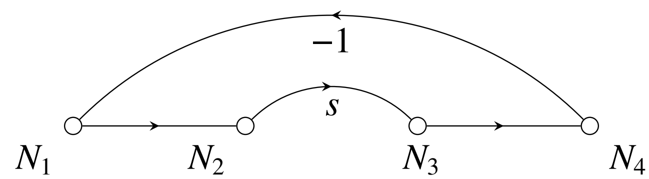

Fig. 1.3.5: L_1

$$L_2 = \frac{s}{-s} = -1 \tag{1.3.2}$$

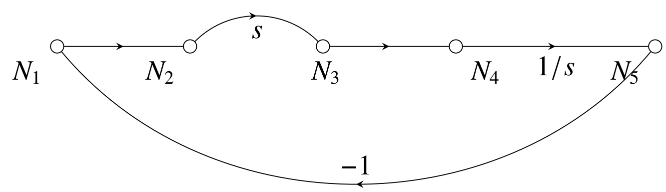

Fig. 1.3.6: L_2

$$L_3 = (\frac{1}{s}) * (-1) = \frac{-1}{s} \tag{1.3.3}$$

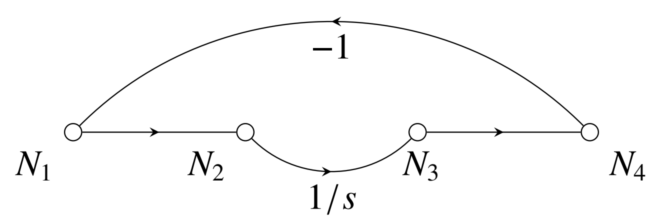

Fig. 1.3.7: L_3

$$L_4 = (\frac{1}{s})(\frac{1}{s})(-1) = \frac{-1}{s^2} \tag{1.3.4}$$

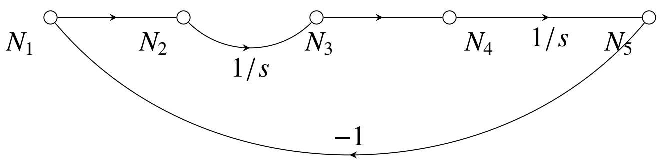

Fig. 1.3.8: L_4

1.4. State Mason's Gain formula and explain the parameters through a table.
Solution: According to Mason's Gain Formula,

$$T = \frac{Y(s)}{X(s)} \tag{1.4.1}$$

$$T = \frac{\sum_{i=1}^{N} P_i \Delta_i}{\Delta} \tag{1.4.2}$$

1.5. Find the transfer function using Mason's Gain Formula.
Solution:
Now,

P_i	i^{th} forward path
$Y(s)$	Output mode
$X(s)$	Input mode
T	Transfer function between $Y(s)$ and $X(s)$
Δ	1-($\sum_{i=1} L_i$)+($\sum_{i=1,j=1} L_i L_j$)-($\sum_{i=1,j=1,k=1} L_i L_j L_k$)+...
L_i	individual loops
$L_i L_j$	products of two non touching loops
$L_i L_j L_k$	products of three non touching loops
Δ_i	obtained from Δ by removing forward path from L_i

TABLE 1.5: Table

$$L_1 = (-1)(s) = -s \tag{1.5.1}$$

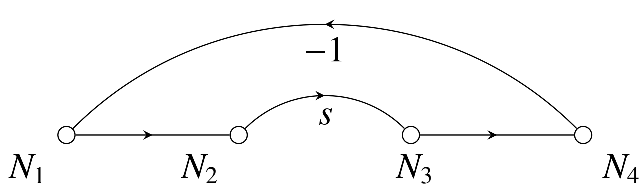

Fig. 1.5.9: L_1

$$L_2 = \frac{s}{-s} = -1 \tag{1.5.2}$$

$$L_3 = (\frac{1}{s}) * (-1) = \frac{-1}{s} \tag{1.5.3}$$

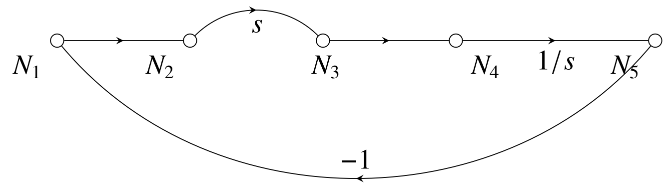

Fig. 1.5.10: L_2

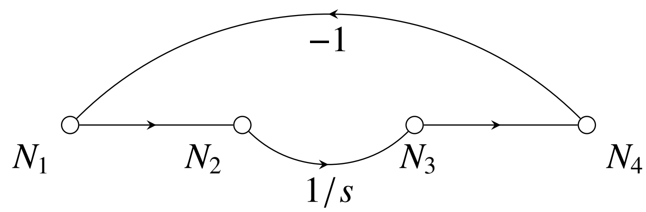

Fig. 1.5.11: L_3

$$L_4 = (\frac{1}{s})(\frac{1}{s})(-1) = \frac{-1}{s^2} \tag{1.5.4}$$

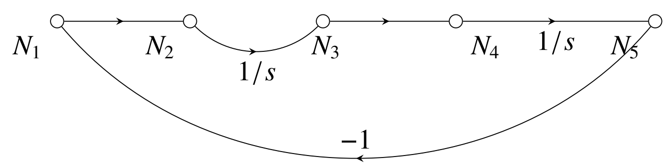

Fig. 1.5.12: L_4

$\Delta = 1 - (-s - 1 - \frac{1}{s} - \frac{1}{s^2})$
$\Delta = \frac{s^3+2s^2+s+1}{s^2}$

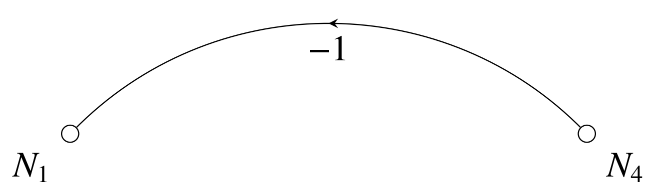

Fig. 1.5.13: Δ_1

After removing forward path from loop1 we will get Delta1
$\Delta_1 = 1$
After removing forward path from loop2 we will get Delta2
$\Delta_2 = 1$
After removing forward path from loop3 we will get Delta4

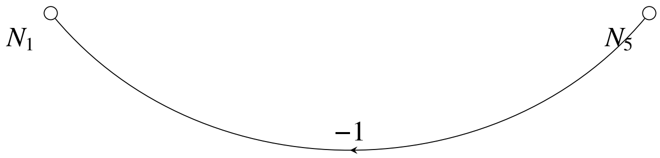

Fig. 1.5.14: Δ_2

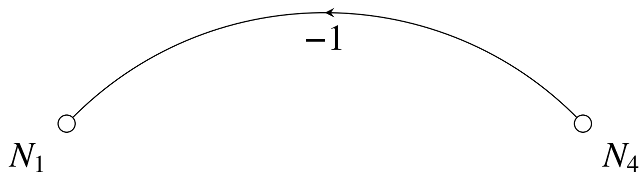

Fig. 1.5.15: Δ_3

$\Delta_3 = 1$

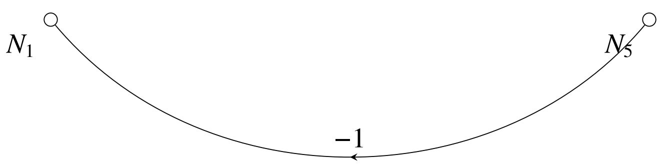

Fig. 1.5.16: Δ_4

After removing forward path from loop4 we will get Delta4
$\Delta_4 = 1$
Here,

$$T = \frac{\sum_{i=1}^{N}(P_i)(\Delta_i)}{\Delta} \tag{1.5.5}$$

$$T = \frac{P_1\Delta_1 + P_2\Delta_2 + P_3\Delta_3 + P_4\Delta_4}{\Delta} \tag{1.5.6}$$

$$T = \frac{1 * 1 + (\frac{1}{s^2}) * 1 + 0 * 1 + 0 * 1}{\frac{s^3+2s^2+s+1}{s^2}} \tag{1.5.7}$$

$$H(s) = \frac{s^2+1}{s^3+2s^2+s+1} \tag{1.5.8}$$

2 Routh Hurwitz Criterion

3 Compensators

4 Nyquist Plot