Contents

***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.

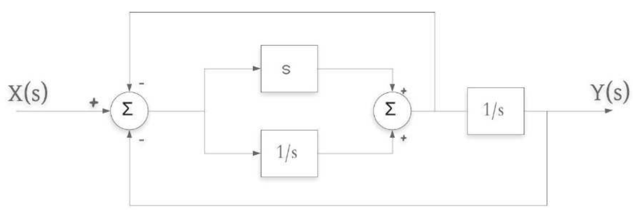


Fig. 1.1.1

**Solution:** Signal flow graph of given above block diagram is

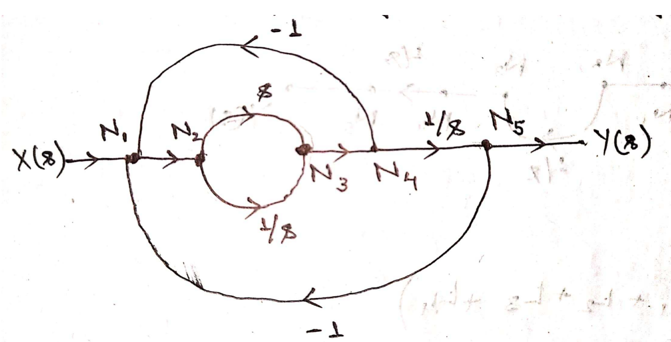


Fig. 1.1.2: signal flow graph

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

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

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

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

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

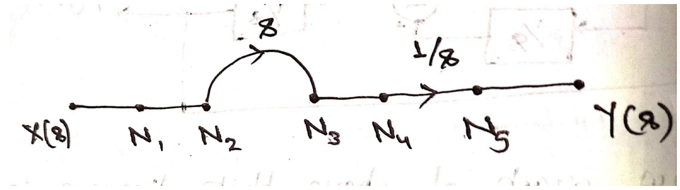


Fig. 1.2.3: P1

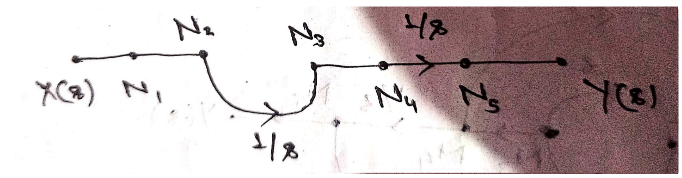


Fig. 1.2.4: P2

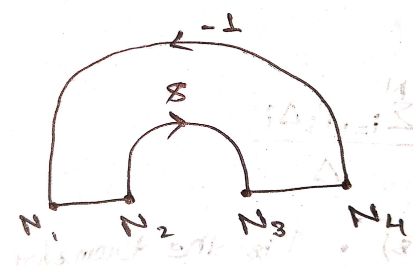


Fig. 1.3.5: L1

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

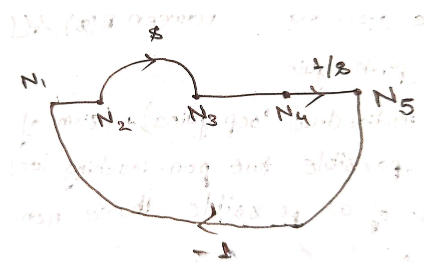


Fig. 1.3.6: L2

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

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

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

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

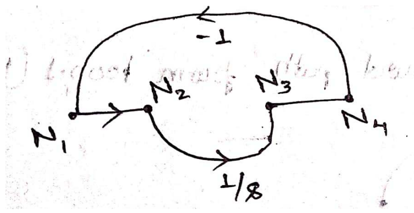


Fig. 1.3.7: L3

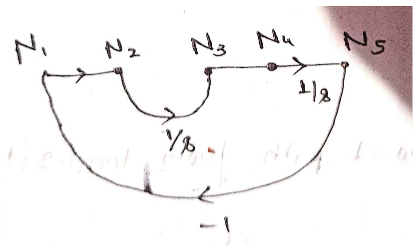


Fig. 1.3.8: L4

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

1.5. Find the transfer function using Mason's Gain Formula.
**Solution:**
Now,
$P_i$ is the $i^{th}$ forward path.
$\Delta$ = 1 - (Sum of all individual loop gains)+(sum of gain products of all possible two non-touching loops)-(sum of gain products of all possible three non-touching loops)+...
$\Delta_i$ is obtained from $\Delta$ by removing the loops which are touching the $i^{th}$ forward path.
$\Delta = 1 - (L_1 + L_2 + L_3 + L_4)$

$$L_1 = (-1)(s) = -s \quad (1.5.1)$$

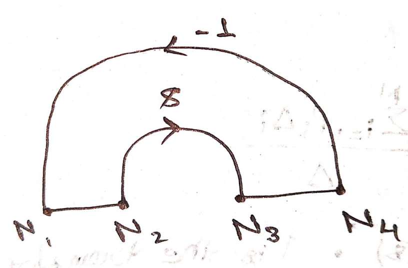


Fig. 1.5.9: L1

$$L_2 = \frac{s}{-s} = -1 \quad (1.5.2)$$

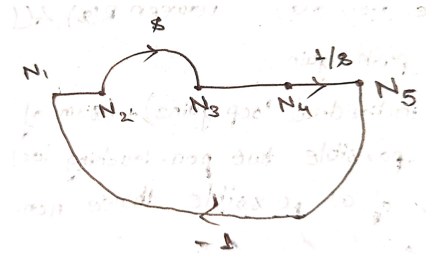


Fig. 1.5.10: L2

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

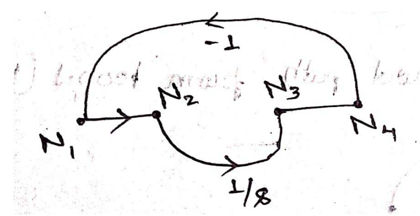


Fig. 1.5.11: L3

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

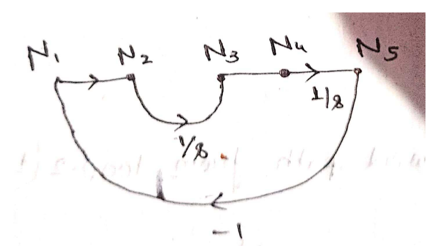


Fig. 1.5.12: L4

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


Fig. 1.5.13: Delta1

After removing forward path from loop1 we will get Delta1
$\Delta_1 = 1$


Fig. 1.5.14: Delta2

After removing forward path from loop2 we will get Delta2
$\Delta_2 = 1$

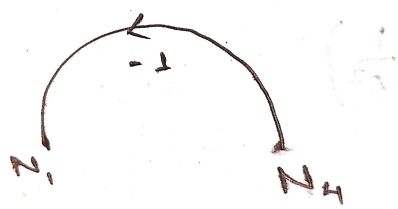


Fig. 1.5.15: Delta3

After removing forward path from loop3 we will get Delta4
$\Delta_3 = 1$

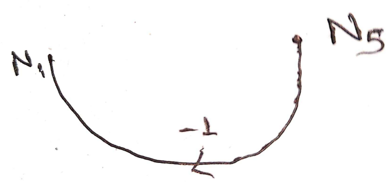


Fig. 1.5.16: Delta4

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