SET 01/03

| USN | | | | | | | | | | | |
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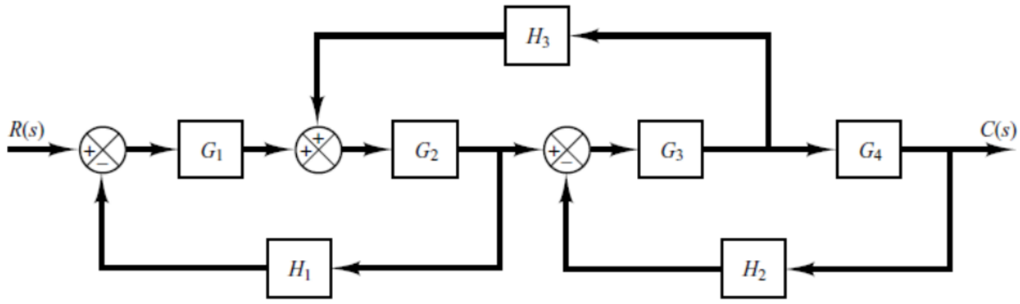
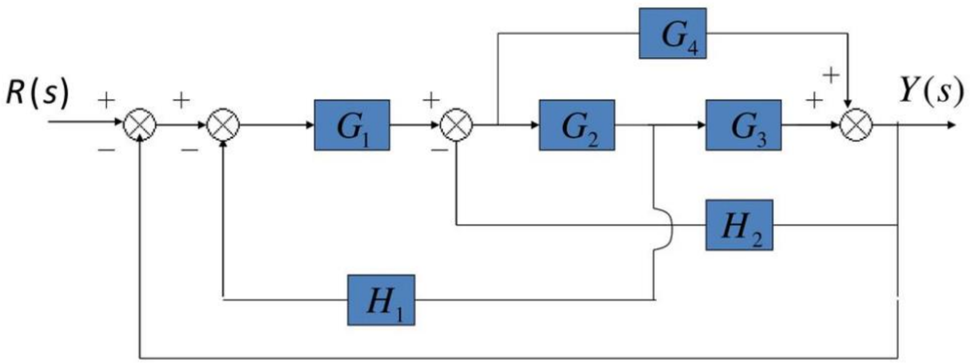
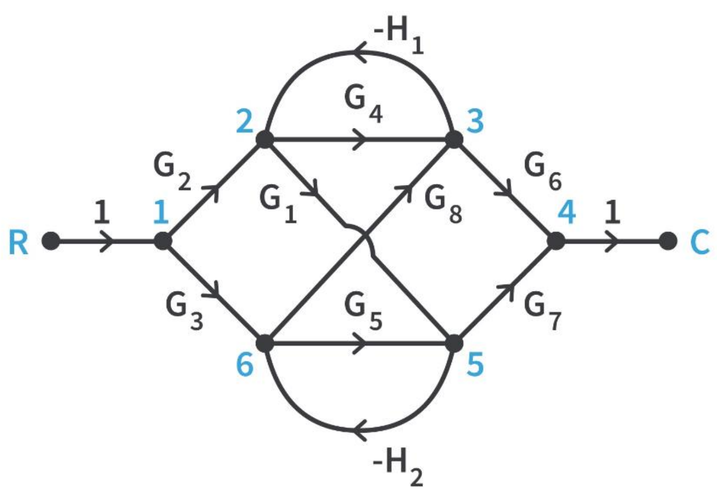
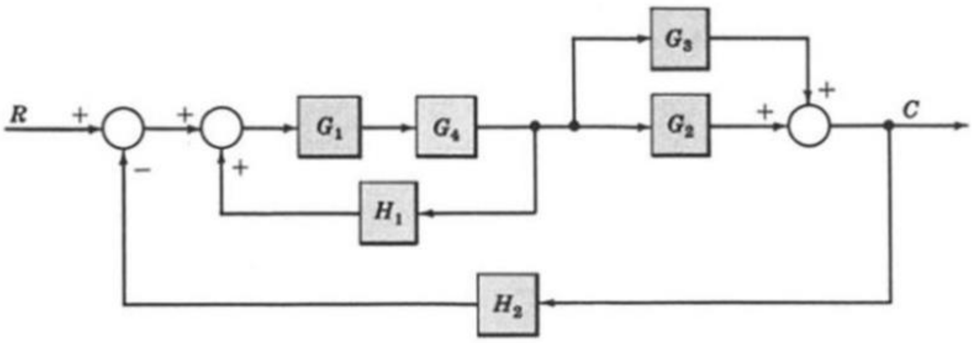
CMR INSTITUTE OF TECHNOLOGY, BENGALURU. ACCREDITED WITH A+ GRADE BY NAAC

**Internal Assessment Test 1 – May. 2022**

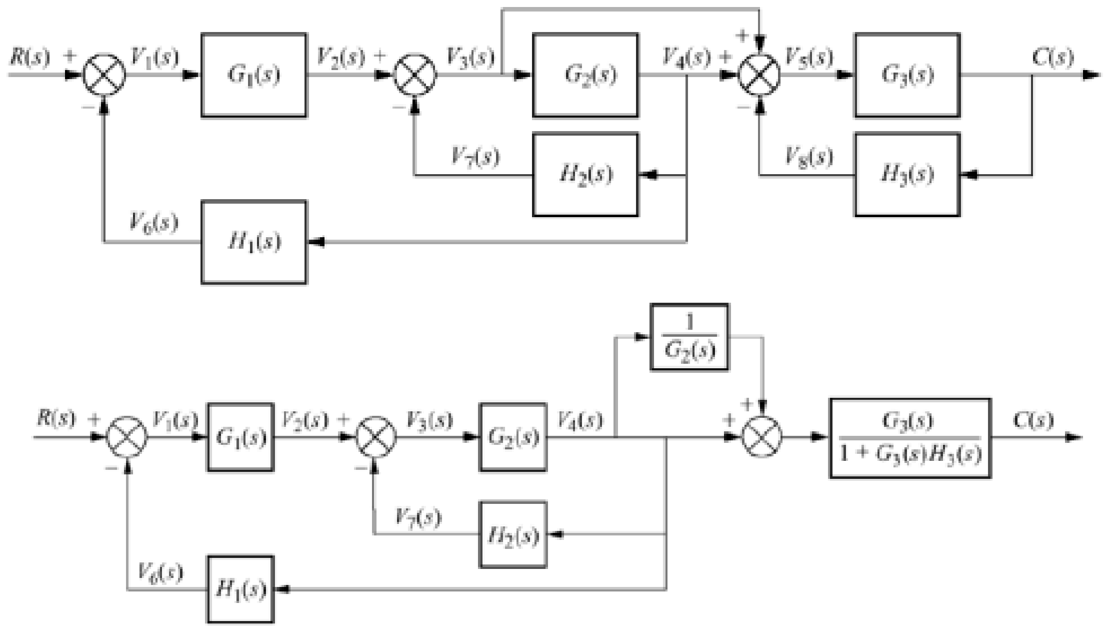
| Sub: | CONTROL ENGINEERING | | | | | Sub Code: | 18ME71 | Branch: | ME |
|---|---|---|---|---|---|---|---|---|---|
| Date: | 20.10.2022 | Duration: | 90 min | Max Marks: | 50 | Sem / Sec: | VII/A&B | | OBE |

| | <u>**Answer All the Questions**</u> | MARKS | CO | RBT |
|---|---|---|---|---|
| 1 | Obtain the transfer function of the given system using block diagram reduction.   | [10] | CO3 | L3 |
| 2 | Obtain the transfer function of the given system using block diagram reduction.   | [10] | CO3 | L3 |
| 3 | Obtain the transfer function of the given system using Mason's Gain Formula.   | [10] | CO3 | L3 |

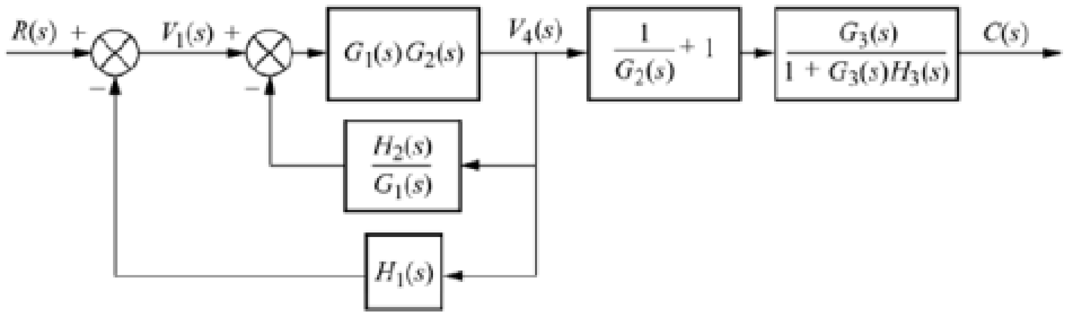
| | | | | |
|---|---|---|---|---|
| 4 | Obtain the transfer function of the given system using Mason's Gain Formula.<br><br> | [10] | CO3 | L3 |
| 5 | Obtain the transfer function of the system represented by the following set of equations using Mason's Gain Formula.<br>$x_2 = a_{12}x_1 + a_{32}x_3 + a_{42}x_4 + a_{52}x_5$<br>$x_3 = a_{23}x_2$<br>$x_4 = a_{34}x_3 + a_{44}x_1$<br>$x_5 = a_{35}x_3 + a_{45}x_4$ | [10] | CO3 | L3 |

CI CCI HOD

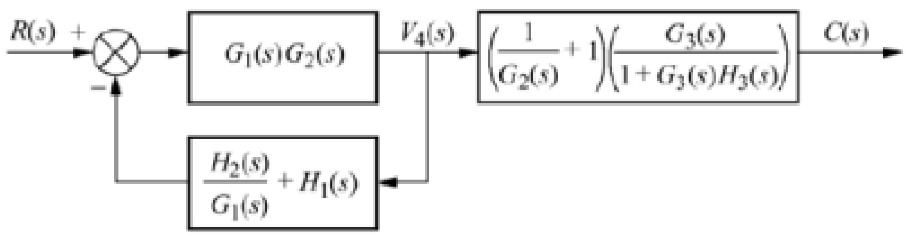
1)


R(s)
V1(s)
G1(s)
V2(s)
V3(s)
G2(s)
V4(s)
V5(s)
G3(s)
C(s)
V7(s)
H2(s)
V8(s)
H3(s)
V6(s)
H1(s)
1/G2(s)
G3(s) / (1 + G3(s)H3(s))

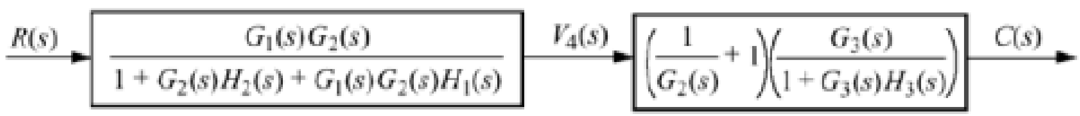
(a)


R(s)
V1(s)
G1(s)G2(s)
V4(s)
1/G2(s) + 1
G3(s) / (1 + G3(s)H3(s))
C(s)
H2(s)/G1(s)
H1(s)

(b)


R(s)
G1(s)G2(s)
V4(s)
(1/G2(s) + 1)(G3(s) / (1 + G3(s)H3(s)))
C(s)
H2(s)/G1(s) + H1(s)

(c)

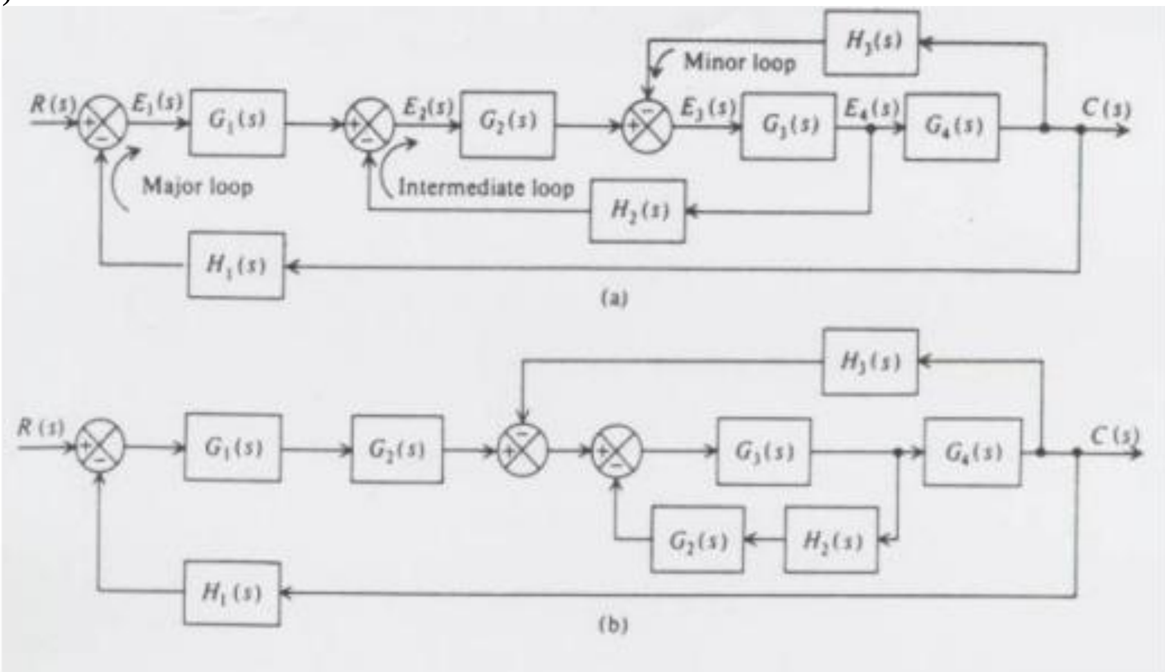

R(s)
G1(s)G2(s) / (1 + G2(s)H2(s) + G1(s)G2(s)H1(s))
V4(s)
(1/G2(s) + 1)(G3(s) / (1 + G3(s)H3(s)))
C(s)

(d)

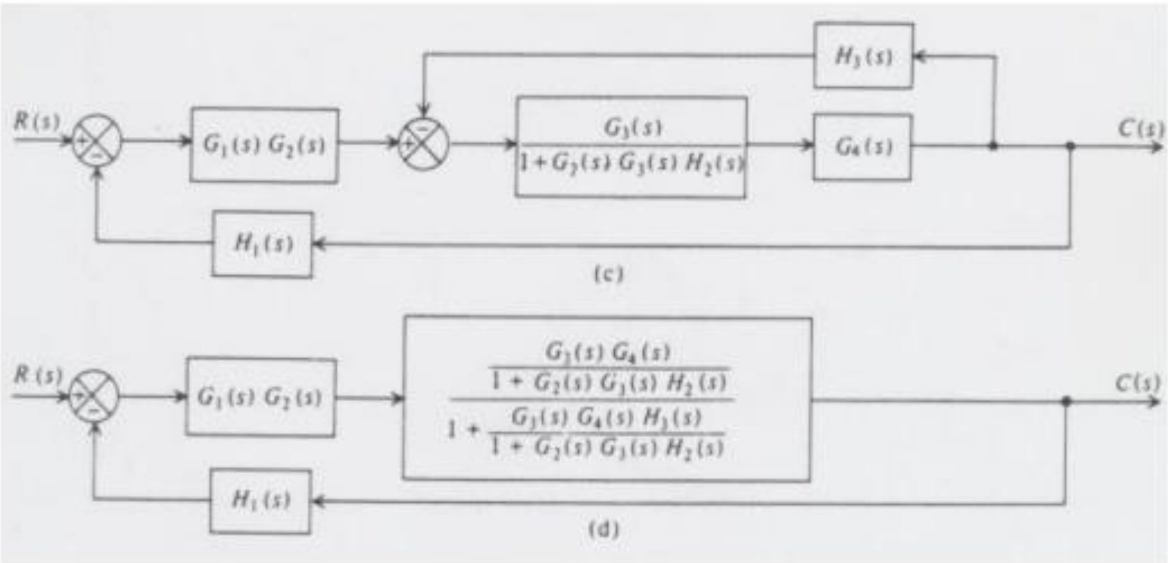

R(s)
G1(s)G3(s)[1 + G2(s)] / [1 + G2(s)H2(s) + G1(s)G2(s)H1(s)][1 + G3(s)H3(s)]
C(s)

(e)

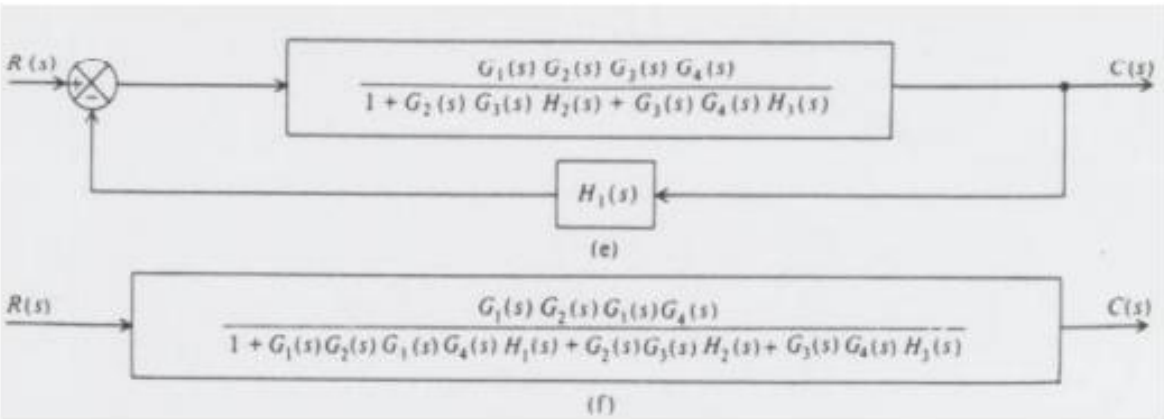
2)



$R(s)$
$E_1(s)$
$G_1(s)$
$E_2(s)$
$G_2(s)$
$E_3(s)$
$G_3(s)$
$E_4(s)$
$G_4(s)$
$C(s)$
$H_3(s)$
Minor loop
Major loop
Intermediate loop
$H_2(s)$
$H_1(s)$
(a)
$R(s)$
$G_1(s)$
$G_2(s)$
$H_3(s)$
$G_3(s)$
$G_4(s)$
$C(s)$
$G_2(s)$
$H_2(s)$
$H_1(s)$
(b)

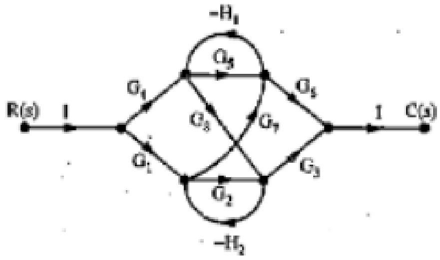
$R(s)$
$G_1(s)\, G_2(s)$
$H_3(s)$
$\frac{G_3(s)}{1+G_2(s)\, G_3(s)\, H_2(s)}$
$G_4(s)$
$C(s)$
$H_1(s)$
(c)
$R(s)$
$G_1(s)\, G_2(s)$
$\frac{\frac{G_3(s)\, G_4(s)}{1+G_2(s)\, G_3(s)\, H_2(s)}}{1+\frac{G_3(s)\, G_4(s)\, H_3(s)}{1+G_2(s)\, G_3(s)\, H_2(s)}}$
$C(s)$
$H_1(s)$
(d)

$R(s)$
$\frac{G_1(s)\, G_2(s)\, G_3(s)\, G_4(s)}{1+G_2(s)\, G_3(s)\, H_2(s)+G_3(s)\, G_4(s)\, H_3(s)}$
$C(s)$
$H_1(s)$
(e)
$R(s)$
$\frac{G_1(s)\, G_2(s)\, G_1(s) G_4(s)}{1+G_1(s) G_2(s)\, G_1(s)\, G_4(s)\, H_1(s)+G_2(s) G_3(s)\, H_2(s)+G_3(s)\, G_4(s)\, H_3(s)}$
$C(s)$
(f)

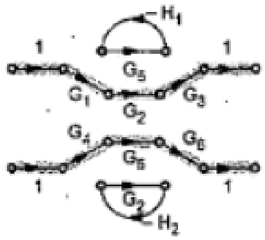
3)

**VTU : Jan.-13, July-13, 15, Marks 10**




**Sol :** The number of forward paths are K = 6.

The forward path gains are,




$$T_1 = G_1G_2G_3, \qquad T_2 = G_4G_5G_6$$

$$T_3 = G_1G_7G_6, \qquad T_4 = G_4G_8G_3$$

$$T_5 = G_4G_8(-H_2)G_7G_6, \; T_6 = G_1G_7(-H_1)G_8G_3$$

The feedback loop gains are,

$$L_1 = -G_5H_1, \; L_2 = -G_2H_2, \; L_3 = +G_7H_1G_8H_2$$

The two nontouching loops are $L_1 L_2$,

$$\therefore \quad L_1L_2 = +G_2G_5H_1H_2$$

$$\therefore \quad \Delta = 1-[L_1+L_2+L_3]+[L_1L_2] = 1 + G_5H_1 + G_2H_2 - G_7G_8H_1H_2 + G_2G_5H_1H_2$$

**For $T_1$, $L_1$ is nontouching.**

$$\therefore \quad \Delta_1 = 1 - L_1 = 1 + G_5H_1$$

**For $T_2$, $L_2$ is nontouching.**

$$\therefore \quad \Delta_2 = 1 - L_2 = 1 + G_2H_2$$

**For $T_3$ to $T_6$ all loops are touching to all forward paths.**

$$\therefore \quad \Delta_3 = \Delta_4 = \Delta_5 = \Delta_6 = 1$$

$$\therefore \quad \text{Gain} = \frac{\Sigma T_K \Delta_K}{\Delta} = \frac{T_1\Delta_1 + T_2\Delta_2 + T_3\Delta_3 + T_4\Delta_4 + T_5\Delta_5 + T_6\Delta_6}{\Delta}$$

$$\therefore \quad \text{Gain} = \frac{G_1G_2G_3(1+G_5H_1) + G_4G_5G_6(1+G_2H_2) + G_1G_7G_6 + G_4G_8G_3 - G_4G_8G_7G_6H_2 - G_1G_3G_7G_8H_1}{1 + G_5H_1 + G_2H_2 - G_7G_8H_1H_2 + G_2G_5H_1H_2}$$

**... Ans.**

4)

**Sol. :** Representing each summing and take off point by a separate node, the signal flow graph is as shown in the Fig. 6.5.6 (a).

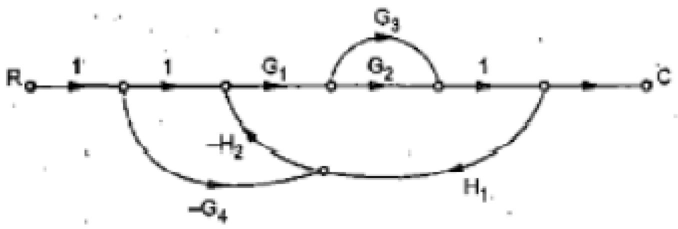



**Fig. 6.5.6**

Forward path gains are,

$$T_1 = G_1G_2,$$

$$T_2 = G_1G_3,$$

$$T_3 = +G_4H_2G_1G_2$$

$$T_4 = G_4H_2G_1G_3$$

The feedback loop gains are,

$$L_1 = -G_1G_2H_1H_2,$$

$$L_2 = -G_1G_3H_1H_2$$

No combination of non-touching loops.

$$\therefore \qquad \Delta = 1-[L_1+L_2]$$

All loops are touching to all the forward paths hence $\Delta_1 = \Delta_2 = \Delta_3 = \Delta_4 = 1$

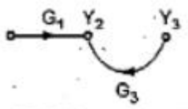
$$\therefore \qquad \frac{C}{R} = \frac{T_1\Delta_1 + T_2\Delta_2 + T_3\Delta_3 + T_4\Delta_4}{\Delta}$$

$$\therefore \qquad \frac{C}{R} = \boxed{\frac{G_1G_2 + G_1G_3 + G_1G_2G_4H_2 + G_1G_3G_4H_2}{1 + G_1G_2H_1H_2 + G_1G_3H_1H_2}}$$

5)

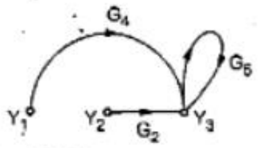
**Sol.** : System node variables are $Y_1, Y_2, Y_3, Y_4$.

Consider equation 1 : This indicates $Y_2$ depends on $Y_1$ and $Y_3$



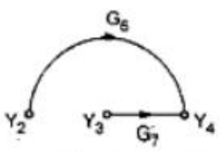

S.F.G. for equation (1)

Consider equation 2 : This indicates $Y_3$ depends on $Y_1, Y_2$ and $Y_3$




S.F.G. for equation (2)

Consider equation 3 : This indicates $Y_4$ depends on, $Y_3$ and $Y_2$




S.F.G. for equation (3)

Combining all three we get, complete S.F.G. as shown in Fig. 6.5.3,

No. of forward paths = K = 4

$$\therefore \text{T.F.} = \sum_{K=1}^{4} \frac{T_K \Delta_K}{\Delta} = \frac{T_1 \Delta_1 + T_2 \Delta_2 + T_3 \Delta_3 + T_4 \Delta_4}{\Delta}$$

... Mason's gain formula

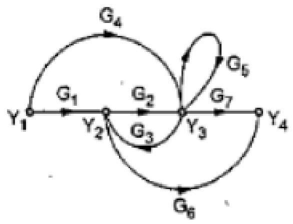



**Fig. 6.5.3**

$T_1 = G_1 G_2 G_7$, $T_2 = G_4 G_7$,

$T_3 = G_1 G_6$, $T_4 = G_4 G_3 G_6$

Individual loops are,


$L_1 = G_2 G_3$


$L_2 = G_5$

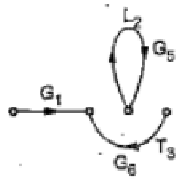
$\therefore \Delta = 1 - [L_1 + L_2] = 1 - G_2 G_3 - G_5$

No nontouching loop combinations.

For $T_1, T_2$ and $T_4$, all loops are touching.

$\therefore \Delta_1 = \Delta_2 = \Delta_4 = 1$

And for $T_3$, '$G_5$' self loop is nontouching,




L₂ nontouching to T₃

$$\therefore \quad \Delta_3 = 1 - G_5$$

$$\frac{Y_4}{Y_1} = \frac{T_1 \Delta_1 + T_2 \Delta_2 + T_3 \Delta_3 + T_4 \Delta_4}{\Delta}$$

$$= \frac{G_1 G_2 G_7 \cdot 1 + G_4 G_7 \cdot 1 + G_1 G_6 (1 - G_5) + G_4 G_3 G_6 \cdot 1}{\Delta}$$

$$\boxed{\frac{Y_4}{Y_1} = \frac{G_1 G_2 G_7 + G_4 G_7 + G_1 G_6 (1 - G_5) + G_4 G_3 G_6}{1 - G_2 G_3 - G_5}}$$