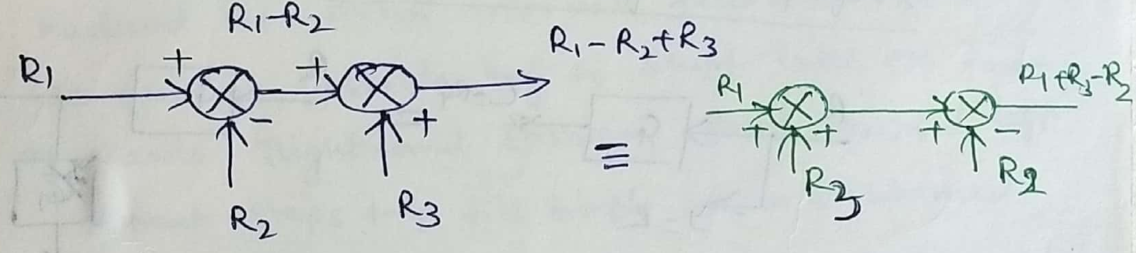
(3)

V1/I

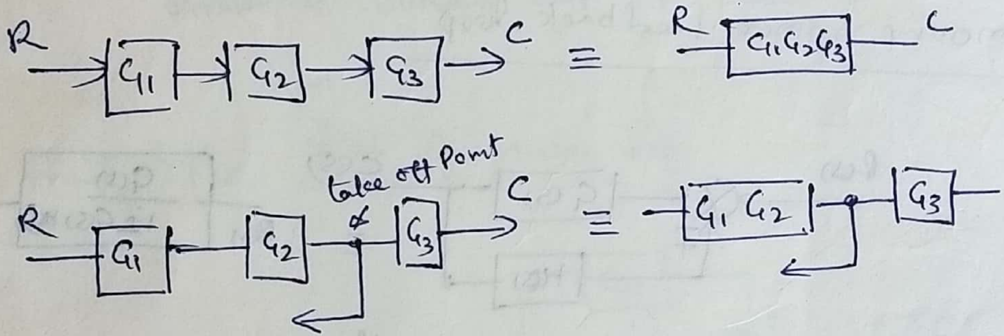
Rules for Block diagram reduction :-

To bring BD into simple form it is necessary to reduce the BD using proper logic such that output of such system and value of any feedback signal not get disturbed.

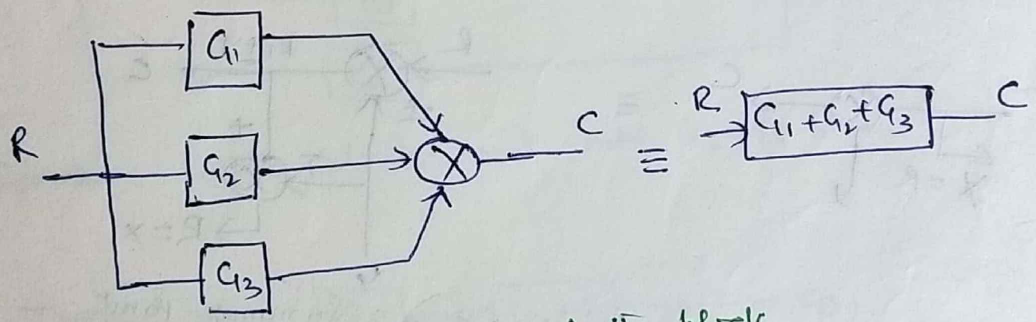
Rule 1 Associative law



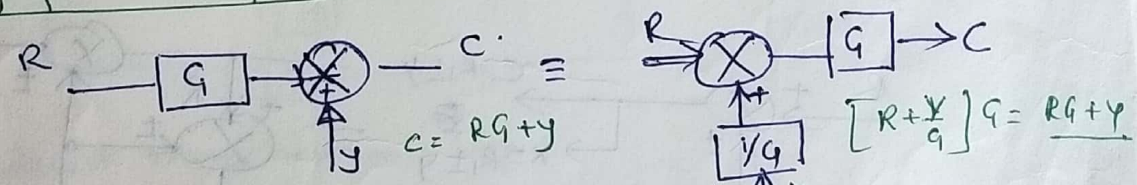
Series block



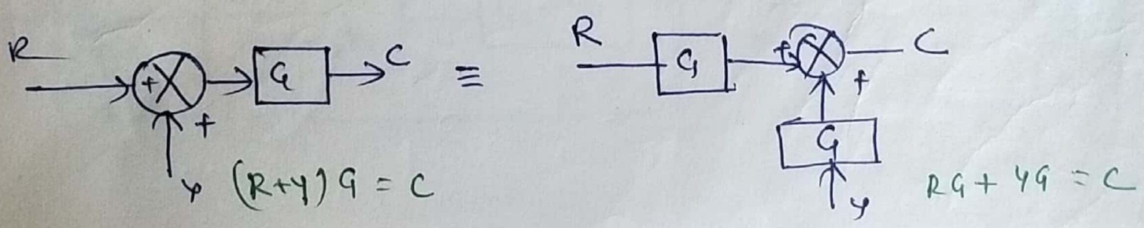
Parallel block



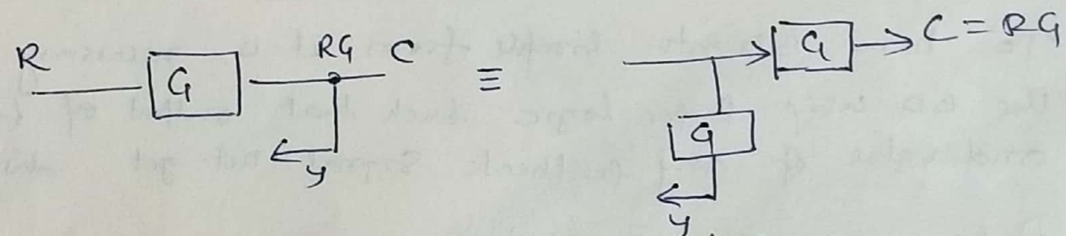
Shifting summing point behind the block



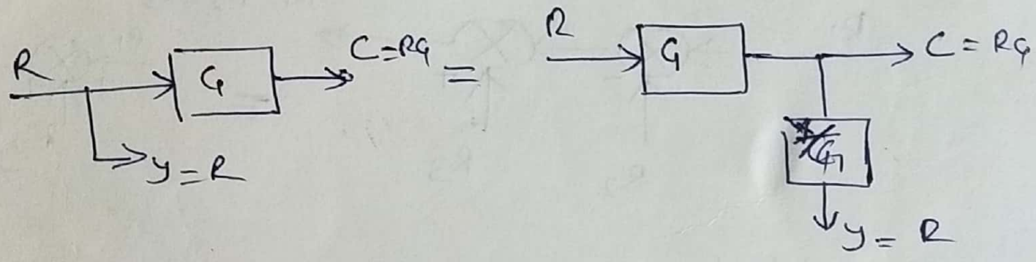
Shifting the summing point beyond the block



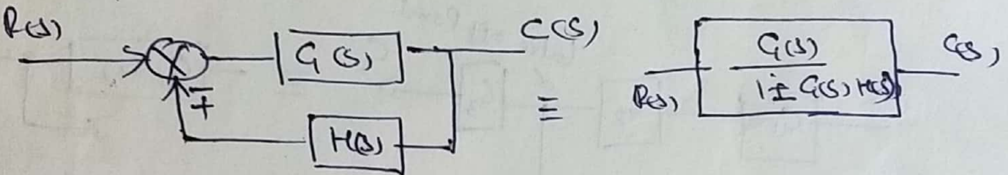
Shifting take off Point behind the block



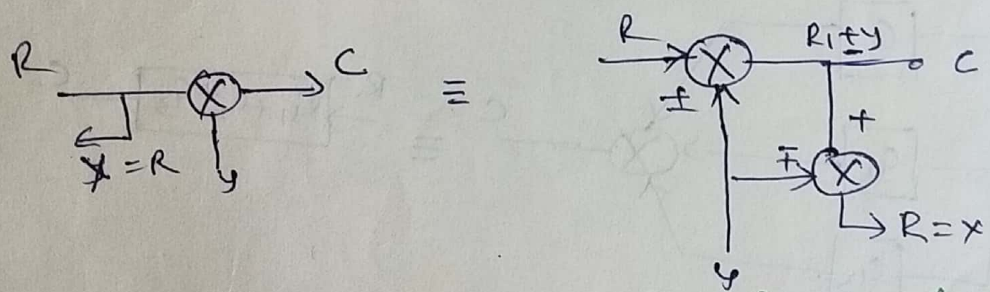
Shifting take off Point beyond the block



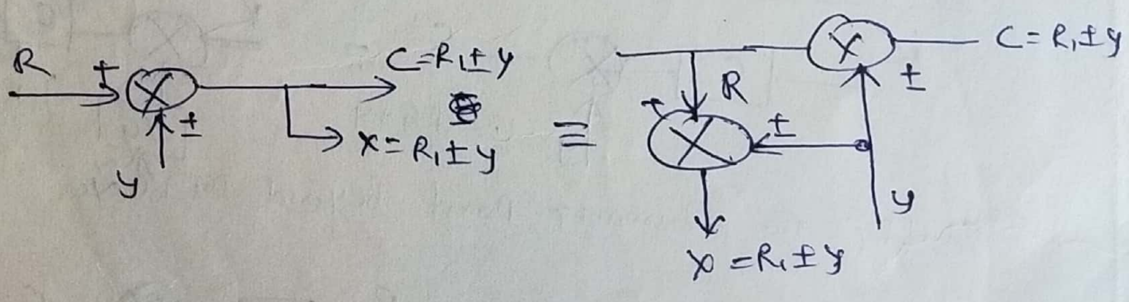
Removing minor feedback loop



Critical rule (shifting take off after summing Point)



Shifting the take off Point before a summing Point



Block diagram reduction Problems

Procedure to Solve Block diagram reduction Problem

(4) Step 1 : Reduce the blocks connected in Series

Step 2 : Reduced the block connected in Parallel

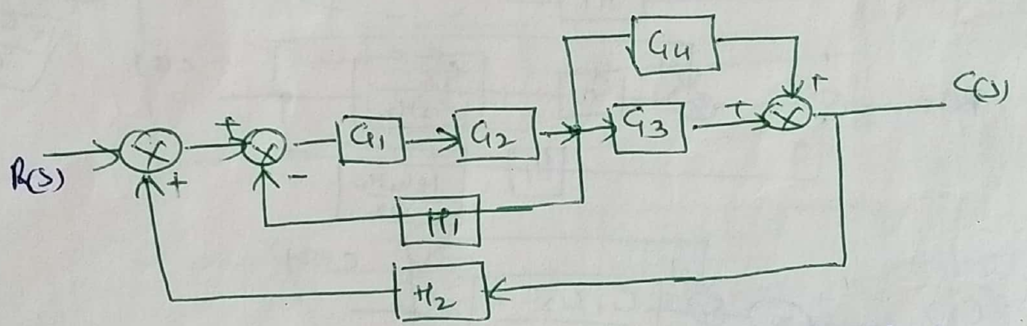
Step 3 : Reduced the minor internal feedback loops

Step 4 : as far as possible try to shift take off Points towards Right and summing Point toward left.

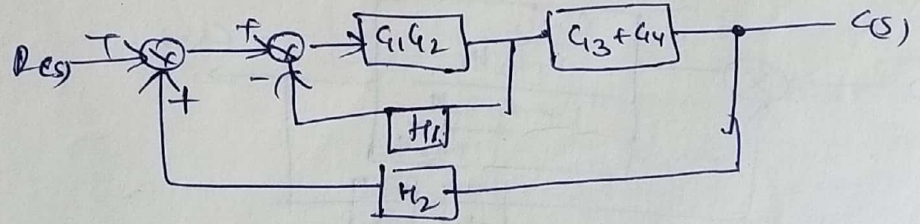
Step 5 : Repeat Steps 1-4 till simple form is obtained

Step 6 : using std TF of simple closed loop System, obtain obtain the closed loop TF $\frac{C(s)}{R(s)}$ of the overall Systems

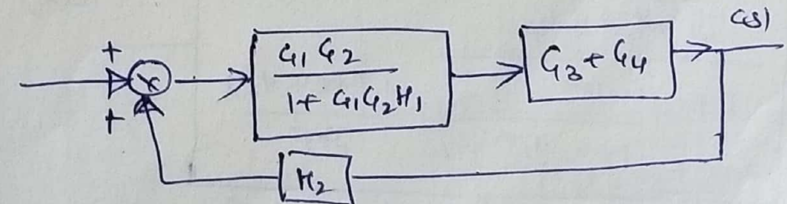
Q.1 find $TF = \frac{C(s)}{R(s)}$ of given fig



① Combine G_1 & G_2 block and Add G_3 & G_4 block



② Reduced minor feed back loop



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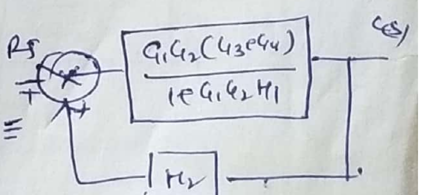
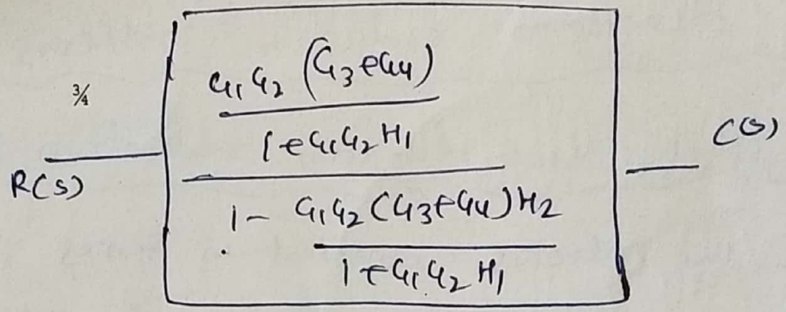
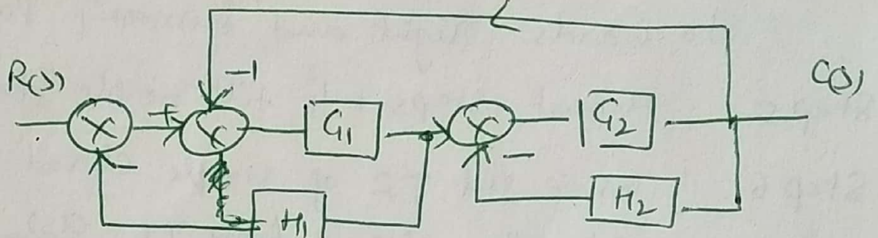


$$= \frac{C(s)}{R(s)} = \frac{G_1G_2(G_3+G_4)}{1+G_1G_2H_1 - G_1G_2(G_3+G_4)H_2}$$

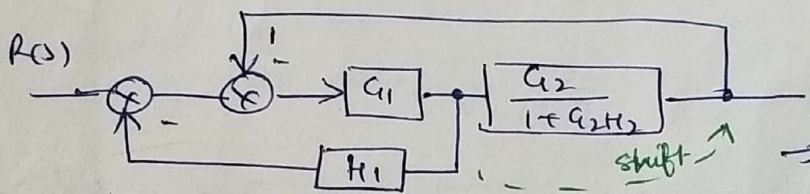


$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 (G_3 + G_4)}{1 + G_1 G_2 H_1 - G_1 G_2 (G_3 + G_4) H_2}$$

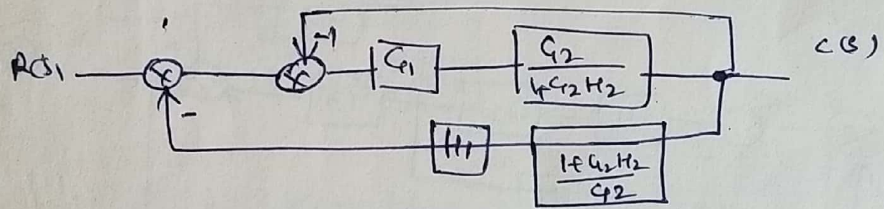
Q. Find $\frac{C(s)}{R(s)}$

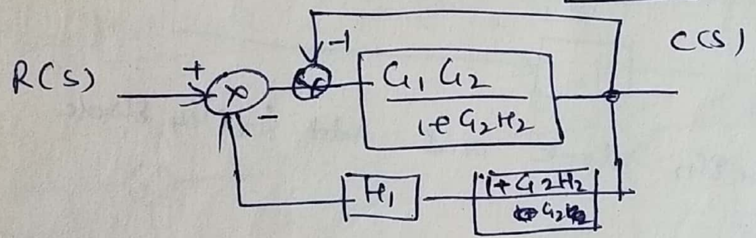


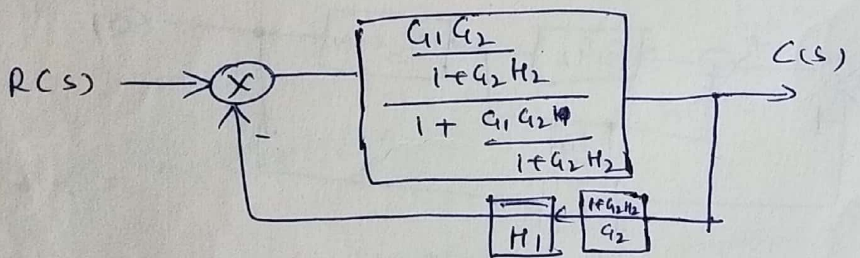
① Remove inner feedback loop

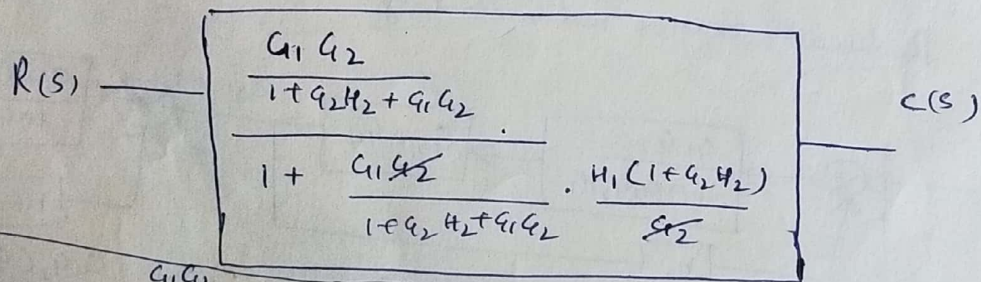


→ to shift divide by $\boxed{\frac{1+G_2H_2}{G_2}}$



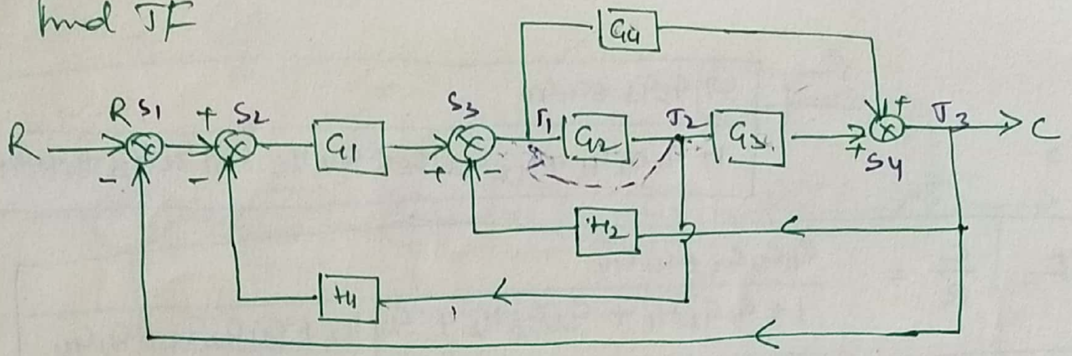


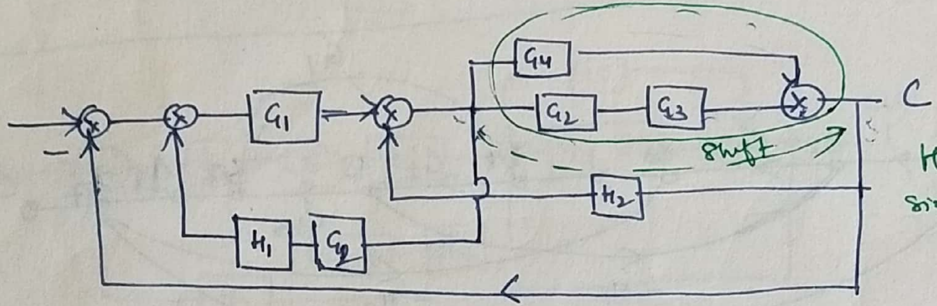




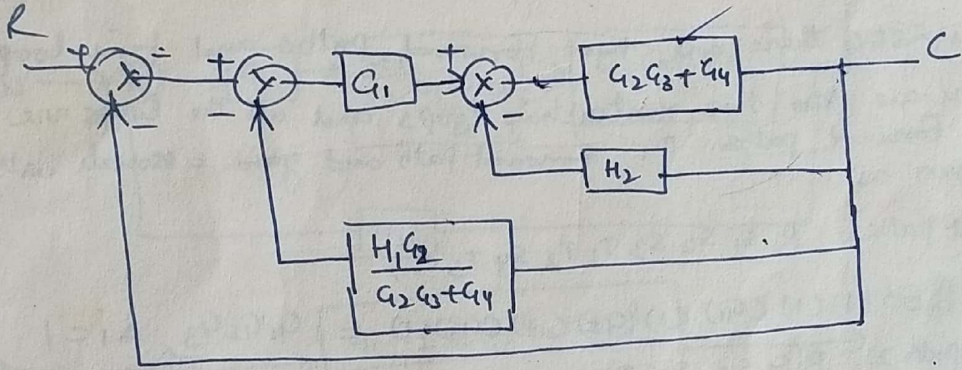
$$\boxed{\frac{C(s)}{R(s)} = \frac{G_1G_2}{1 + G_2H_2 + G_1G_2 + G_1H_1 + G_1G_2H_1H_2}}$$

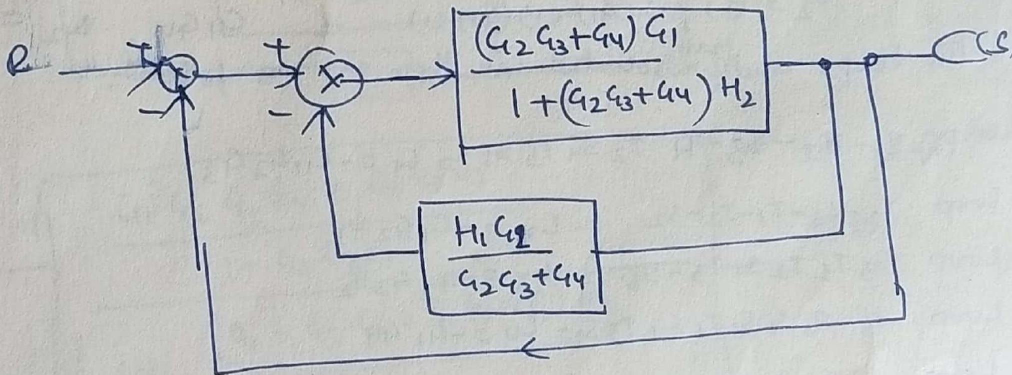
find TF

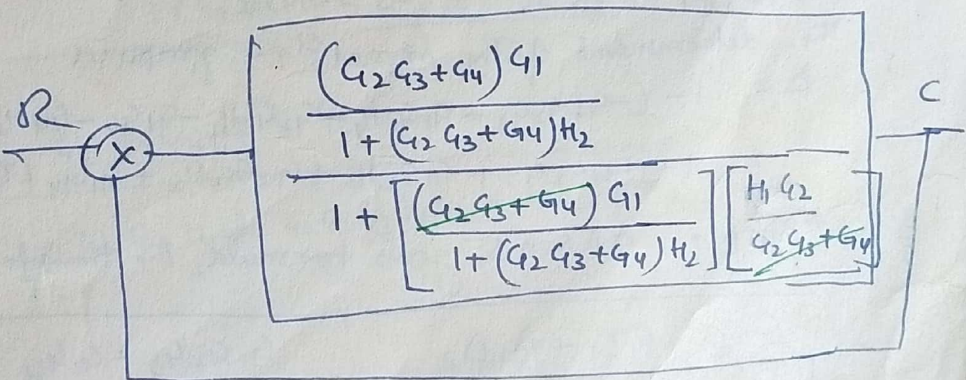




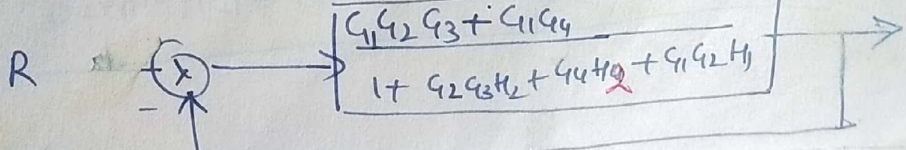
Here two step simplified inner loop and then shift take off point to right







$$\frac{\dfrac{(G_2G_3+G_4)G_1}{1+(G_2G_3+G_4)H_2}}{1+\left[\dfrac{(\cancel{G_2G_3+G_4})G_1}{1+(G_2G_3+G_4)H_2}\right]\left[\dfrac{H_1G_2}{\cancel{G_2G_3+G_4}}\right]}$$

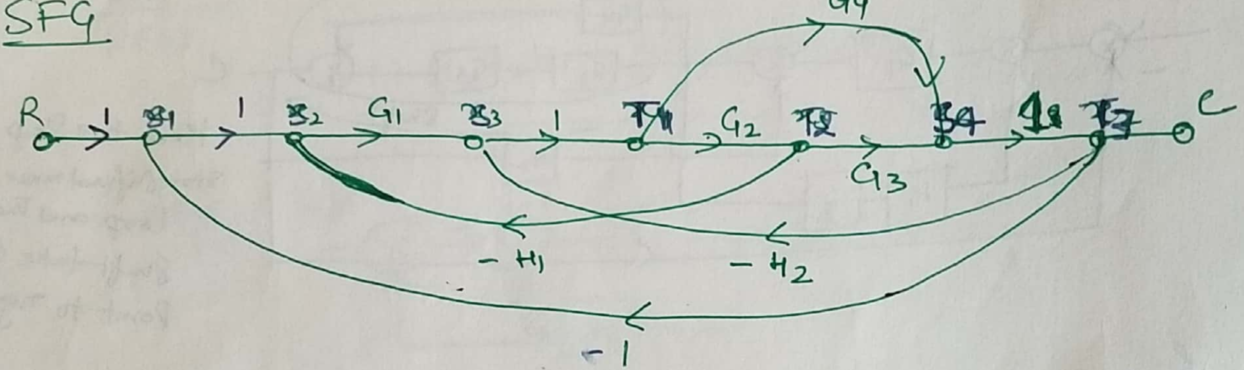


$$\frac{G_1G_2G_3+G_1G_4}{1+G_2G_3H_2+G_4H_2+G_1G_2H_1}$$

$\frac{R}{}$ $\boxed{\dfrac{G_1G_2G_3 + G_1G_4}{1+G_1G_2H_1 + G_2G_3H_2 + G_4H_2 + G_1G_2G_3 + G_1G_4}}$

$$\boxed{TF = \frac{C}{R} = \frac{G_1G_2G_3 + G_1G_4}{1+G_1G_2H_1 + G_2G_3H_2 + G_4H_2 + G_1G_2G_3 + G_1G_4}}$$

SFG



In this SFG there are two Forward paths and five loops and there are ~~two~~ two nontouching loops and all the loops are touch both the forward paths. The Forward path and gain associate with them are given as

Forward path 1 $R\ S_1\ S_2\ S_3\ T_1\ T_2\ S_4\ T_3\ C$,

$$P_1 = (1)(1)(G_1)(1)(G_2)(1)(G_3)(1) = G_1G_2G_3, \quad \Delta_1 = 1$$

Forward Path 2, $R\ S_1\ S_2\ S_3\ T_1 \cdot S_4 - T_3 - C$

$$P_2 = (1)(1)(G_1)(1)(G_4)(1) = G_1G_4, \quad \Delta_2 = 1$$

The loops and gains associated with them are as follows:

Loop $S_1 - S_2 - S_3 - T_1\ T_2\ S_4\ T_3\ S_1 = L_1 = -G_1G_2G_3$

Loop $S_2 - S_3 - T_1 - T_2 - S_2 = L_2 = -G_1G_2H_1$

Loop $S_3\ T_1\ T_2\ S_4\ T_3 - S_3 = L_3 = -G_2G_3H_2$

Loop $R - S_1\ S_2\ S_3\ T_1\ S_4\ T_3\ S_1 = L_4 = -G_1G_4$

Loop $S_3\ T_1\ S_4\ T_3 - S_3 = L_5 = -G_4H_2$

the determinant of The signal flow graph is

$$\Delta = 1 - (-G_1G_2G_3 - G_1G_2H_1 - G_2G_3H_2 - G_1G_4 - G_4H_2)$$

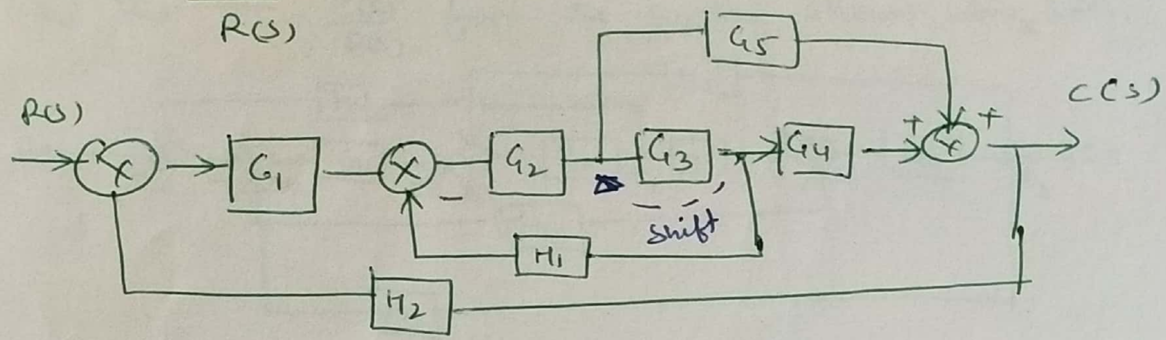
$$= 1 + G_1G_2G_3 + G_1G_2H_1 + G_2G_3H_2 + G_1G_4 + G_4H_2$$

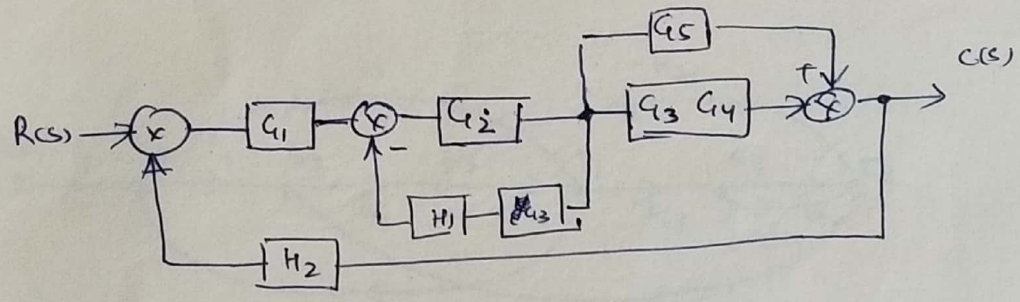
Applying MASON's gain formula, The transfer function is

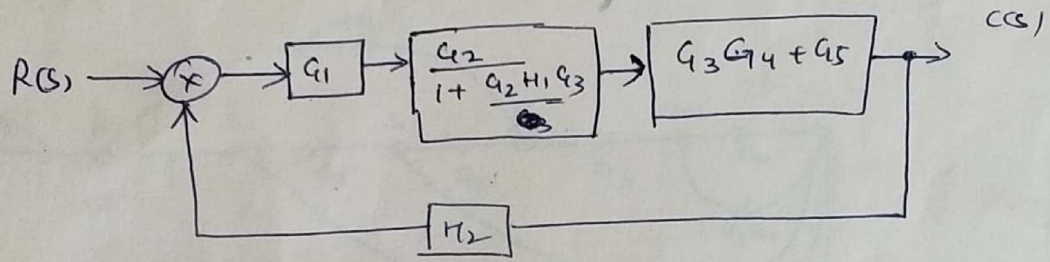
$$\boxed{\frac{C}{R} = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta} = \frac{G_1G_2G_3 + G_1G_4}{1+G_1G_2G_3 + G_1G_2H_1 + G_2G_3H_2 + G_1G_4 + G_4H_2}}$$

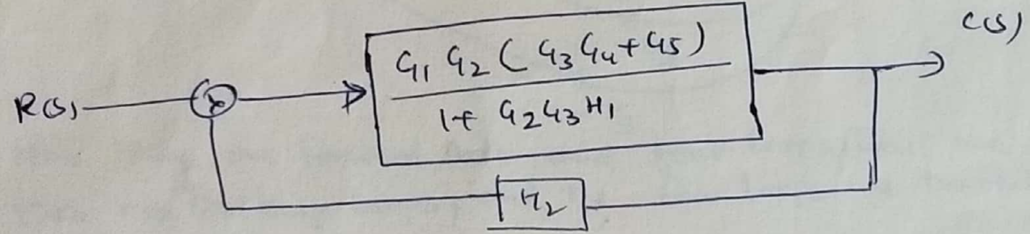
Q

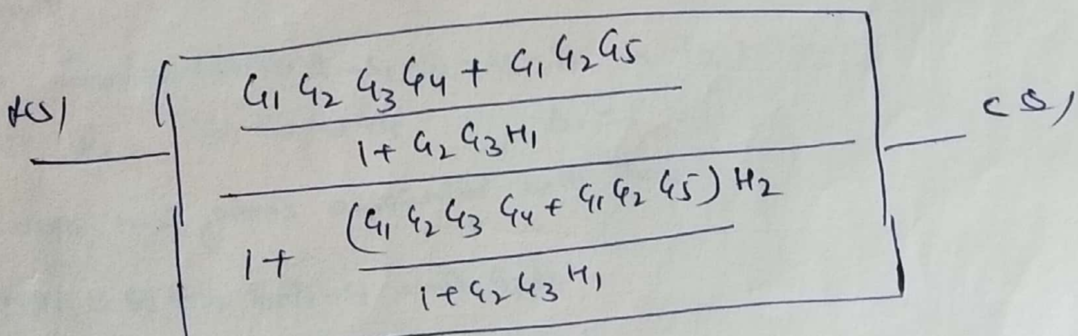
find $\frac{C(s)}{R(s)}$





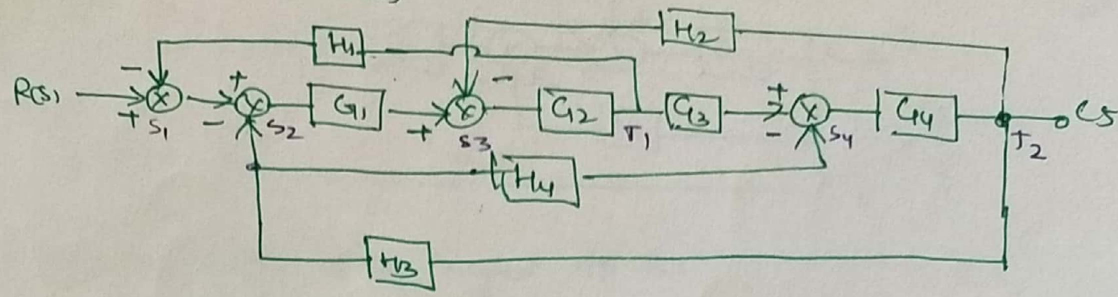


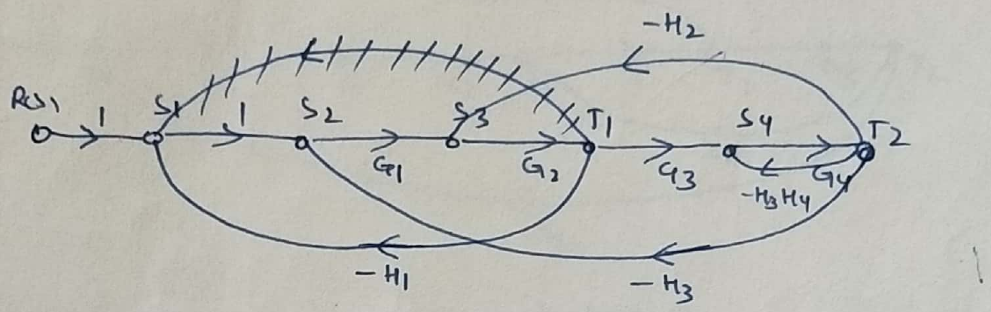


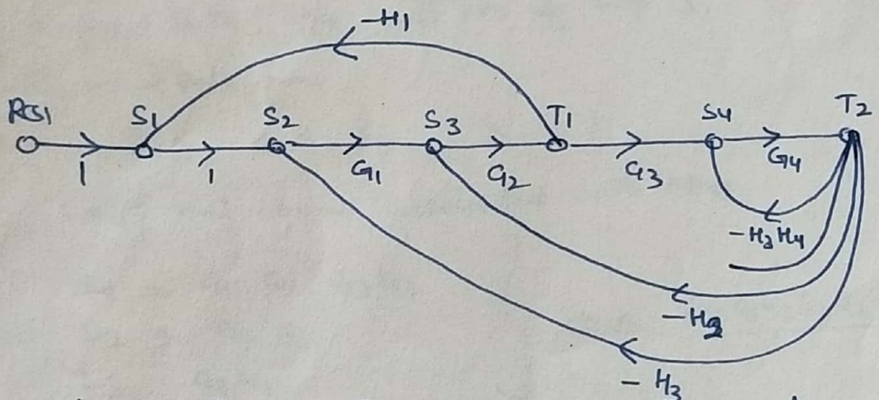


$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_3 G_4 + G_1 G_2 G_5}{1 + G_2 G_3 H_1 + G_1 G_2 G_3 G_4 H_2 + G_1 G_2 G_5 H_2}$$

Q find the TF $\frac{C(s)}{R(s)}$ for the system shown using SFG.







Here only one forward path and four loops, there are one pair of two non touching loops, and the four loops are touching the forward path.

The forward path $R - S_1 - S_2 - S_3 - T_1 - S_4 - T_2$.

$P_1 = G_1 G_2 G_3 G_4$, $\Delta_1 = 1$

Loops and gains associated with them

Loop 1 $= S_1 - S_2\ S_3 - T_1 - S_1 = -G_1 G_2 H_1$

Loop 2 $= S_2 - S_3\ T_1\ S_4\ T_2\ S_2 = -G_1 G_2 G_3 G_4 H_3$

Loop 3 $= S_3\ T_1\ S_4\ T_2\ S_3 = -G_2 G_3 G_4 H_2$

Loop 4 $= S_4 T_2 S_4 = -G_4 H_3 H_4$

the pairs of non touching loops is L_1 & $L_4 = L_{14}$

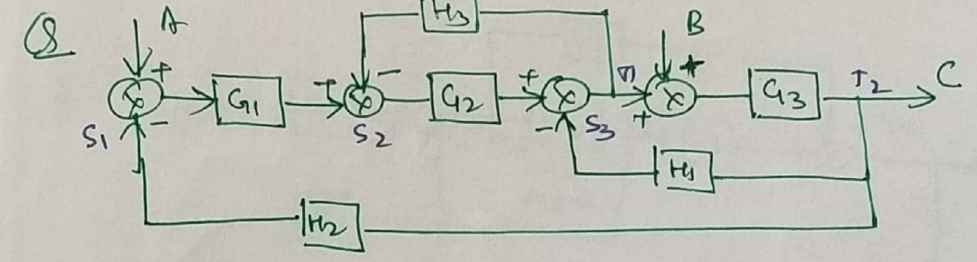
$L_{14} = S_1 - S_2 - S_3 - T_1 - S_1$ & $S_4 T_2 S_4 = G_1 G_2 H_1 G_4 H_3 H_4$

$$\Delta = 1 - (L_1 + L_2 + L_3 + L_4) + L_{14}$$
$$= (1 + G_1G_2H_1 + G_1G_2G_3G_4H_3 + G_2G_3G_4H_2 + G_4H_3H_4 + G_1G_2G_4H_1H_3H_4)$$

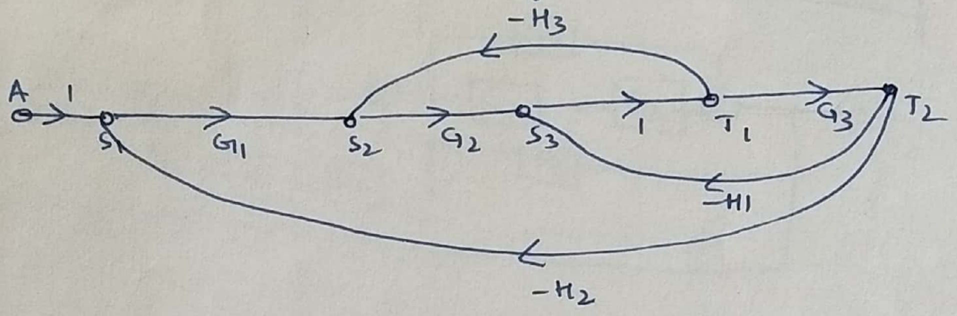
$$TF = \frac{P_1\Delta_1}{\Delta} = \frac{G_1G_2G_3G_4}{\Delta}$$

Find TF when the input R is at (a) station A & (b) at station B

Q



Let I/p is at (A) SFG, neglect i/p B:



Forward Paths one and no of loop 3.

Forward Path gain

$P_1 = G_1 G_2 G_3$, $\Delta_1 = 1$

Loops and gains associated with them

$L_1 = -G_1 G_2 G_3 H_2$

$L_2 = G_2 H_3$

$L_3 \;\; G_3 H_1$

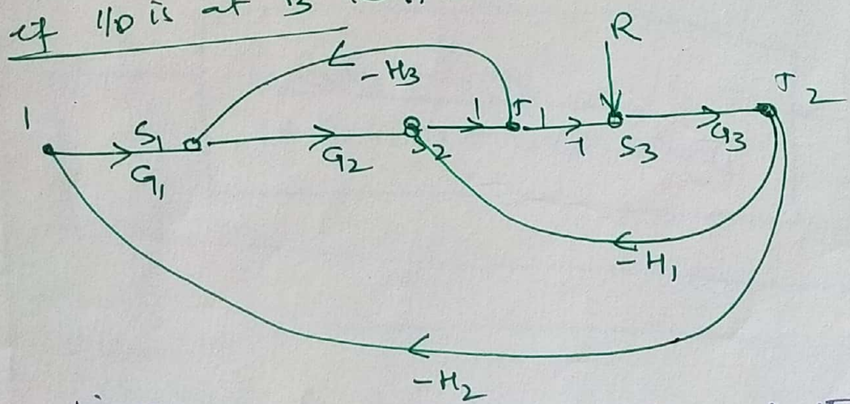
$\Rightarrow \Delta = 1 + G_1 G_2 G_3 H_2 + G_2 H_3 + G_3 H_1$

There are no non touching loops then

C/R due to i/p at A is

$$\boxed{TF = \frac{C}{R} = \frac{P_1 \Delta_1}{\Delta} = \frac{G_1 G_2 G_3}{1 + G_3 H_1 + G_2 H_3 + G_1 G_2 G_3 H_2}}$$

If i/p is at B then SFG



In this case one forward path and three loops.

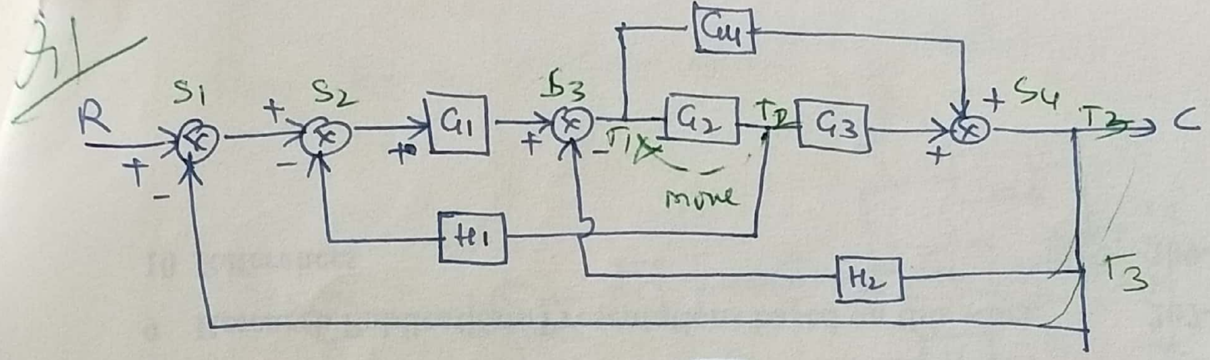
$P_1 = G_3$, $\Delta_1 = 1 + G_2 H_3$

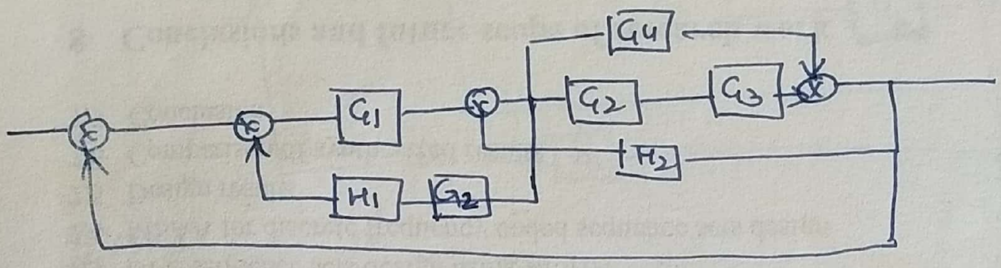
$\Delta = 1 + G_1 G_2 G_3 H_2 + G_3 H_1 + G_2 H_3$

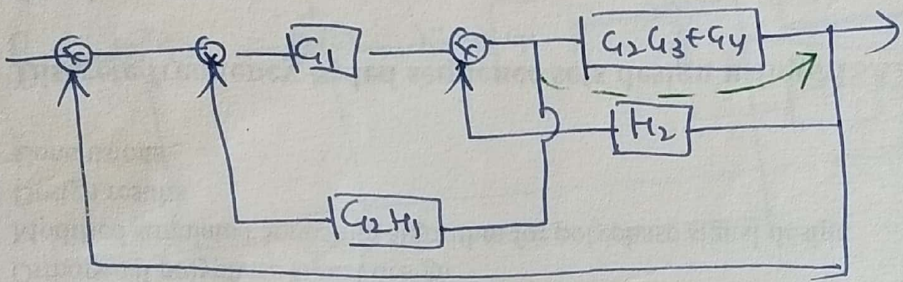
$TF = \frac{P_1 \Delta_1}{\Delta}$

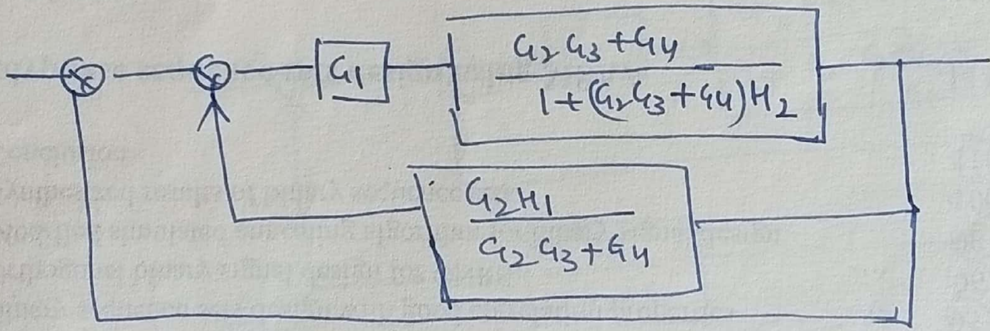
$$\boxed{TF = \frac{G_3(1 + G_2 H_3)}{1 + G_1 G_2 G_3 H_2 + G_3 H_1 + G_2 H_3}}$$

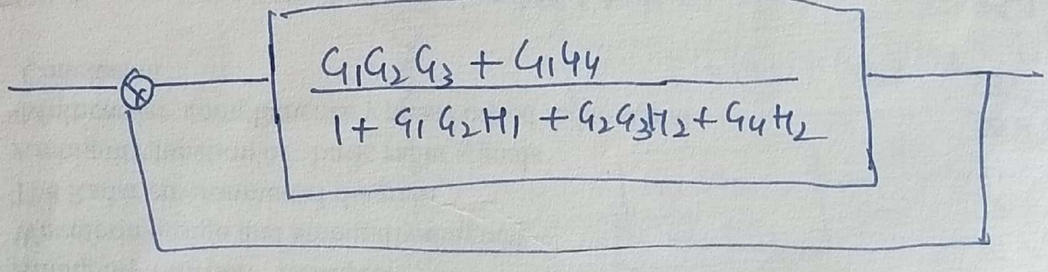
Ai)







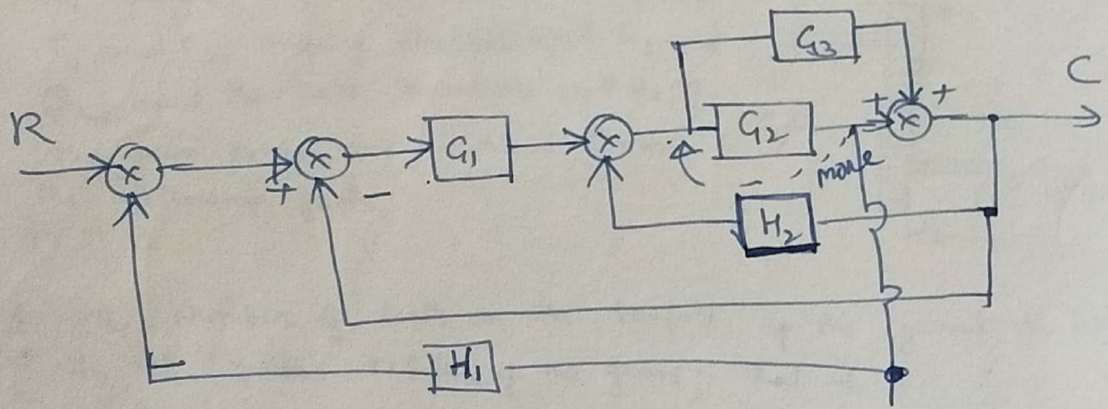


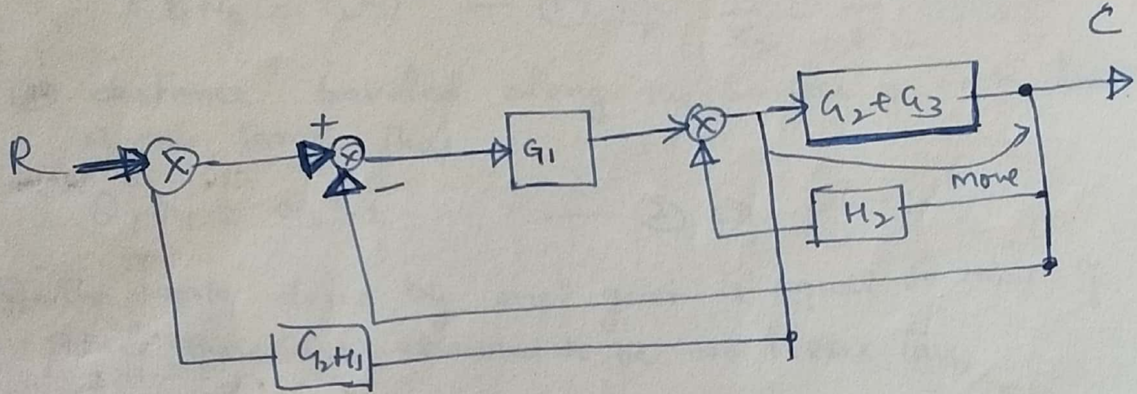


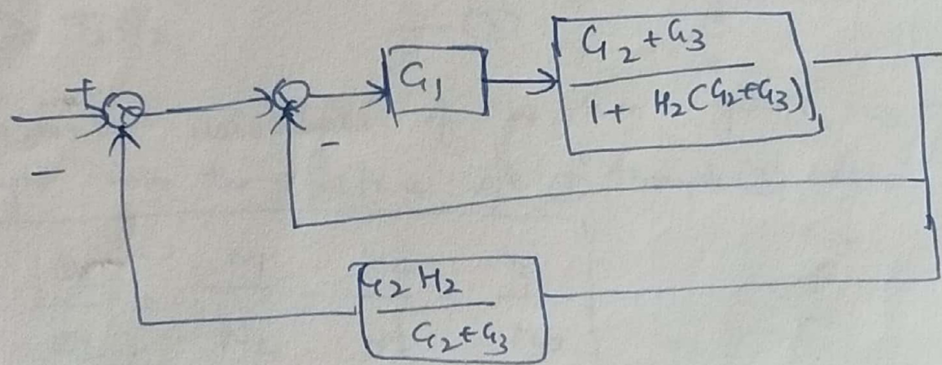
$$\frac{G_1G_2G_3+G_1G_4}{1+G_1G_2H_1+G_2G_3H_2+G_4H_2+G_1G_2G_3+G_1G_4}$$

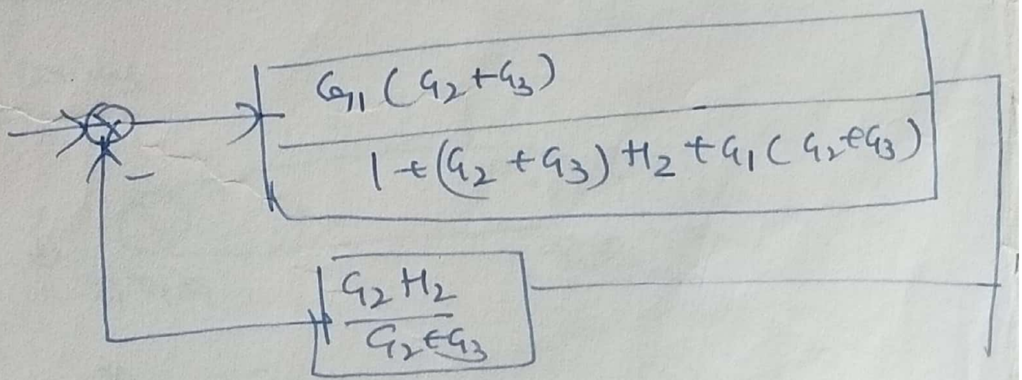
C

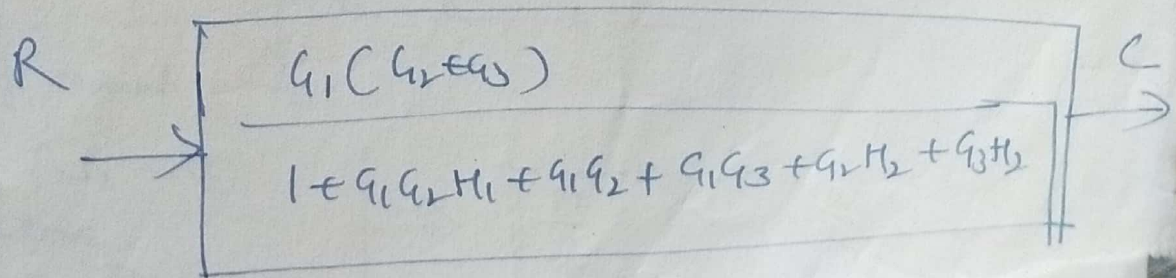
For Block deagram find $\frac{C}{R}$ ratio.





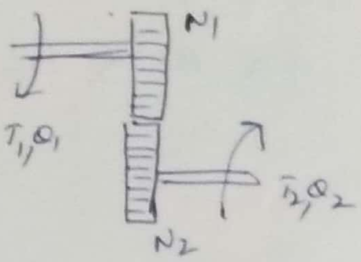






Gear Trains, Levers, and timing Belts

The relationships between the torques, T_1 and T_2, angular displacement θ_1 and θ_2, and the teeth numbers N_1 & N_2 of the gear train are derived from the following facts;



1. The Number of teeth on the surface of the gears is proportional to the radii r_1 & R_2 of the gears; That is,

$$r_1 N_2 = r_2 N_1 \quad — (1) \Rightarrow \frac{r_1}{r_2} = \frac{N_1}{N_2}$$

(2) distance traveled along the surface of each ~~teeth~~ gear is the same, Thus

$$\theta_1 r_1 = \theta_2 r_2 \quad — (2) \Rightarrow \frac{\theta_2}{\theta_1} = \frac{r_1}{r_2}$$

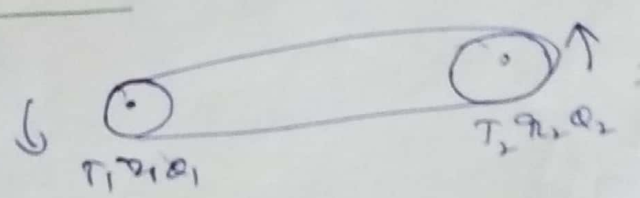
(3) The work done by one gear is equal to that of the other since there are assumed to be no losses, Thus,

$$T_1\theta_1 = T_2\theta_2 \quad — (3) \quad \frac{T_1}{T_2} = \frac{\theta_2}{\theta_1}$$

If the angular velocities of the two gears, ω_1 and ω_2, are brought into the picture, eqn (1) through (3) lead to

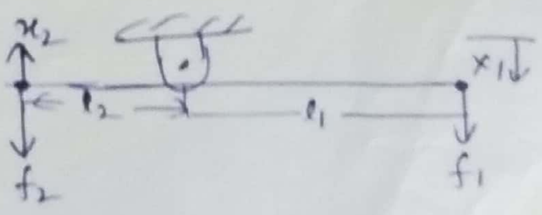
$$\boxed{\frac{T_1}{T_2} = \frac{\theta_2}{\theta_1} = \frac{N_1}{N_2} = \frac{\omega_2}{\omega_1} = \frac{r_1}{r_2}}$$

Belt or Chain Drives



$$\frac{T_1}{T_2} = \frac{r_1}{r_2} = \frac{\theta_2}{\theta_1}$$

Levers



By Law of moment

$$f_1 l_1 = f_2 l_2 \quad — (1)$$

By workdone

$$f_1 x_1 = f_2 x_2 \quad — (2)$$

$$\Rightarrow \boxed{\frac{f_1}{f_2} = \frac{l_2}{l_1} = \frac{x_2}{x_1}}$$

Advantage and disadvantages of Block diagram Presentation :

(1) **Advantages** :- Easy to form the overall block diagram of whole System

(2) The Functional operation of the System is readily visualized by examining the block diagram rather than display physical System itself.

Disadvantage :

- Interaction of blocks
- Concealment of important function
- Reciprocity and nonreciprocity
- No information of construction of System
- not unique
- main Source of energy not shown in the Systems

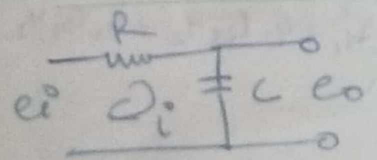
Block diagram

(1) The input & o/p behaviour of a (LTI) Linear System is given by TF

$$G(s) = \frac{C(s)}{R(s)}$$

A convenient graphical representation of this behaviour is the block diagram.

Block diagram of electrical System



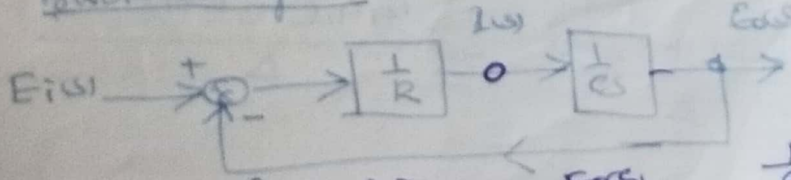
$$i = \frac{e_i - e_o}{R} \text{ or } I(s) = \frac{E_i(s) - E_o(s)}{R} \quad -(1)$$

$$e_o = \frac{1}{C}\int i\,dt \text{ or } E_o(s) = \frac{I(s)}{Cs} \quad -(2)$$

Put I(s) in (2)

$$E_o(s) = \frac{E_i(s) - E_o(s)}{RCs}$$

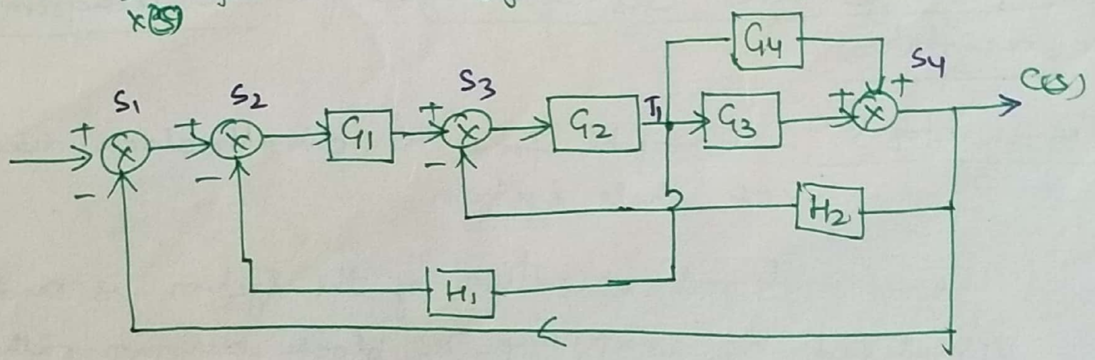
or, Block diagram

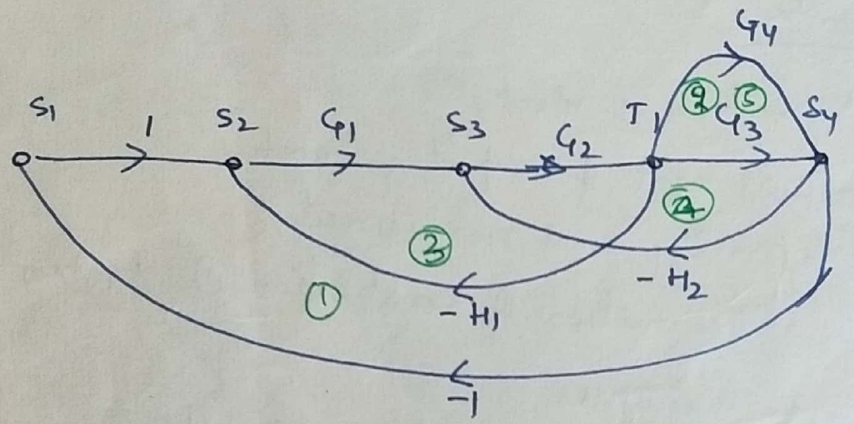


$$\text{or, } TF = \frac{E_o(s)}{E_i(s)} = \frac{1}{1+RCs}$$

from BD = $\frac{E_o(S)}{} = \frac{\frac{1}{RCs}}{} = \frac{1}{1+RCs}$

Find $\frac{X(s)}{X(s)}$ from below figure TR $\frac{C(s)}{R(s)}$

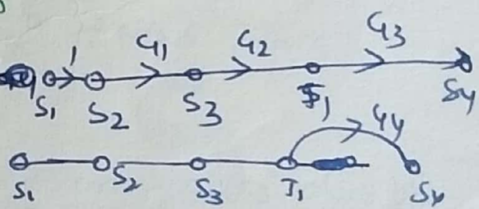




Forward Paths   Path Gain

$P_1 = S_1 - S_2 - S_3 - T_1 - S_4$ (via G_3) $= G_1 G_2 G_3$

$P_2 = S_1 - S_2 - S_3 - T_1 - S_4$ (via G_4) $= G_1 G_2 G_4$



individual loops

Loop 1 $S_1\ S_2\ S_3\ T_1\ S_4 - S_1 = -G_1G_2G_3 = L_{11}$

2 $S_1\ S_2\ S_3\ T_1\ S_4 - S_2(G_4) = -G_1G_2G_4 = L_{12}$

3 $S_2\ S_3\ T_1\ S_2 = -G_1G_2H_1 = L_{13}$

4 $S_3 - T_1\ S_4\ S_3 = -G_2G_3H_2 = L_{14}$

5 $S_3\ T_1\ S_4 - S_3(G_4) = -G_2G_4H_2 = L_{15}$

Pairs of two non touching loops = NIL

$$\Delta = 1 - (L_{11} + L_{12} + L_{13} + L_{14} + L_{15})$$

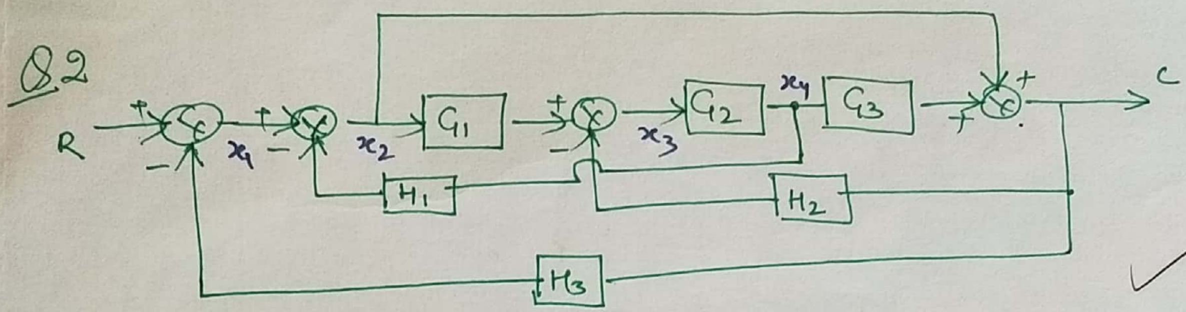
$$\Delta = 1 + G_1G_2G_3 + G_1G_2G_4 + G_1G_2H_1 + G_2G_3H_2 + G_2G_4H_2$$

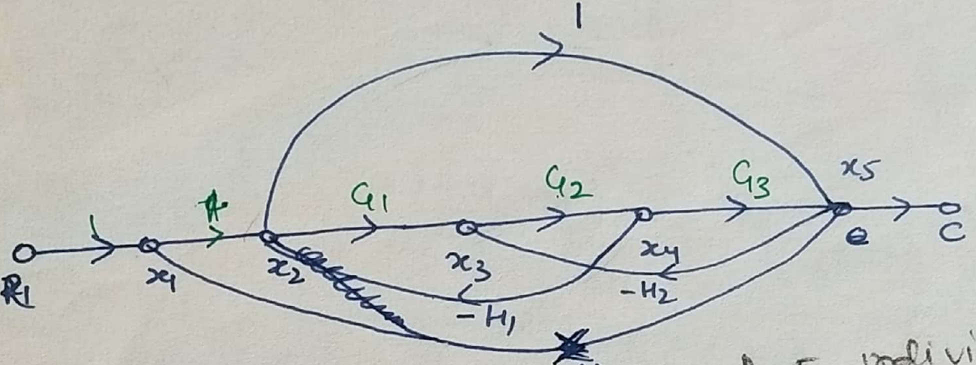
$$\Delta_1 = 1$$

$$\Delta_2 = 1$$

$$\frac{C(s)}{R(s)} = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta} = \frac{G_1G_2(G_3+G_4)}{\Delta}$$

Q.2





Were two Forward path and 5 individual loops

Forward path

$P_1 = R - x_1 - x_2 - x_3 - x_4 - x_5 - C = G_1G_2G_3$

$P_2 = R - x_1 - x_2 - x_5 - C = 1$

For Calculation of Delta (Δ)

Sr no	Loop	Loop gain
L 1	$x_1 - x_2 - x_3 - x_4 - x_5 - x_1$	$-G_1G_2G_3H_3$
L 2	$x_1 - x_2 - x_5 - x_1$	$-H_3$
L 3	$x_2 - x_3 - x_4 - x_2$	$-G_1G_2H_1$
L 4	$x_2 - x_5 - x_3 - x_4 - x_2$	$+G_2H_1H_2$
L 5	$x_3 - x_4 - x_5 - x_3$	$-G_2G_3H_2$

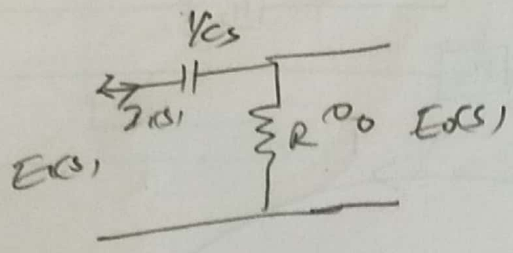
$$TF = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta}$$

$$\Delta = 1 + G_1G_2G_3H_3 + H_3 + G_1G_2H_1 - G_2H_1H_2 + G_2G_3H_2$$

$\Delta 1 = 1$

$\Delta_2 = 1$

$$\boxed{TF = \frac{C}{R} = \frac{G_1G_2G_3 + 1}{1 + G_1G_2G_3H_3 + H_3 + G_1G_2H_1 - G_2H_1H_2 + G_2G_3H_2}}$$



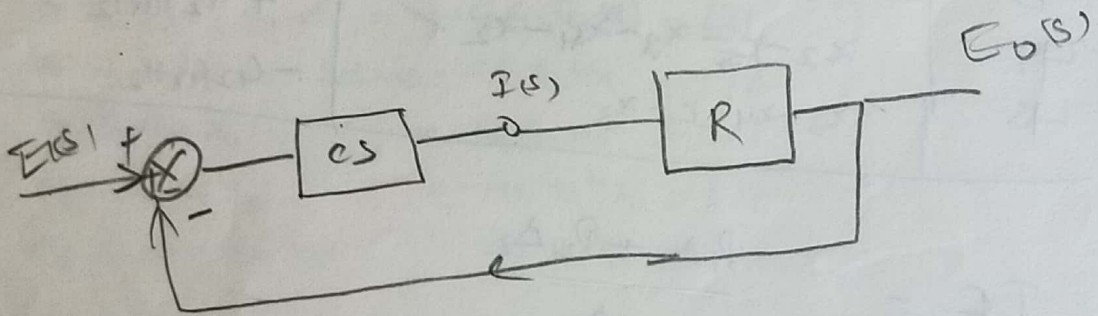
$$I(s) = \left(E_i(s) - E_o(s)\right) Cs$$

$$E_o(s) = I(s)\, R$$

$$E_o(s) = \left[E_i(s) - E_o(s)\right] RCs$$

$$E_o(s)\left[1 + RCs\right] = E_i(s)\, RCs$$

$$\boxed{\frac{E_o(s)}{E_i(s)} = \frac{RCs}{1 + RCs}}$$



$$\frac{RCs}{1+RCs}$$