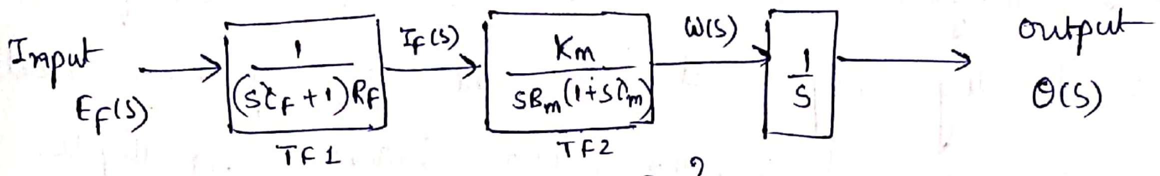
2A - Block Diagrams

A block diagram of a system is a pictorial representation of an actual system.

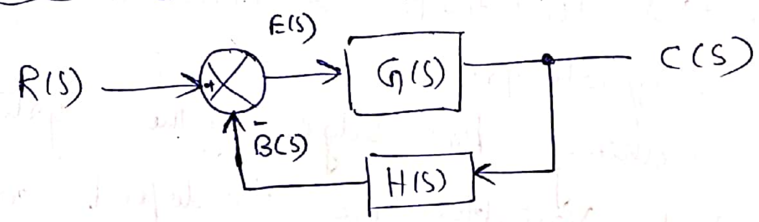
ex: DC motor Block Diagram (field control)



What does it consists of?

- Open loop gains of various systems (ex: field system, mechanical system etc.)
- Signal flow (ex: $I_F(s)$, $\theta(s)$ etc.)

⇒ Block diagram of a closed loop system



$$E(s) = R(s) - B(s) \quad \text{— (1)}$$

$$G(s) = \frac{C(s)}{E(s)} \; ; \quad E(s) = \frac{C(s)}{G(s)} \quad \text{— (2)}$$

$$H(s) = \frac{B(s)}{C(s)} \; ; \quad B(s) = C(s) \cdot H(s) \quad \text{— (3)}$$

Sub (3), (2) in eq (1)

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

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

$$C(s)\left[\frac{1}{G(s)} + H(s)\right] = R(s)$$

$$C(s)\left[\frac{1+G(s)H(s)}{G(s)}\right] = R(s) \Rightarrow \boxed{\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)\,H(s)}}$$

A block diagram contains information regarding dynamic behaviour, but it does not include any information on the physical construction of the system.

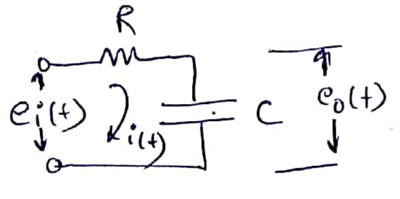
* Block diagram of a system is not unique, it is totally dependent on the assumptions made. Hence a physical system can have multiple block diagrams based on user persepective.

Procedure for Drawing Block diagram :

1. Write the D.Equations that describe the dynamic behaviour of system.
2. take the Laplace transforms, assuming zero initial conditions to obtain algebraic equations.
3. From the working knowledge of the system, the input & output variables are identified and the block diagram for each equation can be drawn.

example :

Consider an RC circuit, as shown below.



(a) Given circuit

Step 1 : D.E

$$i(t) = \frac{e_i(t) - e_o(t)}{R} \quad \text{--- (1)}$$

$$e_o(t) = \frac{1}{C}\int i(t)\,dt \quad \text{--- (2)}$$

Step 2 : Laplace transform

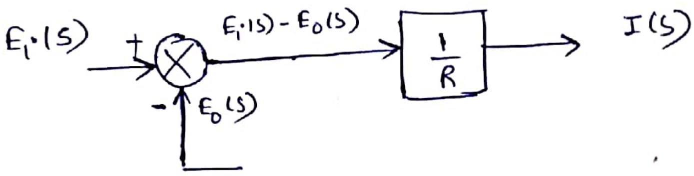
$$I(s) = \frac{E_i(s) - E_o(s)}{R} \quad \text{— (3)}$$

$$E_o(s) = \frac{1}{Cs} I(s) \quad \text{— (4)}$$

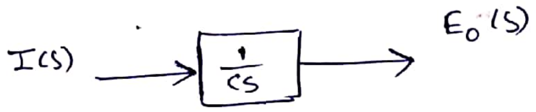
Step (3) : Input Variable is $E_i(s)$

Output Variable is $E_o(s)$

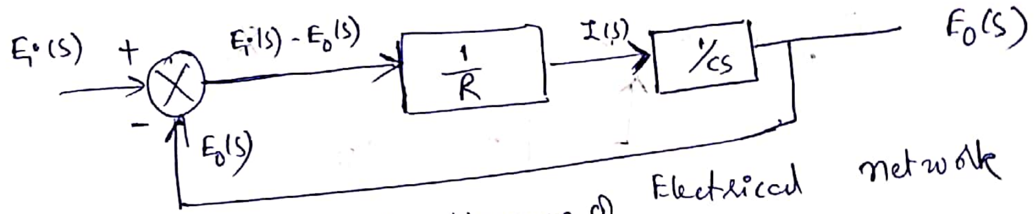
Step 4 :



(b) Block diagram for $I(s)$



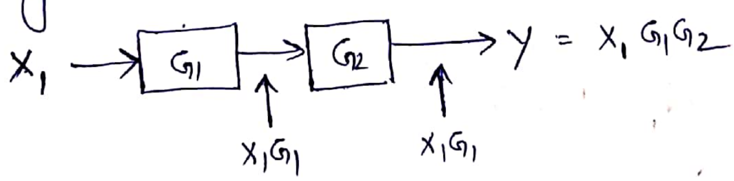
(b) Block diagram for $E_o(s)$



(c) Block diagram of Electrical network

Block diagram Reduction :-

1. Combining blocks connected in cascade.



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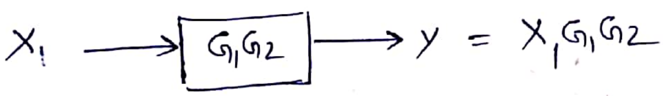
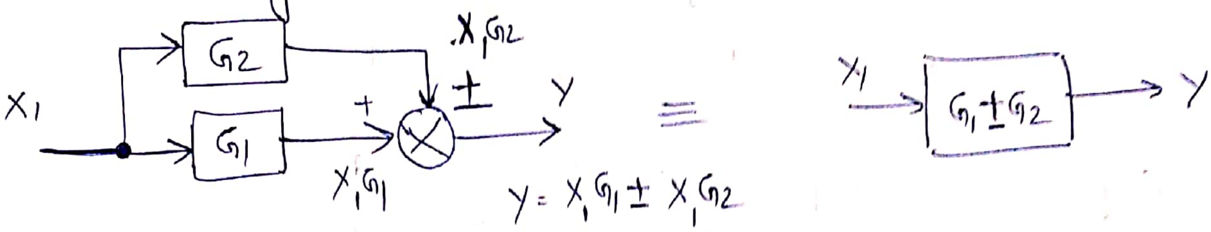


2. Combining blocks connected in parallel.



$y = X_1G_1 \pm X_1G_2$

$y = X_1(G_1 \pm G_2)$

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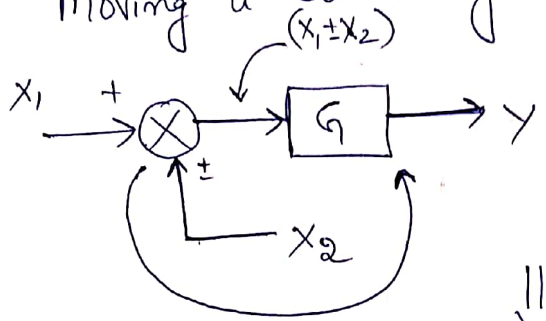
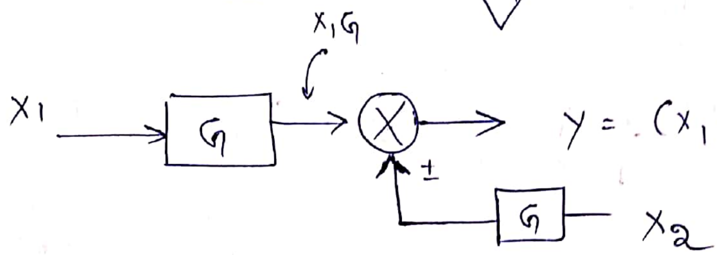
3. Moving a summing point after a block



$y = (x_1 \pm x_2)G$

$\Downarrow$



$y = (x_1 \pm x_2)G$

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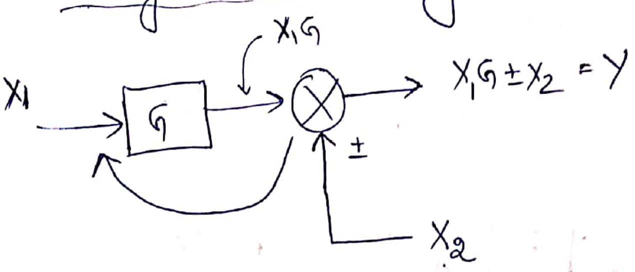
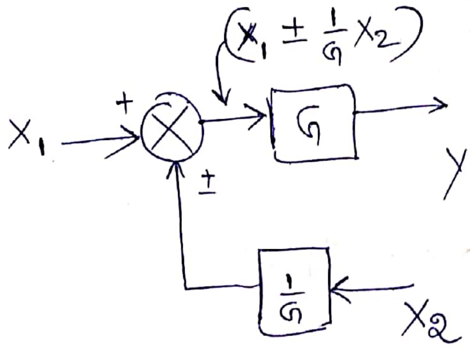
4. Moving a summing point ahead of a block

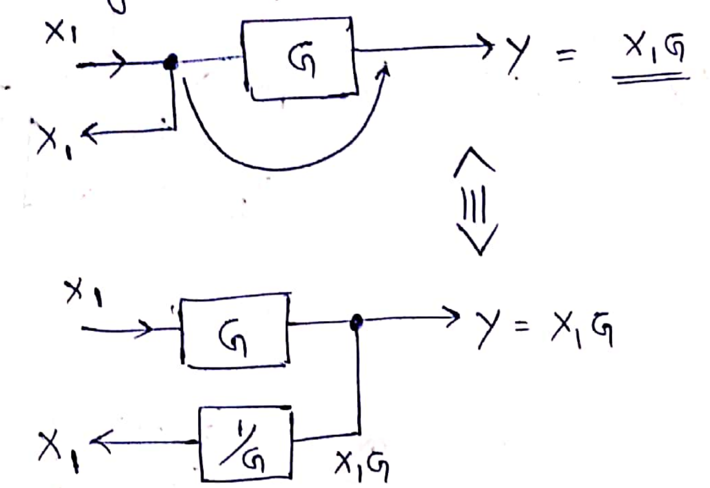


$\Downarrow$

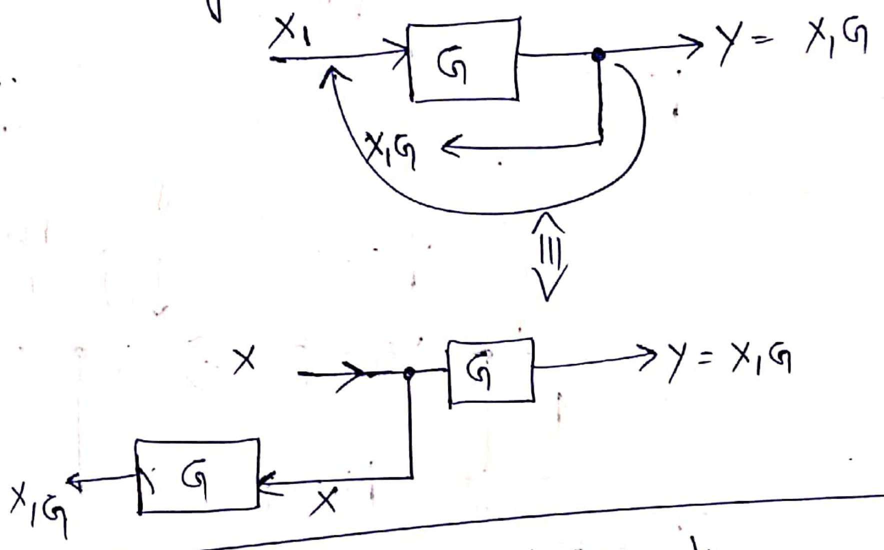


$Y = X_1G \pm X_2$

5. Moving a take off point after a block

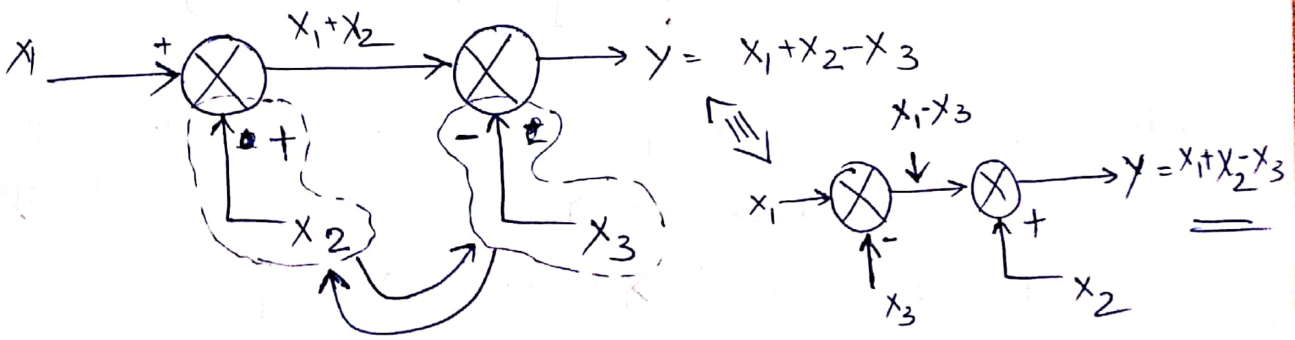


6. Moving a take off point ahead of a block

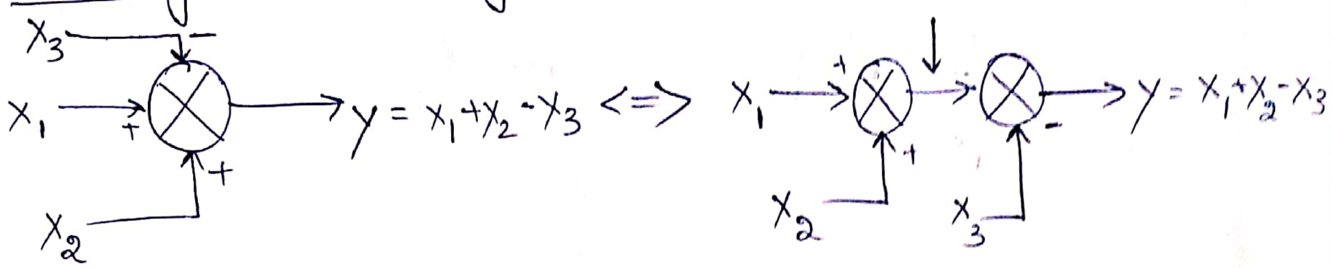


7. Eliminating feedback loop

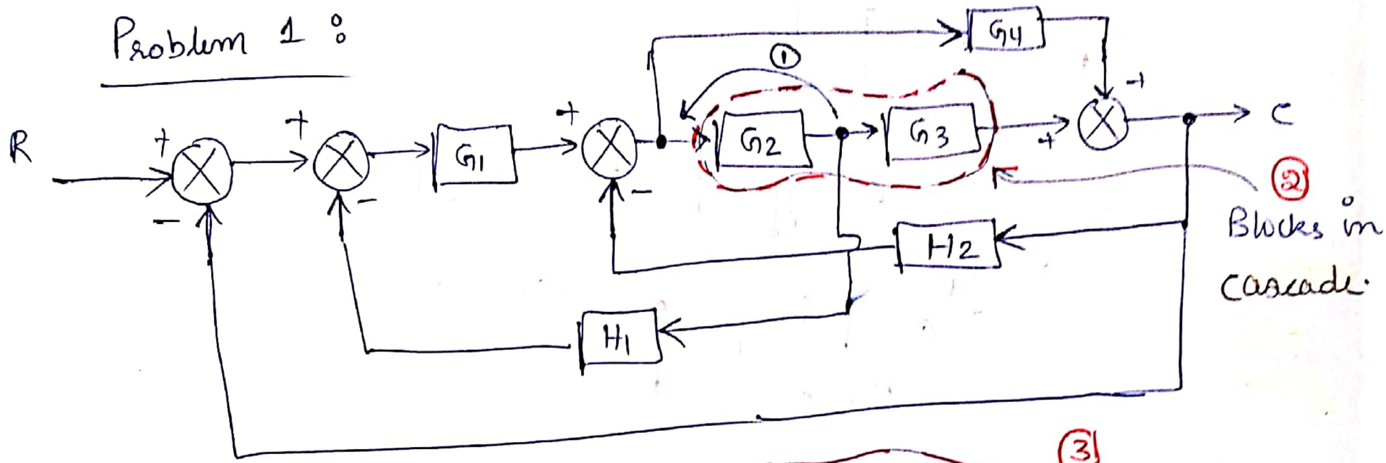
8. Interchanging summing points:

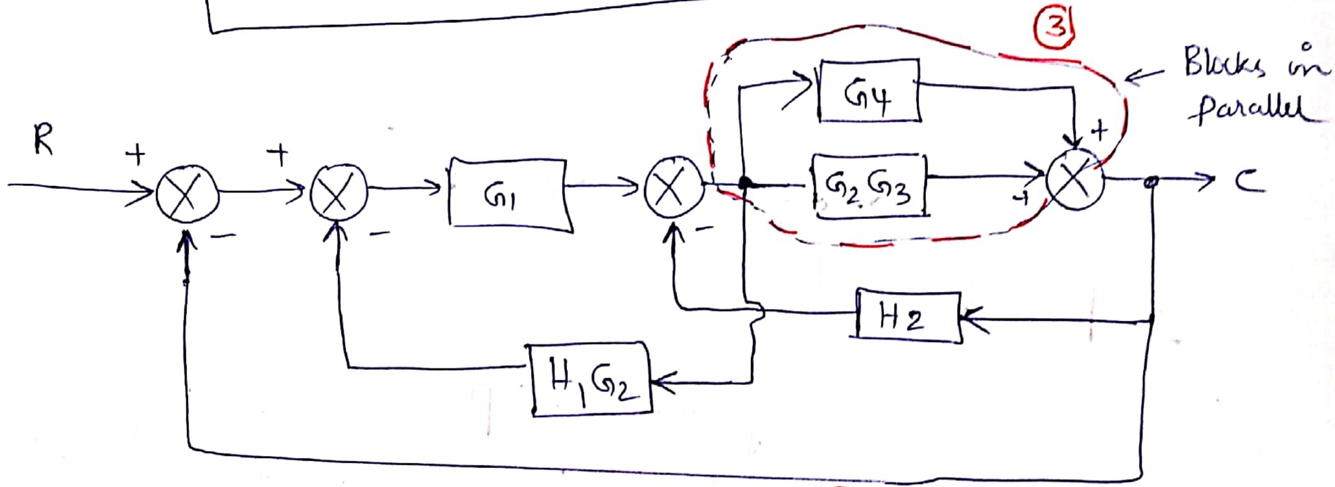


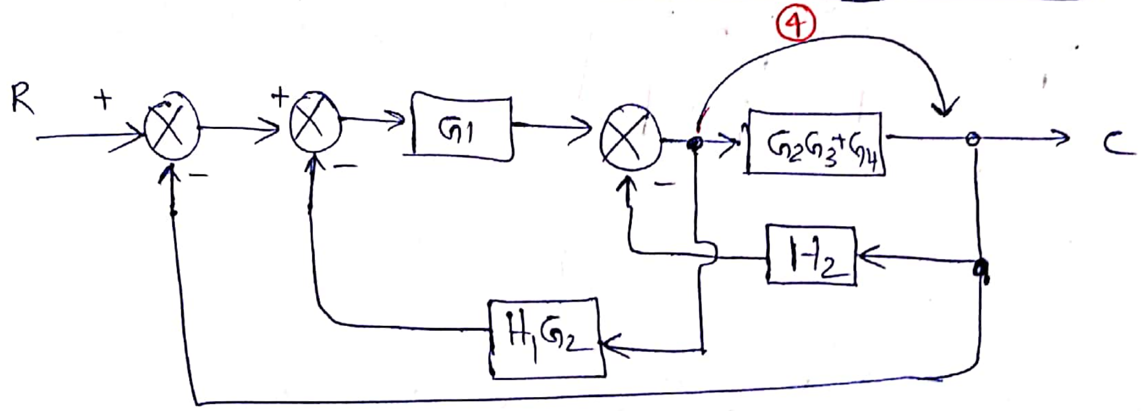
9. Splitting a summing point :-



Problem 1 :





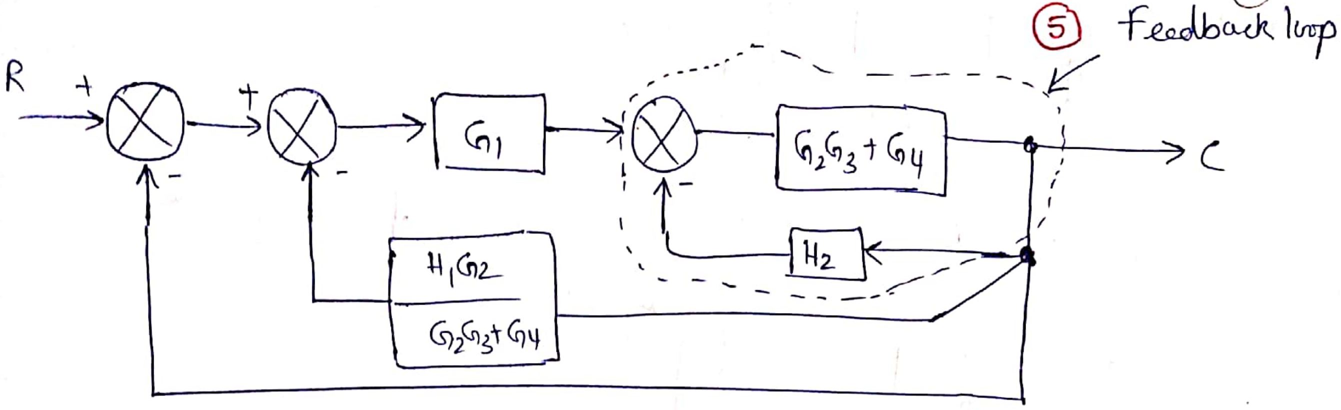


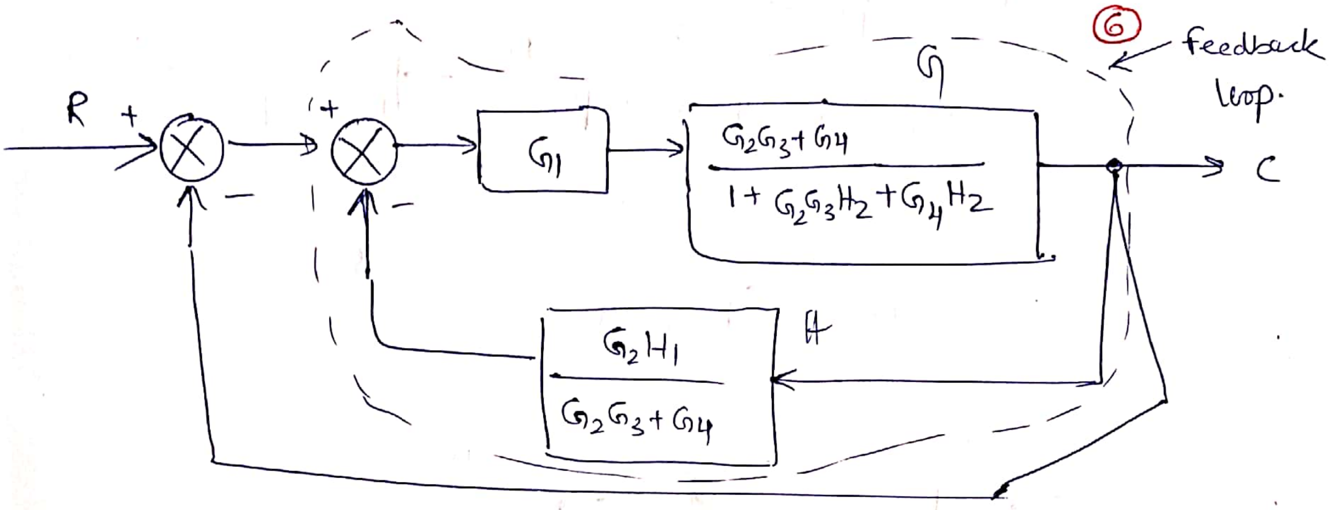
→ ① Shifting "take-off" point before G_2

→ ② cascaded blocks → $\boxed{G_2 G_3}$ →

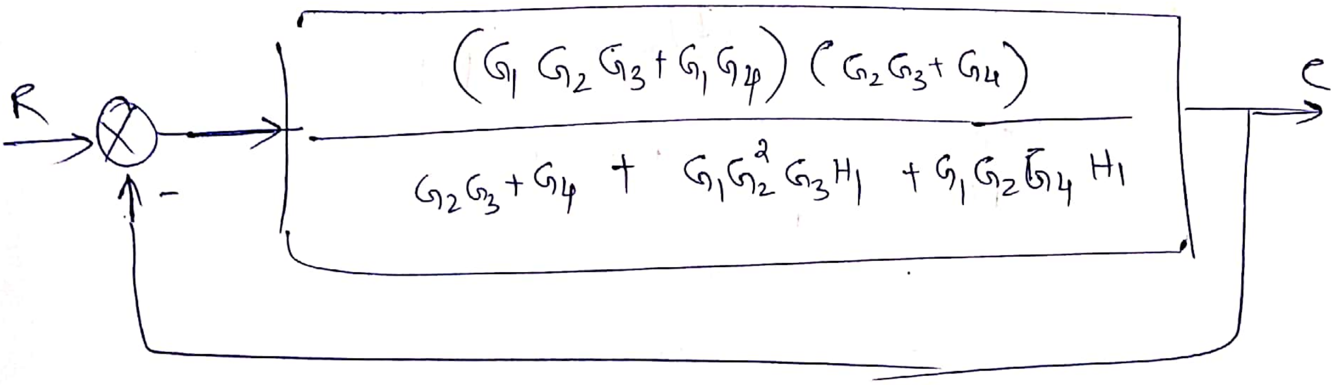
→ ③ Parallel Blocks → $\boxed{G_4 + G_2 G_3}$ →

→ ④ Shifting "take-off" point after a block.



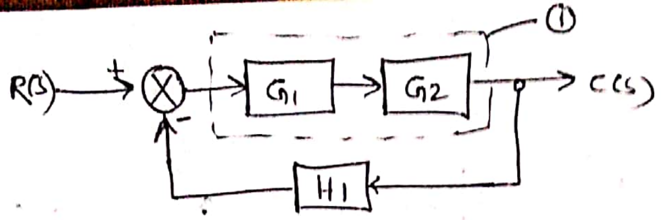


$$\frac{\dfrac{G_1G_2G_3+G_1G_4}{1+G_2G_3\cancel{H_2+G_2}H_2}}{1+\left(\dfrac{G_1G_2G_3+G_1G_4}{1+G_2G_3\cancel{H_2+G_4}H_2}\right)\left(\dfrac{G_2H_1}{G_2G_3+G_4}\right)}$$

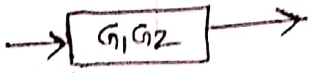


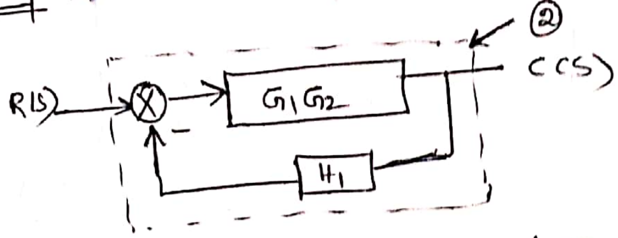
$$\frac{G_1G_2^2G_3^2+G_1G_2G_3G_4+G_1G_2G_3G_4+G_1G_4^2}{G_2G_3+G_4+G_1G_2^2G_3H_1+G_1G_2G_4H_1+(G_1G_2G_3+G_1G_4)(G_2G_3+G_4)}$$

②

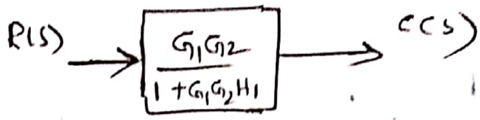


Solution : ① Connected in cascade



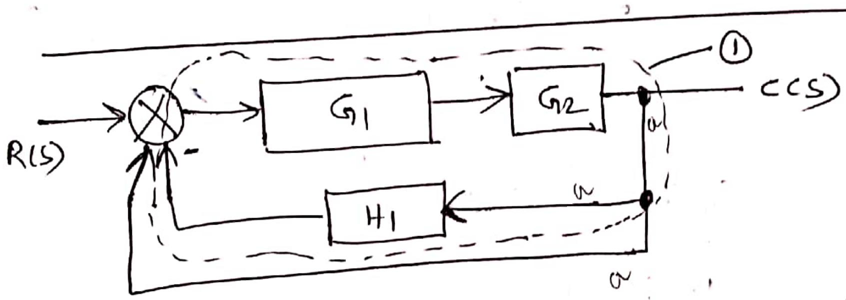


② negative Feedback loop

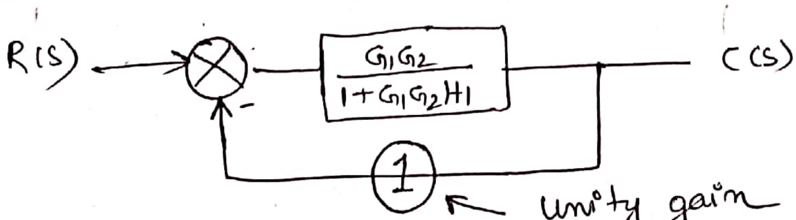


$$\therefore \frac{C(s)}{R(s)} = \frac{G_1G_2}{1+G_1G_2H_1} \quad \text{— ③}$$

③



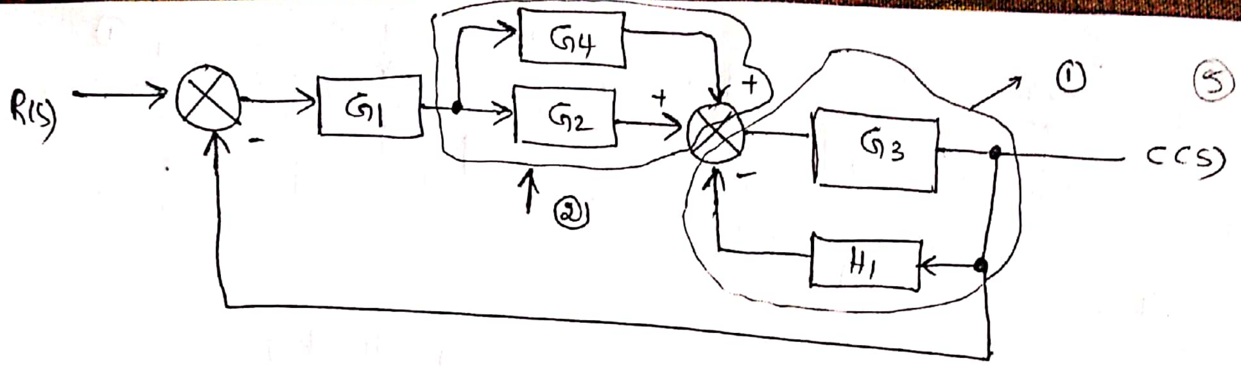
Solution : ① → loop transfer is given by eq ③



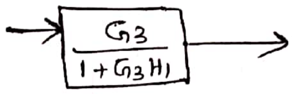
$$\frac{C(s)}{R(s)} = \frac{G_1G_2 / 1+G_1G_2H_1}{1 + \frac{G_1G_2}{1+G_1G_2H_1} \cdot 1}$$

$$\frac{C(s)}{R(s)} = \frac{G_1G_2}{1+G_1G_2H_1 + G_1G_2}$$

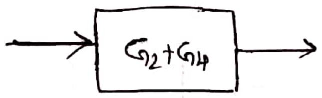
④



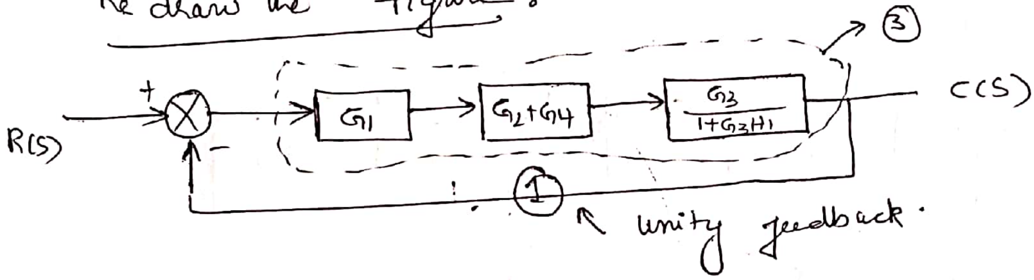
<u>Solution</u>: ① As much as possible, try to identify minor feedback loops first.



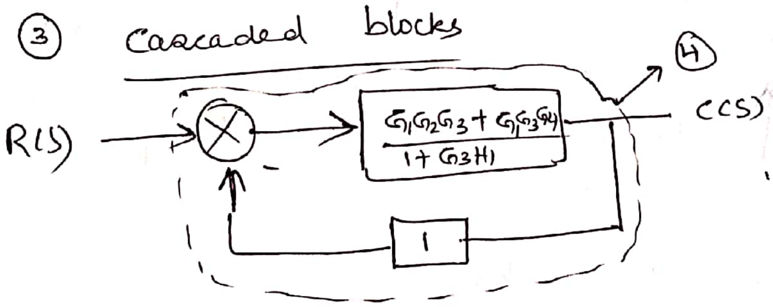
② Blocks connected parallel



<u>Redraw the figure</u>:



③ <u>Cascaded blocks</u>

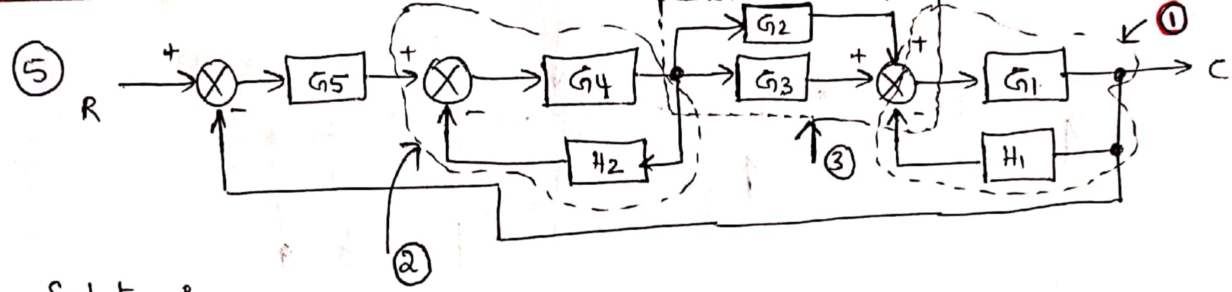


④ Minor feedback loop (-ve F/B)

$$\frac{C(s)}{R(s)} = \frac{\dfrac{G_1G_2G_3+G_1G_3G_4}{1+G_3H_1}}{1+\dfrac{G_1G_2G_3+G_1G_3G_4}{1+G_3H_1}}$$

$$\frac{C(s)}{R(s)} = \frac{G_1G_2G_3+G_1G_3G_4}{1+G_3H_1+G_1G_2G_3+G_1G_3G_4}$$

5



<u>Solution:</u>

① Minor Feedback loop (negative feedback)

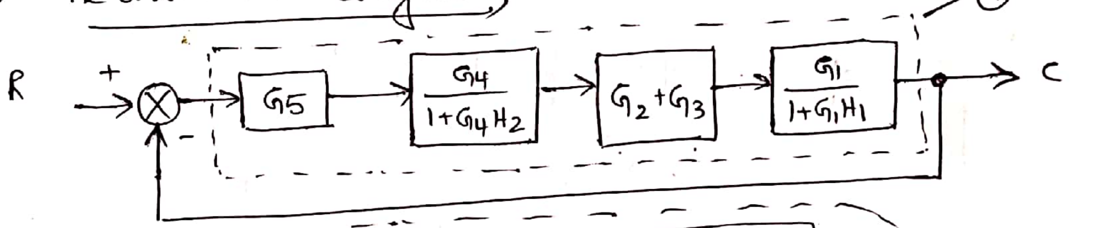
$$\rightarrow \boxed{\frac{G_1}{1+G_1H_1}} \rightarrow$$

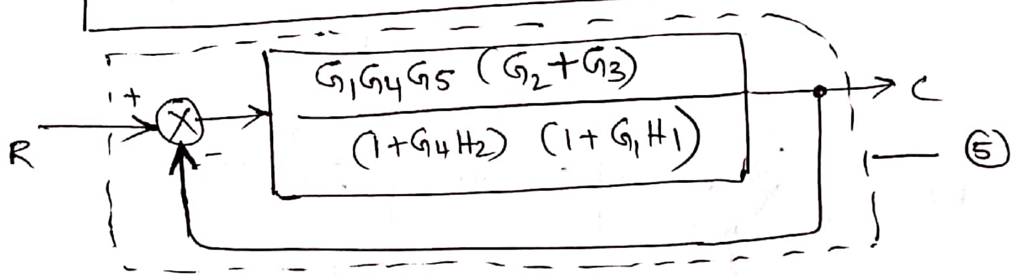
② Minor Feedback loop (-ve feedback)

$$\rightarrow \boxed{\frac{G_4}{1+G_4H_2}} \rightarrow$$

③ Parallel blocks $\rightarrow \boxed{G_2+G_3} \rightarrow$

⇒ <u>Redraw the diagram;</u>





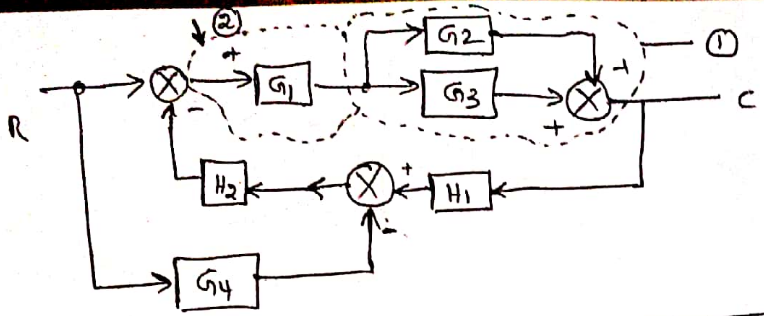
④ Cascaded blocks

⑤ <u>Minor</u> negative feedback

$$\frac{C}{R} = \frac{(G_1G_4G_5)(G_2+G_3)}{G_1G_4G_5(G_2+G_3) + (1+G_4H_2)(1+G_1H_1)}$$

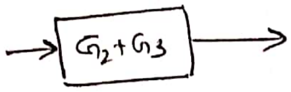
$$T{\cdot}F = \frac{C}{R} = \frac{G_1G_2G_4G_5 + G_1G_3G_4G_5}{1+G_1G_2G_4G_5 + G_1G_3G_4G_5 + G_1H_1 + G_4H_2 + G_1G_4H_1H_2}$$

(6) (6)

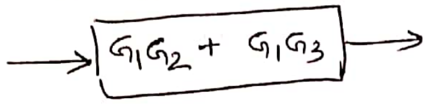


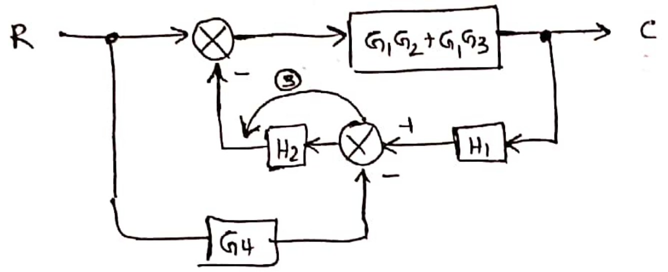
Solution:

(1) Parallel ~~cascaded~~ blocks

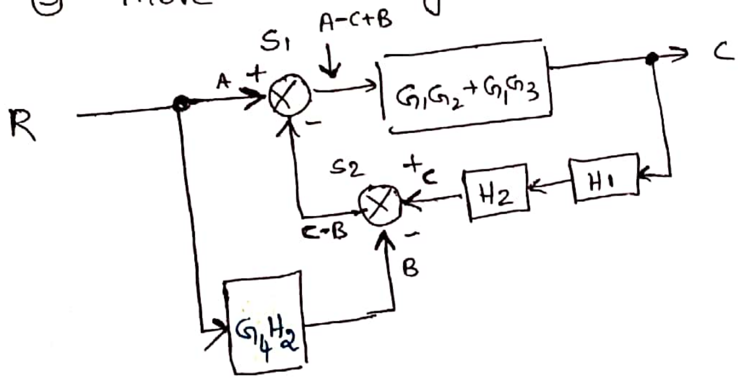


(2) G_1 & (G_2+G_3) Blocks are connected in cascade

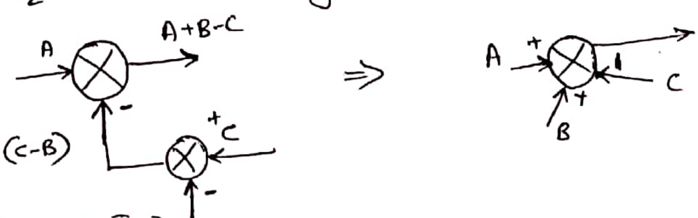


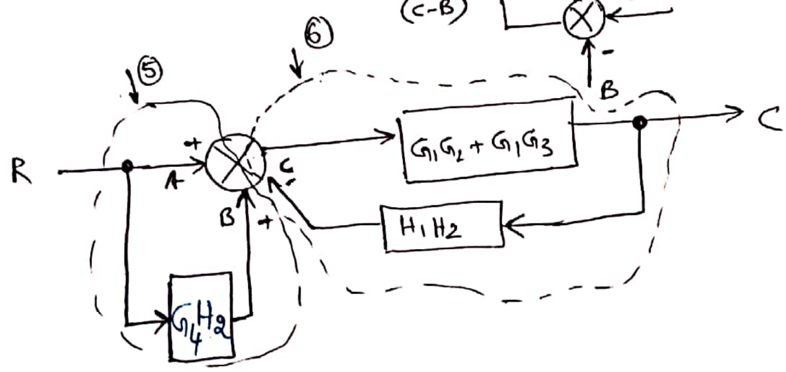


(3) move summing point ahead of H_2

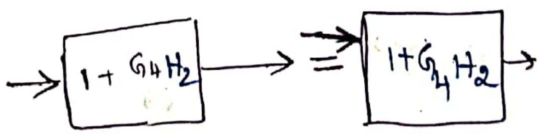


(4) combing S_1 & S_2 into a single summer





(5) Parallel connected blocks



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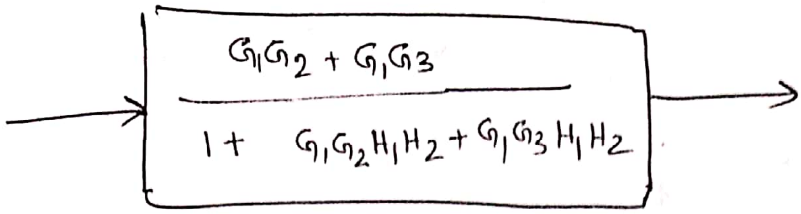
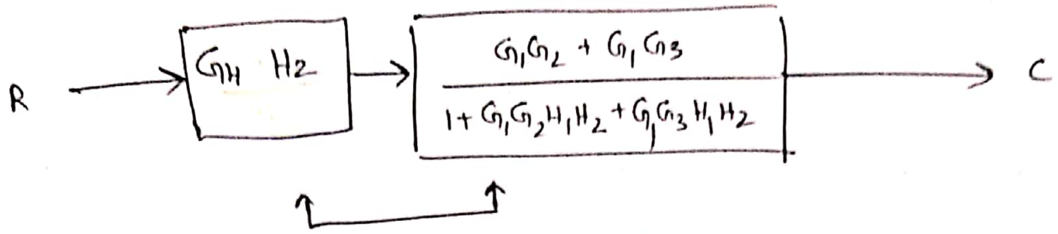


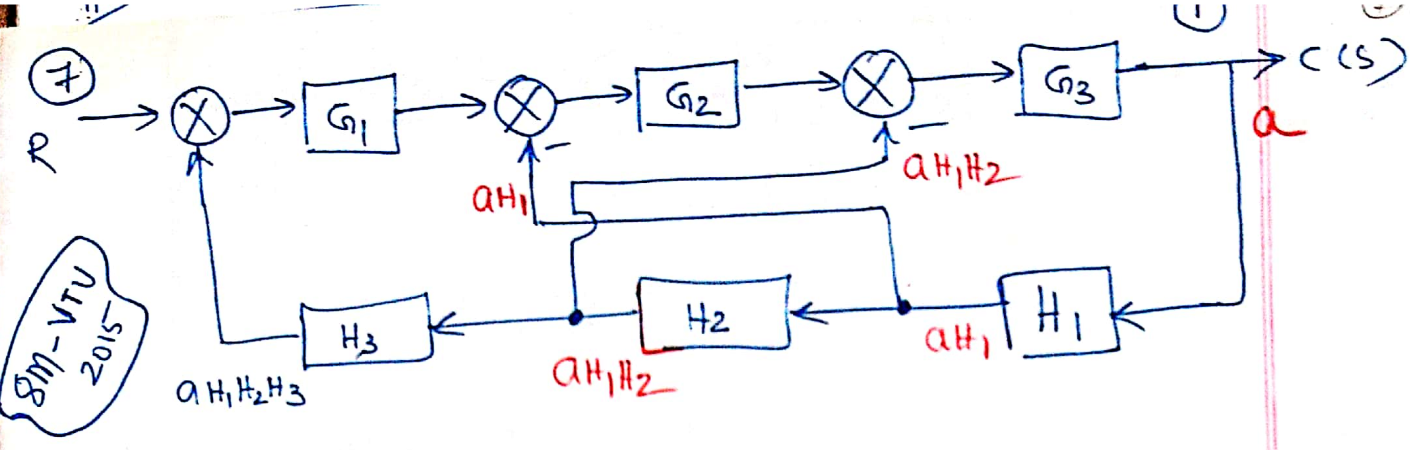


Cascaded blocks.

$$\frac{C(s)}{R(s)} = \frac{G_1G_2G_4 + G_1G_3G_4 + G_1G_2H_2 + G_1G_3H_2}{(G_1G_2H_1H_2 + G_1G_3H_1H_2 + 1)\,H_2}$$

---x---x---

7



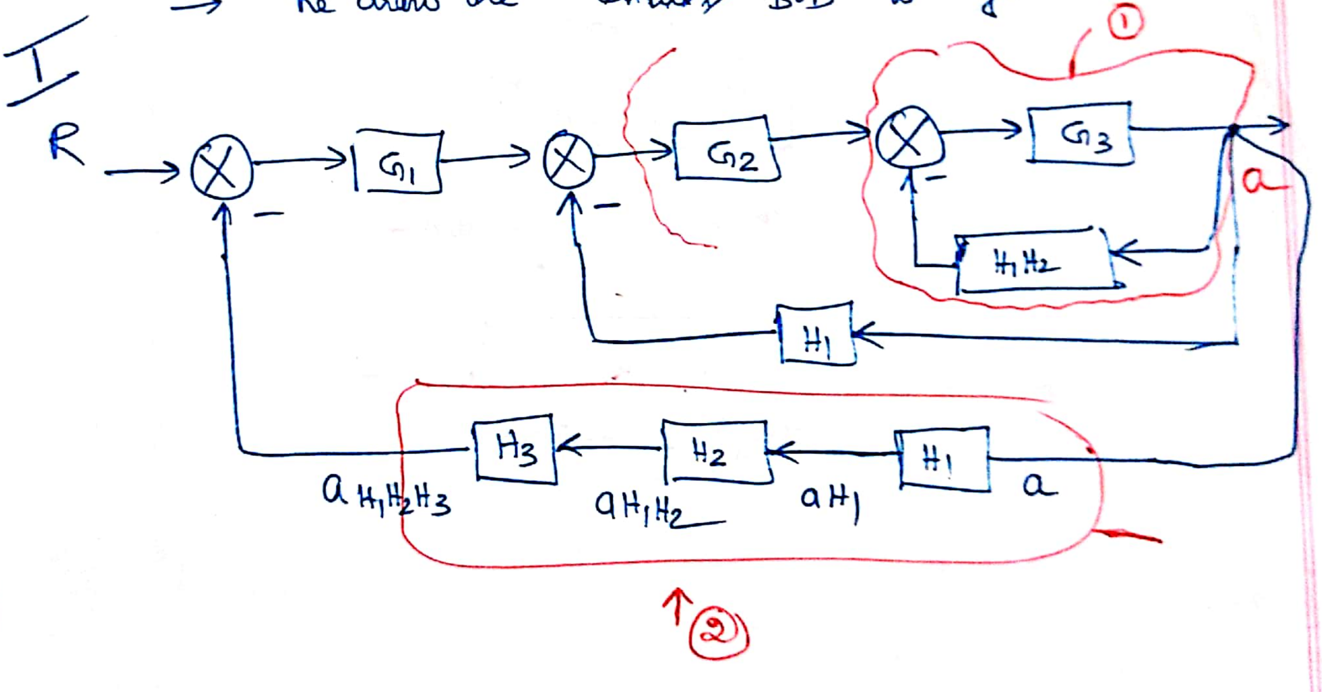
Solution: Let us think of separating out the feedback paths.

→ Say output signal C(S) = some "a"

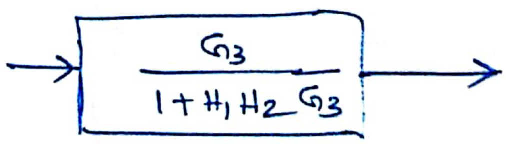
→ write down various signal values @ Suming points.

→ Re draw the ~~diffrent~~ B.D to get the same out put.

I



⇒ ① Blocks connected in -ve Feedback manner



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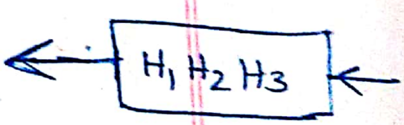
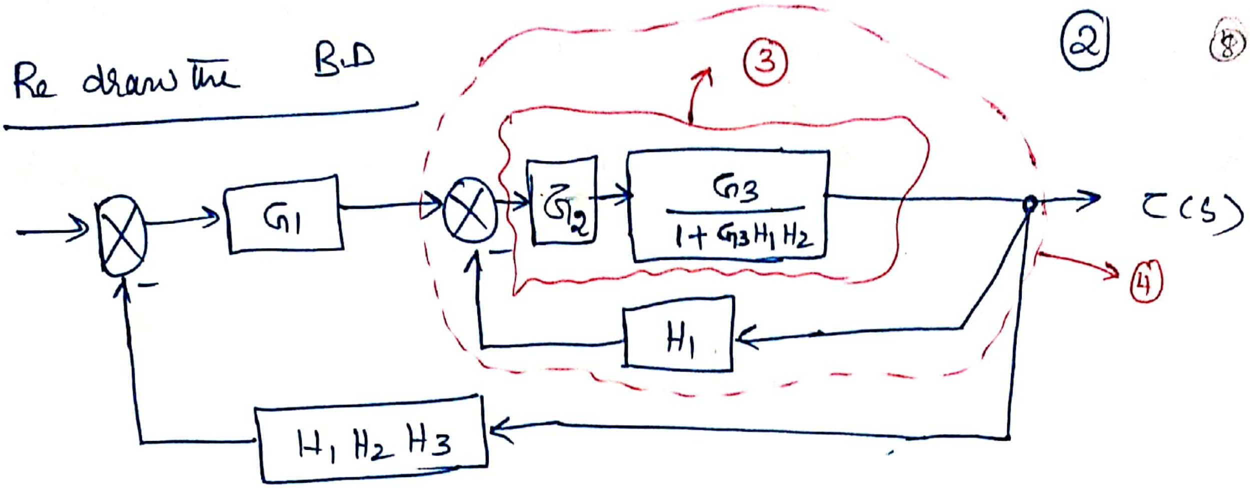
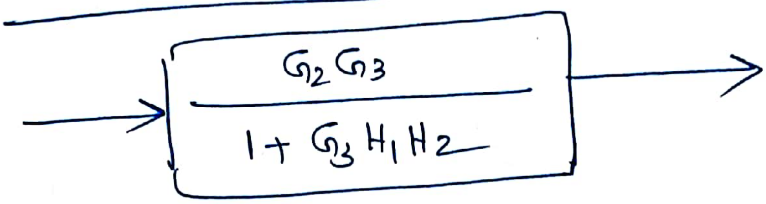
⇒ ② Blocks connected in cascaded manner



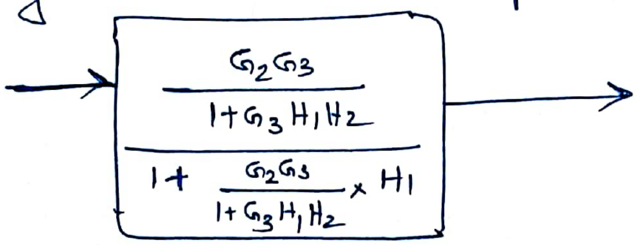
II Re draw the B.D



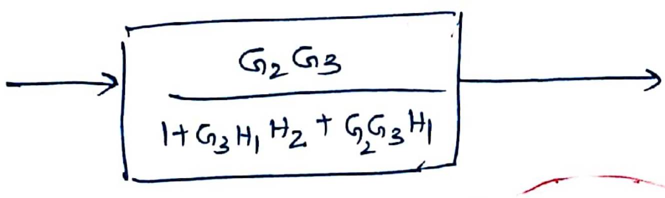
⇒ ③ Cascaded blocks



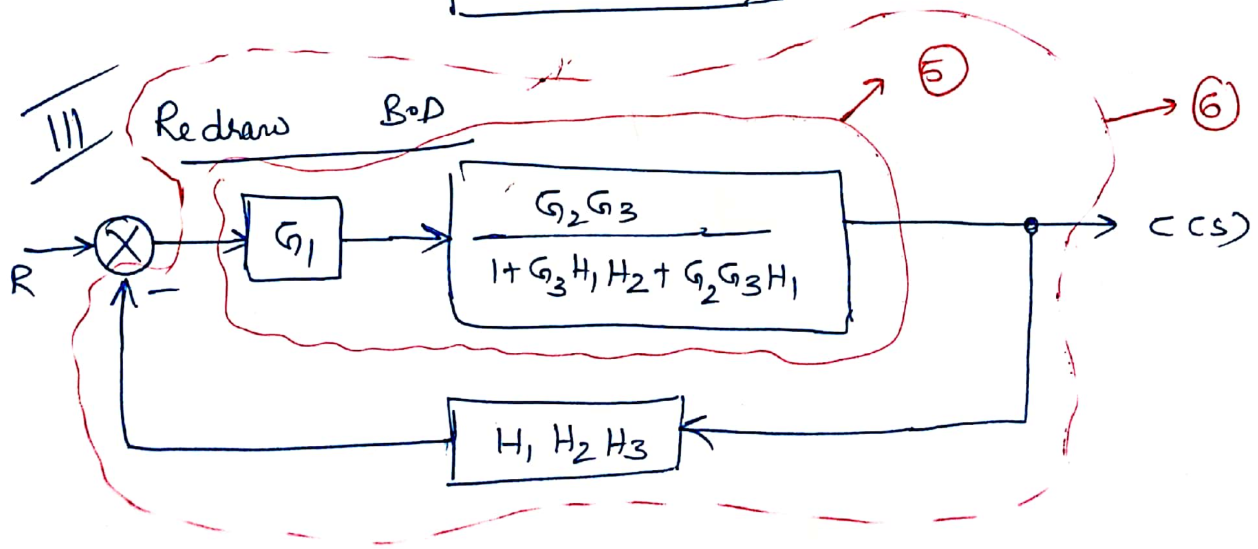
⇒ ④ Negative feedback loop.



taking L.C.M



III Redraw B.D



(9) (3)

⇒ (5) Blocks connected in cascade

$$\longrightarrow \boxed{\dfrac{G_1 G_2 G_3}{1 + G_3 H_1 H_2 + G_1 G_3 H_1}} \longrightarrow$$

43

⇒ (6) Negative feedback loop.

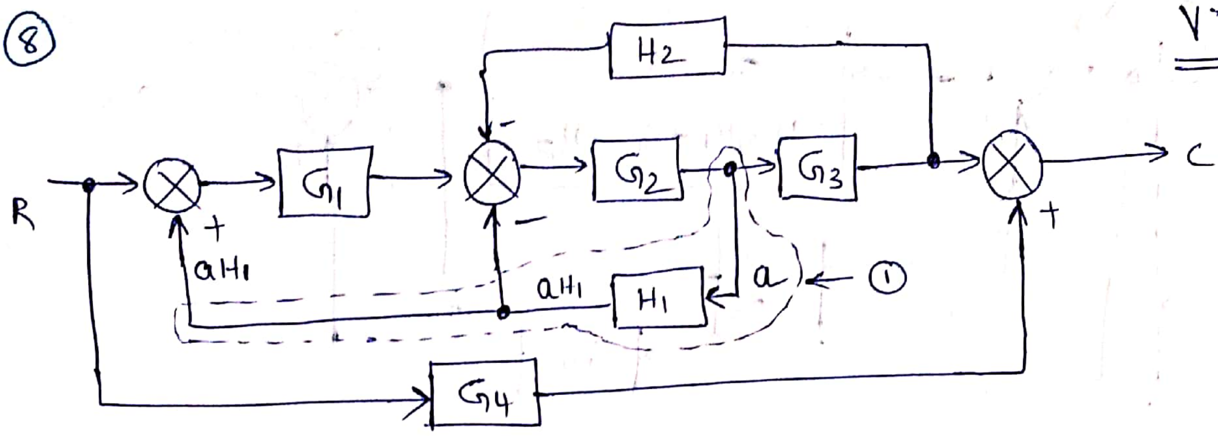
$$\frac{C(s)}{R(s)} = \frac{\dfrac{G_1 G_2 G_3}{1 + G_3 H_1 H_2 \cancel{+ G_1 G_3 H_1}}}{1 + \dfrac{G_1 G_2 G_3 H_1 H_2 H_3}{1 + G_3 H_1 H_2 \cancel{+ G_1 G_3 H_1}}}$$

$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_3}{1 + G_3 H_1 H_2 + G_1 G_3 H_1 + G_1 G_2 G_3 H_1 H_2 H_3}$$

x

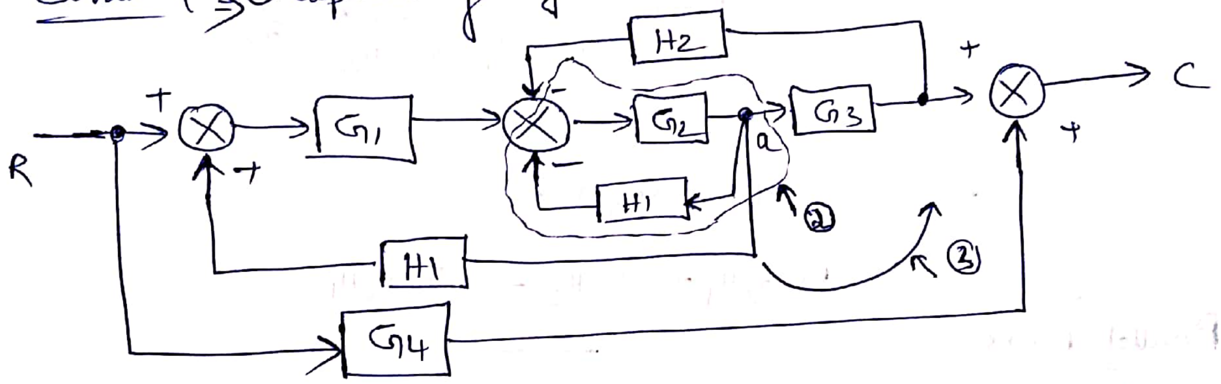
8

VTU (10)



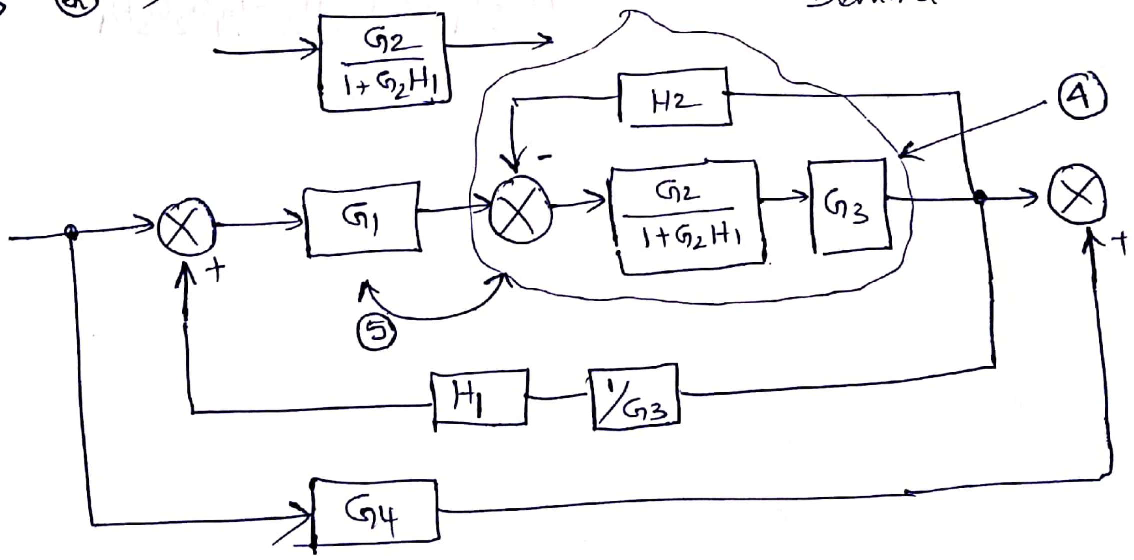
Find $\frac{C}{R}$ using B.D.R technique.

Solution :- ① Separating feedback paths.



③ (take off) shift it behind G_3

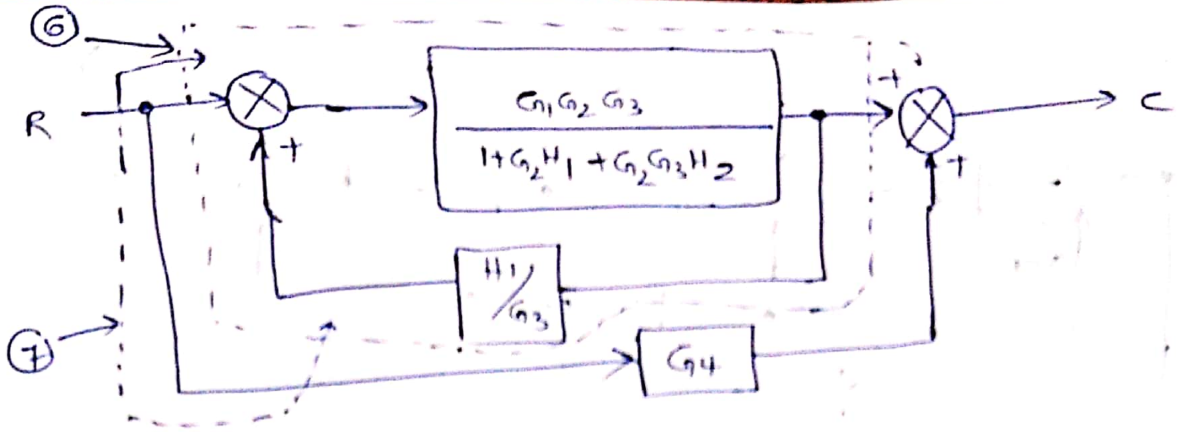
⇒ ② ⇒ feedback loop



⇒ ④ "-ve" F/B loop $\longrightarrow \dfrac{\dfrac{G_2G_3}{1+G_2H_1}}{1+\dfrac{G_2G_3H_2}{1+G_2H_1}} = \dfrac{G_2G_3}{1+G_2H_1+G_2G_3H_2}$

⇒ ⑤ cascaded blocks ⟹ $\boxed{\dfrac{G_1G_2G_3}{1+G_2H_1+G_2G_3H_2}}$

Scanned by CamScanner



⑥ → positive F/B

$$\frac{\dfrac{G_1G_2G_3}{1+G_2H_1+G_2G_3H_2}}{1-\dfrac{G_1G_2G_3}{1+G_2H_1+G_2G_3H_2}\times\dfrac{H_1}{G_3}}$$

$$= \frac{(G_1G_2G_3)\,G_3}{1+G_2H_1+G_2G_3H_2-G_1G_2G_3H_1}$$

Parallel Blocks

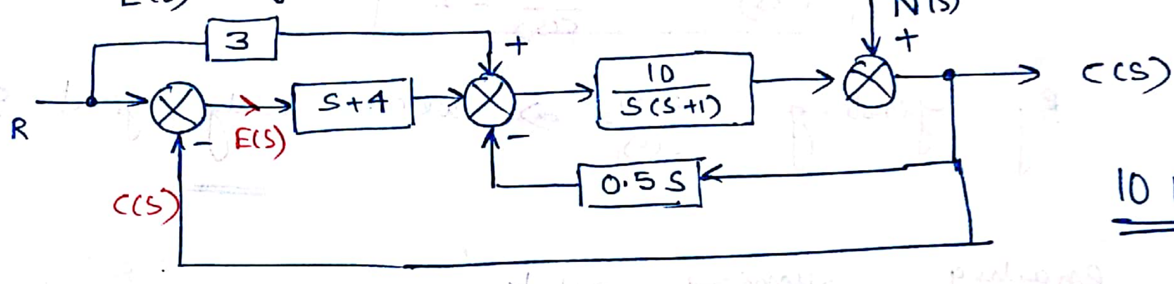
⑦

$$\frac{C(s)}{R(s)} = G_4 + \frac{(G_1G_2G_3)\,G_3}{1+G_2H_1+G_2G_3H_2-G_1G_2G_3H_1}$$

Scanned by CamScanner

(9) The system B.D is given below. Find

(i) $\frac{C(s)}{E(s)}$ if $N(s) = 0$ (ii) $\frac{C(s)}{R(s)}$ if $N(s) = 0$ (iii) $\frac{C(s)}{N(s)}$ if $R(s)=0$

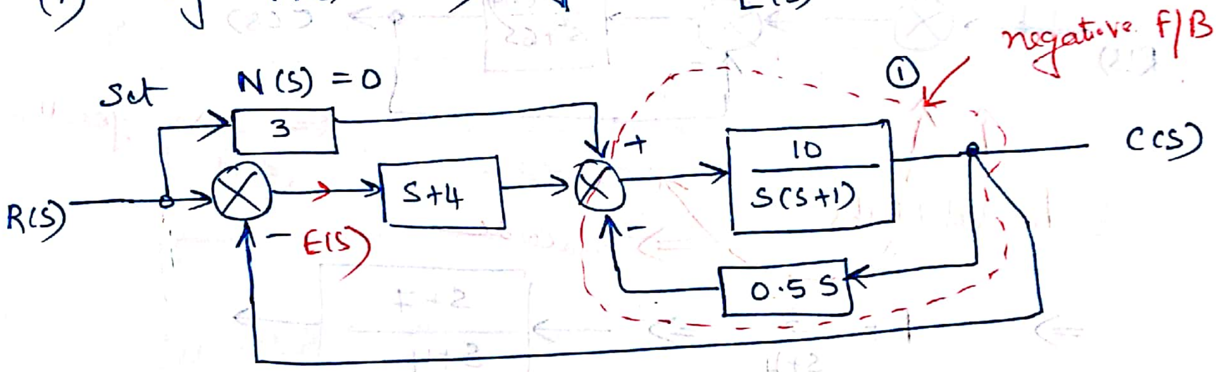


10 Marks

Solution:

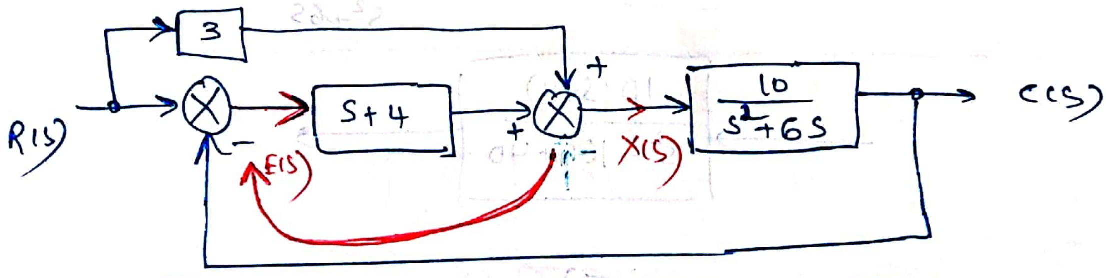
(i) if $N(s) = 0$; find $\frac{C(s)}{E(s)}$

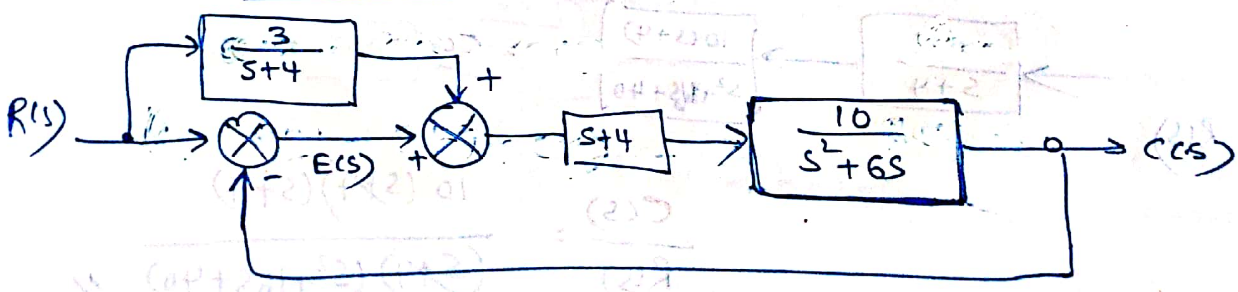
Set $N(s) = 0$



① $\Rightarrow$

$$\frac{\frac{10}{s^2+s}}{1+\frac{10}{s^2+s}\times 0.5s} = \frac{10}{s^2+s+5s} = \frac{10}{s^2+6s}$$



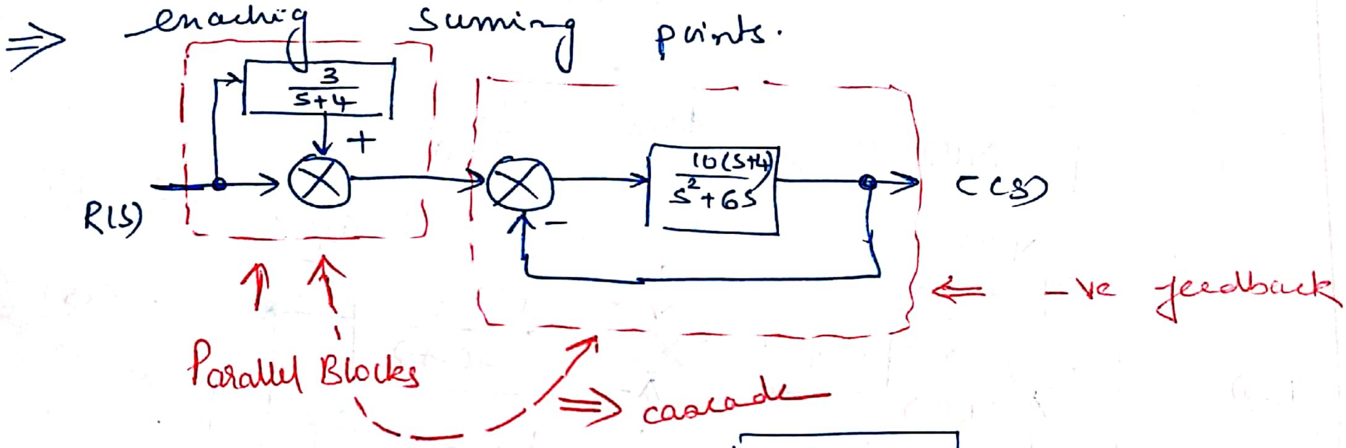


Also $\dfrac{C(s)}{E(s)} = \dfrac{C(s)}{R(s) - C(s)} = \dfrac{1}{\dfrac{R(s)}{C(s)} - 1}$

$$\boxed{\dfrac{C(s)}{E(s)} = \dfrac{1}{\dfrac{R(s)}{C(s)} - 1}}$$

By finding $\dfrac{R(s)}{C(s)}$ ⇒ we can easily find $\dfrac{C(s)}{E(s)}$

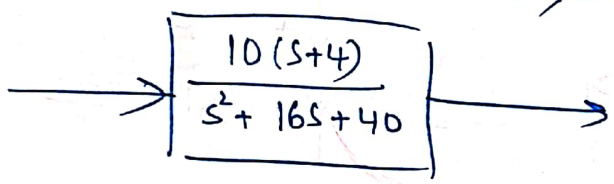
⇒ enaching summing points.

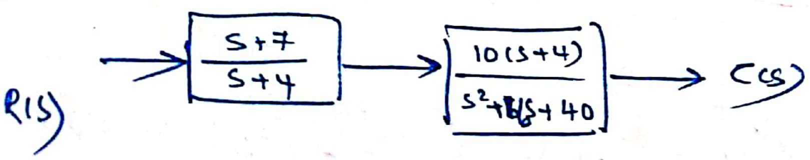


⇒ $1 + \dfrac{3}{s+4}$ ⇒ $\longrightarrow \boxed{\dfrac{s+7}{s+4}} \longrightarrow$

⇒ negative f/B

$$\dfrac{\dfrac{10(s+4)}{s^2+6s}}{1 + \dfrac{10(s+4)}{s^2+6s}} = \dfrac{10(s+4)}{s^2+6s+10s+40}$$





$$\dfrac{C(s)}{R(s)} = \dfrac{10\cancel{(s+4)}(s+7)}{\cancel{(s+4)}(s^2+16s+40)} \;//$$

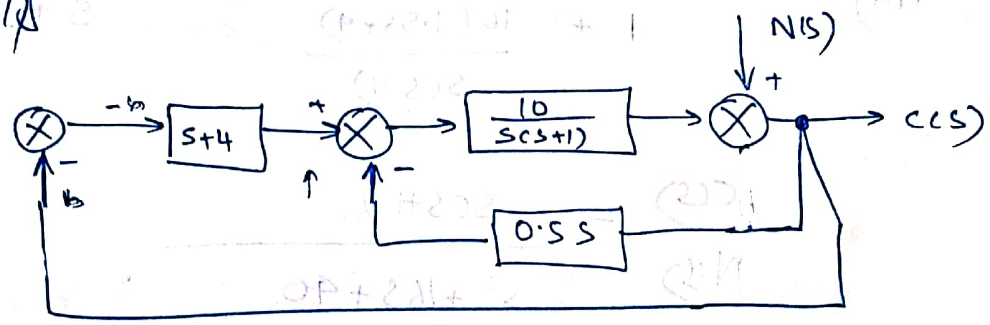
$$\therefore \cancel{\frac{C(s)}{E(s)} = \frac{1}{\frac{10(s+7)}{s^2+16s+40} - 1} = \frac{1}{\frac{10(s+7)-s^2-16s-40}{s^2+16s+40}}}$$

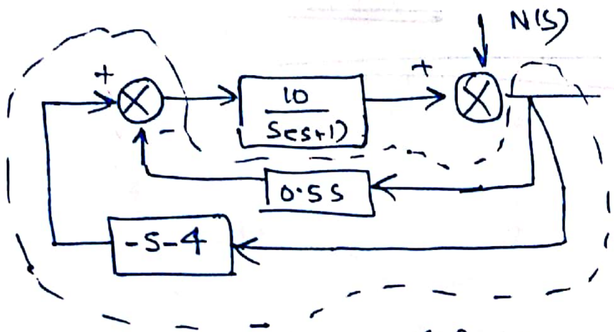
$$\cancel{= \frac{s^2+16s+40}{10s+70-s^2-16s-40} = \frac{s^2+16s+40}{}}$$

$$\frac{C(s)}{E(s)} = \frac{1}{\frac{s^2+16s+40}{10(s+7)} - 1} = \frac{10(s+7)}{s^2+16s+40-10s-70}$$

$$\boxed{\frac{C(s)}{E(s)} = \frac{10(s+7)}{\underline{\underline{s^2+6s-30}}}}$$

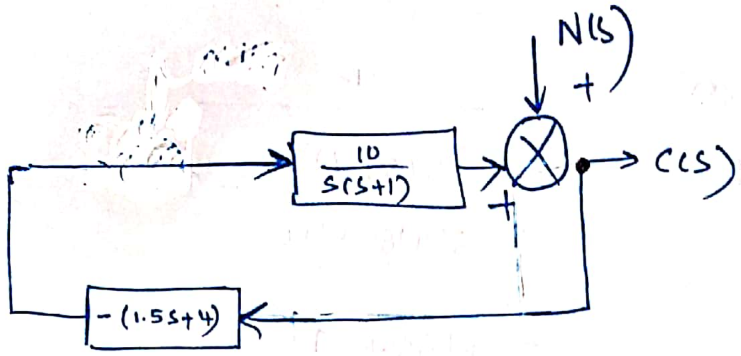
(iii) with $R(s) = 0$.

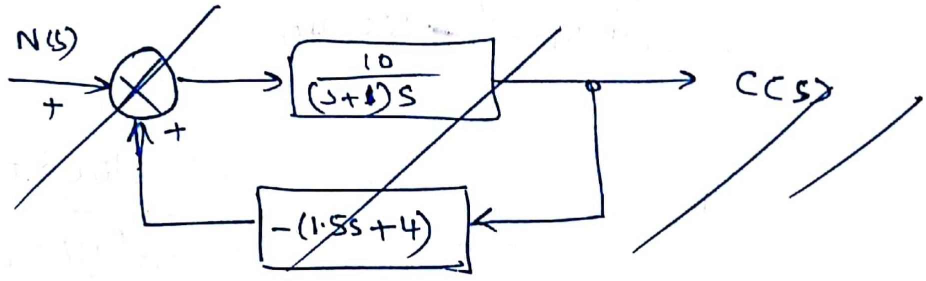


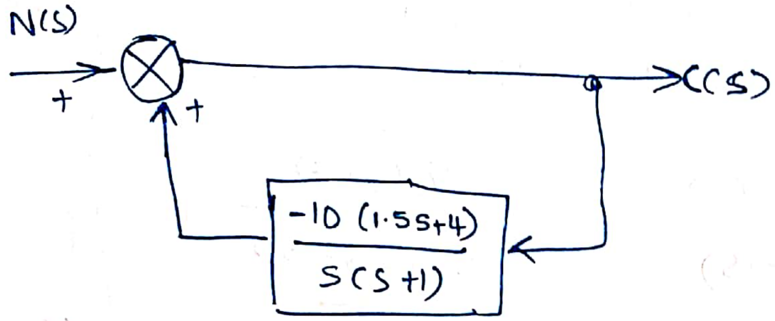


↑ Parallel blocks.

$$-s-4-0.5s$$
$$= -1.5s-4$$
$$= \underline{\underline{-(1.5s+4)}}$$



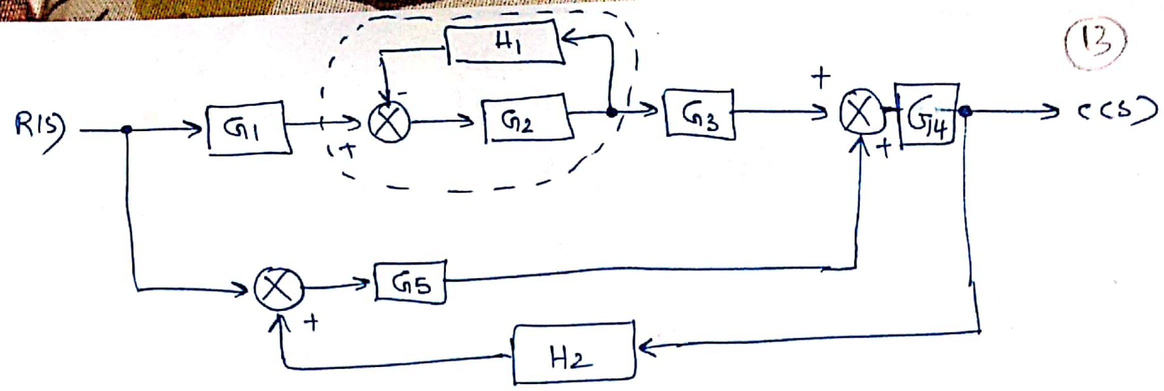


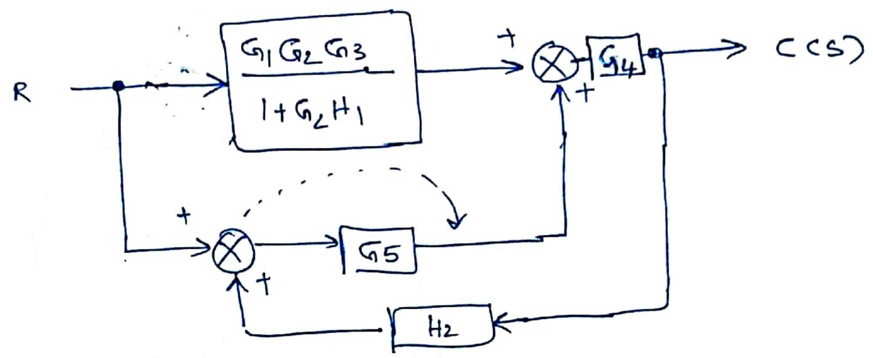


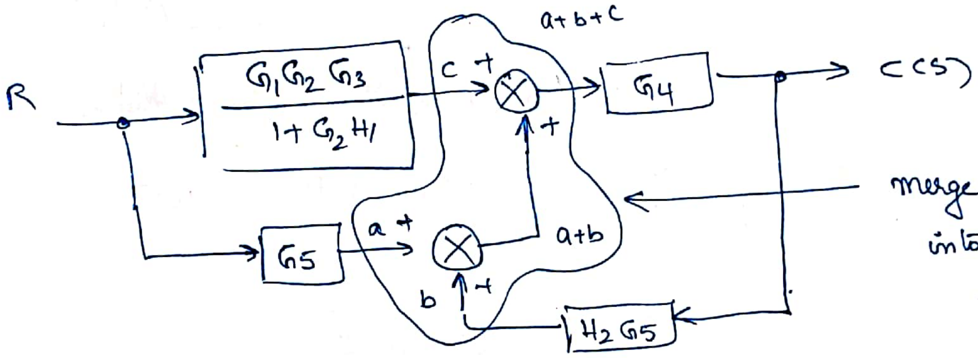
$$\frac{C(s)}{N(s)} = \frac{1}{1 + \frac{10(1.5s+4)}{s(s+1)}} = \frac{s(s+1)}{s^2 + s + 15s + 40}$$

$$\frac{C(s)}{N(s)} = \frac{s(s+1)}{s^2 + 16s + 40}$$

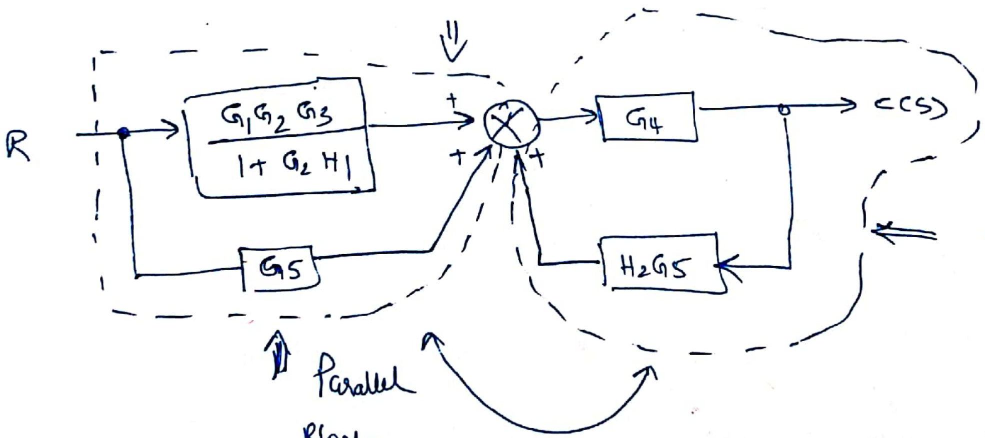
⑩ ⑬







merge 2 summers into a single summer

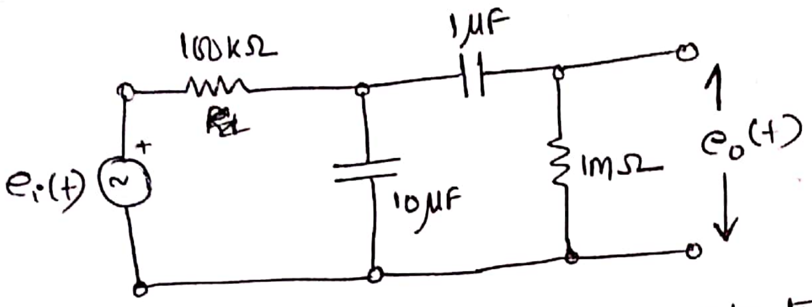


Positive feedback.

Parallel Blocks

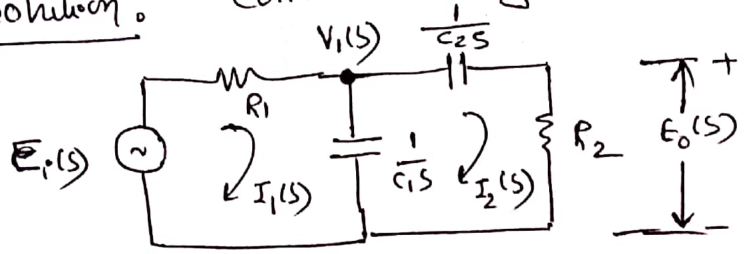
cascade.

$$R \rightarrow \boxed{G_5 + \frac{G_1G_2G_3}{1+G_2H_1}} \rightarrow \boxed{\frac{G_4}{1-G_4G_5H_2}} \rightarrow R(S)$$



• Draw block diagram & evaluate TF $\frac{E_o(S)}{E_i(S)}$

Solution: Convert the given ckt into Laplace domain



Let
$C_1 = 10\mu F$
$C_2 = 1\mu F$
$R_1 = 100K\Omega$
$R_2 = 1M\Omega$

Apply Nodal analysis

Variables are $E_i(S)$, $I_1(S)$, $V_1(S)$, $I_2(S)$ & $E_o(S)$

$$I_1(S) = \frac{E_i(S) - V_1(S)}{R_1} = E_i(S) - V_1(S) \left[\frac{1}{R_1}\right] \quad \text{— (1)}$$

$$V_1(S) = \left[I_1(S) - I_2(S)\right] \times \frac{1}{C_1 S} \quad \text{— (2)}$$

$$I_2(S) = \frac{V_1(S) - E_o(S)}{\left(\frac{1}{C_2 S}\right)} = C_2 S \left(V_1(S) - E_o(S)\right) \quad \text{— (3)}$$

$$E_o(S) = I_2(S)\, R_2 \quad \text{— (4)}$$

⇒ Constructing Block diagram from 4 algebraic Equations.