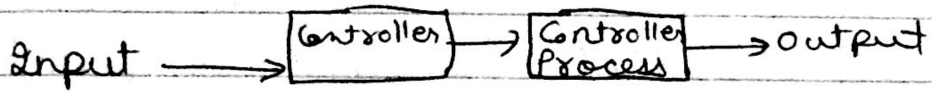
Control System

Intro → Behaviour of the system is described by differential eqn. 2 types :-

i) open loop C.S   ii) closed loop C.S

open loop → → No feedback.
→ Independent of desired o/p.
→ o/p not compared with ref. i/p.

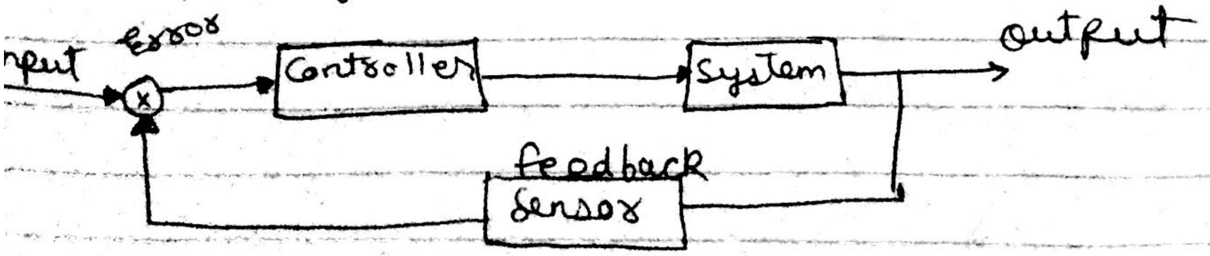


Advantages	Disadvantages
simple	i) Inaccurate
Economical	ii) Not reliable
less maintenance	iii) Slow
Proper calibration is not a problem	iv) Optimization is not possible.

→ immersion rod for water heating.
→ automatic washing machine.

Closed Loop system

feedback
dependent on desired o/p.
one or more feedback possible.
Error signal produce.



Adv.	Disadv.
→ more reliable	→ Expensive
→ faster	→ Diff. maintenanc
→ optimization is possible.	→ complicated installation.

E.g → A.C (Thermostat)

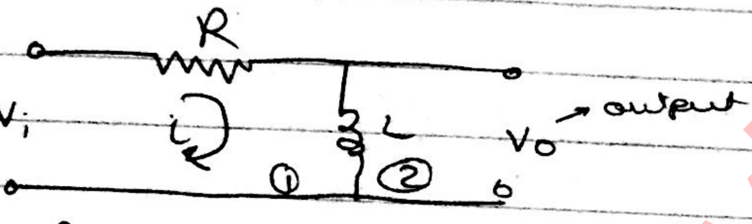
Comparison

Open loop	Closed loop.
i.) Perform accurately if the calibration is good.	i) Perform better be of the feedback.
ii) Easier to build.	ii) Diff. to build. becoz of feedback
iii) More stable	iii) Less stable than open loop.
IV.) Optimization not possible	iv) Optimization is possible.
V.) Economical	V.) Expensive.

Transfer fnt. → ratio of Laplace transform of the o/p to the Laplace transform of i/p. with all initial condition 0.

$$T.F / G(s) = \frac{C(s)}{R(s)}$$

find $G(s)$.



apply KVL.

$$V_i = Ri + L\frac{di}{dt}$$

$$V_i(s) = Ri(s) + sLi(s)$$

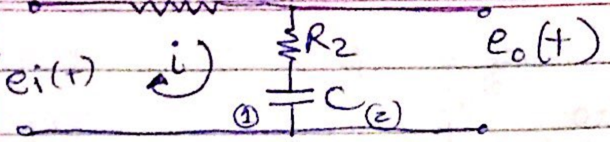
apply KVL in mesh

$$V_o = L\frac{di}{dt}$$

$$V_o(s) = sLi(s)$$

$$G(s) = \frac{V_o(s)}{V_i(s)} = \frac{sLi(s)}{Ri(s) + sLi(s)}$$

Q2→



① $e_i(t) = R\, i(t) + R_2(i(t)) + \frac{1}{C}\int i(t)\, dt$

$E_i(S) = I(S)\left[R_1 + R_2 + \frac{1}{CS}\right]$

② $e_o(t) = R_2\, i(t) + \frac{1}{C}\int i(t)\, dt$

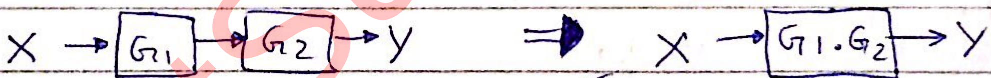
$E_o(S) = I(S)\left[R_2 + \frac{1}{CS}\right]$

$$\text{T.F.} = \frac{E_o(S)}{E_i(S)} = \frac{I(S)\left(R_2 + \frac{1}{CS}\right)}{I(S)\left(R_1 + R_2 + \frac{1}{CS}\right)}$$

$$= \frac{1 + R_2 Cs}{1 + (R_1 + R_2)Cs}$$

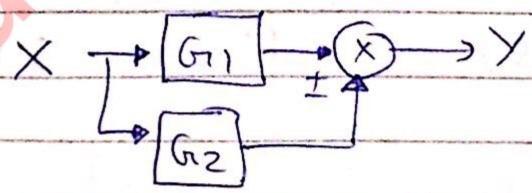
☆ Block diagram Reduction.

i) Combining blocks in Cascade/series.

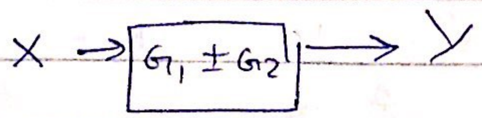


$Y = (G_1 G_2)\, X$

ii) Combining blocks in Parallel

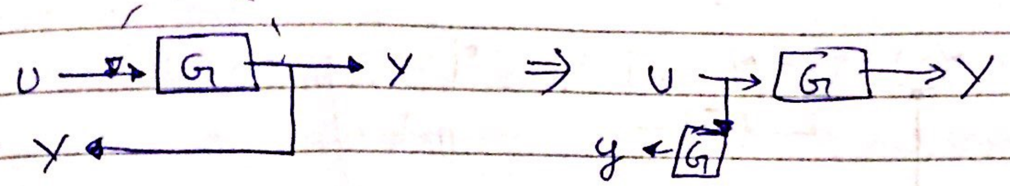


⇓

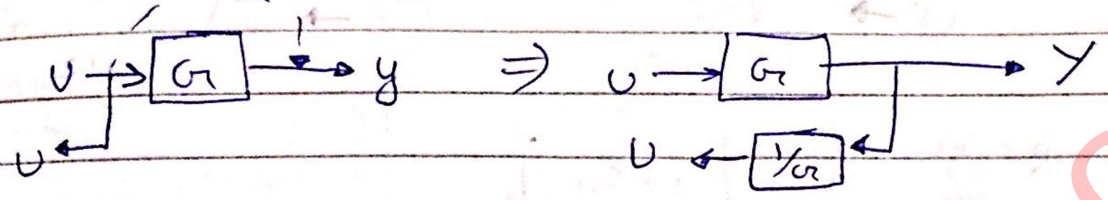


$Y = (G_1 \pm G_2)\, X$

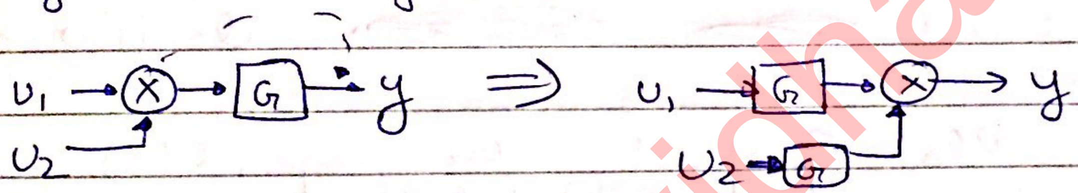
3.) Moving a pickoff point a block



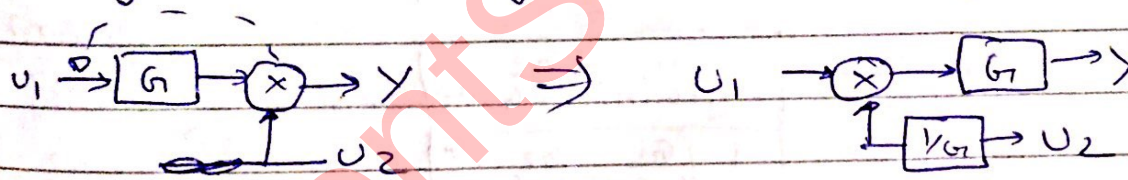
4.) Moving a pickoff point behind a block.



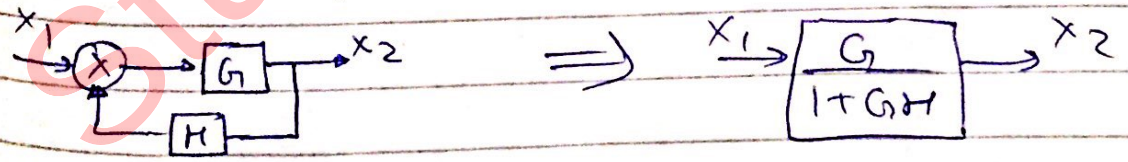
5.) Moving a summing pt. behind a block.



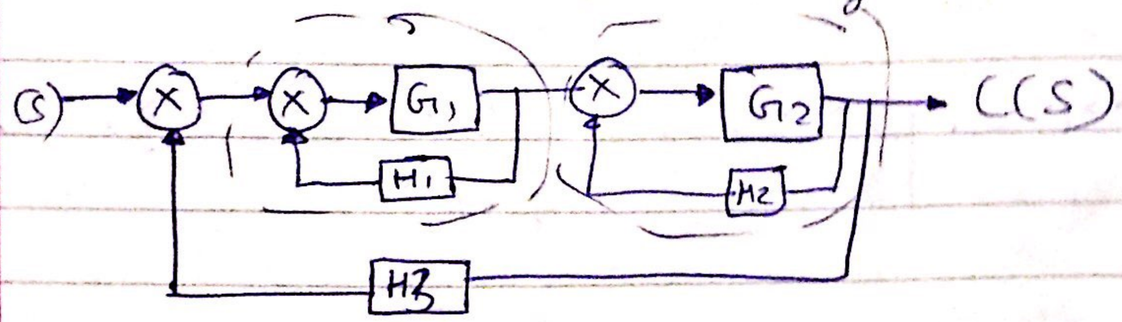
6.) Moving a summing pt. ahead of a block



7.) Eliminating feedback path.

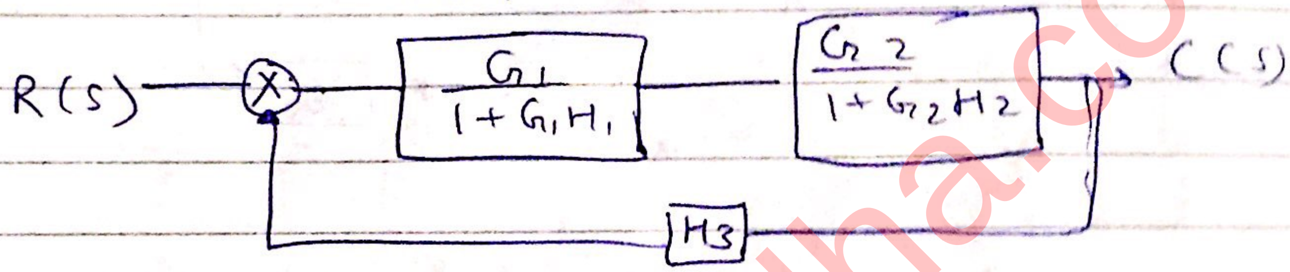


Reduce the block diagram

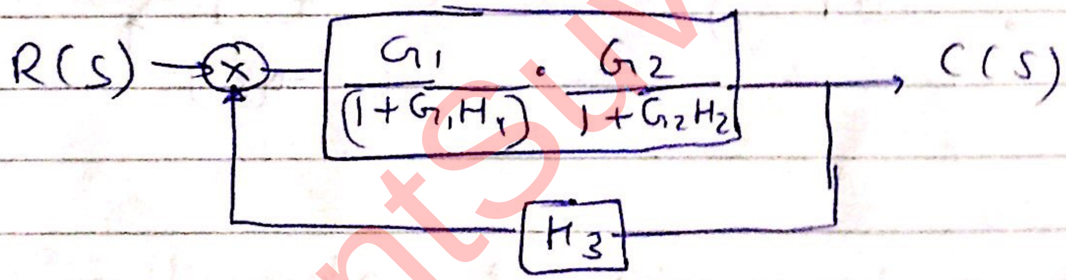


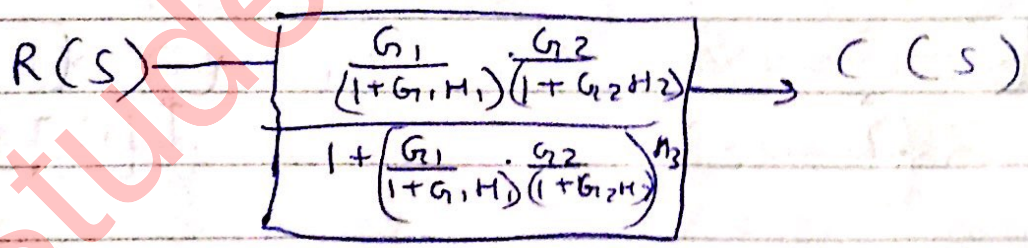
eliminating feedback paths

① → $\frac{G_1}{1+G_1H_1}$ ② → $\frac{G_2}{1+G_2H_2}$



Rule ① →





→ Signal flow Graph

→ Developed by S.J Mason for Block diagram reduction of complicated systems.

→ In signal flow graph, each node ⇒ system variable. Each branch connected b/w 2 nodes ⇒ signal multiplier. Direction of signal flow ⇒ arrow

★ Terminologies

→ Node → variable

→ loop → closed Path

→ Loop Gain → Product of branch transmittances of loop. (Transfer fn b/w 2 nodes)

→ Non-touching loop → No common node

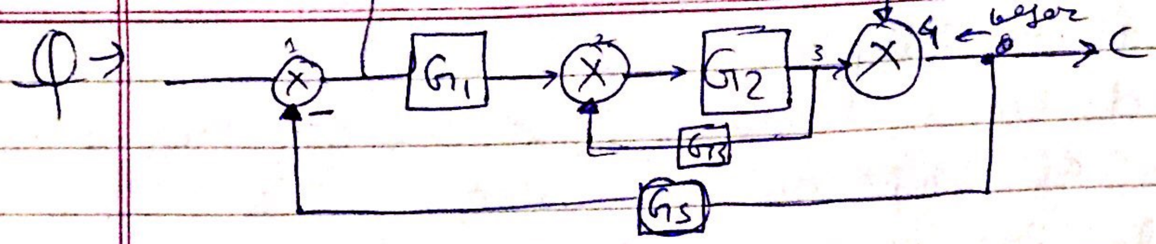
→ f/w path → Path from i/p to o/p node which does not cross any node more than once

→ f/w path Gain → Product of branch transmittance of a fwd. path.

★ Mason's Gain formula

$$T = \sum_K \frac{P_K \Delta_K}{\Delta}$$ where P_K → Path Gain of fwd path.

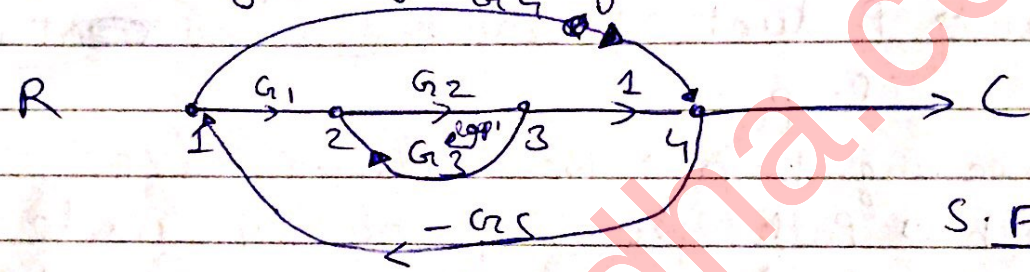
$\Delta = 1 -$ [Sum of all individual loop gain] + [Sum of all possible loop gain of 2 non-touching loops] − [Sum of all possible gain products of 3 non-touching loops] + ...



Rules for B.D to S.F G

→ Represent all variables (summing pt / takeoff pt) by nodes

→ If summing pt is before take off pt. in dirn. of signal flow, use single node



S.F G diag

Mason Gain's formula

$$T_K = \frac{\sum G_K \Delta K}{\Delta}$$

i) f/w paths $= P_1 (1, 2, 3, 4) =$ gain $g_1 (G_1, G_2$

$= P_2 (1, 4) = g_2 (G_4)$

ii) find individual loop gain

$L_1 (2, 3) =$ gain $= G_2 G_3$

$L_2 (1, 4, 1)$ gain $= (-G_4 G_5)$

$L_3 (1, 2, 3, 4)$ $\boxed{\text{gain} = -G_1 G_2 G_5}$

find all 2 not touching loops

L_1 & L_2 are not touching

$L_1 L_2$ (gain $= -G_2 G_3 G_4 G_5$)

calculate Δ,

$\Delta = 1 -$ [sum of individual loop gain]

+ [sum of all 2 not touching]

$$\Delta = 1 - [G_2 G_3 - G_4 G_5 - G_1 G_2 G_5] + [-G_2 G_3 G_4 \ldots$$

$$\Delta = 1 - G_2 G_3 + G_4 G_5 + G_1 G_2 G_5 - G_2 G_3 G_4 G_5$$

Calculate ΔK

Δ_1 = Part of Δ not touching Path 1 (P_1)

$\Delta_1 = 1$

Δ_2 = Part of Δ not touching Path 2 (P_2)

$\Delta_2 = 1 - G_2 G_3$

$$T = \frac{\sum \Delta K P_K}{\Delta} = \frac{\Delta_1 g_1 + \Delta_2 g_2}{\Delta}$$

$$= \frac{1(G_1 G_2) + (1 - G_2 G_3) G_1}{\Delta}$$