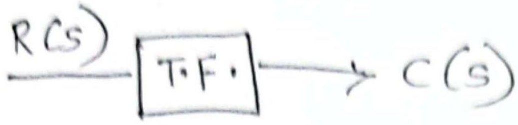
3 Sept 2025

Lecture-7

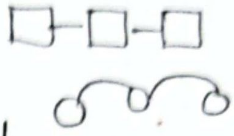
Reduction of Multiple Subsystem

I/p, O/p and system

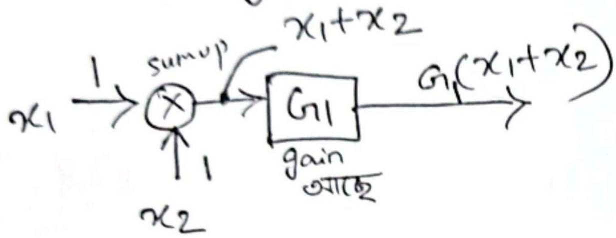
Block Reduction Method



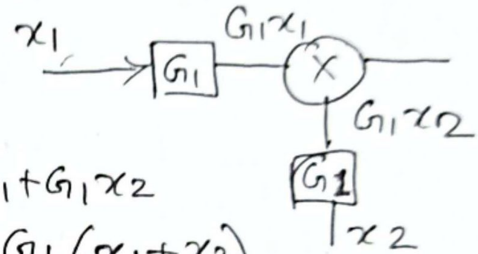
Manson's rule - to reduce signal-flow graph



Block diagram Reduction method

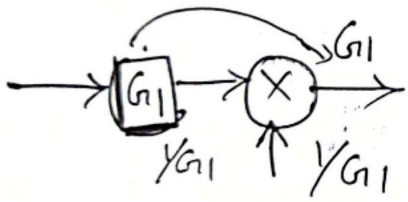


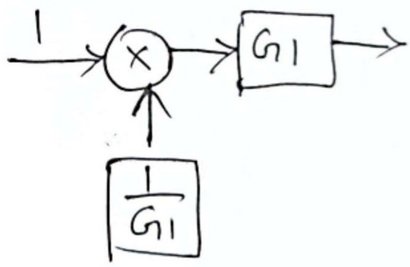
$\equiv$



$G_1x_1+G_1x_2$
$=G_1(x_1+x_2)$

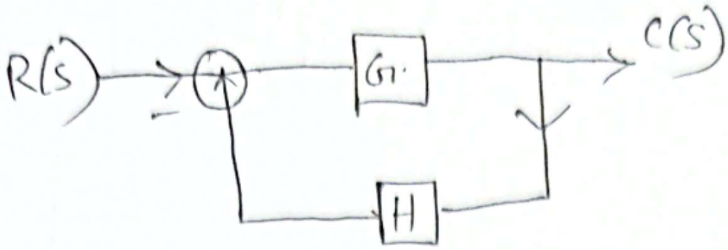
Right past summing junction





Feedback block

Final exam any one will come of 6marks

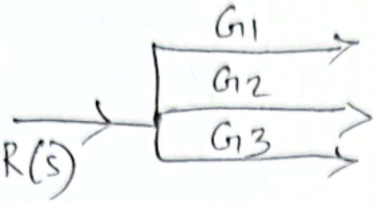


$$= \frac{G}{1+GH}$$

$$1 - G(-H)$$

$$1 - G(+H)$$

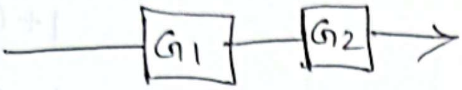
Parallel

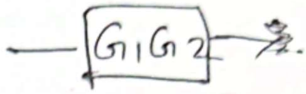


$$= G_1 + G_2 + G_3$$

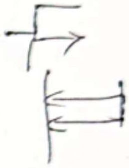
Series

system/block

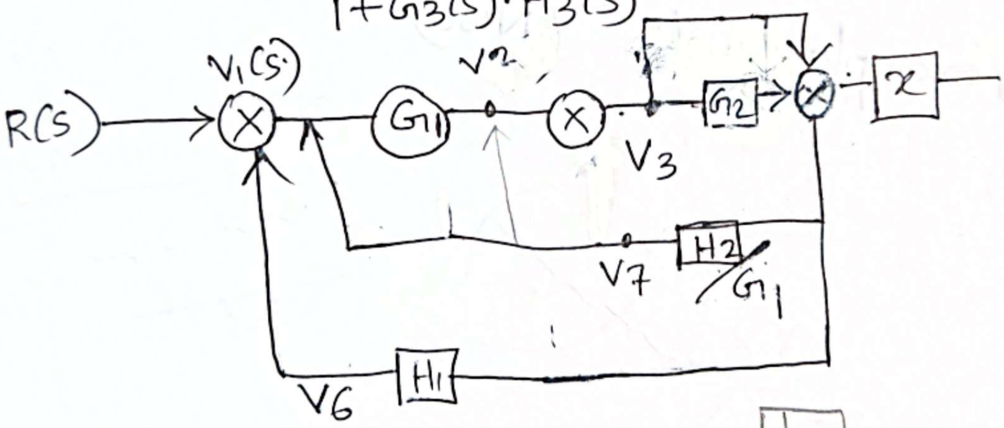


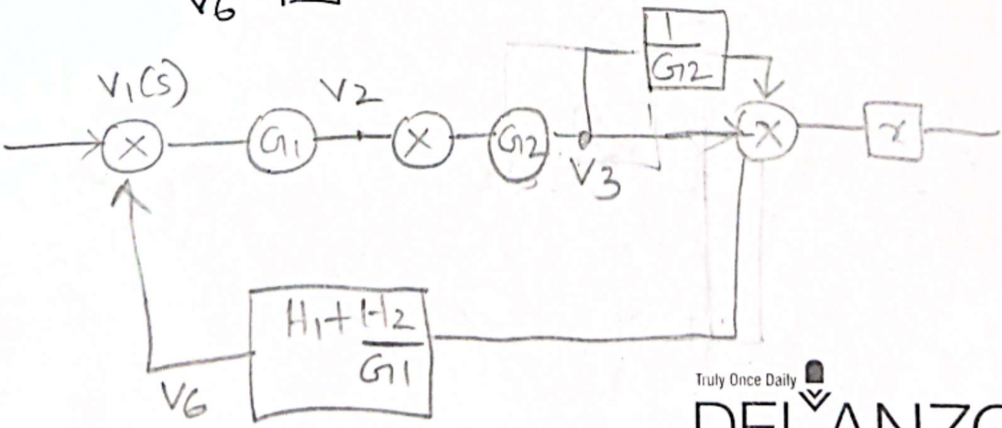


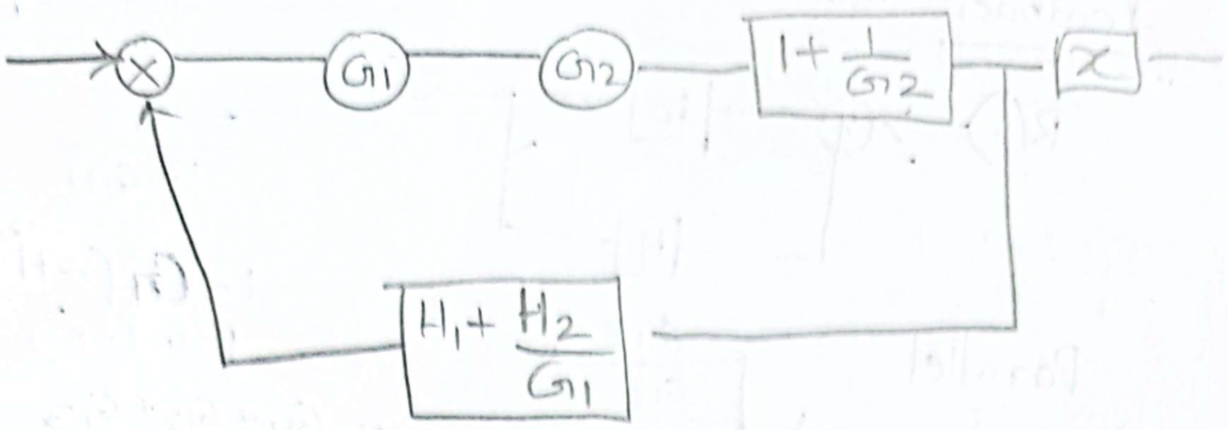
Reduce this system to a single transfer function

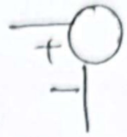


$$\frac{G_3(s)}{1+G_3(s)\cdot H_3(s)}$$



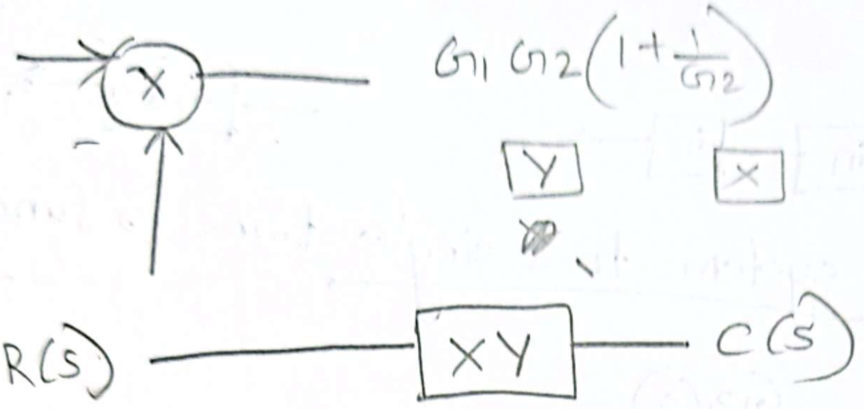






$\frac{G}{1+GH}$

$1-GH$



Practice the example well (N150)

ptember 2025

Meson gain rule

Ex – 5.4 Block diagram to flow

Meson's rule

Loop gain:

Total multiply gain

Loop gain 1 $= G_2 H_1$

$LG2 = G_4 H_2$

$LG3 = G_4 G_5 H_3$

$LG4 = G_4 G_5 G_6 H_3$

1. -1
2. $-G_2 G_3 G_4$
3. $-G_3 G_4$
4. $-G_4$

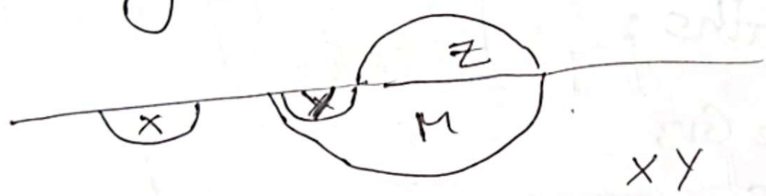
Forward Path Gain:

Input থেকে forward এ how much it goes is forward path

$T_1 = G_1 G_2 G_3 G_4$

1. $G_1 G_2 G_3 G_4 G_5 G_7 = T_1$
2. $G_1 G_2 G_3 G_4 G_6 G_7 = T_2$

Non-Touching Loops: taking 2 at a time



XY
XZ
XM

$G_2 H_1$ X
$G_4 H_2$ Y
$G_4 G_5 H_3$ Z
$G_4 G_6 H_3$ M

Non-Touching loop taking 3 at a time

$$G = \frac{\sum T_k \Delta_k}{\Delta}$$

$\Delta = 1 - \sum$ loop gains $+ \sum N \cdot T \cdot L \cdot 2 - \sum N \cdot T \cdot L \cdot 3$
$+ \sum N \cdot T \cdot L \cdot 4 + \cdots$

$T_1 T_2$

$k =$ No. of forward paths

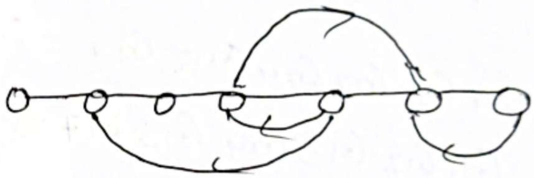
$\Delta k =$

$T_k =$ the kth forward-path gain

Ex - 5

Loop Gains :

1) $-G_1 G_2 H_1$
2) $-G_2 H_2$
3) $-G_3 H_3$



Forward Paths :

$T_1 = G_1 G_2 G_3$

$T_2 = G_1 G_3$

Non-Touching loop taking 2 at a time

1) $(-G_1, G_2 H_1) \cdot (-G_3 H_3)$
$= G_1 G_2 G_3 H_1 H_3$

2) $(-G_3 H_3) \cdot (-G_2 H_2) = G_2 G_3 H_2 H_3$

$$G = \frac{\sum T_k \Delta_k}{\Delta} = \frac{T_1\Delta_1 + T_2\Delta_2}{\Delta}$$

$$\Delta = 1 - [-G_1G_2H_1 - G_2H_2 - G_3H_3] + [G_1G_2G_3H_1H_3 + G_2G_3H_2H_3]$$

$$= 1 + G_1G_2H_1 + G_2H_2 + G_3H_3 + G_1G_2G_3H_1H_3 + G_2G_3H_2H_3$$

$$G = \frac{T_1\Delta_1 + T_2\Delta_2}{\Delta}$$

$T_1 = G_1G_2G_3$

$T_2 = G_1G_3$

$$\Delta_1 = 1 + \cancel{G_1G_2H_1}^{0} + \cancel{G_2H_2}^{0} + \cancel{G_3H_3}^{0} + \cancel{G_1G_2G_3H_1H_3}^{0} + \cancel{G_2G_3H_2H_3}^{0}$$

$\Delta_1 = 1$

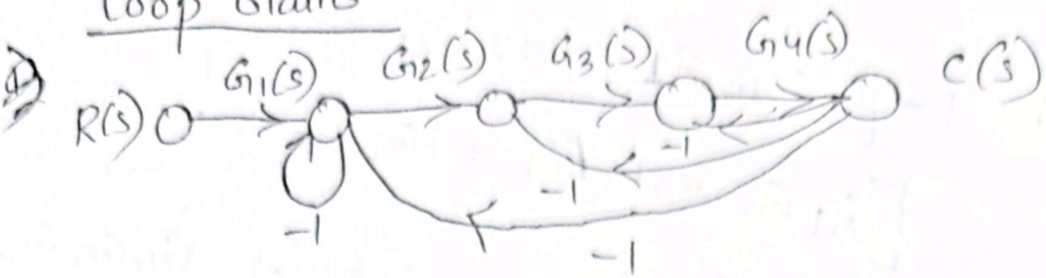
$$\Delta_2 = 1 + \cancel{G_1G_2H_1}^{0} + G_2H_2 + \cancel{G_3H_3}^{0} + \cancel{G_1G_2G_3H_1H_3}^{0} + \cancel{G_2G_3H_2H_3}^{0}$$

$\Delta_2 = 1 + G_2H_2$

$$G = \frac{G_1G_2G_3 \times 1 + (G_1G_3)(1 + G_2H_2)}{\Delta}$$

26) Fig P5.22

Loop Gains



1) -1
2) $-G_4$
3) $-G_3G_4$
4) $-G_2G_3G_4$

Forward Path:-

1) $T_1 = G_1G_2G_3G_4$

Non-touching loops

1) $(-1)(-G_3G_4) = G_3G_4$
2) $(-1)(-G_4) = G_4$

$$G = \frac{\sum T_k \Delta_k}{\Delta} = \frac{T_1\Delta_1}{\Delta}$$

$$\Delta = 1+1+G_2G_3G_4+G_3G_4+G_4+G_3G_4+G_4$$

$$\Delta_1 = 2+\cancel{G_2G_3G_4}^{0}+\cancel{G_3G_4}^{0}+\cancel{G_4}^{0}+\cancel{G_3G_4}^{0}+\cancel{G_4}^{0}$$

$$\Delta_1 = 2$$

27) $G_1 = \dfrac{T_1\Delta_1 + T_2\Delta_2 + T_3\Delta_3 + T_4\Delta_4}{\Delta}$

~~Ex~~ $\boxed{\text{Example } 5.7}$, 5.4

10 September 2025

(4) Response → Time response
→ Frequency response

Time Response → Steady state
→ Transient Response

Poles, Zeros and System Response

Poles: $T(s) = \dfrac{5(s+2)}{(s+3)(s+2)} = \infty$ Denom

$s = -3$

s এর value জন্য T(s) টা infinite হয় that is Pole

Zeros: $T(s) = \dfrac{(s-1)}{(s+3)} = 0$

s এর যে value জন্য T(s) এর value Zero হবে that is Zeros.

$T(s) = \dfrac{(s-1)(s+2)}{(s+2)(s+3)}$

1, -2

See the def^n in the slide

Significance of Poles and Zeros

(In exam one question will come I/p, o/p, fig, explain)

$R(s) = \frac{1}{s}$ → $\boxed{T(s)}$ → $C(s) = T(s) \cdot R(s)$

$T(s) = \frac{s+2}{s+5}$

$$C(s) = \frac{(s+2)}{s(s+5)} = \frac{A}{s} + \frac{B}{s+5} = \frac{2/5}{s} + \frac{3/5}{s+5}$$

$u(t) = 1$; Inverse laplace :

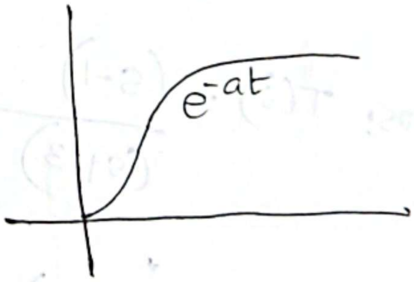
$\frac{1}{s+5}$ e^{-5t}

$$\frac{2}{5} \times 1 + \frac{3}{5} e^{-5t}$$

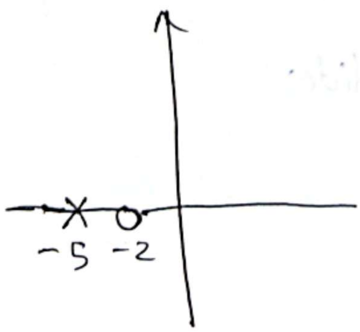
$$A = \left. \frac{(s+2)}{(s+5)} \right|_{s \to 0} = \frac{2}{5}$$

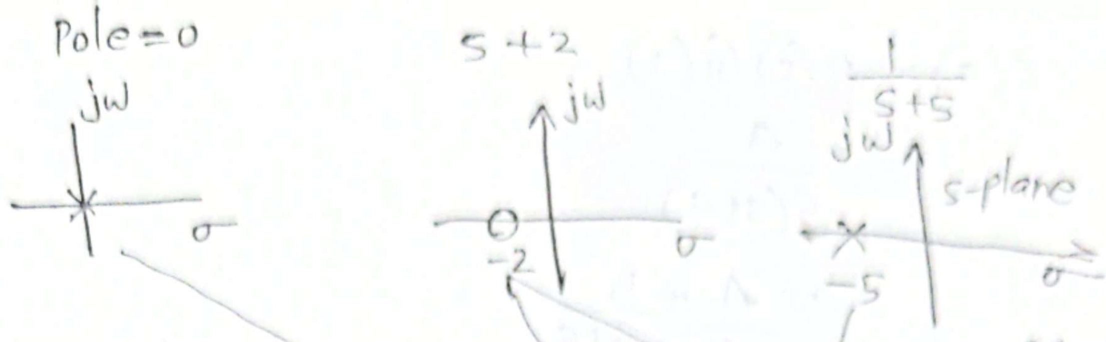
$$B = \left. \frac{(s+2)}{s} \right|_{s \to -5} = \frac{3}{5}$$

$$C(t) = \underbrace{\frac{2}{5}}_{\text{Forced Response}} + \underbrace{\frac{3}{5} e^{-5t}}_{\text{natural response}}$$



$\frac{1}{s}$ Pole=0





Output transform $C(s) = \frac{2/5}{s} + \frac{3/5}{s+5}$

2/5, 3/5 Pole এর কারণে charge হয়েছে

Output time $c(t) = \underbrace{\frac{2}{5}}_{\text{Forced response}} + \underbrace{\frac{3}{5}e^{-5t}}_{\text{Natural response}}$

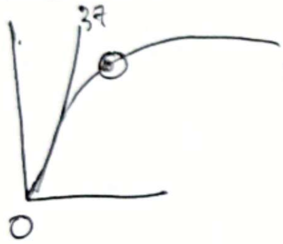
Conclusions/conditions:

1)
2)
3)

Example 4.1

Time constant – exponential signal ~~0 থেকে~~ 37% থেকে down হতে যে time টা দরকার হয় that is time constant

$e^{-at} \approx e^{-t/T_c}$



$$T_c = \frac{1}{a}$$

Rise time: 10% থেকে 90% reach হতে যে time টা দরকার হয় that is rise time

$$0.1 \sim 0.9 = \frac{2.2}{a}$$

Setting time: কোন একটা signal 0 থেকে 98% পৌঁছাতে যে time দরকার হয় সেটা setting time.

$$98\% = \frac{4}{a}$$

$$C(s) = R(s)G(s)$$

$$= \frac{a}{s(s+a)}$$

$$= \frac{A}{s} + \frac{B}{s+a}$$

$A = 1$, $B = -1$

$$C(s) = \frac{1}{s} - \frac{1}{s+a}$$

Inverse laplace

$$C(t) = 1 - e^{-at}$$

$$T_C = \frac{1}{a}$$

Rise time (T_r)

$c(t) = 0.1$, $0.1 = 1 - e^{-at_x}$ $\quad$ $0.9 = 1 - e^{-at_y}$

$$\ln(e^{-at_x}) = \ln(0.9)$$

$$t_x = \frac{0.1}{a}$$

$$\cancel{c(t)} \quad T_r = t_y - t_x = \frac{2.2}{a}$$

T_s :- $c(t) = 0.98$

$$T_s = \frac{4}{a}$$

$t_r = \approx 2.2T$

$2.2 \times 0.02 = 0.044\,s$

$t_s \approx 4T$

$t_s \approx 4 \times 0.002 = 0.08\,s$

Q) $G(s) = \frac{50}{s+50}$

$C(s) = \frac{50}{s(s+50)}$

$= \frac{A}{s} + \frac{B}{s+50}$

$C(s) = \frac{1}{s} - \frac{1}{s+50}$

$T_c = \frac{1}{50} = 0.02s$

Inverse laplace

$= 1 - e^{-50t}$

$T_c = \frac{1}{50} = 0.02s$

~~C(t)~~

Rise time

$C(t) = 0.1$

$0.1 = 1 - e^{-atx}$

$0.1 = 1 - e^{-50tx}$

$-\ln(e^{-50tx}) = \ln(0.9)$

$tx = \frac{1.1}{50} = 0.022$

$0.9 = 1 - e^{-aty}$

$e^{-aty} = 1 - 0.9$

$ty = \frac{0.1}{50} = \cancel{0.002}\ 0.002$

$ty = \frac{0.1}{50}$

$tr = ty - tx$

$= 2.2 \times 0.002 = 0.044s$

Example

5.5) Convert the cascaded, parallel, and feedback forms of the block diagrams shown in Figures 5.3 (a), 5.5 (a), and 5.6 (b), respectively, into signal-flow graphs.

Fig 5.3(a)

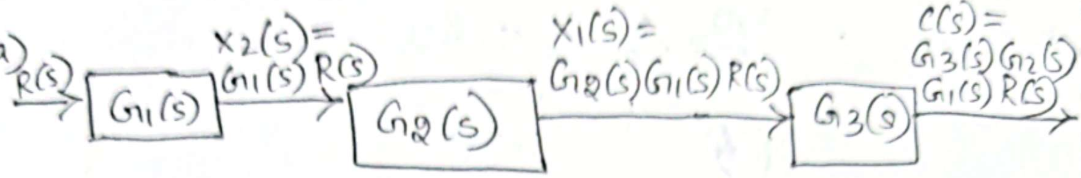


Fig 5.5(a)

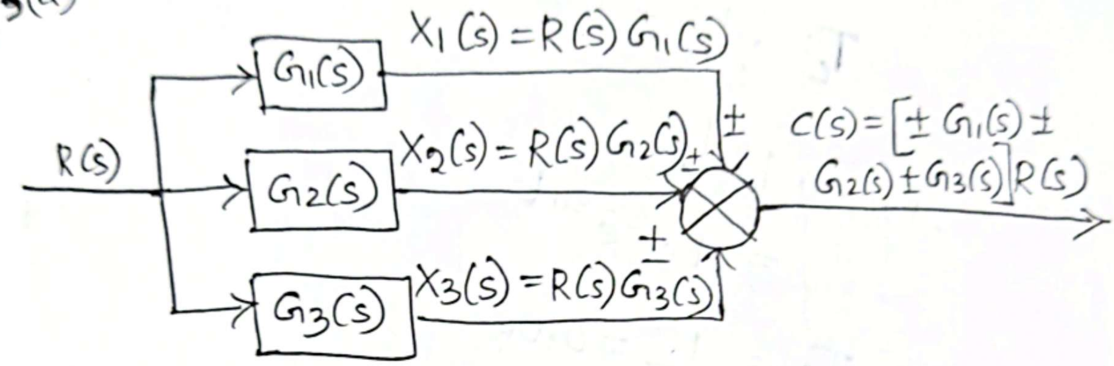
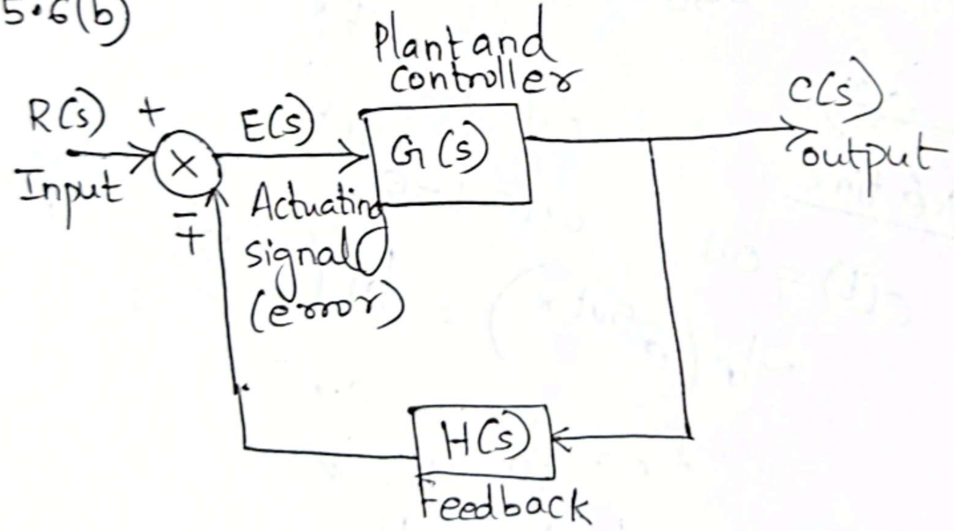
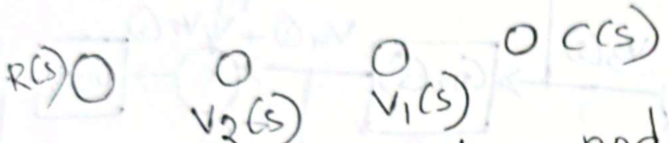


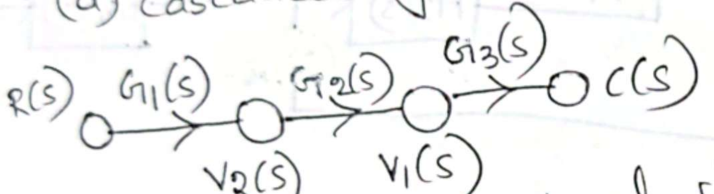
Fig 5.6(b)



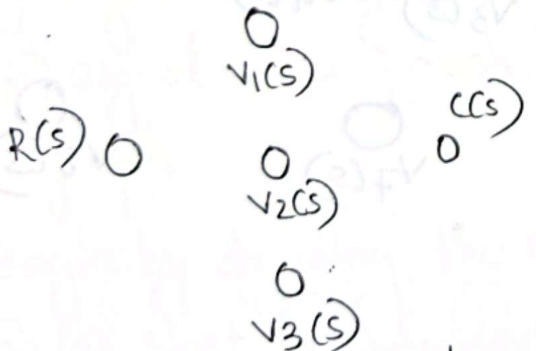
Ans:- In each case, we start by drawing the signal nodes for that system. Next we interconnect the signal nodes with system branches. The signal nodes for the cascaded, parallel, and feedback forms are shown in figure (a), (c), and (e), respectively.
The interconnection of the nodes with branches that represent the subsystems is shown in Fig (b), (d), and (f) for the cascaded, parallel, and feedback forms, respectively.



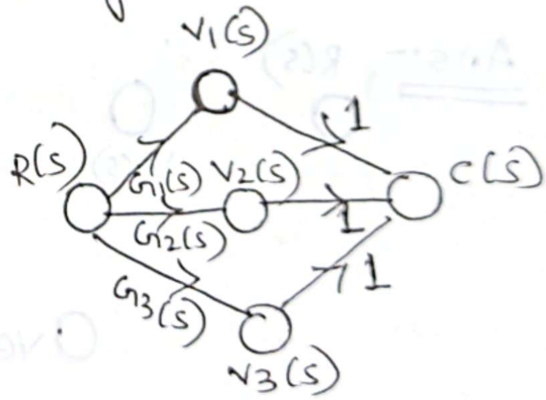
(a) Cascaded system nodes (from Fig 5.3 (a))



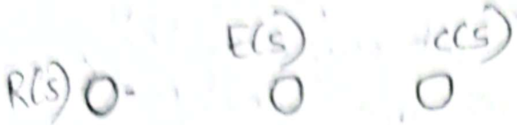
(b) cascaded system signal-flow graph



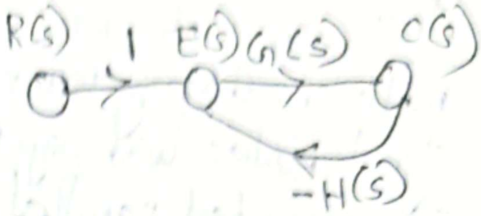
(c) parallel system nodes (from Fig 5.5(a))



(d) parallel system signal-flow graph

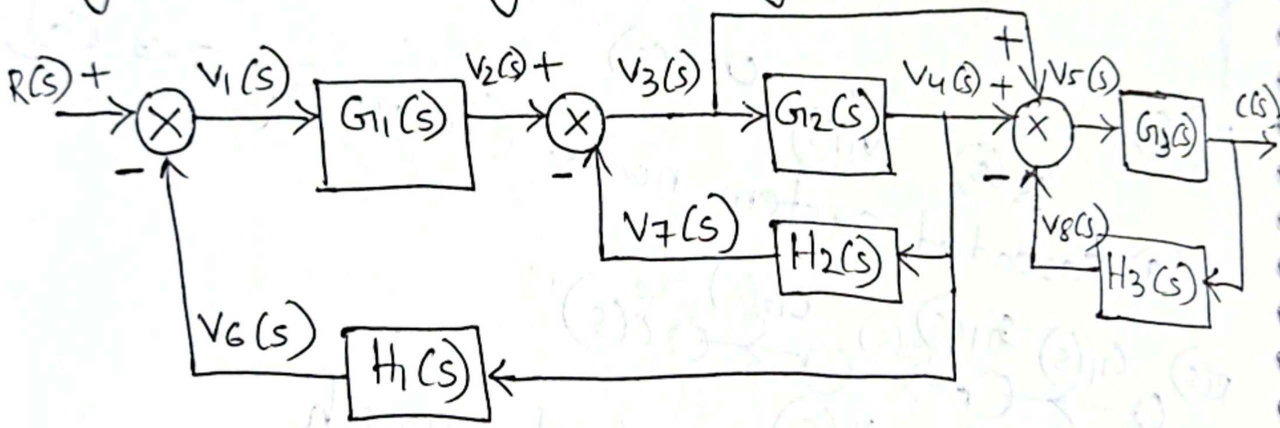


(e) Feedback system nodes (from fig 5.6(b))

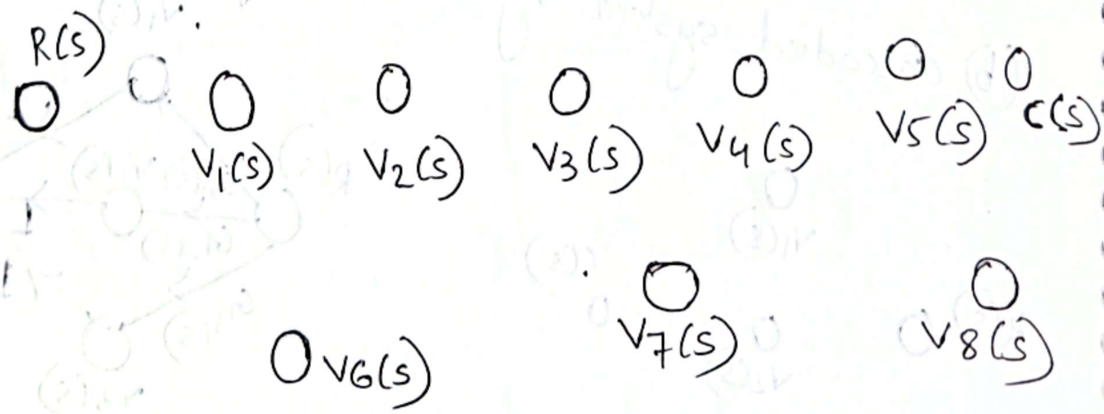


(f) feedback system signal-flow graph

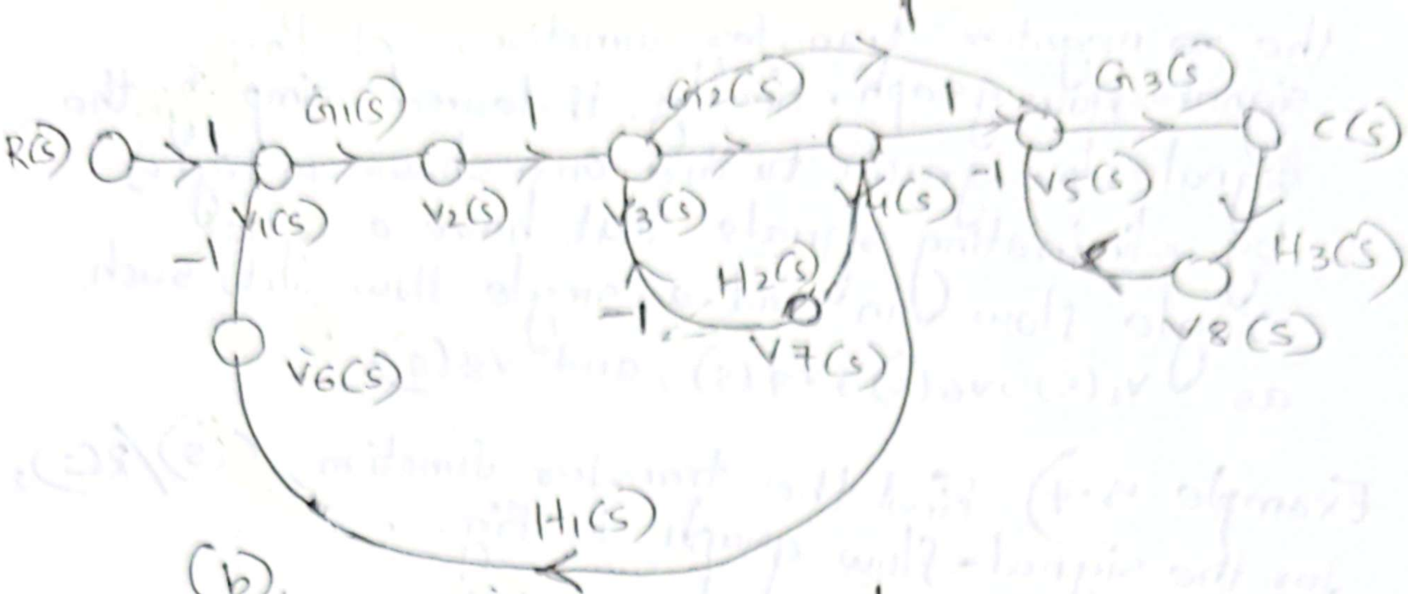
Example 5.6) Convert the block diagram of Figure 5.11 to a signal-flow graph.



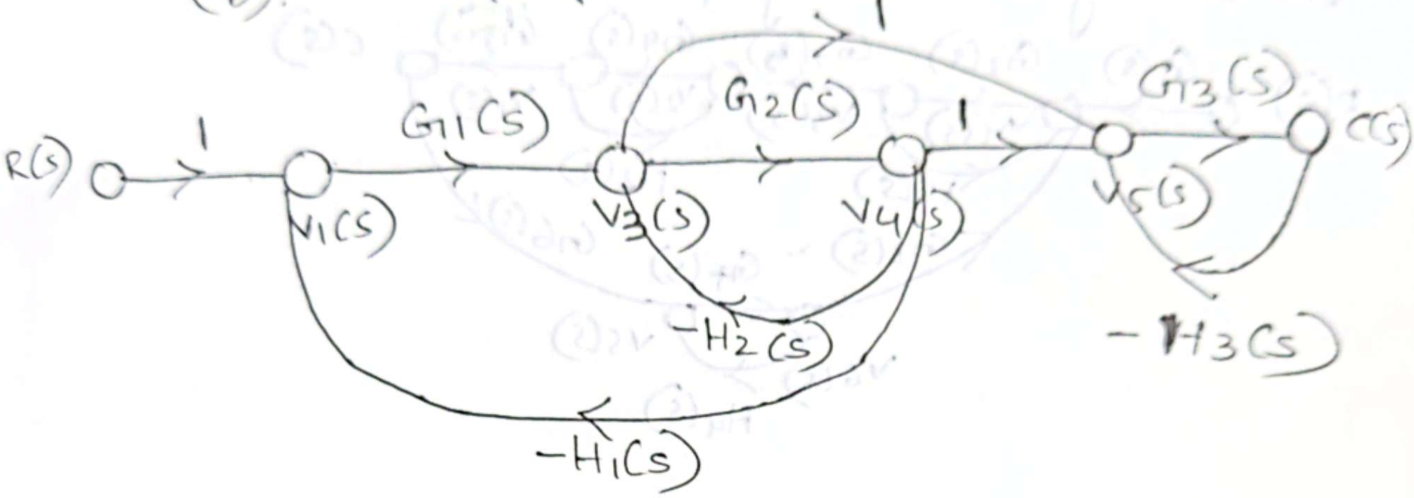
Ans:-



(a)



(b).



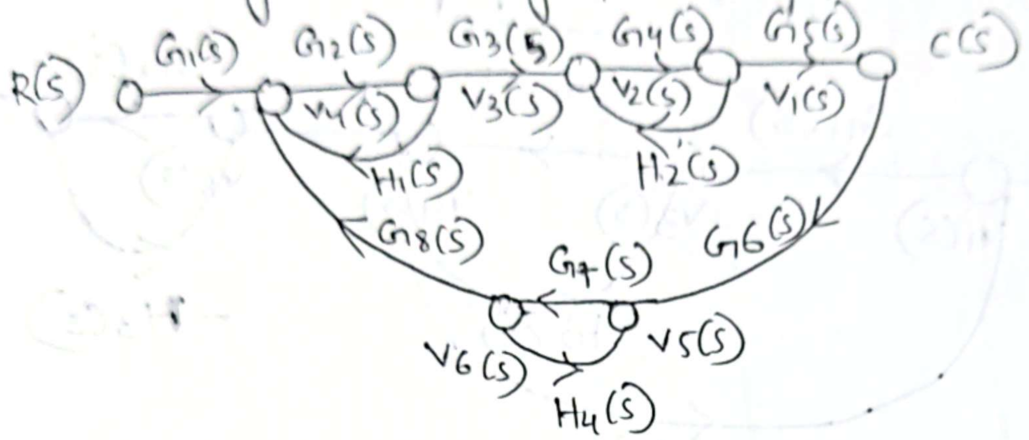
(c)

Fig. Signal-flow graph development: (a) signal nodes; (b) signal-flow graph; (c) simplified signal-flow graph

Begin by drawing the signal nodes, as shown in Fig (a). Next, interconnect the nodes, showing the direction of signal flow and identifying each transfer function. The result is shown Fig (b). Notice that the negative signs at the summing junctions of the block diagram are represented by ~~the~~.

the negative transfer functions of the signal-flow graph. Finally, if desired, simplify the signal-flow graph to the one shown in Fig(c) by eliminating signals that have a single flow in and a single flow out, such as $V_2(s)$, $V_6(s)$, $V_7(s)$, and $V_8(s)$

Example 5.7) Find the transfer function, $C(s)/R(s)$, for the signal-flow graph in Fig.



Loop gains

1) $G_2(s) H_1(s)$
2) $G_4(s) H_2(s)$
3) $G_7(s) H_4(s)$
4) $G_2(s) G_3(s) G_4(s) G_5(s) G_6(s) G_7(s) G_8(s)$

Forward-path gains

$T_1 = G_1(s) G_2(s) G_3(s) G_4(s) G_5(s)$

Non-touching loops taken two at a time:

1) $G_2(s) H_1(s) \quad G_4(s) H_2(s)$
2) $G_2(s) H_1(s) \quad G_7(s) H_4(s)$
3) $G_4(s) H_2(s) \quad G_7(s) H_4(s)$

Non-touching loops taken three at a time :-

$G_2(s)H_1(s)\ G_4(s)H_2(s)\ G_7(s)H_4(s)$

$$G(s) = \frac{C(s)}{R(s)} = \frac{\sum_K T_K \Delta_K}{\Delta} = \frac{T_1\Delta_1}{\Delta}$$

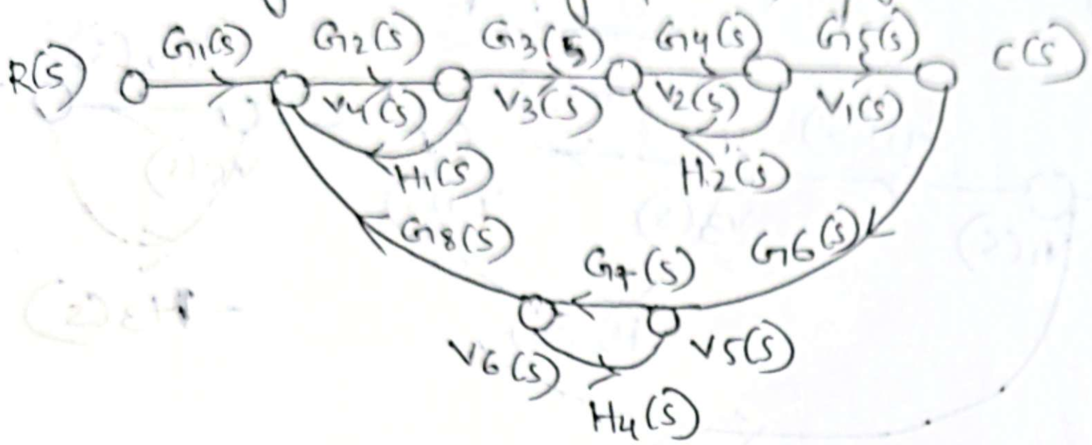
$$\Delta = 1 - \Big[G_2(s)H_1(s) + G_4(s)H_2(s) + G_7(s)H_4(s) + G_2(s)G_3(s)G_4(s)G_5(s)G_6(s)G_7(s)G_8(s)\Big]$$
$$+ \Big[G_2(s)H_1(s)G_4(s)H_2(s) + G_2(s)H_1(s)G_7(s)H_4(s) + G_4(s)H_2(s)G_7(s)H_4(s)\Big]$$
$$- \Big[G_2(s)H_1(s)G_4(s)H_2(s)G_7(s)H_4(s)\Big]$$

$$\Delta_1 = 1 - G_7(s)H_4(s)$$

$$G(s) = \frac{T_1\Delta_1}{\Delta} = \frac{\Big[G_1(s)G_2(s)G_3(s)G_4(s)G_5(s)\Big]\Big[1 - G_7(s)H_4(s)\Big]}{\Delta}$$

the negative transfer functions of the signal-flow graph. Finally, if desired, simplify the signal-flow graph to the one shown in Fig(c) by eliminating signals that have a single flow in and a single flow out, such as $V_2(s)$, $V_6(s)$, $V_7(s)$, and $V_8(s)$

Example 5.7) Find the transfer function, $C(s)/R(s)$, for the signal-flow graph in Fig.



Loop gains

1) $G_2(s)\,H_1(s)$
2) $G_4(s)\,H_2(s)$
3) $G_7(s)\,H_4(s)$
4) $G_2(s)G_3(s)\,G_4(s)\,G_5(s)\,G_6(s)\,G_7(s)\,G_8(s)$

Forward-path gains

$T_1 = G_1(s)\,G_2(s)\,G_3(s)\,G_4(s)\,G_5(s)$

Non-touching loops taken two at a time:

1) $G_2(s)H_1(s)\;\;G_4(s)\;H_2(s)$
2) $G_2(s)\;H_1(s)\;\;G_7(s)\;H_4(s)$
3) $G_4(s)\;H_2(s)\;\;G_7(s)\;H_4(s)$

Non-touching loops taken three at a time:-

$G_2(s)H_1(s)\ G_4(s)H_2(s)\ G_7(s)H_4(s)$

$$G(s)=\frac{C(s)}{R(s)}=\frac{\sum_K T_K \Delta_K}{\Delta}=\frac{T_1\Delta_1}{\Delta}$$

$$\Delta = 1-\Big[G_2(s)H_1(s)+G_4(s)H_2(s)+G_7(s)H_4(s)+G_2(s)G_3(s)G_4(s)G_5(s)G_6(s)G_7(s)G_8(s)\Big]$$
$$+\Big[G_2(s)H_1(s)G_4(s)H_2(s)+G_2(s)H_1(s)G_7(s)H_4(s)+G_4(s)H_2(s)G_7(s)H_4(s)\Big]$$
$$-\Big[G_2(s)H_1(s)G_4(s)H_2(s)G_7(s)H_4(s)\Big]$$

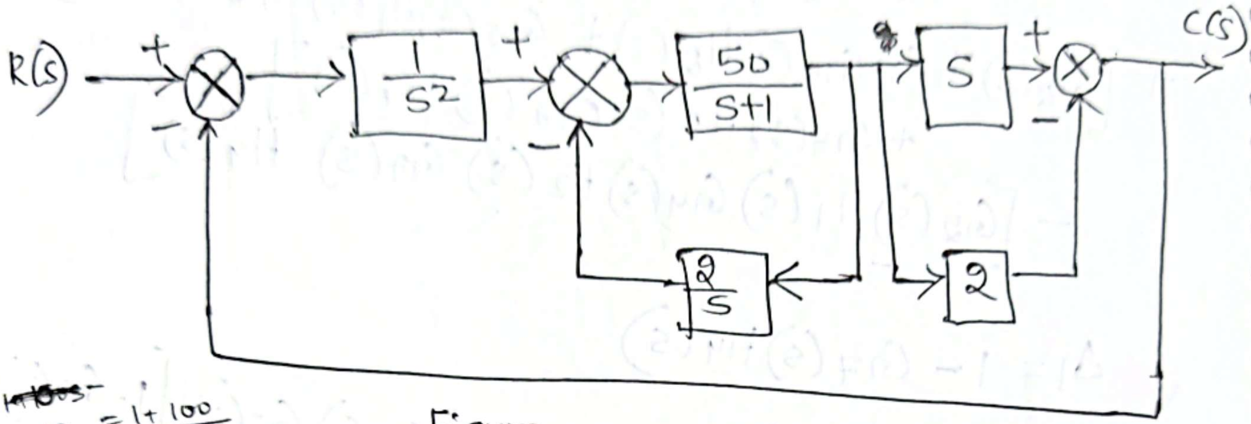
$$\Delta_1 = 1-G_7(s)H_4(s)$$

$$G(s)=\frac{T_1\Delta_1}{\Delta}=\frac{\big[G_1(s)G_2(s)G_3(s)G_4(s)G_5(s)\big]\big[1-G_7(s)H_4(s)\big]}{\Delta}$$

Problems

1) Reduce the block diagram shown in Figure to a single transfer function, $T(s) = C(s)/R(s)$. Use the following methods:

(a) Block diagram reduction

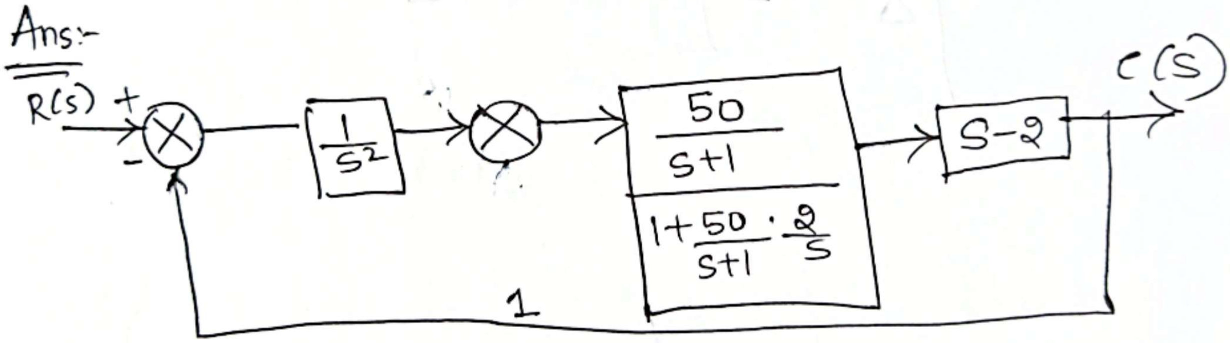


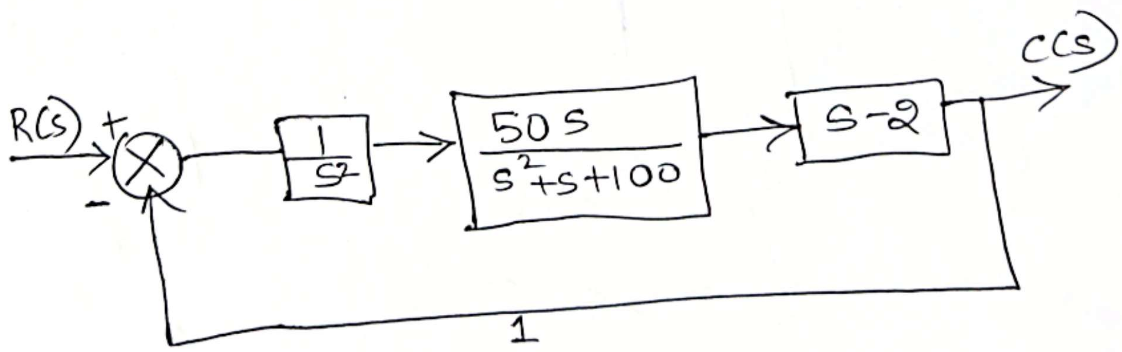
$1+\frac{100}{s(s+1)} = 1+\frac{100}{s^2+s}$

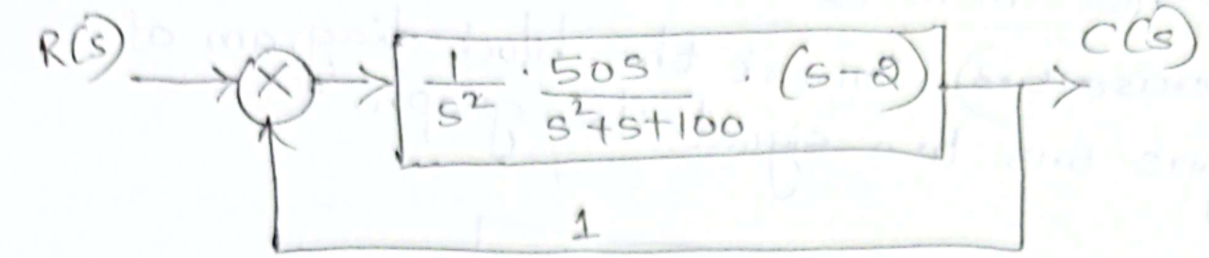
$\frac{s^2+s+100}{s^2+s} = \frac{s^2+s+100}{s(s+1)}$

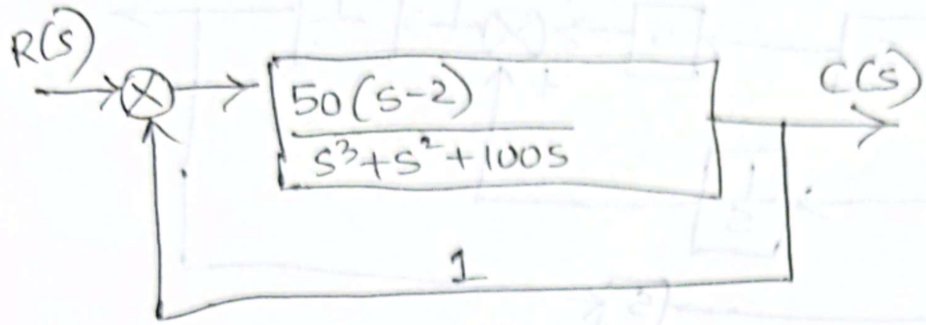
Figure.

Ans:-









$$\frac{50s(s-2)}{s^4+s^3+100s^2}$$

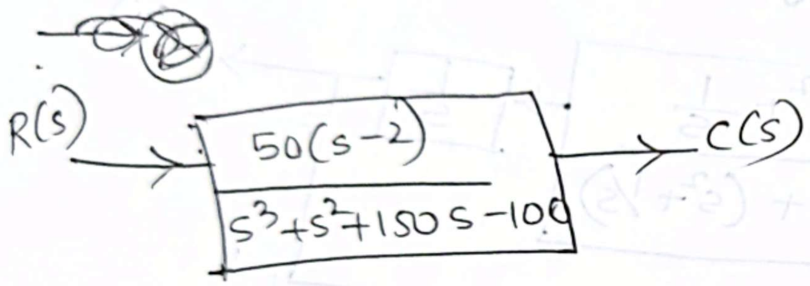
$$\frac{50(s-2)}{s(s^2+s+100)}$$

$$\frac{50(s-2)}{s^3+s^2+100s}$$

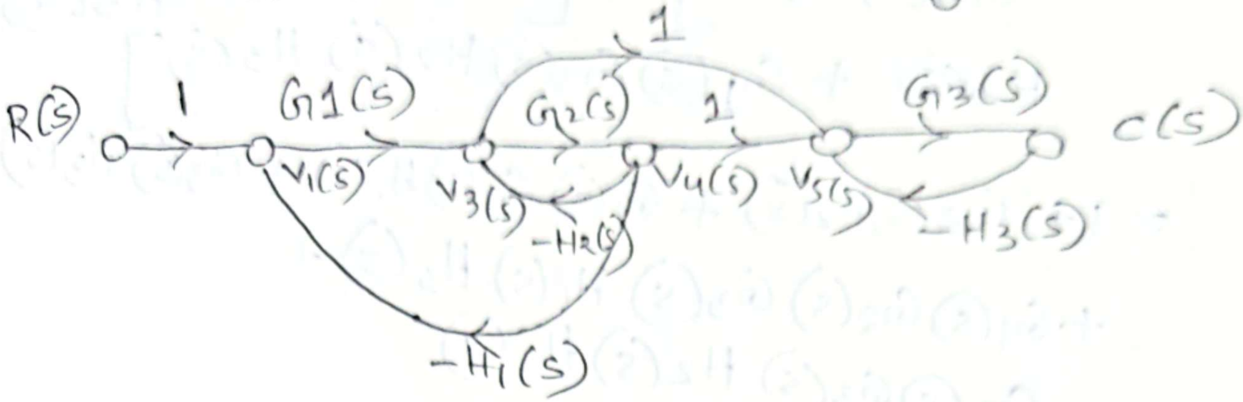
$$\frac{\frac{50(s-2)}{s^3+s^2+100s}}{1+\frac{50(s-2)}{s^3+s^2+100s}}$$

$$\frac{50(s-2)}{s^3+s^2+100s+50s-100}$$

$$\frac{50(s-2)}{s^3+s^2+150s-100}$$



Exercise 5.4) Use Mason's rule to find the transfer function of the signal-flow diagram shown in Figure 5.19 (c). Notice that this is the same system used in Example 5.2 to find the transfer function via block diagram reduction.



Ans:- Loop gains

1) $-G_2(s)H_2(s)$

2) $-G_1(s)G_2(s)H_1(s)$

3) $-G_3(s)H_3(s)$

Forward path gain

1) $T_1 = G_1(s)G_2(s)G_3(s)$

2) $T_2 = G_1(s)G_3(s)$

Non-touching loops gain taken two at a time

1) $(-G_1(s)G_2(s)H_1(s)), (-G_3(s)H_3(s))$

$= G_1(s)G_2(s)G_3(s)H_1(s)H_3(s)$

2) $(-G_2(s)H_2(s))\cdot(-G_3(s)H_3(s)) = G_2(s)G_3(s)H_2(s)H_3(s)$

$$G(s) = \frac{C(s)}{R(s)} = \frac{\sum_k T_k \Delta_k}{\Delta} = \frac{T_1\Delta_1 + T_2\Delta_2}{\Delta}$$

$$\Delta = 1 - \Big[-G_2(s)H_2(s) - G_1(s)G_2(s)H_1(s) - G_3(s)H_3(s)\Big] + \Big[G_1(s)G_2(s)G_3(s)H_1(s)H_3(s) \; \cancel{H_3(s)} + G_2(s)G_3(s)H_2(s)H_3(s)\Big]$$

$$= 1 + G_2(s)H_2(s) + G_1(s)G_2(s)H_1(s) + G_3(s)H_3(s) + G_1(s)G_2(s)G_3(s)H_1(s)H_3(s) + G_2(s)G_3(s)H_2(s)H_3(s)$$

$$\Delta_1 = 1 + \cancelto{0}{G_2(s)H_2(s)} + \cancelto{0}{G_1(s)G_2(s)H_1(s)} + \cancelto{0}{G_3(s)H_3(s)} + \cancelto{0}{G_1(s)G_2(s)G_3(s)H_1(s)H_3(s)} + \cancelto{0}{G_2(s)G_3(s)H_2(s)H_3(s)}$$

$$\Delta_1 = 1$$

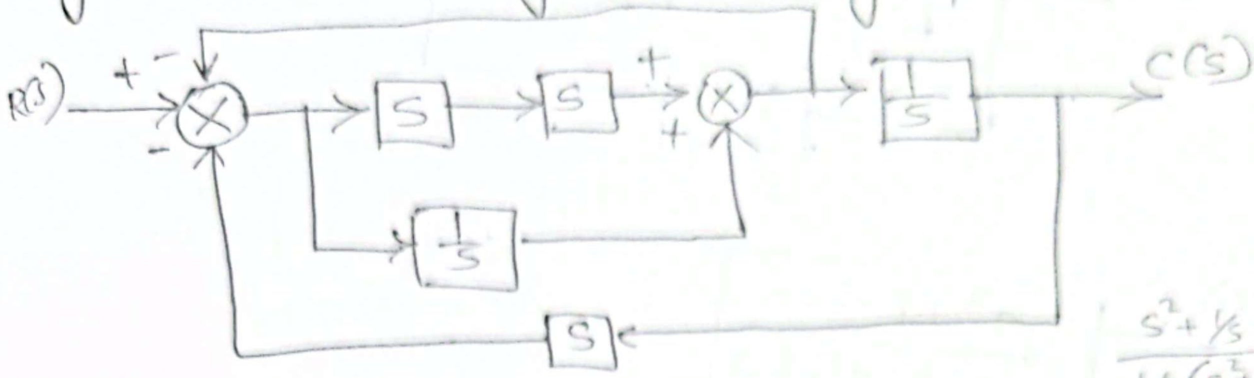
$$\Delta_2 = 1 + G_2(s)H_2(s)$$

$$G(s) = \frac{C(s)}{R(s)} = \frac{T_1\Delta_1 + T_2\Delta_2}{\Delta}$$

$$= \frac{G_1(s)G_2(s)G_3(s) + G_1(s)G_3(s)\big(1 + G_2(s)H_2(s)\big)}{\Delta}$$

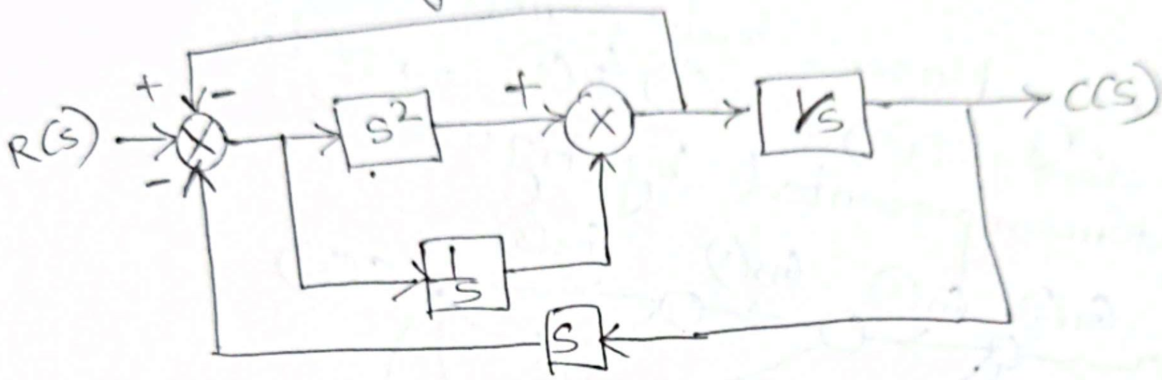
Skill-Assessment

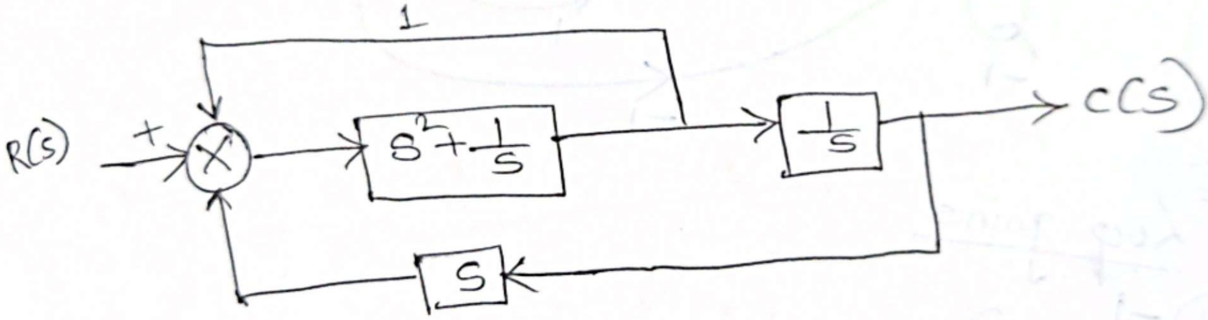
Exercise 5.3) Convert the block diagram of Figure 5.13 to a signal-flow graph.



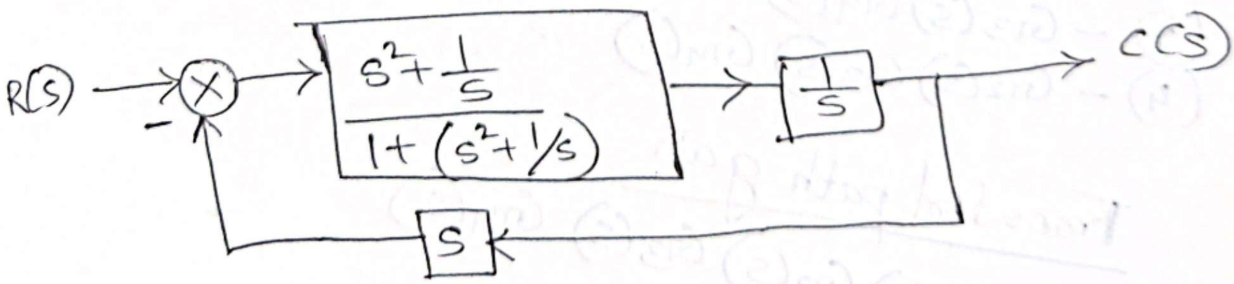
$$\frac{s^2+1/s}{1+(s^2+\frac{1}{s})}$$

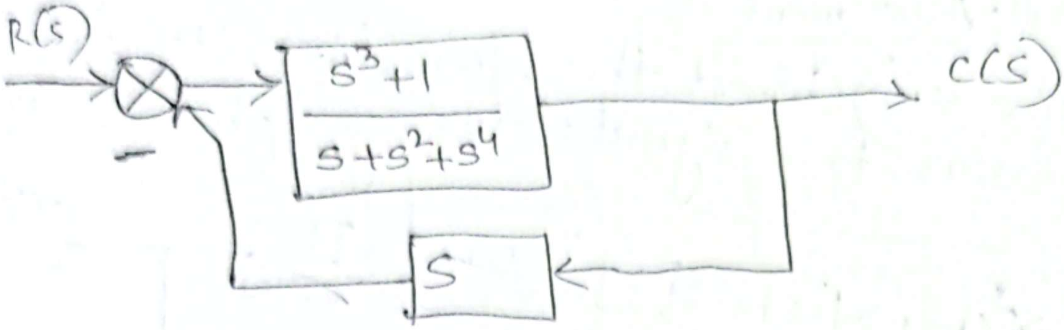
Fig 5.13



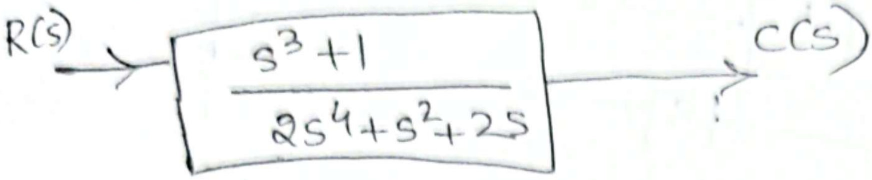


$\frac{s^3+1}{s}$

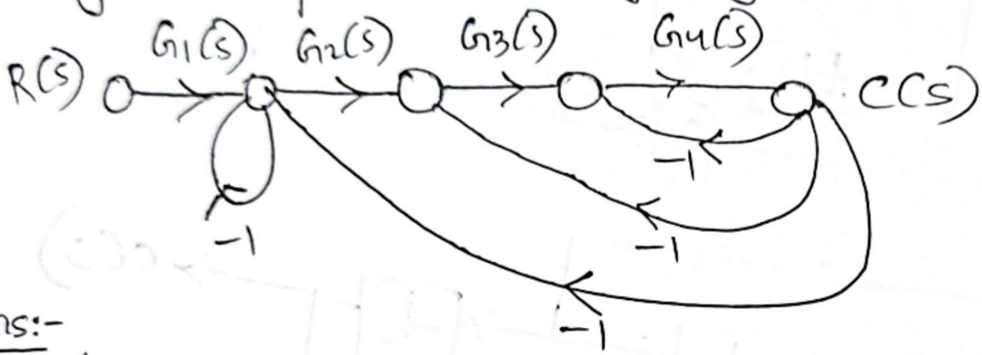




$1+\frac{s^3+1}{s^2+s^4+s}\times s$



26) Using Mason's rule, find the transfer function, $T(s) = C(s)/R(s)$, for the system represented by Figure.



Ans:-

Loop gains

1) -1
2) $-G_4(s)$
3) $-G_3(s)G_4(s)$
4) $-G_2(s)G_3(s)G_4(s)$

Forward path gain

1) $T_1 = G_1(s)G_2(s)G_3(s)G_4(s)$

Non touching loop gains

1) $(-1)(-G_4(s)) = G_4(s)$
2) $(-1)(-G_3(s)G_4(s)) = G_3(s)G_4(s)$

$$G(s) = \frac{C(s)}{R(s)} = \frac{\Sigma_k T_k \Delta_k}{\Delta} = \frac{T_1\Delta_1}{\Delta}$$

$$\Delta = 1 - [-1 - G_4(s) - G_3(s)G_4(s) - G_2(s)G_3(s)G_4(s)] + [G_4(s) + G_3(s)G_4(s)]$$

$$= 2 + G_4(s) + G_3(s)G_4(s) - G_2(s)G_3(s)G_4(s) + G_4(s) + G_3(s)G_4(s)$$

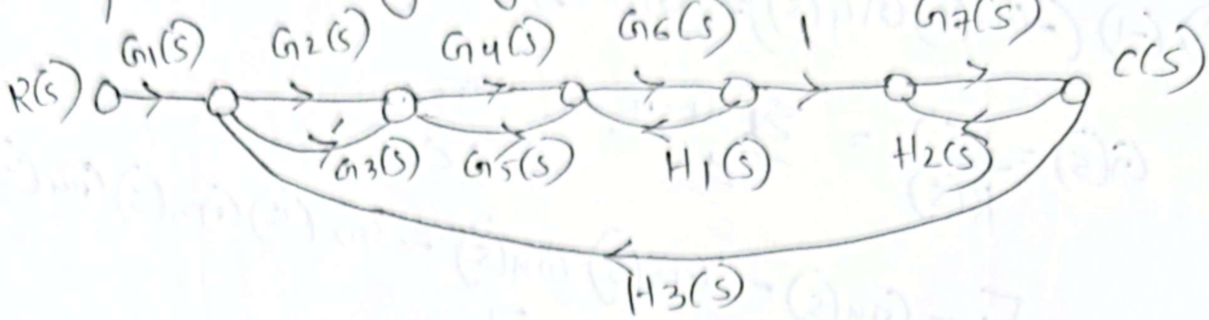
$$\Delta_1 = 2 + \cancelto{0}{G_4(s)} + \cancelto{0}{G_3(s)G_4(s)} + \cancelto{0}{G_2(s)G_3(s)G_4(s)} + \cancelto{0}{G_4(s)} + \cancel{G_3(s)G_4(s)}$$

$$\Delta_1 = 2$$

$$G(s) = \frac{T_1\Delta_1}{\Delta} = \frac{2G_1(s)G_2(s)G_3(s)G_4(s)}{\Delta}$$

$$= \frac{2G_1(s)G_2(s)G_3(s)G_4(s)}{2 + G_4(s) + G_3(s)G_4(s) + G_2(s)G_3(s)G_4(s) + G_4(s) + G_3(s)G_4(s)}$$

27) Using Mason's rule, find the transfer function, $T(s) = C(s)/R(s)$, for the system represented by Figure.



Loop Gains

1) $G_6(s) H_1(s)$
2) $G_7(s) H_2(s)$
3) $G_2(s) G_4(s) G_6(s) G_7(s) H_3(s)$
4) $G_3(s) G_4(s) G_6(s) G_7(s) H_3(s)$
5) $G_2(s) G_5(s) G_6(s) G_7(s) H_3(s)$
6) $G_3(s) G_5(s) G_6(s) G_7(s) H_3(s)$

Forward path gains:

1) $T_1 = G_1(s) G_2(s) G_4(s) G_6(s) G_7(s)$
2) $T_2 = G_1(s) G_3(s) G_4(s) G_6(s) G_7(s)$
3) $T_3 = G_1(s) G_2(s) G_5(s) \cdot G_6(s) G_7(s)$
4) $T_4 = G_1(s) G_3(s) G_5(s) G_6(s) G_7(s)$

Non touching loop gain taken 2 at a time

$G_6(s) H_1(s) \quad G_7(s) H_2(s)$

Non-touching loop taken 3 at a time

Zero (0)

$$G(s) = \frac{C(s)}{R(s)} = \frac{T_1\Delta_1 + T_2\Delta_2 + T_3\Delta_3 + T_4\Delta_4}{\Delta}$$

$$\Delta = 1 - [G_6H_1 + G_7H_2(s) + G_2G_4G_6G_7H_3 + G_2G_5G_6G_7H_3 + G_3G_4G_6G_7H_3 + G_3G_5G_6G_7H_3] + G_6H_1G_7H_2$$

$$\Delta_1 = 1 + G_6H_1 + G_7H_2 + G_2G_4G_6G_7H_3 + G_3G_4G_6G_7H_3 + G_2G_5G_6G_7H_3 + G_3G_5G_6G_7H_3] + G_6G_7H_1H_2$$

$\Delta_1 = 1$ $\Delta_4 = 1$

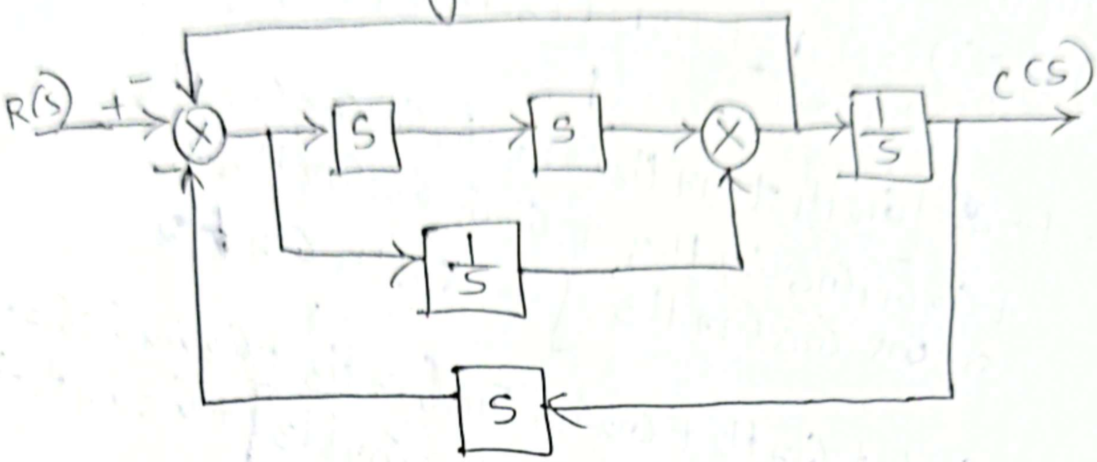
$\Delta_2 = 1$

$\Delta_3 = 1$

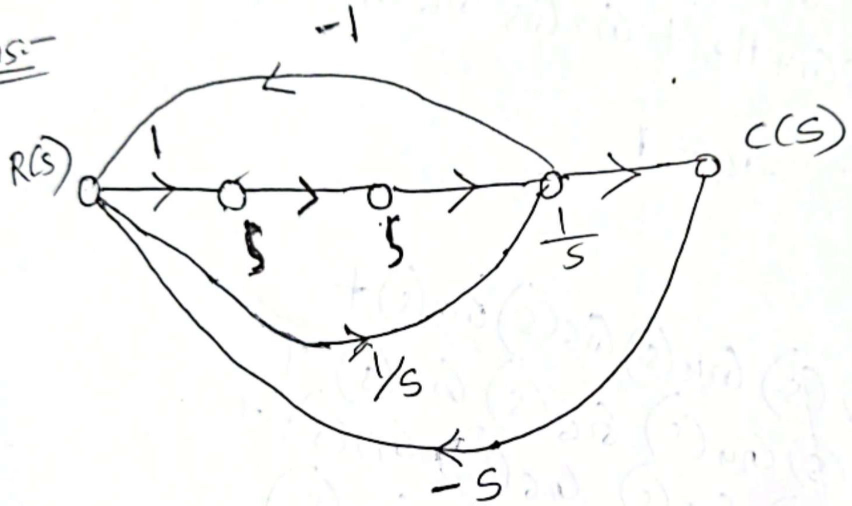
$$G(s) = \frac{G_1(s)G_2(s)G_4(s)G_6(s)G_7(s) + G_1(s)G_3(s)G_4(s)G_6(s)G_7(s) + G_1(s)G_2(s)G_5(s)G_6(s)G_7(s) + G_1(s)G_3(s)G_5(s)G_6(s)G_7(s)}{\Delta}$$

$$= \frac{G_1G_6G_7(G_2G_4 + G_3G_4 + G_2G_5 + G_3G_5)}{\Delta}$$

28) Use Mason's rule to find the transfer function of Fig. 5.13 in the text.



Ans:-



$\frac{1}{s} \times -s \times s^2$

$\frac{1}{s^2} \times s$

$s^2 \times \frac{1}{s}$

$\frac{1}{s} \times \frac{1}{s}$

closed loop gains

1) $-s^2$
2) $-s^2$
3) $\frac{-1}{s}$
4) $\frac{-1}{s}$

Forward path gain

$T_1 = s$

$T_2 = \frac{1}{s^2}$

Non-touching loops — None

$$G(s) = \frac{C(s)}{R(s)} = \frac{T_1\Delta_1 + T_2\Delta_2}{\Delta}$$

$$\Delta = 1 - \left[-s^2 - s^2 - \frac{1}{s} - \frac{1}{s}\right]$$

$$= 1 + 2s^2 + \frac{2}{s}$$

$\Delta_1 = 1$

$\Delta_2 = 1$

$$T(s) = \frac{C(s)}{R(s)} = \frac{T_1\Delta_1 + T_2\Delta_2}{\Delta}$$

$$= \frac{s + \frac{1}{s^2}}{1 + 2s^2 + \frac{2}{s}}$$

$$= \frac{s^3+1}{2s^3+2s^2+2s}$$

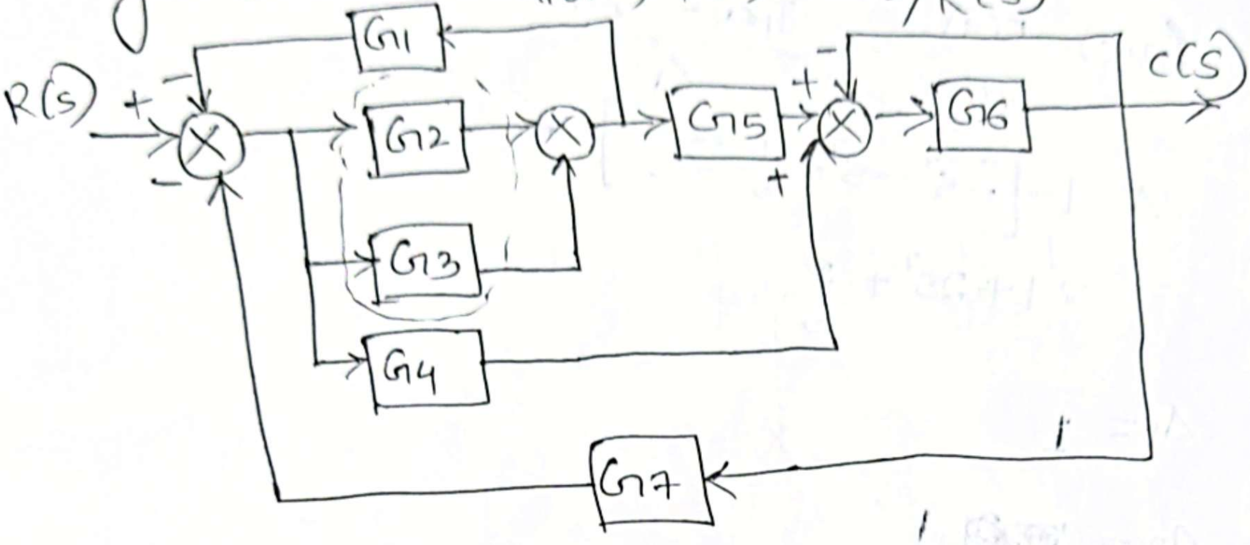
$s + 2s^3 + 2$

$$\frac{\frac{s^3+1}{s^2}}{\frac{s+2s^3+2}{s}}$$

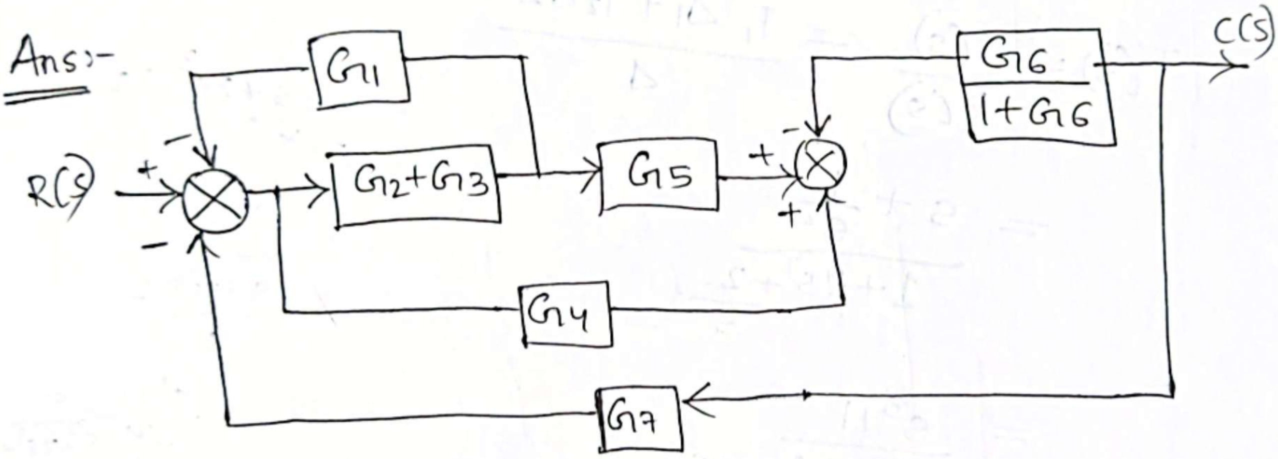
$$\frac{s^3+1}{\cancel{s^2}} \times \frac{\cancel{s}}{s+2s^3+2}$$

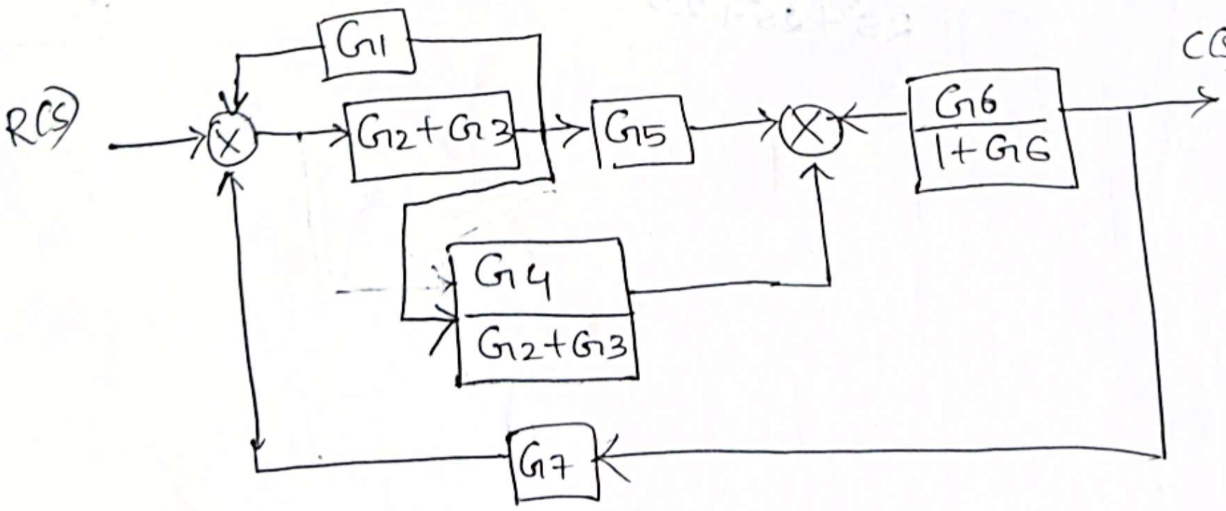
$$\frac{s^3+1}{}$$

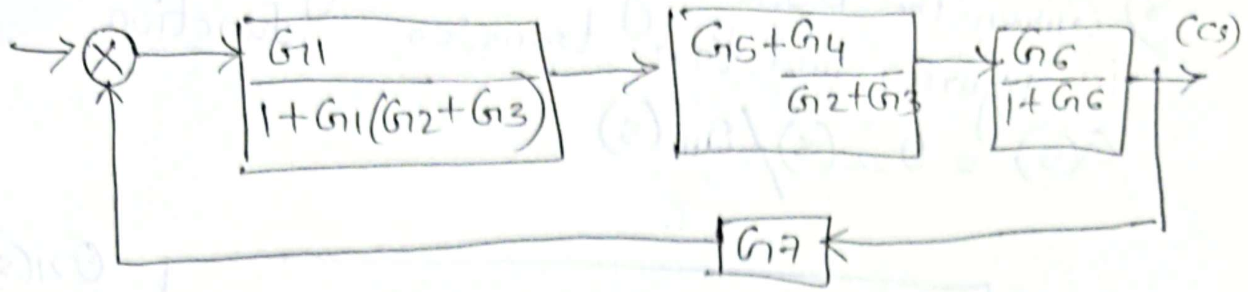
9) Reduce the block diagram shown in Fig. to a single transfer function, $T(s) = C(s)/R(s)$.



Ans:-



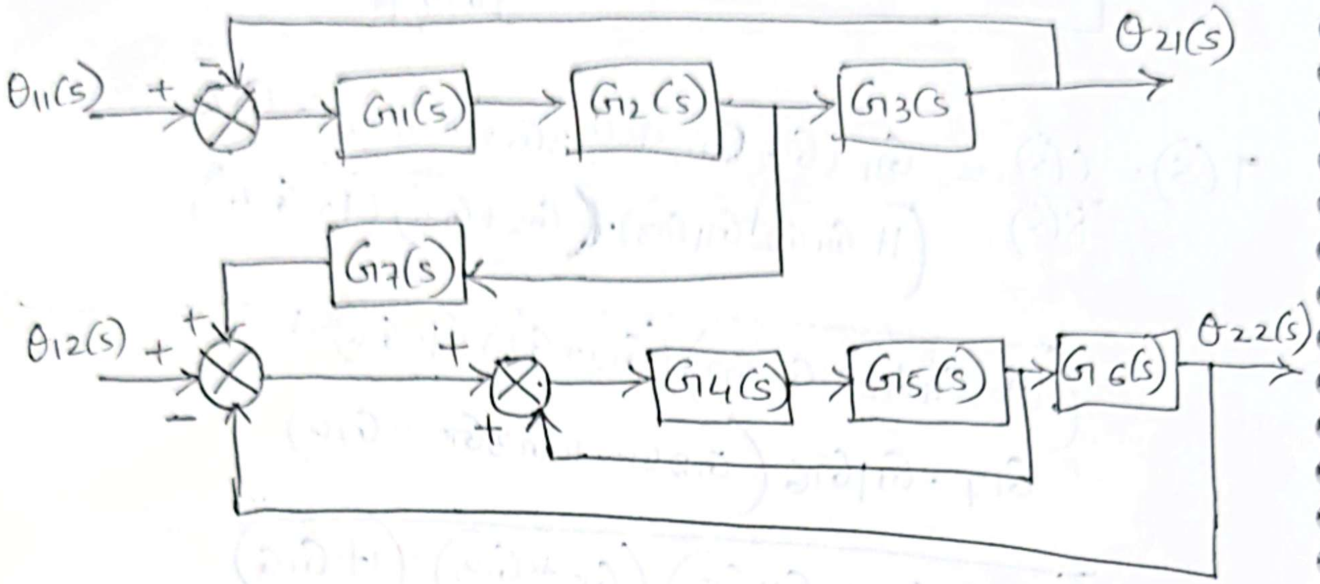




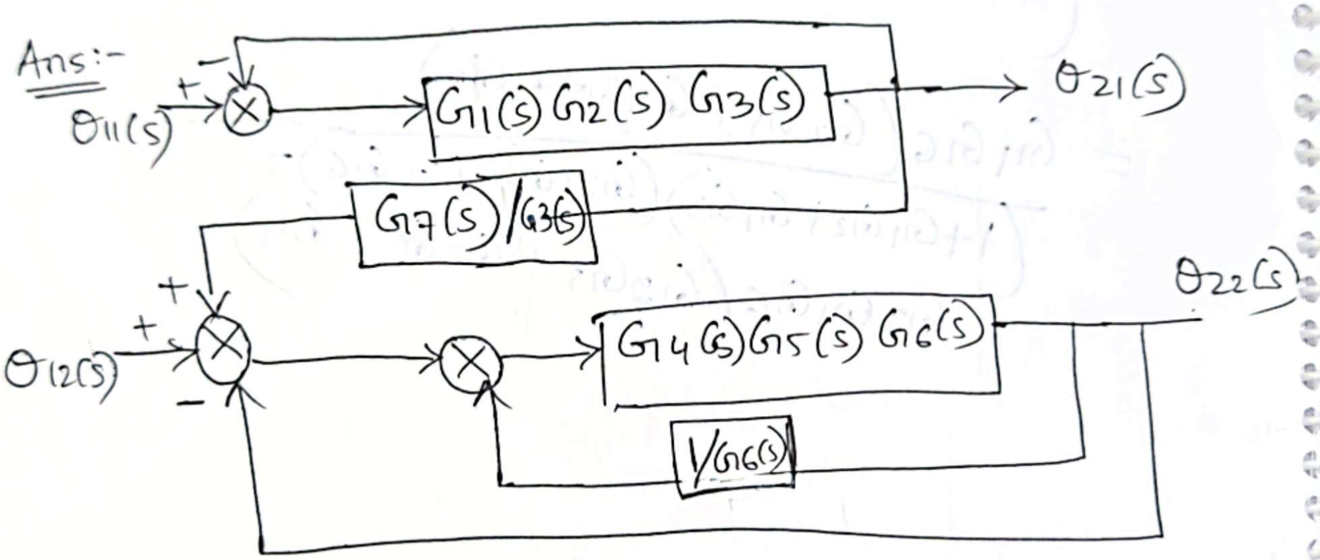
$$T(s)=\frac{C(s)}{R(s)} = \frac{\dfrac{G_1(G_2G_5+G_3G_5+G_4)\times G_6}{(1+G_1G_2+G_1G_3)(G_2+G_3)(1+G_6)}}{\dfrac{(1+G_1G_2+G_1G_3)(G_2+G_3)(1+G_6)+G_7\cdot G_1G_6(G_2G_5+G_3G_5+G_4)}{(1+G_1G_2+G_1G_3)(G_2+G_3)(1+G_6)}}$$

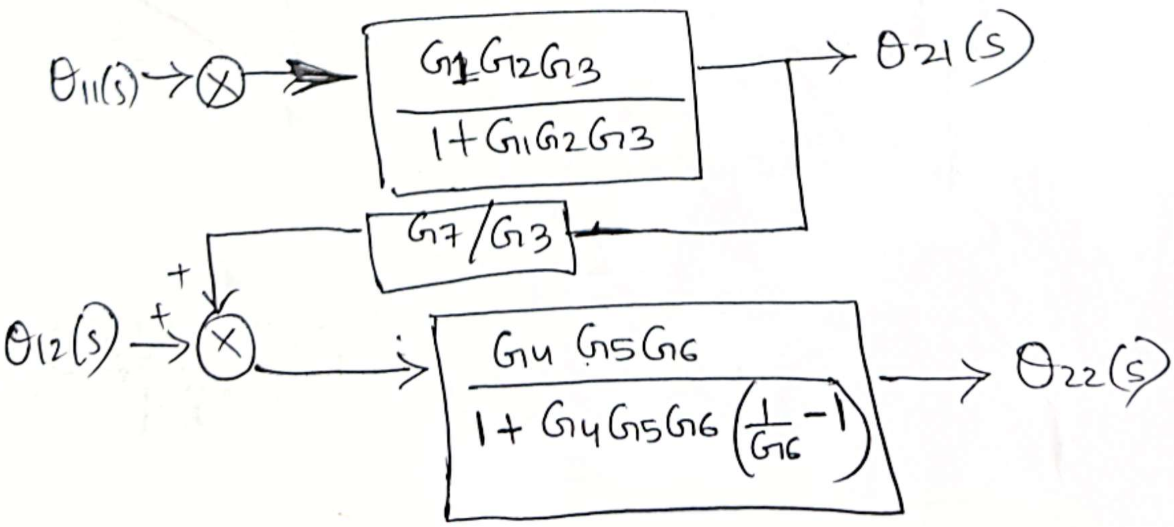
$$= \frac{G_1G_6(G_2G_5+G_3G_5+G_4)}{(1+G_1G_2+G_1G_3)(G_2+G_3)(1+G_6)+G_7G_1G_6(G_2G_5+G_3G_5+G_4)}$$

8) Given the block diagram of a system shown in Figure, find the transfer function $G(s) = \theta_{22}(s)/\theta_{11}(s)$



Ans:-





The gains are now in series:

So, the required transfer function is,

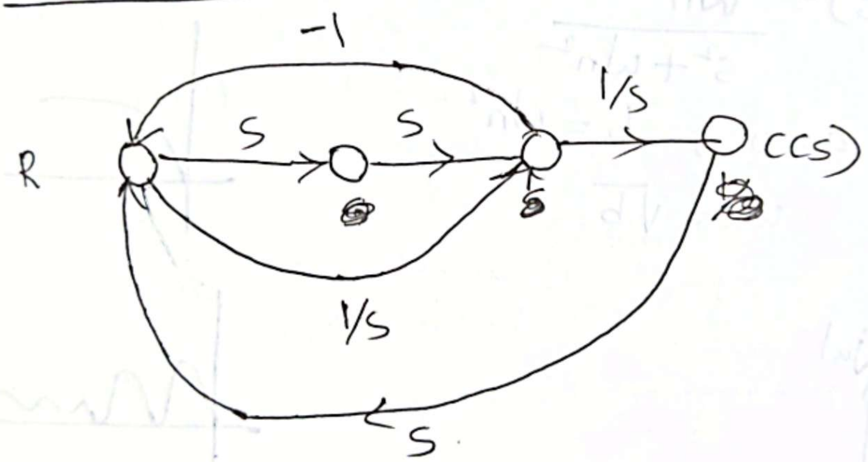
$$G(s) = \frac{\theta_{22}(s)}{\theta_{21}(s)} = \frac{G_1 G_2 G_3}{1+G_1G_2G_3} \times \frac{G_7}{G_3} \times \frac{G_4G_5G_6}{1+G_4G_5G_6\left(1-\frac{1}{G_6}\right)}$$

$$= \frac{G_1G_2G_3G_4G_5G_6G_7}{G_3(1+G_1G_2G_3)(1+G_4G_5G_6 - G_4G_5)}$$

$G_3 + G_1G_2G_3$

$$= \frac{G_1G_2G_3G_4G_5G_6G_7}{1+G_4G_5G_6 - G_4G_5 + G_1G_2G_3 + G_1G_2G_3G_4G_5G_6 - G_1G_2G_3G_4G_5}$$

exercise 5.3



17 September 2025

Natural Frequency : of a 2nd order is the frequency of oscillation.

Damping Ratio:-

 Damping signal

$$\xi = \text{damping ratio} = \frac{\text{Exponential decay } (\sigma)}{\omega_n}$$

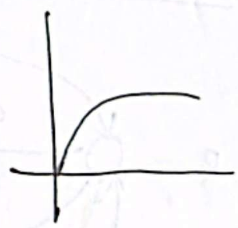
$$G(s) = \frac{b}{s^2 + as + b}$$

Undamped Signal

$$G(s) = \frac{\omega_n^2}{s^2 + \omega_n^2}$$

$a = 0$, $b = \omega_n^2$

$\omega_n = \sqrt{b}$



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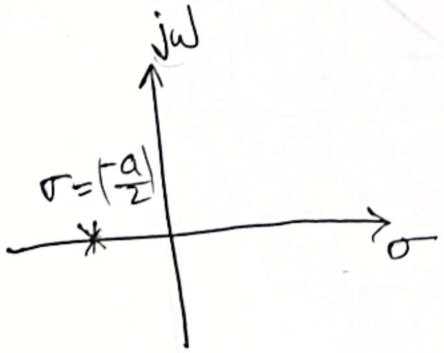


Undamped signal

$\sigma = a/2$

$$\xi = \frac{\sigma}{\omega_n} = \frac{a/2}{\omega_n}$$

$\therefore a = 2\omega_n \xi$

$$G(s) = \frac{b}{s^2+as+b}$$

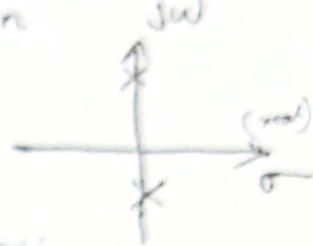
$$= \frac{\omega_n^2}{s^2+2\omega_n \xi s+\omega_n^2}$$

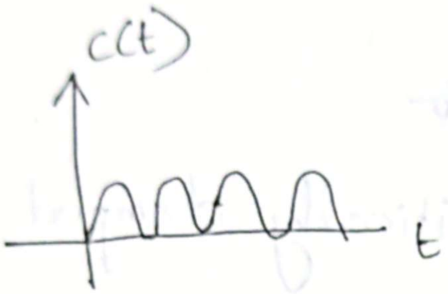
Signal classification based on ξ:

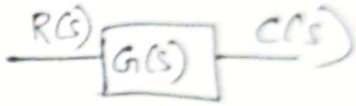
1) $\xi = 0$, $G(s) = \dfrac{\omega_n^2}{s^2+\omega_n^2}$

$$s^2+\omega_n^2 = 0$$

or, $s_{1,2} = \pm\sqrt{-\omega_n^2} = \pm j\omega_n$







2) $0<\xi<1$ $\quad G(s) = \dfrac{\omega_n^2}{s^2+2\omega_n\xi+\omega_n^2}$

$$\boxed{\frac{-b\pm\sqrt{b^2-4ac}}{2a}}$$

Pool $\xrightarrow{eqn}$ $\quad s^2+2\omega_n\xi+\omega_n^2=0$

$$s_{1,2} = \frac{-2\omega_n\xi \pm\sqrt{4\omega_n^2\xi^2-4\omega_n^2}}{2}$$

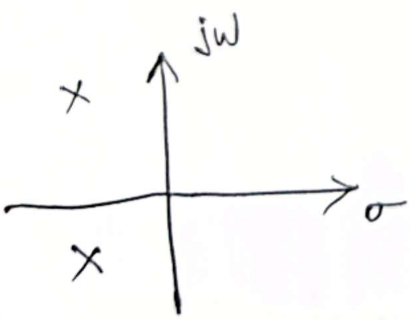
$$= \frac{-\cancel{2}\omega_n\xi \pm 2\omega_n\sqrt{\xi^2-1}}{\cancel{2}}$$

$\sqrt{-1} = j$

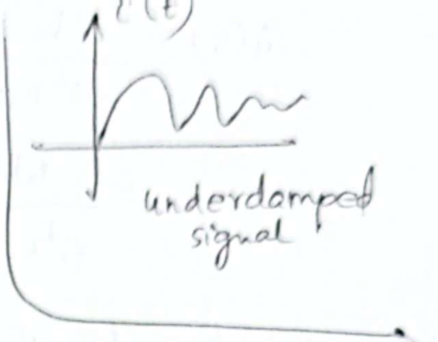
$$= -\omega_n\xi \pm \omega_n\sqrt{-1(1-\xi^2)}$$

$$= -\omega_n\xi \pm j\omega_n\sqrt{1-\xi^2}$$

real + imaginary



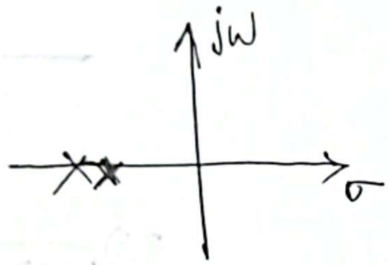
underdamped signal

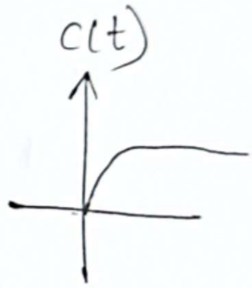


3) $\xi = 1$

$$G(s) = \frac{W_n^2}{s^2 + 2W_n \cdot s + W_n^2}$$

$$S_{1,2} = -\xi W_n$$



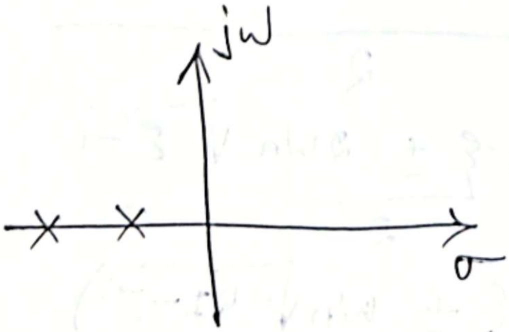


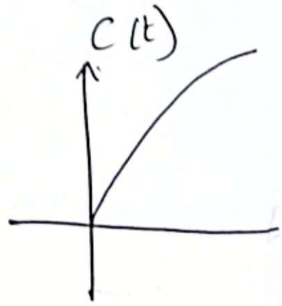
Critically damped signal

4) $\xi > 1$

$$G(s) = \frac{W_n^2}{s^2 + 2W_n \cdot s + W_n^2}$$

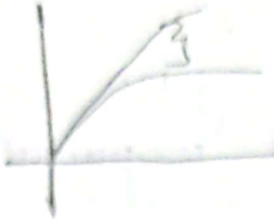
$$S_{1,2} = -\xi W_n \pm \underbrace{W_n\sqrt{\xi^2 - 1}}_{\text{real}}$$





Over damped signal

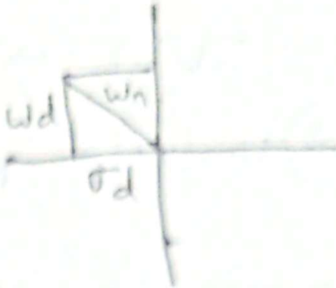
One math will come from this topic in exam



Percentage overshoot signal

Equation:

1) $\xi = \cos\left(\tan^{-1}\dfrac{W_d}{\sigma_d}\right)$



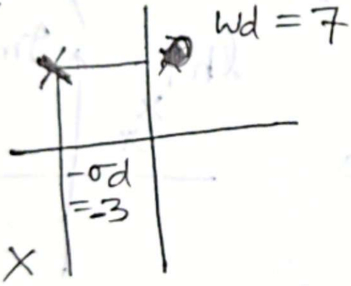
2) $W_n = \sqrt{\sigma_d^{\,2} + W_d^{\,2}}$

3) $T_p = \dfrac{\pi}{W_n\sqrt{1-\xi^2}} = \dfrac{\pi}{W_d}$

4) $\%\,OS = e^{-\left(\xi\pi/\sqrt{1-\xi^2}\right)} \times 100\%$

5) $T_s = \dfrac{4}{\xi W_n} = \dfrac{4}{\sigma_d}$

Exp. 4.6

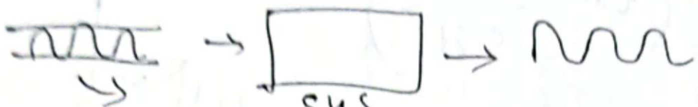


Classifications of systems:-

Using Natural Response:

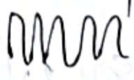
1) Stable : If Natural response zero, time approaches to infinity

BIBO



2) Unstable: Natural response infinite if time appro

$\boxed{\text{BIUO}}$ Bounded Input approaches infinity



3) Marginally stable

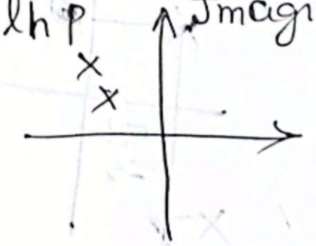
Using the total Response: BIBO

stable: if for every bounded i/p, o/p is bounded.

$H(s) = \frac{s-2}{s+5}$

All pole left side

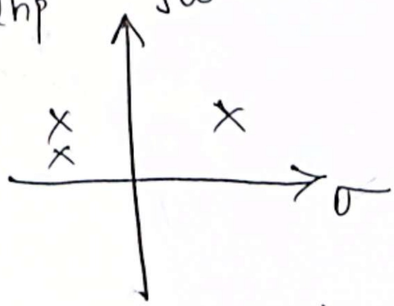
All poles in lhp



unstable: if for every bounded I/p, o/p is bounded.

All pole right side

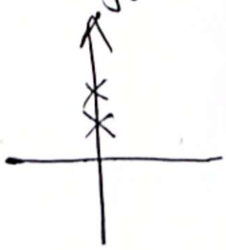
If any one in Rhp



Marginally stable:

All poles remains in jω axis

jωx



$\boxed{\text{VIMP Examcome}}$ Routh - Hurwitz Criterion -

Limitations - Cannot tell the coordinates

$$R(s) \longrightarrow \boxed{\dfrac{N(s)}{a_4 s^4 + a_3 s^3 + a_2 s^2 + a_1 s + a_0}} \longrightarrow C(s)$$

Table 6.2

s^4	a_4	a_2	a_0
s^3	a_3	a_1	0

s^2

$$\frac{-\begin{vmatrix} a_4 & a_2 \\ a_3 & a_1 \end{vmatrix}}{a_3} = b_1 \qquad \frac{-\begin{vmatrix} a_4 & a_0 \\ a_3 & 0 \end{vmatrix}}{a_3} = b_2 \qquad \frac{-\begin{vmatrix} a_4 & 0 \\ a_3 & 0 \end{vmatrix}}{a_3} = 0$$

s^1

$$\frac{-\begin{vmatrix} a_3 & a_1 \\ b_1 & b_2 \end{vmatrix}}{b_1} = c_1 \qquad \frac{-\begin{vmatrix} a_3 & 0 \\ b_1 & 0 \end{vmatrix}}{b_1} = 0 \qquad \frac{-\begin{vmatrix} a_3 & 0 \\ b_1 & 0 \end{vmatrix}}{b_1} = 0$$

s^0

$$\frac{-\begin{vmatrix} b_1 & b_2 \\ c_1 & 0 \end{vmatrix}}{c_1} = d_1 \qquad \frac{-\begin{vmatrix} b_1 & 0 \\ c_1 & 0 \end{vmatrix}}{c_1} = 0 \qquad \frac{-\begin{vmatrix} b_1 & 0 \\ c_1 & 0 \end{vmatrix}}{c_1} = 0$$

$$H(s) = \frac{1000}{1s^3 + 10s^2 + 31s + 1030}$$

s^3	1	31	0
s^2	10	1030	0
s^1	$\dfrac{-\begin{vmatrix} 1 & 31 \\ 10 & 1030 \end{vmatrix}}{10} = -72$	$\dfrac{-\begin{vmatrix} 1 & 0 \\ 0 & 0 \end{vmatrix}}{10} = 0$	$\dfrac{-\begin{vmatrix} 1 & 0 \\ 10 & 0 \end{vmatrix}}{10} = 0$
s^0	103	0	0

$$\frac{\begin{vmatrix} 10 & 1030 \\ -72 & 0 \end{vmatrix}}{-72} \qquad \frac{\begin{vmatrix} 10 & 0 \\ -72 & 0 \end{vmatrix}}{-72} \qquad \frac{\begin{vmatrix} 10 & 0 \\ -72 & 0 \end{vmatrix}}{-72}$$

rhp = 2 , lhp = 3 − 2 = 1

s^3	+	1	31	0
s^2	+	10	103	0
s^1		−72	0	0
s^0	+	103	0	0

2 times sign change

rhp = 2

lhp = 3 − ~~2~~ rhp
= 3 − 2
= 1

↓ Max value (the state) − rhp

lhp = 3 − 2 = 1

unstable

2) $T(s) = \dfrac{10}{s^5+2s^4+3s^3+6s^2+5s+3}$

Ans:-

$$\begin{array}{c|ccc}
s^5 & 1 & 3 & 5 \\
s^4 & 2 & 6 & 3 \\
s^3 & \cancel{0}\ \varepsilon & 7/2 & 0 \\
s^2 & \frac{6\varepsilon-7}{\varepsilon} & 3 & 0 \\
s^1 & \frac{42\varepsilon-49-6\varepsilon^2}{12\varepsilon+4} & 0 & 0 \\
s^0 & 3 & 0 & 0
\end{array}$$

To avoid 0 we write ε

$= -\dfrac{\begin{vmatrix}1 & 3\\ 2 & 6\end{vmatrix}}{2} = \dfrac{6-6}{2} = 0$

$\varepsilon \quad -1, 1$

$-\dfrac{\begin{vmatrix}2 & 6\\ 0 & 7/2\end{vmatrix}}{0} = \infty$

$-\dfrac{\begin{vmatrix}2 & 6\\ \varepsilon & 7/2\end{vmatrix}}{\varepsilon} = \dfrac{6\varepsilon-7}{\varepsilon}$

Label	First column	$\varepsilon = +$	$\varepsilon = -$
s^5	1	+	+
s^4	2	+	+
s^3	ε	+	−
s^2	$6\varepsilon-7/\varepsilon$	−	+
s^1	$42\varepsilon-49-6\varepsilon^2/12\varepsilon-14$	+	+
s^0	3	+	+

$rhp = 2$, $lhp = 5-2 = 3$

System is unstable

From Book learn all this part clearly

24 September 2025

Example 6.4 Determine the number of rhp poles

$$T(s) = \frac{10}{s^5+7s^4+6s^3+42s^2+8s+56}$$

s^5	1	6	8
s^4	$\cancel{7}$ 1	$\cancel{42}$ 6	$\cancel{56}$ 8
s^3	$-\dfrac{\begin{vmatrix}1 & 6\\ 7 & 42\end{vmatrix}}{7} = \cancel{0}$ 28	$-\dfrac{\begin{vmatrix}1 & 8\\ 7 & 56\end{vmatrix}}{7} = \cancel{0}$ 84	$-\dfrac{\begin{vmatrix}1 & 0\\ 7 & 0\end{vmatrix}}{7} = 0$
s^2	$-\dfrac{\begin{vmatrix}1 & 6\\ 1 & 3\end{vmatrix}}{1} = 3$	$-\dfrac{\begin{vmatrix}7 & 56\\ 1 & 3\end{vmatrix}}{7} = 8$	$-\dfrac{\begin{vmatrix}7 & 0\\ 1 & 0\end{vmatrix}}{1} = 0$
s^1	$1/3$	0	0
s^0	8	0	0

যে row তে 0 তার previous row তে যাবো।

$$P(s) = 7s^4 + 42s^2 + 56 \qquad 21-42$$

$$\frac{dP(s)}{ds} = 28s^3 + 84s + 0 \qquad 0-56$$

$$P(s) = s^4 + 6s^2 + 8$$

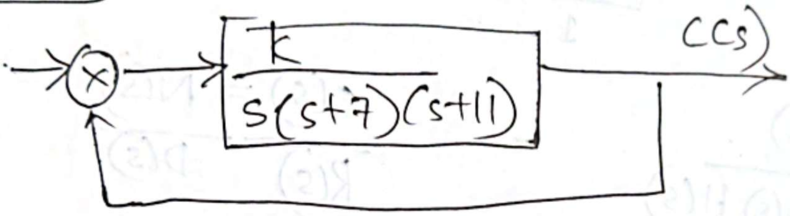
$$\frac{dP(s)}{ds} = 4s^3 + 12s + 0$$

Decision:

	Even($n_1 = 4$) ($s^0 \sim s^4$) → একবারে ও change হয় নাই	Rest (s^5) $n_2 = 1$	Total
			5
rhp	$0 = x$	$0 = y$	0
lhp	$0 = x$	$n_2 - y = 1 - 0 = 1$	1
jw	$n_1 - x - x$ $4 - 0 - 0$ $= 4$	0	4

Marginally stable

Example 6-9



Stable $= 1 = K \quad 0 < K < 1386$

$K > 1386 \rightarrow$ unstable

Unstable $= 0 = K$

Marginally stable $= K = 1386$ যখন সব row value 0

~~Unstable~~

~~Marginally stable~~

8 October 2025

Lecture-10 Root-Lucas

chapter ≈ 8 (Ni'se)

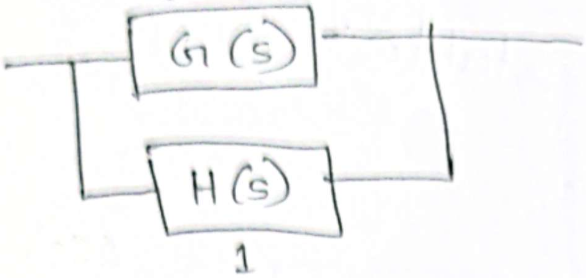
CT-3 Next Wednesday
Topic on today's topic

Final

10 marks CT 10 marks Final

~~Roo~~ Routh table 10/20 marks

→ It is plotting system's Dynamic characteristics



Unity feedback

$$\frac{G(s)}{1+G(s)H(s)} \qquad \frac{C(s)}{R(s)} = \frac{N(s)}{D(s)}$$

$$G(s) = \frac{k}{s(s+2)}$$

[unity feedback system]

$$1+G(s)H(s)=0$$

$$1+\frac{k}{s(s+2)}=0$$

Pole depend on k value

$$s^2+2s+k=0$$

If $k=0$

$s^2+2s=0$

$s=0$, $s=-2$

If $k=1$

$s=-1,-1$

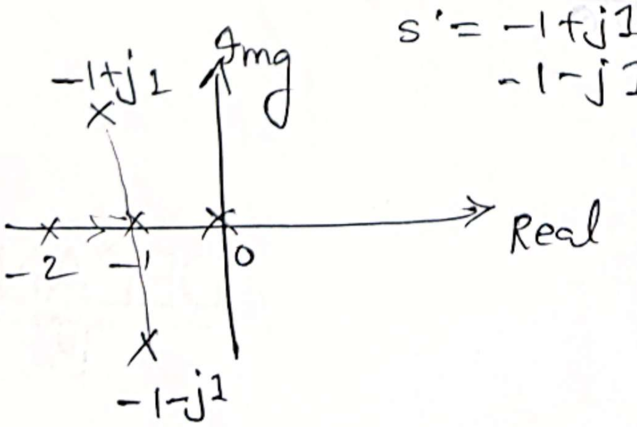
$s^2+2s+1=0$

$(s+1)^2=0$

If $k=2$

$s^2+2s+2=0$

$s' = -1+j1,$
$-1-j1$



Root locus – representation of paths of closed-loop poles as the gain is varied.

Rules of Root locus plot:

Rule 1 :- The root locus is always symmetric w.r.t real axis

$p = 0, -2$

$z = 0$

Rule 2 : Total Loci $= \max(\underset{2}{P}, \underset{0}{Z})$

$= 2$

Rule 3 : Total no. of Asymptotes $= P - Z$

$= 2 - 0 = 2$

Rule 4 : Angle of Asymptotes $\theta = \frac{2x+1}{P-Z} \times 180^\circ$

$x = 0, 1, 2,$

$x = 0 \quad \theta = \frac{1}{2} \times 180^\circ = 90^\circ$

$x = 1 \quad \theta = 270^\circ$

Rule 5 : Centroid of Asymptotes

$$= \frac{\Sigma \text{Real } P - \Sigma \text{Real } Z}{\# \text{ of } P - Z}$$

$P \begin{cases} 1+j2 \\ 1-j3 \end{cases} \quad \begin{cases} 2-j1 \\ 3-j1 \end{cases}$

$= \frac{(1+1) - (2+3)}{2-0}$

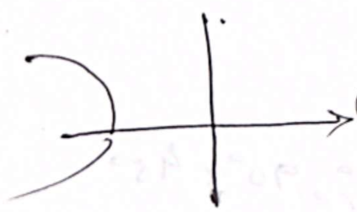
$= \frac{(-2+0) - 0}{2-0} = -1$

Rule 6 : Break away Point

→ ck

Rule 7 : Angle of departure

Rule 8 : Intersection to Img. axis



Angle of departure

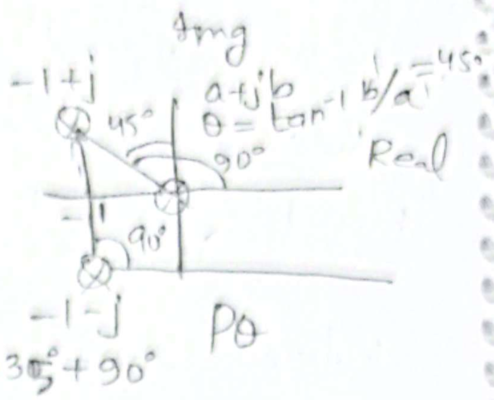
There is no zero

$$\theta_d = 180^\circ - (\Sigma P_\theta - \Sigma Z_\theta)$$

Q) $K(s)H(s) = \dfrac{K}{s(s^2+2s+2)}$

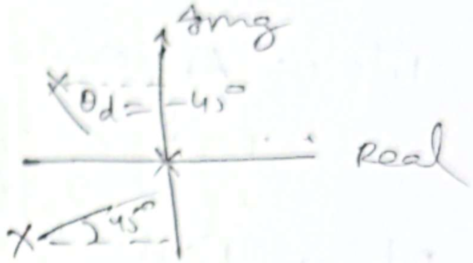
$s = -1 \pm j$ $\quad s(s^2+2s+1+1)$

$s[(s+1)^2+1]$

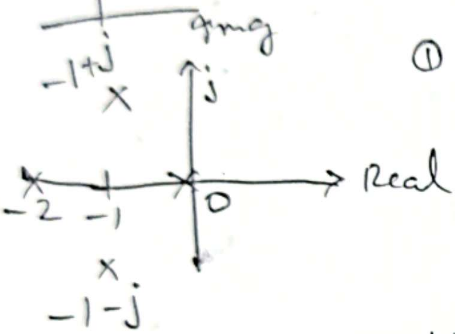


প্রতিটা pole কে reference দিয়ে বাকি গুলো বের করবো

$$\theta_d = 180 - (135^\circ + 90 - 0)$$
$$= -45^\circ$$



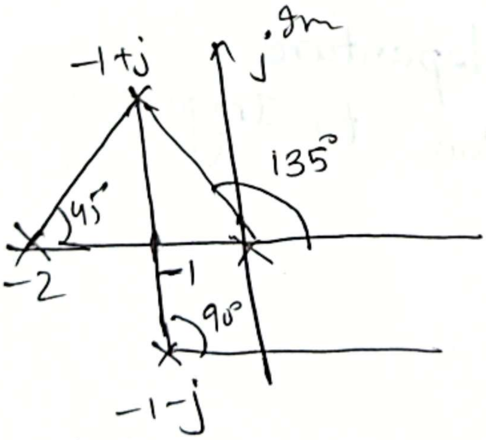
Exp 2:-



① $s(s+2)[(s+1)^2+1] = 0$

$s = 0,\ s+2 = 0 \quad [(s+1)^2+1] = 0$

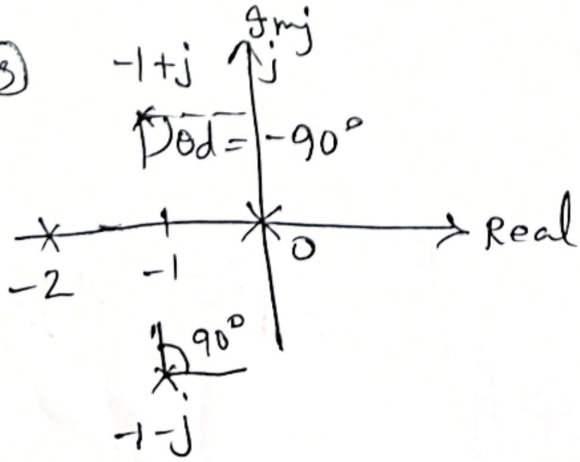
$0, -2, -1+j$



②

Real

③



$135^\circ, 90^\circ, 45^\circ$

Exp 3:- Exam it will come on this topic

Obtain root-locus plot

$$G(s) = \frac{k}{s(s+2)} \qquad \text{Poles} = 0, -2$$

step 1: obtain Loci

No. of poles, $P = 2$

Zeros $Z = 0$

Total loci $= \text{Max}\,(P, Z) = 2$
$ \; 2, 0$

2 No. of Asymptotes

$= P - Z = 2 - 0 = 2$

step 3:- Angle

$$\theta = \frac{2x+1 \times 180^\circ}{P - Z}, \quad x = 0, 1$$

$\theta = 90^\circ, 270^\circ$

step 4:- Centroid of Asymptotes

$$\sigma_c = \frac{(-2) - 0}{2 - 0} = -1$$

step 5:- Break away point

H(s) value not given then 1

$1 + G(s)\,H(s) = 0$

$1 + \frac{k}{s(s+2)} \times 1 = 0$

$s^2 + 2s + k = 0$

$k = -s^2 - 2s$

$\frac{dk}{ds} = 0$

$\frac{dk}{ds} = -(2s) - 2 = 0$

$s = -1$

step 6:- Intersection to Img. axis
$s^2+2s+k=0$

Routh array

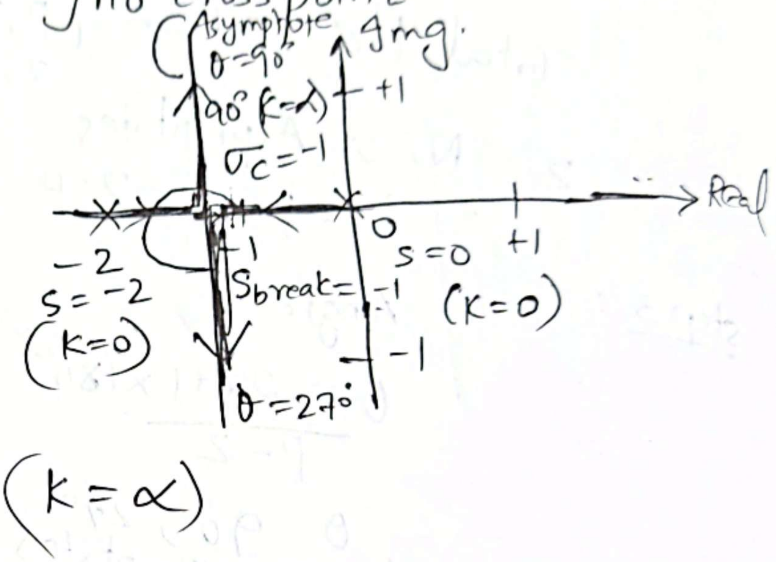
s^2	1	k
s^1	2	0
s^0	k	

stability - If sign no change

Marginal stable
Img. axis cross point

stability $k>0$

No. k for marginal stability no cross point



Q) $G(s)H(s)$

$z=-2,-3$
$p=-1,1$

0 না থাকলে infinite move করে

Example 1,2, before

15 OCT QUIZ

CT- Monday

→ 20 marks

Chpt 8: Root-Locus Technique

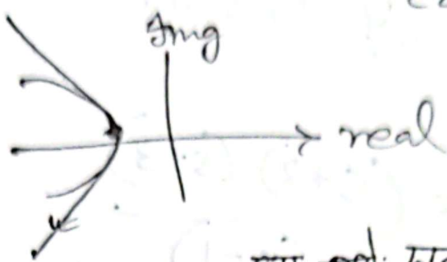
Gain কে verify to change the poles from 0 to ∞

The pole movement / pathway is called Root locus.

Asymptotes- straight ~~along~~ lines, along which the poles of the system tend to move.

coordinate

যেখানে asymptotes টি real axis এ cross করে



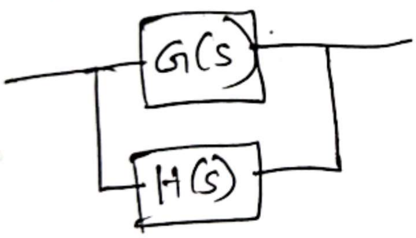
Angle of departure- যে pole থেকে সকল pole departure হবে বলা

Real angle থাকে তাহলে লাগবে।

Breakaway point - x এর

unity $H(s) = 1$

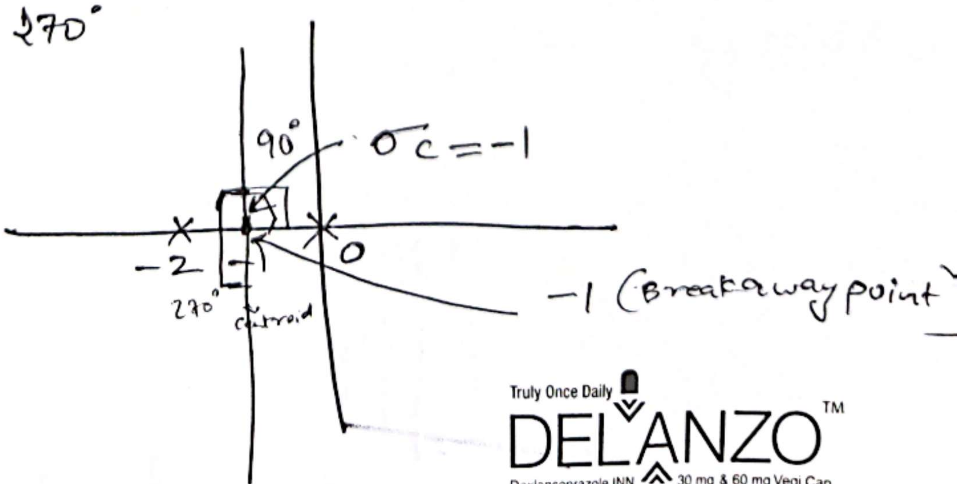
Q) $G(s) = \frac{k}{s(s+2)}$

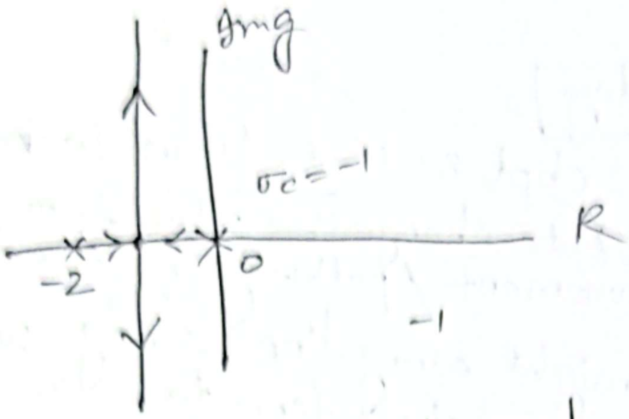


Poles 0, -2.

$\theta = \frac{2x+1}{p-z} \times 180$ $x = 0, 1$

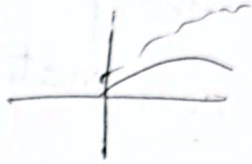
$\theta = 90^\circ, 270^\circ$





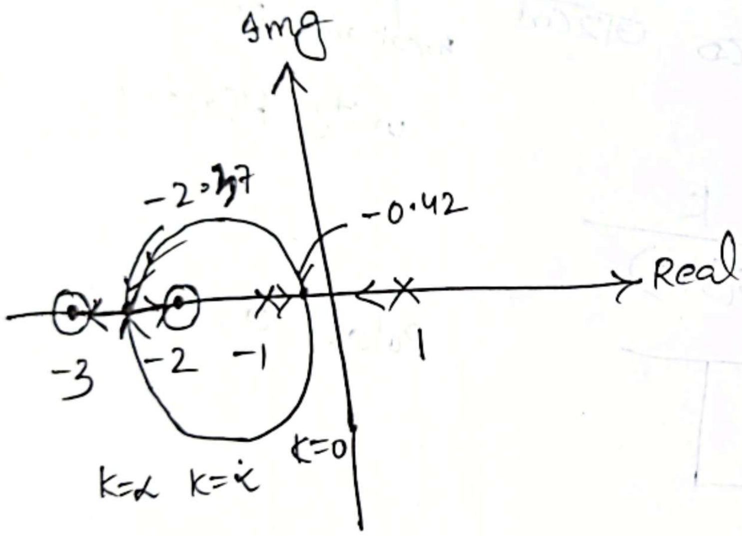
Centroid same place goes to asymptote because at same point

Step 5 Breakaway point and centered point
একই জায়গায় হওয়ার।



Q) $G(s)H(s) = \dfrac{k(s+2)(s+3)}{(s+1)(s-1)}$

0 থেকে infinity gain loop straight



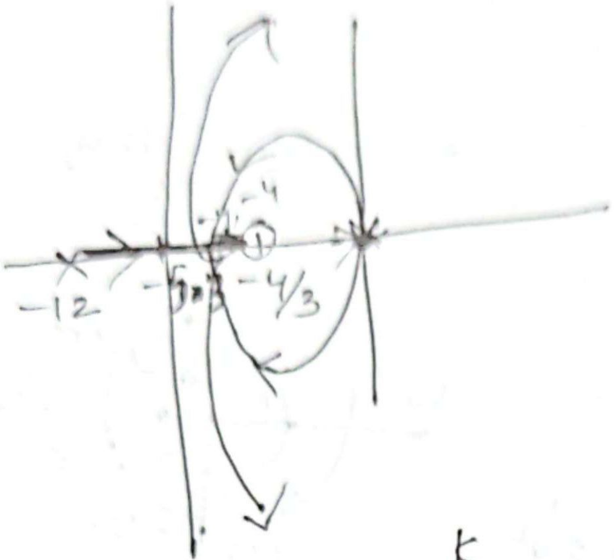
Pole থেকে break away point and search zero

$k = \dfrac{s^2-1}{s^2+5s+6}$

$s = 1, -1$
$k = 0$
$s = -2, -3$
$k = \infty$

Q) $G(s) = \frac{K(s+4/3)}{s^2(s+12)}$

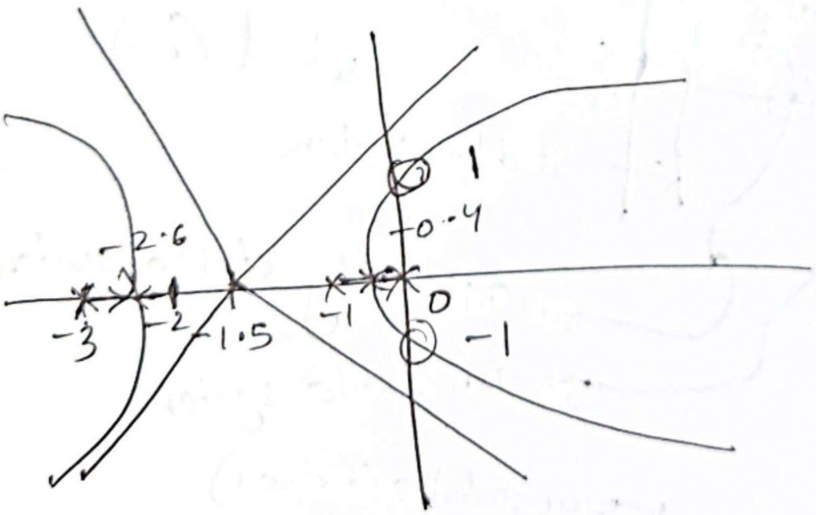
$Z_1 = -4/3 \quad P_1 P_2 = 0, \ P_3 = -12$



Asymptote o
(स्पर्शरेखा का)

Q) $G(s)H(s) = \frac{K}{s(s+1)(s+2)(s+3)}$

$P = 0, -1, -2, -3$



Break
merge
asym

Img axis
crossing point find

15 October 2025 | Root plot |

Polar plot

→ Final exam 10 mark short Q gain phase Margin, unstable, stable

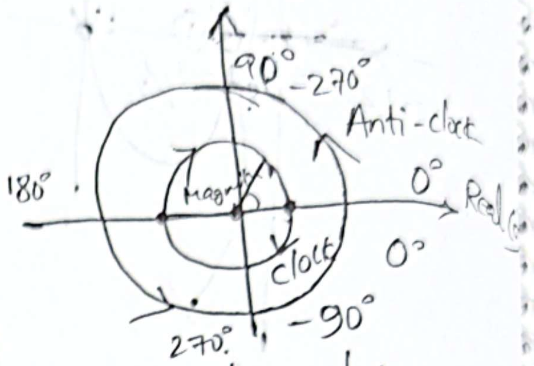
একটি system এর frequency, phase, gain

Polar plot :- Frequency variation সাথে সাথে gain and phase vary করে।

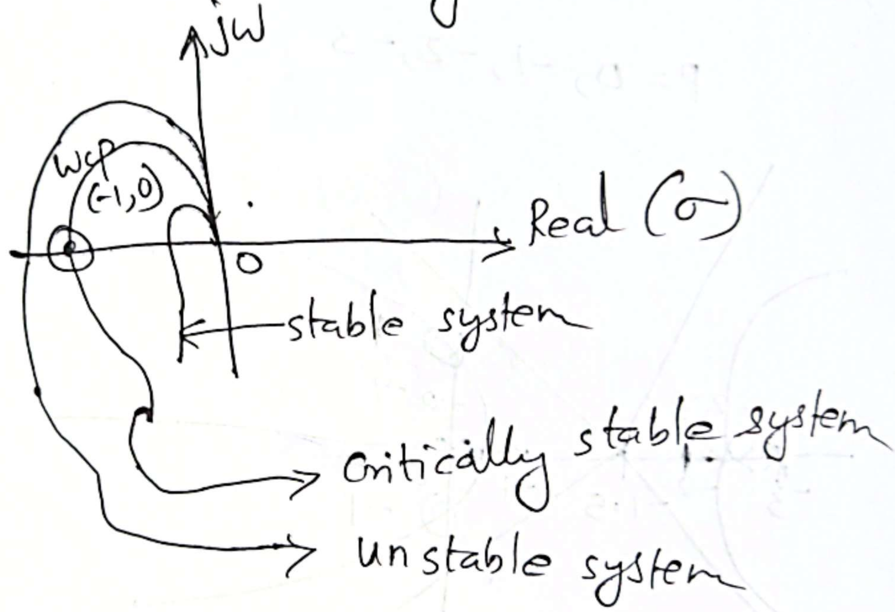
$\omega = 0 \rightsquigarrow \infty$

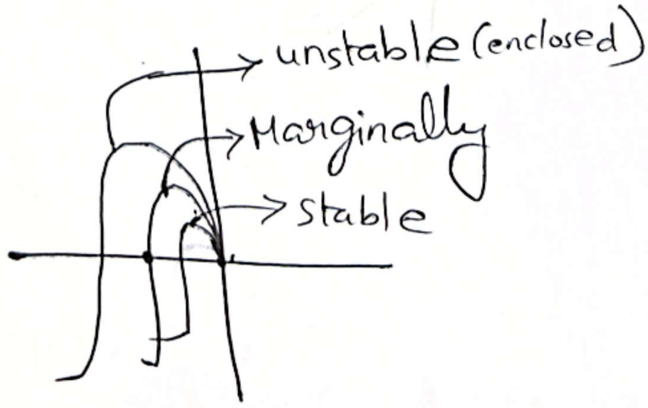
Magnitud & phase w.r.t frequency

+ve angle - anticlockwise
-ve angle - clockwise

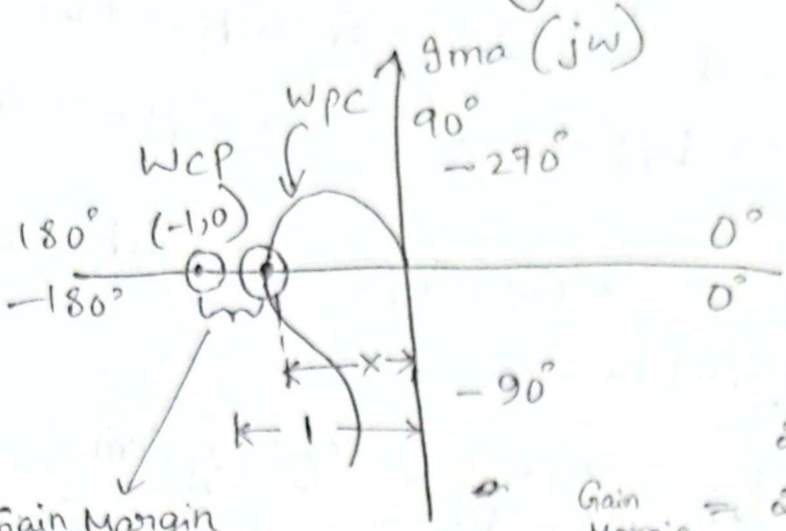


* Advantages of polar plot
* Critical Point and stability of Polar plot





* Phase Cross-over Frequency and Gain Margin :-

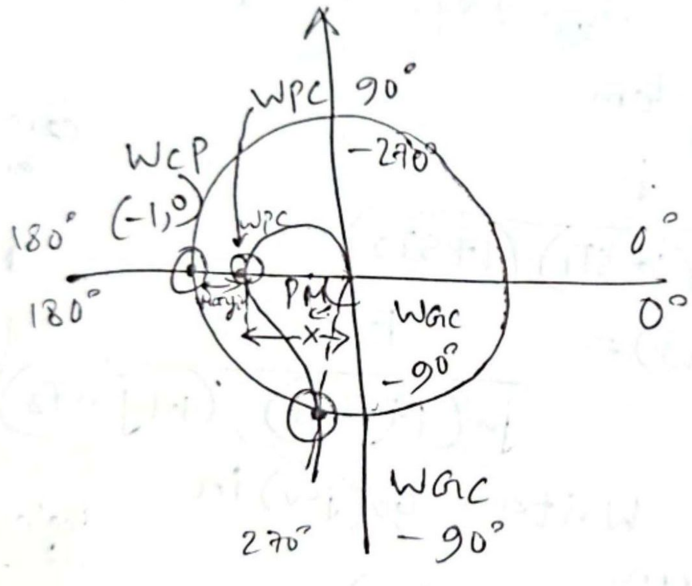


$$20 \log 1 - 20 \log x$$

$$\text{Gain Margin} = 20 \log \frac{1}{x}$$

Gain Margin
logarithmic distance b/w Wcp and wpc

Gain Cross-over frequency and phase margin



Angle is PM
From Gc we get PM

$$W_{pc} > W_{GC}, \text{ Gain Margin (GM) } +$$

* Stability Analysis

stable → $W_{pc} > W_{GC}$ & GM = +ve

Unstable → $W_{PC} < W_{GC}$ & GM = −ve

Marginally stable → $W_{GC} = W_{pc}$ & GM = 0
Critically stable

* Polar plot for Type "0" system

→ Zero number of pole at origin ⇒ Type 0

$\frac{1}{s^2(s+1)(s+2)}$ → Type 2 system

$\frac{1}{s(s+1)(s+2)}$ → Type 1 system

$G(s)\ \frac{(s+2)k}{(s+1)(s+2)}$ → Type 0 system

Type "1" system

$$G(s) = \frac{k}{s(1+sT_1)(1+sT_2)}$$

যেখানে s
Oitha
$s = j\omega$

Mag $\angle\theta$ angle

Step 1 :- $G(j\omega) = \frac{k}{j\omega(1+j\omega T_1)(1+j\omega T_2)}$

$\sqrt{1^2+\omega^2 T_1^2}$

$\sqrt{1^2+\omega^2 T_2^2}$

Step 2 :- ~~G(j~~ Write $G(j\omega)$ in polar form

pole $a+jb$
$= \sqrt{a^2+b^2}$
$-\tan^{-1}\frac{b}{a}$

$$G(j\omega) = |G(j\omega)| \angle G(j\omega)$$

0 থেকে আসলে
$\tan^{-1}\frac{b}{a}$

$$|G(j\omega)| = \frac{k}{\sqrt{1+\omega^2 T_1^2}\sqrt{1+\omega^2 T_2^2}}$$

If $j\omega k$

$+90^\circ$

$$\text{phase} = \angle G(j\omega) = -\tan^{-1}\left(\frac{\omega T_1}{1}\right) - \tan^{-1}\left(\frac{\omega T_2}{1}\right)$$

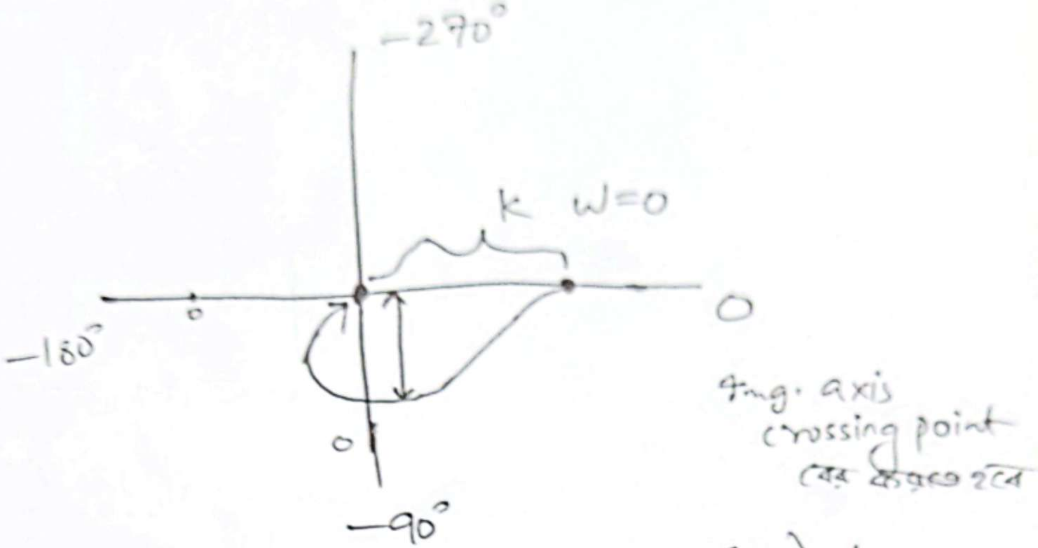
$-0-0=0$

Step3 :- Find Mag. & Phase at $w=0, w=\infty$

at $w=0$ Mag $=K$ phase $=0$

$w=\infty$ Mag $=0$ " $=-180^\circ$ $\frac{K}{\infty}=0$

Step 4 :



Separate real & Img. part of $G(jw)$ by multiplying complex conjugate of denominator

Step5: Intersection to Real Axis

$w=0$

$$\frac{K\sqrt{T_1T_2}}{T_1T_2} \times T_1$$

Type 1 jw -10^{-1}

$90+90+$