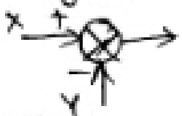
Block diagram :- A block diagram of the system is a pictorial representation of the entire system. It represents the relationship between the input and the output of the entire system. Different blocks are interconnected to each other as per the sequence of operation. By means of block diagram, we can be easily represent of complicated s/m

Block diagram :- It is a pictorial representation of the cause and effect relationship between input and output of the system.

Output : output = Gain × Input. The value of the input is multiplied to the value of block gain to get output.

Summing point :- More than one signal can be added or subtracted at summing point.

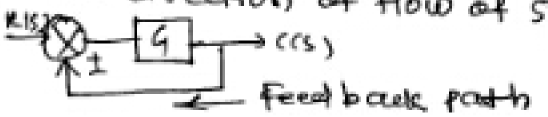


z = x+y or
= x-y

Take off point :- The point from which a signal is taken for the feedback purpose is called take off point.

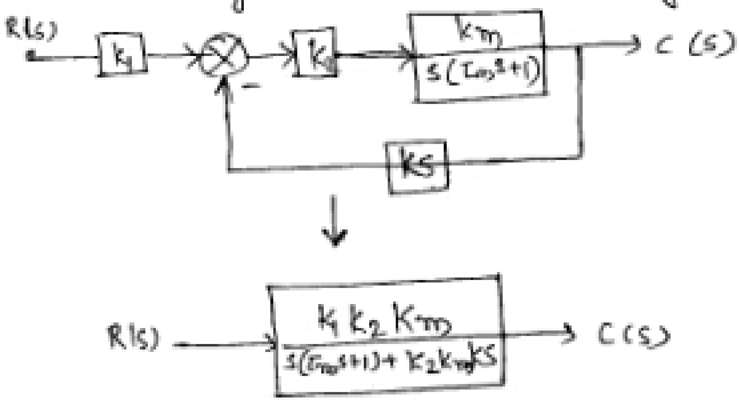
Forward path :- The direction of flow of signal is from input to output.

Feedback path :- The direction of flow of signal is from output to input.

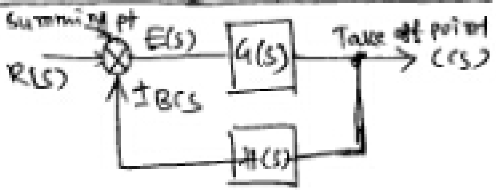


* Block diagram Reduction :- It is necessary to simplify the block diagram to a single block as equivalently, to find the overall transfer function, so that the system behaviour can be studied. Reducing a block diagram to a single block representing the transfer function of the entire control system is known as block diagram.

Example :- considering the simple block diagram of s/m.



* closed loop Transfer function :- Consider



R(s) = Laplace of input signal r(s)
C(s) = Laplace of input c(t)
E(s) = Laplace of error signal
B(s) = Laplace of feedback
G(s) = forward transfer fun^n
H(s) = Feed back transfer fu^n

$\therefore C(s) = E(s)\,G(s)$

$\therefore E(s) = R(s) \pm B(s)$

$\therefore C(s) = [R(s) \pm B(s)]\,G(s)$

$= R(s)G(s) \pm B(s)G(s)$

Now $B(s) = C(s)\cdot H(s)$

$\therefore C(s) = R(s)G(s) \pm C(s)\cdot H(s)\,G(s)$

$\therefore C(s) \mp C(s)\cdot H(s)\cdot G(s) = R(s)G(s)$

$\therefore C(s)\,[1 \mp G(s)H(s)] = R(s)G(s)$.

$\therefore \frac{C(s)}{R(s)} = \frac{G(s)}{1 \mp G(s)H(s)}$

If the system is a negative feedback

$\therefore \frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)}$

If the system is a positive feedback,

$\frac{C(s)}{R(s)} = \frac{G(s)}{1-G(s)H(s)}$

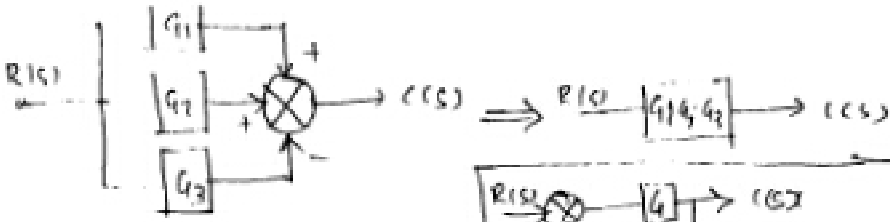
open loop transfer function is given by $= G(s)\cdot H(s)$

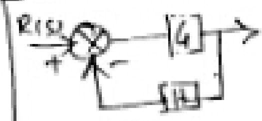
* Rules for block diagram reduction :-

1) Blocks in series or cascade

R(s) |G1| |G2| → C(s) ⟹ R(s) |G1G2| → C(s)

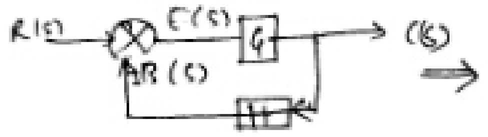
2) Blocks in parallel :-





G & H are in opposite side. Hence G & H are not in parallel

3) Eliminate feedback loop :-



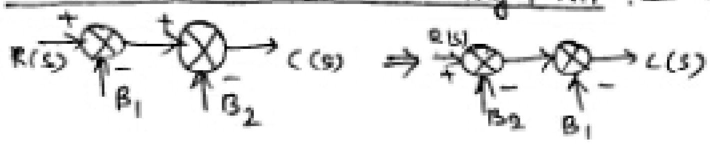
(i) for negative feedback

R(s) $\frac{G(s)}{1+G(s)H(s)}$ → C(s)

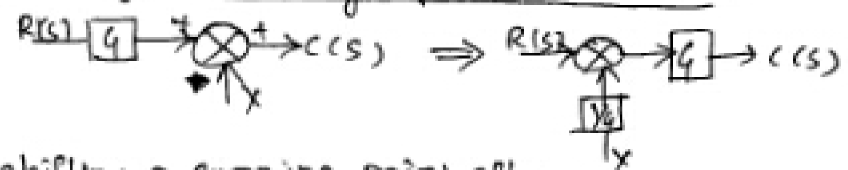
(ii) for positive feedback

R(s) $\frac{G(s)}{1-G(s)H(s)}$ → C(s)

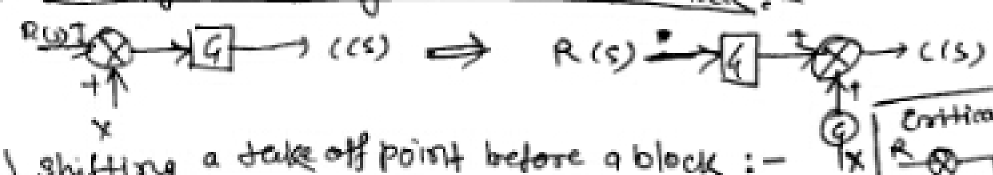
4) Associative law for summing point :- This is applicable only to summing points which are directly connected to each other.

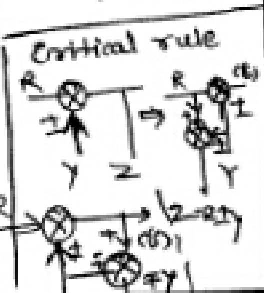


5) shifting a summing pt before a block :-

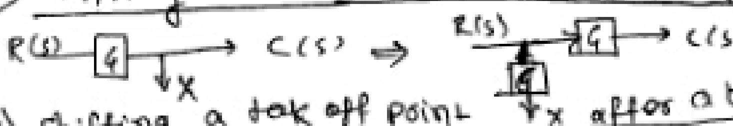


6) shifting a summing point after a block :-

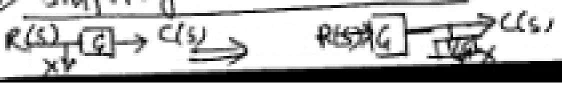




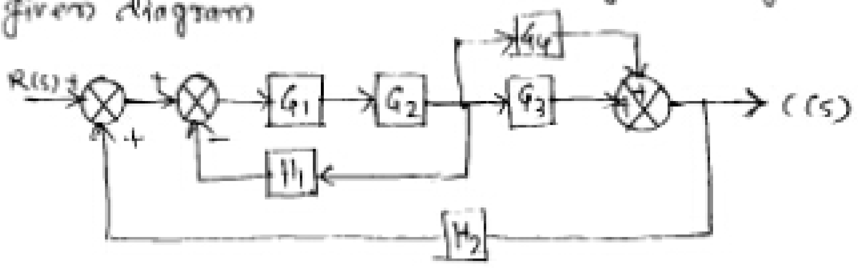
7) shifting a take off point before a block :-



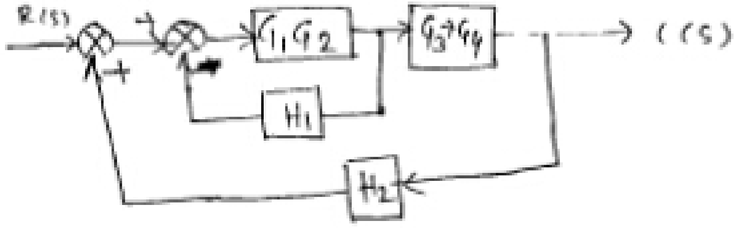
8) shifting a take off point after a block :-

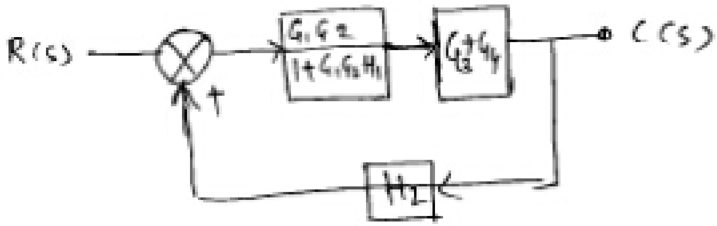


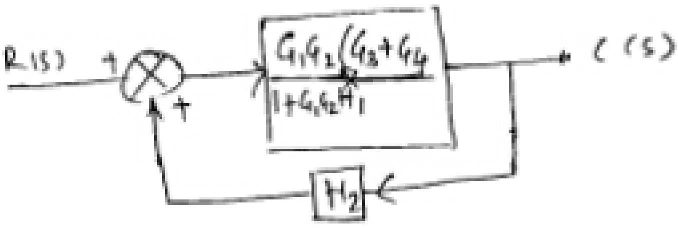
* find the single block equivalent by block diagram reduction for given diagram

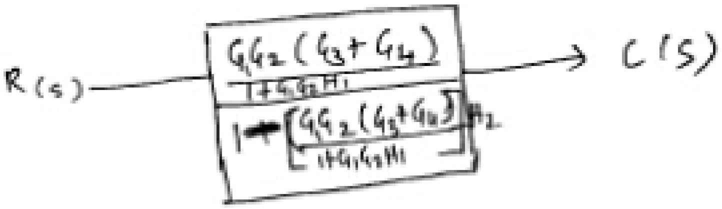


$\Rightarrow$





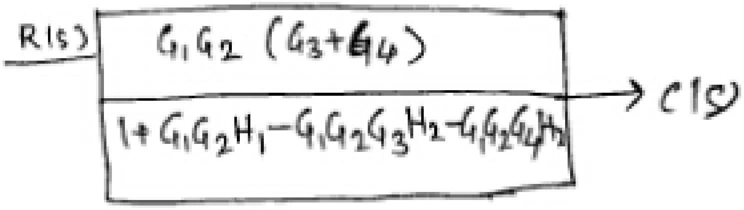




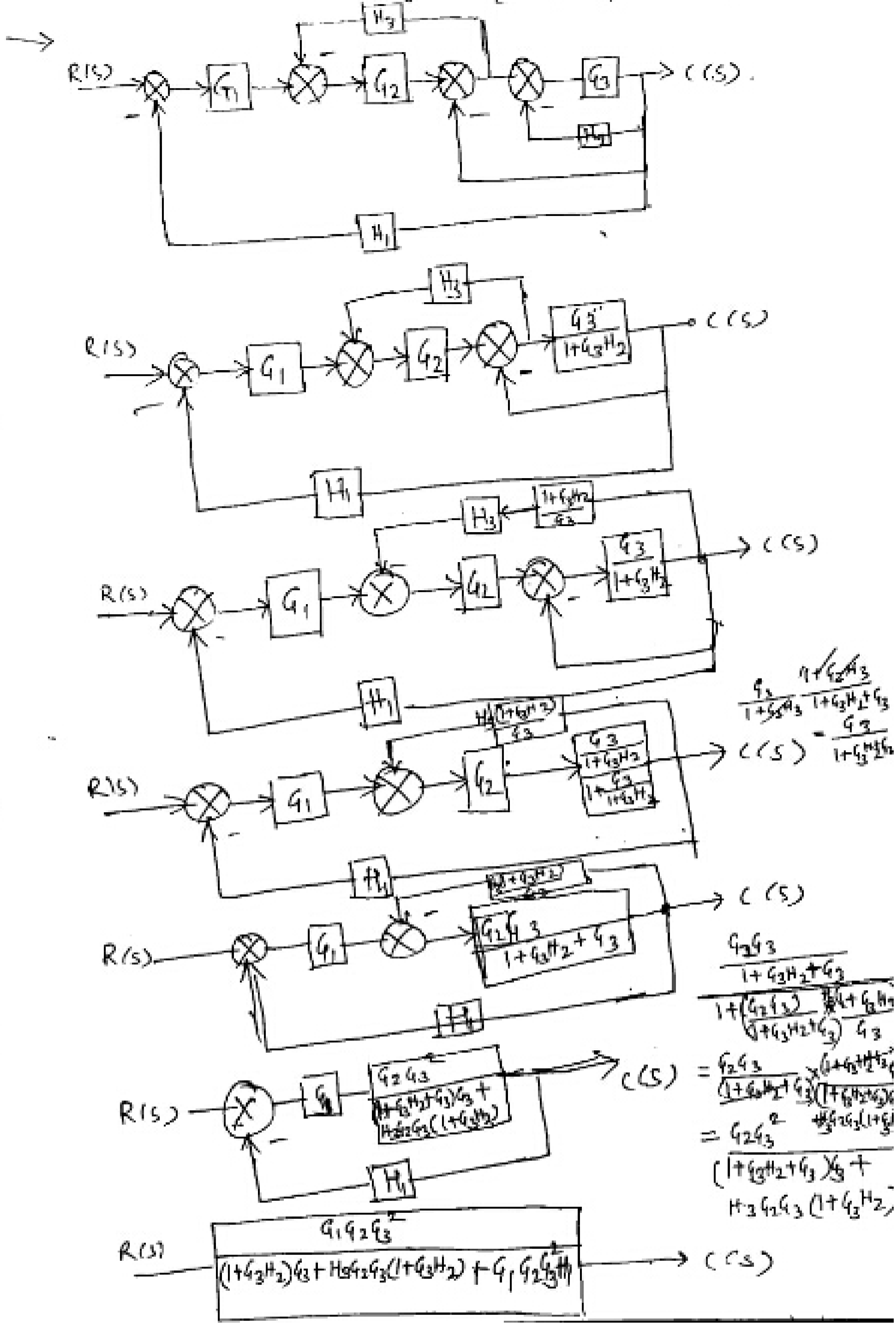
$$= \frac{G_1G_2(G_3+G_4)}{1+G_1G_2H_1 - G_1G_2(G_3+G_4)H_2}$$

$$= \frac{G_1G_2(G_3+G_4)}{1+G_1G_2H_1 - G_1G_2G_3H_2 - G_1G_2G_4H_2}$$

$\therefore$



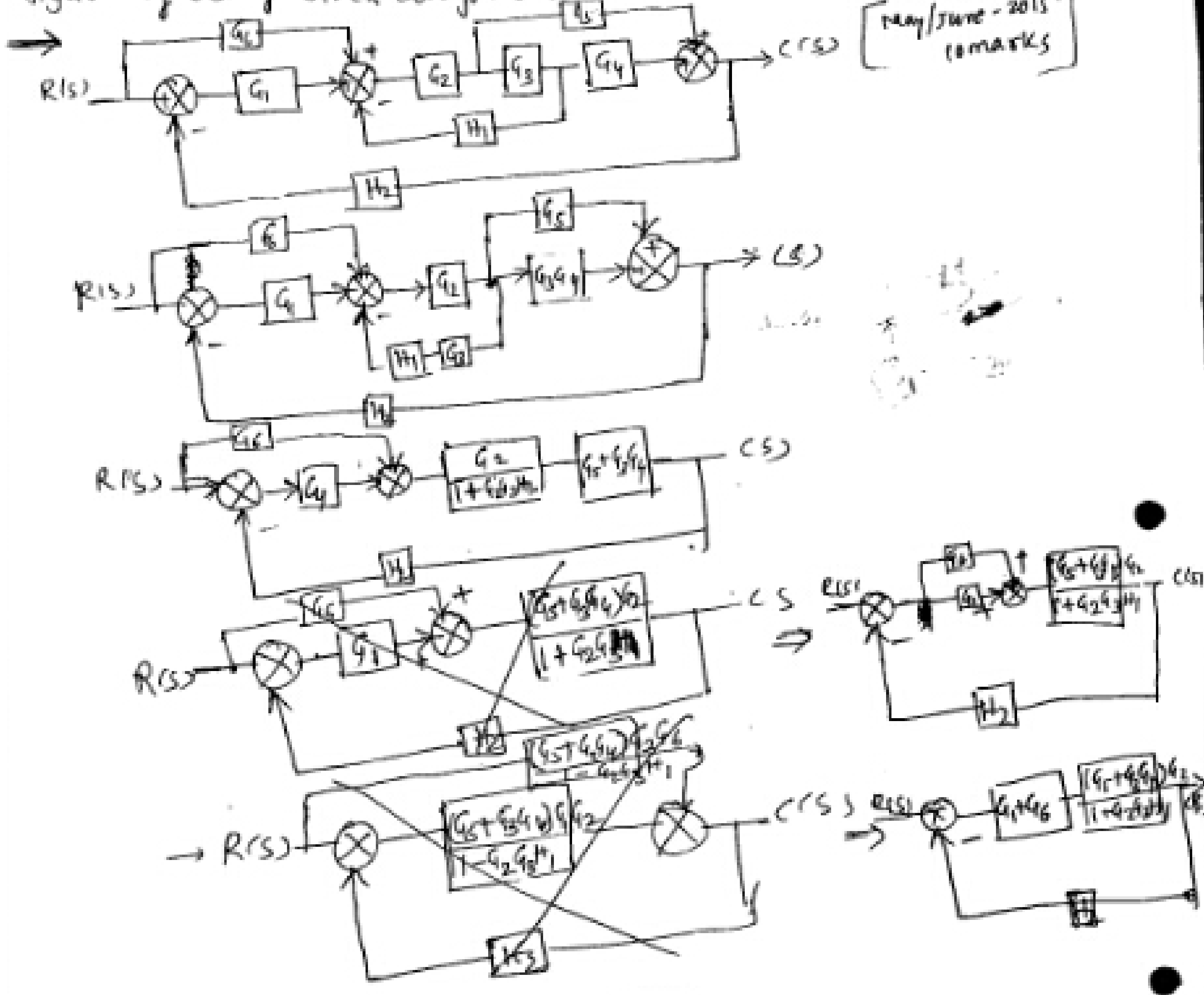
* Find the single transfer function by block diagram reduction of given diagram. [May 2015, Marks 10]

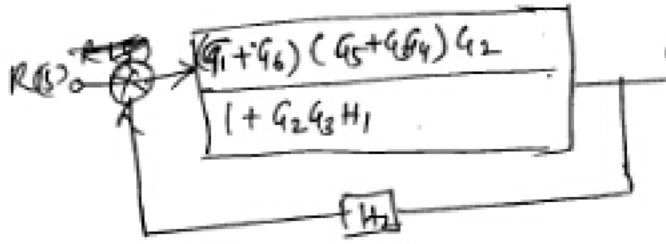


$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_3^2}{(1+G_3H_2)G_3 + H_3G_2G_3(1+G_3H_2) + G_1G_2G_3^2H_1}$$

* Find the transfer function of the block diagram shown in figure by using block diagram reduction method.

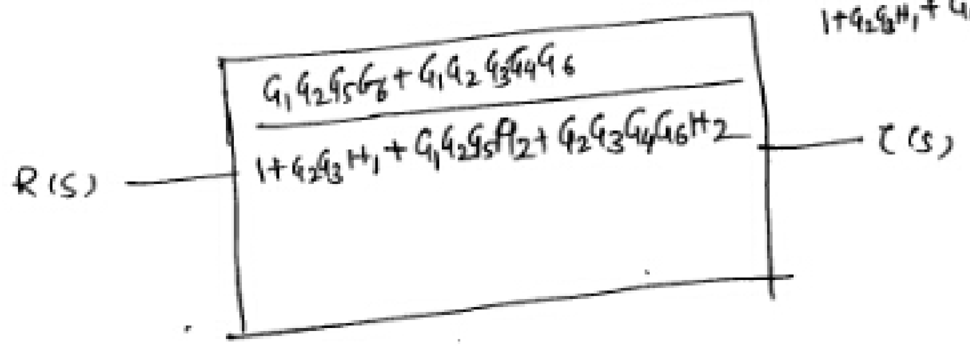
[May/June - 2015 10 marks]



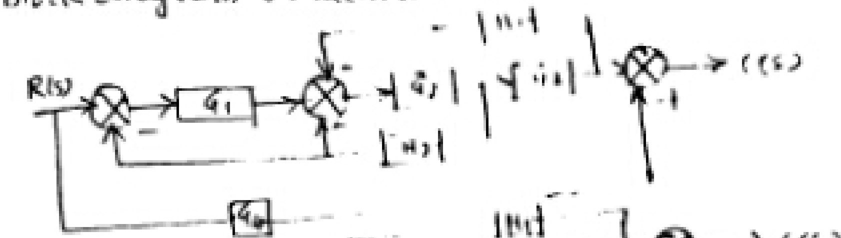


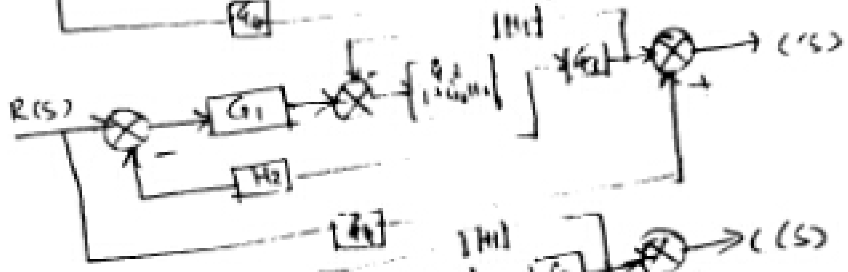
$$\frac{(G_1 G_6)\,(G_2G_5 + G_2G_3G_4)}{(1+G_2G_3H_1) + (G_1+G_6)\,(G_5+G_3G_4)\,G_2H_2}$$

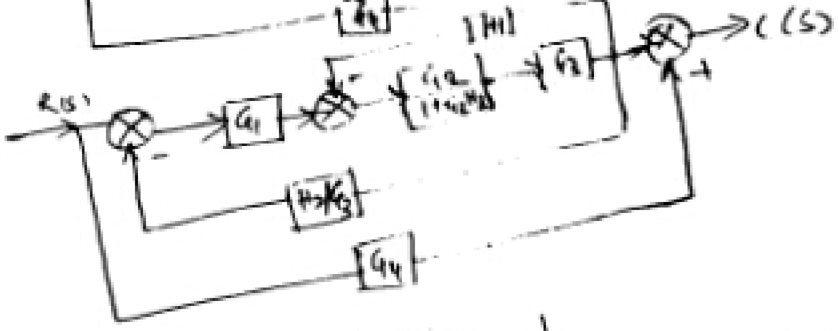
$$= \frac{G_1G_2G_5G_6 + G_1G_2G_3G_4G_6}{1+G_2G_3H_1 + G_1G_2G_5H_2 + G_2G_3G_4G_6H_2}$$

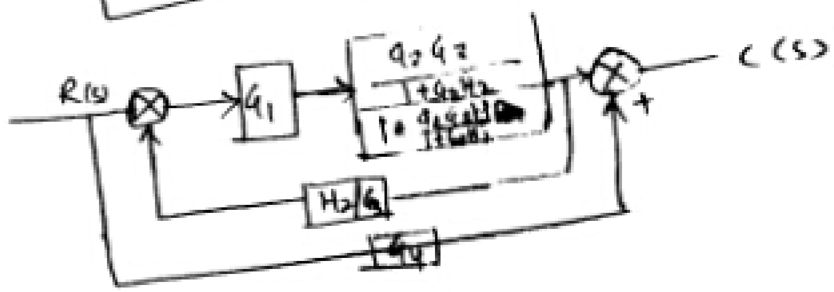


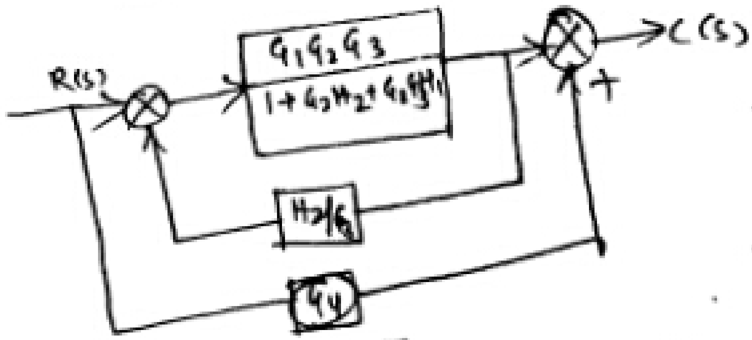
* Find the transfer function from the block diagram using block diagram reduction rules.



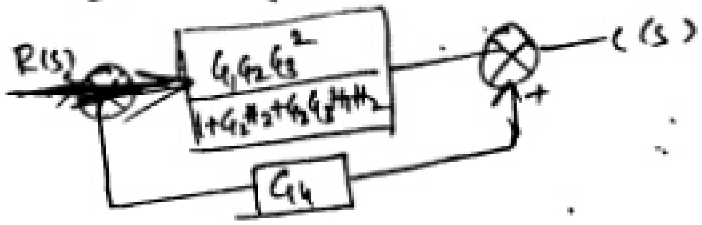




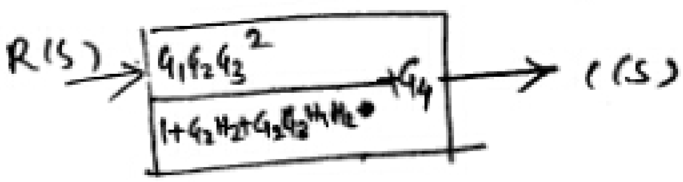




$$\frac{\frac{G_1G_2G_3}{1+G_2H_2+G_2G_3H_1}}{1+\left(\frac{G_1G_2G_3}{1+G_2H_2+G_2G_3H_1}\times\frac{H_2}{G_3}\right)} = \boxed{\frac{G_1G_2G_3^2}{1+G_2H_2+G_2G_3H_1H_2}}$$

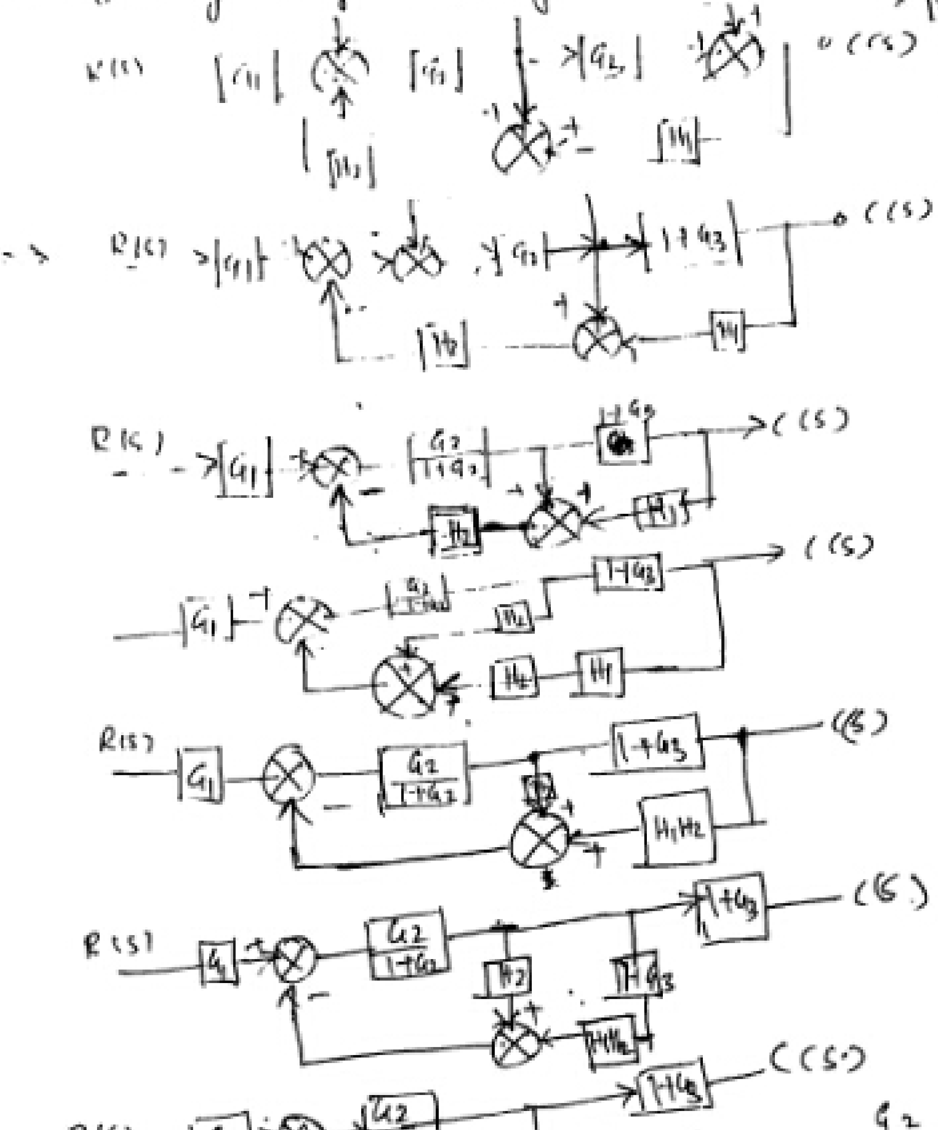


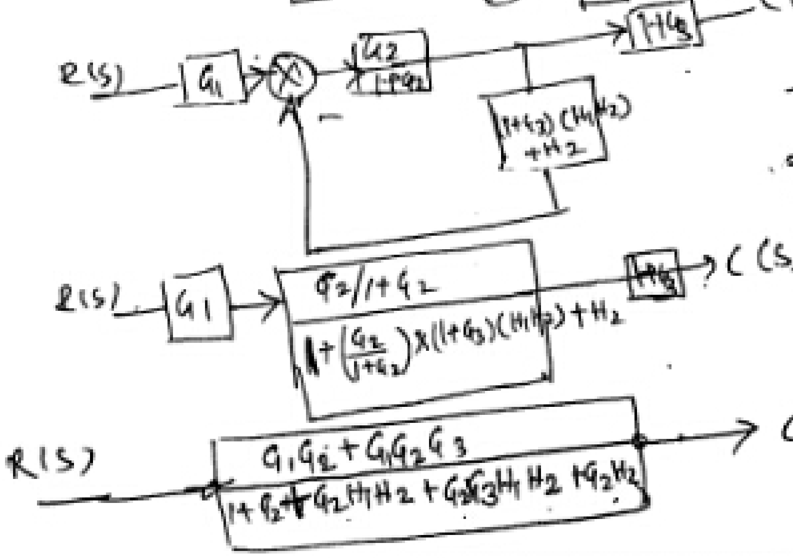
$$\frac{G_1G_2G_3^2}{1+G_2H_2+G_2G_3H_1H_2}+G_4$$



• Obtain the transfer function of block diagram shown in figure by using block diagram reduction method.

* [same problem checked in SFG method]





$$\frac{G_2}{1+G_2+(G_2)(1+G_3)(H_1H_2)+H_2}$$

$$= \frac{G_2}{1+G_2+(G_2+G_2G_3)(H_1H_2)+H_2G_2}$$

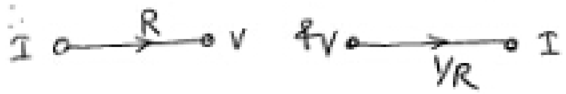
$$\frac{G_2}{1+G_2+G_2H_1H_2+G_2G_3H_1H_2+G_2H_2} \times (1+G_3)$$

Signal flow graphs :-

It is an alternative to block diagram. Signal flow graph consists only of branches unlike block diagram which consist of blocks, signals, summing points and take off points. It is a graphical representation of the relationship between variables of a set of linear algebraic equations. Every linear algebraic equation consists of dependent and independent variables. These variables are represented by small circles called as nodes. The relationship between nodes is represented by drawing a line between two nodes. Such lines are called branches.

Considering two equations –

$V = IR$ & $I = V/R$

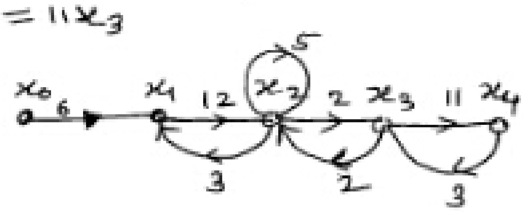


* Consider a system represented by the following equations. Draw the signal flow graph of the system.

$x_1 = 6x_0 + 3x_2$, $x_2 = 12x_1 + 5x_2 + 2x_3$, $x_3 = 2x_2 + 3x_4$

$x_4 = 11x_3$

→

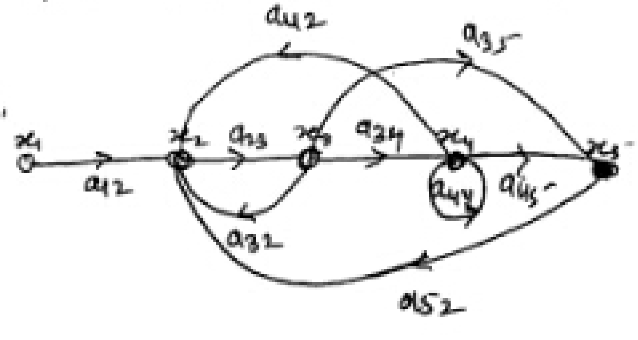


* Consider a system represented by the given set of equations draw the SFG.

$x_2 = a_{12}x_1 + a_{32}x_3 + a_{42}x_4 + a_{52}x_5$, $x_3 = a_{23}x_2$,

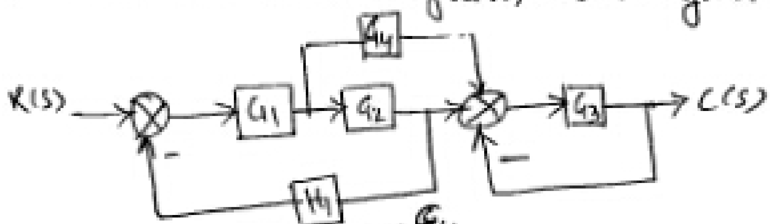
$x_4 = a_{34}x_3 + a_{44}x_4$ $x_5 = a_{35}x_3 + a_{45}x_4$

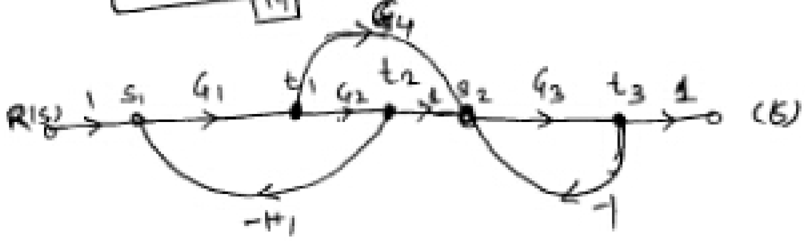
→



* Method to draw SFG from block diagrams:- The block diagram are useful in representing control systems. for complicated systems, block diagram reduction is time consuming. signal flow graph offers a much easier way to obtain the transfer function of the entire system.

* Represent the block diagram as a signal flow graph





* Mason's Gain formula :- The objective of signal flow graph is to find the overall transfer function of the signal flow graph with single formula (mason's gain formula) to achive the same result which is gating in block reduction method. It is a much easier method to obtain the transfer function of the entire control system. Once the signal flow graph is obtained, the T.F of the entire sys is calculated using the mason's gain formula —

$$\text{overall Transfer function} = T.F = \frac{C(s)}{R(s)} = \frac{\sum_i F_i \Delta_i}{\Delta}$$

where i = no. of forward paths,
F_i = Gain of i^{th} forward path
Δ = determinant which is calculated as follow

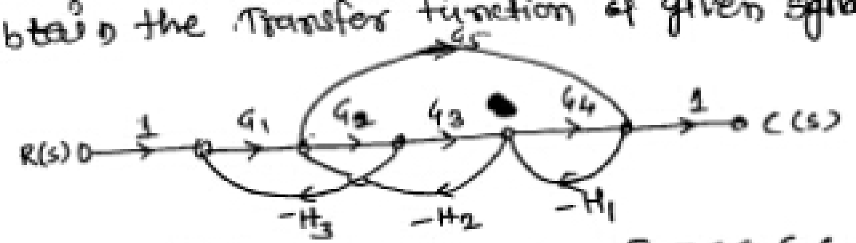
$\Delta = 1 -$ (sum of all individual loop gains including self gains)
+ (sum of all gain products of two non-touching loops)
− (sum of all gain products of three non-touching loops)
+ ....

$\therefore \Delta = 1 - (L_{11} + L_{21} \cdots) + (L_{12} + L_{22} + L_{32}) - (L_{13} + L_{23} + L_{33} + \cdots) + \cdots$

$\therefore \Delta_i$ = the value of Δ for the part of graph not touching to the i^{th} forward path.

$\therefore \Delta_i = (1 -$ All the loops that do not touch th i^{th} forward).

* obtain the Transfer function of given signal flow graph



⇒ Total No. of forward paths = 2, $\therefore F_1 = G_1G_2G_3G_4$; $F_2 = G_1G_5$

Single No. of loops :- $L_{11} = -G_1G_2H_3$, $L_{21} = -G_2G_3H_2$, $L_{31} = -G_4H_1$
$L_{41} = +H_1H_2G_5$

Two non-touching loops :- $L_{12} = (-G_1G_2H_3)(-G_4H_1) = G_1G_2G_4H_1H_3$

three non-touching loops = NiL

$\Delta = 1 - (L_{11} + L_{21} + L_{31} + L_{41}) + L_{12}$
$= 1 - (-G_1G_2H_3 - G_2G_3H_2 - G_4H_1 + G_5H_1H_2) + (G_1G_2G_4H_1H_3)$
$= 1 + G_1G_2H_3 + G_2G_3H_2 + G_4H_1 - G_5H_1H_2 + G_1G_2G_4H_1H_3$.

Take F_1, loops $L_{11}, L_{21}, L_{31}, L_{41}$

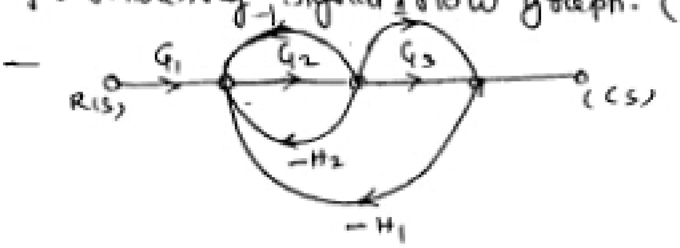
$\therefore \Delta_1 = 1 - 0 = 1$

Take F_2, F_2 all loops above touch path F_2,

$\therefore \Delta_2 = 1$

$$\therefore T.F = \frac{F_1\Delta_1 + F_2\Delta_2}{\Delta} = \frac{G_1G_2G_3G_4 + G_1G_5}{1+G_1G_2H_3+G_2G_3H_2+G_4H_1-G_3H_1H_2+G_1G_2G_3H_1H_3}$$

* Obtain transfer function using Mason's gain formula for following signal flow graph. (May 2007, 10 marks)



$\Rightarrow$ No. of forward path = 2, $F_1 = G_1G_2G_3$ & $F_2 = G_1G_2$

No. of single loops :- $L_{11} = -G_2$, $L_{21} = -G_2H_2$, $L_{31} = -G_2G_3H_1$

$L_{41} = -G_2H_1$

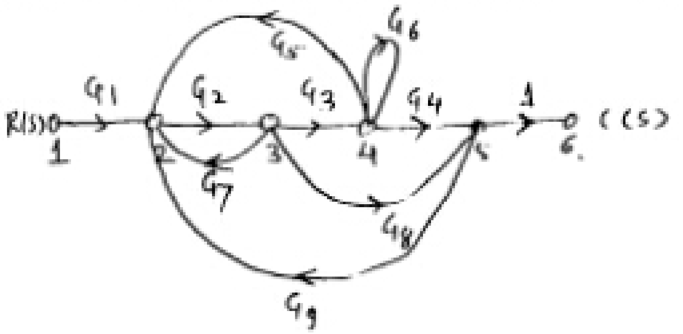
No. of 2 non-touching loops = 0

$\therefore \Delta = 1 - (L_{11}+L_{21}+L_{31}+L_{41}) = 1+G_2+G_2H_2+G_2G_3H_1+G_2H_2$

$\Delta_1 = 1$, $\Delta_2 = 1$

$$\therefore T.F = \frac{F_1\Delta_1 + F_2\Delta_2}{\Delta} = \frac{G_1G_2G_3+G_1G_2}{1+G_2+G_2H_2+G_2G_3H_1+G_2H_2}$$

* obtain tranfer function for the following signal flow graph (Dec-2014, 10 marks)



$\Rightarrow$ No of forward path $\Rightarrow F_1 = G_1G_2G_3G_4,\ F_2 = G_1G_2G_8$

Total No of loops $\Rightarrow L_{11} = G_2G_3G_5,\ L_{21} = G_2G_7,\ L_{31} = G_6,$

$L_{41} = G_2G_8G_9,\ L_{51} = G_2G_3G_4G_9$

No of 2 non-touching loops $\Rightarrow L_{12} = L_{21} \times L_{31} = G_2G_7G_6$

No. of 3 non touching loops $\Rightarrow 0$ (NIL)

$$\therefore \Delta = 1 - (G_2G_3G_5 + G_2G_7 + G_6 + G_2G_8G_9 + G_2G_3G_4G_9) + G_2G_7G_6$$

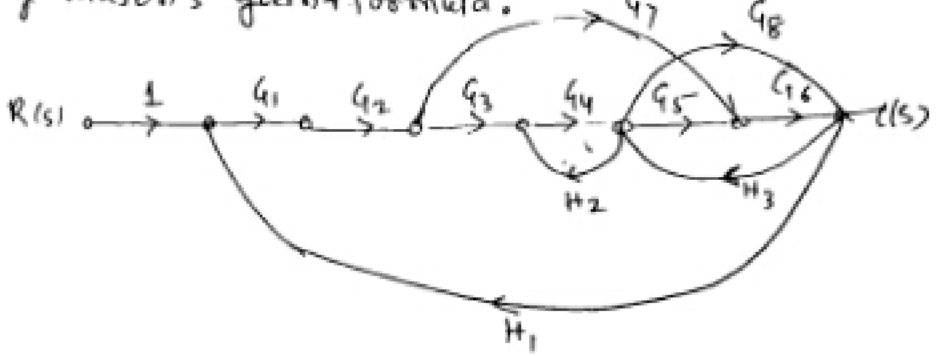
$$\therefore \Delta_1 = 1 - 0 = 1$$

Loop L_{31} does not touch the forward path F_2

$$\therefore \Delta_2 = 1 - L_{31} = (1 - G_6)$$

$$\therefore T.F = \frac{F_1\Delta_1 + F_2\Delta_2}{\Delta} = \frac{G_1G_2G_3G_4 + G_1G_2G_8(1-G_6)}{1 - (G_2G_3G_5 + G_2G_7 + G_6 + G_2G_8G_9 + G_2G_3G_4G_9) + G_2G_7G_6}$$

* For the diagram given below, obtain transfer function using mason's gain formula.



$\Rightarrow$ No. of forward path, $F_1 = G_1G_2G_3G_4G_5G_6$

$F_2 = G_1G_2G_7G_6$

$F_3 = G_1G_2G_3G_4G_8$

Total single loops, $L_{11} = G_1G_2G_3G_4G_5G_6H_1$, $L_{21} = G_4H_2$

$L_{31} = G_5G_6H_3$, $L_{41} = G_8H_3$, $L_{51} = G_1G_2G_7G_6H_1$

$L_{61} = G_1G_2G_3G_4G_8H_1$

No. of 2 non-touching loops $\Rightarrow$ $L_{12} = L_{21} \times L_{51} = G_4H_2G_1G_2G_7G_6H_1$

No. of 3 non-touching loops L_{13} = Nil

$\therefore$ $\Delta = 1 - G_1G_2G_3G_4G_5G_6H_1 - G_4H_2 - G_5G_6H_3 - G_8H_3 - G_1G_2G_7G_6H_1 - G_1G_2G_3G_4G_8H_1 + G_4H_2G_1G_2G_7G_6H_1$

Take F_1; $\Delta_1 = 1 - 0 = 1$,

Take F_2; $\Delta_2 = 1 - L_{21} = 1 - G_4H_2$

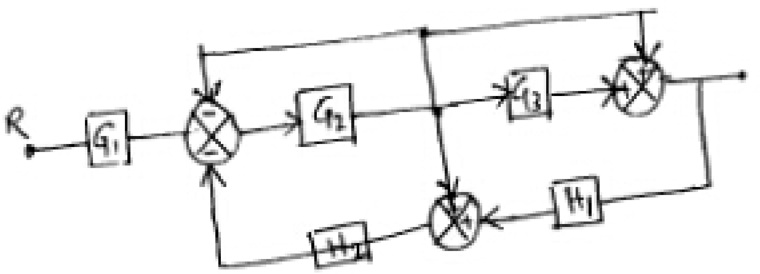
Take F_3; $\Delta_3 = 1 - 0 = 1$

$$T.F = \frac{F_1\Delta_1 + F_2\Delta_2 + F_3\Delta_3}{\Delta}$$

$$= \frac{G_1G_2G_3G_4G_5G_6 + (G_1G_2G_7G_6)(1 - G_4H_2) + G_1G_2G_3G_4G_8}{1 - G_1G_2G_3G_4G_5G_6H_1 - G_4H_2 - G_5G_6H_3 - G_8H_3 - G_1G_2G_7G_6H_1 - G_1G_2G_3G_4G_8H_1 + G_4H_2G_1G_2G_7G_6H_1}$$

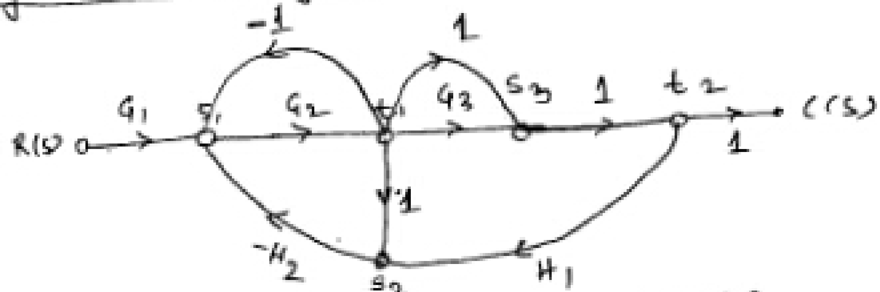
* Draw a signal flow graph for the system shown below and hence obtain the transfer function using mason's gain formula.

(Nov/Dec-2015, 10 marks)



[same problem checked in block diagram reduction method]

→ Signal Flow diagram:-



No. of forward path; $F_1 = G_1G_2G_3$; $F_2 = G_1G_2$

No of single loops; $L_{11} = -G_2H_2$, $L_{21} = -G_2$, $L_{31} = -G_2G_3H_1H_2$

$L_{41} = -G_2H_1H_2$

No. of 2 non-touching loops :- NIL

No. of 3 non-touching loops :- NIL

$\therefore \Delta = 1 + G_2H_2 + G_2 + G_2G_3H_1H_2 + G_2H_1H_2$

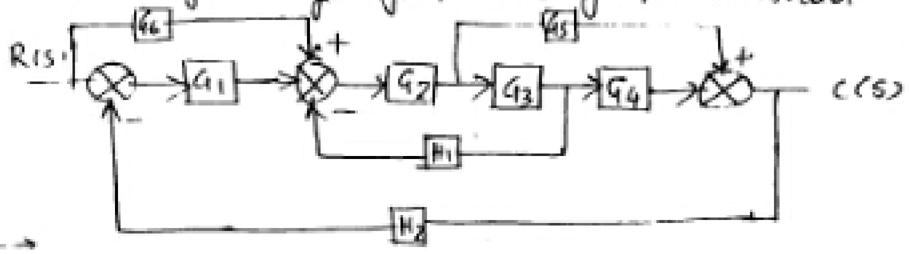
$\therefore \Delta_1 = 1 - 0$

$\therefore \Delta_2 = 1 - 0$

$$\therefore T.F = \frac{F_1\Delta_1 + F_2\Delta_2}{\Delta}$$

$$= \frac{G_1G_2G_3 + G_1G_2}{1 + G_2H_2 + G_2G_3H_1H_2 + G_2 + G_2H_1H_2}$$

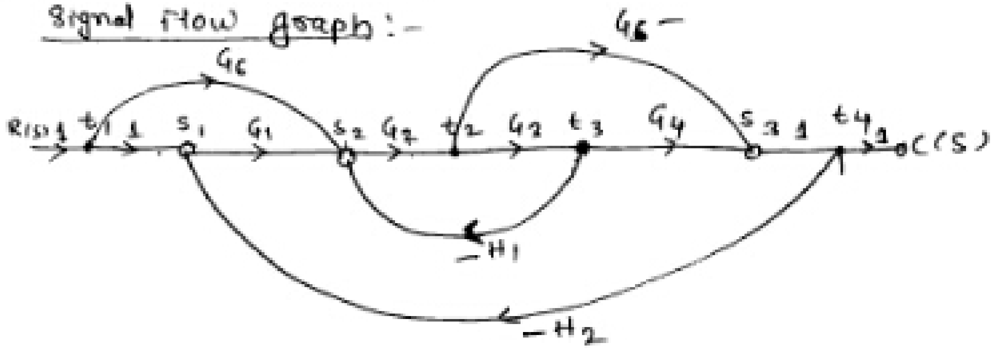
* Find the transfer function of block diagram shown in figure by using signal flow graph method.



< Same problem checked by block reduction method

→

Signal flow graph :-



No. of forward path ; $F_1 = G_1G_2G_3G_4$, $F_2 = G_6G_2G_3G_4$

$F_3 = G_6G_2G_5$ $F_4 = G_1G_2G_5$

No. of single loops ; $L_{11} = -G_2G_3H_1$ $L_{21} = -G_1G_2G_3G_4H_2$

$L_{31} = -G_2G_5H_2G_1$

No of 2 non touching loops ; $L_{12} =$ NIL

$$\Delta = 1 + G_2G_3H_1 + G_1G_2G_3G_4H_2 + G_1G_2G_5H_2$$

$$\Delta_1 = 1 - 0$$

$$\Delta_2 = 1 - 0$$

$$\Delta_3 = 1 - 0$$

$$\Delta_4 = 1 - 0$$

$$T.F = \frac{F_1\Delta_1 + F_2\Delta_2 + F_3\Delta_3 + F_4\Delta_4}{\Delta}$$

$$= \frac{G_1G_2G_3G_4 + G_2G_3G_4G_6 + G_2G_5G_6 + G_1G_2G_3}{1 + G_2G_3H_1 + G_1G_2G_3G_4H_2 + G_1G_2G_5H_2}$$