Control Systems

Subject Code: BEC-26

Third Year ECE

Unit-I

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Lecture 5

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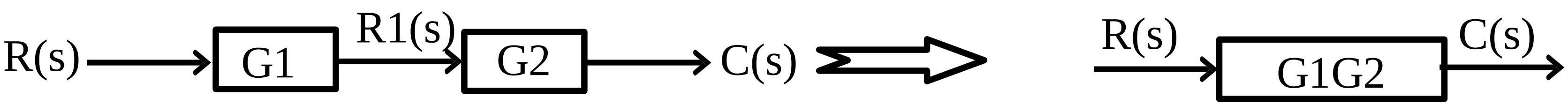
UNIT- I

- Introduction to Control system
  - Control System – Definition and Practical Examples
  - Basic Components of a Control System
- Feedback Control Systems:
  - Feedback and its Effect
  - Types of Feedback Control Systems
  - Transfer Function
- Block Diagrams:
  - Representation and reduction
  - Signal Flow Graphs
- Modeling of Physical Systems:
  - Electrical Networks and Mechanical Systems
  - Force-Voltage Analogy
  - Force-Current Analogy

Block Diagram Reduction Techniques

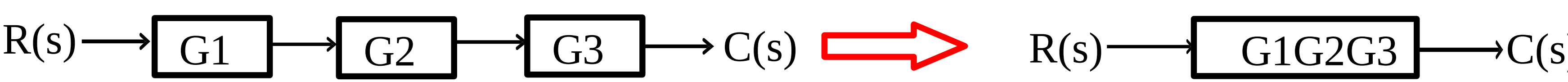
Rule 1:- For blocks in cascade:- Gain of blocks connected in cascade gets multiplied with each other.



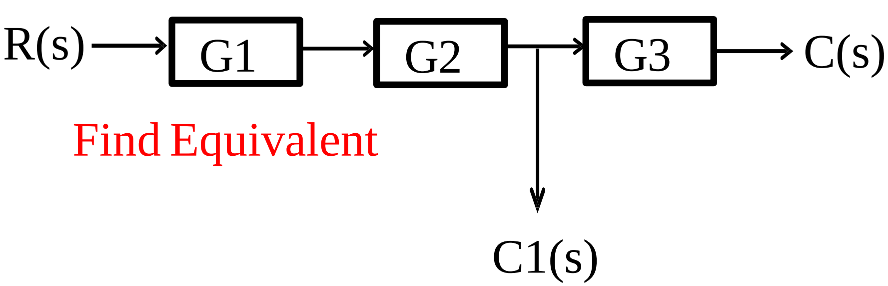
R1(s) = G1R(s)

C(s) = G2R1(s) = G1G2R(s)

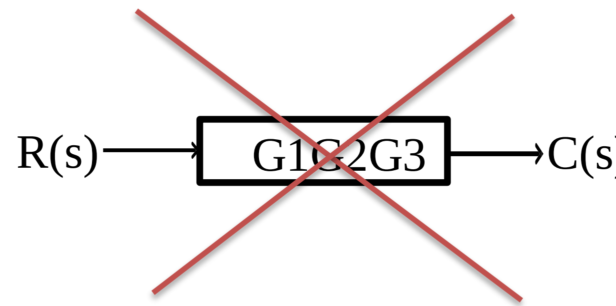
C(s) = G1G2R(s)

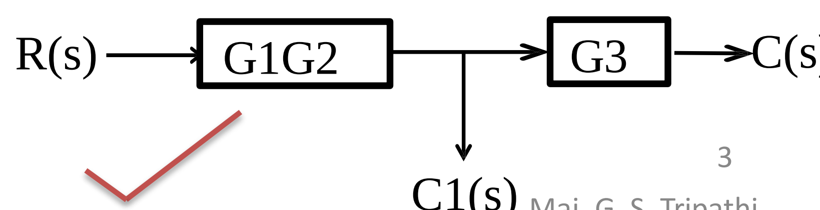


Find Equivalent



Find Equivalent





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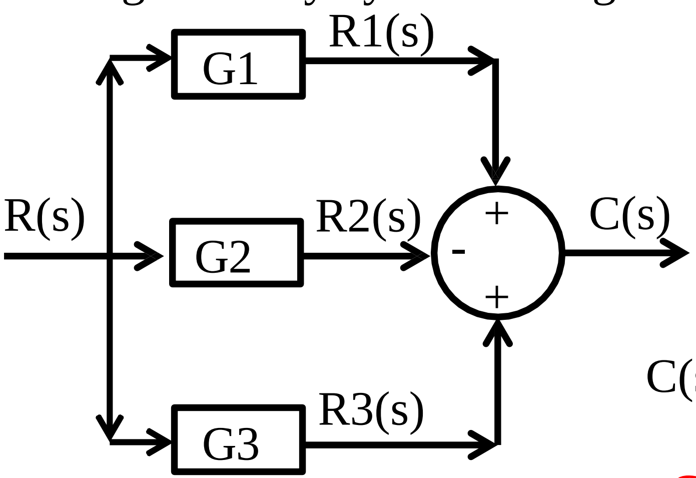
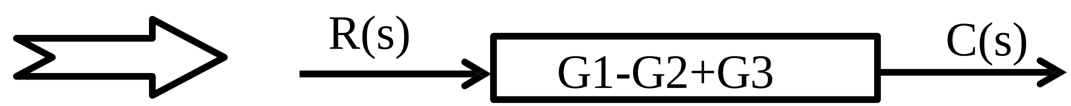
Block Diagram Reduction Techniques

Rule 2:- For blocks in parallel:- Gain of blocks connected in parallel gets added algebraically by considering the sign.





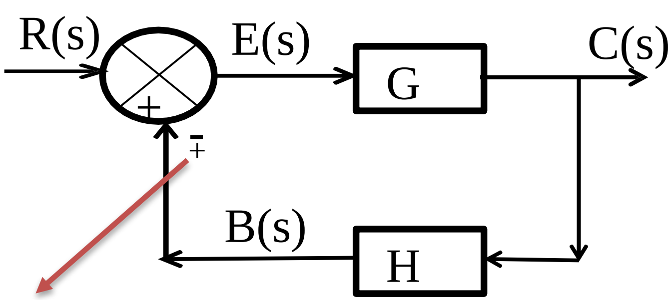
C(s)= R1(s)-R2(s)+R3(s)

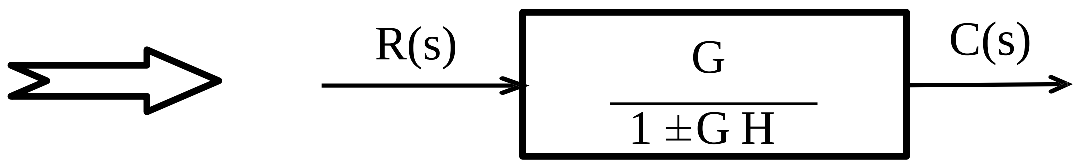
= G1R(s)-G2R(s)+G3R(s)

C(s)=(G1-G2+G3) R(s)

C(s)= (G1-G2+G3) R(s)

Rule 3:- Eliminate feedback loop:- Feedback loop can be either +ve or -ve



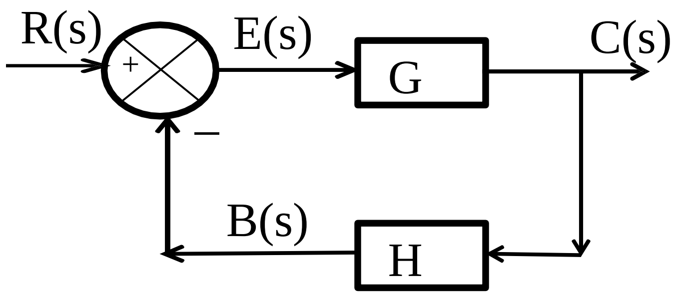


- Sign is of –ve feedback

+ sign is for +ve feedback

Block Diagram Reduction Techniques

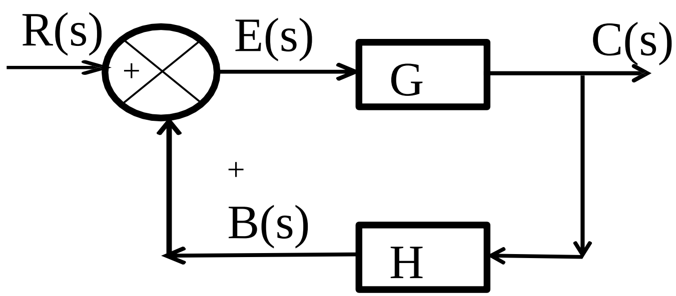
For Negative Feedback



From Shown Figure,

$$E(s) = R(s) - B(s) \text{ and}$$
$$C(s) = G.E(s) = G[R(s) - B(s)] = GR(s) - GB(s)$$
$$\text{But, } B(s) = H.C(s)$$
$$\therefore C(s) = G.R(s) - G.H.C(s)$$
$$C(s) + G.H.C(s) = GR(s)$$
$$\therefore C(s)[1 + G.H(s)] = G.R(s)$$
$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)}$$

For Positive Feedback



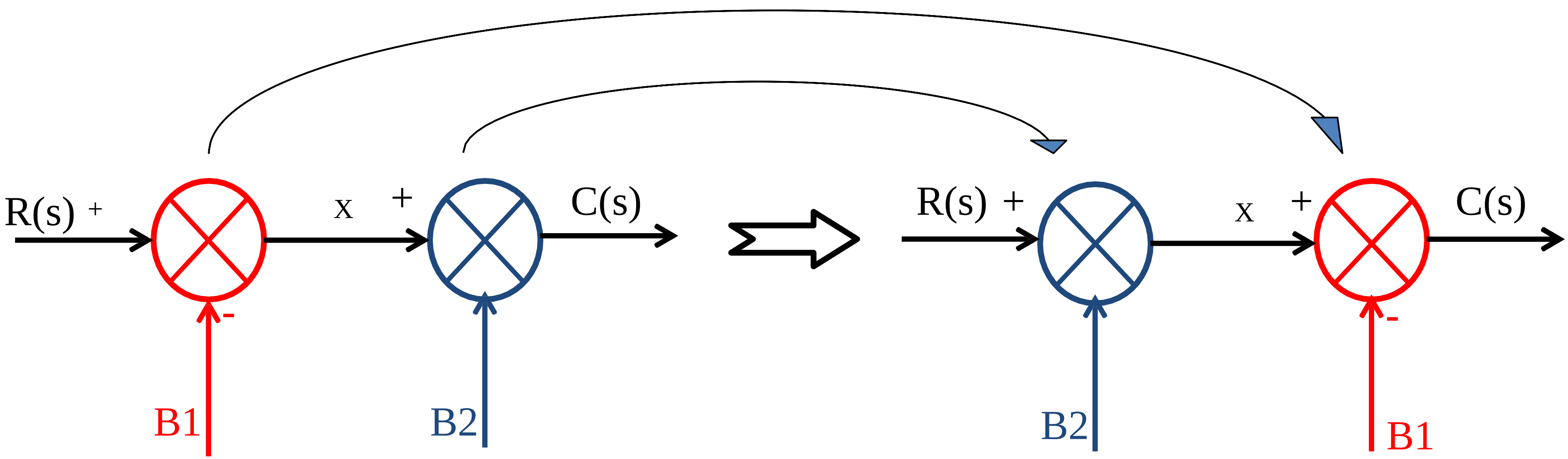
From Shown Figure,

$$E(s) = R(s) + B(s) \text{ and}$$
$$C(s) = G.E(s) = G[R(s) + B(s)] = GR(s) + GB(s)$$
$$\text{But, } B(s) = H.C(s)$$
$$\therefore C(s) = G.R(s) + G.H.C(s)$$
$$C(s) - G.H.C(s) = GR(s)$$
$$\therefore C(s)[1 - G.H(s)] = G.R(s)$$
$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 - G(s)H(s)}$$

Block Diagram Reduction Techniques

Rule 4:- Associative law for summing point:- It hold god for summing point which are directly connected to each other i.e. there is no any summing point or take off point or block in between summing points.

The order of summing points can be changed if two or more summing points are in series.

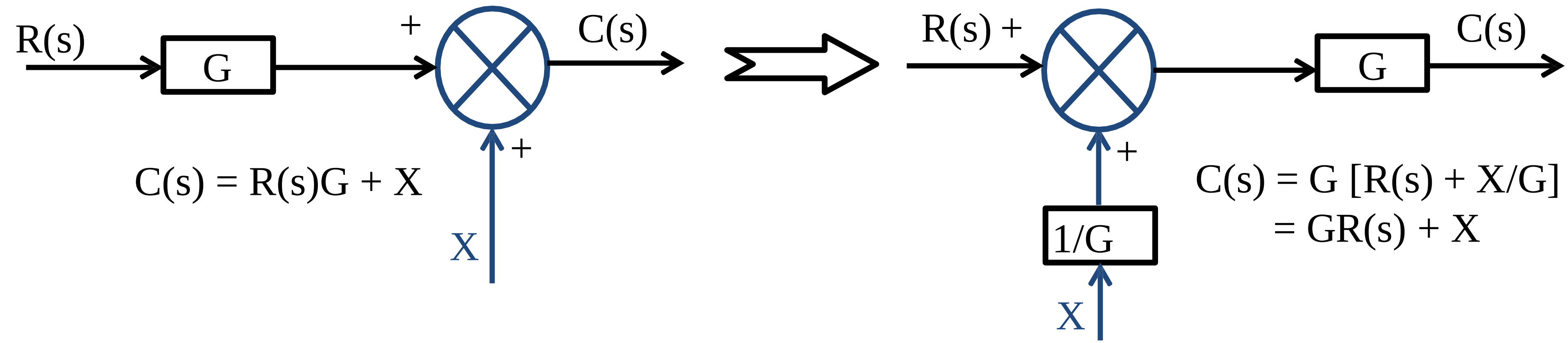


$X = R(s) - B1$
$C(s) = X - B2$
$C(s) = R(s) - B1 - B2$

$X = R(s) - B2$
$C(s) = X - B1$
$C(s) = R(s) - B2 - B1$

Block Diagram Reduction Techniques

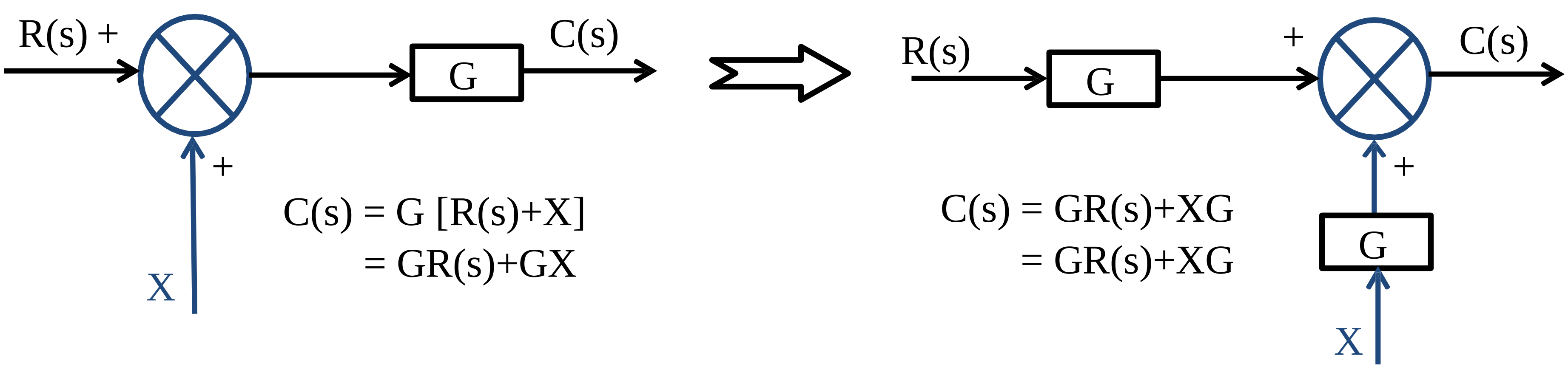
Rule 5:- Shift summing point before block:-



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

$C(s) = G\,[R(s) + X/G]$
$= GR(s) + X$

Rule 6:- Shift summing point after block:-

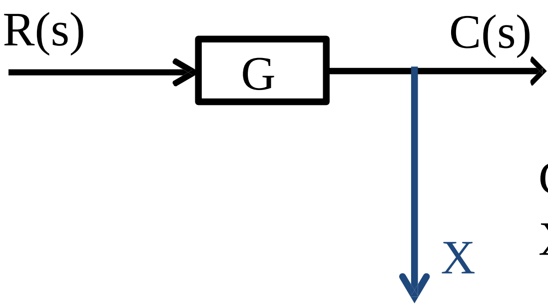


$C(s) = G\,[R(s)+X]$
$= GR(s)+GX$

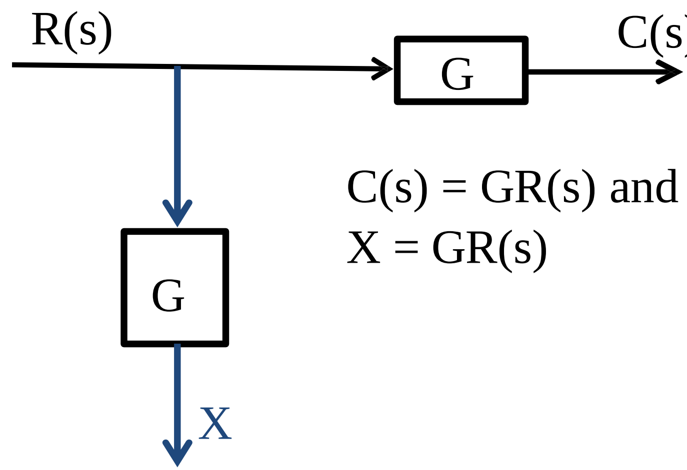
$C(s) = GR(s)+XG$
$= GR(s)+XG$

Block Diagram Reduction Techniques

Rule 7:- Shift a take-off point before the block:-

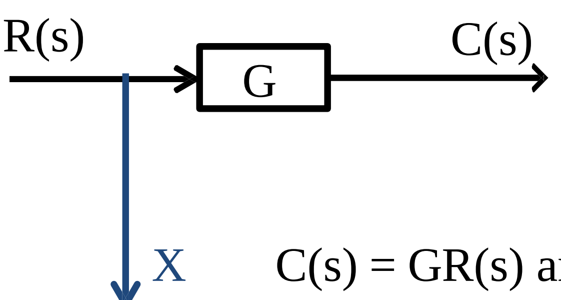


C(s) = GR(s) and
X = C(s) = GR(s)

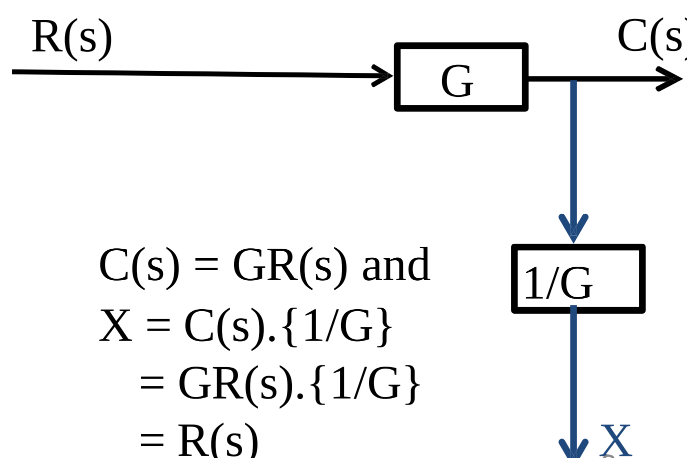


C(s) = GR(s) and
X = GR(s)

Rule 8:- Shift a take-off point after the block:-



C(s) = GR(s) and
X = R(s)



C(s) = GR(s) and
X = C(s).{1/G}
= GR(s).{1/G}
= R(s)

Block Diagram Reduction Techniques

- ✓ While solving block diagram for getting single block equivalent, the said rules need to be applied. After each simplification a decision needs to be taken. For each decision we suggest preferences as

- ✓ First Choice:-

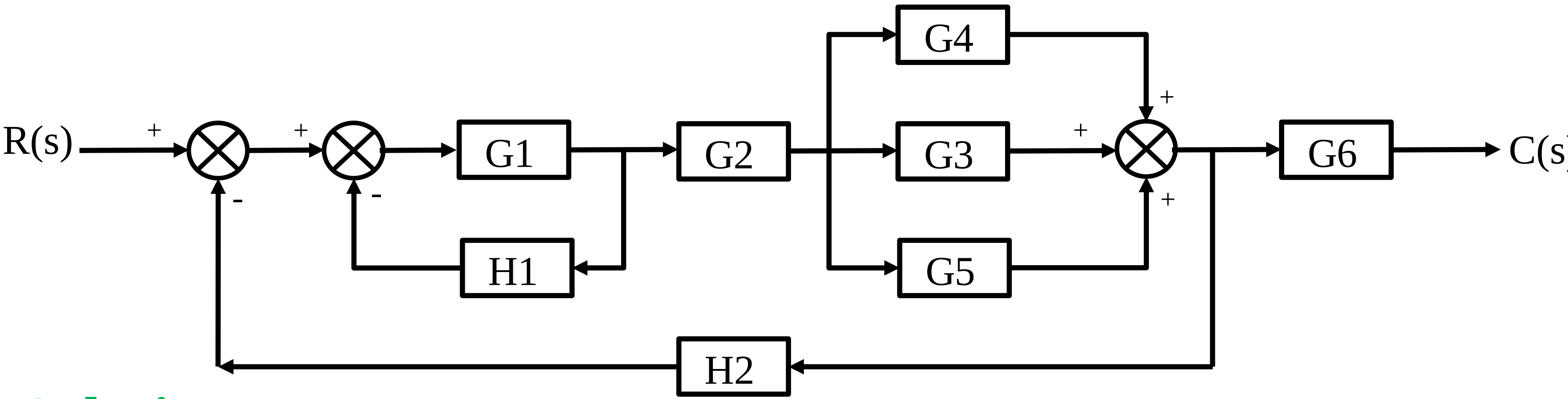
First preference	: Rule 1 (for Series)
Second preference	: Rule 2 (for Parallel)
Third preference	: Rule 3 (for Feedback Loop)

- ✓ Second Choice:- equal preferences to all

Rule 4	: Adjusting summing order
Rule 5/6	: Shifting summing point before/after the block
Rule7/8	: Shifting take off point before/after block

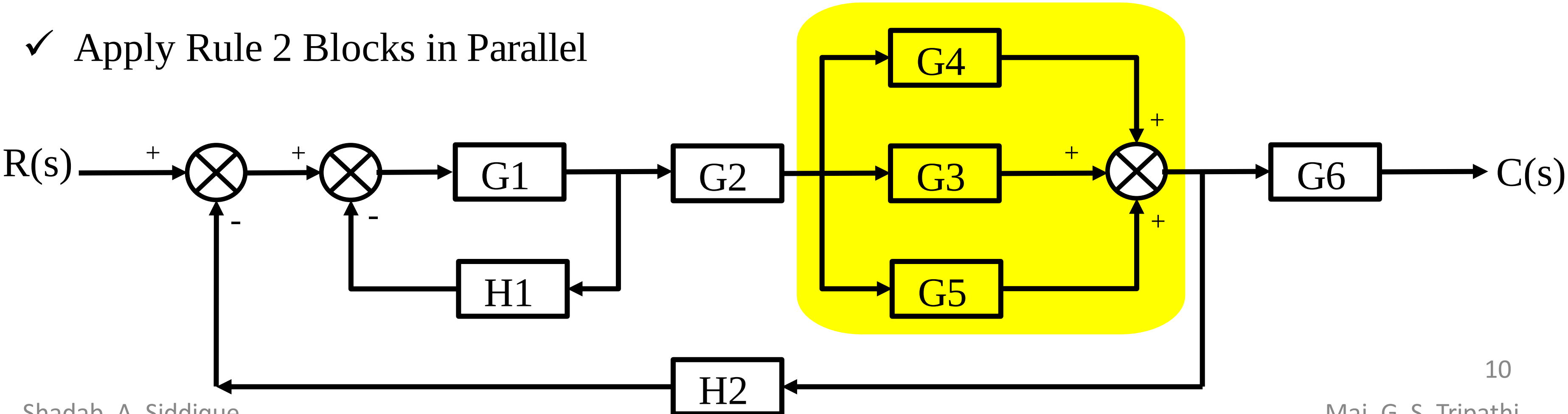
Problem 1:

Determine transfer function of the system shown in the figure.

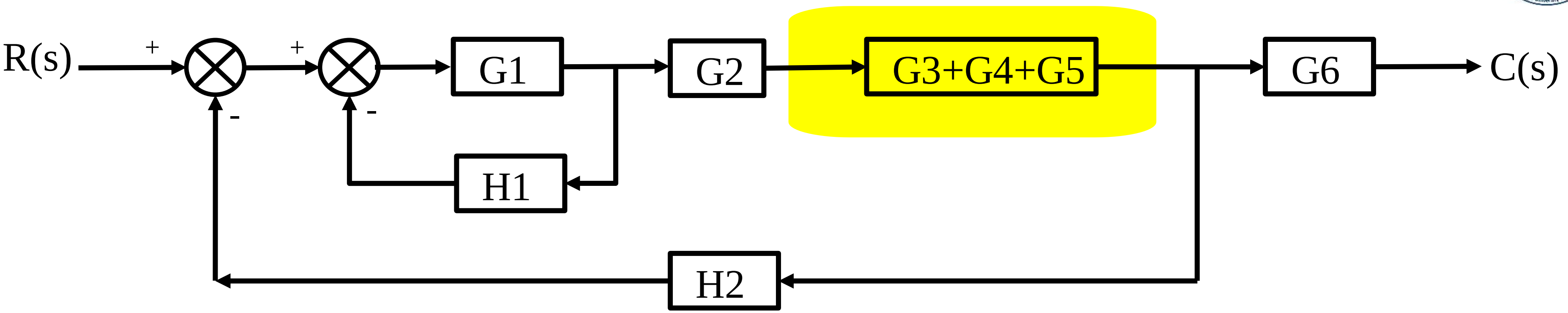


Solution:

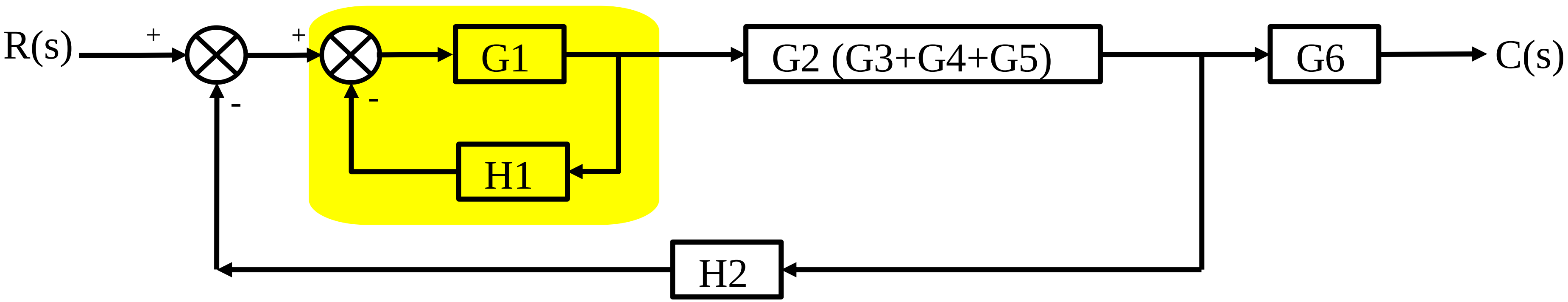
- ✓ Rule 1 cannot be used as there are no immediate series blocks.
- ✓ Hence Rule 2 can be applied to G4, G3, G5 in parallel to get an equivalent of G3+G4+G5
- ✓ Apply Rule 2 Blocks in Parallel



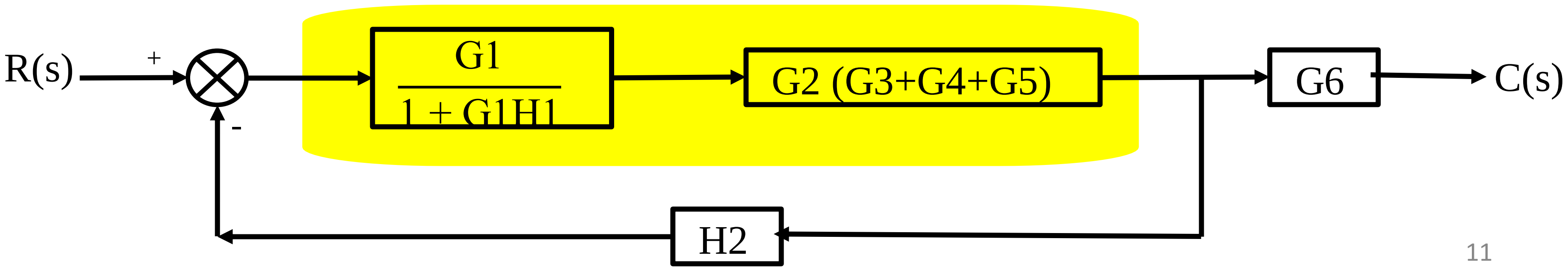
✓ Apply Rule 1 Block in Series



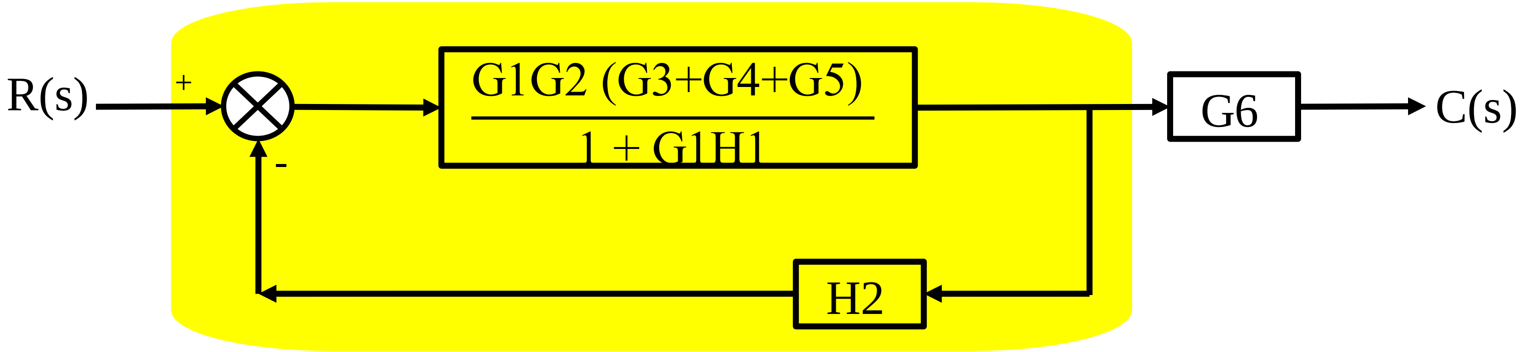
✓ Apply Rule 3 Elimination of feedback



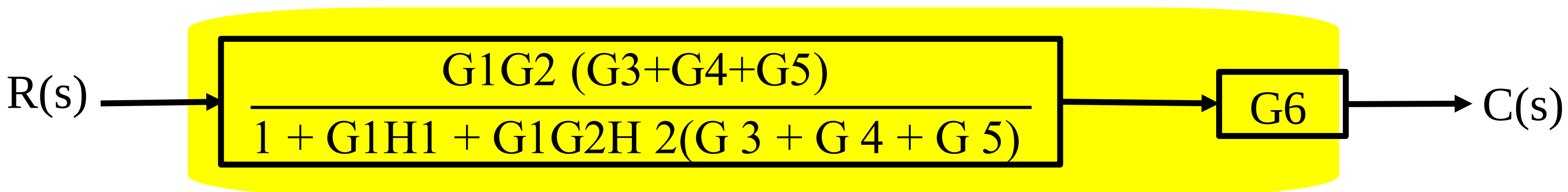
✓ Apply Rule 1 Block in Series



✓ Apply Rule 3 Elimination of feedback loop



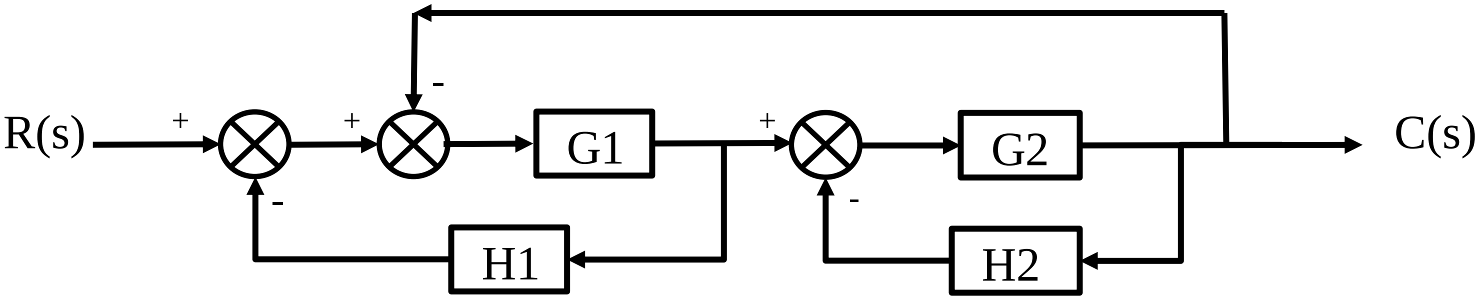
✓ Apply Rule 1 Block in Series



$$\frac{C(s)}{R(s)} = \frac{G1G2G6\,(G3+G4+G5)}{1 + G1H1 + G1G2H\,2(G\,3 + G\,4 + G\,5)}$$

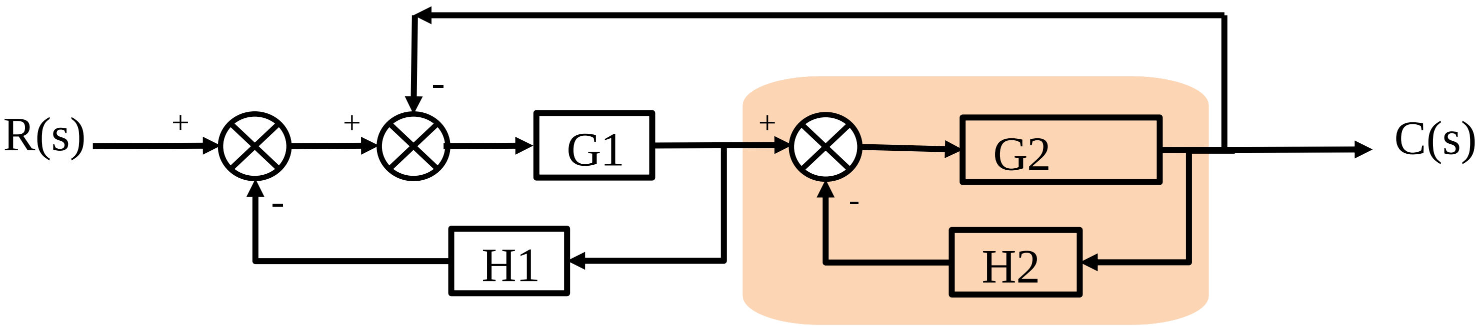
Problem 2:

Determine transfer function of the system shown in the figure.

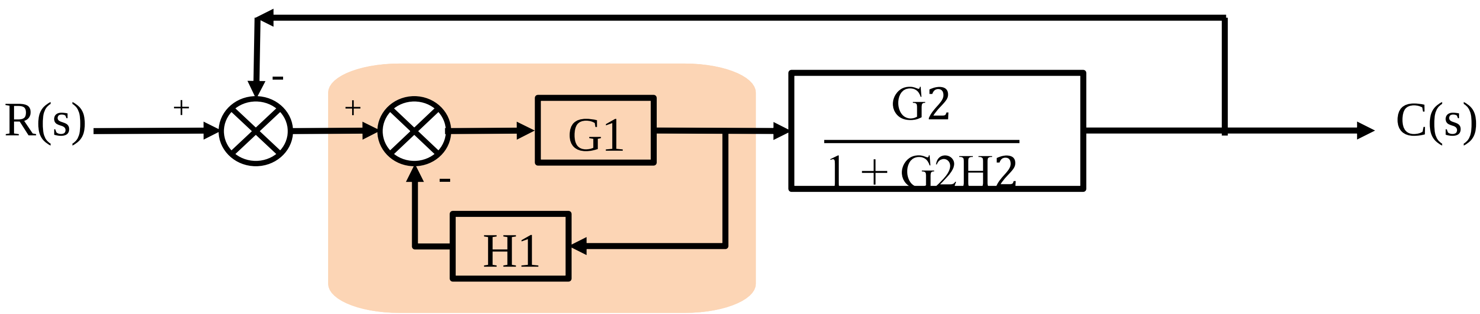


Solution:

- ✓ Apply Rule 3 Elimination of feedback



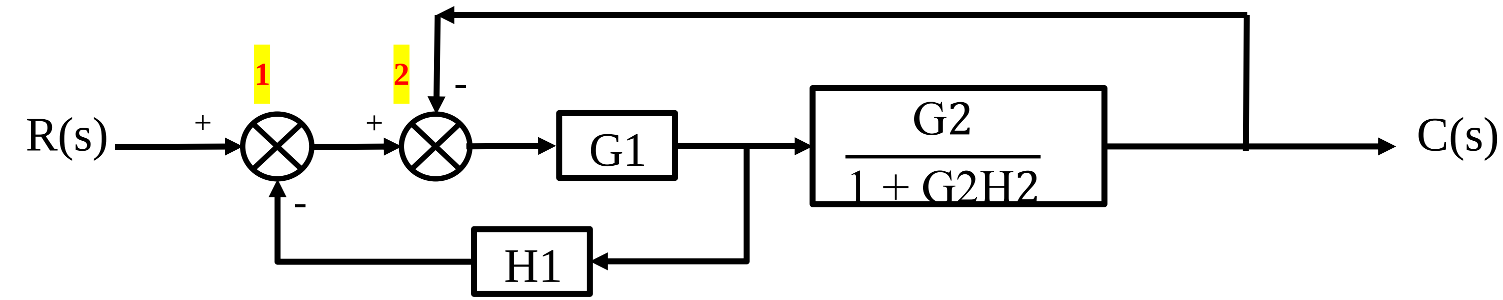
- ✓ Apply Rule 3 Elimination of feedback



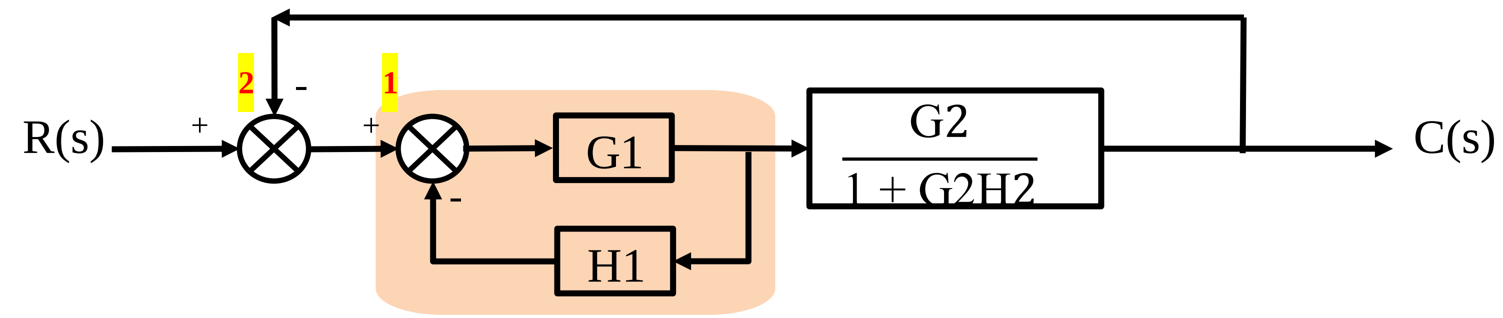
- ✓ Now Rule 1, 2 or 3 cannot be used directly.
- ✓ There are possible ways of going ahead.
  - ✓ Use Rule 4 & interchange order of summing so that Rule 3 can be used on G.H1 loop.
  - ✓ Shift take off point after $\frac{G_2}{1 + G2H2}$ block reduce by Rule 1, followed by Rule 3.

Which option we have to use????

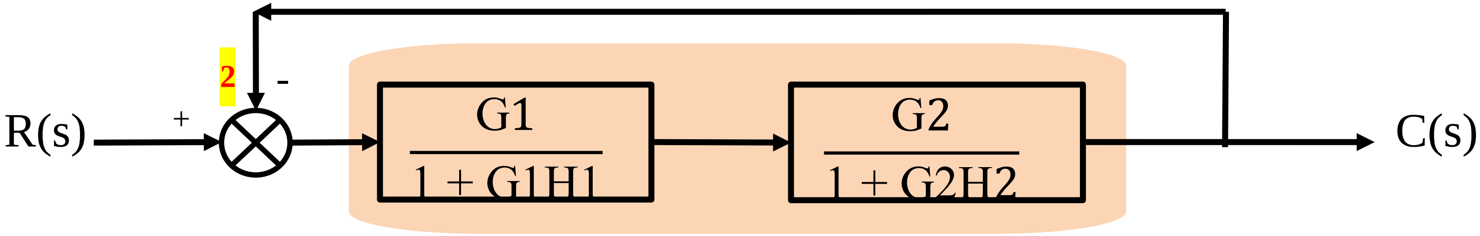
✓ Apply Rule 4 Exchange summing point



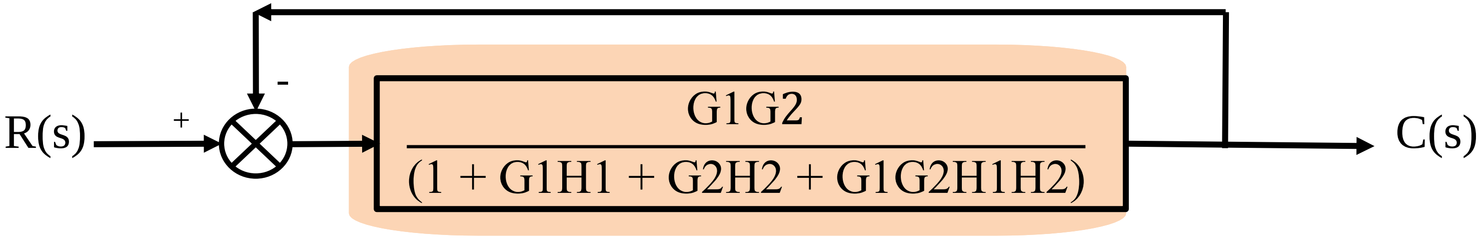
✓ Apply Rule 4 Elimination of feedback loop



- ✓ Apply Rule 1 Block in series



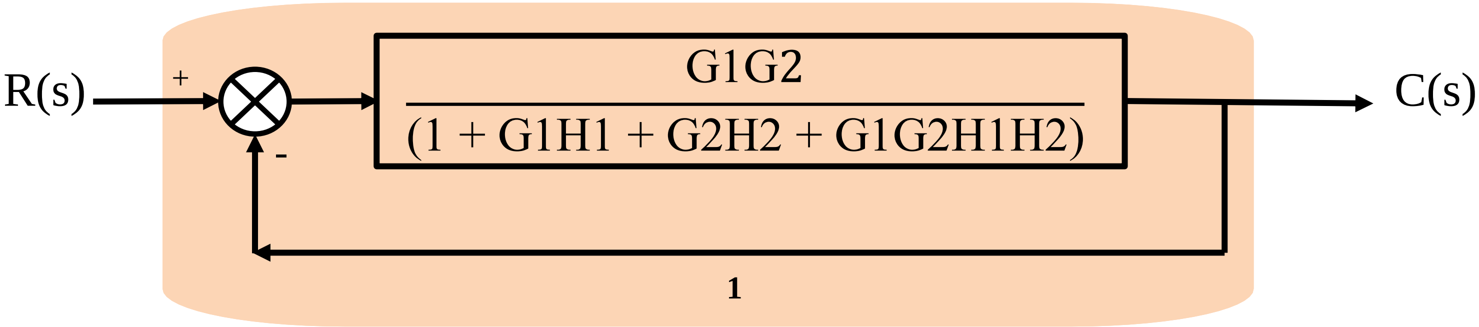
- ✓ Apply Rule 1 Block in series

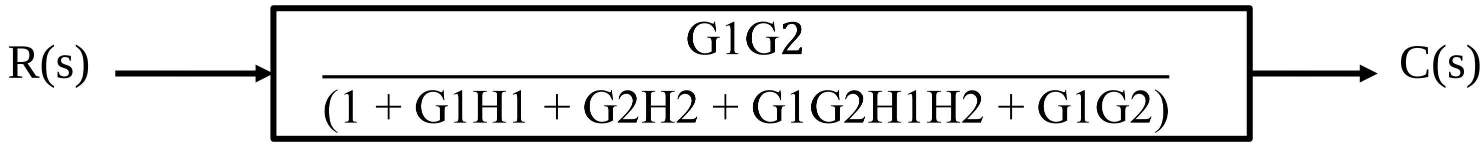


- ✓ Now which Rule will be applied

  -------It is blocks in parallel OR -------It is feed back loop

- ✓ Let us rearrange the block diagram to understand
- ✓ Apply Rule 3 Elimination of feed back loop





$$\frac{C(s)}{R(s)} = \frac{G1G2}{1 + G1H1 + G2H2 + G1G2H1H2 + G1G2}$$

Note 1: According to Rule 4

- ✓ By corollary, one can split a summing point to two summing point and sum in any order