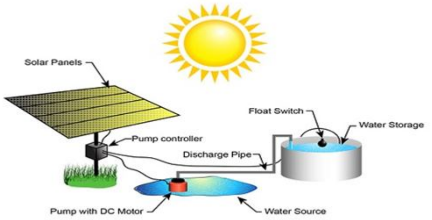


Control System

Block Diagram Reduction Techniques

Content

- Review of Last Lecture.
- Need of Block Diagram.
- Block Diagram Reduction Technique.
- Examples of Block Diagram Reduction.

Learning Objectives

- Able to understand the need of Block diagram in Control System.
- Able to apply various rule of block diagram reduction techniques.

Block Diagram Algebra

- Block diagram is a **shorthand, graphical representation** of a physical system, illustrating the functional relationships among its components.

OR

- A Block Diagram is a shorthand pictorial representation of the **cause-and-effect** relationship of a system.

Block Diagram Algebra

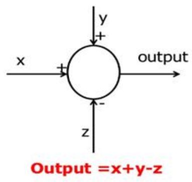
- Entire complicated system can be completely represented by connecting different blocks.
- One block corresponds to one element of system.
- A corresponding block is drawn by inserting a transfer function of that element inside the block.

Components of a Block Diagram for a LTI System

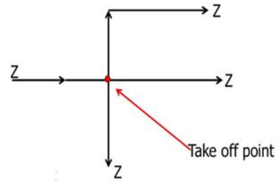
- System components are alternatively called elements of the system.
- Block diagram has four components:
  - ***Signals***
  - ***System/ block***
  - ***Summing junction***
  - ***Pick-off/ Take-off point***

Element of Block Diagram

- **Summing Point :-** Two or more signals can be added or subtracted at summing point.



- **Take-off Point :-** The output signal can be applied to two or more points from a take-off point.



Block Diagram Reduction Techniques

- **Rule 1 :- For Blocks in Series/Cascade**

-Gain of blocks connected in series gets multiplied with each other.

R1(s)=G1R(s)

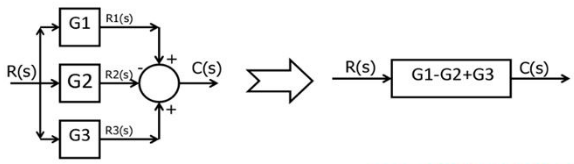
C(s) =G2R1(s)
=G1G2R(s)

C(s)= G1G2R(s)

Block Diagram Reduction Techniques

- **Rule 2 :- For Blocks in Parallel**

-Gain of blocks connected in parallel gets added algebrically.

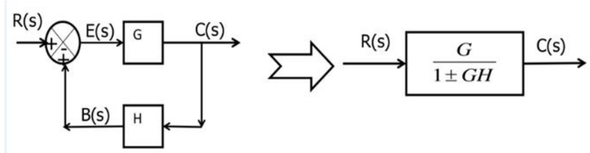


C(s)= R1(s)-R2(s)+R3(s)
= G1R(s)-G2R(s)+G3R(s)
C(s)=(G1-G2+G3) R(s)

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

Block Diagram Reduction Techniques

- **Rule 3:- Elimination of Feedback loop**



$$\frac{C(s)}{R(s)} = \frac{G}{1 \pm GH}$$

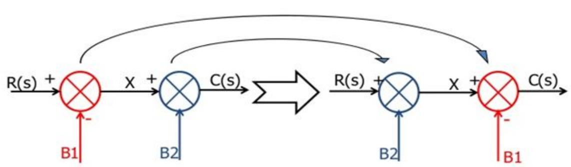
In General

For –ve f/b : +ve sign in above expression & vice-versa.

Block Diagram Reduction Techniques

- **Rule 4:- Associative law for summing point**

- Order of summing point can be changed if two or more summing points are in series.

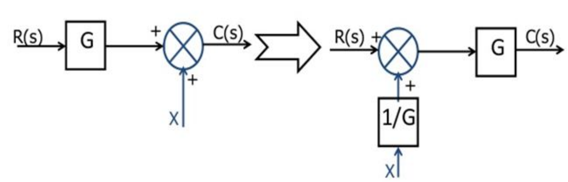


X=R(s)-B1
C(s)=X-B2
C(s)=R(s)-B1-B2

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**

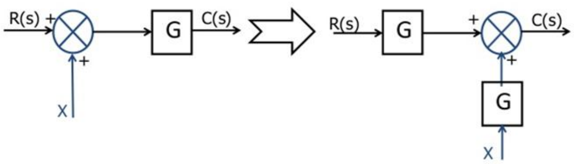


C(s)=R(s)G+X

C(s)=G{R(s)+X/G}
=GR(s)+X

Block Diagram Reduction Techniques

- **Rule 6:- Shift summing point after block**

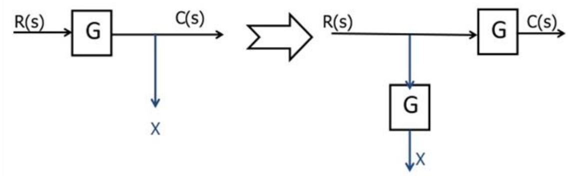


$C(s)=G\{R(s)+X\}$
$=GR(s)+GX$

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

Block Diagram Reduction Techniques

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

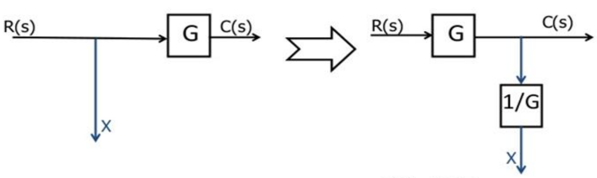


$C(s)=GR(s)$
and
$X=C(s)=GR(s)$

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

Block Diagram Reduction Techniques

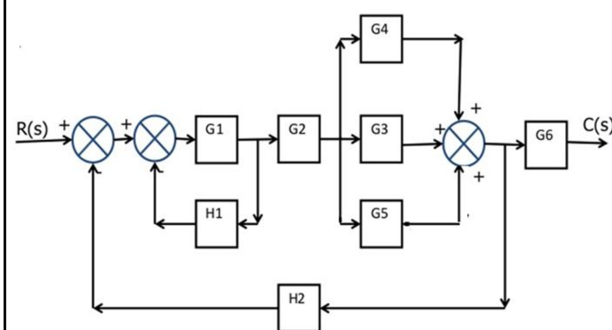
- **Rule 8:- Shift a take-off point after block**



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

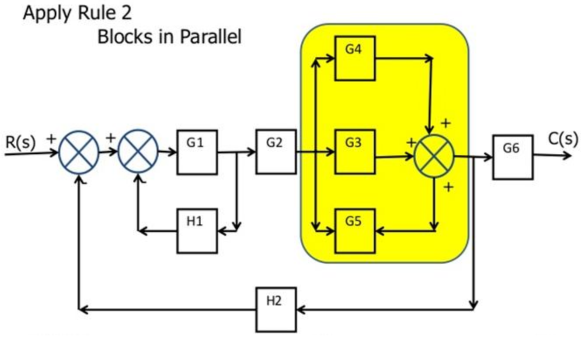
$C(s)=GR(s)$
and
$X=C(s).\{1/G\}$
$=GR(s).\{1/G\}$
$= R(s)$

Example 1:



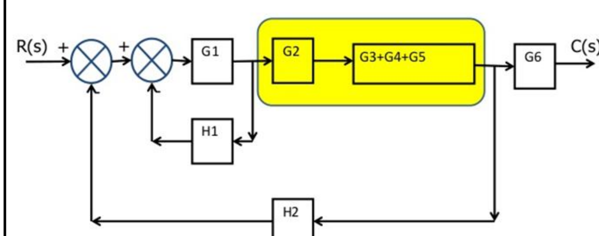
Example 1: Cont....

Apply Rule 2
Blocks in Parallel



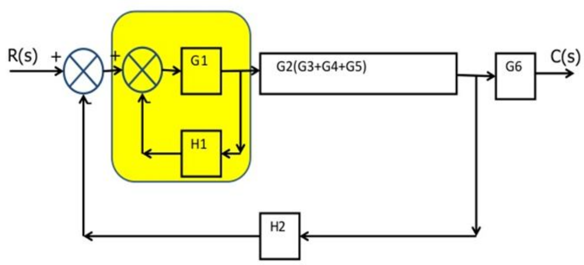
Example 1: Cont....

Apply Rule 1 Blocks in series



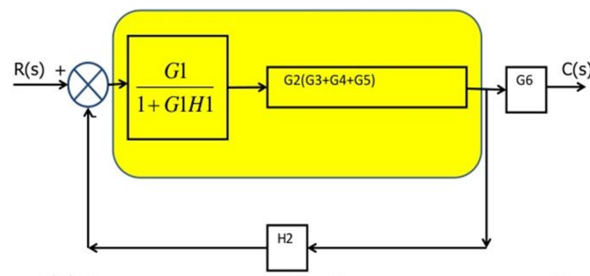
Example 1: Cont....

Apply Rule 3 Elimination of feedback loop



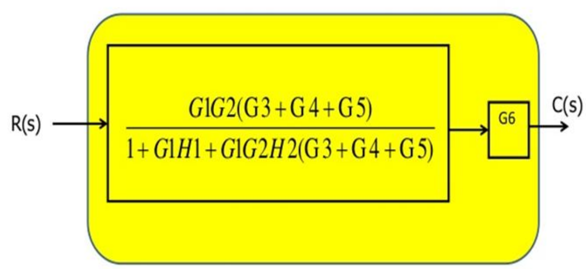
Example 1: Cont....

Apply Rule 1 Blocks in series

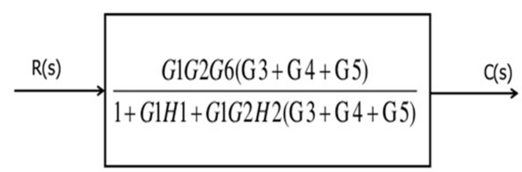


Example 1: Cont....

Apply Rule 1 Blocks in series

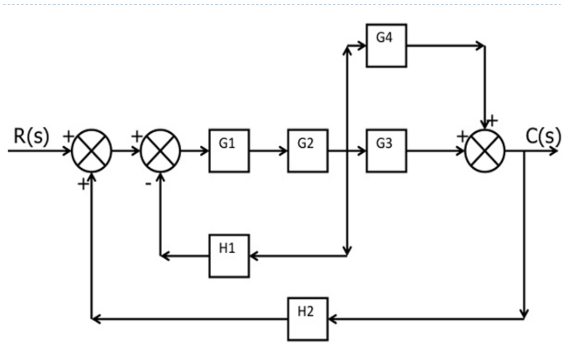


Example 1: Cont....



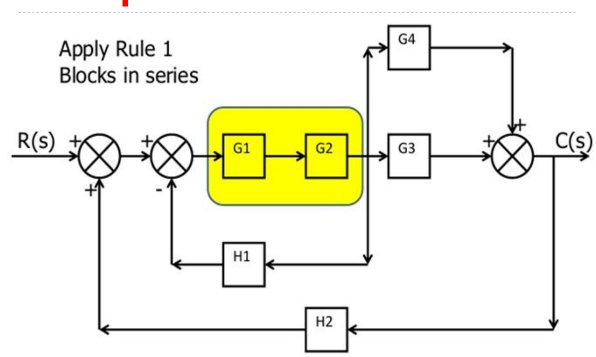
$$\frac{C(s)}{R(s)} = \frac{G1G2G6(G3+G4+G5)}{1+G1H1+G1G2H2(G3+G4+G5)}$$

Example 2:



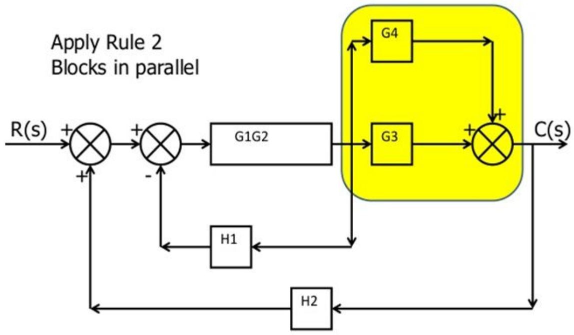
Example 2: Cont....

Apply Rule 1
Blocks in series



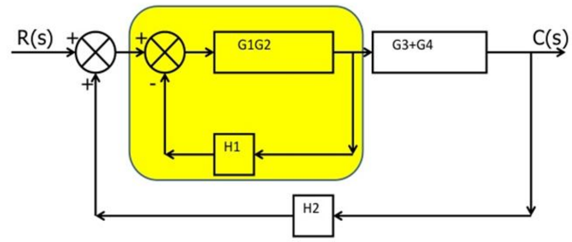
Example 2: Cont....

Apply Rule 2
Blocks in parallel



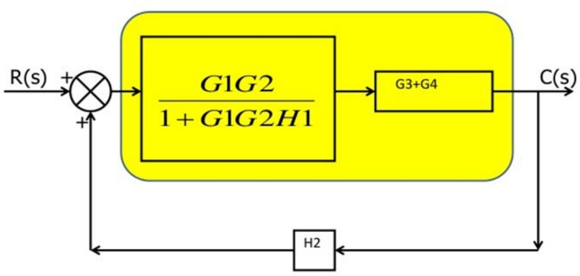
Example 2: Cont....

Apply Rule 3
Elimination of feedback loop



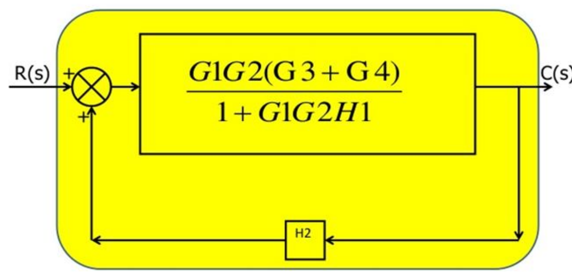
Example 2: Cont....

Apply Rule 2 Blocks in series

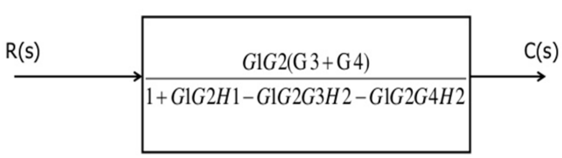


Example 2: Cont....

Apply Rule 3 Elimination of feedback loop

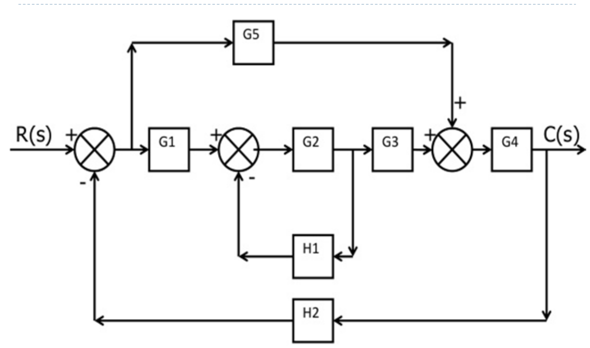


Example 2: Cont....



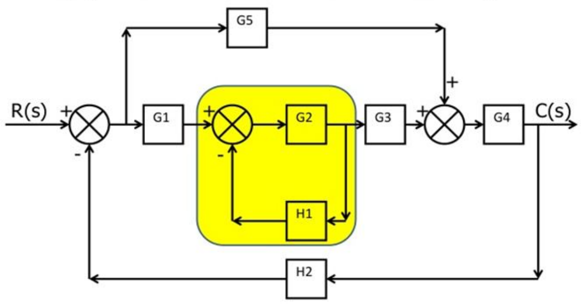
$$\frac{C(s)}{R(s)} = \frac{G1G2(G3+G4)}{1+G1G2H1-G1G2G3H2-G1G2G4H2}$$

Example 3:



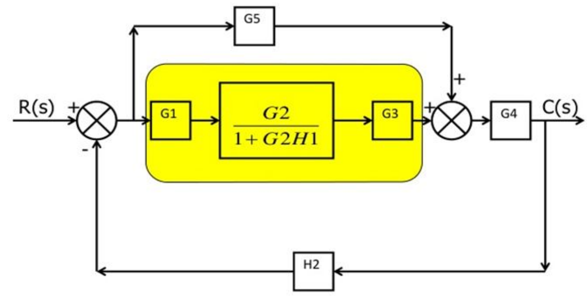
Example 3: Cont....

Apply Rule 3 Elimination of feedback loop



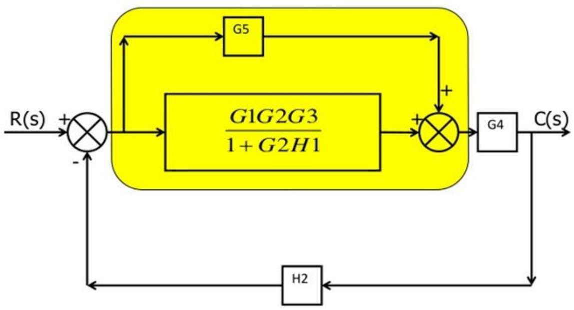
Example 3: Cont....

Apply Rule 1 Blocks in series



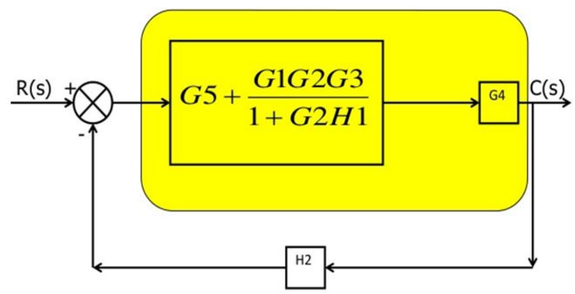
Example 3: Cont....

Apply Rule 2 Blocks in parallel



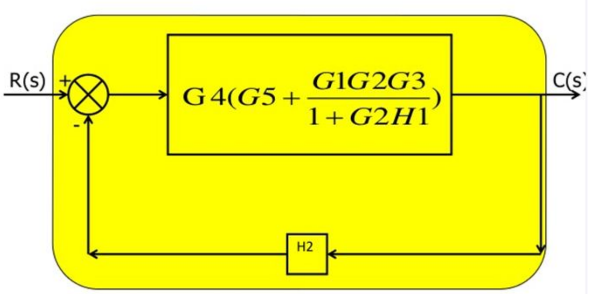
Example 3: Cont....

Apply Rule 1 Blocks in series

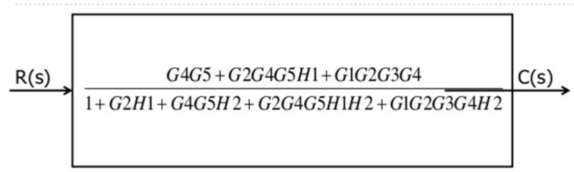


Example 3: Cont....

Apply Rule 3 Elimination of feedback loop

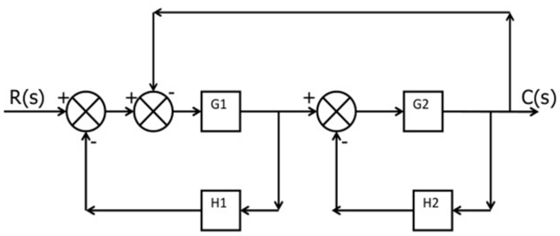


Example 3: Cont....



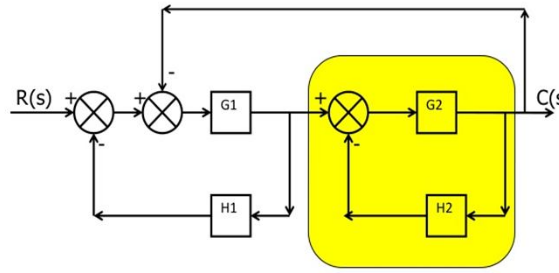
$$\frac{C(s)}{R(s)}=\frac{G4G5+G2G4G5H1+G1G2G3G4}{1+G2H1+G4G5H2+G2G4G5H1H2+G1G2G3G4H2}$$

Example 4:

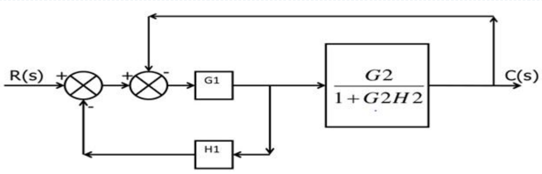


Example 4: Cont....

Apply Rule 3 Elimination of feedback loop



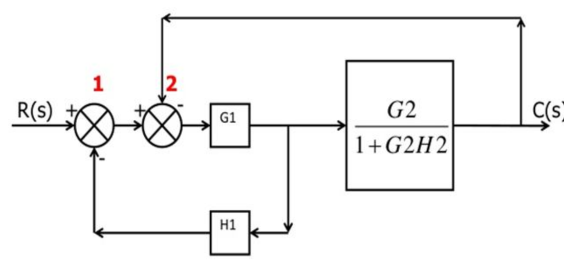
Example 4: Cont....



- Now Rule 1, 2 or 3 cannot be used directly.
- There are possible ways of going ahead.
  - a. Use Rule 4 & interchange order of summing so that Rule 3 can be used on G.H1 loop.
  - b. Shift take off point after $\frac{G2}{1+G2H2}$ block reduce by Rule 1, followed by Rule 3.

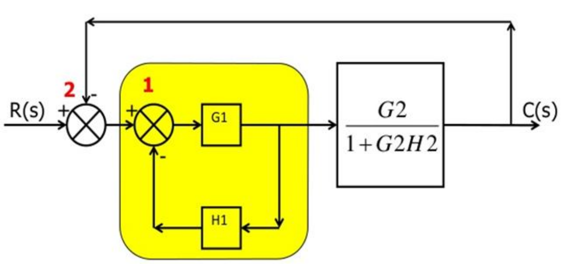
Example 4: Cont....

Apply Rule 4 Exchange summing order



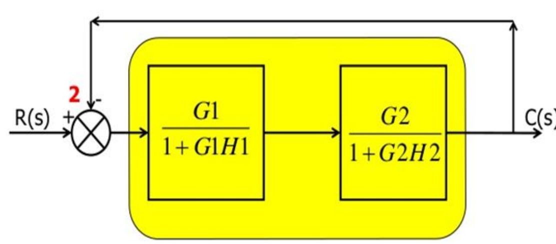
Example 4: Cont....

Apply Rule 3 Elimination feedback loop

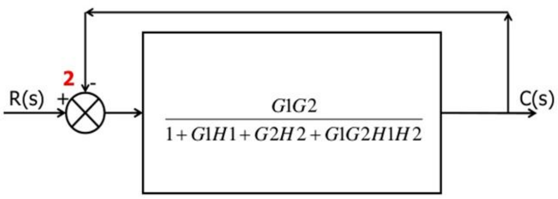


Example 4: Cont....

Apply Rule 1 Bocks in series



Example 4: Cont....



Now which Rule will be applied

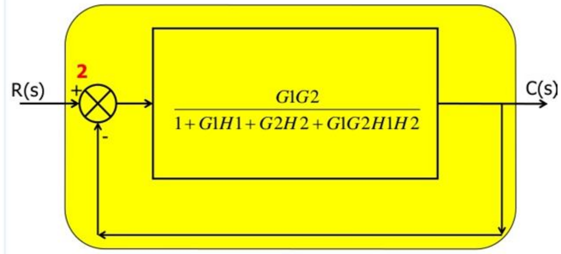
-------It is blocks in parallel **OR**

-------It is feed back loop

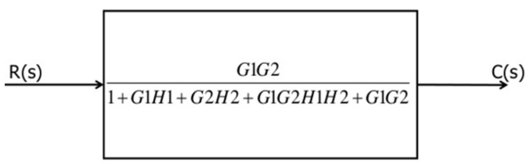
Example 4: Cont....

Let us rearrange the block diagram to understand

Apply Rule 3 Elimination of feed back loop



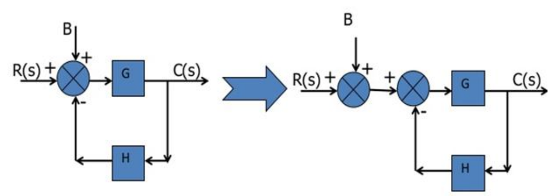
Example 4: Cont....



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

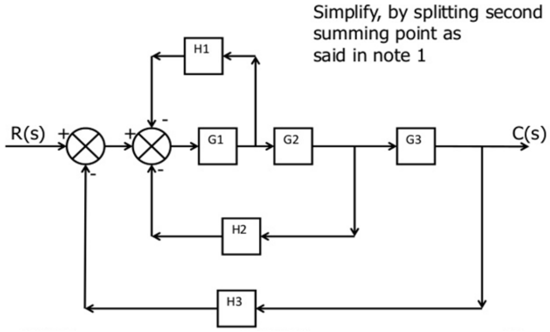
According to Rule 4

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



Example 5:

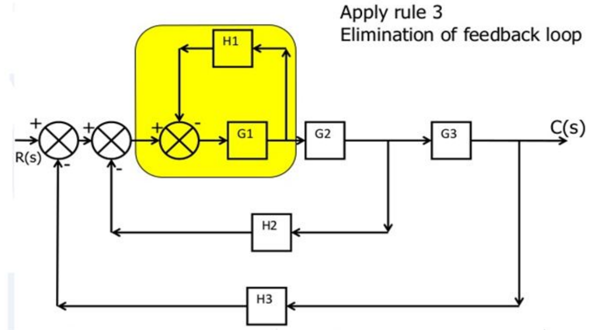
Simplify, by splitting second summing point as said in note 1



Example 5: Cont....

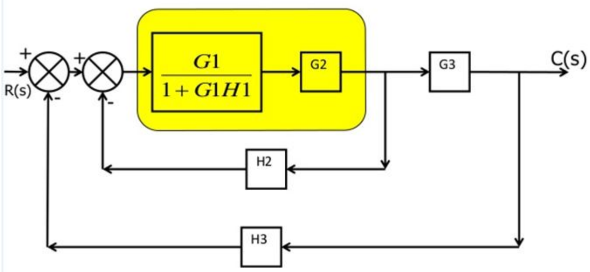
Apply rule 3

Elimination of feedback loop



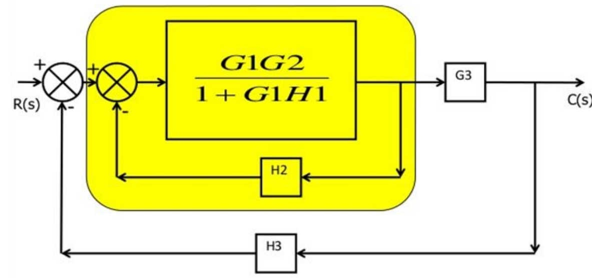
Example 5: Cont....

Apply rule 1 Blocks in series



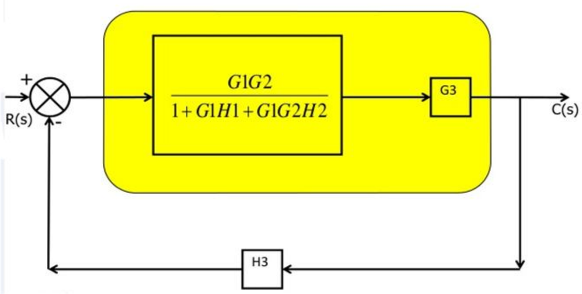
Example 5: Cont....

Apply rule 3 Elimination of feedback loop



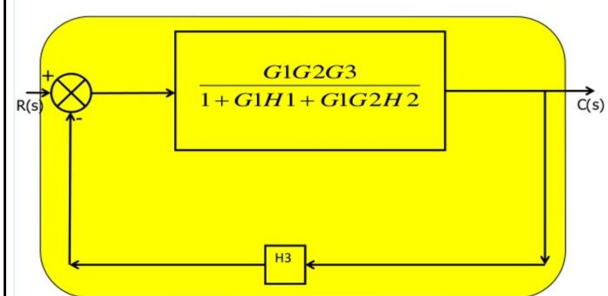
Example 5: Cont....

Apply rule 1 Blocks in series

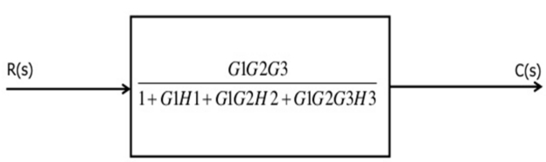


Example 5: Cont....

Apply rule 3 Elimination of feedback loop



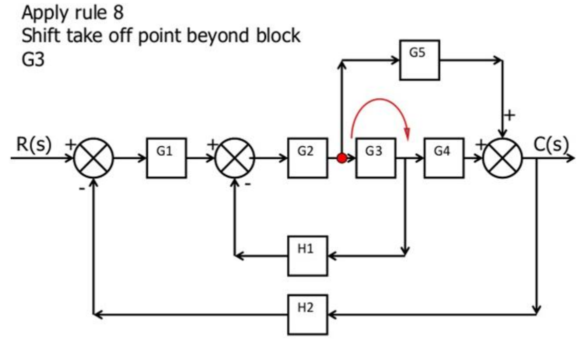
Example 5: Cont....



$$\frac{C(s)}{R(s)} = \frac{G1G2G3}{1+G1H1+G1G2H2+G1G2G3H3}$$

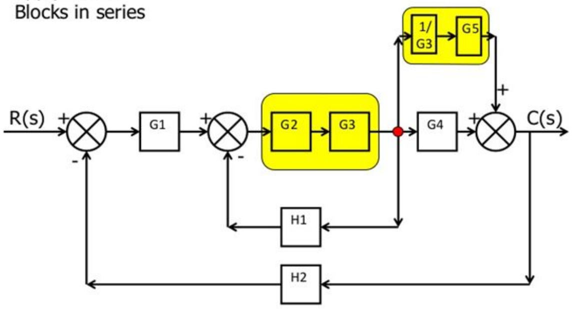
Example 6:

Apply rule 8
Shift take off point beyond block G3



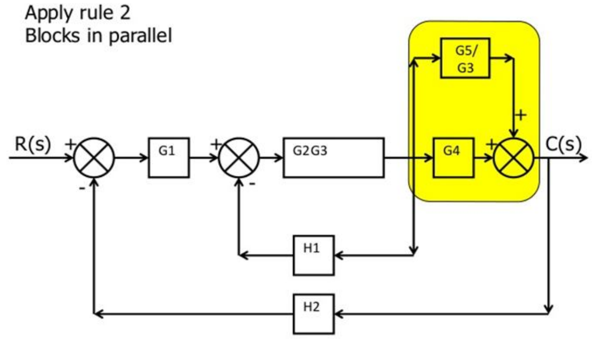
Example 6: Cont....

Apply rule 1
Blocks in series



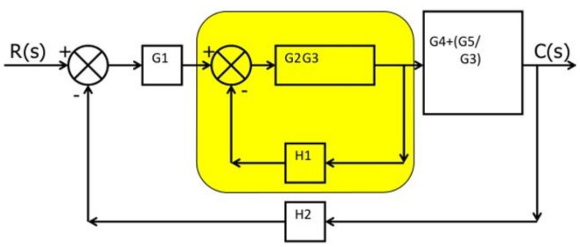
Example 6: Cont....

Apply rule 2
Blocks in parallel



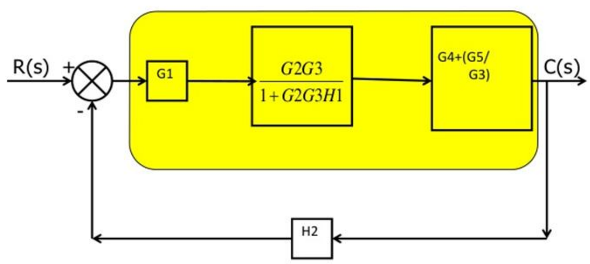
Example 6: Cont....

Apply rule 3
Feedback loop



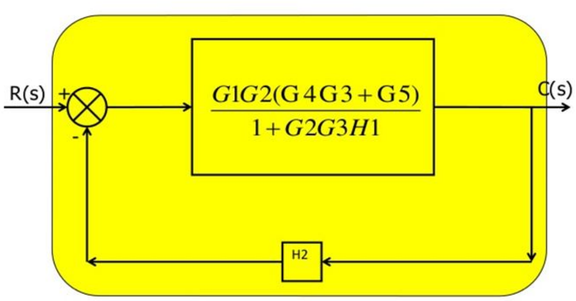
Example 6: Cont....

Apply rule 1
Blocks in series

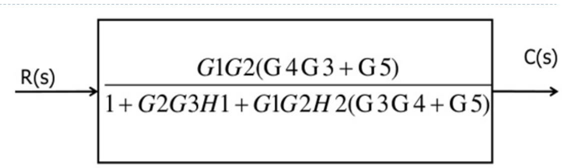


Example 6: Cont....

Apply rule 3 Feedback loop



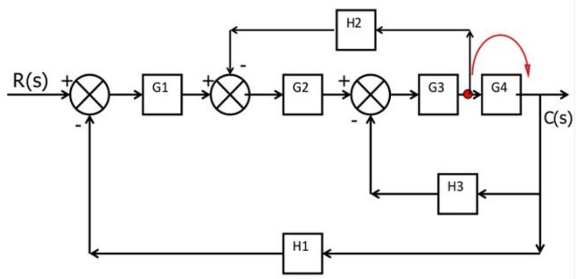
Example 6: Cont....



$$\frac{C(S)}{R(S)} = \frac{G1G2(G4G3+G5)}{1+G2G3H1+G1G2H2(G3G4+G5)}$$

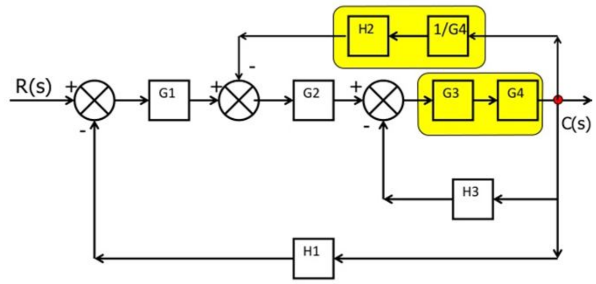
Example 7:

Apply rule 8 Shift take off point after block G4



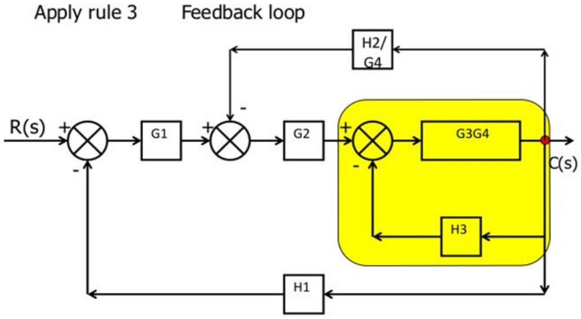
Example 7: Cont....

Apply rule 1 Blocks in series



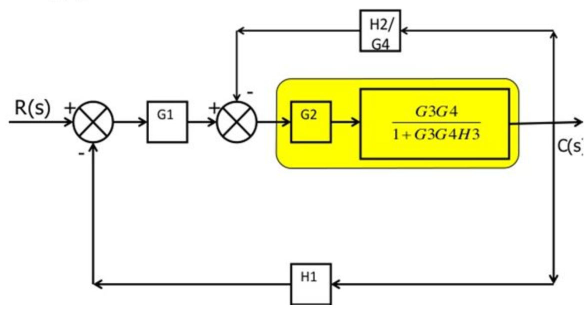
Example 7: Cont....

Apply rule 3 Feedback loop



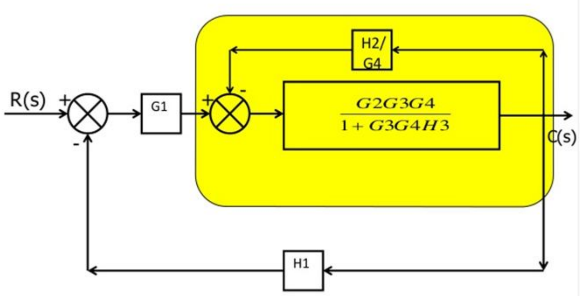
Example 7: Cont....

Apply rule 1 Blocks in series



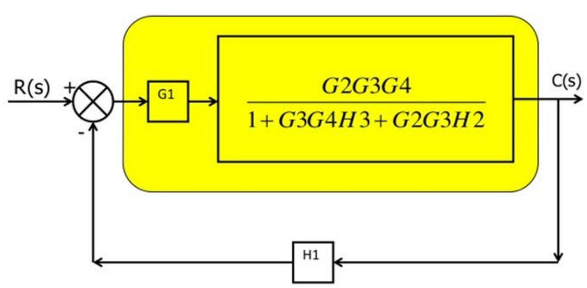
Example 7: Cont....

Apply rule 3 Feedback loop



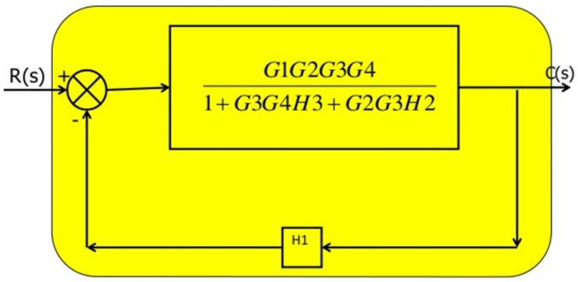
Example 7: Cont....

Apply rule 1 Blocks in series

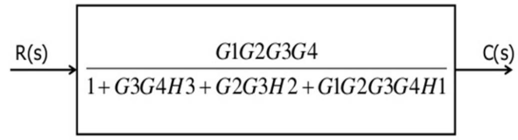


Example 7: Cont....

Apply rule 3 Feedback loop



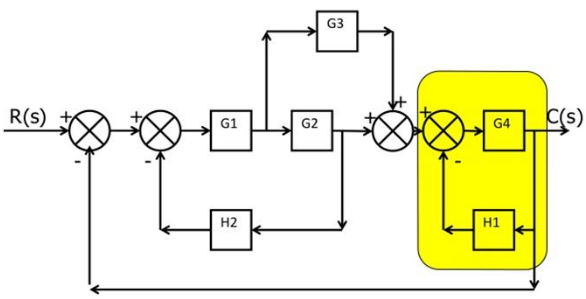
Example 7: Cont....



$$\frac{C(S)}{R(S)}=\frac{G1G2G3G4}{1+G3G4H3+G2G3H2+G1G2G3G4H1}$$

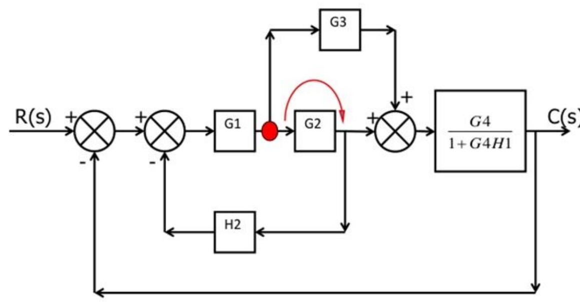
Example 8:

Apply Rule 3 Elimination of Feedback loop



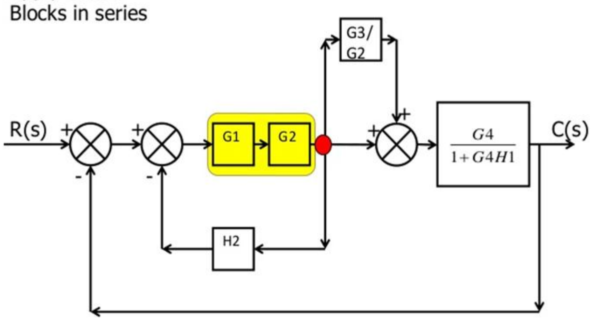
Example 8: Cont....

Apply Rule 8 Shift take off point after block



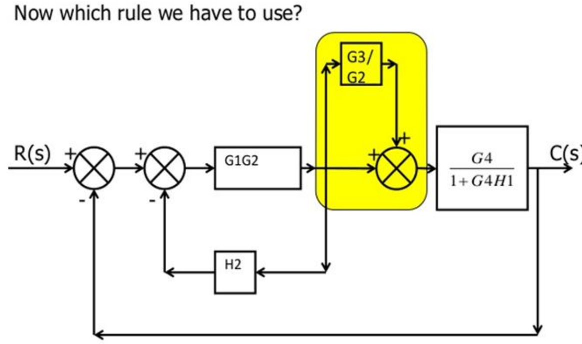
Example 8: Cont....

Apply Rule 1
Blocks in series



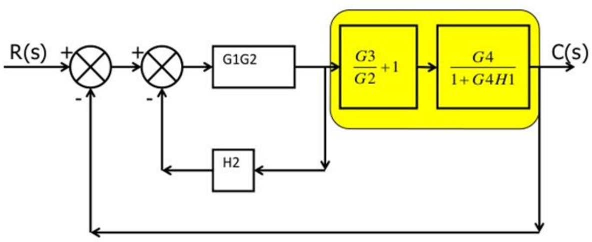
Example 8: Cont....

Now which rule we have to use?



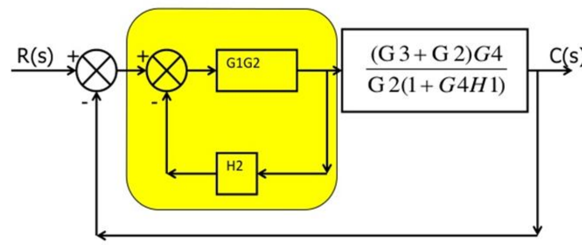
Example 8: Cont....

Apply Rule 1 Blocks in series



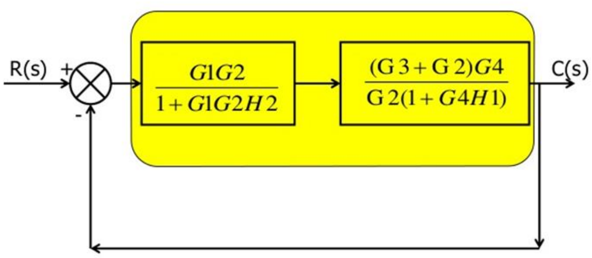
Example 8: Cont....

Apply Rule 3 Elimination of Feedback Loop



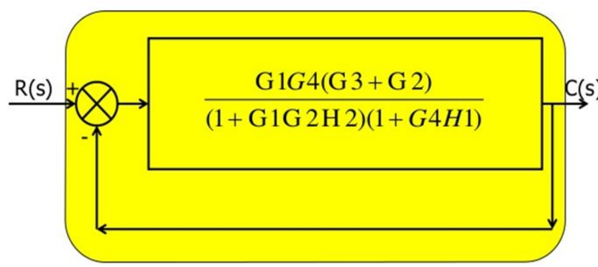
Example 8: Cont....

Apply Rule 1 Blocks in series

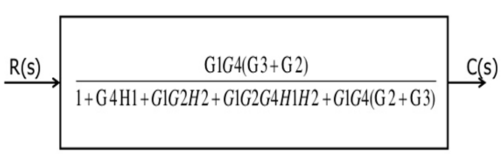


Example 8: Cont....

Apply Rule 3 Elimination of Feedback loop



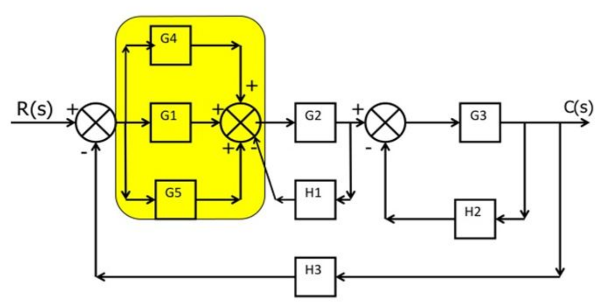
Example 8: Cont....



$$\frac{C(s)}{R(s)} = \frac{G1G4(G3+G2)}{1+G4H1+G1G2H2+G1G2G4H1H2+G1G4(G2+G3)}$$

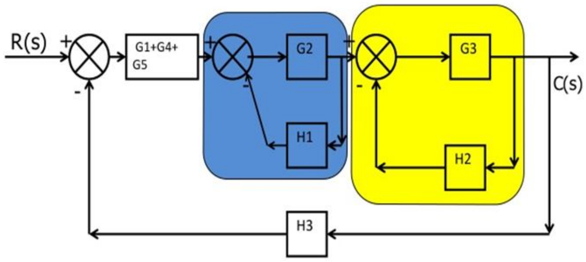
Example 9:

Apply rule 2 Blocks in Parallel



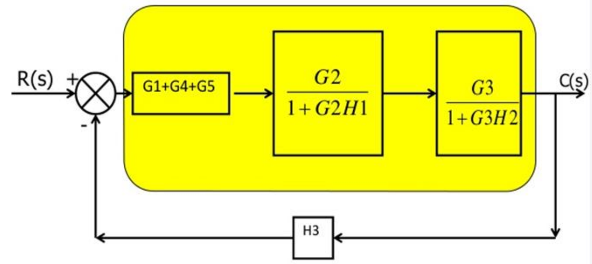
Example 9: Cont....

Apply rule 3 Elimination of Feedback Loop



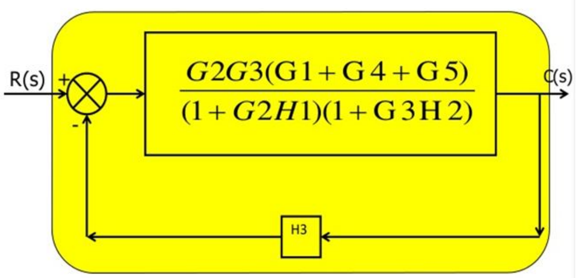
Example 9: Cont....

Apply rule 1 Blocks in Series

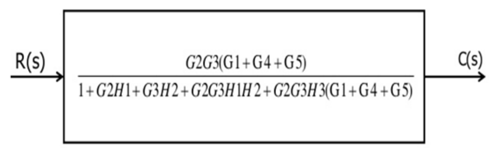


Example 9: Cont....

Apply rule 3 Elimination of Feedback loop



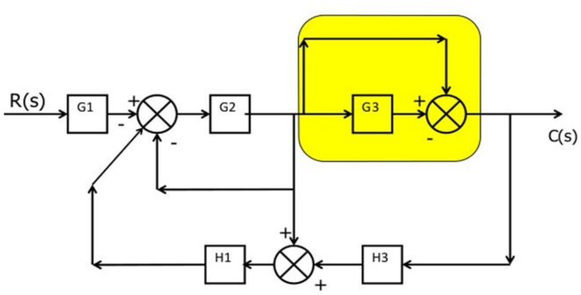
Example 9: Cont....



$$\frac{C(s)}{R(s)} = \frac{G2G3(G1+G4+G5)}{1+G2H1+G3H2+G2G3H1H2+G2G3H3(G1+G4+G5)}$$

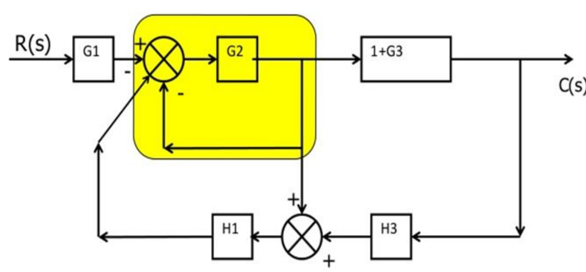
Example 10:

Apply rule 2 Blocks in Parallel



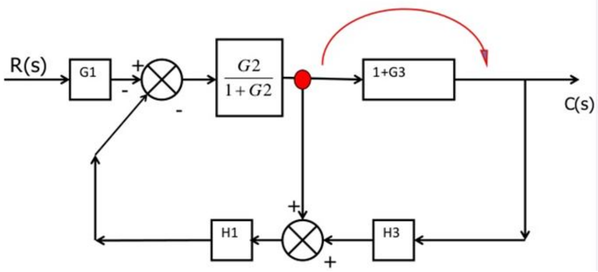
Example 10: Cont....

Apply rule 3 Elimination of Feedback Loop



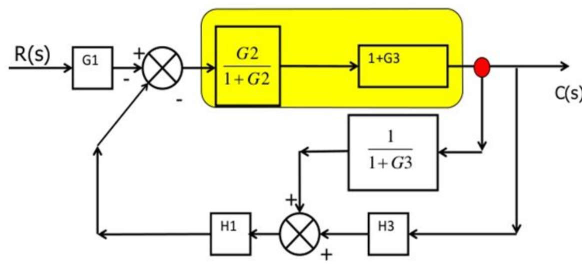
Example 10: Cont....

Apply rule 8 Shift take off point after block



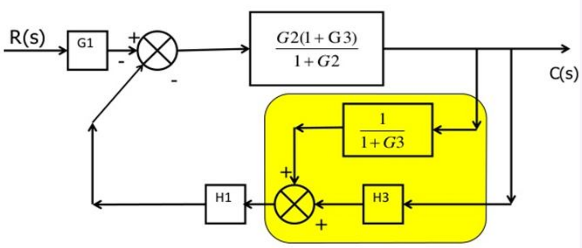
Example 10: Cont....

Apply rule 1 Blocks in series



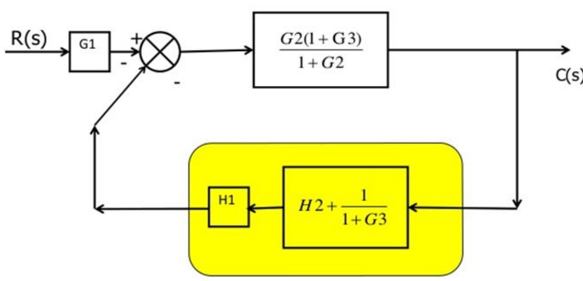
Example 10: Cont....

Apply rule 2 Blocks in Parallel



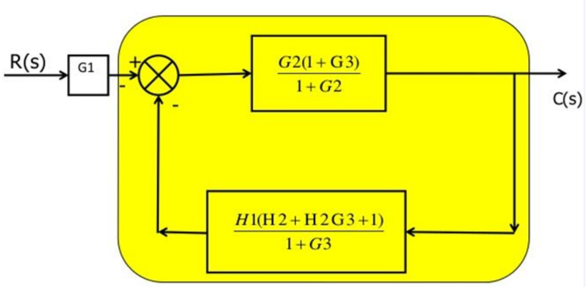
Example 10: Cont....

Apply rule 1 Blocks in Series



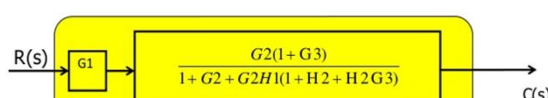
Example 10: Cont....

Apply rule 3 Elimination of Feedback loop

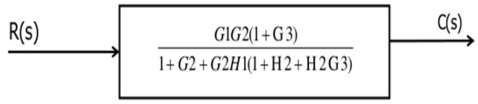


Example 10: Cont....

Apply rule 1 Blocks in series



Example 10: Cont....



$$\frac{C(s)}{R(s)} = \frac{G1G2(1+G3)}{1+G2+G2H1(1+H2+H2G3)}$$

Summary

- Significance of Block Diagram.
- Block Diagram Reduction Techniques.
- Examples of Block Diagram Reduction.