CHAPTER 3

Block Diagrams & Signal flow graphs

By

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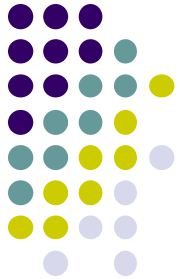
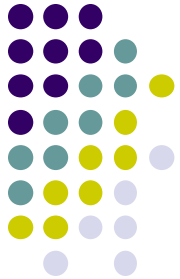


Introduction

Introduction

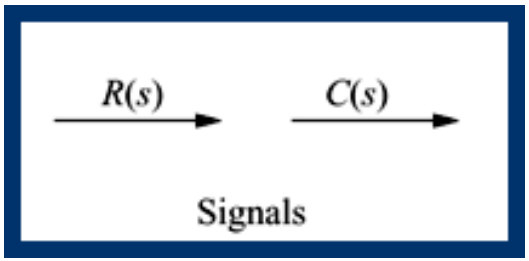
- We have been working with individual subsystems represented by a block with its input and output.
- More complicated systems, however, are represented by the interconnection of many subsystems.
- Since the response of a single transfer function can be calculated, we want to represent multiple subsystems as a single transfer function.
- In this chapter, multiple subsystems are represented in two ways: as block diagrams and as signal-flow graphs.
- Signal-flow graphs represent transfer functions as lines, and signals as small circular nodes.

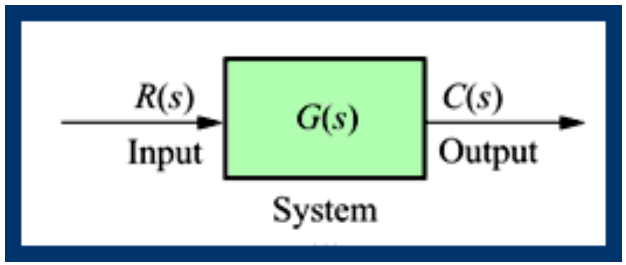


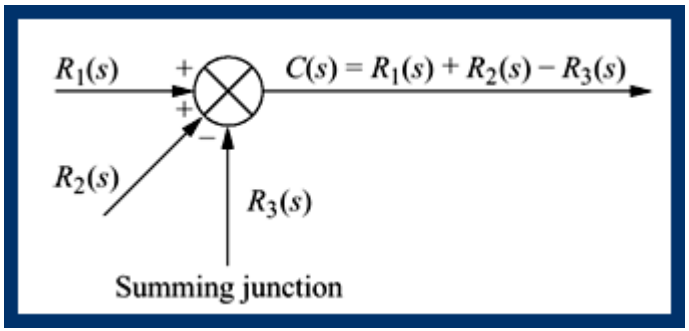
Block Diagrams

Block Diagrams

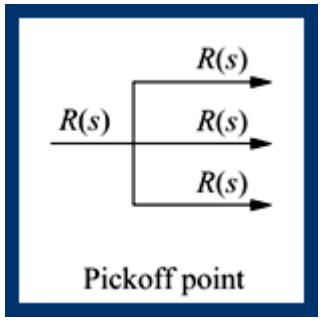
When multiple subsystems are interconnected, a few more schematic elements must be added to the block diagram. These new elements are ***summing junctions*** and ***take off points***.







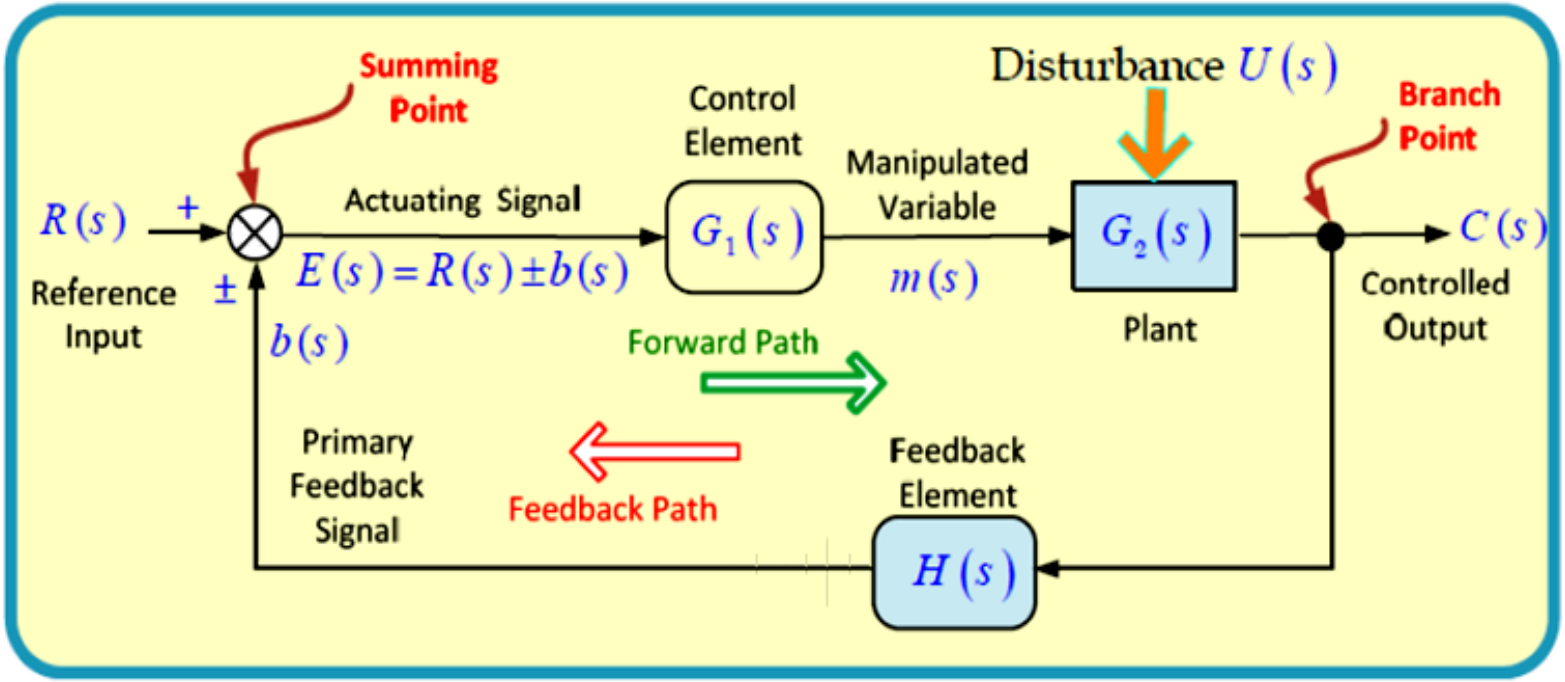
Summing point



Take off point

Block Diagrams

Block diagram components

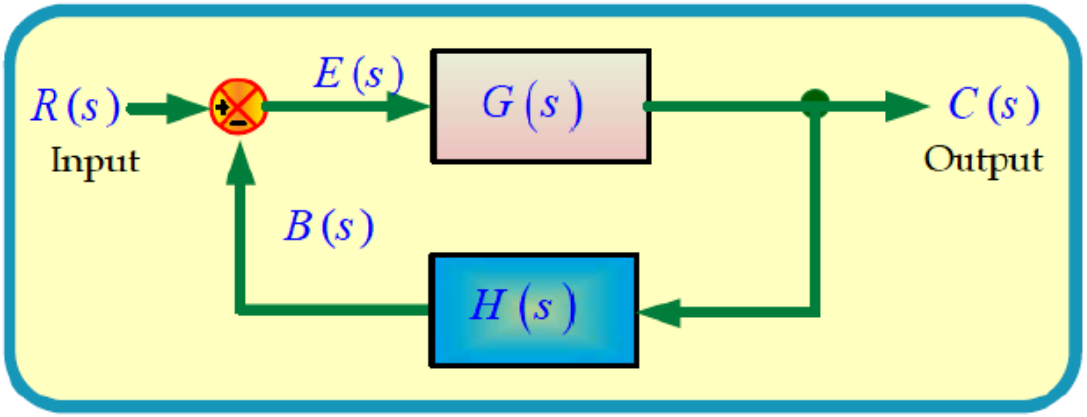


Definitions

- $G(s)$ ≡ Direct transfer function = Forward transfer function.
- $H(s)$ ≡ Feedback transfer function.
- $C(s)/R(s)$ ≡ Closed-loop transfer function = Control ratio
- $C(s)/E(s)$ ≡ Feed-forward transfer function.

Block Diagrams

Closed-Loop Transfer Function



$$C(s) = G(s)\,E(s)$$
$$= G(s)\,[R(s) - B(s)]$$
$$= G(s)\,[R(s) - H(s)C(s)]$$
$$= G(s)R(s) - G(s)H(s)C(s)$$

$$G(s)R(s) = C(s) + G(s)H(s)C(s)$$
$$G(s)R(s) = C(s)[1 + G(s)H(s)]$$

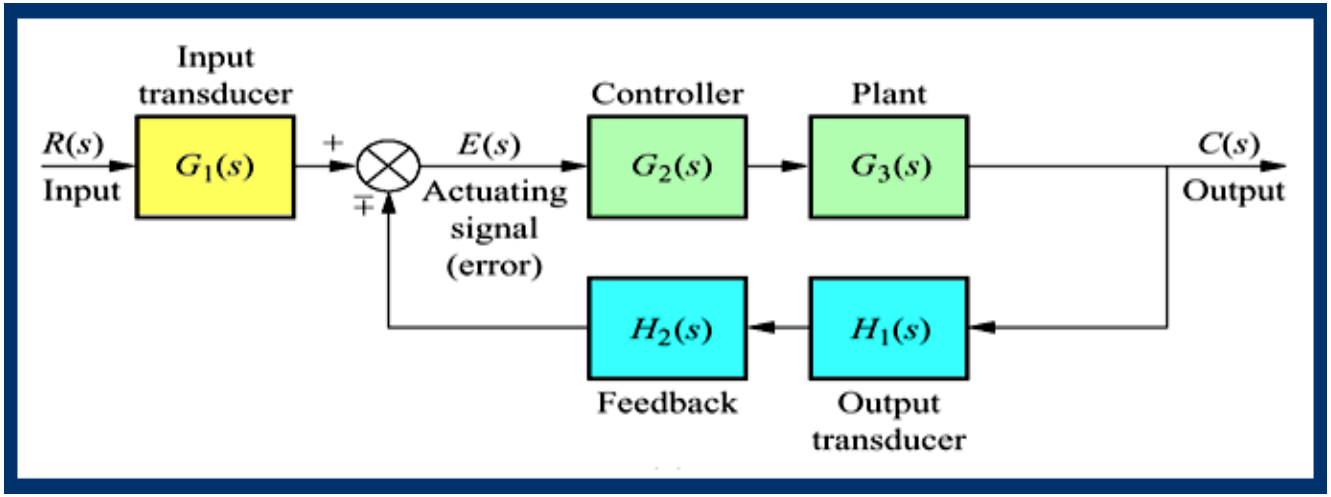
$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)}$$

$C(s)/R(s)$ ≡ Closed-loop transfer function = Control ratio

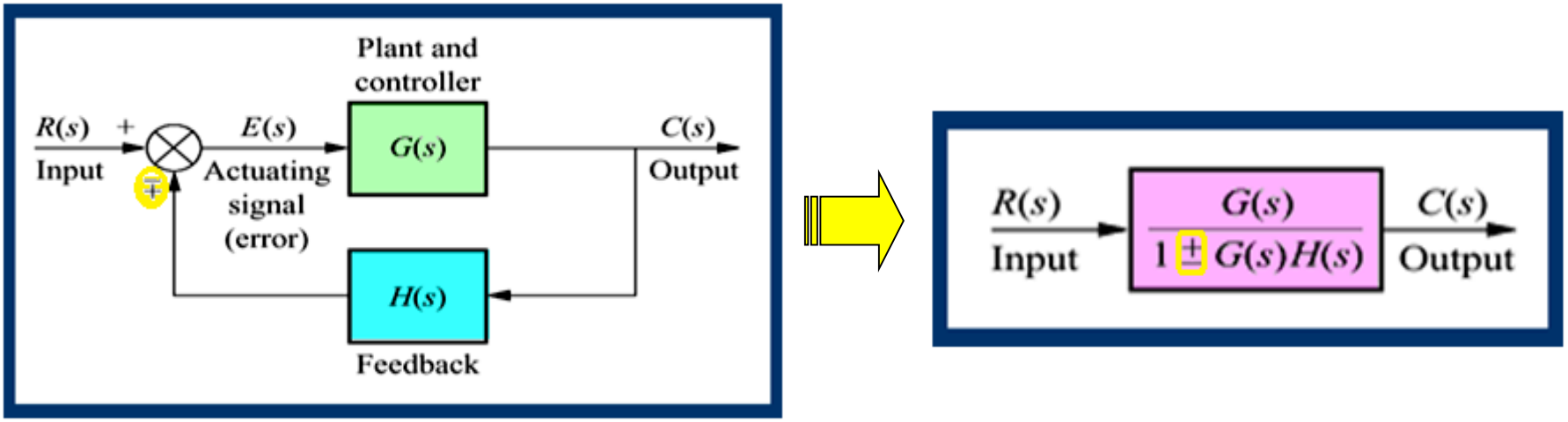
Block Diagrams

Feedback Form

The typical feedback system, is shown in figure below.



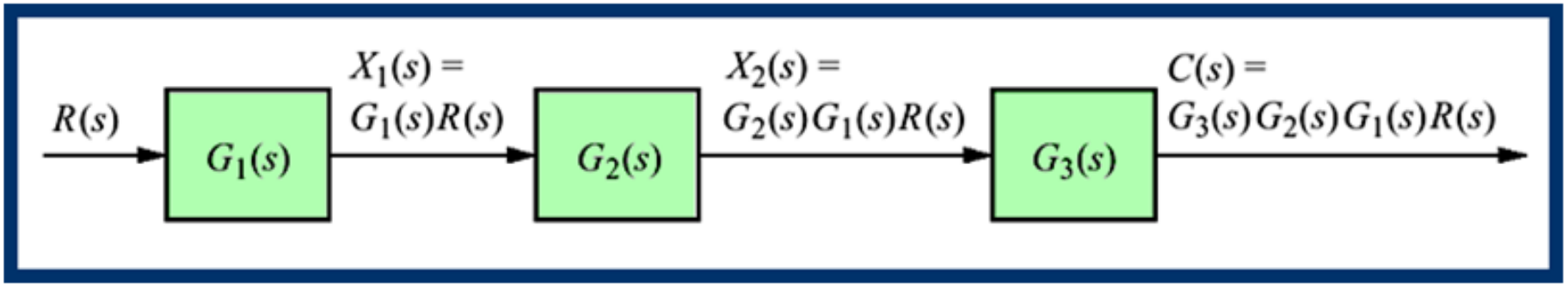
a simplified model is shown in the following Figure.

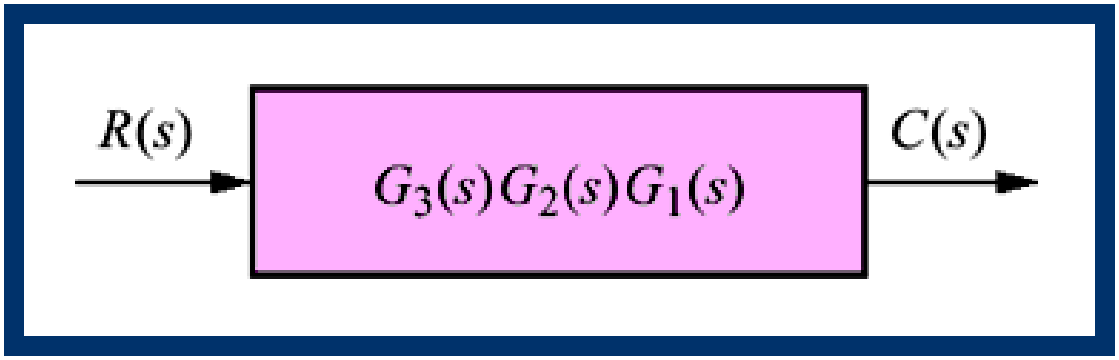


Block Diagram Reduction

Block Diagrams

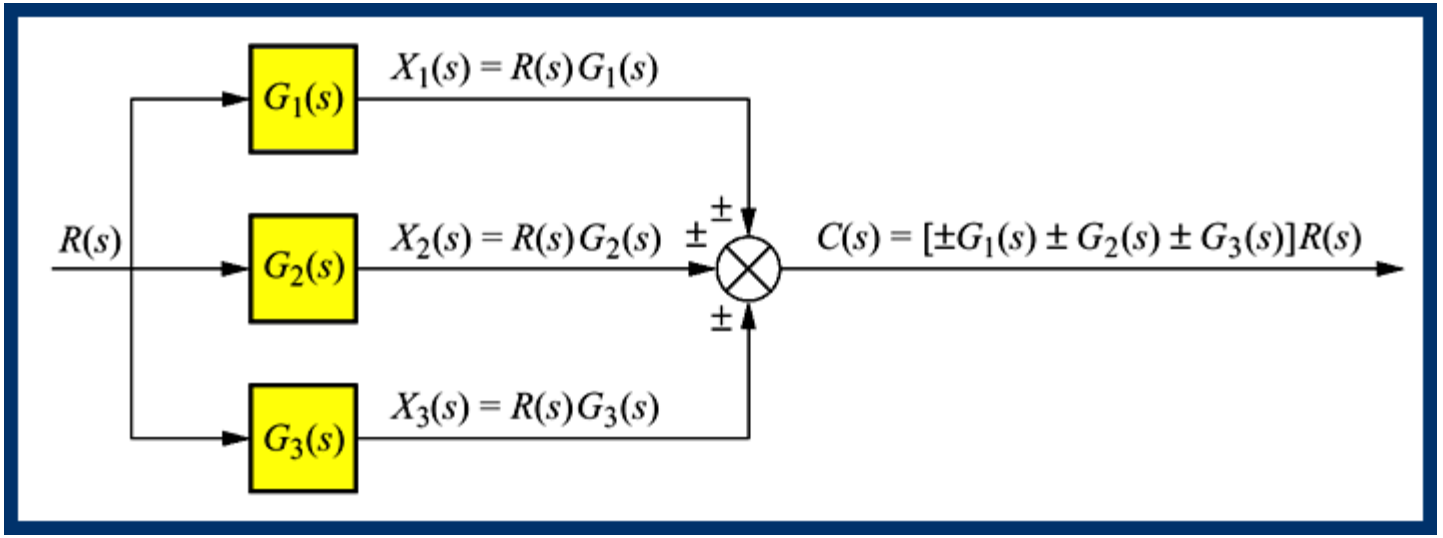
Cascade Form

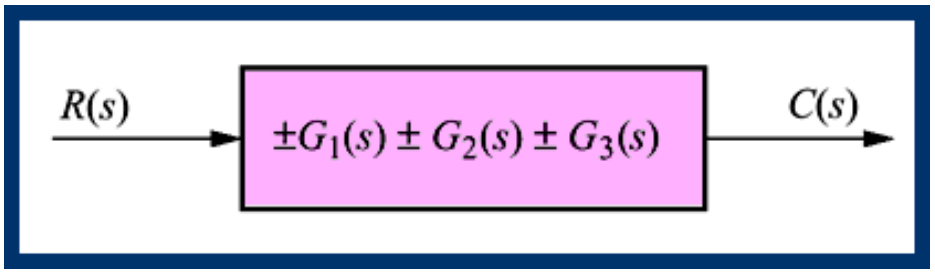




Block Diagrams

Parallel Form

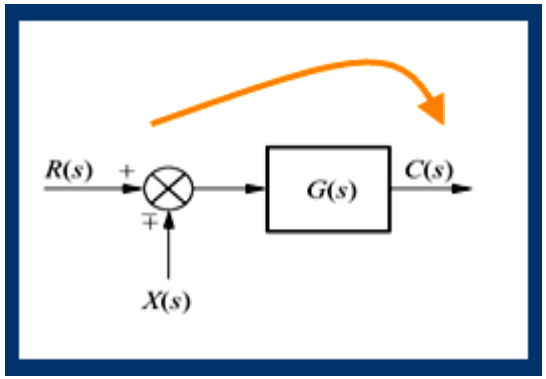




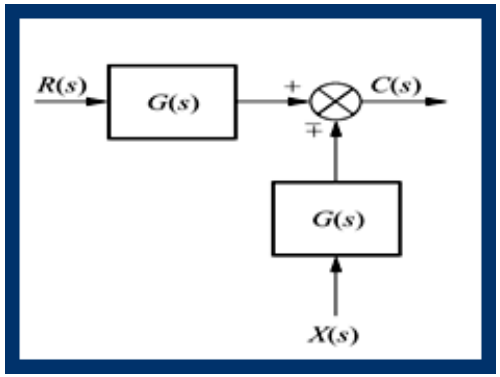
Block Diagrams

Moving Blocks to Create Familiar Forms

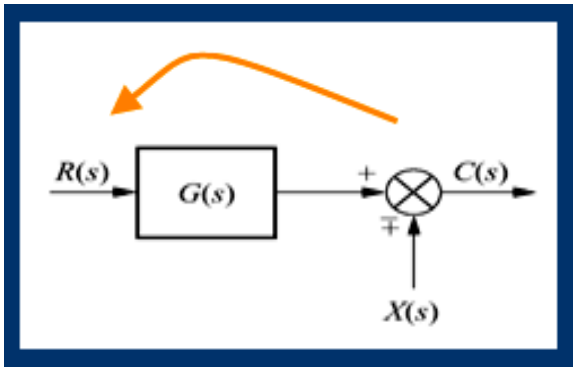
Moving summing point to RIGHT



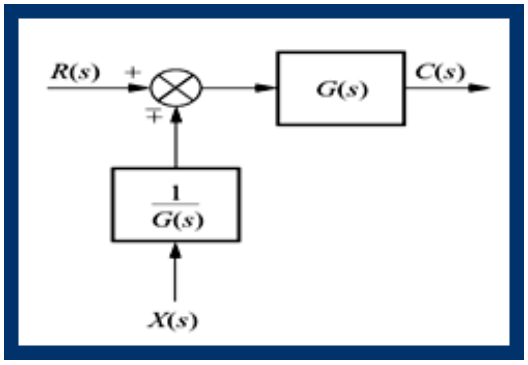
$$C = G(+R \mp X)$$
$$= +GR \mp GX$$



Moving summing point to LEFT



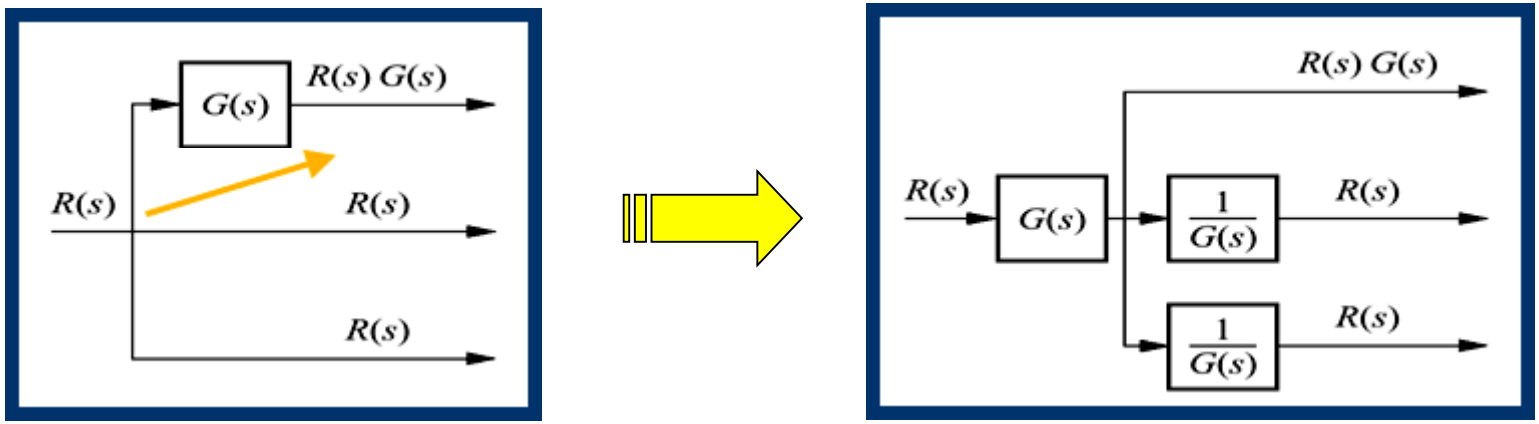
$$C = GR \mp X$$
$$= G(+R \mp X/G)$$



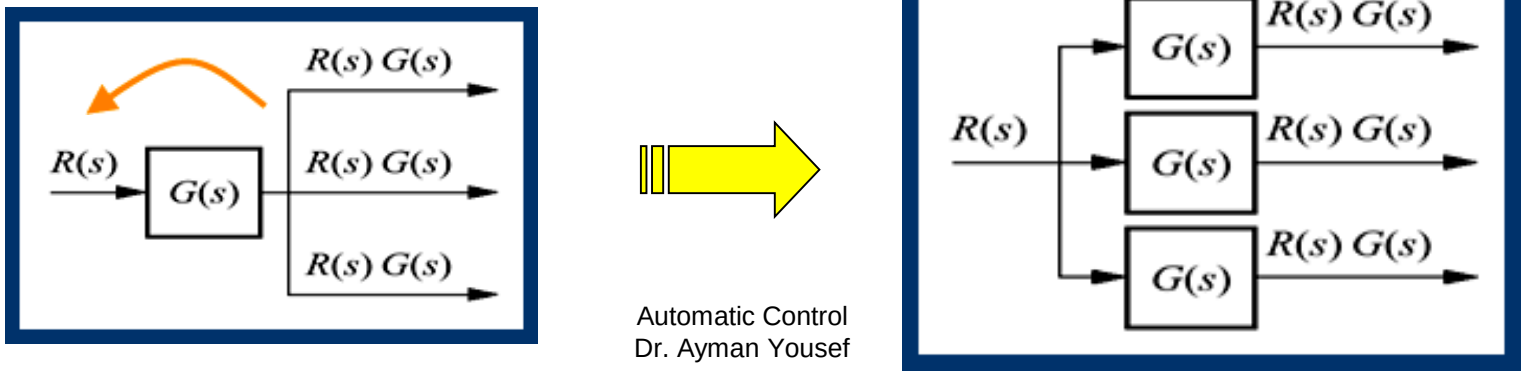
Block Diagrams

Moving Blocks to Create Familiar Forms

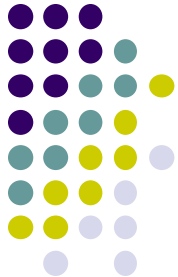
Take off summing point to RIGHT



Take off summing point to LEFT



Block Diagrams

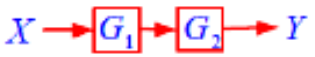
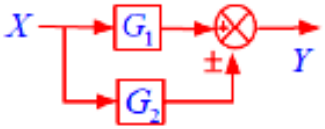
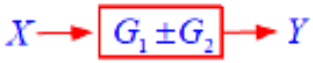
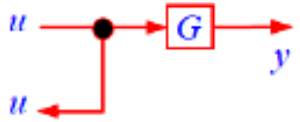
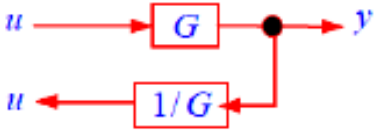
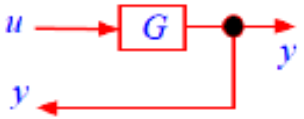
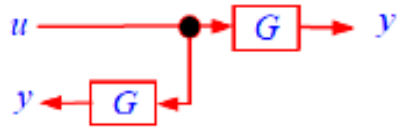
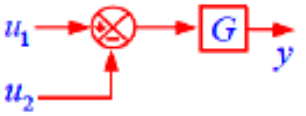
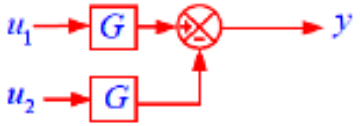
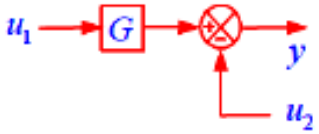
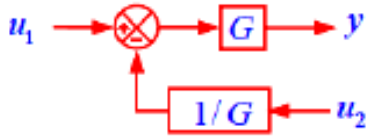


- **Block Diagram Reduction Rules**

1.	Combine all cascade blocks
2.	Combine all parallel blocks
3.	Eliminate all minor (interior) feedback loops
4.	Shift summing points to left
5.	Shift takeoff points to the right
6.	Repeat Steps 1 to 5 until the canonical form is obtained

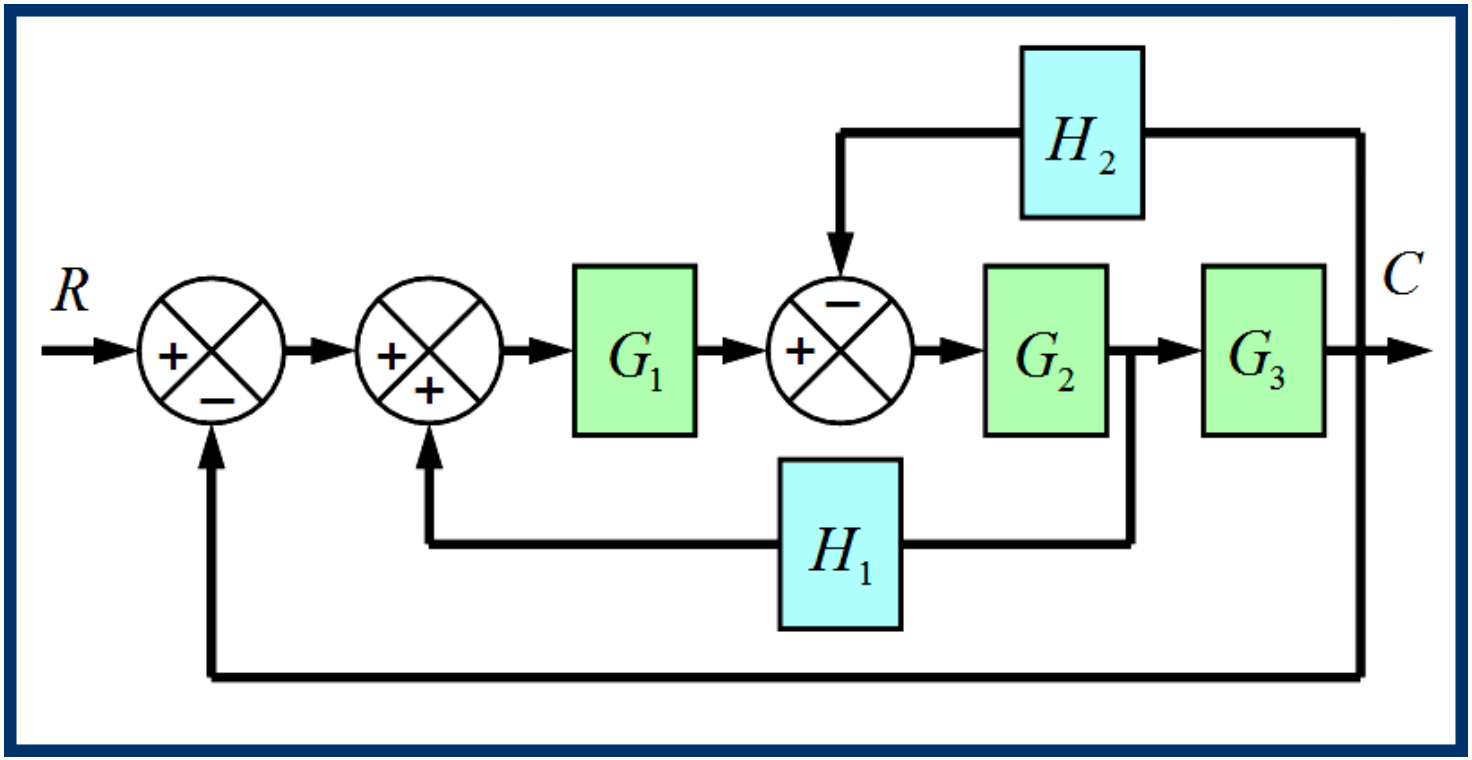
Block Diagrams

- Basic rules with block diagram transformation

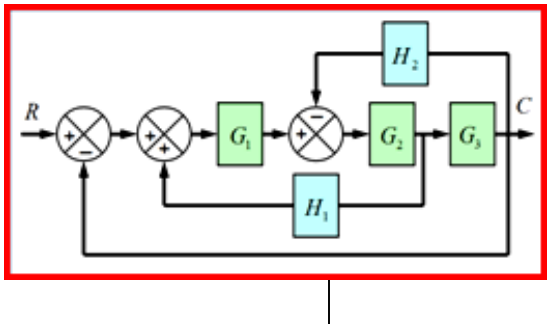
	Manipulation	Original Block Diagram	Equivalent Block Diagram	Equation
1	Combining Blocks in Cascade			$Y = (G_1 G_2) X$
2	Combining Blocks in Parallel; or Eliminating a Forward Loop			$Y = (G_1 \pm G_2) X$
3	Moving a pickoff point behind a block			$y = G u$ $u = \frac{1}{G} y$
4	Moving a pickoff point ahead of a block			$y = Gu$
5	Moving a summing point behind a block			$e_2 = G(u_1 - u_2)$
6	Moving a summing point ahead of a block			$y = Gu_1 - u_2$

Example 1

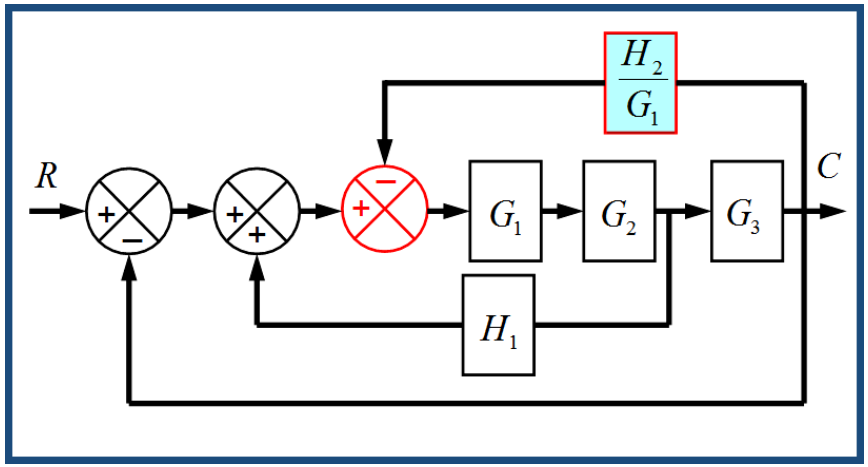
Reduce the system shown to a single T.F.

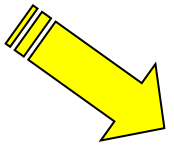


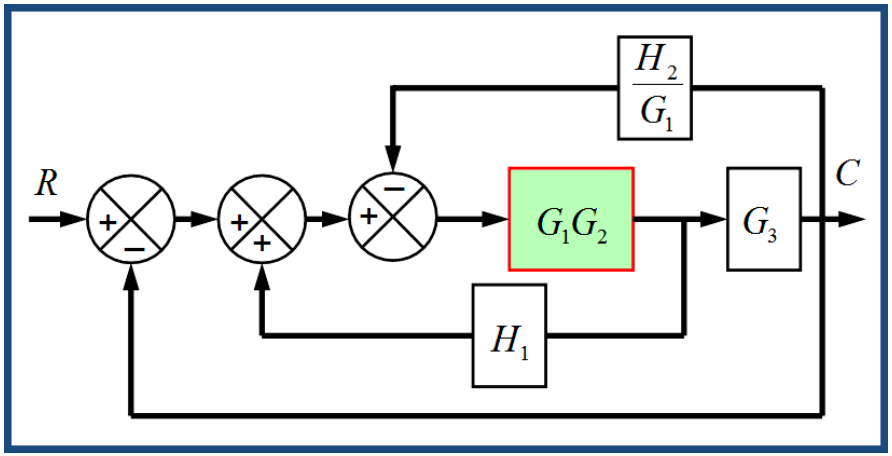
Example 1 (cont'd)



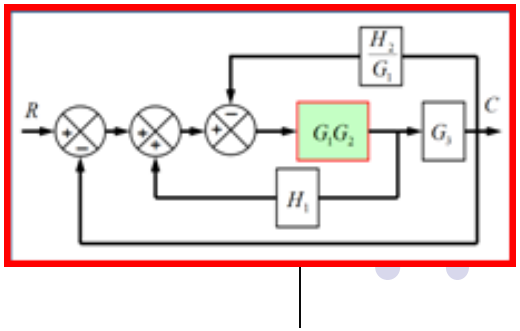
Solution

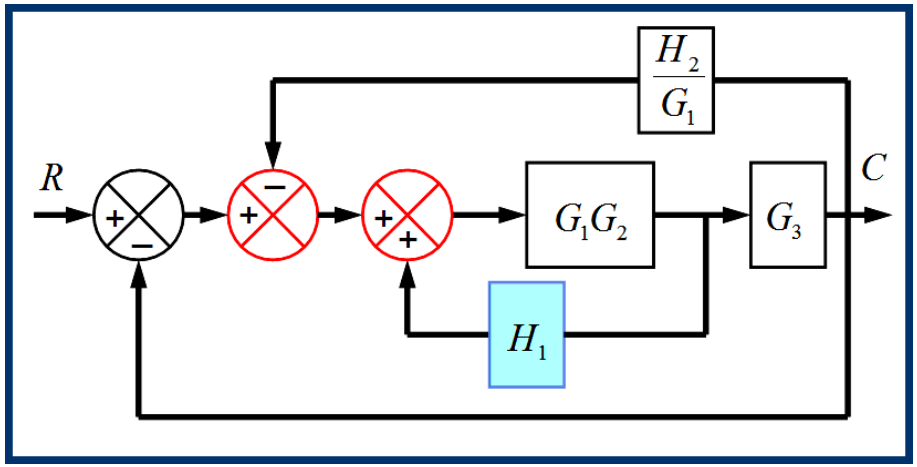


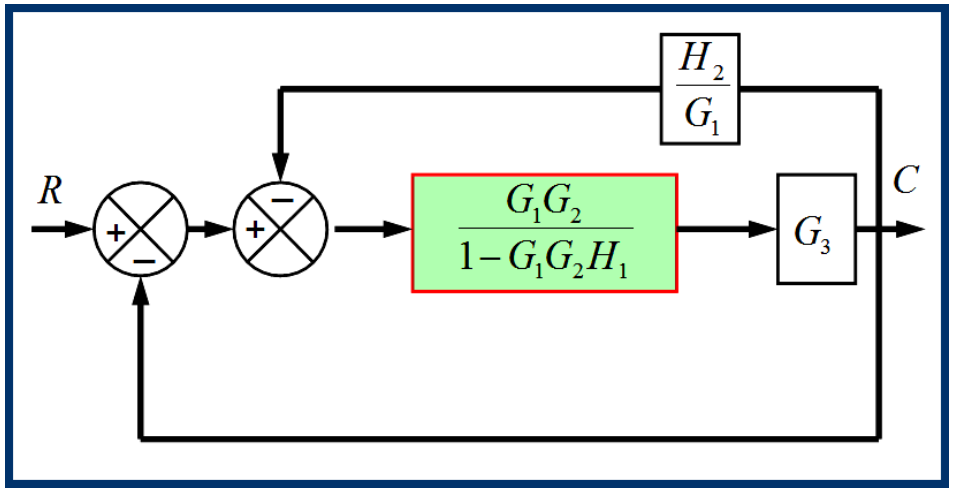




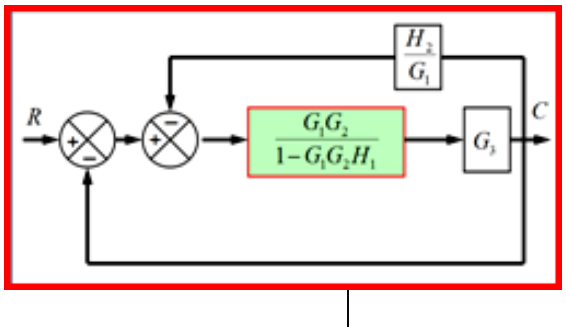
Example 1 (cont'd)

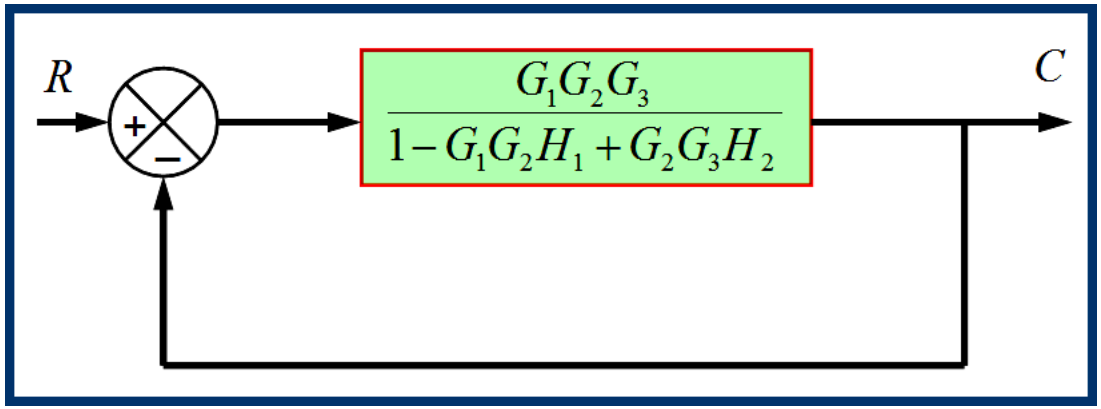


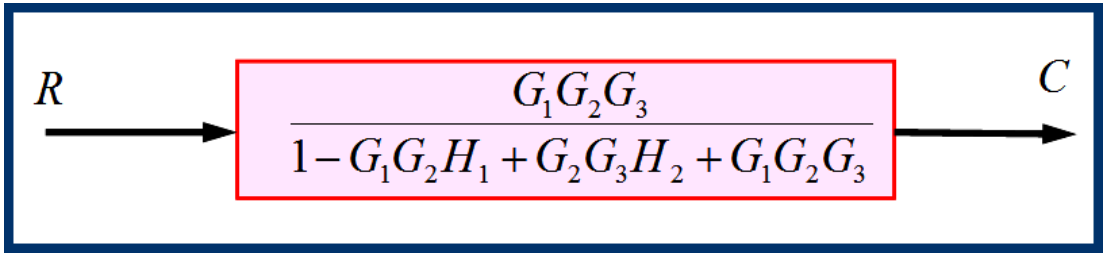




Example 1 (cont'd)

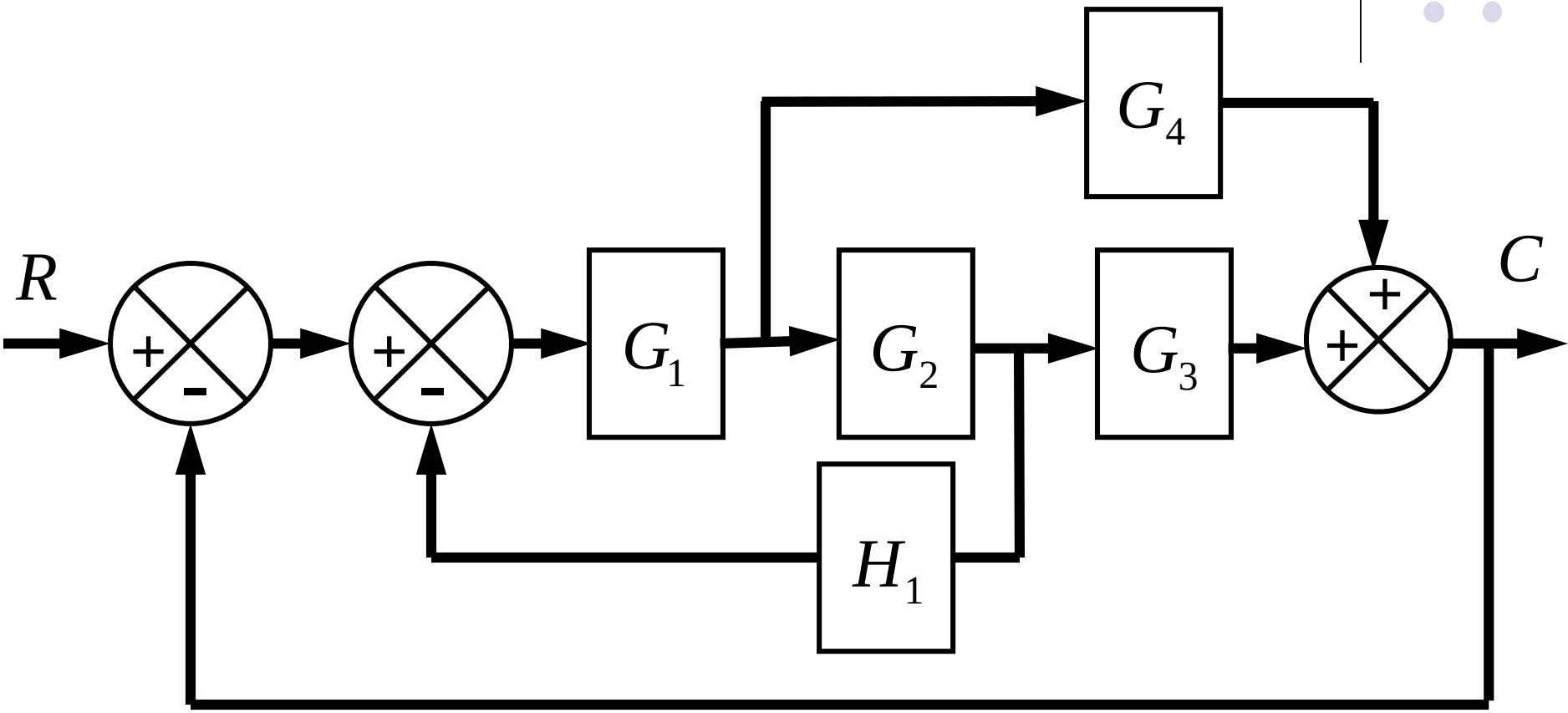






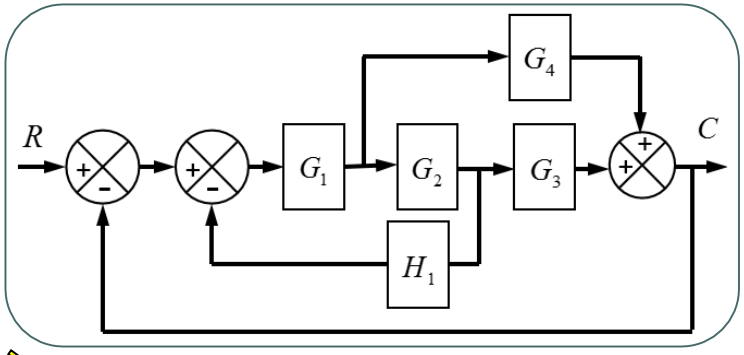
Example 2

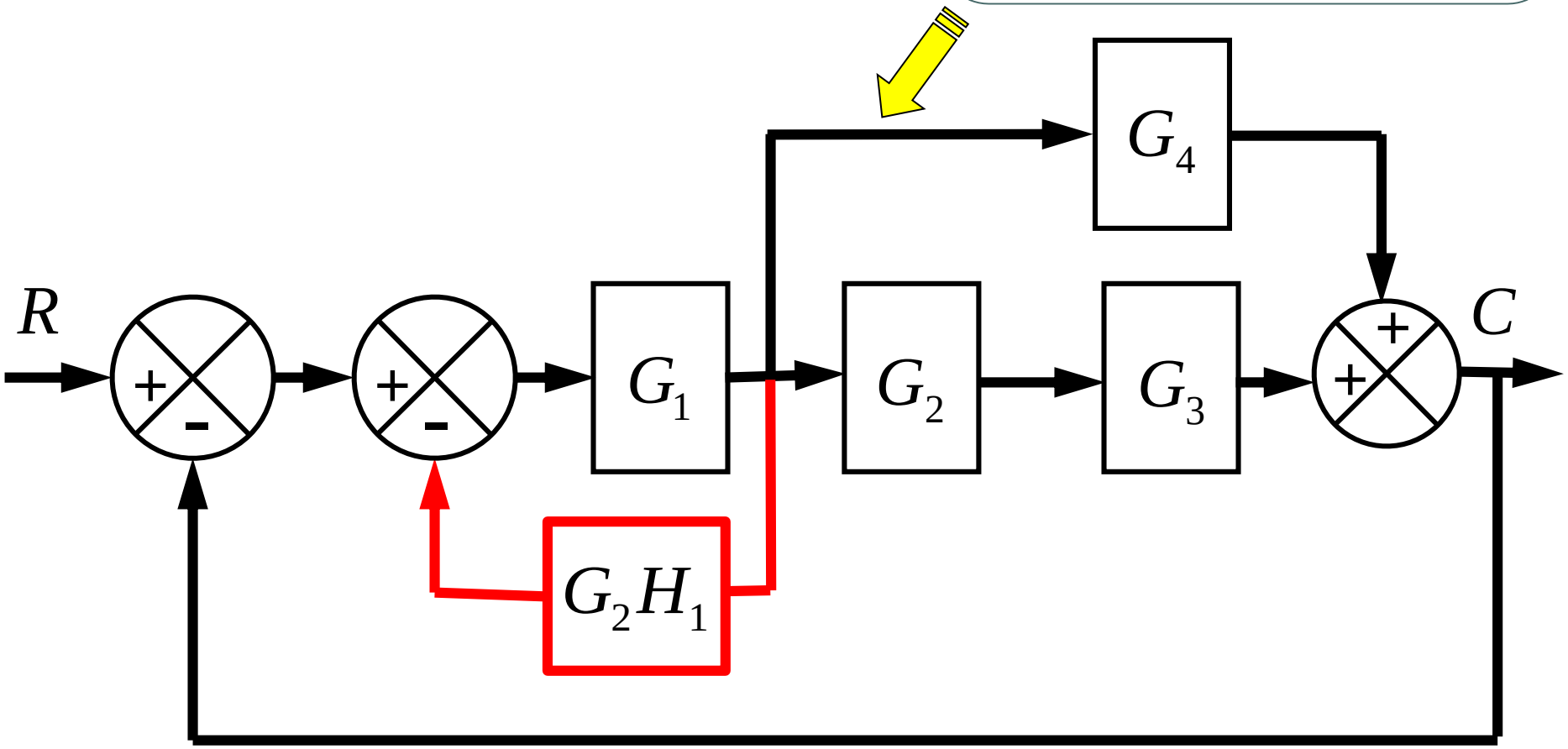
Reduce the system shown to a single T.F.



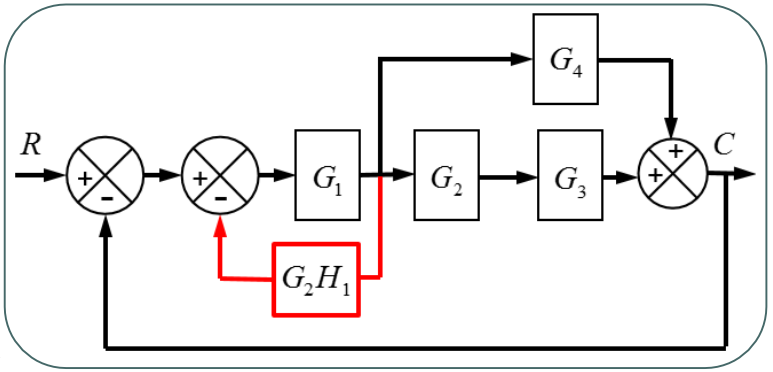
Example 2 (cont'd)

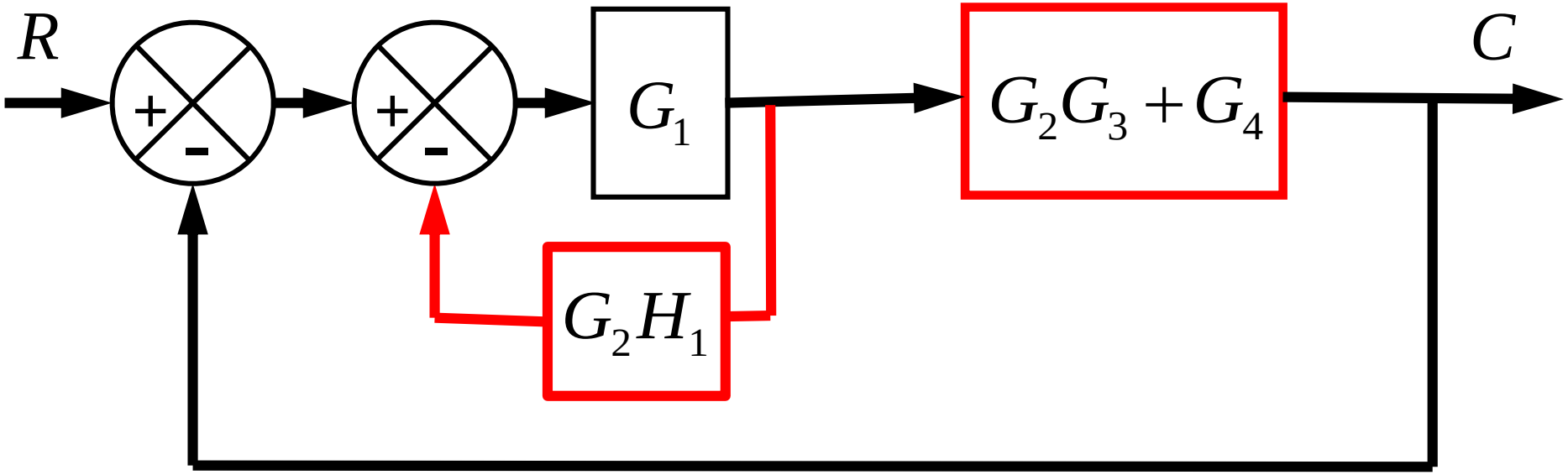
Solution



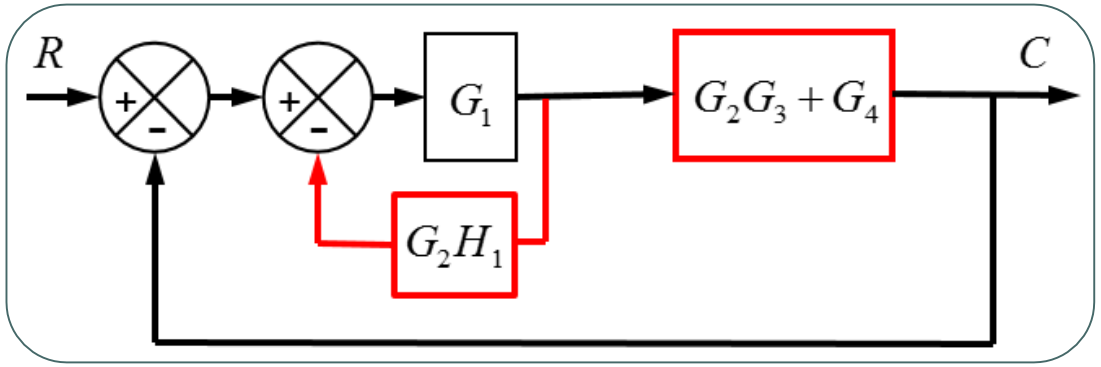


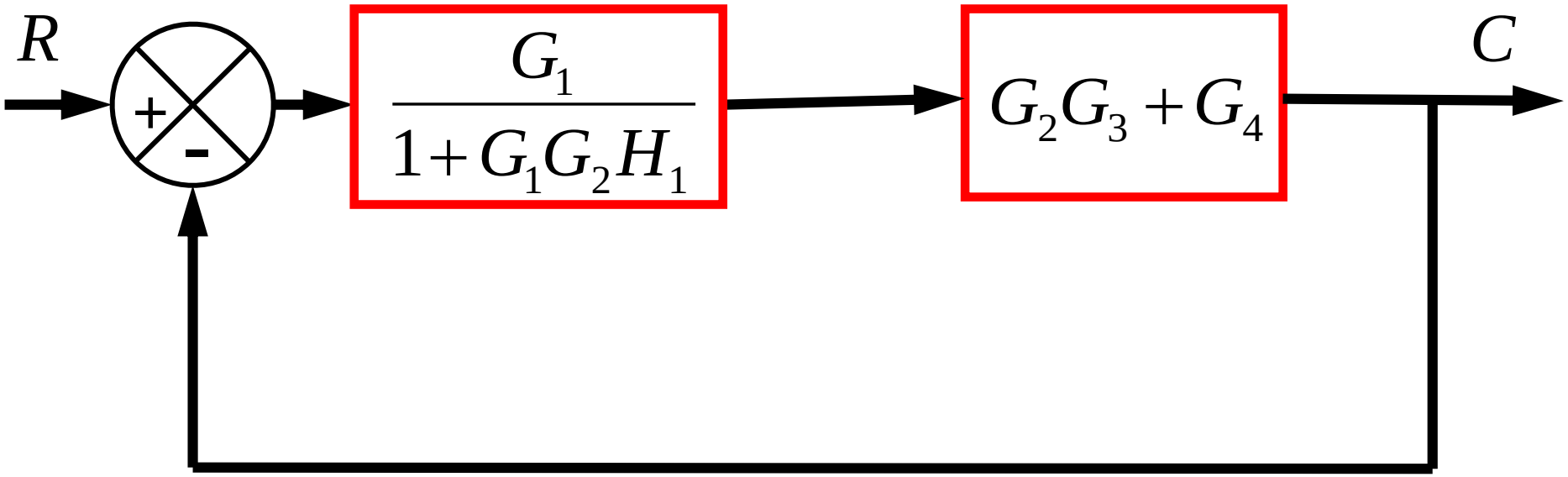
Example 2 (cont'd)



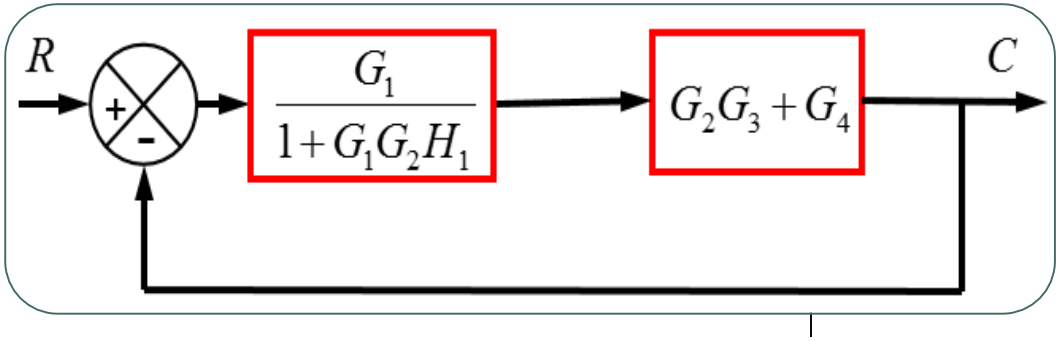


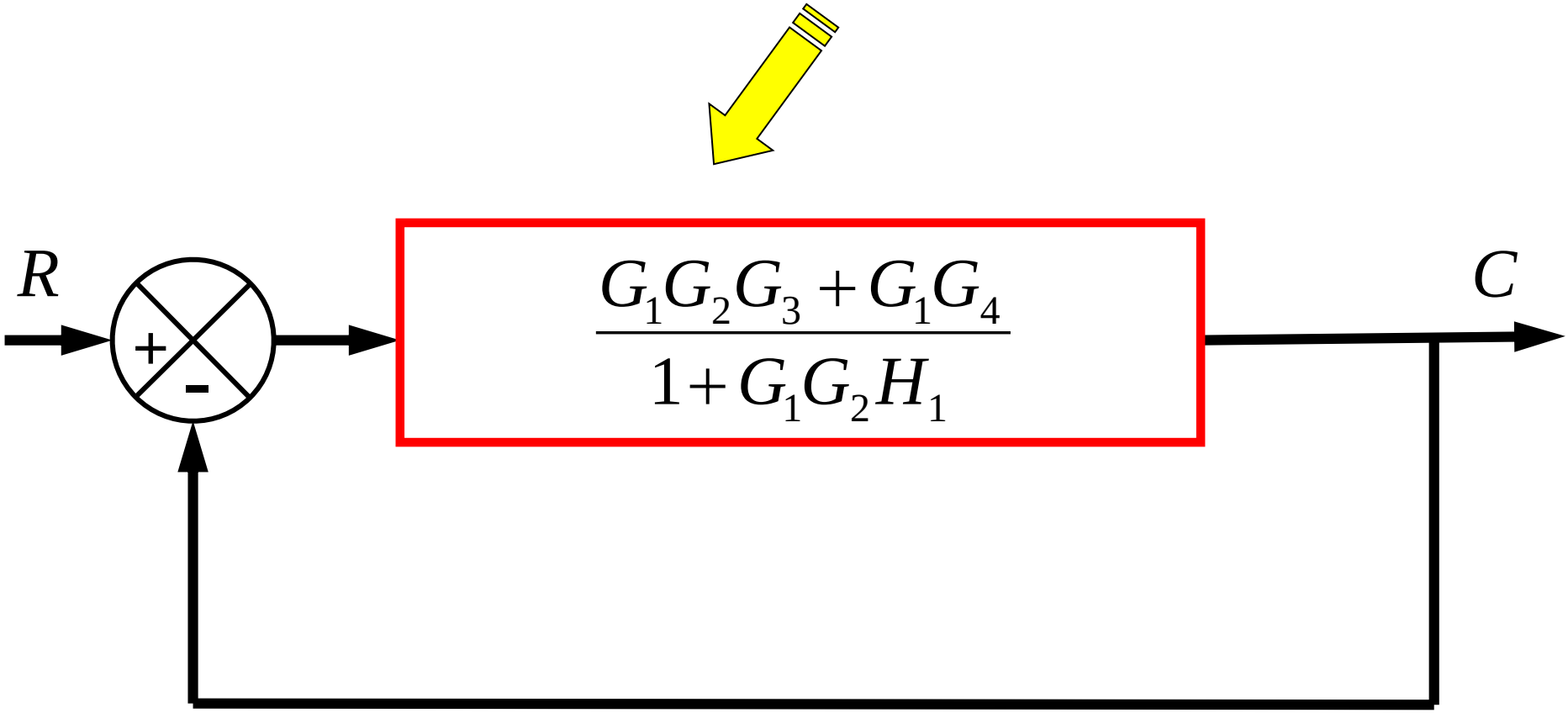
Example 2 (cont'd)



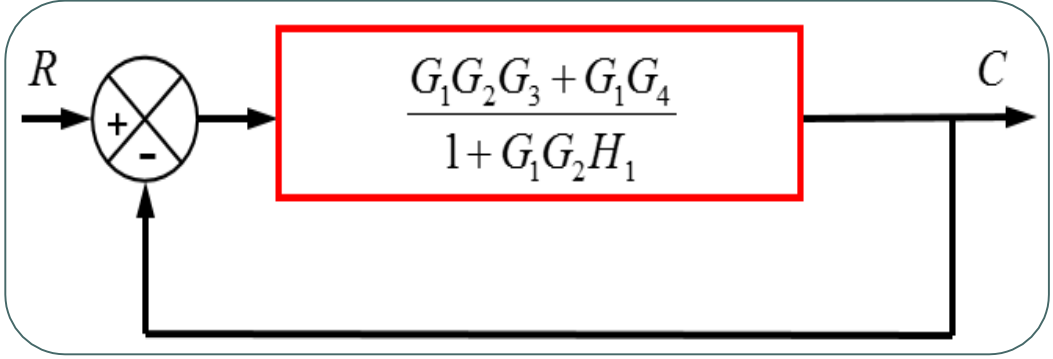


Example 2 (cont'd)





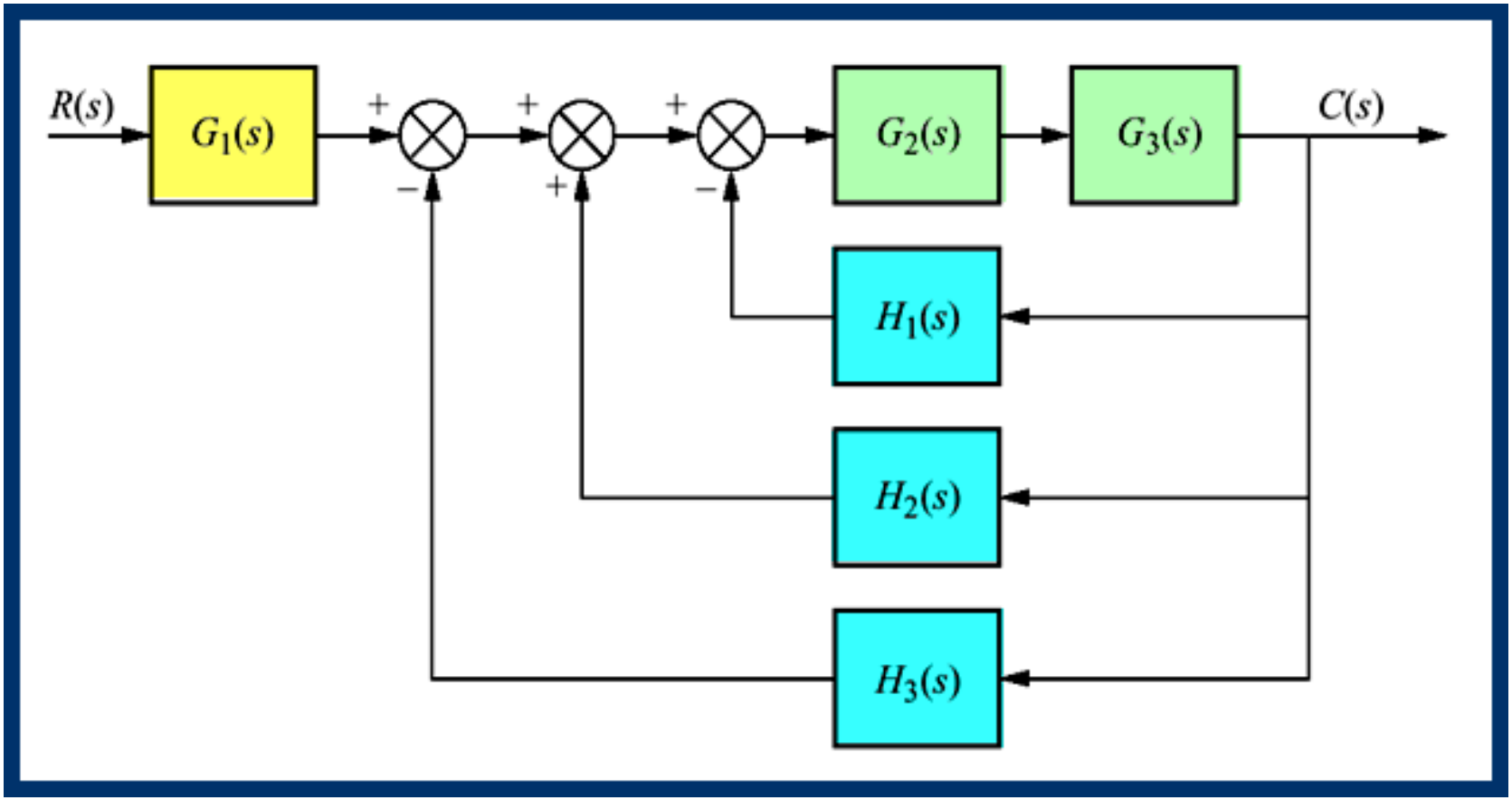
Example 2 (cont'd)



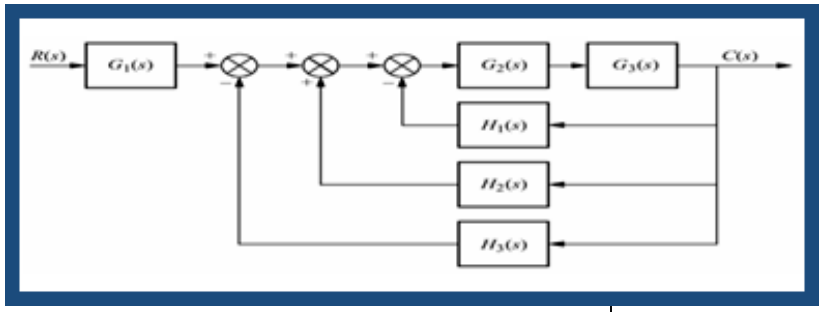
$$R \longrightarrow \frac{G_1G_2G_3+G_1G_4}{1+G_1G_2H_1+G_1G_2G_3+G_1G_4} \longrightarrow C$$

Example 3

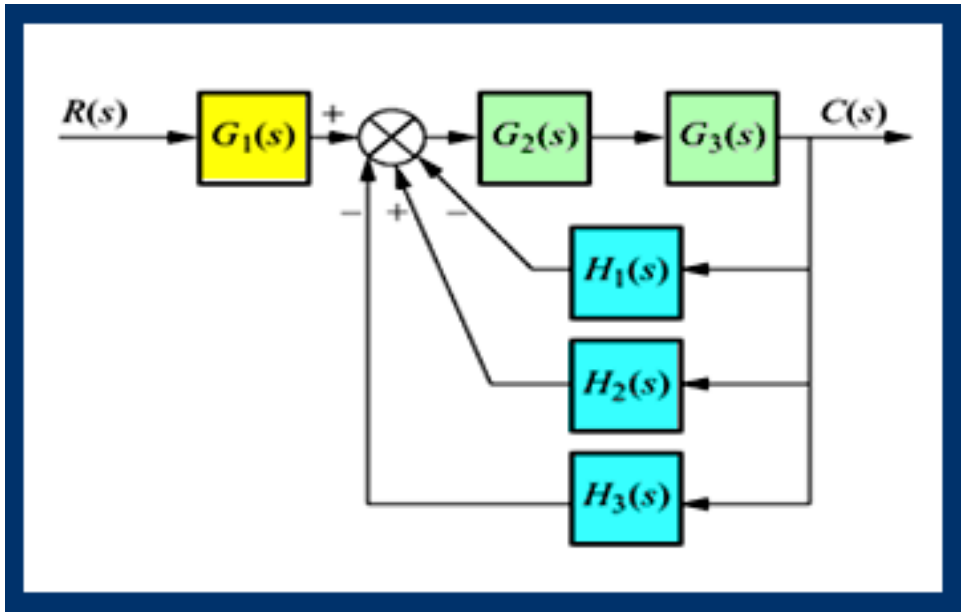
Reduce the block diagram shown to a single T.F.

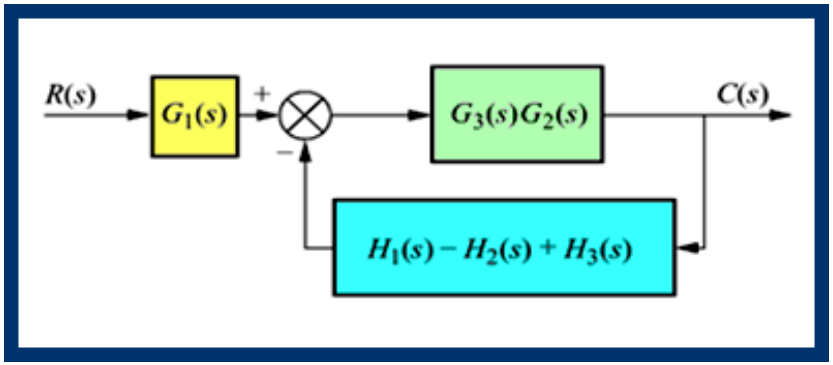


Example 3 (cont'd)



Solution

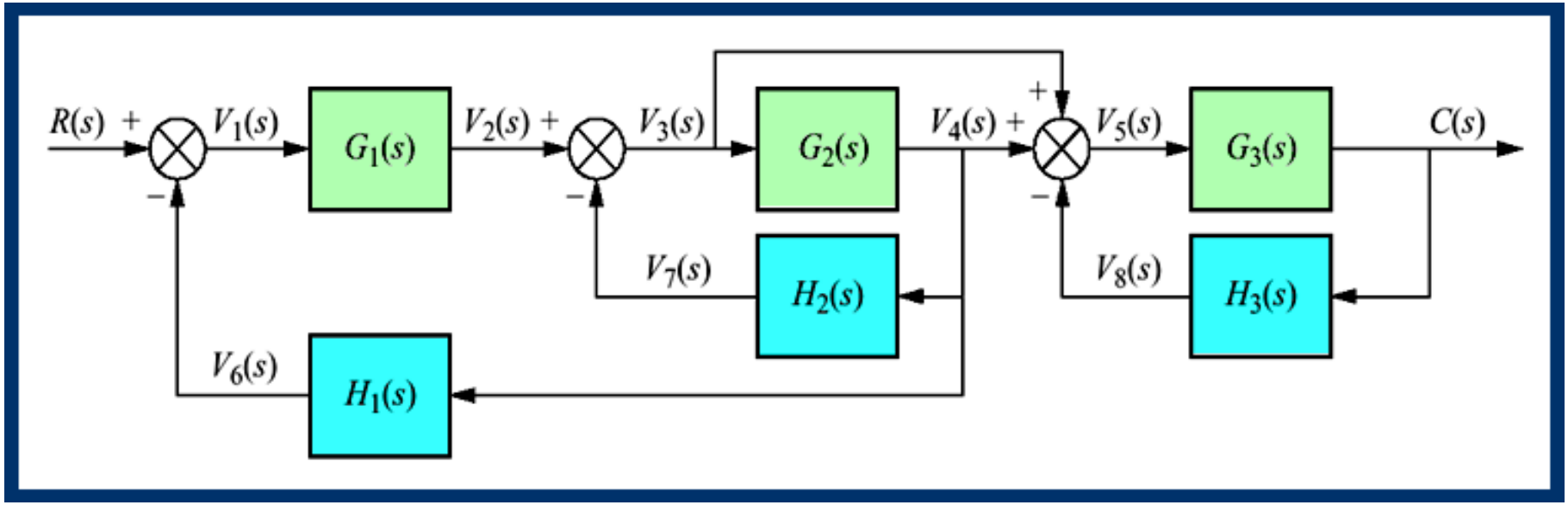




$$R(s) \quad \frac{G_3(s)G_2(s)G_1(s)}{1 + G_3(s)G_2(s)[H_1(s) - H_2(s) + H_3(s)]} \quad C(s)$$

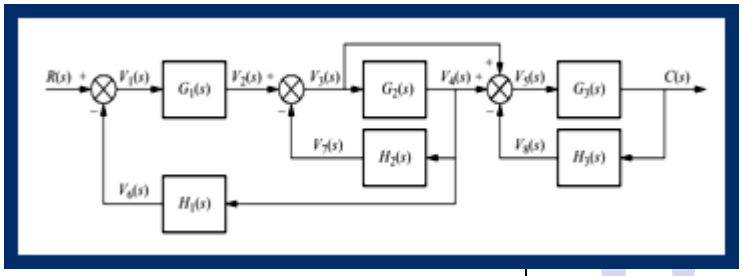
Example 4

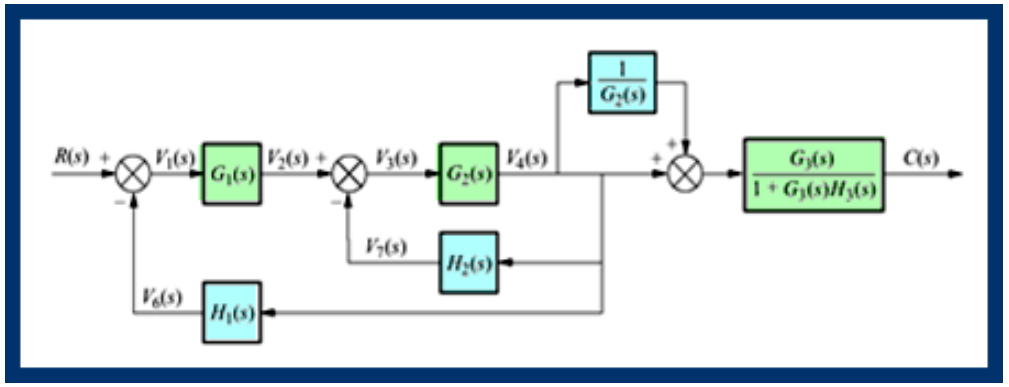
Reduce the system shown to a single T.F.

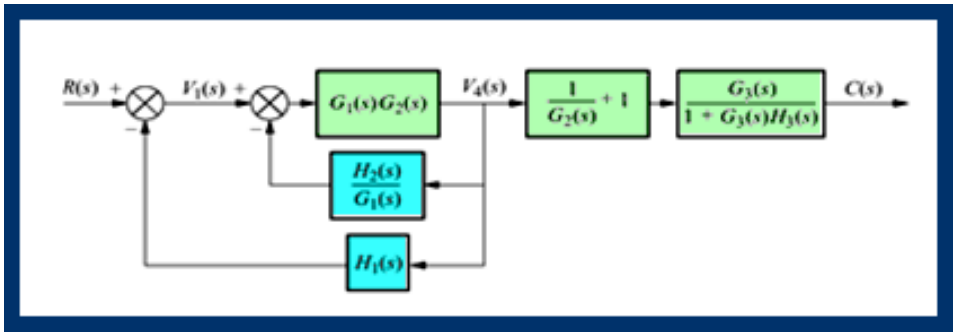


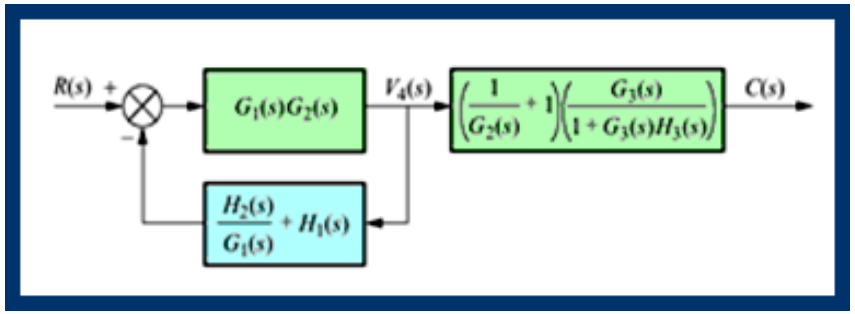
Example 4 (cont'd)

Solution

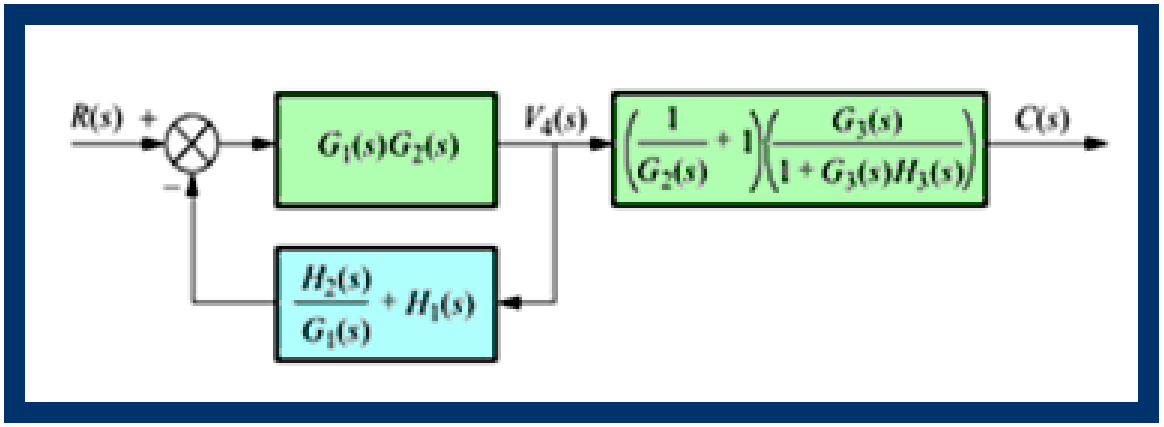


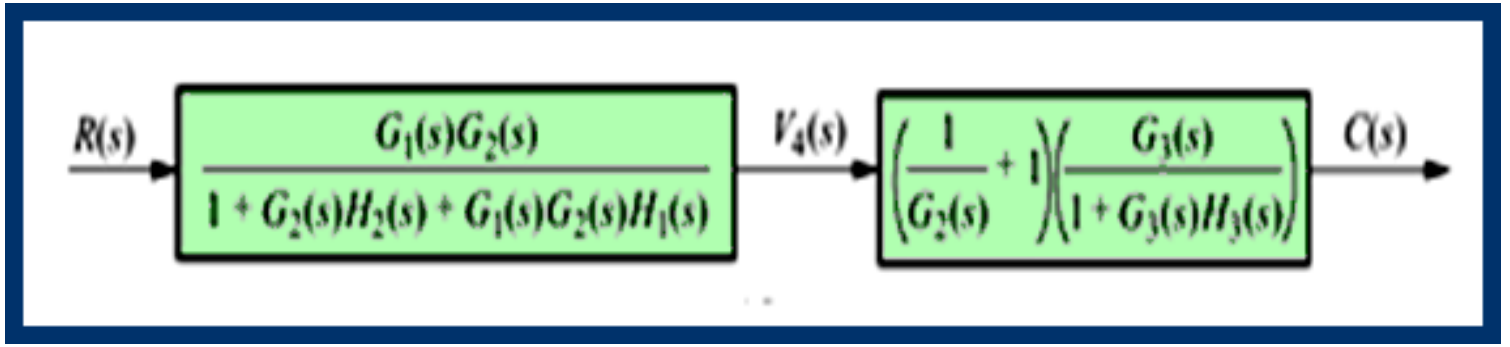


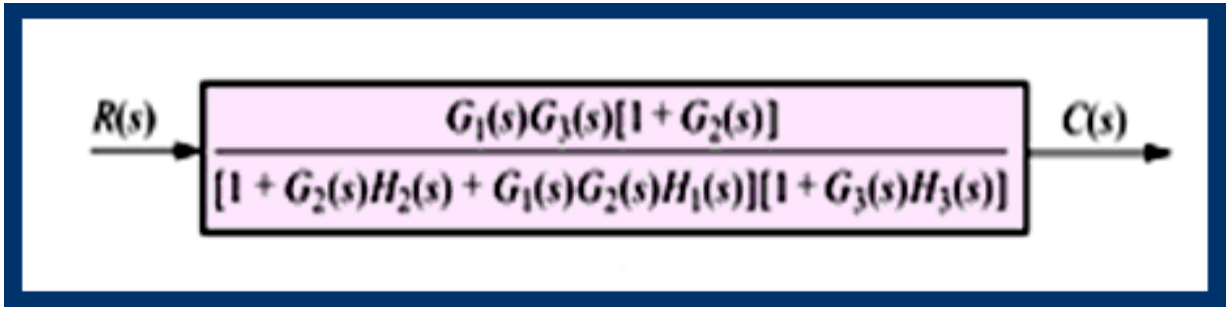




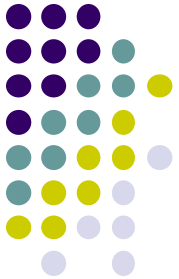
Example 4 (cont'd)







Summary



This Lecture:

– Block Control Diagram Components

– Block Control Diagram Reduction Rules

– Examples

- **Next Lecture:**

– Signal Flow Graphs