BVM Engineering College, VV Nagar

Gujarat Technological University

Control Systems Engineering

Block Diagram Reduction

SEM 4
PRESENTATION

ELECTRONICS & COMMUNICATION DEPT.

Presented By :

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Guided By:

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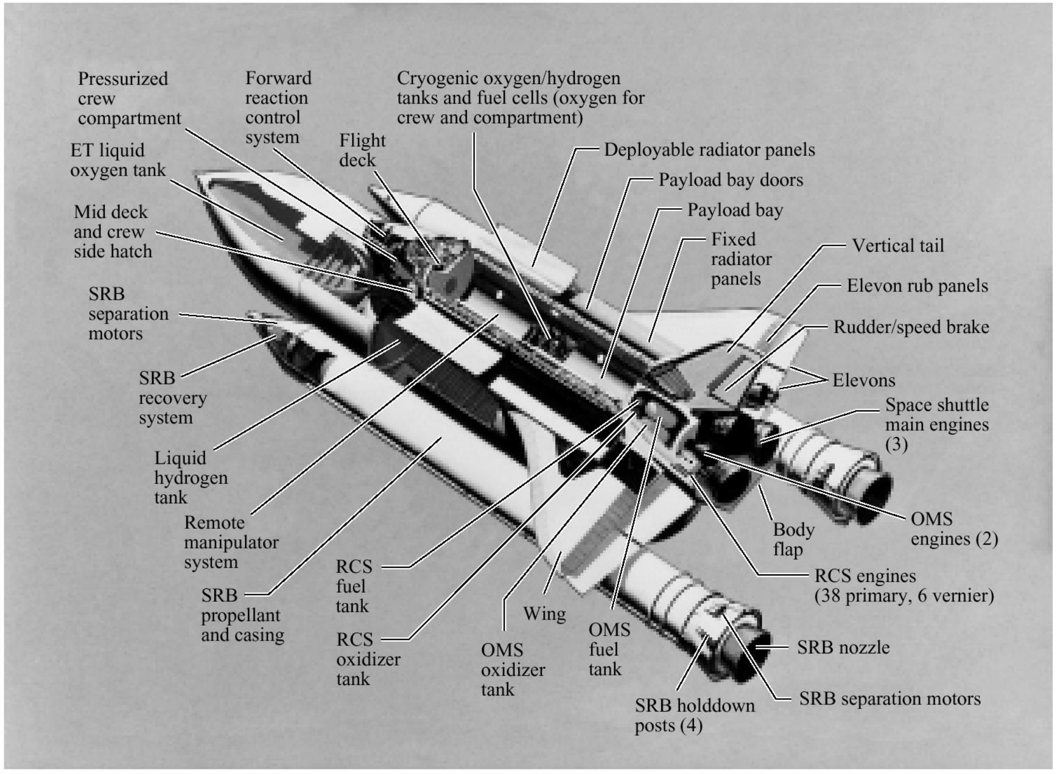
The space shuttle consists of multiple subsystems. Can you identify those that are control systems, or parts of control systems?



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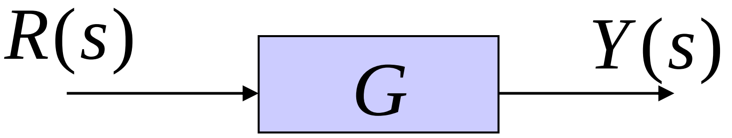
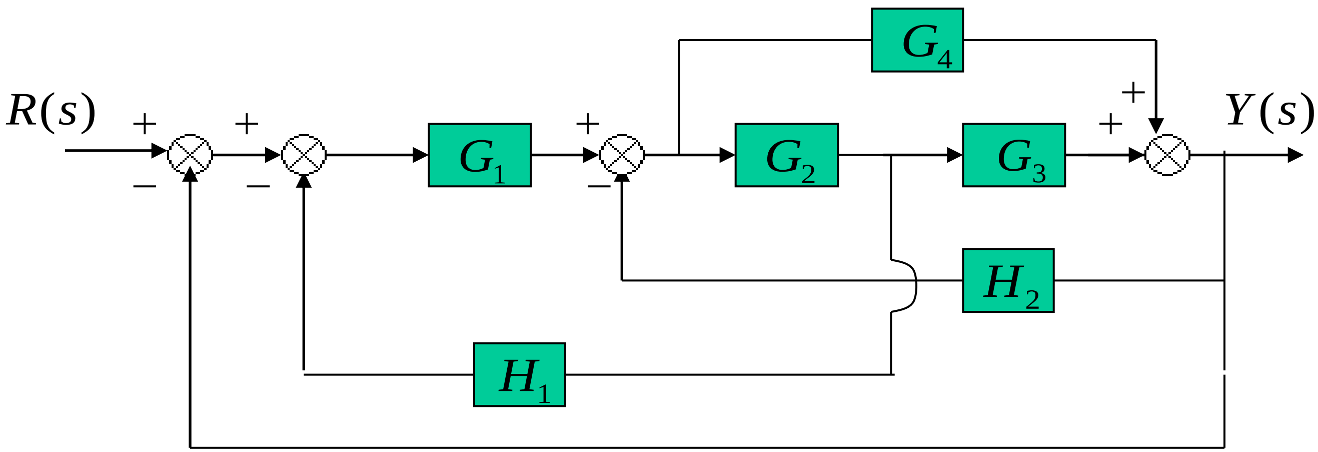
Block diagram

Transfer Function

Consists of Blocks

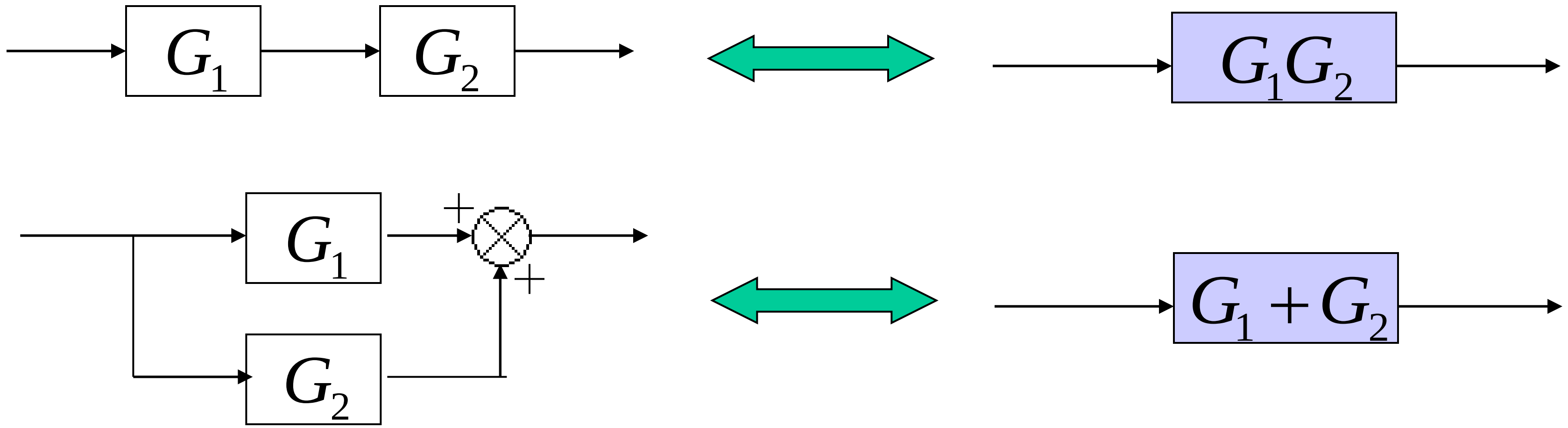
Can be reduced



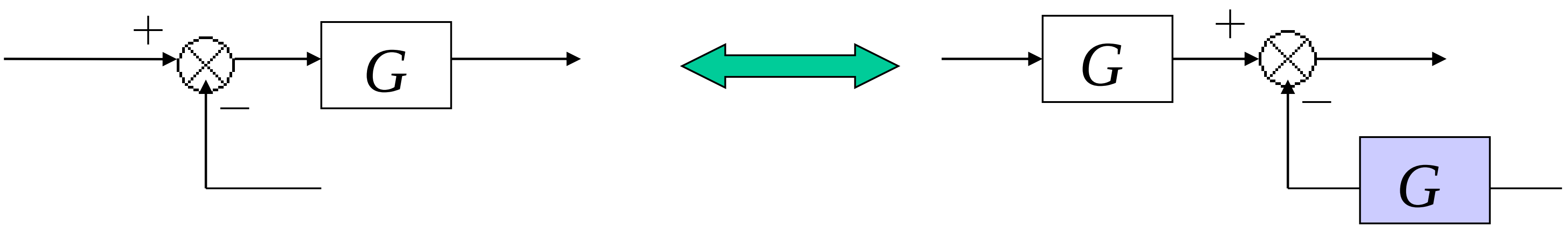


Reduction techniques

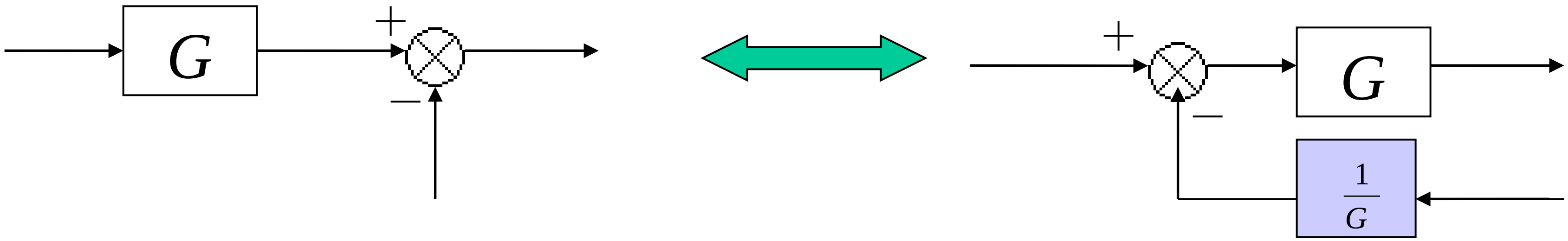
1. Combining blocks in cascade or in parallel



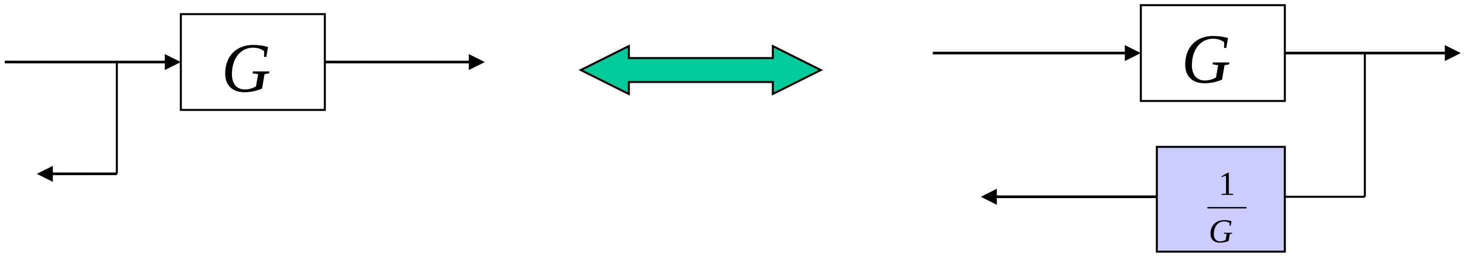
2. Moving a summing point behind a block



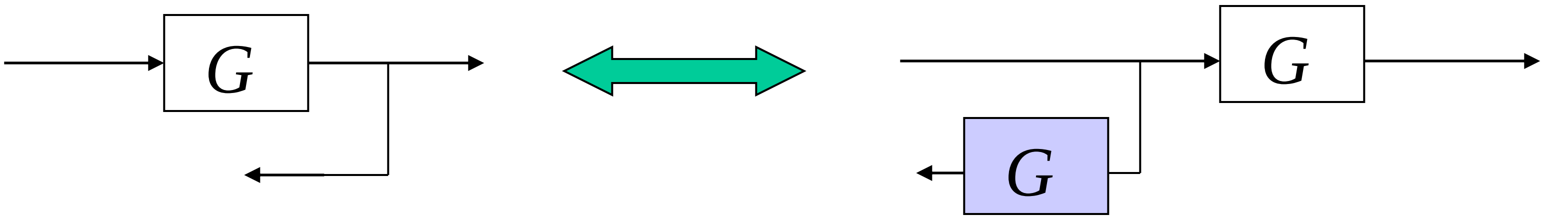
3. Moving a summing point ahead of a block



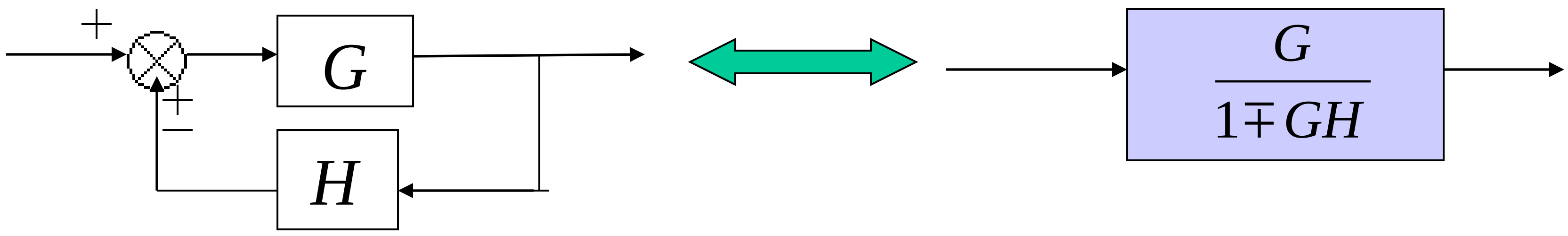
4. Moving a pickoff point behind a block

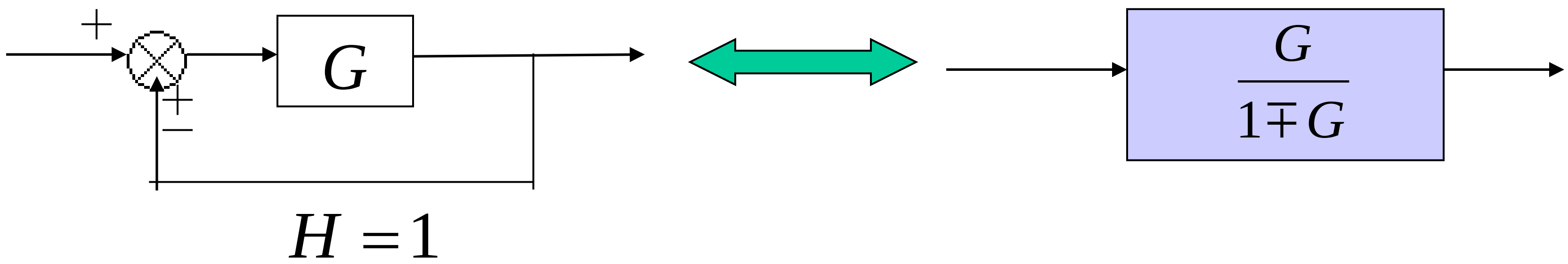


5. Moving a pickoff point ahead of a block

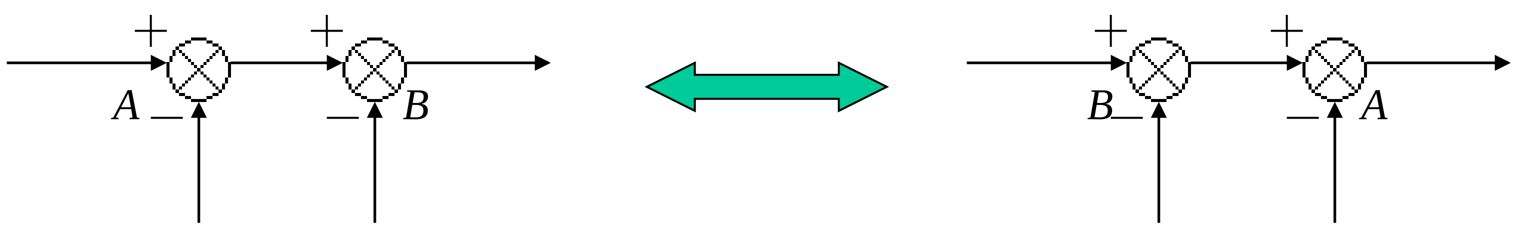


6. Eliminating a feedback loop

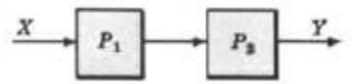
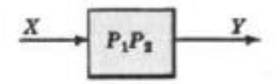
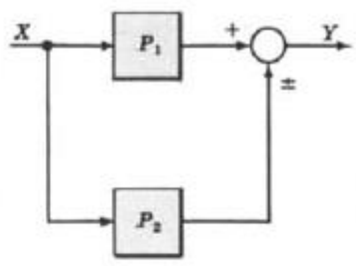
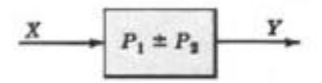
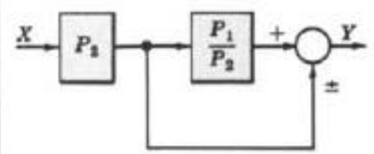
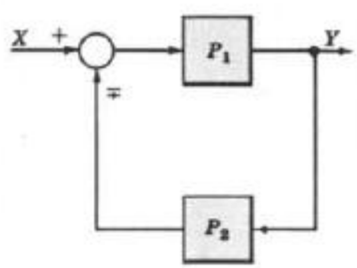
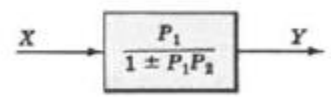
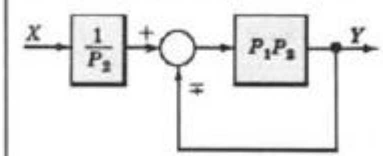




7. Swap with two neighboring summing points

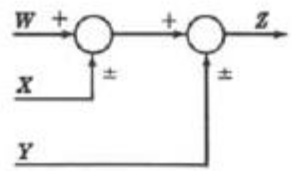
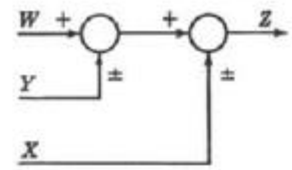
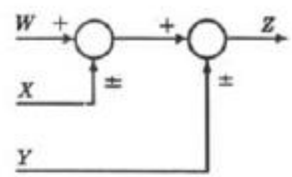
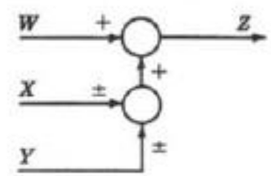
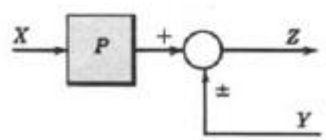
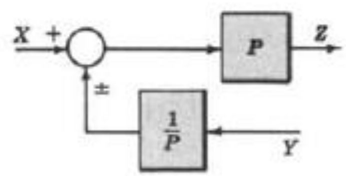
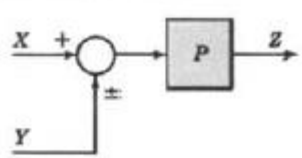
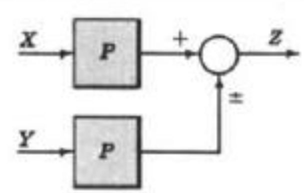


Block Diagram Transformation Theorems

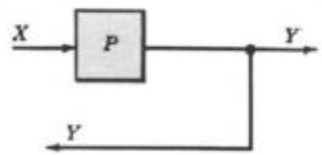
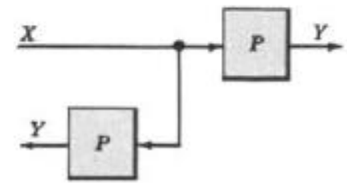
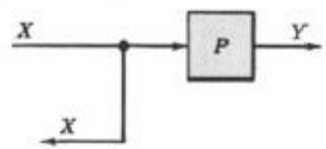
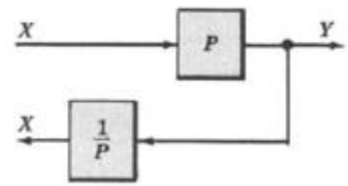
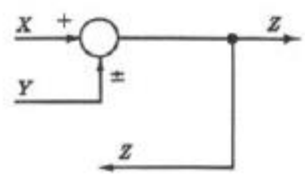
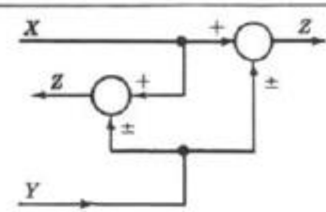
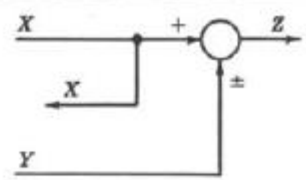
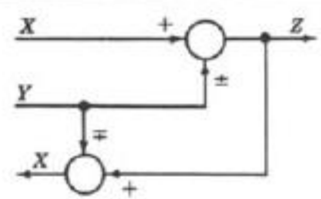
	Transformation	Equation	Block Diagram	Equivalent Block Diagram
1	Combining Blocks in Cascade	$Y = (P_1P_2)X$		
2	Combining Blocks in Parallel; or Eliminating a Forward Loop	$Y = P_1X \pm P_2X$		
3	Removing a Block from a Forward Path	$Y = P_1X \pm P_2X$		
4	Eliminating a Feedback Loop	$Y = P_1(X \mp P_2Y)$		
5	Removing a Block from a Feedback Loop	$Y = P_1(X \mp P_2Y)$		

The letter ***P* is used to represent any transfer function, and *W, X , Y, Z* denote any transformed** signals.

Transformation Theorems Continue:

	Transformation	Equation	Block Diagram	Equivalent Block Diagram
6a	Rearranging Summing Points	$Z = W \pm X \pm Y$		
6b	Rearranging Summing Points	$Z = W \pm X \pm Y$		
7	Moving a Summing Point Ahead of a Block	$Z = PX \pm Y$		
8	Moving a Summing Point Beyond a Block	$Z = P[X \pm Y]$		

Transformation Theorems Continue:

	Transformation	Equation	Block Diagram	Equivalent Block Diagram
9	Moving a Takeoff Point Ahead of a Block	$Y = PX$		
10	Moving a Takeoff Point Beyond a Block	$Y = PX$		
11	Moving a Takeoff Point Ahead of a Summing Point	$Z = X \pm Y$		
12	Moving a Takeoff Point Beyond a Summing Point	$Z = X \pm Y$		

Reduction of Complicated Block Diagrams:

The block diagram of a practical feedback control system is often quite complicated. It may include several feedback or feedforward loops, and multiple inputs. By means of systematic block diagram reduction, every multiple loop linear feedback system may be reduced to canonical form.

The following general steps may be used as a basic approach in the reduction of complicated block diagrams.

Step 1: Combine all cascade blocks using Transformation 1.

Step 2: Combine all parallel blocks using Transformation 2.

Step 3: Eliminate all minor feedback loops using Transformation 4.

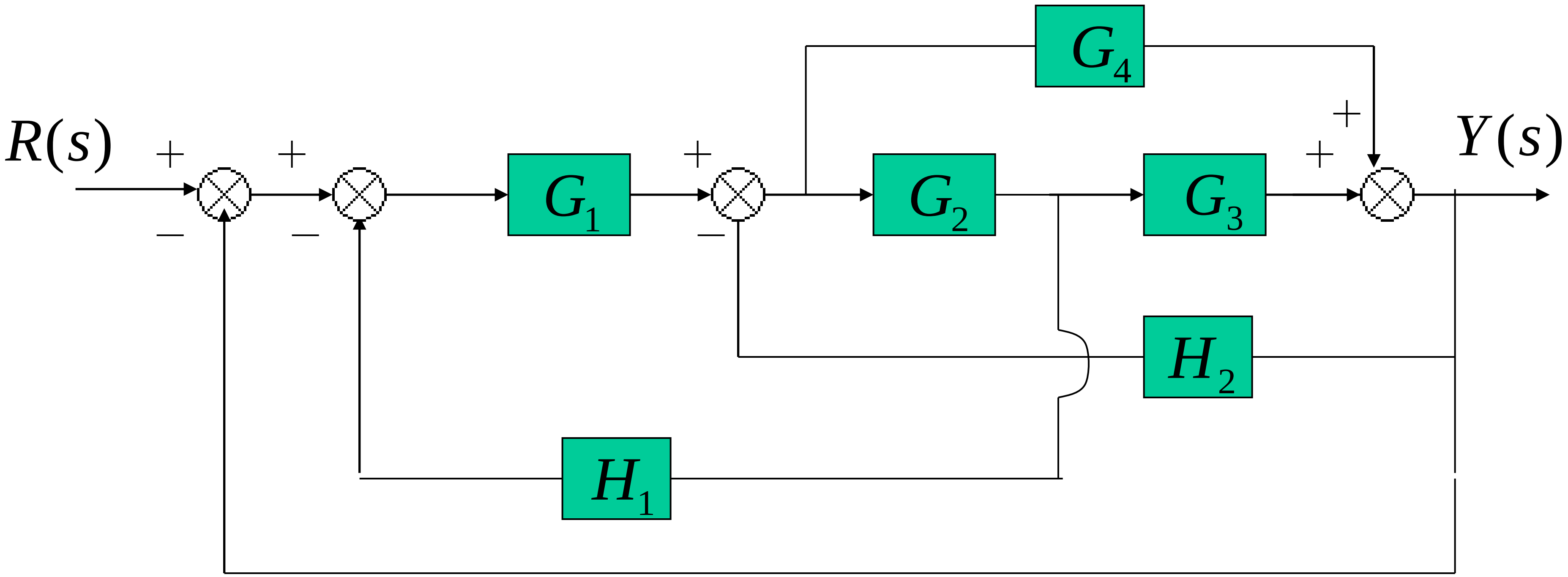
Step 4: Shift summing points to the left and takeoff points to the right of the major loop, using Transformations 7, 10, and 12.

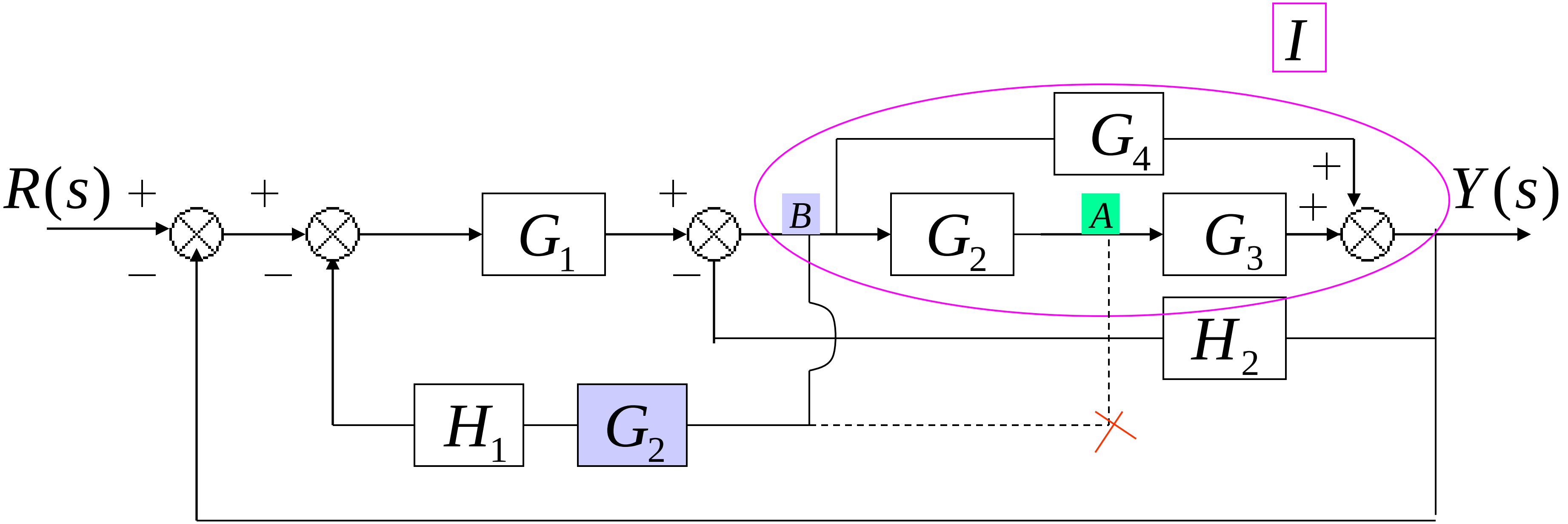
Step 5: Repeat Steps 1 to 4 until the canonical form has been achieved for a particular input.

Step 6: Repeat Steps 1 to 5 for each input, as required.

Example 1

Find the transfer function of the following block diagrams

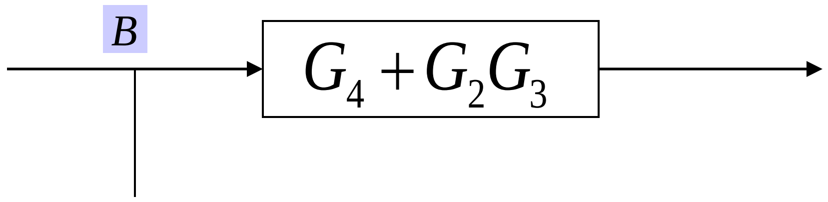


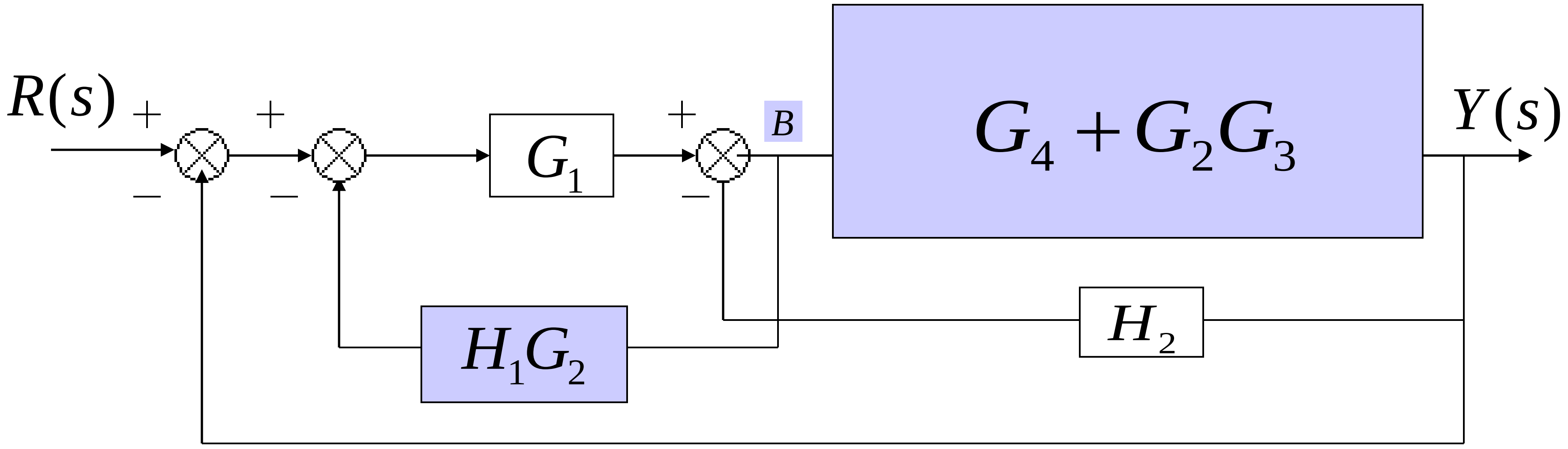


Solution:

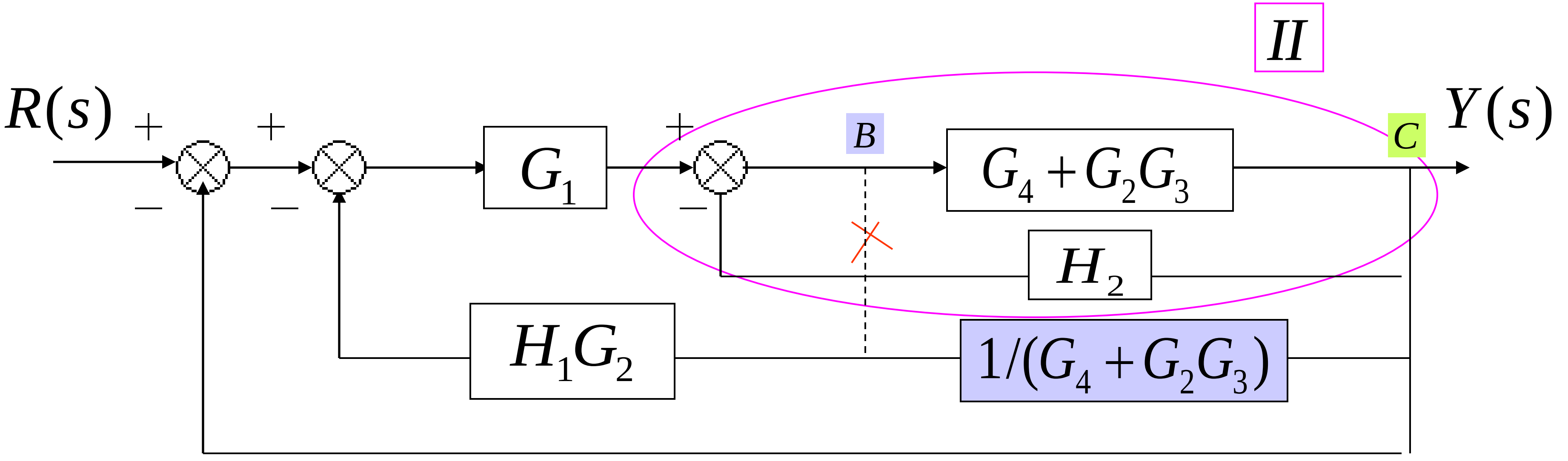
1. Moving pickoff point A ahead of block $\boxed{G_2}$

2. Eliminate loop I & simplify

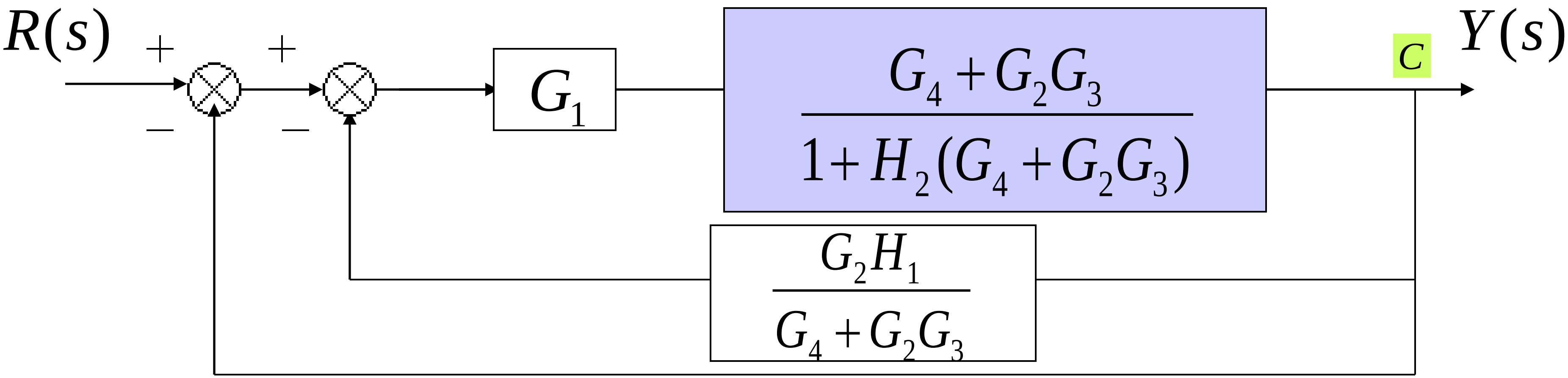




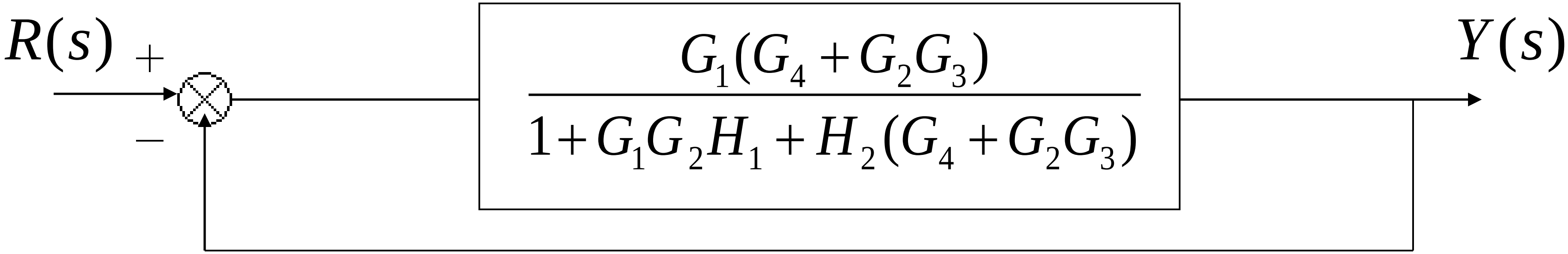
3. Moving pickoff point B behind block $G_4 + G_2G_3$



4. Eliminate loop III



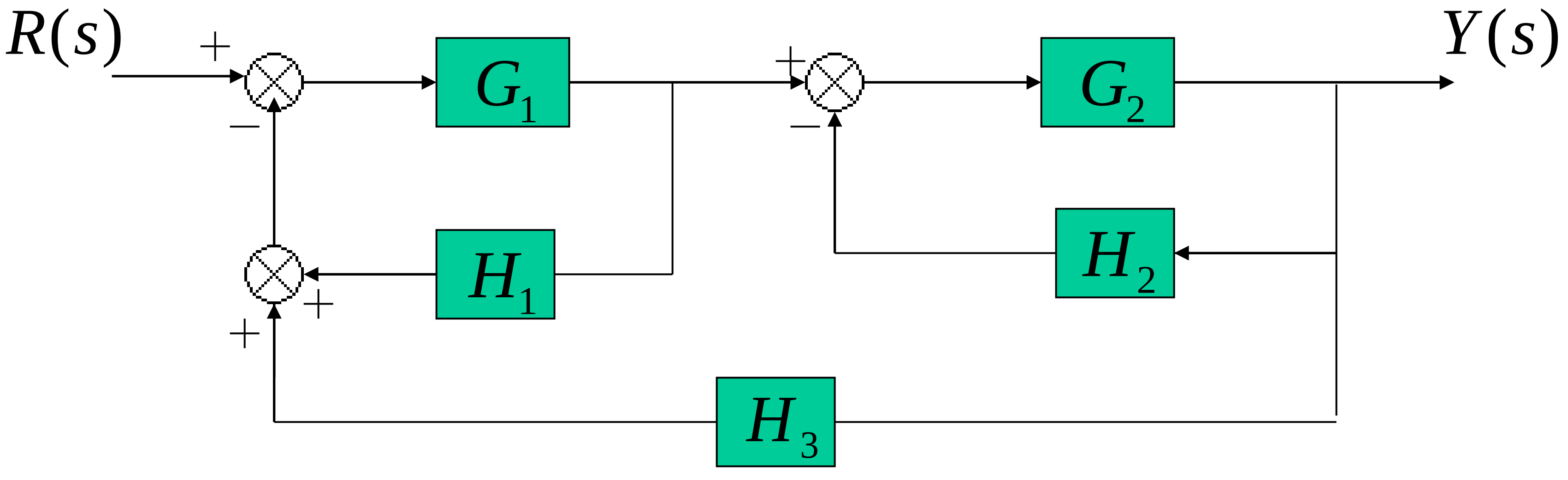
Using rule 6



$$T(s)=\frac{Y(s)}{R(s)}=\frac{G_1(G_4+G_2G_3)}{1+G_1G_2H_1+H_2(G_4+G_2G_3)+G_1(G_4+G_2G_3)}$$

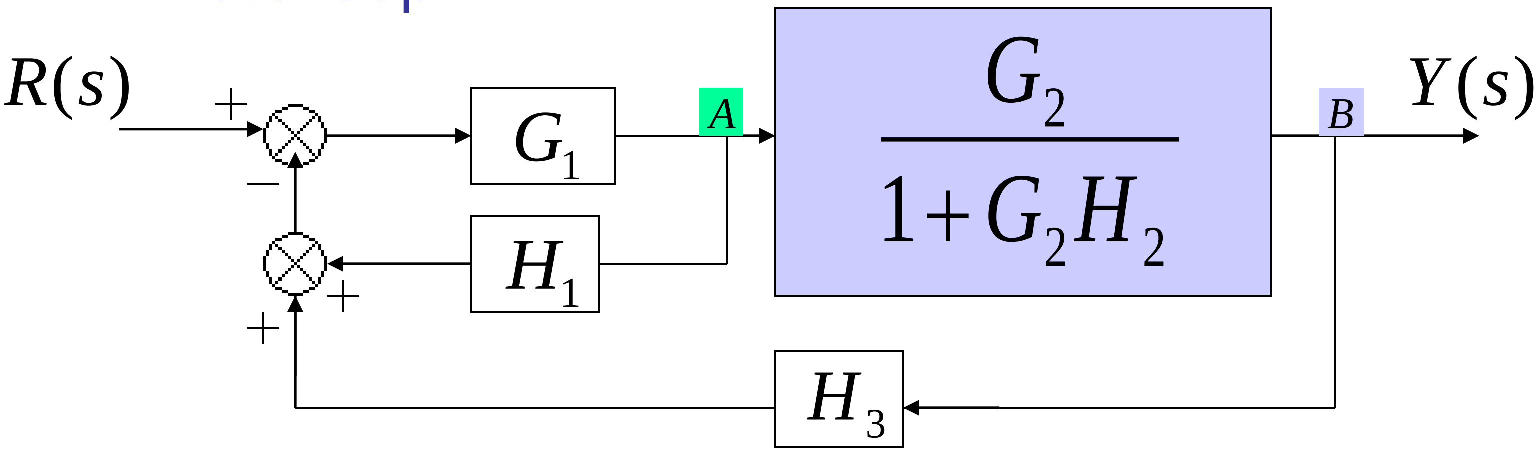
Example 2

Find the transfer function of the following block diagrams

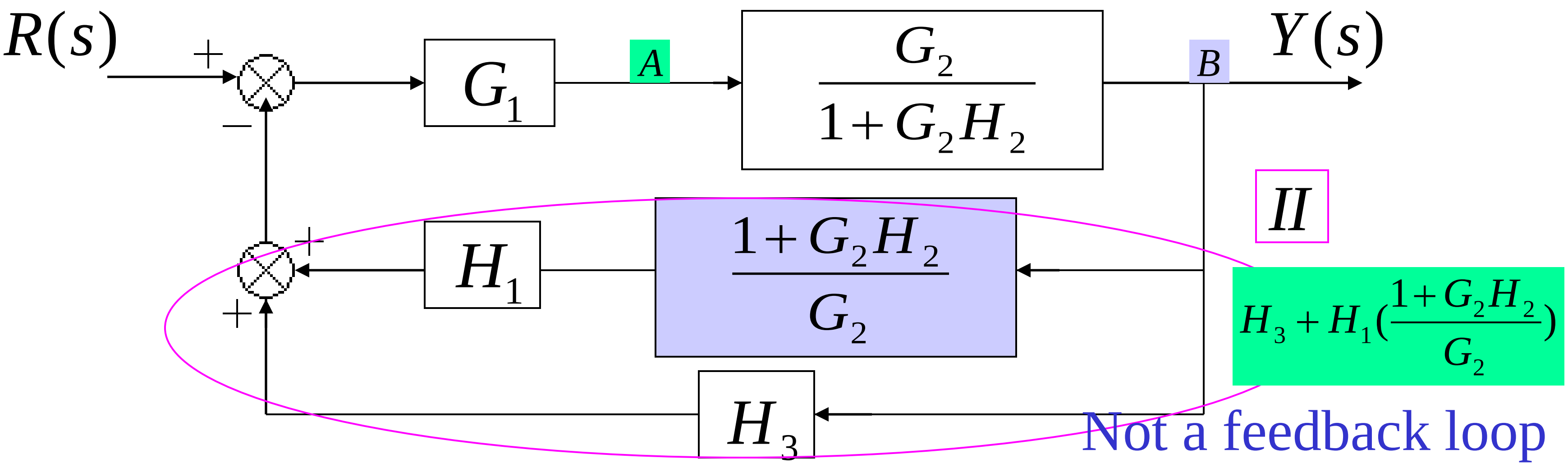


Solution:

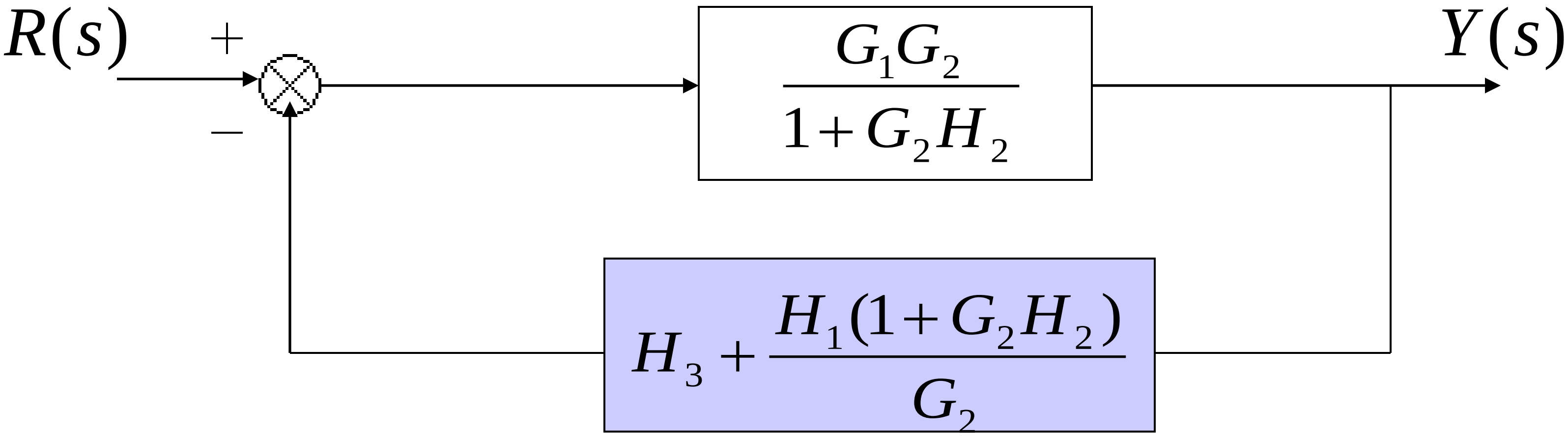
1. Eliminate loop I



2. Moving pickoff point A behind block $\frac{G_2}{1+G_2H_2}$



3. Eliminate loop II

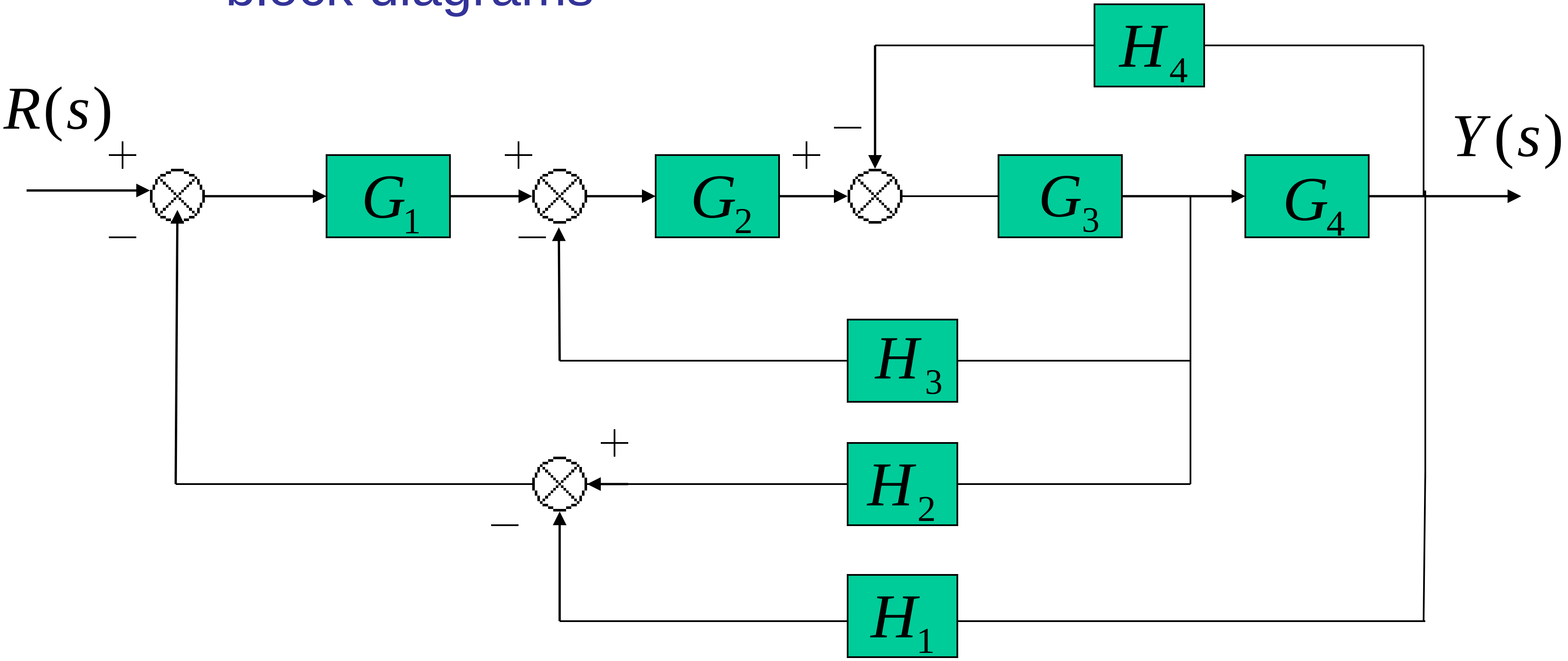


Using rule 6

$$T(s) = \frac{Y(s)}{R(s)} = \frac{G_1G_2}{1+G_2H_2+G_1G_2H_3+G_1H_1+G_1G_2H_1H_2}$$

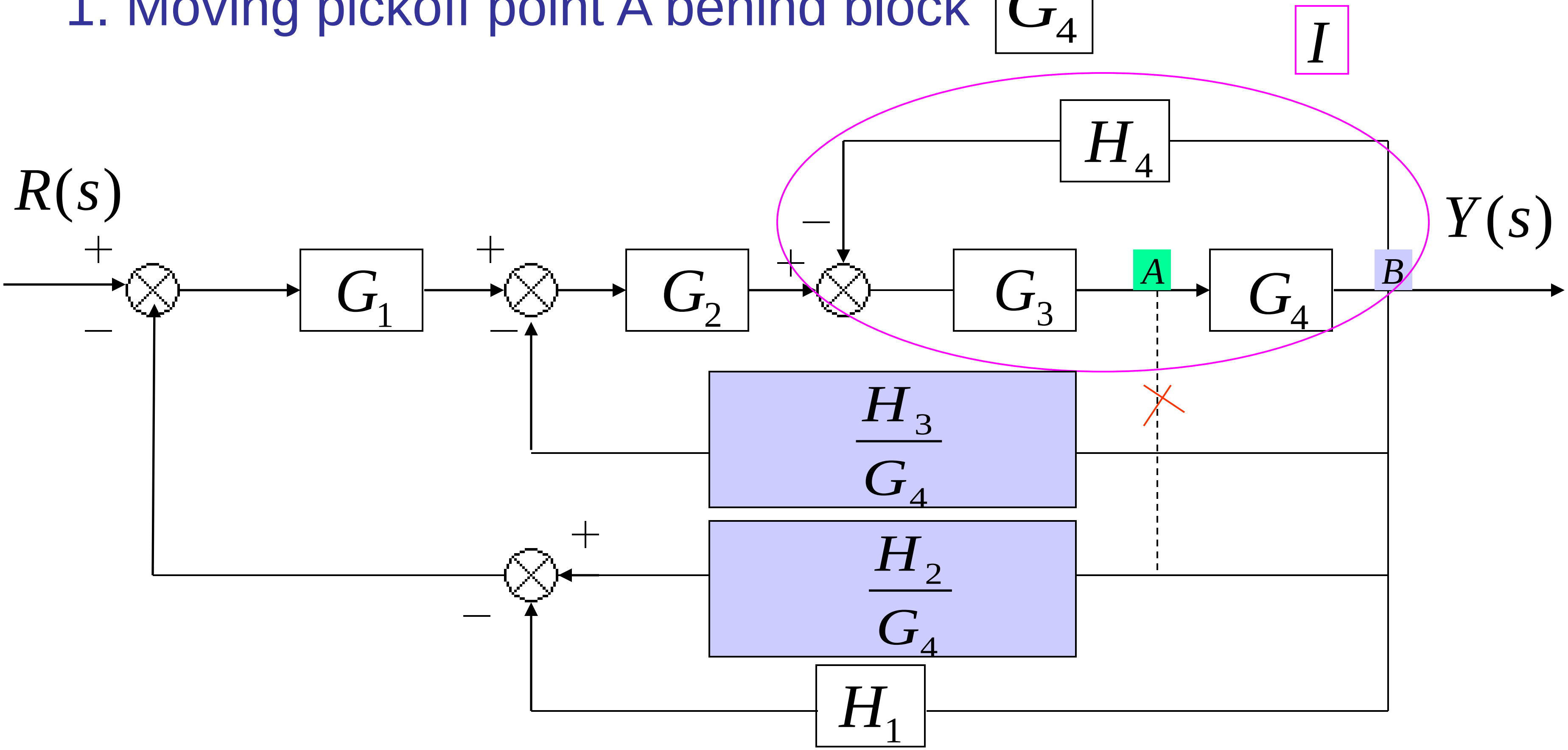
Example 3

Find the transfer function of the following block diagrams

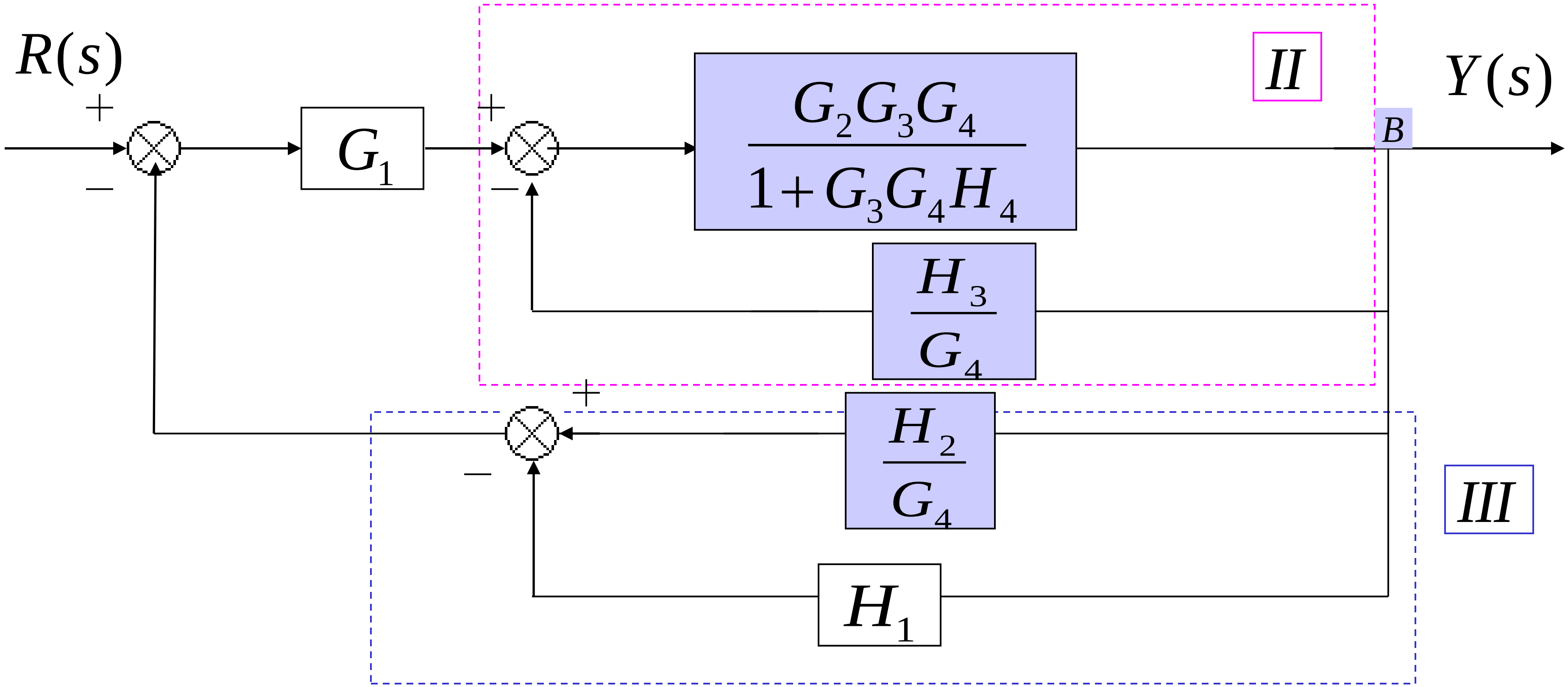


Solution:

1. Moving pickoff point A behind block $\boxed{G_4}$



2. Eliminate loop I and Simplify



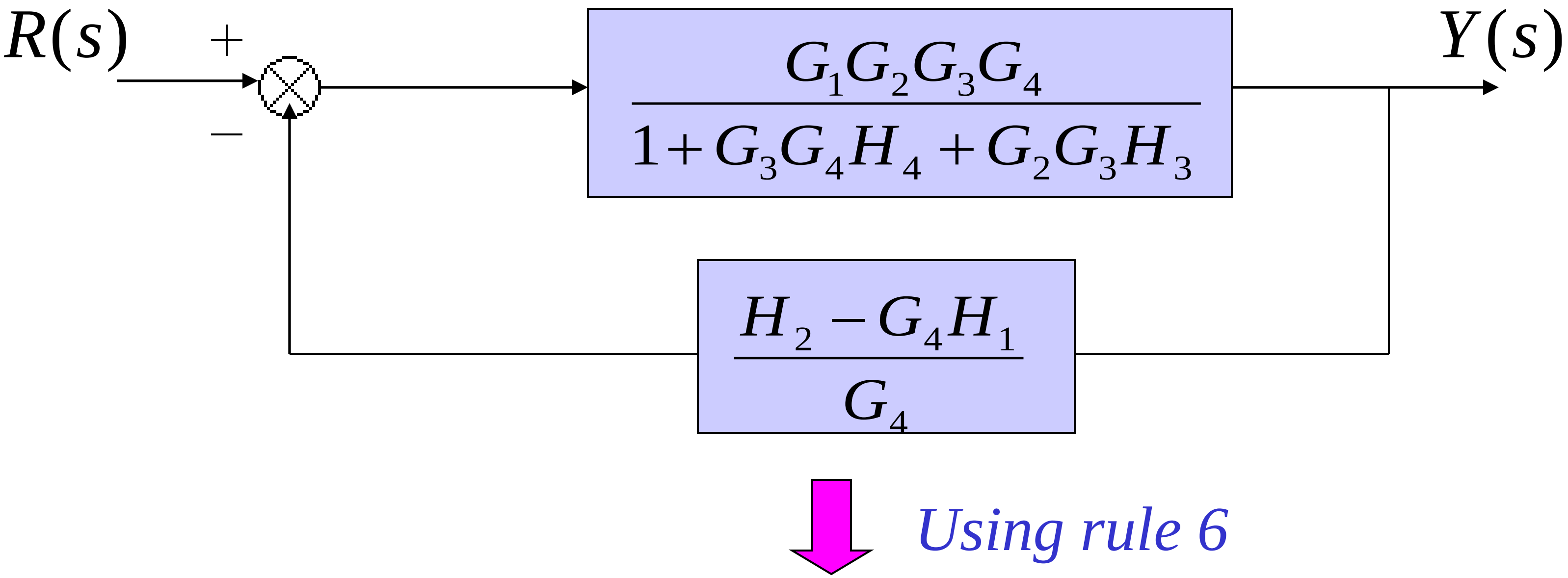
II feedback

$$\frac{G_2G_3G_4}{1+G_3G_4H_4+G_2G_3H_3}$$

III Not feedback

$$\frac{H_2-G_4H_1}{G_4}$$

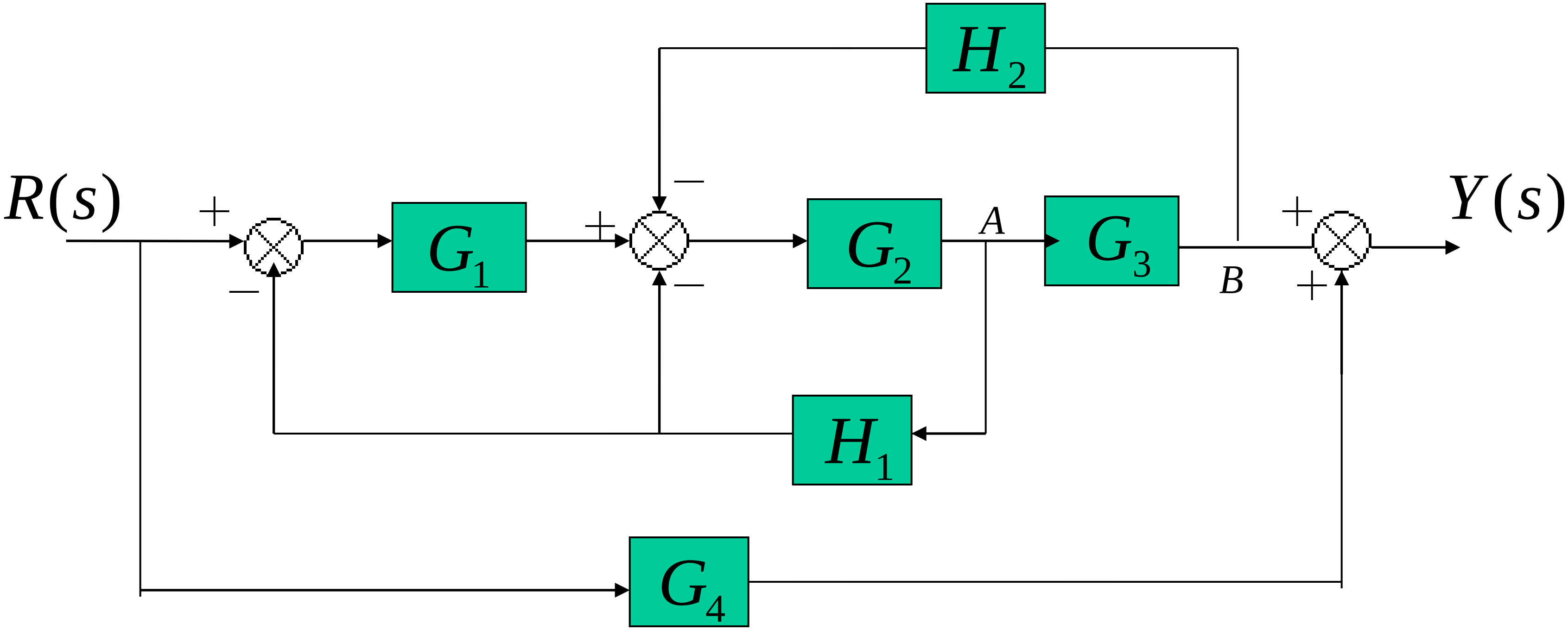
3. Eliminate loop II & IIII



$$T(s)=\frac{Y(s)}{R(s)}=\frac{G_1G_2G_3G_4}{1+G_2G_3H_3+G_3G_4H_4+G_1G_2G_3H_2-G_1G_2G_3G_4H_1}$$

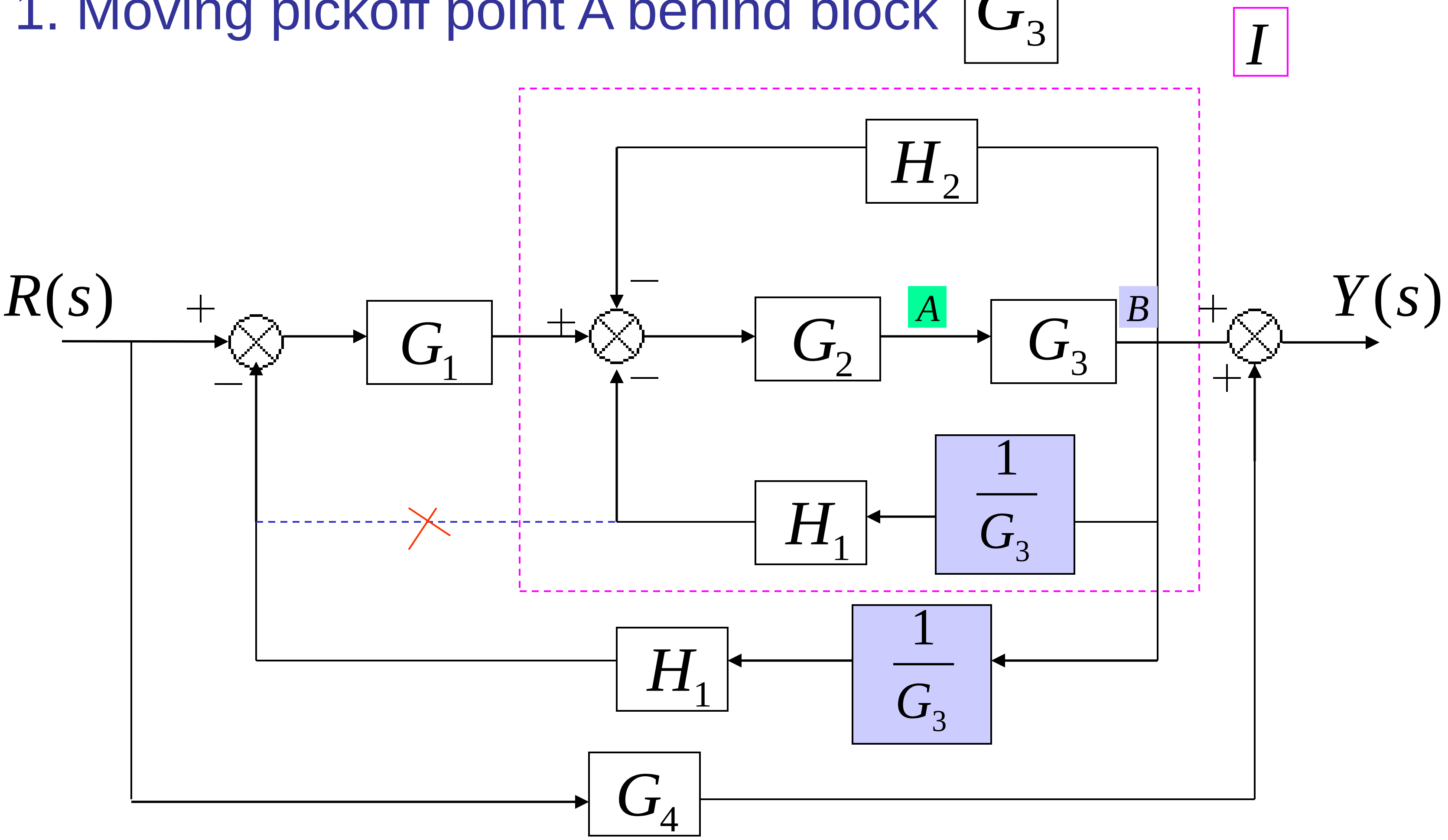
Example 4

Find the transfer function of the following block diagrams

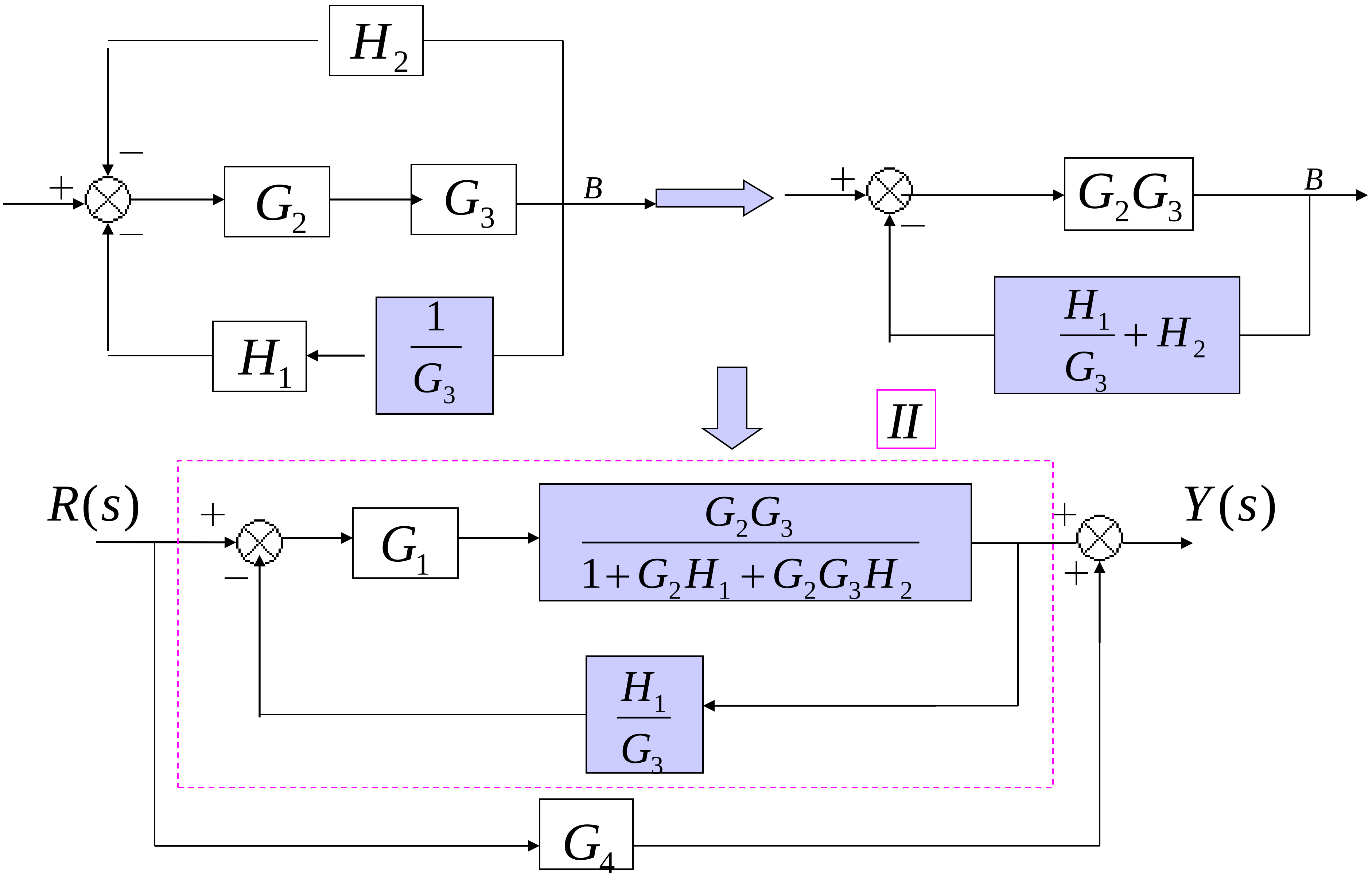


Solution:

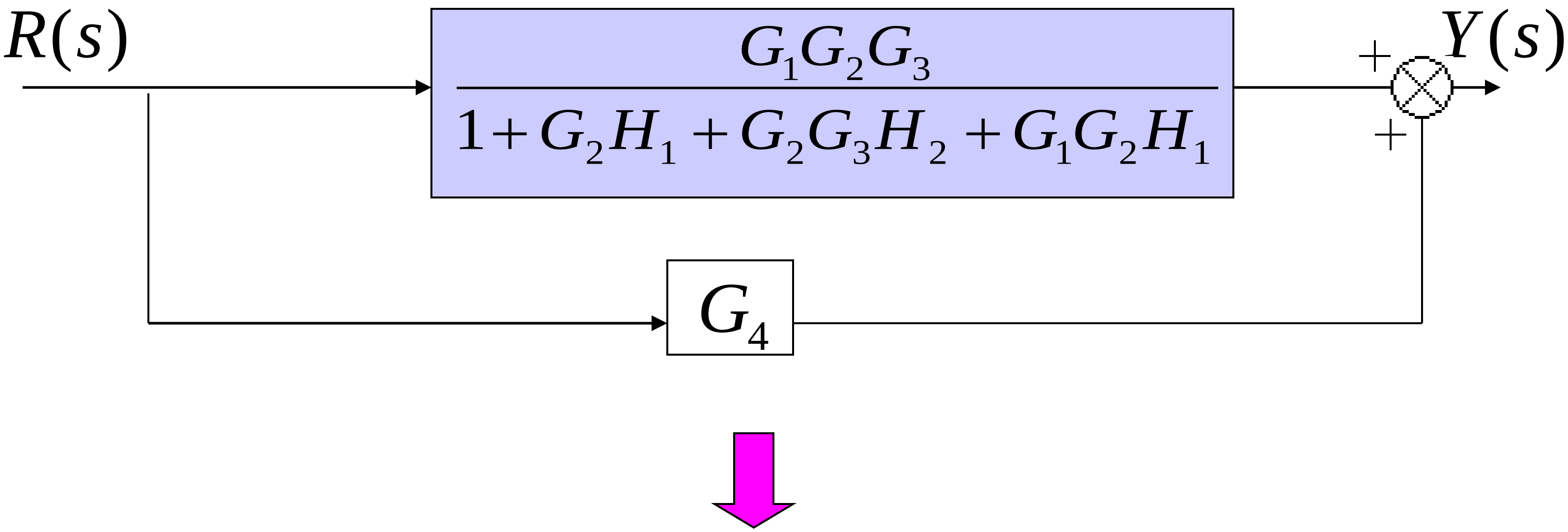
1. Moving pickoff point A behind block $\boxed{G_3}$



2. Eliminate loop I & Simplify



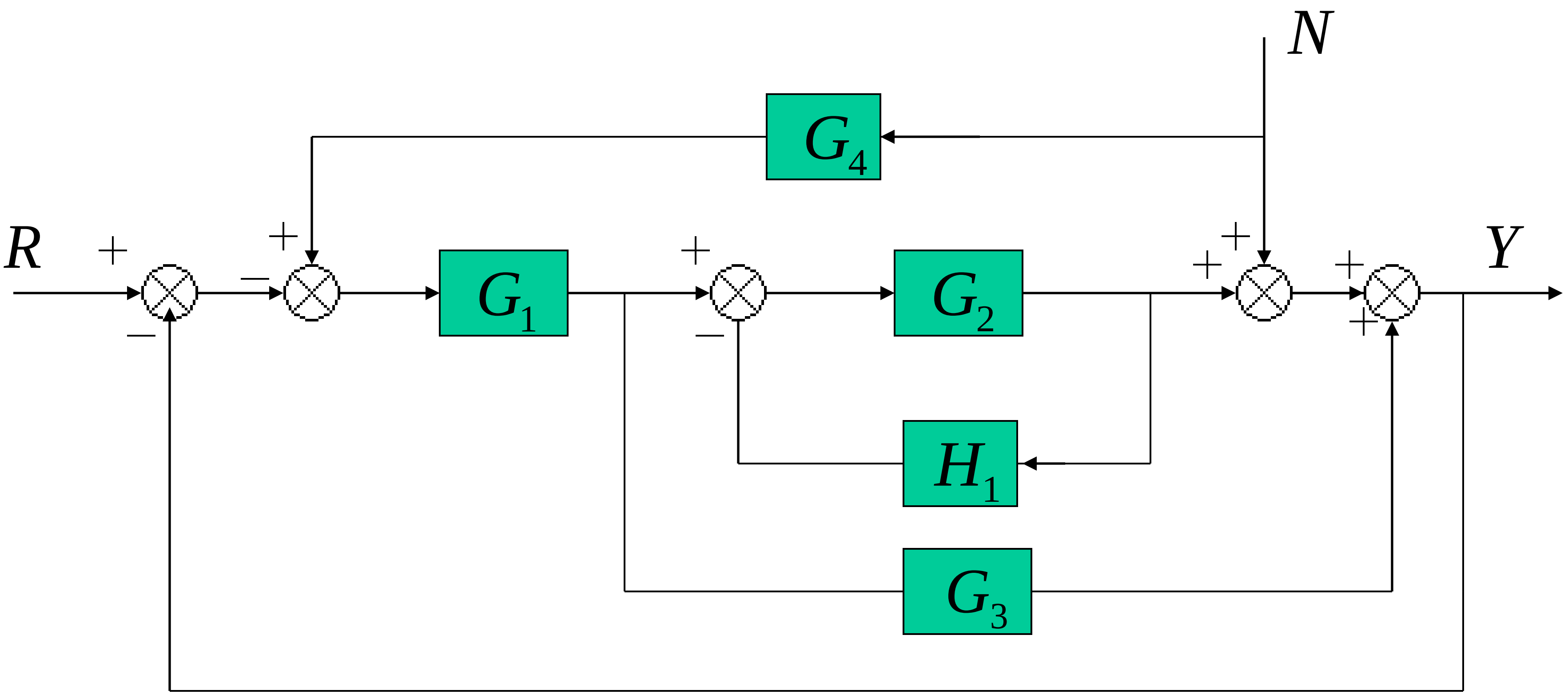
3. Eliminate loop II



$$T(s) = \frac{Y(s)}{R(s)} = G_4 + \frac{G_1 G_2 G_3}{1 + G_2 H_1 + G_2 G_3 H_2 + G_1 G_2 H_1}$$

Example 5

Determine the effect of R and N on Y in the following diagram



In this linear system, the output Y contains two parts, one part is related to R and the other is caused by N:

$$Y = Y_1 + Y_2 = T_1 R + T_2 N$$

If we set N=0, then we can get Y1:

$$Y_1 = Y_{N=0} = T_1 R$$

The same, we set R=0 and Y2 is also obtained:

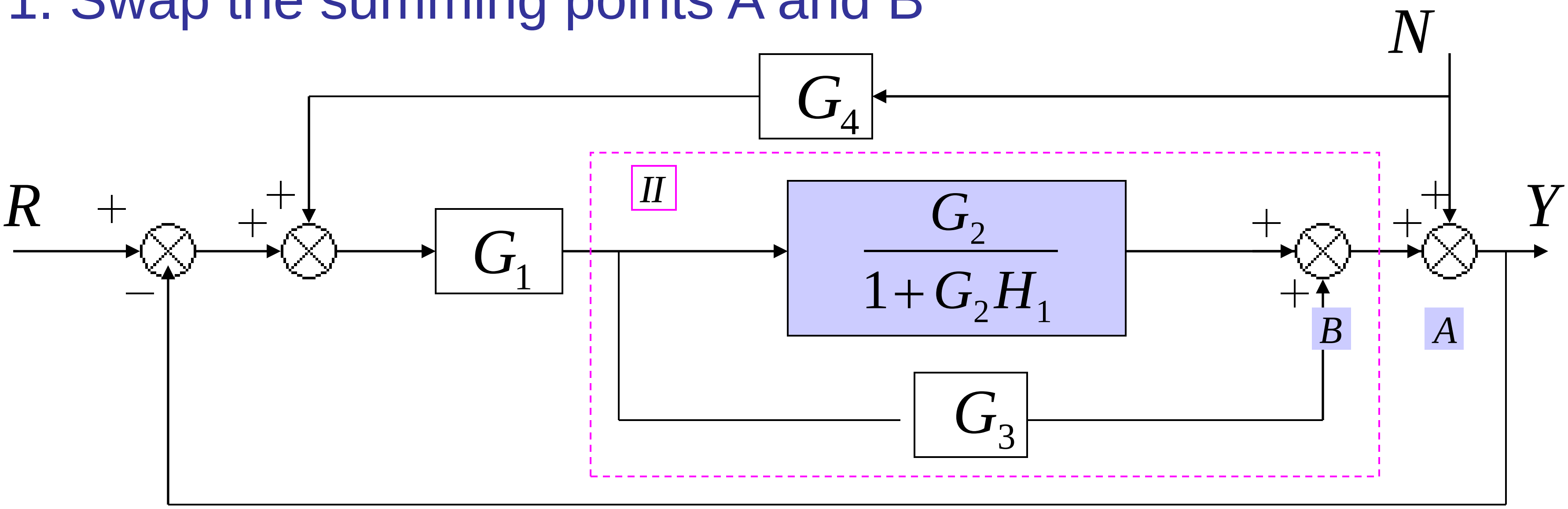
$$Y_2 = Y_{R=0} = T_2 N$$

Thus, the output Y is given as follows:

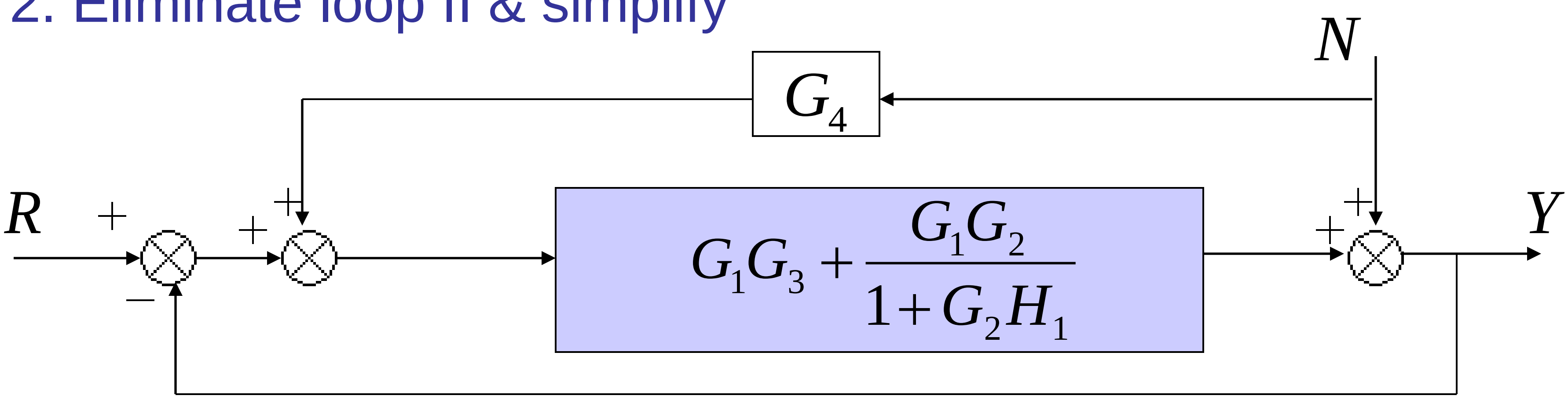
$$Y = Y_1 + Y_2 = Y_{N=0} + Y_{R=0}$$

Solution:

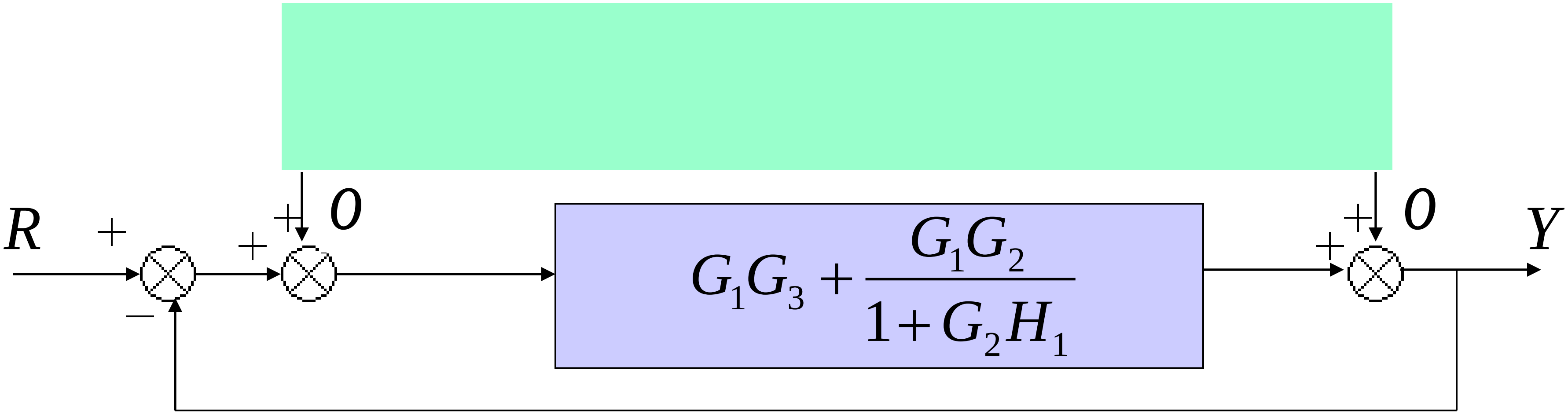
1. Swap the summing points A and B



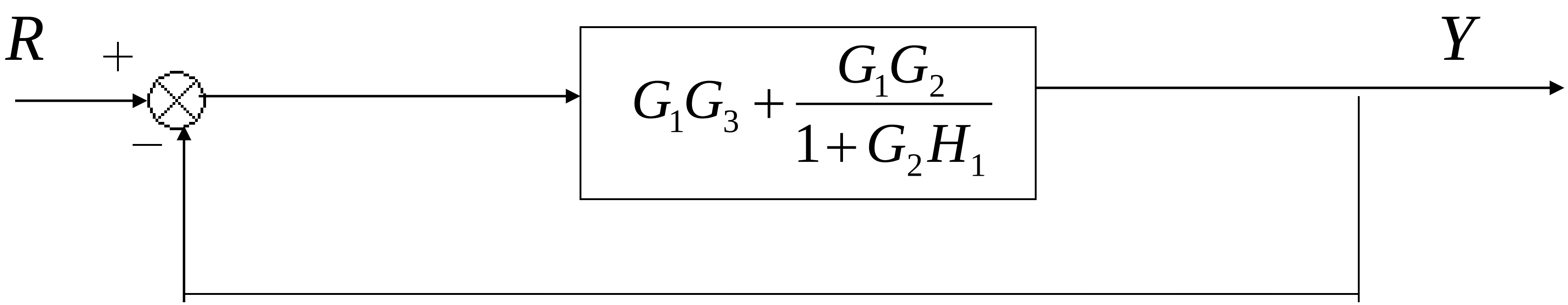
2. Eliminate loop II & simplify



Rewrite the diagram:



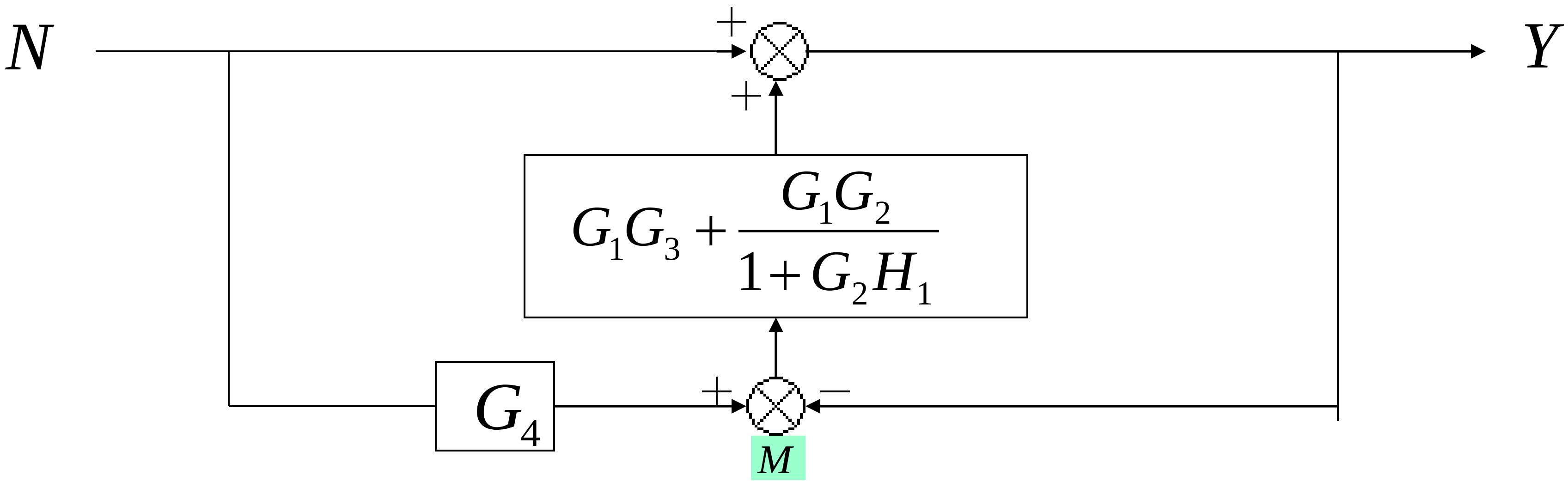
3. Let N=0



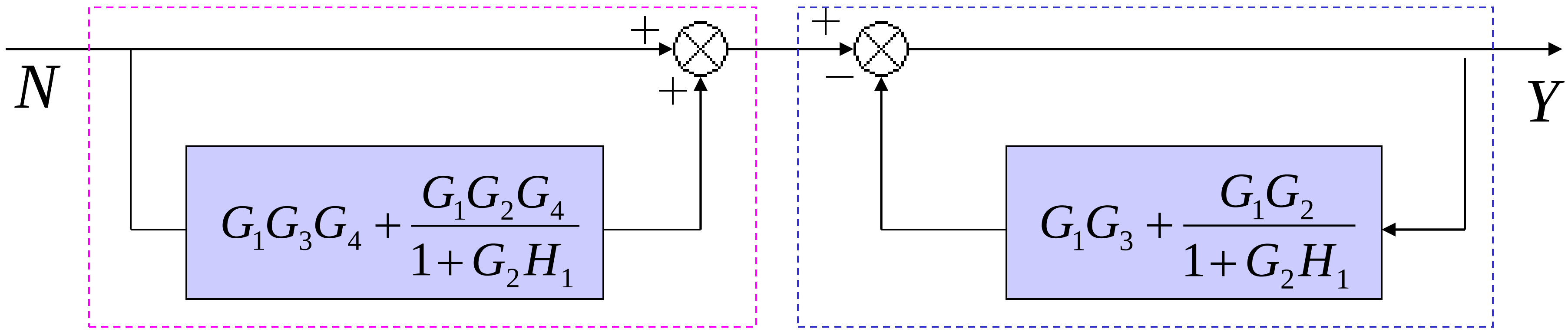
We can easily get Y_1

$$Y_1 = \frac{G_1G_2 + G_1G_3 + G_1G_2G_3H_1}{1 + G_2H_1 + G_1G_2 + G_1G_3 + G_1G_2G_3H_1} R$$

4. Let R=0, we can get:



5. Break down the summing point M:



6. Eliminate above loops:

$$N \longrightarrow \boxed{1+G_1G_3G_4+\frac{G_1G_2G_4}{1+G_2H_1}} \longrightarrow \boxed{\frac{1}{1+G_1G_3+\frac{G_1G_2}{1+G_2H_1}}} \longrightarrow Y$$

$$Y_2=\frac{1+G_2H_1+G_1G_2G_4+G_1G_3G_4+G_1G_2G_3G_4H_1}{1+G_2H_1+G_1G_2+G_1G_3+G_1G_2G_3H_1}N$$

7. According to the principle of superposition, Y_1 and Y_2 can be combined together, So:

$$Y=Y_1+Y_2$$

$$=\frac{1}{1+G_2H_1+G_1G_2+G_1G_3+G_1G_2G_3H_1}[(G_1G_2+G_1G_3+G_1G_2G_3H_1)R$$

$$+(1+G_2H_1+G_1G_2G_4+G_1G_3G_4+G_1G_2G_3G_4H_1)N]$$

THANK YOU !