XMUT315 Control Systems Engineering

Note 4: Block Diagram Modelling

Block Diagram Modelling Guideline

These are rules for simplifying (reducing) the block diagram, which is having many blocks, summing points and take-off points.

- Rule 1 − Check for the blocks connected in series and simplify.
- Rule 2 − Check for the blocks connected in parallel and simplify.
- Rule 3 − Check for the blocks connected in feedback loop and simplify.
- Rule 4 − If there is difficulty with take-off point while simplifying, shift it towards right.
- Rule 5 − If there is difficulty with summing point while simplifying, shift it towards left.
- Rule 6 − Repeat the above steps till you get the simplified form, i.e., single block.

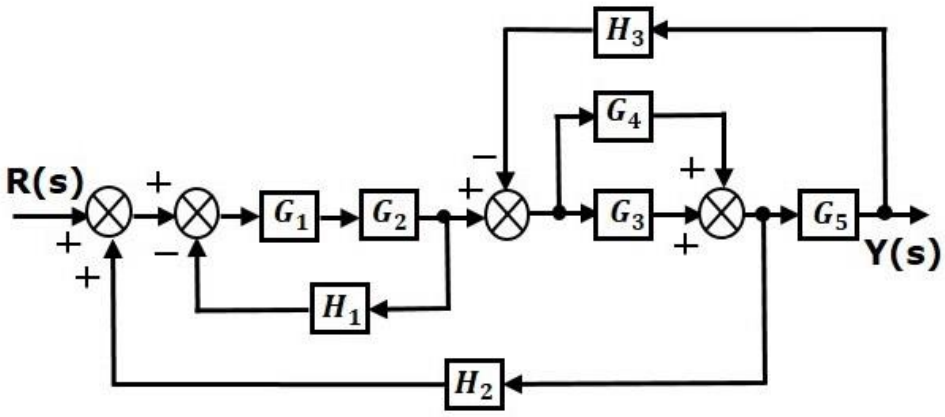
Note: The transfer function present in this single block is the transfer function of the overall block diagram.

Example:

For a control system given in the figure below, simplify the block diagram to a single block.

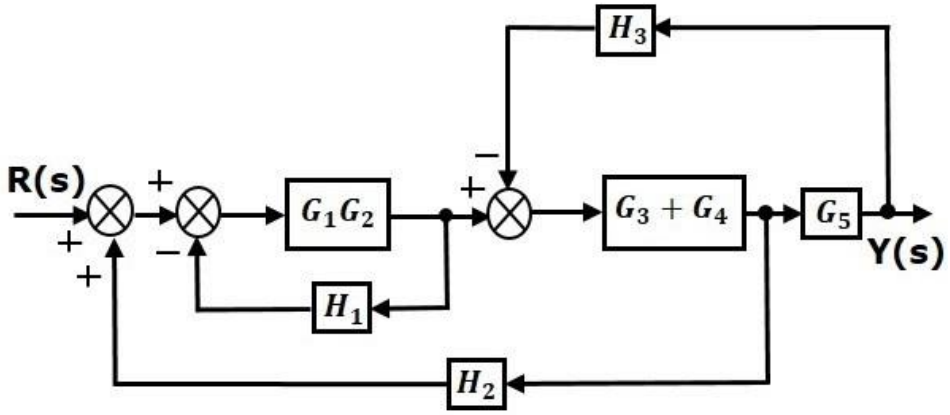
Notice that:

- There are 8 blocks of the subsystems in the diagram.
- The input of the system is $R(s)$ and the output is $Y(s)$.
- There are also various feedback and feedforward implemented in the system

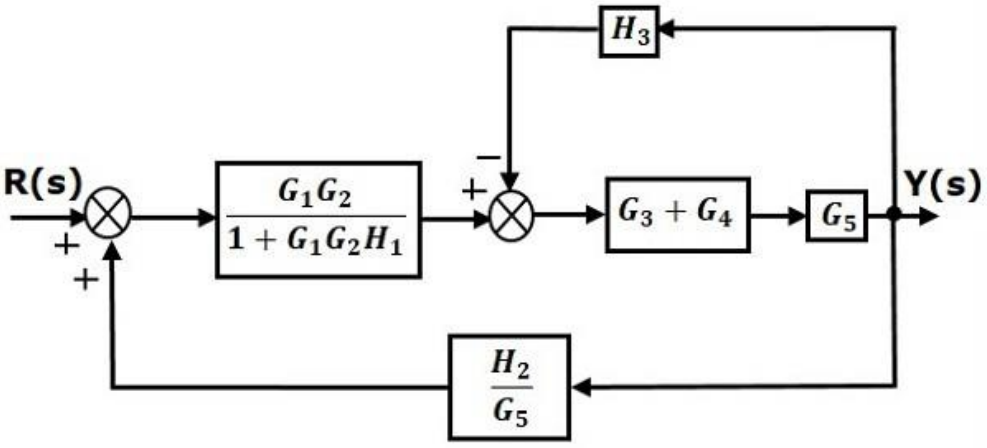


The block diagram is simplified following the guideline as follows:

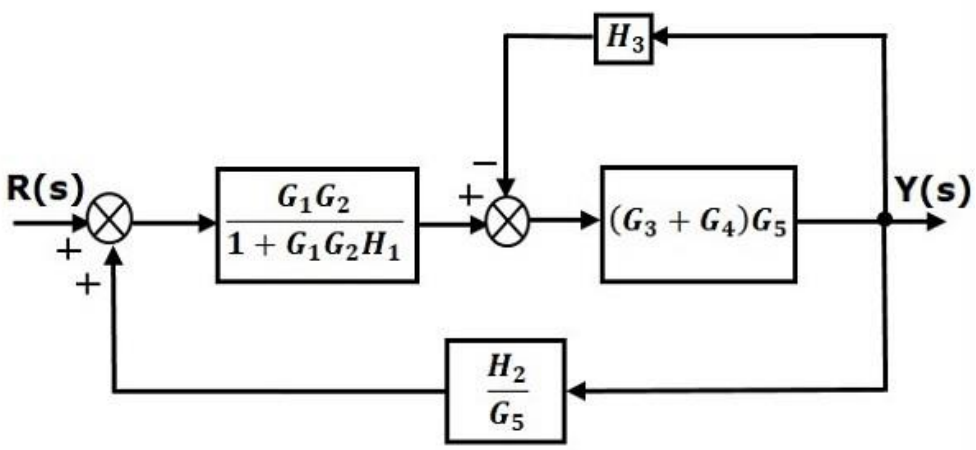
Step 1 − Use Rule 1 for blocks G_1 and G_2. Use Rule 2 for blocks G_3 and G_4. The modified block diagram is shown in the following figure.



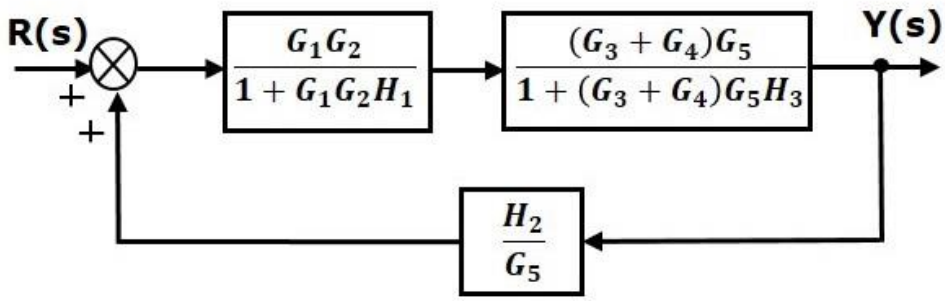
Step 2 − Use Rule 3 for blocks G_1G_2 and H_1. Use Rule 4 for shifting take-off point after the block G_5. The modified block diagram is shown in the following figure.



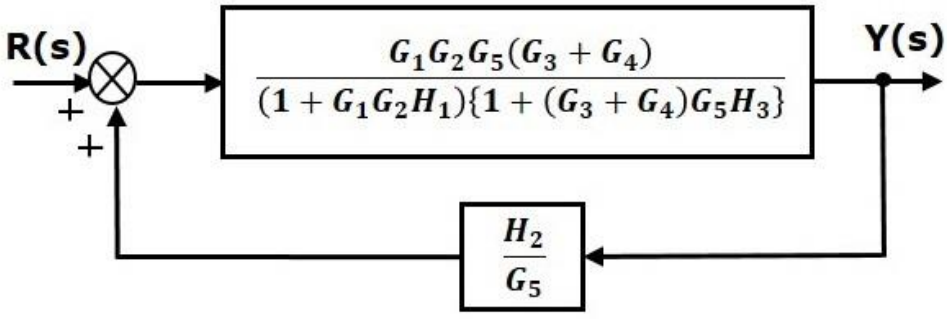
Step 3 − Use Rule 1 for blocks $(G_3 + G_4)$ and G_5. The modified block diagram is shown in the following figure.



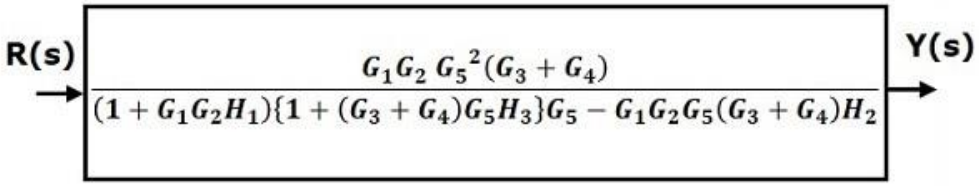
Step 4 − Use Rule 3 for blocks $(G_3 + G_4)G_5$ and H_3. The modified block diagram is shown in the following figure.



Step 5 − Use Rule 1 for blocks connected in series. The modified block diagram is shown in the following figure.



Step 6 − Use Rule 3 for blocks connected in feedback loop. The modified block diagram is shown in the following figure. This is the simplified block diagram.



Therefore, the transfer function of the system is:

$$\frac{Y(s)}{R(s)}=\frac{G_1G_2G_5^2(G_3+G_4)}{(1+G_1G_2H_1)[1+(G_3+G_4)G_5H_3]G_5-G_1G_2G_5(G_3+G_4)H_2}$$

Follow these steps in order to calculate the transfer function of the block diagram having multiple inputs.

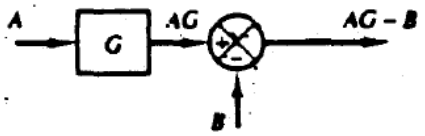
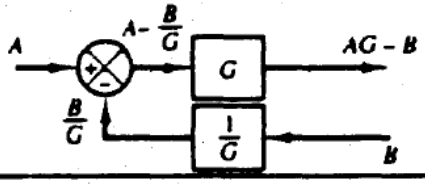
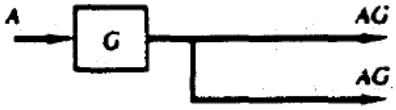
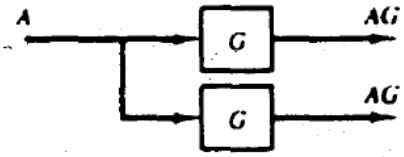
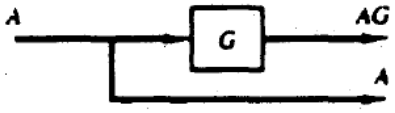
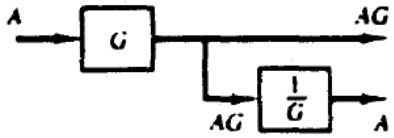
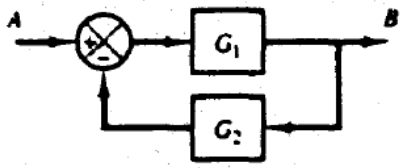
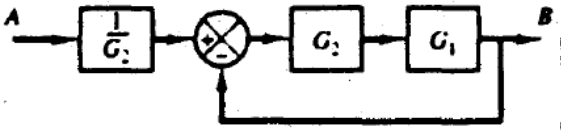
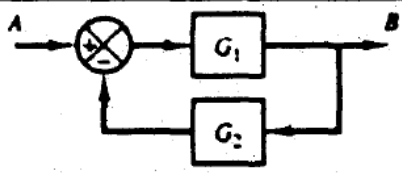
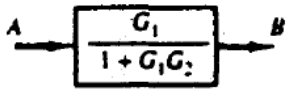
Step 1 − Find the transfer function of block diagram by considering one input at a time and make the remaining inputs as zero.

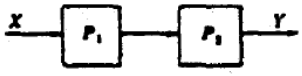
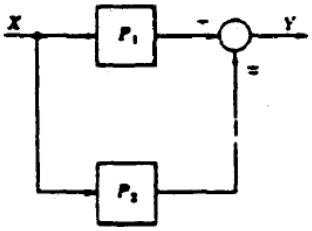
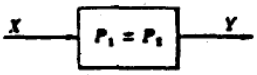
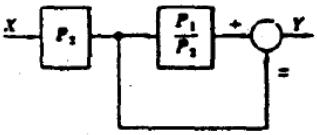
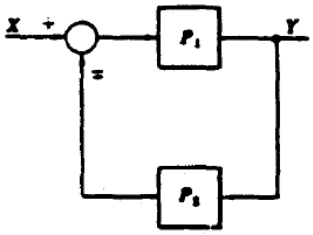
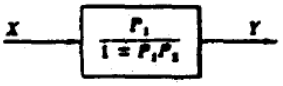
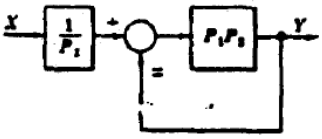
Step 2 − Repeat step 1 for remaining inputs.

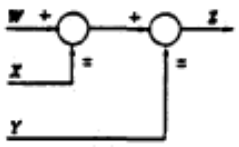
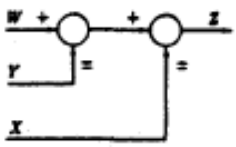
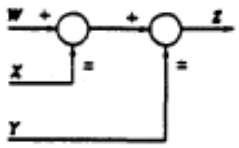
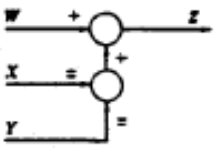
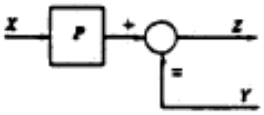
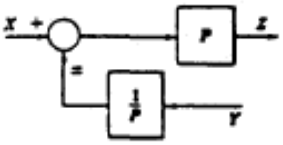
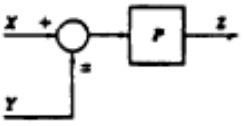
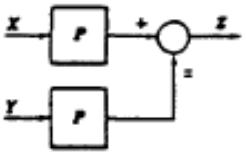
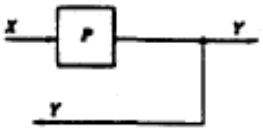
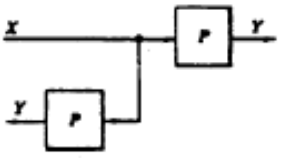
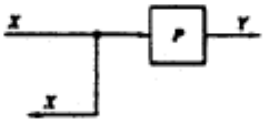
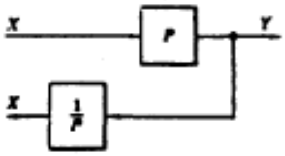
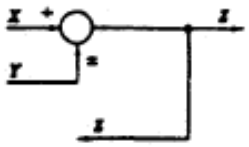
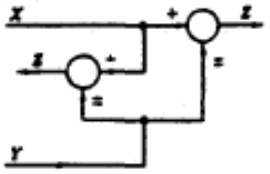
Step 3 − Get the overall transfer function by adding all those transfer functions.

The block diagram reduction process takes more time for complicated systems. Because, we have to draw the (partially simplified) block diagram after each step. So, to overcome this drawback, use signal flow graphs (representation).

Appendix

	Original Block Diagrams	Equivalent Block Diagrams
1		
2		
3		
4		
5		

	Transformation	Equation	Block Diagram	Equivalent Block Diagram
1	Combining Blocks in Cascade	$Y = (P_1 P_2)X$		
2	Combining Blocks in Parallel: or Eliminating a Forward Loop	$Y = P_1X = P_2X$		
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	$Y = P_1(X \mp P_2Y)$		

	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	$Z = P[X \pm Y]$		
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	$Z = X \pm Y$