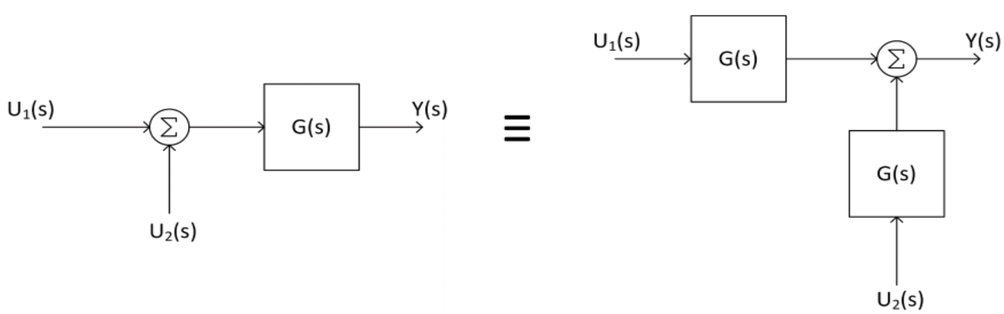
Block Diagram Manipulation

- Often want to simplify block diagrams into simpler, recognizable forms
  - To determine the equivalent transfer function
- Simplify to instances of the three standard forms, then simplify those forms
- Move blocks around relative to summing junctions and pickoff points– simplify to a standard form
  - Move blocks forward/backward past summing junctions
  - Move blocks forward/backward past pickoff points

- The following two block diagrams are equivalent:



$$Y(s) = [U_1(s) + U_2(s)]G(s) = U_1(s)G(s) + U_2(s)G(s)$$

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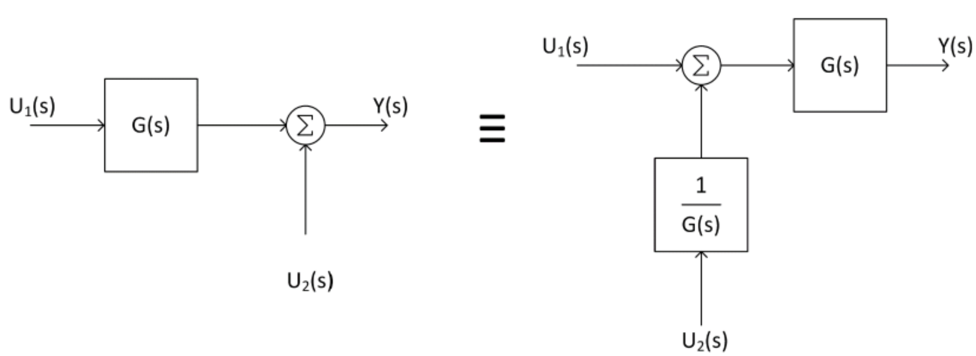

$$Y(s) = U_1(s)G(s) + U_2(s) = \left[U_1(s) + U_2(s)\frac{1}{G(s)}\right]G(s)$$

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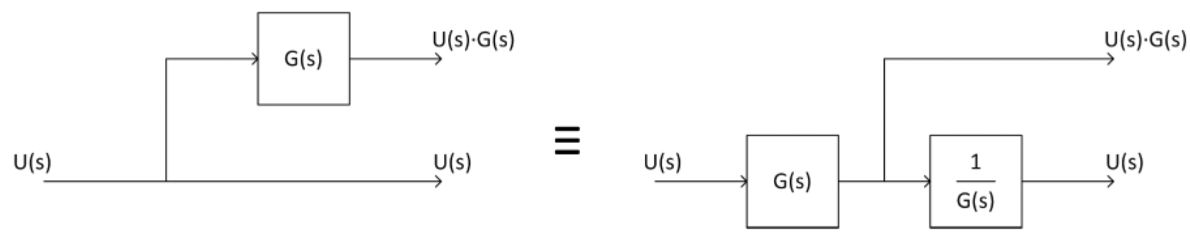
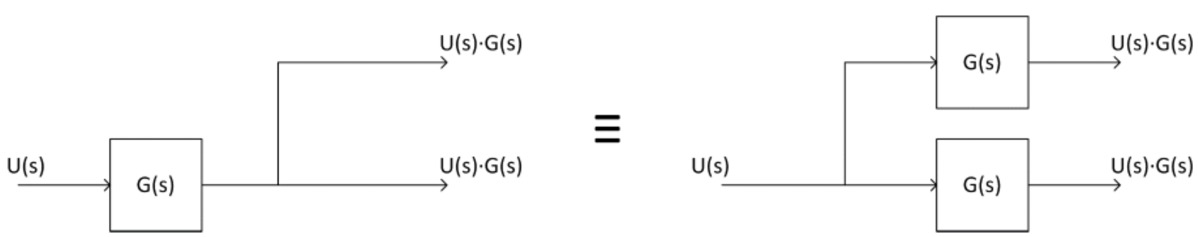
- We can move blocks backward past pickoff points:

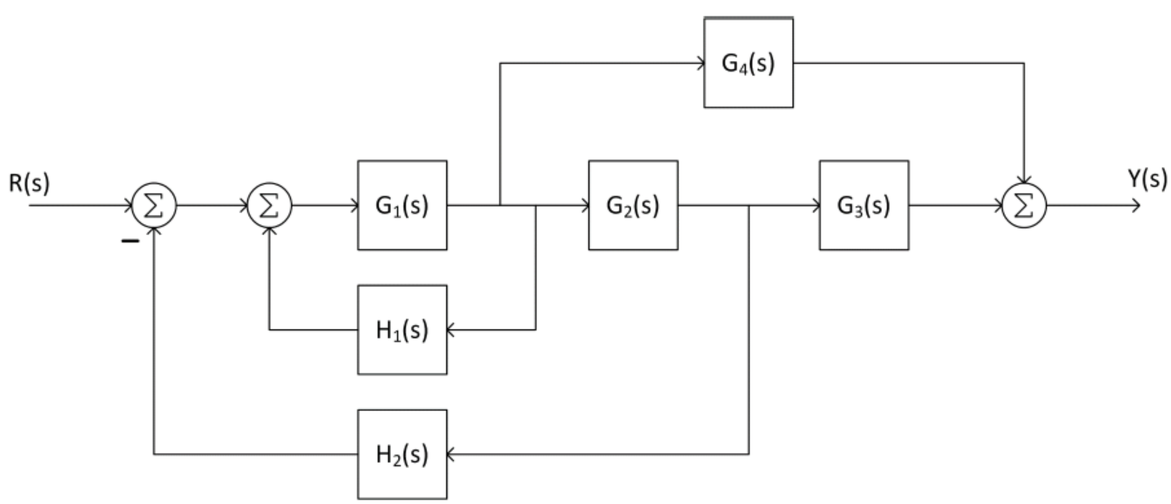


- And, we can move them forward past pickoff points:



Example:

- Find the closed-loop transfer function of the following system through block-diagram simplification



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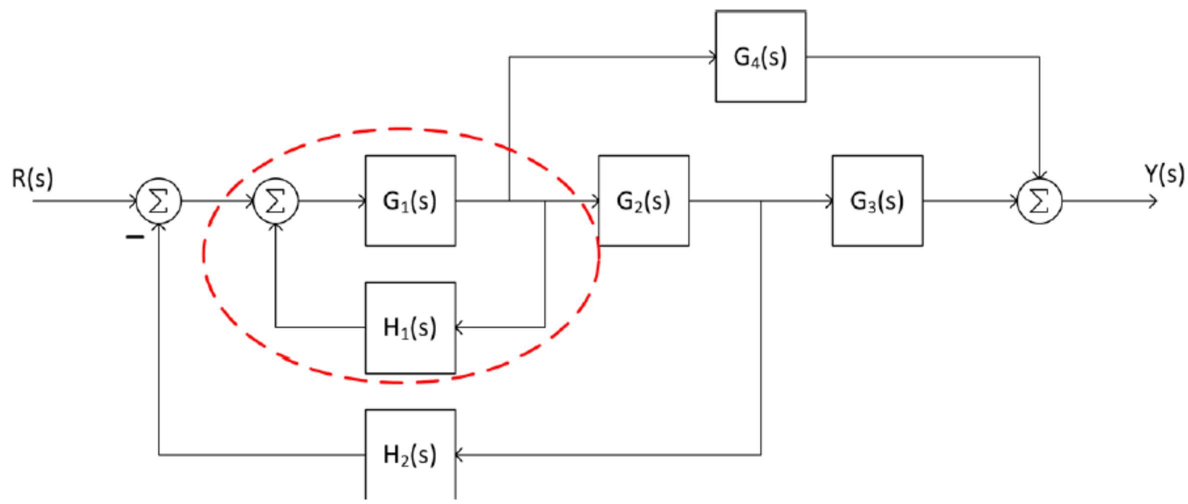
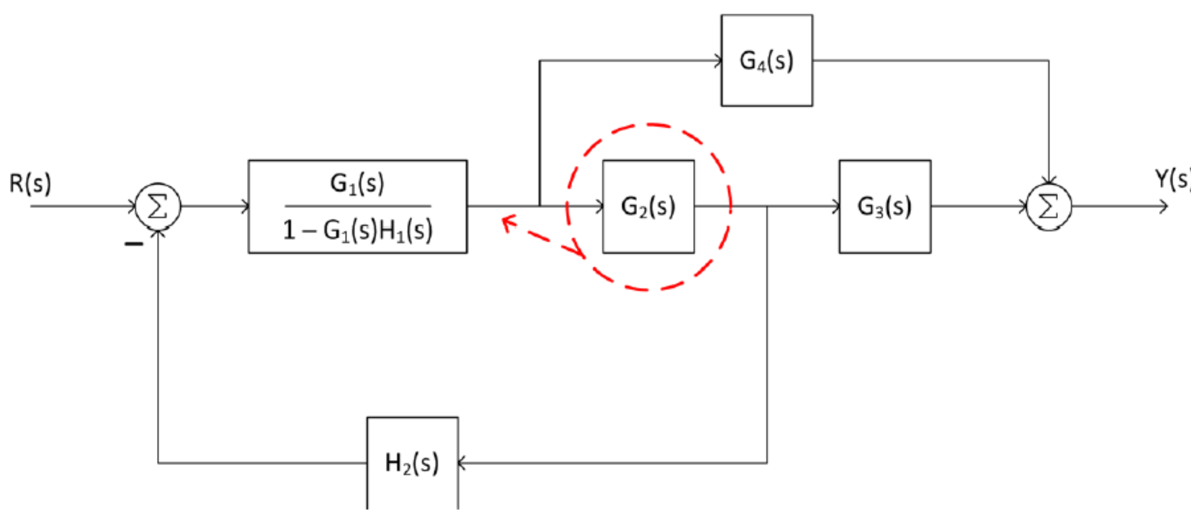
- $G_1(s)$ and $H_1(s)$ are in feedback form



$$G_{eq}(s) = \frac{G_1(s)}{1 - G_1(s)H_1(s)}$$

- Move $G_2(s)$ backward past the pickoff point



- Block from previous step, $G_2(s)$, and $H_2(s)$ become a feedback system that can be simplified

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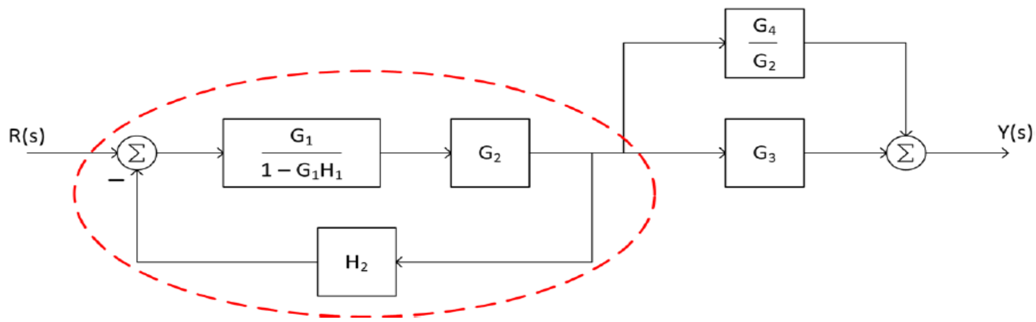
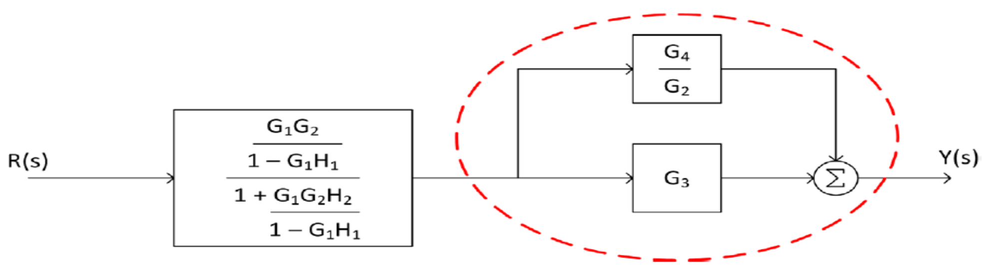
- Simplify the feedback subsystem
- Note that we've dropped the function of s notation, (s), for clarity



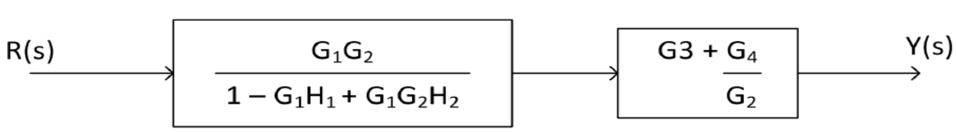
$$G_{eq}(s) = \frac{\frac{G_1 G_2}{1 - G_1 H_1}}{1 + \frac{G_1 G_2 H_2}{1 - G_1 H_1}} = \frac{G_1 G_2}{1 - G_1 H_1 + G_1 G_2 H_2}$$

- Simplify the two parallel subsystems



$$G_{eq}(s) = G_3 + \frac{G_4}{G_2}$$

- Now left with two cascaded subsystems
  - Transfer functions multiply



$$G_{eq}(s) = \frac{G_1 G_2 G_3 + G_1 G_4}{1 - G_1 H_1 + G_1 G_2 H_2}$$

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