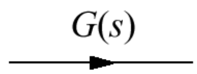
C) <u>SIGNAL FLOW GRAPHS</u>

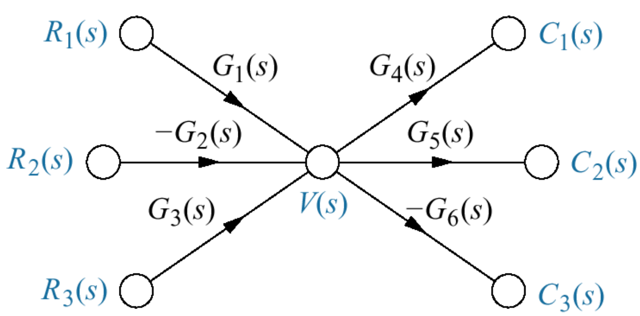
- **An alternative to block diagrams.**
- **It consists only of branches (represent system) and nodes (represents signals).**
  - **Branches**
    - **represented by a line with arrow showing the direction of signal flow through the system**



The transfer function is written close to the line and arrow

  - **Nodes**
    - **represented by a small circle with the signal's name is written adjacent to the node**

- **Example:**



V(s)=

C_1(s)=

C_2(s)=

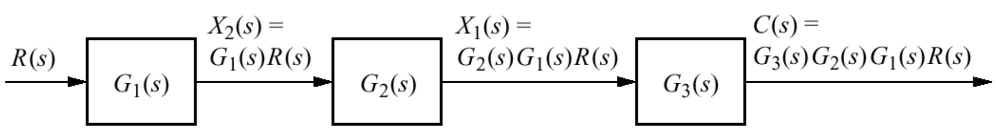
C_3(s)=

- **Converting common block diagrams into signal-flow graphs**

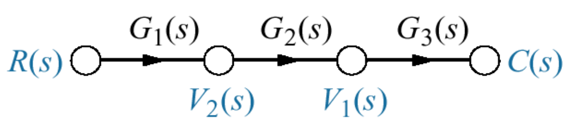
  - **We can convert the block diagrams in cascade, parallel and feedback forms into signal-flow diagrams**

  - **We can start with drawing the signal nodes, and then interconnect the signal nodes with system branches.**

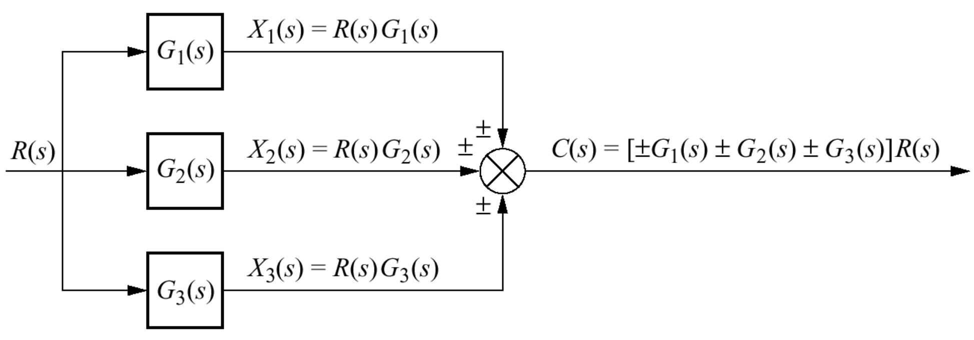
  - **Cascade form:**



into



  - **Parallel form:**



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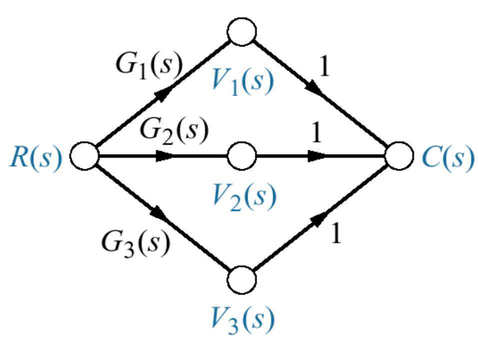
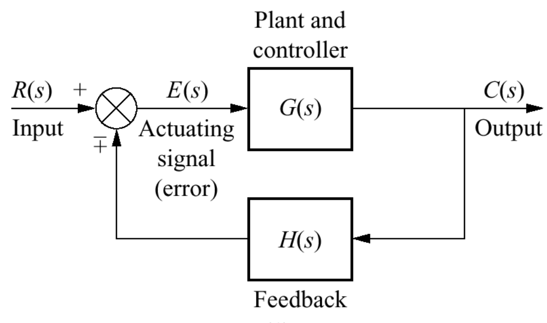


- **Feedback form:**



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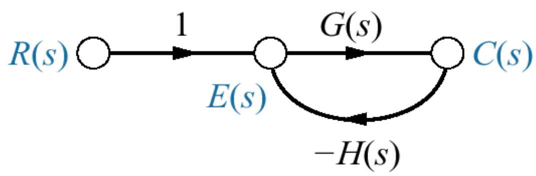
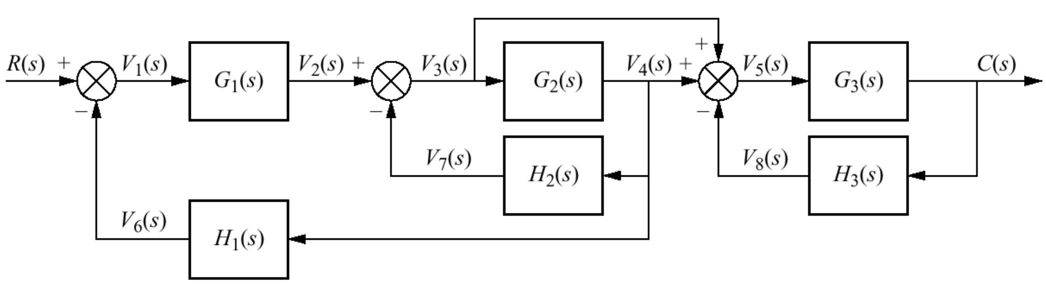
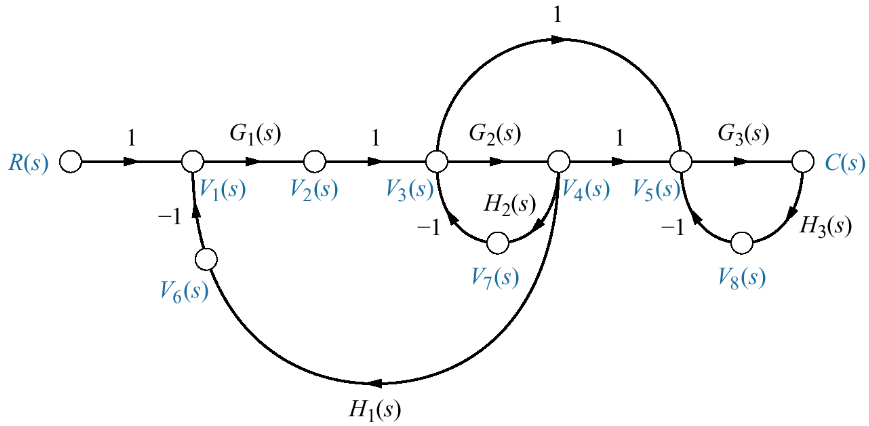


- **Example:**

  Convert the following block diagram into signal-flow graph





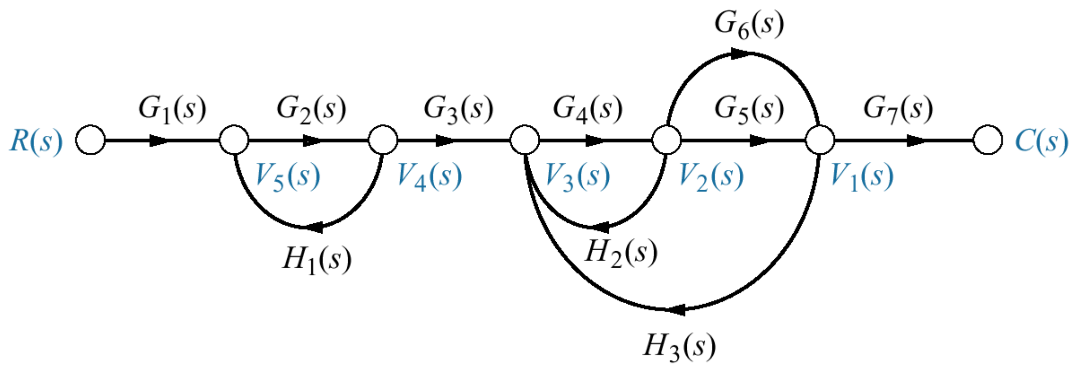
- **Further example: Convert those block diagrams in previous example in the previous section.**

- **Make sure that the reverse (converting from signal flow to block diagram) is also possible.**

D) MASON'S RULE

- **Mason's rule is used to get the single transfer function in the signal-flow graph.**

- **We need to know some important definitions:**



  - **Loop – a closed path which starts and ends at the same node.**

- **Loop gain – the product of branch gains found by traversing a loop.**
    - $G_2(s)H_1(s)$
    - $G_4(s)H_2(s)$
    - $G_4(s)G_5(s)H_3(s)$
    - $G_4(s)G_6(s)H_3(s)$

- **Forward-path – a path from the input node to the output node of the signal-flow graph in the direction of signal flow.**

- **Forward-path gain – the product of gains found by traversing a path from the input node to the output node of the signal-flow graph in the direction of signal flow.**
    - $G_1(s)G_2(s)G_3(s)G_4(s)G_5(s)G_7(s)$
    - $G_1(s)G_2(s)G_3(s)G_4(s)G_6(s)G_7(s)$

- **Non-touching loops – loops that do not have any nodes in common.**
    - $G_2(s)H_1(s)$ **is not touching with** $G_4(s)H_2(s)$, $G_4(s)G_5(s)H_3(s)$ **and** $G_4(s)G_6(s)H_3(s)$

- **Non-touching loops gain – the product of loop gains from non-touching loops taken two, three, four, or more at a time.**
    - $[G_2(s)H_1(s)][G_4(s)H_2(s)]$
    - $[G_2(s)H_1(s)][G_4(s)G_5(s)H_3(s)]$
    - $[G_2(s)H_1(s)][G_4(s)G_6(s)H_3(s)]$

- **Mason's rule**

$$G(s) = \frac{C(s)}{R(s)} = \frac{\sum_k T_k \Delta_k}{\Delta}$$

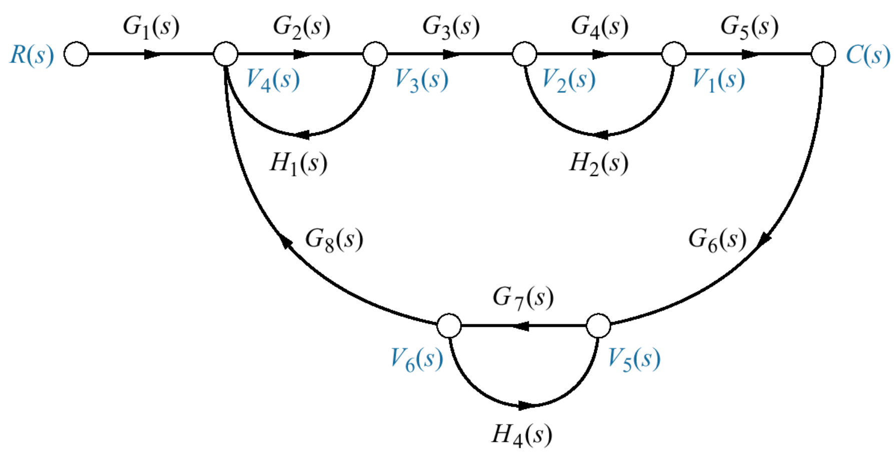
k = number of forward path

T_k = the kth forward-path gain

Δ = 1 - Σ loop gains + Σ non-touching loops gain (taken 2 at a time) - Σ non-touching loops gain (taken 3 at a time) + Σ non-touching loops gain (taken 4 at a time) - …

Δ_k = Δ - Σ loop gain terms in Δ that touch the kth forward path. (In other words, Δ_k is formed by eliminating from Δ those loop gains that touch the kth forward path)

- **Example: Find the transfer function, C(s)/R(s) of the following signal-flow graph,**



- **Forward-path gains**

- **Loop gains**

- **Nontouching loop gains – two at a time**

- **Nontouching loop gains – three at a time**

- Δ

- Δ_k

- **The transfer function by Mason's Rule:**