# SIGNAL FLOW GRAPH

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# Outline

- Introduction to Signal Flow Graphs
  - Definitions
  - Terminologies
- Mason's Gain Formula
  - Examples
- Signal Flow Graph from Block Diagrams
- Design Examples

# Signal Flow Graph (SFG)

- Alternative method to block diagram representation, developed by Samuel Jefferson Mason.

- Advantage: the availability of a flow graph gain formula, also called Mason's gain formula.

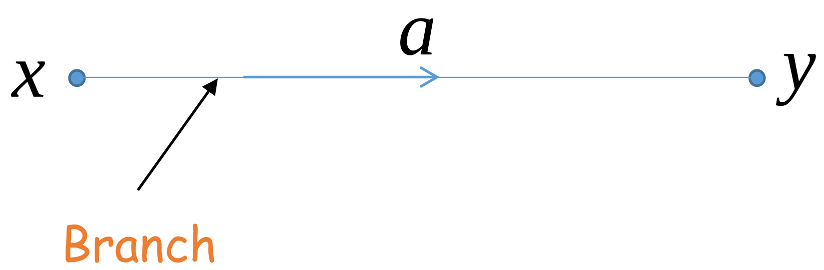
- A signal-flow graph consists of a network in which nodes are connected by directed branches.

- It depicts the flow of signals from one point of a system to another and gives the relationships among the signals.

# Important terminology :

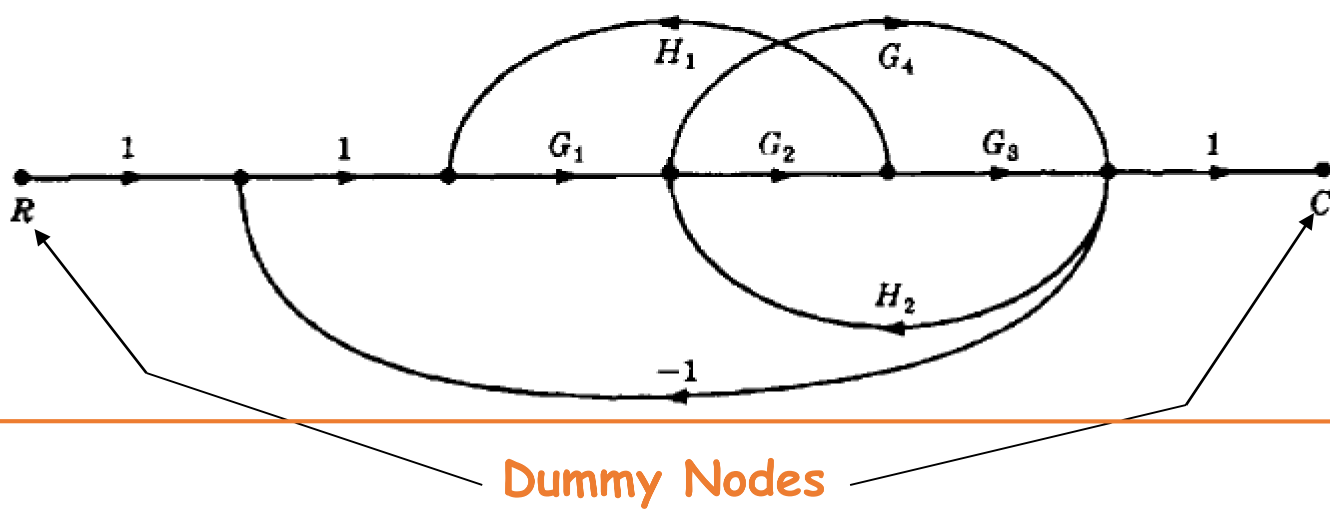
- **Branches :-**

  line joining two nodes is called branch.




- **Dummy Nodes:-**

  A branch having one can be added at i/p as well as o/p.



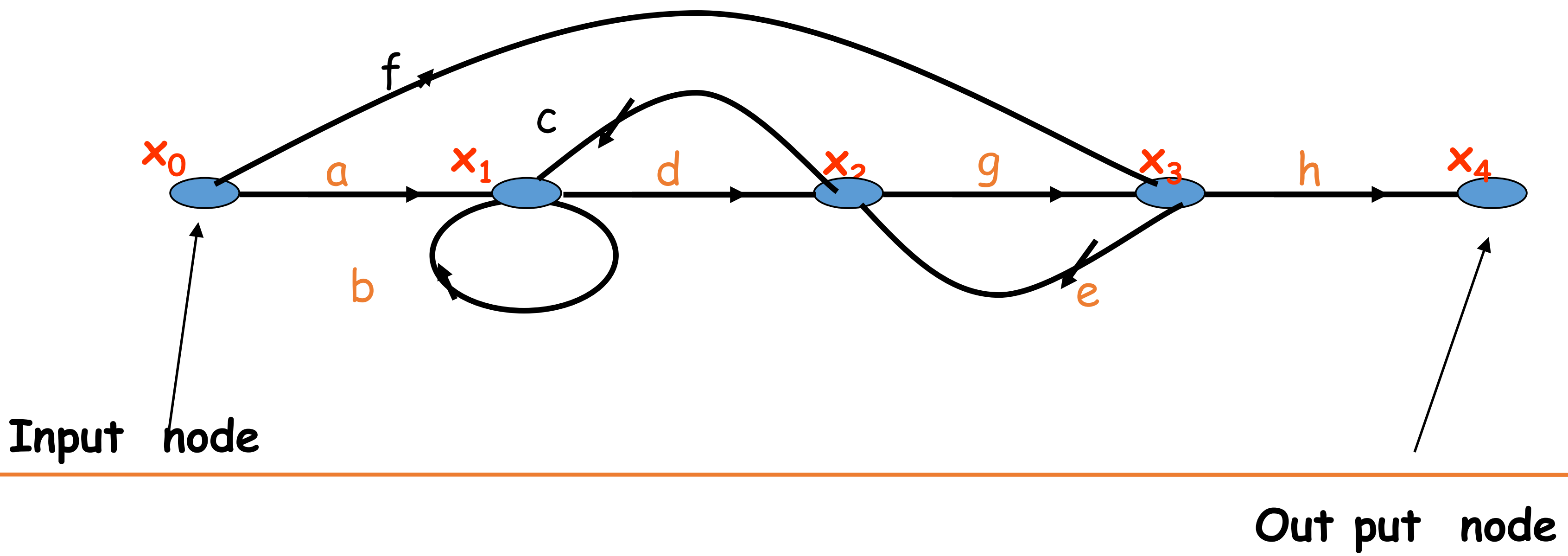
# Input & output node

- **Input node:-**

  It is node that has only outgoing branches.

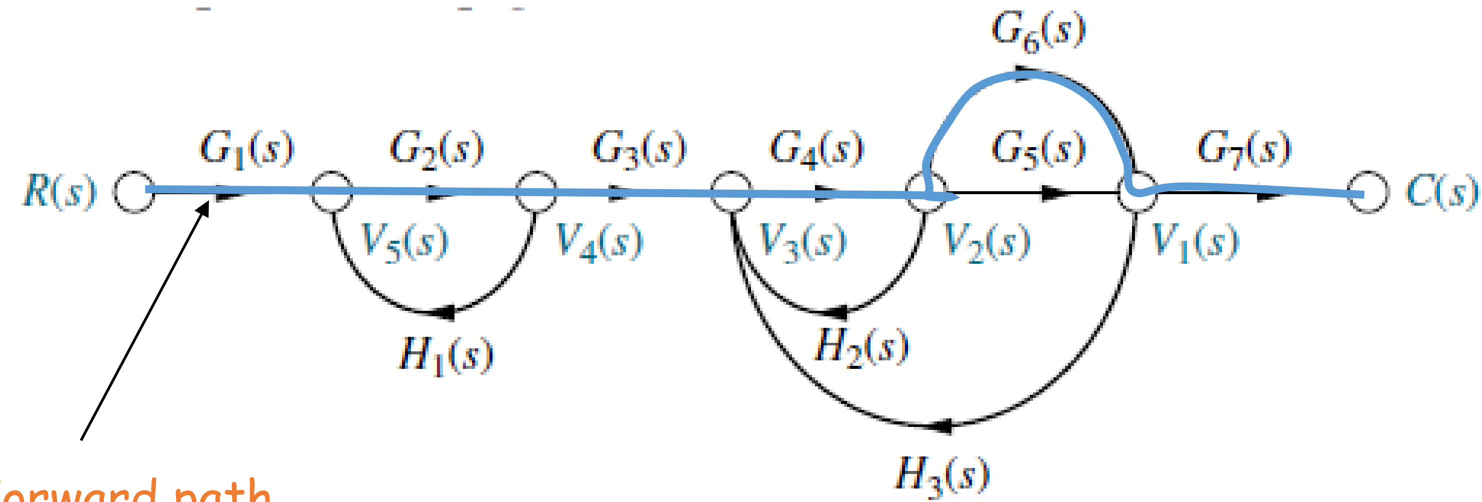
- **Output node:-**

  It is a node that has incoming branches.

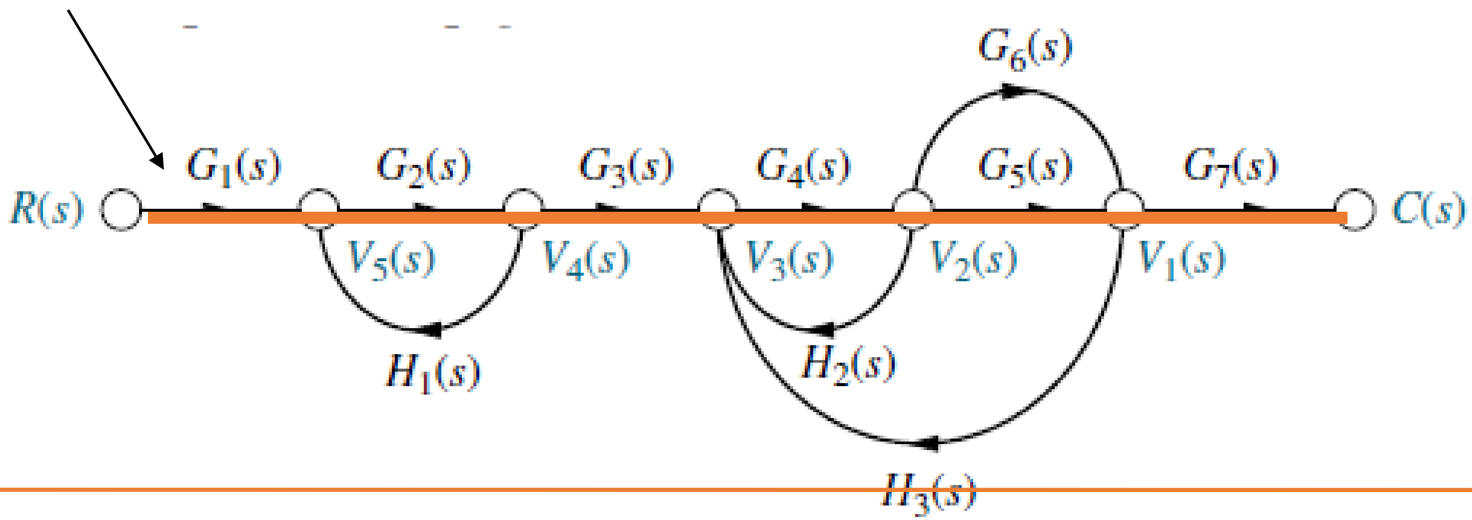


# Forward path:-

- Any path from i/p node to o/p node.

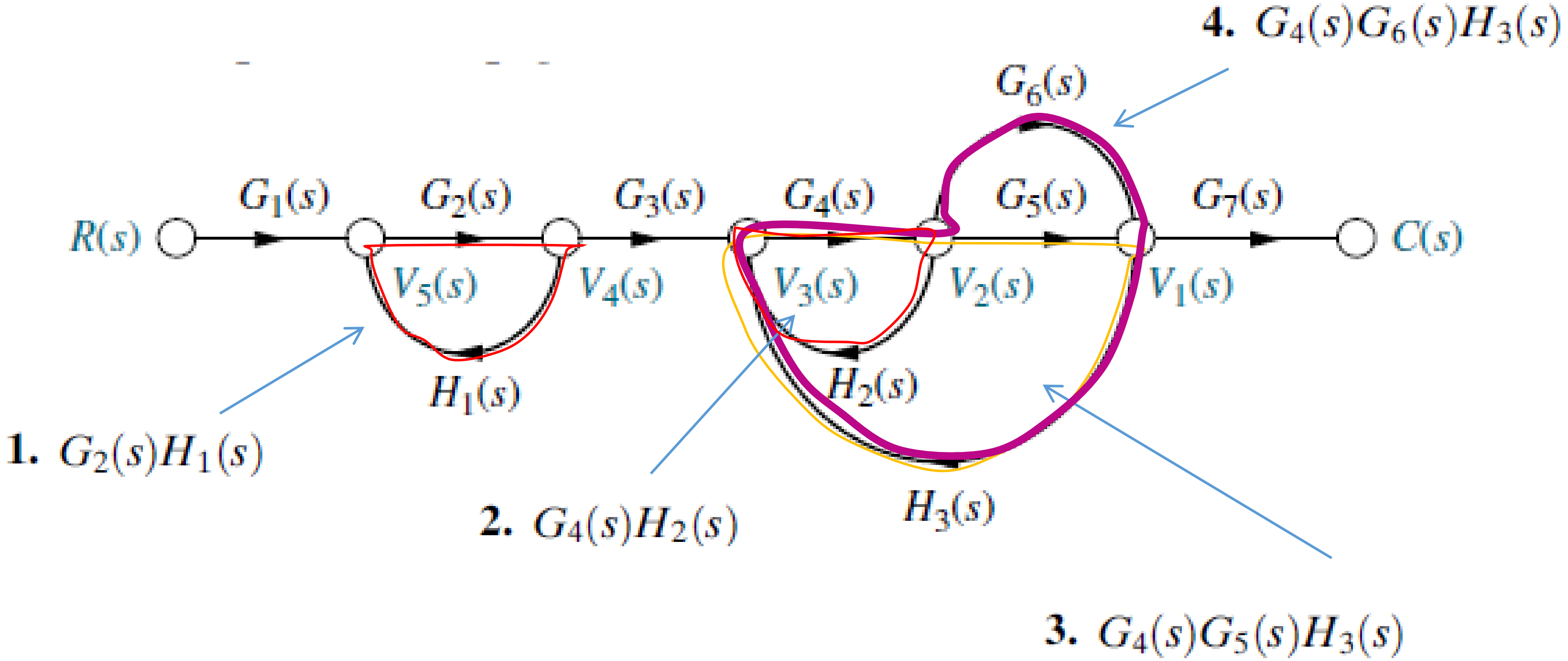



Forward path



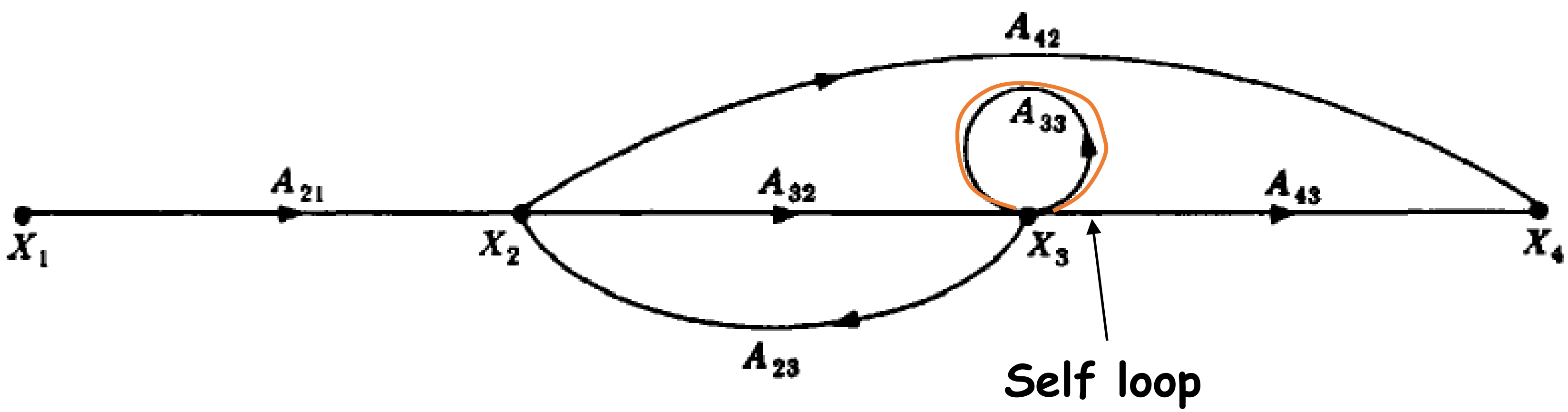
# Loop :-

- A closed path from a node to the same node is called loop.



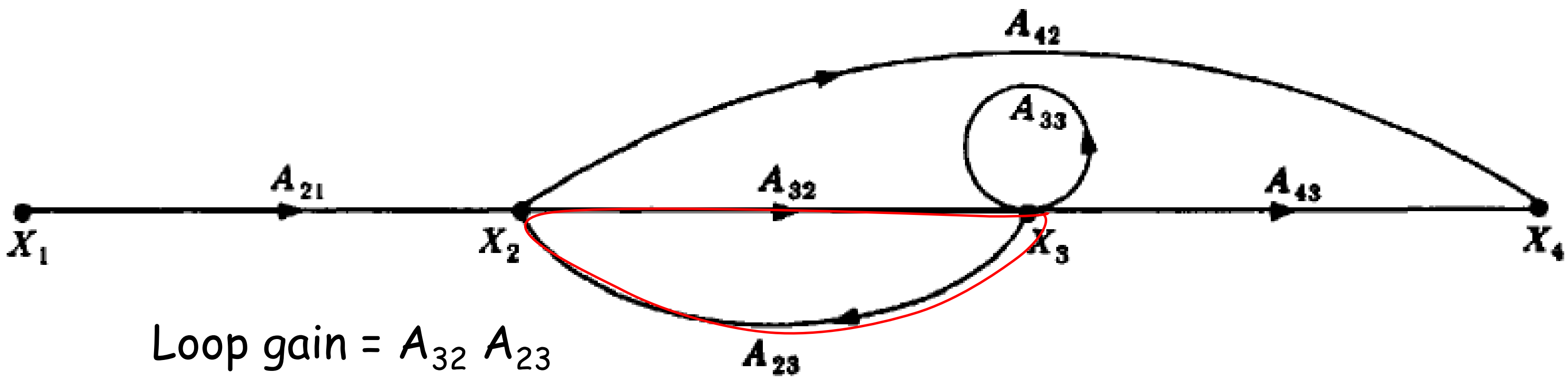
# Self loop:-

•A feedback loop that contains of only one node is called self loop.



# Loop gain:-

The product of all the gains forming a loop




Loop gain = $A_{32}\,A_{23}$

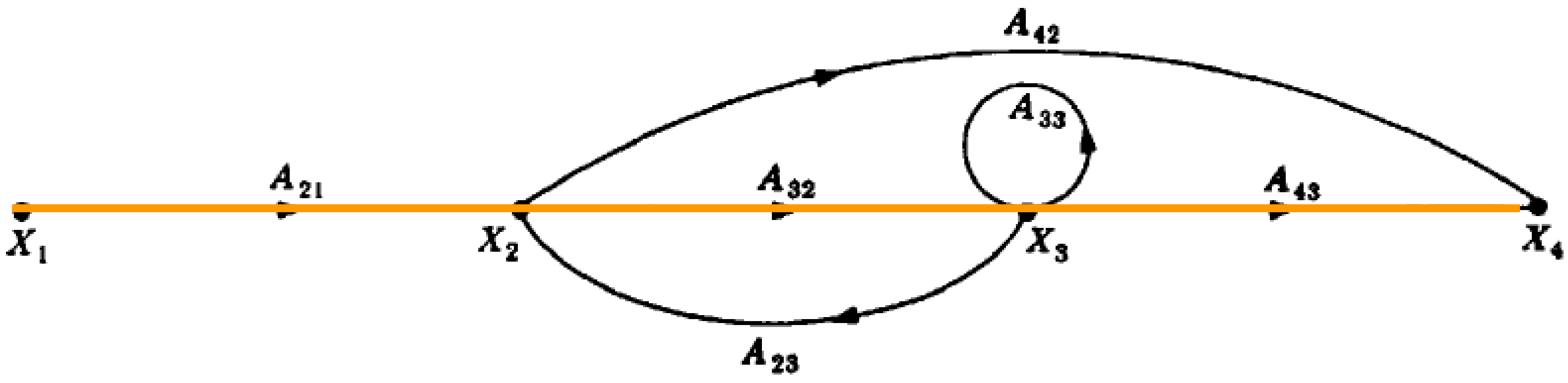
# Path and path gain

**Path:-**

A path is a traversal of connected branches in the direction of branch arrow.

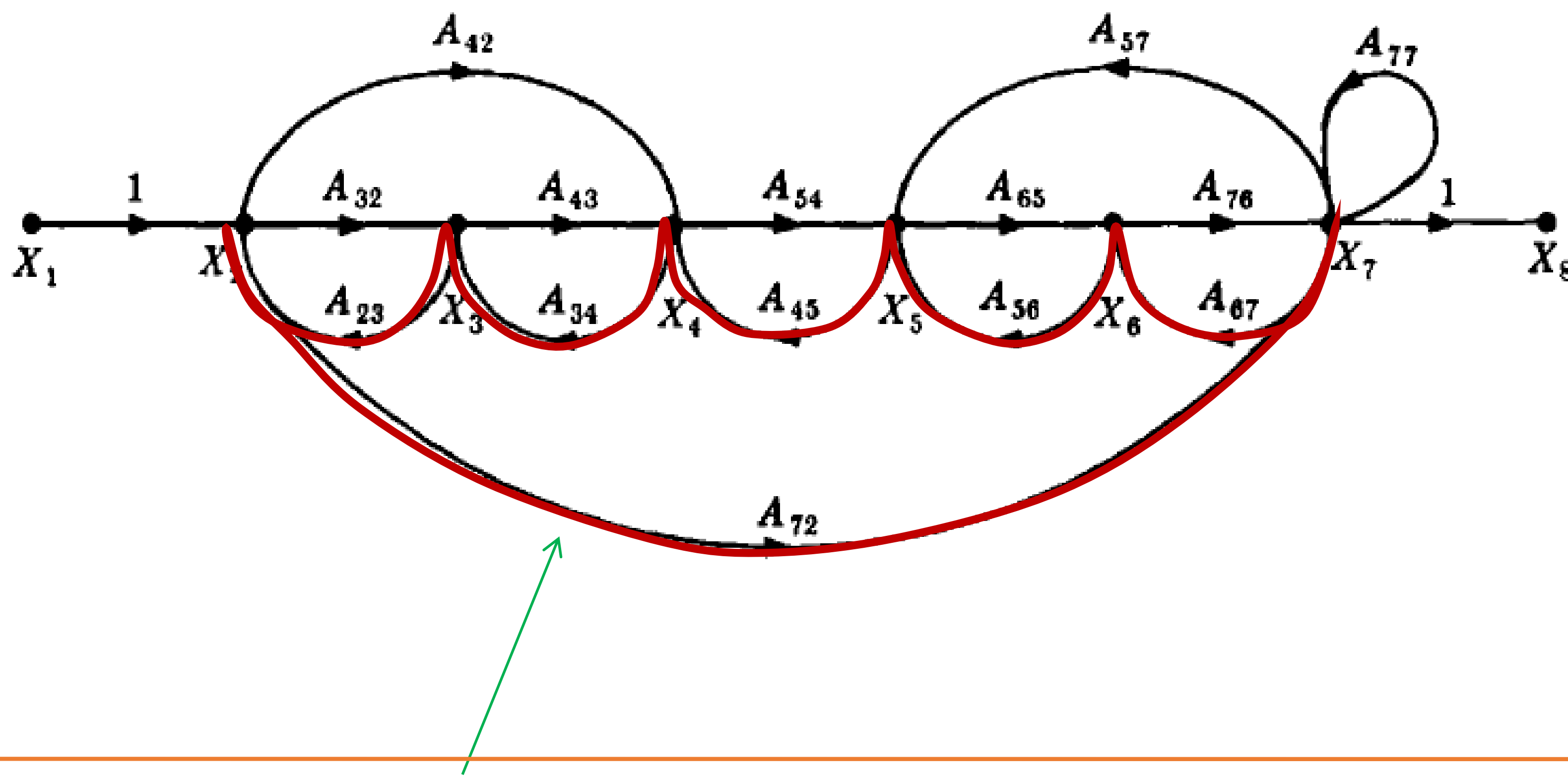
**Path gain:-**

The product of all branch gains while going through the forward path it is called as path gain.



# Feedback path or loop :-

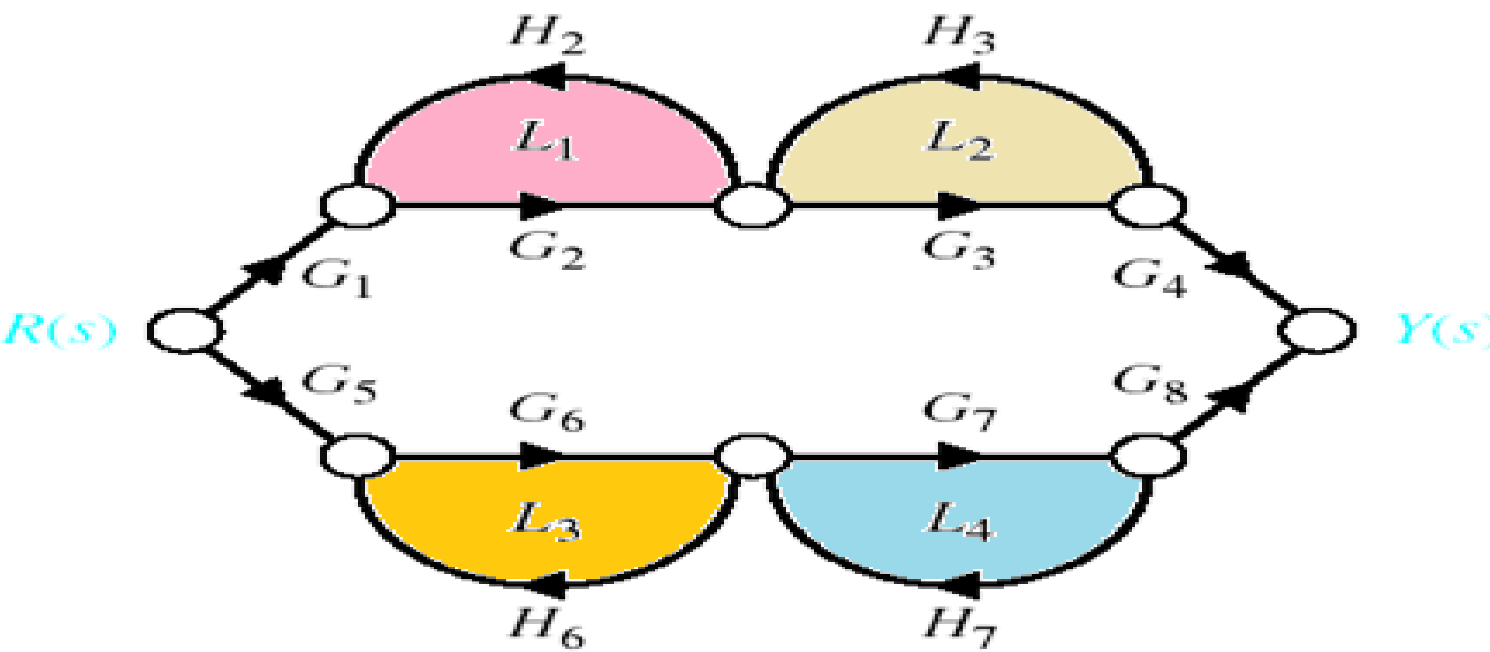
- it is a path to o/p node to i/p node.




$X_2$ to $X_7$ to $X_6$ to $X_5$ to $X_4$ to $X_3$ to $X_2$

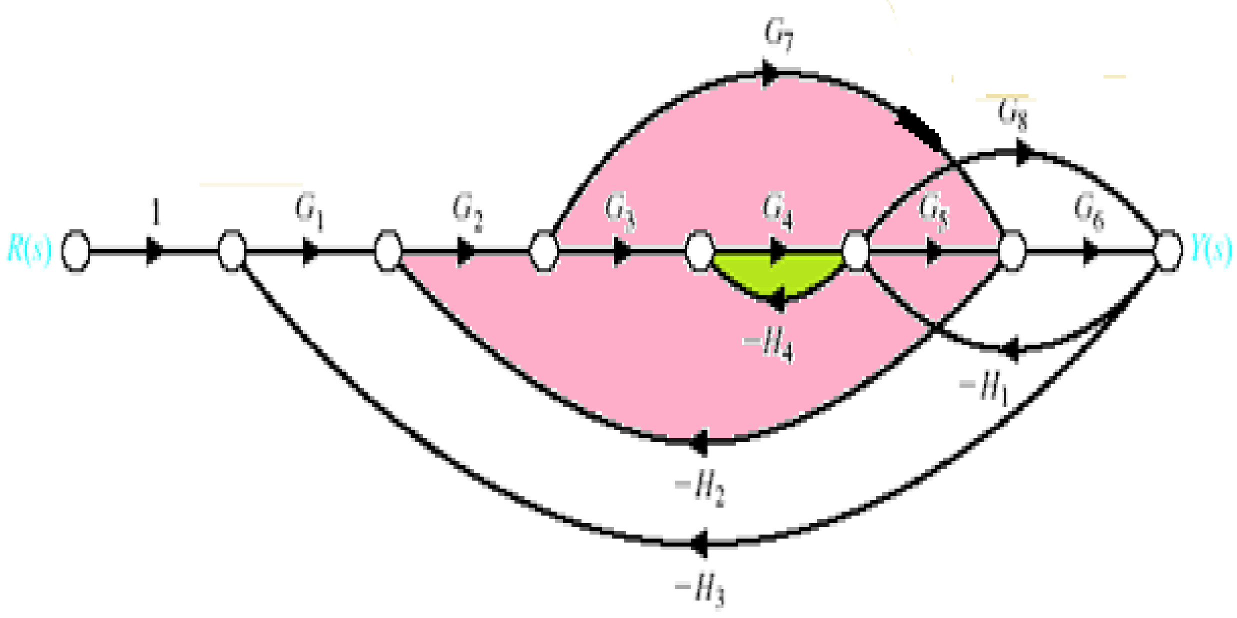
# Touching loops:-

- when the loops are having the common node that the

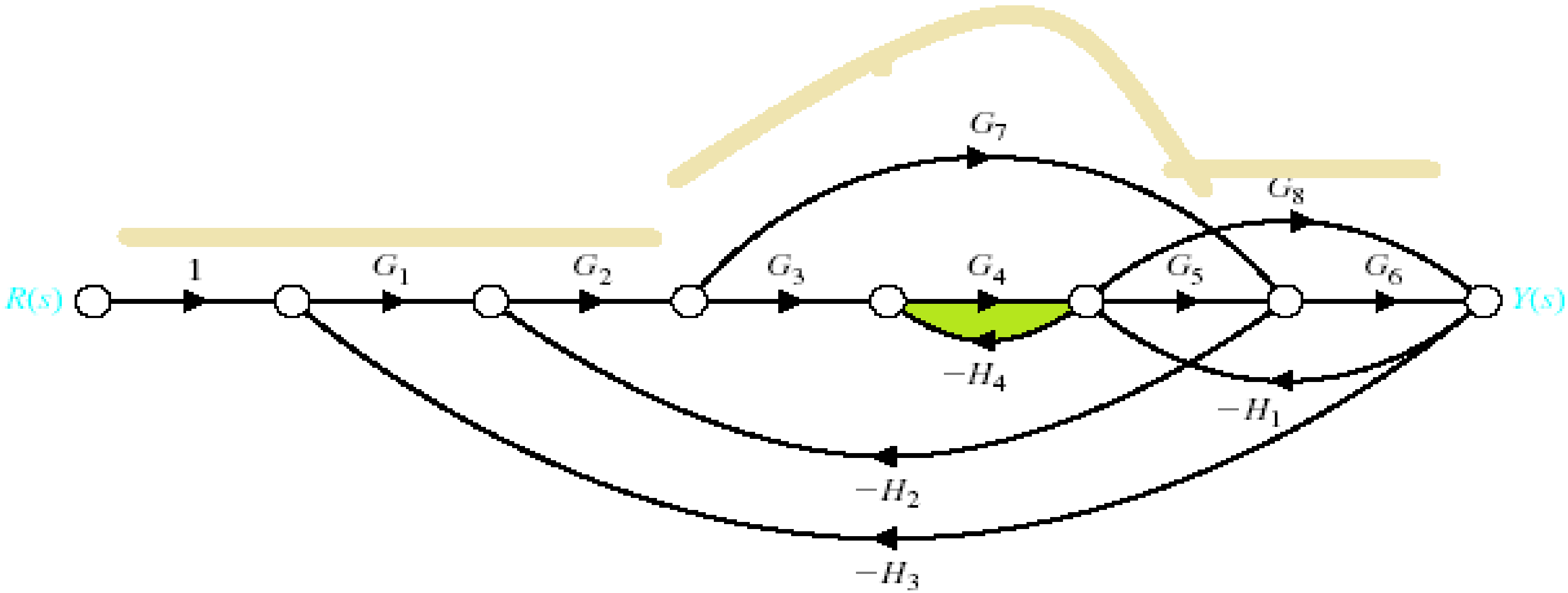


# Non touching loops:-

- when the loops are not having any common node between them that are called as non- touching loops.

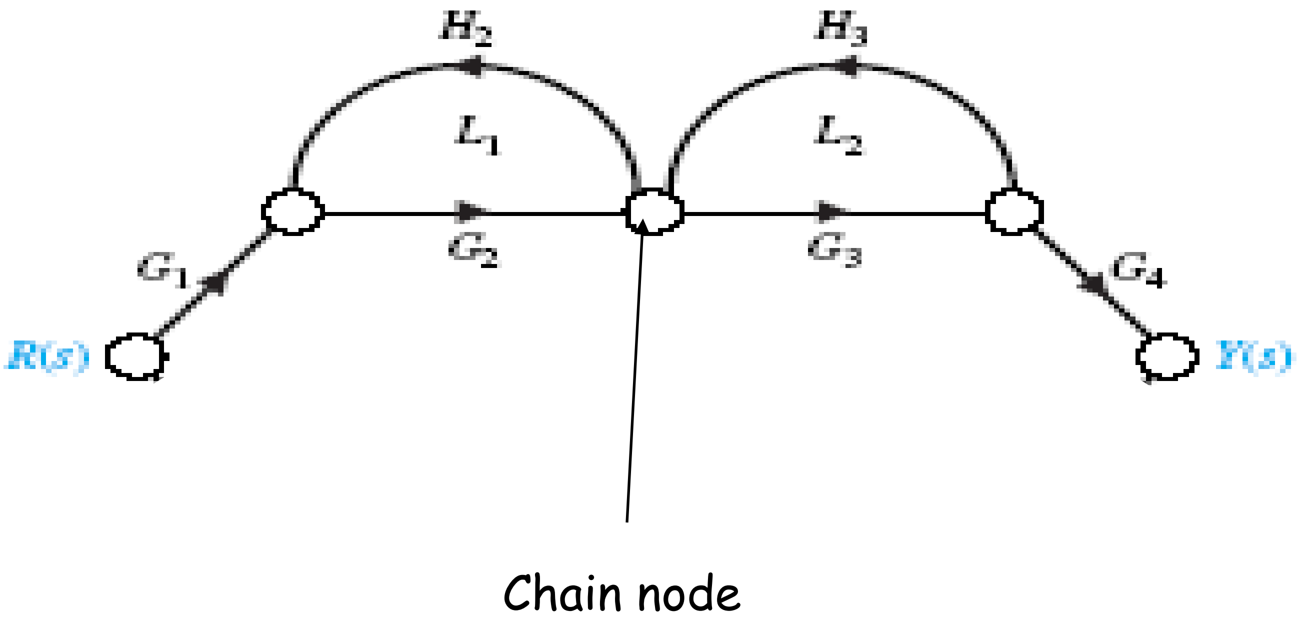


# Non-touching loops for forward paths

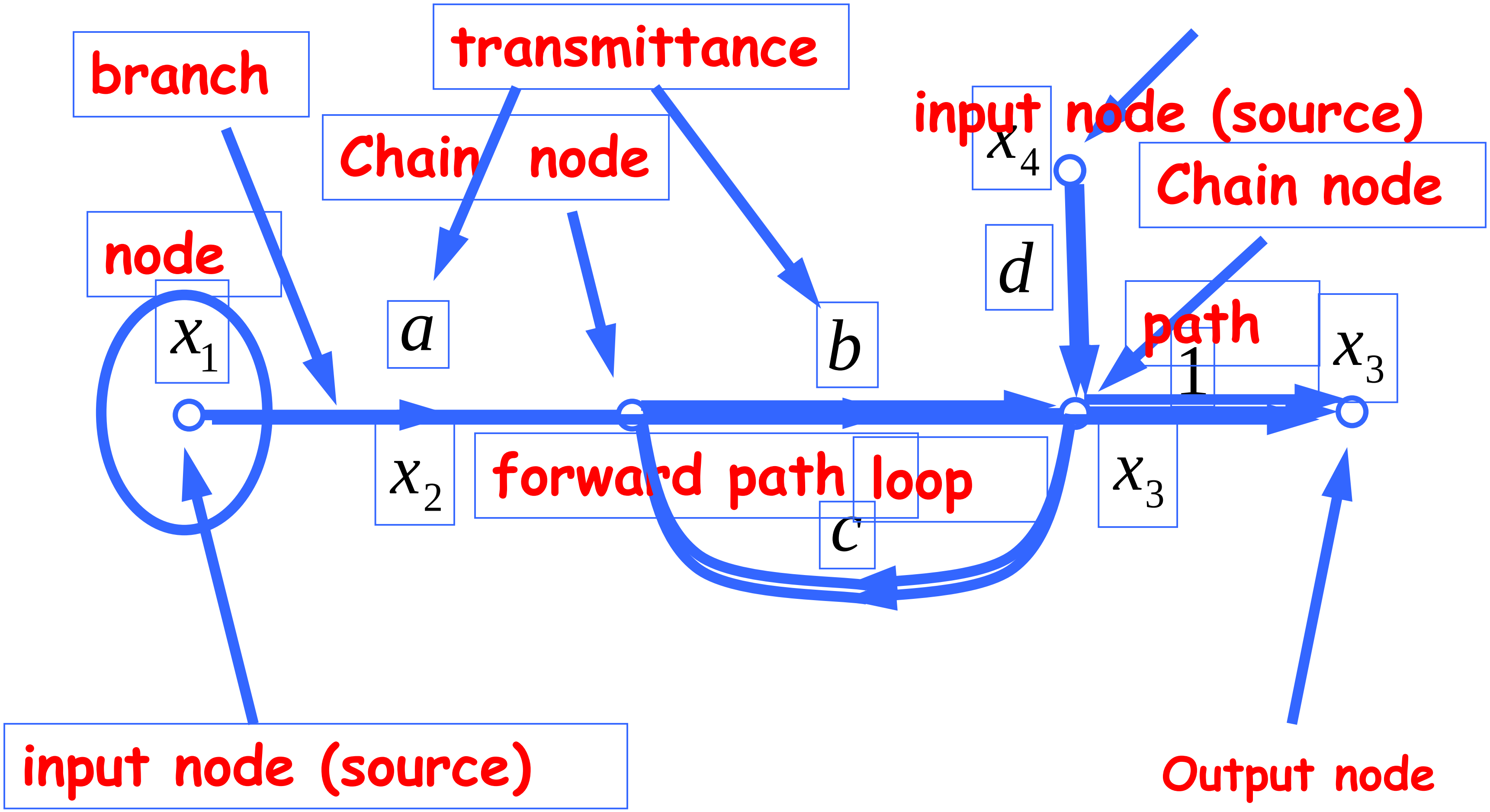


# Chain Node :-

- it is a node that has incoming as well as outgoing branches.



# SFG terms representation



# Mason's Rule (Mason, 1953)

- The block diagram reduction technique requires successive application of fundamental relationships in order to arrive at the system transfer function.

- On the other hand, Mason's rule for reducing a signal-flow graph to a single transfer function requires the application of one formula.

- The formula was derived by S. J. Mason when he related the signal-flow graph to the simultaneous equations that can be written from the graph.

# Mason's Rule :-

- The transfer function, ***C(s)/R(s),*** of a system represented by a signal-flow graph is;

$$\frac{C(s)}{R(s)} = \frac{\sum_{i=1}^{n} P_i \Delta_i}{\Delta}$$

where

- $n$ = number of forward paths.
- $P_i$ = the $i$ th forward-path gain.
- $\Delta$ = Determinant of the system
- $\Delta_i$ = Determinant of the $i$th forward path

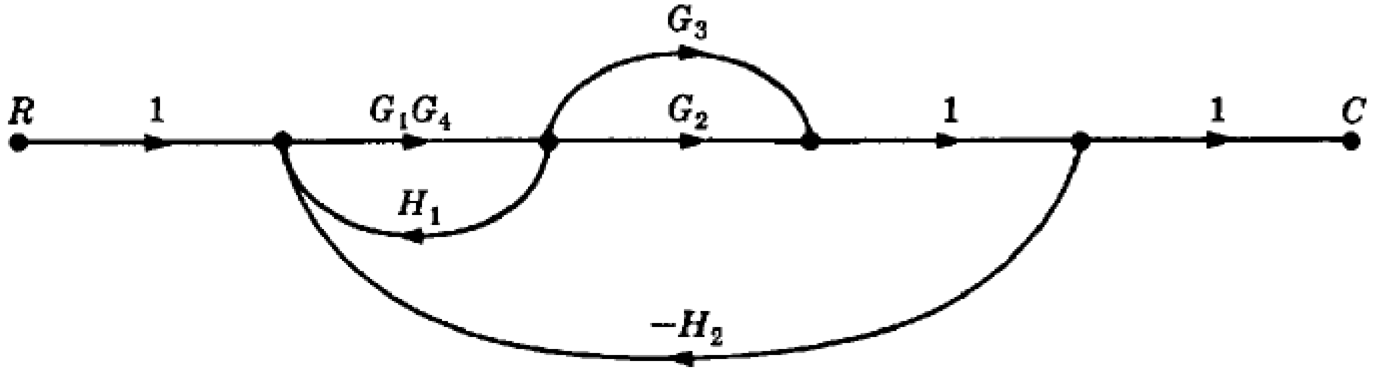
Δ is called the signal flow graph determinant or characteristic function. Since Δ=0 is the system characteristic equation.

$$\frac{C(s)}{R(s)} = \frac{\sum_{i=1}^{n} P_i \Delta_i}{\Delta}$$

Δ = 1- (sum of all individual loop gains) + (sum of the products of the gains of all possible two loops that do not touch each other) – (sum of the products of the gains of all possible three loops that do not touch each other) + … and so forth with sums of higher number of non-touching loop gains

Δ*i* = value of Δ for the part of the block diagram that does not touch the i-th forward path (Δi = 1 if there are no non-touching loops to the i-th path.)

## Example1: Apply Mason's Rule to calculate the transfer function of the system represented by following Signal Flow Graph




There are two forward paths:

$P_1 = G_1G_2G_4$ $\quad$ $P_2 = G_1G_3G_4$

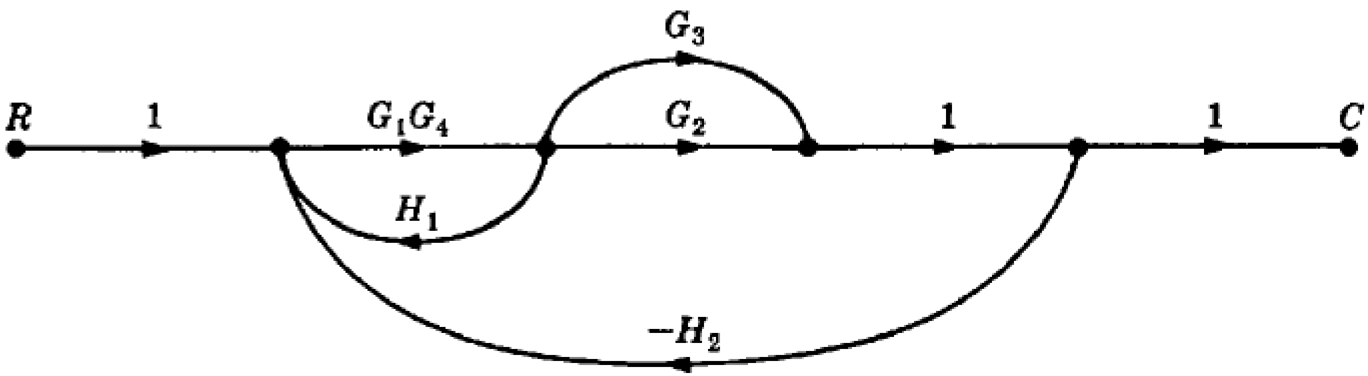
**Therefore,**

$$\frac{C}{R} = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta}$$

**There are three feedback loops**

$$L_1 = G_1G_4H_1, \quad L_2 = -G_1G_2G_4H_2, \quad L_3 = -G_1G_3G_4H_2$$

Continue……



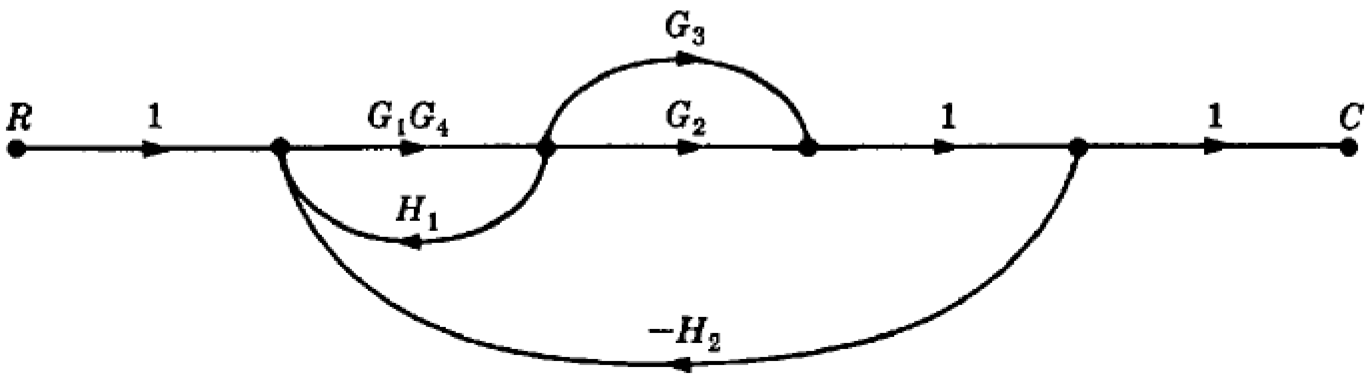

**There are no non-touching loops, therefore**

Δ = 1- (sum of all individual loop gains)

$$\Delta = 1 - \left(L_1 + L_2 + L_3\right)$$

$$\Delta = 1 - \left(G_1G_4H_1 - G_1G_2G_4H_2 - G_1G_3G_4H_2\right)$$

Continue……




**Eliminate forward path-1**

$\Delta_1$ = 1- (sum of all individual loop gains)+...

$\Delta_1 = 1$

**Eliminate forward path-2**

$\Delta_2$ = 1- (sum of all individual loop gains)+...

$\Delta_2 = 1$

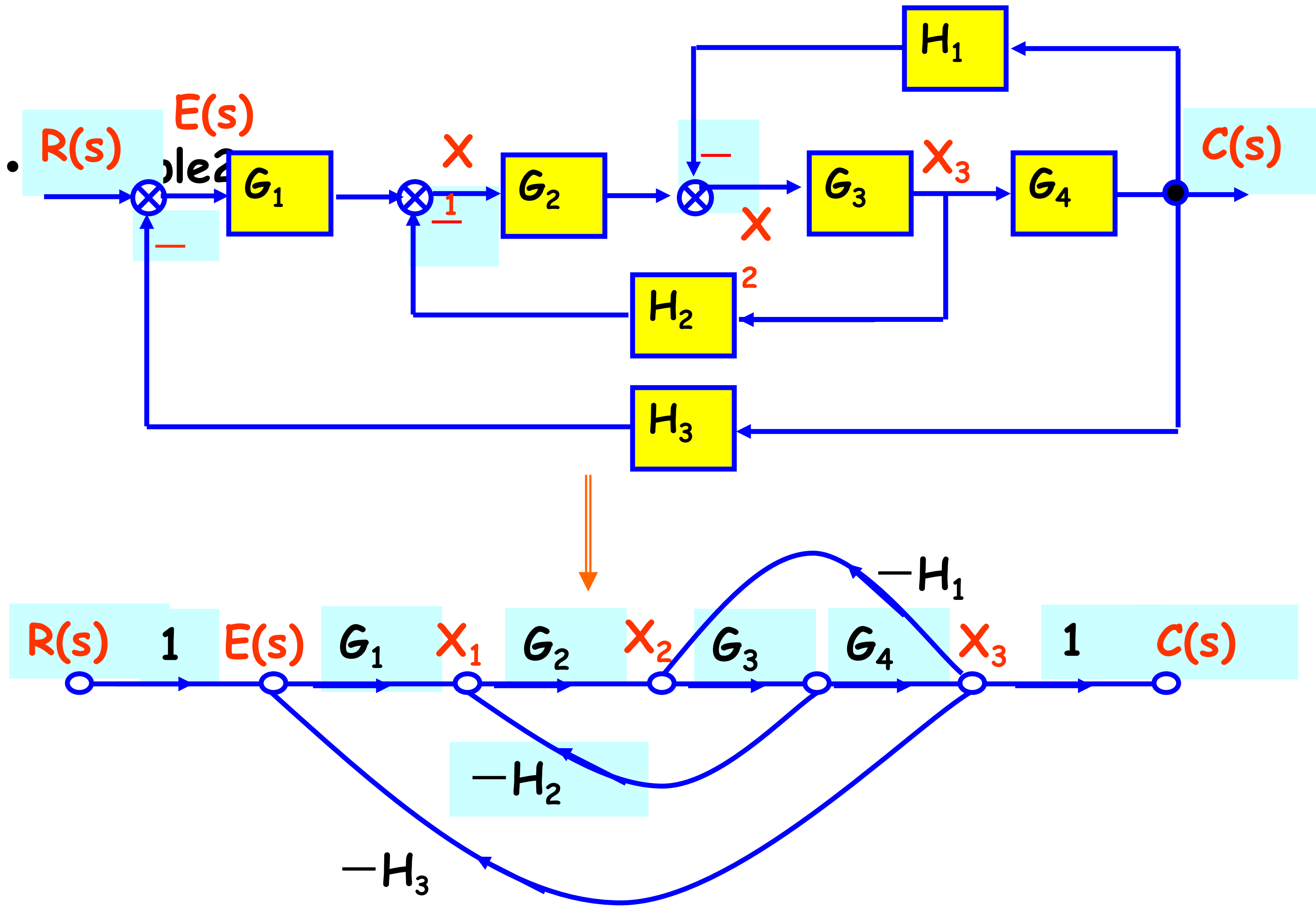
Continue……

$$\frac{C}{R} = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta}$$

$$= \frac{G_1G_2G_4 + G_1G_3G_4}{1 - G_1G_4H_1 + G_1G_2G_4H_2 + G_1G_3G_4H_2}$$

$$= \frac{G_1G_4(G_2 + G_3)}{1 - G_1G_4H_1 + G_1G_2G_4H_2 + G_1G_3G_4H_2}$$

# From Block Diagram to Signal-Flow Graph Models

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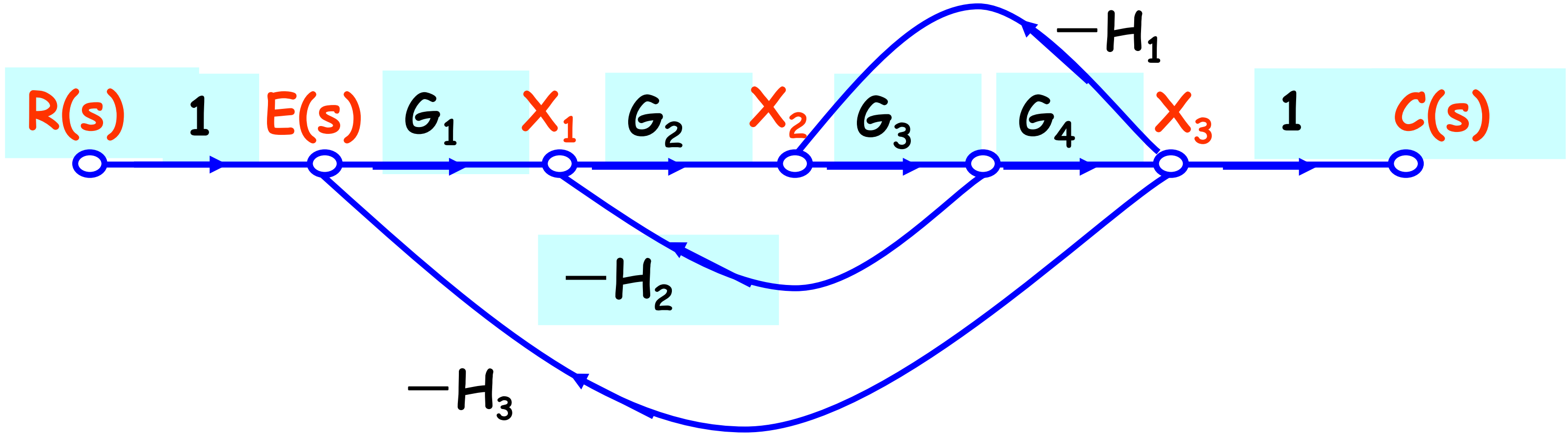


$$\Delta = 1 + (G_1G_2G_3G_4H_3 + G_2G_3H_2 + G_3G_4H_1)$$

$$P_1 = G_1G_2G_3G_4; \qquad \Delta_1 = 1$$

$$G = \frac{C(s)}{R(s)} = \frac{G_1G_2G_3G_4}{1 + G_1G_2G_3G_4H_3 + G_2G_3H_2 + G_3G_4H_1}$$


Thank You!