SNS COLLEGE OF ENGINEERING

Kurumbapalayam (Po), Coimbatore – 641 107

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Redesigning Common Mind & Business Towards Excellence

Build an Entrepreneurial Mindset Through Our Design Thinking FrameWork

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE NAME : 23EET206 CONTROL SYSTEMS AND INSTRUMENTATION

II YEAR ECE /III SEMESTER

Unit 1- Control System Modelling

Topic 7 : Signal Flow Graph

SIGNAL FLOW GRAPH

- 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.

BASICS OF SIGNAL FLOW GRAPH

- Consider a simple equation below and draw its signal flow graph:

$$y = ax$$

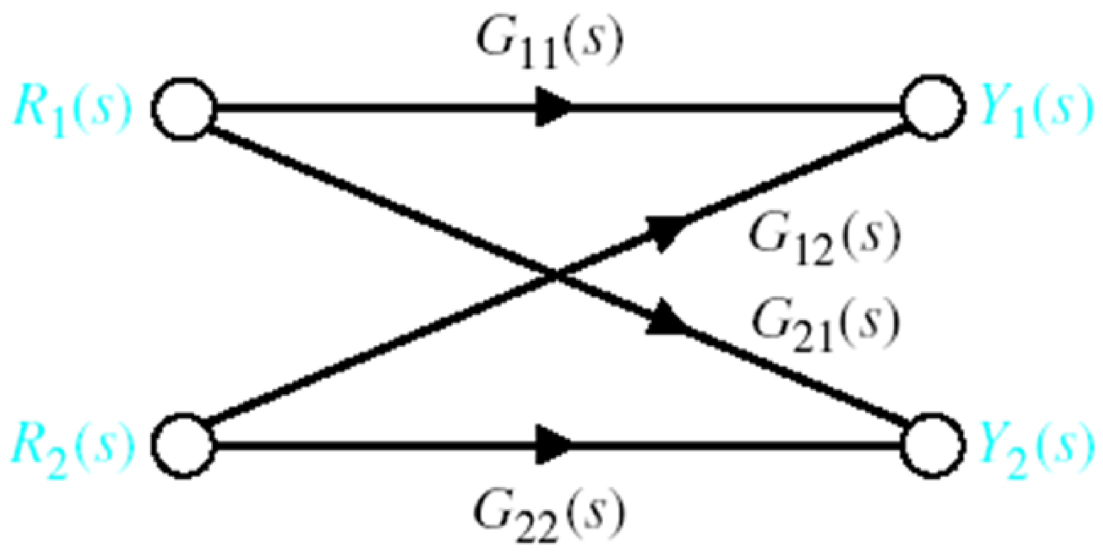
- The signal flow graph of the equation is shown below;

- Every variable in a signal flow graph is designed by a **Node**.
- Every transmission function in a signal flow graph is designed by a **Branch**.
- Branches are always **unidirectional**.
- The arrow in the branch denotes the **direction** of the signal flow.

SIGNAL FLOW GRAPH

$$Y_1(s) = G_{11}(s) \cdot R_1(s) + G_{12}(s) \cdot R_2(s)$$

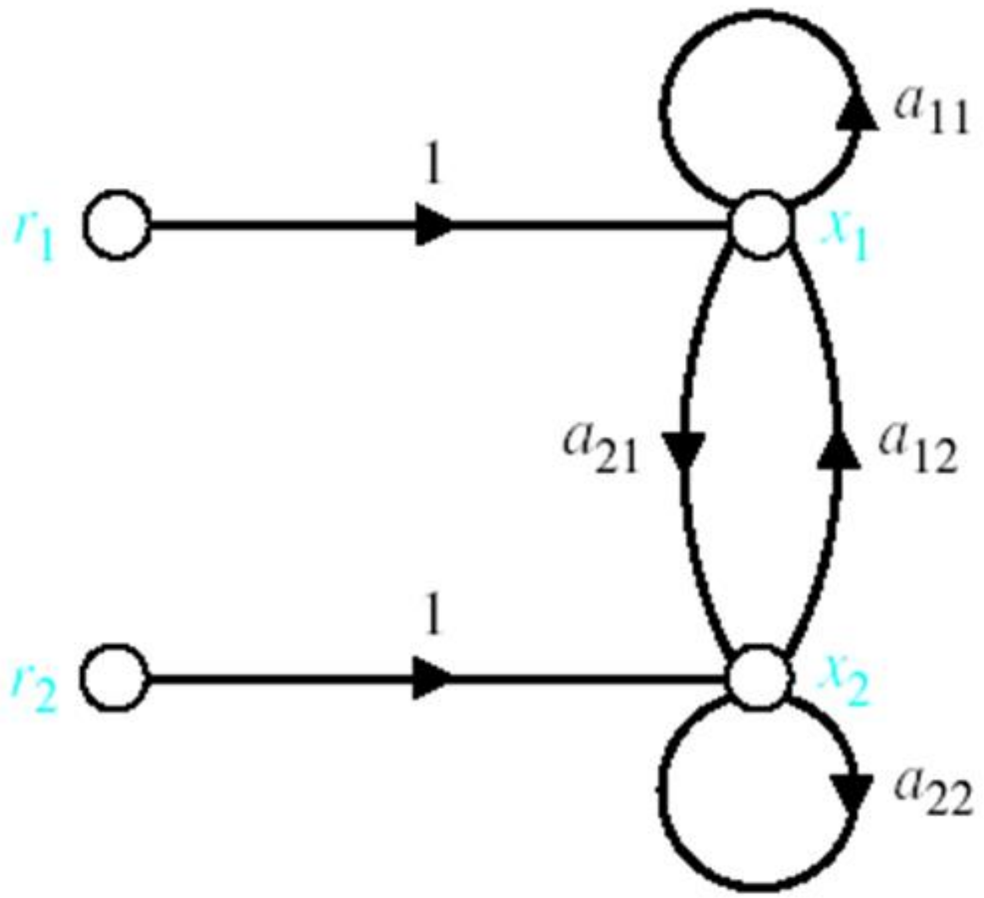
$$Y_2(s) = G_{21}(s) \cdot R_1(s) + G_{22}(s) \cdot R_2(s)$$



r_1 and r_2 are inputs and x_1 and x_2 are outputs

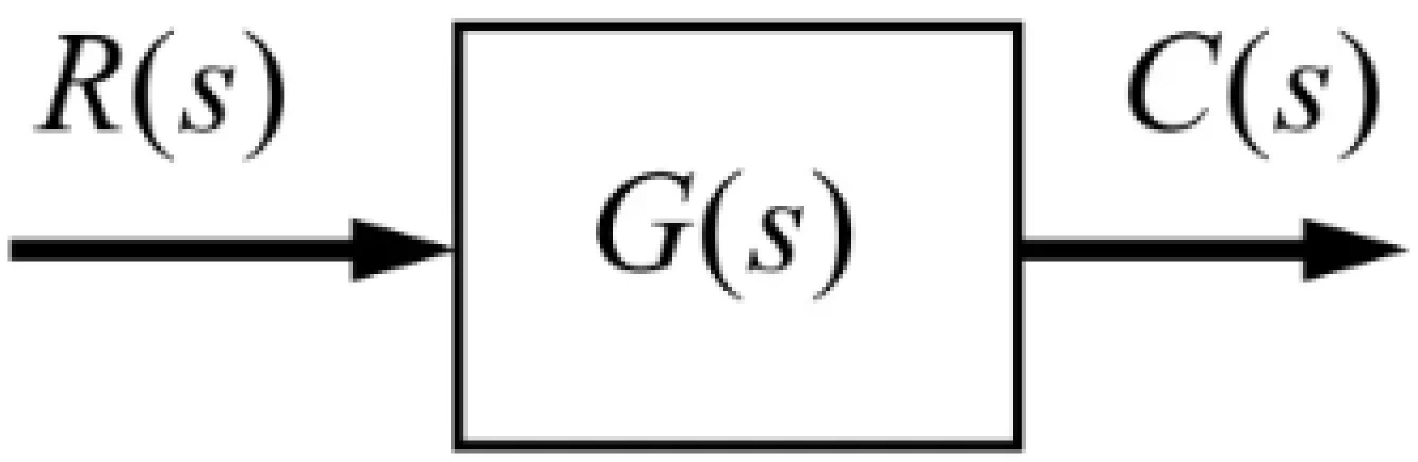
$$a_{11} \cdot x_1 + a_{12} \cdot x_2 + r_1 = x_1$$

$$a_{21} \cdot x_1 + a_{22} \cdot x_2 + r_2 = x_2$$



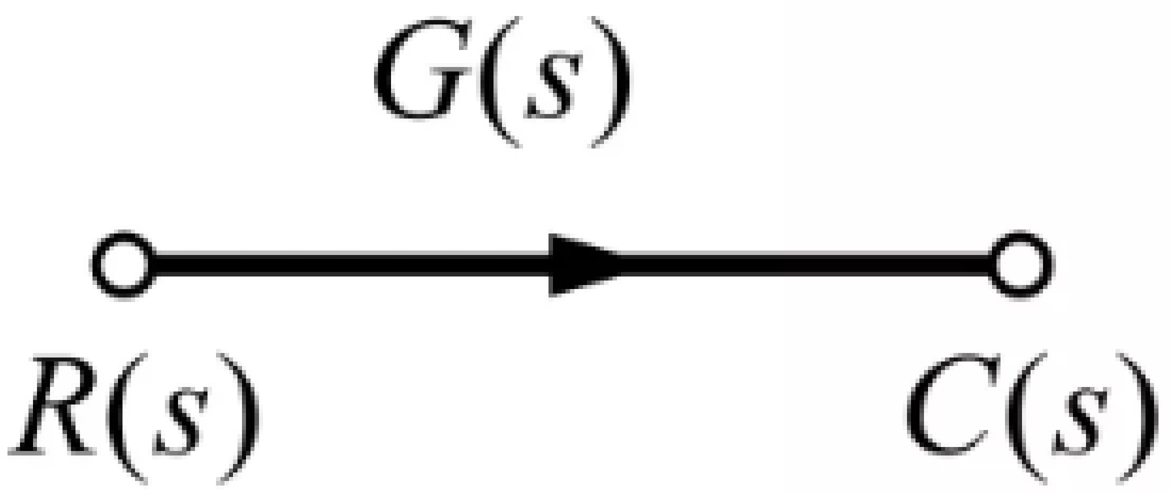
SIGNAL FLOW GRAPH & BLOCK DIAGRAM

block diagram:



In this case at each step block diagram is to be redrawn. That's why it is tedious method. So wastage of time and space.

signal flow graph:



Only one time SFG is to be drawn and then Mason's gain formula is to be evaluated.
So time and space is saved.

SIGNAL FLOW GRAPH & BLOCK DIAGRAM

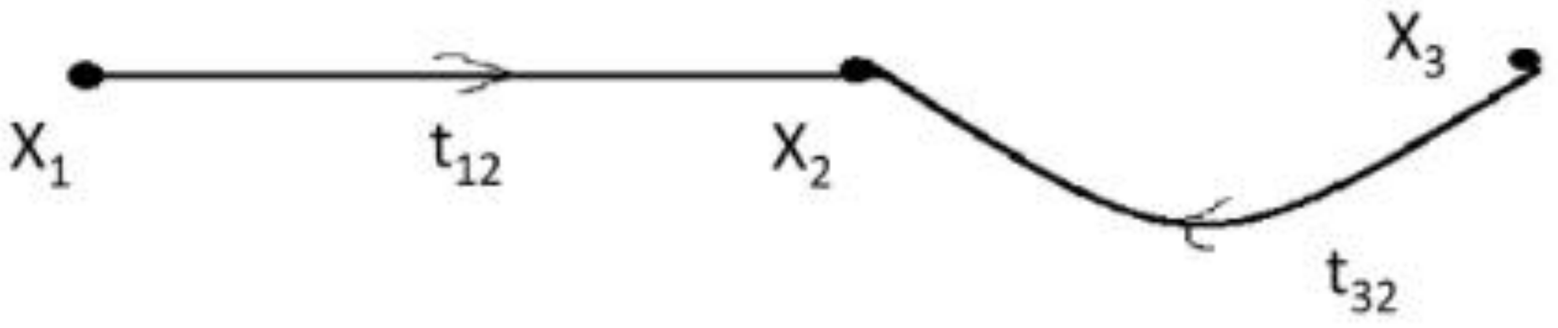
Alternative to block diagram;

Consists only **branches** (systems), and **nodes** (signals)

TERMINOLOGIES IN SIGNAL FLOW GRAPH

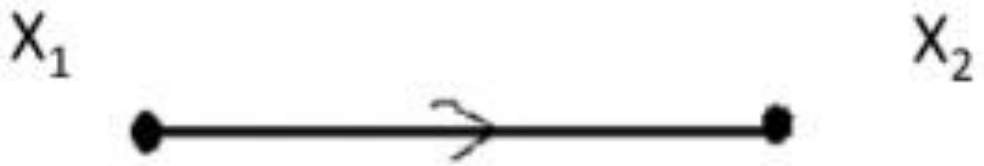
Node: It is a point representing a variable.

$$x_2 = t_{12} x_1 + t_{32} x_3$$



In this SFG there are 3 nodes.

Branch : A line joining two nodes.



Input Node : Node which has only outgoing branches.

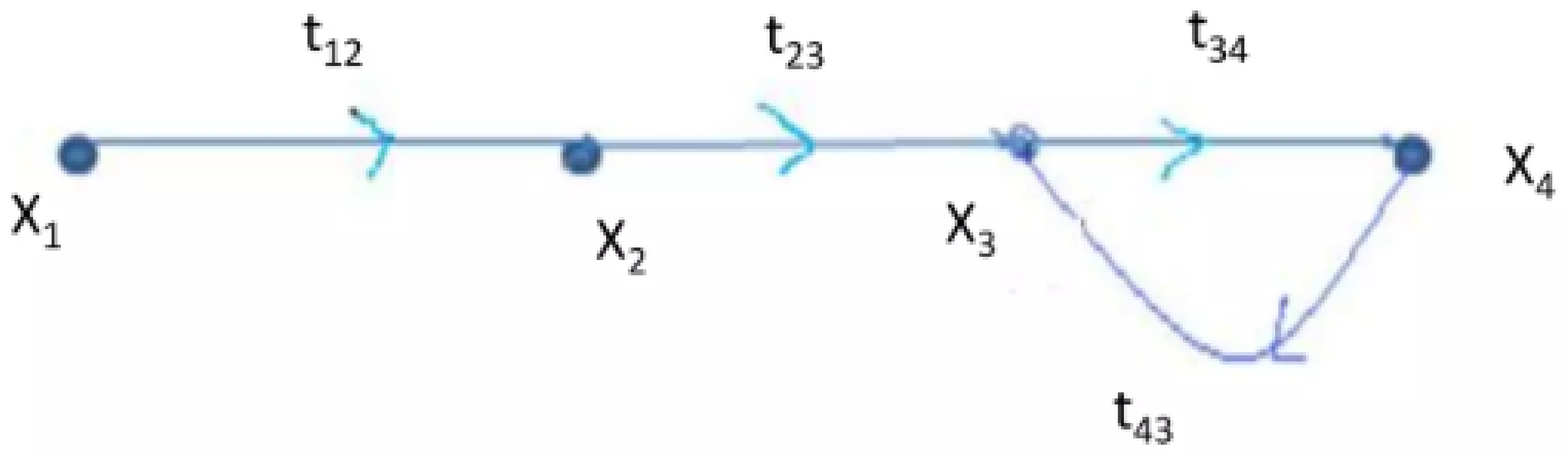
X_1 is input node.

TERMINOLOGIES IN SIGNAL FLOW GRAPH

Output node/ sink node: Only incoming branches.

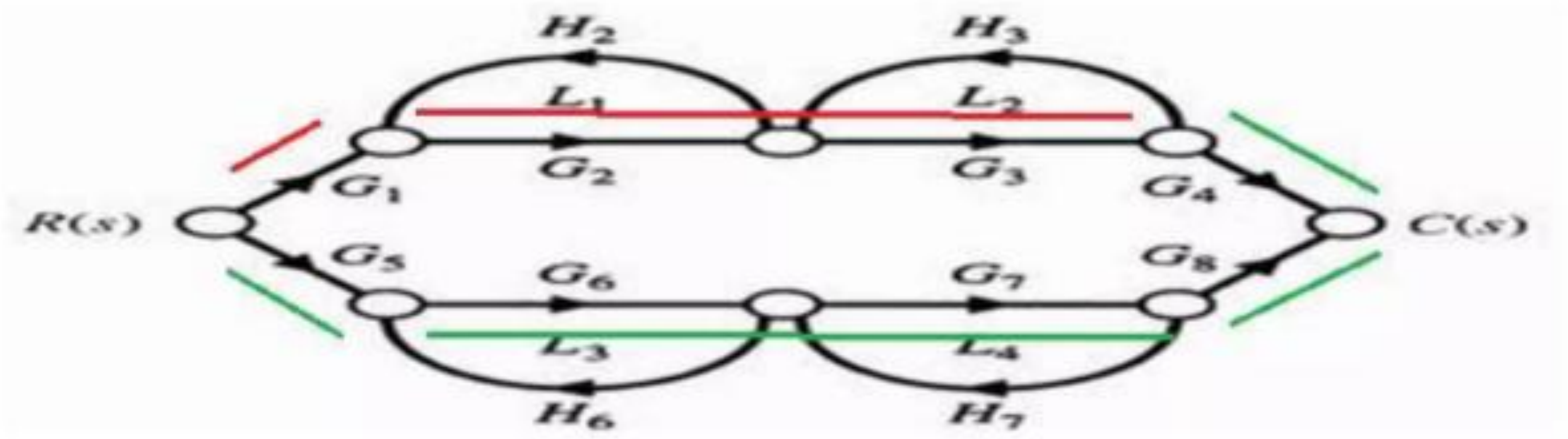
Mixed nodes: Has both incoming and outgoing branches.

Transmittance : It is the gain between two nodes. It is generally written on the branch near the arrow.



TERMINOLOGIES IN SIGNAL FLOW GRAPH

- **Path** : It is the traversal of connected branches in the directio of branch arrows, such that no node is traversed more than once.
- **Forward path** : A path which originates from the input node and terminates at the output node and along which no node is traversed more than once.
- **Forward Path gain** : It is the product of branch transmittances of a forward path.



$P_1 = G_1 G_2 G_3 G_4,\quad P_2 = G_5 G_6 G_7 G_8$

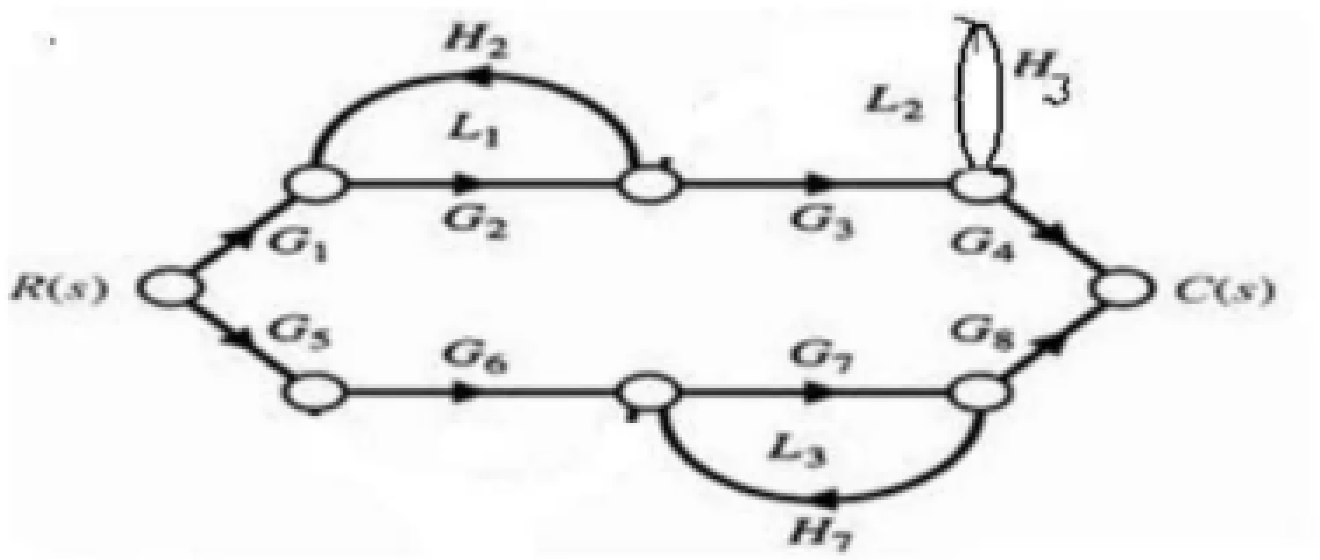
TERMINOLOGIES IN SIGNAL FLOW GRAPH

Loop : Path that originates and terminates at the same node and along which no other node is traversed more than once.

Self loop: Path that originates and terminates at the same node.

Loop gain: it is the product of branch transmittances of a loop.

Non-touching loops: Loops that don't have any common node or branch.



$L_1 = G_2 H_2$ $L_2 = H_3$

$L_3 = G_7 H_7$

Non-touching loops are L1 & L2, L1 & L3, L2 &L3

MASON'S GAIN FORMULA

- A technique to reduce a signal-flow graph to a single transfer function requires the application of one formula.
- The transfer function, C(s)/R(s), of a system represented by a signal-flow graph is

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

k = number of forward path

P_k = the kth forward path gain

Δ = 1 – (Σ loop gains) + (Σ non-touching loop gains taken two at a time) – (Σ non-touching loop gains taken three at a time)+ so on .

Δ_k = 1 – (loop-gain which does not touch the forward path)

References

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2. Benjamin.C.Kuo.,“Automatic Control Systems”, Prentice Hall of India, New Delhi, 9th Edition,2007 (Unit I-III).
3. Richard C. Dorf and Robert H. Bishop, “Modern Control Systems”, Addison, 12th Edition, 2010. (Unit I-III).
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Thank You