# Alexander-Sadiku
# Fundamentals of Electric Circuits

## Chapter 2
## Basic Laws

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# Basic Laws - Chapter 2

2.1 Ohm's Law.
2.2 Nodes, Branches, and Loops.
2.3 Kirchhoff's Laws.
2.4 Series Resistors and Voltage Division.
2.5 Parallel Resistors and Current Division.
2.6 Wye-Delta Transformations.

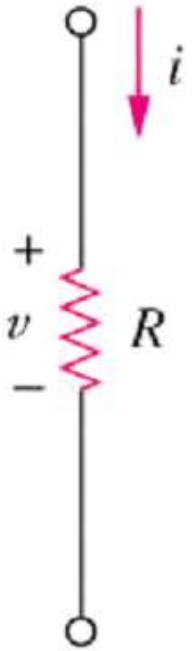
# 2.1 Ohms Law (1)

- Ohm's law states that the voltage across a resistor is directly proportional to the current I flowing through the resistor.

- Mathematical expression for Ohm's Law is as follows:

$$v = iR$$

- Two extreme possible values of R: **0 (zero) and ∞ (infinite)** are related with two basic circuit concepts: short circuit and open circuit.



# 2.1 Ohms Law (2)

- *Conductance* is the ability of an element to conduct electric current; it is the reciprocal of resistance R and is measured in mhos or siemens.

$$G = \frac{1}{R} = \frac{i}{v}$$

- The power dissipated by a resistor:

$$p = vi = i^2 R = \frac{v^2}{R}$$

# 2.2 Nodes, Branches and Loops (1)

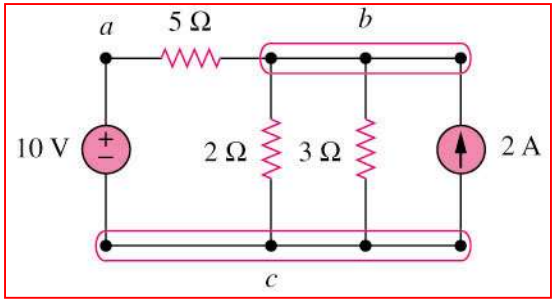
- A branch represents a single element such as a voltage source or a resistor.
- A node is the point of connection between two or more branches.
- A loop is any closed path in a circuit.

- A network with b branches, n nodes, and l independent loops will satisfy the fundamental theorem of network topology:

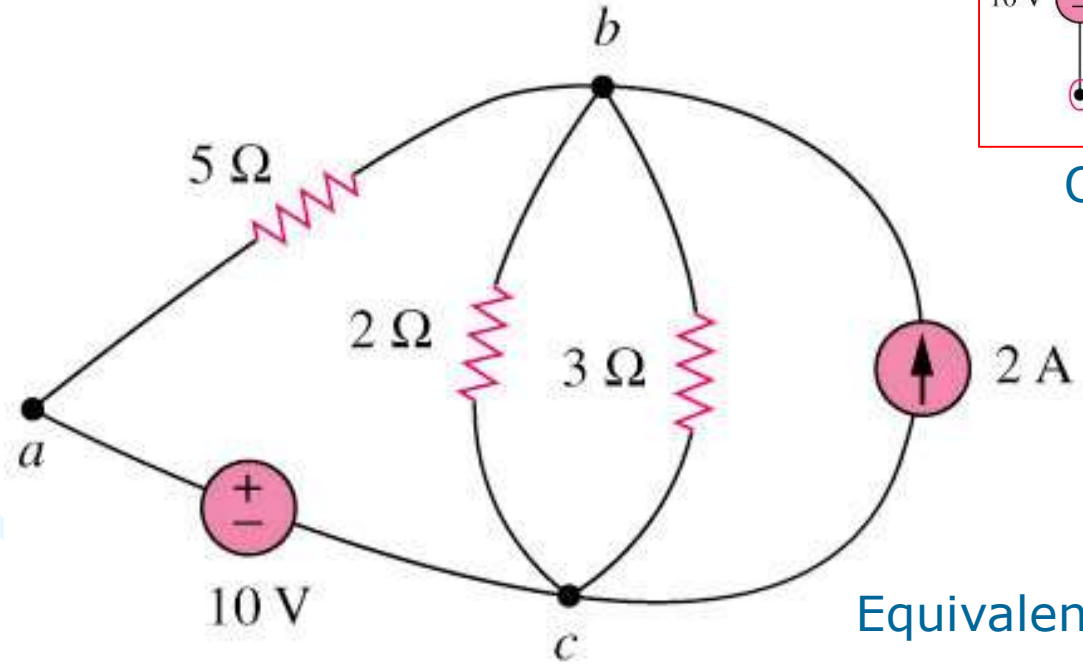
$$b = l + n - 1$$

# 2.2 Nodes, Branches and Loops (2)

**Example 1**




Original circuit



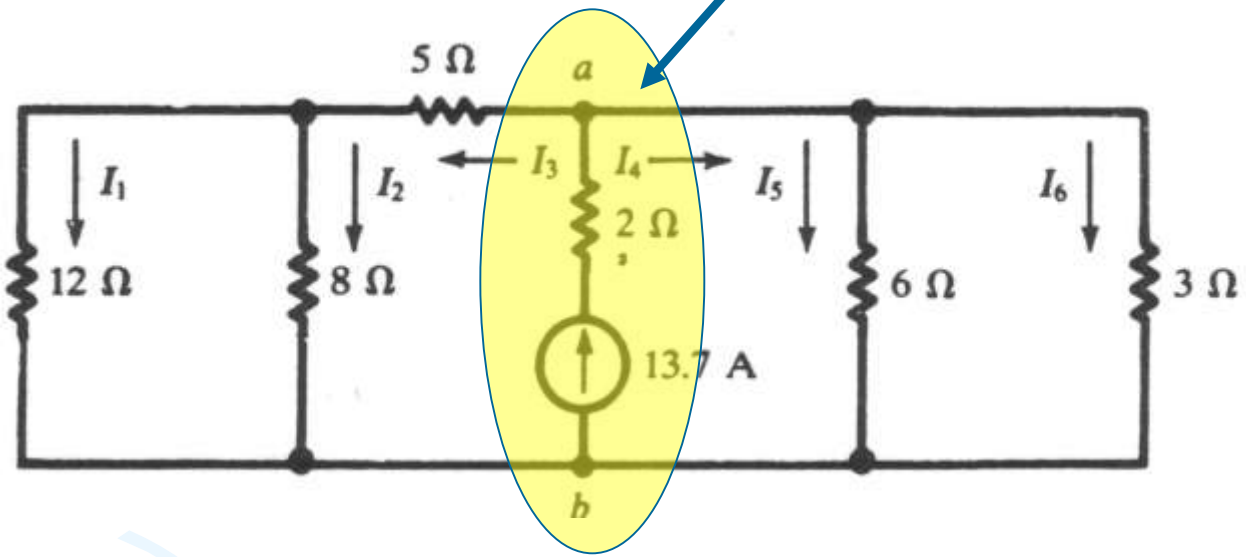

Equivalent circuit

**How many branches, nodes and loops are there?**

# 2.2 Nodes, Branches and Loops (3)

**Example 2**

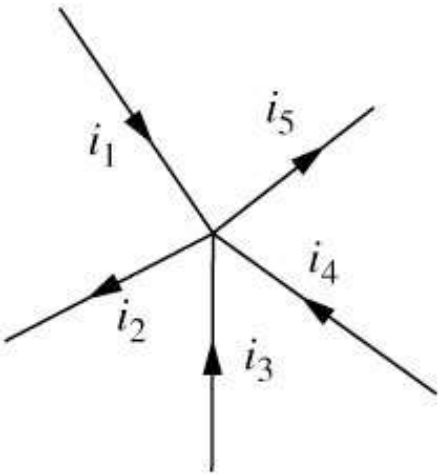
**Should we consider it as one branch or two branches?**

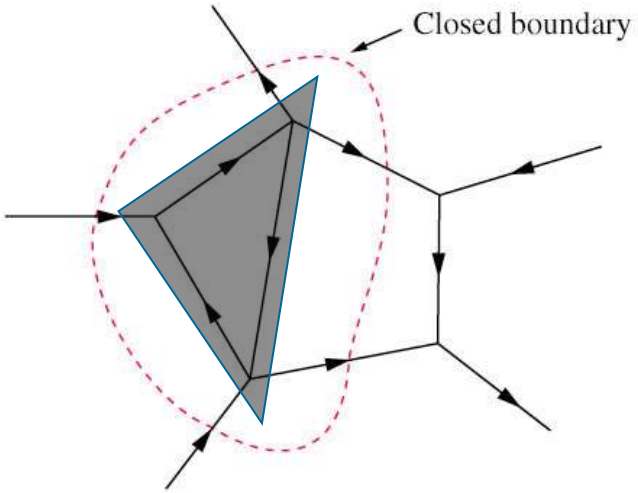



**How many branches, nodes and loops are there?**

# 2.3 Kirchhoff's Laws (1)

- Kirchhoff's current law (KCL) states that the algebraic sum of currents entering a node (or a closed boundary) is zero.



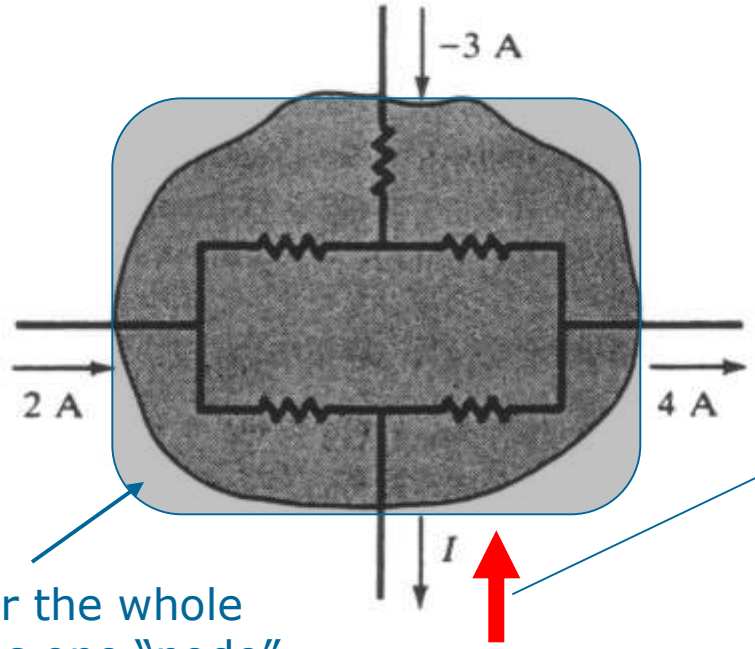

Mathematically,

$$\sum_{n=1}^{N} i_n = 0$$

# 2.3 Kirchhoff's Laws (2)

**Example 4**

- Determine the current I for the circuit shown in the figure below.




We can consider the whole enclosed area as one "node".

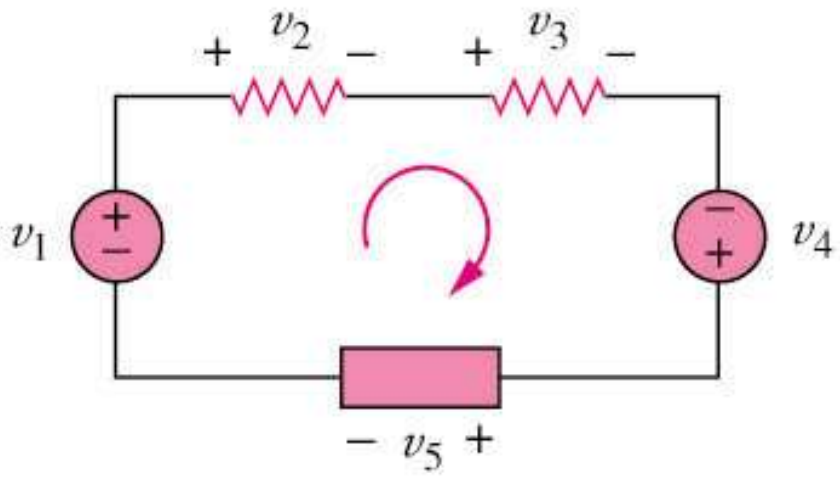
$$I + 4-(-3)-2 = 0$$

$$\Rightarrow I = -5A$$

**This indicates that the actual current for I is flowing in the opposite direction.**

# 2.3 Kirchhoff's Laws (3)

- Kirchhoff's voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop) is zero.

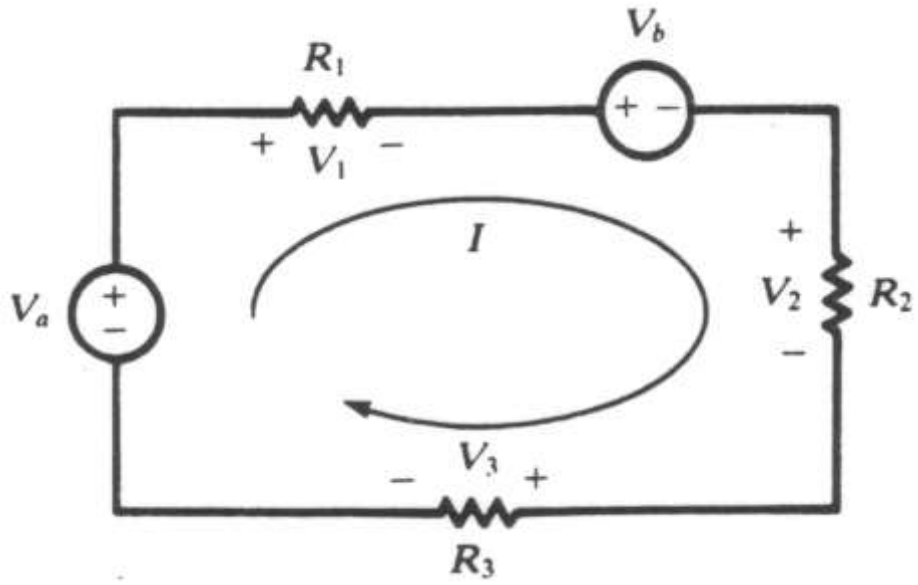



Mathematically, $$\sum_{m=1}^{M} v_n = 0$$

# 2.3 Kirchhoff's Laws (4)

**Example 5**

- Applying the KVL equation for the circuit of the figure below.




$$v_a - v_1 - v_b - v_2 - v_3 = 0$$

$$V_1 = IR_1 \quad v_2 = IR_2 \quad v_3 = IR_3$$

$$\Rightarrow v_a - v_b = I(R_1 + R_2 + R_3)$$

$$I = \frac{v_a - v_b}{R_1 + R_2 + R_3}$$

# 2.4 Series Resistors and Voltage Division (1)

- Series: Two or more elements are in series if they are cascaded or connected sequentially and consequently carry the same current.

- The equivalent resistance of any number of resistors connected in a series is the sum of the individual resistances.

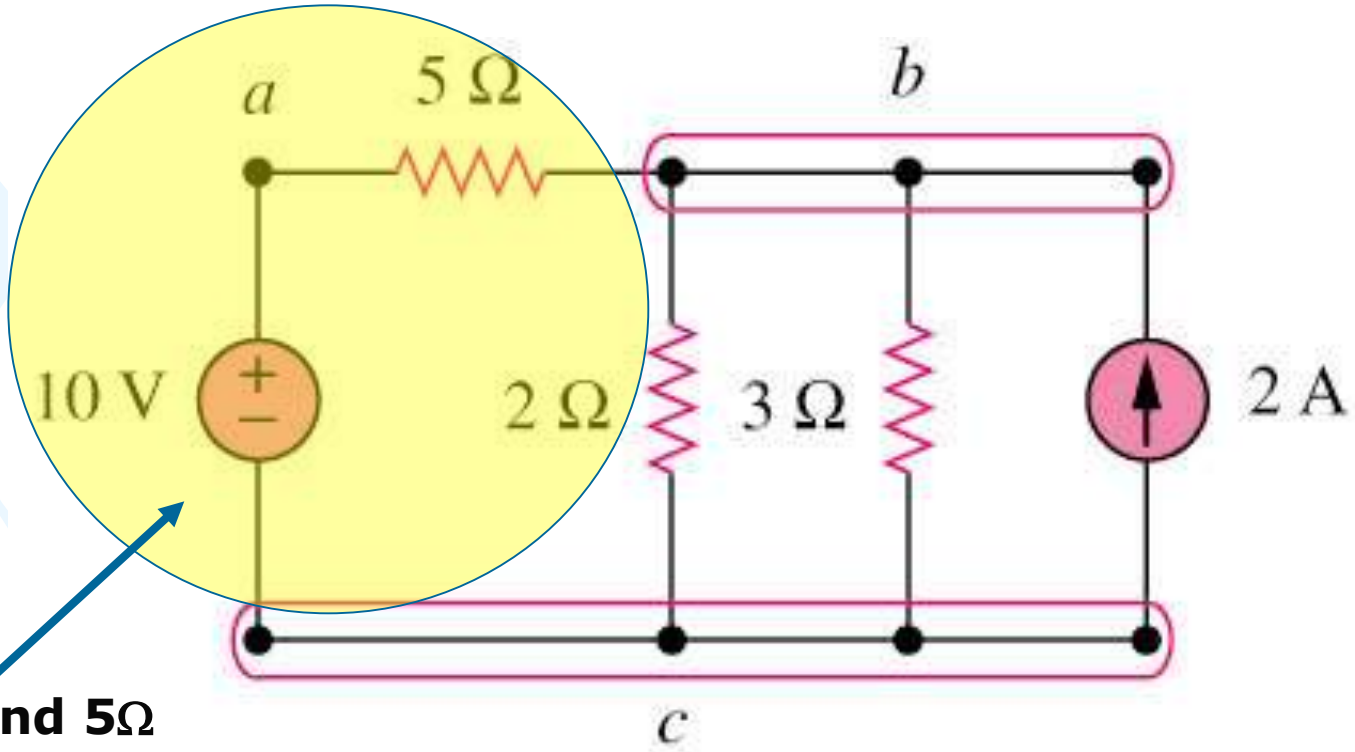
$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n$$

- The voltage divider can be expressed as

$$v_n = \frac{R_n}{R_1 + R_2 + \cdots + R_N} v$$

# 2.4 Series Resistors and Voltage Division (1)

**Example 3**




**10V and 5Ω are in series**

# 2.5 Parallel Resistors and Current Division (1)

- Parallel: Two or more elements are in parallel if they are connected to the same two nodes and consequently have the same voltage across them.

- The equivalent resistance of a circuit with N resistors in parallel is:

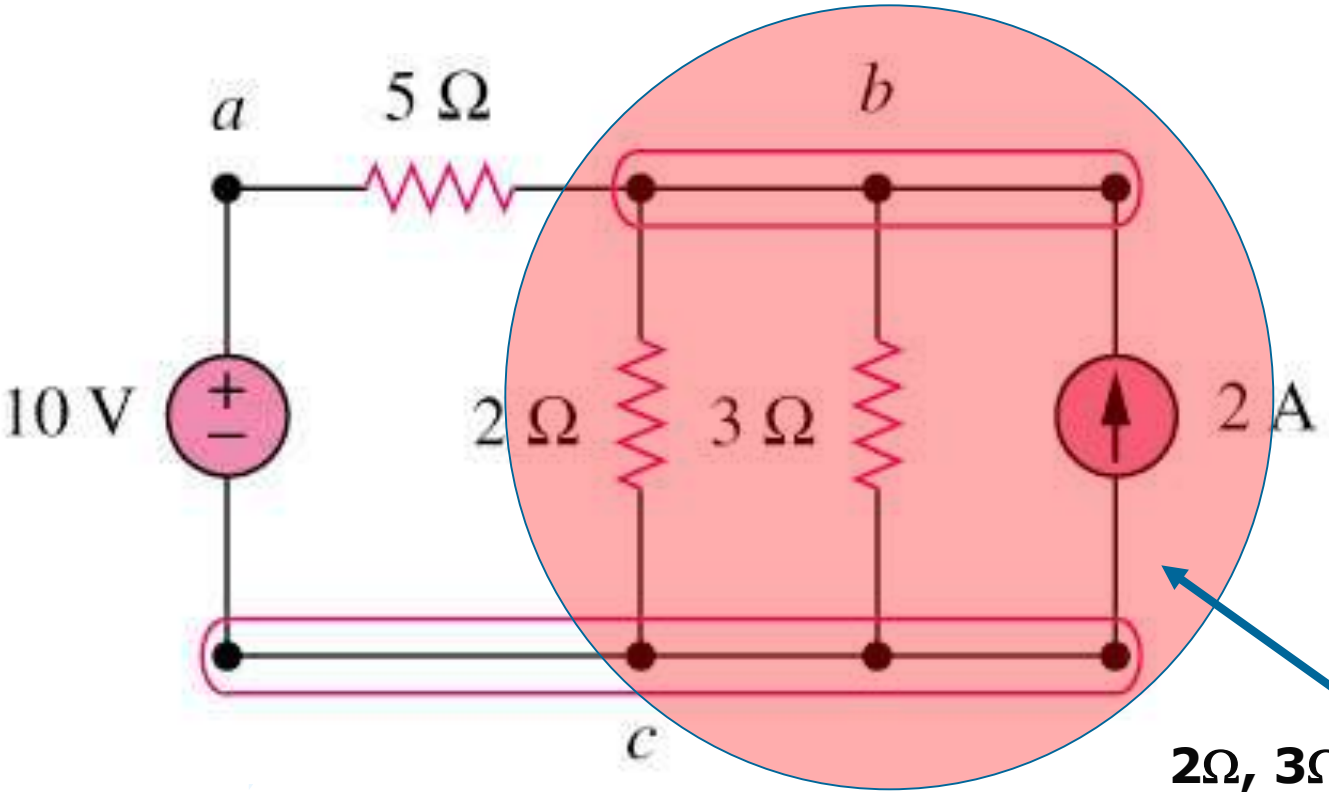
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N}$$

- The total current i is shared by the resistors in inverse proportion to their resistances. The current divider can be expressed as:

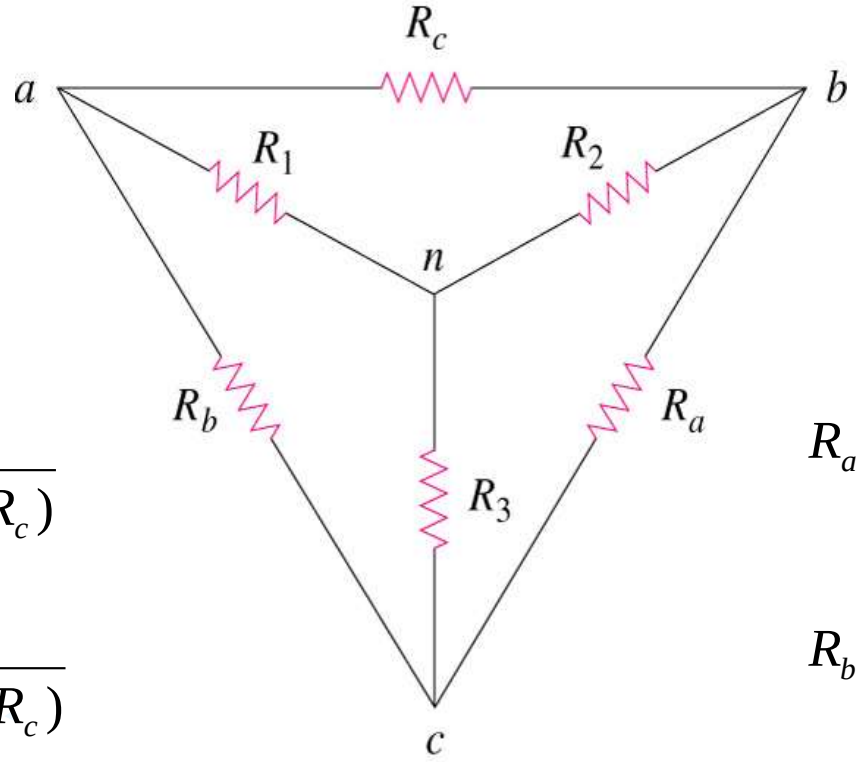
$$i_n = \frac{v}{R_n} = \frac{iR_{eq}}{R_n}$$

# 2.5 Parallel Resistors and Current Division (1)

**Example 4**



# 2.6 Wye-Delta Transformations




**Delta -> Star**

$$R_1 = \frac{R_b R_c}{(R_a + R_b + R_c)}$$

$$R_2 = \frac{R_c R_a}{(R_a + R_b + R_c)}$$

$$R_3 = \frac{R_a R_b}{(R_a + R_b + R_c)}$$

**Star -> Delta**

$$R_a = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_1}$$

$$R_b = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_2}$$

$$R_c = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_3}$$