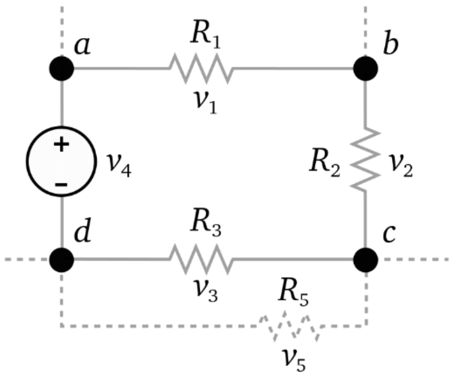
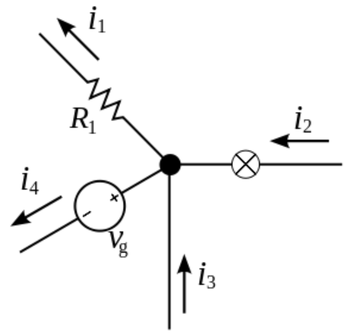
PRINCIPLES OF EE 1

<u>KVL</u>: Kirchhoff's Voltage Law



➔ The sum of all the voltages around a loop is equal to zero. v1 + v2 + v3 - v4 = 0

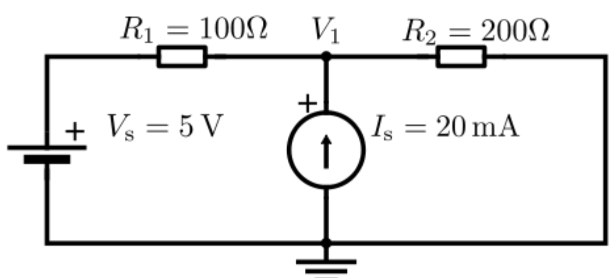
<u>KCL</u>: Kirchhoff's Current Law



➔ The current entering any junction is equal to the current leaving that junction. i2 + i3 = i1 + i4

<u>NODE-VOLTAGE METHOD</u>:

Basic case

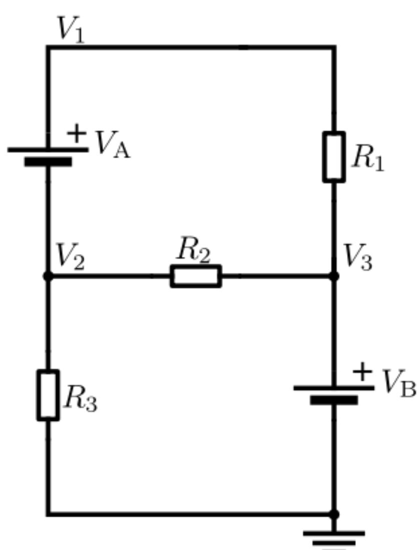


With Kirchhoff's current law, we get:

$$\frac{V_1 - V_S}{R_1} + \frac{V_1}{R_2} - I_S = 0$$

$$\rightarrow V_1 = \frac{14}{3}\ \mathrm{V}$$

Supernode



➔ In this circuit, VA is between two unknown voltages, and is therefore a supernode.

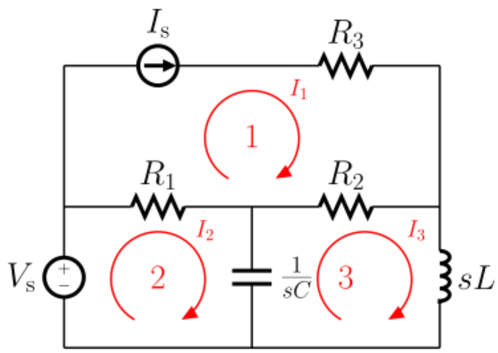
The complete set of equations for this circuit is:

$$\begin{cases} \frac{V_1 - V_B}{R_1} + \frac{V_2 - V_B}{R_2} + \frac{V_2}{R_3} = 0 \\ V_1 = V_2 + V_A \end{cases}$$

By substituting V_1 to the first equation and solving in respect to V_2, we get:

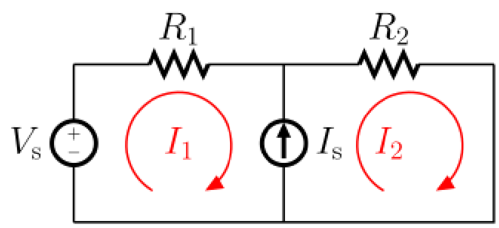
$$V_2 = \frac{(R_1 + R_2)R_3V_B - R_2R_3V_A}{(R_1 + R_2)R_3 + R_1R_2}$$

MESH-CURRENT METHOD:



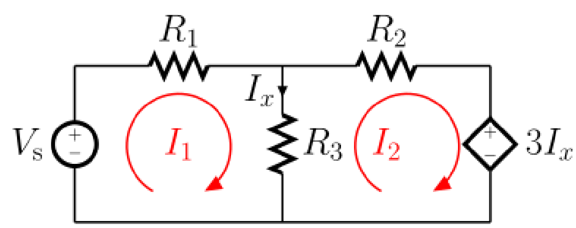
$$\begin{cases} \text{Mesh 1: } I_1 = I_s \\ \text{Mesh 2: } -V_s + R_1(I_2 - I_1) + \frac{1}{sC}(I_2 - I_3) = 0 \\ \text{Mesh 3: } \frac{1}{sC}(I_3 - I_2) + R_2(I_3 - I_1) + sLI_3 = 0 \end{cases}$$

Supermesh



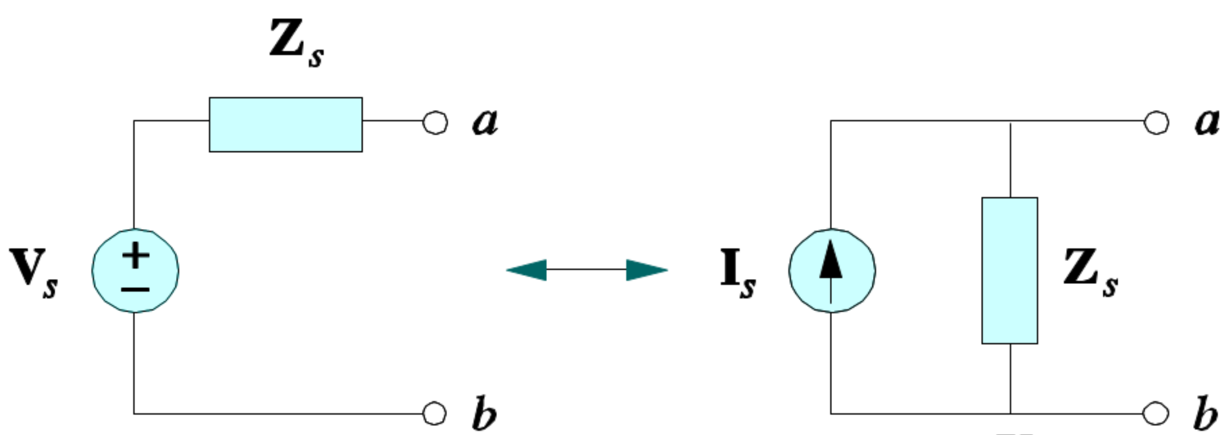
$$\begin{cases} \text{Mesh 1, 2: } -V_s + R_1 I_1 + R_2 I_2 = 0 \\ \text{Current source: } I_s = I_2 - I_1 \end{cases}$$

Dependent sources



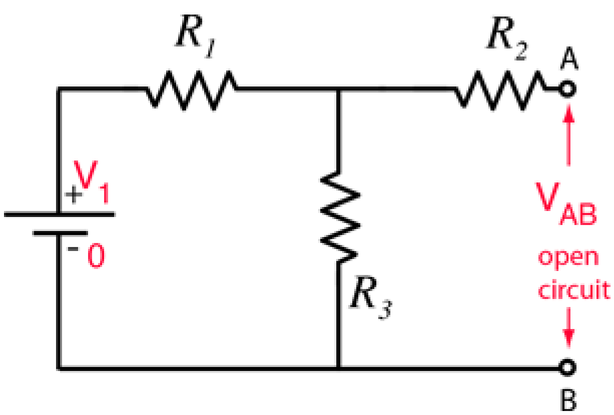
$$\begin{cases} \text{Mesh 1: } -V_s + R_1 I_1 + R_3(I_1 - I_2) = 0 \\ \text{Mesh 2: } R_2 I_2 + 3I_x + R_3(I_2 - I_1) = 0 \\ \text{Dependent variable: } I_x = I_1 - I_2 \end{cases}$$

Source Transformation



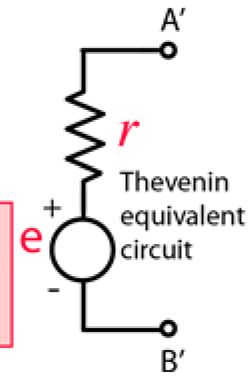
$$\mathbf{V}_s = \mathbf{Z}_s \mathbf{I}_s \qquad \mathbf{I}_s = \frac{\mathbf{V}_s}{\mathbf{Z}_s}$$

THEVENIN'S EQUIVALENT CIRCUIT: V Thevenin = V Open Circuit

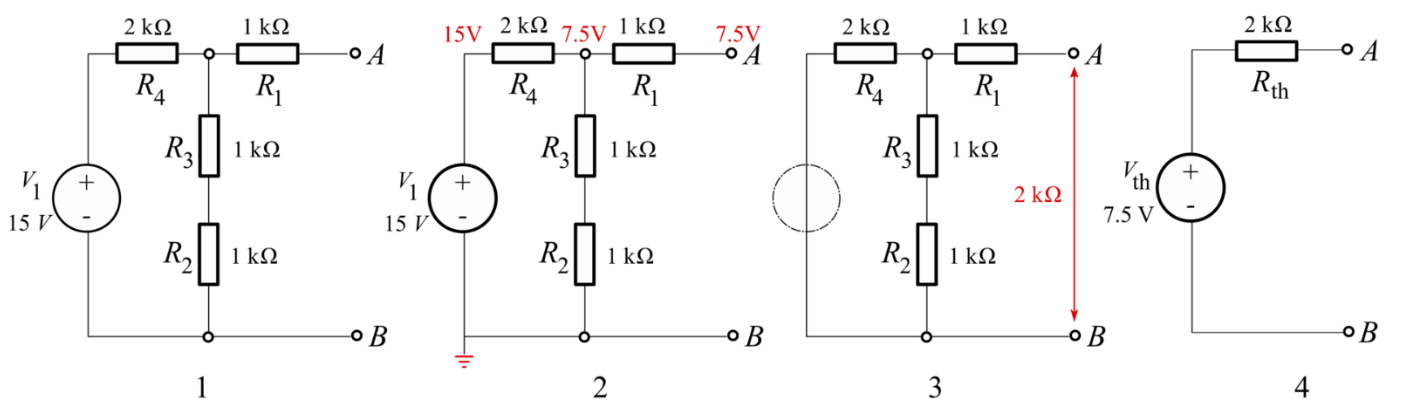


$$e = \frac{V_1 R_3}{R_1 + R_3}$$

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



Example:



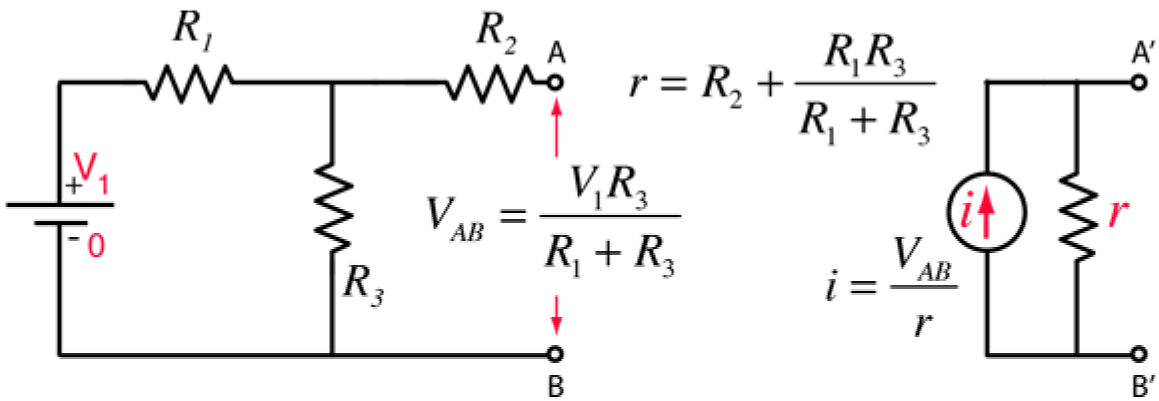
1. Original circuit
2. The equivalent voltage
3. The equivalent resistance
4. The equivalent circuit

$$\begin{aligned} R_{\mathrm{Th}} &= R_{\mathrm{No}} \\ V_{\mathrm{Th}} &= I_{\mathrm{No}} R_{\mathrm{No}} \\ I_{\mathrm{No}} &= V_{\mathrm{Th}} / R_{\mathrm{Th}} \end{aligned}$$

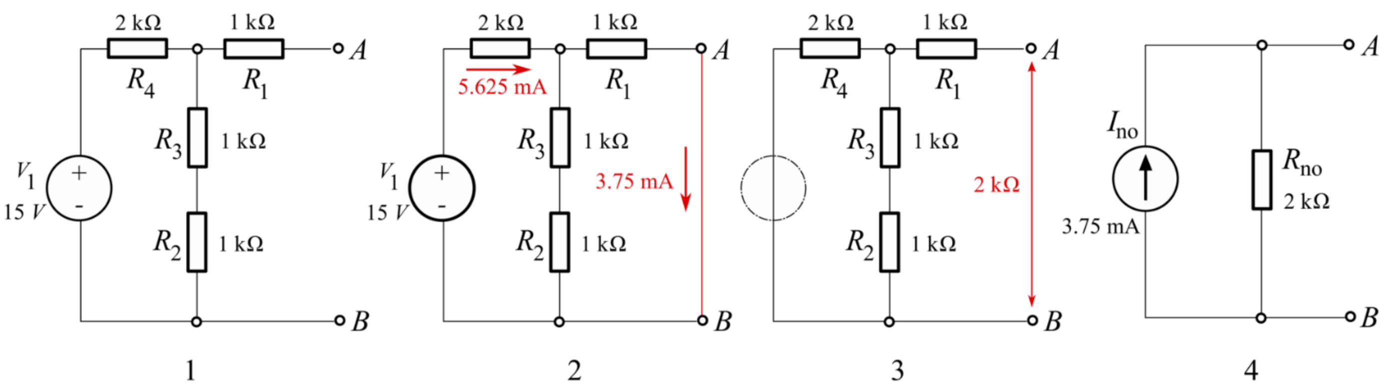
$$\begin{aligned} V_{\mathrm{Th}} &= \frac{R_2 + R_3}{(R_2 + R_3) + R_4} \cdot V_1 \\ &= \frac{1\,\mathrm{k}\Omega + 1\,\mathrm{k}\Omega}{(1\,\mathrm{k}\Omega + 1\,\mathrm{k}\Omega) + 2\,\mathrm{k}\Omega} \cdot 15\,\mathrm{V} \\ &= \frac{1}{2} \cdot 15\,\mathrm{V} = 7.5\,\mathrm{V} \end{aligned}$$

$$\begin{aligned} R_{\mathrm{Th}} &= R_1 + [(R_2 + R_3) \| R_4] \\ &= 1\,\mathrm{k}\Omega + [(1\,\mathrm{k}\Omega + 1\,\mathrm{k}\Omega) \| 2\,\mathrm{k}\Omega] \\ &= 1\,\mathrm{k}\Omega + \left(\frac{1}{(1\,\mathrm{k}\Omega + 1\,\mathrm{k}\Omega)} + \frac{1}{(2\,\mathrm{k}\Omega)} \right)^{-1} \\ &= 2\,\mathrm{k}\Omega \end{aligned}$$

NORTON'S EQUIVALENT CIRCUIT: I Norton = I Short Circuit



Example:



1. The original circuit
2. Calculating the equivalent output current
3. Calculating the equivalent resistance
4. Design the Norton equivalent circuit

$$I_{\mathrm{total}} = \frac{15\mathrm{V}}{2\,\mathrm{k}\Omega + 1\mathrm{k}\Omega \| (1\,\mathrm{k}\Omega + 1\,\mathrm{k}\Omega)} = 5.625\mathrm{mA}.$$

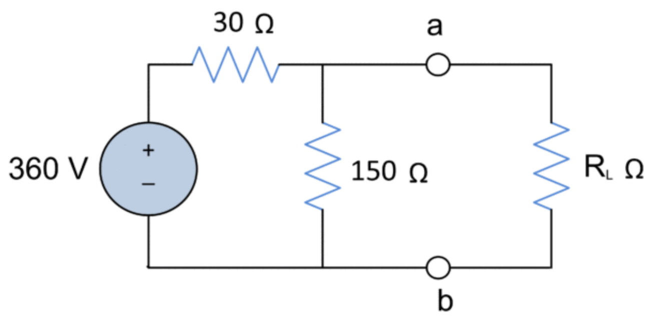
$$I_{\mathrm{no}} = \frac{1\,\mathrm{k}\Omega + 1\,\mathrm{k}\Omega}{(1\,\mathrm{k}\Omega + 1\,\mathrm{k}\Omega + 1\,\mathrm{k}\Omega)} \cdot I_{\mathrm{total}}$$
$$= 2/3 \cdot 5.625\mathrm{mA} = 3.75\mathrm{mA}.$$

$$R_{\mathrm{no}} = 1\,\mathrm{k}\Omega + (2\,\mathrm{k}\Omega \| (1\,\mathrm{k}\Omega + 1\,\mathrm{k}\Omega)) = 2\,\mathrm{k}\Omega.$$

$$\boxed{\begin{aligned} R_{\mathrm{th}} &= R_{\mathrm{no}} \\ V_{\mathrm{th}} &= I_{\mathrm{no}} R_{\mathrm{no}} \\ \frac{V_{\mathrm{th}}}{R_{\mathrm{th}}} &= I_{\mathrm{no}} \end{aligned}}$$

MAXIMUM POWER TRANSFER: $P_{max} = \frac{V_{Th}^2}{4R_L}$, $R_L = R_{Th}$

Example:



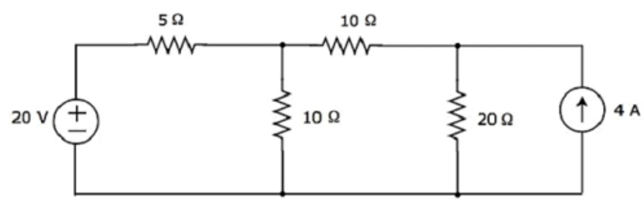
$$V_{th} = V_S = 360 * \frac{150}{150+30}$$

$$V_{th} = V_S = 300\ V$$

$$R_L = R_{th} = R_S = 150\ ||\ 30 = 25\Omega$$

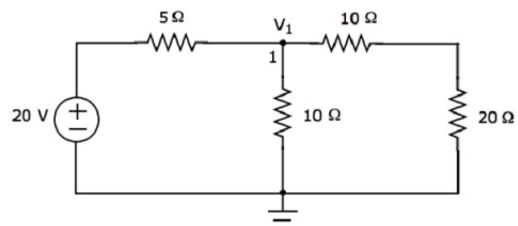
$$\rightarrow\ P_{max} = 900\ W$$

SUPERPOSITION:



Find the current flowing through the 20Ω resistor?

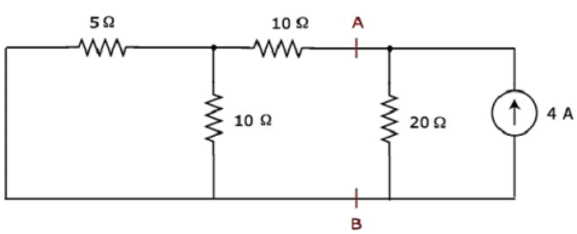
Current Source → Open Circuit



Using Node-voltage method to find V_1 $\Rightarrow V_1 = 12V$

$$I_1 = \frac{V_1}{10+20} = \frac{12}{30} = 0.4A$$

Voltage Source → Short Circuit



$$R_{AB} = (\frac{5\times 10}{5+10}) + 10 = \frac{10}{3} + 10 = \frac{40}{3}\Omega$$

The current I_2 flowing through 20Ω resistor, using current division principle

$$I_2 = I_S(\frac{R_1}{R_1+R_2}) = 4(\frac{\frac{40}{3}}{\frac{40}{3}+20}) = 4(\frac{40}{100}) = 1.6A$$

Adding 2 currents has been found to get the result: $I = I_1 + I_2 = 0.4 + 1.6 = 2A$

<u>THE OPERATIONAL AMPLIFIER:</u>

For ideal op amp:

Input voltage constraint: $v_p = v_n$

Input current constraint: $i_p = i_n = 0$

Basic Operational Amplifier Configurations