Linear Circuits and Systems

Kirchhoff's Circuit Laws and Circuit Analysis Techniques

Course: Linear Circuits and Systems
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Kirchhoff's Current Law (KCL)

- The sum of all currents entering a node must equal to zero
  - *Node equation:* currents entering = currents exiting
- In a closed circuit with N nodes there are $N-1$ independent *node equations*

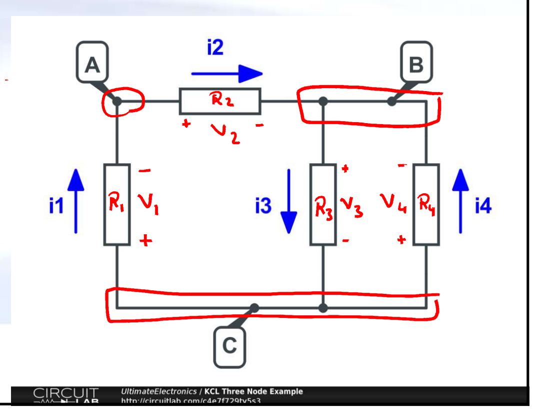
Kirchhoff's Current Law (KCL)

KCL@A: $i_1 = i_2$

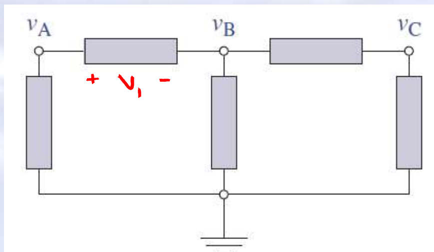
$$\frac{V_1}{R_1} = \frac{V_2}{R_2}$$

KCL@B: $i_2 + i_4 = i_3$

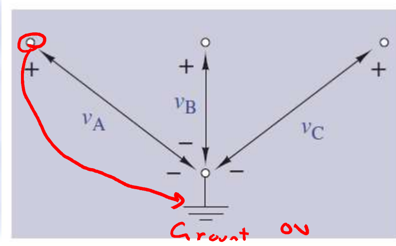
$$\frac{V_2}{R_2} + \frac{V_4}{R_4} = \frac{V_3}{R_3}$$



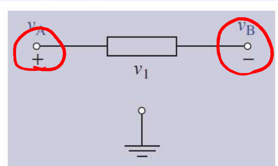
Node Voltage – Terminology



Notation



Interpretation



$$\boxed{V_1 = V_A - V_B}$$

Node Voltage Analysis (NVA)

KCL @A: $i_1 = i_2$

$\rightarrow \frac{V_1}{R_1} = \frac{V_2}{R_2}$

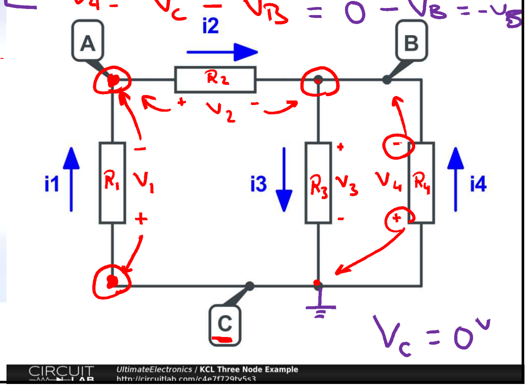
$\frac{-V_A}{R_1} = \frac{V_A - V_B}{R_2} \longrightarrow (1)$

KCL @B: $i_2 + i_4 = i_3$

$\rightarrow \frac{V_2}{R_2} + \frac{V_4}{R_4} = \frac{V_3}{R_3}$

$\frac{V_A - V_B}{R_2} + \frac{-V_B}{R_4} = \frac{V_B}{R_3} \longrightarrow (2)$

$\Rightarrow$
$V_1 = V_C - V_A = 0 - V_A = -V_A$
$V_2 = V_A - V_B = V_A - V_B$
$V_3 = V_B - V_C = V_B - 0 = V_B$
$V_4 = V_C - V_B = 0 - V_B = -V_B$



$V_C = 0^V$

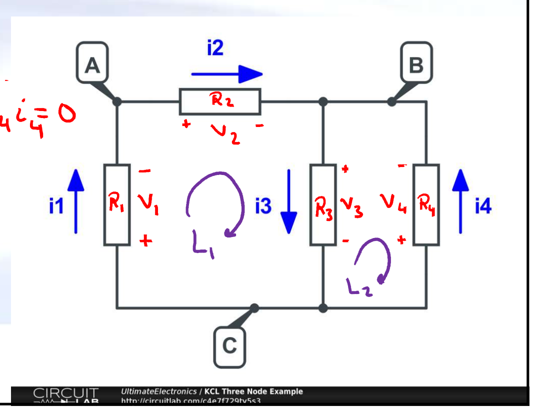
Kirchhoff's Voltage Law (KVL)

- For a loop, the voltage drops across elements in a loop must add to zero.
- In a closed circuit with N loops there are N independent *loop equations*

Kirchhoff's Voltage Law (KVL)

KVL in L1: $V_1 + V_2 + V_3 = 0 \Rightarrow R_1 i_1 + R_2 i_2 + R_3 i_3 = 0$

KVL in L2: $-V_3 - V_4 = 0 \Rightarrow R_3 i_3 + R_4 i_4 = 0$



Loop/Mesh current – Terminology

If the Kth two-terminal element is contained in meshes X and Y, then the element current can be expressed in terms of the two mesh currents as

$$\longrightarrow i_K = i_X - i_Y$$

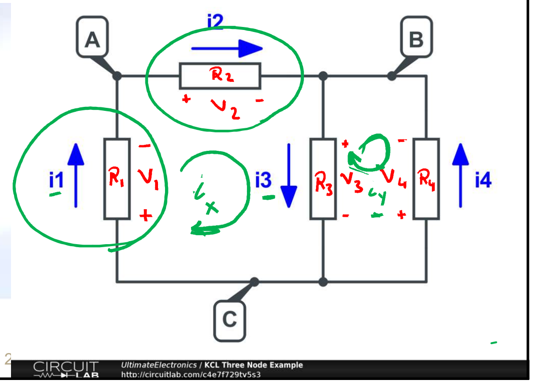
where X is the mesh whose reference direction agrees with the reference direction of i_K.

$i_3 = +i_x - i_y$

$i_1 = +i_x$

$i_2 = i_x$

$i_4 = -i_y$



Mesh Current Analysis (MCA)

KVL in L1: $V_1 + V_2 + V_3 = 0 \Rightarrow R_1 i_1 + R_2 i_2 + R_3 i_3 = 0 \leftarrow$

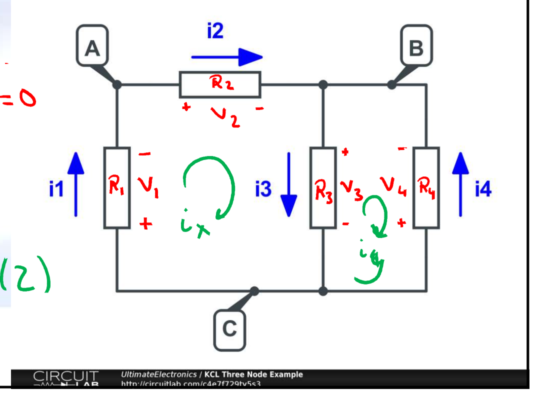
$R_1 i_x + R_2 i_x + R_3 (i_x - i_y) = 0$

$(R_1 + R_2 + R_3) i_x - R_3 i_y = 0 \longrightarrow (1)$

KVL in L2: $-V_3 - V_4 = 0 \Rightarrow R_3 i_3 + R_4 i_4 = 0$

$R_3 (i_x - i_y) + R_4 (-i_y) = 0$

$R_3 i_x - (R_3 + R_4) i_y = 0 \longrightarrow (2)$



Conclusion

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