ELC 2161 — Electronics

Lecture (1)
Circuits Analysis Review

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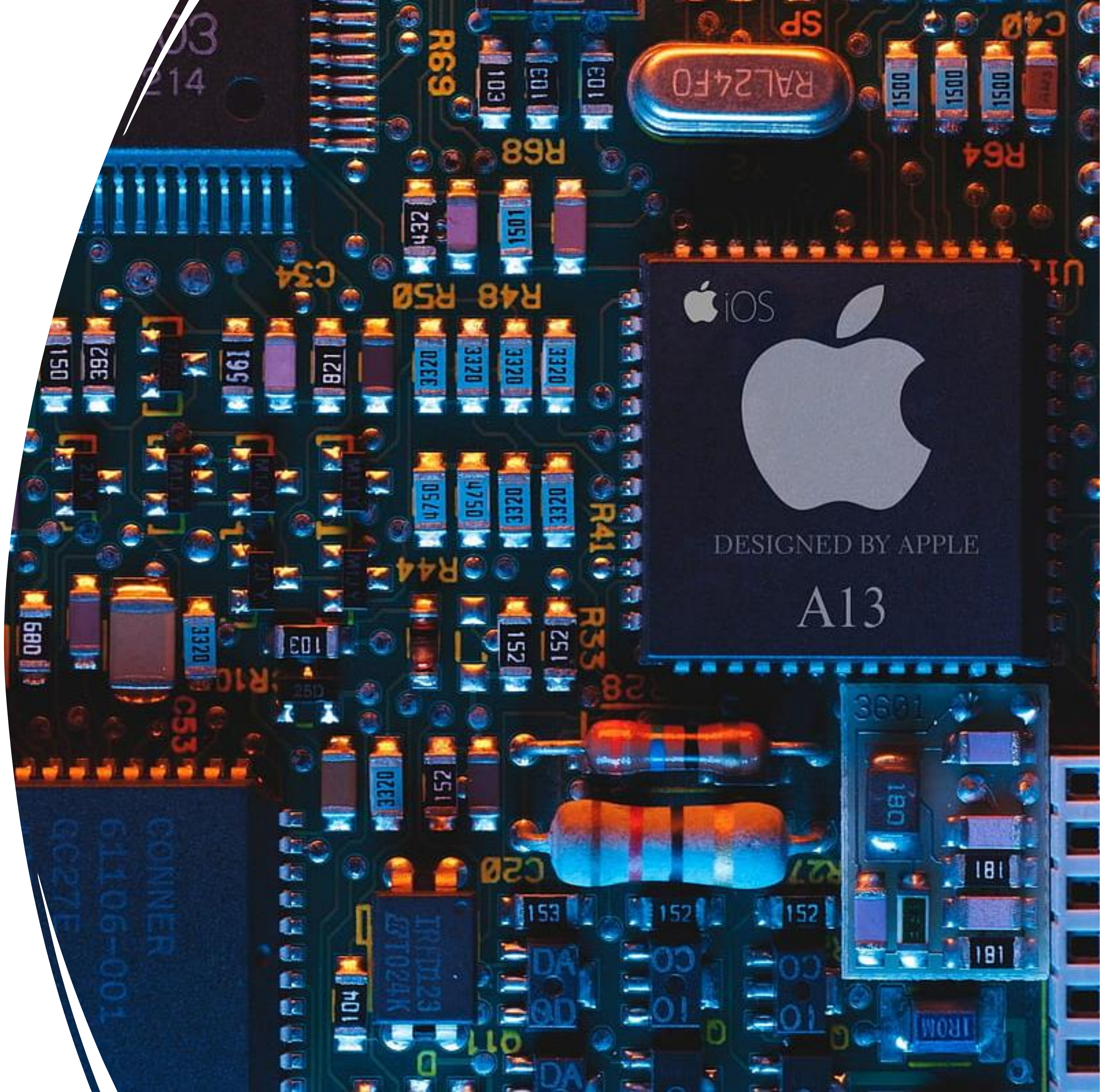
Electronics in Daily Life

- Why do you study Electrical Circuits?
  - No sharp boundaries between the departments.
  - Electrical circuits exist almost everywhere: cell phones, laptops,…etc.
  - This course provides a basic understanding to Electrical circuits (devices, operations, and analysis)



Course Outline

- In this term, we will cover:

- Part (I): Analog – Dr. Omar Bakry
  - Electrical Circuits Review
  - Ideal Diodes and their applications
  - Ideal Operational Amplifiers (OPAMPs) and their applications
  - Semiconductor’s PN Junctions
  - Introduction to BJT/MOS Devices and Operation
  - DC/AC analysis of BJT/MOS Amplifiers

- Part (II): Digital – Dr. Ahmed Samir
  - Digital Systems and Information
  - Combinational logic circuits
  - Karnaugh map
  - Combinational Logic Design
  - Arithmetic Design

Class Overview

- **Instructors:** Dr. Omar Bakry [Analog] and Dr. Ahmed Samir [Digital]
- **TA:** Eng. Sayed Kamel
- Attendance and interactions are highly encouraged (but no grades for attendance ☺)
- **References:**
  - Adel S. Sedra, Kenneth Carless Smith, ***Microelectronic Circuits***. 7th Edition, Oxford University Press.
- Lectures will be uploaded to my CU scholar page:
  - https://scholar.cu.edu.eg/?q=omarba/classes
- Google Classroom will be used to post your grades, assignments and announcements:
  - https://classroom.google.com/c/NjYyNzM2MTQxODQw?cjc=oju3kct

Class Overview

- Grading Policy [subject to refinement]
  - Final Exam: 75 marks (60%)
  - Course work: 50 marks (40%)
    - Midterm: 25pts
    - Two quizzes: 15pts
    - Assignment/project: 10pts

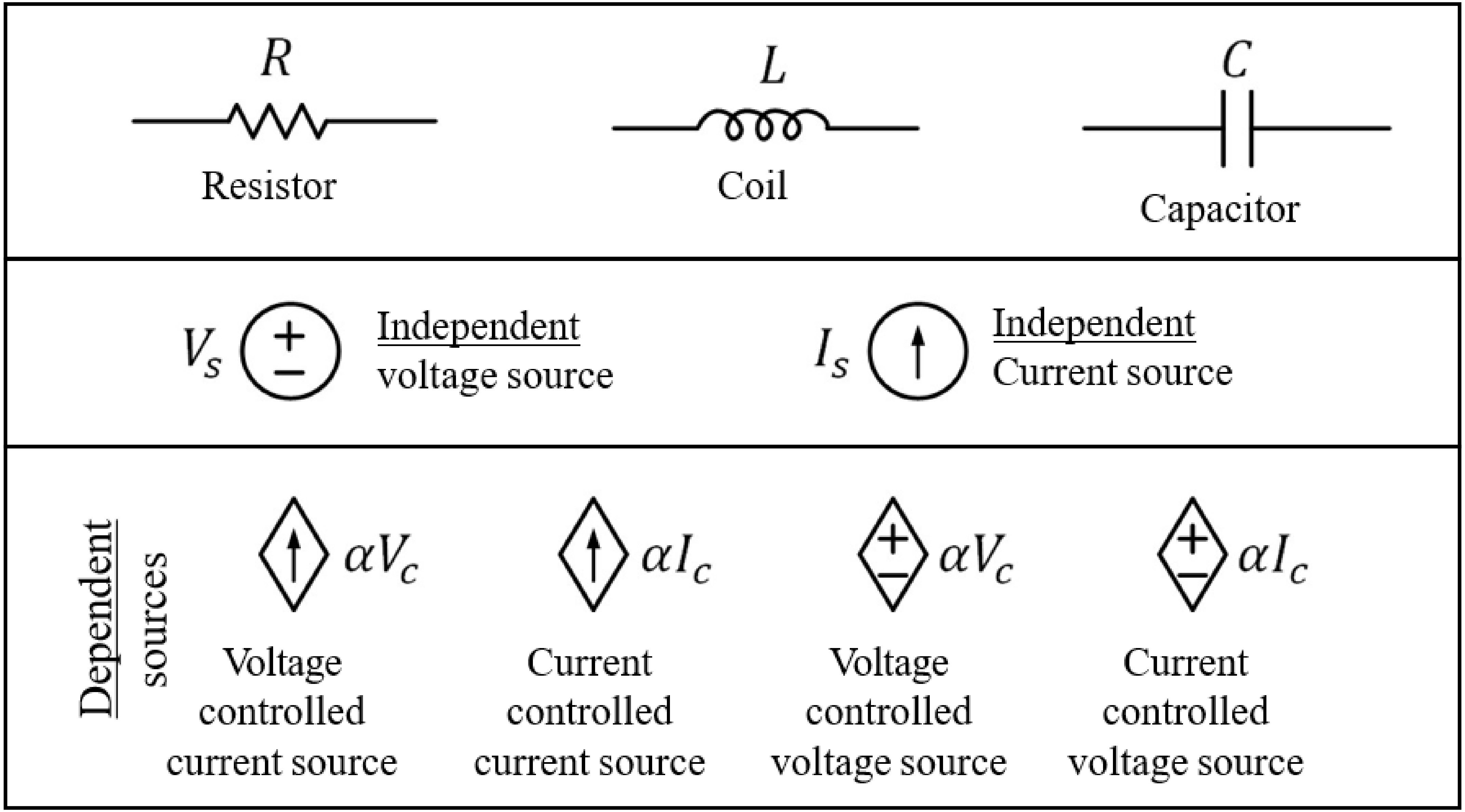
- Office Hours:
  - 30mins after class, Tuesdays (1:30 – 2:00 pm)
  - Additional time slots can be scheduled via email
  - Office Number: 8314 [EECE Building, 3rd floor]

Honor Code [Source: UofM]

- The Honor Code outlines certain standards of ethical conduct for students.
- The policies of the Honor Code apply to graduate and undergraduate students and faculty members. The Honor Code is based on these tenets:
  - Engineers must possess ***personal integrity*** both as students and as professionals. They must be honorable people to ensure safety, health, fairness, and the proper use of available resources in their undertakings.
  - Students in the Faculty of Engineering community are ***honorable and trustworthy*** persons.
  - The students, faculty members, and administrators of the Faculty of Engineering trust each other to uphold the principles of the Honor Code. They are jointly responsible for precautions against violations of its policies.
  - It is ***dishonorable*** for students to receive credit for work that is not the result of their own efforts.

"I have neither given nor received unauthorized aid on this examination, nor have I concealed any violations of the Honor Code."

Symbols Used in Electrical Circuits



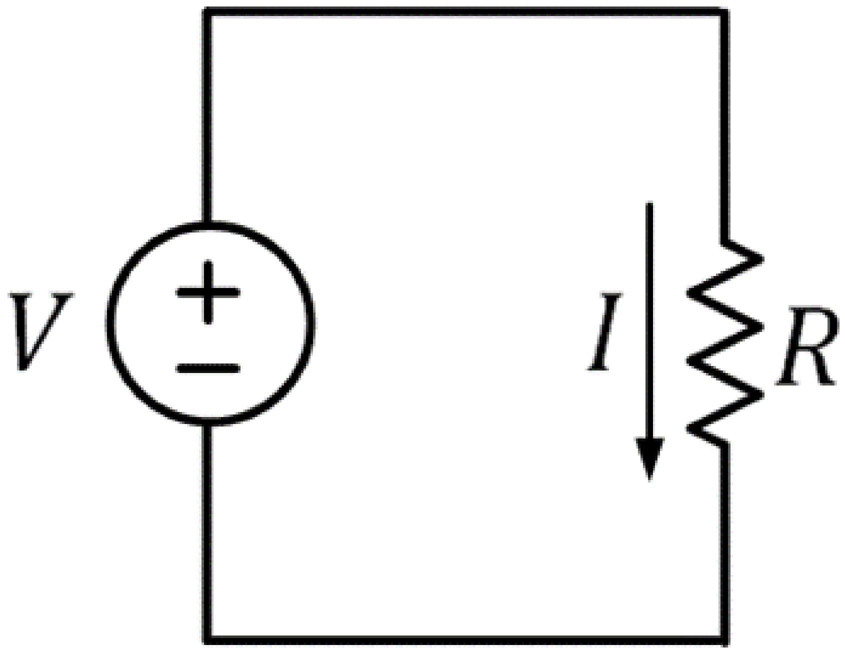
Ohm’s Law

- Ohm’s law states that the current through a resistor is directly proportional to the voltage difference across the resistor terminals

$$V = I \times R$$

$$I = \frac{V}{R}$$

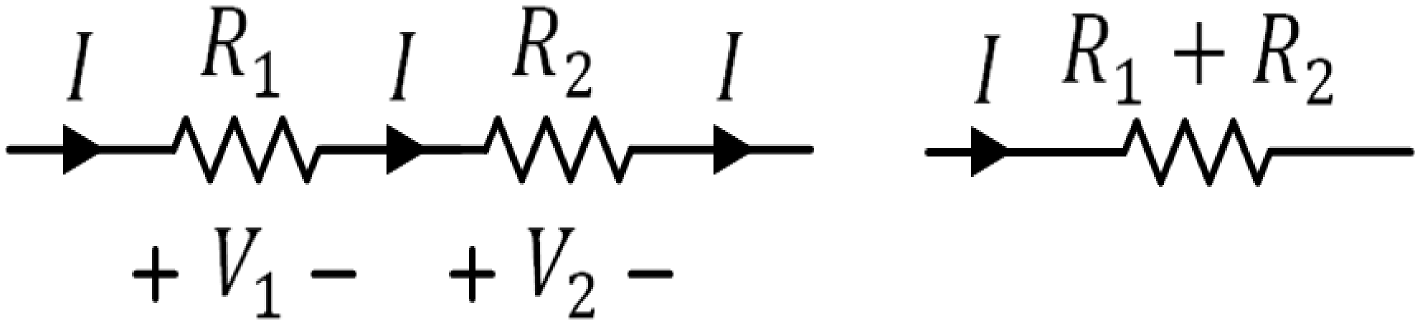
$$R = \frac{V}{I}$$



Series and Parallel Connection

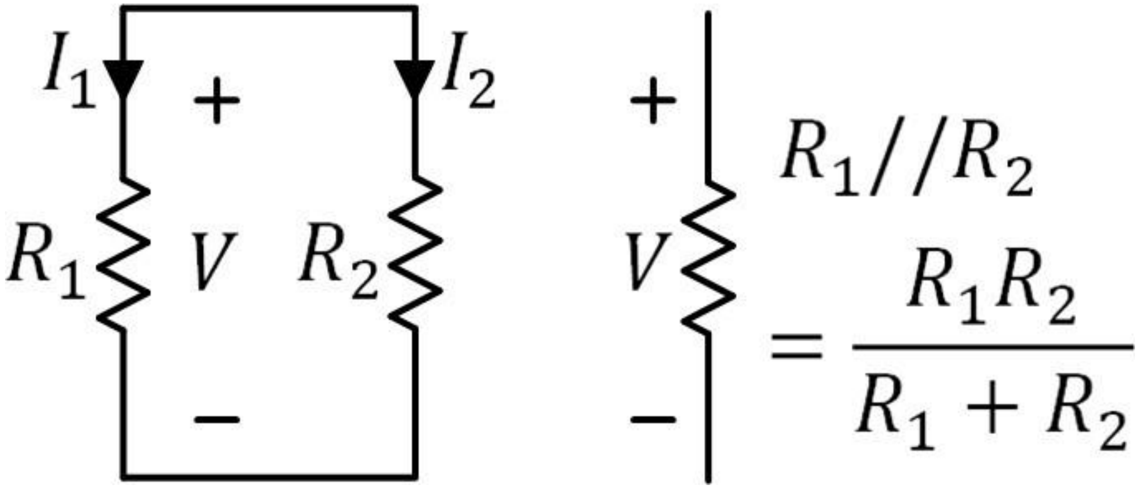
- Series Connection:

$$R_{tot} = \sum_i R_i$$



- Parallel Connection:

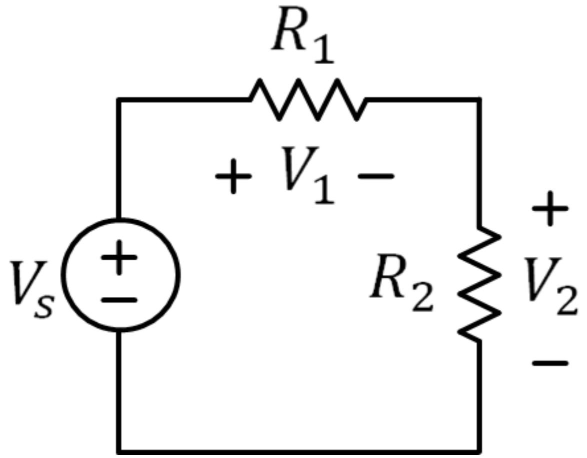
$$\frac{1}{R_{tot}} = \sum_i \frac{1}{R_i}$$



Voltage and Current Dividers

Voltage divider:

- Can be applied only in the case of series elements

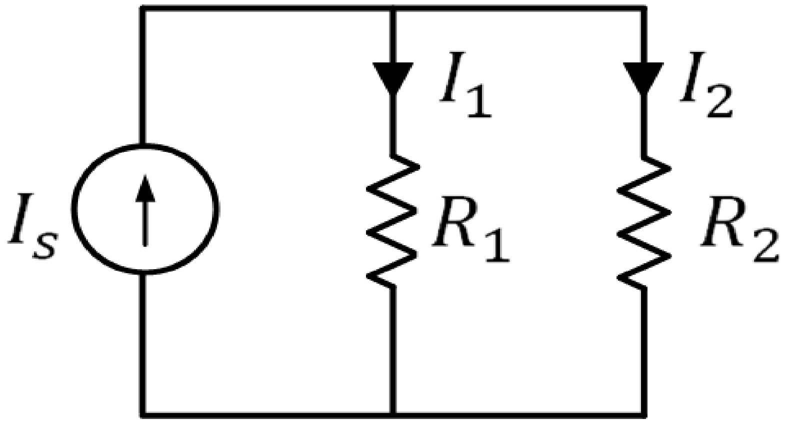


$$V_1 = \frac{R_1}{R_1 + R_2} \times V_S$$

$$V_2 = \frac{R_2}{R_1 + R_2} \times V_S$$

Current divider:

- Can be applied only in the case of parallel elements



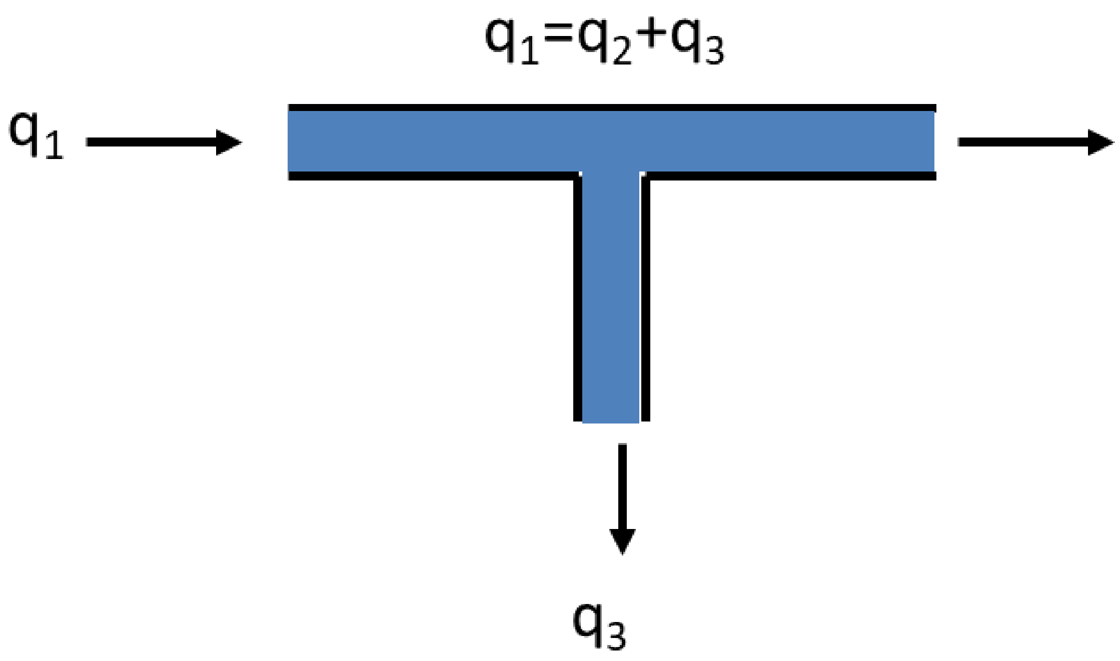
$$I_1 = \frac{R_2}{R_1 + R_2} \times I_S$$

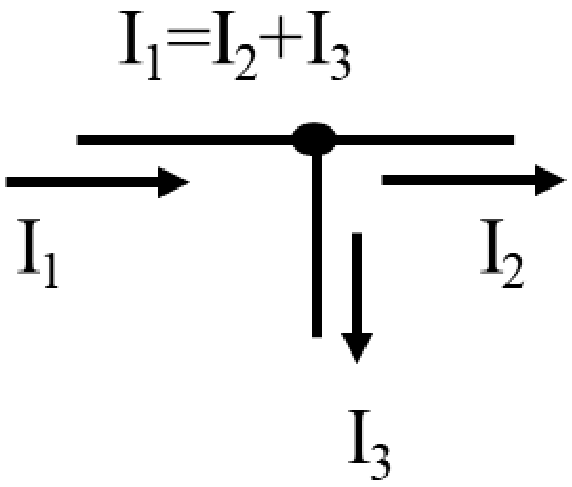
$$I_2 = \frac{R_1}{R_1 + R_2} \times I_S$$

Kirchhoff's Current Law (KCL)

- At any node in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node

$$\sum I_{in} = \sum I_{out}$$





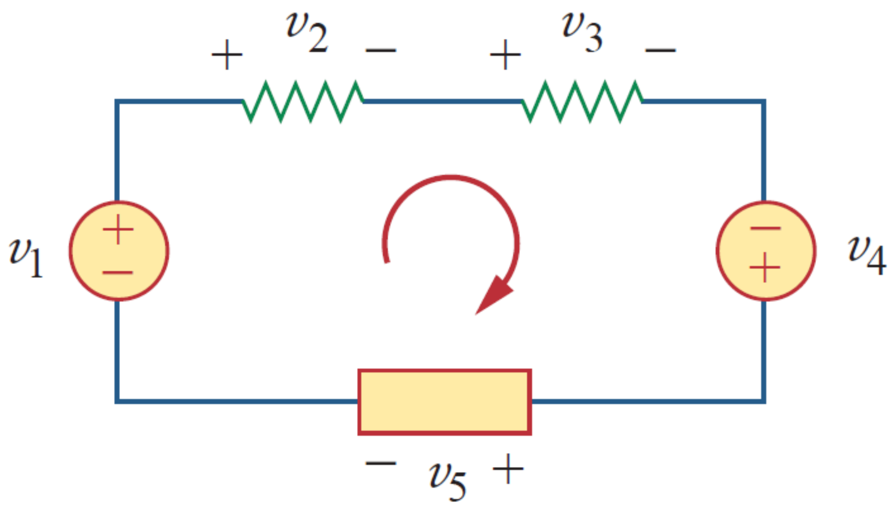
Kirchhoff's Voltage Law (KVL)

- The summation of the voltages around of a loop = 0

$$\sum_{m=1}^{M} V_m = 0$$

$$-v_1 + v_2 + v_3 - v_4 + v_5 = 0$$

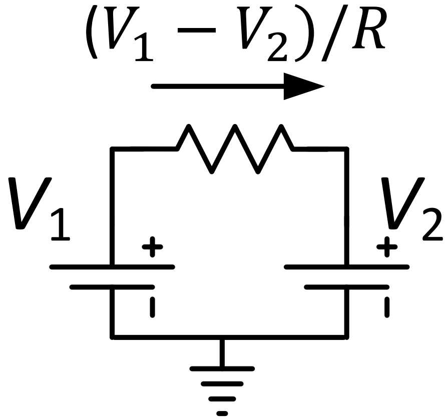
$$v_1 + v_4 = v_2 + v_3 + v_5$$

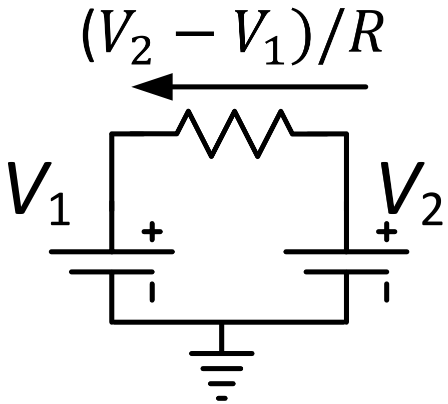


Sum of voltage drops = Sum of voltage rises

Nodal Analysis

- Select a node as the reference node.
- Assign voltages to the remaining nodes: $v_1, v_2, \dots, v_{n-1}$.
- The voltages are referenced with respect to the reference node.
- Apply KCL to each of the non-reference nodes.
- Use Ohm's law to express the branch currents in terms of node voltages.
  - Both representations are equivalent

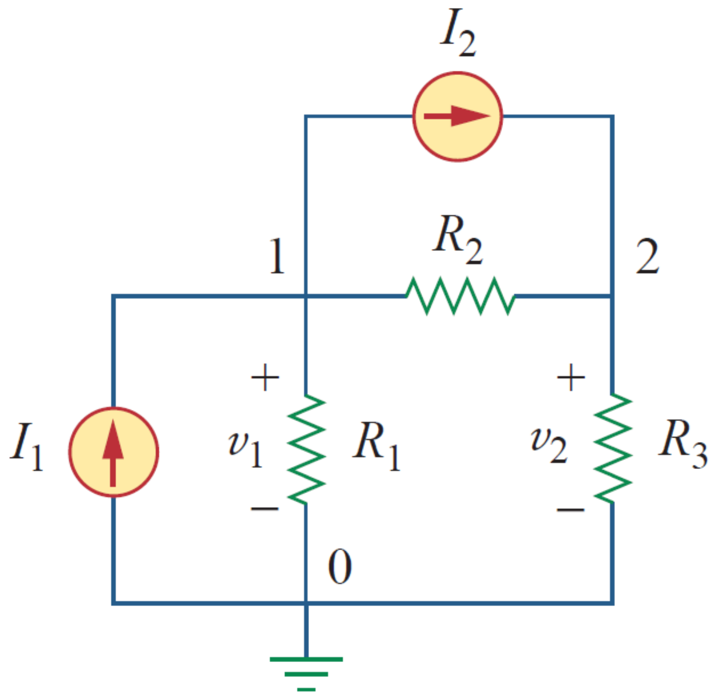




- Solve the resulting simultaneous equations to obtain the unknown node voltages.

Nodal Analysis : Example

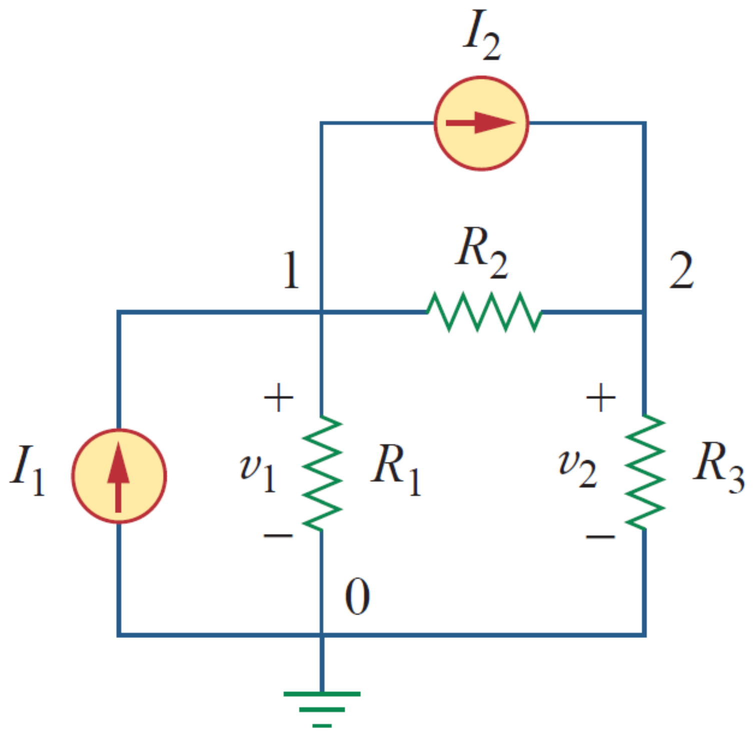
- Find the node voltages for the shown circuit using Nodal analysis



- **Solution:**
- Step#1: Assign node voltages
- Notes
  - v_1 is actually v_{10} (voltage difference between node 1 and node 0)
  - Voltage difference between node (1) & node (2): $v_{12} = v_{10} - v_{20} = v_1 - v_2$

Nodal Analysis : Example

- Step#2: Applying KCL at each non-reference node
- $I_1 = I_2 + i_{R1} + i_{R2} \quad \Rightarrow \quad I_1 = I_2 + G_1\, v_1 + G_2\,(v_1 - v_2)$
- $I_2 + i_{R2} = i_{R3} \quad \Rightarrow \quad I_2 + G_2\,(v_1 - v_2\,) = G_3\, v_2$
- Applying Ohm's law
- $i_{R1} = \frac{v_1 - 0}{R_1} = G_1 v_1$
- $i_{R2} = \frac{v_1 - v_2}{R_2} = G_2(v_1 - v_2)$
- $i_{R3} = \frac{v_2 - 0}{R_3} = G_3 v_2$



$$i = \frac{v_{\text{higher}} - v_{\text{lower}}}{R}$$

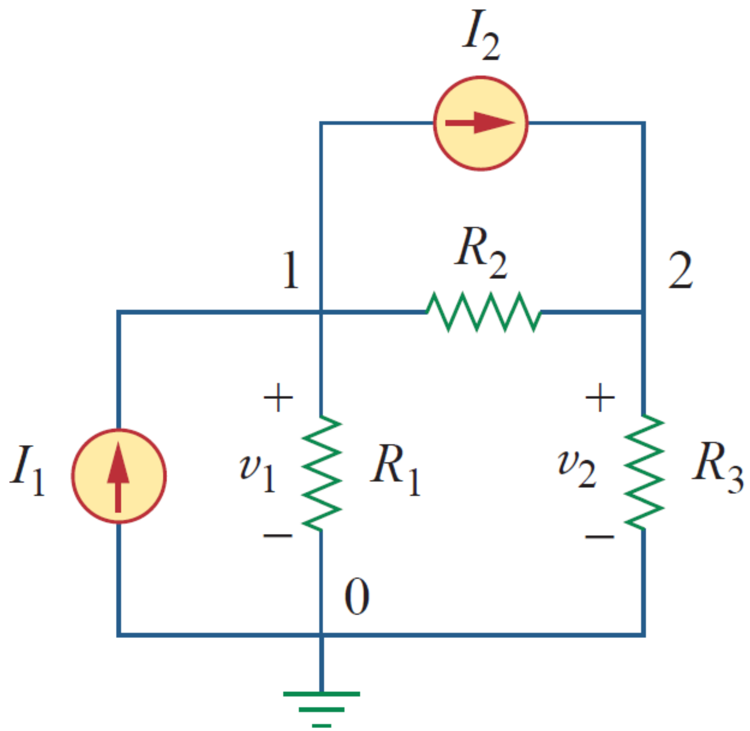
Nodal Analysis : Example

- $I_1 = I_2 + G_1\, v_1 + G_2\,(v_1 - v_2)$
- $(G_1 + G_2)v_1 + (-G_2)v_2 = I_1 - I_2$

- $I_2 + G_2\,(v_1 - v_2\,) = G_3\, v_2$
- $(-G_2)v_1 + (G_2 + G_3)v_2 = I_2$

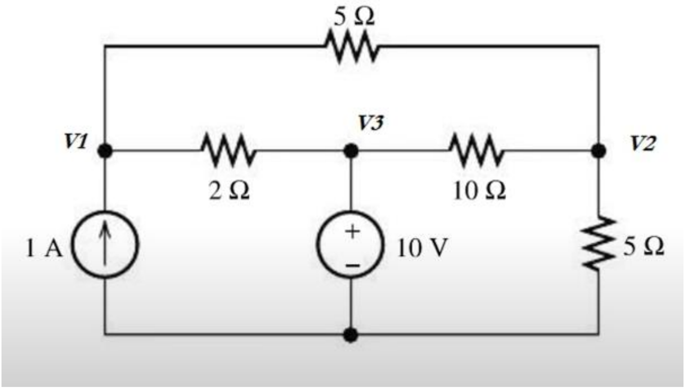
- $\begin{bmatrix} G_1 + G_2 & -G_2 \\ -G_2 & G_2 + G_3 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} I_1 - I_2 \\ I_2 \end{bmatrix}$

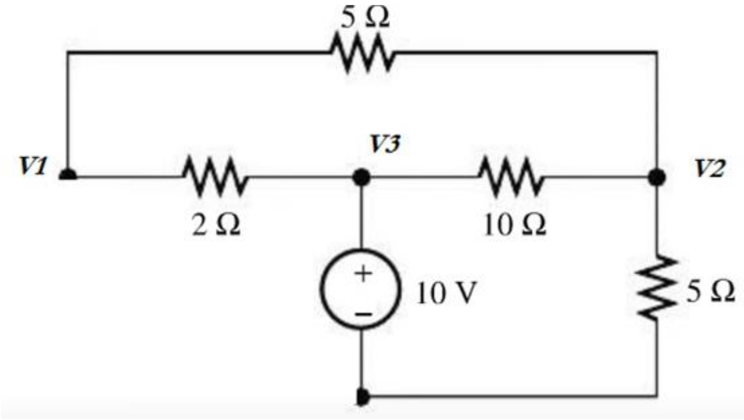
- Solve for v_1 *and* v_2.

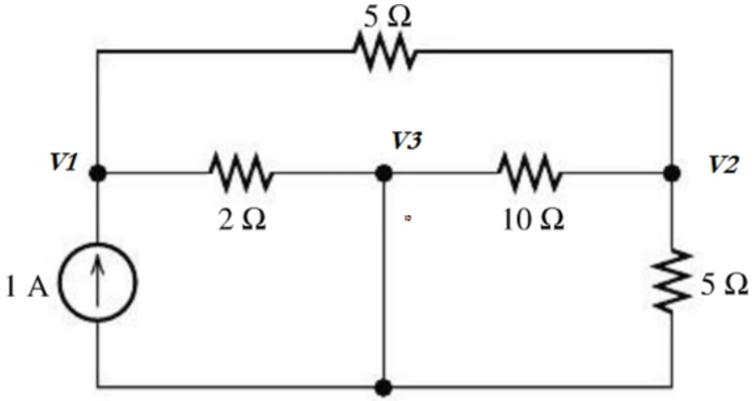


Superposition Theorem

- The voltage across (or current through) an element in a linear circuit is the algebraic sum of the voltages across (or currents through) that element due to each independent source acting alone.
- Steps
  1. Turn off all independent sources except one
  2. To turn off voltage source, replace it by short circuit
  3. To turn off current source replace it by open circuit
  4. Repeat for other sources
  5. Add the contribution of each source to find the final answer

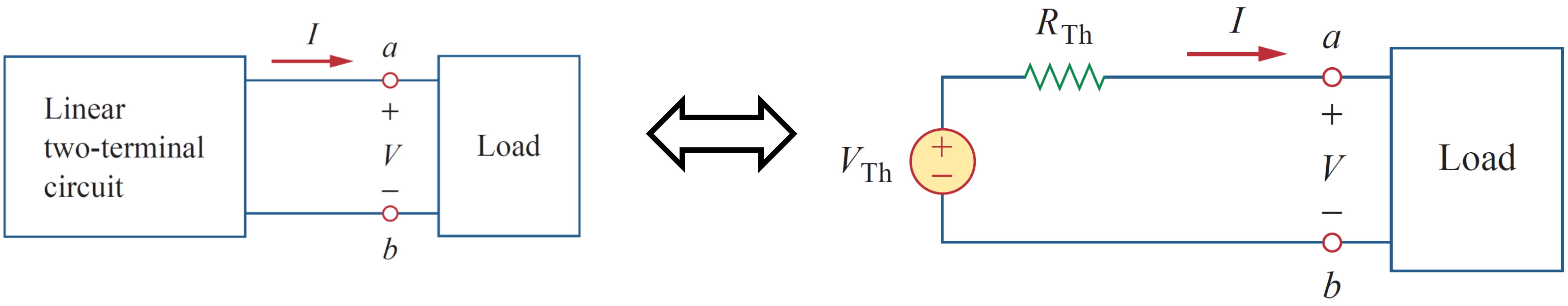






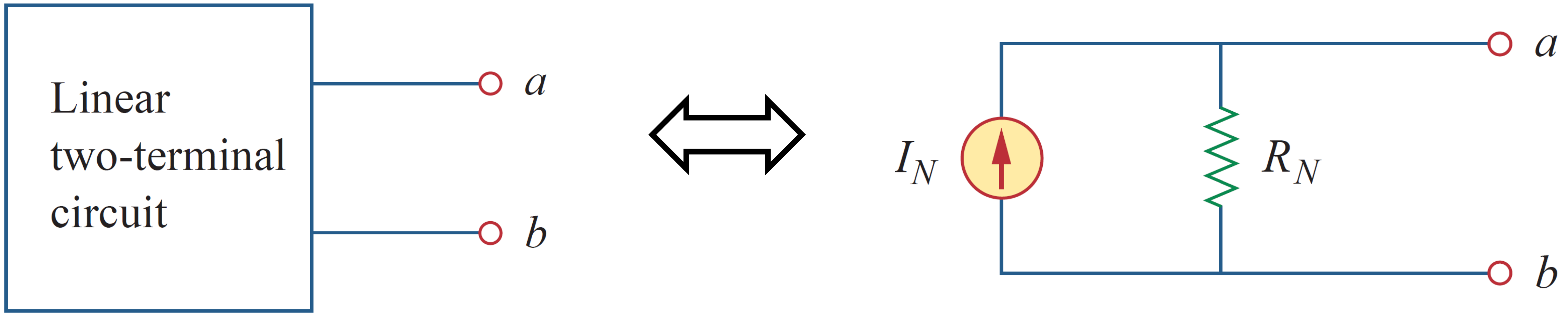
Thevenin's Theorem

- A linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{Th} in series with a resistor R_{Th}
- V_{Th} is the open-circuit voltage at the terminals of the load
- R_{Th} is the input or equivalent resistance seen at the terminals of the load with the independent sources turned off.



Norton's Theorem

- A linear two-terminal circuit can be replaced by an equivalent circuit consisting of a current source I_N in parallel with a resistor R_N
- I_N is the short-circuit current through the a/b terminals
- R_N is the input or equivalent resistance at the terminals with the independent sources turned off.
- $Notes$: $R_N = R_{TH}, \quad V_{TH} = R_N I_N$



AC Circuits

Sinusoid Phasor Transformation

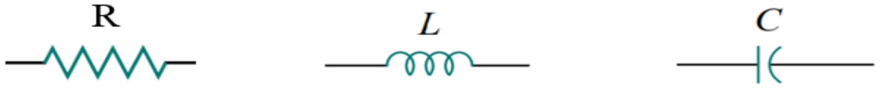
Time domain representation	Phasor domain representation
$V_m \cos(\omega t + \phi)$	$V_m \angle \phi$
$V_m \sin(\omega t + \phi)$	$V_m \angle \phi - 90^\circ$
$I_m \cos(\omega t + \theta)$	$I_m \angle \theta$
$I_m \sin(\omega t + \theta)$	$I_m \angle \theta - 90^\circ$

Summary of voltage-current relationships

Element	Time domain	Frequency domain
R	$v = Ri$	$\mathbf{V} = R\mathbf{I}$
L	$v = L\dfrac{di}{dt}$	$\mathbf{V} = j\omega L\mathbf{I}$
C	$i = C\dfrac{dv}{dt}$	$\mathbf{V} = \dfrac{\mathbf{I}}{j\omega C}$

AC Circuits

Impedance and Admittance



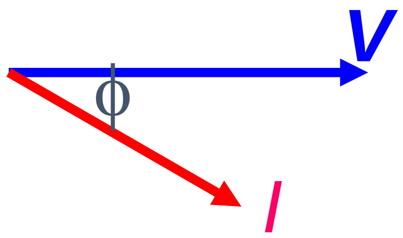
R	L	C
$V = RI$	$V = j\omega LI$	$V = \dfrac{I}{j\omega C}$
$Z = R$	$Z = j\omega L$	$Z = \dfrac{1}{j\omega C}$
$Y = \dfrac{1}{R}$	$Y = \dfrac{1}{j\omega L}$	$Y = j\omega C$

For a circuit with multiple elements, the equivalent Z can be calculated using parallel and series combinations. It ends up being a complex number.

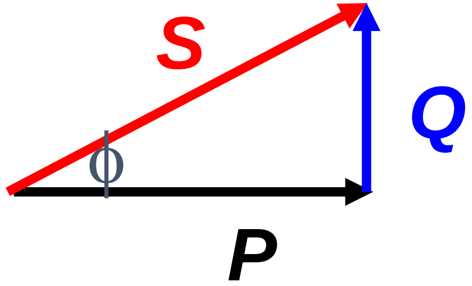
- Impedance $\boldsymbol{Z = R + jX}$
  - $\boldsymbol{R}$ is the equivalent, while X is the reactance
  - $\boldsymbol{Z}$ is inductive if $\boldsymbol{X}$ is +ve
  - $\boldsymbol{Z}$ is capacitive if $\boldsymbol{X}$ is –ve
  - $\boldsymbol{Z}, \boldsymbol{R},$ and $\boldsymbol{X}$ have the units of Ω
- Admittance $\boldsymbol{Y = G + jB}$
  - $\boldsymbol{G}$ is the conductance, while B is the susceptance
  - $\boldsymbol{Y}$ is inductive if $\boldsymbol{B}$ is -ve
  - $\boldsymbol{Y}$ is capacitive if $\boldsymbol{B}$ is +ve
  - $\boldsymbol{Y}, \boldsymbol{G},$ and $\boldsymbol{B}$ have the units of Ω^{-1}

AC Circuits – AC Power

- Complex Power:
  - $S = \frac{1}{2} V_m I_m^* = V_{rms} I_{rms}^*$
  - $S = V_{rms} I_{rms} \cos(\theta_v - \theta_i) + jV_{rms} I_{rms} \sin(\theta_v - \theta_i)$
  - $S = \frac{1}{2} I_m^2 (R + jX) = I_{rms}^2 (R + jX) = P + jQ$
  - Apparent power $= |S| = V_{rms} I_{rms}$ VA



- Active power:
  - real part of the complex power S, measured in W
  - $P = I_{rms}^2 R = V_{rms} I_{rms} \cos(\theta_v - \theta_i)$ W



- Reactive power:
  - imaginary part of the complex power S, measured in VAR
  - $Q = I_{rms}^2 X = V_{rms} I_{rms} \sin(\theta_v - \theta_i)$ VAR

- Power Factor $= \cos(\theta_v - \theta_i)$
  - $0 < PF < 1$