Electric Circuits
Lecture 1 Introduction

EE2210, Fall 2022

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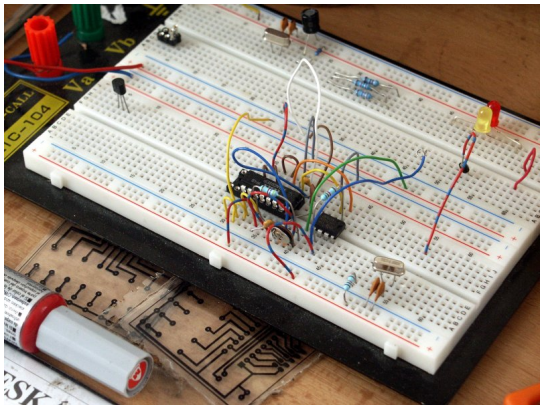
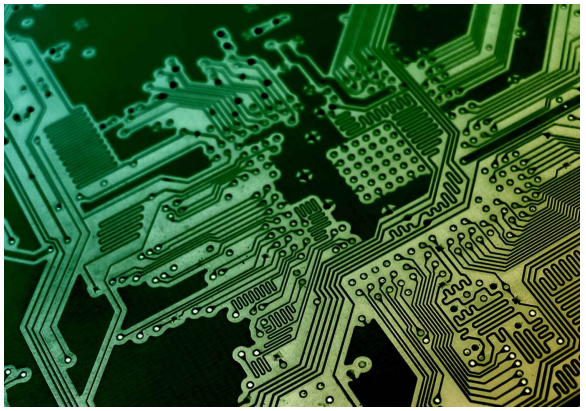
Lecture Outline

- Course introduction
- Electric circuit variables (Chapter 1 in the textbook)
  - Voltage and current.
  - Power and energy.
- Circuit elements (Chapter 2 in the textbook)





Course Info

- Instructor: Jenny Yi-Chun Liu 劉怡君
- Email: jennyliu@gapp.nthu.edu.tw
- Time & location: Mon 10:10am-12pm, Wed 9-9:50am @ Delta 215
  - Starting from the 2nd week (Sept. 21st), remote classes on every Wednesday (temporarily).
- Office hours: by appointment
- Course website: iLMS (notes and videos)
- TAs: 曾柏勳, 陳志育, 王柏翰, 郭施謙, 李孟儒, 羅偉倫
- TA session: Thur 6-8pm @ EECS 518
- Feedback anytime!

What is this class all about?

- This course introduces the fundamental circuit concepts and circuit analysis techniques.
- Main topics include resistive networks, circuit laws and analytical techniques, linear circuit analysis, energy storage elements, first-order and second-order circuits, sinusoidal steady state, and MOSFET amplifiers.

Course Goals

- Understand the basic circuit principles on which the design of electronic systems is based.
- Analyze and design simple electronic circuits in time and frequency domains.
- Analyze the circuits with energy storage elements.
- Understand the concept of employing models to represent nonlinear and active elements.

Weekly Schedule (Tentative)

Week	Date	Lecture
1	Sept 12	Introduction
	Sept 14	Resistive circuits
2	Sept 19	
	Sept 21	
3	Sept 26	Circuit theorems
	Sept 28	
4	Oct 3	
	Oct 5	First-order circuits
5	Oct 10	Holiday
	Oct 12	First-order circuits
6	Oct 17	
	Oct 19	
7	Oct 24	
	Oct 26	Operational amplifiers
8	Oct 31	
	Nov 2	Review
9	Nov 7	Midterm
	Nov 9	Second-order circuits

Week	Date	Lecture
10	Nov 14	Second-order circuits
	Nov 16	No class (sports day)
11	Nov 21	Second-order circuits
	Nov 23	
12	Nov 28	Sinusoidal steady state
	Nov 30	
13	Dec 5	
	Dec 7	Energy and power
14	Dec 12	
	Dec 14	Frequency response
15	Dec 19	
	Dec 21	
16	Dec 26	Impedance
	Dec 28	
17	Jan 2	Holiday
	Jan 4	Review
18	Jan 9	Final exam

Course Materials

- Textbooks
  - Lecture notes (will be posted online)
  - Richard C. Dorf and James A. Svoboda, *Introduction to Electric Circuits*, Wiley.
- Reference materials
  - James W. Nillson and Susan A. Riedel, *Electric Circuits*, Pearson Prentice Hall.
  - Anant Agarwal and Jeffrey H. Lang, *Foundations of Analog and Digital Electronic Circuits*, Morgan Kaufmann Publisher, Elsevier.
  - Others available on course website.

Course Grading

- Four items make the final grade.
  - Homework: 20%
  - Quizzes: 20% (In-class)
  - Midterm: 30%
  - Final: 30%
  - For all quizzes/exams: calculator allowed. Closed book.
- Please comply with the honor code.
  - Cheating leads to 0%.

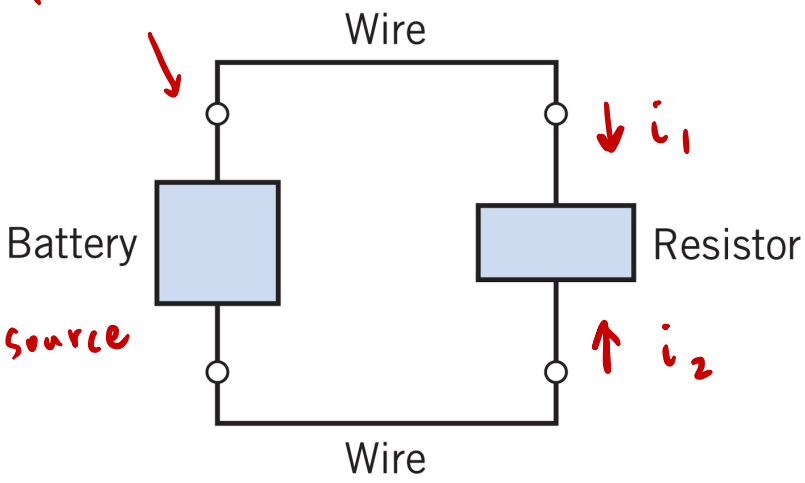
Chapter 1
Electric Circuit Variables

Introduction

- Circuits: various electrical elements connected together in a closed form so that an electric current may flow continuously.
- Electrical power sources have mobility and flexibility.
- Applications of circuits:
  - Generation, transmission, and consumption of electric power and energy.
  - Encoding, decoding, storage, retrieval, transmission, and processing of information.

Electric Circuit and Current

two-terminal (node)



$i_1 = -i_2$

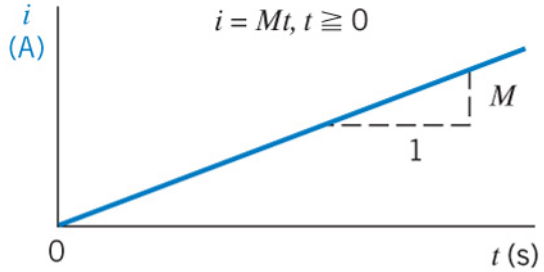
- Current: time rate of change of electric charges past a given point.

$$i = \frac{dq}{dt} \quad (\text{ampere, A})$$

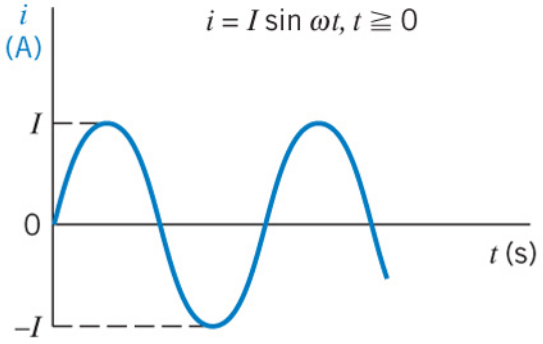
q: coulomb, C

t: second, s

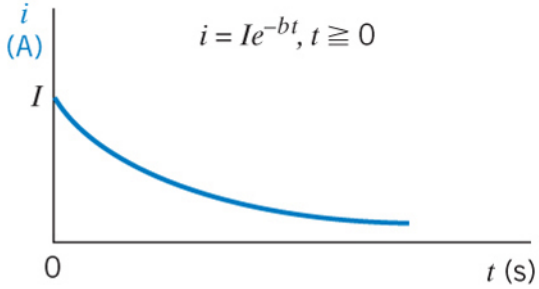
Forms of Electric Current



ramp (a)



(b) sinusoido

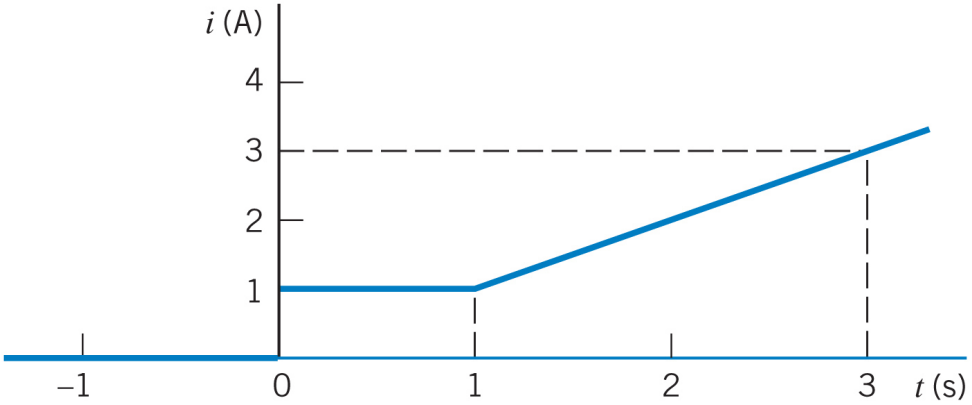


(c) exponential

- direct current (dc) : current with a constant magnitude
- alternating current (ac) : time-varying current
- From $i = \frac{dq}{dt} \Rightarrow q(t) = \int_{-\infty}^{t} i(\tau)d\tau = \int_{0}^{t} i(\tau)d\tau + q(t=0)$

Example 1.2-2

- Find the charge that has entered the terminal of an element for t = 0 to t = 3 s when the current entering the element is shown in the figure.

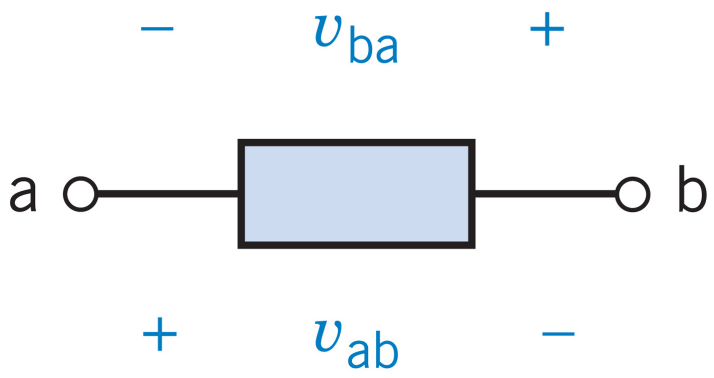


$$i(t) = \begin{cases} 0, & t < 0 \\ 1, & 0 < t \le 1 \\ t, & t > 1 \end{cases}$$

$$\Rightarrow q(t=3) - q(t=0) = \int_0^3 i(\tau)\,d\tau$$

$$= \int_0^1 1\,dt + \int_1^3 t\,dt = 5\ C$$

Voltage



$v_{ba} = -v_{ab}$

- Voltage across an element = energy required to move a unit positive charge from "−" terminal to "+" terminal.

$$v = \frac{dw}{dq} \quad (\text{volt, V})$$

w: energy (joule , J)

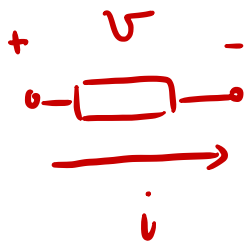
q: C

Power and Energy

- Power : time rate of energy

$$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = v \cdot i$$

p : watts, W



$$w = \int_{-\infty}^{t} p(\tau)\, d\tau$$

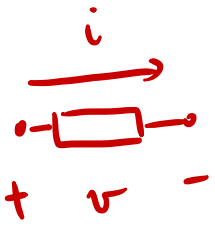
Chapter 2
Circuit Elements

- Linearity
- Active and passive components
- Resistors
- Independent sources
- Open circuits and short circuits
- Voltmeters and ammeters
- Dependent sources

Linearity

- Linear components: the element's excitation and response satisfy the linearity principle.
  - Principle of superposition. and homogeneity.

1. Superposition :



$v_1 \longrightarrow i_1$

$v_2 \longrightarrow i_2$

$v_1 + v_2 \longrightarrow i_1 + i_2$

2. Homogeneity : $v_1 \rightarrow i_1$

$k \cdot v_1 \rightarrow k \cdot i_1$

k: constant

element | component | device

Example 2.2-2

- Consider an element with the following expression: $v = i^2$

i : excitation, v : response

Given $i_1 \Rightarrow v_1 = i_1^2$ ✓

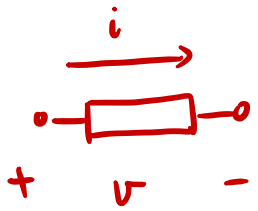
$i_2 \Rightarrow v_2 = i_2^2$ ✓

$i_1 + i_2 \Rightarrow v_3 = (i_1 + i_2)^2 \neq i_1^2 + i_2^2$

∴ nonlinear component

Active and Passive Elements

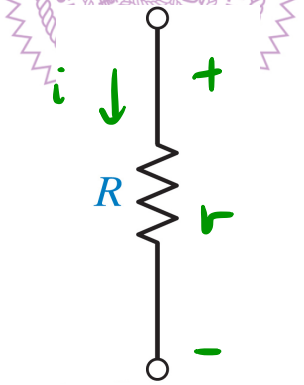
- Passive elements: absorb energy to the circuits.
  - Example: resistors, capacitors, inductors.
- Active elements: provide energy to the circuits.
  - Example: battery, generators, transistors.



$w \geq 0$ passive

$w < 0$ active

Resistors



- Resistor: a passive two-terminal element that has electrical resistance.
  - Resistivity (ρ) resists the flow of current.
  - Resistivity: largely depend on the materials. Insulator has high resistivity and metal has low resistivity.

- Resistance $R = \rho \cdot \frac{L}{A}$ (ohm, Ω)

  L: length

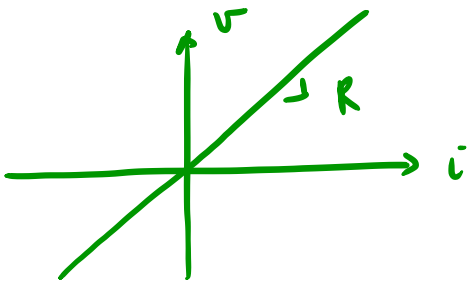
  A: cross-section area

- $G = \frac{1}{R}$ (siemens, S, Ω^{-1})

  Conductance

$v = R \cdot i$ linear component

=

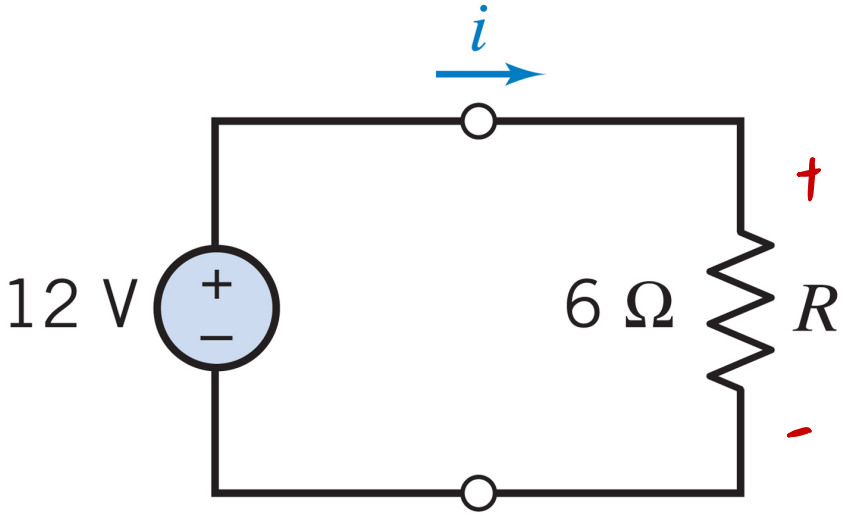


- Power delivered to $R = v \cdot i = v \cdot \frac{v}{R} = \frac{v^2}{R}$

  $= R \cdot i \cdot i = R \cdot i^2$

Example 2.4-1

- Find the current, power and energy supplied by the electric source to the resistor.



$v = 12\ V$

$i = \frac{12}{6} = 2\ A$

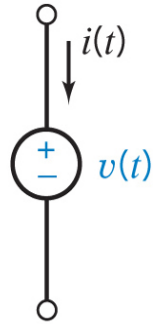
$p = v \cdot i = 24\ W$

$w = \int_0^t 24 \cdot dt = 24t \quad J$

Independent Sources

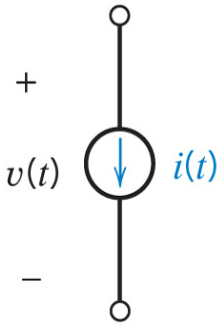
- Independent source: voltage or current generator that supplies voltage or current independent of other circuit variables.

- open circuit: i ↓ | + v − | $R = \infty$, $i = 0$



(a)

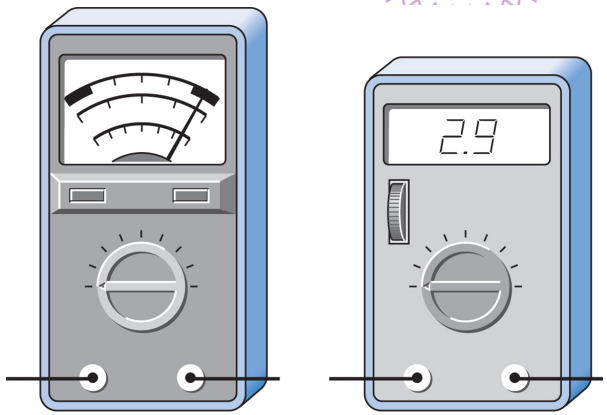
- short circuit: i ↓ | + v − | $R = 0$, $v = 0$



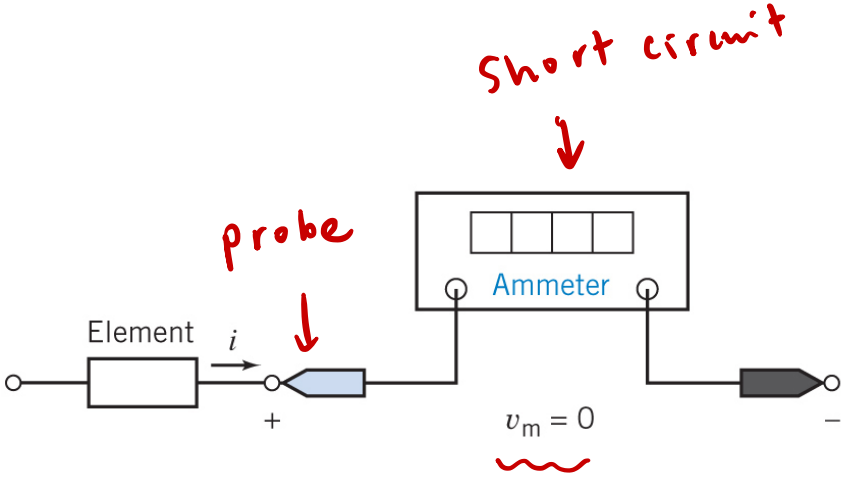
(b)

Voltmeters and Ammeters

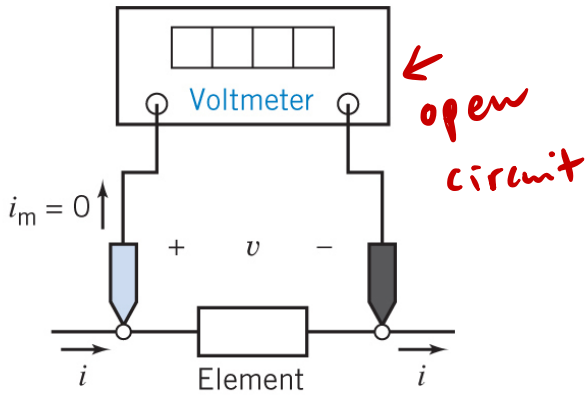
- Measure the dc voltage and current.



(a) (b)



(a)

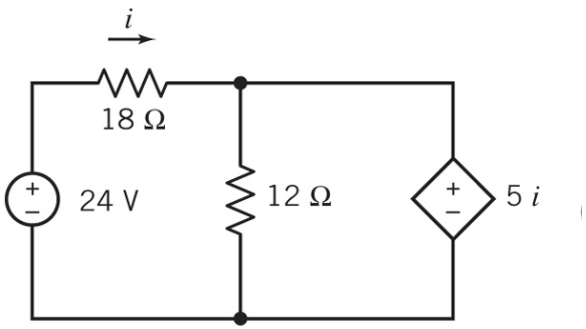


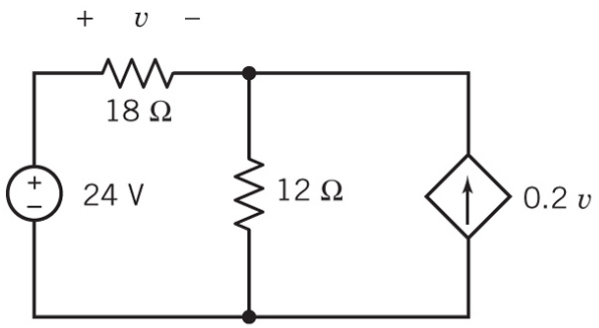
(b)

Dependent Sources

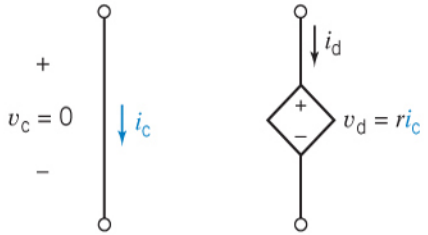
Example: transistors, amplifiers,

- Dependent sources model the situation where the voltage or current of one circuit element is dependent on the voltage or current of the second circuit element.



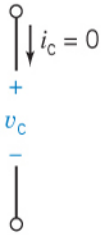


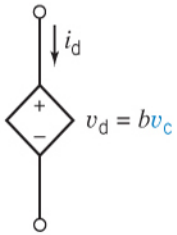
Types of Dependent Sources



1. CCVS

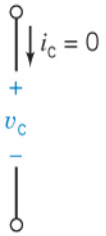
r: V/A (unit)

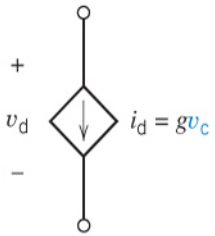




2. VCVS

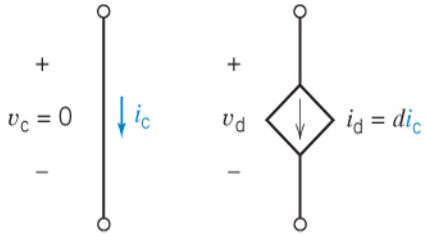
b: V/V





3. VCCS

g: A/V



4. CCCS

d: A/A