University of Technology

Biomedical Engineering Department

Electrical Circuits

First Sage

Lecture (1)

By

Asst. Lec. Asia Sh. Ahmed

Introduction to Electrical Circuits

1. Basic Concept and Basic Law

1.1 Basic Concept

1.1.1 System of Units

As electrical engineers, we deal with measurable quantities. Our measurement, however, must be communicated in a standard language that virtually all professionals can understand, irrespective of the country where the measurement is conducted. Table 1.1 shows the six units and one derived unit that are relevant to this text. The SI units are used throughout this text. One great advantage of the (SI International System of Units)unit is that it uses prefixes based on the power of 10 to relate larger and smaller units to the basic unit. Table 1.2 shows the SI prefixes and their symbols. For example, the following are expressions of the same distance in meters (m):

600,000,000 mm 600,000 m 600 km

TABLE 1.1

Six basic SI units and one derived unit relevant to this text.

Quantity	Basic unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Charge	coulomb	C

TABLE 1.2

The SI prefixes.

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

1.1.2 Charge and Current

Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C). charge e on an electron is negative and equal in magnitude to 1.602×10^{-19} C.

Electric current is the time rate of change of charge, measured inamperes (A). Mathematically, the relationship between current i, charge q, and time is:

$$i \triangleq \frac{dq}{dt}$$

$$Q \triangleq \int_{t_0}^{t} i\, dt$$

A direct current (dc) is a current that remains constant with time. The symbol I is used to represent such a constant current. An alternating current (ac) is a current that varies sinusoidally with time. A time varying current is represented by the symbol i.

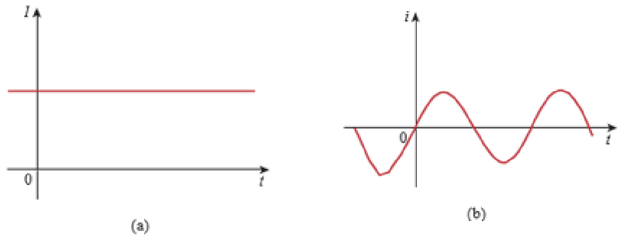


Figure (1.1): Two common types of current: (a) directcurrent (dc), (b) alternating current (ac).

Example

Determine the total charge entering a terminal between $t = 1$ s and $t = 2$ s if the current passing the terminal is $i = (3t^2 - t)$ A.

Solution:

$$Q = \int_{t=1}^{2} i\,dt = \int_{1}^{2} (3t^2 - t)\,dt$$

$$= \left(t^3 - \frac{t^2}{2}\right)\Big|_1^2 = (8 - 2) - \left(1 - \frac{1}{2}\right) = 5.5 \text{ C}$$

1.1.3 Voltage

Voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V). The plus (+) and minus (—) signs are used to define reference direction or voltage polarity. For the V_{ab} this means that the potential of Point a is higher than point b.

$$V_{ab} = V_a - V_b$$

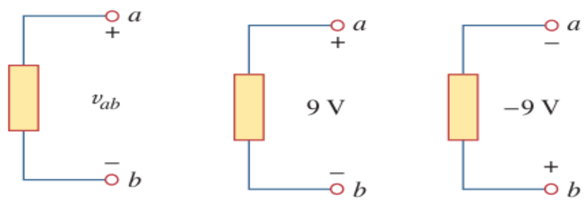


Figure (1.2): Polarity of voltage V_{ab}

1.1.4 Power and Energy

Power is the time rate of expending or absorbing energy, measured in watts (W).

$$p \triangleq \frac{dw}{dt}$$

where p is power in watts (W), w is energy in joules (J), and t is time in seconds (s).

$$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = vi$$

$$p = vi$$

the energy absorbed or supplied by an element from time t_0 to time t is:

$$w = \int_{t_0}^{t} p\,dt = \int_{t_0}^{t} vi\,dt$$

Energy is the capacity to do work, measured in joules (J).The electric power utility companies measure energy in watt-hours (Wh), where: 1Wh = 3600 J

How much energy does a 100-W electric bulb consume in two hours? **Example**

Solution:

$$w = pt = 100\ (\text{W}) \times 2\ (\text{h}) \times 60\ (\text{min/h}) \times 60\ (\text{s/min})$$
$$= 720{,}000\ \text{J} = 720\ \text{kJ}$$

This is the same as

$$w = pt = 100\ \text{W} \times 2\ \text{h} = 200\ \text{Wh}$$

1.1.5 Circuits Elements

An electric circuit is an interconnection of the elements. Circuit analysis is the process of determining voltages across (or the currents through) the elements of the circuit. There are two types of elements found in electric circuits:

A. **passive elements (are resistors, capacitors, and inductors)**
B. **active elements (generators, batteries, and operational amplifiers)**

An active element is capable of generating energy while a passive element is not. The most important active elements are voltage or current sources that generally deliver power to the circuit connected to them. There are two kinds of sources: independent and dependent sources.

A. An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit elements.
B. An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.

1.2 Basic Laws

1.2.1 Ohm's Law

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

$$v \propto i$$

$$v = iR$$

The *resistance R* of an element denotes its ability to resist the flow ofelectric current, it is measured in ohms (Ω).

A short circuit is a circuit element with resistance approaching zero.

An open circuit is a circuit element with resistance approaching infinity.

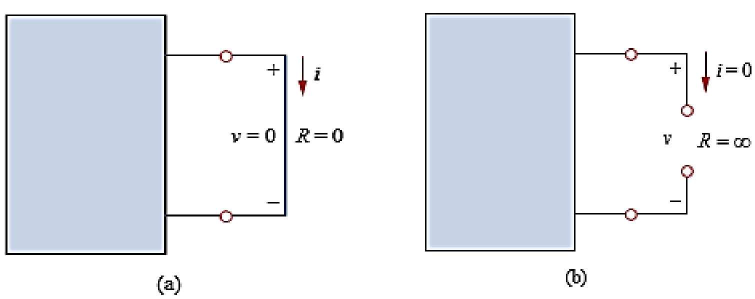


Figure (2.1): (a) Short circuit (R = 0), (b) Open circuit(R = ∞).

A useful quantity in circuit analysis is the reciprocal of resistance R, known as *conductance* and denoted by G:

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

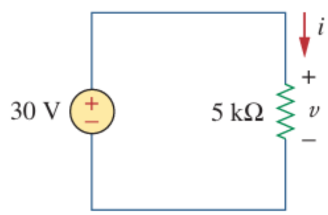
Conductance is the ability of an element to conduct electric current; it is measured in mhos ( ) or siemens (S).

$$i = Gv$$

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

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

Example: In the circuit shown, calculate the current *i*, the conductance *G*, and the power *p*.



Solution:

$$i = \frac{v}{R} = \frac{30}{5 \times 10^3} = 6 \text{ mA}$$

The conductance is

$$G = \frac{1}{R} = \frac{1}{5 \times 10^3} = 0.2 \text{ mS}$$

$$p = vi = 30(6 \times 10^{-3}) = 180 \text{ mW}$$

$$p = i^2R = (6 \times 10^{-3})^2 5 \times 10^3 = 180 \text{ mW}$$

$$p = v^2G = (30)^2 0.2 \times 10^{-3} = 180 \text{ mW}$$

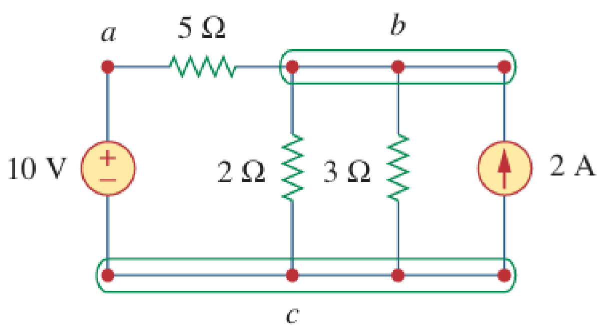
1.2.2 Nodes, Branches and Loops

A node is the point of connection between two or more branches.

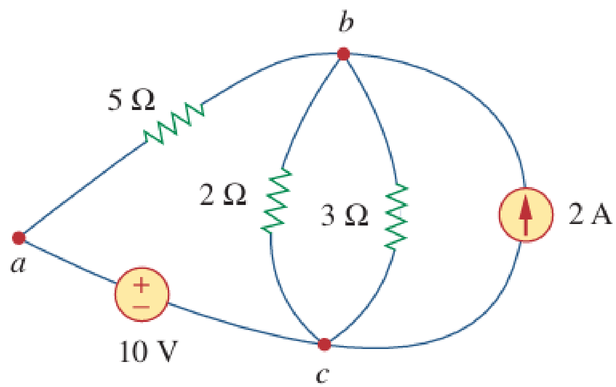
A branch represents a single element such as a voltage source or aresistor.

A loop is any closed path in a circuit.

Example: determine the number of branches, nodes, and the independent loops for the circuit shown :



As a branch represents any two-terminal element. The circuit in Figure has five branches, namely, the 10-V voltage source, the 2-A current source, and the three resistors.



Example : How many branches and nodes does the circuit in Fig. (2.2) have ? Identify the elements that are in series and in parallel.

Solution:

Five branches and three nodes are identified in Fig. 2.2. The 1-Ω and 2-Ω resistors are in parallel. The 4-Ω resistor and 10-V source are also in parallel.

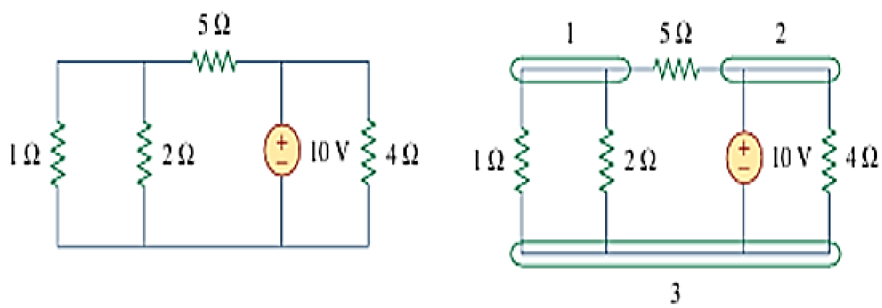


Figure (2.2)