BASICS OF ELECTRIC CIRCUITS

Text: Basic Engineering Circuit Analysis, 8th edition by J. D. Irwin and R. M. Nelms

Basic concepts:
(Refer to sections 1, 2 and 3 in chapter 1 of your text)

Electric circuit:
A circuit is an interconnection of electrical components.

Electric charge: is one of the fundamental quantities and exists in every atom.

Symbol: Q or q

Unit: Coulomb (C).

Electric Current: The time rate of change of charge. \( i(t) = \frac{dq}{dt} \)

Symbol: \( i(t) \) or \( i \) or \( I \) depending on whether the current is constant or time varying quantity.

Unit: Ampere (A); \( 1 \cdot A = \frac{1 \cdot C}{1 \cdot s} \)
Types of currents:  
→ Alternating current (ac)  
→ Direct current (dc)

Current waveform can be a sine or a cosine function.  
Current has a steady level.

Current flow in a conductor (wire or any element) is specified by two indicators.  
1. Direction of current flow, and  
2. Value (magnitude)  
   - For ac currents, the magnitude varies with time  
   - For dc currents, current has a steady value

\[ I = 5 \text{ A} \]

5A current flows from point A to point B; this is same as a negative current of magnitude 5A flowing from B to A.

\[ I = -5 \text{ A} \]
Voltage (Potential Difference):

Voltage => Work done on \( q \) to move it from point A to point B per unit charge

=> Difference in potential energy per unit charge

Symbol: \( V \) or \( v(t) \)

Unit: Volt (V); \( 1 \cdot V = \frac{1 \cdot J}{1 \cdot C} \)

Representation of a potential in a circuit:

Consider the following example.

In representing a potential, it is important to identify both the polarity (direction) and the magnitude.

If we are dealing with a differential amount of charge and energy, then

\[
v = \text{voltage} = \frac{dw}{dq}
\]

\[
dw = \text{work done}
\]

\[
dq = \text{change}
\]

By multiplying both sides by current,

\[
\therefore v \cdot i = \frac{dw}{dq} \left( \frac{dq}{dt} \right) = \frac{dw}{dt} \Rightarrow \text{Power, } p
\]
Power: The time rate of change of energy is defined as power.

Symbol: $P$ or $p$.

Unit: Watts (W).

$1 \text{ W} = 1 \text{ J} / 1 \text{ s}$.

In general $i$, $v$ and $p$ are used to represent time varying parameters.

\[ \Delta w = \int_{t_1}^{t_2} p \cdot dt = \int_{t_1}^{t_2} v \cdot idt \]

Power can be equated to the product of current and voltage.

In ac circuits,

\[ p(t) = i(t) \cdot v(t) \]

(Voltage and current are considered as time varying parameters). Alternatively, we can define the power in ac circuits in a more specific form later, in terms of voltage, current and power factor.

In dc circuits,

\[ P = I \cdot V \text{ in dc circuits (steady values)} \]

Hence the unit of power can be defined as:

\[ 1 \text{ W} = 1 \text{ V} \cdot 1 \text{ A} \]
Sign convention for Power:
(Passive Sign Convention)

\[ p(t) = v(t) \cdot i(t) \quad \text{Or simply, } p = v \cdot i \]

The product of \( v \cdot i \) with their attendant signs, defines the magnitude and sign of the power.

If \( p(t) \) is positive, then the element absorbs power.

If \( p(t) \) is negative, then the element supplies power to the rest of the circuit.

**Examples:**

**(a)**

Voltage across the element = 4 V
Current through the element = 2A with “arrow” as marked.

\[ P = (4V)(2A) = 8W \implies \text{Since is positive, the element absorbs the power.} \]
Voltage across the element = -20V
Current through the element = 2A

BUT, the current enters at a negative terminal; hence, \( P = - (V \cdot I) \)

\[ \therefore P = (-(-20V))(2A) = 40W \]

Circuit Elements:
- Active elements (Sources)
- Passive elements ( Loads )

Active elements: Voltage Sources and Current Sources
=> Can be of two types; independent or dependent sources.

Independent Sources:

Independent Voltage Sources:
Such sources are two terminal components that maintain a specified voltage across their terminals, independent of the current.
Independent Current Sources:

Such sources are two terminal components that supply a specified current regardless of the voltage across the terminals.

\[ i(t) \]

Arrow indicates the positive direction of current flow

Dependent Sources:

Dependent Voltage Source:

Dependent or controlled voltage sources have a voltage across them which depends on a variable, \( x \) (voltage or current) elsewhere in the circuit.

Dependent Current Source:

Similarly, dependent current sources have a current, which depends on a variable, \( x \) (voltage or current) elsewhere in the circuit.

⇒ Often you find these in electronic circuits as representative models for transistors.

Examples of circuits with different types of dependent sources are presented below.
Dependent Sources:

(a) Voltage Dependent Voltage Source

\[ V = \mu V_s \]

*The parameter \( \mu \) represents voltage to voltage ratio*

(b) Current dependent Voltage Source

\[ V = y I_s \]

(c) Voltage Dependent Current Source

\[ I = g V_s \]

(d) Current dependent current source

\[ I = \beta I_s \]

*The parameter \( \beta \) represents current to current ratio*