Electric circuits

Lecture # 2

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Chapter #2: Circuit Elements.

There are five basic circuit elements:
- Voltage sources, current sources, resistors (covered at Chapter 2).
- Inductors, capacitors (at Chapter 6).

* Electrical source

is a device that is capable of converting nonelectric energy to electric energy and vice versa.
- E.g. Discharging battery converts chemical energy to electric one.
- Charging battery converts electric energy to chemical energy.

A generator operates in the mechanical-to-electric mode.
A motor operates in the electric-to-mechanical mode.

* Ideal voltage source

is a circuit element that maintains a prescribed voltage across its terminals.

* Ideal current source

is a circuit element that maintains a prescribed current through its terminals.

Sources

- Independent
- Dependent (Controlled source)

- Establishes a voltage or current in a circuit without relying on voltages or currents elsewhere in the circuit.
- Establishes a voltage or current whose value depends on the value of a voltage or current elsewhere in the circuit.

\[ V_s = \alpha U_x \]

[Circle]

\[ V_s = \alpha C_x \]

[Diamond]
Active element (electric source) is one that models a device capable of generating electric energy.

Passive elements (Resistors, Inductors, Capacitors) are ones that model devices that cannot generate electric energy.

Connection of Sources:

- Voltage Sources:
  - Parallel: 1) Same magnitude 2) Same polarity
    
    ![Parallel Connection Diagram]
    
    Series: No condition
    
    ![Series Connection Diagram]
    
    \[ V_T = V_1 + V_2 \]
    \[ V_T = V_1 - V_2 \]
    \[ V_T = V_1 - V_2 \]

- Current Sources:
  - Series: 1) Same magnitude 2) Same direction
    
    ![Series Connection Diagram]
    
    Parallel: No condition
    
    ![Parallel Connection Diagram]
Which is valid and which is not will be valid

\[ U_X = 5V \]
\[ V_X = 3V \]
\[ U_X, 5V \]
\[ V_X, 3V \]
\[ I_X = 2A \]
\[ V_4 = 4C \]
\[ I_X = 2A \]
\[ C_4 = 0A \]

* Ohm's law (Electrical Resistance): 
\[ \frac{R}{U} \] 
\[ \frac{R}{U} \]
\[ V = IR \]
\[ V = \text{Voltage (Volts)} \] (V)
\[ I = \text{Current (Amps)} \] (A)
\[ R = \text{Resistor (ohms)} \] (Ω)

* The reciprocal of resistance = Conductance (G)
\[ G = \frac{1}{R} \] S, S = Siemens

\[ P = IU \]
\[ = I^2R = \frac{V^2}{G} \]
\[ = V^2/R = V^2, G \]

For passive elements, P > 0 ⇒ absorb power
For active elements, P < 0 ⇒ generate power.
1. **Kirchhoff's laws**
   
   a) **Kirchhoff's Current Law (KCL)**
   
   "The algebraic sum of all the currents at any node equals zero."
   
   A node is a point where two or more circuit elements meet.
   
   node a: \[ c_1 + c_4 - c_2 - c_3 = 0 \]
   
   node b: \[ c_2 + c_3 - c_1 - c_6 - c_9 = 0 \]
   
   node c: \[ c_6 - c_3 = 0 \]
   
   node d: \[ c_9 + c_6 + c_c = 0 \]

2. **Kirchhoff's Voltage Law (KVL)**
   
   "The algebraic sum of all the voltages around any closed path in a circuit equals zero."

   Path 1: \[ U_1 - V_2 = U_4 + V_b + U_3 = 0 \]
   
   Path 2: \[ U_a - V_3 - V_6 = 0 \]
   
   Path 3: \[ V_5 - U_b + U_4 + V_c = 0 \]
   
   Path 4: \[ U_7 + U_1 - U_2 + U_c + U_d - V_a = 0 \]
Example 1

\[ V_b = 150 \text{ V} \]

\[ 6 \text{ A} \] Check if \( P_{\text{diode}} = P_{\text{gen}} \) for the circuit??

\[ \text{Solution} \]

at node D1
\[ 120 = -6c_1 - 60c_2 = 0 \]
\[ 120 = 60c_1 - 60(c_1 + 6) = 0 \]
\[ 180 = 60c_1 \Rightarrow c_1 = -3 \text{ A} \]
\[ c_2 = 3 \text{ A} \]

\[ P_{\text{lor}} = R^2 \Rightarrow (-3)^2 (6) = 90 \text{ W} \]
\[ P_{\text{loc}} = R^2 (6) = 486 \text{ W} \]

\[ P_{\text{rev}} = -IV = -(-3)(12) = 36 \text{ W} \]
\[ P_{\text{tin}} = -(6)(18) = -900 \text{ W} \]

\[ P_{\text{tot}} = P_{\text{diode}} + P_{\text{lor}} + P_{\text{loc}} + P_{\text{rev}} = 90 + 486 + 36 - 900 = 90 \text{ W} \]

\[ \therefore P_{\text{diode}} = P_{\text{gen}} \]

Example 2

\[ c_2 = c_1 + 3c_1 \Rightarrow c_2 = 7c_1 \]

\[ 5 - 5c_1 + 1 - 6c_2 = 0 \]
\[ 6 - 5c_1 - 6 \times 3c_1 = 0 \]
\[ c_1 = 25 \text{ mA} \]
\[ c_2 = 775 \text{ mA} \]
\[ c_3 \approx 30 \times c_1 = 750 \text{ mA} \]
\[ V_b = 6 \times 1.5 = 9.0 \, V \]

\[ V_{1.8k} = 1.3 \, V = 8 \, V - V_c \]

\[ V_c = 6.6 \, V \]

\[ V = V_b - V_c = 9.65 - 6.65 = -2 \, V \]

\[ P_{s4k} = (25 \, m)^2 \times (54 \, k) = 3.375 \times 10^{-5} \, W \]

\[ P_{k} = (750 \, m)^2 \times (18 \, k) = 3.6375 \, mW \]

\[ P_{1.8k} = (750 \, m)^2 \times (1.8 \, k) = 1.5125 \, mW \]

\[ P_{25k} = 750 \, m \times 2 = 1500 \, mW \]

\[ P_{55} = 5 \times 25 \, m = 125 \, mW \]

\[ P_{15} = 1 \times 25 \, m = 25 \, mW \]

\[ P_{85} = 8 \times 750 \, m = 6000 \, mW \]

Total Power = \[ P_{s4k} + P_{k} + P_{1.8k} + P_{25k} \]

\[ = 6150 \, mW \]

Total Power = \[ P_{s4k} + P_{k} + P_{1.8k} + P_{25k} + P_{85} \]

\[ = 6150 \, mW \]

\[ P_{\text{Total}} = P_{\text{gen}} \]

\[ \text{HW Questions:} \]
\[ 2.5, 2.6, 2.7, 2.11, 2.14, 2.17, 2.19, 2.25, 2.29, 2.37 \]