**Circuit Representation**

![Circuit Diagram](image)

**Common Circuit Elements**

- **Branch:** single element, such as a resistor or source
- **Node:** connection point between two or more branches
- **Extraordinary Node:** connection point between at least 3 branches
- **Loop:** closed path in a circuit

![Circuit Diagram](image)
Terminology

Planar Circuits

Planar circuits: can be drawn in 2-D without branches crossing each other.
Whenever possible, re-draw circuit to simplify!

Charge & Current

Unit of charge = coulomb

\[ e = 1.6 \times 10^{-19} \text{ (C)} \]
Electron Drift

Response time = 0.2 microsecond
Actual travel time = 10 days!!

Current

Example 1-1: Charge Transfer

Given:
\[ i(t) = \begin{cases} 
0 & \text{for } t < 0, \\
6 - 2t & \text{for } t \geq 0.
\end{cases} \]

Determine: (a) \( q(t) \)
(b) \( \Delta Q(1,2) \)

Solution:
\[ dq = i \, dt \\
\int_{-\infty}^{t} dq = \int_{-\infty}^{t} i \, dt \\
q(t) - q(-\infty) = \int_{-\infty}^{t} i \, dt \\
q(t) = \int_{-\infty}^{t} i \, dt \]
Example 1-1: Charge Transfer (cont.)

(b) \[ q(t) = \int_0^t \frac{e^{-\alpha t}}{2} \, dt = \frac{e^{-\alpha t} - 1}{\alpha^2}, \]  
\[ \Rightarrow q(1) = \frac{e^{-\alpha} - 1}{\alpha^2}. \]

\[ \Delta Q(t_2) - \Delta Q(t_1) = \int_{t_1}^{t_2} e^{-\alpha t} \, dt = \frac{e^{-\alpha t_2} - e^{-\alpha t_1}}{\alpha}. \]

For \( t_1 = 1 \) and \( t_2 = 2 \), and \( e^{-\alpha} = 0.2 \),

\[ \Delta Q(2) = \int_0^2 \frac{0.2 \, dt}{e^{-\alpha}} - \frac{e^{-2\alpha} - 1}{\alpha^2} = 0.45 \, C. \]

Voltage & Power

Any material

\[ V_{ab} = \frac{dw}{dq}, \]

The voltage between location \( a \) and location \( b \) is the ratio of \( dw \) to \( dq \), where \( dw \) is the energy in joules (J) required to move (positive) charge \( dq \) from \( b \) to \( a \) (or negative charge from \( a \) to \( b \)).

Reference/Ground

- Choose reference point for potential
- Assign potential at reference = 0, called \textit{ground}
- Now all potentials are relative to ground terminal
Measuring Voltage & Current

- **Voltmeter**: measures voltage without drawing current
- **Ammeter**: measures current without dropping voltage

Open Circuit & Short Circuit

- **Open circuit**: no path for current flow \( (R = \infty) \)
- **Short circuit**: no voltage drop \( (R = 0) \)

Power

Rate of expending or absorbing energy

\[
P = \frac{dv}{dt} = \frac{dw}{dq} = \frac{dq}{dt} = \frac{dV}{dt}
\]

Units: watts
One watt is power rate of one joule of work per second. \( 1 \text{ W} = 1 \text{ A} \times 1 \text{ V} \)
Passive Sign Convention

Passive Sign Convention

\[ p > 0 \quad \text{power delivered to device} \]

\[ p < 0 \quad \text{power supplied by device} \]

*Note that current is defined as arriving at (+) side of \( p \).

Example 1-4: Energy Consumption

- **Given:** Resistor consuming 20 W before switch turned off at \( t = 0 \).
  
  Also
  
  \[ v(t) = 100e^{-2t} \quad \text{V} \quad \text{for} \ t > 0 \]

- **Determine:** Total energy consumed by resistor after \( t = 0 \).

- **Solution:**
  
  \[ i(t) = \frac{20}{100} = 0.2 \quad \text{A} \quad \text{for} \ t \geq 0. \]

  The instantaneous power is
  
  \[ p(t) = v(t) \cdot i(t) = \left(100e^{-2t}\right) \cdot 0.2 = 20e^{-2t} \quad \text{W}. \]

  \[ W = \int_{0}^{\infty} p(t) \, dt = \frac{20}{2} \left(1-e^{-2t}\right) \bigg|_{0}^{\infty} = 5 \quad \text{J}. \]

Circuit Elements: Independent Sources

- **Independent Sources**
  
  - Ideal Voltage Source
    
    \[ V_{o} \]
  
  - Ideal Current Source
    
    \[ I_{o} \]
  
  - Any Source

  \[ V(t) = \text{Any source} \]

  \[ I(t) = \text{Any source} \]
Circuit Elements: Dependent Sources

I-V for Sources

- Current/voltage fixed for independent sources
- What does a non-ideal source look like?
- Dependent sources vary with reference voltage/current
- What are units for slope?

Equivalent Circuit Using Dependent Source
Example 1-5: Dependent Source

Given:

- Source is CCVS

Determine: \( V_1 \)  
Solution: \( I_1 = \frac{10}{2} = 5 \text{ A} \)

Consequently:

\( V_1 = 4I_1 = 4 \times 5 = 20 \text{ V} \).

Switches

- Diagrams of various switch configurations.

Summary

Chapter 1 Relationships

- General
  - Direction of \( i \) is into boundary of device
  - Power
    - \( P = \text{device shunts power} \)
    - \( P = \text{device delivers power} \)

- Relationships
  - Resistance: \( R = \frac{V}{I} \)
  - Capacitance: \( C = \frac{Q}{V} \)
  - Inductance: \( L = \frac{V}{I} \)