Main Template

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Contents

1 Basic Concepts

1.1 Charge and Current

Charge **1.1**

Charge (Q) is an electrical property of the atomic particles of which matter consists, measures in coulombs (C).

Throughout this course, it is generally the charge of an electron (e) that will be considered.

$$e = -1.602 \cdot 10^{-19}\ C$$

Thus, if there is some known quantity of electrons n, the total charge of those electrons can be calculated:

$$Q = n \cdot e$$

Current relates closely with charge, being a measurement of the movement of charge (or electrons).

Current **1.2**

Electric current (I) is the rate of change of charge, measured in amperes (A).

Since current is a rate of change (over time) of charge, current and charge relate as each other's (anti)derivative.

$$I(t) = \frac{dQ}{dt}\ A \qquad\qquad Q(t) = \int I(t)\,dt\ C$$

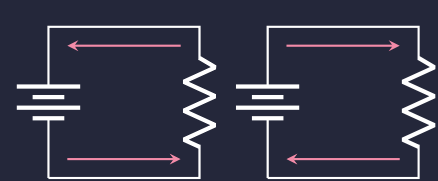
1.2 Direct vs. Alternating Current

1.2.1 Direct Current

Direct Current **1.3**

A direct current (dc) flows only in one direction and can be constant or time varying.

There are two ways of describing the *direction* in which the electrons flow in a direct current: **conventional flow** and **electron flow**. Both are shown in Figure 1.



(a) Conventional (b) Electron

Figure 1: Electron Flow in Direct Currents

1.2.2 Alternating Current

Direct current flow isn't the only way current can flow. Some currents utilize **Alternating Current (AC)**.

Alternating Current **1.4**

An alternating current (ac) is a current that changes direction with respect to time.

1.3 Voltage

Voltage **1.5**

Voltage (or *potential difference*) is the *energy required* to move a unit charge from a reference point (-) to another point (+), measured in Volts (V).

The potential different that voltage measures is a literal different in potential between two points in a circuit. As seen in Figure 2, the voltage from a to b is different than the voltage from b to a.

Figure 2: Potential Difference

The energy required to move an object is expressed in Joules (J), and remains consistent with measurements of energy to move regular objects like a elevator up a shaft. Since voltage is the energy per unit charge, it can be expressed as:

$$v(t) = v_b - v_b = \frac{dw}{dQ} = \frac{dE}{dQ}$$

Where w is work and E is energy.

1.4 Power and Energy

Power **1.6**

Power (P) is the rate of change of energy measured in watts (W).

Previously, it's been seen that current is the rate of change of charge (1.1), and voltage is the amount of energy required to move charge (1.3). Putting these two ideas together, it follows that power can be expressed as the product of current and voltage:

$$P = I \cdot V$$

Power is the rate of change of charge multiplied by the amount of energy required to move some charge. Another way of expressing this in terms of calculus is:

$$P(t) = \frac{dE}{dt} = \frac{dE \cdot dQ}{dt \cdot dQ} = \frac{dE}{dQ} \cdot \frac{dQ}{dt}$$

Where

$$V(t) = \frac{dE}{dQ} \qquad \text{and} \qquad I(t) = \frac{dQ}{dt}$$

Energy **1.7**

Energy is the capacity to do work measured in Joules (J).

$$E(t) = \int P(t)\,dt$$

Currents follow the **Law of Conservation of Energy**. This means that the total change in energy within a closed circuit must sum to zero:

$$\sum P = 0$$

Thus, the total power supplied to a circuit must be equal to the total power absorbed by that circuit.

The difference between supplying and absorbing energy is a matter of convention and does not matter given that it remains consistent throughout the full analysis of a circuit. Generally, the **passive sign convention** is used.

Passive Sign Convention **1.8**

Passive sign convention is satisfied when the current enterts through the positive terminal of an element and $P = +V \cdot I$. If the current enters through the negative terminal, $P = -V \cdot I$.

1.5 Categorization of Components

1.5.1 Passive and Active Components

Rather than trying to understand full circuits at once, it is easier to break them into two groups: **passive** components and **active** components.

Passive Components **1.9**

Passive components are ones that don't require any power supply to operate. For example, a resistor or a capacitor are both passive components.

Active Circuits **1.10**

Active components require power to operate. In other words, they need to be connected to a power supply to function. Logic gates (74LSXX) are active since they require a power supply.

1.5.2 Linear vs. Non-Linear Components

Another way to divide components is between **linear** and **non-linear**.

Linear Components **1.11**

Linear components are... They also can be subdivided into components that store energy (capacitors and inductors) and components that dissipate energy (resistors).

Non-Linear Components **1.12**

...

1.6 Circuit Elements

Ideal Independent Source **1.13**

An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit elements.

Ideal Dependent Source **1.14**

Also called an *Ideal Controlled Source*, this is an active element in which the source quantity is controlled by another voltage or current.

There are four types of dependent sources:

1. Voltage Controlled Voltage Source (VCVS)
2. Voltage Controlled Current Source (VCCS)
3. Current Controlled Voltage Source (CCVS)
4. Current Controlled Current Source (CCCS)

1.7 Basic Laws

1.7.1 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.

Ohm's Law

$$R = \rho \cdot \frac{l}{A} \tag{1.1}$$

When there is current flowing through a wire with resistance approaching zero, a **short circuit** is created. Conversely, an **open circuit** is where the resistance in a circuit approaches infinity.

Resistance and conductance are inversely related. It is the ability of an element of conduct electric current; it is measured in mhos or siemens (S).

1.7.2 Nodes, Branches, and Loops

Branch **1.15**

Represents a single element in a circuit such as a resistor or power supply.

Node **1.16**

The point of connection between two or more branches.

Loop **1.17**

A loop is any *closed* path in a circuit. Generally, loops are defined as the smallest possible path.

By analyzing the nodes connection branches of a circuit, elements can be found to be in parallel or in series.

Parallel **1.18**

Elements are in parallel if they share two nodes.

Series **1.19**

Elements are in series if they *exclusively* share a node.

It is possible for elements to be neither in series or in parallel. These situations aren't problematic, but require somewhat different techniques to analyze.

1.7.3 Kirchhoff's Laws

Kirchhoff's Current Law **1.20**

Kirchhoff's Current Law (KCL) states that the algebraic sum of currents entering a node (or a closed boundary) is zero:

$$\sum_{n=1}^{N_{branch}} i_n = 0$$

Kirchhoff's Voltage Law **1.21**

Kirchhoff's Voltage Law (KVL) states that the algebraic sum of all voltages around a closed path is zero:

$$\sum_{m=1}^{M_{branch}} v_m = 0$$