C Team - Circuits

Ray Liu

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1 Components of a Circuit

1.1 Battery

Chemical processes in a **battery** deliver charge around a circuit. In other words, it allows **current** to flow in a circuit by providing a potential difference (roller coaster analogy). Current is the rate of charge flow. Mathematically, it can be expressed as

$$I = \frac{\Delta Q}{\Delta t} \tag{1}$$

The SI unit for current is an amp (A), which is equivalent to a Coulomb/second (C/s).

1.2 Resistor

A **resistor** inhibits current flow in a circuit. **Resistance** is defined by

$$R = \frac{V}{I} \tag{2}$$

The SI unit for resistance is an ohm (Ω), which is equivalent to a volt/amp (V/A).

Rearranging, we can obtain Ohm's Law:

$$V = IR \tag{3}$$

1.3 Capacitor

A **capacitor** is a circuit component that *stores charge*. It structurally consists of 2 conductors (one positively charged, one negatively charged) separated by an insulator. **Capacitance** is a capacitor's "capacity", or ability, to store charge. It is given mathematically as

$$C = \frac{Q}{V} \tag{4}$$

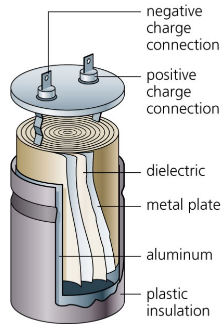
The SI unit for capacitance is a farad (F), which is equivalent to a coulomb/volt (C/V).

In a capacitor, an electric field is created from the positive and negatively charged plates. Thus, a capacitor also has a potential difference (voltage).

Recall from our last lecture that the capacitance of a parallel plate capacitor is

$$C = \frac{\epsilon_0 A}{d}, \tag{5}$$

where A is the area of each parallel plate, and d is the separation between the plates.



The amount of energy in any capacitor is

$$U = \frac{1}{2}QV = \frac{1}{2}CV^2 \tag{6}$$

2 Kirchhoff's Rules

There are two rules (called Kirchhoff's Rules) that govern the behavior of all circuits.

1. Loop rule: The sum of the voltages around a circuit is 0 (since electrostatic force is conservative).
2. Junction rule: The total current flowing into a junction equals the total current flowing out of a junction.

3 Equivalence Resistance

An **equivalent resistor** models multiple resistors in a circuit as a single resistor. This can often by used to simplify problems. You should already be familiar with what series and parallel circuits are from your exciting Design and Technology class. The equivalence resistance in a series circuit is

$$R_{eq} = R_1 + R_2 + ... \tag{7}$$

The equivalence resistance in a parallel circuit is

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + ... \tag{8}$$

These can be derived using Kirchhoff's rules.

4 Equivalence Capacitance

The same concepts can be applied to capacitance. However, the equivalence capacitance of series and parallel circuits are the exact opposite of that of resistors. For a series circuit,

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + ... \tag{9}$$

For a parallel circuit,

$$C_{eq} = C_1 + C_2 + ... \tag{10}$$

5 A Real World Application: Cameras

A real world application that demonstrates the importance of batteries, resistors, and capacitors is in the flash of a camera. The flash of a camera is actually a discharge of a capacitor after it has been charged over time. If there was no capacitor, a battery of very high voltage would be required to supply to power needed for a camera flash. Resistors also play their role in a camera flash by regulating the current flow so that the flash occurs at the same time as the picture is taken.