CAPACITOR & CAPACITANCE - PHYSICS

Physics

A capacitor consists of two conductive electrodes, or plates, separated by a dielectric.

Capacitance

The capacitor's capacitance (*C*) is a measure of the amount of charge (*Q*) stored on each plate for a given potential difference or *voltage* (*V*) which appears between the plates:

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

In SI units, a capacitor has a capacitance of one farad when one coulomb of charge is stored due to one volt applied potential difference across the plates. Since the farad is a very large unit, values of capacitors are usually expressed in microfarads (μF), nanofarads (nF), or picofarads (pF).

When there is a difference in electric charge between the plates, an electric field is created in the region between the plates that is proportional to the amount of charge that has been moved from one plate to the other. This electric field creates a potential difference $V = E \cdot d$ between the plates of this simple parallel-plate capacitor.

The **capacitance** is proportional to the surface area of the conducting plate and inversely proportional to the distance between the plates. It is also proportional to the permittivity of the dielectric (that is, non-conducting) substance that separates the plates.

The capacitance of a parallel-plate capacitor is given by:

$$C \approx \frac{\varepsilon A}{d}; A \gg d^2$$

where ε is the permittivity of the dielectric, *A* is the area of the plates and *d* is the spacing between them.

In the diagram, the rotated molecules create an opposing electric field that partially cancels the field created by the plates, a process called dielectric polarization.

Stored energy

As opposite charges accumulate on the plates of a capacitor due to the separation of charge, a voltage develops across the capacitor due to the electric field of these charges. Ever-increasing work must be done against this ever-increasing electric field as more charge is separated. The energy (measured in joules, in SI) stored in a capacitor is equal to the amount of work required to establish the voltage across the capacitor, and therefore the electric field.

The energy stored is given by:

$$E_{\mathrm{stored}} = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}VQ$$

Where V is the voltage across the capacitor.

The maximum energy that can be (safely) stored in a particular capacitor is limited by the maximum electric field that the dielectric can withstand before it breaks down. Therefore, all capacitors made with the same dielectric have about the same maximum energy density (joules of energy per cubic meter).

Hydraulic model

As electrical circuitry can be modeled by fluid flow, a capacitor can be modeled as a chamber with a flexible diaphragm separating the input from the output. As can be determined intuitively as well as mathematically, this provides the correct characteristics:

- The pressure difference (voltage difference) across the unit is proportional to the integral of the flow (current)
- A steady state current cannot pass through it because the pressure will build up across the diaphragm until it equally opposes the source pressure.
- But a transient pulse or alternating current can be transmitted
- The capacitance of units connected in parallel is equivalent to the sum of their individual capacitances

Source: http://www.juliantrubin.com/encyclopedia/electronics/capacitor.html