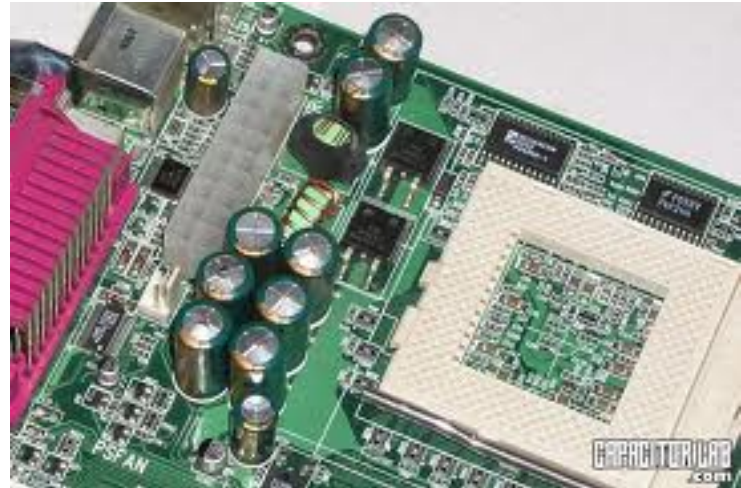


Capacitors

David Frazier and John Ingram

Introduction

- Used in most electronic devices
- Comes in a variety of sizes



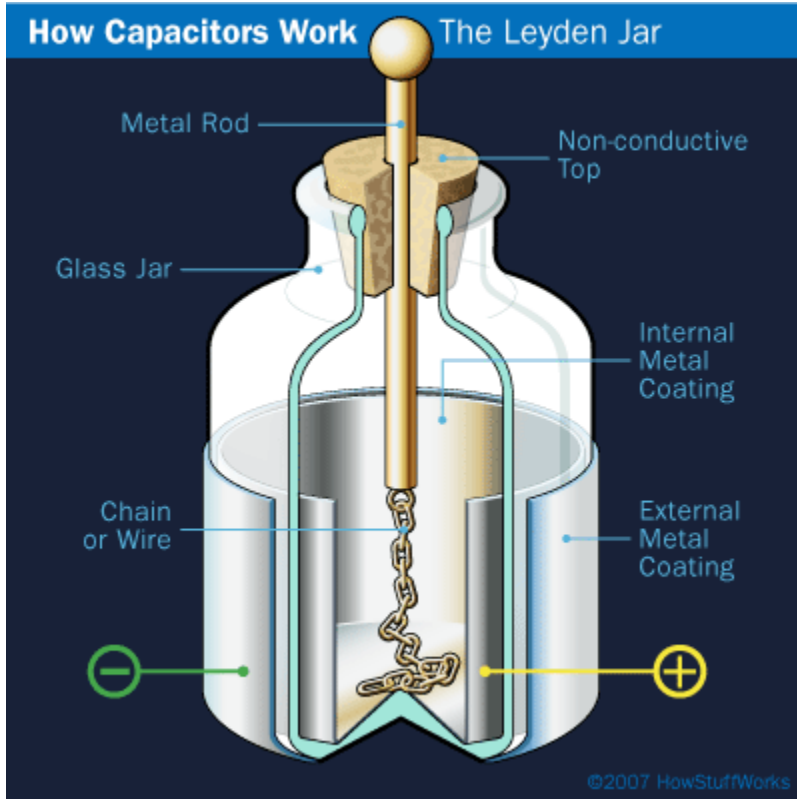
Basic Function

The basic function of a capacitor is to store energy.

Common usage include local energy storage, voltage spike protection, and complex signal filtering.



History



Records indicate that German Scientist Ewald Georg von Kleist invented the capacitor in 1745.

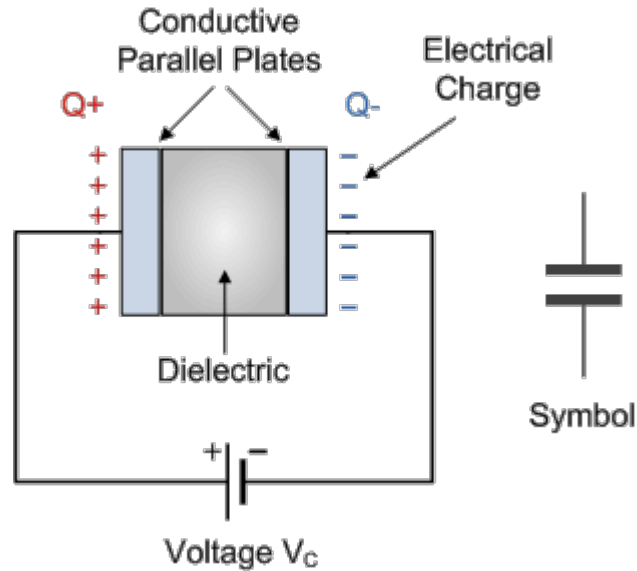
In the case of the Leyden Jar, the glass of the bottle was the dielectric material.

Benjamin Franklin

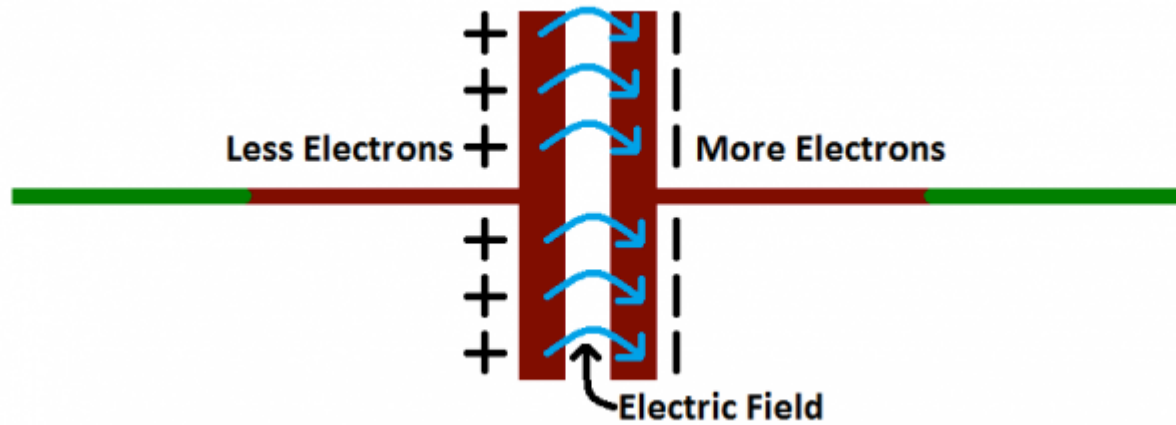


- Used Leyden jars to create a “battery”
- Used in the famous Kite Experiment
- First electrochemical battery did not appear until 1800

How they work



- Two parallel metallic plates separated by a dielectric material
- Dielectric material is non-conductive
- Positive and Negative Charges collect on separate plates



- Electrons get stuck on one plate. That plate develops a negative charge. Positive charges get pushed to the other plate.
- Two plates are attracted to each other, but the dielectric material keeps them forever apart.
- This creates an Electric Field, and the capacitor is storing the charge.

Water Analogy

- If you had a hose that needed to maintain a certain pressure, you could store water in tanks along the way
- If the pressure dropped, you could maintain the pressure by adding water from the tanks
- Water tanks are functioning like capacitors

Capacitance

- the measure of a Capacitor's ability to store an electrical charge
- Measured in Farads
- Capacitance is one Farad when one Coulomb is stored on the plates by one Volt

Calculating Capacitance

$$C = \epsilon_r \frac{A}{4\pi d}$$

ϵ_r - the **relative permittivity** of the dielectric material

A - The area the plates overlap

d - The distance between the plates

Charge Stored on Each Plate

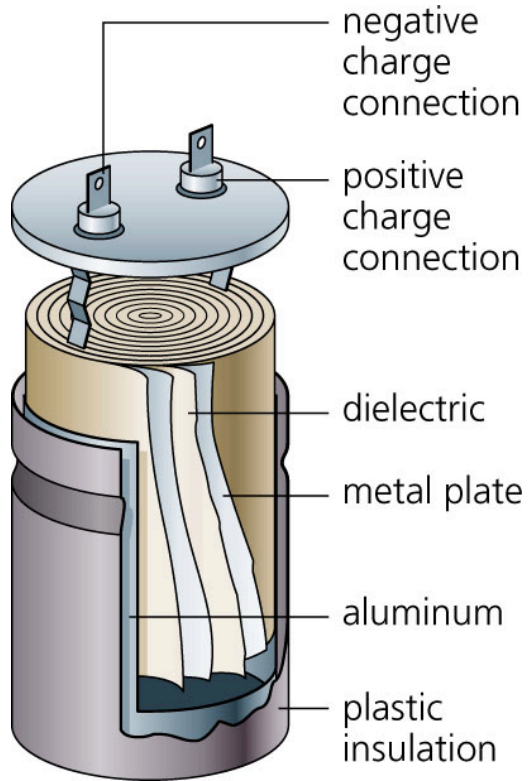
$$Q = CV$$

Q - Charge stored on each plate

C - Capacitance

V - applied voltage

Inside a typical Capacitor



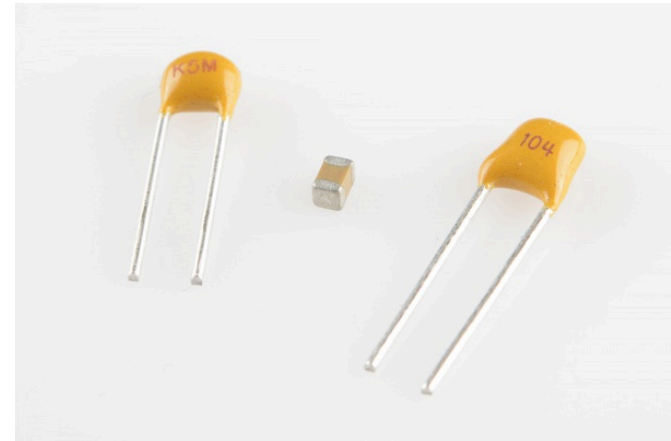
Types of Capacitors

There are all sorts of capacitor types. When deciding which to use, there are several factors to consider:

- Size
- Maximum voltage
- Leakage current
- Equivalent series resistance (ESR)
- Tolerance

Ceramic Capacitors

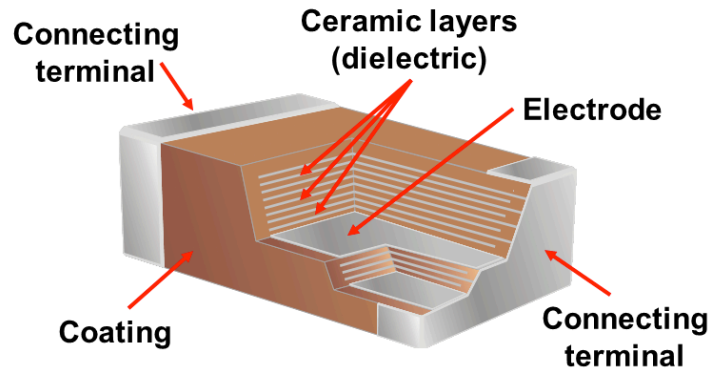
- The most commonly used and produced capacitor
- The name comes from the material from which their dielectric is made.
- Small size both physically and capacitance-wise.
- Don't normally go up to $10\mu\text{F}$ even.
- Has lower ESR and leakage currents than electrolytic caps. Cheapest type.



Two Types of Ceramic Capacitors

Class 1: High stability and low losses. Compensates for the influence of temperature in resonant circuit applications.

Class 2: Has high volumetric efficiency for buffer, by-pass and coupling applications.

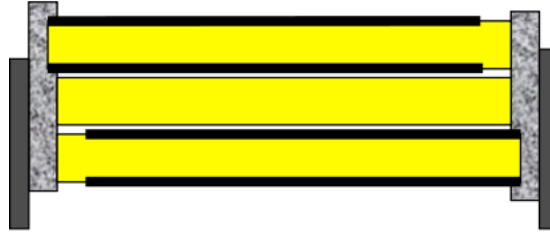


Film Capacitors

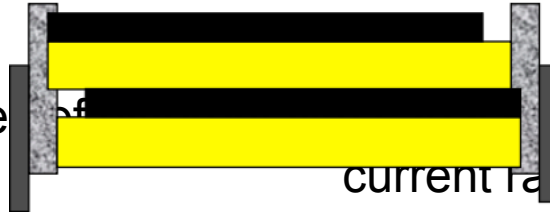
- Plastic film capacitors - non polarized capacitors with an insulating plastic film as a dielectric.
- The dielectric films are drawn to a thin layer and are not destroyed by breakdowns or shorts between electrodes.
- The direct contact gives the films the advantage of having very short current paths.
- Has low leakage. Suitable for applications with high surge currents.



Plastic film,
Single-sided metallized
Standard pulse strength



Plastic film,
Double-sided metallized
High pulse strength



Film/foil construction
Very high pulse strength

Three examples of increasing surge
current ratings.

Aluminum Electrolytic Capacitors

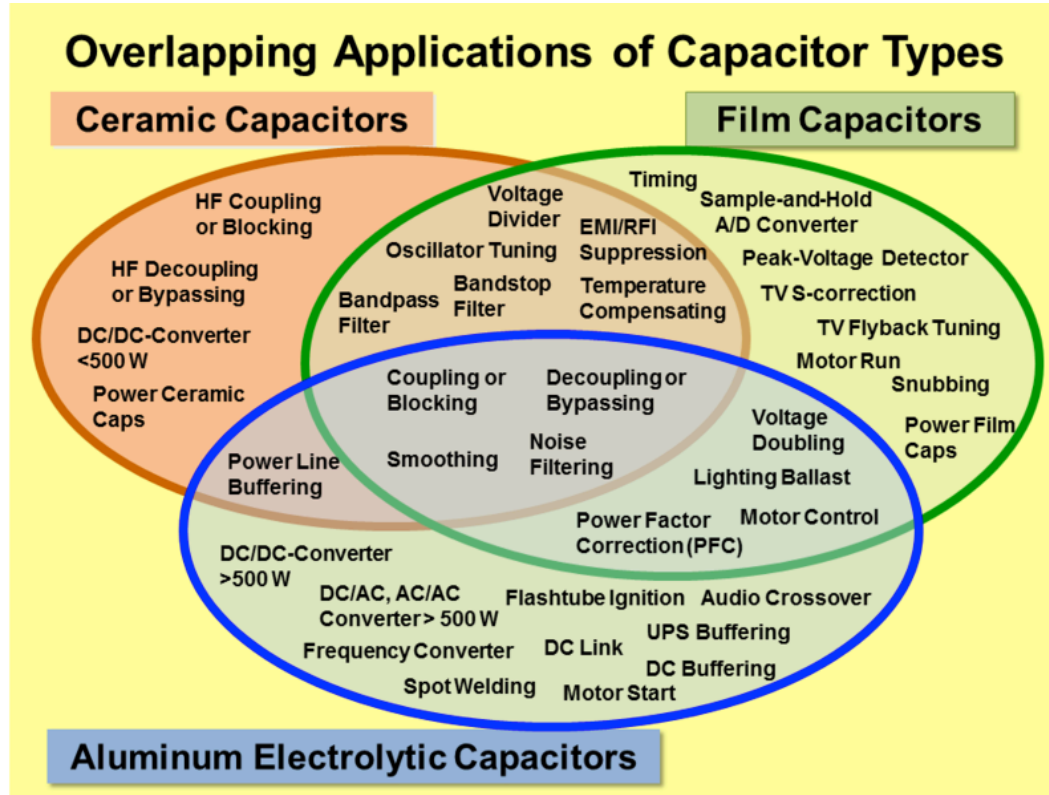
- Have a LOT of capacitance in a relatively small volume.
- Common for ranges between $1\mu\text{F}$ and 1mF .
- Has high maximum voltage ratings.
- Really well suited for high-voltage applications.
- We used the aluminum electrolytic capacitors in our breadboarding.



Electrolytic Capacitors Continued

- Electrolytic caps are usually polarized. and have two pins, a positive one called an anode, and a negative one called a cathode.
- Notorious for leakage. They allow small amounts of current to run through the dielectric from one terminal to the other.
- Makes electrolytic caps less-than-ideal for energy storage.

Capacitor Applications

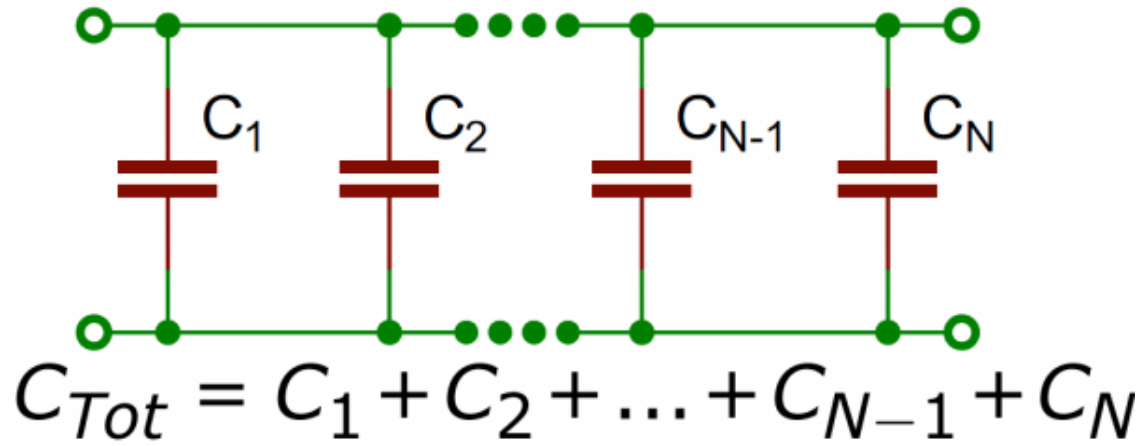


Capacitors in Parallel

Much like resistors, you can put multiple capacitors together and create a combined capacitance.

Capacitors, however, add together in a way that's completely the opposite of resistors.

When you put capacitors in parallel, the total capacitance is the sum of the capacitance of the different capacitors.



Capacitors in Series

Parallel is clunky and hard to do. Put them in a series.



$$\frac{1}{C_{Tot}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_{N-1}} + \frac{1}{C_N}$$

$$C_{Tot} = \frac{C_1 C_2}{C_1 + C_2}$$

You can use “product-over-sum” for two capacitors.



Sources

Bugg, D.V. Electronics Circuits, Amplifiers and Gates, Second Edition
Taylor & Francis 2006

<https://learn.sparkfun.com/tutorials/capacitors>

http://www.electronics-tutorials.ws/capacitor/cap_1.html

<http://electronics.howstuffworks.com/capacitor3.htm>