Capacitors

Introduction

Capacitors appear in many areas of science and technology and have a variety of uses. In GCSE Electronics capacitors are used with resistors to make timing circuits. They are also used in power supplies in smoothing circuits. In A level Electronics capacitors are used to make frequency dependent circuits such as audio tone controls. In A level physics their structure and relationship to electric fields is considered.

Capacitors are passive components - they don't need a power supply to operate. Their function is to store electrical charge (and hence energy) and they can store and release this charge over a period of time. Usually in electronics everything happens (almost) instantly and so it is useful to find a component that functions over an extended period of time - capacitors enable us to make timing circuits and oscillators.

Caution must be exercised when handling large value capacitors as they can store a lethal charge, even when disconnected from the supply voltage.

Capacitance

The capacitance (C) of a capacitor (a measure of how much charge it can store) is measured in Farads (F). A Farad is a very BIG capacitance indeed and so we usually use capacitors that have a smaller value. The standard abbreviations are:

- millifarad (mF) = 10^{-3} F
- microfarad (μF) = 10^{-6} F
- nanofarad (nF) = 10^{-9} F
- picofarad (pF) = 10^{-12} F

Therefore

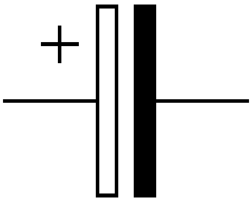
- 1 mF = 1000 μF = 1000,000 nF = 1000,000,000 pF
- 1 μF = 1000 nF = 1000,000 pF
- 1 nF = 1000 pF

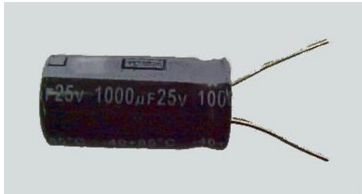
It is important to be able to convert between these different units

Working Voltage

Capacitors have another specification called the working voltage. The working voltage is the maximum voltage that can be applied to a capacitor. If the maximum working voltage is exceeded then the insulation inside the capacitor is damaged and it may conduct causing the capacitor to heat up with undesirable consequences. Electrolytic capacitors are particularly prone to failing spectacularly when used at too high a voltage. In short, capacitors that exceed their safe working voltage tend to blow up. You have been warned.

Types of Capacitor - Electrolytic



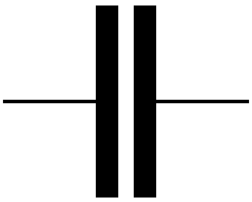


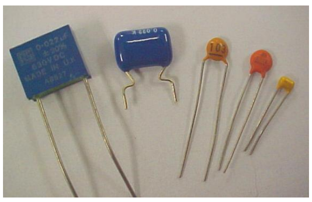
Electrolytic capacitors have the following properties:

- Large capacitance, usually > 1 μF
- Low safe working voltages, typically 25 V
- Construction is a fairly large metal canister
- MUST be connected the right way round

IMPORTANT: Electrolytic capacitors have a white stripe down one side which indicates the negative side/connection. Electrolytic capacitors usually have the capacitance and safe working voltage printed on them.

Types of Capacitor - Non Electrolytic





Non-Electrolytic capacitors have the following properties:

- Small capacitances, usually < 1 μF
- High safe working voltages, typically 63 V or > 100 V
- Construction is a small ceramic blob
- Can be connected either way round

Non-Electrolytic capacitors usually have the capacitance and safe working voltage printed on them in number code as shown below.

Reading Capacitor Values

High capacity capacitors are usually big enough to have their value written on them (usually in μF). The working voltage is also shown on the capacitor.

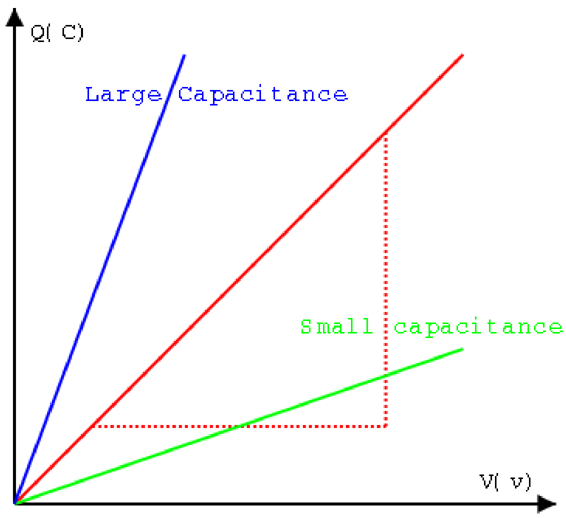
Smaller value capacitors also tend to be physically small and so a code is used to identify their value. The code is a three digit code that gives the value in pF. The first two digits give the value, the last digit gives the number of zero's

E.g:

- 102 = 1 0 00 pF = 1 nF
- 473 = 4 7 000 pF = 47 nF
- 331 = 3 3 0 pF = 0.33 nF
- 104 = 1 0 0000 pF = 100 nF = 0.1 μF

Storing Charge

Capacitors store charge in the same way that a bucket stores water. A voltage is needed to force the charge onto the plates of the capacitor. Therefore a charged capacitor must have a voltage across it and/or a capacitor with a voltage across it must be charged. The amount of charge stored depends on (a) the voltage used to "push the charge in" ... the greater the voltage, the greater the charge stored ... and (b) the "capacity" or size of the capacitor. The capacity is called the Capacitance and is a measure of how much charge can be stored per volt. To continue the analogy, the capacitance of a capacitor is like the width of the bucket whereas the voltage is like the depth to which the bucket is filled. If the bucket is very wide then even a shallow depth stores a large volume of water. In the same way, a large value capacitor stores a lot of charge at just a few volts.



Charge (Q) - measured in Coulombs (C)

Voltage (V) - forces charge to move into the capacitor

Capacitance (C) - a measure of how much charge a capacitor can store per volt

The relationship is:

$Q = C \times V$

If the charge stored on a capacitor is plotted as a function of voltage then we expect a linear relationship

Note: Don't get Capacitance (C) and the unit of charge - Coulombs (C) - mixed up!

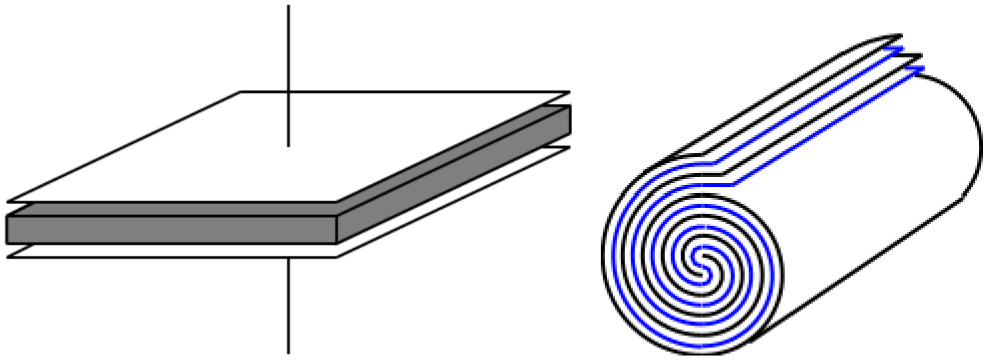
E.g. The charge stored on a 1000 μF capacitor charged to 12 V is:

$Q = C \times V = 1000 \times 10^{-6} \times 12 = 0.012$ C

If the charging current were 10 mA then this would take 1.2 seconds to charge fully

Structure of Capacitors

A capacitor is basically a pair of parallel plates separated by an insulator. The plates and insulator are usually rolled up like a swiss roll!



The capacitance depends upon three factors - the area of the plates (A), the separation of the plates (d) and the properties of the insulator represented by a constant epsilon (ε_r). The capacitance of a pair of parallel plates is given by:

$$C = \varepsilon_0 \varepsilon_r A / d$$

C - Capacitance (Farads)

ε_0 - Permittivity of free space = 8.85×10^{-12} Fm^{-1}

ε_r - Relative permittivity of insulator (no units)

A - Area of plates (m^2)

d - Plate separation (m)

Website

https://www.electronicsteaching.com/Electronics_Resources/DocumentIndex.html