CaYPT
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CERAMIC VS ELECTROLYTIC VS MYLAR CAPACITORS

Author: William Deng

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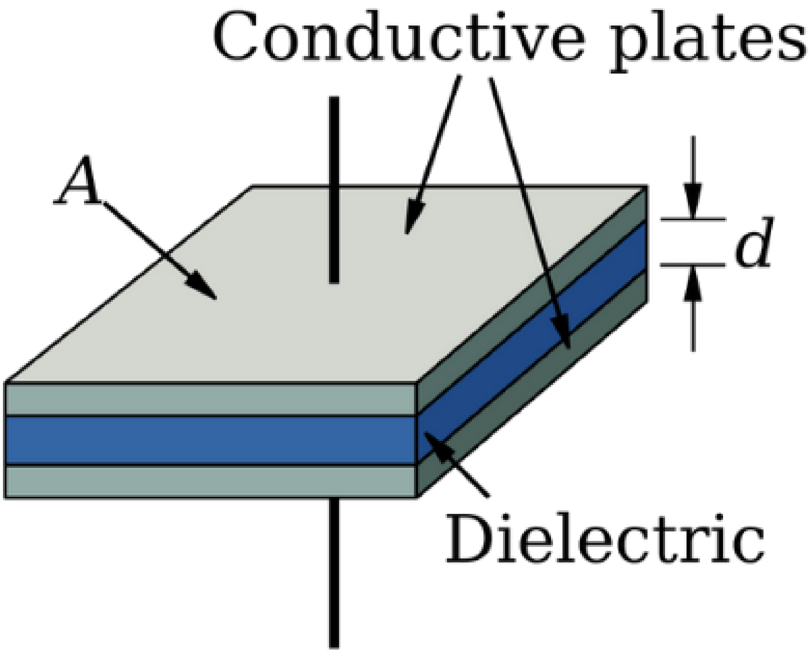
Abstract

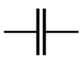
In this SOP, the principle of operation of ceramic capacitors, electrolytic capacitors, and mylar capacitors is documented. The ceramic capacitors, electrolytic capacitors, and mylar capacitors available in the lab are listed.

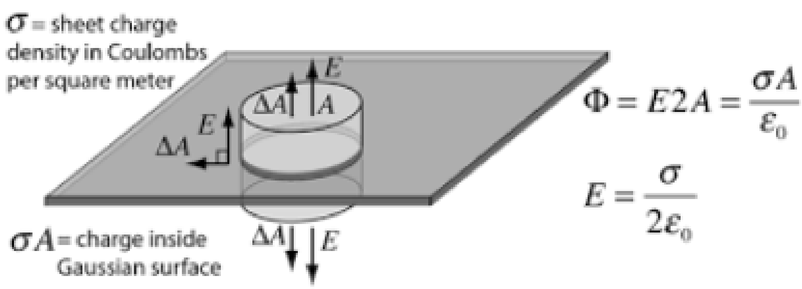
Contents

1 Ceramic, Electrolytic, Mylar Capacitors Principle of Operation

In general, capacitors may be conceptualized as two plates of metal parallel to each other with an insulating dielectric in between the plates.



 Schematic symbol for ceramic and mylar capacitors. When a potential difference is applied between the two plates (from an external battery for instance), an electric current is induced in the circuit in the sense that the plate at a higher potential will become positively charged whereas the plate at a lower potential will become negatively charged. This accumulation of charge on the two plates induces an electric field that is approximately uniform from the positively charged plate to the negatively charged plate. [1] By constructing a Gaussian pillbox, it can be shown using Maxwell's equations that the uniform electric field of an infinite uniformly charged plate is given by:



So for two uniformly and oppositely charged plates (a.k.a. a capacitor), each plate generates an electric field, and the two fields superimpose constructively to give the *net* electric field between the plates:

$$E = \frac{\sigma}{\epsilon_0}$$

Therefore, multiplying both sides of the above equation by the separation distance d between the plates, noting that the voltage across the capacitor is just $V = Ed$, and expanding the surface charge density σ as $\sigma = \frac{Q}{A}$ (where Q is the charge on the plates and A is each plate's area) leads to the expression:

$$\frac{Q}{V} = \epsilon_0 \frac{A}{d} \equiv C$$

where C is the *capacitance* of the capacitor, an extrinsic property of any capacitor that is only a function of geometric parameters. Strictly speaking however, this expression for the capacitance is only valid when one assumes that the dielectric between the plates is vacuum. If instead the dielectric has a relative permittivity $\epsilon_r > 1$, the above expression for the capacitance C reads:

$$C = \epsilon_r \epsilon_0 \frac{A}{d}$$

So it is clear that by using a more polarizing dielectric (i.e. increasing ϵ_r), one can increase a capacitor's capacitance. Since the *electric current* I that flows "through" a capacitor is *defined* by:

$$I = Q$$

This leads to the standard IV-equation for a capacitor:

$$I = CV$$

The *power* P developed by a capacitor may be computed as:

$$P = VI = CV^2$$

Using integration by parts, the time integral of the capacitor's power P yields the energy E stored in its electric field:

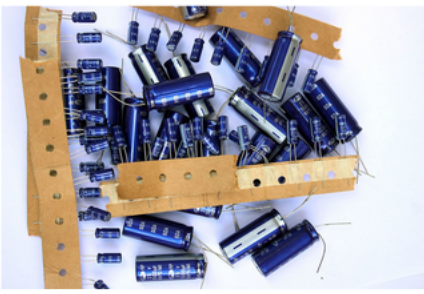
$$E = \int P dt = C \int V^2 dt = \frac{1}{2} C V^2$$

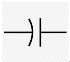
Thus far, we have reviewed the basic principles of operation for arbitrary capacitors. Now we focus on each of the specific types of capacitors.

Ceramic capacitors are essentially several alternating layers of metal and ceramic sandwiched together, where in this case the ceramic that the capacitor is made of *is* the dielectric. This is physically similar to multiple capacitors connected in series, so a ceramic capacitor's capacitance can be calculated by taking the capacitance associated with each layer and multiplying by the number of layers present.[2]

Ceramic capacitors are often divided by application into 2 classes, namely *class 1 ceramic capacitors* and *class 2 ceramic capacitors*. The former are more suited for high stability and resonant circuit applications, while the latter are more suited for buffer, bypass, and coupling applications.

Electrolytic capacitors are polarized capacitors in the sense that when you use them in circuits, you must ensure that their *anode* (positively charged plate) is operating at a higher voltage than their *cathode* (negatively charged plate) **at all times**. Otherwise, they will literally smoke and blow up! Operating an electrolytic capacitor past its rated voltage is also a bad idea. [3]The cathode of an electrolytic capacitor will be labeled on the capacitor itself, as in the image below:



 Schematic for an electrolytic capacitor (the curved plate represents the negatively-charged cathode whereas the flat plate represents the positively-charged anode).
Electrolytic capacitors are really just one metal plate (usually aluminum) submerged in an electrolyte (hence the name). The metal plate represents the anode, where redox reactions occur with the electrolyte. This forms a thin insulating oxide layer that acts as the "dielectric" in this context. The "other plate" (or the negatively-charged cathode) is then the remaining electrolyte itself. Due to the incredible thinness of the oxide layer, we see that electrolytic capacitors are able to achieve relatively large capacitances. As a result, they are good for passing or bypassing low-frequency signals and for storing large amounts of energy. They can also be used to decouple or to filter noise in power supplies.
Finally, *mylar capacitors* (also referred to as *polyester capacitors*) are similar to ceramic capacitors but where the dielectric is made out of polyester (specifically polyethylene terephthalate or PET) instead of ceramic. Due to the properties of polyester, mylar capacitors are able to withstand higher voltages and higher temperatures without malfunctioning. They are ideal for high-frequency filtering applications due to their low equivalent resistances, and they are also able to withstand sharp voltage and current spikes. [4]

2 Ceramic, Electrolytic, and Mylar Capacitors at the Lab

2.1 Ceramic capacitors at the lab

- 2.2 nF
- 4.7 nF
- 10 nF
- 22 nF
- 47 nF
- 100 nF
- 10 pF
- 22 pF

- 47 pF
- 100 pF
- 220 pF
- 470 pF

2.2 Electrolytic capacitors at the lab

- 1 µF, 50 *v* (the second number is the voltage rating of the electrolytic capacitor)
- 3.3 µF, 100 *v*
- 4.7 µF, 50 *v*
- 10 µF, 50 *v*
- 22 µF, 50 *v*
- 47 µF, 35 *v*
- 100 µF, 35 *v*
- 470 µF, 35 *v*
- 1000 µF, 25 *v*

2.3 Mylar capacitors at the lab

- 0.022 µF
- 0.01 µF
- 0.1 µF
- 0.22 µF

REFERENCES

[1] Capacitor. https://en.wikipedia.org/wiki/Capacitor.

[2] Ceramic capacitor. https://en.wikipedia.org/wiki/Ceramic_capacitor.

[3] Electrolytic capacitor. https://en.wikipedia.org/wiki/Electrolytic_capacitor.

[4] Mylar capacitor. https://components101.com/capacitors/mylar-capacitor#:~:text=What%20is%20a%20Mylar%20capacitor,also%20called%20as%20polyester%20capacitor.