Capacitor Tutorial

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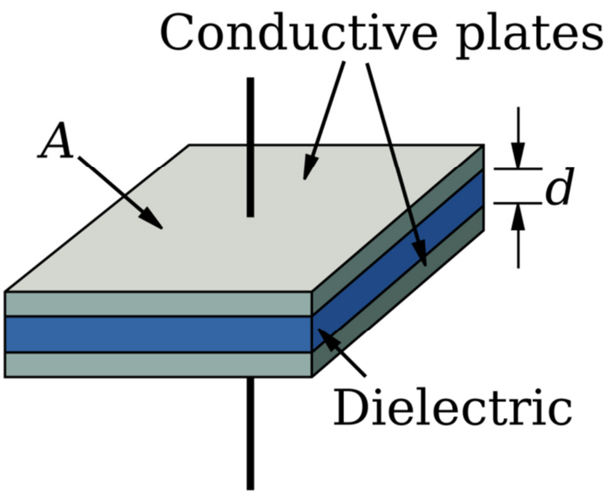
What is a Capacitor?

Capacitors are devices that can store a charge. Physically, a capacitor is made up of conductive plates separated by a dielectric material.



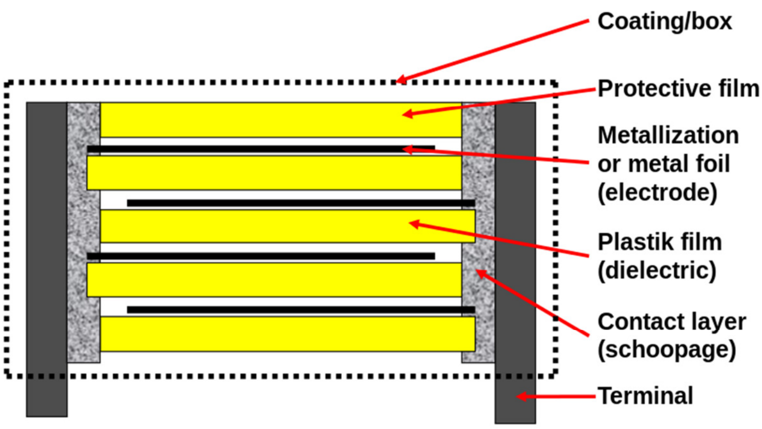
Capacitance = $\frac{kA}{d}$

Capacitance is calculated by the above formula, in which k is a constant, A area, and d the distance between plates.

Modern capacitors are made from a polypropylene film (dielectric), which is coated on one side with Aluminium (plate). This is called MPP (metalized polypropylene), and typically the film is 5-20microns thick, and the metal is approximately 0.5micron thick.

How to make a Capacitor

- Calculate the capacitance needed, and the plate area required
- Determine what strength of dielectric is needed
- Select the width of film to be used
- From the known area, calculate the length of the plates
- Roll the film/plates up into a cell
- Attach wires to the end of the cell



You can even build your own capacitor using Aluminium Foil and Paper or Clingfilm!

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Critical Factors in a Capacitor

There are six factors that are critical to the overall quality and reliability of the capacitor. These are:

- Quality of the film used
- Thickness of the dielectric
- Metal spray on the end of the cell (schoopage)
- How well contaminants were avoided in the production process
- Cell dimensions
- Capability to conduct heat

Film Quality

Traditionally, the majority of high quality film manufacturers are European, such as from Finland. There are a number of Asian manufacturers and whilst some are adequate, reports are varied. This is not to say there aren't good quality films to be found outside of Europe, nor are all films from Europe good quality! However, the capacitors with the best reputations are European. The capacitor's ability to withstand voltage differential is due to the quality and thickness of the polymer (polypropylene) at the molecular level, and if this gets modified in any way, the dielectric strength is affected. For example, if the film is 'deformed' by physical pressure, the dielectric strength reduces. Similarly, if the film gets too warm, its molecular structure changes and the dielectric strength reduces. Any quality issues that are evident in the raw polypropylene will be an issue in the capacitor – this could include mechanical stresses altering the molecular structure during manufacture, contaminants accidently built into the film, or other problems.

Thickness of the Dielectric

Capacitor manufacturers are under pressure all the time to make smaller and smaller capacitors. The only way to do this is use thinner and thinner films, which unfortunately reduces the voltage withstand of the capacitor. A smaller capacitor will likely be cheaper, but it will be less robust, and will fail sooner. There are many ways to specify a capacitor to 'hide' things such as very thin film, so care needs to be taken when reading comparisons, ensuring you have the actual data about the film thickness.

Metal Spray

The metal spray process looks simple, but it is rather complex. There are a number of parameters that control the process and if they are not 'spot-on', the capacitor will fail prematurely – usually from over-heating. What is even more perplexing is that it is very difficult for a manufacturer to test the quality of their metal spray. The only sure real measure of metal spray quality is the lifetime of the capacitor, years after installation.

Production Process Control

Assuming the film is good and the capacitor design is good, this can all be undone by a manufacturing process that builds contaminants into the cell, or builds moisture in, or mechanically stresses the film, thereby changing its breakdown specifications. A high quality, controlled manufacturing process is critical.

Cell Dimensions

Apart from the obvious reasons to have a variety of dimensions available to make different physical size capacitors, there are electrical reasons also. A short, fat capacitor will outperform a tall, skinny capacitor **every** time. This is a key point not well understood in the market place, and not well understood by many capacitor manufacturers! Most capacitors that fail do so because of thermal issues, so any design parameters that reduce heat generation will make a better capacitor.

Heat Conduction Capability

There are several sources of heat in the capacitor, including but not limited to:

- Losses within the cell
- Losses within the metal spray and/or connections
- Losses caused by overheating (such as caused by harmonics)
- Heat caused by the cell breaking down
- Ambient air temperature too high

Some level of heat will always be generated inside the cell. It's how that heat leaves the cell that determines whether the cap is a robust design or not. For example – if there 5 watts of heat are being generated, yet only 4 watts can be effectively dissipated to the outside, then the cell will fail. The heat **must** be able to be released from the cell quickly and efficiently to ensure a long life. To this end, to extend the life of a capacitor:

1) Choose a cap with the lowest losses available
2) Choose a cap with sufficient voltage rating so as to not suffer voltage breakdown (dielectric failure)
3) Choose a cell with the most favourable dimensions (short and fat)
4) Remove harmonics from the supply that the capacitors are connected to
5) Keep the can surface temperature within the manufacturer's specifications by air flow/temperature

Lastly, the thorny question of oil filled versus resin versus gas filled. Without any doubt, an oil filled capacitor will run cooler. Some companies will tell you different to this, but this is simply not true. For thermal considerations, oil is best – typically by 8 degrees! There are other concerns with oil-filled capacitors – costs being the biggest issue. kVArCorrect uses capacitors that are filled with a special resin – they are not as good at conducting heat as oil filled capacitors, but they have many other benefits, including complying with specifications that demand 'dry' capacitors.

About the Author

The opinions expressed here are the researched views of Allan Ramson, General Manager, kVArCorrect Ltd. All claims have been substantiated by testing and observations from the Australasian market between 2007 and 2018. Having been associated with the design, manufacture and supply of many thousands of power factor capacitors and over 500 power factor systems, kVArCorrect are confident that the KBR capacitors are the best capacitors tested and used.