Thermal Management of Electrolytic Capacitors

Function of capacitors

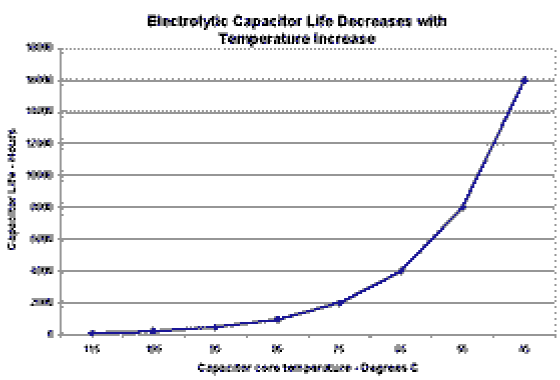
Capacitors act as an electrical accumulator, taking in excess power to help maintain a constant voltage or power level. Analogous to a shock absorber in a car, the capacitor acts to slow any changes in the input power, while allowing a metered amount of energy to exit. In the automobile, bumps in the road cause the changes in input power, and the result of slowing these changes is a smooth ride. In the electrical circuit, the capacitor takes variations in the input and creates a regulated output. The difference between the input and output energy converts to heat within the capacitor.

In typical power electronics applications, the electrolytic capacitor takes delivered AC power and converts it to a constant voltage output. Since mechanical components are becoming increasingly sensitive to voltage transients, the demand on electrolytic capacitors and the heat generated by this demand continue to increase.

In many high power applications, such as motor drives, power supplies, and arc-welding equipment, multiple capacitors work together to achieve regulated input power. In some cases, as many as 20 or 30 large capacitors are required to achieve system isolation from power or voltage spikes. Each of these parts shares the input ripple voltage load and will equally share the heat accumulation.

Why do capacitors fail?

Electrolytic capacitors use a semi-liquid electrolyte inside the case to make electrical contact with the foil windings. This electrical interface is inherent in the capacitor’s ability to carry current and function as an energy storage unit for the electrical power input. When the interface between the electrolyte and the metallic foil windings begins to degrade, the electrical connection begins to fail. Heat build up is the primary cause of this degradation, which, depending on severity, can cause either short-term catastrophic failure, or long term functional degradation. Similar to the life expectancy of a silicon semiconductor die, the life expectancy of an electrolytic capacitor relates directly to its internal temperature. Every 10° C increase in internal temperature halves the component lifetime.



The structure and materials used in the capacitor make heat dissipation more difficult. To operate properly, the case must be electrically isolated from the core where heat is generated. The voltage breakdown of the insulation materials is often in excess of 350 volts DC. However, materials that have a high enough dielectric constant to have this high a breakdown voltage are, by nature, very poor thermal conductors. The insulation adds a thermal resistance that limits the amount of heat that can be rejected from the core. Any external cooling can only dissipate what heat can escape through this limiting thermal resistance. This leads to inner temperatures that are substantially higher than ambient. The result is shorter capacitor lifetime.

What can be done to help

Cooling a capacitor will extend its life. Alternatively, taking away more heat from the capacitor gives it more power carrying ability. Whether the goal is longer life or higher power, the solution is cooling.

The traditional method for cooling capacitors is to provide physical isolation. With enough air space around the capacitor, it will stay sufficiently cool for most applications. In higher power cases, the larger heat load may necessitate the addition of a fan, which can actively pass cooling air over the capacitor bank.

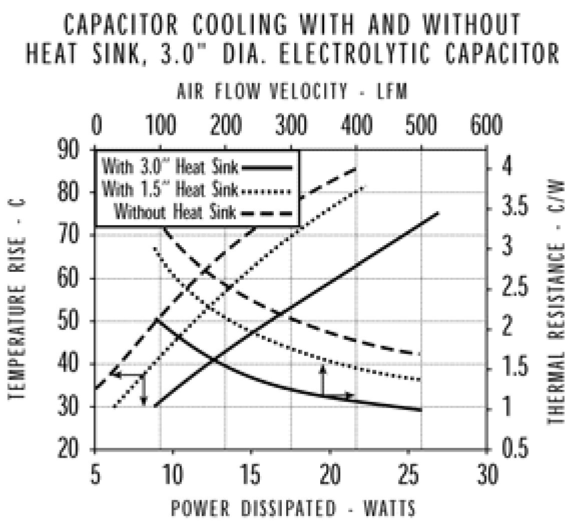
In many current applications, however, the internal temperature requirements have been ignored: many times the capacitor banks are so densely packed that the capacitor bodies are touching. Even though the capacitor specifications usually require a 1" spacing, the demand for smaller packages overrides the capacitor's need for cooling. The result of this tight spacing is shorter capacitor lifetime.

The limited thermal conduction path out of the capacitor makes cooling more difficult. In most cases, the primary thermal conduction path (the path of least resistance) is from the closed or flat end of the capacitor. Some heat also passes through the terminal end. Capacitor heat loads are small: typically 5 to 10 Watts in a 3 inch diameter capacitor.

One way to cool these capacitors is to attach the part to an aluminum chassis or panel. This not only cools the part, but it also mechanically attaches it to the system. Conventional or laminated busbars aid in heat removal through the terminal end.

An external heat dissipater, or heat sink, can increase heat removal further, increasing the life of the capacitor. This additional heat sinking can take many forms. The most common heat sink is an aluminum extrusion that attaches to the closed end of the capacitor. Newer extruded heat sinks consist of semicircular extrusions, designed to clamp to the external case of the capacitor. This unique design not only provides a heat dissipation cooling surface, but acts as a system-mounting clamp as well. These parts work well with both natural convection airflow and with forced convection airflow when additional heat must be removed.

There are many other methods to remove capacitor heat. Some are as simple as ensuring a good conduction path between the closed end of the part and a large thermal conductor. Folded fin material wrapped around the capacitor and attached with a clamp is another innovative way to increase cooling surface area. The folded fin material is flexible, and is available in many fin thicknesses and densities. This additional cooling surface area can make a big difference in capacitor lifetime.



Conclusion

Controlling the internal temperature of electrolytic capacitors ensures system life and performance. The cooling of the capacitors can take many forms, from the tradition of physical isolation to the addition of extended heat transfer surfaces. Keeping the core temperatures of the capacitors regulated, and within the manufacturers' specifications, improves end-product reliability, saving warranty and repair costs for both manufacturer and end-user.