KEMET
ENGINEERING CENTER

New C4AK Series High Temperature, Long Life DC-Link Film Capacitors

Feedback

The demands on DC-Link capacitors are increasing steadily. The expectation for capacitors in DC filtering and energy storage is to operate at higher temperatures, in more extreme conditions, and longer lifetimes, than ever before. Automotive and industrial applications lead those demands for better performance, but existing power box, DC-link film technologies cannot achieve them. They cannot reach extended life at high-temperature ranges beyond the 105°C ambient and 125°C hot spot limits. And

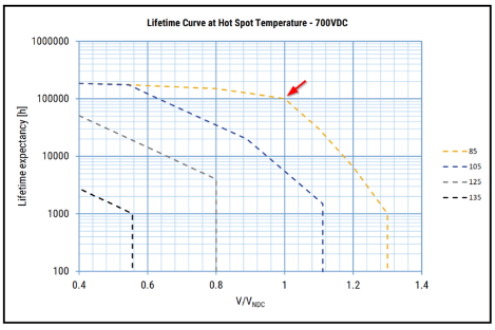
even as temperatures approach those limits, voltage derating is necessary for proper and safe operation.

KEMET's new C4AK series offers a unique solution, with a metallized film technology that can reach extended life beyond 125°C (4,000 h) and up to 135°C hot spot temperatures. These power box DC-link film capacitors are ideal for automotive, energy, and industrial applications where high-temperature, harsh environment, and miniaturization are required.

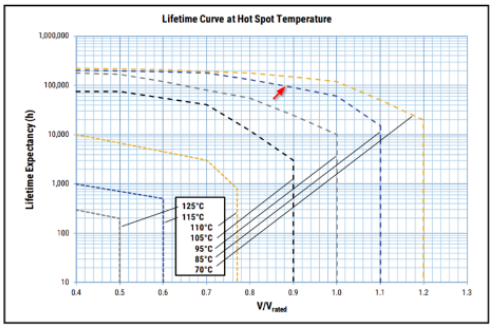
Temperature Ratings and Lifetime

With the new C4AK series, designers can now utilize DC-Link film technology with a lifetime of up to 4,000 hours at 125°C hot-spot temperature and require less voltage and current derating than other available film technologies. For example, the C4AK (700 VDC) does not require voltage derating up to 85°C hot-spot temperature in the life-plot comparison below. In contrast, the C4AQ-M solution requires a voltage derating factor at 85°C (<0.9) to still meet the 100,000 hours life expectancy at the same hot-spot temperature.

C4AK (700VDC) does not need derating up to 85 °C



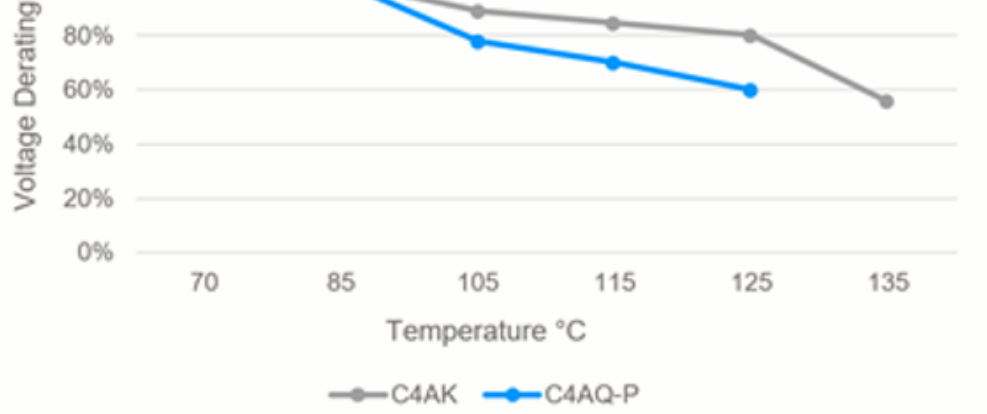
C4AQ-M solution requires a voltage derating factor at 85 °C (<0.9)



Another example of this lessened need for voltage derating at high temperatures is shown in the below comparison plot versus the new DC-Link solution. In this example, the C4AK technology

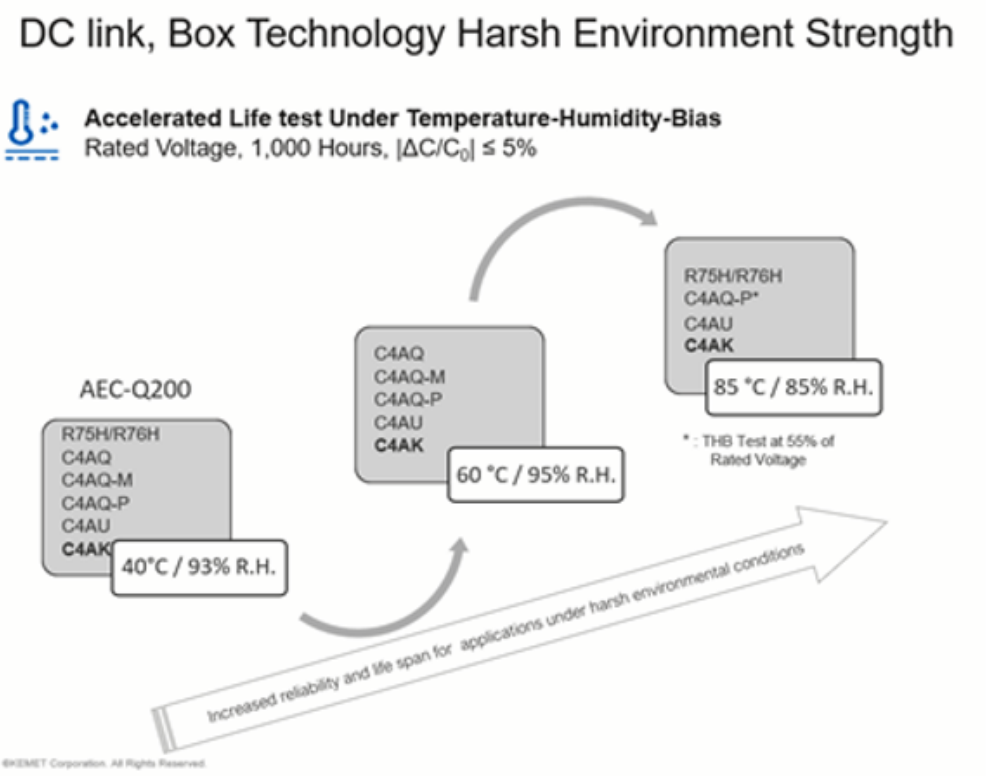
requires less voltage derating beyond the 85°C hot-spot than C4AQ-P technology. C4AQ-P is capable of reaching a 125°C hot spot temperature. This capability translates into higher voltage capability at high hot-spot temperatures and the possibility of using fewer capacitors (miniaturization).

Feedback



Harsh Environment Capabilities

Beyond its high-temperature capability, the C4AK capacitor technology is a robust solution for harsh environmental applications with high humidity content. The C4AK series surpasses the standard qualification of AEC-Q200 regarding accelerated life test under temperature-humidity-bias (THB) conditions specification for film capacitors (1,000 hours at 40°C / 93% R.H., rated voltage). This capacitor series introduces extended reliability under extremely harsh environmental conditions with THB test specifications up to 1,000 hours at 85°C / 85% R.H. / rated voltage. See the image below for more details on the KEMET DC-Link Harsh Environment classification for the DC-Link, film power box series.



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High dV/dt Capability

The dV/dt capability of a capacitor is a measure of its ability to survive sudden changes in applied voltage without failure. In a real (non-ideal) capacitor, this is determined by the current capability, equivalent series resistance (ESR), and physical structure of the capacitor. Hi dV/dt capability means the capacitor can survive applications with faster transitions – faster switching, fast noise, and so on – without being damaged.

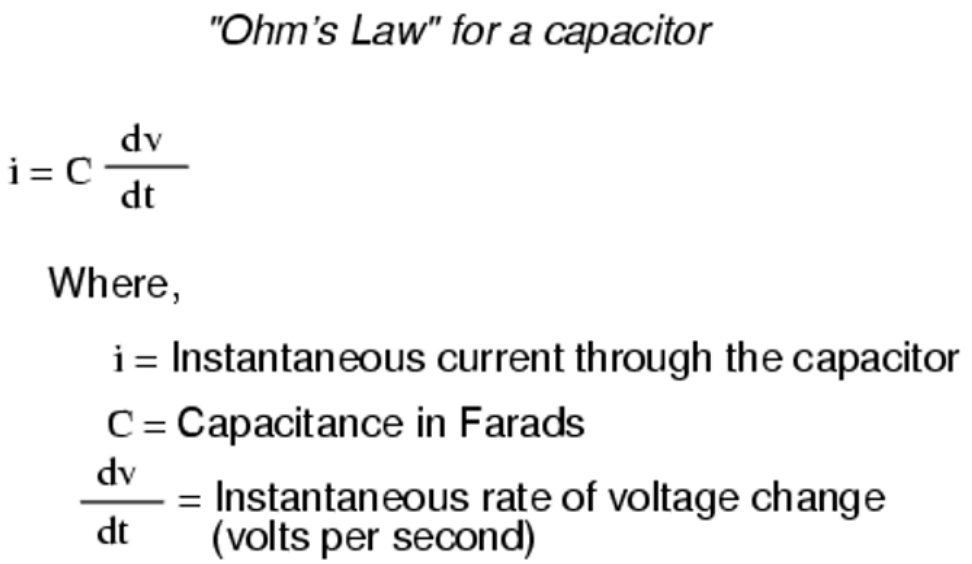

Image source: https://www.allaboutcircuits.com/textbook/direct-current/chpt-13/capacitors-and-calculus/

The C4AK series reaches dV/dt levels up to 40 V/µs due to its unique metallized film element connected to the terminal connections. This high dV/dt capability enables it to work with high-frequency repetitive voltage peaks, such as those related to the on/off stages of switching semiconductor devices or any other current fluctuation in the DC-bus.

Miniaturization

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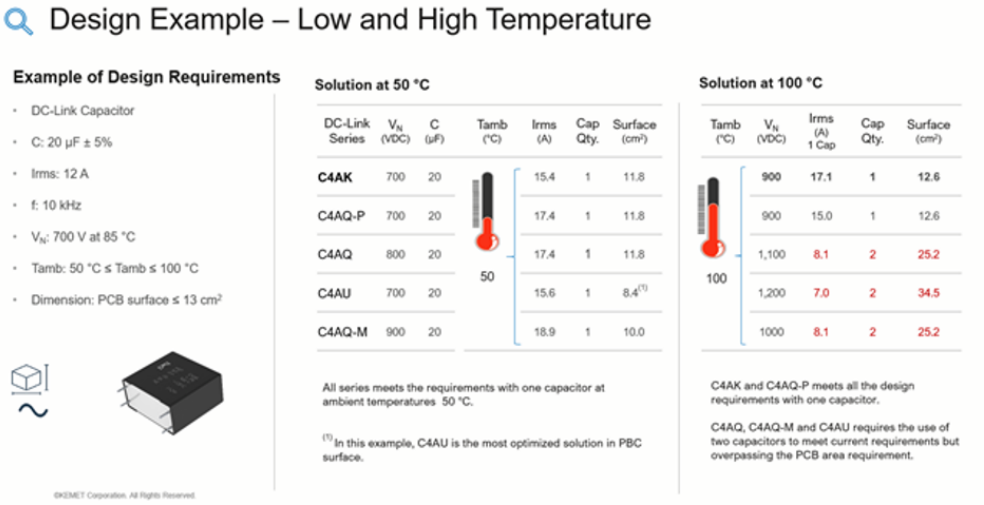
Thanks to its innovative film material with higher dielectric strength per V/µm than other high-temperature DC-Link film technologies on the market and its better voltage and current derating capability at high temperatures, KEMET's C4AK series provides an excellent solution to designers seeking to miniaturize their PCB.

Designers can now use smaller and fewer capacitors that result in miniaturization of their printed circuit board designs. The below comparison example between the C4AK series and other KEMET Power Box Technologies for low and high-temperature applications shows the miniaturization advantages of the C4AK solution KEMET: C4AK 20 µF/900 Vdc can manage 17.1 A with the smaller PCB surface area at 100°C.



Self-Healing Capabilities

The electrical properties of capacitor dielectrics are heavily dependent on the dielectric material and defects contained therein. These defects can be inherent to the material itself, the manufacturing process, or damage caused by voltage transients. Certain types of capacitors have self-healing capabilities, where these flaws are mitigated, improving performance and extending the life of the capacitor. Self-healing capacitors are less likely to fail catastrophically, and more likely to fail in a safe manner if they do – open, instead of short circuiting.

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Metallized film capacitors, such as the C4AK series, are self-healing capable. When dielectric damage occurs that threatens the integrity of the capacitor, the resulting arcing serves to vaporize the conductive metallization around the fault area, resulting in a “healed” capacitor.

KEMET’s C4AK series has a better self-healing capacity than some of the other high-temperature DC-Link solutions available in the market because of its innovative dielectric material. For example, DC-Link capacitors that use PEN film dielectric for high-temperature applications have more limited self-healing properties and lower volts per micrometer strength capability. The high dielectric strength of the C4AK means a high safety grade for high-power applications at high temperatures.

Applications – E-Chargers, Heater, and Battery Systems

Electric compressors (E-Chargers or E-Turbos) help boost and optimize power to internal combustion and hybrid vehicles. These devices operate at temperatures around 105°C ambient or higher. Standard DC-Link film capacitors would be severely limited in the amount of ripple current they could provide at those high temperatures.

The automotive design industry requires E-Chargers to handle operation up to 125°C temperatures with an average of 60% and up to 70% of the I_{rms} current during normal operations, and peak operating temperature that can reach up to 135°C in passive mode. These requirements make the situation more critical and challenging for polypropylene film capacitor technology. Because the C4AK technology can manage the high current density and low voltage derating up to 135°C hot spot, and with extended operational life, it brings new solutions to designers’ needs for high-density energy film capacitors under those extreme temperatures.

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A similar situation occurs with heater systems, DC/DC converters,

and inverters that need to operate near heat sources and under minimum design space in electric vehicle (EVs) designs. For these critical applications requiring high current and temperature ratings beyond what other DC-link film technologies can offer, the C4AK is an excellent solution to meet designers' needs.

KEMET's C4AK Metallized – E-Chargers, Heater, and Battery Systems

The C4AK film power box technology reaches a capacitance of up to 70 µF at rated DC voltage ranges of 700 V and 900 V, with a maximum operating temperature of 135°C and a life expectancy of 4,000 hours at 125°C and 1,000 hours at 135°C. This series is designed to withstand harsh environmental conditions at 85°C and 85 % R.H. for 1,000 hours at rated DC voltage, showing the highest humidity robustness performance.

KEMET's new C4AK DC-Link capacitor technology brings significant benefits to the electronics community with its long life under high-temperature and humidity conditions, high capacitance density, excellent self-healing, high ripple current for high-frequency applications, and automotive qualification (AEC-Q200). In addition, the C4AK is a low-content halogen solution frequently required by the automotive industry. Typical applications include DC filtering, DC-link, energy storage in power electronics.

For more information, visit https://ec.kemet.com/dc-link/.

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