Derating of Aluminum Electrolytic Capacitors in UltraVolt High Voltage Power Supplies

UltraVolt uses conservative derating practices to ensure reliable operation and long lived power supplies. One critical component that has a significant impact on mean time before failure (MTBF) is the aluminum electrolytic capacitor. The capacitors used in UltraVolt power supplies have an operating temperature range of -55°C to +105°C. This technical note outlines the part selection practices and derating guidelines UltraVolt uses to maximize the life of the power supply.

Typical electrolytic capacitor data sheets specify a lifetime in hours (usually thousands of hours) at a maximum operating temperature. For example, the capacitor typically used in UltraVolt power supplies is rated at 5000 hours at +105°C. This part was selected for its long lifetime and high operating temperature.

An electrolytic capacitor is considered to be outside its endurance when one of the following conditions occurs: the capacitance changes by at least 35%, the dissipation factor increases by at least 300%, or the DC leakage current is greater than the initial specified value. These values may vary from manufacturer to manufacturer but are typical parameters used to define the component's lifespan.

The circuit in the high-voltage power supply is designed to tolerate the changes to the capacitor's characteristics and still operate reliably; but these parameter shifts are useful for calculating an expected lifetime of the unit based on operating conditions. The operating temperature of the part is the key factor in determining the expected lifetime. Since most UltraVolt power supplies are fully encapsulated, the entire unit runs at a fairly uniform temperature. In addition to the internal operating temperature of the unit, the capacitor ripple current acting on the ESR (internal resistance of the capacitor) will cause self-heating, which must be taken into account in figuring the lifetime.

As the operating temperature of the capacitor goes down, the expected lifespan increases. The expected lifespan will double for every ten-degree drop in temperature. A typical UltraVolt power supply has a specified maximum operating temperature of +65°C; at this temperature, the capacitor lifetime is expected to double 4 times. In other words, a 5000 hour part will last 80,000 hours. If the operating temperature is held to even lower levels - perhaps 20°C over an ambient of 20°C - expected lifespans, conservatively, can be 320,000 hours. In many applications, the power supply is running at a temperature lower than the maximum rated and at an output power also lower than its maximum rated. Accounting for real world operating conditions, selecting the proper capacitor for a well designed circuit can lead to very high reliability and a lifespan of several hundred thousand hours.

The numbers calculated above are based on a well-defined shift in the capacitor's characteristics. These shifts in value do not necessarily represent the point of failure for the circuit. The point of failure for the power supply will be several multiples of the calculated lifespan of the part. The data sheet for the hi-rel capacitors defines lifespan as when capacitance drops by 35%, yet a drop in capacitance of 50% or more can easily be tolerated by the circuit.

There are many other capacitor technologies available, each well suited for particular applications. The aluminum electrolytic capacitor is best suited for applications as it is used in UltraVolt high voltage power supplies. As noted in the discussion above, UltraVolt uses conservative and robust design practices which will provide high reliability and long life.