XP Power

TECHNICAL ARTICLE

ELECTROLYTIC CAPACITOR LIFETIME IN POWER SUPPLIES

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Electrolytic capacitors are an essential ingredient in AC/DC power supplies providing high Capacitance x Voltage (CV) product and low Equivalent Series Resistance (ESR) in low volume packages that simply cannot be achieved cost effectively using alternative parts. The service life of these electrolytic capacitors is an increasingly key design parameter in power supplies.

With power density demands increasing and as the only component wear out mechanism in the product, the electrolytic capacitors used in the design determine the service life of the power supply and hence either the service life or the service interval, if the equipment is maintained, of the end application.

To determine the service life of the power supply it is important to understand the shortest lifetime part in the overall design which, depending on topology & applied ripple current, design layout, capacitor design lifetime, capacitor temperature rating and local heating effects, varies from one product to another and may change under low and high line input conditions.

It is not unusual for the external heating effects to outweigh the internal heating effects especially in today's increasingly compact designs. Actual service life is also dependent on the temperature rises experienced when installed in the application and the mission profile of the end equipment defining average operating temperature over the equipment lifetime, usage hours per day etc.

As described above, there are a number of key factors determining the expected service life of electrolytic capacitors used within the supply; design lifetime at rated temperature, local heating effects, temperature de-rating and magnitude and frequency of applied ripple currents.

Design Lifetime at Rated Temperature

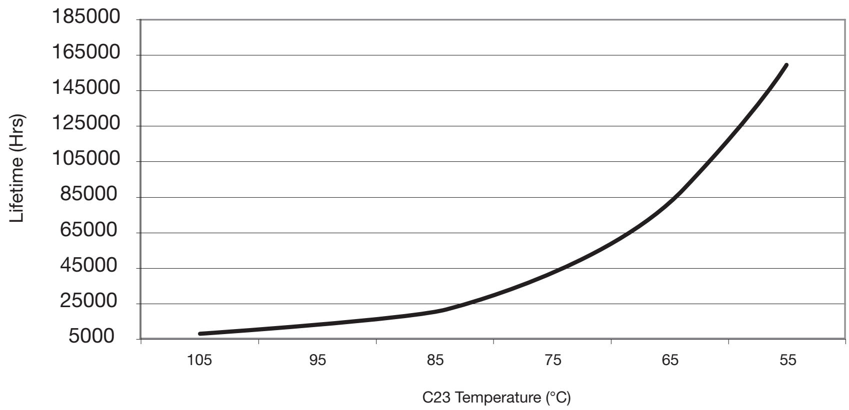
Manufacturers of electrolytic capacitors specify the design lifetime at the maximum rated ambient temperature, usually 105°C. This design lifetime can vary from as little as one or two thousand hours to ten thousand hours or more. The longer the design lifetime, the longer the component will last in a given application and ambient temperature.

Manufacturers also provide calculations to determine lifetime in application, these are based on the Arrhenius equation for temperature dependence of reaction rates which determines that the reaction rate doubles for every 10°C rise in temperature. Put another way the lifetime doubles for each 10°C reduction in temperature meaning that a capacitor rated at 5000 hours at 105°C would have a service life of 10,000 hours at 95°C and 20,000 hours at 85°C.

The basic equation is given below and the curve plots the service life against ambient temperature.

$$L = L_0 \times 2^{\left(\frac{T_{max} - T_a}{10}\right)}$$

L : Estimated life (Hr)
L_0 : Life at rated temperature (Hr)
T_{max} : Rated Temperature (°C)
T_a : Ambient Temperature (°C)



Applied Ripple Current and Frequency of Operation

In addition to the ambient temperature and local heating effects, the application of ripple currents further heat the capacitor core and are generally factored into the manufacturer's lifetime equations.

Ripple currents are generated by the switching and rectification processes on both the input and output stages of the supply causing power dissipation within the electrolytic capacitor. The magnitude & frequency of these ripple currents depends on the topology adopted in the design of active Power Factor Correction (PFC), where used, and the main converter power stage and varies from design to design.

The power dissipated within the capacitor is determined by the RMS ripple current and the capacitor ESR at the applied frequency. The temperature rise at the component core is determined by the power dissipated, the radiation factor of the component package and the temperature difference factor or slope from the core to the case as determined by the component manufacturer.

The maximum ripple current that may be applied to the capacitor is usually specified at maximum ambient temperature and 100/120 Hz. Multiplication factors can be applied depending upon the ambient temperature in actual use and the frequency of the applied ripple current with ESR decreasing as frequency increases.

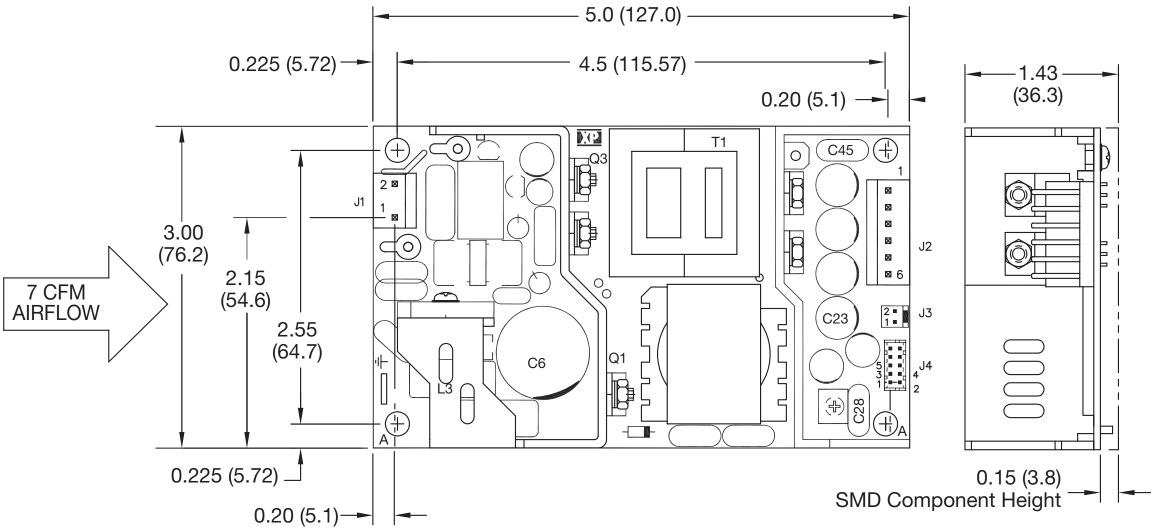
Power Supply Lifetime

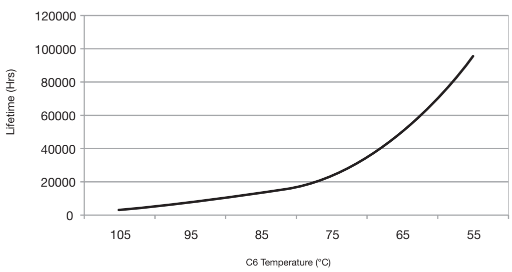
These factors are all taken into account by the power supply designer and power supply manufacturers apply design de-rating rules to ensure that product lifetime is adequate.

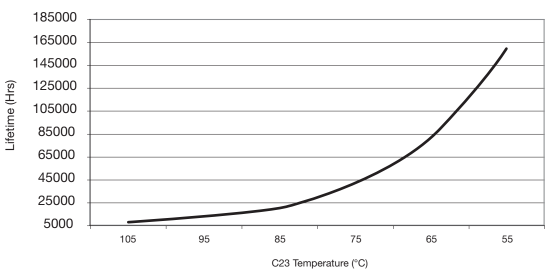
These design de-rating rules do not account for the mission profile, environment, mounting orientation, positioning, surrounding space, applied load and system cooling/venting arrangements once installed in the end equipment. Capacitor lifetime, particularly in convection or naturally cooled environments should be reassessed based on the installation.

Clearly, measurement of applied ripple currents is not practical but, given that all factors in the overall equipment and power supply design result in the effective operating temperature of the component, a good indication of the service life of each capacitor can be determined by measurement of its case temperature and the application of the Arrhenius equation and mission profile to the base lifetime specified by the component manufacturer.

Many power supply data sheets, such as XPs GCS series, identify the key components determining the service life of the product, particularly those requiring external cooling to be provided by the end equipment and those designed for convection cooled applications. This is to assist the system designer in determining power supply service life in the end application.
The mechanical drawing below identifies the components and the curves indicate expected service life of the power supply based on the temperature of two capacitors (C6 & C23).







Enclosed power supplies incorporating their own cooling fan are less susceptible to the end application environment provided that the ambient temperature is within specification and there is adequate clearance for cooling.

The table below indicates the estimated service life of capacitors with design lifetimes of 2000 and 5000 hours at various temperatures and assumes twenty four hour operation for seven days per week when converting the service hours to service years. Equipment with a mission profile of 8-10 hours per day, 5 days per week, for example, would experience significantly longer service life as a result.

Temperature	2000 Hour Rated	5000 Hour Rated
105 °C	2000 hrs (0.23 years)	5000 hrs (0.57 years)
95 °C	4000 hrs (0.46 years)	10000 hrs (1.14 years)
85 °C	8000 hrs (0.91 years)	20000 hrs (2.28 years)
75 °C	16000 hrs (1.82 years)	40000 hrs (4.56 years)
65 °C	32000 hrs (3.65 years)	80000 hrs (9.31 years)
55 °C	64000 hrs (7.30 years)	160000 hrs (18.2 years)*

*Lifetime calculations above 15 years should be considered as 15 years maximum