

Aluminium Electrolytic Capacitors' performance in Very High Ripple Current and Temperature Applications

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Introduction

The main limiting factor, for electrolytic capacitors, in e.g. automotive power applications, is very often the ripple current capability. This article is focusing on the possibility to dramatically increase the capacitor performance, by using capacitors designed with low internal thermal resistance, together with optimization of the application thermal management.

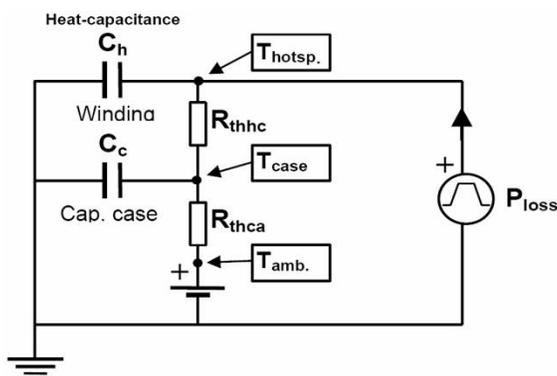
Ripple current capability

A low ESR value is normally considered to be the most important parameter to achieve a high ripple current capability. The ESR and ripple current, results in power loss and in internal temperature rise. The operational life is reduced if the capacitor operates at high temperature. The internal capacitor temperature (hot-spot temperature, T_h), is not only dependent of the power loss. The thermal parameters of the capacitor also have a significant impact on the hot-spot temperature. A low thermal resistance path will reduce hot-spot temperature and/or increase the ripple current capability.

Thermal model

The capacitor thermal model described below is built up by thermal resistances (R_{thhc} and R_{thca}) and thermal capacitances (C_h and C_c). With known thermal parameters, it is possible to simulate and predict the capacitor temperature and calculate operational life.

thermal capacitor model:



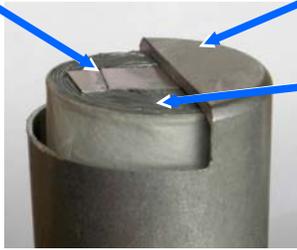
Heat- sinking of the capacitor body

By reducing the external thermal resistance, it is possible to dramatically increase the ripple current capability. Even with “standard” electrolytic capacitors heat- sinking of the capacitor body will result in a significant improvement. Achieving 60- 70% increased current capability, is possible, as a result of reducing the external heat resistance (R_{thca}).

New capacitor generation - significant performance gain

Evox Rifa has introduced a new generation of axial capacitors. The PEG 220-226 series of capacitors, are designed with 50- 70% reduced internal thermal resistance, (R_{thhc} , this compared with all other comparable axial capacitors available on the market). The low thermal resistance is achieved by metallic contact between the cathodic foil and bottom of the capacitor casing.

Winding tabs,
welded to
bottom of
capacitor



Bottom of
capacitor case
(cut)

Winding with
extended
cathodic foil

The winding is mounted with axial pressure ⇒
Metallic contact between the cathode foil and
the bottom of case, resulting in low thermal
resistance



Axial force on the Al-deck, gives pressure to the winding

Capacitor, extended cathode design

The extended cathode technology has during decades been in use for large Al-electrolytic screw terminal capacitors. High power applications in cars, now brings similar requirements also for smaller capacitors.

Winding with extended cathode, together with other improvements, results in a significant increase in ripple current capability. Up to 28A ripple current, continuous load, is possible to specify, at a capacitor case temperature of 125°C (Ø20x 43mm- case).

To achieve this performance the capacitor body needs to be heat- sined. As a comparison, the ripple current for some of the best capacitors on the market today is 14-15 A (heat- sined, 125°C, same case-size).

Example - Continuous load:

Capacitor ripple current: 26.7A, ≥5 kHz. (Cont. load). Applied DC voltage: ≤ 18VDC

Application chassis temp.: 116.7°C. External thermal resistance (cap. body to metallic chassis): $R_{thca} = 1.6 \text{ }^\circ\text{C/W}$

This value is achievable by heat sining approximately one third of the capacitor body, using thermal conductive paste or glue.

Capacitor article, fulfilling above requirements:

PEG 225 HJ4480Q (4800µF, 25V, Ø20x 35mm), ESR(≥5kHz, ≥125°C)= 7.3mΩ (max), $R_{thhc} = 2.4 \text{ }^\circ\text{C/W}$ (internal thermal resistance)

Calculated temperatures and operational life (Lop):

Power loss: $26.7^2 \times 0.0073 = 5.2 \text{ W}$, Steady state, thermal conditions (cont. load): Cap. case temp. (T_c):

$116.7^\circ\text{C} + 5.2\text{W} \times 1.6 \text{ }^\circ\text{C/W} = 125^\circ\text{C}$. Capacitor, hot-spot temperature (T_h =winding temp.):

$116.7^\circ\text{C} + 5.2\text{W} \times (2.4+1.6) \text{ }^\circ\text{C/W} = 137.5^\circ\text{C}$.

Operational life for an electrolytic capacitor is direct related to the capacitor hot-spot temperature (max winding temperature). The above described capacitor type is capable of minimum 4 kh operational life at described conditions (⇒ $T_h = 137.5 \text{ }^\circ\text{C}$).

Test results and experience verify that the operational life (Lop, minimum) can be described by following formula:

$$L_{op} = 85 \text{ kh} * 2^{((85-T_h)/12)}$$

(12°C decreased temperature results in an factor of 2 longer operational life. Specified Lop for PEG 225 is 85kh at $T_h = 85^\circ\text{C}$ and 2 kh at 150°C)

Test results, verifying capacitor specification

[accelerated test, 12°C increased temperature compared with specified temp., at rated ripple current]:

Tested capacitor article: PEG 225 HJ4480Q, Test conditions, as described in above example but tested at 12 °C higher temperature⇒ Case temperature 137 °C, hot-spot temperature 149,5 °C. Ripple current load: 27 A. Test duration: 2000 h

Parameter change after test:

	$\Delta\text{Cap} (\mu\text{F})$	$\Delta\text{tan d} (\%)$	$\Delta\text{ESR}(100\text{kHz})$
mean	-6,4%	+8,1%	+5,2%
max	-5,3%	+45%	+23%
min	-10,8%	-4,5%	±0,0%

Comments: The capacitor specification are fulfilled, also after 2000h at accelerated conditions.
[at +12 °C increased temp]

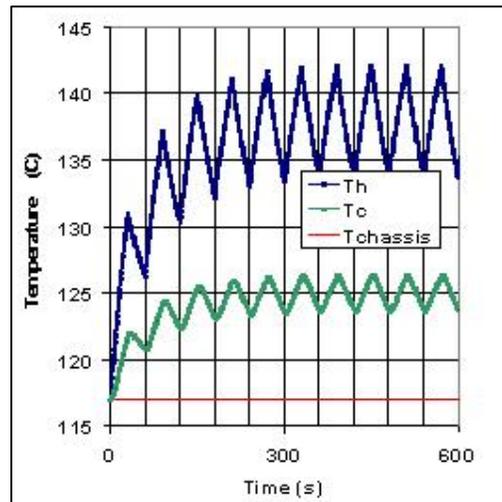
Example, intermittent load (simulation and measurements):

50% Duty Cycle, 40A, 5kHz, 30s “on”, 30s “off”, applied DC voltage: 16V, application chassis temperature: 117°C
Capacitor mounted with low thermal resistance path, to metallic chassis, $R_{thca} = 1.6 \text{ }^\circ\text{C/W}$.

Capacitor article:

PEG 226 KL 4270Q (2700 μF , 40V, $\varnothing 20 \times 43\text{mm}$), $\text{ESR}(>5\text{kHz}, >125^\circ\text{C}) = 6.7\text{m}\Omega$ (max),
 $R_{thhc} = 2.4^\circ\text{C/W}$, $C_h = 18.4 \text{ }^\circ\text{C/J}$, $C_c = 4.6 \text{ }^\circ\text{C/J}$

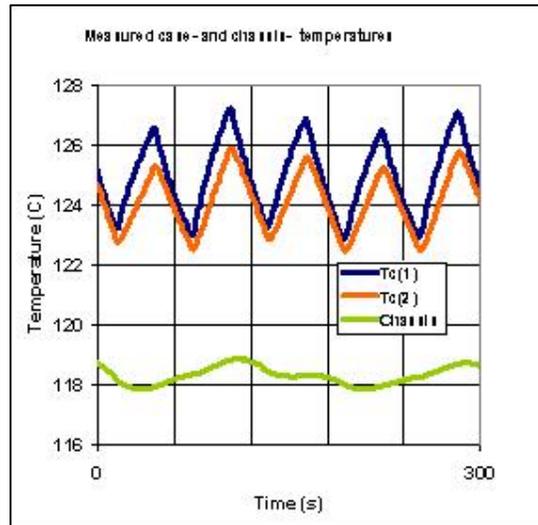
Thermal simulation:



Calculated hot-spot temperature (T_h) and capacitor case temperature (T_c)

Verifying measurement, intermittent load

50% Duty Cycle, 40A, 5kHz, 30s “on”, 30s “off”, applied DC voltage: 16V, PEG 226 KL 4270Q (2700 μF , 40V, $\varnothing 20 \times 43\text{mm}$)



*Measurements, intermittent load, (50%, 40A, 5kHz)
(Case temperatures, two capacitors):*

Parametric changes after 1000h of intermittent operation: ESR (100kHz, 20°): + 3.5%, Capacitance (100Hz, 20°): -2.5%. Remark: The capacitors still fulfil the specification for new capacitors



Test set-up, capacitors mounted with low thermal resistance path, to metallic chassis:

Summary

In high ripple current applications like automotive power, it's possible to gain a significant advantage by using capacitors designed with optimized thermal parameters. Further significant improvement is possible to achieve by heat-sinking the capacitors.