4. LIFE OF ALUMINUM ELECTROLYTIC CAPACITORS

4.1. Life and Ambient Temperature

Life of aluminum electrolytic capacitor is temperature dependant and it is doubled when ambient temperature is 10℃ lower, based on Arrhenius's Law.
Thus, the relation of life and ambient temperature is given per equation 4.1.

$$L = L_0 \times 2^{\frac{T_{max} - T_a}{10}} \quad \text{----- 4.1}$$

L : Estimated Lifetime (Hr)
L_0 : Specified Lifetime (Hr)
T_{max} : Maximum Category Temperature (°C)
T_a : Ambient Temperature (°C)

4.2. Life and Ripple Current

(1) Temperature At Top Of Case and at Core Of Aluminum Electrolytic Capacitor When Ripple Current Is Applied

Aluminum electrolytic capacitor generates Joule's heat when ripple current is applied, due to higher loss in comparison with other type of capacitors. Heat rise of capacitor is given per equation 4.2.

$$\Delta T_c = \frac{I^2 \times R}{\beta \times S} \quad \text{----- 4.2}$$

ΔT_c : Surface heat rise (℃)
I : Ripple current (Arms)
R : ESR of capacitor (Ω)
S : Surface area of capacitor (cm^2)
β : Heat radiation factor (W/℃•cm^2)

Value of β is generally becomes smaller as surface area becomes bigger. β value approximation is expressed as equation 4.3.

$$\beta = 2.3 \times 10^{-3} \times S^{-0.2} \quad \text{----- 4.3}$$

Where β is a factor when heat rise is measured at top of capacitor.

(2) Temperature Slope Between Core And Case Surface Of Capacitor

Temperature slope between core and case surface of capacitor is expressed as equation 4.4.

$$\Delta T_j = \alpha \bullet \Delta T_c = \Delta T_s \bullet \left(\frac{I}{I_0}\right)^2 \quad \text{----- 4.4}$$

ΔT_j : Heat rise at core (℃)
α : Factor of temperature difference between core and surface
ΔT_c : Heat rise at surface (℃)
ΔT_s : Heat rise at core when rated ripple current is applied (℃)
I : Actual ripple current converted to specified frequency (Arms) (see Note in below)
I_0 : Rated ripple current (Arms)

Table 4-1 Temperature Difference Factor (Radial Lead Capacitors)

Case Dia (mm)	4 to 8	10, 12.5	14.5 to 18
α	1	1.1	1.2

Table 4-2 Temperature Difference Factor (Snap-In Capacitors)

Case Dia (mm)	20	22	25	30	35
α	1.3	1.3	1.4	1.5	1.64

Notes) Conversion To Specified Frequency

a) From actual frequency to specified frequency

Using frequency coefficient listed in catalog, actual ripple current value is converted to the value at specified frequency by equation 4.5.

$$I = \frac{I_x}{k} \quad \text{----- 4.5}$$

I : Converted ripple current value to specified frequency (Arms)
I_x : Actual ripple current (Arms)
K : Frequency coefficient in catalog

b) When actual ripple current consists of several different frequency components

Ripple current at specified frequency is calculated by using frequency coefficient at each frequency component per equation 4.6.

$$I = \sqrt{\left(\frac{I_1}{k_1}\right)^2 + \left(\frac{I_2}{k_2}\right)^2 + \left(\frac{I_3}{k_3}\right)^2} \quad \text{----- 4.6}$$

I : Converted ripple current value to specified frequency (Arms)
I_n : Actual ripple current (Arms)
k_n : Frequency coefficient listed in catalog

(3) Heat rise by ripple current and Estimated Life
Equation for Calculating the Life of Electrolytic Capacitors Other Than the Screw Terminal Type (JIS Type CE33)

As stated in previous paragraph, aluminum electrolytic capacitor generates heat when ripple current is applied, due to Joule's heat. And the heat rise should be considered when you estimate life expectancy. As it is experimentally confirmed that the heat rise makes the life shorter than calculation with Arrhenius's law, it is generally known that the life is doubled at 7 to 10℃ lower temperature when heat rise at core of capacitor is 10°C and 4 to 6°C lower temperature when it is 20°C . Equation 4.7 and 4.8 are life estimation formula with consideration of above including experimental error.

- Products specified endurance with applying rated ripple current

$$L = L_0 \times 2^{\frac{T_{max} - T_a}{10}} \times 2^{\left(\frac{\Delta T_s}{A_0} - \frac{\Delta T_j}{A}\right)} \quad \text{------ 4.7}$$

- Products specified endurance with applying rated DC voltage

$$L = L_0 \times 2^{\frac{T_{max} - T_a}{10}} \times 2^{\left(-\frac{\Delta T_j}{A}\right)} \quad \text{------ 4.8}$$

L : Estimated Lifetime (Hr)
L_0 : Specified Lifetime (Hr)
T_{max} : Maximum Category Temperature (°C)
T_a : Ambient Temperature (°C)

ΔT_j : Heat Rise at Core of the capacitor by ripple current (℃)
A : Temperature factor when acceleration ratio becomes 2

$$A = 10 - 0.25 \times \Delta T_j \quad \left(0 \le \Delta T_j \le 20\right)$$

A_0: $A_0 = 10 - 0.25 \times \Delta T_s$

ΔT_s : Heat rise at core when rated ripple current is applied (℃)

*If applicable below, please contact us.
- The case that heat rise (ΔT_j) exceeds 20°C by applying ripple current.
- Product whose maximum category temperature (T_{max}) exceed 105°C.
- HXG series (CE692).

Equation for Calculating the Life of Screw Terminal Type Electrolytic Capacitors (JIS Type CE33)

The life of screw terminal type electrolytic capacitors (JIS Type CE33) has been experimentally confirmed to follow a rule of double the life for every 10℃ dec rease, even allowing for heat rise generated by ripple current application. In addition life expectancy is affected also by electrolyte consumption due to leakage current during voltage application. Taking this into account, the equation for calculating the life expectancy of the screw terminal type electrolytic capacitor is expressed as follows.

$$L = Lo \times 2^{\frac{Tmax - Ta}{10}} \times 2^{\left(\frac{\Delta Ts}{10} - \frac{\Delta Tj}{10}\right)} \times \left(\frac{Vr}{Va}\right)^{2.5} \quad \text{------ 4.9}$$

However, in the case of Va/Vr < 0.6, (Vr/Va) takes the constant value of 1.66.

L : Estimated Lifetime (Hr)
L_0 : Specified Lifetime (Hr)
T_{max} : Maximum Category Temperature (°C)
T_a : Ambient Temperature (°C)
ΔT_j : Heat rise (at core of the capacitor) by ripple current (°C)
ΔT_s : Heat rise at core when rated ripple current is applied (°C)
V_r : Rated Voltage (V d.c.)
V_a : Applied Voltage to Capacitor (V d.c.)

Please let us know when heat rise exceeds 30℃.

∗ The equation to estimate life expectancy is based on our accelerated test data; however, the Estimated life calculated using the equation includes a margin of error. Therefore, we recommend that designers allow an ample safety factor between the result of the equation and the designed service life. In the event that the result of the estimation exceeds 15 years, we recommend that 15 years be taken as the maximum service life.