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°C 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 actual life (Hrs)
L_0 : Life at max. operating temp. (Hrs)
T_{max} : Max. Operating Temperature (°C)
T_a : Actual 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 (°C)
I : Ripple current (Arms)
R : ESR of capacitor (Ω)
S : Surface area of capacitor (cm^2)
β : Heat radiation factor (W/°C•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 (°C)
α : Factor of temperature difference between core and surface
ΔT_c : Heat rise at surface (°C)
ΔT_s : Heat rise by specified ripple current (°C)
I : Actual ripple current converted to specified frequency (Arms) (see Note in below)
I_0 : Specified ripple current (Arms)

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

Case Dia (mm)	3 to 8	10, 12.5	16, 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) Estimated Life And Heat Rise By Ripple Current

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°C 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 is a life estimation formula with consideration of above including experimental error.

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

L : Estimated useful life (hours)
L_0 : Actual useful life at max. temperature with rated voltage and specified ripple current (hours)
T_{max} : Maximum operating temperature (°C)
T_a : Ambient temperature (°C)
ΔT_j : Heat rise at core of capacitor with actual ripple current (°C)
A : Temperature factor when acceleration ratio becomes 2

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

A_0 : $A_0 = 10 - 0.25 \times \Delta T_s$
ΔT_s : Specified heat rise when maximum ripple current specification is determined (°C)

Please let us know when heat rise exceeds 20°C.