ALUMINUM ELECTROLYTIC CAPACITORS

■ TECHNICAL NOTE

1-3-2 Tan δ (tangent of loss angle or dissipation factor):
The Tan δ is the ratio of the resistive component (R_{ESR}) to the capacitive reactance ($1/\omega C$) in the equivalent series circuit, and its measuring conditions are the same as the capacitance.

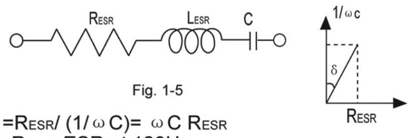


Fig. 1-5

$\tan\delta = R_{ESR}/(1/\omega C) = \omega C R_{ESR}$
where : R_{ESR}=ESR at 120Hz
$\omega = 2\pi f$
f=120Hz
The Tan δ shows higher values as a measuring frequency increases and a measuring temperature decrease.

1-3-3 Equivalent series resistance (ESR)
The ESR is comprised of the resistance due to aluminum oxide layer and electrolyte/separator combination and other resistance effected with foil length, foil surface area, etc.
The ESR value depends on the temperature. Dectreasing the temperature makes the resistivity of the electrolyte increase with the result of the ESR increasing.
As the measuring frequency increases, the ESR decreases and reaches an almost constant value that is mainly the frequency-independent resistance due to electrolyte/separator combination.

1-3-4 Impedance (Z):
The impedance is the resistance which opposes the flow of alternating current at a specific frequency. It is related to capacitance (C) and inductance (L) in terms of capacitive and inductive reactance, and also related to the ESR. It is expressed as follows:

$$Z=\sqrt{ESR^2+(X_L-X_C)^2}$$

Where: $X_c = 1/\omega C = 1/2\pi fC$
$X_L = \omega L = 2\pi fL$

1-3-5 Leakage current:
The dielectric of a capacitor has a very high resistance which prevents the flow of DC current. However, due to the characteristics of the aluminum oxide layer that functions as a dielectric in contact with electrolyte, a small amount of current, called leakage current, will flow to reform and repair the oxide layer while a voltage is being applied. A high leakage current flows in the first minutes as a voltage is applied to the capacitor, and then the leakage current will decrease and reach an almost steady-state value with time.

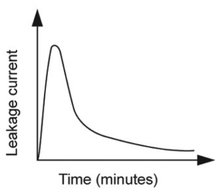


Fig. 1-6 Leakage current vs. Time

Measuring temperature and voltage affect the leakage current. The leakage current shows higher values as the temperature and voltage increase.

2 About the Life of an Aluminum electrolytic Capacitor
2-1 Estimation of life with minimal ripple current (negligible).
Generally, the life of an aluminum electrolytic capacitor is closely related with its ambient temperature and the life will be approximately the same as the one obtained by Arrhenius' equation.

■ TECHNICAL NOTE

$$L=L_o \times 2^{\left(\frac{T_o-T}{10}\right)} \text{ ---------(1)}$$

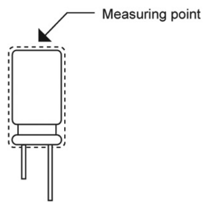
Where L: Life at temperature T
L_o: Life at temperature T_o
The effects to the life by derating of applied voltage etc. are neglected because they are small compared to that by the temperature.

2-2 Estimation of life considering the ripple current.
The ripple current affects the life of a capacitor because the internal loss (ESR) generates heat. The generated heat will be:
$P=I^2R$ ··················(2)
Where I: Ripple current (Arms)
R: ESR (Ω)
With increase in the temperature of the capacitor:

$$\triangle T=\frac{I^2R}{A\cdot H} \text{ ---------(3)}$$

Where △T: Temperature increase in the capacitor core (deg.)
I: Ripple current (Arms)
R: ESR (Ω)
A: Surface area of the capacitor (cm^2)
H: Radiation coefficient (Approx. $1.5\sim2.0\times10^{-3}W/cm^2\times$℃)

The above equation (3) shows that the temperature of a capacitor increase in proportion to the square of the applied ripple current and ESR, and in inverse proportion to the surface area. Therefore, the amount of the ripple current determines the heat generation, which affects the life. The value of △T varies depending on the capacitor types and operating conditions. The usage is generally desirable if △T remains less than 5℃. The measuring point for temperature increase due to ripple current is shown below;



Test results:
(1) The life equation considering the ambient temperature and the ripple current will be:

$$L=L_0 \times 2^{\left(\frac{T_0-T}{10}\right)} \times K^{\left(\frac{-\triangle T}{10}\right)} \text{ ---------(4)}$$

Where L_0: Life at DC operation (h)
K: Ripple acceleration factor
(K=2, if with in allowable ripple current)
(K=4, if exceeding allowable ripple current)
T_0: Maximum guaranteed temperature (℃)
T: Operating temperature (℃)
△T: Temperature increase at capacitor core (deg.)
(2) The life equation based on the life with the rated ripple current applied under the maximum guaranteed temperature will be a conversion of the above equation (4), as below:

$$L=L_0 \times 2^{\left(\frac{T_0-T}{10}\right)} \times K^{\left(\frac{\triangle T_0-\triangle T}{10}\right)} \text{ ---------(5)}$$