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/ωC) in the equivalent series circuit, and its measuring conditions are the same as the capacitance.

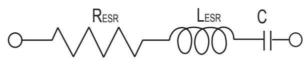
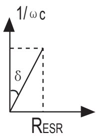


Fig. 1-5



$\tan\delta = R_{ESR}/(1/\omega C) = \omega C R_{ESR}$
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.

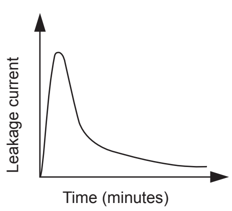


Fig. 1-6 Leakage current vs. Time

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.

1-3-2 Tan δ （损耗角正切）
在等效电路中，等效串联电阻ESR同容抗1/ωC之比称之为Tan δ，其测量条件与电容量相同。

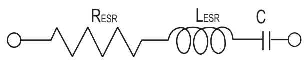
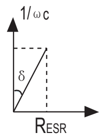


图 1-5



$\tan\delta = R_{ESR}/(1/\omega C) = \omega C R_{ESR}$
其中：R_{ESR}=ESR（120 Hz）
$\omega = 2\pi f$
f=120Hz
Tan δ 随着测量频率的增加而变大，随测量温度的下降而增大。

1-3-3 □等效串联电阻（ESR）
由铝箔氧化膜的介质电阻、电解液以及电解纸的复合电阻以及由于引出线与铝箔的接触电阻共同构成了等效串联电阻。
等效串联电阻的值和温度有关系。温度下降，电解液电阻率上升，从而导致等效串联电阻上升，
测试频率的上升，等效串联电阻下降并几乎达到一个常数值，该值主要是由电解液和电解纸引起的与频率无关的复合电阻。

1-3-4 阻抗（Z）：
在特定的频率下，阻碍交流电通过的电阻就是所谓的阻抗（Z）。它与容量以及电感密切相关，并且与等效串联电阻ESR也有关系。具体表达式如下：

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

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

1-3-5 漏电流：
电容器的介质对直流电具有很大的阻碍作用。然而，由于铝氧化膜介质上浸有电解液，在施加电压时，重新形成以及修复氧化膜的时候会产生一种很小的称之为漏电流的电流，刚施加电压时，漏电流较大，随着时间的延长，漏电流会逐渐减小并最终保持稳定。

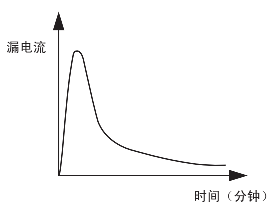


图 1-6 漏电流随时间变化特征图

测试温度和电压对漏电流具有很大的影响。漏电流会随着温度和电压的升高而增大。

2. 铝电解电容器的寿命
2-1. 忽略纹波电流时的寿命推算
一般而言，铝电解电容器的寿命与周围的环境温度有很大的关系，其寿命可以由以下公式计算。