

**5. CHARGE AND DISCHARGE APPLICATION OF ELECTROLYTIC CAPACITOR**

Performance deterioration of aluminum electrolytic capacitor is accelerated by repeated charge and discharge. The speed of deterioration is determined by operating conditions. For example, the higher the voltage and smaller the discharge resistance, the tougher it is on the capacitor. Also the deterioration is accelerated when charge and discharge takes place very quickly, or in high ambient temperatures.

Therefore, it is required to select type of capacitor considering its operating condition.

There are two major factors to accelerated deterioration of capacitor performance through charge and discharge. The first factor is heat rise caused by the charge and discharge current, and the second is the change in the cathode foil surface caused by the discharge current and subsequent gas generation. These factors are explained hereunder.

**5.1. Heat Rise Caused by Charge and Discharge Current**

For capacitors subjected to frequent charge and discharge cycles through very low discharge resistance (less than a few ohms) such as flash units for cameras and welding machines, heat rise due to high charge/discharge current is the main factor in performance deterioration.

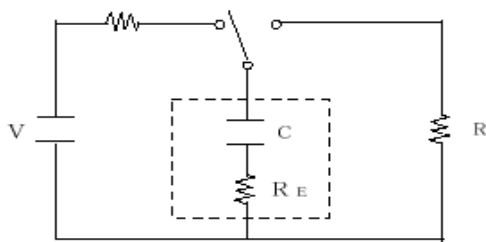


Fig. 5.1

- V : Charging voltage (V)
- C : Capacitance of the capacitor (μF)
- RE: ESR of the capacitor (Ω)
- R : Discharging resistance (Ω)
- T : Charge-discharge cycle (s)
- W : Energy loss inside the capacitor (J)

Due to its structure, the aluminum electrolytic capacitor has an internal resistance shown in figure 5.1. The internal resistance is due to the characteristics of the electrolyte, electrode foils and oxide film. Power loss W due to the internal resistance occurring at discharge is indicated as equation 5.1.

$$W = \frac{CV^2}{2} \times \frac{R_E}{R + R_E} \times \frac{1}{T} \quad (\text{J}) \quad \text{-----} \quad 5.1$$

Heat rise through this power loss causes the internal temperature of the capacitor to increase. This temperature increase continues until thermal equilibrium is reached between the heat rise and heat radiation from capacitor surface.

As internal temperature increases, the oxide film on the anode foil progressively deteriorates, accelerating degradation of the capacitor, which is apparent in an increase of leakage current and internal resistance.

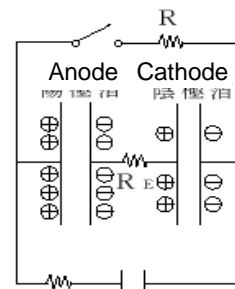
Therefore, capacitors must be used that are designed with lower internal resistance to minimize heat rise and promote long life when used with applications that have low discharge resistance and involve frequent charge and discharge.

When the charge and discharge current is extremely high, a capacitor must be used that is designed to lower dielectric loss, and with low internal resistance, as dielectric loss of the oxide film on the anode foil is another factor in performance deterioration.

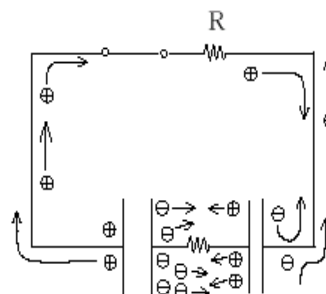
**5.2. Effect of Discharge on Cathode Foil**

When the capacitor is subjected to frequent and repeated on-off cycles, such as with power supply for audio amplifiers, formation of an oxide film on the cathode foil is considered a pivotal factor in performance deterioration. This phenomenon relates to the amount of electric charge being discharged and the capacitance value of the cathode foil.

**(a) Charging**



**(b) Discharging**



**(c) After the completion of discharge**

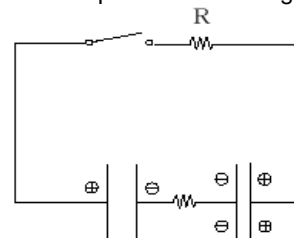


Fig. 5.2

The behavior of the electric charge from the charging stage until the discharging stage is illustrated in Figure 5.2. The charge is stored in both the anode foil and the cathode foil as per Figure 5.2 (a) during the charging stage. When it moves to the discharging stage, each electric charge moves to neutralize polarity. However, when the electric charge stored in the anode foil is greater than that in the cathode foil, extra charges remain after the discharge completes, as per Figure 5.2 (c). This is the same phenomenon as when the cathode foil is charged with positive polarity.

When the voltage exceeds the voltage able to be withstood by the oxide film on the cathode foil, the oxide film starts to grow with the decreasing current flow. Eventually, the capacitance of the cathode foil decreases and the capacitance of the capacitor decreases accordingly, as it is a composition of anode and cathode capacitance. Gas generation caused by this electro-chemical reaction makes the internal pressure of the capacitor increase.

A detailed explanation is given hereunder of the voltage applied to the cathode foil when discharge is completed.

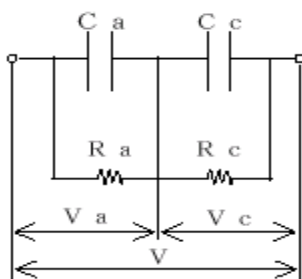


Fig. 5.3

When DC voltage is applied to the capacitor, the voltage is distributed to the anode foil and the cathode foil in proportion to the ratio of  $R_a$  and  $R_c$ , where  $R_a \gg R_c$ , as illustrated in Figure 5.3.

Generally,  $C_a < C_c$ , but the relation of the electric charge stored in the anode foil to the cathode foil is indicated in equation 5.2.

$$C_a V_a > C_c V_c \quad (Q_a > Q_c) \quad \text{-----} \quad 5.2$$

When the capacitor is discharged at this stage, the amount of the electric charge ( $Q_a - Q_c$ ) remains, and  $V_c'$  calculated with equation 5.3 is applied to cathode foil. (Figure 5.4)

$$V_c' = \frac{Q_a - Q_c}{C_a + C_c} = \frac{V_a C_a - C_c V_c}{C_a + C_c} \quad \text{-----} \quad 5.3$$

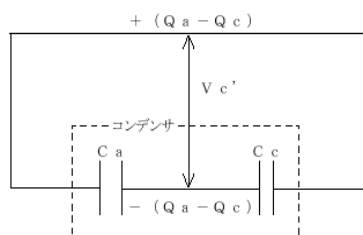


Fig. 5.4

Therefore, the withstanding voltage of the cathode foil  $V'$  must be higher than  $V_c'$ .

$$V' \geq V_c'$$

$$V' \geq \frac{C_a V_a - C_c V_c}{C_a + C_c}$$

Where  $V_a = V - V_c$ ,

$$V' \geq \frac{C_a V - V_c (C_a + C_c)}{C_a + C_c}$$

$$V' \geq \frac{C_a V}{C_a + C_c} - V_c$$

$$V' \geq \frac{V}{1 + \frac{C_c}{C_a}} - V_c \quad \text{-----} \quad 5.4$$

- $C_c$ : Capacitance of cathode ( $\mu\text{F}/\text{cm}^2$ )
- $C_a$ : Capacitance of anode ( $\mu\text{F}/\text{cm}^2$ )
- $V$ : Charging voltage (V)
- $V_c$ : Voltage applied to cathode on charging (V)
- $V'$ : Withstand voltage of cathode in the following direction (V)

From above equation, stabilization of capacitor performance should be achievable by increasing the voltage of cathode foil and making capacitance ratio cathode foil and making the capacitance ratio of  $C_c/C_a$  as large as possible.  $V'$  is generally known as being between 1.0 and 1.5 volts. As with standing voltage of oxide film on the cathode foil may be reduced, or its distribution widened, in high ambient temperatures, it is essential to use cathode foil with a stable and delicate oxide film. There may be occasions when formed foil is used as cathode foil. If this is a concern, please consult us for a specific solution.