1-1 Precautions in Using Aluminum Electrolytic Capacitors

Please note the following recommendations when using capacitors:

1. Electrolytic capacitors for DC applications require polarization. Confirm the polarity before use. The circuit life may be shortened or the capacitor may be damaged if inserted in reversed polarity. For use on circuits whose polarity is occasionally reversed, or whose polarity is unknown, use non-polar capacitors. Also note that the electrolytic capacitors cannot be used for AC applications.

2. Do not apply a voltage exceeding the capacitor's voltage rating. If a voltage exceeding the capacitor's voltage rating is applied, the capacitor may be damaged by increased leakage current. When using the capacitor with AC voltage do not exceed the rated voltage.

3. Do not allow excessive ripple current passing. Use the electrolytic capacitor at current value within the permissible ripple range. If the ripple exceeds the specified value, request capacitors for high ripple current applications.

4. Ascertain the operation temperature range. Use the electrolytic capacitors according to the specified operation temperature range. Use at room temperature will ensure a longer life.

5. The electrolytic capacitor is not suitable for circuits which are charged and discharged repeatedly. If used in circuits which are charged and discharged repeatedly, the capacitance value may drop or the capacitor may be damaged. Please consult our engineering department for assistance in these applications.

6. When capacitors have been left unused for long time, use them only after due voltage treatments. Long storage of capacitors tends to rise their leakage current levels. In such cases, be sure to provide the necessary voltage treatment before use.

7. Be careful of temperature and time when soldering. When soldering a printed circuit board with various components, care must be taken that the soldering temperature is not too high and that the dipping time is not too long. Otherwise, there will be adverse effect on the electrical characteristics and insulation sleeve of electrolytic capacitors. In the case of small-size electrolytic capacitors, nothing abnormal will be occurred if dipping is performed at less than 260°C for less than 10 seconds.

8. Cleaning circuit boards after soldering. Halogenated hydrocarbon cleaning solvents are not recommended for use in cleaning capacitors supplied with exposed seal end seals. Where cleaning with a halogenated solvent is desired, capacitors should be ordered with an Epoxy-coated end seal.

9. Do not apply excessive force to the lead wires or terminals. If excessive force is applied to the lead wires and terminals, they may be broken or their connections on the internal elements may be affected. (For strength of terminals, please refer to JIS C5102 and C5141.)

10. Keep the following clearance between the vent of the capacitor and the case of the appliance. Do not block the operation of the vent, unless otherwise described on the catalogues or product specifications. The narrower clearance may adversely affect the vent operation and result in an explosion of the capacitor.

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<table>
<thead>
<tr>
<th>Case diameter</th>
<th>Clearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>ϕ 6.3 to ϕ 16 mm</td>
<td>2 mm minimum</td>
</tr>
<tr>
<td>ϕ 18 to ϕ 35 mm</td>
<td>3 mm minimum</td>
</tr>
<tr>
<td>ϕ 40 mm &amp; up</td>
<td>5 mm minimum</td>
</tr>
</tbody>
</table>

Fig. 1-1

Attention
- The description in this catalogue is subject to change without prior notice for product improvement. Therefore, please confirm the specification before ordering products.
- The general characteristics, reliability data, etc., described in this catalogue should not be construed as guaranteed values; they are merely standard values.
- Before using the products, please read the notes in this catalogue carefully for proper use.
1-2 Technical Concepts

1. The material and structure of Electrolytic Capacitors

Electrolytic Capacitor is a simple module. It simply contains an insulator between relative conductors in an electrode. The major internal raw material contains an element constructed by an separator paper wrap around the anode foil and cathode foil, which is then impregnated with the electrolyte, inserted into an aluminum case and sealed.

*According to the inflict electric wave & using purpose, it basically with some classified purposes as below:

1. DC Voltage:
   a. For Momentary High Voltage: For using to the impulse generator such as the shock wave resistance test of the heavy electric machine.
   b. For High Electric Current: For using to the welding machine, X-Ray facility, copy machine and discharge processing device.
   c. For DC High Voltage: The electrolytic capacitor and rectifier composing, a special DC high voltage been happened after charged, for using to the power of electronic microscope and accelerator.
   d. For Integration & Memory: For either memory circuit or compare circuit inside the calculator.

2. The DC voltage that with alternate ingredient:
   a. For Wave Filter: Combination with the chip resistor & inductor as a internet, to be past by DC current or some frequency to closure or decline some other frequency.
   b. For Bypass: A parallel track that outside from the circuit element, the IC
   c. For Coupling: Combination of the electrolytic capacitor, chip resistor and inductor and thus coupling together.
   d. For Arising of Toothed Wave: Composing of RC charge/discharge circuit through the electrolytic capacitor as well as the resistor and a toothed wave to be created by the RC charge/discharge circuit.
   e. For Reverse (Change) of Circuit: The equipment for change the AC voltage to DC voltage.

2. Production Processes

1. Etching: The process to increase surface area of aluminum foil by using chemical erosion or chemical corrosion method is called Etching. Normally chemical corrosion method uses the ripple current of electrolyte, combination of the liquid and temperature to determine the size, shape, and quantity of the dense network of microscopic channels on the aluminum foil surface.

2. Forming: The production process of the anode aluminum foil of electrolytic capacitors is by anodic oxidation of the etched aluminum foil. The production of the cathode aluminum foil sometimes involves oxidation in special purposes. This anodic oxidation process is called Forming. Boric acid or organic acid is used for high voltage forming and phosphoric acid or ammonium adipate is used for low voltage forming in order to obtain stable natural oxide layer of $\text{Al}_2\text{O}_3$.

3. Slitting: The cutting of the aluminum foil and separator paper according to the required length.

4. Winding: The stitching or cold welding of cut anode and cathode foils and tab terminal, and wrap the electrolytic paper in between the anode and cathode, then fix the end with glue or sticky tape, and attached leads is called the capacitor “element”.

5. Impregnation: The process of eliminating water from the elements by pressurizes or vacuum in order to soak the element with the electrolyte is called Impregnation. The elements fully filled with electrolyte then centrifuged to remove excess electrolyte.

6. Assembly: The elements seal with rubber to stop the leakage of electrolyte then slip into a sleeve to form the final product.

7. Aging: The purpose of Aging is to repair the oxide film damage by recharging and electrolyte.

1-3 The Function of Electrolytic Capacitors

The electrolytic capacitors could be widely used in appliance (ie. TV, radio, audio equipment, washing machine and air conditioner, etc.), computer equipment (mother board, image device & the peripherals such as the printer, drawing device, scanner, etc.), communication equipment, estate equipment, measure instrument and also the industrial instrument, airplane, firebomb, satellite, etc. as a piloting equipment.
1-4 Basic Electrical Characteristics

1. Capacitance (E.S.C.)

\[ C : \text{Capacitance (F)} \]
\[ R : \text{Equivalent series resistance (Ω)} \]
\[ L : \text{Equivalent series inductance (H)} \]

The capacitive component of the equivalent series circuit (equivalent series capacitance ESC) is determined by applying an alternate voltage of 0.5V at a frequency of 120 Hz.

Temperature dependence of the capacitance

The capacitance of an electrolytic capacitor depends on the temperature; with decreasing temperature, the viscosity of the electrolyte increases reducing its conductivity. The capacitance will decrease if the temperature decreases. Furthermore, temperature drifts cause armature dilatation and therefore capacitance changes (up to 20%, depending on the series considered, from 0 to 80°C). This phenomenon is more evident for electrolytic capacitors than for other types.

2. Dissipation factor (tan δ)

The dissipation factor is the ratio between the active and the reactive power for a sinusoidal waveform voltage. It can be thought as a measurement of the gap between an actual and an ideal capacitor.

\[ \text{D.F.} = \tan \delta \times 100 \% = \frac{\omega CR}{2 \pi f Z} \times 100 \% \]

where: 
\[ R = \text{Equivalent Series Resistance (Ω)} \]
\[ C = \text{Equivalent Series Capacitance (F)} \]
\[ \omega = 2 \pi f \]

The tan δ is measured with the same setup as for the series capacitance ESC.

3. Equivalent series resistance (E.S.R.)

The equivalent series resistance is the resistive component of the equivalent series circuit. The ESR value depends on frequency and temperature and is related to the tan δ by the following equation:

\[ \text{ESR} = \frac{\tan \delta}{2 \pi f \text{ ESC}} \]

The tolerance limits of the rated capacitance must be taken into account when calculating this value.

Frequency dependence of the capacitance

The effective capacitance value is derived from the impedance curve, as long as the impedance is still in the range where the capacitance component is dominant.

\[ C = \frac{1}{2 \pi f Z} \]

Temperature dependence of the capacitance

The capacitance of an electrolytic capacitor depends on the temperature; with decreasing temperature, the viscosity of the electrolyte increases reducing its conductivity. The capacitance will decrease if the temperature decreases. Furthermore, temperature drifts cause armature dilatation and therefore capacitance changes (up to 20%, depending on the series considered, from 0 to 80°C). This phenomenon is more evident for electrolytic capacitors than for other types.
4. Impedance (Z)
The impedance of an electrolytic capacitor results from the following individual equivalent series components:

- Capacitive reactance predominates at low frequencies.
- With increasing frequency, the Capacitive reactance \( X_C = \frac{1}{\omega C} \) decreases until it reaches the order of magnitude of the electrolyte resistance \( R_e \) (A).
- When the capacitor's resonance frequency is reached \( \omega_0 = \sqrt{\frac{1}{LC}} \), capacitive and inductive reactance mutually cancel each other.
- Above this frequency, the inductive reactance of the winding and terminals \( \omega L \) becomes effective and leads to an increase in impedance.

\[ Z = R_e (A - B) \]

Where:
\( VF \) = Forming voltage
\( VR \) = Rated Voltage
\( VS \) = Surge voltage

Generally speaking, it can be estimated that \( C_e \approx 0.01 C_o \).

The impedance as a function of frequency (sinusoidal waveform) for different temperature values can be represented as follows (typical values):

5. Leakage current (L.C.)
Due to the aluminum oxide layer that serves as a dielectric, a small current will continue to flow even after a DC voltage has been applied for long periods. This current is called leakage current. A high leakage current flows after applying a voltage to the capacitor and then decreases in a few minutes (e.g., after a prolonged storage without any applied voltage). In the course of the continuous operation, the leakage current will decrease and reach an almost constant value.

After a voltage is applied, the leakage current will gradually decrease to its normal level.

The relationship between the leakage current and the applied voltage can be shown schematically as follows:

\[ I \quad V_f \quad V_R \quad V_s \]

Where:
\( V_f \) = Forming voltage
\( V_R \) = Rated Voltage
\( V_s \) = Surge voltage

If this level is exceeded, a large quantity of heat and gas will be generated and the capacitor could be damaged.

\[ Z = \frac{1}{\omega C} \]

Generally speaking, it can be estimated that \( C_e \approx 0.01 C_o \).

The impedance as a function of frequency (sinusoidal waveform) for different temperature values can be represented as follows (typical values):
1-5 Reliability

(1) The bathtub curve:
Aluminum electrolytic capacitors feature failure rates shown by the following bathtub curve.

![Bathtub curve](image)

a. Initial failure period
Deficient Capacitors include any products before dispatch that may have some deficiency caused by the design, production process or used in inappropriate environments.

b. Random failure period
The capacitors have a low defect ratio in the period after it has been stabilized.

c. Wear out failure period
The performance of capacitors will decrease with an increase in usage period. The malfunction rate may vary due to the structural design.

1-6 Circuit Design

(1) Environmental and Mounting Conditions
★ Please make sure the environmental and mounting conditions to which the capacitor will be exposed to are within the conditions specified in TEAPO's catalog.

(2) Operating Temperature, Equivalent Series Resistance(ESR), Ripple Current and Load Life
★ MTTF(Mean-Time-TO-Failure) means the useful life at room temperature 25°C

Load life:
If the capacitor's max. operating temperature is at 105°C (85°C), then after applying capacitor's rated voltage (WV) for L0 hours at 105°C (85°C), the capacitor shall meet the requirements in detail specification. Where L0 is called "load life" or "useful life (lifetime) at 105°C (85°C)".

\[ L_x = L_0 \times \left( \frac{T_0 - T_x}{5} \right) \]

Where
- \( L_x \): Expected life period (hrs) at actual operating temperature
- \( L_0 \): Expected life period (hrs) at maximum operating temperature allowed
- \( T_0 \): Maximum operating temperature (°C) allowed
- \( T_x \): Actual operating ambient temperature (°C)
- \( I_0 \): Actual applied ripple current (mArms) at operating frequency \( f_0 \) (Hz)
- \( I_x \): Rated maximum permissible ripple current \( I_{rms} \) (mArms) x frequency multiplier \( C_f \) at \( f_0 \) (Hz)

The (ripple) life expectancy at a lower temperature than the specified maximum temperature may be estimated by the following equation, but this expectancy formula does not apply for ambient below -40°C.

Ripple life:
If the capacitor's max. operating temperature is at 105°C (85°C), then after applying capacitor's rated voltage (WV) with the ripple current for \( L_x \) hours at 105°C (85°C), the capacitor shall meet the requirements in detail specification. Where \( L_x \) is called "load life" or "useful ripple life (ripple lifetime) at 105°C (85°C)".

\[ L_x = L_0 \times \left( \frac{\Delta T_0}{\Delta T_x} \right)^2 \times K_{c1}\times K_{c2} \]

where
- \( \Delta T_0 \): Temperature increase in the capacitor core (degree)
- \( \Delta T_x \): Temperature rise (°C) of capacitor case
- \( K_{c1} \): Transfer coefficient between element and case of capacitor from table below
- \( K_{c2} \): Transfer coefficient between case and environment

The usage is generally desirable if \( \Delta T \) remains less than 5°C. The measuring point for temperature increase due to ripple current is shown below.

\[ \Delta T = I R / AH \]

where
- \( \Delta T \): Temperature increase in the capacitor core (degree)
- \( I \): Ripple current(Arms.)
- \( R \): ESR(Ω)

At this time the increase in the capacitor temperature will be:

\[ P = I^2 R \]

The above equation (4) shows that the temperature of a capacitor increases 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 values of \( \Delta T \) varies depending on the capacitor types and operating conditions.

The usage is generally desirable if \( \Delta T \) remains less than 5°C. The measuring point for temperature increase due to ripple current is shown below.

(3) Application
★ Aluminium Electrolytic Capacitors are normally polarized. Reverse voltage or AC Voltage should not be applied. When polarity may flip over, non-polar type capacitors should be used, but the non-polar type cannot be used for AC circuits.

(4) Applied Voltage
★ Do not exceed the rated voltage of capacitor.
ALUMINUM ELECTROLYTIC CAPACITORS

(5) Insulation
★ Aluminum Electrolytic Capacitors should be electrically isolated from among the following points.

a. Aluminum case, cathode lead wire, anode lead wire and circuit pattern.

b. Auxiliary terminals of snap-in type, anode terminal, outward terminal and circuit pattern.

(6) Conditions of use
★ Aluminum Electrolytic Capacitors must not be used under the following conditions:

a. Ambient conditions that include toxic gasses such as hydrogen sulfide, sulfuric acid, nitrous acid, chlorine, ammonia, etc.

b. Ambient conditions that expose the capacitors to ozone, ultraviolet rays and radiation.

c. Severe vibration or shock that exceeds the conditions specified in the catalog or specifications sheets.

★ Avoid reflowing twice if possible.

(7) Recommended design considerations
★ When designing a circuit board. Please pay attention to the following:

a. Make the hole spacing on the PC board match the lead space of the capacitor.

b. There should not be any circuit pattern or circuit wire above the capacitors.

c. In case the capacitor’s vent is facing the PC board, make a gas release hole on PC board.

d. Do not install screw terminal capacitor with end seal side down.

(8) Aluminum Electrolytic Capacitors
Be careful not to deform the capacitor during installation.
★ Please confirm that the lead spacing of the capacitor matches the hole spacing of the PC board prior to installation.
★ The snap-in type of capacitors should be mounted firmly on the surface of PC board.
★ Avoid excessive force when clinching lead wire during auto-insertion process.
★ Avoid excessive shock to capacitors by automatic insertion machine, during mounting, parts inspection or centering operations.
★ Please utilize supporting material such as strap or adhesive to mount capacitors to PC board when it is anticipated that vibration or shock is applied.

1-7 Caution for Mounting

(1) Caution before assembly
★ Aluminum Electrolytic Capacitors cannot be recycled after mounting and applying electricity in unit. The capacitors that are removed from PC board for the purpose of measuring electrical characteristics at a periodical inspection should only be recycled to the same position.
★ Aluminum Electrolytic Capacitors may accumulate charge naturally during storage. In this case, discharge through a 1K Ω resistor before use.
★ Leakage current of Aluminum Electrolytic Capacitors may be increased during long storage time. In this case, the capacitors should be subject to voltage treatment through a 1K Ω resistor before use.

(2) In the assembly process
★ Please confirm ratings before installing capacitors on the PC board.
★ Please confirm polarity before installing capacitors on the PC board.
★ Do not drop capacitors on the floor, nor use a capacitor that was dropped.
★ Be careful not to deform the capacitor during installation.
★ Please confirm that the lead spacing of the capacitor matches the hole spacing of the PC board prior to installation.
★ The snap-in type of capacitors should be mounted firmly on the PC board without a gap between the capacitor body and the surface of PC board.
★ Avoid excessive force when clinching lead wire during auto-insertion process.
★ Avoid excessive shock to capacitors by automatic insertion machine, during mounting, parts inspection or centering operations.
★ Please utilize supporting material such as strap or adhesive to mount capacitors to PC board when it is anticipated that vibration or shock is applied.

(3) Soldering
★ All TEAPO’s cp wires of electrolytic capacitors are without lead (Pb).
★ Soldering conditions(temperatures, times) should be within the specified conditions which are described in the catalog or specification sheets.
★ If it is necessary that the leads must be formed due to a mismatch of the lead space to hole space on the board, bend the lead prior to soldering without applying too much stress to the capacitor.
★ If soldering capacitor has to be withdrawn from the PW board by soldering iron, the capacitor should be removed after the solder has melted sufficiently in order to avoid stress to the capacitor or lead wires.
★ Soldering iron should never touch the capacitor’s body.

(4) Flow soldering
★ Do not dip capacitor’s body into melted solder.
★ Din of flow soldering for the capacitors should be limited at 260°C, 10sec.
★ Flux should not be adhered to capacitor’s body but only to its terminals.
★ Other devices which are mounted near capacitors should not touch the capacitors.

(5) Reflow soldering condition
★ For reflow, use a thermal condition system such as infrared radiation or hot blast. Vapor heat transfer systems are not recommended.
★ Observe proper soldering conditions(temperature, time, etc.) Do not exceed the specified limits.
★ Repeated reflowing:
* Avoid reflowing twice if possible.
* If repeated reflowing is unavoidable, contact us after measuring the first and the second reflow profiles and reflow interval at your side.
* Do not attempt to reflow three times.

(6) Lead free type reflow soldering condition
For Aluminum Electrolytic Capacitors
★ For reflow, use a thermal condition system such as infrared radiation or hot blast. Vapor heat transfer systems are not recommended.
★ Observe proper soldering conditions(temperature, time, etc.) Do not exceed the specified limits.
★ Repeated reflowing:
* Avoid reflowing twice if possible.
* If repeated reflowing is unavoidable, contact us after measuring the first and the second reflow profiles and reflow interval at your side.
* Do not attempt to reflow three times.

<table>
<thead>
<tr>
<th>Size</th>
<th>T</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>φ4<del>φ5 (4</del>5V)</td>
<td>250</td>
<td>10</td>
</tr>
<tr>
<td>φ6.3<del>φ10 (4</del>5V)</td>
<td>260</td>
<td>5</td>
</tr>
<tr>
<td>φ4<del>φ10 63</del>100V</td>
<td>250</td>
<td>5</td>
</tr>
</tbody>
</table>
For Conductive Polymer Aluminum Solid Capacitors

Cleaning conditions: Total cleaning time shall be within 5 minutes by immersion, ultrasonic or other method. (Temperature of the cleaning agent shall be 60°C or lower.) After cleaning, capacitors should be dried using hot air for minimum of 10 minutes along with the PC board. Hot air temperature should be below the maximum operating temperature of the capacitor. Insufficient drying after water rinse may cause appearance problems, sleeve may shrink, or the bottom-plate may bulge etc…

Please let us know in advance the solvent name and conditions for your PWB Cleaning.

1-8 Emergency Action

1. If you see smoke due to the operation of safety vent, turn off the main switch or pull out the plug from the outlet.
2. Do not put your face near the safety vent as gas which in over 100°C will be emitted when the safety vent operates. If the gas has entered your eyes, please flush your eyes immediately in pure water. If you breathed the gas, immediately wash out your mouth and throat with water. Do not ingest electrolyte. If your skin is exposed to electrolyte, please wash it away using soap and water.

1-9 Storage Condition

1. Aluminum electrolytic capacitors should not be stored in high temperatures or where there is a high level of humidity. The suitable storage condition is 5~35°C and less than 75% in relative humidity.
2. Aluminum electrolytic capacitors should not be stored in damp conditions such as water, saltwater spray or oil spray.
3. Do not store aluminum electrolytic capacitors in an environment full of hazardous gas (hydrogen sulfide, sulfurous acid gas, nitrous acid, chlorine gas, ammonium, etc.)
4. Aluminum electrolytic capacitors should not be stored under exposure to ozone, ultraviolet rays or radiation.
5. If a capacitor has been stored for more than one year under normal temperature (shorter if high temperature) and it shows increased leakage current, then a treatment by voltage application is recommended.

1-10 Environment - Related Substances

All TEAPO's capacitors comply to RoHS (Restriction of Hazardous Substances) requirements where Chromium VI (Cr+6), Cadmium (Cd), Mercury (Hg), Lead, polychlorinated biphenyls (PCBs), Polybrominated diphenyl ethers (PBDEs), Polybrominated biphenyl ethers (PBDEs / PBBs) have not detected (lower than MDL Methad Detection Limit) per SGS certification test report.

1-11 Disposal

Please dispose capacitors in either of the following ways:

1. Incinerate capacitors after crushing parts of making a hole on the capacitor body.
2. Bury capacitors in the ground. Please have a disposal specialist do it.
The Characteristics of Endurance Test

1. Capacitance Change Ratio

2. Dissipation Factor Change

3. Leakage Current Change
### Typical Failure Modes and Their Factors

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Internal Phenomenon</th>
<th>Main Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Production Factor</td>
</tr>
<tr>
<td>Open</td>
<td>Corrosion</td>
<td>Leads improperly connected</td>
</tr>
<tr>
<td>Short</td>
<td>Infiltration of Cl⁻ (Chloride ion)</td>
<td>Leads improperly connected</td>
</tr>
<tr>
<td>Capacitance reduction</td>
<td>Insulation breakdown of film or electrolytic paper</td>
<td>Burrs on foil or lead</td>
</tr>
<tr>
<td>tanδ increased</td>
<td>Reduced anode foil capacitance</td>
<td>Metal particles in capacitor</td>
</tr>
<tr>
<td></td>
<td>Reduced cathode foil capacitance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electrolyte evaporation</td>
<td>Insufficient electrolyte</td>
</tr>
<tr>
<td>Leakage current increased</td>
<td>Deterioration of oxide film</td>
<td>Defect in oxide film</td>
</tr>
<tr>
<td>Vent operated</td>
<td>Increase in internal pressure</td>
<td>Increase in internal temperature</td>
</tr>
</tbody>
</table>

### Factors
- **Production Factor**
  - Leads improperly connected
  - Burrs on foil or lead

- **Application Factor**
  - Used for Halogenated solvent
  - Stress applied to leads
  - Used in a high temperature
  - Excessive ripple current
  - Over voltage applied
  - Reverse voltage applied
  - Used for a long period of time