Technology

![Diagram showing voltage and capacitance for different types of capacitors: Ceramic, Film, Tantalum, Ta Polymer, Aluminum Electrolytic, EDLC.]
Aluminum Element

13
Al
ALUMINUM
26.9815923

Aluminum:
Chemical Symbol: Al
Atomic Number: 13
Atomic Mass: 26.9815923
Discovered in 1825
Aluminum Properties

• Most abundant element to be found in earth’s crust (8.1%, after O & Si)
• Reasonable corrosion resistance due to the formation of air-formed Aluminum oxide in nature
• Thicker Aluminum oxide using electrochemical method (anodizing)
• Aluminum oxide is a good dielectric substance

Useful Properties of Aluminum:
✓ Light weight
✓ Good electrical conductivity
✓ Good thermal conductivity
✓ Non-toxic
✓ Non-magnetic
✓ No reaction with alcohol & other organic solvent
✓ High reflectivity of light
✓ Environmentally friendly
PCB Mount Electrolytic

- PCB mounted electrolytics are polarized, small form factor capacitors.
- The high capacitance value of these capacitors is usually suited to passing, bypassing, and decoupling applications.

4 common types of PCB mount Electrolytic capacitors:

- SMD
- Snap-In
- Radial
- Press-Fit
PCB Mount
Electrolytic Products

PCB Mount Electrolytics
- Snap-In
- Press-Fit
- Radial
- SMD

PCB Mount Solid Polymer Electrolytics
- Radial
- SMD
New Press-Fit Termination

➢ Capacitor is pressed into the PCB, not soldered
➢ Specific poke yoke terminations
➢ Eliminates the problems of soldering on thick PCB copper tracks
➢ Eliminates fractured solder joints
➢ Quick exchange of components

Press-Fit Pin Material

Material:
Copper Nickel Silicon Alloy CuNiSi R580 (C19010)

Plating:
• Ni 1.5-3μ all over
• Sn 100% mat 0.4-1.1μ on press-fit area
• Sn 100% mat 3-6μ on the remaining area
Press-Fit
Solution for Multiple Issues

1. Soldering Problems
   - Heavy copper tracking on the PCB acts as a heat sink which makes soldering difficult.
   - This can cause cold spots, voids, splatter, cracks etc.

2. Washing Issues
   - More aggressive washing of pcb after reflow soldering can force water under insulating sleeves of electrolytics.
   - Avoiding reflow / washing means expensive and additional processes such as hand soldering, automated selective soldering, or hand washing of components.

3. Field Work
   - Preventive Maintenance of soldered components often means replacing the entire (and costly) PCB.

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Construction
Aluminum Electrolytic
Traditional Aluminum Electrolytic Can

Construction

- Cathode Foil
- Anode Foil
- Separator Paper
- Foil Tabs
Traditional Electrolytic Capacitor Elements

$$C = \frac{\varepsilon_r \varepsilon_0 A}{d}$$
Anode Foil

Formed Cross-Section

Surface of foil

Dark area in the middle is solid core (Al)

3500 times magnification

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Electrolyte Composition

- High conductivity, neutral pH
  - Acid + Base -> Salt

- Wide operational temperature range
  - Stay conductive across range

- Provides ability to reform oxide
  - Controlled level of water

- Compatibility with paper and deck material
  - Hydrogen gas absorber

- Low flammability, low toxicity
Separator Papers

• Materials (pulp)
  – Kraft, manila, esparto, hemp
  – Combinations of pulp are often used

• Properties
  – Thickness 12µm to 90µm
  – Density 0.3 to 0.8 g/cm³, uniform density, minimum pinholes
  – Simplex – single type of paper
  – Triplex – three papers joined together

• Usage
  – 1 to 3 papers used between anode and cathode
  – Up to 5-6 actual layers when triplex paper used
Forward bias is same as formation bias.
If the dielectric gets thin enough, the forward bias voltage will form new dielectric
Thinner than original because $V_{\text{Formation}} > V_{\text{Rating}} > V_{\text{application}}$
PCB Mount Electrolytic

Important Parameters

- **Capacitance Loss**
  Is strongly dependant on Temperature and Frequency

- **Impedance**
  Is strongly dependant on Temperature and Frequency

- **ESR**
  Is strongly dependant on Temperature and Frequency

- **DC-Leakage (DCL)**
  Is strongly dependant on Temperature and Voltage

- **End of Life**
  Is strongly dependant on Voltage, Temperature, and Ripple Current
The capacitance of an electrolytic capacitor depends upon temperature:

➢ With decreasing temperature the viscosity of the electrolyte increases which in turn reduces the electrolytics conductivity.
Electrolytic Parameters

Capacitance (RC-Ladder)

\[
t_{c1} = C_1 \times R_1 \\
\]  
\[
t_{c2} = C_2 \times (R_1 + R_2) \\
\]  
\[
t_{c3} = C_3 \times (R_1 + R_2 + R_3) \\
\]  
\[
t_{cn} = C_n \times (R_1 + R_2 + R_3 \ldots + R_n) \\
\]
Chemical changes within the electrolyte and drying are causing the capacitance to decrease over time.

- Decreasing conductivity
- Increasing viscosity
- Reduced electrode contact

This effect is accelerated with leakage current and temperature caused by ESR and e.g. ripple current load.

➢ Technology Solutions

- More stable electrolyte systems
- Lower gassing and diffusion rates
- Improved & consistent quality anode foil (lower leakage current)
- Lower ESR designs
- Improved thermal conductivity
Equivalent Series Resistance is the resistive component of the capacitors equivalent circuit model.

ESR value depends on frequency and temperature.
The DC leakage current is a small current that flows through a capacitor when voltage is applied, between the two conductive plates.

Leakage current is primarily caused by imperfections in the oxide layer. This current varies mainly depending on the applied voltage, time, and capacitor temperature.

This steady state value is known as the operating leakage current.

The leakage current of an Aluminum Electrolytic capacitor increases when the component is stored for a long period of time.
End of Life Criteria

- **Catastrophic failure:**
  - Open or short circuit

- **Mechanical failure:**
  - Operation of safety vent often seen as split sleeve

- **Parametric failure:**
  - Capacitance change > ±10% or
  - ESR > 2x initial value or
  - Impedance > 3x initial value or
  - Leakage current > specified limit

*Comparisons between capacitor manufacturers should be made using the same criteria.*
End of Life
Aluminum Electrolytic

\[ Lop = Lopr \times 2 \times \frac{(T_{max} - T_{amb})}{10} \]
Aluminum Polymer Design and Characteristics
Solid Aluminum Polymer Capacitors

- Construction of Aluminum Electrolytic
- How Traditional Aluminum Electrolytic Work
- What Makes Solid Aluminum Polymer Different
- Performance of Solid Aluminum Polymer over Life
- Comparison
Aluminum Polymer Capacitor

Why Wound Aluminum Polymer?

Aluminum Polymer

✓ No electrolyte leakage
✓ Longer application life
✓ Higher ripple current capability

Lower ESR  Longer Life
Greater Stability

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Aluminum Polymer Capacitor Construction
Aluminum Polymer Block Diagram

- Anode Foil
- Oxide Layer
- Conductive Solid Polymer (PEDOT)
- Cathode Foil
- Separator Paper
Is the Conductive Polymer an Electrolytic?

- Solid material that provides the cathode connection.
- Does not “dry up” like a wet electrolyte - **It’s Solid**!
- The conductivity is an order of magnitude higher than a traditional electrolyte.
Ripple Current Characteristics

Allowable Ripple Current (100kHz 105°C)

- 33µF/16V
- 47µF/16V
- 100µF/10V
- 220µF/10V

Bar chart showing allowable ripple current for different capacitance and voltage combinations. The chart compares aluminum electrolytic and conductive polymer electrolytic capacitors.
Temperature Stability Characteristics

Example: ESR @100KHz 47uF/250V 8*12

- ESR (Ω) vs Temperature (°C)
  - Red line: Aluminum Electrolytic
  - Blue line: Conductive Polymer Electrolytic

- ESR values at different temperatures:
  - 233 mΩ at 0°C
  - 254 Ω at 125°C
Frequency Characteristics

Ultra low impedance at high frequency (Low ESR) (25°C)

Impedance (Ω) vs. Frequency (Hz)

- Red line: Aluminum Electrolytic
- Blue line: Conductive Polymer Electrolytic
Expected Life with Temperature Derating

- Capacitor Life [H]
  - 50,000
  - 100,000
  - 150,000
  - 200,000

Temperature [°C]
- 105
- 100
- 95
- 90
- 85
- 80
- 75
- 70
- 65

Aluminum Electrolytic
Conductive Polymer Electrolytic

\[ L_x = L_0 \times 2^{\frac{To-Tx}{10}} \]
Polymer vs. Wet Electrolytic

**Similarities**

- Form Factors
- Voltages
- Capacitances

**Advantages**

- Polymer – much lower ESR:
  - Less heat, more ripple current
- Lifetime
  - No electrolyte to dry out
- Stability
  - Temperature causes less parameter shift
Market & Applications Features & Benefits

Market Segments
- Consumer
- Telecommunications
- Computer
- Industrial
- Medical
- AUTO (infotainment/comfort control)

Applications
- LED driver power supplies
- Laptop power supplies
- Mobile phone chargers
- Computer motherboards
- Professional power amplifiers
- Industrial control systems

Features & Benefits
- Through-hole and surface mount form factor
- Ultra low impedance
- High ripple current capability
- Longer life capability
- Stable characteristics in a very low temperature range
- RoHS compliant
Aluminum Hybrid Design and Characteristics
Aluminum Technology
Axial Hybrid

- Conductivity independent
- ESR reduction, Temperature independent
- Ripple Current increased capability
- Downsizing
## Aluminum Electrolytic Comparison

<table>
<thead>
<tr>
<th></th>
<th>Frequency Characteristics</th>
<th>Temp Characteristics</th>
<th>Ripple Current</th>
<th>Leakage Current</th>
<th>Life</th>
<th>Price</th>
<th>AEC-Q200</th>
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<tbody>
<tr>
<td>&quot;Wet&quot; Electrolytic</td>
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</table>

- Low - Fair - Good - Best
- Temperature affects ESR. ESR affects cap roll-off vs. frequency.
Electrolytic Product Portfolio

- Axial/Radial
- Screw Terminal
- Snap-In
- Press-Fit
- Radial / Single Ended
- SMD
- Conductive Polymer Single Ended
- Conductive Polymer SMD

Varistors
Relays
Thank You!