Aluminum Electrolytic Capacitors – Failure Modes

APEC 2018 in San Antonio Capacitor Workshop
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Leader Product Marketing
eiCap Capacitor Division

Background:
• More than 10 years of work experience in electronics industry
• Background in Global Sales & Marketing, Industrial Engineering and Quality Management
• In charge for strategic sales conception and global market penetration of capacitor division at WE
Agenda

• Definition of Failure
• End of Lifetime = Failure?
• E-Cap Failure Modes
• Failures & Root Causes
• Common Failures
Definition of Failure
Definition of Failure

Manufacturers job at production to minimize such cases

Depending on dimensioning and mission profile

Product failures can happen at any time like:

- Early Birds - occur at new devices
  - Early Failures

- Unexpected Failures
  - Random Failure

- At the End of Lifetime
  - Wear Out Failures

>> overall observed failures result in Bath Tub Curve
End of Lifetime = Failure?
What means Endurance, Load Life and Useful Life?
End of Lifetime = Failure?

- **Aluminum Electrolytic Capacitor**

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>Endurance / Evaluation Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Time</td>
<td>1000h@105°C</td>
</tr>
<tr>
<td>Voltage</td>
<td>Full Rated Voltage</td>
</tr>
<tr>
<td>Current</td>
<td>Full Ripple Current</td>
</tr>
<tr>
<td>ΔC</td>
<td>Within +/- 20% of Initial Value</td>
</tr>
<tr>
<td>DF</td>
<td>&lt; 200% of initial value</td>
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<tr>
<td>Leakage Current</td>
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- **Aluminum Polymer Capacitor**

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<tr>
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</tr>
<tr>
<td>ESR</td>
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Endurance and Useful Life as example with WCAP-AIG8 series

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<th>WE Matchcode</th>
<th>WCAP-AIG8</th>
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<tr>
<td>Life</td>
<td>Endurance</td>
</tr>
<tr>
<td>Time</td>
<td>2000 h</td>
</tr>
<tr>
<td>Test condition</td>
<td>85°C, V_R, I_R</td>
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**Requirements**

1. $\Delta C/C \leq \pm 20\%$
2. $DF \leq 2$ times of the specified value
3. $LC \leq$ specified value
4. Capacitor without visible damage

- $\Delta C/C \leq \pm 40\%$
- $DF \leq 4$ times of the specified value
- $LC \leq$ specified value
- Capacitor without visible damage

- It is necessary to check this for each manufacturer because it is not standardized!

- Not the specification of the manufacturer finally determines the lifetime, it will be the dimensioning and selection of the proper capacitor for your design

>> How much capacitance drift is acceptable and still the application is running properly? <<
Major Factors for Aging of E-Caps

- The following factors mainly accelerate the aging behavior of an e-cap:
  - **Temperature**
    - electrolyte loss / dry out
    - leakage current >> oxide degradation
  - **Ripple Current**
    - self heating >> electrolyte loss / dry out
  - **Voltage Level**
    - leakage current >> oxide degradation

These effects result in:
- >> capacitance decrease
- >> increase of ESR
- >> DF change
Failure Modes
Failure Modes

- **Leakage Current Increase**
- **Capacitance Drop / ESR Change / DF Change**
- **Open Circuit**
- **Open Vent**
- **Electrolyte Leakage**

**Short Circuit**
Failures & Root Causes
Failure Modes

All effects result in an increase of internal pressure:
Failure Modes

- bad contact to terminal
- disconnection to terminals
- electrolyte dry out

Open Circuit
Failure Modes

- Oxide layer degradation
- Electrolyte vaporization
- Electrolyte dry out

Results in a rise of the internal pressure

Capacitance Drop / ESR Increase / DF Change
Failure Modes

- Poor sealing
- Internal pressure rise
- Electrolyte leakage
- Open vent
- Internal corrosion
- Deterioration of oxide layer
- Leakage current increase
- Leads to open and short circuit
Root Causes during Production

- Impurities or metal particles
- Contamination by chloride
- Deficiency in oxide layer
- Burred foil
- Poor sealing
- Poor connections
- Electrolyte Leakage
- Short Circuit
- Leakage Current Increase
- Open Circuit
Root Causes within Application or by Aging

- excessive thermal stress
- rapid charge and discharge
- overvoltage
- wrong polarity
- high ripple current
- mechanical stress
- Short and Open Circuit
- Open Vent / Electrolyte Leakage
- Capacitance Drop / ESR Increase / DF Change
Common Failures
Common Failures
Common Failures
Common Failures
Thanks for your attention!