Accelerated Aluminum Electrolytic Capacitor Life Testing: How to Pick the Most Reliable E-Cap in a Few Weeks

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Overview

- **E-caps**
  - Introduction
  - External Construction
  - Internal Construction

- **E-cap Failure**
  - Catastrophic
  - Degradation
  - Wear-out
  - Criteria

- **Testing**
  - How to Choose an E-cap
  - Traditional
  - Trends in Traditional Data
  - Accelerated Calculations
  - Accelerated Critical Weight Loss
  - Accelerated Calculations
  - Accelerated Wear-Out Failure Mode
  - Benefits of Accelerated Approach

- **Accelerated Life Test**
  - Suppliers A & B Overview
  - Suppliers A & B Rate of Weight Loss
  - Suppliers A & B Critical Weight Loss
  - Suppliers A & B Comparison
  - Suppliers C & D Overview
  - Suppliers C & D Rate of Weight Loss
  - Suppliers C & D Critical Weight Loss
  - Suppliers C & D Comparison

- **Conclusions**
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E-caps – Introduction

Industrial customer communication interface PCBA from Monico Inc.

Digital media player PCBA from Shenzhen Sinetech Electronic Co Ltd.

Automotive asset tracking PCBA from Theta Engineering Inc.

Comparison of datasheet lifetime, traditional test (life)time, and accelerated test time.
E-caps – External Construction

E-cap external construction.

Anode (+)  Al can  Cathode (-)  Rubber bung  Vent

Four types of E-cap leads:
- Radial lead
- Axial lead
- Screw terminal
- Snap in
E-caps – Internal Construction

Internal sandwich structure of an E-cap.

Top-down view of the rolled sandwich structure of an E-cap.

CT scan showing the crimped seal between the can and the bung.
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E-cap Failure – Catastrophic

- Catastrophic failure
  - Overstress
    - Voltage
    - Current
  - Temperature
  - Reverse polarity
  - Bad electrolyte

Catastrophic failure resulting in significant leakage of electrolyte from E-cap vent.

Catastrophic failure resulting in blown capacitors.
E-cap Failure – Degradation

- Degradation failure
  - Wear-out
  - Bad electrolyte
E-cap Failure – Wear-Out

Apply ripple and bias

Heating of the capacitor from applied ripple current causes evaporation of the electrolyte.

Internal pressure increase from electrolyte evaporation facilitates electrolyte egress between the rubber bung and Al case.
# E-cap Failure – Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitance Change</td>
<td>Within +/- 20% of initial value</td>
</tr>
<tr>
<td>Dissipation Factor*</td>
<td>Not more than 200% of the specified value</td>
</tr>
<tr>
<td>Leakage Current</td>
<td>Initial specific value or less</td>
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*Proportional to Equivalent Series Resistance (ESR).
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### Testing – How to Choose an E-cap

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Voltage (V)</th>
<th>Capacitance (µF)</th>
<th>Max Operating Temperature</th>
<th>Size</th>
<th>Ripple (mAmps 85°C 120 Hz)</th>
<th>Endurance (Load) Life*</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>10</td>
<td>470</td>
<td>85°C</td>
<td>8 x 9</td>
<td>360</td>
<td>2000</td>
</tr>
<tr>
<td>W</td>
<td>10</td>
<td>470</td>
<td>85°C</td>
<td>6.3 x 11</td>
<td>350</td>
<td>2000</td>
</tr>
<tr>
<td>X</td>
<td>10</td>
<td>470</td>
<td>85°C</td>
<td>6.3 x 11</td>
<td>320</td>
<td>2000</td>
</tr>
<tr>
<td>Y</td>
<td>10</td>
<td>470</td>
<td>85°C</td>
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*See datasheet for information on test conditions. Typically at rated temperature and voltage, but may or may not apply ripple current. Datasheets for example capacitors stated only max temperature with rated voltage were applied.
Apply rated ripple and bias at rated temperature.

Oven and ripple current heating causes electrolyte evaporation.

Turn off electricity and cool to room temperature.

No. Continue testing.

Did ESR have a >200% increase from the initial value?

Measure ESR

Electrical characterization

Weight: 1.432 g

Weigh.
## Testing – Trends in Traditional Data

### Weight Loss

![Graph showing linear relationship between time and weight loss.](image)

Linear throughout entire test lifetime of an E-cap population.

### % Increase ESR

![Graph showing exponential relationship between time and % increase in ESR.](image)

Exponential behavior that is relatively constant until approach time to failure.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Impact on Rate of Weight Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>▲</td>
</tr>
<tr>
<td>Applied ripple current</td>
<td>▲</td>
</tr>
<tr>
<td>Heat dissipation</td>
<td>▼</td>
</tr>
<tr>
<td>Space between bung and can</td>
<td>▲</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Impact on Time to 200% Increase in ESR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrolyte stability</td>
<td>▲</td>
</tr>
<tr>
<td>Initial ESR measurement</td>
<td>▼</td>
</tr>
</tbody>
</table>
1. Critical weight loss at 200% increase in ESR is calculated using the ESR-Weight Loss curve
2. Rate of weight loss is extrapolated to the critical weight loss and the corresponding time is recorded as the accelerated test lifetime
Puncture a hole in the capacitor.

Oven heating causes electrolyte evaporation.

Turn off heat and cool to room temperature.

Weigh.

Did ESR have a >200% increase from the initial value?

Measure ESR

Electrical characterization

Yes. Testing is complete.

No. Continue testing.

Weight: 1.432 g
Testing – Accelerated Wear-Out Failure Mode

Critical weight loss test

Dried out, off white paper indicative of electrolyte evaporation.

Grey paper indicative of electrolyte saturation.

As-received
Testing – Benefits of Accelerated Approach

- 500 – 1,000 hours of testing for rate of weight loss and critical weight loss data
  - Time is dependent on capacitor size
  - Traditional testing lasts 1,000 to >10,000 hours with significant variability (0.5x – 3x) when compared to datasheet lifetime
- Allows for determination of relative reliability of capacitors with comparable electrical and physical characteristics under same test conditions
  - Useful for determining which supplier is more reliable for the same application
  - Traditional testing calculates actual time to failure for a given population of capacitors
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The accelerated test approach was used to compare the behavior of the following two E-caps:

### Supplier Comparison Table

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<tr>
<th>Supplier</th>
<th>Capacitance (µF)</th>
<th>Size (mm)</th>
<th>Rated Lifetime (hrs)</th>
<th>Voltage (V)</th>
<th>Rated Ripple Current (mA RMS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>68</td>
<td>18 x 31.5</td>
<td>10,000</td>
<td>450</td>
<td>1575</td>
</tr>
<tr>
<td>B</td>
<td>68</td>
<td>18 x 40</td>
<td>&gt;15,000</td>
<td>450</td>
<td>1517</td>
</tr>
</tbody>
</table>

*Ripple applied at 120 Hz.*
Accelerated Life Test – Suppliers A & B Rate of Weight Loss

450 V, 68 μF

- **Supplier A**: Rate of Weight Loss ≈ \(\frac{1}{2}\) **Supplier B**: Rate of Weight Loss
- **Supplier A** capacitors have a better seal between the can and bung
Accelerated Life Test – Suppliers A & B Critical Weight Loss

450 V, 68 μF

- Supplier A<sub>Critical Weight Loss</sub> ≈ Supplier B<sub>Critical Weight Loss</sub>
- Chemical stability of Supplier A and Supplier B electrolyte is comparable
Accelerated Life Test – Suppliers A & B Comparison

- Accelerated life test results indicate that the Supplier A E-cap is more reliable than Supplier B
- This is opposite what the datasheet lifetimes suggest
The accelerated test approach was used to compare the behavior of the following E-caps:

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<tbody>
<tr>
<td>C</td>
<td>2.2</td>
<td>10 x 20</td>
<td>10,175</td>
<td>450</td>
<td>43</td>
</tr>
<tr>
<td>D</td>
<td>2.2</td>
<td>10 x 20</td>
<td>5,000</td>
<td>450</td>
<td>29</td>
</tr>
</tbody>
</table>

*Ripple applied at 120 Hz.*
Accelerated Life Test – Suppliers C & D Rate of Weight Loss

450 V, 2.2 μF

- Supplier C<br>  Rate of Weight Loss ≈ 2 Supplier D<br>  Supplier C capacitors have a worse seal between the Al can and bung
Accelerated Life Test – Suppliers C & D Critical Weight Loss

450 V, 2.2 μF

- **Supplier C**
  - Critical Weight Loss ≈ 2.5
- **Supplier D**
  - Critical Weight Loss

- **Supplier C** capacitors have a more chemically stable electrolyte
Accelerated life test results indicate that the Supplier C E-cap is more reliable than Supplier D.

This supports what the datasheet lifetimes suggest.
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Conclusions

- The AI ECap accelerated life test approach is an effective way to compare the reliability of the same capacitors from different manufacturers under applied test conditions.

- Test results indicated that datasheet lifetime values can be inaccurate when compared to the reliability test results.

Comparison of datasheet lifetime, traditional test (life)time, and accelerated test time.
Stephani Gulbrandsen is a Member of the Technical Staff at DfR Solutions. Prior to this she completed a master’s degree at Georgia Tech in Materials Science and Engineering. Stephani has used her research experience to develop accelerated electrolytic capacitor testing.

In her free time she enjoys cooking and spending time with her family.