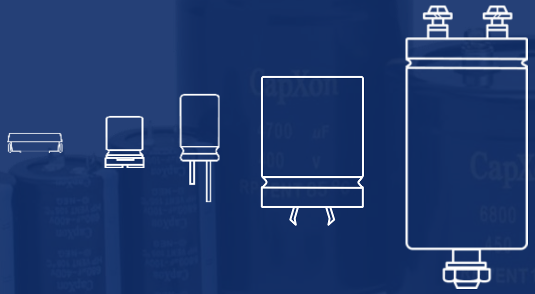
CAPXON

E-Cap technologies

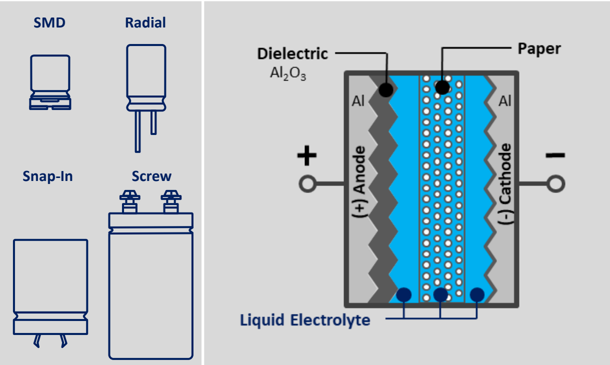
When things get rough...



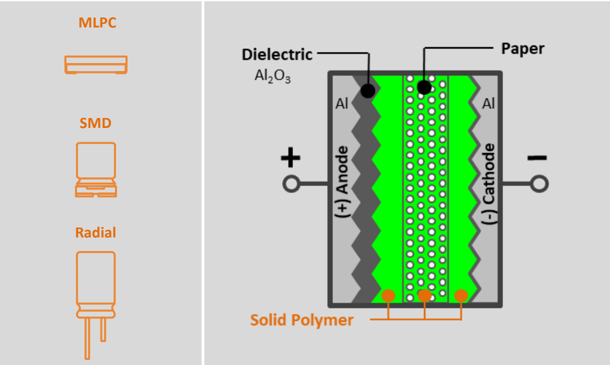
CapXon - Manufacturer for professional

aluminum electrolytic, conductive polymer and hybrid electrolytic capacitors as well as etched and formed aluminum foil

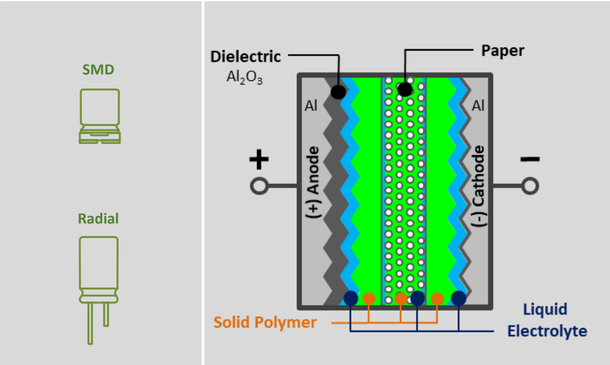
Al E-Cap Technologies



Aluminum Electrolytic	
Rated Voltage ▪ V_R	4 VDC to 650 VDC
Cathode Material	Liquid Electrolyte
Self-healing of Dielectric	Yes
Package	Widest range in all sizes
Stability	Reduced performance at low temperature
Lifetime	Limited life at high temperature
Reliability	AEC-Q200 qualified
Max. Temp. Range	85°C up to 130°C



Solid Conductive Polymer	
Rated Voltage ▪ V_R	2.5 VDC to 100 VDC
Cathode Material	Solid Conductive Polymer
Self-healing of Dielectric	No
ESR	Ultra-low ESR at high frequency
Stability	Stable for low and high temperature
Lifetime	Very stable and long life – no dry out
Reliability	Only internal standard qualification
Max. Temp. Range	85°C up to 125°C



Hybrid Conductive Polymer	
Rated Voltage ▪ V_R	16 VDC to 400 VDC
Cathode Material	Solid Conductive Polymer & Liquid Electrolyte
Self-healing of Dielectric	Yes
ESR	Very low ESR at high frequency
Stability	Even more stable than liquid type
Leakage current. ▪ I_{LEAK}	Lower leakage current than Solid Conductive Polymer Type
Reliability	AEC-Q200 qualified
Max. Temp. Range.	105°C up to 150°C

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ADVANTAGES WHAT MAKES HYBRID POLYMER SO INTERESTING?

As a mix of the two worlds, the hybrid polymer technology offers the best performance of high-capacity storage components

Liquid Electrolyte

- High voltage capabilities
- High temperature performance
- Low leakage current

+

Solid Conductive Polymer

- High ripple current
- High lifetime perfomance
- Low ESR

=

Hybrid Polymer

- Best performance of both worlds

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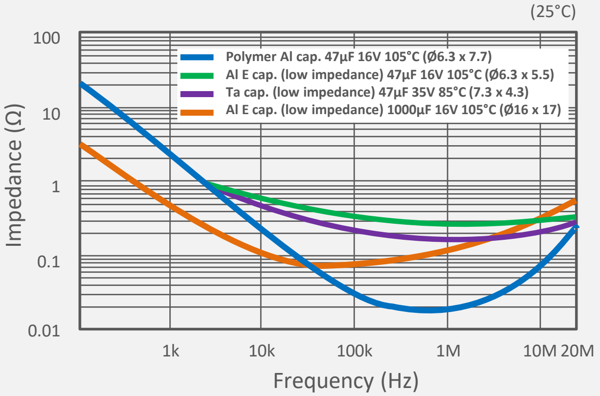
Polymer e-caps and other cap technologies

Solid Conductive Polymer Cap. | Al E Cap. | Tantalum Cap. | MLCC

Impedance vs. Frequency



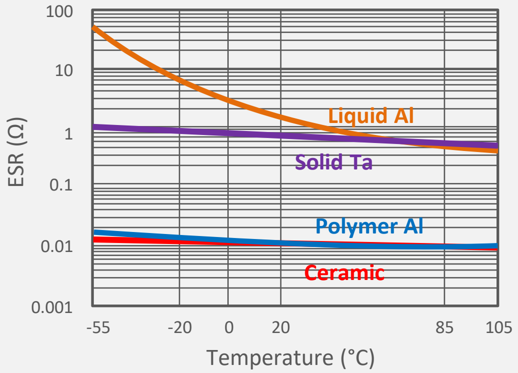
Low impedance at high frequency

Allows large ripple current

Discharges quickly

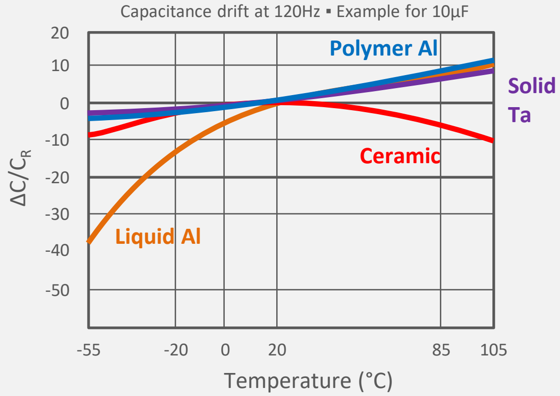
Coupling to remove the ripple in the circuit, pulse, electrostatic and other various kinds of noise

ESR vs. Temperature



ESR hardly changes with temperature

ΔC/C$_R$ vs. Temperature



Stable capacitance in a wide temp. range

Positive temp. coefficient

Extremely stable at low temp.

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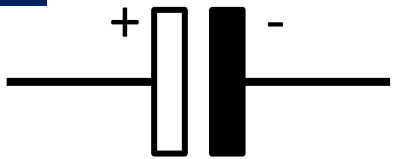
Al E-Cap Technology – it is still a parallel plate



$$C = \varepsilon \cdot \frac{A}{d}$$

Major factors for capacitance:

Surface Area A:

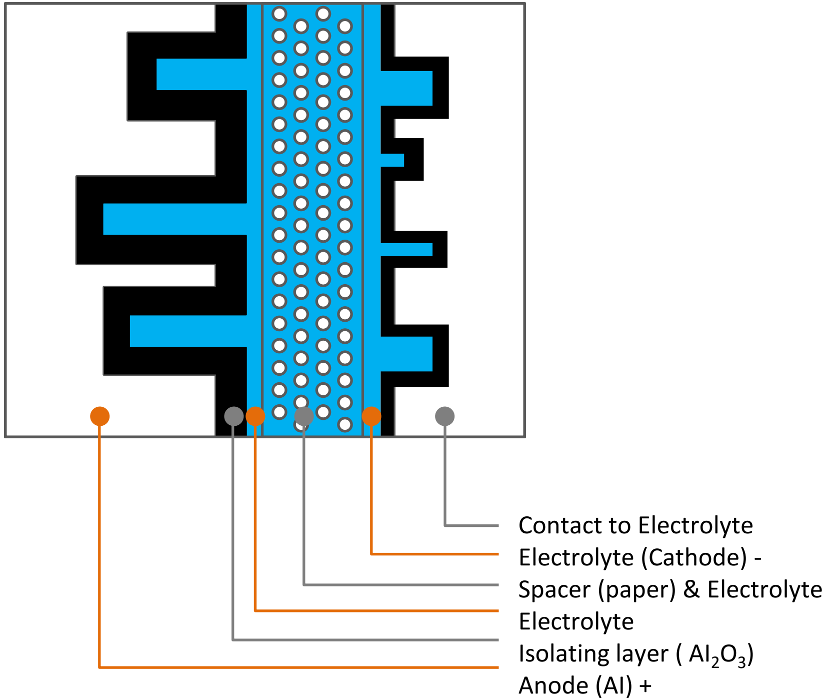
- Is enlarged by roughening of anode foil (~ 30 – 140 times)

Distance d:

- Very thin Al_2O_3 oxide layer

Electrolyte / Electrode:

- Fluid second plate of the capacitor (cathode) that contacts the dielectric layer / oxide on top of the roughened anode foil



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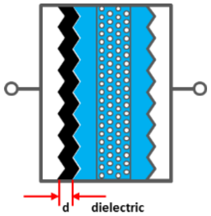
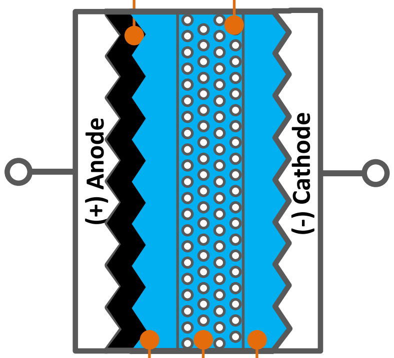
Al E-Cap Technology



$$C = \varepsilon \cdot \frac{A}{d}$$

How to increase capacitance?

- Anode of the capacitor
- Increase the surface by etching of anode foil
- Very thin layer of dielectric forming Al_2O_3 layer
- Fill the rough surface impregnating electrolyte
- Contact cathode foil



A new electrolytic capacitor is like a fresh and full glass of beer ;-)

Model of a simple aluminum electrolytic capacitor

When things get rough?

Electrical Stress

- Applied Voltage
- Surge Stress
- Applied Ripple
- Charge / Discharge Speed

Mechanical Stress

- Vibration
- G-Shock

Ambient Stress

- Temperature
- Relative Humidity

>> Temperatue is the major factor for aging of e-caps

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Importance of ESR

The ESR* is influenced by…

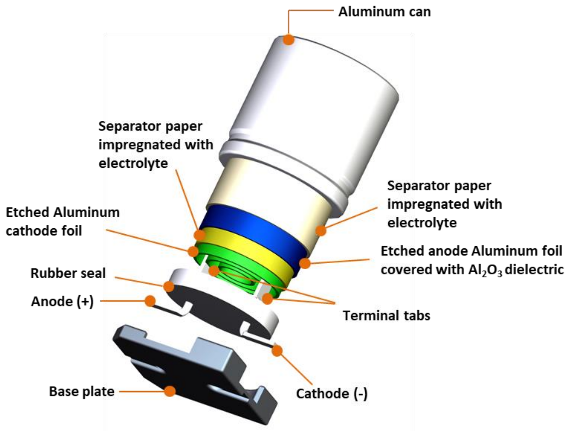
*Equivalent Series Resistance

Ohmic losses

- the contact resistances of the electrode contact
- the connection to the external connections
- the connections themselves

Dielectric losses

- tan δ



Problem of Power Dissipation

<u>Example:</u>

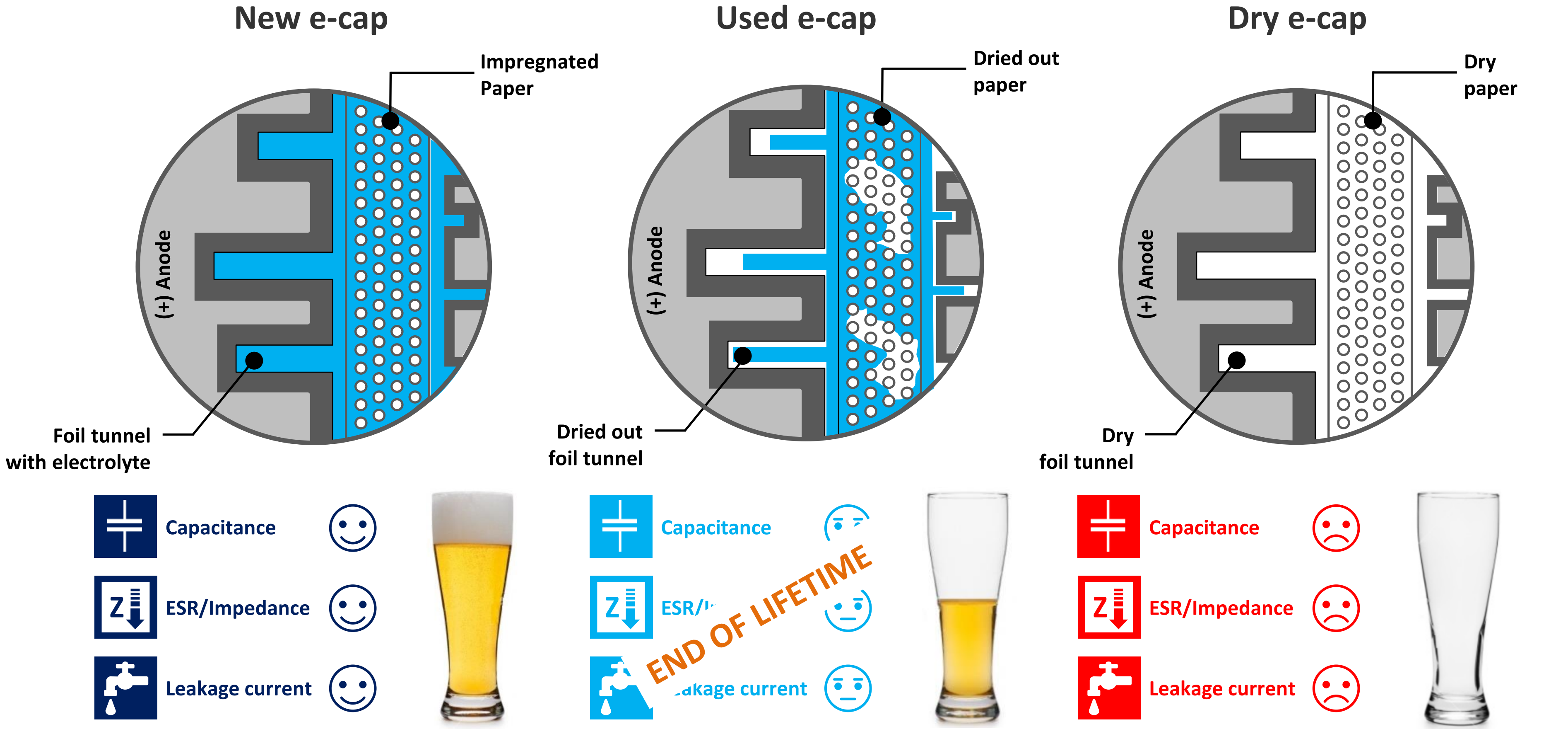
ESR = 800mΩ and I_{AC} at 120Hz = 3.5A

This results in a power loss of

$$P = (3.5A)^2 \cdot 800m\Omega = \underline{\underline{9.8W}}$$

How does it smell when the cap is cooking?

Aging of Al E-Cap capacitors



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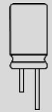
E-Cap Technology Comparison

Case	V_R (V)	C_R (µF)	Size ø DxL (mm)	Technology	Part Number	ESR (mΩ, 100kHz)	Leakage current (µA) after 2 min	Maximum permissible ripple current (mA, RMS)	Temperature Range	Endurance (h)
	16	270	8 x 11.5	**Liquid**	GF271M016F115ETD	**120**	**43**	**600**	-40°C to +105°C	3000
			8 x 9	**Hybrid**	AS271M016F090PTD	**26**	**43.2**	**2000**	-55°C to +105°C	7000
			8 x 11.5	**Polymer**	PL271M016F115PTD	**9**	**864**	**5600**	-55°C to +105°C	2000

Aluminum Electrolytic

$$L_A = L_0 \cdot 2^{\frac{T_{0\_Max} - T_A}{10°C}}$$

10°C reduced
2 x lifetime

Endurance Calculation

3000h@105°C

95°C	6000 h
85°C	12000 h
75°C	24000 h
65°C	**48000 h**

Hybrid Polymer

$$L_A = L_0 \cdot 2^{\frac{T_{0\_Max} - T_A}{10°C}}$$

10°C reduced
2 x lifetime

Endurance Calculation

7000h@105°C

95°C	14000 h
85°C	28000 h
75°C	56000 h
65°C	**112000 h**

Solid Conductive Polymer

$$L_A = L_0 \cdot 10^{\frac{T_{0\_Max} - T_A}{20°C}}$$

20°C reduced
10 x lifetime

Endurance Calculation

2000h@105°C

95°C	6325 h
85°C	20000 h
75°C	63246 h
65°C	**200000 h**

L_0… Endurance value per datasheet
L_A… Expected life within application
T_0… Max. temp. according datasheet
T_A… Application temperature

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Understanding the EOL?

Example: CapXon - KL Series / Al E-Eap Radial THT with 105°C max.:

Lifetime Test		
Endurance 105°C (V_R & I_R applied)	Test	**5 000 hours**
	$\Delta C/C_R$	≤ ±20% of initial measured value
	tanδ	≤ 200% of initial specified value
	I_{Leak}	≤ the initial specified value

Aging by stress in application will result in:

- **Capacitance drop**
- **ESR increase**
- **DF increase**
- **I_{leak} increase**

Endurance describes a referenced spec. change window and not a failure mode / defect after time!

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Understanding the EOL?

Example: CapXon - KL Series / Al E-Eap Radial THT with 105°C max.:

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	I_{Leak}	≤ the initial specified value

Manufacturer describes the spec change…

But **design engineers define the EOL / application stability criterias!**

If capacitance margin is higher vs. manufacturer spec.
>> you prolong the expected life

If capacitance margin is lower vs. manufacturer spec.
>> you shorten the expected life

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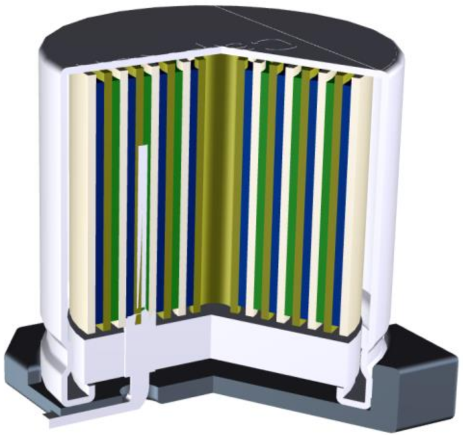
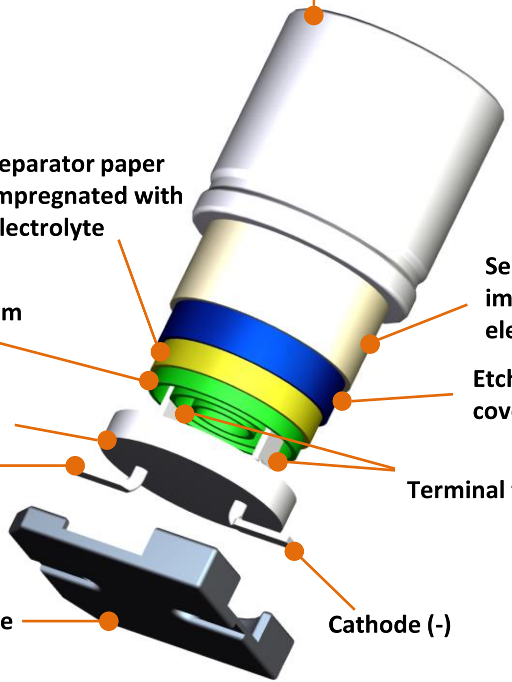
E-Caps – Construction

SMD type





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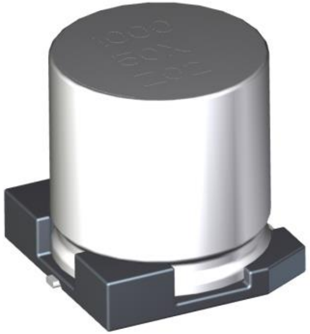
E-Cap Technology

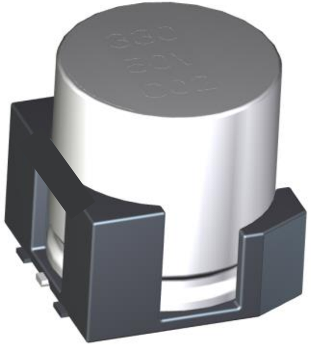
SMD type ▪ Standard vs. Vibration Proof (VP)

10G

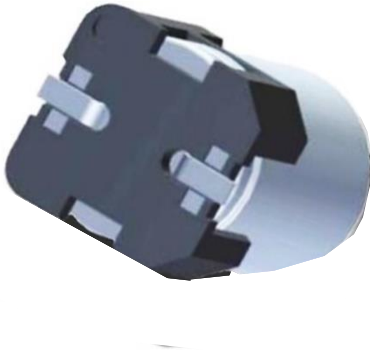


2 Pads

30G – 50G



6 Pads



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Al E-Caps

Main Failure Modes

- **Open circuit** – ***Wear-out Failure Mechanism***

  The typical failure mechanism of polymer capacitor is caused
  from the deterioration of conductive polymer, as polymer chain conductivity drops
  at aging it causes:

  >> C↓ - capacitance decrease
  >> ESR↑ - ESR increase
  >> DF↑ - DF increase

- **Short circuit** – ***Accidental Failure Mode***

  Rarely caused and worst case situation, can happen due to breakdown of dielectric Al_2O_3 layer by exceeding allowed load or applying overstress like:

  - *Electrical stress (over-voltage or exssive applied current)*
  - *Thermal stress*
  - *Mechanical Stress*

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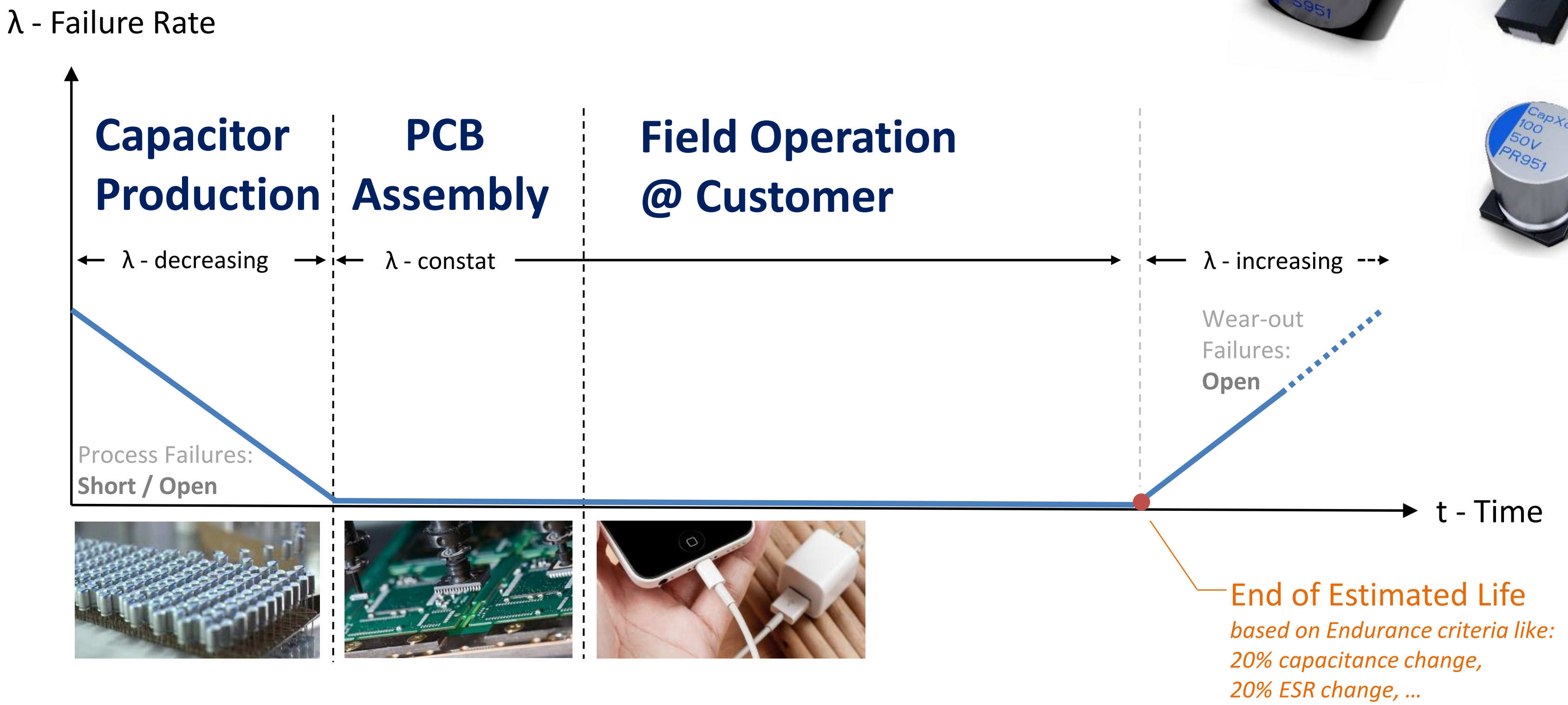
Al E-Caps

Main Failure Modes



Harsh Environment vs. AEC-Q200

Is AEC-Q200 the answer to all your problems for vibration and high temp.?

>> From my perspective it is just a partial yes, but you need to dig deeper!

- **Be aware it covers a proper variety of tests, but does not tell you anything about production stability and monitoring of such continuous quality**
- **There is no definition of Al e-caps tesing for vibration levels above 5G**
- **Temperature limits are set by manufacturer**

Customer needs to closely read what was really tested and to which extend!!!

Professional is ...

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