Difference Between Traditional Aluminum Electrolytic and Polymer Capacitors

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Capacitor Workshop

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Short Introduction of Today‘s Presenter

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Background:

- More than 10 years of work experience in electronics industry
- Background in Electronics, Power Supply Development and formerly worked as Field Application Engineer
- In charge for technical product services and application support of capacitor division at WE

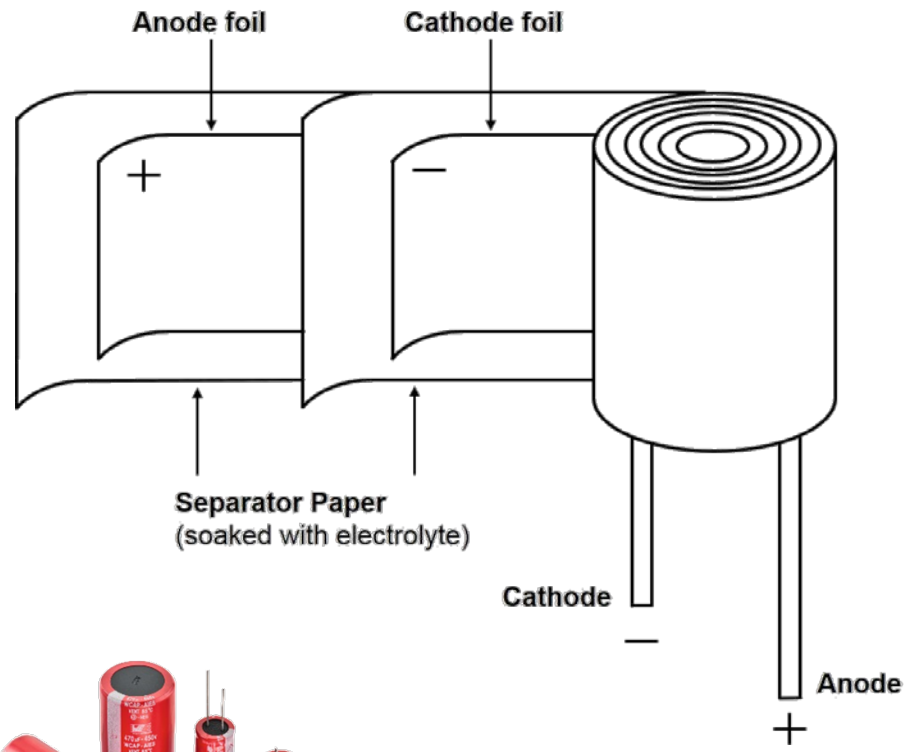
Agenda

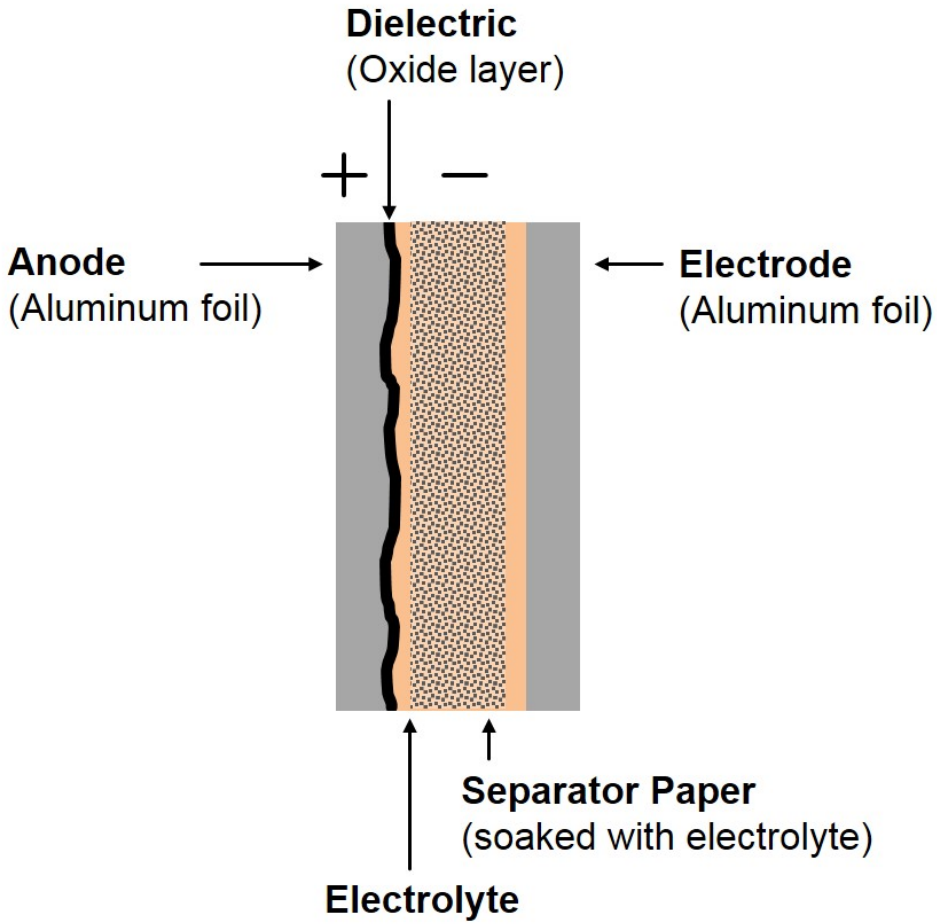
- Construction of Aluminum Capacitors
- Equivalent Circuit
- Self – Healing Capabilities
- Expected Lifetime Calculation

CONSTRUCTION OF ALUMINUM CAPACITORS

Construction of Aluminum Capacitors

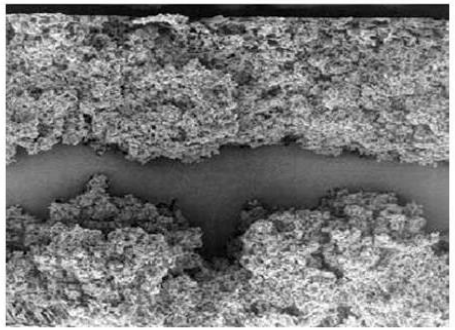
- **Construction of Aluminum E-Cap**



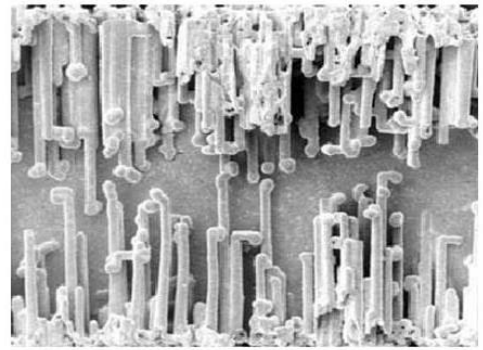


Construction of Aluminum Capacitors

- Anode foil **low rated voltage** less roughness
- Surface treatment (electrolysis)
- Minimum foil thickness => mechanical and voltage strength

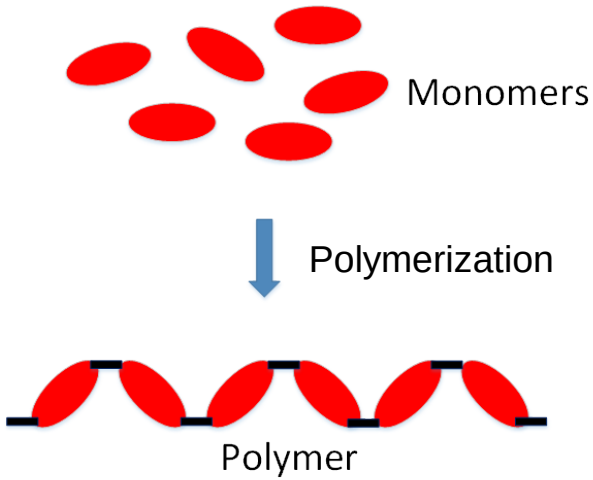


- Anode foil **high rated voltage** high roughness



Construction of Aluminum Capacitors

- **Impregnated anode foil**
- **Similar winding process**
- **Usage of Monomer**
- **Drying and aging process up to 8hrs**



EQUIVALENT CIRCUIT

Equivalent Circuit – ESR

- **ESR causes heat generation**
- **Max. allowable ΔT due to self-heating**
- **Maximum ESR normally specified at 120Hz or 100kHz, @20°C**
- **ESR can be calculated like following:**

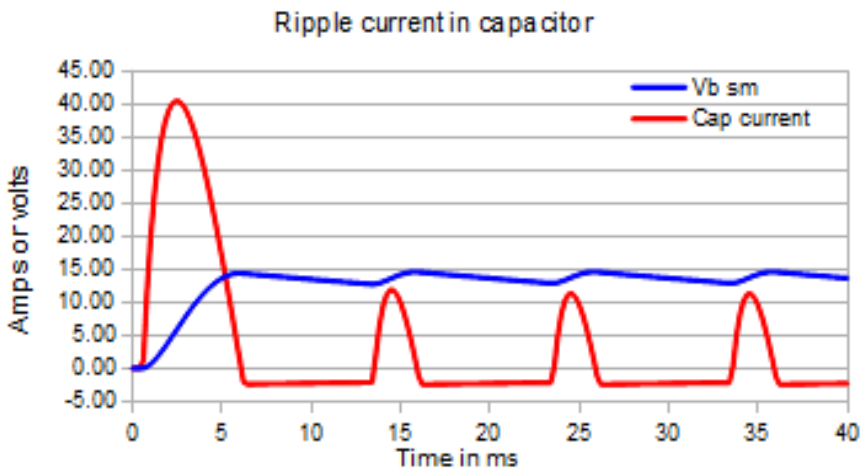
$$ESR = \frac{tan\,\delta}{2 * \pi * f * C} = tan\,\delta * X_C$$

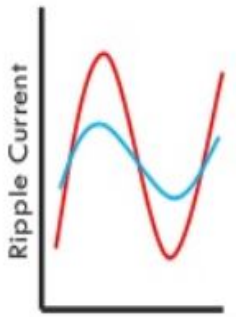
$$X_C = \frac{1}{2 * \pi * f * C} = \frac{1}{\omega * C}$$

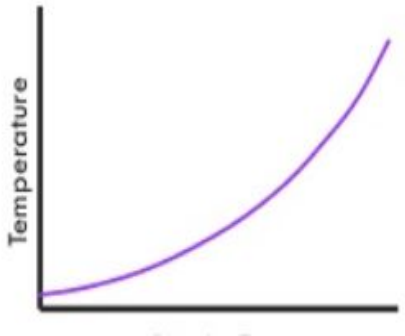
Quality of mechanical connections e.g. the pin stitching will massively influence the ESR value

Equivalent Circuit – ESR

- **Ripple current is the AC component of an applied source (SMPS)**
- **Ripple current causes heat inside the capacitor due to the dielectric losses**
- **Caused by the changing field strength and the current flow through the capacitor**



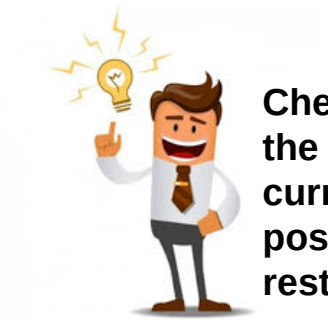




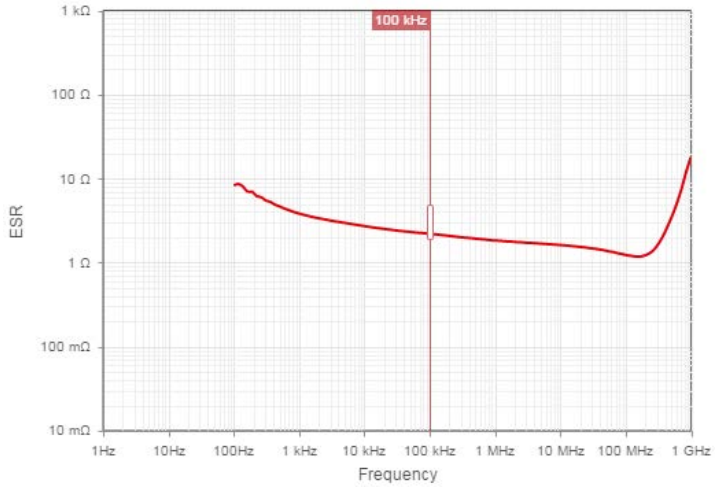
Electrolytic conductivity (reciprocal of electrolytic resistivity) of Aluminum Polymer caps a hundred times higher compared to Electrolytic: 4S/cm to 0.04S/cm

Equivalent Circuit – ESR & Ripple Current Capabilities

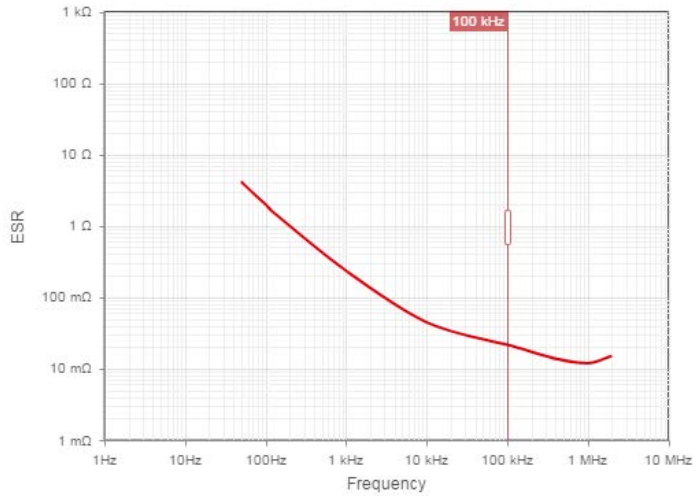
- **Aluminum Electrolytic 10µF, 25V (865060440001)**
- **ESR@100kHz ~ 2.2Ω**
- **Ripple Current rating@100kHz ~ 90mA**



Check the datasheet for the frequency and ripple current ratings, as well as possible environmental restrictions

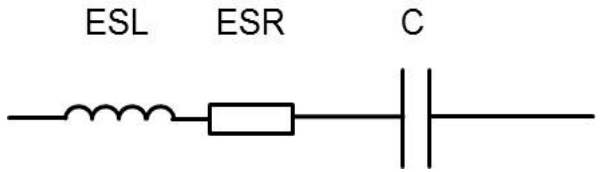


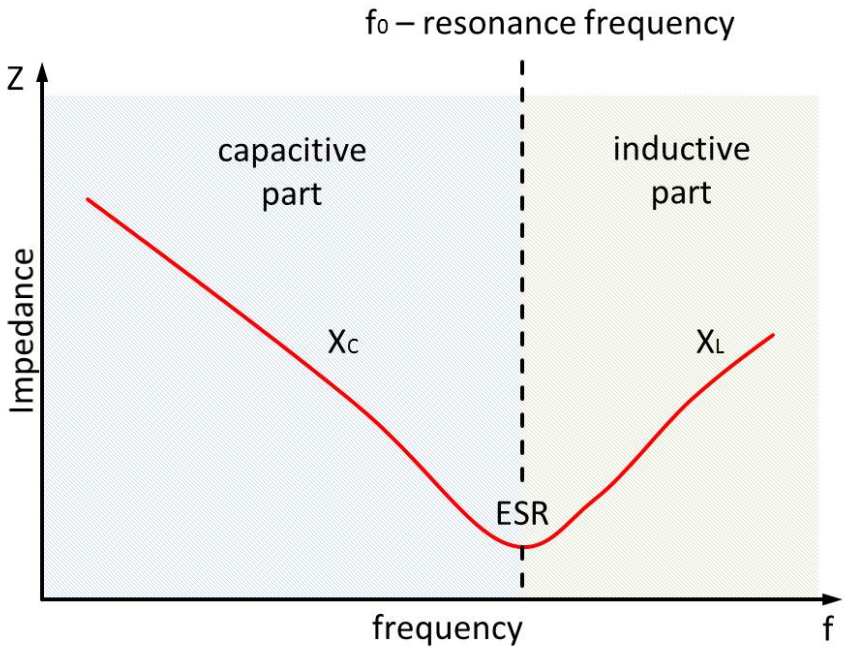
- **Aluminum Polymer 10µF, 25V (875105544001)**
- **ESR@100kHz ~ 21.6mΩ**
- **Ripple Current rating approx. 2.2A**

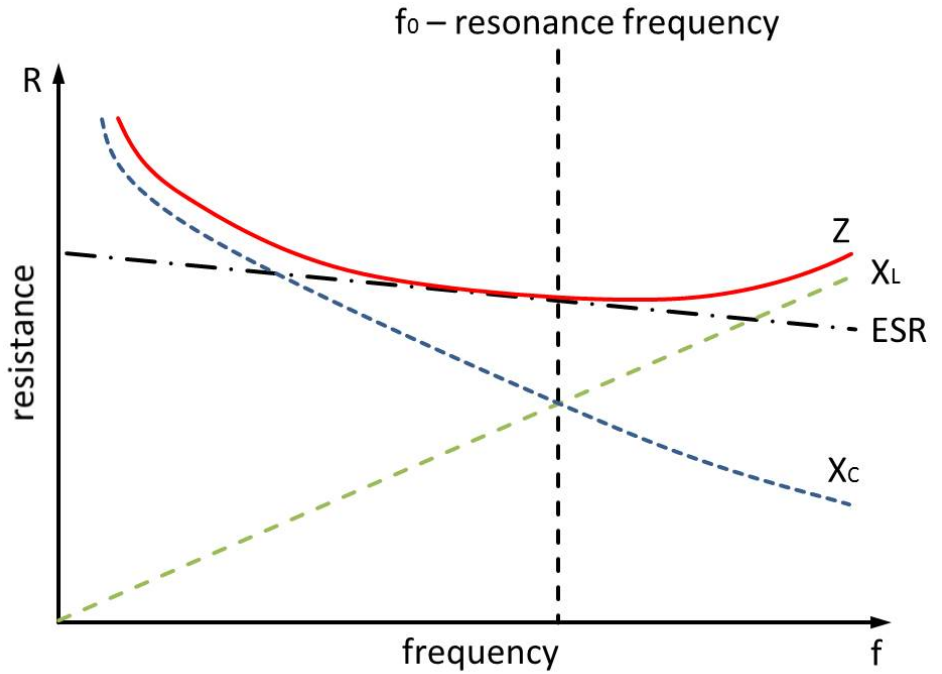


Equivalent Circuit – Impedance Z

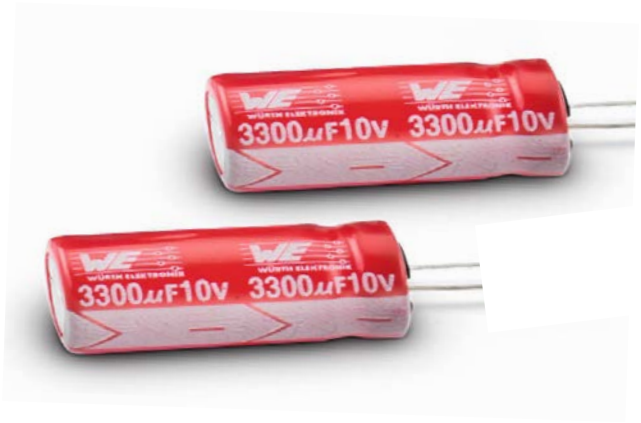
- $Z = \sqrt{ESR^2 + (X_L - X_C)^2} = \sqrt{ESR^2 + \left((2 * \pi * f * ESL) - \left(\frac{1}{2*\pi*f*C}\right)\right)^2}$







Equivalent Circuit – Impact of Form Factor – ESL



N – number of windings

N ↓

ESL ↓

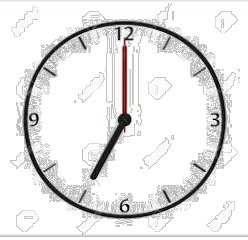
N ↑

ESL ↑

- **Basically same capacitance and voltage values**
- **Different DxL relation**
- **Similar effective foil size**
- **Less foil windings**
- **Similar behavior to coils**

If low ESL is most important for your application, but there are height restrictions, its possible to bent the pins by 90° and use in parallel to PCB, like mainly in flat screens

Equivalent Circuit – Leakage Current



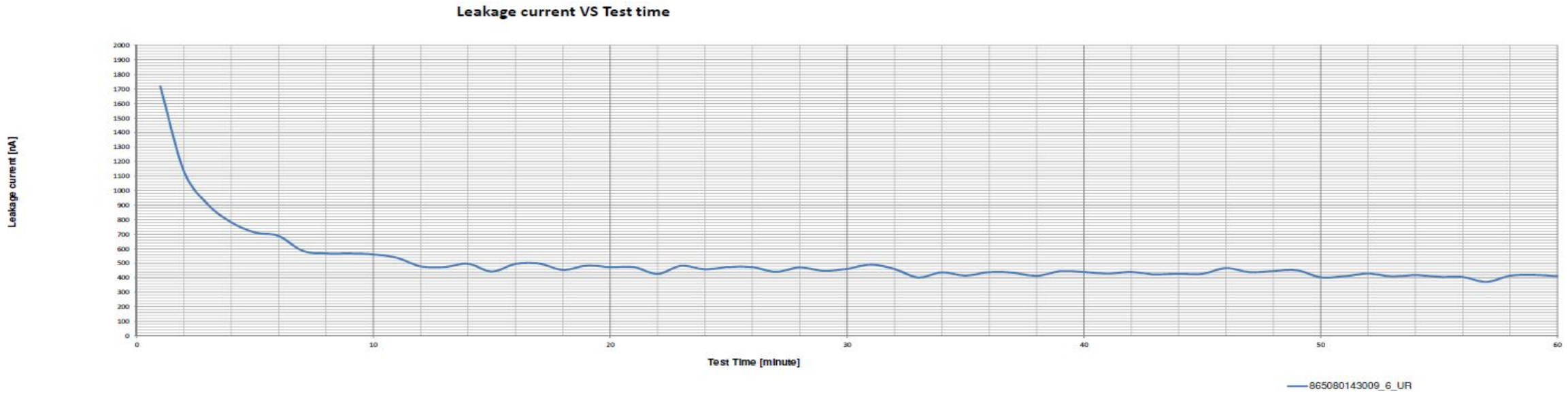
- **WE- P/N: 865080143009**
- **220µF; 6.3V; 2,000h; 105°C**

Measurements in nA @0:00 – 6:00 min

1	2	3	4	5	6	
1720	1134	907	782	712	688	

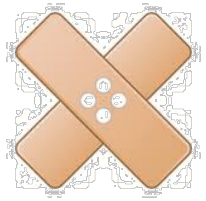
Measurements in nA @56:00 – 60:00

56	57	58	59	60	
405	371	414	420	410	



SELF – HEALING CAPABILITIES

Self – Healing Capabilities



- **Aluminum Electrolytic capacitors possess self healing capabilities**
- **Self healing means – recover the thickness of the AL_2O_3 dielectric layer**
- **Thickness of dielectric layer important for the capacitor's performance**
- **Thickness will be reduced by:**
  - **Time – chemical reaction (oxidation) will reduce the dielectric layer while the capacitor is not in operation**
  - **Overvoltage**
  - **Wrong polarity**
- **Thickness will be increased in operation or with forming (low voltage applied with current limits controlled)**

Self – Healing Capabilities – Comparison

- **Aluminum Electrolytic**

- **Liquid electrolyte contains water**
- **Oxygen ions will react with AL**
- **Increase the dielectric layer**
- **Capability will be reduced over time**

- **Aluminum Solid Polymer**

- **Solid Polymer inside the element**
- **Limited air between the can & the element**
- **Very limited self-healing possible**

EXPECTED LIFETIME CALCULATION

Expected Lifetime Calculation

- **Aluminum Electrolytic**

$$L = L_0 * 2^{\frac{T_0 - T_x}{10}}$$

L = expected lifetime

L_0 : Specified lifetime

T_a =temperature of application

T_0 : Max. Operating Temperature [℃]

T_x : Ambient temperature [℃]

- **Aluminum Polymer**

$$L = L_0 * 10^{\frac{T_0 - T_x}{20}}$$

L = expected lifetime

L_0 : Specified lifetime

T_a =temperature of application

T_0 : Max. Operating Temperature [℃]

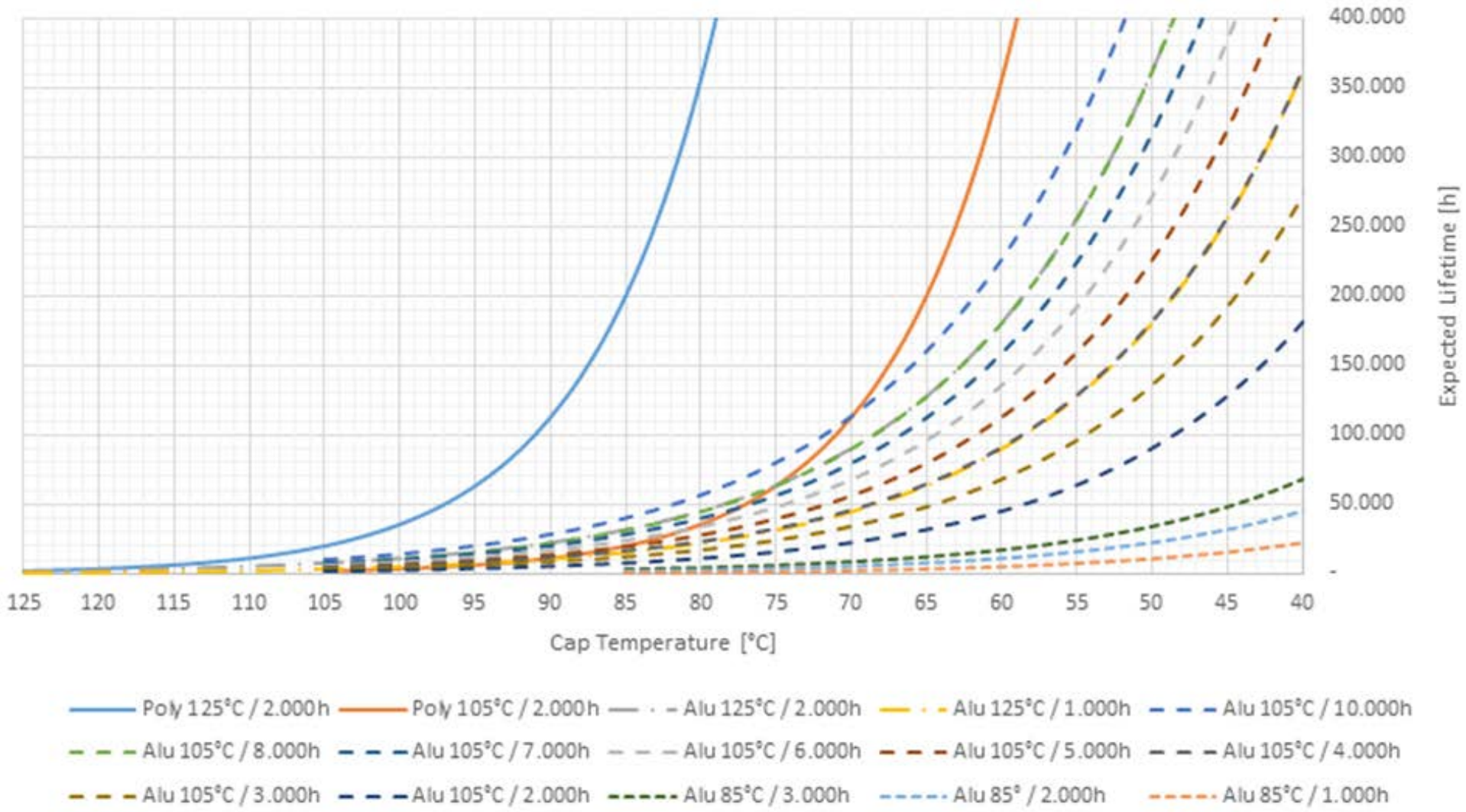
T_x : Ambient temperature [°C]

Comparison of Expected Lifetime: Aluminum vs. Polymer Capacitor

Application Temperature	AL Polymer Cap	AL Electrolytic Cap	Factor Poly vs. Alu	Alu-Cap	Factor Poly vs. Alu
105 °C	2.000 h	**2.000 h**	1,00	**5.000 h**	0,40
95 °C	6.300 h	4.000 h	1,58	10.000 h	0,63
85 °C	20.000 h	8.000 h	2,50	20.000 h	1,00
75 °C	63.000 h	16.000 h	2,94	40.000 h	1,58
65 °C	**200.000 h**	**32.000 h**	**5,25**	**80.000 h**	**2,50**
55 °C	630.000 h	64.000 h	8,84	160.000 h	3,94
45 °C	2.000.000 h	128.000 h	14,62	320.000 h	6,25

Comparison of Expected Load Life: Aluminum vs. Polymer Capacitor

All ratings over 10 years are very much theoretically, most AL Electrolytic Cap manufacturer may only expect lifetime calculations up to 10-15 years



Conclusion

Application	Aluminum Electrolytic	Aluminum Solid Polymer
Filter		
DC-DC Converter		
Battery powered appl.		
Low / green energy		
Low temperature		
High temperature		
Audio		
Higher vibration		

Thanks for your attention!