



Aluminum Electrolytic vs. Polymer – Two Technologies – Various Opportunities



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Wurth Electronics @APEC 2017

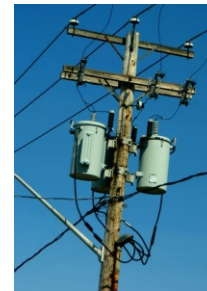
Agenda



Electrical Parameter



Technology Comparison

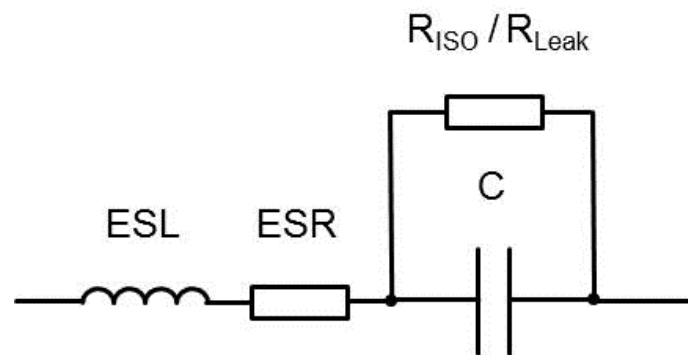


Application



ESR – How to Calculate?

- **ESR – Equivalent Series Resistance**
- **ESR causes heat generation within the capacitor when AC ripple is applied to the capacitor**
- **Maximum ESR is normally specified @ 120Hz or 100kHz, @20°C**
- **ESR can be calculated like below:**

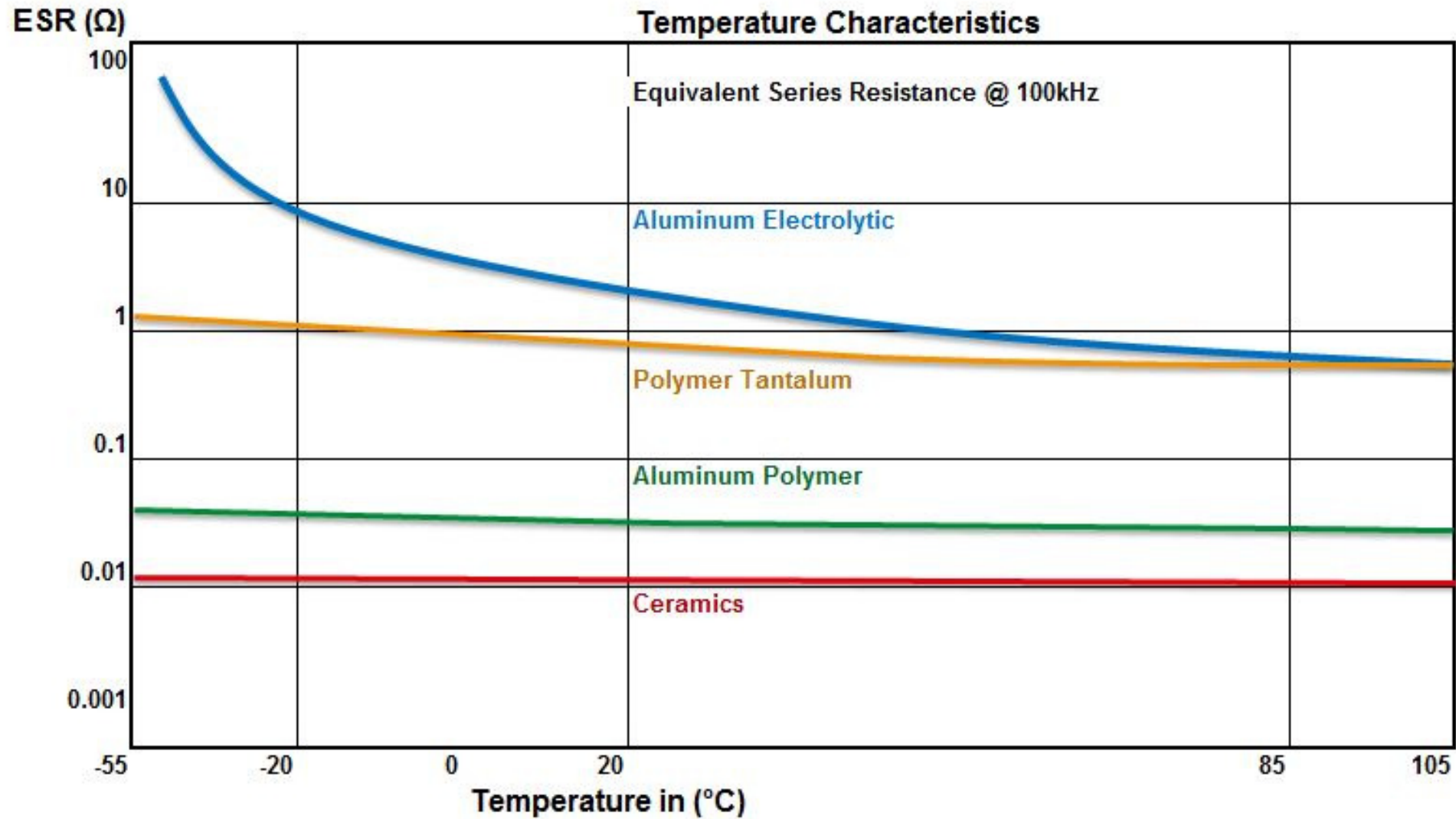


$$ESR = \frac{\tan \delta}{2 * \pi * f * C} = \tan \delta * X_C$$

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



ESR – Temperature Characteristics

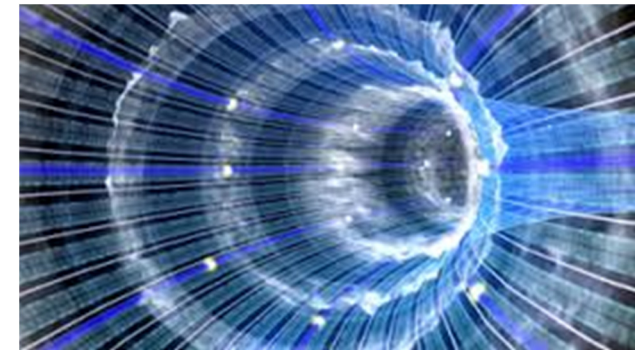


Electrolytic Conductivity



➤ Aluminum Electrolytic

- Caused by the liquid electrolyte the conductance response is deeply affected
- Rated up to 0.04 S/cm



➤ Aluminum Polymer

- Solid Polymer pushes the conductance response to much higher limits
- Rated up to 4 S/cm

Electrical Values – Who's Best in Class?

Aluminum Electrolytic

- ESR approx. 85mΩ
- Ripple Current rating approx.
630mA



Aluminum Polymer

- ESR approx. 11mΩ
- Ripple Current rating approx.
5,500mA

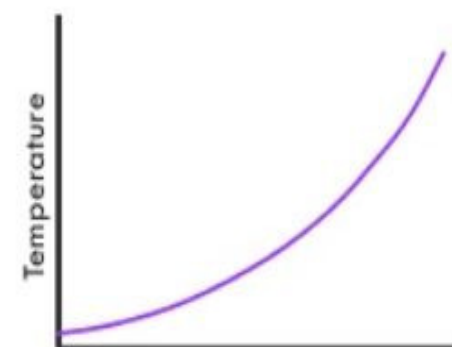
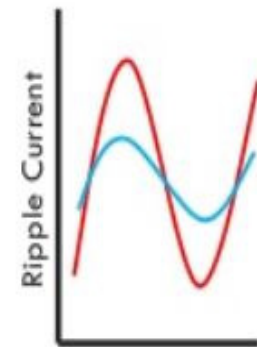
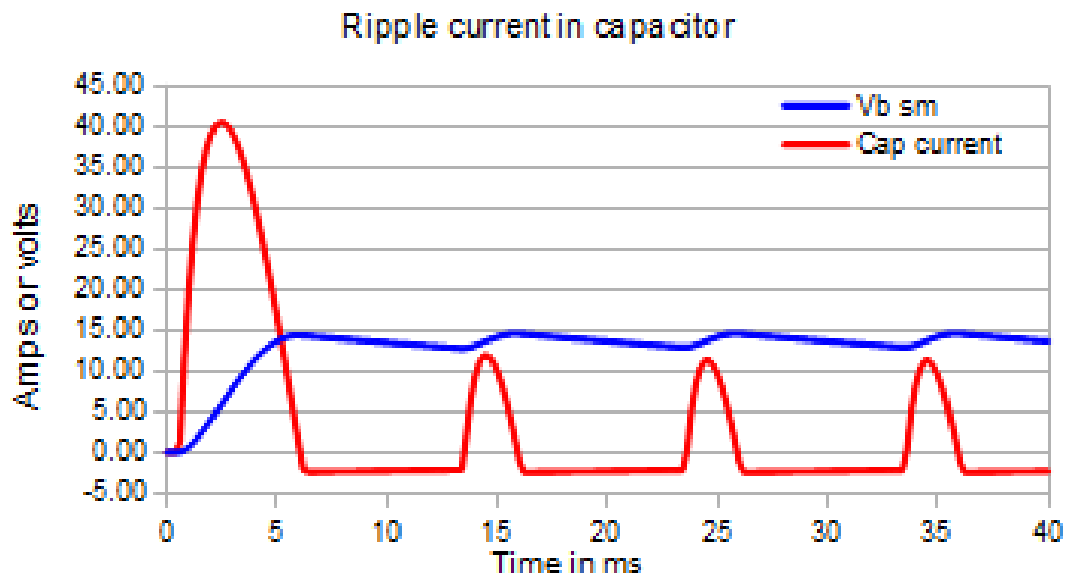
Tantalum Polymer

- ESR approx. 200mΩ
- Ripple Current rating approx.
1,900mA



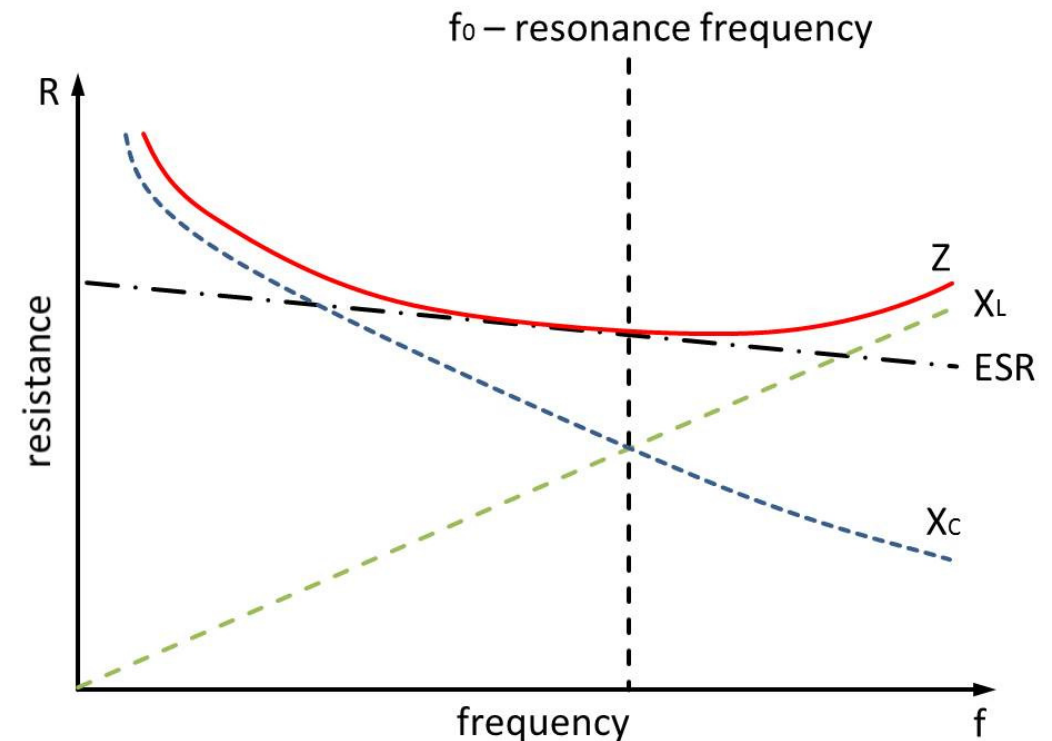
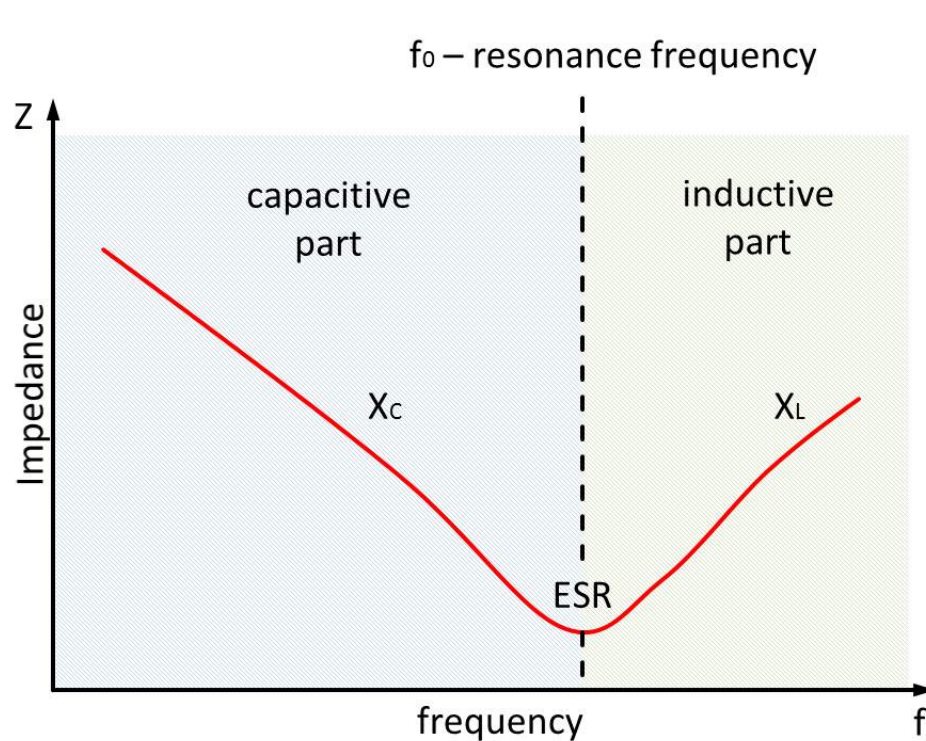
Ripple Current >> Temperature Rise

- 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



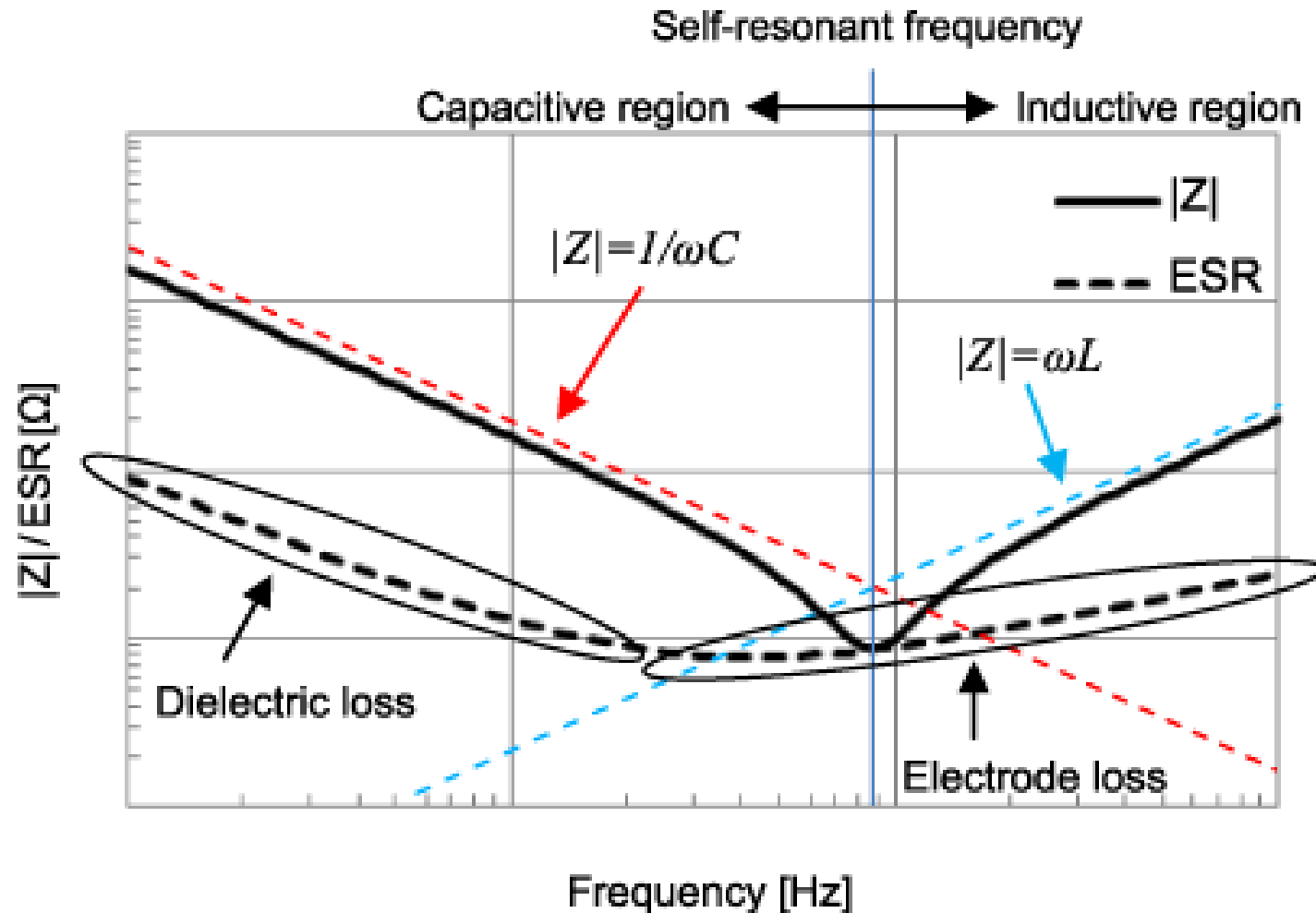
Impedance Z

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



Impedance Z

➤ Impedance over frequency added with ESR ratio

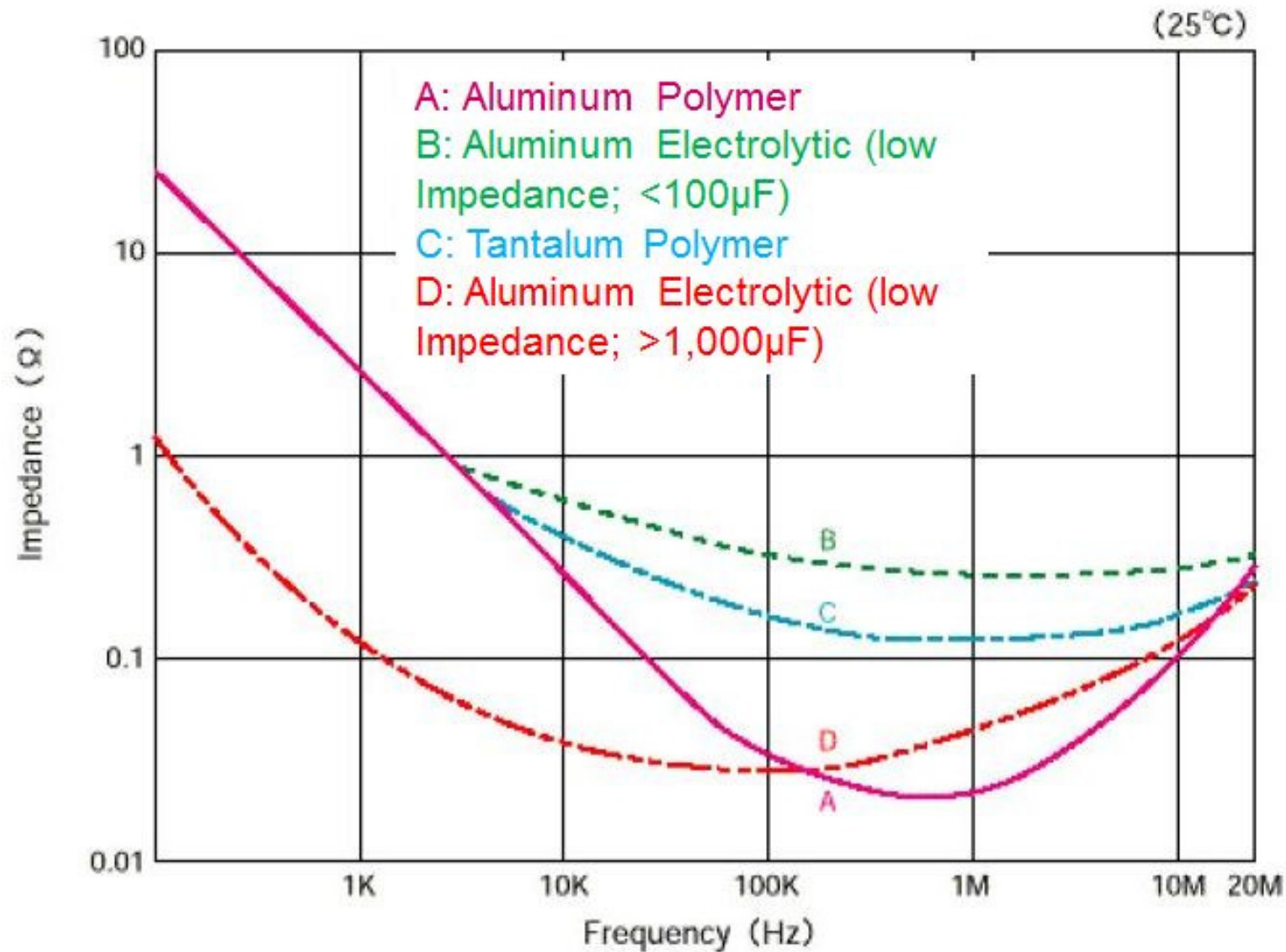


Impedance @ High Frequencies



- **Aluminum Polymer Capacitors have excellent high frequency characteristics**
- **ESR value is ultra low compared to Electrolytic's and Tantalum's within 100KHz~1MHz**
- **E.g. couple capacitors, pulse, ESD and audio equipment**

Impedance @ High Frequencies

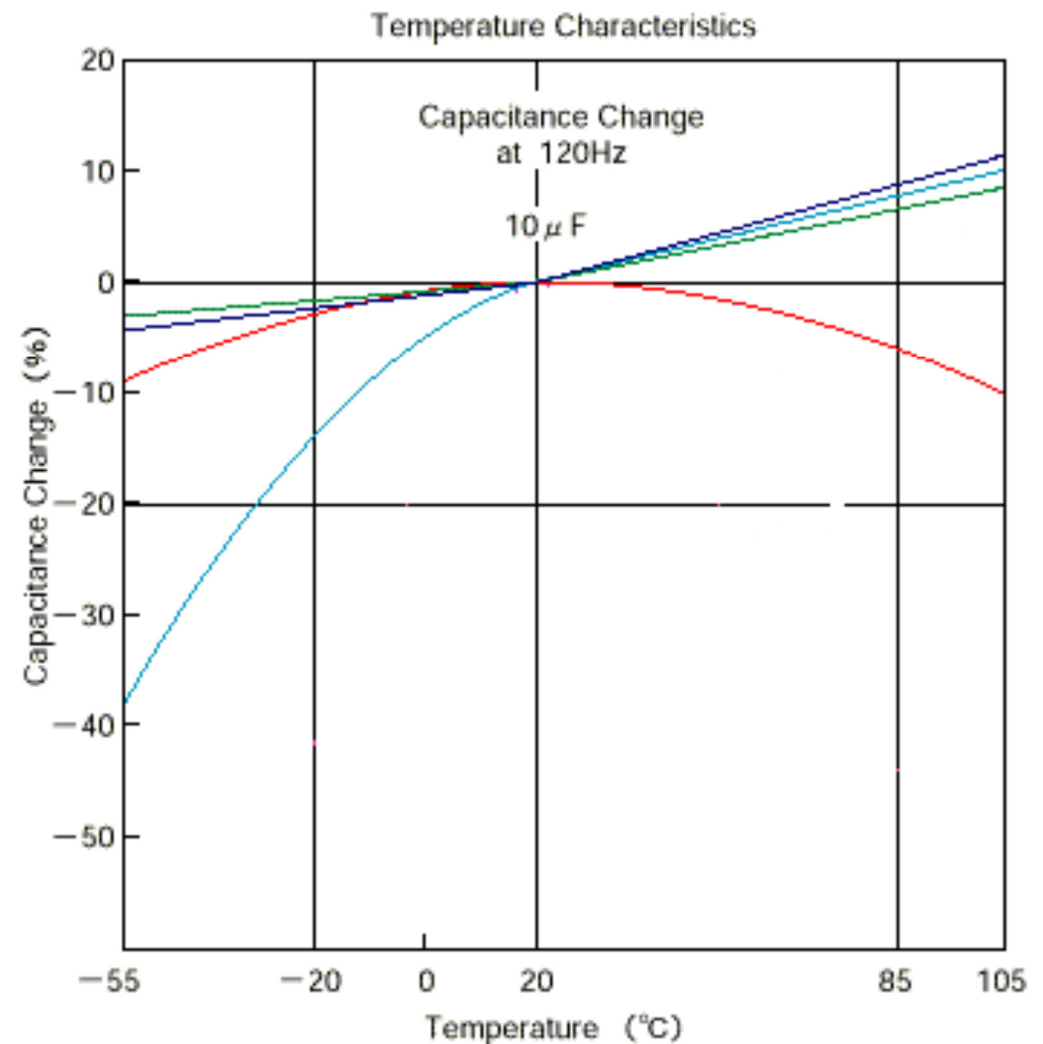


Temperature Characteristics in Comparison



Aluminum Electrolytic
Aluminum Polymer
Tantalum Polymer
Ceramic

- Aluminum Polymer with excellent low temperature stability
- Low ion mobility inside liquid results in both, capacitance decline and ESR rise

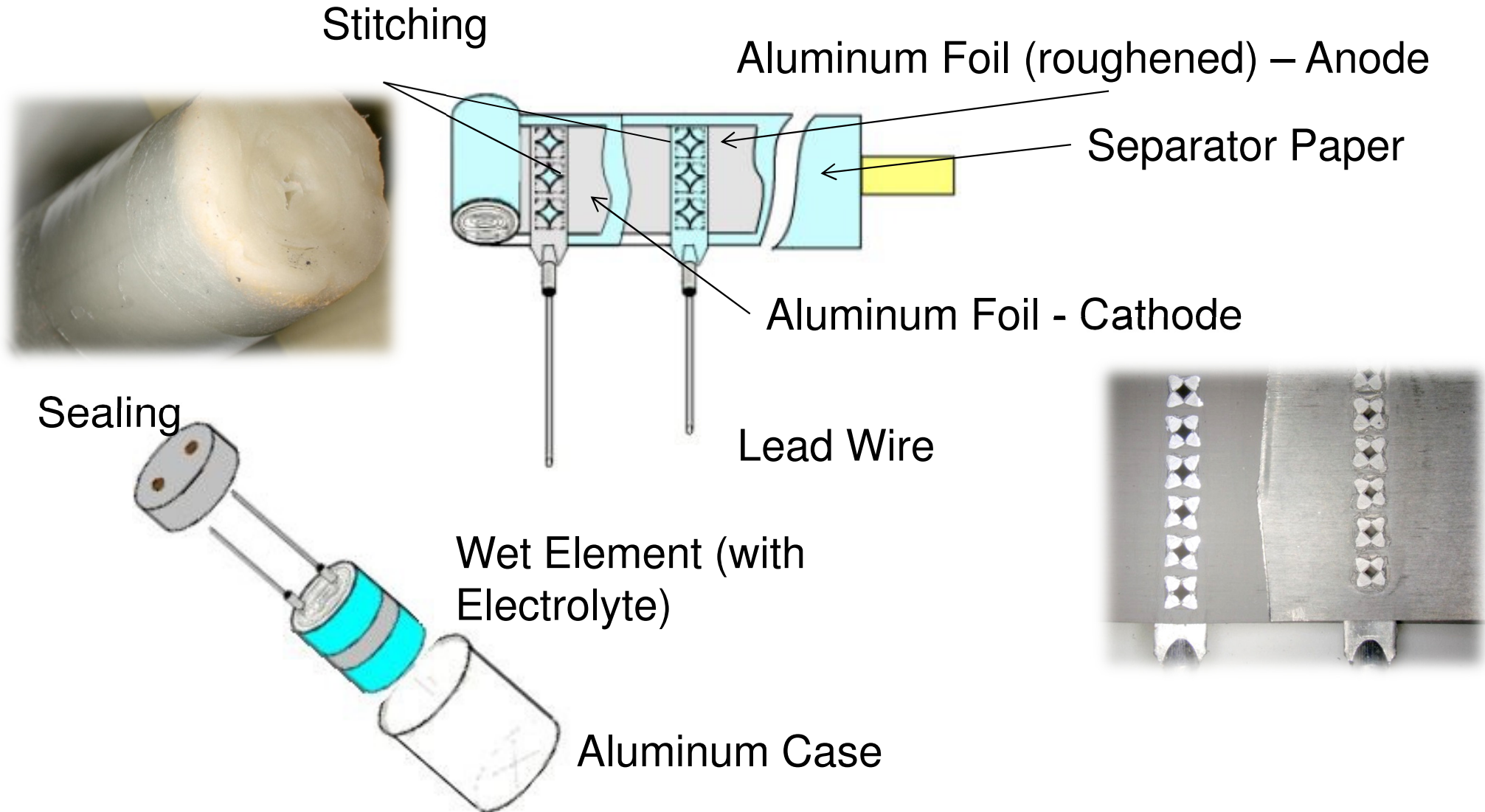




Aluminum Electrolytic Capacitor



Construction of Aluminum Electrolytic Capacitor



Roughness of Aluminum Foil

- **Anode foil of caps with low rated voltage shows less roughness – shorter process time**



- **Surface treatment to increase roughness and respectively the effective surface**
- **Maximum thickness of foil $\leq 1\mu\text{m}$**
- **Comparison: paper / separator with 6 to $8\mu\text{m}$ thickness**

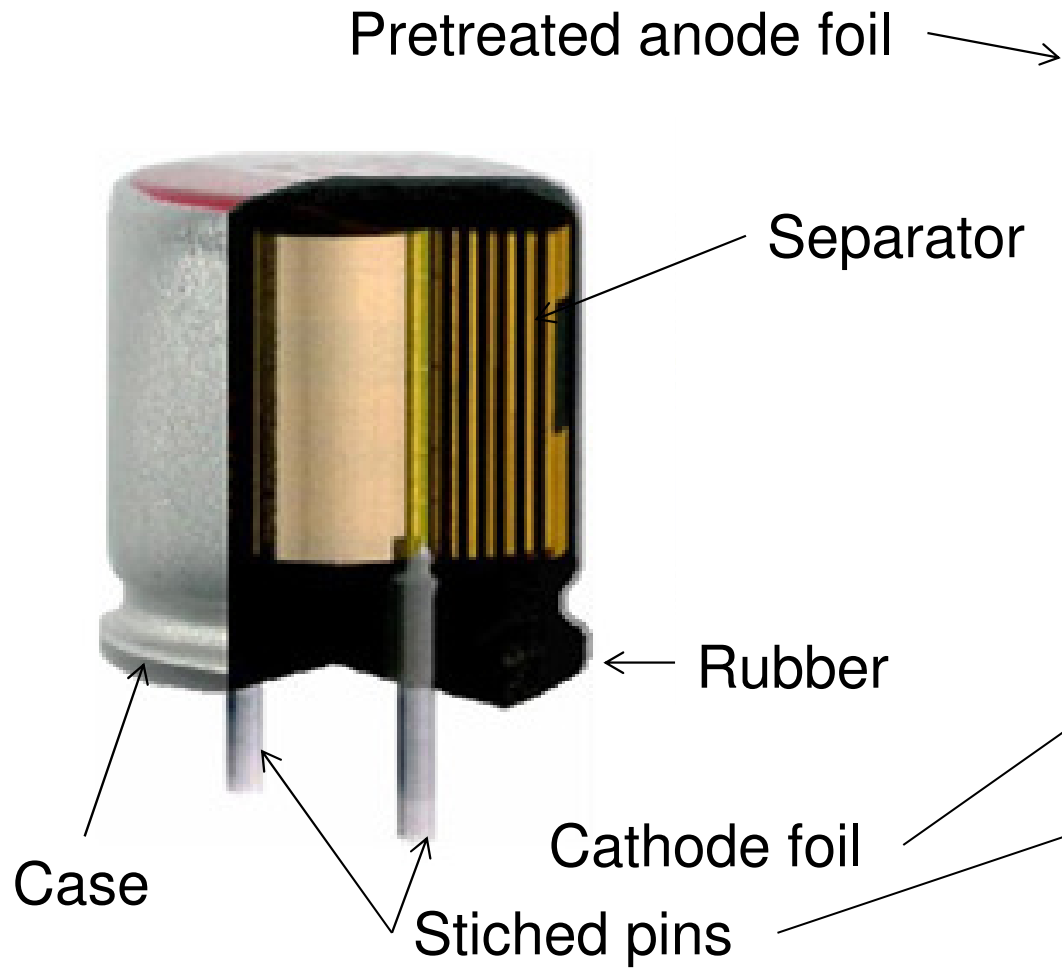
- **Anode foil for high rated voltage shows extremely high roughness – less final foil thickness – long process time**



Aluminum Polymer Capacitor



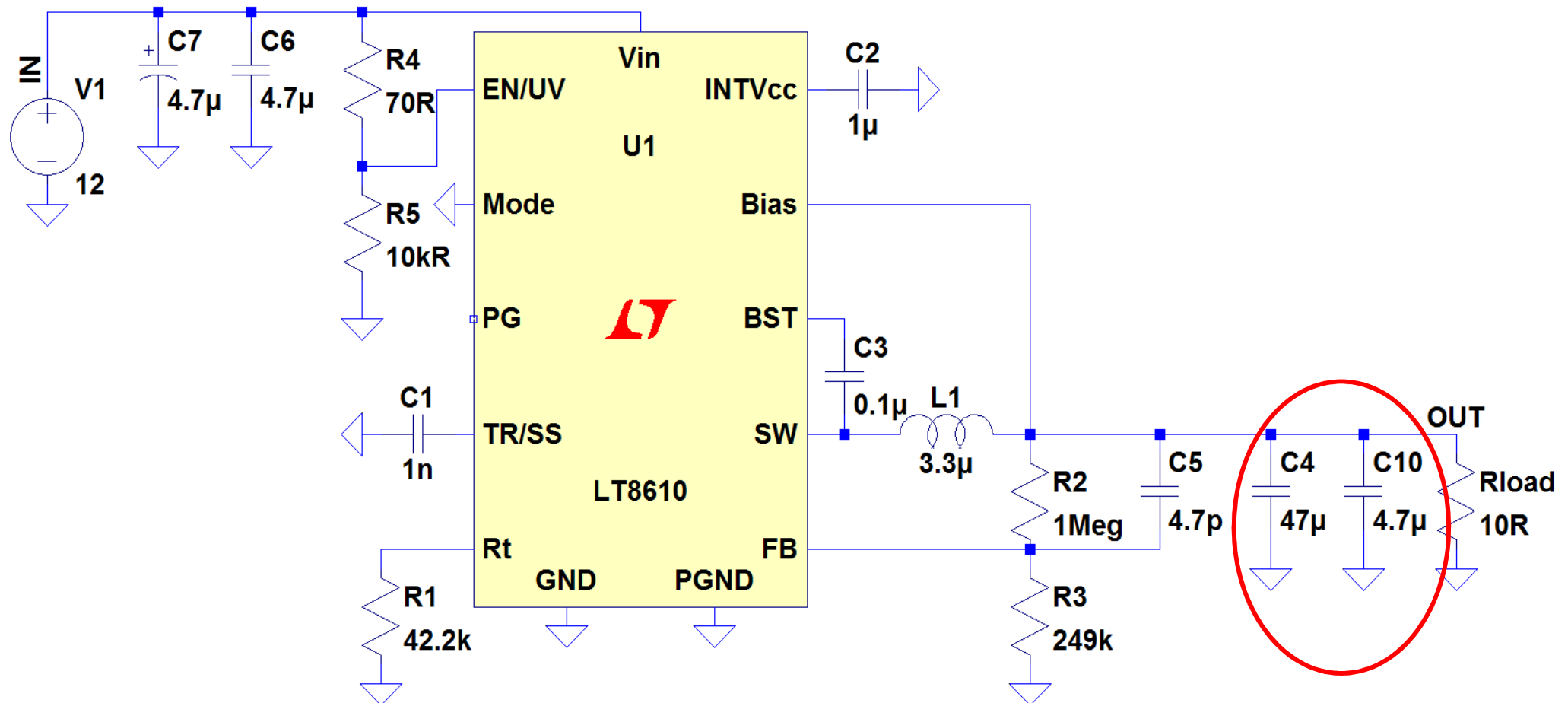
Construction of Aluminum Polymer Capacitor



Application - Output Cap Comparison Performance Lytic vs. Polymer



LT8610
Input: 12V
Output: 5V @ 0,5A



Output Cap Comparison – Electrolytic vs. Polymer



LT8610

V_{in} : 12V

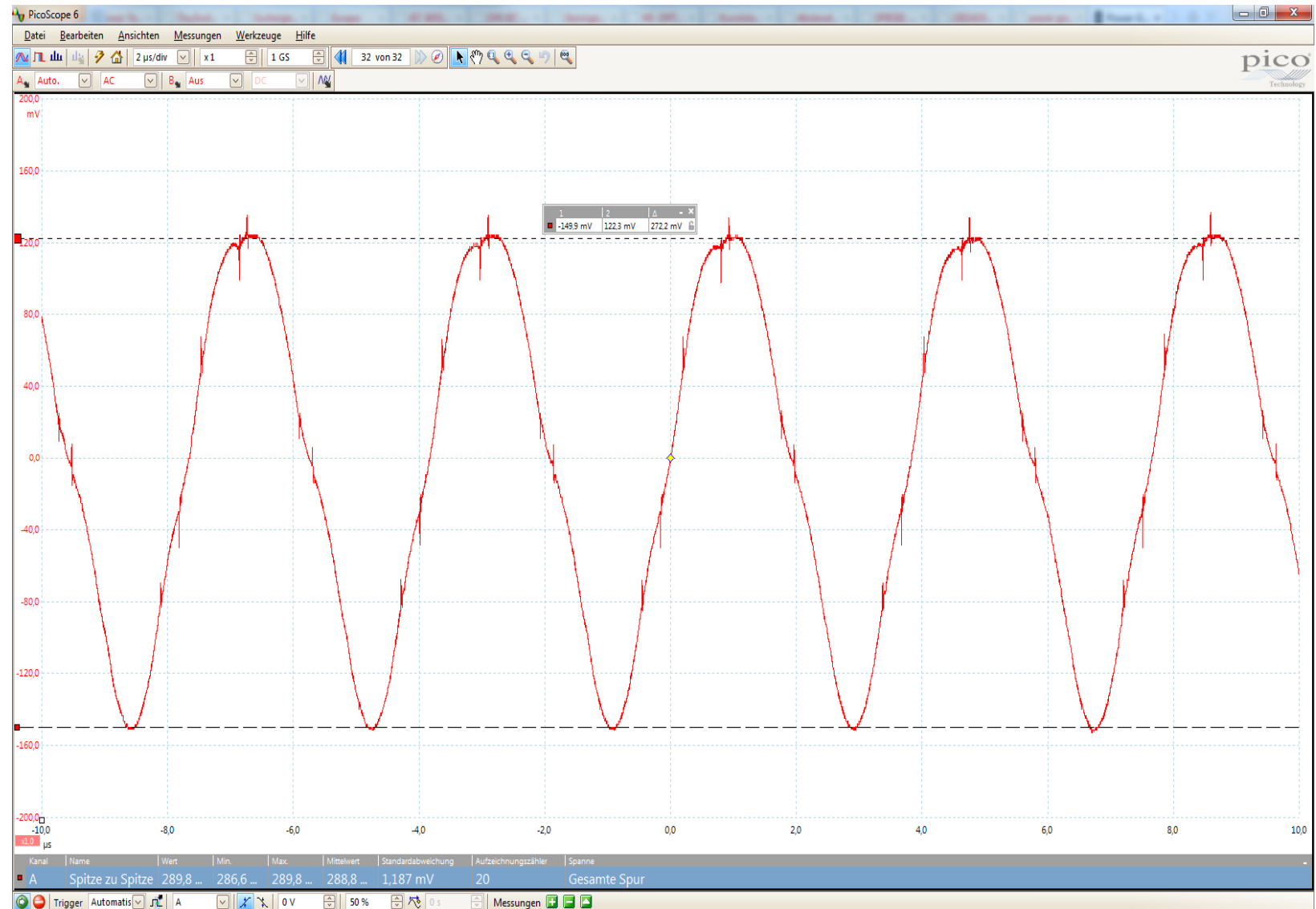
V_{out} : 5V

I_{out} : 1A

f_{sw} : 1MHz

C_{out} = **Alu-Lytic**
25V; 4.7 μ F

ΔV : 272mV



Output Cap Comparison – Electrolytic vs. Polymer



LT8610

V_{in} : 12V

V_{out} : 5V

I_{out} : 1A

f_{sw} : 1MHz

C_{out} = Polymer
25V; 4.7 μ F

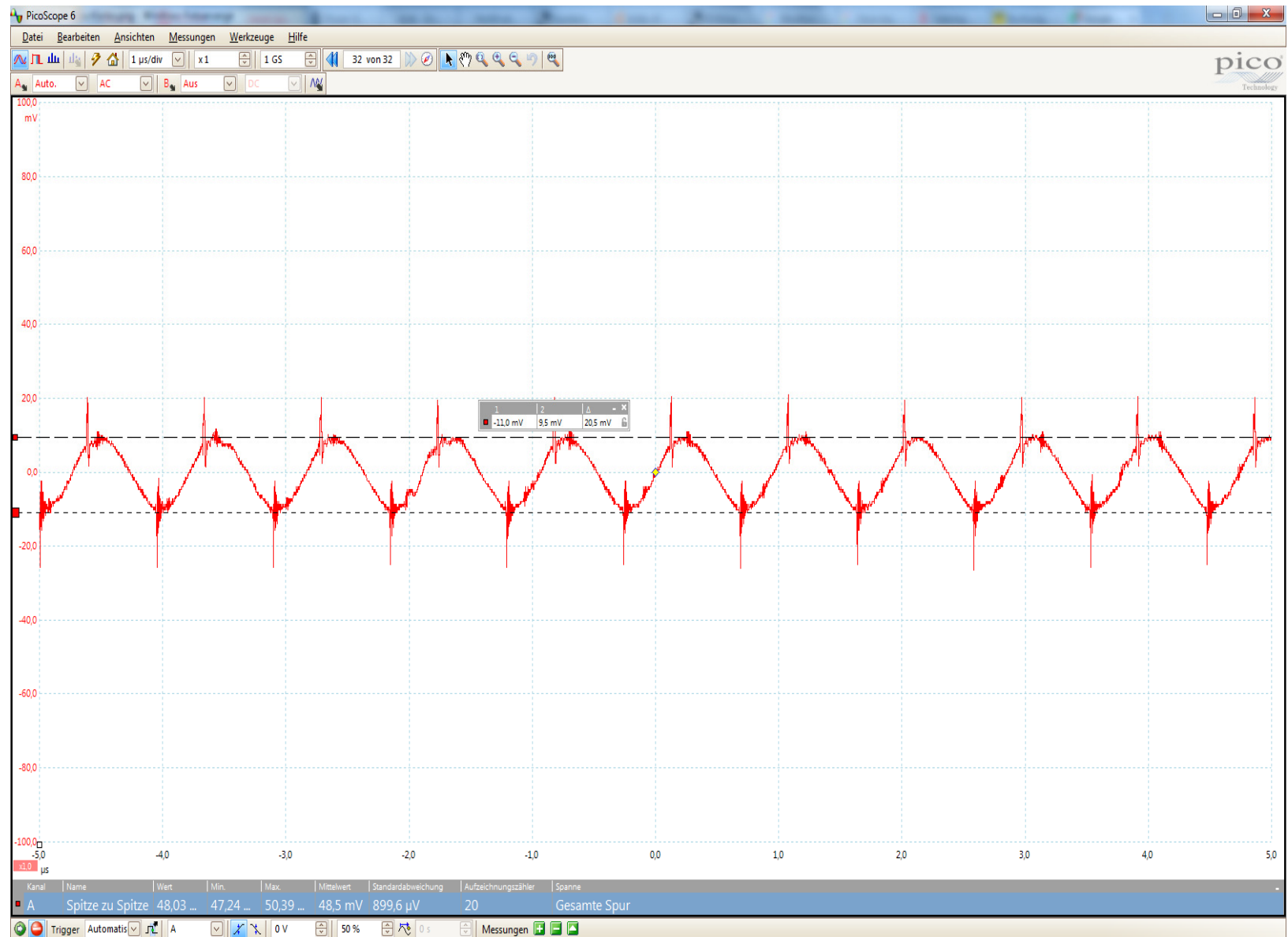
ΔV : 20.5mV

Result:

272mV

vs.

20.5mV



Comparison Polymer- / Aluminum-Electrolytic Capacitor

➤ Aluminum- Electrolytic-Capacitor

- Higher voltage ratings available (up to 600V)
- Way cheaper pricing (same capacitance and voltage rating)
- Better leakage current behavior than Polymer
- Load life will be calculated as following:

$$L_x = L_{nom} * 2^{\frac{T_0 - T_a}{10}}$$



➤ Polymer- Electrolytic-Capacitor:

- Smaller ESR than Aluminum-Cap >> higher allowable ripple current
- No dry-out behavior like Aluminum-Cap (solid electrolytic)
- Higher expected lifetime / load life
- Load life will be calculated as following:

$$L_x = L_{nom} * 10^{\frac{T_0 - T_a}{20}}$$



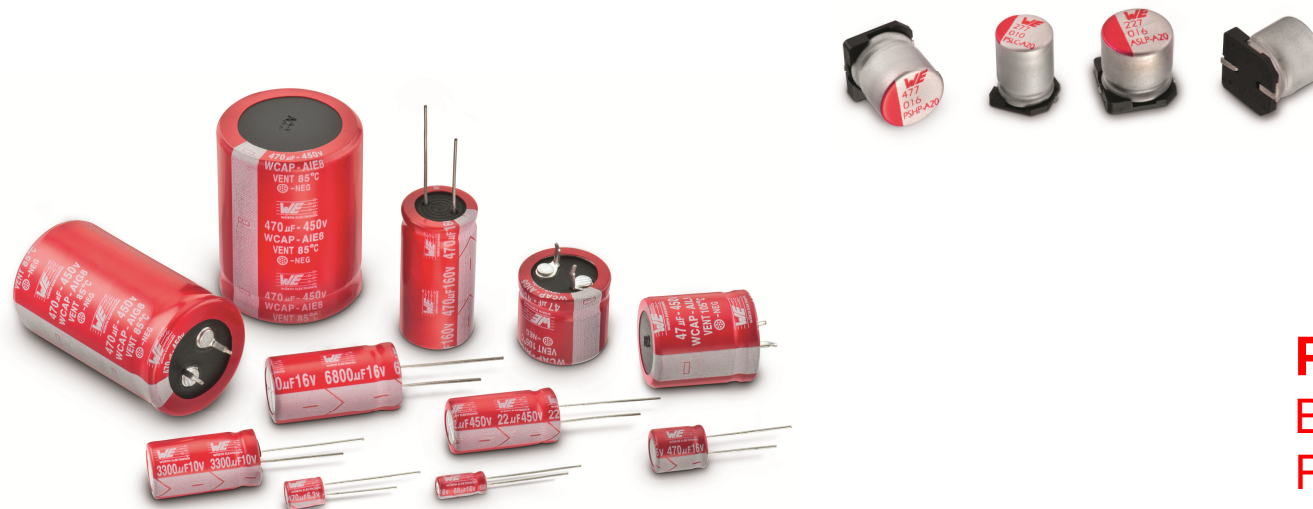
L_x = expected lifetime; T_0 = upper temperature limit ; T_a =temperature of application



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Thank you



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