HOW CAPACITORS BEHAVE UNDER EXTREME TEMPERATURES

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WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

AGENDA

- Temperature definition for different technologies
- Why we have this temperature definition?
- Temperature measurement setup and results
- What is the influence and consequence of temperature?

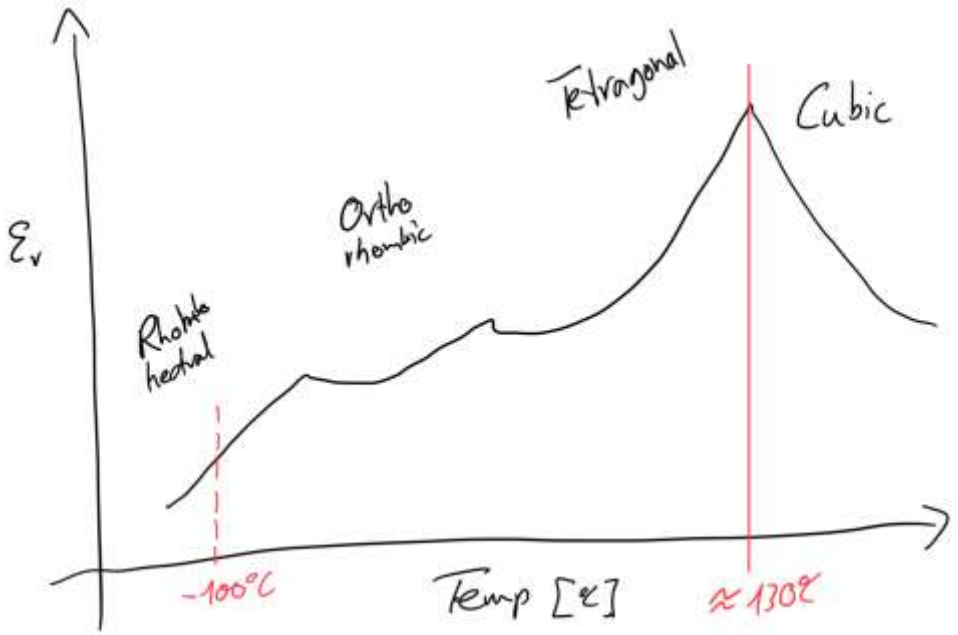
TEMPERATUR DEFINITION FOR DIFFERENT TECHNOLOGIES

TEMPERATURE BEHAVIOUR OF MLCC

Class 2 ceramic

- Consist of barium titanate
  - Consider Currie temperature
- Typical and often used specification is X7R
- Temperature behaviour defined due to the EIA coding

1st character		2nd character		3rd character	
Letter	Lower temperature limit	Number	Upper temperature limit	Letter	Capacitance change over permitted temperature range
X	-55 °C	2	+45 °C	A	± 1.0 %
Y	-30 °C	4	+65 °C	B	± 1.5 %
Z	+10 °C	5	+85 °C	C	± 2.2 %
		6	+105 °C	D	± 3.3 %
		7	+125 °C	E	± 4.7 %
		8	+150 °C	F	± 7.5 %
		9	+200 °C	P	± 10 %
				R	± 15 %
				S	± 22 %
				T	+22 % / -33 %
				U	+22 % / -56 %
				V	+22 % /-82 %



TEMPERATURE BEHAVIOUR OF ELECTROLYTIC CAPACITOR

Aluminum electrolytic and polymer capacitor

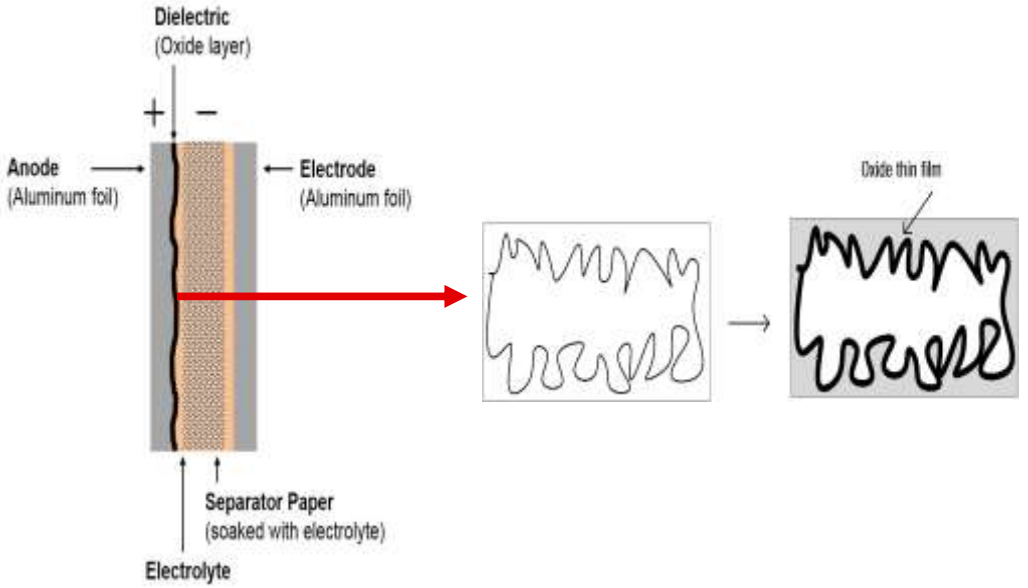
- Different operating temperature ranges
  - -25 up to 85 °C or 105 °C
  - -40 °C and -55 °C possible
  - 150 °C types available

- Low temperature
  - Electrolyte can freeze
- High temperature
  - Electrolyte can dry out
  - Damage of the used plastic materials
- Polymer is better at low temperature
  - High Temperature is critical for the electrochemistry

- Shelf Life test for aging behaviour

General Information:

Aluminum Electrolytic Capacitors	
Storage Conditions	5-35 °C, < 75% RH
Operating Temperature	-55 °C up to +105 °C
Endurance	2000 h @ / 100 V (DC) / max. Iripple
Test conditions of Electrical Properties: +20°C, 35% RH if not specified differently	
FIT according to separate documentation	
Component conform to REACh and RoHS requirements and standards	



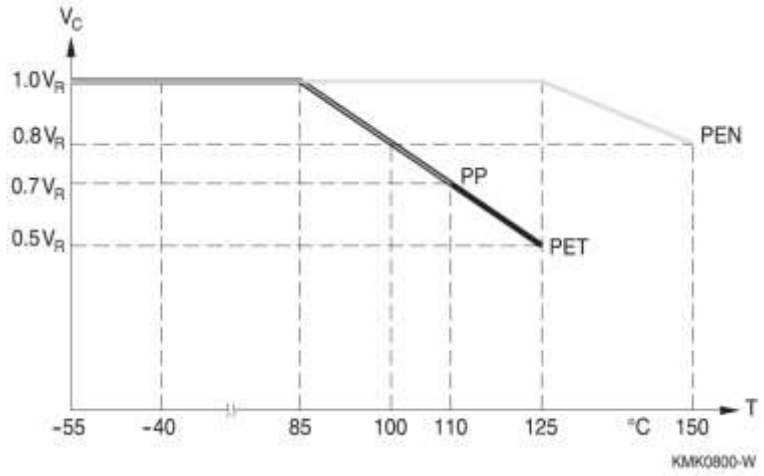
TEMPERATURE BEHAVIOUR OF FILM CAPACITOR

Film capacitor

- Temperature behaviour change due to the base material
  - Polypropylene
  - Polyester
  - PEN
- Limitation due to chemistry
- Change of parameter
  - DC voltage vs. temperature
  - DF vs. temperature
  - Capacitance vs. temperature

General Information:

X2-Safety Class Capacitor; MKP - Metallized Polypropylene		
Storage Conditions	5-35 °C, < 75% RH	
Operating Temperature	-40 °C up to +105 °C	
Maxium Selfheating (Rated)	7	°C
Climate Category: 40/ 105/ 56/ B		
Test conditions of Electrical Properties: +20 °C, 35% RH if not specified differently		
FIT according to separate documentation		
Component conform to REACh and RoHS requirements and standards		
Only designed to be used in parallel to the mains, not approved for series applications.		



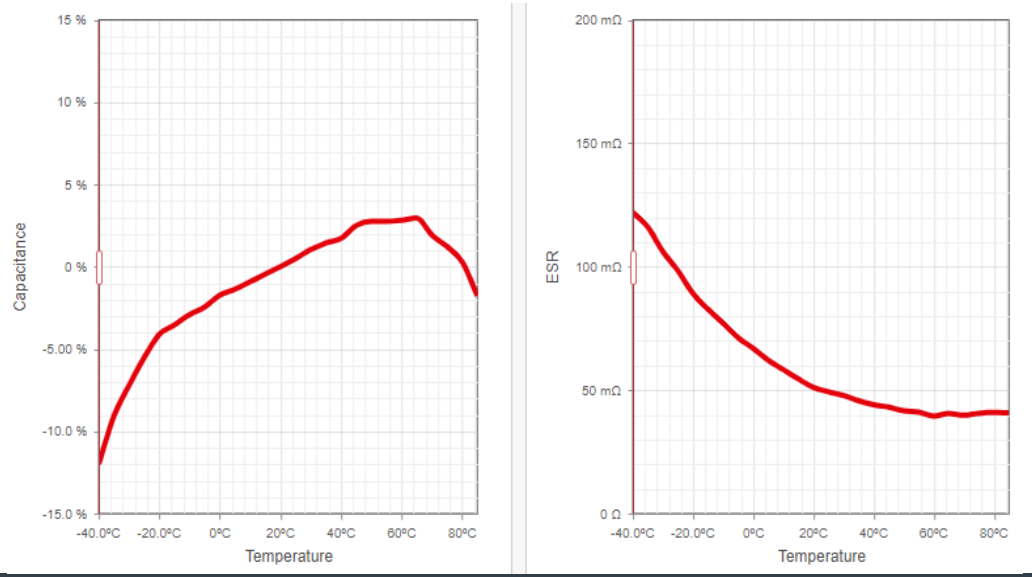
TEMPERATURE BEHAVIOUR OF SUPERCAPACITOR

Supercapacitor

- What is inside a Supercapacitor
  - Electrolyte
  - Coconut (activated carbon)
- Why we have this temperature limitation?
  - Because of the electrolyte
- ESR change over temperature, too

General Information:

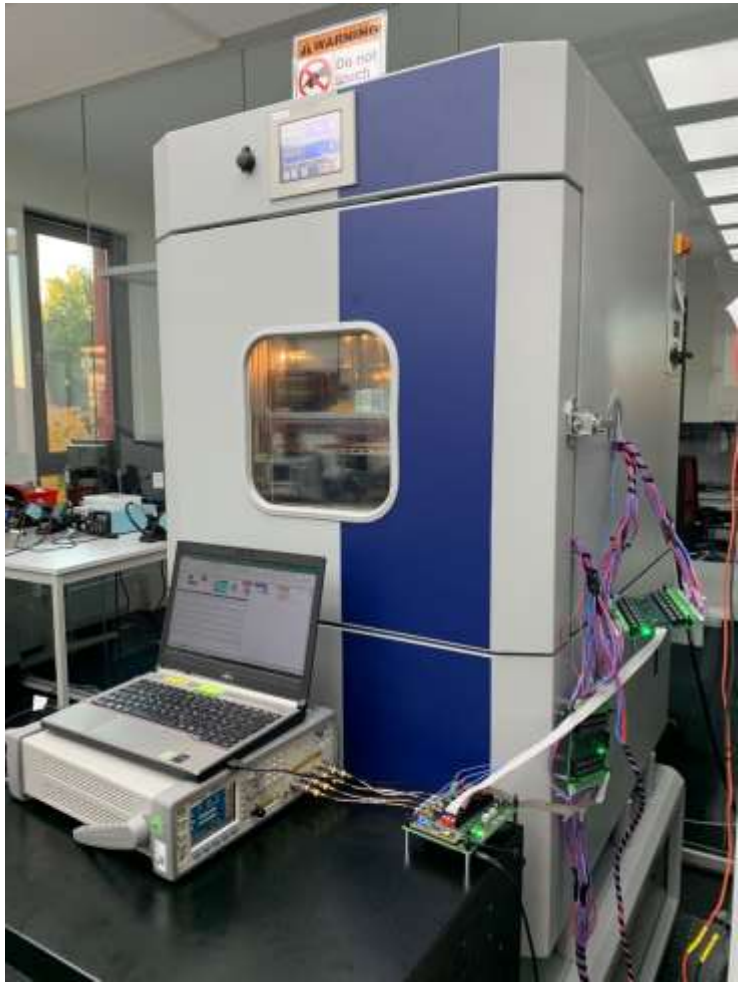
Storage Conditions (in original packaging)	15 °C up to + 35 °C; 10 % up to 75 % RH		
Operating Temperature	-40 up to +65 °C		
Moisture Sensitivity Level (MSL)	1		
Life Cycle		500000	Cycles
Weight	m	2.1	g
Test conditions of Electrical Properties: +20 °C, 35 % RH if not specified differently			
Component conform to REACh and RoHS requirements and standards			



TEMPERATURE MEASUREMENT SETUP

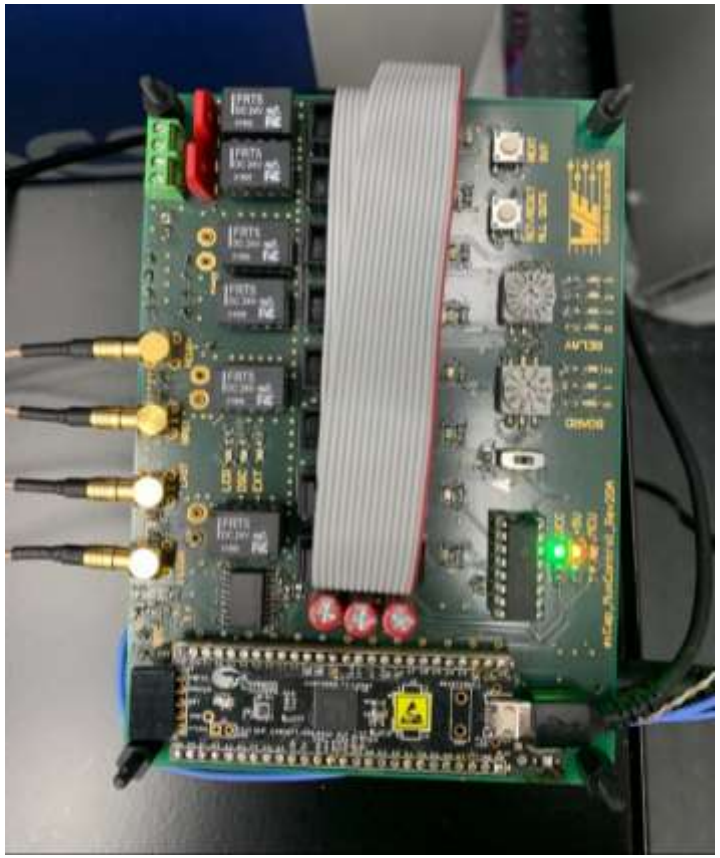
TEMPERATURE MEASUREMENT SETUP

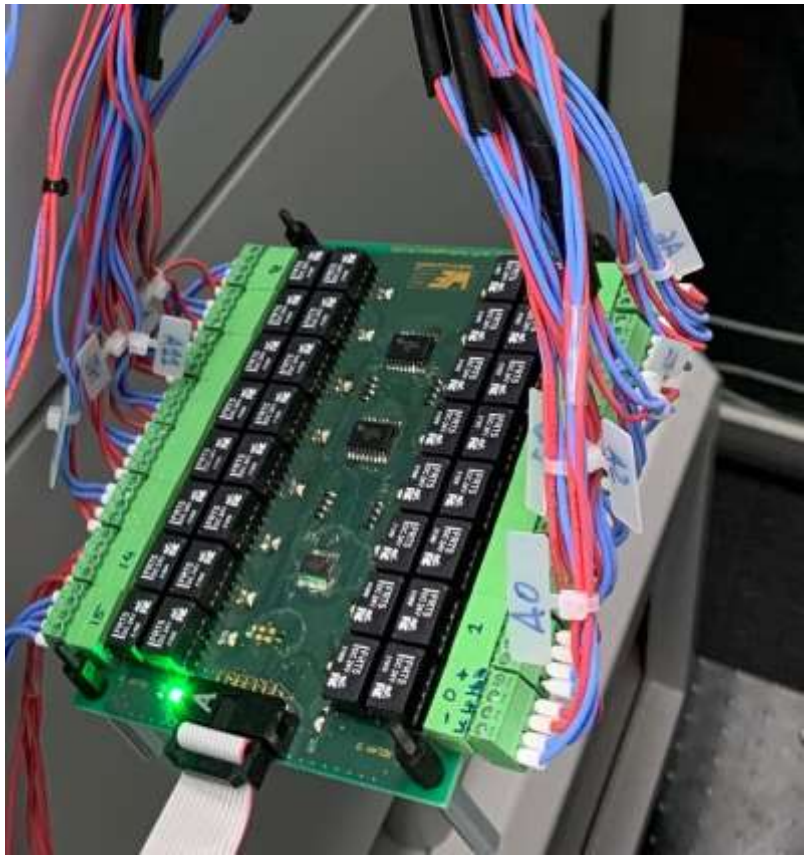
- Climatic Chamber ATT DY110C
- Negative and positive temperature possible
  - -70°C up to +180°C
- Measurements with relative humidity
  - 10% up to 95% RH
- Volume of 110l
- Problem?
  - We can only measure one article with the LCR bridge
- Solution
  - Self developed multiplexer



TEMPERATURE MEASUREMENT SETUP

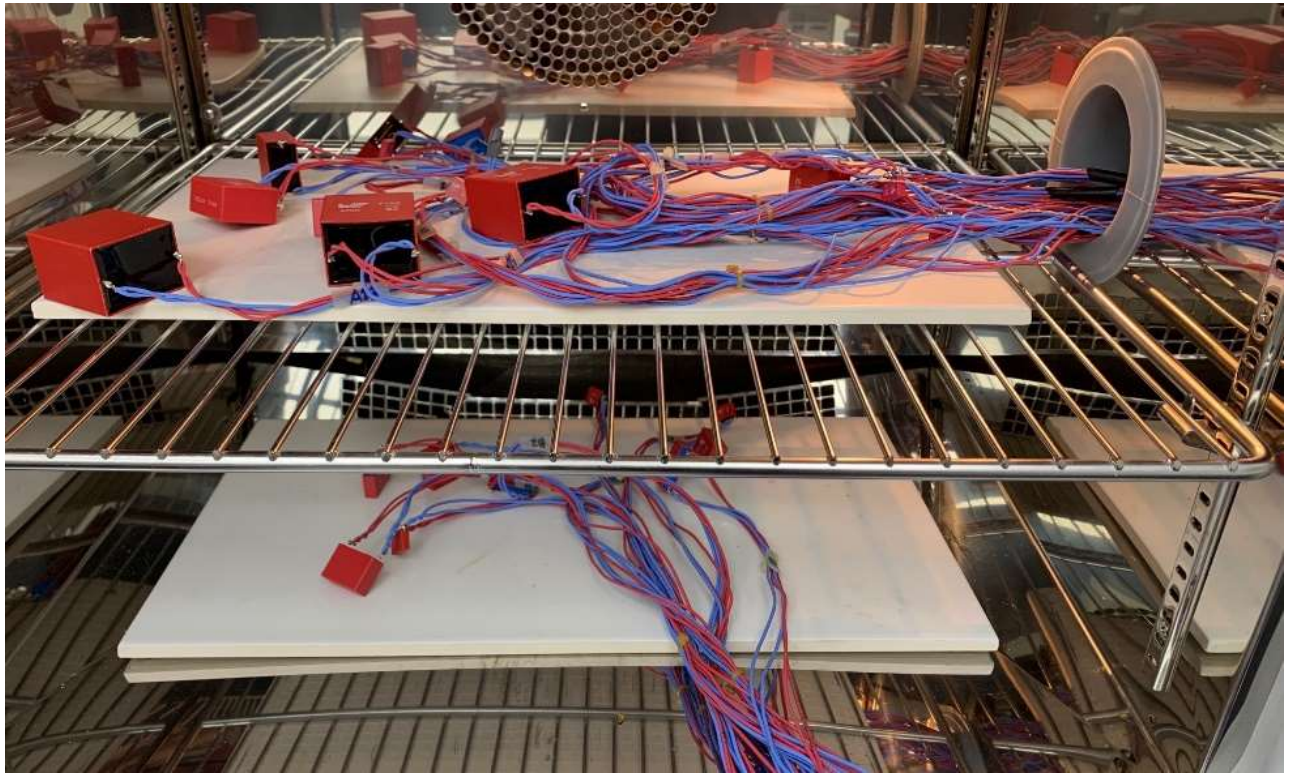
- Multiplexer contacts the capacitor part by part
- We have a control unit and a relays board
- Control unit interacts with the pc and controls the relays
- PSoC from Cypress Semiconductor

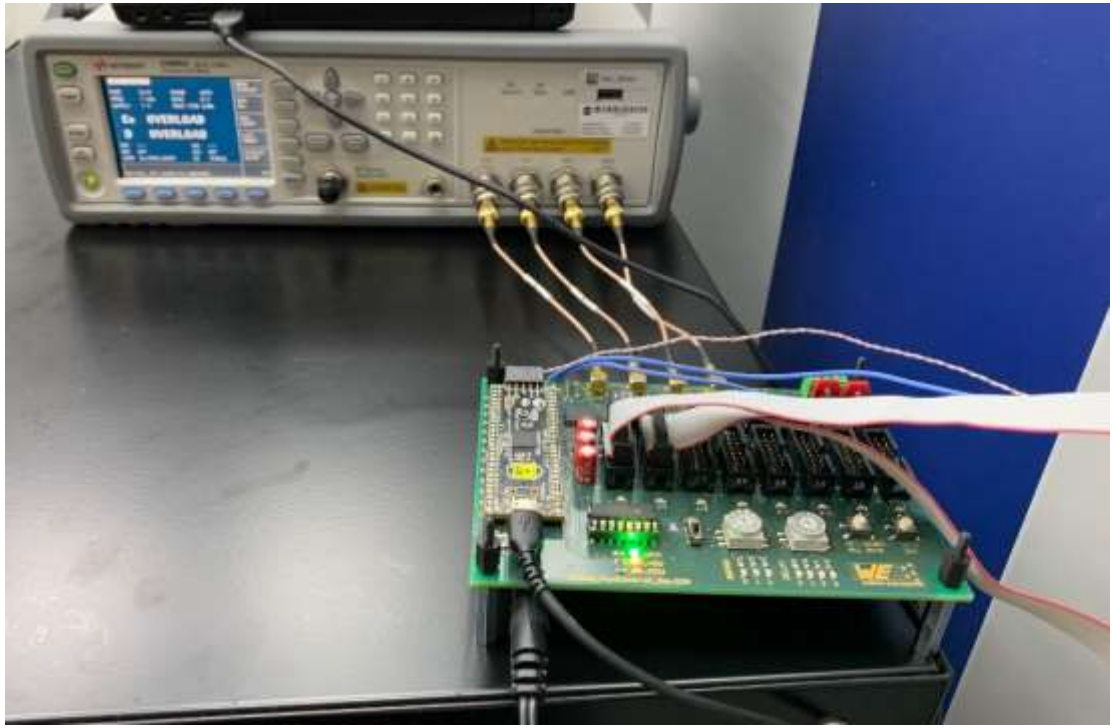




TEMPERATURE MEASUREMENT SETUP

- Cable soldered at each component
- 4 wire measurement





MEASUREMENT RESULTS

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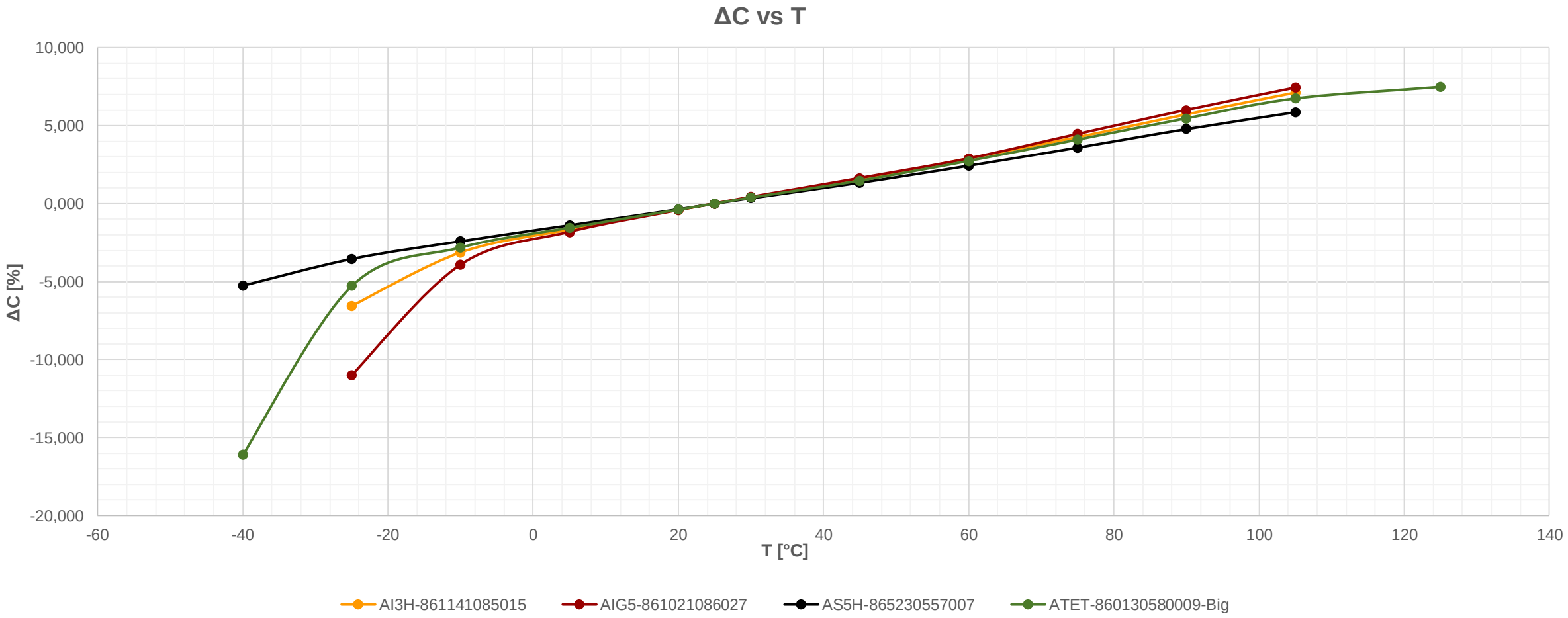
Aluminum electrolytic and polymer capacitors



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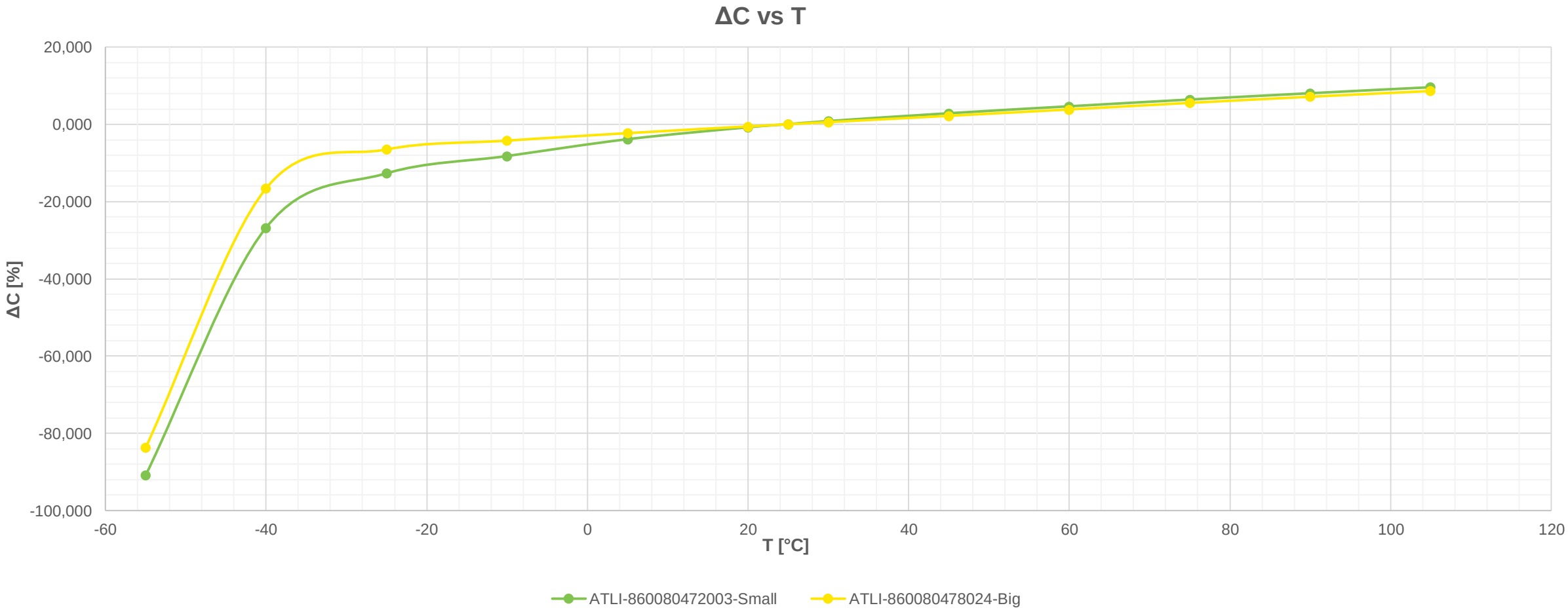

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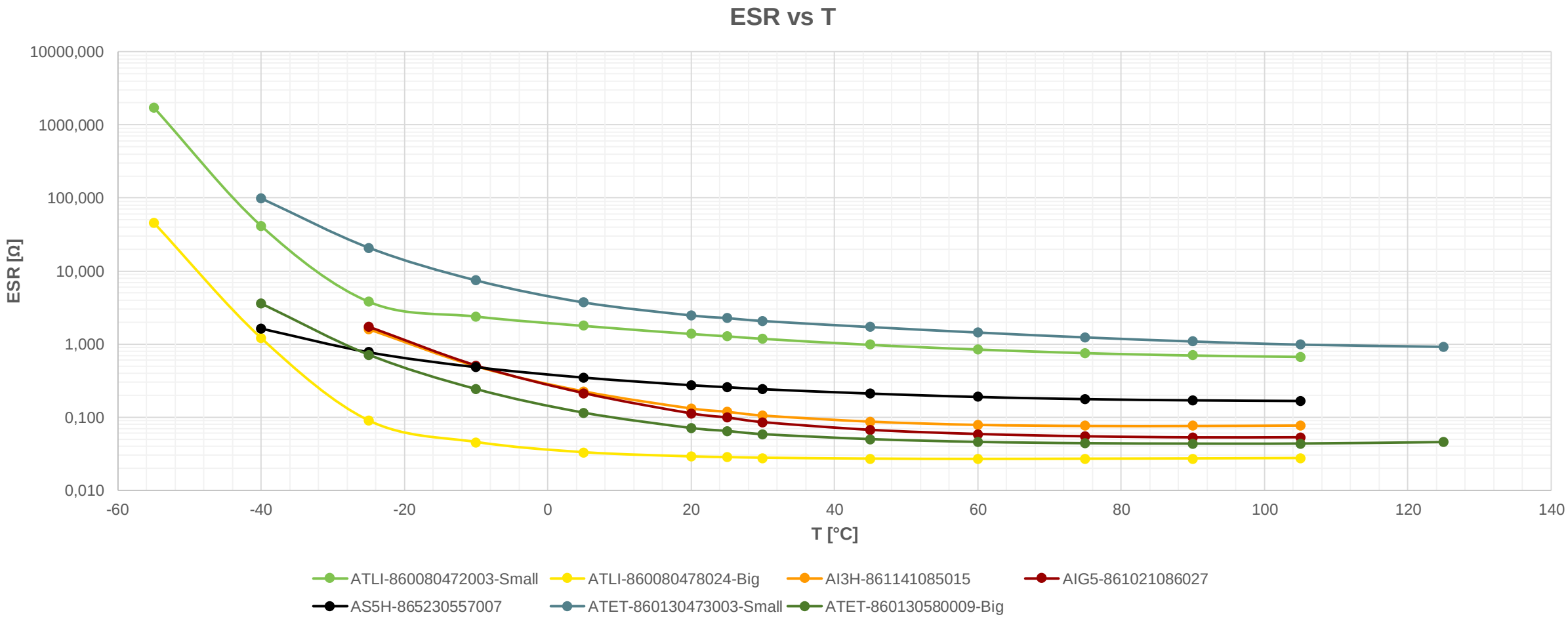

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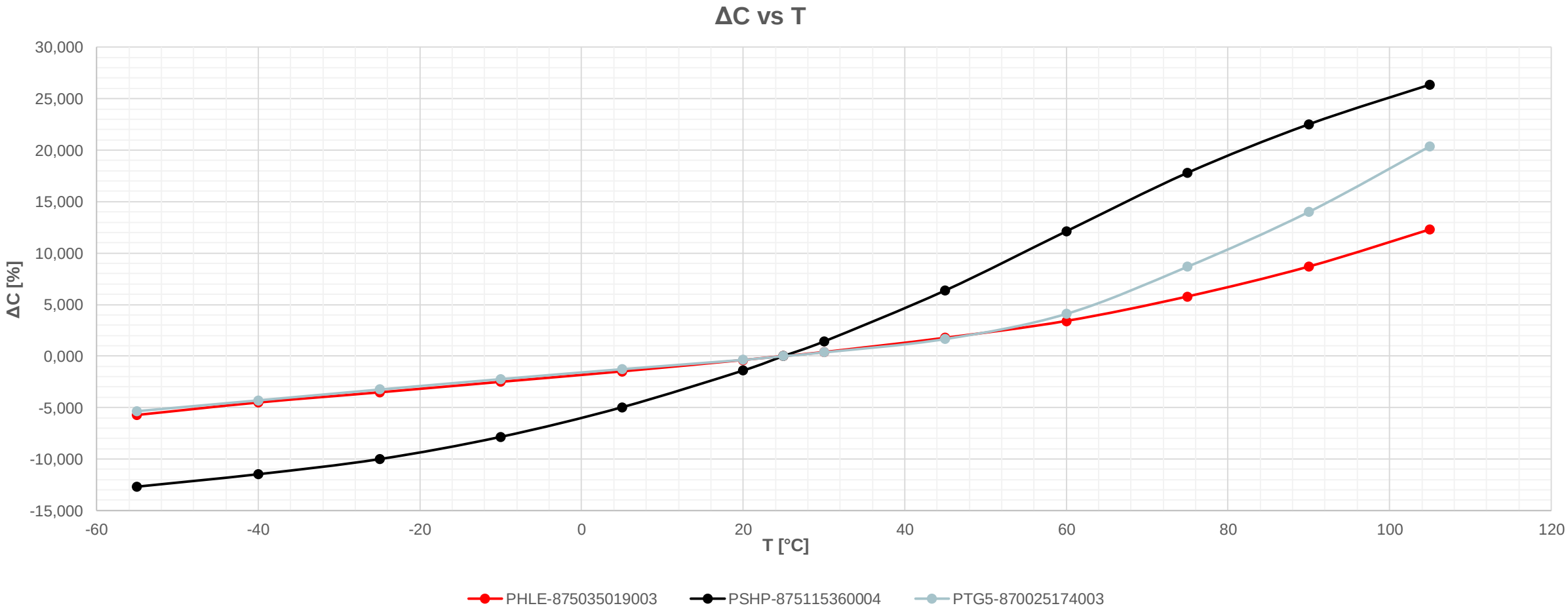
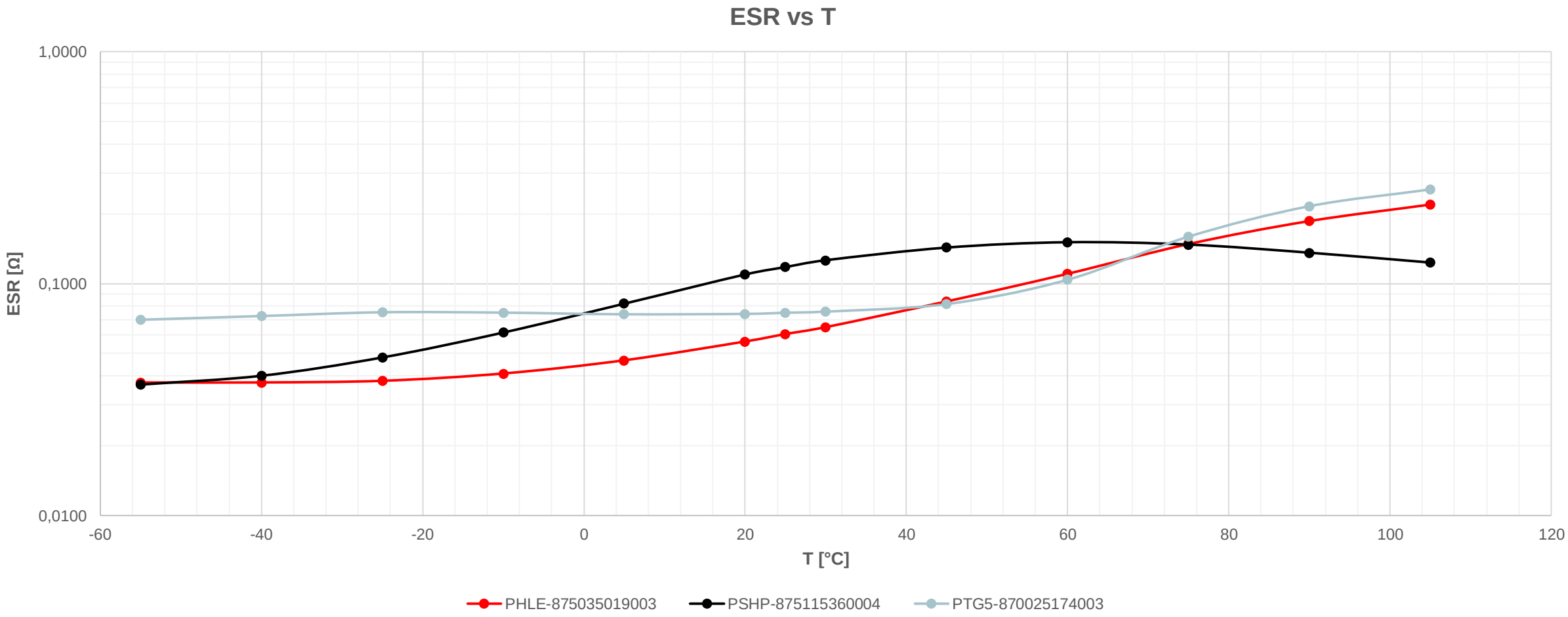


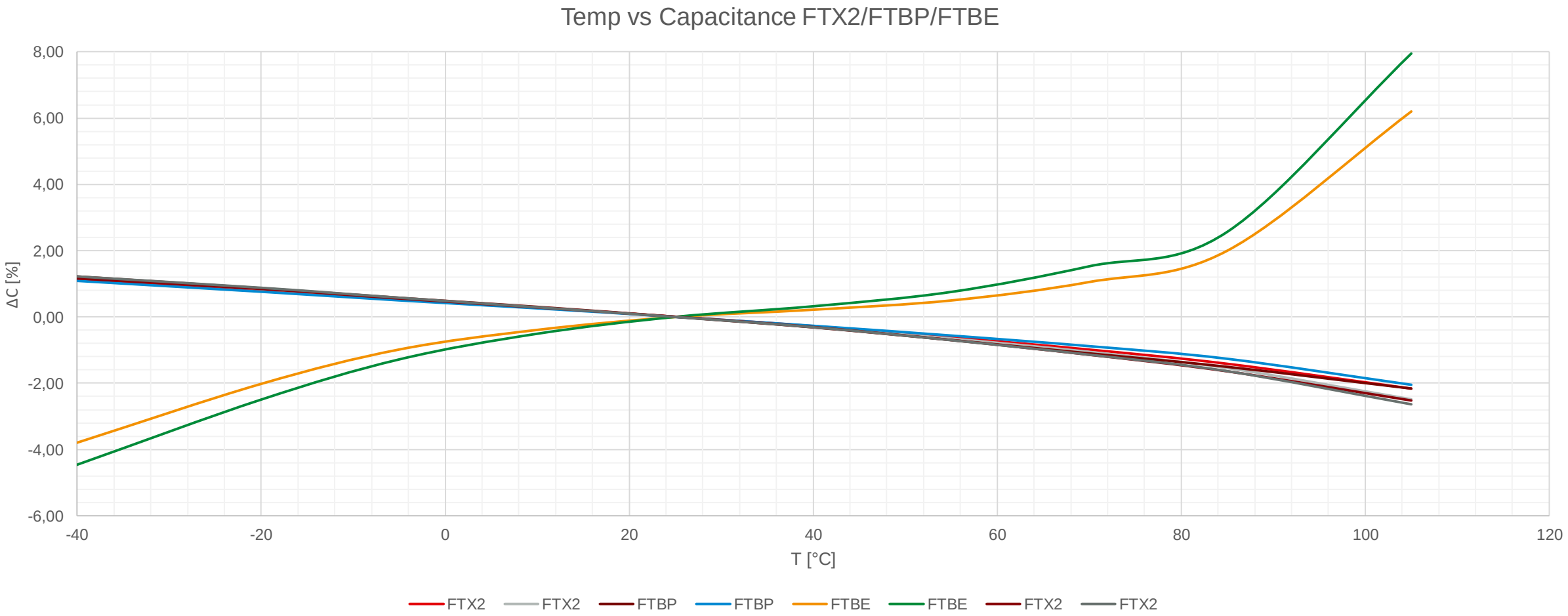
MEASUREMENT RESULTS

ESR measurement



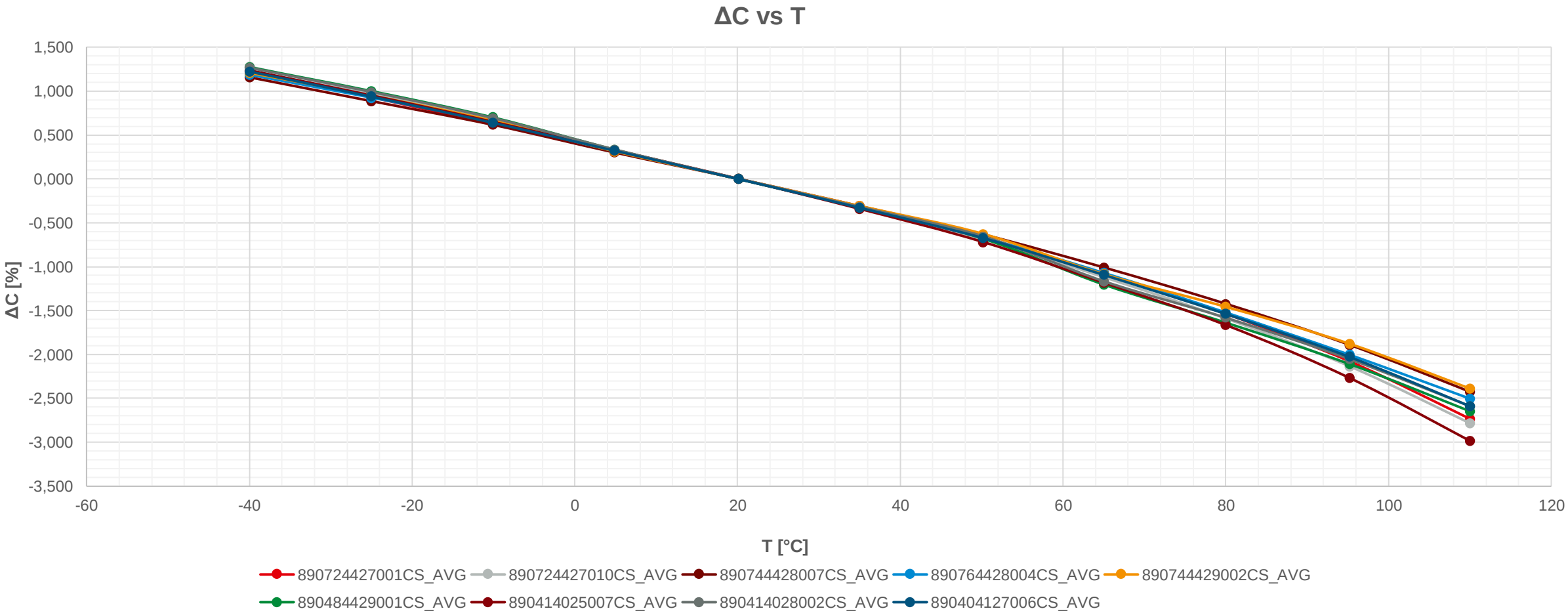
MEASUREMENT RESULTS

Film capacitor different base material



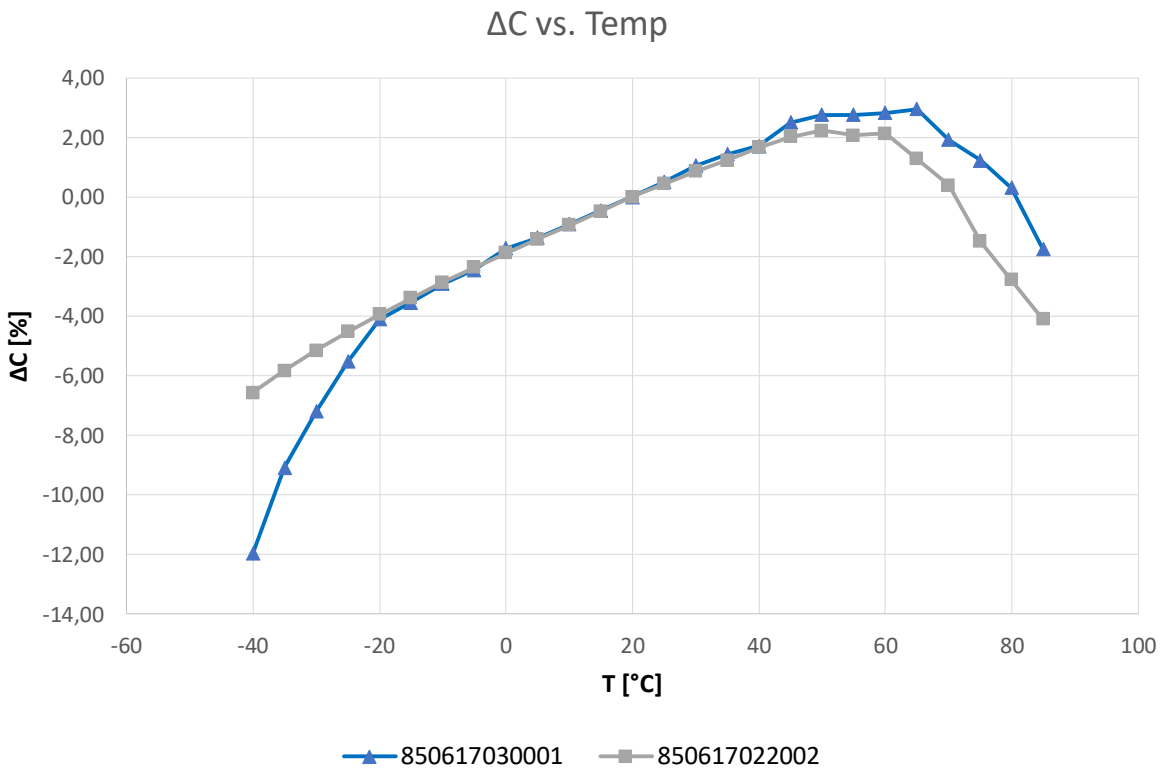
MEASUREMENT RESULTS

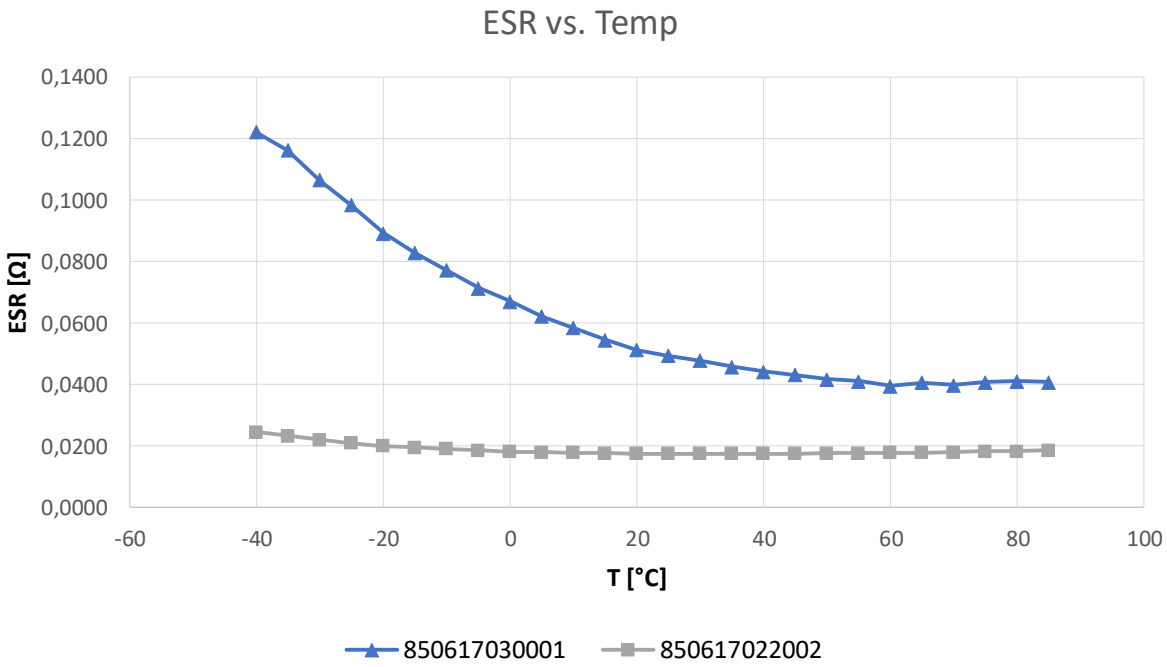
Film capacitor different base material – dc link capacitor



MEASUREMENT RESULTS

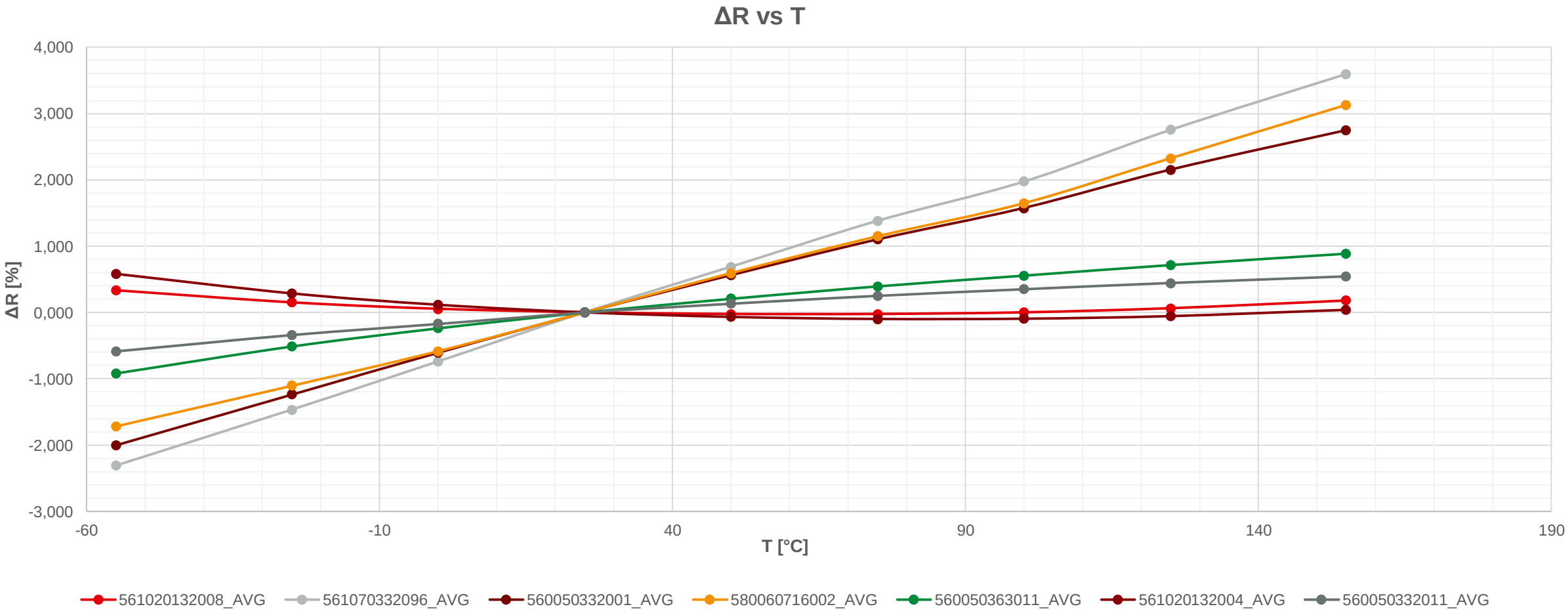
Supercapacitor





MEASUREMENT RESULTS

What about resistance?



WHAT IS THE CONSEQUENCE OF TEMPERATURE

What is the influence and consequence of temperature

Aging / expected lifetime

- MLCC
  - Capacitance and DF change over temperature
  - Dependencies due to the material
    - Structural change
  - Material itself is uncritical
    - Overheating is not an issue

- Aluminum electrolytic / polymer capacitor
  - Expected lifetime
    - In operation
    - In storage condition
  - Temperature definition due to electrolyte
  - Electrical performance is influenced

- Film
  - Temperature vs. DC rated voltage
  - Capacitance and DF change over temperature
  - High humidity plus temperature is critical
    - Degradation of the metallization

- Supercapacitor
  - Specific temperature definition
  - Operating temperature influence the lifetime
    - In combination with voltage
  - Rated voltage vs. operating temperature

CONCLUSION

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- Capacitor have temperature dependencies
- Check datasheet to get the first feeling
- Check extended data from the vendors
- Ask the vendor for specific data for extreme temperature ranges
- Try it in your application under your conditions