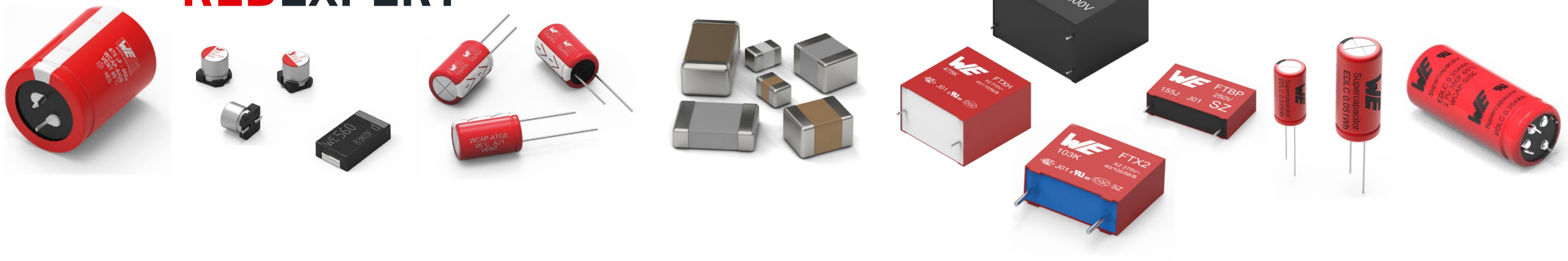
REDEXPERT®



HOW CAPACITOR MEASUREMENTS AND SPECIFICATIONS CAN HELP YOU SELECT THE CORRECT CAPACITOR

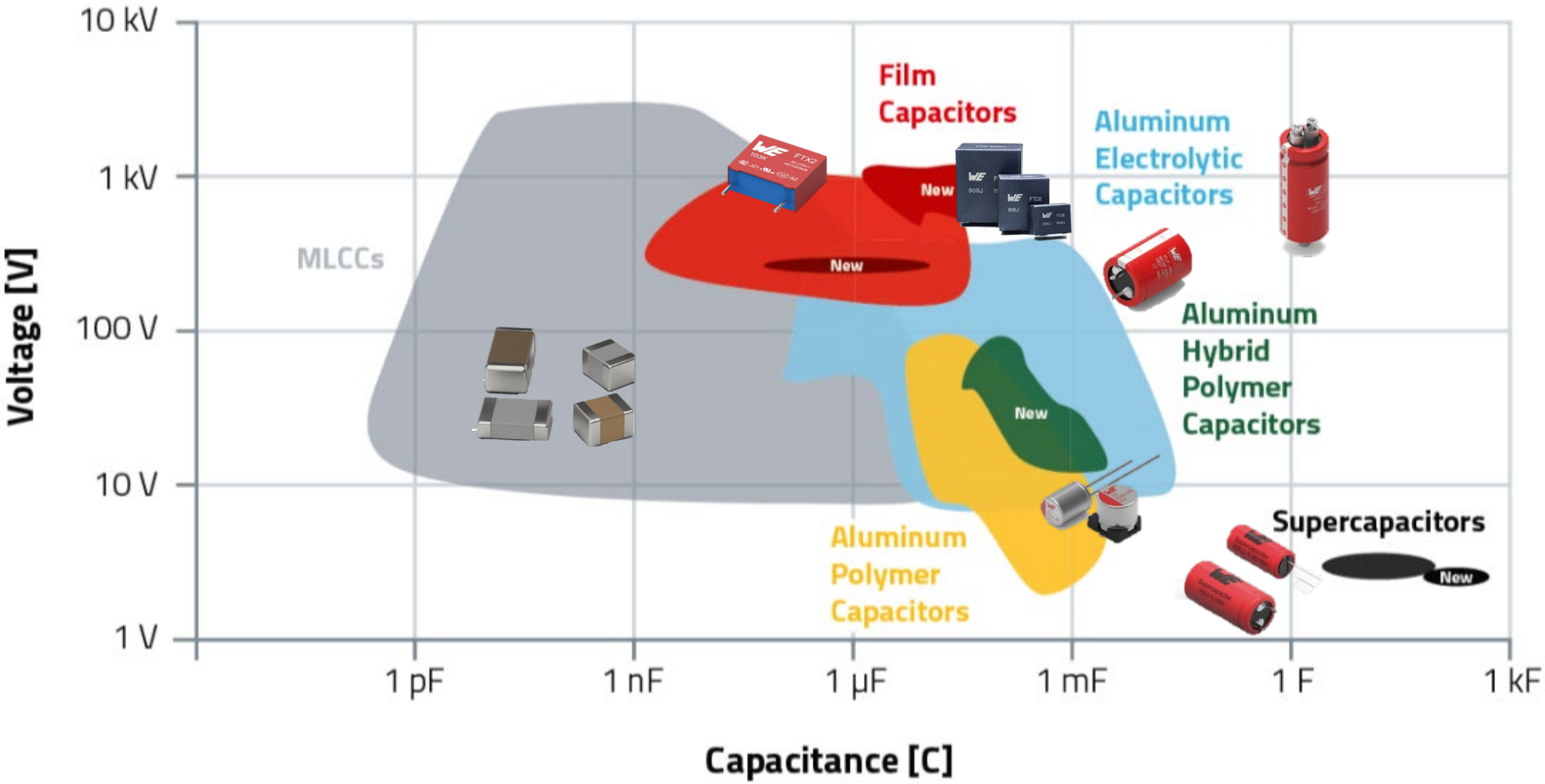
WE Digital Days 2025
Jon Izkue Rodriguez – Product Management Capacitors & Resistors

WÜRTH ELEKTRONIK
MORE THAN YOU EXPECT

AGENDA

- REDEXPERT Capacitor Modules
- MLCC – Multilayer Ceramic Capacitors
  - Test signals
  - Beyond the datasheet information
    - Pre-condition and polarized state
    - DC-Bias and AC signal
    - Temperature impact with DC-Bias
    - DC-Bias over time
    - DC-Bias simulation model
- Aluminum Electrolytic Capacitor and alternatives
  - Ripple current calculations in REDEXPERT
  - Lifetime Calculator in REDEXPERT
- Voltage ratings of capacitors
- Summary

WÜRTH ELEKTRONIK – CAPACITORS PORTFOLIO



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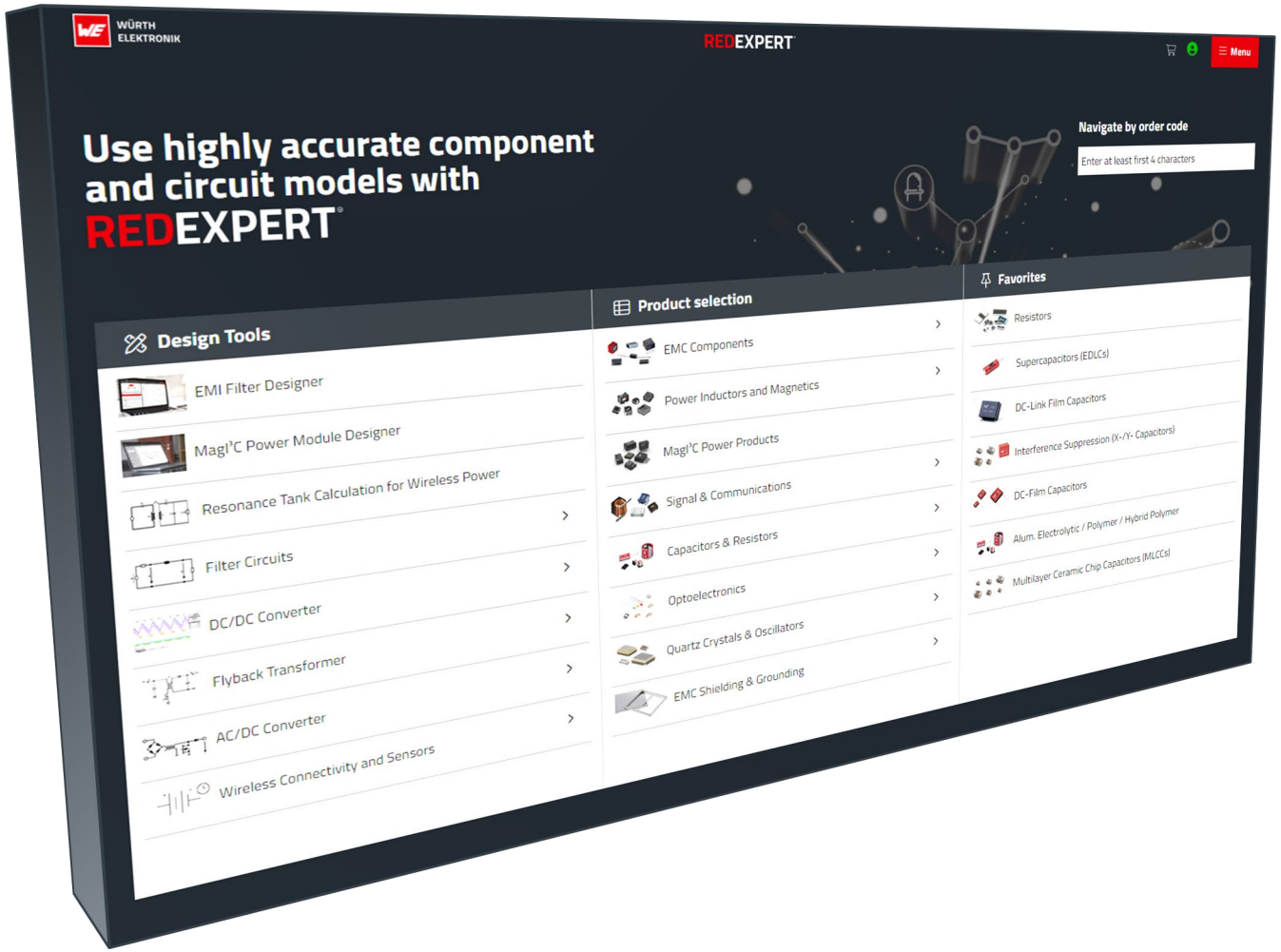
Free online component selection tool by Würth Elektronik



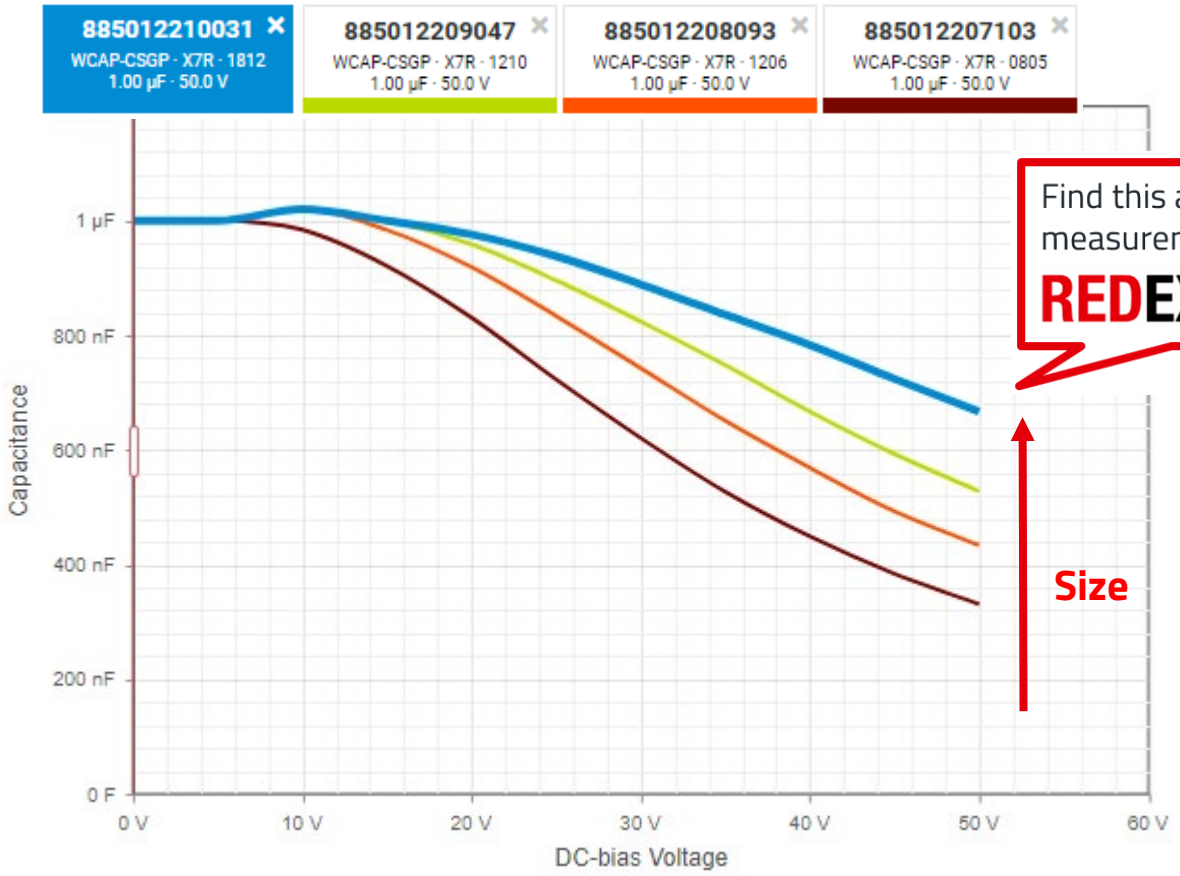
redexpert.we-online.com

- Free to use
- Sign in needed for some functions
- **Use same WE ID for MyWE and REDEXPERT!**
- Free simples with one click
- Design and simulation tools
- Capacitor selection modules:
  - MLCC
  - Aluminum Caps (Electrolytic, Polymer, Hybrid)
  - Safety EMC Capacitors (X2 and Y2/X1)
  - DC-Link Film Capacitors
  - DC-Film Capacitors
  - Supercapacitors

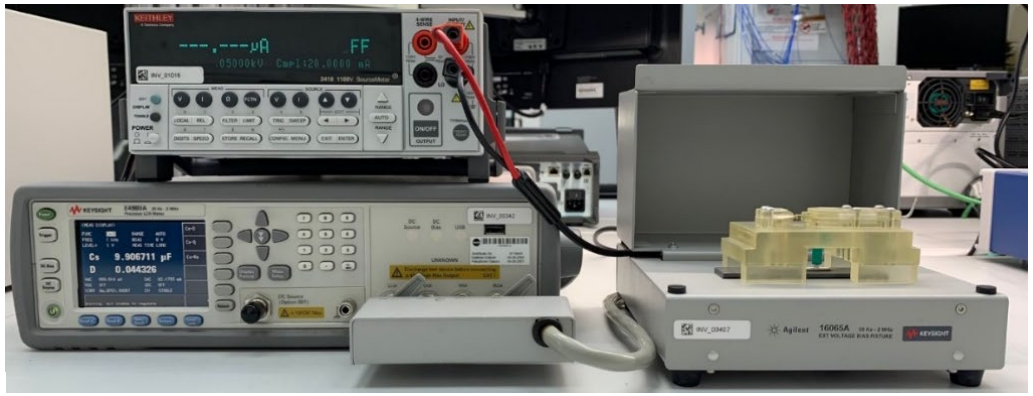
CERAMIC CAPACITORS SPECIFICATION AND MEASUREMENTS

A LOOK INTO THE DATASHEET

DC Bias is… more than you expect



Find this and more measurements in **REDEXPERT®**

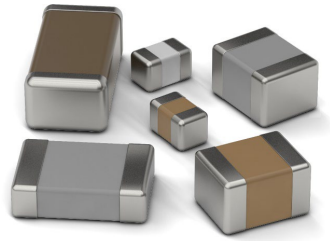


- Capacitance drop affects only Class II Ceramic Capacitors
- Heavily dependent on size
- No specification on the datasheet!
- Only reference curves or simulation models

CERAMIC CAPACITOR SPECIFICATION

MLCC with 10 µF and 50 V rating

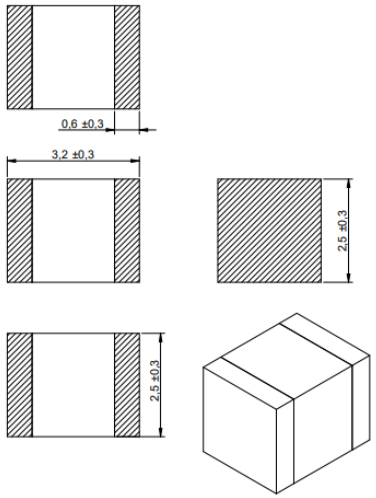
WCAP-CSGP 885012209073 - X7R Class II



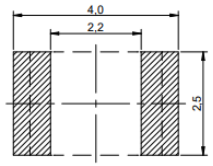
A lot of information is concentrated in this table

Most users only want to see 10µF and 50V

Dimensions: [mm]



Recommended Land Pattern: [mm]



Scale- 10 :1

Schematic:

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Capacitance	C	1 ±0.2 V_{RMS}, 1 kHz ±10% @25 °C	10	µF	±10%
Rated Voltage	V_R		50	V (DC)	max.
Dissipation Factor	DF	1 ±0.2 V_{RMS}, 1 kHz ±10% @25 °C	10	%	max.
Insulation Resistance	R_{ISO}	Apply V_R for 120 s max.	0.01	GΩ	min.

Precondition for Class II MLCC measurement: Apply a preheat treatment @150 ±10 °C for 1 hour. The measurement should be applied after 24 ±2 hrs the part was stored under ambient conditions. There is not any precondition necessary for Class I MLCC.

General Information:

	General Purpose MLCC
Ceramic Type	X7R Class II
Temperature Coefficient	± 15 % max.
Operating Temperature	-55 up to +125 °C
Storage Conditions (in original packaging)	5 °C up to + 35 °C; 10 % up to 75 % RH
Moisture Sensitivity Level (MSL)	1
Dielectric Strength	5 sec. @250 % V_R, Charge & Discharge Current <50 mA
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	

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

Würth Elektronik eiSos GmbH & Co. KG
EMC & Inductive Solutions
Max-Eyth-Str. 1
74638 Waldenburg
Germany
Tel. +49 (0) 79 42 945 - 0
www.we-online.com
eiSos@we-online.com

CHECKED	REVISION	DATE (YYYY-MM-DD)	GENERAL TOLERANCE	PROJECTION METHOD
PSL	002.000	2021-01-03	DIN ISO 2768-1m	

DESCRIPTION: **WCAP-CSGP Ceramic Capacitors 1210**

TECHNICAL REFERENCE: X7R1210106K050DFCT10.00

ORDER CODE: **885012209073**

SIZE/TYPE	BUSINESS UNIT	STATUS	PAGE
1210	eiCap	Valid	1/8

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Capacitance	C	1 ±0.2 V_{RMS}, 1 kHz ±10% @25 °C	10	µF	±10%
Rated Voltage	V_R		50	V (DC)	max.
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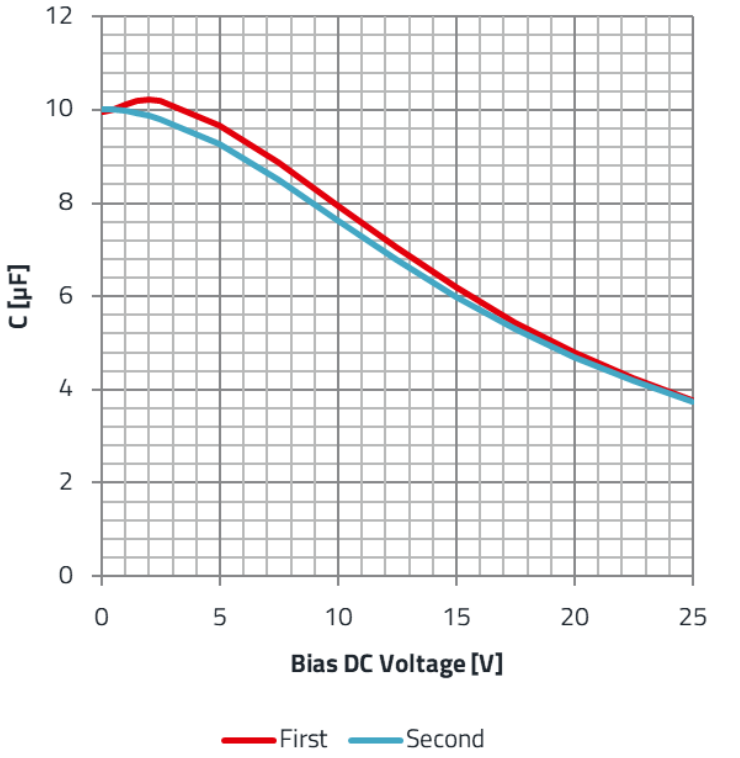
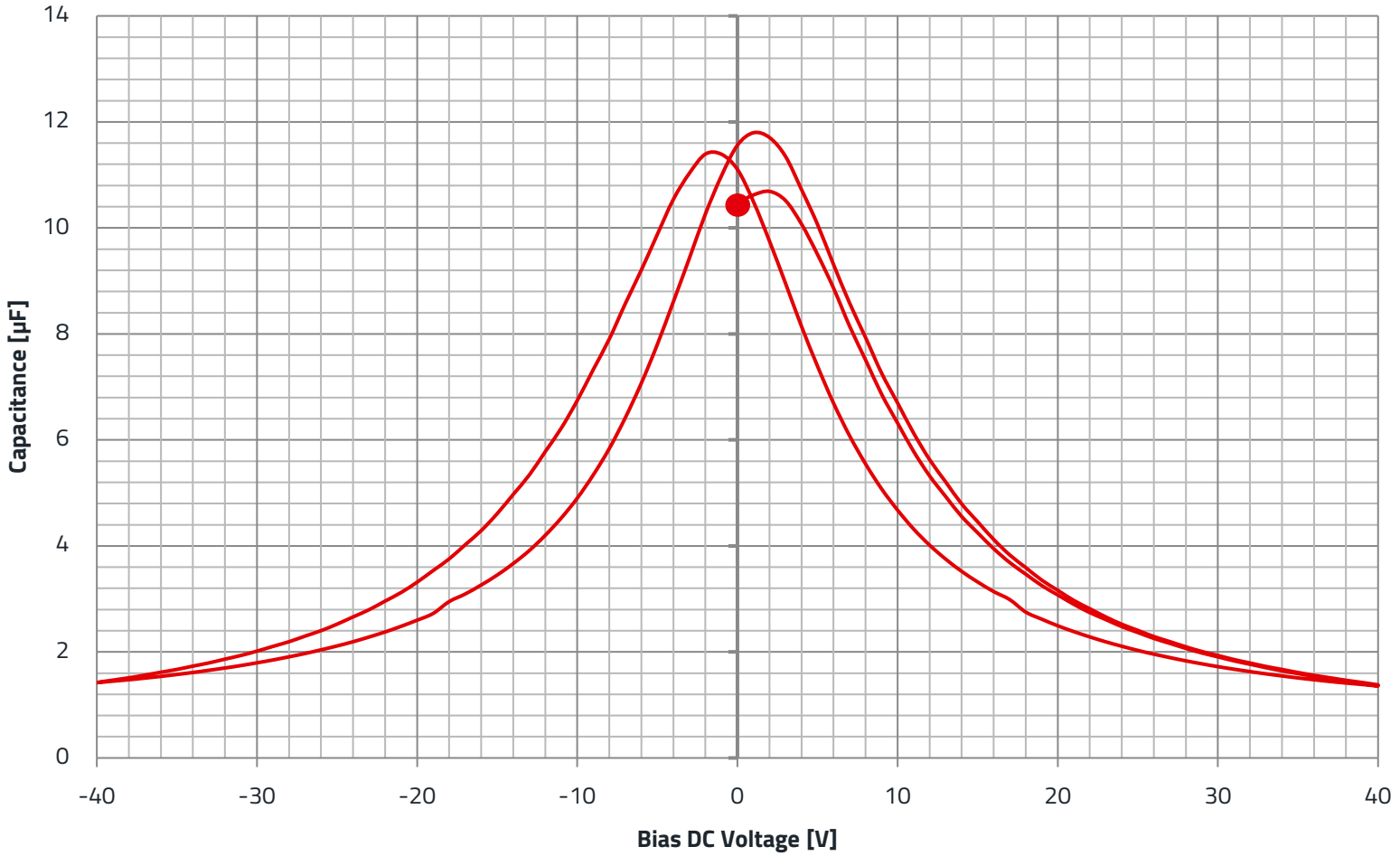
CERAMIC CAPACITOR

Pre-conditioning and polarized state of dielectric

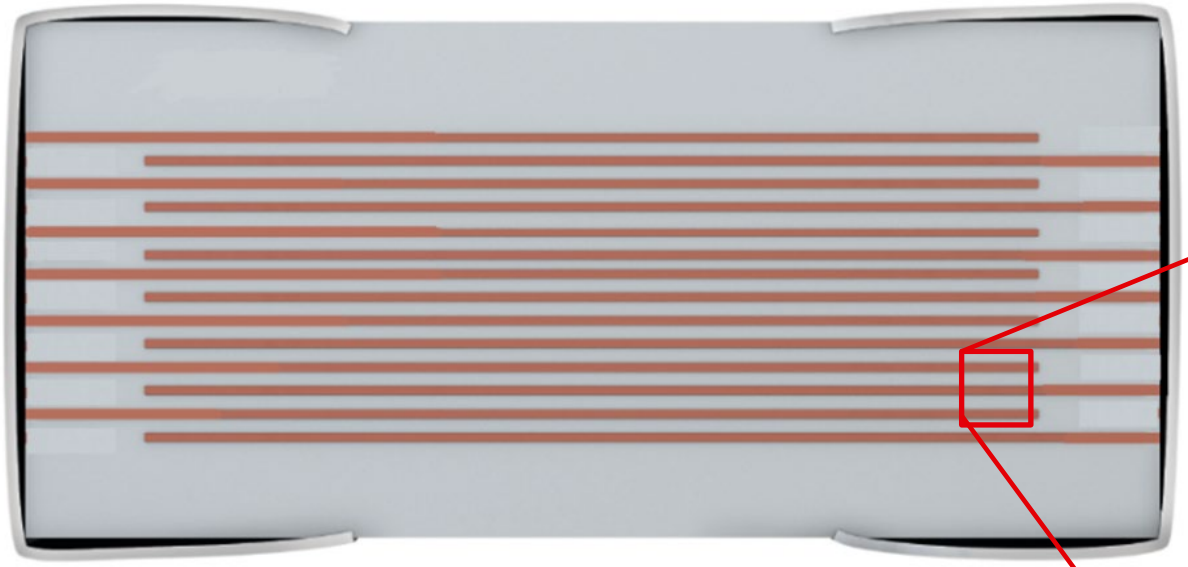
Precondition for Class II MLCC measurement: Apply a preheat treatment @150 ±10 °C for 1 hour. The measurement should be applied after 24 ±2 hrs the part was stored under ambient conditions. There is not any precondition necessary for Class I MLCC.

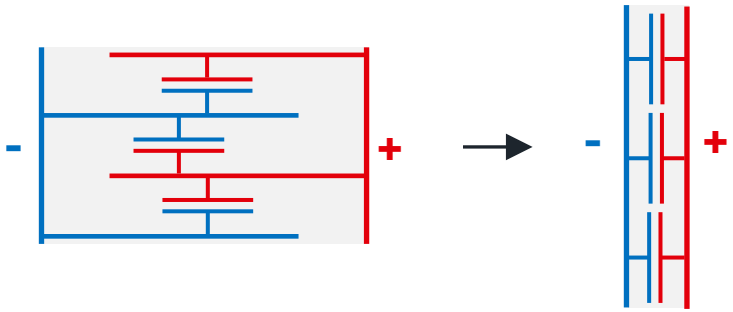


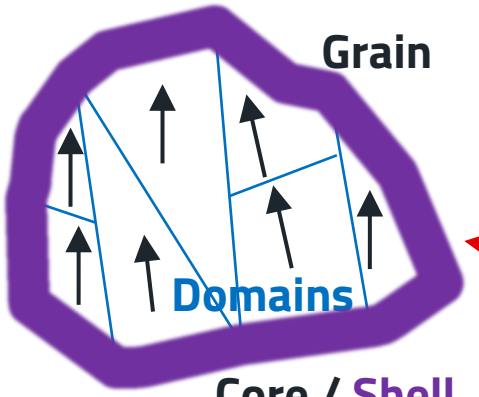


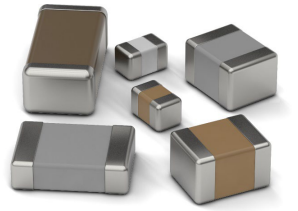
CERAMIC CAPACITOR MEASUREMENTS

MLCC Structure

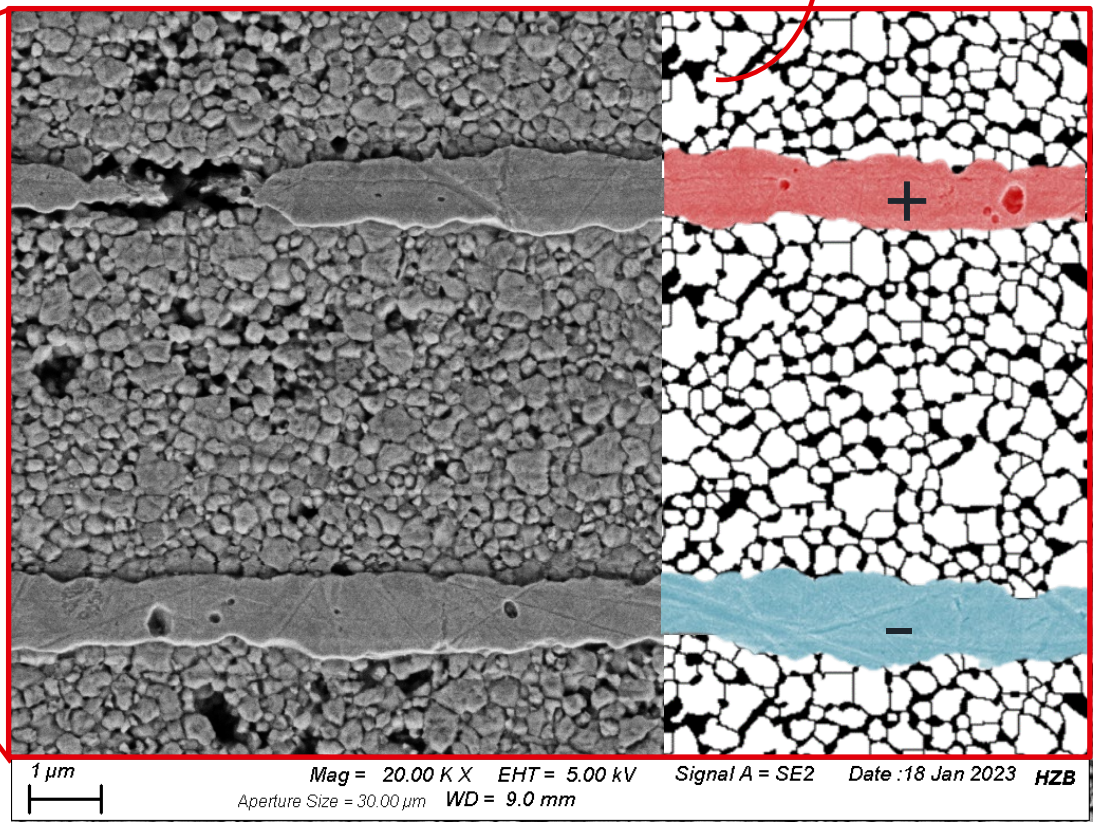








Core / Shell



CERAMIC CAPACITOR SPECIFICATION

AC Test signal measurement

- MLCC with 10 µF and 50 V rating

WCAP-CSGP 885012209073 - X7R Class II

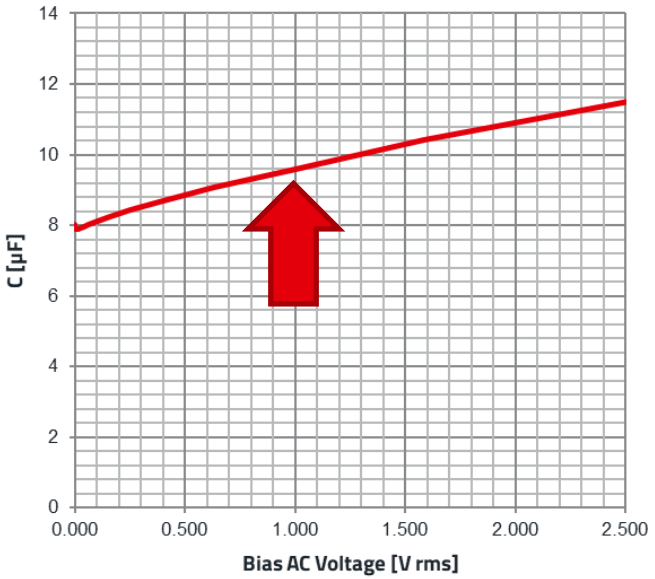
Find this and more measurements in **REDEXPERT®**

Electrical Properties:

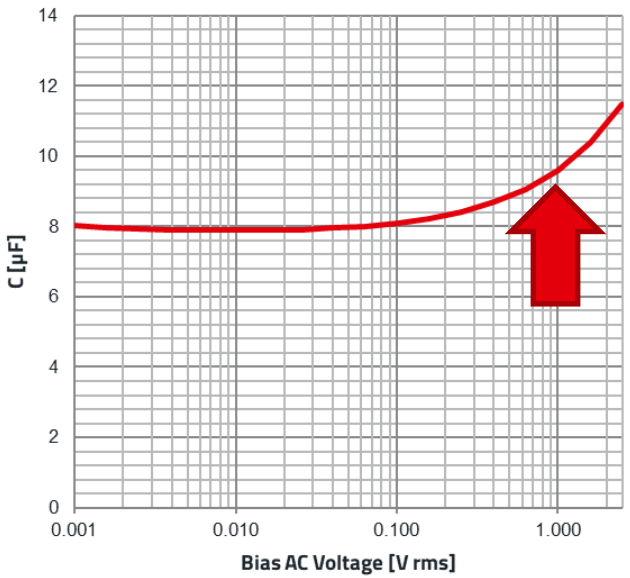
Properties		Test conditions	Value	Unit	Tol.
Capacitance	C	1 ±0.2 V_{RMS}, 1 kHz ±10% @25 °C	10	µF	±10%
Rated Voltage	V_R		50	V (DC)	max.
Dissipation Factor	DF	1 ±0.2 V_{RMS}, 1 kHz ±10% @25 °C	10	%	max.
Insulation Resistance	R_{ISO}	Apply V_R for 120 s max.	0.01	GΩ	min.

Precondition for Class II MLCC measurement: Apply a preheat treatment @150 ±10 °C for 1 hour. The measurement should be applied after 24 ±2 hrs the part was stored under ambient conditions. There is not any precondition necessary for Class I MLCC.

C vs AC-level



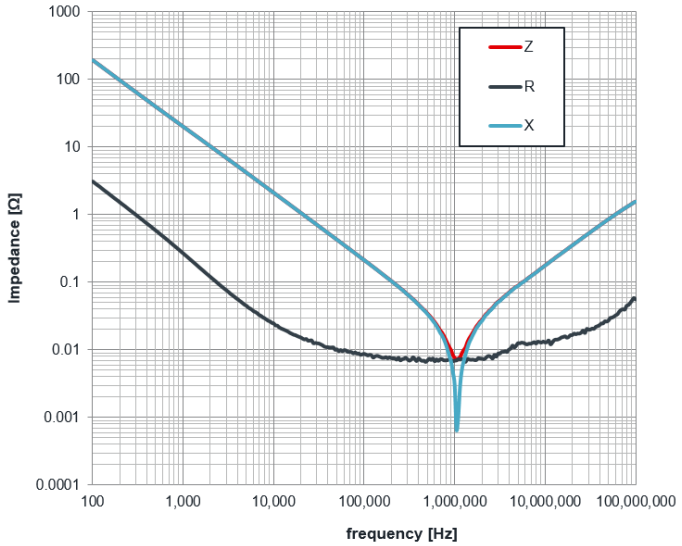
C vs AC-level (logarithmic)



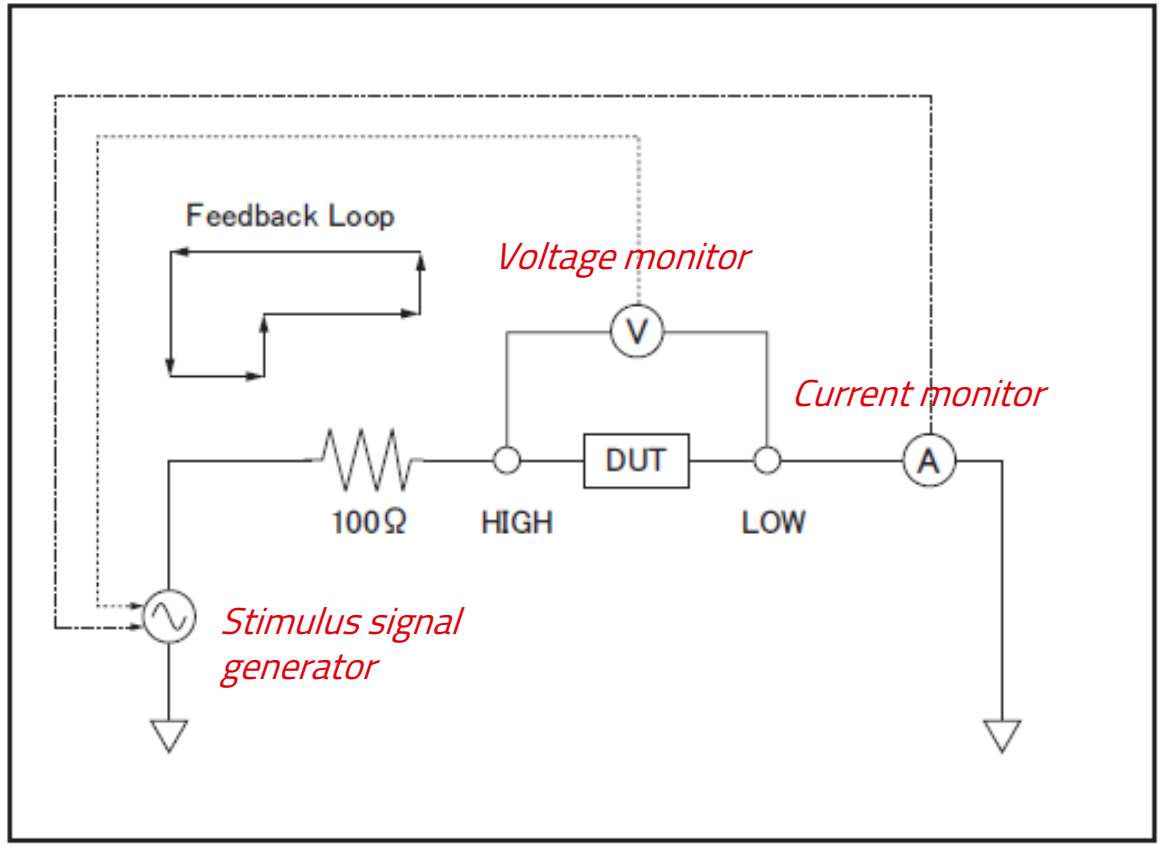
MEASUREMENT OF SPECIFICATION

Why measure ceramic capacitor at that a specific level?

- Specification only reached at high voltage level
- Stimulus series impedance and signal generator limitations give the maximum level at the DUT
- Low frequency required for higher impedance of the DUT



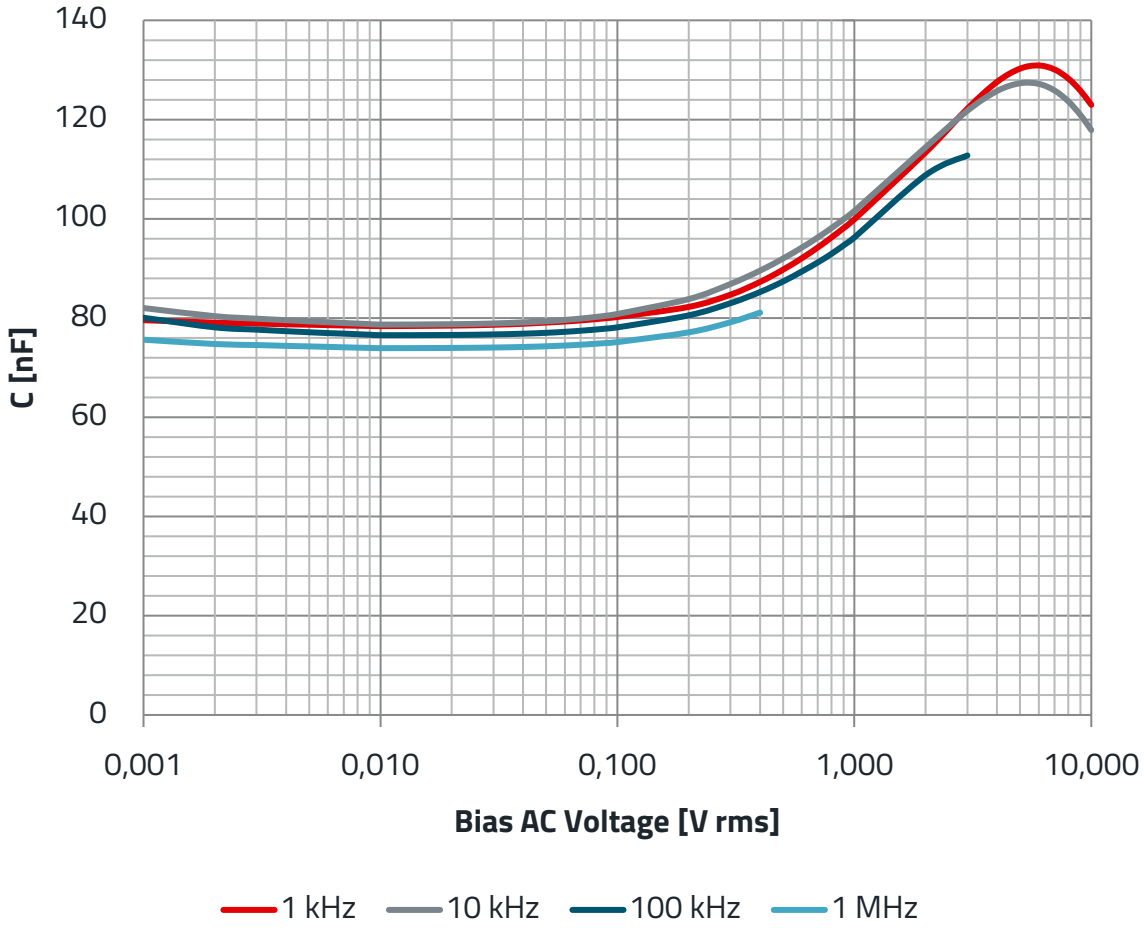
Feedback Circuit



MEASUREMENT OF SPECIFICATION

Why measure ceramic capacitor at that frequency?

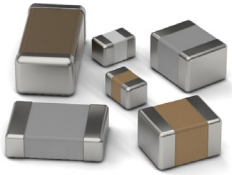
- High capacitance class II MLCCs used in switched mode converters
  - High frequency > 50 kHz and harmonics
  - Low voltage ripple – 10-100s of mV
  - Get heated by other components (switch, inductor)



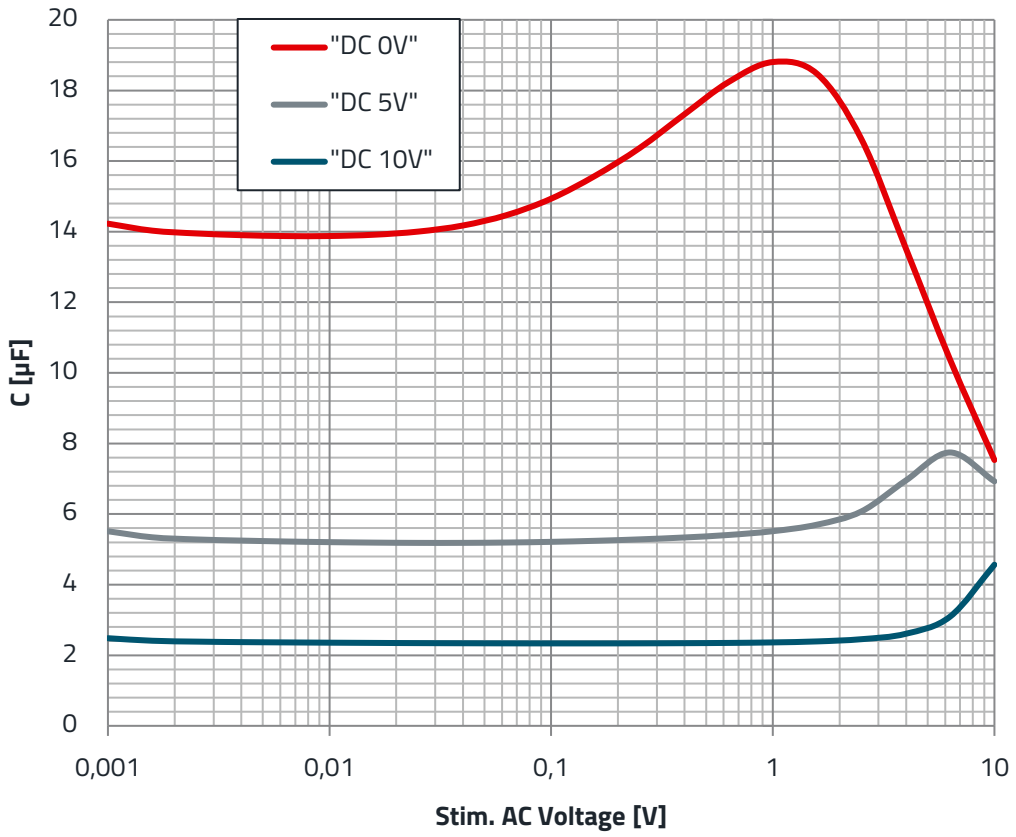
MEASURING CERAMIC CAPACITORS

AC sweep with DC Bias

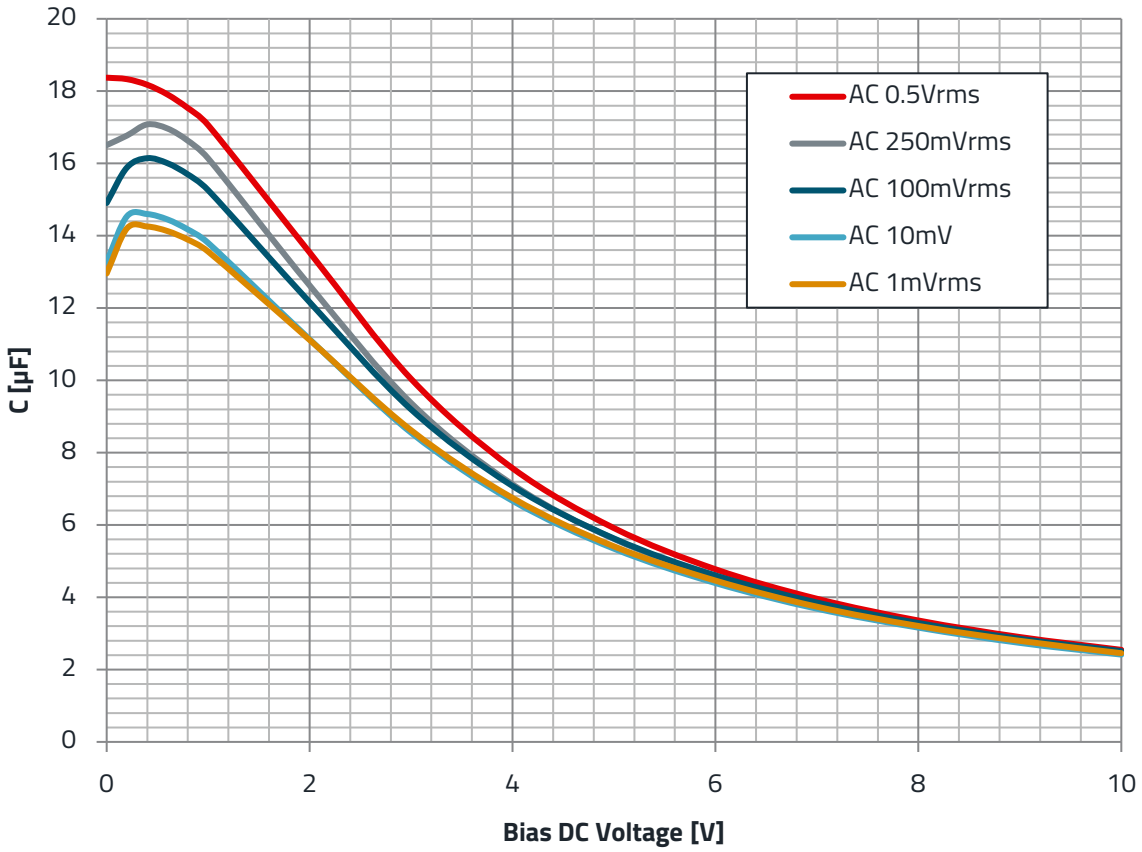
Example: 885 012 106 032
WCAP-CSGP – 22 µF, 10V size 0603



Capacitance vs AC-level (120 Hz)



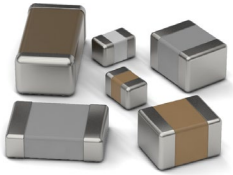
Capacitance vs DC-level



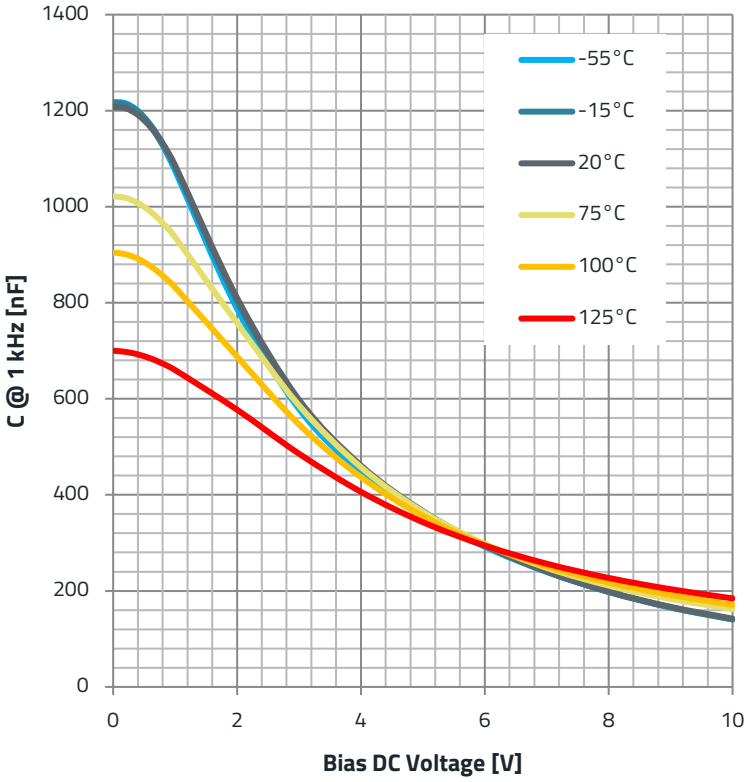
MEASURING CERAMIC CAPACITORS

DC bias at different temperatures

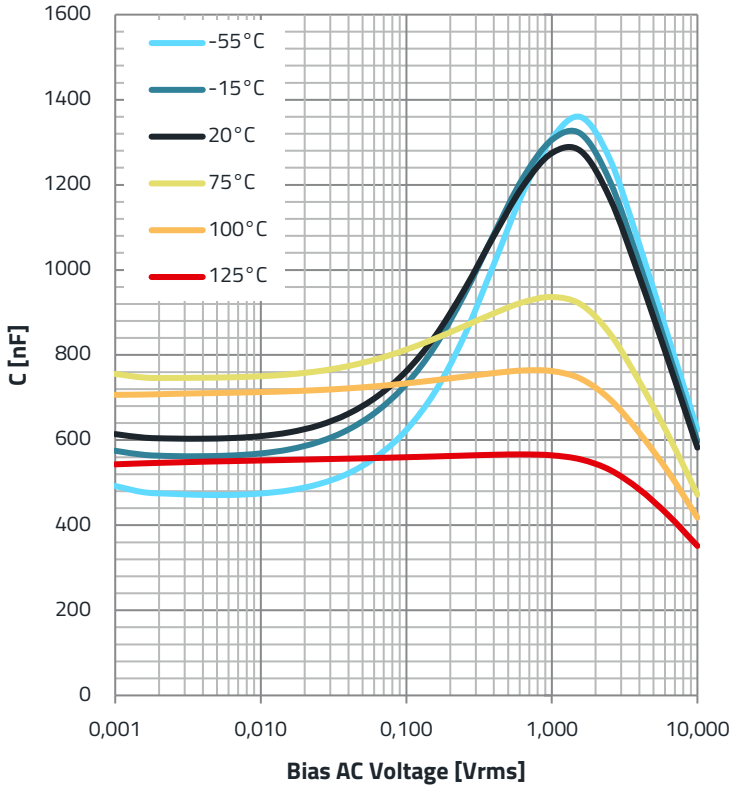
Example: 885 012 105 012 WCAP-CSGP – 1 µF, 10V size 0402



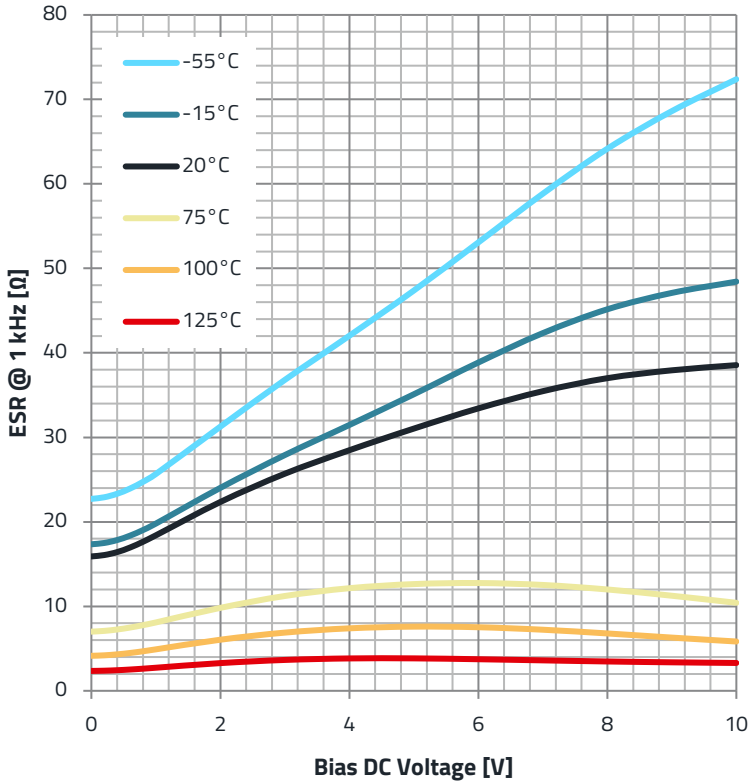
Capacitance vs DC-Bias



Capacitance vs AC-level

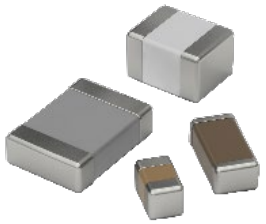


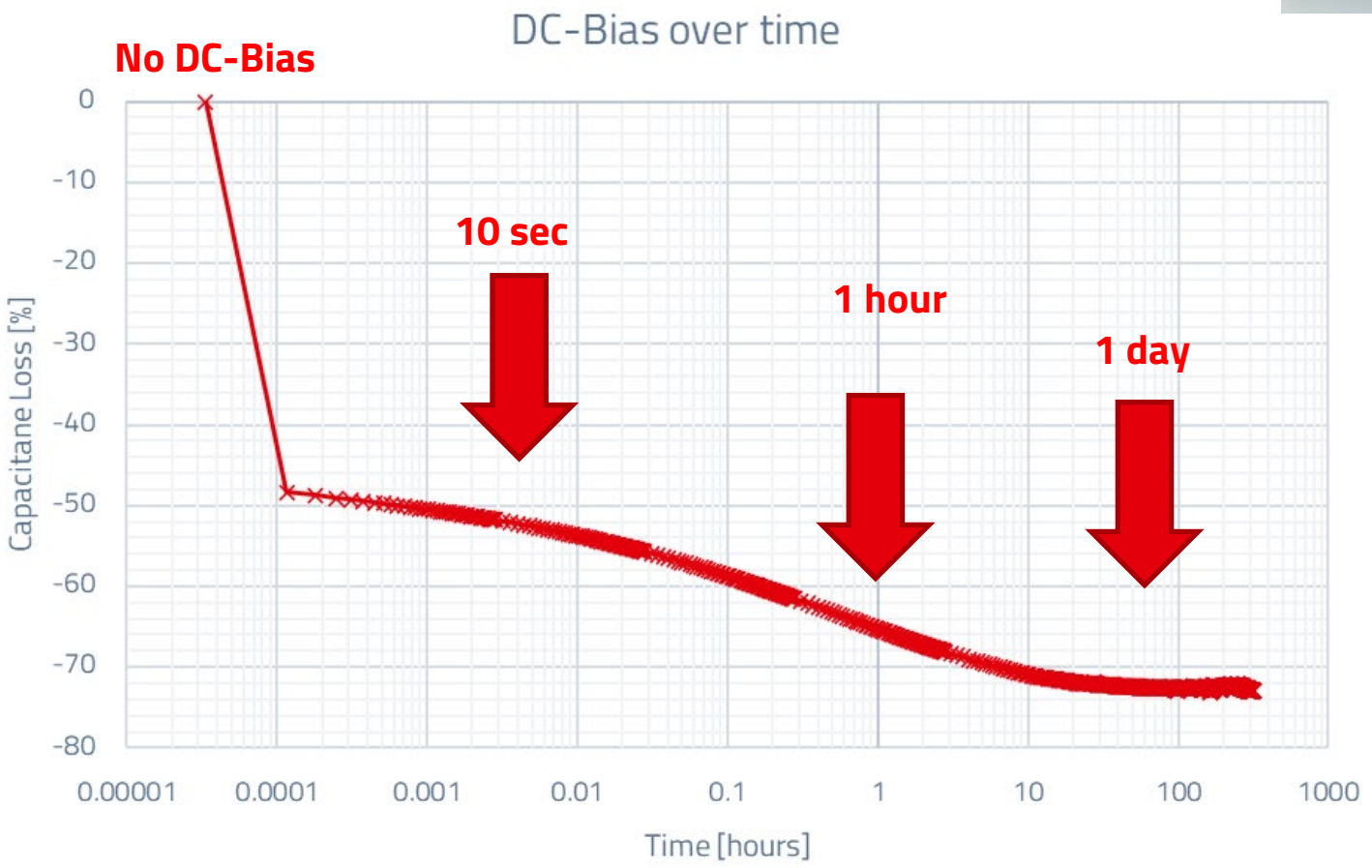
ESR vs DC-Bias



MEASURING CERAMIC CAPACITORS

Capacitance loss from DC Bias over time





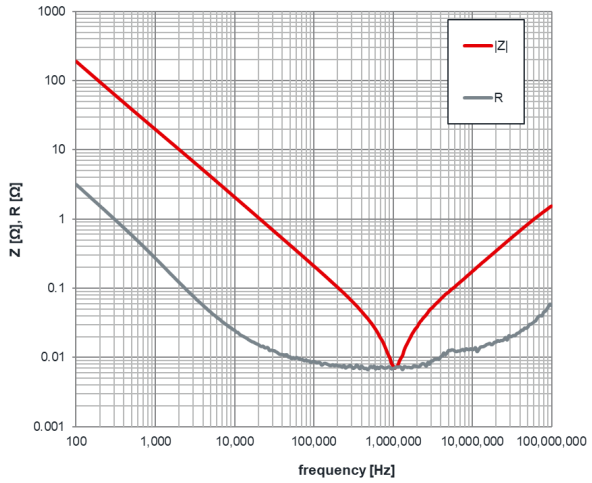
Example of 885012208066:
2.2 µF, 25 V, Size 1206

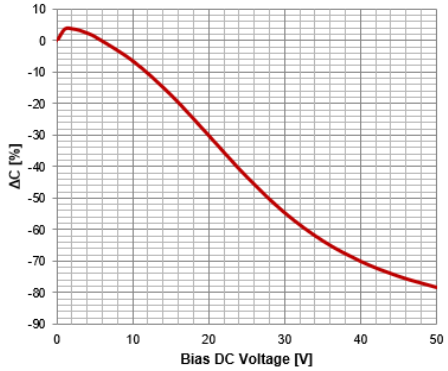
- C@10sec = 1.10 µF = -50%
- C@1h = 0.83 µF = -65%
- C@1d-14d = 0.67 µF = -72%

BASICS OF CAPACITORS

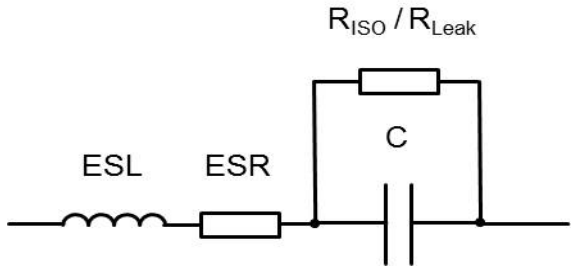
Impedance Curve and Equivalent Circuit Model

Measurements





Equivalent Circuit + Model




```
.subckt 1210_885012209073_10uF 1 2
Rser 1 3 0.00803494307495
Lser 2 4 4.01881911E-10
C1 3 4 0.00001
Rpar 3 4 5000000
.ends 1210_885012209073_10uF
*******
```

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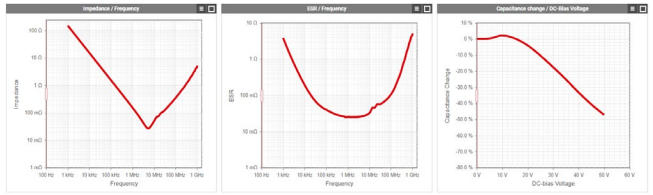
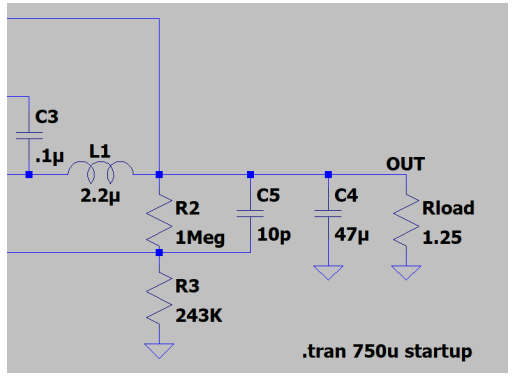
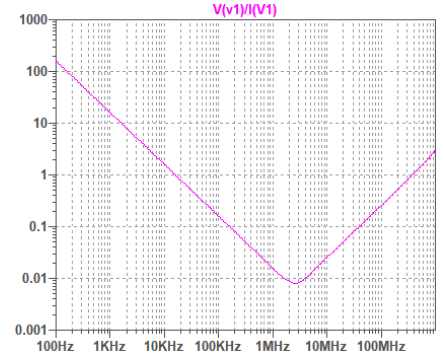


Simulation





WÜRTH ELEKTRONIK

REDEXPERT

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From lab to desk in seconds with REDEXPERT®

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- MagI³C Power Module Designer
- Resonance Tank Calculation for Wireless Power
- Filter Circuits
- DC/DC Converter
- Wireless Connectivity and Sensors
- Capacitor lifetime calculator
- Optoelectronics
- Power Magnetics

Product selection

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- Power Inductors and Magnetics
- MagI³C Power Products
- Signal & Communications
- Capacitors & Resistors
- Optoelectronics
- Quartz Crystals & Oscillators
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Send us a quick email here and let us know! Just click here.

Nina
Hallo, wie kann ich Ihnen helfen?

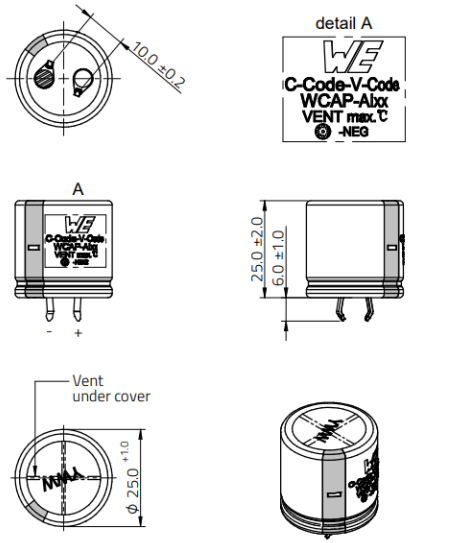
Ihre Nachricht

ELECTROLYTIC CAPACITORS

ALUMINUM ELECTROLYTIC CAPACITOR SPECIFICATION

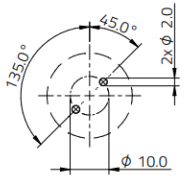
WCAP-AIG8 – Snap-In Alum Electrolytic 82 µF ± 20%; 450 V(DC);

Dimensions: [mm]



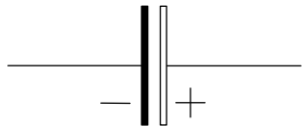
Scale - 1:1.25

Recommended Hole Pattern: [mm]



Scale - 1:1.25

Schematic:



Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Capacitance	C	0.25 V/ 120 Hz/ +20 °C	82	µF	±20%
Rated Voltage	V_R		450	V (DC)	max.
Surge Voltage	V_S	1000 cycles @ 20 °C	495	V (DC)	max.
Leakage Current	I_{Leak}	5 min./ +20 °C	738	µA	max.
Dissipation Factor	DF	0.25 V/ 120 Hz/ +20 °C	20	%	max.
Ripple Current	I_{RIPPLE}	120 Hz @ 85 °C	900	mA	max.
ESR	R_{ESR}	0.25 V/ 120 Hz/ +20 °C	3230	mΩ	max.

General Information:

Aluminum Electrolytic Capacitors	
Operating Temperature	-25 °C up to +85 °C
Storage Conditions (in original packaging)	5 °C up to + 35 °C; 10 % rH up to 75 % rH
Endurance	2000 h
Moisture Sensitivity Level (MSL)	1
Test conditions of electrical properties: +20 °C, 35 % rH if not specified differently	
FIT according to separate documentation	
Surge Voltage: charging time 30 s, discharging time 330 s for a cycle	

RoHS COMPLIANT | REACh COMPLIANT | HALOGEN FREE

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

Würth Elektronik eiSos GmbH & Co. KG
EMC & Inductive Solutions
Max-Eyth-Str. 1
74638 Waldenburg
Germany
Tel. +49 (0) 79 42 945 - 0
www.we-online.com
eiSos@we-online.com

CHECKED	REVISION	DATE (YYYY-MM-DD)	GENERAL TOLERANCE	PROJECTION METHOD
FPu	001.002	2025-07-07	DIN ISO 2768-1m	

DESCRIPTION: **WCAP-AIG8 Aluminum Electrolytic Capacitors**

TECHNICAL REFERENCE: ANA0250820M450DSIC3B000

ORDER CODE: **861011484008**

SIZE/TYPE	BUSINESS UNIT	STATUS	PAGE
25.0 x 25.0	eiCap	Valid	1/10

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Capacitance	C	0.25 V/ 120 Hz/ +20 °C	82	µF	±20%
Rated Voltage	V_R		450	V (DC)	max.
Surge Voltage	V_S	1000 cycles @ 20 °C	495	V (DC)	max.
Leakage Current	I_{Leak}	5 min./ +20 °C	738	µA	max.
Dissipation Factor	DF	0.25 V/ 120 Hz/ +20 °C	20	%	max.
Ripple Current	I_{RIPPLE}	120 Hz @ 85 °C	900	mA	max.
ESR	R_{ESR}	0.25 V/ 120 Hz/ +20 °C	3230	mΩ	max.

ALUMINUM ELECTROLYTIC CAPACITOR SPECIFICATION

Ripple current is more than you expect – Multipliers in page 3

Multiplier for Ripple Current vs. Frequency

Voltage [V_R]/ Frequency [Hz]	50 (60)	120	300	1K	10K	50K-100K
$6.3 \le V_R \le 100$	0.88	1.00	1.07	1.15	1.15	1.15
$160 \le V_R \le 250$	0.81	1.00	1.17	1.32	1.45	1.5
$315 \le V_R \le 600$	0.77	1.00	1.16	1.30	1.41	1.43

Lifetime Performance:

Test Conditions	Useful life	Endurance	Shelf Life
Lifetime	5000 h @ 85 °C	2000 h @ 85 °C	1000 h @ 85 °C
Voltage	$V_{R\ applied}$	$V_{R\ applied}$	None
Current	I_R	I_R	None
Δ C	≤ ±20 % of initial measured value	≤ ±15 % of initial measured value	≤ ±15 % of initial measured value
DF	≤ 200 % of the initial specified value	≤ 175 % of the initial specified value	≤ 175 % of the initial specified value
Leakage Current	≤ the initial specified value	≤ the initial specified value	≤ the initial specified value
Failure Rate	≤0.01 %/ 1000 h		
Comment			Before measurement: Restore capacitor to 20 °C, apply for V_R for 30 min.

Multiplier for Ripple Current vs. Temperature:

Temperature [°C]	45	65	85
Multiplier	1.55	1.25	1

This is only for calculation. Changes of other conditions will influence the lifetime. The lifetime calculation has to consider the application specific parameters which are applied to the capacitor. (e.g. ambient temperature, ripple current)

- **Frequency Multipliers**
  - Available for electrolytic, polymer and hybrid
  - Related to lower ESR and lower Vpp at high freq.
- **Temperature Multipliers**
  - Only for Snap-In and Screw Termination
  - Higher self-heating allowed at low operating temp.
  - **NOTE: It WILL affect lifetime!**
- Example
  - Datasheet: 900 mA @ 120 Hz @ 105°C
  - My application: 20 kHz ripple at 60°C
    - 900 * 1.41 * 1.55 = **1967 mA @ 20 kHz @ 60°C**

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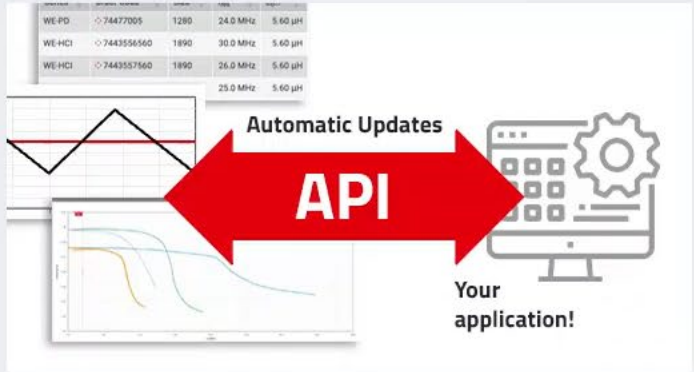

Accurate component data in your company?

In REDEXPERT you can see the bias curves, for example for Inductors and Ceramic capacitors. You can also see the equivalent circuit parameters. How would it be, if you had all this data internall
make your work easier? Would it help your
The data in REDEXPERT and its appl
not exchanged manually, it is retrieve
application easily and will be updated automatically.

Claudia
Melden Sie sich, falls Sie Fragen haben.

ALUMINUM ELECTROLYTIC CAPACITOR SPECIFICATION

Lifetime Perfomance Information Table (page 3)

Multiplier for Ripple Current vs. Frequency

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$160 \le V_R \le 250$	0.81	1.00	1.17	1.32	1.45	1.5
$315 \le V_R \le 600$	0.77	1.00	1.16	1.30	1.41	1.43

Lifetime Performance:

Test Conditions	Useful life	Endurance	Shelf Life
Lifetime	5000 h @ 85 °C	2000 h @ 85 °C	1000 h @ 85 °C
Voltage	$V_{R\ applied}$	$V_{R\ applied}$	None
Current	I_R	I_R	None
Δ C	≤ ±20 % of initial measured value	≤ ±15 % of initial measured value	≤ ±15 % of initial measured value
DF	≤ 200 % of the initial specified value	≤ 175 % of the initial specified value	≤ 175 % of the initial specified value
Leakage Current	≤ the initial specified value	≤ the initial specified value	≤ the initial specified value
Failure Rate	≤0.01 %/ 1000 h		
Comment			Before measurement: Restore capacitor to 20 °C, apply for V_R for 30 min.

Multiplier for Ripple Current vs. Temperature:

Temperature [°C]	45	65	85
Multiplier	1.55	1.25	1

This is only for calculation. Changes of other conditions will influence the lifetime. The lifetime calculation has to consider the application specific parameters which are applied to the capacitor. (e.g. ambient temperature, ripple current)

- **Endurance**
  - Test conditions that must be fulfilled
  - This is the basis for lifetime calculations
  - End of life conditions are restrictive
- **Useful Life**
  - **Only for Snap-In and Screw Termination**
  - Longer useful life than endurance
  - End of life conditions have larger margins
  - NOTE: Includes increased failure rate!
- **Shelf Life**
  - Additional unloaded specification
  - Test is less severe than endurance

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WÜRTH ELEKTRONIK

REDEXPERT Alum. Electrolytic / Alum. Polymer / Hybrid Polyn

Menu

Lifetime Calculator

Filters: $V_R \geq 400$ V | 100 µF ≤ C ≤ 300 µF

79 items

Order Code	Series	Spec	Technology	Series Description	C	To...	V_R	DF	I@70 °C @20 ...	Specified Max. I_{Ripple}	I_{leak}	T_{min}	T_{max}	Lifetime	Asse...	Width	Height	Length
861021485025	WCAP-AIG5		Alum. Electrolytic	Snap-In - General Purpose +10...	270 µF	±20%	450 V	< 20 %	3.51 A	1.48 A @120 Hz @105 °C	2.43 mA	-25 °C	105 °C	2000.0 h	Snap-In		51.0 mm	
861021486030	WCAP-AIG5		Alum. Electrolytic	Snap-In - General Purpose +10...	270 µF	±20%	450 V	< 20 %	3.51 A	1.48 A @120 Hz @105 °C	2.43 mA	-25 °C	105 °C	2000.0 h	Snap-In		42.0 mm	
861011485017	WCAP-AIG8		Alum. Electrolytic	Snap-In - General Purpose +85...	270 µF	±20%	450 V	< 20 %	3.34 A	2.00 A @120 Hz @85 °C	2.43 mA	-25 °C	85.0 °C	2000.0 h	Snap-In		46.0 mm	
861011486021	WCAP-AIG8		Alum. Electrolytic	Snap-In - General Purpose +85°C	270 µF	±20%	450 V	< 20 %	3.34 A	2.00 A @120 Hz @85 °C	2.43 mA	-25 °C	85.0 °C	2000.0 h	Snap-In		37.0 mm	
861221486020	WCAP-AIE8		Alum. Electrolytic	Snap-In - Long Life +85°C	270 µF	±20%	450 V	< 20 %	3.17 A	1.90 A @120 Hz @85 °C	1.05 mA	-25 °C	85.0 °C	3000.0 h	Snap-In		30.0 mm	
861221485016	WCAP-AIE8		Alum. Electrolytic	Snap-In - Long Life +85°C	270 µF	±20%	450 V	< 20 %	3.16 A	1.89 A @120 Hz @85 °C	1.05 mA	-25 °C	85.0 °C	3000.0 h	Snap-In		35.0 mm	
861141485018	WCAP-AI3H		Alum. Electrolytic	Snap-In - Long Life +105°C	270 µF	±20%	450 V	< 20 %	3.03 A	1.28 A @120 Hz @105 °C	1.05 mA	-25 °C	105 °C	3000.0 h	Snap-In		40.0 mm	
861141486021	WCAP-AI3H		Alum. Electrolytic	Snap-In - Long Life +105°C	270 µF	±20%	450 V	< 20 %	3.03 A	1.28 A @120 Hz @105 °C	1.05 mA	-25 °C	105 °C	3000.0 h	Snap-In		35.0 mm	
861011484013	WCAP-AIG8		Alum. Electrolytic	Snap-In - General Purpose +85°C	220 µF	±20%	450 V	< 20 %	2.94 A	1.76 A @120 Hz @85 °C	1.98 mA	-25 °C	85.0 °C	2000.0 h	Snap-In		51.0 mm	

861021485025 — WCAP-AIG5 — 270 µF · 450 V

861021486030 — WCAP-AIG5 — 270 µF · 450 V

861011485017 — WCAP-AIG8 — 270 µF · 450 V

Click and type or drop an Order Code here

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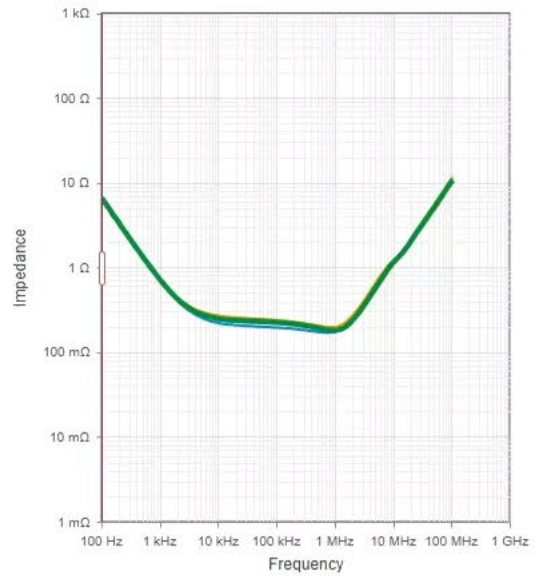
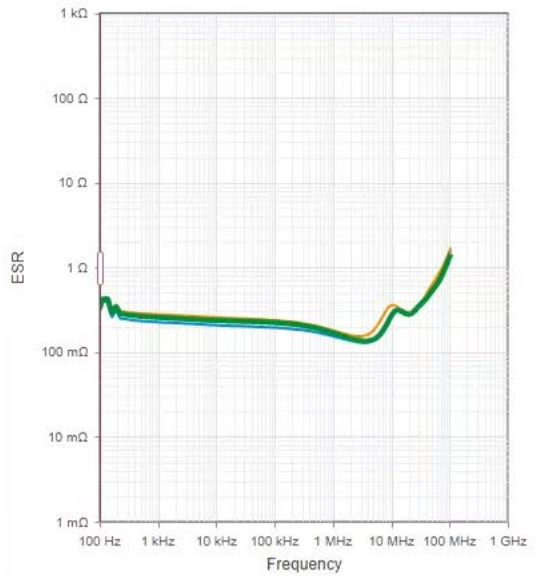
MORE

Show Panel: Z vs. F | ESR vs. F | I_{RMS} vs. F | I_{RMS} vs. T

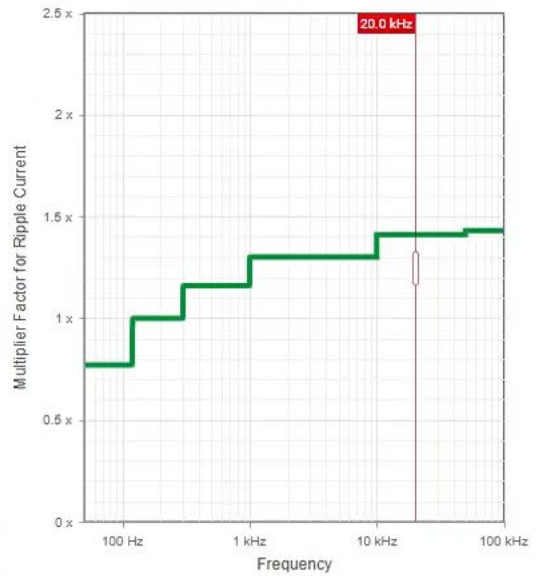
Impedance / Frequency



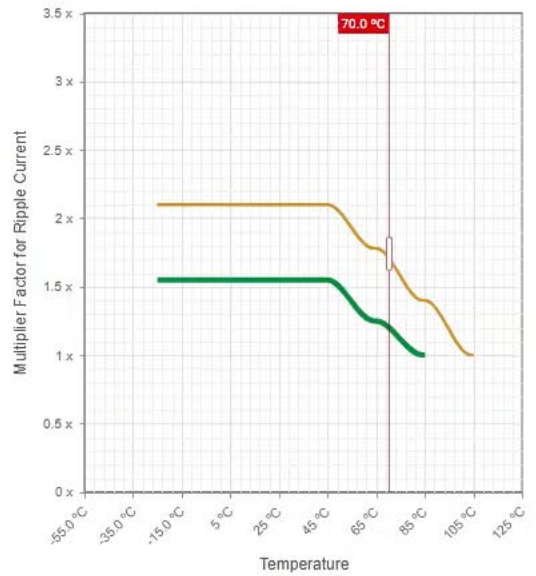
ESR / Frequency



Multiplier Factor for Ripple Current / Frequency



Multiplier Factor for Ripple Current / Temperature



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VOLTAGE RATINGS OF DC CAPACITORS

Different technologies, different limitations

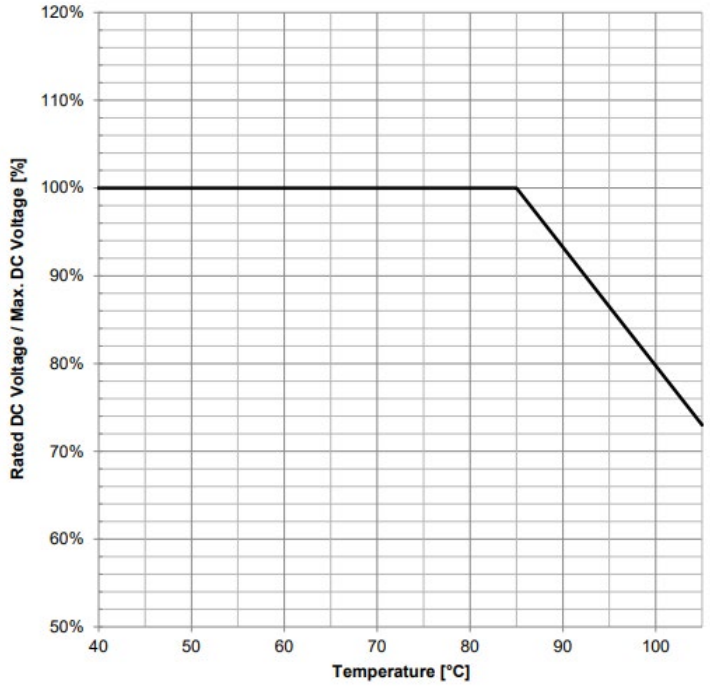
VOLTAGE RATING AND VOLTAGE DERATING

Case: Film Capacitors for DC Applications

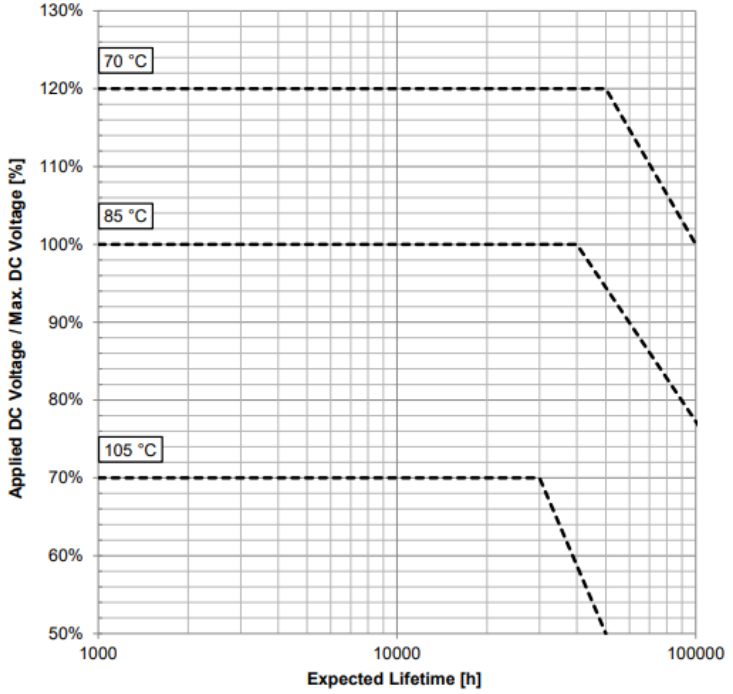
Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Capacitance	C	1 V / 1 kHz ± 0.2 kHz	3	µF	±5%
Rated Voltage	V_R	up to 85 °C	1000	V (DC)	max.
Rated Voltage	V_R	@ 105 °C	730	V (DC)	max.

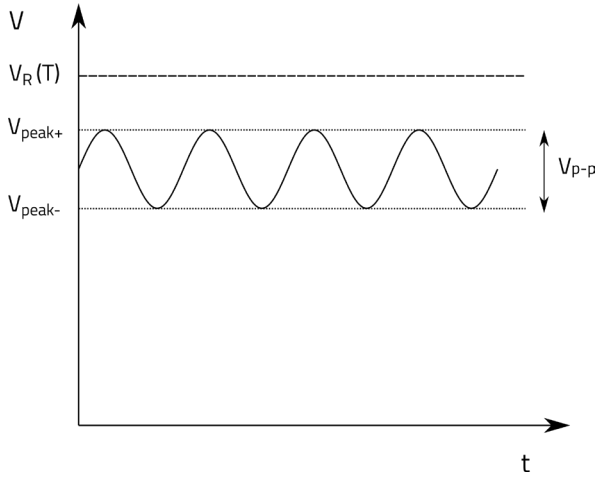
Voltage Derating:



Lifetime (Typical Curve):

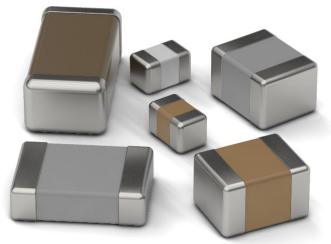


- Operating voltage affects lifetime in combination with ambient temperature + humidity
- To achieve longer operating life, it is possible to derate voltage for high temperature



VOLTAGE RATING AND VOLTAGE DERATING

Case: Ceramic Capacitors / MLCC for DC applications



- DC Voltage have significant impact in Class II ceramic capacitors
- Limited impact of voltage on lifetime
- Surge voltages and overvoltage may produce microcracking

Case: Aluminum Electrolytic/Polymer

- DC Voltage has a dielectric reforming / healing effect
  - Isolation is increased and leakage is reduced
- Performance not affected
- Lifetime only affected in high voltage (>160 V) capacitors
  - Up to factor 125% for

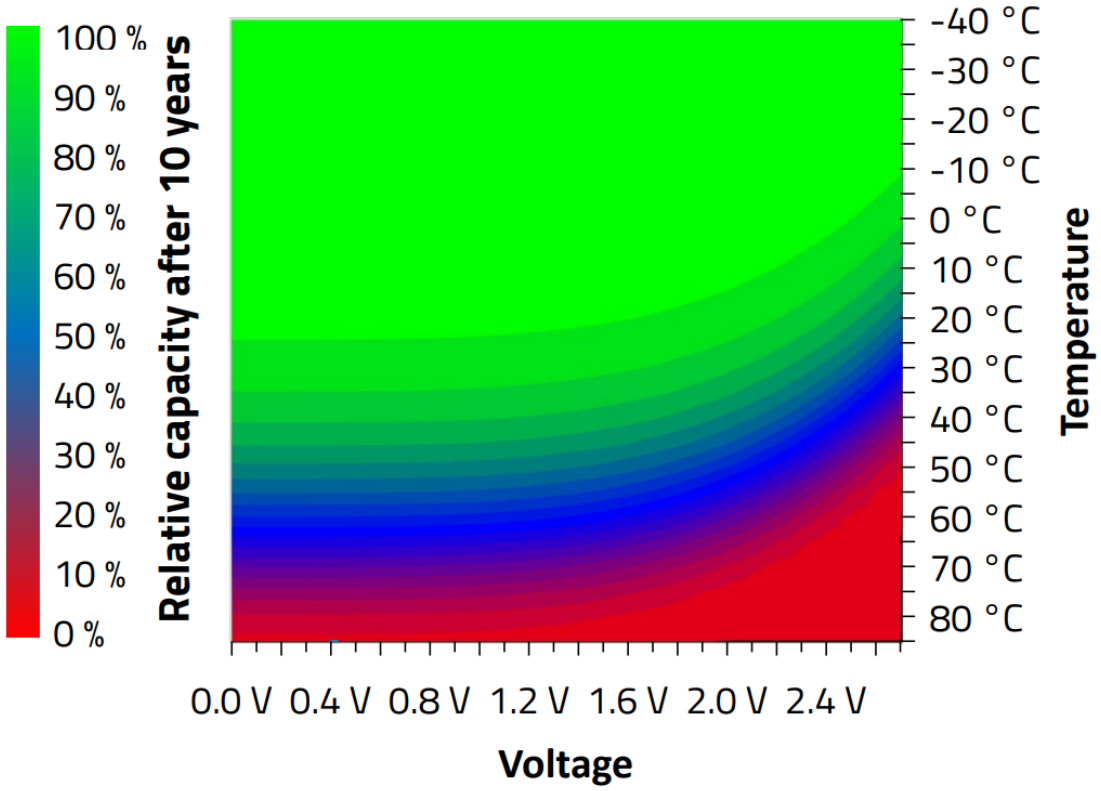
VOLTAGE RATING AND VOLTAGE DERATING

Case: Supercapacitors - Electric double layer capacitors

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Capacitance	C	10 mA/ F	50	F	+30%/-10%
Rated Voltage	U_R	@ 65 °C	2.7	V (DC)	max.
Rated Voltage	U_R	@ 85 °C	2.3	V (DC)	max.
Surge Voltage	U_S	@ 65 °C	2.85	V (DC)	max.

- DC Voltage have a clear impact in the useful life of EDLCs:
  - Higher voltage up to rated voltage will accelerate capacitance loss over time
- Use at higher voltages may be acceptable if capacitor temperature is low
- Check our Application Note: *"SN012 How does a Supercapacitor age? Lifetime Model of Electric Double Layer Capacitors"*

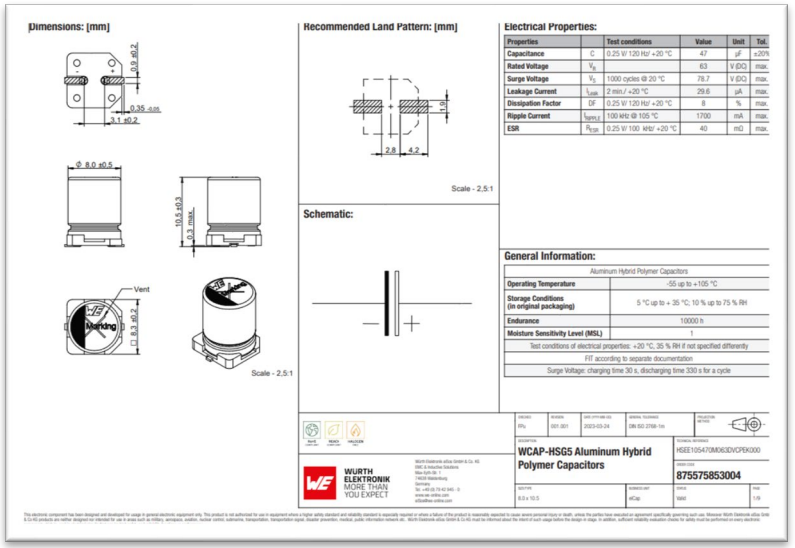


CAPACITOR MEASUREMENTS AND SPECIFICATIONS

Summary

Read the datasheet!

- Added value single PN Datasheets
- Conditions and certifications
- Cautions and warnings



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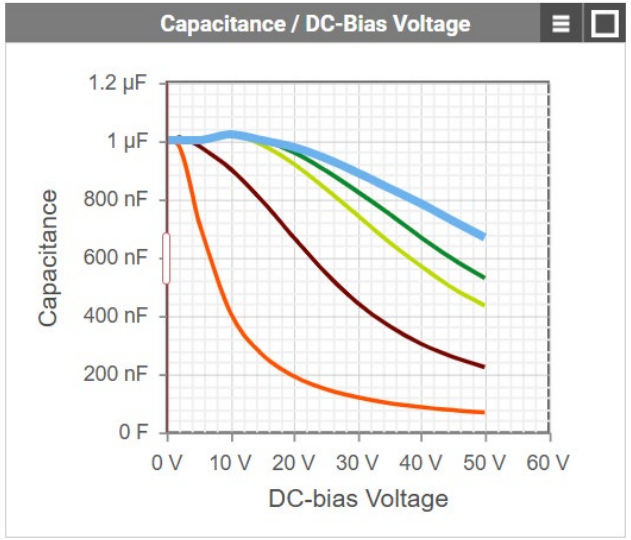

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