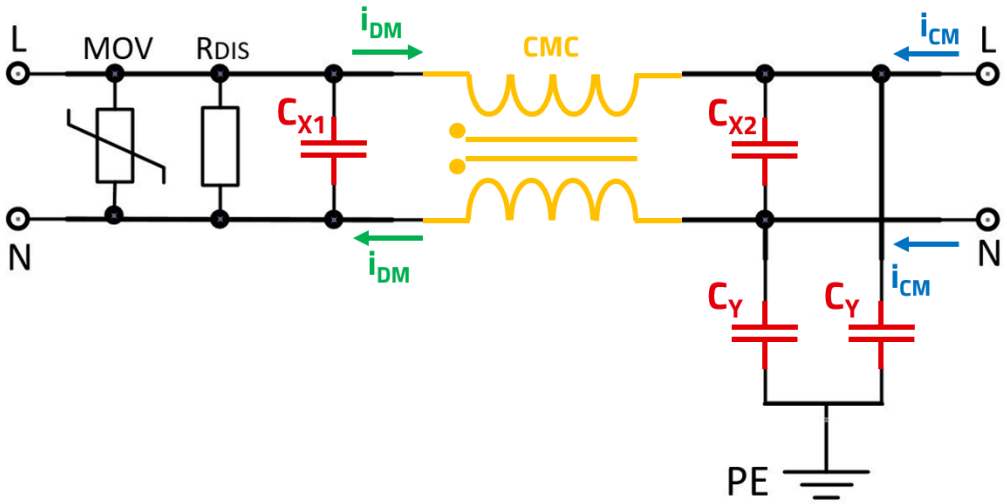
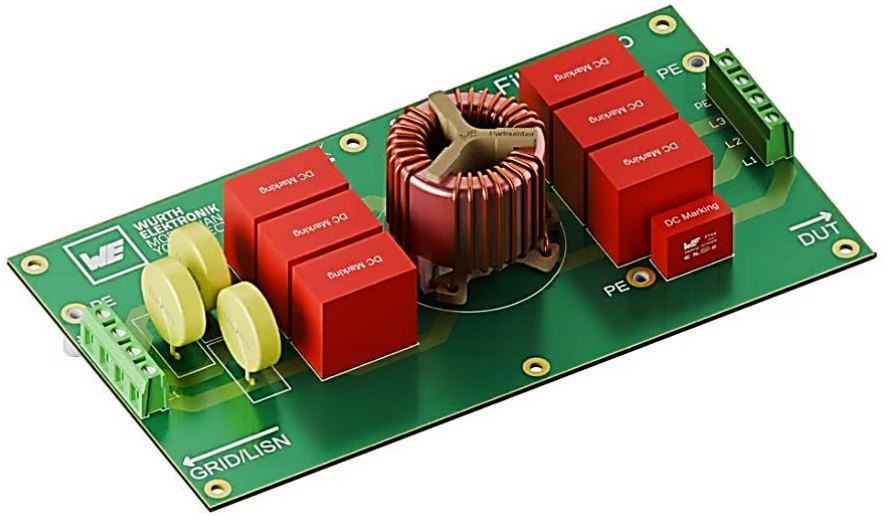




SAFETY BY DESIGN: X AND Y INTERFERENCE SUPPRESSION CAPACITORS FOR POWER LINE FILTERS

Jon Izkue Rodriguez
Product Management Capacitors & Resistors

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

WÜRTH ELEKTRONIK
MORE THAN YOU EXPECT

AGENDA

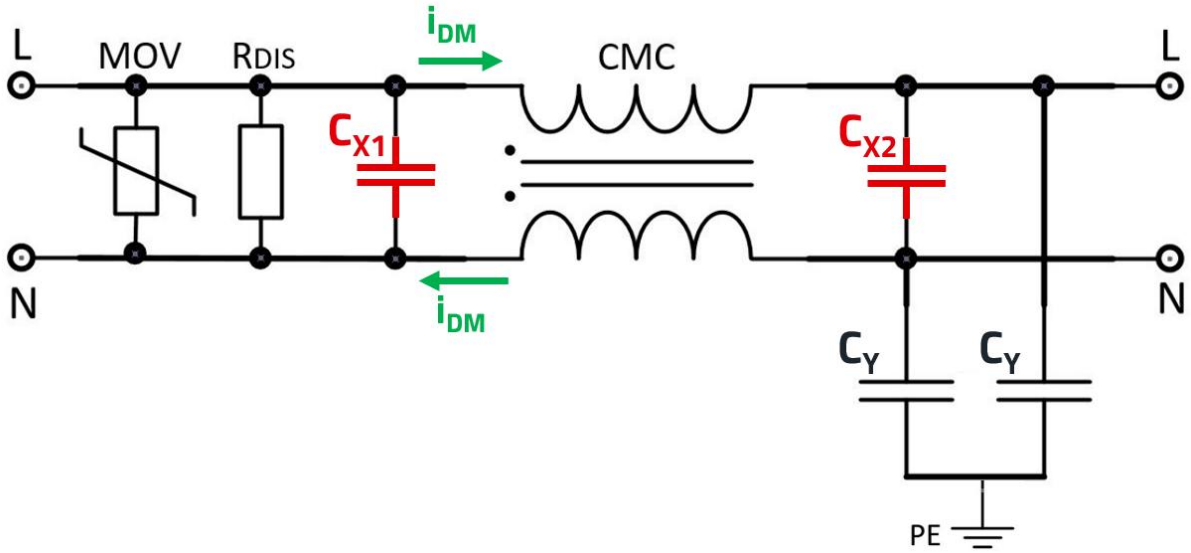
- Introduction
- X and Y Safety Interference Suppression Capacitors
- Main capacitor technologies and products
- IEC 60384-14 and reliability testing
- X and Y Capacitors Würth Elektronik Portfolio
- Würth Elektronik eiSos: Solutions & Resources
- Summary

X AND Y CAPACITORS IN MAINS SUPPLY FILTERS

X AND Y CAPACITORS IN MAINS SUPPLY FILTERS

Standard IEC 60384-14

- **Class X Capacitors**
  - **Differential Mode noise suppression**
  - Connected between phases or between phase and neutral
    - In three-phase systems, they can be connected in star (wye) or delta configuration
  - Protection from surge and impulse voltage
  - Capacitor may be damaged during operation without fire

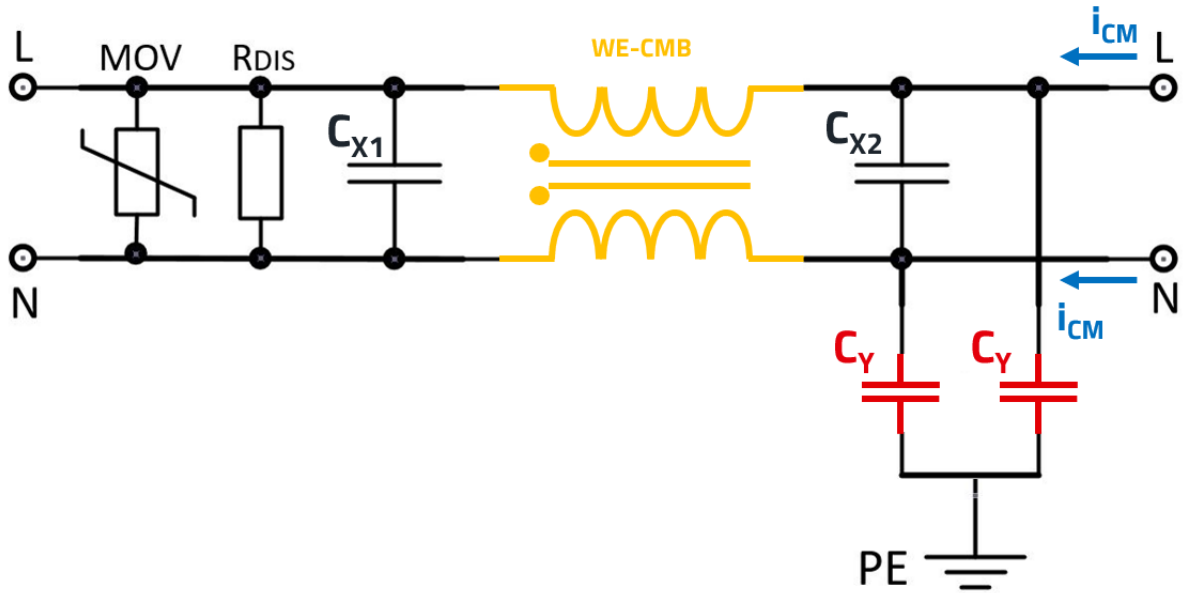


X AND Y CAPACITORS IN MAINS SUPPLY FILTERS

Standard IEC 60384-14

- **Class Y Capacitors**
  - **Common Mode noise suppression**
  - Connected between each phase and protective earth
  - Additional safety requirements
  - Designed to fail open!
  - Maximum capacitance limited by „leakage to earth“
  - May be used across the isolation barrier

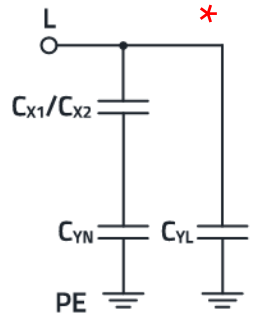
    (e.g. Flyback converter)



X AND Y CAPACITORS IN MAINS SUPPLY FILTERS

Maximum Y Capacitance limited by leakage to earth

- "Leakage" calculation:



$$I_{LEAK} = V_{GRID} \cdot 2\pi \cdot f_{GRID} \cdot \left(C_{YL} + \frac{C_{XG} \cdot C_{YN}}{C_{XG} + C_{YN}}\right) \quad (29)$$

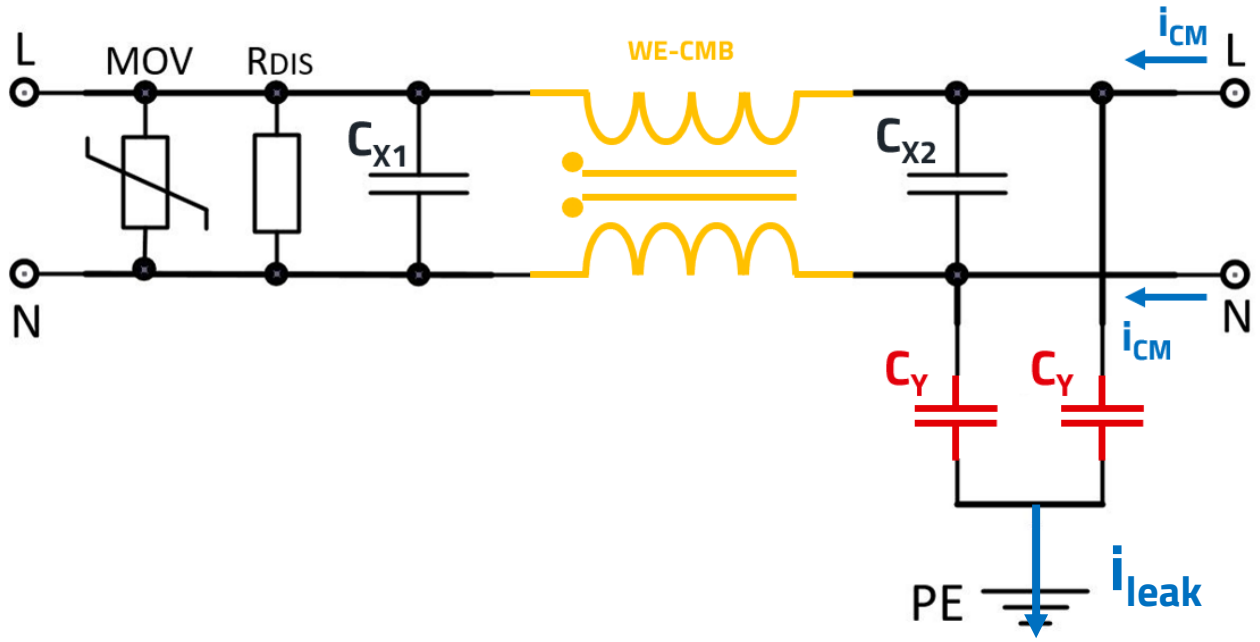
$$C_{XG} = C_{X1} + C_{X2} \quad (30)$$

Example:

C_{X1}, C_{X2} = each 1 µF; C_{Y1}, C_{Y2} = each 5.6 nF; 230 V / 50 Hz

Worst case tolerance: Line voltage + 10%; capacitance + 20%

$$I_{Leak} = 253\ V \cdot 2\pi \cdot 50\ Hz \cdot \left(5.6\ nF + \frac{2.4\ \mu F \cdot 5.6\ nF}{2.4\ \mu F + 5.6\ nF}\right) = 0.89\ mA \quad (31)$$



*ANP015 | 1-Phase Line Filter Design - Andreas Nadler and Stefan Klein (WE eiSos)

X AND Y CAPACITORS IN MAINS SUPPLY FILTERS

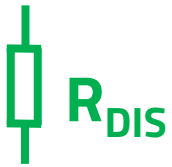
Discharge Resistors for X Capacitance

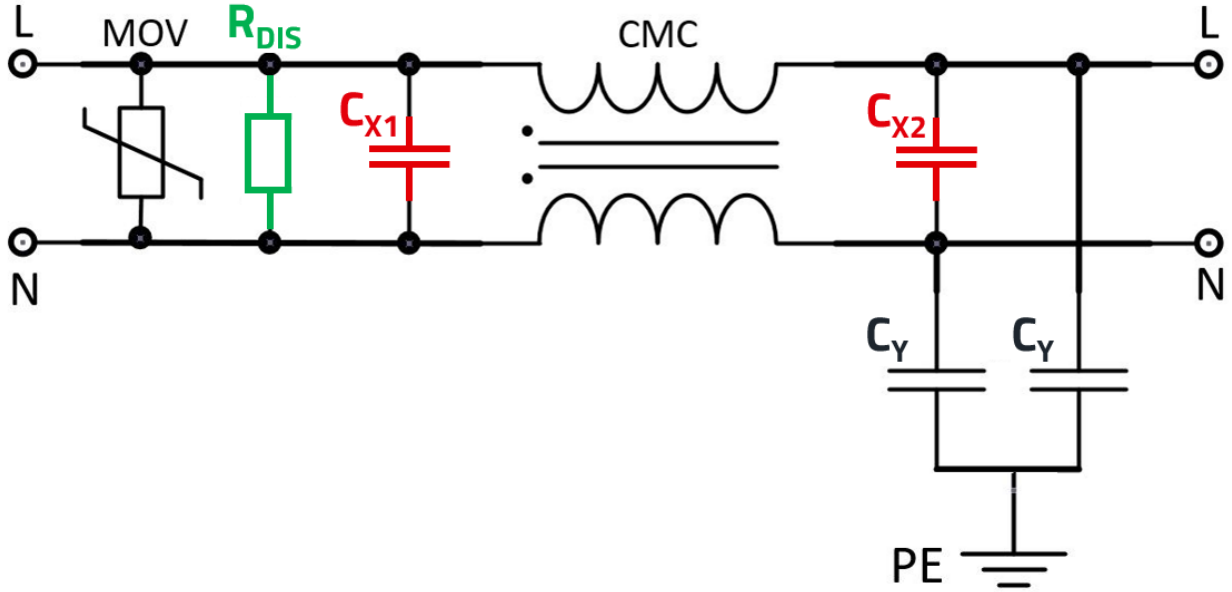
- Safety requirement from several norms
  - IEC 60335-1, IEC 62368-1, IEC 60601-1…

- X Capacitance (between L and N) include
  - Mainly X Capacitors
  - Y Capacitors in series
  - Varistor/MOV capacitance

$$C_{tot} = C_{X1} + C_{X2} + C_{ParaMOV} + \left(\frac{1}{\frac{1}{C_{YL}} + \frac{1}{C_{YN}}} \right)^{*}$$

- Resistor must be properly sized for
  - Resistance value for specified discharge time
  - Power dissipation
  - Clearance/creepage and insulation
  - Overvoltage

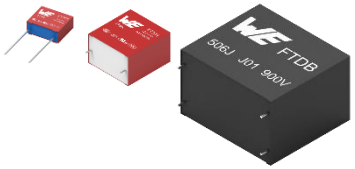




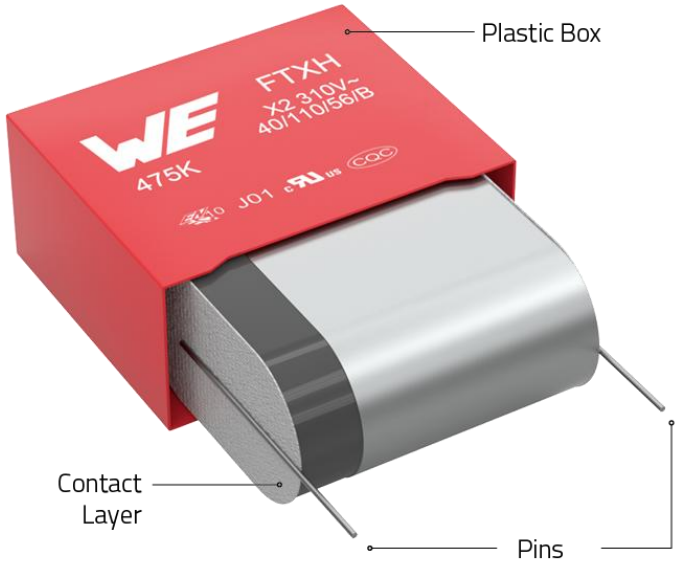
*ANP015 | 1-Phase Line Filter Design - Andreas Nadler and Stefan Klein (WE eiSos)

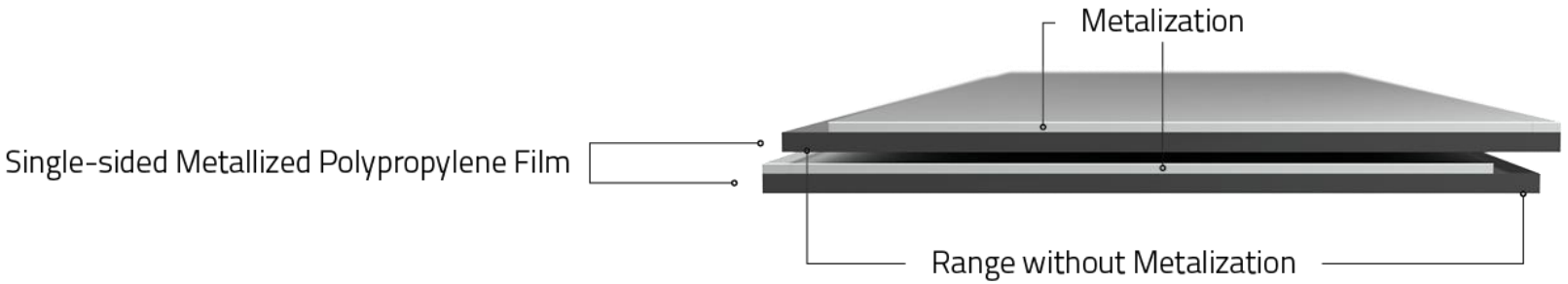
CAPACITOR TECHNOLOGIES

INTERFERENCE SUPPRESSION CAPACITOR TECHNOLOGIES



Construction of a X2 Metallized Film Capacitor

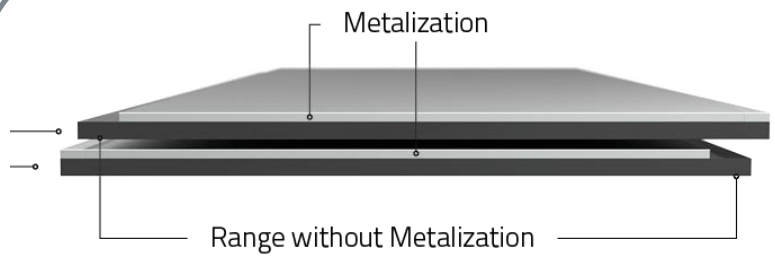


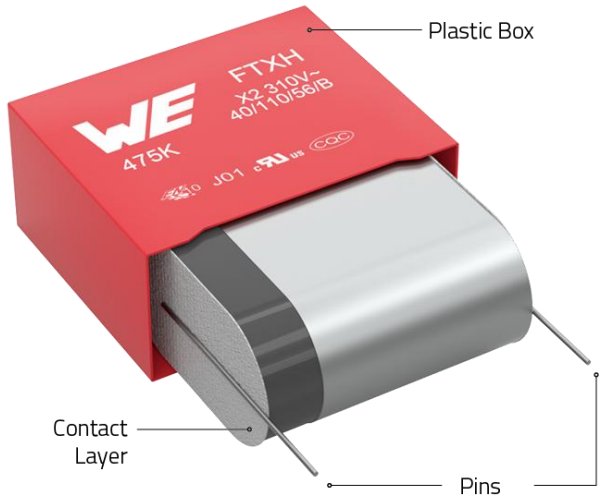


INTERFERENCE SUPPRESSION CAPACITOR TECHNOLOGIES

Construction and internal structure of metallized film Capacitors

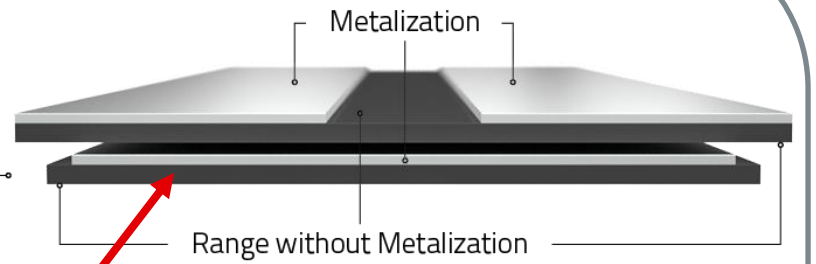
X2 Film Capacitor



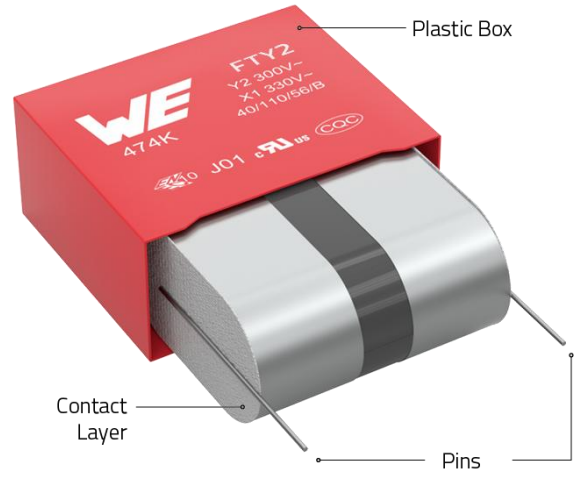


Single-sided Metallized Polypropylene Film

Y2/X1 Film Capacitor

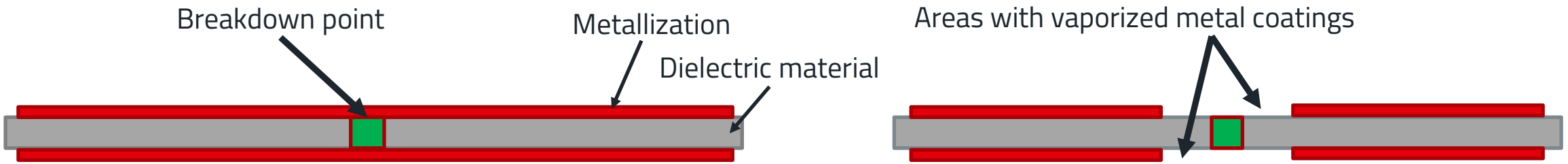


Inner electrode

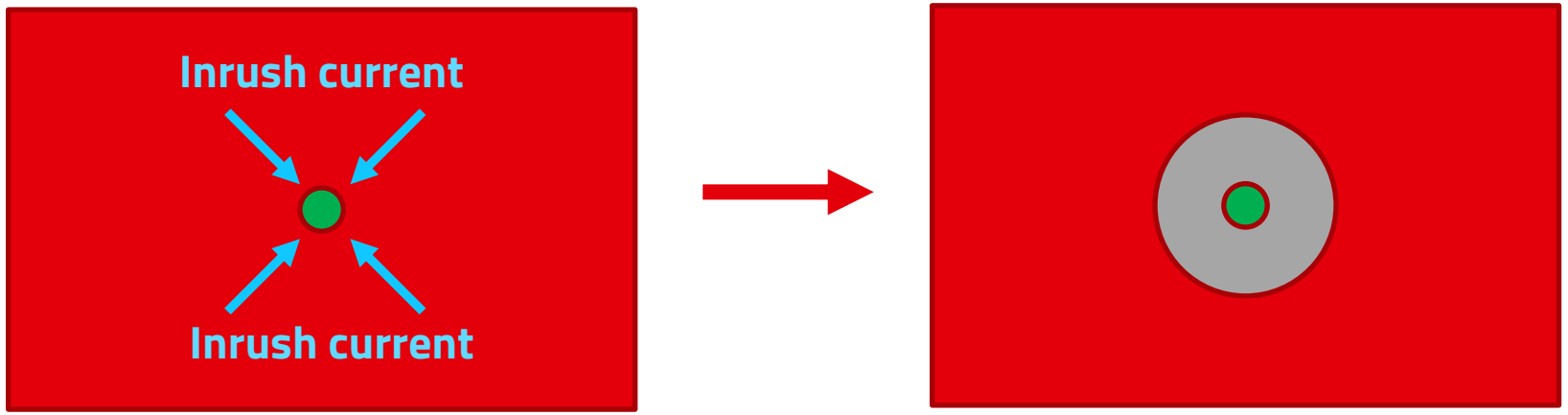


INTERFERENCE SUPPRESSION CAPACITOR TECHNOLOGIES

Self-healing of metallized film capacitors

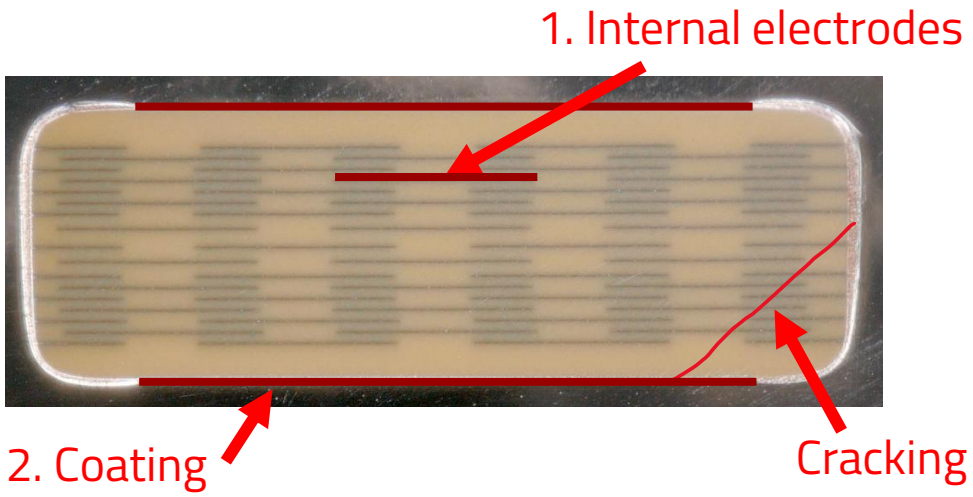


short circuit -> high current density -> evaporation zone

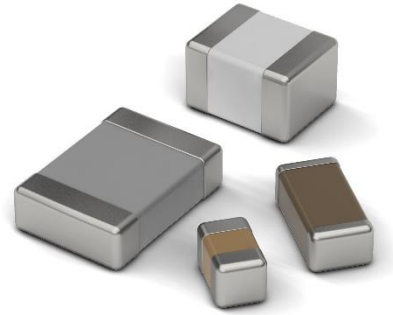


INTERFERENCE SUPPRESSION CAPACITOR TECHNOLOGIES

Special construction of X/Y Safety MLCCs



- 1. Floating/internal electrodes
  - High voltage rating and against surge voltage
  - Protection against short circuit by cracking
  - Open circuit failure mode
- 2. Coating applied on the external faces of the substrate
  - Protection against surface arcing and environment



Safety MLCCs - WCAP-CSSA Series

- X2 and Y2/X1
- Voltage Rating 250 VAC

- Class I (NP0) or Class II (X7R)
- Capacitances 680 pF to 4700 pF
- Sizes from 1808 to 2220
  - Clearance at least 3 mm (1808) or 4 mm (2220)
- Very high Isolation resistance
- Certificates: TÜV, UL

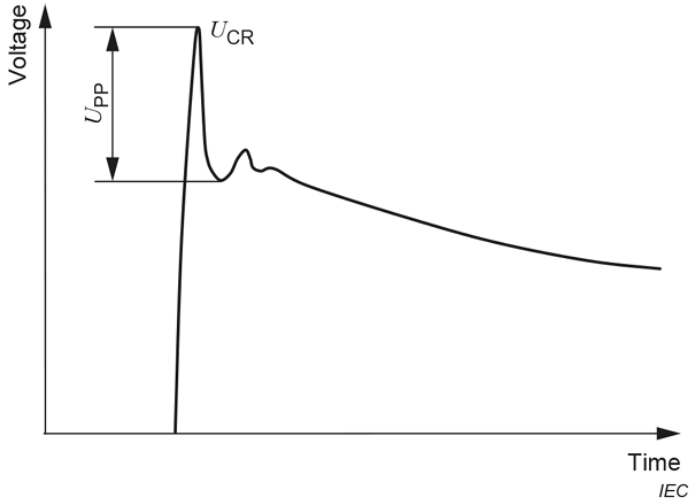
STANDARD RELIABILITY OF SAFETY CAPACITORS

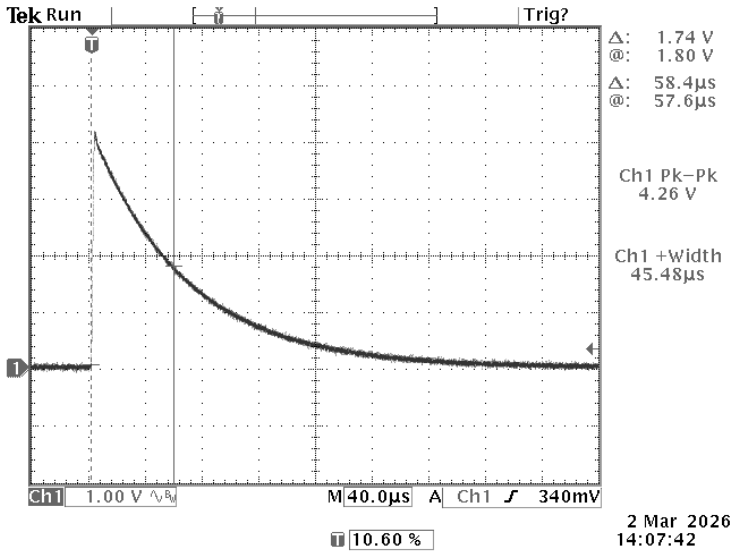
STANDARD RELIABILITY OF SAFETY CAPACITORS

IEC 60384-14 - Impulse Voltage Test

- Destructive Test
- Capacitors are subjected to 24 pulses
- After 3 pulses without self-healing or flashover is a pass
- Verification of self-healing with the use of oscilloscope curve
- Capacitor electrical check after test

Safety Class	Max. Impulse according to IEC - 60384-14
X1	4kV (C≤ 1µF)
X2	2,5 kV (C≤ 1µF)
Y1	8 kV
Y2	5 kV

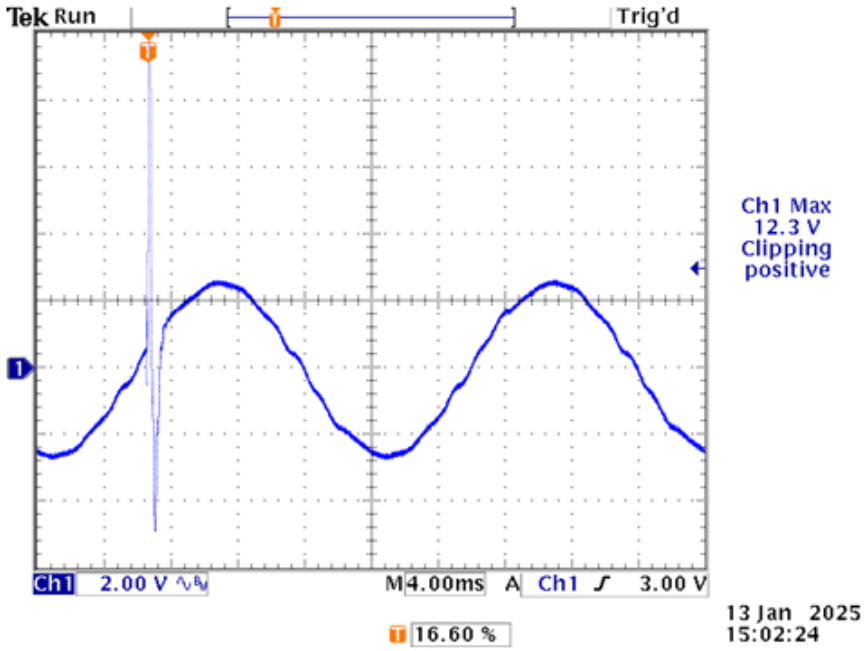




STANDARD RELIABILITY OF SAFETY CAPACITORS

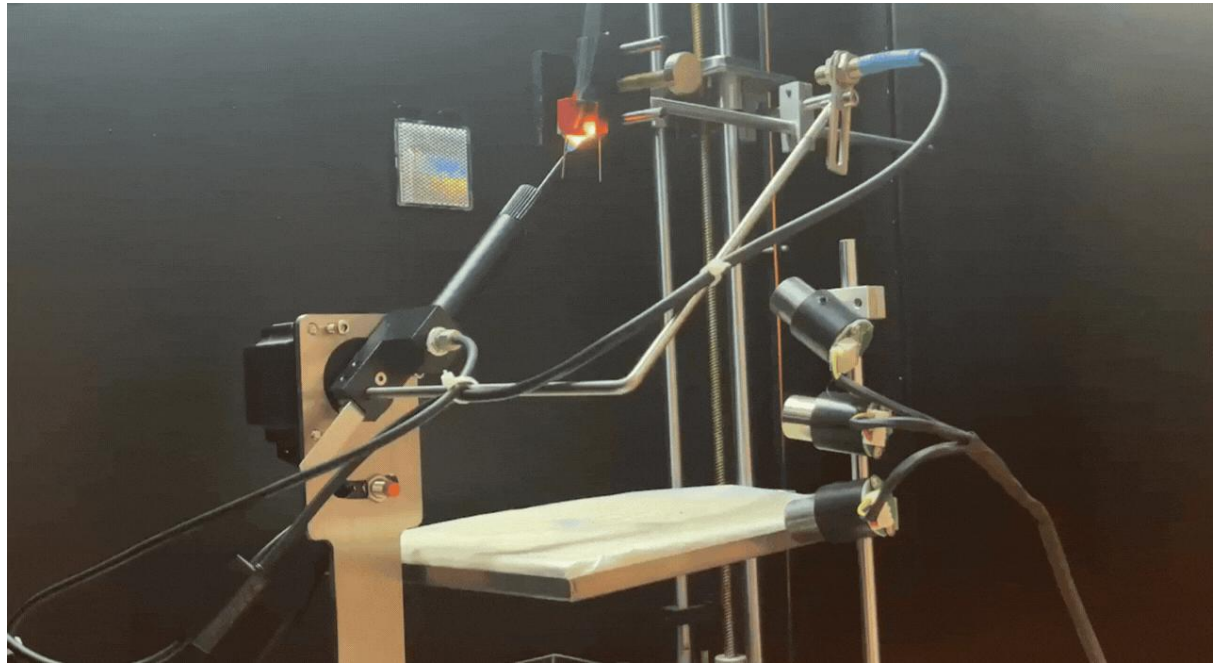
IEC 60384-14 - Active Flammability Test

- Rated AC voltage applied with additional voltage impulses of specified energy
- Check if the component + cloth will ignite by the pulse energy
- Destructive Test



FILM CAPACITORS

IEC 60384-14 - Passive Flammability Test

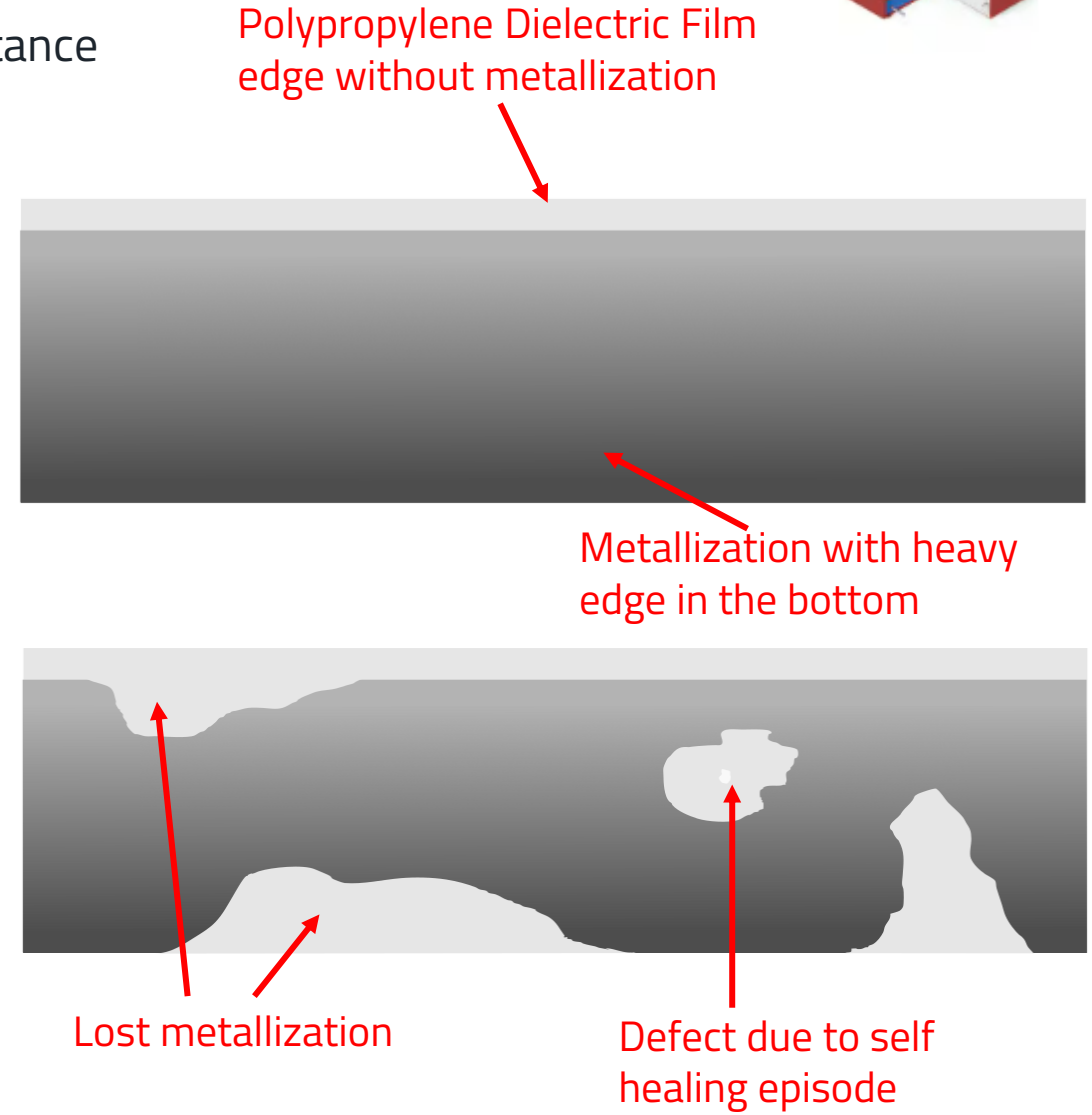


- External flame is applied for a specified time between 10 and 60 seconds
- Capacitor construction
  - Flame retardant epoxy filling
  - Flame extinguishing case materials
- Related material qualification is the UL 94V-0 rating

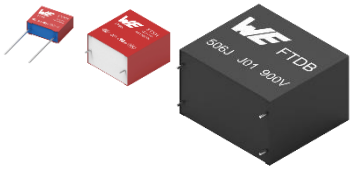
STANDARD RELIABILITY OF SAFETY CAPACITORS

IEC 60384-14: Damp heat, steady state - Degradation of the capacitance

- Overall capacitance loss and increase of ESR due to the loss and damage of the metallization layer
- Mechanisms:
  - Electrochemical Corrosion
  - Self-Healing
  - Partial Discharge Erosion
- Electrochemical corrosion is affected by humidity and accelerated in combination with temperature and voltage
- Self-healing happens with higher voltage and accelerated by temperature
- Partial discharge happens with voltage and is affected by temperature and humidity

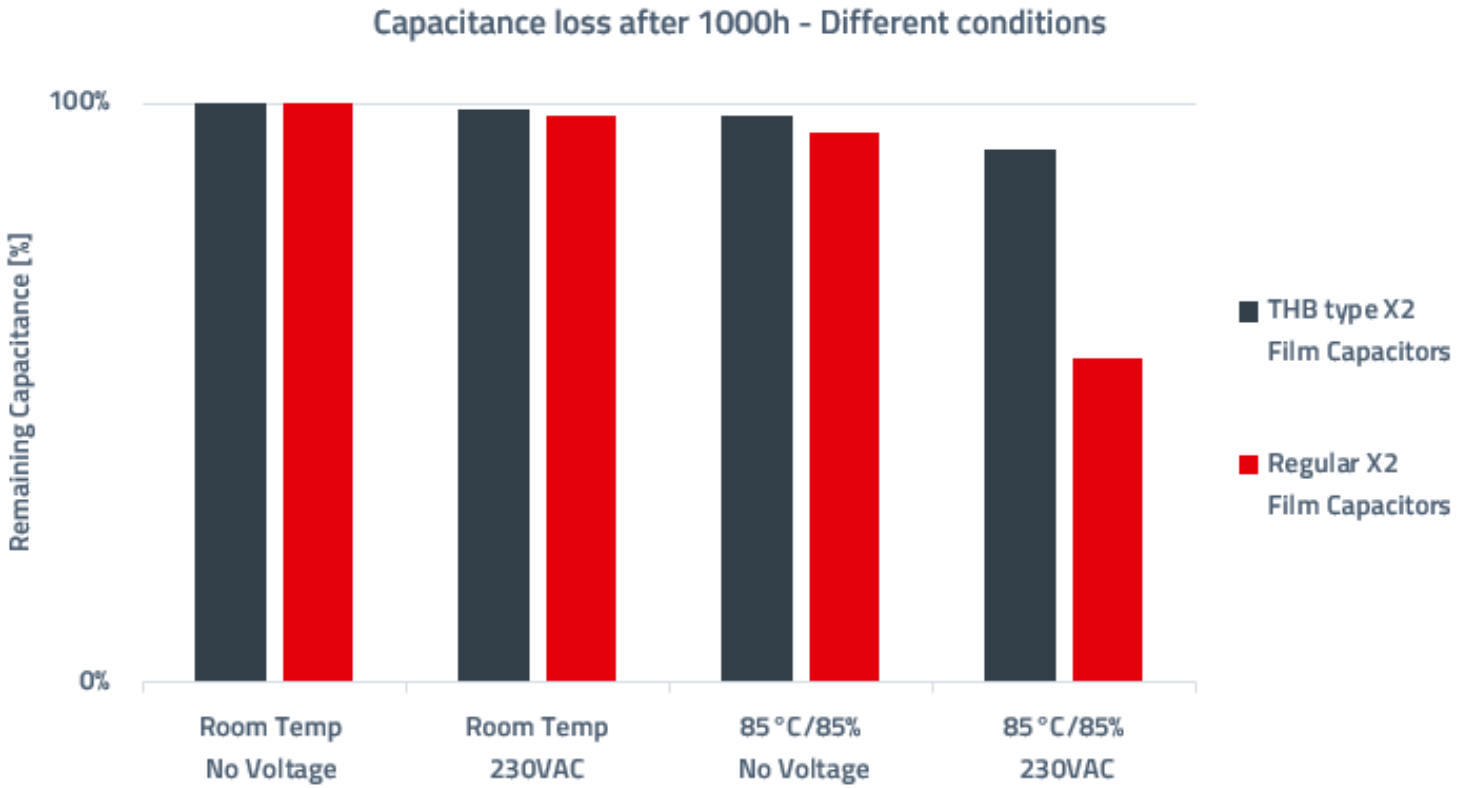


STANDARD RELIABILITY OF SAFETY CAPACITORS



THB-Test - Temperature Humidity Bias – Damp heat steady state, degradation of the capacitance

- Temperature: 85 °C
- Relative humidity: 85 %
- AC Voltage: V_{Rated}
- Duration: 1000 h



STANDARD RELIABILITY OF SAFETY CAPACITORS

Degradation of the capacitance - THB X2 Capacitors

WCAP-FTXH
X2 THB Series
Datasheet

Environmental Tests:

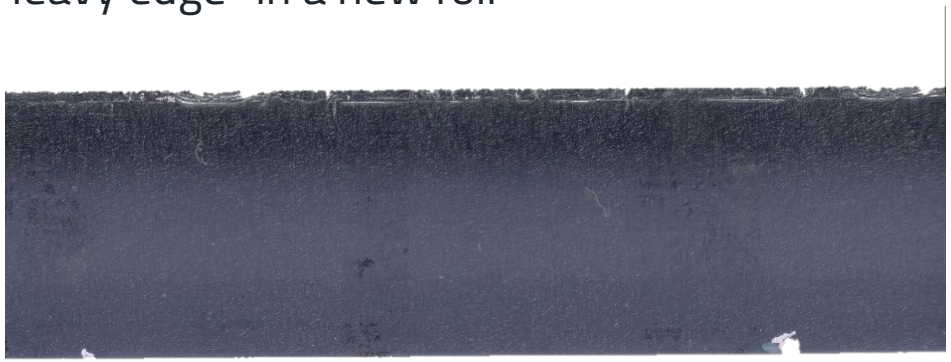
Properties	Standard	
Active Flammability	IEC 60384 - 14	max. 24 surge pulses @ 2.5 kV (one pulse every 5 seconds)
Passive Flammability	IEC 60384 - 14	in combination with IEC 60381 - 1 & IEC 60695 - 11 - 5
Vibration	IEC 60068 - 2 - 6	all 3 directions, 2 hours each @ 10 - 55 - 10 Hz, amplitude 0.75 mm or 10 g
Damp Heat	IEC 60068 - 2 - 78	40°C, 95% RH, 56 days
Humidity Robustness Test	Internal test in accordance to IEC 60384 - 14	85 °C, 85 % RH, 1000 hrs @ 310 V(AC)

Ambient Temp.	Relative Humidity	Absolute Humidity
20°C	35%	**6.05 g/m³**
25°C	50%	**11.5 g/m³**
40°C	95%	**48.5 g/m³**
85°C	85%	**297 g/m³**

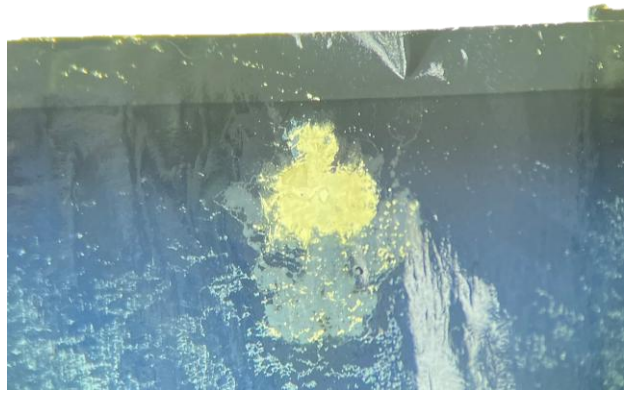
STANDARD RELIABILITY OF SAFETY CAPACITORS

Foil images

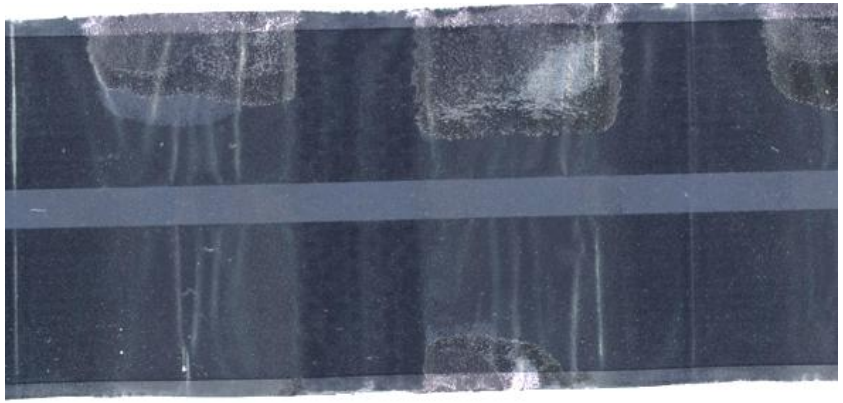
- „Heavy edge“ in a new foil



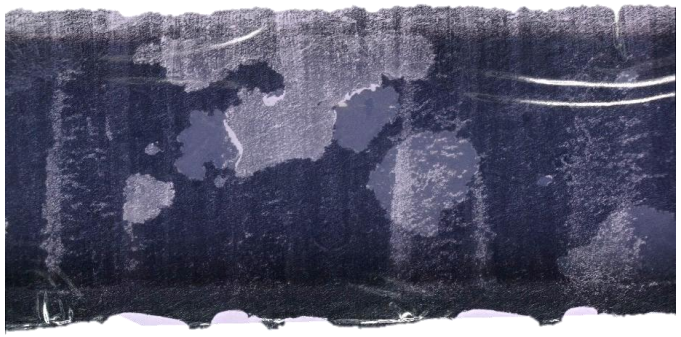
- Self healing defect in the metallization



- New foil with split electrode (internal series connection)



- After 85 °C / 85% test



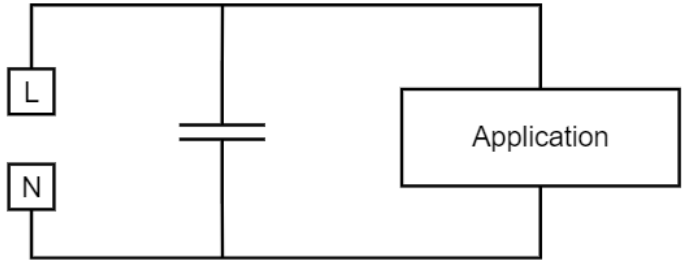
FILM CAPACITOR APPLICATIONS

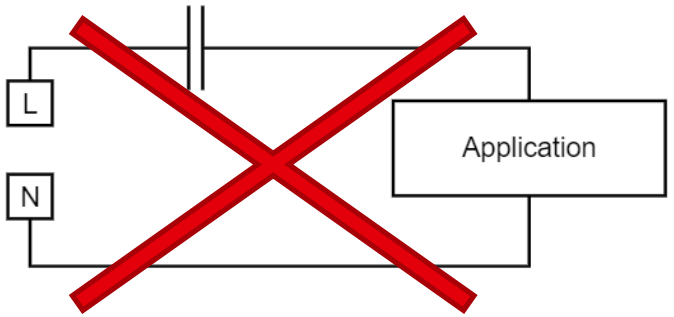
In series to mains applications – Capacitive power supply

- Datasheet of WCAP-FTX2 - 890324025045CS

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.		

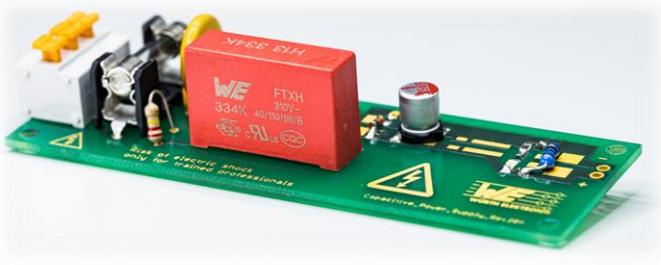


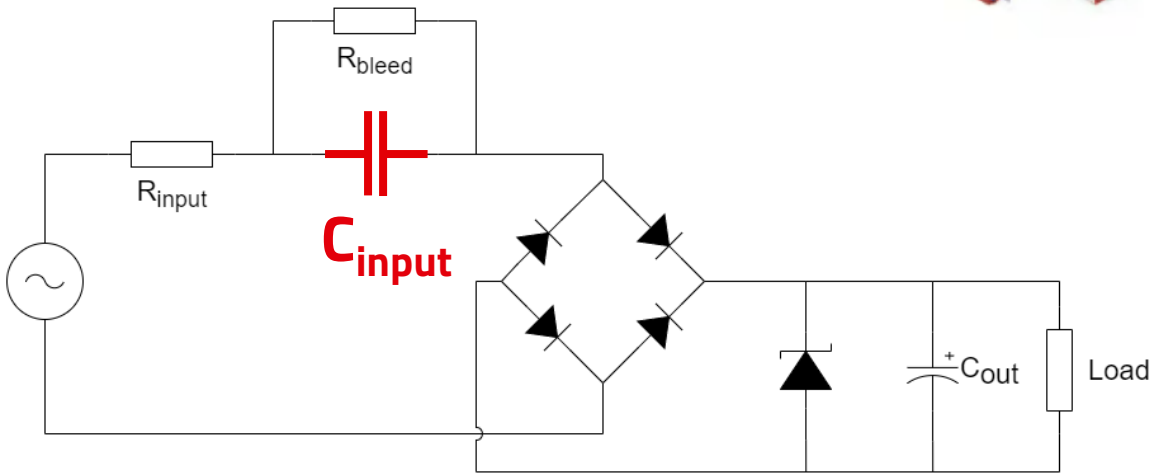


FILM CAPACITOR APPLICATIONS

In series to mains applications – Capacitive power supply

- Input capacitor acts as the main dropper in an AC voltage divider
- Sometimes called “series-to-mains” application
- X2 Capacitors are usually used because the AC Voltage rating is the same
- Not the X2 intended use:
  - Most manufacturers forbid or discourage this use of regular X2 capacitors!
  - **Only some of our WCAP-FTXH capacitors are approved for this application (see datasheet)**





General Information:

X2-Safety Class Capacitor THB; MKP - Metallized Polypropylene		
Operating Temperature	-40 up to +110 °C	
Storage Conditions (in original packaging)	5 °C up to + 35 °C; 10 % up to 75 % RH	
Maximum Selfheating (Rated)	10	°C
Moisture Sensitivity Level (MSL)	1	
Climatic Category	40/110/56/B	
Application	Across the mains or in series with the mains	
THB: Suitable for Harsh Environmental Conditions		
Test conditions of electrical properties: +20 °C, 35 % RH if not specified differently		
FIT according to separate documentation		

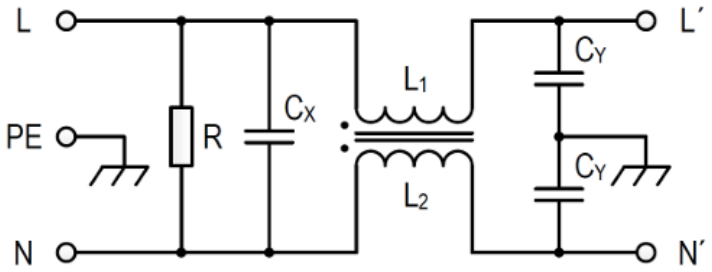
FINAL POINTS

SAFETY BY DESIGN: X AND Y INTERFERENCE SUPPRESSION CAPACITORS

Summary

Usage of X & Y Capacitors

- Regulated by IEC 60384-14
- Certification of components
- Reliability tests
  - Impulse voltage
  - Active & passive flammability
  - Lifetime & harsh environment
  - Failure mode



Safety Capacitor Technologies

- Only high reliability technologies are available
- Ceramic chips have voltage and size limitations
- Temperature and humidity could accelerate degradation of metallized film capacitors

Resources

- Application Notes
- Contact your Sales Representatives and Field Application Engineers
- Use REDEXPERT for the component selection
  - ***redexpert.we-online.com***
- Contact me:
  - Jon.izkue-rodriguez@we-online.de
  - Additional measurements
  - Find me in LinkedIn

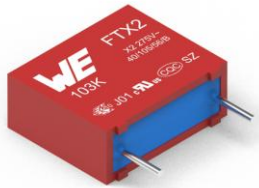
WÜRTH ELEKTRONIK EISOS – X AND Y CAPACITOR SOLUTIONS

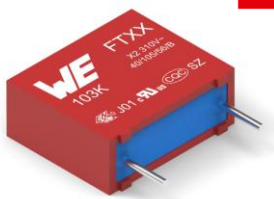
More than you expect

Portfolio Flyer 2026

X2 Capacitors

EXTENDED





WCAP-FTX2

Safety MKP Film Capacitors THB Class X2 275 V_{AC}

WCAP-FTXX

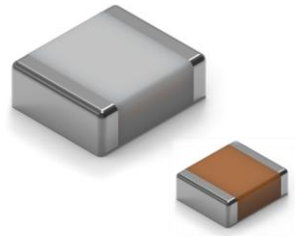
Safety MKP Film Capacitors Class X2 310 V_{AC}

WCAP-FTXH

Safety MKP Film Capacitors THB Class X2 310 V_{AC}

Y2 / X1 Capacitors

NEW



WCAP-FTY2

Safety MKP Film Capacitors Class Y2/X1 300/330 V_{AC}

WCAP-CSSA

Safety MLCCs Class X2 and Class Y2/X1 250 V_{AC}

REDEXPERT Safety X & Y Interference Suppression Capacitors module (Link)

WÜRTH ELEKTRONIK | REDEXPERT Interference Suppression Capacitors (X-/Y-Capacitors) | Menu

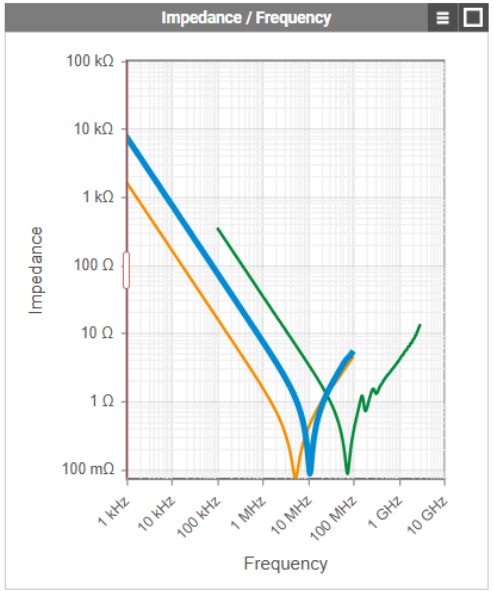
Filters: Class = Y2 / X1 — 49 items

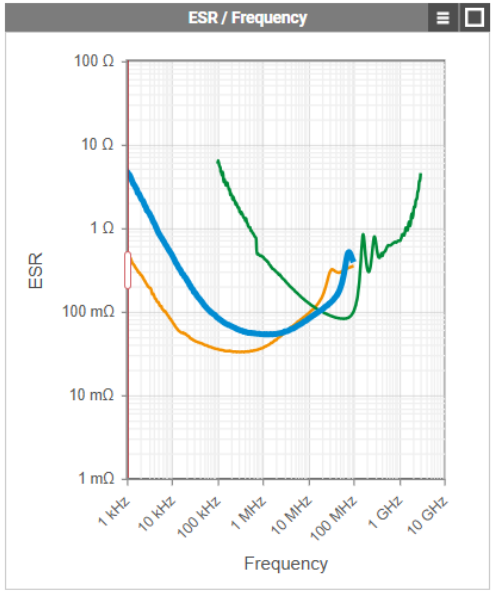
Order Code	Series	I...	Spec	Cla...	Type	Pitch/Size	C	Tol	$V_{R\,X}$(...	$V_{R\,Y}$(AC)	V_R(DC)	DF ...	DF ...	DF ...	R_{iso}	dV/dt
890404125007CS	**WCAP-FTY2**			**Y2 / X1**	**Film Capacit...**	**P15 mm**	**22.0 nF**	**±10%**	**330 V**	**300 V**	**1.00 kV**	**< 0.15 %**	**< 0.20 %**		**> 25.0 GΩ**	**600**
890404125008CS	WCAP-FTY2	✓		Y2 / X1	Film Capacit...	P15 mm	39.0 nF	±10%	330 V	300 V	1.00 kV	< 0.15 %	< 0.20 %		> 25.0 GΩ	600
890404125009CS	WCAP-FTY2	✓		Y2 / X1	Film Capacit...	P15 mm	56.0 nF	±10%	330 V	300 V	1.00 kV	< 0.15 %	< 0.20 %		> 25.0 GΩ	600
890404125010CS	WCAP-FTY2			Y2 / X1	Film Capacit...	P15 mm	47.0 nF	±10%	330 V	300 V	1.00 kV	< 0.15 %	< 0.20 %		> 25.0 GΩ	600
890404125011CS	WCAP-FTY2			Y2 / X1	Film Capacit...	P15 mm	68.0 nF	±10%	330 V	300 V	1.00 kV	< 0.15 %	< 0.20 %		> 25.0 GΩ	600
890404125012CS	WCAP-FTY2	✓		Y2 / X1	Film Capacit...	P15 mm	82.0 nF	±10%	330 V	300 V	1.00 kV	< 0.15 %	< 0.20 %		> 25.0 GΩ	600
890404126001CS	WCAP-FTY2	✓		Y2 / X1	Film Capacit...	P22.5 mm	150 nF	±10%	330 V	300 V	1.00 kV	< 0.15 %	< 0.20 %		> 25.0 GΩ	500

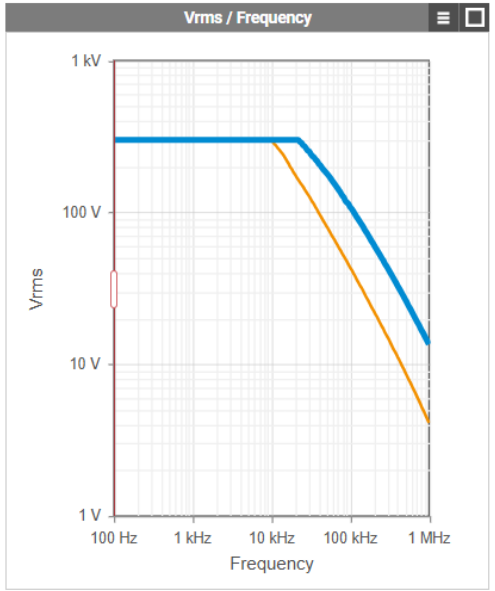
890404125007CS — WCAP-FTY2 · P15 mm · 22.0 nF · 330 V
890404126003CS — WCAP-FTY2 · P22.5 mm · 100 nF · 330 V
8853522140011 — WCAP-CSSA · 2220 · 4.70 nF · 250 V
Click and type or drop an Order Code here

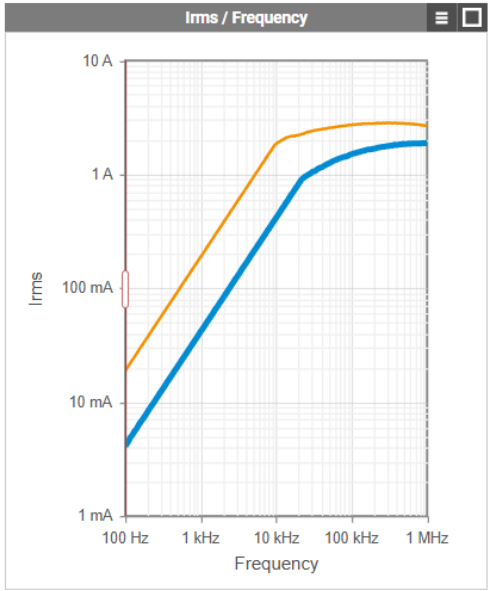
ADD | MORE

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







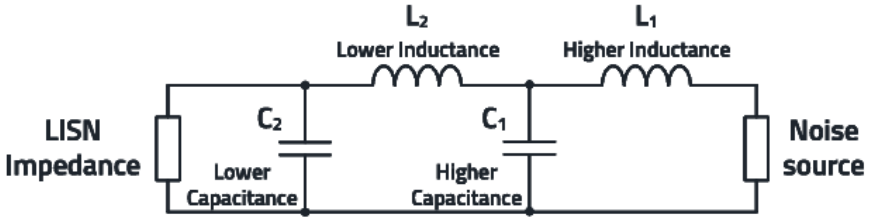


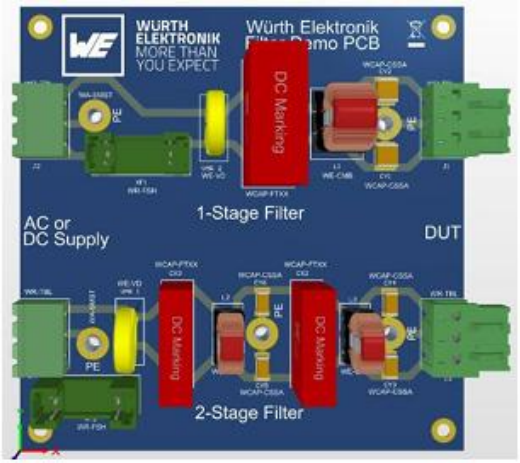
ADDITIONAL RESOURCES

Application notes

ANP015 | Line filter – The last barrier in the switch mode power supply

By Andreas Nadler and Stefan Klein

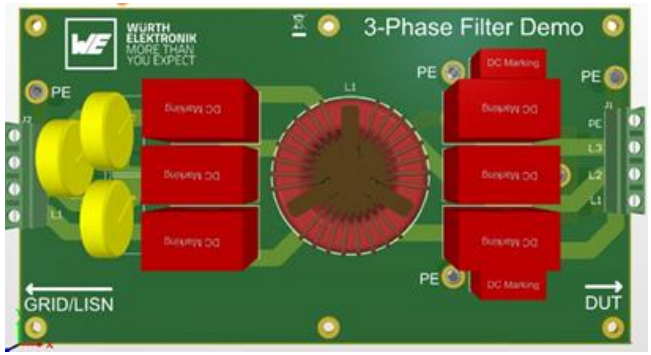


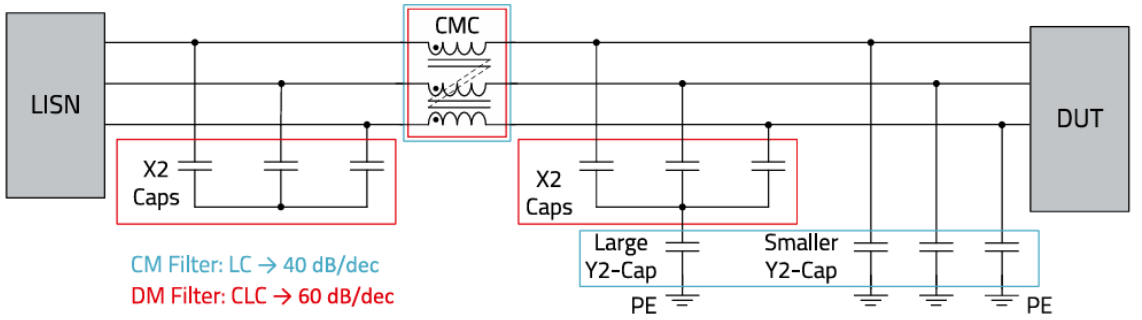


Link

ANP137 | 3-Phase EMI Filter Design Measurement – Calculation – Simulation

By Andreas Nadler



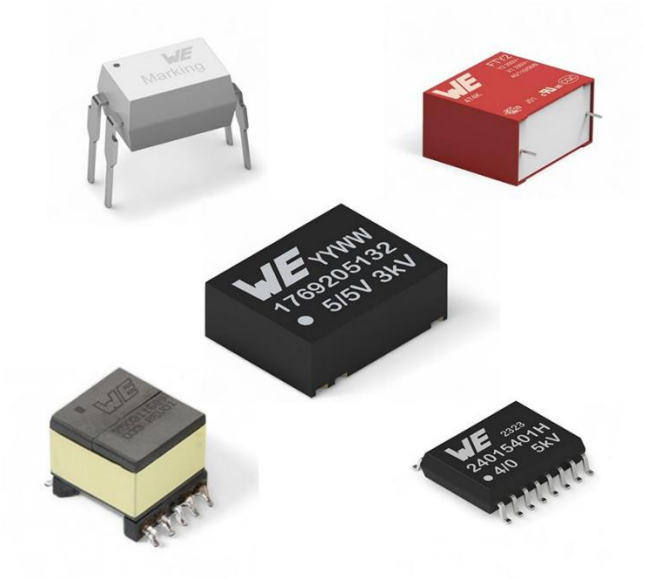


Link

ADDITIONAL RESOURCES

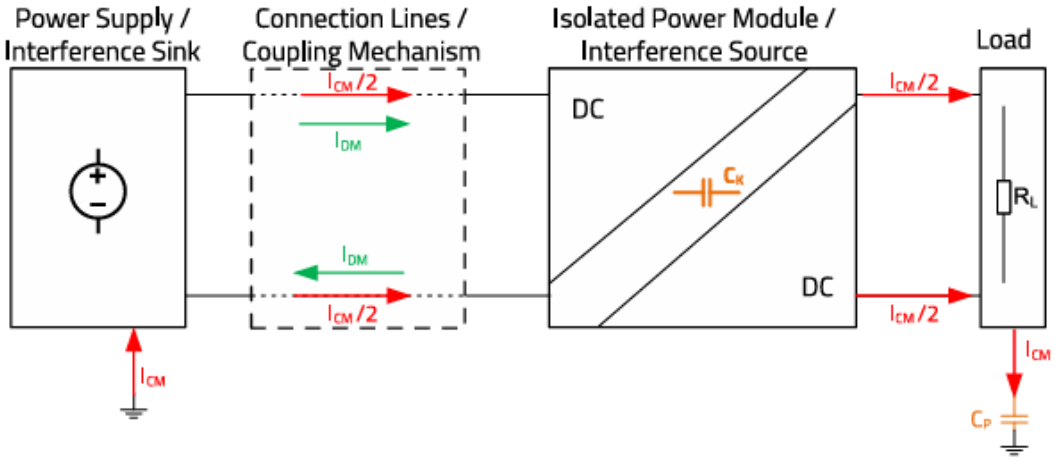
Application notes (more)

ANP151 | Mastering Galvanic Isolation: Ensuring Safety in High-Power Electronics with Würth Elektronik Products
By Timur Uludag



Link

ANS022 | Bridge capacitor for isolated power modules, the whole truth, no myths
By Timur Uludag

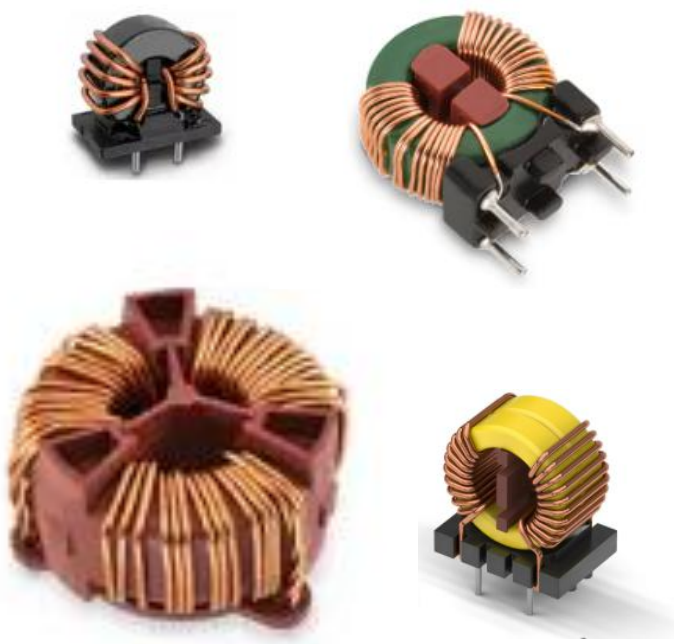


Link

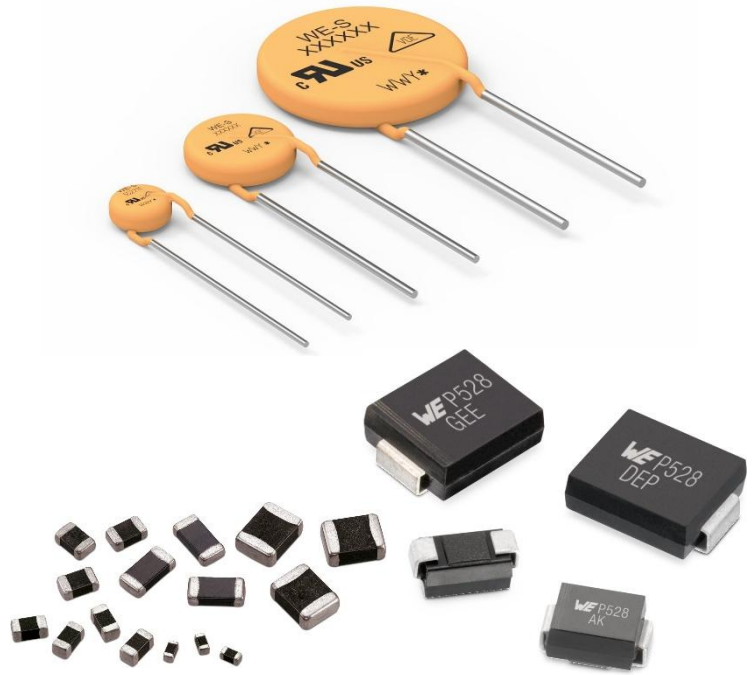
WÜRTH ELEKTRONIK EISOS – OTHER FILTER SOLUTIONS

More than you expect

Common Mode Chokes



Surge Protection Devices



WE-CLFS Line Filter

Questions

& Answers

We are here for you now!
Ask us directly via our chat or via E-Mail.

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