EMC Filters - From components to design

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Information about the Webinar

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Qs & As: 10 - 15 Min

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Agenda

- Introduction
- The need for filters and the topologies
- Components and technologies
- Choosing a component for a filter
- Design and simulation of a filter
- How to destroy a filter

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- **Introduction**
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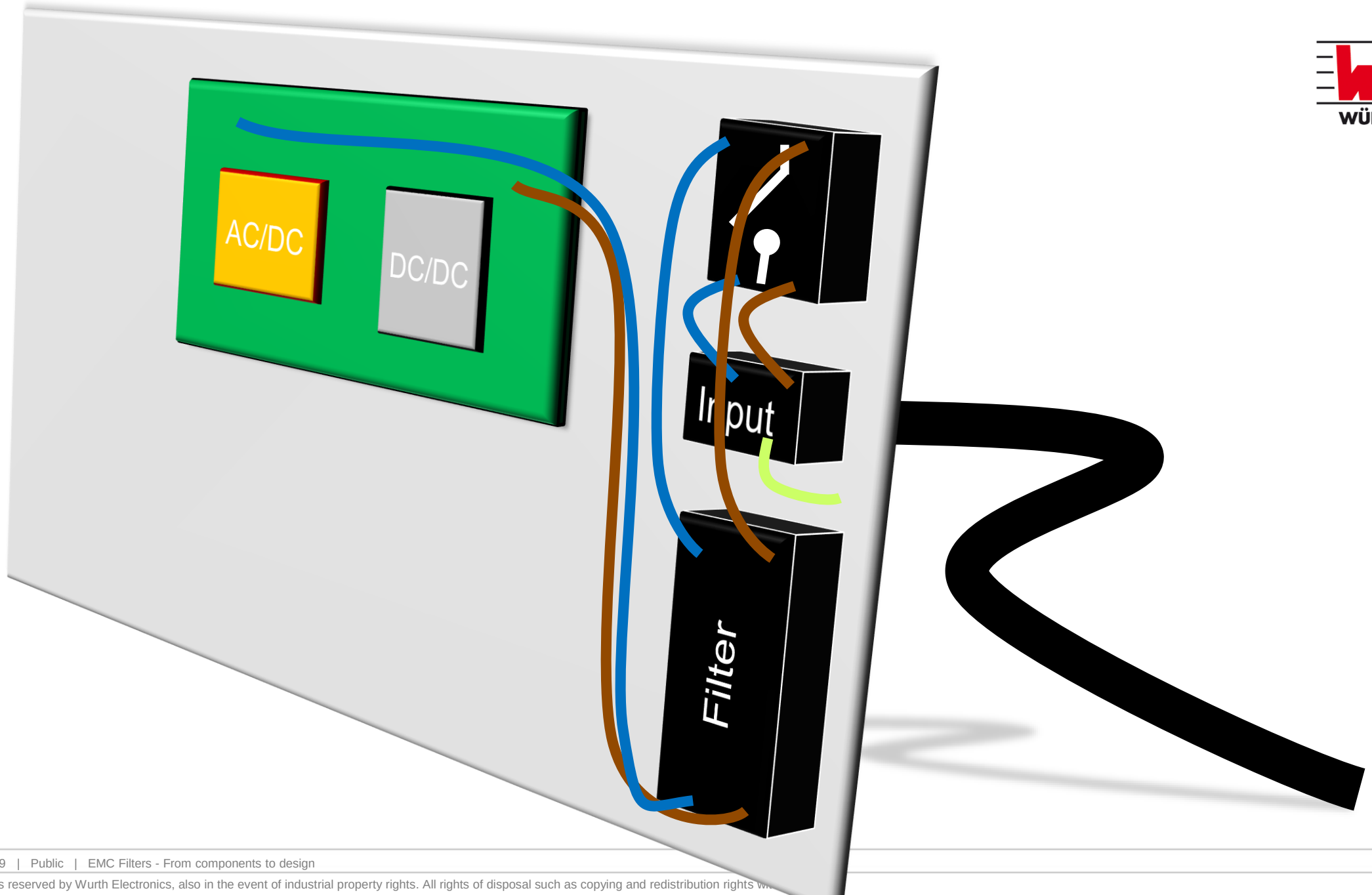
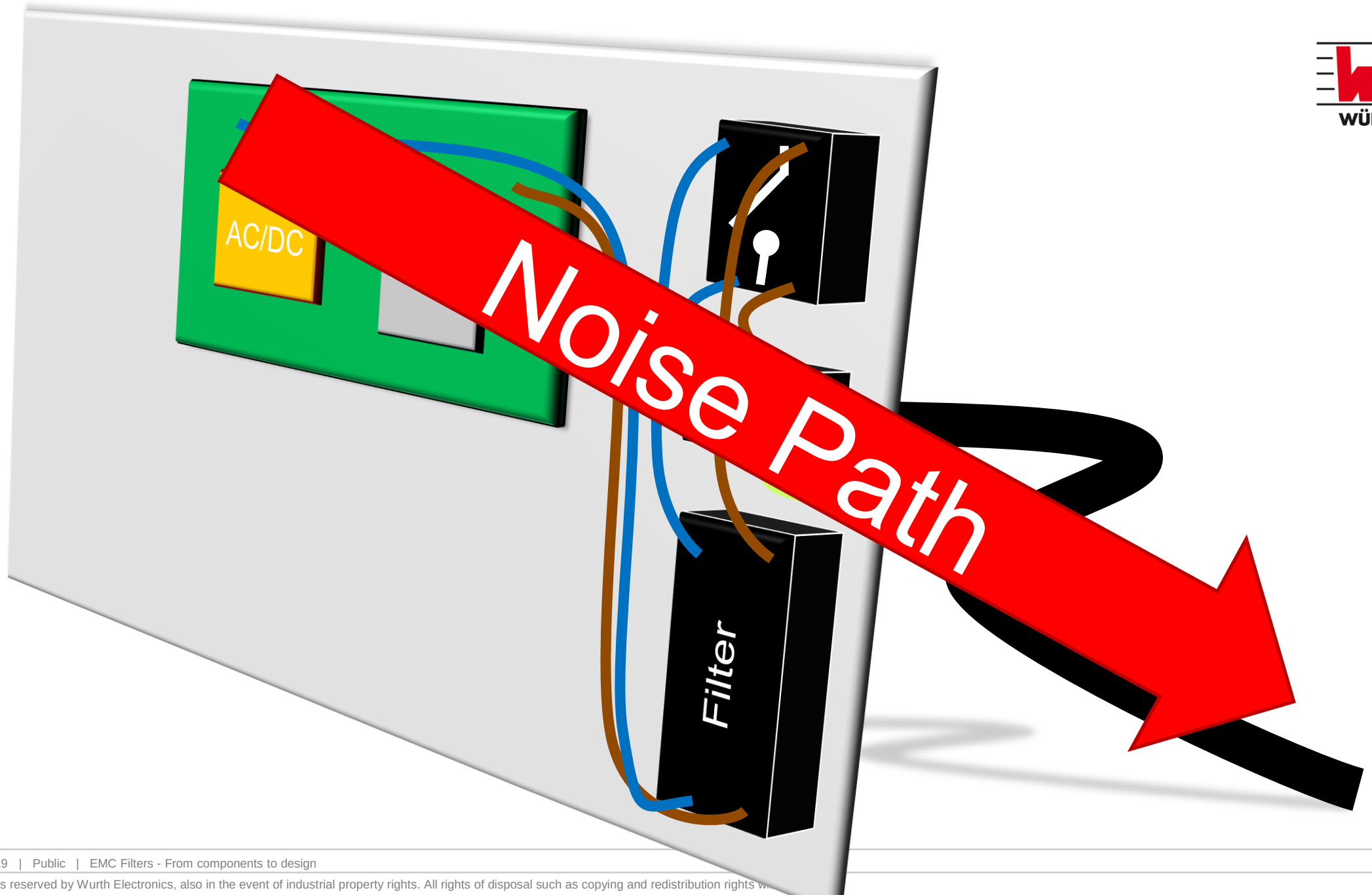
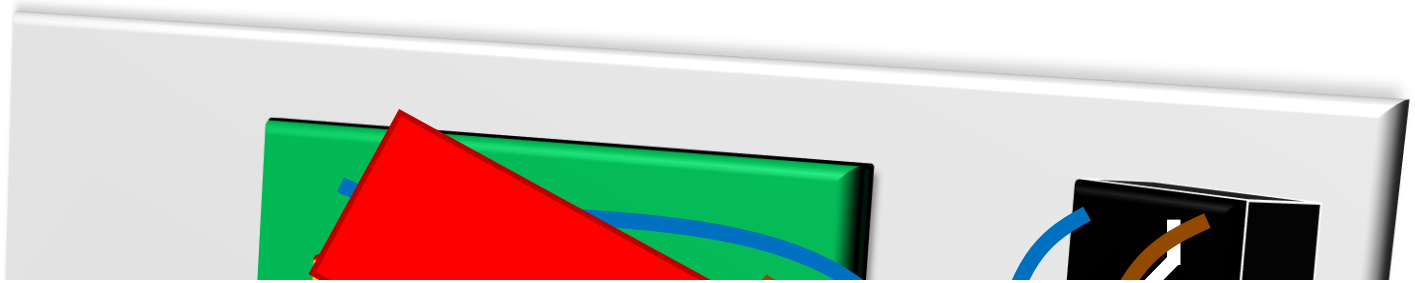
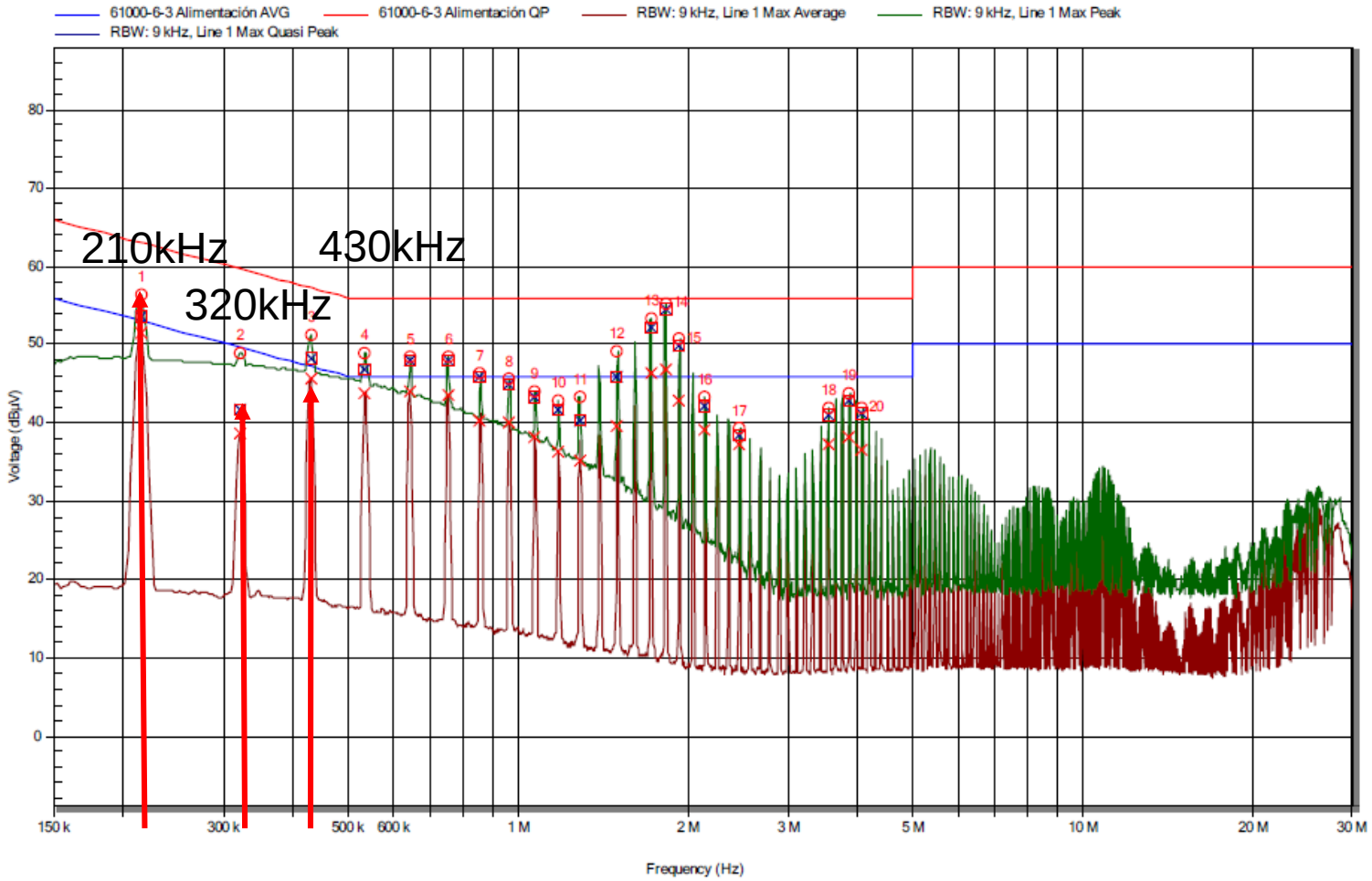


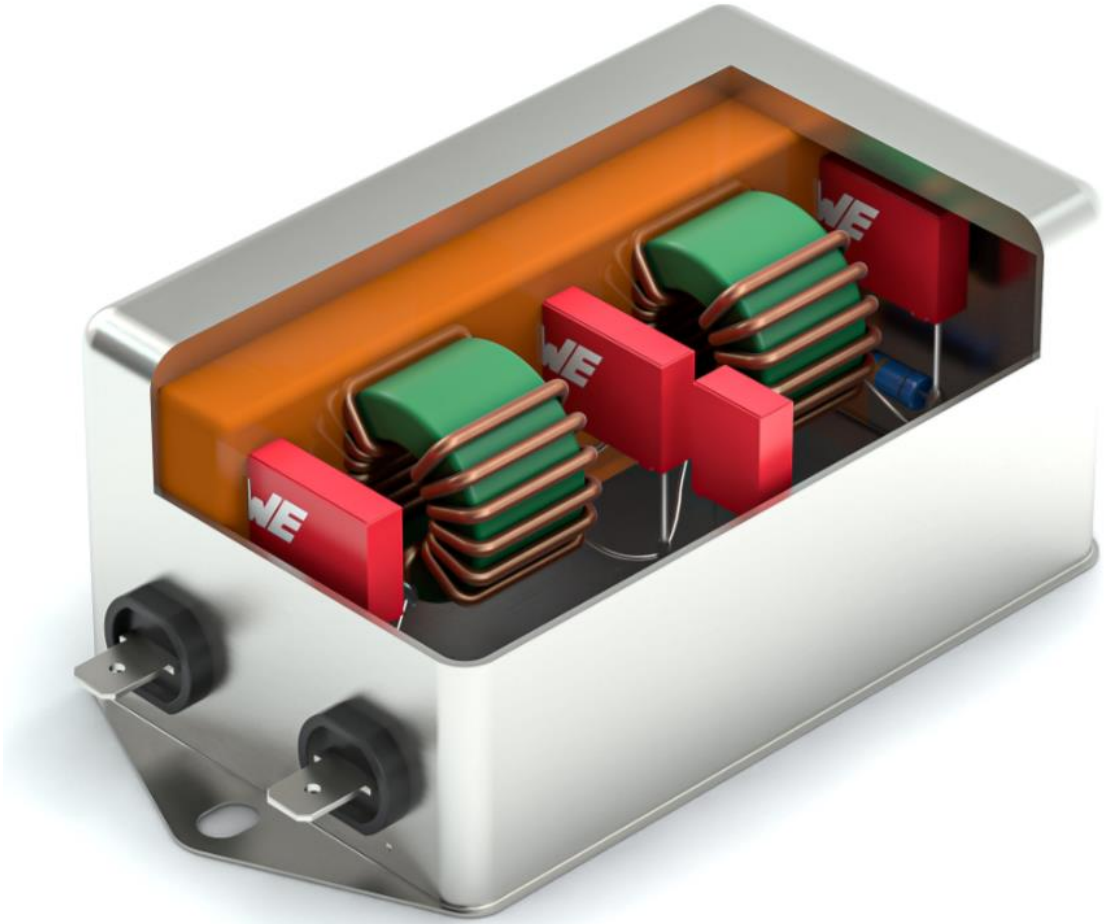




RadiMation



Filter



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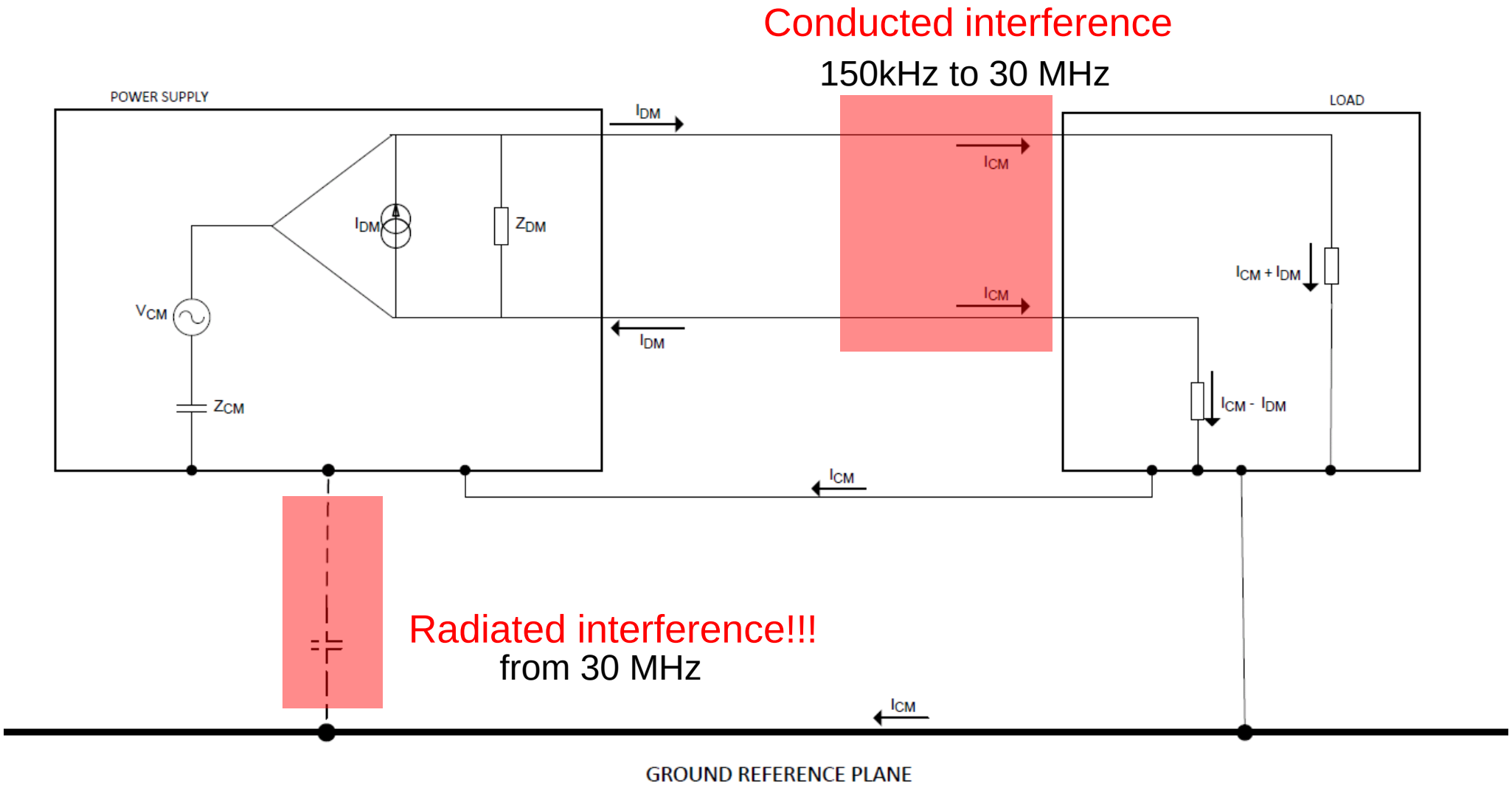
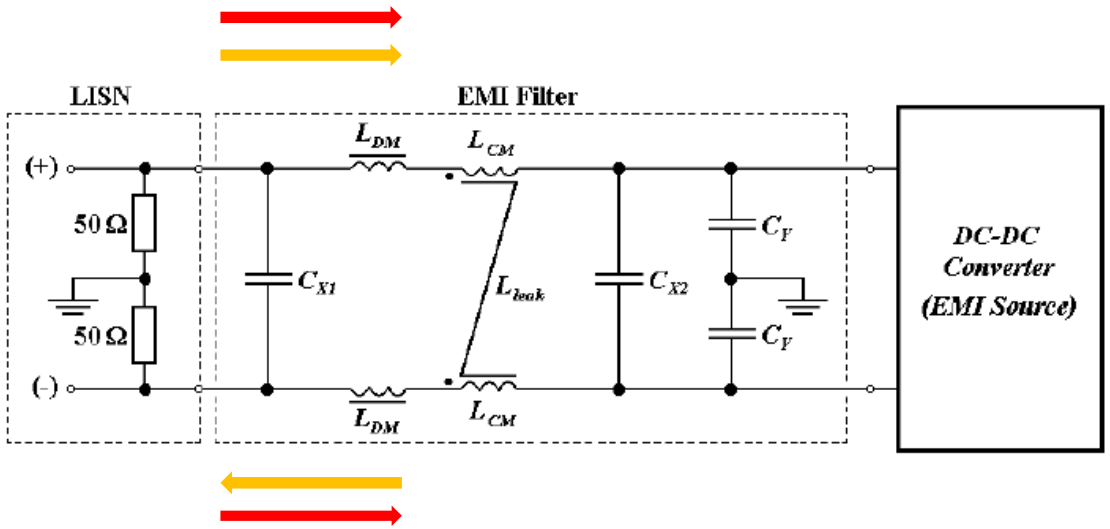
The need for filters

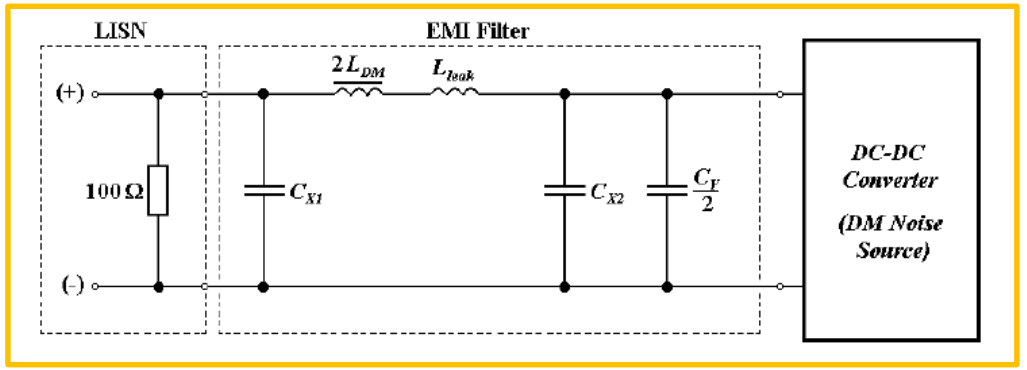


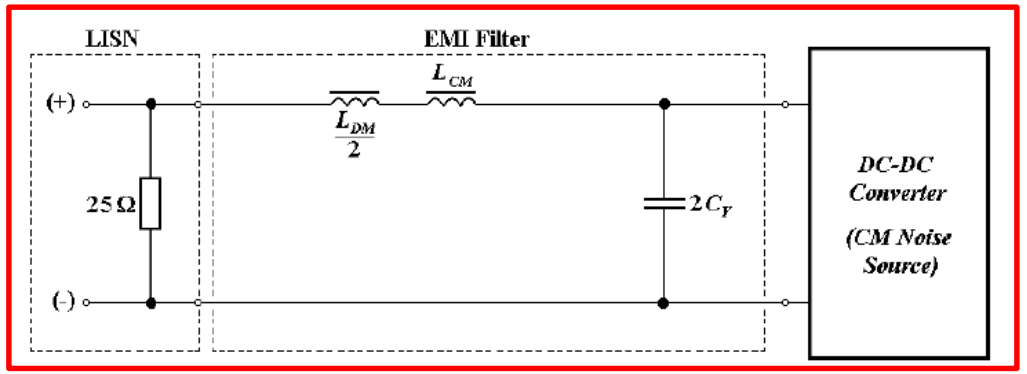
Typ. Design of a filter

Same effect in DM and CM?



Differential mode

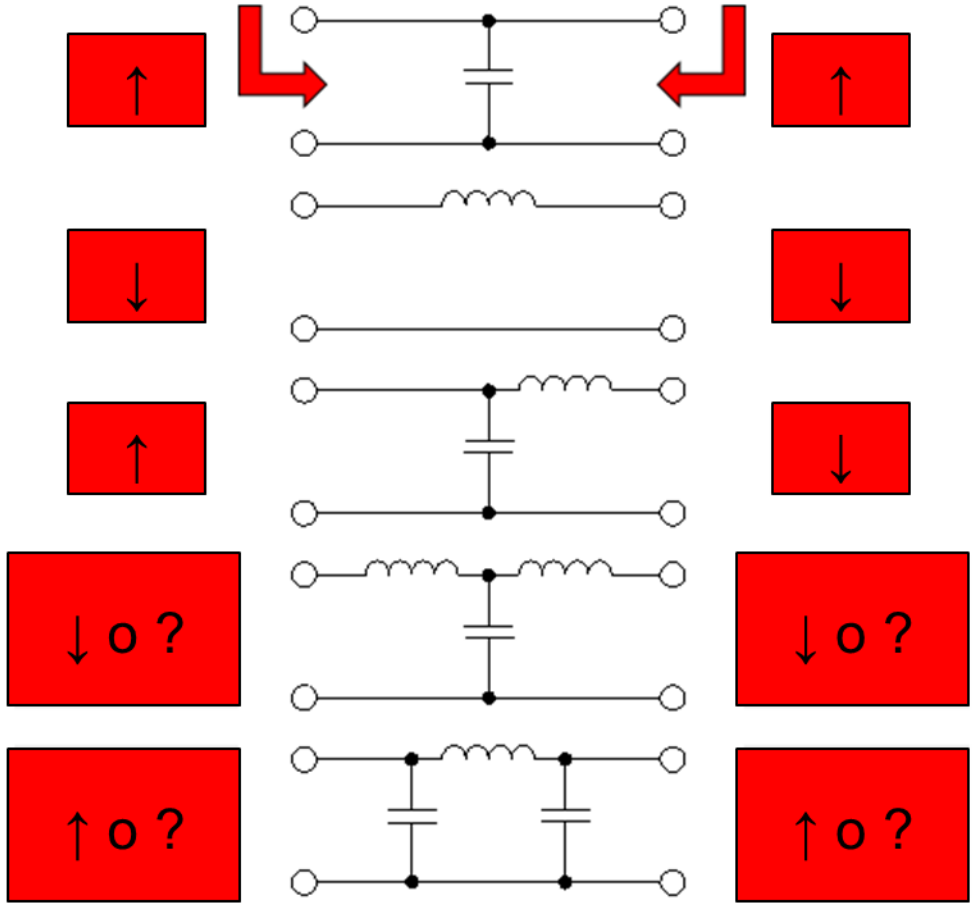




Common mode

Topology

Effects on the filter?
Filtering through reflection or dissipation



Number of reactive components?

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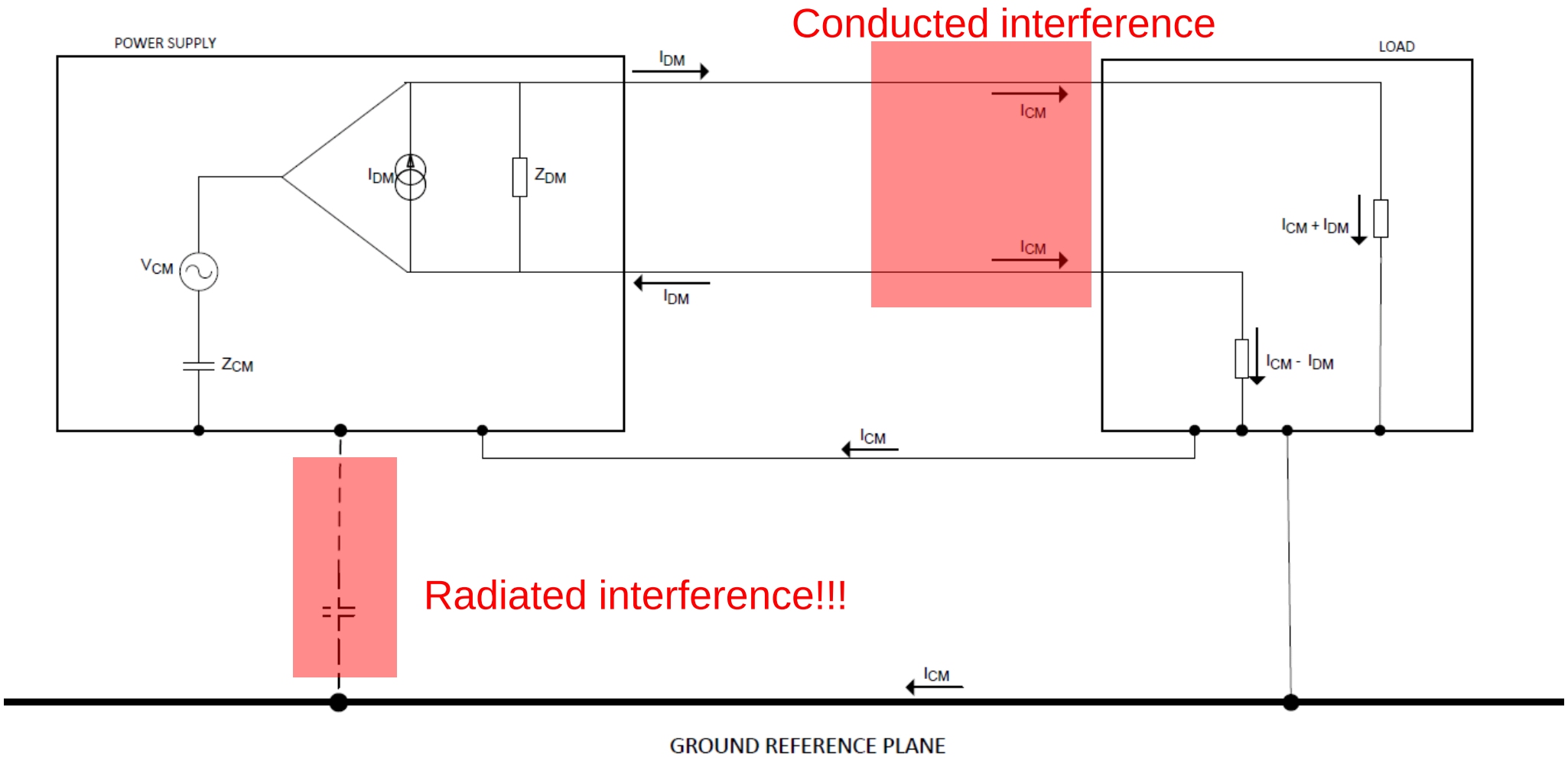
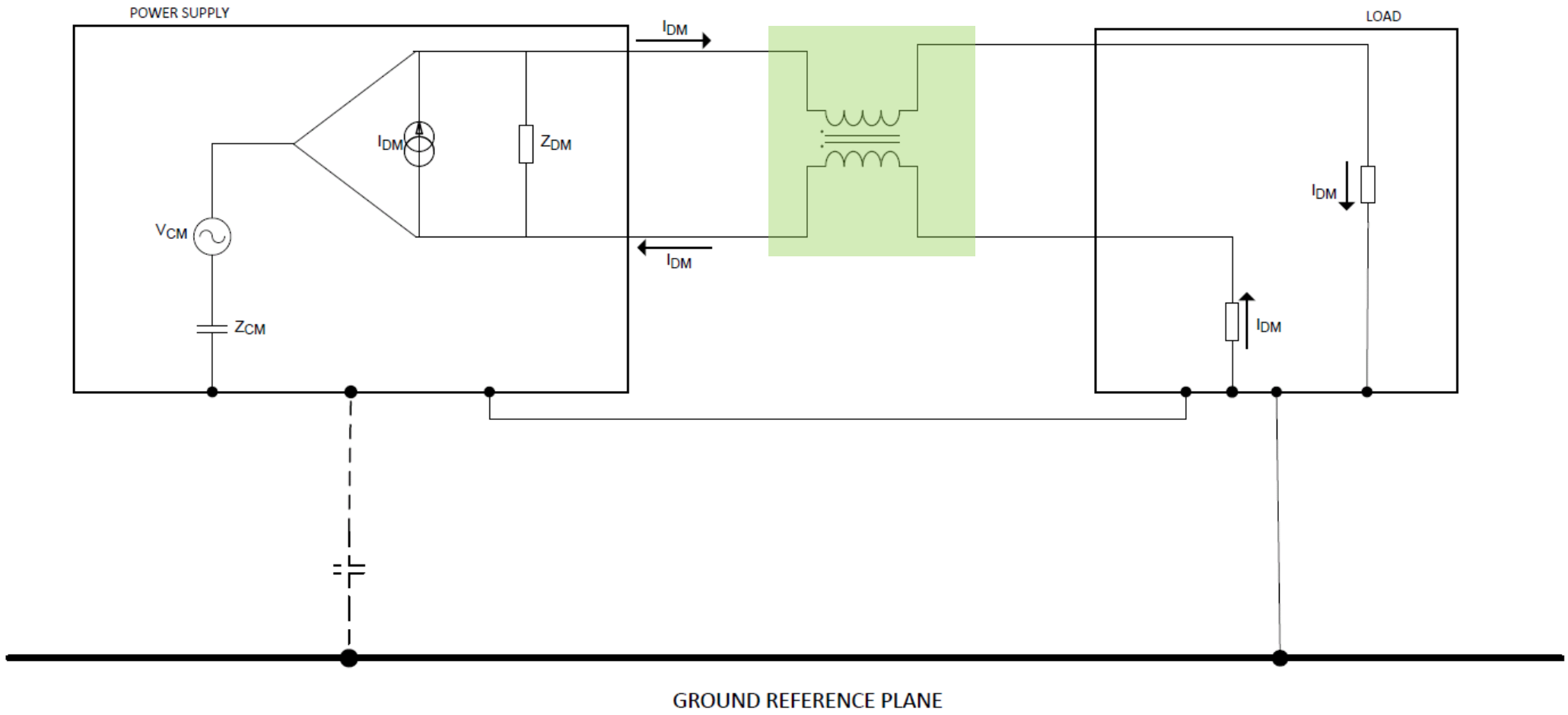
COMMON MODE FILTERS

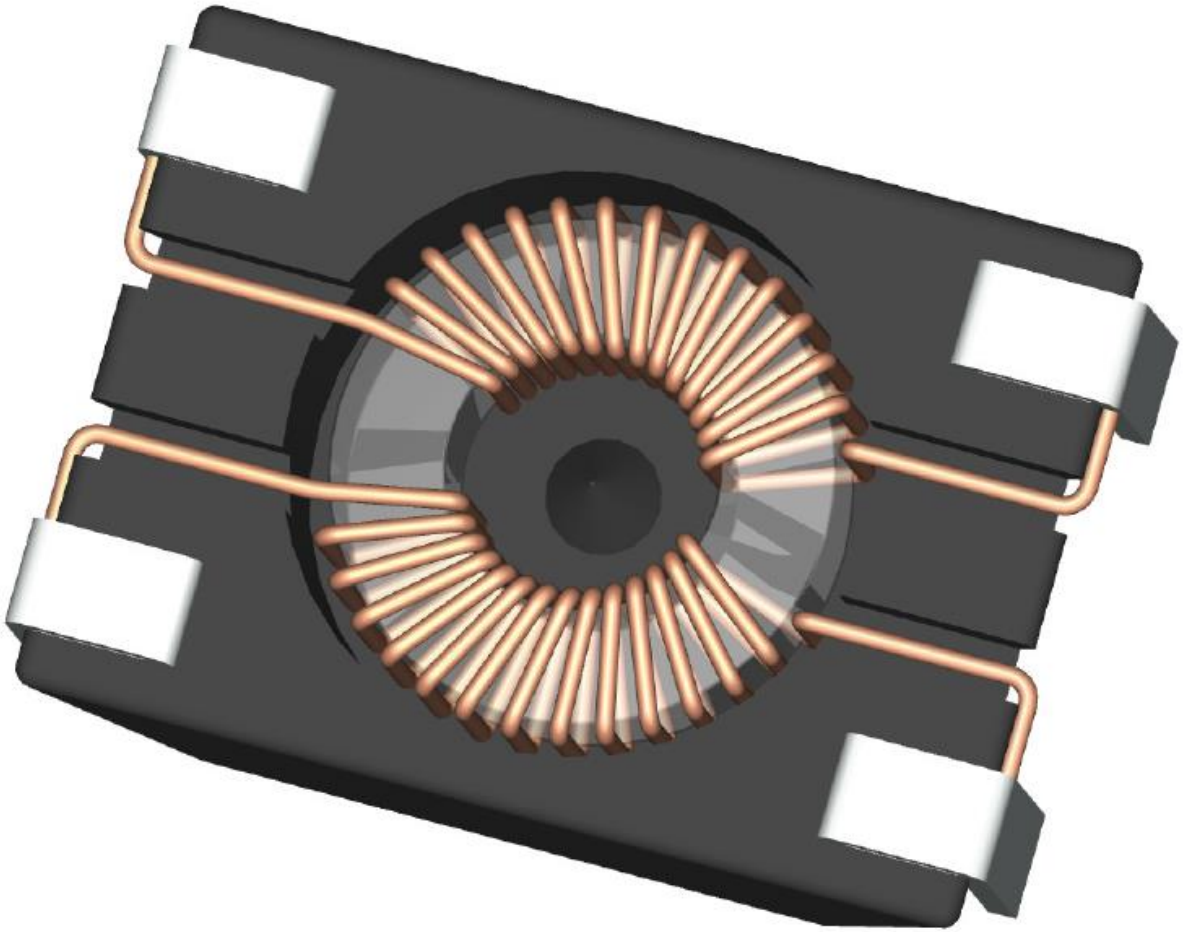
The problem



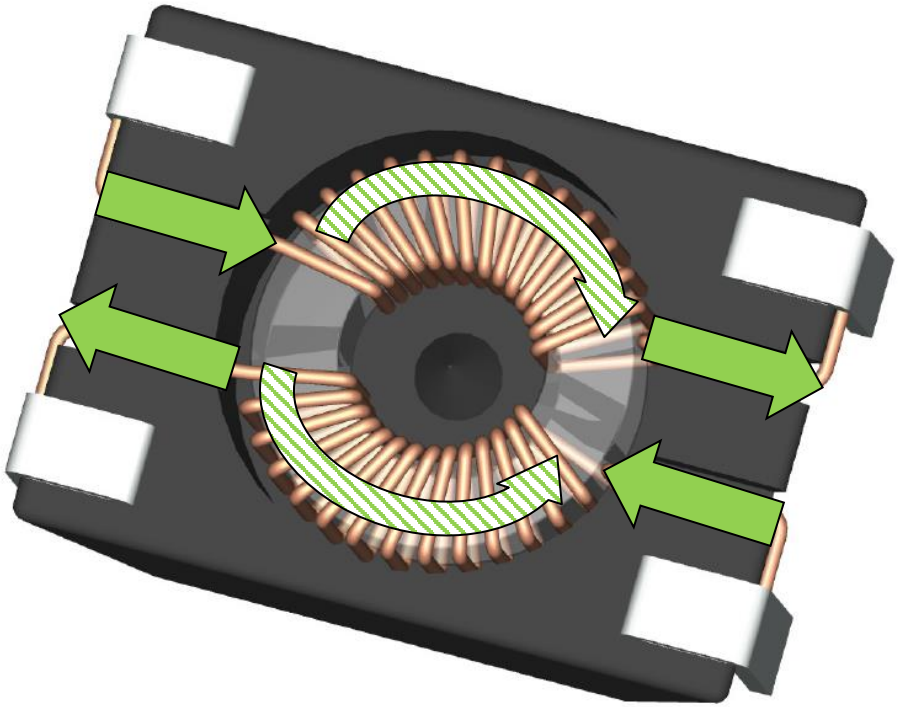
The solution



Structure



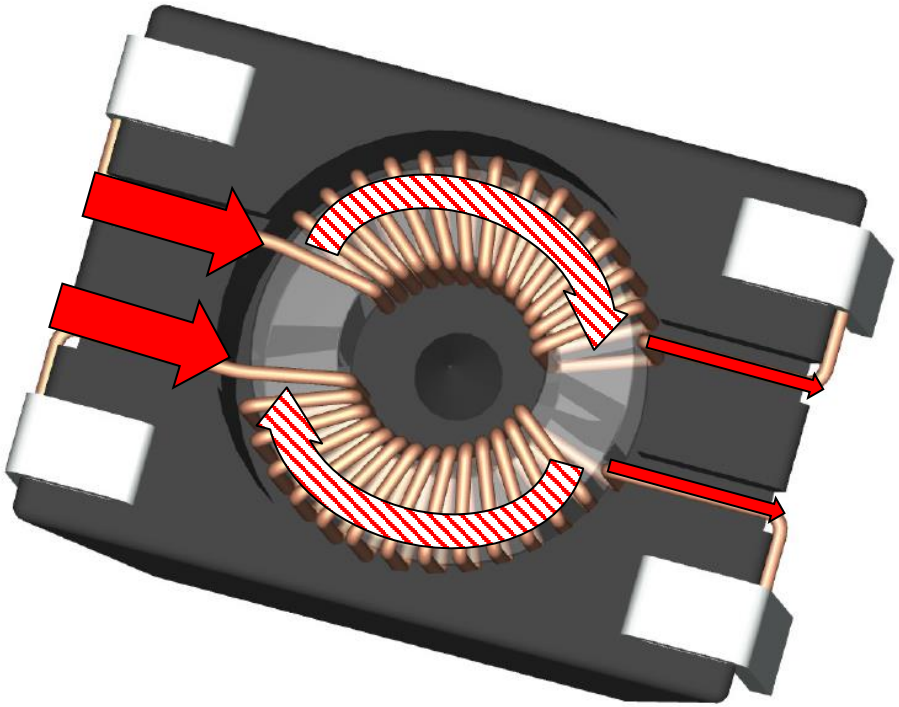
Differential mode



Current flow

Magnetic flux

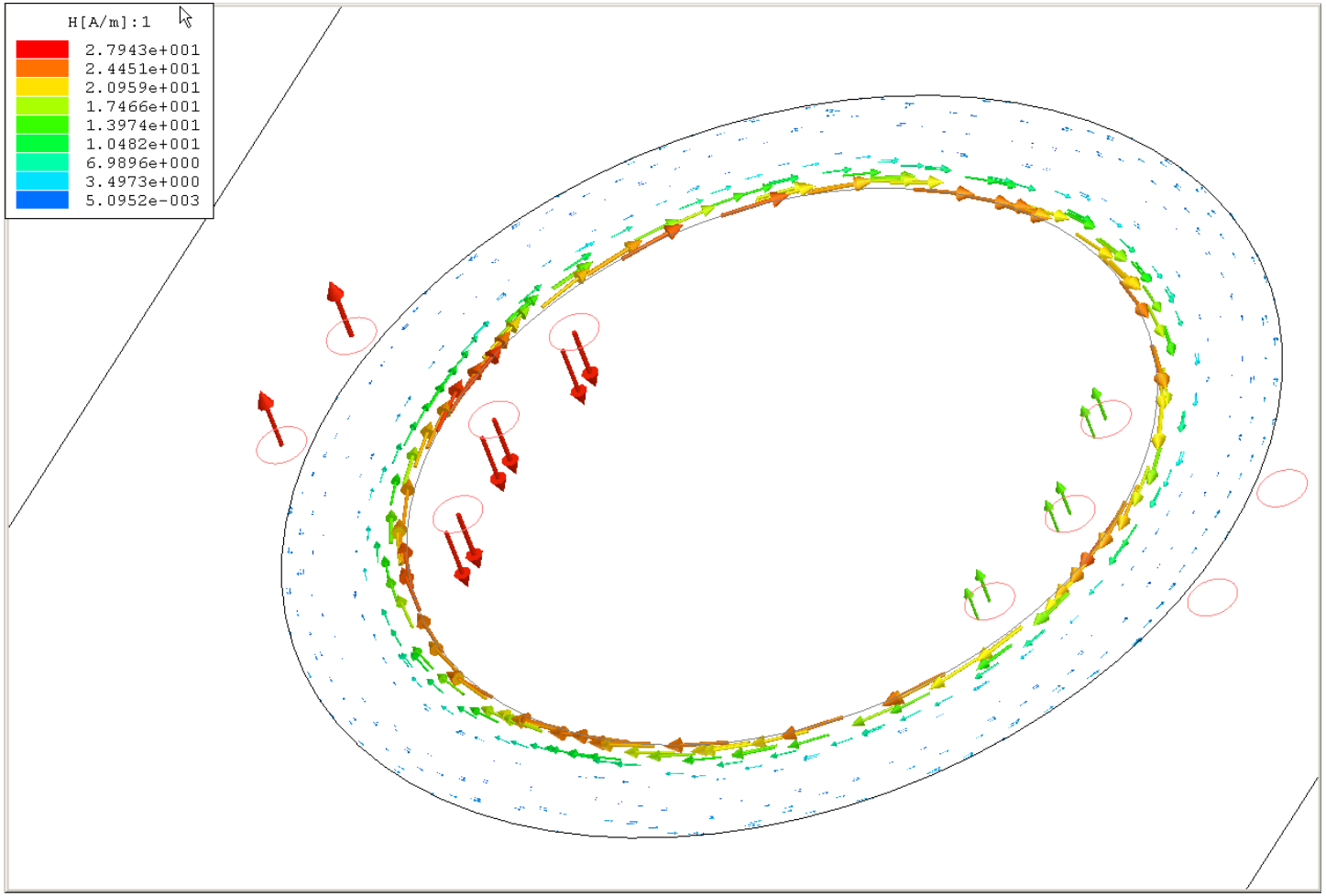
Common mode



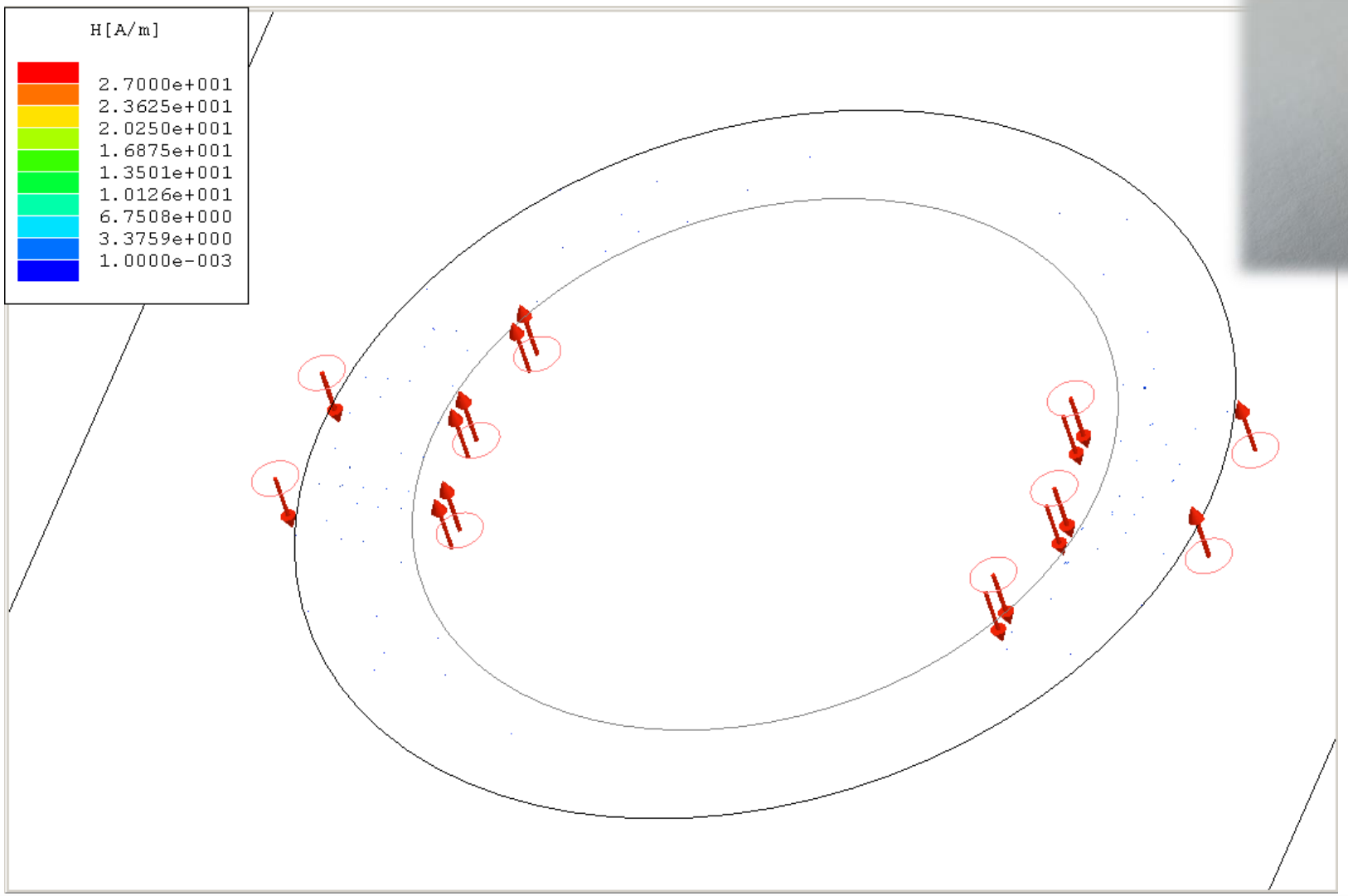
Current flow

Magnetic flux

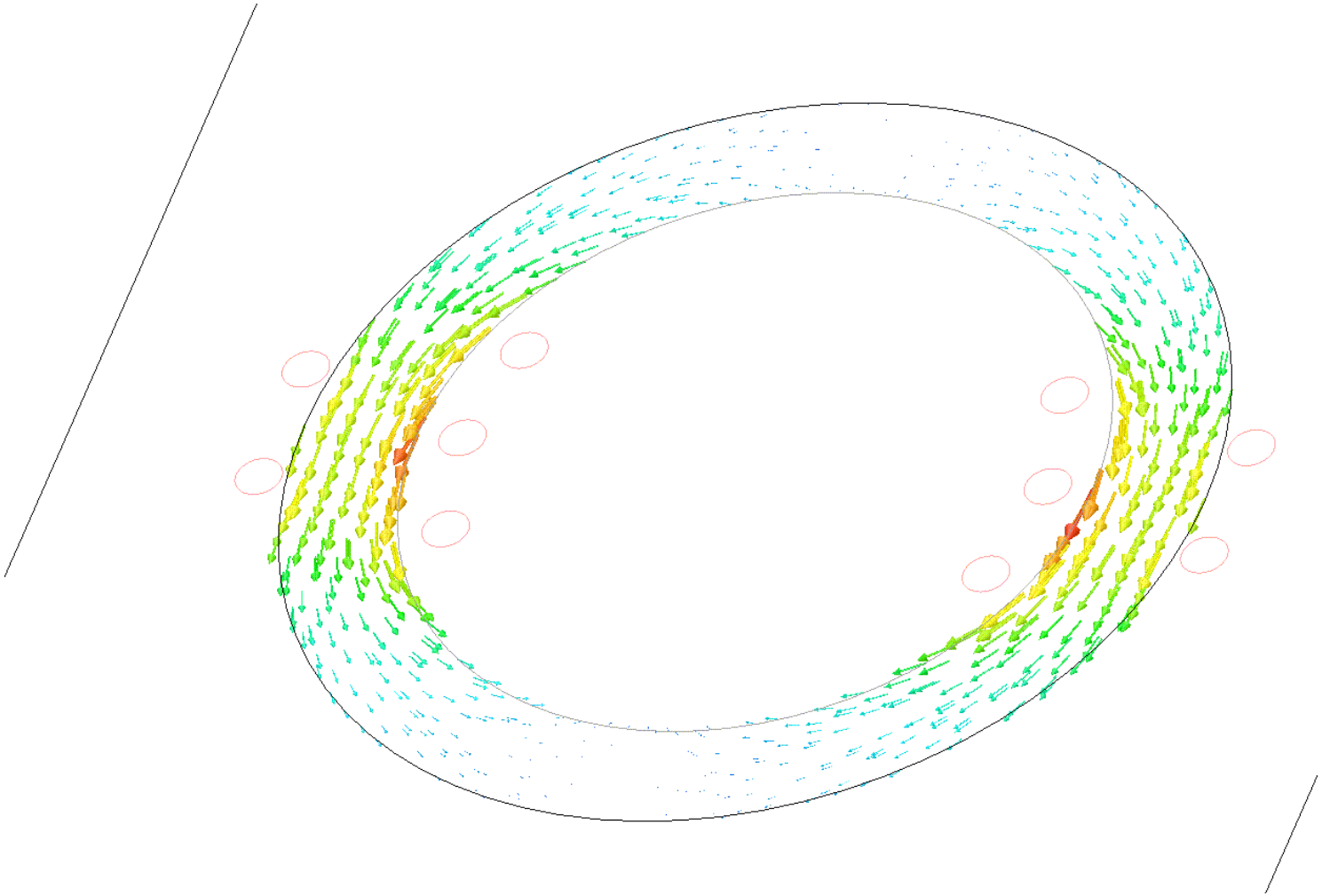
Simulation – 1 winding



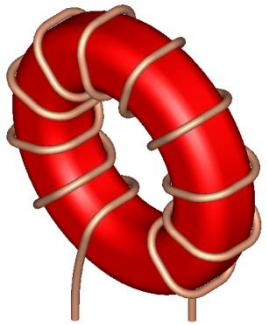
Simulation – Differential mode



Simulation - Zoom – 20x



Permeability – complex permeability



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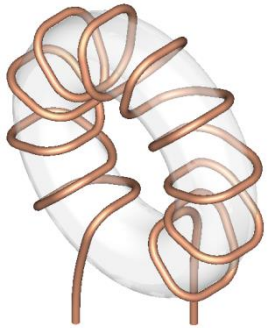


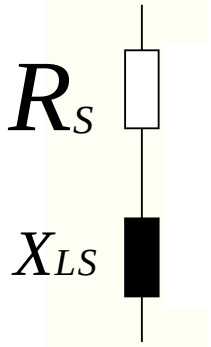
*

Impedance from core and windings

Impedance of winding w/o core

core material

$$\underline{Z} = j\omega L_0 * \left(\mu' - j\mu''\right)$$



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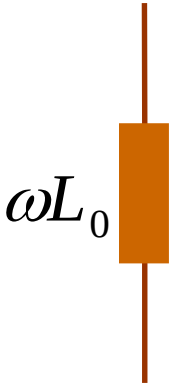

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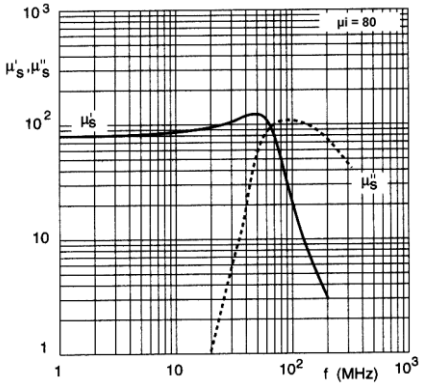
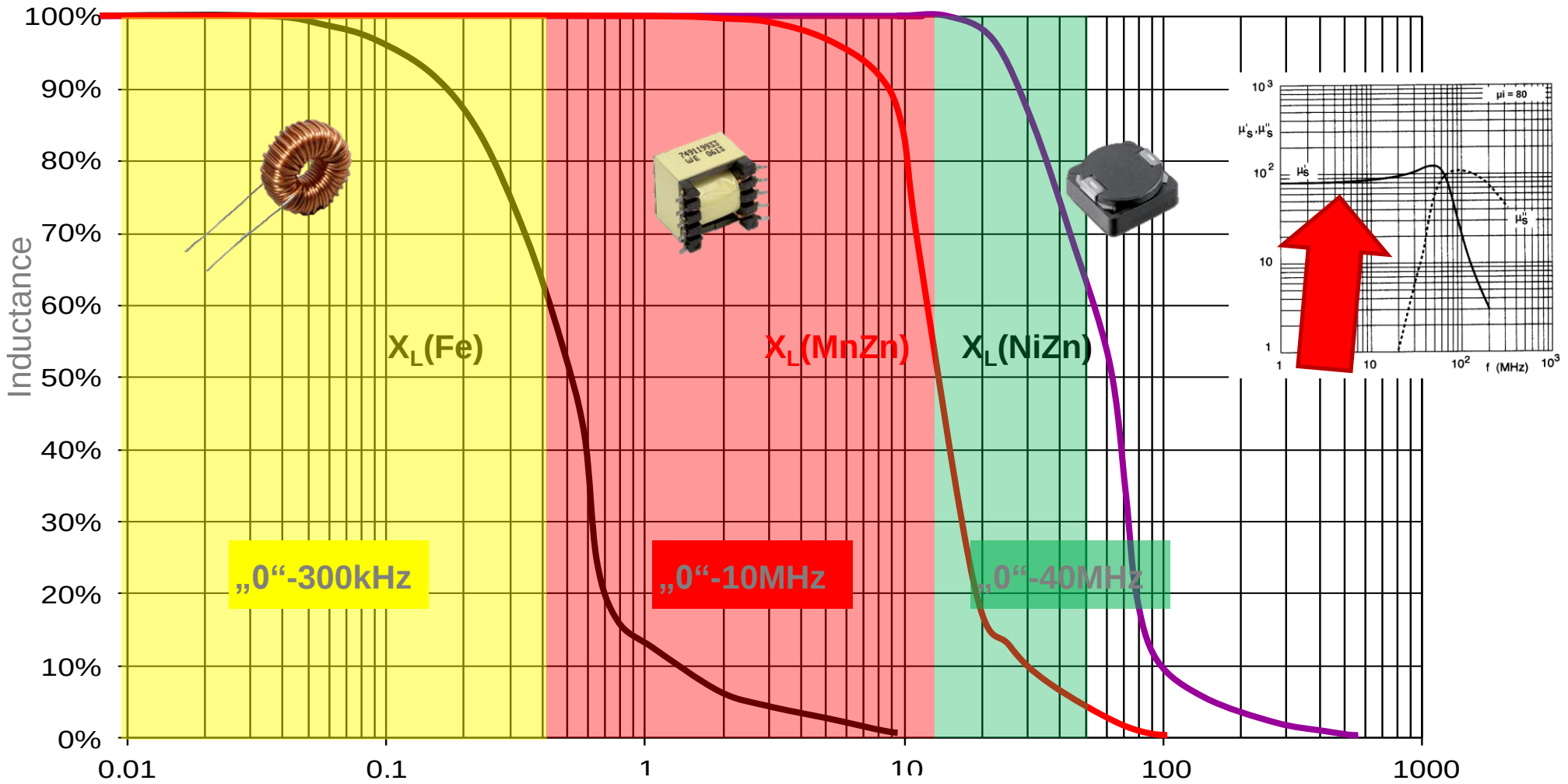


Materials – Inductors (Storage)



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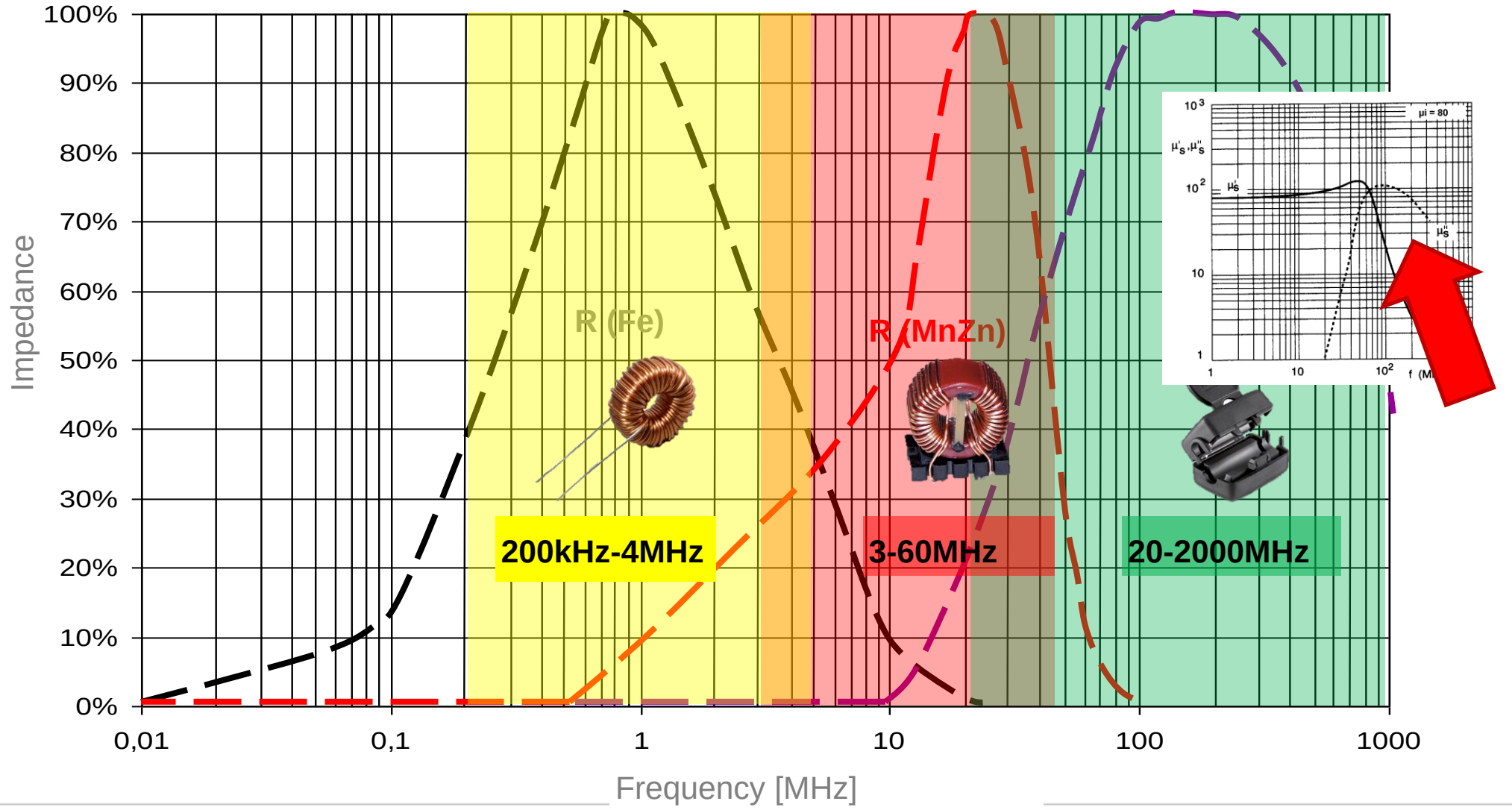
Materials – Choke (Filter)



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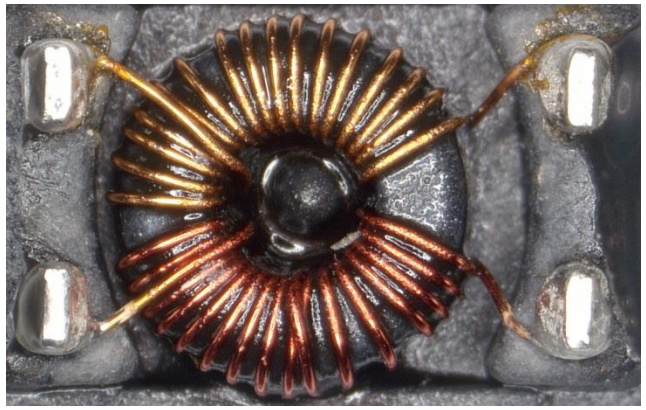
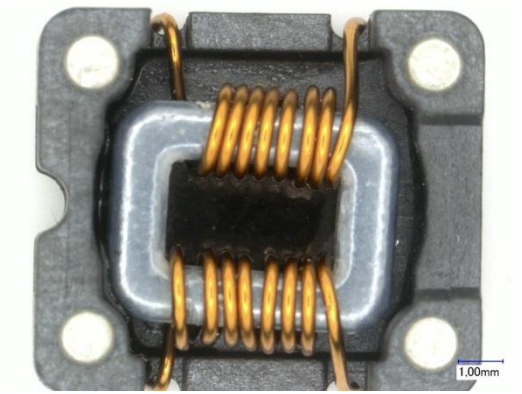
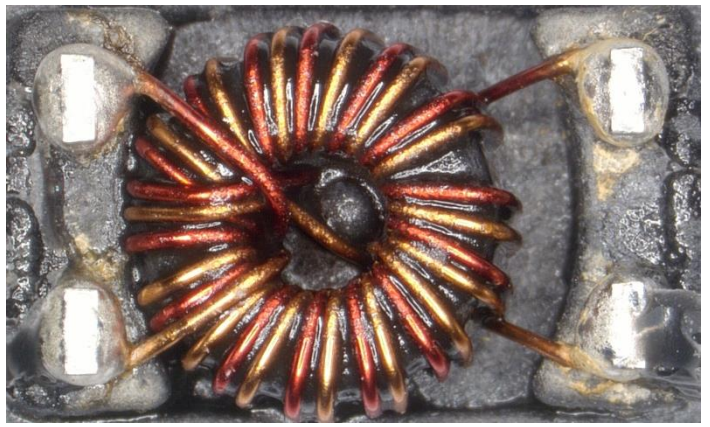
Winding styles

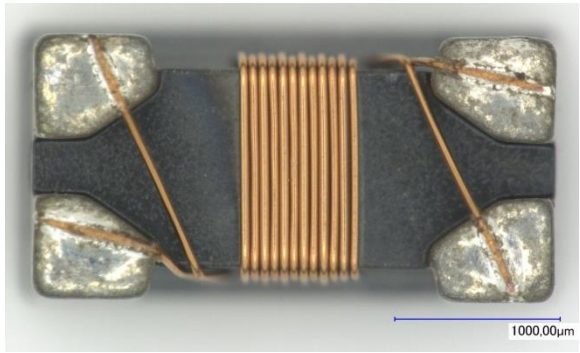
Sectional



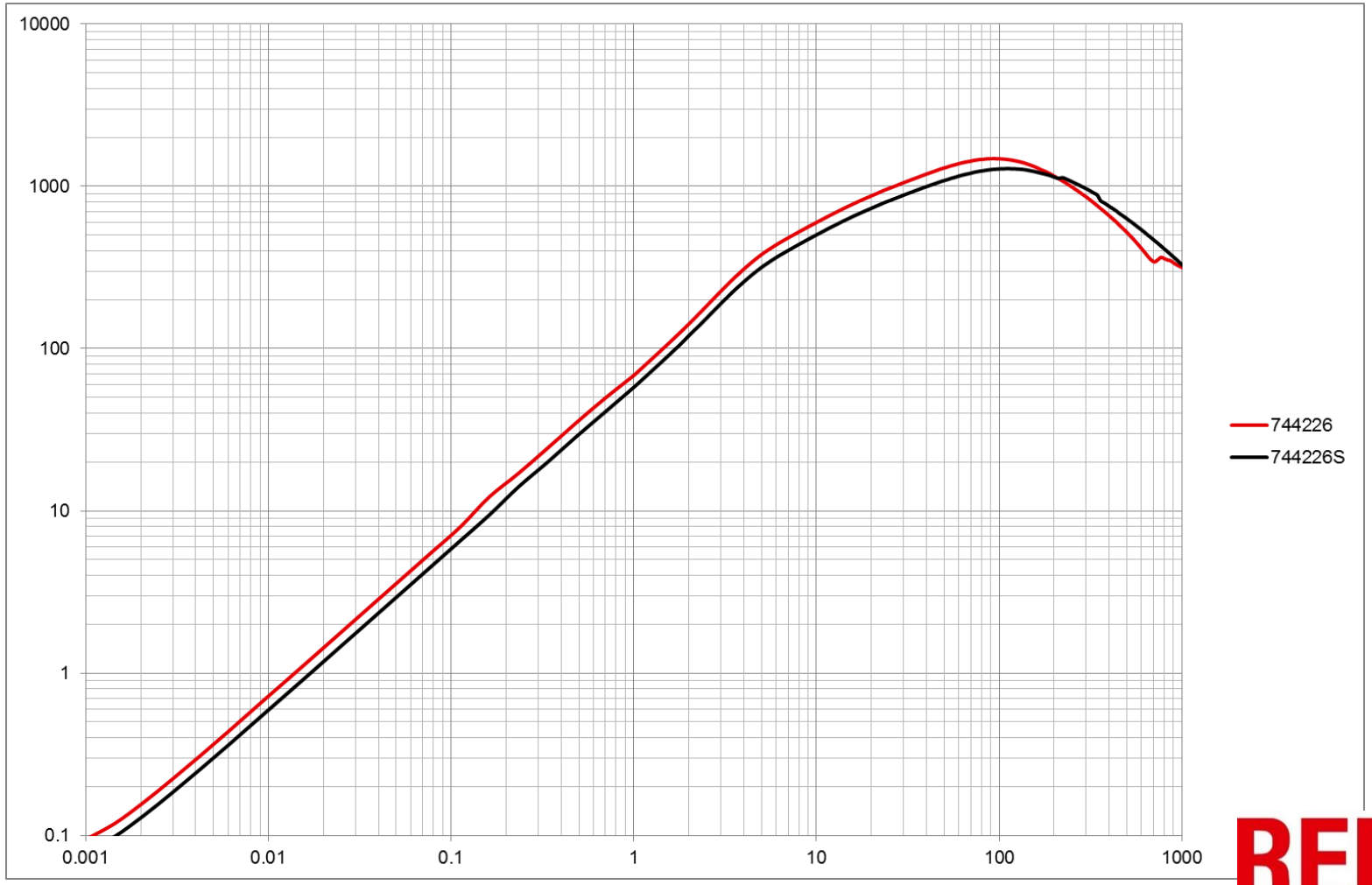


Bifilar

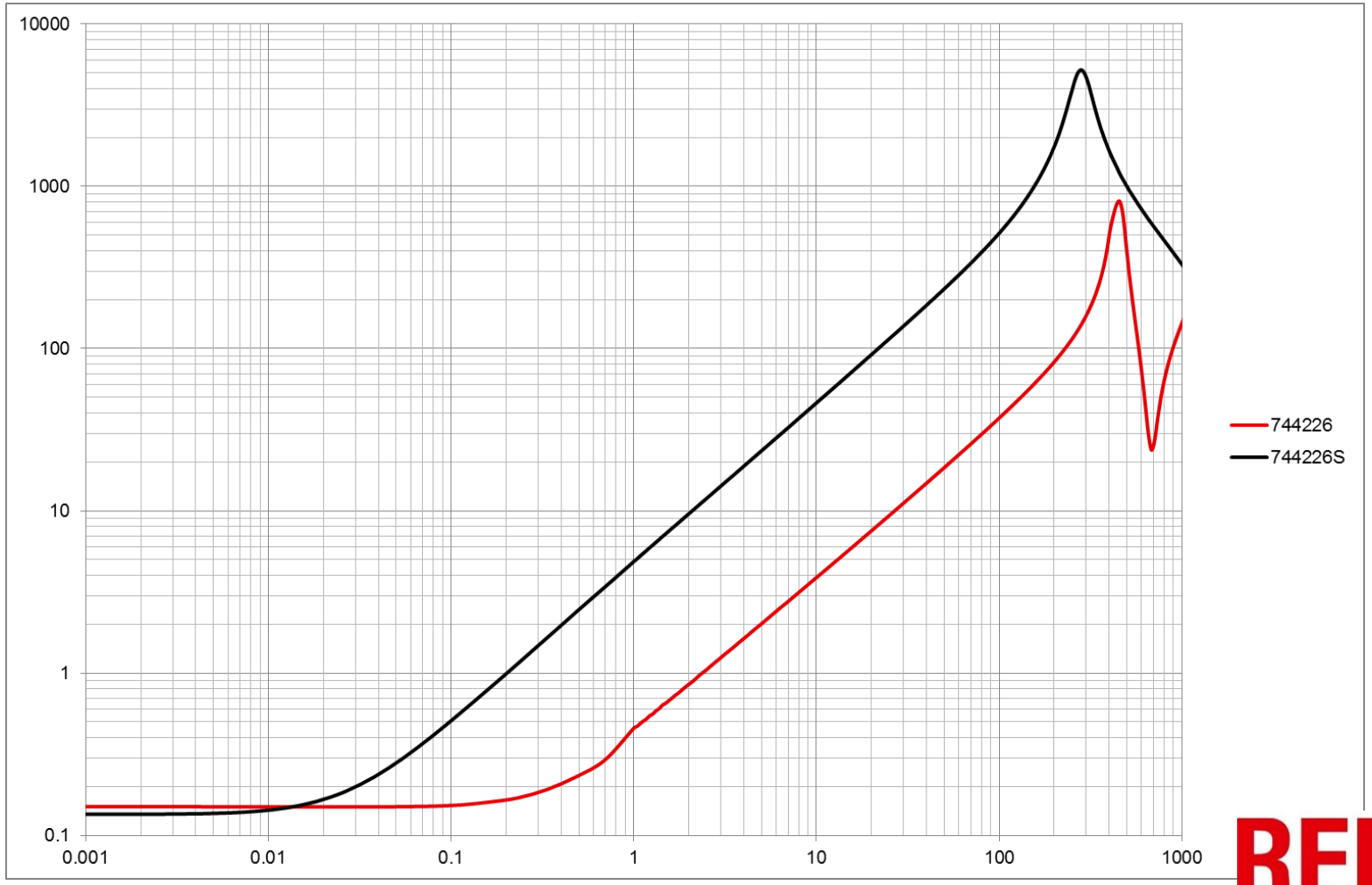




Winding styles – Common mode



Winding styles – Differential mode



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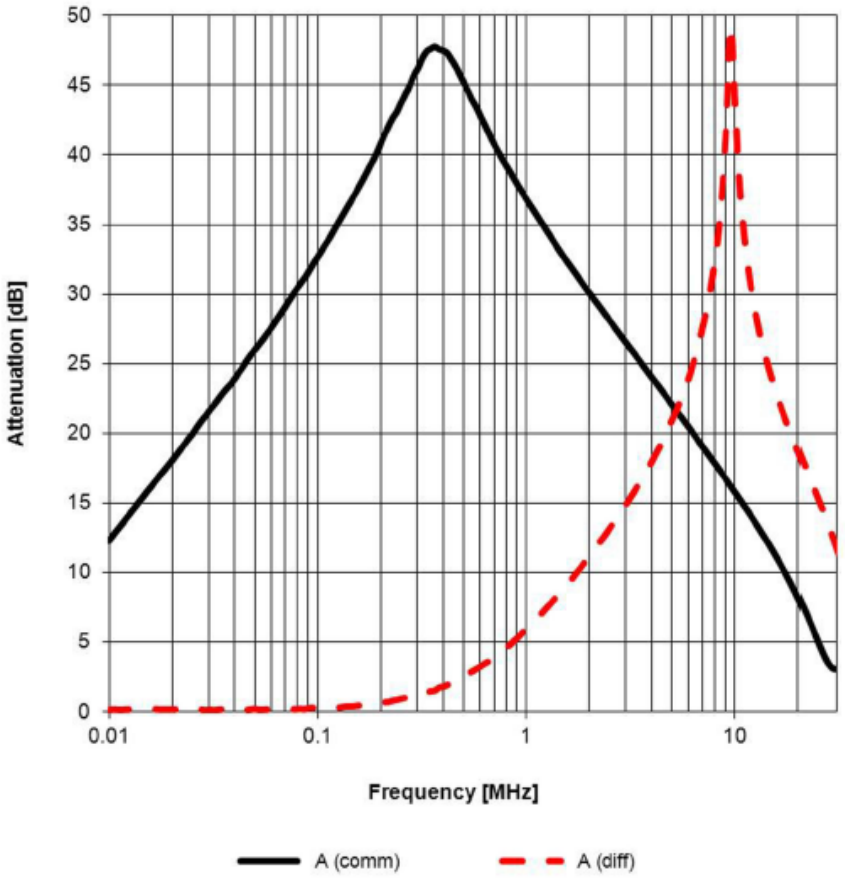
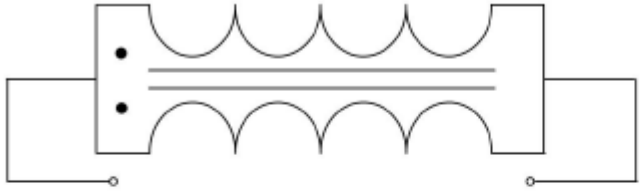
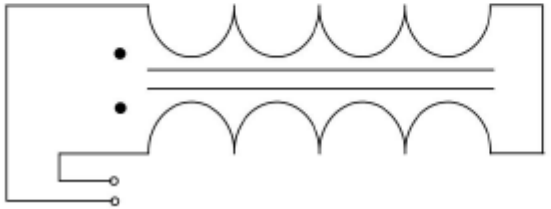
Insertion loss

F Typical Insertion Loss Characteristics:





Common Mode



Differential Mode

Zo = 50 Ohm ?

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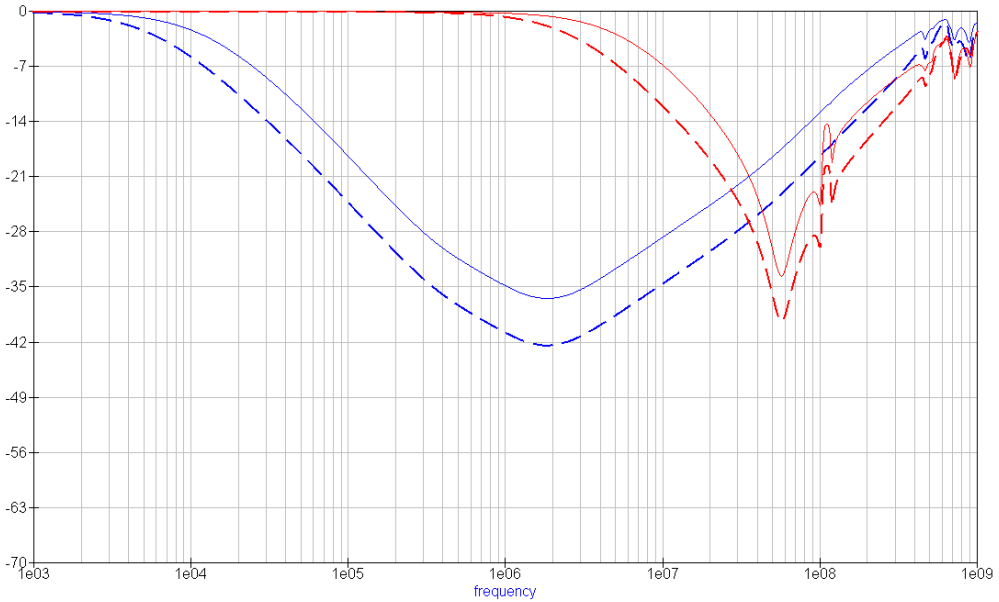
Insertion loss – 4 Ports



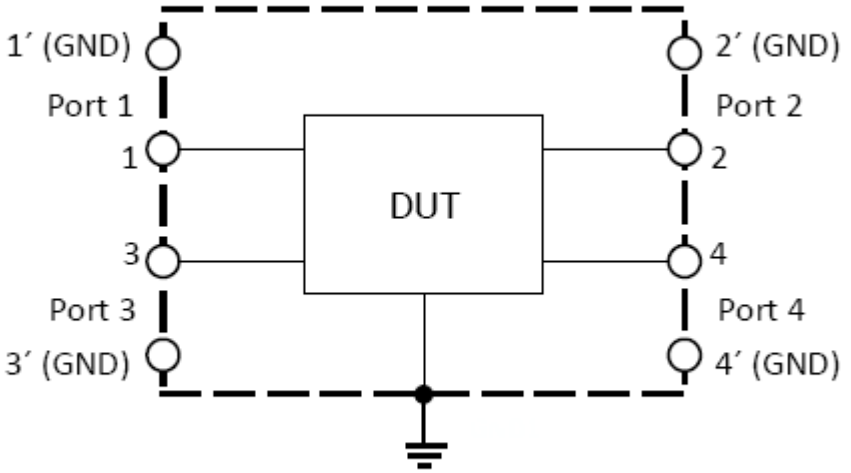
100/100 Ohm Insertion Loss Diff Mode

50/50 Ohm Insertion Loss Diff Mode

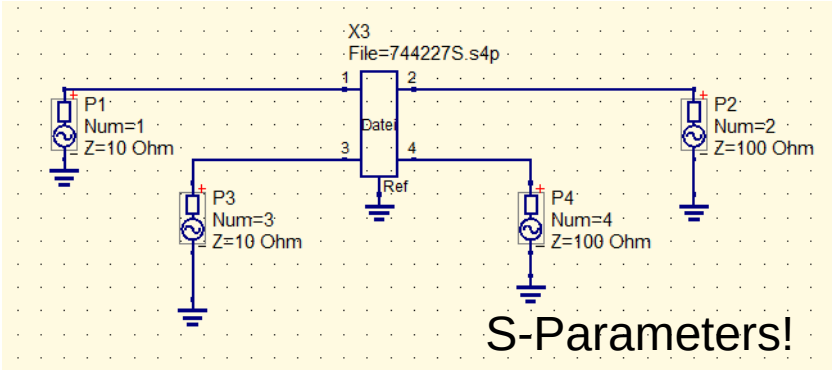
100/100 Ohm Insertion Loss Common Mode

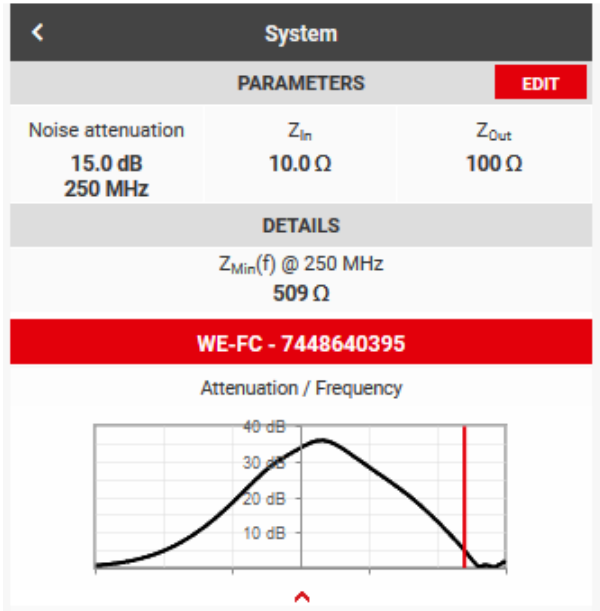
50/50 Ohm Insertion Loss Common Mode

According to CISPR 17



Network Analyzer: Keysight E5080A or equivalent





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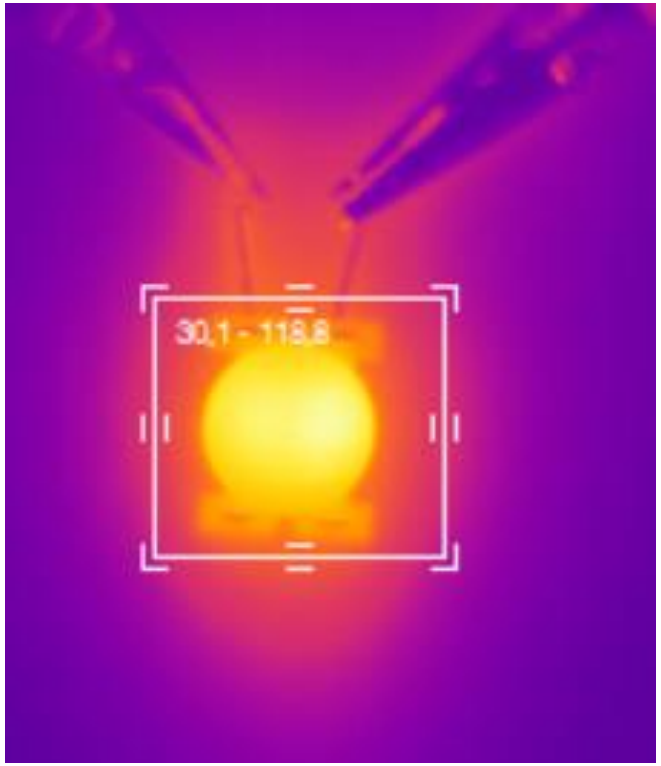
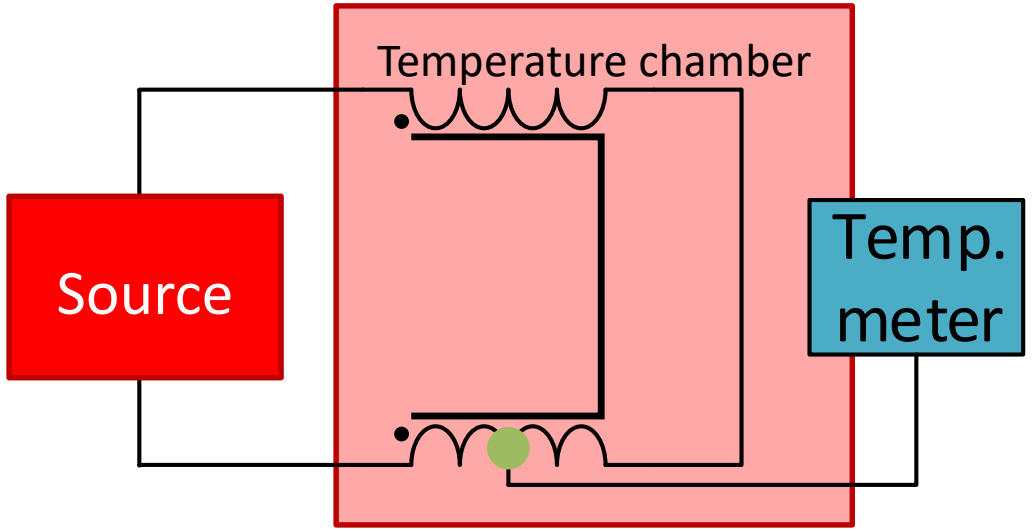
Rated current

Rated current	$\Delta T = 40\ K$	I_R	1000	mA	max.





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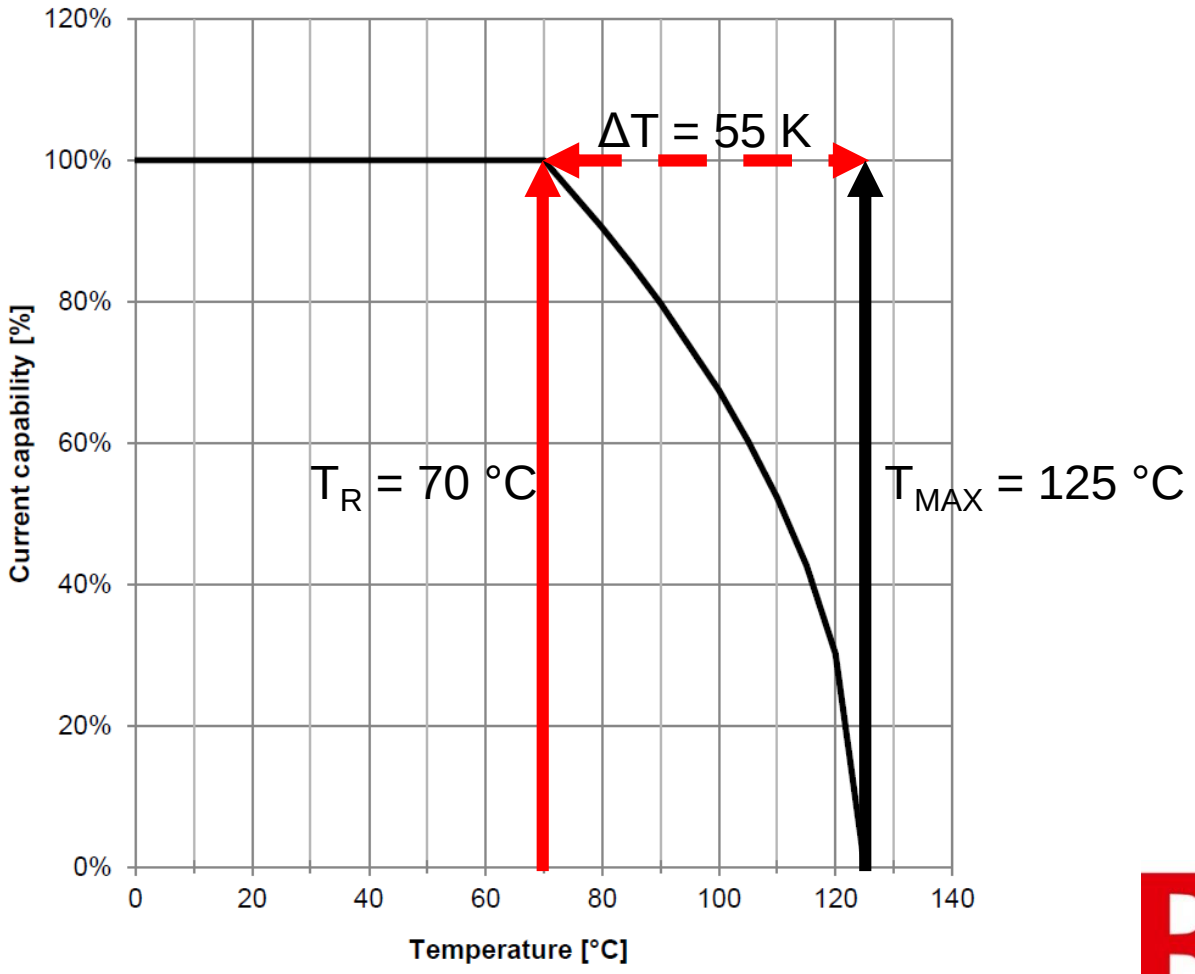
Derating



Properties		Test conditions	Value	Unit	Tol.
Number of windings	N		2		
Inductance	L	10 kHz/ 100 mV	0.82	mH	min.
Inductance	L	10 kHz/ 100 mV	1.1	mH	typ.
Rated Current	I_R	@ 70 °C/ ΔT < 55 K	2.6	A	max.
DC Resistance	R_{DC}	@ 20 °C	0.07	Ω	±15%
Rated Voltage	V_R	50 Hz	250	V (AC)	max.
Insulation Test Voltage	V_T	50 Hz/ 5 mA/ 2 sec.	2000	V (AC)	

General Information:

It is recommended that the temperature of the component does not exceed +125 °C under worst case conditions	
Operating Temperature	-40 up to +125 °C
Ambient Temperature (referring to I_R)	-40 up to +70 °C
Storage Conditions (in original packaging)	< 40 °C ; < 75 % RH
Moisture Sensitivity Level (MSL)	1
Temperature Rise < 55 K	
Test conditions of Electrical Properties: +20 °C, 33 % RH if not specified differently	

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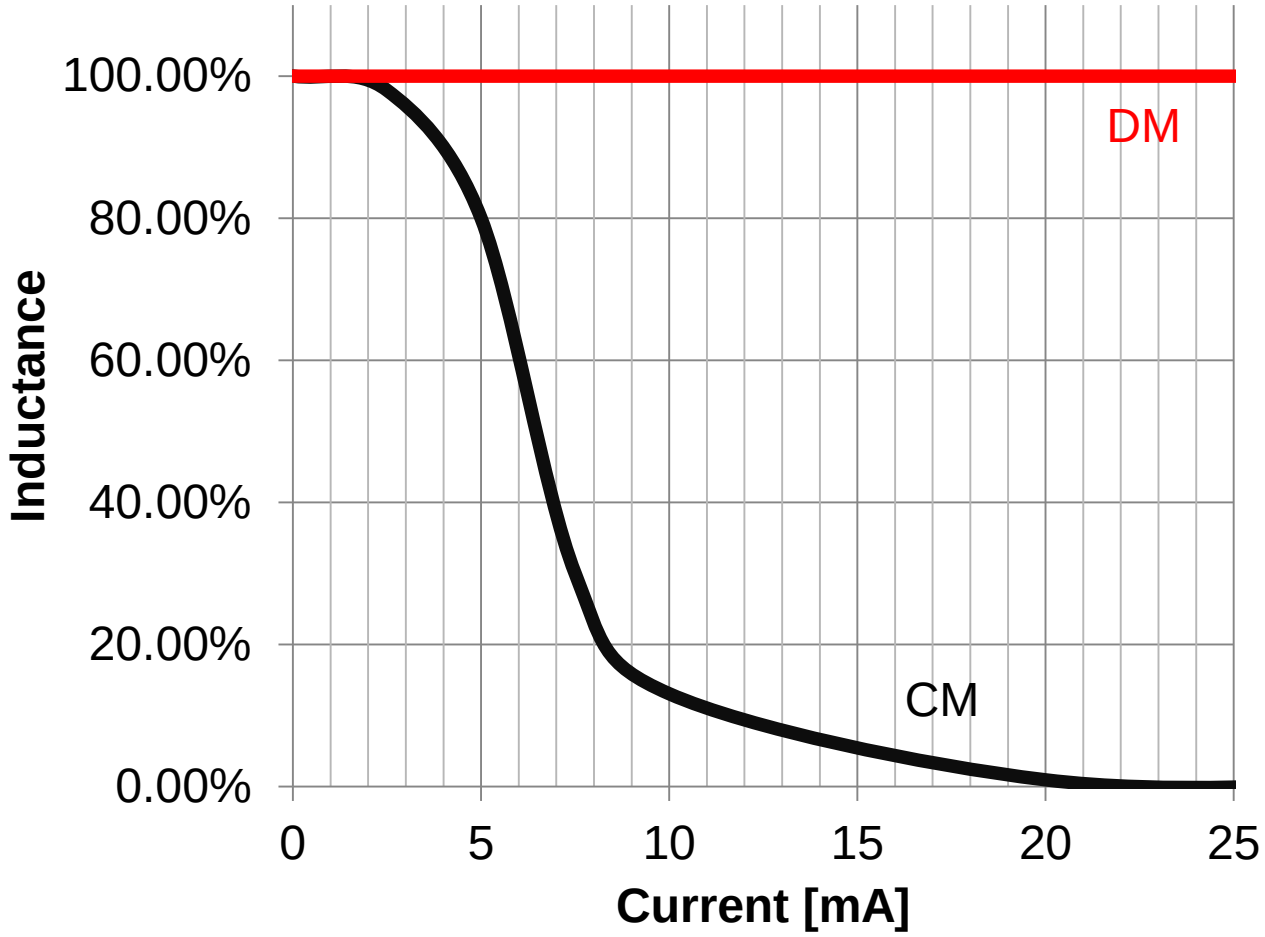
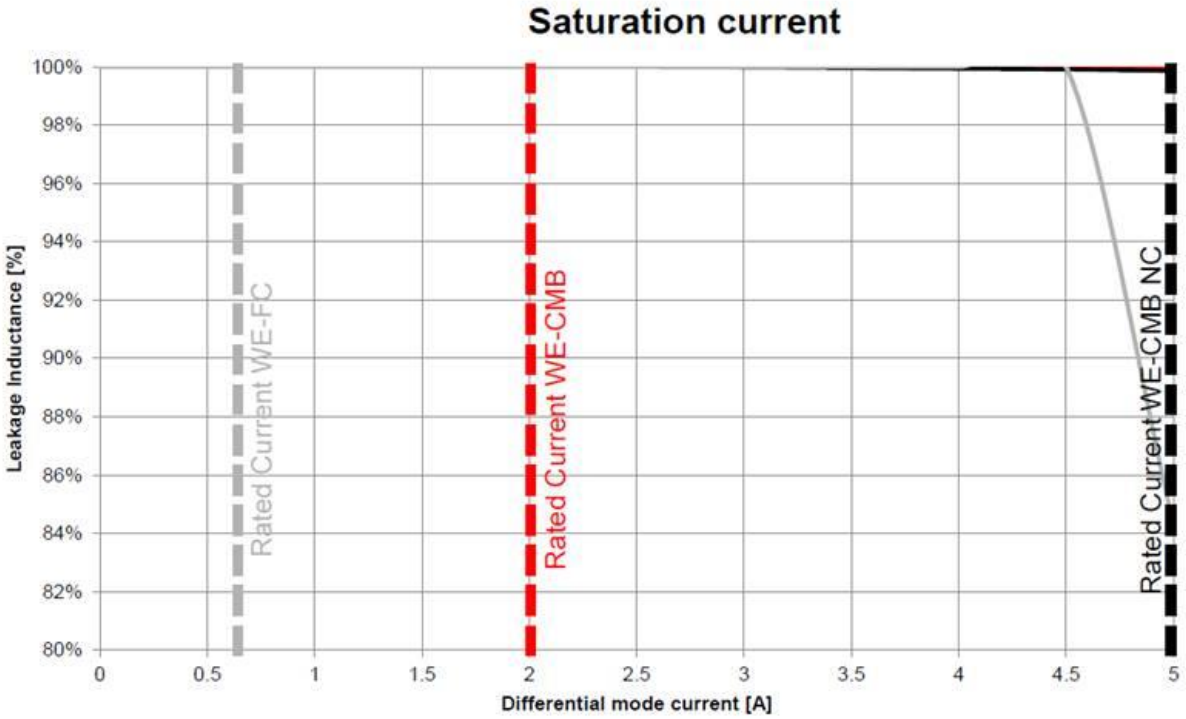
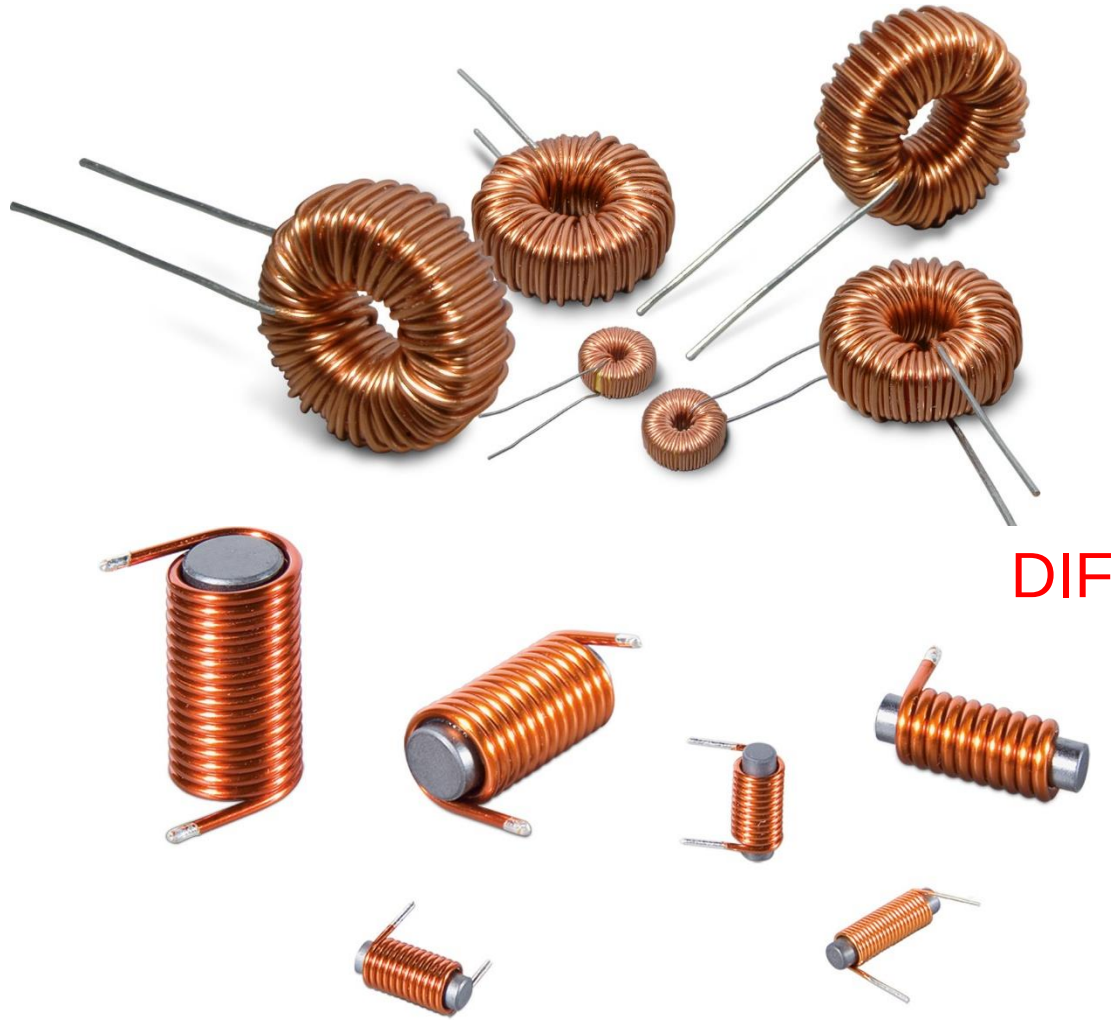
Saturation







DIFFERENTIAL MODE FILTERS

Construction of a differential mode filter

WÜRTH ELEKTRONIK

WE-SD

WE-FI

Material – High losses

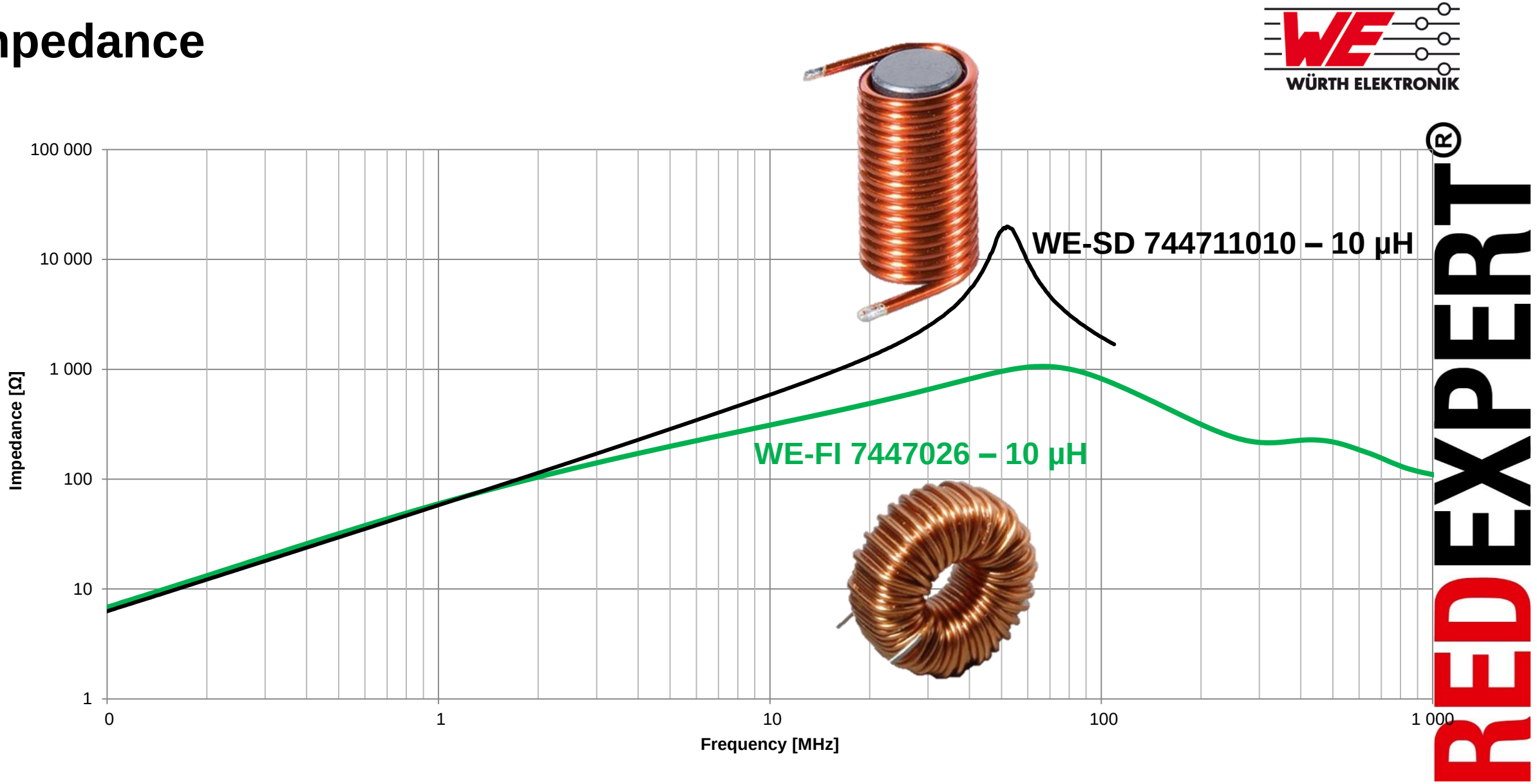
MnZn
Iron powder

Relevant parameter

Frequency characterization
Impedance

Saturation? Rated current?

Impedance



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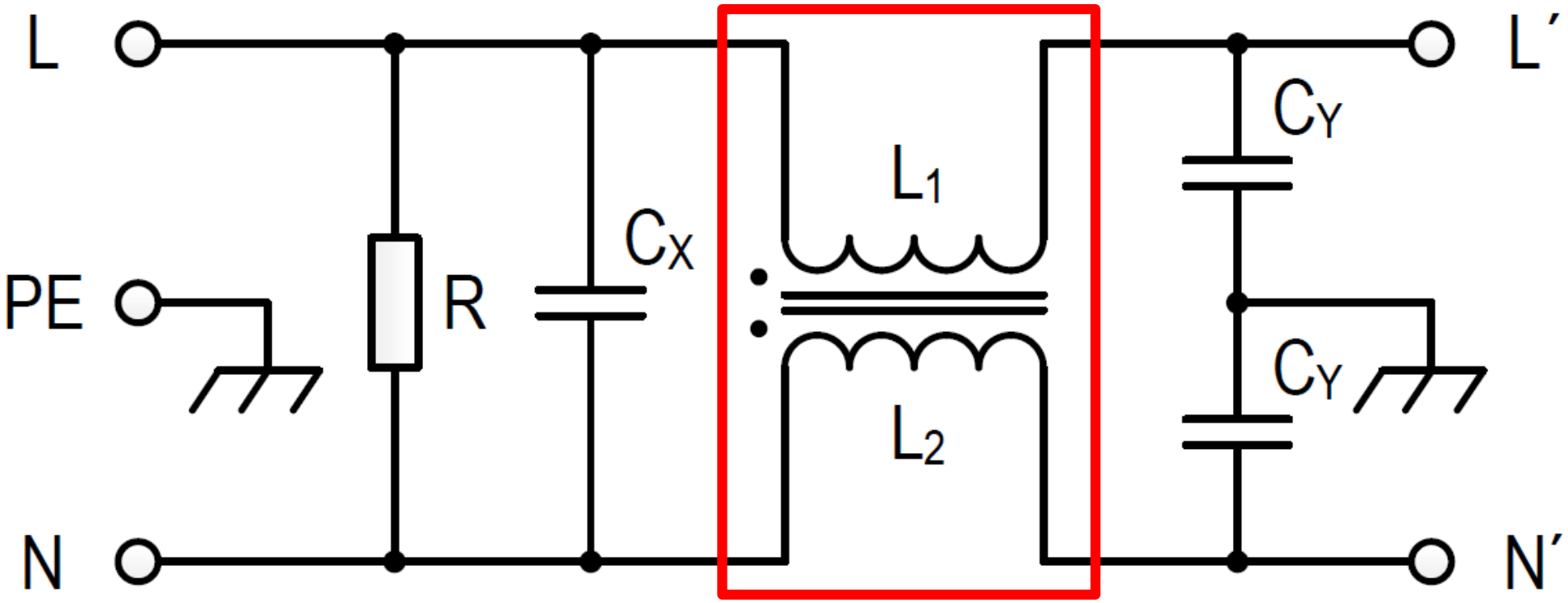
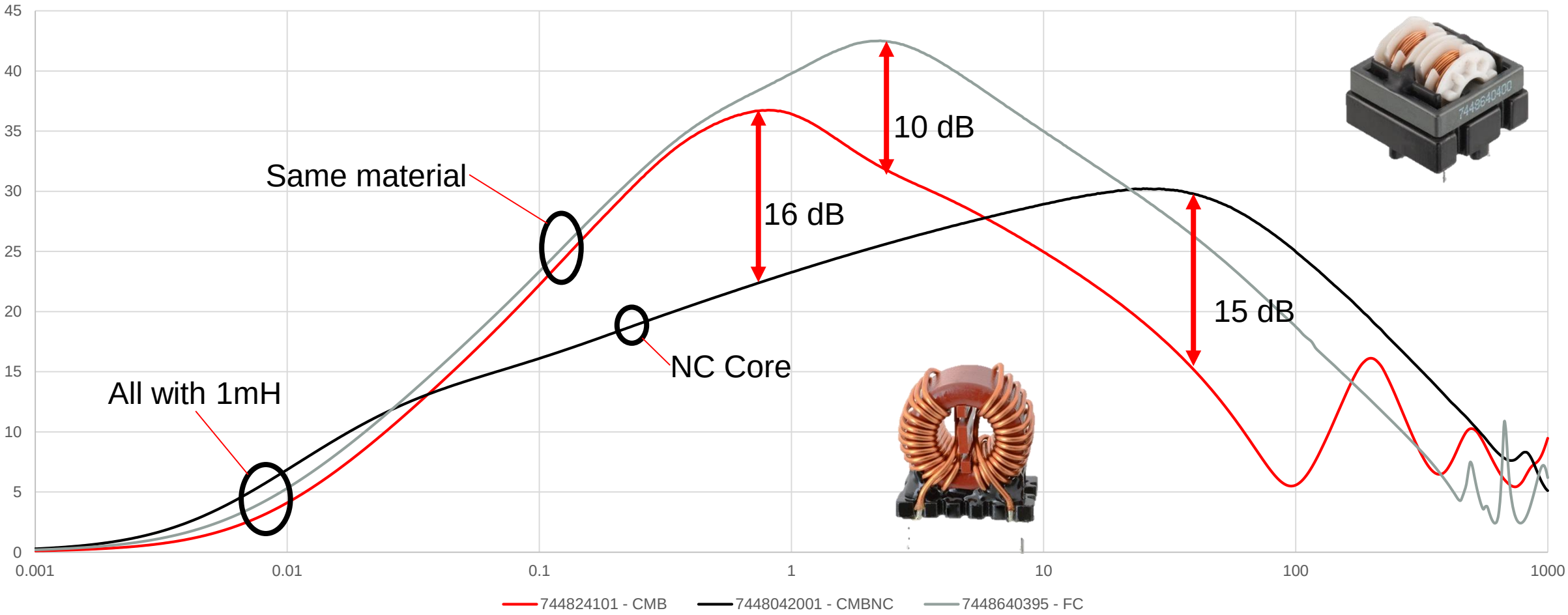
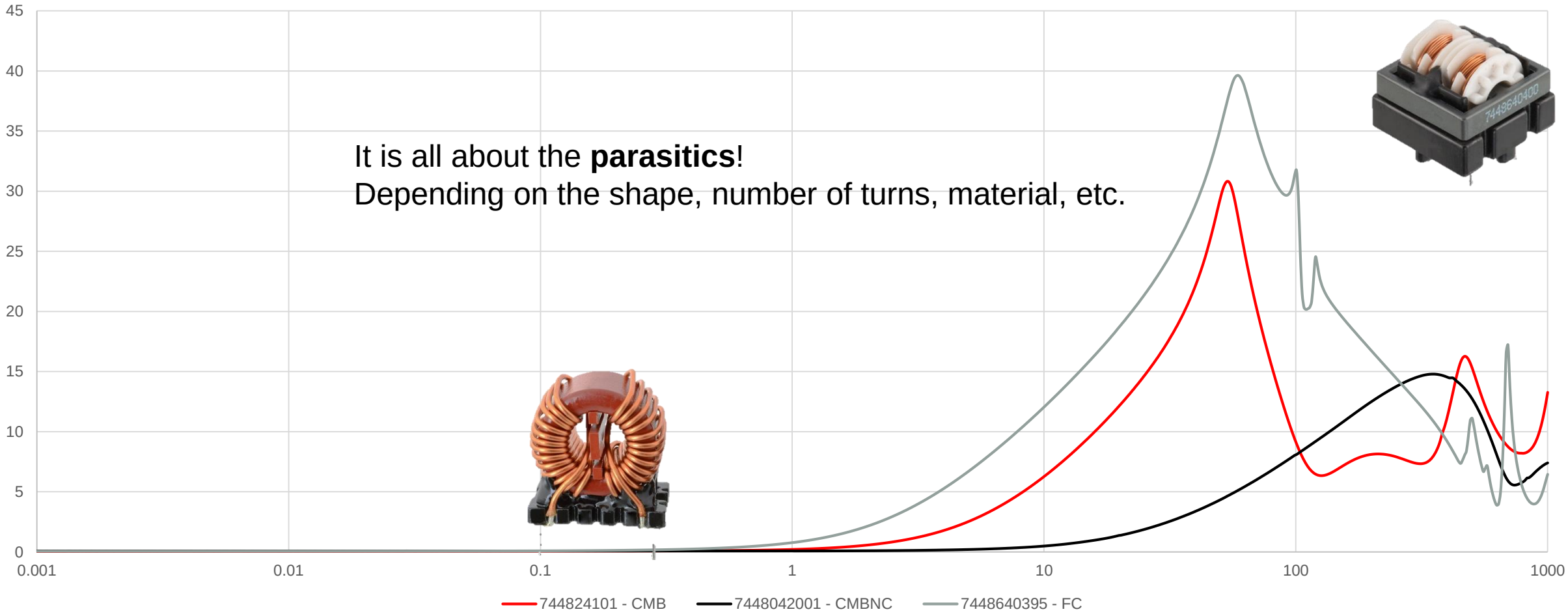
What am I filtering?



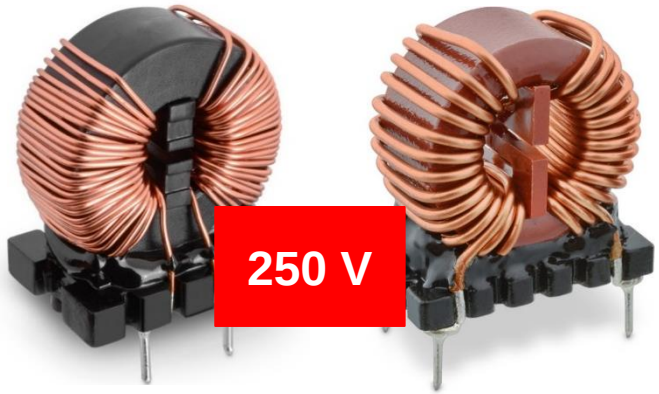
Common mode attenuation



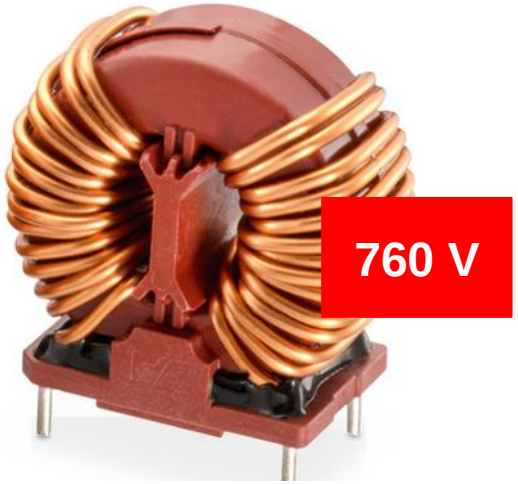
Differential mode attenuation



Working voltage



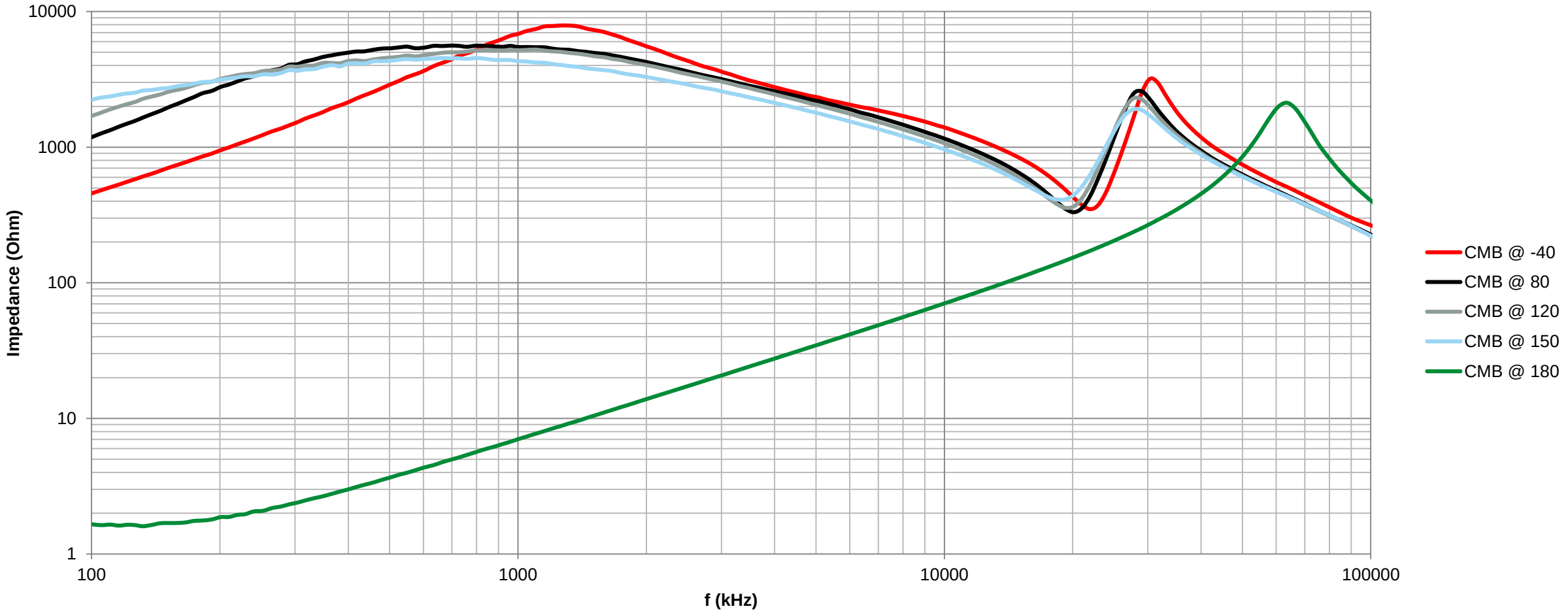
250 V



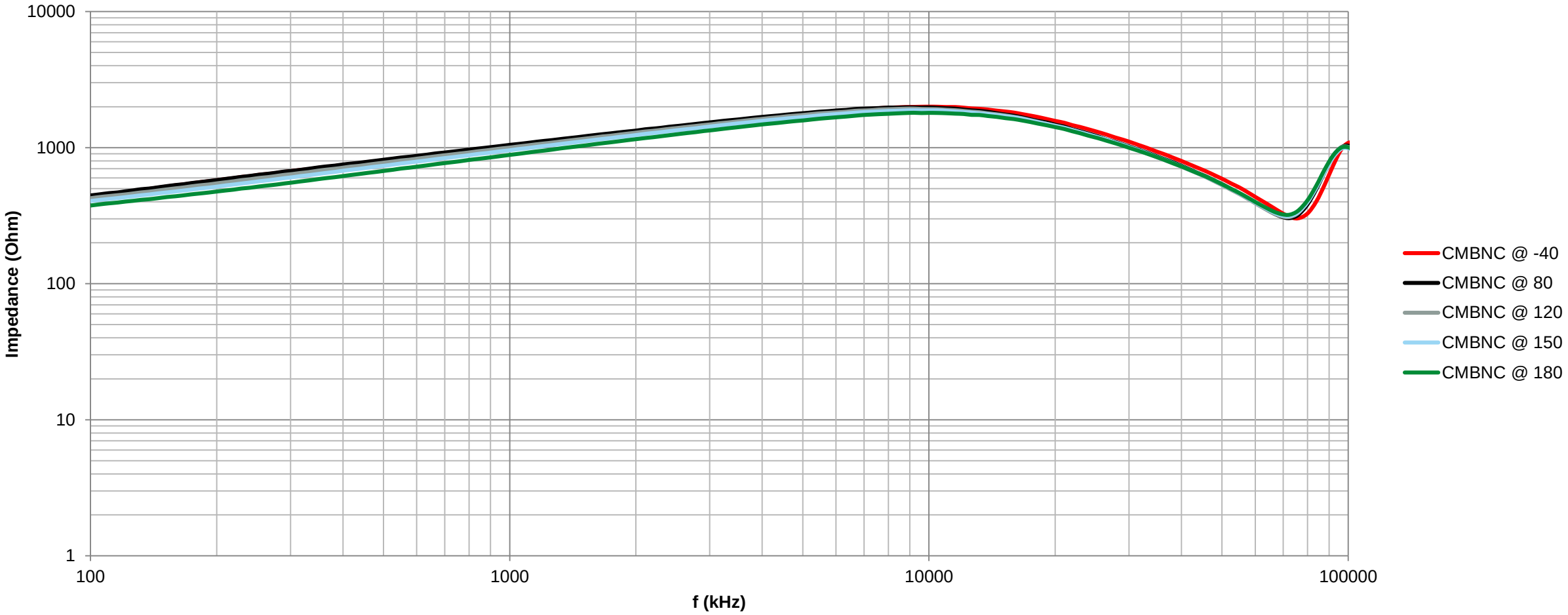
760 V

20 – 60 V

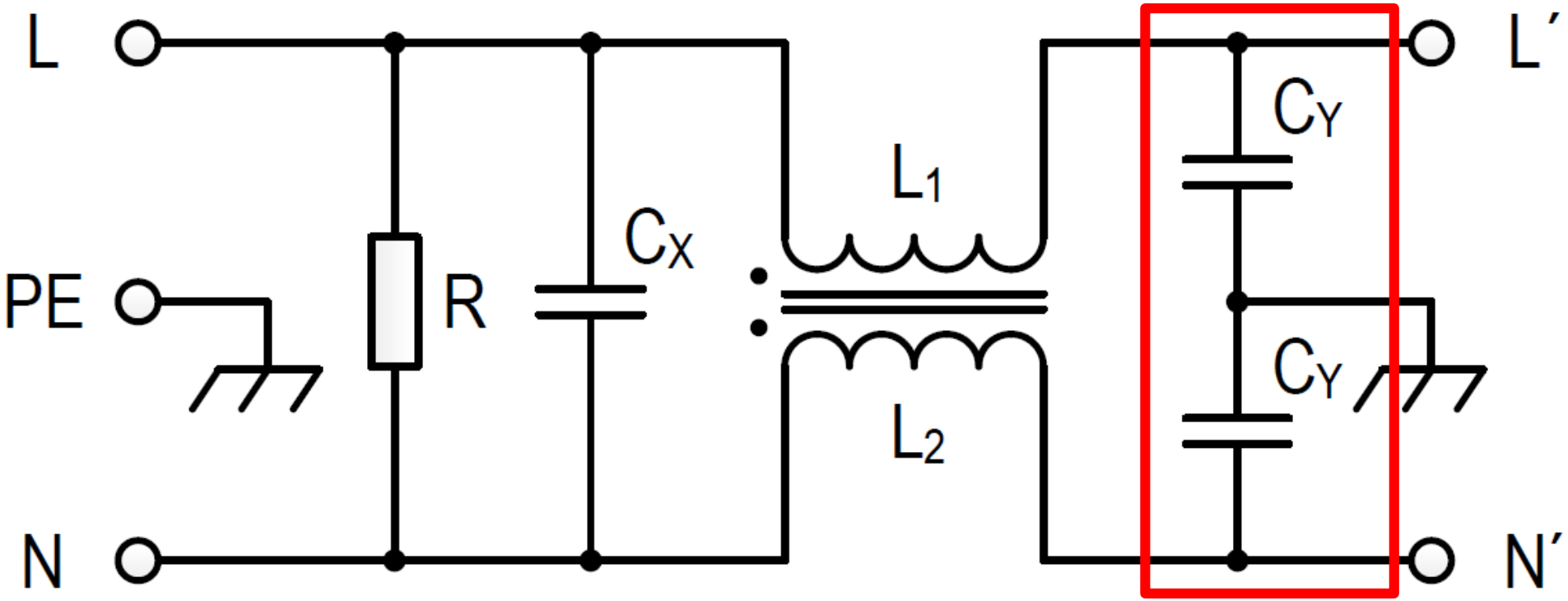
Temperature – WE-CMB



Temperature – WE-CMBNC



What am I filtering?



CY – Leakage current

$$I_{LK} = \frac{U_R}{Z_{C_Y}}$$

$$I_{LK} = 2 * \pi * f_R * U_R * C_Y$$

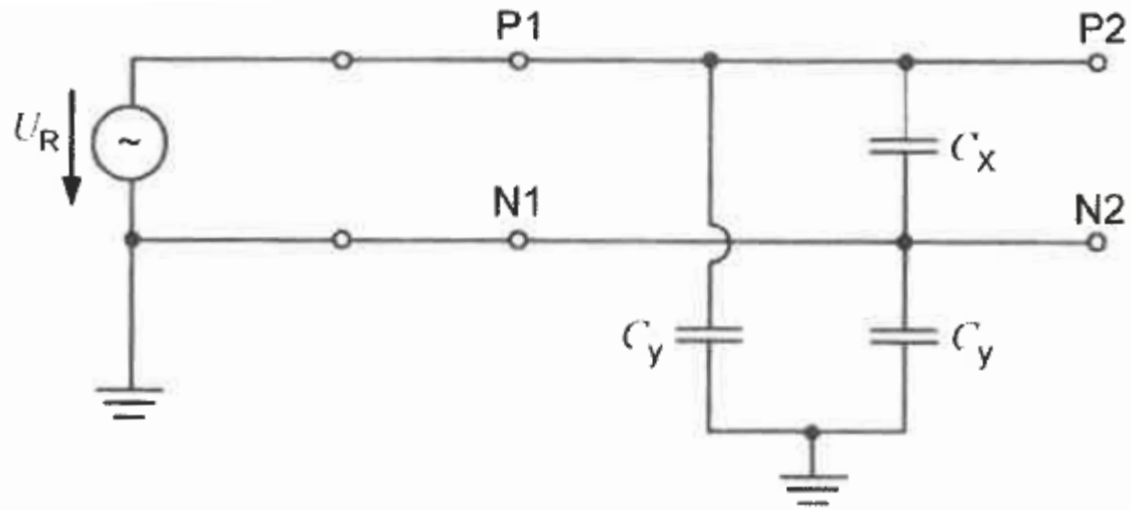


Bild A.2 – Ableitstrom für zweipolige Filter

WE-CLFS Complete Line Filter Solution

- VR: 250 V (AC/DC)
- 1-Phase Filter
- Climatic Category 25/100/21
  (from -25 to +100°C /
  21 days Humidity test)
- Fast on connectors (max. 20A)
- Chassis Mounting (M4)

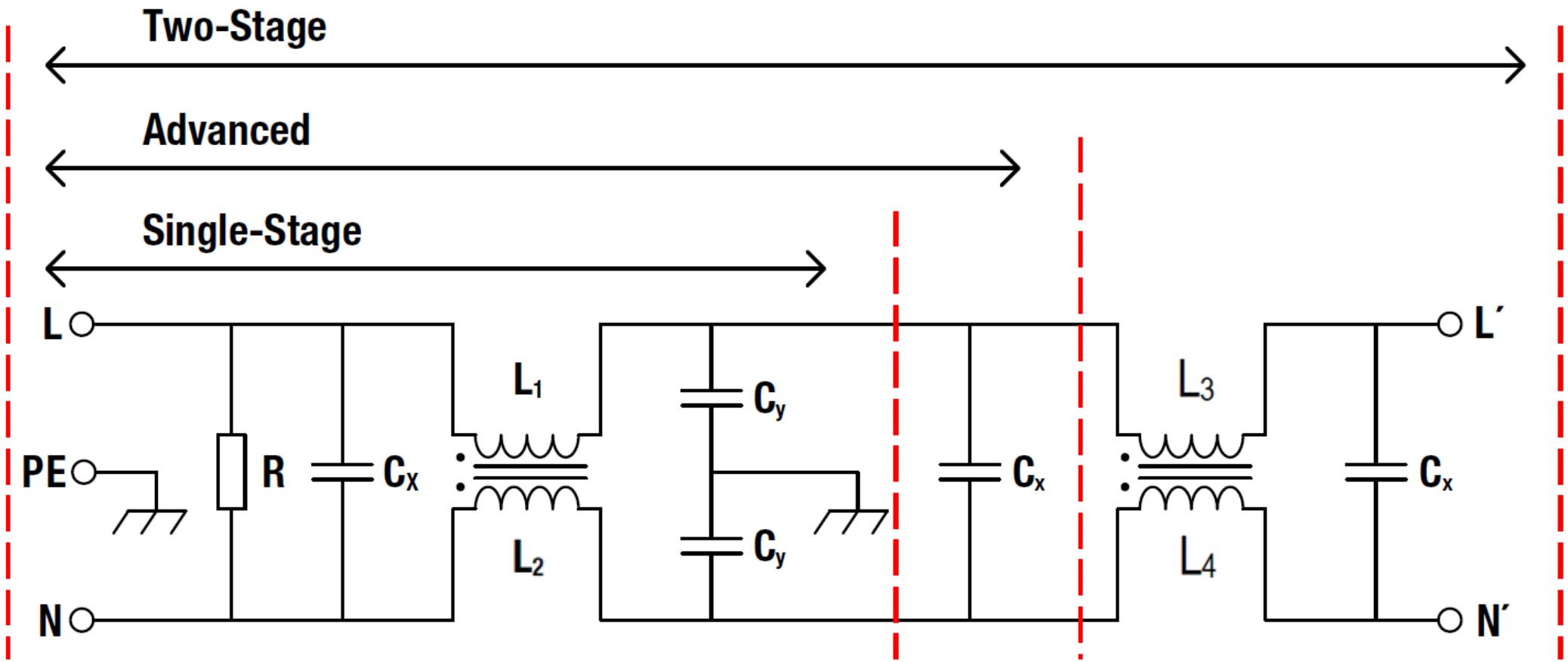
Single-Stage

Single-Stage
Advanced

Two-Stage

- Certifications:

WE-CLFS Complete Line Filter Solution



WE-CLFS Complete Line Filter Solution

WE-Article number	Rated Current I_R [A]	Inductance L1 and L2 [mH]	Y-Capacitors Cy [nF]	X-Capacitors Cx [µF]	bleeding resistor R [kOhm]
810912001	1.5	20	2.2	0.22	1000
810912003	3	10	3.3	0.33	1000
810912006	6	10	3.3	0.33	1000
810912008	8	6	4.7	0.47	680
810912010	10	6	4.7	0.47	680
810912012	12	2.2	6.8	0.68	470
810912014	14	2.2	6.8	0.68	470
810912020	20	1	10	1	330

+ (Rated Current) + (Y-Capacitors) + (X-Capacitors)

- (Inductance) - (bleeding resistor)

- **During the design of the filter was important to keep the performance through the increasing rated current. The following effects were consider:**
  - Inductance is reduced. Thicker wire in the same core – Reduced number of turns
  - CY increased to compensate the reduction of nominal inductance
  - CX increased to compensate the reduction in the leakage inductance due to the small number of turns.
  - R reduced to keep $\tau = RC < 1$

Agenda

- Introduction
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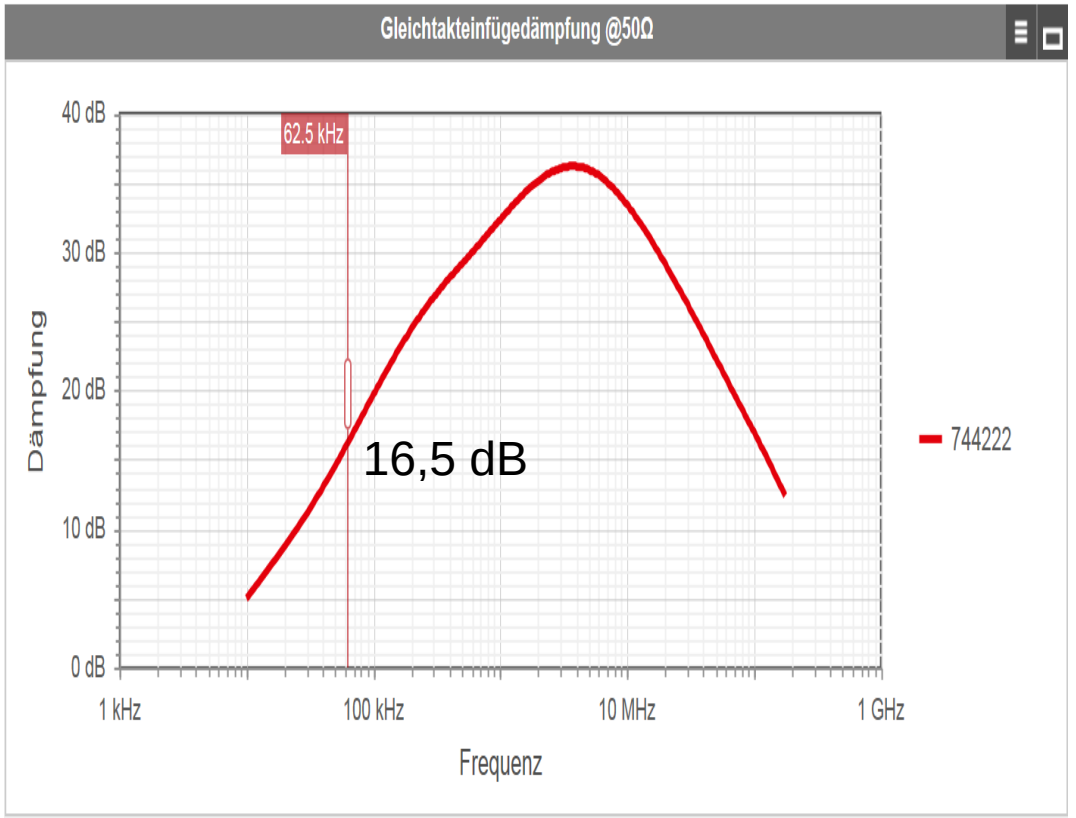
- **Design and simulation of a filter**
- How to destroy a filter

Simulation of a filter for RS485 Specifications - EMI

- Where could most of the radiation come?
- RS-485 max. Cable length → 1,2 km
- 1,2 km= $\frac{\lambda}{4}$ → High efficiency Antenna!
- $f_\lambda = \frac{c}{\lambda} = \frac{300000\frac{km}{s}}{4{,}8km} = 62{,}5\ kHz$

REDEXPERT®

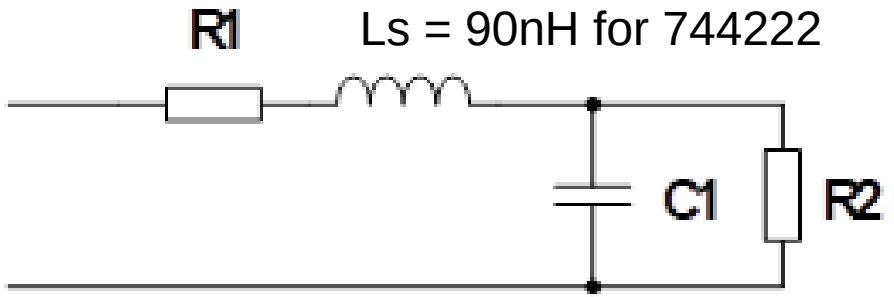
744222



Simulation of a filter for RS485
Specifications – Datarate in differential mode

- Datarate max. 12Mbps (6MHz Base frequency with NRZ)
- 3dB frequency defined at 15MHz

- R1=R2=120 Ohm (RS-485)
- C1?
- A = 3dB @ 15MHz!
- After some calculations
- C1=181,38 pF

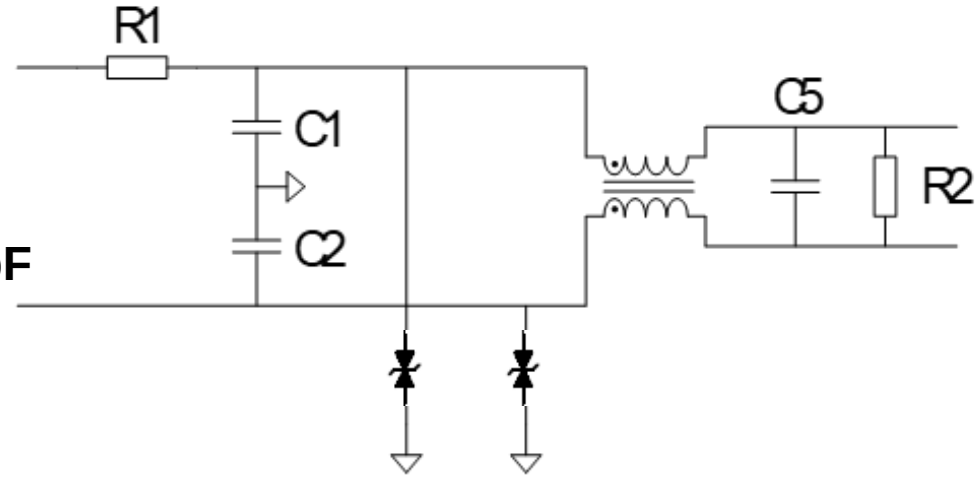


- What is C1?

Simulation of a filter for RS485 Specifications - Datarate

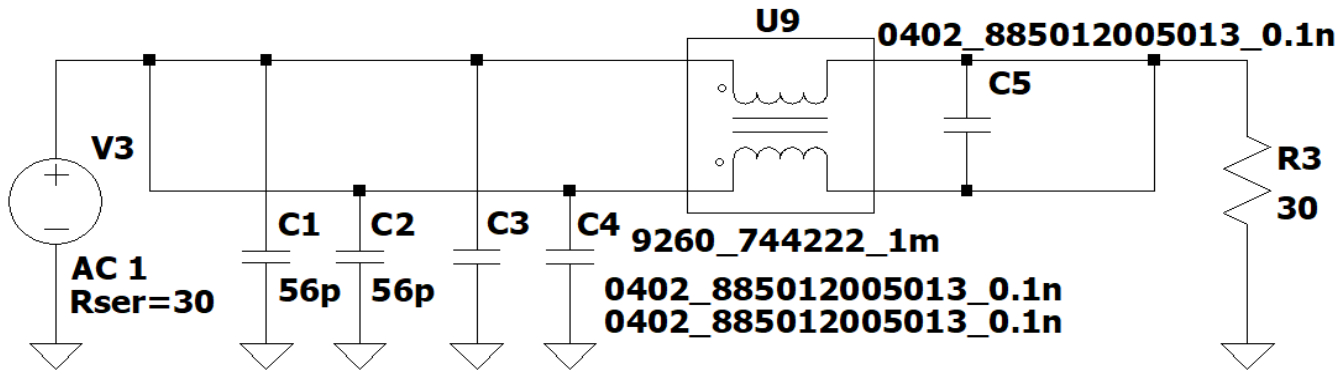
- Max Capacitance of the channel 181,38 pF

- TVS Diodes = 56 pF
- Cy = 100 pF
- Cx = 100 pF
- **Ctotal?**
- **Ctotal = 100pF + 56/2pF + 100/2pF = 178 pF**

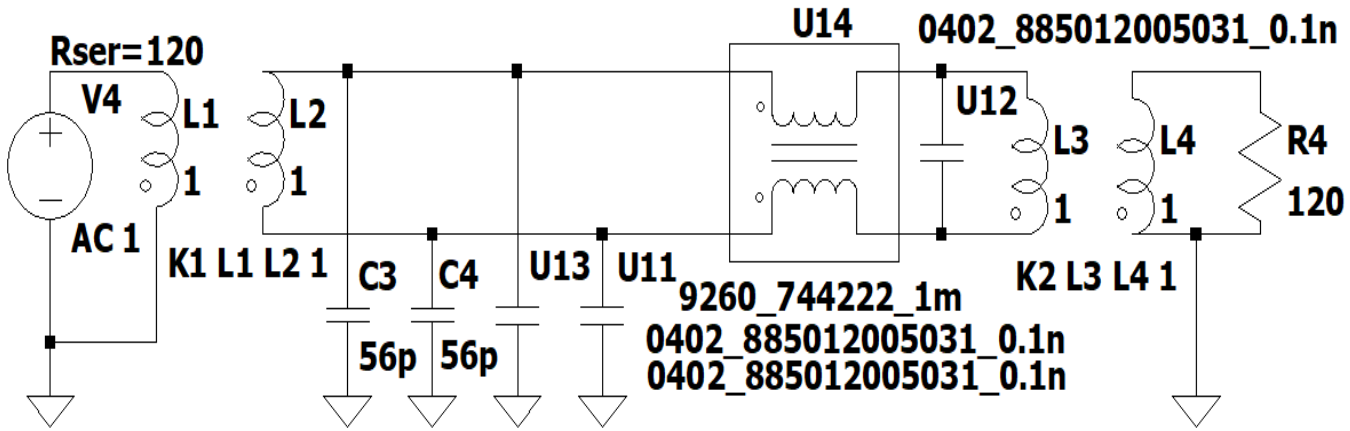


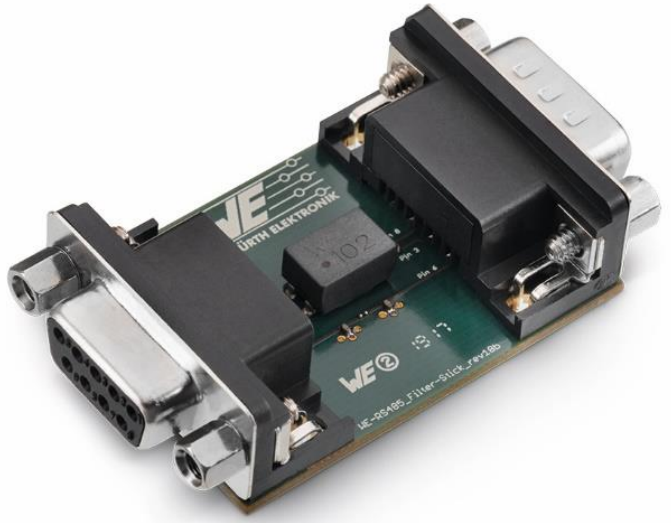
Simulation of a filter for RS485

Common Mode

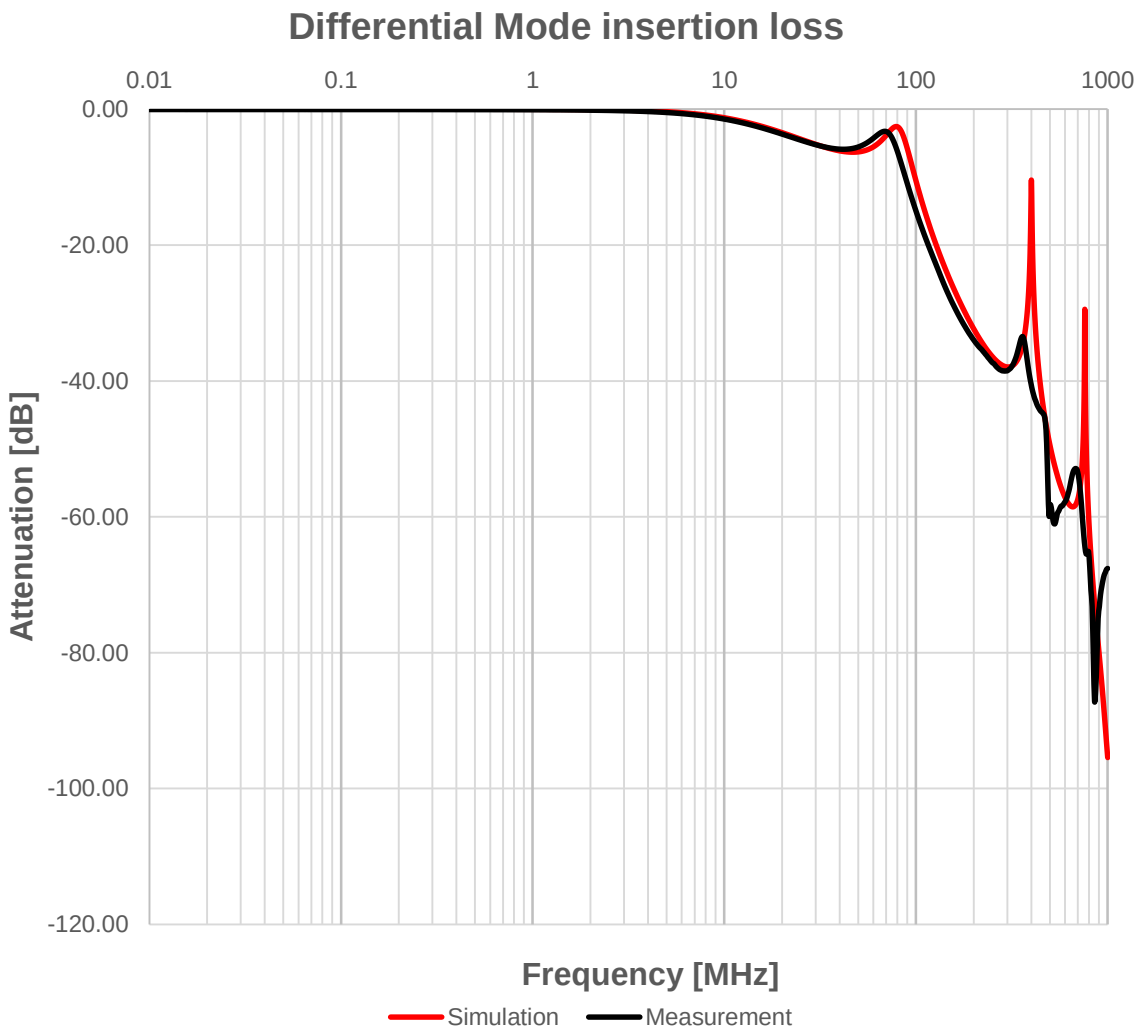


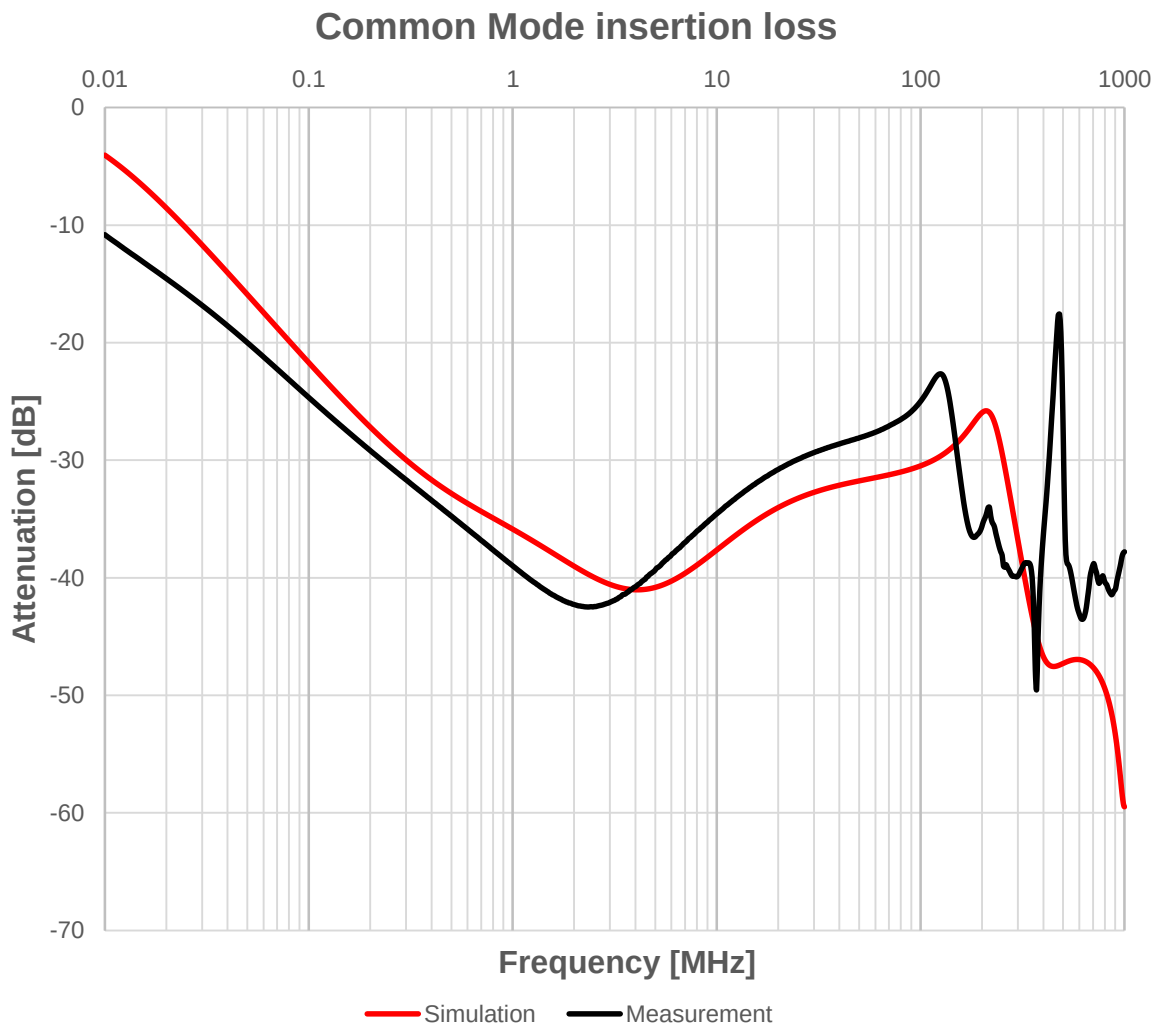
Differential Mode





Simulation of a filter for RS485





Design your EMC Filter

WÜRTH ELEKTRONIK

Test Board	
Quantity:	10

Resistor	
Quantity:	10
R:	1MΩ

WA-SNSR	
702 936 000	
Quantity:	20
Length:	15.9 mm

WR-TBL	
691 134 710 002	
Quantity:	10
VDE:	450 VAC/24 A
UL:	300 VAC/16 A
$R_{contact}$:	20 mΩ
0.05 up to 2 mm² Wires	

WR-SMSH			
746611 3		746611 4	
Quantity:	10	Quantity:	10
I_R:	50 A	I_R:	50 A
Thread:	M3	Thread:	M4

WCAP-FTX2	
890 324 023 025	
Pitch:	10 mm
C:	0.15 µF
U_R:	275 VAC
dV/dt:	300 V/µS

890 324 022 007	
Pitch:	7,5 mm
C:	0.015 µF
U_R:	275 VAC
dV/dt:	500 V/µS

890 324 023 006	
Pitch:	10 mm
C:	0.01 µF
U_R:	275 VAC
dV/dt:	500 V/µS

WCAP-CSSA	
885 352 211 002	
Quantity:	10
C:	680 pF
U_R:	250 VAC
Safety Class:	X1/ Y2

885 352 211 003	
Quantity:	10
C:	1000 pF
U_R:	250 VAC
Safety Class:	X1/ Y2

885 352 213 011	
Quantity:	10
C:	1000 pF
U_R:	250 VAC
Safety Class:	X1/ Y2

885 352 213 015	
Quantity:	10
C:	2200 pF
U_R:	250 VAC
Safety Class:	X1/ Y2

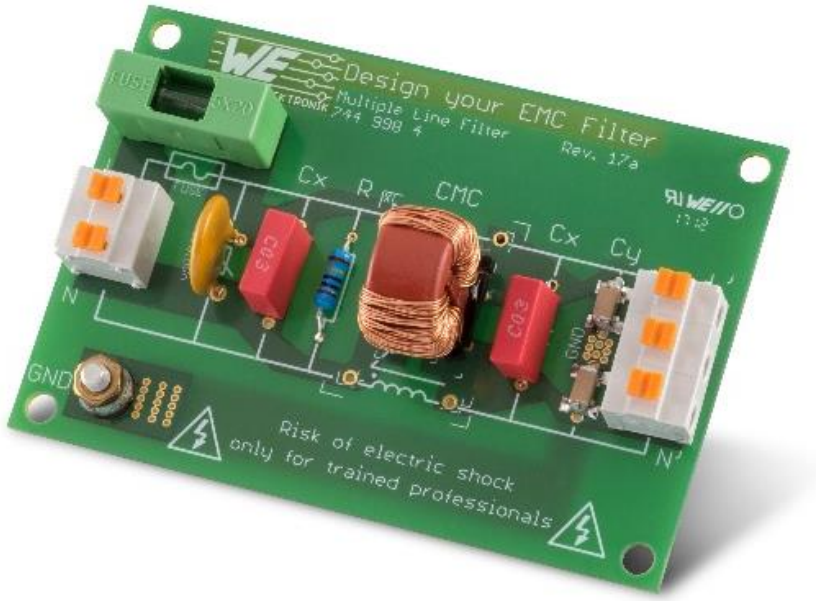
WE-CMBNC	
M	
744 803 0509	
Quantity:	1
L:	9 mH
I_R:	5 A
R_{DC}:	28 mΩ
L	
744 804 0707	
Quantity:	1
L:	7 mH
I_R:	7 A
R_{DC}:	20 mΩ

WE-CMB			
S		M	
744 822 301		744 823 601	
Quantity:	2	Quantity:	2
L:	1 mH	L:	1 mH
I_R:	3 A	I_R:	6 A
R_{DC}:	35 mΩ	R_{DC}:	13 mΩ
744 822 222		744 823 422	
Quantity:	2	Quantity:	2
L:	2.2 mH	L:	2.2 mH
I_R:	2 A	I_R:	4 A
R_{DC}:	70 mΩ	R_{DC}:	30 mΩ
744 822 233		744 823 305	
Quantity:	2	Quantity:	2
L:	3.3 mH	L:	5 mH
I_R:	1.5 A	I_R:	2.5 A
R_{DC}:	120 mΩ	R_{DC}:	95 mΩ
744 822 110		744 823 210	
Quantity:	2	Quantity:	2
L:	10 mH	L:	10 mH
I_R:	1 A	I_R:	2 A
R_{DC}:	360 mΩ	R_{DC}:	125 mΩ
744 822 120		744 823 220	
Quantity:	2	Quantity:	2
L:	20 mH	L:	20 mH
I_R:	0.5 A	I_R:	1.5 A
R_{DC}:	540 mΩ	R_{DC}:	270 mΩ

744 824 101		744 824 622		744 824 433		744 824 310	
Quantity:	2	Quantity:	2	Quantity:	2	Quantity:	2
L:	1 mH	L:	2.2 mH	L:	3.3 mH	L:	10 mH
I_R:	10 A	I_R:	6 A	I_R:	4 A	I_R:	3 A
R_{DC}:	7 mΩ	R_{DC}:	20 mΩ	R_{DC}:	35 mΩ	R_{DC}:	105 mΩ
744 824 220							
Quantity:	2						
L:	20 mH						
I_R:	2 A						
R_{DC}:	220 mΩ						

WE-LF			
744 662 400 07		744 662 200 2	
Quantity:	1	Quantity:	1
L:	0.7 mH	L:	2.2 mH
I_R:	4 A	I_R:	2 A
R_{DC}:	27 mΩ	R_{DC}:	100 mΩ

744 662 100 7		744 662 002 7	
Quantity:	1	Quantity:	1
L:	6.8 mH	L:	27 mH
I_R:	1 A	I_R:	0.4 A
R_{DC}:	300 mΩ	R_{DC}:	1.200 mΩ



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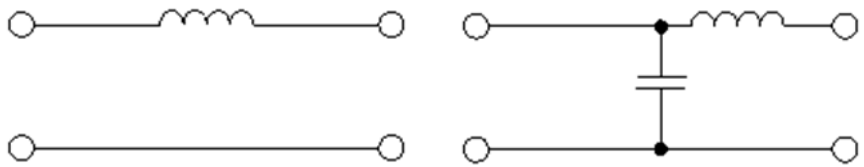
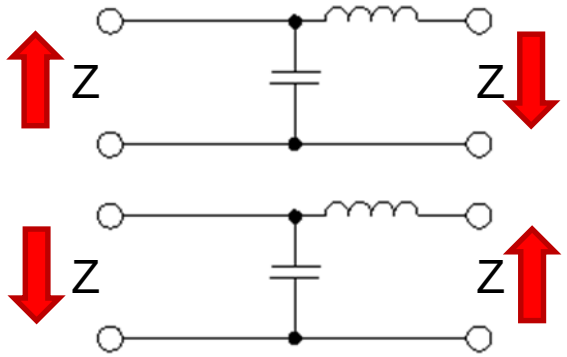
Why your filter is not working ....

- **Order of filter is correct?**



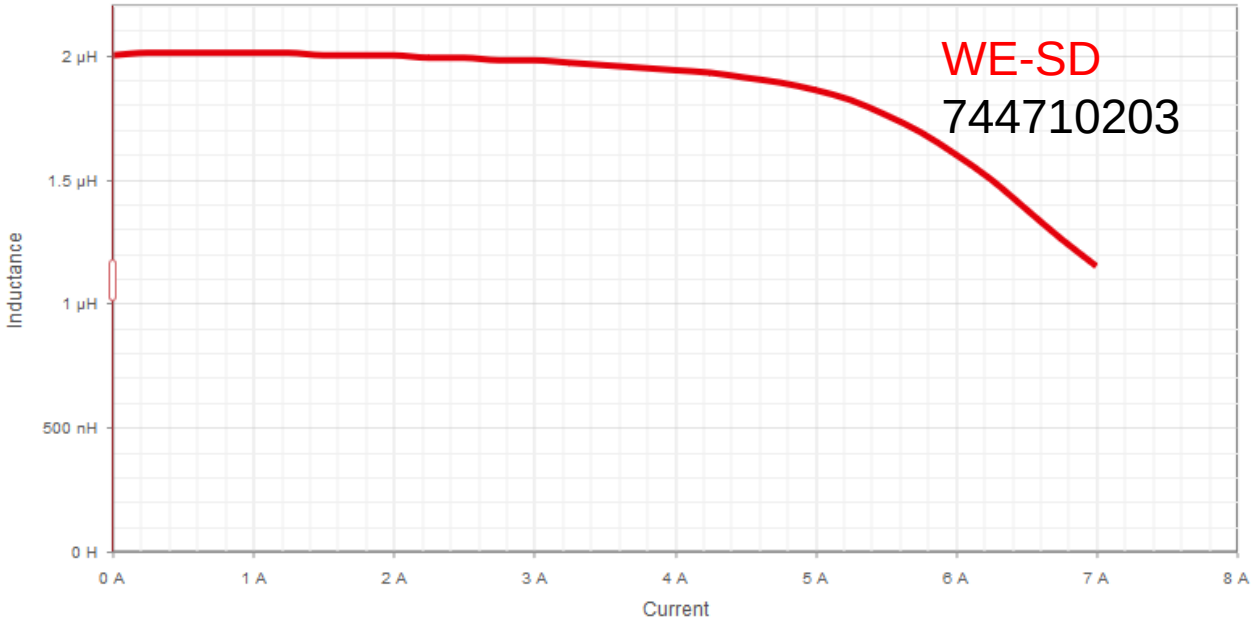
- **Wrong orientation?**



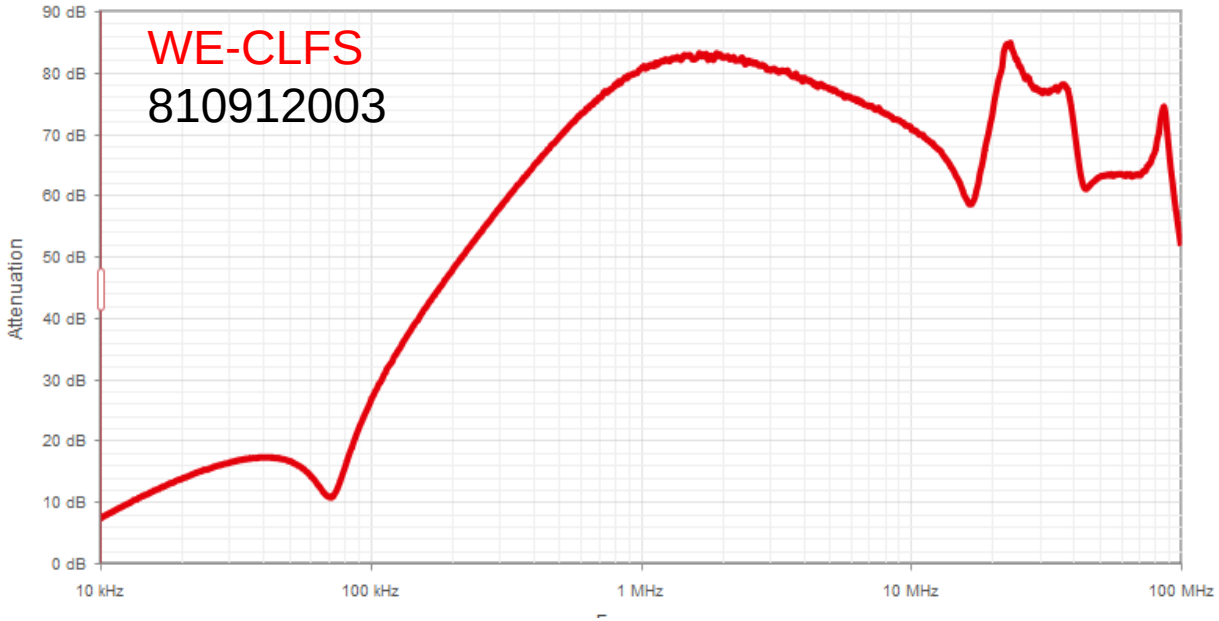
- **Wrong mode?:**

Why your filter is not working ....

- **Saturation of inductors?**

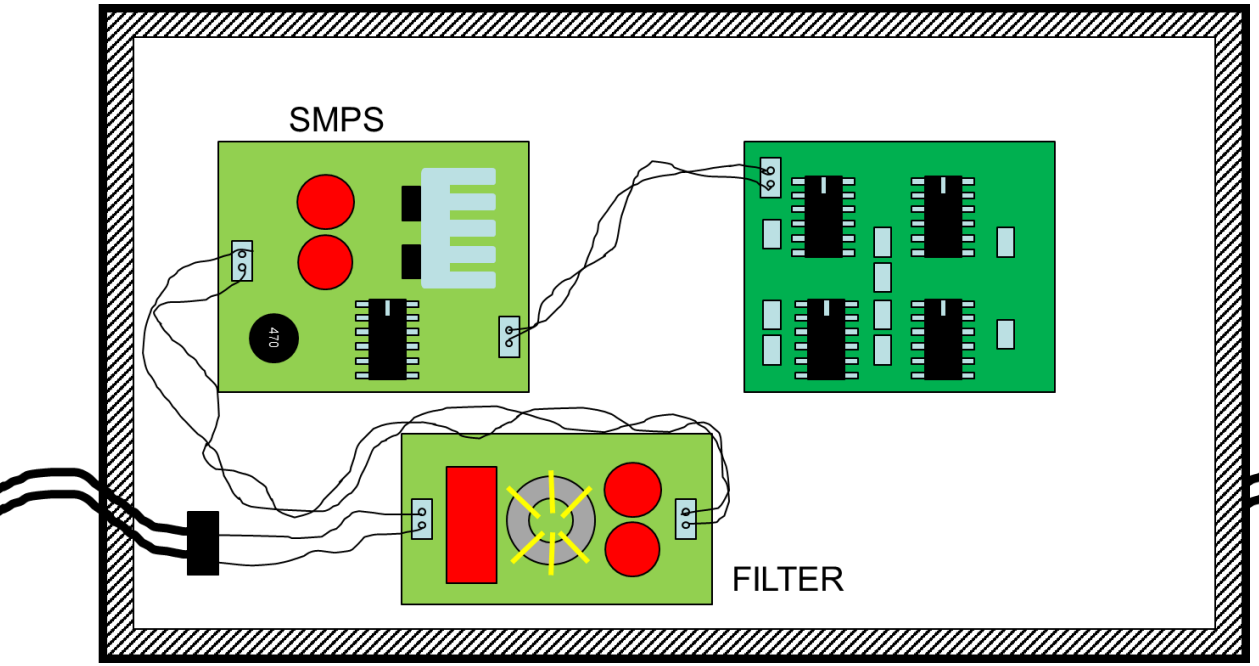


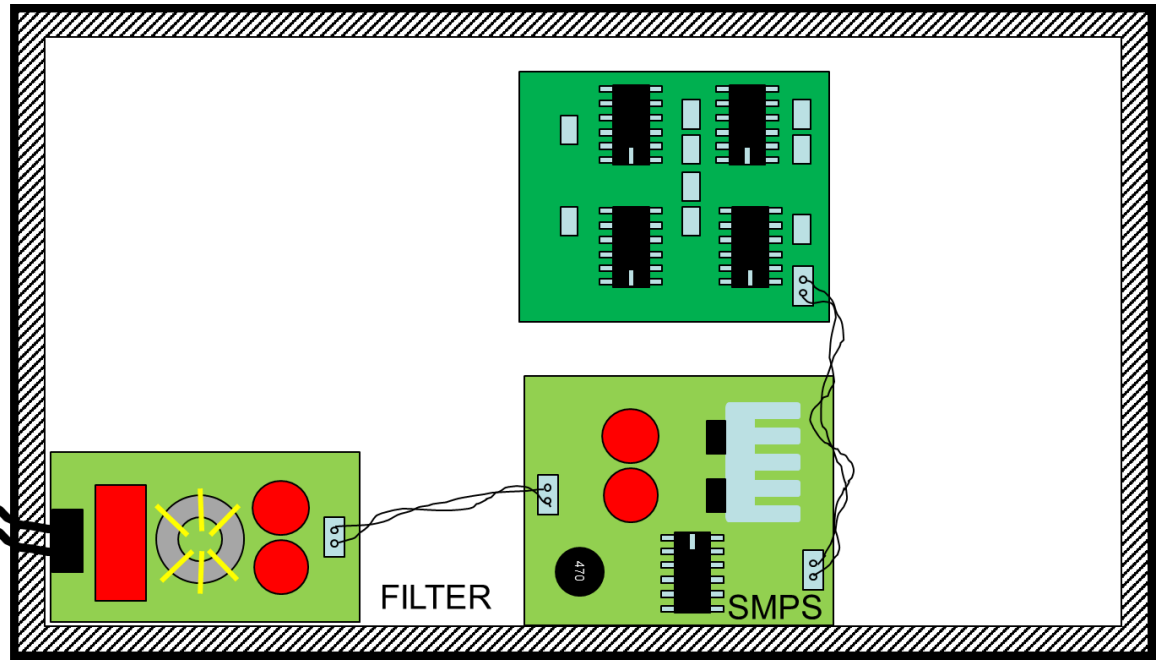
- **Parasitics in some frequency?**



Why your filter is not working ....

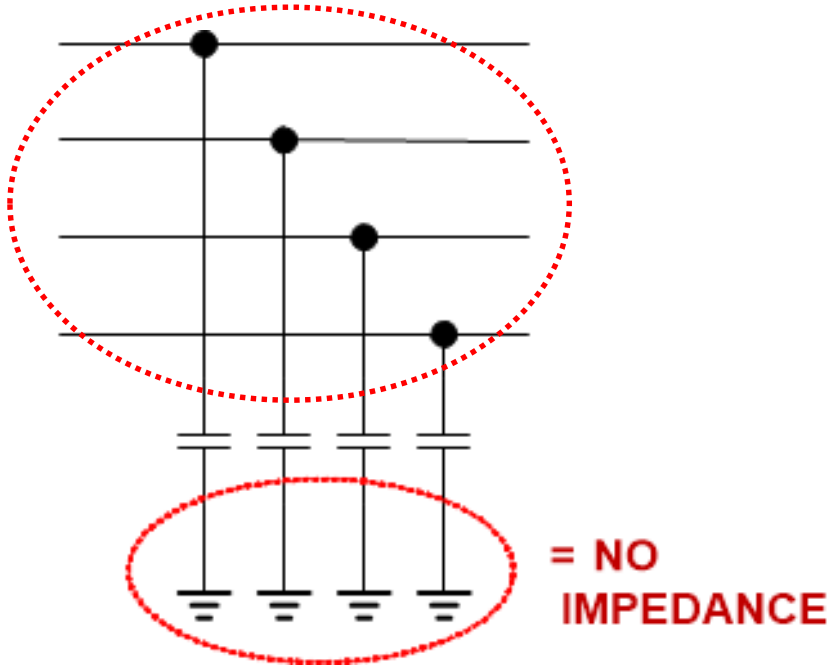
- **Dangerous location?**
- **I/O Feedback**



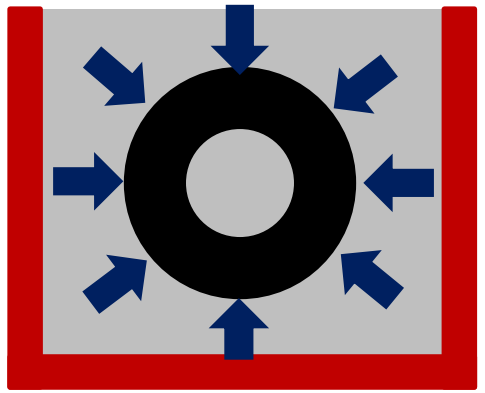


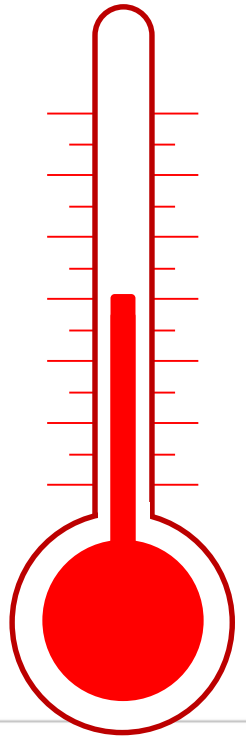
Why your filter is not working ....

- **Parasitics in layout?**



- **Potting materials?**
- **Low cost "equivalents"?**





Questions & Answers

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

eiSos-webinar@we-online.com