EMC AC LINE FILTER

Carpov Pascual, Field Application Engineer

EXTERNAL

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

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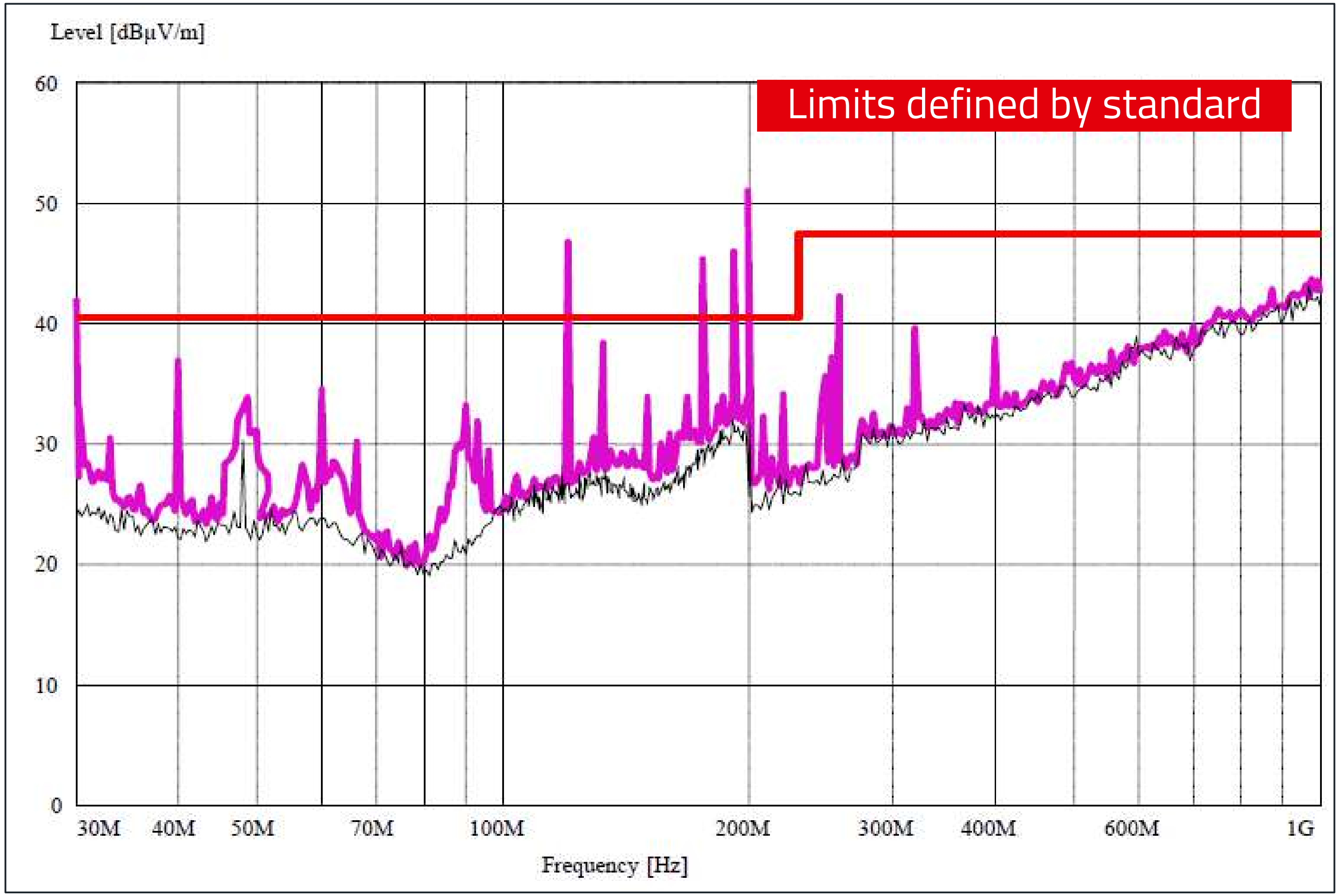
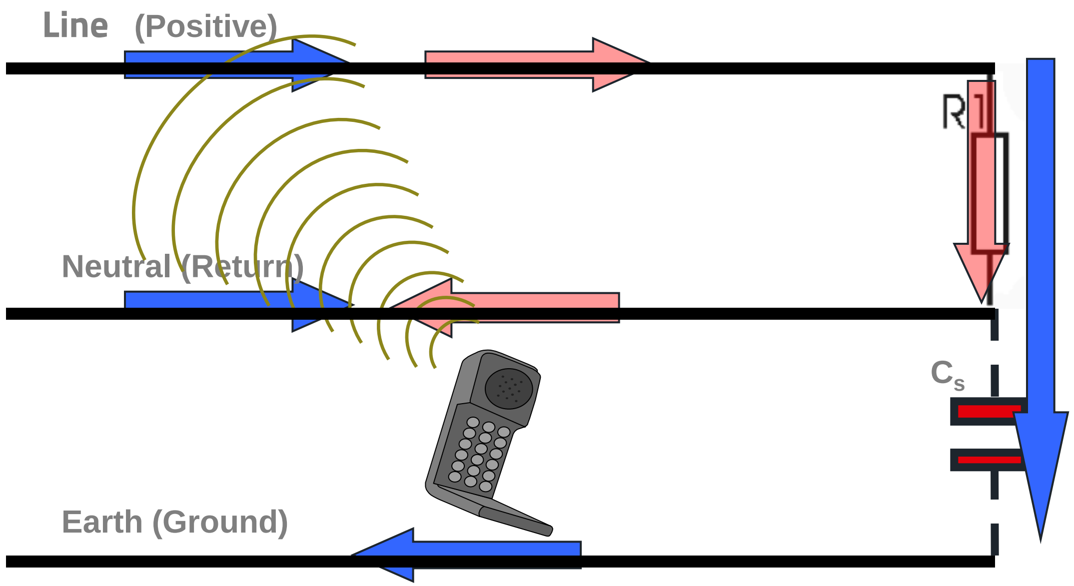
** Some presentation images have clickable web links*

WHY DO WE NEED FILTER?



TRANSMISSION MODE

- **Recognize the transmission mode:**



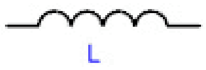
Differential Mode

noise or signals on a line(s) with a return path

Common Mode

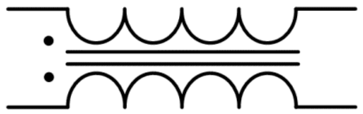
noise on all lines propagating in the same direction with respect to earth

Against Differential Mode Noise



Use a differential Ferrite or choke

Against Common Mode Noise

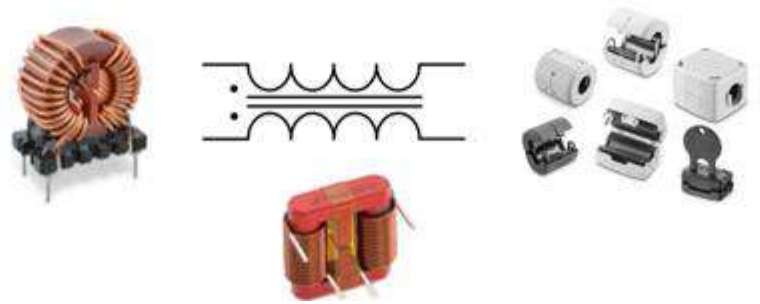


Use a Common mode Choke

DIFFERENT TYPE OF NOISES

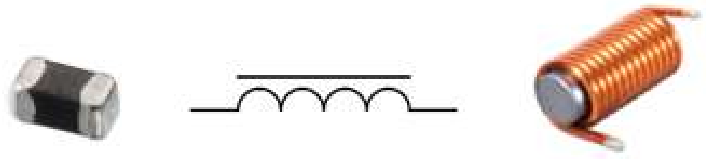
- **Common Mode Noise**

Use a common mode choke or snap ferrite



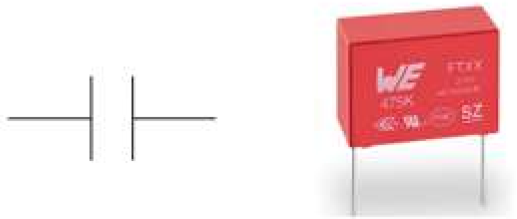
- **Differential Mode Noise**

Use a ferrite bead or filter choke

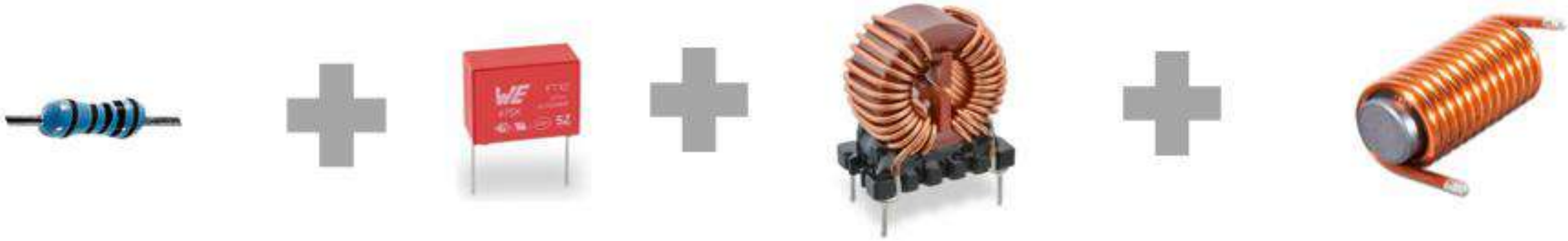


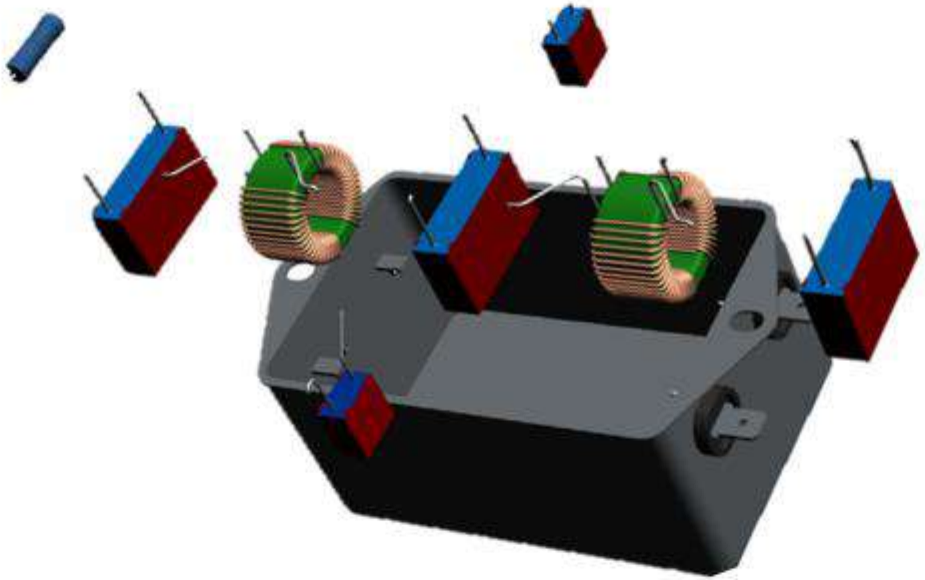
- **Both Common Mode and Differential Mode Noises**

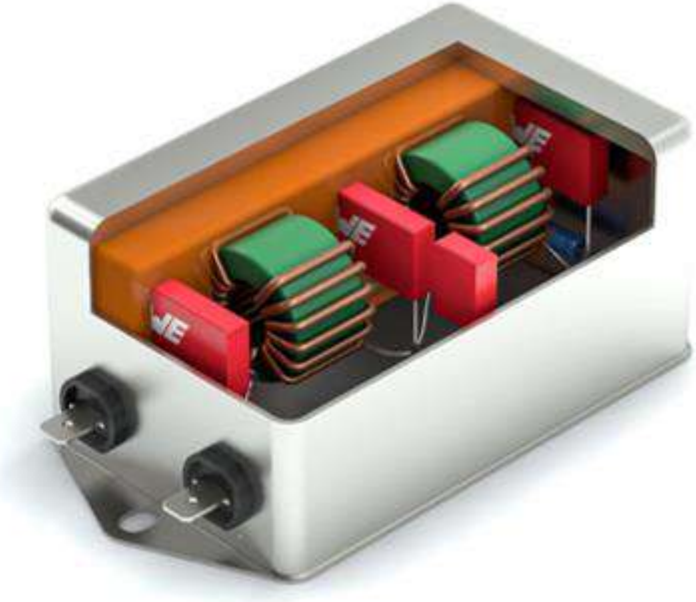
Use a capacitor



WHAT IS A FILTER?

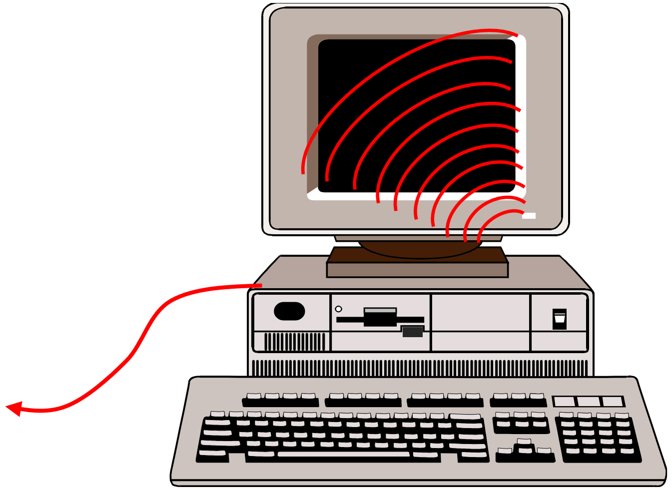






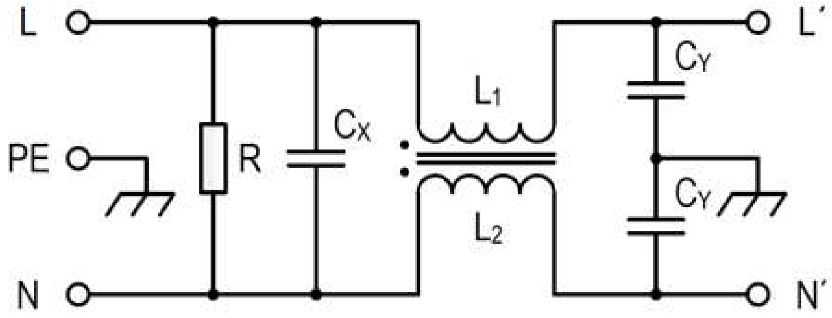
EMISSION VS. IMMUNITY

- **Emission**
  - We measure the **noise** generated by the **product.**
- Use of filter
  - To reduce the noise generated by the product.



- **Immunity / Susceptibility**
  - We try to **disturb** the product
- Use of filter
  - To reduce the noise which came from external sources.

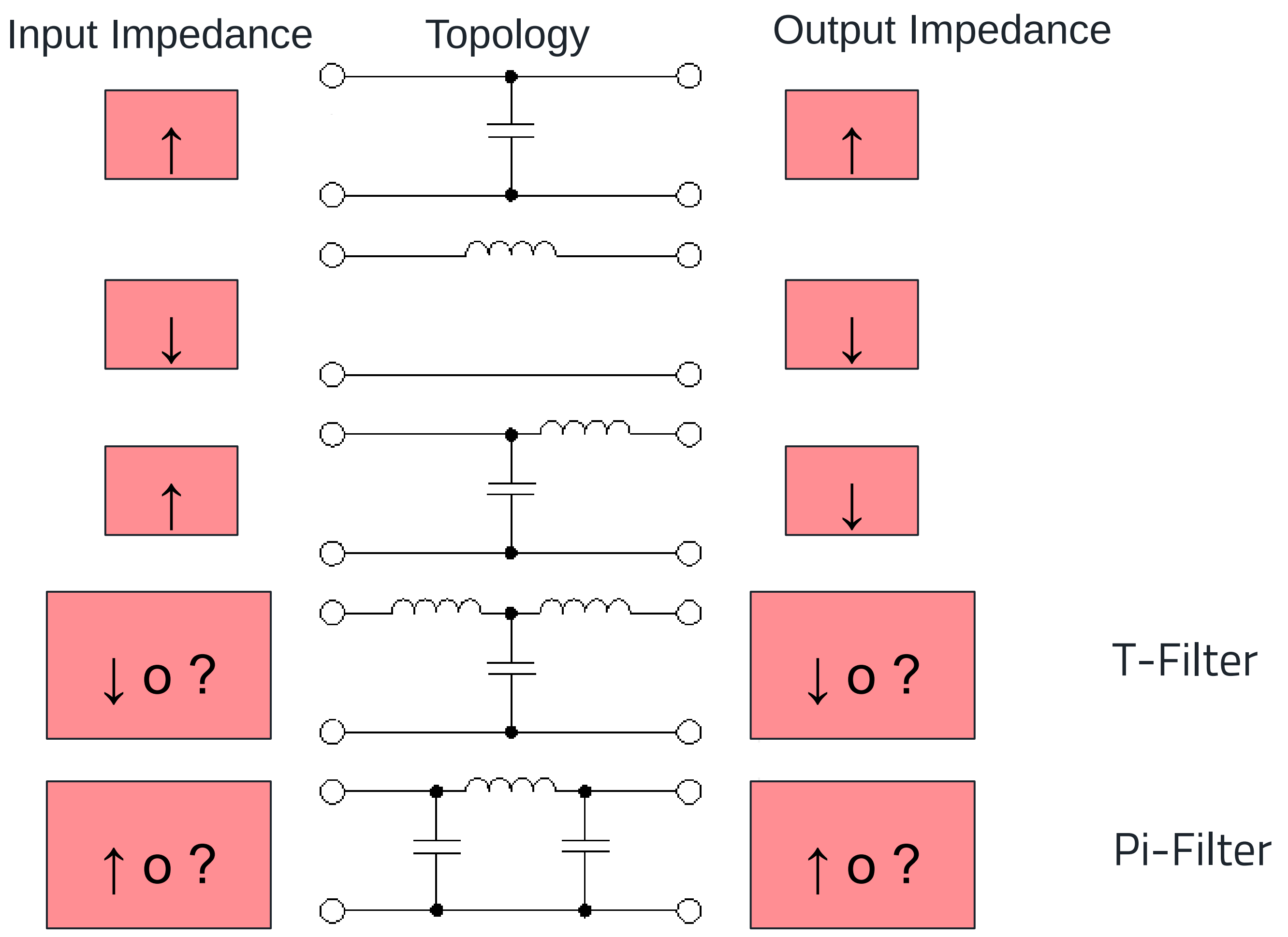
CONTENTS



FILTER TOPOLOGY

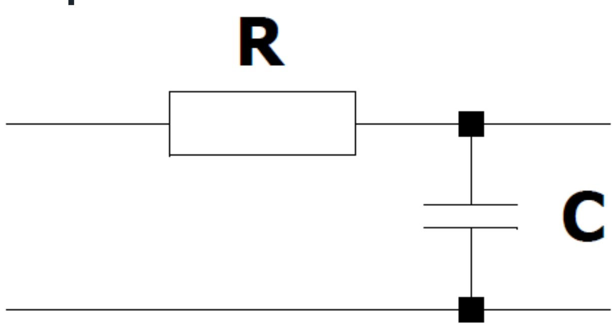
$$X_C = \frac{1}{2\pi f C}$$

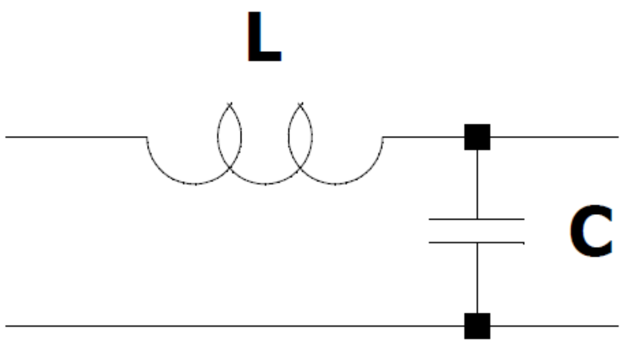
$$X_L = 2\pi f L$$



FILTER CIRCUITS

Low pass

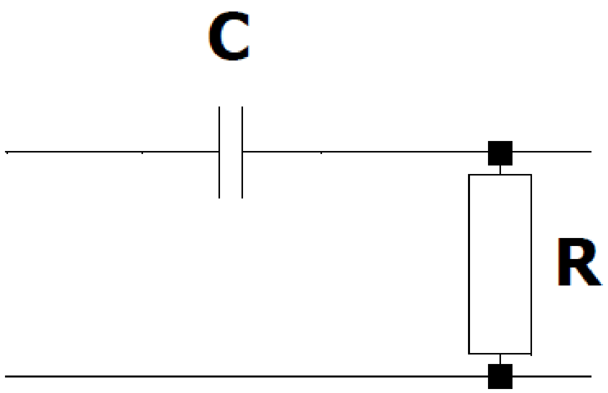


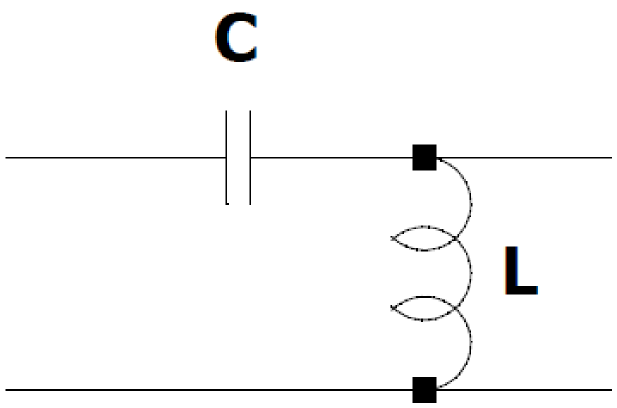


- **Attenuate high** frequency signals
- Low frequency signals go through without attenuation

Number of order = Number of reactive (L or C) parts

High pass





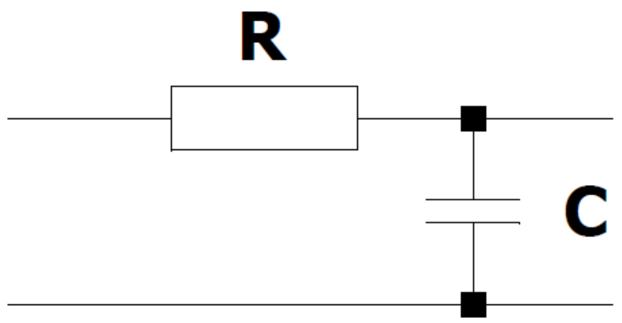
- **Attenuate low** frequency signals
- High frequency signals go through without attenuation

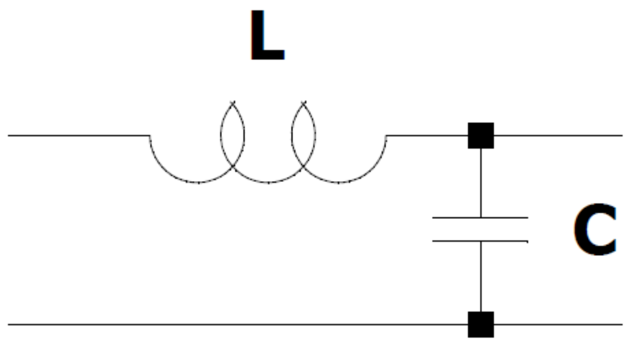
WHAT DO WE WANT TO FILTER?

- Example: Lighting applications
  - Mains 250 VAC at 50/60 Hz – Indoor, outdoor commercial
  - Low Voltage 12/24 VAC – Architectural and outdoor landscape/garden

- Noise at much higher frequencies
  - Radiated Emissions (RE) 30 MHz – 1 GHz
  - Conducted Emissions (CE) 150 KHz – 30 MHz

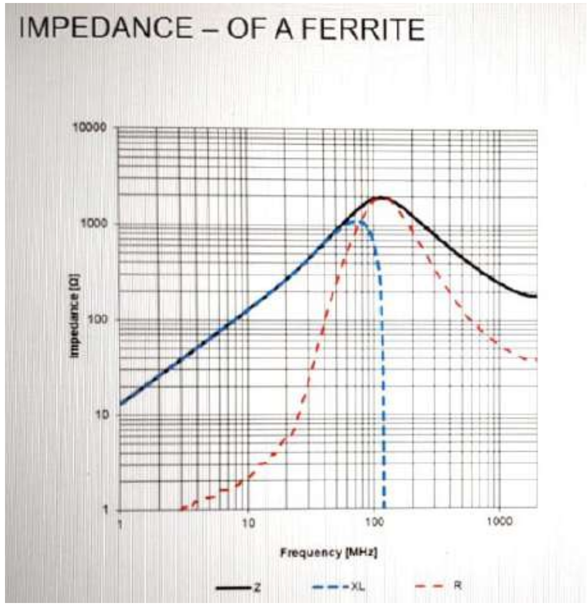
→ **Lowpass**





MAIN PARAMETERS

- **Cutoff frequency (f_c)**
  - Frequency at which we arrive -3db (per reactive part).
  - From this frequency the attenuation starts.
  - Resistance = Reactance/Imaginary (Z): best parameter setting to filter at the intended cutoff frequency.
- **Attenuation (A)**
  - Depending on frequency.
  - 20db/dec for each reactive part.
- **Rule of Thumb**
  - The cutoff frequency should be at least one decade **before** the noise frequency starts.



QUESTION #1

Capacitors can be used to filter what mode(s) of noise?

a) Differential mode. ✓

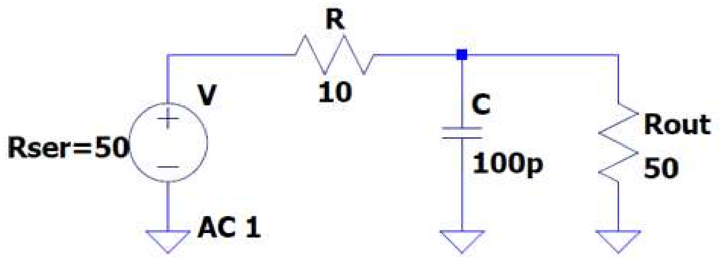
b) Standby mode.

c) Transmission mode.

d) Common mode. ✓

EXAMPLE – IDEAL LOW-PASS FILTER 1ST ORDER

- **Ideal filter**
  - No parasitics



Cutoff frequency :

$$f_c = \frac{1}{2\pi RC}$$

$$= \frac{1}{2 * \pi * ((50+10) * 50/(50+10+50)) * 100 * 10^{-12}}$$
$$= 58.36 \text{ MHz}$$

Cutoff frequency

@ 3dB attenuation

58,36 MHz

Attenuation per decade

20dB/dec

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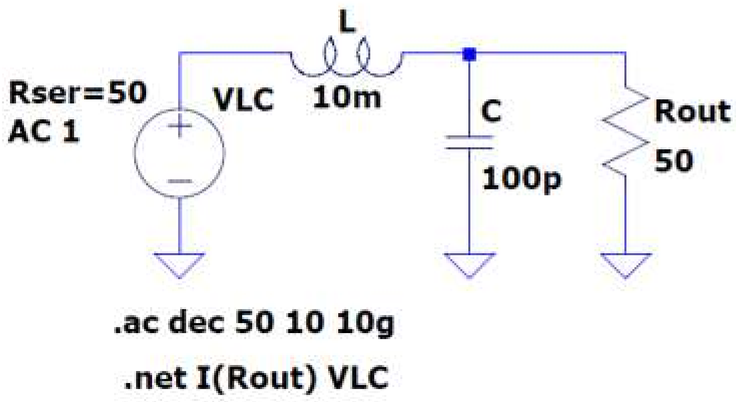
EXAMPLE – IDEAL LOW-PASS FILTER 2ND ORDER

- **Ideal filter**
  - No parasitics



Cutoff frequency

@ 6dB attenuation

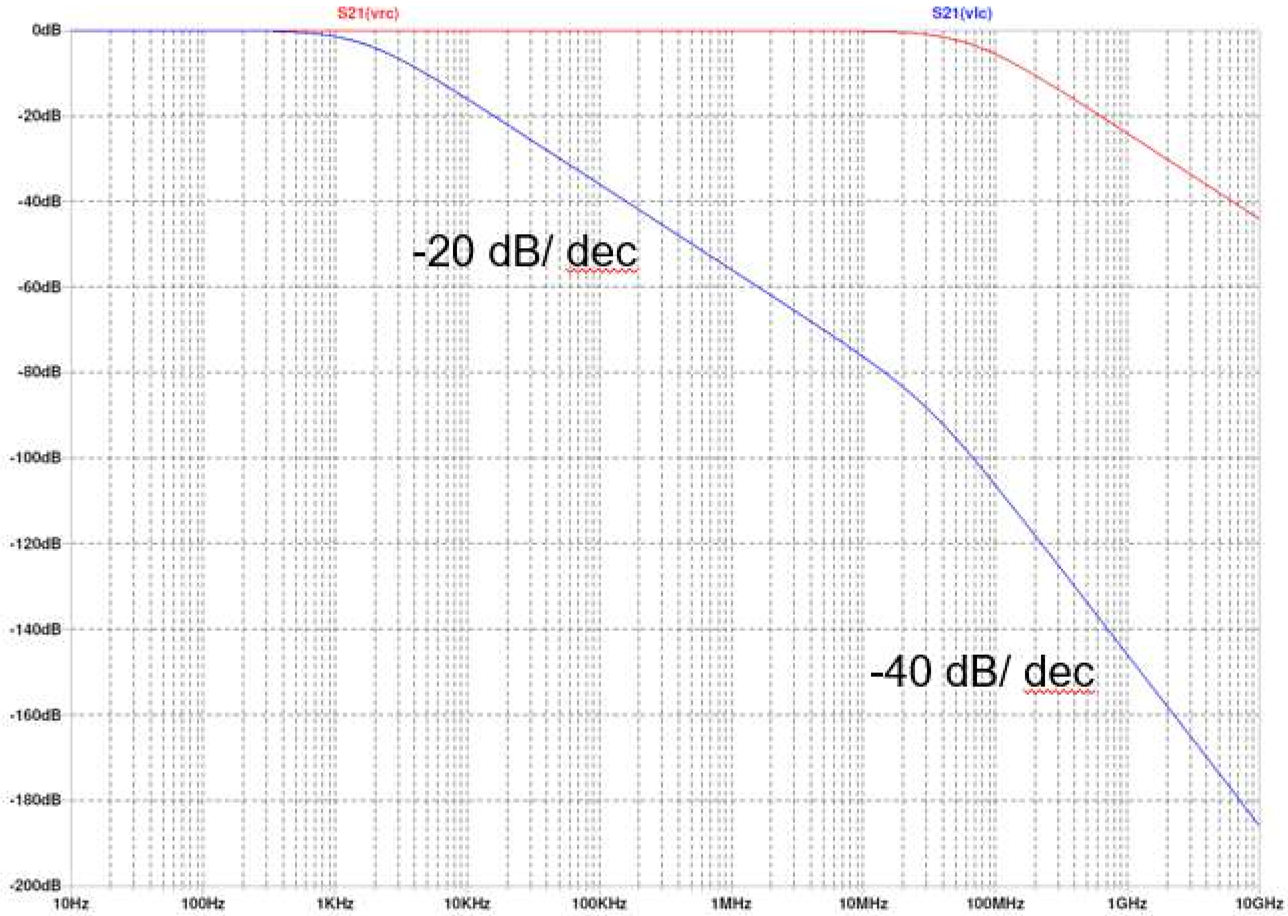
≈ 2,7 kHz

$$X_C = X_L$$

$$f_c = \frac{1}{2\pi\sqrt{LC}}$$

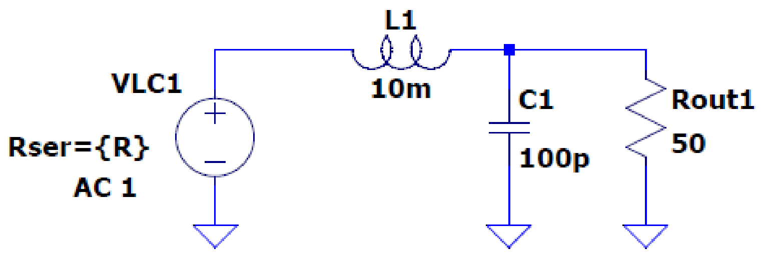
Attenuation per decade

40dB/dec



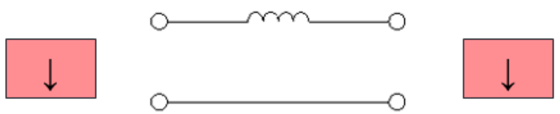
SOURCE IMPEDANCE

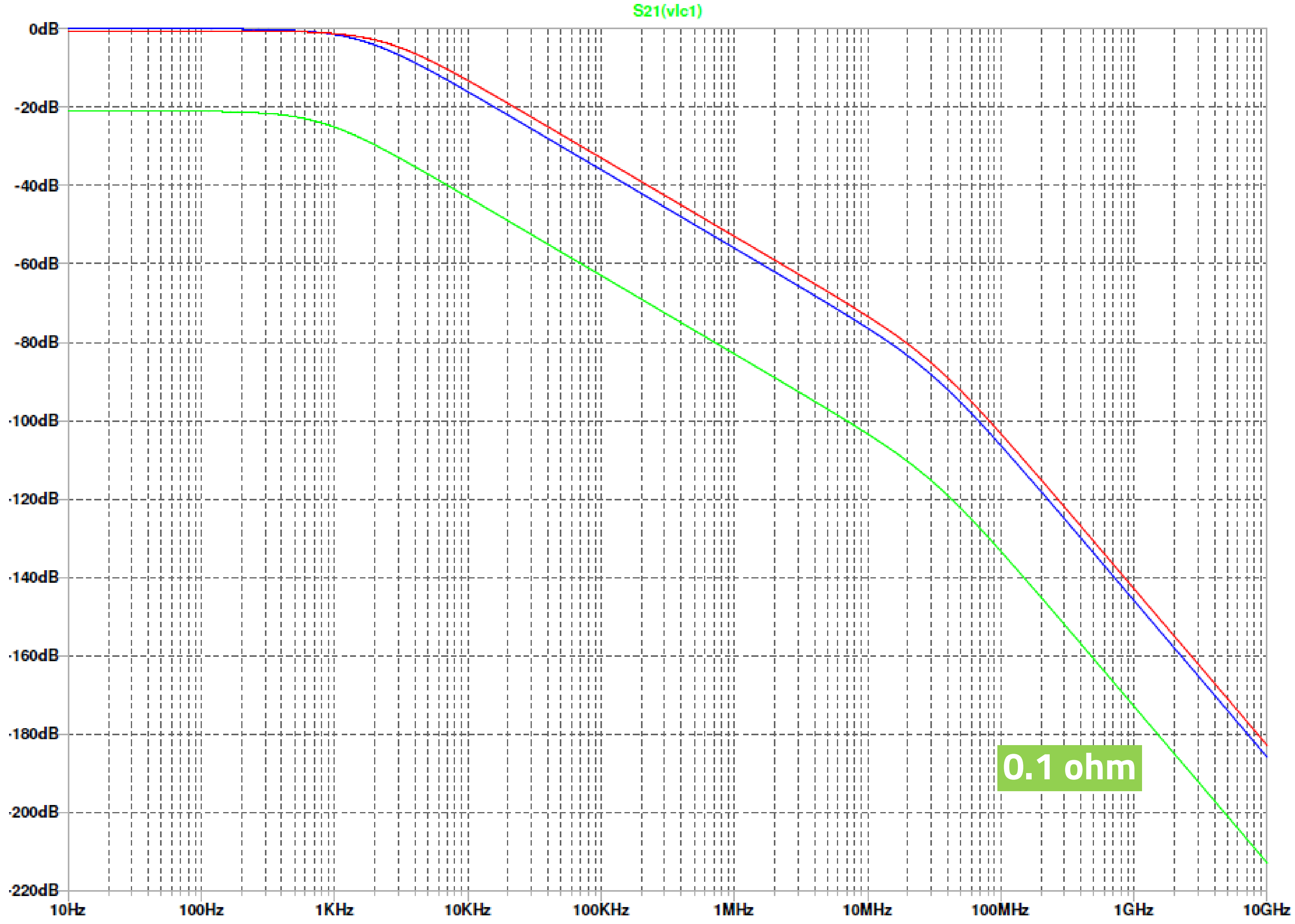
- **Simulation**



.net I(Rout1) VLC1

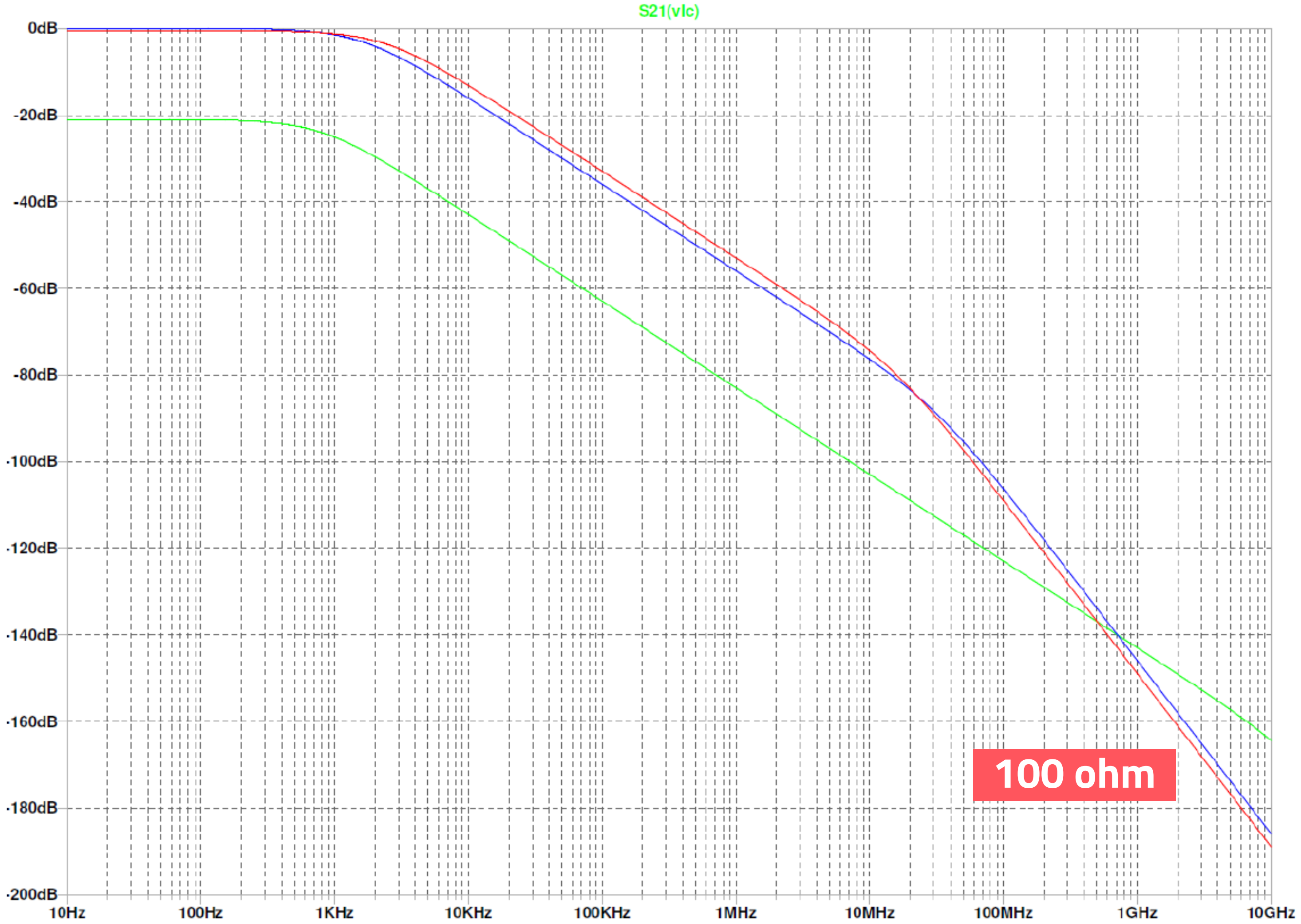
$$R_{input} = 0.1/50/100\ Ohm$$

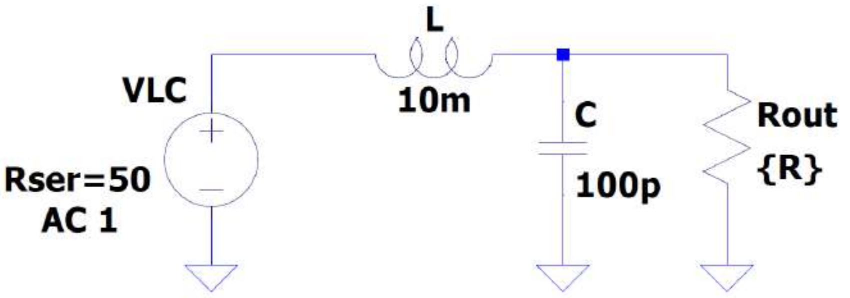




LOAD IMPEDANCE

- **Simulation**



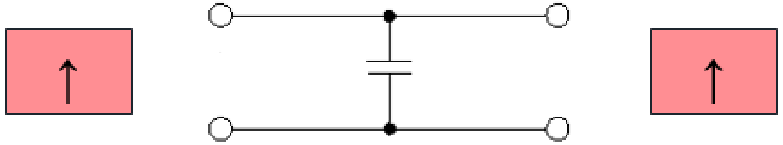


.step param R list 0.1 50 100

.ac dec 50 10 10g

.net I(Rout) VLC

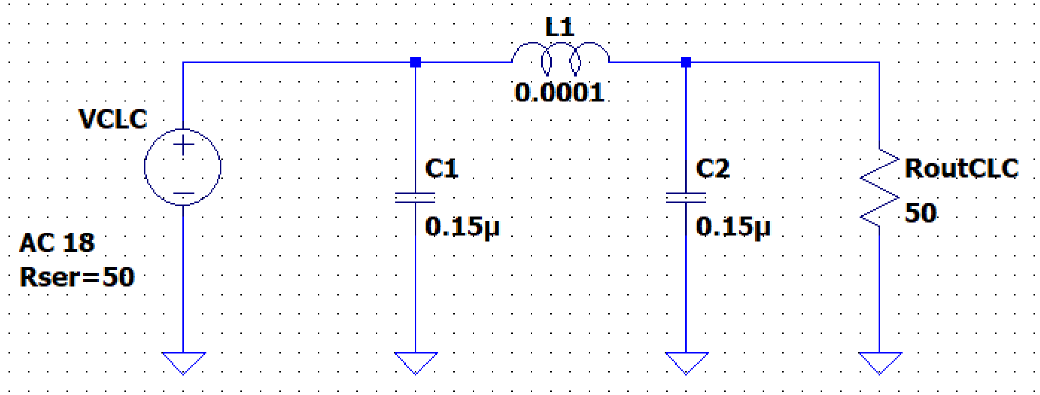
$$R_{output} = 0{,}1/50/100\ Ohm$$



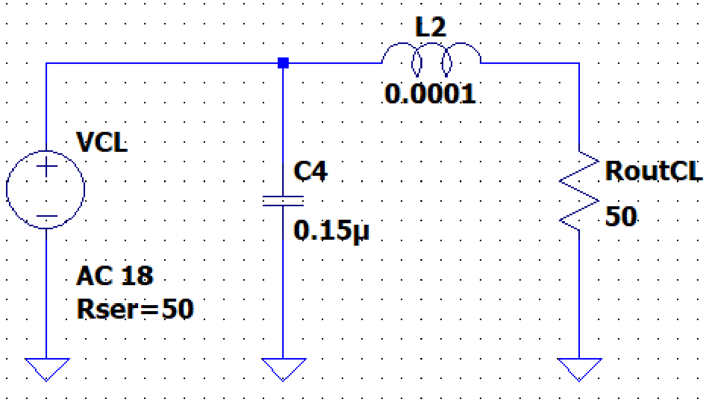
QUESTION #2

Which has the better attenuation? And how many order of filter?

a)



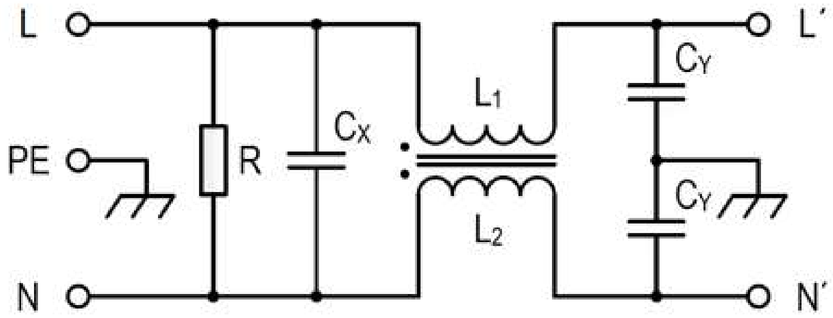
b)



✓ 3rd order = 3 reactive components

CONTENTS

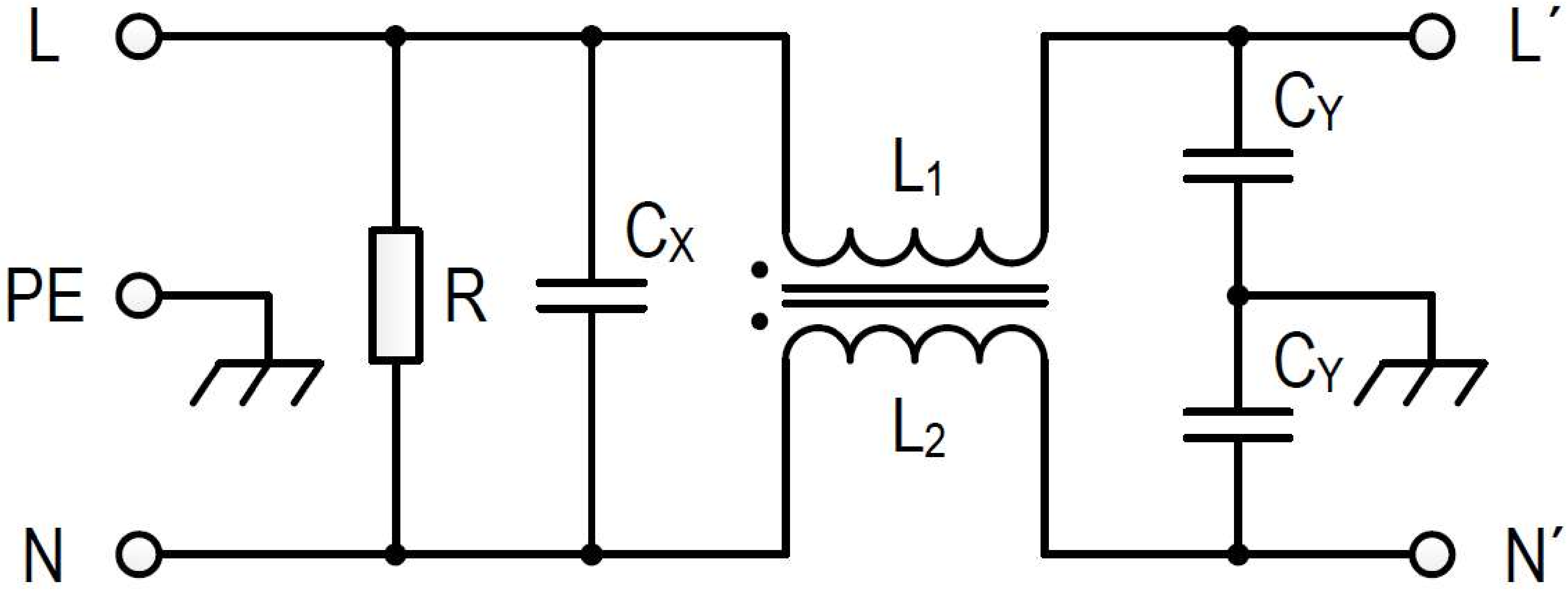
- Overview
- Filter basics
- **EMC filter components**
- WE-CLFS
  - Typical datasheet information
  - More than you expect
- REDEXPERT
- Design your EMC Filter kit
- Demo



EMC FILTER

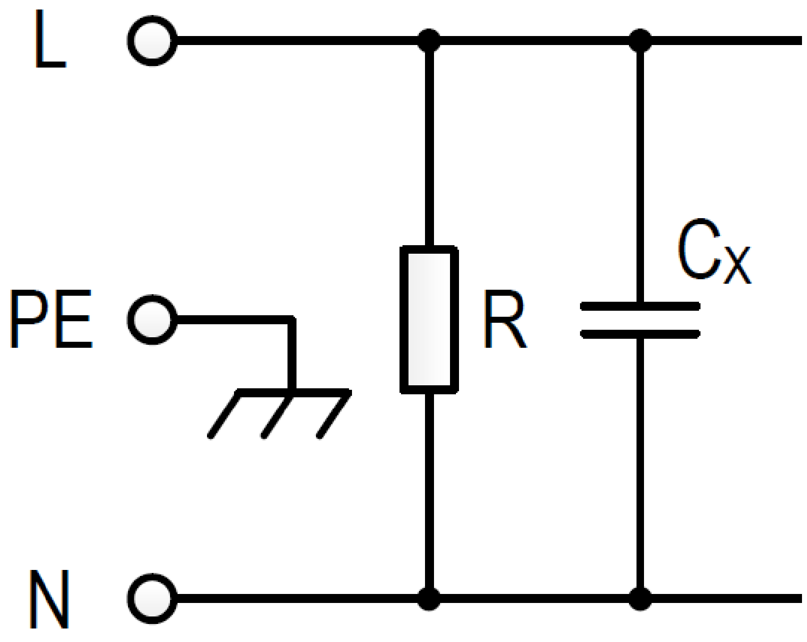
- **Topology**

combination of differential and common mode



DISCHARGE RESISTOR

- **Resistance Value Selection**



- R should be as high as possible -> Low Power consumption
- R should be as small as possible to discharge fastly

rule: $\tau = RC < 1$

??

DISCHARGE RESISTOR

- **Calculation**

- Example: Single-Stage Advanced PN: [810912020]

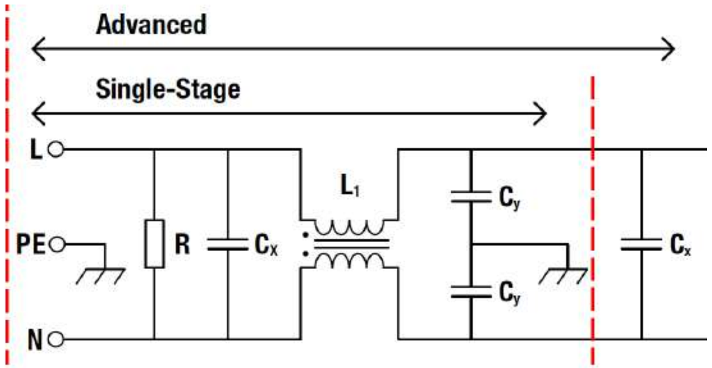
$$CGes = 2 \times 1\mu F * 1.1 + (5nF * 1.2)$$

$$CGes = 2{,}206\mu F$$

$$\tau\ (RC\ time\ constant) = RC_{ges} \quad \text{->}\ \tau=1$$

$$R = \frac{1}{Cges} = 453309\Omega\ \text{->}\ Maximum\ value$$

- Next possible value: 330k Ω*1.1 = 363k Ω



810912020:

Cx = 1µF +10% tolerance

Cy = 10nF + 20% tolerance

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Rated Voltage	V_R	250 V (AC), 50/60 Hz 250 V (DC)	250	V	max.
Rated Current	I_R	@ 40 °C/ ΔT< 60 K	20	A	max.
Leakage Current	I_{Leak}	250 V (AC)/ 50 Hz	0.785	mA	typ.
DC Resistance	R_{DC}	@ 20 °C	10	mΩ	max.
Inductance	L	10 kHz/ 0.1 mA	1	mH	+50%/-30%
X2-Capacitance	C_X	1 kHz/ 1 V	1	µF	±10%
Y2-Capacitance	C_Y	1 kHz/ 1 V	10	nF	±20%
Discharge Resistance	R	@ 20 °C	330	kΩ	±10%
Insulation Test Voltage L->PE	V_{T1}	50 Hz/ 2 s/ 15 mA	2000	V (AC)	max.
Insulation Test Voltage L->N	V_{T2}	2 s/ 10 mA	1075	V (DC)	max.

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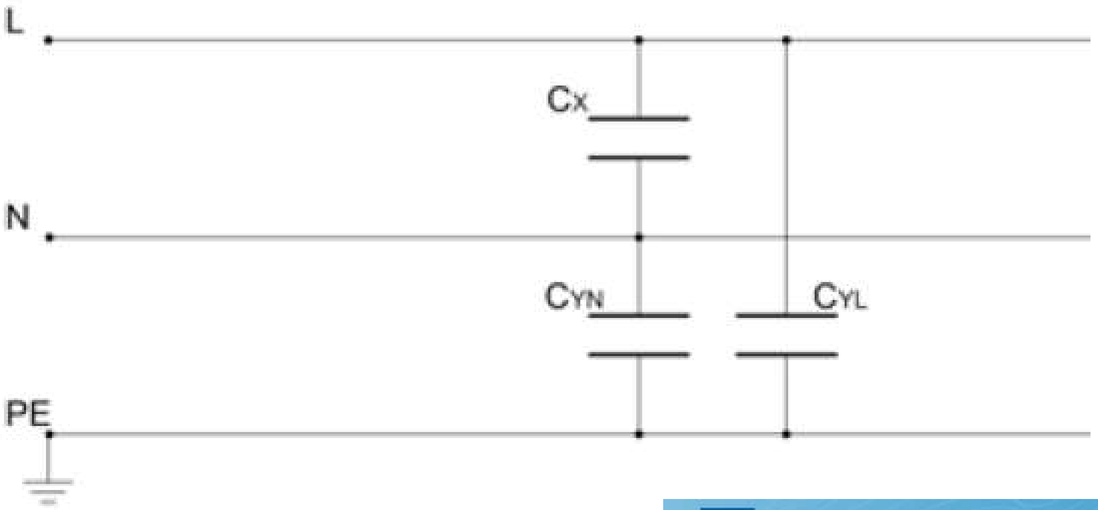
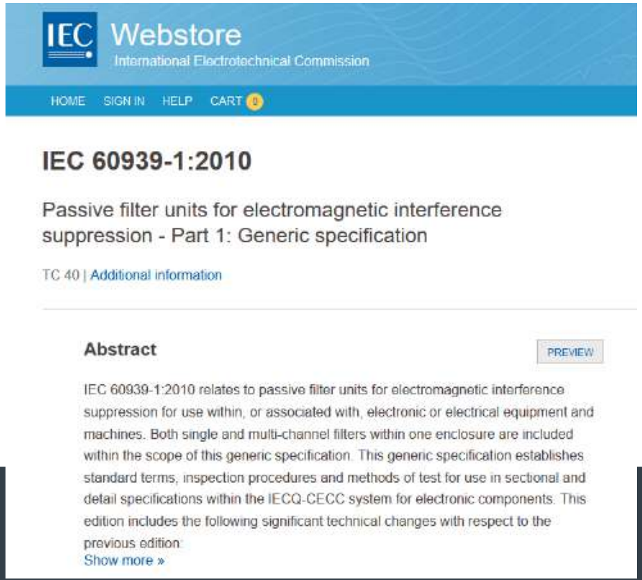
LEAKAGE CURRENT

- Regular Operation



$$I_{LEAK} = 2\pi * f * C_{YL} * V$$

according to 60939-1



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International Electrotechnical Commission
HOME SIGN IN HELP CART

IEC 60939-1:2010

Passive filter units for electromagnetic interference suppression - Part 1: Generic specification

TC 40 | Additional information

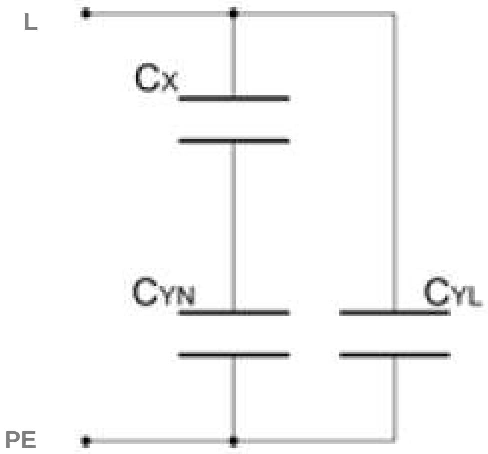
Abstract

PREVIEW

IEC 60939-1:2010 relates to passive filter units for electromagnetic interference suppression for use within, or associated with, electronic or electrical equipment and machines. Both single and multi-channel filters within one enclosure are included within the scope of this generic specification. This generic specification establishes standard terms, inspection procedures and methods of test for use in sectional and detail specifications within the IECQ-CECC system for electronic components. This edition includes the following significant technical changes with respect to the previous edition:

Show more »

- Neutral Line Interruption (worst case)

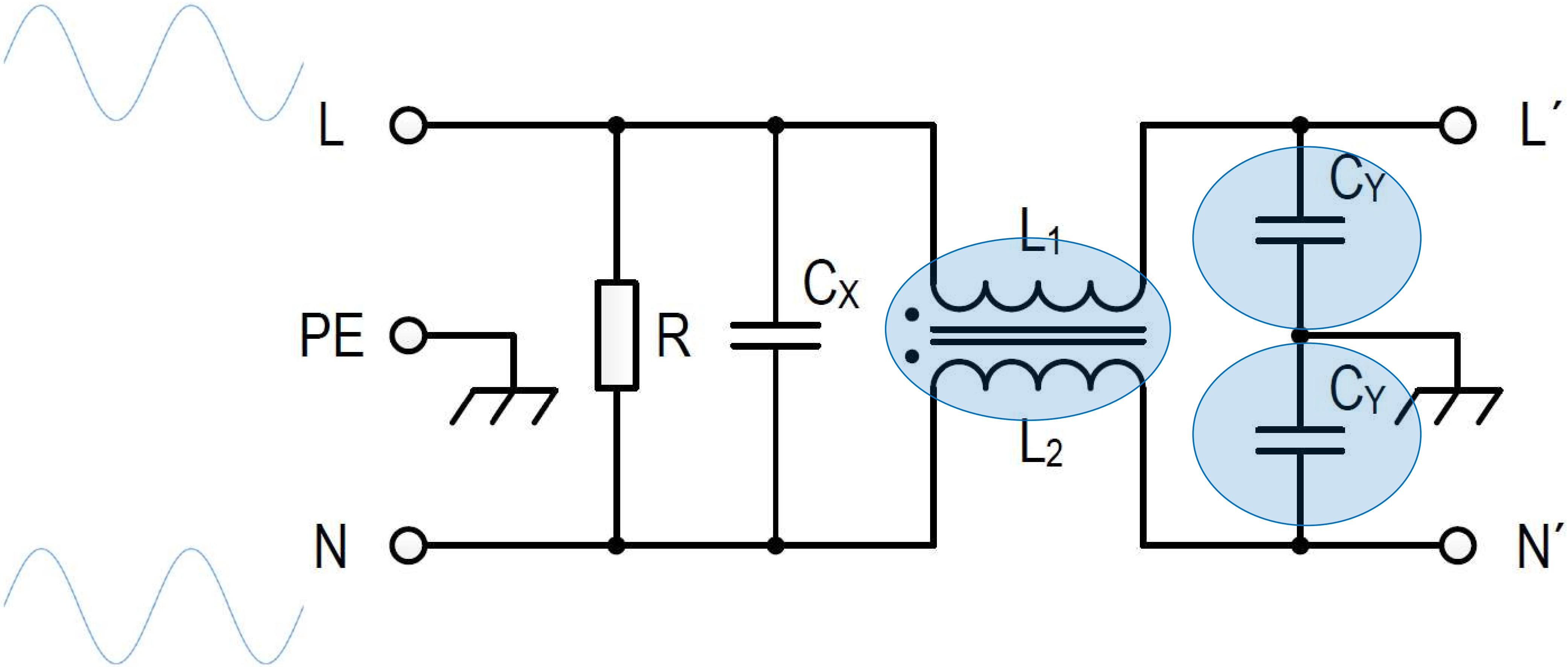


$$I_{LEAK} = 2\pi * f * Cges * V$$

$$I_{LEAK} < 3.5 \text{ mA}$$

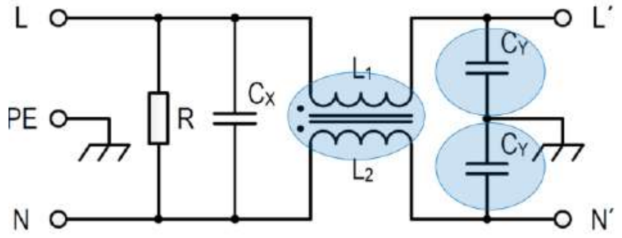
$$C_{ges} = C_{YL} + \frac{1}{\frac{1}{C_{YN}} + \frac{1}{C_X}}$$

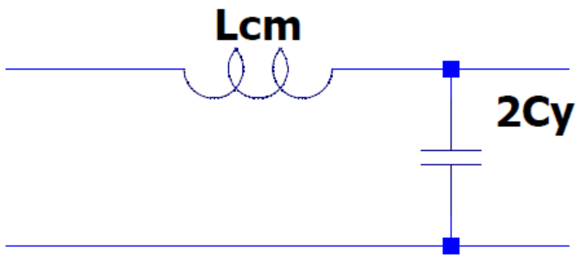
COMMON MODE

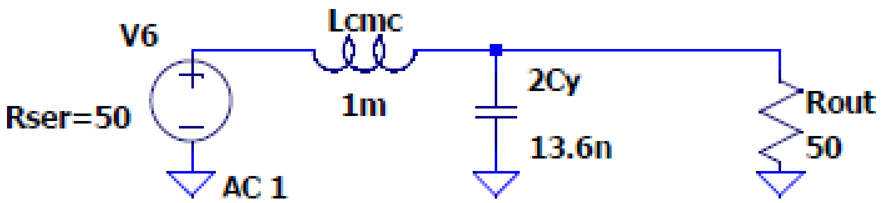


COMMON MODE

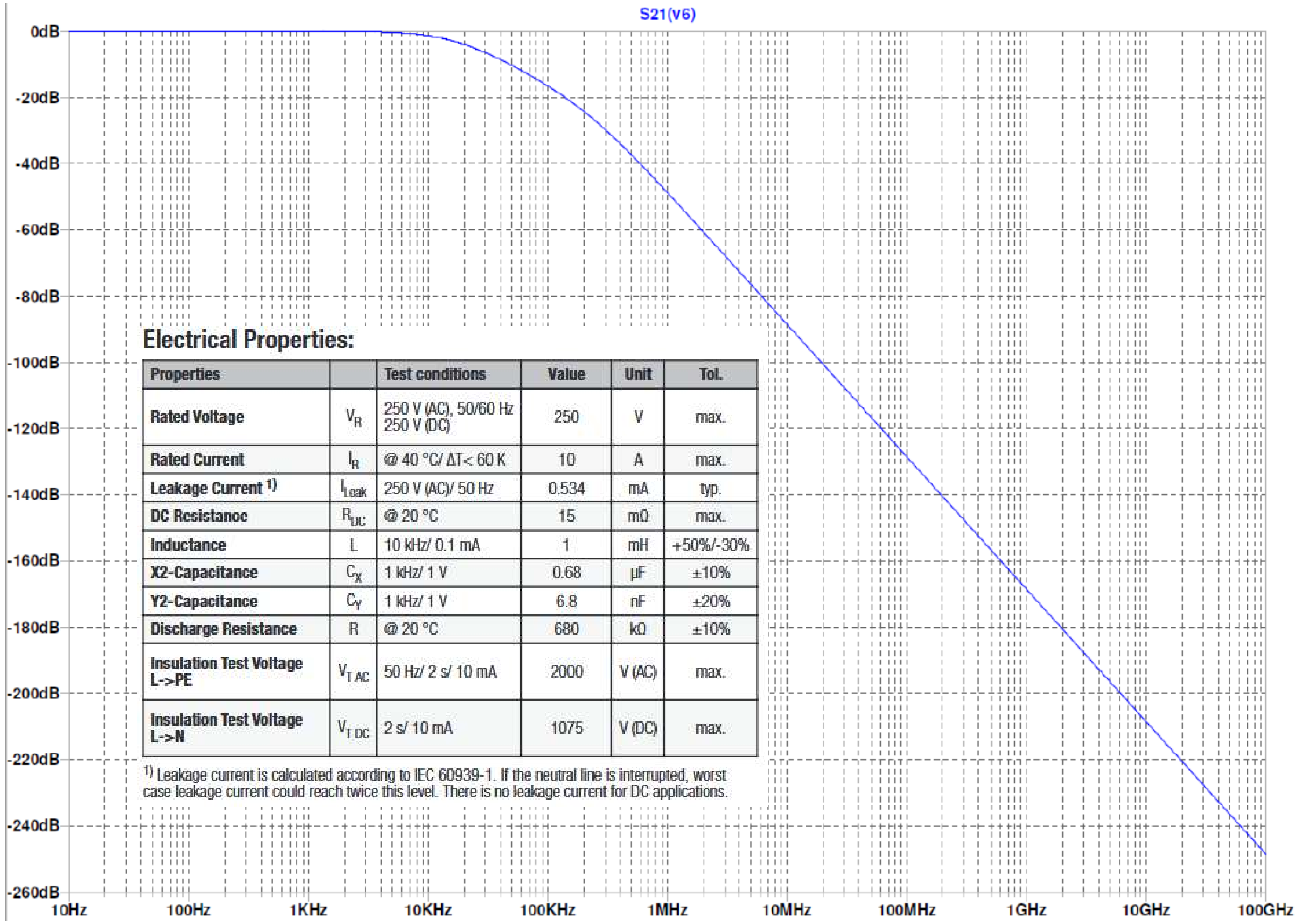
- Example. 810911010







.net I(Rout) V6

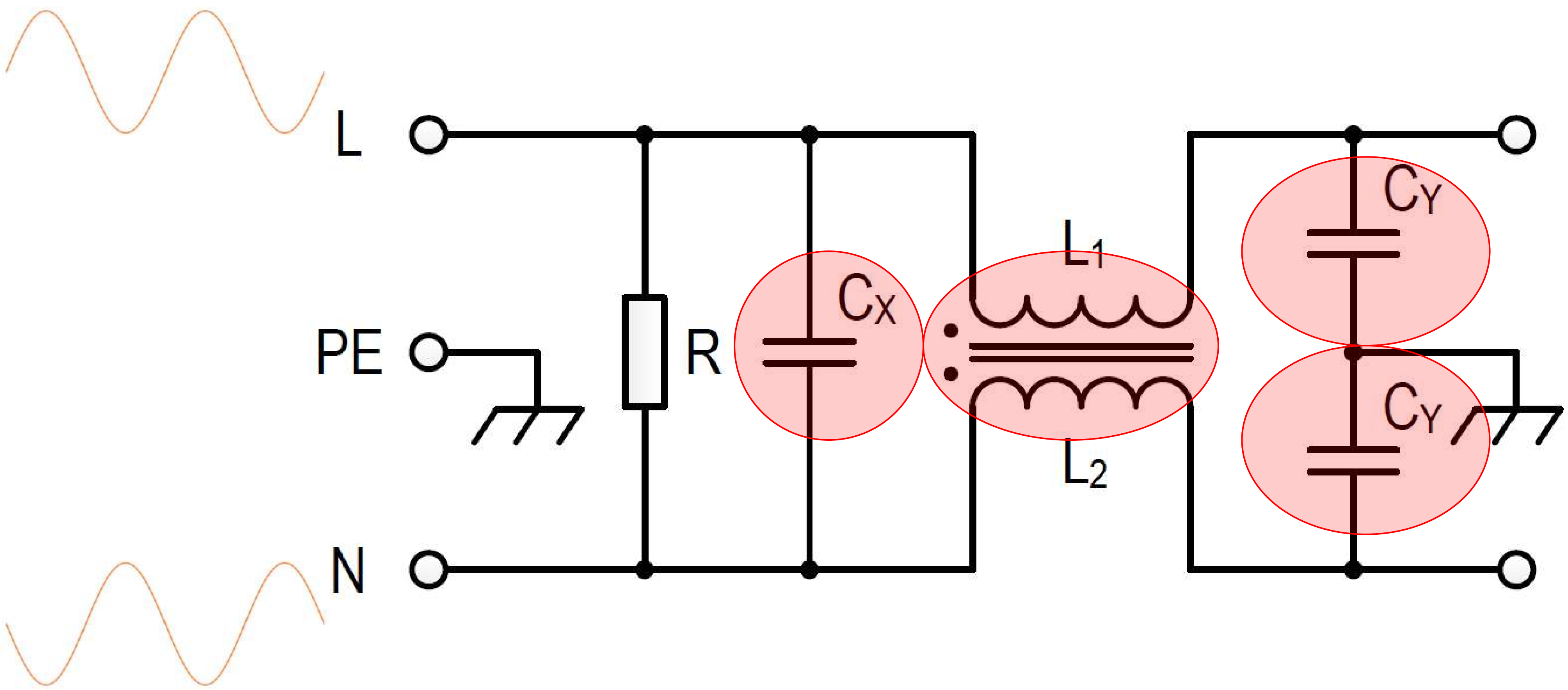


Electrical Properties:

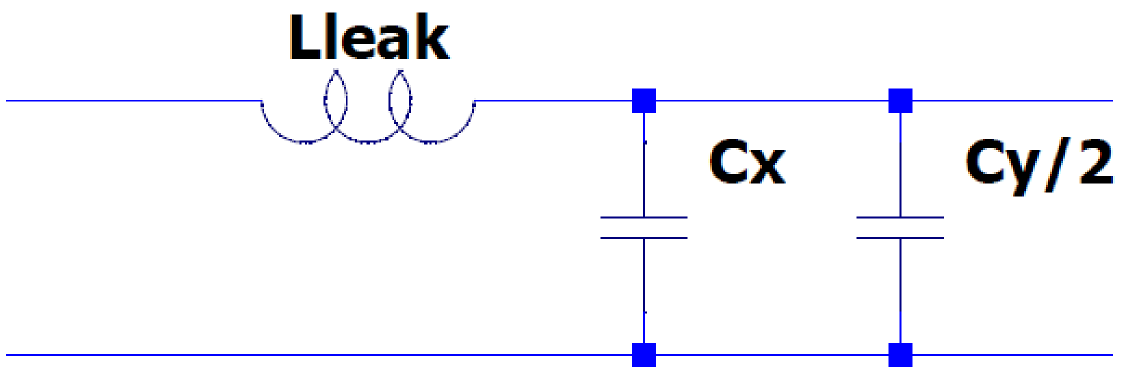
Properties		Test conditions	Value	Unit	Tol.
Rated Voltage	V_R	250 V (AC), 50/60 Hz 250 V (DC)	250	V	max.
Rated Current	I_R	@ 40 °C/ ΔT< 60 K	10	A	max.
Leakage Current [1]	I_{Leak}	250 V (AC)/ 50 Hz	0.534	mA	typ.
DC Resistance	R_{DC}	@ 20 °C	15	mΩ	max.
Inductance	L	10 kHz/ 0.1 mA	1	mH	+50%/-30%
X2-Capacitance	C_X	1 kHz/ 1 V	0.68	µF	±10%
Y2-Capacitance	C_Y	1 kHz/ 1 V	6.8	nF	±20%
Discharge Resistance	R	@ 20 °C	680	kΩ	±10%
Insulation Test Voltage L->PE	$V_{T\ AC}$	50 Hz/ 2 s/ 10 mA	2000	V (AC)	max.
Insulation Test Voltage L->N	$V_{T\ DC}$	2 s/ 10 mA	1075	V (DC)	max.

[1] Leakage current is calculated according to IEC 60939-1. If the neutral line is interrupted, worst case leakage current could reach twice this level. There is no leakage current for DC applications.

DIFFERENTIAL MODE



DIFFERENTIAL MODE



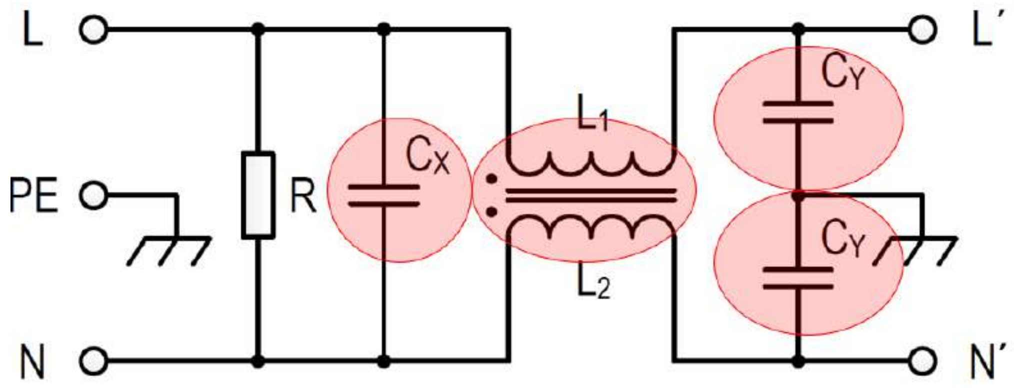
Lleak is the leakage current inductance

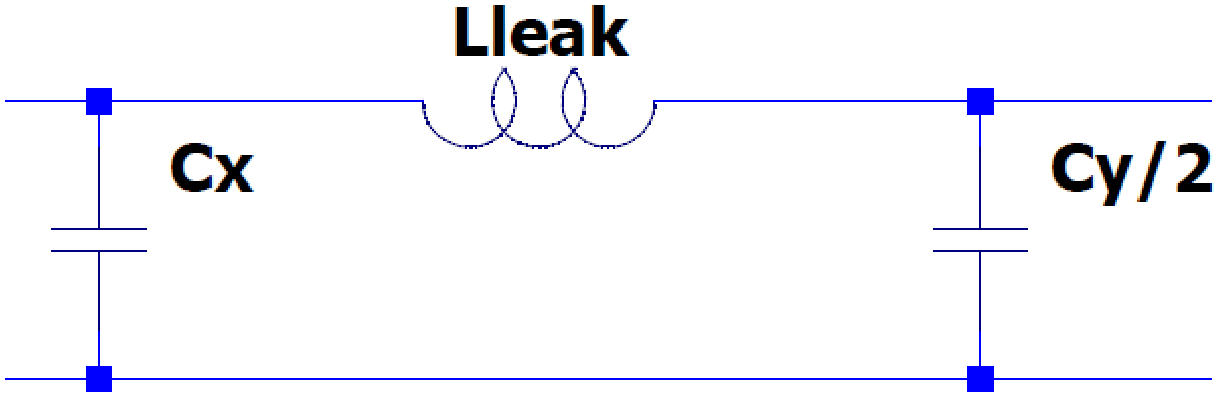
Lleak 1% of L CMC

Why here Cy/2?

Whats the difference?

What happen here with the two caps?

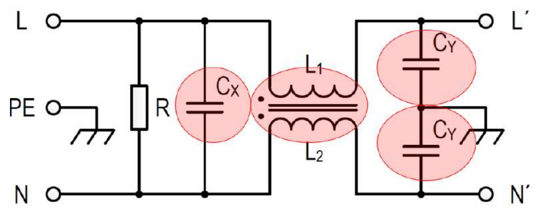


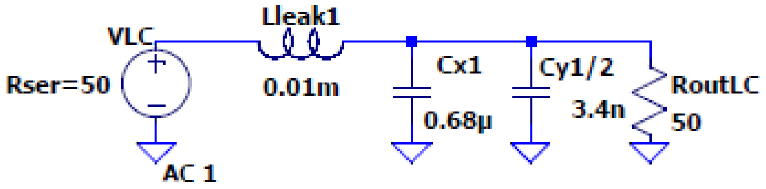


DIFFERENTIAL MODE EXAMPLE

- Example: 810911010

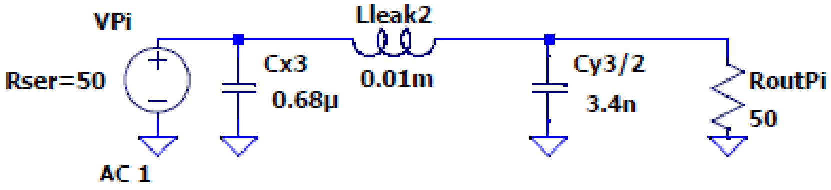
Inductance	L	10 kHz/ 0.1 mA	1	mH	+50%/-30%
X2-Capacitance	C_X	1 kHz/ 1 V	0.68	µF	±10%
Y2-Capacitance	C_Y	1 kHz/ 1 V	6.8	nF	±20%



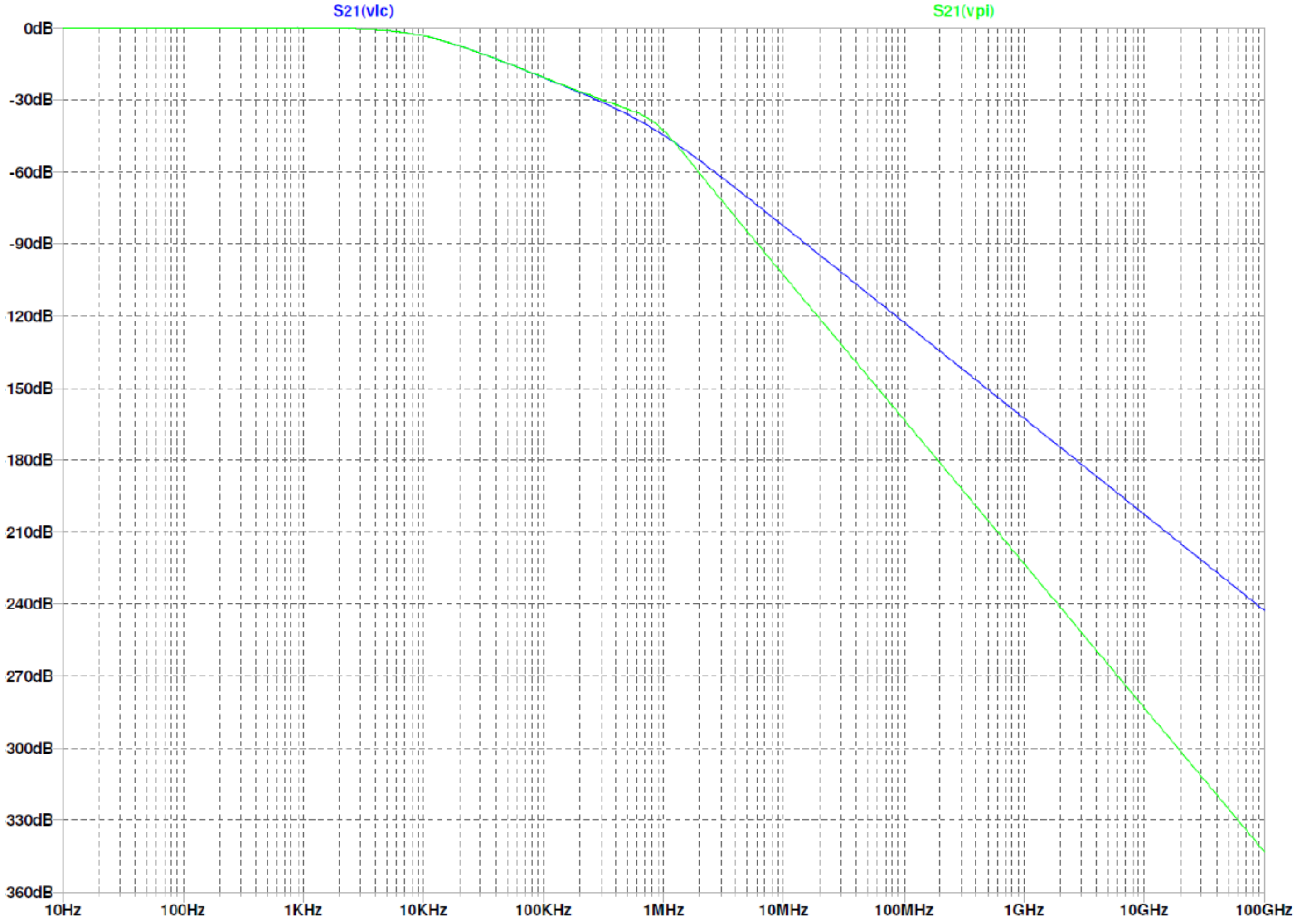


.ac dec 50 10 100g

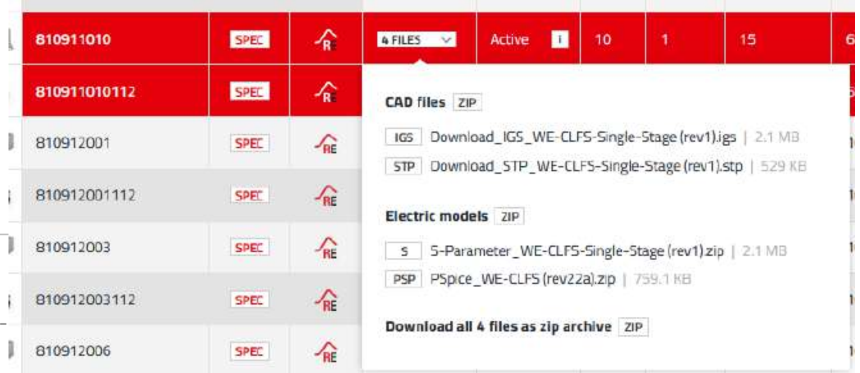
.net I(RoutLC) VLC

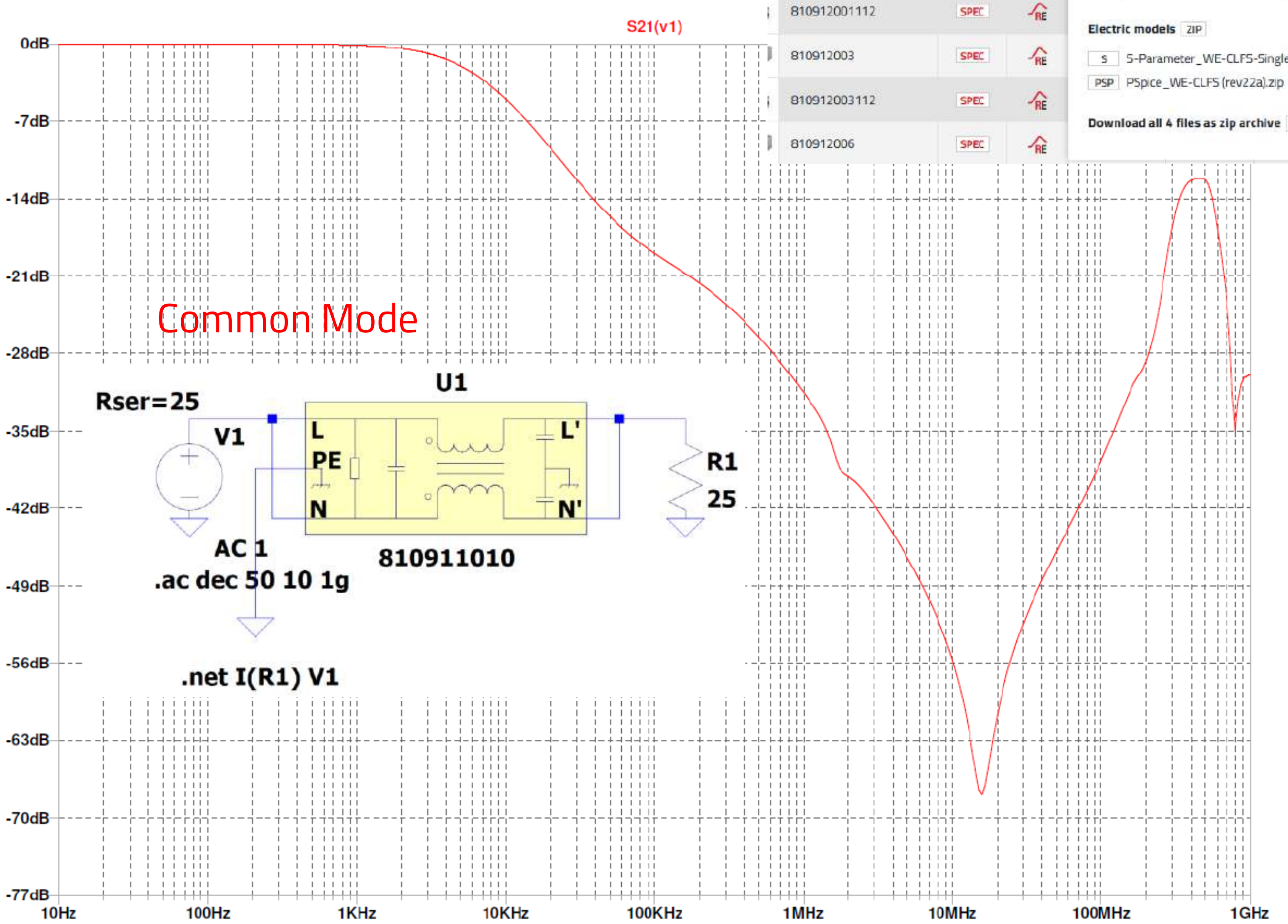


.net I(RoutPi) VPi



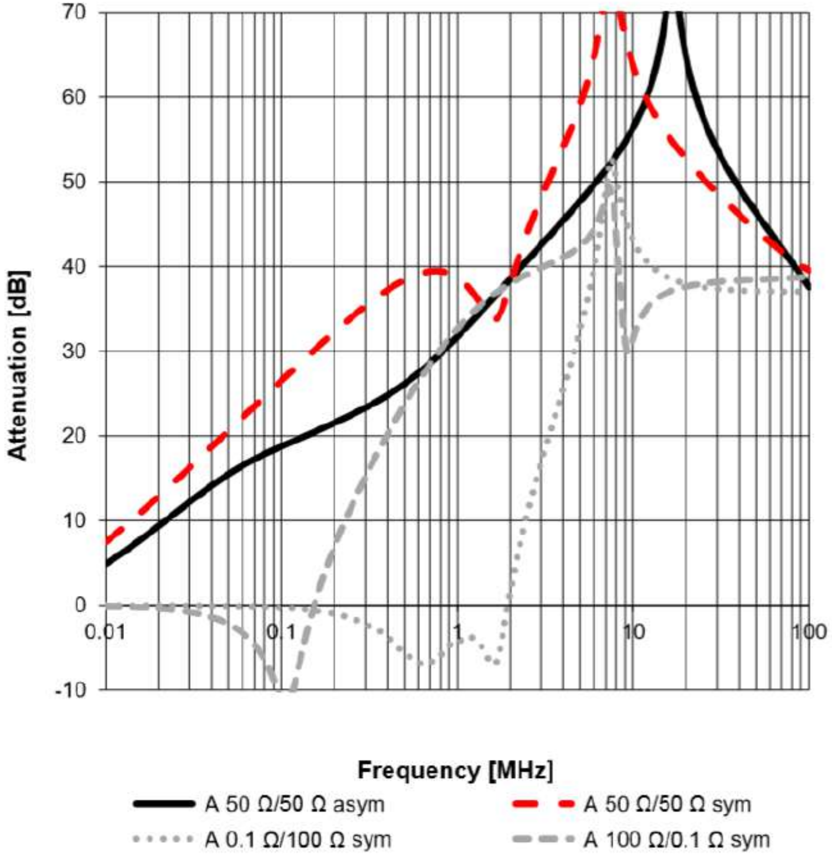
EXAMPLE: 810911010





810911010 Datasheet

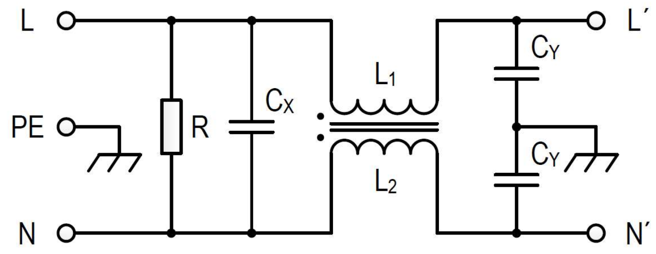
- Actual measurements

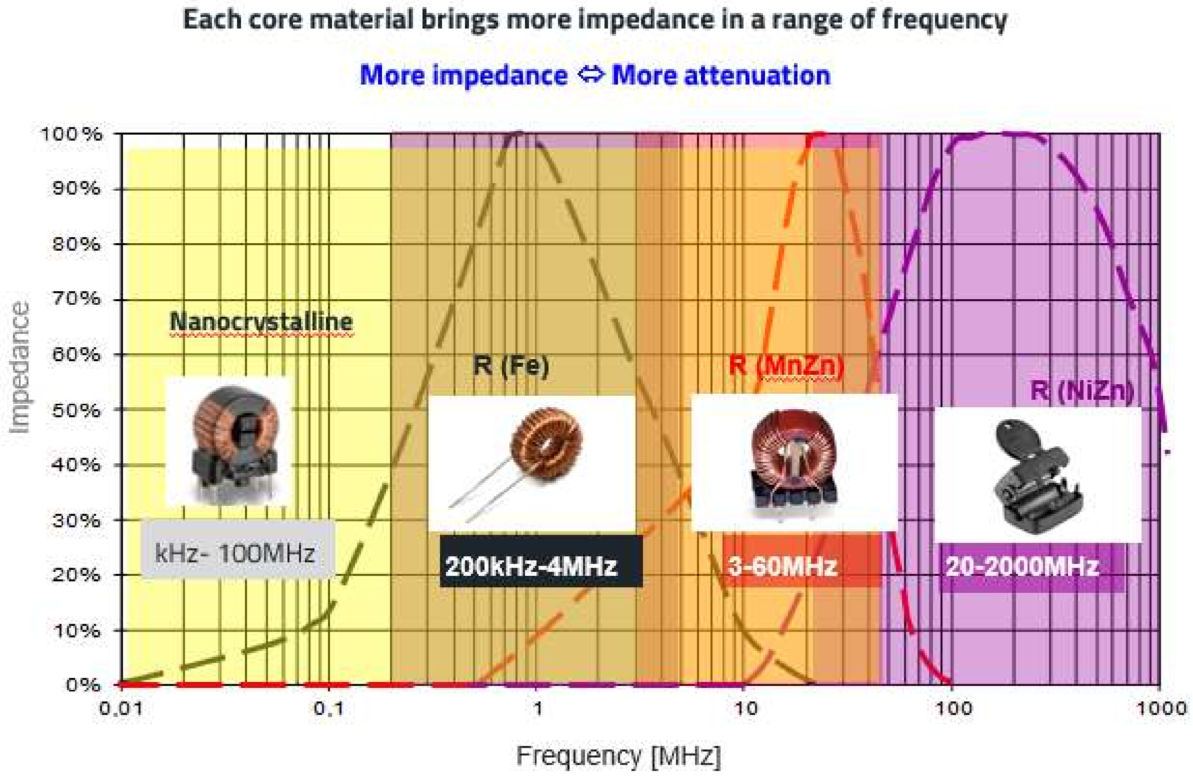


REDEXPERT®

HOW TO CREATE A GOOD FILTER?

- Common or differential mode noise?
- Frequency area of the noise
  - Choose a CMC with the right core material
  - Cutoff frequency one decade before the noise
- What attenuation do we need?
  - Choose the "right" CMC
  - Number of reactive parts
- Source and load impedance
  - In datasheet we show 50/50 ohm for reference.
- Special requirements?
  - Medical devices

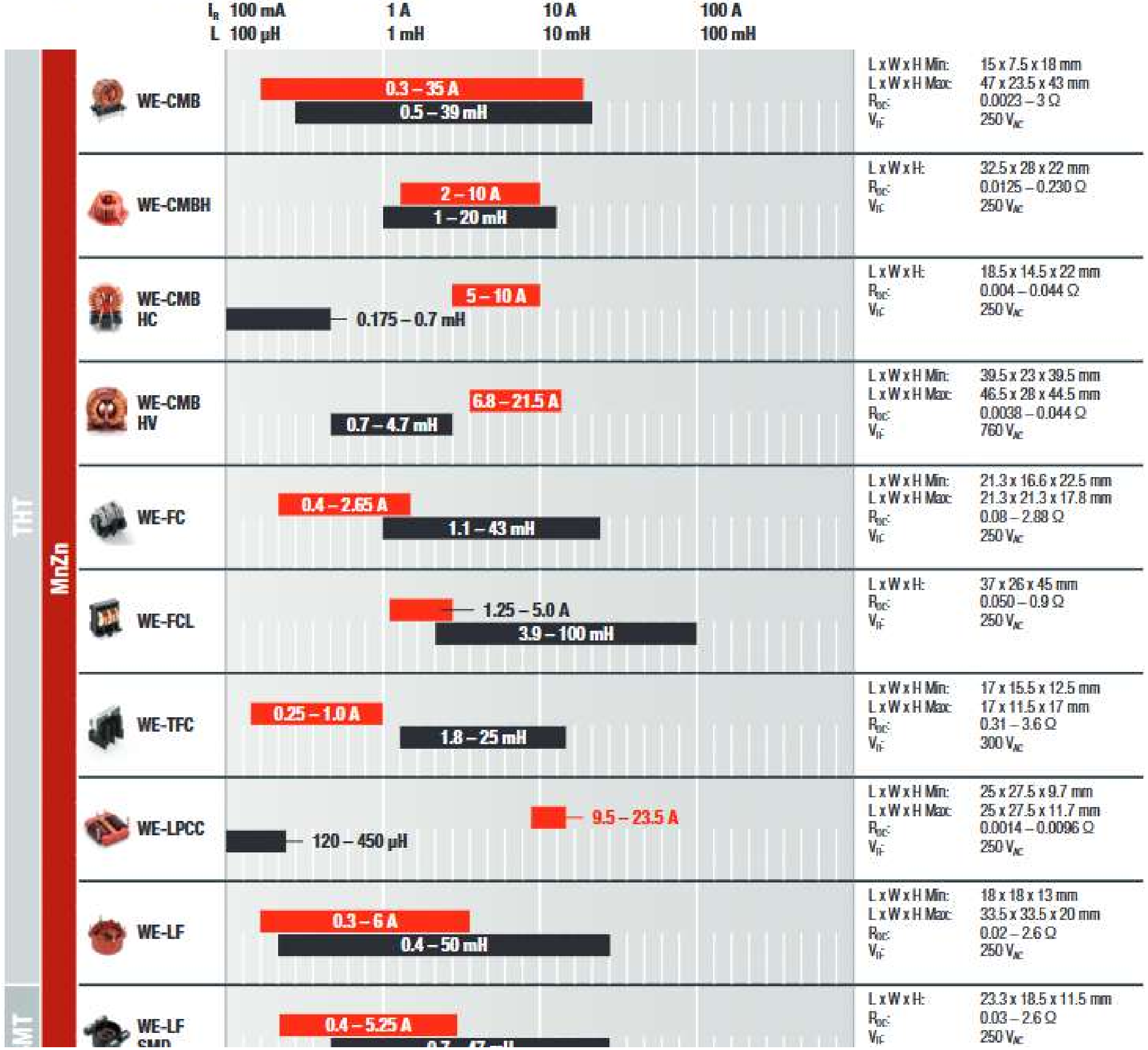




CORE MATERIAL AND FREQUENCY

Common Mode Chokes for Mains Power Lines

Single Phase Common Mode Chokes (2 Windings)



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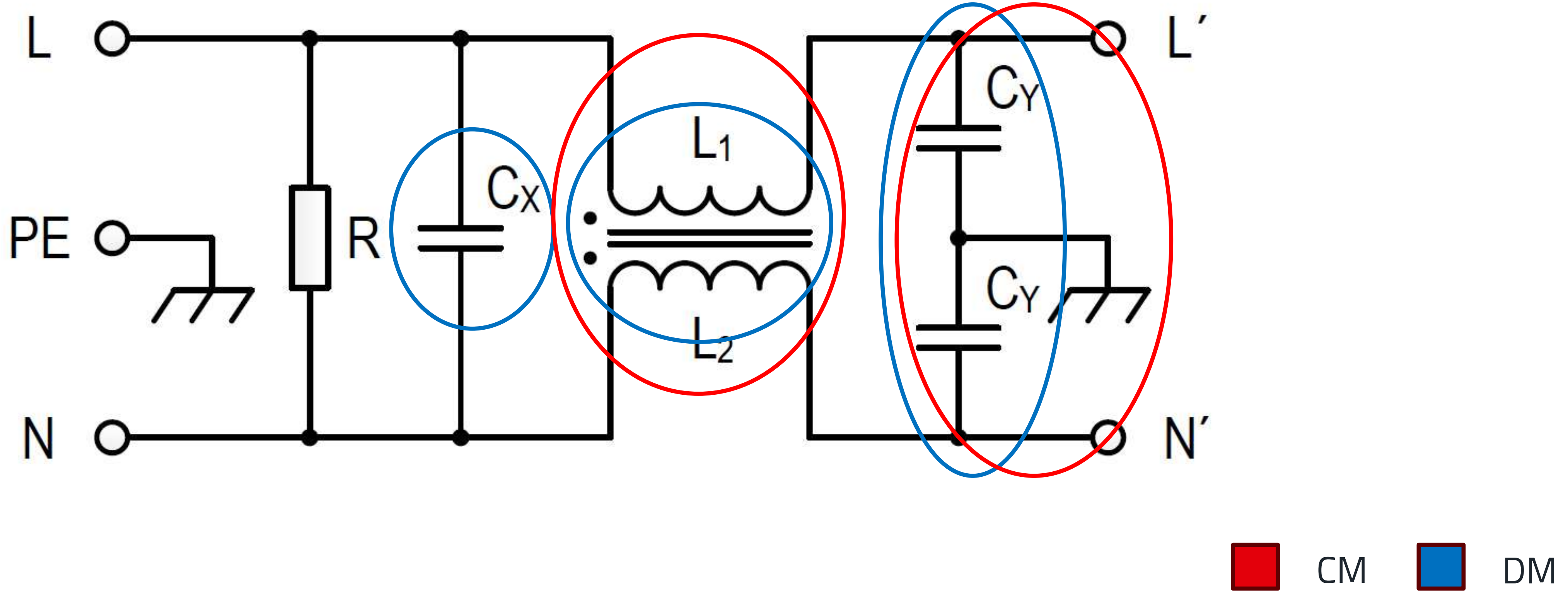
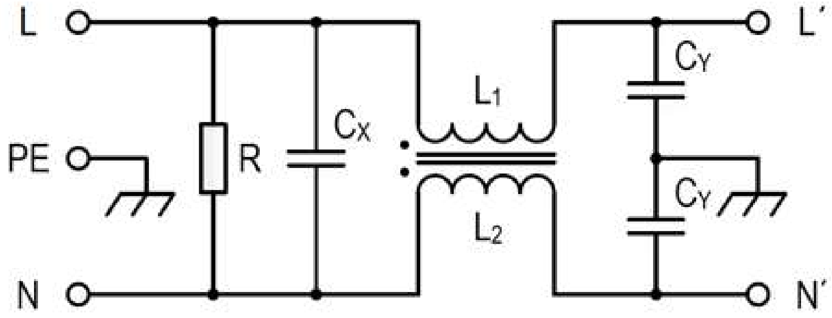
QUESTION #3

Which filters are for common-mode noise and differential mode noise?



CONTENTS

- Overview
- Filter basics
- EMC filter components
- **WE-CLFS**
  - Typical datasheet information
  - More than you expect
- REDEXPERT
- Design your EMC Filter kit
- Demo

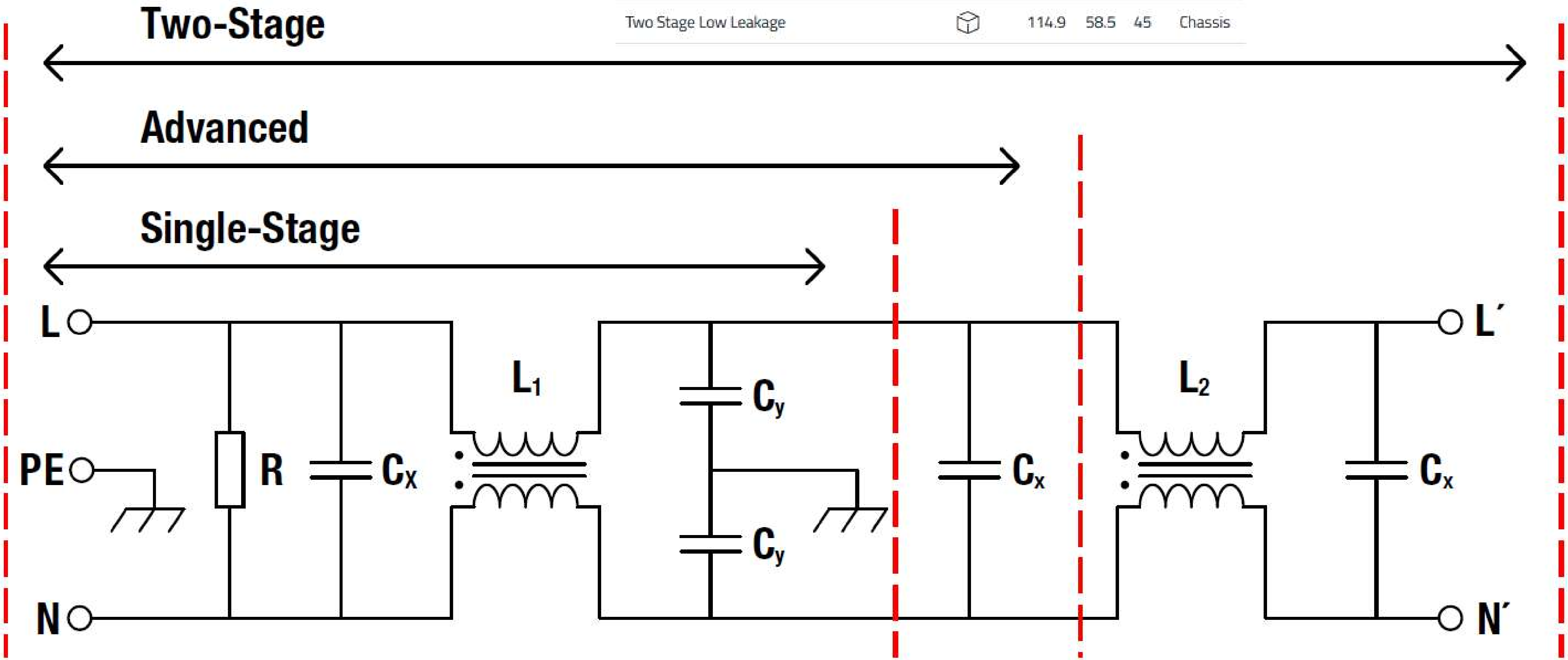


WE-CLFS SCHEMATICS

Size	Dimensions	L (mm)	W (mm)	H (mm)	Mount
Single-Stage		64	35	29	Chassis
Single Stage Low Leakage		64	35	29	Chassis
Single-Stage-Advanced		75	51.8	29	Chassis
Single Stage Advanced Low Leakage		75	51.8	29	Chassis
Two-Stage		114.9	58.5	45	Chassis
Two Stage Low Leakage		114.9	58.5	45	Chassis

Low Leakage Version

- Without Y-capacitors, for a leakage current of almost 0mA
- Suitable for industrial applications with strict requirements against leakage current or already exhausted leakage current values within the application.



WE-CLFS MATCH CODE SETUP

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

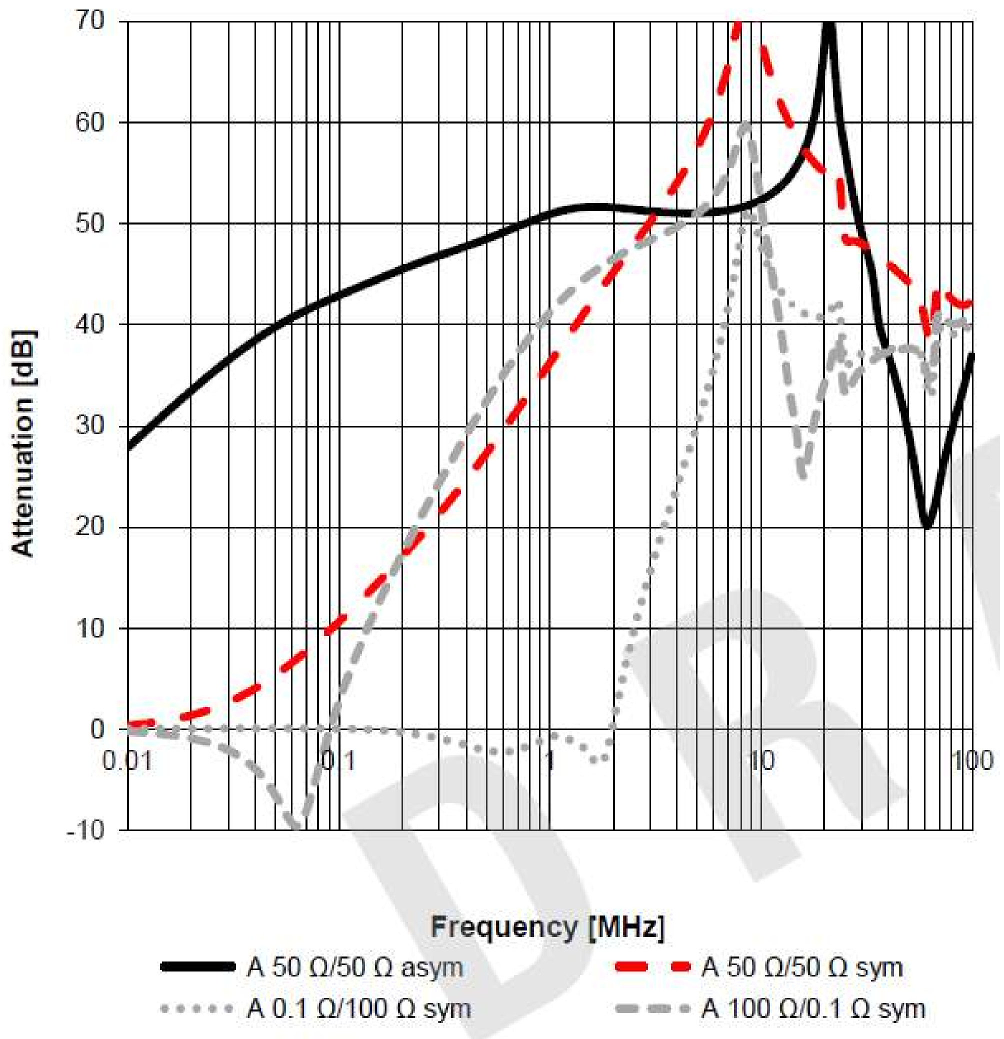
+ - + + -

We increase the rated current, **stable performance is required**, following effects appear:

- Inductance Drop: Using a thicker wire while using the same core -> Less turns possible
- CY increases to compensate decreasing inductance
- CX increases to compensate decreasing leakage inductance
- R decreases to keep $\tau = RC < 1$

WE-CLFS INSERTION LOSS

Typical Insertion Loss:



- Different system impedances possible (worst case)
- 0.1Ω/100Ω & 100Ω/0.1Ω also available up to 100 MHz
- Asymmetrical = Common mode
- Symmetrical = Differential mode

WE-CLFS RATED CURRENT

Rated Current	I_R	@ 40 °C/ ΔT< 60 K	1.5	A	max.

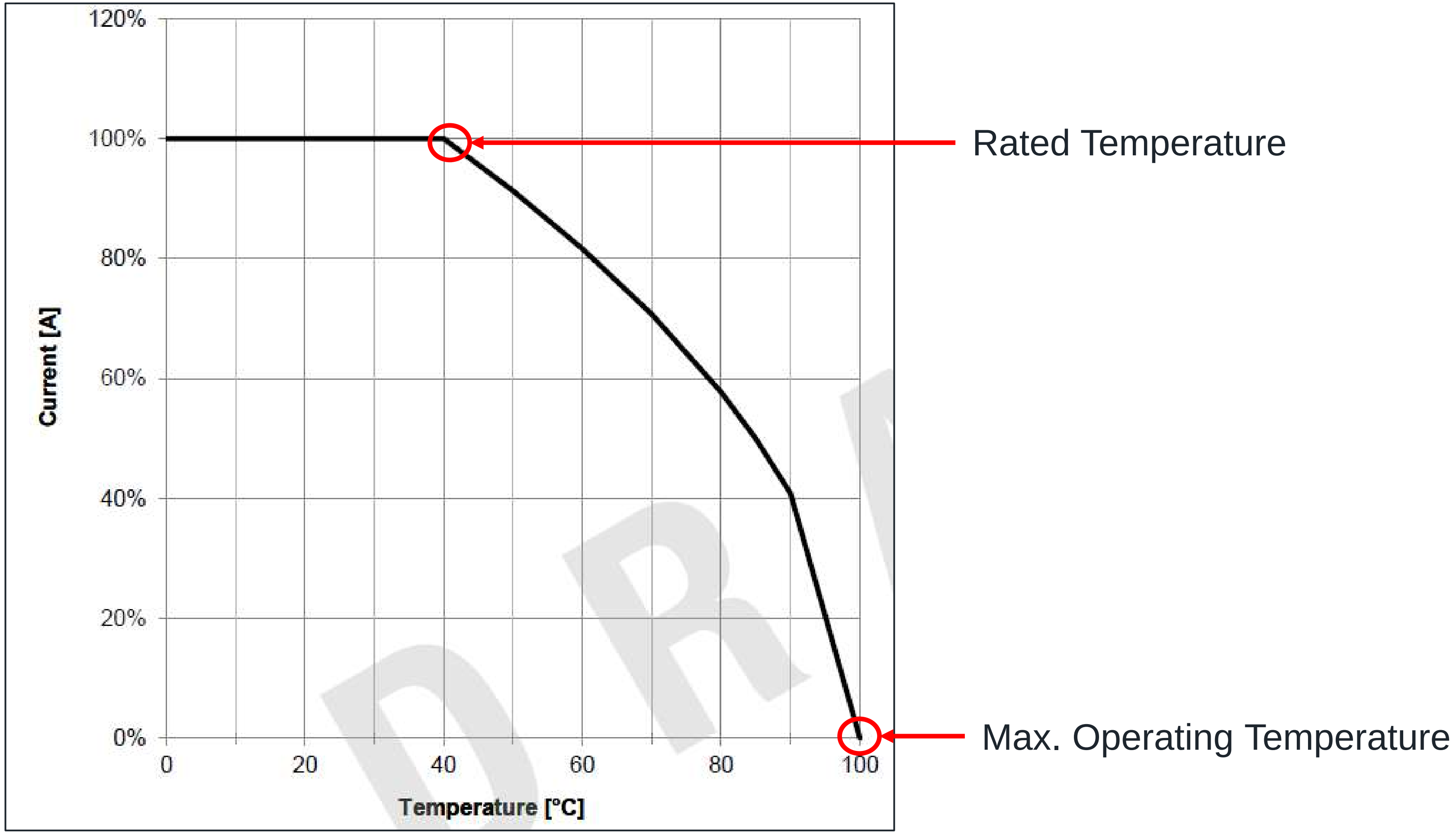
Rated Temperature

Max. Temperature Rise @ Rated Temperature

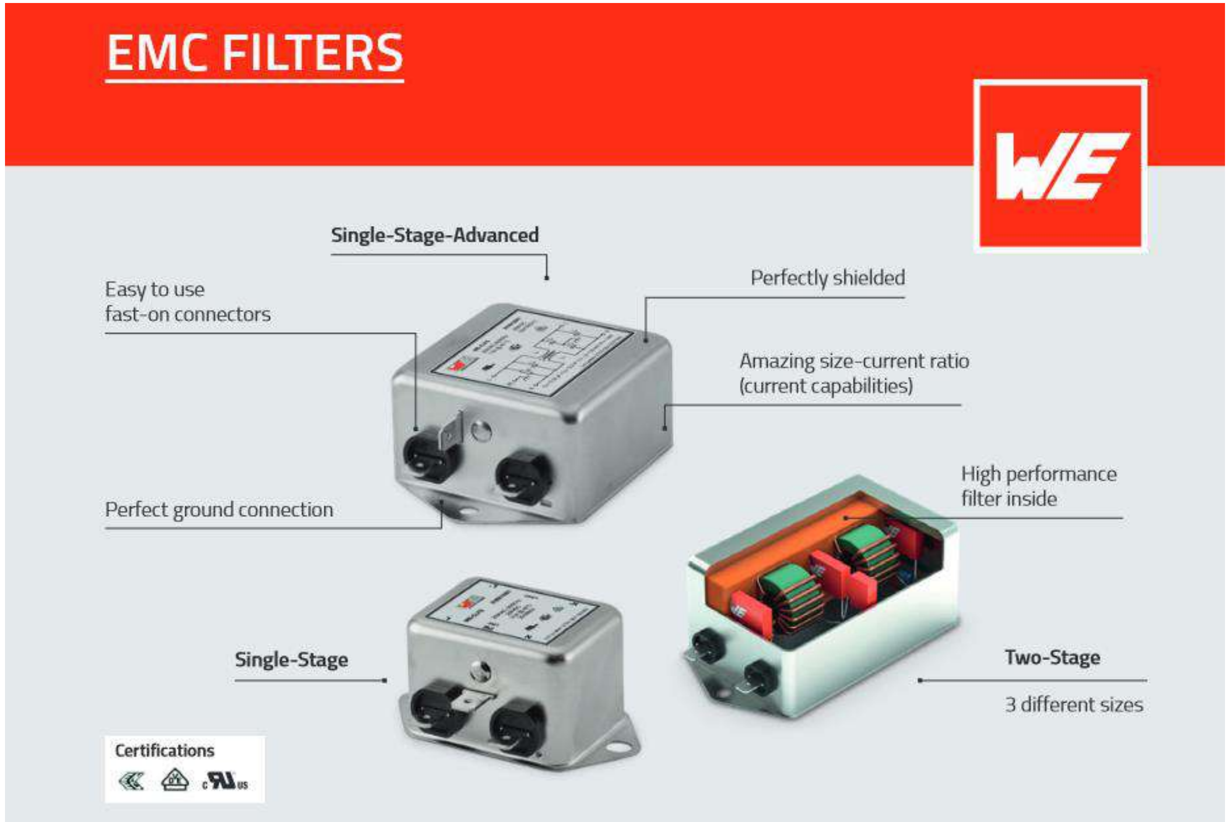
General Information:

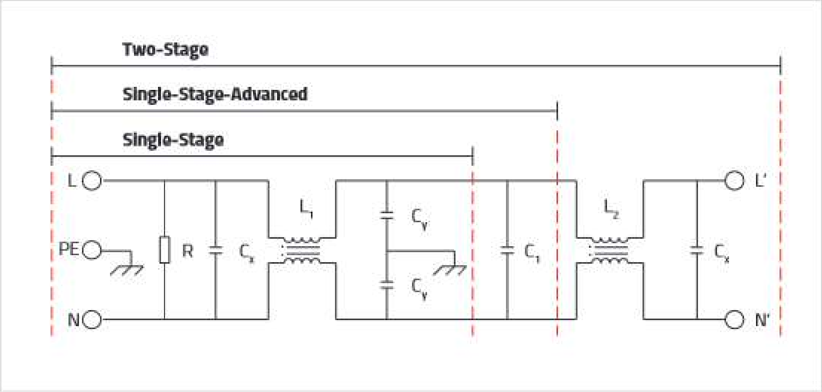
Operating Temperature	-25 up to +100 °C		
Climatic Category	25/100/21		
Rated Temperature	T_R	40	°C

WE-CLFS DERATING



WE-CLFS





Discharge Resistor R:
Discharge of capacitors.
Important safety standards

Common Mode Choke L:
High common and partly differential mode attenuation, without deriving any leakage current to ground

X-Capacitor Cx:
Increase the differential mode attenuation

Y-Capacitor Cy:
Strongly increases common and partly differential mode attenuation, driving some leakage current to ground

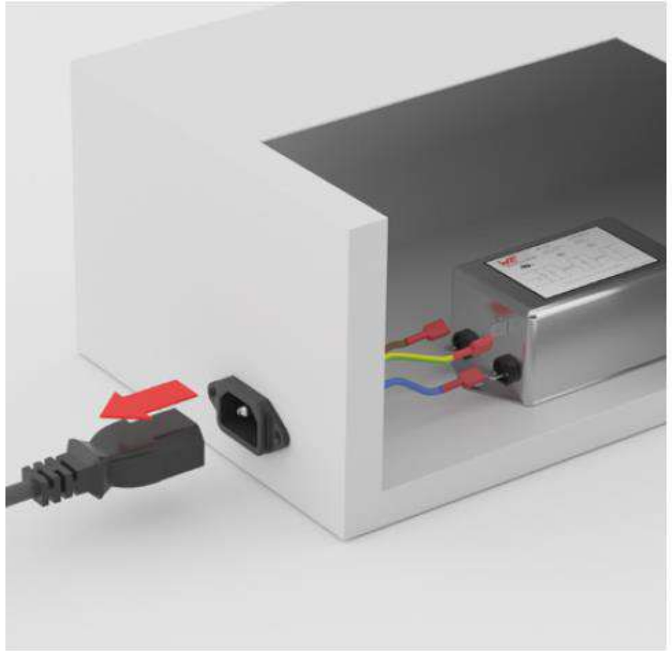
Additionally available
Spice models: Real simulation due to measured data (s-parameter) not a simulation of the single components.

More information about WE-CLFS:
www.we-online.com/we-clfs

Compare our EMC filters in REDEXPERT:
www.we-online.com/redexpert-emc-filters

WE-CLFS MOUNTING INSTRUCTIONS

1. Safety Rules



While mounting and removing, the electronic component shall be operated in voltage-free condition pursuant to the five safety rules described in the standard EN 50110-1.

1. Disconnect
2. Secure against re-energization
3. Determine voltage absence
4. Grounding and short-circuiting
5. Cover or fence off adjacent, energized parts

2. Ground Connection

To establish a low impedance path for parasitic currents, the filter housing shall have a wide connection area to the ground plane. The ground plane shall be free of paint or other isolating materials.

A solid connection to the grounding plane is established with M4 screws. The tightening torque varies with the selected screw and should not exceed the limit of 5 Nm.

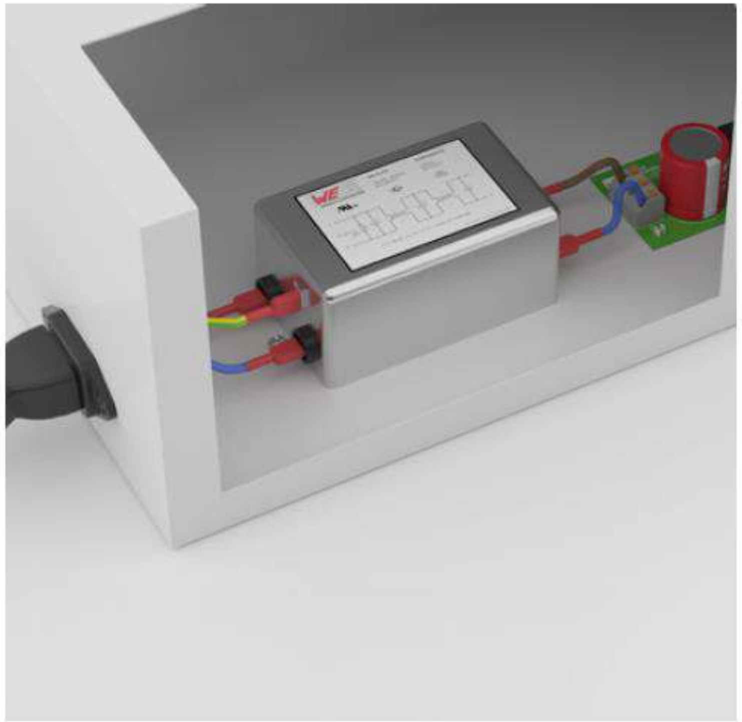
3. Protective Earth (PE) Connection

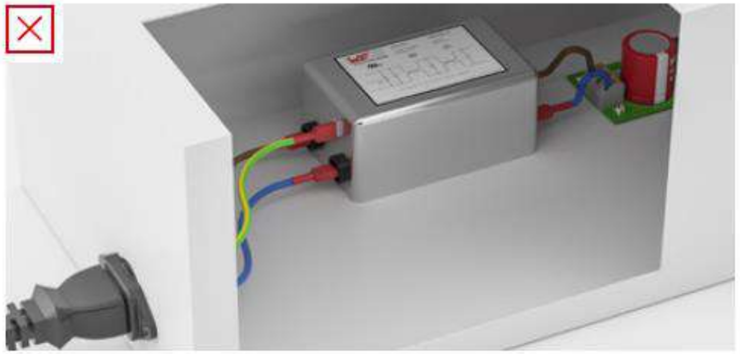
The protective earth connection shall be the first to be connected while installing the filter and shall be the last to be disconnected. It's crucial to prepare the protective earth connection with careful consideration of the leakage current.

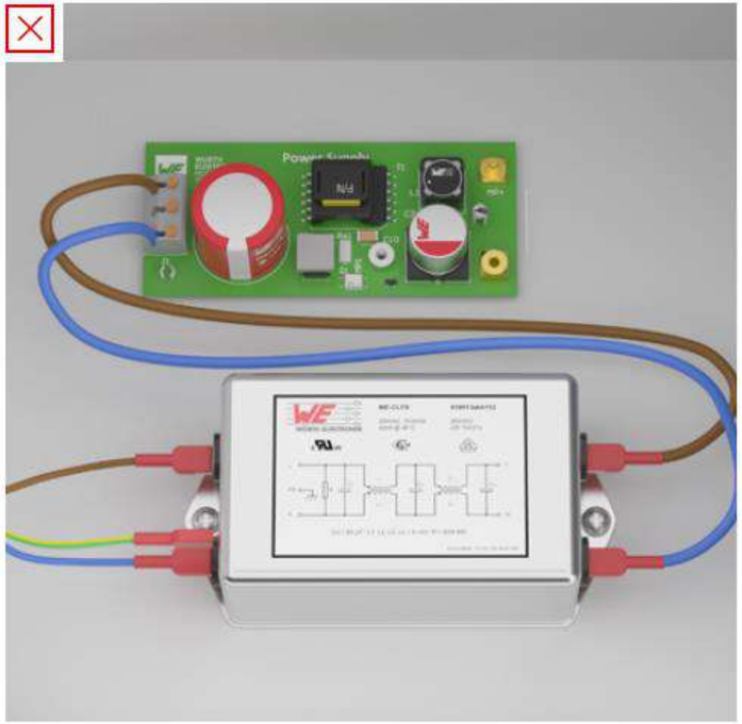
*The colors of the cables are chosen according to the European standard. Please refer to the standard that applies to you.

WE-CLFS MOUNTING INSTRUCTIONS

4. Placement







Filter Position

The filter position is suggested to be close as possible to the application. If there are long distances between the filter and application, it is recommended to shield the cables, otherwise, the functionality might be affected.

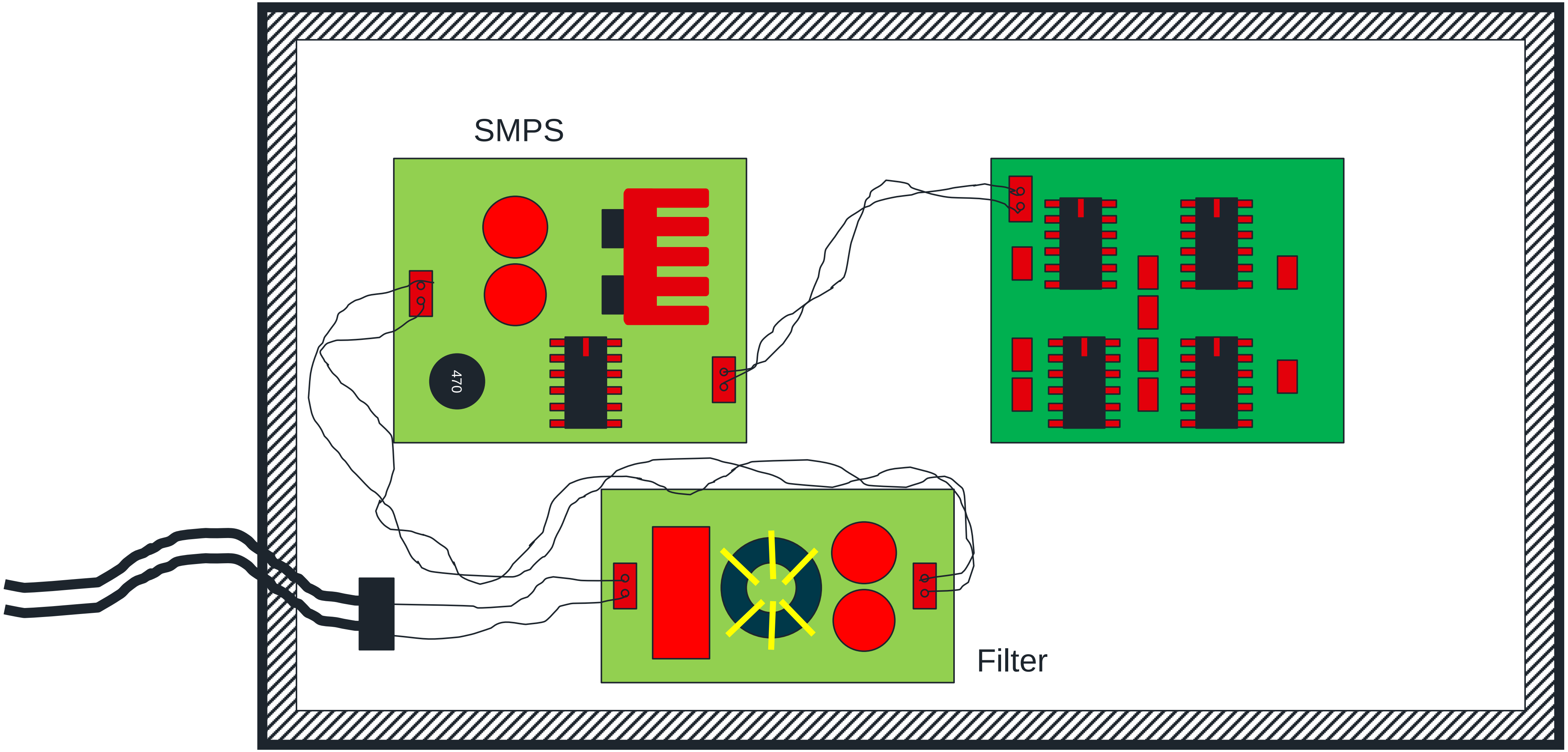
Short Connections

Keep the connection to the PE as short as possible. Use short cables to minimize the parasitic effects of the setup.

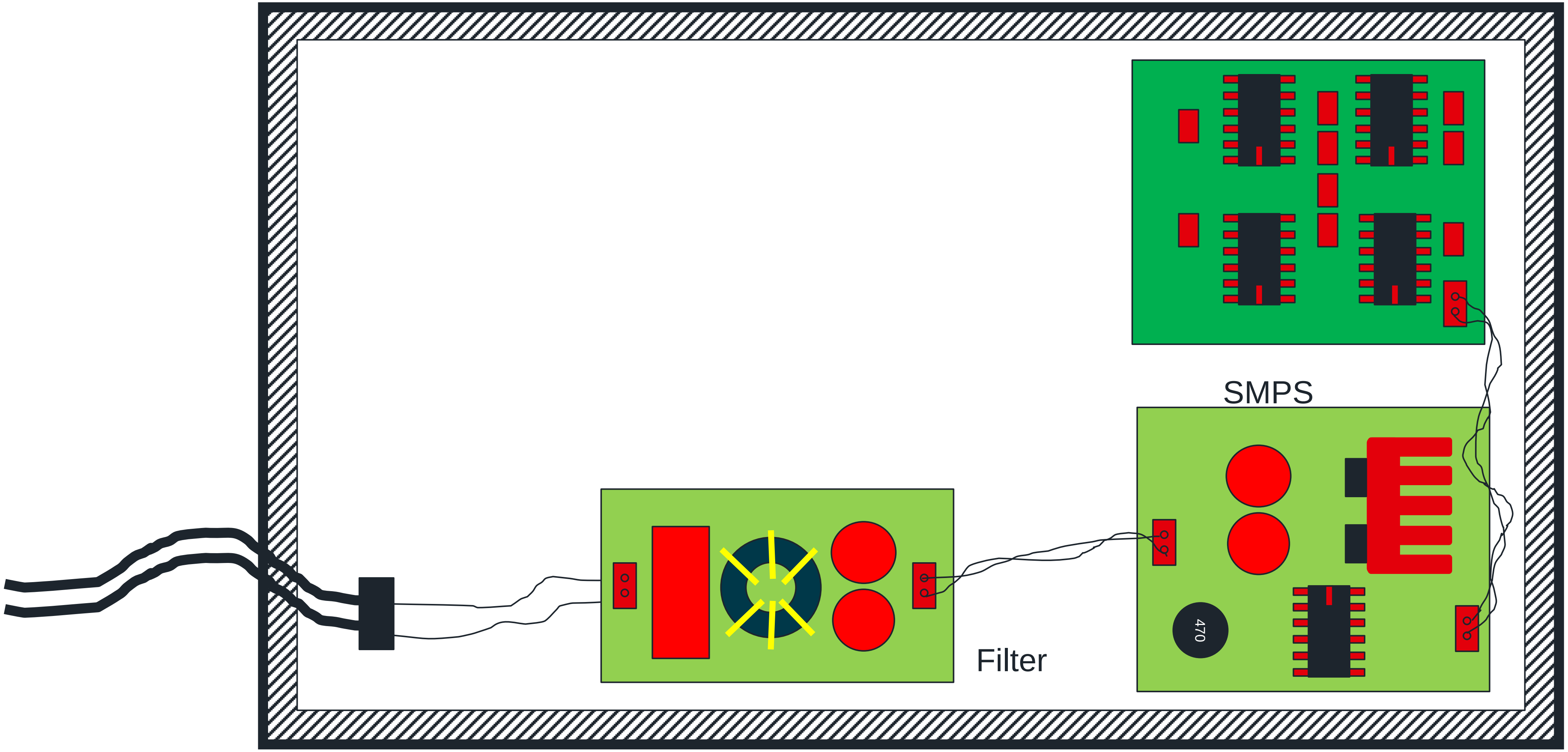
Minimize Crosstalk

To minimize crosstalk do not place incoming and outgoing cables next to each other.

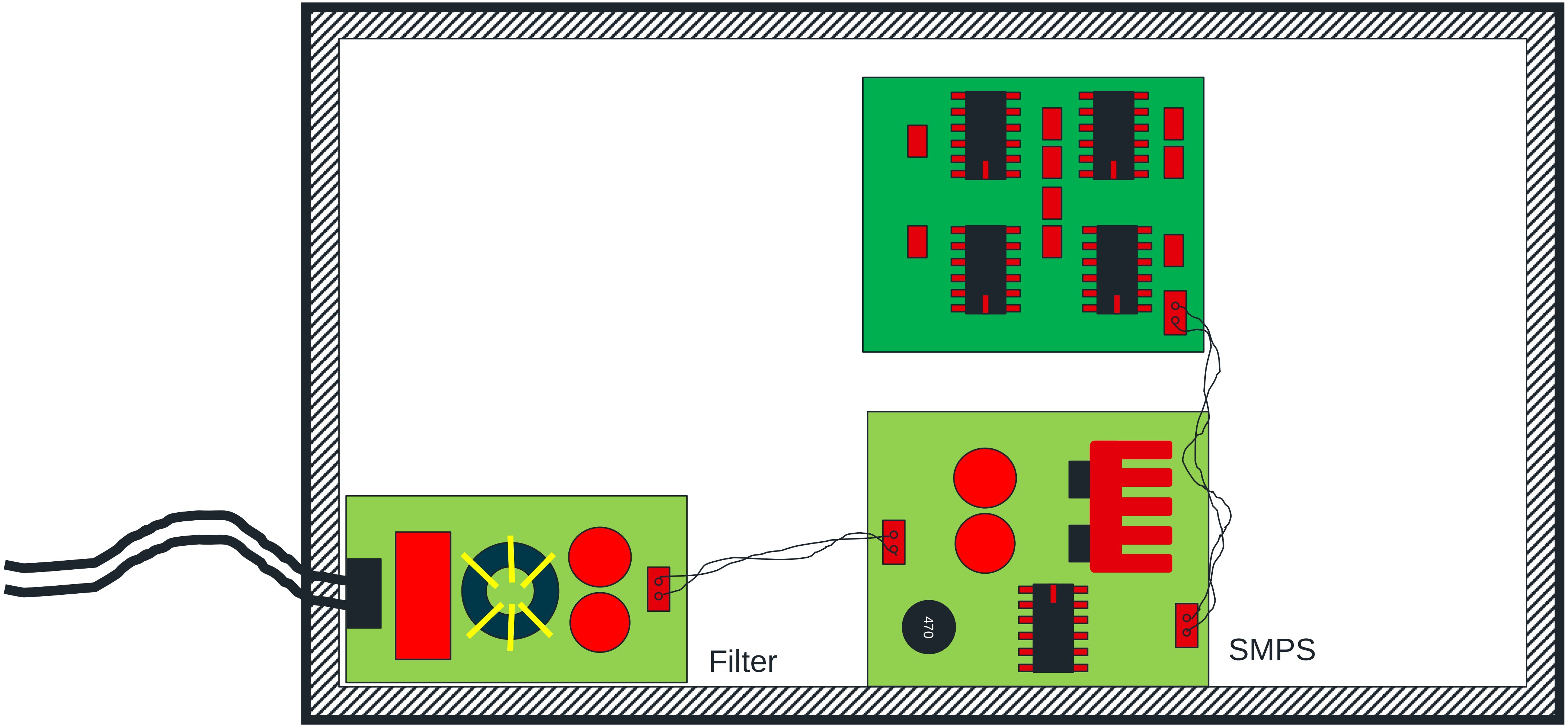
IMPROVING THE DESIGN – V1.0



IMPROVING THE DESIGN – V1.1

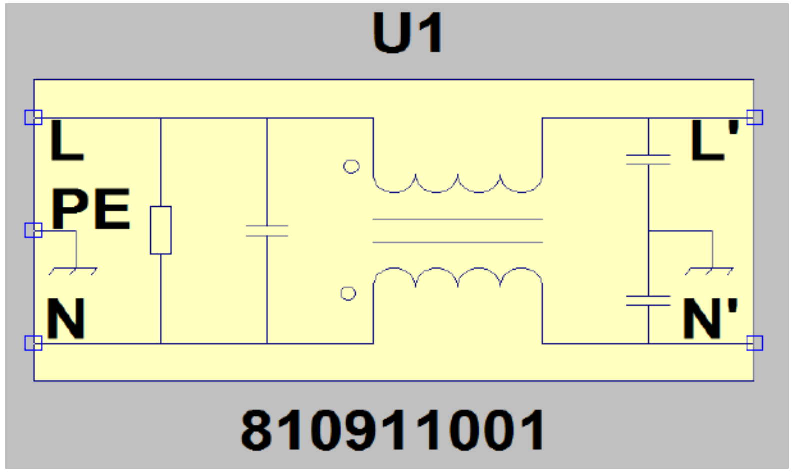


IMPROVING THE DESIGN – V2.0

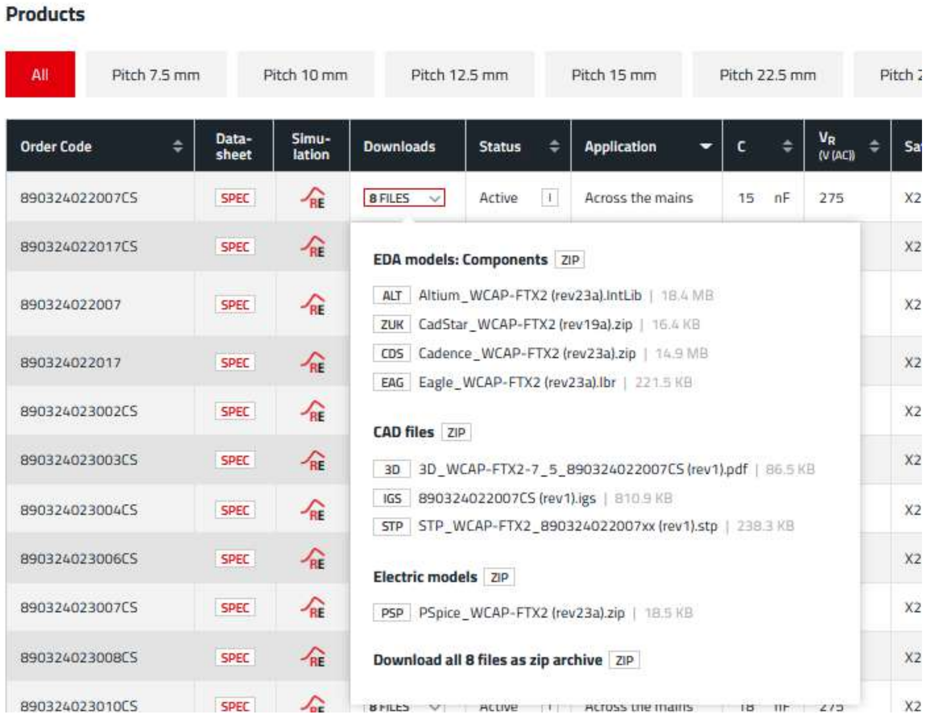


MORE THAN YOU EXPECT!

- WE use Film Capacitors
  - have a good temperature and aging behavior
- S-Parameters & LT-Spice Models
  - made from S-parameters
  - We are the only manufacturer that has this.



vs.



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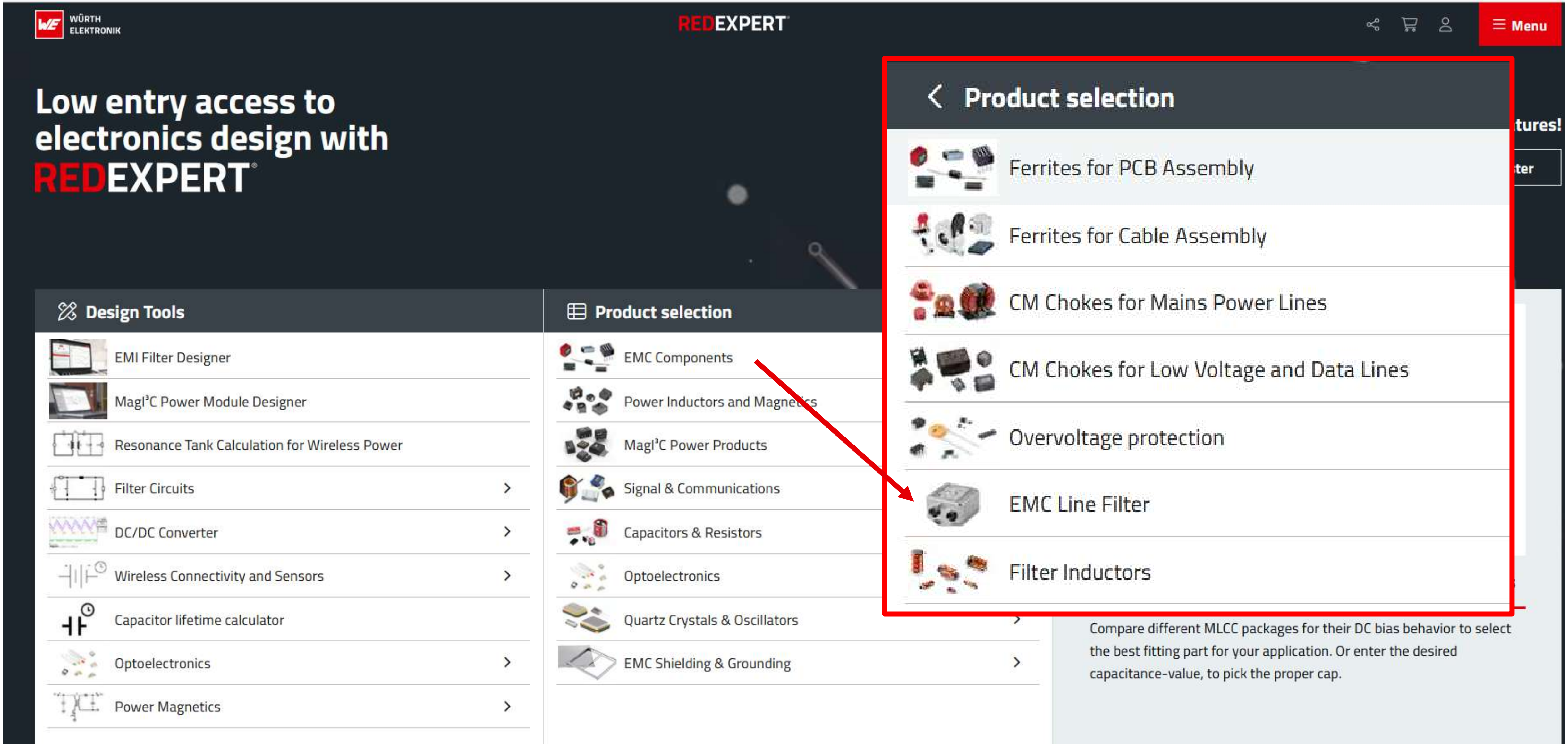
WÜRTH ELEKTRONIK
REDEXPERT
Menu
Low entry access to electronics design with REDEXPERT
Design Tools
EMI Filter Designer
MagI³C Power Module Designer
Resonance Tank Calculation for Wireless Power
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Power Magnetics
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MagI³C Power Products
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Capacitors & Resistors
Optoelectronics
Quartz Crystals & Oscillators
EMC Shielding & Grounding
Product selection
Ferrites for PCB Assembly
Ferrites for Cable Assembly
CM Chokes for Mains Power Lines
CM Chokes for Low Voltage and Data Lines
Overvoltage protection
EMC Line Filter
Filter Inductors
tures!
ter
Compare different MLCC packages for their DC bias behavior to select the best fitting part for your application. Or enter the desired capacitance-value, to pick the proper cap.

REDEXPERT

EMC Line Filter - REDEXPERT

https://redexpert.we-online.com/we-redexpert/en/#/redexpert-embedded

WÜRTH ELEKTRONIK | REDEXPERT EMC Line Filter | MENU

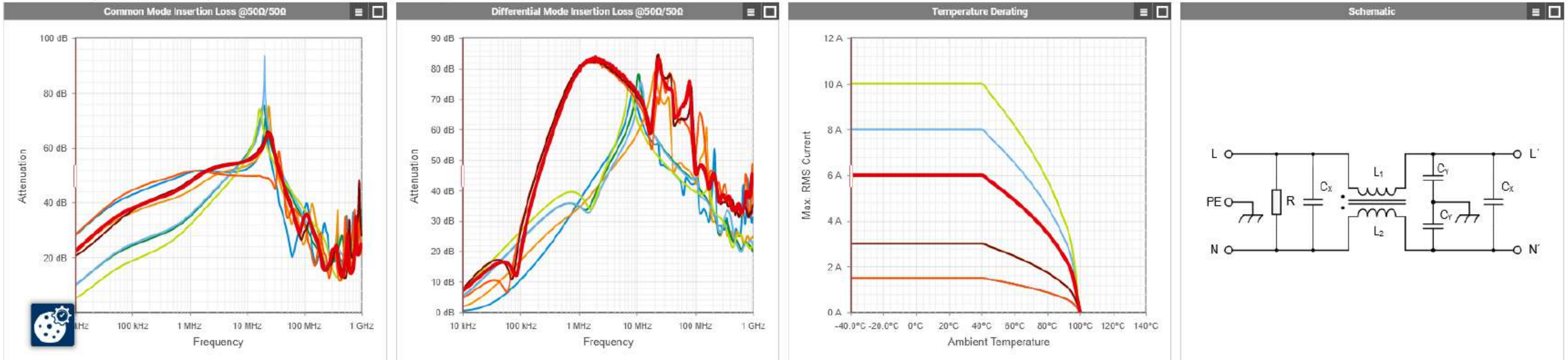
34 items

Order Code	Series	Size	Spec	V_R	I_R	I_{leak}	L	C_X	C_Y	R	R_{DC}	$V_{T,AC}$(L->PE)	$V_{T,DC}$(L->N)	Weight	Length	Width	Height	Lines	T_{Op}	Assembling
810911001	WE-CLFS	Single-Stage		250 V	1.50 A	173 µA	20.0 mH	100 nF	2.20 nF	1.00 MΩ	300 mΩ	2.00 kV	1.075 kV	70.0g	64.0 mm	35.0 mm	29.0 mm	2	100°C	Chassis
810911003	WE-CLFS	Single-Stage		250 V	3.00 A	173 µA	10.0 mH	220 nF	2.20 nF	1.00 MΩ	100 mΩ	2.00 kV	1.075 kV	70.0g	64.0 mm	35.0 mm	29.0 mm	2	100°C	Chassis
810911006	WE-CLFS	Single-Stage		250 V	6.00 A	369 µA	2.20 mH	470 nF	4.70 nF	1.00 MΩ	30.0 mΩ	2.00 kV	1.075 kV	74.0g	64.0 mm	35.0 mm	29.0 mm	2	100°C	Chassis
810911008	WE-CLFS	Single-Stage		250 V	8.00 A	369 µA	2.20 mH	470 nF	4.70 nF	1.00 MΩ	20.0 mΩ	2.00 kV	1.075 kV	76.0g	64.0 mm	35.0 mm	29.0 mm	2	100°C	Chassis
810911010	WE-CLFS	Single-Stage		250 V	10.0 A	534 µA	1.00 mH	680 nF	6.80 nF	680 kΩ	15.0 mΩ	2.00 kV	1.075 kV	75.0g	64.0 mm	35.0 mm	29.0 mm	2	100°C	Chassis
810912001	WE-CLFS	Single-Stag...		250 V	1.50 A	173 µA	20.0 mH	220 nF	2.20 nF	1.00 MΩ	300 mΩ	2.00 kV	1.075 kV	129g	75.0 mm	51.8 mm	29.0 mm	2	100°C	Chassis
810912003	WE-CLFS	Single-Stag...		250 V	3.00 A	259 µA	10.0 mH	330 nF	3.30 nF	1.00 MΩ	100 mΩ	2.00 kV	1.075 kV	134g	75.0 mm	51.8 mm	29.0 mm	2	100°C	Chassis

810911001 Single-Stage 250 V · 1.50 A | 810911003 Single-Stage 250 V · 3.00 A | 810911006 Single-Stage 250 V · 6.00 A | 810911008 Single-Stage 250 V · 8.00 A | 810911010 Single-Stage 250 V · 10.0 A | 810912001 Single-Stage Advanced 250 V · 1.50 A | 810912003 Single-Stage Advanced 250 V · 3.00 A | Click and type or drop an Order Code here

ADD | MORE

Show Panel: CMA50/50 DMA50/50 DMA0.1/100 DMA100/0.1 DEC Schematic Product Picture



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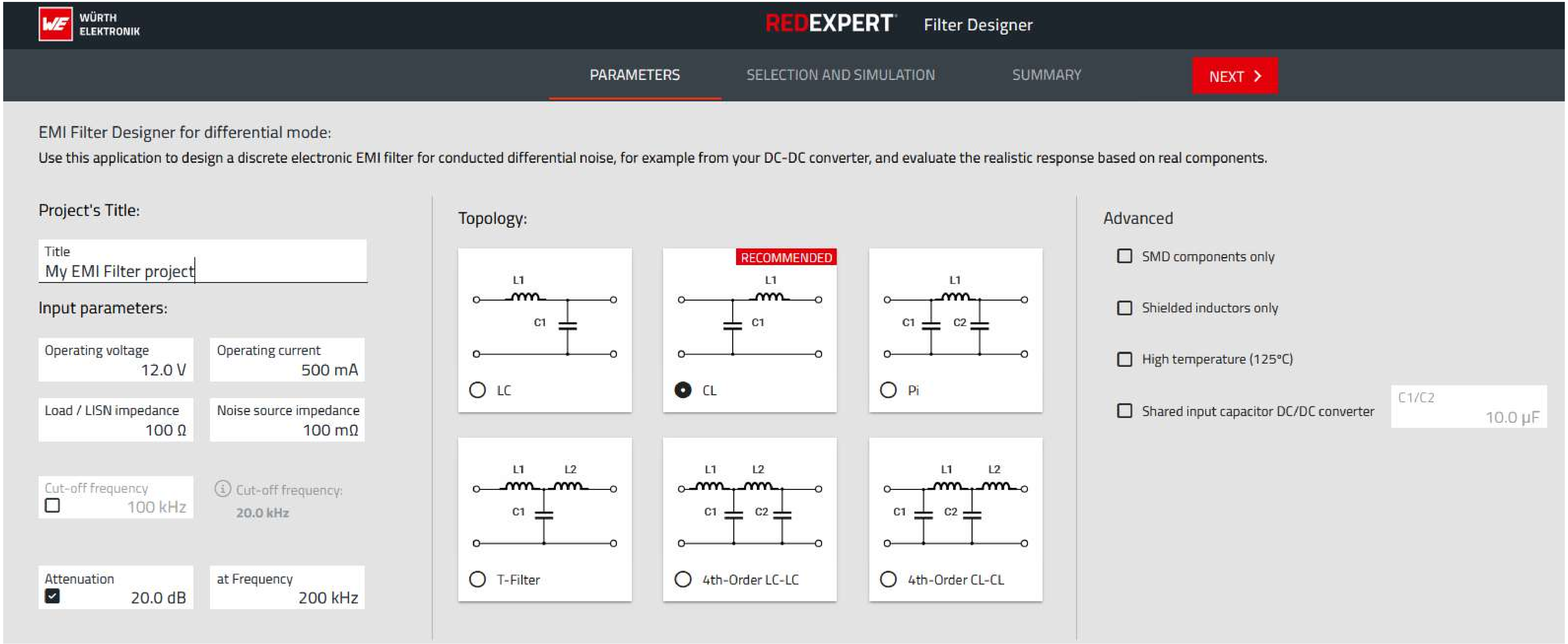

WÜRTH ELEKTRONIK
REDEXPERT Filter Designer
PARAMETERS
SELECTION AND SIMULATION
SUMMARY
NEXT
EMI Filter Designer for differential mode:
Use this application to design a discrete electronic EMI filter for conducted differential noise, for example from your DC-DC converter, and evaluate the realistic response based on real components.
Project's Title:
Title
My EMI Filter project
Input parameters:
Operating voltage
12.0 V
Operating current
500 mA
Load / LISN impedance
100 Ω
Noise source impedance
100 mΩ
Cut-off frequency
100 kHz
Cut-off frequency:
20.0 kHz
Attenuation
20.0 dB
at Frequency
200 kHz
Topology:
RECOMMENDED
L1
C1
L2
C2
LC
CL
Pi
T-Filter
4th-Order LC-LC
4th-Order CL-CL
Advanced
SMD components only
Shielded inductors only
High temperature (125°C)
Shared input capacitor DC/DC converter
C1/C2
10.0 µF

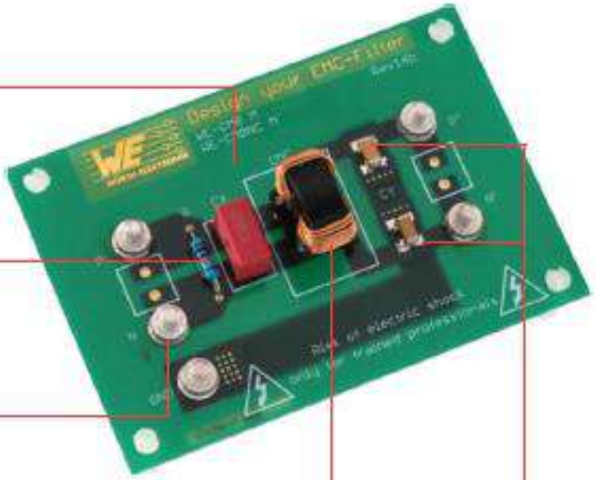
DESIGN YOUR EMC FILTER KIT - 744998

What are our EMC filters made of?

X-Capacitor
- Increases the differential mode attenuation

Discharge Resistor
- Discharge of X-Capacitor
- Important for safety

SMD Power Elements
- High current connection in SMD assembling



Common Mode Choke
- High common mode and partly differential mode attenuation

Y-Capacitors
- Strongly increases common mode and partly differential mode attenutation, driving some leakage current to ground

Effect of the single components to the filter behaviour

DEMO OF AC FILTERING

Carpov Pascual, Field Application Engineer

CONTENTS

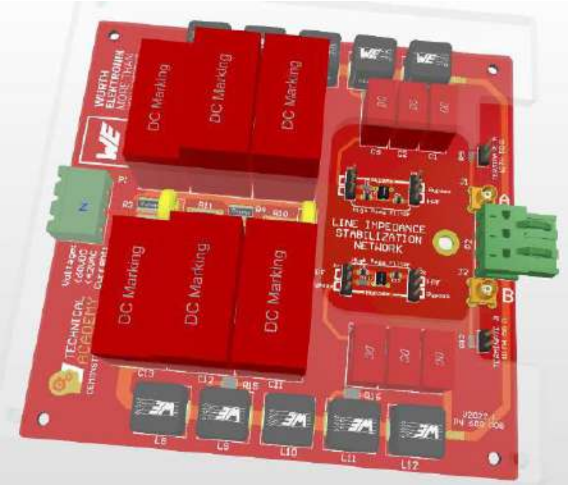
Demo of AC EMC Filtering

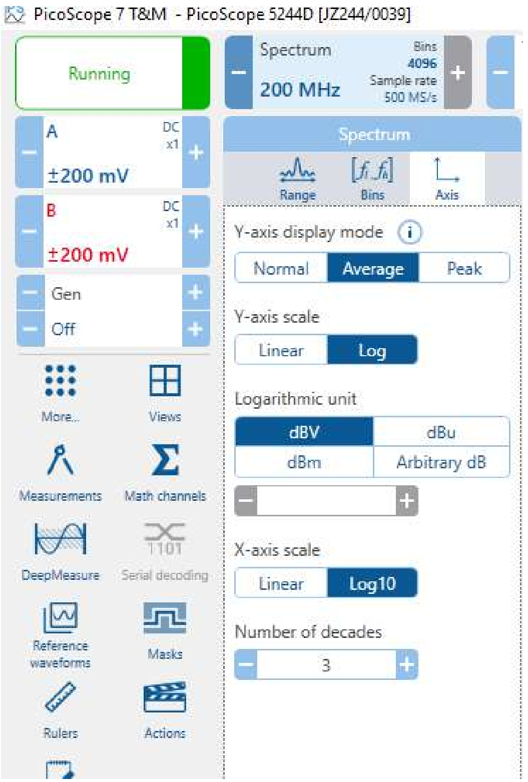
- Materials and tools.
- Test setup.
- Measurements.
  - Without filter
  - With filter
- Simulations and REDEXPERT.
- Conclusions.

** Some presentation images have clickable web links*

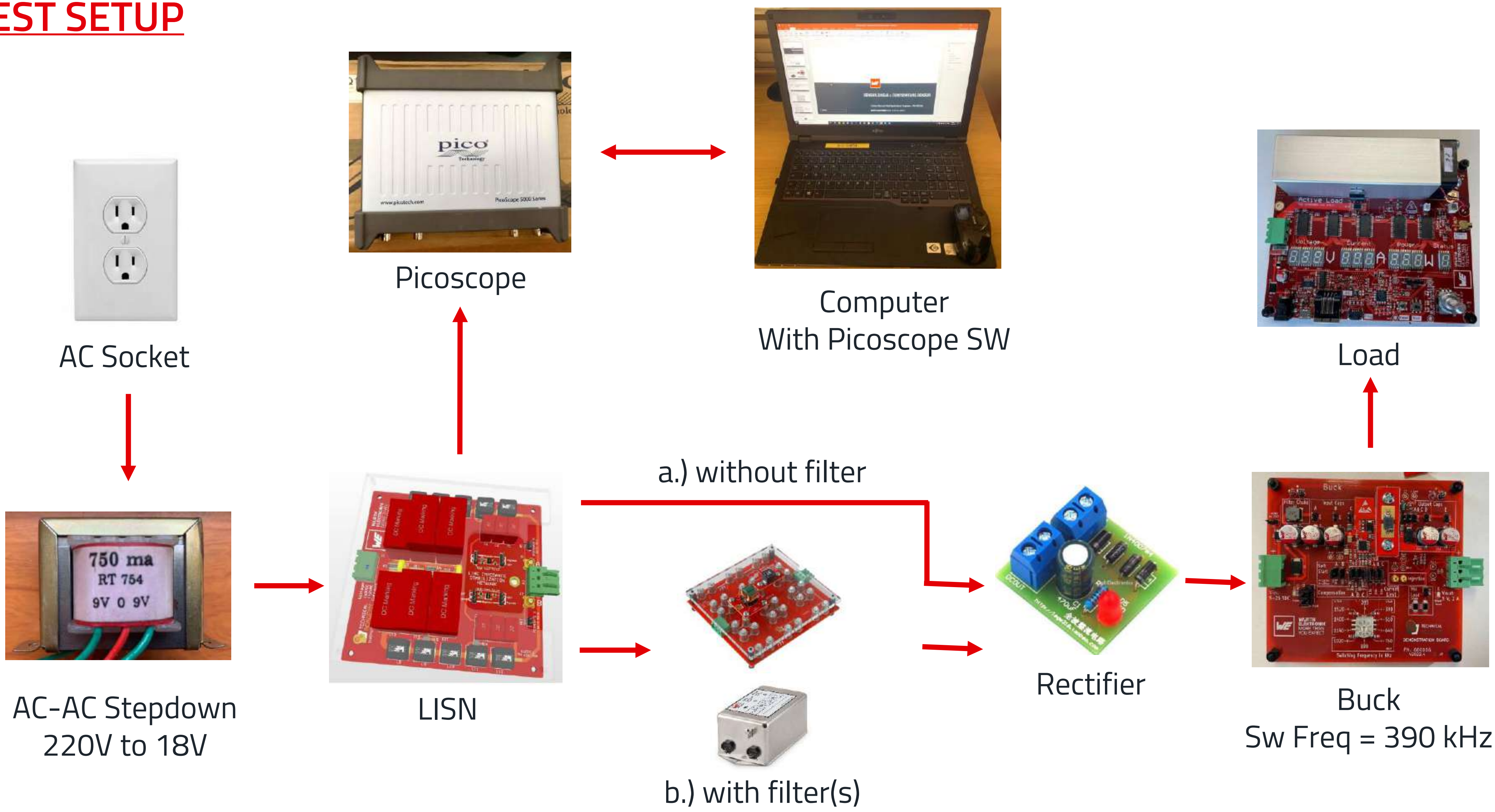
MATERIALS AND TOOLS

- Step down transformer
- Bridge rectifier
- FAE demo kit
  - Line Impedance Stabilization Network (LISN)
  - Step down DC-DC converter (Buck)
  - Load
  - Configurable filter board
- Discrete inductors and capacitors
- WE-CLFS parts
- Oscilloscope and spectrum analyzer
- Multimeter



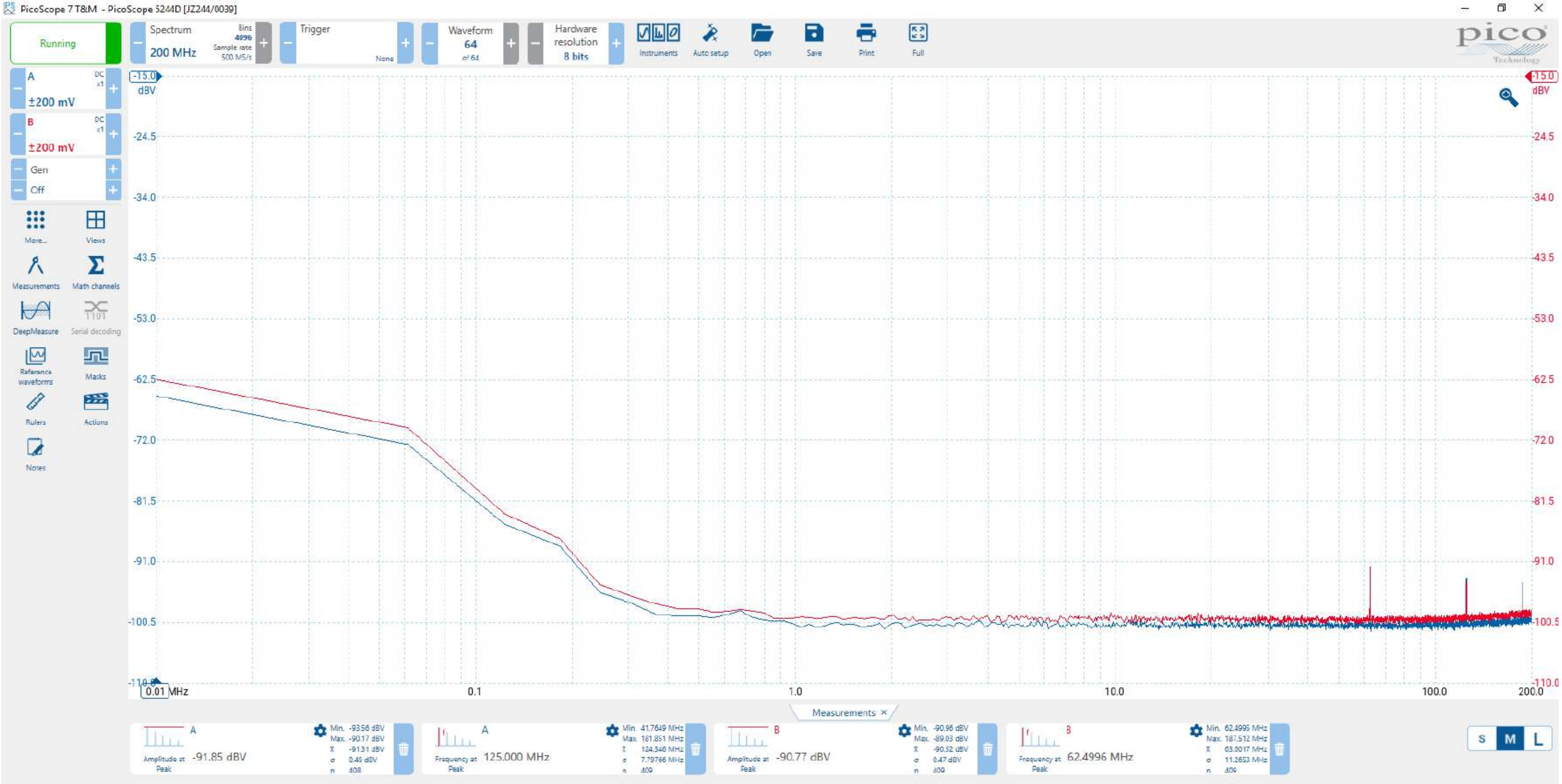


TEST SETUP


Picoscope
Computer
With Picoscope SW
AC Socket
Load
a.) without filter
750 ma
RT 754
9V 0 9V
AC-AC Stepdown
220V to 18V
LISN
Rectifier
Buck
Sw Freq = 390 kHz
b.) with filter(s)

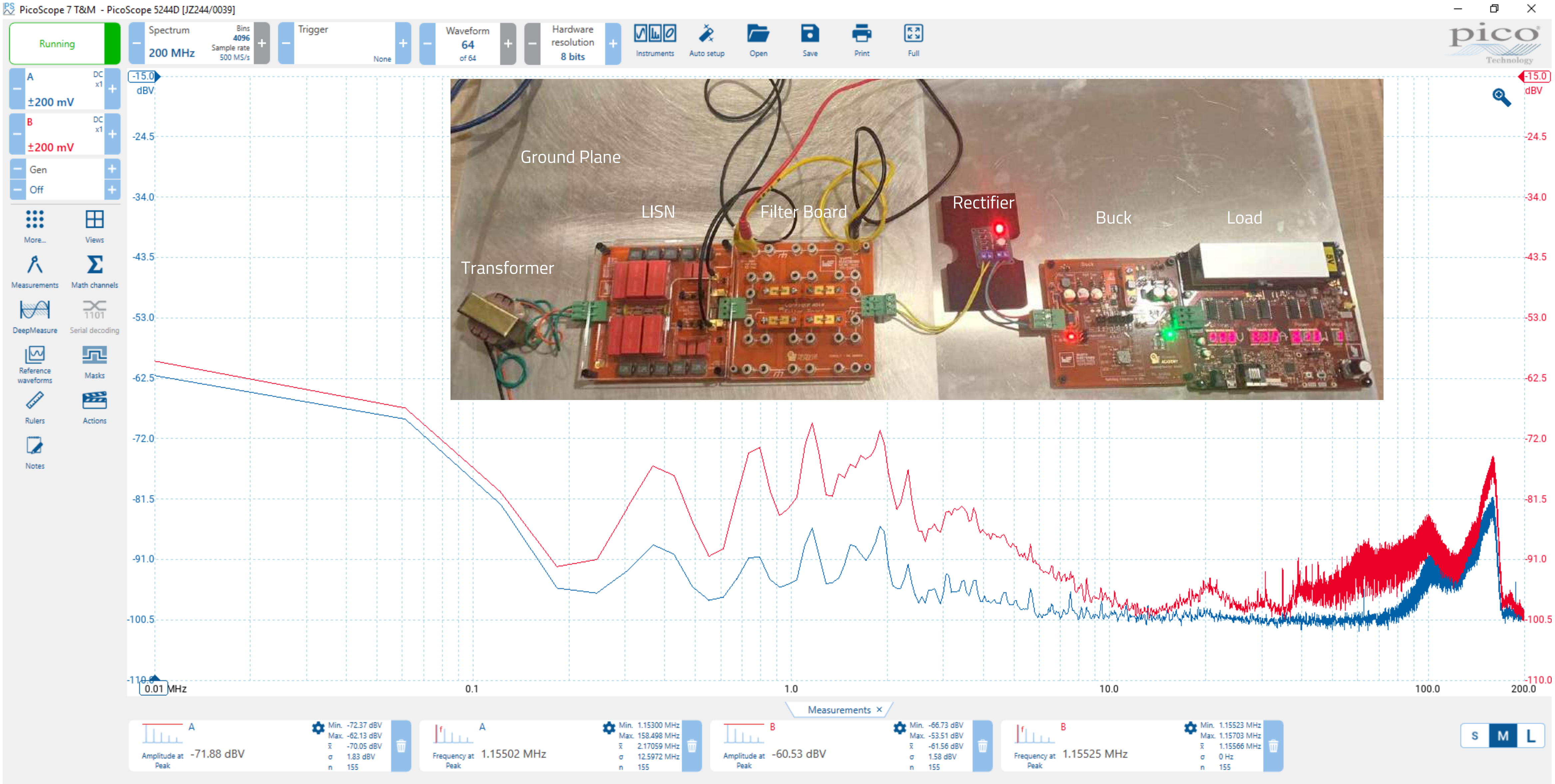
NOISE FLOOR

CM DM



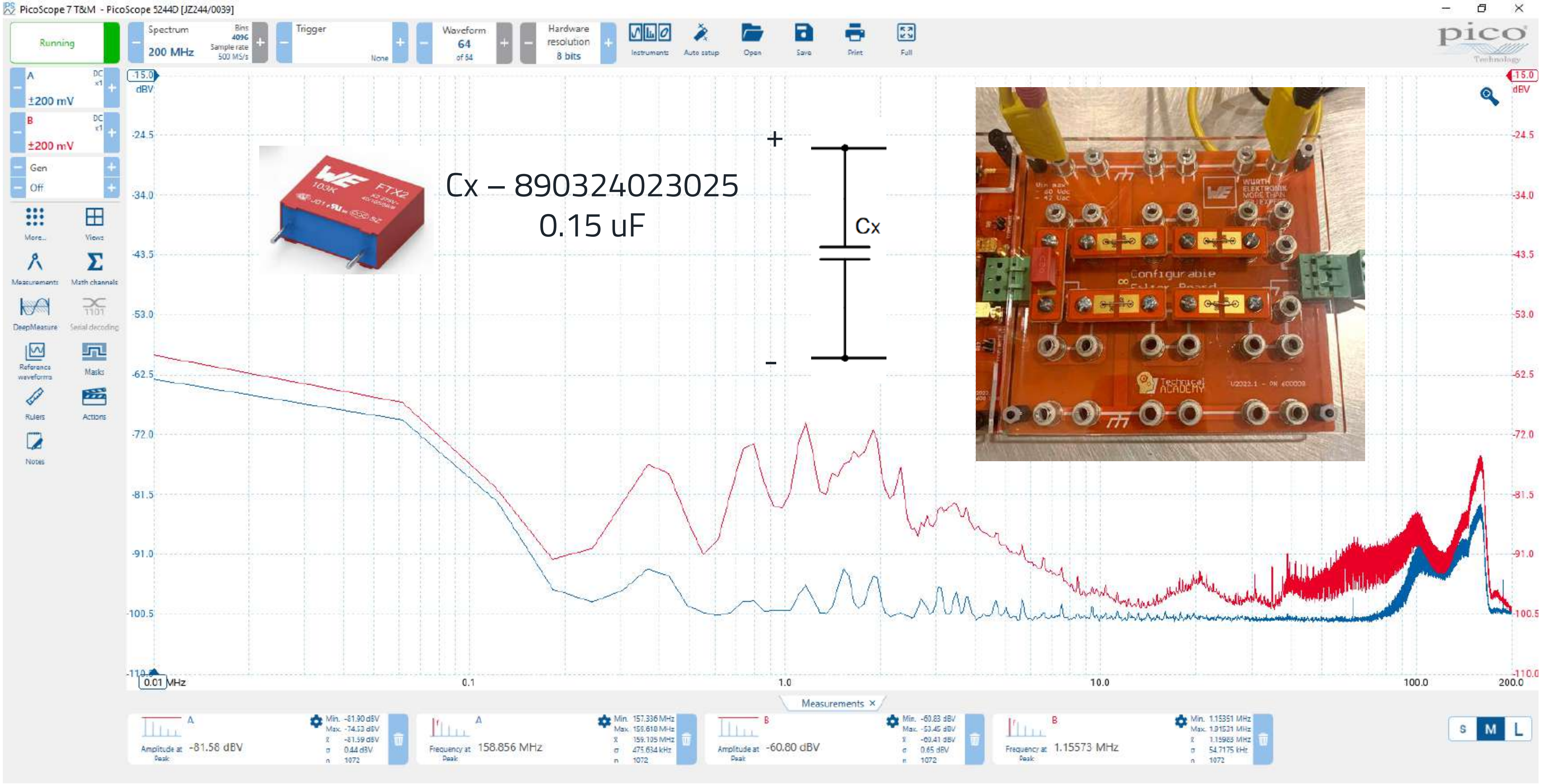
WITHOUT FILTER

CM DM



WITH CX

CM DM



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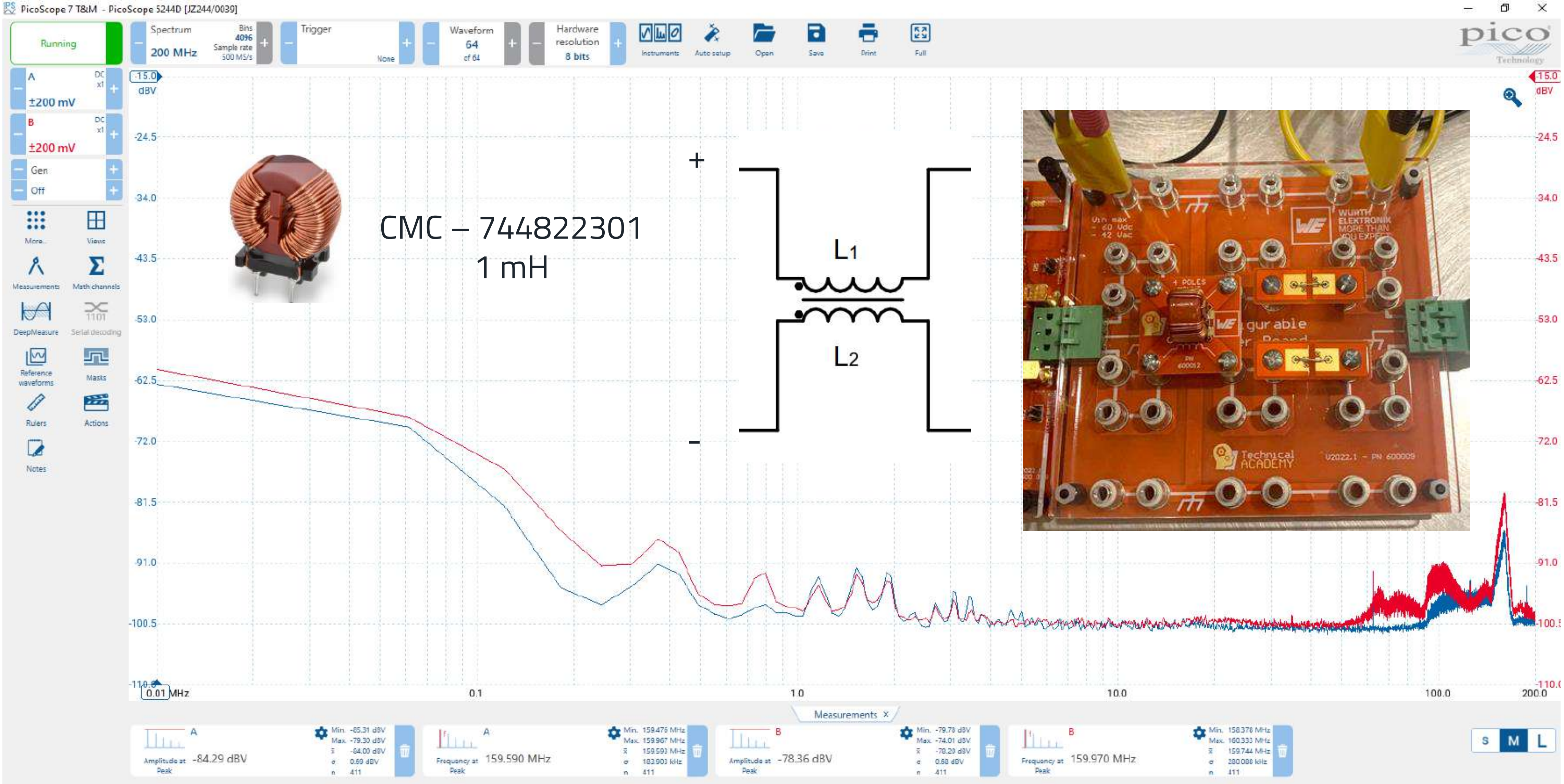
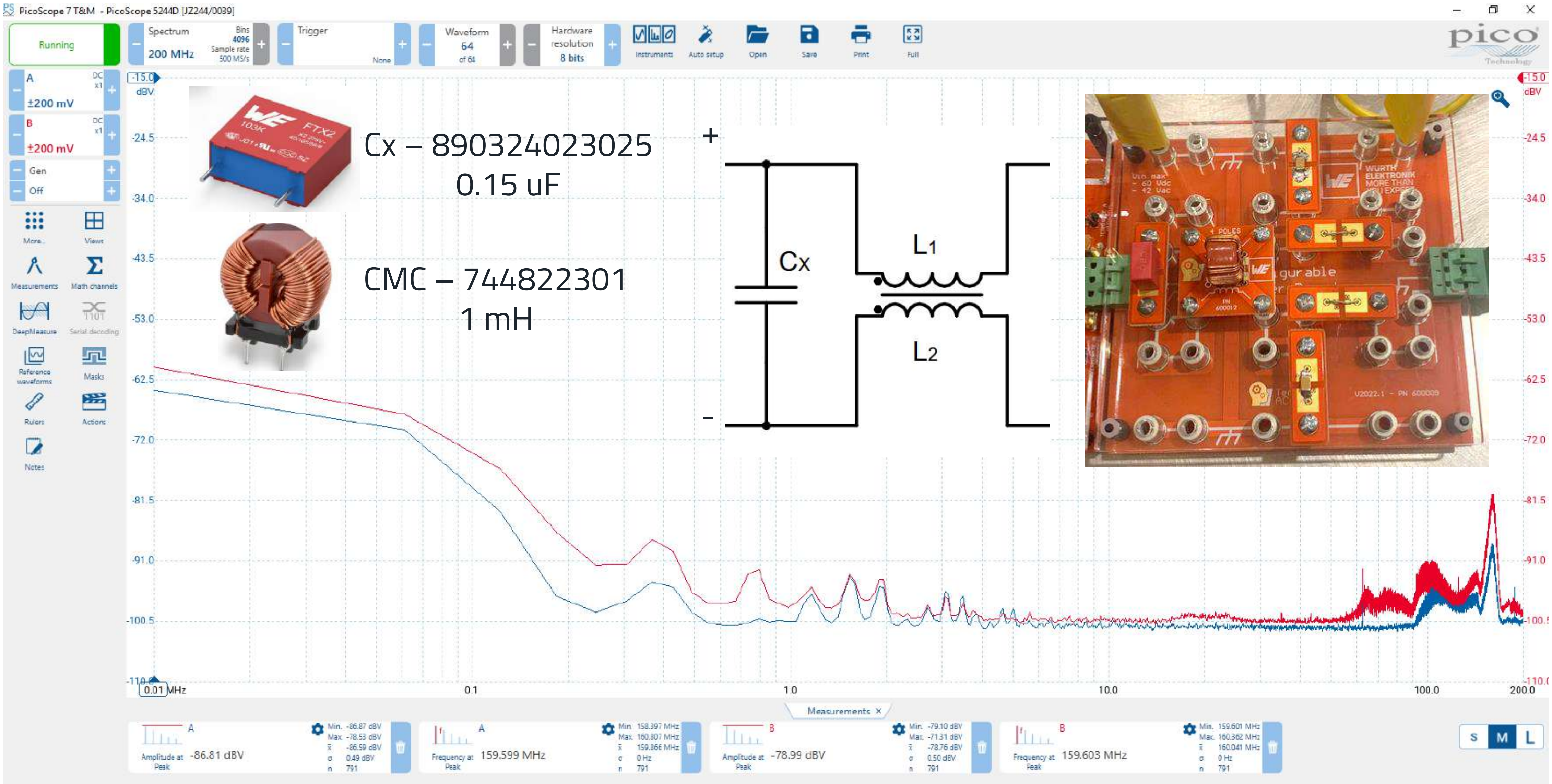
WITH CMC

CM DM



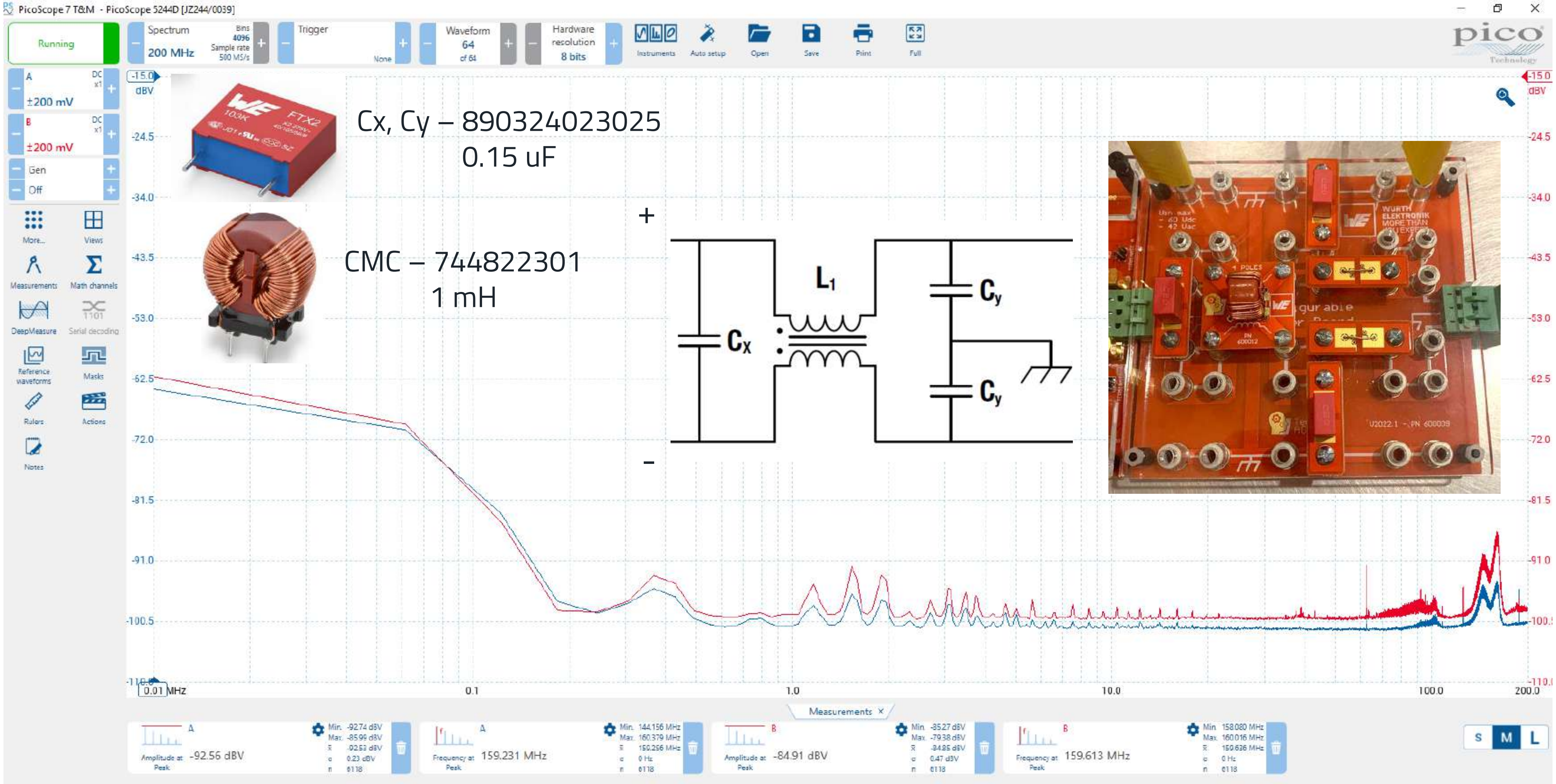
WITH CX + CMC

CM DM



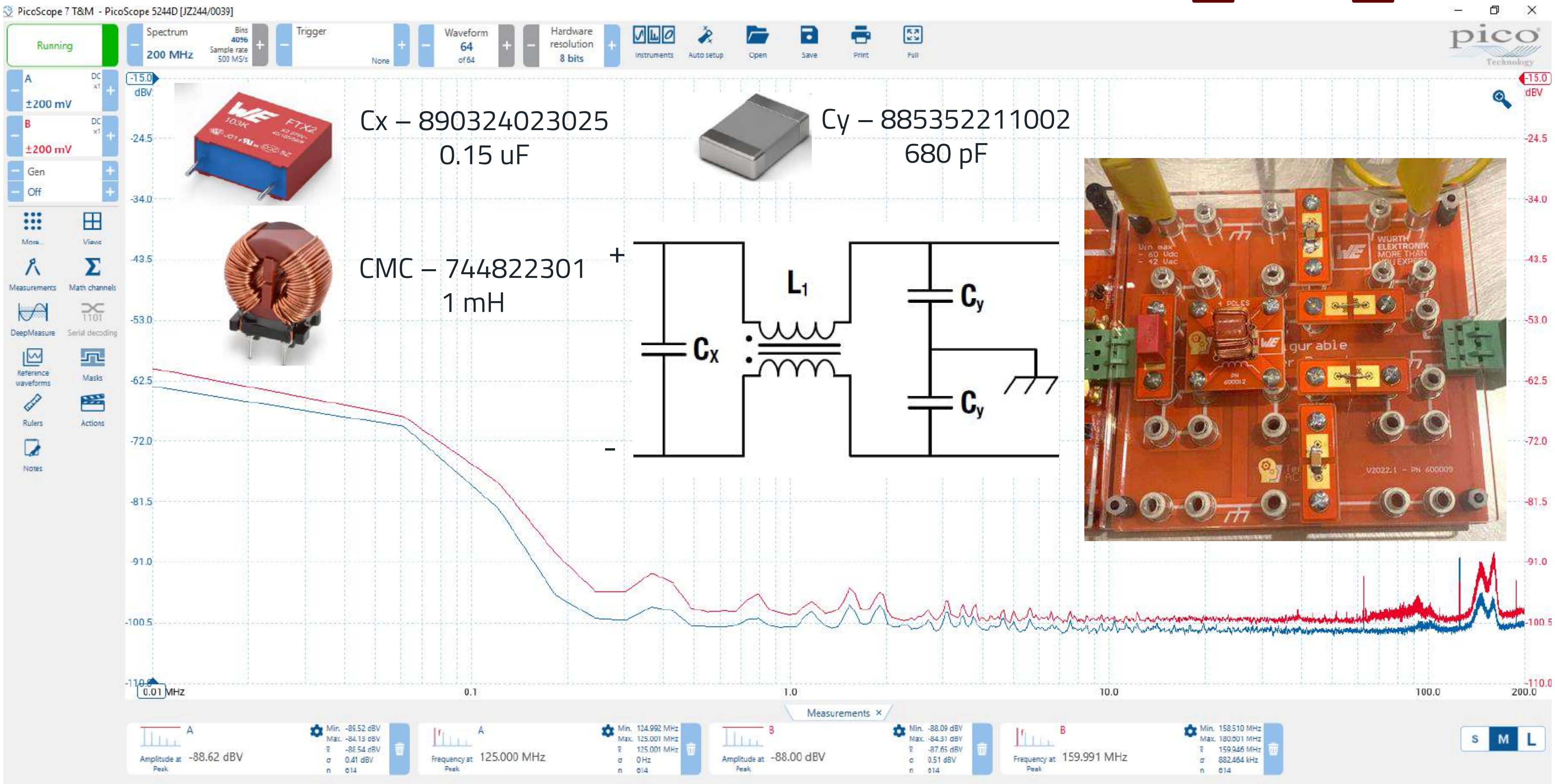
WITH CX + CMC + CY

CM DM



WITH CX + CMC + CY

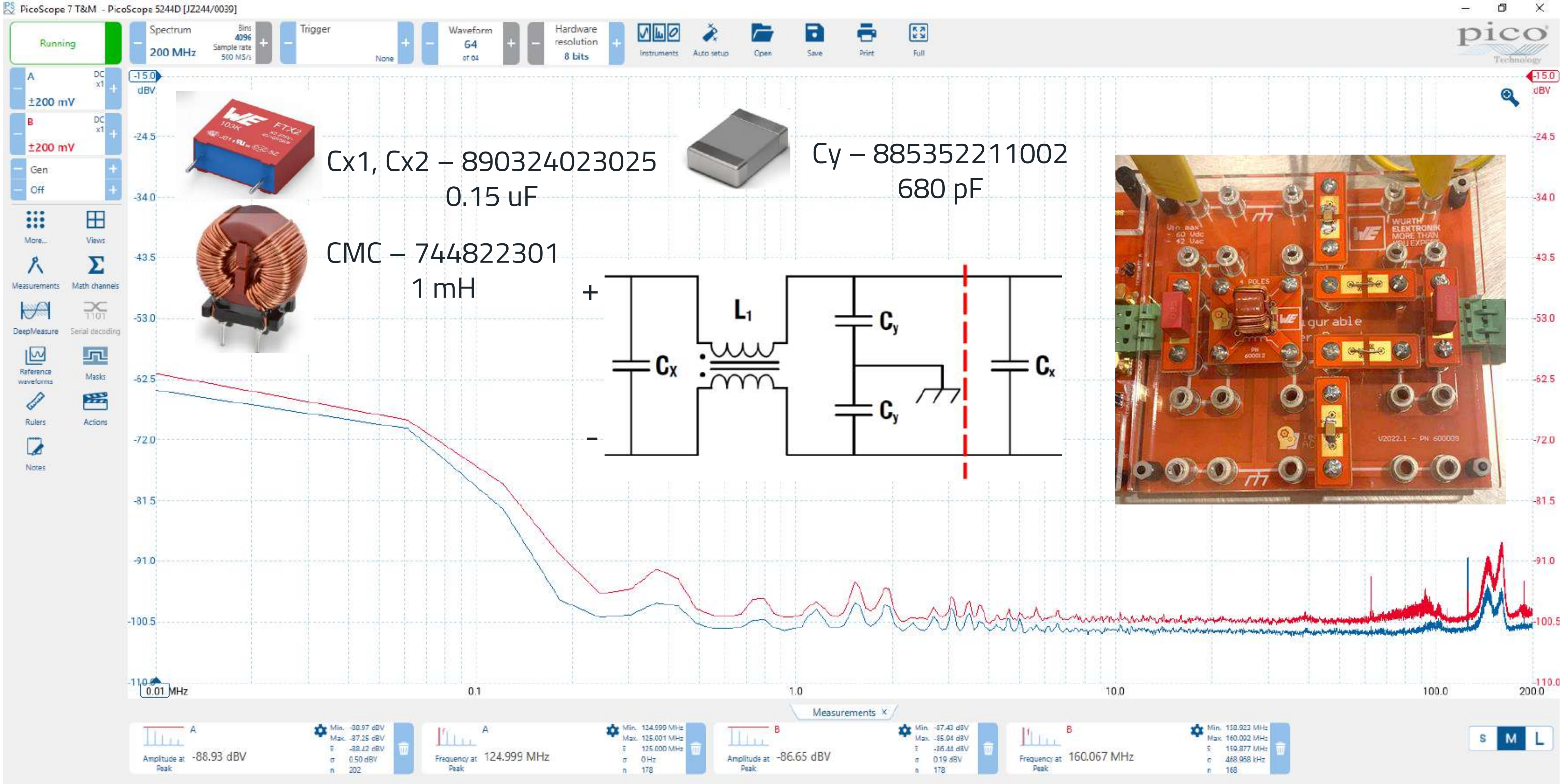
CM DM



REDEXPERT®

WITH CX + CMC + CY 680 + CX

CM DM



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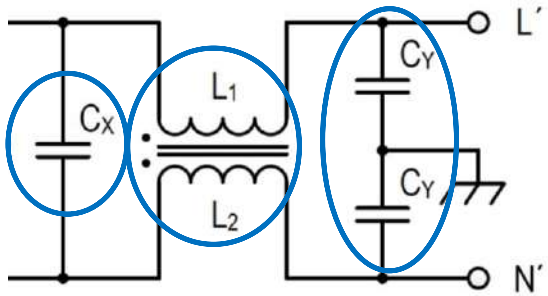
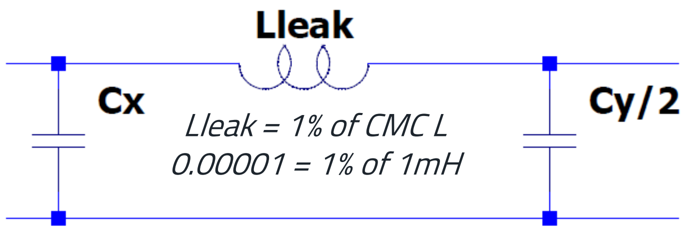
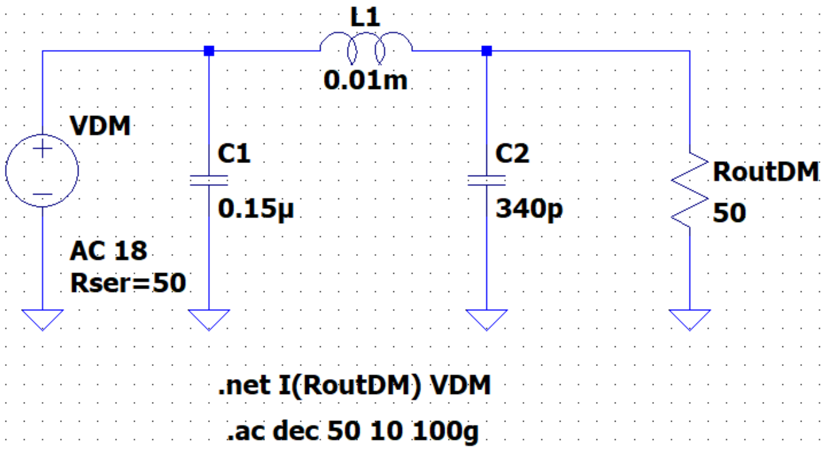
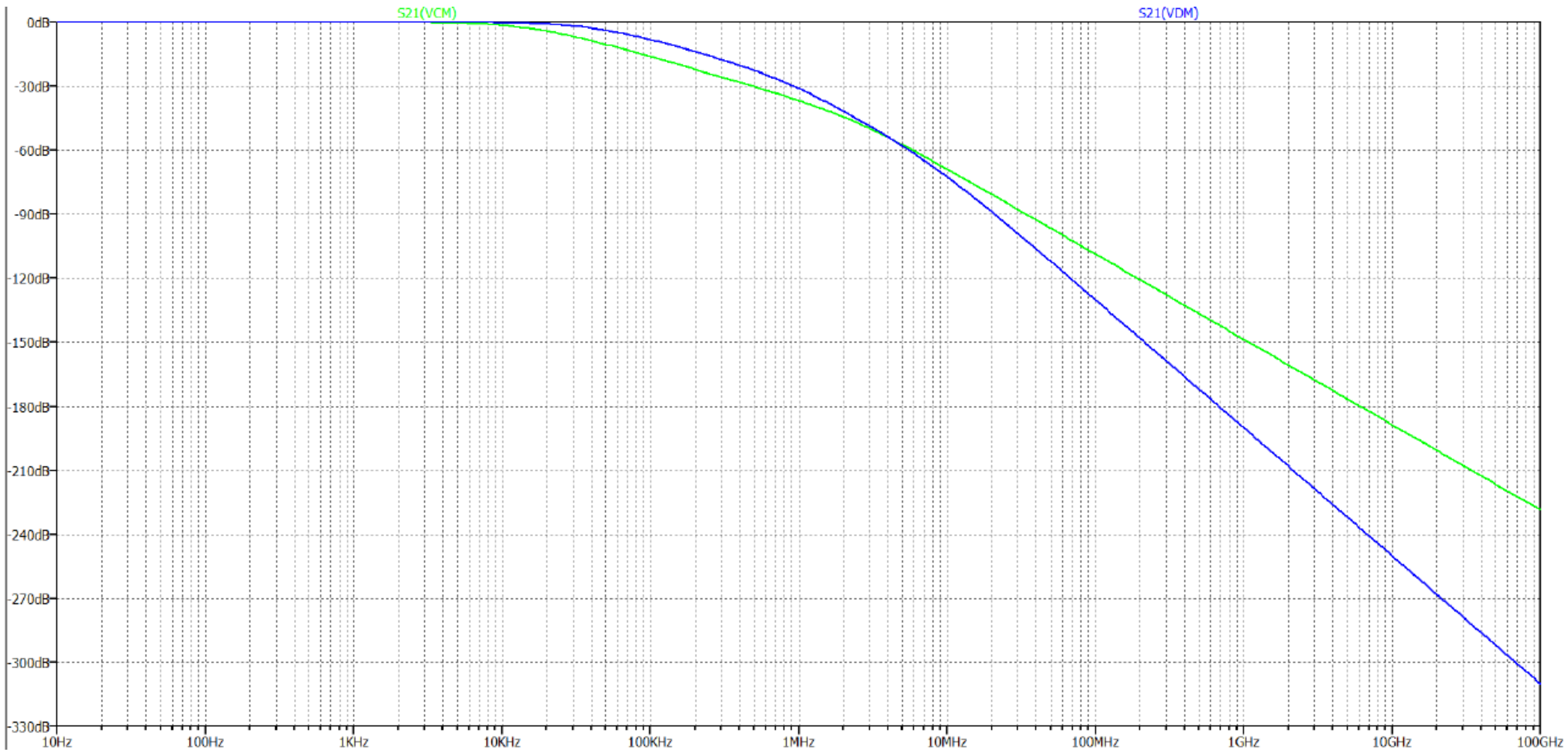
SIMULATION

Differential Mode



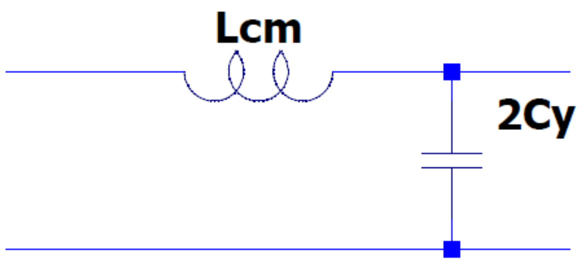


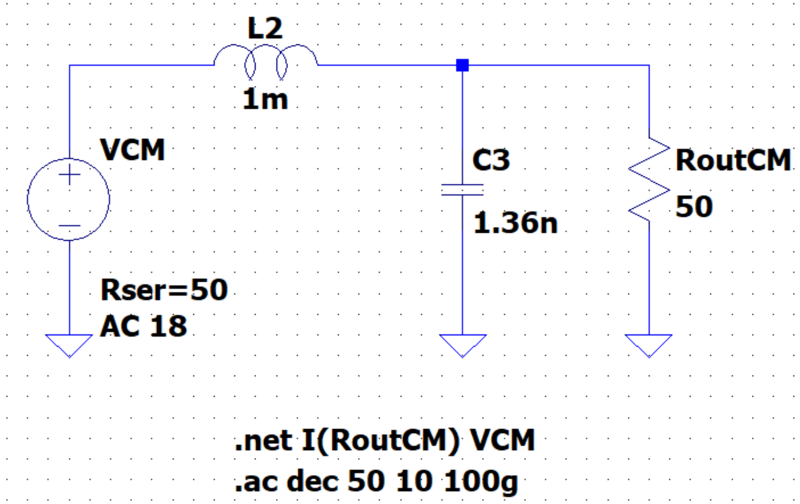


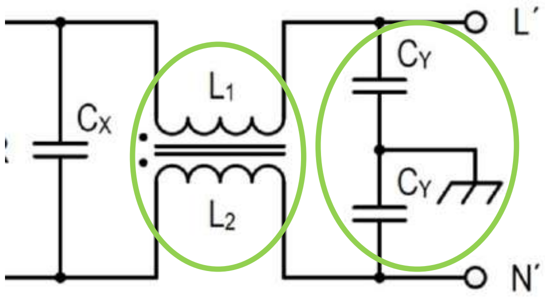


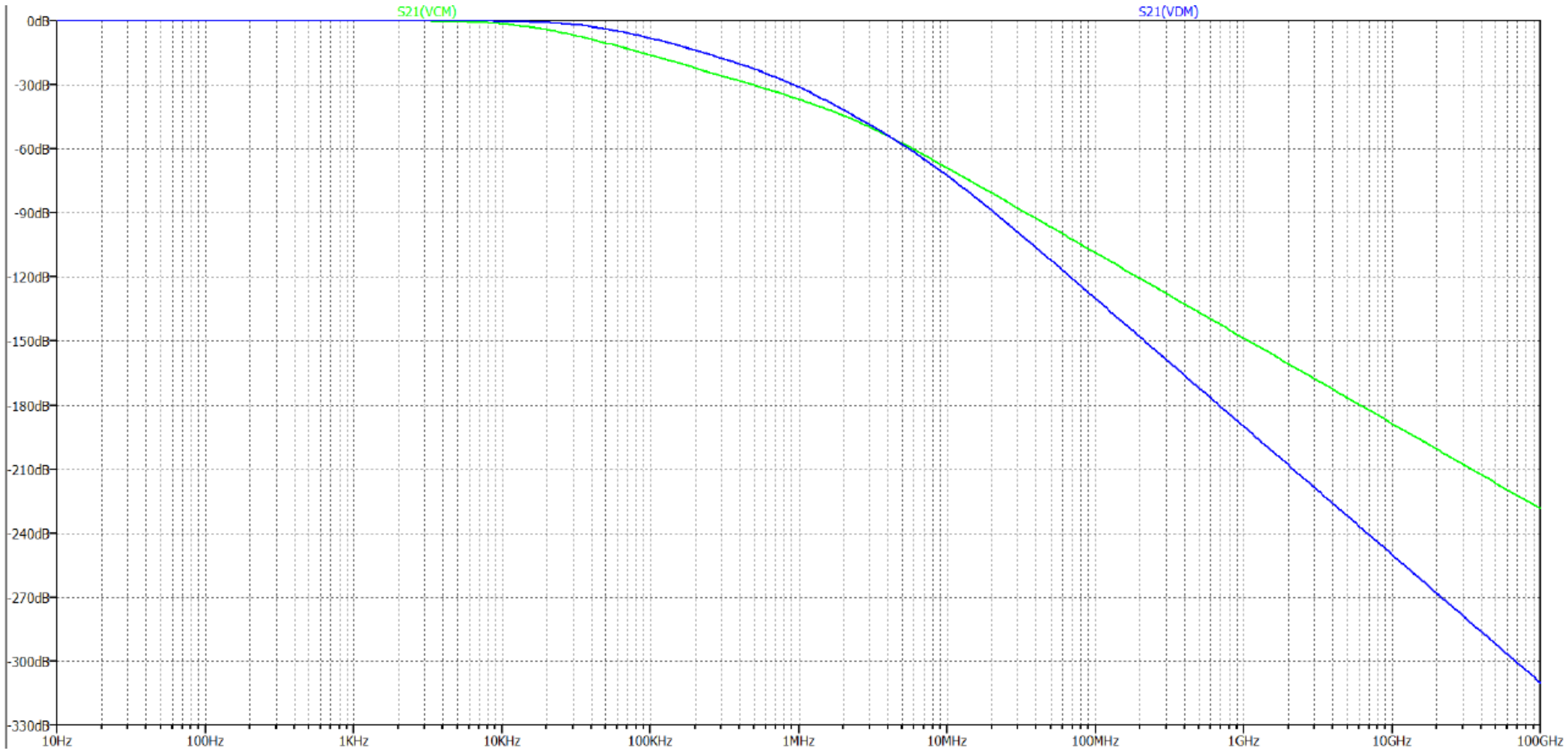
SIMULATION

Common Mode





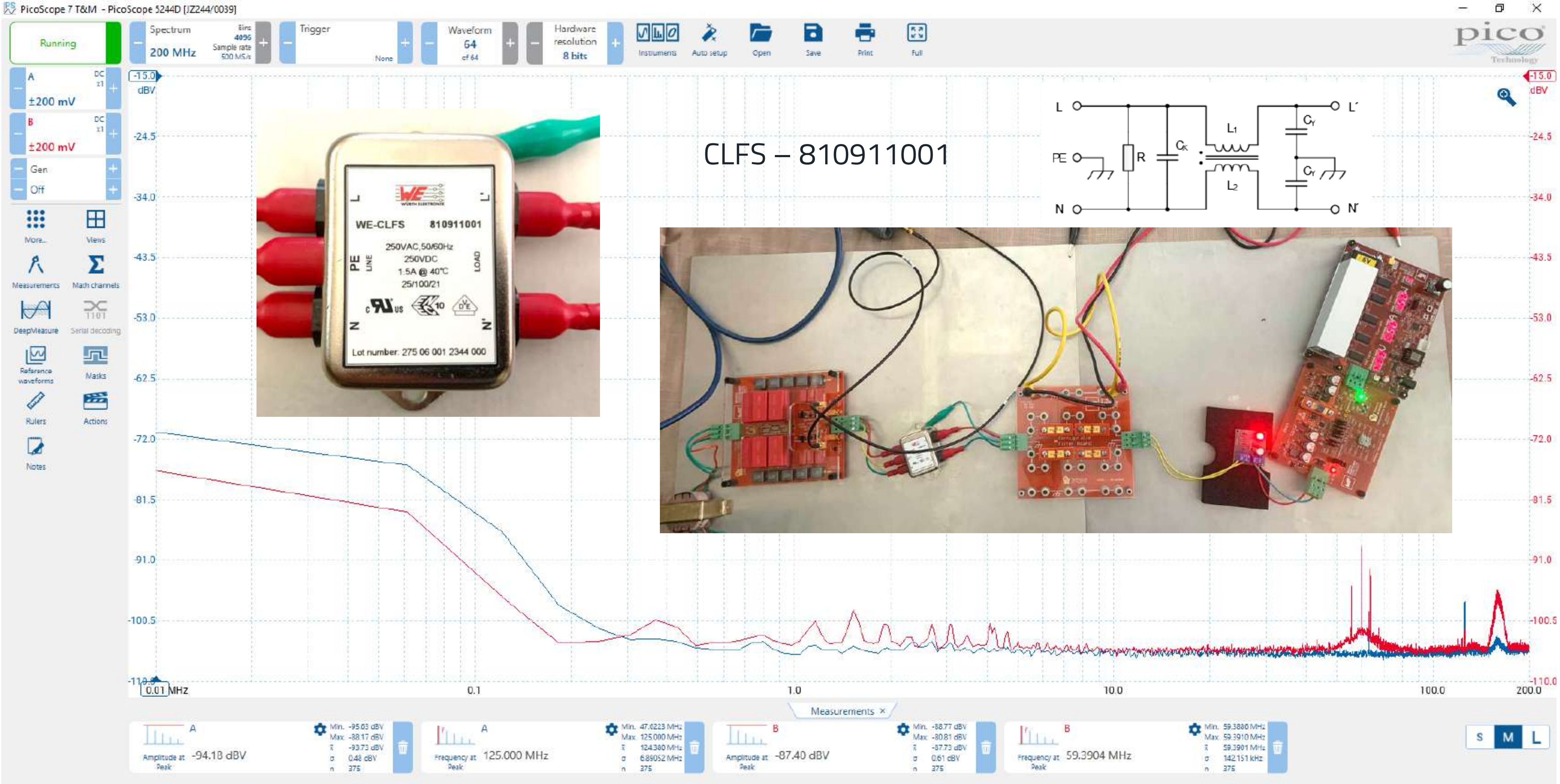




REDEXPERT®

WITH CLFS

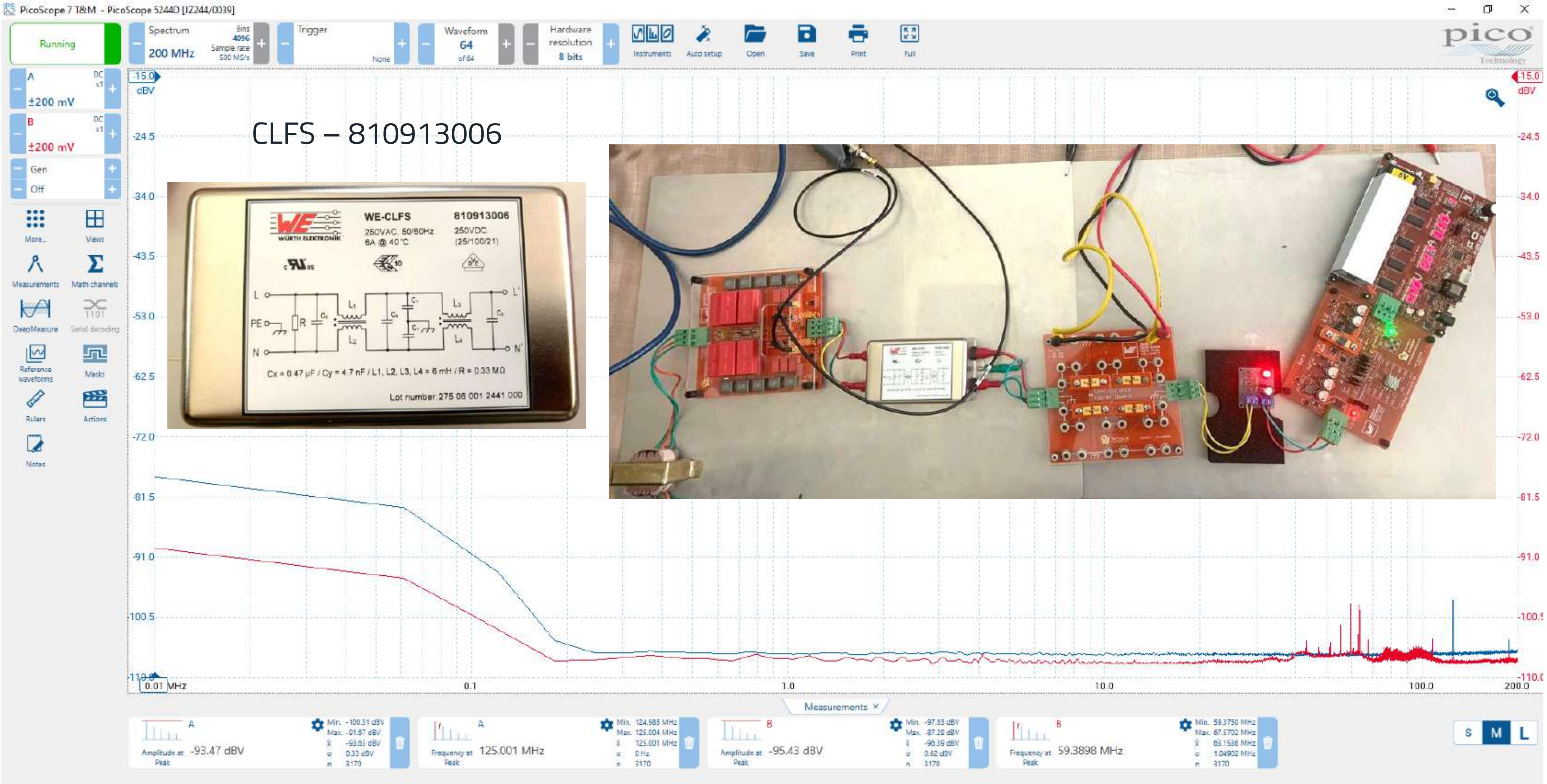
CM DM



REDEXPERT®

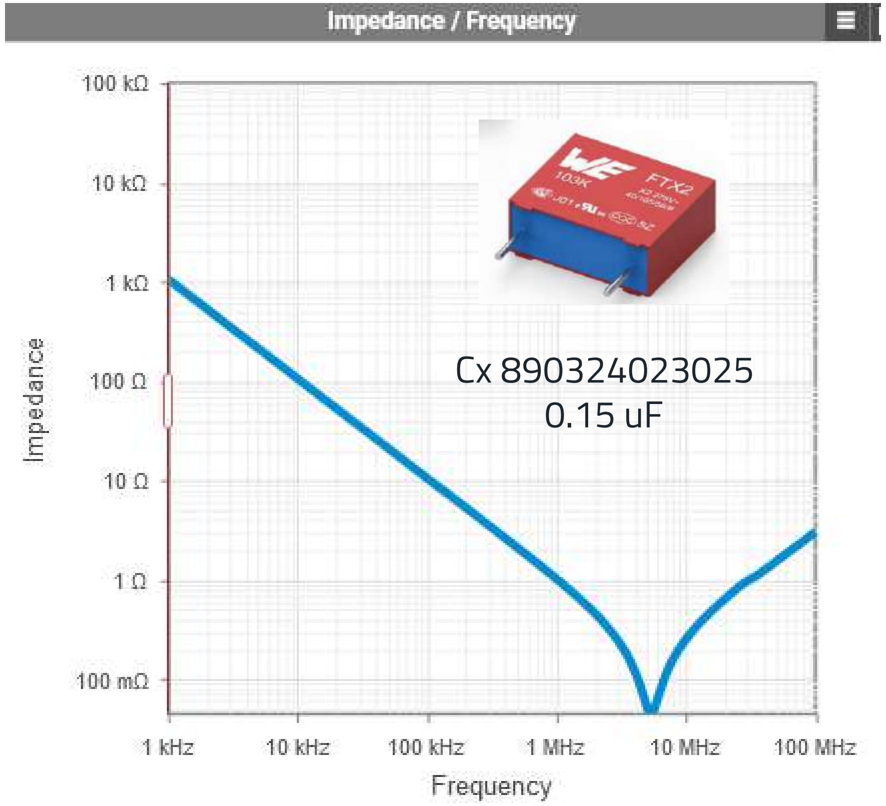
WITH CLFS

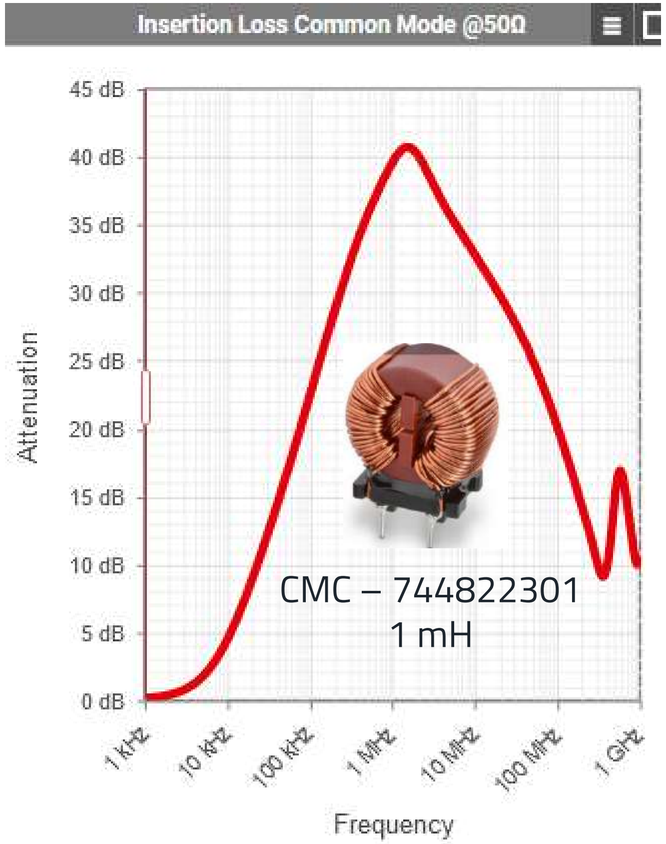
CM DM

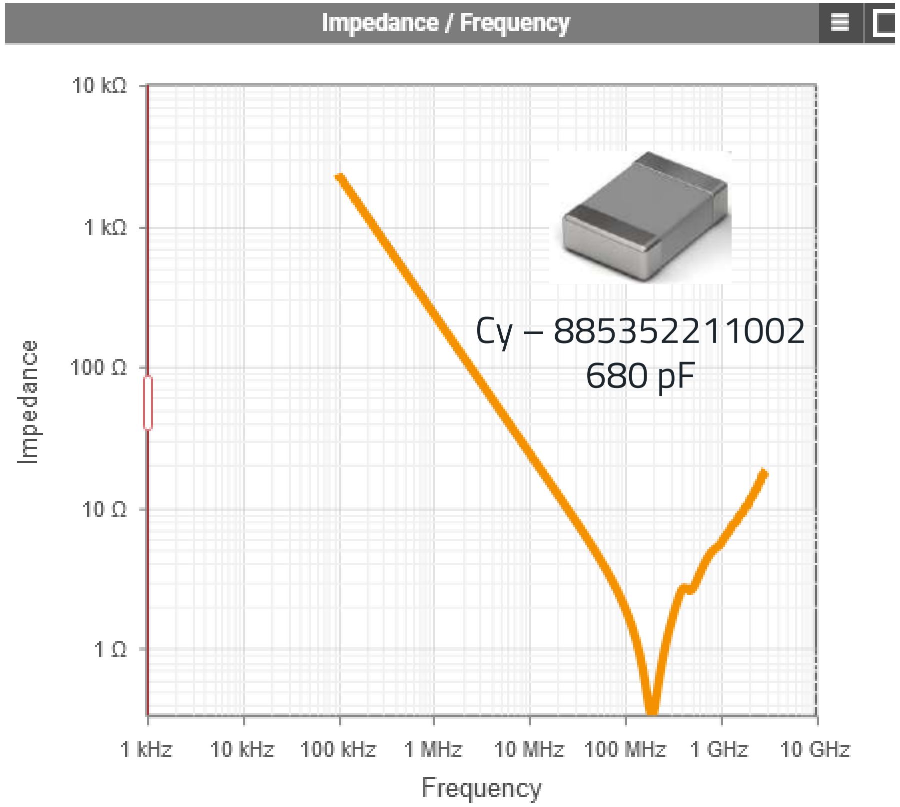


REDEXPERT

With discrete CX – CMC - CY

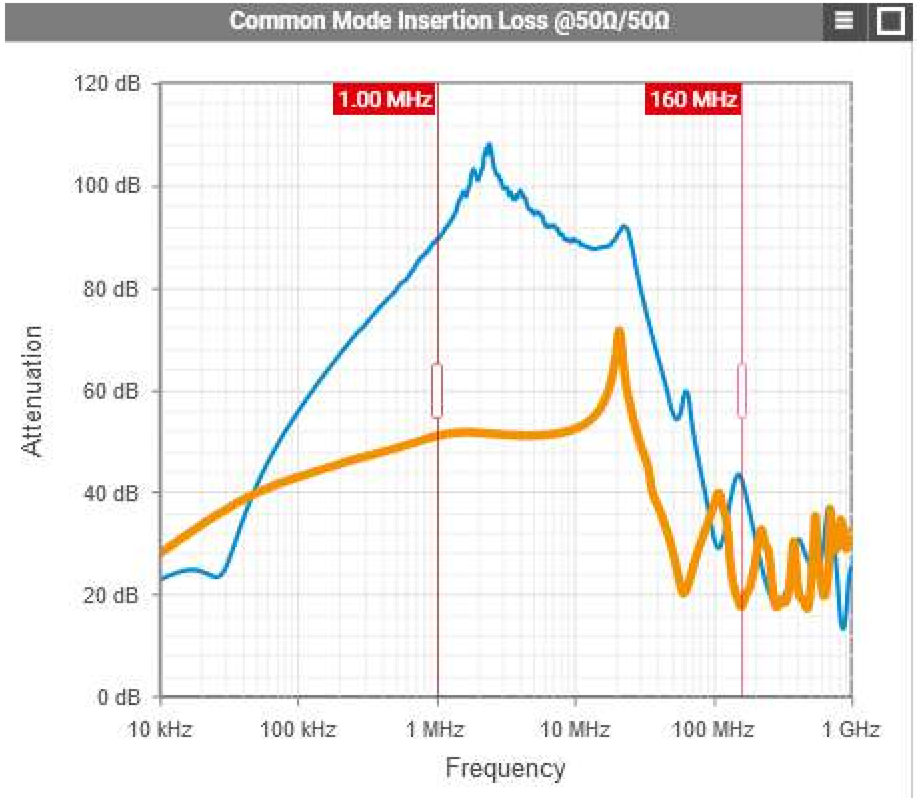


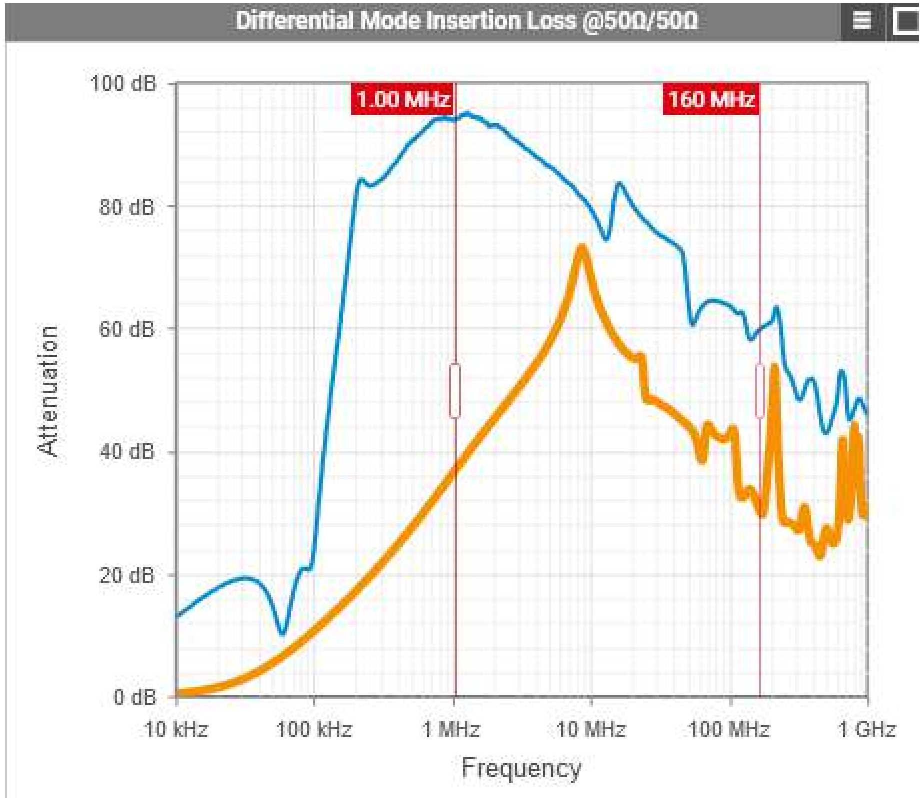


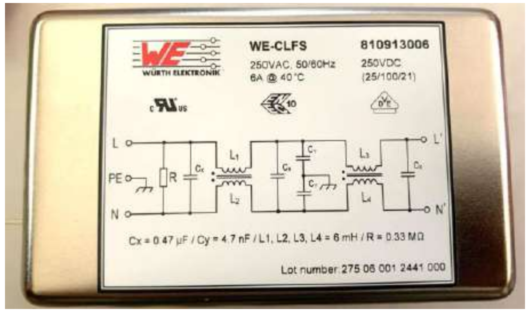


REDEXPERT

With CLFS







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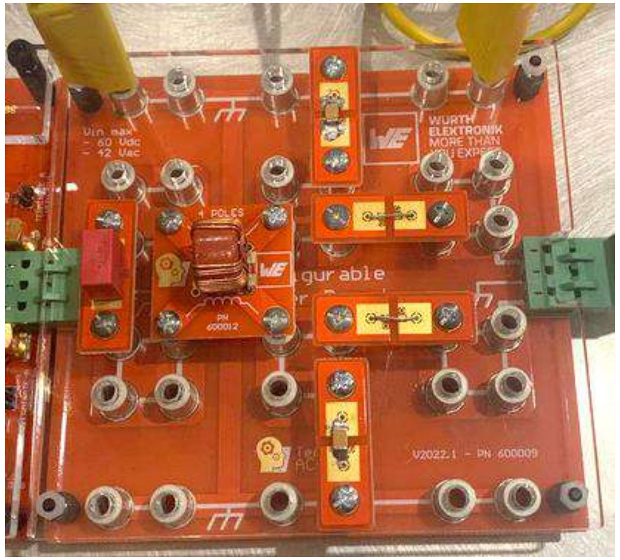
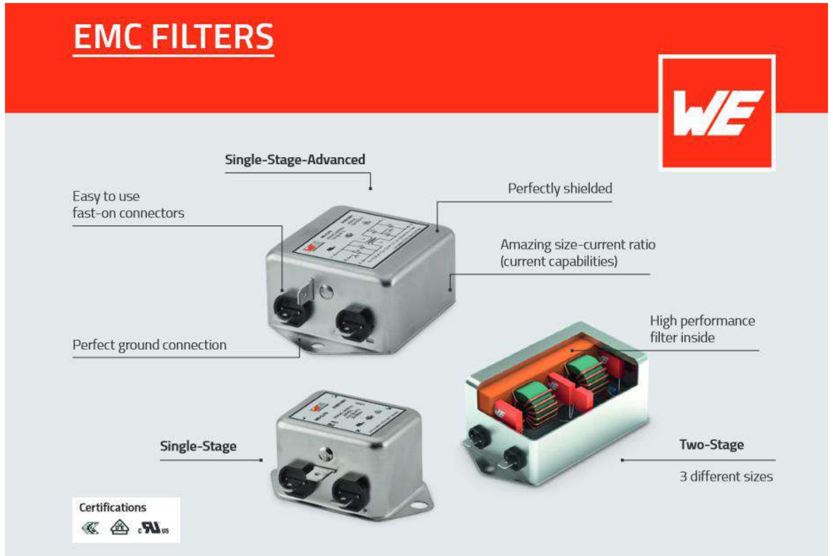
CONCLUSION

- Sufficient filtering is obtained with discrete CX-CMC-CY configuration, like the CLFS single-stage diagram, for the given test setup.
- Simulation and REDEXPERT data support the discrete filters measurement results, having enough attenuation on the suspected frequencies.
- With proper component selection, using discrete components can also have favorable filtering results like the CLFS filters.
- Need to ensure appropriate grounding setup to have optimized measurements.





THANK YOU

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