ANOTHER CONDUCTED EMISSIONS DEMO?

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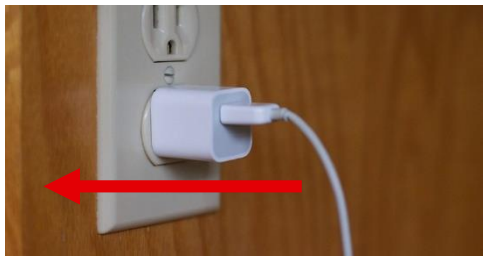
Technical Academy– Applications Engineer

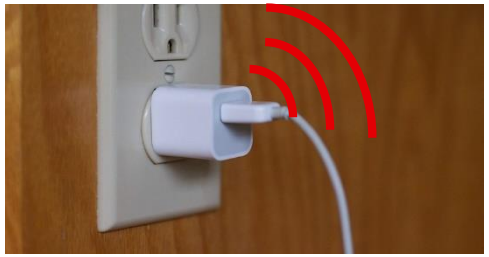
AGENDA

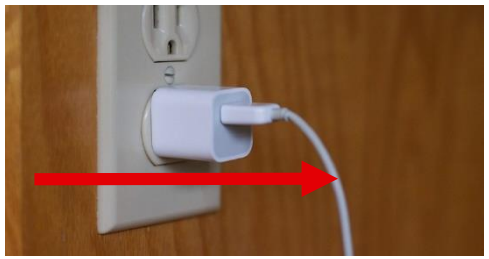
- Fundamentals of conducted emissions
- Test Setup (Flyback board, load, LISN, ground plane, test receiver)
- CMC Selection
  - Comparison of different core materials
- X Capacitors
- Y Capacitors
- Will the filter design pass?

Electromagnetic Compatibility

- Emission
  - Conducted
  - Radiated
- Immunity
  - Conducted
  - Radiated

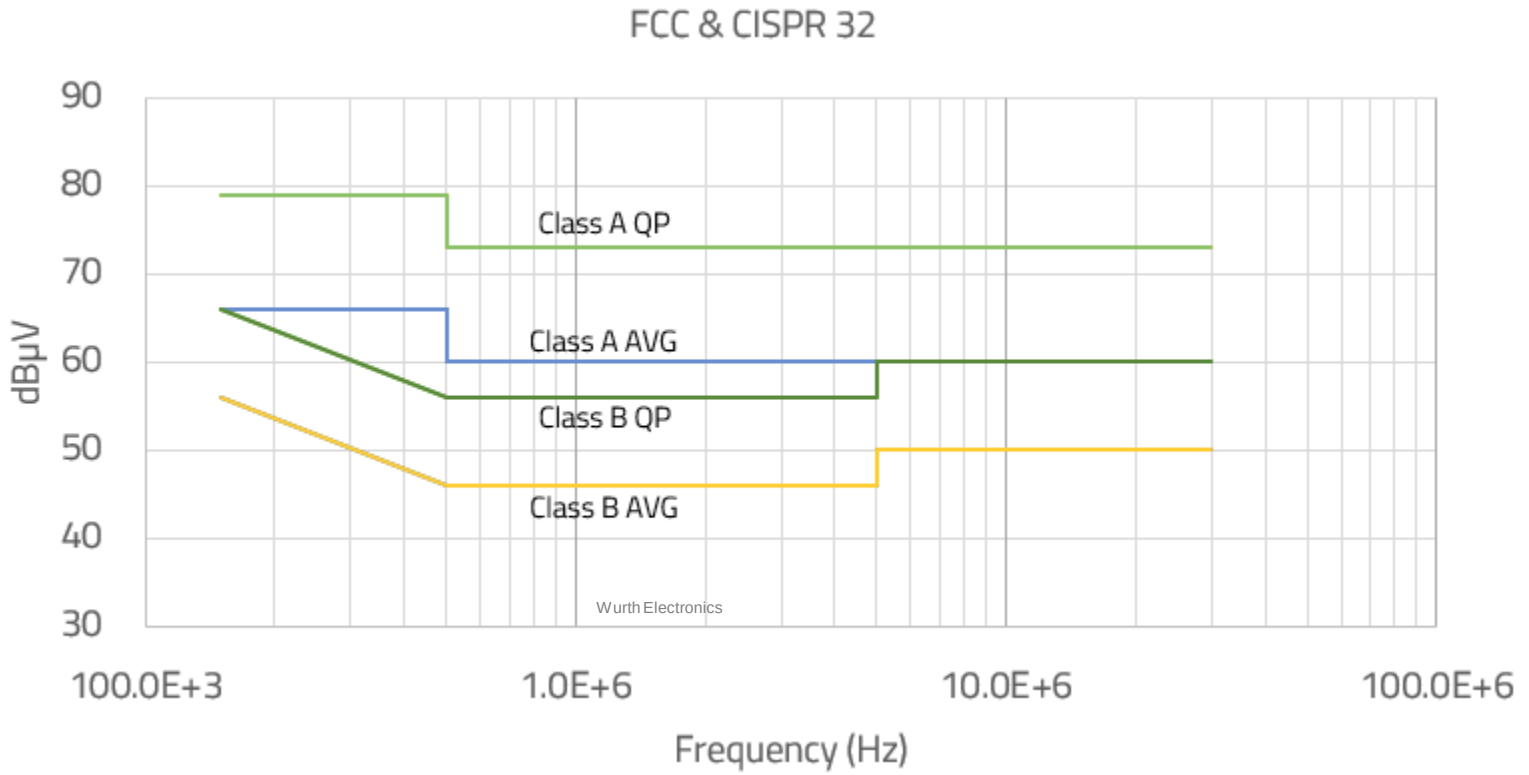




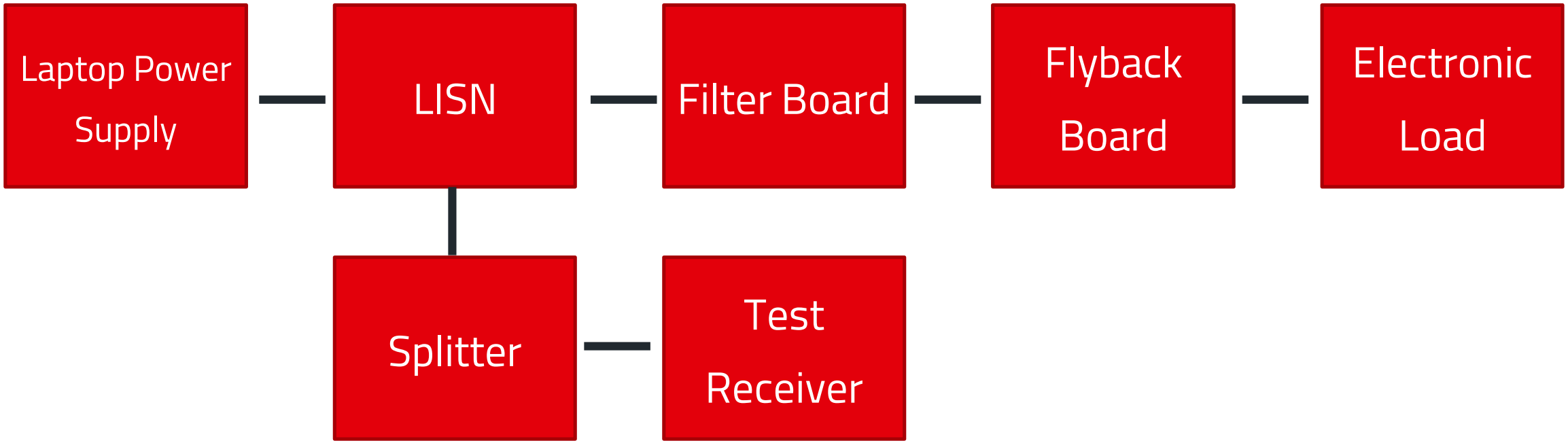


CONDUCTED EMISSIONS LIMITS

- Limit lines shown for Quasipeak and average.
- Why Care?
  - If you want to sell your product, you will need to comply with these limits otherwise you could face large financial penalties. Ignorance is not a defense!



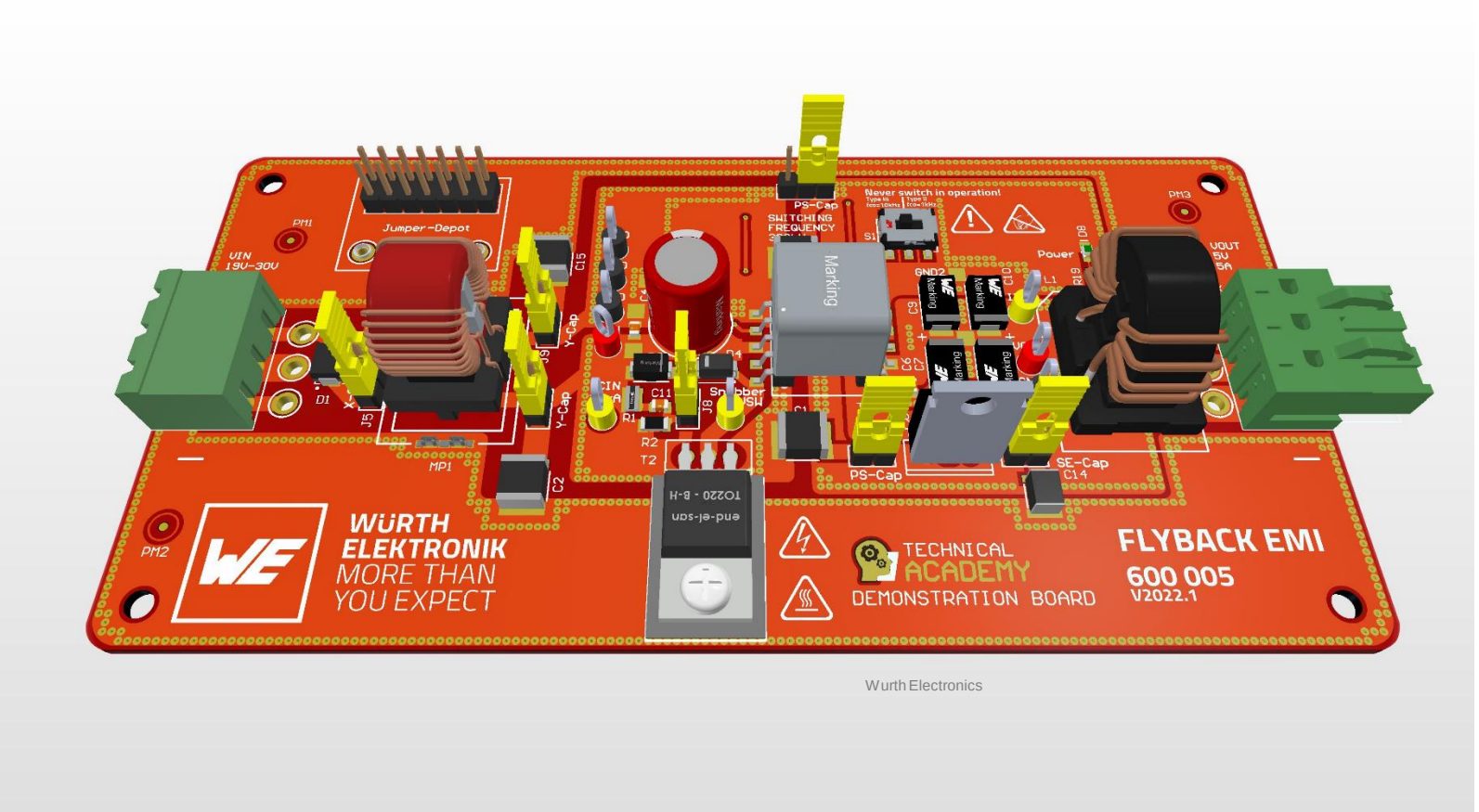
TEST SETUP



Picture Caption

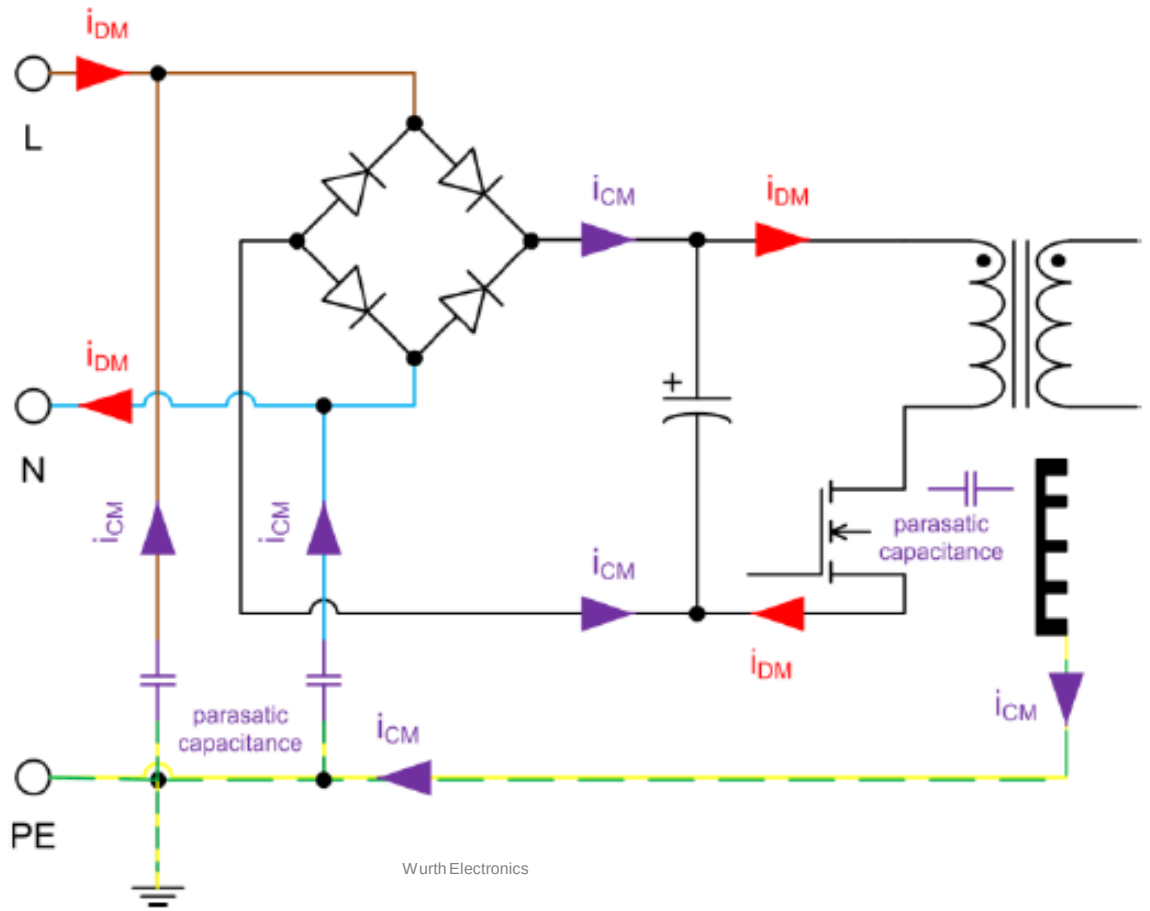
FLYBACK BOARD

- DC/DC Flyback-Converter CCM (Continuous Conduction Mode)
  - U_{in} = 19V (19-30V)
  - U_{out} = 5V
  - $I_{out,max}$ = 4A (20W)
  - f_{sw} ≈ 300kHz
  - Efficiency ≈ 90%
- IC: ADP1071-2 (Analog Devices)
  - with synchronous rectifier
- Transformer: 749119550
- MOSFETs in TO220-package



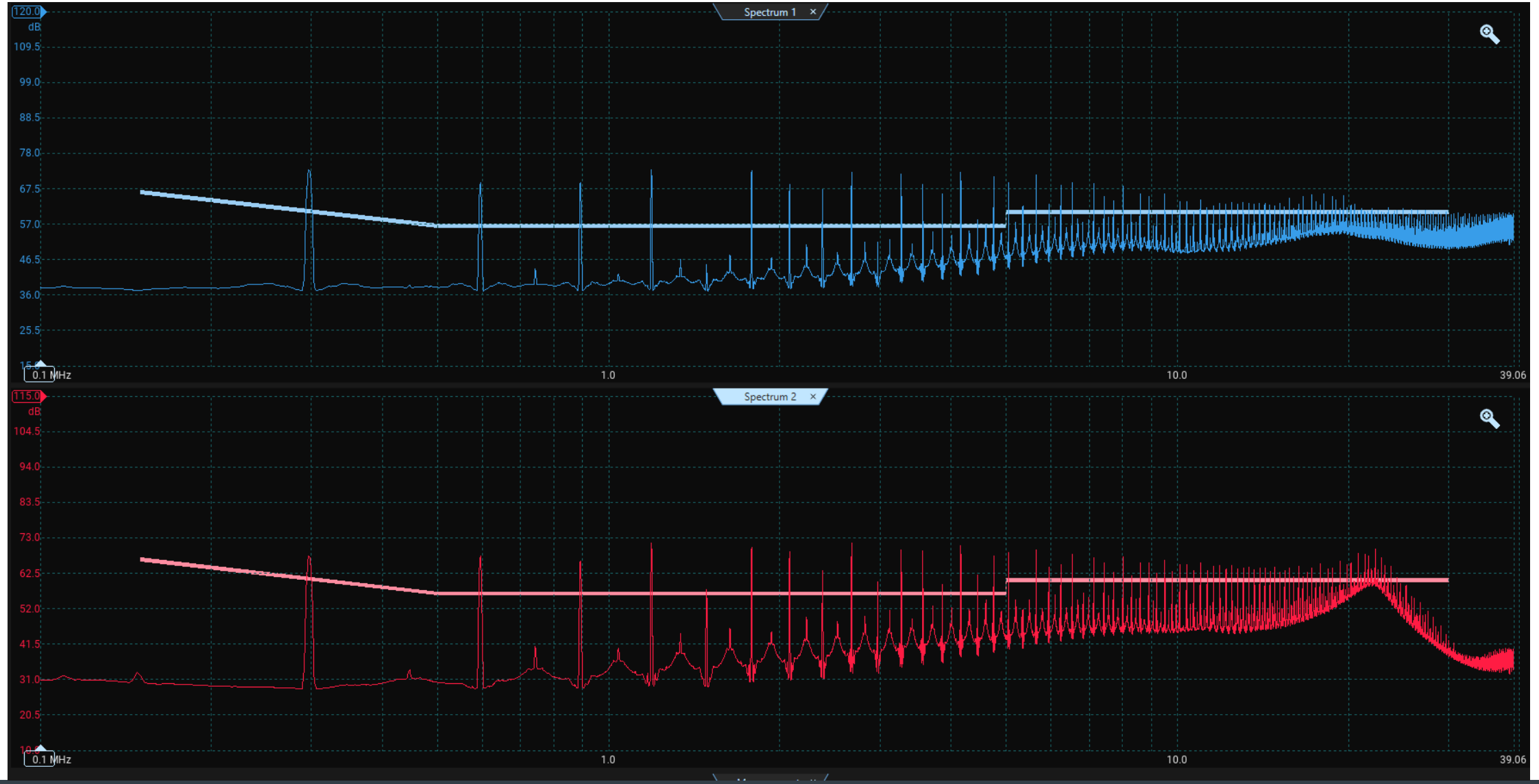
BASIC CONCEPTS

- Differential Mode
- Common Mode

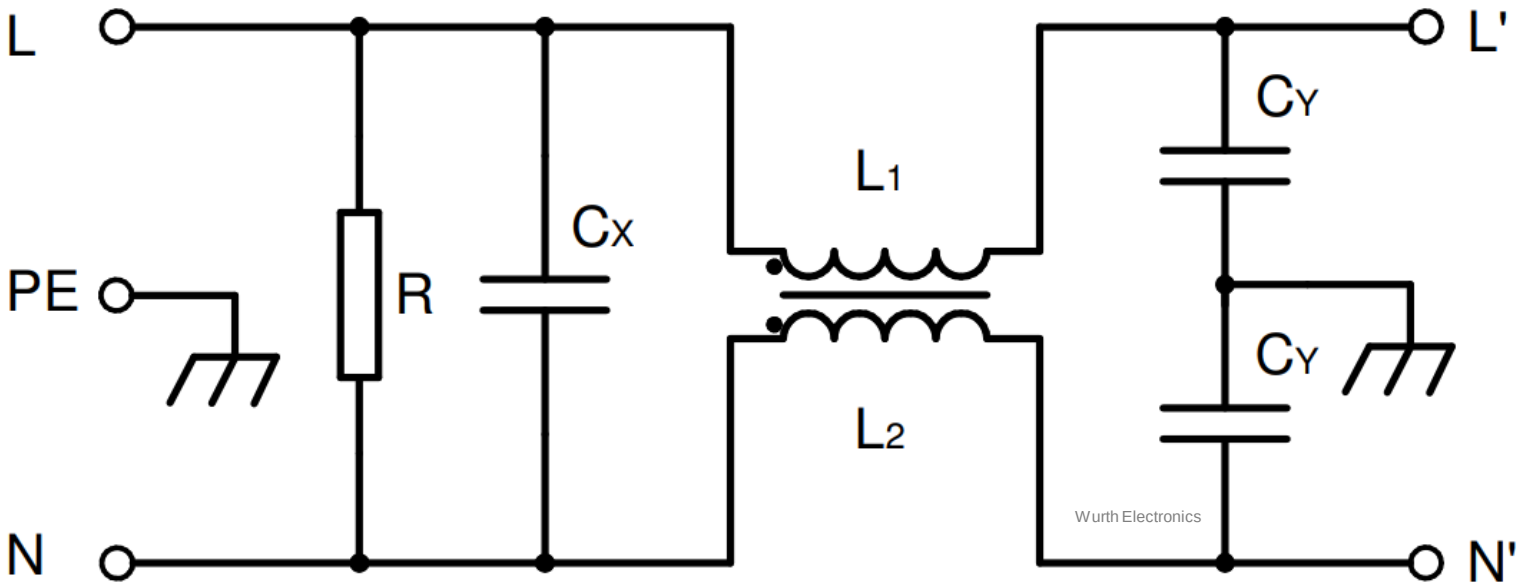


BASELINE TEST

BLUE IS CM AND RED IS DM



BASIC LINE FILTER



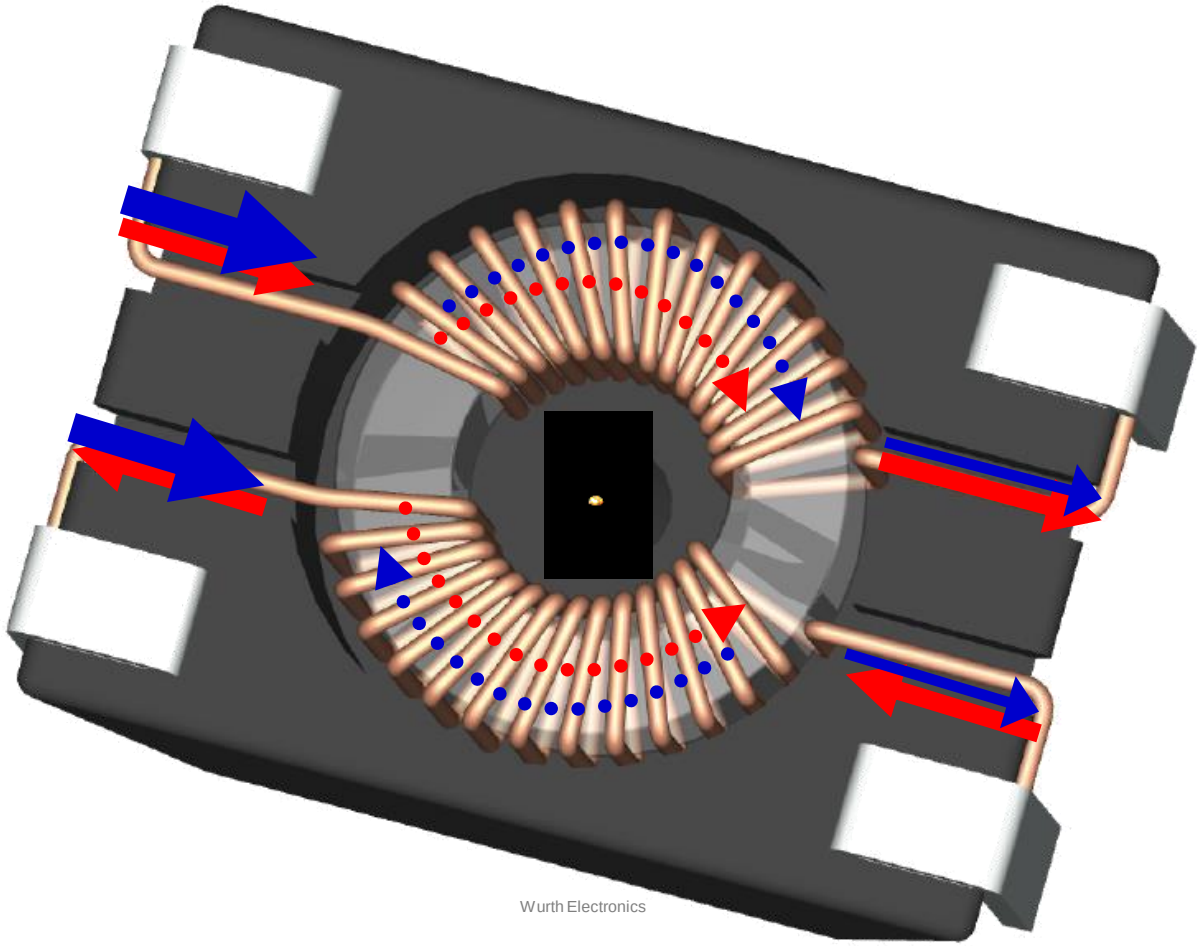
Add varistor between Line and Neutral for overvoltage protection!

CMC SELECTION

WHAT IS A COMMON MODE CHOKE?

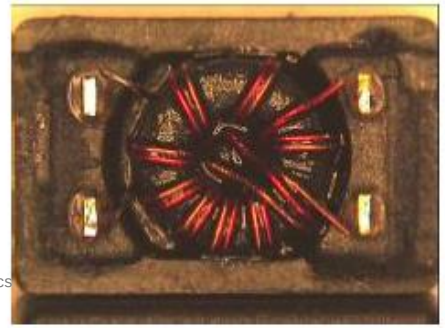
- It is a Bi-directional filter
  - From device to outside environment
  - From outside environment to inside device
- Intended Signal - Differential mode
- Interference Signal (noise) – Common Mode

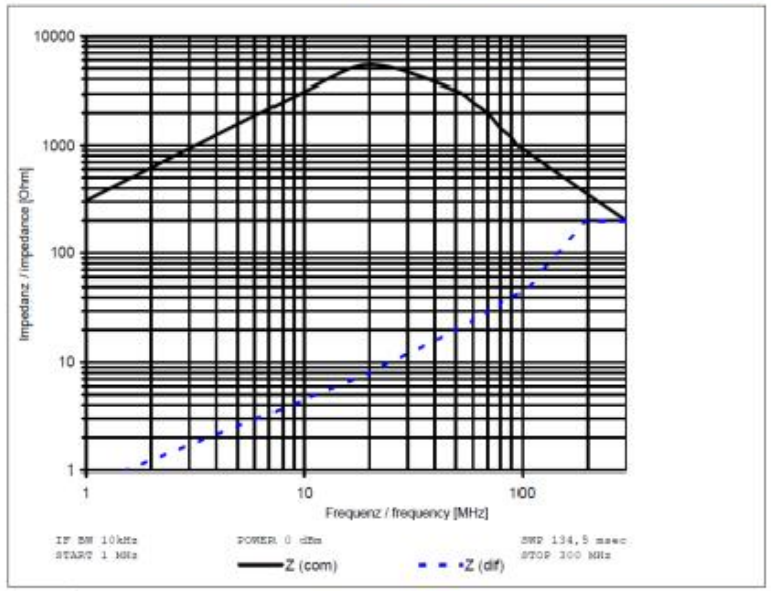
- Conclusion:
- “almost” no affect the signal - Differential mode
- high attenuation to the interference signal (noise) – Common Mode



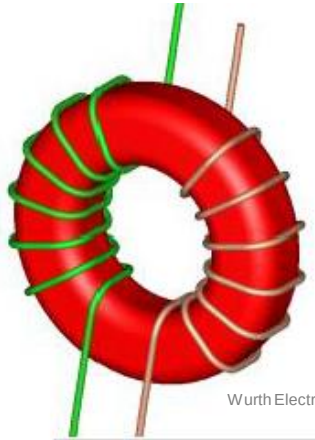
CHOOSING A CMC

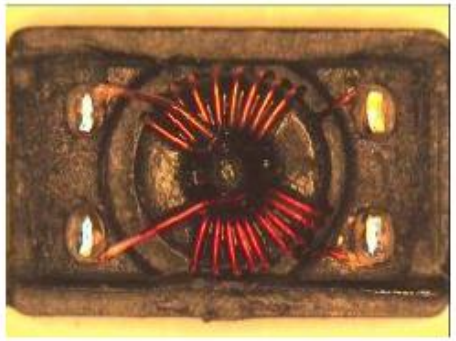
bifilar

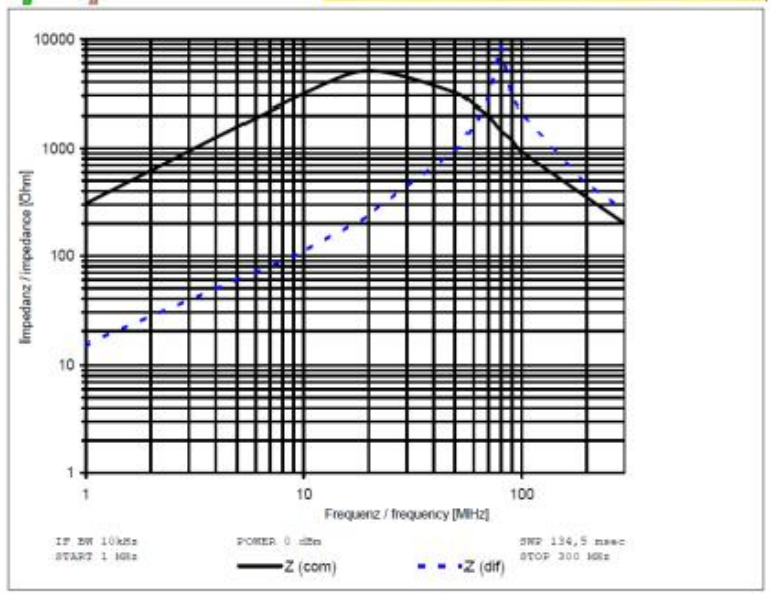




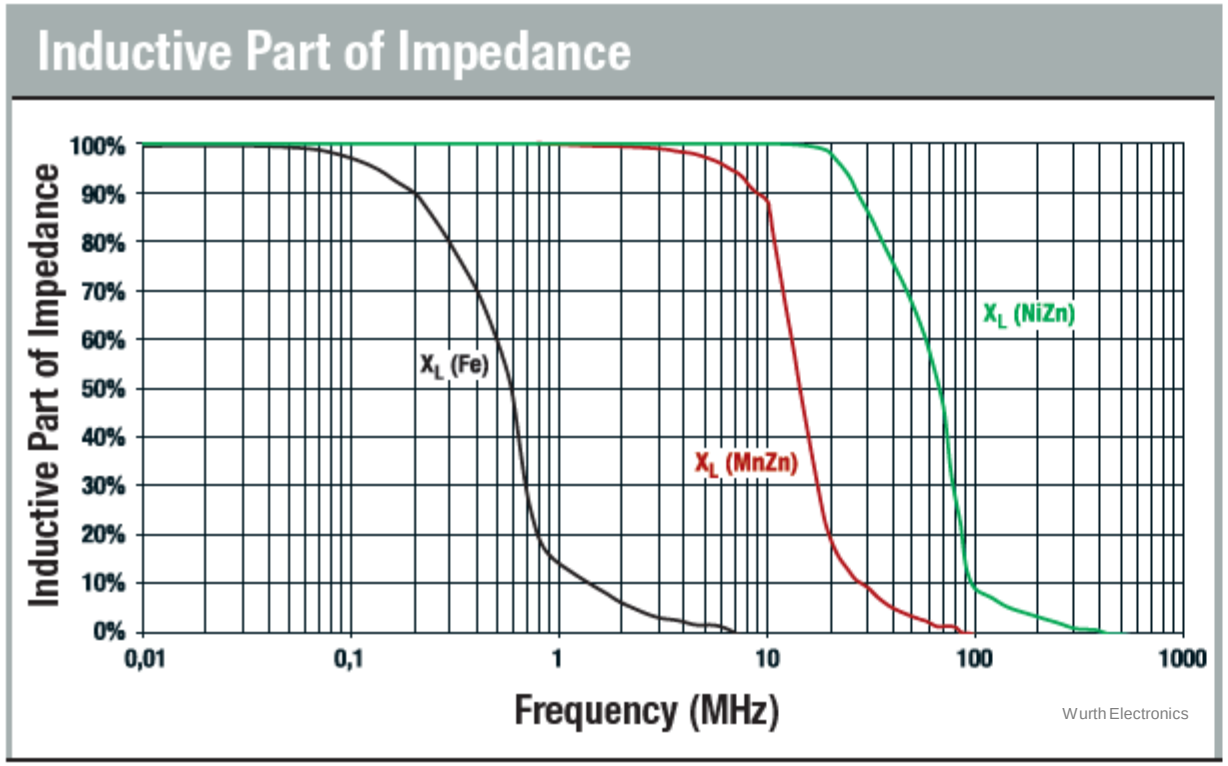
sectional

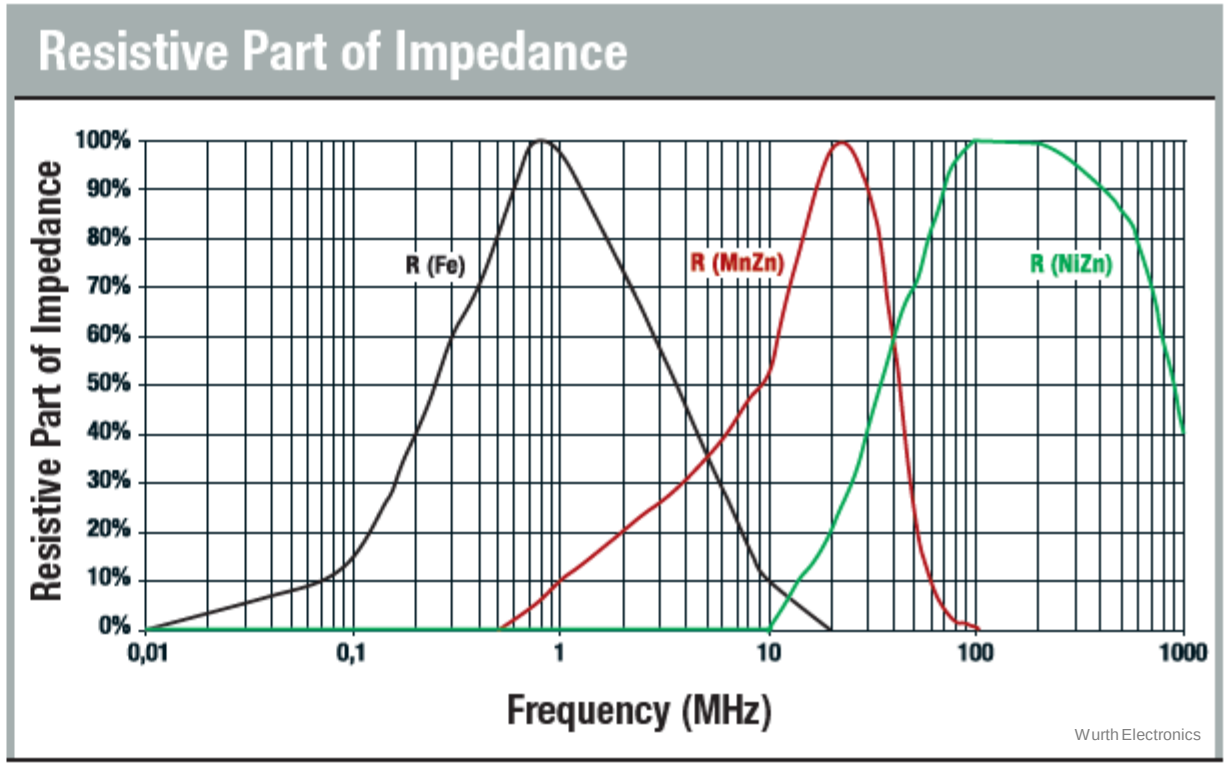






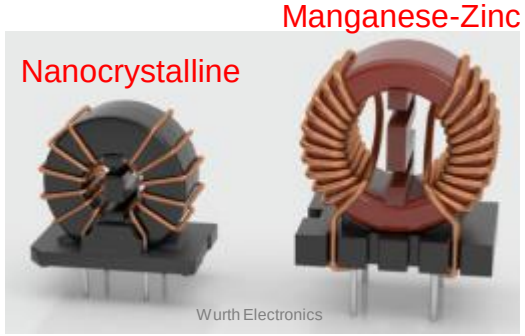
CHOOSING A CMC - CORE MATERIAL

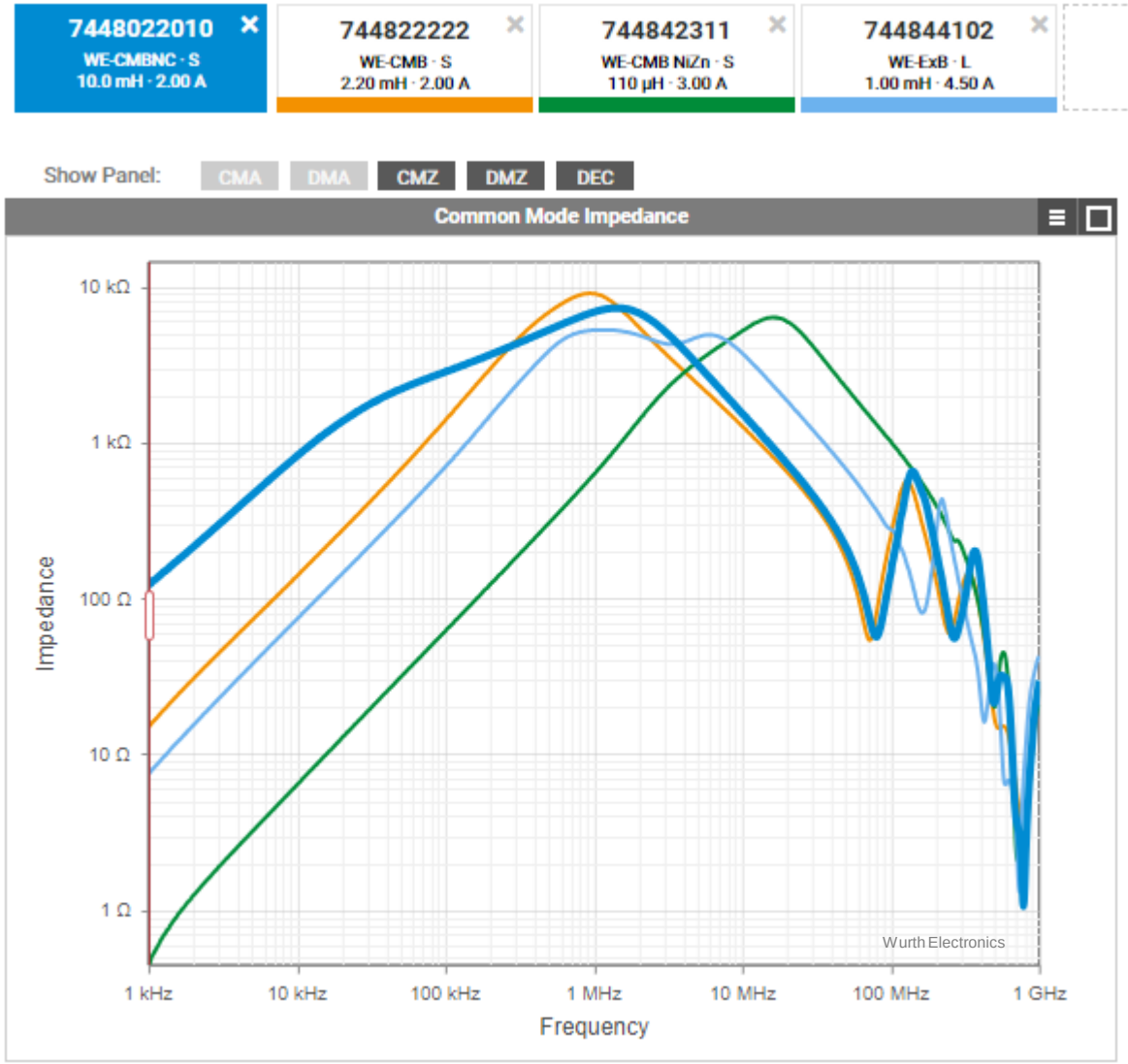




CORE MATERIALS COMPARISON

- MnZn
- NiZn
- Both together
- Nanocrystalline





WÜRTH ELEKTRONIK

REDEXPERT CM Chokes for Mains Power Lines

System

Filters: Is selected

Order Code	Series	Size	Spec	V_R	L_0	I_R	$Z_{CM, Min}$ @300 kHz	Lines	T_{op}	V_T	Assembli...	L	W	H	L_S	Certificates
744822222	WE-CMB	S		250 V	2.20 mH	2.00 A	4.48 kΩ	2	125°C	1.50 kV	THT	17.5 mm	13.0 mm	22.0 mm		
7448022010	**WE-CMBNC**	**S**		**250 V**	**10.0 mH**	**2.00 A**	**4.27 kΩ**	**2**	**125°C**	**1.50 kV**	**THT**	**18.0 mm**	**14.0 mm**	**22.0 mm**		
744821201	WE-CMB	XS		250 V	1.00 mH	2.00 A	1.90 kΩ	2	125°C	1.50 kV	THT	15.0 mm	7.50 mm	18.0 mm		
7448012002	WE-CMBNC	XS		250 V	1.60 mH	2.00 A	1.00 kΩ	2	125°C	1.50 kV	THT	14.0 mm	7.50 mm	16.0 mm		
744842311	WE-CMB NiZn	S		250 V	110 µH	3.00 A	183 Ω	2	125°C	1.50 kV	THT	18.5 mm	14.5 mm	22.0 mm		
744841247	WE-CMB NiZn	XS		250 V	47.0 µH	2.00 A	91.1 Ω	2	125°C	1.50 kV	THT	16.0 mm	7.50 mm	17.5 mm		

7448012002 · WE-CMBNC · XS · 1.60 mH · 2.00 A

7448022010 · WE-CMBNC · S · 10.0 mH · 2.00 A

744821201 · WE-CMB · XS · 1.00 mH · 2.00 A

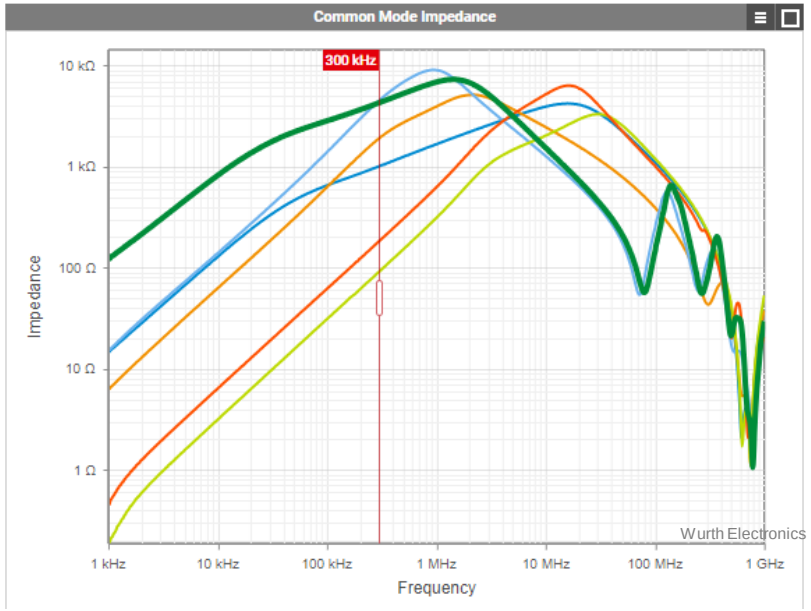
744822222 · WE-CMB · S · 2.20 mH · 2.00 A

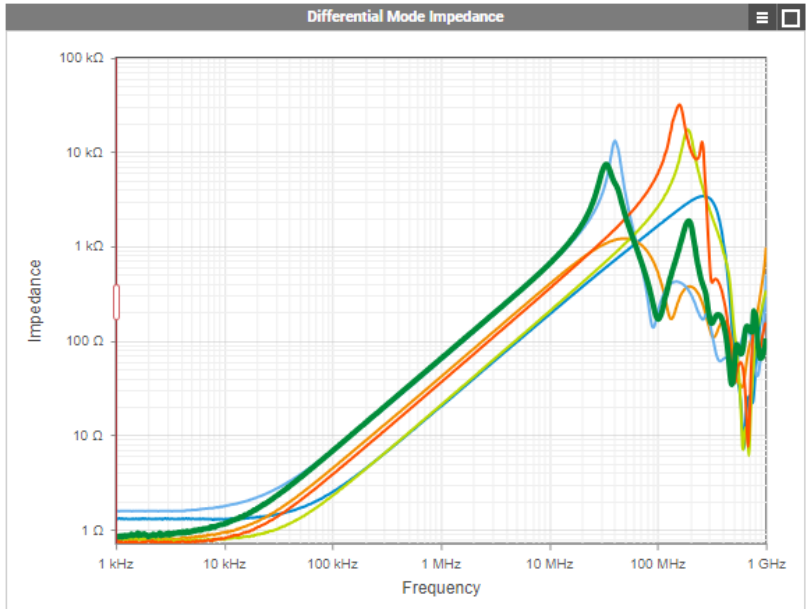
744841247 · WE-CMB NiZn · XS · 47.0 µH · 2.00 A

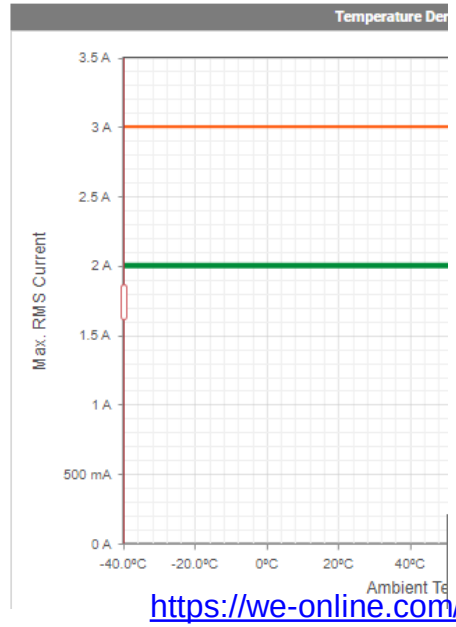
744842311 · WE-CMB NiZn · S · 110 µH · 3.00 A

Click and type or drop an Order Code here

Show Panel: CMA DMA CMZ DMZ DEC



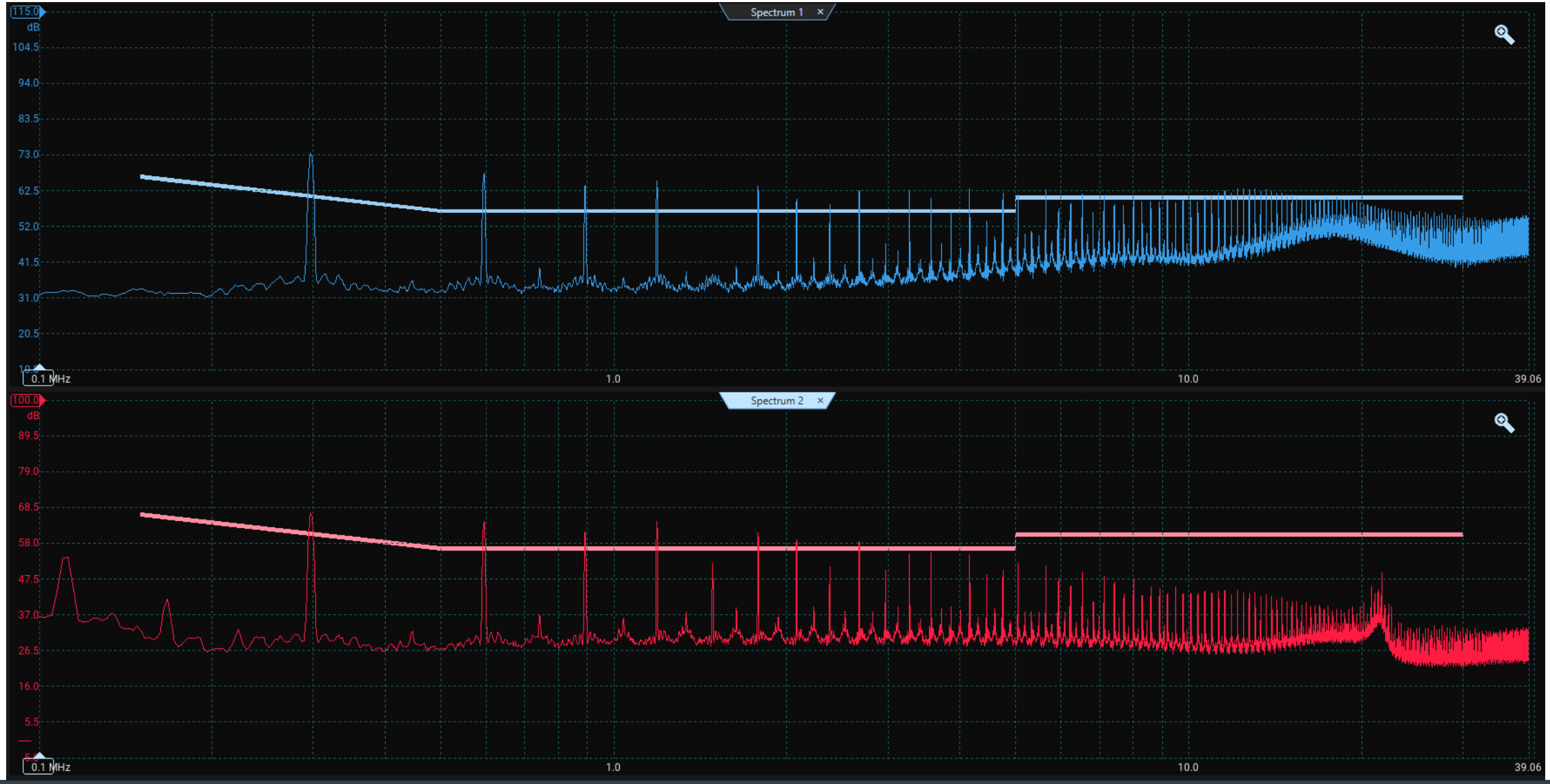




https://we-online.com/re/5oCBbSaH

CMC DEMO

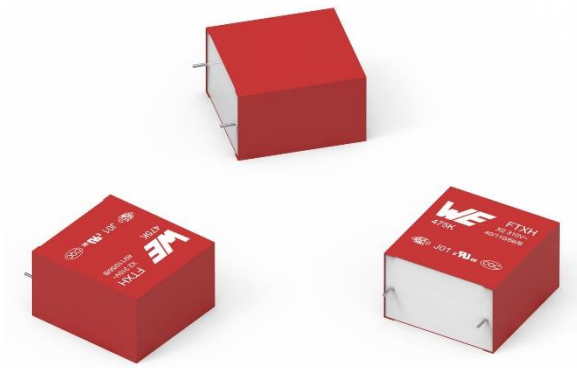
BLUE IS CM AND RED IS DM

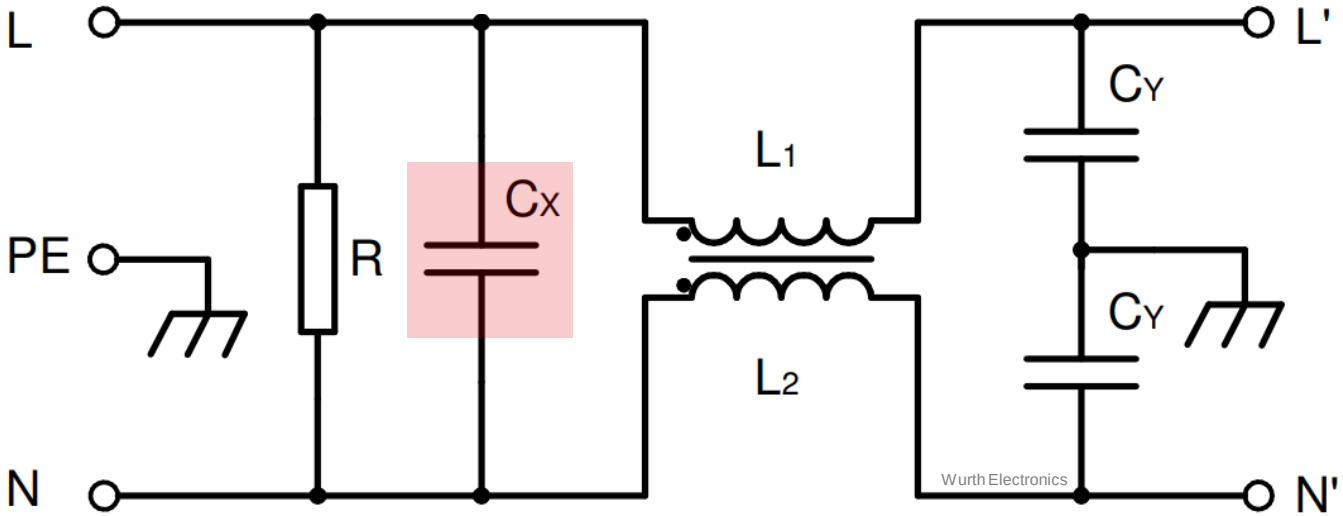


X CAPACITOR SELECTION

X CAPACITORS

- X capacitors are meant to filter differential noise.
- Need to meet special safety criteria since they are connected to between line and neutral.
- X1 - Peak Impulse 4 kV
- X2 – Peak Impulse 2.5 kV
- X class capacitors can be substituted by Y class capacitors of the same or higher voltage rating.





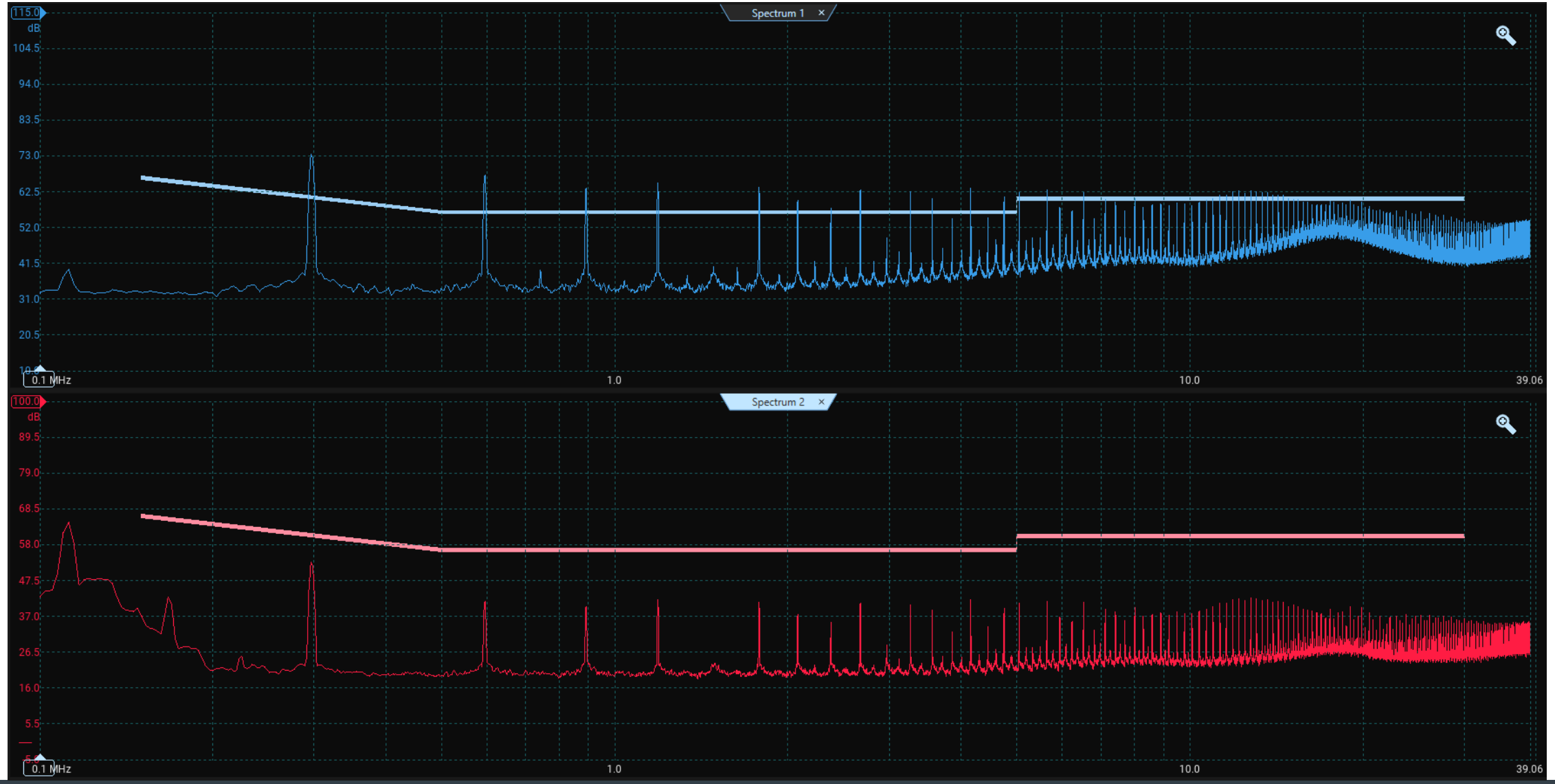
CALCULATING X CAPACITOR VALUE

Estimating Differential (Leakage) Inductance

- $f_{DM} = \frac{1}{2\pi\sqrt{L_{DM} \cdot C_x}}$
- $C_x = \frac{1}{(2\pi \cdot f_{DM})^2 \cdot L_{DM}} = \frac{1}{(2\pi \cdot 25kHz)^2 \cdot 10mH \cdot 0.025}$
- $C_x = 162nF$

X capacitor DEMO

BLUE IS CM AND RED IS DM



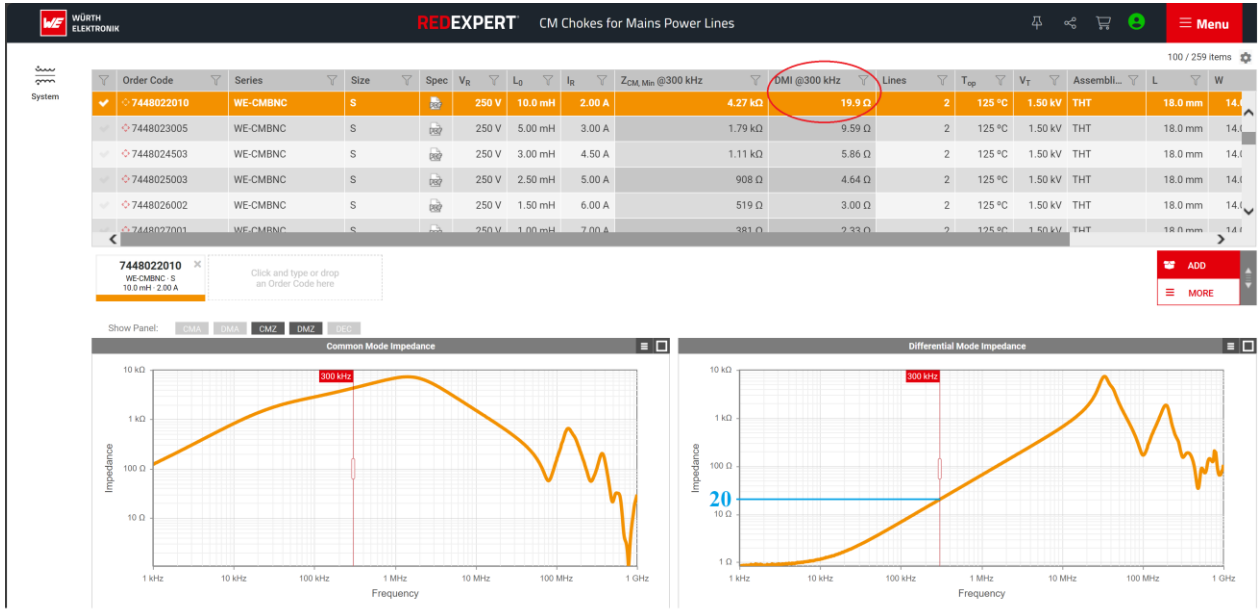
WHERE DID MY IMPEDANCE GO?

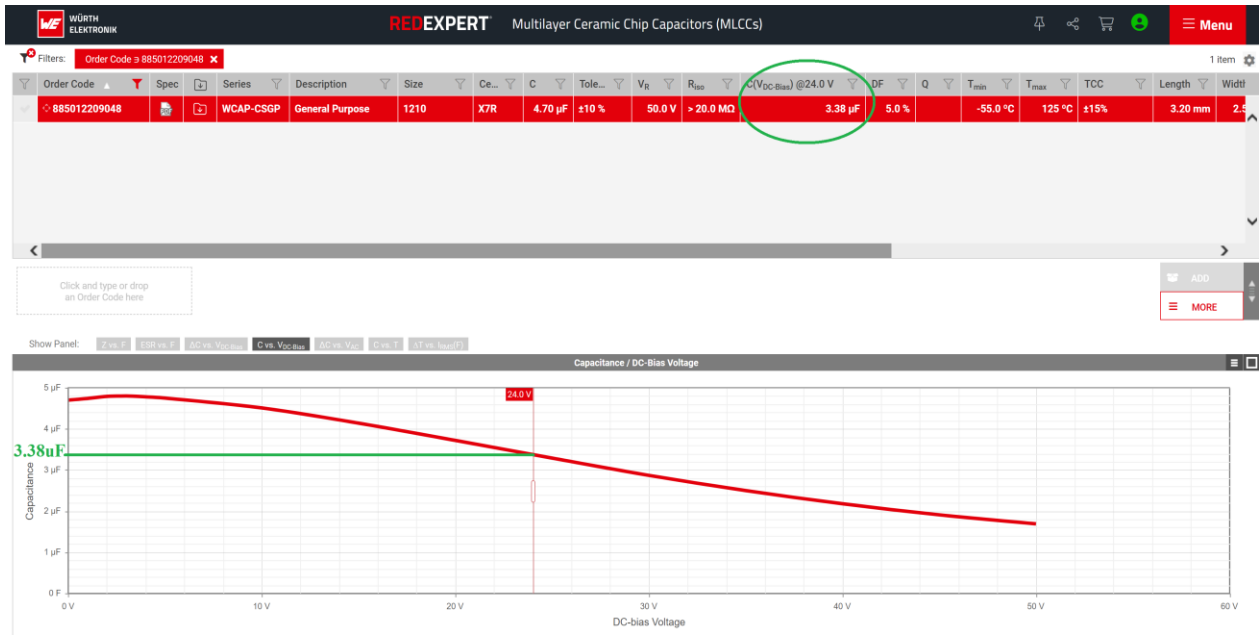
CALCULATING X CAPACITOR VALUE

Calculating Differential (Leakage) Inductance

- $L_{DM} = \frac{Z_{DM}}{2\pi \cdot f_{DM}} = \frac{20}{2\pi * 300KHz} = 10\text{uH}$
- $C_x = \frac{1}{(2\pi \cdot f_{DM})^2 \cdot L_{DM}}$

  $= \frac{1}{(2\pi \cdot 25kHz)^2 \cdot 10uH}$
- $C_x = 4.7uF$
- $C_{x\_Effective} = 3.4uF$





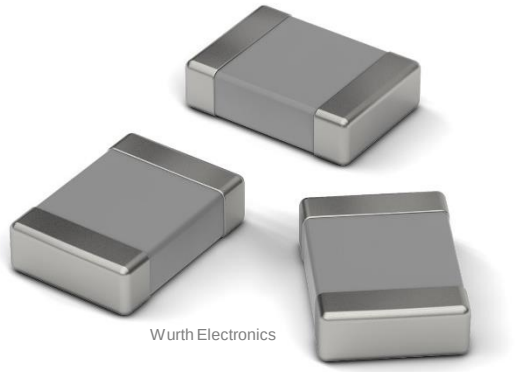
CALCULATING X CAPACITOR VALUE

So which One is it?

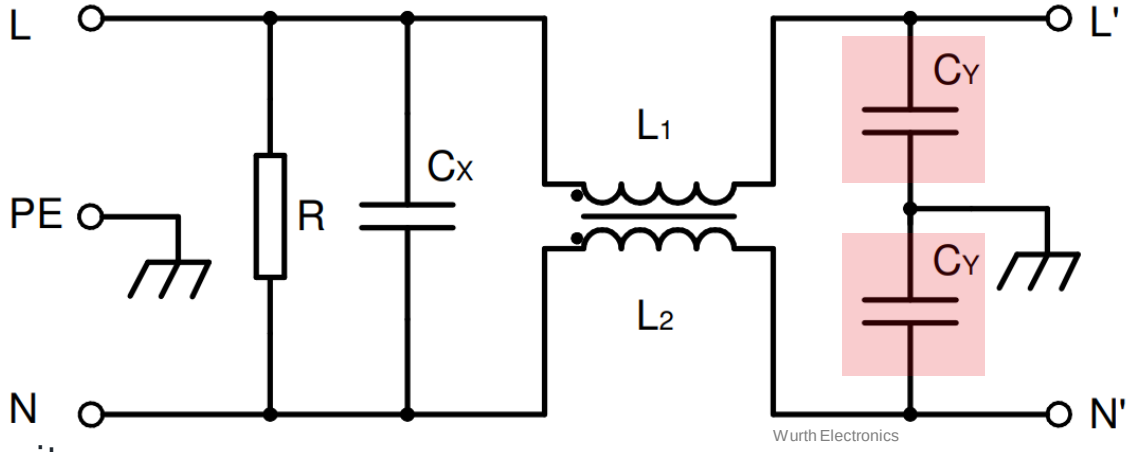
- $f_{Cut-off\_DM} = \frac{1}{2\pi\sqrt{L_{DM} \cdot C_x}}$
- $f_{Cut-off\_DM\_Estimate} = \frac{1}{2\pi\sqrt{10uH \cdot 162nF}} = 130\text{KHz}$
- $f_{Cut-off\_DM\_Calculated} = \frac{1}{2\pi\sqrt{10uH \cdot 3.4uF}} = 26.2\text{KHz}$
- $Att_{DM\_Estimate} = \log(\frac{f_{SW}=300KHz}{f_{DM\_Estimate}=130KHz}) \cdot 40\text{dB} = 14\text{dB}$
- $Att_{DM\_Calculated} = \log(\frac{f_{SW}=300KHz}{f_{DM\_Estimate}=26KHz}) \cdot 40\text{dB} = 42\text{dB}$

Y CAPACITOR SELECTION

Y CAPACITORS



- Y capacitors filter common mode noise
- Need to meet special safety criteria since they are connected to earth.
- Y1
  - Double or Reinforced Insulation
  - 0-500V rated voltage
  - 8 kV peak impulse voltage
- Y2
  - Basic or supplementary insulation
  - 150-500V rated voltage
  - 5 kV peak impulse voltage
- Y4
  - Basic or supplementary insulation
  - 0-150V
  - 2.5 kV peak impulse voltage



- Y class capacitors can only be substituted by Y class capacitors of the same or higher voltage rating!

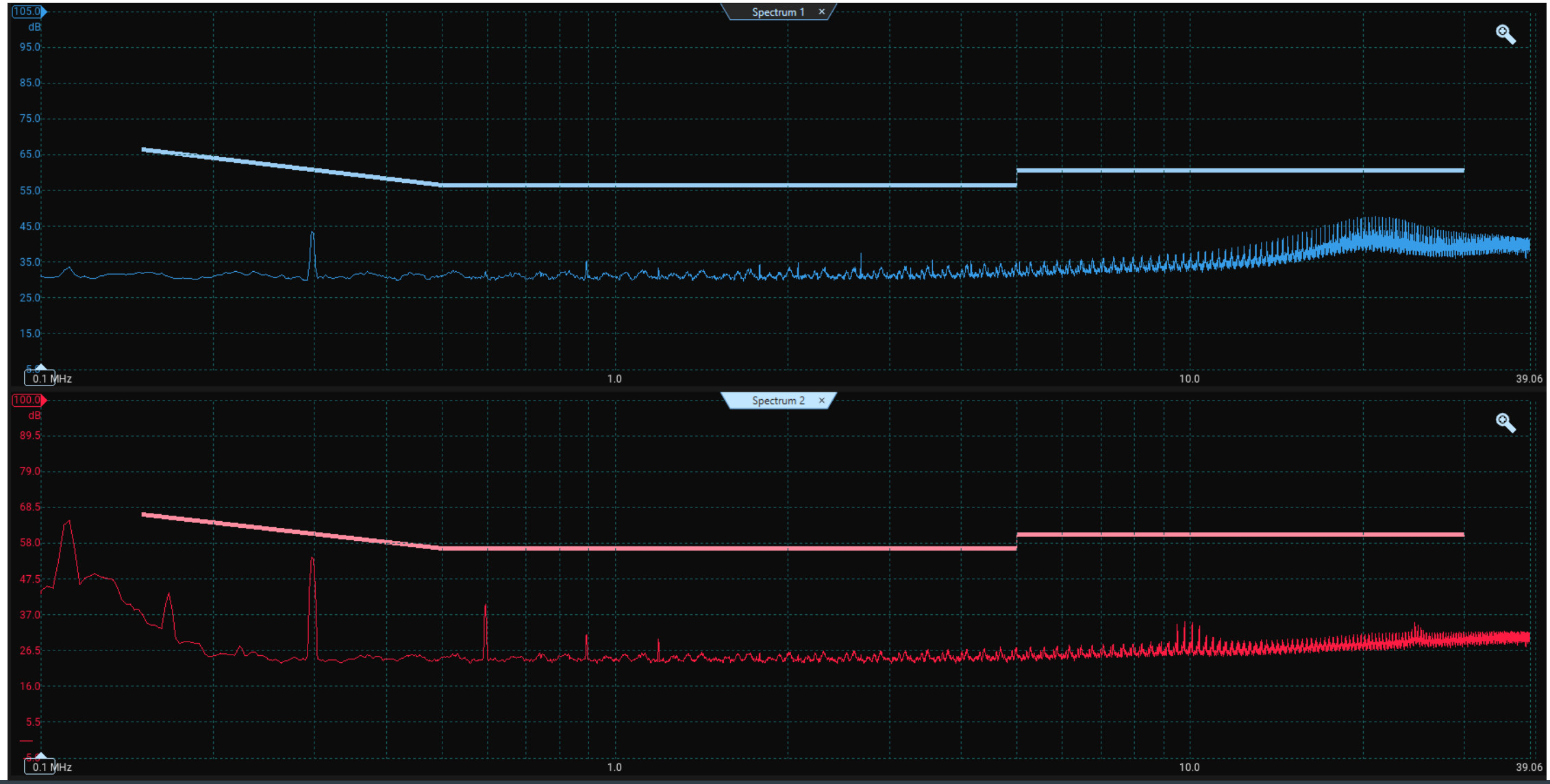
CALCULATING Y CAPACITOR VALUE

- $f_{CM} = \frac{1}{2\pi\sqrt{L_{CM} \cdot C_y}}$
- $C_y = \frac{1}{(2\pi \cdot f_{CM})^2 \cdot L_{CM}} = \frac{1}{(2\pi \cdot 25kHz)^2 \cdot 10mH}$
- $C_y = 4100pF$

Pay attention to leakage current limits for your standard!

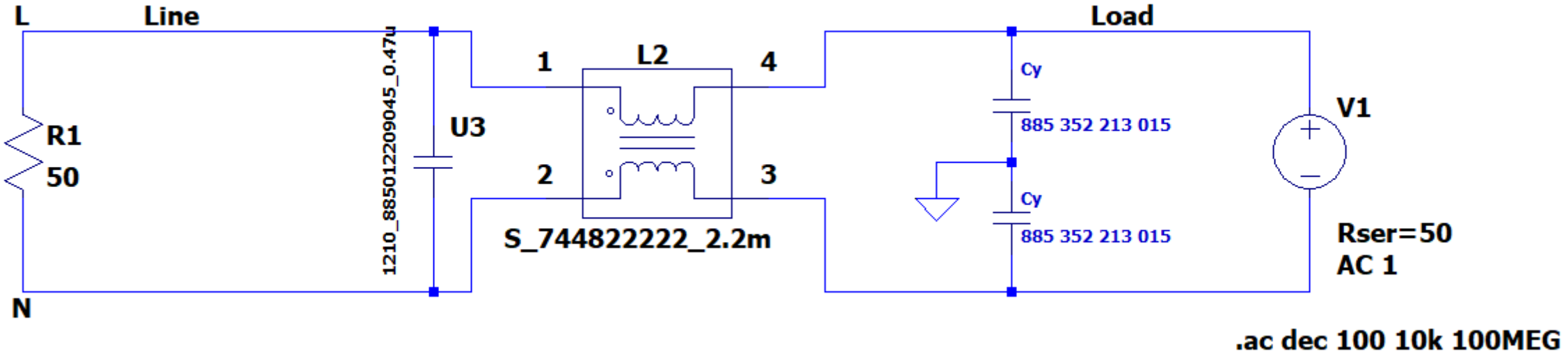
Y capacitor DEMO

BLUE IS CM AND RED IS DM



FILTER IN LT SPICE

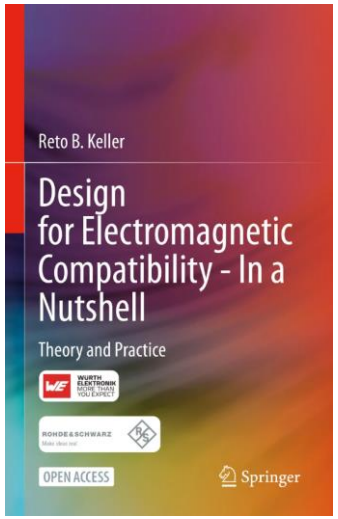
- Models found in the “Contrib” folder in LTspice.
- Latest updates automatically downloaded when LTspice is updated.
- Use equivalent circuits of real components.
- Do not use to simulate saturation! (Since models do not include accurate nonlinear BH loop



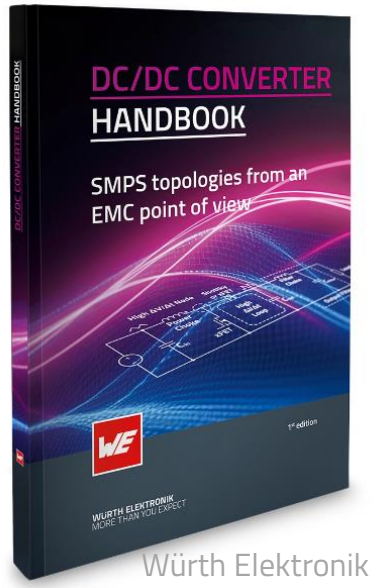
NEED DESIGN HELP?

- 7 different textbooks (magnetics, Ltspice, etc.) Nearly 1000 pages of practical information.
- Over 110 application notes
- Local assistance (email, phone, video call, online chat, etc.)
- Design for Electromagnetic Compatibility--In a Nutshell: Theory and Practice | SpringerLink

Würth Elektronik



Keller, Reto, Design for Electromagnetic Compatibility – In a Nutshell, Springer Cham, Nov. 22, 2022



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