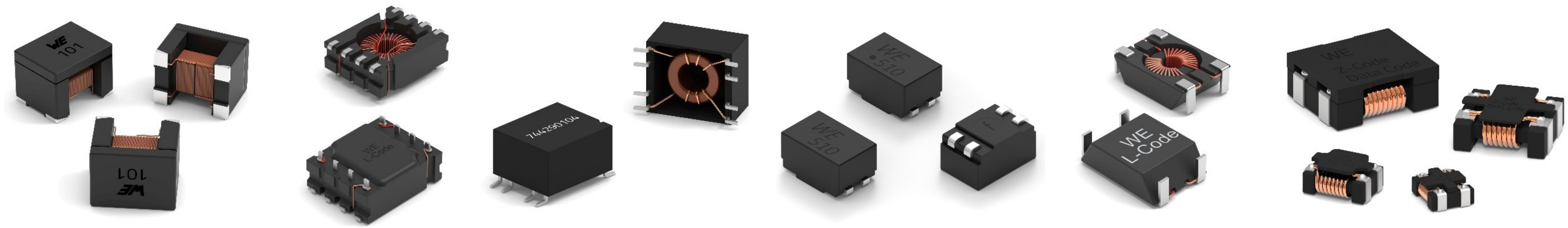


CHARACTERIZATION AND SELECTION OF COMMON MODE CHOKE PARAMETERS FOR DC AND DATA/SIGNAL LINES

Ashiro Chen & Iván Arias – Product Management

OUTLINE

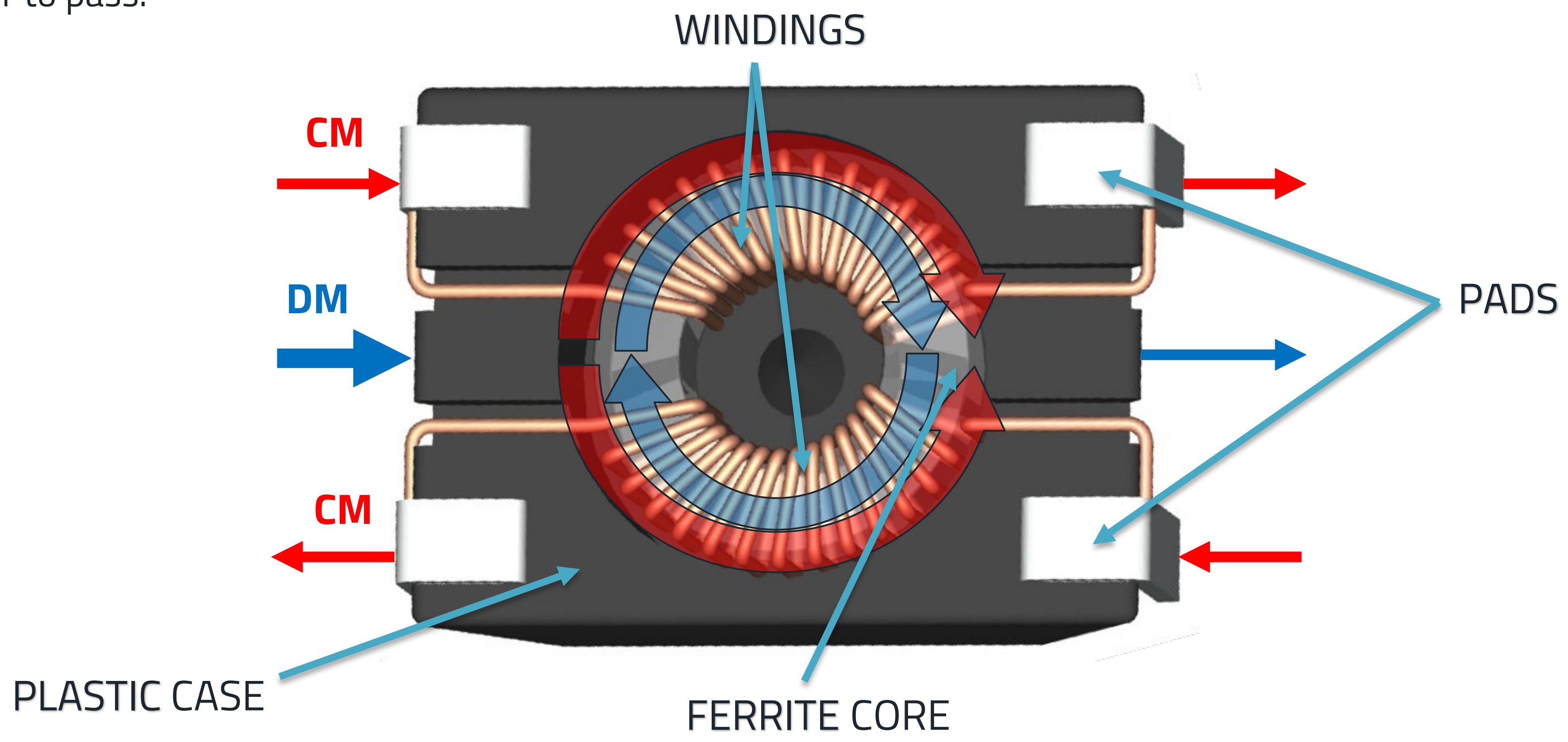
Structure of the presentation

- What is a Common Mode Choke (CMC)?
- Why Common Mode Chokes?
- WE-Portfolio overview and Application Areas
- Characterization Methodology
- Application Case Studies
- Selection Criteria
- Practical Example
- Last Developments and New releases
- Q&A

WHAT IS A COMMON MODE CHOKE (CMC)?

How It Works?

- Filter that blocks high-frequency noise that is common to two or more lines (CM), while allowing the desired signal (DM) power to pass.

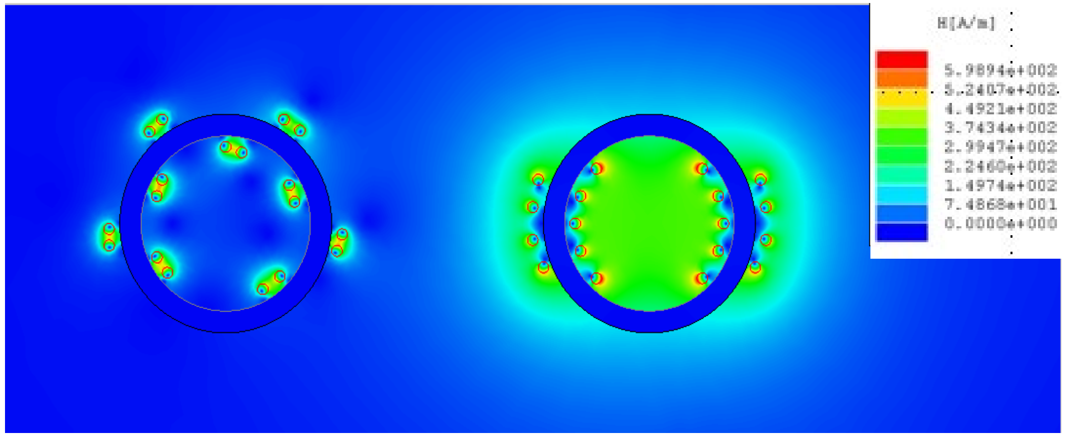


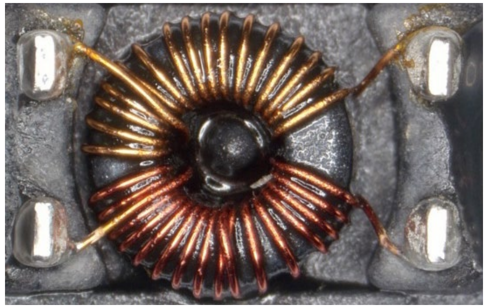
WHAT IS A COMMON MODE CHOKE (CMC)?

Bifilar vs Sectional: Data Lines and DC Low Power

Bifilar winding: Shows the lowest attenuation in differential mode. These chokes are recommended for data lines, where a high isolation is not needed and some high speed signals are involved.

Sectional winding: Shows the highest attenuation in differential mode. This chokes are recommended for power lines, where a high isolation is mandatory and the power delivery is happening at low frequency.

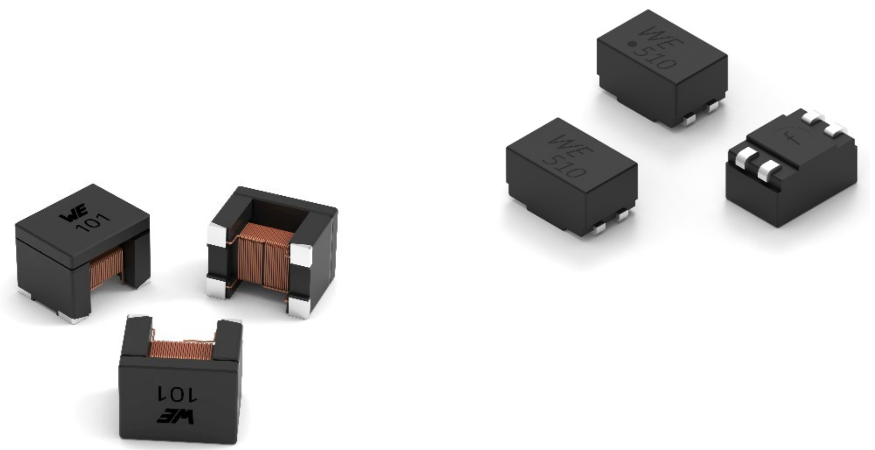


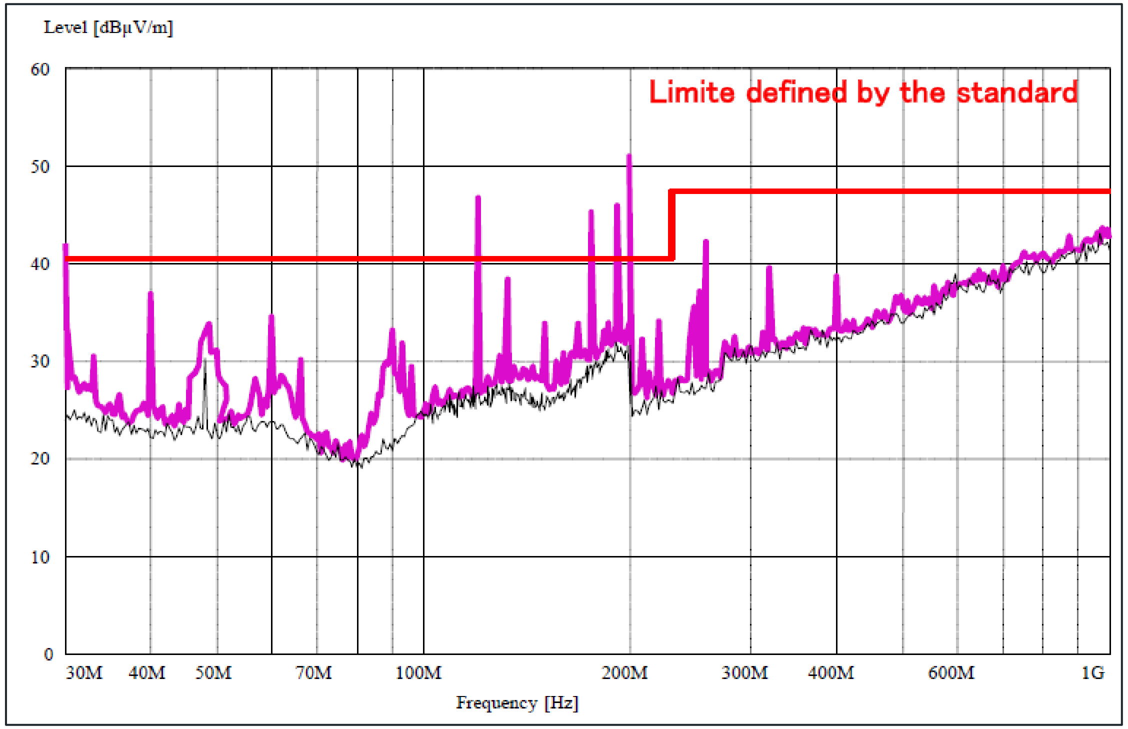


WHY COMMON MODE CHOKES?

Benefits

- Suppress electromagnetic interference (EMI)
- Ensure compliance with EMC standards
- Preserve signal integrity





WHY COMMON MODE CHOKES?

Comparison With Alternative Solutions

Series	CMDC	CNSW	SCC	SL2	CBF, RFI, PBF	STAR, AFB, SAFB
Function	Common Mode Choke	**Common Mode Choke**	Common Mode Choke	Common Mode Choke	Ferrite bead	Snap ferrites
Figure						
Application	Filtering DC Power Supply paths in the low voltage range. High Ir	Filtering Signal Data Lines, also for high transfer rates	Filtering DC Power Supply paths in the low voltage range	Filtering DC and Data lines	Attenuating differential interference signals in the HF range	Attenuating CM interference in HF Range on Cables
Advantages	Low parasitic capacitance, ferrite loss R < typ. 5 MHz	High Symmetry, low losses	High inductance values, high leakage inductance	Very wide value range between 10 uH to 20 mH	Frequency selective measure are possible	Can be subsequently assembled on cables

EMC Products overview for informed and effective selection

- **ANP 146** | Theoretical Insights and Practical Applications of the WE-CMDC Series Common Mode Chokes

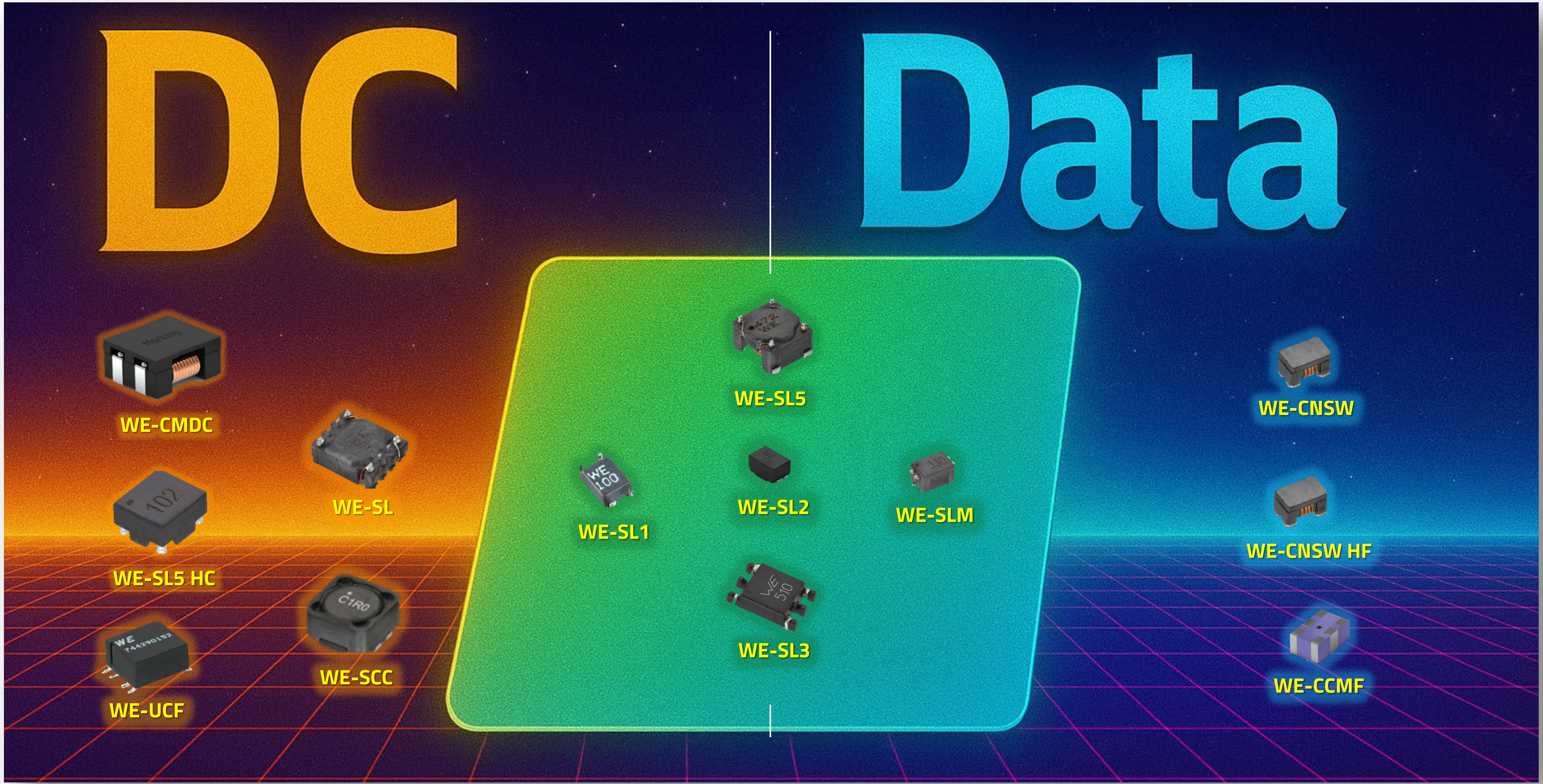
WHY COMMON MODE CHOKES?

Most Common Noise Sources and Characteristics

Applications	Probable Noise Source	Main Frequency (reference)	CMC benefit
Power supplies, IoT, LED drivers	Active Switching	100 kHz – 1 MHz	Blocks CM Noise along cables
Cameras, robotics, PoE	Inrush / Capacitive Load	< 1kHz	Dampens overshoot and ringing
Instrumentation	Ground loop or floating reference	500 kHZ – 50 MHz	Suppresses CM
Power + Data	Fast buses: USB, WiFi, CAN	10 MHz – 500 MHz	Reduces Common mode coupling of digital signals on DC line
Industrial	EMI from Motors/ Relays	10 kHZ – 5 MHz	Isolates DC line from inductive noise sources

WÜRTH ELEKTRONIK PORTFOLIO

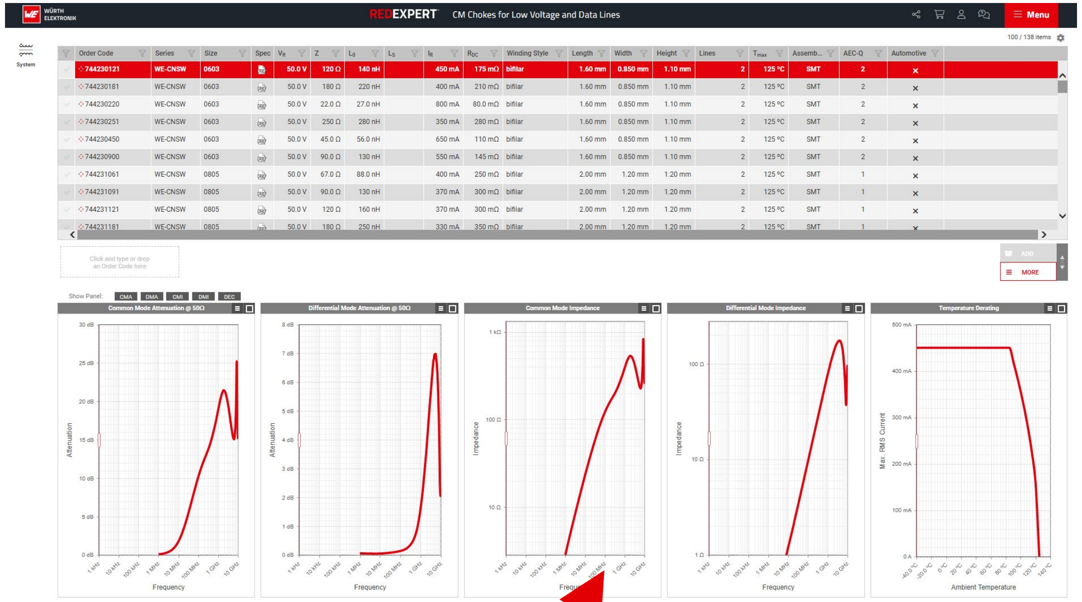
Understanding the Product Series

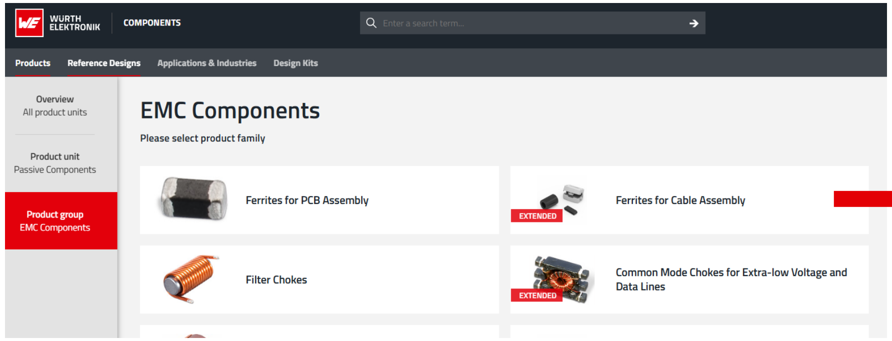


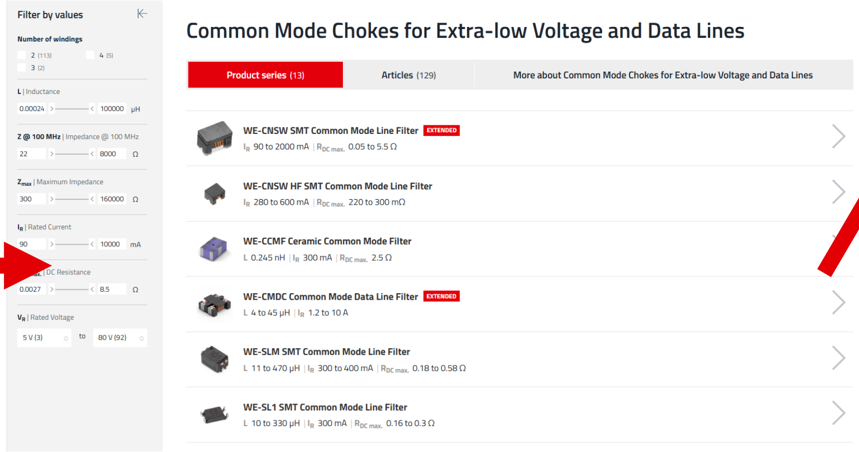
WÜRTH ELEKTRONIK PORTFOLIO

How to navigate

- RedExpert
  - Online platform for simple selection, simulation, and design-in



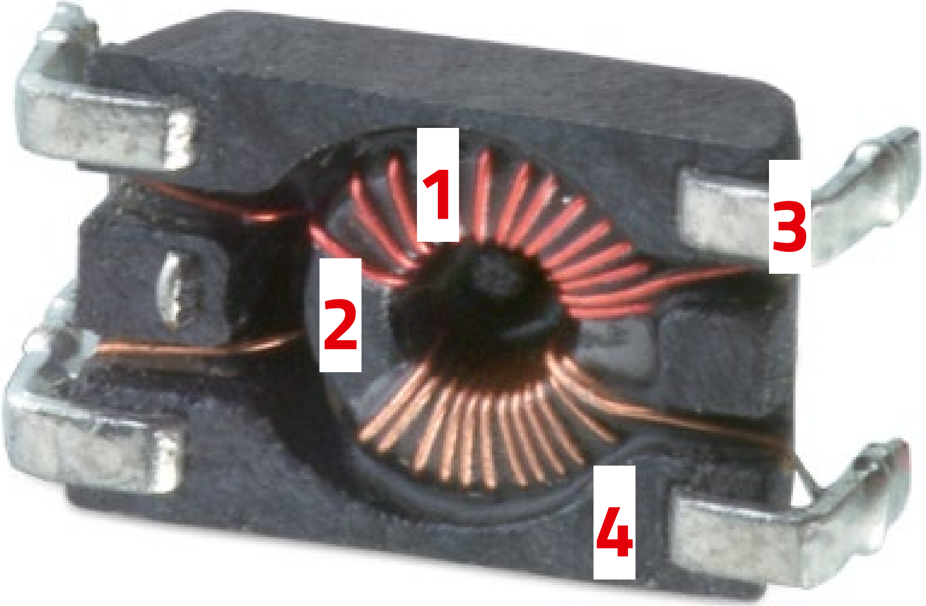




CHARACTERIZATION METHODOLOGY

CMC definition

- Design parameters
  - 1. Wire thickness and isolation + number of turns
  - 2. Core material
  - 3. Pads/Pins
  - 4. Case



CHARACTERIZATION METHODOLOGY

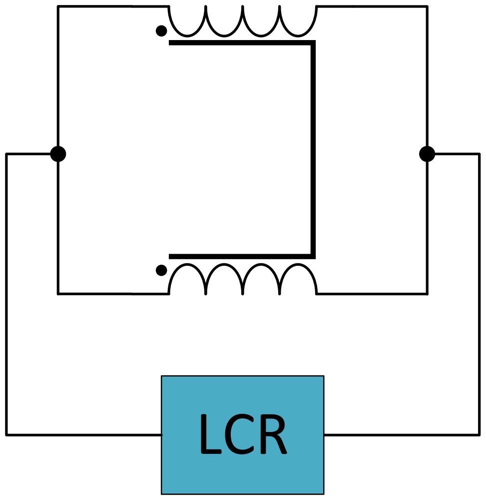
CMC definition

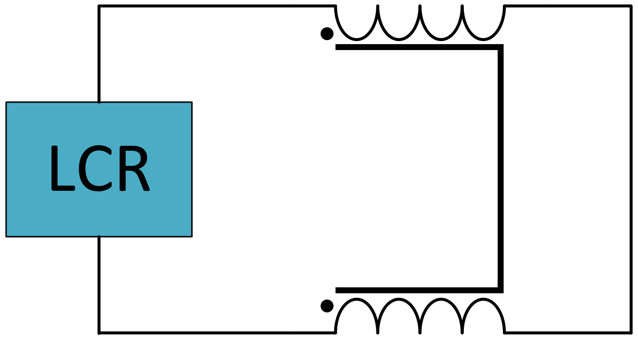
- **Inductance (L) and Leakage Inductance**

- **Physical relation**:
  - **Core material & geometry** → main driver of common mode inductance.
  - **Winding style (bifilar vs sectional)** → controls coupling factor; more coupling = lower leakage inductance.

- **Limitations**:
  - Measurement frequency of LCR must be noted (typically 10 kHz / 100 kHz).
  - L values vary strongly with frequency → don’t extrapolate blindly.
  - Leakage inductance must be measured with windings in differential mode, not CM.

- **Note:**
  - The tolerance for this parameter is typically **high**, in the range of **25–50%**.





CHARACTERIZATION METHODOLOGY

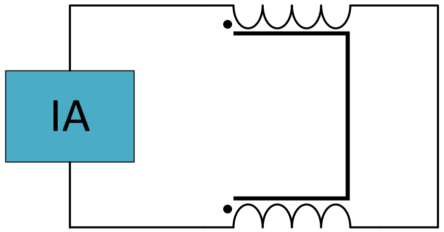
CMC definition

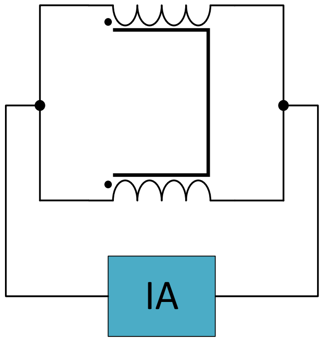
- **Impedance (Z) vs Frequency (F)**

- **Physical relation**:
  - **Core losses** and **material permeability** → determine frequency response.
  - **Interwinding capacitance** (spacing, layer buildup) → defines resonances and high-frequency roll-off.

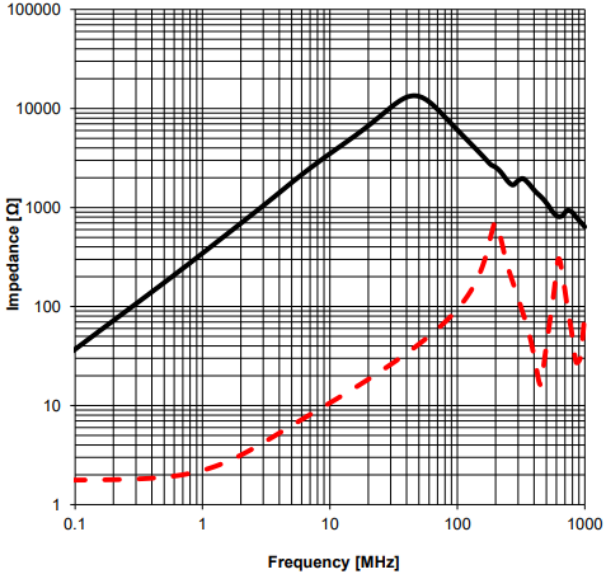
- **Limitations**:
  - Fixture needed for DM and CM.
  - Calibration process.

- **Note:**
  - The curves shown are **typical values**.

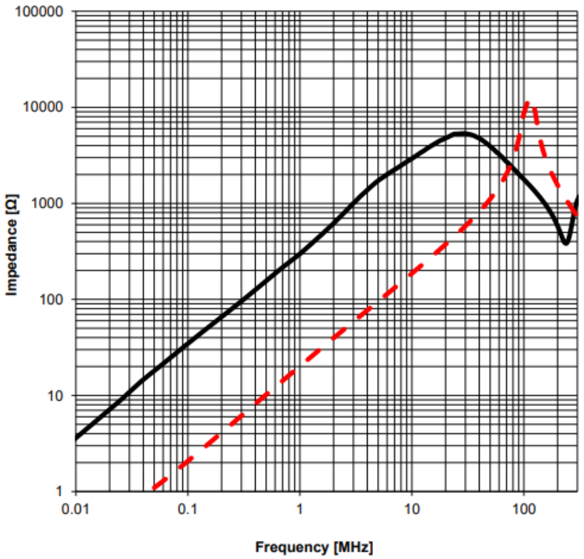




51uH - Bifilar



51uH - Sectional



CHARACTERIZATION METHODOLOGY

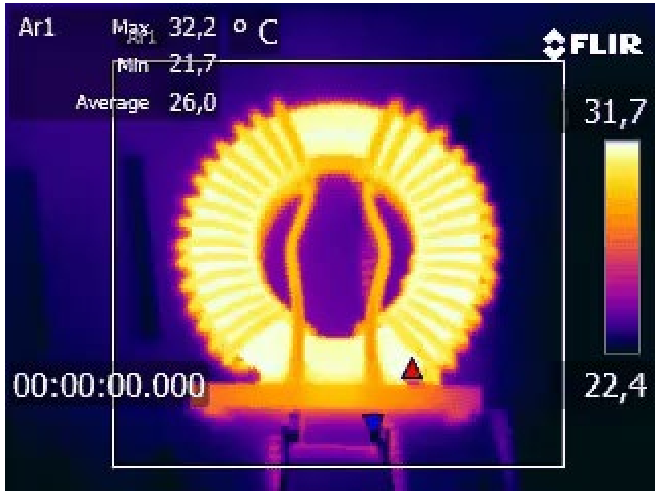
CMC definition

- **Rated Current (I_R)**

- **Physical relation**:
  - **Wire cross-section** → conduction losses.
  - **Core cross-section & material** → saturation and core losses.
  - **PCB footprint & copper planes** → heat dissipation capacity.

- **Limitations**:
  - Rated current is not a universal constant; it depends on PCB design, cooling, ambient.

- **Note**:
  - Thermal rise limit is defined in the datasheet: $\Delta T = 40\ K$



CHARACTERIZATION METHODOLOGY

CMC definition

- **DCR (DC Resistance)**

- **Physical relation**:
  - **Wire diameter & length (number of turns)** → directly proportional to copper resistance.
  - **Pad design & solder terminations** can add extra milliohm contributions.

- **Limitations**:
  - Temperature dependency (e.g. Cu has ~0.39%/°C increase).
  - Contact resistance during measurement can distort low-value results.

- **Note:**
  - A **fixture is required** for this measurement.
  - The **maximum DCR value** is indicated in the **datasheet**, representing the **worst-case scenario** for the introduced losses.

CHARACTERIZATION METHODOLOGY

CMC definition

- **S-Parameters (S_{11}, S_{21})**

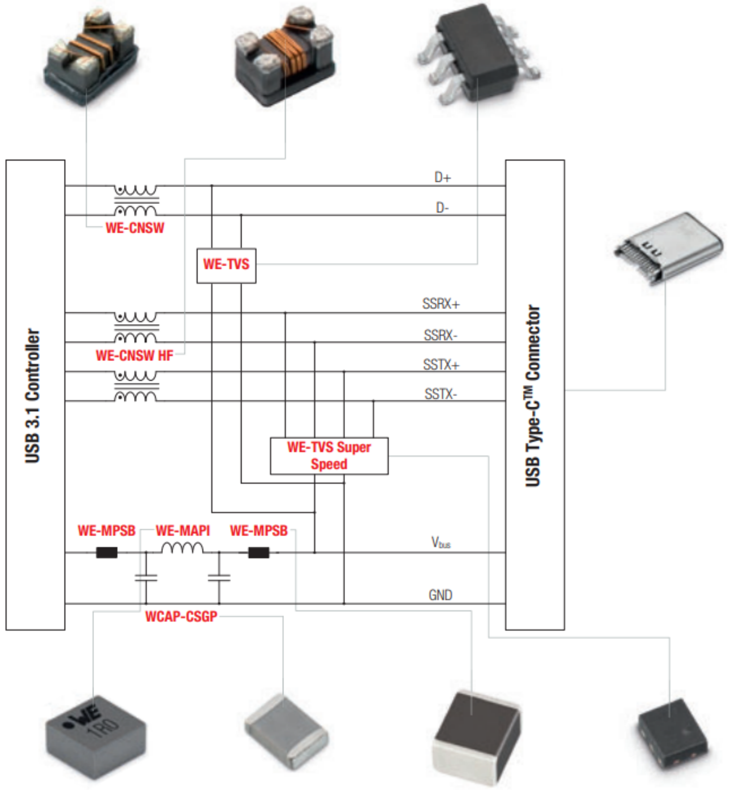
- **Physical relation**:
  - **All choke elements (core, wire, interwinding capacitance, pads)** appear as a 4-port network.
  - Helps understand **insertion loss** and **return loss** in real circuits.

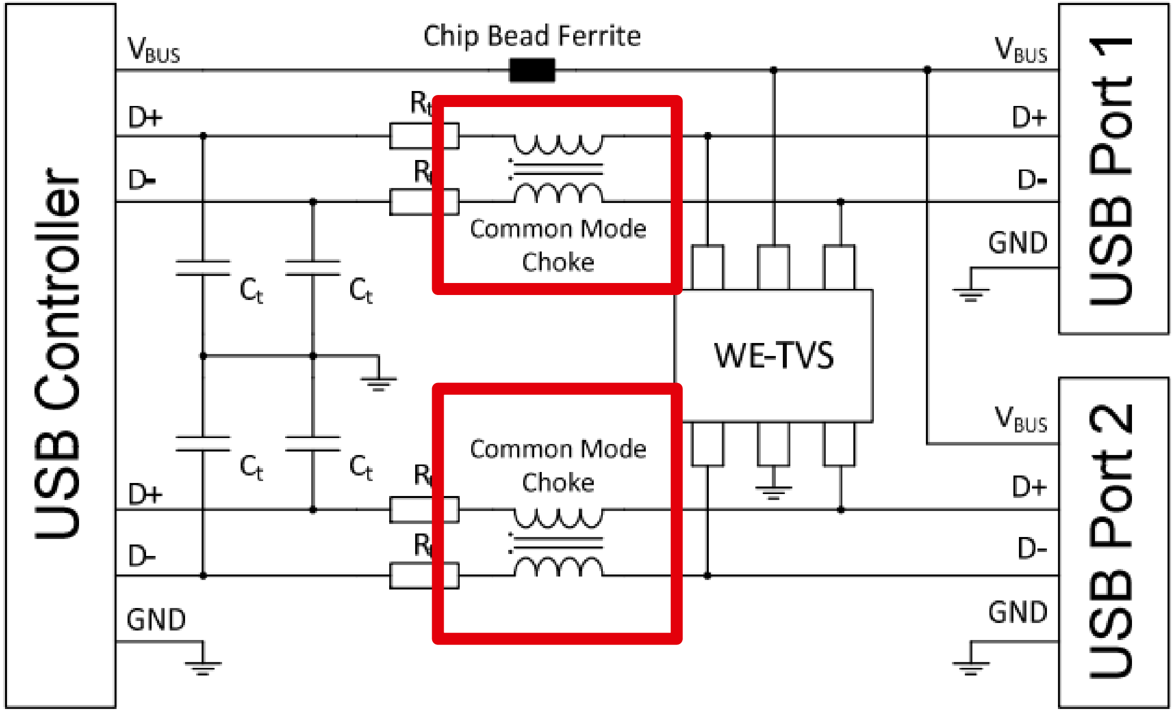
- **Limitations**:
  - Requires proper 4-port measurement setup and calibration.
  - S-parameters are linear, frequency-domain → don't show saturation or thermal effects.

CMC IN DATA LINES

Applications: USB | Ethernet

- Ethernet 100/1000BASE-T

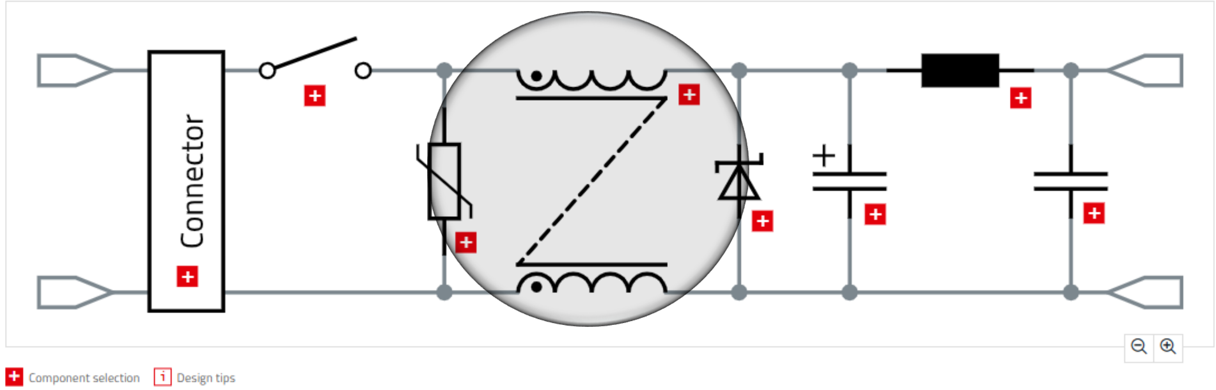


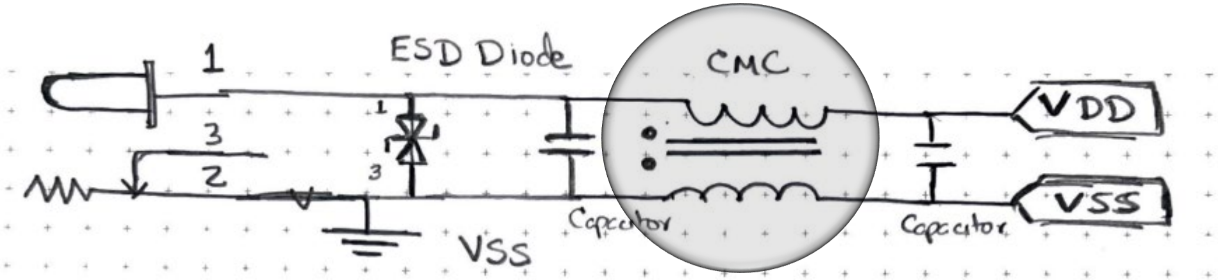


CMC IN DC LINES

Applications: DC Filter

Carlos Hernandez design

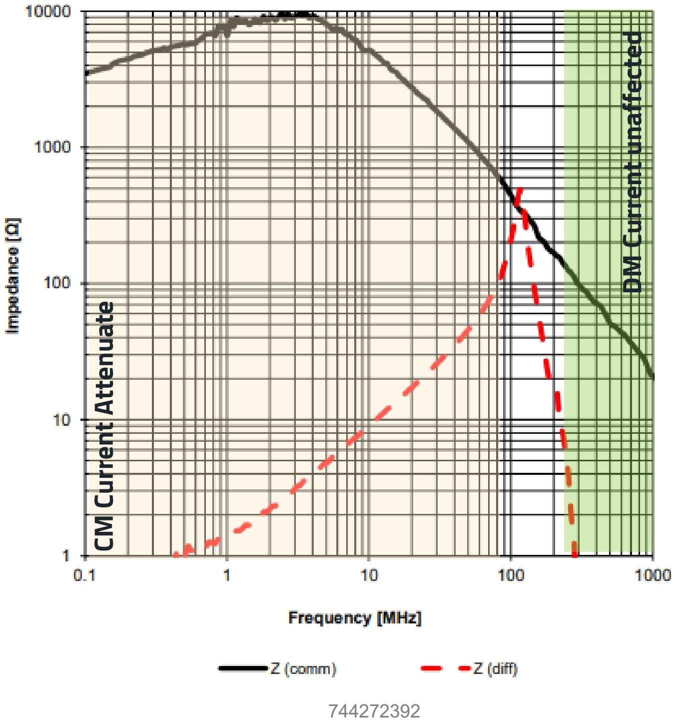


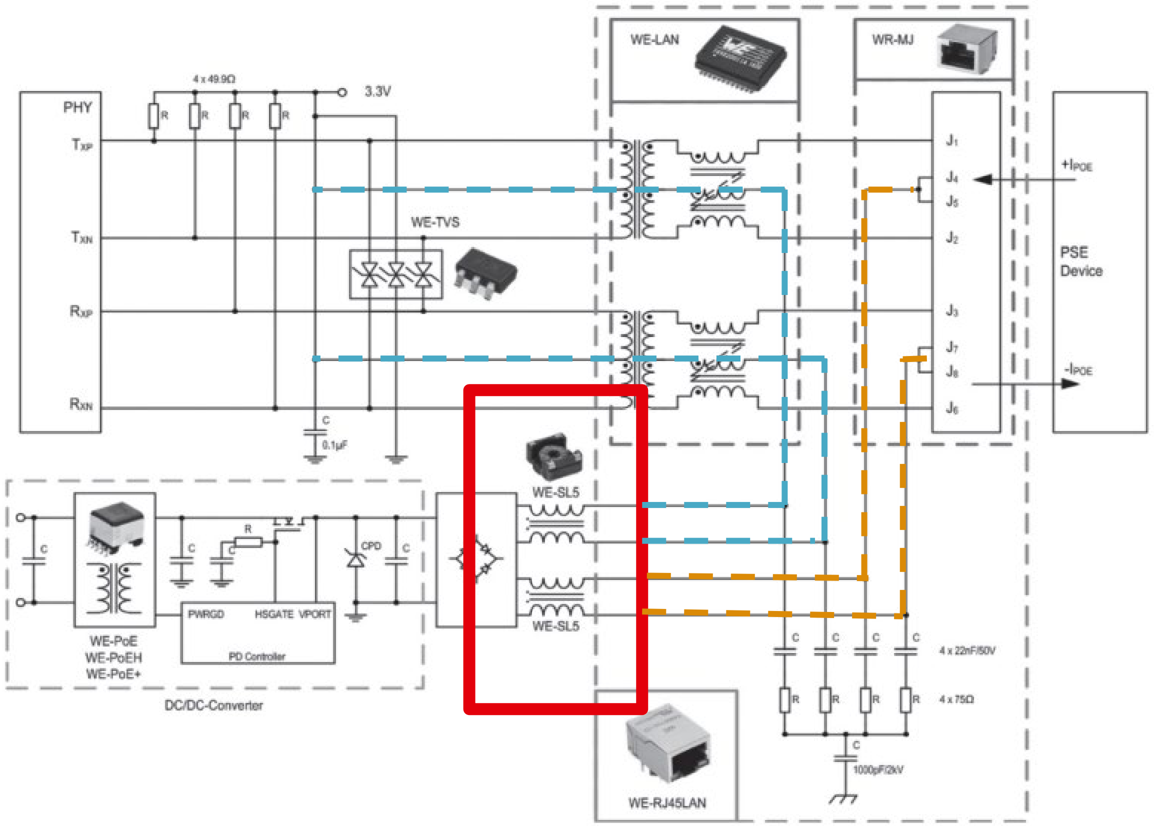


CMC IN MIXED APPLICATIONS (DC+DATA)

Applications: “mixed”

- The LAN-PoE Connection

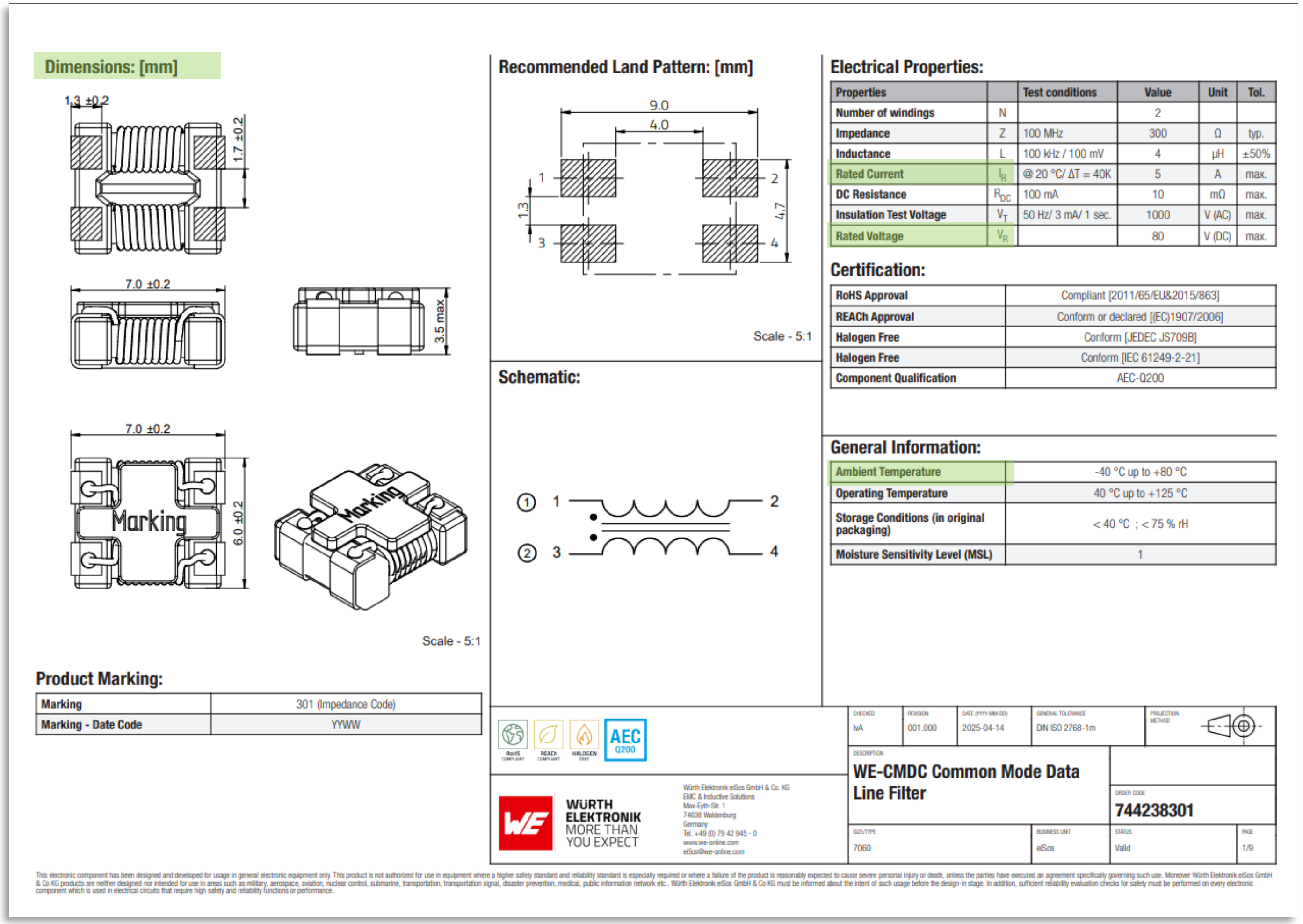




SELECTION CRITERIA

Process

1. Define Design Constraints	
Working Current	Rated Current **[IR]**
Working Voltage	Rated Voltage **[VR]**
Available Space	Dimensions **[mm]**
Environment conditions	Ambient temperature **[°C]**



Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Number of windings	N		2		
Impedance	Z	100 MHz	300	Ω	typ.
Inductance	L	100 kHz / 100 mV	4	µH	±50%
Rated Current	I_R	@ 20 °C/ ΔT = 40K	5	A	max.
DC Resistance	R_{DC}	100 mA	10	mΩ	max.
Insulation Test Voltage	V_T	50 Hz/ 3 mA/ 1 sec.	1000	V (AC)	max.
Rated Voltage	V_R		80	V (DC)	max.

Certification:

RoHS Approval	Compliant [2011/65/EU&2015/863]
REACh Approval	Conform or declared [(EC)1907/2006]
Halogen Free	Conform [JEDEC JS709B]
Halogen Free	Conform [IEC 61249-2-21]
Component Qualification	AEC-Q200

General Information:

Ambient Temperature	-40 °C up to +80 °C
Operating Temperature	40 °C up to +125 °C
Storage Conditions (in original packaging)	< 40 °C ; < 75 % rH
Moisture Sensitivity Level (MSL)	1

Product Marking:

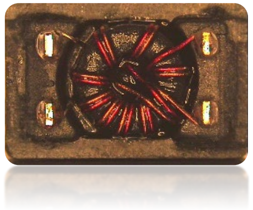
Marking	301 (Impedance Code)
Marking - Date Code	YYWW

SELECTION CRITERIA

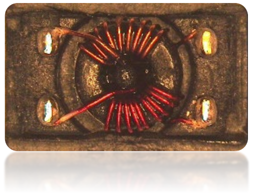
Process

2. Application Type	
Data Line	Winding Style: Bifilar
DC Line	Winding Style: Sectional

- **Bifilar winding**
  - Higher symmetry between wires
  - Lower leackage inductance
  - **Lower differential mode impedance**



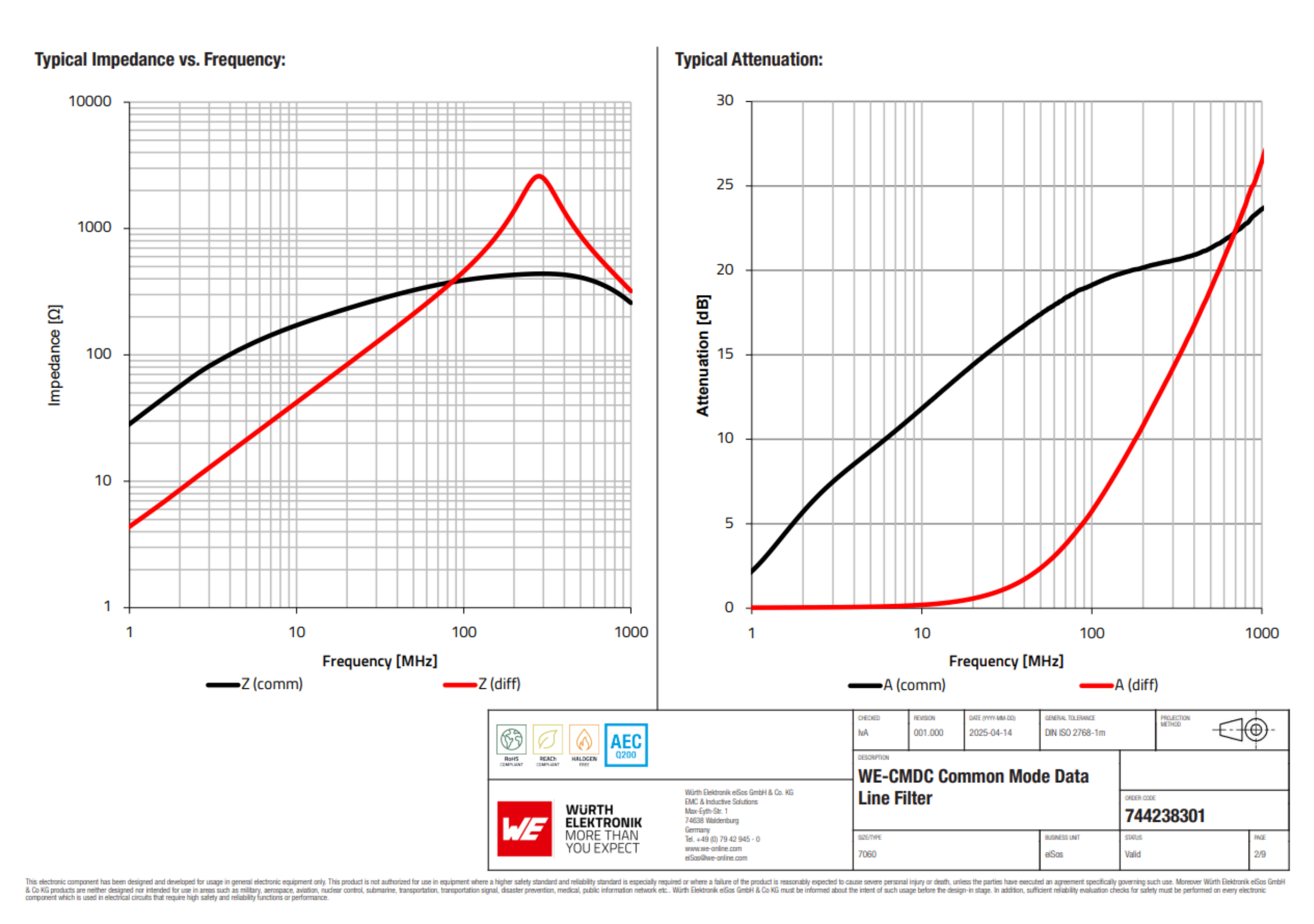
- **Sectional winding**
  - Less symmetry between wires
  - Higher leackage inductance
  - **Higher differential mode impedance**



SELECTION CRITERIA

Process

3. Frequency Performance	
Digital Signal Must pass unaffected	DM Impedance DM Attenuation
Attenuate Noise and Harmonics	CM Impedance CM Attenuation



SELECTION CRITERIA

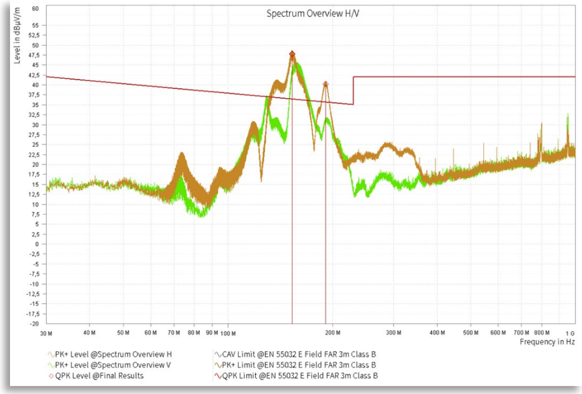
Process

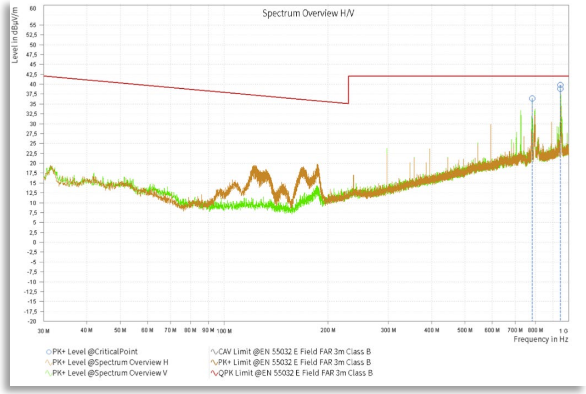
4. Design Tips and	
Check the voltage Drop	DC Resistance **[Rdc]**
Place CMC Close to connector	
Design Filter adding a capacitor if needed	Inductance

5. Measure and iterate

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Number of windings	N		2		
Impedance	Z	100 MHz	300	Ω	typ.
Inductance	L	100 kHz / 100 mV	4	µH	±50%
Rated Current	I_R	@ 20 °C/ ΔT = 40K	5	A	max.
DC Resistance	R_{DC}	100 mA	10	mΩ	max.
Insulation Test Voltage	V_T	50 Hz/ 3 mA/ 1 sec.	1000	V (AC)	max.
Rated Voltage	V_R		80	V (DC)	max.





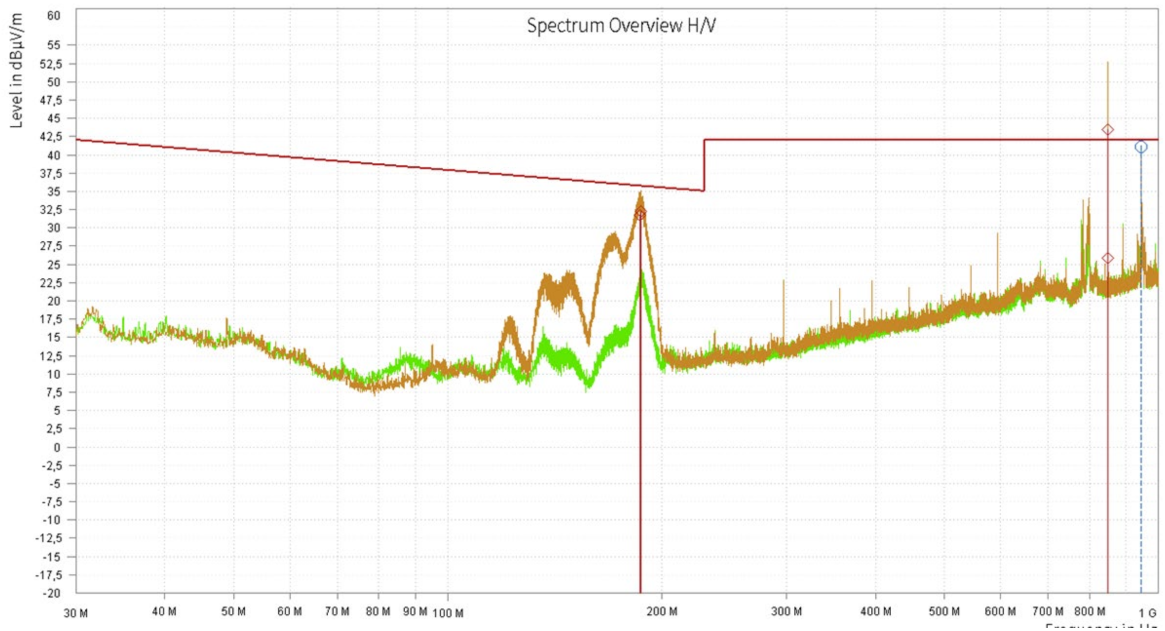
PRACTICAL EXAMPLE

- A designer is developing an application where a LED-Screen is needed for an industrial machine control. He notices that there is an electromagnetic noise that is affecting the screen, generating a flicker.

- He decides to use a CMC to filter the noise from the screen power supply.

- Specifications
  - Working Voltage 24 VDC
  - Working Current: 2,5 A.
  - Acceptable voltage drop 100mV
  - Available Space: 10 mm x 10 mm x 4 mm

- Let's find the proper CMC!



PRACTICAL EXAMPLE

Voltage drop calculation

- 744238102: We check the voltage drop using the RDC: 20mOhms X 2.5 A = 50 mV < 100 mV

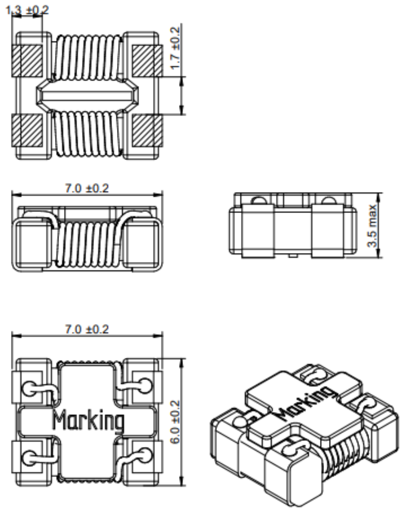
Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Number of windings	N		2		
Impedance	Z	100 MHz	1000	Ω	typ.
Inductance	L	100 kHz / 100 mV	12.5	µH	±50%
Rated Current	I_R	@ 20 °C/ ΔT = 40K	3	A	max.
DC Resistance	R_{DC}	100 mA	20	mΩ	max.
Insulation Test Voltage	V_T	50 Hz/ 3 mA/ 1 sec.	1000	V (AC)	max.
Rated Voltage	V_R		80	V (DC)	max.

- 744238132: We check the voltage drop using the RDC: 25mOhms X 2.5 A = 62,5 mV < 100 mV

Properties		Test conditions	Value	Unit	Tol.
Number of windings	N		2		
Impedance	Z	100 MHz	1300	Ω	typ.
Inductance	L	100 kHz / 100 mV	14	µH	±50%
Rated Current	I_R	@ 20 °C/ ΔT = 40K	2.5	A	max.
DC Resistance	R_{DC}	100 mA	25	mΩ	max.
Insulation Test Voltage	V_T	50 Hz/ 3 mA/ 1 sec.	1000	V (AC)	max.
Rated Voltage	V_R		80	V (DC)	max.

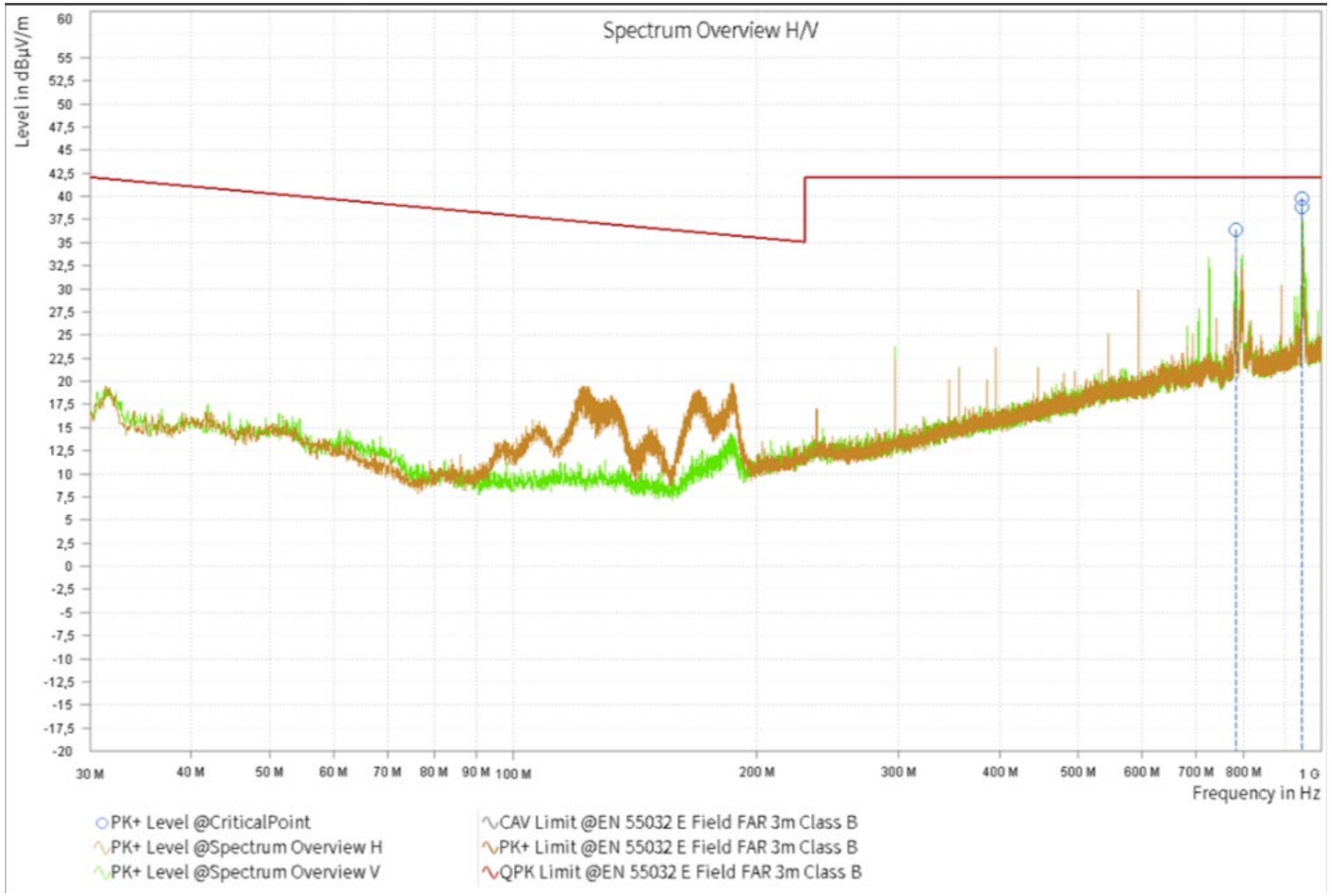
Dimensions: [mm]



Scale - 5:1

PRACTICAL EXAMPLE

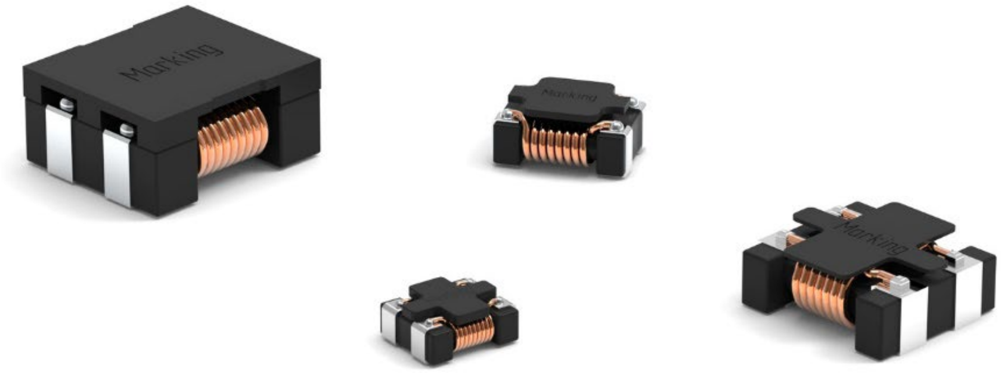
Results after implementing the suggested CMC by WE

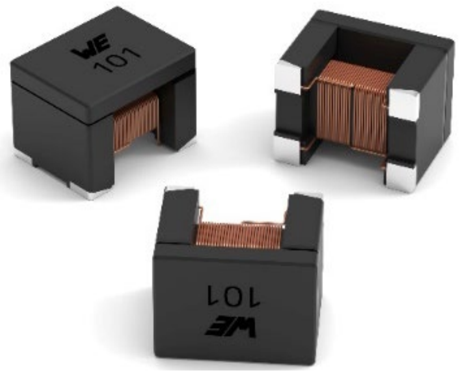


NEW RELEASES

New on the catalogue!

- **WE-CMDC** Series expansion: sizes 7060, 9070 and 1513!
- **WE-CNSW** Series Expansion: size 1210!





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Iván Arias: ivan.arias@we-online.com

– Product Management –