Conducted EMI

Midcom WÜRTH ELEKTRONIK

WURTH ELECTRONICS MIDCOM INC.

2010

Retlif Labs

Presented by: Douglas Toth

Topics

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1. EMI/EMC – General Information – Why need EMI reduction?
2. Materials – Frequencies for Effectiveness
3. Shielded and Un-shield comparison
4. Inductors vs. Ferrites
5. Common Mode and Differential Mode
6. Conducted EMI emission analysis
7. Information on Transformers

Switching Regulator Topologies

Switch mode power supply

- **Non-Isolated**
  - **Step-down converter** — WE-PD
  - **Step-up converter** — WE-PD
  - **SEPIC converter** — 2 xWE-PD or 1x WE-DD
- **Isolated**
  - **Flyback converter** — WE-PoE, WE-FLEX with airgap
  - **Forward converter** — WE-FLEX w/o airgap + WE-PD
  - **Push-Pull converter** — WE-FLEX w/o airgap + WE-PD

Insulation Voltage — **WE-PoE**

→ 0-100V ------------ -------→ 0-500V -------------------- → >=1500V

Switching Regulator Topologies

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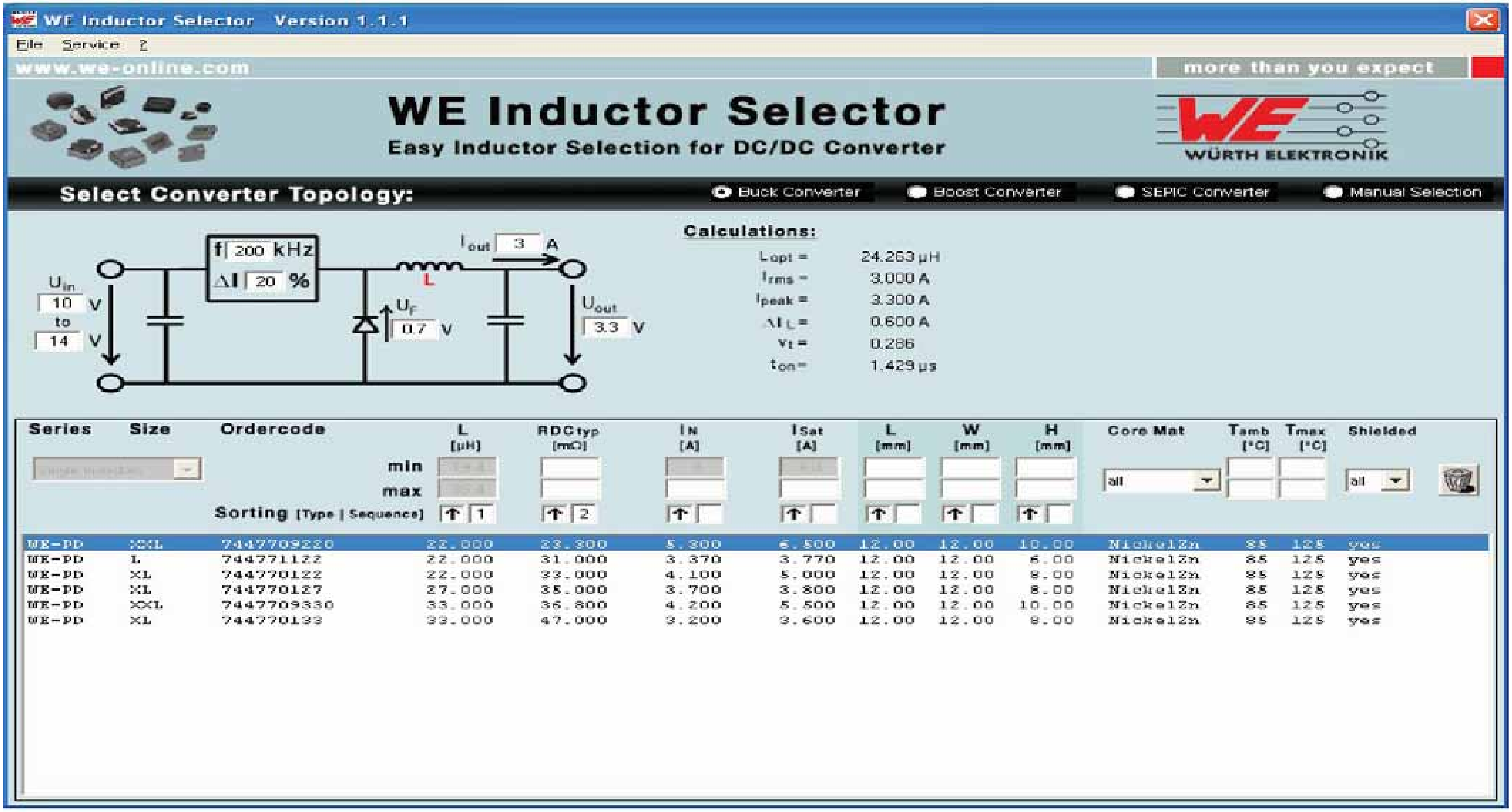
Switching Regulator Topology	Inductive Components
Step-down-converter (Buck-Converter)	Storage inductor => WE-SI/FI or WE-HC-/ or WE-PD-Series
Step-up-Converter (Boost-Converter)	Storage inductor => WE-SI/FI or WE-HC-/ or WE-PD-Series
SEPIC Single ended primary inductance converter CUK converter	Coupled storage inductor with two windings or two identical storage inductors => WE-DD or WE-FLEX (with airgap !)
Flyback-Converter	Flyback-transformer => WE-FLEX (gap !)
Forward-Converter	Transformer and storage inductor => WE-FLEX (no gap !)
Push-pull Converter	Transformer and storage inductor => WE-FLEX (no gap !)

Inductor Selector Guide



Interference - Transmitter / Receiver

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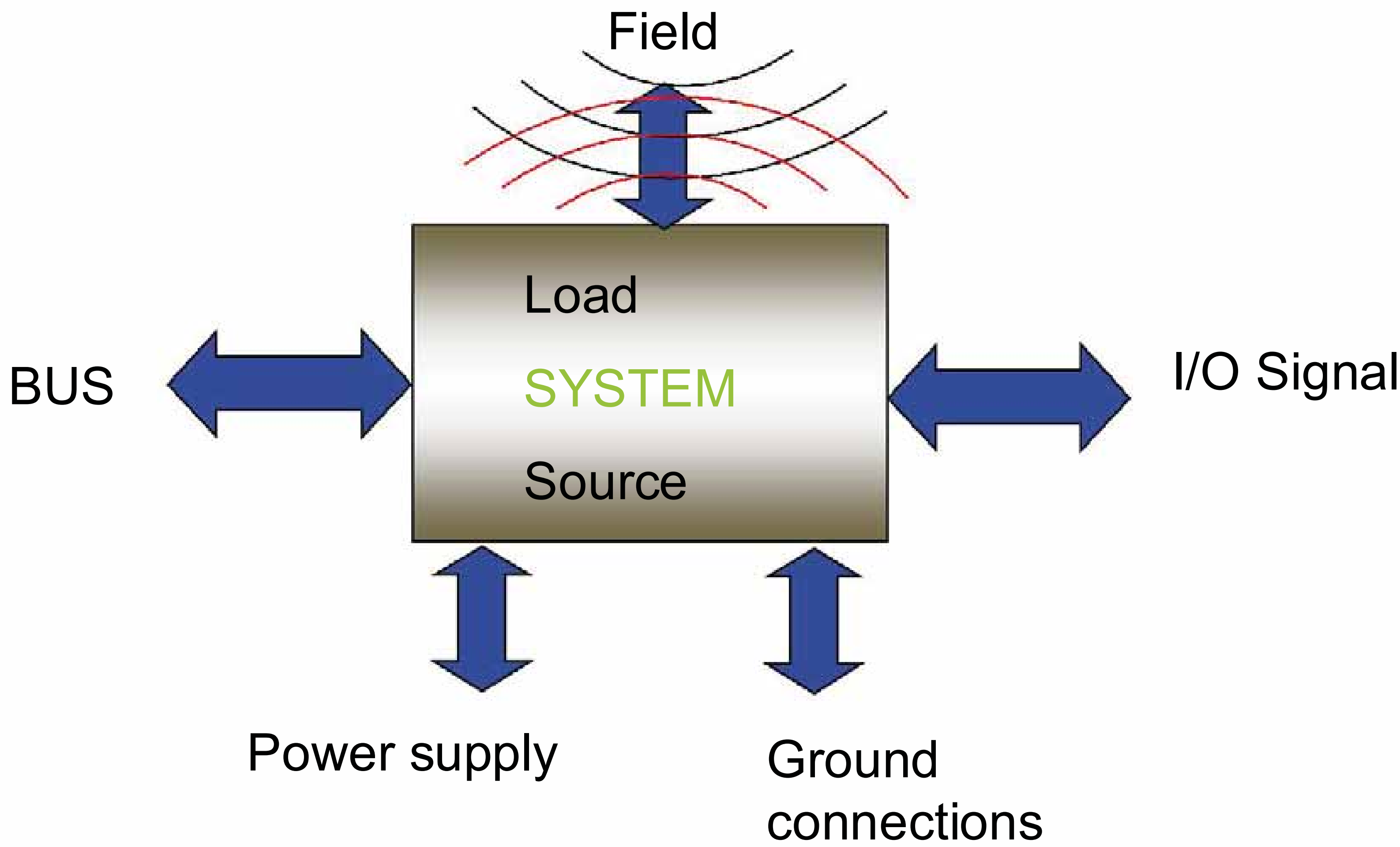

Interference - Frequency Range for EMI Tests

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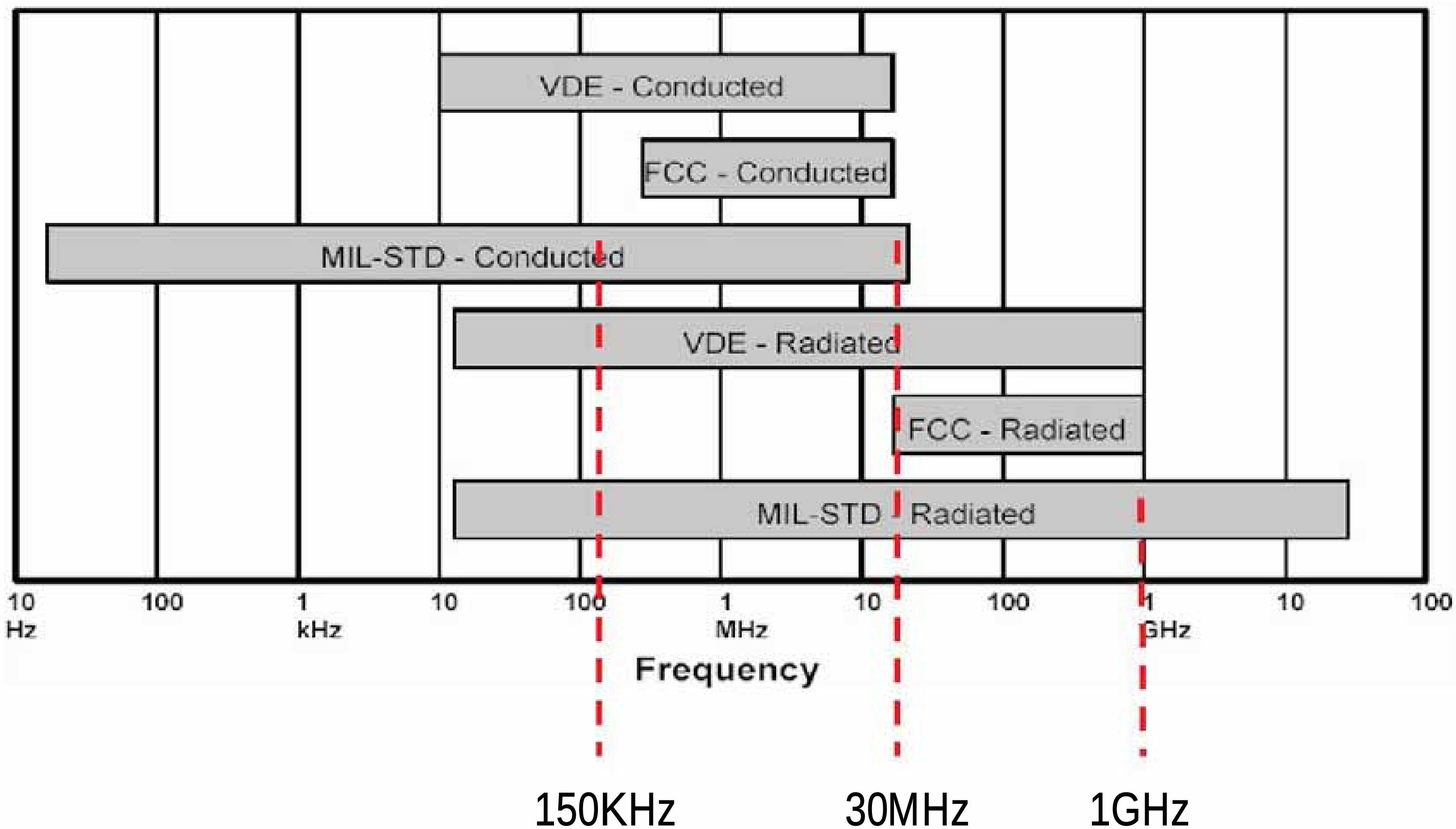
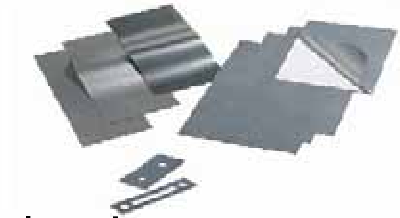
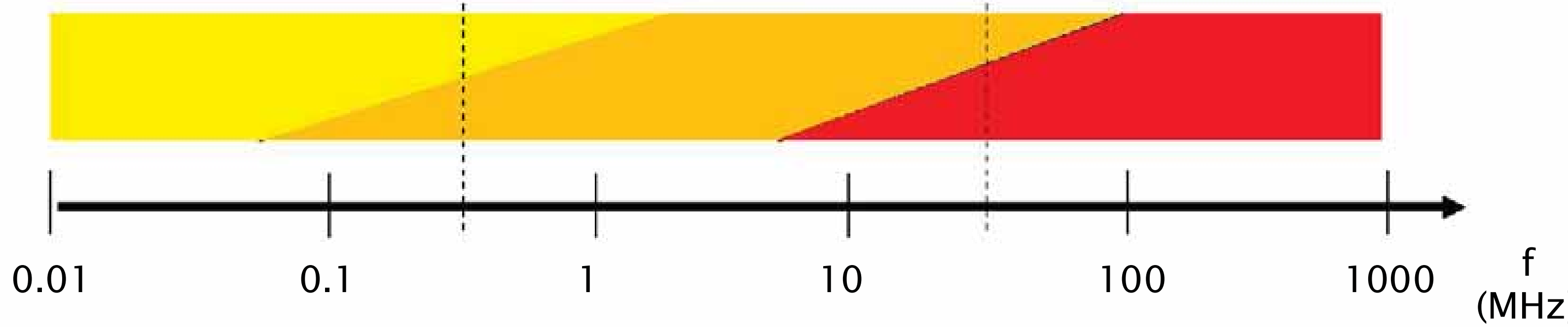


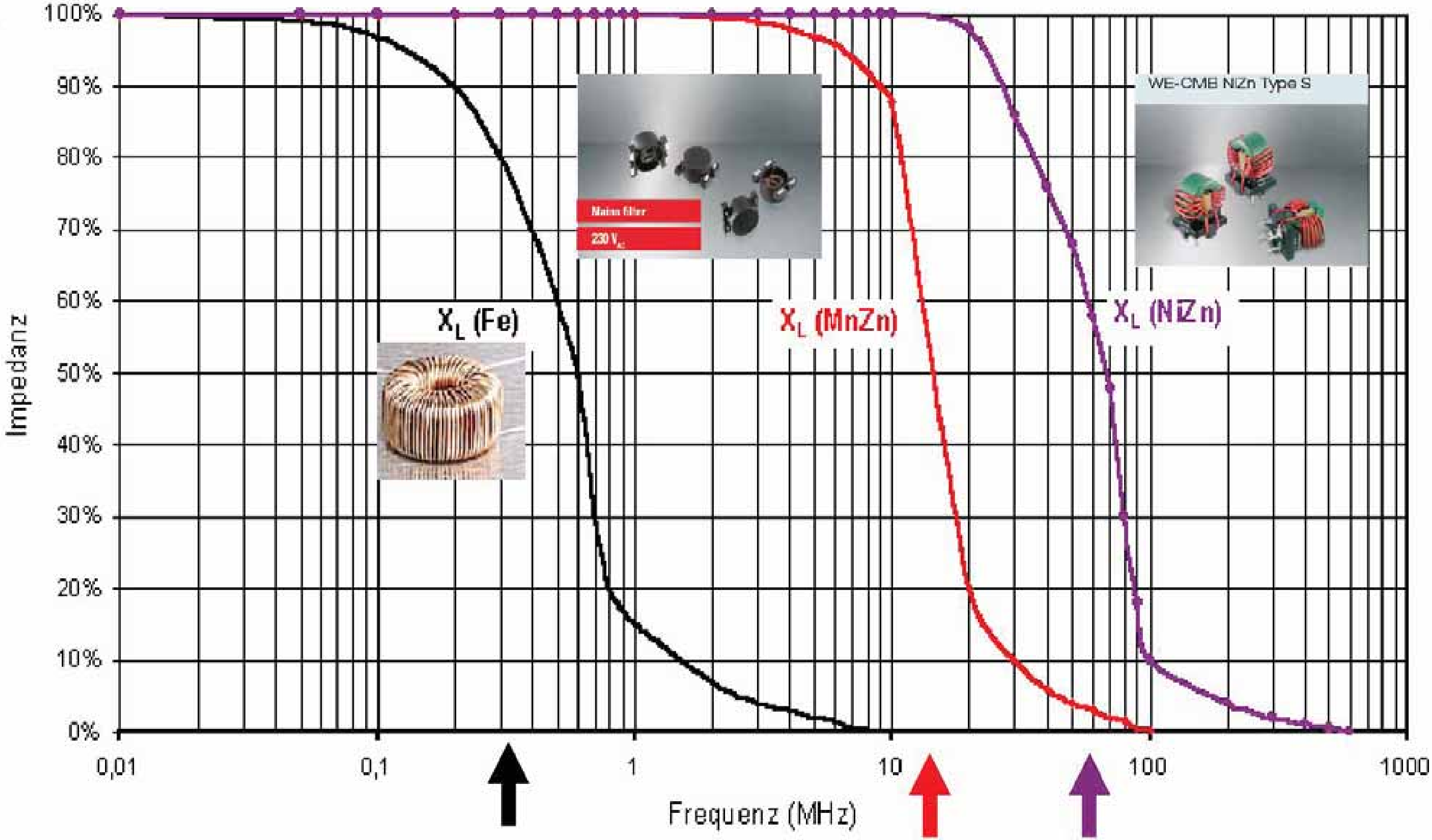
Interference Characteristics

	Symmetrical	Asymmetrical	Field
	conducted noise	coupled noise	radiated noise
	Powder–, rod core chokes	CM– chokes	EMI ferrites, shielding





Comparison of Core Materials: Inductive behavior



EMI: Conducted Emission Measurement

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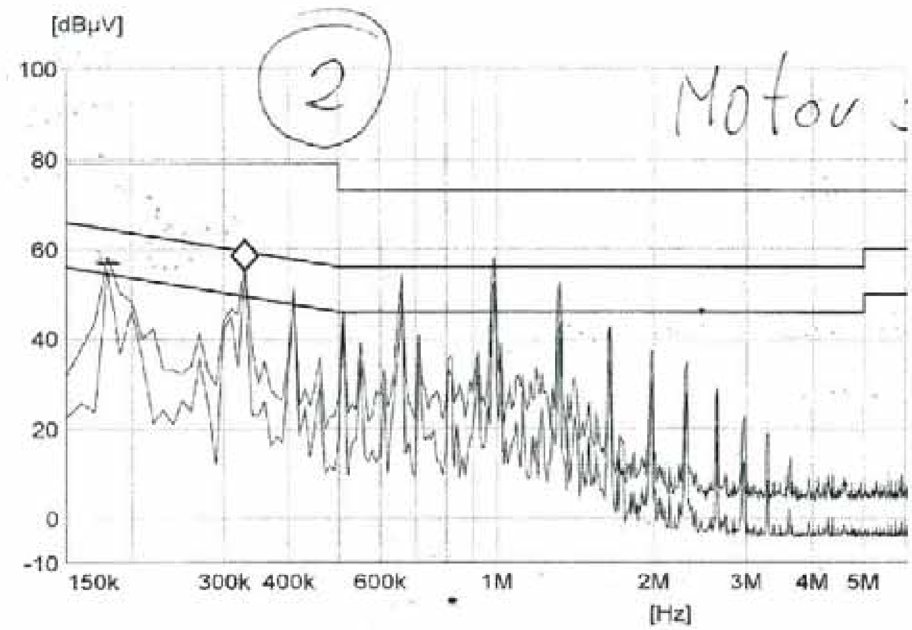
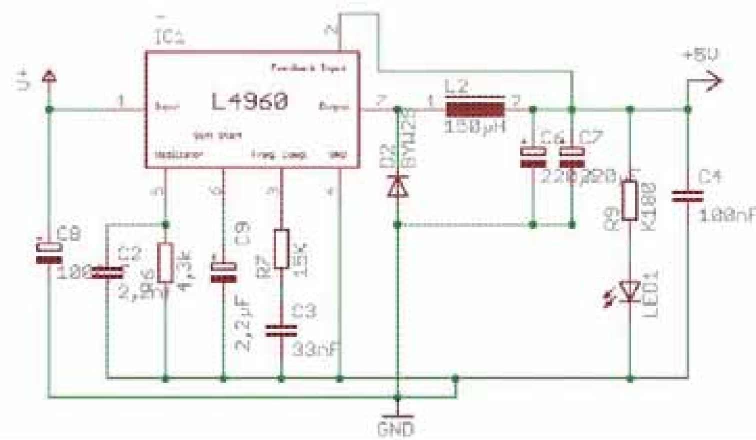
- **Power supply V 1.0**



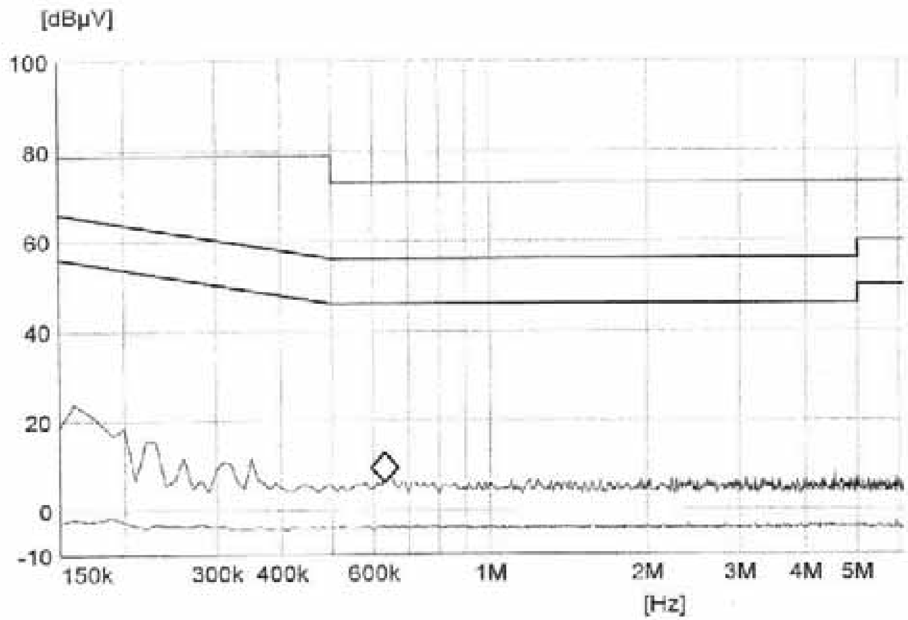
PCB

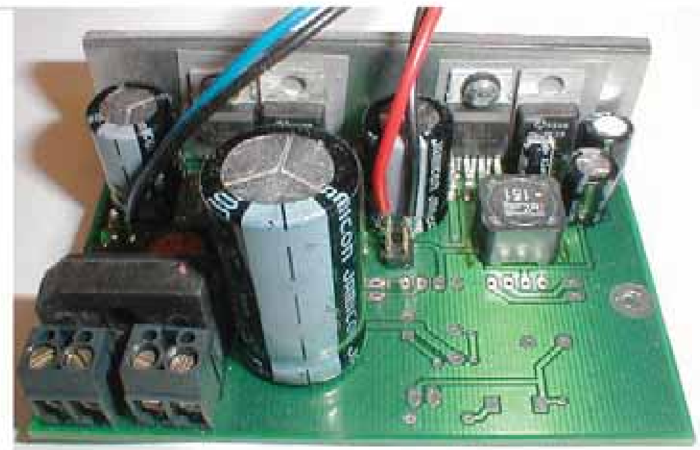
Buck Converter ST L4960/2.5A/fs 85-115KHz



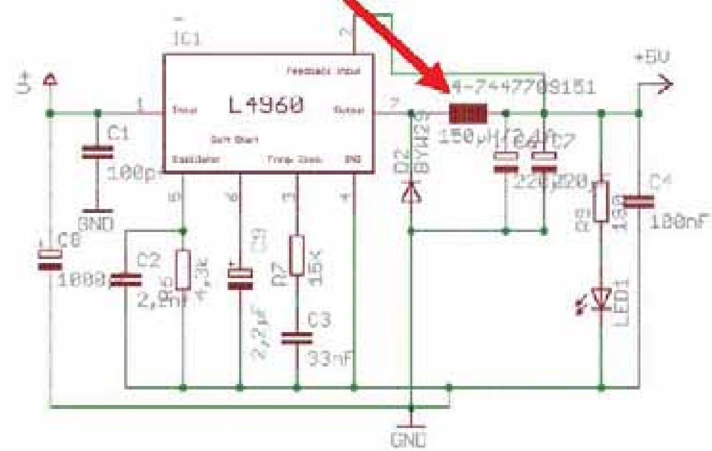
EMI: Conducted Emission Measurement

- **Power supply V 1.1**





PCB



Schematic

EMI: Be Aware:

- Select the right parts for your application

- Do not always look on cost

Very easy solution with a dramatic result!!!

Choke before

or

Choke after

EMI: Shielded vs. Unshielded Power Inductor

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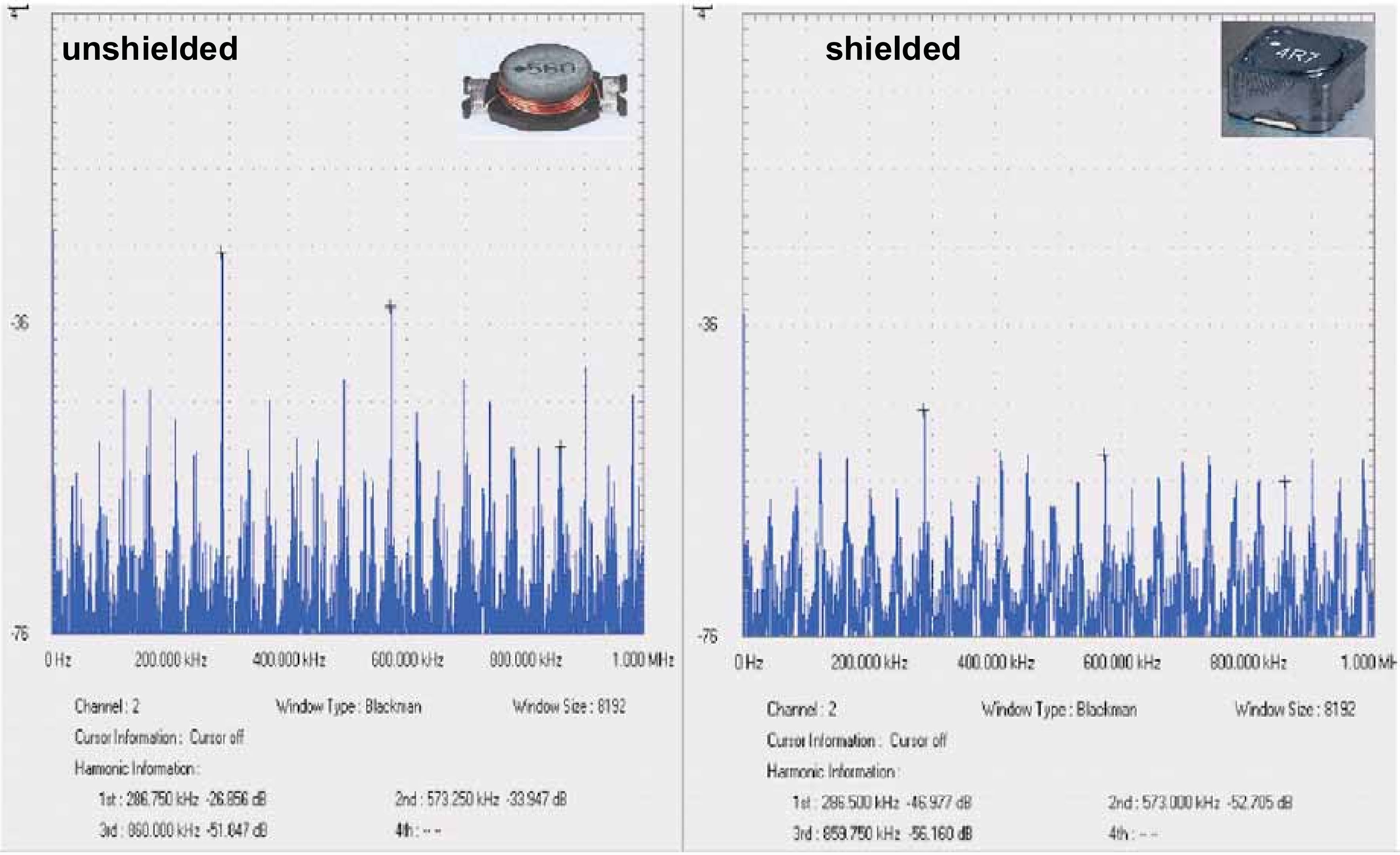

EMI: Shielded vs. Unshielded Power Inductor

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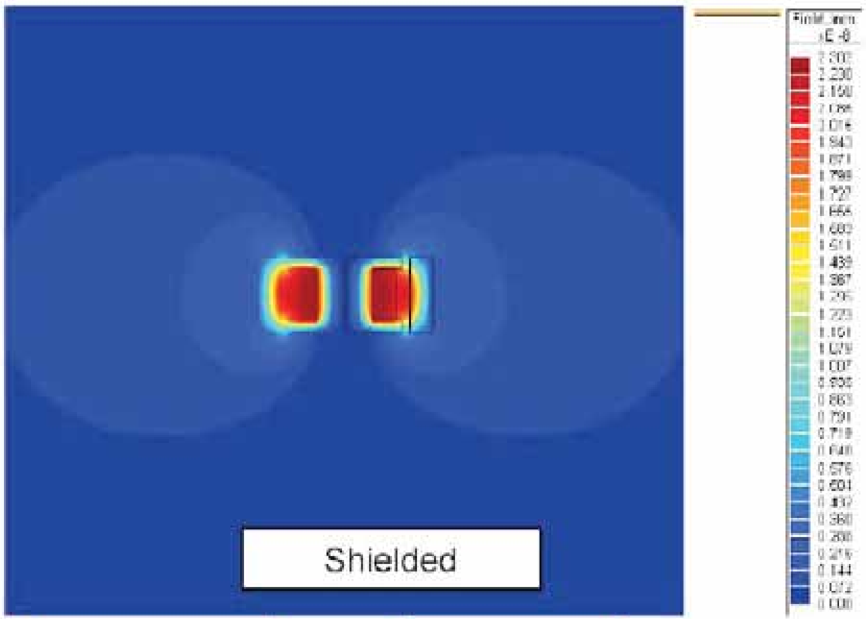
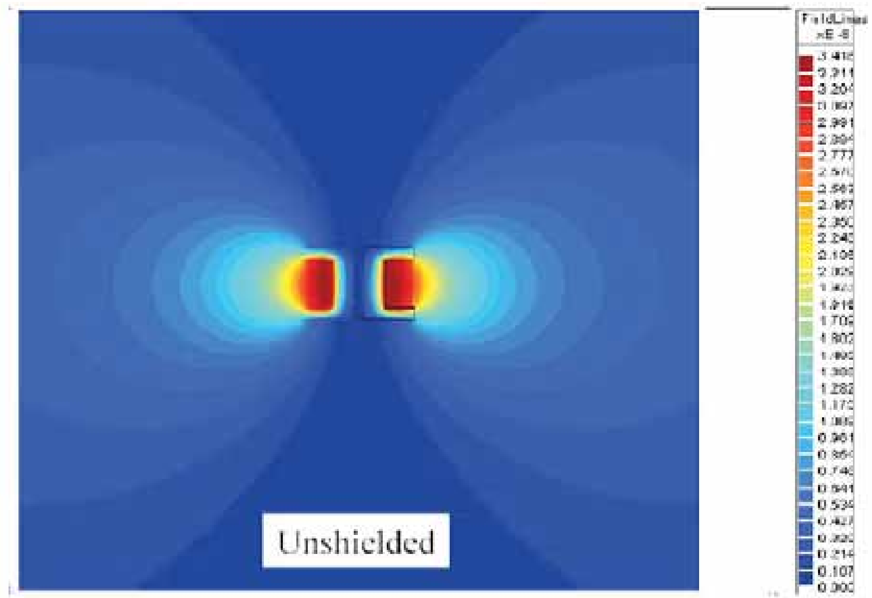
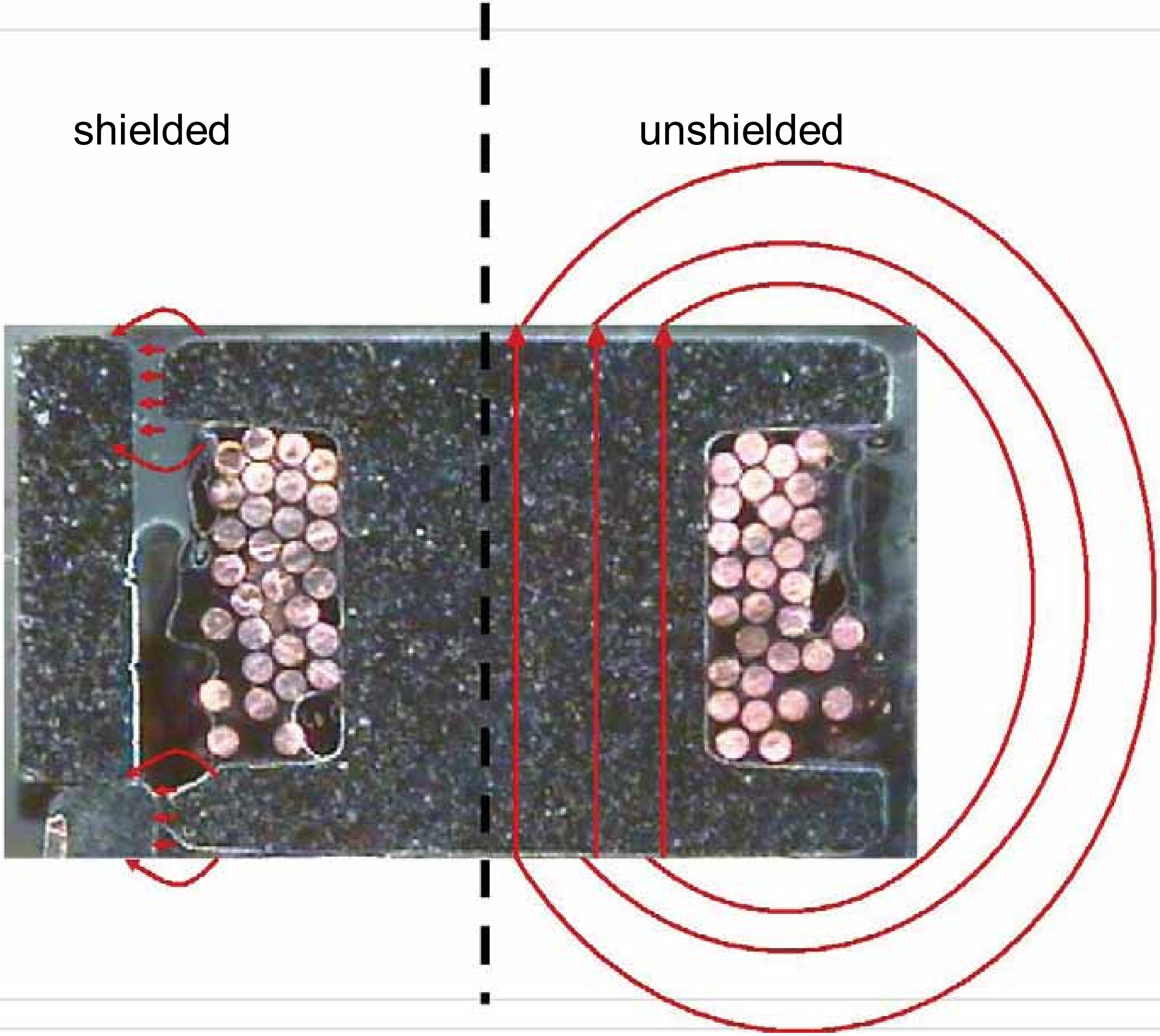




EMI: Shielded vs. Unshielded Power Inductor

- Magnetic field



What is the main different between a Inductor and EMC-Ferrite?

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=> Application Storage Choke: (Inductor)

Request: **lowest possible losses** at application frequency

high Q-factor

=> Application as absorber-filter: (EMC Ferrite)

Request: **highest losses possible** at application frequency range

low Q-factor

Ferrite Material

Ferrite Inductors WE-CBF

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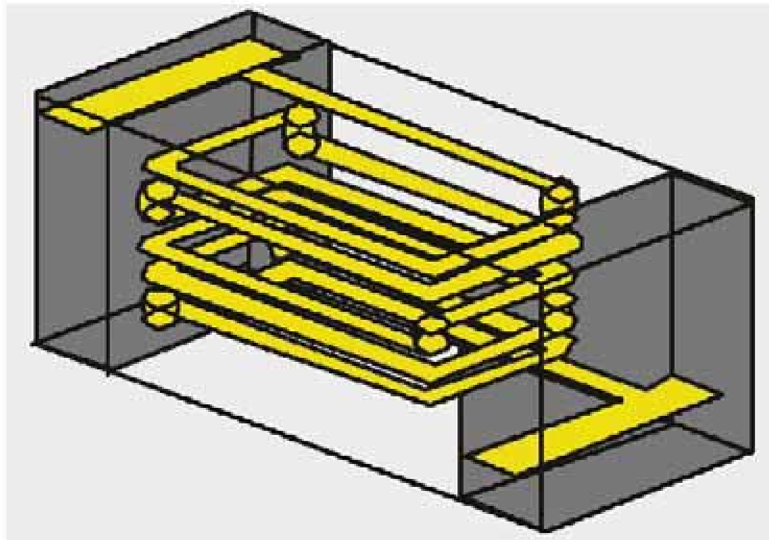
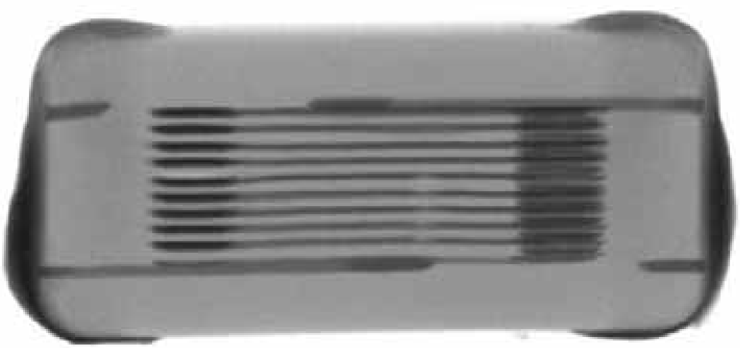
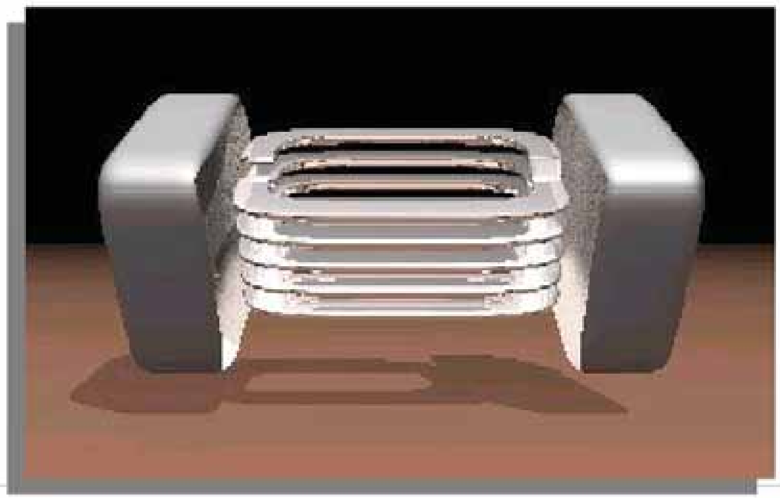
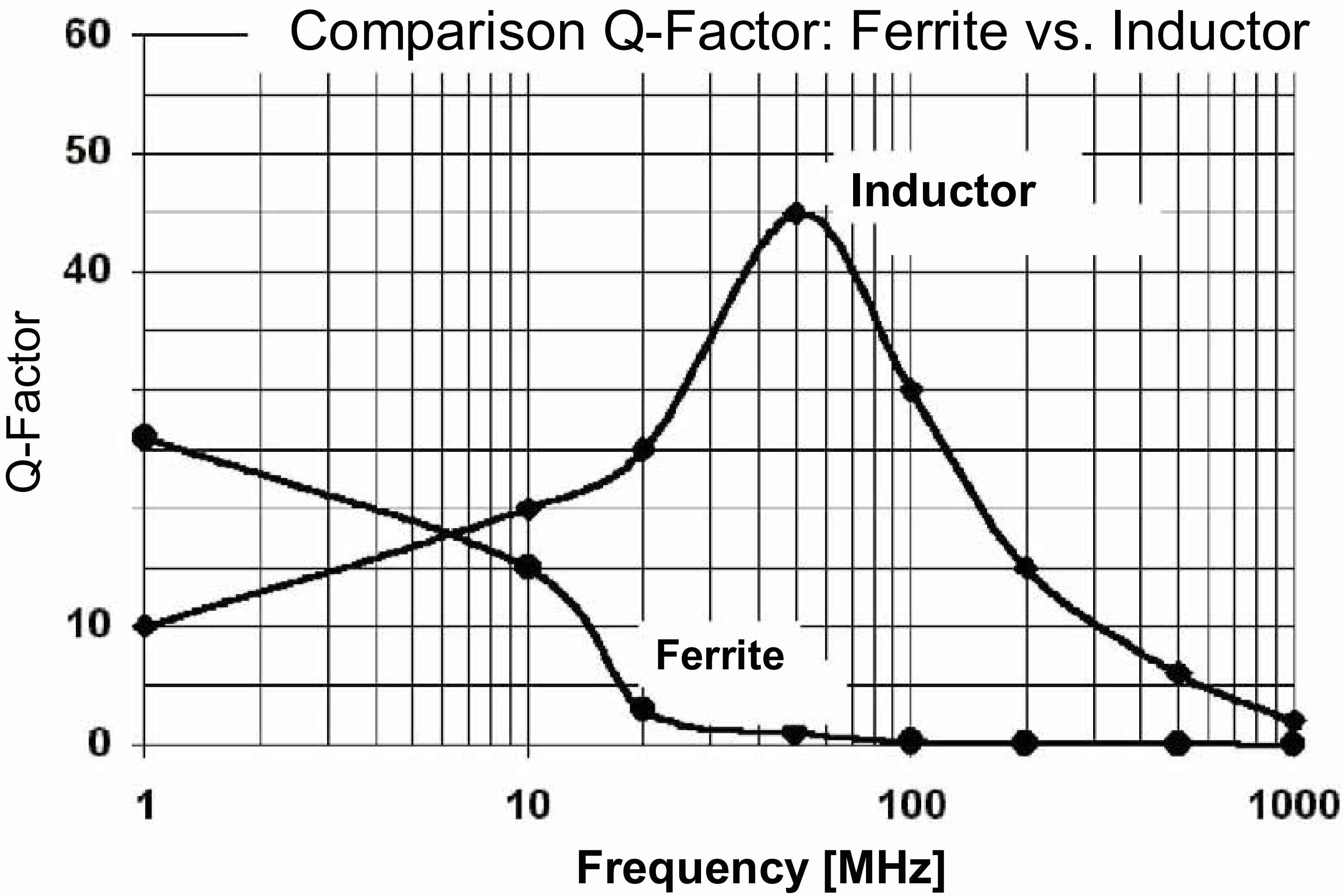




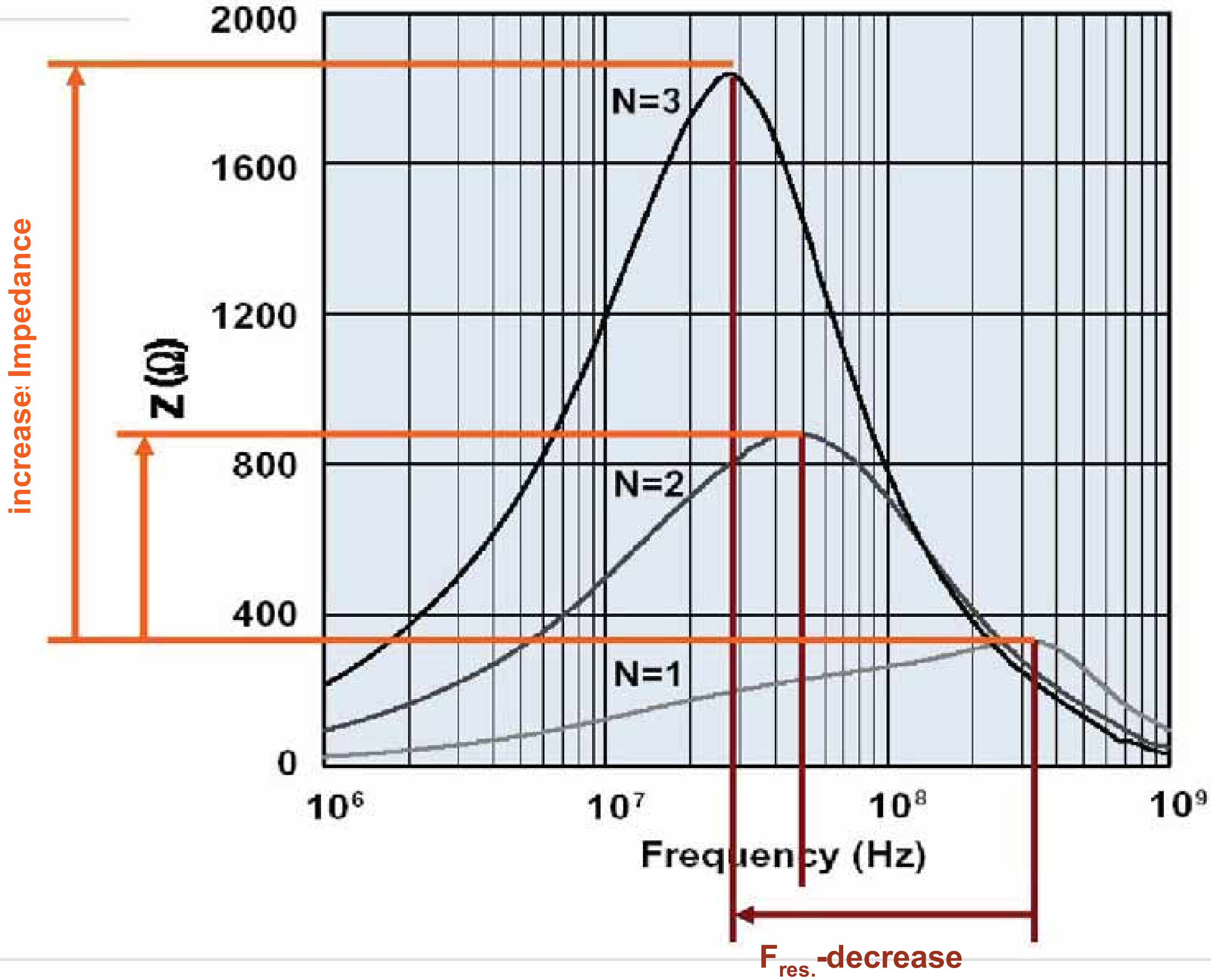


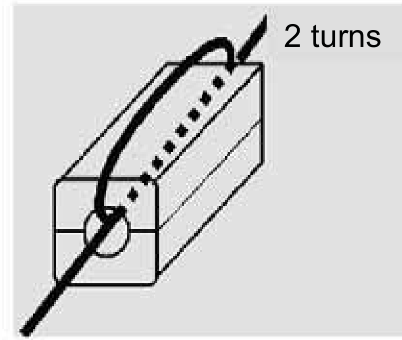
Inductor vs. EMI-Ferrite:



$$Q = \frac{XL}{R_{Losses}}$$

Impedance increase vs. numbers of turns





Why CMC‘s instead of Chip Beads

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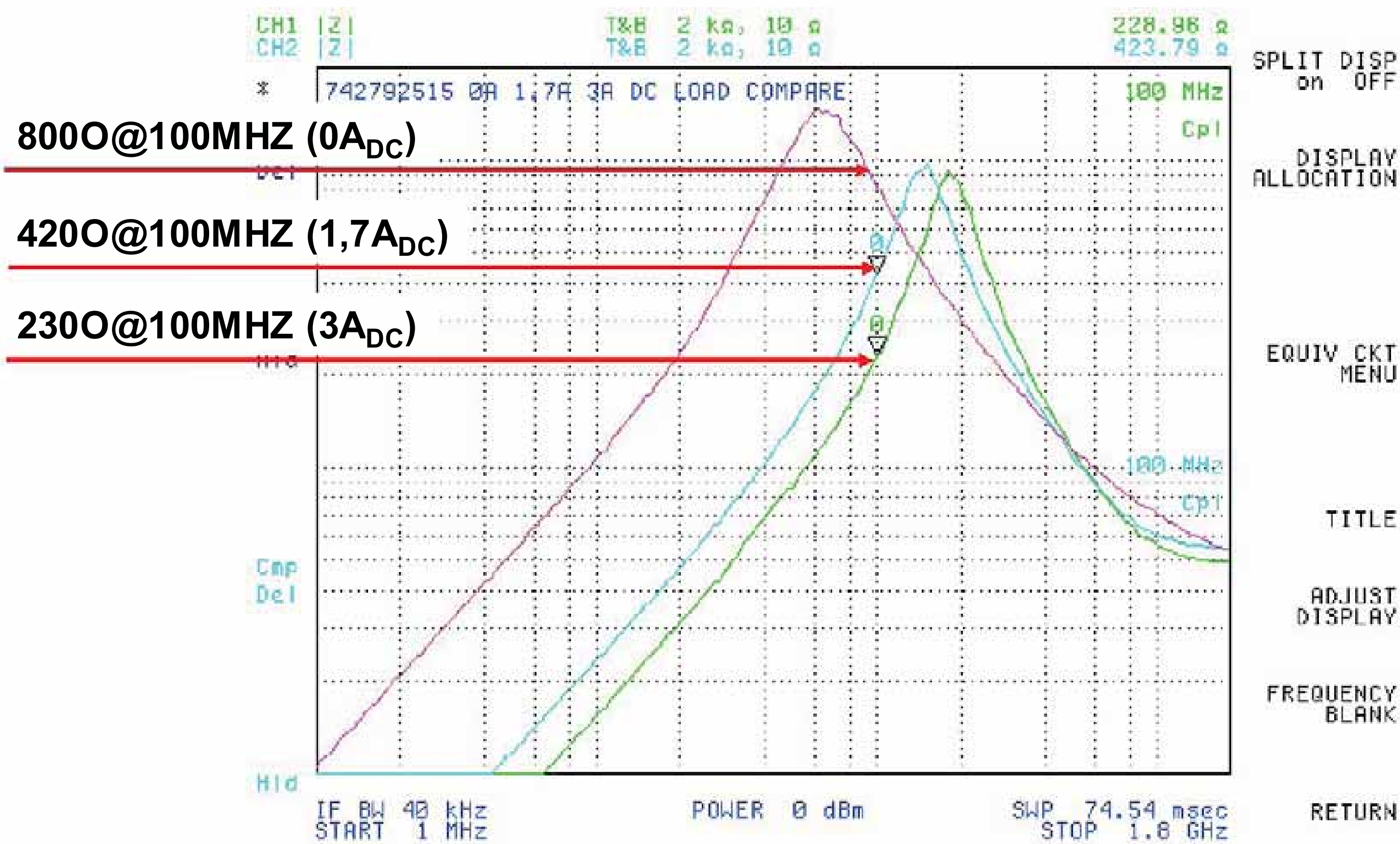
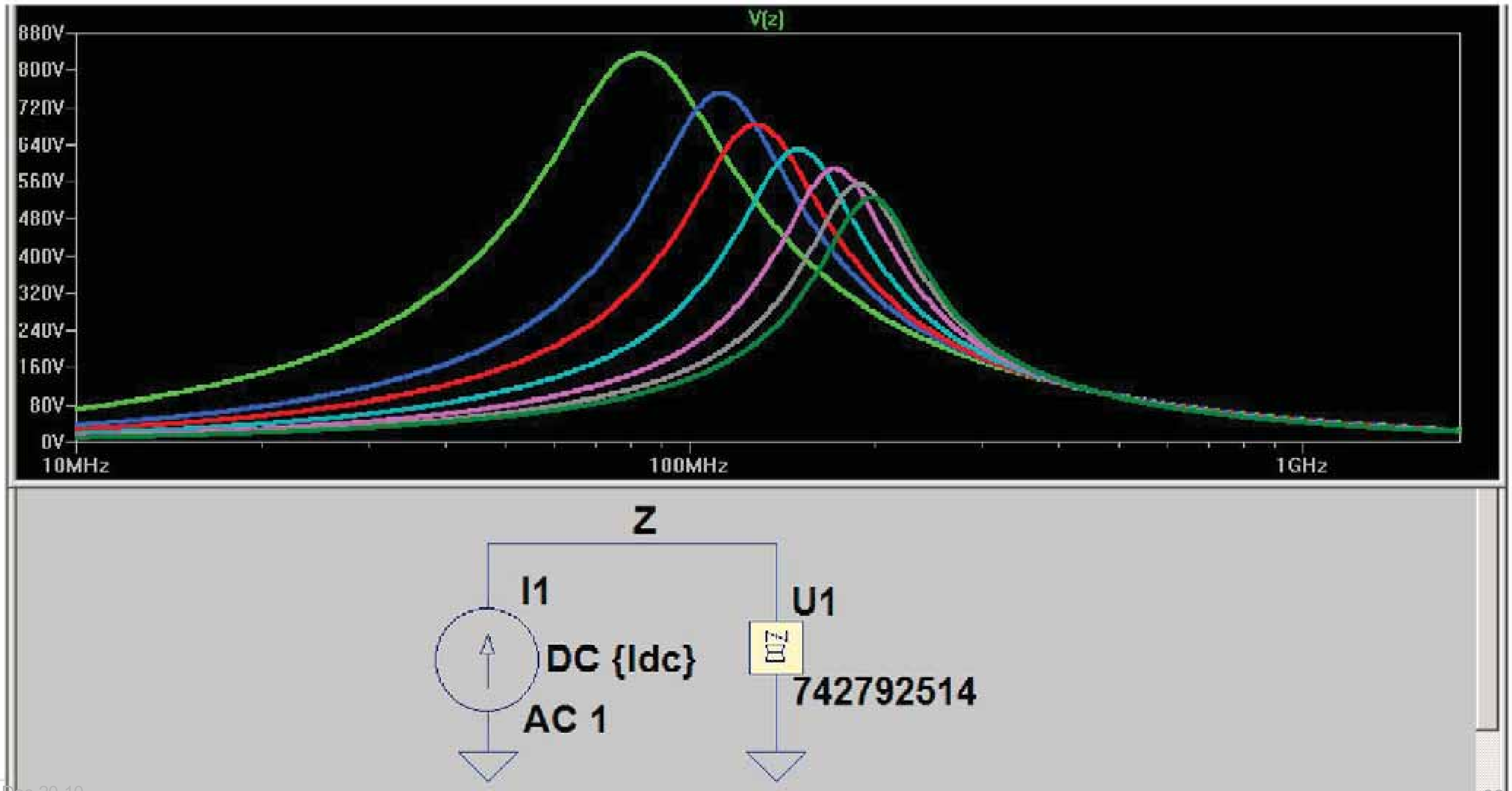
Impect of DC-bias (pre-magnetization (saturation)



742792515 (3A typ)

Impact of DC-Bias (pre-magnetization (saturation)



Common Mode Choke

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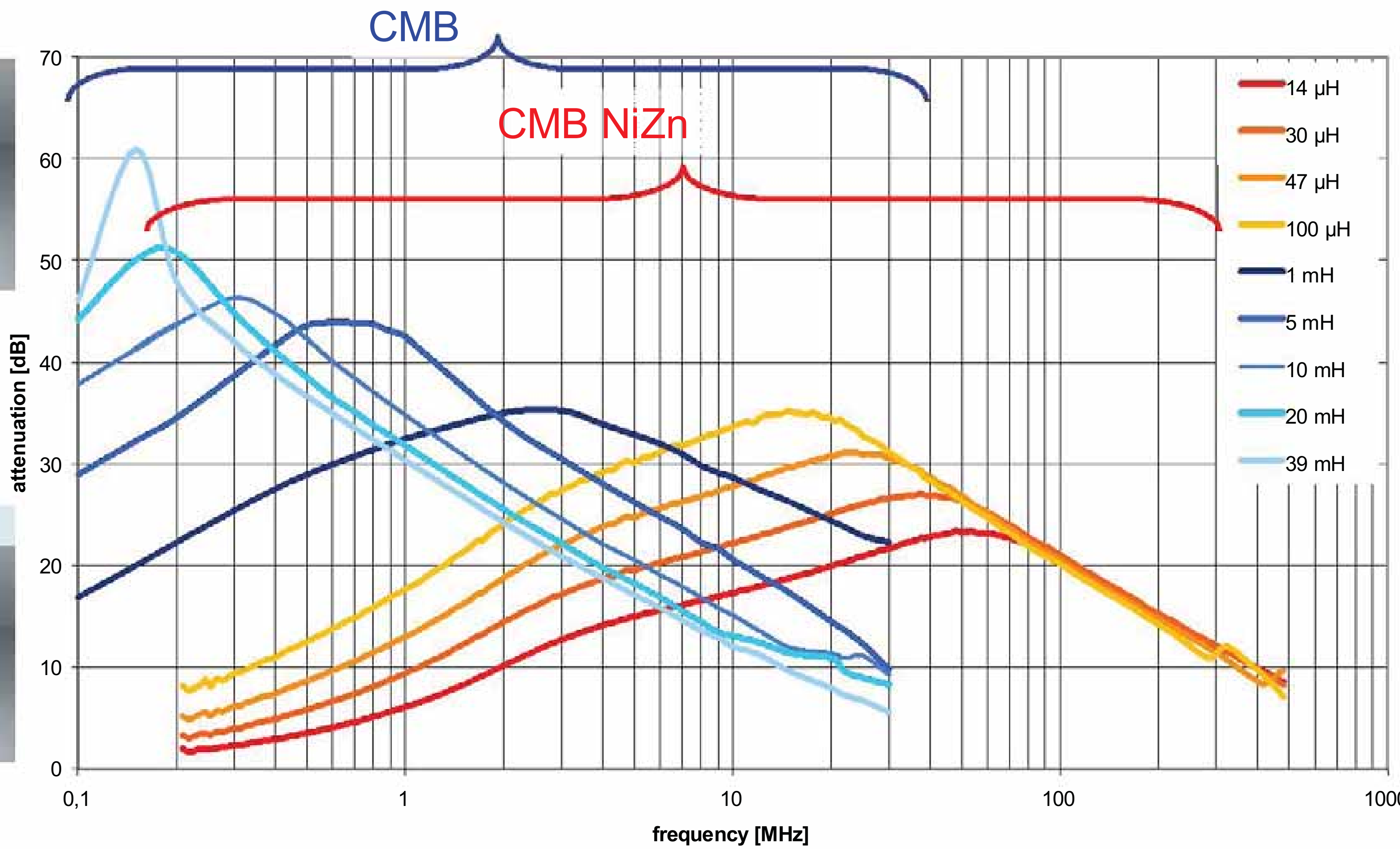
- comparison common mode chokes CMB – CMB NiZn

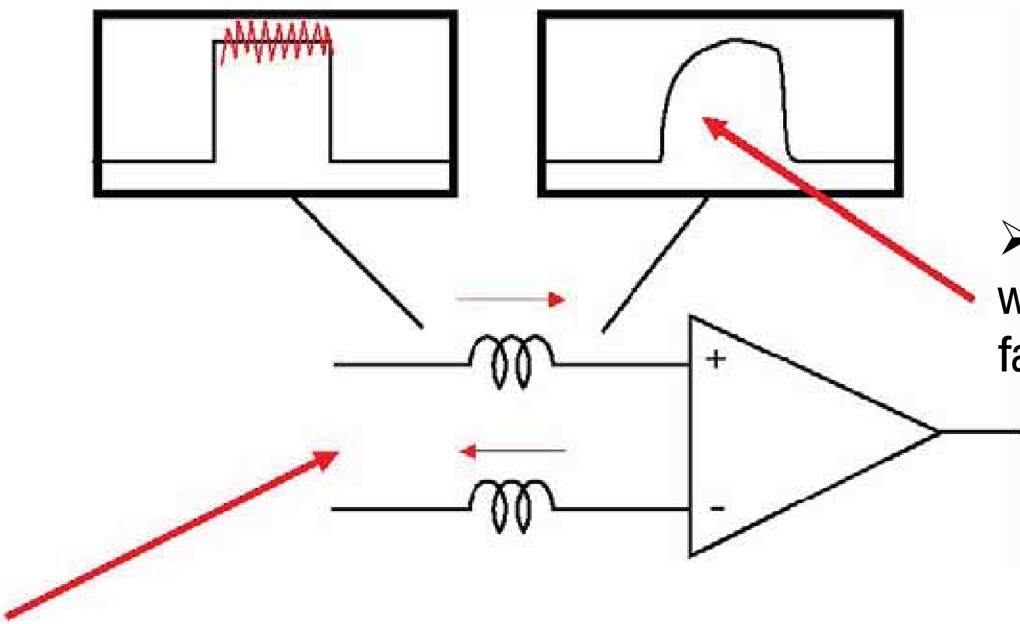
WE-CMB NiZn Type S



Advantage of a Common Mode Choke

Filtering with two inductors or chip beads

Signal before filtering after filtering



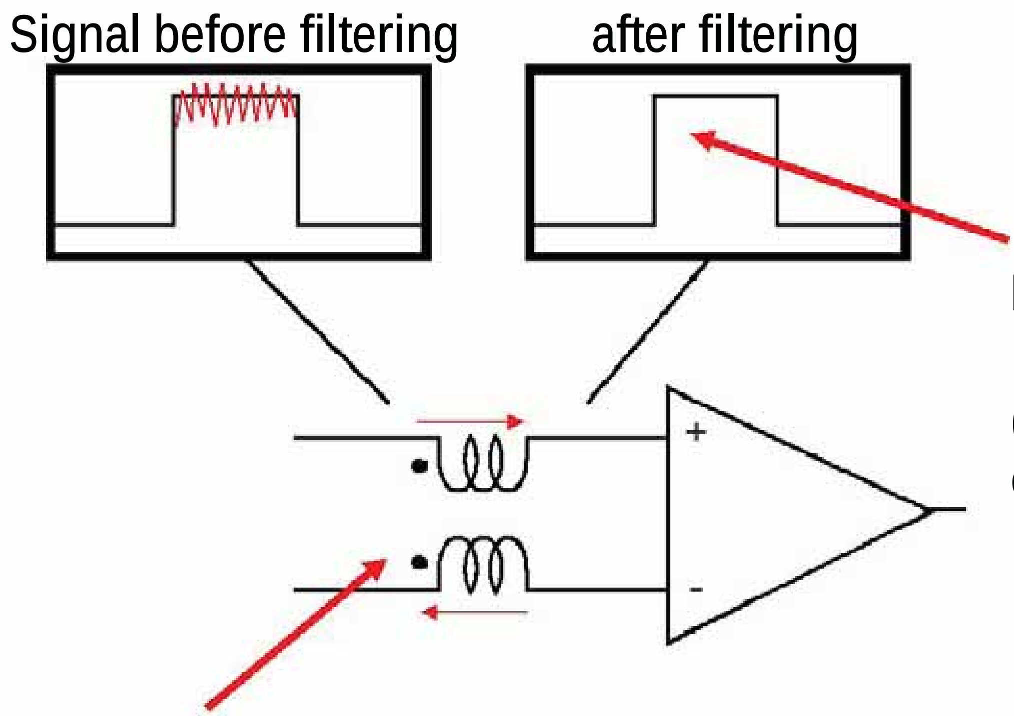
➢Rise-time of the signal is affected, which could cause problems for fast data and signal lines

which occurs from the DC current the filtering performance is shortened.

➢because of the pre-magnetization (saturation)

Advantage of a Common Mode Choke

Filtering with a Common Mode Choke



➢ no affect on the signal rise-time, because of magnetic field compensation

➢ no influence of the wanted signal

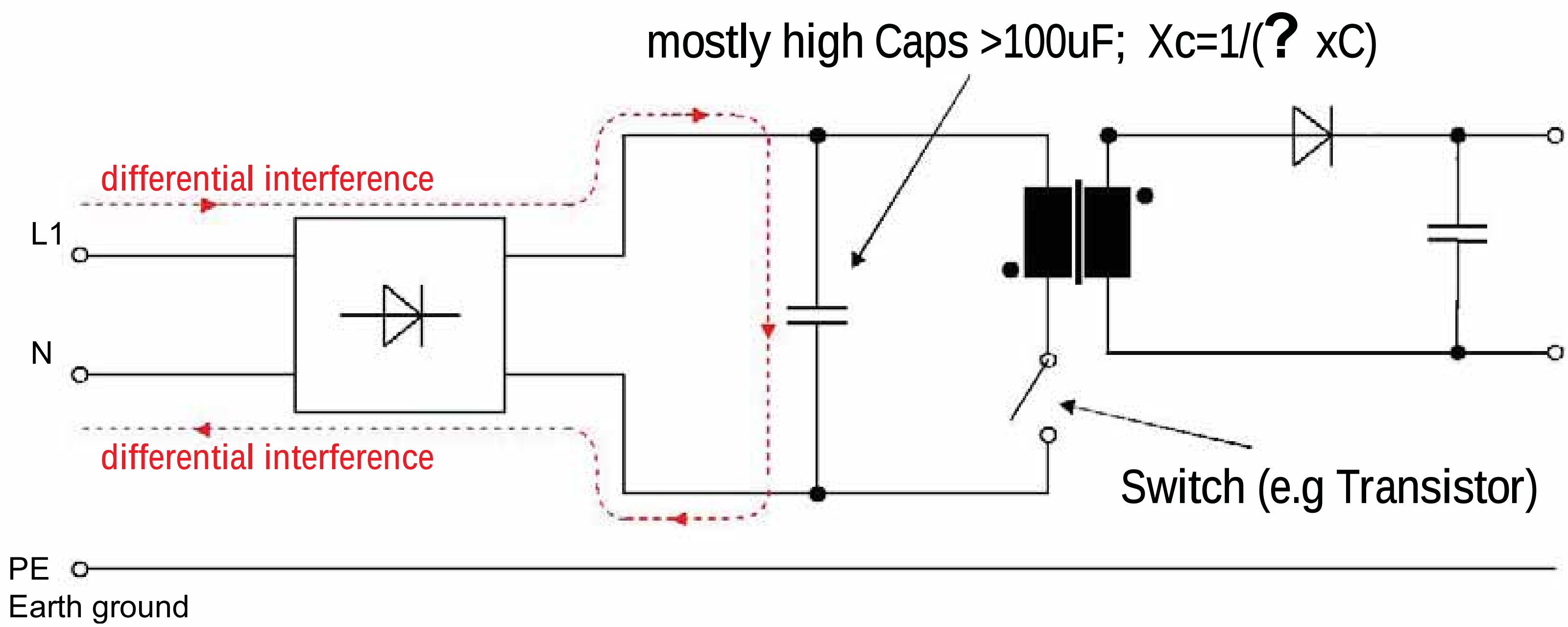
(the two windings are magnetically coupled)

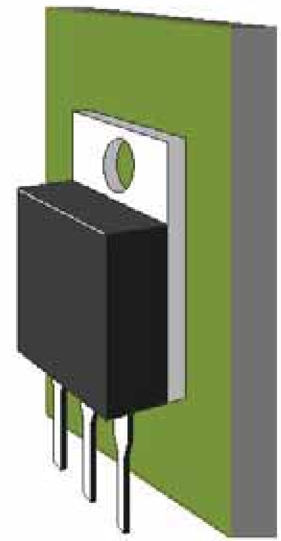
➢ no pre-magnetization (saturation) occurs from the DC current, because of magnetic coupling

➢ much better performance vs. two separate inductors or ferrites

Differential Noise Example: Flyback Converter

Appearance of ***differential noises*** on the input line of a Flyback Converter





differential interference occurs mainly at *lower* frequencies

Common Mode Noise Example: Flyback Converter

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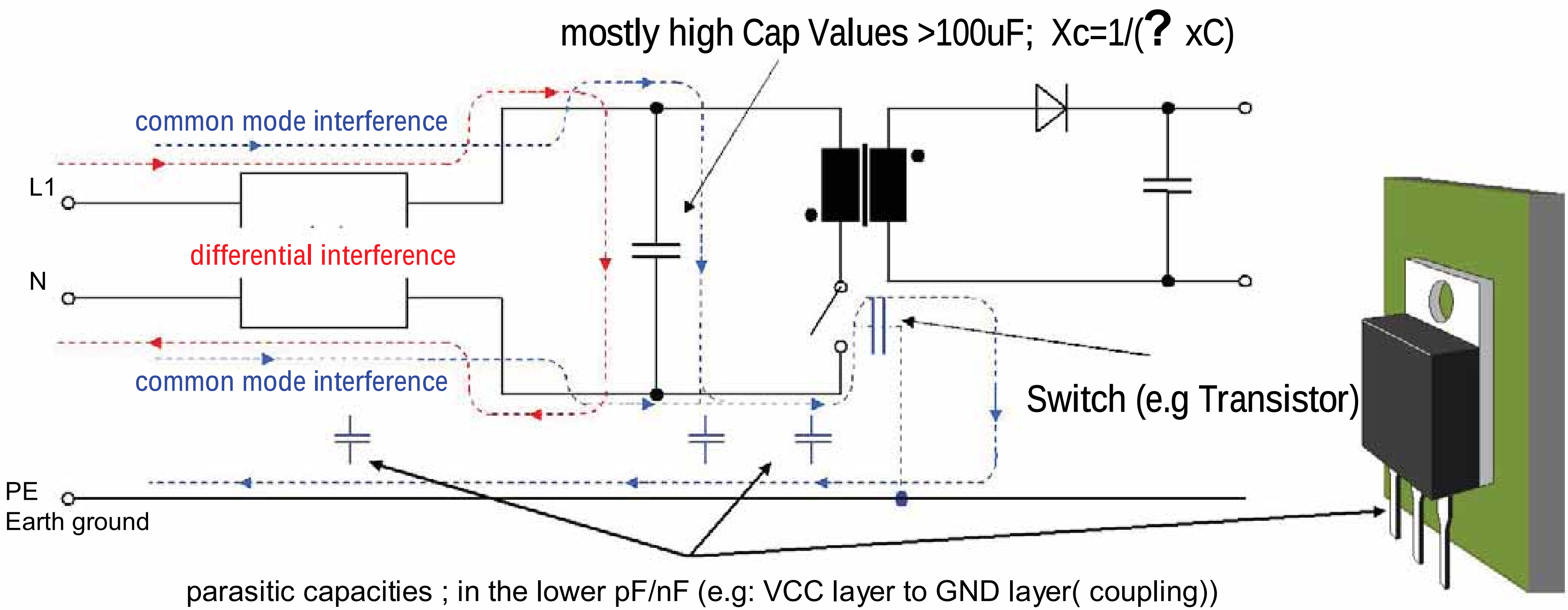
Appearance of ***common mode noises*** on the input line of a Flyback Converter



common mode interference occurs mainly at *higher* frequencies

Filtering Noise Example: Flyback Converter

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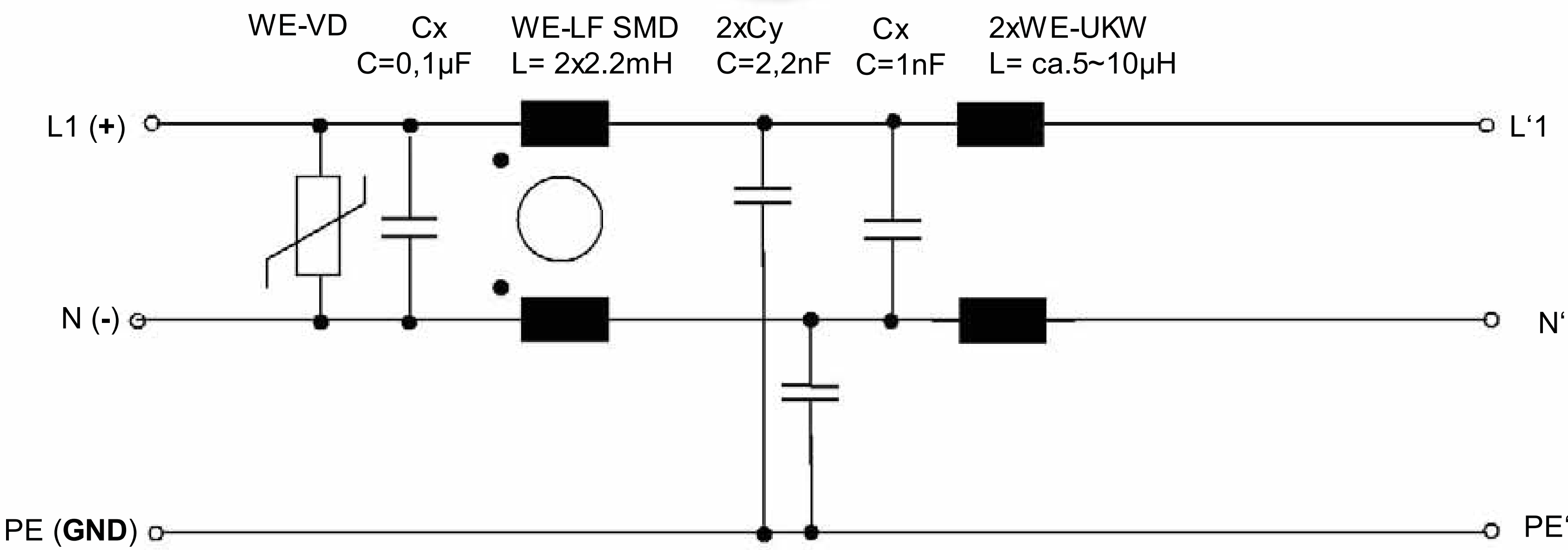
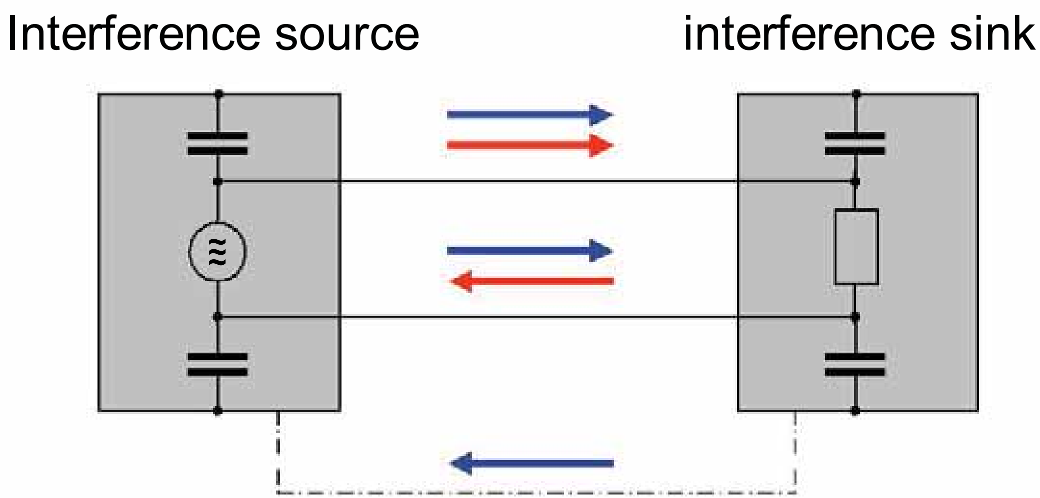
Filtering the mains power line for common mode and differential mode



Common mode / Differential mode



differential mode current

symmetrical interference voltage

Common mode current

Asymmetrical interference voltage

The DIFFERENTIAL Mode Signal creates a Flux in opposite directions – Thereby canceling

The COMMON MODE signal does not cancel and an Inductive Impedance is created thereby acting as a filter

Functionality of a common mode choke:

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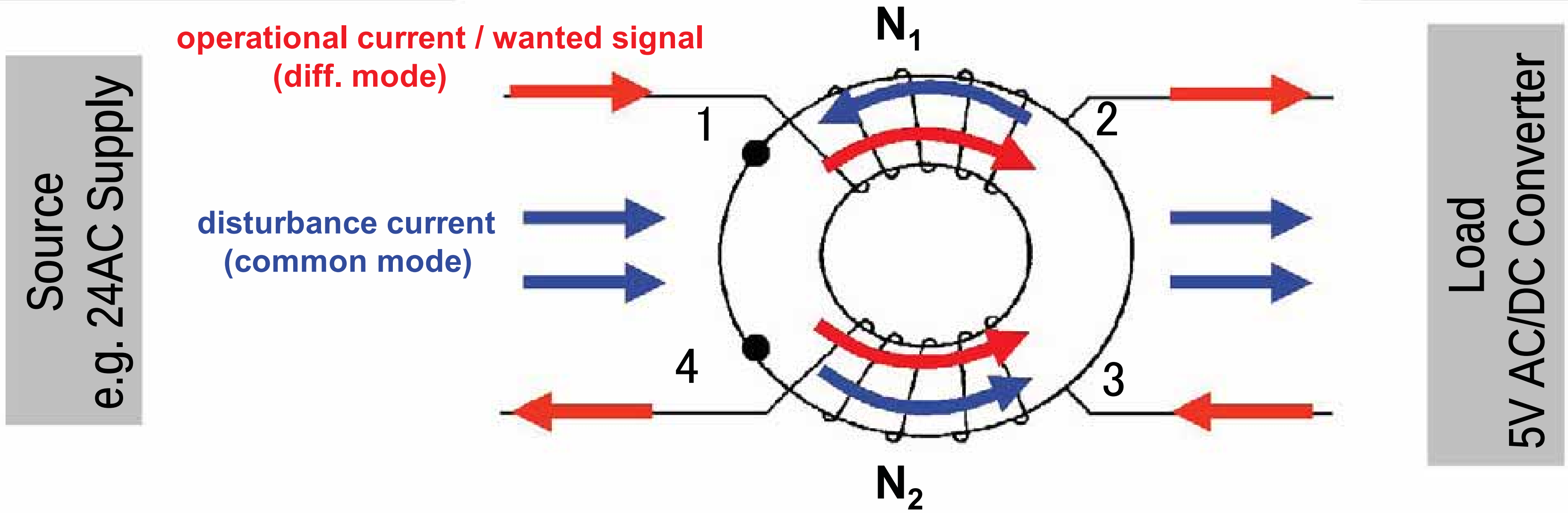
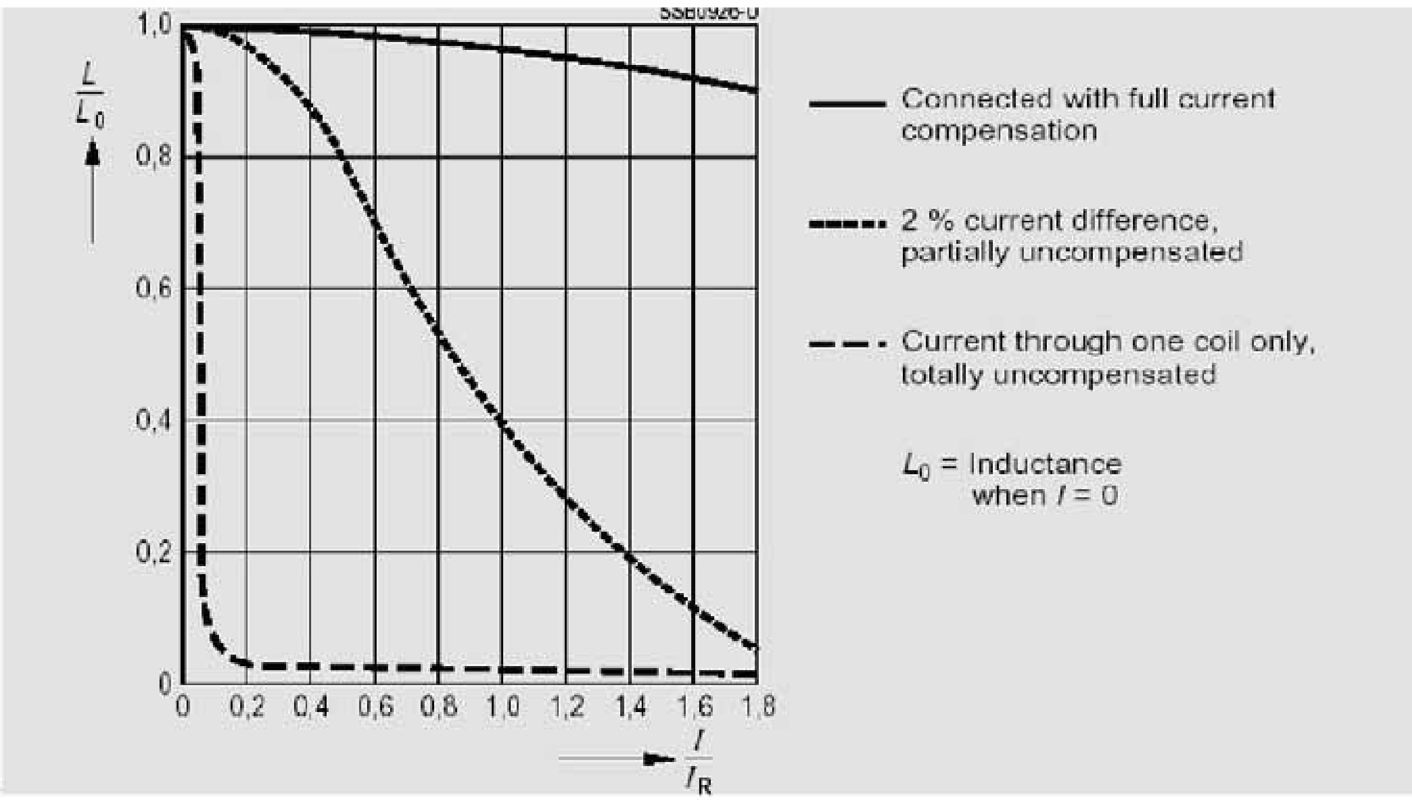


The DIFFERENTIAL Mode Signal creates a Flux in opposite directions – Thereby canceling
The operational current (diff. mode) is routed by all relevant conductors through the core (e.g. +/- or L/N). That´s why the magnetic fields of these two conductors compensate each other to zero => no influence on the wanted signal

The COMMON MODE signal does not cancel and an Inductive Impedance is created thereby acting as a filter
The disturbance current flows on both wires in the same direction and generates a magnetic field in the toroidal core => the choke is able to filter unwanted noises.

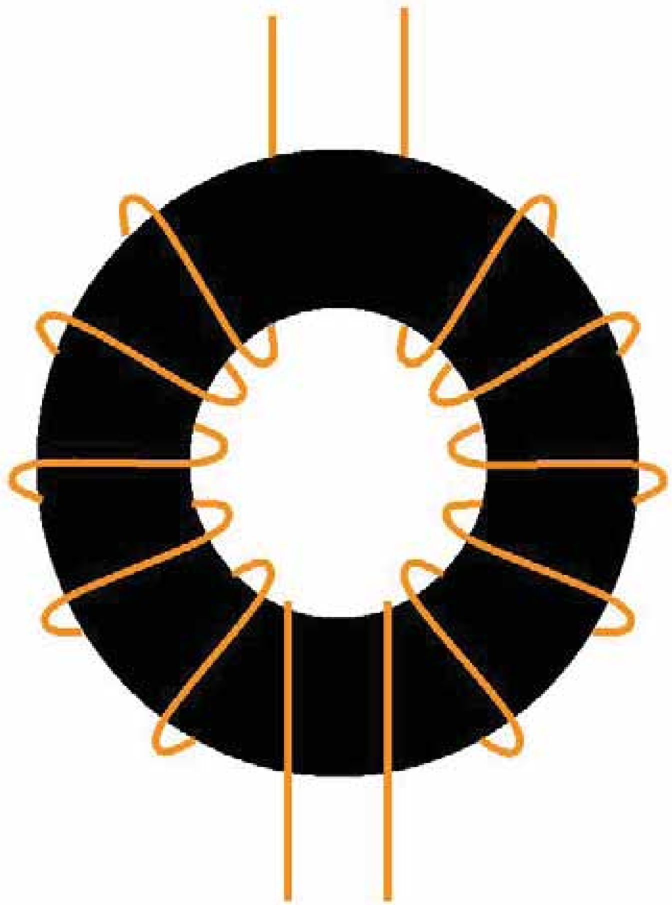
Unbalanced Current

- the operating current on both conductors is almost the same. When the difference between input and output current is too big, the common mode choke is no longer compensated and starts saturating very fast !



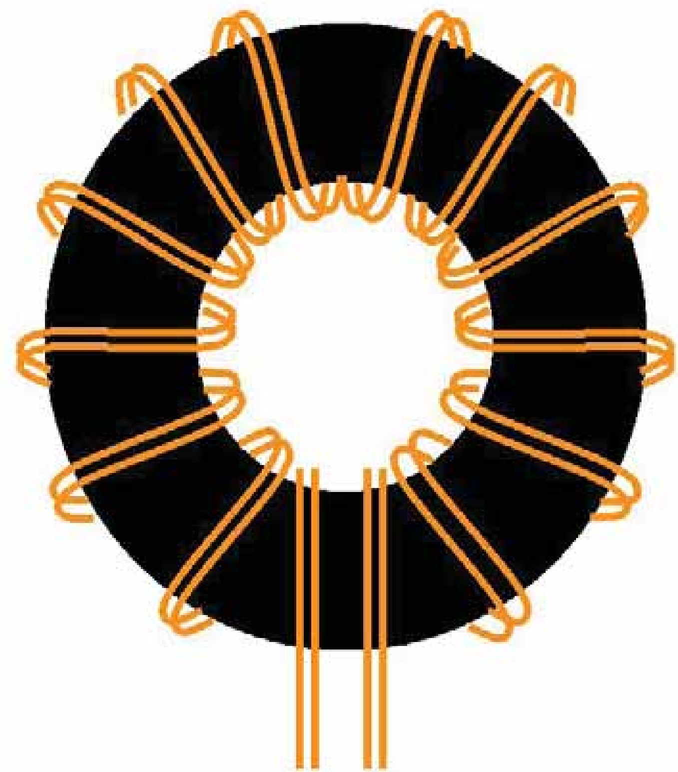
Common Mode Choke

sectional winding



< advantage? >

bifilar winding



Stray inductance: Bifilar / Sectional

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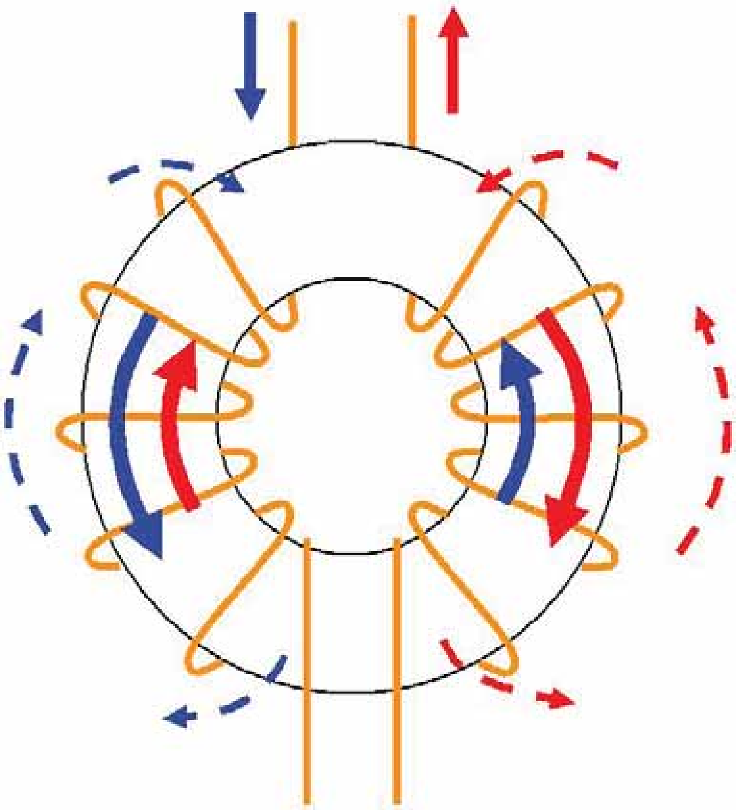
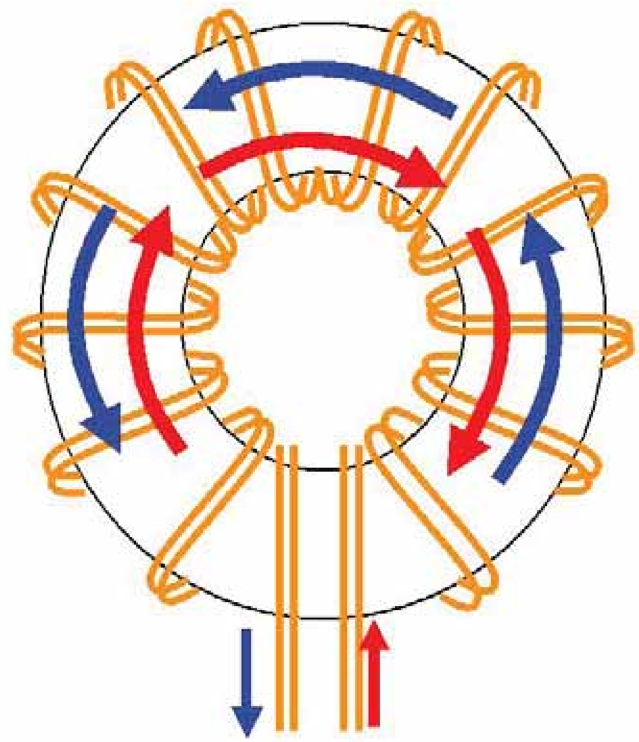
Sectional



$L_S \sim 0{,}5 \ldots 2\% * L_R$

Bifilar

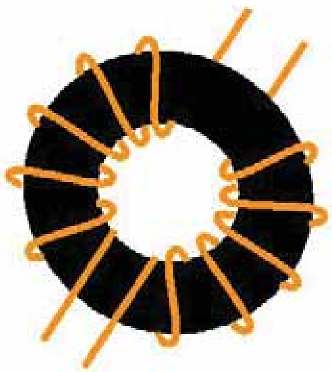


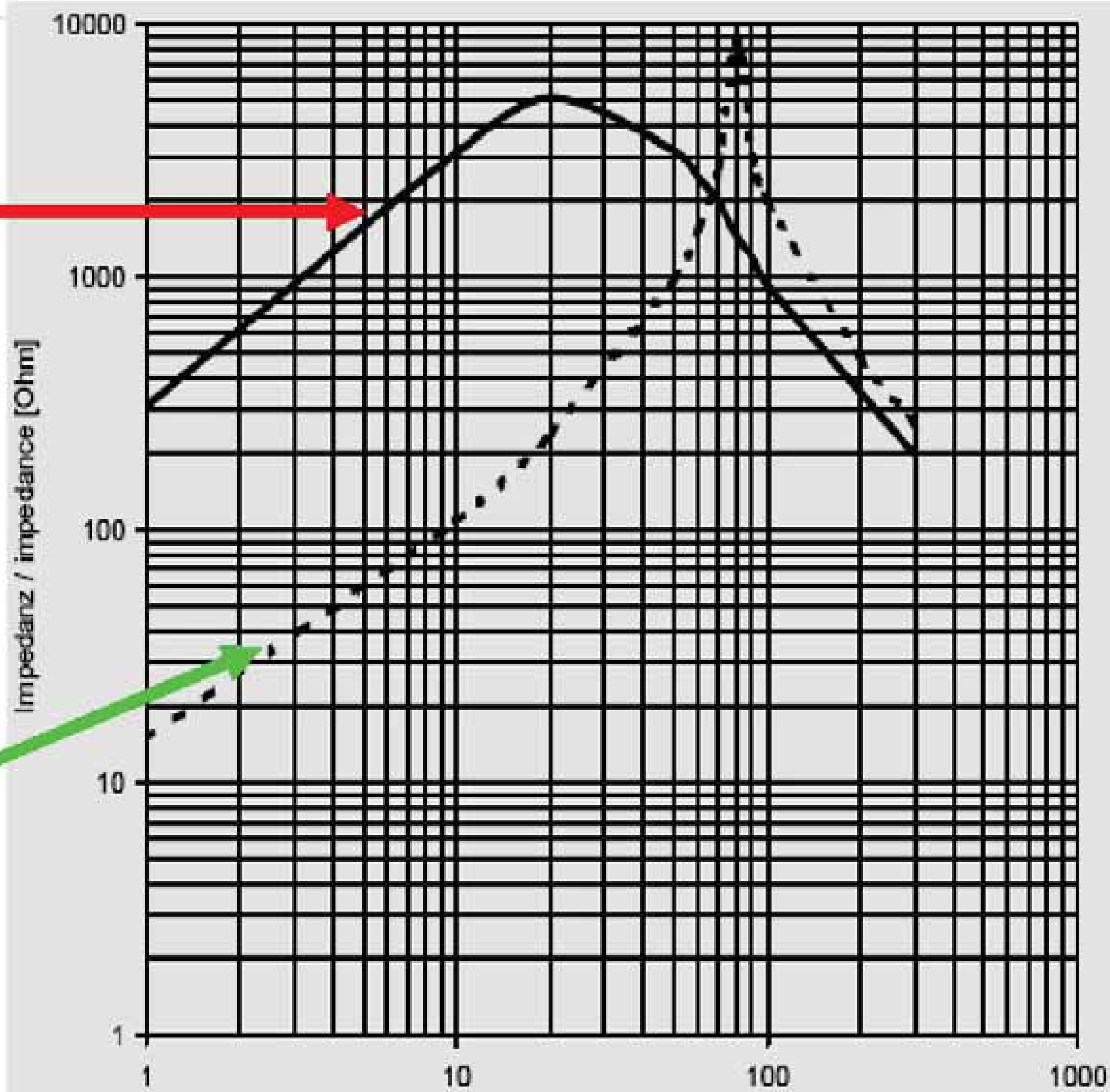
$L_S \sim 0{,}1 \ldots 1{,}0\ ‰ * L_R$

Sectional winding:

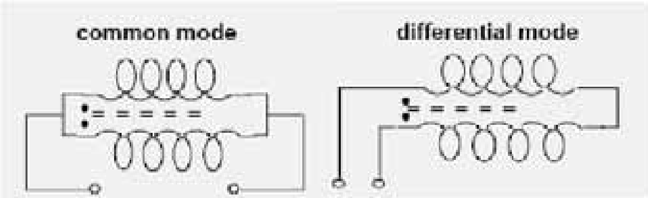
For example: WE-SL2 744227S

Common Mode suppression





Differential Mode suppression is high!



Bifilar winding vs. Sectional winding

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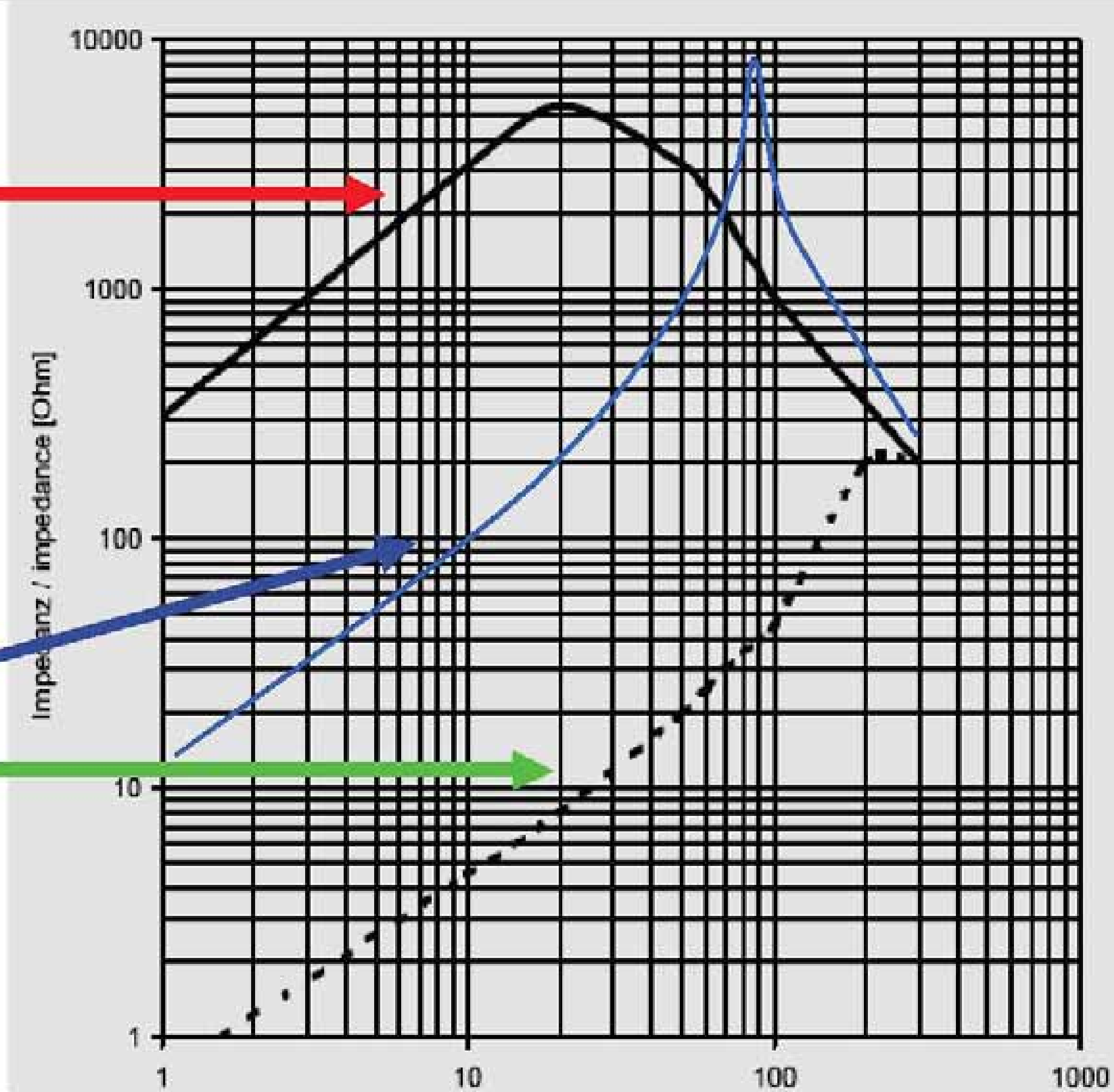
For example: WE-SL2 744227

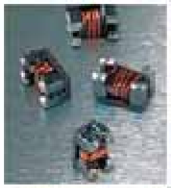
Common Mode suppression

Differential Mode S-Type

Differential Mode suppression is low!



Common mode chokes for SMD:

		Size [mm]	Impedance [O]	Current [A]	Application
WE-CNSW		2.0 x 1.2 x 1.2 3.2 x 1.6 x 1.9	130 – 910 60 – 400	0.28 – 0.4 0.20 – 0.37	USB 2.0 Firewire/ high speed dataline
WE-SL		12.7 x 10.5 x 5,75	1100 – 14400	0.20 – 2.70	ISDN Telecom Applications
WE-SL 1 **744212xxx**		6.5 x 3.6 x 1.65	300 – 2000	0.30	PCMCIA cards
WE-SL 2		9.2 x 6.0 x 5.0	1000 – 20000	0.40 – 1.60	VCC Power & Datalines
WE-SL 3 **744252/253xxx**		9.2 x 6.6 x 2.5	1250 – 5000	0.50 – 0.70	VCC Power & Datalines higher current ratings
WE-SL 5 **744272xxx**		10.0 x 8.2 x 6.5	290 – 13000	0.35 – 2.50	VCC Power Lines

Common Mode Choke

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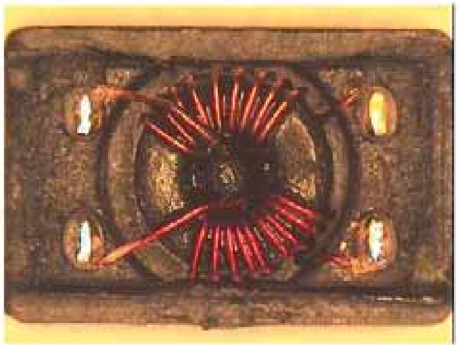
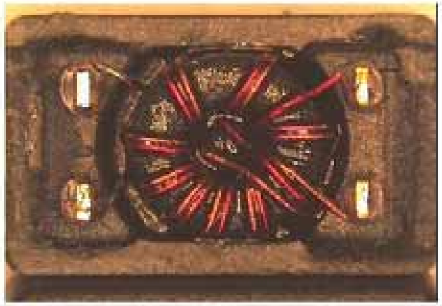
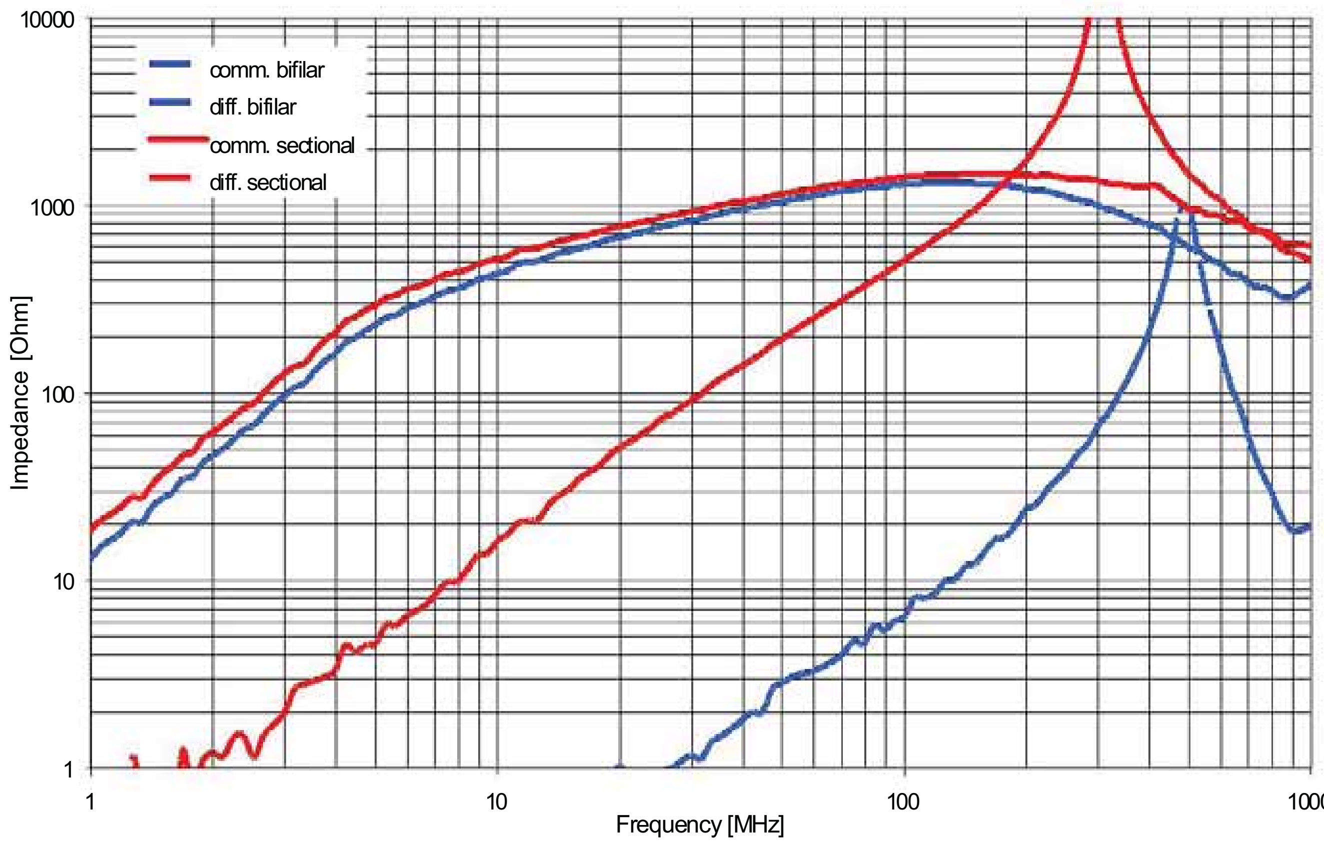
- different designs

WE-SL2 744226S
<u>sectional winding</u>

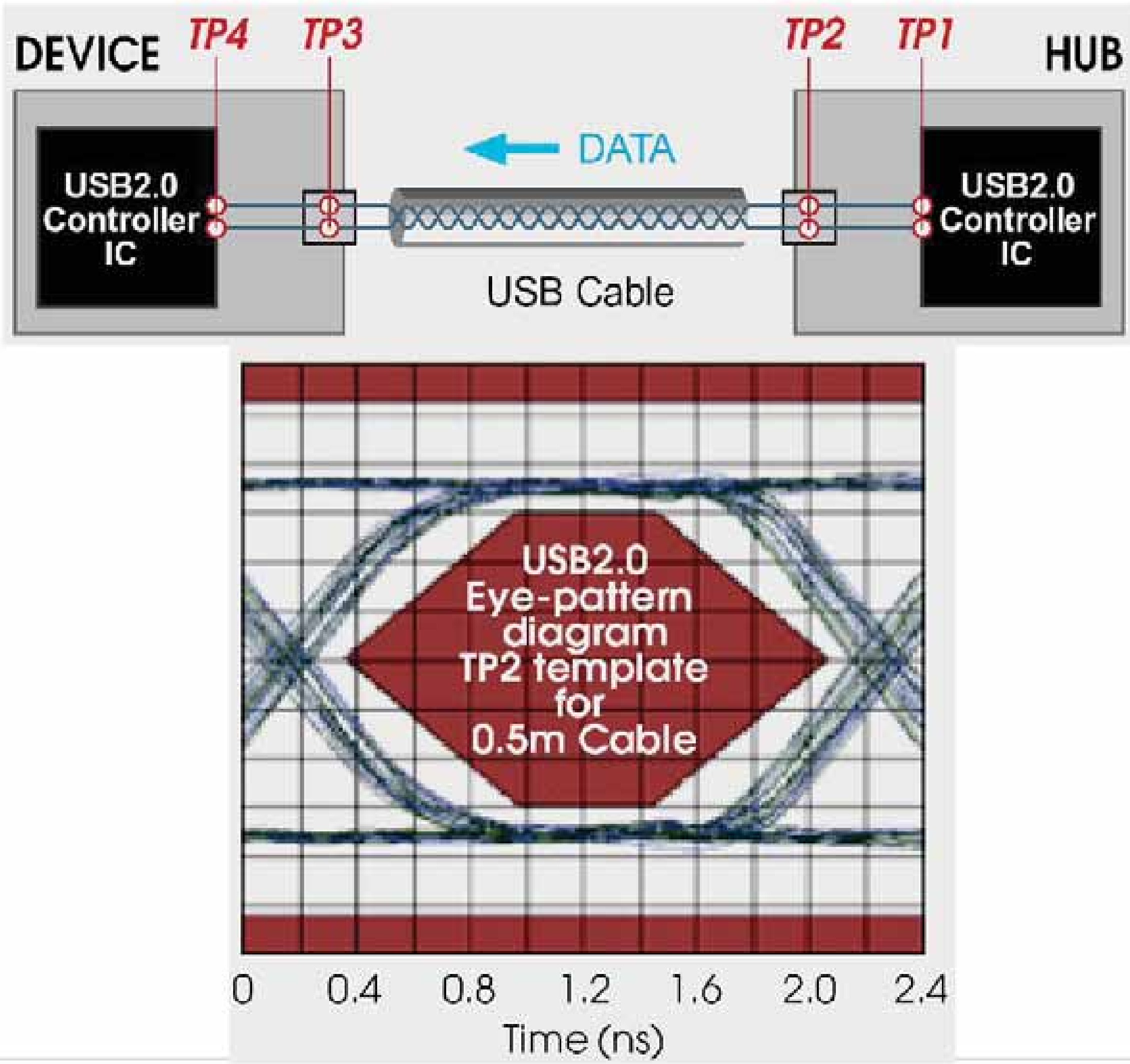


WE-SL2 7442276
<u>bifilar winding</u>





CMC - USB 2.0 Filtering for Common Mode Noise



CMC- USB 2.0 Filtering with WE-CNSW

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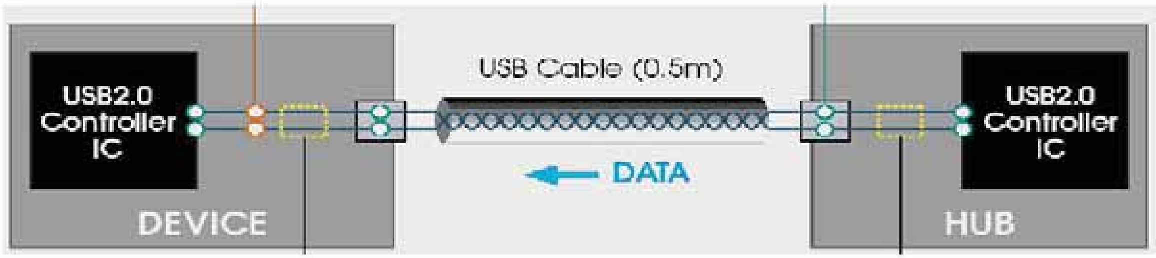
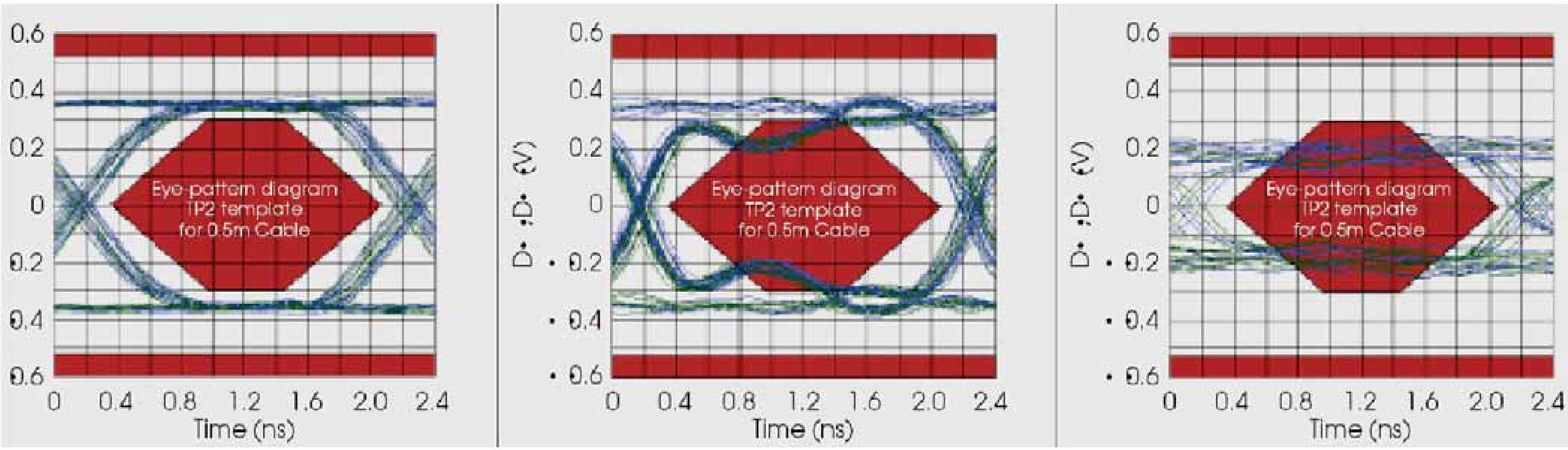
measurement point TP2



EMI-filter EMI-filter



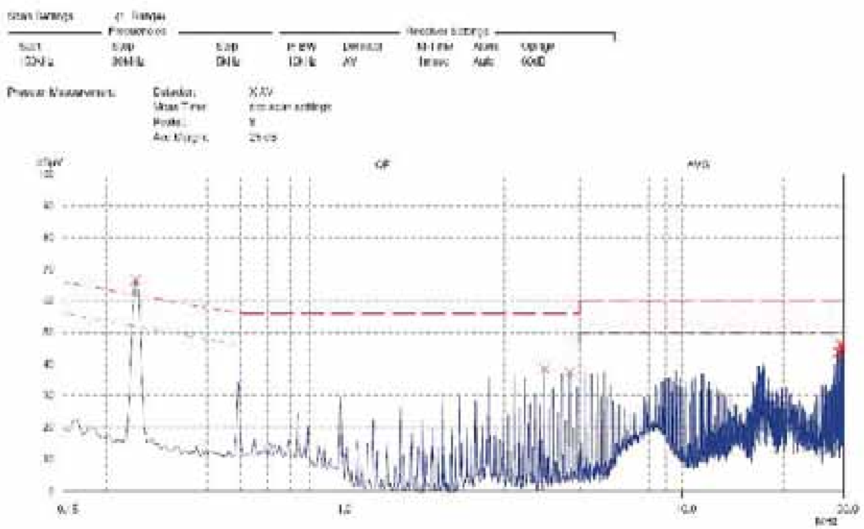
90 Ohm @ 100 MHz C.M.
20 Ohm @ 240 MHz D.M.

600 Ohm @ 100 MHz C.M
40 Ohm @ 240 MHz D.M.

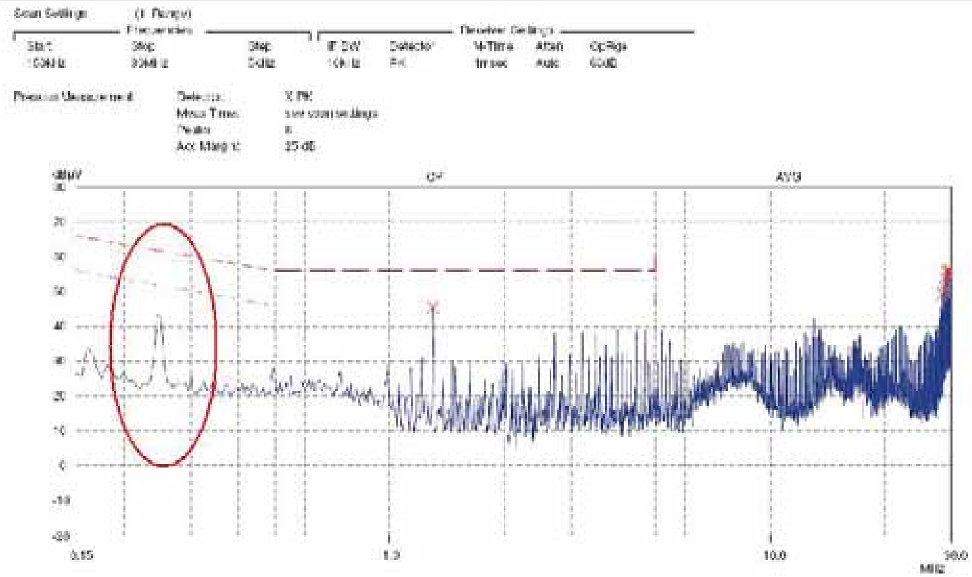
WE-CBF
120 Ohm @ 100 MHz

Too much differential mode impedance distorts the USB 2.0 eye pattern

How Much Inductance is Needed?



before



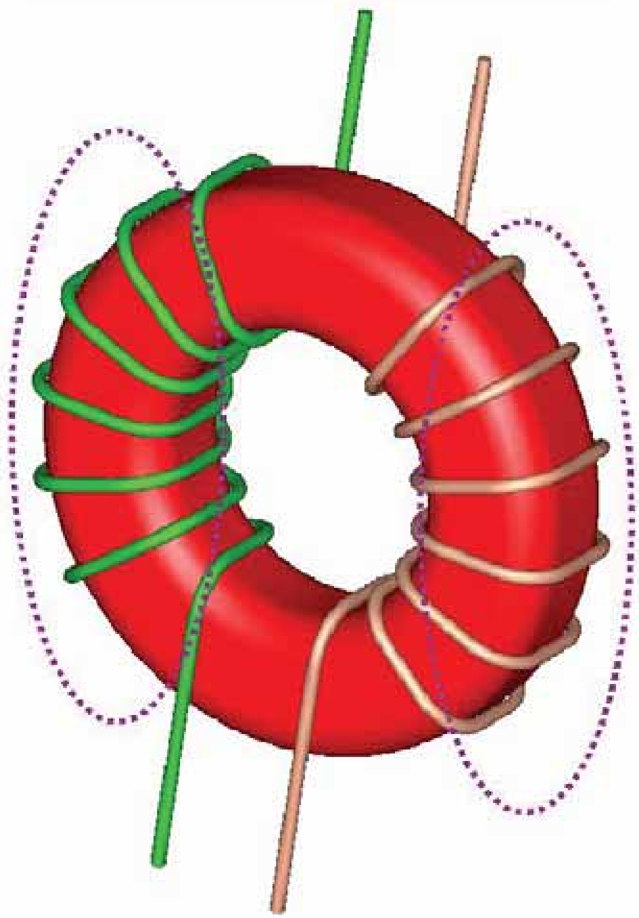
after
only changed one component

30mH!

Common Mode Choke (Sectional)

- When do we offer a sectional winding?

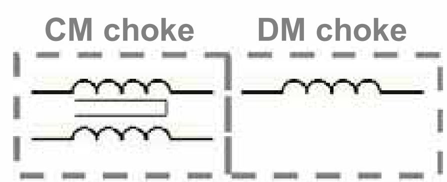
sectional



- **power supply : "high" voltage application**
- **signal : low and high speed signal**

→ only solution to guarantee distances between the two winding according to IEC60938 or UL1283
max. voltage application : 250 VAC / DC

→ high leakage inductor



→ two products in one
(preferred for power supplies)

→ max. voltage : print in data sheet

Common Mode Choke (Bifilar)

- data signal application

bifilar → low leakage inductor

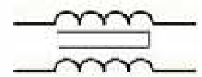
- **power supply : low voltage application**
- **signal : only low speed signal**

→ low voltage application
(42 VAC / 80V DC)

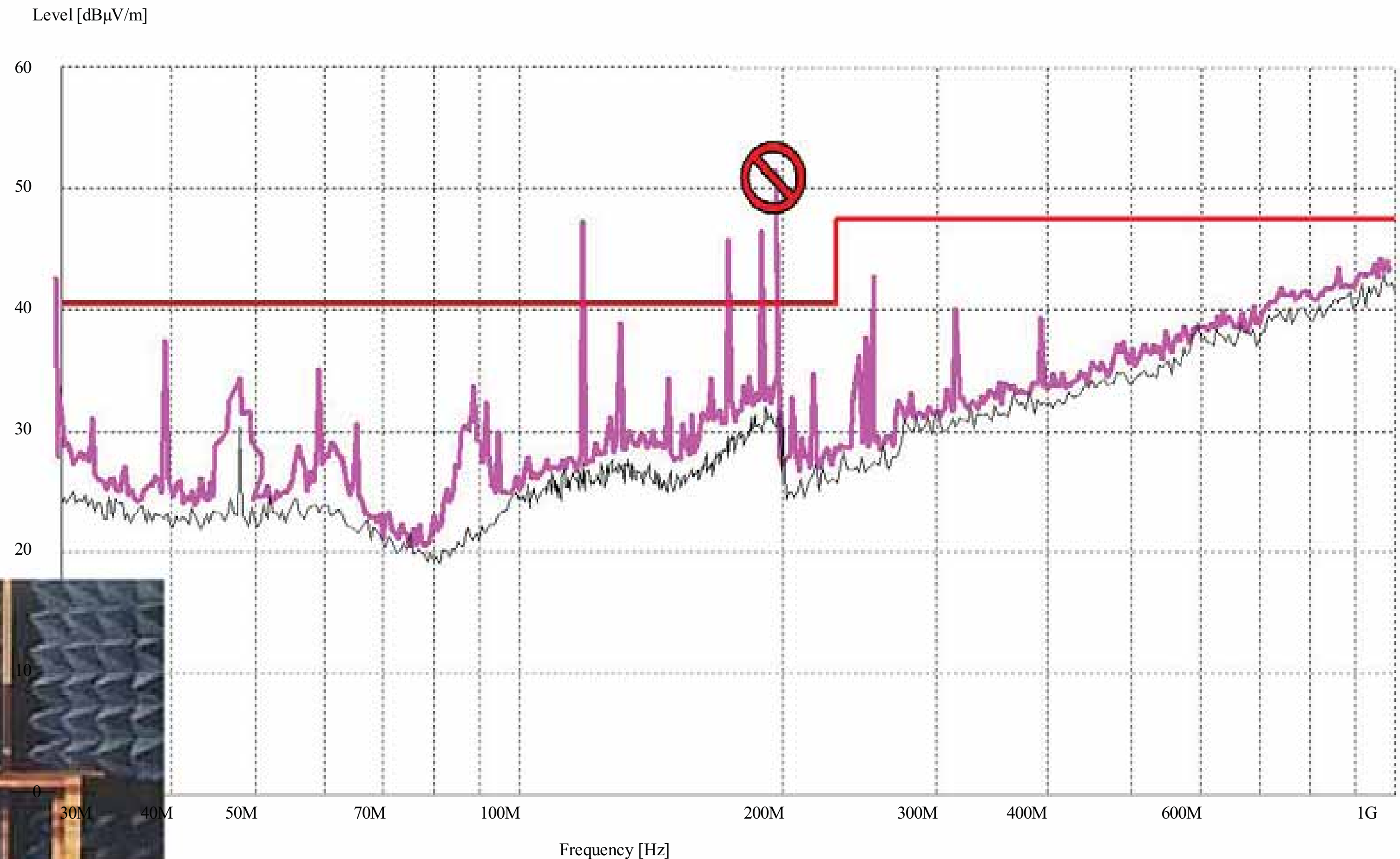
Common Mode Choke

Midcom WÜRTH ELEKTRONIK

- comparison Common Mode to Single Choke

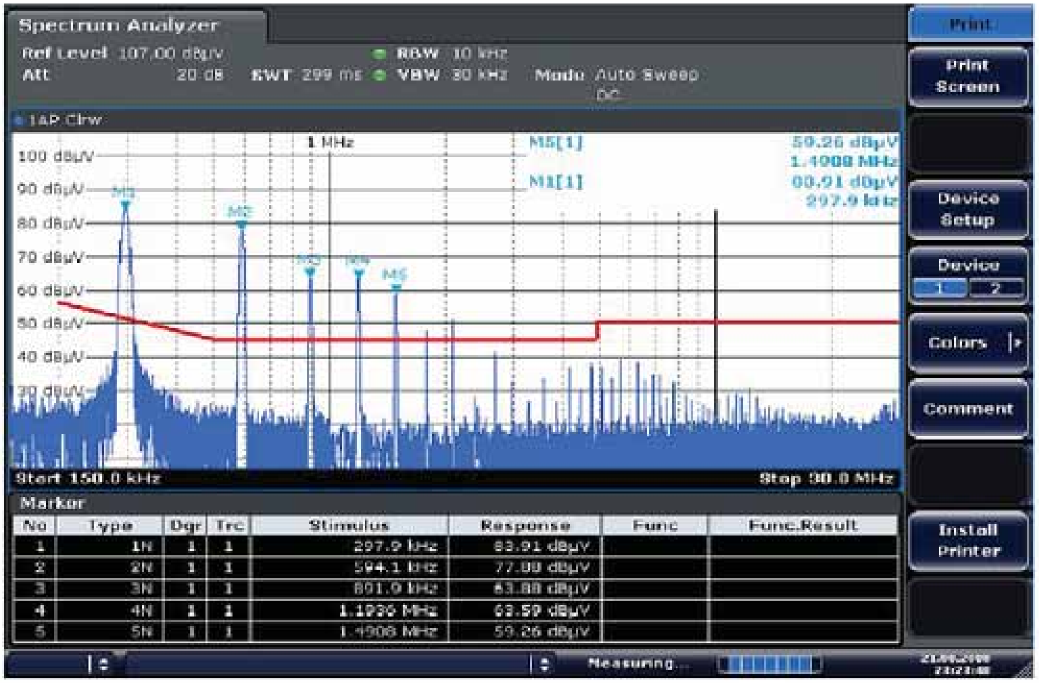
	current compensated or common mode choke 	single choke 
common mode impedance	high	low to medium
differential mode impedance	low	medium
dependency of impedance from load current	independent	depends on “core“
attenuation of used signal	low	high

What Impedance is Needed?



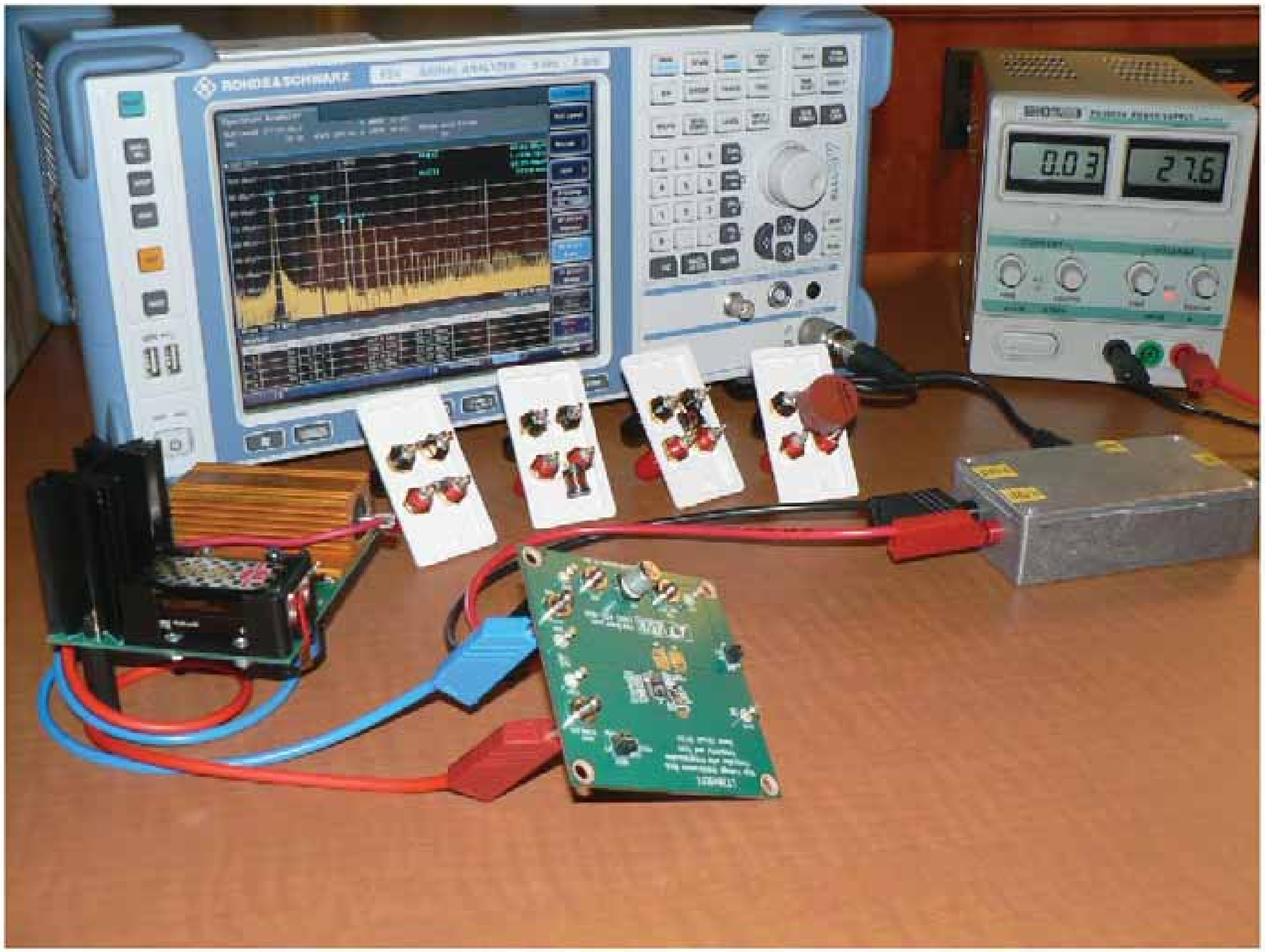
Conducted Emissions Example – Test and Compare

- **Chip Bead**
- **Differential Choke**
- **Bifilar Wound Common Mode Choke**
- **Sector Wound Common Mode Choke**



Conducted Emissions Example - Test Setup

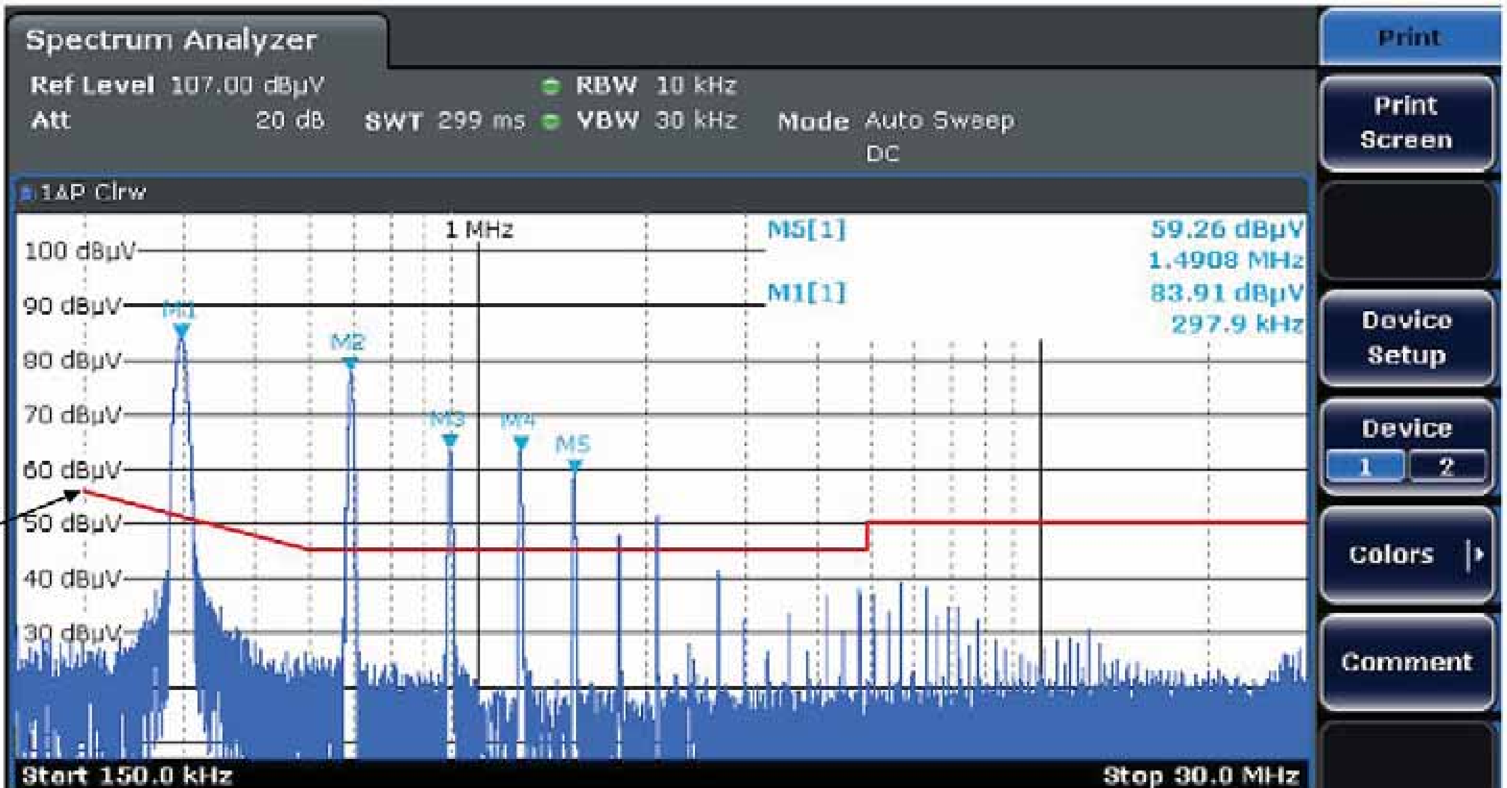
Midcom WÜRTH ELEKTRONIK



a) no load
b) 1.5A load
300KHz fsw.

Conducted Emissions Example – Demo Board

Midcom WÜRTH ELEKTRONIK

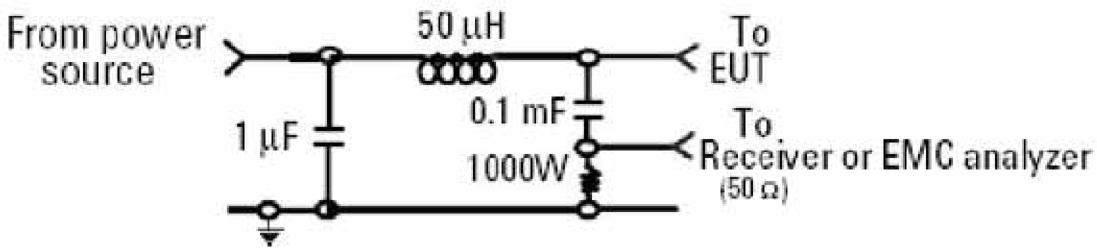


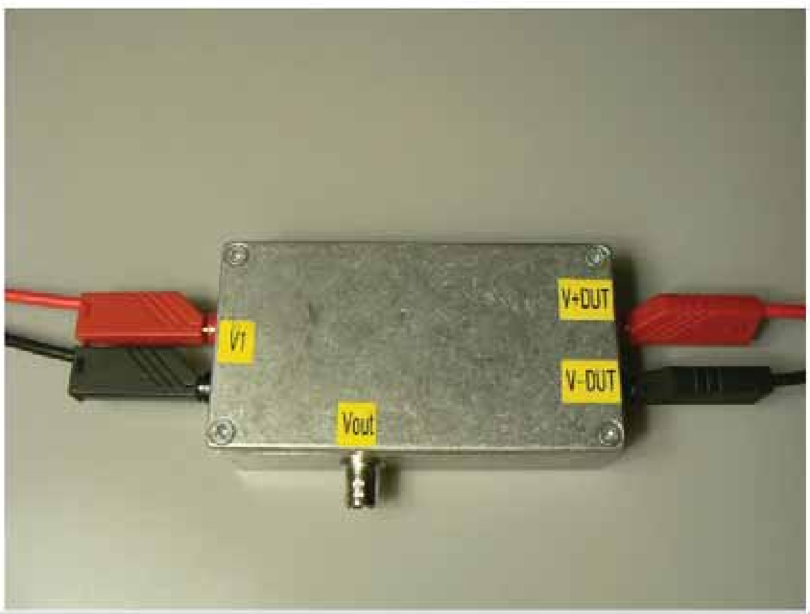
No	Type	Dgr	Trc	Stimulus	Response	Func	Func.Result
1	1N	1	1	297.9 kHz	83.91 dBµV		
2	2N	1	1	594.1 kHz	77.88 dBµV		
3	3N	1	1	891.9 kHz	63.88 dBµV		
4	4N	1	1	1.1936 MHz	63.59 dBµV		
5	5N	1	1	1.4908 MHz	59.26 dBµV		

FCC Class B limit

Conducted Emissions Example - LISN

Line Impedance Stabilization Network (LISN)



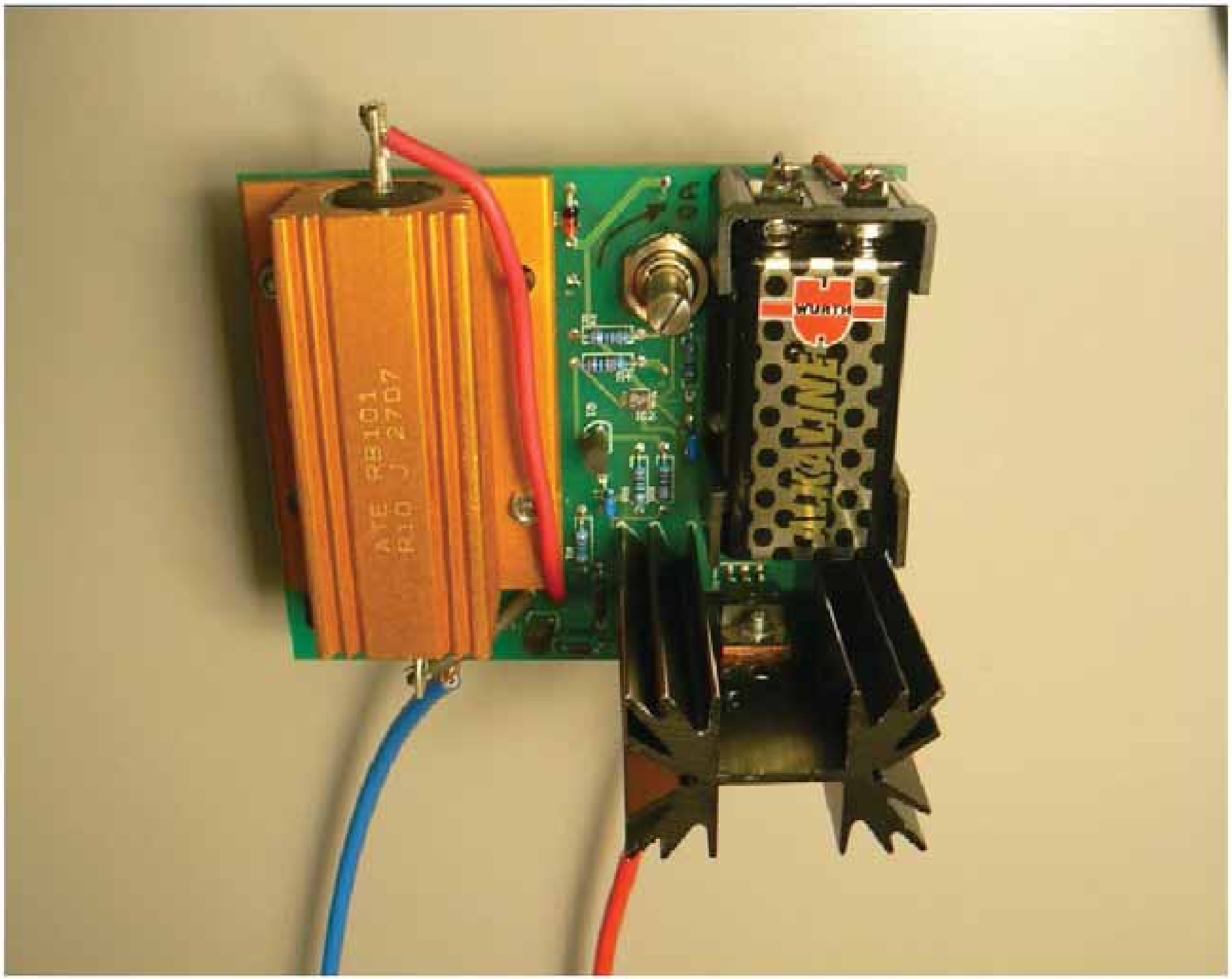


- Isolates DUT (device under test) from Power Source (typically mains) Noise
- Provide characteristic Impedance to DUT (50ohms in this case)
- Path for Conducted noise from DUT to Spectrum Analyzer

The 1 µF in combination with the 50 µH inductor is the filter that isolates the mains from the EUT. The 50 µH inductor isolates the noise generated by the EUT from the mains. The 0.1 µF couples the noise generated by the EUT to the EMC analyzer or receiver. At frequencies above 150 kHz, the EUT signals are presented with a 50-Ω impedance.

Conducted Emissions Example – Electrical Load

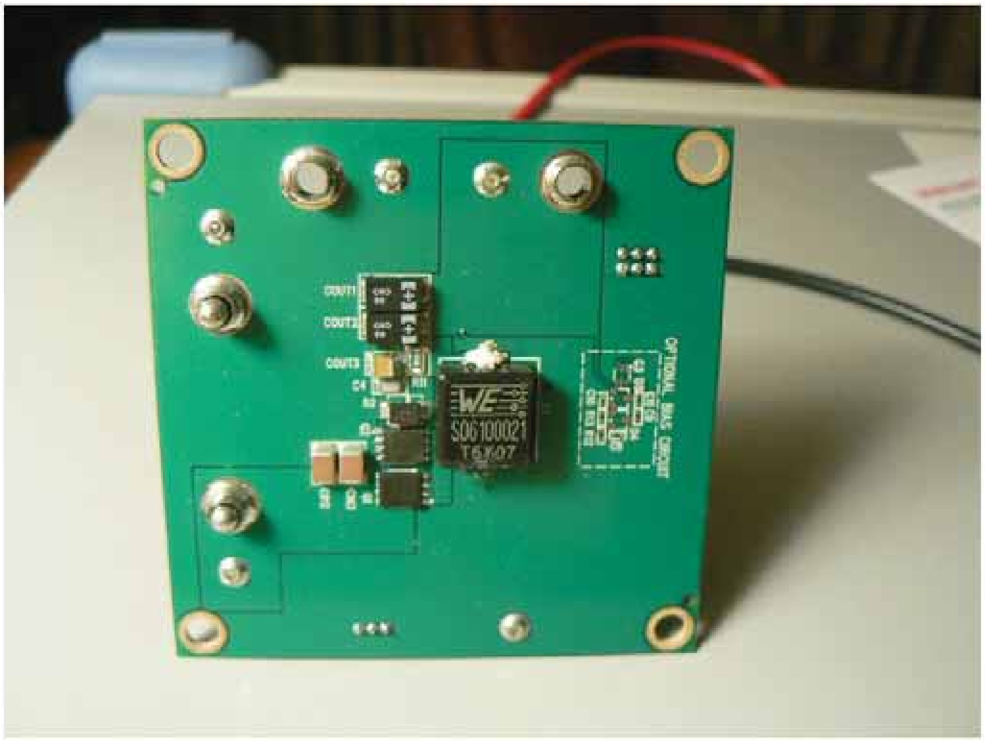
Midcom WÜRTH ELEKTRONIK



Conducted Emissions Example – Test Board

Midcom WÜRTH ELEKTRONIK

- DC/DC Converter
- Input Voltage20V-25V
- Output Voltage12V/6.25A
- Fsw: 300KHz

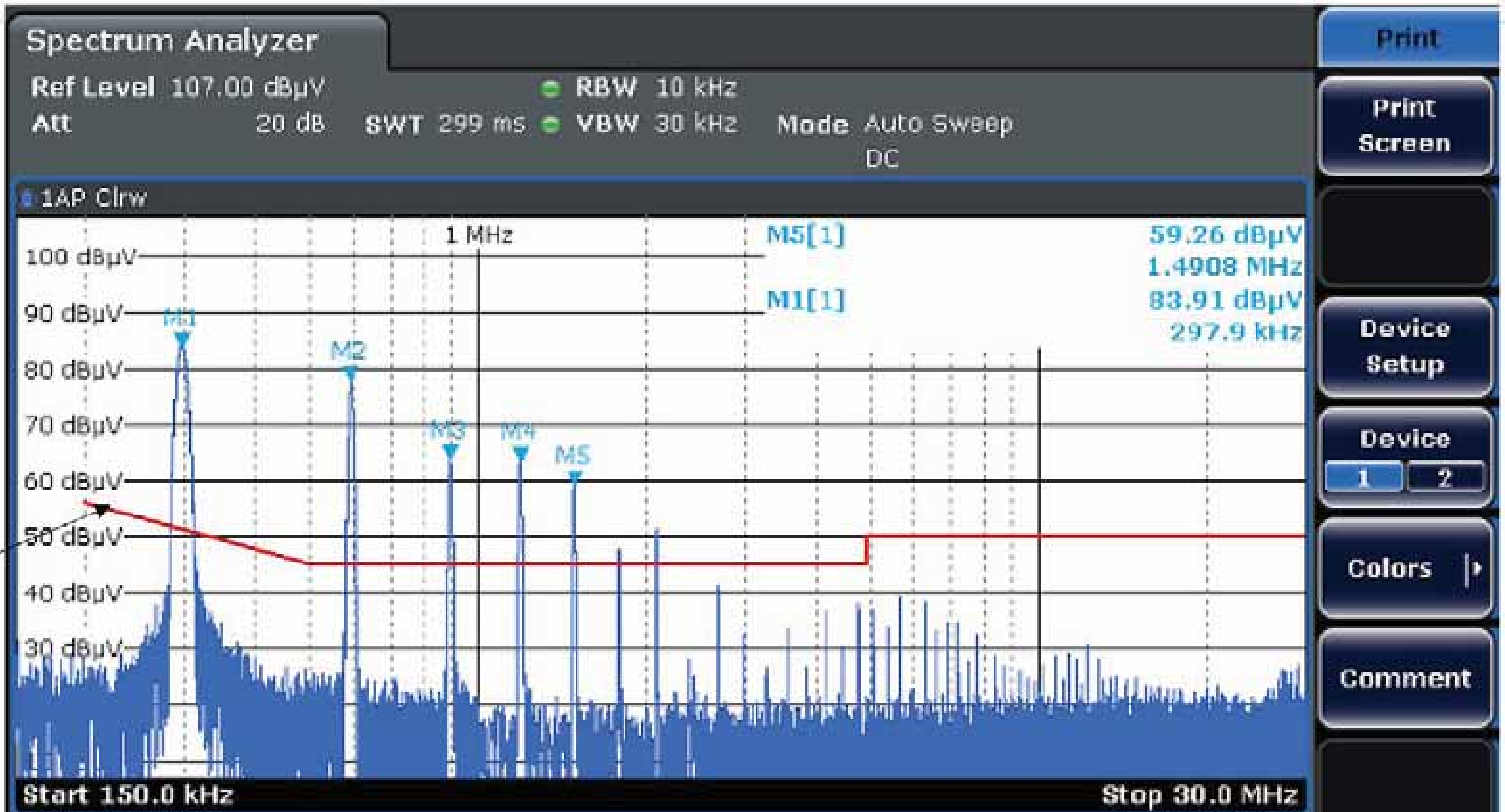


Testcondition:

- no load
- max. load 1.5A

Conducted Emissions Example – No Filter

Midcom WÜRTH ELEKTRONIK



No	Type	Dgr	Trc	Stimulus	Response	Func	Func.Result
1	1N	1	1	297.9 kHz	83.91 dBµV		
2	2N	1	1	594.1 kHz	77.88 dBµV		
3	3N	1	1	891.9 kHz	63.88 dBµV		
4	4N	1	1	1.1936 MHz	63.59 dBµV		
5	5N	1	1	1.4908 MHz	59.26 dBµV		

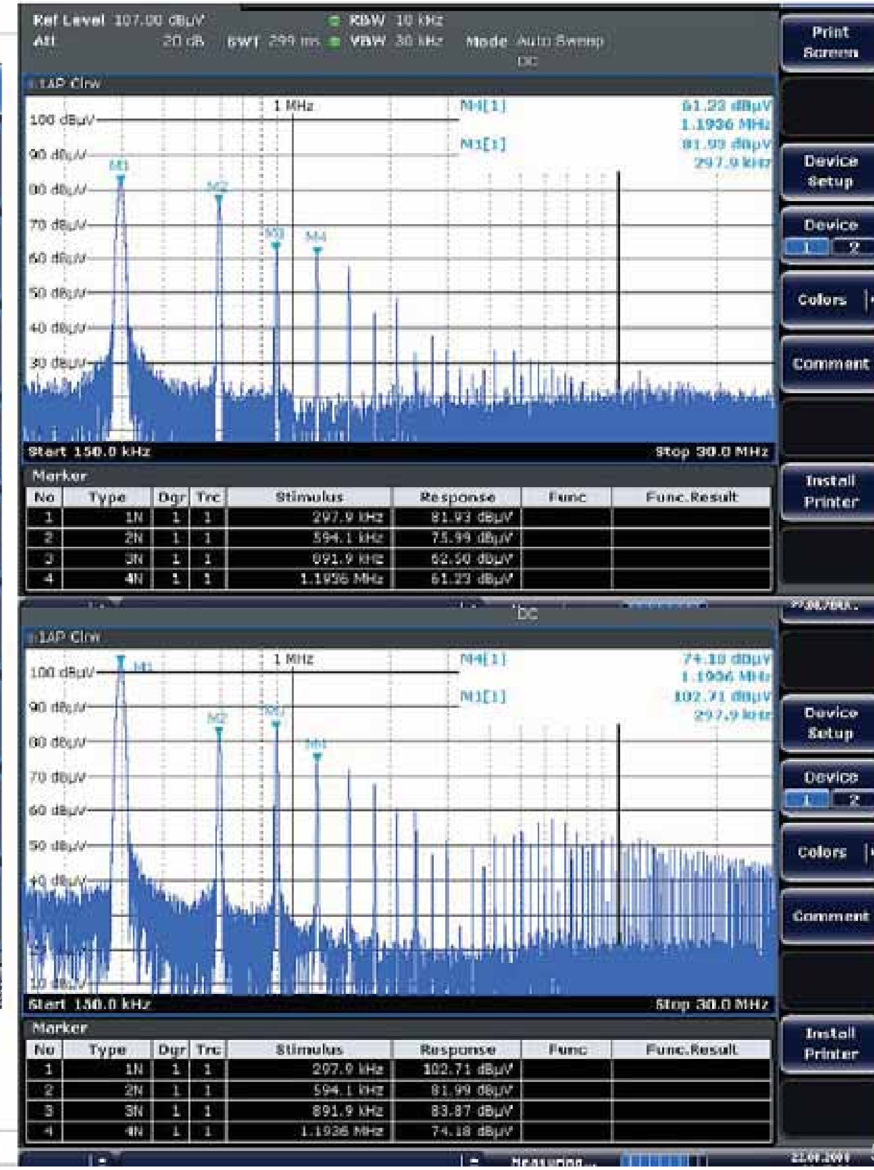
FCC Class B limit

Conducted Emissions Example – Chip Bead

Chip Bead 530**?** / 3A

Conducted Emissions Example – Chip Bead Results

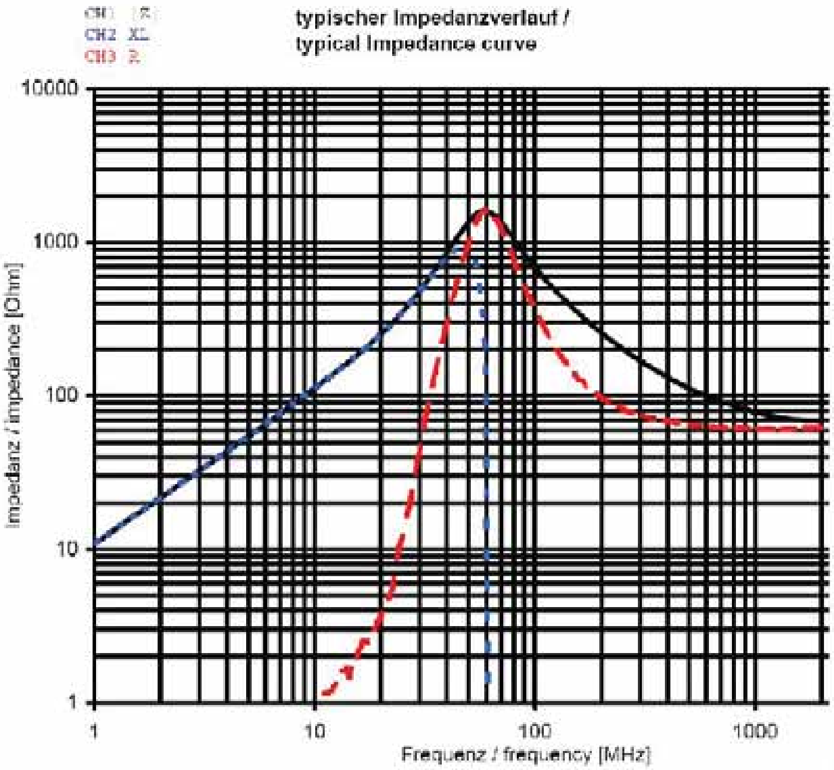
no load >

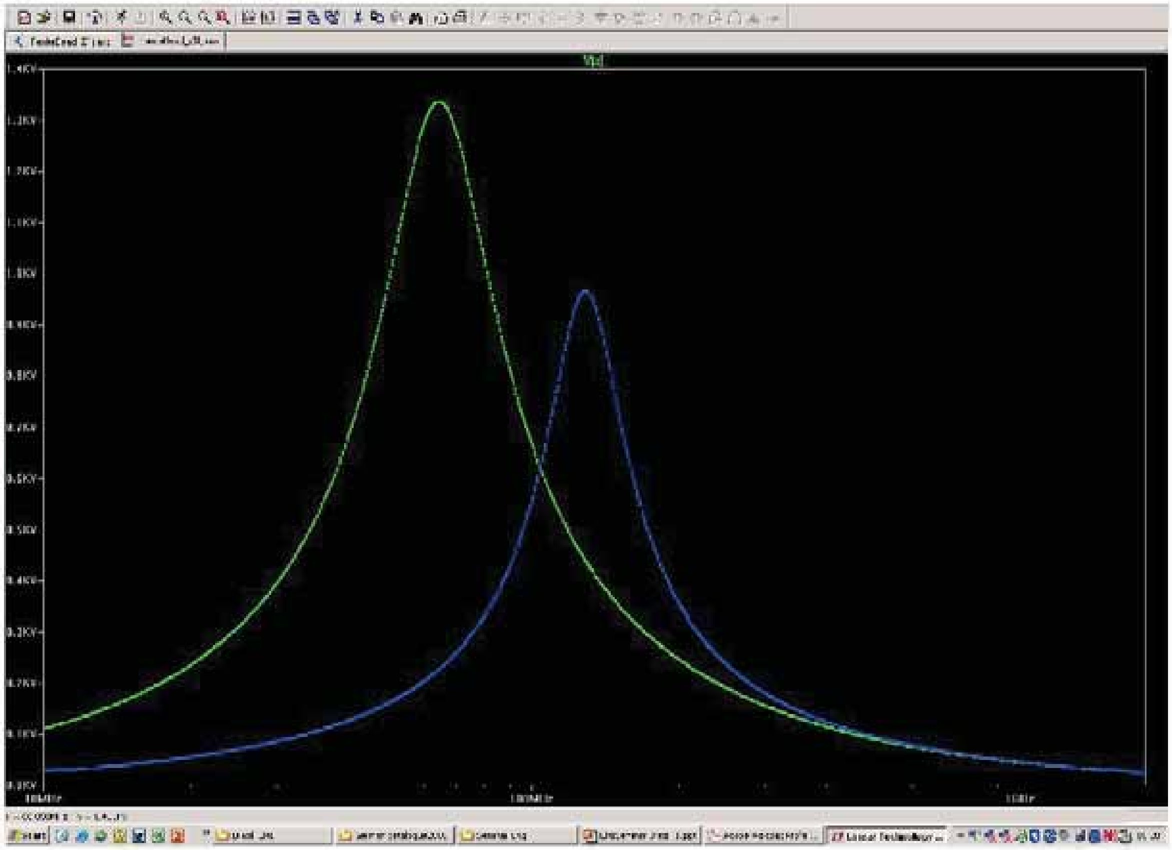


Chip Bead 530? / 3A

load 1.5A>

Conducted Emissions Example – Chip Bead

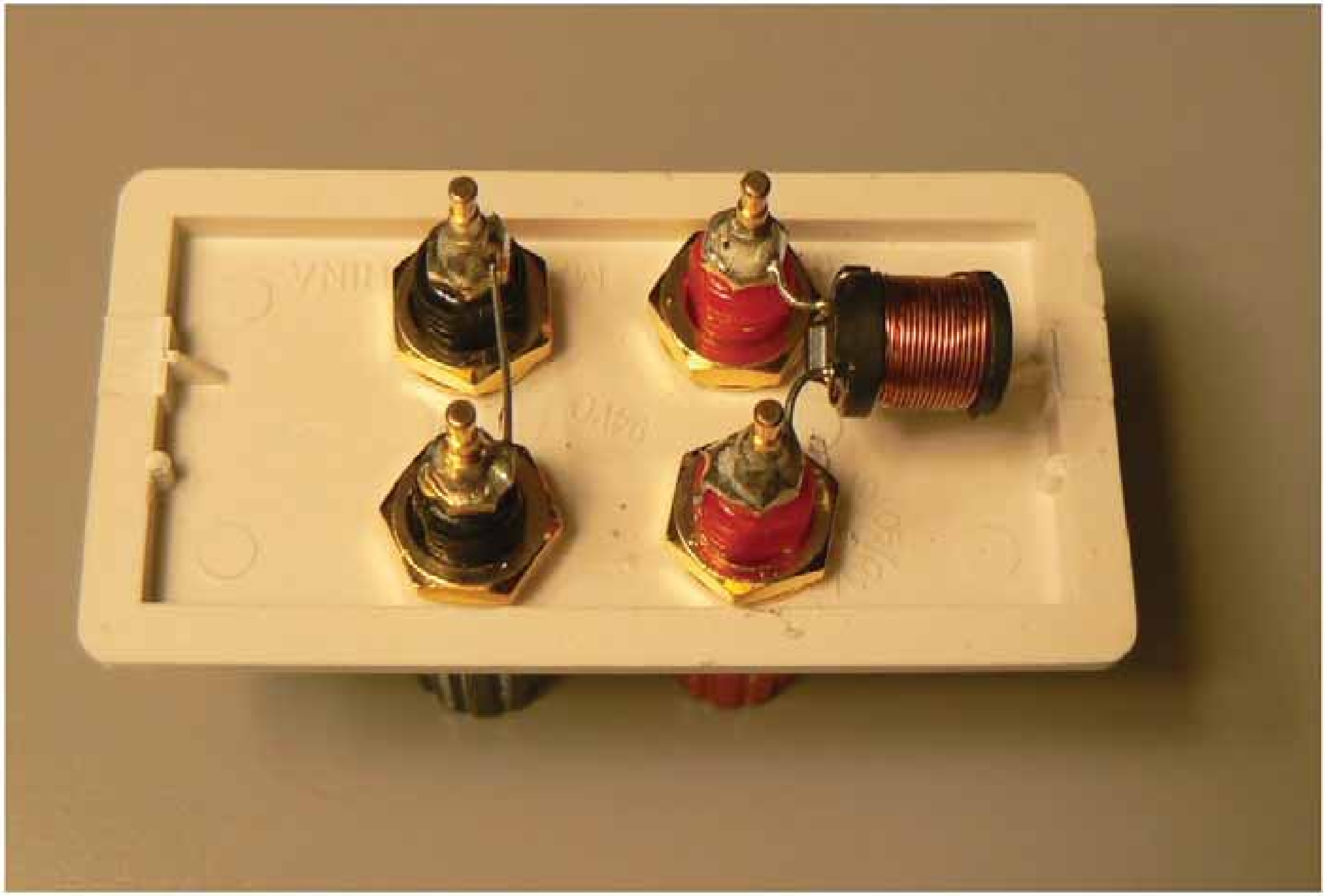




Chip Bead 530**?** / 3A

Conducted Emissions Example – Differential Choke

Midcom WÜRTH ELEKTRONIK



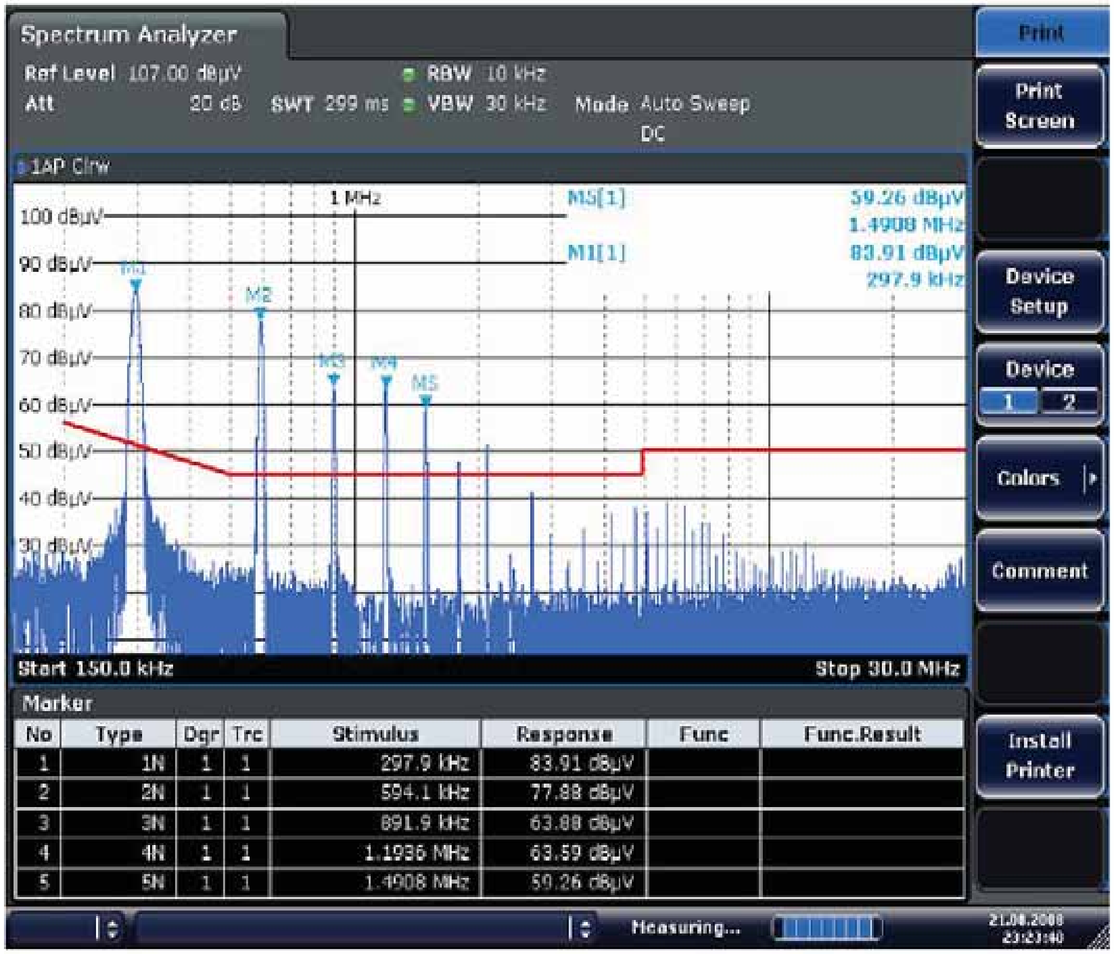
Differential Line Choke 220uH

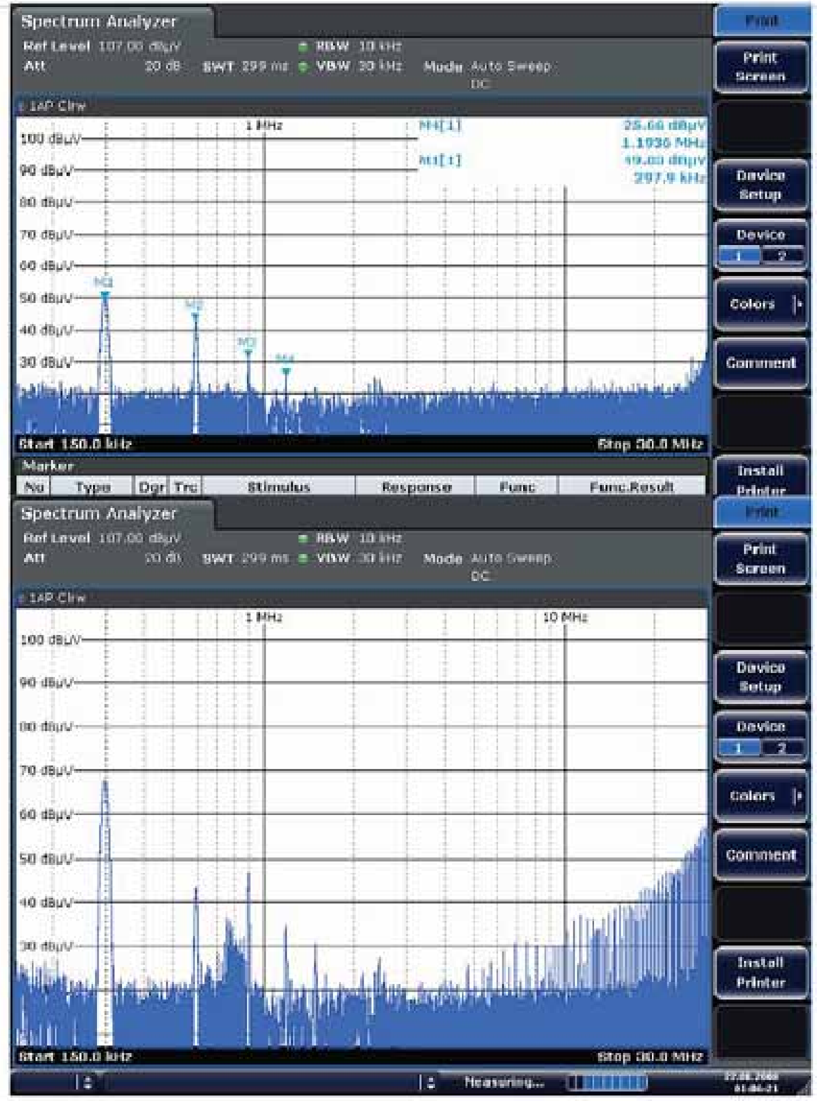
Conducted Emissions Example – Differential Choke Results

Midcom

WÜRTH ELEKTRONIK

no load >





load 1.5A>

Conducted Emissions Example – Bifilar CMC

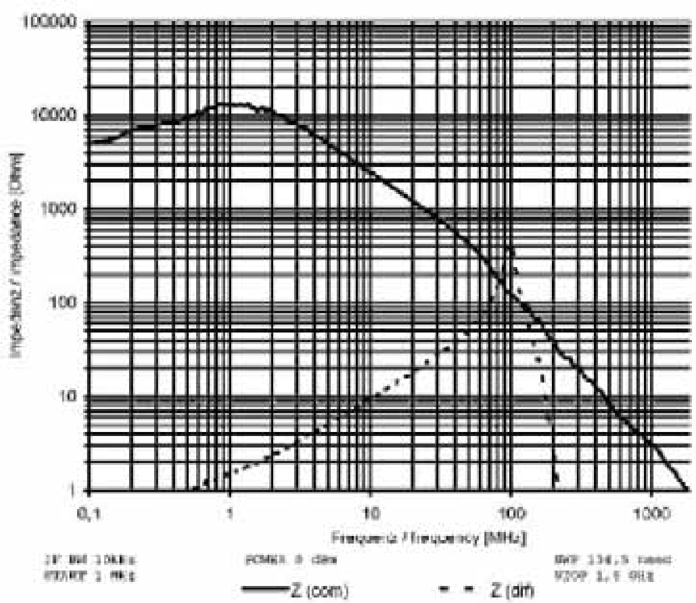
CMC 4.7mH Bifilar Winding

Conducted Emissions Example – Bifilar CMC

Midcom
WÜRTH ELEKTRONIK

Artikel-Nr.	Induktivität (µH)	R_{DC} (Ω)	I_N (mA)	Impedanz max. (Ω)
744272121	2 x 120	0,025	2500	400
744272221	2 x 220	0,032	2200	780
744272251	2 x 250	0,035	2000	970
744272471	2 x 470	0,065	1600	1750
744272102	2 x 1000	0,180	950	3600
744272222	2 x 2200	0,300	750	7500
744272332	2 x 3300	0,360	650	8900
744272392	2 x 3900	0,540	520	9600
744272472	2 x 4700	0,720	350	13000

744 272 472



Warning: Don't try this at home!

For Demonstration Purposes Only!

Load is 1.5A

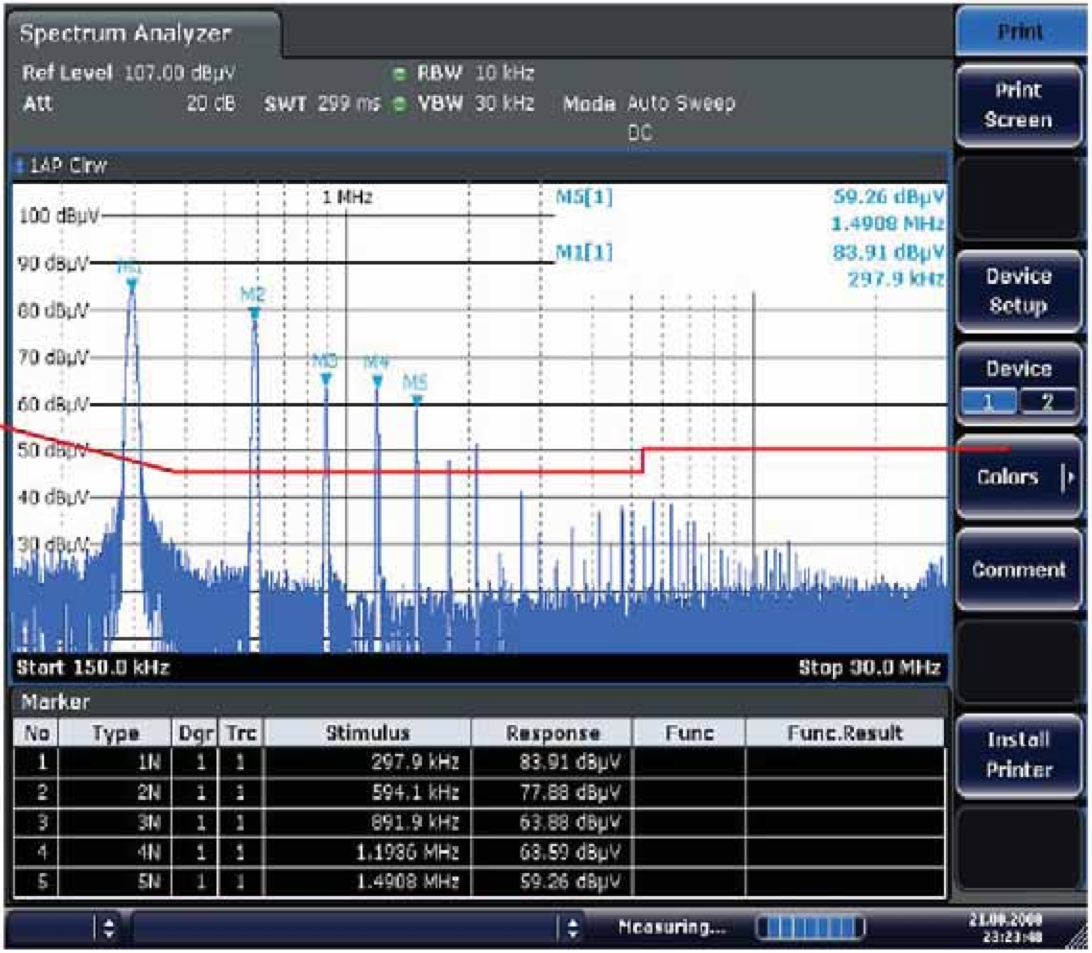
And..... CMC

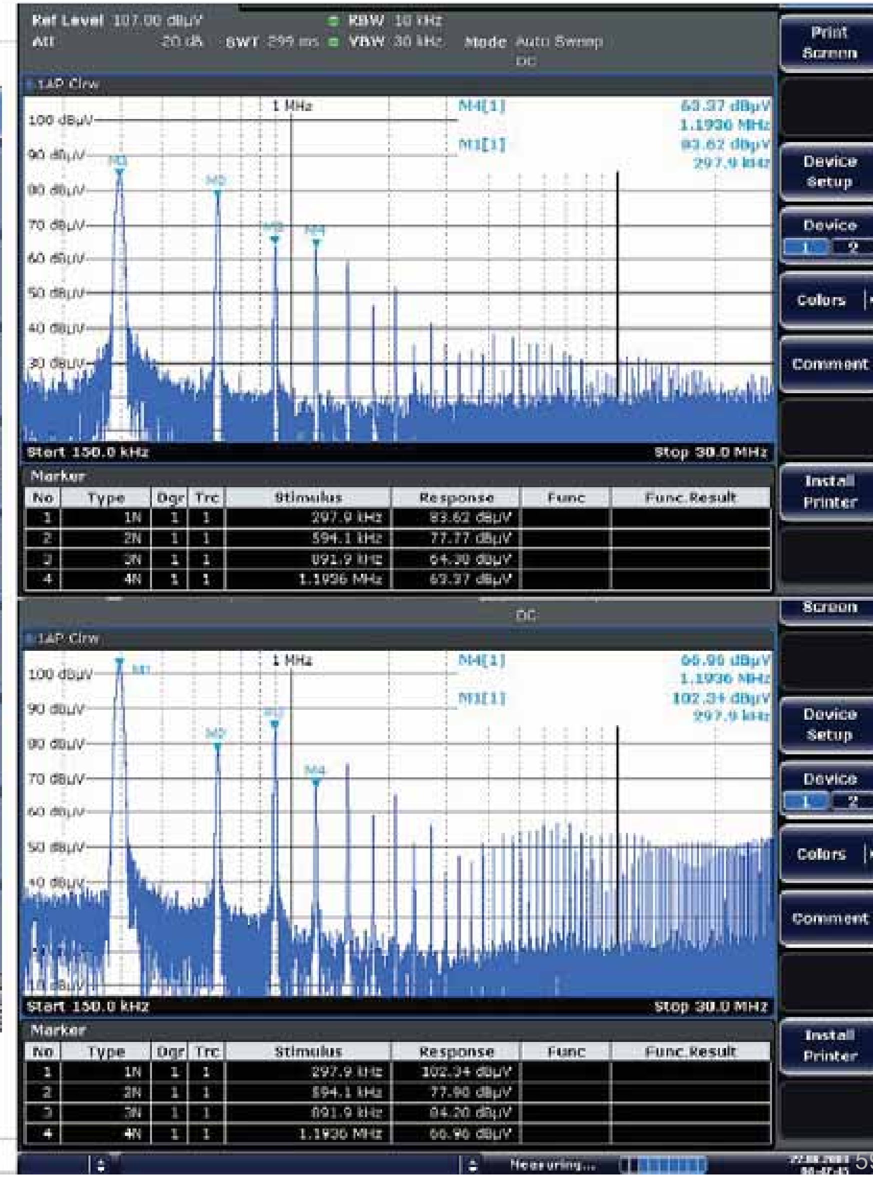
CMC 4.7mH Bifilar Winding

Conducted Emissions Example – Bifilar CMC Results

Midcom WÜRTH ELEKTRONIK

no load >



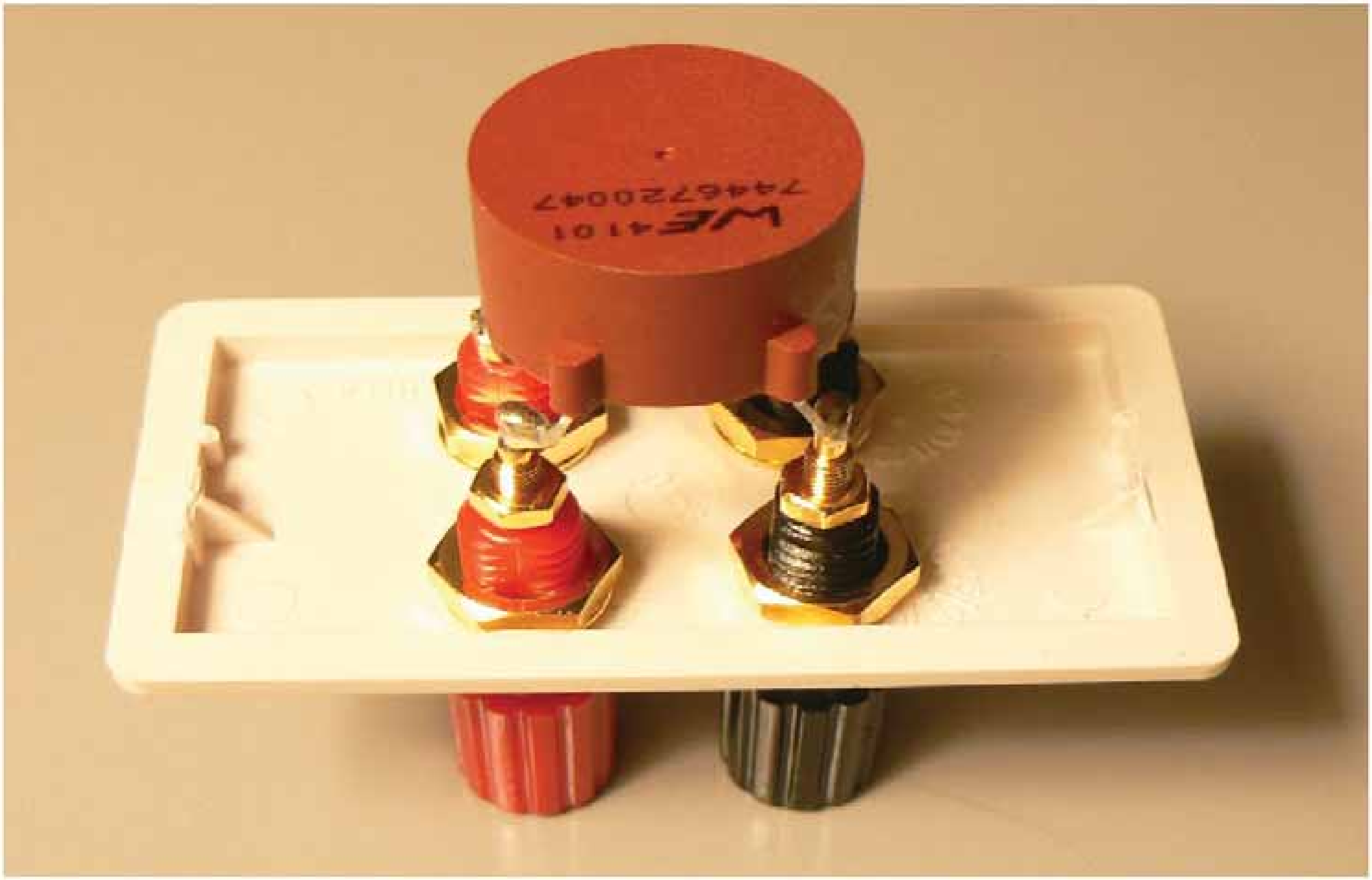


CMC 4.7mH Bifilar Winding

load 1.5A>

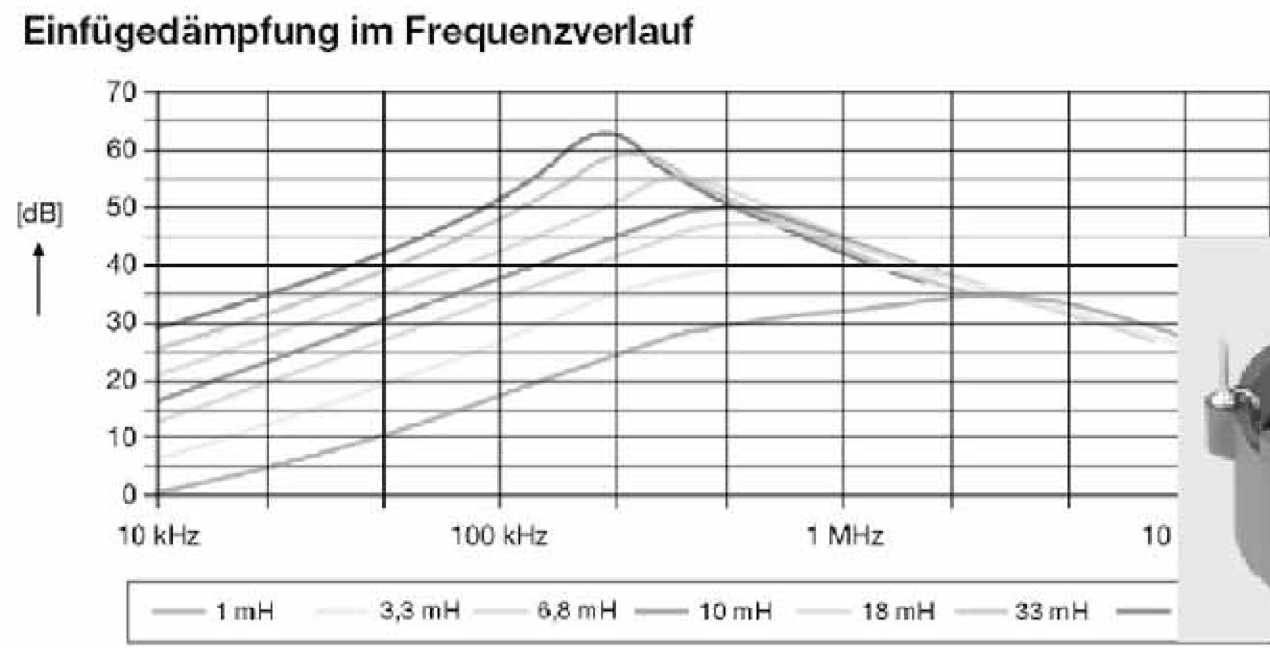
Conducted Emissions Example – Sector CMC

Midcom WÜRTH ELEKTRONIK



CMC 47mH sectional winding

Conducted Emissions Example – Sector CMC



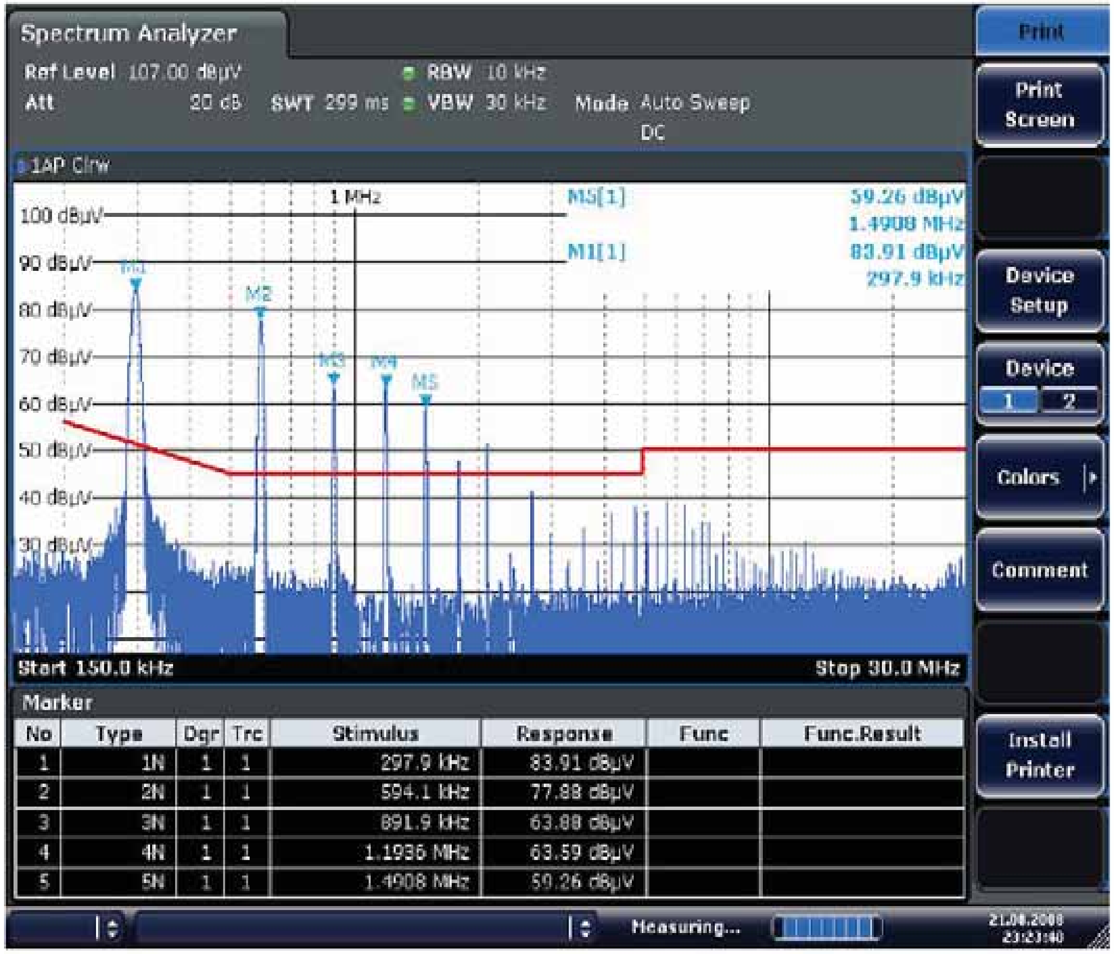
CMC 47mH Sectional Winding

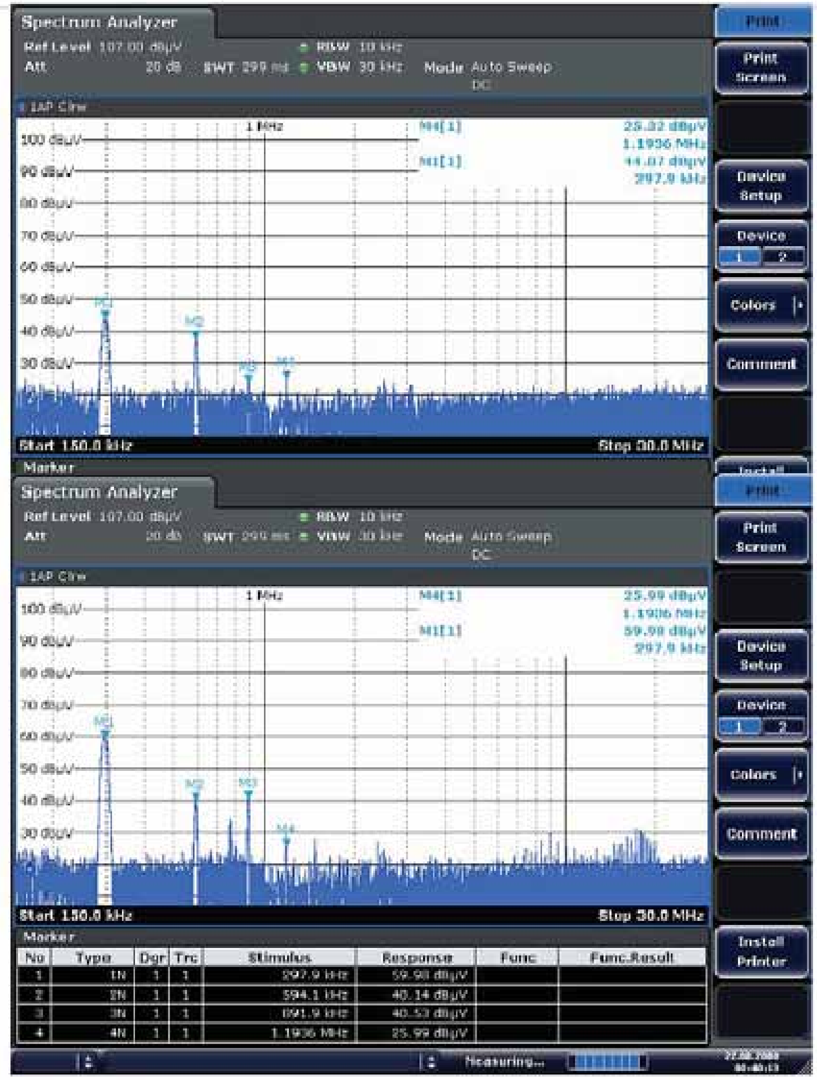
Leakage Inductance Ls~ 250uH (5% of L)

Conducted Emissions Example – Sector CMC Results

Midcom WÜRTH ELEKTRONIK

no load >



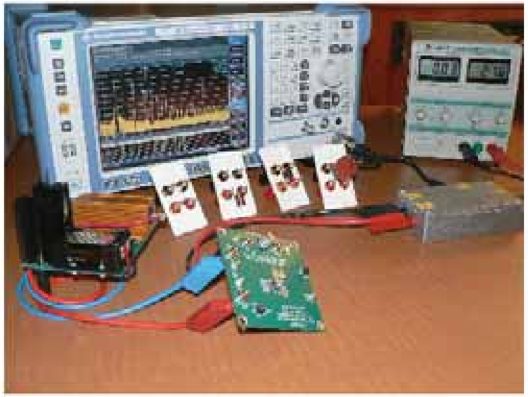


CMC 47mH sectional winding

load 1.5A>

Conducted Emissions Example - Conclusions

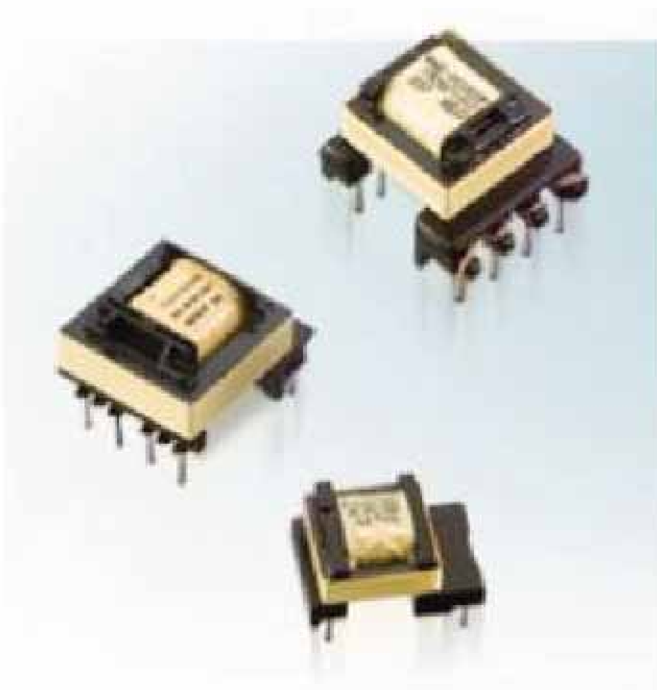
Midcom WÜRTH ELEKTRONIK

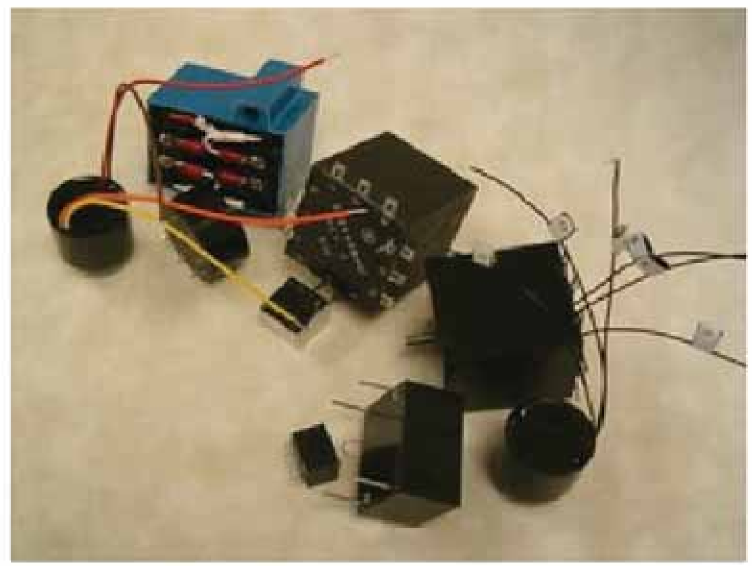


- High Frequency Noise Appears Under Load
- Noise is Differential Mode
- Differential Choke
  – Attenuates low frequency noise because of SRF
- Bifilar CMC
  – Does not attenuate because of very low leakage inductance.
- Sector CMC
  – Attenuates both high and low because of leakage inductance with high SRF.
- Chip Bead
  – Without a load there is some affect at high frequencies, but with a load the bead pre-magnetizes and there is no affect at all.

Transformers for EMC – What to Choose

Midcom WÜRTH ELEKTRONIK





Transformers for EMC – No Antennas Please!

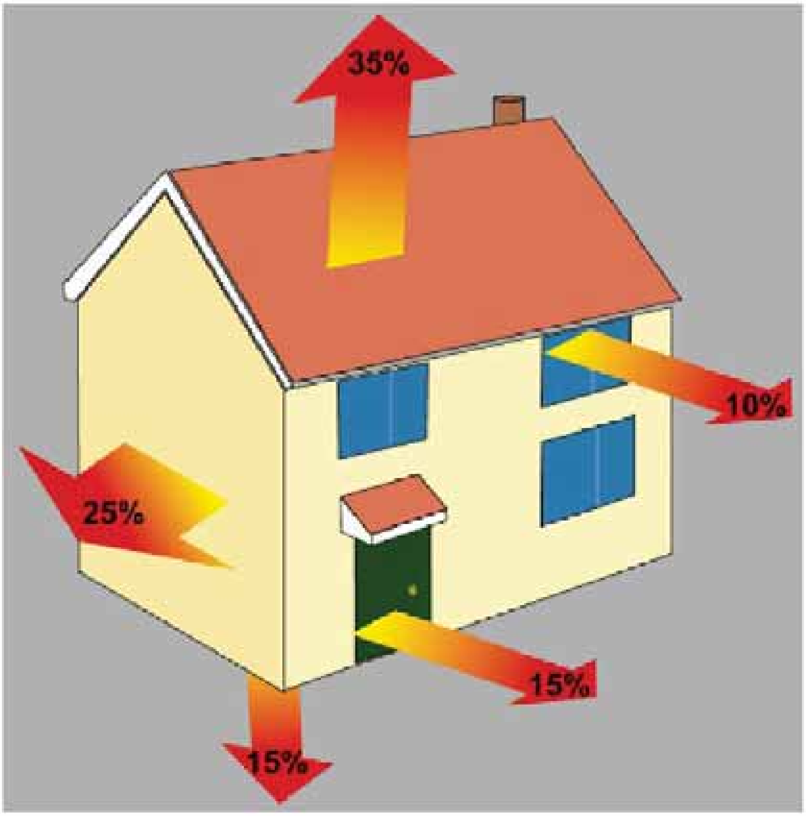
Enough Said!

Flying Leads Make Great Antennas.

Estimate Component Losses

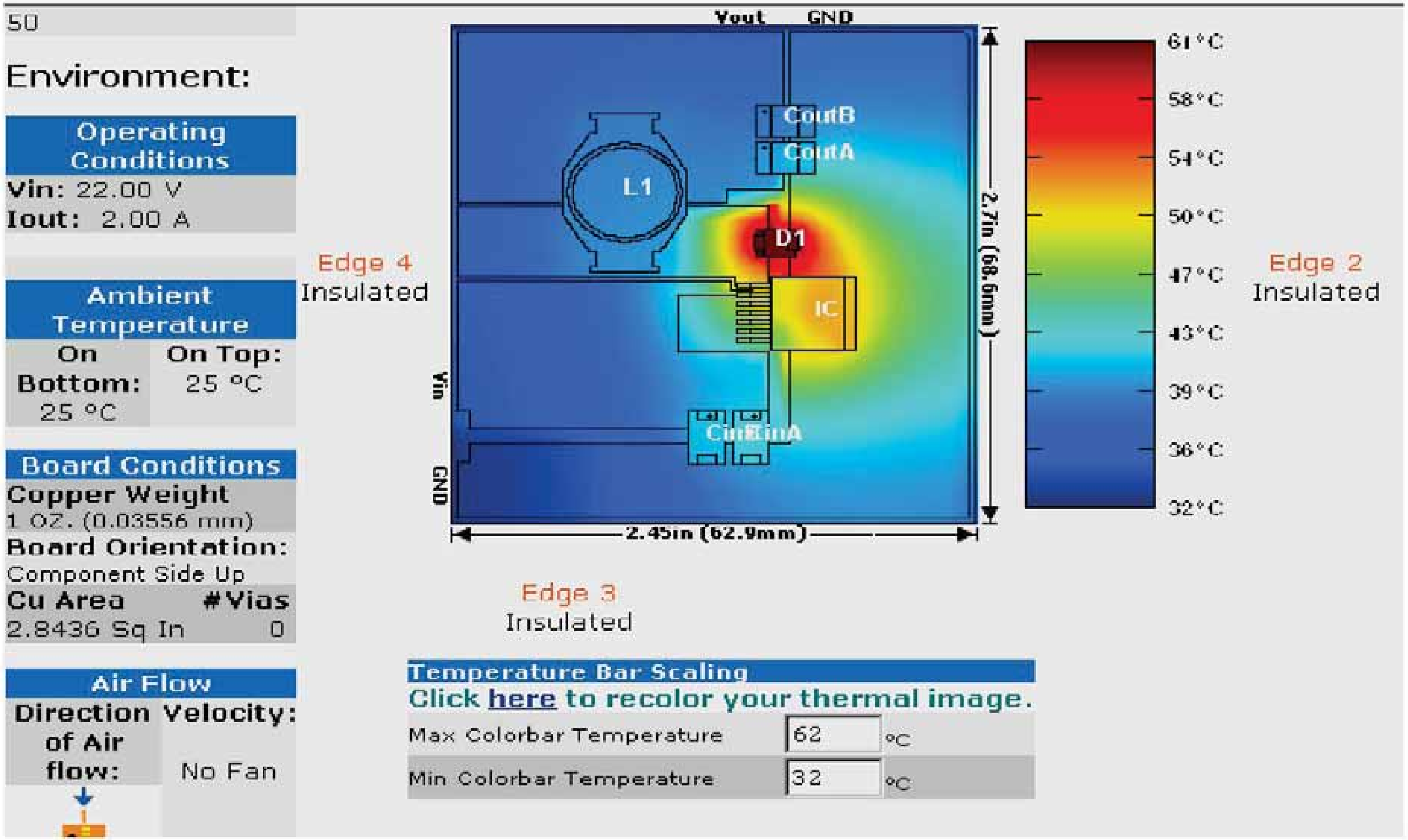
- Efficiency is ~ 75-85% Typical
  - 33% Switch
  - 57% Output Rectifiers
  - 5% Magnetics
  - 5% Miscellaneous

So where are your losses?



Where are the losses ?

Midcom WÜRTH ELEKTRONIK



Losses in transformers and inductors

$$P_{total} = P_{Cu} + P_{FE}$$

- **Copper losses**
  - **DC losses**
  - **AC losses**
    - **Skin Effect**
    - **Proximity Effect**
- **Core losses**
  - **Hysteresis loss**
  - **Eddy current losses**

Practical Formulas for Calculation of Temperature Rise ?T for WE-PD,WE-DD

Midcom WÜRTH ELEKTRONIK

WE-PD Typ „S" (744778_, 7447789_); WE-DD „S":

$$\Delta T \approx \left(\frac{P_{tot}}{2{,}875}\right)^{0{,}826}$$

P_{tot} in (mW) and ΔT in (°C)

WE-PD Typ „M" (744777_, 7447779_), WE-DD „M":

$$\Delta T \approx \left(\frac{P_{tot}}{3{,}218}\right)^{0{,}826}$$

P_{tot} in (mW) and ΔT in (°C)

WE-PD Typ „L" (744771_); WE-DD „L":

$$\Delta T \approx \left(\frac{P_{tot}}{6{,}321}\right)^{0{,}826}$$

P_{tot} in (mW) and ΔT in (°C)

WE-PD Typ „XL" (744770_); WE-DD „XL":

$$\Delta T \approx \left(\frac{P_{tot}}{8{,}045}\right)^{0{,}826}$$

P_{tot} in (mW) and ΔT in (°C)

Example: As calculated:

744 770 147

Ptot=233mW

$$?T = \left(\frac{233}{8.045}\right)^{0{,}826} ÷$$

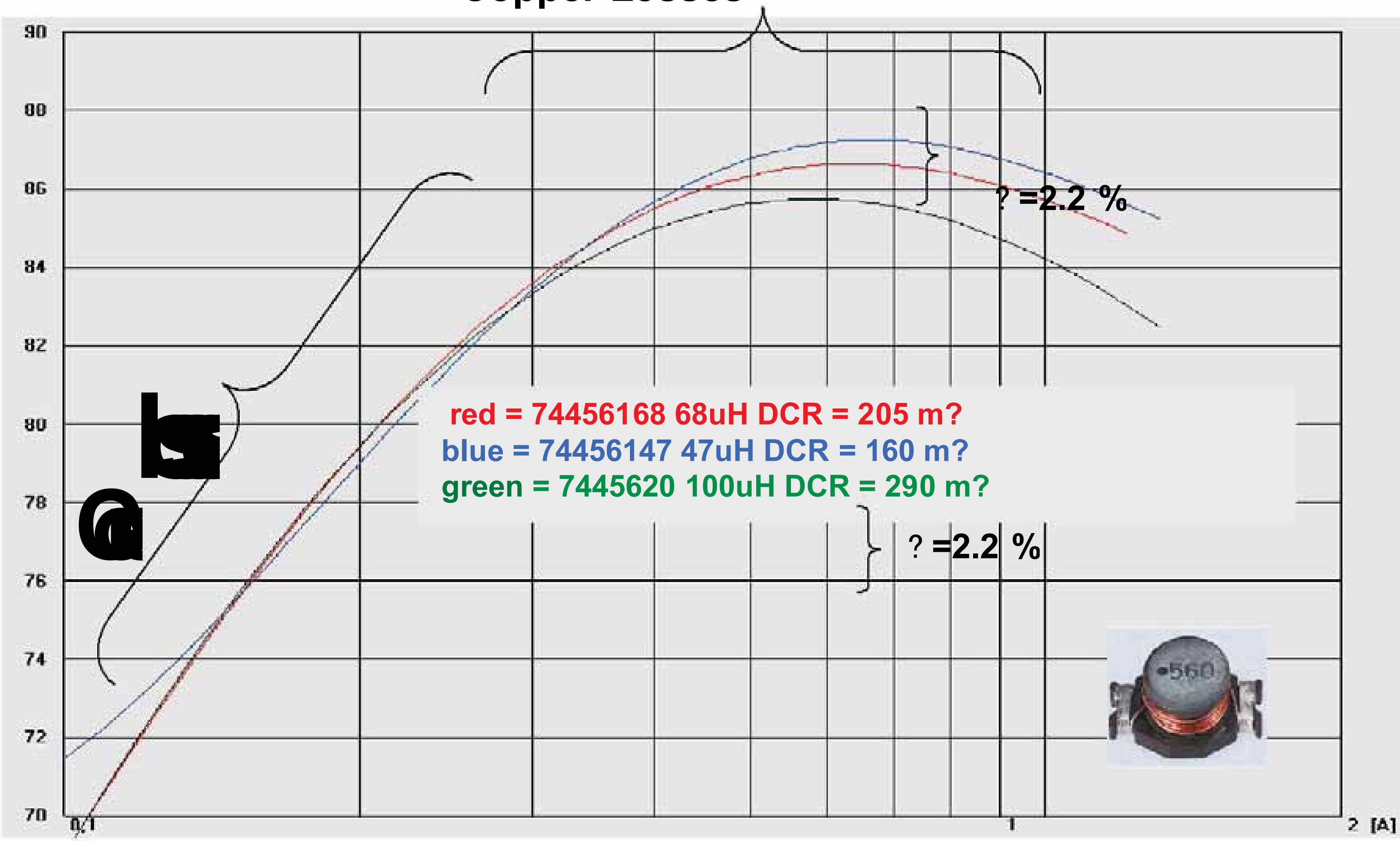
= 16,1°C

Trilogy of Inductors
Pages 222-223

Core/Copper Loses & Efficiency

Midcom WÜRTH ELEKTRONIK

Copper Losses



Practical way for core loss calculation P_{core} by using I_{max} and ripple current ?I for WE-PD

Midcom WÜRTH ELEKTRONIK

PD size XL	$$P_{core\,(mW)\_744770x} = 12 \cdot f_{(kHz)}^{1,274} \cdot \left(\frac{\Delta I}{I_{max}}\right)^{1,9}$$
PD size L	$$P_{core\,(mW)\_744771x} = 7,2 \cdot f_{(kHz)}^{1,274} \cdot \left(\frac{\Delta I}{I_{max}}\right)^{1,9}$$
PD size M	$$P_{core\,(mW)\_744777x} = 2 \cdot f_{(kHz)}^{1,274} \cdot \left(\frac{\Delta I}{I_{max}}\right)^{1,9}$$
PD size S	$$P_{core\,(mW)\_744778x} = 1,6 \cdot f_{(kHz)}^{1,274} \cdot \left(\frac{\Delta I}{I_{max}}\right)^{1,9}$$

Trilogy of Inductors
Pages 220-221

What more do you need?

Look at our Book:

Chap.1: Basics
keep it simple, stupid

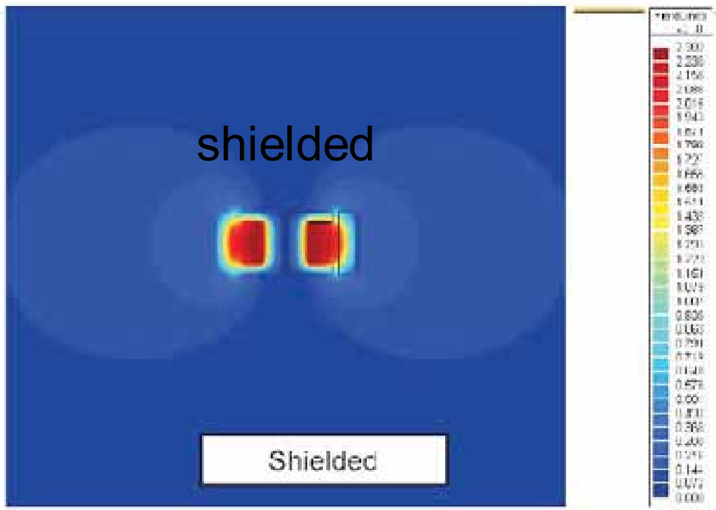
Chap.2: Components
Descriptions, Applications, Simulation
Models and many more

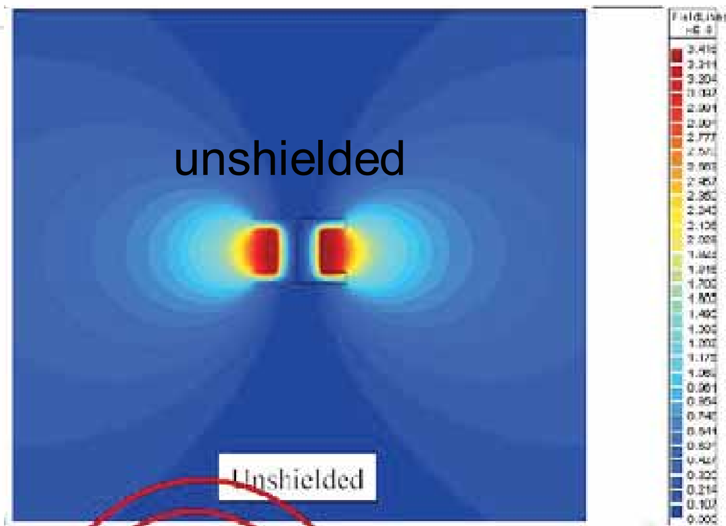
Chap.3: Filter-Circuits
Design, Grounding, Layout, Tips

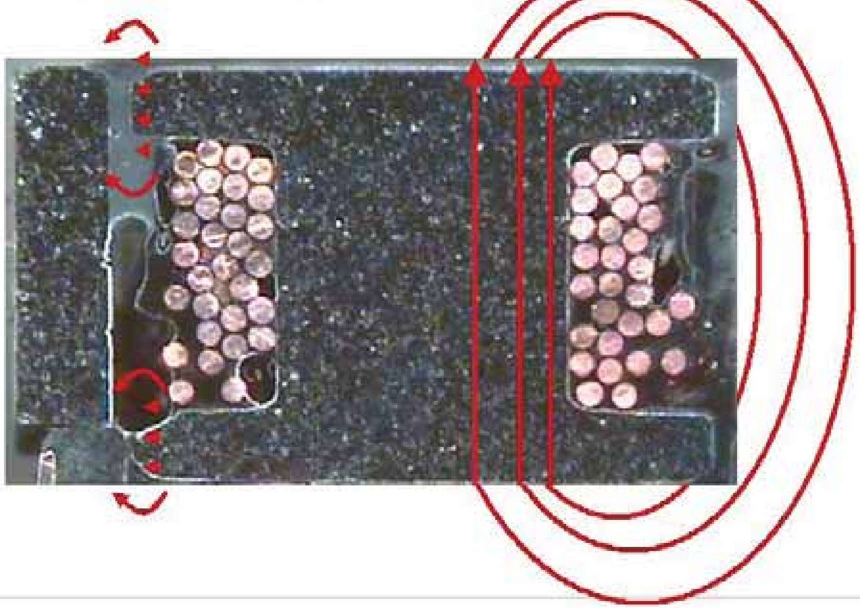
Chap.4: Applications
Circuit, suggested parts, Layout

Chap.5: Appendices
from A to Z

Transformers for EMC – No External Gaps



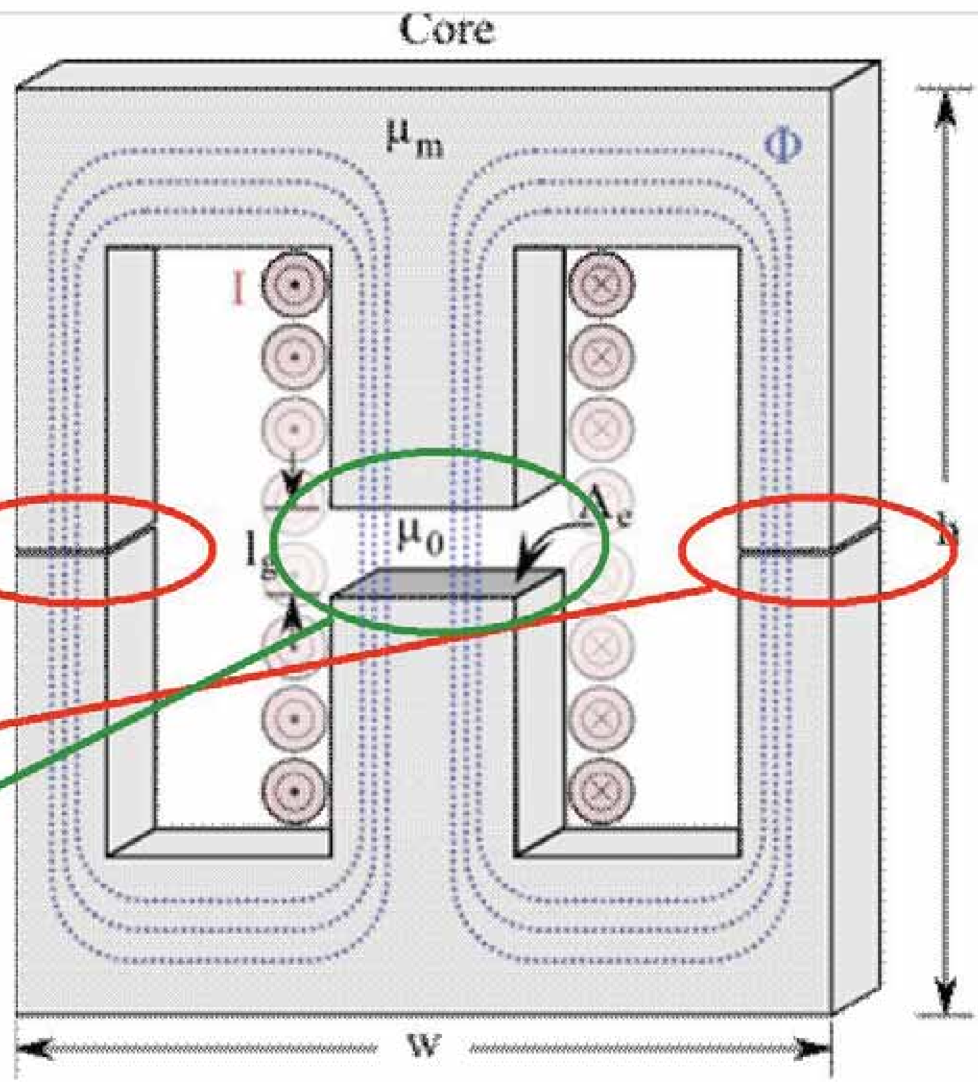




Transformers for EMC – No External Gaps

Midcom WÜRTH ELEKTRONIK

- Center Leg Gap Only
  - Windings Shield
- No Gaps in Outer Legs
  - Nothing to Shield



No Gaps Here

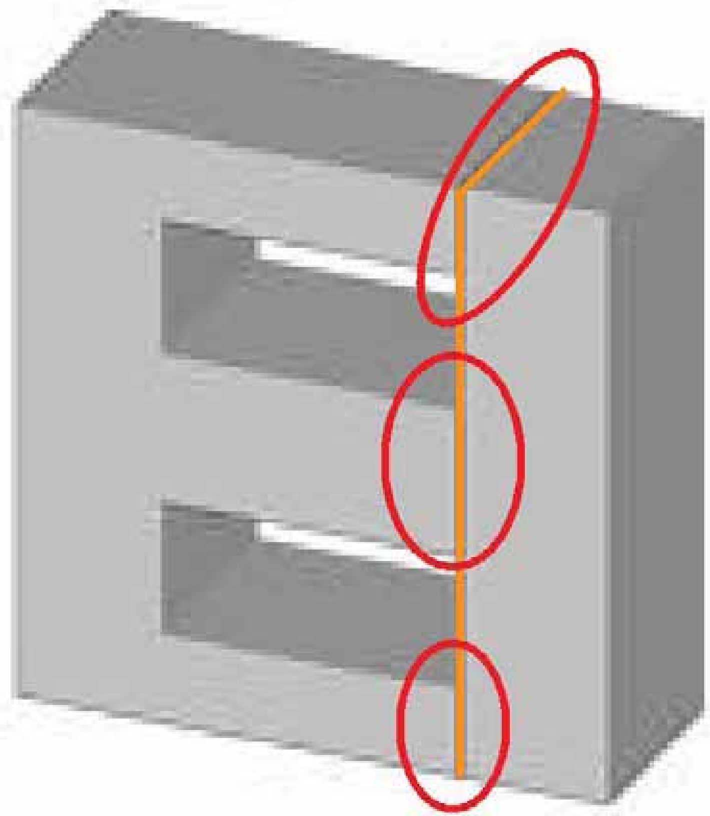
Gap Here

Transformers for EMC – No EI Core

Midcom WÜRTH ELEKTRONIK

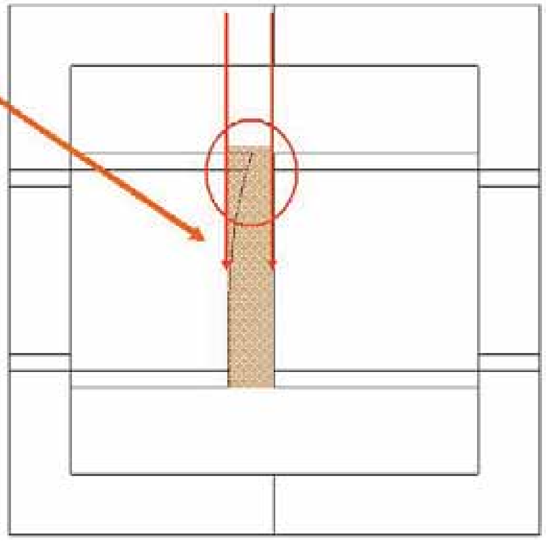
- EI Core Style
- Mylar or Tape Used for Gap
- Three Unshielded Gaps

Not a good solution!



Transformers for EMC – Gap

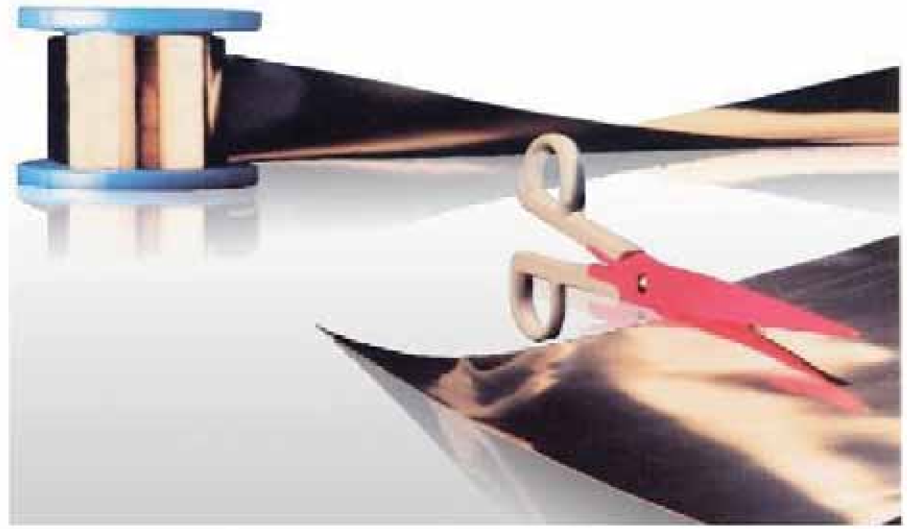
- Gap Must be Perpendicular to Flux Lines
  - Here Only One Side is Gapped
- Uneven Gaps Are Inefficient, Why?
  - Core Saturates at Minimum Gap.
  - Requires a Larger Gap
- Also Larger Gap – More Potential EMI

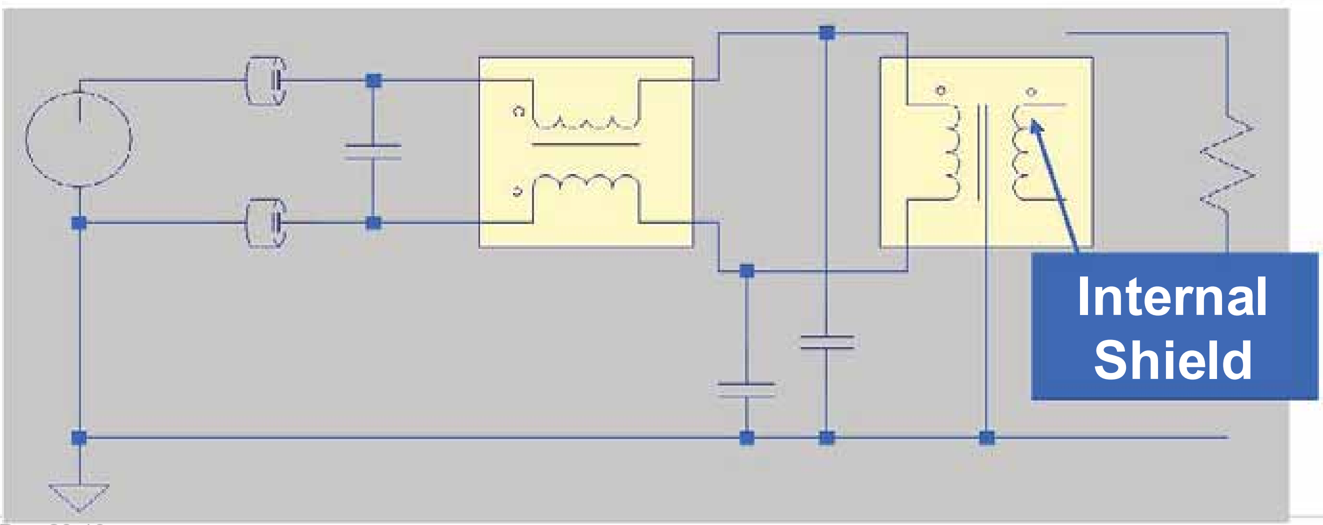


Transformers for EMC – Internal Shields

Midcom WÜRTH ELEKTRONIK

- Shield both Conducted and Radiated Noise
- Copper Foil or Wound Magnet Wire?
- Copper Foil Shields – Expensive, Why?
  - Must Build Shield
  - Must be Cuffed with Tape
  - Winding Machine Stopped to Apply
- All Shields Take Away from Winding Area

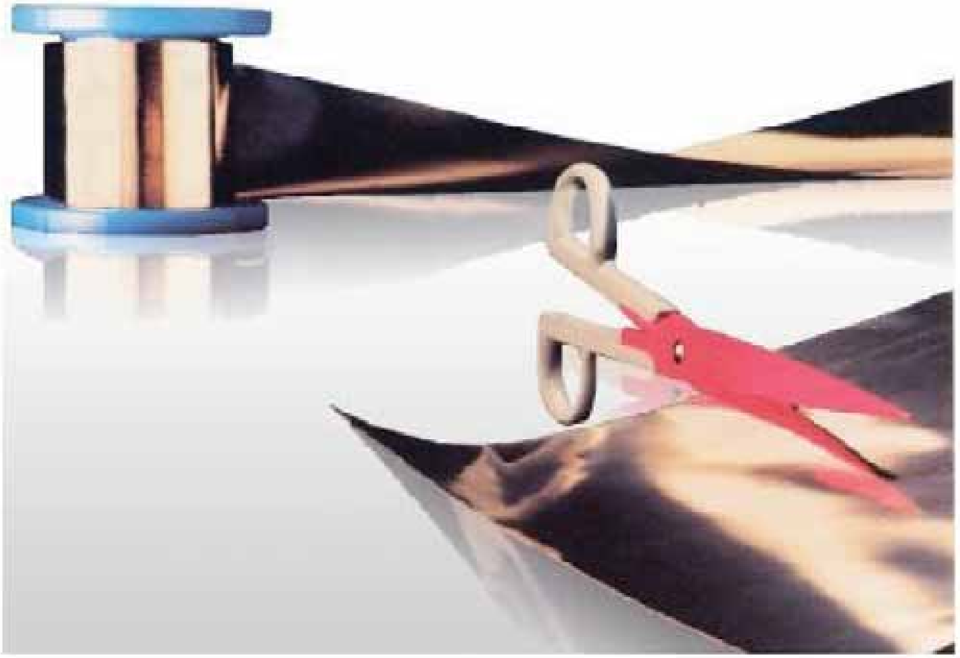


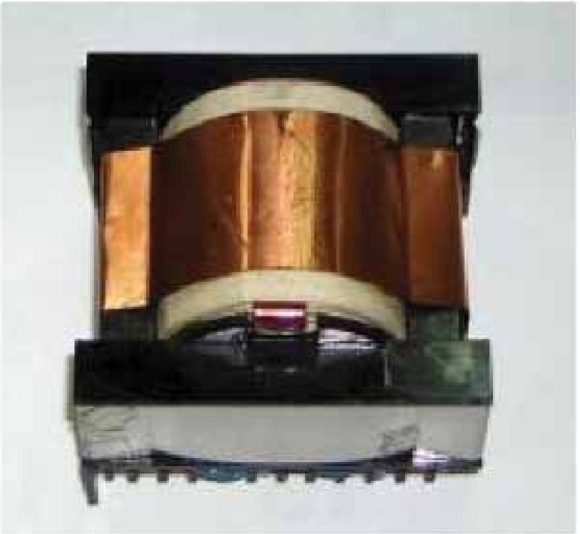


Transformers for EMC – External Shields

Midcom WÜRTH ELEKTRONIK

- How Do External Shields Differ from Internal Shields?
- Shields Radiated Noise ONLY!
- As Expensive as Internal Shields

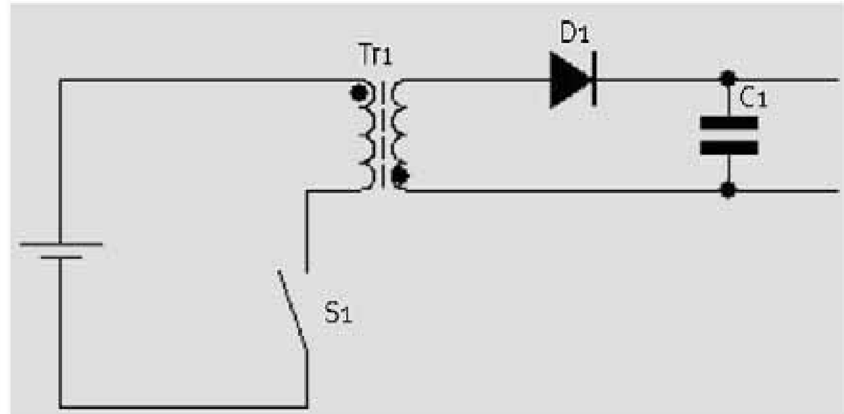




Transformers for EMC – Multi-layer Primary Termination

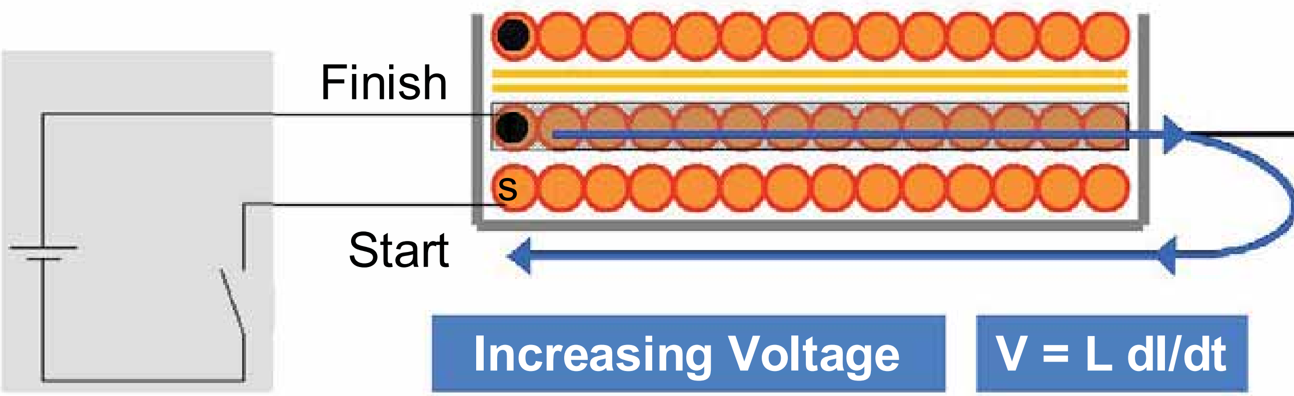
Midcom WÜRTH ELEKTRONIK

- How does One Terminate a Multi-layer Primary?
- Terminate Start to Switch so Subsequent Layer/s Shield High dv/dt Windings from outside world.



Note Polarity Dots on Finish, Is this Okay?

Perfectly Consistent.



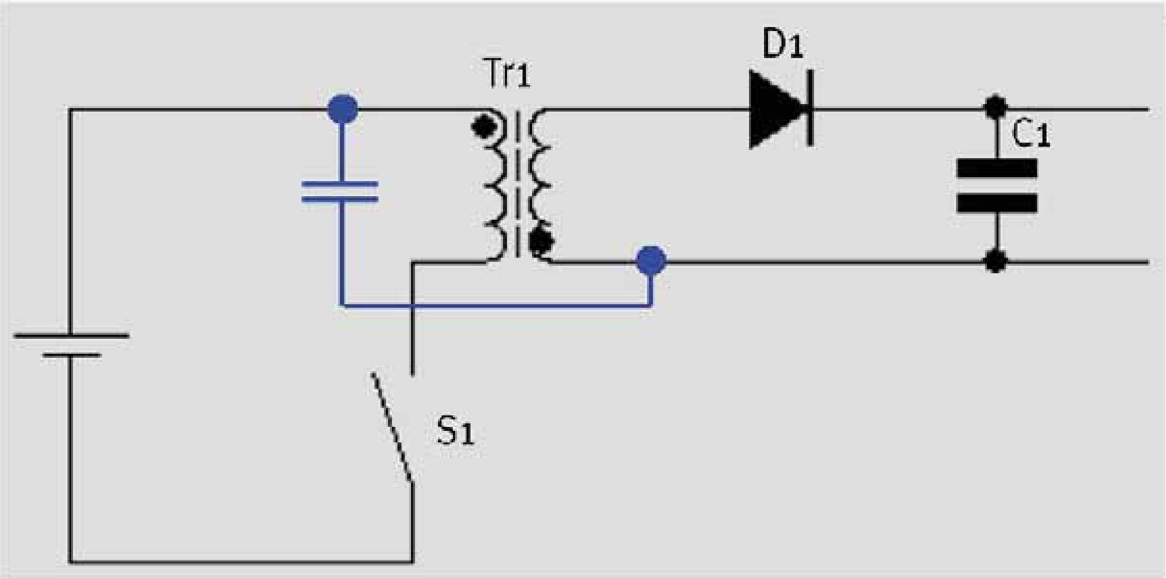
Subsequent Winding Acts as Shield

Increasing Voltage

V = L dI/dt

Transformers for EMC – Y-Cap Termination

Midcom WÜRTH ELEKTRONIK



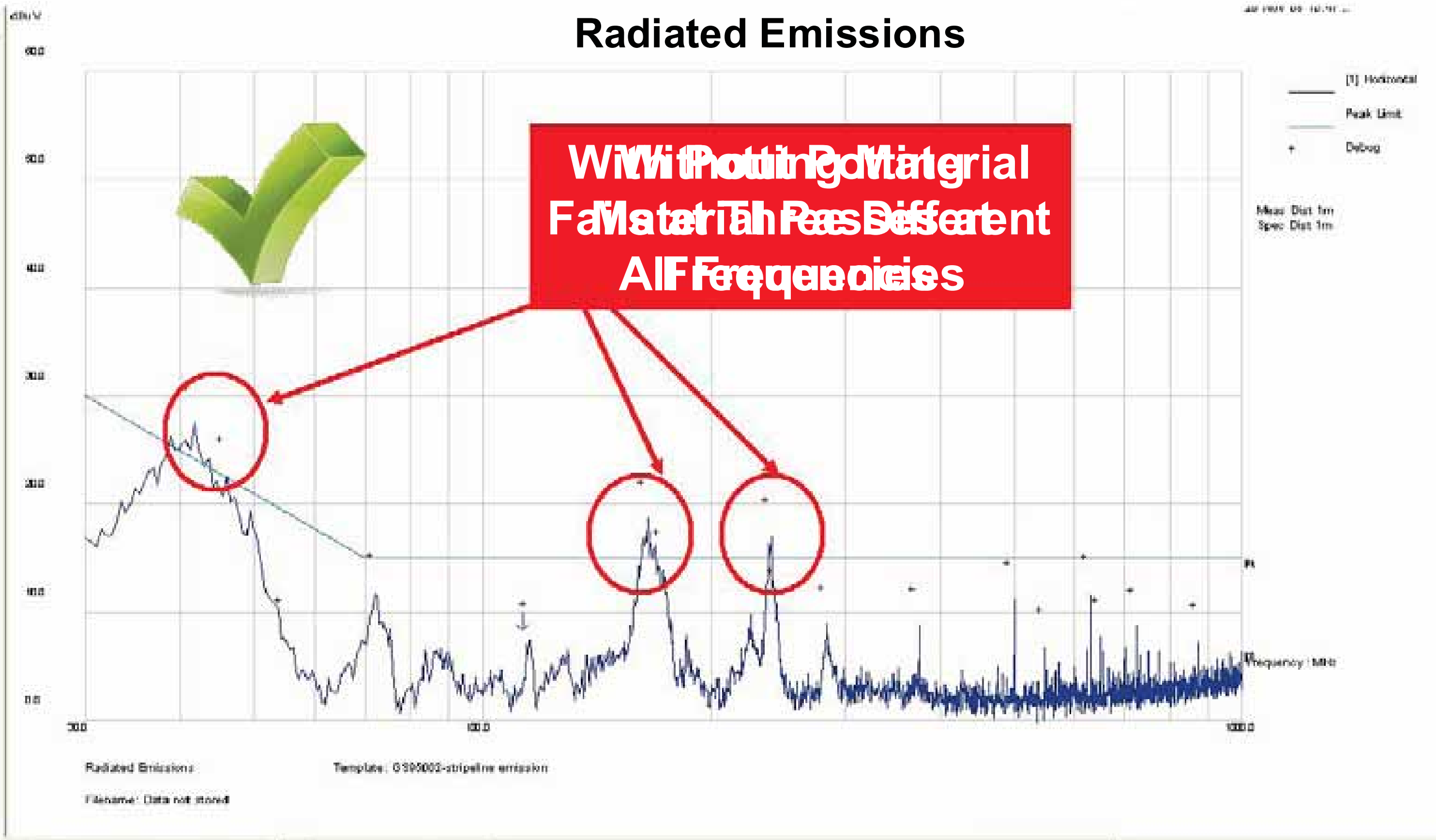
- Noise Couples Through the Transformer via C_{ww}
  - Noise Seeks Path to Primary Circuit
  - Without Path, Noise May Become Conducted Emissions
- Y-Cap Across Transformer Reduces Noise
  - Tune the Capacitor for Optimum Loss vs. Noise Reduction
  - Capacitor Usually in the 2.2nF to 4.7nF range
  - Y-Caps to Transformer Terminals not on Switch nor on Diode
  - Close to Transformer as Possible

What Can We Do?

Decrease Cww?

What Else Can We Do?

Transformers for EMC – No Varnish or Potting



List of Debug Frequencies

Debug Peak

No	Frequency MHz	Raw dBuV	Cable Loss	AF dB	Level dBuV	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV	Margin dB	Pass /Fail	Comments
1	41.640	47.0	10.4	-30.0	27.4	Peak [Scan]	H	100	0	24.2	3.2	Fail	
2	46.005	42.1	10.4	-30.0	22.6	Peak [Scan]	H	100	0	22.4	.1	Fail	
3	54.735	27.2	10.4	-30.0	7.7	Peak [Scan]	H	100	0	19.3	-11.6	Pass	
4	72.196	31.1	10.5	-29.9	11.7	Peak [Scan]	H	100	0	15.0	-3.2	Pass	
5	115.360	26.6	10.6	-29.8	7.4	Peak [Scan]	H	100	0	15.0	-7.5	Pass	
6	164.830	37.4	10.7	-29.5	18.6	Peak [Scan]	H	100	0	15.0	3.6	Fail	

Assessment: Debug Scan / Formal Peak Test / Both

Storage: Trace 1 / Trace 2 / Both

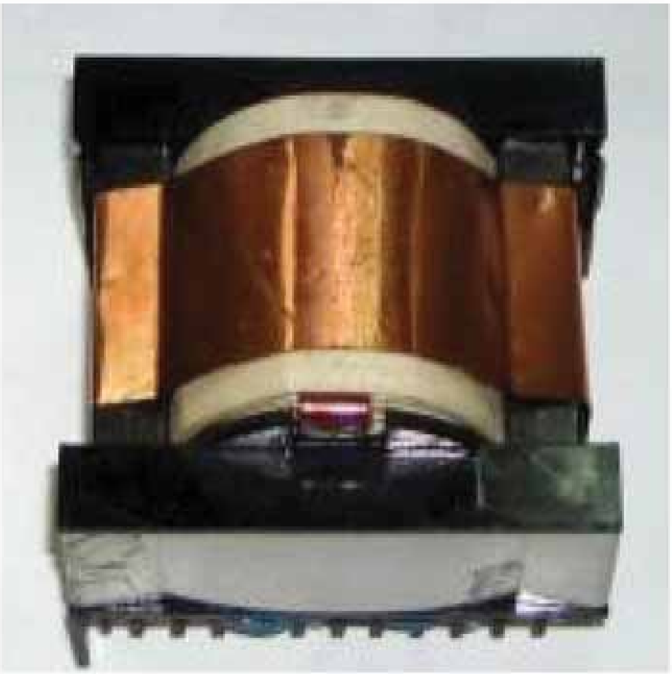
Begin Assessment

Library of Known Ambients

Transformers for EMC - Small Designs

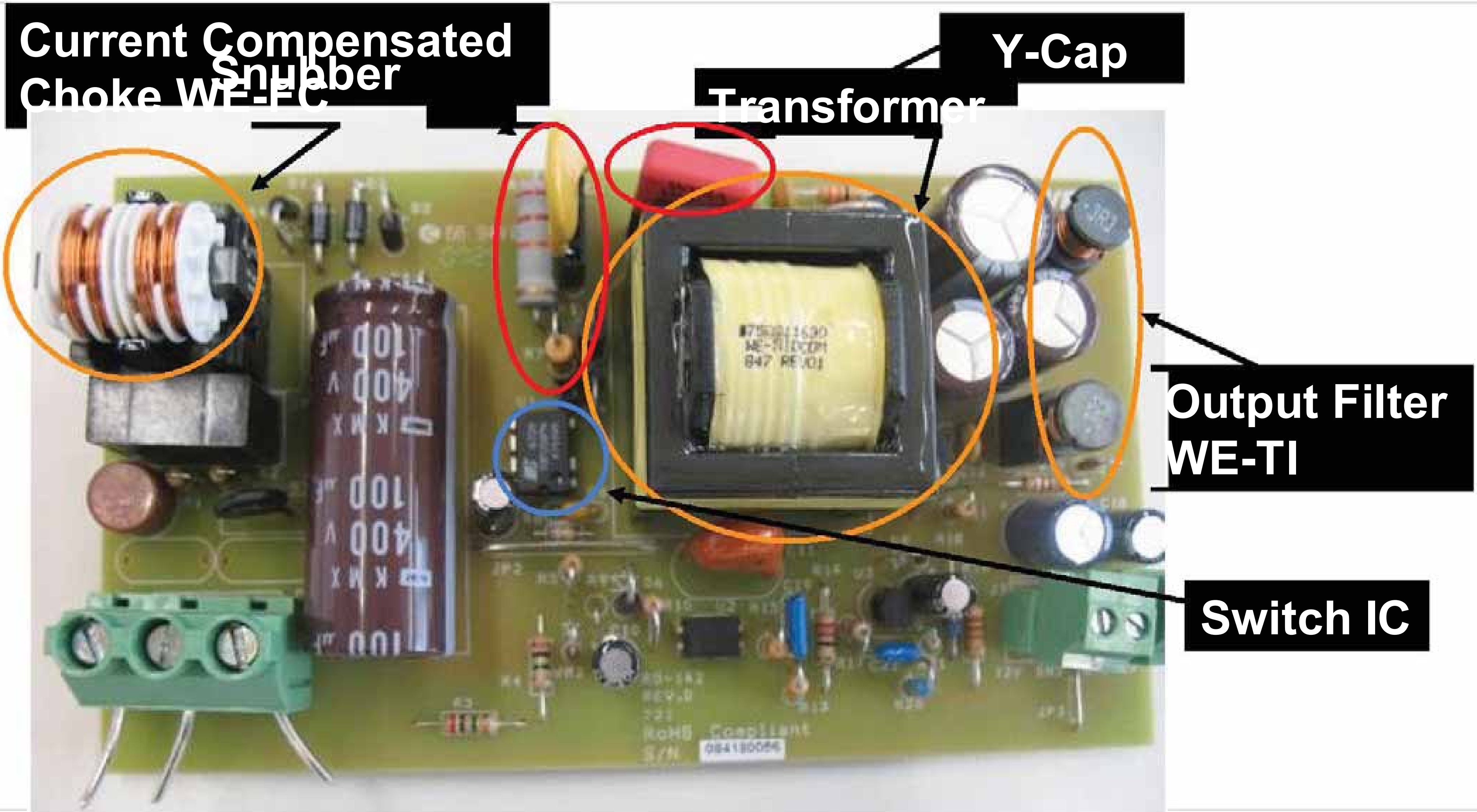
Why Build Smaller Designs?

- **Build Smaller More Compact Transformers**
- Smaller Transformers have less Parasitics
  - Less Capacitance
  - Smaller Leads (ie. Smaller Antennas)
  - Smaller Gaps
  - Less Leakage Inductance
- Less Conducted and Less Radiated Noise



Transformers for EMC – Power Supply

Midcom WÜRTH ELEKTRONIK



Transformers for EMC – Schematic

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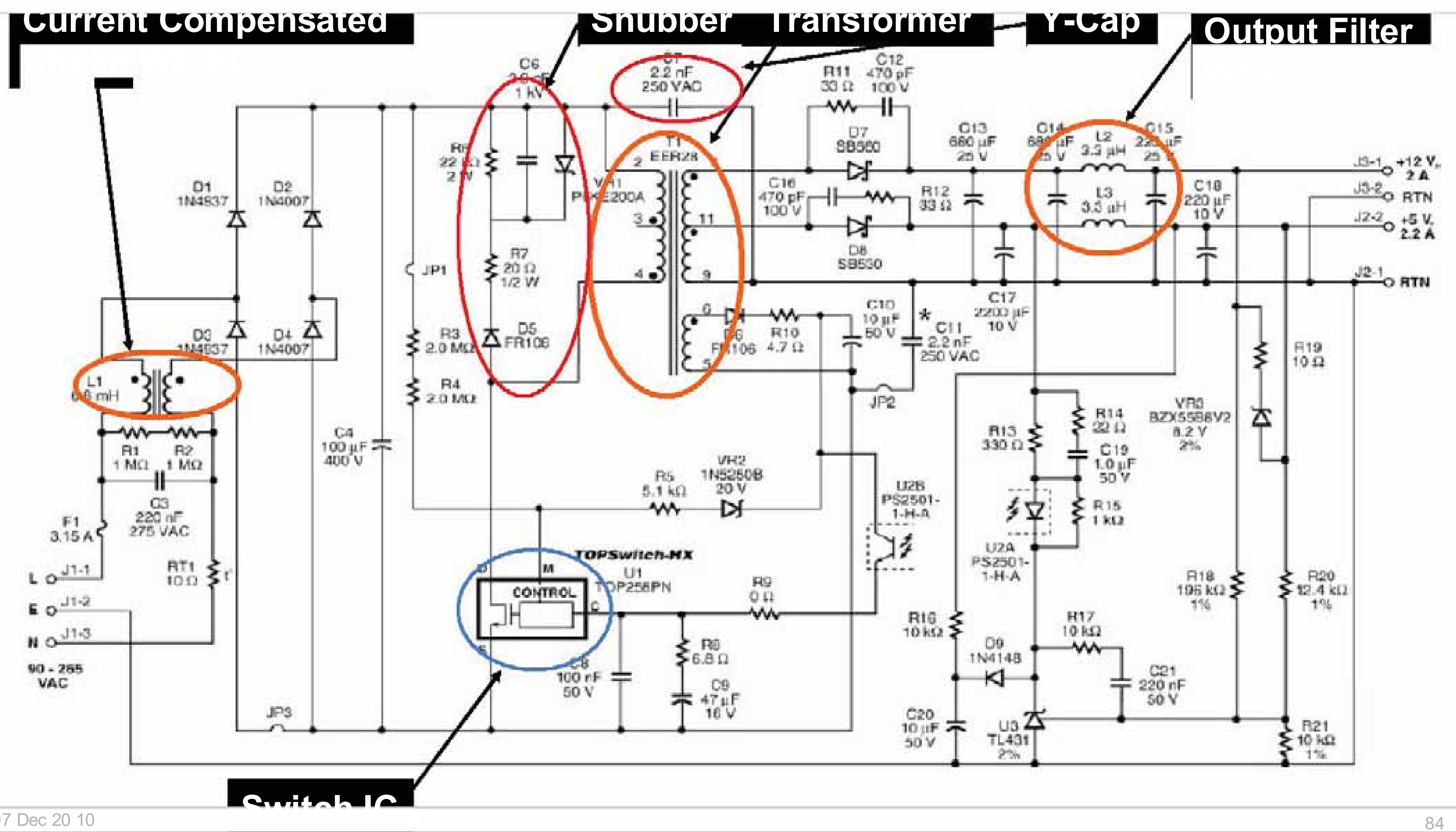

Transformers for EMC – Example 1

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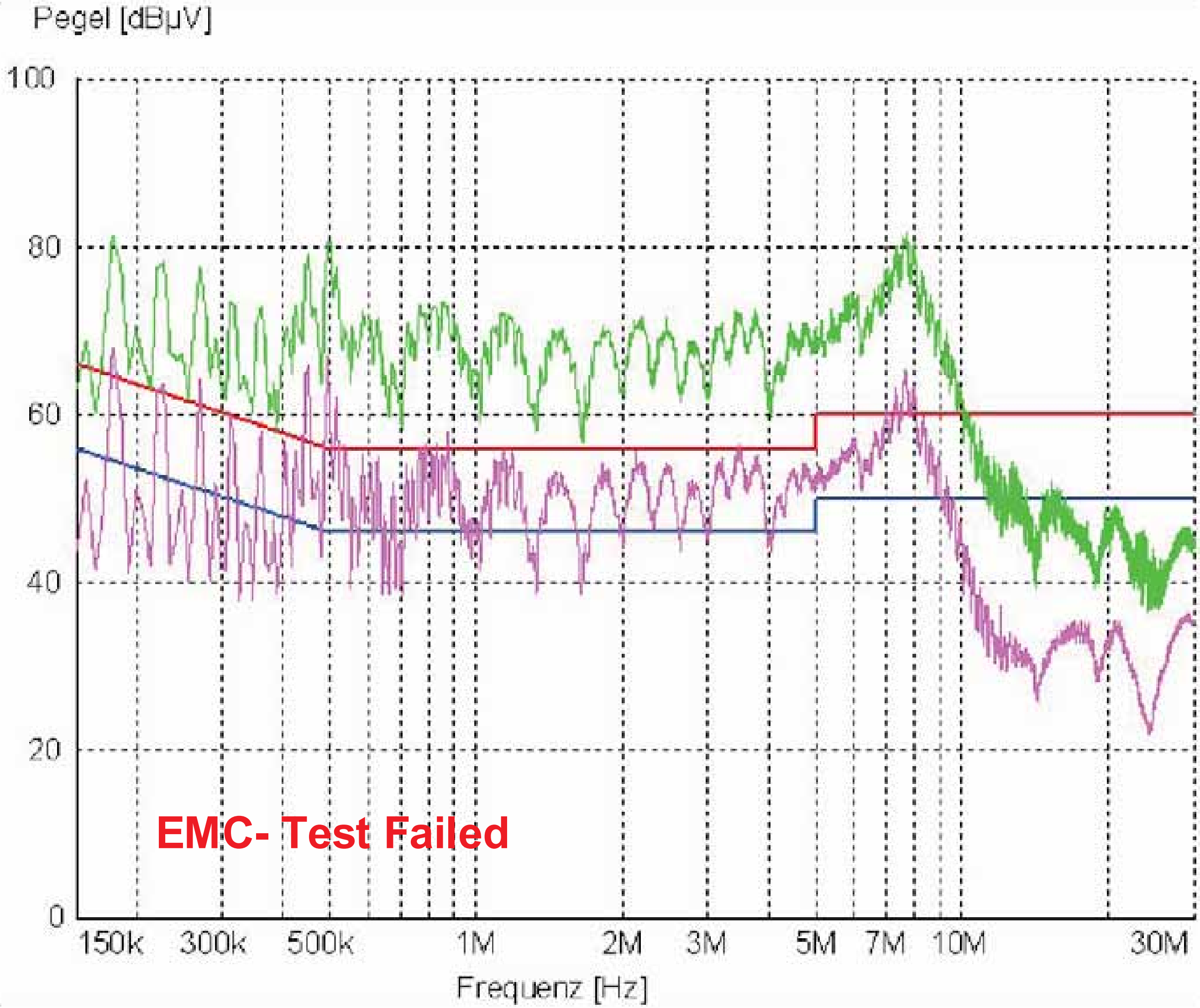
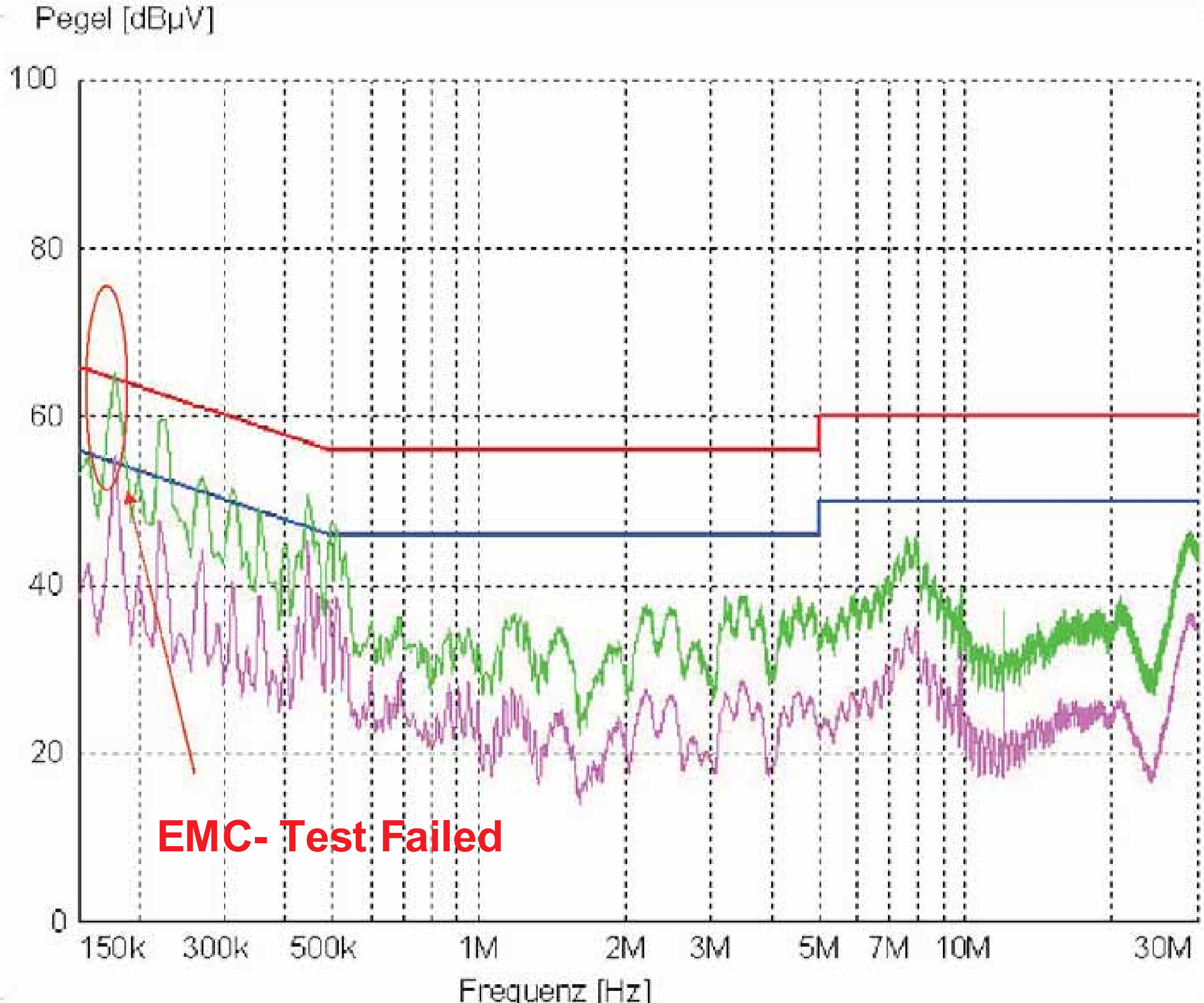


- **Without Current Compensated Choke**
- **With Adjusted Snubber**
- **Without Adjusted Y-Cap**

Peak
Avg.
Peak
Avg.

Transformers for EMC – Example 2



- With Current Compensated Choke
- With Adjusted Snubber
- Without Adjusted Y-Cap

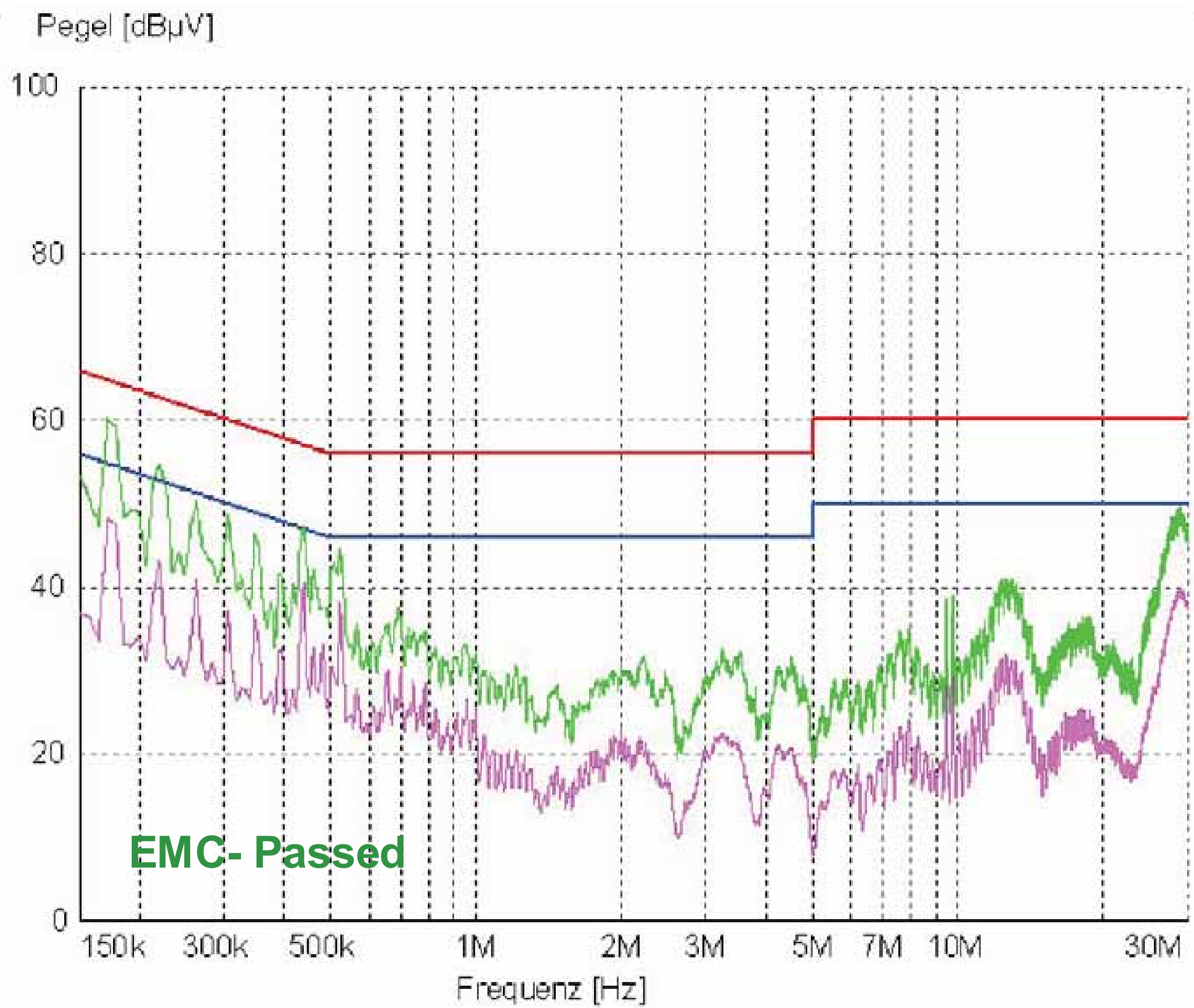
Peak

Avg.

Peak

Avg.

Transformers for EMC – Example 3



- With Current Compensated Choke
- With Adjusted Snubber
- With Adjusted Y-Cap

Peak

Avg.

Peak

Avg.

Transformers for EMC – Example 4

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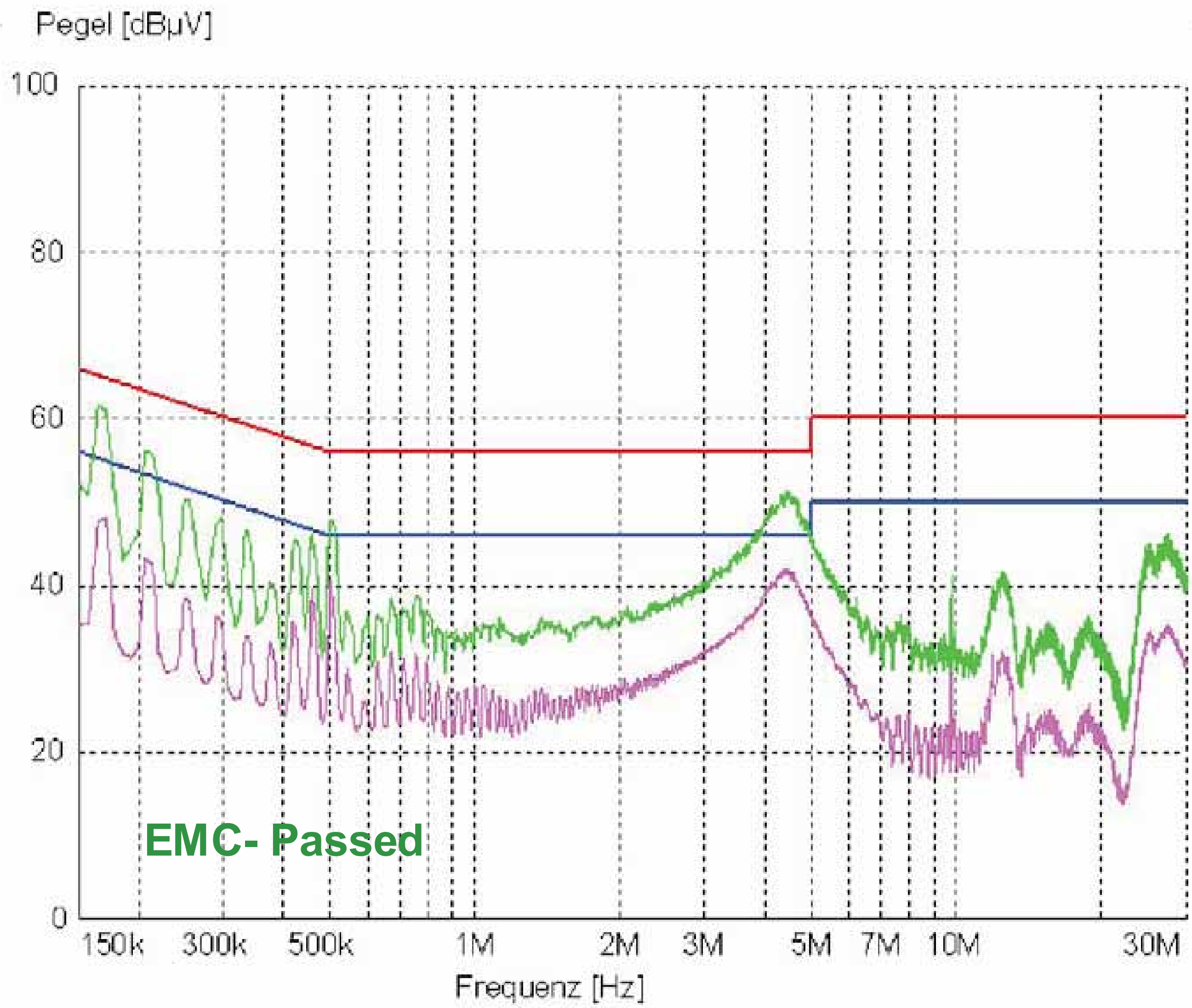


- **With Current Compensated Choke**
- **Without Adjusted Snubber**
- **With Adjusted Y-Cap**

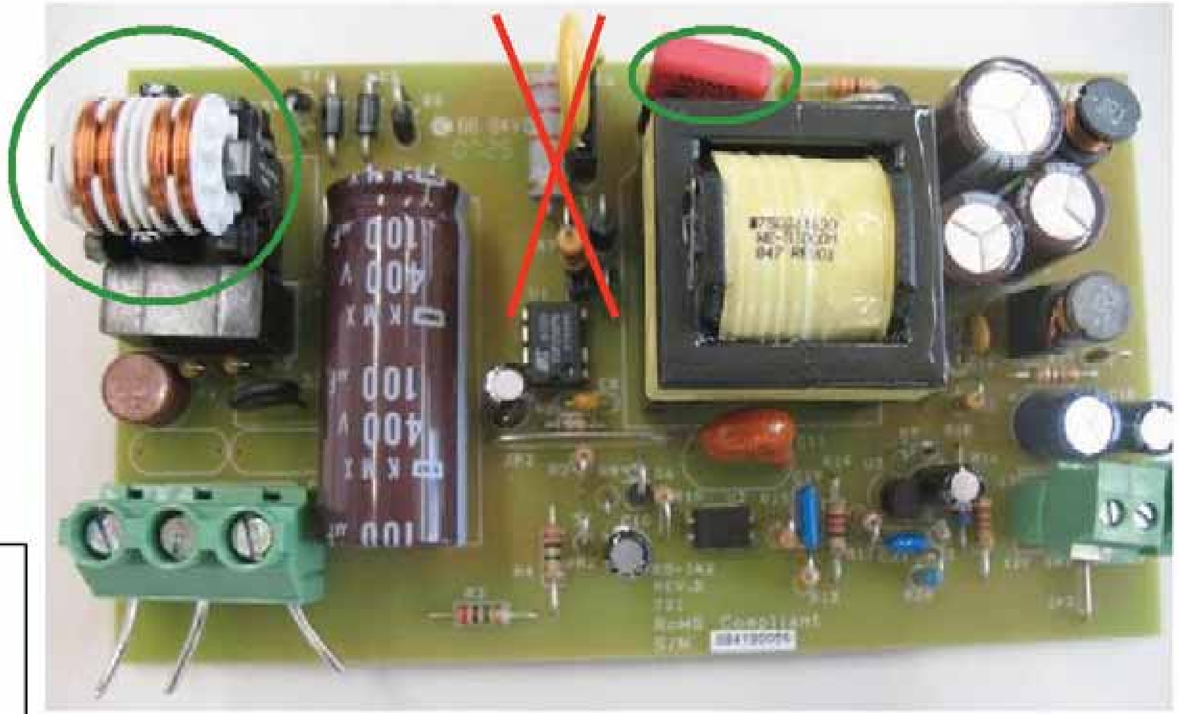
Peak

Avg.

Peak

Avg.

Transformer for EMC – Conclusion for this Supply



- Necessary to Pass
  - Current Compensated Choke
  - Y-Caps
- Not Necessary to Pass
  - Optimized Snubber

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Linear Technology
Neuer Katalog 2003 ab sofort
Partnerschaft mit IC-Herstellern
Fachbuch "Trilogie der Induktivitäten"

Inductor Selector Guide

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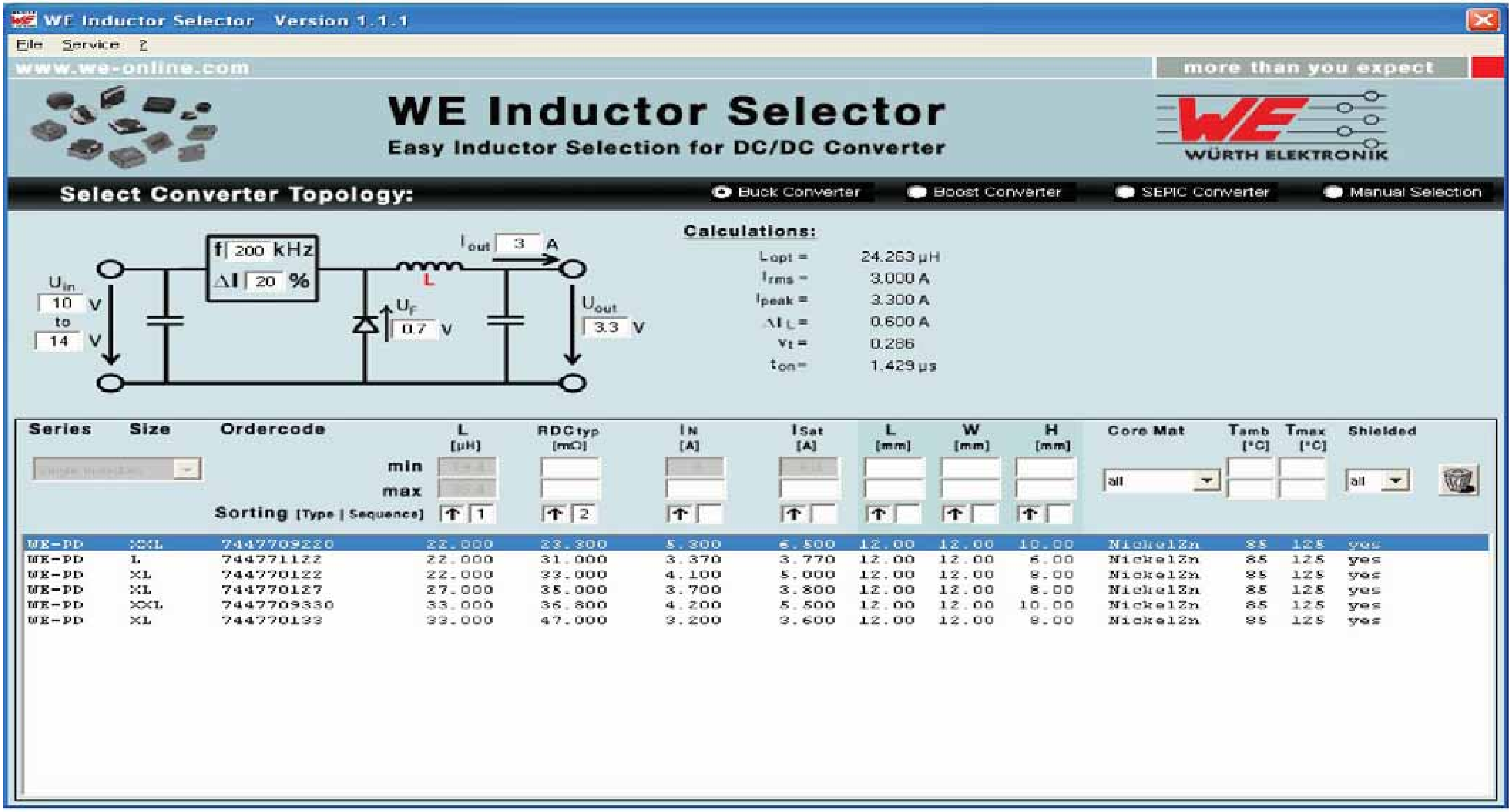

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What more do you need?

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Look at our Book:

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keep it simple, stupid

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Descriptions, Applications, Simulation
Models and many more

Chap.3: Filter-Circuits
Design, Grounding, Layout, Tips

Chap.4: Applications
Circuit, suggested parts, Layout

Chap.5: Appendices
from A to Z

Any Questions?

Thank you from –
the Wurth Electronics Midcom East Coast