more than you expect

WÜRTH ELEKTRONIK

Switched Mode Power Supply with high efficiency and best EMI design

Speaker:

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Area Sales Manager

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Agenda

- EMC Basics
- REDEXPERT
  - Practical component selection
- Design Your own Line Input Filter
- Conduced Emissions Measurements
  - Practical Measurements

Conducted Emission

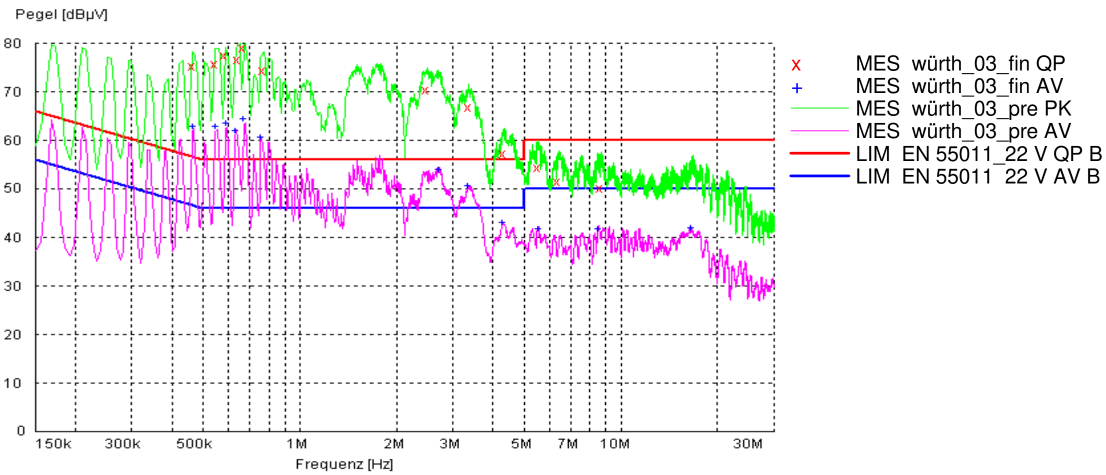
- Conducted emission over wideband
- Caused by ripple current at input lines (common mode - / differential mode noise)
- EMC requirements for *„Conducted Emission“* according ETSI, CEN, CENELEC

- E.g.: EN 55011: 2016 (Industrial, scientific and medical (ISM) radio-frequency equipment)

66 - 56dBµV @ 150<KHz<500KHz (QP)
56 - 46dBµV @ 150<KHz<500KHz (Av)

56dBµV @ 0,5<MHz<5 (QP)
46dBµV @ 0,5<MHz<5 (Av)

60dBµV @ 5<MHz<30 (QP)
50dBµV @ 5<MHz<30 (Av)



Radiated Emission

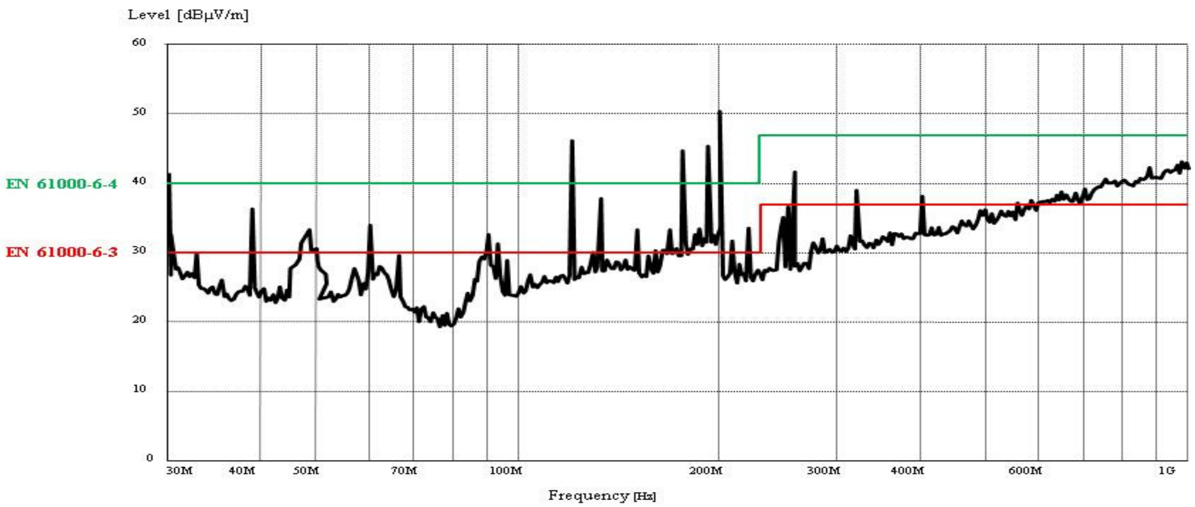
- Radiated emission over wideband
- Caused by:
  - Power traces on PCB
  - Power choke of DC/DC converter
- EMC requirements for *„Radiated Emission"* according ETSI, CEN, CENELEC

- EN 61000-6-3 : 2011-09 (Home)

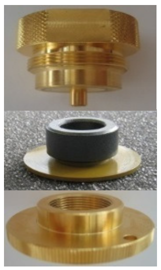
30dB @ 30MHz~230MHz µV/m
37dB @ 230MHz~1GHz µV/m

- EN 61000-6-4 : 2011-09 (Industrial)

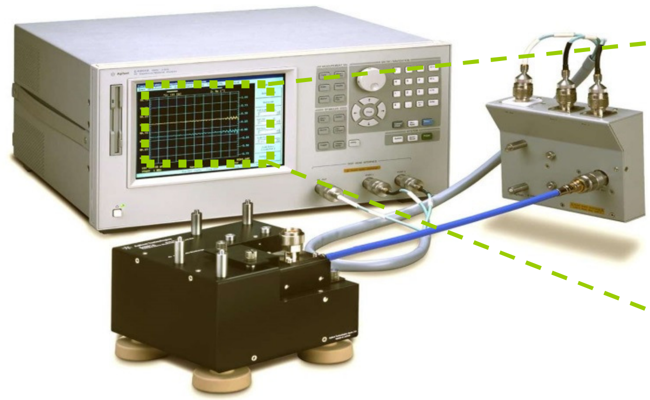
40dB @ 30MHz~230MHz µV/m
47dB @ 230MHz~1GHz µV/M

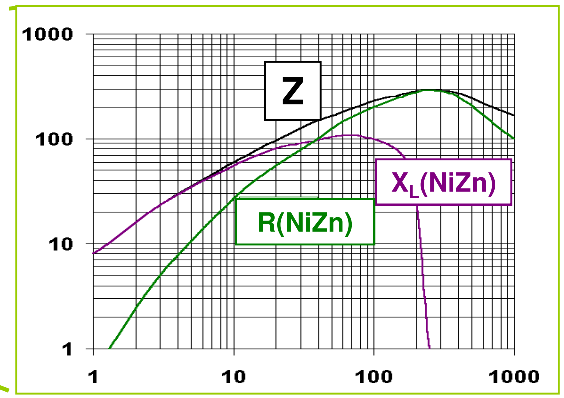


Permeability – complex permeability



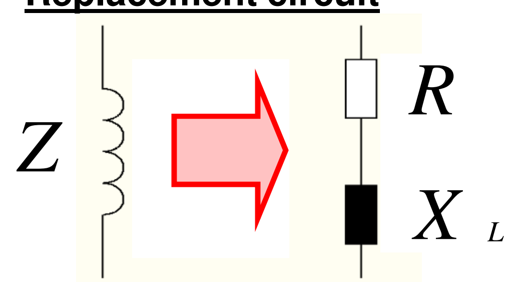
=1 turn





Core material-Parameter

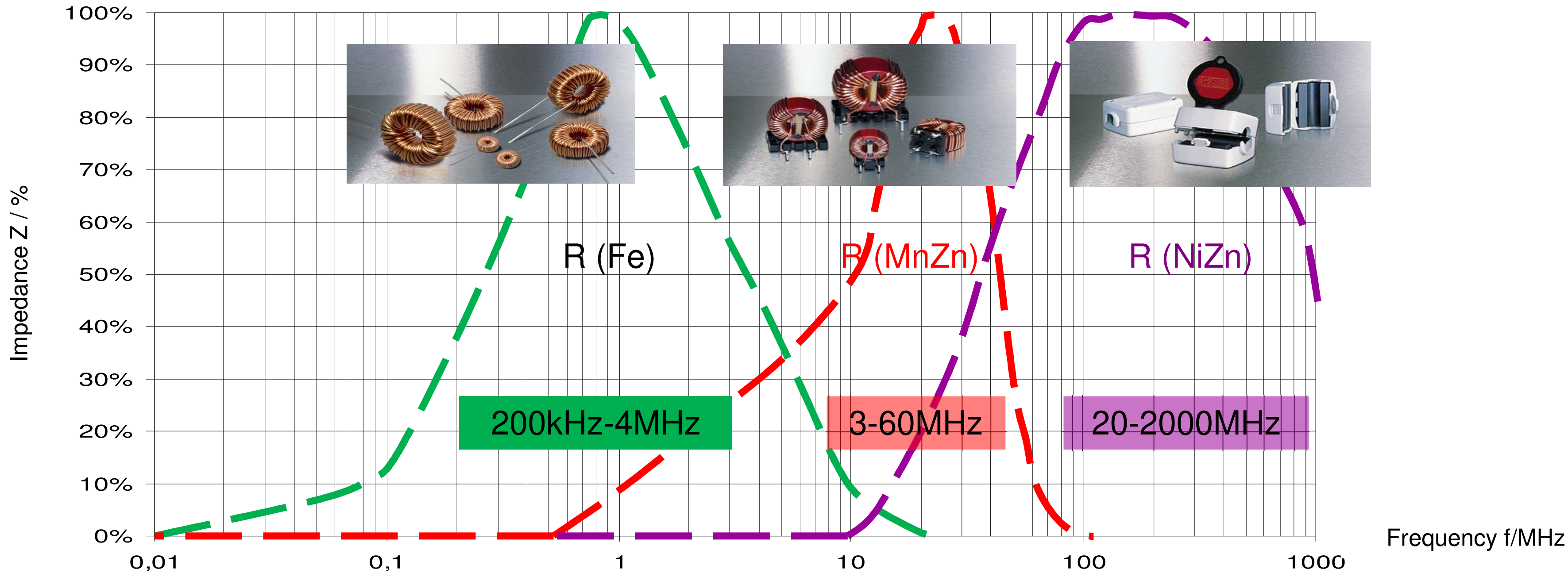
<u>Replacement circuit</u>



$$Z = \sqrt{R^2 + X_L^2}$$

Core materials- Chokes (filtering)

Noise frequency range must be known



Transmission Modes & Filter Topologies

Recognizing the coupling mode

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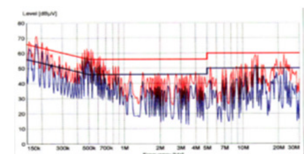
- **common mode noise ?**
- **differential mode noise ?**

Common mode or differential mode?

Take a Snap Ferrite and fix it on the cable (both lines e.g. VCC and GND)

if noise is reduced or noise immunity increase



you have Common Mode Interference

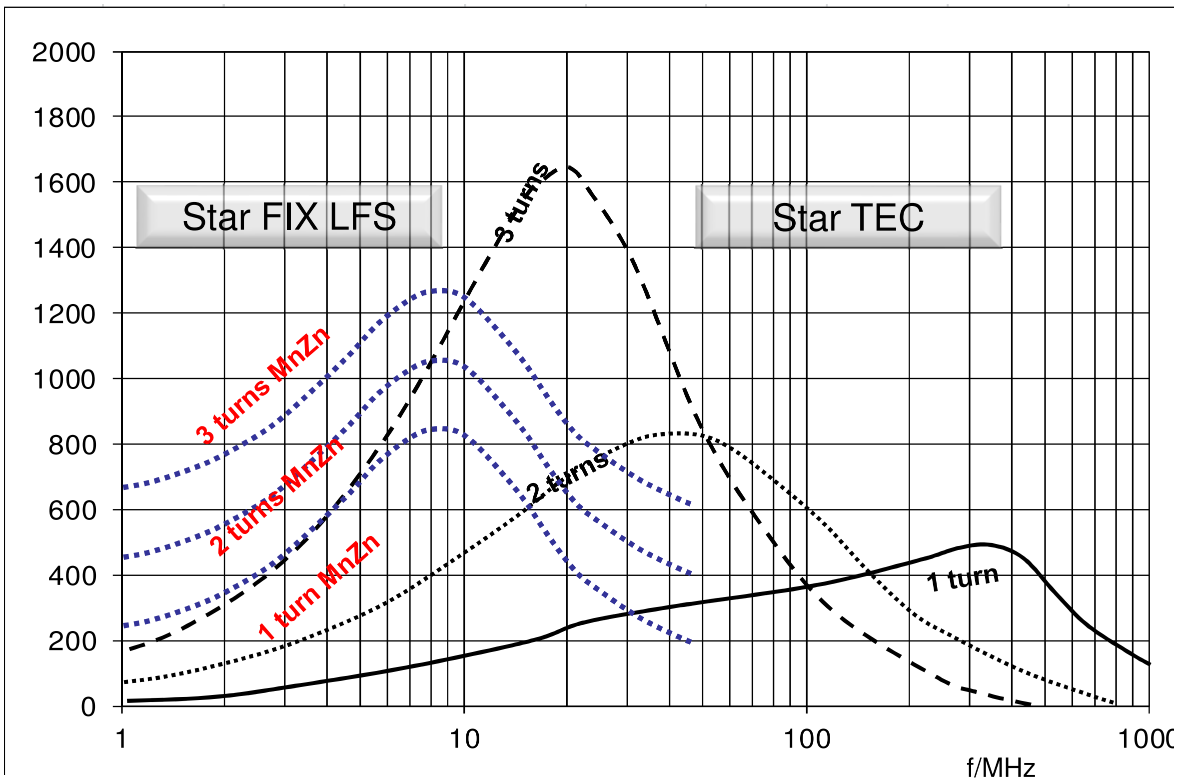
e.g. Common mode choke

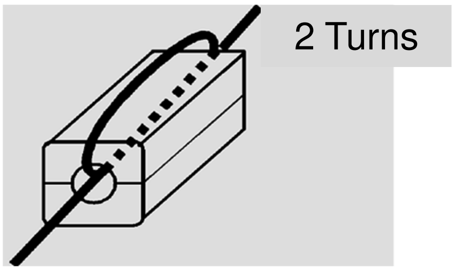
If not

you have Differential Mode Interference

e.g. chip bead ferrite

Snap on ferrite – typical behavior

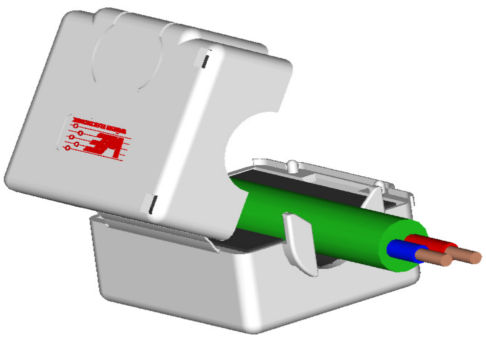




Increase the no. of turns means:

Snap on ferrite - Construction

- Snap on ferrite acts as an CMC
- Absorbs common mode Interferences
- Comparable with bifilar winding CMC

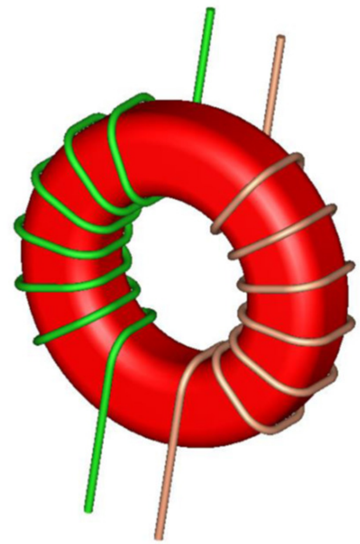


Common Mode Choke – Winding Style

- bifilar

- Power supply: low voltage application
- Signal: low speed signal and High speed Signal

- sectional

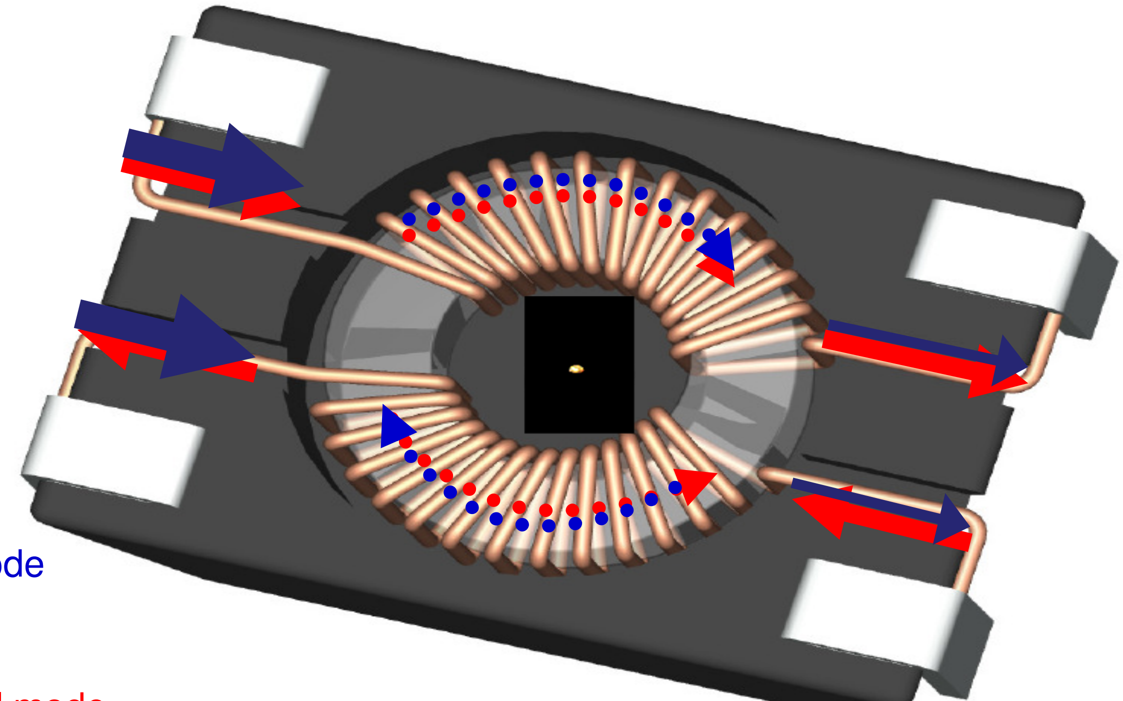


- Power supply: „high“ voltage application and low voltage DC applications; according to IEC60938 or UL1283

Common Mode Filter – How it works

It is a Bi-directional filter

- From device to outside environment
- From outside environment to inside device



Intended Signal - Differential mode

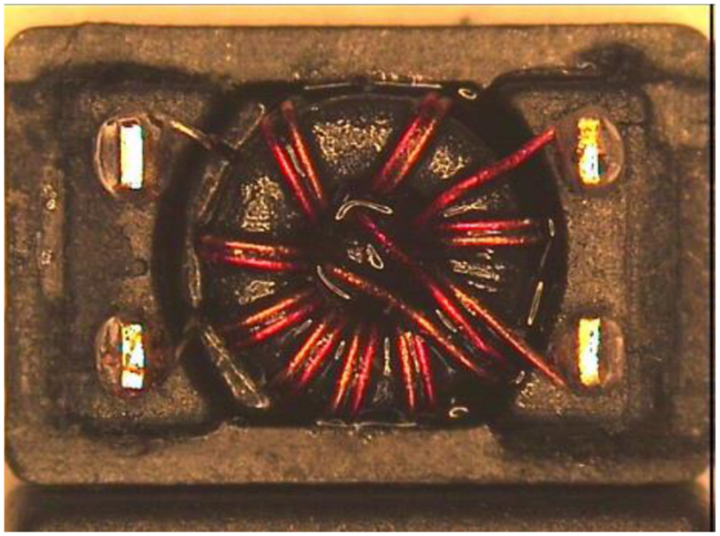
Interference Signal (noise) – Common Mode

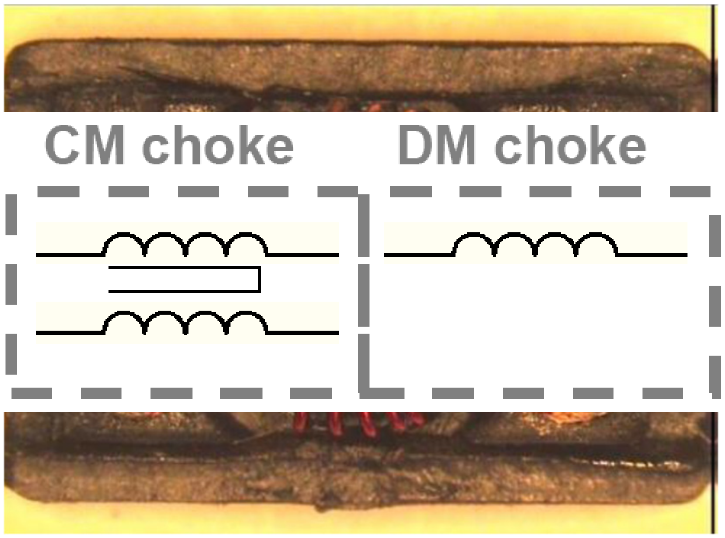
Conclusion:

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

Common Mode Choke – Winding Style

- bifilar WE-SL2 744226
- sectional WE-SL2 744226S



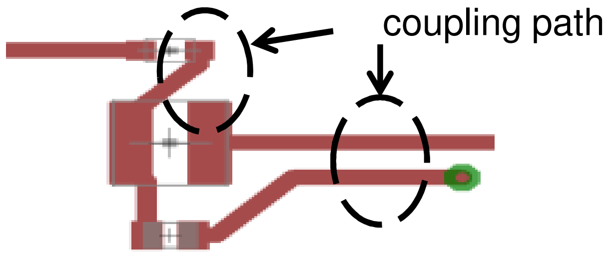


- low leakage inductor
- high leakage inductor

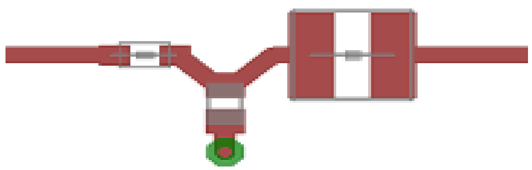
PCB - LAYOUT RECOMMENDATIONS

PCB-Layout recommendations

T-filter



not recommended



recommended

- Keep PCB traces as short as possible
- Avoid indirect trace routing
- Avoid any kind couplings → "*capacitive*", "*inductive*"
- AC-current should flow across capacitor
- Short way for AC-current direct to GND (place double via's to GND)

PCB-Layout recommendations

common mode noise filter

not recommended | not recommended | recommended

- **Avoid indirect routing of power traces**
- **Avoid any kind of couplings → "*capacitive*", "*inductive*" … etc …**
- **AC-current should flow across common mode choke**
- **Route power traces on component layer**
- **Do not use via's**

REDEXPERT®

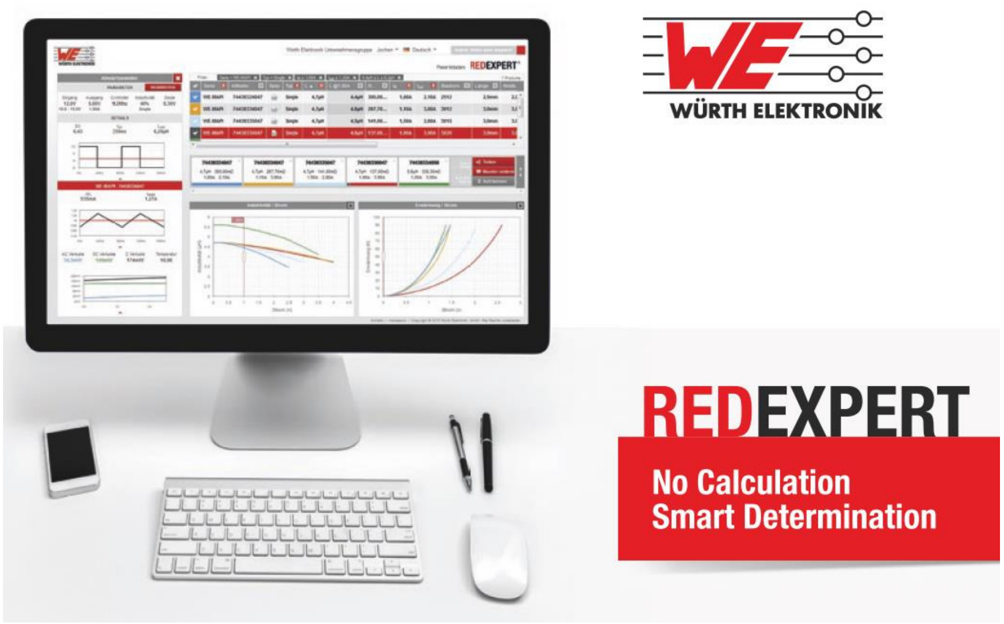

World's most accurate AC loss model
The losses determined with REDEXPERT are based on real time DCDC measurements with its typical current and voltage waveforms. Besides all core and winding losses they do also consider losses in the air gap.
Calculate the AC losses
Power Inductors
REDEXPERT

REDEXPERT®: What is it?

Online platform for easy component selection

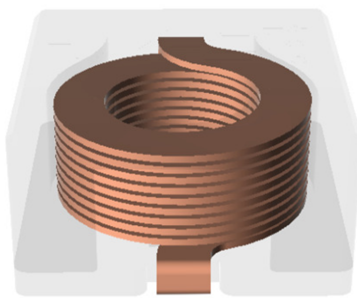
Select | Compare | Simulate

- **Live updates**
- **Easy component comparison**
- **Several design tools integrated**
- **Share results and searches easily online**



World‘s most accurate AC loss model

$$\boxed{P_{\text{total}} = P_{\text{dc}} + P_{\text{ac}} = P_{\text{Cu,dc}} + \left(P_{\text{Cu,ac}} + P_{\text{core,ac}}\right)}$$



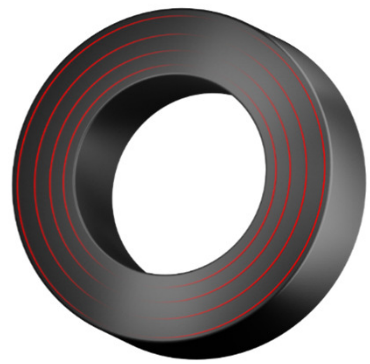
- Winding losses:
  - DC losses
  - AC losses (skin effect, proximity effect)
- Core losses:
  - Hysteresis losses
  - Eddy current losses

World‘s most accurate AC loss model

Würth model

- Consideration of:
  - Real core shapes
  - Winding structure
    - Winding losses
  - Losses due to air gap (fringing effects)

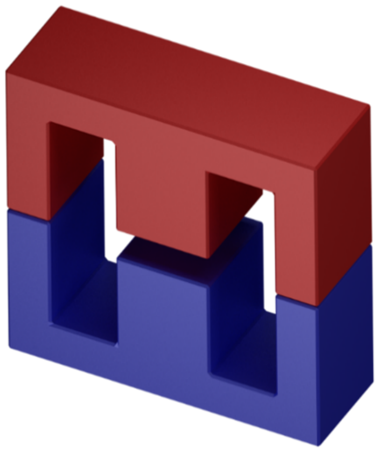
Steinmetz model



- Consideration of:
  - Toroidal cores without an air gap

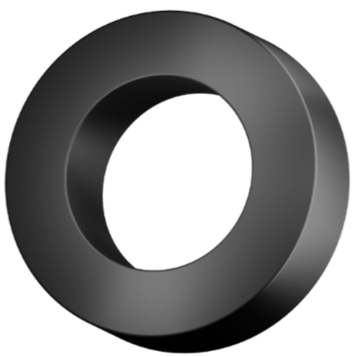
World‘s most accurate AC loss model

Würth model



- Material combination supported, i.e. NiZn, MnZn, iron powder, metal alloy, etc.

Steinmetz model



- Only single material, mainly for NiZn, MnZn
- Not applicable for iron powder & metal alloy

World‘s most accurate AC loss model

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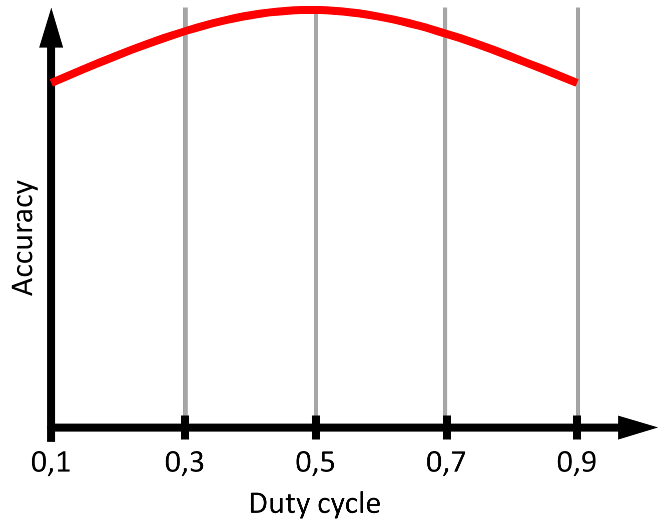
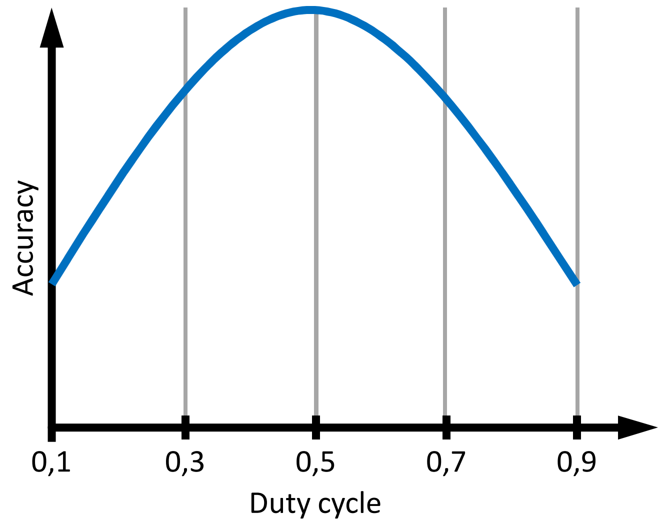
Würth model



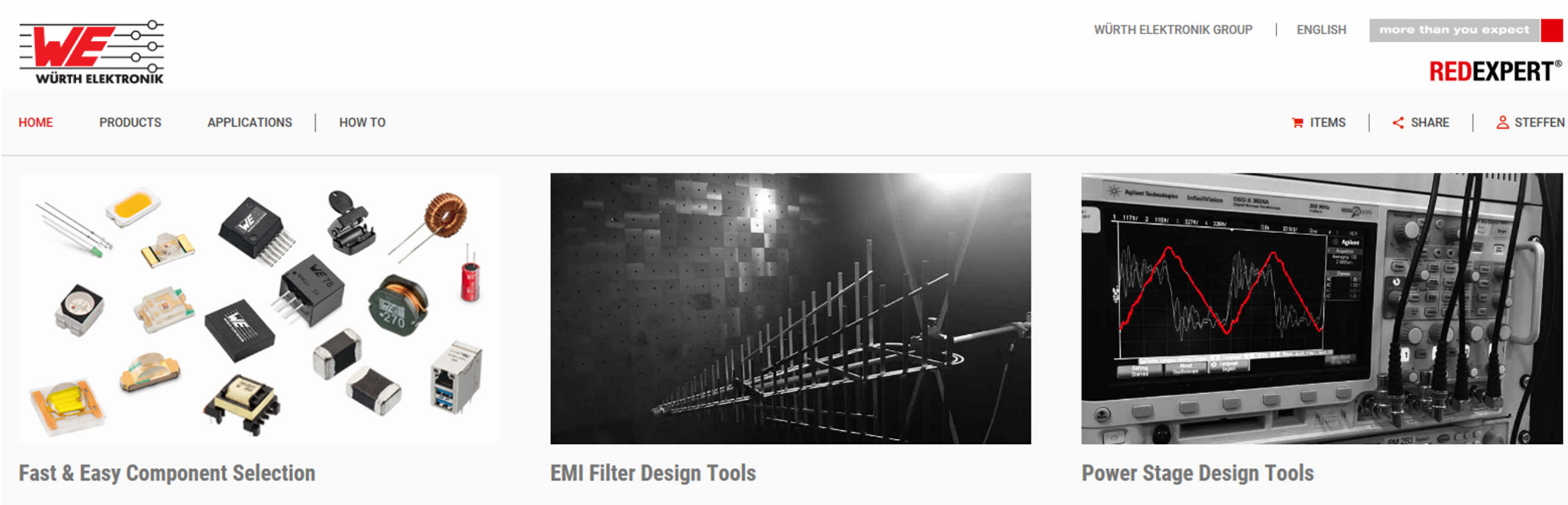
- Highest accuracy over wide d.c. range

Steinmetz model

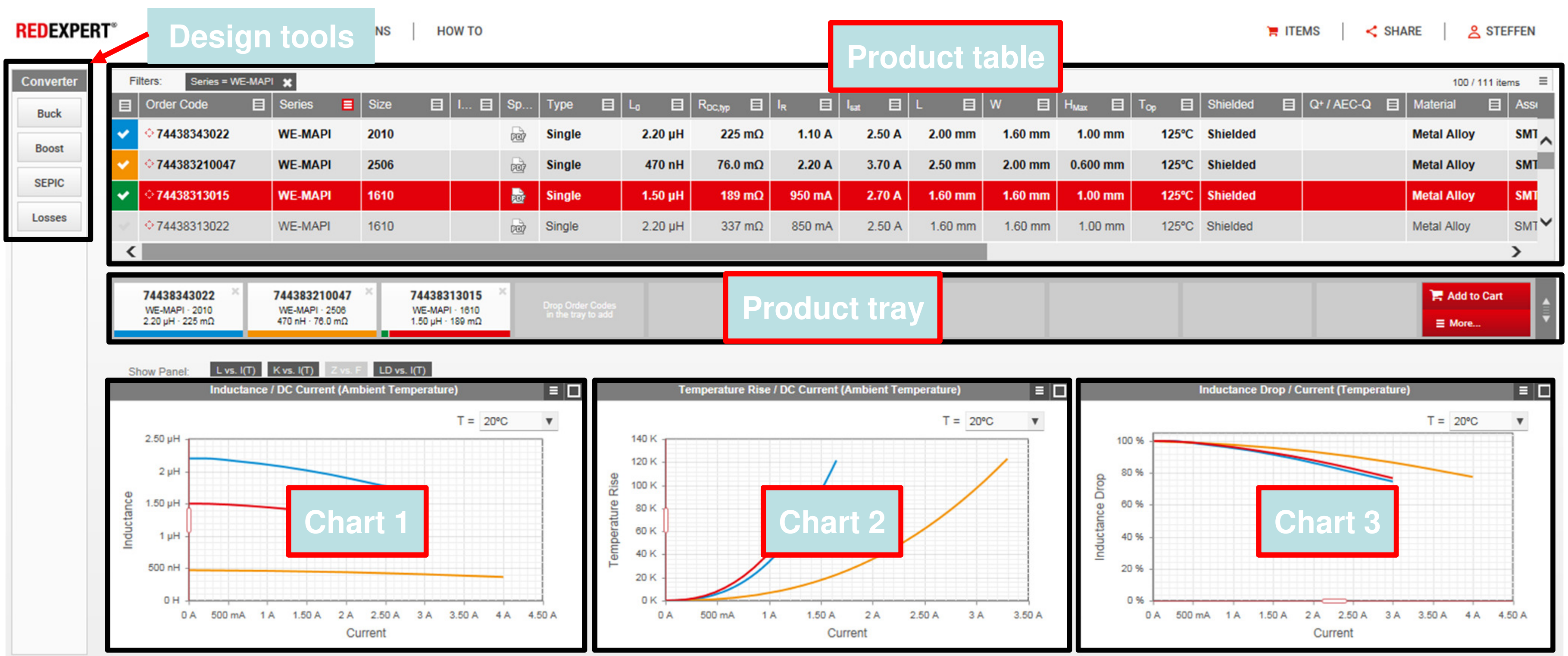


- Acceptable accuracy for ring cores at 50%, worse for other d.c.

Start screen



User interface



Select | Compare | Simulate

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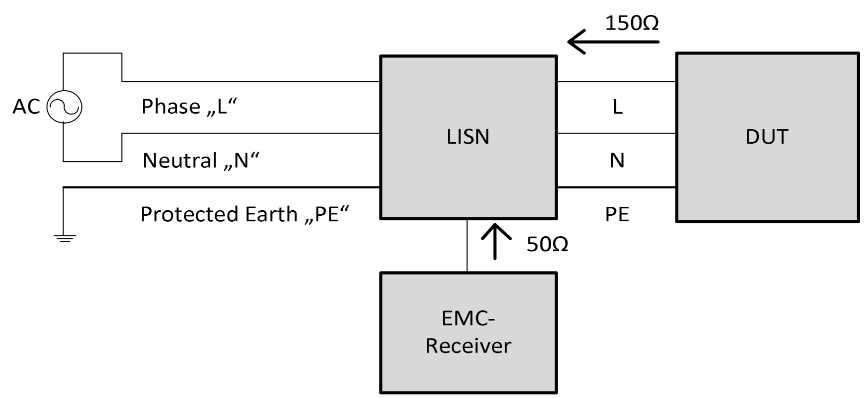
Conducted emissions Measurement

Conducted Emission test setup



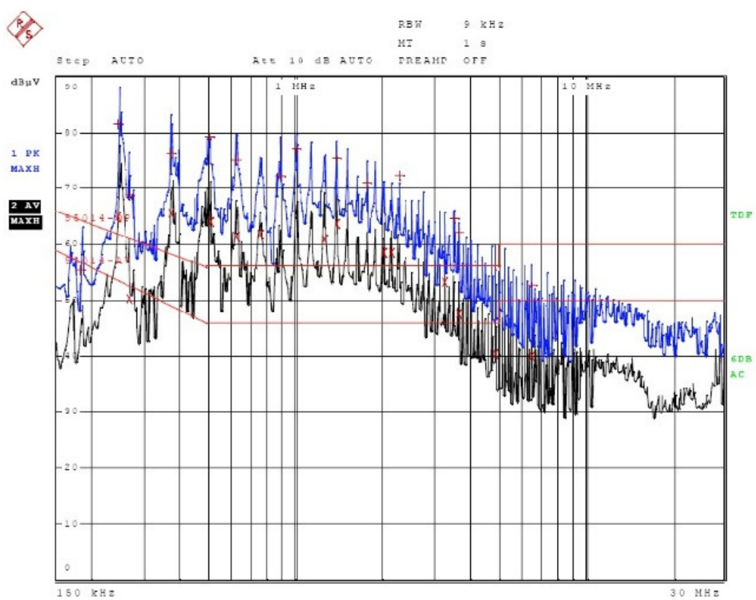
- **LISN: „Line Impedance Stabilization Network“**
  - ➢ **Create known impedance on power lines for DUT**
  - ➢ **F**ilter mains voltage and cut higher frequency
  - ➢ **Transfer conducted emission noise to EMC-Receiver**
- EMC-chamber is recommended but not required

EUT

- Switch Mode Power Supply
- Flyback Topology
- Off – line high voltage converter
  - Operating frequency 115 kHz

Conducted Emissions Measurement
No Input Filter; line L

LINE L



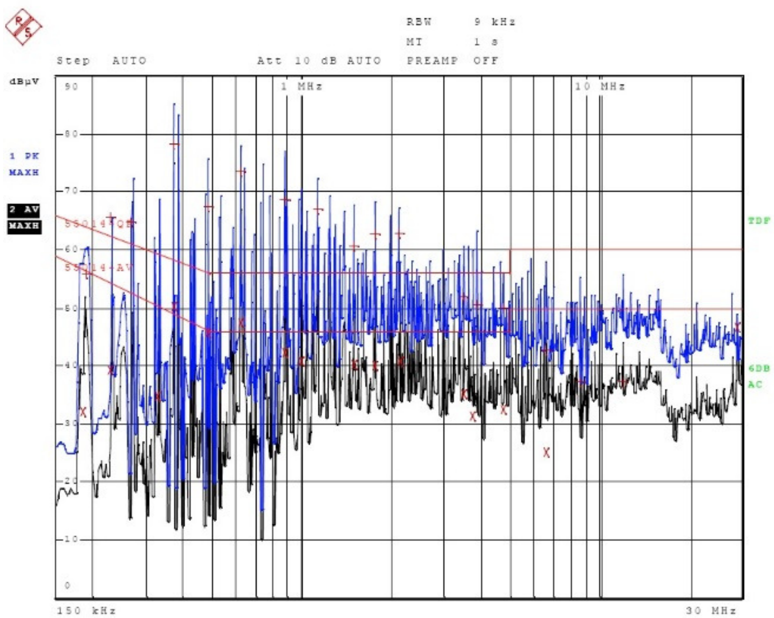
Final Measurement

Meas Time: 1 s
Margin: 5 dB
Subranges: 29

Trace	Frequency	Level (dBµV)	Detector	Delta Limit/dB
1	502.000000000 kHz	79.15	Quasi Peak	23.15
1	1.002000000 MHz	77.11	Quasi Peak	21.11
1	246.000000000 kHz	81.36	Quasi Peak	19.47
1	1.378000000 MHz	75.31	Quasi Peak	19.31
1	622.000000000 kHz	75.23	Quasi Peak	19.23
2	506.000000000 kHz	64.00	CISPR Averag	18.00
1	370.000000000 kHz	76.23	Quasi Peak	17.73
2	1.382000000 MHz	63.65	CISPR Averag	17.65
2	374.000000000 kHz	65.44	CISPR Averag	16.31
1	2.258000000 MHz	72.23	Quasi Peak	16.23
1	878.000000000 kHz	72.14	Quasi Peak	16.14
2	750.000000000 kHz	61.77	CISPR Averag	15.77
2	618.000000000 kHz	61.39	CISPR Averag	15.39
1	1.754000000 MHz	70.94	Quasi Peak	14.94
2	1.246000000 MHz	60.72	CISPR Averag	14.72
2	2.006000000 MHz	58.56	CISPR Averag	12.56
2	2.134000000 MHz	58.46	CISPR Averag	12.46
2	246.000000000 kHz	64.98	CISPR Averag	11.32
1	3.514000000 MHz	64.51	Quasi Peak	8.51
1	266.000000000 kHz	68.68	Quasi Peak	7.44
2	3.262000000 MHz	53.17	CISPR Averag	7.17
1	3.638000000 MHz	62.09	Quasi Peak	6.09
2	3.634000000 MHz	47.48	CISPR Averag	1.48
1	4.890000000 MHz	56.13	Quasi Peak	0.13
2	266.000000000 kHz	50.20	CISPR Averag	-2.61
2	4.886000000 MHz	40.46	CISPR Averag	-5.54

Conducted Emissions Measurement
No Input filter; line N

LINE N



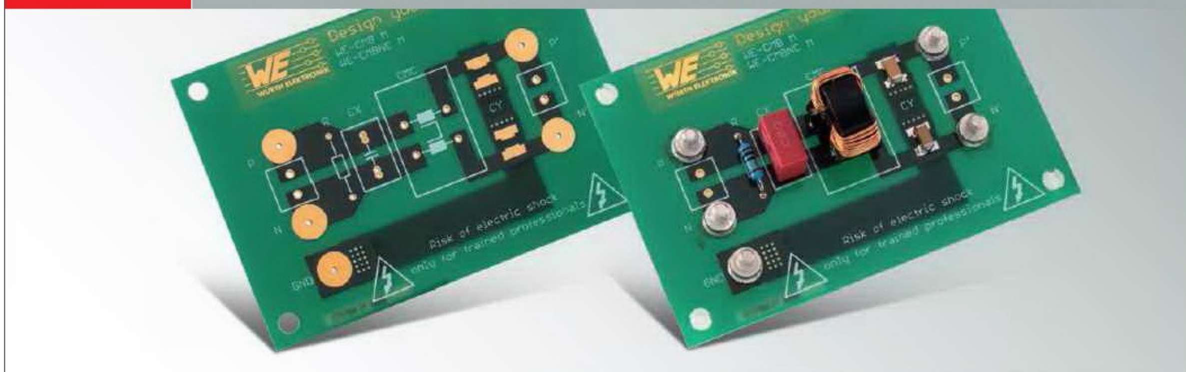
Final Measurement

Meas Time: 1 s
Margin: 5 dB
Subranges: 33

Trace	Frequency	Level (dBµV)	Detector	Delta Limit/dB
1	370.000000000 kHz	78.20	Quasi Peak	- 5. 00 dB 19.70
1	622.000000000 kHz	73.41	Quasi Peak	17.41
1	874.000000000 kHz	68.51	Quasi Peak	12.51
1	482.000000000 kHz	67.39	Quasi Peak	11.09
1	1.130000000 MHz	66.94	Quasi Peak	10.94
1	2.126000000 MHz	62.93	Quasi Peak	6.93
1	1.750000000 MHz	62.74	Quasi Peak	6.74
1	1.494000000 MHz	60.69	Quasi Peak	4.69
1	270.000000000 kHz	64.78	Quasi Peak	3.66
1	230.000000000 kHz	65.73	Quasi Peak	3.28
2	622.000000000 kHz	47.28	CISPR Averag	1.28
2	370.000000000 kHz	50.22	CISPR Averag	0.97
2	482.000000000 kHz	45.61	CISPR Averag	-0.78
2	28.966000000 MHz	46.61	CISPR Averag	-3.39
2	874.000000000 kHz	42.32	CISPR Averag	-3.68
1	3.498000000 MHz	51.91	Quasi Peak	-4.09
2	990.000000000 kHz	40.76	CISPR Averag	-5.24
2	2.134000000 MHz	40.65	CISPR Averag	-5.35
1	3.874000000 MHz	50.48	Quasi Peak	-5.52
2	1.494000000 MHz	40.20	CISPR Averag	-5.80
2	1.750000000 MHz	40.05	CISPR Averag	-5.95
1	4.754000000 MHz	49.98	Quasi Peak	-6.02
1	190.000000000 kHz	55.79	Quasi Peak	-8.25
2	3.498000000 MHz	35.07	CISPR Averag	-10.93
2	4.754000000 MHz	32.43	CISPR Averag	-13.57
2	3.746000000 MHz	31.28	CISPR Averag	-14.72

Design Your own Line Input Filter

DESIGN KIT
Design your EMC Filter



CONTENT:

- Common Mode Chokes
- Capacitors
- Terminal Blocks
- SMD Power Elements
- Resistors
- Test Boards
- Self-Retaining Spacer

Order Code 744 998
Version 2.0

www.we-online.com

Design your EMC Filter

Test Board

Quantity:	10

Resistor

Quantity:	10
R:	1MΩ

WA-SNSR

702 936 000	
Quantity:	20
Length:	15.9 mm

WR-TBL

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

WR-SMSH

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

WCAP-FTX2

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

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

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

WCAP-CSSA

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

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

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

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

WE-LF

744 662 400 07		744 662 200 2		744 662 100 7		744 662 002 7	
Quantity:	1	Quantity:	1	Quantity:	1	Quantity:	1
L:	0.7 mH	L:	2.2 mH	L:	6.8 mH	L:	27 mH
I_R:	4 A	I_R:	2 A	I_R:	1 A	I_R:	0.4 A
R_{DC}:	27 mΩ	R_{DC}:	100 mΩ	R_{DC}:	300 mΩ	R_{DC}:	1.200 mΩ

WE-CMBNC

M

744 803 050 9	
Quantity:	1
L:	9 mH
I_R:	5 A
R_{DC}:	28 mΩ

L

744 804 070 7	
Quantity:	1
L:	7 mH
I_R:	7 A
R_{DC}:	20 mΩ

WE-CMB

S		M		L	
744 822 301		744 823 601		744 824 101	
Quantity:	2	Quantity:	2	Quantity:	2
L:	1 mH	L:	1 mH	L:	1 mH
I_R:	3 A	I_R:	6 A	I_R:	10 A
R_{DC}:	35 mΩ	R_{DC}:	13 mΩ	R_{DC}:	7 mΩ
744 822 222		744 823 422		744 824 622	
Quantity:	2	Quantity:	2	Quantity:	2
L:	2.2 mH	L:	2.2 mH	L:	2.2 mH
I_R:	2 A	I_R:	4 A	I_R:	6 A
R_{DC}:	70 mΩ	R_{DC}:	30 mΩ	R_{DC}:	20 mΩ
744 822 233		744 823 305		744 824 433	
Quantity:	2	Quantity:	2	Quantity:	2
L:	3.3 mH	L:	5 mH	L:	3.3 mH
I_R:	1.5 A	I_R:	2.5 A	I_R:	4 A
R_{DC}:	120 mΩ	R_{DC}:	95 mΩ	R_{DC}:	35 mΩ
744 822 110		744 823 210		744 824 310	
Quantity:	2	Quantity:	2	Quantity:	2
L:	10 mH	L:	10 mH	L:	10 mH
I_R:	1 A	I_R:	2 A	I_R:	3 A
R_{DC}:	360 mΩ	R_{DC}:	125 mΩ	R_{DC}:	105 mΩ
744 822 120		744 823 220		744 824 220	
Quantity:	2	Quantity:	2	Quantity:	2
L:	20 mH	L:	20 mH	L:	20 mH
I_R:	0.5 A	I_R:	1.5 A	I_R:	2 A
R_{DC}:	540 mΩ	R_{DC}:	270 mΩ	R_{DC}:	220 mΩ

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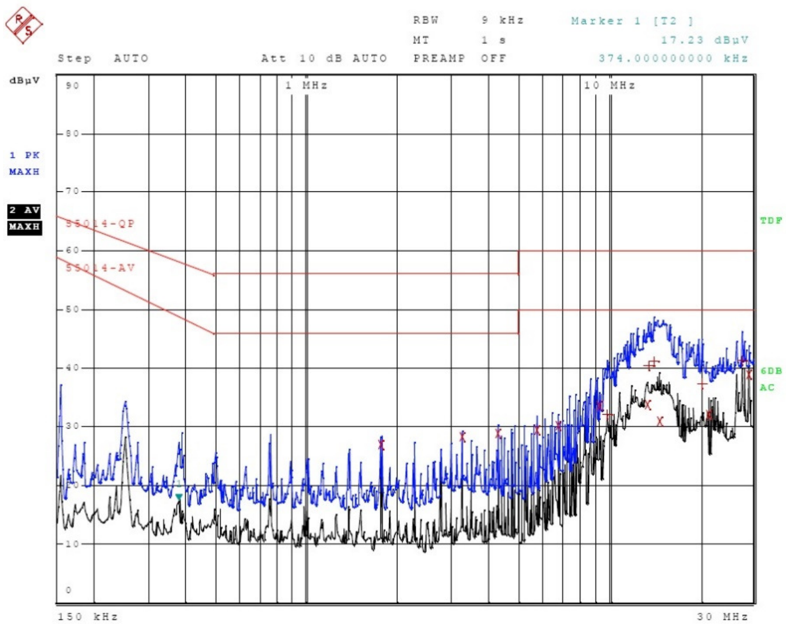
Conducted Emissions Measurement
With input Filter; Line; (Cx=0,47uF, L=2x10mH, Cx=0,33uF;)

LINE L



Final Measurement

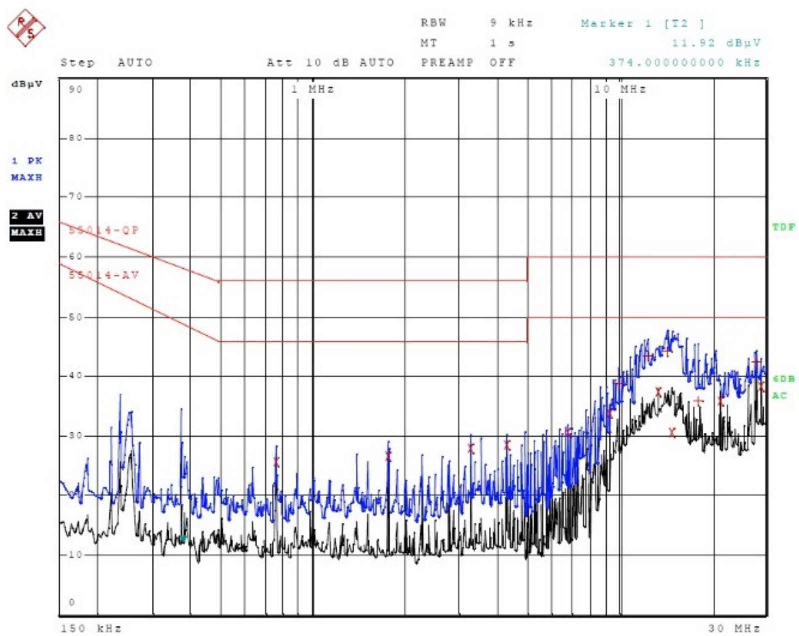
Meas Time: 1 s
Margin: 20 dB
Subranges: 15

Trace	Frequency	Level (dBµV)	Detector	Delta Limit/dB
2	28.966000000 MHz	38.81	CISPR Averag	-11.19
2	13.354000000 MHz	33.83	CISPR Averag	-16.17
2	9.318000000 MHz	33.53	CISPR Averag	-16.47
2	4.282000000 MHz	28.78	CISPR Averag	-17.22
2	3.274000000 MHz	28.27	CISPR Averag	-17.73
2	21.414000000 MHz	31.98	CISPR Averag	-18.02
1	27.454000000 MHz	41.36	Quasi Peak	-18.64
1	14.038000000 MHz	41.10	Quasi Peak	-18.90
2	1.762000000 MHz	26.98	CISPR Averag	-19.02
2	14.658000000 MHz	30.88	CISPR Averag	-19.12
1	13.534000000 MHz	40.46	Quasi Peak	-19.54
2	6.802000000 MHz	30.22	CISPR Averag	-19.78
2	5.794000000 MHz	29.44	CISPR Averag	-20.56
1	20.298000000 MHz	37.26	Quasi Peak	-22.74
1	9.898000000 MHz	32.00	Quasi Peak	-28.00

Conducted Emissions Measurement
With input Filter; line N; (Cx=0,47uF, L=2x10mH, Cx=0,33uF)

WÜRTH ELEKTRONIK

LINE N



Final Measurement

Meas Time: 1 s
Margin: 20 dB
Subranges: 15

Trace	Frequency	Level (dBµV)	Detector	Delta Limit/dB
2	28.966000000 MHz	38.32	CISPR Averag	-11.68
2	13.350000000 MHz	37.41	CISPR Averag	-12.59
2	21.406000000 MHz	35.92	CISPR Averag	-14.08
1	14.310000000 MHz	44.19	Quasi Peak	-15.81
2	9.318000000 MHz	33.77	CISPR Averag	-16.23
1	12.430000000 MHz	43.43	Quasi Peak	-16.57
1	27.954000000 MHz	42.43	Quasi Peak	-17.57
2	4.282000000 MHz	28.37	CISPR Averag	-17.63
2	3.274000000 MHz	27.89	CISPR Averag	-18.11
2	6.798000000 MHz	30.56	CISPR Averag	-19.44
2	1.762000000 MHz	26.50	CISPR Averag	-19.50
2	14.790000000 MHz	30.49	CISPR Averag	-19.51
2	754.000000000 kHz	25.58	CISPR Averag	-20.42
1	9.918000000 MHz	38.82	Quasi Peak	-21.18
1	18.070000000 MHz	35.86	Quasi Peak	-24.14