WÜRTH ELEKTRONIK

Filtering with high efficiency and best EMI design

Speaker:

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REQUIREMENTS IN EMC

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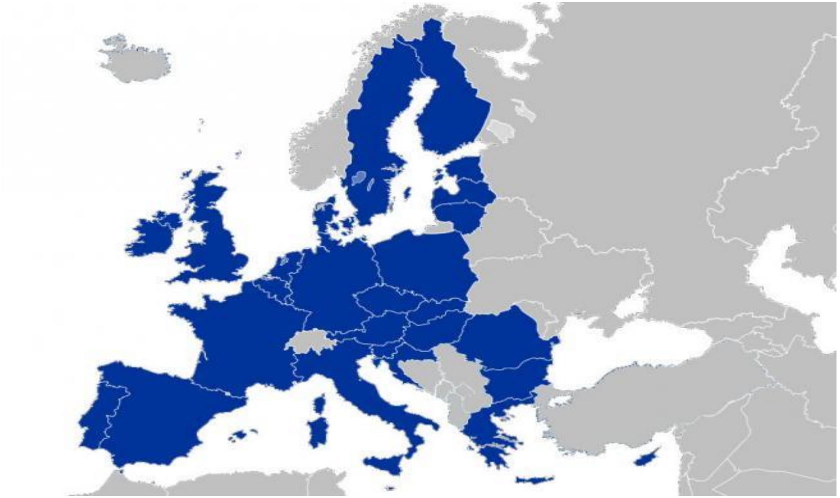
CE Marking



- With the formation of the single European market, standardization was required to remove technical barriers trade.
- New Approach Directives were introduced to remove these barriers to trade

- 20 regulations and directives:

    LVD - Low Voltage Directive 2014/35/EU

    EMC - Electromagnetic Compatibility 2014/30/EU

    R.E.D. - Radio Equipped Directive 2014/53/EU

    MD - Machinery Directive 2014/90/EU

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What is the meaning of EMC ?

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What’s all the fuss about EMC?

- In Europe, we have a mechanism called CE Marking
- It is applicable to any electrical/electronic product
- EMC Directive , regulation to ensure that intentional RF transmission signals are not interfered with
- Ensures that Electrical/Electronic devices continue to operate as intended in a Electro Magnetic Environment
- **Failure to comply with the law can be an offence, either criminal, civil or both**

§

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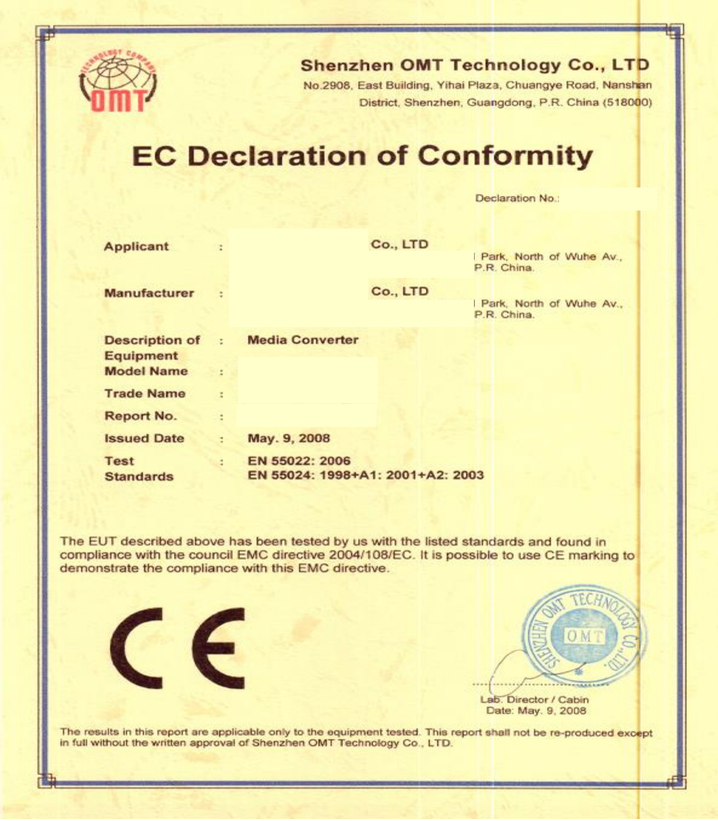
What is the meaning of the CE logo ?



Shenzhen OMT Technology Co., LTD
No.2908, East Building, Yihai Plaza, Chuangye Road, Nanshan District, Shenzhen, Guangdong, P.R. China (518000)

EC Declaration of Conformity

Declaration No.:

Applicant	:	Co., LTD Park, North of Wuhe Av., P.R. China.
Manufacturer	:	Co., LTD Park, North of Wuhe Av., P.R. China.
Description of Equipment	:	Media Converter
Model Name	:	
Trade Name	:	
Report No.	:	
Issued Date	:	May. 9, 2008
Test Standards	:	EN 55022: 2006 EN 55024: 1998+A1: 2001+A2: 2003

The EUT described above has been tested by us with the listed standards and found in compliance with the council EMC directive 2004/108/EC. It is possible to use CE marking to demonstrate the compliance with this EMC directive.

Lab. Director / Cabin
Date: May. 9, 2008

The results in this report are applicable only to the equipment tested. This report shall not be re-produced except in full without the written approval of Shenzhen OMT Technology Co., LTD.

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Other International EMC approval marks

- **Federal Communications Commission**

- **Voluntary Control Council for Interference**

- **Australian Communications and Media Authority**

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Conducted Emission

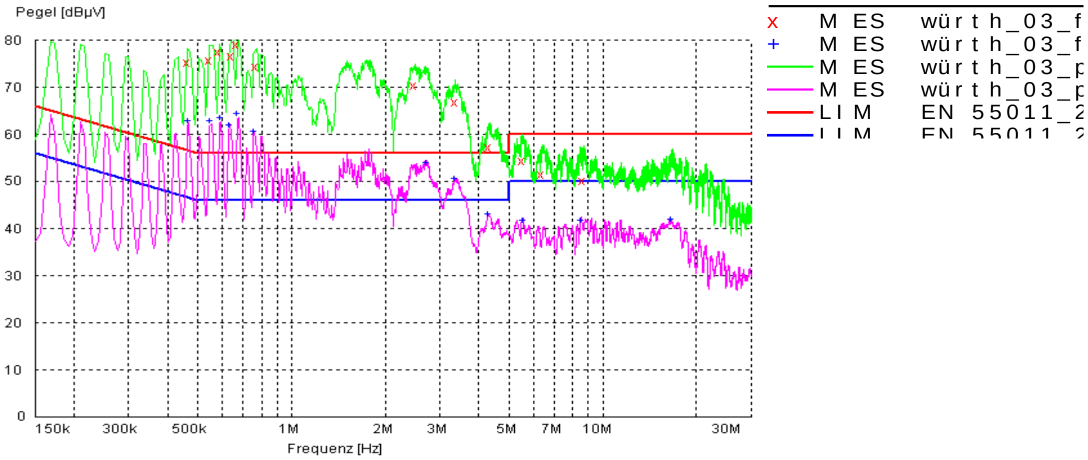
- Conducted emission over wideband
- Caused by ripple current at input lines (common mode - / differential mode noise)
- EMC requirements for *„Conducted Emission“* according ETSI, CEN, CENELEC

- E.g.: EN 55013:2017-03 (Sound & TV broadcast receivers and associated 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)



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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 & Commercial)

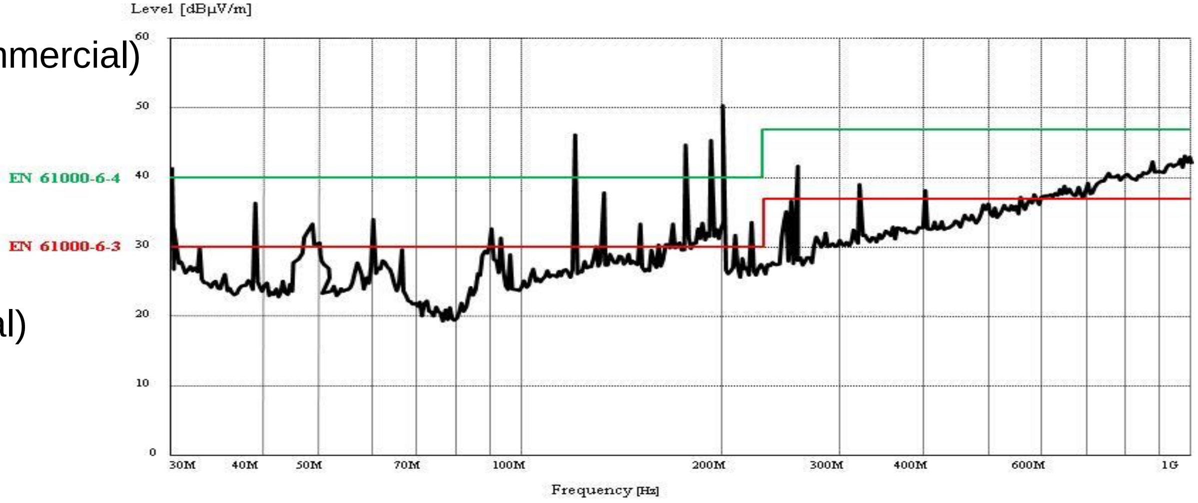
30dB @ 30MHz~230MHz µV/m

37dB @ 230MHz~1GHz µV/m

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

40dB @ 30MHz~230MHz µV/m

47dB @ 230MHz~1GHz µV/M



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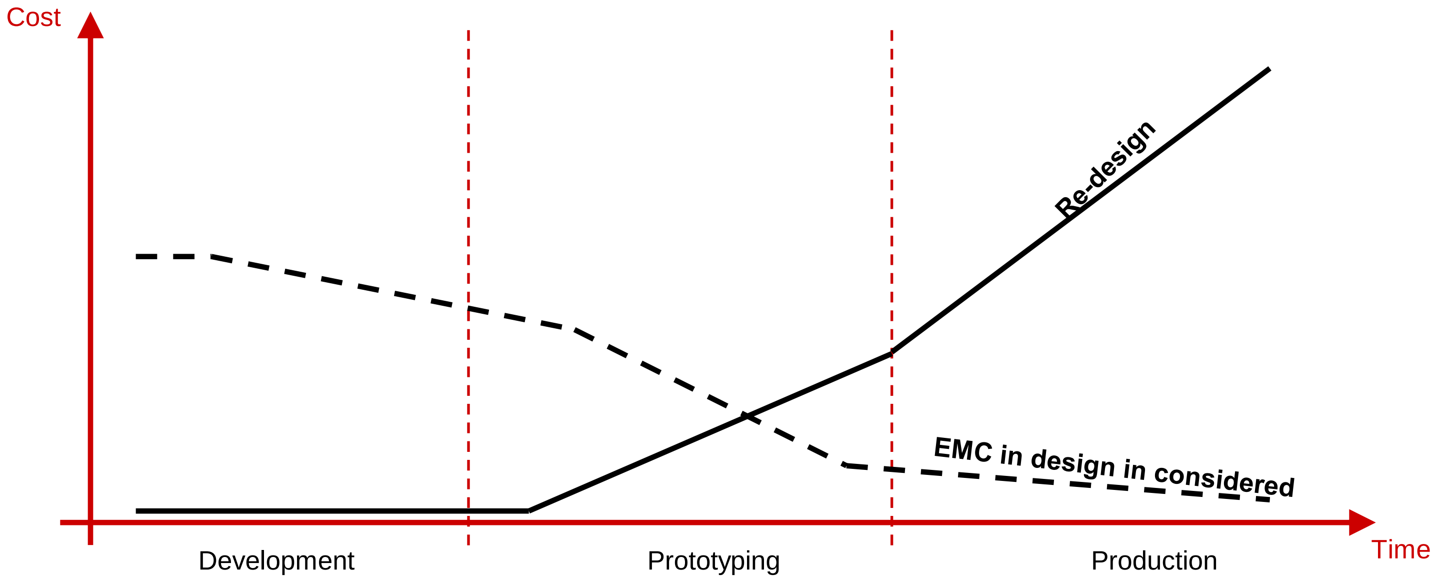
Design phase for EMC

- Economical point of view:
- Depends on you when will start to design EMC conform



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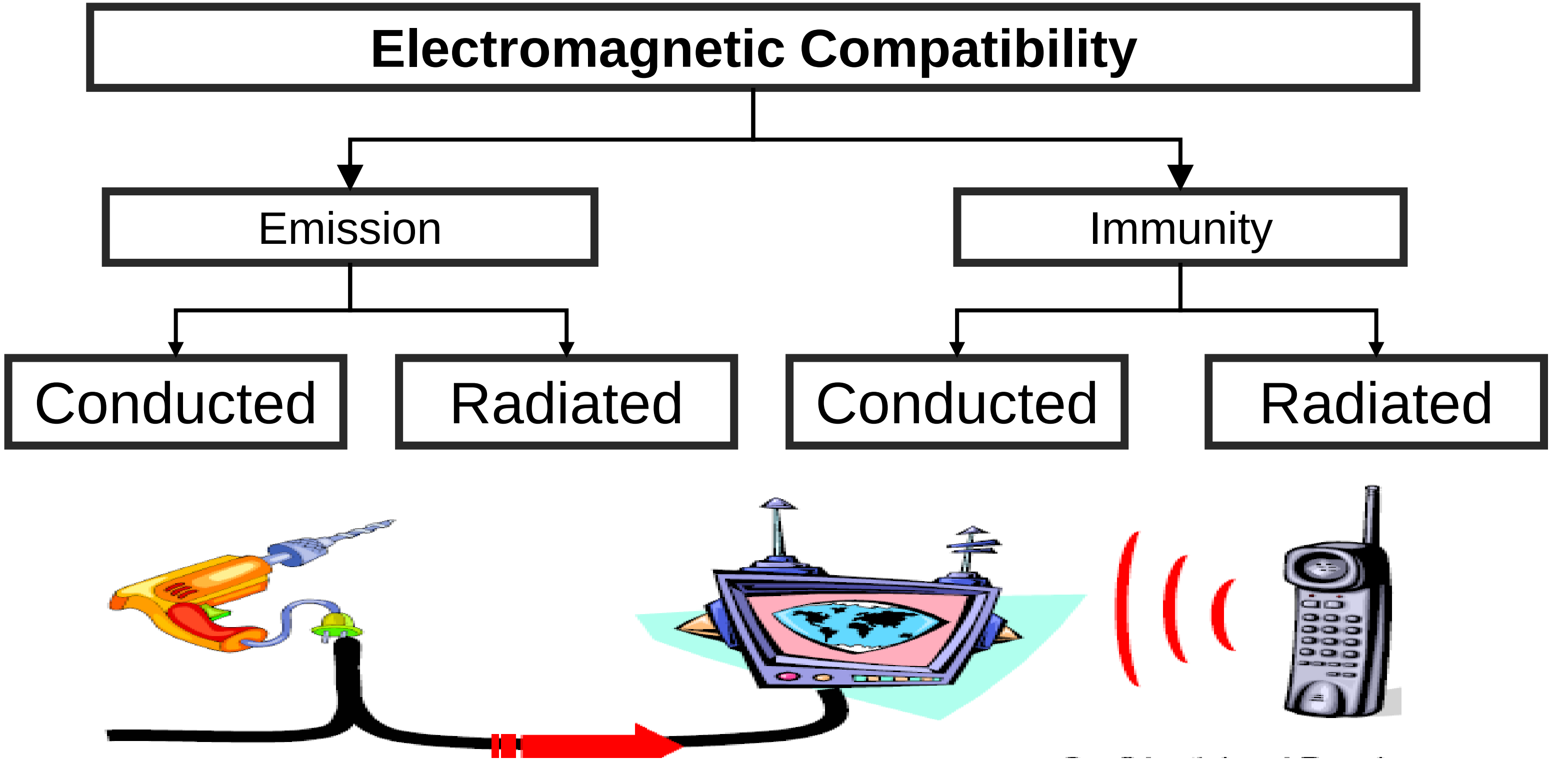
EMC – Basic Test



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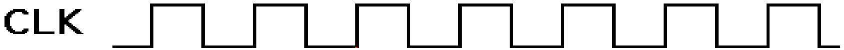
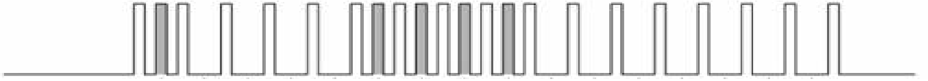
What causes EMI in a product?

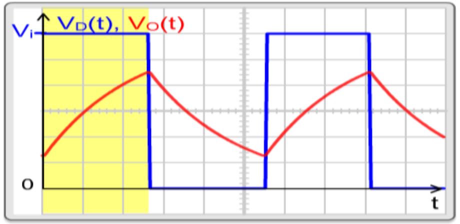
- **Clock frequencies.** E.g Crystal 25MHz,
  CPU 2.6GHz

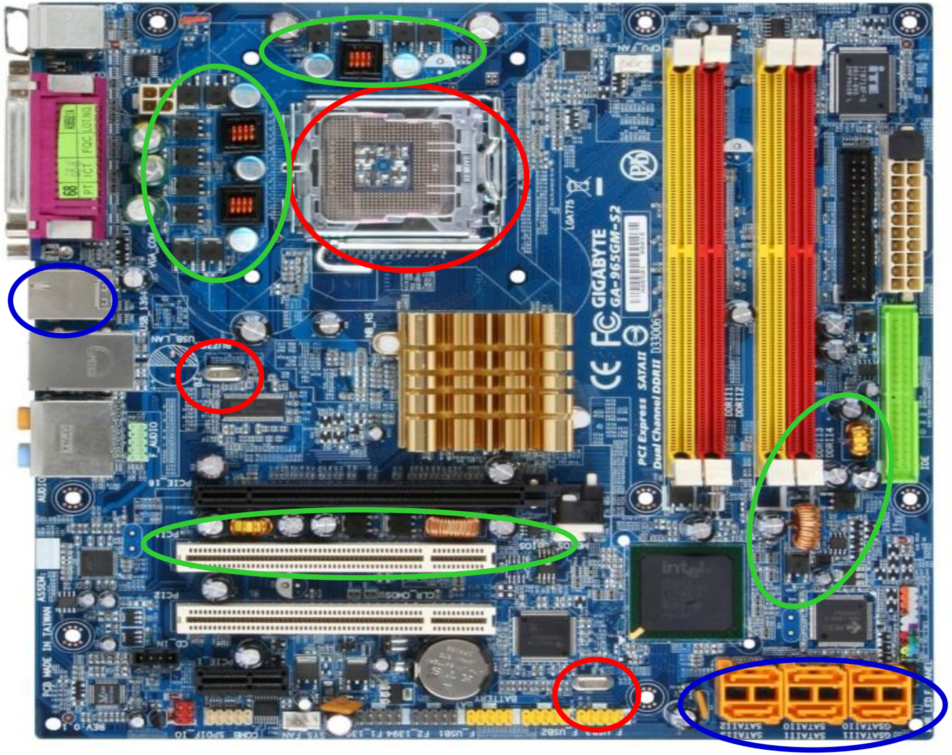


- **Data rates.** E.g USB 2.0 480Mbps,
  SATA II 300Mbps



- **DC/DC convertors** and Switch mode power supplies (**SMPS**) E.g 135kHz, 2MHz





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Magnetic and Material Basics

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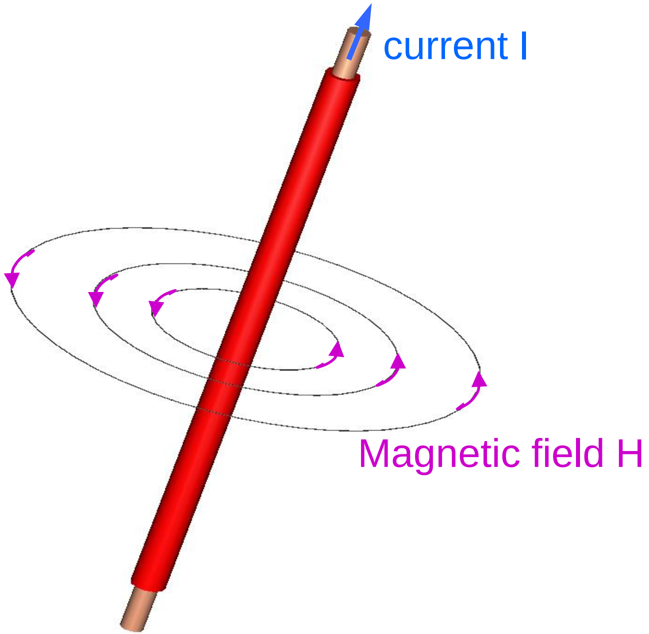
The magnetic field

Each electric powered wire generates an electro magnetic field



Field model

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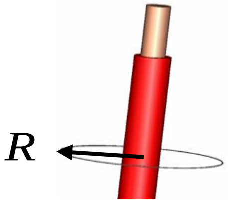
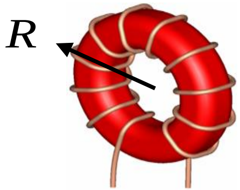
Magnetic field- Magnetic field strength

Straight wire



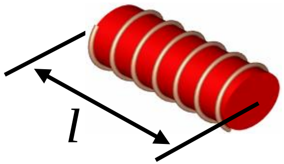
$$H = \frac{I}{2 \cdot \pi \cdot R}$$

Toroidal core



$$H = \frac{N \cdot I}{2 \cdot \pi \cdot R}$$

Rod core



$$H = \frac{N \cdot I}{l}$$

The magnetic field strength is dependent from:

- No. of turns
- current
- dimension
- and

NOT FROM MATERIAL

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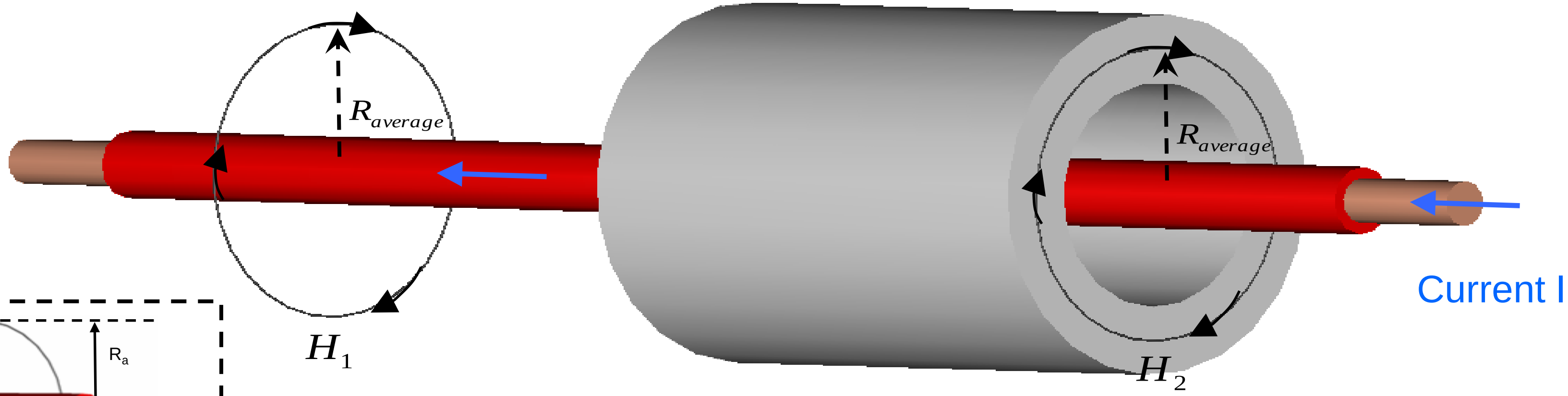
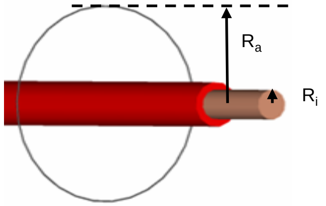
Magnetic field- Magnetic field strength





$$R_{average} = (R_a - R_i)$$

$$H_1 = H_2 = H = \frac{I}{2 \cdot \pi \cdot R_{average}}$$

$$B_1 \; \neq \; ? \; = \; B_2$$

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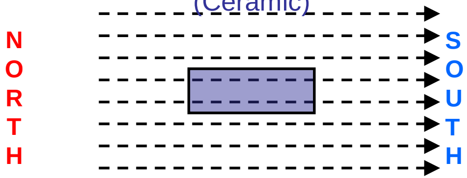
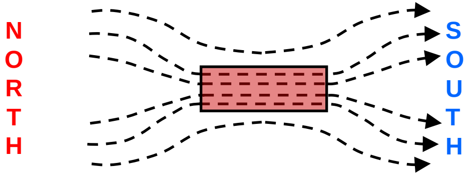
The magnetic field

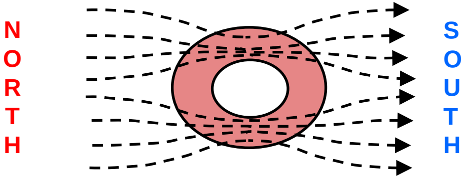
Air
(Ceramic)



Rod core ferrite



Ring core ferrite



Induction in air:

$$B = \mu_0 \cdot H$$

linear function, because μr = 1 => constant!

Induction in a ferrite:

$$B = \mu_0 \cdot \mu_r \cdot H$$

The relative permeability is a: **material- frequency- temperature- current- pressure-** **-dependent parameter**

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Permeability – Core material parameter

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Temperature influnce

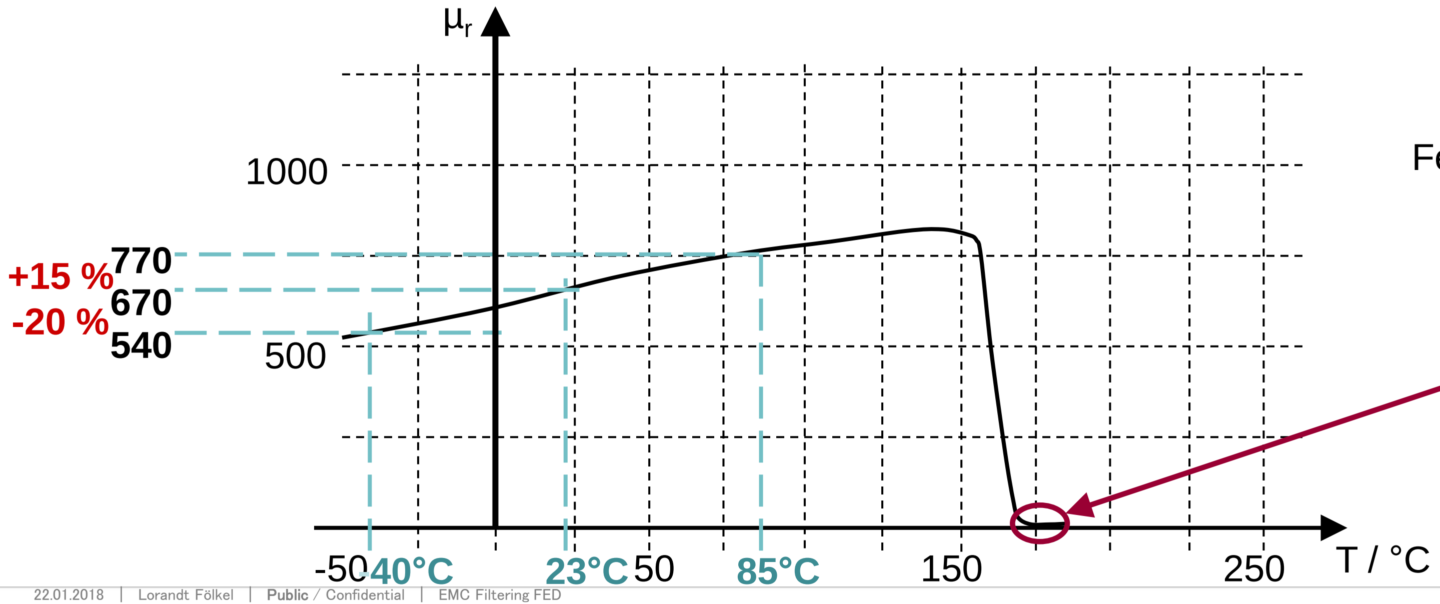
- The magnetization depends from the temperature

T ↑ ⇝ therm. movement ↑ ⇝ Alignment ↓

⇝ Alignment of elementary magnets

⇓

Ferromagnetic change to Paramagnetic



Curie-temperature

μ_r = ? 1

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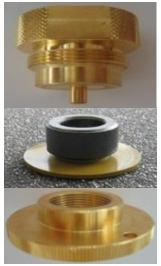
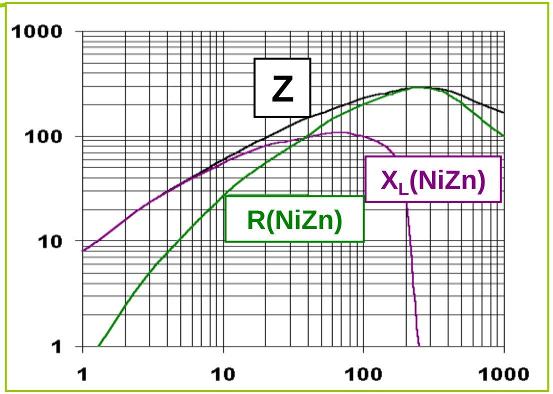
Permeability – complex permeability

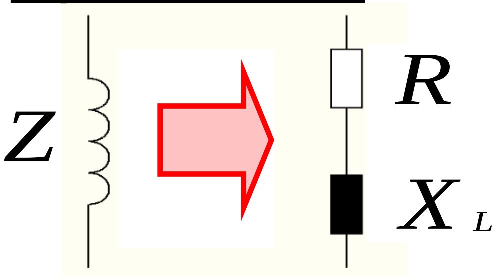


=1 turn



Core material-Parameter

Replacement circuit



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

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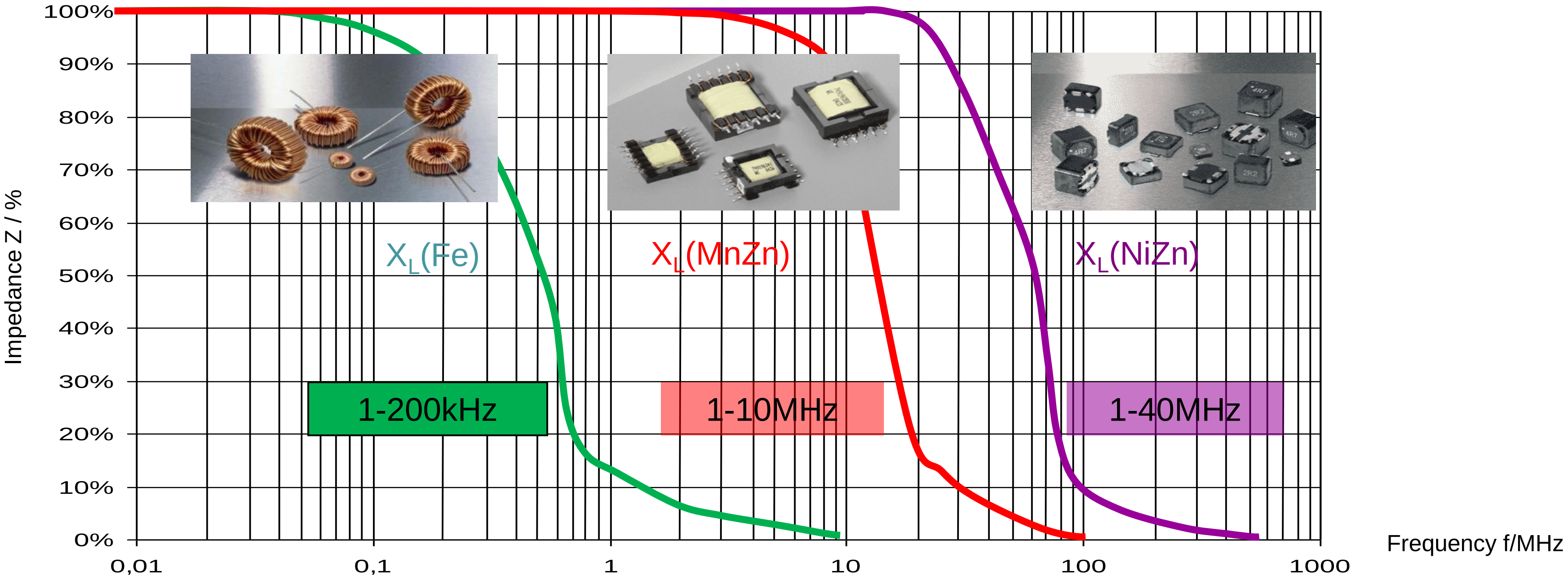
Core materials - Inductors (Energy storage)

Which switching frequency do you use?



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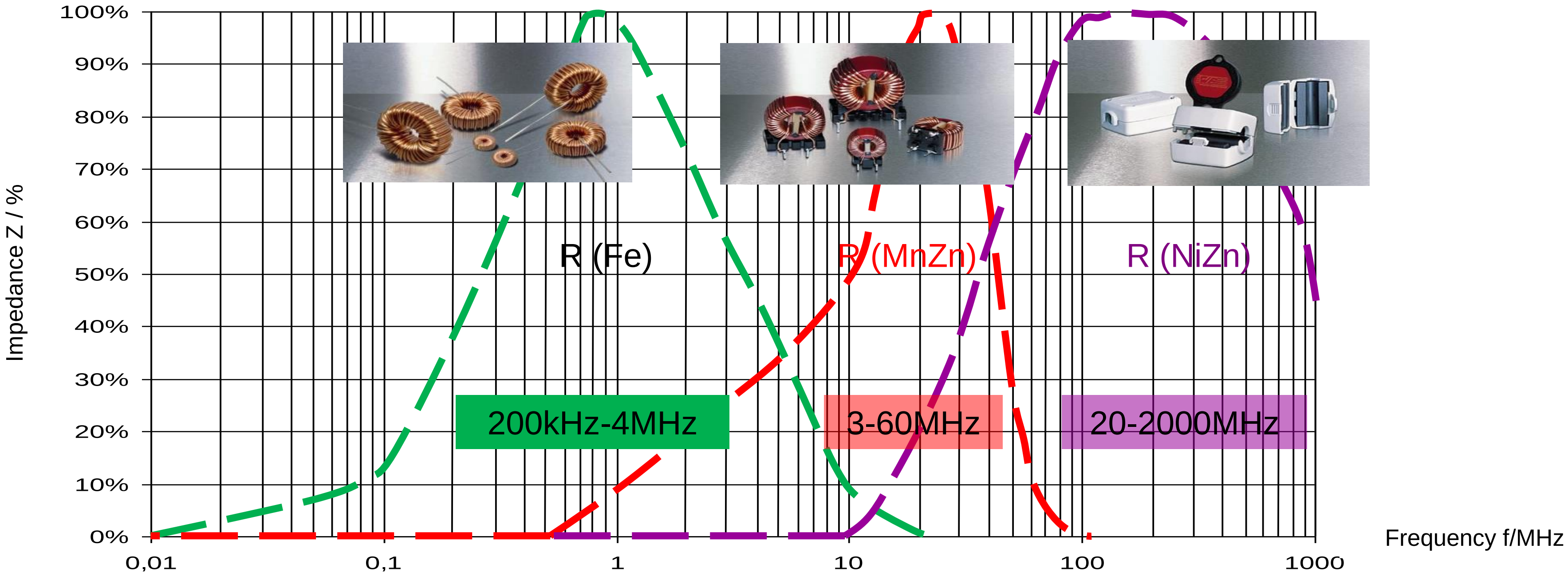
Core materials- Chokes (filtering)

Noise frequency range must be known



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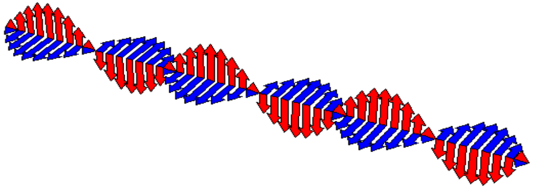
Core Losses

e.g. electrical energy transformed into → thermal energy

Electro Magnetic energy cannot disappear, it will be just transformed into other energy form →energy conservation law



the core losses from ferrite transform the noise energy into heat

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Transmission Modes & Filter Topologies

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EMC - Coupling

→ **Primary procedure**

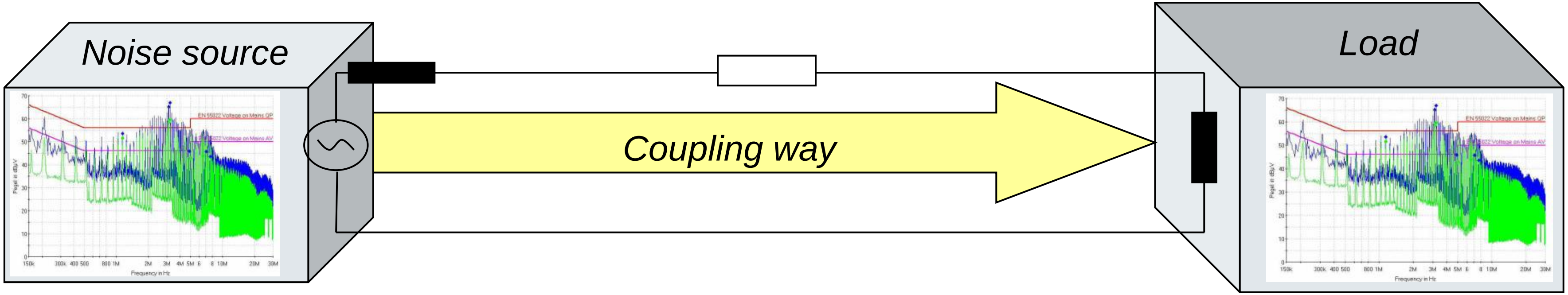
…to aim at source a low noise

→ **Secondary procedure**

… eliminate the noise thru interrupting the coupling way

→ **Tertiary procedure**

… increase the noise immunity at load



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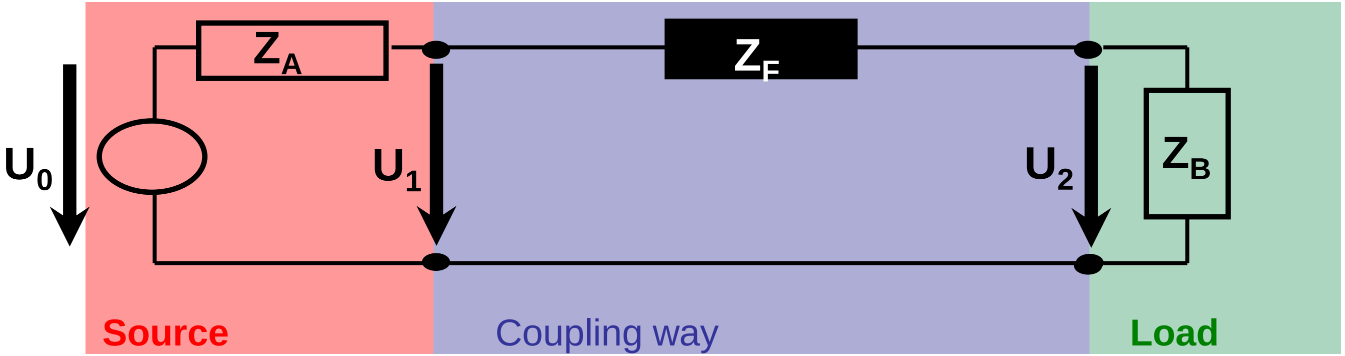
Insertion loss – Mathematical Definition



- System attenuation

$$A = 20 \cdot \log \frac{Z_A + Z_F + Z_B}{Z_A + Z_B} \quad in\ (dB)$$

- Impedance

$$Z_F = \left[10^{\frac{A}{20}} \cdot (Z_A + Z_B) \right] - (Z_A + Z_B) \quad in\ (\Omega)$$

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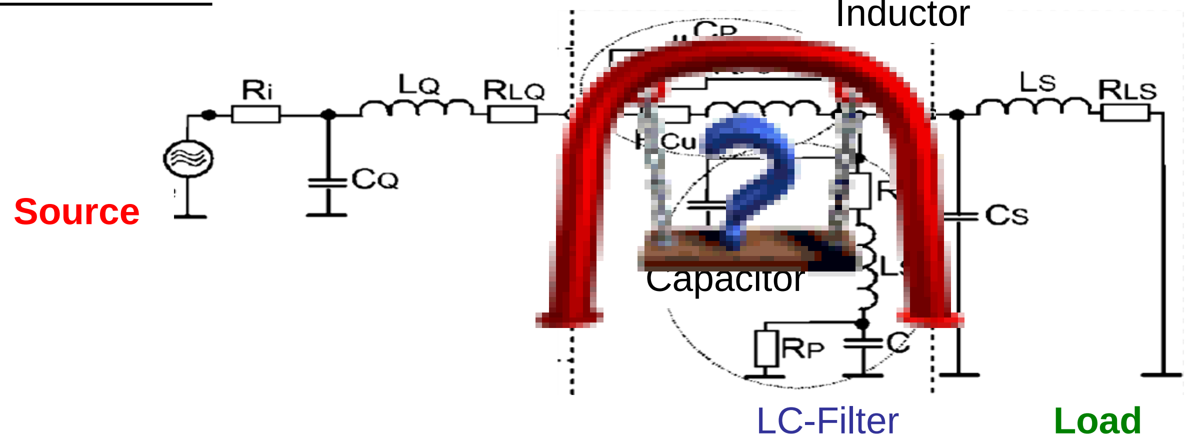
Insertion loss - Definition

Eqivalent circuit:



- Practical values for source and load impedances:

→ Ground planes	<1 … 2 Ω
→ Vcc distribution	10 … 20 Ω
→ Video- /Clock- /Data line	50 … 90 Ω
→ long data lines	90 … >150 Ω

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Check the results in the EMC lab

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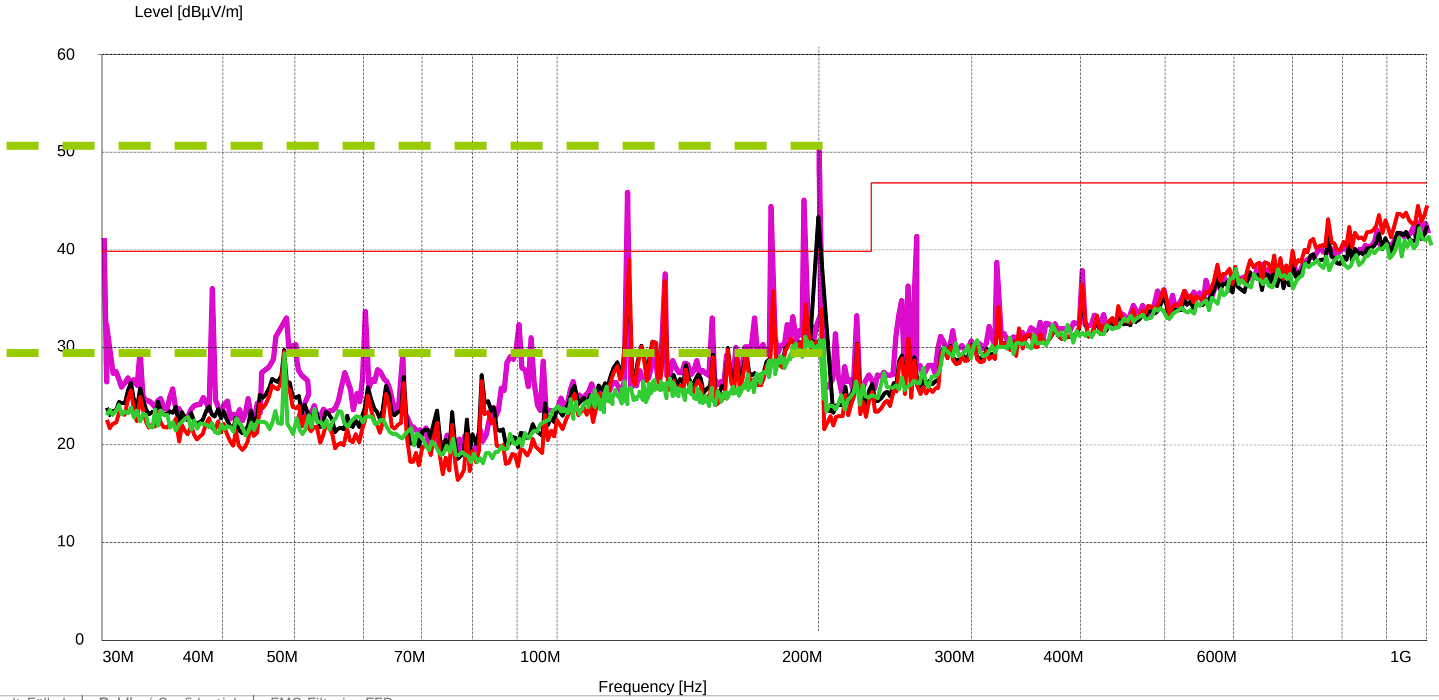
→ Measuring the emission and compare with the solution



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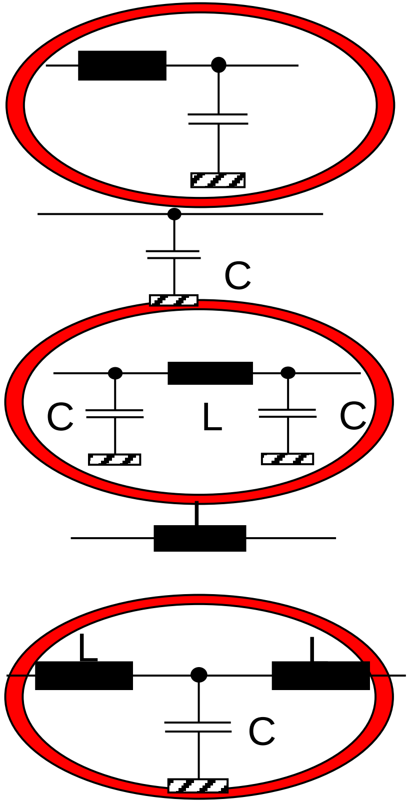
Insertion loss – recommended filter topology

Source Impedance	Filter	Load Impedance
low		high
high		high
high or unknown		high or unknown
low		low
low or unknown		low or unknown



→ small C = higher SRF

Choose ferrite bead or inductors L which
= build no resonance with C
= broadband filter

Pay attention to:

SRF of used components

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SHIELD VS. UNSHIELD

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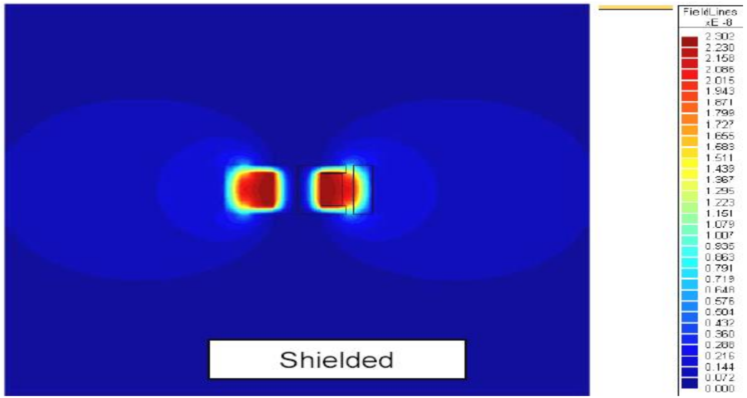
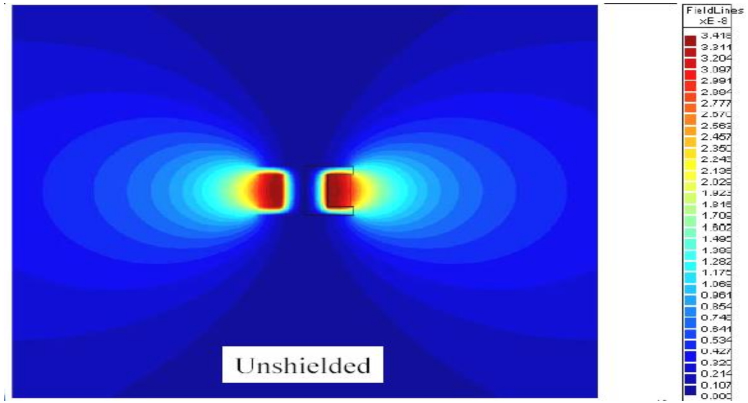
Magnetic field leakage





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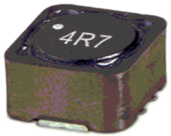
Radiation by inductor

WE - PD2 unshielded

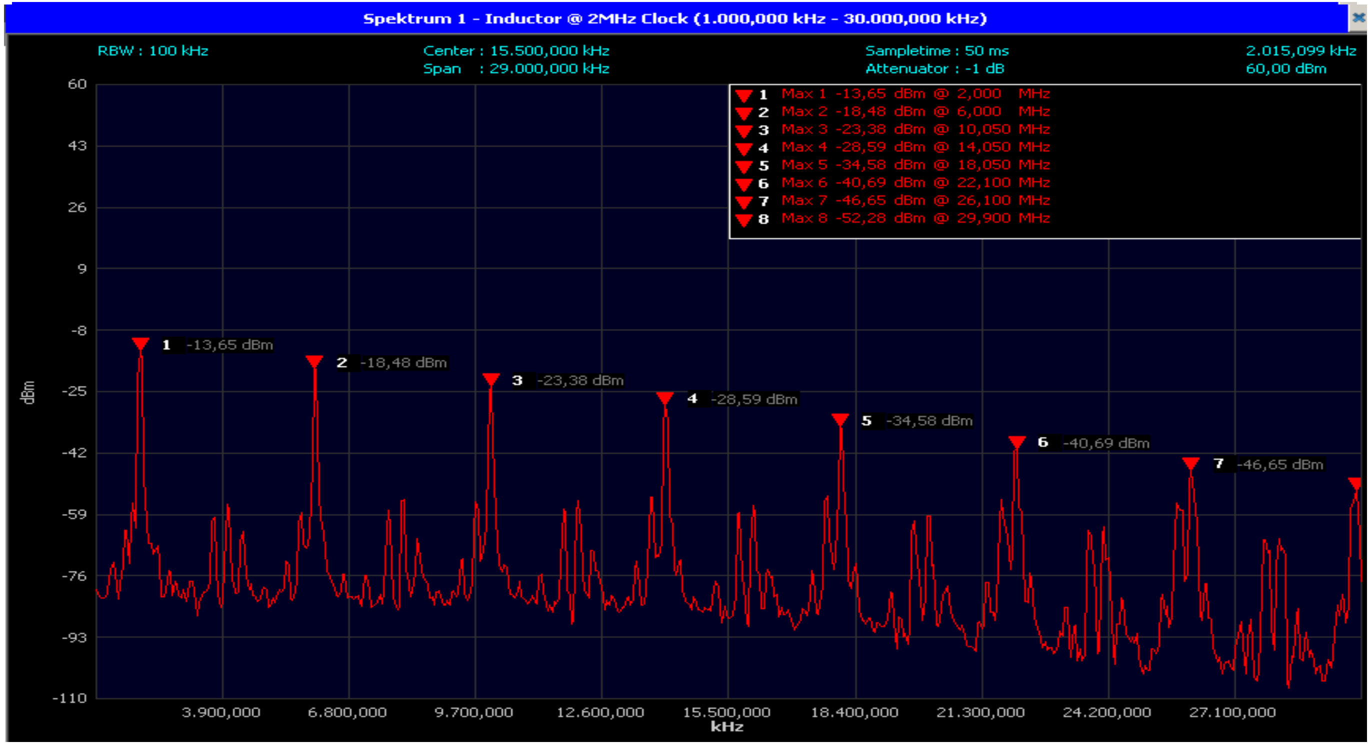
10µH, 2MHz Clock, 1A

WE – PD shielded

10µH, 2MHz Clock, 1A



19dBm difference



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Magnetic leakage shielded vs. unshielded

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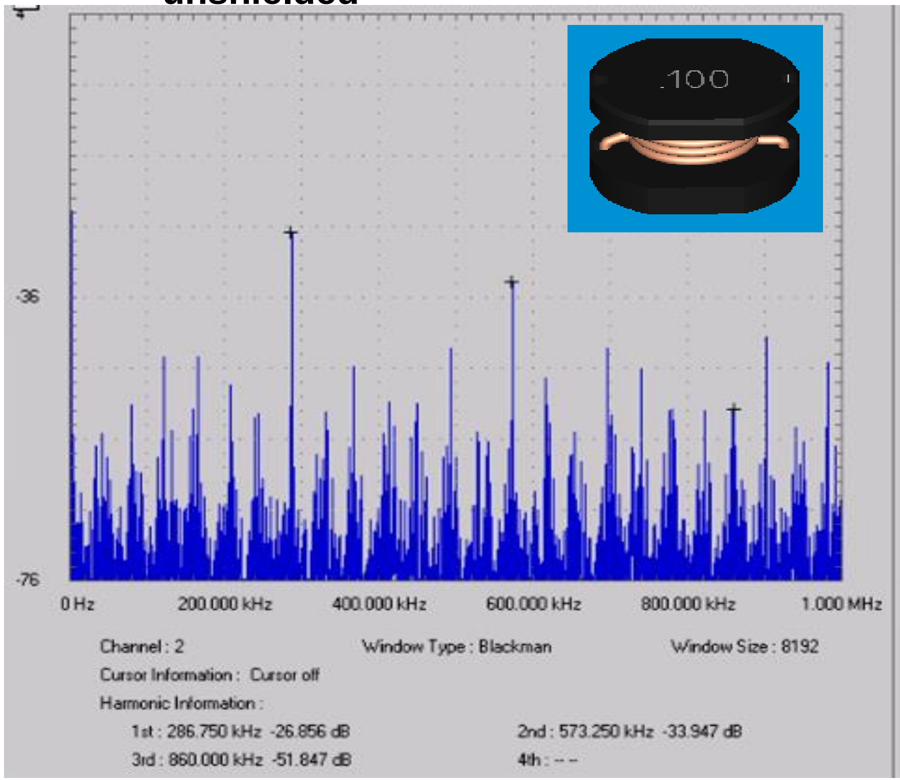
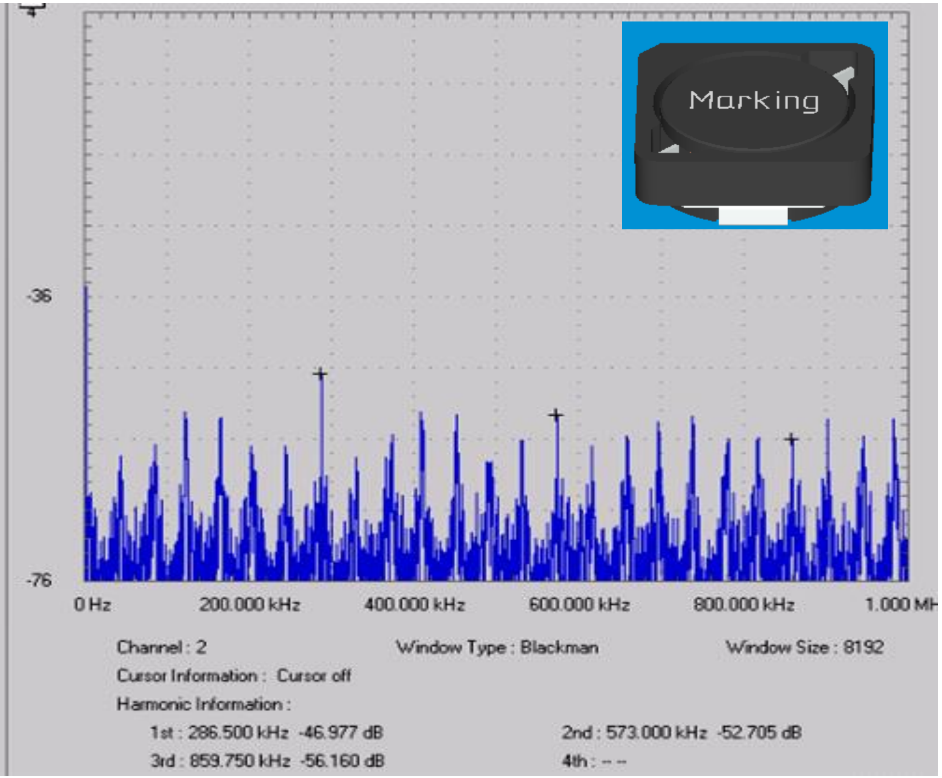
unshielded



shielded



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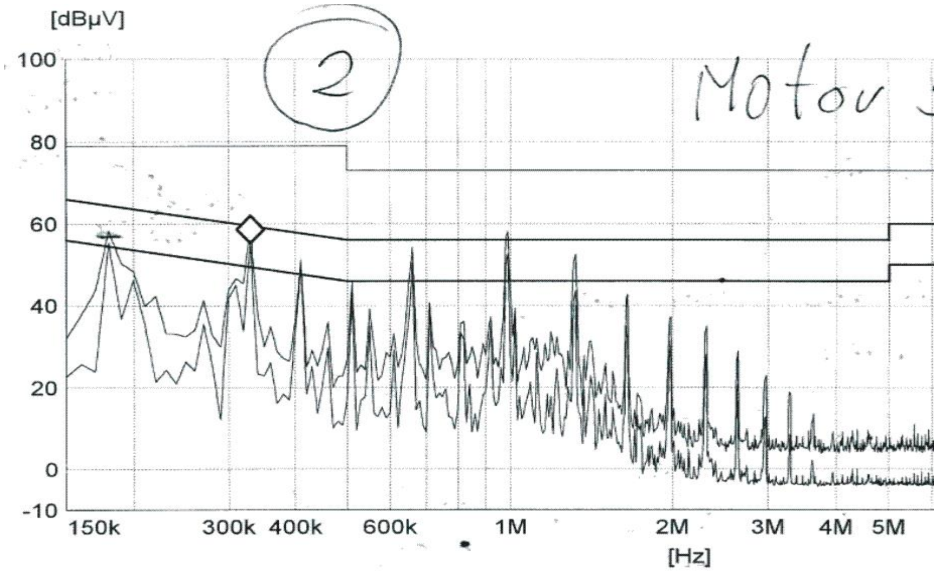
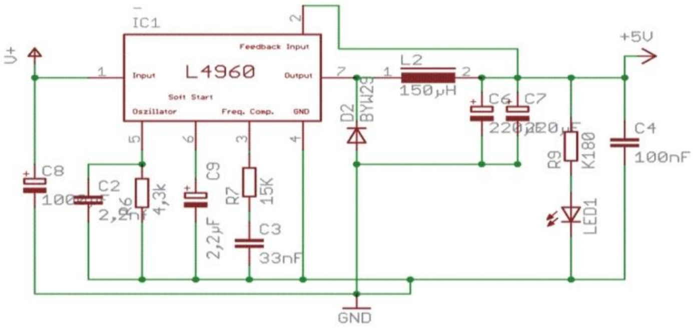
Magnetic Fields – Conducted Emission Measurement

Power supply V 1.0





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

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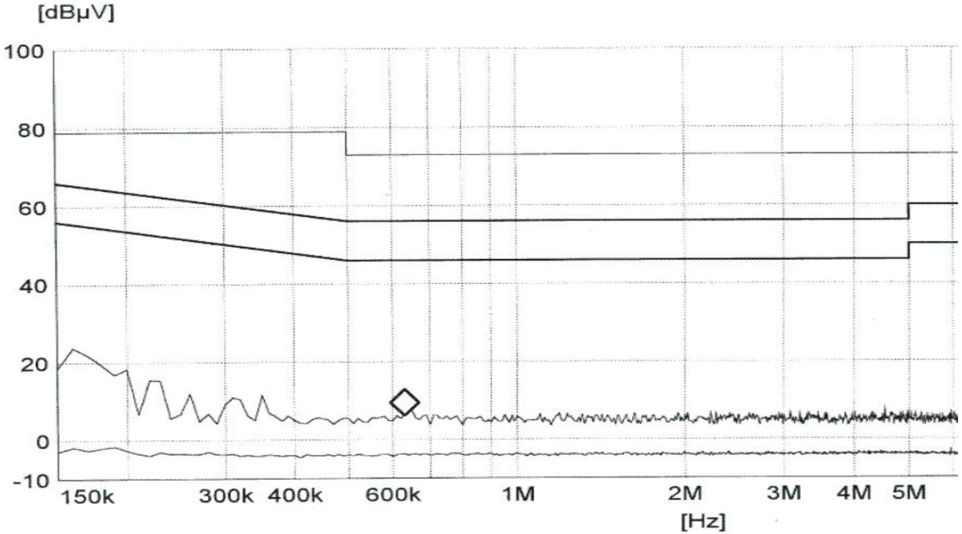
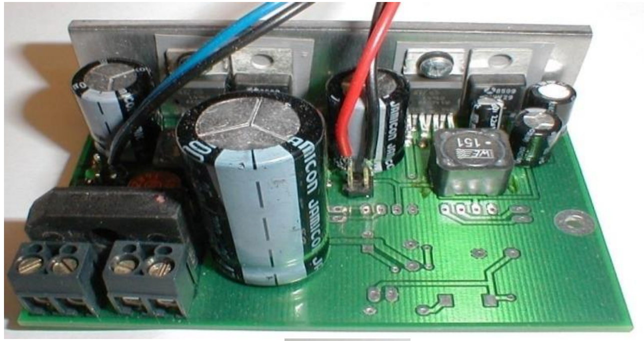
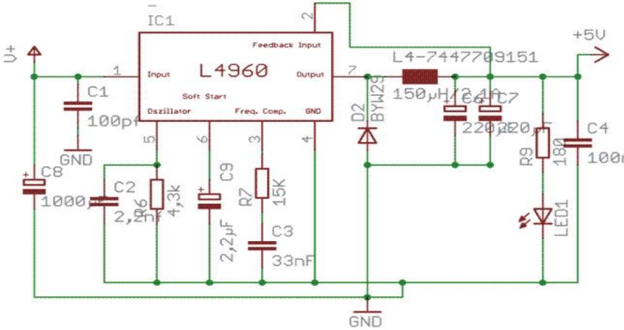
Magnetic Fields – Conducted Emission Measurement

Power supply V 1.1





PCB



Schematic

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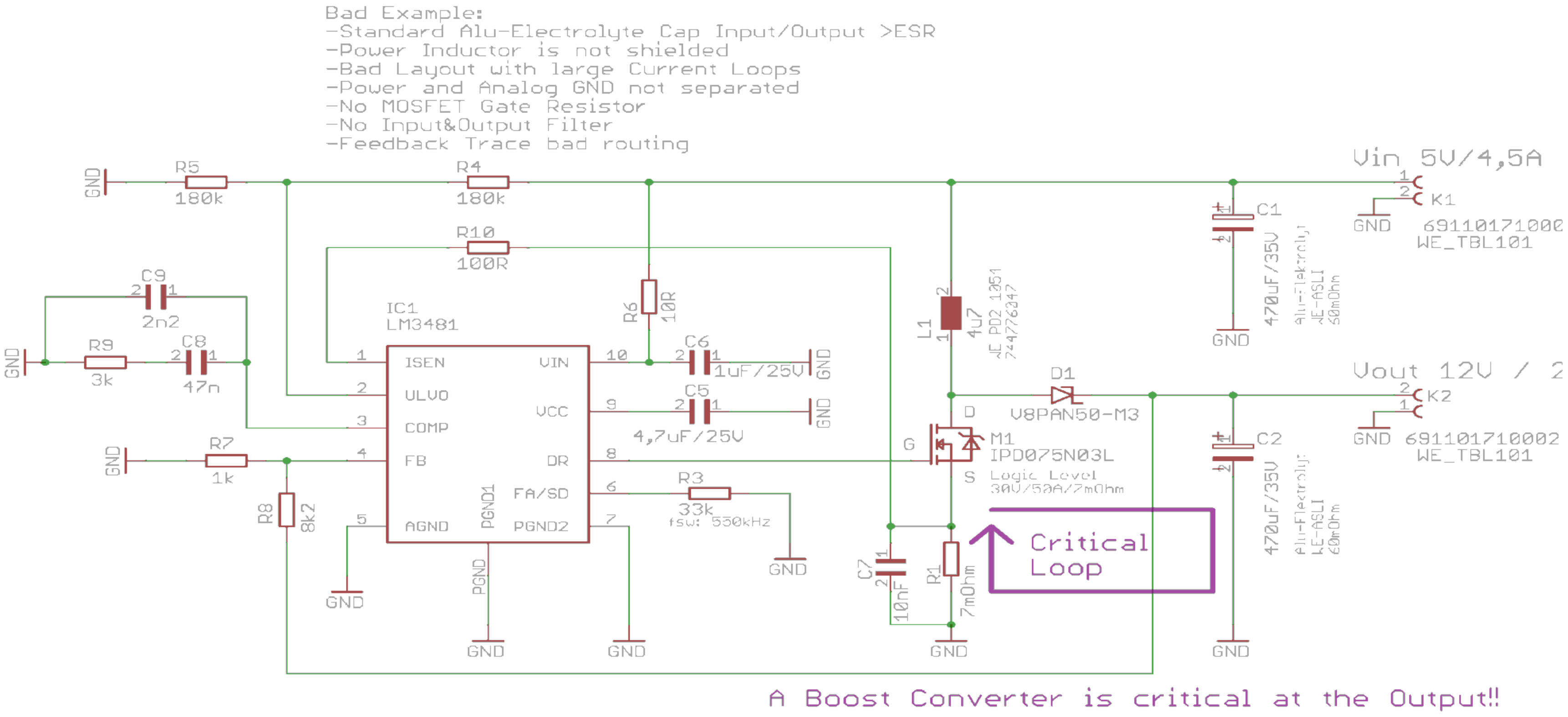
Boost converter Bad Example



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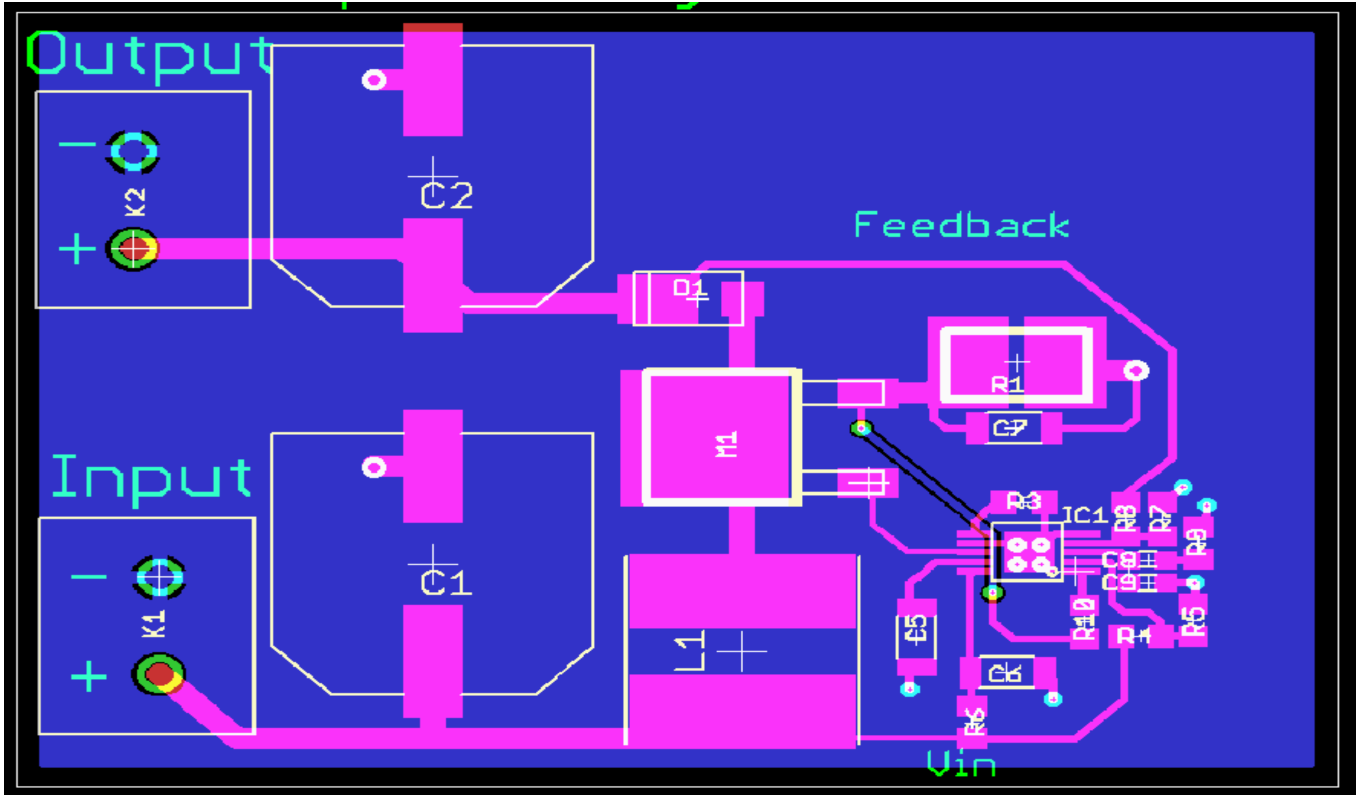
Boost converter Bad Example



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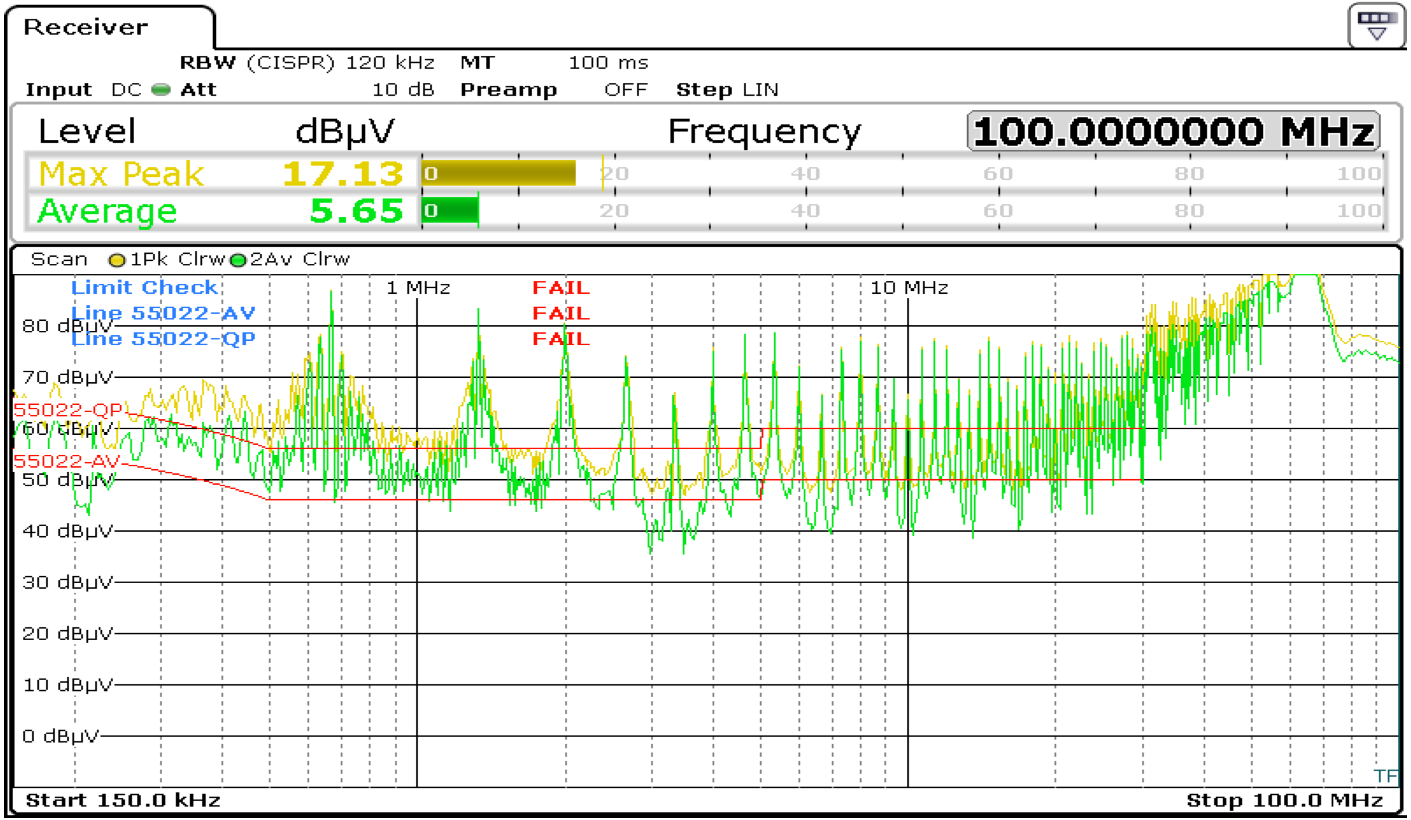
Boost converter Bad Example no filter



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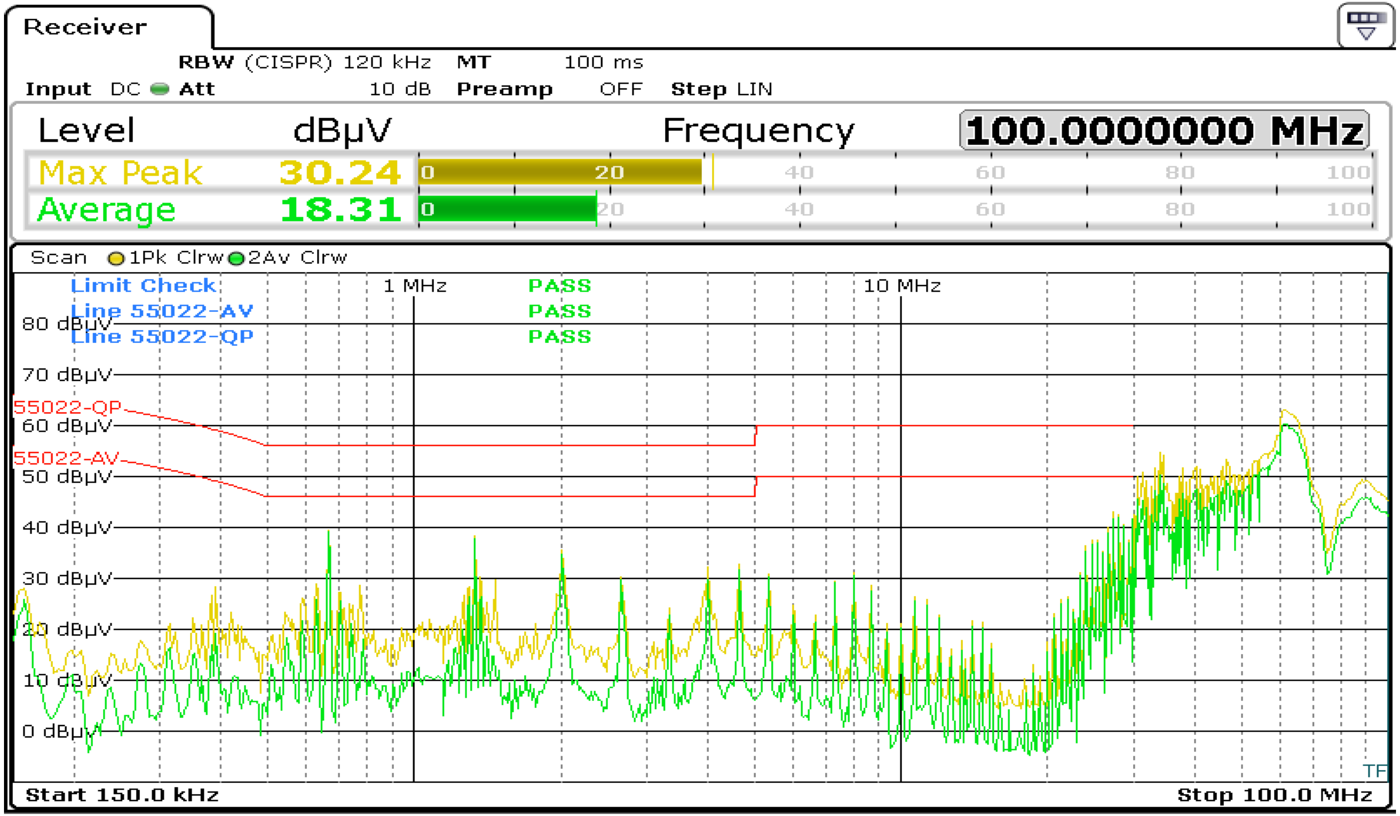
Boost converter Bad Example with filter



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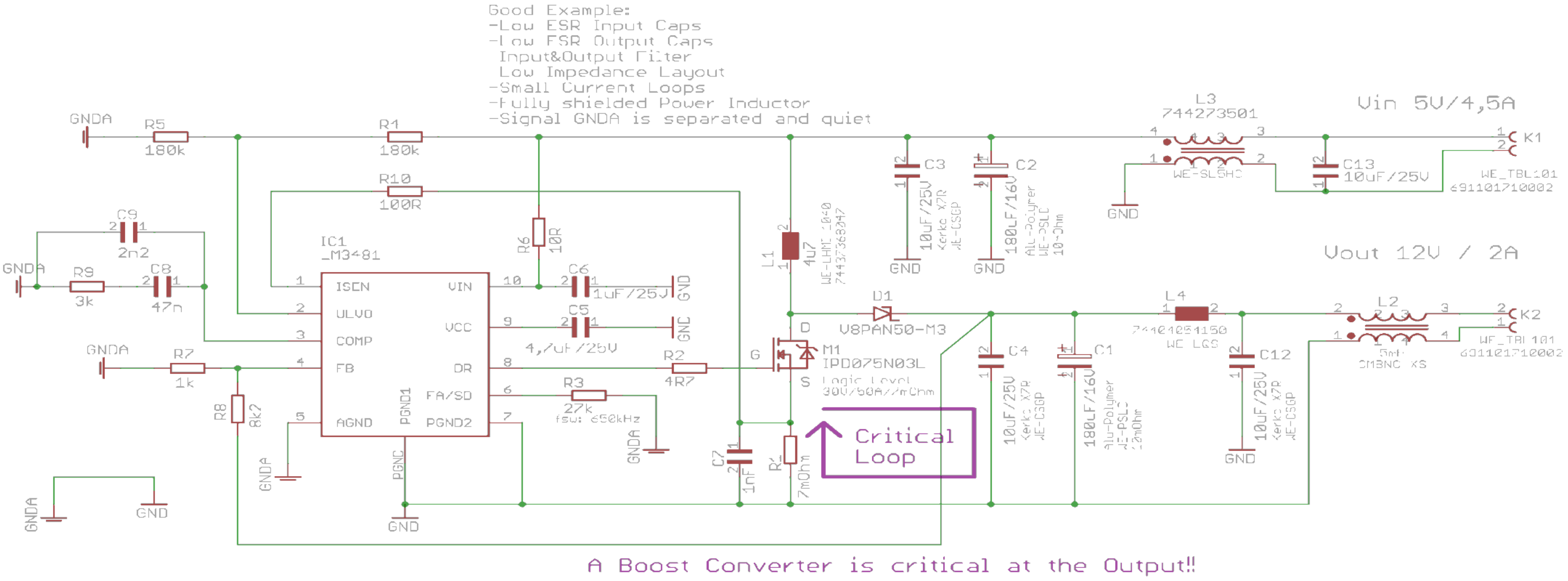
Boost converter Good Example



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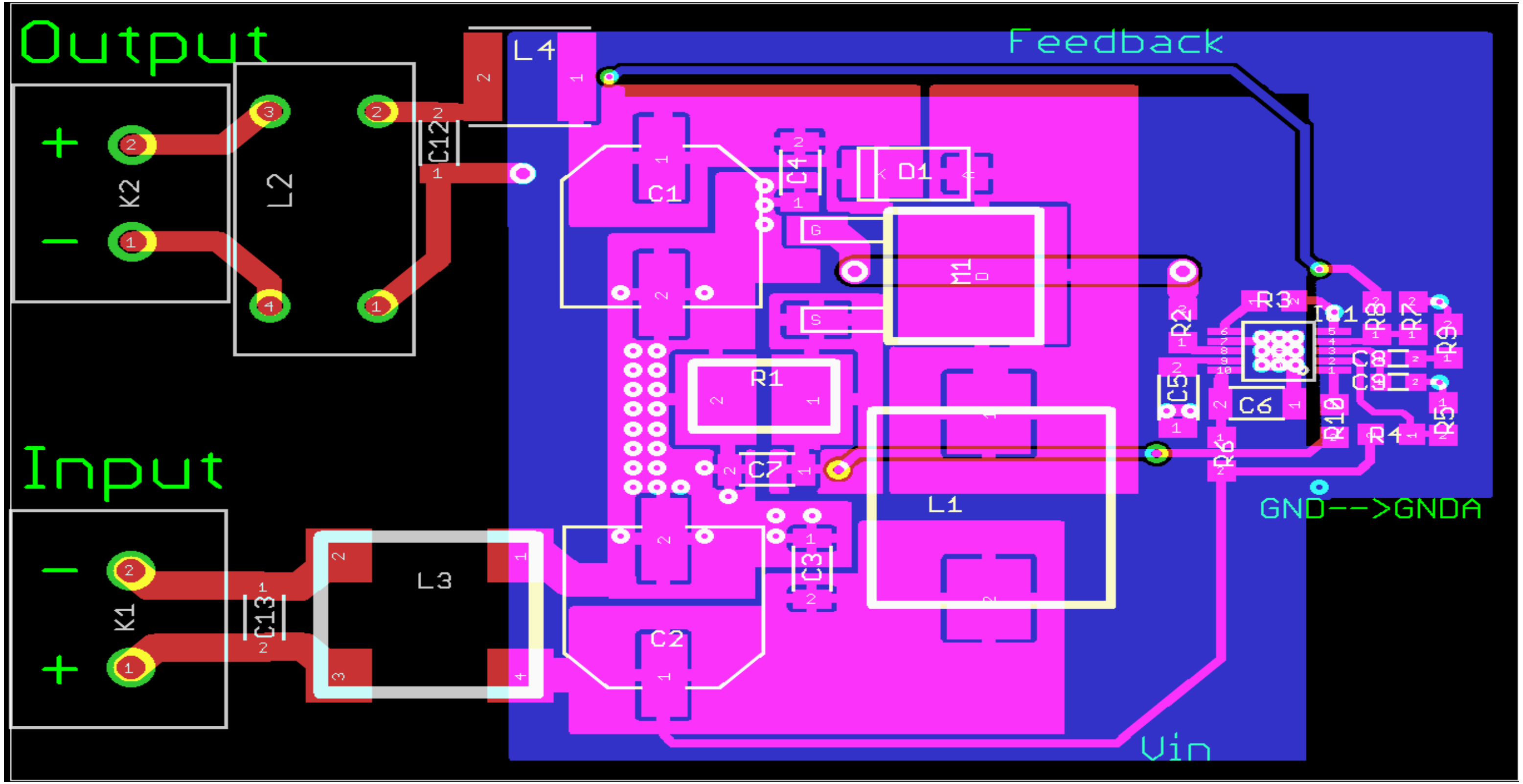
Boost converter Good Example



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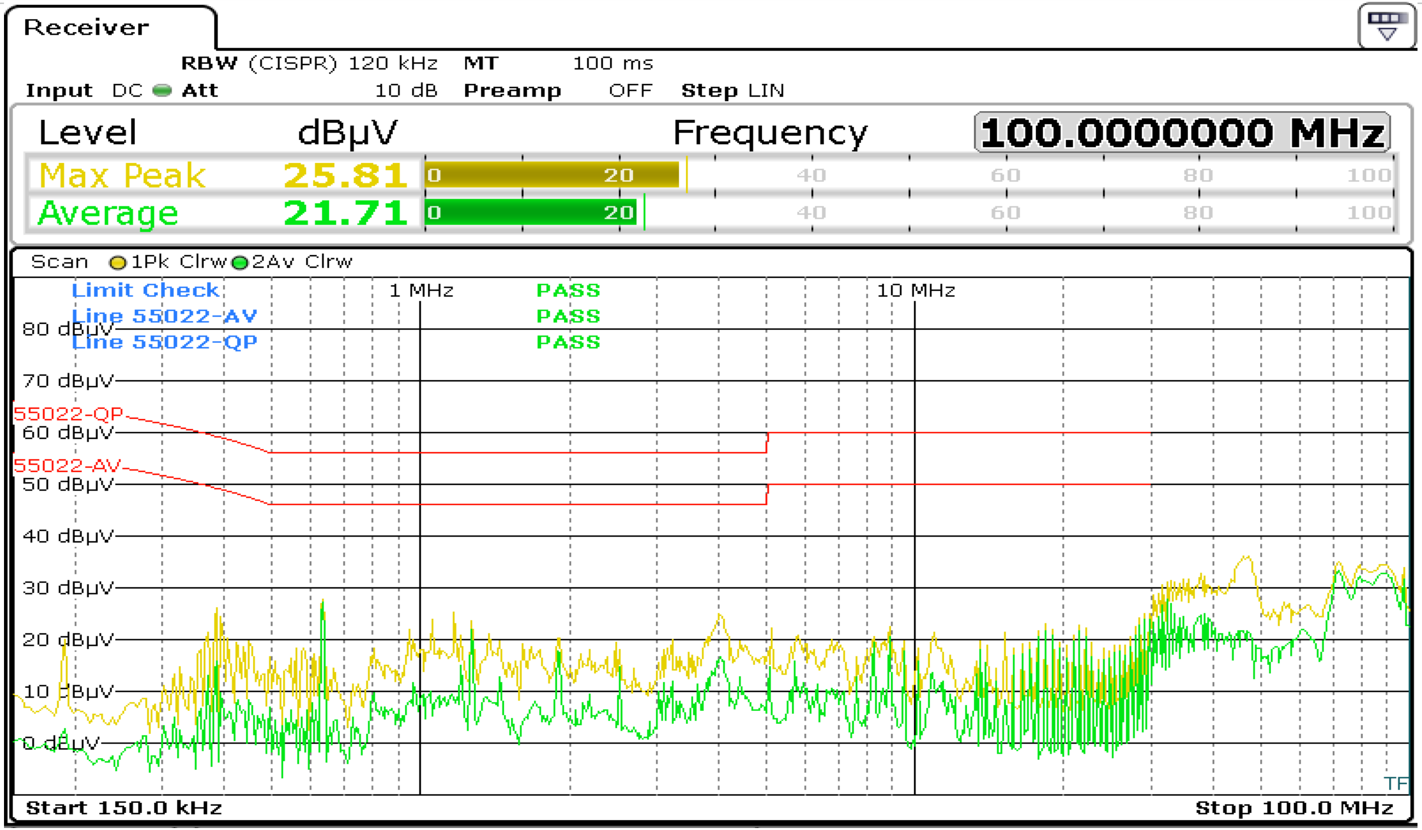
Boost converter Good Example



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EXAMPLES FOR BAD DESIGN

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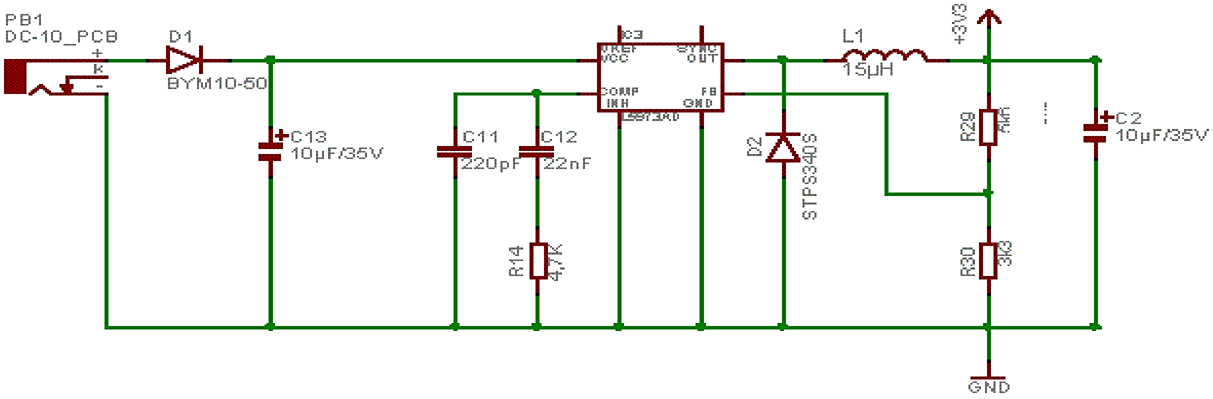
Example for Bad Design

- Un insolated DC/DC converter



- No input filter
- Bad Layout

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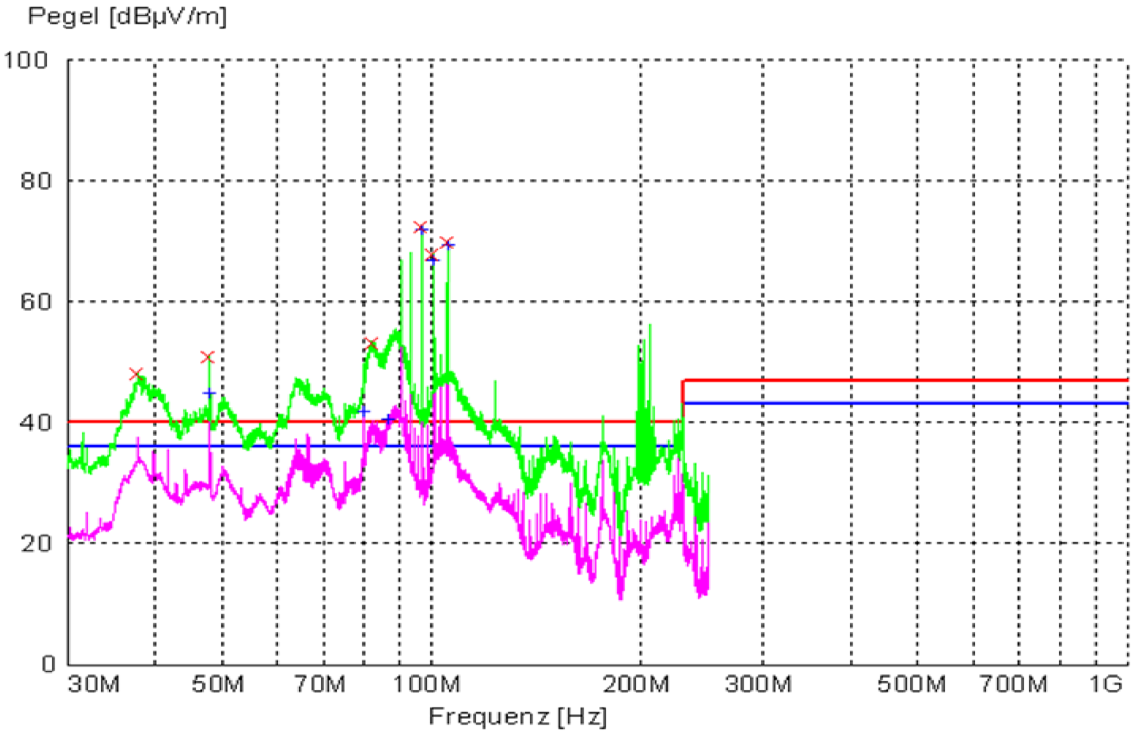
Example for Bad Design

- High emissions for radiated
- Limits over shooted



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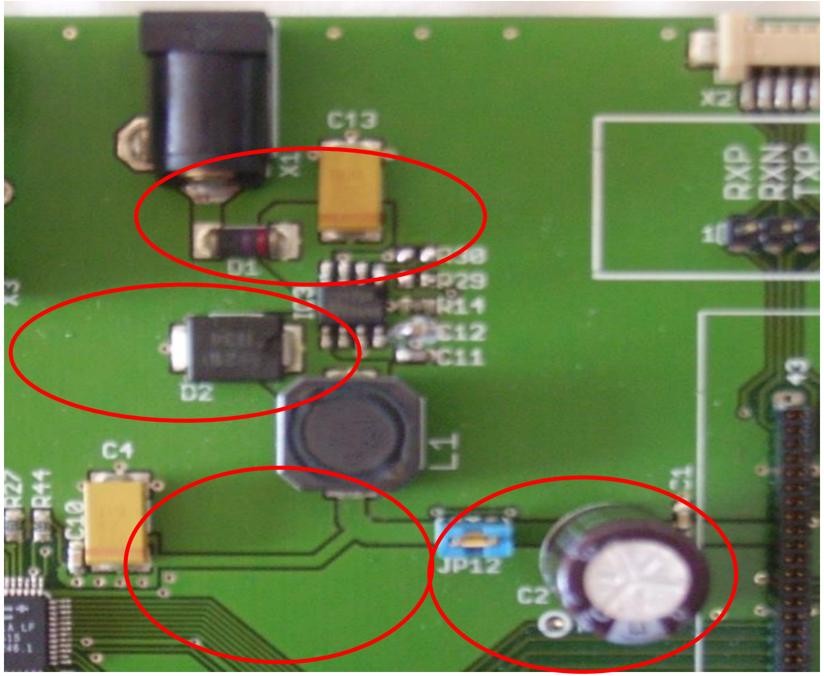
Example for Bad Design

- No input filter
- Simple 2 layer
- Wrong position for output capacity
- Bad Ground routing



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DESIGN TOOLS

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REDEXPERT

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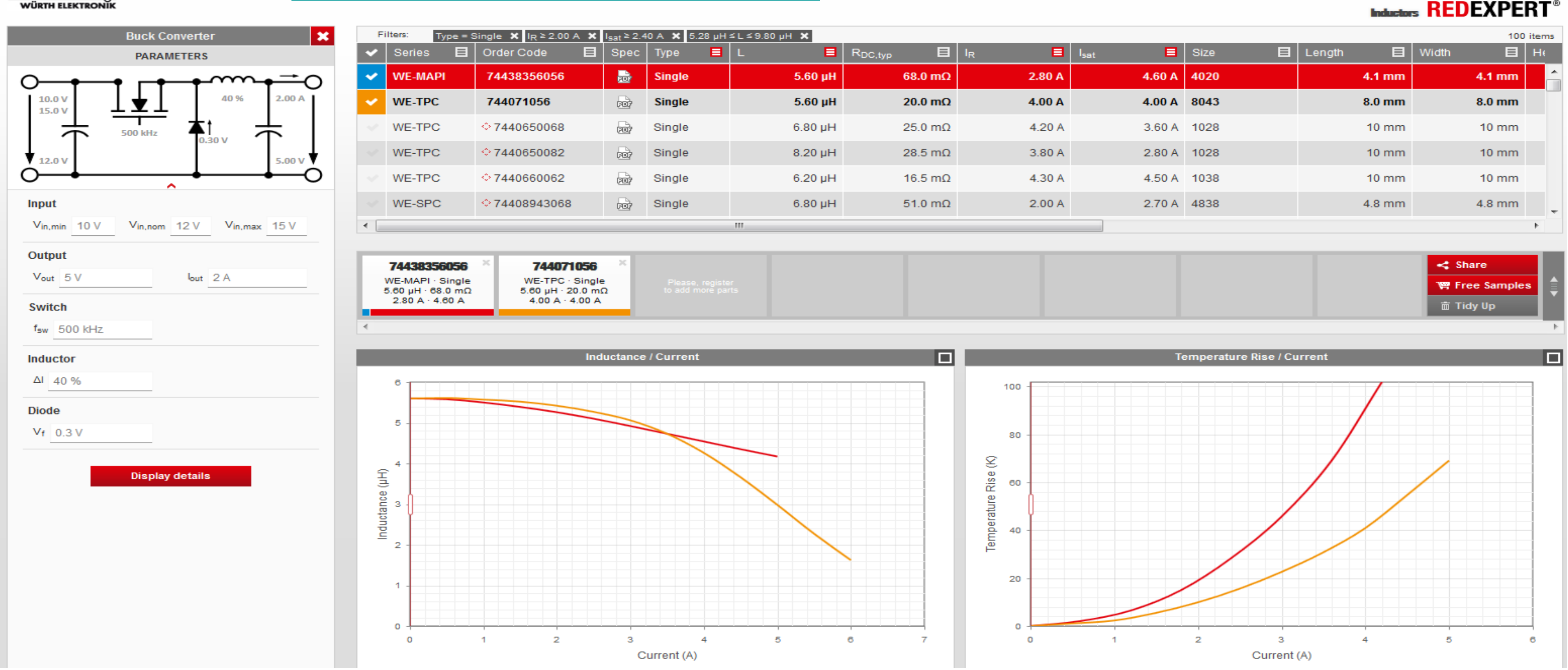

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Simulation – WEBENCH

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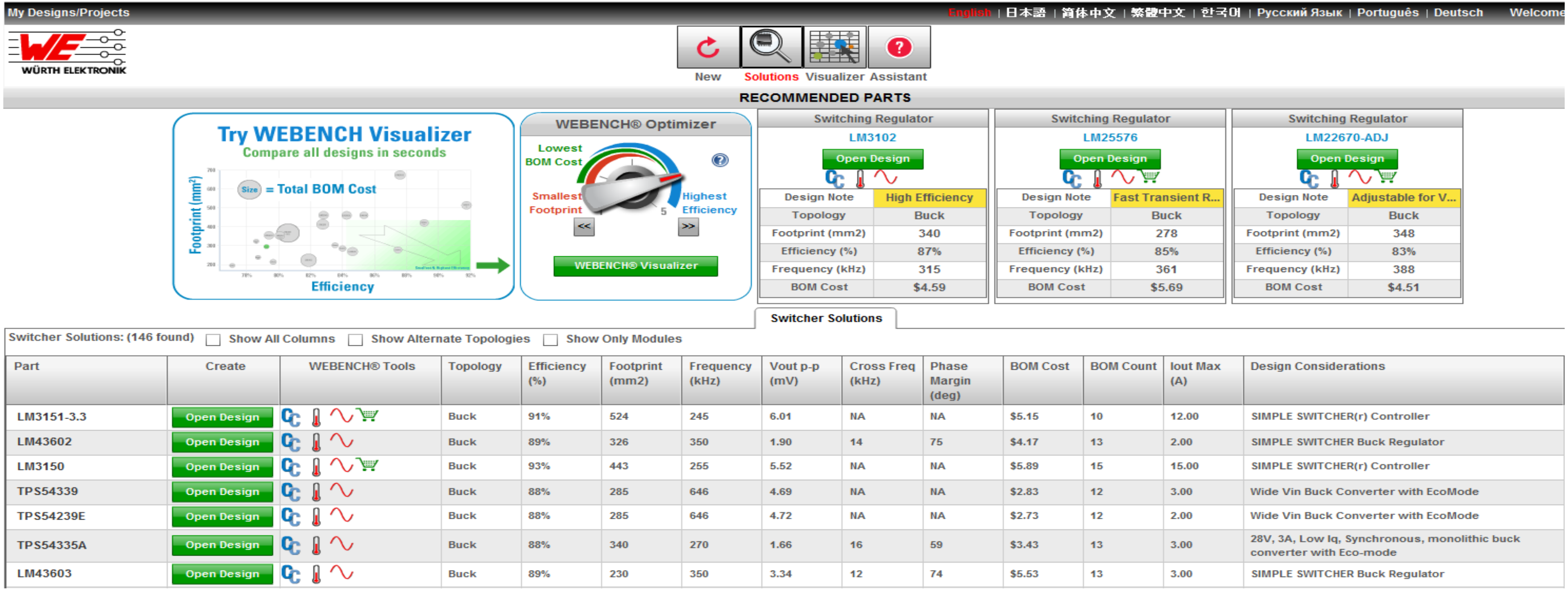
- http://www.we-online.de/web/de/electronic_components/toolbox_pbs/webench.php



	Switching Regulator	Switching Regulator	Switching Regulator
Part	LM3102	LM25576	LM22670-ADJ
Design Note	High Efficiency	Fast Transient R...	Adjustable for V...
Topology	Buck	Buck	Buck
Footprint (mm2)	340	278	348
Efficiency (%)	87%	85%	83%
Frequency (kHz)	315	361	388
BOM Cost	$4.59	$5.69	$4.51

Part	Create	WEBENCH® Tools	Topology	Efficiency (%)	Footprint (mm2)	Frequency (kHz)	Vout p-p (mV)	Cross Freq (kHz)	Phase Margin (deg)	BOM Cost	BOM Count	Iout Max (A)	Design Considerations
LM3151-3.3	Open Design		Buck	91%	524	245	6.01	NA	NA	$5.15	10	12.00	SIMPLE SWITCHER(r) Controller
LM43602	Open Design		Buck	89%	326	350	1.90	14	75	$4.17	13	2.00	SIMPLE SWITCHER Buck Regulator
LM3150	Open Design		Buck	93%	443	255	5.52	NA	NA	$5.89	15	15.00	SIMPLE SWITCHER(r) Controller
TPS54339	Open Design		Buck	88%	285	646	4.69	NA	NA	$2.83	12	3.00	Wide Vin Buck Converter with EcoMode
TPS54239E	Open Design		Buck	88%	285	646	4.72	NA	NA	$2.73	12	2.00	Wide Vin Buck Converter with EcoMode
TPS54335A	Open Design		Buck	88%	340	270	1.66	16	59	$3.43	13	3.00	28V, 3A, Low Iq, Synchronous, monolithic buck converter with Eco-mode
LM43603	Open Design		Buck	89%	230	350	3.34	12	74	$5.53	13	3.00	SIMPLE SWITCHER Buck Regulator

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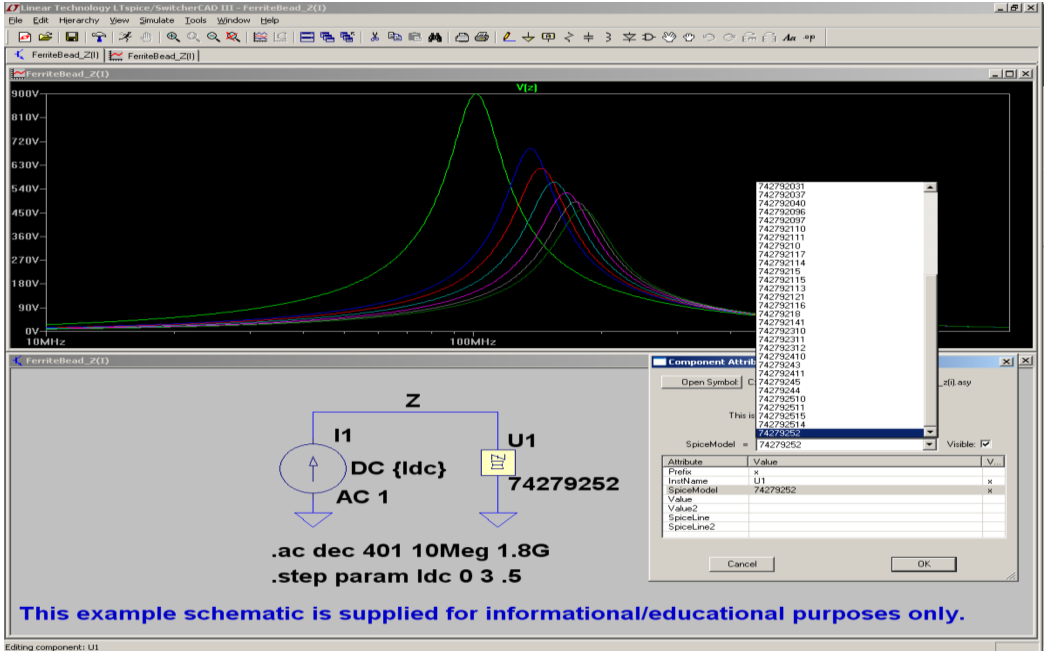
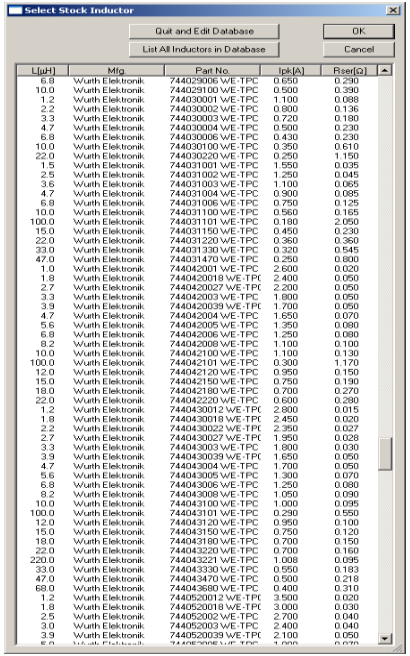
Simulation – LTSpice IV

- http://www.linear.com/designtools/software/#LTspice





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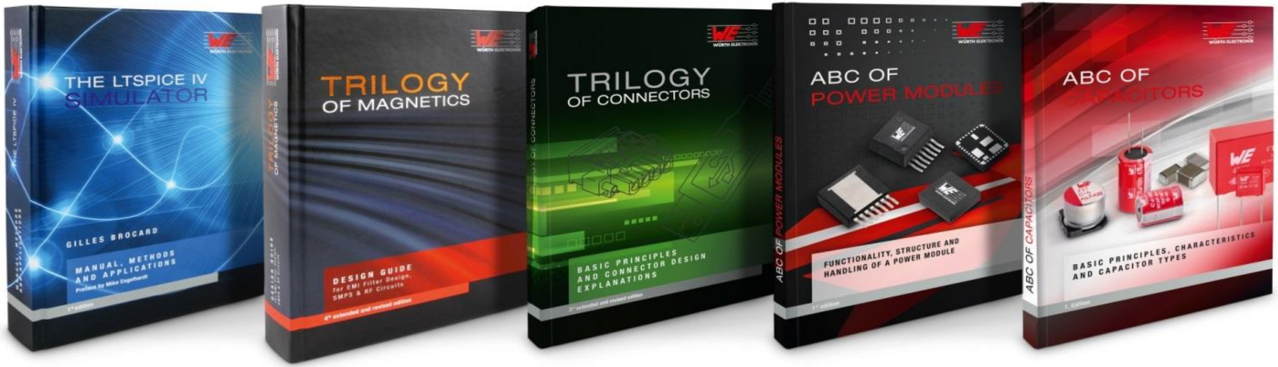
Trilogies



- 1. **LTspice Book**
  → How to use and build spice models
- 2. **Trilogy of Magnetics**
  → Design Guide for EMI Filter Design, SMPS & RF Circuits
- 3. **Trilogy of Connectors**
  → Basic Principles and Connector Design Explanations
- 4. **ABC of Power Modules**
  → Functionality, Structure and Handling of a Power Module
- 5. **ABC of Capacitors**
  →Basic principles, characteristics and capacitor types

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If you still have questions?

Just call us: we try to help you

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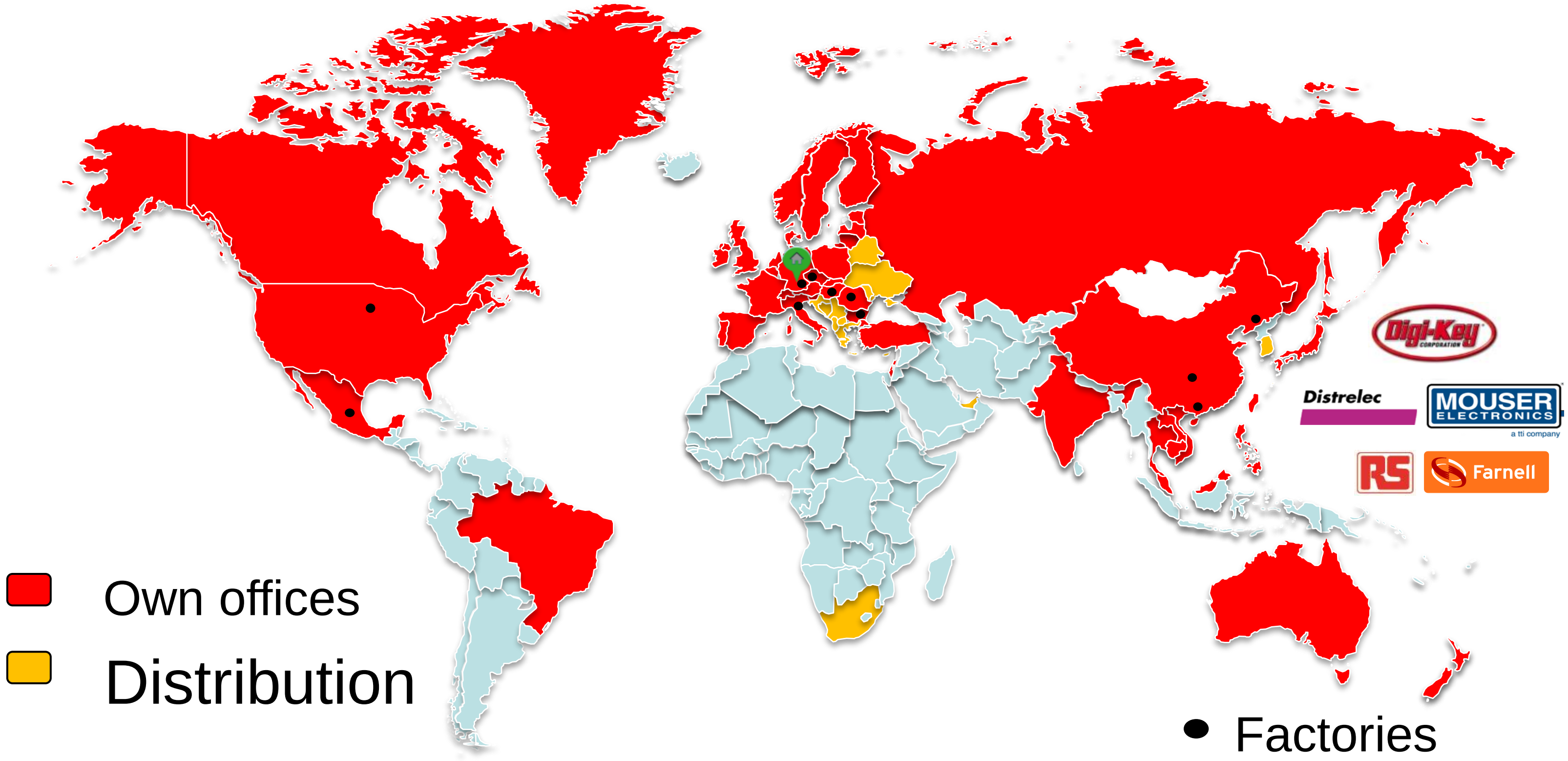
Headquarter in Germany



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Technical support needed?

Ask our design engineer Lorandt Fölkel

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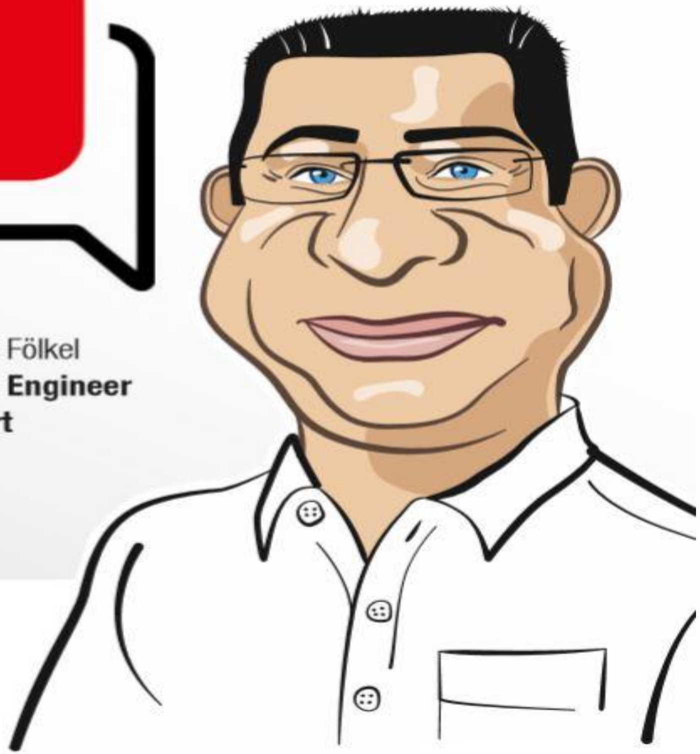

Lorandt Fölkel
Design Engineer at heart

or contact me directly:
askLorandt@we-online.com

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