

Filtering with high efficiency and best EMI design



**more
than you
expect**

Speaker:

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Field Application Engineer &
Business Development Manager

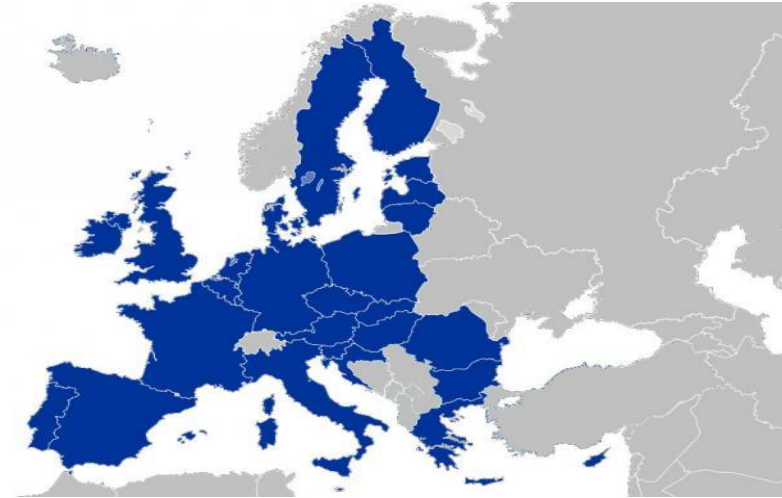
lorandt.foelkel@we-online.de



REQUIREMENTS IN EMC

CE Marking

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



What is the meaning of EMC ?






What is the meaning of the CE logo ?

CE





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.

CE



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.

Other International EMC approval marks



- **Federal Communications Commission**



- **Voluntary Control Council for Interference**



- **Australian Communications and Media Authority**



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 - 56dB μ V @ 150<KHz<500KHz (QP)

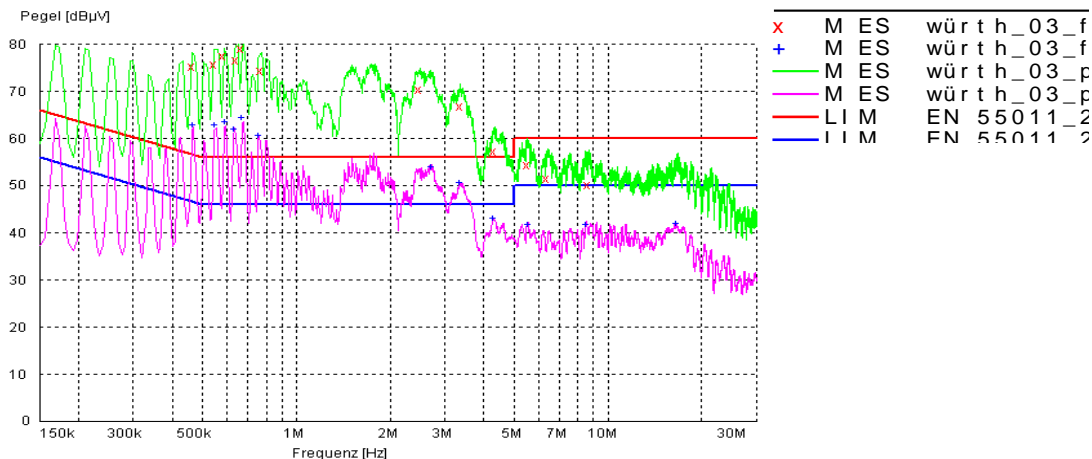
56 - 46dB μ V @ 150<KHz<500KHz (Av)

56dB μ V @ 0,5<MHz<5 (QP)

46dB μ V @ 0,5<MHz<5 (Av)

60dB μ V @ 5<MHz<30 (QP)

50dB μ V @ 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 & Commercial)

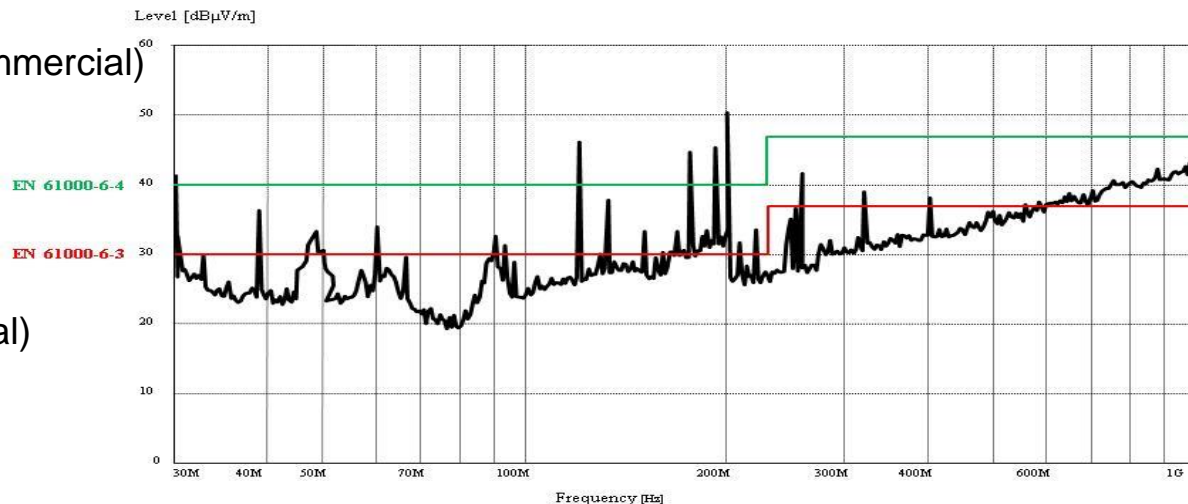
30dB @ 30MHz~230MHz $\mu\text{V}/\text{m}$

37dB @ 230MHz~1GHz $\mu\text{V}/\text{m}$

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

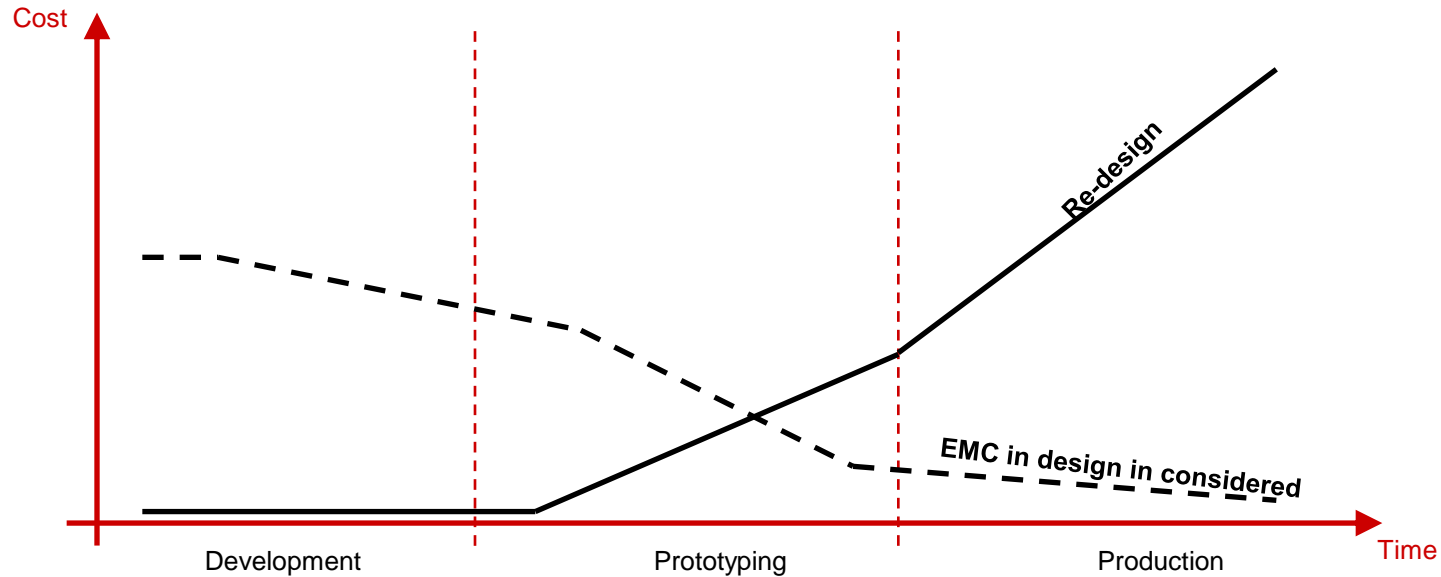
40dB @ 30MHz~230MHz $\mu\text{V}/\text{m}$

47dB @ 230MHz~1GHz $\mu\text{V}/\text{M}$

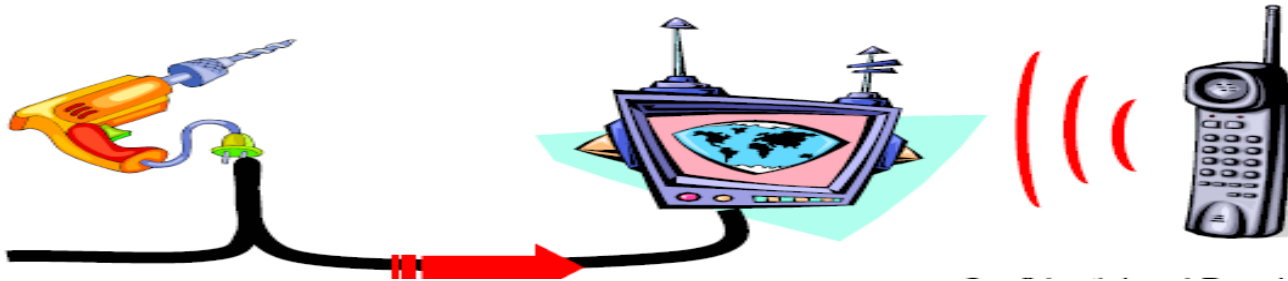
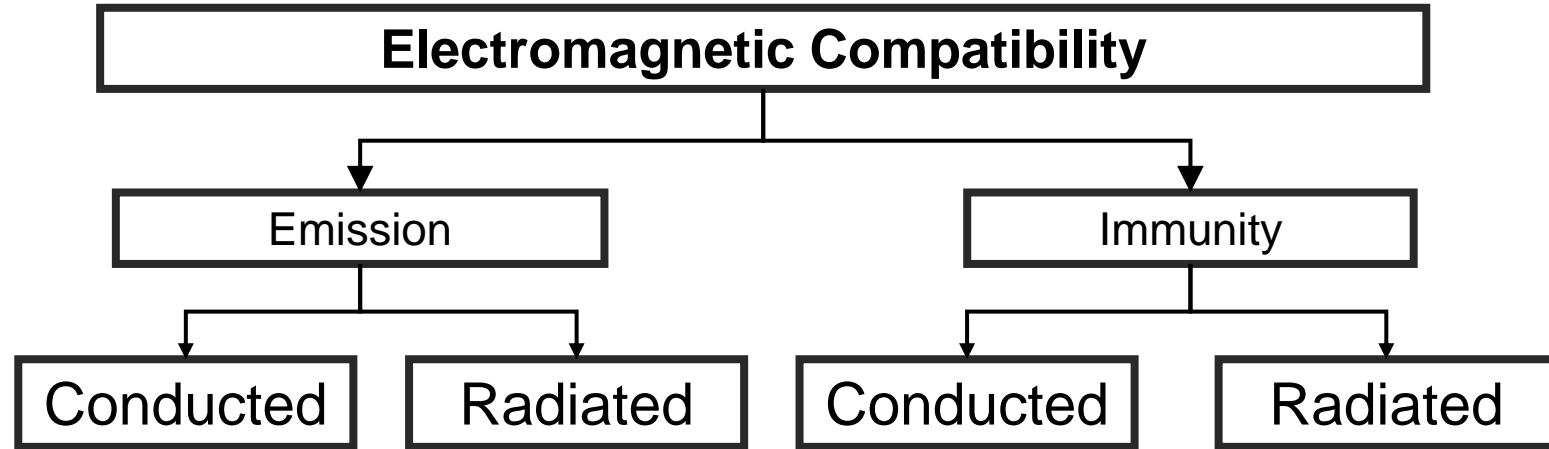


Design phase for EMC

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



EMC – Basic Test



What causes EMI in a product?

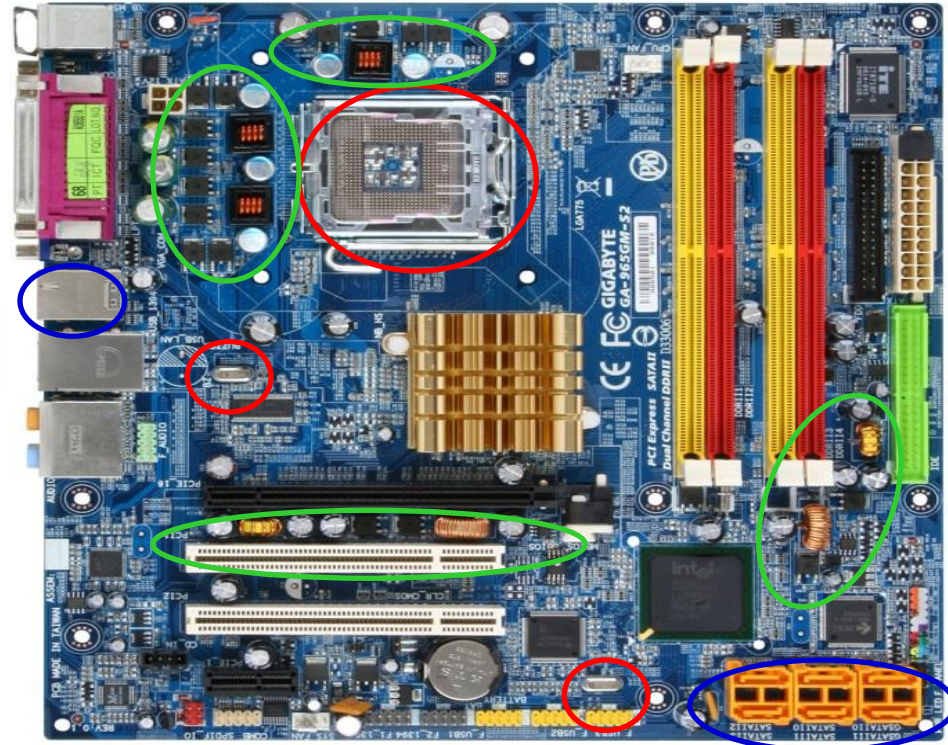
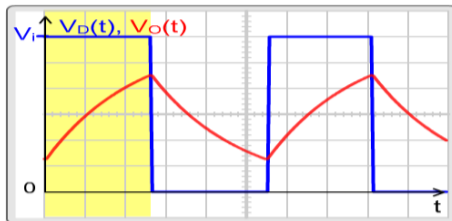
- **Clock frequencies.** E.g Crystal 25MHz,
CPU 2.6GHz



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



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

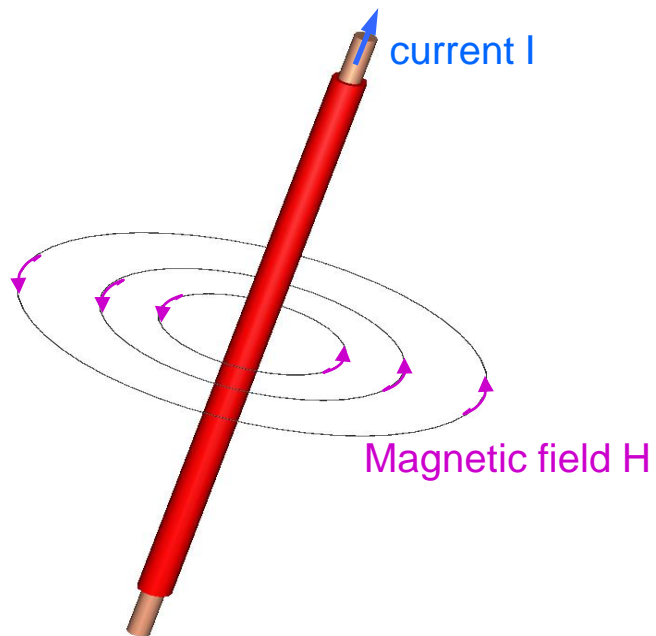




Magnetic and Material Basics

The magnetic field

Each electric powered wire generates an electro magnetic field

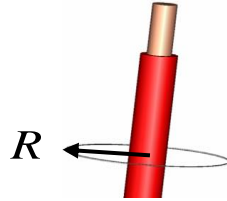


Field model



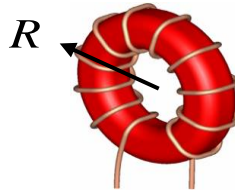
Magnetic field- Magnetic field strength

Straight wire



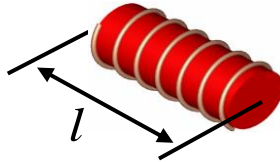
$$H = \frac{I}{2 \cdot \pi \cdot R}$$

Toroidal core



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

Rod core



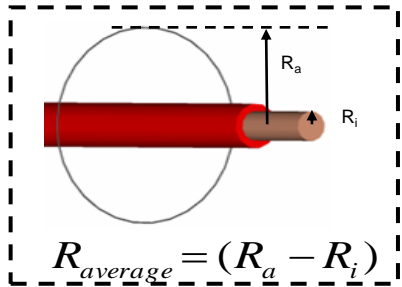
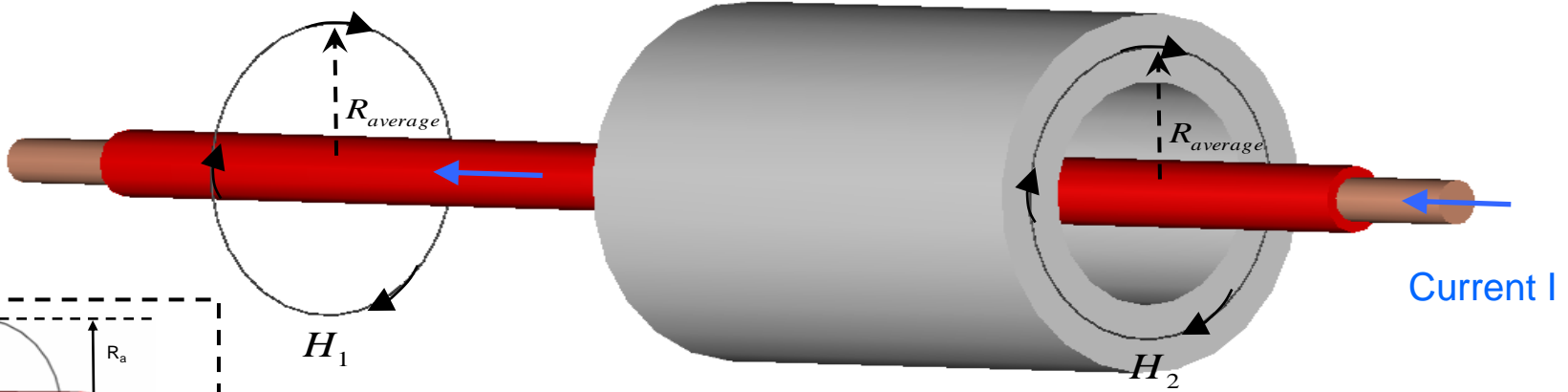
$$H = \frac{N \cdot I}{l}$$

The magnetic field strength is dependent from:

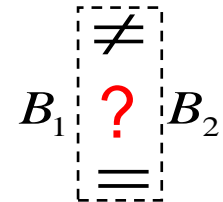
- No. of turns
- current
- dimension
- and

NOT FROM MATERIAL

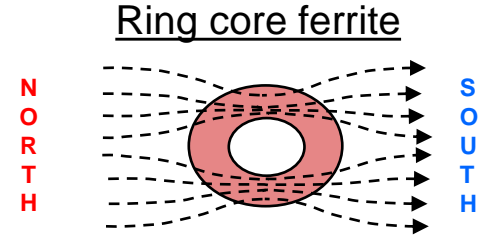
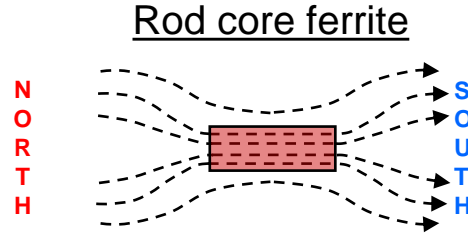
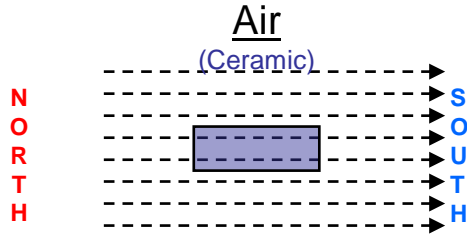
Magnetic field- Magnetic field strength



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



The magnetic field



Induction in air:

$$B = \mu_0 \cdot H$$

linear function, because $\mu_r = 1 \Rightarrow$ constant!

Induction in a ferrite:

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

material-
frequency-
temperature-
current-
pressure-

-dependent parameter

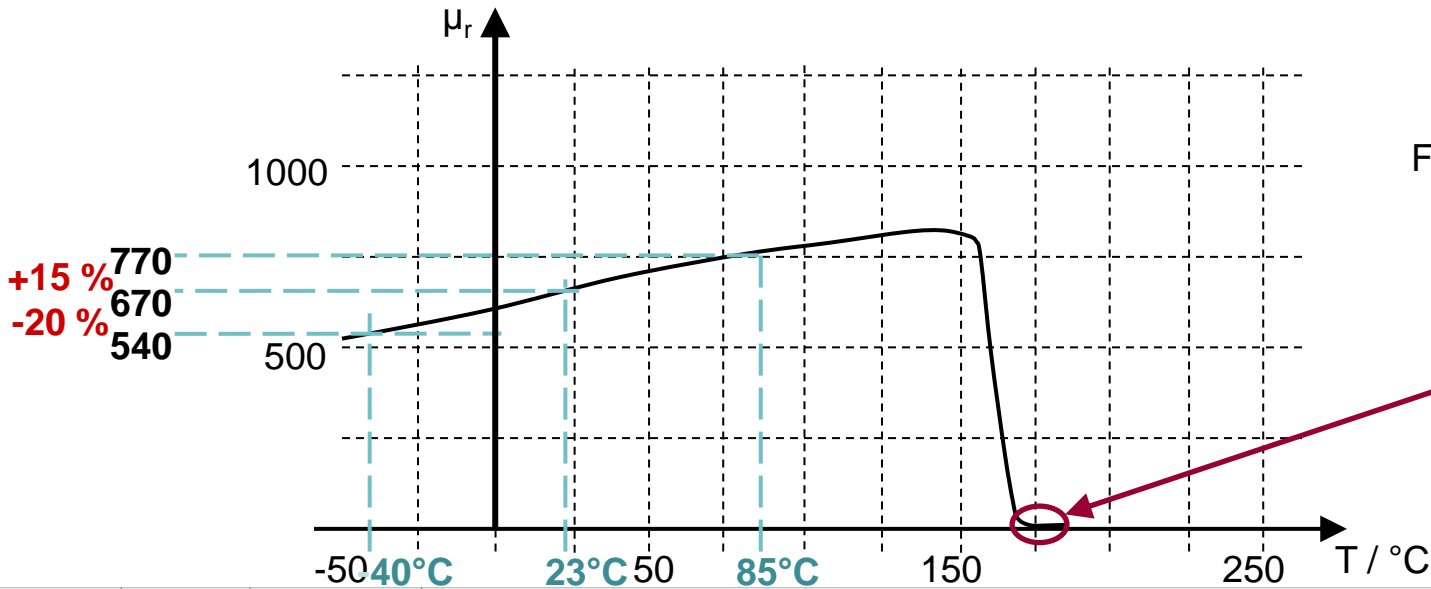
The relative permeability is a:



Permeability – Core material parameter

Temperature influence

- The magnetization depends from the temperature



Alignment of elementary magnets

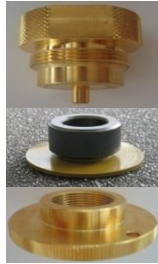


Ferromagnetic change to Paramagnetic

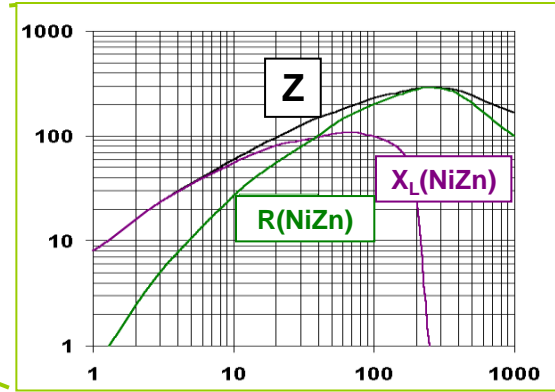
Curie-temperature

$$\mu_r = ? 1$$

Permeability – complex permeability

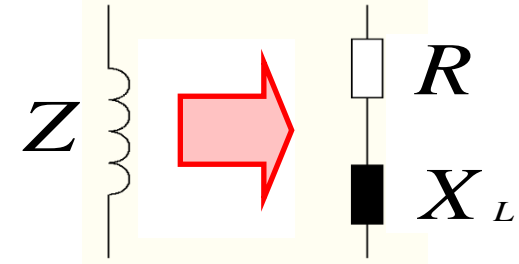


=1 turn



Core material-Parameter

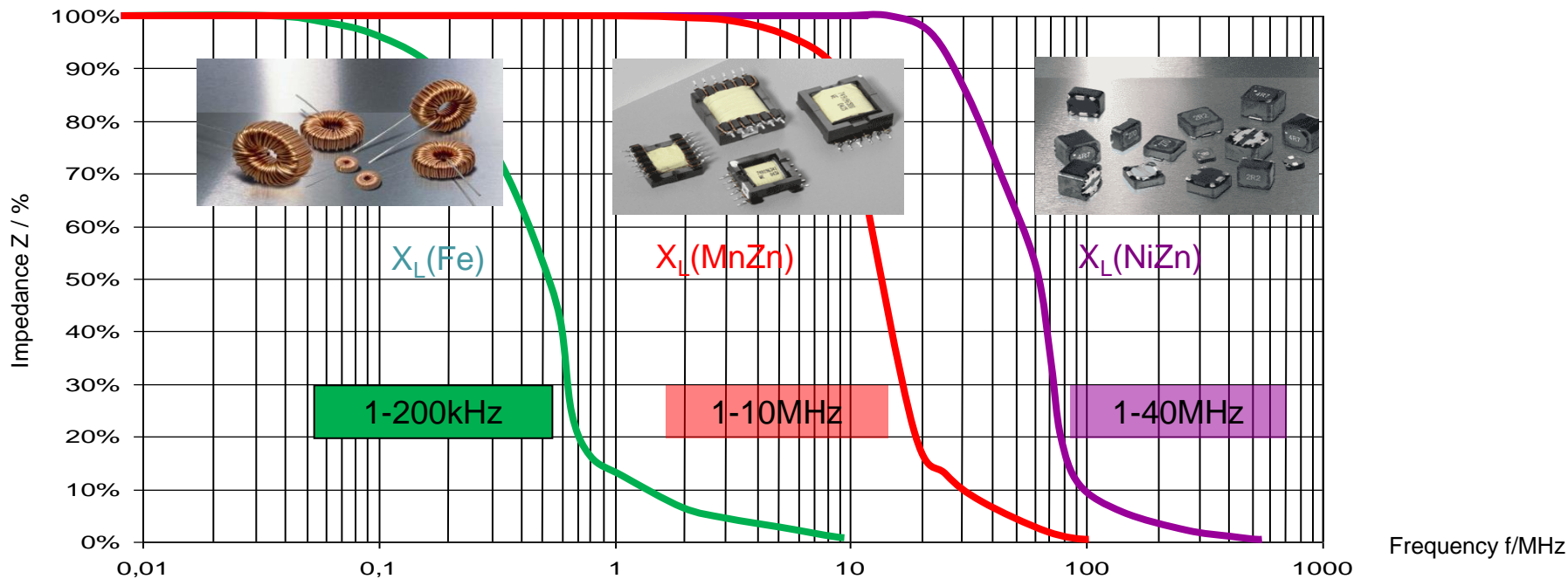
Replacement circuit



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

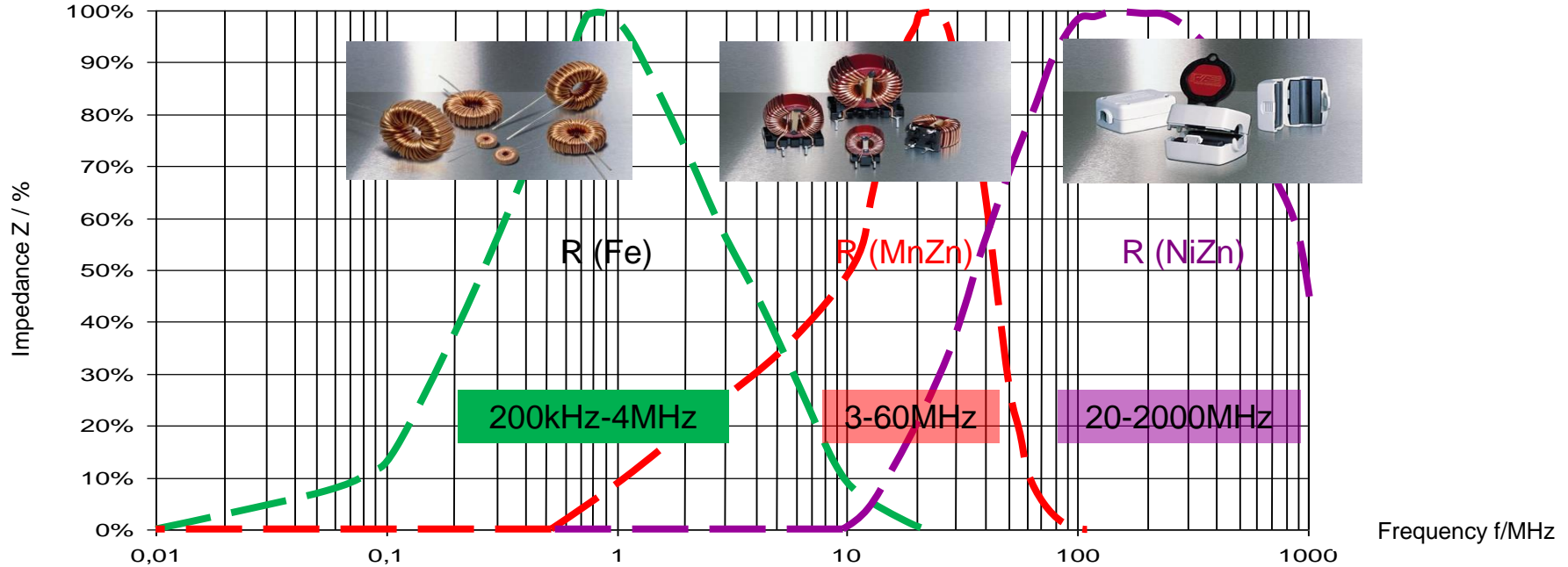
Core materials - Inductors (Energy storage)

Which switching frequency do you use?



Core materials- Chokes (filtering)

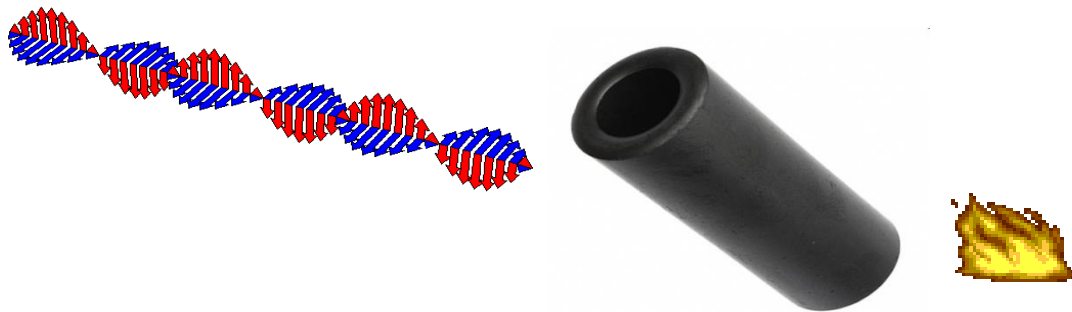
Noise frequency range must be known



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



Transmission Modes & Filter Topologies

EMC - Coupling

→ Primary procedure

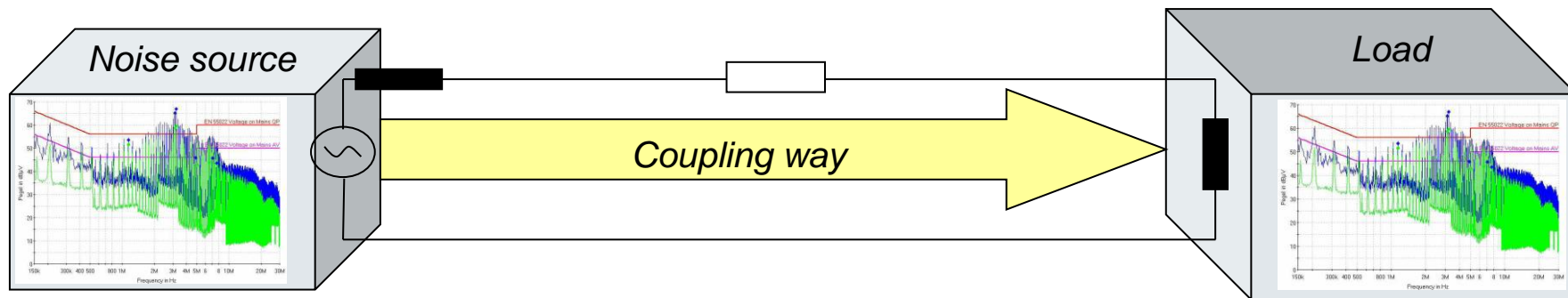
...to aim at source a low noise

→ Secondary procedure

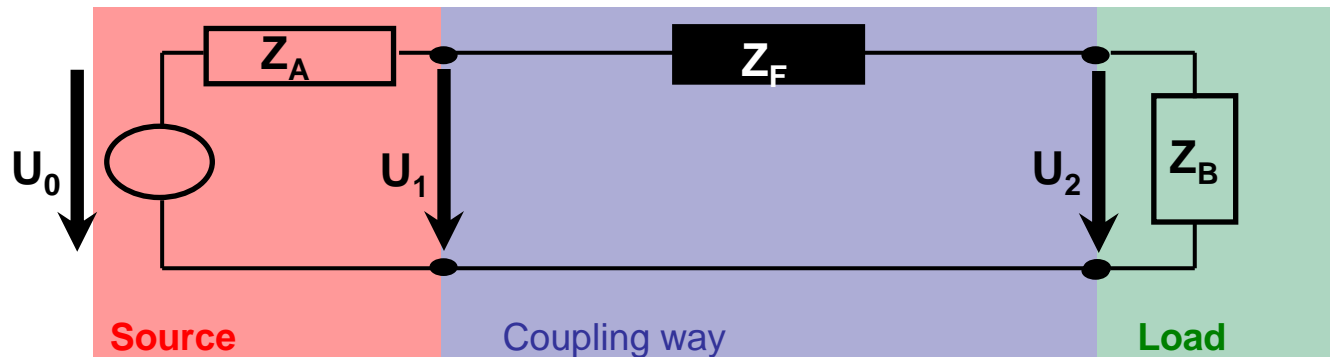
... eliminate the noise thru interrupting the coupling way

→ Tertiary procedure

... increase the noise immunity at load



Insertion loss – Mathematical Definition



- System attenuation

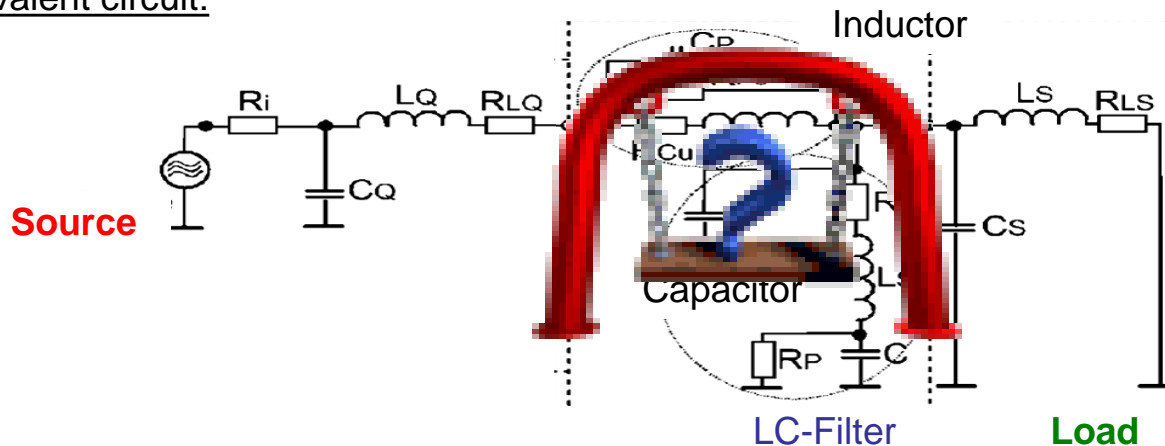
$$A = 20 \cdot \log \frac{Z_A + Z_F + Z_B}{Z_A + Z_B} \quad \text{in (dB)}$$

- Impedance

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

Insertion loss - Definition

Equivalent circuit:

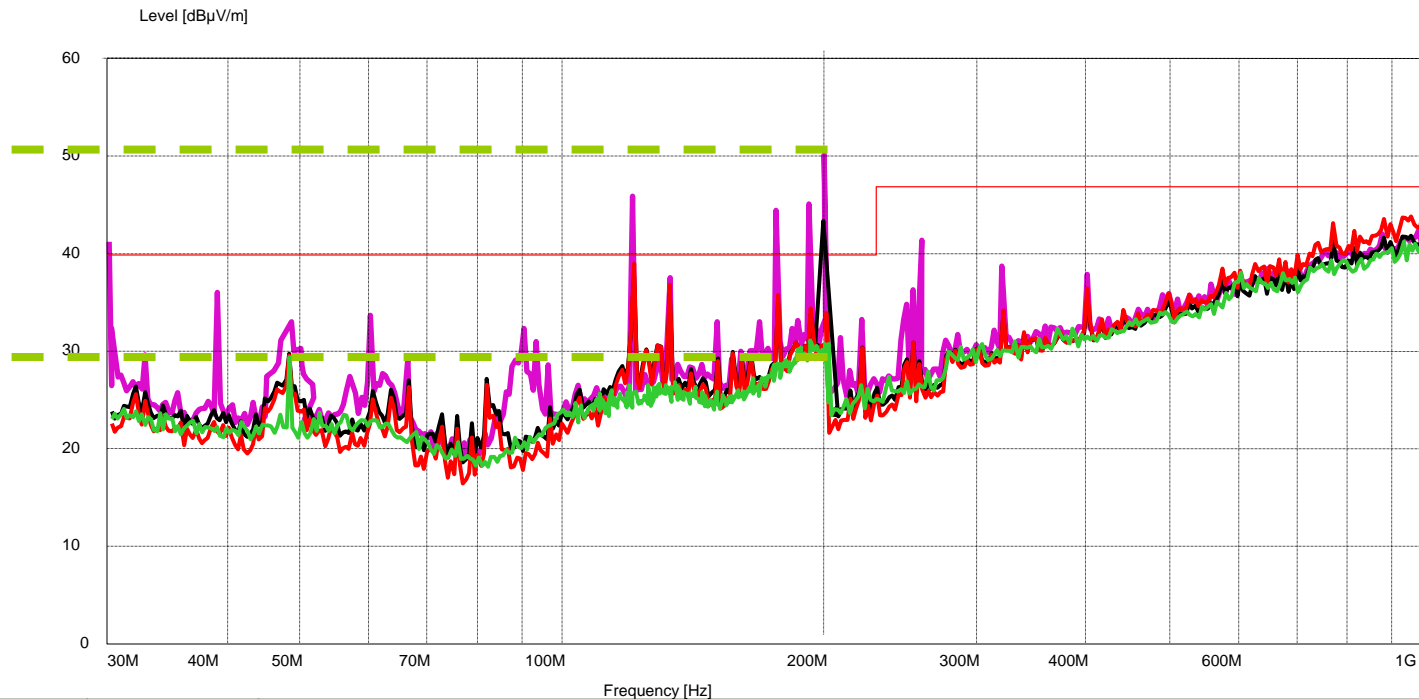


- Practical values for source and load impedances:

→ Ground planes	$<1 \dots 2 \Omega$
→ Vcc distribution	$10 \dots 20 \Omega$
→ Video- /Clock- /Data line	$50 \dots 90 \Omega$
→ long data lines	$90 \dots >150 \Omega$

Check the results in the EMC lab

→ Measuring the emission and compare with the solution



Insertion loss – recommended filter topology

Source Impedance

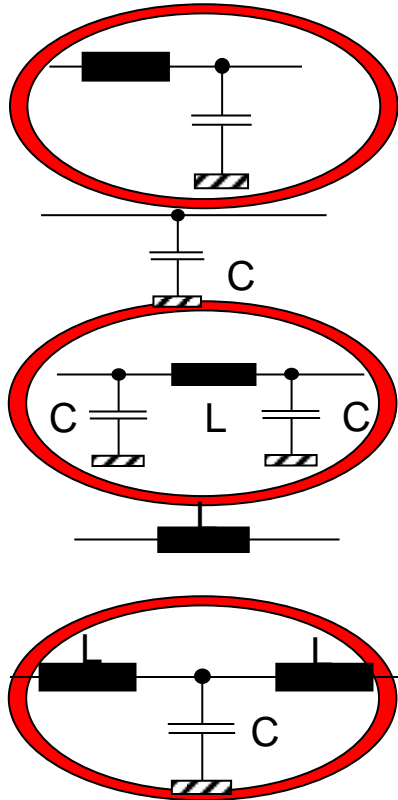
low

high

high or unknown

low

low or unknown



Load Impedance

high

high

high or unknown

low

low or unknown

→ small C = higher SRF

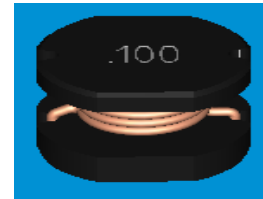
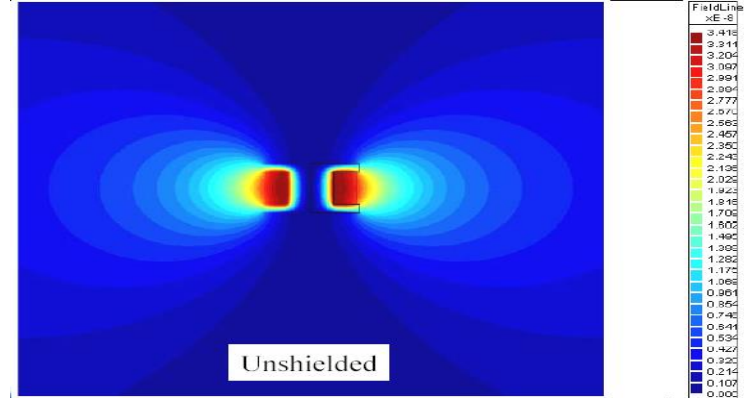
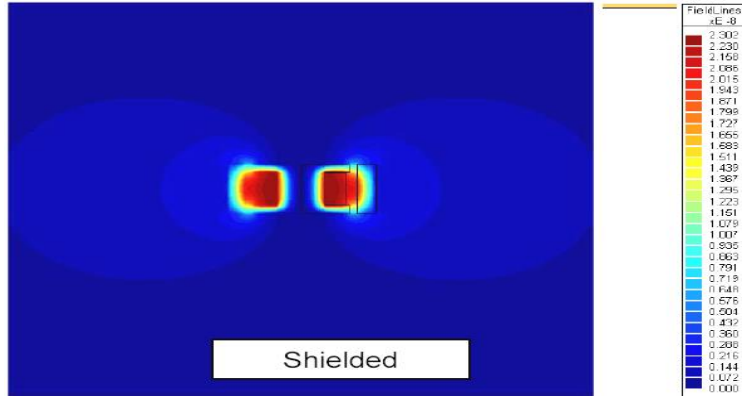
Choose ferrite bead or inductors L which = build no resonance with C = broadband filter

Pay attention to:
SRF of used components



SHIELD VS. UNSHIELD

Magnetic field leakage



Radiation by inductor

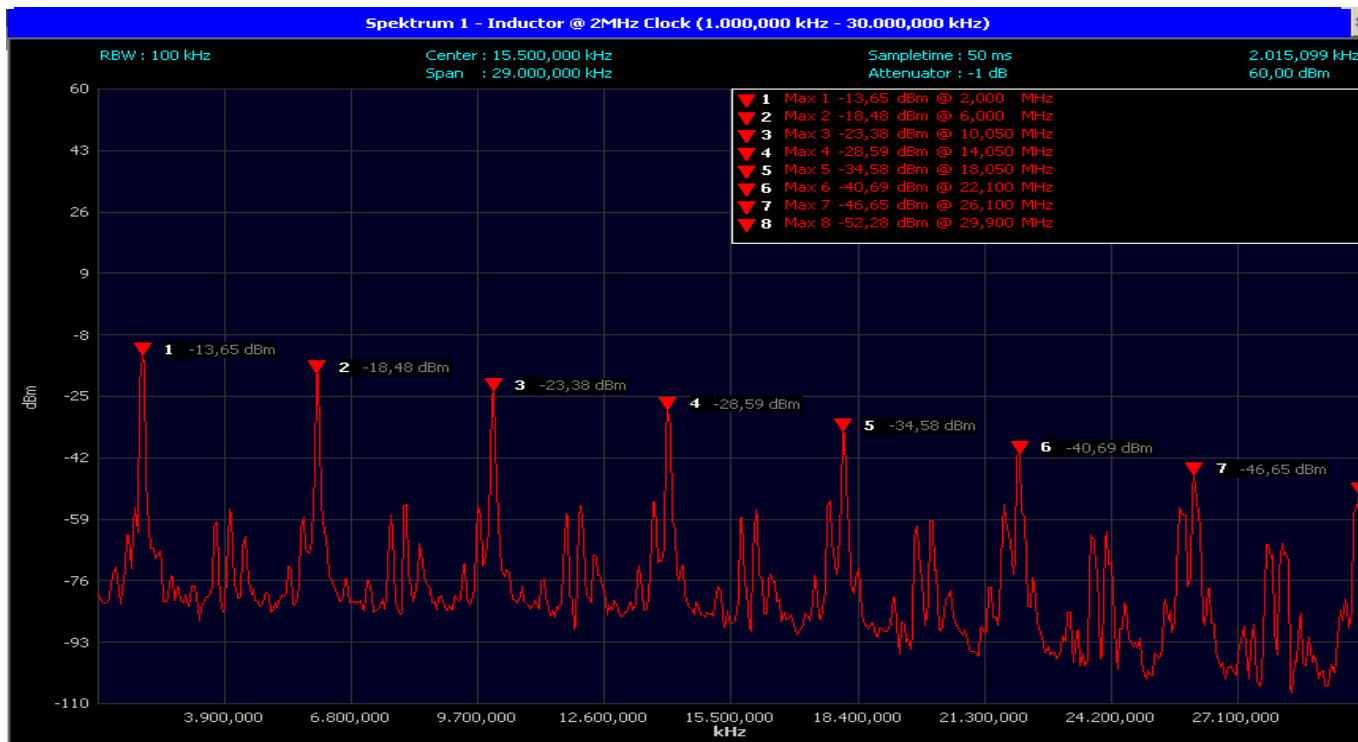
WE - PD2 unshielded
10 μ H, 2MHz Clock, 1A



WE – PD shielded
10 μ H, 2MHz Clock, 1A

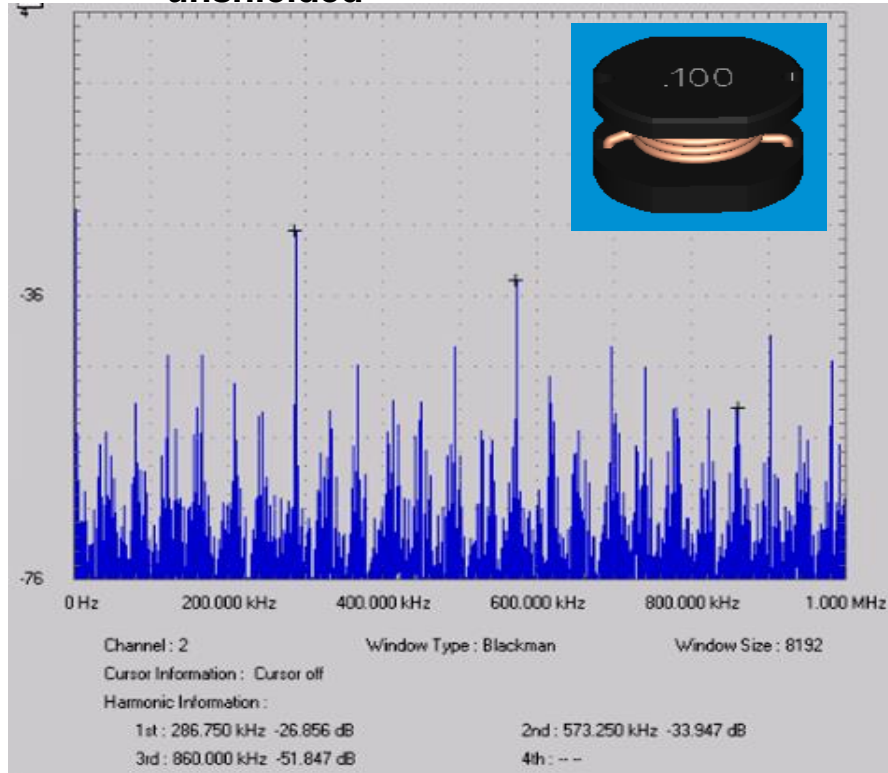


19dBm difference

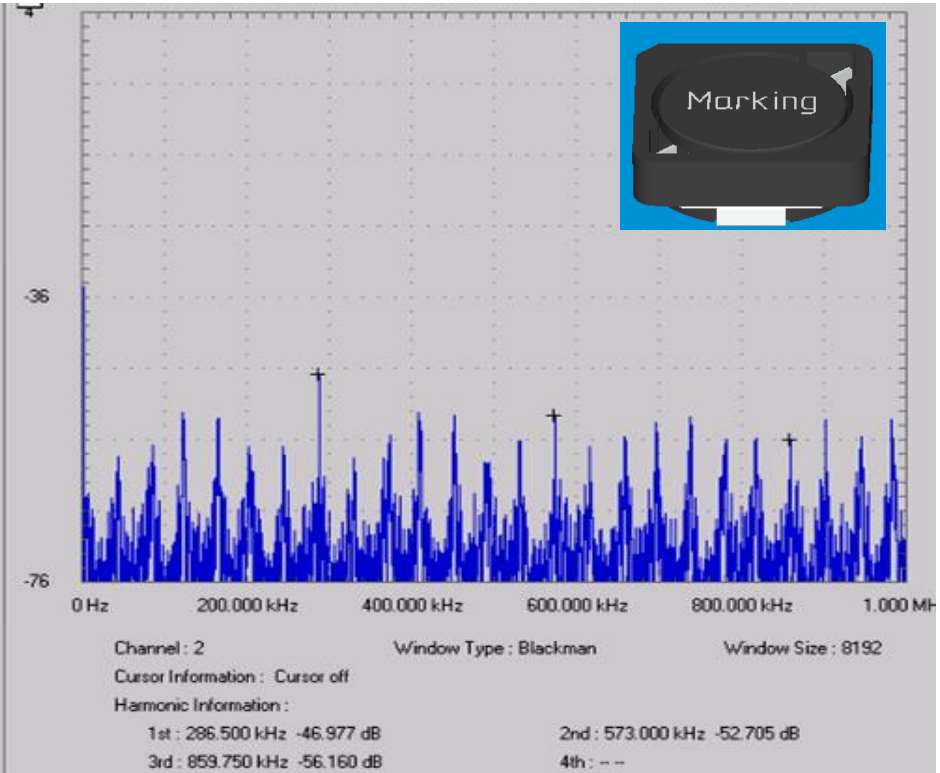


Magnetic leakage shielded vs. unshielded

unshielded

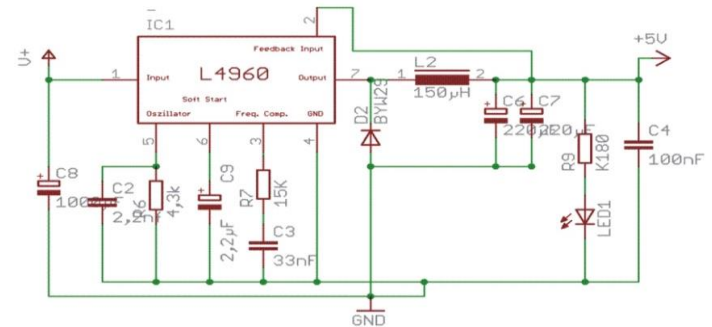
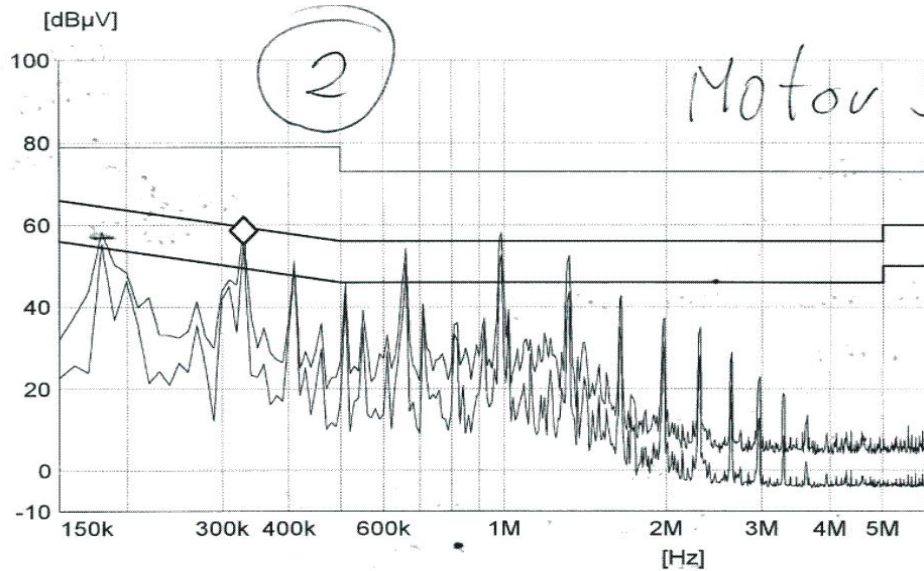


shielded



Magnetic Fields – Conducted Emission Measurement

Power supply V 1.0

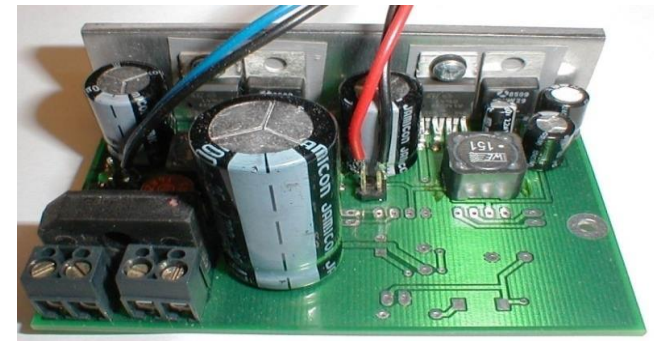
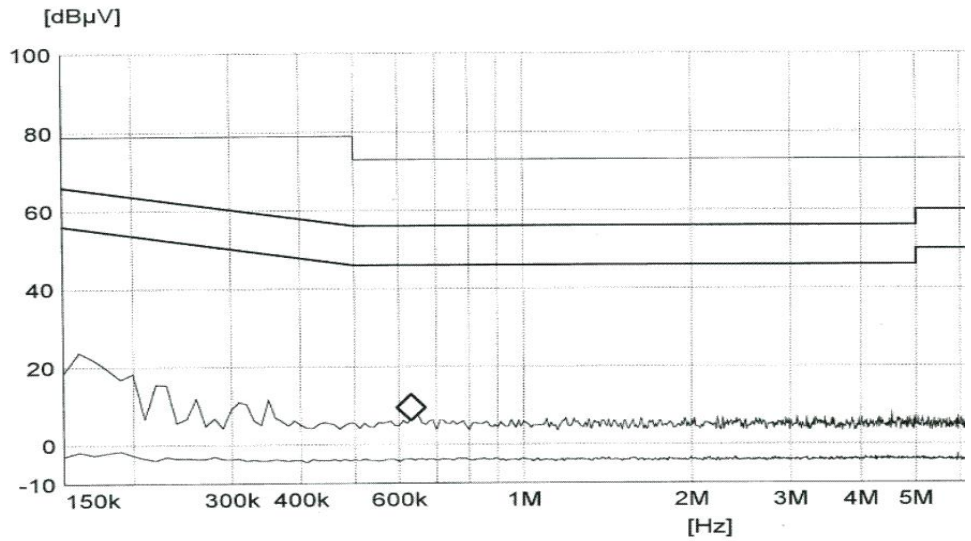


Buck Converter ST L4960/2.5A/fs 85-115KHz

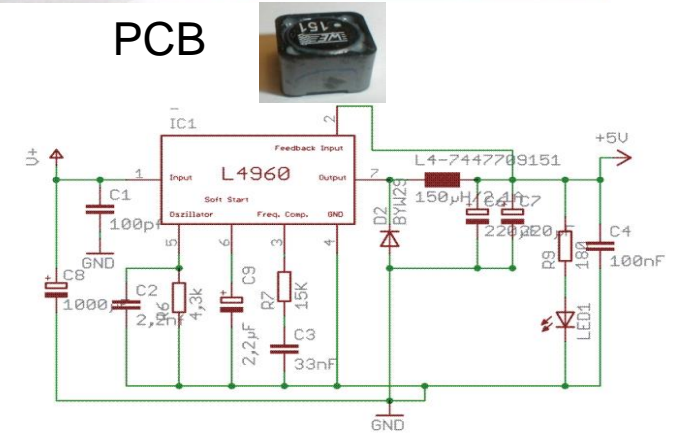


Magnetic Fields – Conducted Emission Measurement

Power supply V 1.1



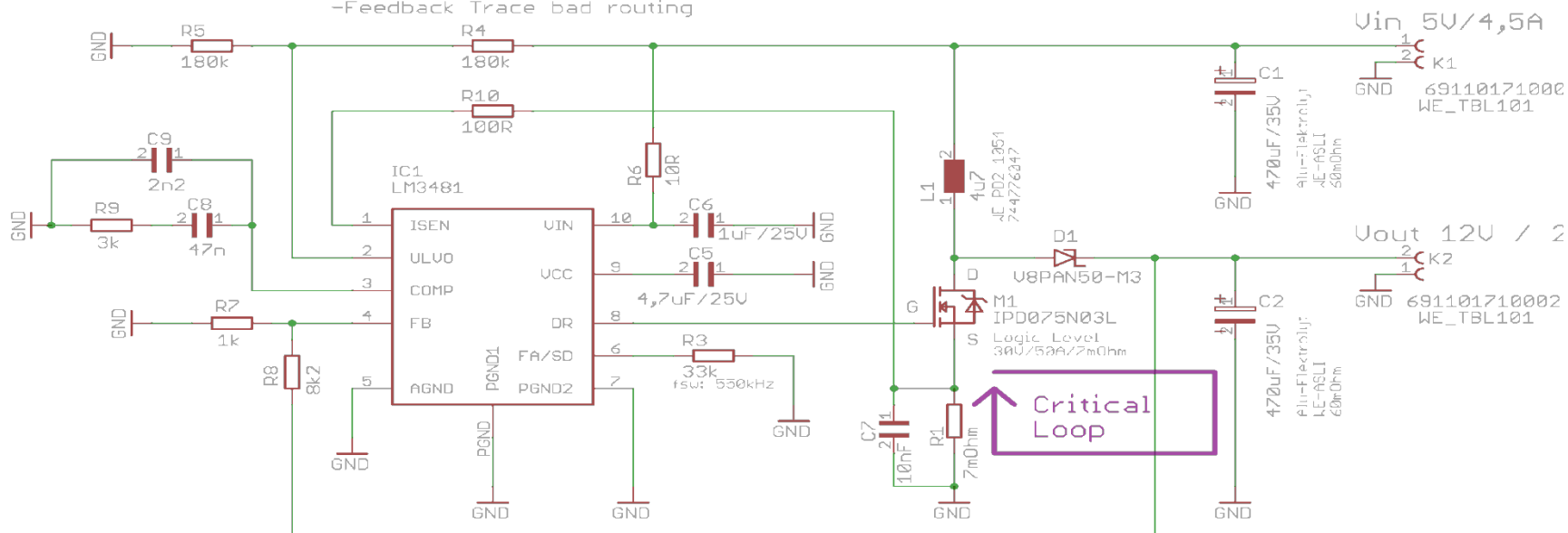
PCB



Schematic

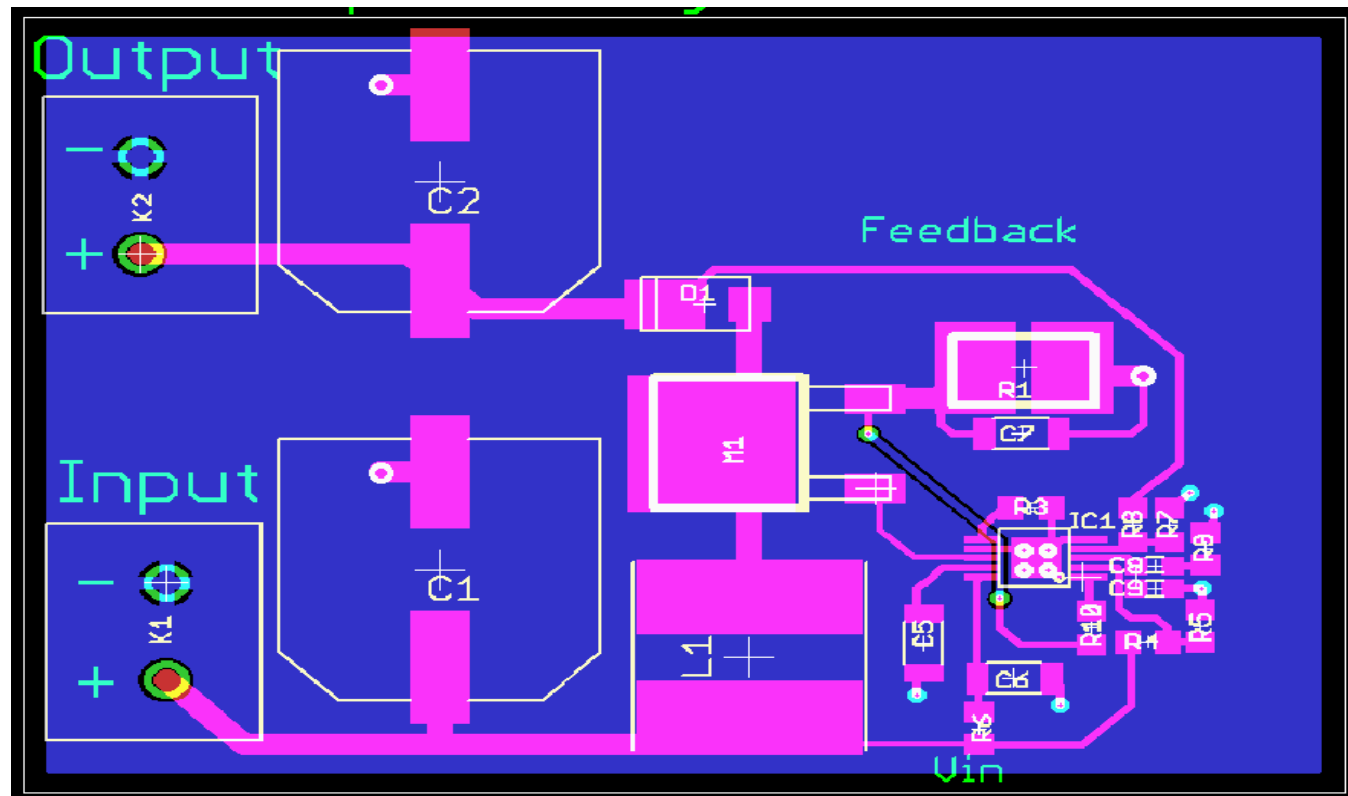
Boost converter Bad Example

- Bad Example:
- Standard Alu-Electrolyte Cap Input/Output >ESR
 - Power Inductor is not shielded
 - Bad Layout with large Current Loops
 - Power and Analog GND not separated
 - No MOSFET Gate Resistor
 - No Input&Output Filter
 - Feedback Trace bad routing

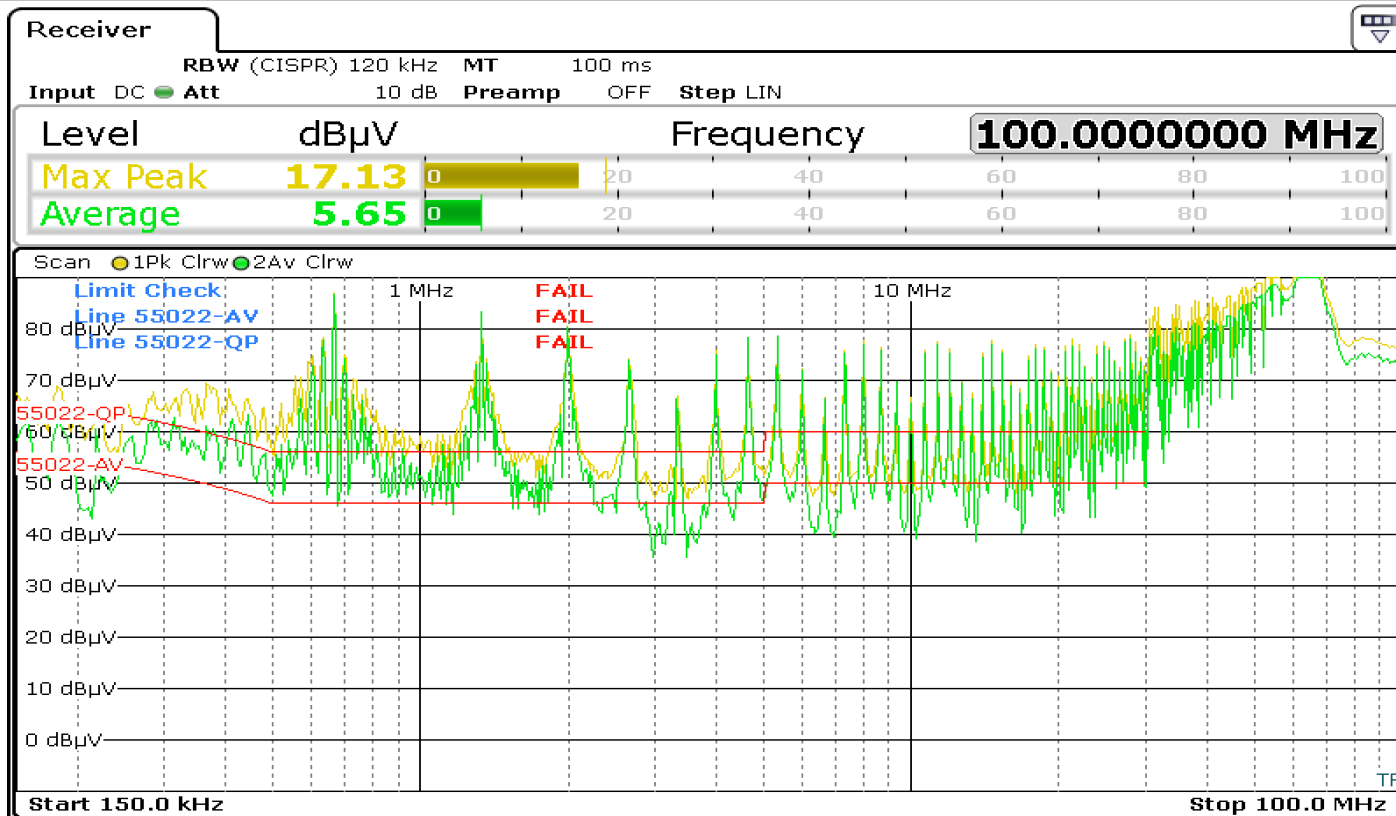


A Boost Converter is critical at the Output!!

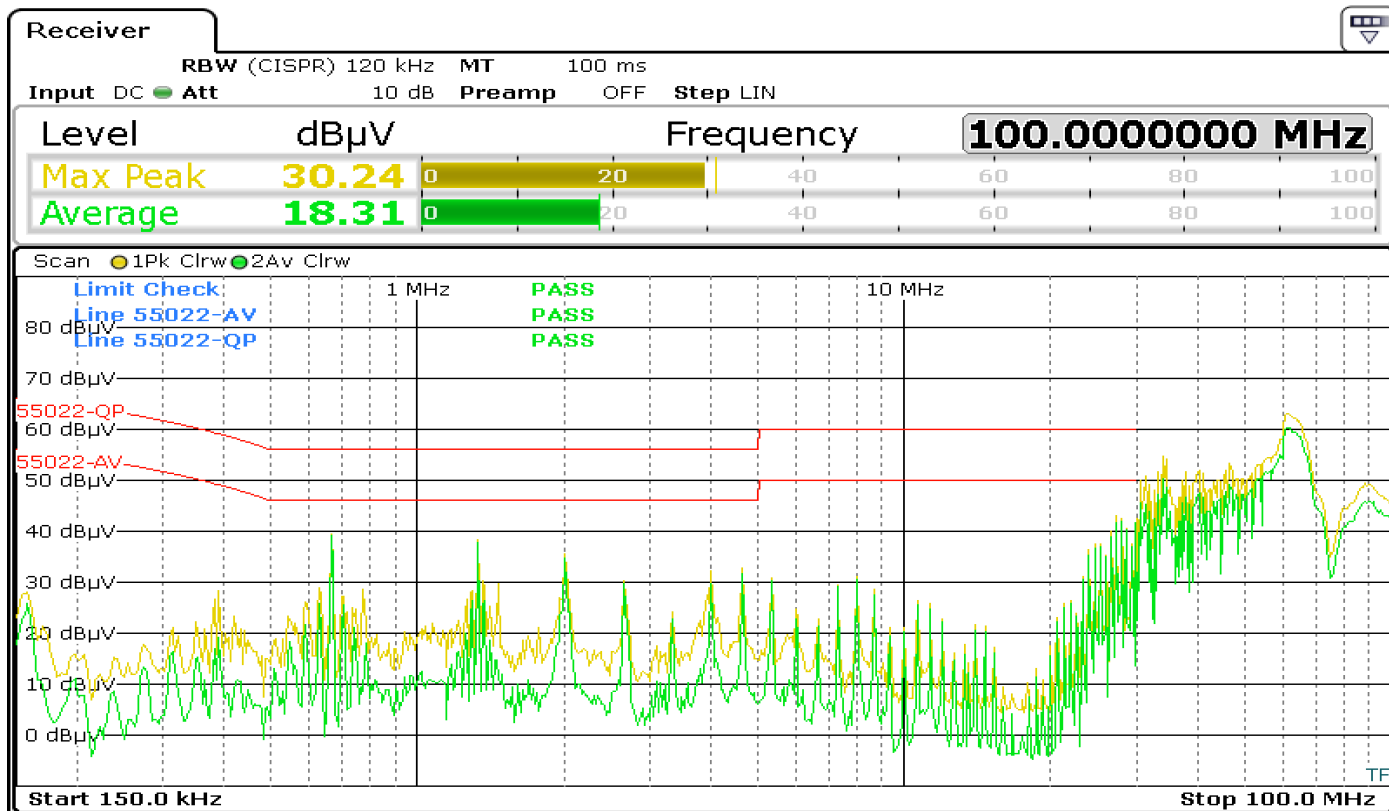
Boost converter Bad Example



Boost converter Bad Example no filter

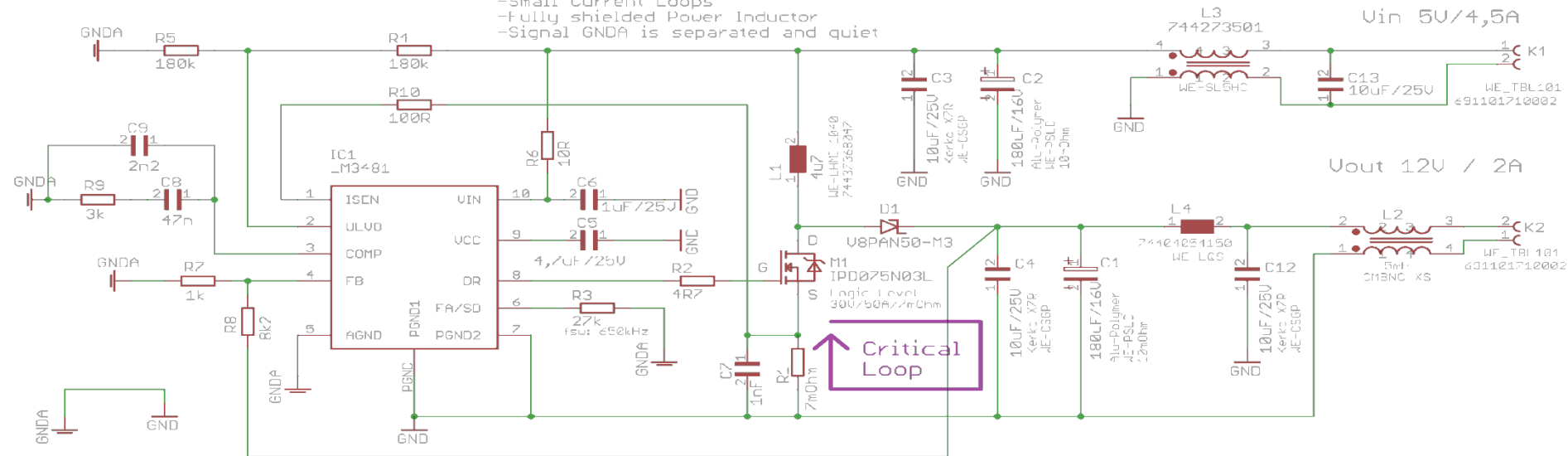


Boost converter Bad Example with filter



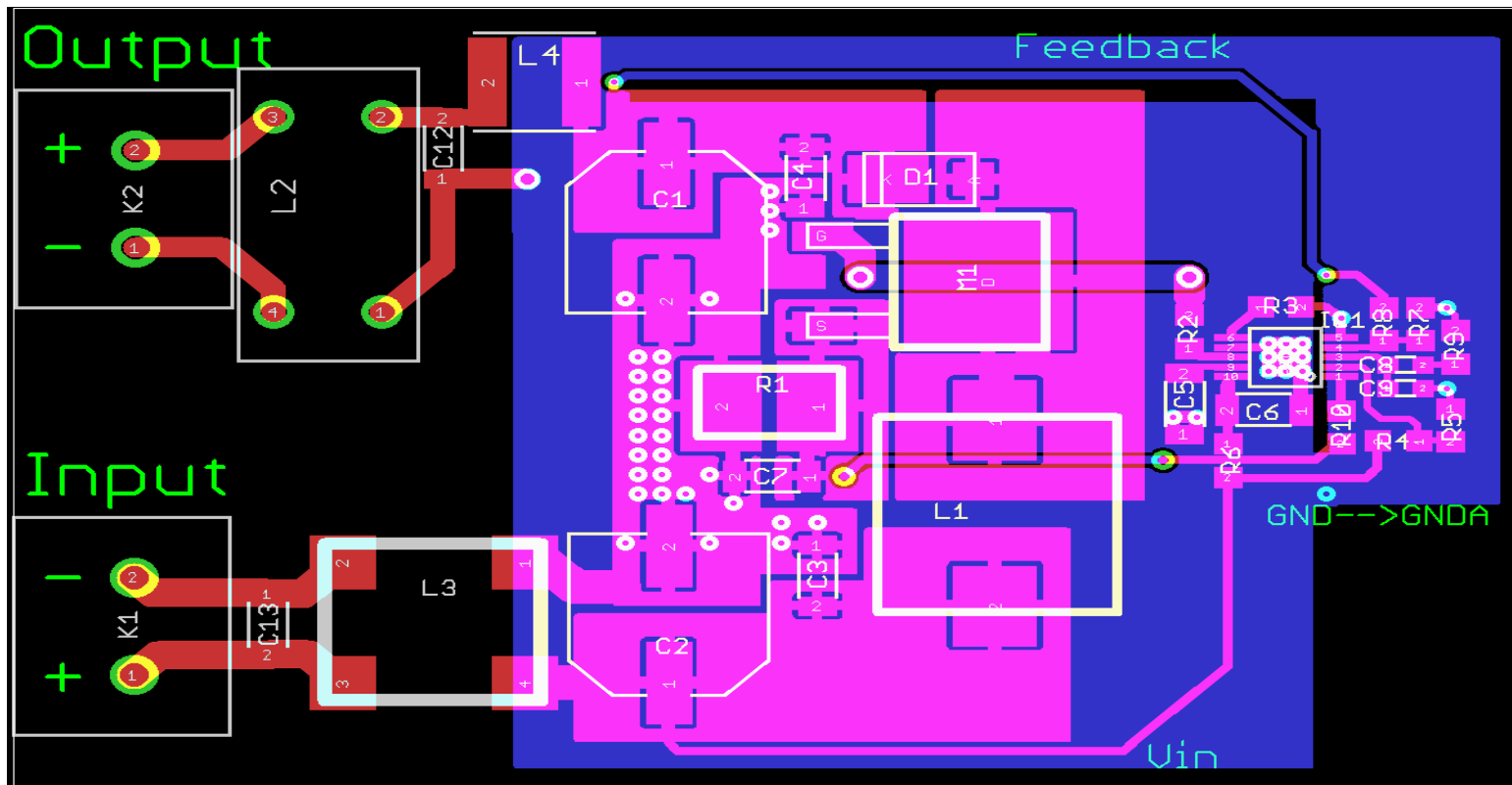
Boost converter Good Example

Good Example:
 -Low ESR Input Caps
 -Low FSR Output Caps
 Input&Output Filter
 Low Impedance Layout
 -Small Current Loops
 -Fully shielded Power Inductor
 -Signal GND is separated and quiet

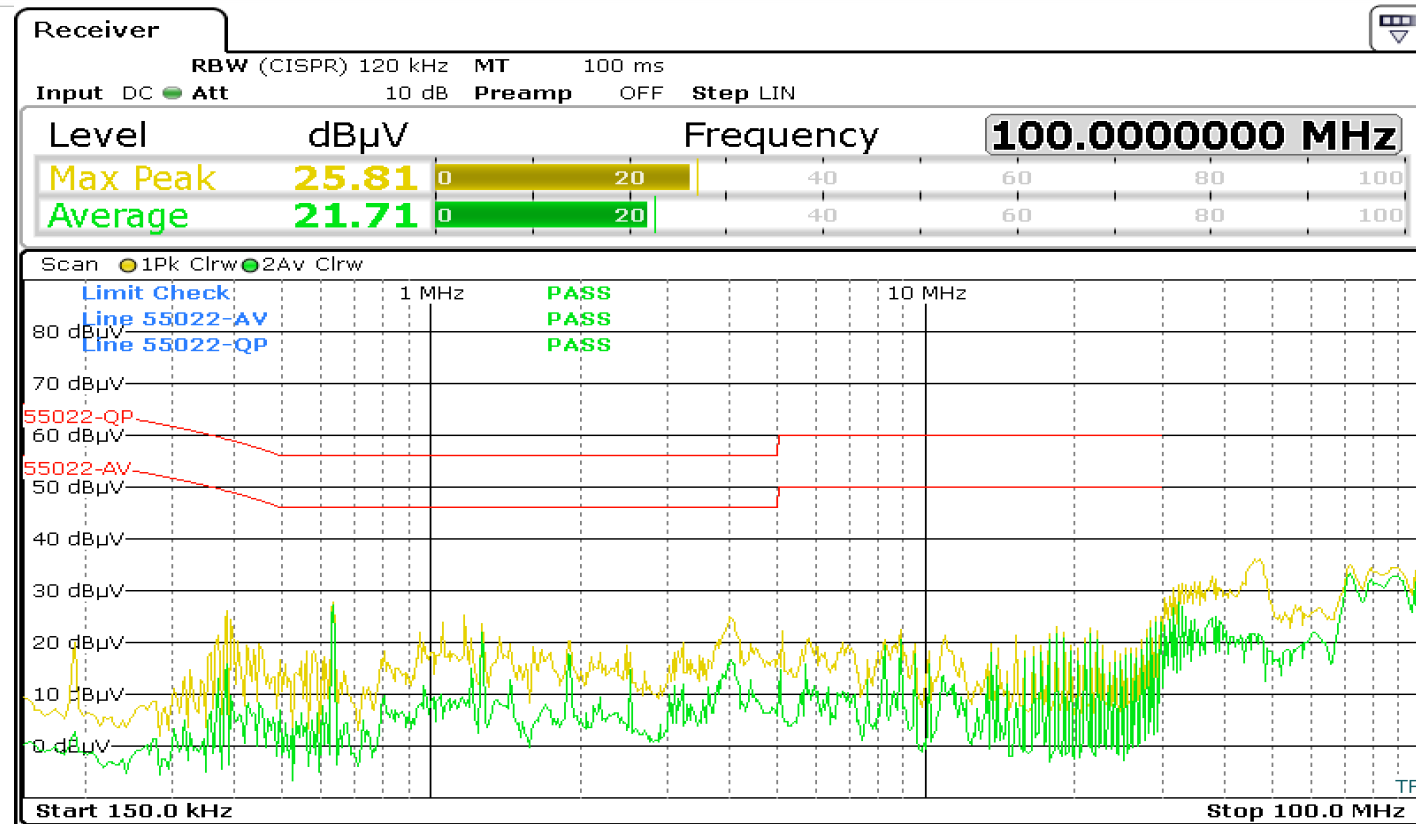


A Boost Converter is critical at the Output!!

Boost converter Good Example



Boost converter Good Example

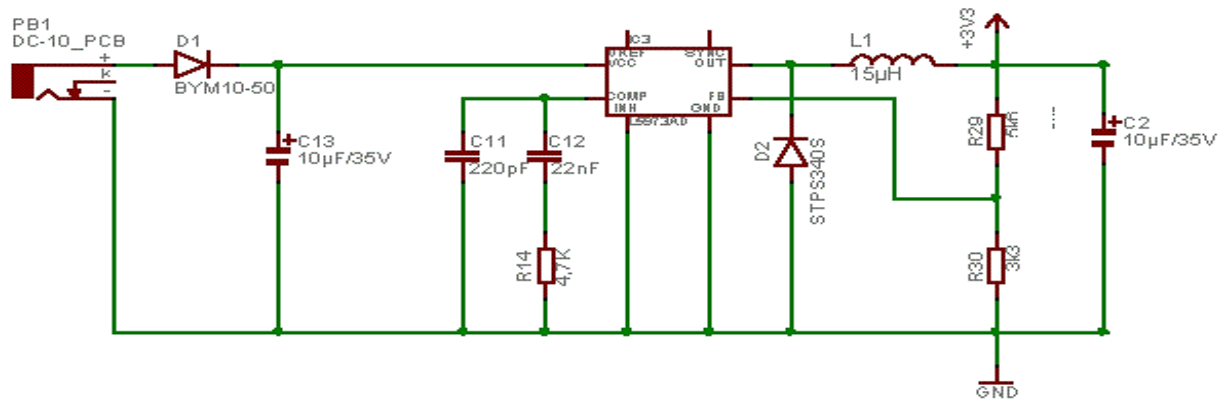




EXAMPLES FOR BAD DESIGN

Example for Bad Design

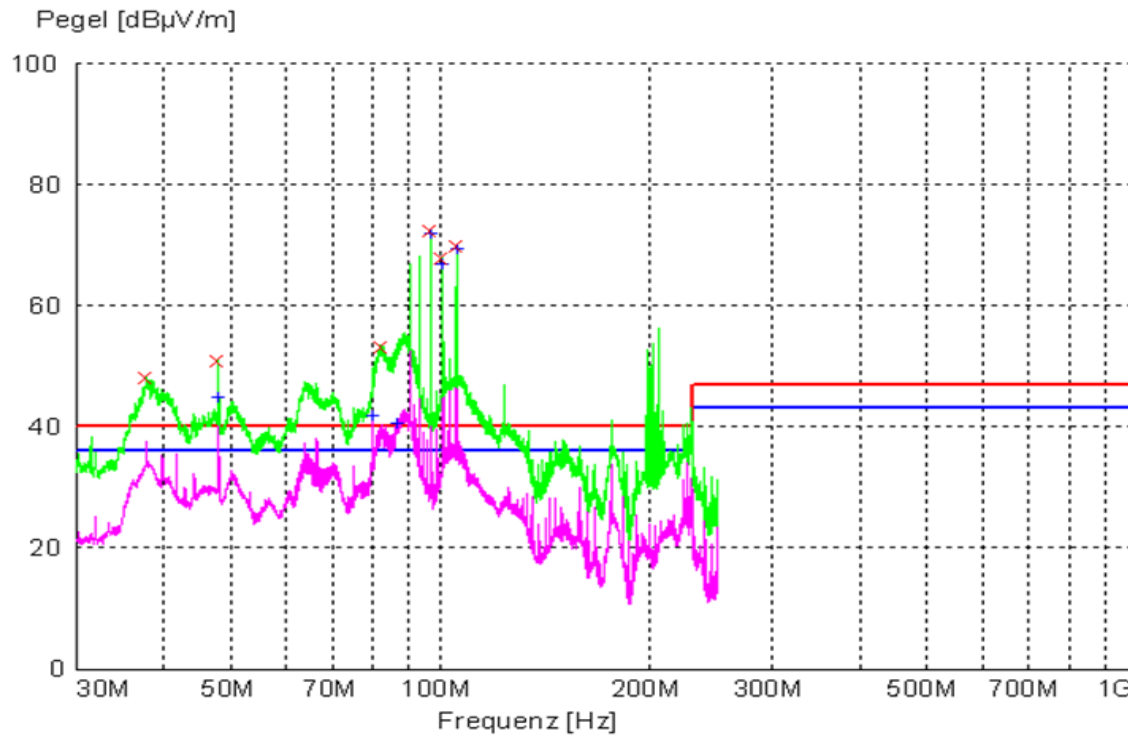
- Uninsulated DC/DC converter



- No input filter
- Bad Layout

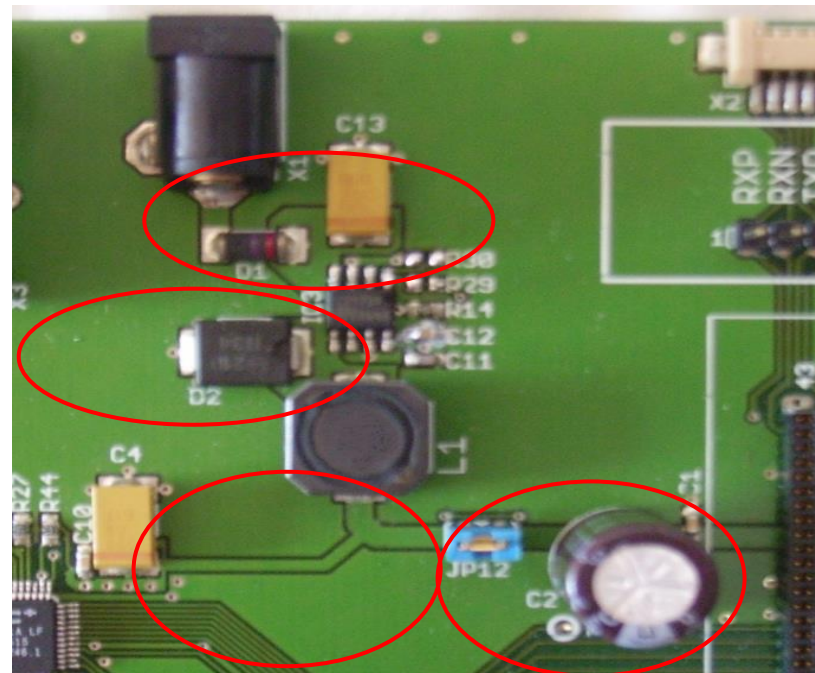
Example for Bad Design

- High emissions for radiated
- Limits over shooted



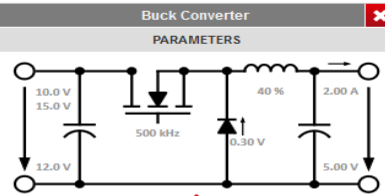
Example for Bad Design

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





DESIGN TOOLS



PARAMETERS

Input
 Vin_min 10 V Vin_nom 12 V Vin_max 15 V

Output
 Vout 5 V Iout 2 A

Switch
 fsw 500 kHz

Inductor
 ΔI 40 %

Diode
 Vf 0.3 V

Display details

Filters: Type = Single | Ir ≤ 2.00 A | Isat ≥ 2.40 A | 5.28 μH ≤ L ≤ 9.80 μH

Series	Order Code	Spec	Type	L	RDC,typ	Ir	Isat	Size	Length	Width	Ht
WE-MAPI	74438356056	PDF	Single	5.60 μH	68.0 mΩ	2.80 A	4.60 A	4020	4.1 mm	4.1 mm	
WE-TPC	744071056	PDF	Single	5.60 μH	20.0 mΩ	4.00 A	4.00 A	8043	8.0 mm	8.0 mm	
WE-TPC	7440650068	PDF	Single	6.80 μH	25.0 mΩ	4.20 A	3.60 A	1028	10 mm	10 mm	
WE-TPC	7440650082	PDF	Single	8.20 μH	28.5 mΩ	3.80 A	2.80 A	1028	10 mm	10 mm	
WE-TPC	7440660062	PDF	Single	6.20 μH	16.5 mΩ	4.30 A	4.50 A	1038	10 mm	10 mm	
WE-SPC	74408943068	PDF	Single	6.80 μH	51.0 mΩ	2.00 A	2.70 A	4838	4.8 mm	4.8 mm	

74438356056

WE-MAPI - Single
5.60 μH · 68.0 mΩ
2.80 A · 4.60 A

744071056

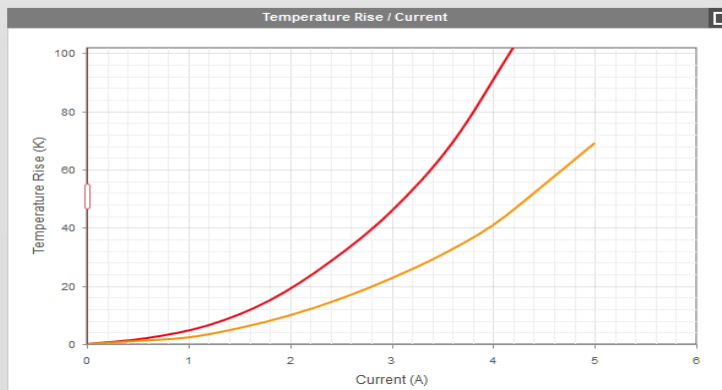
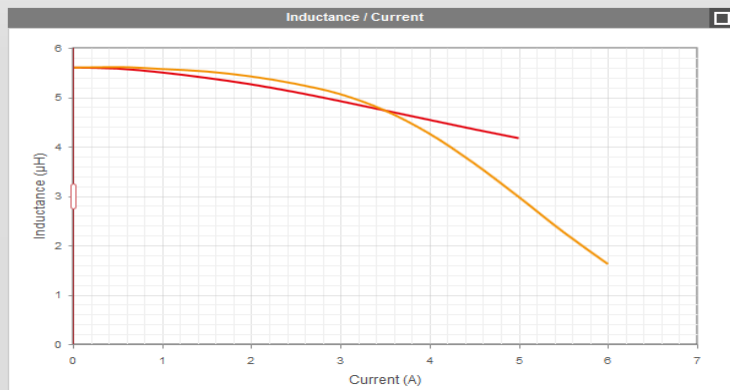
WE-TPC - Single
5.60 μH · 20.0 mΩ
4.00 A · 4.00 A

Please, register to add more parts

Share

Free Samples

Tidy Up





Simulation – WEBENCH

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

My Designs/Projects English | 日本語 | 简体中文 | 繁體中文 | 한국어 | Русский язык | Português | Deutsch | Welcome

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RECOMMENDED PARTS

Try WEBENCH Visualizer
Compare all designs in seconds

Efficiency

WEBENCH® Optimizer

Lowest BOM Cost

Smallest Footprint

Highest Efficiency

WEBENCH® Visualizer

Switching Regulator
LM3102

Open Design

Design Note	High Efficiency
Topology	Buck
Footprint (mm2)	340
Efficiency (%)	87%
Frequency (kHz)	315
BOM Cost	\$4.59

Switching Regulator
LM25576

Open Design

Design Note	Fast Transient R...
Topology	Buck
Footprint (mm2)	278
Efficiency (%)	85%
Frequency (kHz)	361
BOM Cost	\$5.69

Switching Regulator
LM22670-ADJ

Open Design

Design Note	Adjustable for V...
Topology	Buck
Footprint (mm2)	348
Efficiency (%)	83%
Frequency (kHz)	388
BOM Cost	\$4.51

Switcher Solutions

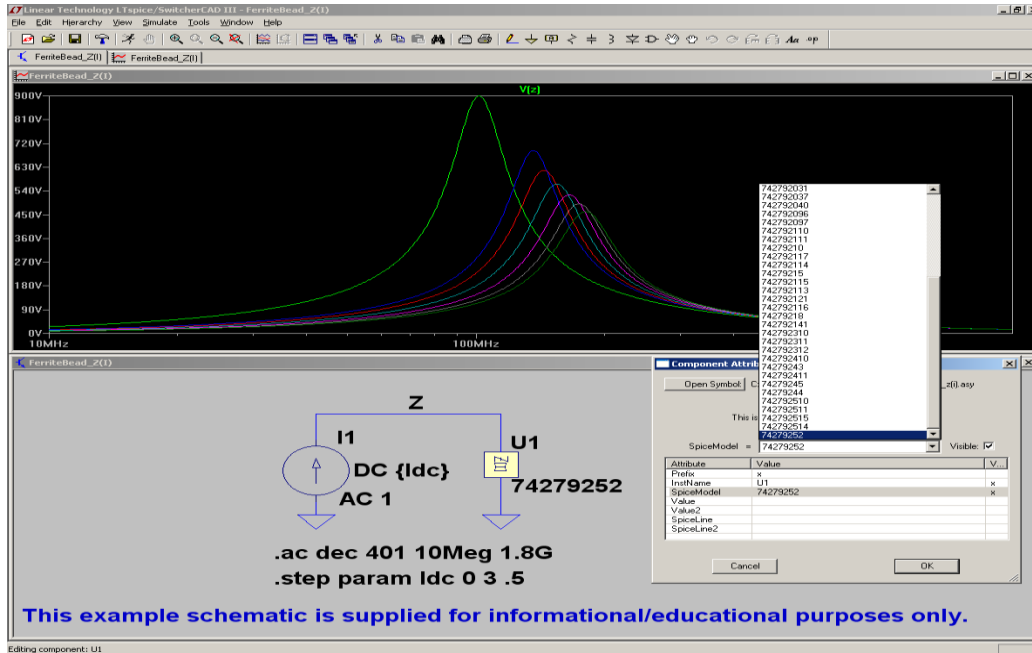
Switcher Solutions: (146 found) Show All Columns Show Alternate Topologies Show Only Modules

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



Simulation – LTSpice IV

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

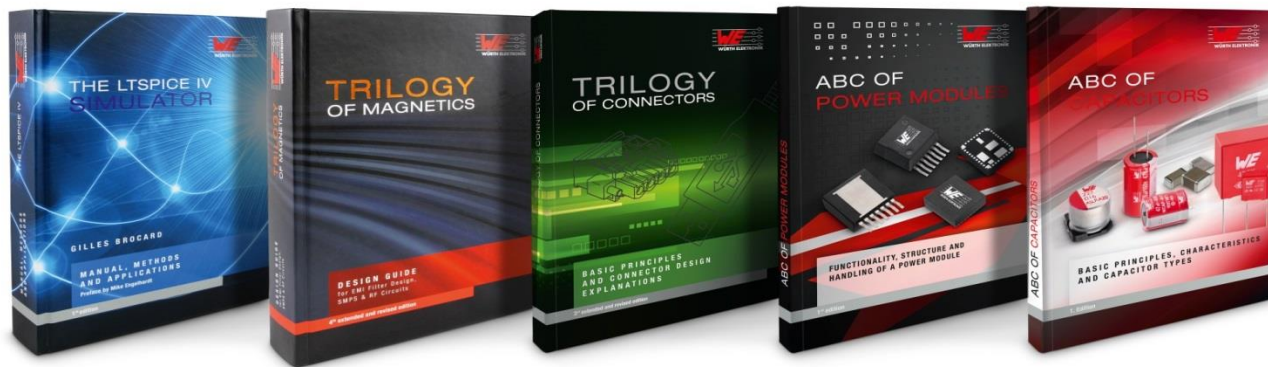


Select Stock Inductor

L[μH]	Mfg	Part No.	Ip[A]	Rise[μs]
6.8	Würth Elektronik	744029006 WE-TPC	0.650	0.290
10.0	Würth Elektronik	744029100 WE-TPC	0.950	0.390
1.2	Würth Elektronik	744030001 WE-TPC	1.100	0.088
2.2	Würth Elektronik	744030002 WE-TPC	0.800	0.136
3.3	Würth Elektronik	744030003 WE-TPC	0.720	0.180
4.7	Würth Elektronik	744030004 WE-TPC	0.500	0.230
6.8	Würth Elektronik	744030005 WE-TPC	0.430	0.290
10.0	Würth Elektronik	744030100 WE-TPC	0.350	0.610
22.0	Würth Elektronik	744030200 WE-TPC	0.250	1.150
1.5	Würth Elektronik	744031001 WE-TPC	1.550	0.035
2.5	Würth Elektronik	744031002 WE-TPC	1.250	0.045
3.6	Würth Elektronik	744031003 WE-TPC	1.100	0.085
4.7	Würth Elektronik	744031004 WE-TPC	0.900	0.085
6.8	Würth Elektronik	744031005 WE-TPC	0.750	0.125
10.0	Würth Elektronik	744031100 WE-TPC	0.560	0.165
100.0	Würth Elektronik	744031101 WE-TPC	0.180	2.050
15.0	Würth Elektronik	744031150 WE-TPC	0.450	0.290
22.0	Würth Elektronik	744031200 WE-TPC	0.360	0.360
33.0	Würth Elektronik	744031300 WE-TPC	0.320	0.545
47.0	Würth Elektronik	744031470 WE-TPC	0.250	0.800
1.0	Würth Elektronik	744042001 WE-TPC	2.600	0.020
1.8	Würth Elektronik	7440420018 WE-TPC	2.400	0.050
2.7	Würth Elektronik	7440420027 WE-TPC	2.200	0.050
3.3	Würth Elektronik	744042003 WE-TPC	1.800	0.050
3.9	Würth Elektronik	7440420039 WE-TPC	1.700	0.050
4.7	Würth Elektronik	744042004 WE-TPC	1.650	0.070
5.6	Würth Elektronik	744042005 WE-TPC	1.350	0.080
6.8	Würth Elektronik	744042006 WE-TPC	1.250	0.080
8.2	Würth Elektronik	744042008 WE-TPC	1.100	0.100
10.0	Würth Elektronik	744042100 WE-TPC	1.100	0.130
100.0	Würth Elektronik	744042101 WE-TPC	0.300	1.170
12.0	Würth Elektronik	744042120 WE-TPC	0.950	0.150
15.0	Würth Elektronik	744042150 WE-TPC	0.750	0.190
18.0	Würth Elektronik	744042180 WE-TPC	0.700	0.270
22.0	Würth Elektronik	744042200 WE-TPC	0.600	0.280
1.2	Würth Elektronik	7440430012 WE-TPC	2.900	0.015
1.8	Würth Elektronik	7440430018 WE-TPC	2.450	0.020
2.2	Würth Elektronik	7440430022 WE-TPC	2.350	0.027
2.7	Würth Elektronik	7440430027 WE-TPC	1.950	0.028
3.3	Würth Elektronik	744043003 WE-TPC	1.800	0.030
3.9	Würth Elektronik	7440430039 WE-TPC	1.550	0.050
4.7	Würth Elektronik	744043004 WE-TPC	1.700	0.050
5.6	Würth Elektronik	744043005 WE-TPC	1.300	0.070
6.8	Würth Elektronik	744043006 WE-TPC	1.250	0.080
8.2	Würth Elektronik	744043008 WE-TPC	1.050	0.090
10.0	Würth Elektronik	744043100 WE-TPC	1.000	0.095
100.0	Würth Elektronik	744043101 WE-TPC	0.290	0.550
12.0	Würth Elektronik	744043120 WE-TPC	0.950	0.100
15.0	Würth Elektronik	744043150 WE-TPC	0.750	0.120
18.0	Würth Elektronik	744043180 WE-TPC	0.700	0.150
22.0	Würth Elektronik	744043200 WE-TPC	0.600	0.160
220.0	Würth Elektronik	744043221 WE-TPC	1.008	0.095
33.0	Würth Elektronik	744043300 WE-TPC	0.550	0.183
47.0	Würth Elektronik	744043470 WE-TPC	0.450	0.218
68.0	Würth Elektronik	744043680 WE-TPC	0.400	0.310
1.2	Würth Elektronik	7440520012 WE-TPC	2.700	0.040
1.8	Würth Elektronik	7440520018 WE-TPC	3.000	0.030
2.5	Würth Elektronik	744052002 WE-TPC	2.700	0.040
3.0	Würth Elektronik	744052003 WE-TPC	2.400	0.040
3.3	Würth Elektronik	7440520039 WE-TPC	2.100	0.050

This example schematic is supplied for informational/educational purposes only.

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

If you still have questions?

Just call us: we try to help you

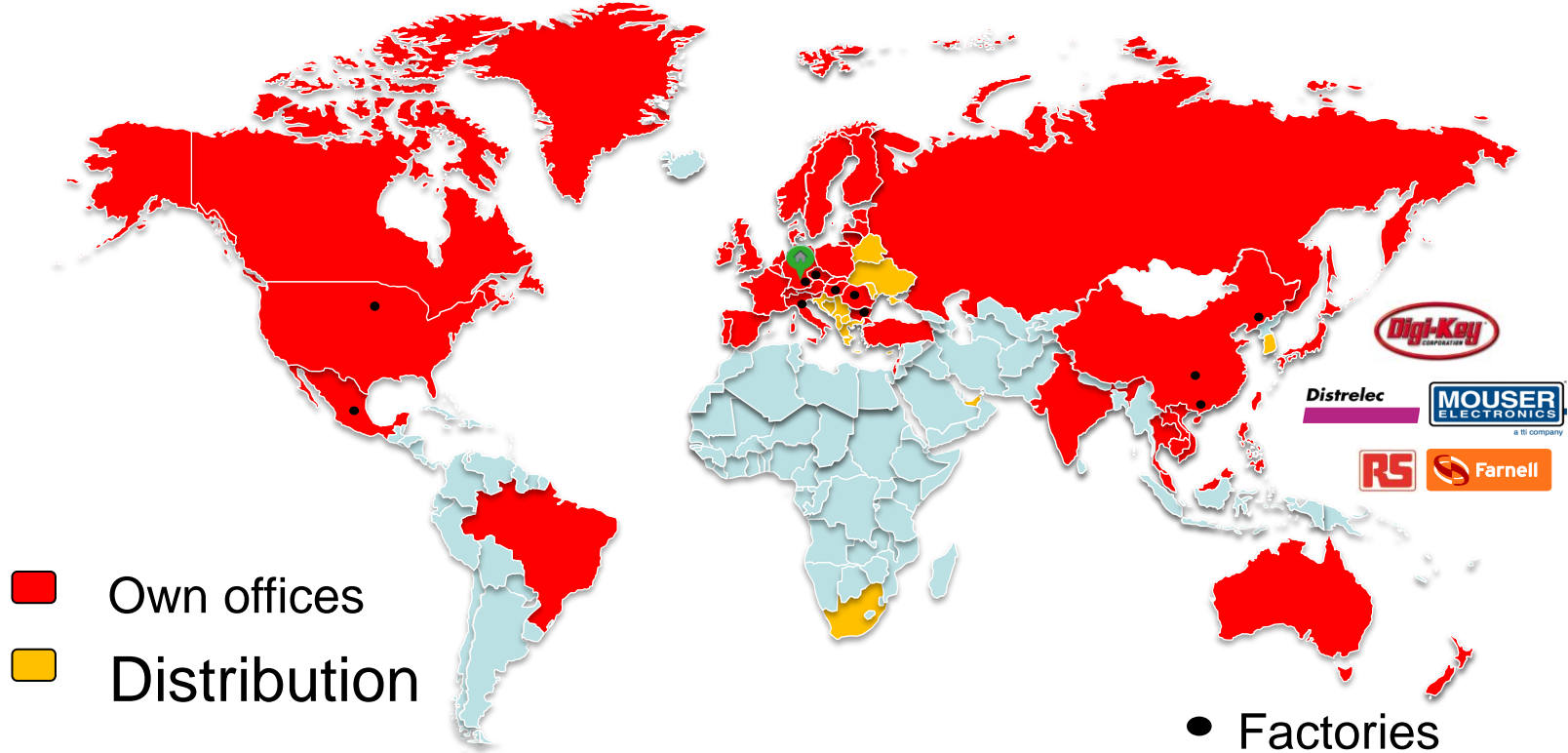
Don't give up !!!



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