WÜRTH ELEKTRONIK

High Power Converter – 150 W Buck-Boost in Detail

APEC 2019 in Anaheim

Capacitor Workshop PSMA

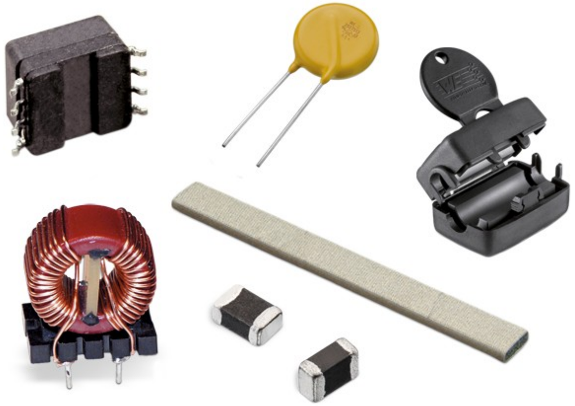
Andreas Nadler

Field Application Engineer

Short Introduction of Today‘s Presenter

Andreas Nadler

Field Application Engineer
EMC & Inductive Solutions



+49 7942945 4098

andreas.nadler@we-online.com

www.we-online.com

Background:

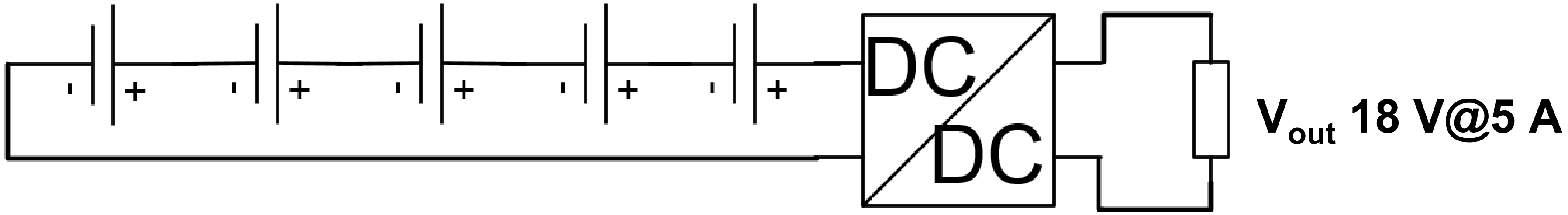
- Many years of experience as hardware engineer in the field of switched-mode power supplies, EMC and analogue circuit technology
- Since 2015 working as Field Application Engineer

Agenda

- What is the Purpose?
- Component Selection
- Layout Analysis & EMC Properties
- Efficiency and Temperature Measurement
- Conclusion

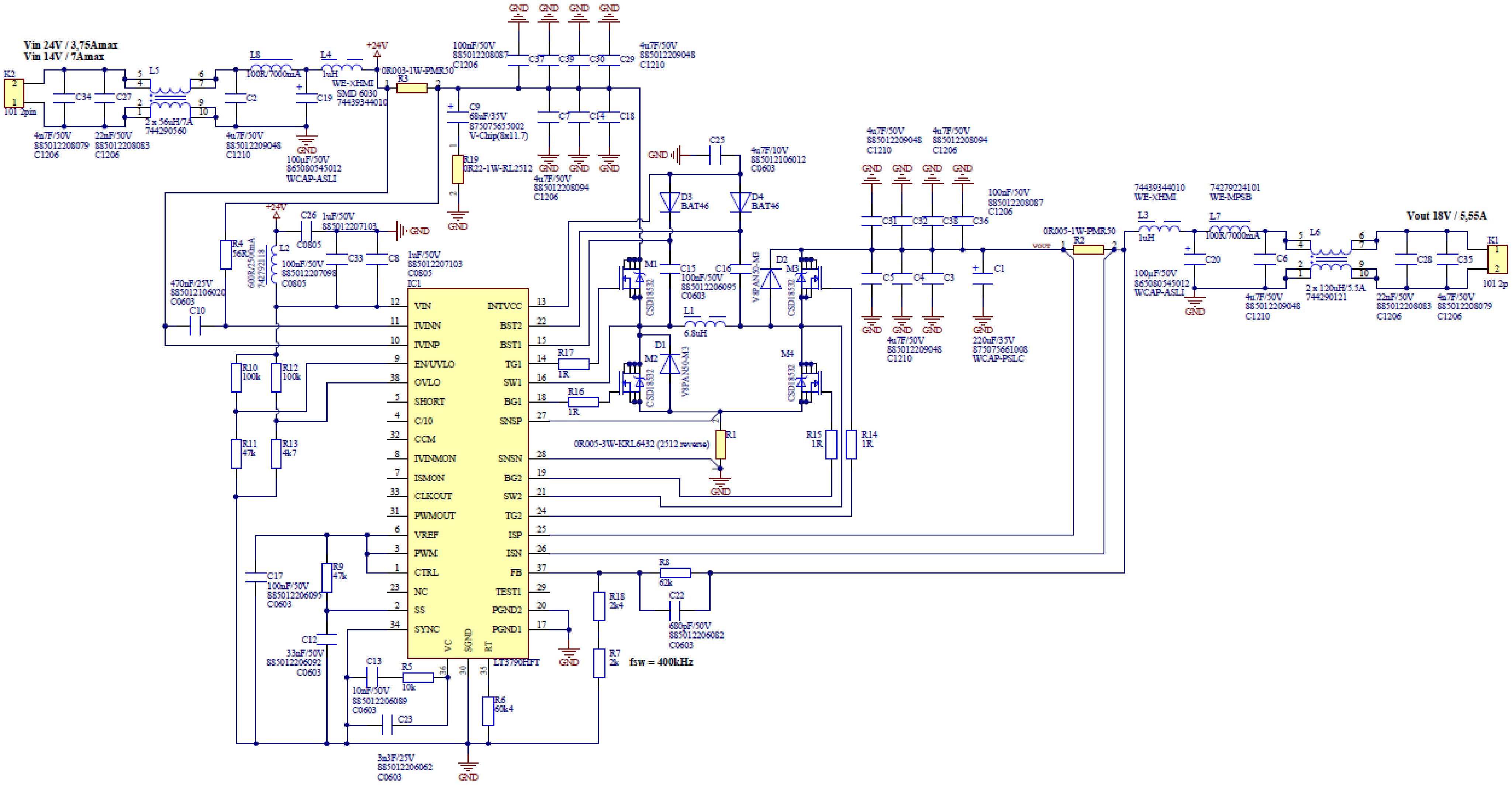
What is the Purpose?

- The voltage of a battery with 5 lithium ion cells in series should be regulated to stable 18 V_{DC}
- The voltage of a cell varies ~ 3.0 V to 4.2 V



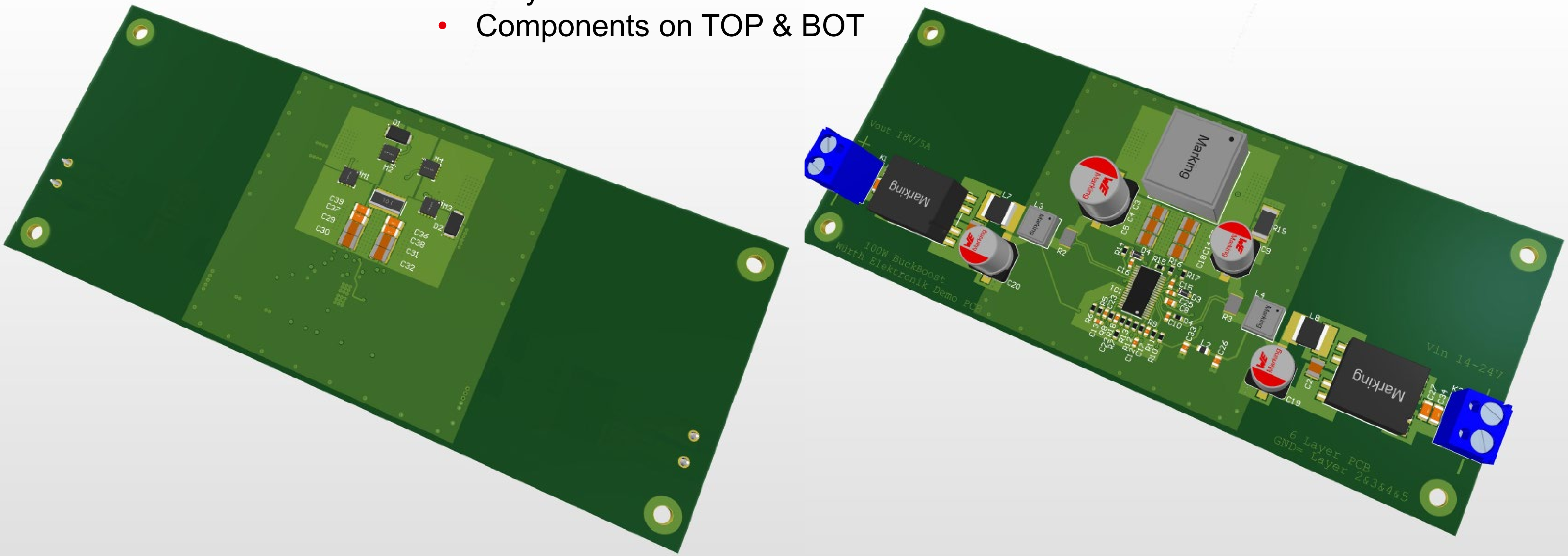
- 5 cells in series gives an input voltage range of 15 V to 21 V
- Continuous current of 5 A is required
- The DC/DC converter is to be designed for a input voltage range from 14 V to 24 V

Buck-Boost with LT3790 & external MOSFETs

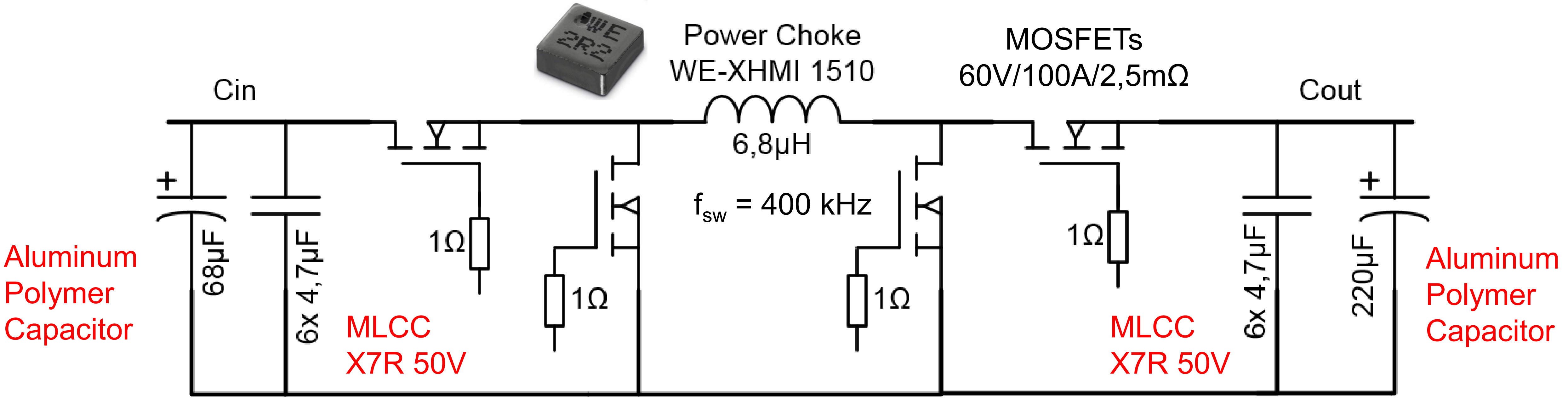


Buck-Boost with LT3790 & external MOSFETs

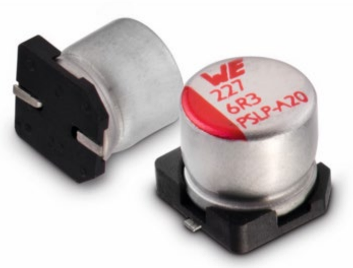
- 6 layer PCB
- Components on TOP & BOT



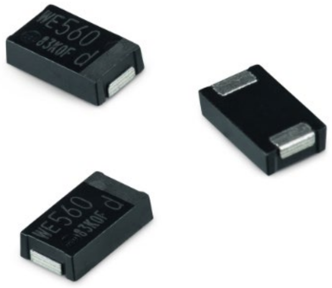
Power Stage with low ESR/ESL Capacitors



WCAP-CSGP



WCAP-PSLC

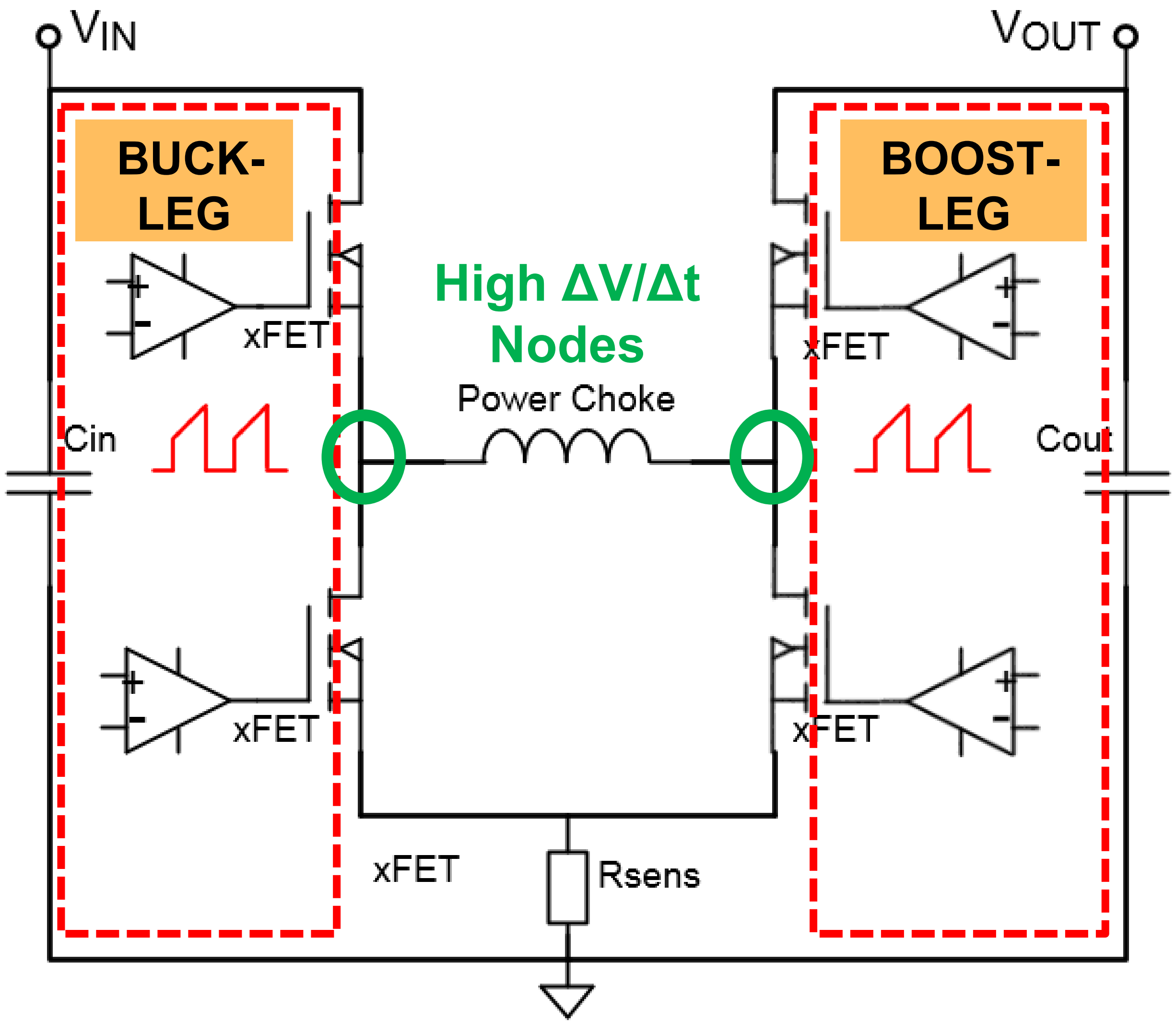


WCAP-PHGP

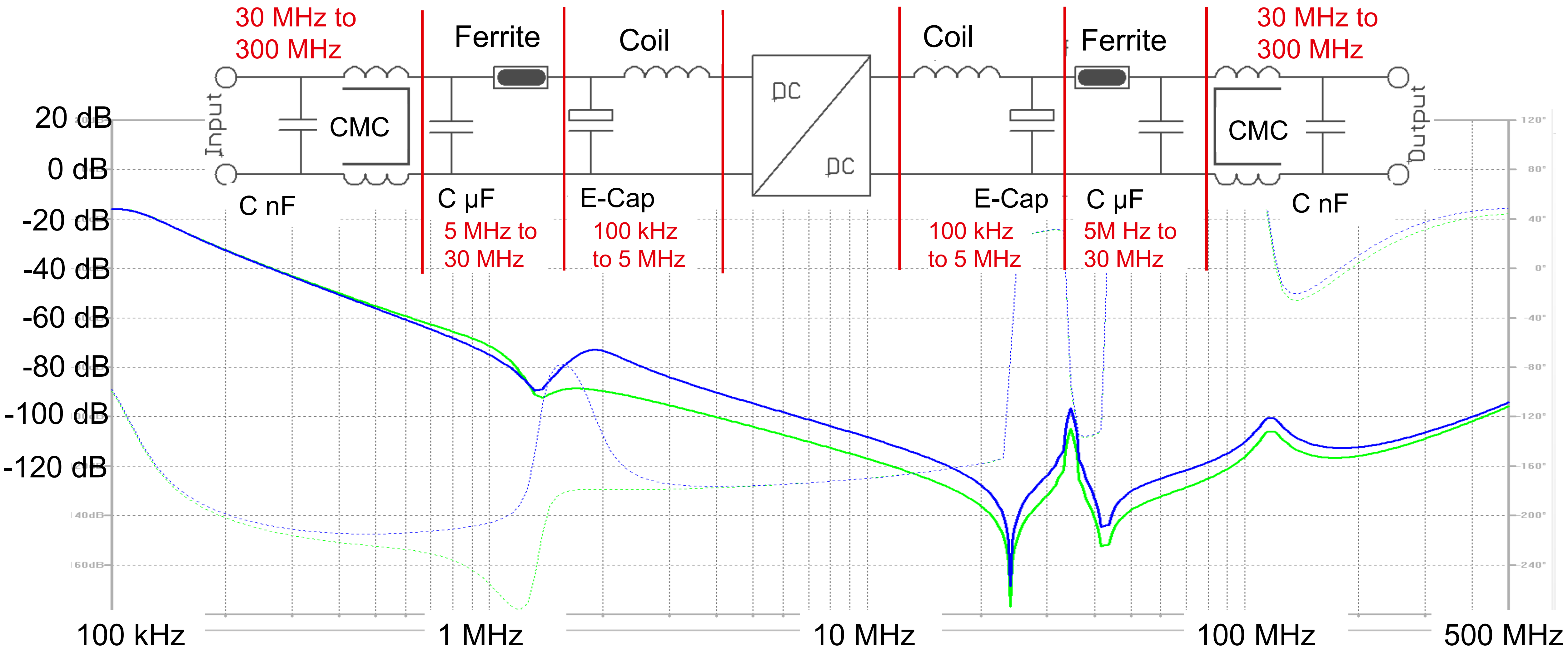
Critical ΔI/Δt Loops & high ΔV/Δt Nodes

Requirements for the design:

- **Long I/O connection cables (1 m)**
- **No shielding possible**
- **Emission Limits CISPR32 Class B**
- **Efficiency over 95% @ 100 W**



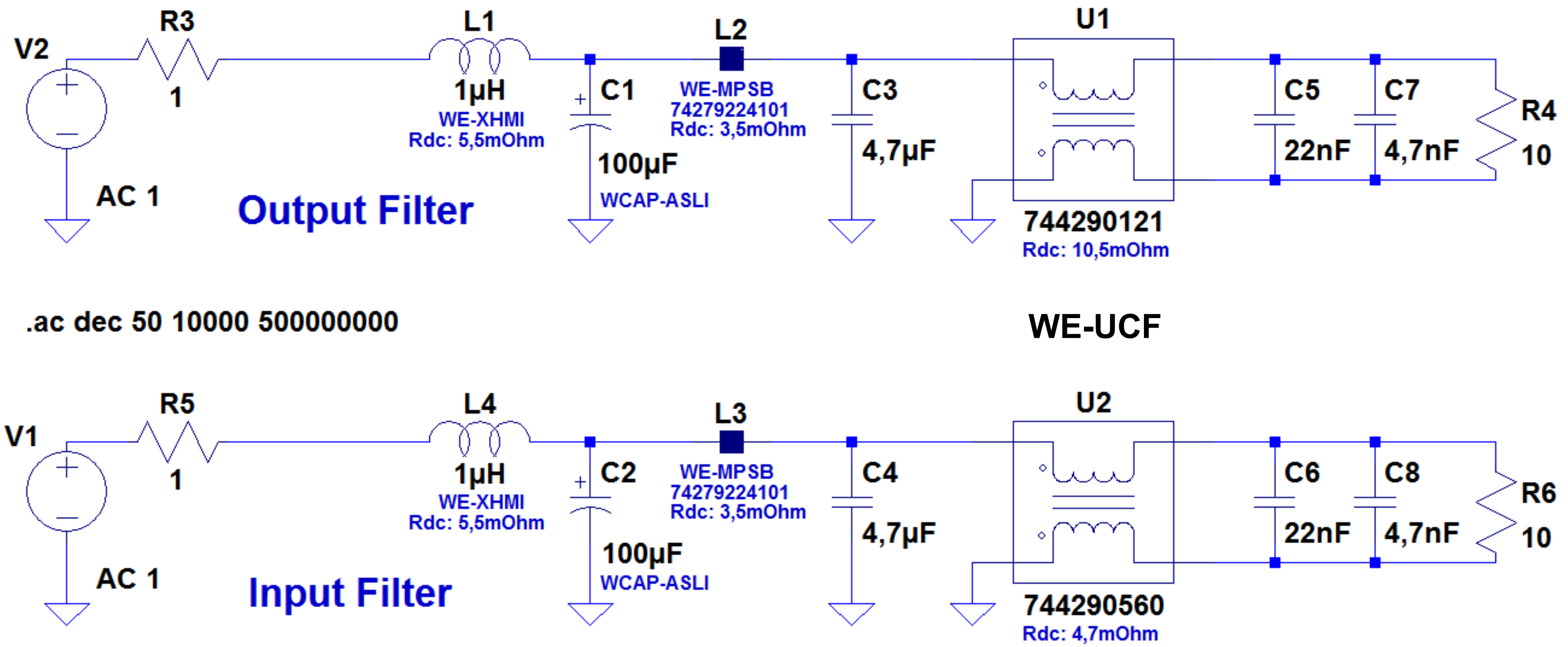
Simulation of the I/O Filter Components



Simulation of the I/O Filter Components in LTspice

All components are simulated with parasitic elements:

- **Losses on the output filter:** $I^2 * R_{dc} = 5.5\ A^2 * 30\ m\Omega = 907\ mW$
- **Losses on the input filter:** $I^2 * R_{dc} = 7\ A^2 * 18.4\ m\Omega = 902\ mW$



Calculation of the input capacitors (REDEXPERT)

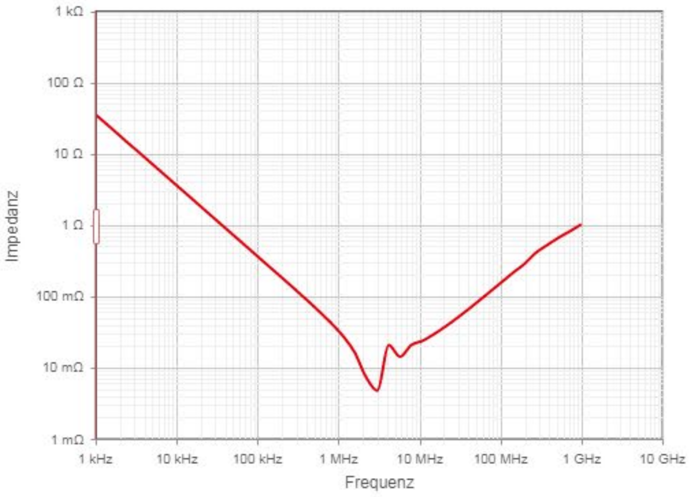
- **Calculation of input capacitors for max. allowed AC voltage**

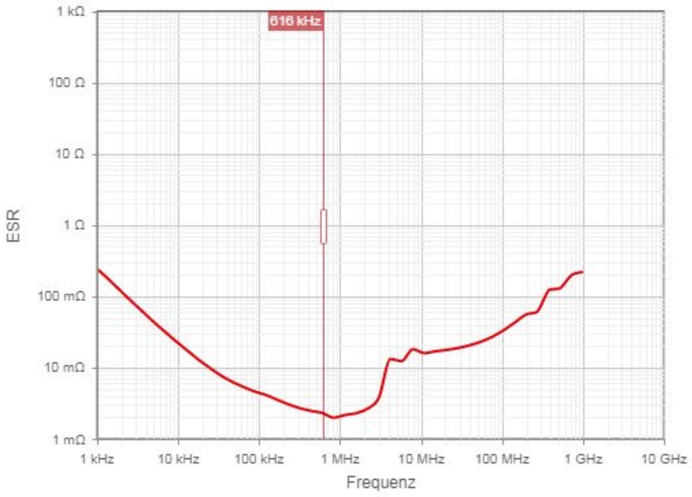
$$C_{in} \geq \frac{D \times (1 - D) \times I_{outmax}}{\Delta V_{in\,pp} \times f_{sw}} \qquad C_{in} \geq \frac{0.78 \times (1 - 0.78) \times 5.5A}{100\ mVpp \times 400\ kHz} = 21\ \mu F$$

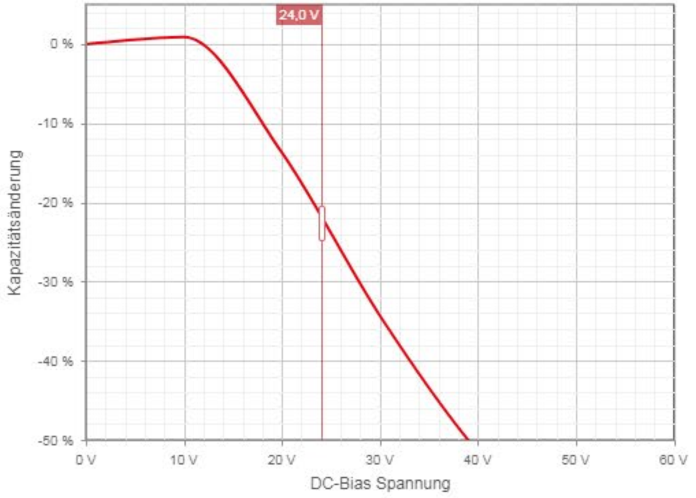
- **Selected : 6 x 4.7 µF / 50 V / X7R = 28.2 µF - 20% DC-Bias = 23 µF**

Filter: Bauform = 1210 | Typ = X7R | C ≥ 4,70 µF | U_R ≥ 50,0 V — 1 Produkt

Artikel-Nr.	Serie	Bauform	Spez	Typ	Artikelb...	C	U_R	R_{iso}	ESR @6...	ΔC(V_{DC}-...	DF	Q	Länge	Breite	Höhe	T_{max}	Montage
885012209048	WCAP-CS...	1210	PDF	X7R	X7R12104...	4,70 µF	50,0 V	> 20,0 MΩ	2,29 mΩ	-21,9 %	5,0 %		3,20 mm	2,50 mm	1,25 mm	125°C	SMT

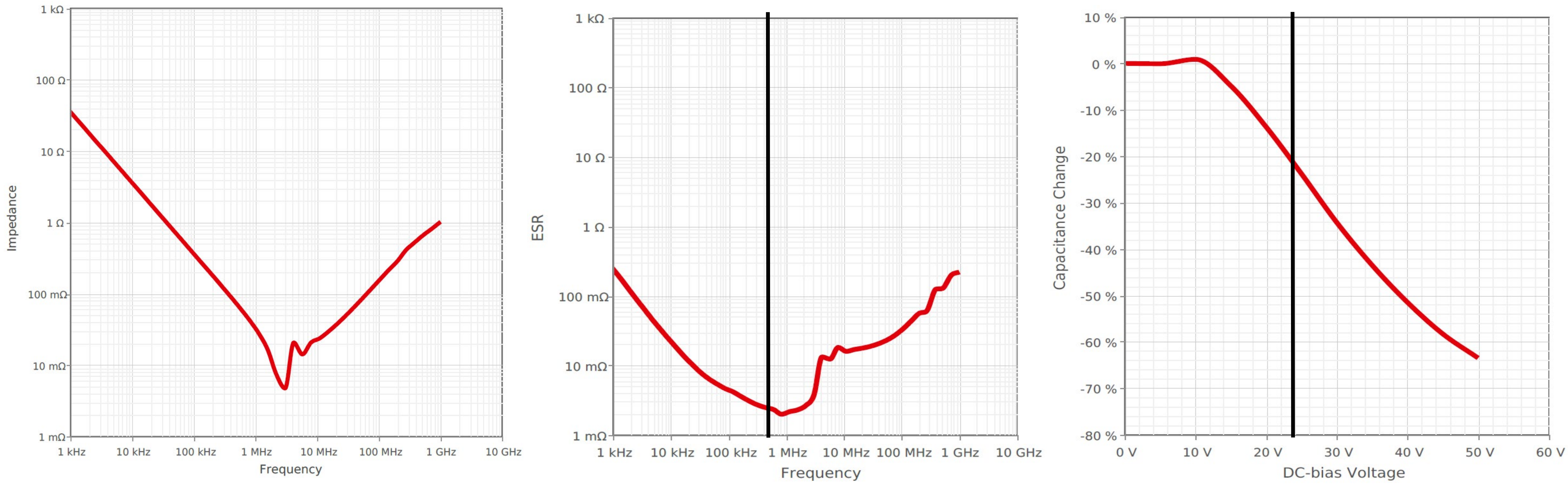






Calculation of the input capacitors (REDEXPERT)

Order Code	Series	Size	In	Spec	Ty...	Description	C	V_R	R_{iso}	ESR @400 kHz	$\Delta C(V_{DC\text{-}Bias})$ @24.0 V	DF
885012209048	WCAP-CSGP	1210		PDF	X7R	X7R1210475K050DFCT10000	4.70 µF	50.0 V	> 20.0 MΩ	2.53 mΩ	-21.8 %	5.0 %



Filter Damping to fulfil Middlebrooks Criteria

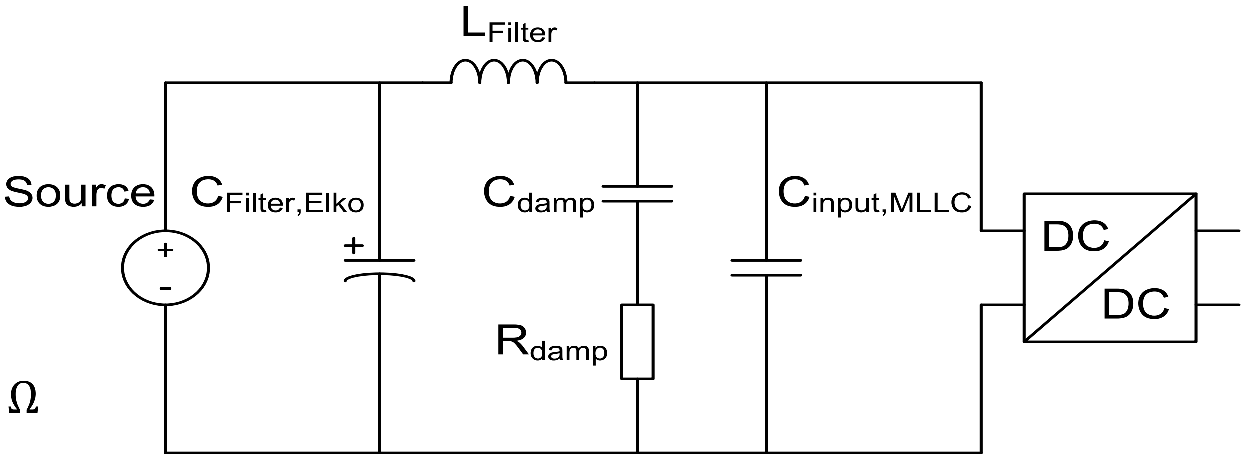
- **Calculation of the Aluminum Polymer Capacitor**

$$C_{damp} \sim 4 \times C_{inMLCC} = 4 \times 23\ \mu F = 92\ \mu F$$

- **Selected: 68 µF => WCAP-PSLC with 35 V**

$$R_{damp} = \sqrt{\frac{L_{Filter}}{C_{inMLCC}}}$$

$$R_{damp} = \sqrt{\frac{1\mu H}{23\mu F}} = 0.2\ \Omega$$



WRIS-KSKE

- ***Details for DC/DC filter design, stability etc. → Wurth Electronic AppNote ANP044***

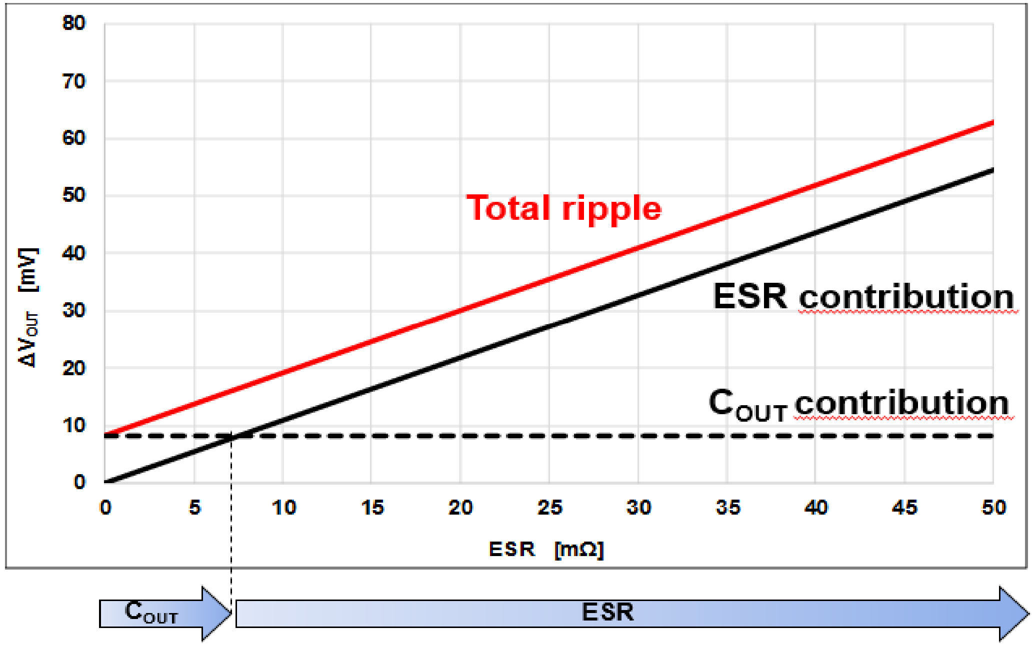
Calculation of the Output Capacitors

- **Maximum coil current ΔI in Buck Mode = 1.6 A**

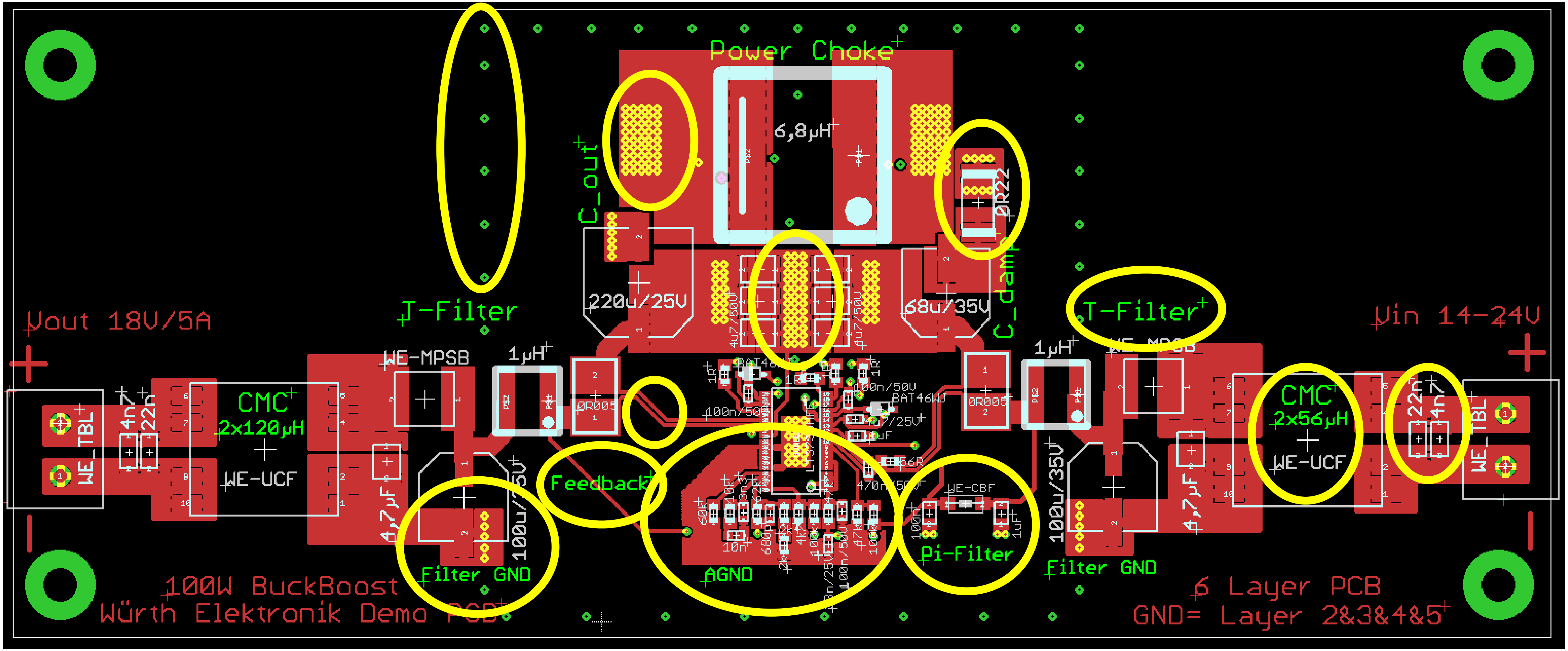
$$C_{OUT} \geq \frac{\Delta I_L}{8 * V_{OUT\ ripple} * f_{SW}} \qquad C_{OUT} \geq \frac{1.6\ A}{8 * 20mV * 400\ kHz} = 25\ \mu F$$

- **Selected:**
  - **6 x 4.7 µF / 50 V / X7R**
  - **28.2 µF – 15% DC-Bias = <u>24 µF</u>**

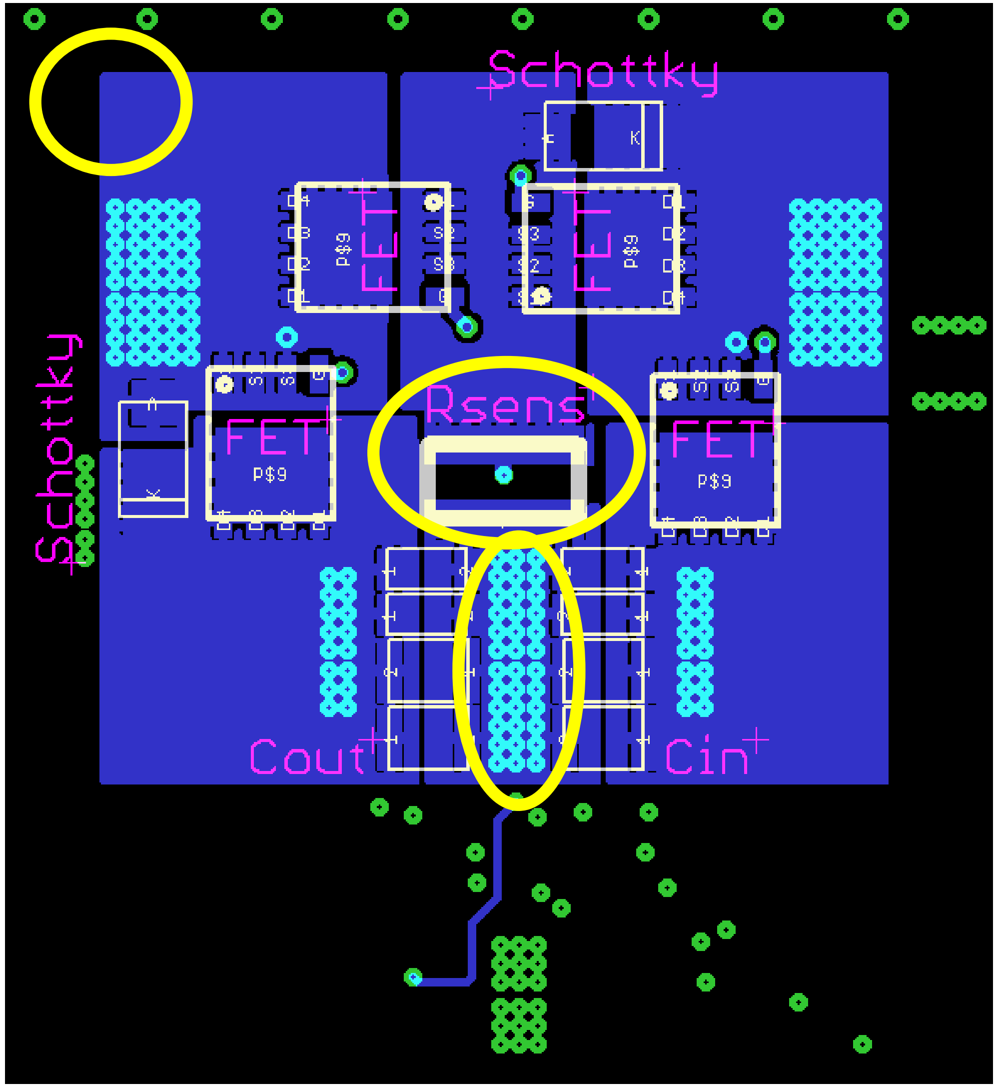
- **<u>Plus:</u>**
  - **Aluminum Polymer Capacitor for transient response**
  - **WCAP-PSLC 220 µF / 25 V**

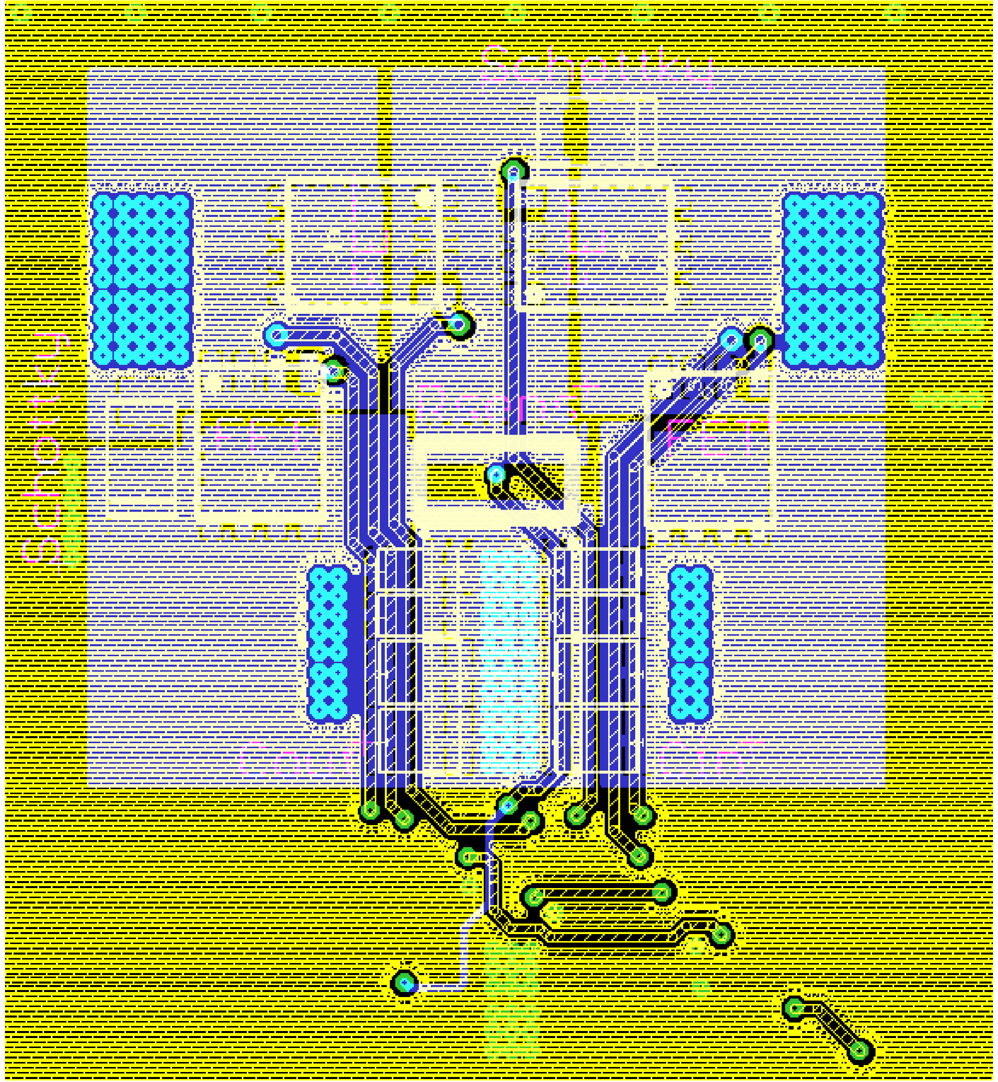


Analysis of the Layout - TOP



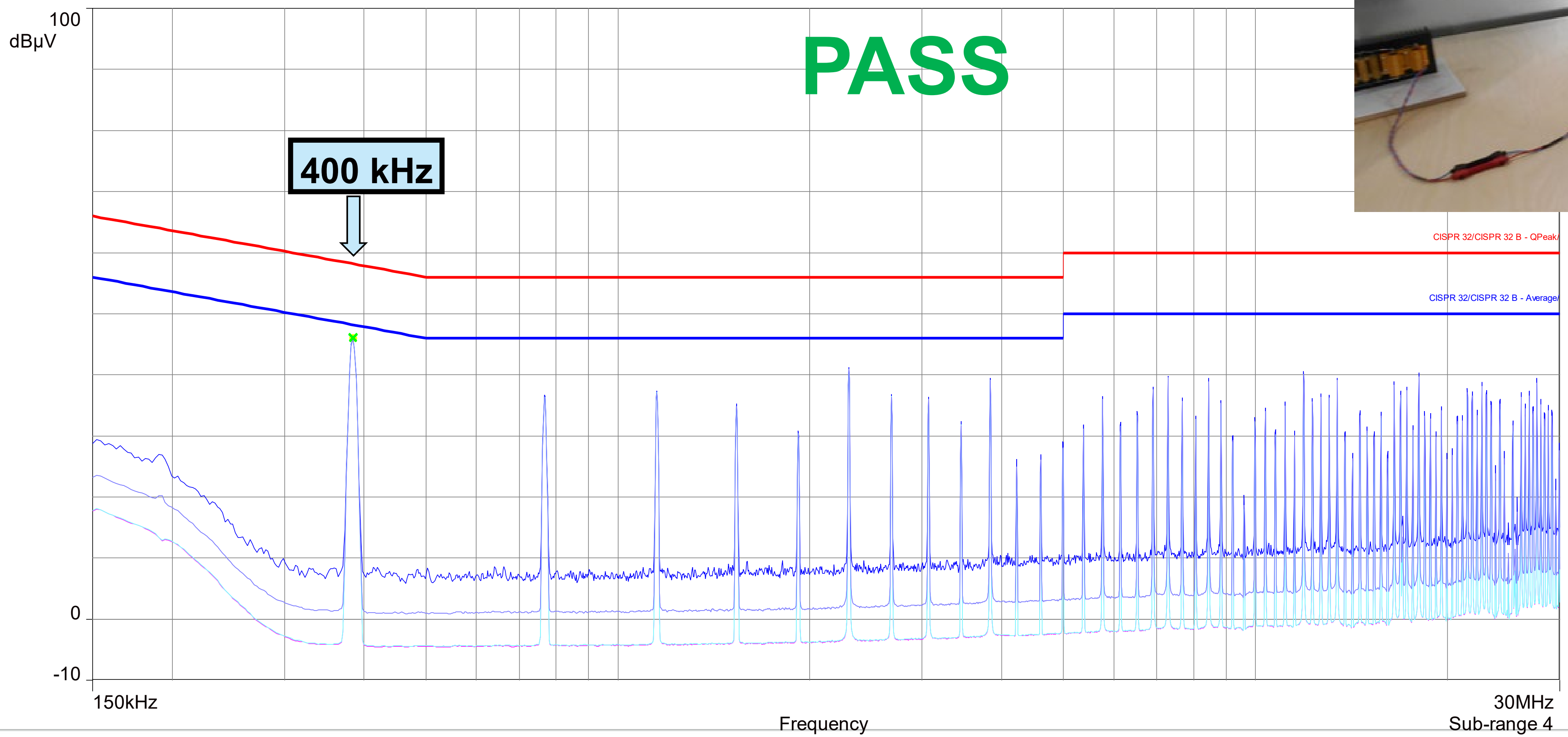
Analysis of the Layout - BOTTOM & Inner Layers

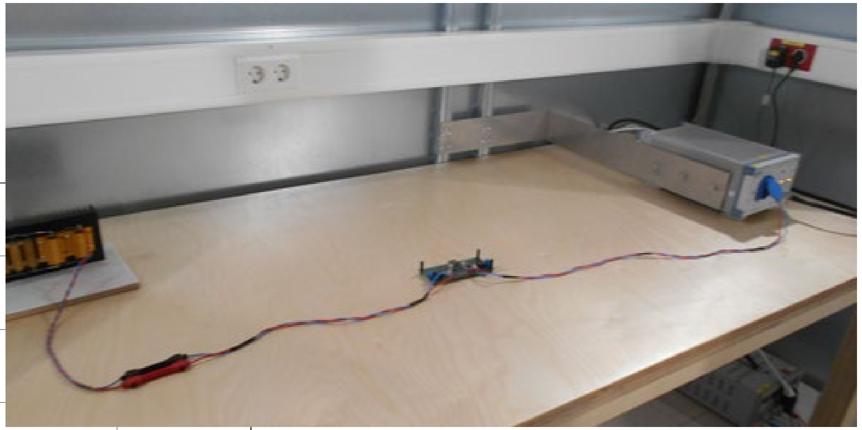




EMC - Conducted Emission Test

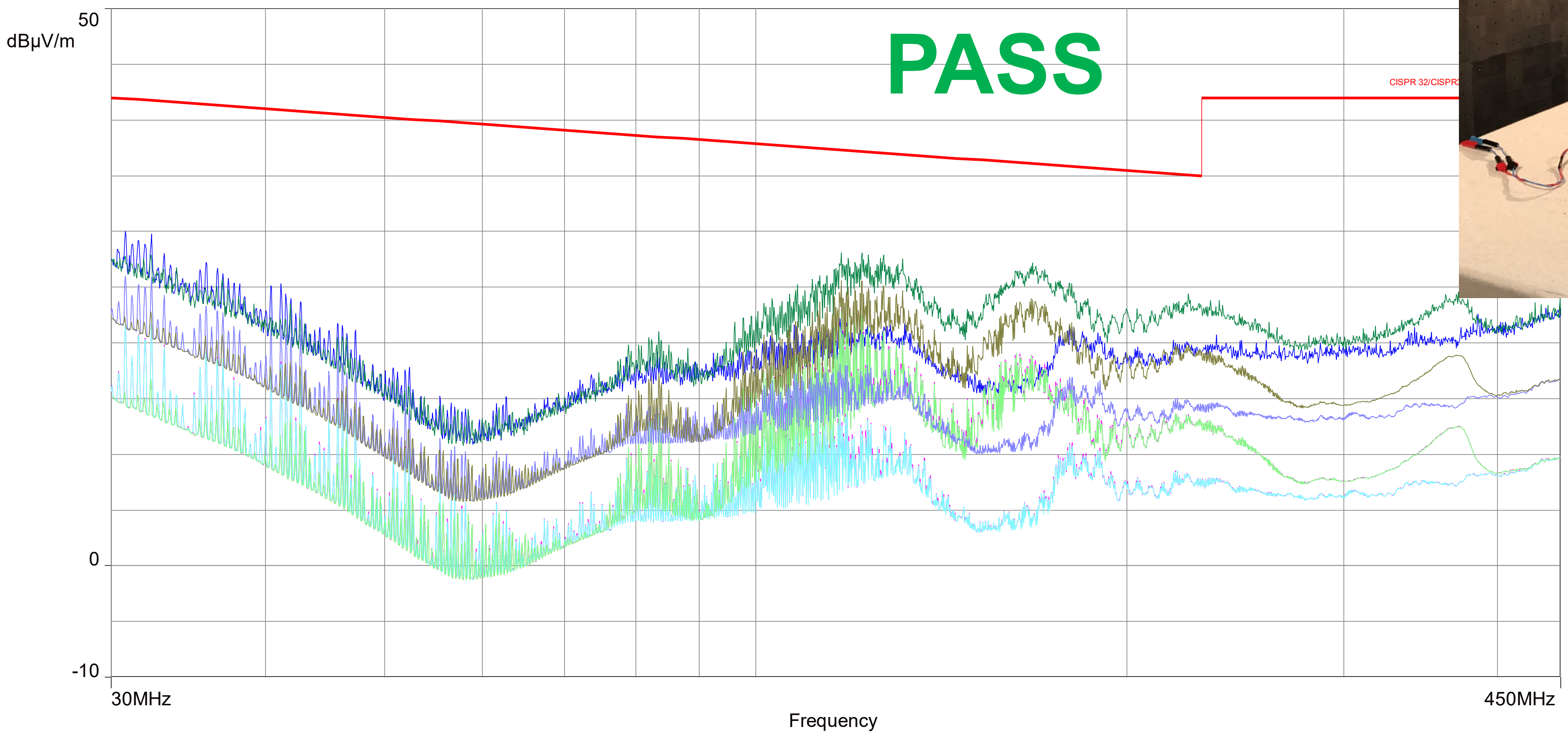
- **Conducted emission 150 kHz – 30 MHz**
- **Buck Mode 100 W**

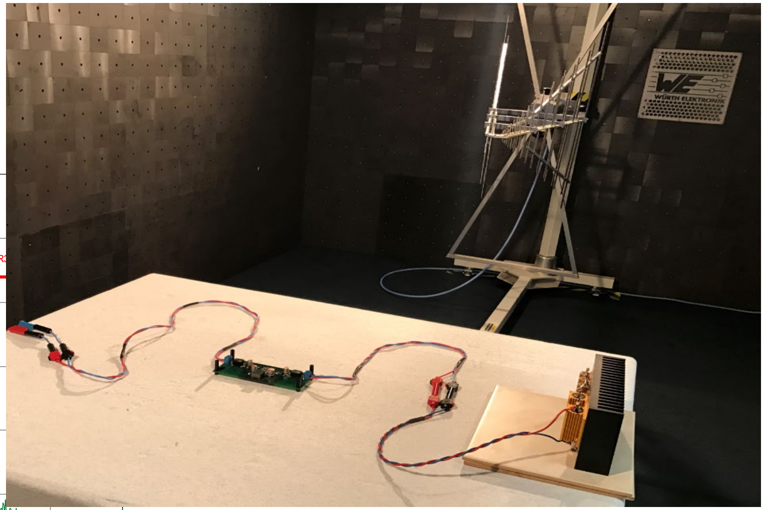




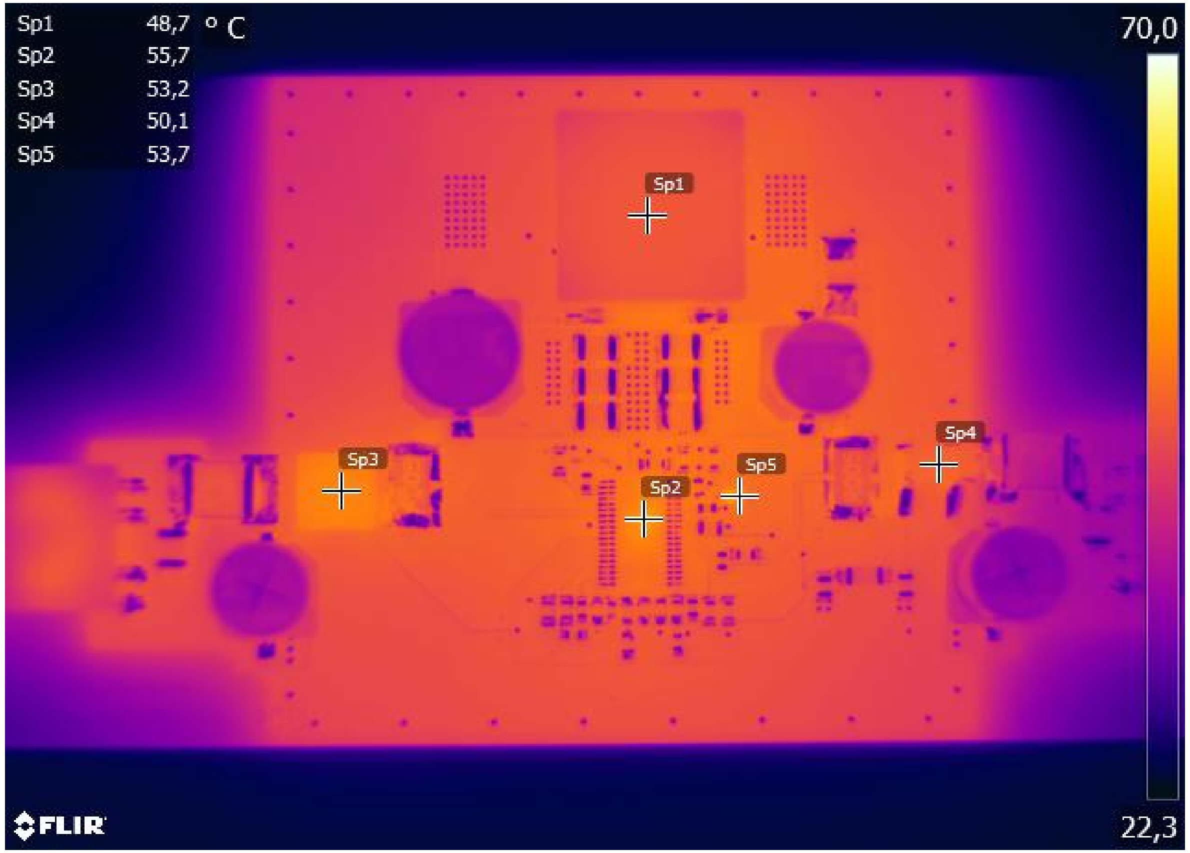
EMC - Radiated Emission Test

- Radiated emission 30 MHz – 450 MHz
- Buck Mode 100 W





Temperature of the PCB & Components



TOP side

BOTTOM side

Efficiency @ 100W → Buck Mode 96,5% & Boost Mode 95,6%

Questions?