Status of Aachen-1B Activities

Lutz Feld, Katja Klein, Martin Lipinski, Joelle Savelberg

RWTH Aachen University

DRD7.1.b Meeting, February 7th, 2025

Objective of Work

- **Characterization of novel DC-DC converters, both standalone and in-system**
  - Efficiency, line and load regulation, conducted and radiated noise, thermal aspects, silicon module noise performance, minimization of material, integration aspects...
  - Profit from previous projects:
    - DC-DC conversion powering system of the CMS Phase-1 pixel detector (based on FEAST2)
    - Hybrid circuits for the CMS Phase-2 Outer Tracker upgrade with a 2-step DC-DC scheme (based on bPOL12V, bPOL2V5)

- Explore the use of DC-DC converters with a high conversion ratio in silicon modules, using **bPOL48V by CERN**

- Characterization of **DC-DC converters developed by FH Dortmund**, targeting an application in pixel module readout chips

Funding Situation

- Relevant funding agency: BMBF (Bundesministerium für Bildung und Forschung)
- Funding period: 7/2024-6/2027
- In Germany a consortium named “Si-D“ has been formed: groups working on DRD3 and DRD7
- Common proposal but with separate parts (and separate funding) for each institute
    - Each group proposes its work packages and timeline, with milestones

Outcome:

- We received funding for 1 PhD position, travel money, and 45k invest money for setups & PCB production
- PhD Position filled in September: Joelle Savelberg
    - Fully trained and on top of all setups, she did all measurements

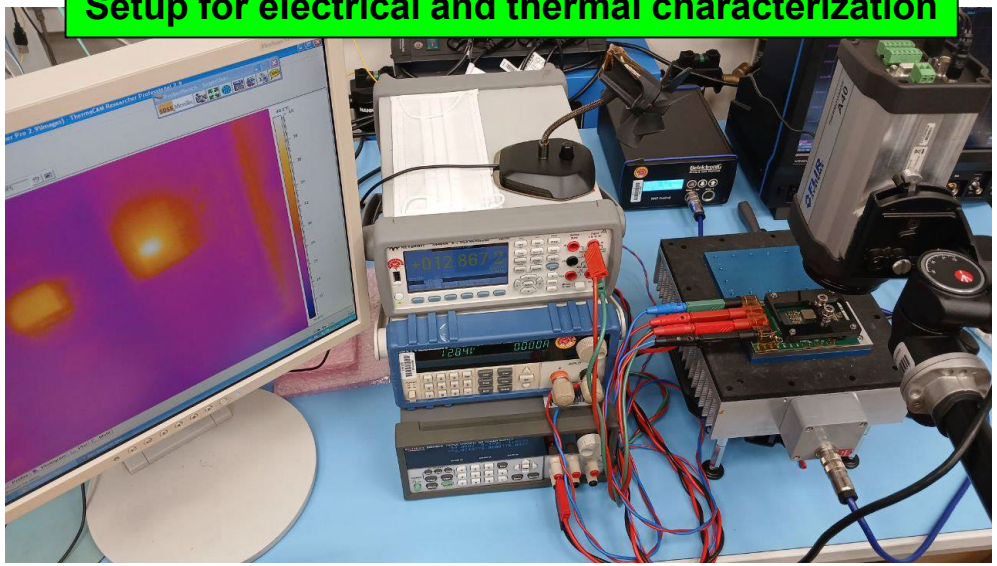
Work Plan

Nr.	Arbeitspakete bzw. Meilensteine (Kurzbezeichung)	2024 III	2024 IV	2025 I	2025 II	2025 III	2025 IV	2026 I	2026 II	2026 III	2026 IV	2027 I	2027 II
1	WP1: Integration and characterization of the CERN DC-DC board	x	x										
2	MS1: Operation of a silicon strip module with 48V DC-DC conversion provided from an external PCB			o									
3	WP2: Development of an optimized DC-DC board			x	x	x							
4	MS2: Operation of a silicon strip module with 48V DC-DC conversion using a plug-on board					o							
5	WP3: Integration of a bPOL48V DC-DC converter into a tracker hybrid						x	x	x	x	x	x	x
6	MS3: Operation of a silicon strip module with on-hybrid 48V DC-DC conversion												o
7	WP4: Characterization of an on-chip DC-DC converter targeting integration into a generic pixel readout chip	x	x	x	x	x	x	x	x	x	x	x	x
8	MS4: On-chip DC-DC converter fully characterized												o

Status of Setups

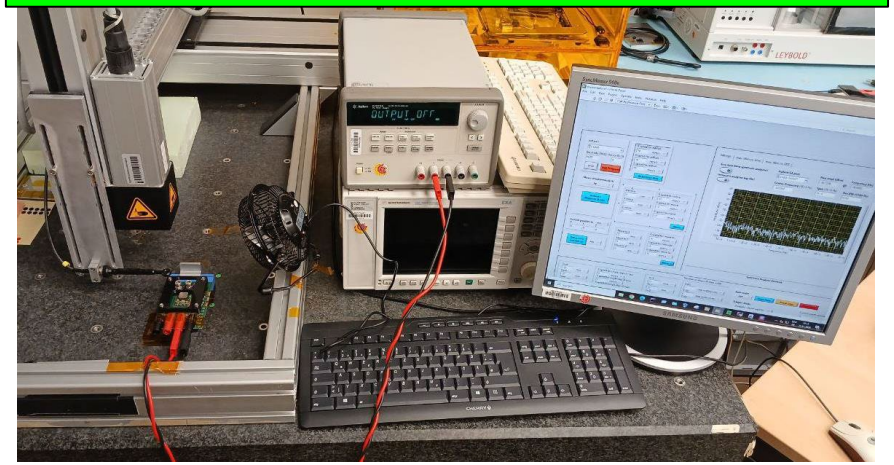
Several setups have been re-commissioned
and adapted to the bPOL48V and are fully operational:

Setup for electrical and thermal characterization



Setup for conductive Common and Differential Mode noise measurements

Setup for measurements of radiated emissions

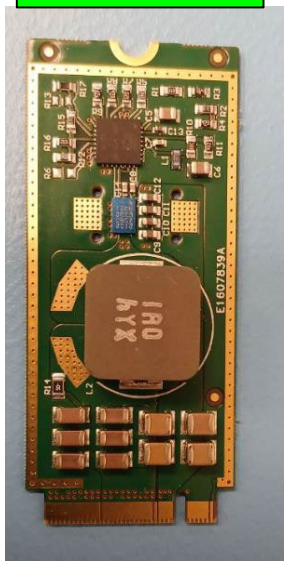


Available Prototypes

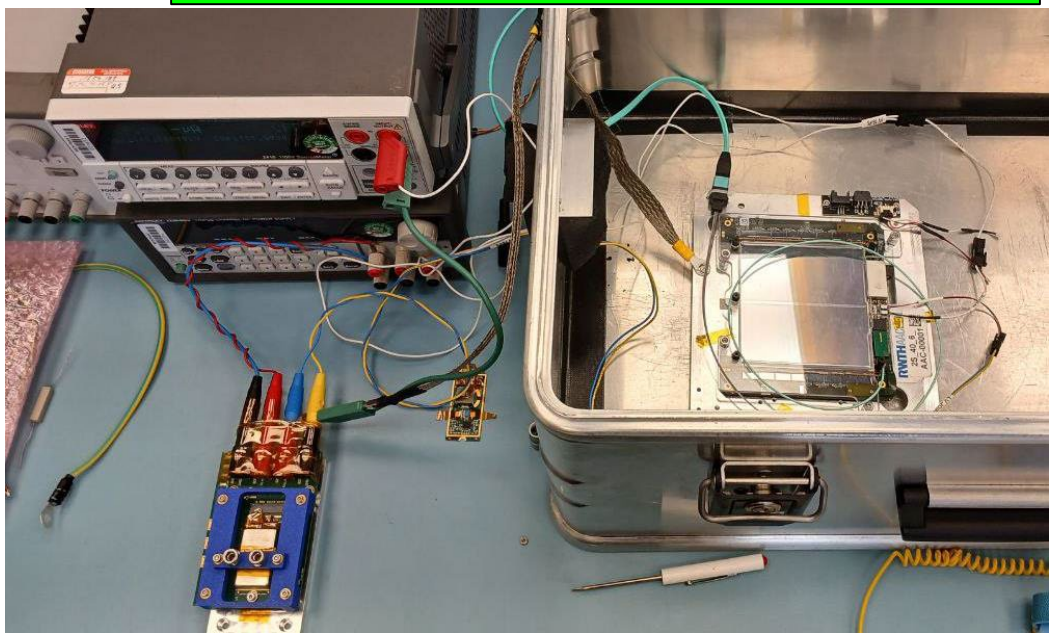
- We received two generations of bPOL48V prototypes from CERN and started to characterize them
  - EDA-04668 and EDA-04866
  - First results were discussed with Stefano Michelis in December
- Measurements with a “2S” CMS silicon strip module have also recently started (3-step scheme for the moment)
- All measurements shown are for the EDA-04866 board, unless noted otherwise

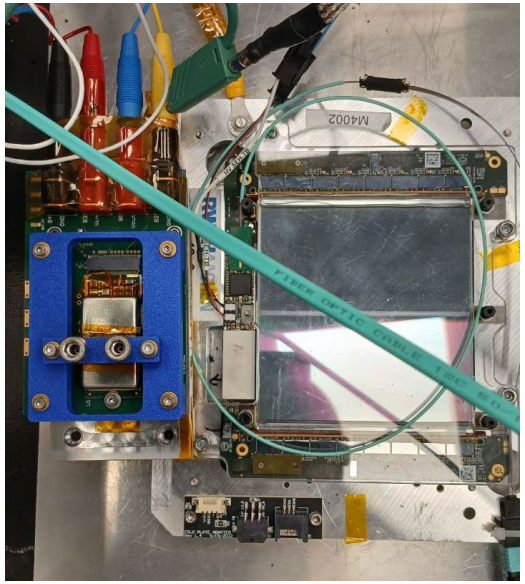
EDA-04668

EDA-04866



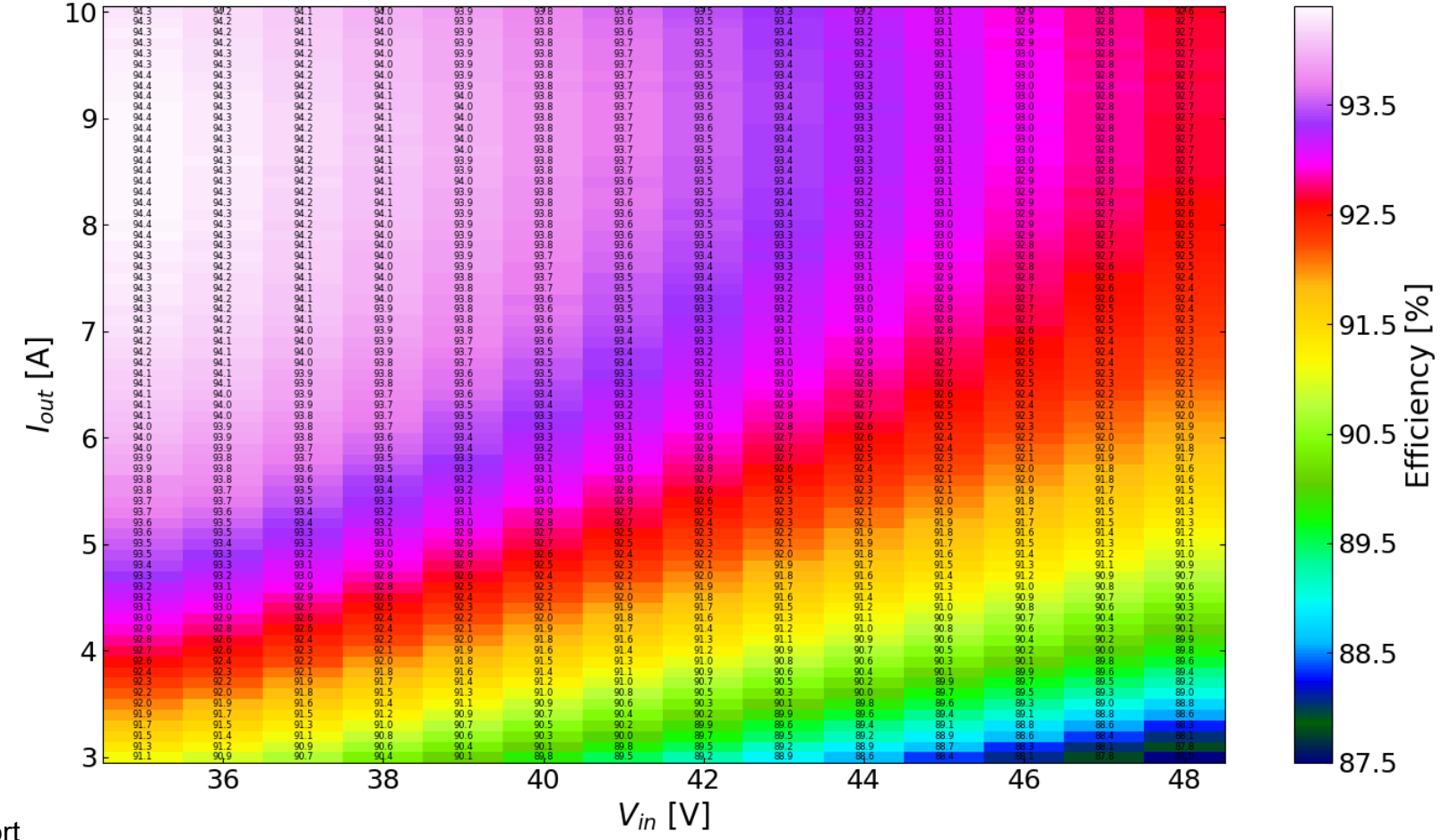
EDA-04866 powering a CMS silicon module (via bPOL12V and bPOL2V5)





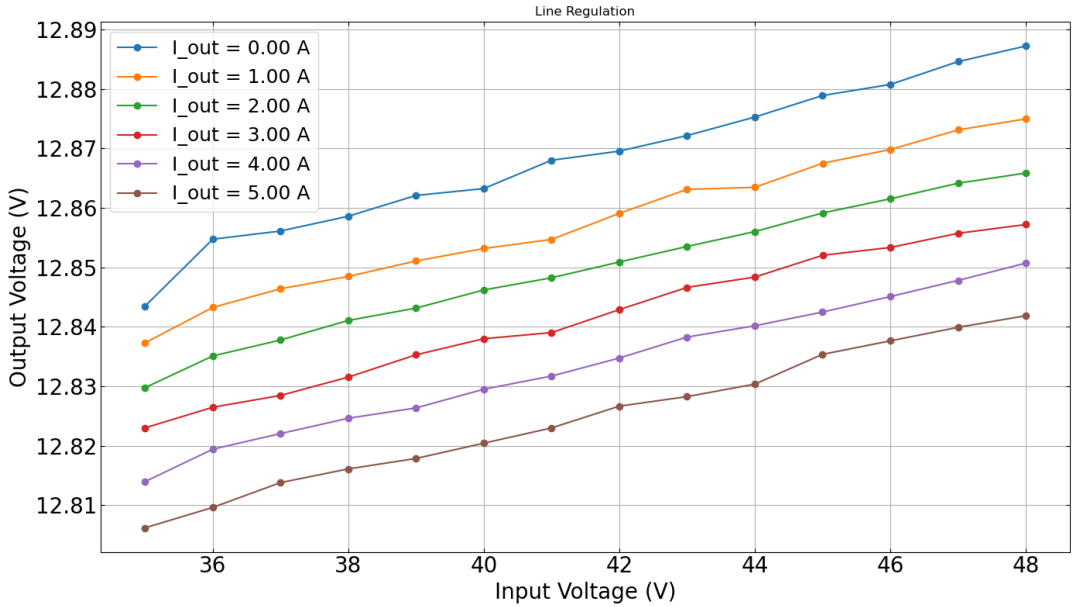
Efficieny

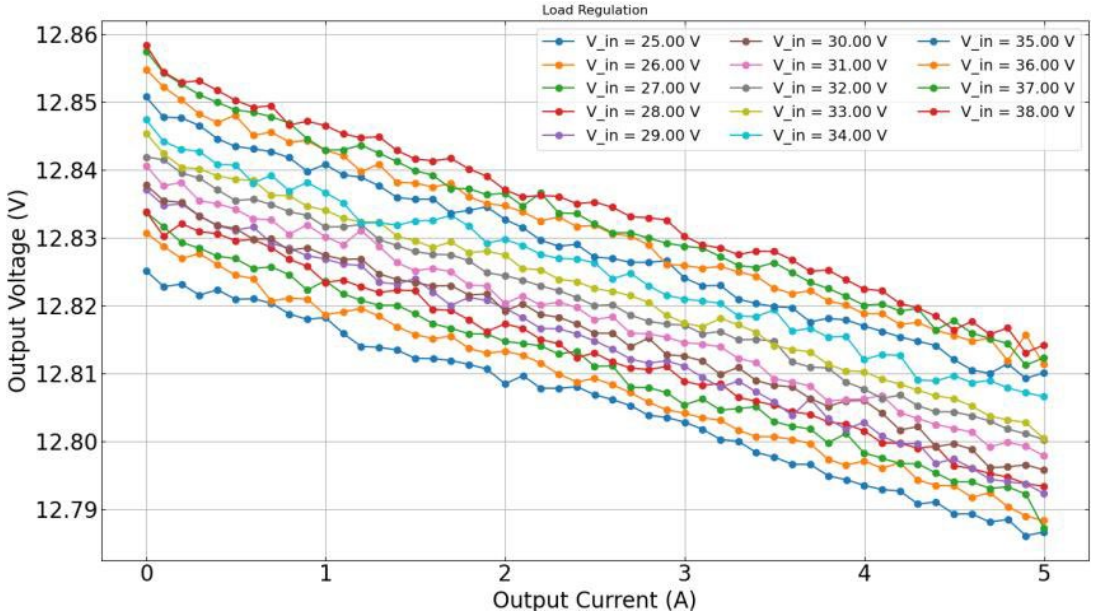
- High-granularity scan of input voltage and load current, at room temperature
- Efficiency above 90% in most of the parameter space
- Measuring now also at cold, effect seems small



Line and Load Regulation

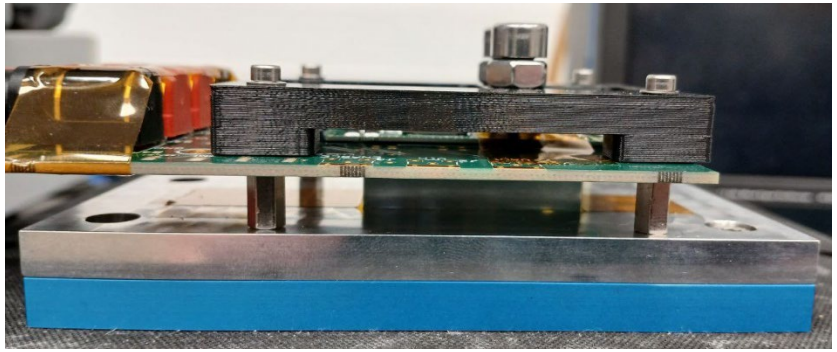
- Line regulation measured as function of load current
  - Mean of 0.4% per 1V input voltage change
- Load regulation measured as a function of input voltage
  - Mean of 0.7% per 1A of output current change
- Looking at this now also as a function of temperature

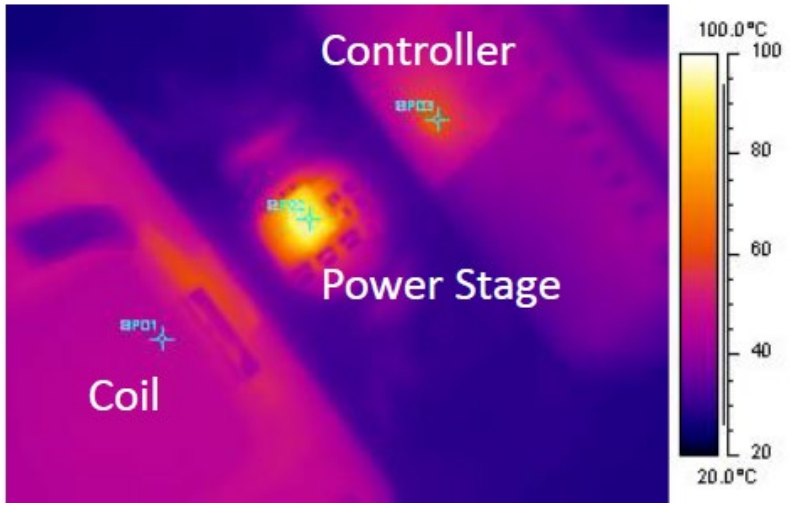


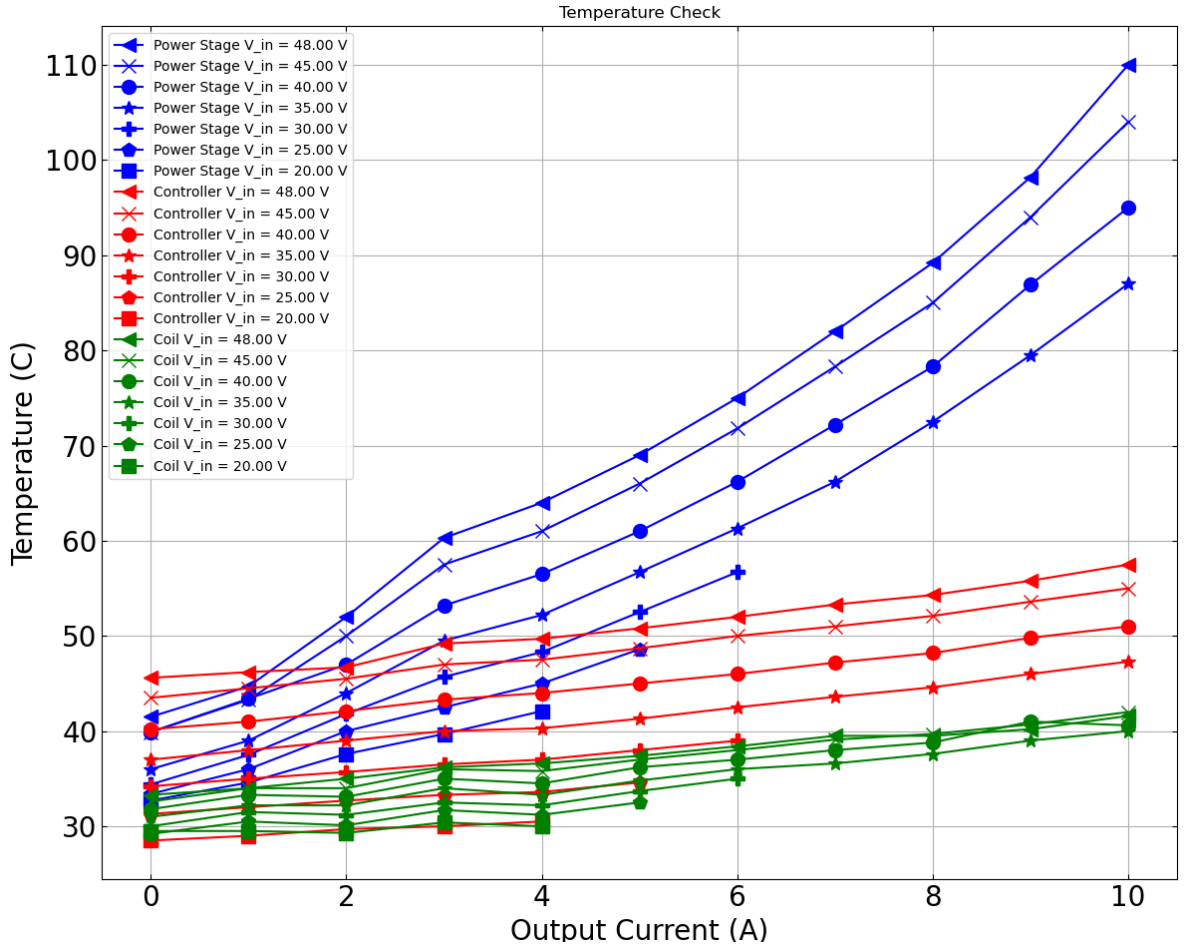


Temperature Measurements

- DC-DC converter is mounted on the cold plate of a Peltier cooler, set to +20°C
- Temperature of coil, controller and power stage measured with a thermal camera, for various loads and input voltages
- Cooling is important

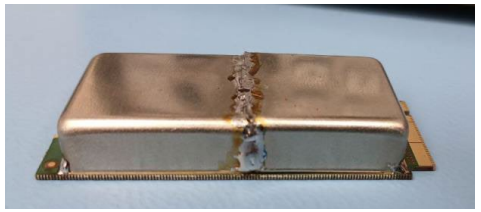


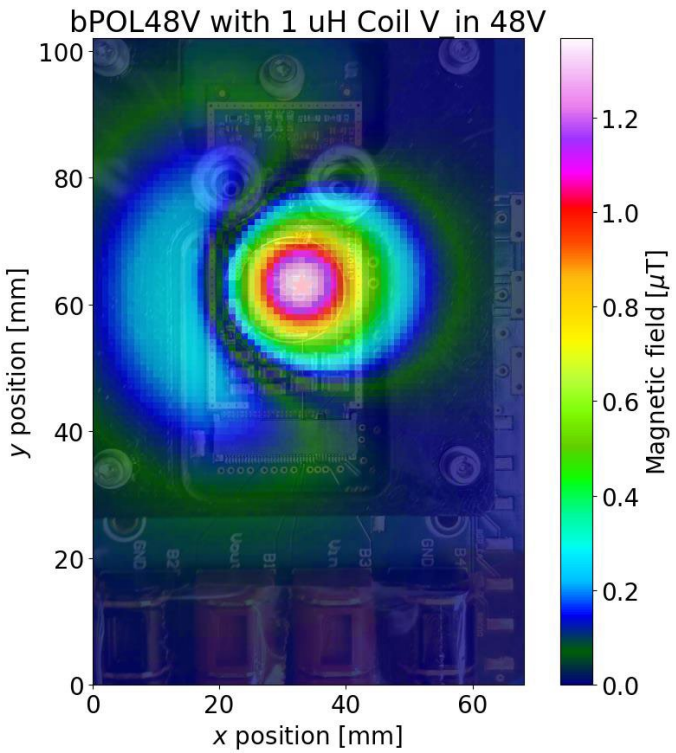


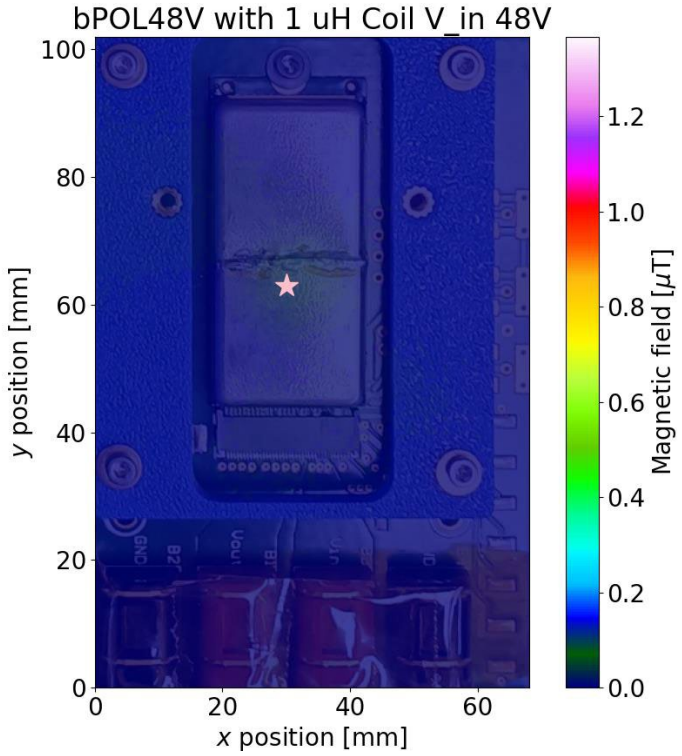


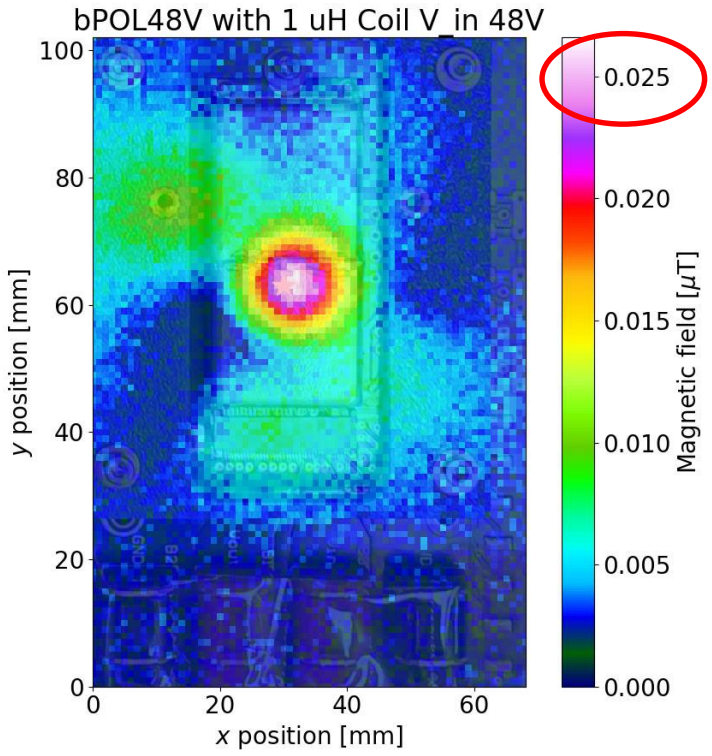
Radiated Emissions, Shielding

- 2D-scan of radiated emissions ~5mm above DC-DC board
- Factor ~50 improvement with shielding
  - 300µm thick “Nickel-Silber” = Alpacca, a Cu-Ni-Zn alloy
  - Commercial product, two shields soldered together (not meant for final application)
- Remaining emission still at position of coil, perhaps due to soldering of the shield



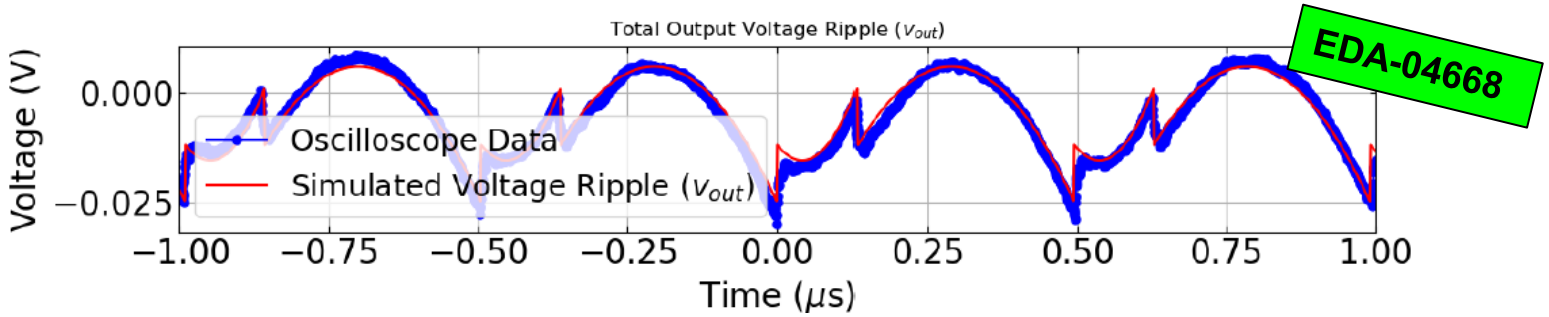


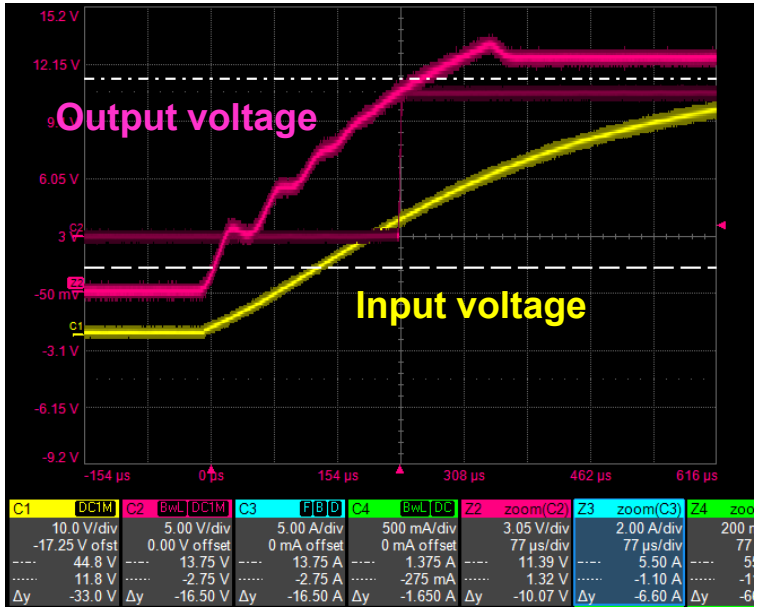


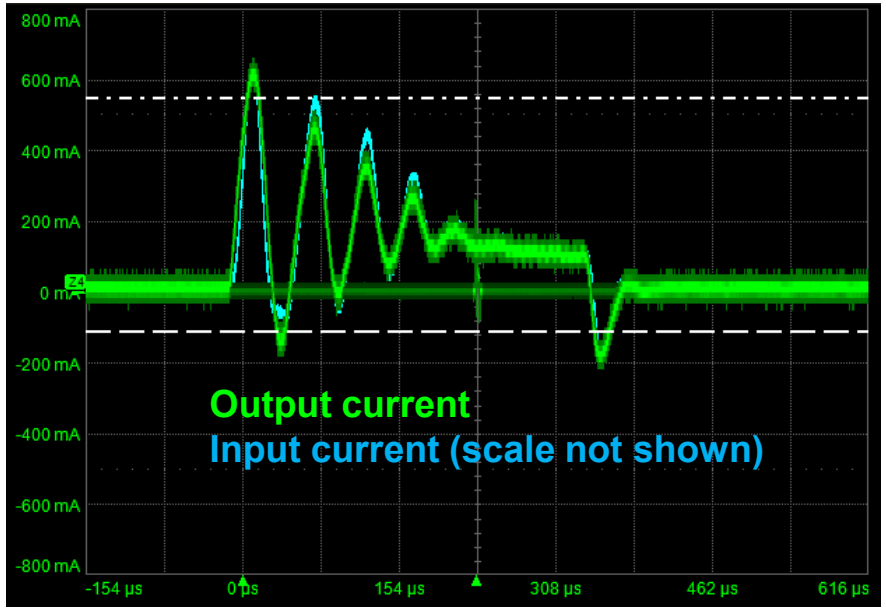


Oscilloscope Measurements

- Measurement of voltage ripple: ~30mV pp, with high frequency spikes up to 100mV pp
- Able to simulate low frequency ripple (with parameters optimized)
- Some “features” seen in switch-on curves; switch-off looks clean

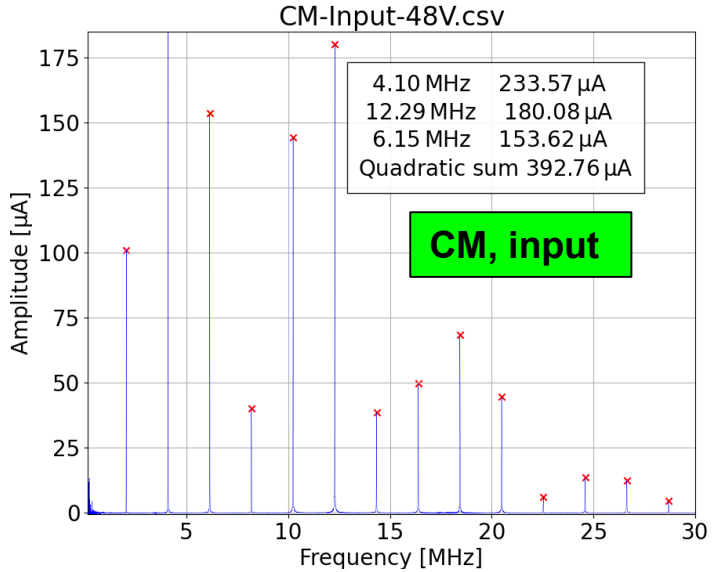


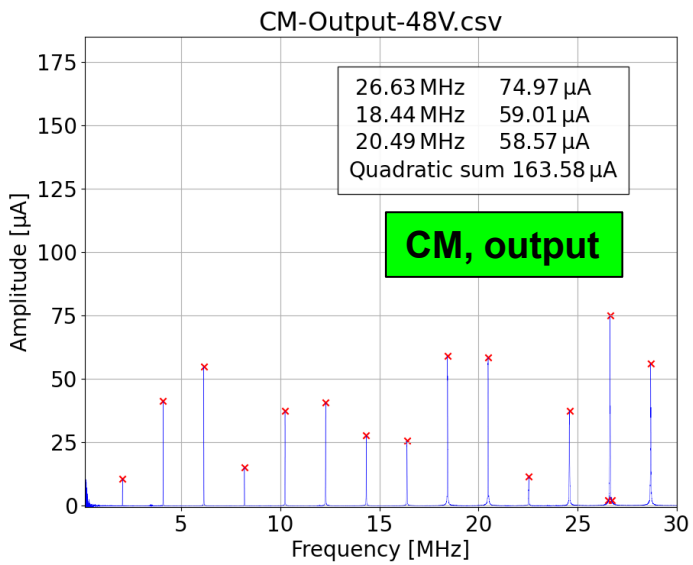


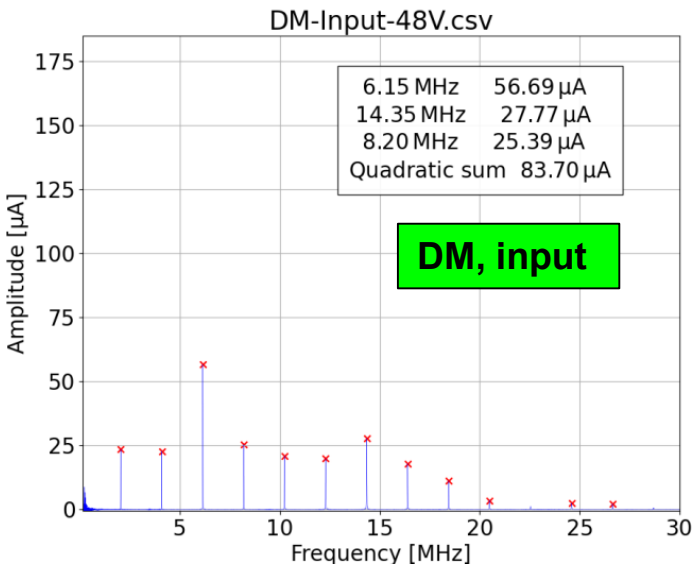


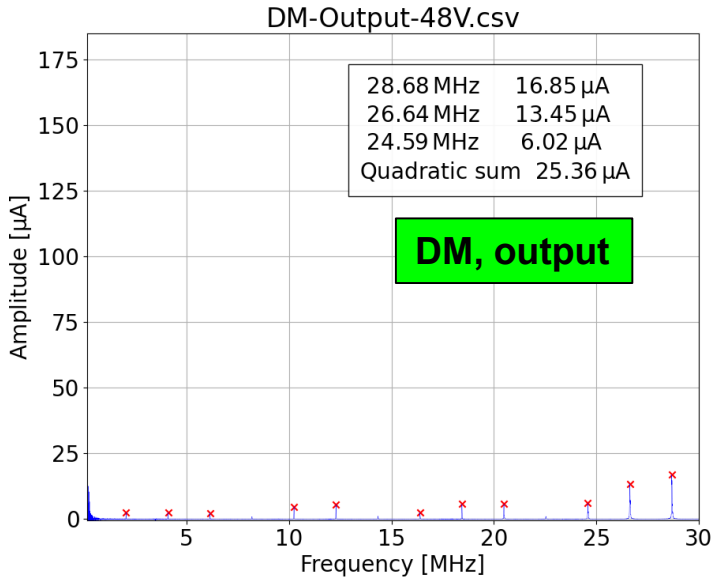
Conducted Noise Spectra

- Differential and Common Mode noise spectra at the board's input and output
- Board design optimized for low DM noise at the output



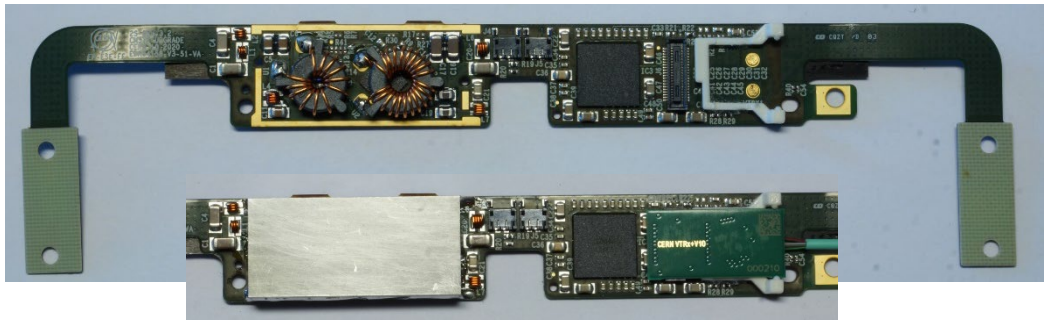


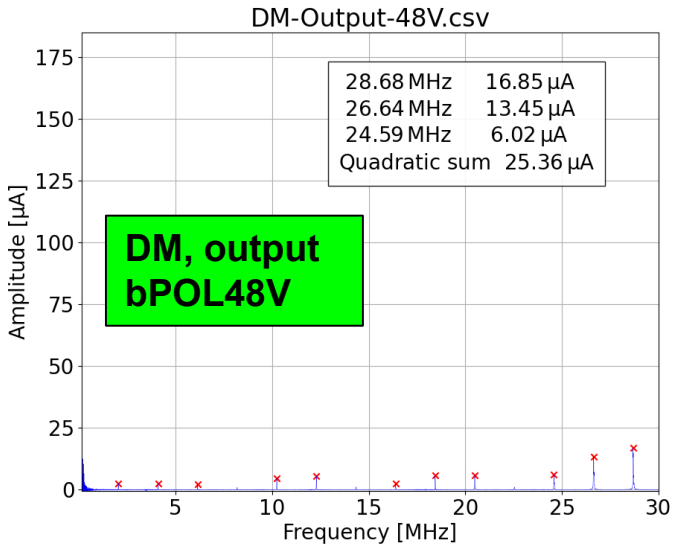


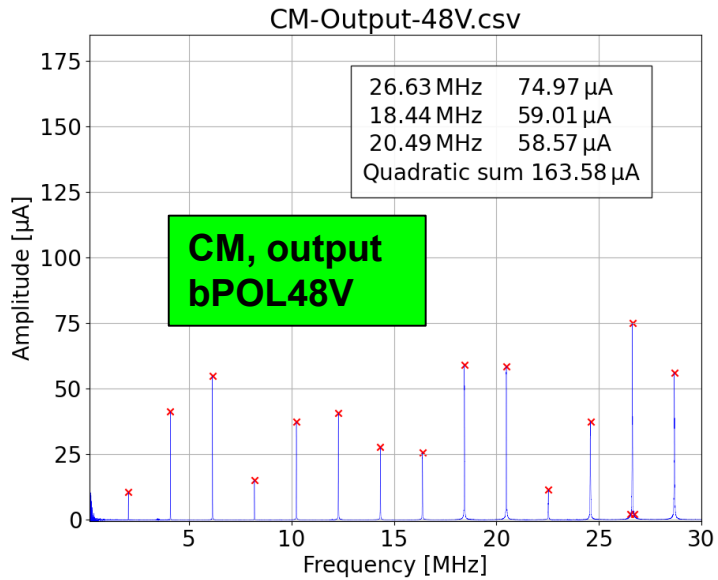


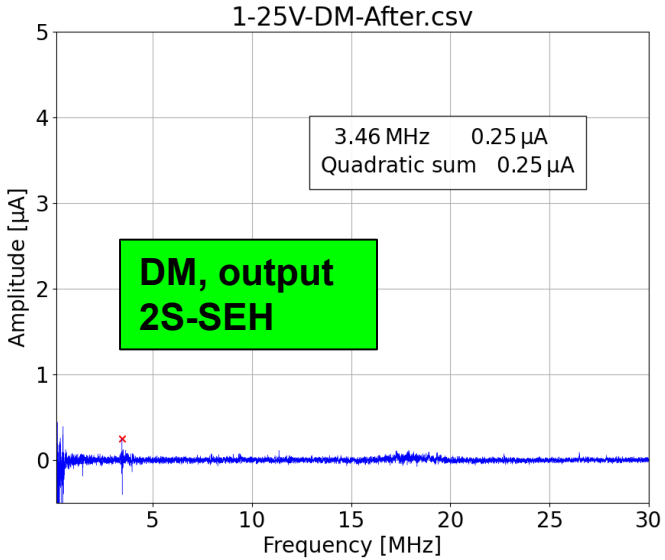
Conducted Noise Spectra

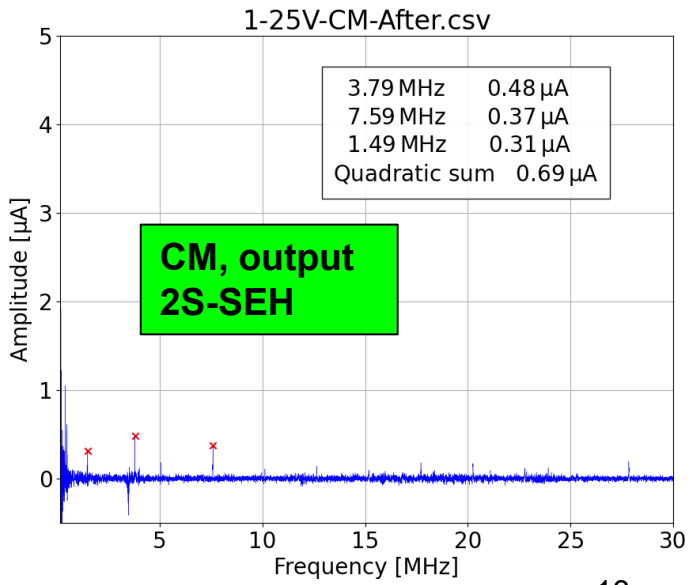
- Comparison with a CMS service hybrid (2S-SEH)
  - Features a 2-step DC-DC conversion scheme
  - bPOL12V and bPOL2V5
- Differences are large, some work to be done...











Next Steps

- Many more ideas and requests for bPOL48V:
  - Measure cold in a climatic chamber (started)
  - Move from ferrite coil to PCB coil (CERN), implying new prototype
  - Compare shielding options
  - Move to more realistic strip module powering schemes
  - Explore how to decrease noise

- Receive DC-DC converter prototype from FH Dortmund (in contact)