Achieving EM Conducted Emission compliance for high voltage conversion with switching frequency above 1.3 MHz

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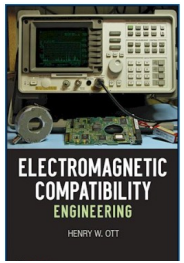
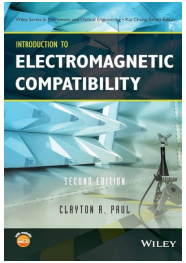
Agenda

- Minimum requirements
- The problem
- High frequency noise implications and drawbacks
- Traditional methods and tradeoffs
- The device under test
- EMI baseline
- A potential filter solution
- Conclusions

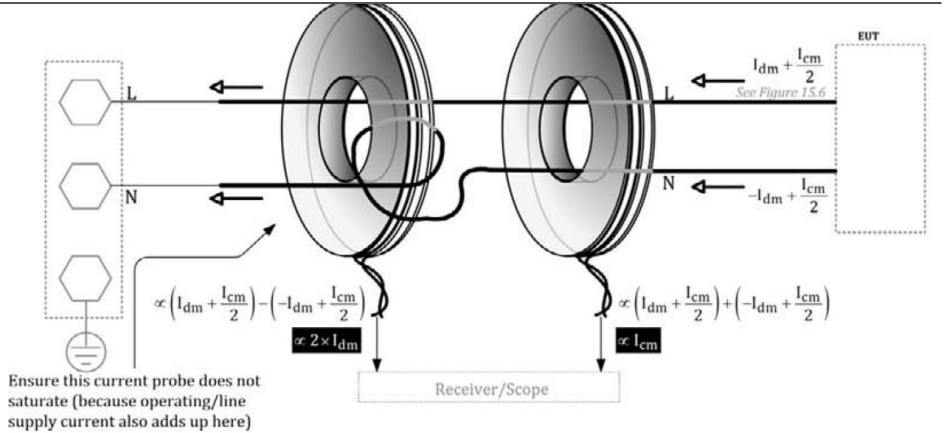
Background

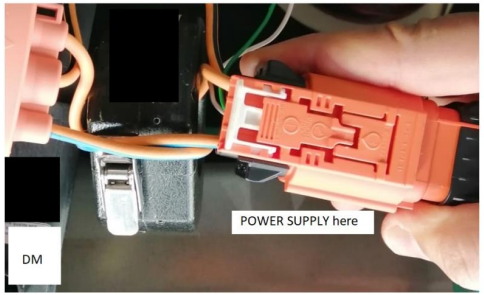
- Electromagnetic compatibility basics
- Differential Mode (DM) and Common Mode (CM) noise in switching power supplies
- The LISN
- Practical EMI Filter Design course

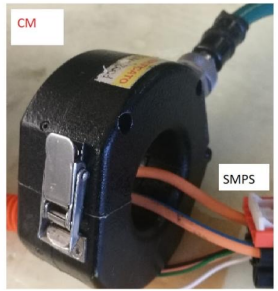




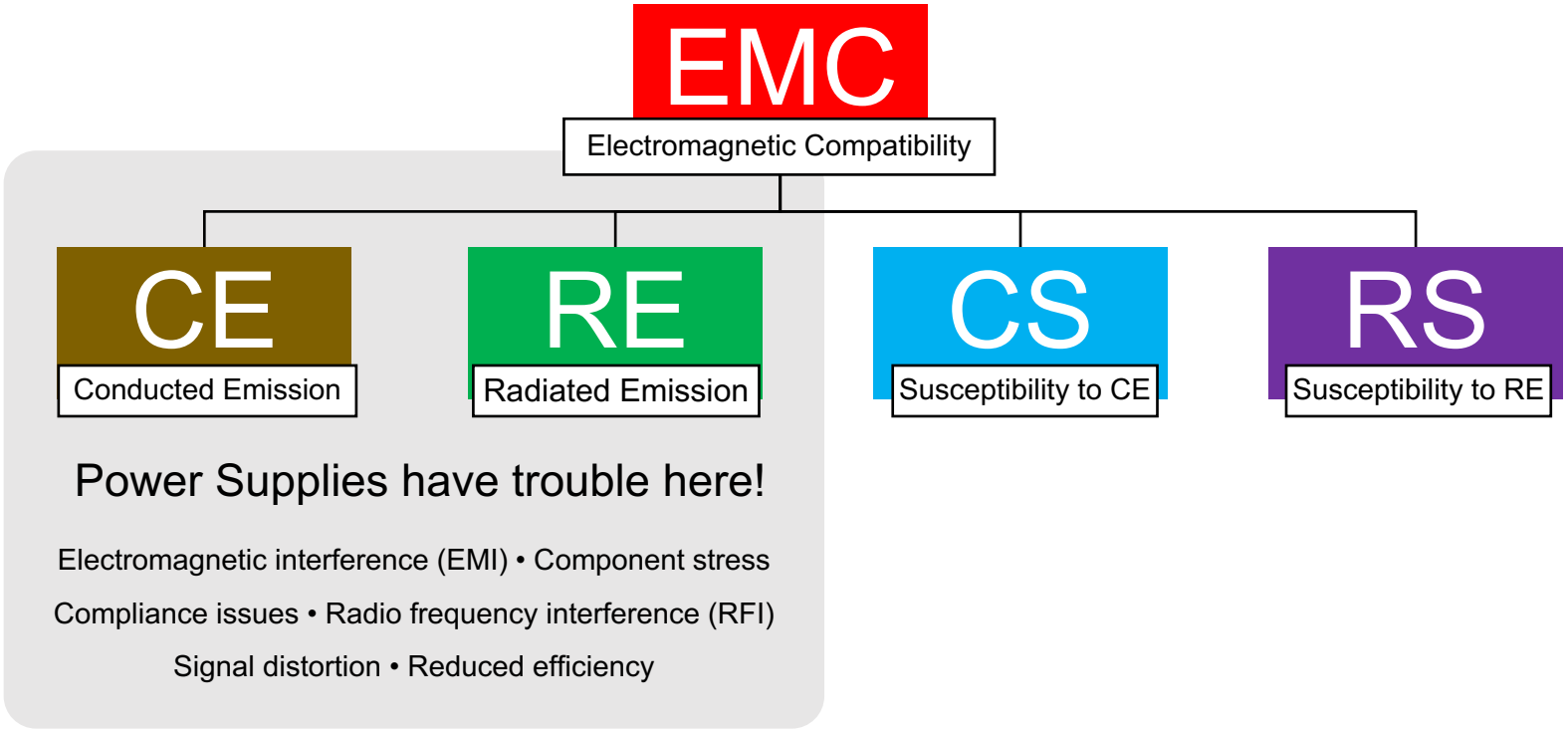
Practical EMI Filter Design
Rohde & Schwarz
Issued Jan 2018







High frequency noise implications and drawbacks



Traditional methods and tradeoffs

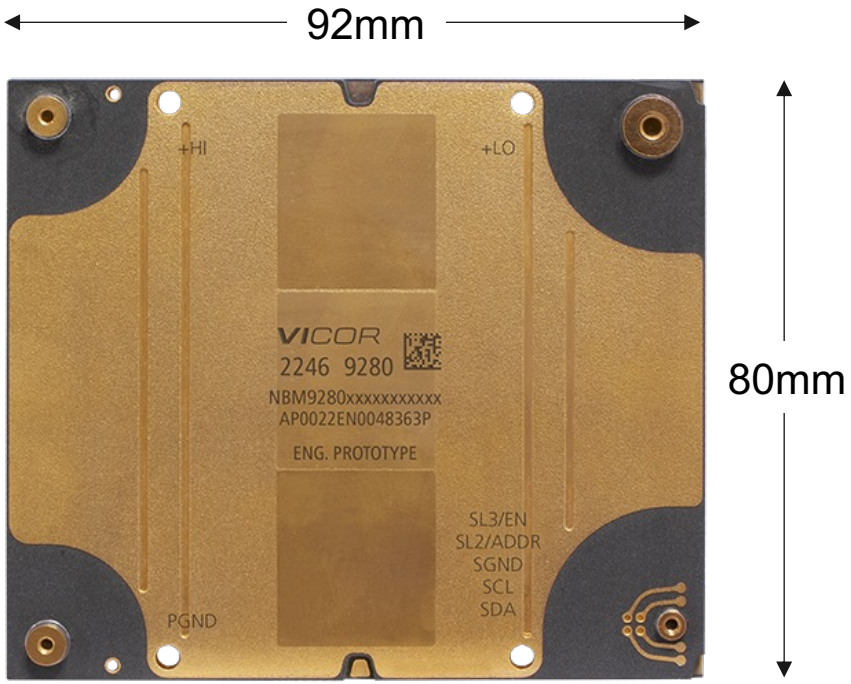
- Input / output filters
- Shielding
- Grounding techniques
- Snubber circuits
- Spread spectrum techniques
- Soft switching

How do we minimize EMI?

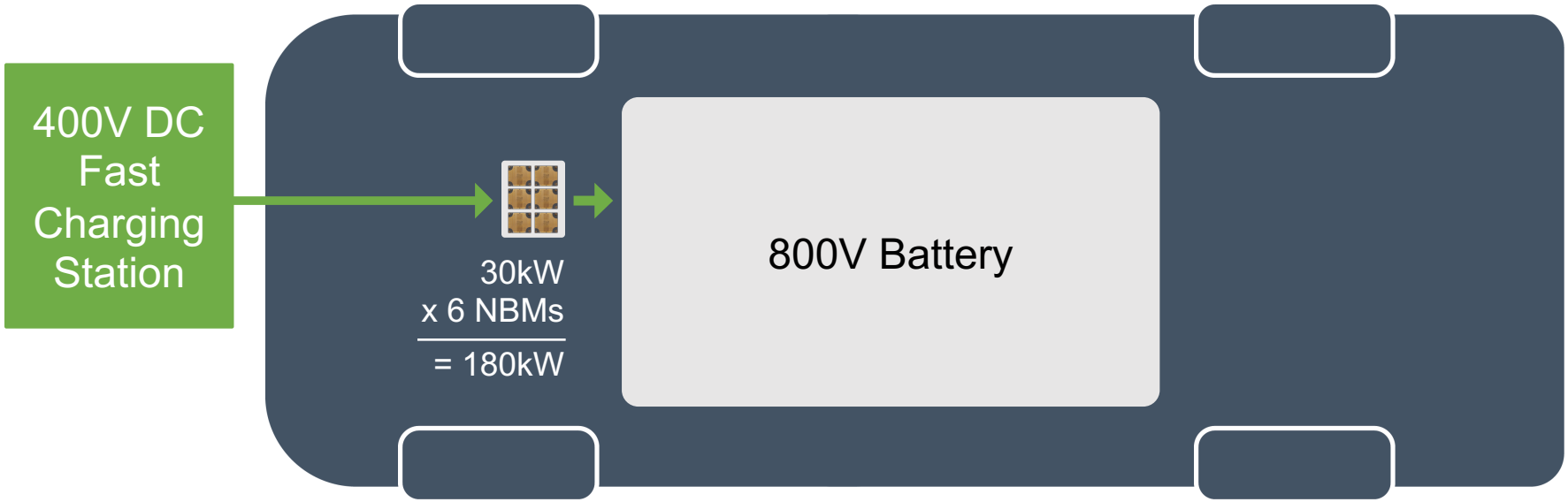
The Device Under Test (DUT): Vicor NBM9280 power module

- 99% peak efficiency
- Non-isolated
- Bidirectional power flow
- **30kW**

Product Ratings			
Step-Up Operation K = 2/1	V_{LO} = 400V (200 – 460V)	V_{HI} = 800V (400 – 920V) No Load	I_{HI} = up to 37.5A
Step-Down Operation K = 1/2	V_{HI} = 800V (400 – 920V)	V_{HI} = 800V (400 – 920V) No Load	I_{LO} = up to 75A

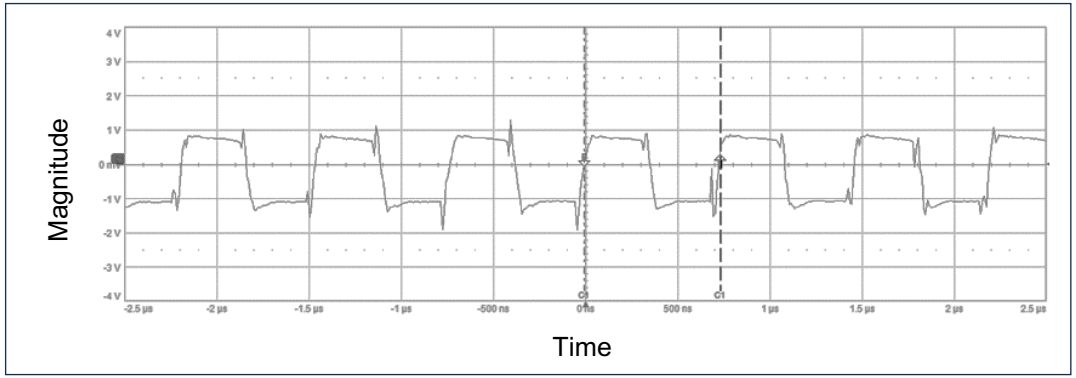


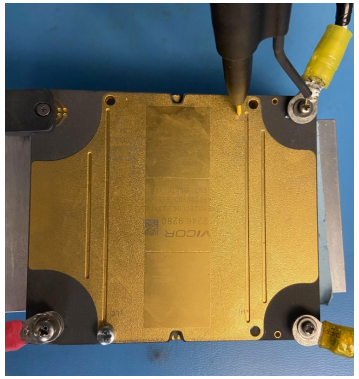
An automotive application of the NBM9280

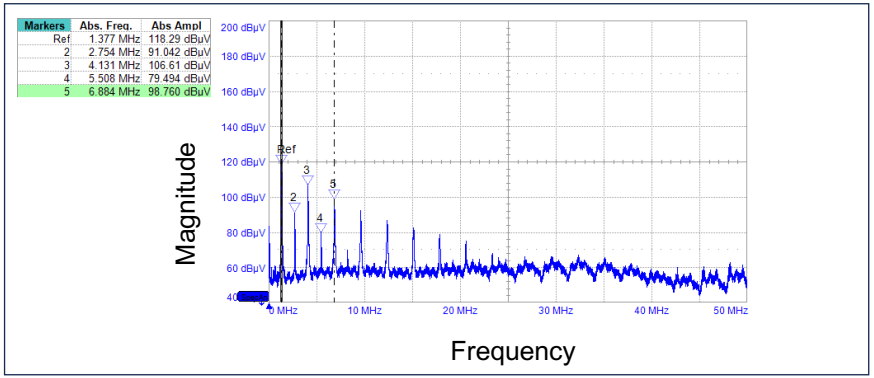


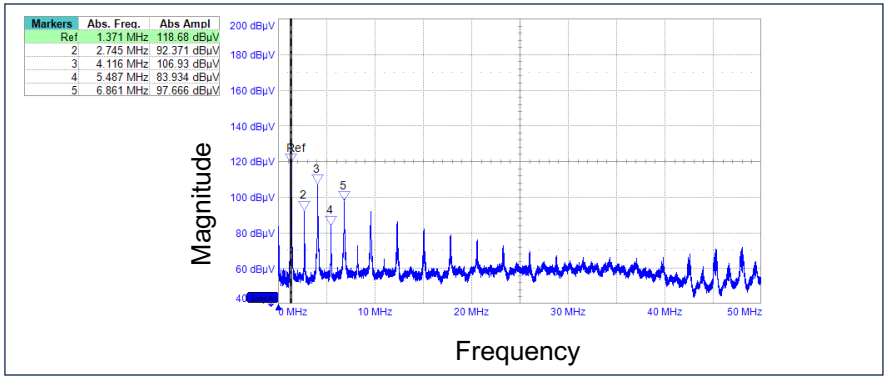
Is the DUT Common Mode noise Load dependent?

NO,
it isn't!

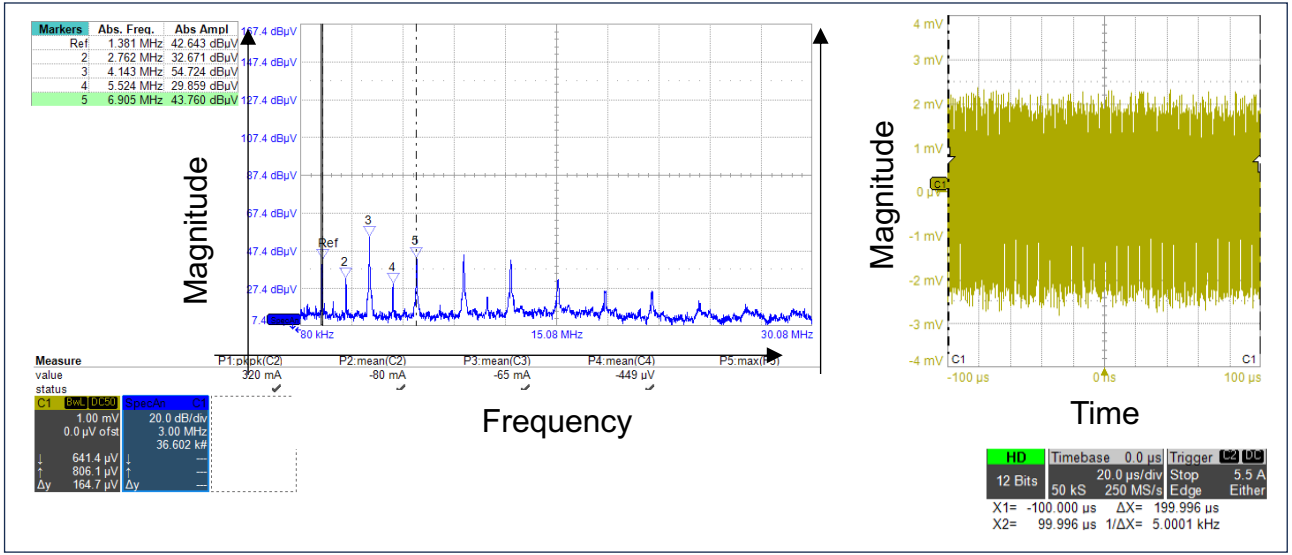






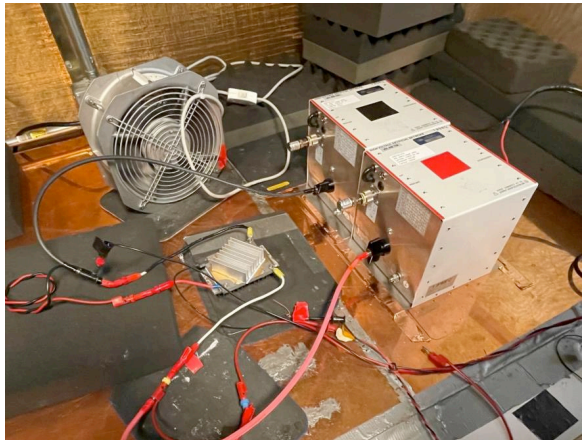


Sensing the Common mode noise: an alternative strategy



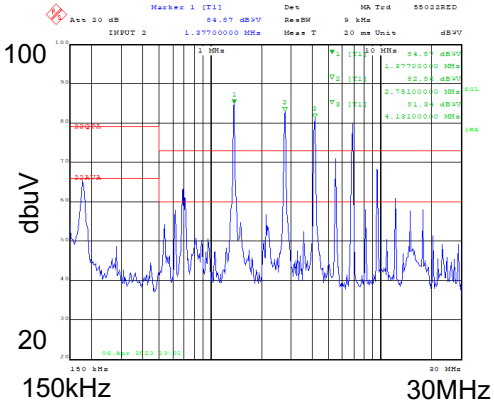
An EM “sniffer” represents a NO-invasive alternative method to extract the CM noise.

By isolating the metallization of NBM9280 from ground plane, the noise level can be reduced.

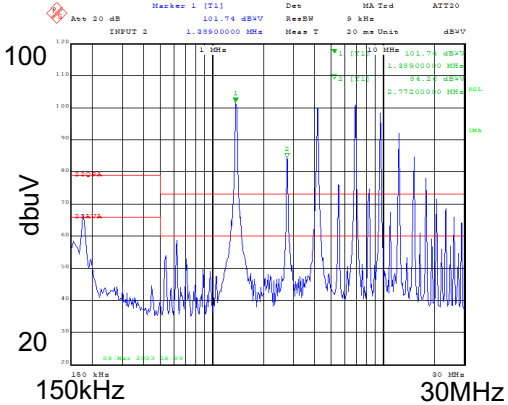


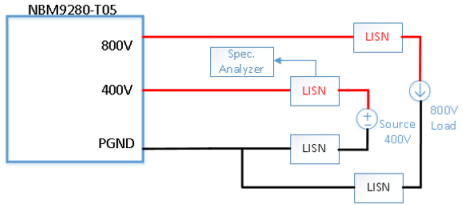
	Metallization connected to GND [dBuV]	Metallization Isolated from GND [dBuV]
1	101.74	84.87
2	84.26	82.86
3	100	81.34
4	~76	~71
5	~100	~80
6	~75	~58

No load – metallization isolated from ground plane



No load – metallization connected to ground plane





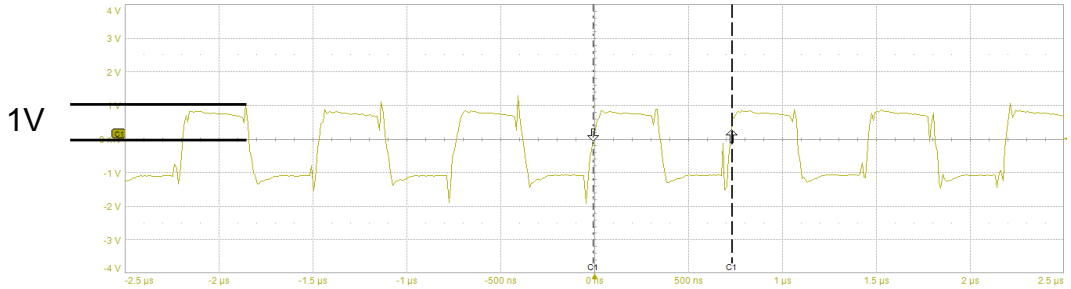
Test setup

Conducted Emission

Peak measurement effect of keeping the metallization isolated

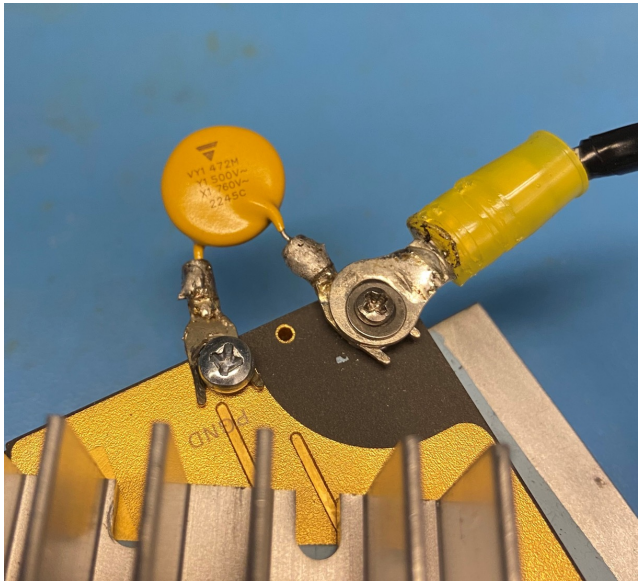
The bypass Capacitor: can we choose it arbitrarily?

Without bypass capacitor

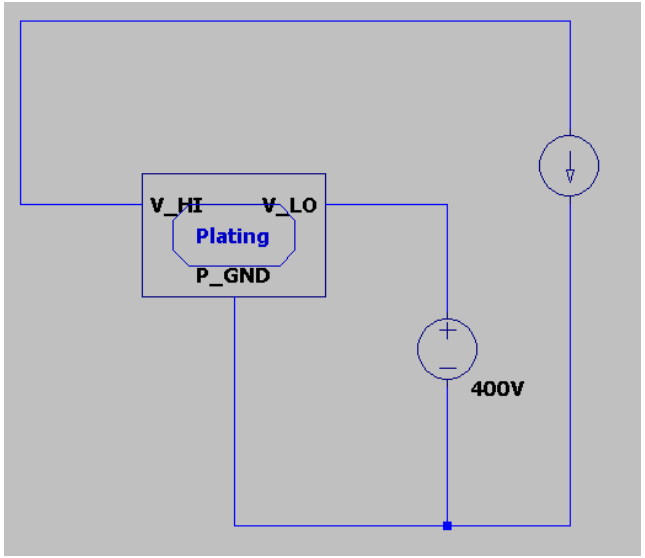


With bypass capacitor

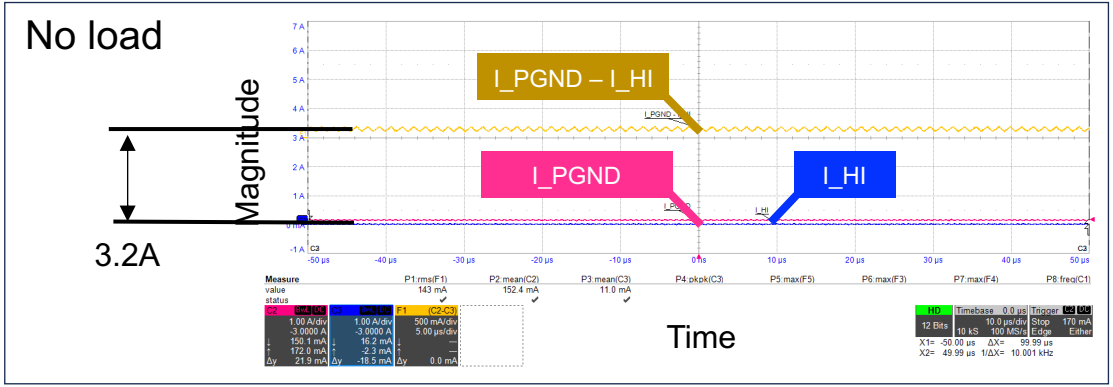
The noise level on metallization of NBM9280 with and without 4.7nF bypass Y caps

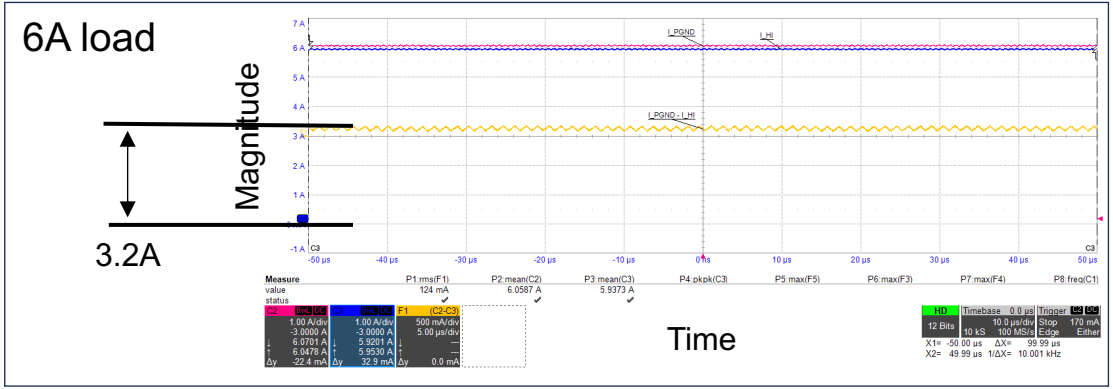


Current Unbalanced: The current on the HI path and PGND path is not equal !!!

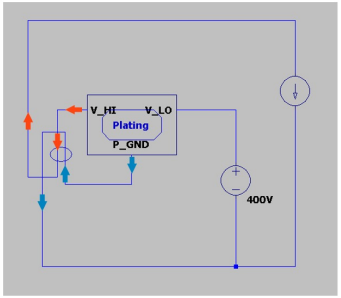


The current direction in step-up mode is shown.

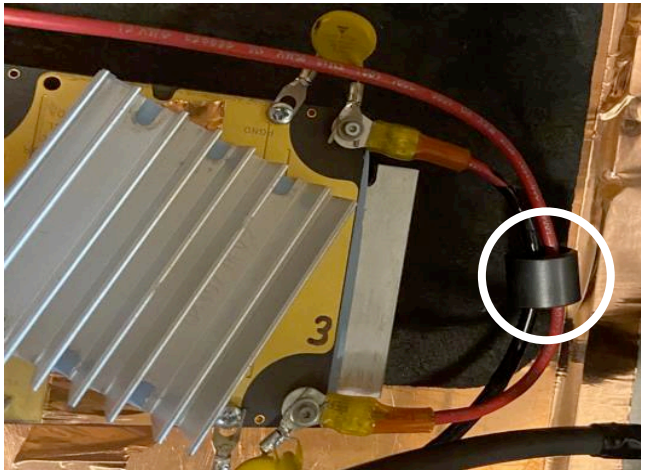


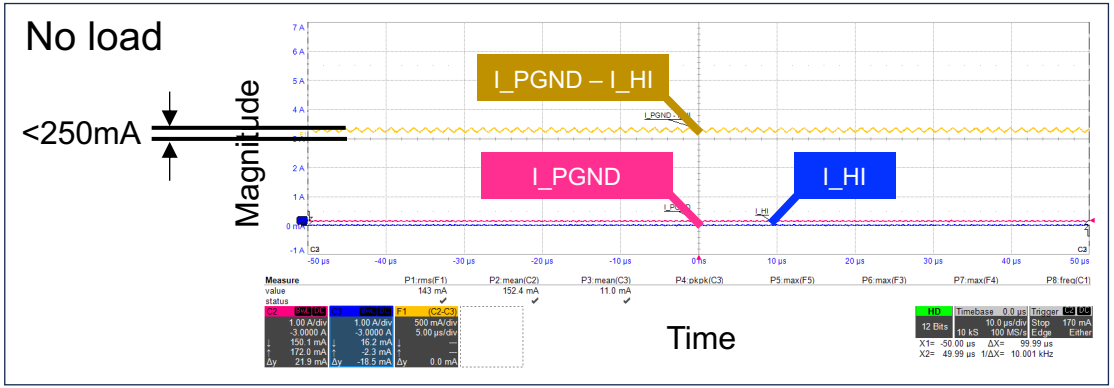


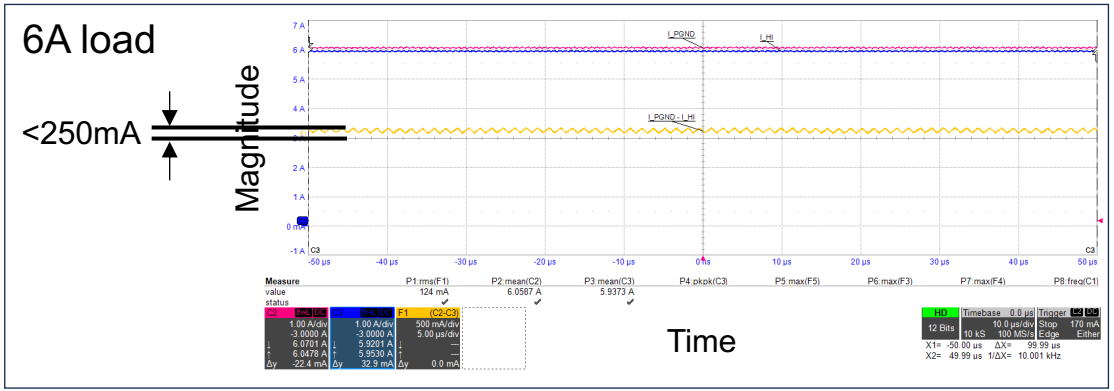
Improving the Unbalanced Current Condition



One way to smoothen the ripple on $I_{PGND} - I_{HI}$ is to use a ferrite core on HI and PGND wire in a way the currents oppose each other.



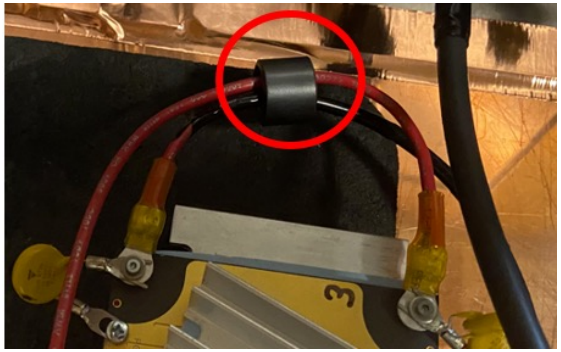




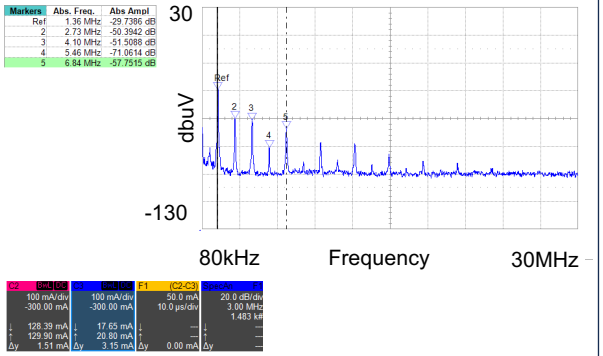
Spectrum of IPGND – IHI

- One way to implement such a is shown as follows
- Implementing this solution on the PCB can be challenging due to the very high integration level of the part

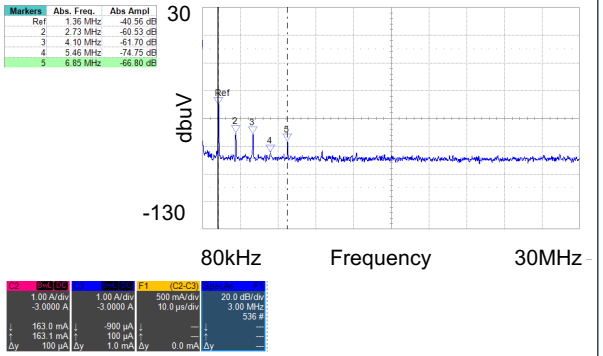
Ferrite core part # 2643626302



No Ferrite on HI/PGND

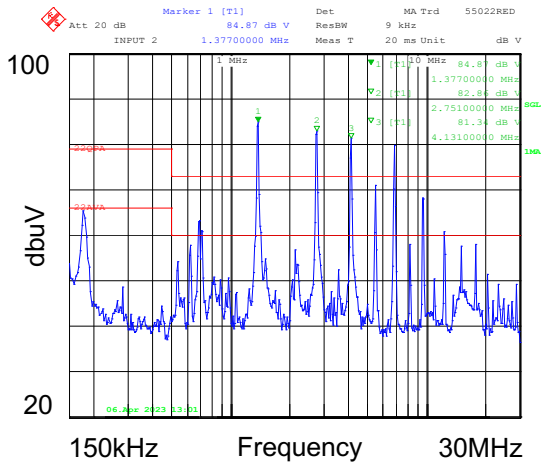


With Ferrite on HI/PGND

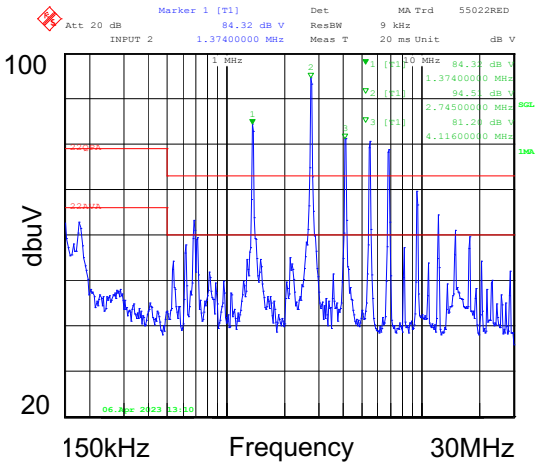


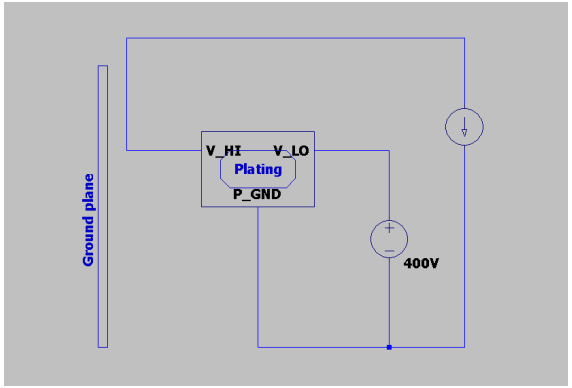
Conducted Emission – Base Line

No load



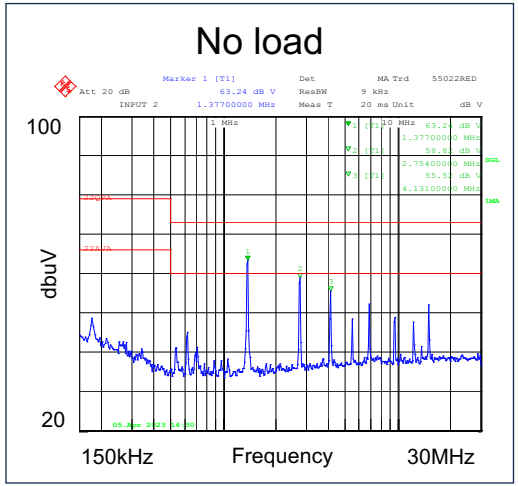
6kW load

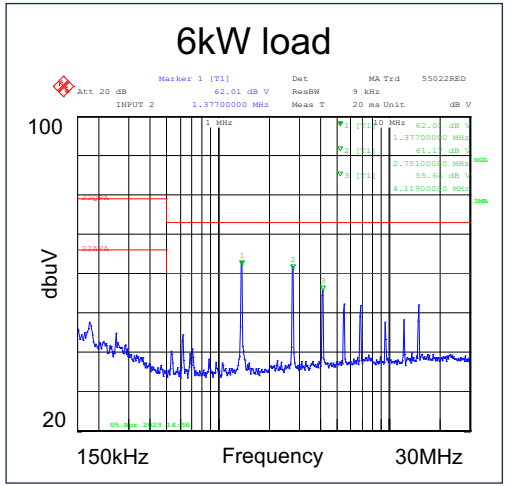


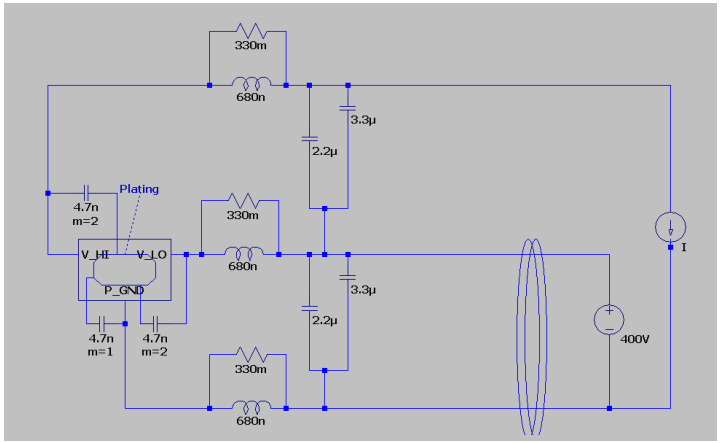


	No Load [dBuV]	6kW load [dBuV]
1	84.87	84.32
2	82.86	94.51
3	81.34	81.20
4	~71	~80
5	~80	~78
6	~58	~57

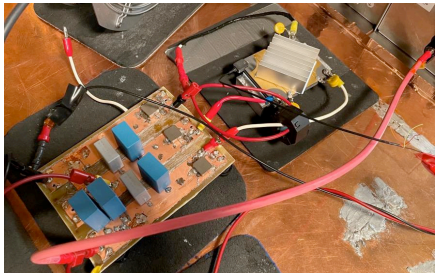
Peak Measurement and BOM of filter #2 out of 4







	No Load [dBuV]	6kW load [dBuV]
1st	63.24	62.01
2nd	58.62	61.17
3rd	55.52	55.64
4th	~47	~52
5th	~53	~52



QTY	Part #
2	BFC233922225
2	B32924J3335K
3	MPXV1D1770LR68
5	VY1472M61Y5UC63V0
1	00431176451
3	330 mOhm resistor

Summary of the Results

	No Filter (metallization not Isolated)	No Filter (metallization Isolated)	Filter #1	Filter #2	Filter #3	Filter #4
1st [dBuV] @ 1.37MHz	101.74	84.87	63.24	47.9	52.37	55.6
2nd [dBuV] @ 2.75MHz	84.26	82.86	58.62	55.25	55.75	55.6
3rd [dBuV] @ 4.13MHz	100	81.34	55.52	41.8	40.56	46.1
4th [dBuV] @ 5.5MHz	~76	~71	~47	~42	~46	44.95
5th [dBuV] @ 6.88MHz	~100	~80	~53	~40	~44	~45
Rate of 2nd increase due to loading [dBuV/kW]	~3.34	~3.34	0.41	0.67	~0	~0

Conclusions

- Amplitude of odd harmonics are load independent
  - However, even harmonics will increase as the result of loading.
- Keeping the metallization on NBM9280 isolated from the ground improves the EMI conducted emission result.
- The increase in the 2nd harmonic component can be mitigated by implementing PI filter.
- Satisfying CISPR 25-Class 4 & 5 (more stringent limits) still needs more attenuation on the 1st harmonics
  - One possible solution is implementing a ferrite core on HI/PGND which results in more attenuation on 1st harmonic
  - Or considering a double stage filter

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Thank you

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Questions?

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