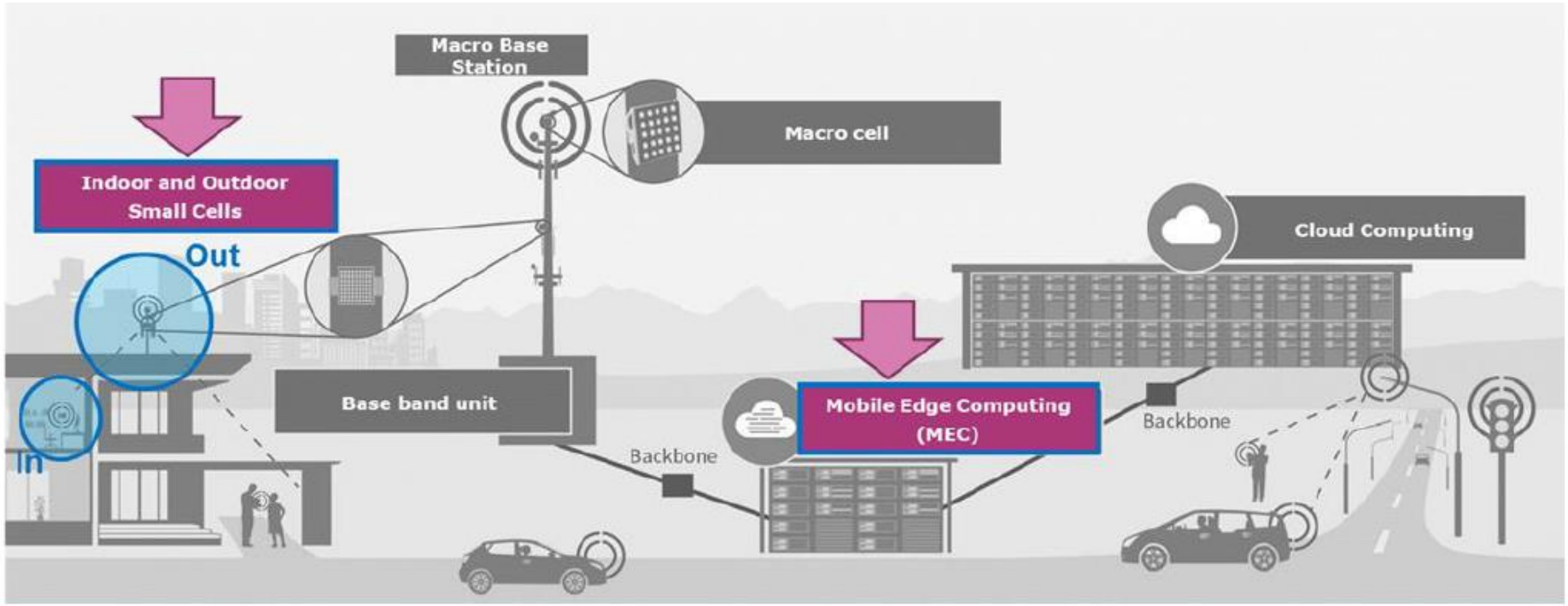
12 V / 1 kW fan-less PSU for outdoor 5G & edge computing

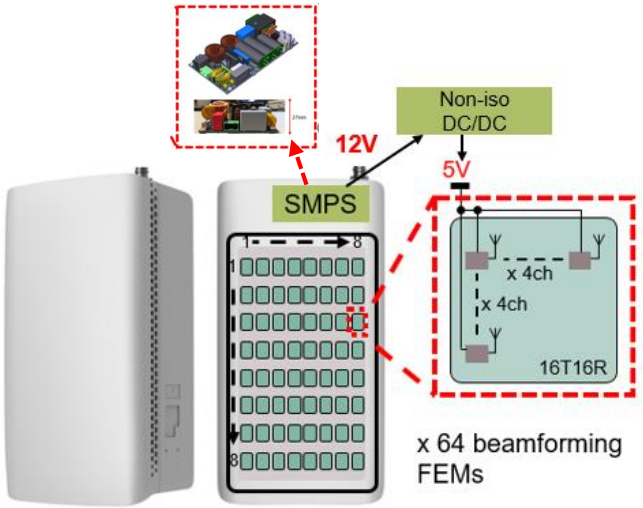
Telecom Rectifiers in 5G Outdoor Small Cell and Mobile Edge Computing ecosystem

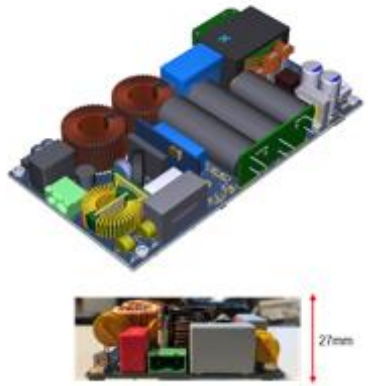


- Mounted close to the telecom equipment on a pole or wall
- Compact size & low profile
- Outdoor harsh environmental conditions

(sources: HIRO EMDC & Supermicro outdoor edge systems)

Design Challenges:
High power density & thin form factor PSUs in outdoor environment

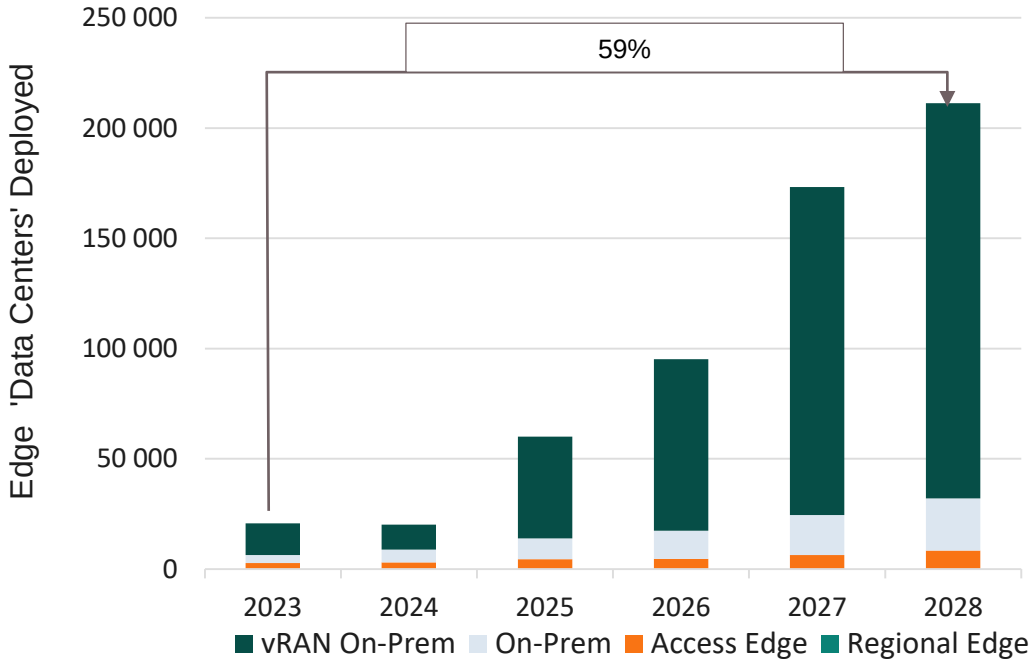


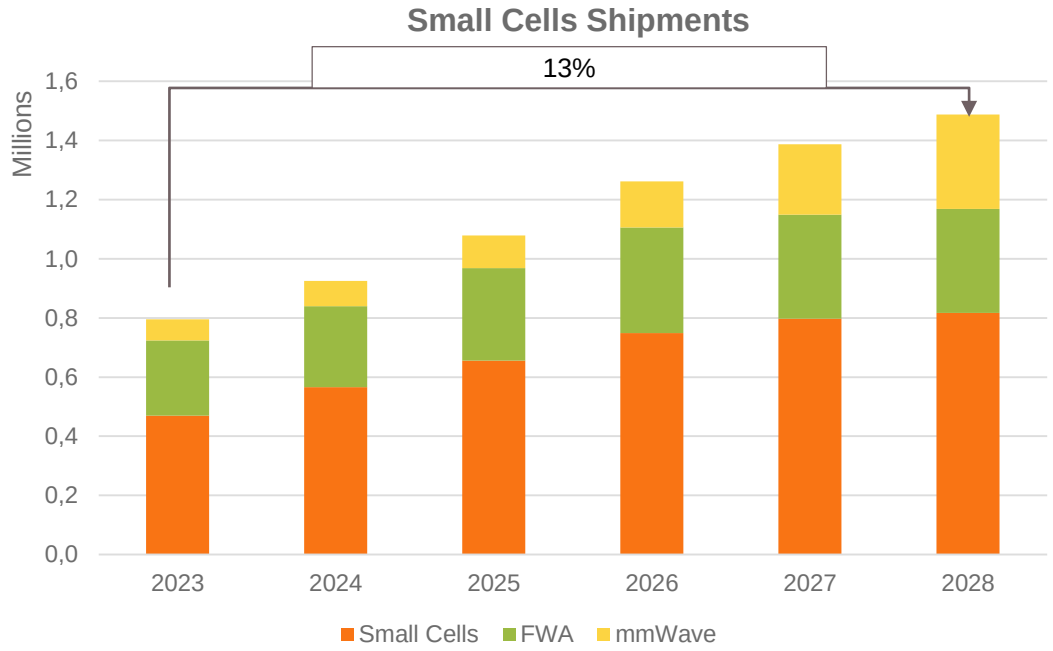


What	Why	How

• Fan-less/convection cooled PSU designs
• Building height ~22-27mm, in some cases down to 18.5mm especially when the PSU is integrated together with RU
• Wide input voltage and operating temperature range
• Stringent EMI requirements
	• Less cabinets, more tower/pole/wall mounted PSUs
	  • Less floor rental fee → CAPEX reduction.
	  • Less power consumption and maintenance → OPEX reduction
	• Closer connection to Radio Equipment or even integration with it.
	• Proliferation of 5G small cells, edge computing in the next 10 years
		• Metal Baseplate/chassis Cooling
		• Full SMD designs, preferably top side cooling
		• Massive Surge Protection required
		• Large use of planar magnetics
		• 3D assembly

REF_1KW_PSU_5G_GAN and SIC addressing 5G Small Cells and Edge Computing markets



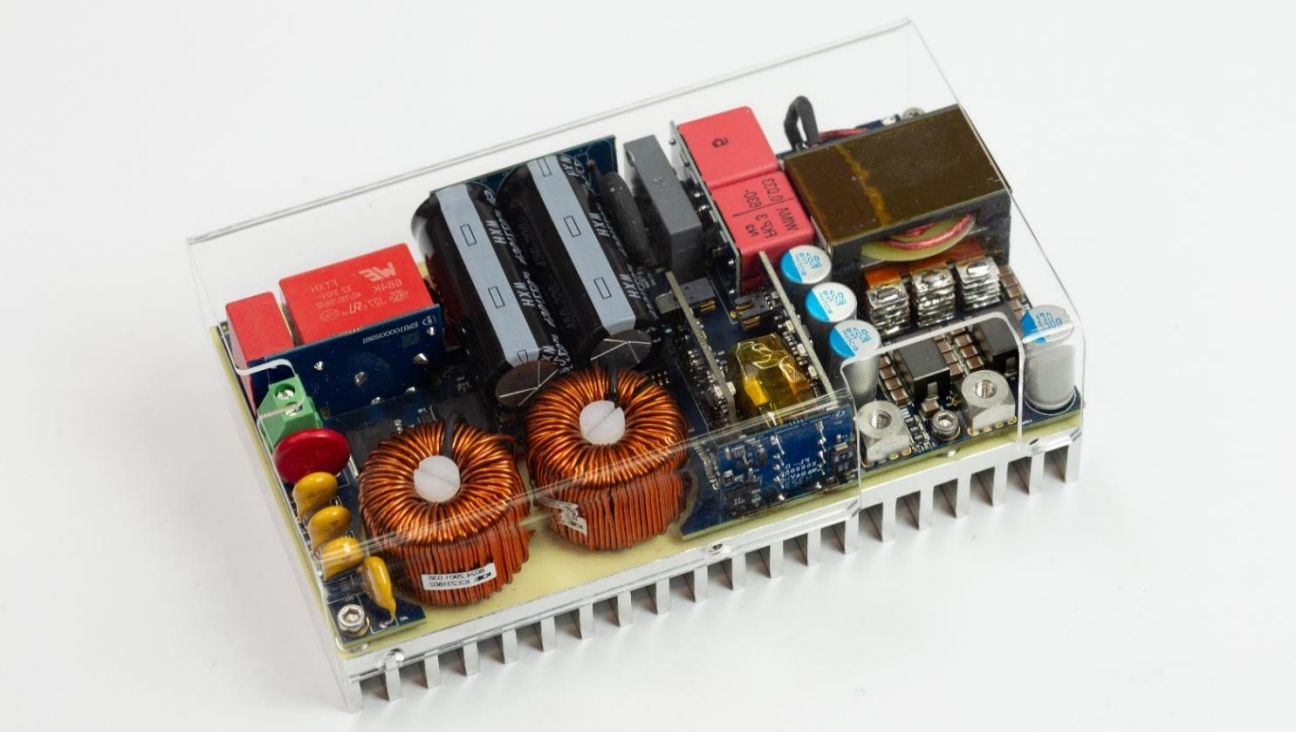


- **Regional Edge:** Mobile Edge Computing (MEC) site located in metro area (20-100 servers per site)
- **Access Edge Data Center:** MEC edge cloud location closer to RAN aggregation sites (4-8 servers per site) (commonly called "far edge")
- **On-Prem:** MEC location residing on-site at enterprise locations (1-5 servers per site) and is typically not open to additional enterprise customers.
- **vRAN:** ‘on-prem data center’ used for CU/DU (Baseband), which doesn’t have extra capacity for commercial Edge applications (1-5 servers per site).

- **Small cell:** base stations that attach to a small segment of a macro site to extend their service coverage and/or increase network capacity
- **mmWave:** small radios operating at high frequencies (typically 24-39GHz) usually deployed in dense urban areas such as downtown, stadiums, train stations, malls, and areas with high data capacity requirements.
- **Fixed Wireless Access:** base stations used to provide wireless broadband connectivity between two fixed points, for example a mobile network cell tower and a FWA device in a customer's home.

1 kW PSU - introduction

5G & edge computing environment



Technical details

PFC key requirements	Value
Input voltage	Nom. 100 - 230 V_{AC}
Output voltage	12 V_{DC}
Output current	83 A
Output power	1000 W
Efficiency	≥ 96% peak (HL, ML) ; ≥ 95% peak (LL,ML)
Cooling	Natural convection
Ambient Temperature	-40 to 70° C

Infineon Components

- 600V CoolGaN,650V CoolSiC, 600V CoolMOSS7,BSC009N04LSSC
- 1EDB9275F,1EDN9550,1EDB8275,1EDN8511,1EDN7550
- XMC4000 Series

Features

- CCM Totem Pole PFC
- HB LLC
- Full digital control in both PFC and LLC
- Fan-less design

Benefits

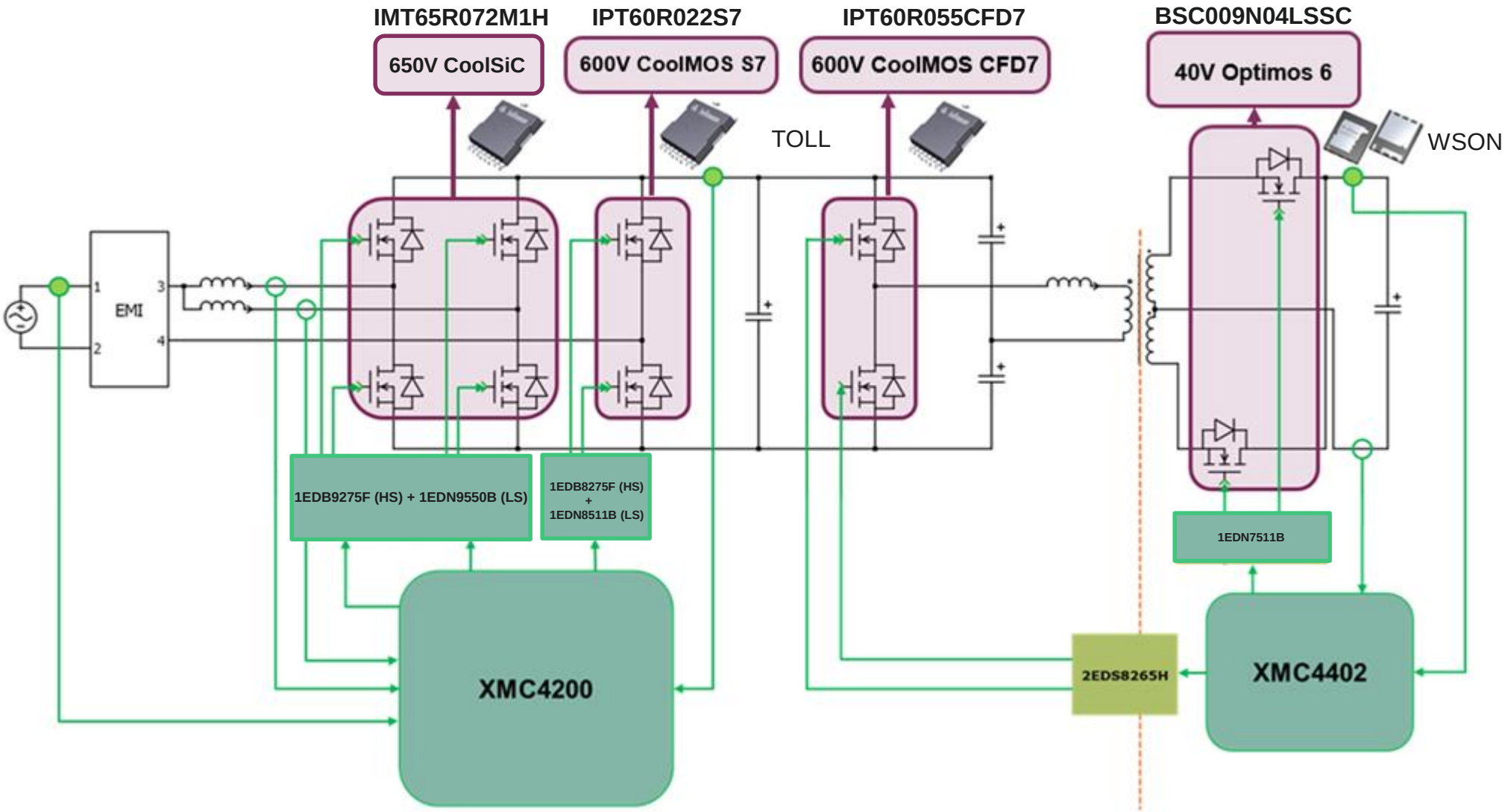
- Addressing the new requirements of outdoor Edge Computing SMPS
- Innovative fan-less cooling concept demonstrator
- Low profile
- Dimensions:80x150x27mm (WxLxH)

1 kW PSU – Specifications

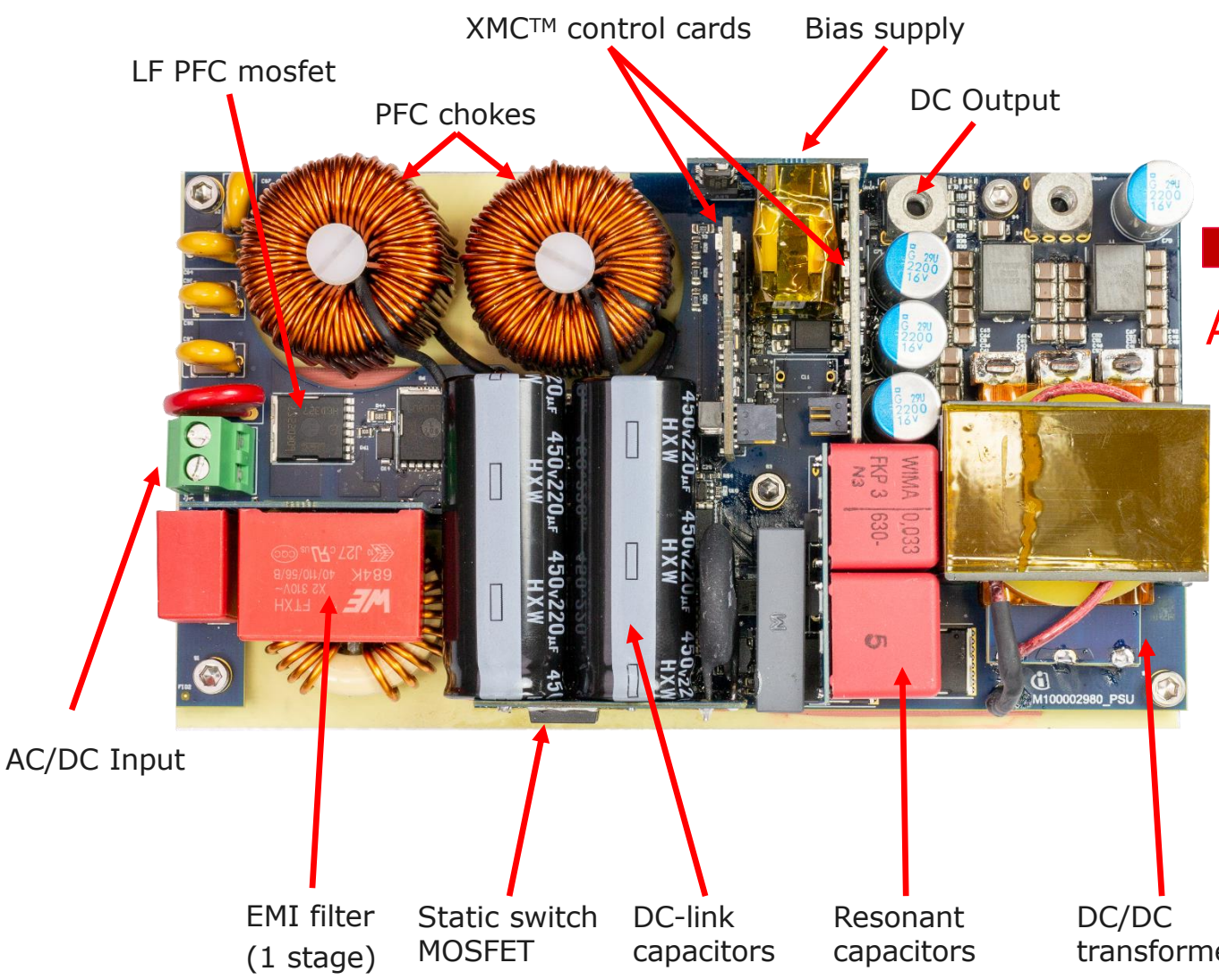
Parameter	Value
Nominal AC input voltage	100V-230V RMS
DC-Link output voltage	400V
DC output voltage	12V
Max output current	8.3-83A
Input current fuse	16A
Hold-up time	10ms@1000W

Requirements	Conditions	Specifications
Efficiency target	230V AC input,12V DC output 115V AC input,12V DC output	η 96% peak (HL, ML) η 95% peak (LL, ML)
Power factor and THD	100V AC to 240V AC	Lower than 10% from 20% of the load
Load transient	0A to 83A, 1A/µs 83A to 0A, 1A/µs	|ΔVout| less than 1.2Vpk
Cooling		Natural convection
EMC		EN 55022 class A with 6dB margin

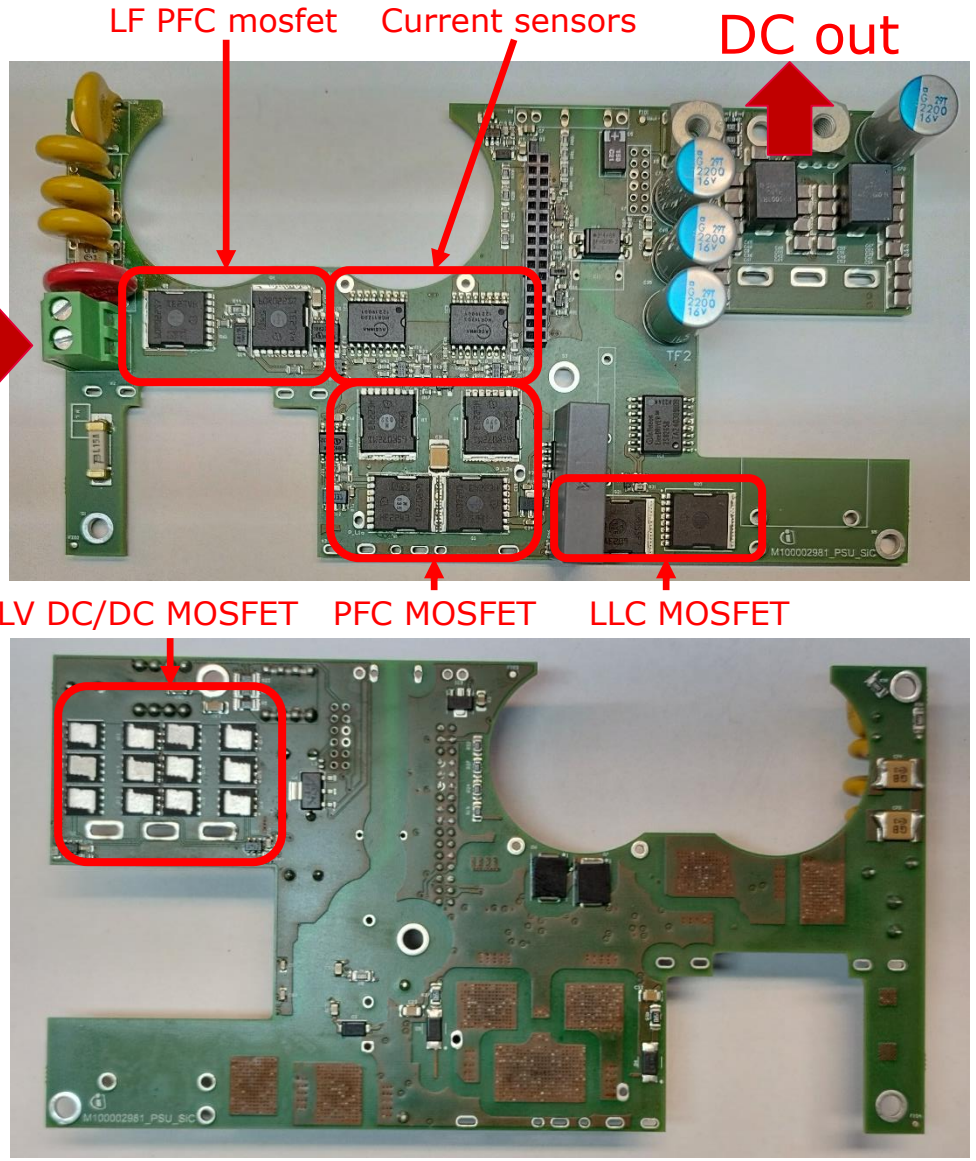
1 kW PSU – architecture



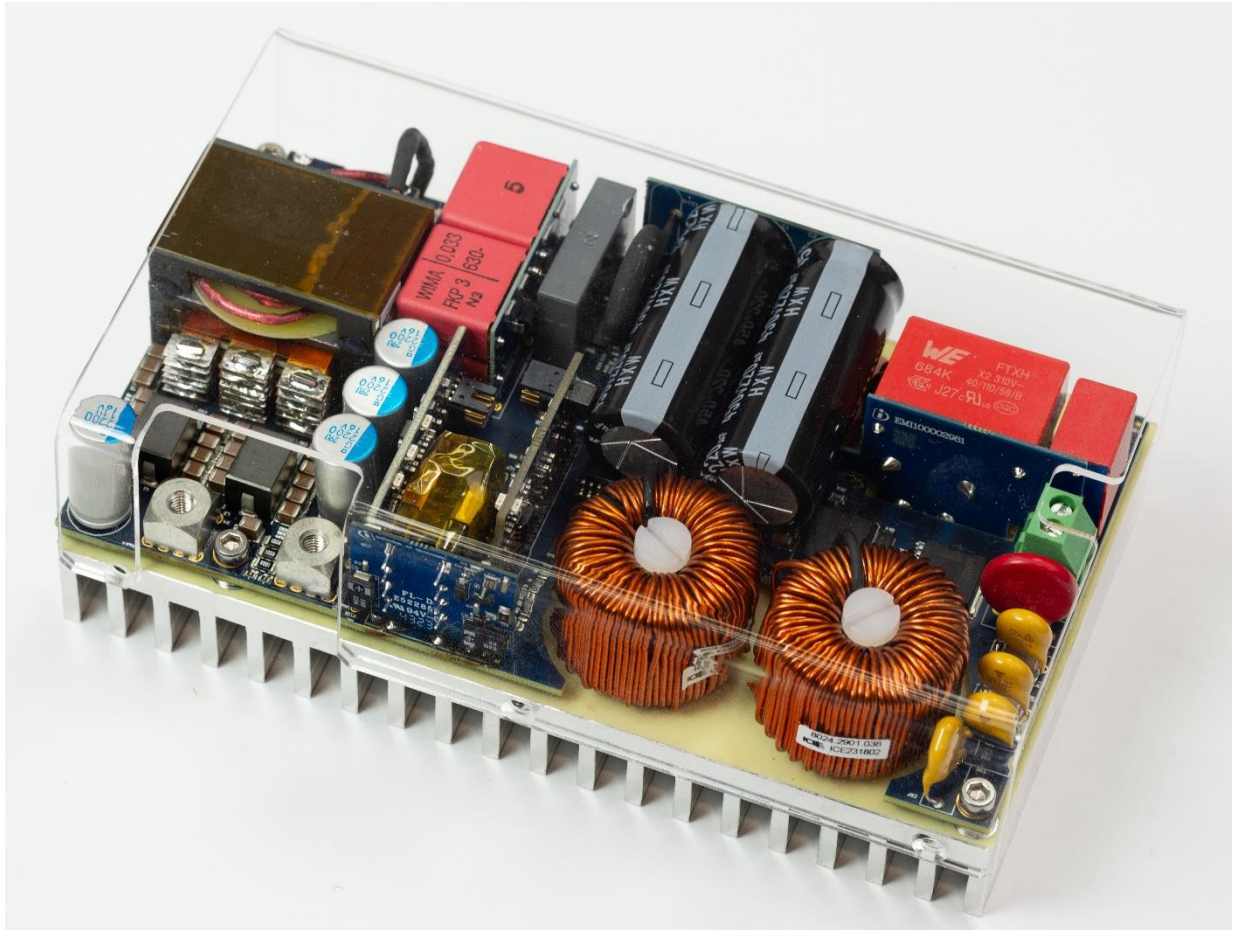
1 kW PSU – hardware implementation



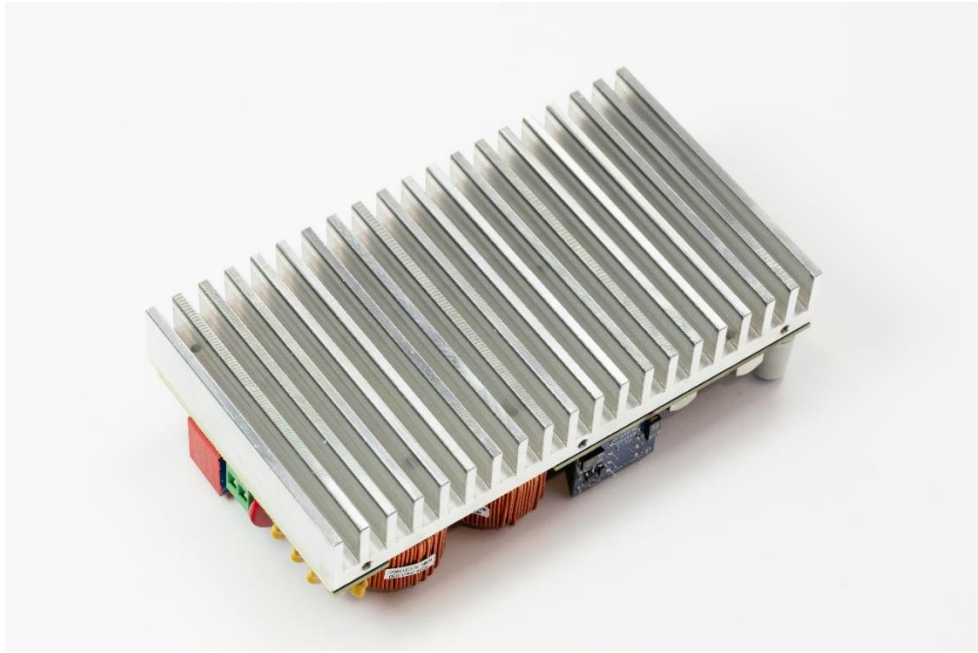
AC



1 kW PSU – Reference board with enclosure

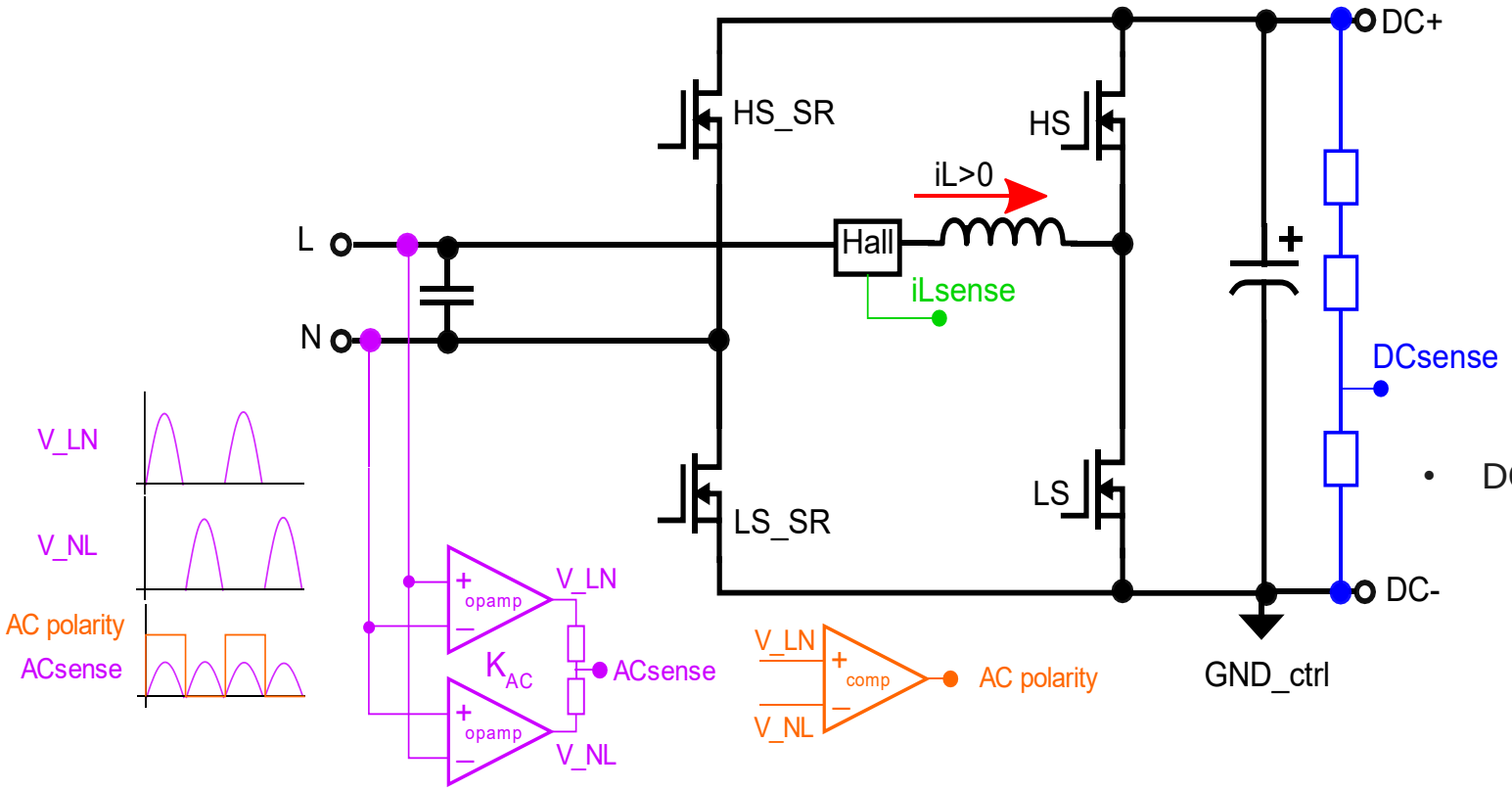


- Board with Heatsink and plastic enclosure
- Plastic enclosure for showcase
- AC/DC and DC-DC connectors
- Customized heatsink



1 kW PSU – Totem-pole PFC

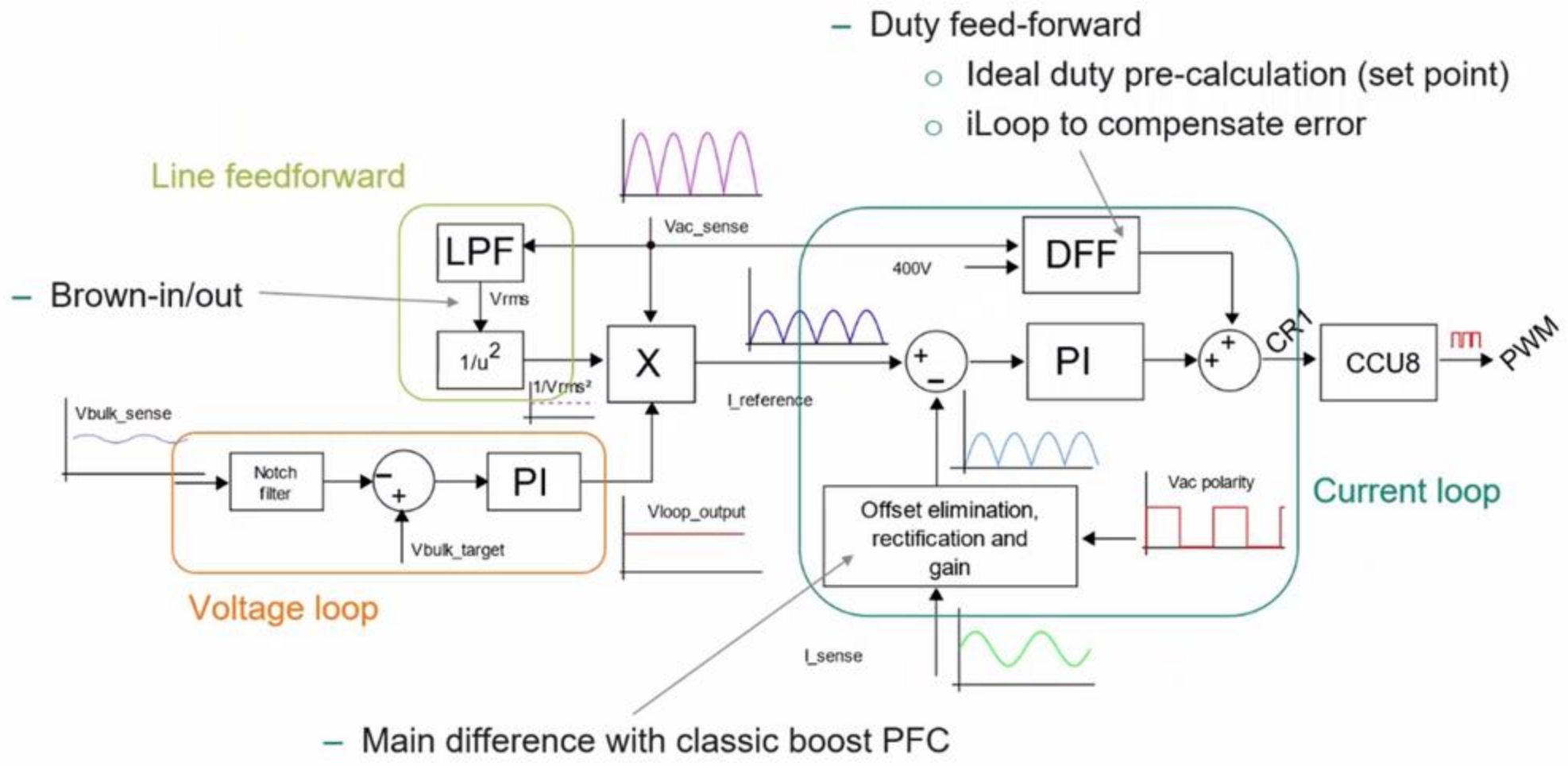
- PFC inductor current is positive and negative
- Hall effect current sensor with offset to half of XMC supply voltage



- DC-Link sensing with resistor divider

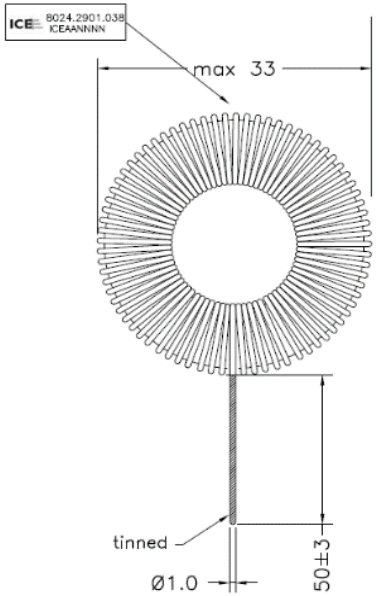
- AC line sensing: Gain + rectification
- Polarity detection required

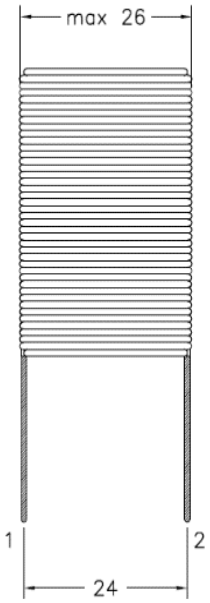
1 kW PSU – Control structure/block diagram



1 kW PSU – PFC choke design

Material: CH270060GTE18
Number of turns: 90
Wire used: AWG 18 (1.1 mm diameter)
Max height: 26mm
Resulting inductance is: 1mH





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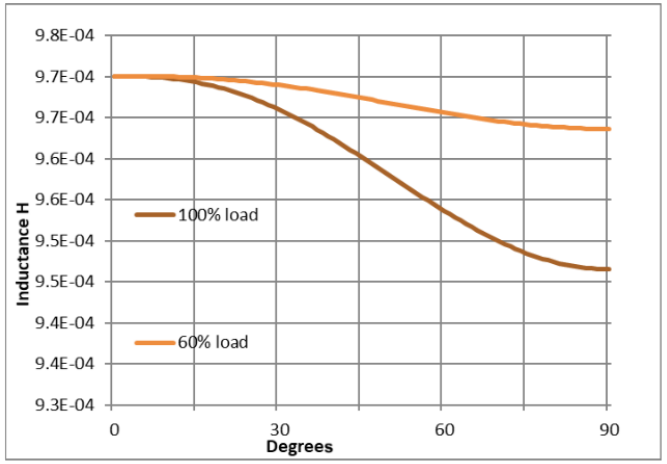
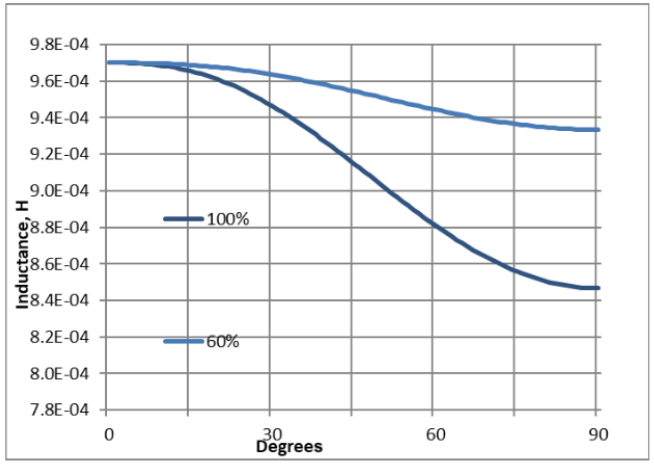
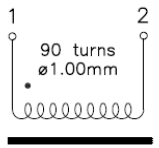


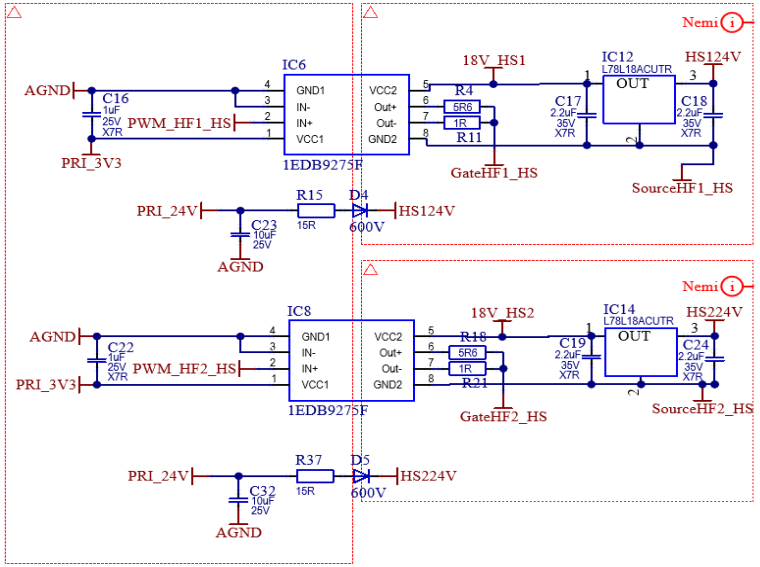
B

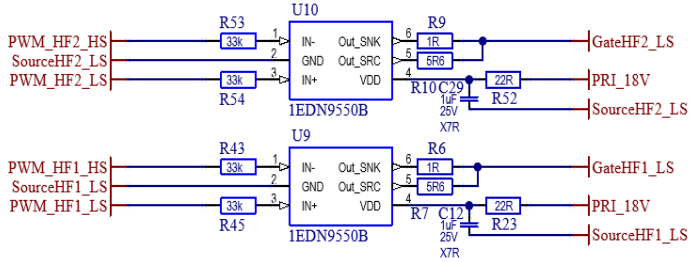




1 kW PSU – CoolSic™ high frequency driving stage with bootstrapping

- Proposal: include linear regulator (LDO) to eliminate modulation
- Modifications in respect to classical bootstrapping supply for high-side driver
  - 24V generated from bias voltage (voltage doubler – A)
  - Only 12V bias required (as CoolMOS™ driving)
  - LDO for low-side (LS) 18V driver supply – B
  - LDO for high-side (HS) 18V driver supply – B





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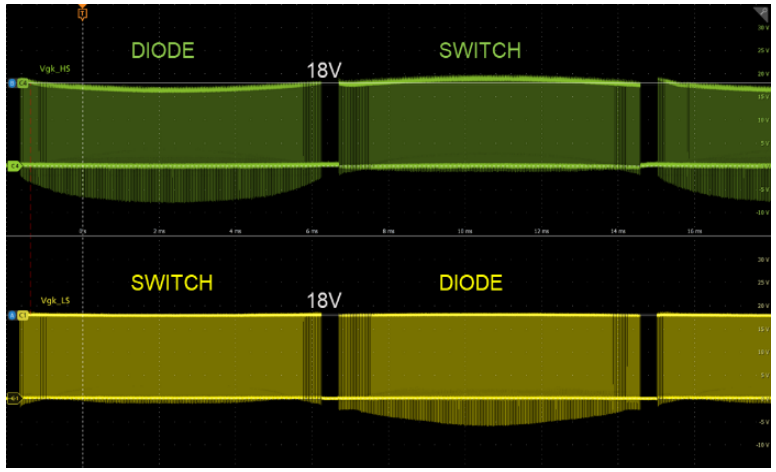

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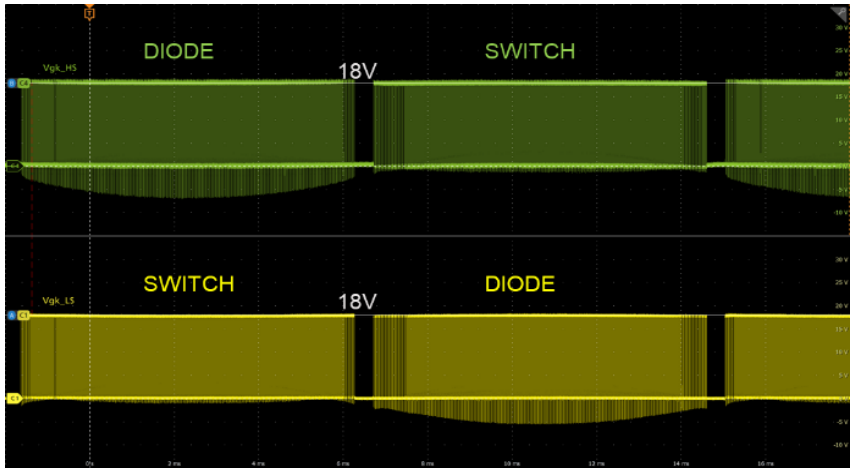
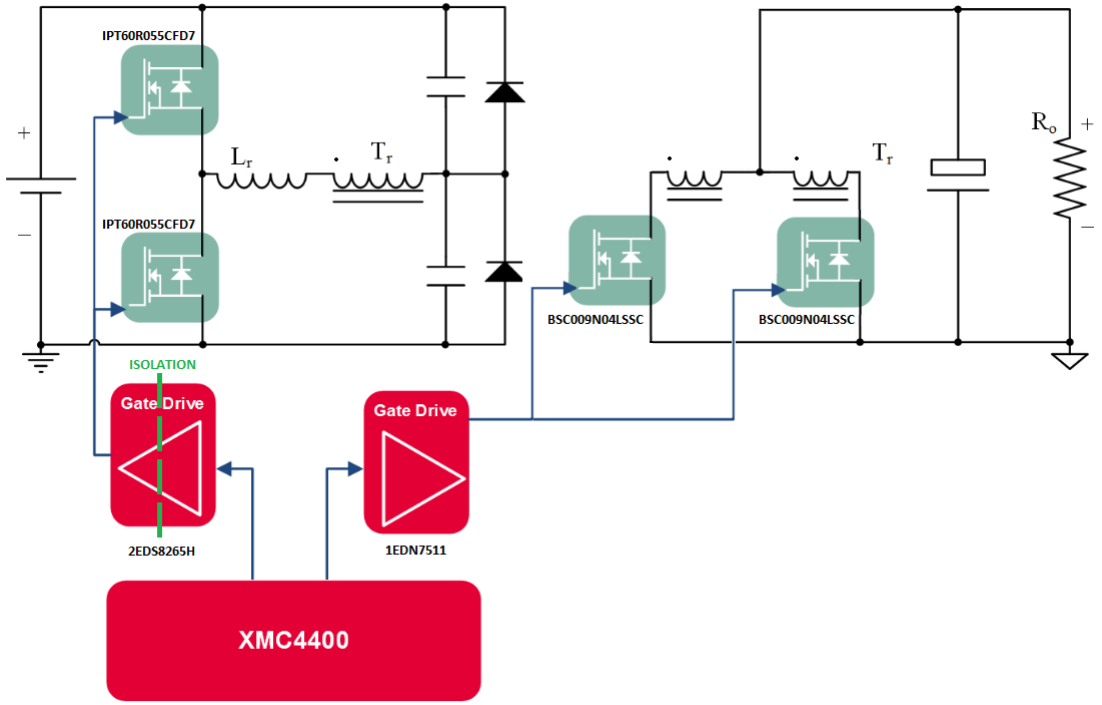
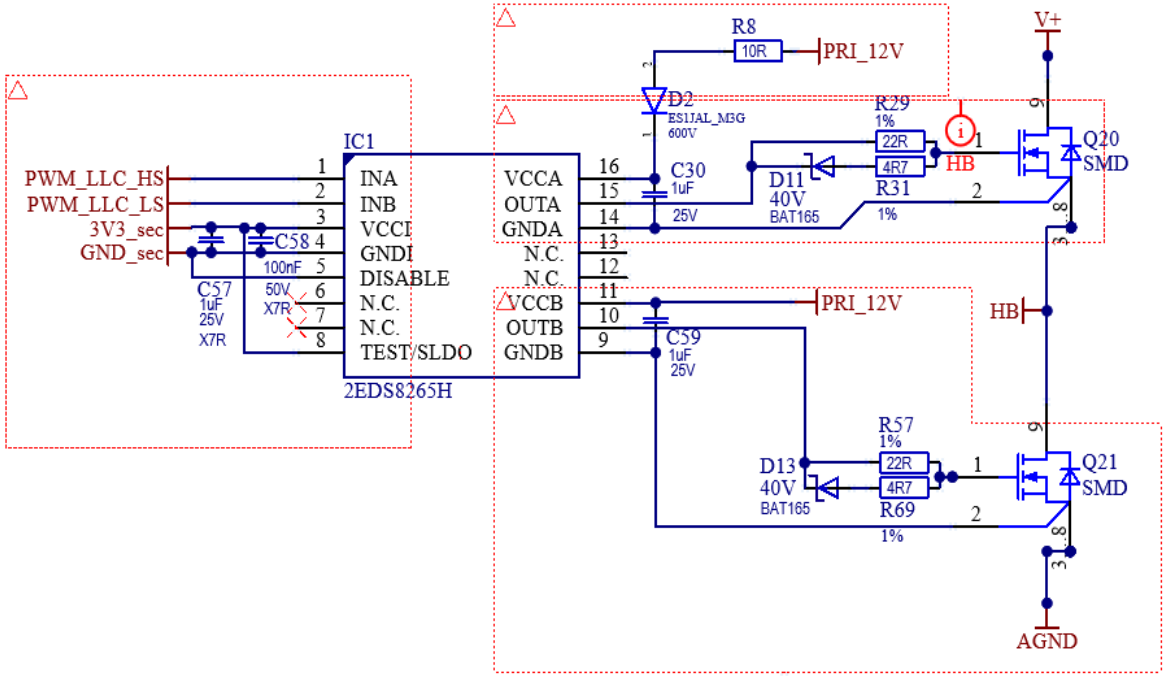


1 kW PSU – CoolMoS™ LLC driving



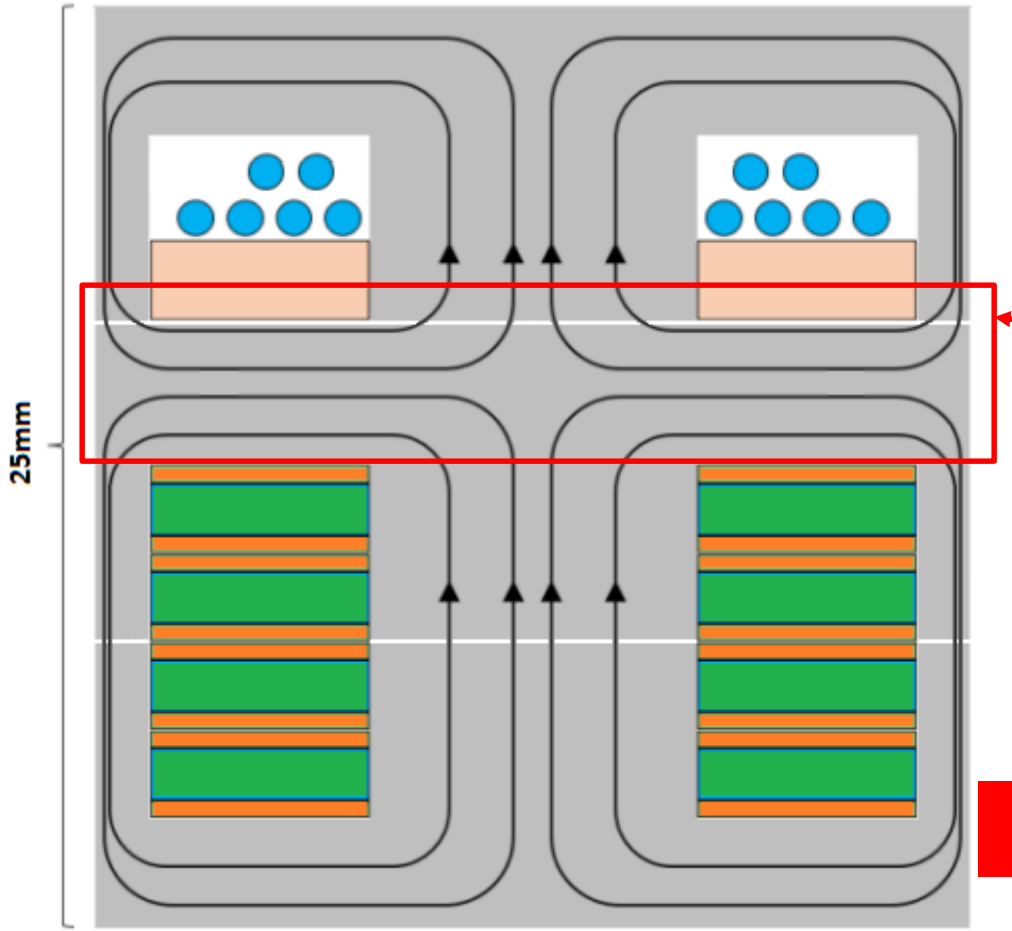
- **LLC primary mosfets:** IPT60R055CFD7 (TOLL package)
- **Secondary mosfets:** 12xBSC009N04LSSC

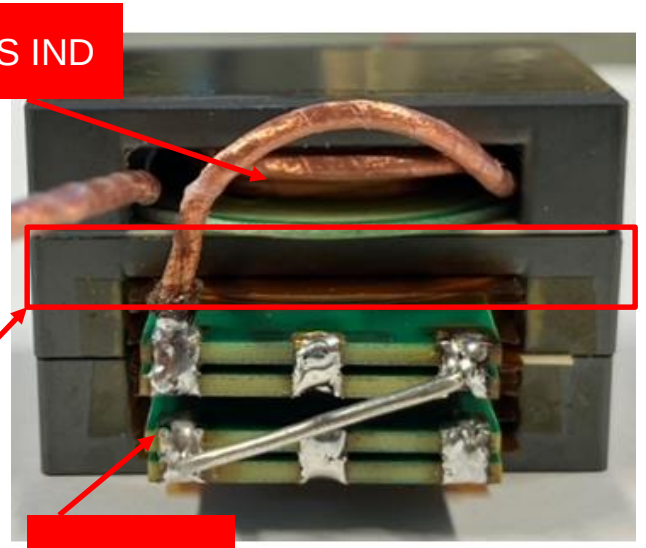
- **Primary mosfet driving**:
  - 2EDS8265H for safety isolation
  - Bootstrapping tecqnique for HS
- **Secondary mosfet driving: 1EDN7511B**

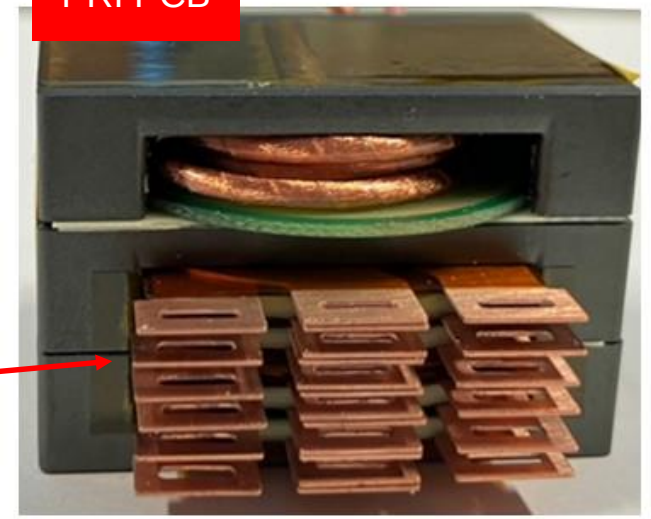


1 kW PSU – Simplified structure of the LLC transformer

Transformer Construction			
	Kapton		0.05
	Sec_1		0.32
	Kapton		0.05
	Sec_2		0.32
	Spacer		0.15
	Kapton		0.05
	Primary		1.255
	Kapton		0.05
	Spacer		0.15
5.110	Sec_1		0.32
	Kapton		0.05
	Sec_2		0.32
	Spacer		0.15
	Kapton		0.05
	Primary		1.255
	Kapton		0.05
	Spacer		0.15
	Sec_1		0.32
	Kapton		0.05
	Gap		0.2
	Kapton		0.05
	Sec_2		0.32
	Spacer		0.15
	Kapton		0.05
	Primary		1.255
	Kapton		0.05
	Spacer		0.15
	Sec_1		0.32
	Kapton		0.05
5.110	Sec_2		0.32
	Spacer		0.15
	Kapton		0.05
	Primary		1.255
	Kapton		0.05
	Spacer		0.15
	Sec_1		0.32
	Kapton		0.05
	Sec_2		0.32
	Kapton		0.05

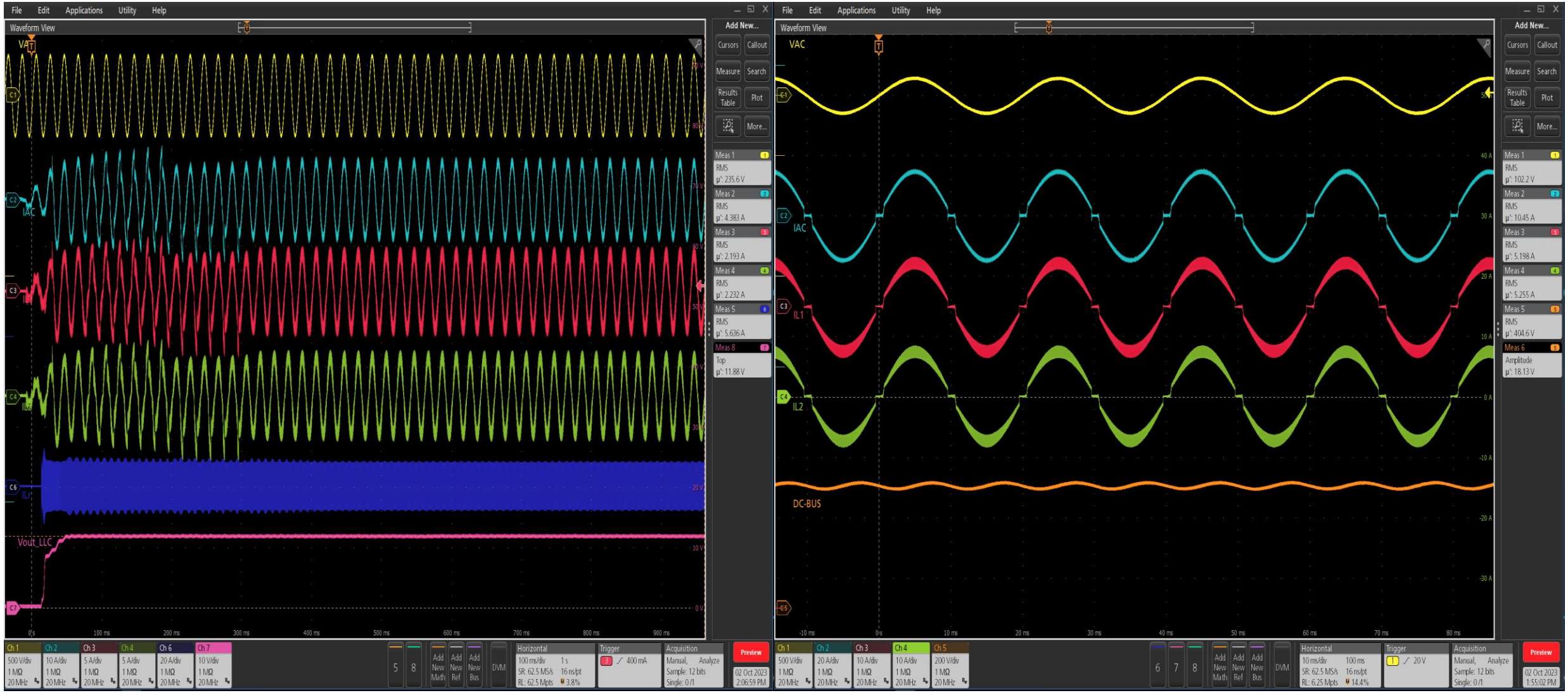




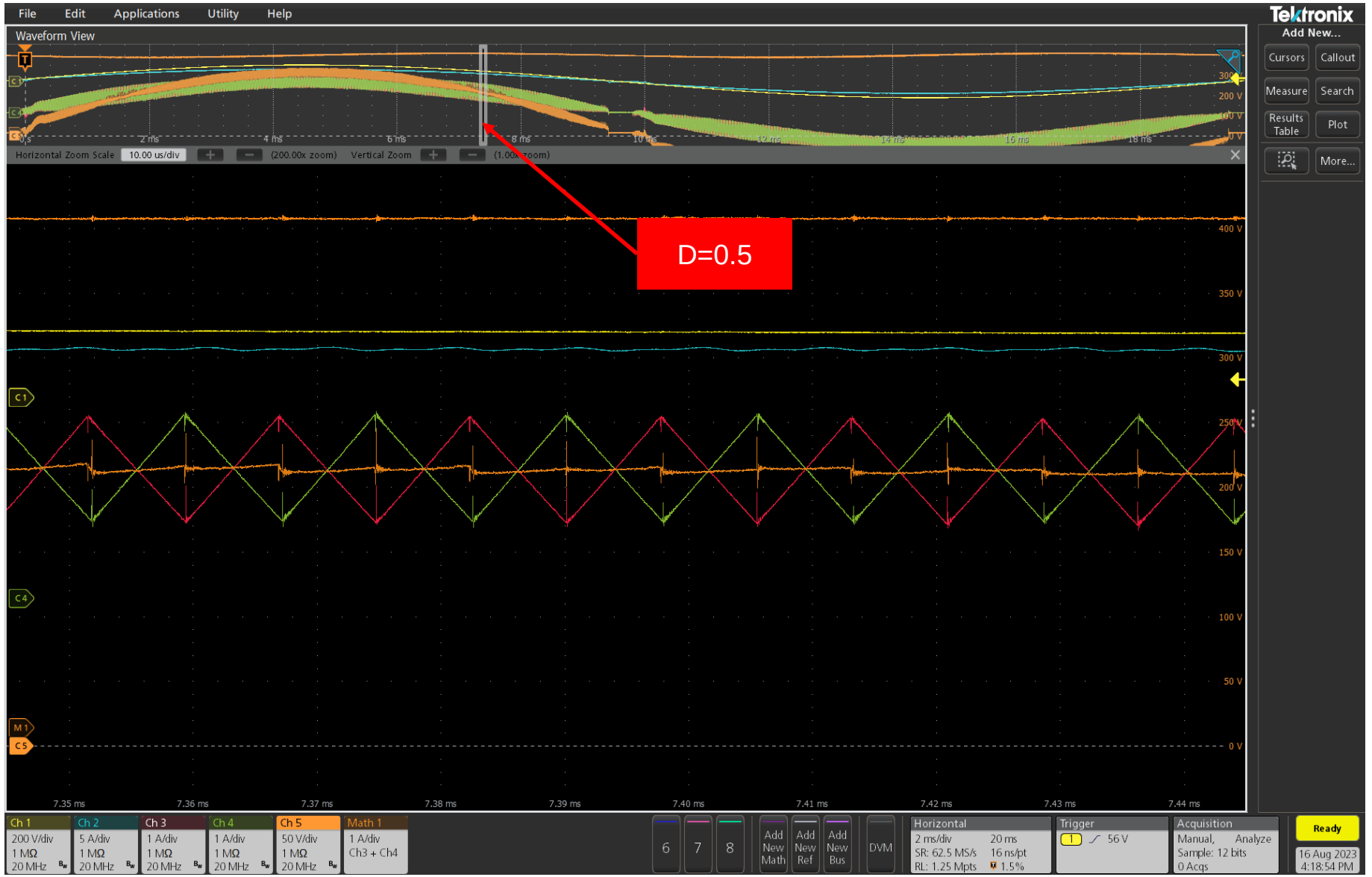


1 kW PSU – Experimental Results (SiC/GaN Version)

Test: VAC = 230V RMS; Full load (FL)



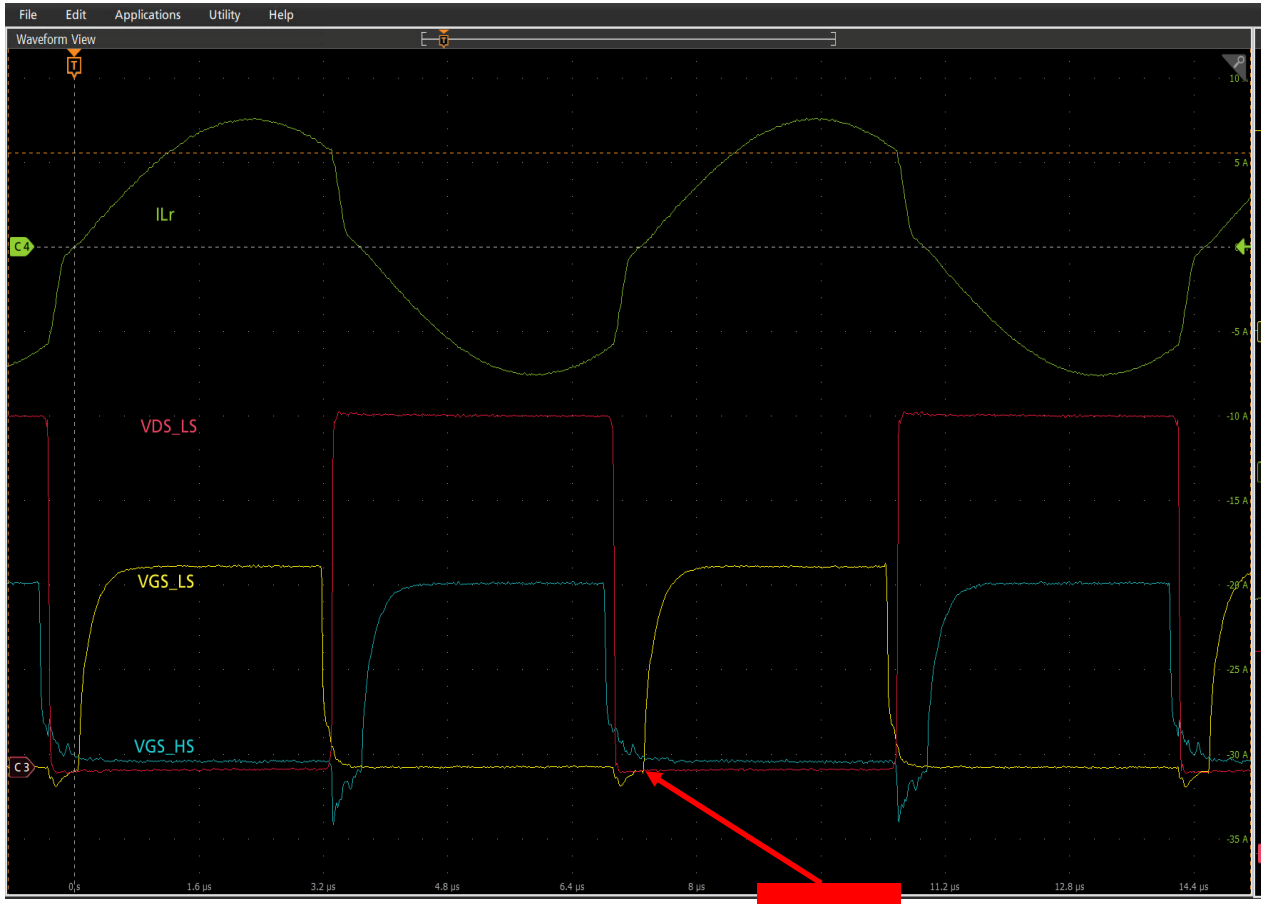
1 kW PSU – Effect of the interleaving (SiC/GaN Version)

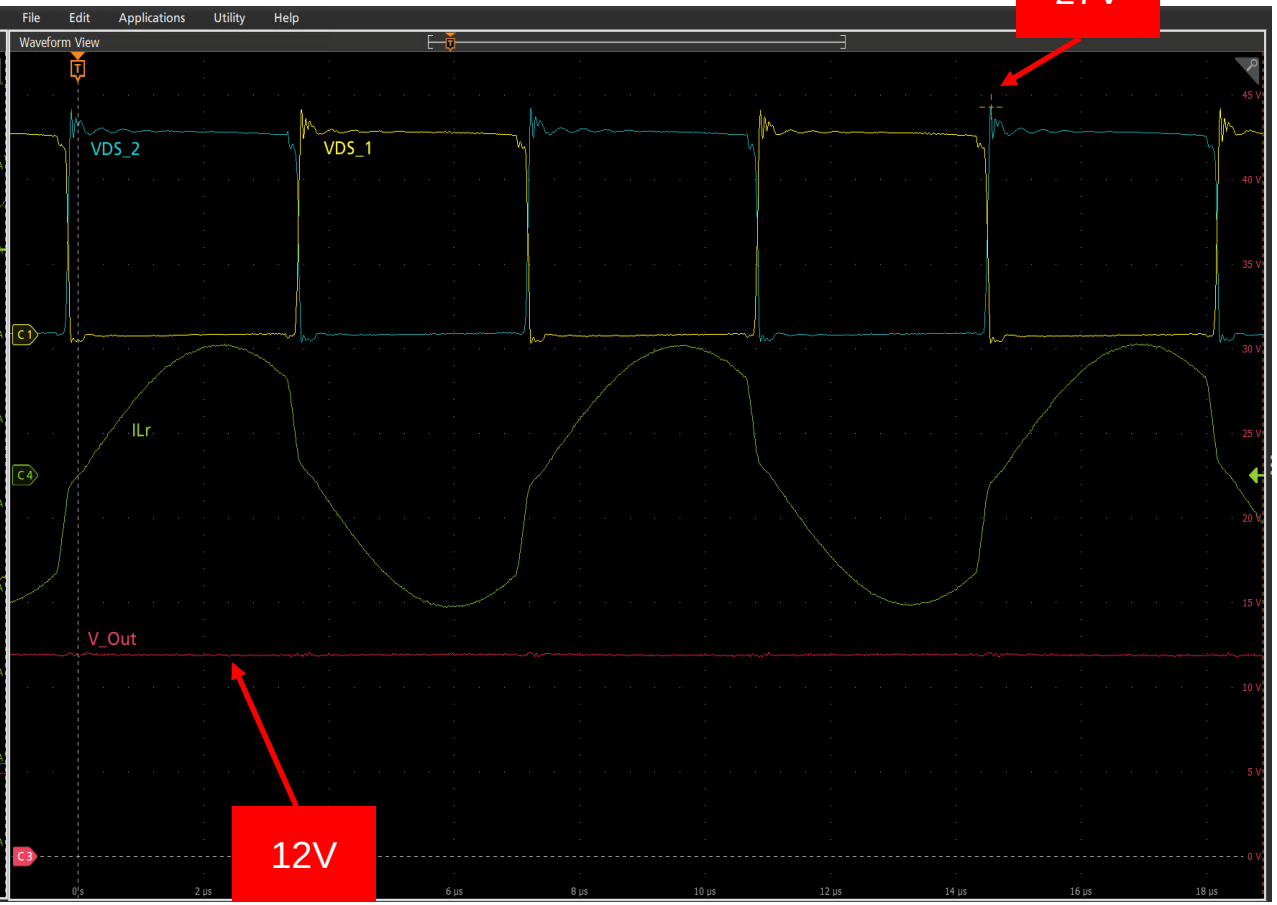


1 kW PSU – LLC steady state Full Load

Primary side

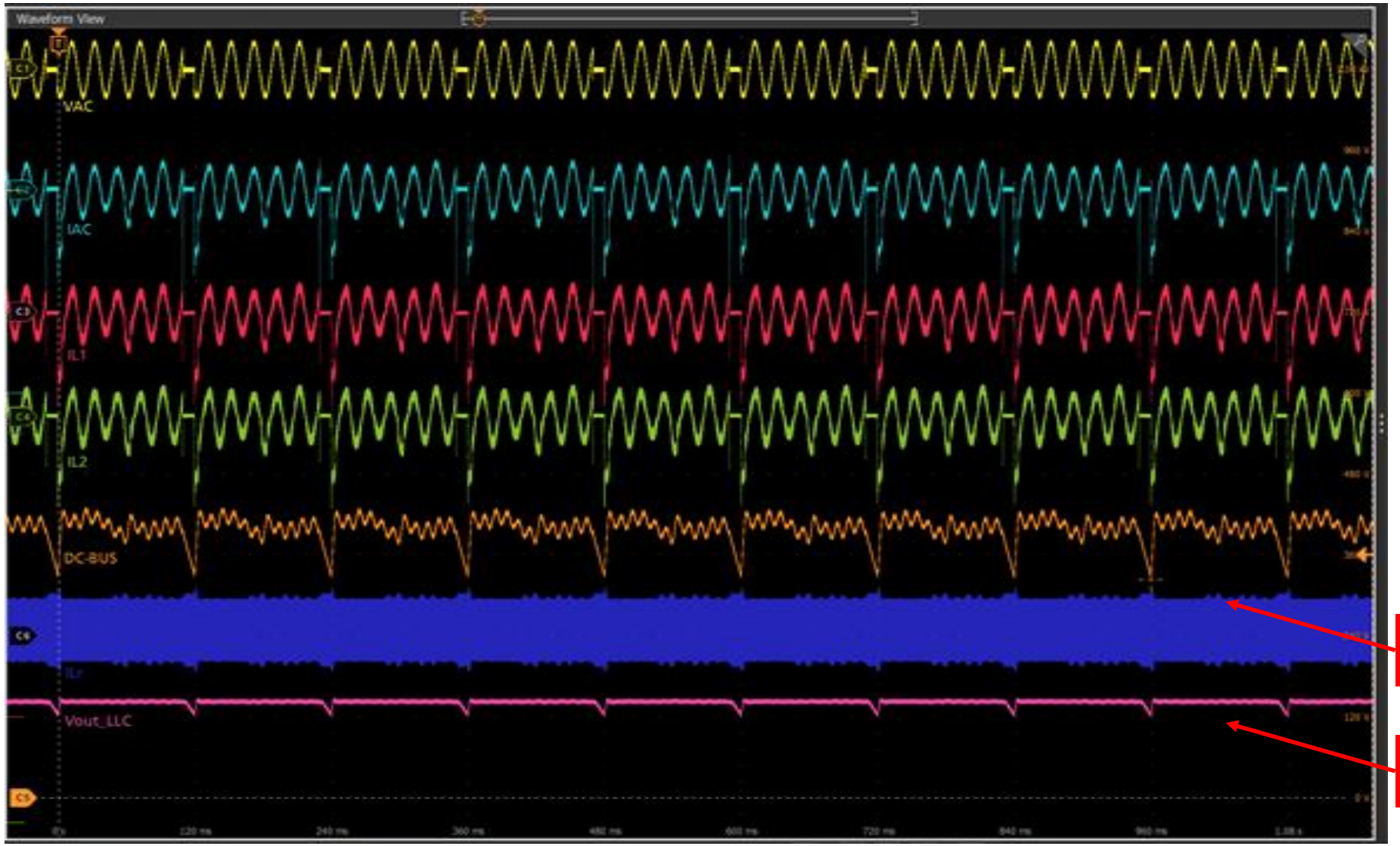
Secondary side



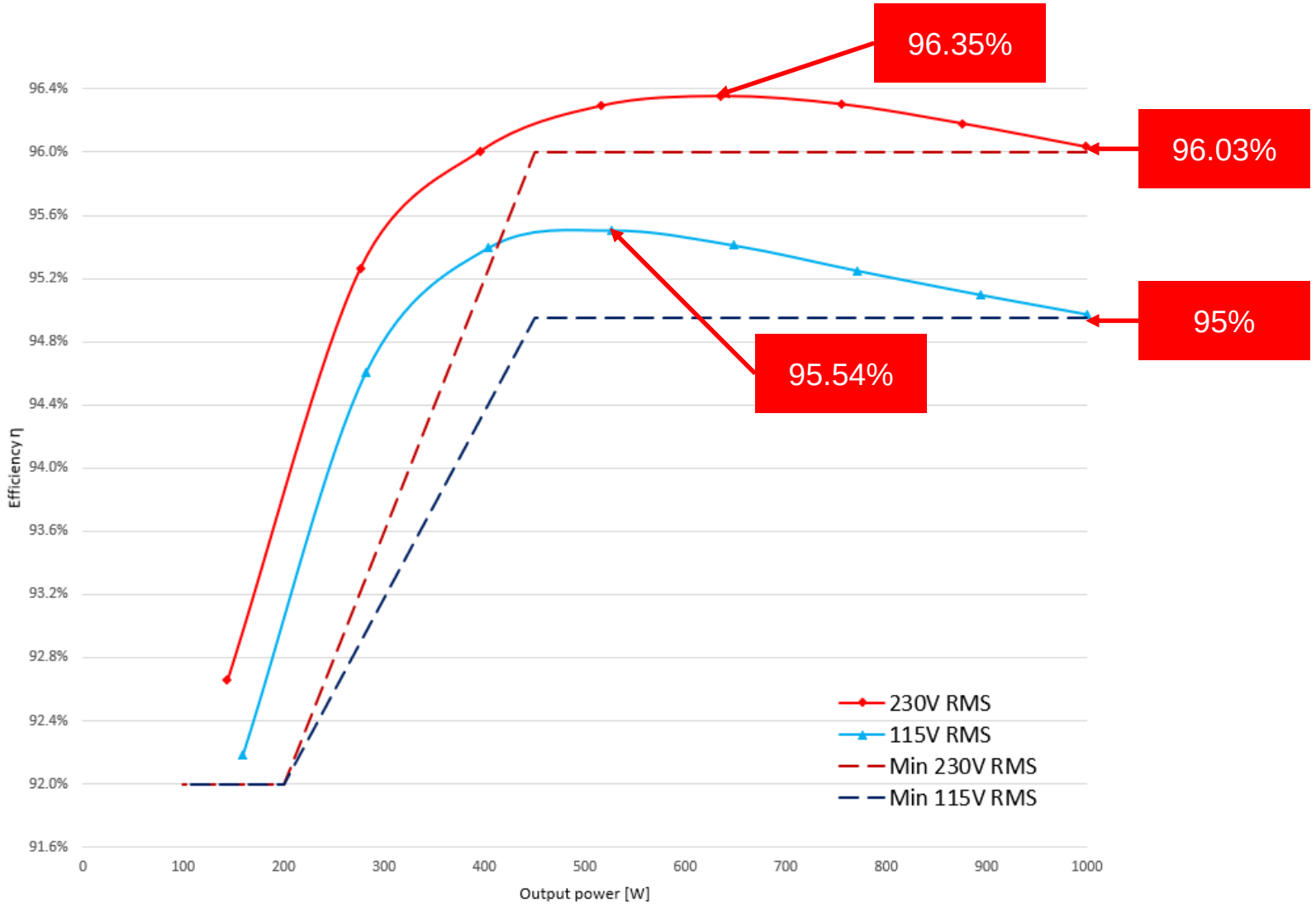


1 kW PSU – Line cycle drop out (SiC/GaN Version)

Test: VAC = 230V RMS;LCDO @ 45° of input voltage, 10 times with a 100ms interval between each repetition; Full Load

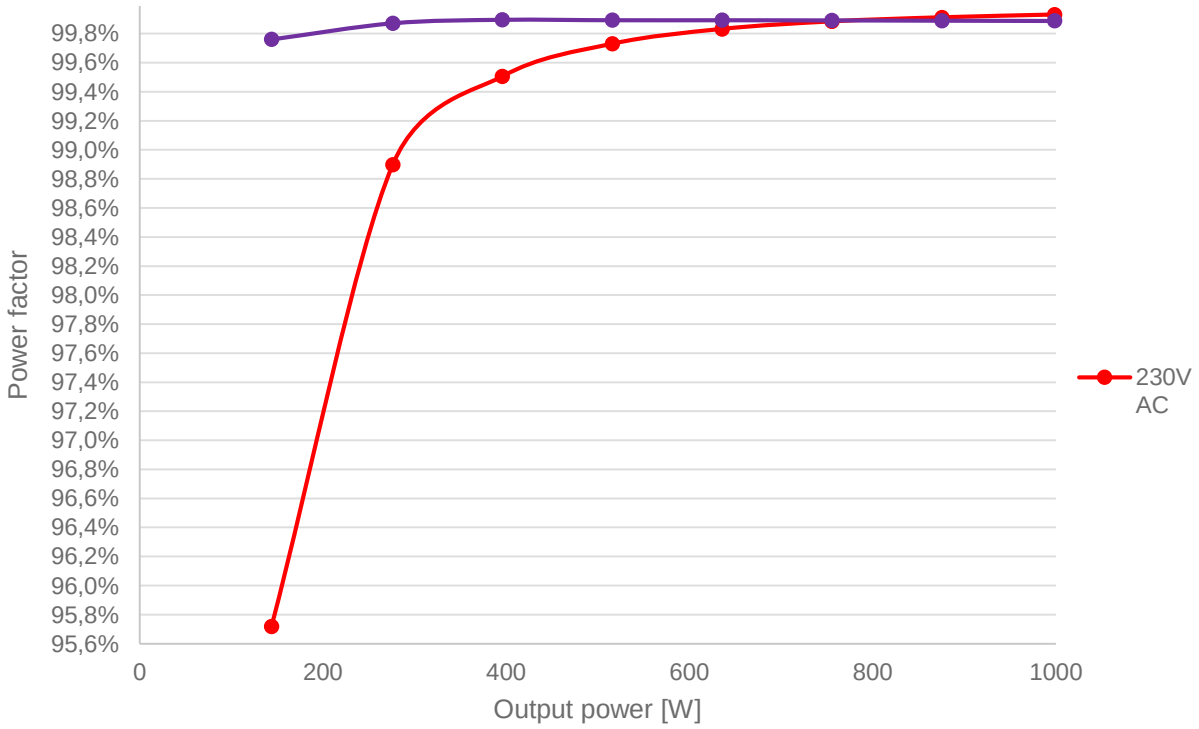


1 kW PSU – Efficiency(SiC Version)

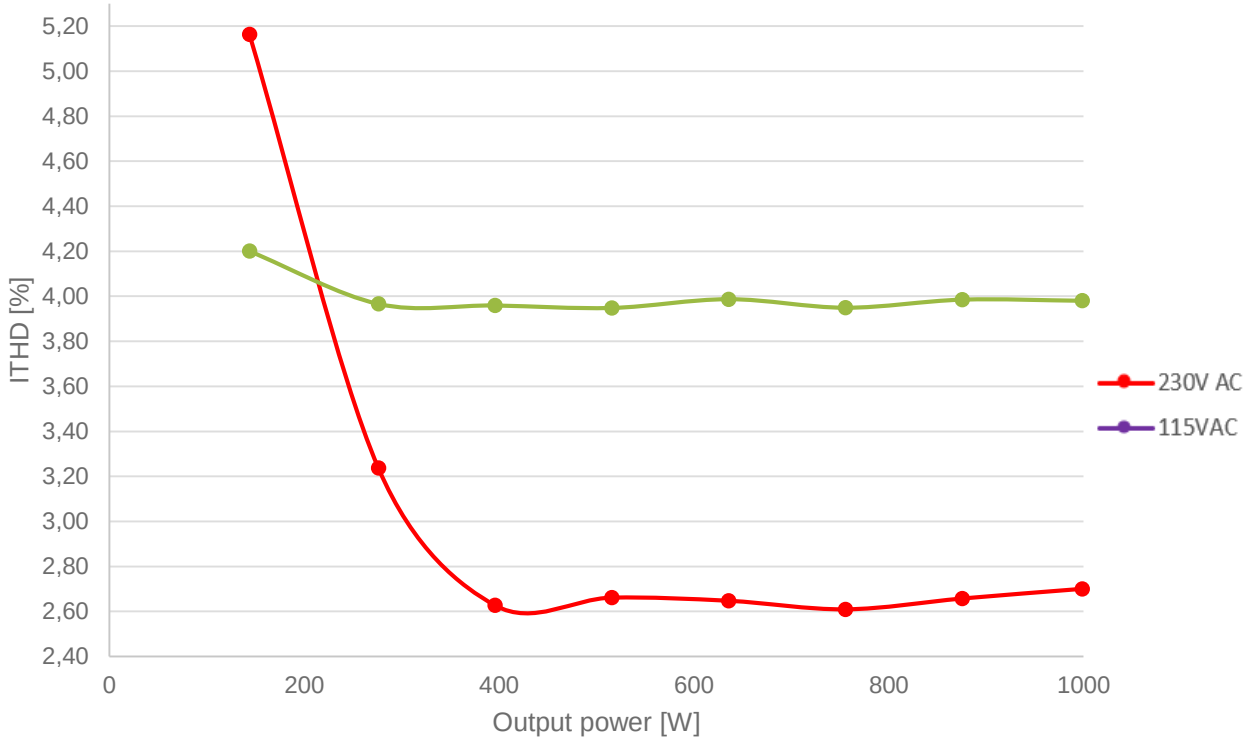


1 kW PSU – THD & Power factor & THD (SiC/GaN)

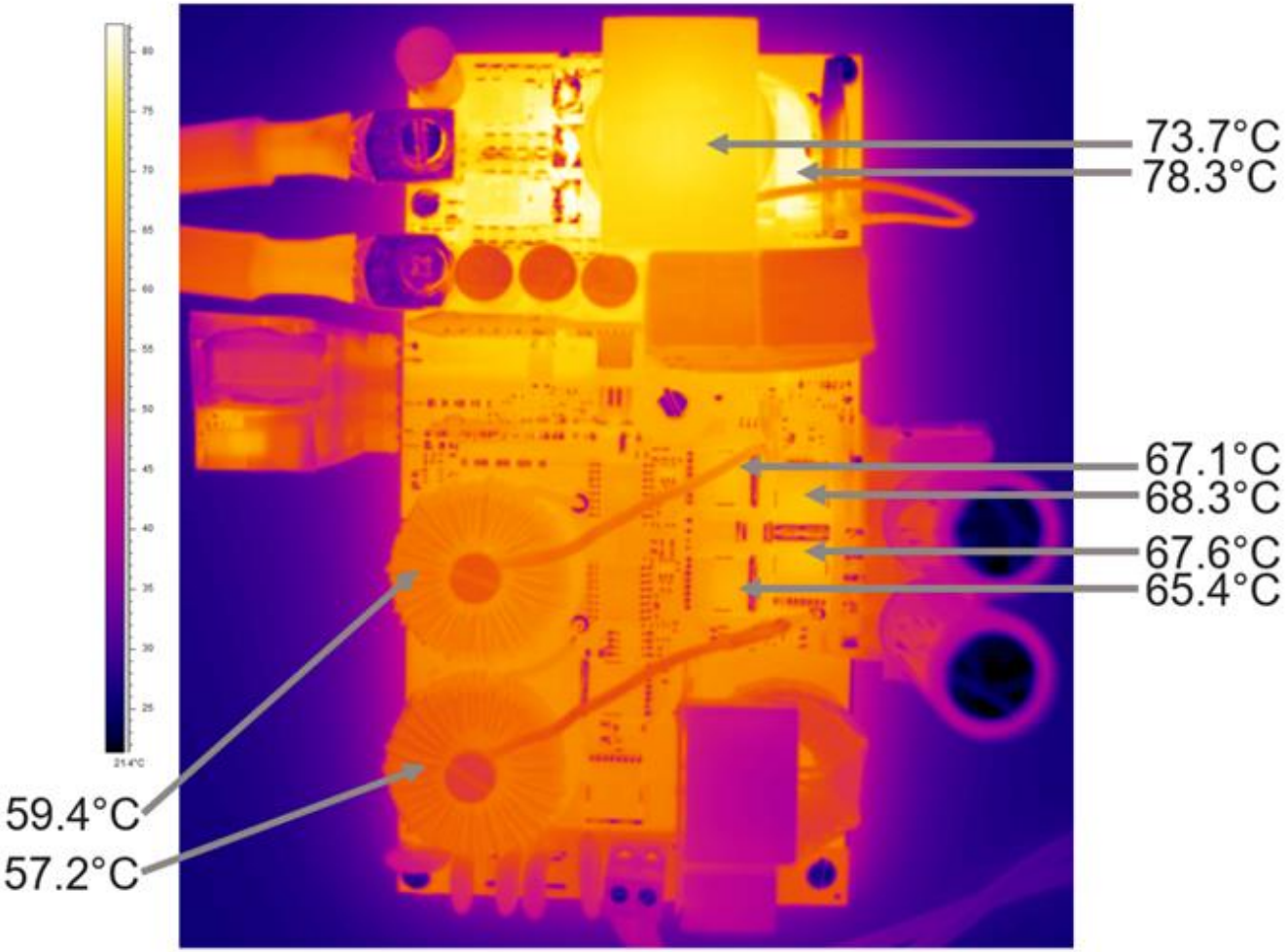
Power factor

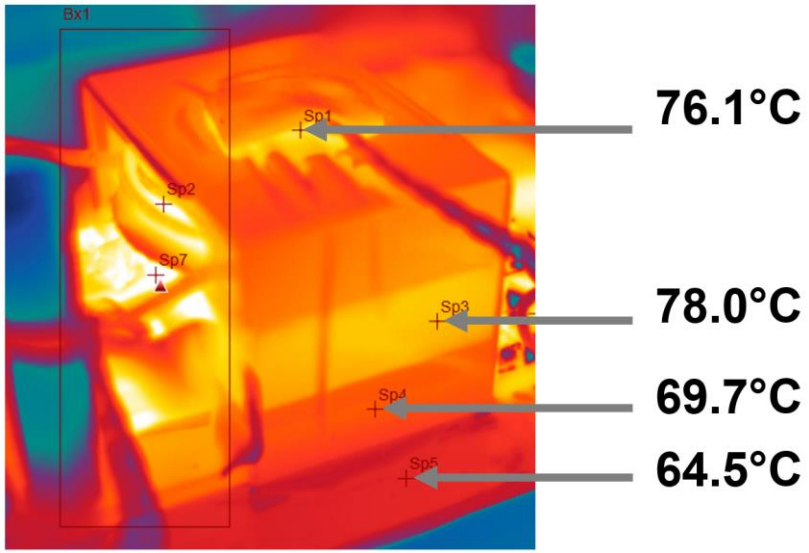


THD [%]



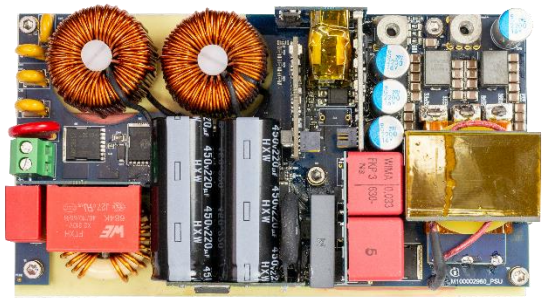
1 kW PSU – Thermal characterization at 115 V AC at 100% of load



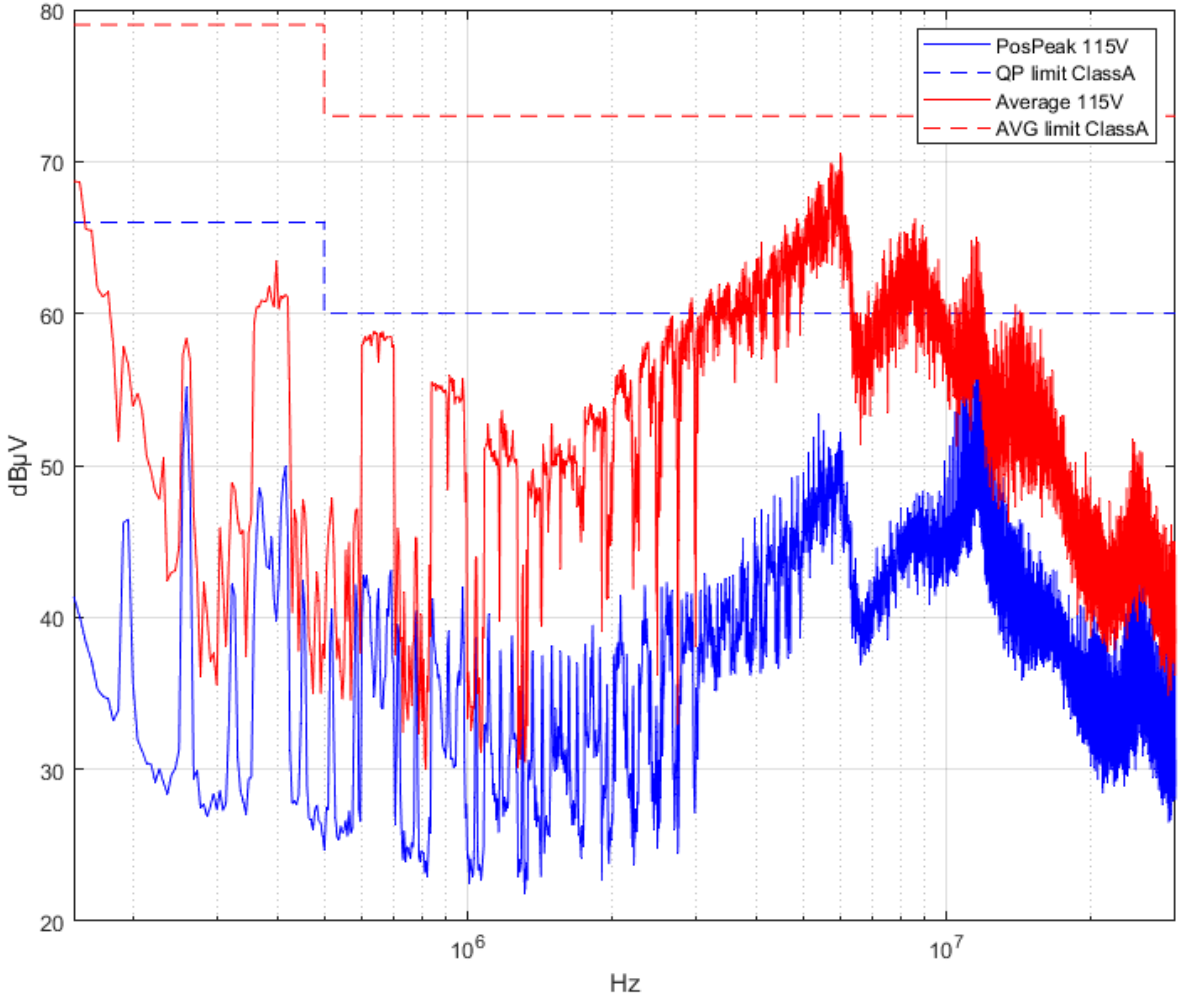


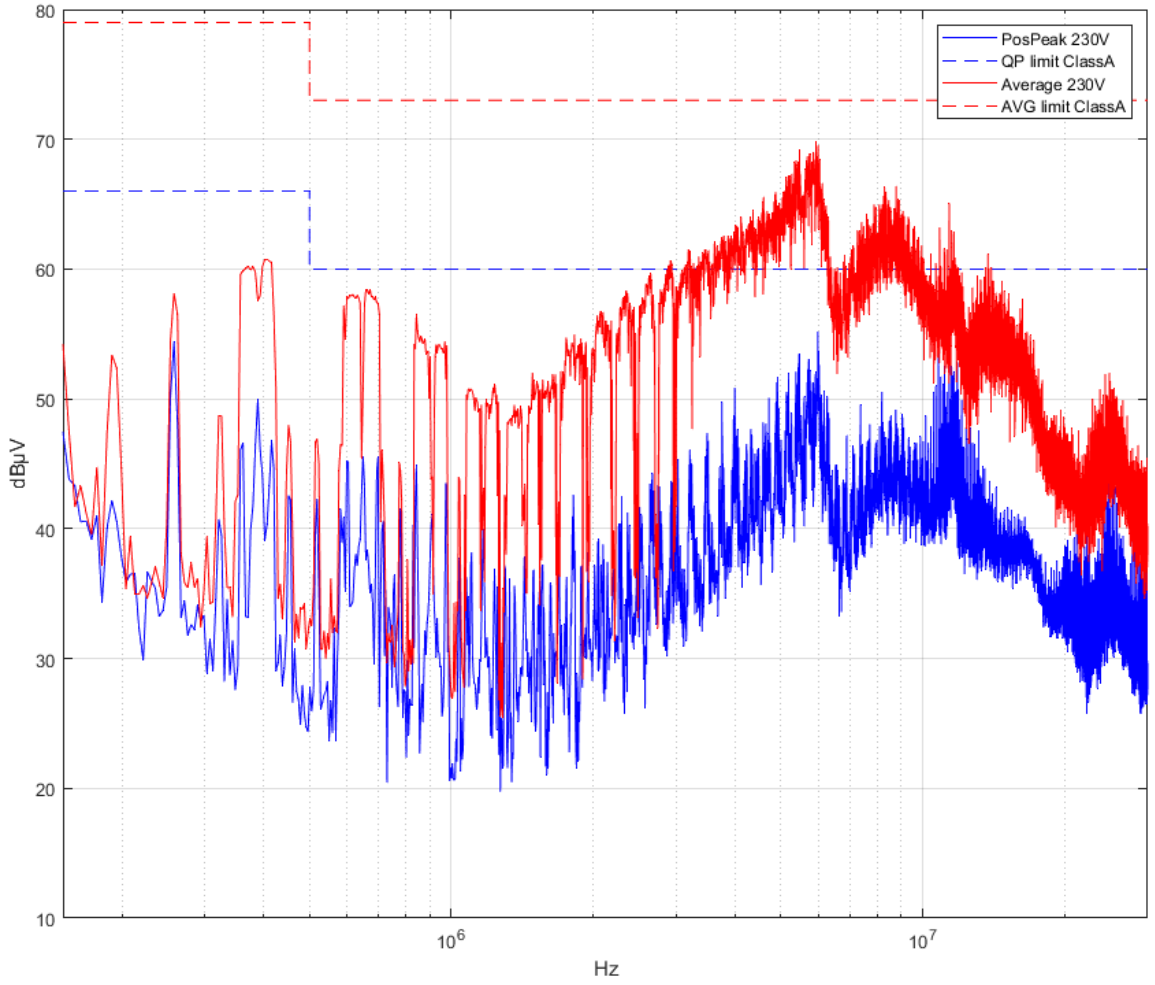
1 kW PSU – EMC: Setup

- EMI measurements in Villach lab
  - No certified set-up
- Lab set-up as shown in figure:
  - LISN between DUT and AC source
  - Spectrum analyzer
  - Resistive load



1 kW PSU – EMC: Class A limits





Contacts

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SAR Telecom Rectifier: Di Domenico Francesco (PSS GAN SAM SAA SAR)

AMG Telecom Rectifier: Morral Eduardo (SMD C3 AMG ICT&SDC)

AMK Telecom Rectifier & Server SMPS: Chou Justin (SMD C3 GC G)

Confluence pages

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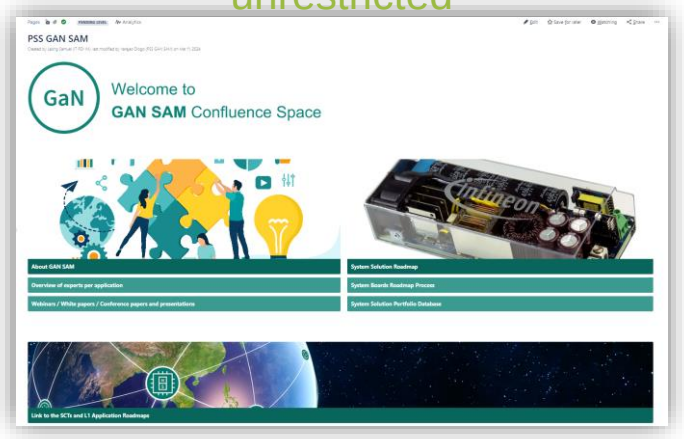

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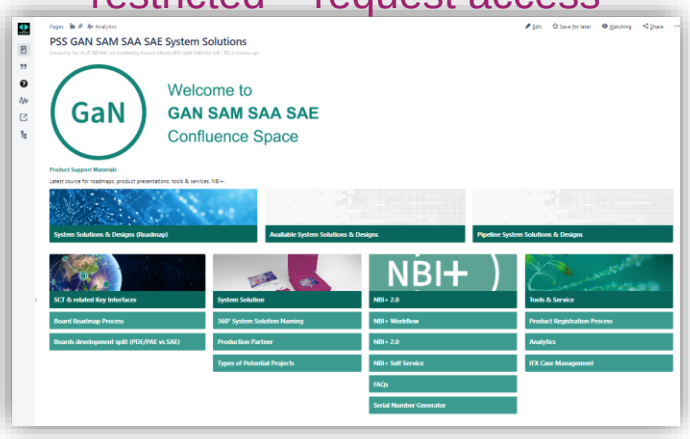

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Infineon