1.6 kW Titanium PSU with CoolMOS™ 600 V CFD7, Q-DPAK and XMC™

EVAL_1K6W_PSU_CFD7_QD

About this document

Scope and purpose

This application note describes a complete Infineon system solution for a 1600 W server power supply unit (PSU) which achieves the 80 PLUS Titanium standard. The EVAL_1K6W_PSU_CFD7_QD board is a server power supply composed of a continuous conduction mode (CCM) bridgeless power factor corrector (PFC) with bi-directional switch and a half-bridge LLC DC-DC resonant converter. This document presents the board using CoolMOS™ MOSFETs and CoolSiC™ Schottky diodes in top-side cooled SMD package (Q-DPAK and D-DPAK) as well as the specifications and the main results obtained during the test of the 1600 W server PSU.

The Infineon components used in this 1600 W server PSU are:

- CoolMOS™ 600 V G7 in D-DPAK, 600 V CoolMOS™ CFD7 in Q-DPAK superjunction (SJ) MOSFETs, and 650 V CoolSiC™ G6 Schottky diode in D-DPAK
- OptiMOS™ 6 40 V MOSFET
- EiceDRIVER™ 1EDI20N12AF isolated and 2EDN7524F non-isolated gate drivers
- XMC1402 and XMC4200 microcontrollers
- CoolSET™ ICE2QR2280G Quasi Resonant (QR) flyback controller

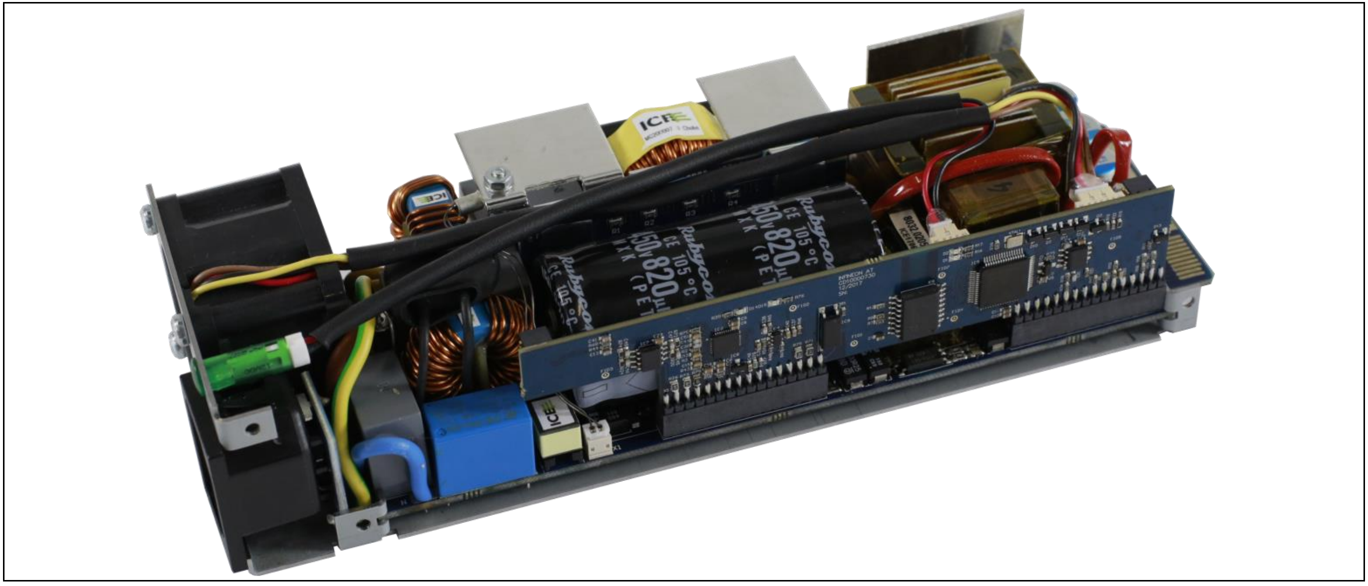

Figure 1 1600 W Titanium server power supply with top-side cooled CoolMOS™ and CoolSiC™

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1 Background and system description

The trend in SMPS in recent years has been towards increased power density with optimized cost. For achieving this higher power density, high efficiency is a key parameter to minimize heat dissipation. Infineon's 800 W server power supply unit (PSU) ([1] and [2]) demonstrates achievable efficiency levels, outperforming 80 PLUS Platinum efficiency. However, if higher power is needed with the same form factor, thus increasing the power density, an even higher efficiency is required to further reduce the heat dissipation and make the design thermally feasible.

The 1600 W server PSU (EVAL_1K6W_PSU_CFD7_QD Evaluation Board) complies with 80 PLUS Titanium as shown in Figure 2. The top-side cooling (TSC) packages (D-DPAK and Q-DPAK), allow keeping the same form factor as the previously introduced 800 W server PSU. Therefore, the power density is increased to 44 W/in^3 for the 1600 W power supply design.

Note: Due to production variations and measurement setup, efficiency variations up to ±0.2 percent could occur with respect to the results shown.

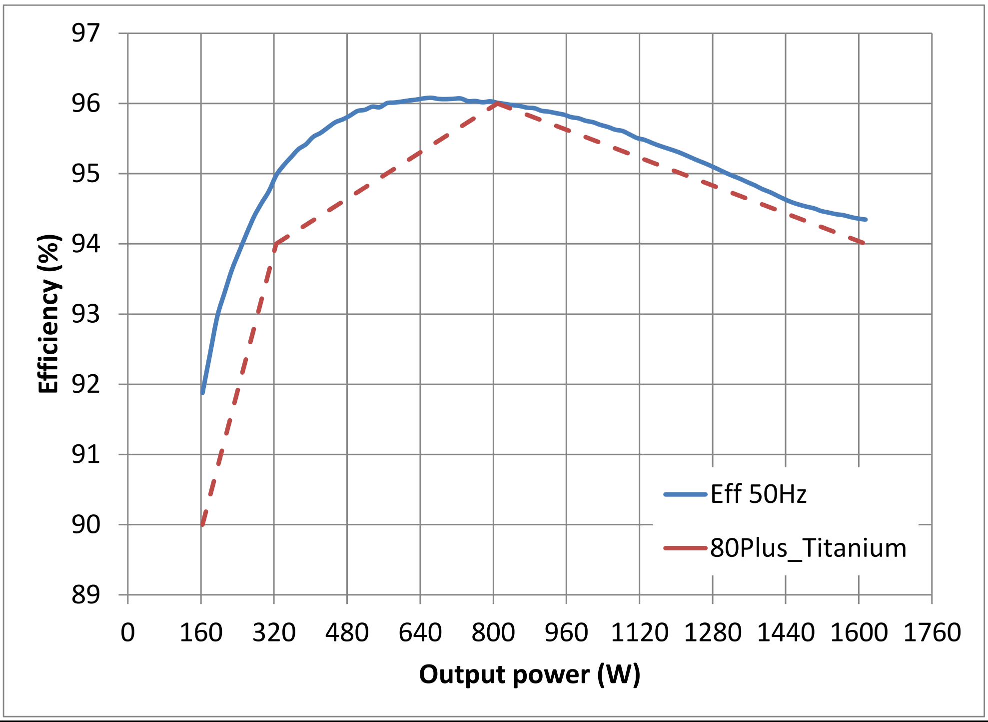


Figure 2 Measured efficiency of the 1600 W server PSU complying with the Titanium efficiency standard

The efficiency shown can be achieved by using the CoolMOS™ 600 V CFD7 and G7 together with CoolSiC™ 650 V G6 Schottky diodes. The outstanding performance of these semiconductor technologies, together with the D-DPAK and Q-DPAK SMD packages with top-side cooling, enables an efficient system thinking [3] and [4].

The devices used in the implementation of EVAL_1K6W_PSU_CFD7_QD server PSU are:

- CoolMOS™ 600 V, 75 mΩ CFD7 in Q-DPAK TSC package (IPDQ60R075CFD7) and 8 A 650 V CoolSiC™ G6 Schottky diodes in D-DPAK TSC package (IDDD08G65C6), for PFC

- CoolMOS™ 600 V, 50 mΩ G7 in D-DPAK TSC package (IPDD60R050G7) and OptiMOS™ 6 40 V, 7 mΩ in Super SO-8 package (BSC007N04LS6) for LLC
- OptiMOS™ 6 40 V, 7 mΩ in Super SO-8 package (BSC007N04LS6) as O-ring switch
- EiceDRIVER™ 1EDI20N12AF isolated and 2EDN7524F non-isolated gate drivers
- ICE2QR2280G QR flyback controller with integrated CoolMOS™ 800 V for the bias auxiliary supply
- XMC1402 (PFC) and XMC4200 (LLC) microcontrollers for control implementation

This document will describe the system and board of the 1600 W server SMPS, as well as the specifications and main test results. For more information on Infineon semiconductors, see the Infineon website as well as the Infineon evaluation board search and the different websites for the different implemented components:

- CoolMOS™ power MOSFETs
- OptiMOS™ power MOSFETs
- CoolSiC™ Schottky diodes
- Gate driver ICs
- QR CoolSET™
- XMC™ microcontrollers

1.1 System description

The EVAL_1K6W_PSU_CFD7_QD design consists of a bridgeless PFC with a bi-directional switch [8] as the AC-DC stage and a half-bridge LLC with Synchronous Rectification (SR) as the DC-DC stage (Figure 3). The power supply has been designed to comply with the requirements of a datacenter server operation.

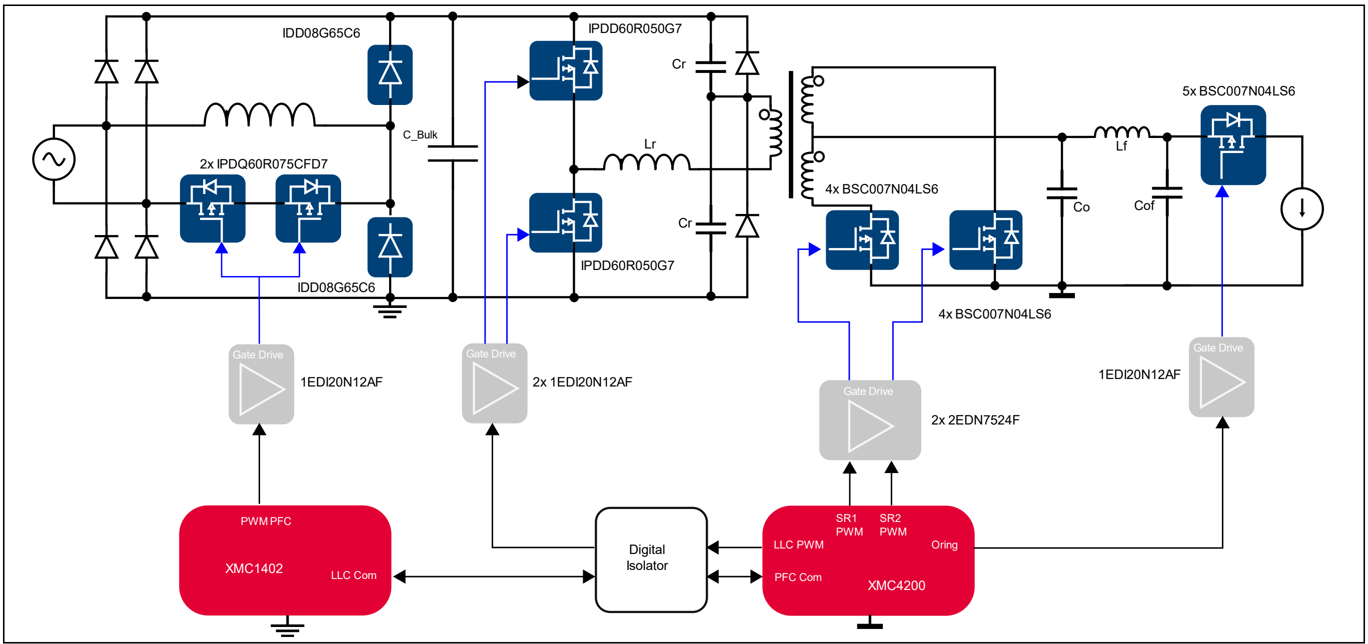


Figure 3 **Simplified diagram of 1600 W Titanium server PSU with D-DPAK and Q-DPAK TSC (EVAL_1K6W_PSU_CFD7_QD) Infineon power semiconductors.**

The PFC stage is operated exclusively at high-line (176 Vrms minimum, 230 Vrms nominal) in CCM with a switching frequency of 65 kHz. The bulk capacitance is designed to comply with 10 ms hold-up time (Table 1). The PFC function to achieve bulk voltage control at an adequate level for the DC-DC converter, while demanding high-quality current from the grid, is implemented in an Infineon XMC1402 microcontroller. For more information on PFC control implementation in the XMC™ 1000 family, see [1], [2], [5], and [6].

The DC-DC stage is an LLC resonant topology with center-tapped transformer and SR. The resonant frequency of the implemented resonant tank is 160 kHz and the operating switching frequency is allowed to move in the range from 52 kHz to 300 kHz. The targeted output voltage is 12.2 V with a nominal output current of 132 A. The LLC control is implemented in an XMC4200 Infineon microcontroller, which includes voltage regulation, burst mode operation, output overcurrent protection (OCP) and overvoltage protection (OVP), and timer configuration for CoolMOS™ and OptiMOS™ safe operation. For more information on digital control implementation of LLC in the XMC™ 4000 family, see [1], [2], and [7].

O-ring switches are mounted for efficiency consideration of the full system solution. However, no advance O-ring function is included in the control implementation. Furthermore, an I^2C channel is reserved in the secondary controller, which would enable PM-Bus communication.

1.2 Board description

Figure 4 shows a placement of the different sections of the EVAL_1K6W_PSU_CFD7_QD server PSU with Infineon D-DPAK and Q-DPAK power semiconductors.

Board specifications:

- **Length:** 19.3 cm
- **Width:** 7 cm
- **Height:** 4.4 cm
- **Power density:** 44 W/in^3

Component placement:

On the left, the fuse and the NTC inrush current limiter are placed together with the input relay immediately after the AC input connector. This is followed by a two-stage EMI filter. In the middle section, the AC-DC stage and the bulk capacitor are placed. On the right side, the DC-DC converter, the O-ring switches and the output connector are placed. The bias converter generates the required supplies for the driving and control circuitry. The control board is placed along the side of the power supply. The power semiconductors in TSC packages of the PFC and primary half-bridge of the LLC are placed in a power board attached to a heatsink, as shown in the pink area of Figure 4.

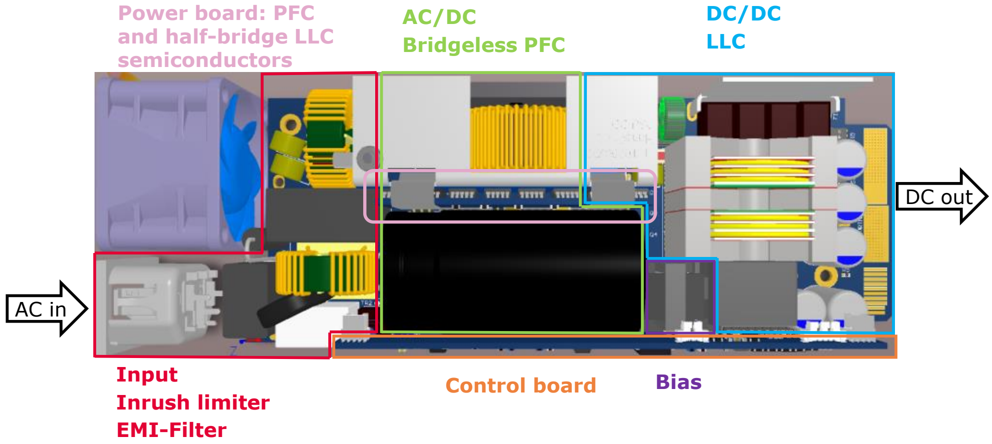


Figure 4 **Placement of the different sections in the 1600 W PSU with Infineon TSC CoolMOS™ and CoolSiC™**

1.2.1 Output connector

EVAL_1K6W_PSU_CFD7_QD includes a host board for the output connector, as for the Infineon 800 W server power supply evaluation board [1]. This board includes power connectors and a sensing point for the output voltage as well as a switch for remote on-off (Figure 5 – left). The voltage of the sensing connection (12 V sense – GND sense) is the one used for DC output regulation and can be used for output sensing in external equipment.

Furthermore, the host board enables the connection of the output voltage terminals to the fan supply (Fan 12 V – Fan GND). However, an external fan supply is only possible by directly accessing the connector pin. In that case, the second pin of the signal connector (Fan 12 V in Figure 5 – right) must be lifted to provide the proper fan supply voltage.

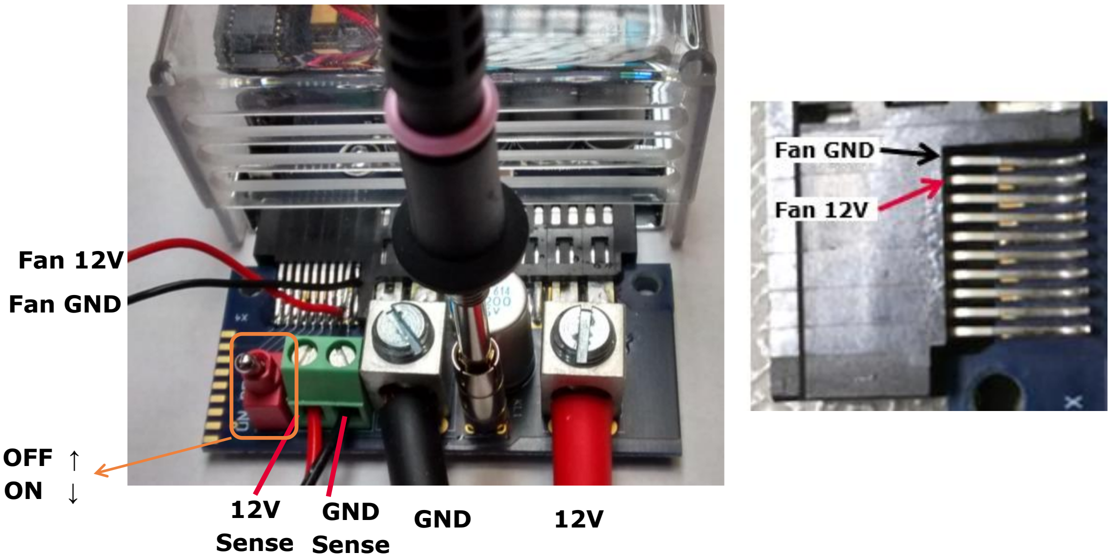


Figure 5 **Output connector PCB with the connections and remote on/off switch (left) and detail of fan connection pins (right).**

1.3 Power board with TSC (D-DPAK/Q-DPAK) power semiconductors

The use of the top-side cooled D-DPAK and Q-DAK packages enable different system thinking and the inclusion of SMD packages in high-power SMPS applications ([3] and [4]) as shown in Figure 4.

The use of CoolMOS™ G7 and CFD7 transistors in both PFC and LLC allow loss reduction due to improvement of different figures of merit [3], [4]. Furthermore, the forward voltage in the CoolSiC™ G6 diode is reduced, contributing to lower diode losses [3]. The lower losses together with an improved thermal resistance, which compensates the lower dissipation area in respect to leaded packages, and the low profile of the top-side cooled SMD package, enable mounting of the PFC and half-bridge switches to share the same heatsink.

The use of a power board (Figure 6) enables an increase of power density, while having optimized commutation loops and therefore, low parasitic inductances. This power board, which mounts the PFC CoolMOS™ CFD7 switches and CoolSiC™ G6 Schottky diodes, together with the LLC CoolMOS™ G7 half-bridge switches, is vertically placed in the central part of the PSU in front of the fan (the pink area in Figure 4). In this case, six parts are soldered to the power board and share the same heatsink, which is attached by using pressure clips as shown in Figure 7. The heatsink includes an NTC for monitoring the temperature for protection and for adapting the fan speed.

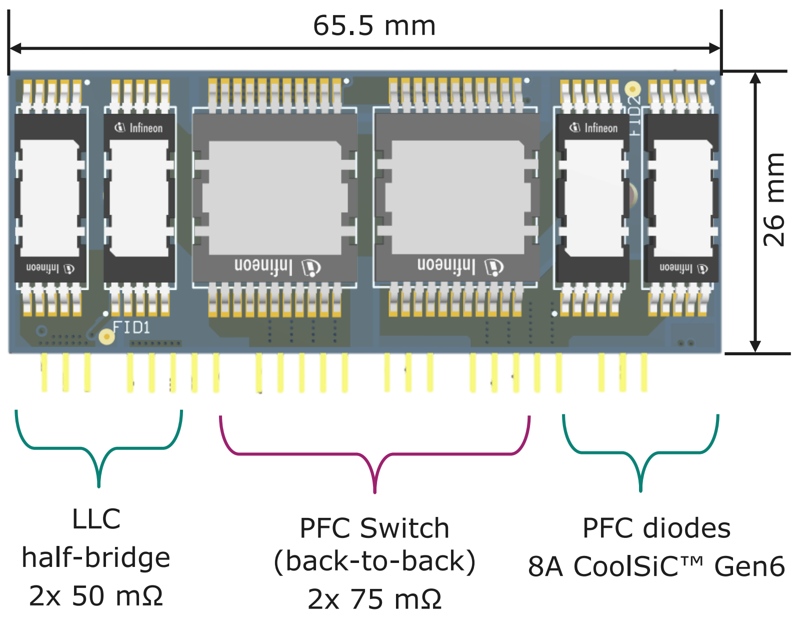


Figure 6 Power board mounting the Infineon D-DPAK and Q-DPAK semiconductors for the PFC and half-bridge LLC

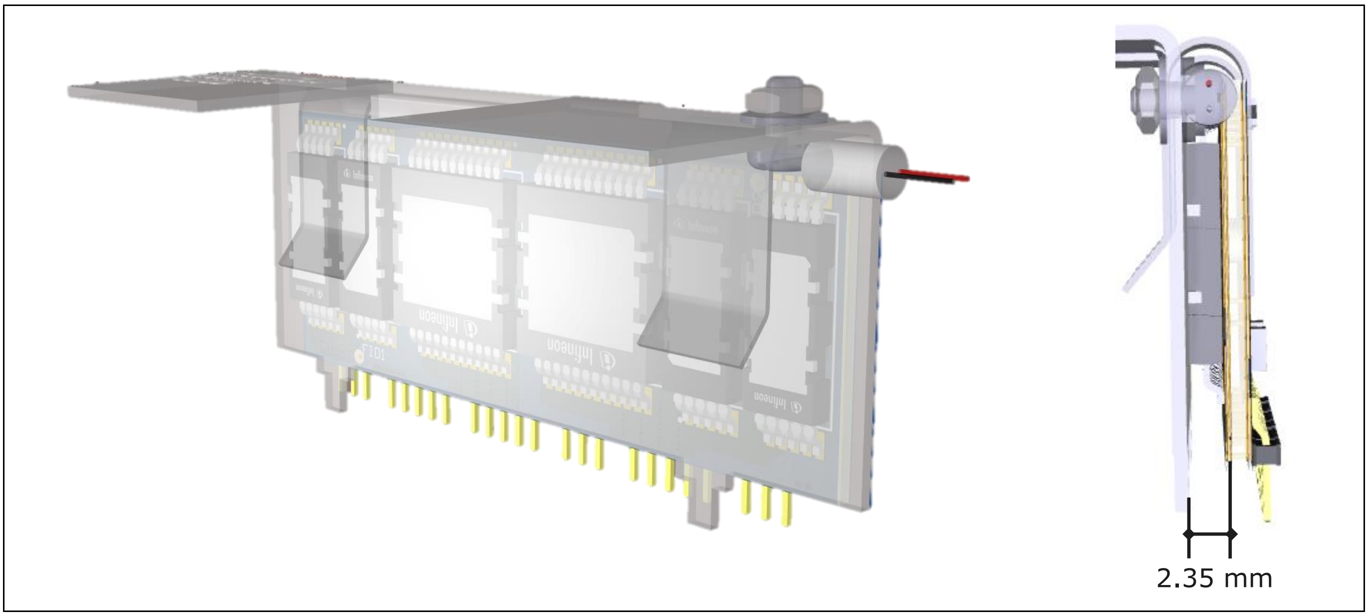


Figure 7 **Heatsink mounting for the power board of EVAL_1K6W_PSU_CFD7_QD**

2 Specification and test results

This chapter presents the specifications, performance, and behavior of the 1600 W server PSU developed using CoolMOS™ in TSC package. Table 1 shows the demonstrator performance and specifications under several steady-state and dynamic conditions.

Table 1 Summary of specifications and test conditions for the 1600 W PSU

<table>
<tr><th colspan="2">Test</th><th>Conditions</th><th colspan="2">Specification</th></tr>
<tr><td colspan="2">Efficiency test</td><td>230 Vrms, 50 Hz/60 Hz, 10 percent to 100 percent load</td><td colspan="2">80 PLUS Titanium efficiency.
η_{pk} = 96 percent at 800 W (50 percent load)</td></tr>
<tr><td colspan="2">Current THD</td><td>230 Vrms, 50 Hz/60 Hz, 10 percent to 100 percent load</td><td colspan="2">THDi less than 10 percent from 20 percent load</td></tr>
<tr><td colspan="2">Power factor</td><td>230 Vrms, 50 Hz/60 Hz, 10 percent to 100 percent load</td><td colspan="2">PF more than 0.95 from 20 percent load</td></tr>
<tr><td colspan="2">Output voltage</td><td>–</td><td colspan="2">12.2 V</td></tr>
<tr><td colspan="2">Steady-state V_{out} ripple</td><td>230 Vrms, 50 Hz/60 Hz, 10 percent to 100 percent load</td><td colspan="2">$|\Delta V_{out}|$ less than 120 $mV_{pk\text{-}pk}$</td></tr>
<tr><td colspan="2">Inrush current</td><td>230 Vrms, 50 Hz/60 Hz, measured on the first AC cycle</td><td colspan="2">I_{in_peak} less than 30 A</td></tr>
<tr><td rowspan="2">Power line disturbance</td><td>AC lost (hold-up time)</td><td>230 Vrms, 50 Hz, 10 ms at 100 percent load, 20 ms at 50 percent load</td><td rowspan="2">$|\Delta V_{out}|$ less than 240 mV_{pk}</td><td rowspan="2">No damage:
* PSU soft-start if bulk voltage under 310 V
* PSU soft-start if V AC out of range for certain time</td></tr>
<tr><td>Voltage sag</td><td>200 Vrms, 50Hz/60Hz, different sag conditions, 100 percent load</td></tr>
<tr><td colspan="2">Brown-out</td><td>–</td><td colspan="2">174 V on; 168 V off</td></tr>
<tr><td colspan="2" rowspan="2">Load transient</td><td>1 A ↔ 66 A, 0.5 A/µs</td><td colspan="2" rowspan="2">$|\Delta V_{out}|$ less than 240 mV_{pk}</td></tr>
<tr><td>66 A ↔ 133 A, 0.5 A/µs</td></tr>
<tr><td colspan="2" rowspan="4">OCP</td><td>30 s at 141 A</td><td colspan="2" rowspan="3">LLC off
Resume of operation requires bulk voltage to drop under 310 V</td></tr>
<tr><td>10 s at 149 A</td></tr>
<tr><td>1 ms at 168 A</td></tr>
<tr><td>Output terminals in short-circuit</td><td colspan="2">Detection within switching cycle.
Resumption of operation requires bulk voltage to drop under 310 V</td></tr>
<tr><td colspan="2">EMI conducted</td><td>230 Vrms, 50 Hz, full load, resistive load, lab setup</td><td colspan="2">Complies with Class B limits</td></tr>
</table>

2.1 Performance and steady-state waveforms

In this chapter, the steady-state waveforms are presented together with the efficiency and the Power Factor (PF) and THD achieved in the 1600 W server PSU presented in this application note. The PSU operates only in high-line (from 176 V to 265 V line voltage) with a nominal input voltage of 230 Vrms. Therefore, the efficiency is presented for this nominal voltage. As shown in Figure 8, the Infineon 1600 W PSU with TSC CoolMOS™ CFD7 and G7 and CoolSiC™ G6 achieves Titanium efficiency.

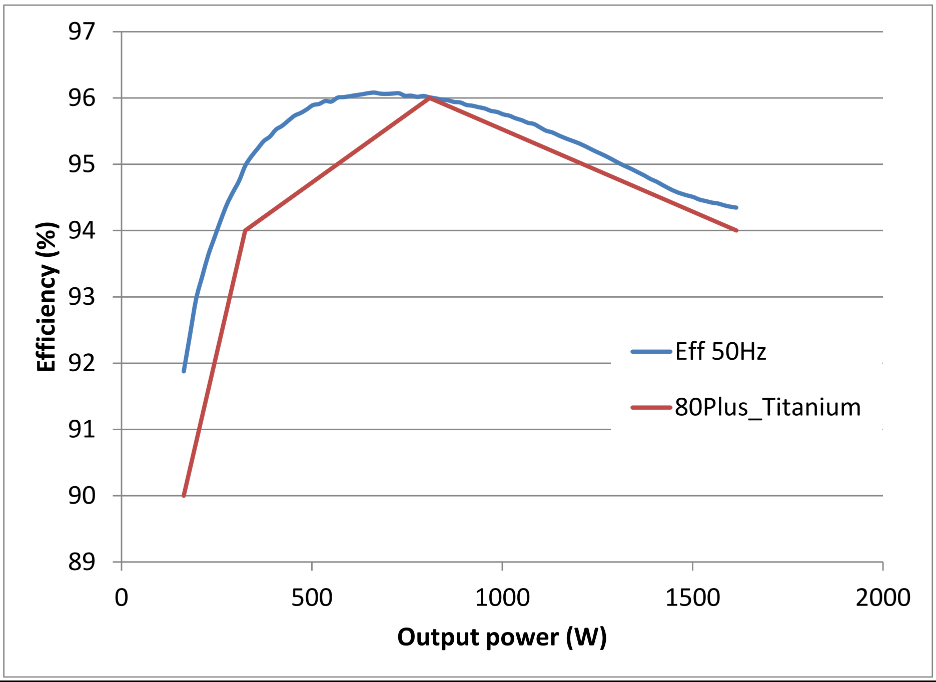


Figure 8 **Measured efficiency at 230 V 50 Hz input voltage**

Figure 9 depicts the measured PF and THD. The achieved PF is over 0.95 when the output power is higher than the 20 percent of the nominal output power, i.e., 320 W, for both 50 Hz and 60 Hz input voltage. In the case of the THD, the distortion is under 10 percent for output power over the 20 percent level for both 50 Hz and 60 Hz input voltage.

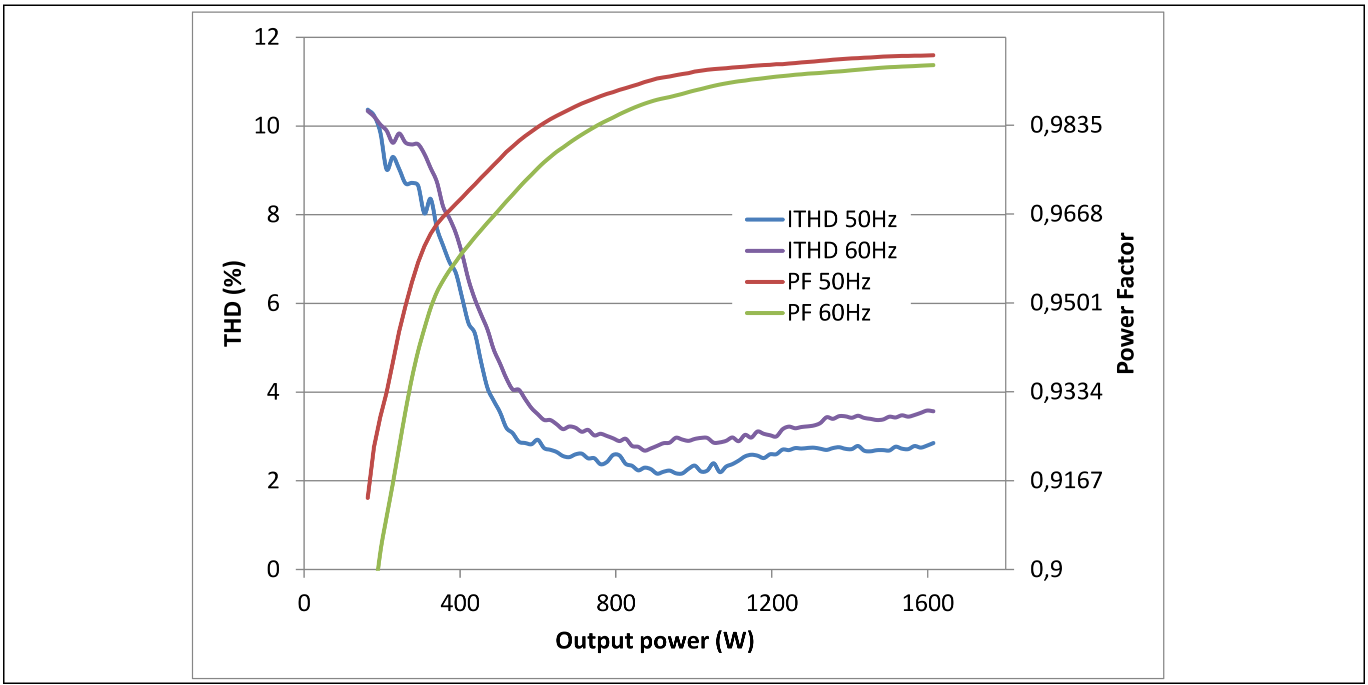


Figure 9 **Measured THD and power factor at 230 V input voltage for both 50 Hz and 60 Hz**

The main waveforms of the PSU are presented for different output power levels for 50 Hz (Figure 10) and 60 Hz (Figure 11) at nominal input voltage. As it can be seen, the input current presents low distortion according to the previously presented curve and the output voltage ripple is under the specified ±120 mV range.

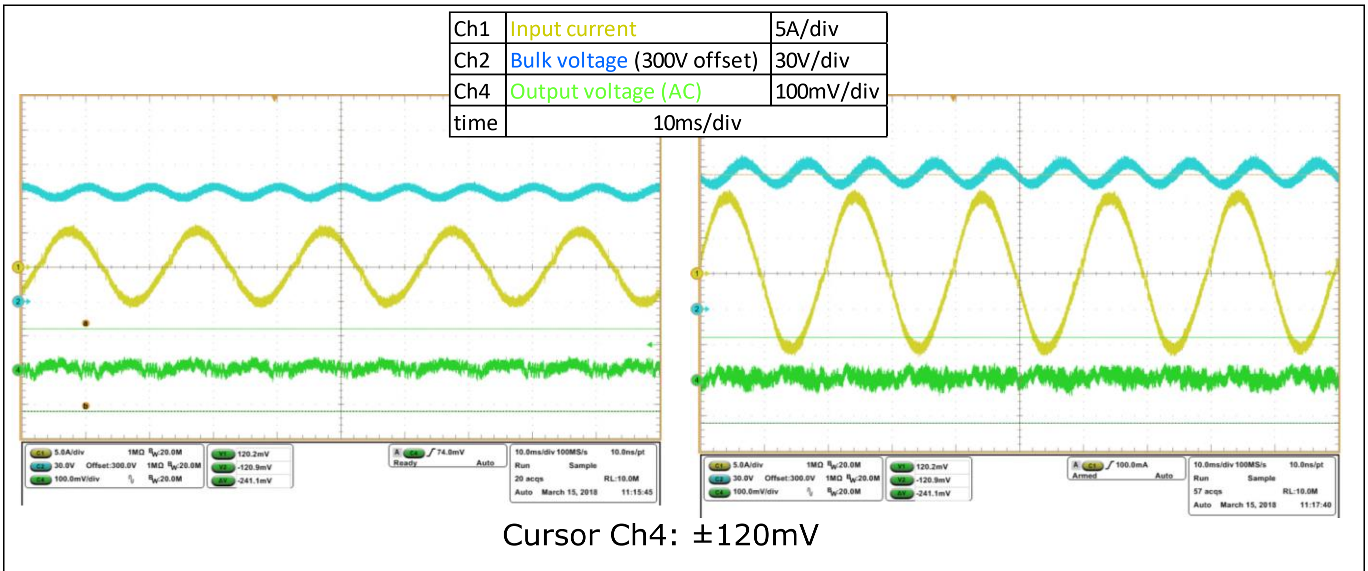


Figure 10 **Steady-state waveforms at 230 V 50 Hz for 50 percent load (left) and 100 percent load (right)**

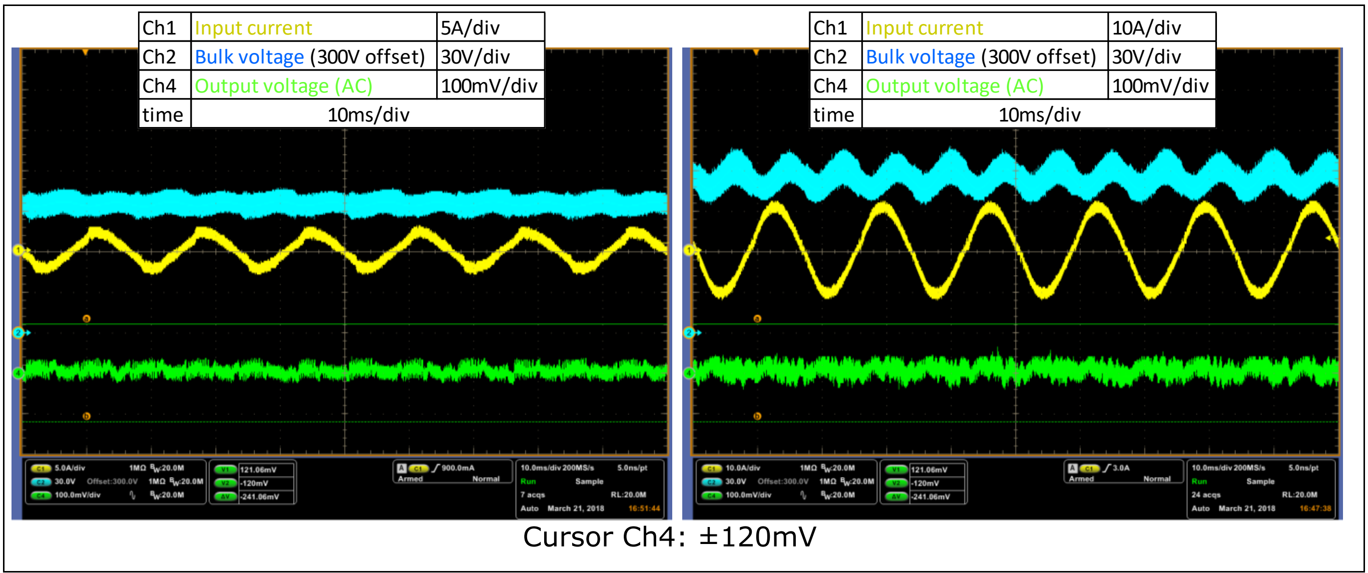


Figure 11 **Steady-state waveforms at 230 V 60 Hz for 20 percent load (left) and 100 percent load (right)**

2.2 Inrush current

In the PSU, the inrush current when connecting to the AC source is limited with an NTC. This resistor is short-circuited by a parallel relay before start-up if the input and output voltage conditions to start the PFC are met. The inrush current is measured at the first AC cycle and it is independent on the output load. In Figure 12, the full-load start-up of the server PSU is presented and the inrush current is highlighted. According to the measurement, the inrush current is significantly under the specified 30 A in Table 1.

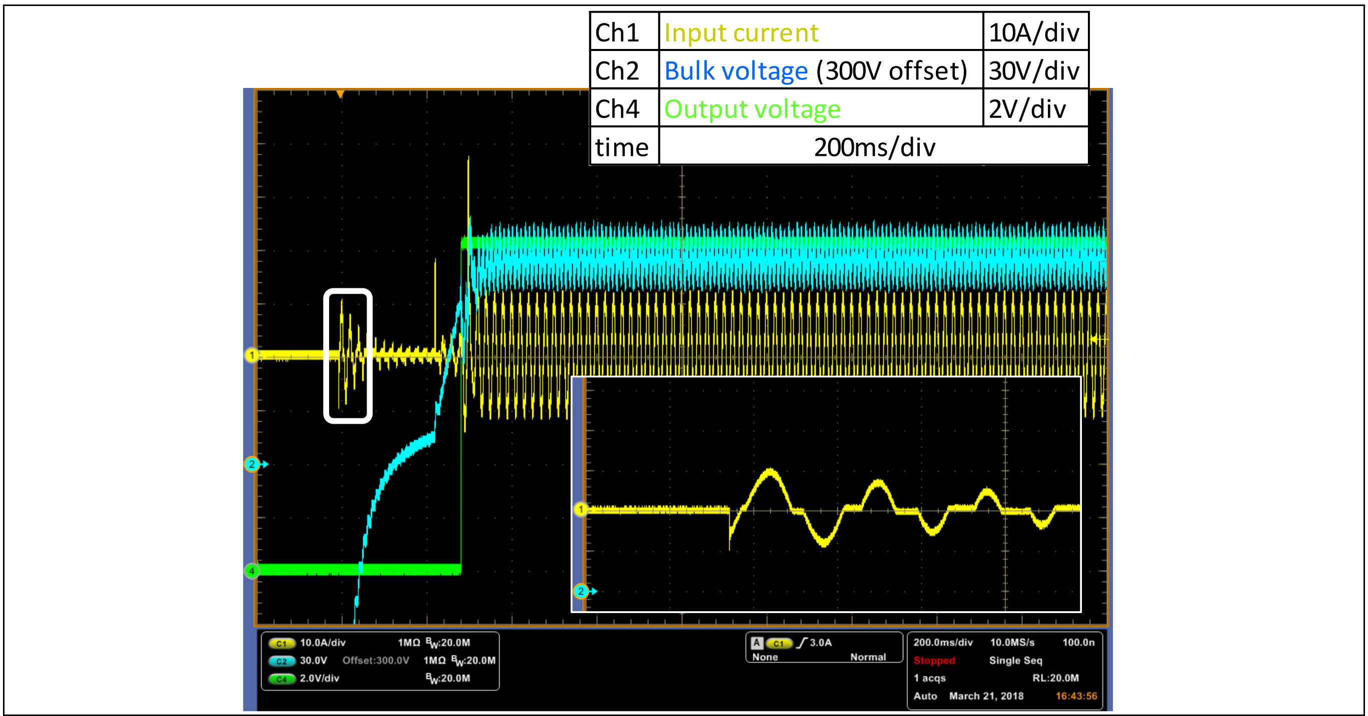


Figure 12 **Inrush current of the 1600 W server PSU at full-load start-up**

2.3 Power line disturbance

Two main line disturbance conditions can occur when connected to the grid. On one side, the AC can be lost during a certain time – Line Cycle Drop Out (LCDO) – and on the other side, the AC voltage can suddenly decrease to an abnormal value – voltage sag. This section introduces the test conditions for both disturbances as well as the SMPS performance when those conditions are applied using a programmable AC source.

2.3.1 Line cycle drop-out

The 1600 W power supply operates exclusively in high-line. Therefore, the AC LCDO capability is tested from 230 V to 0 V. Different timing, related to the specified hold-up time and the line frequency is applied as shown in Table 2. The test results (Figure 13 and Figure 14) show that the output voltage is within the specified dynamic variation regardless of the start angle of the voltage drop-out. In case the drop-out is longer than specified, output voltage regulation can be lost, and even a turn-off and restart of the unit is possible if the bulk voltage falls to 310 V.

Table 2 Applied voltage cycles for LCDO test at different loads with 50 Hz AC input voltage

		1st to 10th time (100 ms period)	
Applied voltage	230 V AC	0 V AC	230 V AC
Timing at different load conditions	50 percent load	20 percent (20 ms)	80 percent (80 ms)
	100 percent load	10 percent (10 ms)	90 percent (90 ms)

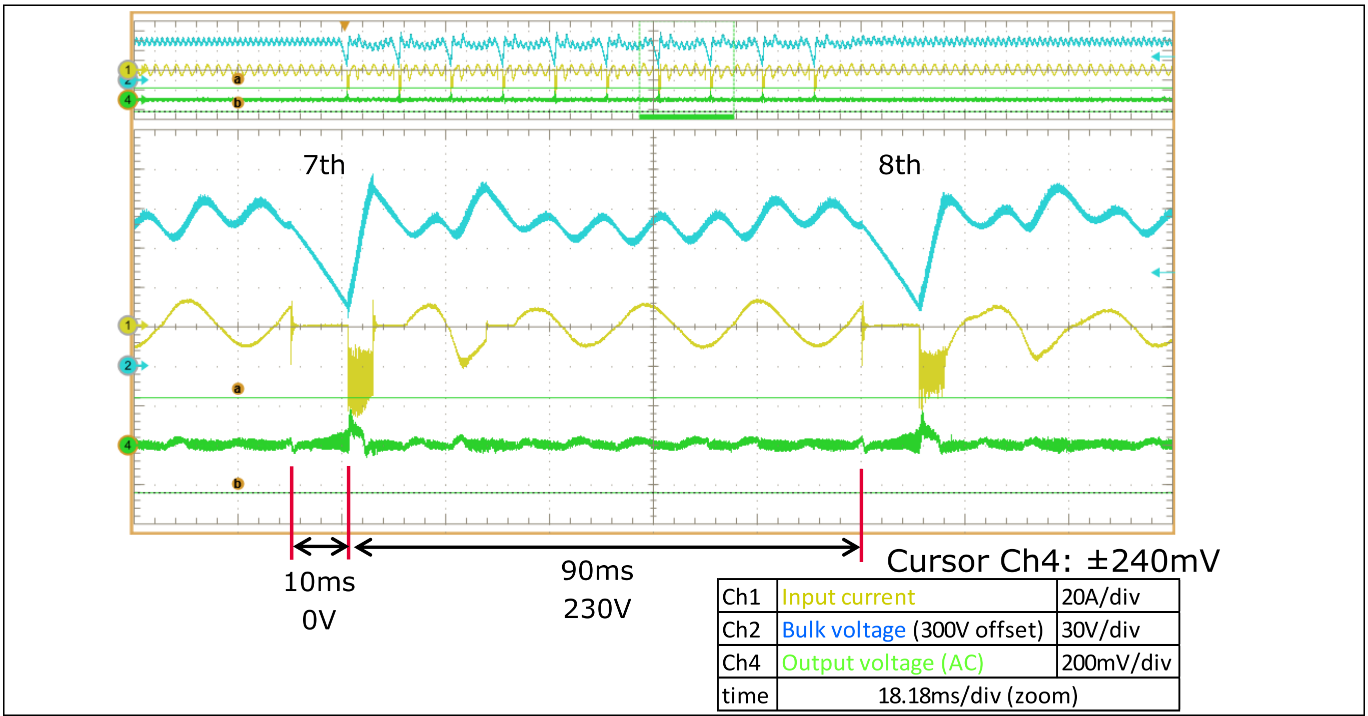


Figure 13 Detail of the 7th and 8th repetition in a 10 ms LCDO test at 230 V AC, 50 Hz and 100 percent load with a starting angle of 45 degrees

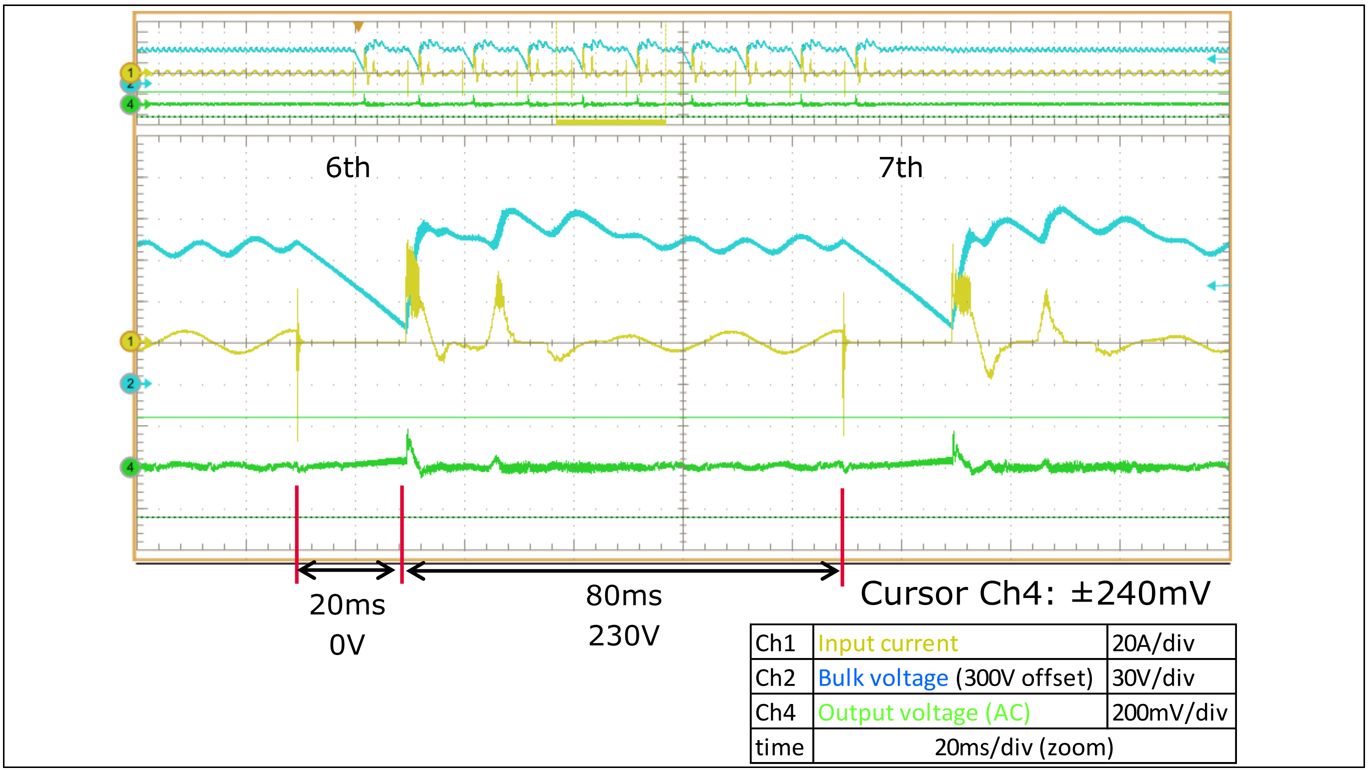


Figure 14 Detail of the 6th and 7th repetition in a 20 ms LCDO test at 230 V AC, 50 Hz and 50 percent load with a starting angle of 90 degrees

2.3.2 Voltage sag

For high-line, two different voltage sag conditions (Table 3) are considered and tested. Figure 15 shows the PSU behavior with voltage sag according to Table 3. As observed, the output voltage is not affected by the input voltage variation. However, if the voltage sag lasts longer than specified in the table, the power supply turns off and restarts with soft-start after an idle time. Figure 16 shows this behavior when a voltage sag to 150 V is applied for longer than 2 s.

Table 3 Voltage sag conditions applied in the 1600 W PSU test

		1st to 10th time	
–	Steady AC input	Voltage sag (time)	Period
AC input	200 V AC	130 V AC (0.5 s)	5 s
	200 V AC	150 V AC (2 s)	20 s

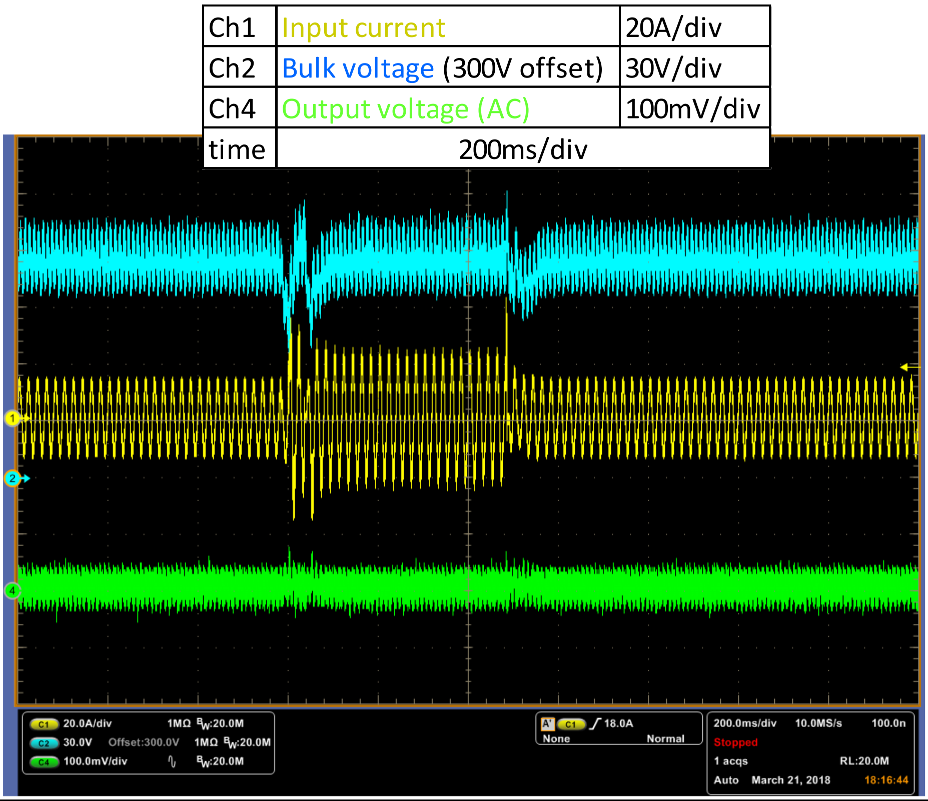


Figure 15 Main waveforms during a 500 ms and 130 V AC voltage sag at full load

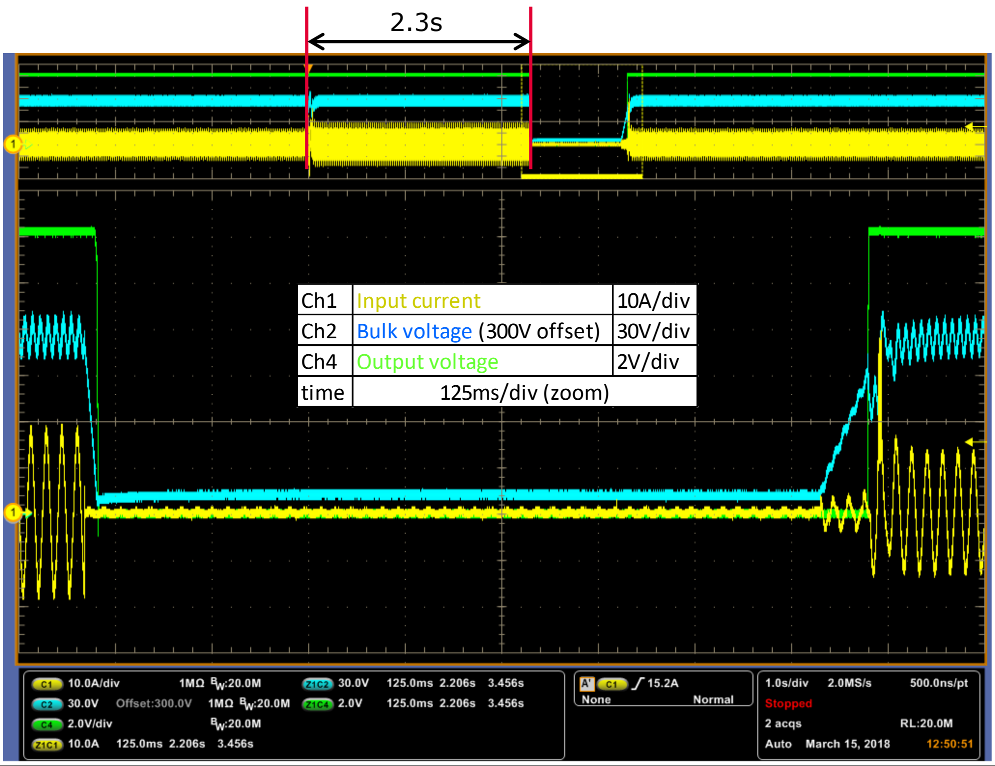


Figure 16 SMPS resumes operation after 150 V AC voltage sag applied for 3.5 seconds at full load

2.4 Output voltage dynamic behavior

In addition to power line disturbance, two other dynamic perturbances can affect the performance of the power supply shown:

- Load voltage variation
- Input voltage variation

2.4.1 Load transient response

As specified in Table 1, light-load (1 A) to half-load (66 A) and half-load to full-load (132 A) with 0.5 A/µs steps are considered. Figure 17 and Figure 18 show two examples for the different load steps at different repetition ratios. In all the tested cases, the output voltage dynamic ripple is within ±240 mV of the steady-state voltage of 12.2 V.

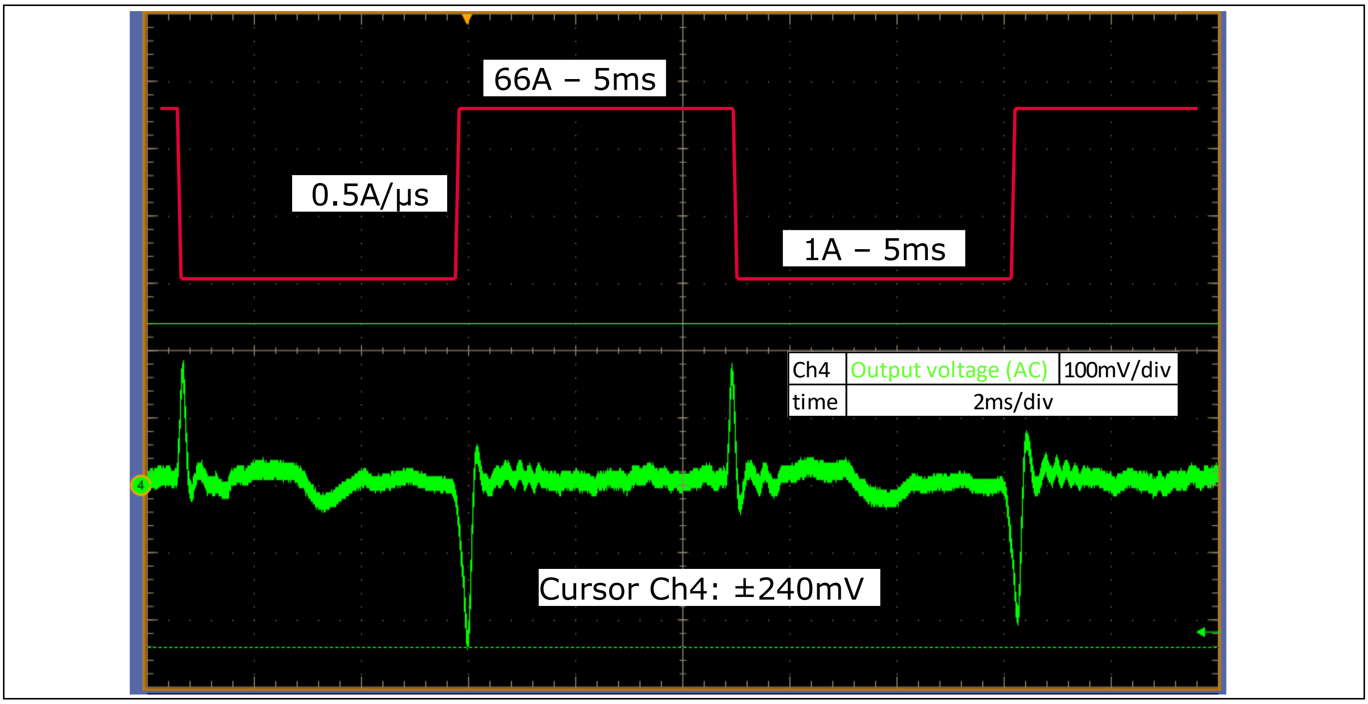


Figure 17 Output voltage response to 1 A to 66 A dynamic load steps with 0.5 A/µs current slope every 5 ms

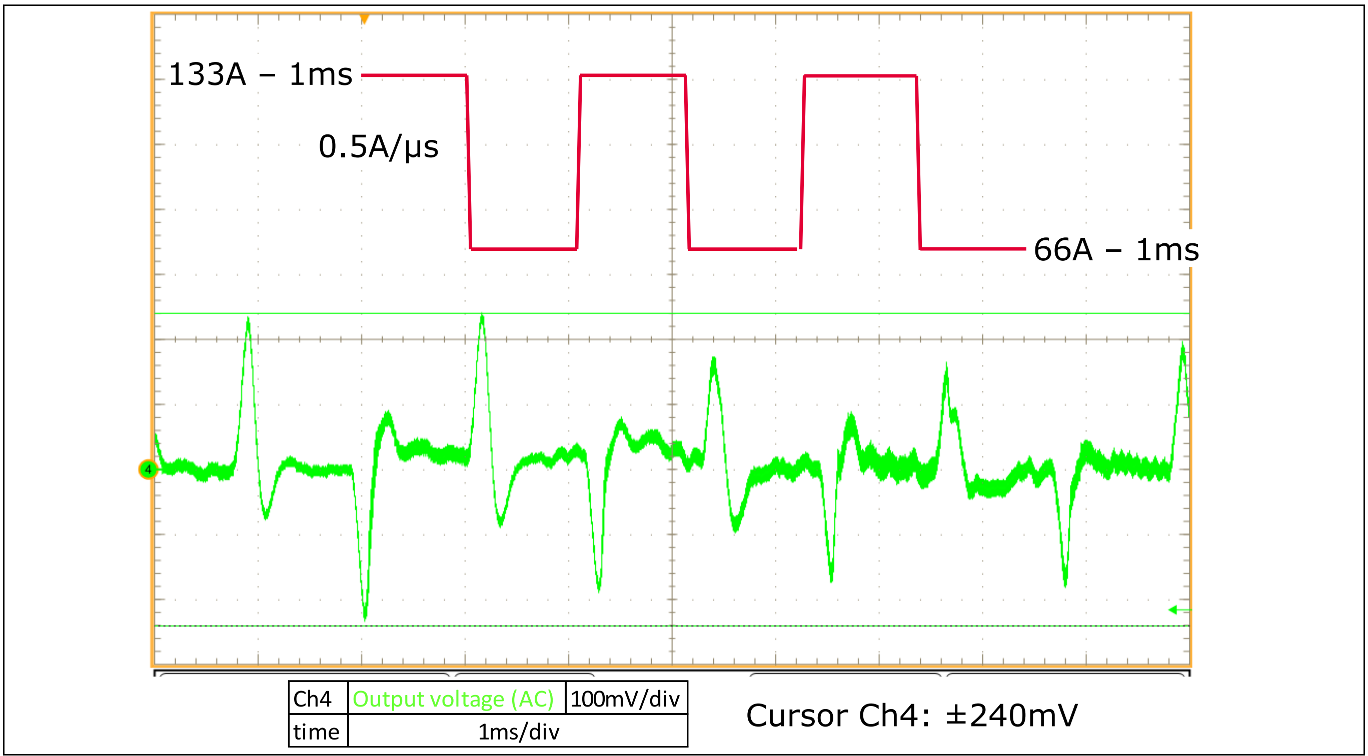


Figure 18 Output voltage response to 132 A to 66 A dynamic load steps with 0.5 A/µs current slope every 1 ms

2.4.2 Input voltage variation

Input voltage variations, as seen in the power line disturbance section, modify the bulk voltage and ultimately affect the output voltage ripple. This can occur as well when the input voltage varies even within the normal operation range, as shown in Figure 19.

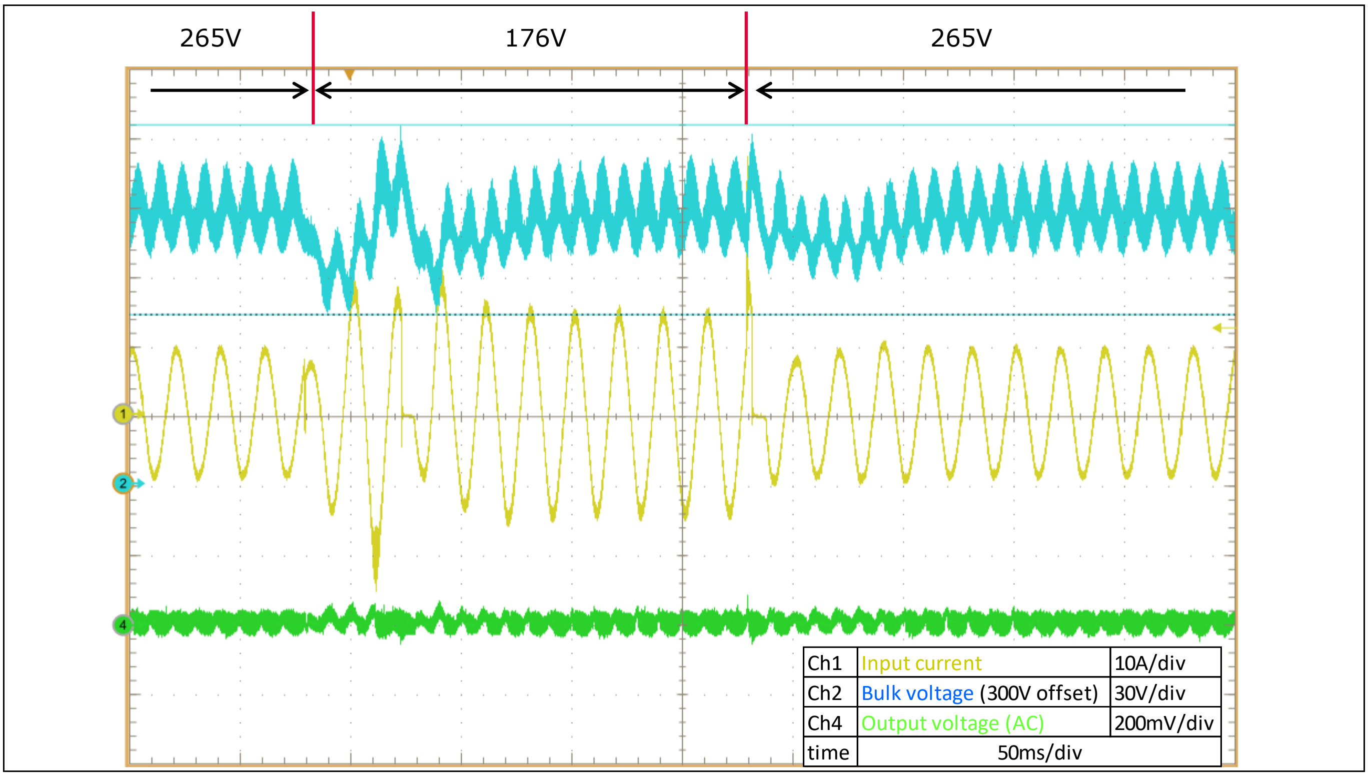


Figure 19 **Maximum (265 V AC) to minimum (176 V AC) line voltage variation at full-load operation**

2.4.3 Burst mode

The DC-DC stage of the 1600 W PSU goes into burst mode operation in light- or no-load conditions, and in those dynamic conditions where the output voltage regulation is lost due to maximum frequency limitation (300 kHz). Figure 20 shows the output voltage ripple for no-load operation of the PSU when the LLC converter is in burst mode.

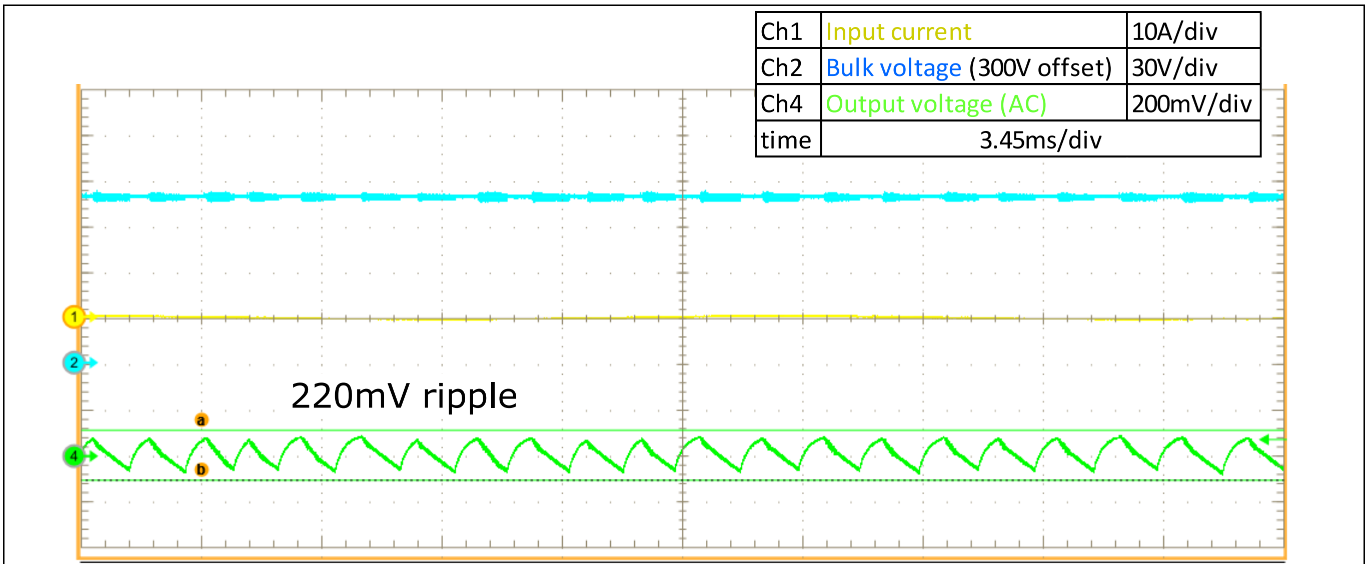


Figure 20 **Output voltage ripple in burst mode at no-load operation**

2.5 Protections

Both stages in the 1600 W server PSU implement protections to ensure robust and reliable operation.

In the case of PFC, the brown-out protection considers the possible voltage sag as already introduced. Furthermore, average and peak inductor current limitations are implemented as well as bulk voltage monitoring for both under- and overshoot.

Regarding the LLC, apart from switching frequency limitation (52 kHz to 300 kHz), two main protections are implemented:

- Overcurrent
- Overvoltage

2.5.1 Overcurrent protection (OCP)

The programmed OCP levels together with the maximum allowed time for each level, are introduced in Table 1. Figure 21 shows the unit reaction to a 152 A load current. This protection latches the DC-DC converter in the PSU and the bulk voltage must go under 310 V to allow a PSU restart.

In addition, a fast short-circuit protection is implemented by comparing the resonant current with a fixed level, set to 56 A. This enables detection of a very heavy overload within a few switching cycles. The power supply can also be restarted when the bulk voltage decreases under 310 V after a short-circuit fault.

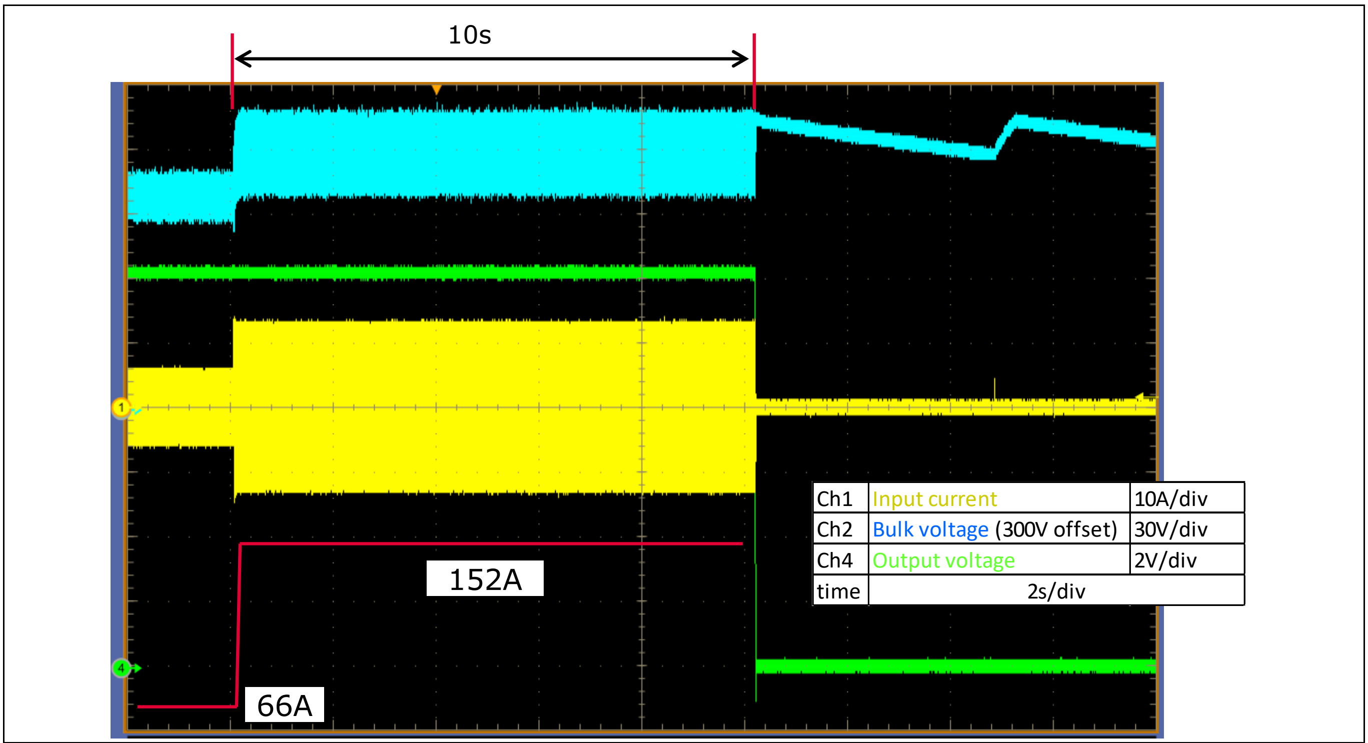
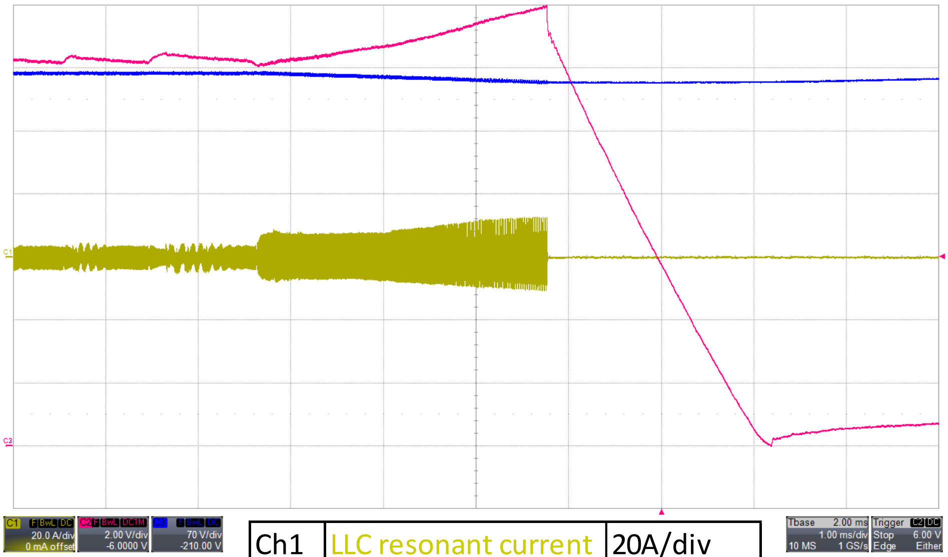


Figure 21 LLC converter of the 1600 W SMPS shut-down due to 155 A OCP

2.5.2 Overvoltage protection (OVP)

In case of control issues in the DC-DC stage of the power supply, OVP is set to 14 V. Figure 22 shows the mentioned protection when the LLC is operated with a modified control loop, which is allowing the output voltage to reach the OVP level.



Ch1	LLC resonant current	20A/div
Ch2	Output voltage	2V/div
Ch3	Bulk voltage	70V/div
time	1ms/div	

Figure 22 OVP triggered in the PSU with a modified control loop

2.6 Conducted EMI

The high power density 1600 W server PSU with Q-DPAK and D-DPAK includes an EMI filter to comply with the electromagnetic emission standards. In this case, the conducted EMI complies with CISPR 22 Class B limits as shown in Figure 23. Pure resistive load is used for the conducted EMI test and the converter runs at nominal output power with nominal (230 V) input voltage at 50 Hz.

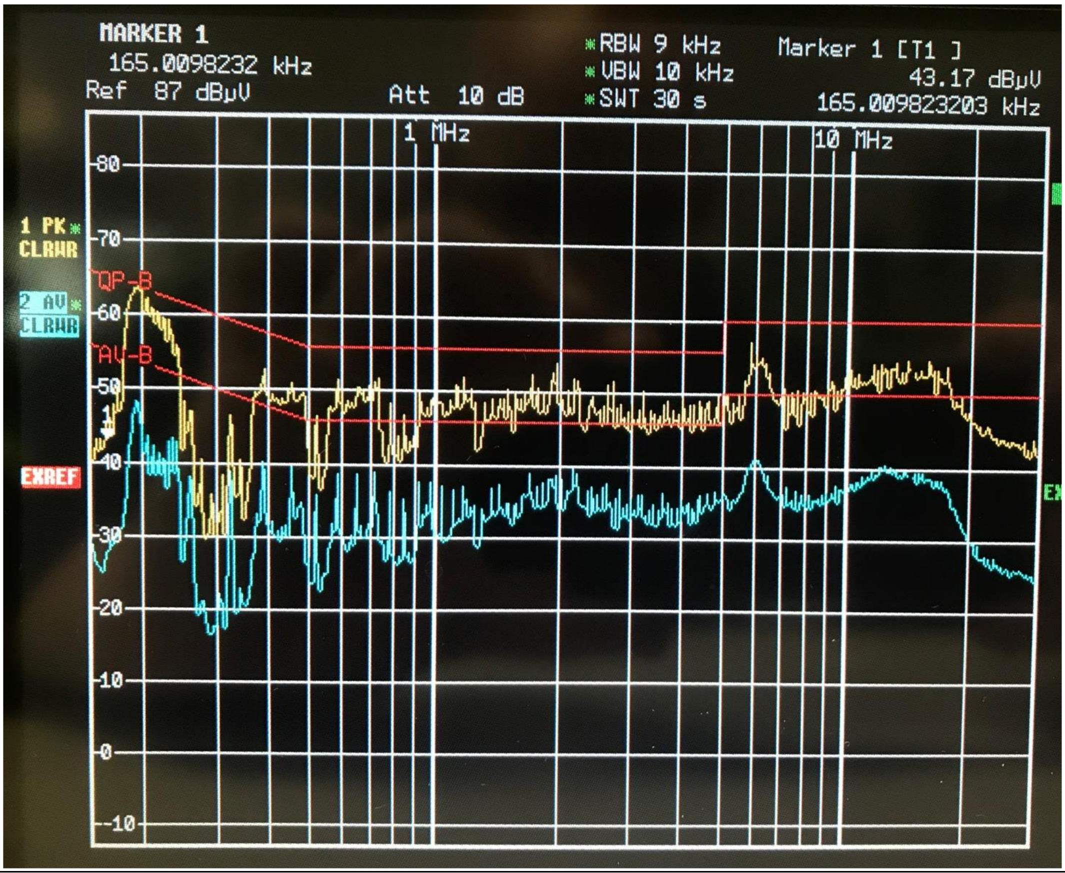


Figure 23 **Measured EMI conducted emissions (yellow: quasi-peak, blue: average), compared to Class-B CISPR 22 limits, at 230 V AC input and 1600 W output resistive load**

2.7 Thermal measurements

A long-time test has been run with attached Type K thermocouplers to the main devices of EVAL_1K6W_PSU_CFD7_QD. The test has been run for nominal input voltage (230 V_{RMS}) as well as the minimum input voltage (176 V_{rms}), which is the worst case for the PFC operation. In both cases, nominal load (132 A at 12.2 V output) has been applied during the test at room temperature. The tested unit was enclosed and the fan was controlled by the secondary side controller according to the heatsink temperature and supplied from the server power supply output.

The results presented in this section provide the thermal performance of the 1600 W server power supply with TSC Infineon power semiconductors introduced in this document. Figure 24 shows the measured temperatures for different parts of the PSU:

- **PFC switch:** Both CoolMOS™ in the back-to-back configuration were monitored and the hottest device during the test is presented
- **PFC diode:** In this case, one of the two CoolSiC™ diodes has been measured
- **PFC choke**
- **Low-side CoolMOS™ of the LLC half-bridge**
- **LLC transformer**

- **LLC synchronous rectifiers:** The measurement was made for one device from both SR branches and the worst case is shown
- **Oring switch:** As in the SR case, one of the paralleled devices has been sampled in these measurements

Since the LLC input is regulated by the AC-DC stage, no temperature difference is expected when changing the input AC voltage as shown in Figure 24 (right). In the case of the PFC, it is clear that the worst case is the lowest AC voltage (dashed line on Figure 24 – left) due to the higher current in the circuit. In that case, the PFC choke is the hottest point of the PFC. In the nominal voltage case (solid lines), the PFC switch is the hottest spot of the PFC. The maximum temperature in both PFC and LLC is in the same range (about 85°C), which provides margin enough in case the ambient temperature increases.

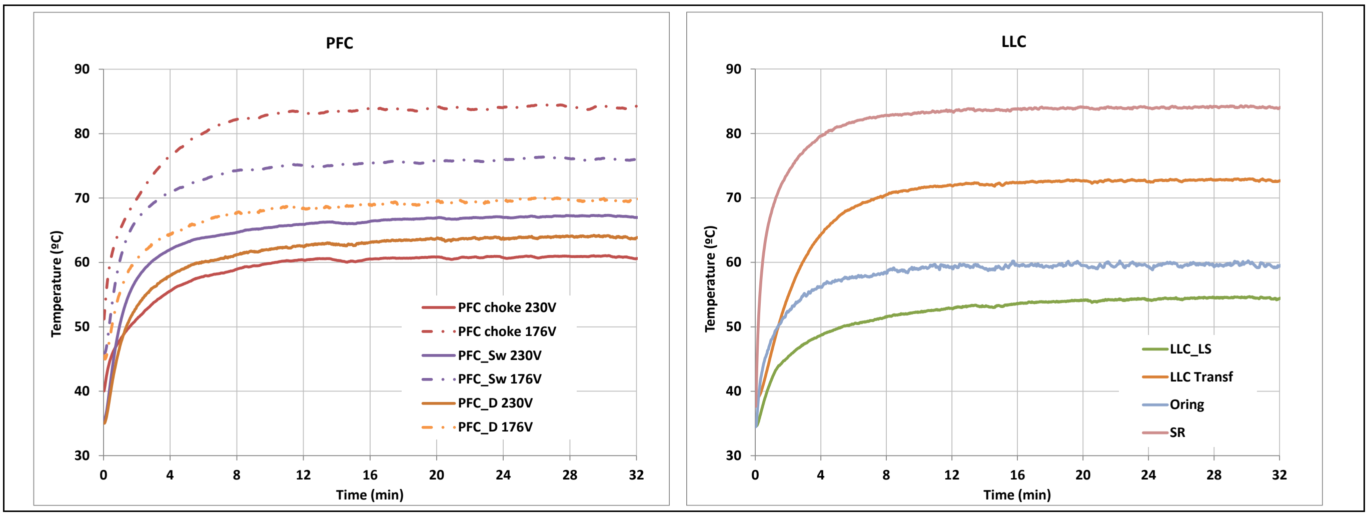


Figure 24 Temperature evolution for PFC (left) and LLC (right) during long-term test of EVAL_1K6W_PSU_CFD7_QD at room temperature.

3 Summary

This document presents a 1600 W server PSU (EVAL_1K6W_PSU_CFD7_QD) which complies with the 80 PLUS Titanium efficiency standard — efficiency is over 96 percent at 50 percent load. The achieved power density is 44 W/in3, which is enabled by the use of SMD packages.

The top-side cooling Q-DPAK and D-DPAK packages are utilized in a power board, which allows reduced commutation loops. Furthermore, the combination of these packages with CoolMOS™ CFD7 and G7 and CoolSiC™ G6 diode technologies enables mounting all the semiconductors in the same heatsink. As a result, a high-performance server power supply with a considerable increase in power density is presented in this document.

The presented board does not only provide excellent efficiency and high power density, but it also implements different input and output current and voltage protections and complies with typical server specifications in terms of input current quality or dynamic load changes. Furthermore, the 1600 W PSU presents a robust performance under AC abnormal conditions, such as voltage sag and line cycle drop out.

4 Schematics

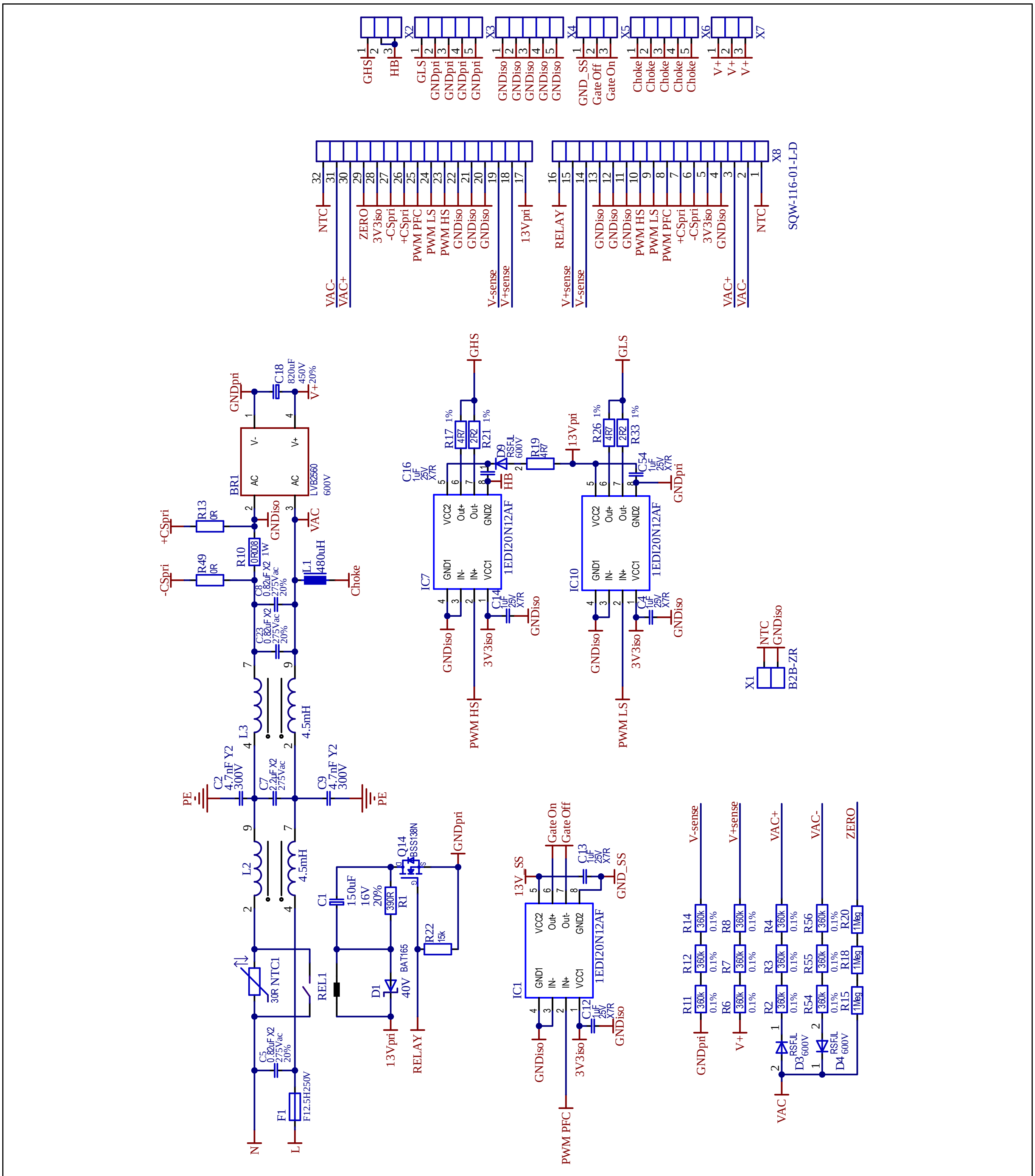


Figure 25 **PFC schematic of EVAL_1K6W_PSU_CFD7_QD, which includes the NTC, power board and primary-side control board connectors, as well as the PFC and LLC half-bridge drivers. The PFC switch and diode are in the power board**

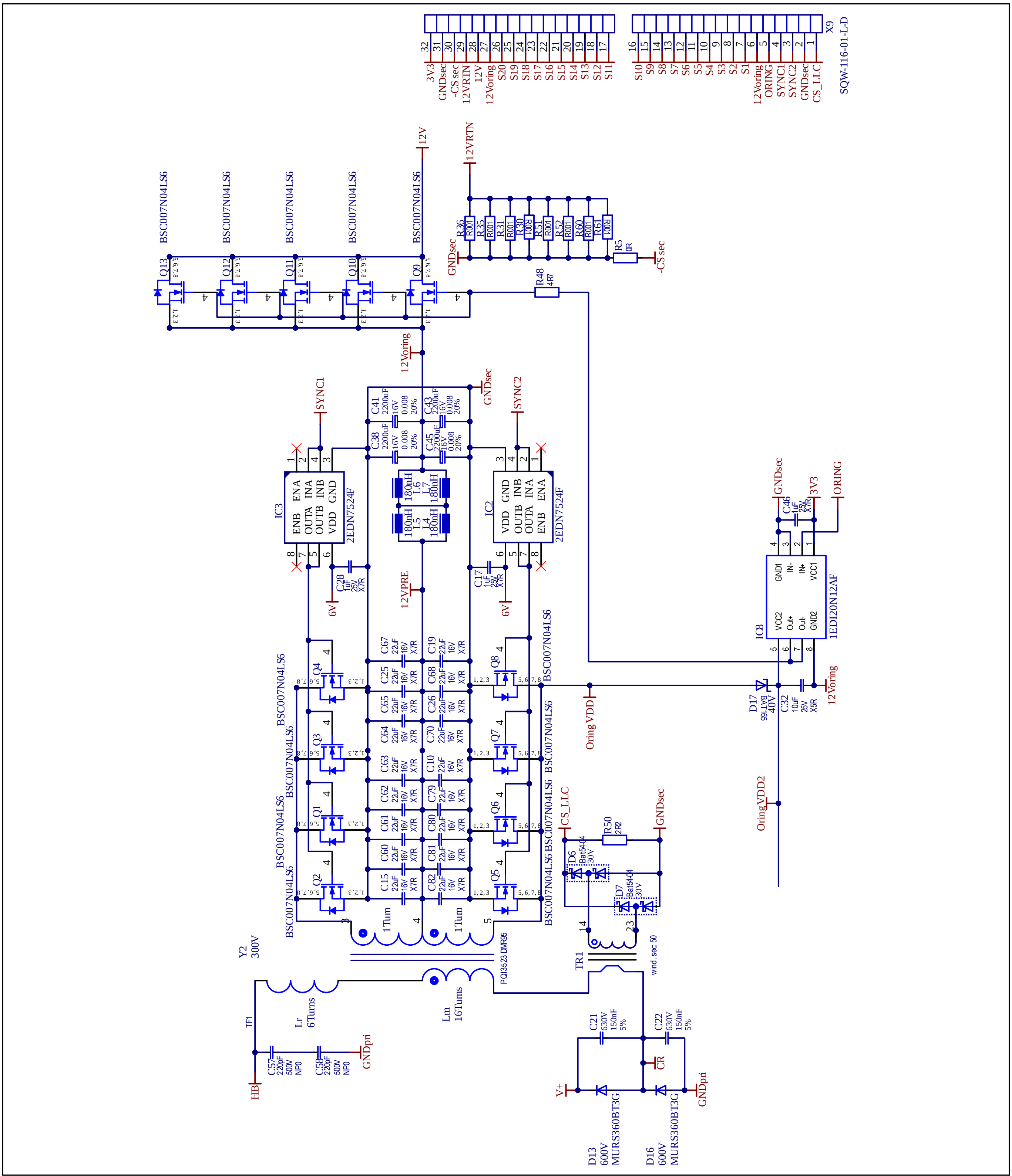


Figure 26 LLC schematic of EVAL_1K6W_PSU_CFD7_QD with the secondary-side control board connector. The primary-side switches and drivers are in the power board and PFC schematic

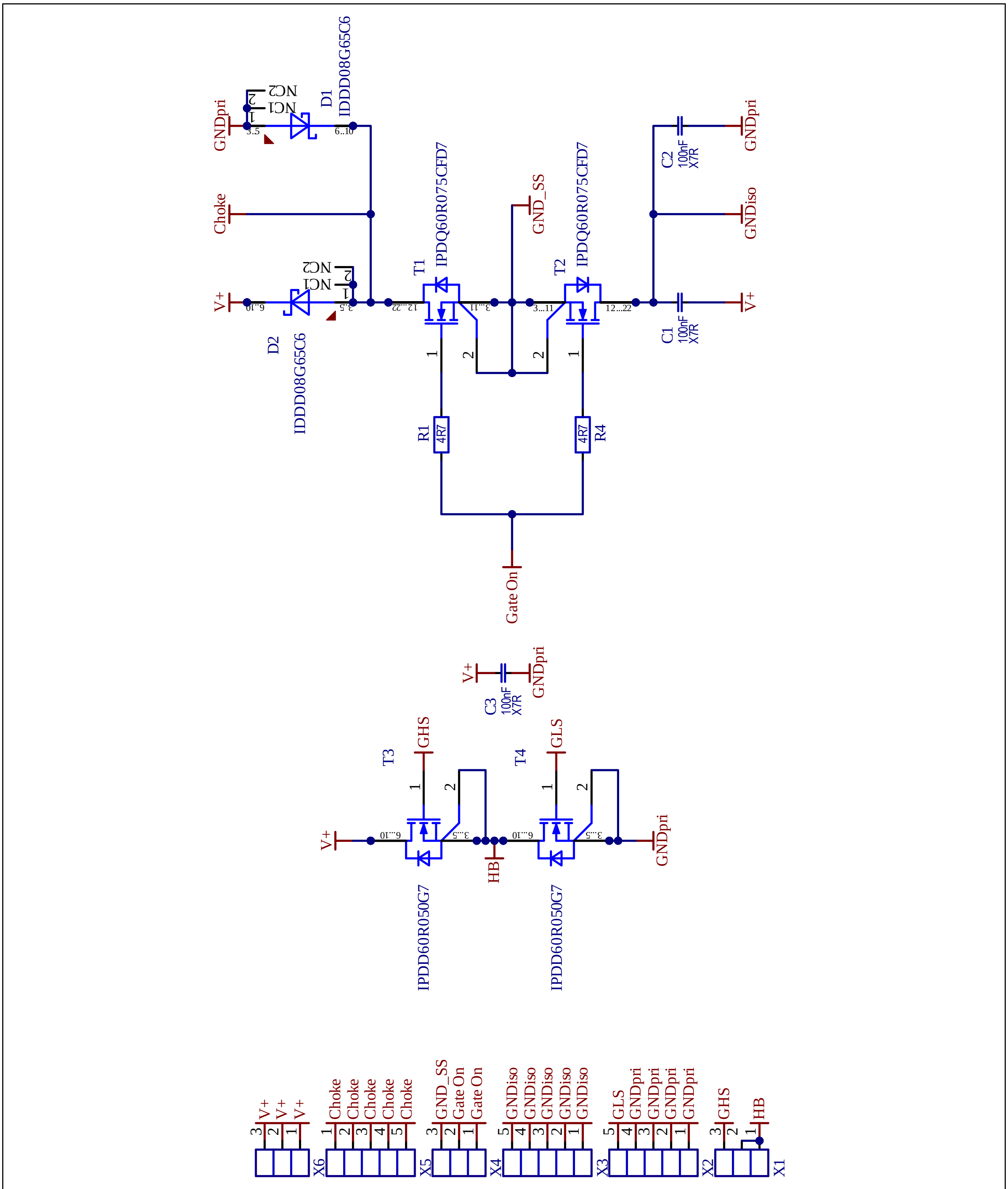


Figure 27 Power board schematic for the TSC Q-DPAK and D-DPAK power semiconductors of EVAL_1K6W_PSU_CFD7_QD

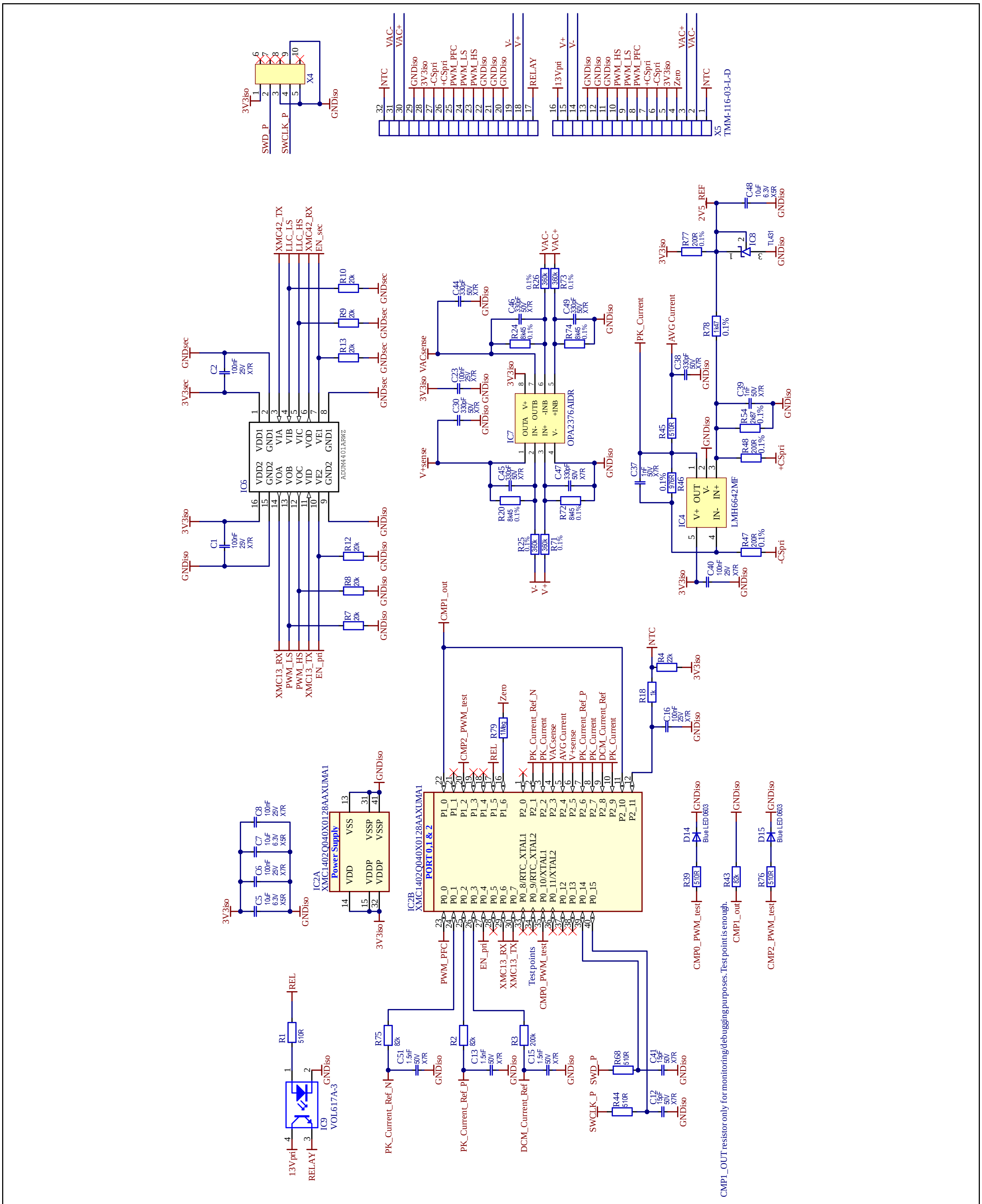


Figure 28 **Primary-side controller (XMC1402) schematic, including the digital isolator for primary-secondary communication**

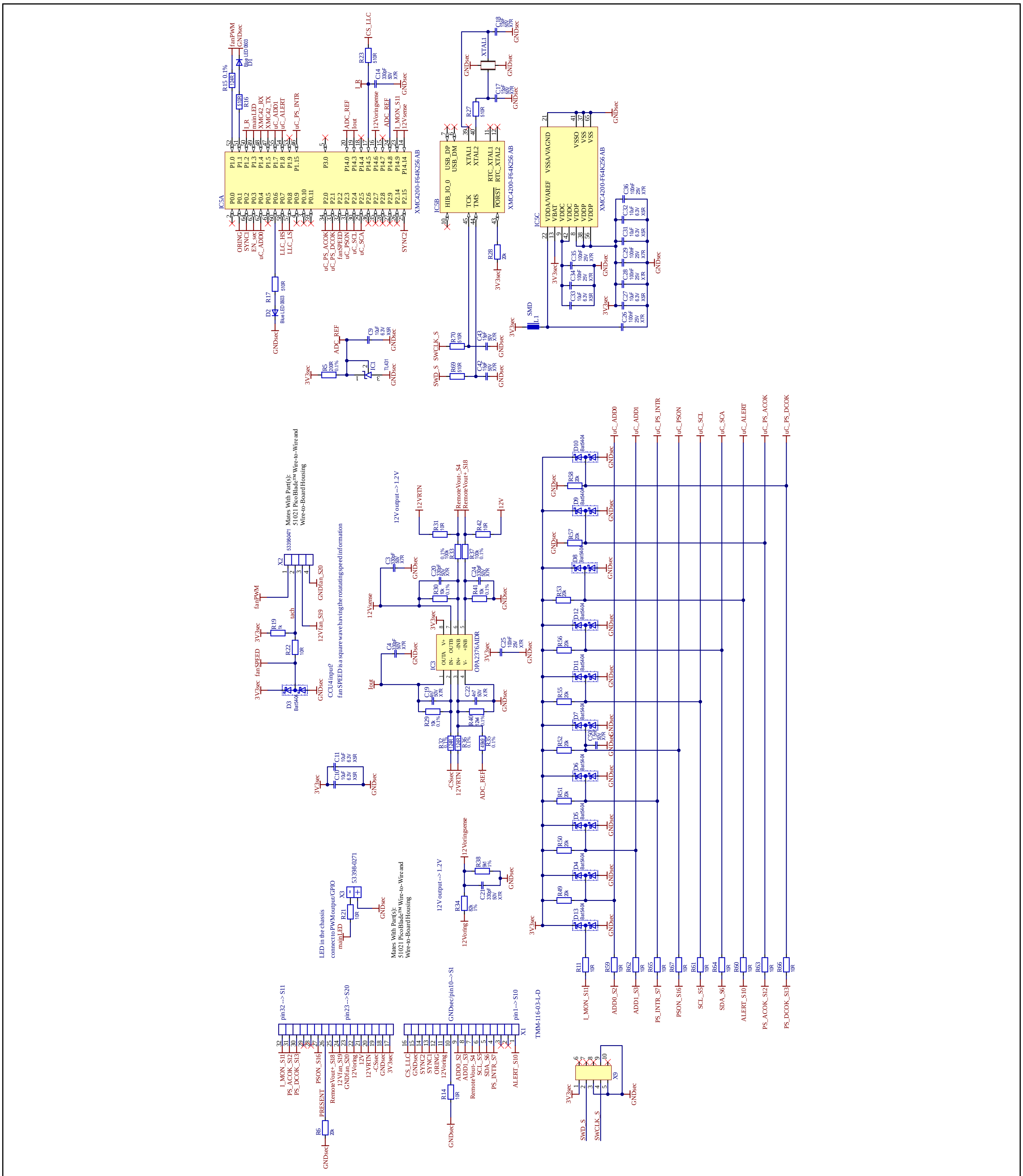


Figure 29 **Secondary-side controller (XMC4200) schematic, including the signaling for the PSU output connector**

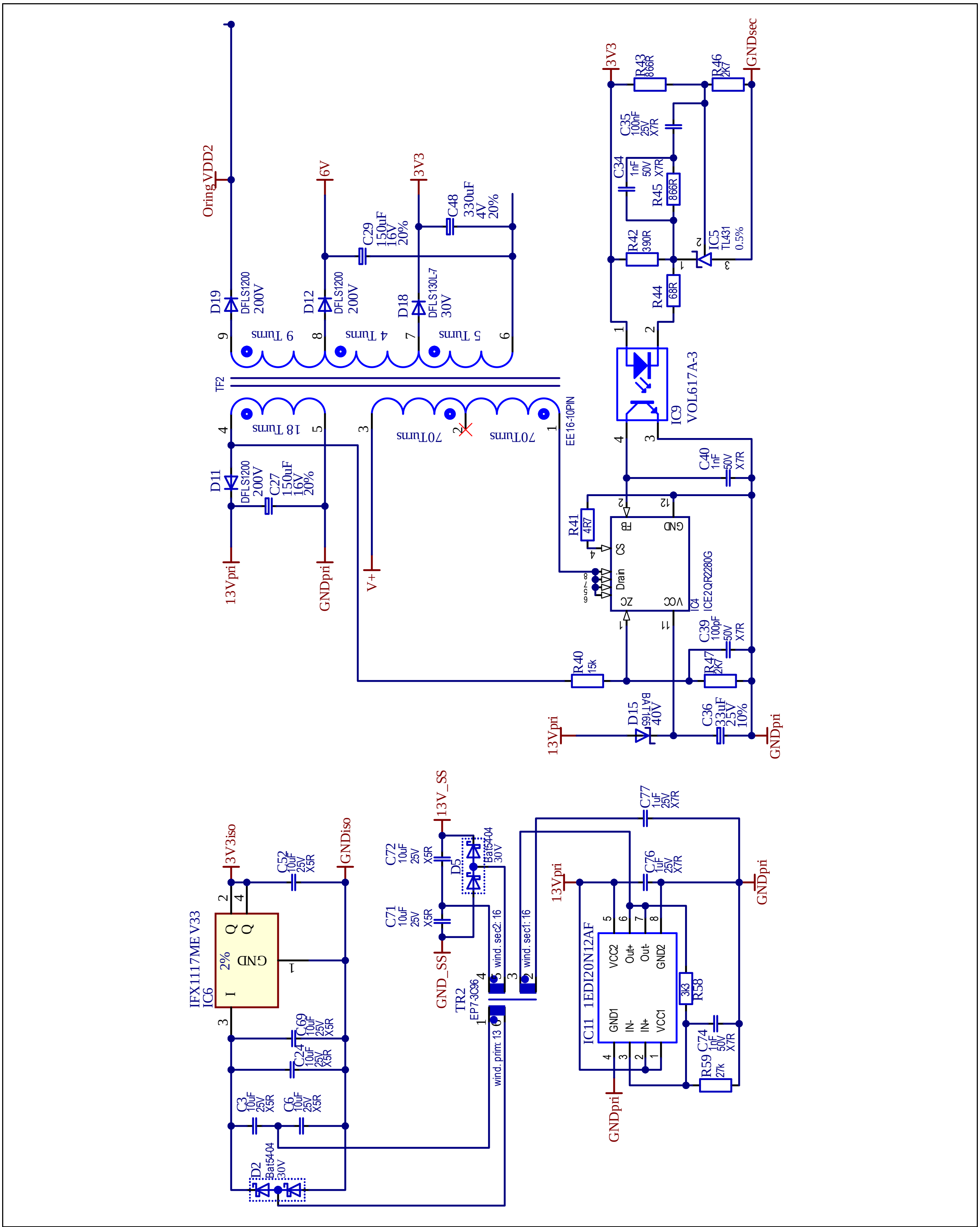


Figure 30 Auxiliary power supply (bias) of EVAL_1K6W_PSU_CFD7_QD

5 Bill of materials (BoM)

Table 4 Main board components

Designator	Value	Tolerance	Voltage	Description	Comment
IC2, IC3	**2EDN7524F**	–	–	**Integrated circuit**	**SMD**
IC1, IC7, IC8, IC10, IC11	**1EDI20N12AF**	–	–	**Integrated circuit**	**SMD**
IC4	**ICE2QR2280G**	–	–	**Integrated circuit**	**SMD**
IC6	**IFX1117ME V33**	**2 percent**	**15 V**	**Integrated circuit**	**SMD**
NTC1	30 R	20 percent	–	NTC resistor	THT
R1	390 R	1 percent	–	Resistor	SMD
R10	0R008	1 percent	–	Resistor	SMD
R42	390 R	1 percent	–	Resistor	SMD
R44	68 R	1 percent	–	Resistor	SMD
R58	3k3	1 percent	–	Resistor	SMD
R59	27 k	1 percent	–	Resistor	SMD
R2, R3, R4, R6, R7, R8, R11, R12, R14, R54, R55, R56	360 k	0.1 percent	–	Resistor	SMD
R22, R40	15 k	1 percent	–	Resistor	SMD
R43, R45	866 R	1 percent	–	Resistor	SMD
R46, R47	2K7	1 percent	–	Resistor	SMD
R15, R18, R20	1 Meg	1 percent	–	Resistor	SMD
R21, R33, R50	2R2	1 percent	–	Resistor	SMD
R5, R13, R49	0 R	1 percent	–	Resistor	SMD
R17, R19, R26, R41, R48	4R7	1 percent	–	Resistor	SMD
R30, R31, R35, R36, R51, R52, R60, R61	R001	1 percent	–	Resistor	SMD
REL1	OJE-SS-112HM	–	12 V	Relay	THT
Q14	BSS138N	–	60 V	MOSFET	SMD
Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13	BSC007N04LS6	–	40 V	MOSFET	SMD
L1	480 µH	–	–	Magnetic	THT
TF1	PQI3523 DMR95	–	–	Magnetic	THT
TF2	EE16-10PIN	–	–	Magnetic	THT
TR1		–	–	Magnetic	THT
TR2	EP7-3C96	–	–	Magnetic	THT
L2, L3	4.5 mH	–	–	Magnetic	THT
L4, L5, L6, L7	180 nH	–	–	Magnetic	SMD
IC5	TL431	0.5 percent	–	Integrated circuit	SMD
IC9	VOL617A-3	–	–	Integrated circuit	SMD

Designator	Value	Tolerance	Voltage	Description	Comment
F1	F12.5H250V	–	–	Fuse	THT
D1, D8, D15, D17	BAT165	–	40 V	Schottky diode	SMD
D2, D5, D6, D7	BAT54-04	–	30 V	Schottky diode	SMD
BR1	LVB2560	–	600 V	Bridge diode	THT
D18	DFLS130L-7	–	30 V	Diode	SMD
D13, D16	MURS360BT3G	–	600 V	Diode	SMD
D11, D12, D19	DFLS1200	–	200 V	Diode	SMD
D3, D4, D9	RSFJL	–	600 V	Diode	SMD
X1	B2B-ZR	–	–	Connector	THT
X8, X9	SQW-116-01-L-D	–	–	Connector	THT
C18	820 µF	20 percent	450 V	Polarized capacitor	THT
C36	33 µF	10 percent	25 V	Polarized capacitor	SMD
C48	330 µF	20 percent	4 V	Polarized capacitor	SMD
C1, C27, C29	150 µF	20 percent	16 V	Polarized capacitor	SMD
C30, C38, C41, C43, C45	2200 µF	20 percent	16 V	Polarized capacitor	THT
C7	2.2 µF X2	20 percent	275 V AC	Foil capacitor	THT
C21, C22	150 nF	5 percent	630 V	Foil capacitor	THT
C5, C8, C23	0.82 µF X2	20 percent	275 V AC	Foil capacitor	THT
C35	100 nF	X7R	25 V	Ceramic capacitor	SMD
C39	100 pF	X7R	50 V	Ceramic capacitor	SMD
C4, C12, C13, C14, C16, C17, C28, C46, C54, C76, C77	1 µF	X7R	25 V	Ceramic capacitor	SMD
C31, C33	100 nF		500 V	Ceramic capacitor	SMD
C57, C58	220 pF	NP0	500 V	Ceramic capacitor	SMD
C10, C11, C15, C19, C20, C25, C26, C37, C42, C44, C47, C49, C60, C61, C62, C63, C64, C65, C67, C68, C70, C79, C80, C81, C82	22 µF	X7R	16 V	Ceramic capacitor	SMD
C2, C9, C56	4.7 nF	Y2	300 V	Ceramic capacitor	THT
C34, C40, C74	1 nF	X7R	50 V	Ceramic capacitor	SMD
C3, C6, C24, C32, C52, C69, C71, C72	10 µF	X5R	25 V	Ceramic capacitor	SMD

Table 5 Power board components

Designator	Value	Tolerance	Voltage	Description	Comment
T1, T2	**IPQD60R075CDF7**	–	–	**600 V CoolMOS™ CFD7 power transistor, 600 V (VDS)**	**SMD**
T3, T4	**IPDD60R050G7**	–	–	**600 V CoolMOS™ G7 power transistor, 600 V (VDS)**	**SMD**
D1, D2	**IDDD08G65C6**	–	–	**650 V CoolSiC™ G6 Schottky diode**	**SMD**
R1, R4	10 R	1 percent		Resistor	SMD
C1, C2, C3	100 nF	–	500 V	Ceramic capacitor	SMD
X1, X4, X6	MMT-103-01-L-SH	–	–	Connector	SMD
X2, X3, X5	MMT-105-01-L-SH	–	–	Connector	SMD

Table 6 Control board components

Designator	Value	Tolerance	Voltage	Description	Comment
IC2	**XMC1402-Q040X0128AAXUMA1**	–	–	**Integrated circuit**	**SMD**
IC5	**XMC4200-F64K256AB**	–	–	**Integrated circuit**	**SMD**
C1, C2, C6, C8, C16, C23, C25, C26, C28, C29, C34, C35, C36, C40	100 nF	X7R	25 V	Ceramic capacitor	SMD
C3, C4, C14, C20, C21, C24, C30, C38, C44, C45, C46, C47, C49	330 pF	X7R	50 V	Ceramic capacitor	SMD
C5, C7, C9, C10, C11, C27, C31, C32, C33, C48	10 µF	X5R	6.3 V	Ceramic capacitor	SMD
C12, C17, C18, C41, C42, C43	15 pF	X7R	50 V	Ceramic capacitor	SMD
C13, C15, C50, C51	1.5 nF	X7R	50 V	Ceramic capacitor	SMD
C19, C22	4 n7	X7R	50 V	Ceramic capacitor	SMD
C37, C39	1 nF	X7R	50 V	Ceramic capacitor	SMD
D1, D2, D14, D15	Blue LED 0603	–	–	LED diode	SMD
D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13	BAT54-04	–	–	Diode	SMD
IC1, IC8	TL431	–	–	Integrated circuit	SMD
IC3, IC7	OPA2376AIDR	–	–	Integrated circuit	SMD
IC4	LMH6642MF	–	–	Integrated circuit	SMD
IC6	ADUM4401ARWZ	–	–	Integrated circuit	SMD

Designator	Value	Tolerance	Voltage	Description	Comment
IC9	VOL617A-3	–	–	Integrated circuit	SMD
L1	Ferrite bead 60 Ω at 100 mHz	–	–	Magnetic	SMD
R1, R16, R17, R23, R27, R39, R44, R45, R68, R69, R70, R76	510 R	1 percent	–	Resistor	SMD
R2, R34, R43, R75	82 k	1 percent	–	Resistor	SMD
R3	200 k	1 percent	–	Resistor	SMD
R4	22 k	1 percent	–	Resistor	SMD
R5, R47, R48, R77	200 R	0.1 percent	–	Resistor	SMD
R6, R7, R8, R9, R10, R12, R13, R28, R49, R50, R51, R52, R53, R55, R56, R57, R58	20 k	1 percent	–	Resistor	SMD
R11, R14, R21, R22, R31, R42, R59, R60, R61, R62, R63, R64, R65, R66, R67	10 R	1 percent	–	Resistor	SMD
R15, R32, R36	124 R	0.1 percent	–	Resistor	SMD
R18, R19	1 k	1 percent	–	Resistor	SMD
R20, R24, R72, R74	8k45	0.1 percent	–	Resistor	SMD
R25, R26, R71, R73	360 k	0.1 percent	–	Resistor	SMD
R29, R30, R41	10 k	0.1 percent	–	Resistor	SMD
R33, R37	100 k	0.1 percent	–	Resistor	SMD
R35	49k9	0.1 percent	–	Resistor	SMD
R38	9k1	1 percent	–	Resistor	SMD
R40	12k4	0.1 percent	–	Resistor	SMD
R46	976 R	0.1 percent	–	Resistor	SMD
R54	2k87	0.1 percent	–	Resistor	SMD
R78	1k47	0.1 percent	–	Resistor	SMD
R79	1 Meg	1 percent	–	Resistor	SMD

Designator	Value	Tolerance	Voltage	Description	Comment
X1, X5	TMM-116-03-L-D	–	–	Connector	SMD
X2	53398-0471	–	–	Connector	SMD
X3	53398-0271	–	–	Connector	SMD
X4, X9	–	–	–	Connector	SMD
XTAL1	12 MHz	–	–	Crystal oscillator	SMD

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Revision history

Document revision	Date	Description of changes
V 1.0	2024-06-24	Initial release

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Edition 2024-06-24

Published by

Infineon Technologies AG

81726 Munich, Germany

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Document reference

AN093434