XDP™ XDPS2221E: PFC + hybrid-flyback combo IC for 120 W USB PD evaluation board with three outputs

About this document

Scope and purpose

This document presents information about the 120 W USB Power Delivery (PD) evaluation board, showcasing the XDP™ digital power XDPS2221E controller for power factor correction (PFC) + hybrid-flyback (HFB) in a three-port USB PD application for USB PD charging.

Infineon's system solution includes the following components:

- CoolMOS™ P7 devices in the active bridge rectification
- CoolGaN™ Drive GSD1623-N1 device as PFC switch
- CoolGaN™ Transistor Dual IGI65D1414A3M as half-bridge switching device
- EZ-PD™ CCG7SC CYPD7171 controller for the USB PD extended power range (EPR) control of each of the three USB outputs

The system is referred as an "evaluation design" for a few reasons: it is not designed for the highest power density, and it has a separate output board that is derived from the reference design based on CCG7SC controller "REF_CCG7SC_120W_3C [1]. Although the power stage is equivalent to the existing 140 W reference design "REF_XDPS2221_140W1", the transformer and PFC choke can be further optimized for even better efficiency and power density. With an improved transformer design, an efficiency of more than 94% at a 90 V AC input can be easily achieved for an output power of 140 W (one output board design at 28 V and 5 A condition). For more information about those two reference boards, see the references section at the end of this document.

The document presents the performance data and design information of the evaluation board. This design exhibits a very low standby power (< 75 mW), meets the DoE Level VII power supply efficiency requirements, and offers excellent tiny load efficiency for an output power under 20 W.

Intended audience

The intended audiences for this document are switched-mode power supply design engineers and users of this 120 W evaluation board.

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"Evaluation boards and reference boards" shall mean products embedded on a printed circuit board (PCB) for demonstration and/or evaluation purposes, which include, without limitation, demonstration, reference and evaluation boards, kits and design (collectively referred to as "reference boards").

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Safety precautions

Note: Please note the following warnings regarding the hazards associated with development systems.

Table 1 Safety precautions

	Warning: *The DC-link potential of this board is up to 1000 V DC. When measuring voltage waveforms by oscilloscope, high-voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	Warning: *The evaluation or reference board contains DC bus capacitors, which take time to discharge after removal of the main supply. Before working on the drive system, wait five minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	Warning: *The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by oscilloscope. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.*
	Warning: *Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.*
	Caution: *The heatsink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.*
	Caution: *Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.*
	Caution: *The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with ESD control procedures, refer to the applicable ESD protection handbooks and guidelines.*
	Caution: *A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.*
	Caution: *The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.*

Table of contents

1 XDP™ XDPS2221E overview

The XDP™ XDPS2221E controller is an easy- to-use, highly integrated device including the multimode PFC controller, the hybrid-flyback (HFB) controller, and three gate drivers for the PFC switch and hybrid-flyback switches. The high level of integration for both PFC and HFB stages makes this controller the perfect choice for wide input – wide output applications. One such application is USB PD adapter and battery chargers as presented in this evaluation board. For detailed information about this control IC, see the datasheet [2].

A short summary of the product, its main features, the IC pin layout, and the main benefits for the customer is given below.

1.1 Product highlights

- Digital combo controller for PFC boost and DC-DC hybrid-flyback in DSO-14 (150 mil) package
- Novel zero-voltage switching (ZVS) hybrid-flyback (asymmetrical half-bridge) topology for ultra-high system efficiency
- Integrated gate drivers supporting GaN and Si switches
- 600 V high-voltage integrated start-up cell for internal biasing and fast VCC charging
- Burst-mode operation for lowest no-load standby power and tiny load requirements
- Adaptive PFC bus voltage and PFC enable/disable control to maximize average and light-load efficiency
- Supports USB PD standard V3.1 extended power range (EPR) with wide output voltage range up to 28 V
- Comprehensive set of protections
- Configurable parameters for protection modes and system performance
- MFIO communication pin configurable as active bridge rectification enable (ACT_EN) or external signal feed for over-temperature (OTP_NTC)
- Pb-free lead plating, halogen-free (according to IEC61249-2-21), and RoHS compliant

1.2 PFC control

- Configurable PFC QRM operation for improved average efficiency
- Pulse skipping for improved light-load efficiency
- Automatic PFC disable/enable control depending on operating conditions
- Adaptive PFC bus voltage level following operating conditions

1.3 Hybrid-flyback control

- Peak current-mode control for robust and fast input and load control
- ZVS operation of high-side and low-side switch (with ZVS pulse insertion in DCM)
- Configurable multimode operation for improved average and light-load efficiency

1.4 IC pin configuration

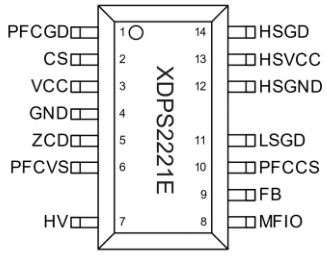


Figure 1 **XDP™ XDPS2221E pin configuration**

1.5 Main customer benefits

1.5.1 Low bill of materials

- PFC + HFB control with gate drivers in one 14-pin DSO package for direct driving of CoolMOS™, CoolGaN™, and legacy GaN Systems transistors
- Integrated start-up cell for V_{CC} initial charge-up
- Potential transformer size reduction compared to other flyback topologies

1.5.2 High system performance

- High system efficiency
- High power density design
- Independent enable and disable control of active bridge controller and PFC stage to guarantee low power consumption in no-load and light load conditions
- Good efficiency in tiny load conditions and low standby power to meet DOE Level VII

1.5.3 Unique controller in the market

- The most suitable controller for applications with wide AC input and wide output voltage range, such as USB PD EPR adapters and battery chargers
- Embedded digital core supporting configurable parameters for optimum system performance

1.5.4 Selected (system) control features

The following innovative features enable high system efficiency throughout all line, load, and USB PD output voltage conditions, ensuring ow no-load power consumption:

- The hybrid-flyback topology is used as an isolated DC-DC stage, featuring implemented control features and operation modes such as continuous resonant mode (CRM), zero-voltage resonant valley switching (ZV-RVS), and burst mode.
- The adaptive PFC stage output voltage and hybrid-flyback output voltage are adjusted based on the AC-input voltage to USB PD output voltage ratio, ensuring optimum performance and high system efficiency.
- The output DC-DC buck stage can operate in bypass mode, allowing it to be bypassed in cases where the requested USB PD voltage matches the adapted hybrid-flyback voltage.

2 Board hardware

2.1 Overview

The 120 W USB PD evaluation board uses the XDP™ digital combo controller XDPS2221E, CoolGaN™ Transistor Dual IGI65D1414A3M device, CoolGaN™ Drive GSD1623 device, and the EZ-PD™ CCG7SC controller CYPD7171 [3]. It targets applications such as USB PD charger adapters for smartphones and mobile computers, featuring a very wide input and output voltage ranges.

Figure 2 shows the top view of the complete board system, consisting of a main power board, an input active bridge rectifier board, VCC board, and an output board containing three USB PD output boards. The AC input connection points are located on the bottom left side and marked accordingly. The output connector is the USB Type-C connector located on each of the three USB PD EPR boards. JP 200 is the UART connector that may be used for the configuration of the XDP™ XDPS2221E or for reading MFIO pin signals.

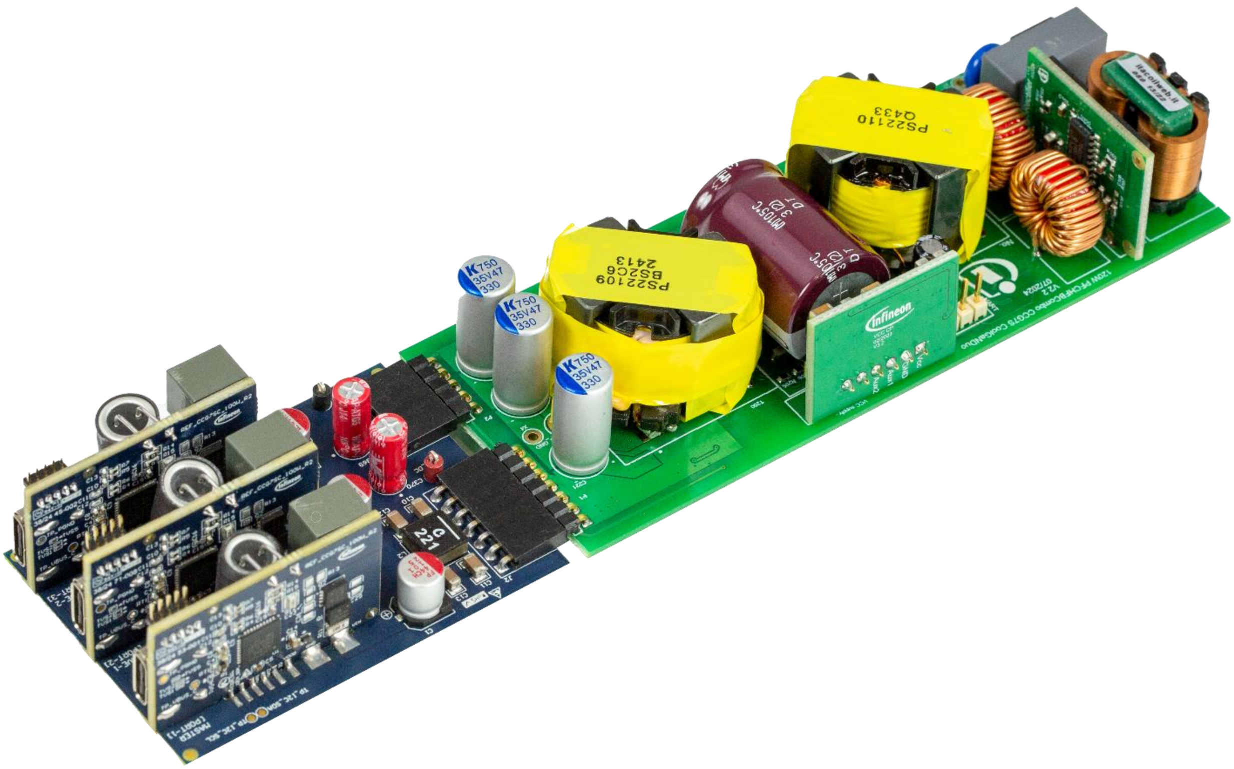


Figure 2 **EVAL_XDPS2221E_120W_3C evaluation board**

2.1.1 Input electrical requirements

Table 1 lists the electrical requirements for the input of the 120 W evaluation board.

Table 1 Input electrical requirement

Parameter	Symbol	Value			Unit	Condition
		Min.	Typ.	Max.		
AC voltage	V AC	90	–	264	V_{RMS}	Maximum range
		100	–	240	V_{RMS}	Nominal range
AC frequency	f_{AC}	47	–	63	Hz	–
Brown-in	–	–	85	–	V	–
Brown-out	–	–	75	–	V	–
X-capacitor discharge time	–	–	–	1	s	–

2.1.2 Output electrical requirements

Table 2 is showing the output electrical requirements.

Table 2 Output electrical requirements

Parameter	Symbol	Value			Unit	Condition
		Min.	Typ.	Max.		
Output voltage	V_{out}	–	5	–	V	Mean value of the standard fixed USB PD voltages, at 115 V and 230 V AC input
		–	9	–	V	
		–	15	–	V	
		–	20	–	V	
Output current	I_{out}	0	–	5	A	–
Start-up time	–	–	–	1.5	s	5 V output at cold start-up

2.1.3 Key components

The following Infineon components are used on the board.

Table 3 Key components

Item	Component
PFC + HFB controller	XDP™ XDPS2221E
USB PD controller	EZ-PD™ CCG7SC CYPD7171
Active bridge switches	IPL60R085P7
PFC switch	CoolGaN™ Drive GSD1623-N1
HFB switches	CoolGaN™ Dual IGI65D1414A3M
SR MOSFET	BSC034N10LS5
V_{CC} regulator switch	BSS169
Output buck / bypass switch	BSZ063N04LS6

2.1.4 Board and PCB information

The board and PCB information are summarized in Table 4.

Table 4 Board dimensions and power density

Board	Item	Value	Unit
Power board	Dimensions	114 x 45 x 25	mm
	Power density	≈ 15	W / in^3
	PCB	2	Layers
Output board	Dimensions	62 x 45 x 23	mm
	Power density	-	-
	PCB	2 (base) / 4 (USB PD)	Layers

2.2 Evaluation board system

The system consists of the main power board, an active bridge rectifier board, a VCC bias board, and an output base board comprising 3 USB PD daughter boards. The hybrid-flyback combo controller XDP™ XDPS2221E controls both the PFC and HFB stages. The CoolGaN™ Dual IGI65D1414A3M device was chosen, having both the high-side and low-side GaN switches integrated in one package. The PFC switch, a CoolGaN™ Drive GSD1623-N1 device, is based on a 150 mΩ e-mode GaN transistor with integrated intelligent gate driver and lossless current sense. Having the overcurrent protection integrated into GSD1623-N1, the PFC stage does not require any PFC shunt. At the output side, Infineon's USB PD EZ-PD™ controller CYPD7171 is used for all the three output ports. This controller enables the communication with the end device and output voltage management as well as controlling the regulation loop of the HFB and driving the buck or bypass switches at the output, based on the requested output voltage.

In the following sections, the schematics and printed circuit board (PCB) layout design information of these boards is shown, while the bills of materials (BOMs) of the boards can be found in Section 4.1.

2.2.1 Evaluation board schematics

The schematics of all the boards of this evaluation board system are shown in Figure 3 to Figure 9.

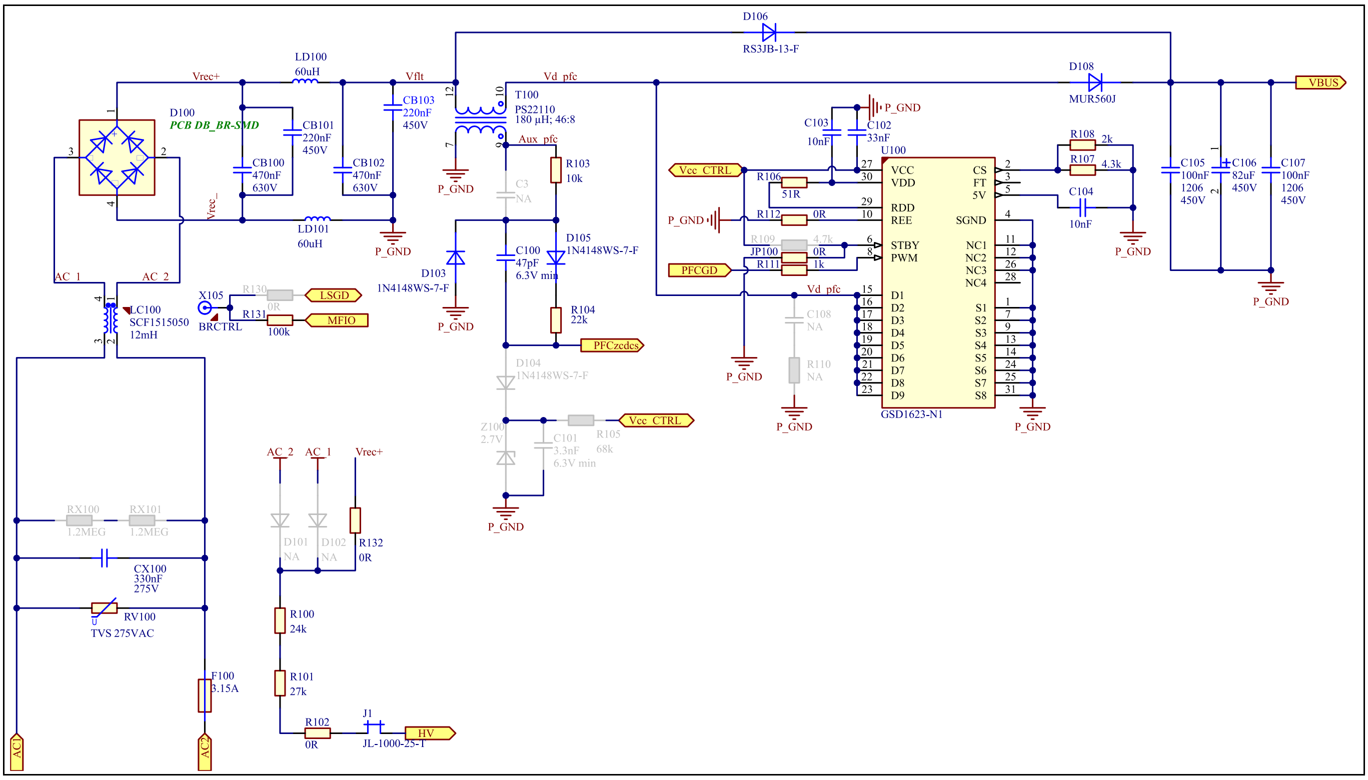


Figure 3 PFC stage schematic

Figure 3 shows the power circuitry of the AC input and PFC stage, including the input protection, EMI filter, and the start-up cell feed resistors R132, R100, R101, and R102. The PFC main switch U100 is the CoolGaN™ Drive GSD1623-N1 that integrates a high-performance e-Mode GaN FET with integrated gate drive and loss-less current sense. The GaN Power IC is driven directly by the XDP™ XDPS2221E from the PFCGD pin through R111. The PFC zero-crossing detection (ZCD) circuit is processing the Aux_pfc signal from the auxiliary winding of the PFC choke T100 via R103, D103, C100, D105, and R104. The resulting processed signal PFC_{zcdcs} is sent to the PFCCS pin of the controller.

The active bridge board is shown in Figure 4. It comprises the active bridge controller U100 and the CoolMOS™ P7 IPL60R085P7 FETs Q100, Q101, Q102, and Q103. To save power, U100 is disabled at no-load and at very light load conditions via BRCTRL signal generated by the MFIO pin of XDPS2221E. The MFIO pin is configured for ACT_EN function.

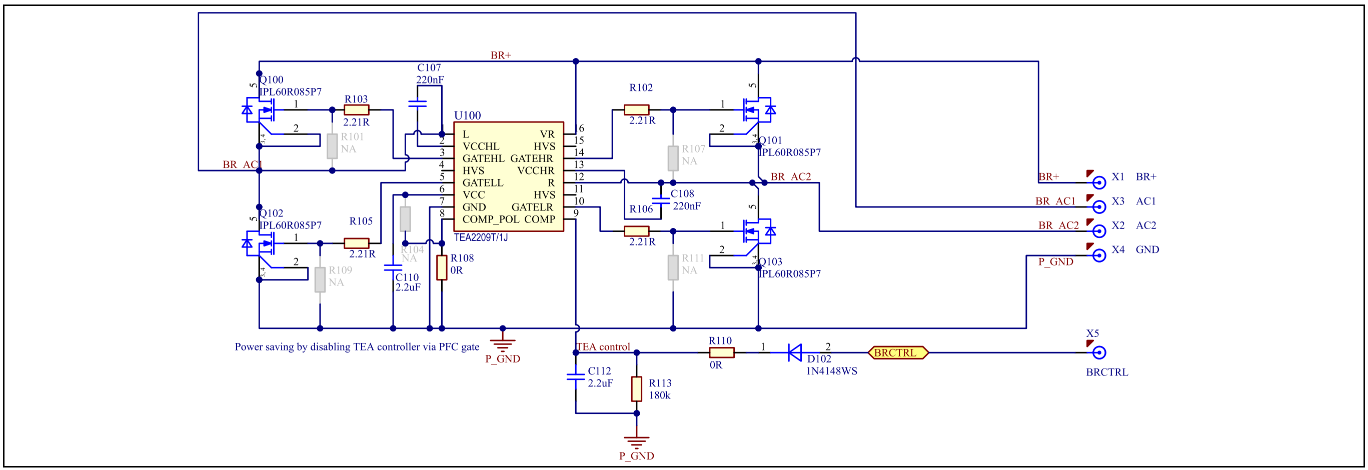


Figure 4 **Active bridge rectifier board schematic**

The hybrid-flyback DC to DC stage ,which is based on a half-bridge structure, is controlled by XDP™ XDPS2221E combo IC as shown in Figure 5.

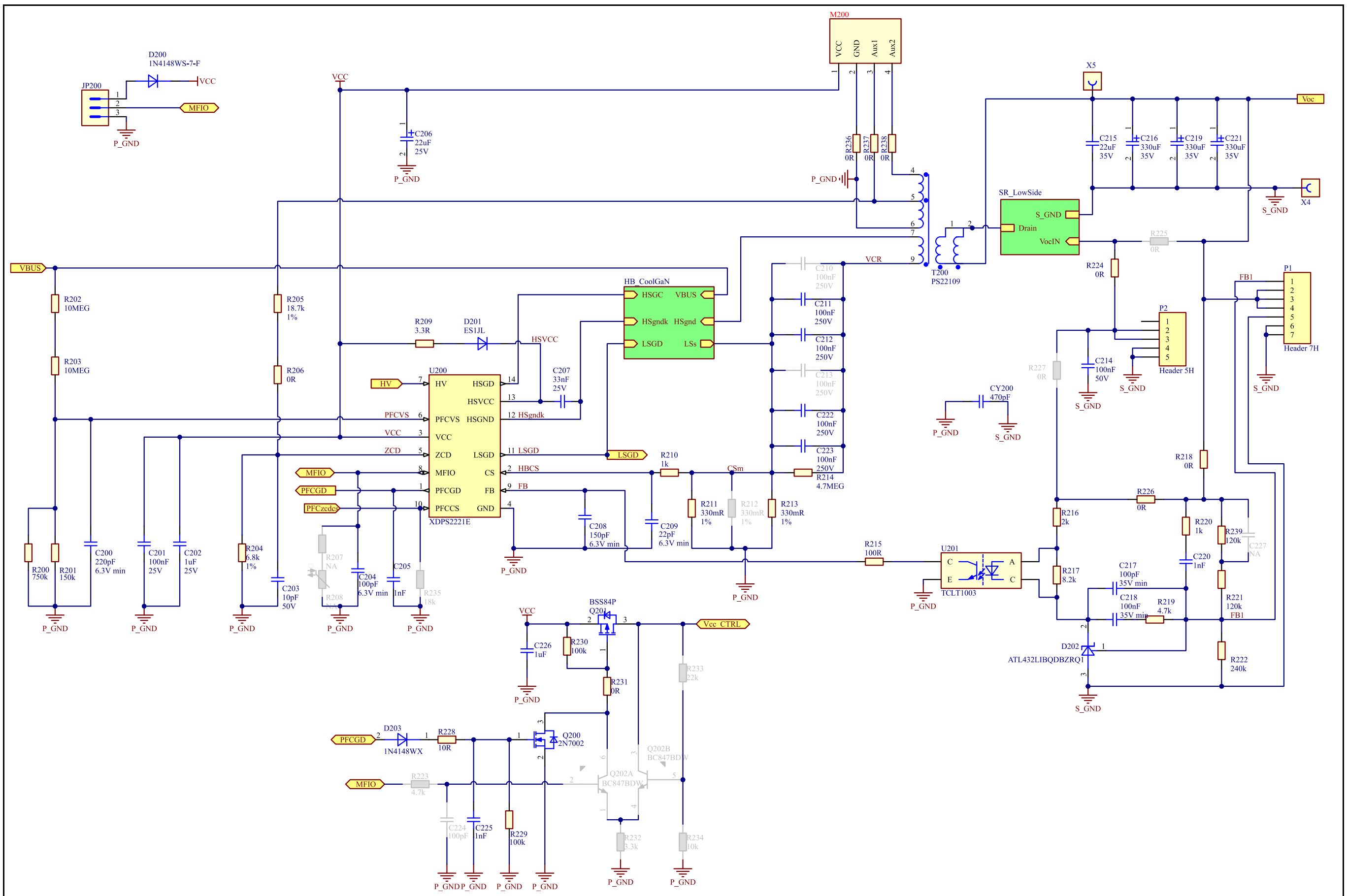


Figure 5 **HFB stage schematic**

The primary winding of the T200 transformer is connected to the half-bridge switching node at one end and to the resonant capacitors (C211, C212, C222, and C223) at the other end. The shunt resistors (R211 and R213) are used to sense the current through the transformer primary winding for HFB peak current regulation. For accurate switching timing, the signal from the auxiliary winding (Na1: 5 to 6) is used. It generates a ZCD signal using devices R204 and R205. The resistors R200, R201, R202, and R203 are used for the PFC VBUS voltage sensing. The connector JP200 is used for the parameter configuration via UART communication and also for debugging.

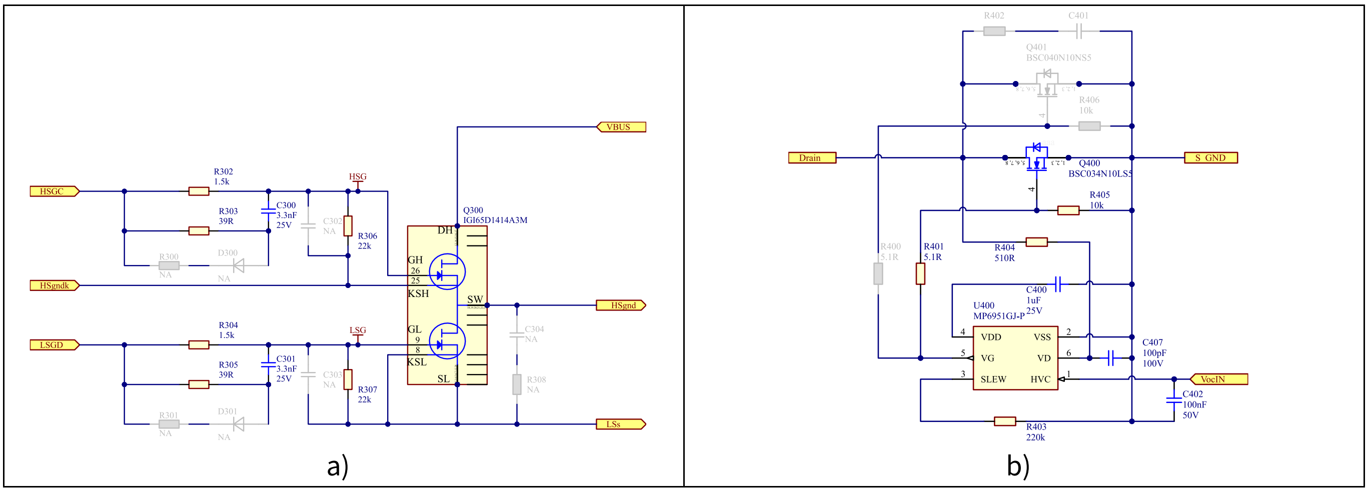


Figure 6 Schematic: a) half-bridge schematic (CoolGaN™ Duo), b) synchronous rectifier schematic

The half-bridge schematic and secondary side synchronous rectifier schematic are depicted in Figure 6.

In Figure 7, the schematic of the VCC supply board is shown. This bias supply is based on a charge pump circuit that is fed by Vaux1 and Vaux2 voltages generated by auxiliary windings Na1 and Na2.

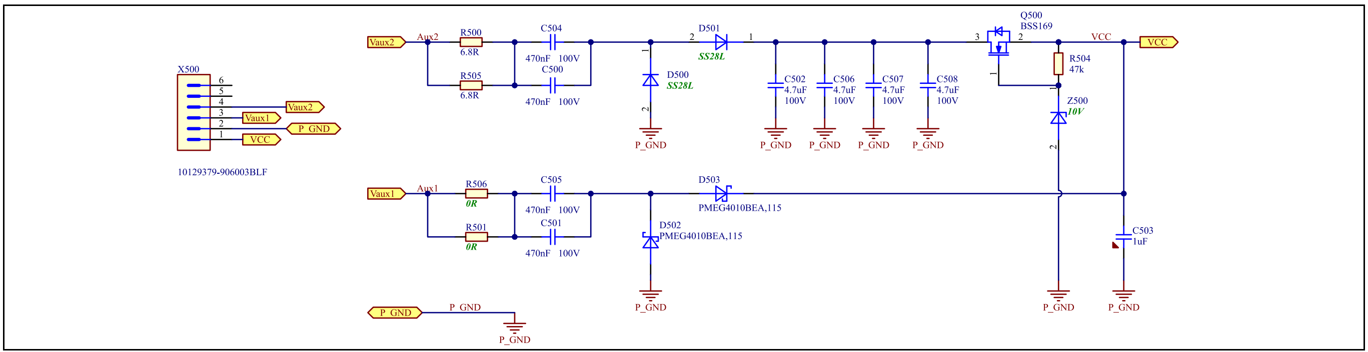


Figure 7 VCC supply board schematic

The output base board connects the HFB and the output USB PD boards, thereby ensuring communication between them. The auxiliary supply controlled by U360 is used for USB PD and HFB synchronous rectifier IC 5 V supply.

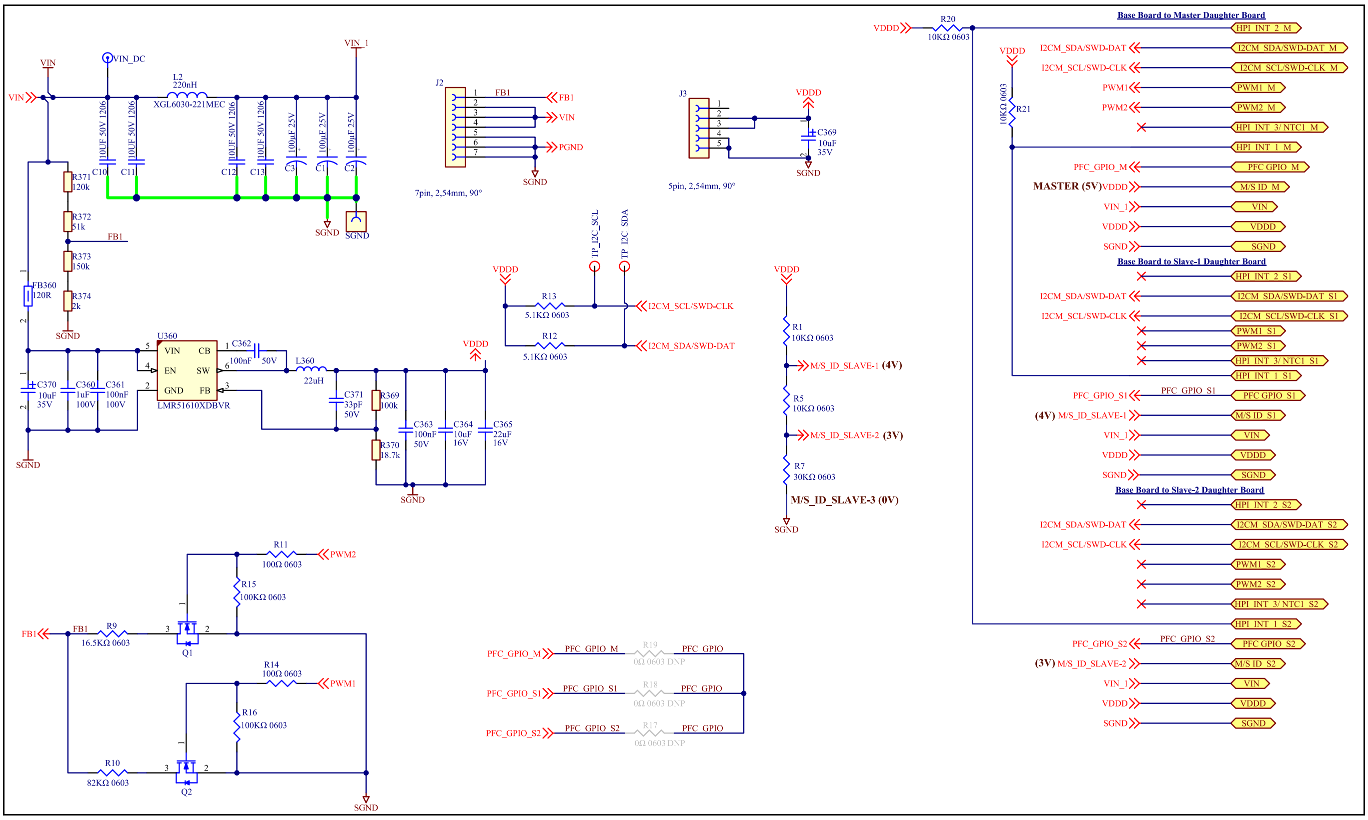


Figure 8 **Output base board schematic**

The USB PD daughter board is based on the EZ-PD™ controller CYPD7171, as shown in Figure 9.

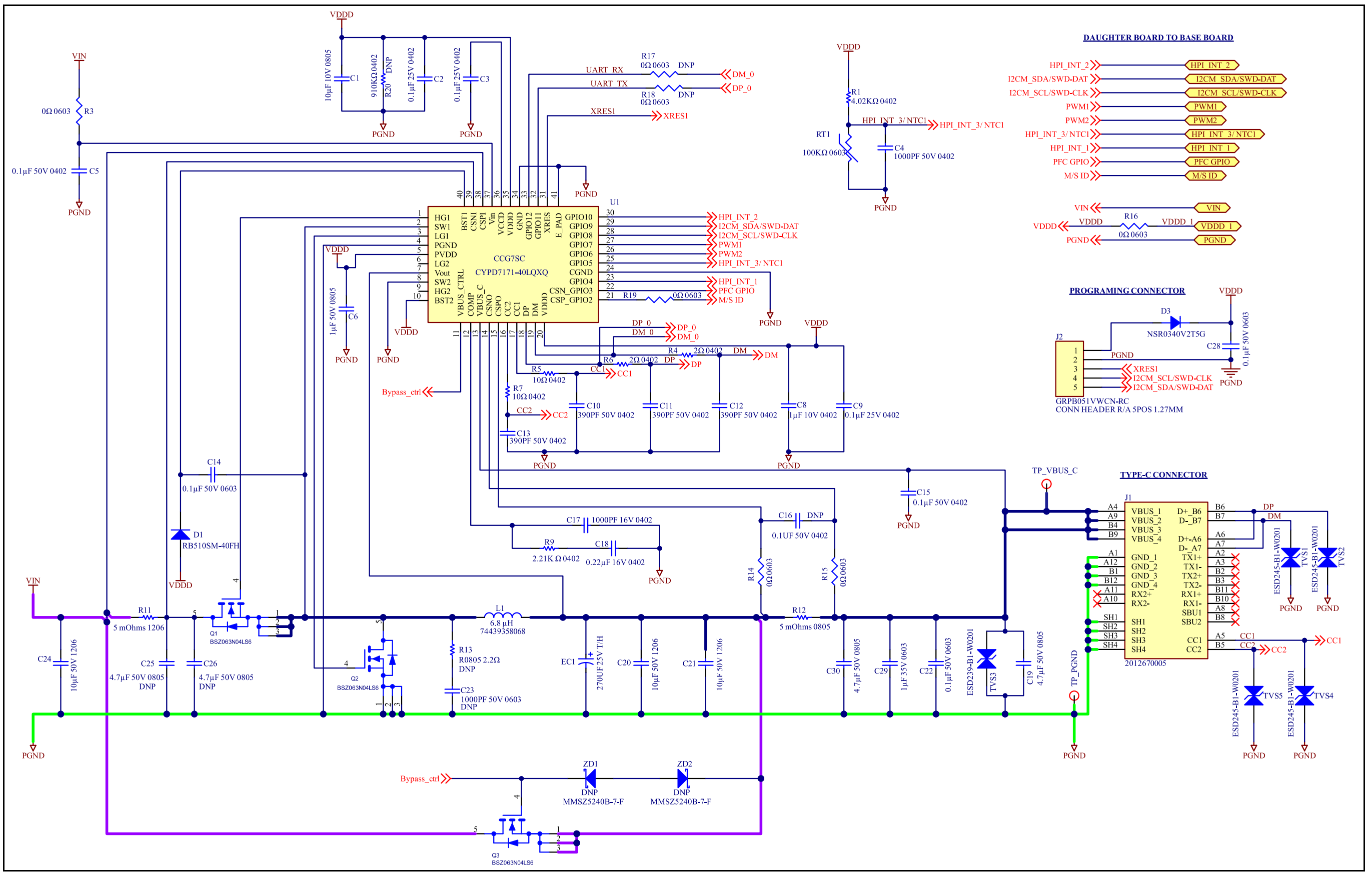


Figure 9 USB PD daughter board schematic

The CCG7SC USB PD controller CYPD7171 is the central piece of the schematic, controlling the communication with the end device that serves as the load, driving the buck converter and setting the necessary HFB output voltage for correct operation. The circuit consisting of Q2, L1, and the capacitors C25, C26, EC1, C20, C21, is the step-down converter (buck) that is needed to regulate the requested output voltage. In some cases, this stage can be bypassed by the switch Q3 for improved efficiency. The Q1 switch serves as the output or safety switch for the USB PD output before the USB Type-C connector. The output current at the Type-C connector is sensed by the shunt resistors R11 or R12 depending on the case and fed to the PD control IC. The controller CYPD7171 communicates with the end device via the communication lines CC1 or CC2 and sets the output voltage level of the HFB accordingly through the signals PWM1 and PWM2.

2.2.2 Evaluation board PCB layout design

The 120 W USB PD evaluation board PCB layout design information is depicted from Figure 10 to Figure 17.

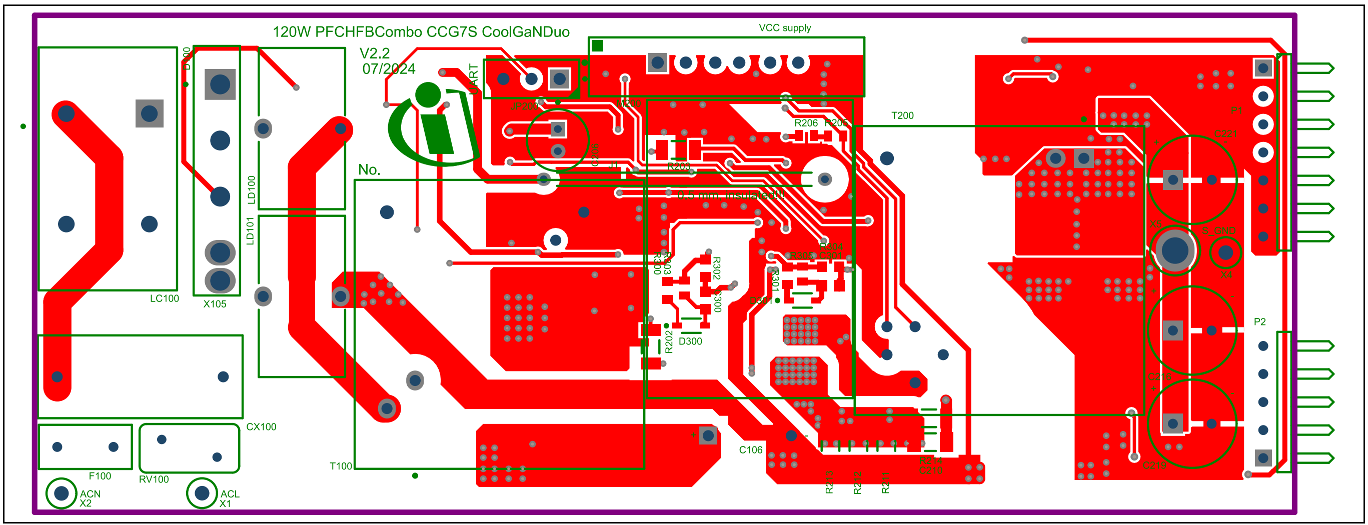


Figure 10 120 W power board layout – top layer

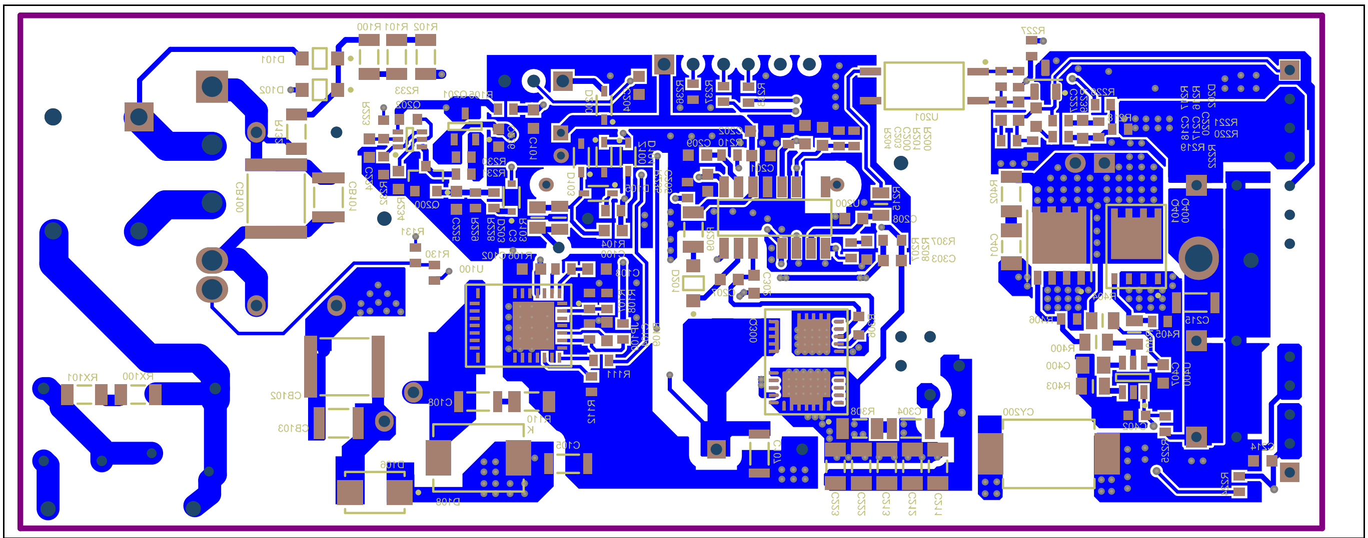


Figure 11 120 W power board layout – bottom layer

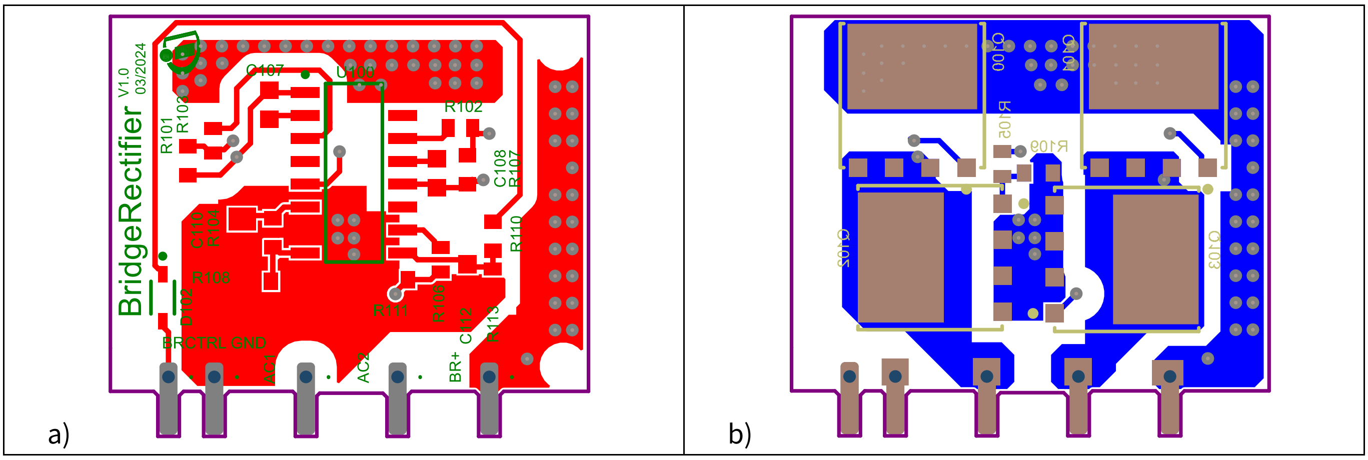


Figure 12 Active bridge rectifier board layout – a) top layer, b) bottom layer

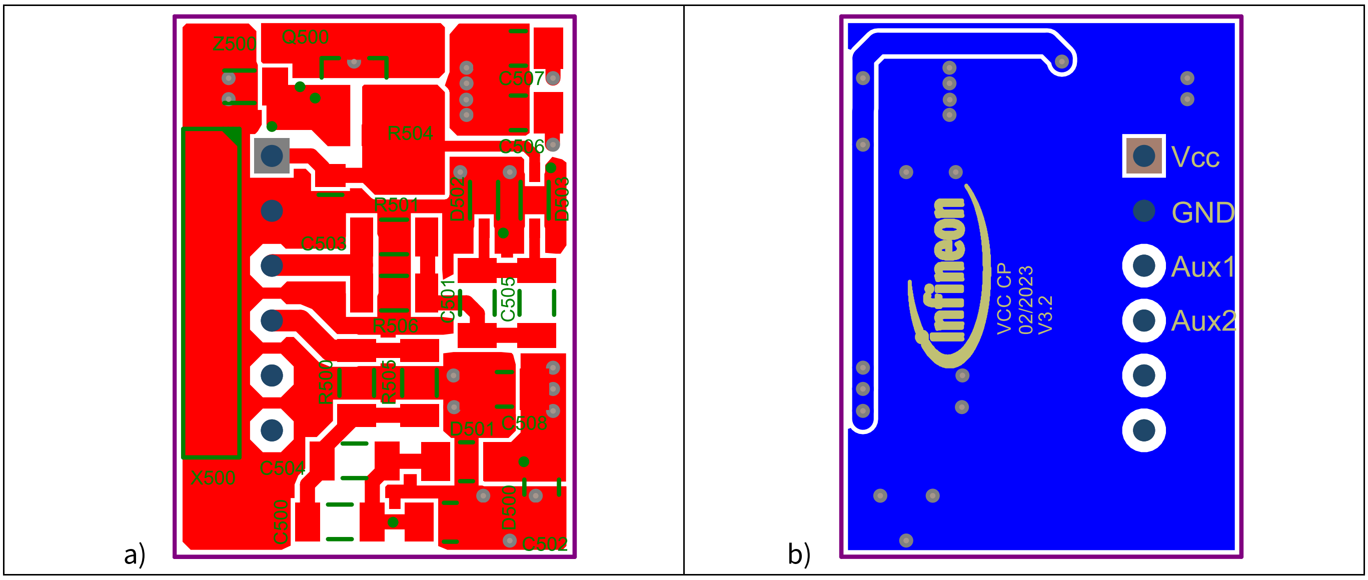


Figure 13 VCC supply board layout – a) top layer, b) bottom layer

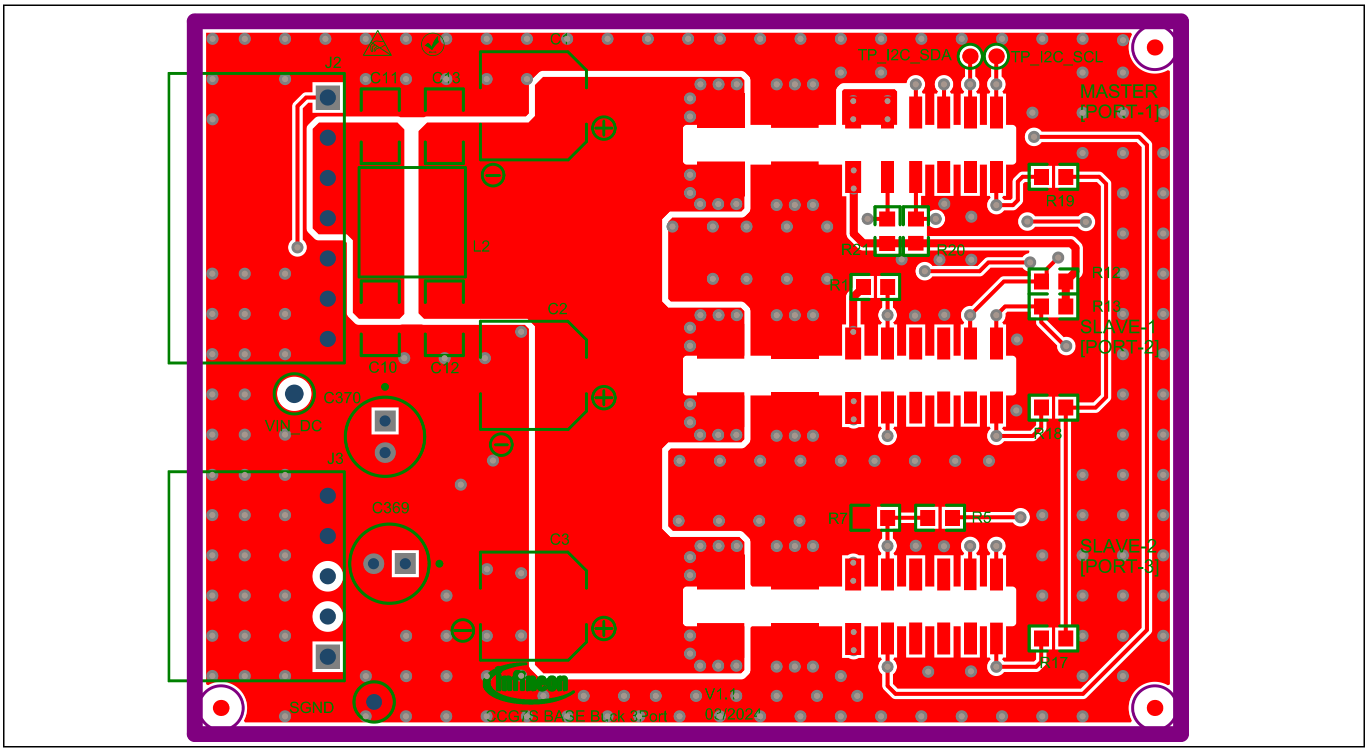


Figure 14 Output base-board layout – top layer

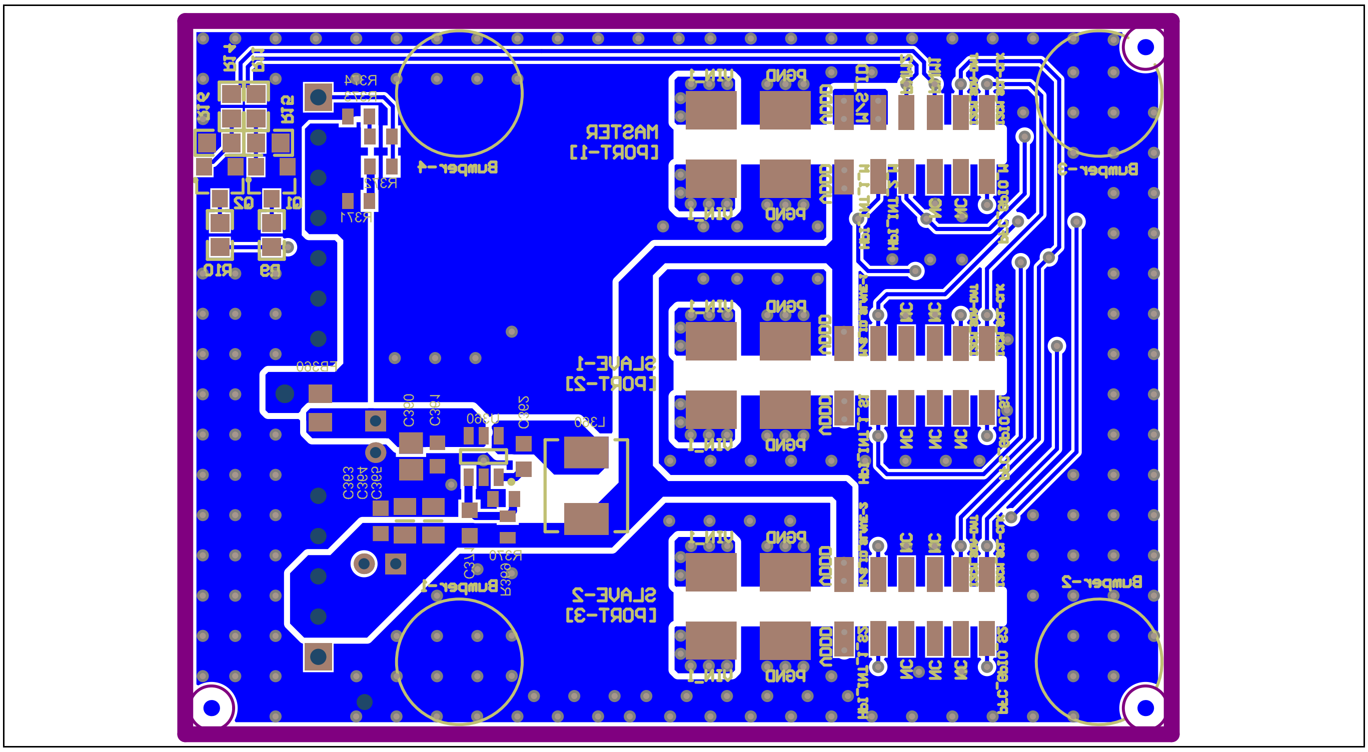


Figure 15 Output base-board layout – bottom layer

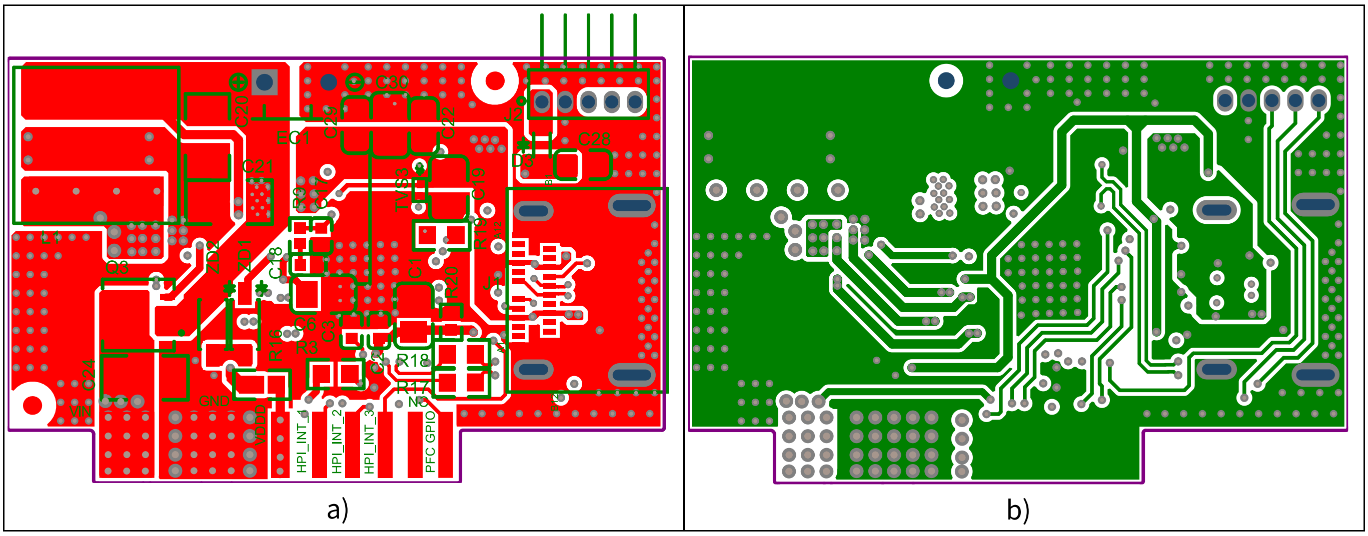


Figure 16 USB PD board layout – a) top layer, b) layer 2

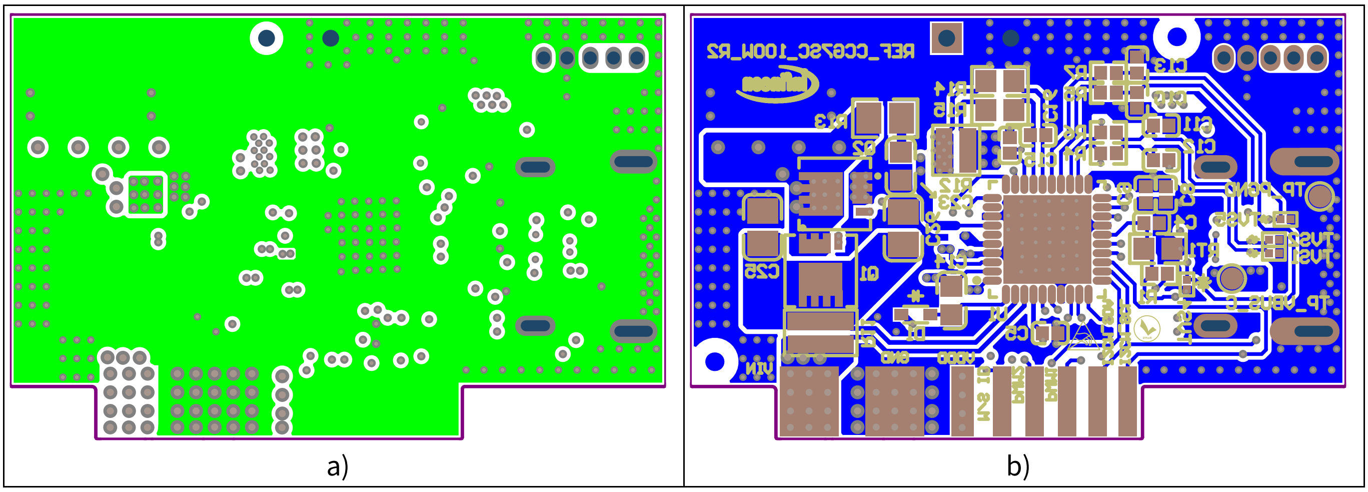


Figure 17 USB PD board layout – a) layer 3, b) bottom layer

3 System performance

The key measurement results are illustrated in the following sections.

3.1 Efficiency and standby power

The four-point average efficiency of the board measured at the Type-C connector is shown in Table 5. As it can be seen in the table, the four-point average efficiency is high enough to meet stringent efficiency standards set by the DoE Level VII power supply conversion efficiency requirements.

Table 5 Efficiency as a percentage, measured at the Type-C connector for one output loaded

V AC (V)	I_{out} / V_{out} (V)	100 percent	75 percent	50 percent	25 percent	Average	Average acc. DoE Level VII
115	5	87.67	87.02	85.48	80.85	85.25	85.00
	9	90.45	90.59	89.42	86.45	89.22	88.85
	15	92.68	92.73	91.63	90.65	91.92	89.00
	20	93.87	94.06	93.28	91.96	93.29	89.00
230	5	88.61	88.35	87.37	84.01	87.08	85.00
	9	91.45	91.61	91.03	88.71	90.70	88.85
	15	92.64	92.25	92.34	91.16	92.09	89.00
	20	94.54	94.01	93.95	92.56	93.76	89.00

The four-point efficiency at the lower line and higher line input voltage, measured for all possible output voltages (5V, 9 V, 15 V, and 20 V) is shown in Figure 18 and Figure 19, respectively.

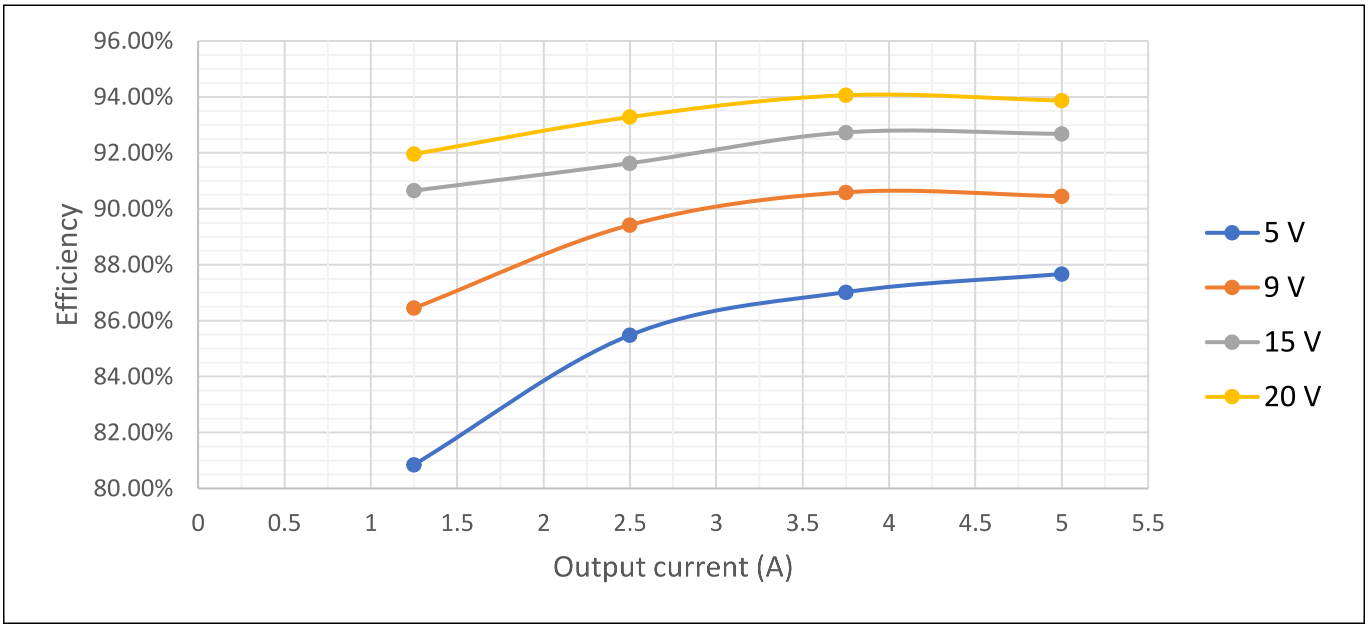


Figure 18 Efficiency vs. load at 115 V AC input

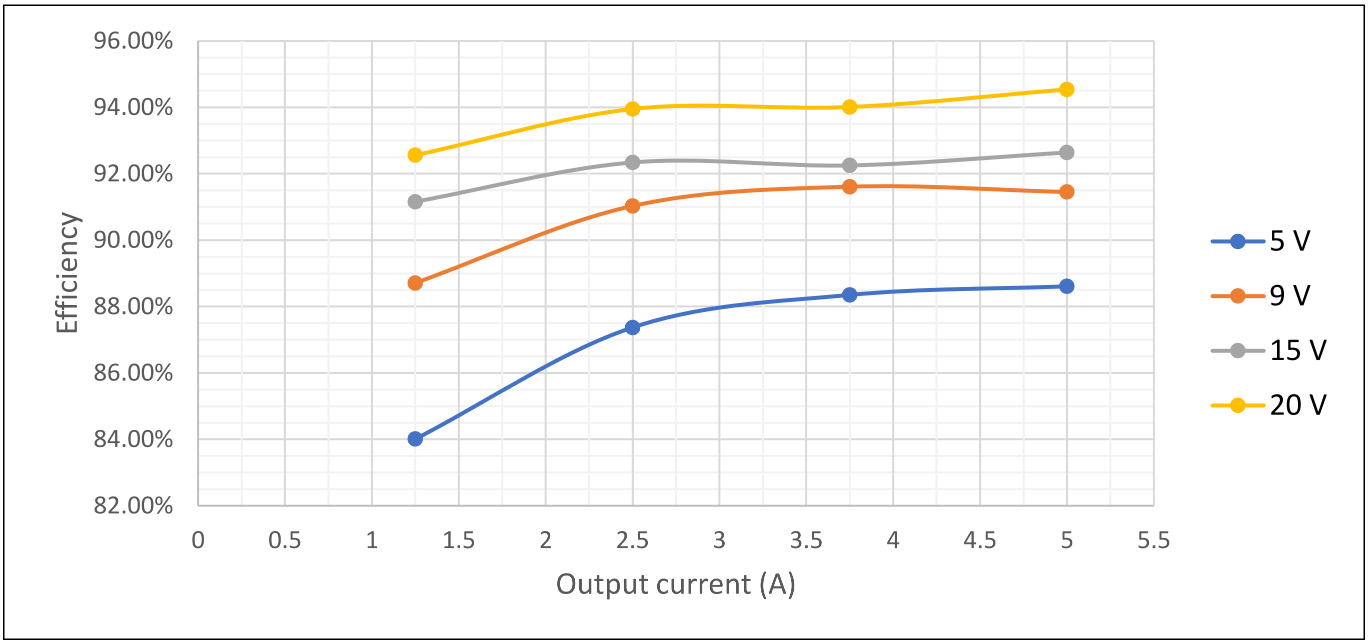


Figure 19 Efficiency vs. load at 230 V AC input

System standby input power is measured, and the results are shown in Table 6. For standby input power, no load is connected to the output, and the USB Type-C cable is unplugged.

The standby input power measurements are performed for two scenarios. One scenario consists of the output board with 3 USB-C outputs connected to the power board. In this case, for standby power measurement, no cable is connected to any of the outputs. The other scenario is where a special USB-C board is connected to the output of the power board. This special board contains only one USB-C output and is based on CYPD3175, similar to the one in the refence design REF_XDPS2221_140W1 [4]. The tiny load measurements were performed with the 3 USB-C output board and one output loaded. The efficiency data for the tiny load test is shown in Table 7.

Table 6 Standby input power measurements

Measurement \ V AC (V)	115	230
Total standby input power with three output board	55 mW	72 mW
Total standby input power with one output board	49 mW	57 mW

Table 7 Efficiency at tiny load measurements with 20 V output

Output power (mW) \ V AC (V)	115	230
250	58.8%	59.3%
500	69.0%	71.0%
1000	74.7%	79.0%
2000	79.3%	83.7%
5000	82.2%	85.4%
10000	88.5%	90.1%
15000	90.5%	92.1%

V AC (V) / Output power (mW)	115	230
20000	91.6%	93.0%

3.2 Conducted EMI emissions measurement

The EMI measurement results for the full output power of 120 W are presented in this section. In this case, each output is precisely loaded with 40 W, 20 V and 2 A. The average (AVG) and quasi-peak (Q-Peak) tests were performed at both low line (115 V AC) and high line (230 V AC), and each measurement is done on both live (L) and neutral (N) phases.

Figure 20 to Figure 23 shows the conducted EMI scan plots.

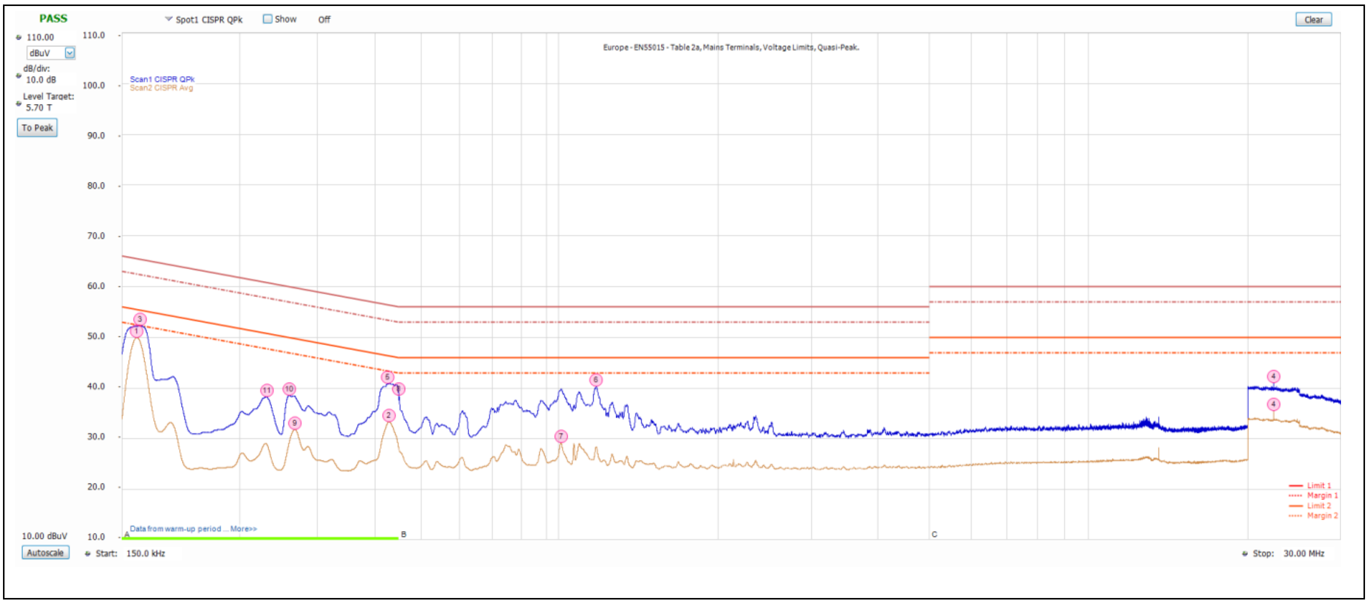


Figure 20 Q-peak and AVG conducted EMI test result plot for 115 V AC input and N phase

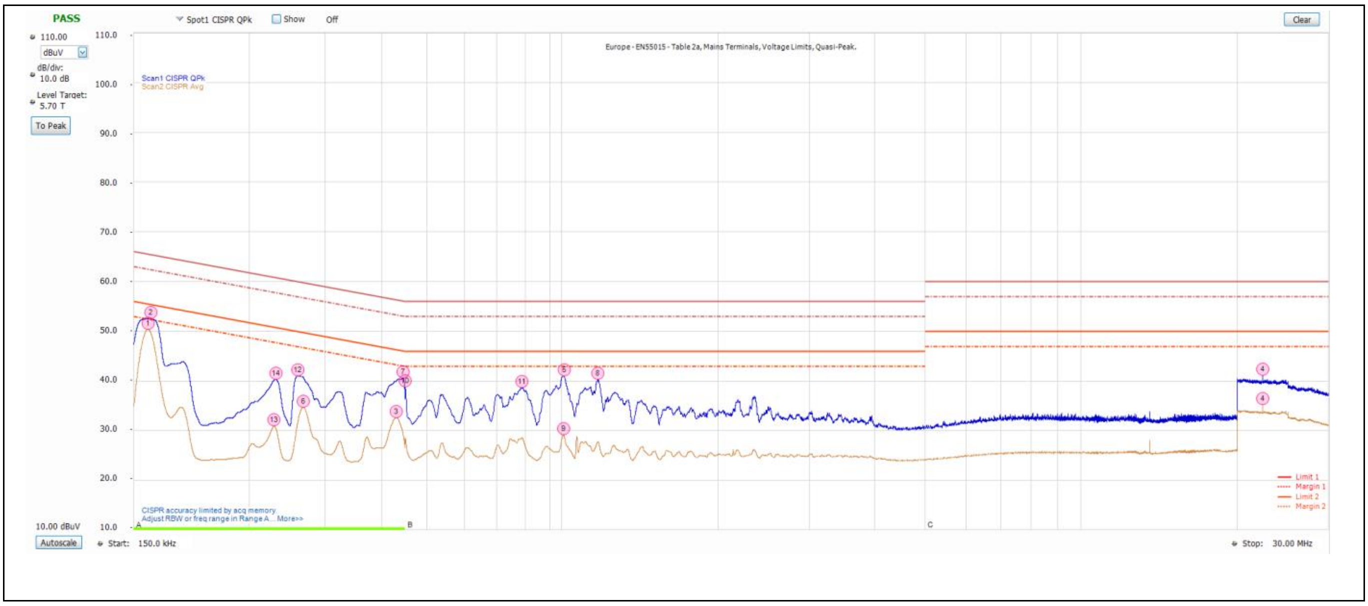


Figure 21 Q-peak and AVG conducted EMI test result plot for 115 V AC input and L phase

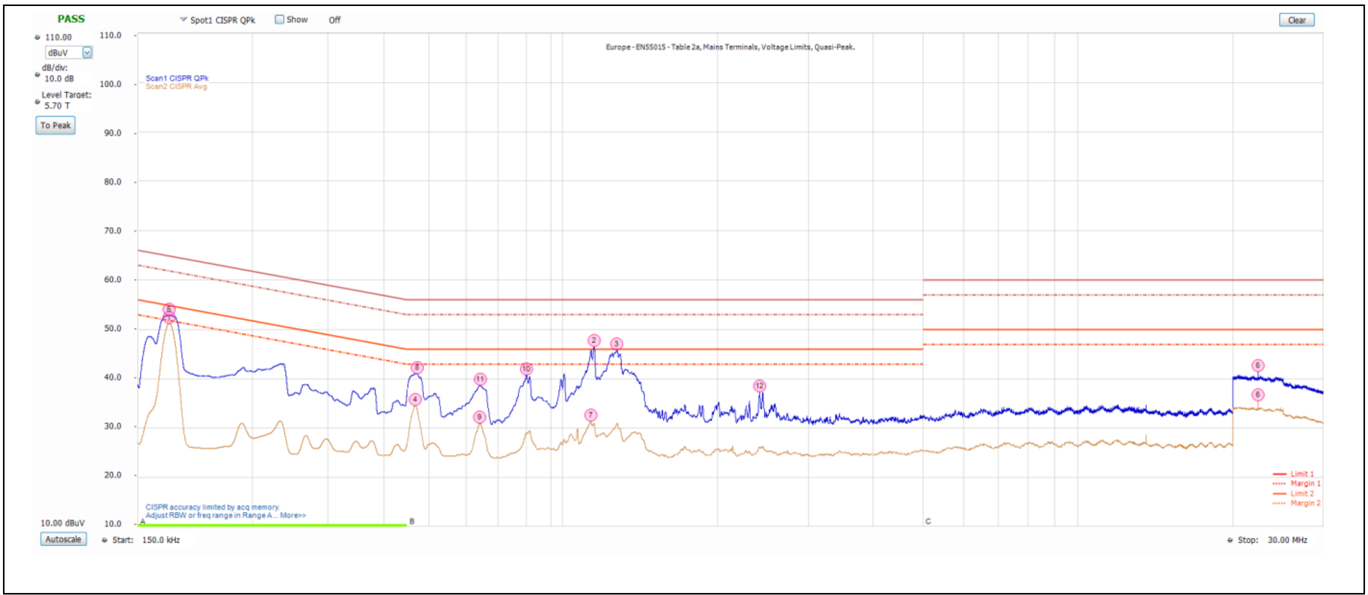


Figure 22 Q-peak and AVG conducted EMI test result plot for 230 V AC input on N phase

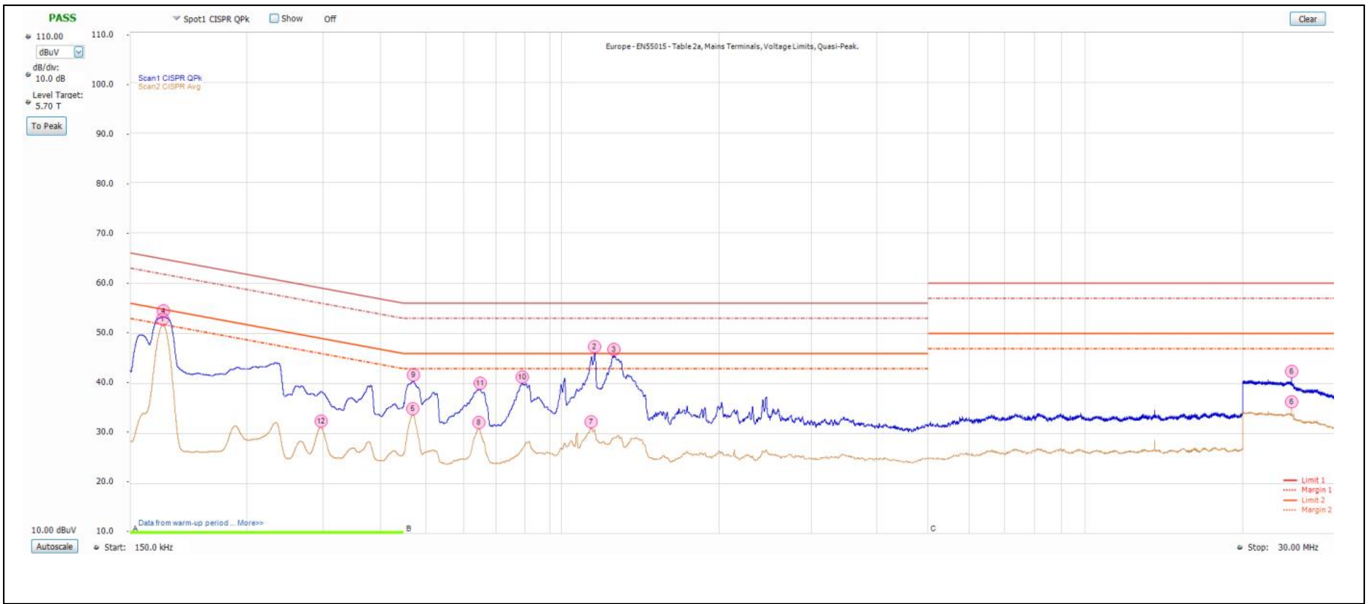


Figure 23 Q-peak and AVG conducted EMI test result plot for 230 V AC input and L phase

3.3 Output voltage ripple

The measurement of the output voltage ripple is done after the USB Type-C output connector. The plots showing the output voltage ripple measurements results are presented in Figure 24. When measured at 115 V AC input, at 100% load, the highest ripple was observed at 15 V output with the peak-to-peak value of 58 mV. For the same input voltage but at 5 V output and 100% load, a maximum value of 29 mV peak-to-peak was measured. For a 230 V AC input, the 15 V output and 100% load indicates a peak-to-peak value of 57 mV. For the same input voltage, with 5 V output voltage and 100% load, the value measured is 38 mV peak-to-peak.

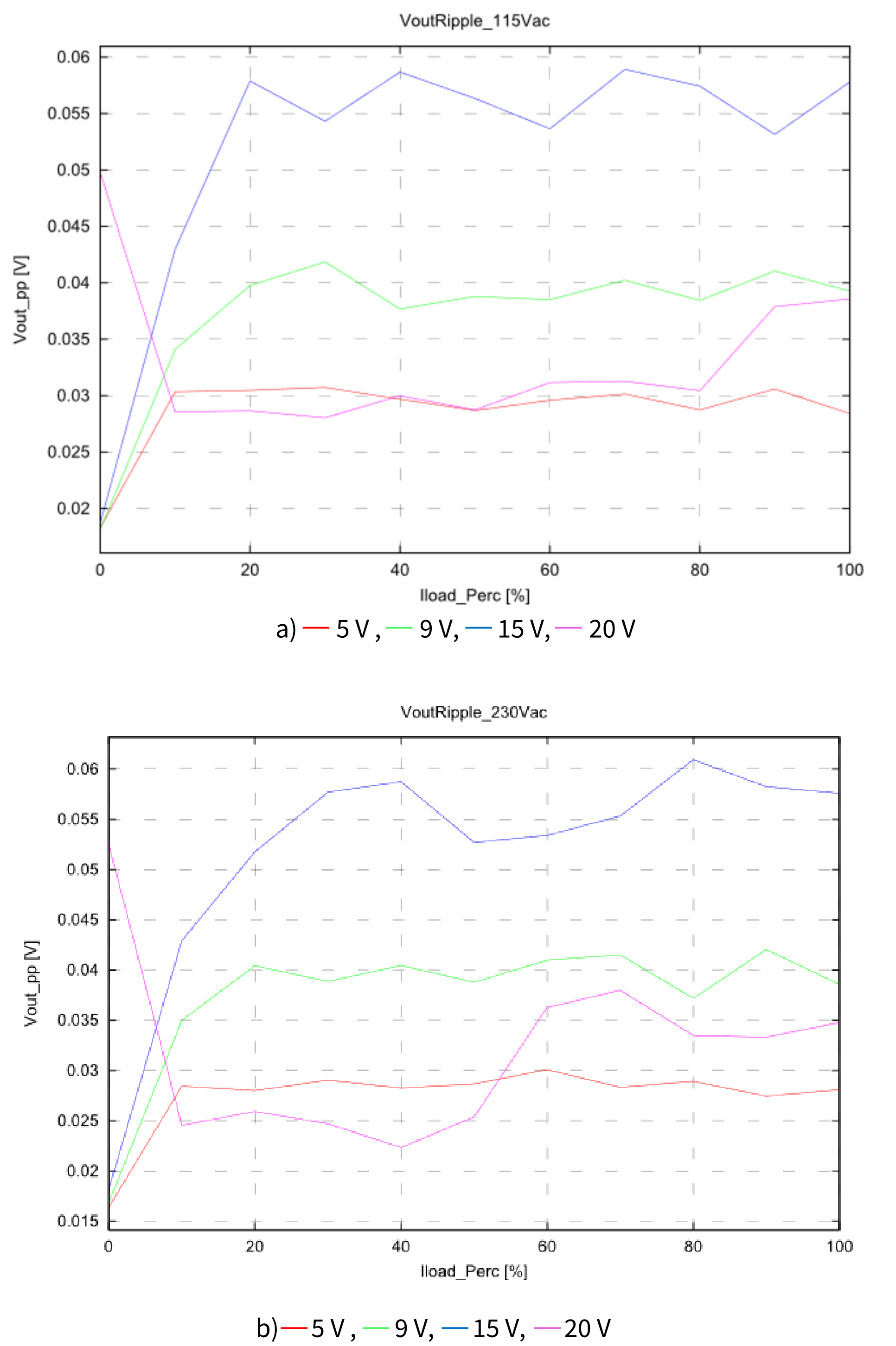


Figure 24 **Output voltage ripple waveform and measurement: a) 115 V AC input; b) 230 V AC input**

3.4 PFC performance

In this section, the PFC performance data is presented, which is quantified by the power factor, harmonic currents, and the total harmonic distortion measurements. The power factor measurements were performed at 115 V AC and 230 V AC for a load from 100% down to 10% with 10% steps. The results of this test are presented in Table 8.

Table 8 Power factor measurement

Load (%) \ V AC (V)	115	230
100	0.997	0.977
90	0.996	0.973
80	0.995	0.967
70	0.994	0.958
60	0.992	0.946
50	0.989	0.926
40	0.984	0.894
30	0.973	0.835
20	0.945	0.718
10	0.838	0.479

The plotted values of the power factor measurement are displayed in Figure 25.

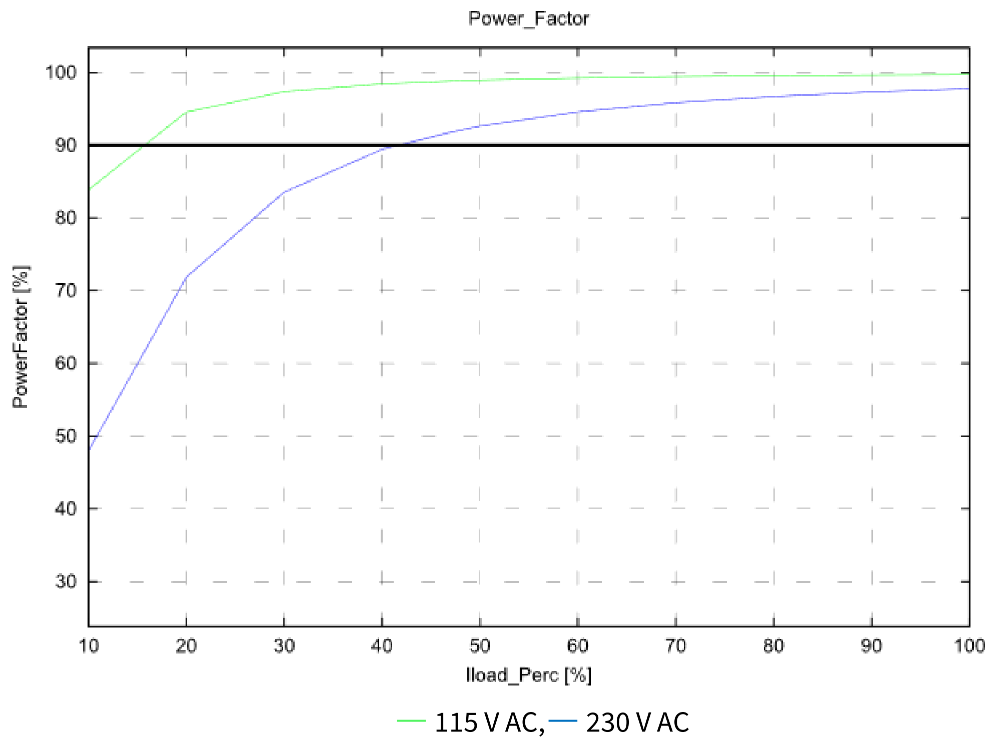


Figure 25 Power factor plot

The measurements for harmonic currents were performed on the evaluation board at 115 V AC and 230 V AC reveal low values which are under the limits, as displayed in Figure 26. In Figure 27 , the total harmonic distortion is shown.

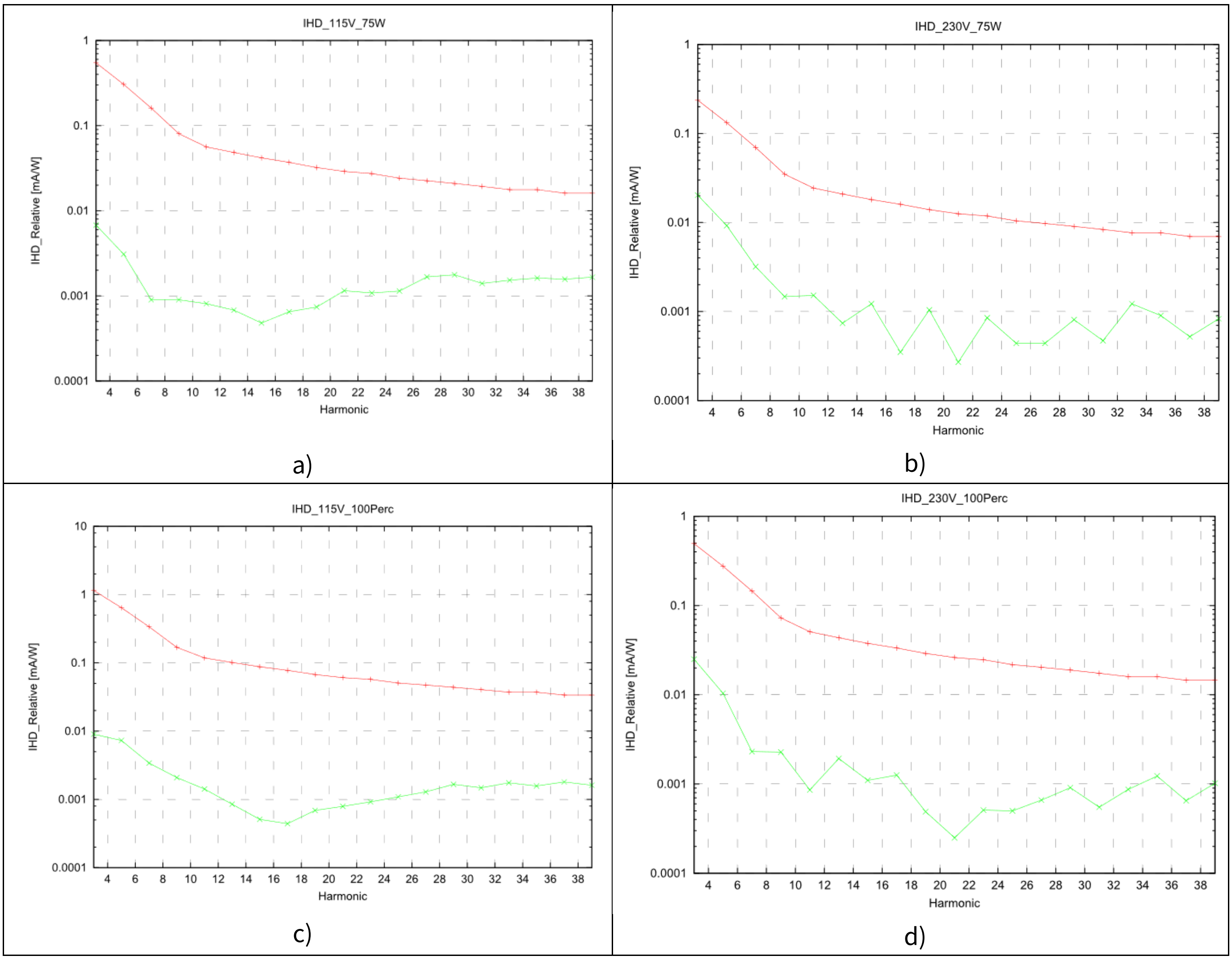


Figure 26 Harmonics current (green line) and its limit from IEC 61000-3-2 (red line): a) 115 V AC, 75 W, b) 230 V AC, 75 W, c) 115 V AC, 120 W, and d) 230 V AC, 120 W

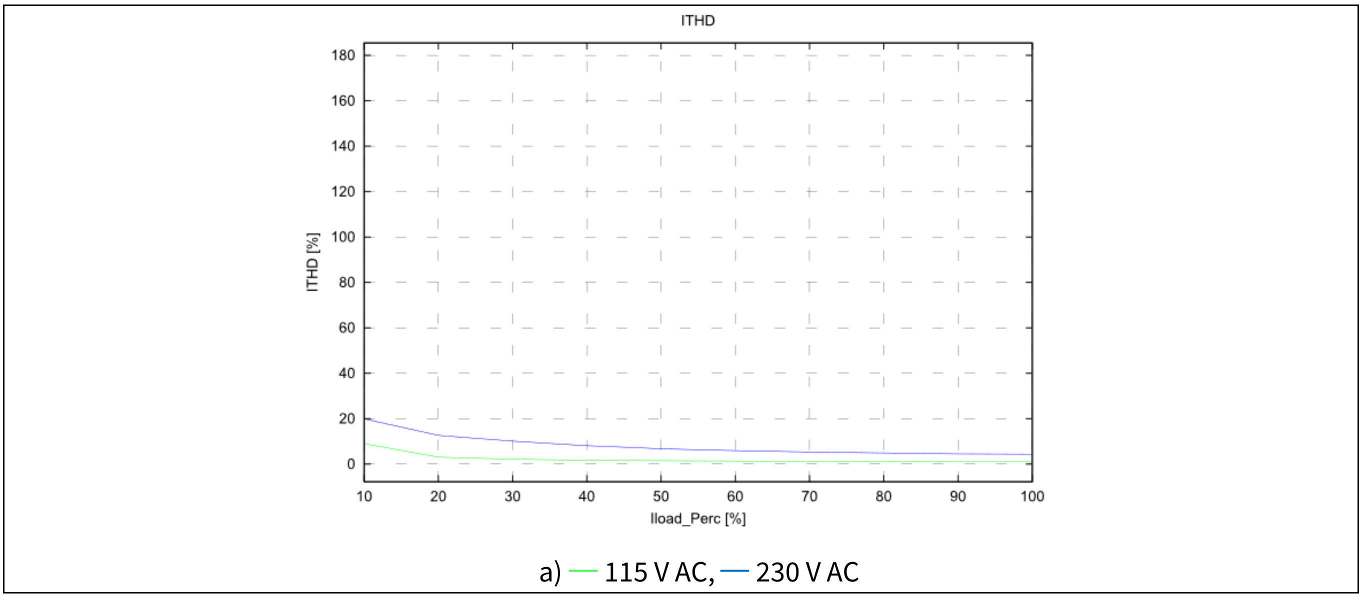
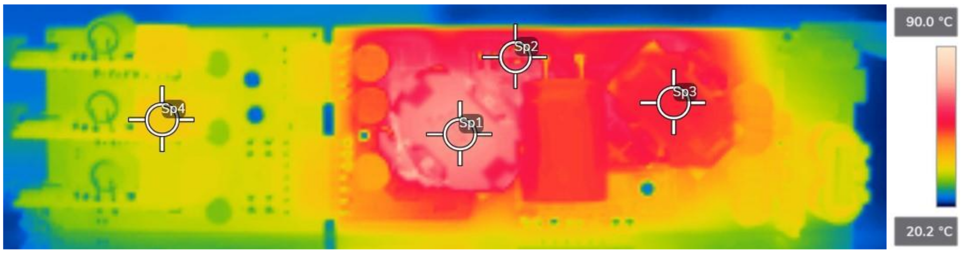


Figure 27 Total harmonic distortion plot

3.5 Thermal measurement

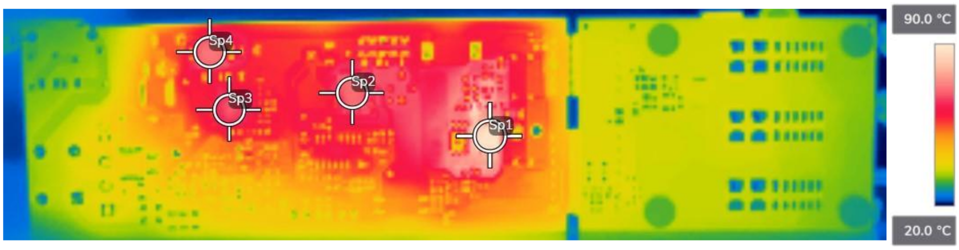
The following images in Figure 28 are the infrared (IR) thermal images of the board at 115 V AC and 230 V AC input and full power output (120 W) after 1-hour burn-in time and at 24°C ambient temperature.

Measurements	
Sp 4 USB PD	43.8 °C
Sp 1 Transformer	74.2 °C
Sp 2 HFB shunts	60.0 °C
Sp 3 PFC choke	59.5 °C



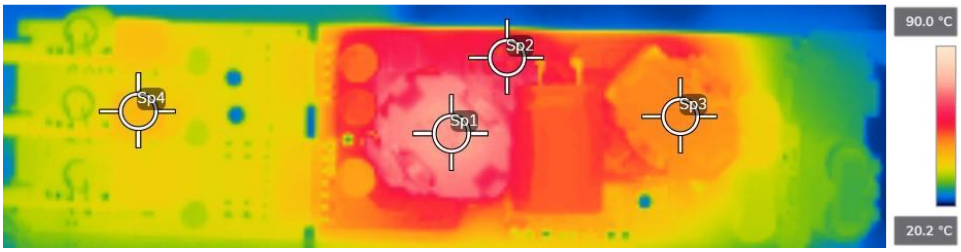
a)

Measurements	
Sp 1 SR	88.2 °C
Sp 2 HB GaN IC	73.6 °C
Sp 3 PFC IC	71.7 °C
Sp 4 PFC Diode	74.4 °C



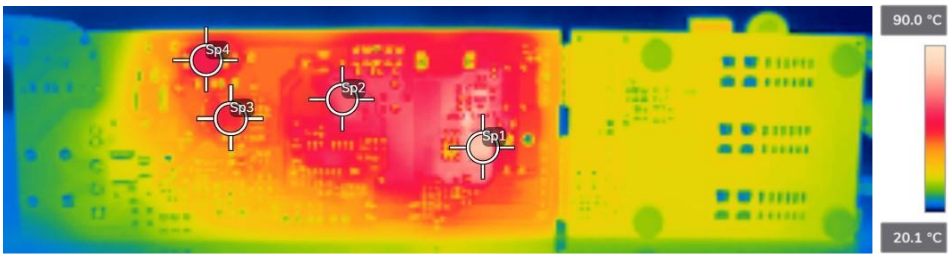
b)

Measurements	
Sp 1 Transformer	74.9 °C
Sp 2 HFB shunts	64.3 °C
Sp 3 PFC choke	50.5 °C
Sp 4 USB PD	45.0 °C



c)

Measurements	
Sp 1 SR	81.3 °C
Sp 2 HB GaN IC	70.0 °C
Sp 3 PFC IC	58.5 °C
Sp 4 PFC Diode	63.5 °C



d)

Figure 28 Thermal images: a) 115 V AC top, b) 115 V AC bottom, c) 230 V AC top, d) 230 V AC bottom

The measurements show that the device with the highest temperature captured on the board is the SR MOSFET, reaching a temperature of 88.2 °C at 115 V AC input voltage. The temperature of CoolGaN™ Transistor Dual device is reaching 73.6 °C at 115 V AC and the CoolGaN™ Drive device of 71.7 °C at the same input voltage.

4 Appendices

This section describes the following information:

- Bills of materials (BOMs) of the boards
- Information on the magnetic devices

4.1 Bills of materials of the boards

This section provides the list of all the components used in the boards that are part of the evaluation board. Each table is the complete BOM for each board in the system.
While the given component voltage class shows its required operating voltage, some components on the board may have higher specification values due to the component's availability. Unless otherwise indicated in the BOM, 5 percent or better tolerance applies to the standard SMD resistors, and X7R or better or higher voltage class applies to the standard ceramic capacitors.

Table 9 Power board BOM

No.	Quantity	Designator	Description
1	1	C100	Cap 47pF/ 6.3V min/ 0603/ C0G/10%
2	2	C102, C207	Cap 33nF/ 25V/ 0603/ X7R/5%
3	2	C103, C104	Cap 10nF/ 25V/ 0603/ X7R/5%
4	2	C105, C107	Cap 100nF/ 450V/ 1206/ /10%
5	1	C106	Cap 82uF/ 450V/ THT/Radial/ /20%
6	1	C200	Cap 220pF/ 6.3V min/ 0603/ C0G/2%
7	1	C201	Cap 100nF/ 25V/ 0603/ X7R/5%
8	1	C202	Cap 1uF/ 25V/ 0603/ X7R/10%
9	1	C203	Cap 10pF/ 50V/ 0603/ /2.5%
10	1	C204	Cap 100pF/ 6.3V min/ 0603/ C0G/5%
11	1	C205	Cap 1nF/ 25V/ 0603/ X7R/10%
12	1	C206	Cap 22uF/ 25V/ THT/Radial/ /20%
13	1	C208	Cap 150pF/ 6.3V min/ 0603/ C0G/5%
14	1	C209	Cap 22pF/ 6.3V min/ 0603/ C0G/5%
15	4	C211, C212, C222, C223	Cap 100nF/ 250V/ 1206/ X7R/10%
16	2	C214, C218	Cap 100nF/ 50V, 35V min/ 0603/ X8L/10%
17	1	C215	Cap 22uF/ 35V/ 1206/ X5R/20%
18	3	C216, C219, C221	Cap 330uF/ 35V/ THT/Radial/ /20%
19	1	C217	Cap 100pF/ 35V min/ 0603/ C0G/2%
20	2	C220, C225	Cap 1nF/ 50V/ 0603/ C0G/5%
21	1	C226	Cap 1uF/ 25V/ 0603/ X5R/10%
22	2	C300, C301	Cap 3.3nF/ 25V/ 0603/ X7R/5%
23	1	C400	Cap 1uF/ 25V/ 0805/ X7R/10%
24	1	C402	Cap 100nF/ 50V/ 603/ X7R/10%

No.	Quantity	Designator	Description
25	1	C407	Cap 100pF/ 100V/ 0603/ C0G/2%
26	2	CB100, CB102	Cap 470nF/ 630V/ 2220/ /10%
27	2	CB101, CB103	Cap 220nF/ 450V/ 1210/ /10%
28	1	CX100	Cap 330nF/ 275V/ Radial Type/ /10%
29	1	CY200	Cap 470pF/ / SMD/ /10%
30	1	D100	Dio PCB DB_BR-SMD/ / PCB/ /
31	3	D103, D105, D200	Dio 1N4148WS-7-F/ / SOD-323/ /
32	1	D106	Dio RS3JB-13-F/ / SMB/ /
33	1	D108	Dio MUR560J/ 600V/ SMD/ /
34	1	D201	Dio ES1JL/ 600V/ SMA/ /
35	1	D202	Pow ATL432LIBQDBZRQ1/ / SOT-23-3 (DBZ)/ /
36	1	D203	Dio 1N4148WX/ 100V/ SOD-323/ /
37	1	F100	Res 3.15A/ 63V/ THT/ /
38	1	J1	Con JL-1000-25-T/ / JP-THT-JL-1000-25-T/ /
39	2	JP100, R112	Res 0R/ 75V/ 0603/ /0%
40	1	JP200	Con HTSW-103-07-G-S/ / CON-THT-2.54-3-1-8.38/ /
41	1	LC100	Ind 12mH/ / THT/ /30%
42	2	LD100, LD101	Ind 60uH/ / THT/ /20%
44	1	P1	Con/ / HDR1X7H/ /7 pin 90 deg. 2.54 mm
45	1	P2	Con/ / HDR1X5H/ /5 pin 90 deg. 2.54 mm
46	1	Q200	Tra 2N7002/ / PG-SOT23/ /
47	1	Q201	Tra BSS84P/ / PG-SOT23/ /
48	1	Q300	IGI65D1414A3M/ / IFX-SMD-IGI65D1414A3M/ /
49	1	Q400	Tra BSC034N10LS5/ / PG-TDSON-8-7/ /
50	1	R100	Res 24k/ 200V/ 1206/ /1%
51	1	R101	Res 27k/ 200V/ 1206/ /1%
52	2	R102, R132	Res 0R/ 200V/ 1206/ /0%
53	1	R103	Res 10k/ 150V/ 0805/ /1%
54	1	R104	Res 22k/ 75V/ 0603/ /1%
55	1	R106	Res 51R/ 75V/ 0603/ /1%
56	1	R107	Res 4.3k/ 75V/ 0603/ /1%
57	2	R108, R216	Res 2k/ 75V/ 0603/ /1%
58	1	R111	Res 1k/ 75V/ 0603/ /1%
59	3	R131, R229, R230	Res 100k/ 75V/ 0603/ /1%
60	1	R200	Res 750k/ 75V/ 0603/ /1%
61	1	R201	Res 150k/ 75V/ 0603/ /1%
62	2	R202, R203	Res 10MEG/ 200V/ 1206/ /1%
63	1	R204	Res 6.8k/ 75V/ 0603/ /1%
64	1	R205	Res 18.7k/ 75V/ 0603/ /1%

No.	Quantity	Designator	Description
65	8	R206, R218, R224, R226, R231, R236, R237, R238	Res 0R/ 75V/ 0603, [NoValue]/ /0%, 0R
66	1	R209	Res 3.3R/ 200V/ 1206/ /1%
67	1	R210	Res 1k/ 75V/ 0603/ /1%
68	2	R211, R213	Res 330mR/ 675V/ 1206/ /1%
69	1	R214	Res 4.7MEG/ 400V/ SMD/ /5%
70	1	R215	Res 100R/ 150V/ 0805/ /1%
71	1	R217	Res 8.2k/ 75V/ 0603/ /1%
72	1	R219	Res 4.7k/ 75V/ 0603/ /1%
73	1	R220	Res 1k/ 75V/ 0603/ /1%
74	2	R221, R239	Res 120k/ 75V/ 0603/ /1%
75	1	R222	Res 240k/ 75V/ 0603/ /1%
76	1	R228	Res 10R/ 75V/ 0603/ /1%
77	2	R302, R304	Res 1.5k/ 50V/ 0603/ /1%
78	2	R303, R305	Res 39R/ 75V/ 0603/ /1%
79	2	R306, R307	Res 22k/ 75V/ 0603/ /1%
80	1	R401	Res 5.1R/ 150V/ 0805/ /1%
81	1	R403	Res 220k/ 150V/ 0805/ /1%
82	1	R404	Res 510R/ 150V/ 0805/ /1%
83	1	R405	Res 10k/ 75V/ 0603/ /1%
84	1	RV100	Res TVS 275VAC/ 275Vac/ VARRR500W60L900T440H1100B/ /
85	1	T100	180 µH; 46:9/ / TR_070-5680 - MH1-only - Pin7-9-10-12/ /
86	1	T200	Tra PS22109/ / EQ2513CE/ /
87	1	U100	GSD1623-N1/ / GSD1623-N1/ /
88	1	U200	XDPS2221E/ / SOIC127P600X175-14N-1/ /
89	1	U201	Int TCLT1003/ / SMD/ /
90	1	U400	Int MP6951GJ-P/ / TSOT23-6/ /

Table 10 Active bridge board BOM

No.	Quantity	Designator	Description
1	2	C107, C108	Cap 220nF/ 50V/ 0603/ X7R/10%
2	1	C110	Cap 2.2uF/ 50V/ 805/ X7R/10%
3	1	C112	Cap 2.2uF/ 50V/ 603/ X5R/10%
4	1	D102	Dio 75V/ / SOD-323/ /
5	4	Q100, Q101, Q102, Q103	Tra IPL60R085P7/ / PG-VSON-4-1/ /
6	4	R102, R103, R105, R106	Res 2.21R/ 75V/ 0603/ /1%

No.	Quantity	Designator	Description
7	2	R108, R110	Res 0R/ 50V/ 0603/ /1%
8	1	R113	Res 180k/ 75V/ 0603/ /1%
9	1	U100	TEA2209T/1J/ / SOIC127P600X175-16N-10/ /

Table 11 VCC board BOM

No.	Quantity	Designator	Description
1	4	C500, C501, C504, C505	Cap 470nF/ 100V/ 1206/ X7R/10%
2	4	C502, C506, C507, C508	Cap 4.7uF/ 100V/ 1206 (3216)/ /10%
3	1	C503	Cap 1uF/ 50V/ 0805/ X5R/10%
4	2	D500, D501	Dio SS28L/ 80V/2A/ SOD-123F-2/ /
5	2	D502, D503	Dio PMEG4010BEA,115/ / SMD/ /
6	1	Q500	Tra BSS169/ / PG-SOT23/ /
7	2	R500, R505	Res 6.8R/ 200V/ 1206/ /1%
8	2	R501, R506	Res 0R/ 200V/ 1206/ /1%
9	1	R504	Res 47k/ 75V/ 0603/ /1%
10	1	X500	Con 10129379-906003BLF/ / THT/ /
11	1	Z500	Dio 10V/ 10V/ SOD-123/ /

Table 12 Output base board BOM

No.	Quantity	Designator	Description
1	3	C1, C2, C3	Cap 100µF 25V SMD/ / CAP_ALUM6.3X6.6X6.6X8N/ /
2	4	C10, C11, C12, C13	Cap 10µF 50V 1206/ / 1206_C/ /
3	1	C360	Cap 1uF/ 100V/ 0805/ /10%
4	1	C361	Cap 100nF/ 100V/ 0603/ X7R/10%
5	2	C362, C363	Cap 100nF/ 50V/ 0603/ X8L/10%
6	1	C364	Cap 10uF/ 16V/ 0805/ X5R/10%
7	1	C365	Cap 22uF/ 16V/ 0805/ X5R/20%
8	2	C369, C370	Cap 10uF/ 35V/ THT/Radial/ /20%
9	1	C371	Cap 33pF/ 50V/ 0603/ C0G/5%
10	1	FB360	Ind 120R/ / 0805/ /25%
11	1	J2	Con 7pin, 2,54mm, 90°/ / THT/ /
12	1	J3	Con 5pin, 2,54mm, 90°/ / THT/ /
13	1	L2	220nH/ / XGL6060/ /
14	1	L360	Ind 22uH/ / SMD/ /20%
15	2	Q1, Q2	Tra 2N7002 60V 300MA SOT23-3/ / SOT23-3/ /

No.	Quantity	Designator	Description
16	4	R1, R5, R20, R21	Res 10KΩ 0603/ / 0603_R/ /
17	1	R7	Res 30KΩ 0603/ / 0603_R/ /
18	1	R9	Res 16.5KΩ1/10W 0603/ / 0603_R/ /
19	1	R10	Res 82KΩ 1/10W 0603/ / 0603_R/ /
20	2	R11, R14	Res 100Ω 1/5W 0603/ / 0603_R/ /
21	2	R12, R13	Res 5.1KΩ 1/10W 0603/ / 0603_R/ /
22	2	R15, R16	Res 100KΩ 1/10W 0603/ / 0603_R/ /
23	1	R369	Res 100k/ 75V/ 0603/ /1%
24	1	R370	Res 18.7k/ 75V/ 0603/ /1%
25	1	R371	Res 120k/ 75V/ 0603/ /1%
26	1	R372	Res 51k/ 75V/ 0603/ /1%
27	1	R373	Res 150k/ 75V/ 0603/ /1%
28	1	R374	Res 2k/ 75V/ 0603/ /1%
29	1	SGND	Con 5001/ / CON-THT-TP-5001/ /BLACK
30	1	U360	Pow IC Buck LMR51610XDBVR/ / SOT-23-6 (DBV)/ /
31	1	VIN_DC	Con 5000 / / CON-THT-TP-5001/ /RED

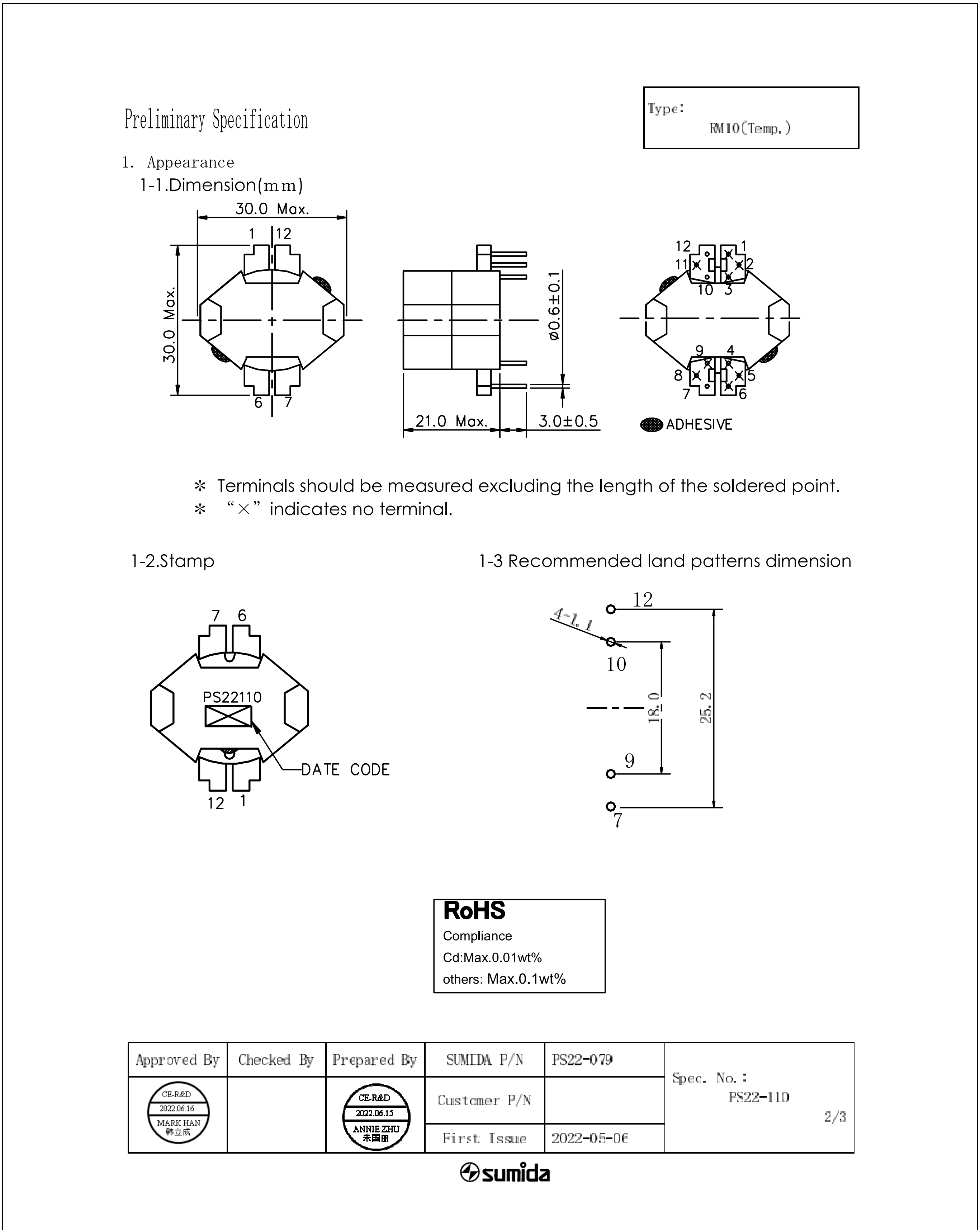
Table 13 USB PD board BOM for one piece

No.	Quantity	Designator	Description
1	1	C1	Cap 10µF 10V 0805/ / 0805_C/ /
2	3	C2, C3, C9	Cap 0.1µF 25V 0402/ / 0402_C/ /
3	1	C4	Cap 1000PF 50V 0402/ / 0402_C/ /
4	2	C5, C15	Cap 0.1µF 50V 0402/ / 0402_C/ /
5	1	C6	Cap 1µF 50V 0805/ / 0805_C/ /
6	1	C8	Cap 1µF 10V 0402/ / 0402_C/ /
7	4	C10, C11, C12, C13	Cap 390PF 50V 0402/ / 0402_C/ /
8	3	C14, C22, C28	Cap 0.1µF 50V 0603/ / 0603_C/ /
9	1	C16	Cap 0.1UF 50V 0402/ / 0402_C/ /
10	1	C17	Cap 1000PF 16V 0402/ / 0402_C/ /
11	1	C18	Cap 0.22µF 16V 0402/ / 0402_C/ /
12	2	C19, C30	Cap 4.7µF 50V 0805/ / 0805_C/ /
13	3	C20, C21, C24	Cap 10µF 50V 1206/ / 1206_C/ /
14	1	C29	Cap 1µF 35V 0603/ / 0603_C/ /
15	1	D1	Dio RB510SM-40FH 40V 100MA / / SOD-523/ /
16	1	D3	Dio NSR0340V2T5G 40V 250MA SOD523/ / SODFL1608X70N/ /
17	1	EC1	Cap 270µF 25V 8 x 9.5 mm T/H/ / CAPAD350W60L900D800B/ /
18	1	J1	Con USB3.1 TYPEC 24P SMD RA/ / MOLEX_2012670005/ /

No.	Quantity	Designator	Description
19	1	J2	Con HEADER R/A 5POS 1.27MM/ / HEADER R/A 5POS 1.27MM/ /
20	1	L1	Ind 6.8 µH/ / WE-XHMI-8080/ /
21	3	Q1, Q2, Q3	MOSFET N-CH 40V 15A/40A/ / BSZ063N04LS6/ /
22	1	R1	Res 4.02KΩ 0402/ / 0402_R/ /
23	5	R3, R14, R15, R16, R19	Res 0E 0603/ / 0603_R/ /
24	2	R4, R6	Res 2Ω 0402/ / 0402_R/ /
25	2	R5, R7	Res 10Ω 0402/ / 0402_R/ /
26	1	R9	Res 2.21K Ω 0402/ / 0402_R/ /
27	1	R11	Res 5 mOhms 1206/ / SUSUMU-KRL3216/ /
28	1	R12	Res 5 mOhms 0805/ / SUSUMU-KRL2012/ /
29	1	R20	Res 910KΩ 0402/ / 0402_R/ /
30	1	RT1	RT 100KΩ 0603/ / 0603_R/ /
31	4	TVS1, TVS2, TVS4, TVS5	Dio ESD245B1W0201E6327XTSA1/ / DFN58X28X16-2N/ /
32	1	TVS3	Dio TVS ESD239B1W0201E6327XTSA1 / / DFN58X28X16-2N/ /
33	1	U1	PD IC CYPD7171-40LQXQ CCG7SC/ / QFN50P600X600X60-41N/

4.2 Information on the magnetic devices

This section presents the information about the PFC choke and the HFB transformer. Figure 29 and Figure 30 shows the PFC choke specification sheet, while Figure 31 and Figure 32 illustrates the specification sheet of the transformer. Both the choke and transformer are built using RM10 cores with 3C95 ferrite material and standard bobbins with some pins trimmed/removed. The air gap in the center leg of the cores is adjusted in such way that the main inductance for the PFC choke is 190 µH and the primary inductance of the hybrid-flyback transformer is 230 µH. Both magnetic devices are varnished, and the transformer is connected to PGND. The transformer has a copper band for shielding, wrapped around and covering the windings and core legs.



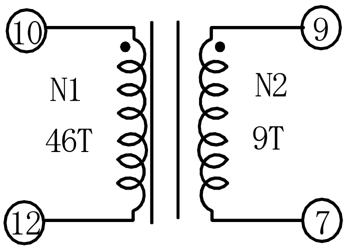
Approved By	Checked By	Prepared By	SUMIDA P/N	PS22-079	Spec. No.: PS22-110 2/3
CE-R&D 2022.06.16 MARK HAN 韩立成		CE-R&D 2022.06.15 ANNIE ZHU 朱国丽	Custmer P/N		
			First Issue	2022-05-06	

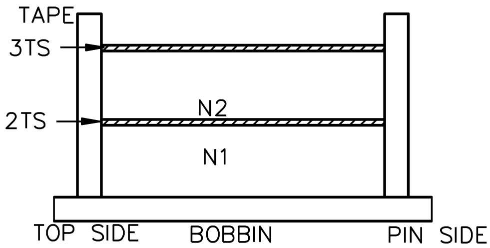
Figure 29 PFC choke specification part 1

Preliminary Specification

Type:
RM10 (Temp.)

2.Coil specification
2-1.Electric schematic





" ● "indicates winding polarity.

2-2.Electrical characteristic (at 25℃, unless of otherwise specified)

Items		Specification	Measuring conditions
Inductance	(10-12)	190μH±10% Within	100kHz/0.1V
L0(-30%)	(10-12)	8.5A	100kHz ,0.1V
RMS	(10-12)	2.9A	△T=40℃
Turns ratio	(10,12) : (9,7)	46:9 ±3%	

3.Remarks
* Operating temperature:-40℃～+85℃(Including coil self temperature rising).
* Storage temperature:-40℃～+85℃.

Note :	Spec. No. : PS22-110 3/3

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Figure 30 PFC choke specification part 2

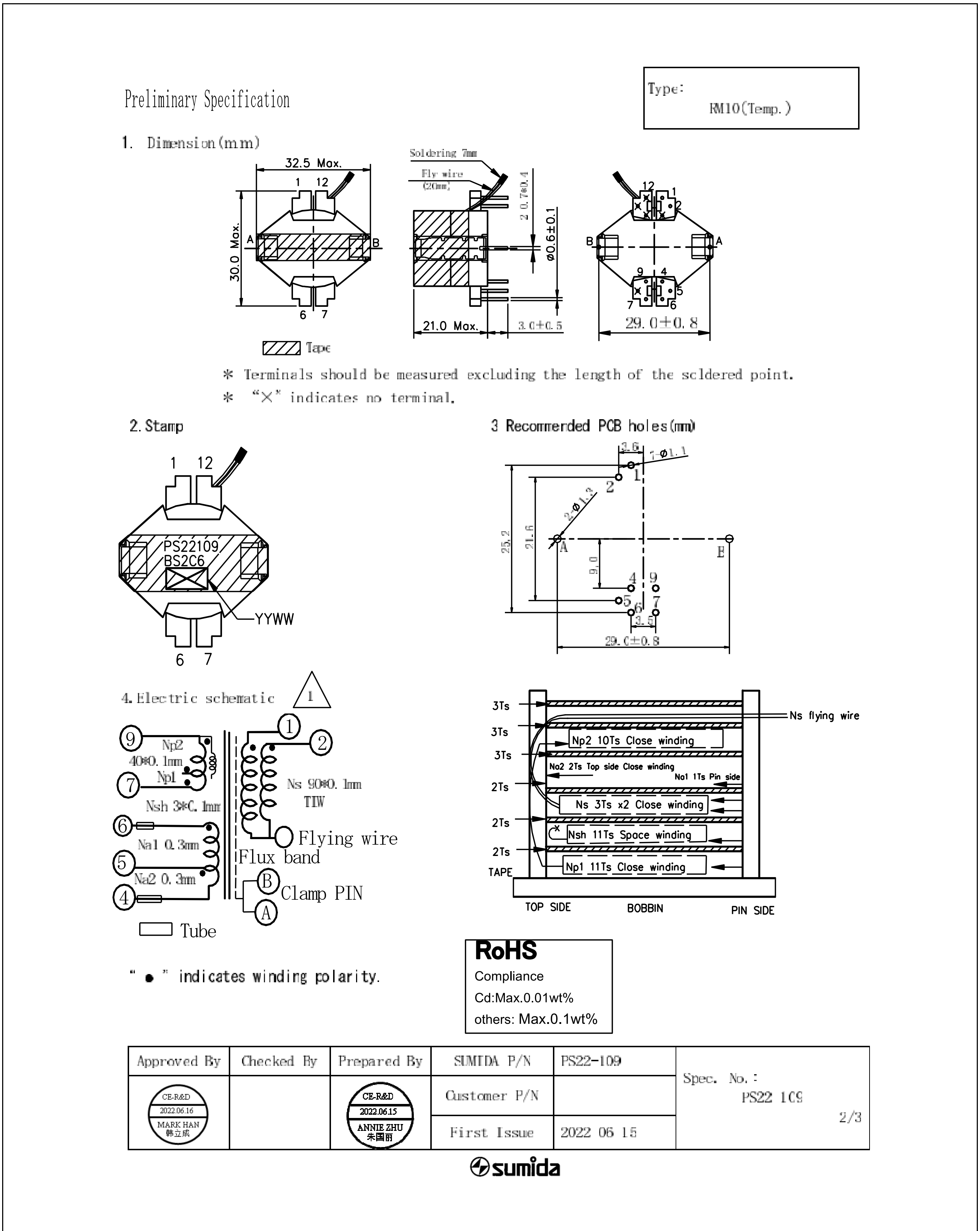

Figure 31 HFB transformer specification part 1

Preliminary Specification

Type: RM10 (Temp.)

5.Electrical characteristic (at 25℃, unless of otherwise specified)

Items	Specification	Measuring conditions
Inductance (9-7)	230 μH±10% Within	150kHz/0.1V CA
Inductance drop (9 7)	≦35% I0	150kHz, 0.1V 3.4A
Rated current (9 7)	1.4Arms	△T=40℃
Rated current (1,2-Fly)	8.3Arms	△T=40℃
Hi-Pot (9,7,6,5,4) - (1,2,Fly)	AC 3000Vrms	50/60Hz, 1mA, 2s
Hi Pot Coil Core	AC 500Vrms	50/60Hz, 1mA, 2s
Hi-Pot (9,7) - (6,5,4)	AC 500Vrms	50/60Hz, 1mA, 2s
Turn ration (Np:Ns:Na1:Na2)	21:3:1:2 ±3%	

6. The materials according to OBJY2 E176884 system designation 130(B) BS2, SBI4.2.

No.	Part name		Material description	Manufacture Factory	UL File No.
①	Bobbin		Phenolic resin PM9630 or PM9820	SUMIMOTO BAKELITE CO., LTD	E41429
②	Core		Ferrite Core 3C95 or TPW33 or HE6	FERROXCUBE TDG HOLDING CO.,LTD HEC	N/A
③	wire	TIW	F&B XXXB (φ0.1*90 Triple insulated Litz wire)	F&B TECHNOLOGY CO LTD	E315265
		Litzwire	(φ0.10*40) MW75C or MW 79 C	EASEBOND ELECTRICAL MATERIAL(DONGGUAN) CO.,LTD HAIYIN YIZHI CHANGTONG SUPER MICRO. WIRE CO.,LTD	E173779 E263385
		Enameled copper wire	MW 79 C or MW 80-C or MW 82 C or MW 83 C	JUNG SHING WIRE CO.,LTD. TAI-I COPPER(GUANGZHOU) CO.,LTD SAINT(SHANGDONG) ELECTRIC CO.,LTD	E174837 E234896 E194410
④	Clip		Material SK7	FIN SGINE ELECTRIC CO.,LTD or etc.	N/A
⑤	Terminal		Phosphor bronze	Various	N/A
⑥	Glue		Epoxy	NAGASE CHEMTEX CORPRATION	N/A
⑦	Interlamination insulation tape		1318 or CT280 or CT281	3M COMPANY HUIZHOU YAHUA STICKING TAPE CO.,LTD	E17385 E495875
⑧	Copper foil tape		Adhesive copper tape CP 3002	JINGJIANG YAHUA PRESSURE SENSITIVE GLUE CO.,LTD	E165111
⑨	Tubing		CB-TT-L	CHANGYUAN ELECTRONICS GROUP CO LTD	E180908

7. Remarks

＊ Operating temperature:-40℃～+125℃(Including coil self temperature rising).

＊ Storage temperature: 40℃～+125℃.

Note :	Spec. No. : PS22 109
	3/3

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Figure 32 **HFB transformer specification part 2**

References

[1] Infineon Technologies AG: *120 W high-efficient USB-C PD adapter using EZ-PD™ CCG7SC: REF_CCG7SC_120W_3C,* Product page; Available online

[2] Infineon Technologies AG: *XDPS2221E PFC + Hybrid-flyback combo controller,* Datasheet*;* Available online

[3] Infineon Technologies AG: *Highly Integrated USB PD and DC-DC controller for single and multiport charging applications*, Product page; Available online

[4] Infineon Technologies AG: *140 W reference board for ultra-high power density in USB-C chargers with EPR and adapters: REF_XDPS2221_140W1*; Product page; Available online

Revision history

Document revision	Date	Description of changes
V 1.0	2025-03-03	Initial release

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