250 W AC-DC converter reference design for micromobility applications

Using XDP™ XDPS2221E hybrid-flyback combo controller

About this document

Scope and purpose

This document is an engineering report for a 250 W AC-DC converter reference design which uses Infineon's XDP™ XDPS2221E digital power hybrid-flyback (HFB) combo controller. The XDP™ XDPS2221E PWM combines multimode AC-DC PFC and DC-DC hybrid-flyback controllers, ideal for wide output voltage range designs. The integration of PFC and hybrid-flyback into a single package optimizes the system performance by harmonized operation of the two stages and reduces the external bill of material components.

The converter has an extraordinary high peak efficiency of over 95% and two control inputs that define the setpoints for the constant current (CC) and constant voltage (CV) regulation loops. Therefore, it is a perfect match for battery charging applications in combination with a safety switch and charging controller. It is also suitable for use in general switching mode power supply (SMPS) applications. A universal input voltage range ensures combability to different residential voltages across the world.

The hybrid-flyback topology enables an small transformer size, comparable to resonant half-bridge and much smaller than standard flyback topologies. Unlike resonant topologies the transformer construction is as simple as that of a standard flyback, without the need to minimize leakage inductance. By utilizing only consumer grade silicon-based switches, thepresented solution achieves a great balance of cost and performance which results in a competitive system cost.

This document contains information regarding the design features and test setup, board specifications, board design data, performance data, and bill of materials (BOM) including transformer specifications.

Intended audience

The intended audiences for this document are design engineers, technicians, and developers of electronic systems.

V 1.0
2025-07-07

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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 VDC. 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 heat sink 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 electrostatic 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 as well as 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 battery chargers as presented in this reference design. For detailed information about this control IC, see the datasheet [1].

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
- 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

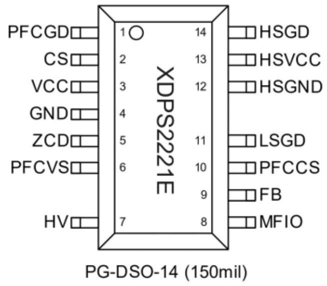


Figure 1 XDP™ XDPS2221E pin configuration

Main customer benefits

1.5 Low bill of materials

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

1.6 High system performance

- High system efficiency
- High power density design
- Enable and disable control of PFC stage to guarantee low power consumption in no-load and light load conditions
- Good efficiency in tiny load conditions and low standby power

1.7 Unique controller in the market

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

1.8 Selected (system) control features

The following innovative features enable high system efficiency throughout all line, load, and battery voltage conditions:

- 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 output voltage ratio, ensuring optimum performance and high system efficiency

2 Board specifications

Table 1 Input and output specifications

Description	Symbol	Value	Unit
Input voltage range	V_{in}	90 to 264	V AC
Input frequency range	f_{in}	50 to 60	Hz
CC_{set} range (see Figure 6)	CC_{set}	0 to 3.3	V DC
CV_{set} range (see Figure 7)	CV_{set}	0 to 3.3	V DC
Output voltage range	V_{out}	18 to 55	V DC
Nominal output current	I_{outnom}	5.0	A
High mains peak efficiency at full output power (V_{in} = 230 V AC; V_{out} = 50 V; I_{out} = 5.0 A)	$\eta_{HM,peak}$	95.5	%
Average efficiency at high line (V_{in} = 230 V AC; V_{out} = 50 V)	$\eta_{HM,avg}$	94.1	%
Low mains peak efficiency at full output power (V_{in} = 115 V AC; V_{out} = 50 V; I_{out} = 5.0 A)	$\eta_{LM,peak}$	93.9	%
Average efficiency at low line (V_{in} = 115 V AC; V_{out} = 50 V)	$\eta_{LM,avg}$	93.1	%

Table 2 highlights the key components and board dimensions of the reference board.

Table 2 Reference board key components and dimensions

Item	Component
HFB combo controller IC	XDPS2221E
PFC-stage	IPA60R060P7
Half-bridge	IPAN60R180CM8
SR-stage	ISC073N12LM6
Others	BSS169, 2N7002
PCB dimensions (L x W x H)	237 mm x 50 mm x 27 mm

3 Test setup and safety instructions

This AC-DC reference design includes the hybrid-flyback (HFB) stage with Infineon's XDP™ XDPS2221E digital combo power hybrid-flyback controller and the output regulation circuit (CC-control and CV-control feature). A programming interface gives access to the XDPS2221E for parameter configuration and failure mode reporting, see also [1].

The reference design comes with different assembly features to customize it to address different preferences:

- Optional CoolSET™ daughterboard slot
- Active or passive secondary side rectification with heatsink space
- Multiple capacitor style options (MLCC in SMD style, leaded MLCC or film capacitor) for resonant circuit and VCC charge pump circuit
- Additional X-capacitor assembly option for line filter adjustments

The design has a reserved slot for an optional CoolSET™ daughterboard including a QR flyback stage with Infineon's ICE5AR4770AG flyback controller and provides an independent constant 5 V auxiliary supply for the secondary side. This daughterboard is not included in the reference design but can be requested separately. More details can be found in the report of the 170 W reference design [3].

To implement a battery charger with this reference design, a battery safety switch must be connected in order to guarantee safe operation.

Attention: ***For safety reasons, it is prohibited to connect this reference design board to any battery without adding the battery safety switch externally.***

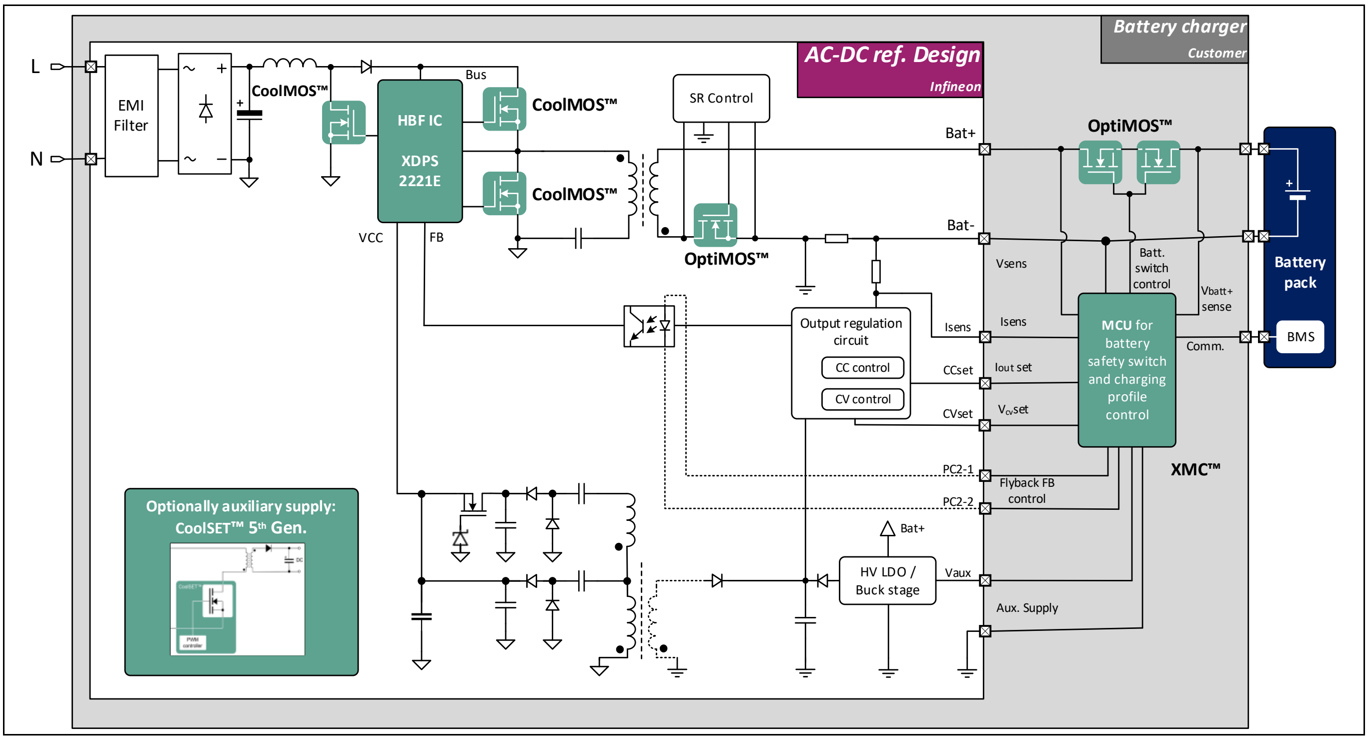


Figure 2 Test setup of AC-DC reference design with external battery

3.1 CC-mode test setup

The charging behavior test has been performed with the following test setup.

Attention: ***Lethal voltages are present on this reference design. Do not operate the board unless you are trained to handle high-voltage circuits. Do not leave this board unattended when it is powered up.***

In order to set the desired charging current and the voltage the CC_{set} and CV_{set} value is controlled via an external DC source, according to Figure 5 and Figure 6. An electronic load in CV mode is used to evaluate the board performance. The board needs either to start up with applied load to operate in CC-mode or can be driven out of the CV-mode into CC-mode during operation, see a) of below's test procedure description.

Test procedure

1. Connect AC source to L and N (state: off)
2. Connect a DC load in CV-mode to the battery interface X201, turn on load in range of V_{out} 18 V – 55 V
3. Connect CV_{set} and CC_{set} signals from the control interface X200 to 2 separate channels of an DC source (common GNDS)
4. Set the CV_{set} signal to high (3.3 V) to avoid CV loop overtake when V_{out} crosses the set value
5. Set the CC_{set} signal to the desired charging current in range of I_{out} 0.5 A – 5 A, see Figure 5
6. Before turning on the AC-source, make sure the CV_{set} and CC_{set} signal is already applied and the load is turned on. Now turn on the AC source to power up the board in Vin range 90 Vac – 264 Vac
7. After the board has powered up, change CC_{set} according to your needs in range of I_{out} 0.5 A – 5 A. Please be aware, if you turn off the DC load in CV-mode during operation, the CV-loop gets active and Vout changes to the set value by CV_{set}
   a) In case you want to transition from the CC-mode to the CV-mode, lower the CV_{set} signal close to the actual output voltage V_{out} and turn off the DC load. Now the board operates in CV-loop and you change the mode of the DC load to CC mode with a set CC voltage in range of I_{out} 0.5 A – 5 A

Note: *The CC_{set} signal needs to be higher than the set current of the DC load to avoid overtaking from the CC-loop. You may turn on the load.*

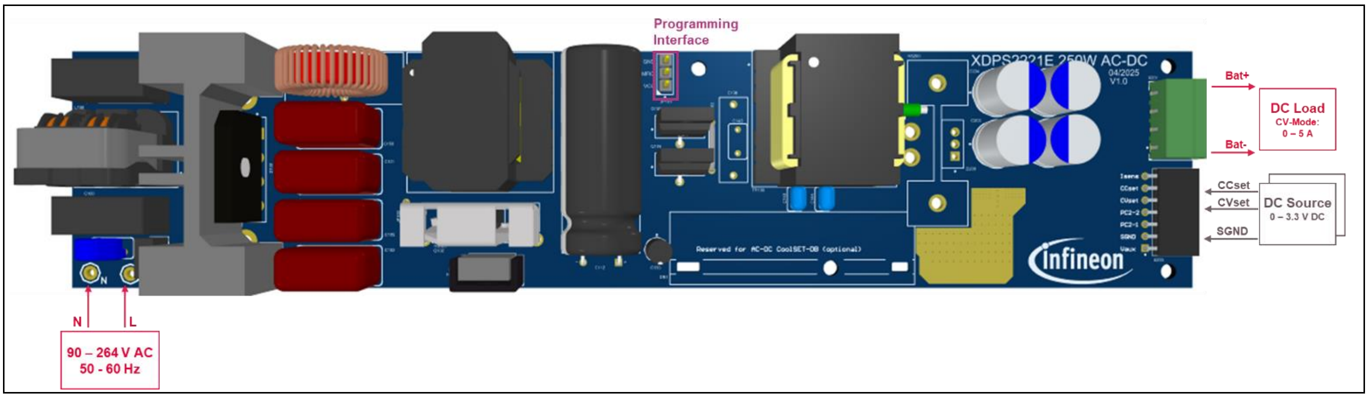


Figure 3 **CC-mode test setup with electronic load and settings via DC source**

3.2 CV-mode test setup

All mentioned measurements except of charging behavior have been performed with the following test setups.

Attention: ***Lethal voltages are present on this reference design. Do not operate the board unless you are trained to handle high-voltage circuits. Do not leave this board unattended when it is powered up.***

In order to set the desired charging current and the voltage the CC_{set} and CV_{set} value is controlled via an external DC source, according to Figure 5 and Figure 6. An electronic load in CC mode is used to evaluate the board performance.

Test procedure

1. Connect AC source to L and N (state: off)
2. Connect a DC load in CC-mode to the battery interface X201 (state: off)
3. Connect CV_{set} and CC_{set} signals from the control interface X200 to 2 separate channels of an DC source (common GNDS)
4. Set the CC_{set} signal to high / (3.3 V – 5 V) to avoid CC loop overtake when I_{out} crosses the set value
5. Set the CV_{set} signal to the desired output voltage in range of V_{out} 18 V – 55 V, see Figure 6
6. Before turning on the AC-source, make sure the CV_{set} and CC_{set} signal is already applied. Now turn on the AC source to power up the board in Vin range 90 Vac – 264 Vac
7. After the boards has powered up to the set V_{out}, you may turn on DC load in range of I_{out} (0.5 A – 5 A)
   a) In case you want to transition from the CV-mode to the CC-mode, change the CC_{set} signal to the desired charging current and the DC load mode to CV mode with a set CV voltage close to the actual $V_{out.}$ Note that the CV_{set} signal needs to be higher than the set voltage of the DC load to avoid overtaking from the CV-loop

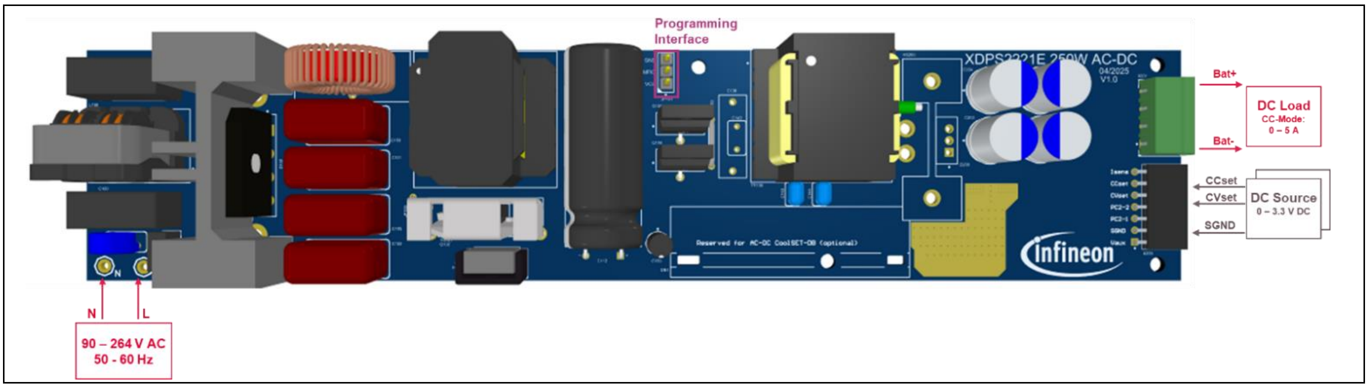


Figure 4 **CV-mode test setup with electronic load and settings via DC source**

3.3 SMPS-mode test setup

Constant Voltage (CV) mode is the typcial operating mode in Switch-Mode Power Supplies (SMPS) that is widely used in various applications. In CV mode, the SMPS regulates the output voltage to a fixed value, ensuring a stable and consistent voltage supply to the load.

Attention: ***Lethal voltages are present on this reference design. Do not operate the board unless you are trained to handle high-voltage circuits. Do not leave this board unattended when it is powered up.***

In case you want to evaluate the reference design for general SMPS application it is recommended to operate the board exclusively in CV-mode and disable the CC-mode with the following steps.

Assembly changes

1. Remove Diode D202 to disable CC-loop
   Set desired output voltage via the voltage divider R229+R230 / R231 | R233 to match the reference voltage of V_{ref} =3.0 V for the comparator according to formula, default V_{outmax} = 55 V

$$V_{out} = 3.0V \frac{R229+R230+\left(\frac{R231*R233}{R231+R233}\right)}{\left(\frac{R231*R233}{R231+R233}\right)}$$

Equation 1

Attention: ***Please be aware that the HFB stage is optimized for maximum load at V_{OUT} = 50V while assembled components can handle a maximum voltage stress of V_{MAX} =63 V. You might need to perform further adjustments to optimize the system performance to the new set V_{OUT}.***

Test procedure

1. Connect AC source to L and N (state: off)
2. Connect a DC load in CC-mode to the battery interface X201 (state: off)
3. In case you want to vary the output voltage V_{out}, connect CV_{set} from the control interface X200 to an DC source (common GNDS), otherwise leave CV_{set} signal open
4. Set the CV_{set} signal to the desired output voltage, V_{ref} represents V_{out}
5. Leave the CC_{set} signal open
6. Before turning on the AC-source, make sure the CV_{set} signal is already applied if used. Now turn on the AC source to power up the board in Vin range 90 Vac – 264 Vac
7. After the boards has powered up to the set V_{out}, you may turn on DC load in range of I_{out} (0.5 A – 5 A)

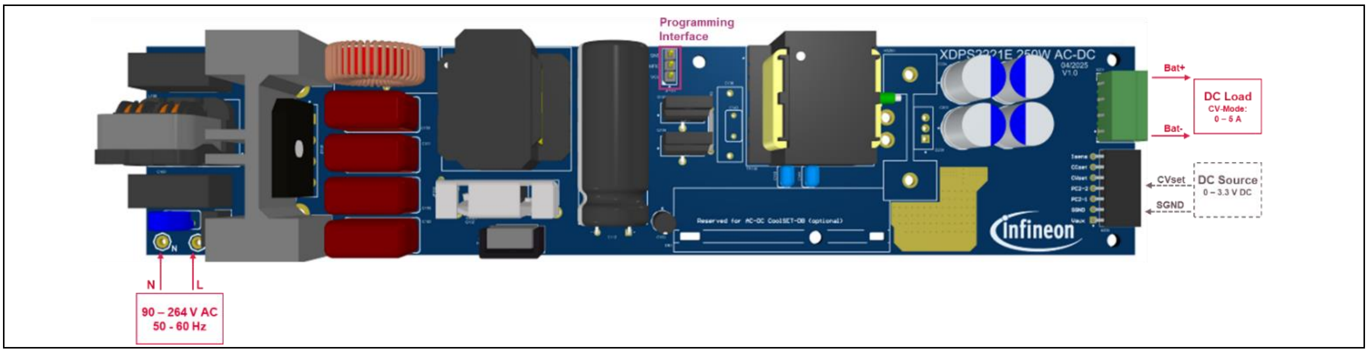


Figure 5 **SMPS-mode test setup with electronic load**

3.4 CC_{set} and CV_{set} control signals

Set the CC_{set} value via control interface connector Xout2, Pin 6 according to the desired charging current, as described in Figure 6. By default, the CC_{set} is not set internally and needs to be set from external DC supply.

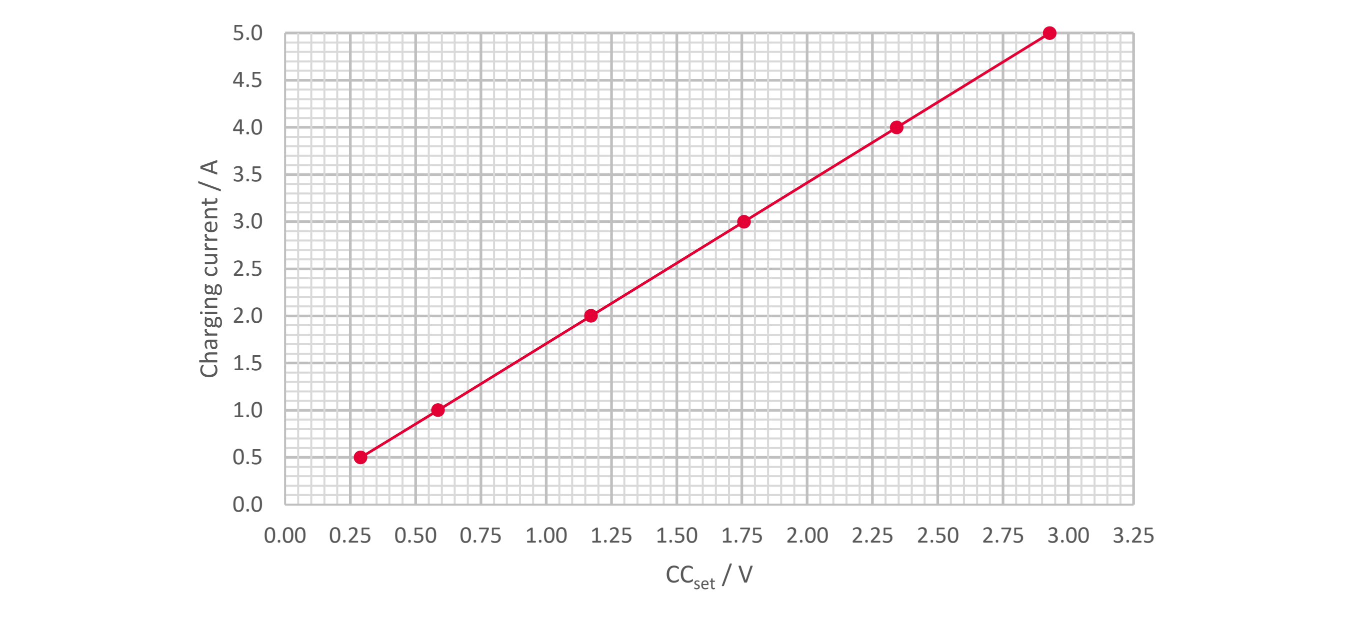


Figure 6 CC_{set} values for desired charging current

Set the CV_{set} value via control interface connector Xout2, Pin 5 according to the desired CV voltage, as described in Figure 7. By default, the CV_{set} value is set to 3.00 V via a resistor network, so the output voltage is set to the maximum value V_{outmax} = 55 V.

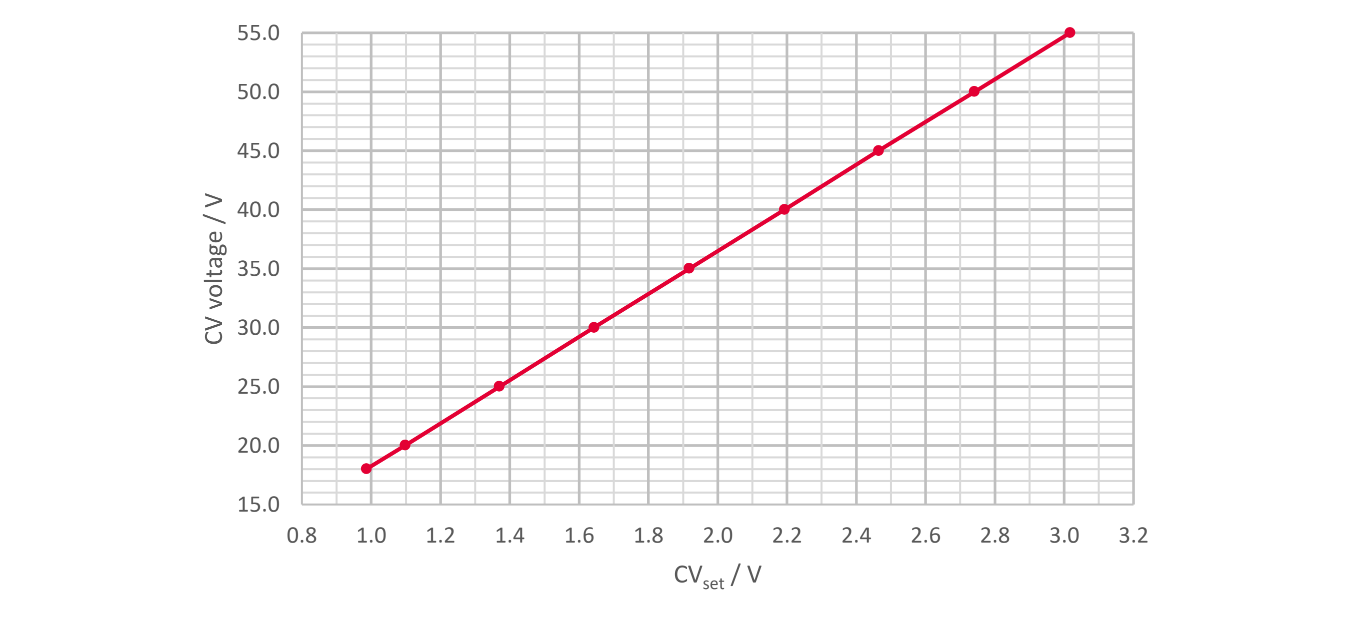


Figure 7 CV_{set} values for desired CV voltage

Note: The accuracy of the set charging current and CV voltage are depending on the tolerance of the shunt resistor of current sensing and resistor network of voltage sensing as well as the accuracy of the reference voltage.

4 Performance data

The performance data have been measured with the CV-mode test setup described in Figure 4.

4.1 System-efficiency and standby power

The system-efficiency was measured with different input voltage V_{in} across the whole universal input voltage range. The battery load was simulated via an electronic load in CV mode. The board was placed on a laboratory bench under free air convection.

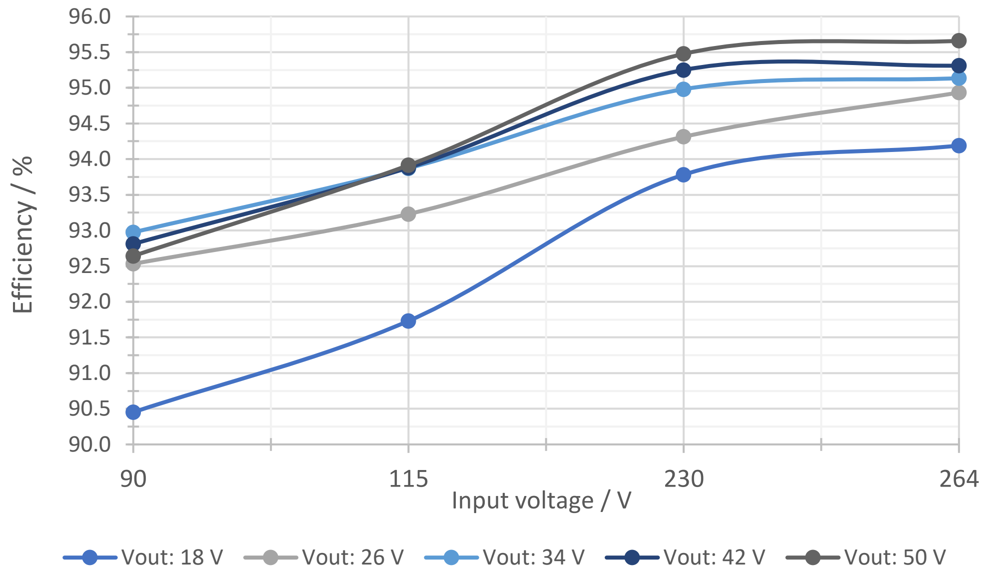


Figure 8 System-efficiency at different input voltages

Average efficiency at high line

The average efficiency was measured at different output voltages and loads at high mains with a nominal input voltage V_{in}: 230 V AC – see plot in Figure 9 and data's in Table 2.

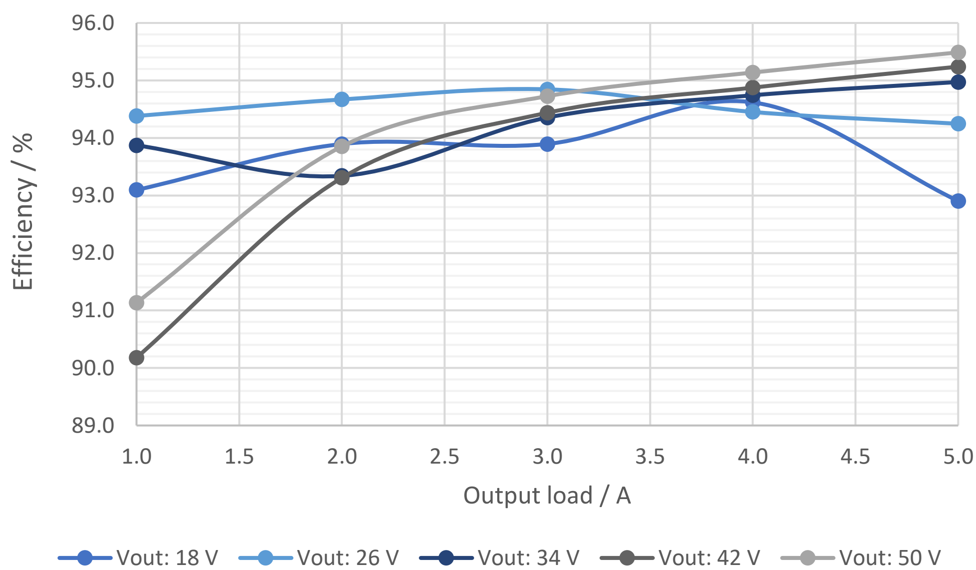


Figure 9 Average efficiency at different load levels and V_{in}: 230 V AC

Table 3 Average efficiency at high mains

V AC (V_{RMS})	Output load (V)	I_{out} (A)	I_{out} (%)	Efficiency	Average efficiency
230	18	1.00	20%	93.1	93.7
		2.00	40%	93.9	
		3.00	60%	93.9	
		4.00	80%	94.6	
		5.00	100%	92.9	
230	26	1.00	20%	93.9	94.4
		2.00	40%	94.4	
		3.00	60%	94.7	
		4.00	80%	94.8	
		5.00	100%	94.5	
230	34	1.00	20%	93.9	94.3
		2.00	40%	93.3	
		3.00	60%	94.4	
		4.00	80%	94.7	
		5.00	100%	95.0	
230	42	1.00	20%	90.2	93.6
		2.00	40%	93.3	
		3.00	60%	94.4	
		4.00	80%	94.9	
		5.00	100%	95.2	
230	**50**	1.00	20%	91.1	94.1
		2.00	40%	93.9	
		3.00	60%	94.7	
		4.00	80%	95.1	
		5.00	**100%**	**95.5**	

Average efficiency at low mains

Figure 10 illustrates the efficiency measurement results for different load levels in low mains case with a nominal input voltage V_{in}: 115 V AC – see plot in Figure 10 and data's in Table 4.

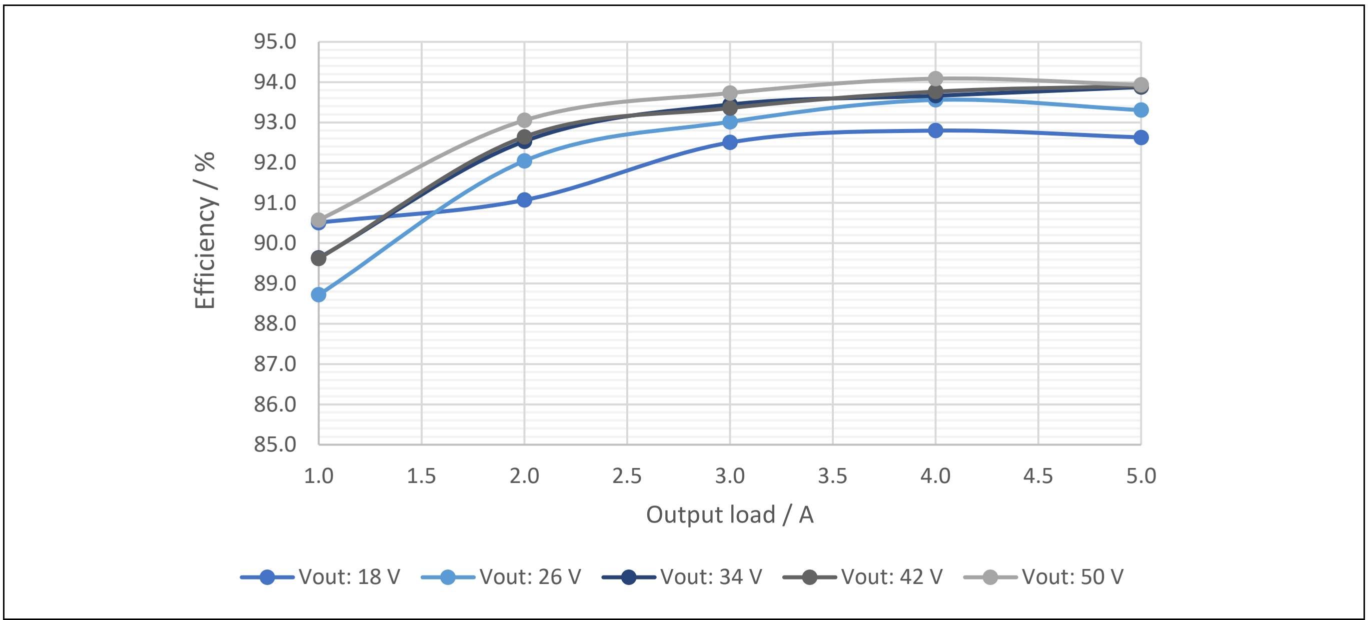


Figure 10 Average efficiency at different load levels and V_{in}: 115 V AC

Table 4 Average efficiency at low mains

V AC (V_{RMS})	Output load (V)	I_{out} (A)	I_{out} (%)	Efficiency	Average efficiency
115	18	1.00	20%	90.5	91.9
		2.00	40%	91.1	
		3.00	60%	92.5	
		4.00	80%	92.8	
		5.00	100%	92.6	
115	26	1.00	20%	88.7	92.1
		2.00	40%	92.0	
		3.00	60%	93.0	
		4.00	80%	93.6	
		5.00	100%	93.3	
115	34	1.00	20%	89.6	92.6
		2.00	40%	92.5	
		3.00	60%	93.4	
		4.00	80%	93.7	
		5.00	100%	93.9	
115	42	1.00	20%	89.6	92.7
		2.00	40%	92.6	
		3.00	60%	93.4	
		4.00	80%	93.8	

V AC (V_{RMS})	Output load (V)	I_{out} (A)	I_{out} (%)	Efficiency	Average efficiency
		5.00	100%	93.9	
115	50	1.00	20%	90.6	93.1
		2.00	40%	93.1	
		3.00	60%	93.7	
		4.00	80%	94.1	
		5.00	100%	93.9	

Standby input power

The standby input powered was measured while the operating in CV-mode (see 3.2) at different V_{out} without any load attached. Figure 11 shows the input power consumption under no-load condition across the input voltage range.

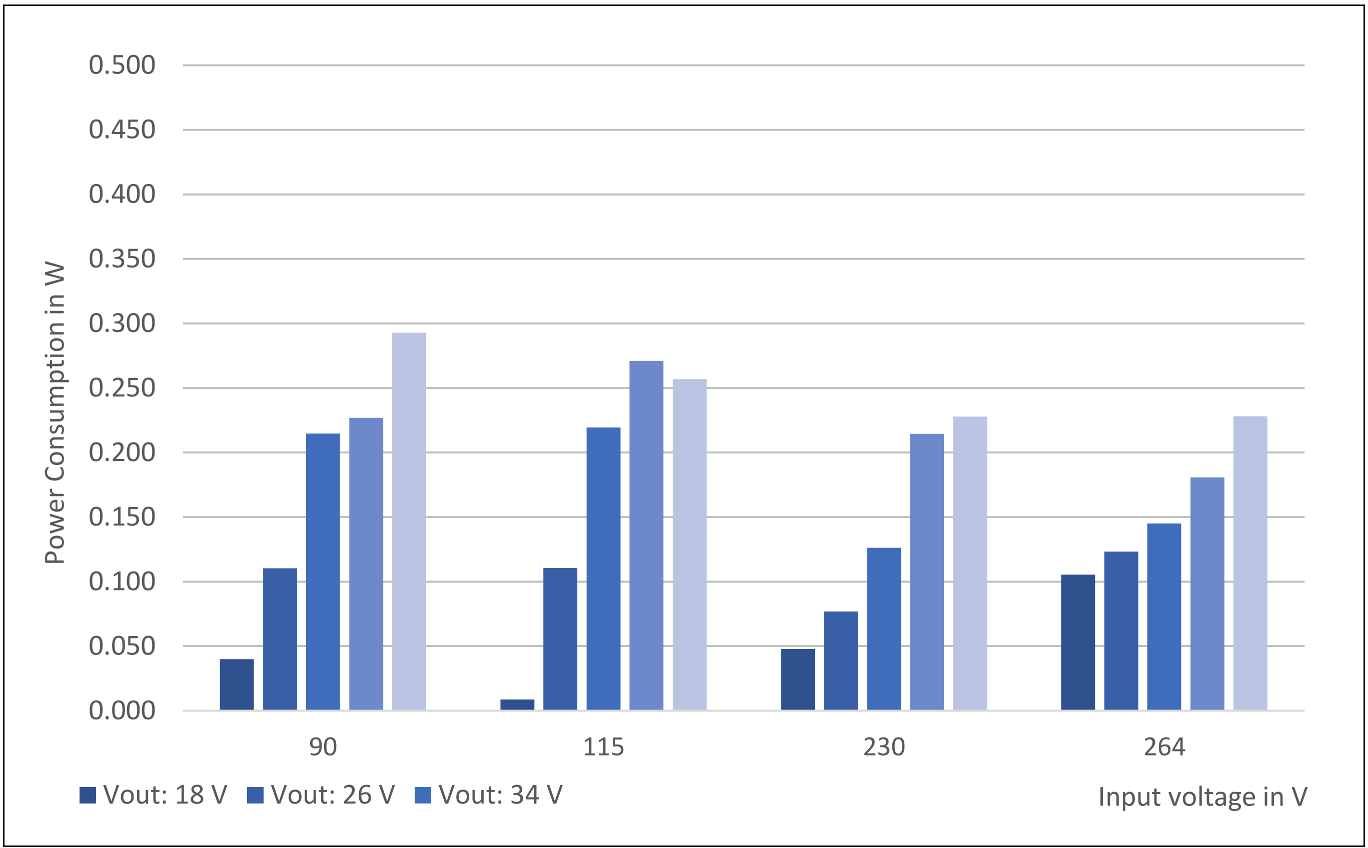


Figure 11 **Standby input power**

4.1 Charging behavior

4.1.1 Emulated 48 V battery pack

Figure 12 shows the measured system-efficiency to determine the average efficiency while charging a 48 V battery pack with default CV setting (CV_{set} ~ 3.0 V) and external CC setting to 5.0 A (CC_{set} ~ 3.0 V) for nominal charging current. At V_{outmax} of 55 V, CV control takes over and limits the battery voltage accordingly. The battery pack was emulated via an electronic DC-load operating in CV-mode, sweeping across the cell voltages with respect to the state of charge.

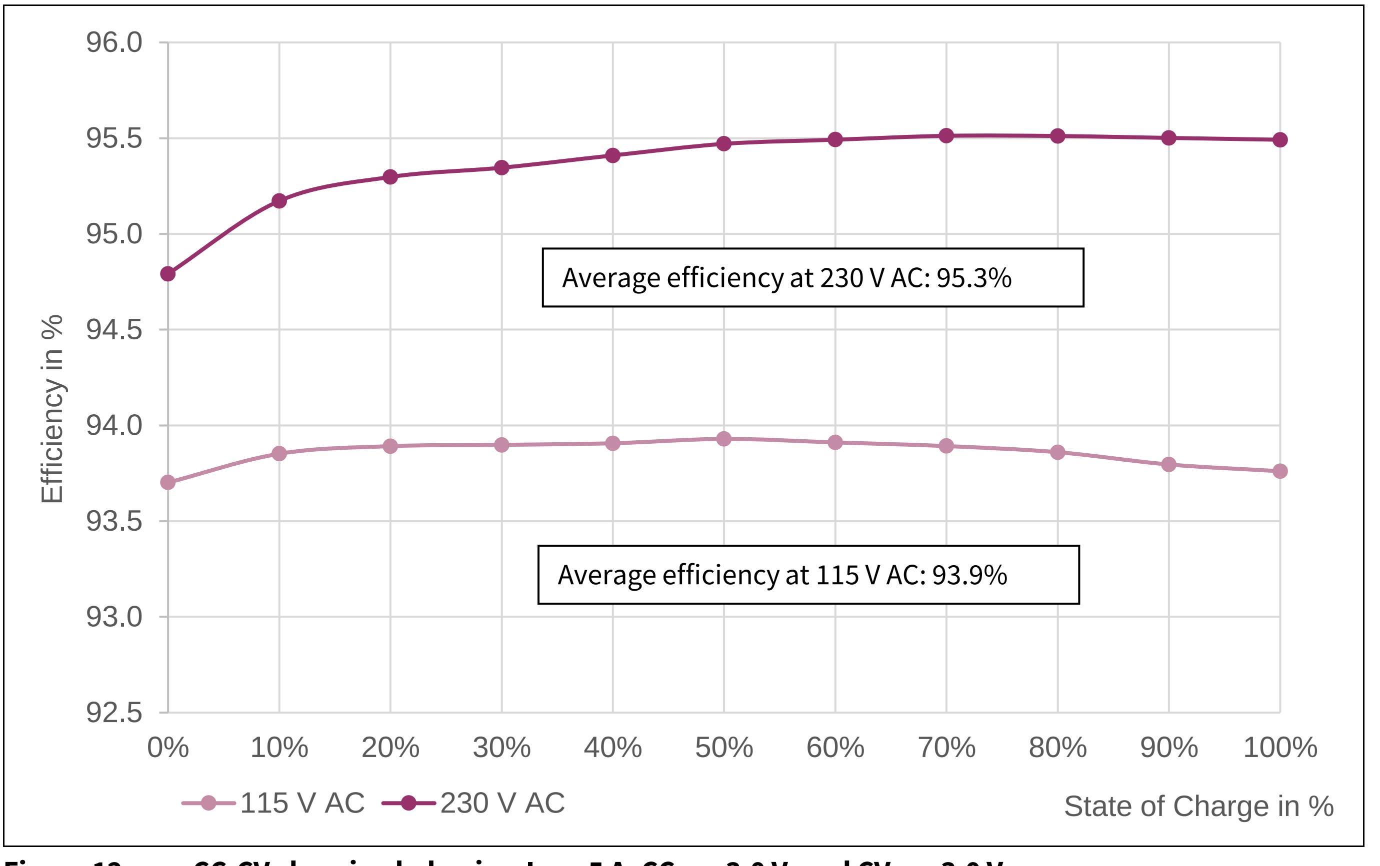


Figure 12 CC-CV charging behavior, I_{out} = 5 A, CC_{set} = 3.0 V, and CV_{set} = 3.0 V

4.1.2 Emulated 36 V battery pack

Figure 13 shows the measured average system-efficiency for a 36 V battery pack with CV setting (CV_{set} ~ 2.3 V) and external CC setting to 5.0 A (CC_{set} ~ 3.0 V) for nominal charging current. At V_{out} of 42 V, CV control takes over and limits the battery voltage accordingly. The battery pack was emulated via an electronic DC-load operating in CV-mode, sweeping across the cell voltages with respect to the state of charge.

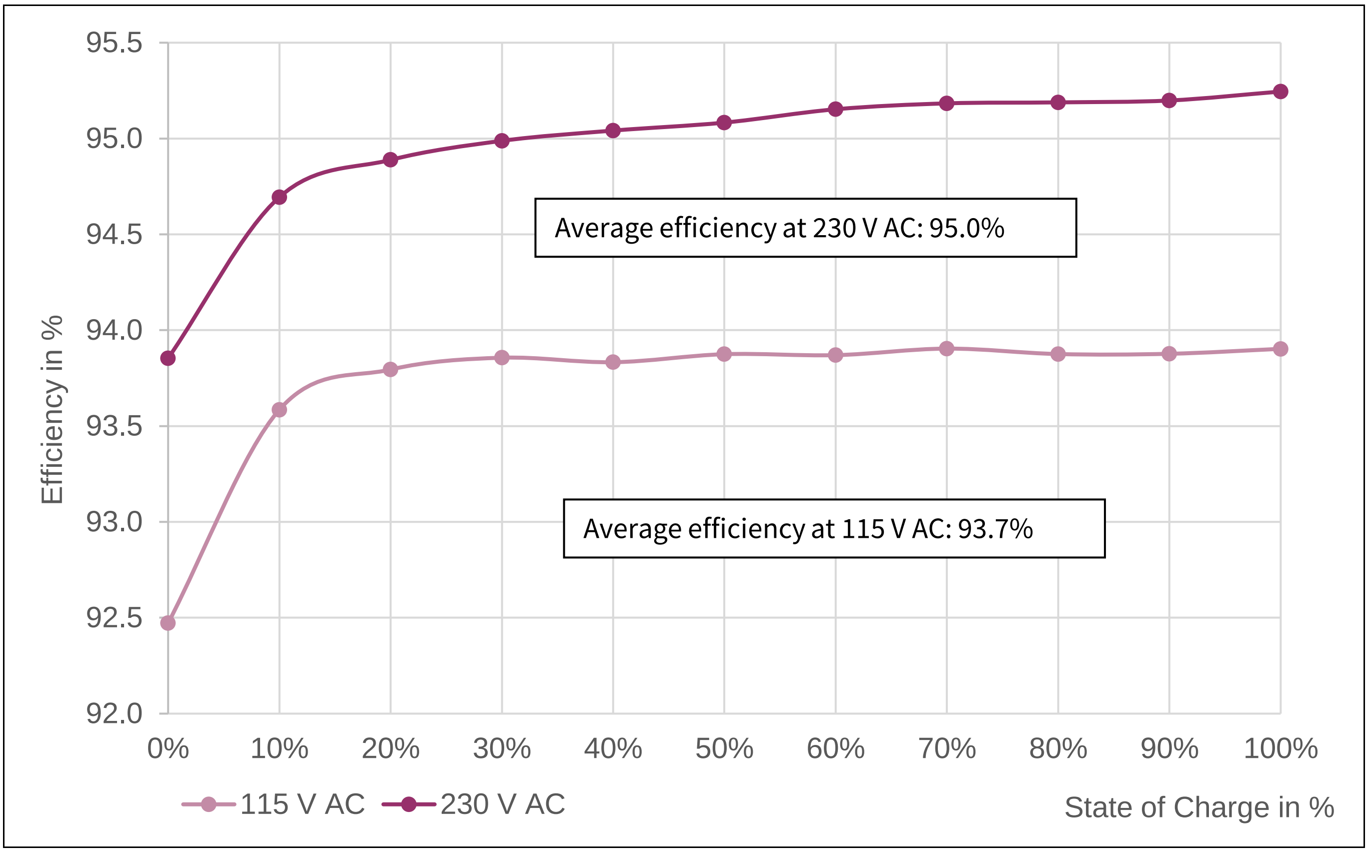


Figure 13 CC-CV charging behavior, I_{out}= 5 A, CC_{set} = 3.0 V, and CV_{set} = 2.3 V

4.2 PFC Performance

The PFC performance is shown by the power factor, harmonic currents and the total harmonic distortion (THD) measurements. The measurements were performed for the input voltages of 115 V AC and 230 V AC at different load in percentage of I_{outnom} = 5 A at the nominal output voltage V_{outnom}: 50 V and presented in the following chapter.

Power factor

Table 5 Power factor measurement

Load (%) \ V AC (V)	115	230
40	0.984	0.871
60	0.990	0.926
80	0.993	0.951
100	0.995	0.966

The following Figure 14 shows the data out of the table.

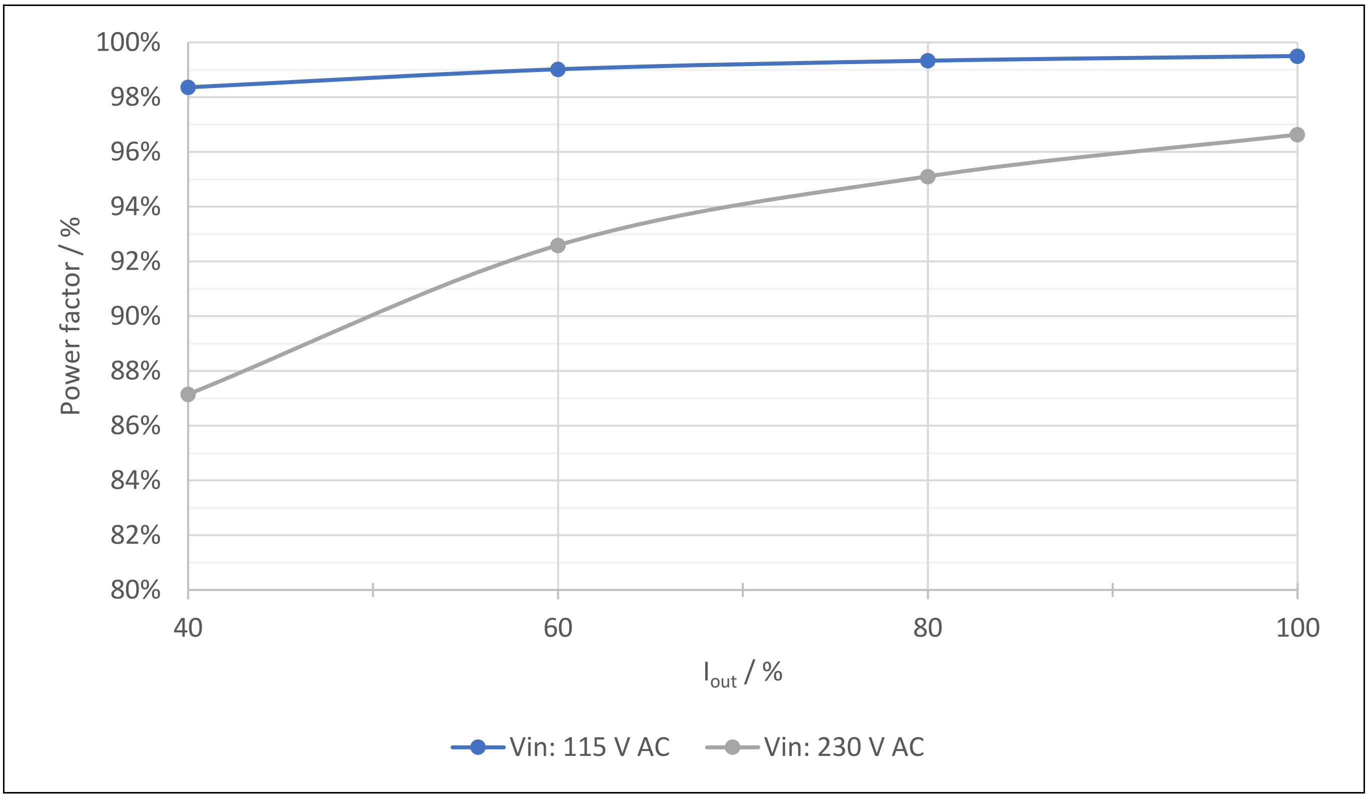


Figure 14 Plot of power factor measurements

Harmonic currents and THD

The harmonic current was measured at the nominal output voltage V_{outnom} = 50 V for different output loads 2 A to 5 A and compared to Class D limit line of IEC 61000-3-2.

Note: *For V_{in}= 115 V AC the limit line was modified according to JIS C 61000-3-2 [2].*

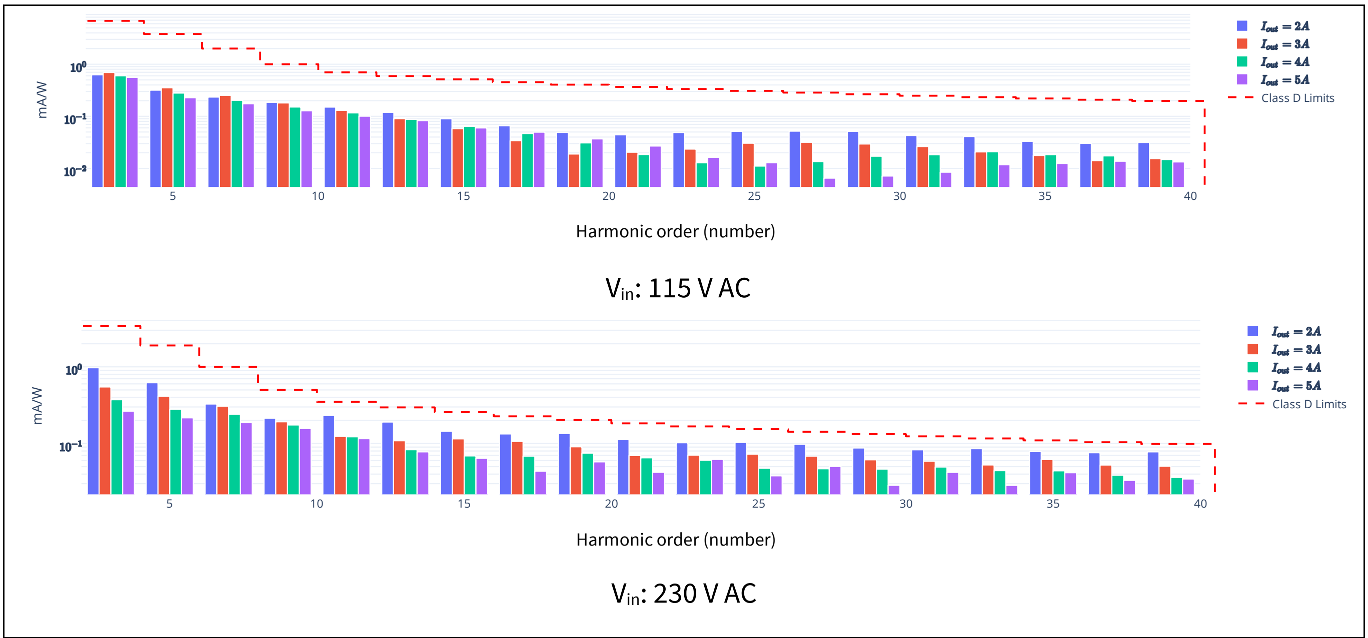


Figure 15 Harmonic currents plot for V_{outnom} = 50 V and V_{in} = 115 V AC and 230 V AC

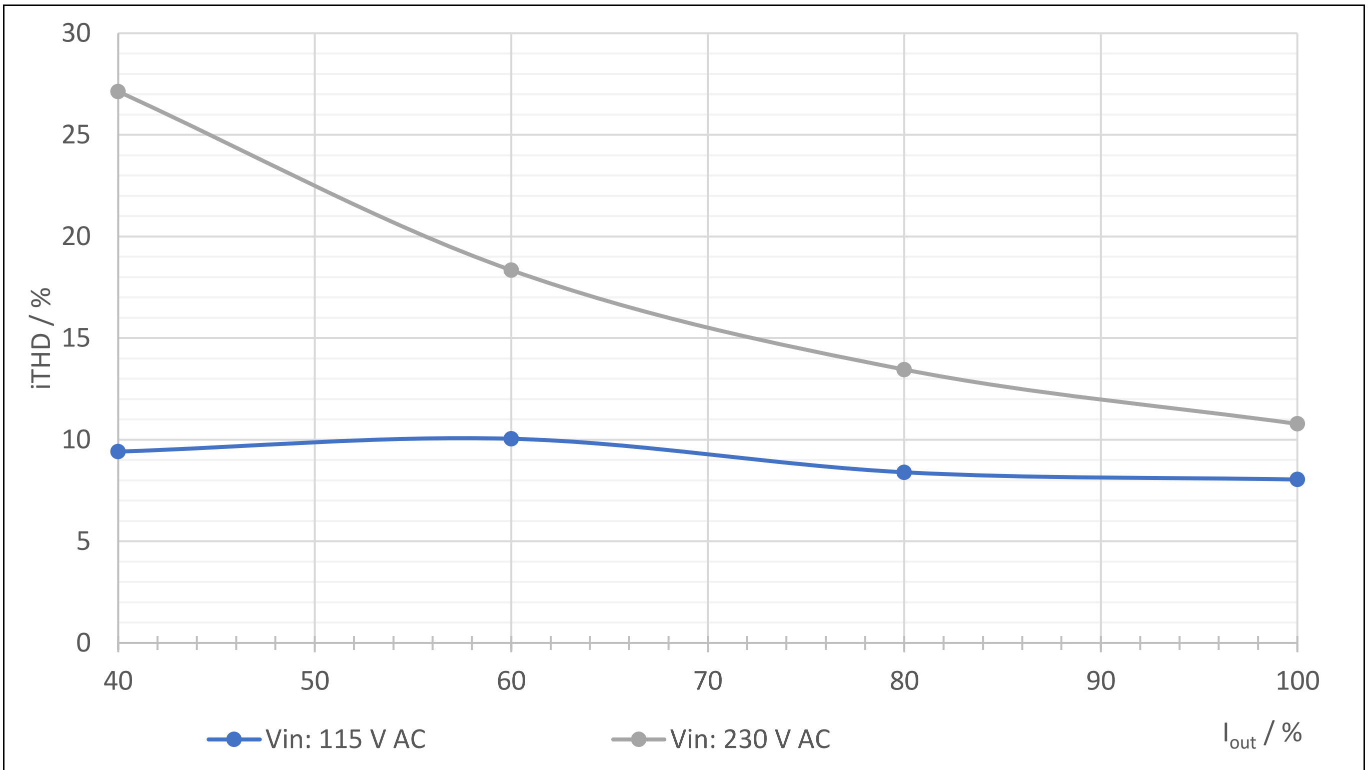


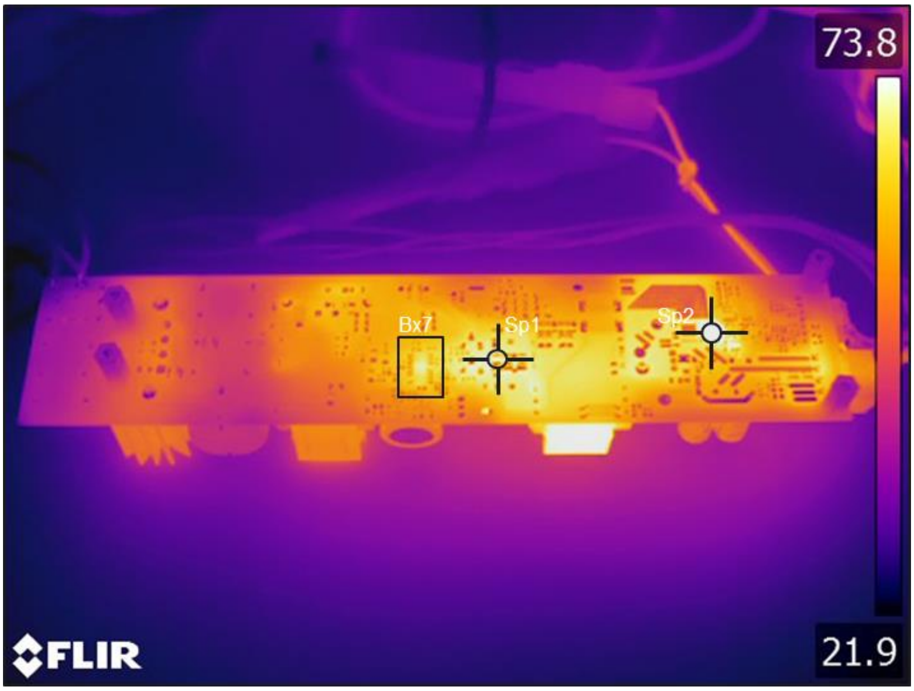
Figure 16 Total harmonic distortion plot for V_{outnom} = 50 V and V_{in} = 115 V AC and 230 V AC

4.3 Thermal measurement

The open-frame thermal measurement was done after one hour of operation at nominal output load, using an infrared thermography camera. The ambient temperature was approximately 25°C.

V_{in}: 230 V AC after 1 hour of operation

V_{in} = 230 V AC, P_{out} = 250 W



Parameters	
Emissivity	0.95
Reflected temp.	25.0°C
Atmospheric temp.	25.0°C
Relative humidity	50.0%

Camera information	
Camera model	FLIR T600
Lens	FOL13
Camera serial	55905689
Field of view	45.01

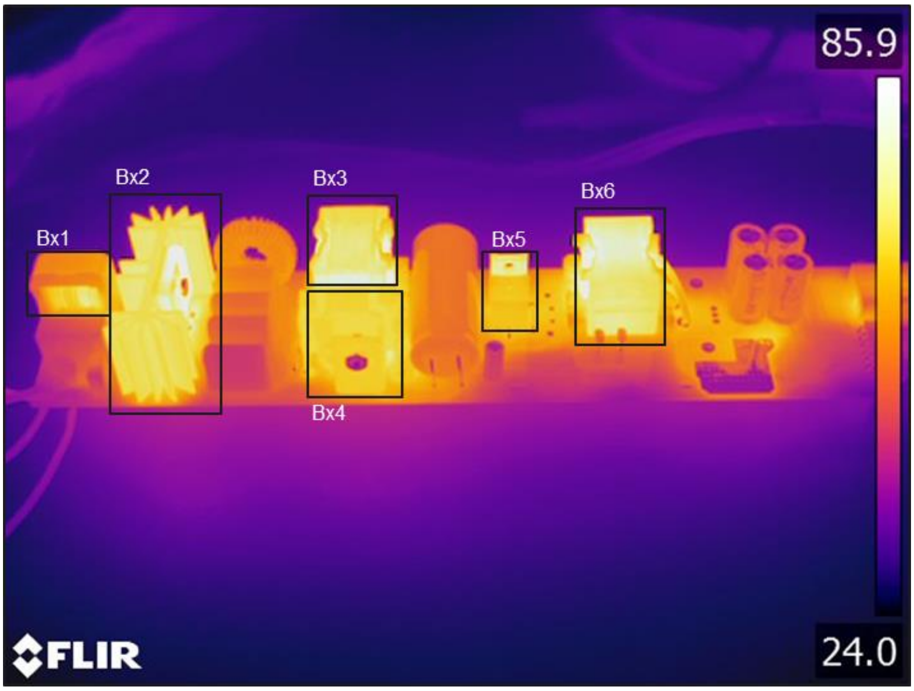
Figure 17 Infrared thermal image of PCB top and bottom side 230 V AC

Table 6 Temperature spots of PCB top and bottom side at 230 V AC

No.	Designator	Function	Component	Temperature (Max.)
Bx1	L100	Common-mode choke	SSR21NV-M35047	31.8°C
Bx2	D100 + HS100	Bridge rectifier + Heatsink	GBU8K + SK-459-25-M-STS	47.0°C
Bx3	TR101	PFC inductor	NP2025-19146-A	53.7°C
Bx4	D109 + HS102	PFC diode + Heatsink	MUR1560G + 577002B00000G	58.8°C
Bx5	Q104, Q105	Half-bridge CoolMOS™	IPAN60R180CM8	74.2°C
Bx6	TR100	HFB transformer	NP2024-17723-D	85.2°C
Bx7	U100	HFB controller	XDPS2221E	69.0°C
Sp1	C137	Resonant capacitor	C1210X104KCRACTU	72.6°C
Sp2	Q200	SR MOSFET OptiMOS™	ISC073N12LM6	77.2°C

V_{in}: 90 V AC after 1 hour of operation

V_{in} = 90 V AC, P_{out} = 250 W



Parameters

Emissivity	0.95
Reflected temp.	25.0°C
Atmospheric temp.	25.0°C
Relative humidity	50.0%

Camera information

Camera model	FLIR T600
Lens	FOL13
Camera serial	55905689
Field of view	45.01

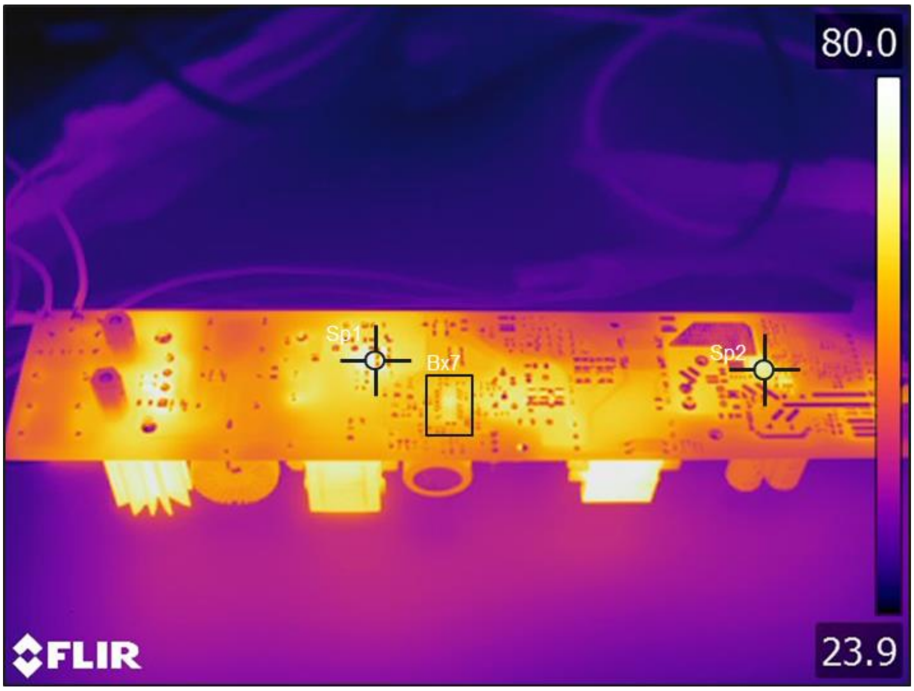


Figure 18 Infrared thermal image of PCB top and bottom side 90 V AC

Table 7 Temperature spots of PCB top and bottom side 90 V AC

No.	Designator	Function	Component	Temperature (Max.)
Bx1	L100	Common-mode choke	SSR21NV-M35047	82.4°C
Bx2	D100 + HS100	Bridge rectifier + Heatsink	GBU8K + SK-459-25-M-STS	85.4°C
Bx3	TR101	PFC inductor	NP2025-19146-A	86.0°C
Bx4	Q102 + HS101	PFC FET + Heatsink	IPA60R060P7 + FK 224 SA 220 1	77.7°C
Bx5	Q104, Q105	Half-bridge CoolMOS™	IPAN60R180CM8	82.9°C
Bx6	TR100	HFB transformer	NP2024-17723-D	87.1°C
Bx7	U100	HFB controller	XDPS2221E	76.4°C
Sp1	R113, R114, R115	PFC shunt resistors	Res 150mR/ / 1206/ /1%	78.4°C
Sp2	Q200	SR MOSFET OptiMOS™	ISC073N12LM6	77.1°C

4.4 Conducted emissions

The conducted emissions test was performed at full output power according to EN 55014 for household appliances, electric tools and similar apparatus. The measurement was performed in phase and neutral configuration with a rated input voltage of 115 V AC / 50 Hz and 230 V AC / 50 Hz. The results reveal that there is sufficient margin, higher than the limit of 6 dB as shown in the plots from Figure 19 to Figure 22.

The measurement equipment used for this emissions test was Rohde & Schwarz HM6050-2 and Tektronix RSA503A. A variable wire resistor adjusted to 10 Ω was used as a load.

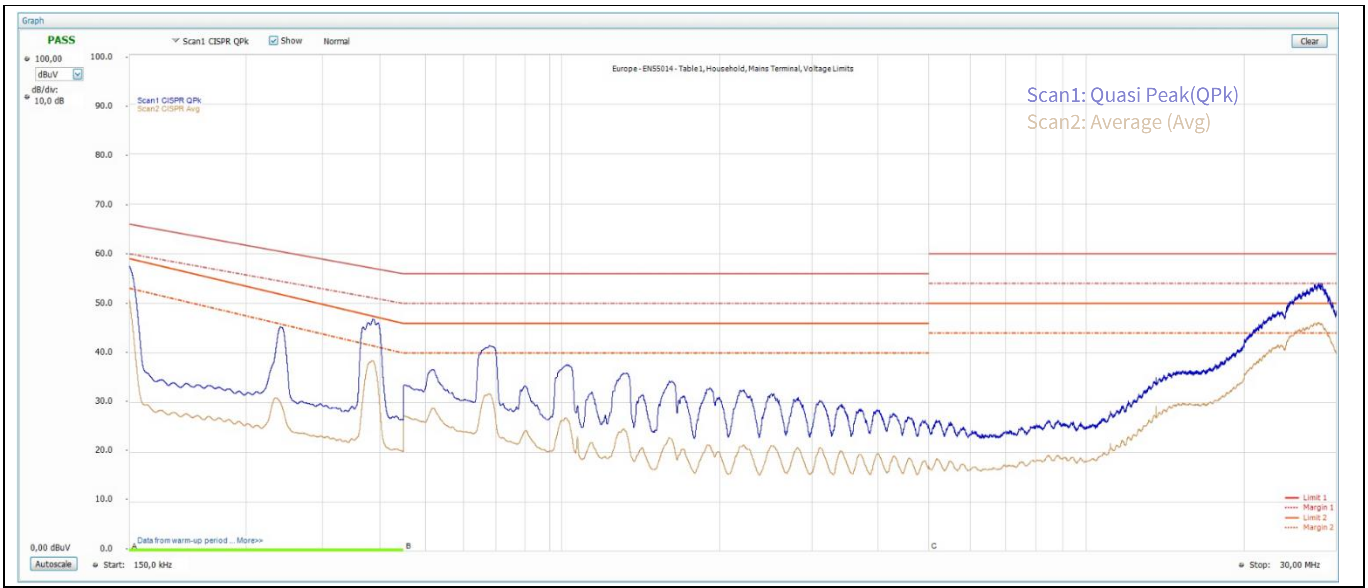


Figure 19 Conducted emissions – phase line 230 V AC

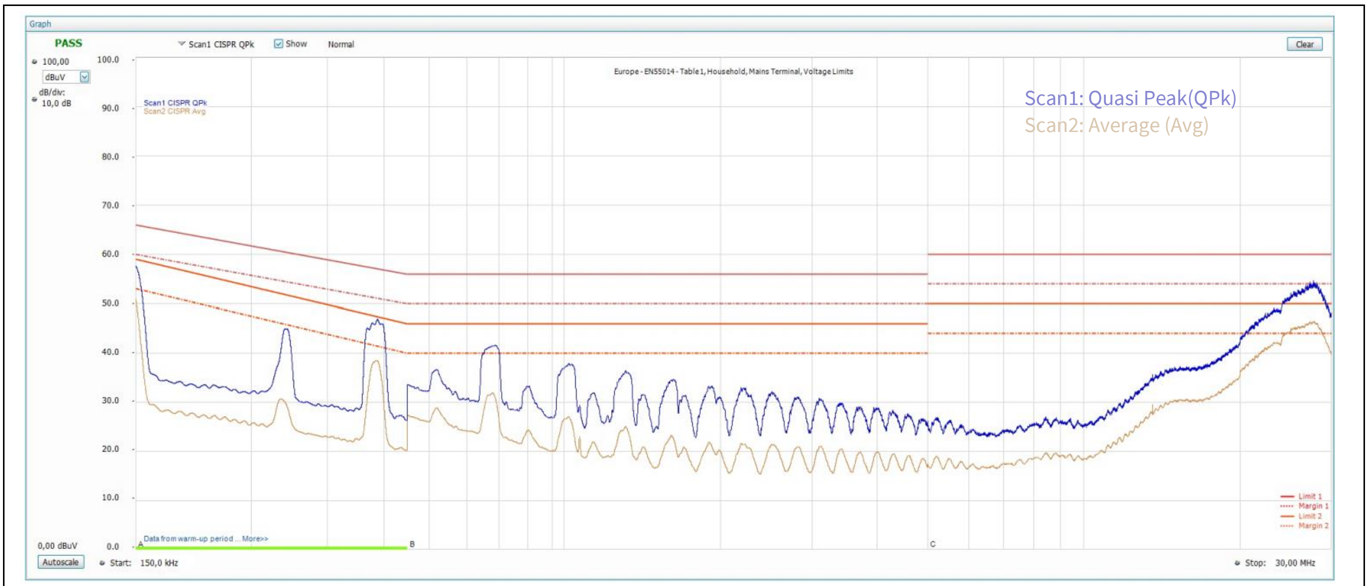


Figure 20 Conducted emissions – neutral line 230 V AC

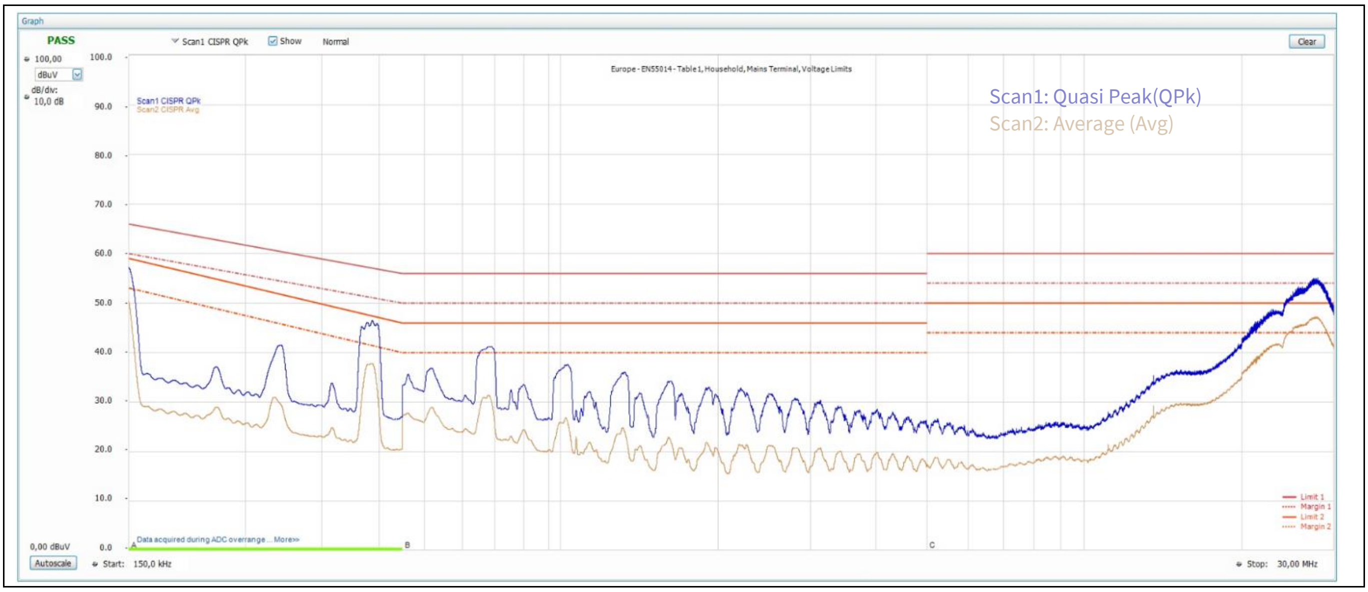


Figure 21 **Conducted emissions – phase line 115 V AC**

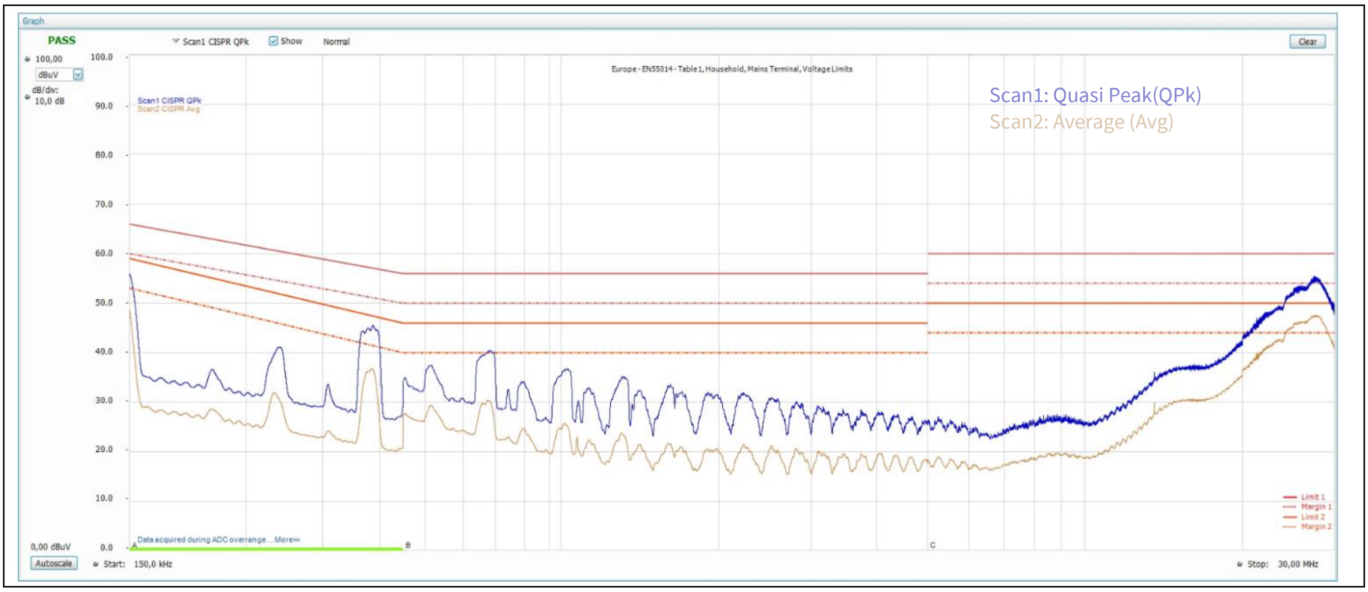


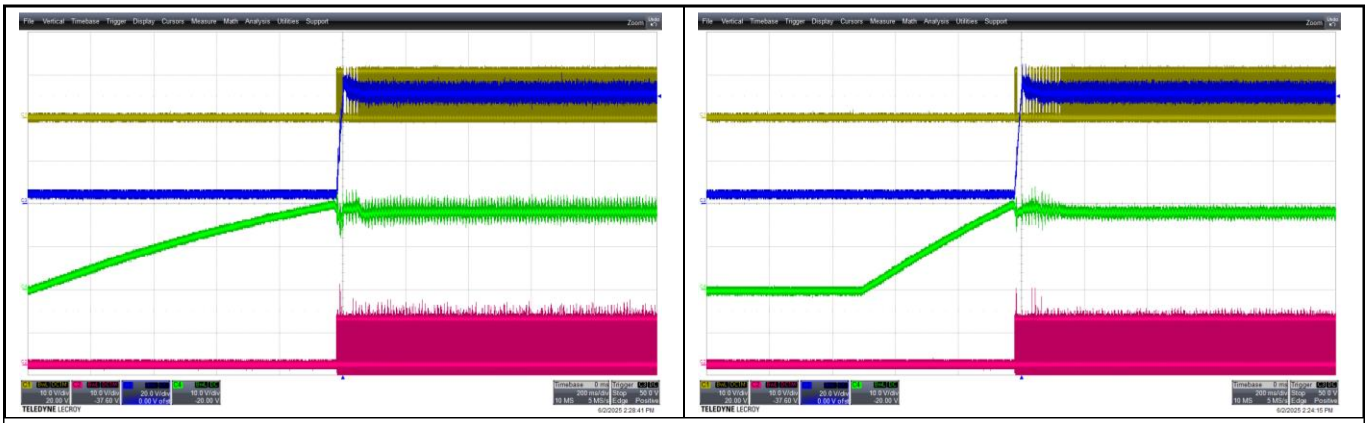
Figure 22 **Conducted emissions – neutral line 115 V AC**

5 Switching waveforms

This chapter contains switching waveforms for start-up phase and steady state of PFC and HFB stage.

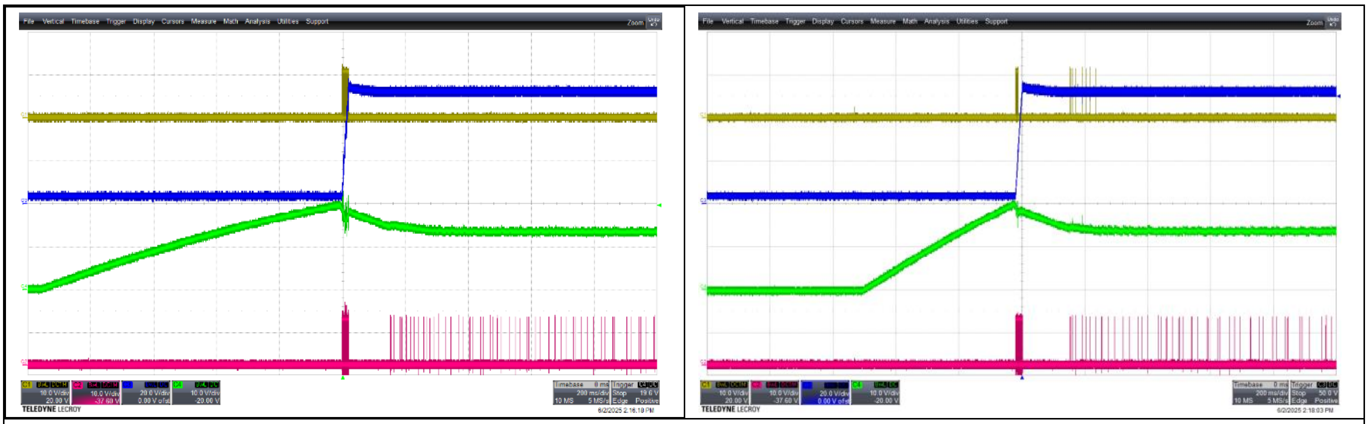
5.1 Start-up

Start-up behavior was measured at full-load condition and V_{in} 115 V AC and 230 V AC in CC-mode. The HFB operates in continuous resonant mode (CRM) – see Figure 23. After start-up at no-load condition, the HFB remains in burst mode (BM) mode, as shown in Figure 24.



C1: LSGD C2: PFCGD C3: V_{out} C4: V_{cc}

Figure 23 Start-up at full load, 115 V AC input (left) and 230 V AC input (right)

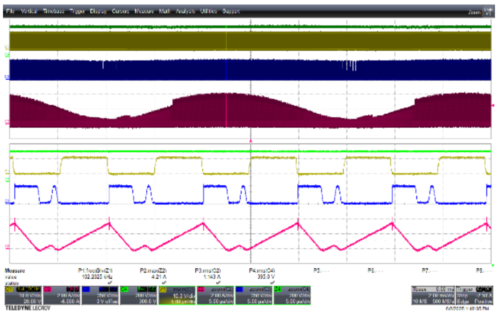


C1: LSGD C2: PFCGD C3: V_{out} C4: V_{cc}

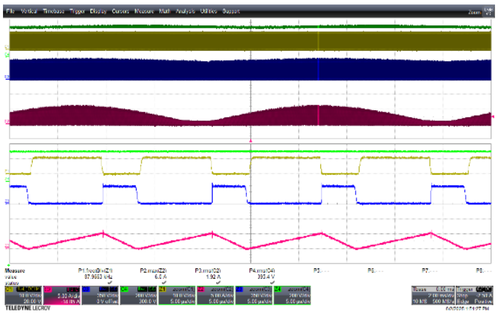
Figure 24 Start-up at no-load, 115 V AC input (left) and 230 V AC input (right)

5.2 Steady state

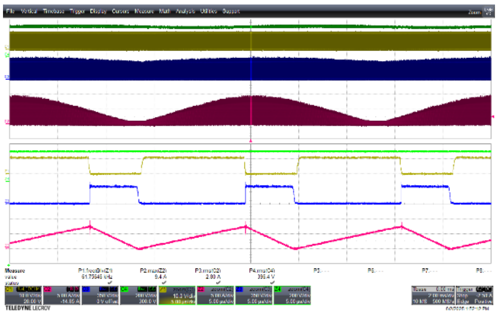
The following graphs show the typical waveforms of the PFC stage at different load cases.



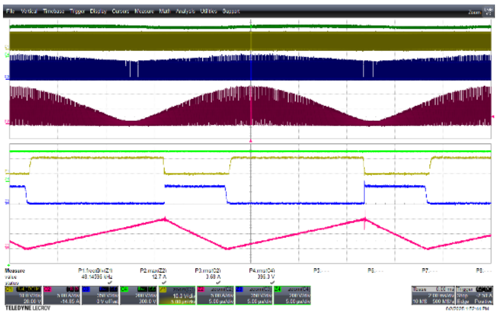
V_{in}: 90V AC, V_{outnom}: 50 V, I_{out}: 1.25 A



V_{in}: 90V AC, V_{outnom}: 50 V, I_{out}: 2.50 A



V_{in}: 90V AC, V_{outnom}: 50 V, I_{out}: 3.75 A

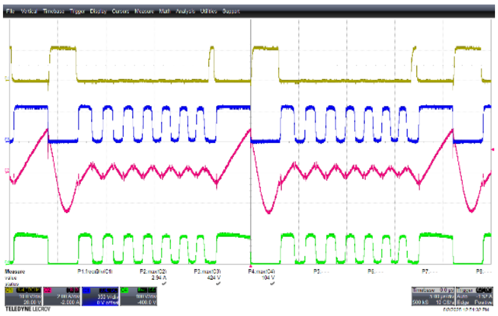


V_{in}: 90V AC, V_{outnom}: 50 V, I_{out}: 5.00 A

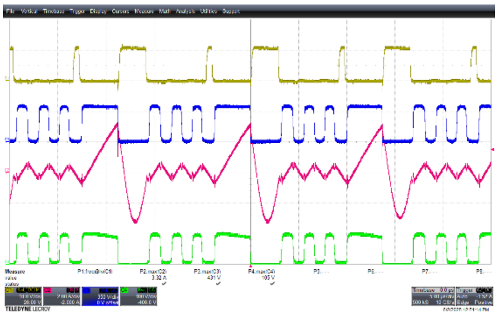
C1: PFCGD C2: I_{PFC} C3: PFC_d C4: V_{BUS}

Figure 25 Steady state of PFCstage in different load cases

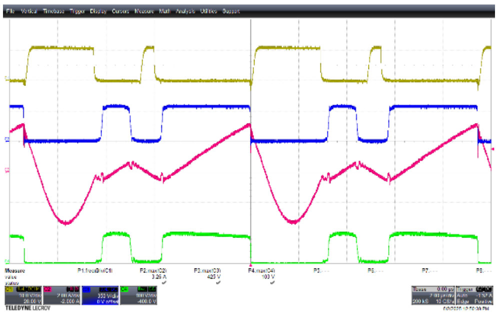
The steady state waveforms of the HFB stage are illustrated below.



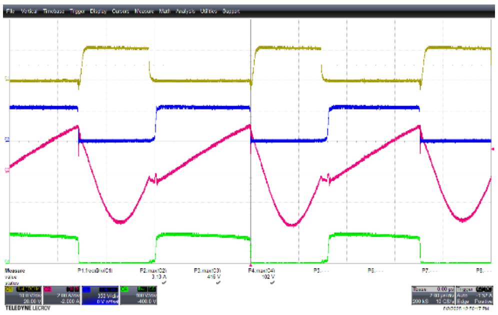
V_{in}: 115V AC, V_{outnom}: 50 V, I_{out}: 1.25 A



V_{in}: 115V AC, V_{outnom}: 50 V, I_{out}: 2.50 A



V_{in}: 115V AC, V_{outnom}: 50 V, I_{out}: 3.75 A



V_{in}: 115V AC, V_{outnom}: 50 V, I_{out}: 5.00 A

C1: LSGD C2: I_{SW} C3: V_{SW} C4: V_{SR}

Figure 26 Steady state of HFB stage in different load cases

6 Schematic and layout

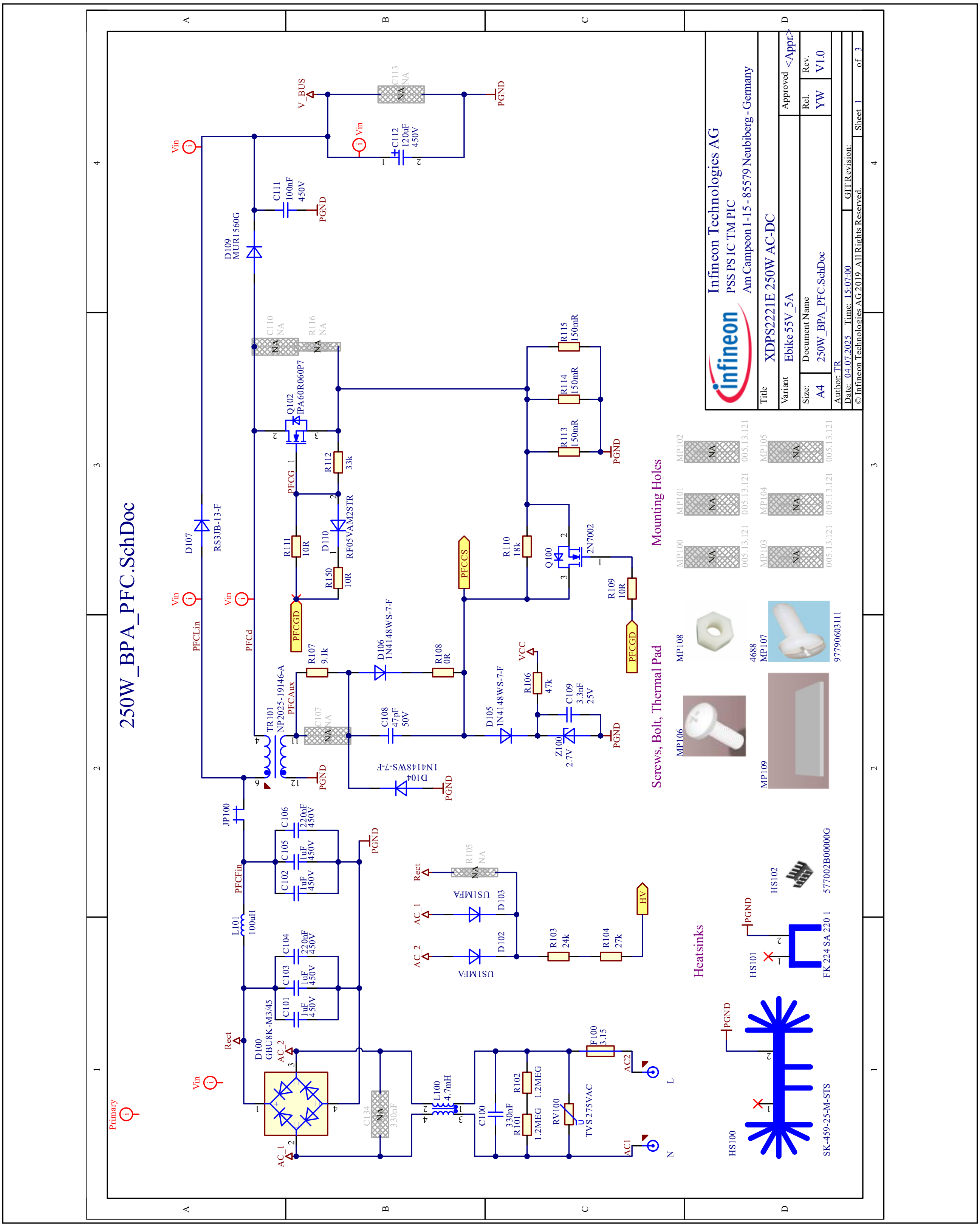


Figure 27 Reference board schematic – EMI filter and PFC stage

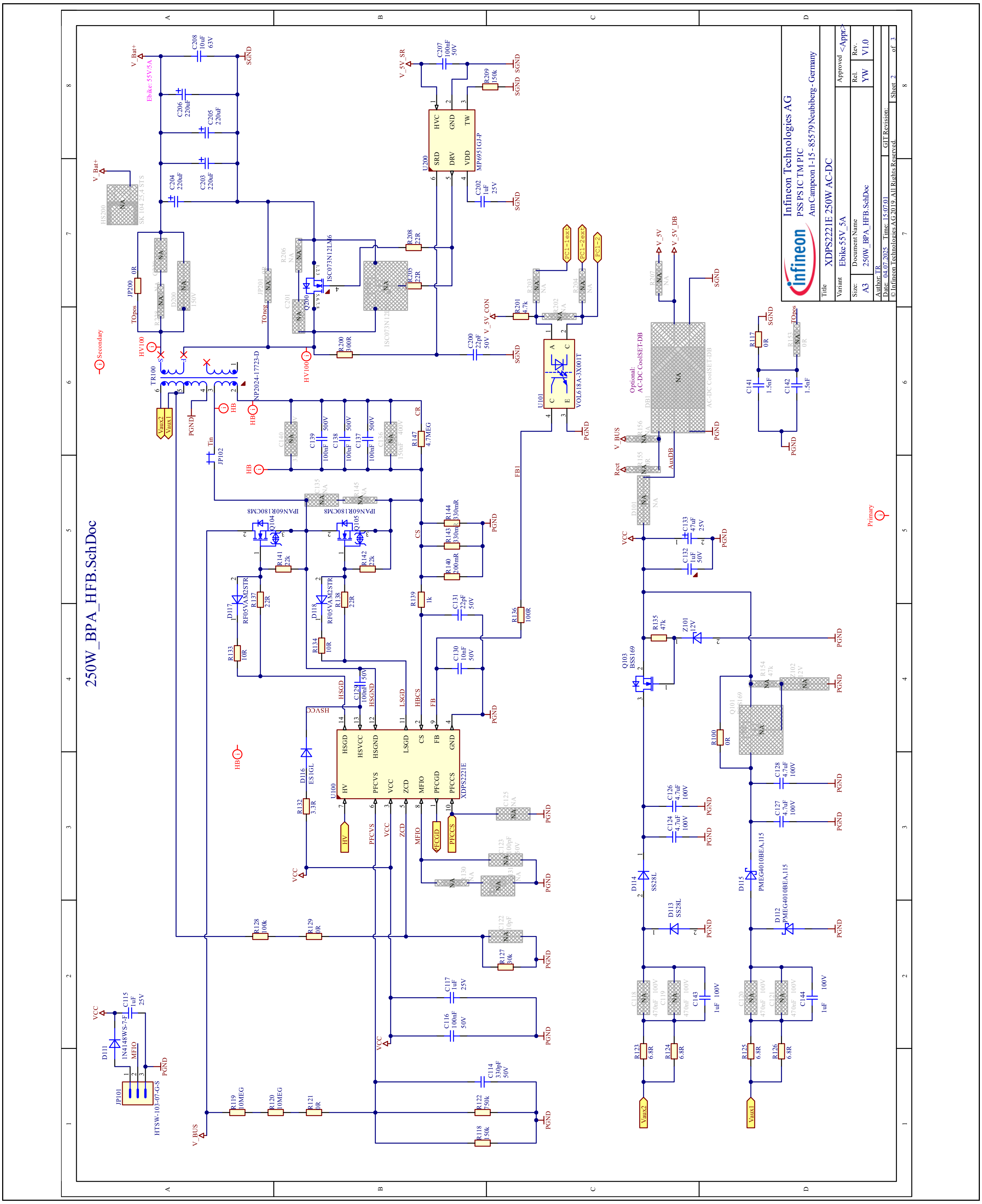


Figure 28 **Reference board schematic – HFB stage and VCC circuit**

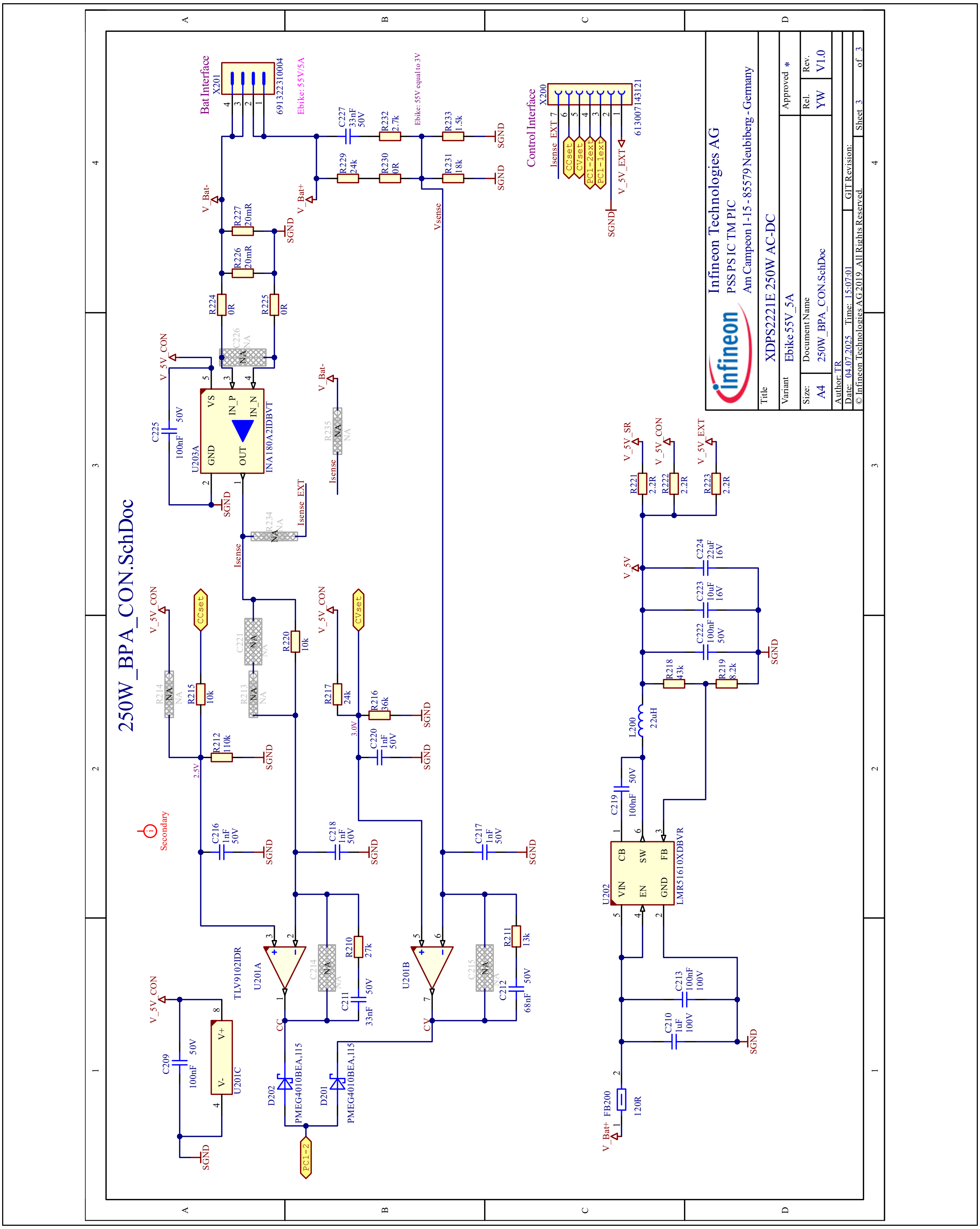


Figure 29 Reference board schematic – control circuit and secondary supply

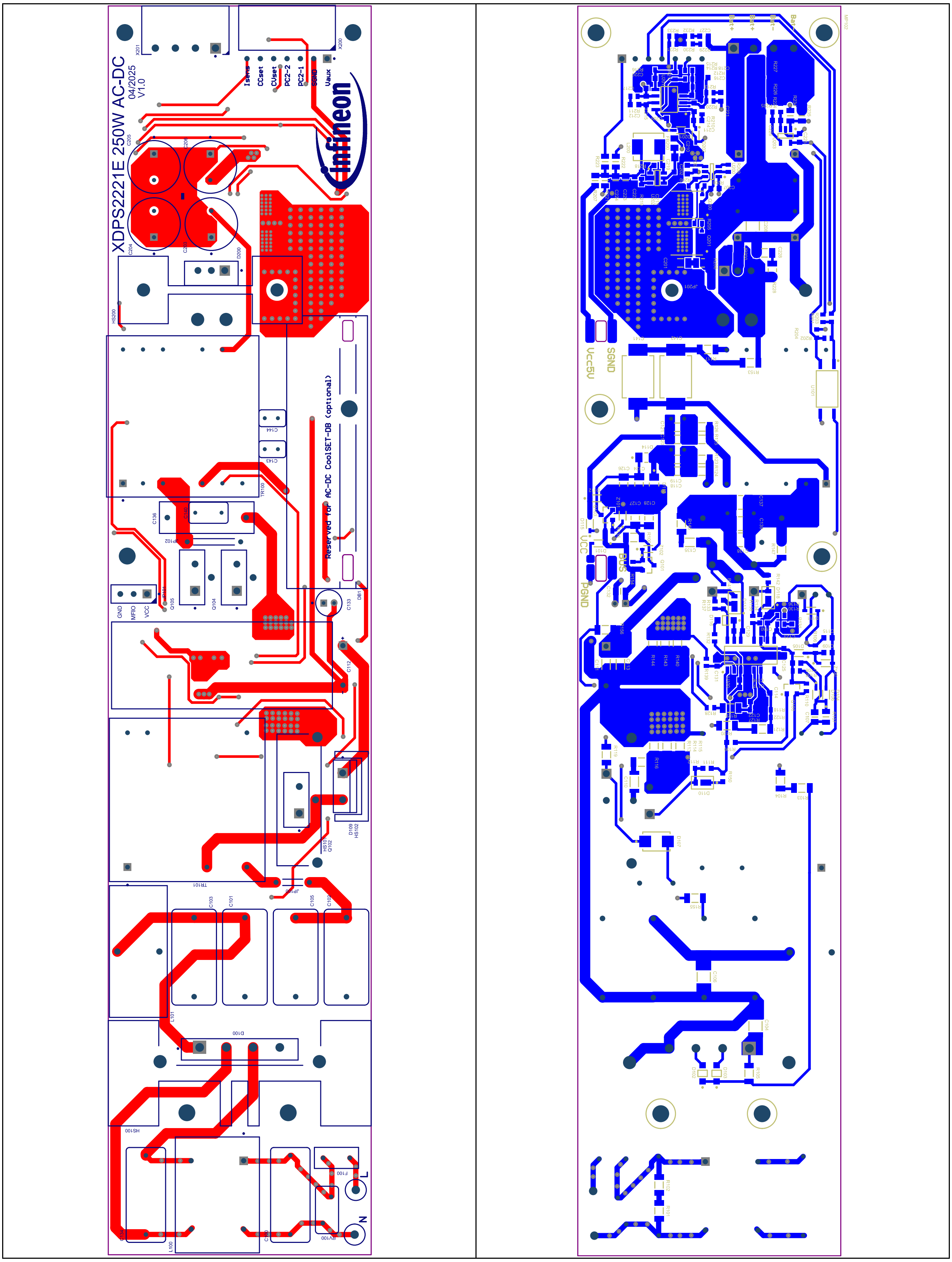


Figure 30 Reference board PCB top (left) and bottom (right)

7 Bill of materials and specifications

7.1 BOM of XDP™ XDPS2221E digital power 250 W AC-DC reference design

Table 8 BOM of reference board

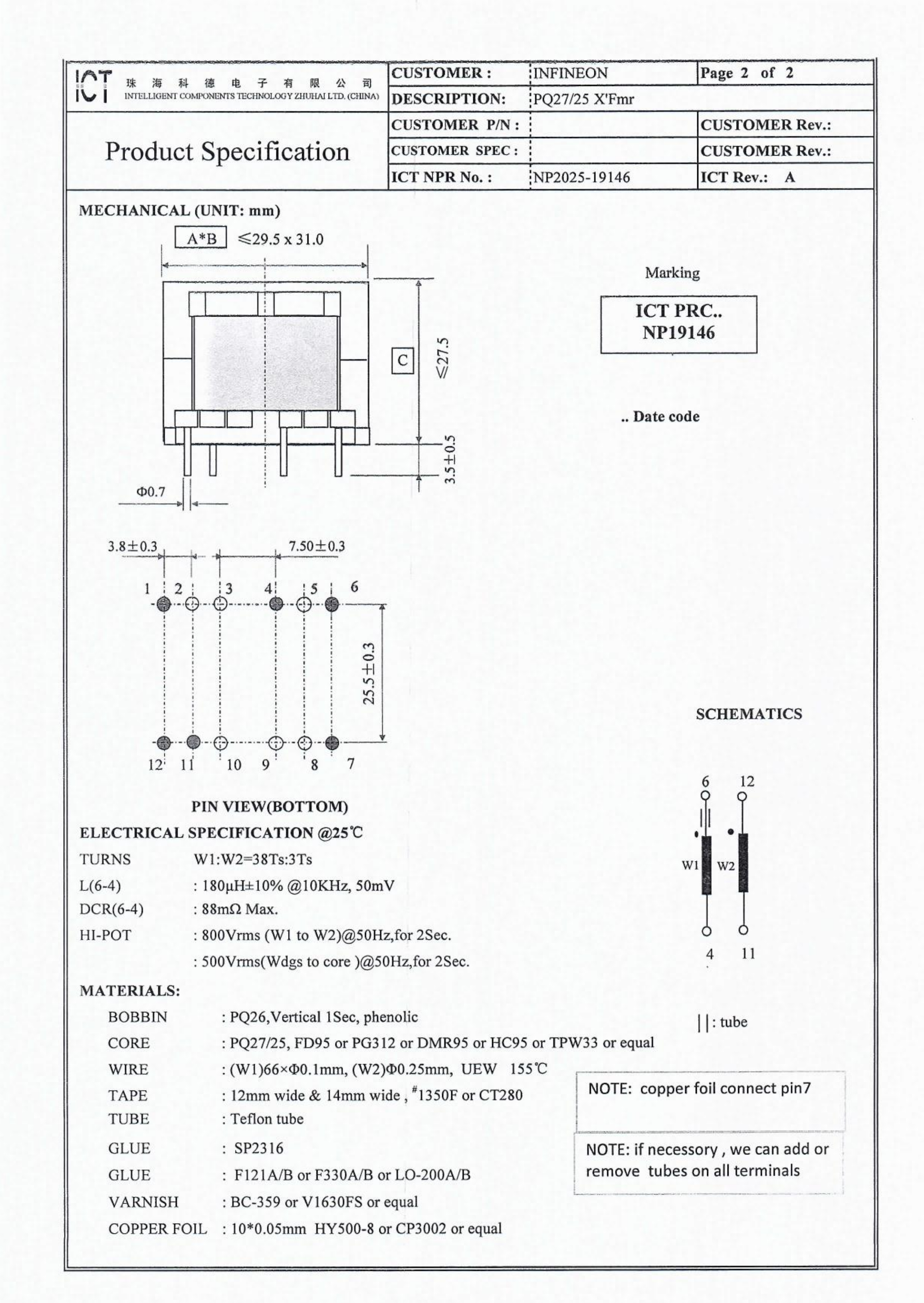
Designator	Description	Manufacturer	Part number
C100	Cap 330 nF/ 560V/ THT/Radial/ /20%	Kemet	R46KI333040P0M
C101, C102, C103, C105	Cap 1 uF/ 450V/ THT/Radial/ MKT/10%	Panasonic	ECQ-E2W105KH
C104, C106	Cap 220 nF/ 450V/ 1210/ /10%	–	–
C108	Cap 47 pF/ 50V/ 0603/ C0G/2%	–	–
C109	Cap 3.3 nF/ 25V/ 0603/ X7R/5%	–	–
C111	Cap 100 nF/ 450V/ 1206/ /10%	–	–
C112	Cap 120 uF/ 450V/ THT/Radial/ /20%	Rubycon	450BXW120MEFR18X40
C114	Cap 330 pF/ 50V/ 0603/ X7R/5%	–	–
C115, C117, C202	Cap 1 uF/ 25V/ 0603/ X7R/10%	–	–
C116, C129, C207, C219, C222, C225	Cap 100 nF/ 50V/ 0603/ X8L/10%	–	–
C123	Cap 100 pF/ 50 V/ 0603/ C0G/5%	–	–
C124, C126, C127, C128	Cap 4.7 uF/ 100 V/ 1206 (3216)/ /10%	–	–
C130	Cap 10 nF/ 50 V/ 0603/ X7R/5%	–	–
C131, C200	Cap 22 pF/ 50 V/ 0603/ C0G/5%	–	–
C132	Cap 1 uF/ 50 V/ 0805/ X5R/10%	–	–
C133	Cap 47 uF/ 25 V/ THT/ /20%	Wurth Elektronik	860020472006
C137, C138, C139	Cap 100 nF/ 500 V/ 1210/ X7R/10%	Kemet	C1210X104KCRACTU
C141, C142	Cap 1.5 nF/ / SMD/ /20%	–	–
C143, C144	Cap 1 uF/ 100 V/ THT/Radial/ X7R/10%	–	–
C203, C204, C205, C206	Cap 220 uF/ 63 V/ THT/ /20%	Kemet	A759MY227M1JAAE45
C208	Cap 10 uF/ 63 V/ 1210/ X7R/20%	–	–
C209	Cap 100 nF/ 50 V/ 0603/ X7R/5%	–	–
C210	Cap 1 uF/ 100 V/ 0805/ /10%	–	–
C211, C227	Cap 33 nF/ 50 V/ 0603/ X7R/20%	–	–
C212	Cap 68 nF/ 50 V/ 0603/ X7R/5%	–	–
C213	Cap 100 nF/ 100 V/ 0603/ X7R/10%	–	–
C216, C217, C218, C220	Cap 1 nF/ 50 V/ 0603/ C0G/1%	–	–
C223	Cap 10 uF/ 16 V/ 0805/ X5R/10%	–	–

Designator	Description	Manufacturer	Part number
C224	Cap 22 uF/ 16 V/ 0805/ X5R/20%	–	–
D100	Dio GBU8K/ / SIP-4/ /	ON Semiconductor	GBU8K
D102, D103	Dio US1MFA/ / SOD-23FL (CASE 425AB)/ /	ON Semiconductor	US1MFA
D104, D105, D106, D111	Dio 1N4148WS-7-F/ / SOD-323/ /	Diodes Incorporated	1N4148WS-7-F
D107	Dio RS3JB-13-F/ / SMB/ /	Diodes Incorporated	RS3JB-13-F
D109	Dio MUR1560G/ / TO-220AC (CASE 221B)/ /	ON Semiconductor	MUR1560G
D110, D117, D118	Dio 200V/ / SMD/ /	ROHM Semiconductors	RF05VAM2STR
D112, D115, D201, D202	Dio PMEG4010BEA,115/ / SMD/ /	Nexperia	PMEG4010BEA,115
D113, D114	Dio SS28L/ 80 V/2 A/ SOD-123F-2/ /	Multicomp	SS28L
D116	Dio ES1GL/ / SMA/ /	Taiwan Semiconductor	ES1GL R3G
F100	Res 3.15/ 63 V/ THT/ /	Belfuse	RSTA 3.15 AMMO
FB200	Ind 120R/ / 0805/ /25%	MuRata	BLM21AG121BH1D
HS100	Mec SK-459-25-M-STS/ / THT/ /	Fischer Elektronik	SK-459-25-M-STS
HS101	Mec FK 224 SA 220 1/ / Heat Sink/ /	Fischer Elektronik	FK 224 SA 220 1
HS102	Mec 577002B00000G/ / THT/ /	Aavid Thermalloy	577002B00000G
JP100	Con JL-250-25-T/ / JP-THT-JL-250-25-T/ /	Samtec	JL-250-25-T
JP101	Con HTSW-103-07-G-S/ / CON-THT-2.54-3-1-8.38/ /	Samtec	HTSW-103-07-G-S
JP102	Con JL-400-25-T/ / JP-THT-JL-400-25-T/ /	Samtec	JL-400-25-T
JP200	Res 0R/ / 0612/ /	Vishay	RCL06120000Z0EA
L100	Ind 4.7 mH/ / THT/ /	Kemet	SSR21NV-M35047
L101	Ind 100 uH/ / THT/ /20%	Wurth Elektronik	7447070
L200	Ind 22 uH/ / SMD/ /20%	Bourns	SRP5015TA-220M
Q100	Tra 2N7002/ / PG-SOT23/ /	Infineon Technologies	2N7002
Q102	Tra IPA60R060P7/ / PG-TO220-3-313/ /	Infineon Technologies	IPA60R060P7
Q103	Tra BSS169/ / PG-SOT23/ /	Infineon Technologies	BSS169
Q104, Q105	Tra IPAN60R180CM8/ / PG-TO220-3-323/ /	Infineon Technologies	IPAN60R180CM8
Q200	Tra ISC073N12LM6/ / PG-TDSON-8-46/ /	Infineon Technologies	ISC073N12LM6
R100, R117, R121, R129	Res 0R/ 200V/ 1206/ /	–	–
R101, R102	Res 1.2MEG/ 200 V/ 1206/ /1%	–	–
R103	Res 24k/ 200 V/ 1206/ /1%	–	–
R104	Res 27k/ 200 V/ 1206/ /1%	–	–
R106	Res 47k/ 75 V/ 0603/ /1%	–	–

Designator	Description	Manufacturer	Part number
R107	Res 9.1k/ 150 V/ 0805/ /1%	–	–
R108	Res 0R/ 75 V/ 0603/ /0%	–	–
R109	Res 10R/ 50 V/ 0603/ /1%	–	–
R110	Res 18k/ 75 V/ 0603/ /1%	–	–
R111, R133, R134, R150	Res 10R/ 50 V/ 0603/ /1%	–	–
R112	Res 33k/ 75 V/ 603/ /1%	–	–
R113, R114, R115	Res 150mR/ / 1206/ /1%	Vishay	RCWE1206R150FKEA
R118, R209	Res 150k/ 75 V/ 0603/ /1%	–	–
R119, R120	Res 10MEG/ 200 V/ 1206/ /1%	–	–
R122	Res 750k/ 75 V/ 0603/ /1%	–	–
R123, R124, R125, R126	Res 6.8R/ 200 V/ 1206/ /1%	–	–
R127, R215, R220	Res 10k/ 75 V/ 0603/ /1%	–	–
R128, R218	Res 43k/ 75 V/ 0603/ /1%	–	–
R132	Res 3.3R/ 75 V/ 0603/ /1%	–	–
R135	Res 47k/ 75 V/ 0603/ /1%	–	–
R136	Res 100R/ 75 V/ 0603/ /1%	–	–
R137, R138, R205, R208	Res 22R/ 75 V/ 0603/ /1%	–	–
R139	Res 1k/ 75 V/ 0603/ /1%	–	–
R140	Res 200mR/ / 1206/ /1%	–	–
R141, R142	Res 22k/ 75 V/ 0603/ /1%	–	–
R143, R144	Res 330mR/ 675 V/ 1206/ /1%	Bourns	CRM1206-FX-R330 E LF
R147	Res 4.7MEG/ 400 V/ SMD/ /5%	–	–
R200	Res 300R/ 75 V/ 0603/ /1%	–	–
R201	Res 4.7k/ 75 V/ 0603/ /1%	–	–
R210	Res 27k/ 75 V/ 0603/ /1%	–	–
R211	Res 13k/ 75 V/ 0603/ /1%	–	–
R212	Res 110k/ 75 V/ 0603/ /1%	–	–
R216	Res 36k/ 75 V/ 0603/ /1%	–	–
R217, R229	Res 24k/ 75 V/ 0603/ /1%	–	–
R219	Res 8.2k/ 75 V/ 0603/ /1%	–	–
R221, R222, R223	Res 2.2R/ 150 V/ 0805/ /1%	–	–
R224, R225, R230	Res 0R/ 50 V/ 0603/ /0R	–	–
R226, R227	Res 20mR/ / 1206/ /1%	Panasonic	ERJ-B2CFR02V

Designator	Description	Manufacturer	Part number
R231	Res 18k/ 75 V/ 0603/ /1%	–	–
R232	Res 2.7k/ 75 V/ 0603/ /1%	–	–
R233	Res 1.5k/ 75 V/ 0603/ /1%	–	–
RV100	Res TVS 275VAC/ 275 Vac/ VARRR500W60L900T440H1100B/ /	Epcos	B72207S0271K101
TR100	Tra NP2024-17723-D/ / THT/ /	ICT	NP2024-17723-D
TR101	Tra NP2025-19146-A/ / THT/ /	ICT	NP2025-19146-A
U100	Int XDPS2221E/ / PG-DSO-14/ /	Infineon Technologies	XDPS2221E
U101	Opt VOL618A-3X001T/ / LSOP-4/ /	Vishay	VOL618A-3X001T
U200	Int MP6951GJ-P/ / TSOT-23-6/ /	Monolithic Power Systems	MP6951GJ-P
U201	Ana TLV9102IDR/ / SOIC-8/ /	Texas Instruments	TLV9102IDR
U202	Pow LMR51610XDBVR/ / SOT-23-6 (DBV)/ /	Texas Instruments	LMR51610XDBVR
U203	Ana INA180A2IDBVT/ / SOT23-5 (DBV)/ /	Texas Instruments	INA180A2IDBVT
X200	Con 613007143121/ / THT 7 PIN 2.54 mm pitch/ /	Wurth Elektronik	613007143121
X201	Con 691322310004/ / WR-TBL/ /	Wurth Elektronik	691322310004
Z100	Dio 2.7 V/ / SOD323/ /	Nexperia	BZX384-C2V7,115
Z101	Dio 12 V/ / SOD-323F (SC-90)/ /	Nexperia	BZX84J-B12,115

7.2 Magnetics specifications



ICT 珠海科德电子有限公司 INTELLIGENT COMPONENTS TECHNOLOGY ZHUHAI LTD. (CHINA)	CUSTOMER :	INFINEON	Page 2 of 2
	DESCRIPTION:	PQ27/25 X'Fmr	
Product Specification	CUSTOMER P/N :		CUSTOMER Rev.:
	CUSTOMER SPEC :		CUSTOMER Rev.:
	ICT NPR No. :	NP2025-19146	ICT Rev.: A

MECHANICAL (UNIT: mm)

ELECTRICAL SPECIFICATION @25℃

TURNS	W1:W2=38Ts:3Ts
L(6-4)	: 180μH±10% @10KHz, 50mV
DCR(6-4)	: 88mΩ Max.
HI-POT	: 800Vrms (W1 to W2)@50Hz,for 2Sec.
	: 500Vrms(Wdgs to core)@50Hz,for 2Sec.

MATERIALS:

BOBBIN	: PQ26,Vertical 1Sec, phenolic
CORE	: PQ27/25, FD95 or PG312 or DMR95 or HC95 or TPW33 or equal
WIRE	: (W1)66×Φ0.1mm, (W2)Φ0.25mm, UEW 155℃
TAPE	: 12mm wide & 14mm wide , #1350F or CT280
TUBE	: Teflon tube
GLUE	: SP2316
GLUE	: F121A/B or F330A/B or LO-200A/B
VARNISH	: BC-359 or V1630FS or equal
COPPER FOIL	: 10*0.05mm HY500-8 or CP3002 or equal

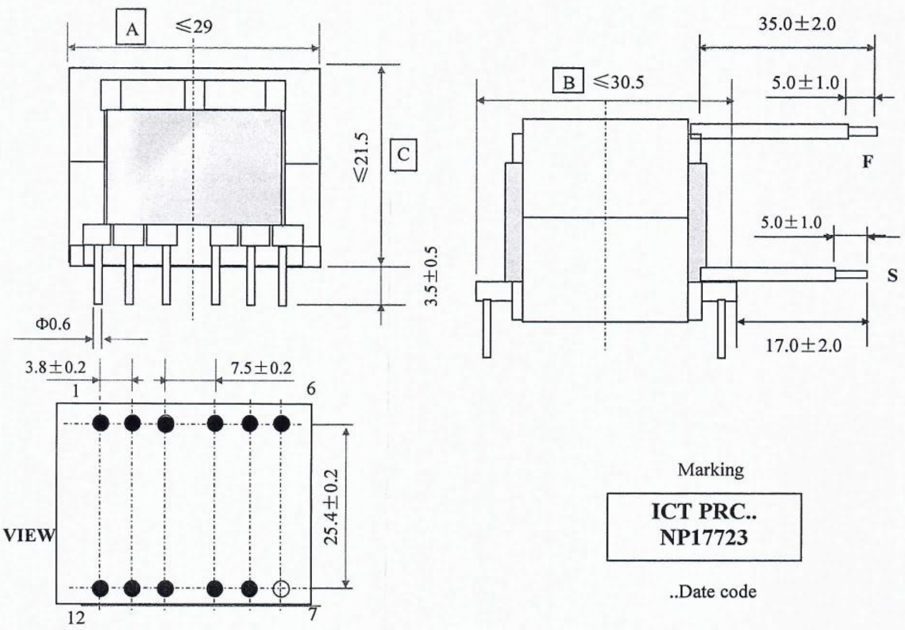
NOTE: copper foil connect pin7

NOTE: if necessory , we can add or remove tubes on all terminals

Figure 31 PFC choke specification of NP2025-19146-A

ICT 珠海科德电子有限公司 INTELLIGENT COMPONENTS TECHNOLOGY ZHUHAI LTD. (CHINA)	CUSTOMER :	INFINEON	Page 2 of 2
	DESCRIPTION:	PQ27/10/19 X'Fmr	
Product Specification	CUSTOMER P/N :		CUSTOMER Rev.:
	CUSTOMER SPEC		CUSTOMER Rev.:
	ICT NPR No. :	NP2024-17723	ICT Rev.: D

MECHANICAL (UNIT: mm)



Marking

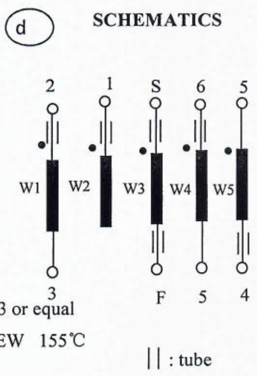
ICT PRC..
NP17723

..Date code

ELECTRICAL SPECIFICATION @25℃

TURNS	W1:W2:W3:W4:W5=22Ts:1layer:5Ts:1Ts:1Ts
L(2-3)	: 180μH±10% @10KHz, 50mV
DCR(2-3)	: 80mΩ Max.
HI-POT	: 3700Vrms (W3 to W1,W2,W4,W5)@50Hz,for 2Sec.
	: 1000Vrms (Wdgsto Core)@50Hz,for 2Sec.

SCHEMATICS



MATERIALS:

BOBBIN	: PQ26,Vertical 1Sec, phenolic
CORE	: PQ27/10/19, FD95 or PG312 or DMR95 or HC95 or TPW33 or equal
WIRE	: (W1)40×Φ0.1mm,(W2)4×Φ0.1mm, (W4,W5)Φ0.3mm , UEW 155℃
WIRE	:(W3)110*Φ0.1mm,triple insulation litz wire
TAPE	: 10.0mm wide, #1350F or CT280
TUBE	: Teflon tube
GLUE	: F121A/B or F330A/B or LO-200A/B
GLUE	: SP2316
VARNISH	: BC-359 or V1630FS or equal

NOTE: if necessary , we can add or remove tubes on all terminals

Rev.	Change history
B	W2 from pin3 adjust to pin 4
C	renew design
D	W2 adjust from pin4 to pin1& add fill glue

Figure 32 Transformer specification of NP2024-17723-D

References

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

[2] Japanese Standards Association *JIS C 61000-3-2 Electromagnetic compability (EMC) Part 3-2: Limits*; Available online

[3] Infineon Technologies AG: *170 W AC-DC converter reference design with wide input for eBike chargers, Engineering Report*; Available online

Revision history

Document revision	Date	Description of changes
V 1.0	2025-07-07	Initial release

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