50 W QR open frame SMPS reference design with VIPERGAN50 and SRK1001

Introduction

The evaluation board implements a robust adapter with output overvoltage, output undervoltage, output over power, and output short-circuit protection. This reference design is based on STMicroelectronics semiconductors and helps designers develop adapters with a reduced bill of materials for a cost-effective and rapid design.

This document describes the STDES-VPGAN50FL 15 V/50 W SMPS with 176–265 VAC input voltage range, set in isolated quasi-resonant (QR) flyback topology with secondary side regulation (SSR) and the following characteristics:

- Peak efficiency: >94.5%
- Input power consumption in no load condition: <100 mW @ 230 VAC
- Compliant with IEC55022 Class B conducted EMI, even with reduced EMI filter
- RoHS compliant

The evaluation board has been developed using the advanced new VIPERGAN50 offline switcher by ST, with the following features:

- 650 V PowerGaN with embedded senseFET (Si) and HV startup
- QR operation with dynamic blanking time and adjustable valley synchronization delay functions to maximize efficiency at any input line and load condition
- Valley-lock to ensure constant valley skipping
- Input voltage feedforward compensation for mains-independent OPP intervention
- Adaptive burst mode for advanced power management in light load conditions
- Frequency jittering for EMI suppression

Enhanced system reliability is ensured by the built-in soft-start function and the following set of protections:

- Input OVP (settable)
- Brown-in and brown-out (settable)
- Output OVP (settable)
- Output overload
- OCP LEB
- Embedded thermal shutdown

1 Overview

The main features of the STDES-VPGAN50FL are:

- Input voltage: universal AC 176 to 265 VAC with 47 to 63 Hz frequency
- Output voltage: 12 VDC
- Output power: 12 V, 4.15 A, 50 W max.
- Form factor (LxWxH): 107.7 x 68.4 x 20 mm
- Efficiency: peak efficiency >94.5%
- Quasi-resonant operation (QR) with dynamic blanking time and adjustable valley synchronization delay functions to maximize efficiency at any input line and load condition
- Integrated GaN IC, the VIPERGAN50, allowing a compact and simplified PCB layout and bill of material reduction
- AC-DC for openframe

Figure 1. STDES-VPGAN50FL top view

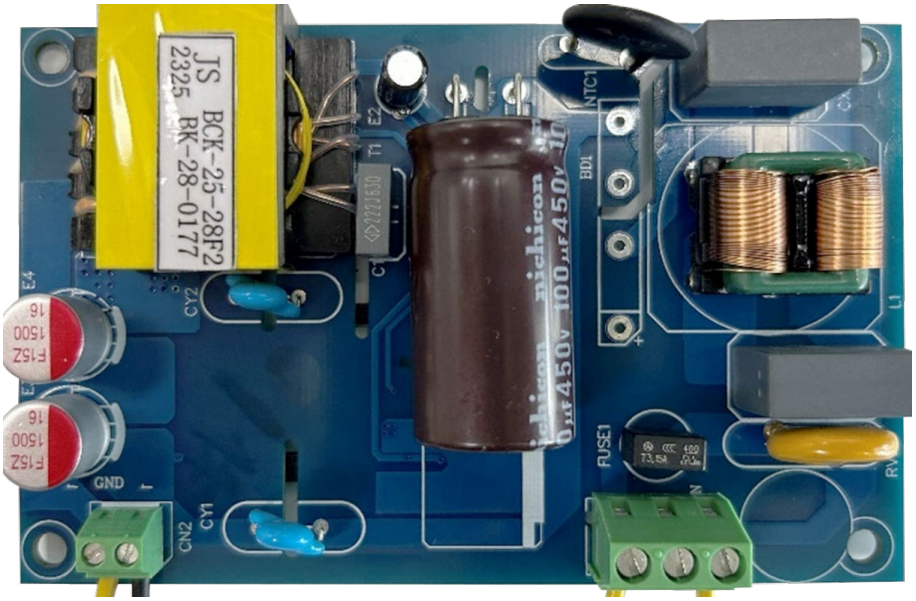
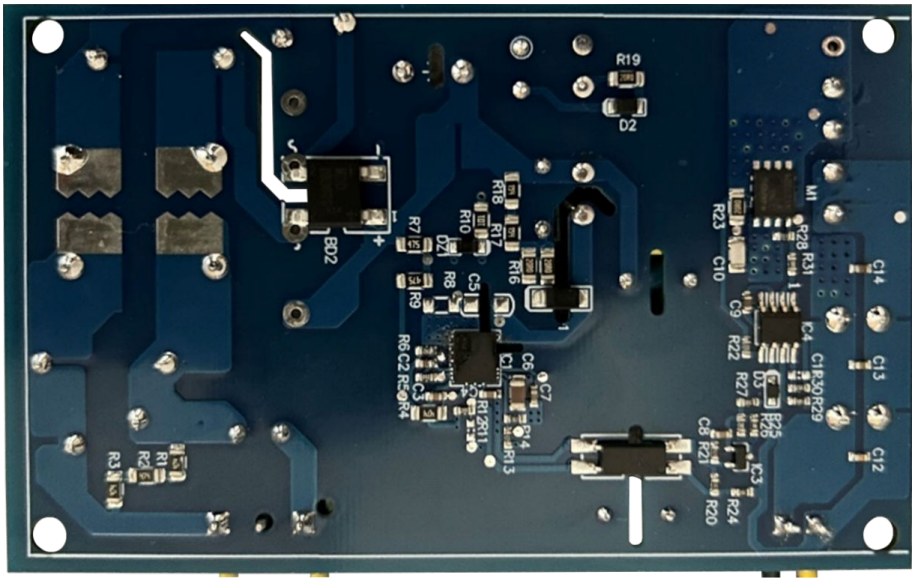


Figure 2. STDES-VPGAN50FL bottom view



2 Specifications

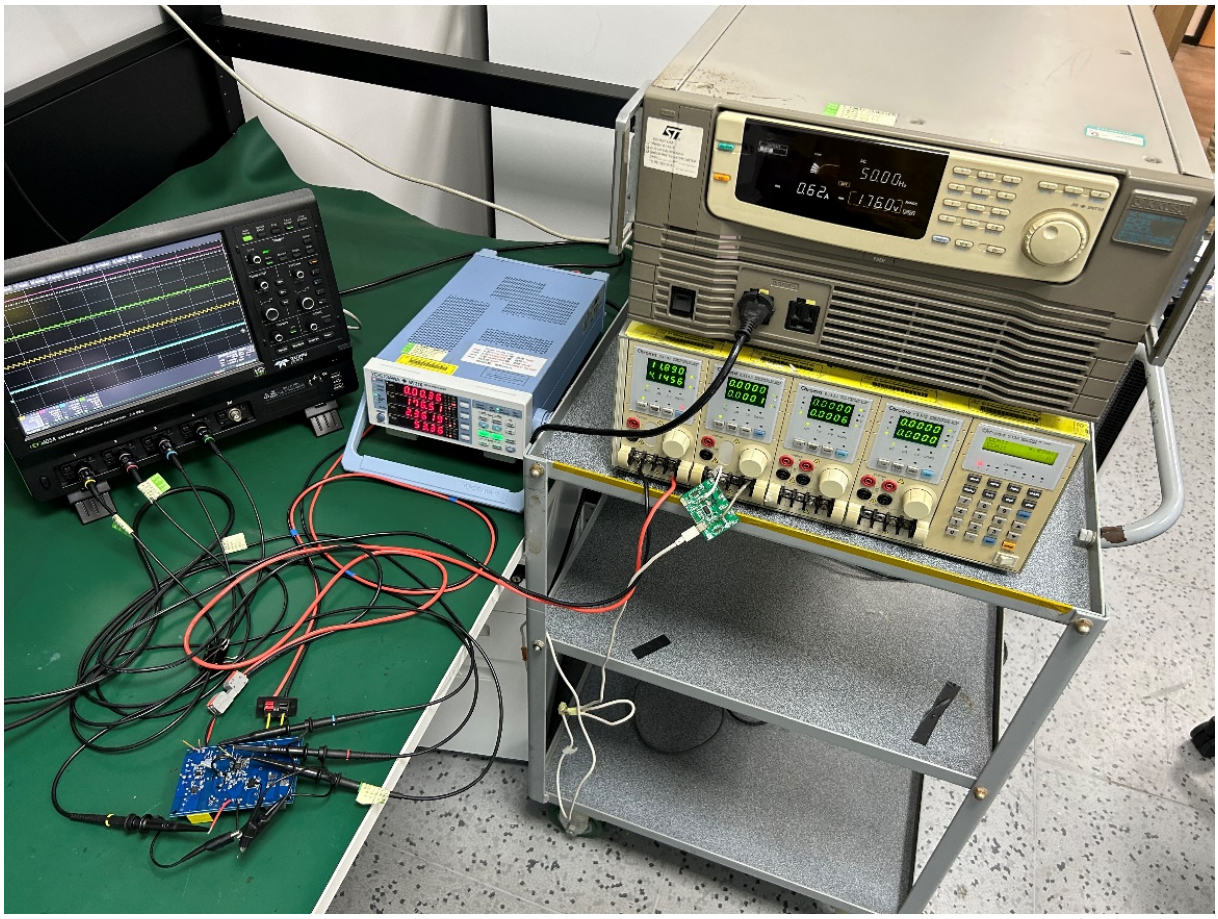
Table 1. STDES-VPGAN50FL electrical specifications

Symbol	Parameter	Test conditions	Min.	Nominal	Max.	Unit
Input parameters						
V_{IN}	Input line voltage		176	230	265	Vrms
f_{LINE}	Input line frequency		47	50/60	63	Hz
P_{STBY}	No load input power	V_{IN}=176V_{RMS} V_{IN}=230V_{RMS}	64	98		mW
Output parameters						
V_{OUT}	Output voltage	V_{IN}=176V_{RMS}~ 264V_{RMS} I_{OUT}= 0A~ 4.15A		12		V
V_{ripple}	Output voltage ripple	Peak to peak value with 20 MHz bandwidth		110		mV
I_{out}	Output current		0		4.15	A
P_{out}	Continuous output power		0		50	W
η	Efficiency at 50 W	V_{IN}=176 Vac	93.59	94.34	94.86	%
		V_{IN}=230 Vac	92.65	94.27	95.06	

3 Test setup

- 1 x STDES-VPGAN50FL reference design board
- 1 x Chroma AC power supply PCR 500L
- 1 x Chroma 6334 high speed DC load mainframe
- 1 x power analyzer YOKOGAWA WT310
- 1 x mixed signal oscilloscope TELEDYNE LECROY HDO4034
- Ambient temperature = 25°C

Figure 3. STDES-VPGAN50FL test setup



4 Measurements, waveforms, and test data

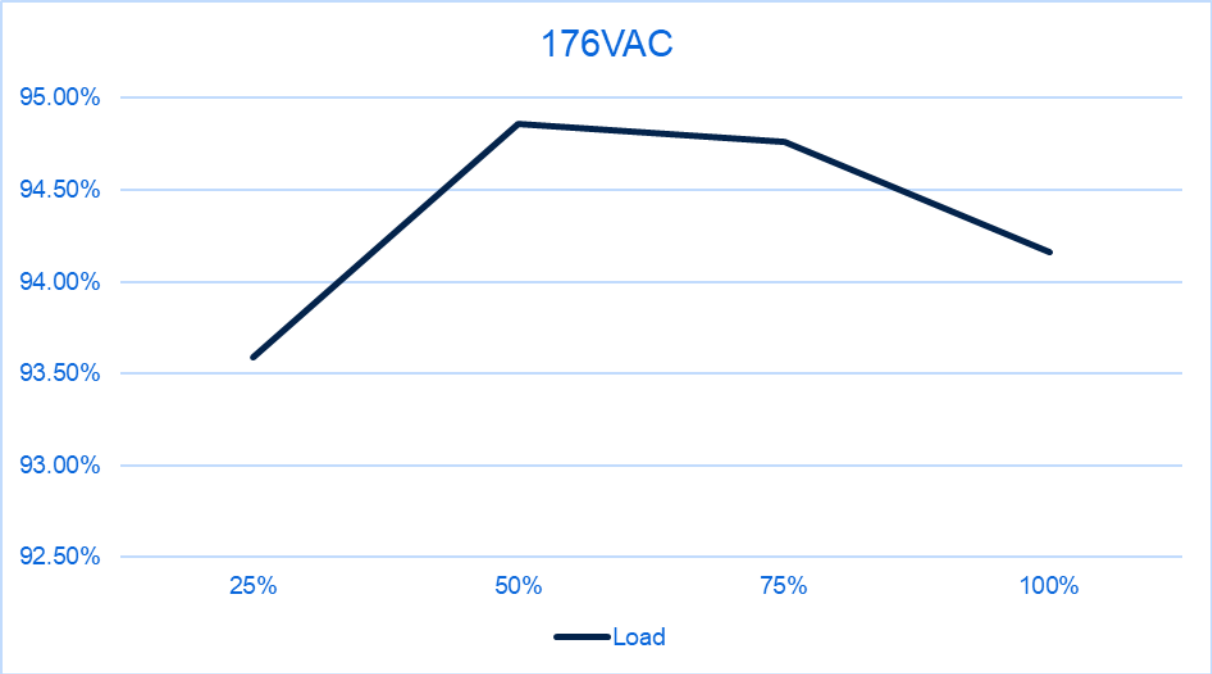
4.1 Efficiency test results

4.1.1 Efficiency at 176 VAC input

Table 2. STDES-VPGAN50FL efficiency at 176 VAC input

Condition	% of full loading	Efficiency
176 V_{AC} 50 Hz input	25 (1.042 A)	93.59%
	50 (2.075 A)	94.86%
	75 (3.108 A)	94.76%
	100 (4.157 A)	94.16%
Four-point average result		94.34%

Figure 4. STDES-VPGAN50FL efficiency at 176 VAC input

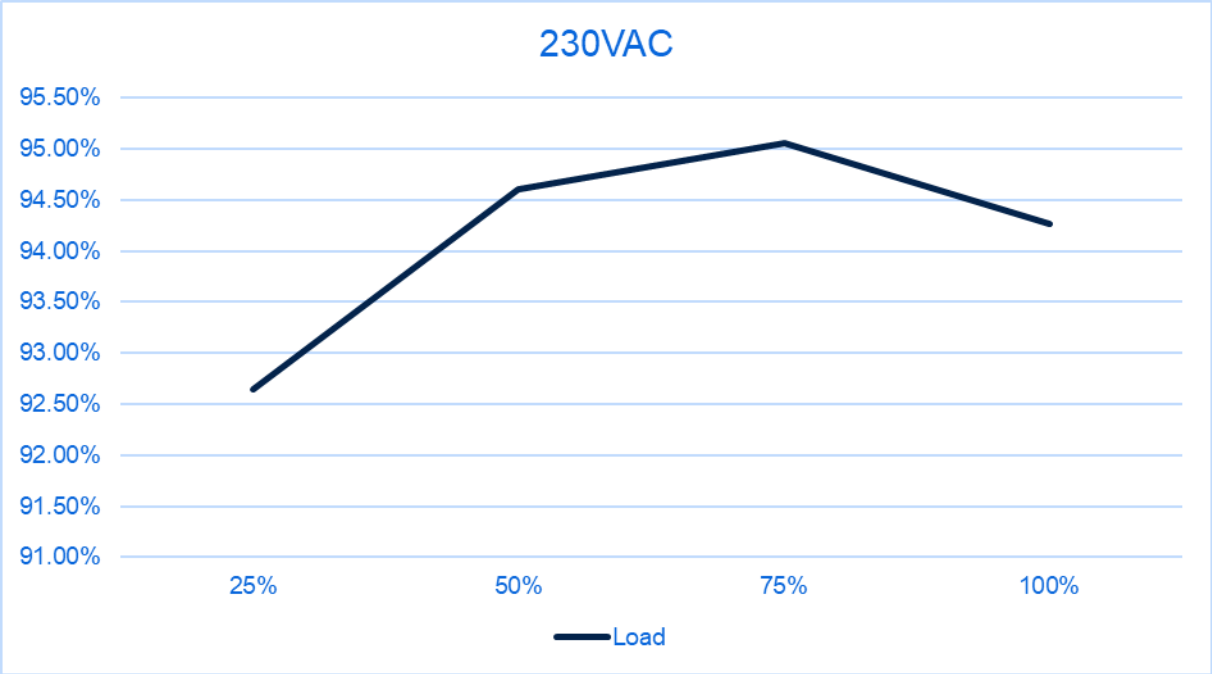


4.1.2 Efficiency at 230 VAC input

Table 3. STDES-VPGAN50FL efficiency at 230 VAC input

Condition	% of full loading	Efficiency
230 VAC 50 Hz input	25 (1.042 A)	92.65%
	50 (2.075 A)	94.60%
	75 (3.108 A)	95.06%
	100 (4.157 A)	94.77%
Four-point average result		94.27%

Figure 5. STDES-VPGAN50FL efficiency at 230 VAC input



4.1.3 Standby power consumption

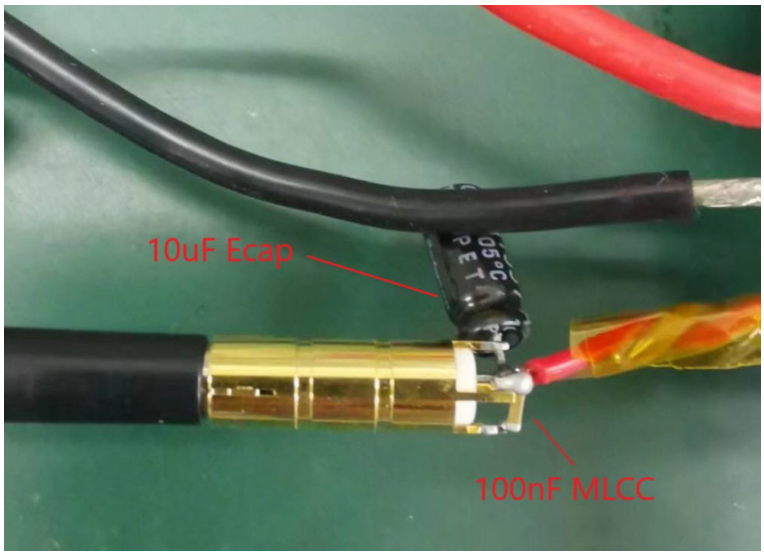
Table 4. Standby power consumption

VIN (V_{AC})	P (mW)
176	64
230	98

4.2 Ripple and noise

4.2.1 V_{OUT} ripple & noise test setup: test at the end of PCB

Figure 6. Ripple & noise test setup probe with 10 µF electrolytic capacitor and 100 nF ceramic capacitor



4.2.2 Ripple & noise results

Figure 7. Ripple and noise at 176 VAC input with full load, Vpeak-peak = 110 mV (1 of 2)

CH1 V_{OUT}

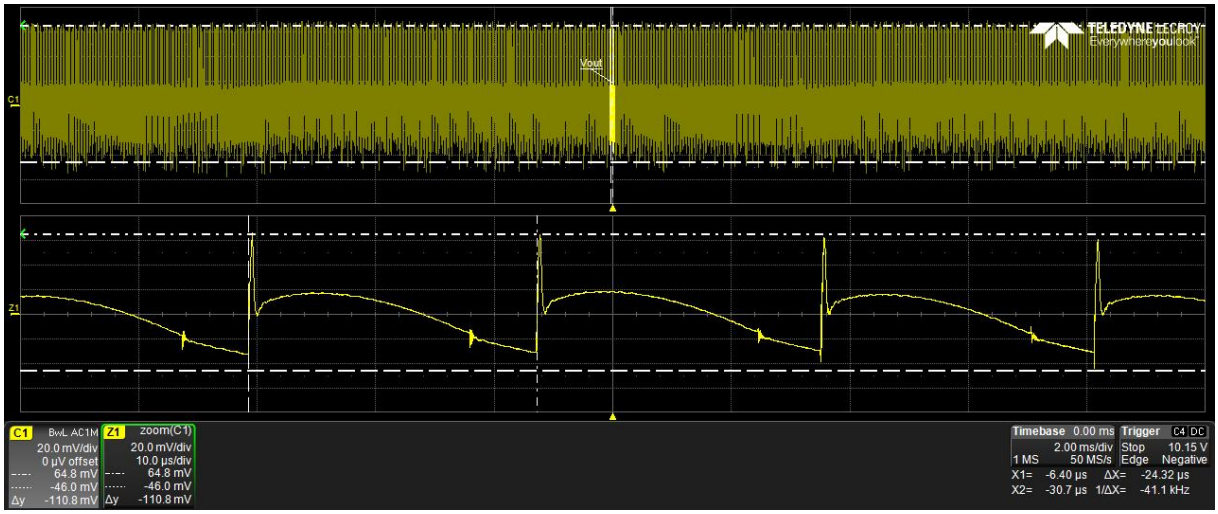
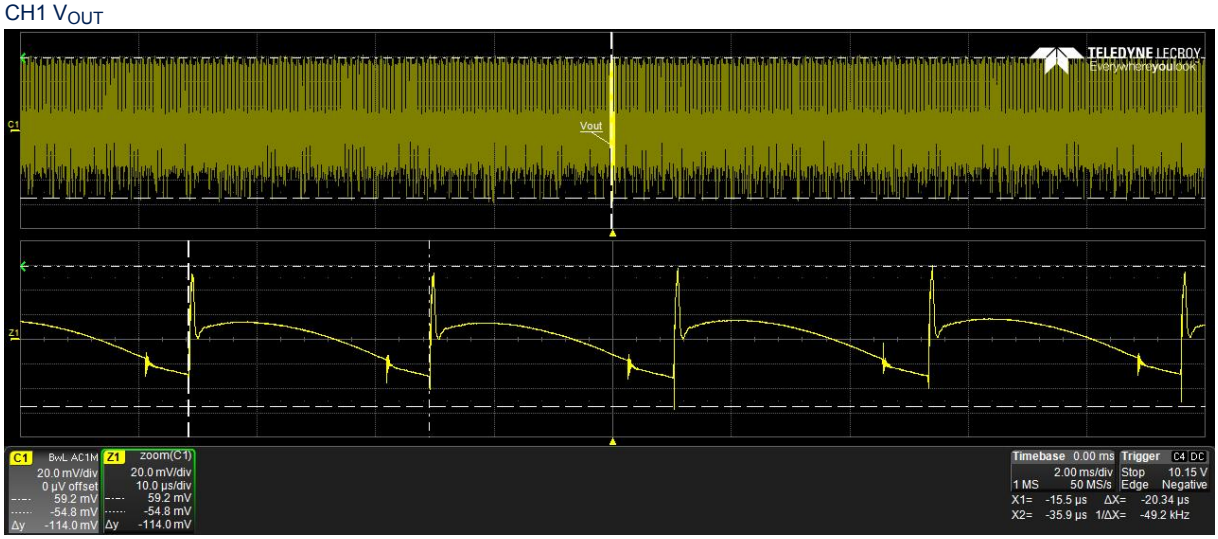


Figure 8. Ripple and noise at 230 VAC input with full load, Vpeak-peak = 114 mV (2 of 2)

CH1 V_{OUT}



4.3 Typical waveforms

4.3.1 Startup waveforms

Figure 9. Startup waveforms at 176 Vac 4.15 A

CH1-V_{BUS} CH2-V_{GS} CH3-V_{OUT} CH4-V_{DS}

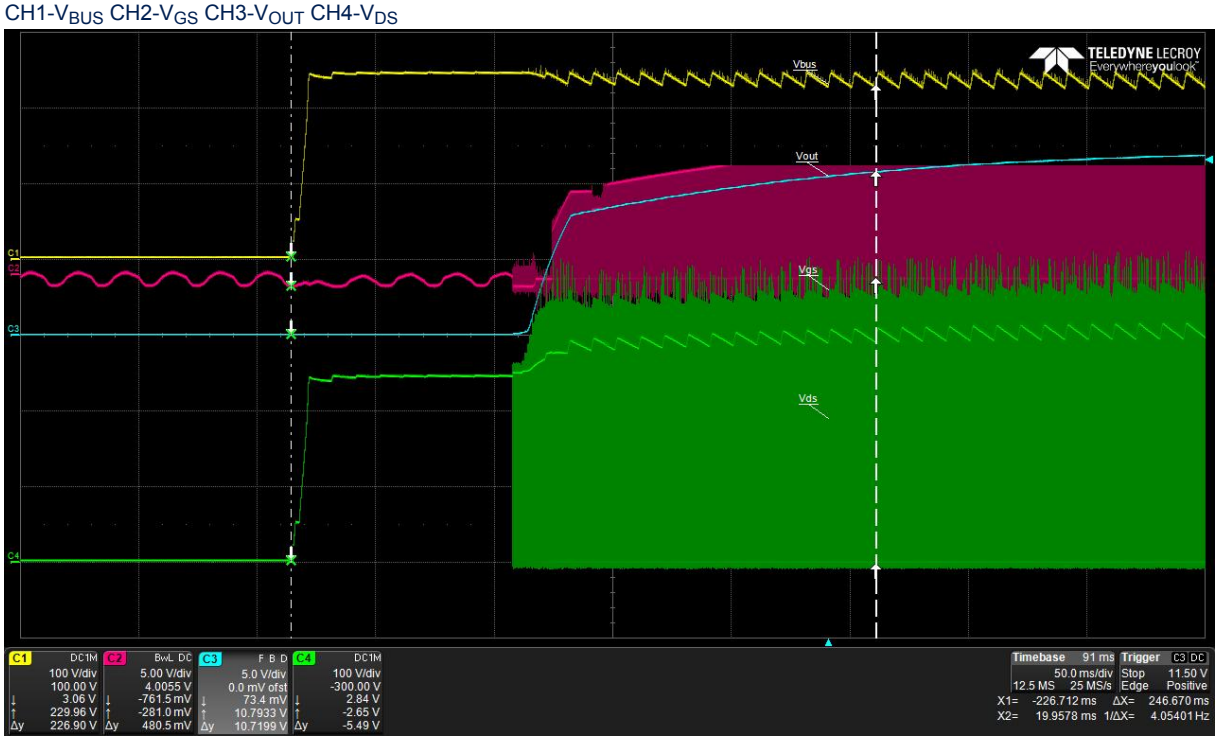
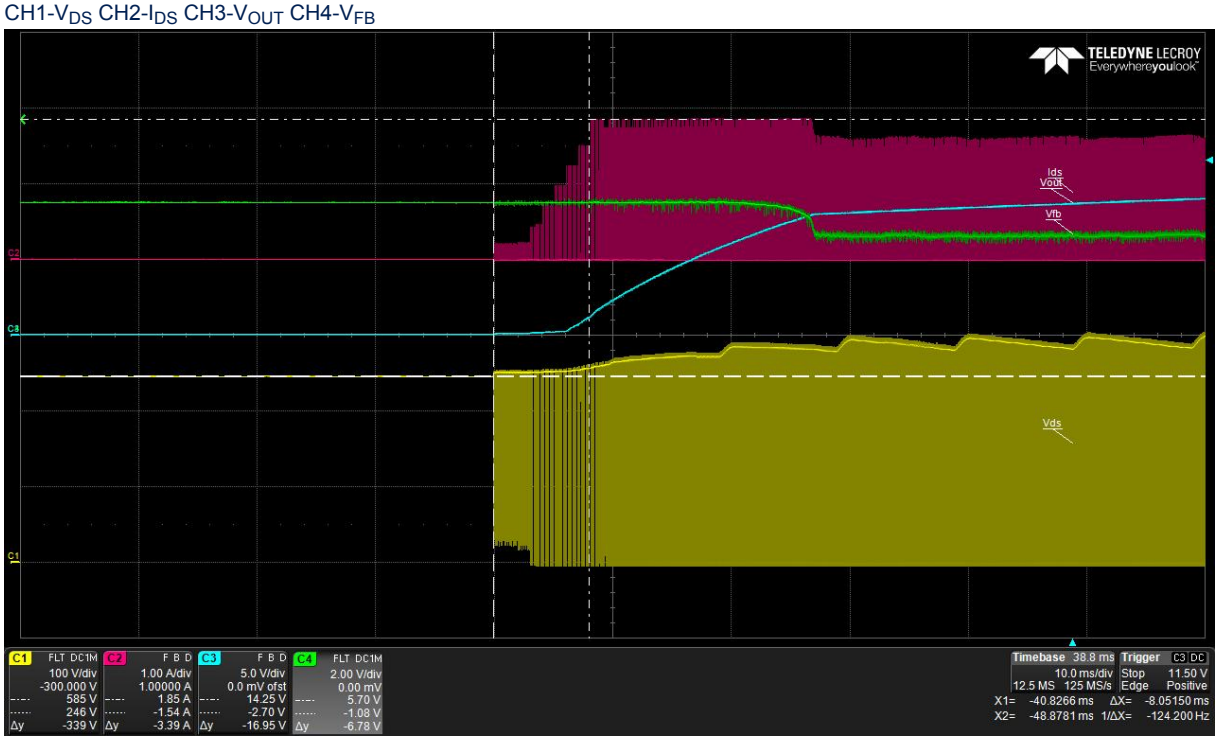


Figure 10. Soft-start waveforms at 176 Vac 4.15 A

CH1-V_{DS} CH2-I_{DS} CH3-V_{OUT} CH4-V_{FB}



4.3.2 Normal operation waveform

Figure 11. Primary side typical waveforms, normal operation with 230 VIN 12 VOUT/half load 2.075 A

CH1-V_{DS} CH2-I_{DS}

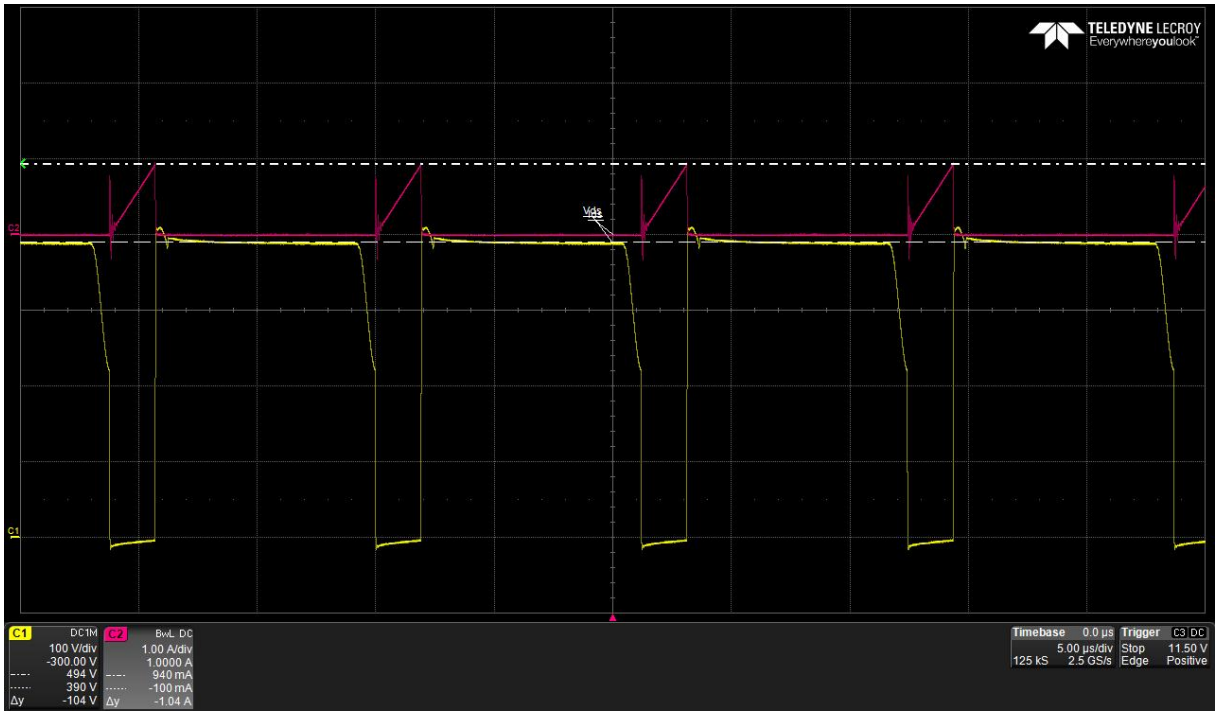


Figure 12. Primary side typical waveforms, normal operation with 230 VIN 12 VOUT/full load 4.15 A

CH1-V_{DS} CH2-I_{DS}

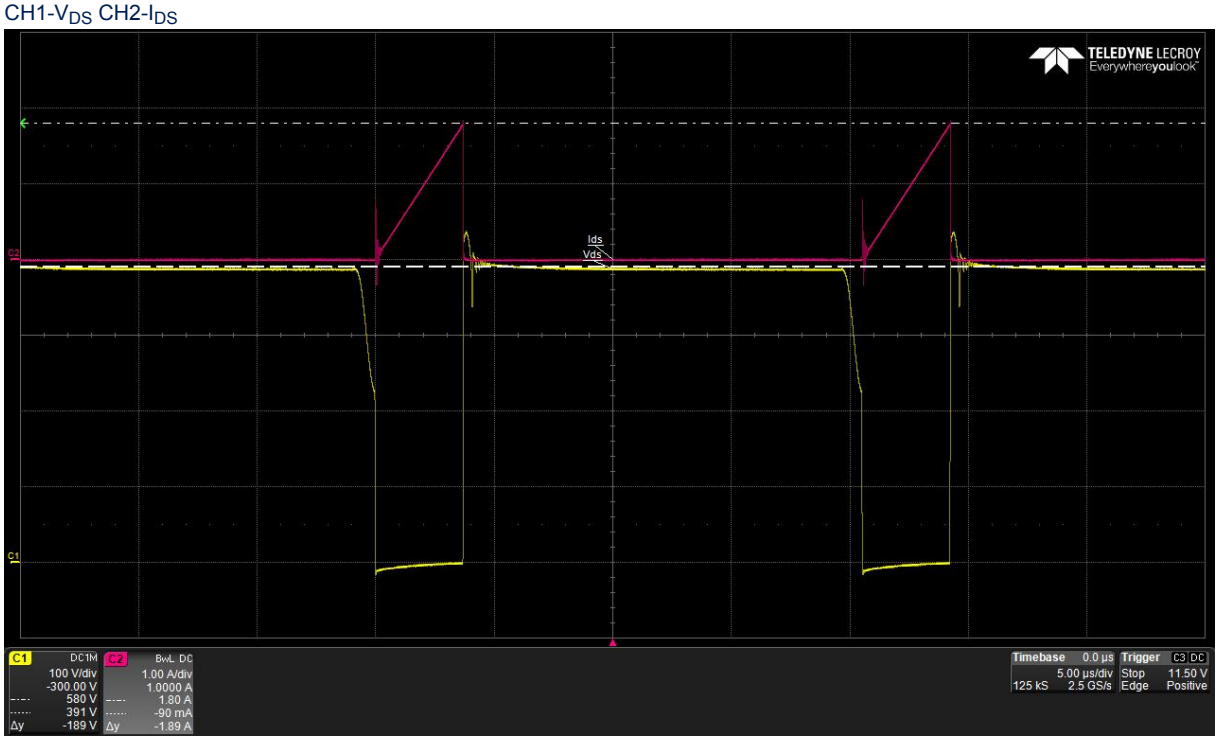
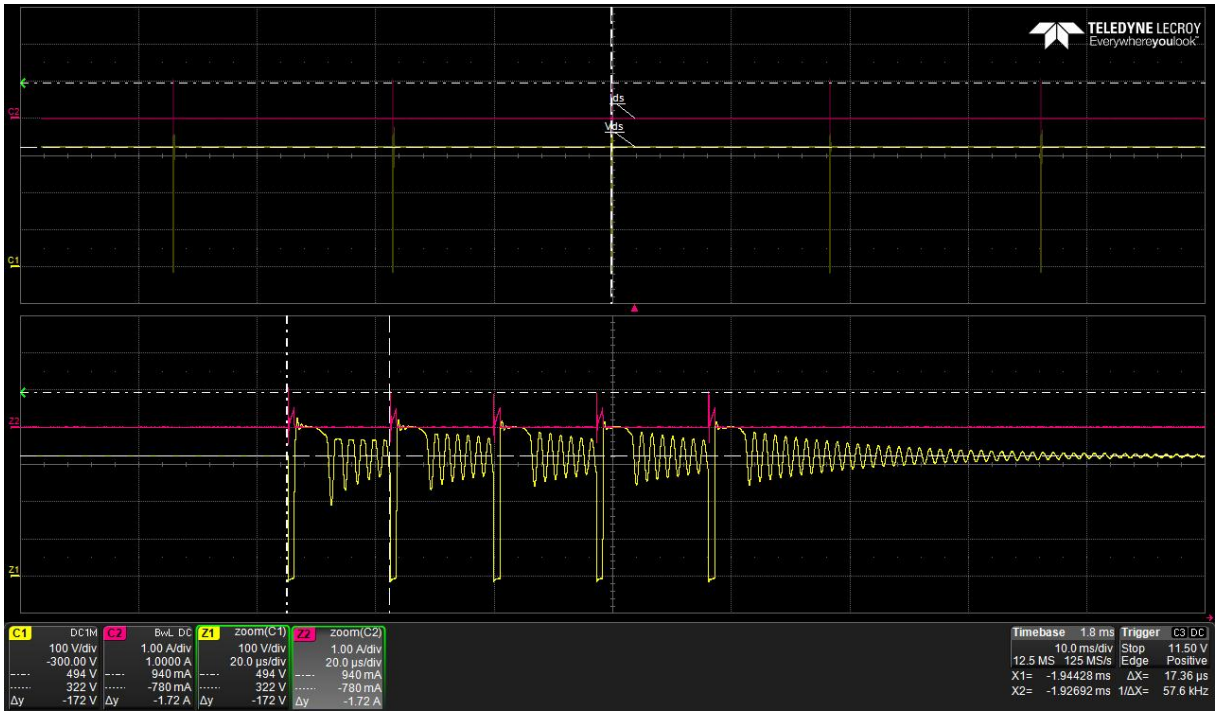


Figure 13. Primary side typical waveforms, normal operation with 230 VIN 12 VOUT/no load 0 A

CH1-V_{DS} CH2-I_{DS}



4.3.3 Short-circuit protection

Figure 14. Output short-circuit

CH1-V_{DD} CH2-I_{DRAIN} CH3-V_{OUT} CH4-V_{FB}

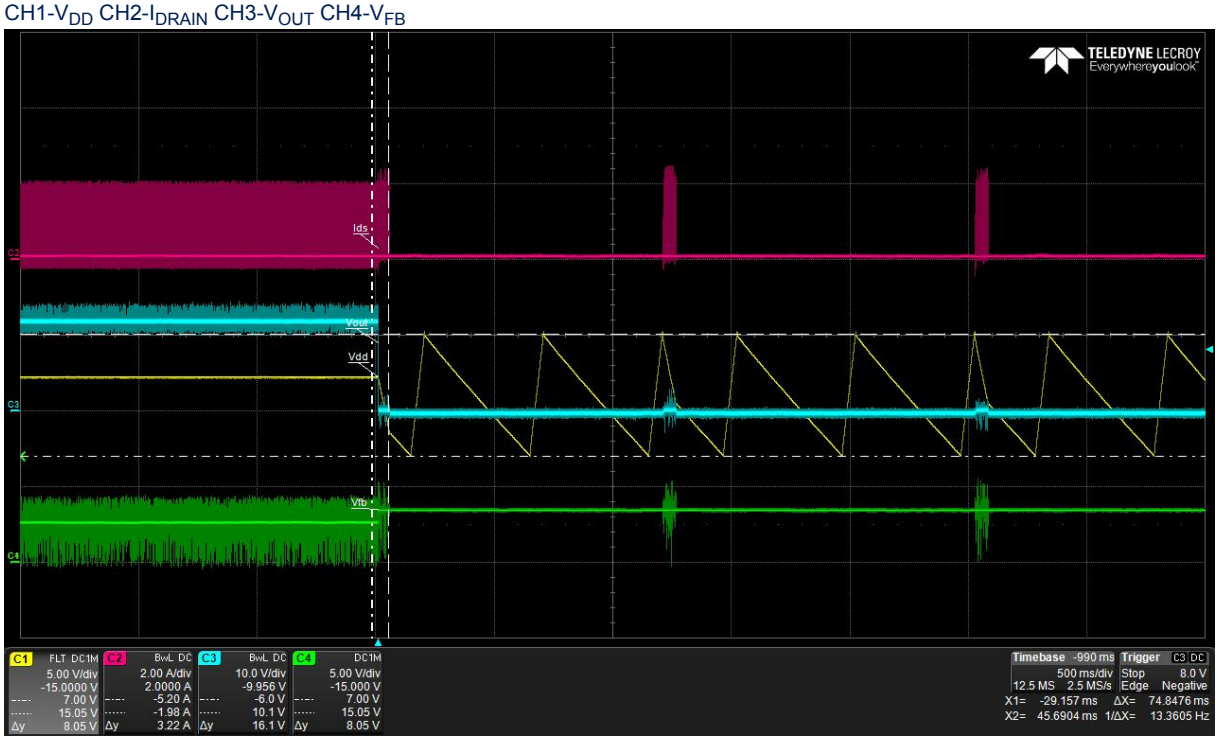
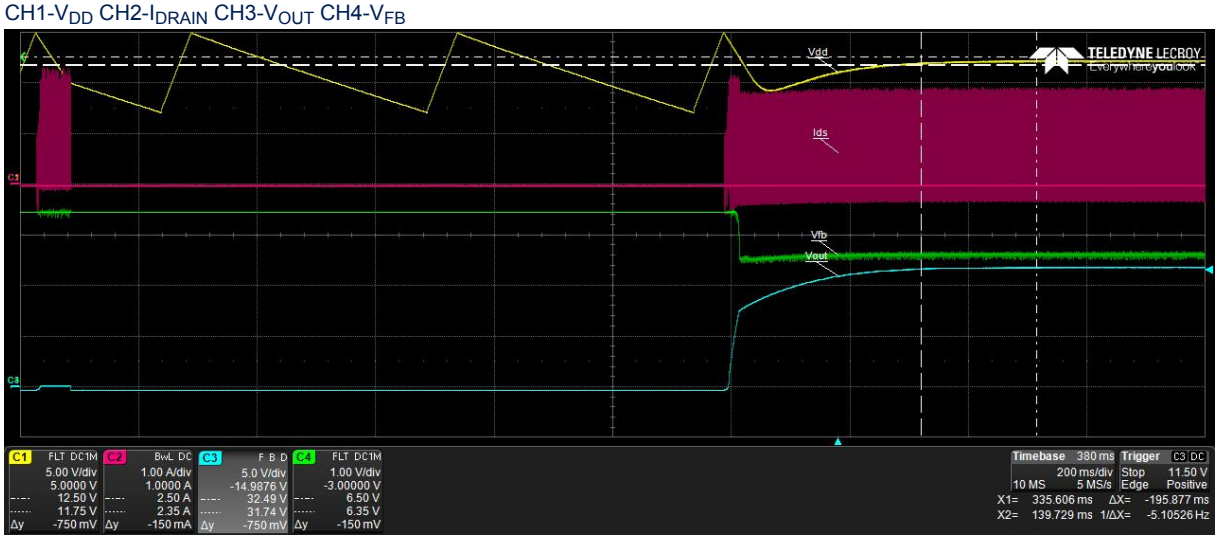


Figure 15. Output short-circuit removed and IC restart

CH1-V_{DD} CH2-I_{DRAIN} CH3-V_{OUT} CH4-V_{FB}



4.3.4 Input OVP

Figure 16. VIN = 265–285 VAC, input OVP triggered

CH1-V_{BUS} CH2-V_{OUT} CH3-V_{DD} CH4-V_{iOVP}

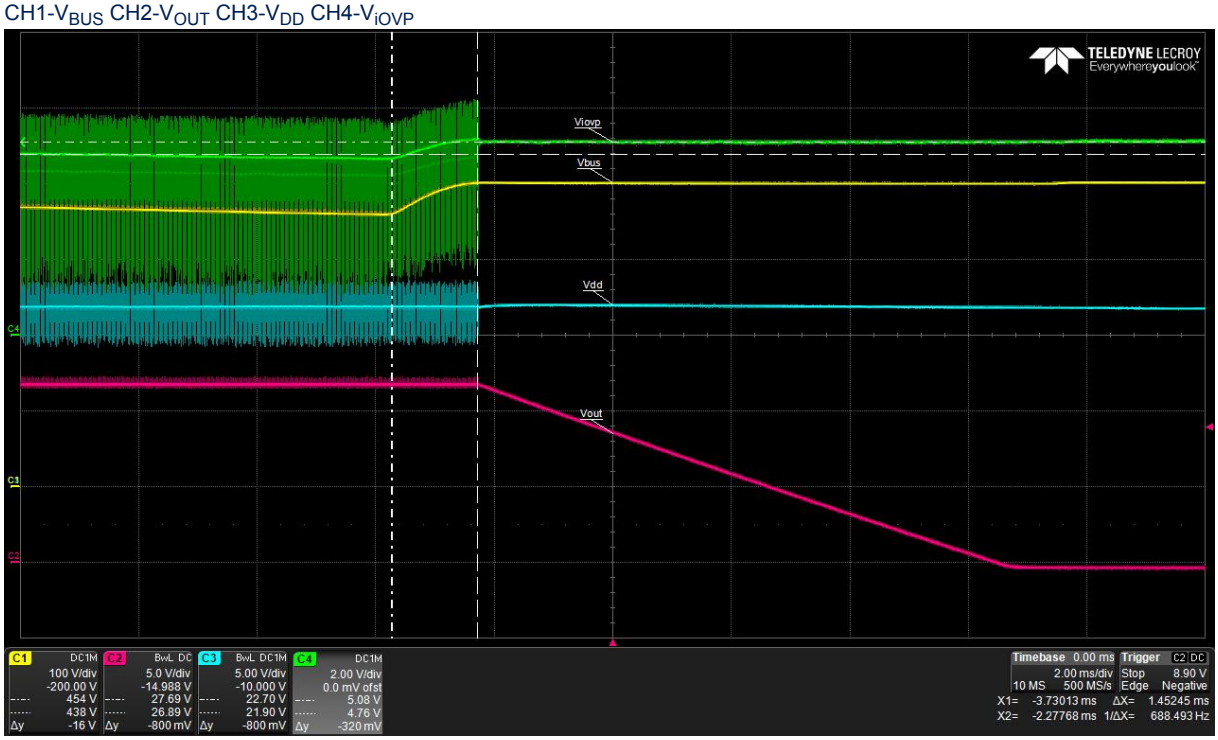
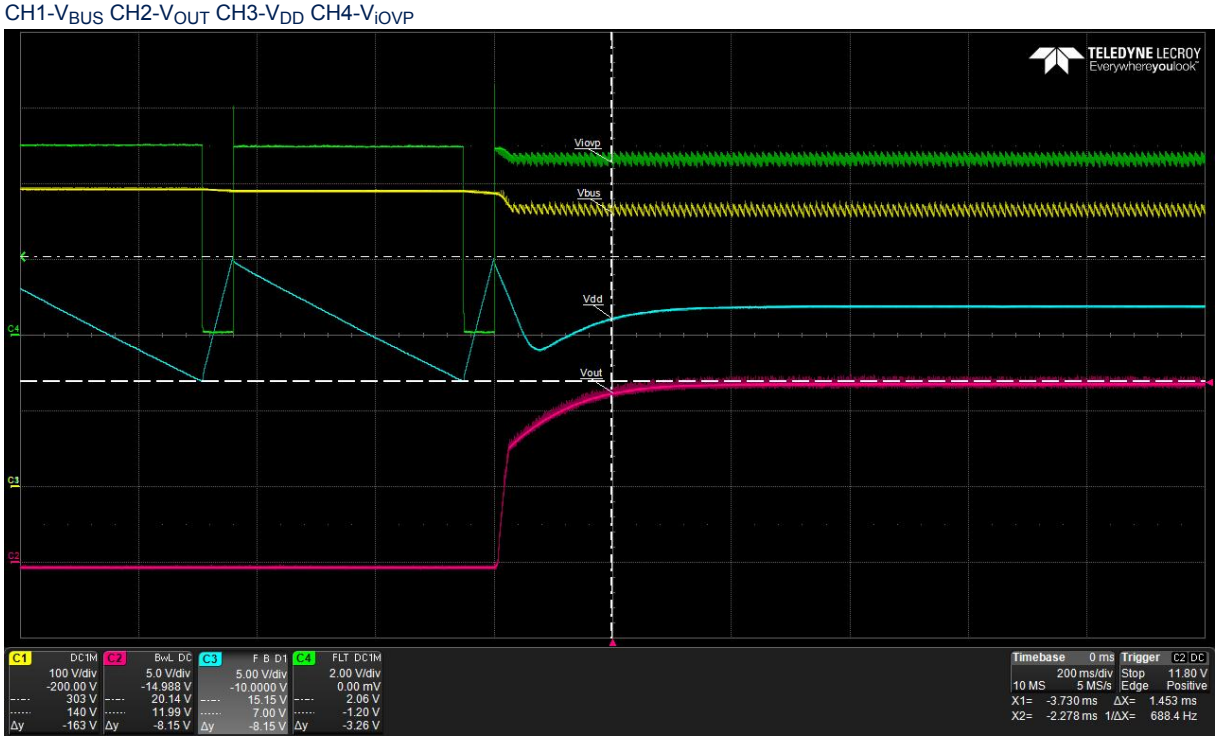


Figure 17. VIN = 285–265 VAC, input OVP removed and normal operation restored

CH1-V_{BUS} CH2-V_{OUT} CH3-V_{DD} CH4-V_{iOVP}



4.3.5 Brown-out/-in protection

Figure 18. VIN = 176–120 Vac, brown-out triggered and IC stop

CH1-V_{BUS} CH2-V_{DD} CH3-V_{ZCD} CH4-V_{BR}

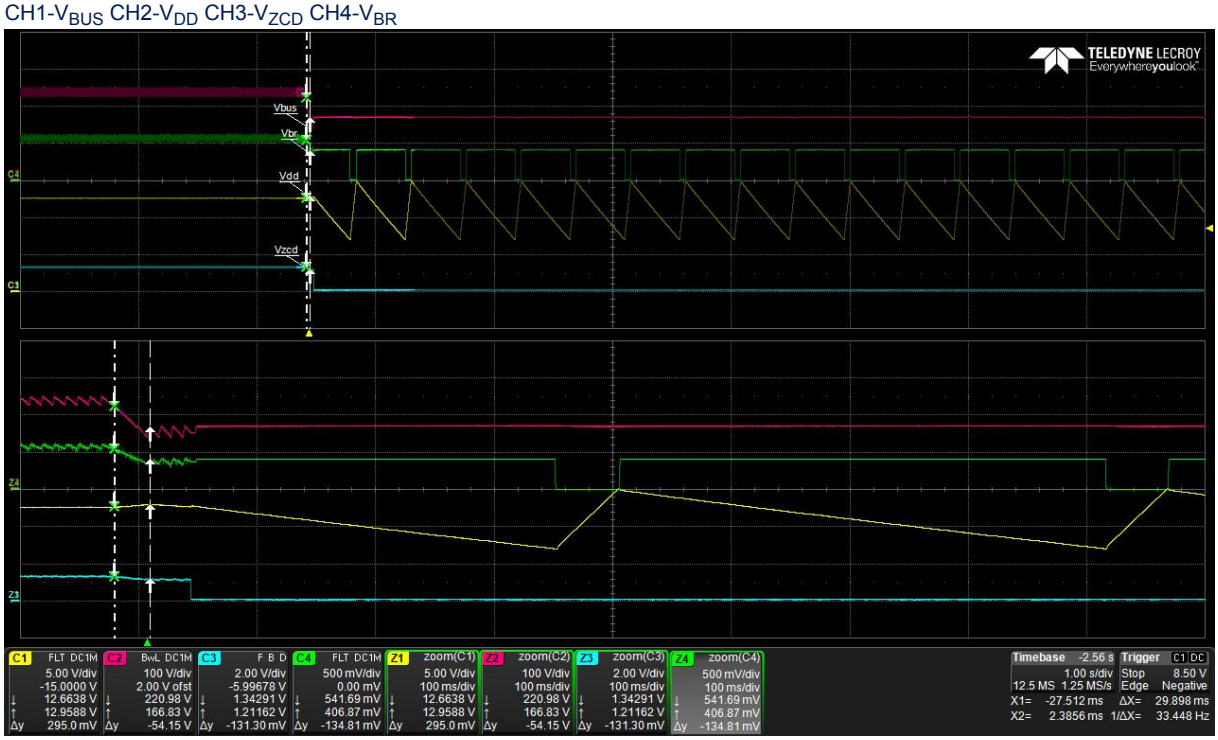
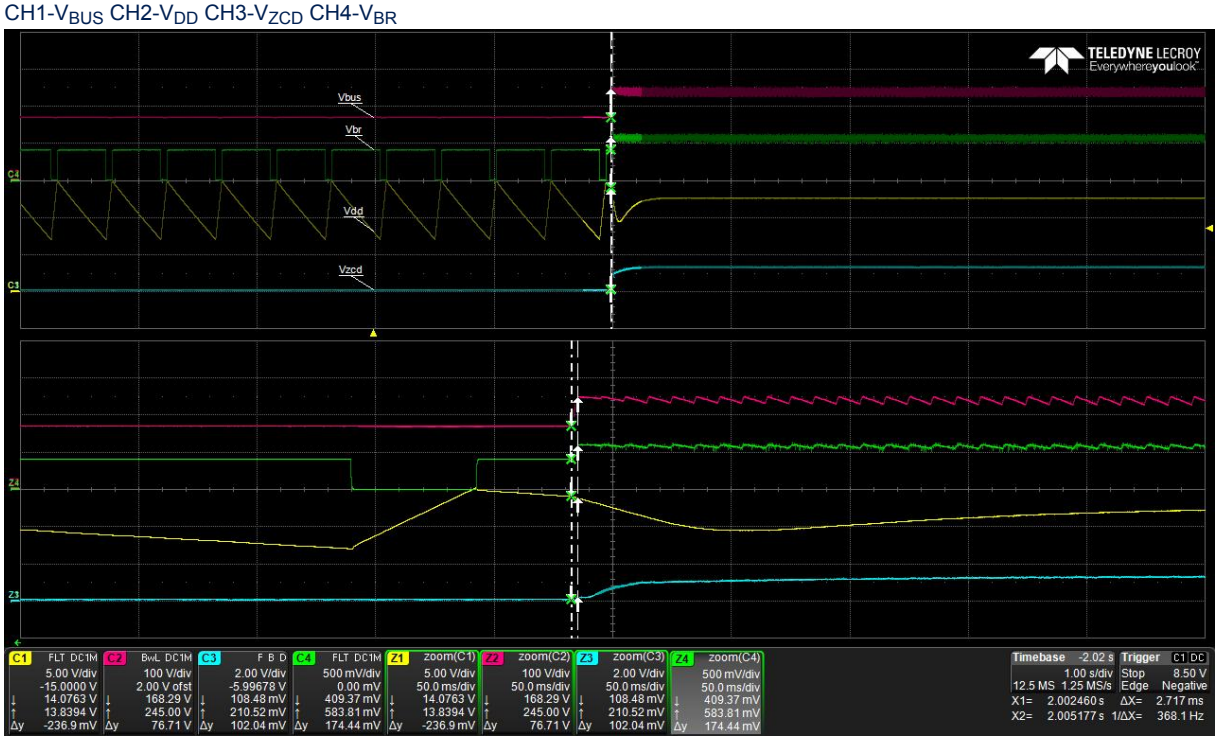


Figure 19. VIN =120–176 VDC, brown-in triggered and IC start

CH1-V_{BUS} CH2-V_{DD} CH3-V_{ZCD} CH4-V_{BR}



4.3.6 Output OVP

Figure 20. OVP IC stop

CH1-V_{FB} CH2-V_{OUT} CH3-V_{DD} CH4-V_{ZCD}

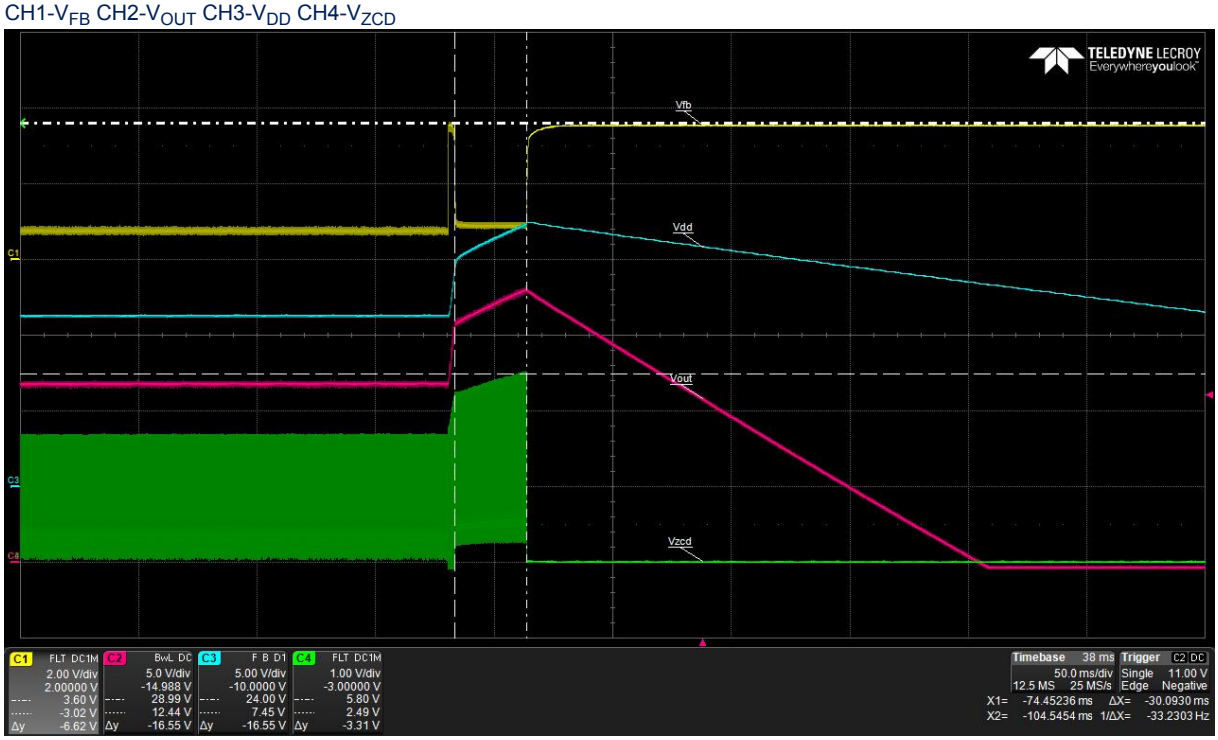


Figure 21. OVP at turn-on

CH1-V_{FB} CH2-V_{OUT} CH3-V_{DD} CH4-V_{ZCD}

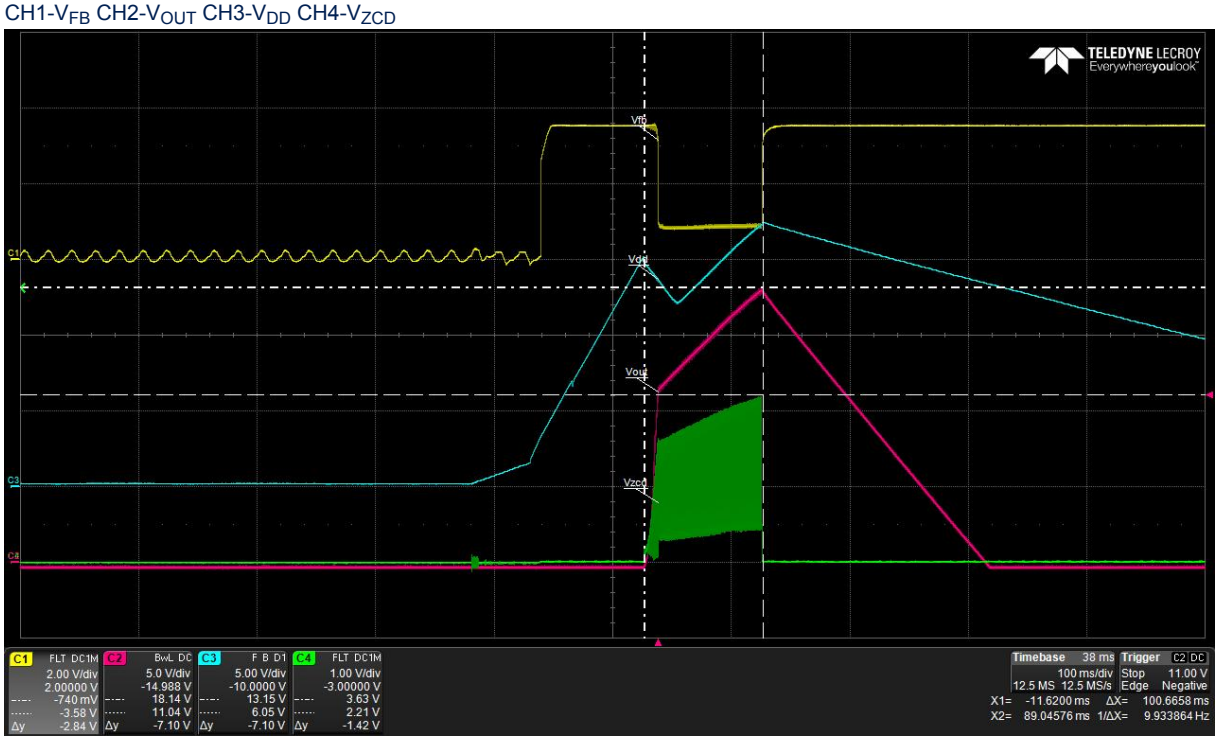
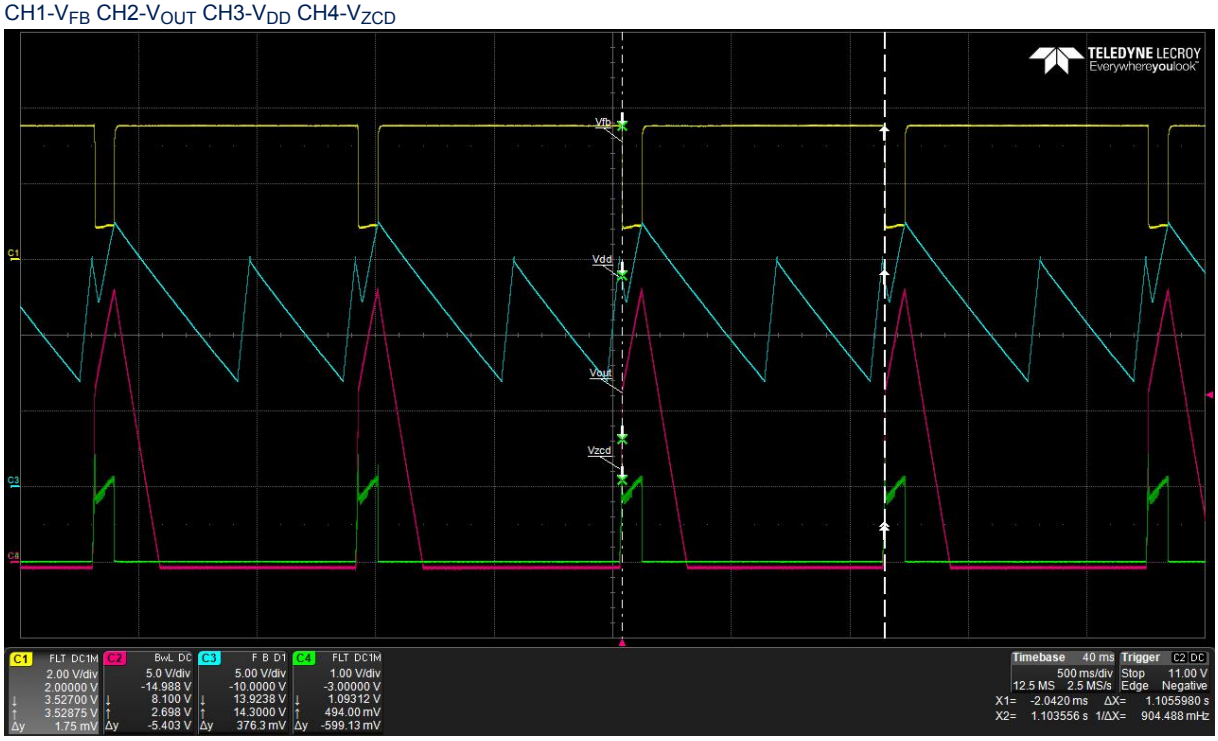


Figure 22. OVP steady-state, TRESTART

CH1-V_{FB} CH2-V_{OUT} CH3-V_{DD} CH4-V_{ZCD}



4.3.7 No-load and full-load switching waveforms

Figure 23. Full-load to no-load 230 Vac

CH1-V_{DS} CH2-V_{DD} CH3-V_{OUT}CH4-I_{DS}

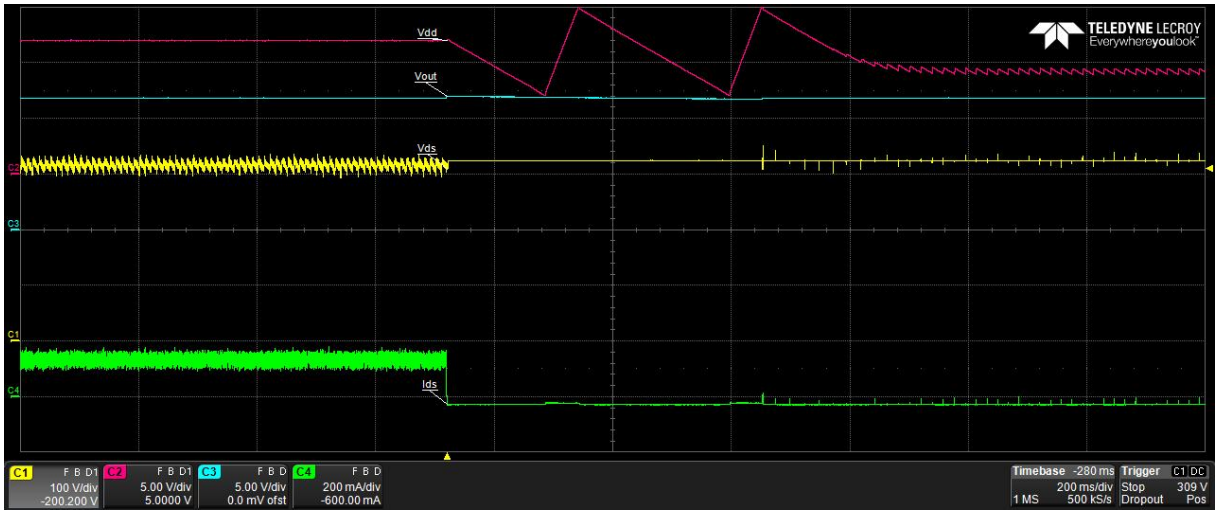
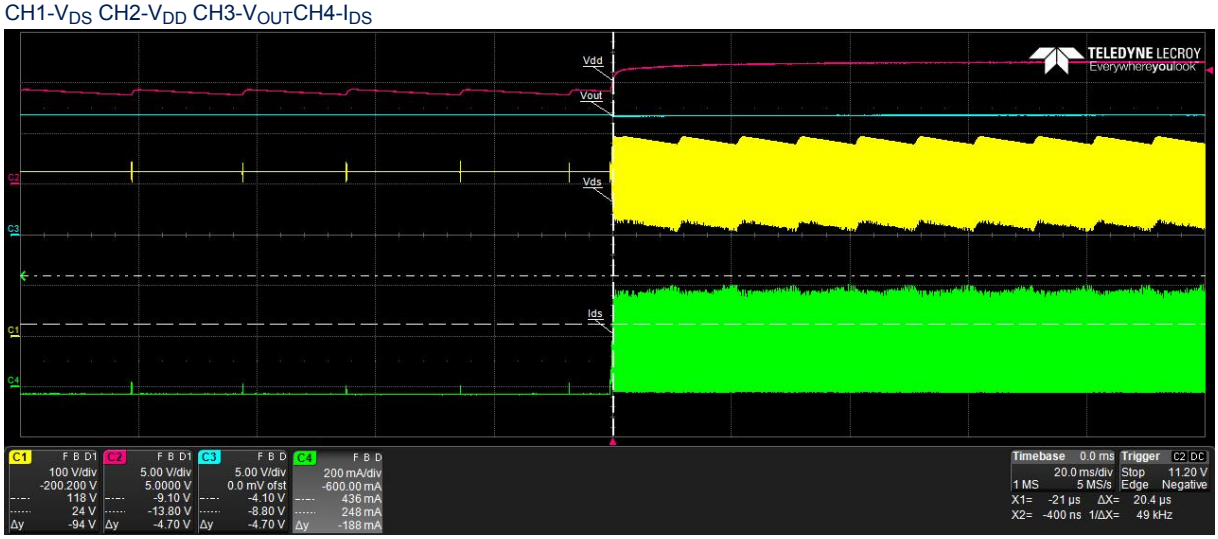


Figure 24. No-load to full-load 230 Vac

CH1-V_{DS} CH2-V_{DD} CH3-V_{OUT}CH4-I_{DS}



4.4 Thermal performance

Figure 25. Key component thermals at 12 V/4.15 A:176 VAC input, top

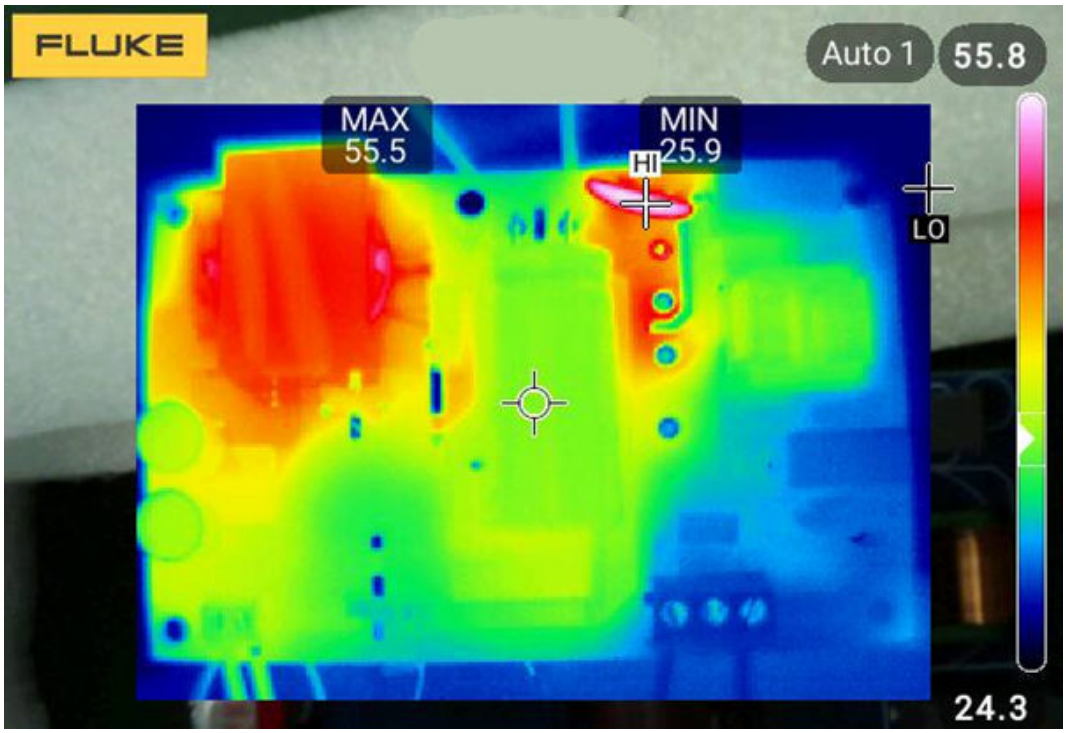


Figure 26. Key component thermals at 12 V/4.15 A:230 VAC input, top

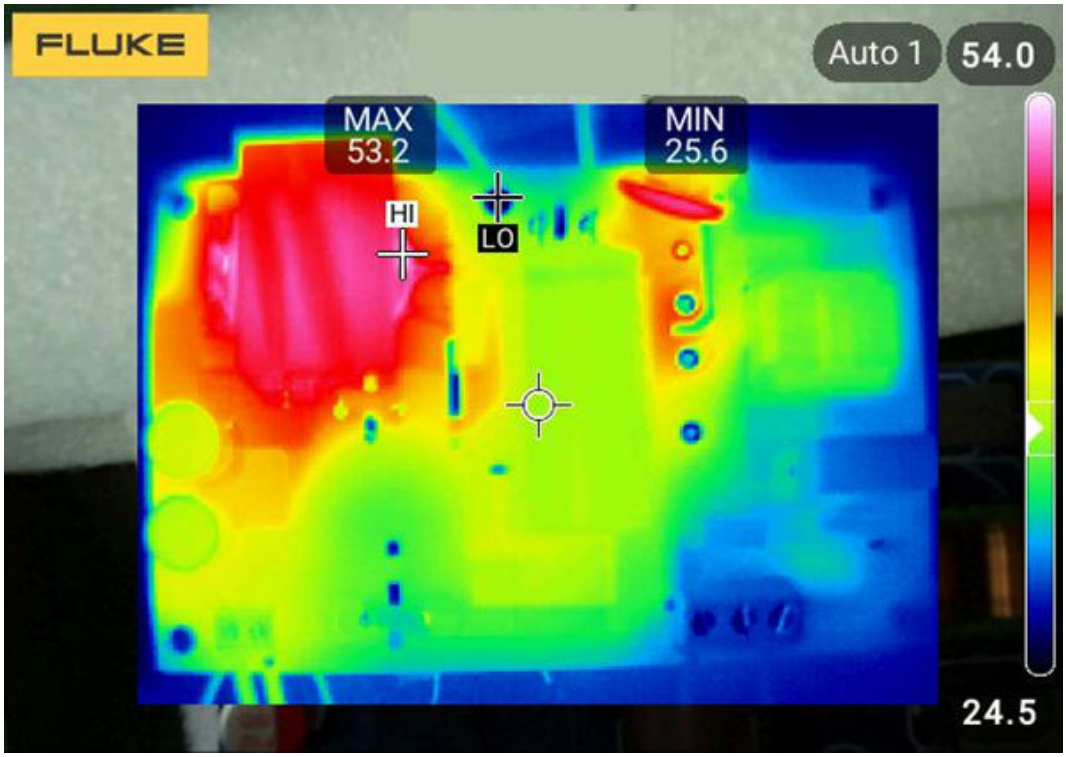


Figure 27. Key component thermals at 12 V/4.15 A:176 VAC input, bottom

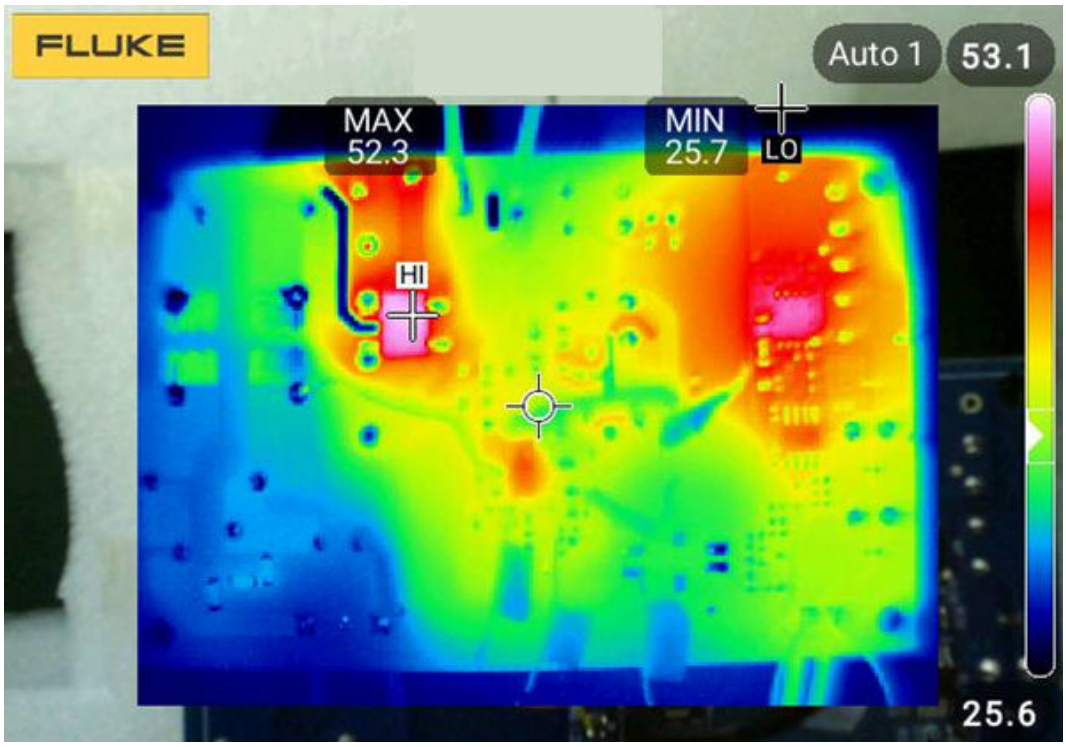
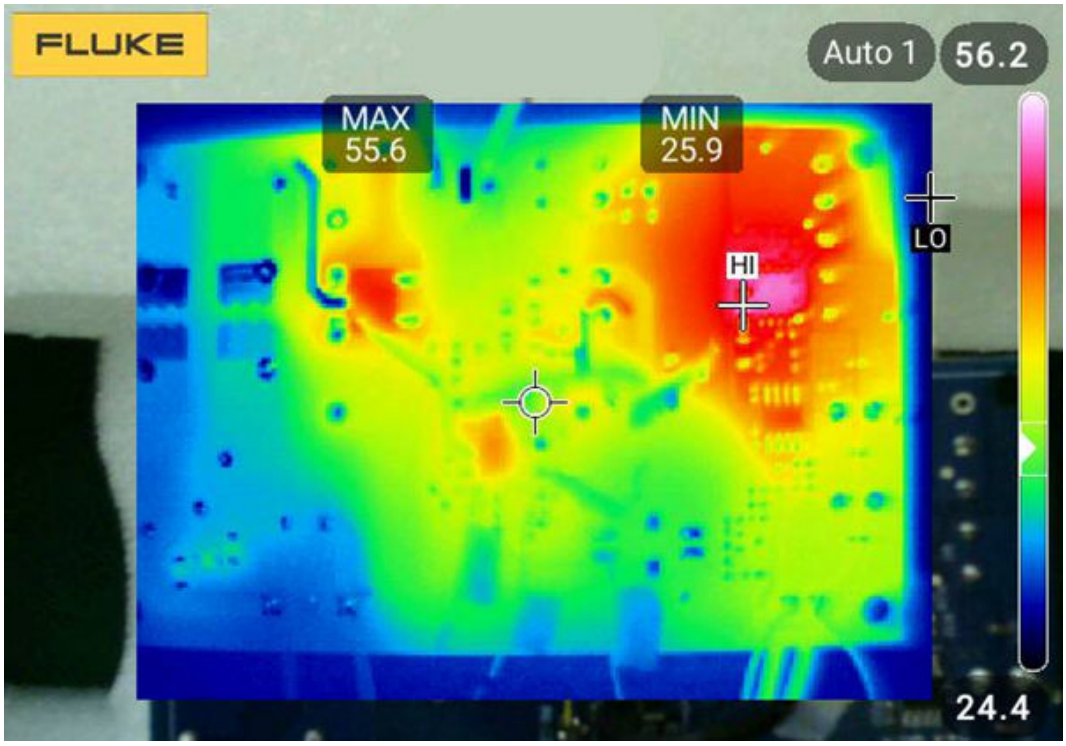
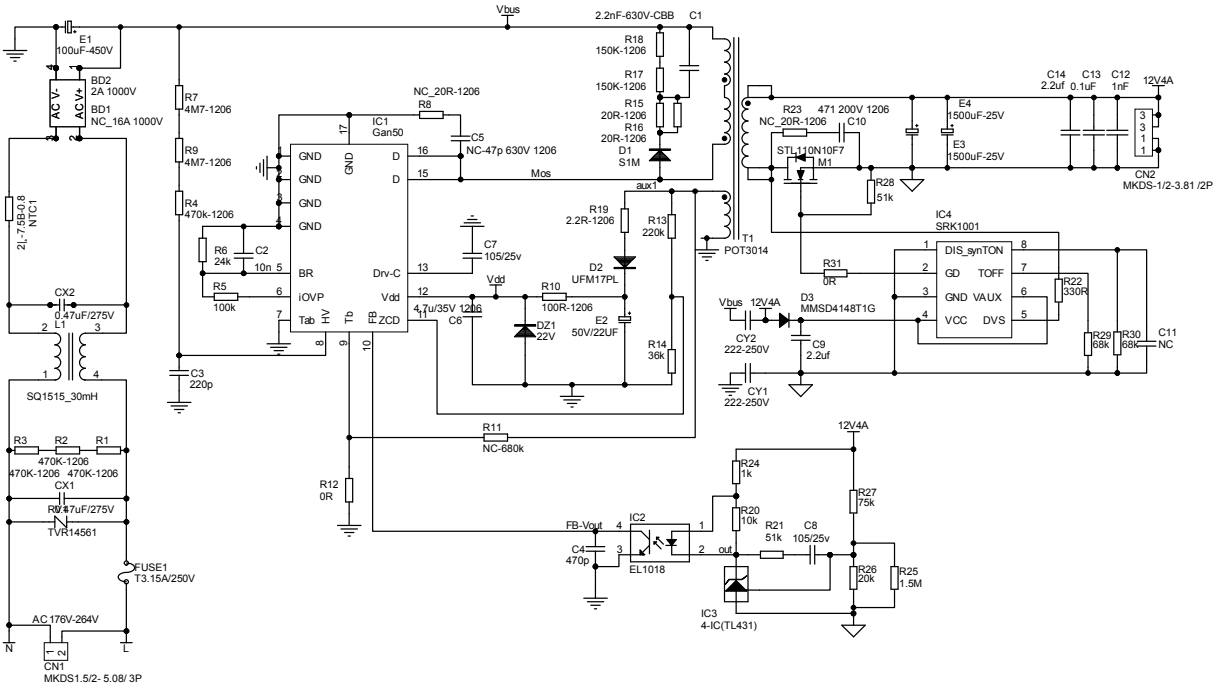


Figure 28. Key component thermals at 12 V/4.15 A:230 VAC input, bottom



5 Schematic diagrams

Figure 29. **STDES-VPGAN50FL circuit schematic**



6 Bill of materials

Table 5. **STDES-VPGAN50FL bill of materials**

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	1	BD2	2A 1000V, DBS, 1000 V, 2 A	Diode Bridge	MDD	DB307S
2	1	C1	2.2nF/630V, P=7.5mm, 630 V, ±10%	Film cap	FARATRONIC	C322J222J30C000
3	1	C2	10nF, 0603, 50 V, ±10%	Ceramic Cap	SUP	C0603X7R103K500NT
4	1	C3	220pF, 0603, 50 V, ±10%	Ceramic Cap	SUP	C0603X7R221K500NT
5	1	C4	470pF, 0603, 50 V, ±10%	Ceramic Cap	SUP	C0603X7R471K500NT
6	1	C6	4.7uF, 1206, 50V, ±10%	Ceramic Cap	SUP	C1206X5R475K500NT
7	2	C7, C8	105K(1uF), 0603, 25V, ±10%	Ceramic Cap	SUP	C0603X5R105K250NT
8	2	C9, C14	225K(2.2uF),06 03, 25 V, ±10%	Ceramic Cap	SUP	C0603X5R225K250NT
9	1	C10	470pF, 1206, 200 V, ±5%	Ceramic Cap	YAGEO	CC1206JKNPOABN471
10	1	C12	102K(1nF), 0603, 50 V, ±10%	Ceramic Cap	SUP	C0603X7R102K500NT
11	1	C13	104K(100nF)/50 V 0603 50 ±10%	Ceramic Cap	SUP	C0603X7R104K500NT
12	1	CN1	MKDS1.5/2-5.08/ 3P, P=5.08mm	Connctor pitch 5mm-3W	PHOENIX CONTACT	MKDS1.5/2- 5.08/ 3W
13	1	CN2	MKDS- ½- 3.81/ 2P, P=3.81mm	Connctor Pitch 3.81mm,2W	PHOENIX CONTACT	MKDS-1/2-3.81 /2W
14	2	CX1, CX2	0.22uF/, P=15mm, 275 V, ±10%	Safty cap	FARATRONIC	C42P2224K6SC000
15	2	CY1, CY2	C812, P=7.5mm, 250 V, ±20%	Safty cap	Murata	DE2E3KY222MN3AM02F
16	1	D1	S1M, SMA(DO-214A C), 1000 V, 1 A	Fast diode 1kV,1A,VF=1.1 V@1A	MDD	S1M
17	1	D2	1KV/0.15A, SOD-123FL, 1000 V, 1 A	Fast diode	SUNMATE	UFM17PL
18	1	D3	75V 0.15A, SOD-323, 75 V, 0.15 A	Diode	CJ	1N4148WS
19	1	DZ1	22V/0.59W, SOD-123, 22 V, 0.59 W, ±1.82%	Zener diode	Nexperia	BZT52-B22J

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
20	1	E1	100uF-450V, Radial,18x35.5 mm, 450 V, ±20%	E-cap	Nichicon	UCS2W101MHDFZX
21	1	E2	50V/22uF, Radial,5x11mm, 50 V, ±20%	E-cap	Rubycon	50YXF22MEFC 5*11mm
22	2	E3, E4	16V, 1500uF Radial, 10x12mm, 16 V, ±20%	Plymer-cap	Aishi	SPZ1CM152G12O00RA
23	1	FUSE1	T3.15A/250V, Radial,P=5.08mm, 250 V, 3.15 A	Fuse	LITTELFUSE	40013150000
24	1	IC1	ViperGaN50, SMT	flyback	ST	ViperGan50
25	1	IC2	EL1018, SOP-4-2.54mm 80	opto-coupler	EVERLIGHT	EL1017
26	1	IC3	TL432AIL3T, SOT-23	36 V, 0.1 A, ±1%	ST	TL432AIL3T
27	1	IC4	SRK1001, SO8	Sync-controller	ST	SRK1001
28	1	L1	SQ1515_30mH, Horizontal type	Common Choke	Dali Electronic	PSQ1515H-253UB
29	1	M1	STL110N10F7, PowerFLAT	NMOS,DFN5X6, 7mOhm, 5x6, 100 V, 107 A, 136 W	ST	STL110N10F7
30	1	NTC1	2.2 Ohms 0.591" (15.00mm), BULK / P=7.5mm, 7 A, ±20%	NTC ICL 2.2 OHM 20% 7A 15MM	EPCOS	B57237S0229M000
31	4	R1,R2,R3,R4	470K-1206, 1206, 1/4 W, ±5%	Resistors	SUP	RR3216(1206)L474JT
32	1	R5	100k, 0603, 1/10 W, ±1%	Resistors	SUP	RR1608(0603)L1003FT
33	1	R6	24k, 0603, 1/10 W, ±1%	Resistors	SUP	RR1608(0603)L2402FT
34	2	R7, R9	4M7-1206, 1206, 1/4 W, ±5%	Resistors	SUP	RR3216(1206)L475JT
35	2	R8, R23	NC_20R-1206, 1206, 1/4 W, ±1%	Resistors	SUP	RR3216(1206)L20R0FT
36	1	R10	100ohm-1206, 1206, 1/4 W, ±5%	Resistors	SUP	RR3216(1206)L101JT
37	2	R12, R31	0ohm, 0603, 1/10 W, ±5%	Resistors	SUP	RR1608(0603)L0R0JT
38	1	R13	220k, 0603, 1/10 W, ±1%	Resistors	SUP	RR1608(0603)L2203FT

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
39	1	R14	36k, 0603, 1/10 W, ±1%	Resistors	SUP	RR1608(0603)L3602FT
40	2	R15, R16	20ohm-1206, 1206, 1/4 W, ±1%	Resistors	SUP	RR3216(1206)L20R0FT
41	2	R17, R18	150K-1206, 1206, 1/4 W, ±5%	Resistors	SUP	RR3216(1206)L154JT
42	1	R19	2.2ohm-1206, 1206, 1/4 W, ±5%	Resistors	SUP	RR3216(1206)L2R2JT
43	1	R20	10K, 0603, 1/10 W, ±5%	Resistors	SUP	RR1608(0603)L103JT
44	2	R21, R28	51K, 0603, 1/10, ±5%	Resistors	SUP	RR1608(0603)L513JT
45	1	R22	330ohm, 0603, 1/10 W, ±1%	Resistors	SUP	RR1608(0603)L3300FT
46	1	R24	1k, 0603, 1/10 W, ±5%	Resistors	SUP	RR1608(0603)L102JT
47	1	R25	1.5M, 0603, 1/10 W, ±1%	Resistors	SUP	RR1608(0603)L1504FT
48	1	R26	20k, 0603, 1/10 W, ±1%	Resistors	SUP	RR1608(0603)L2002FT
49	1	R27	75k, 0603, 1/10 W, ±1%	Resistors	SUP	RR1608(0603)L7502FT
50	2	R29, R30	68k, 0603, 1/10 W, ±1%	Resistors	SUP	RR1608(0603)L6802FT
51	1	RV1	TVR14561, Φ=14mm, 560 V	TVR	TKS	TVR14561KSY
52	1	T1	POT3014	Transformer	Jingshi	PC95POT3014-10PIN

7 Transformer details

Figure 30. Transformer dimensions

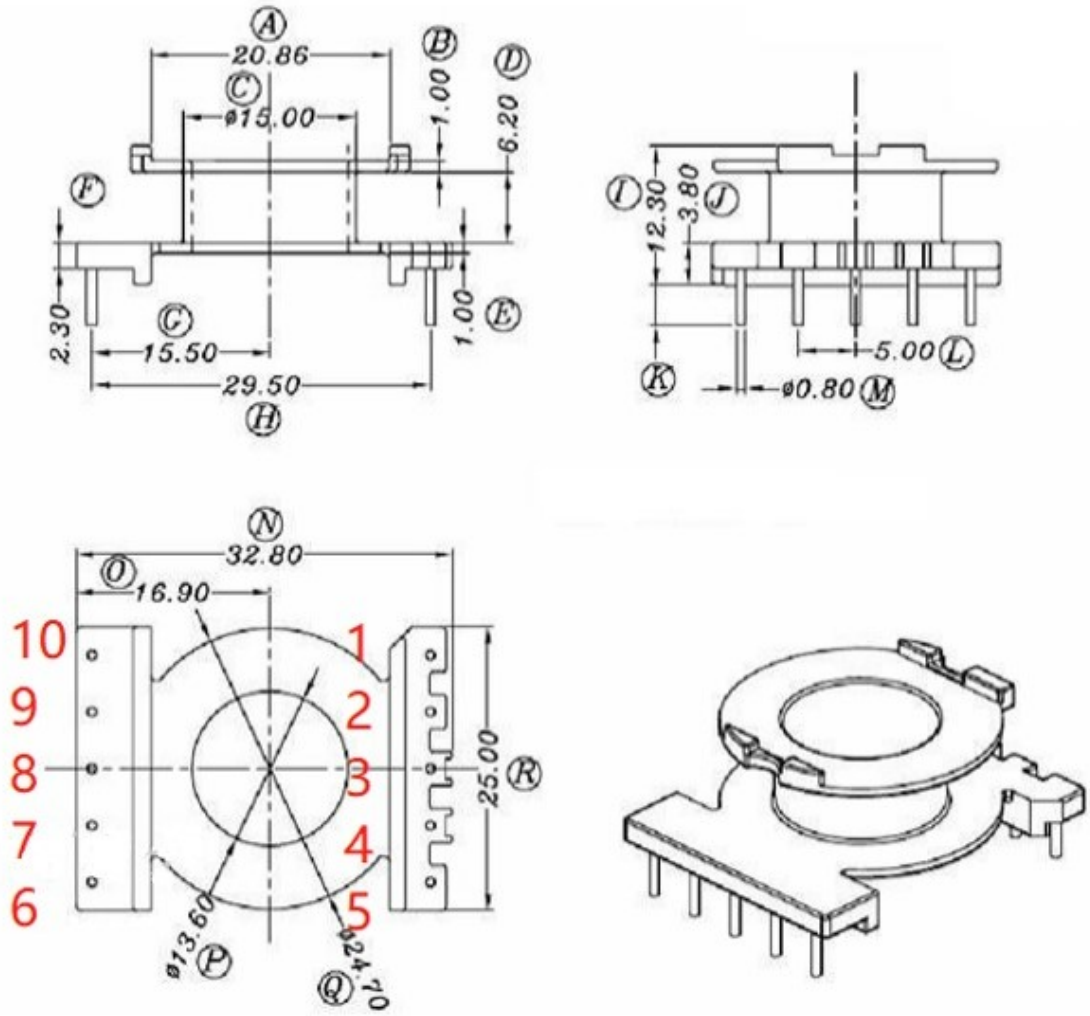


Table 6. Transformer specifications

Inductance Lp=770 µH (±15%), Llk <7.7 µH @ 10 KHz/1 V, (short-circuit 2, 3, 4, 5)

Winding	Top	End	Wire specification	Number of turns	Winding mode	Number of layers of insulation tape
N1	7	8	φ0.3	18	Close winding 1 layer	0.05x 6.0 x2Ts
N2	3	4	TIW φ0.1 *40	6	Close winding 1 layer	0.05x 6.0 x2Ts
N3	8	6	φ0.3	18	Close winding 1 layer	0.05x 6.0 x2Ts
N4	10	9	φ0.3	6	Uniform winding 1 layer	0.05x 6.0 x2Ts
N5	2	5	TIW φ0.1 *40	6	Close winding 1 layer	0.05x 6.0 x2Ts

- The copper wires of each layer winding must be evenly arranged and must not be concentrated on one side.
- Cut off feet 8 and 1.
- Pin cables need a sleeve.
- Wide tape completely covers the magnetic core.

8 EMI measurements

Figure 31. QP and average measurements at 230 Vac and full load, LINE

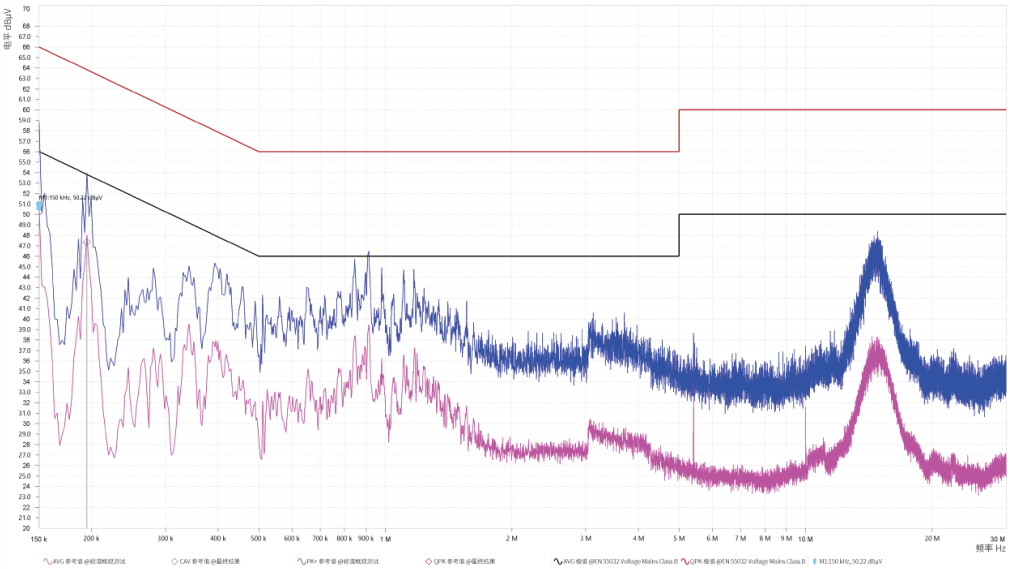
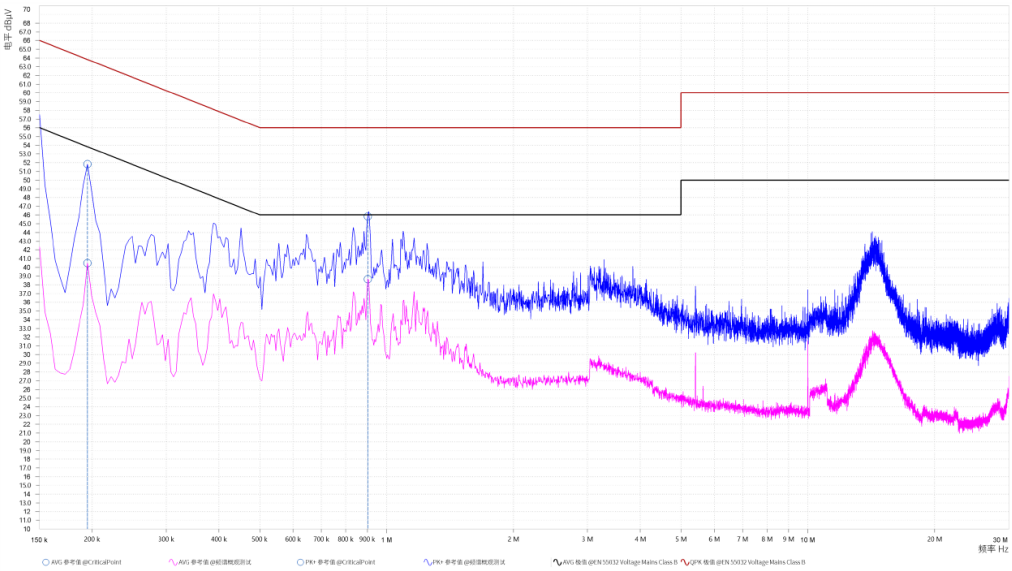


Figure 32. QP and average measurements at 230 Vac and full load, NEUTRAL



9 Board layout

Figure 33. Main board layout

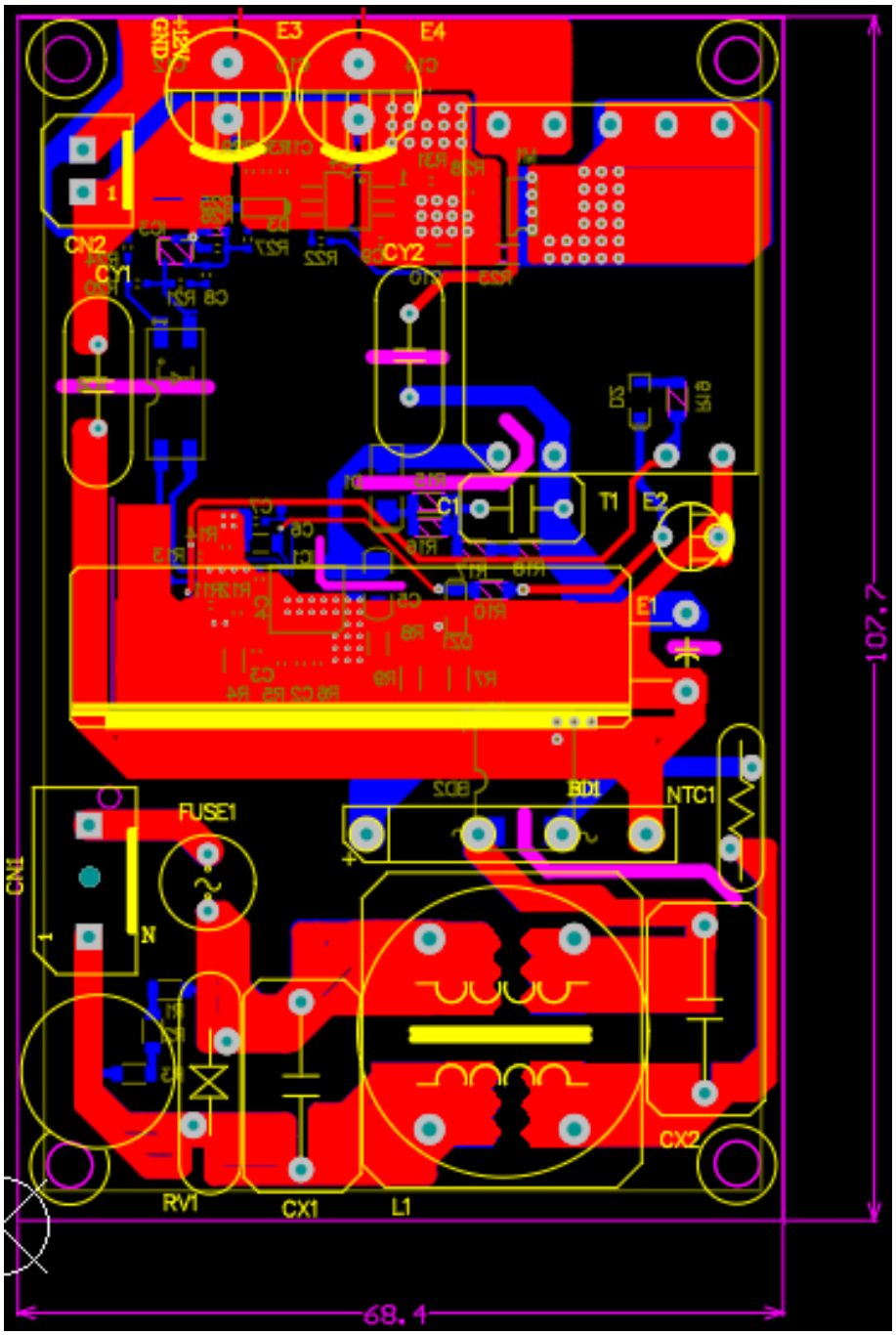


Figure 34. Main board layout: top overlay, bottom overlay & bottom layer

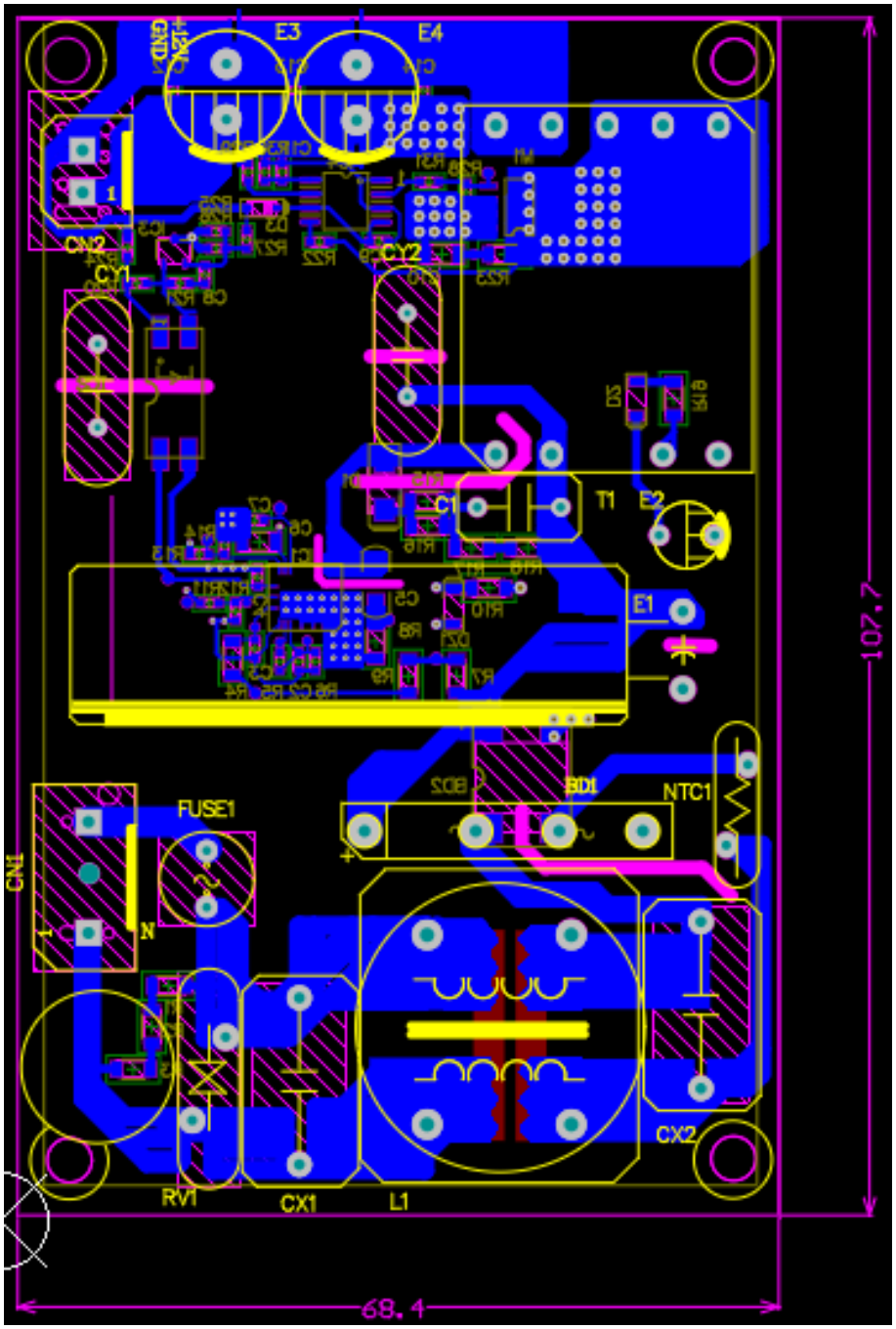
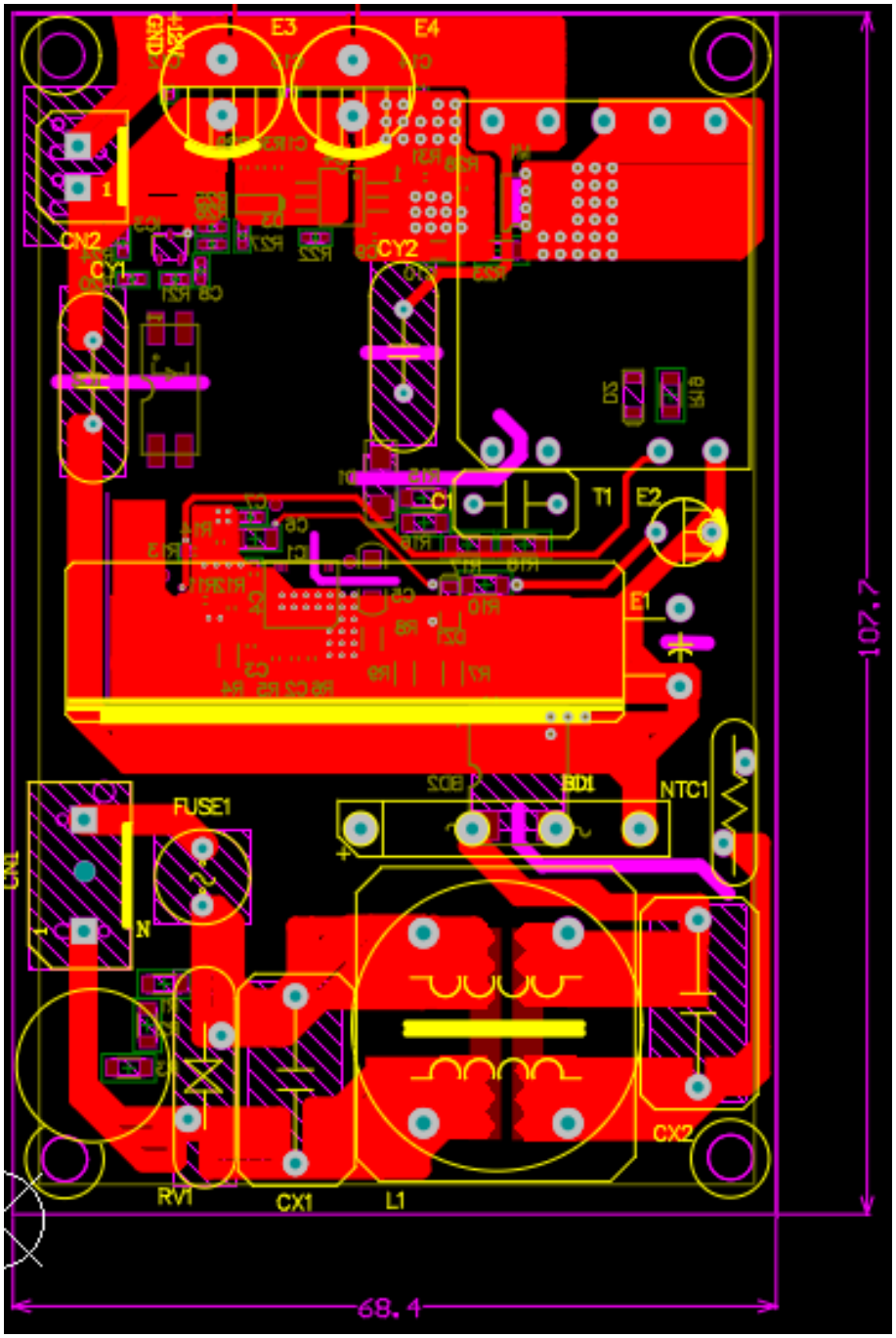


Figure 35. Mainboard layout: top overlay, bottom overlay & top layer



10 Conclusions

The test results demonstrate the excellent performance of the STDES-VPGAN50FL. The reference design achieves a peak efficiency of over 94.5%, which is a significant advantage. The quasi-resonant topology reduces switching losses, while the low quiescent current consumption ensures best-in-class no-load consumption. The VIPERGAN50 offline quasi-resonant flyback converter can operate in different modes depending on the converter's load condition. The primary switching losses are minimized by using quasi-resonant technology, while the highly efficient and optimized synchronous rectification controller minimizes secondary losses. With the highly integrated VIPERGAN50 IC, users can implement the benefits of GaN technology without having to address GaN driving complexities, thereby enhancing the application's robustness. The controller is optimized for high-frequency GaN driving, allowing fast and effective layout simplifications. All these features ensure lower power losses and excellent thermal performance.

Appendix A Reference design warnings, restrictions and disclaimer

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Revision history

Table 7. **Document revision history**

Date	Revision	Changes
08-Feb-2024	1	Initial release.

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