140 W HFB-PAG2S (REF_140W_HFB_PAG2S) Solution Board test report

Devices – XDPS2221, CYPAS213 A1-32LQXQ

About this document

Scope and purpose

This test report provides power management test results of the 140 W HFB-PAG2S (REF_140W_HFB_PAG2S) Type-C power charger and adapter solution board. The tests were performed on the board, which is equipped with Infineon's XDPS2221 on the primary and CYPAS213 A1-32LQXQ on the secondary sections respectively.

Intended audience

This document is intended for anyone using the 140 W PFC+HFB USB PD+SR high power density charger and adapter solution with highly integrated Infineon XDP™ and EZ-PD™ solutions.

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1 Introduction

The XDPS2221 PWM controller is a highly integrated device combining a multimode AC-DC PFC controller and a multimode DC-DC hybrid-flyback controller. The integration of PFC and hybrid-flyback into a single controller enables reduction of external bill-of-materials (BOM) components and optimizes the system performance by joint operation of the two stages. It is meant to be used in USB-PD chargers/adapters with a wide output voltage of up to 28 V. The system efficiency can further be increased using Infineon's CoolMOS™, CoolGaN™, and OptiMOS™ transistors.

Infineon's EZ-PD™ PAG2S CYPAS213 is an integrated secondary-side controller with USB Power Delivery controller and synchronous rectifier. EZ-PD™ PAG2S CYPAS213 is targeted towards USB-Type C power adapters; it also fits well into several other applications:

- supports high-efficiency AC-DC flyback designs with USB Power Delivery, Qualcomm Quick Charge, and other standard charging protocols
- supports USB Power Delivery Extended Power Range (EPR) mode
- supports synchronous rectification in quasi-resonant (QR), critical conduction mode (CrCM), discontinuous conduction mode (DCM), and continuous conduction mode (CCM), and switching frequency up to 300 kHz
- supports output VBUS protections like overvoltage protection (OVP), undervoltage protection (UVP), overcurrent protection (OCP), short-circuit protection (SCP), and system over-temperature protection (OTP)

Figure 1 shows a power adapter application diagram implementing a primary-side-controlled synchronous flyback system. In this system, EZ-PD™ PAG2S CYPAS213 engages the internal error amplifier (EA) to take the feedback from the secondary side and pass it on to the primary controller over an isolation barrier like an optoisolator. The primary-side controller can be any standard flyback controller. In this topology, EZ-PD™ PAG2S integrates three key features: secondary-side rectification, charging protocol control, and fault protection.

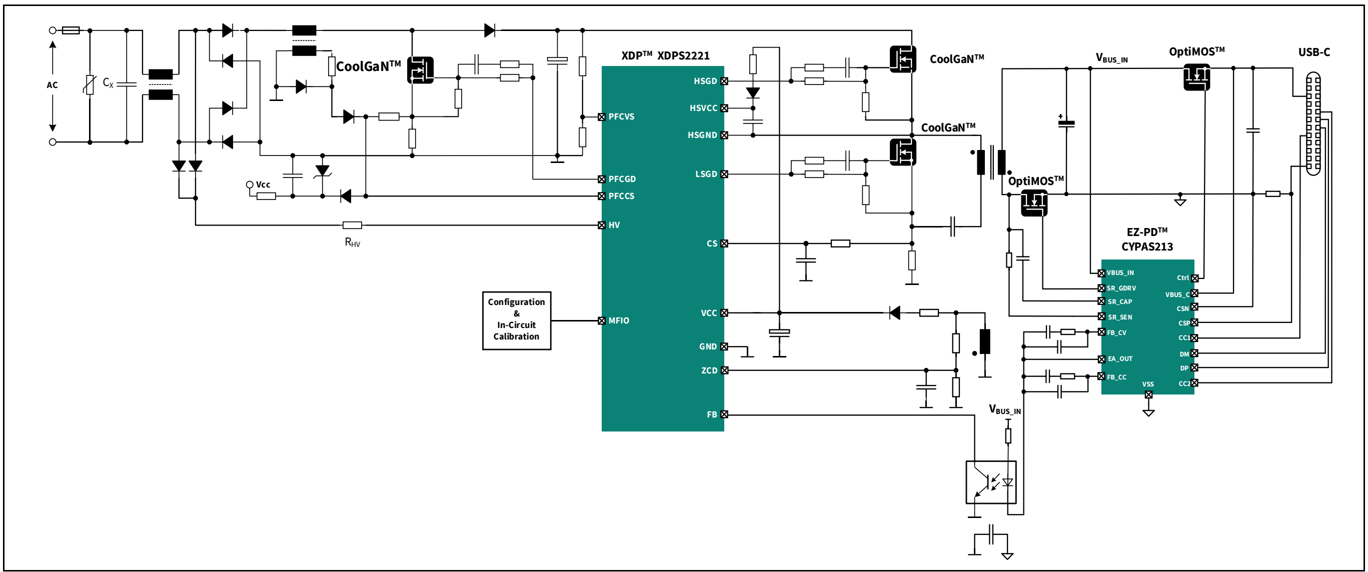


Figure 1 **Simplified application diagram of USB PD adapter with PFC hybrid-flyback primary control**

2 Test setup

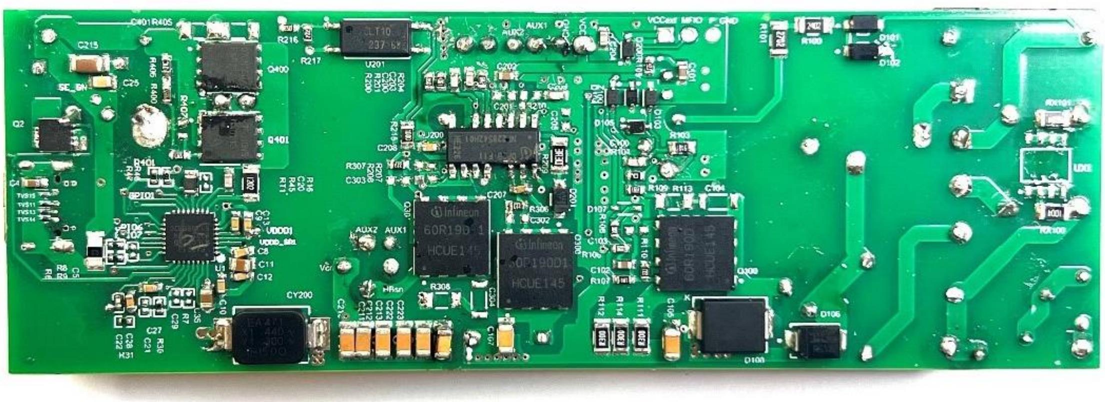
2.1 Device under test (DUT)

The device under test is the 140 W HFB-PAG2S HFB Solution Board (XDPS2221 + CYPAS213A1).

Table 1 EZ-PD™ HFB-PAG2S solution kit details

DUT contents	Description
XDPS2221	Primary controller
CYPAS213A1	Secondary controller
Firmware version	Build 291

Top view of the solution board



Bottom view of the solution board

Figure 2 PCB dimensions (mm): 117.5 (L) × 38 (W) × 22 (H)

Note: All the tests mentioned in this report are carried-out under an open-frame condition.

2.2 DUT setup

Figure 3 Physical Power-Z KM002C device (front and rear view)

The DUT is connected to a Power-Z tester using a USB Type-C EPR cable. After a successful connection, the Power-Z does a PDO discovery and displays it on the UI. The solution kit is pre-configured with 7 SPR PDOs (4 fixed PDOs and 3 PPS PDOs) and 2 EPR PDOs (1 fixed PDO & 1 AVS PDO) in 140 W HFB+PAG2S demo board:

- PDO 1: 5 V, 5 A fixed
- PDO 2: 9 V, 5 A fixed
- PDO 3: 15 V, 5 A fixed
- PDO 4: 20 V, 5 A fixed
- PDO 5: 3.3 V to 11 V, 5 A PPS
- PDO 6: 3.3 V to 16 V, 5 A PPS
- PDO 7: 3.3 V to 21 V, 5 A PPS
- EPR fixed PDO: 28 V, 5 A
- EPR AVS PDO: 15 V to 28 V, 5 A

You can either choose the suitable pre-configured PDO or configure a new one using Infineon's EZ-PD™ Configuration Utility software and HW device called PAT (CCGPROG PAT), and not Power-Z. For more details on PAT tester and UI, see USBCEE product details webpage.

Type C-C cable (0.8-m long) used for all the tests in this report, is an EPR capable cable L00UC007-NB-R.

2.3 Test equipment

Table 2 Test equipment list

Test setup	Description
Oscilloscope	Tektronix MDO4104C
Power meter	Yokogawa WT310E
Digital multimeter (V_o and I_o)	Keysight 34465A
Programmable AC source	Chroma 61501
Electronic load	Chroma 63113A
Thermal camera	Flir E75/T-type thermocouples

3 Power management test results

Note: All the tests mentioned in this report are carried-out under an open-frame condition. The results documented here are based on the test reports of the 140 W HFB-PAG2S (REF_140W_HFB_PAG2S) Solution Board.

3.1 Efficiency 4-pt average

Table 3 Efficiency results

Parameter	Standard (minimum value)		Unit	Test condition	Test result	
	DoE Level-6	CoC v5 Tier 2			115 V_{ac}/60 Hz	230 V_{ac}/50 Hz
Four-point average efficiency (average of 25%, 50%, 75%, and 100% load)	81.97	82.47	%	V_o = 3.3 V_{dc}, I_o = 5.0 A	85.33	89.18
	84.24	85	%	V_o = 5.0 V_{dc}, I_o = 5.0 A	87.74	90.45
	87.73	88.85	%	V_o = 9.0 V_{dc}, I_o = 5.0 A	90.59	92.36
	88	89	%	V_o = 15.0 V_{dc}, I_o = 5.0 A	91.18	93.36
	88	89	%	V_o = 20.0 V_{dc}, I_o = 5.0 A	92.28	93.55
	88	89	%	V_o = 28.0 V_{dc}, I_o = 5.0 A	92.43	93.45
CoC v5 Tier2 10% load efficiency		73.08	%	V_o = 3.3 V_{dc}, I_o = 0.5 A	83.25	84.77
		75.47	%	V_o = 5.0 V_{dc}, I_o = 0.5 A	86.57	87.20
		78.85	%	V_o = 9.0 V_{dc}, I_o = 0.5 A	87.05	89.83
		79	%	V_o = 15.0 V_{dc}, I_o = 0.5 A	81.52	88.18
		79	%	V_o = 20.0 V_{dc}, I_o = 0.5 A	84.76	88.59
		79	%	V_o = 28.0 V_{dc}, I_o = 0.5 A	86.43	86.57
No load consumption	210	150	mW	No USB sink attached	43.30	69.60

Note:

- *Peak efficiency at full power: 94.98% (at 265 V_{ac}–63 Hz, 28 V–5 A)*
- *V_{out} for efficiency calculations is measured across V_{bus_C} at board end*
- *Variation of ±0.3 % in 4-point average efficiency and ±1 % in 10 % efficiency can be observed*

The following figures record the percentage efficiency against percentage load graphs for 90 V_{ac}/47 Hz, 115 V_{ac}/60 Hz, 20 V_{ac}/50 Hz, and 265 V_{ac}/63 Hz respectively.

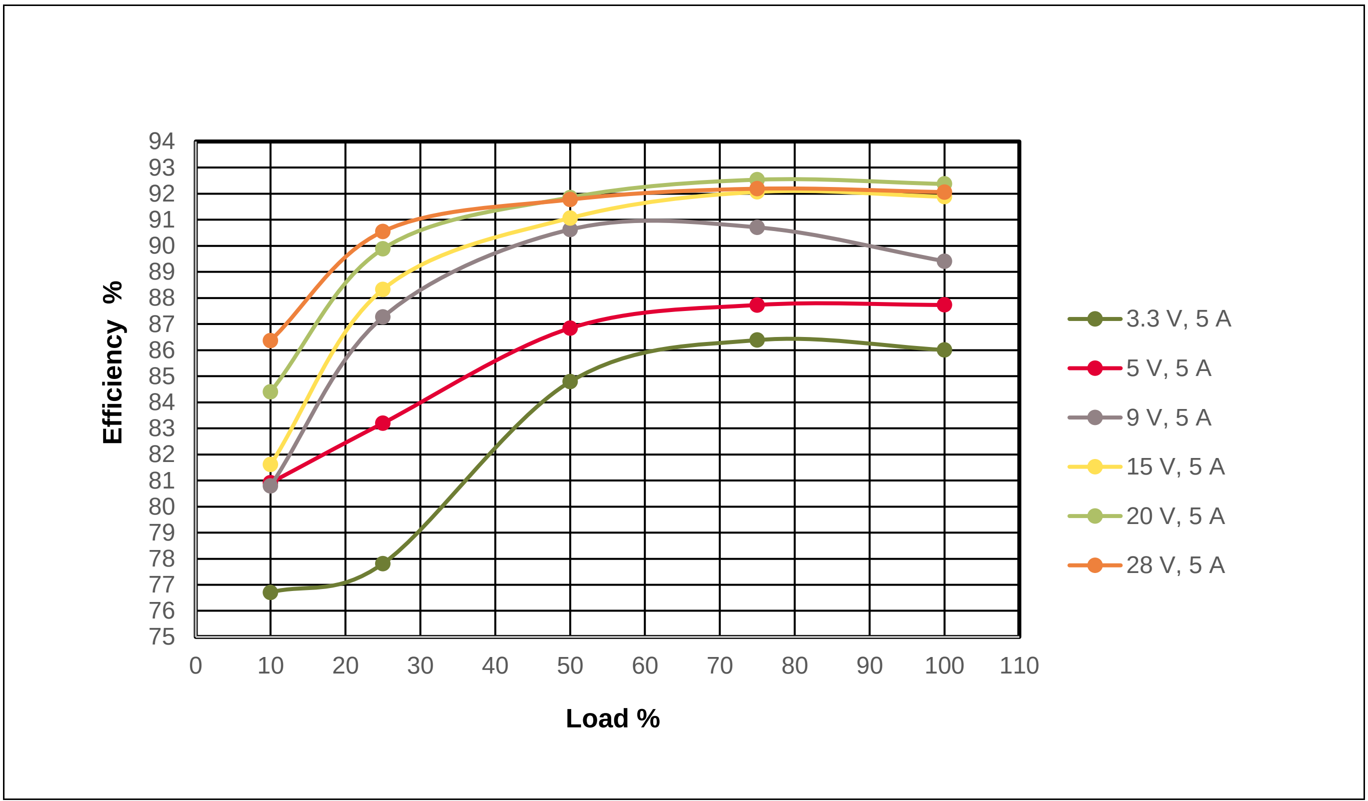


Figure 4 **Efficiency at 90 V_{ac}/47 Hz**

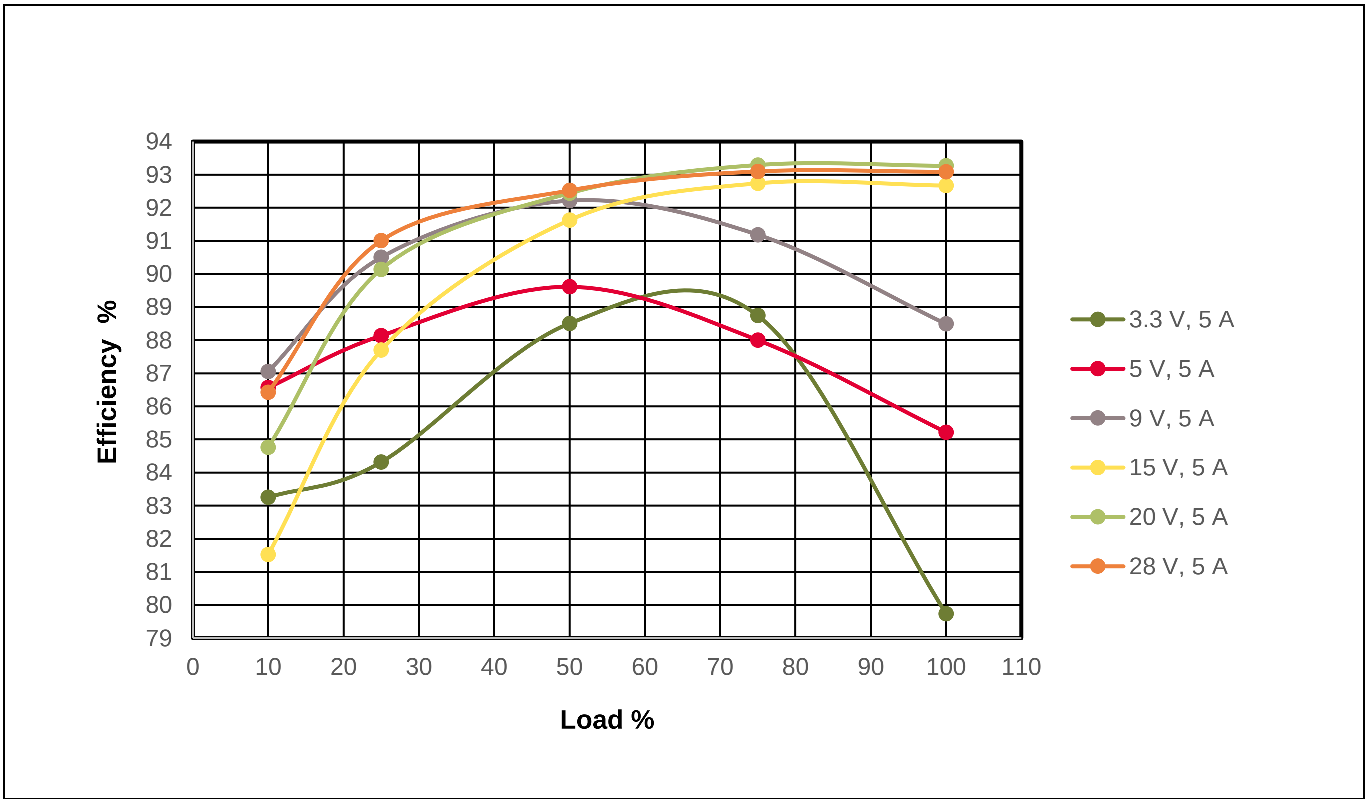


Figure 5 **Efficiency at 115 V_{ac}/60 Hz**

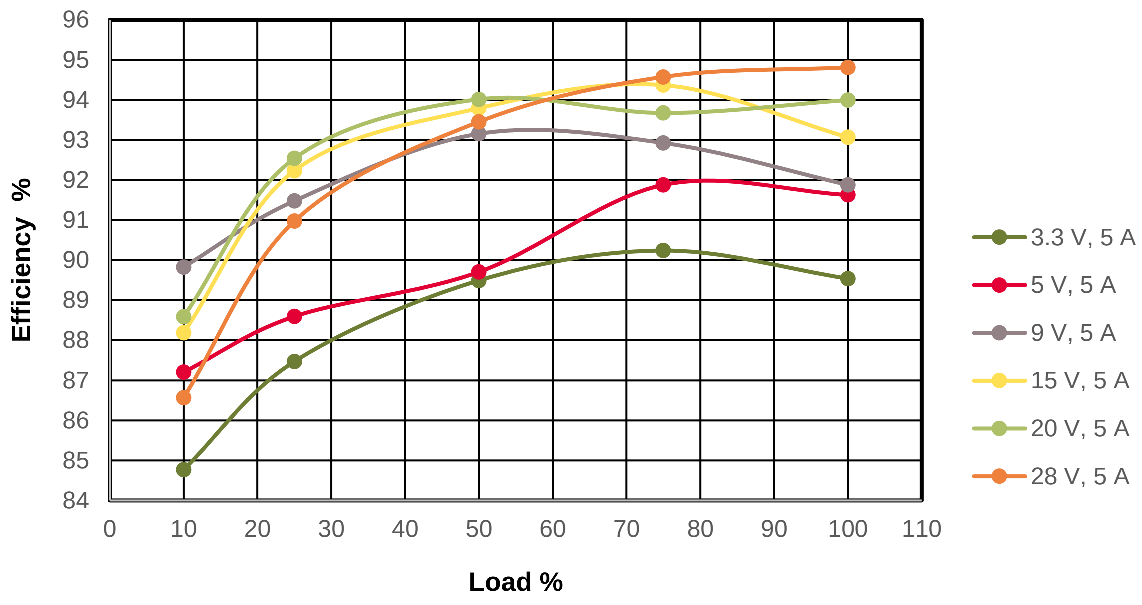


Figure 6 **Efficiency at 230 V_{ac}/50 Hz**

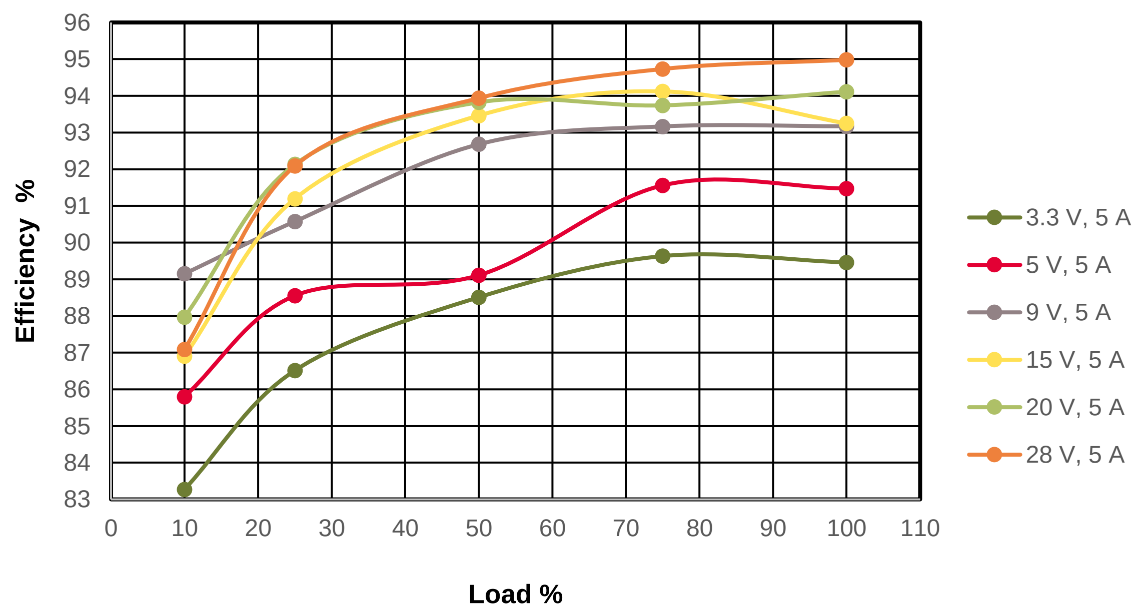
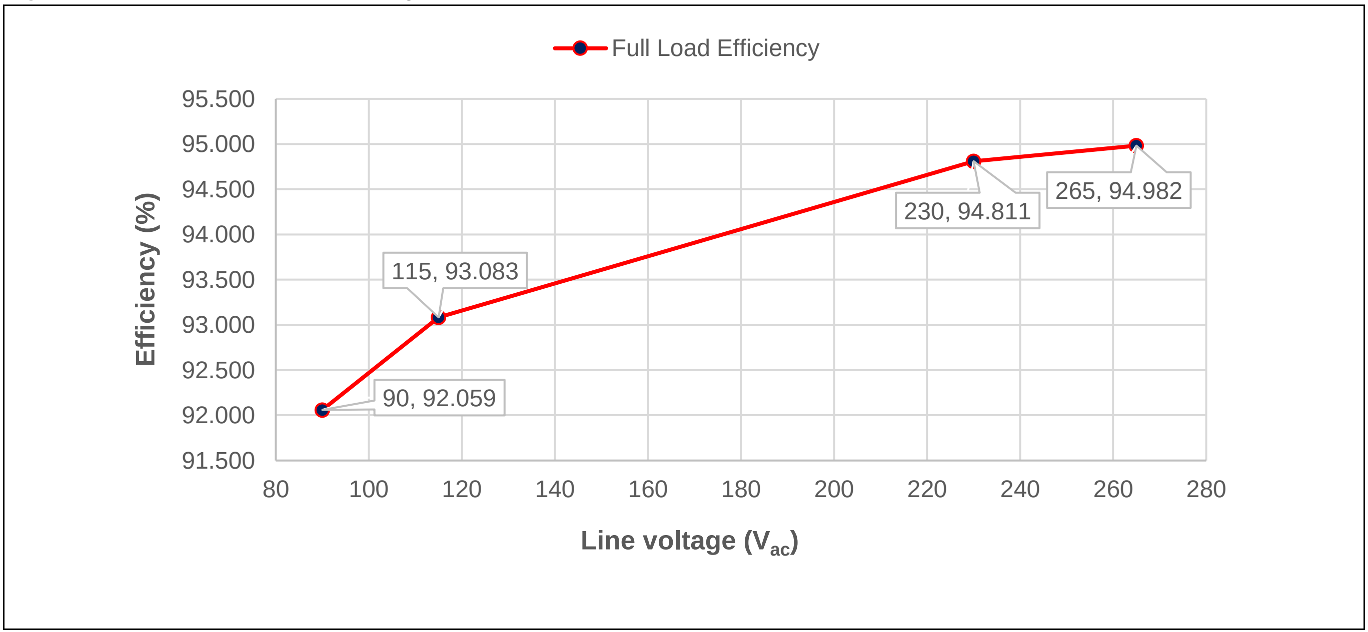


Figure 7 **Efficiency at 265 V_{ac}/63 Hz**

Table 4 Efficiency results at different line conditions at V_{out} = 28 V

$V_{r\,ms}$	Input power (W)	V_{out} (V)	I_{out} (A)	Frequency (kHz)	Efficiency (%)	4-point average	CoC Tier 2 (%)	Efficiency status
90 V_{ac}/47 Hz	16.155	27.967	0.4989	39.36	86.368	86.368	79	Pass
	38.552	27.954	1.2488	70.42	90.550	91.643	89	Pass
	76.05	27.933	2.4986	125	91.773			
	113.48	27.909	3.7485	208.3	92.190			
	151.48	27.897	4.9988	175.4	92.059			
115 V_{ac}/60 Hz	16.144	27.968	0.4989	35.84	86.430	86.430	79	Pass
	38.362	27.956	1.2488	69.93	91.005	92.427	89	Pass
	75.44	27.935	2.4986	126.6	92.522			
	112.39	27.913	3.7485	208.3	93.097			
	149.83	27.9	4.9988	175.4	93.083			
230 V_{ac}/50 Hz	16.12	27.971	0.4989	35.84	86.568	86.568	79	Pass
	38.375	27.955	1.2488	64.1	90.971	93.452	89	Pass
	74.68	27.935	2.4983	149.3	93.452			
	110.64	27.914	3.7485	208.3	94.573			
	147.11	27.902	4.9988	178.6	94.811			
265 V_{ac}/63 Hz	16.01	27.971	0.4985	37.31	87.093	87.093	79	Pass
	37.914	27.959	1.2488	69.93	92.091	93.936	89	Pass
	74.31	27.938	2.4986	147.1	93.939			
	110.45	27.916	3.7481	212.8	94.732			
	146.85	27.903	4.9988	172.4	94.982			

Figure 8 Full power efficiency at different line conditions



3.2 Tiny load requirements

Table 5 EuP Lot 6 results

V_{in} (V_{ac})	P_{in} (avg)	V_{out}	I_{out}	P_{out}	Efficiency (%)
115 V_{ac}, 60 Hz	0.383 W	5 V	0.05 A	250 mW	65.69
115 V_{ac}, 60 Hz	0.377 W	9 V	0.0277 A	250 mW	66.58
115 V_{ac}, 60 Hz	0.453 W	15 V	0.0167 A	250 mW	55.20
115 V_{ac}, 60 Hz	0.451 W	20 V	0.0125 A	250 mW	55.63
115 V_{ac}, 60 Hz	0.490 W	28 V	0.0089 A	250 mW	51.12
230 V_{ac}, 50 Hz	0.376 W	5 V	0.05 A	250 mW	66.91
230 V_{ac}, 50 Hz	0.371 W	9 V	0.0277 A	250 mW	67.37
230 V_{ac}, 50 Hz	0.396 W	15 V	0.0167 A	250 mW	62.76
230 V_{ac}, 50 Hz	0.427 W	20 V	0.0125 A	250 mW	58.75
230 V_{ac}, 50 Hz	0.483 W	28 V	0.0089 A	250 mW	53.32

Note:

- *The data is taken after 15 minutes of warm-up time at 230 V_{ac}, 50 Hz, 28 V, 5 A*
- *Since there are variations in input power, average input power over a 5-minute duration is considered*
- *The measurement is done via WTViewerEfree software with line filter ON*

3.3 Standby power consumption

Table 6 Standby power results

V_{in} (V_{ac})	90 V_{ac}/47 Hz	115 V_{ac}/60 Hz	230 V_{ac}/50 Hz	264 V_{ac}/63 Hz
Input power	58.1 mW	43.3 mW	69.6 mW	65.1 mW

The standby power consumption with input line voltage graph is shown in Figure 9.

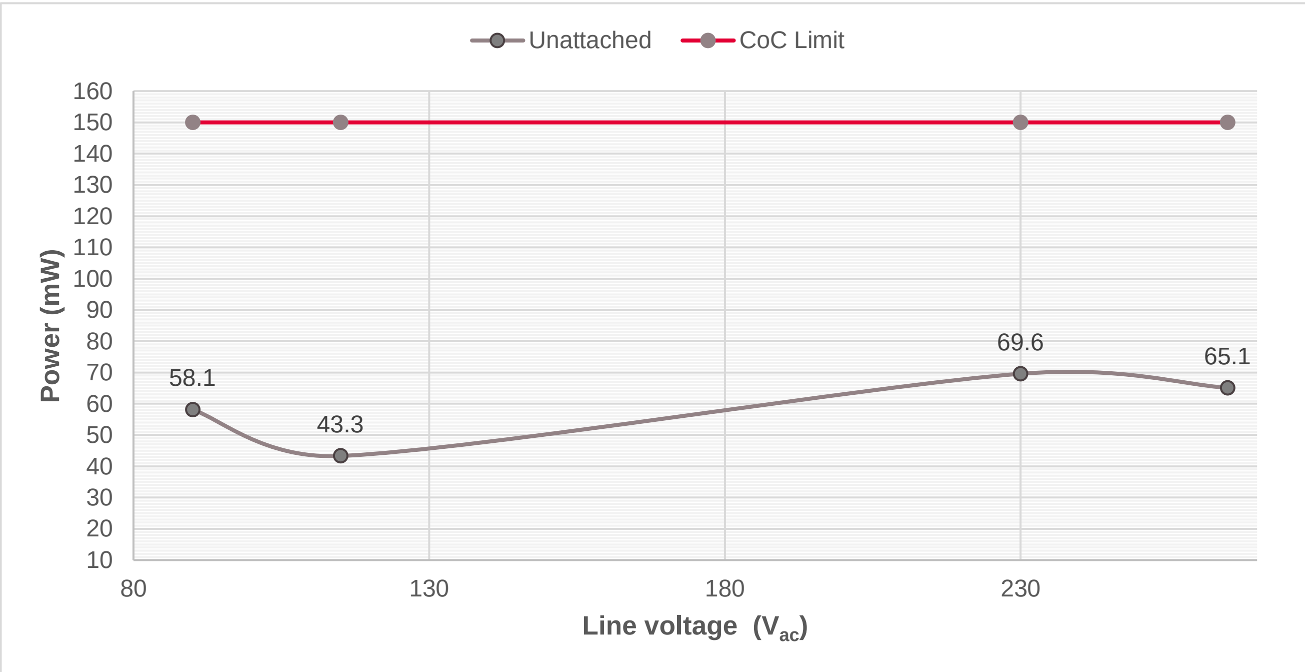


Figure 9 Standby power vs Coc Tier 2 criteria

Note:

- *There should be atleast 15 minutes of warm-up time before starting to measure standby power*
- *Average input power over a 15-minute duration is considered*
- *The measurement is done via WTViewerEfree software with line filter ON*

3.4 Output voltage and current regulation

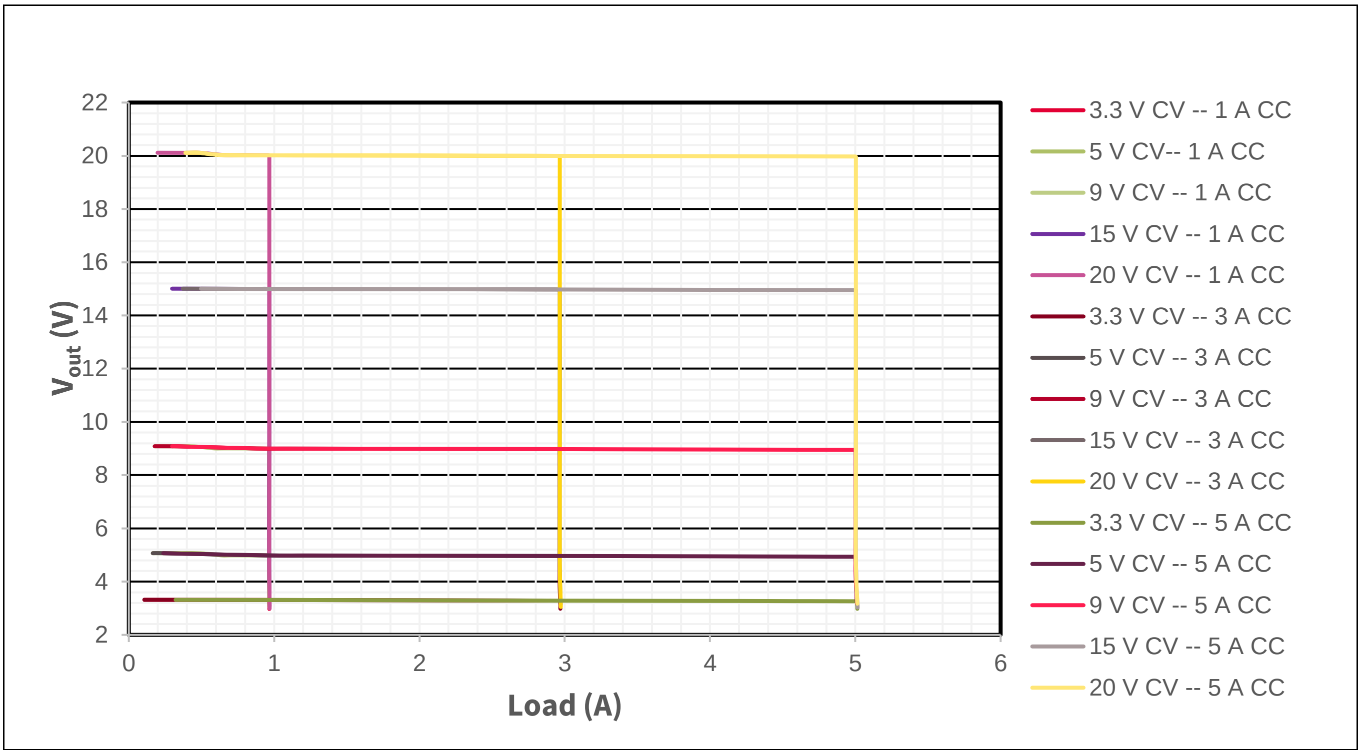


Figure 10 CV-CC regulation curve at 115 V_{ac}/60 Hz

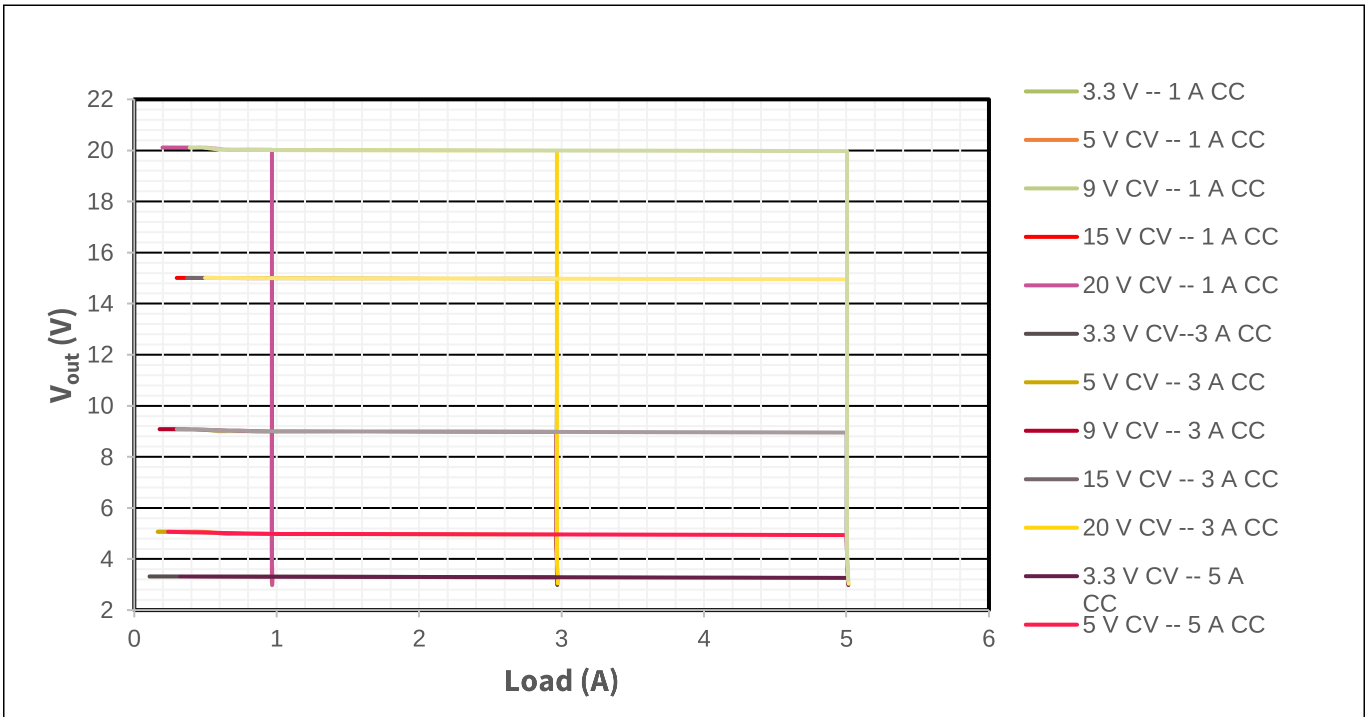


Figure 11 CV-CC regulation curve at 230 V_{ac}/50 Hz

Table 7 CC limits at 115 V_{ac}/60 Hz

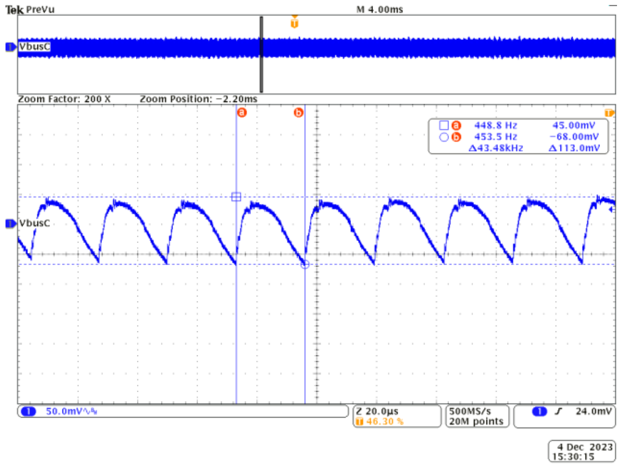
Input 115 V_{ac}/60 Hz					
V_{out}/I_{out}	**1 A**	**2 A**	**3 A**	**4 A**	**5 A**
3.3 V	0.969	1.970	2.971	3.976	5.013
5.0 V	0.967	1.967	2.966	3.969	5.004
9.0 V	0.967	1.966	2.965	3.968	5.003
15.0 V	0.966	1.966	2.966	3.968	5.003
20.0 V	0.966	1.966	2.965	3.968	5.003
28.0 V	No CC region in AVS-EPR PDO				

Table 8 CC limits at 230 V_{ac}/50 Hz

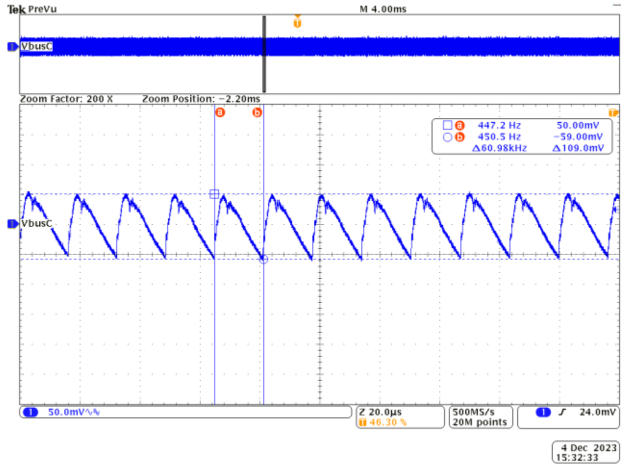
Input 230 V_{ac}/50 Hz					
V_{out}/I_{out}	**1 A**	**2 A**	**3 A**	**4 A**	**5 A**
3.3 V	0.967	1.968	2.97	3.975	5.013
5.0 V	0.966	1.966	2.966	3.968	5.003
9.0 V	0.966	1.966	2.965	3.968	5.003
15.0 V	0.966	1.966	2.965	3.968	5.004
20.0 V	0.966	1.966	2.965	3.969	5.004
28.0 V	No CC region in AVS-EPR PDO				

3.5 Output voltage ripple peak-to-peak

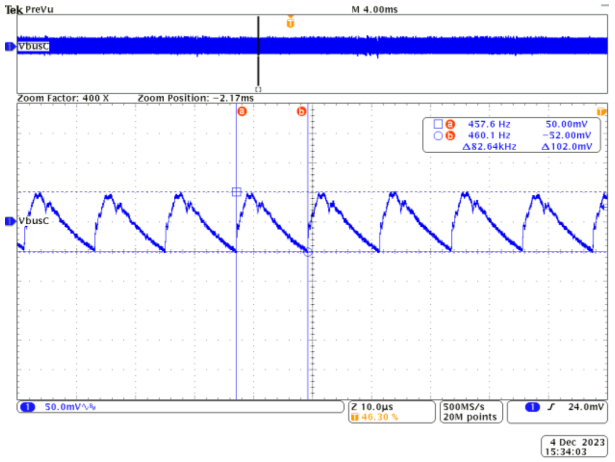
Note: Ripple measurement is done at the board end using lecroy probe adapter PK6-5MM-105.



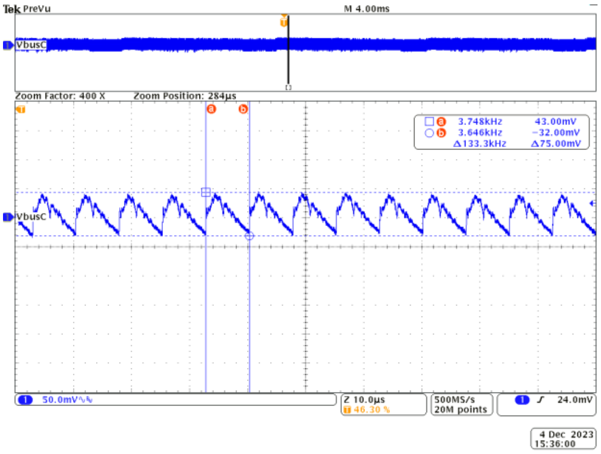
3.3 V, 5 A, Ripple (p-p) = 113 mV



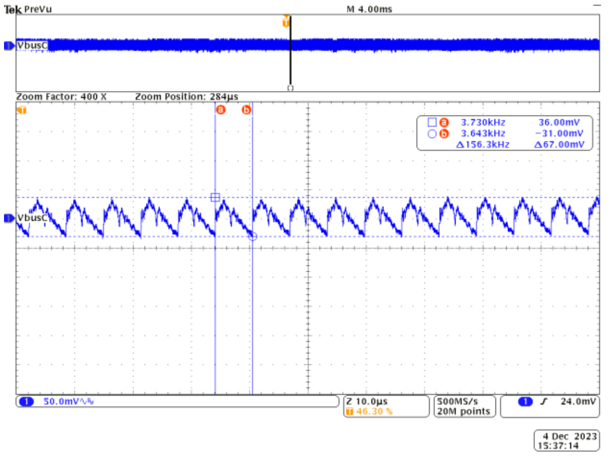
5 V, 5 A, Ripple (p-p) = 109 mV



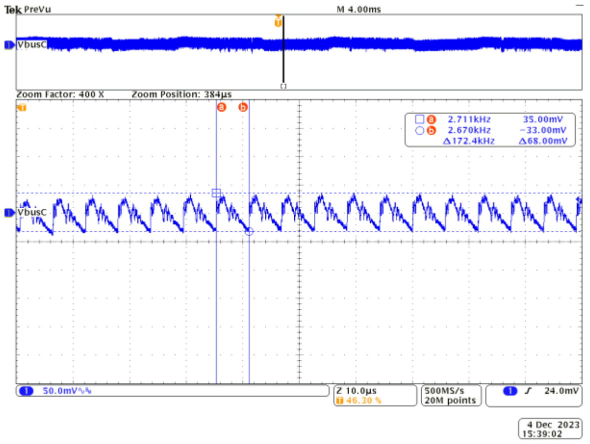
9 V, 5 A, Ripple (p-p) = 102 mV



15 V, 5 A, Ripple (p-p) = 75 mV

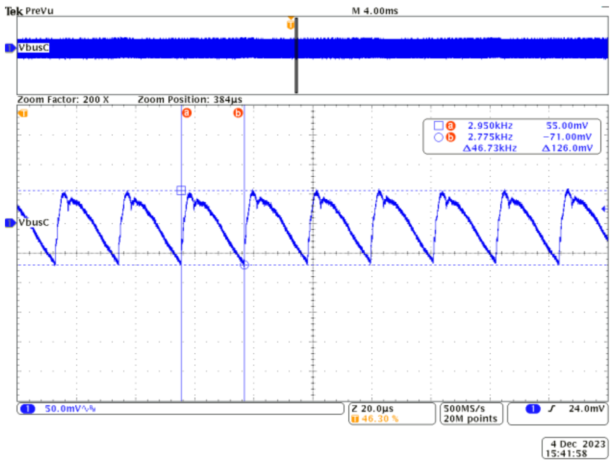


20 V, 5 A, Ripple (p-p) = 67 mV

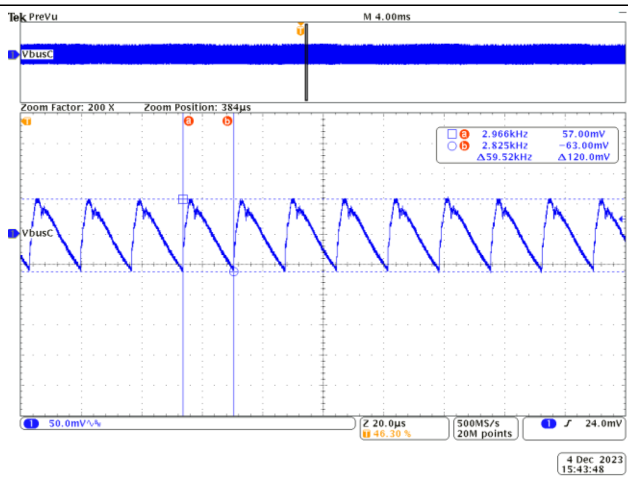


28 V, 5 A, Ripple (p-p) = 68 mV

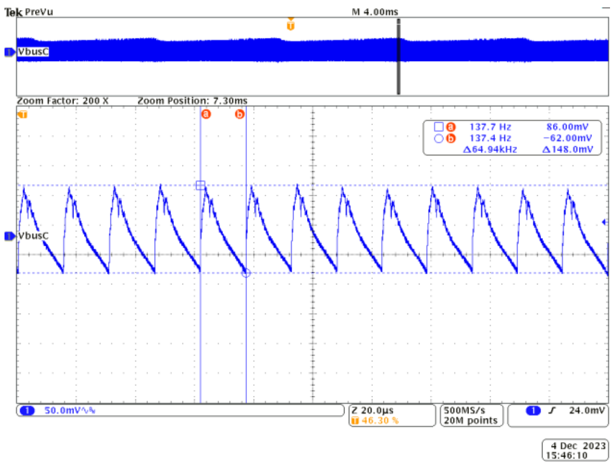
Figure 12 Ripple and noise at 90 V_{ac}, 47 Hz (CH1: V_{bus_c})



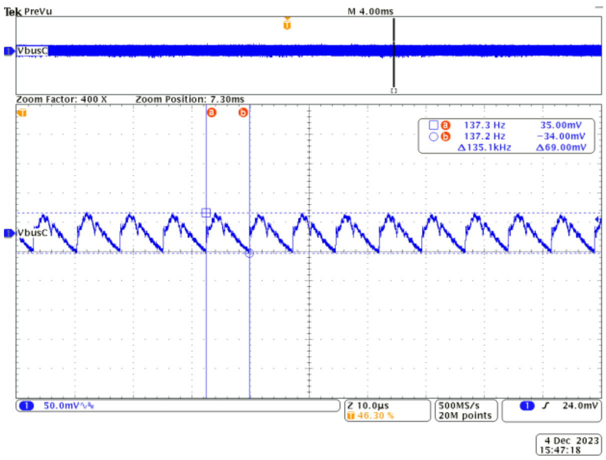
3.3 V, 5 A, Ripple (p-p) = 126 mV



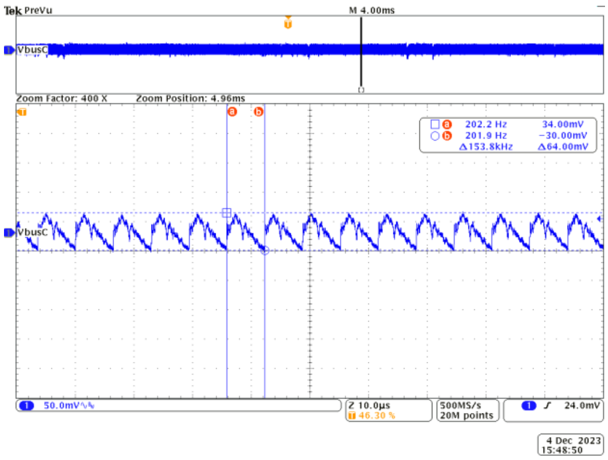
5 V, 5 A, Ripple (p-p) = 120 mV



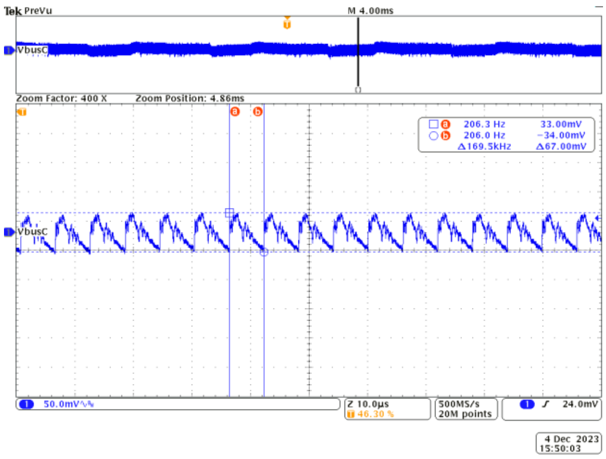
9 V, 5 A, Ripple (p-p) = 148 mV



15 V, 5 A, Ripple (p-p) = 69 mV

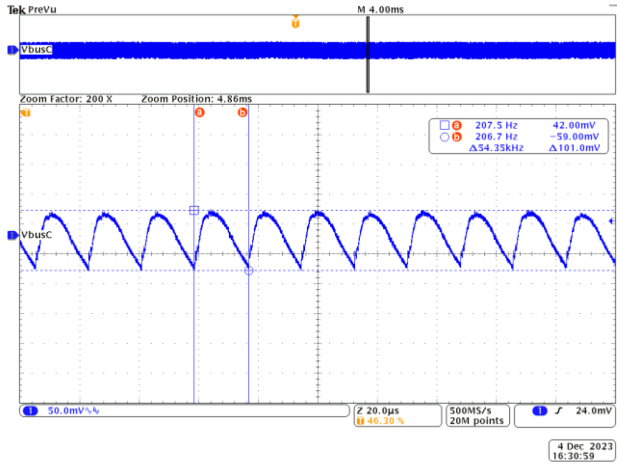


20 V, 5 A, Ripple (p-p) = 64 mV

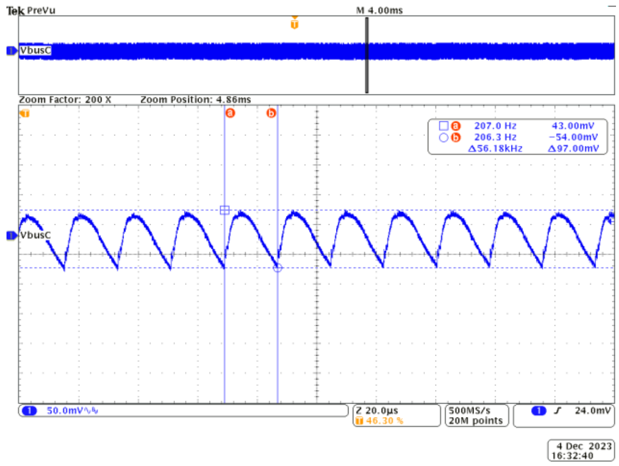


28 V, 5 A, Ripple (p-p) = 67 mV

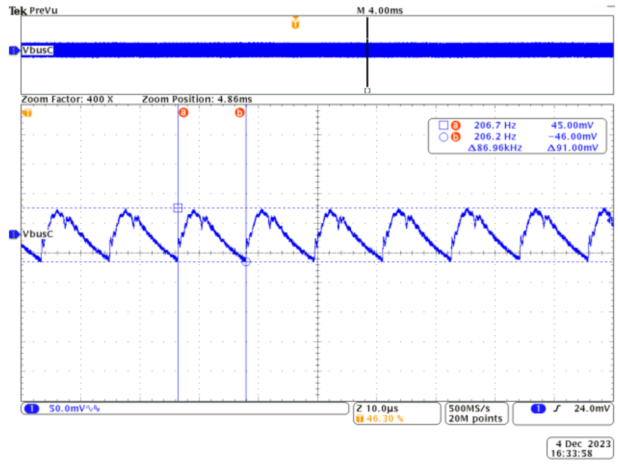
Figure 13 Ripple and noise at 115 V_{ac}, 60 Hz (CH1: V_{bus_c})



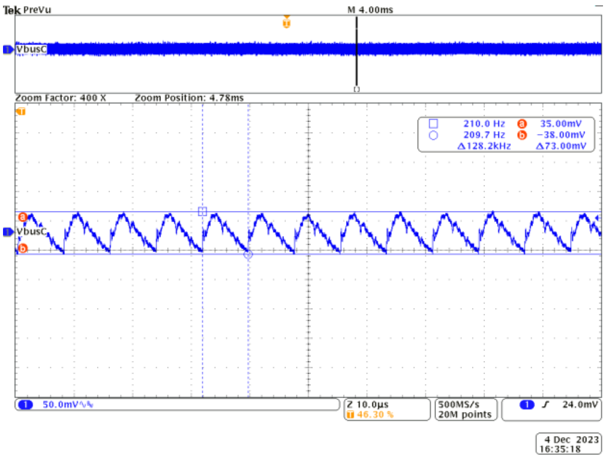
3.3 V, 5 A, Ripple (p-p) = 101 mV



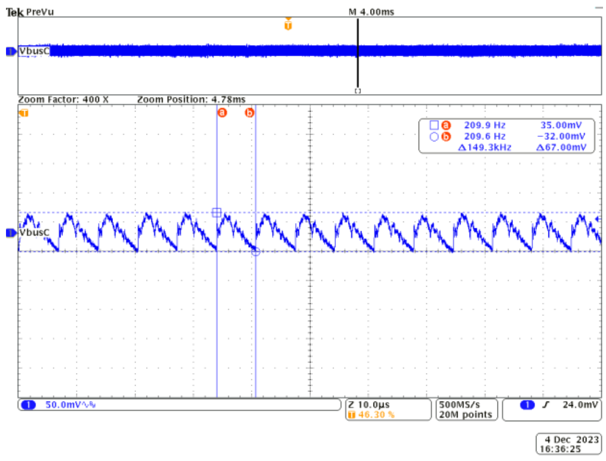
5 V, 5 A, Ripple (p-p) = 97 mV



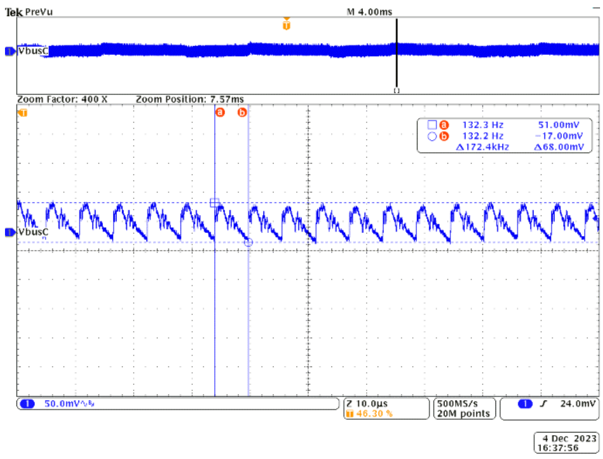
9 V, 5 A, Ripple (p-p) = 91 mV



15 V, 5 A, Ripple (p-p) = 73 mV

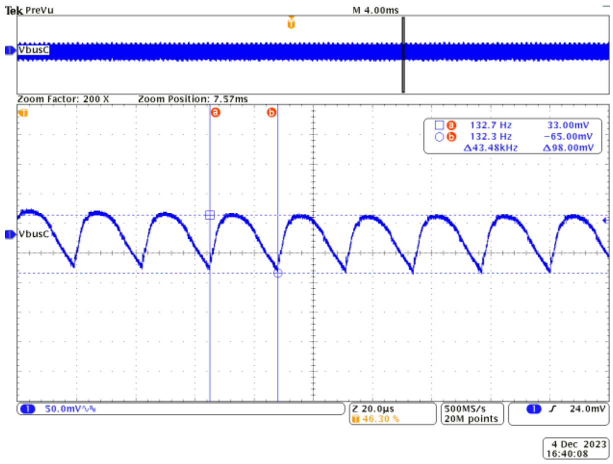


20 V, 5 A, Ripple (p-p) = 67 mV

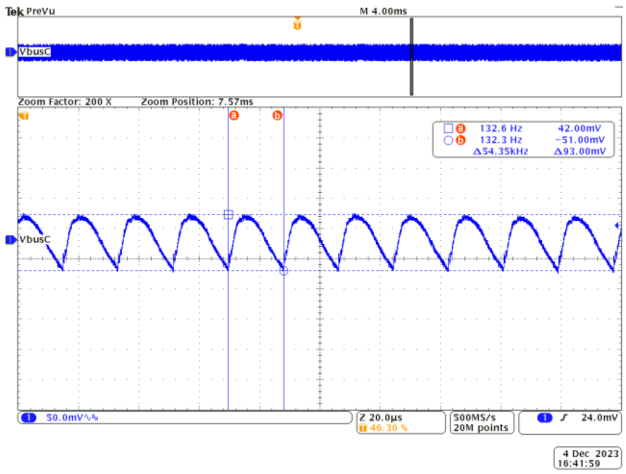


28 V, 5 A, Ripple (p-p) = 68 mV

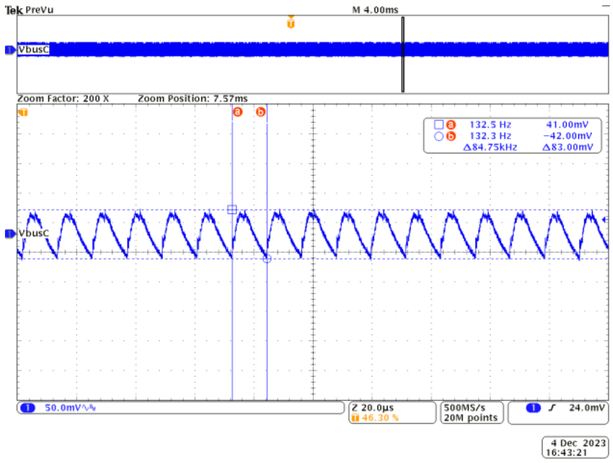
Figure 14 Ripple and noise at 230 V_{ac}, 50 Hz (CH1: V_{bus_c})



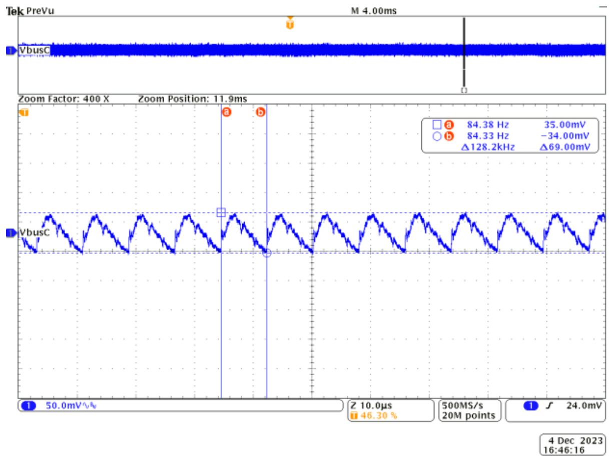
3.3 V, 5 A, Ripple (p-p) = 98 mV



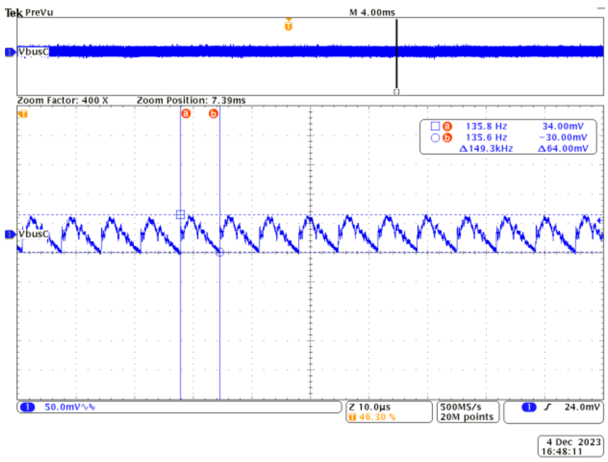
5 V, 5 A, Ripple (p-p) = 93 mV



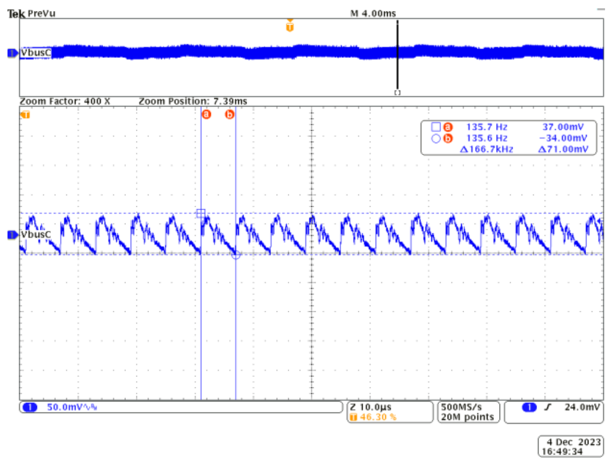
9 V, 5 A, Ripple (p-p) = 83 mV



15 V, 5 A, Ripple (p-p) = 69 mV



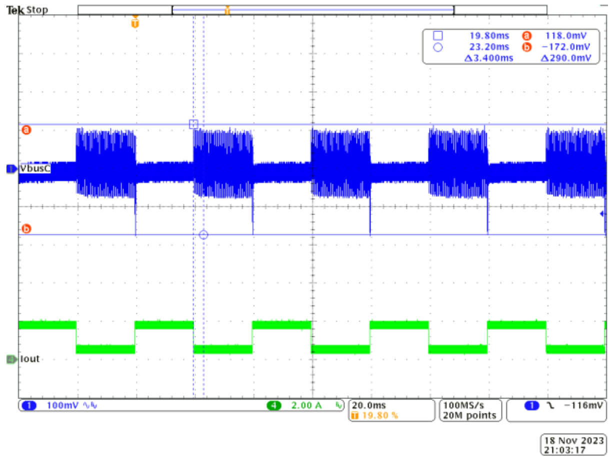
20 V, 5 A, Ripple (p-p) = 64 mV



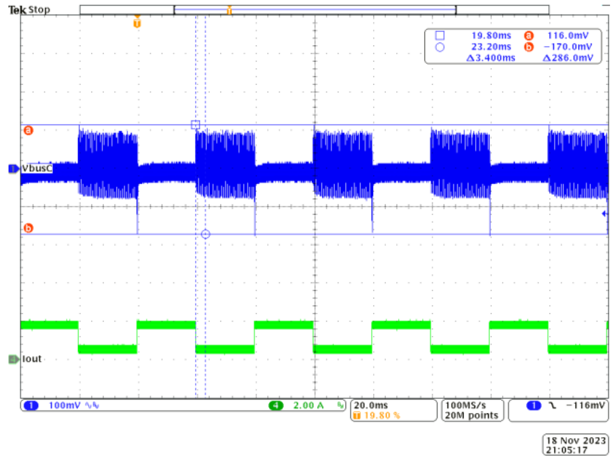
28 V, 5 A, Ripple (p-p) = 71 mV

Figure 15 **Ripple and noise at 265 V_{ac}, 63 Hz (CH1: V_{bus_c})**

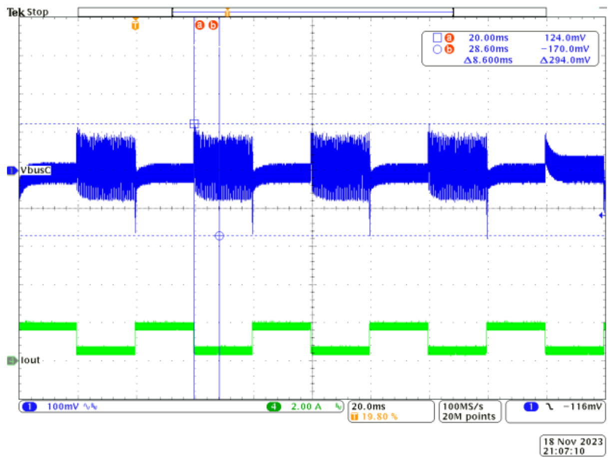
3.6 Output load dynamic response settling time



3.3 V – 0.5 A to 1.75 A, settling time = 3.4 ms



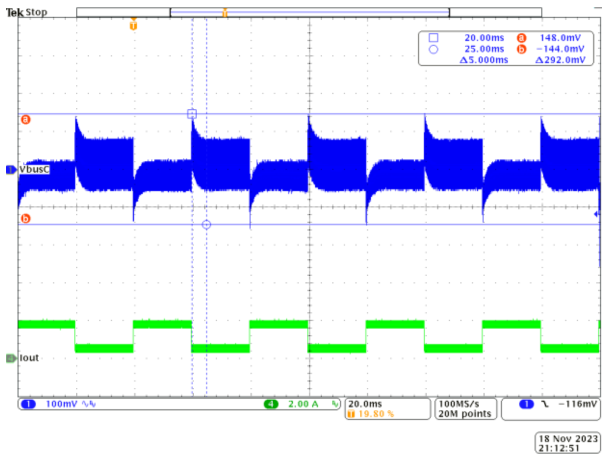
5 V – 0.5 A to 1.75 A, settling time = 3.4 ms



9 V – 0.5 A to 1.75 A, settling time = 8.6 ms

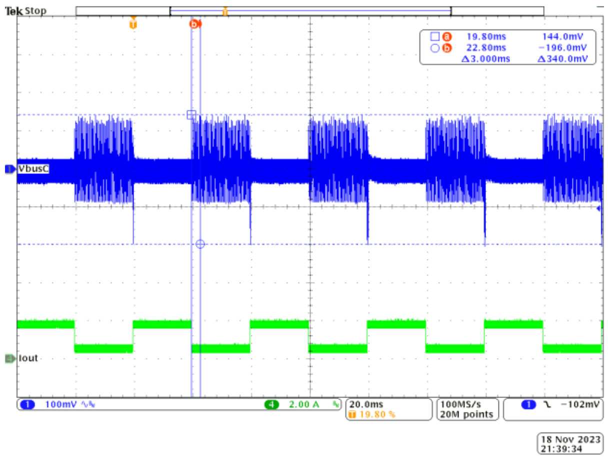
15 V – 0.5 A to 1.75 A, settling time = 8.6 ms

20 V – 0.5 A to 1.75 A, settling time = 7 ms

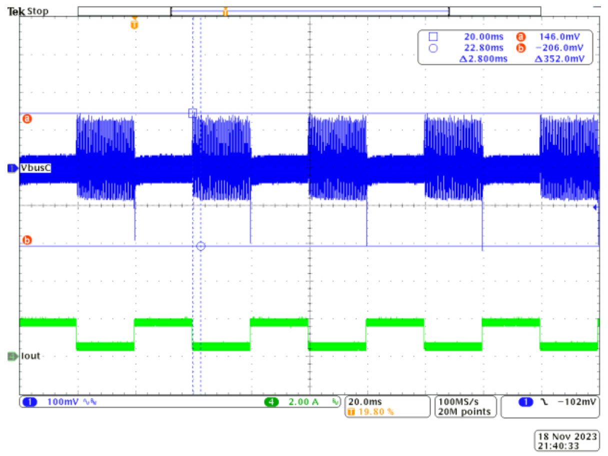


28 V – 0.5 A to 1.75 A, settling time = 5 ms

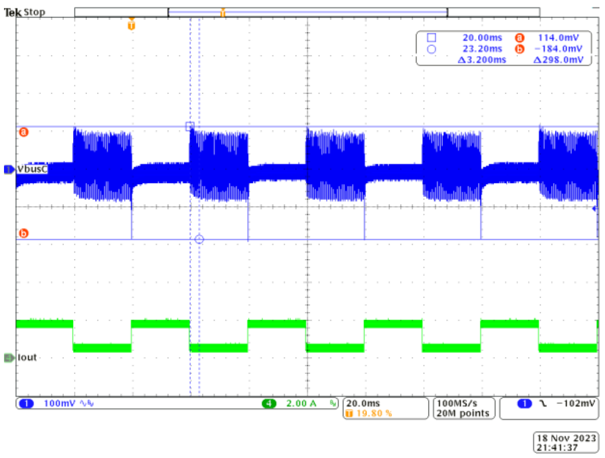
Figure 16 Output dynamic response at V_{ac} = 115 V_{ac}, 60 Hz, load transition = 10% to 35%, T1 = 20 ms, T2 = 20 ms, slew rate = 0.5 A/µs, (CH1: V_{bus_c}, Ch4: I_{out})



3.3 V – 0.5 A to 1.75 A, settling time = 3 ms



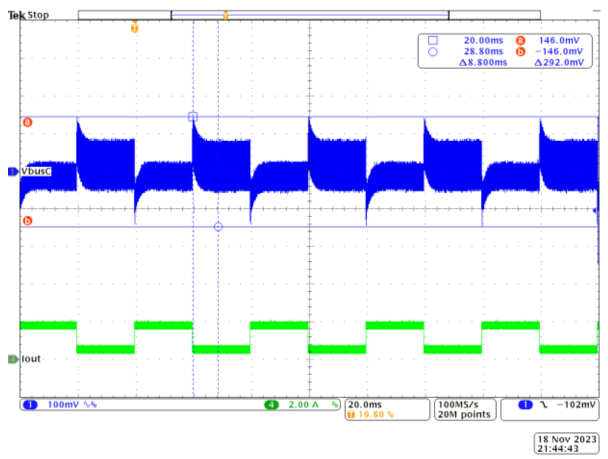
5 V – 0.5 A to 1.75 A, settling time = 2.8 ms



9 V – 0.5 A to 1.75 A, settling time = 3.2 ms

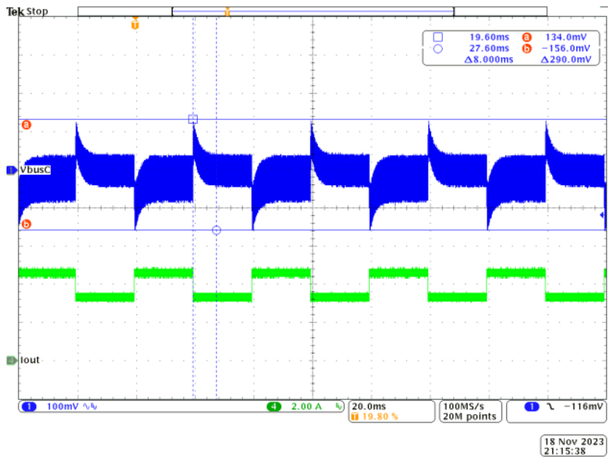
15 V – 0.5 A to 1.75 A, settling time = 7.6 ms

20 V – 0.5 A to 1.75 A, settling time = 8.6 ms

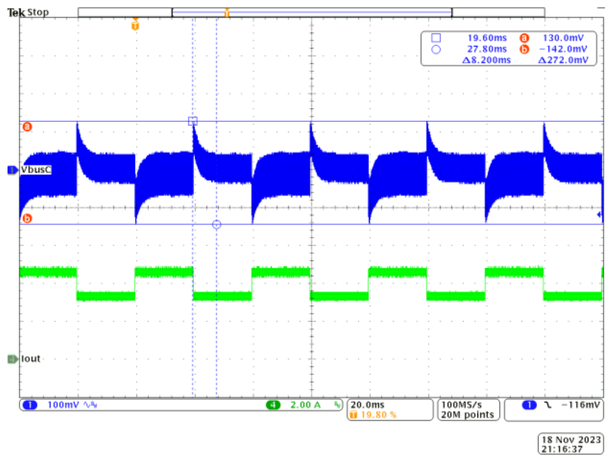


28 V – 0.5 A to 1.75 A, settling time = 8.8 ms

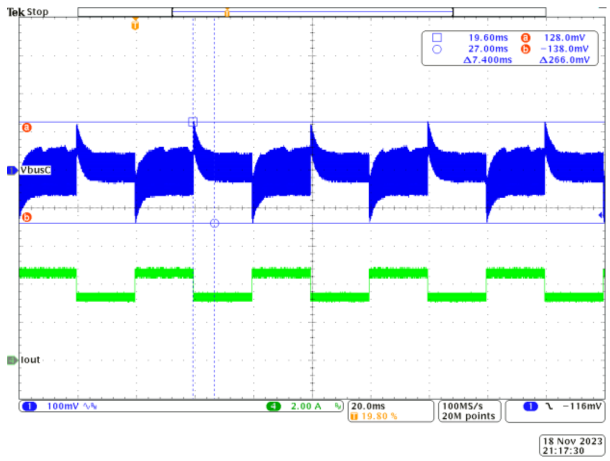
Figure 17 Output dynamic response at V_{ac} = 230 V_{ac}, 50 Hz, load transition = 10% to 35%, T1 = 20 ms, T2 = 20 ms, slew rate = 0.5 A/µs, (CH1: V_{bus_c}, Ch4: I_{out})



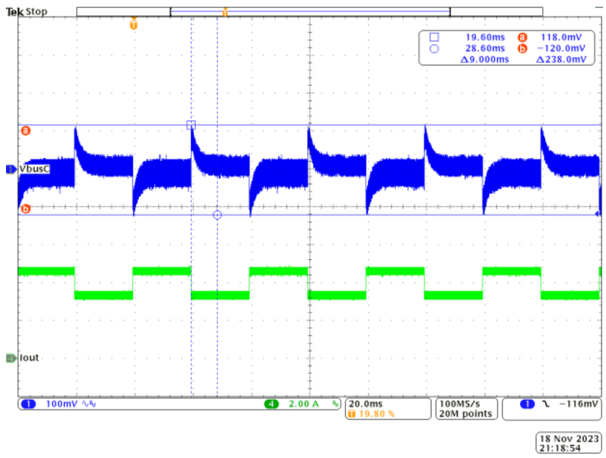
3.3 V – 3.25 A to 4.5 A, settling time = 8 ms



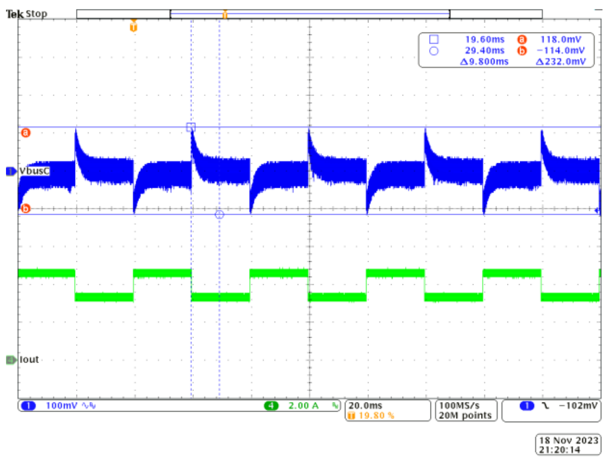
5 V – 3.25 A to 4.5 A, settling time = 8.2 ms



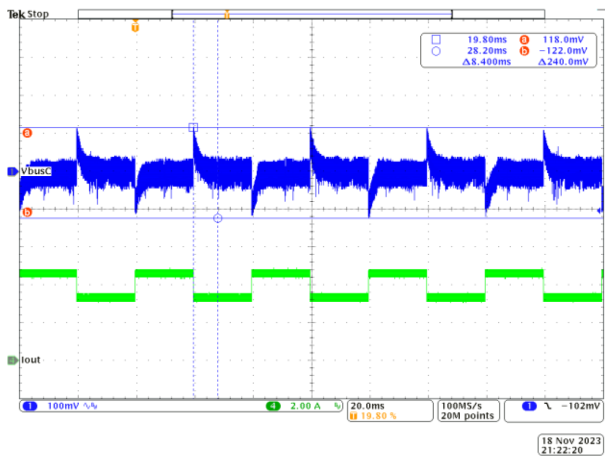
9 V – 3.25 A to 4.5 A, settling time = 7.4 ms



15 V – 3.25 A to 4.5 A, settling time = 9 ms

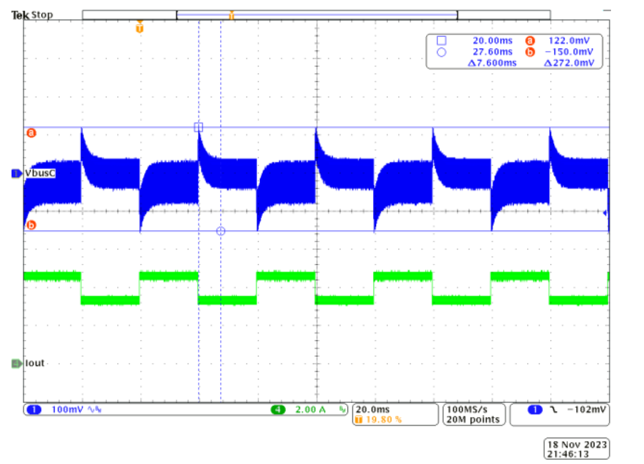


20 V – 3.25 A to 4.5 A, settling time = 9.8 ms

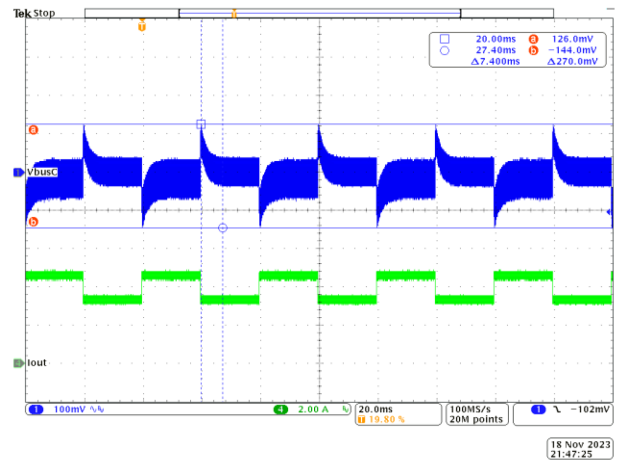


28 V – 3.25 A to 4.5 A, settling time = 8.4 ms

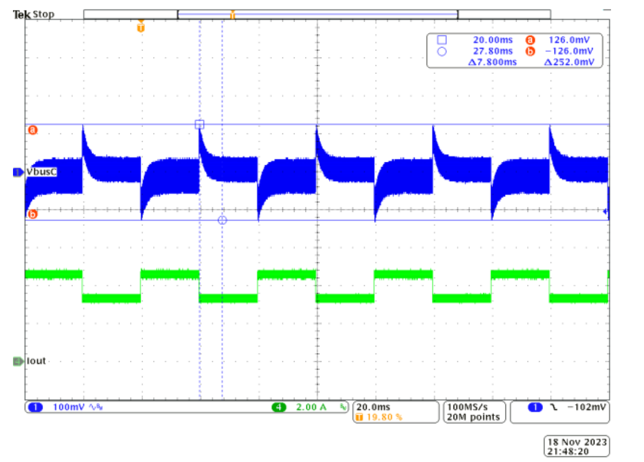
Figure 18 Output dynamic response at V_{ac} = 115 V_{ac}, 60 Hz, load transition = 65% to 90%, T1 = 20 ms, T2 = 20 ms, slew rate = 0.5 A/µs, (CH1: V_{bus_c}, Ch4: I_{out})



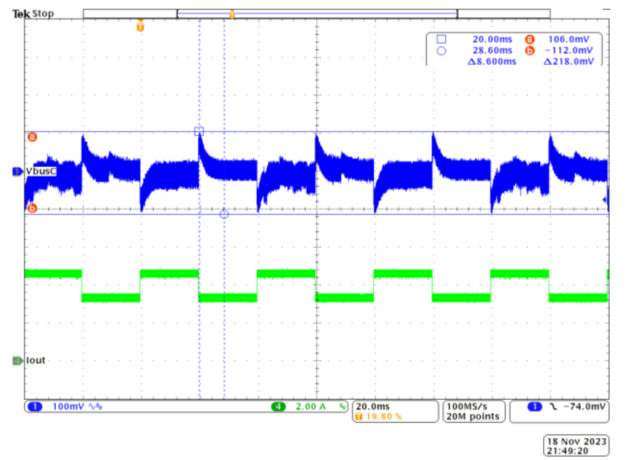
3.3 V – 3.25 A to 4.5 A, settling time = 7.6 ms



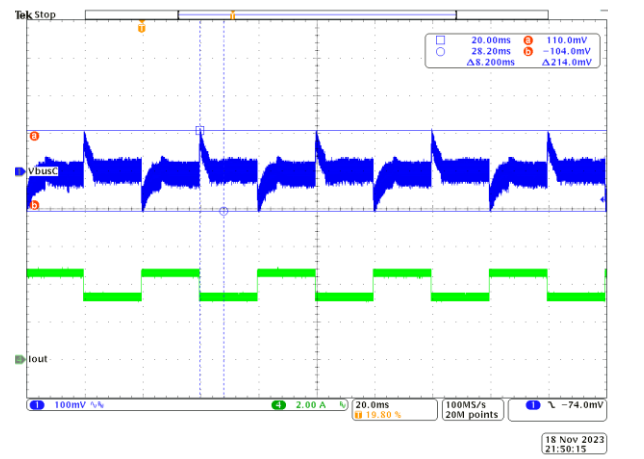
5 V – 3.25 A to 4.5 A, settling time = 7.4 ms



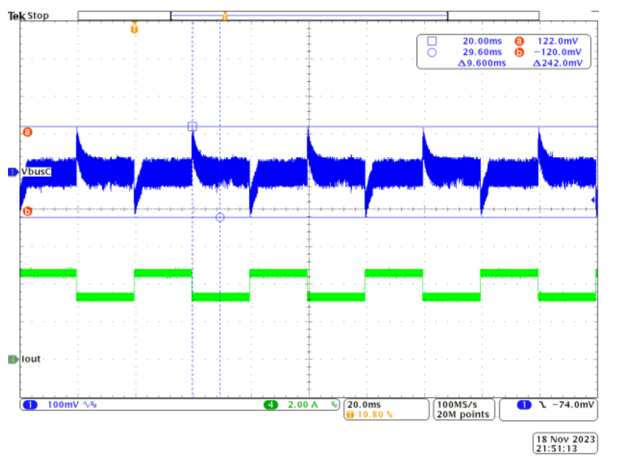
9 V – 3.25 A to 4.5 A, settling time = 7.8 ms



15 V – 3.25 A to 4.5 A, settling time = 8.6 ms

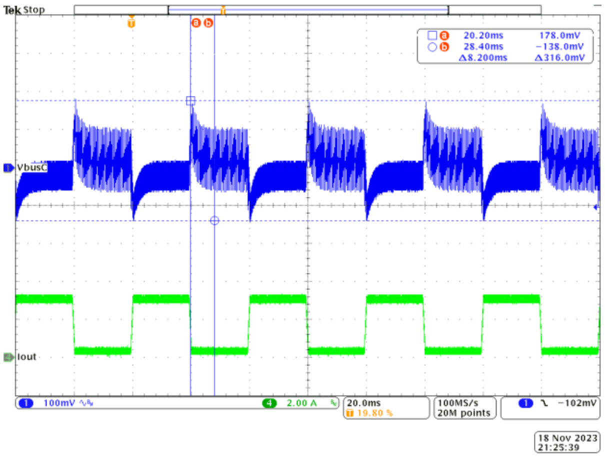


20 V – 3.25 A to 4.5 A, settling time = 8.2 ms

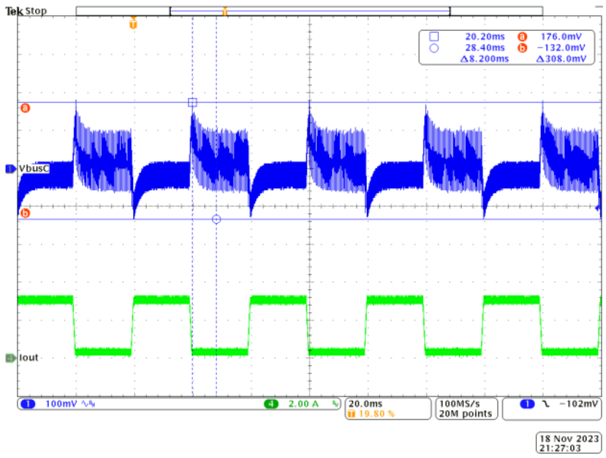


28 V – 3.25 A to 4.5 A, settling time = 9.6 ms

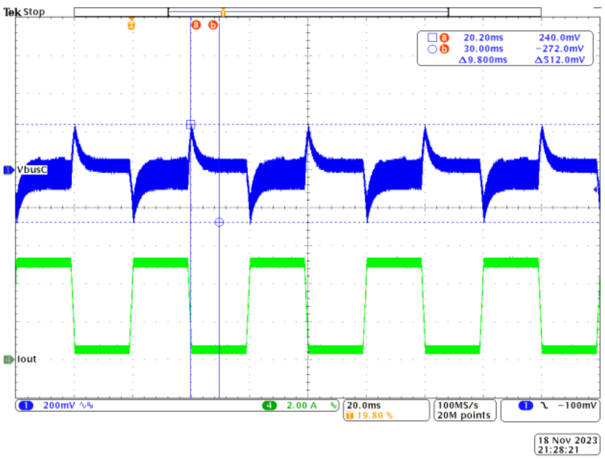
Figure 19 Output dynamic response at V_{ac} = 230 V_{ac}, 50 Hz, load transition = 65% to 90%, T1 = 20 ms, T2 = 20 ms, slew rate = 0.5 A/µs, (CH1: V_{bus_c}, Ch4: I_{out})



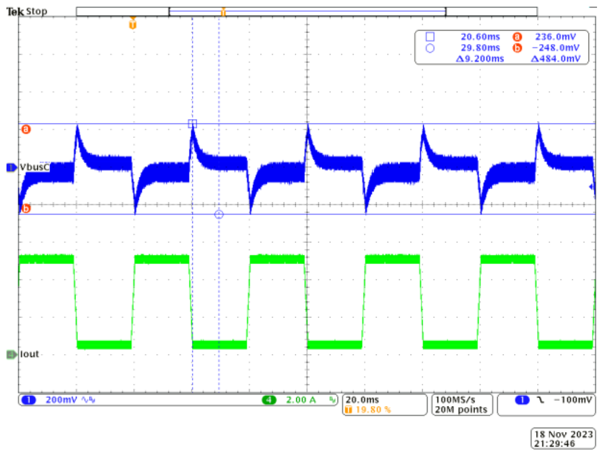
3.3 V – 0.3 A to 3 A, settling time = 8.2 ms



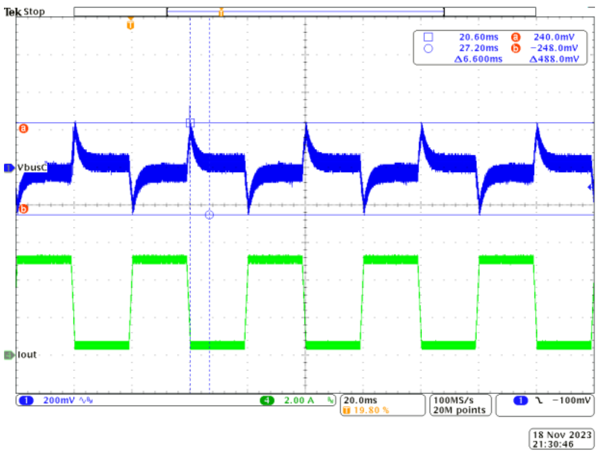
5 V – 0.3 A to 3 A, settling time = 8.2 ms



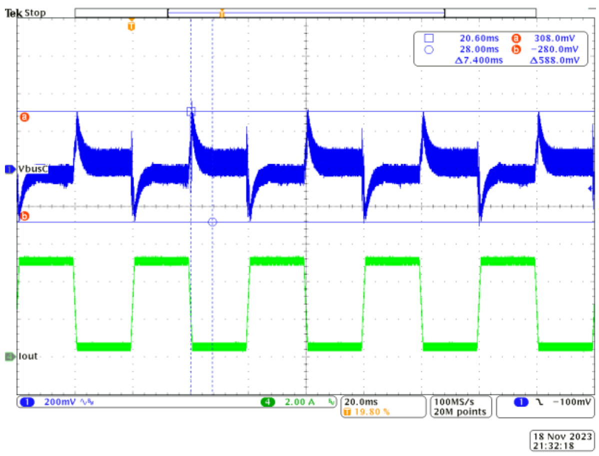
9 V – 0.5 A to 5 A, settling time = 9.8 ms



15 V – 0.5 A to 5 A, settling time = 9.2 ms

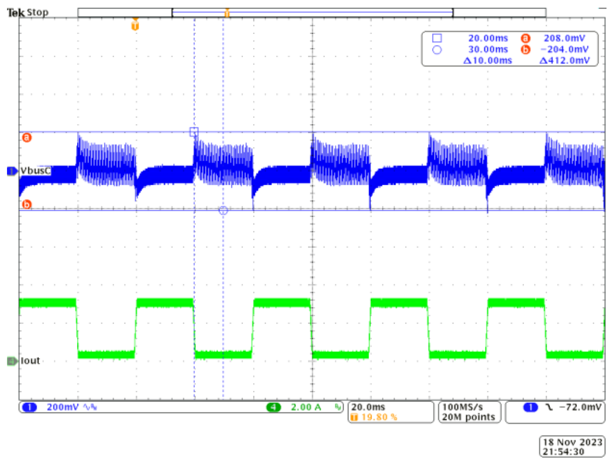


20 V – 0.5 A to 5 A, settling time = 6.6 ms

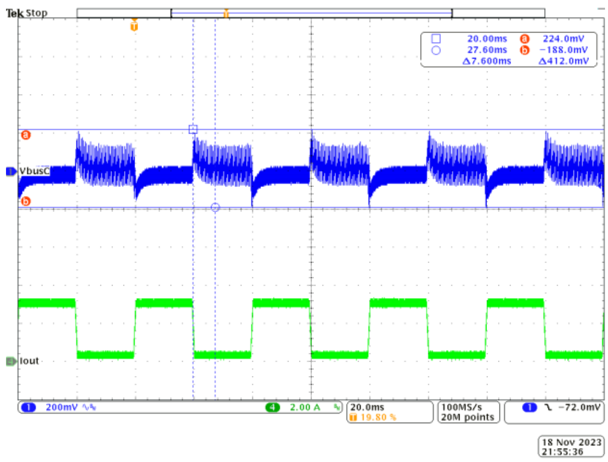


28 V – 0.5 A to 5 A, settling time = 7.4 ms

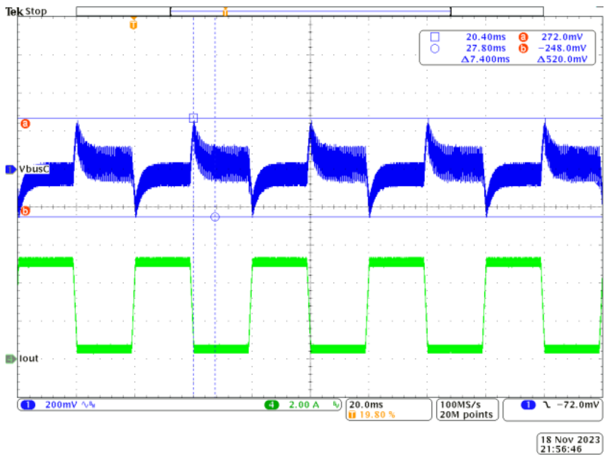
Figure 20 Output dynamic response at V_{ac} = 115 V_{ac}, 60 Hz, T1 = 20 ms, T2 = 20 ms, Slew Rate = 3.2 mA/µs (CH1: V_{bus_c}, Ch4: I_{out})



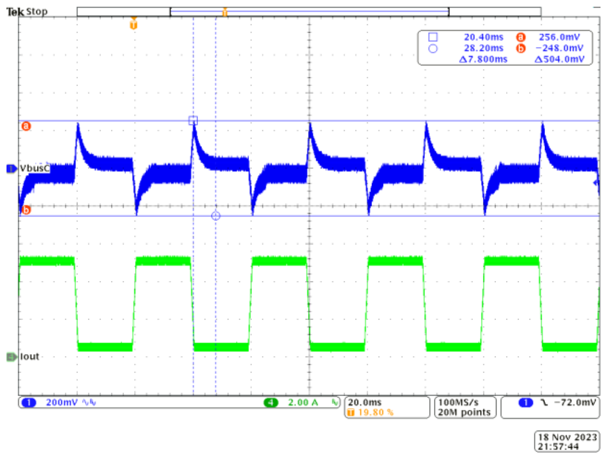
3.3 V – 0.3 A to 3 A, settling time = 10 ms



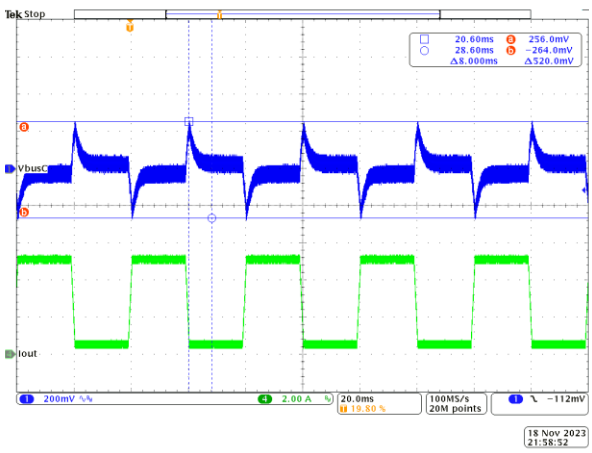
5 V – 0.3 A to 3 A, settling time = 7.6 ms



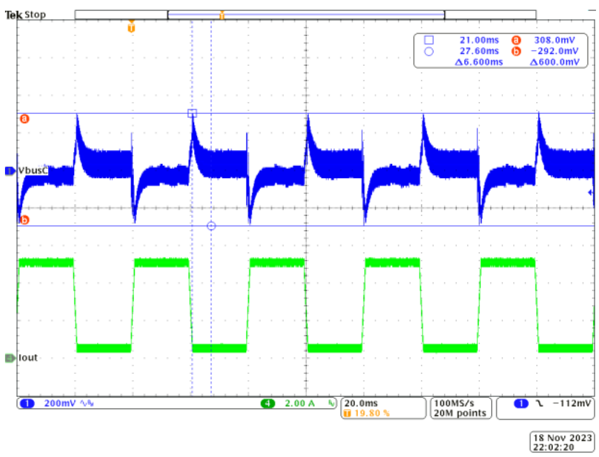
9 V – 0.5 A to 5 A, settling time = 7.4 ms



15 V – 0.5 A to 5 A, settling time = 7.8 ms



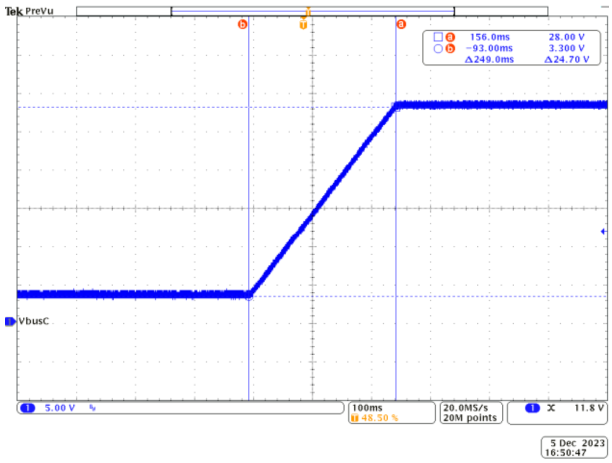
20 V – 0.5 A to 5 A, settling time = 8 ms



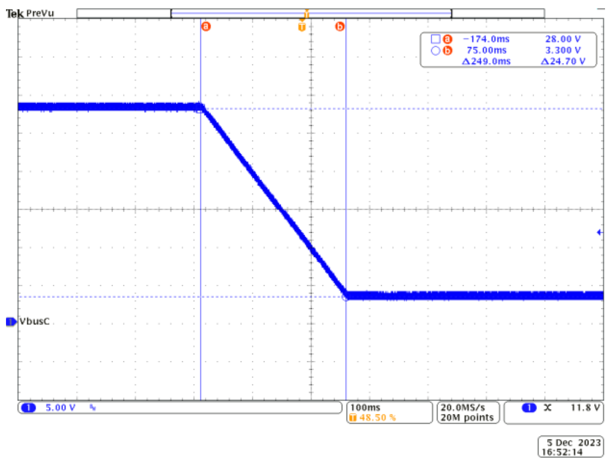
28 V – 0.5 A to 5 A, settling time = 6.6 ms

Figure 21 Output dynamic response at V_{ac} = 230 V_{ac}, 50 Hz, T1 = 20 ms, T2 = 20 ms, Slew Rate = 3.2 mA/µs (CH1: V_{bus_c}, Ch4: I_{out})

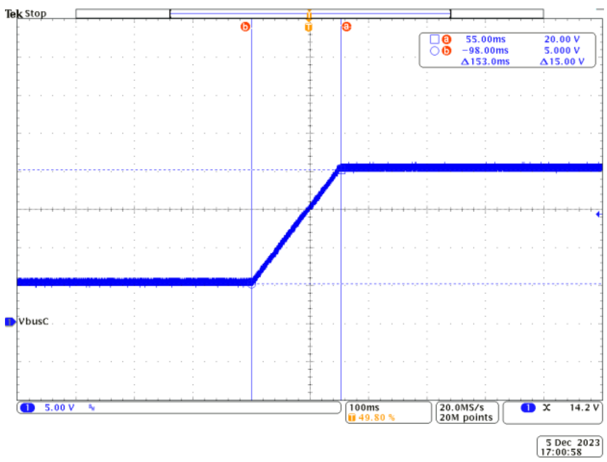
3.7 Output voltage transfer transition



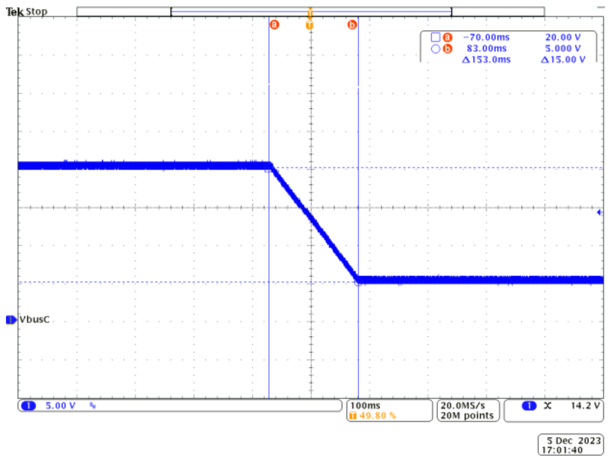
V_{out} = 3.3 V to 28 V, I_{out}=0 A
Transition time = 249 ms
Slew rate = 0.099 V/ms



V_{out} = 28 V to 3.3 V, I_{out}=0 A
Transition time = 249 ms
Slew rate = -0.099 V/ms

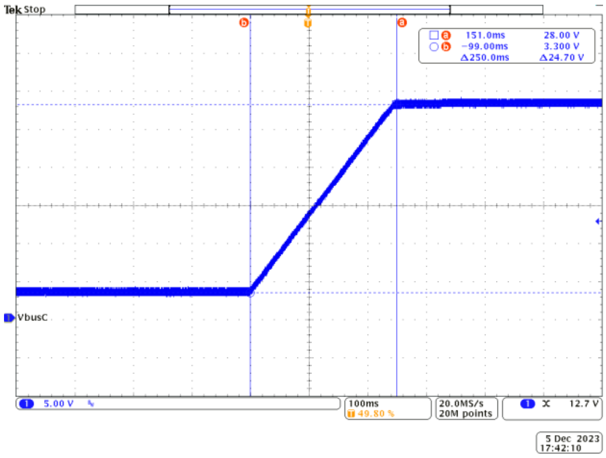


V_{out} = 5 V to 20 V, I_{out}=0 A
Transition time = 153 ms
Slew rate = 0.098 V/ms

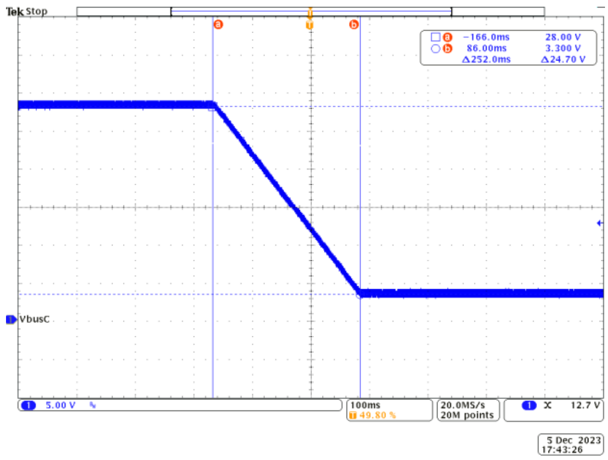


V_{out} = 20 V to 5 V, I_{out}=0 A
Transition time = 153 ms
Slew rate = -0.098 V/ms

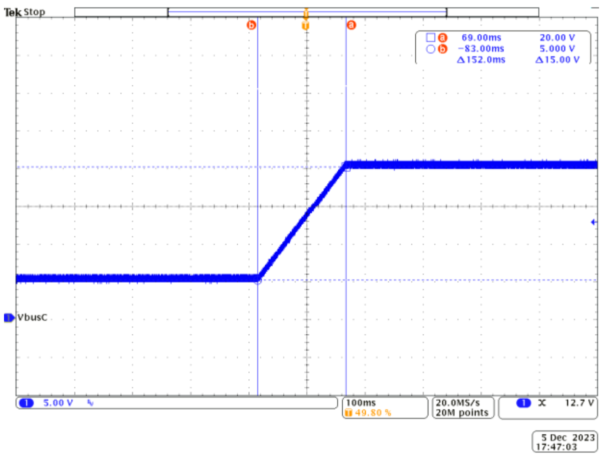
Figure 22 Output voltage transition at V_{ac} = 115 V_{ac}, 60 Hz (CH1: V_{bus_c})



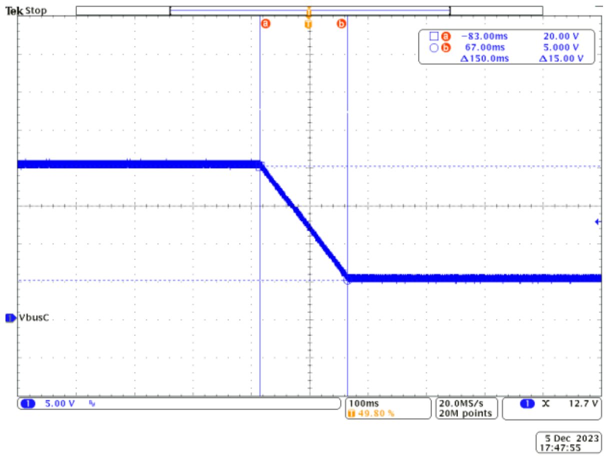
V_{out} = 3.3 V to 28 V, I_{out}=0 A
Transition time = 250 ms
Slew rate = 0.099 V/ms



V_{out} = 28 V to 3.3 V, I_{out}=0 A
Transition time = 252 ms
Slew rate = -0.098 V/ms



V_{out} = 5 V to 20 V, I_{out}=0 A
Transition time = 152 ms
Slew rate = 0.098 V/ms

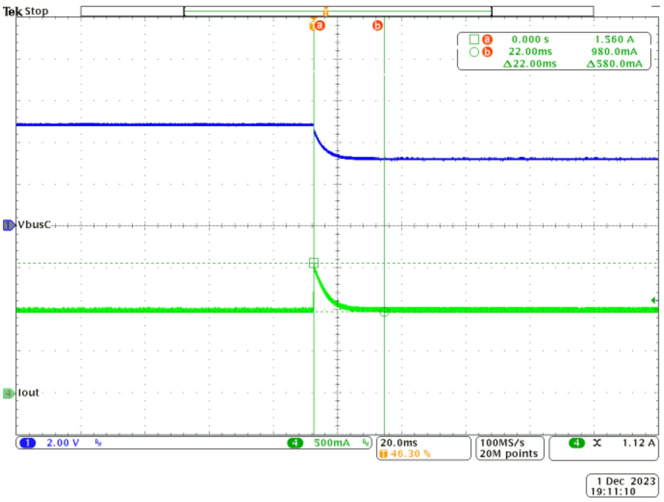


V_{out} = 20 V to 5 V, I_{out}=0 A
Transition time = 150 ms
Slew rate = -0.100 V/ms

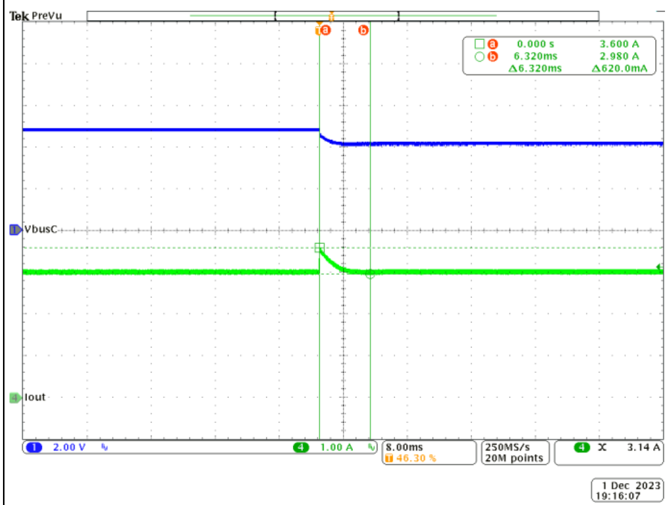
Figure 23 Output voltage transition at V_{ac} = 230 V_{ac}, 50 Hz (CH1: V_{bus_c})

3.8 Output current overshoot and settling time (CC region)

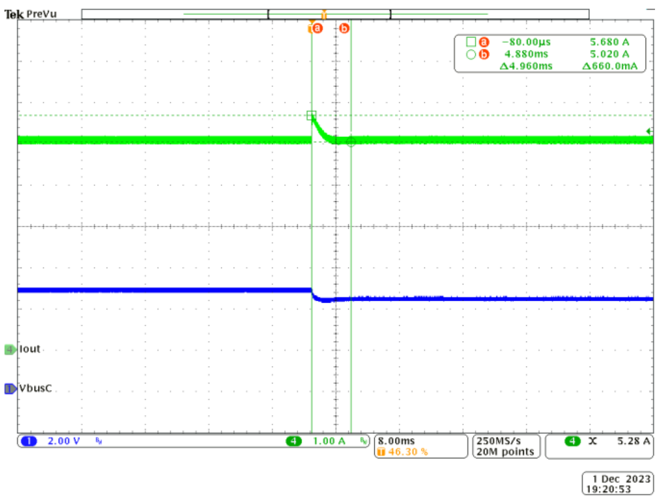
The output current overshoot and settling time at V_{ac} = 115 V_{ac}, 60 Hz, is shown in Figure 24.



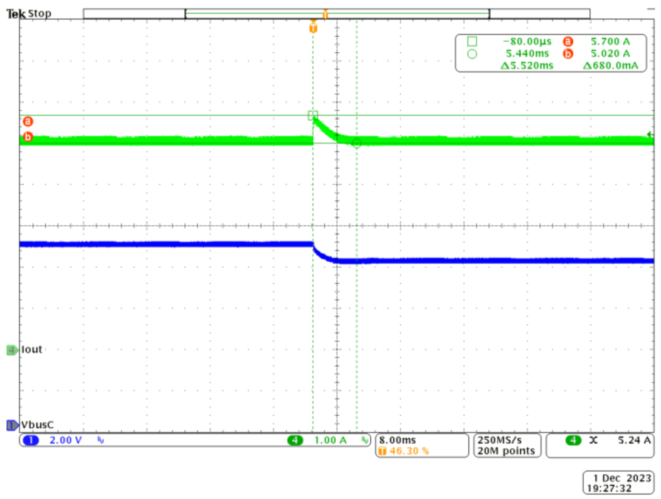
V_{out} = 5 V, I_o = 1.1 A to 1.6 A
I_o (limit) = 1 A, CR* mode: R = 4.8 Ω to 3.124 Ω
I_o overshoot = 580 mA, settling time = 22 ms



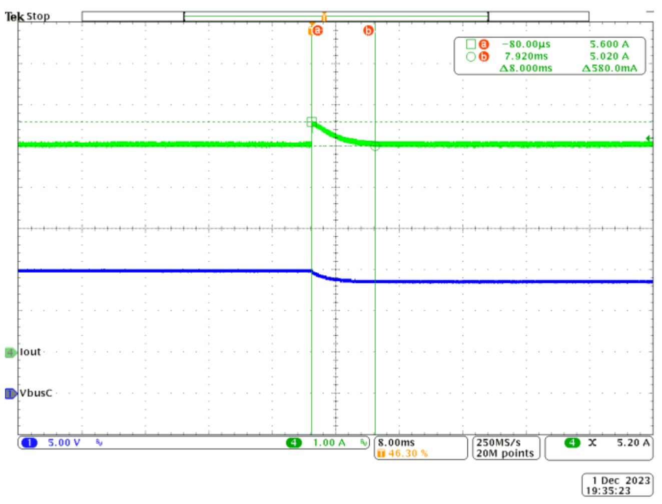
V_{out} = 5 V, I_o = 3.1 A to 3.6 A
I_o (limit) = 3 A, CR* mode: R = 1.45 Ω to 1.233 Ω
I_o overshoot = 620 mA, settling time = 6.32 ms



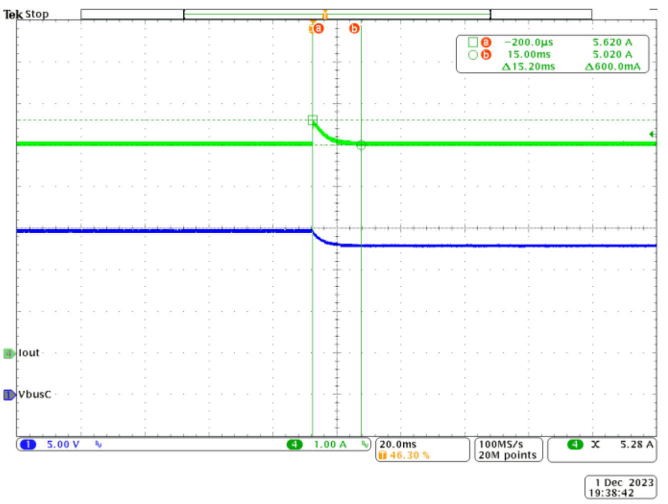
V_{out} = 5 V, I_o = 5.1 A to 5.6 A
I_o (limit) = 5 A, CR* mode: R = 0.8 Ω to 0.718 Ω
I_o overshoot = 660 mA, settling time = 4.96 ms



V_{out} = 9 V, I_o = 5.1 A to 5.6 A
I_o (limit) = 5 A, CR* mode: R = 1.6 Ω to 1.441 Ω
I_o overshoot = 680 mA, settling time = 5.52 ms



V_{out} = 15 V, I_o = 5.1 A to 5.6 A
I_o (limit) = 5 A, CR* mode: R = 2.8 Ω to 2.534 Ω
I_o overshoot = 580 mA, settling time = 8 ms

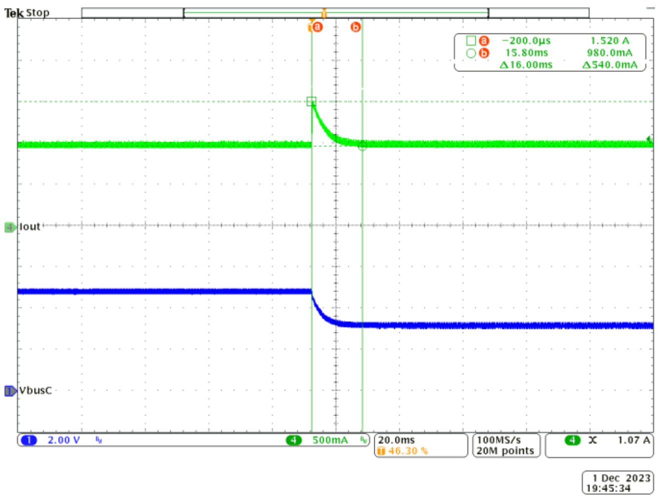


V_{out} = 20 V, I_o = 5.1 A to 5.6 A
I_o (limit) = 5 A, CR* mode: R = 3.75 Ω to 3.398 Ω
I_o overshoot = 600 mA, settling time = 15.2 ms

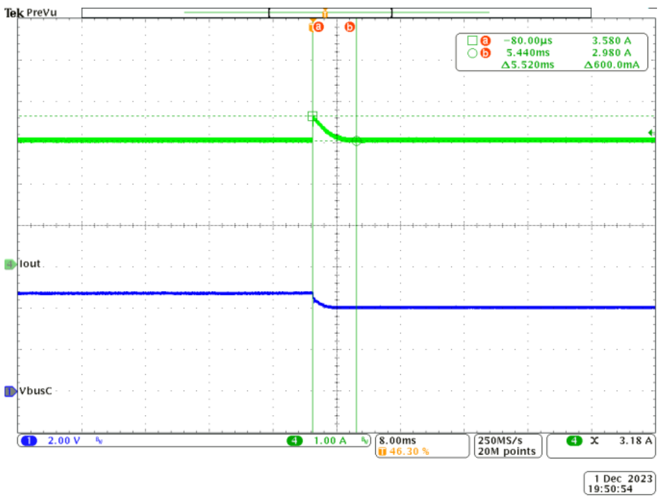
Figure 24 Output current overshoot and settling time at V_{ac} = 115 V_{ac}, 60 Hz (CH1: V_{bus_C}, CH4: I_{out})

*Note: * **CR mode** is the mode the electronic load (E-load) should be set at. The resistance value mentioned is specific to E-loads, length of the cable used from E-load to the DUT end, and the length of Type-C cable.*

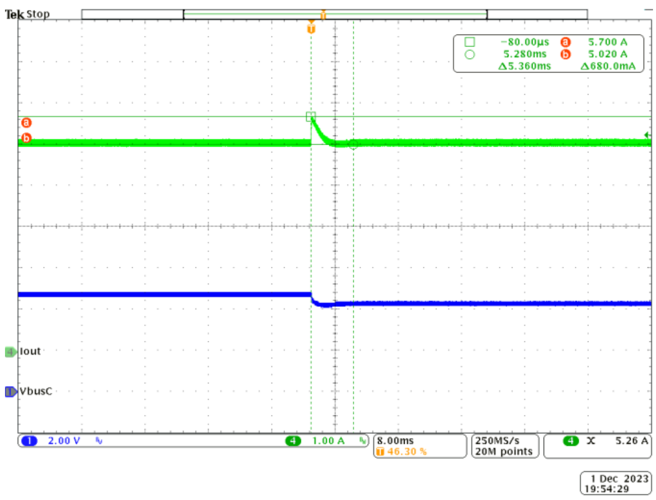
The output current overshoot and settling time at V_{ac} = 230 V_{ac}, 50 Hz, is shown in Figure 25.



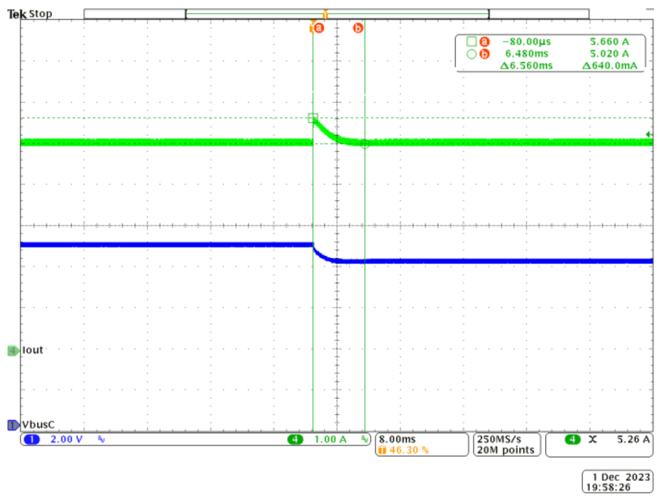
V_{out} = 5 V, I_o = 1.1 A to 1.6 A
I_o (limit) = 1 A, CR* mode: R = 4.8 Ω to 3.123 Ω
I_o overshoot = 540 mA, settling time = 16 ms



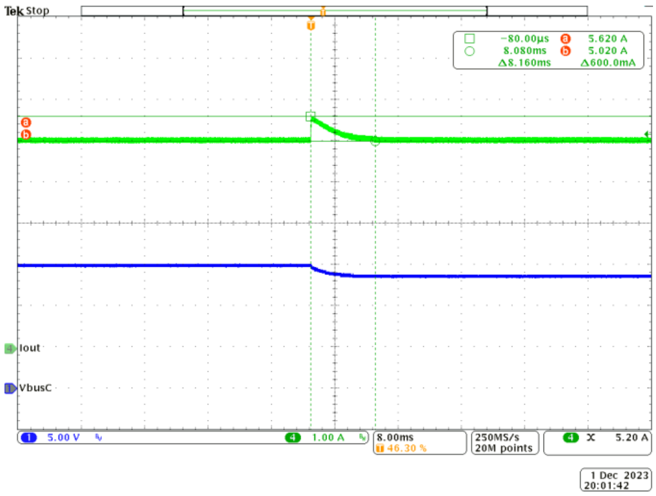
V_{out} = 5 V, I_o = 3.1 A to 3.6 A
I_o (limit) = 3 A, CR* mode: R = 1.45 Ω to 1.22 Ω
I_o overshoot = 600 mA, settling time = 5.52 ms



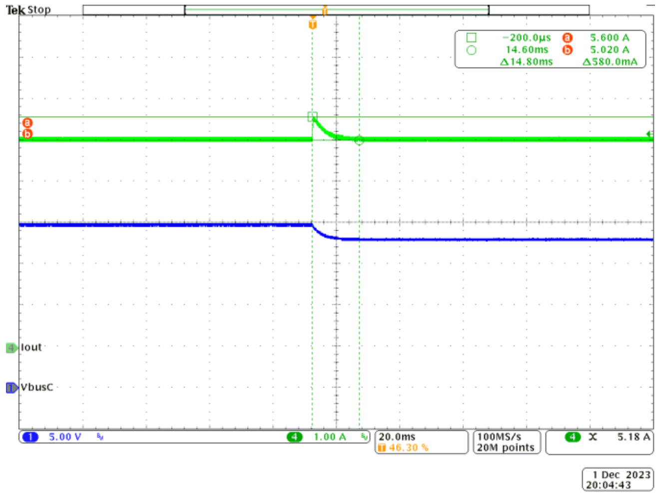
V_{out} = 5 V, I_o = 5.1 A to 5.6 A
I_o (limit) = 5 A, CR* mode: R = 0.8 Ω to 0.712 Ω
I_o overshoot = 680 mA, settling time = 5.36 ms



V_{out} = 9 V, I_o = 5.1 A to 5.6 A
I_o (limit) = 5 A, CR* mode: R = 1.6 Ω to 1.441 Ω
I_o overshoot = 640 mA, settling time = 6.56 ms



V_{out} = 15 V, I_o = 5.1 A to 5.6 A
I_o (limit) = 5 A, CR* mode: R = 2.8 Ω to 2.535 Ω
I_o overshoot = 600 mA, settling time = 8.16 ms



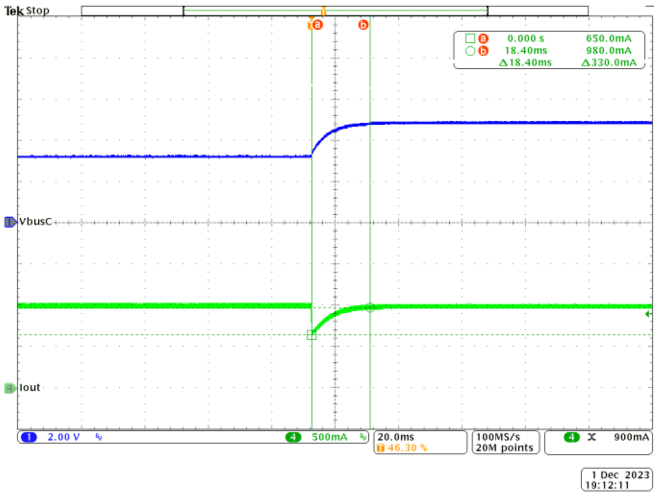
V_{out} = 20 V, I_o = 5.1 A to 5.6 A
I_o (limit) = 5 A, CR* mode: R = 3.75 Ω to 3.398 Ω
I_o overshoot = 580 mA, settling time = 14.8 ms

Figure 25 Output current overshoot and settling time at V_{ac} = 230 V_{ac}, 50 Hz (CH1: V_{bus_C}, CH4: I_{out})

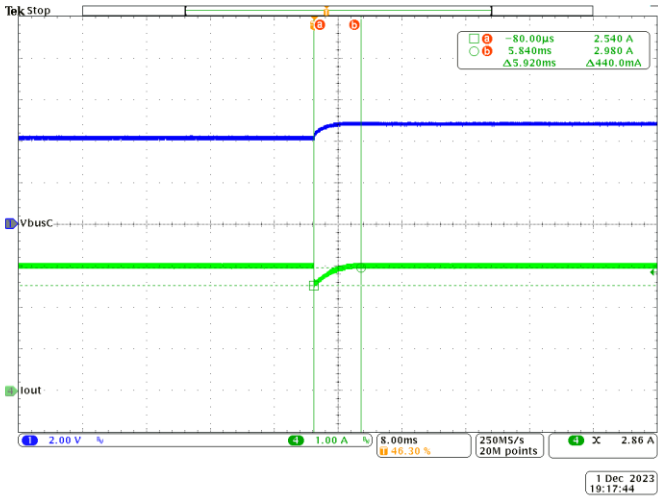
Note: * ***CR mode*** *is the mode the electronic load (E-load) should be set at. The resistance value mentioned is specific to E-loads, length of the cable used from E-load to the DUT end, and the length of Type-C cable.*

3.9 Output current undershoot and settling time (CC region)

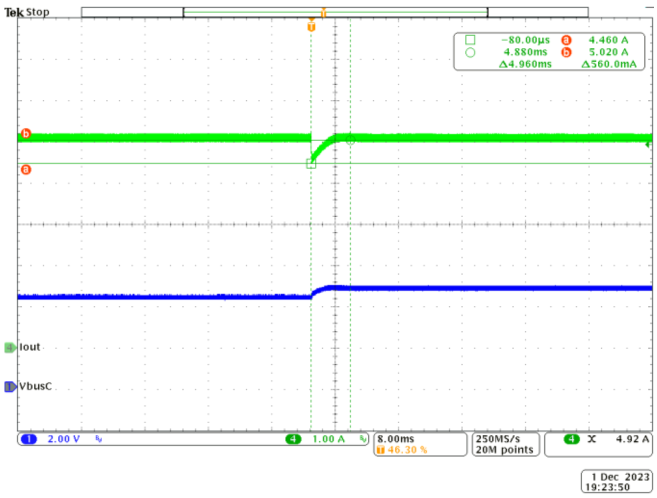
The output current undershoot and settling time at V_{ac} = 115 V_{ac}, 60 Hz, is shown in Figure 26.



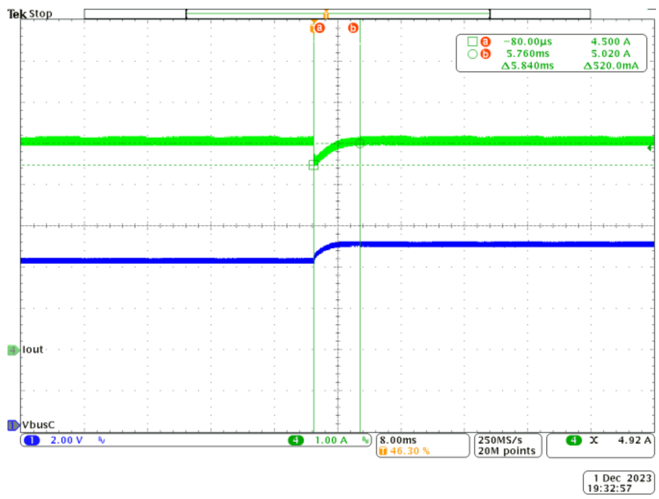
V_{out} = 5 V, I_o = 1.6 A to 1.1 A
I_o (limit) = 1 A, CR* mode: R = 3.124 Ω to 4.7 Ω
I_o undershoot = 330 mA, settling time = 18.4 ms



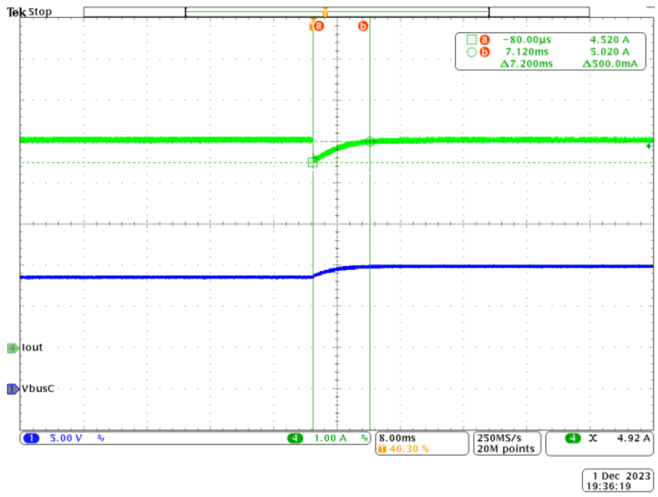
V_{out} = 5 V, I_o = 3.6 A to 3.1 A
I_o (limit) = 3 A, CR* mode: R = 1.233 Ω to 1.45 Ω
I_o undershoot = 440 mA, settling time = 5.92 ms



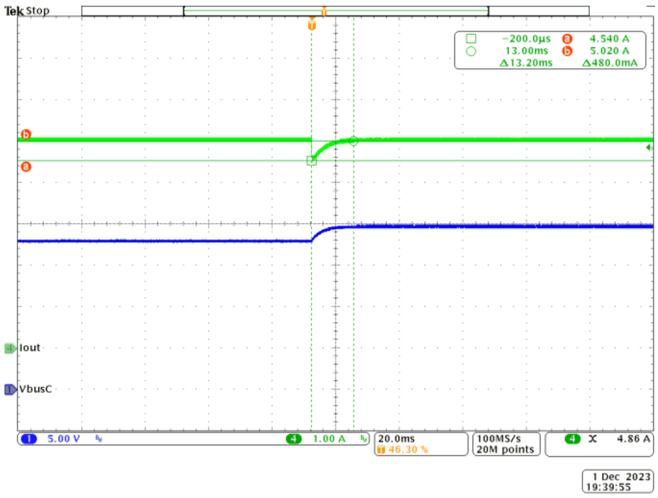
V_{out} = 5 V, I_o = 5.6 A to 5.1 A
I_o (limit) = 5 A, CR* mode: R = 0.718 Ω to 0.8 Ω
I_o undershoot = 560 mA, settling time = 4.96 ms



V_{out} = 9 V, I_o = 5.6 A to 5.1 A
I_o (limit) = 5 A, CR* mode: R = 1.441 Ω to 1.6 Ω
I_o undershoot = 520 mA, settling time = 5.84 ms



V_{out} = 15 V, I_o = 5.6 A to 5.1 A
I_o (limit) = 5 A, CR* mode: R = 2.534 Ω to 2.8 Ω
I_o undershoot = 500 mA, settling time = 7.2 ms

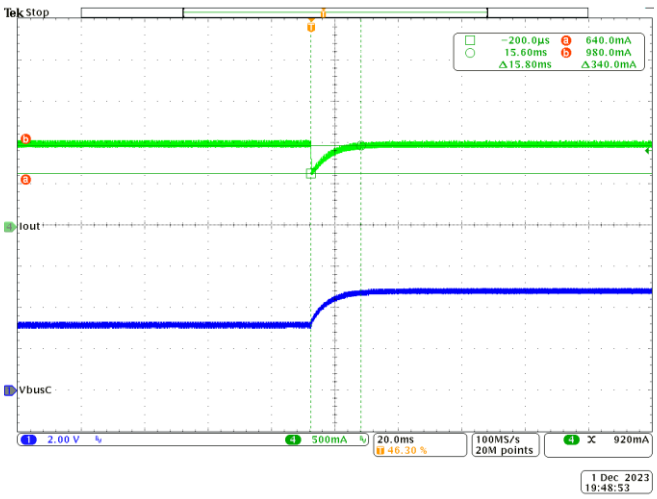


V_{out} = 20 V, I_o = 5.6 A to 5.1 A
I_o (limit) = 5 A, CR* mode: R = 3.398 Ω to 3.75 Ω
I_o undershoot = 480 mA, settling time = 13.2 ms

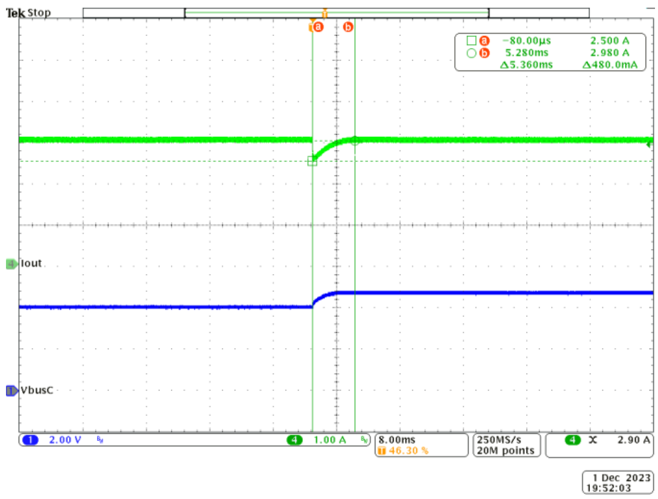
Figure 26 Output current undershoot and settling time at V_{ac} = 115 V_{ac}, 60 Hz (CH1: V_{bus_C}, CH4: I_{out})

Note: ** **CR mode** is the mode the electronic load (E-load) should be set at. The resistance value mentioned is specific to E-loads, length of the cable used from E-load to the DUT end, and the length of Type-C cable.*

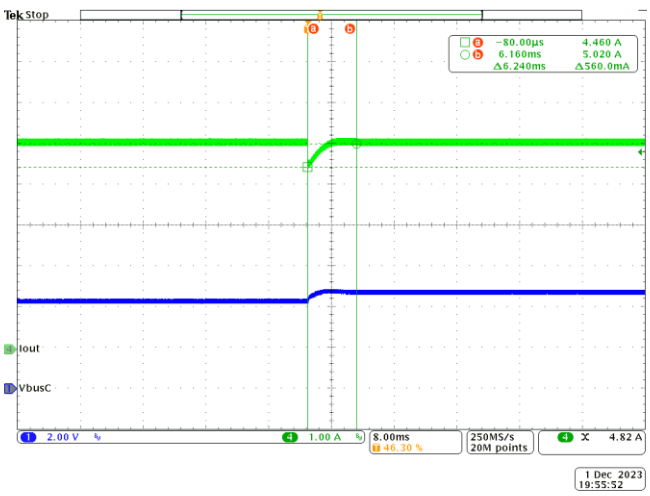
The output current undershoot and settling time at V_{ac} = 230 V_{ac}, 50 Hz, is shown in Figure 27.



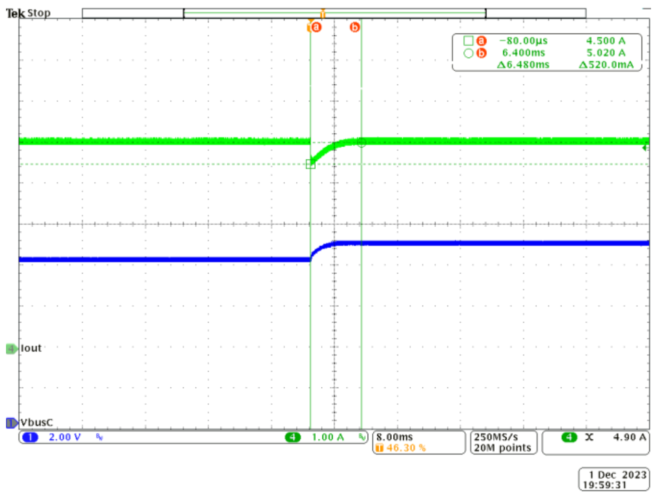
V_{out} = 5 V, I_o = 1.6 A to 1.1 A
I_o (limit) = 1 A, CR* mode: R = 3.123 Ω to 4.8 Ω
I_o undershoot = 340 mA, settling time = 15.8 ms



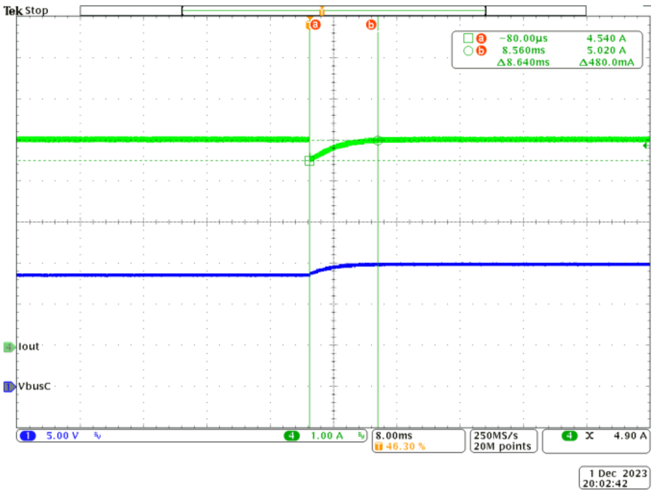
V_{out} = 5 V, I_o = 3.6 A to 3.1 A
I_o (limit) = 3 A, CR* mode: R = 1.22 Ω to 1.45 Ω
I_o undershoot = 480 mA, settling time = 5.36 ms



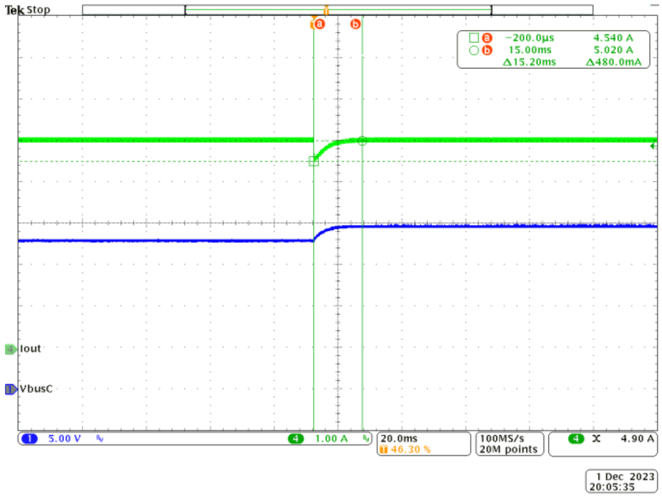
V_{out} = 5 V, I_o = 5.6 A to 5.1 A
I_o (limit) = 5 A, CR* mode: R = 0.712 Ω to 0.8 Ω
I_o undershoot = 560 mA, settling time = 6.24 ms



V_{out} = 9 V, I_o = 5.6 A to 5.1 A
I_o (limit) = 5 A, CR* mode: R = 1.441 Ω to 1.6 Ω
I_o undershoot = 520 mA, settling time = 6.48 ms



V_{out} = 15 V, I_o = 5.6 A to 5.1 A
I_o (limit) = 5 A, CR* mode: R = 2.535 Ω to 2.8 Ω
I_o undershoot = 480 mA, settling time = 8.64 ms



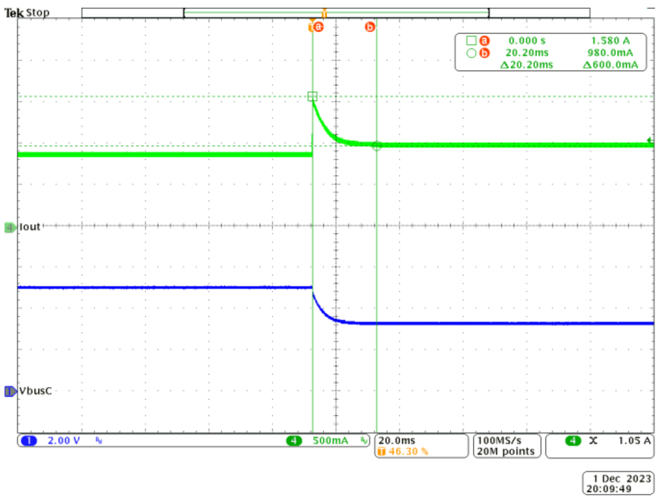
V_{out} = 20 V, I_o = 5.6 A to 5.1 A
I_o (limit) = 5 A, CR* mode: R = 3.398 Ω to 3.75 Ω
I_o undershoot = 480 mA, settling time = 15.2 ms

Figure 27 Output current undershoot and settling time at V_{ac} = 230 V_{ac}, 50 Hz (CH1: V_{bus_C}, CH4: I_{out})

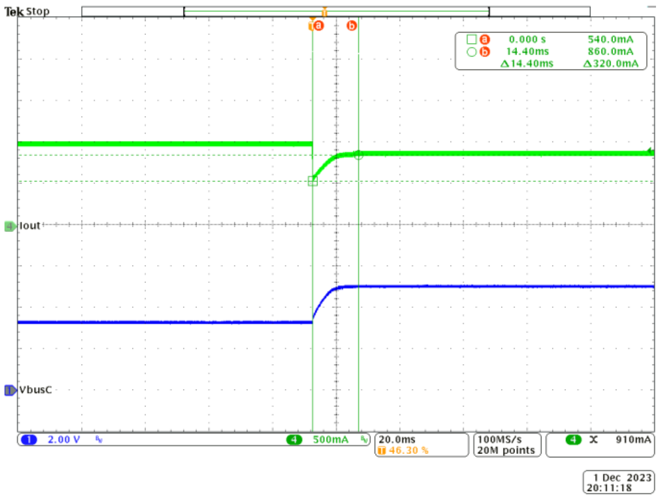
Note: * ***CR mode*** *is the mode the electronic load (E-load) should be set at. The resistance value mentioned is specific to E-loads, length of the cable used from E-load to the DUT end, and the length of Type-C cable.*

3.10 CV-CC transition time

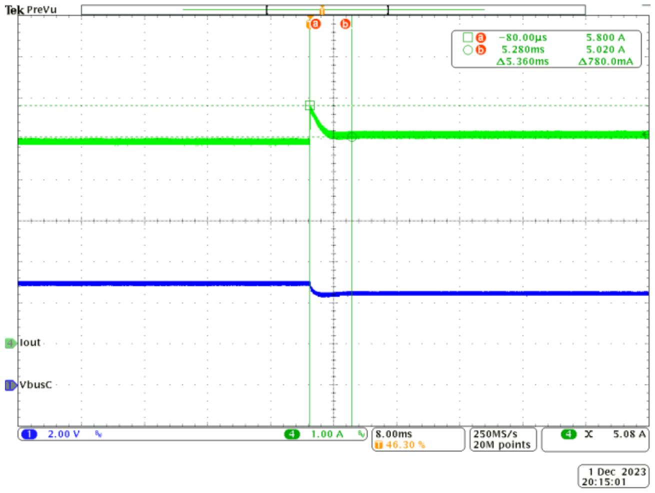
The CV to CC region transition at V_{ac} = 115 V_{ac}, 60 Hz, is shown in Figure 28.



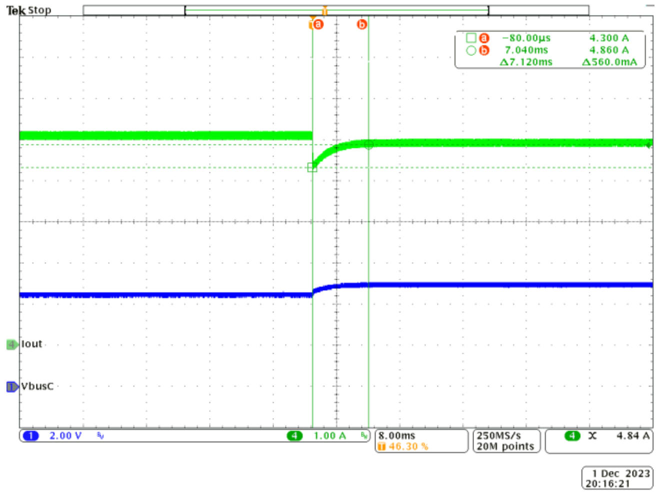
V_{out} = 5 V, I_o = 0.85 A to 1.5 A
I_o (limit) = 1 A, CR* mode: R = 5.71 Ω to 3.23 Ω
I_o overshoot = 600 mA, settling time = 20.2 ms



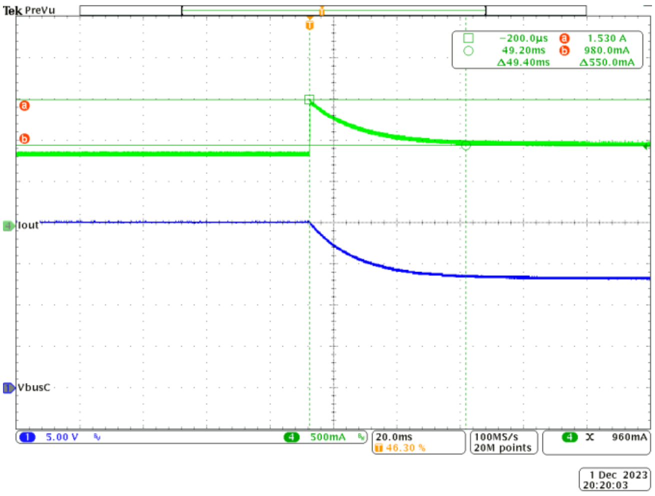
V_{out} = 5 V, I_o = 1.5 A to 0.85 A
I_o (limit) = 1 A, CR* mode: R = 3.23 Ω to 5.71 Ω
I_o undershoot = 320 mA, settling time = 14.4 ms



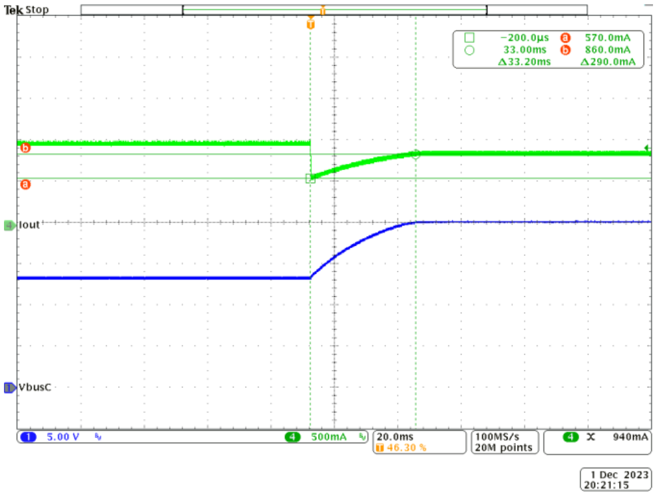
V_{out} = 5 V, I_o = 4.85 A to 5.5 A
I_o (limit) = 5 A, CR* mode: R = 0.876 Ω to 0.749 Ω
I_o overshoot = 780 mA, settling time = 5.36 ms



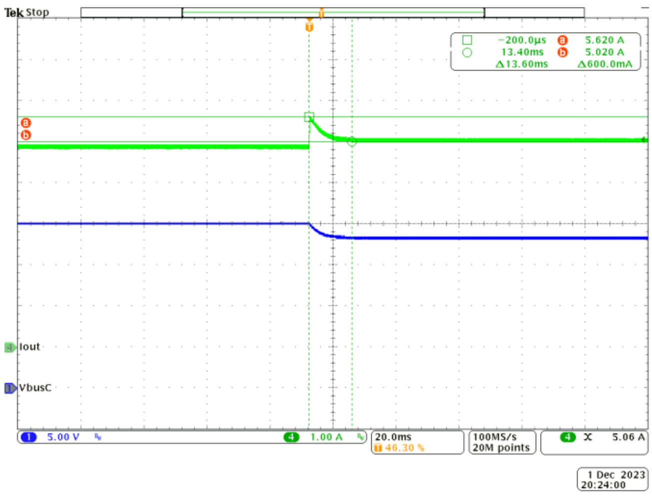
V_{out} = 5 V, I_o = 5.5 A to 4.85 A
I_o (limit) = 5 A, CR* mode: R = 0.749 Ω to 0.876 Ω
I_o undershoot = 560 mA, settling time = 7.12 ms



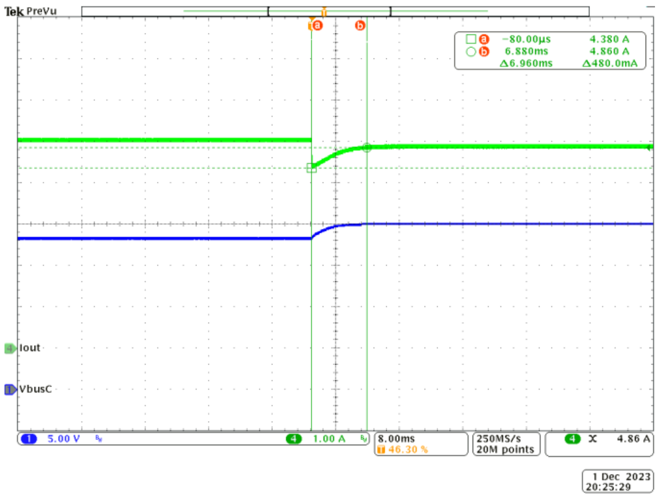
V_{out} = 20 V, I_o = 0.85 A to 1.5 A
I_o (limit) = 1 A, CR* mode: R = 23.3 Ω to 13.395 Ω
I_o overshoot = 550 mA, settling time = 49.4 ms



V_{out} = 20 V, I_o = 1.5 A to 0.85 A
I_o (limit) = 1 A, CR* mode: R = 13.395 Ω to 23.3 Ω
I_o undershoot = 290 mA, settling time = 33.2 ms



V_{out} = 20 V, I_o = 4.85 A to 5.5 A
I_o (limit) = 5 A, CR* mode: R = 3.97 Ω to 3.472 Ω
I_o overshoot = 600 mA, settling time = 13.6 ms

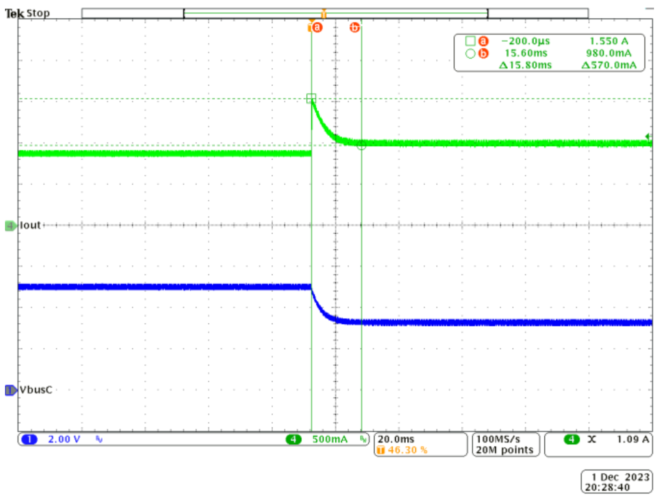


V_{out} = 20 V, I_o = 5.5 A to 4.85 A
I_o (limit) = 5 A, CR* mode: R = 3.472 Ω to 3.97 Ω
I_o undershoot = 480 mA, settling time = 6.96 ms

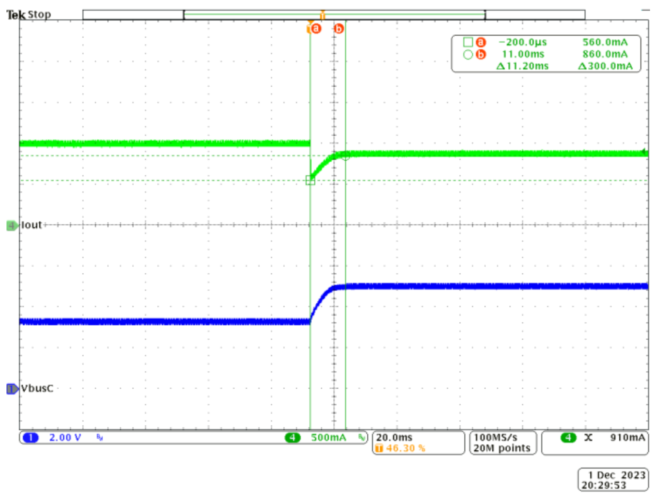
Figure 28 CV to CC region transition at V_{ac} = 115 V_{ac}, 60 Hz (CH1: V_{bus_c}, CH4: I_{out})

*Note: * **CR mode** is the mode the electronic load (E-load) should be set at. The resistance value mentioned is specific to E-loads, length of the cable used from E-load to the DUT end, and the length of Type-C cable.*

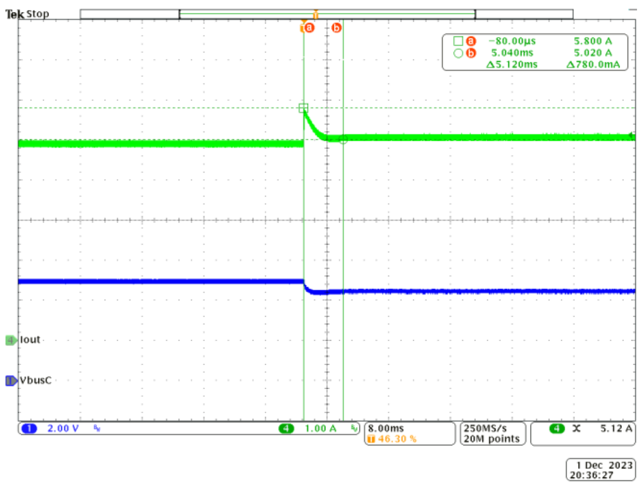
The CV to CC region transition at V_{ac} = 230 V_{ac}, 50 Hz, is shown in Figure 29.



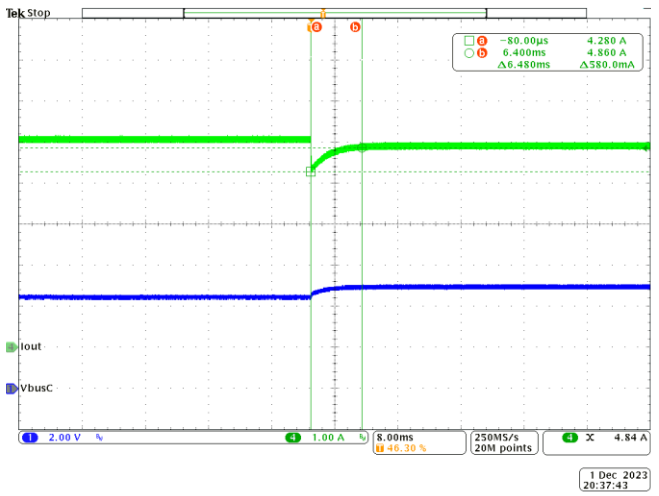
V_{out} = 5 V, I_o = 0.85 A to 1.5 A
I_o (limit) = 1 A, CR* mode: R = 5.71 Ω to 3.244 Ω
I_o overshoot = 570 mA, settling time = 15.8 ms



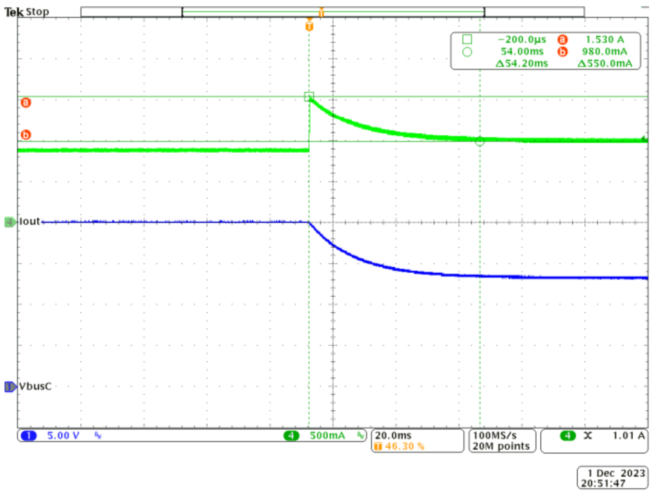
V_{out} = 5 V, I_o = 1.5 A to 0.85 A
I_o (limit) = 1 A, CR* mode: R = 3.244 Ω to 5.71 Ω
I_o undershoot = 300 mA, settling time = 11.2 ms



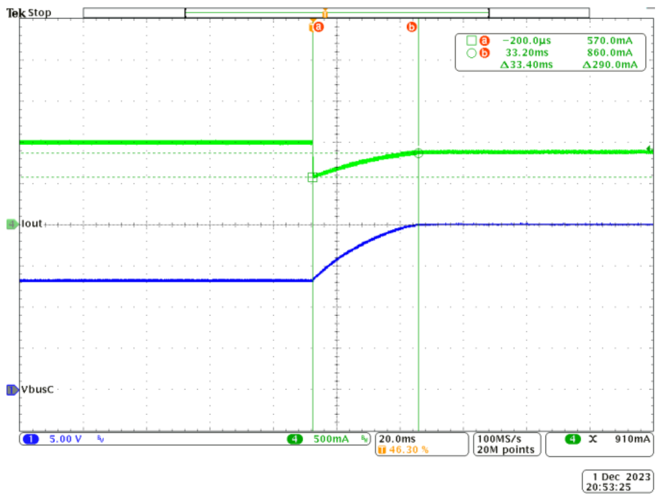
V_{out} = 5 V, I_o = 4.85 A to 5.5 A
I_o (limit) = 5 A, CR* mode: R = 0.874 Ω to 0.748 Ω
I_o overshoot = 780 mA, settling time = 5.12 ms



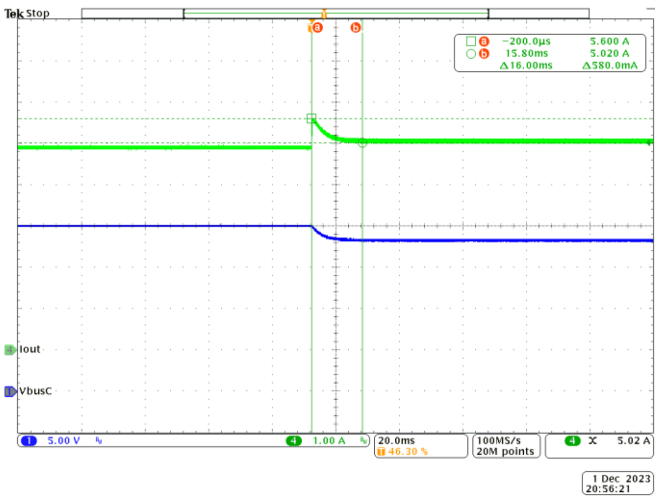
V_{out} = 5 V, I_o = 5.5 A to 4.85 A
I_o (limit) = 5 A, CR* mode: R = 0.748 Ω to 0.874 Ω
I_o undershoot = 580 mA, settling time = 6.48 ms



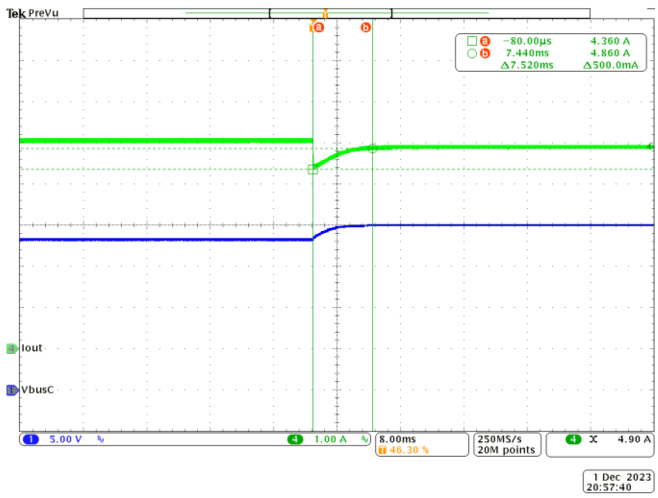
V_{out} = 20 V, I_o = 0.85 A to 1.5 A
I_o (limit) = 1 A, CR* mode: R = 23.3 Ω to 13.406 Ω
I_o overshoot = 550 mA, settling time = 54.2 ms



V_{out} = 20 V, I_o = 1.5 A to 0.85 A
I_o (limit) = 1 A, CR* mode: R = 13.406 Ω to 23.3 Ω
I_o undershoot = 290 mA, settling time = 33.4 ms



V_{out} = 20 V, I_o = 4.85 A to 5.5 A
I_o (limit) = 5 A, CR* mode: R = 3.97 Ω to 3.473 Ω
I_o overshoot = 580 mA, settling time = 16 ms

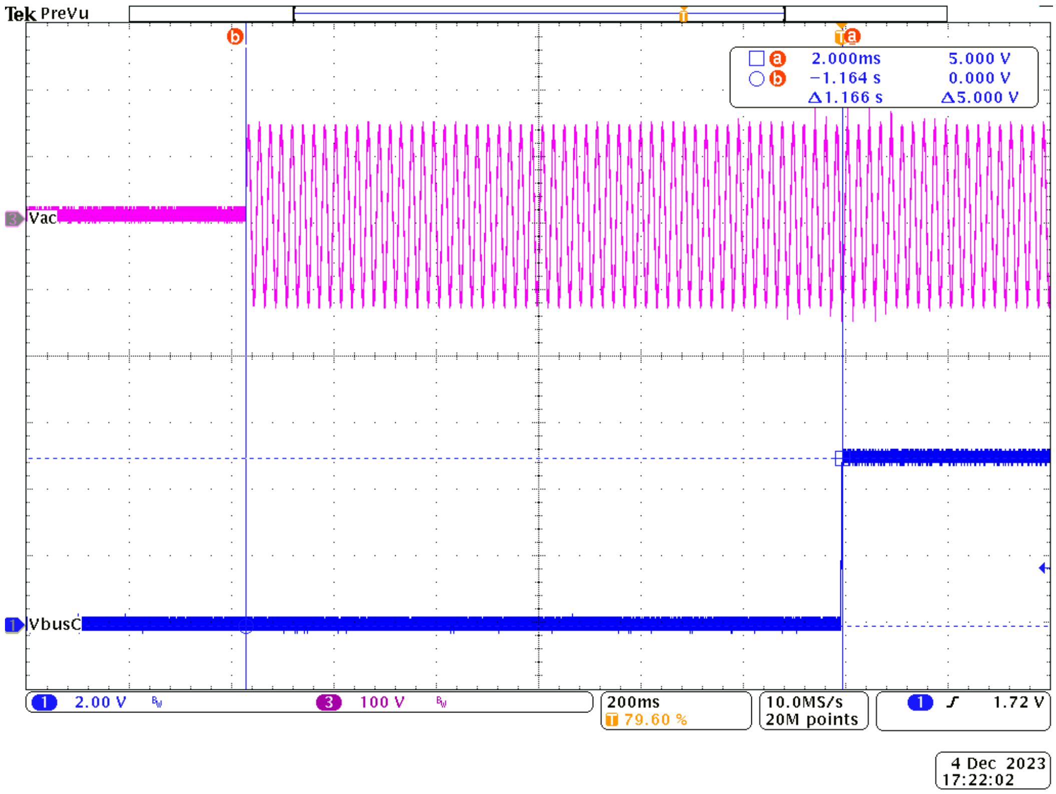


V_{out} = 20 V, I_o = 5.5 A to 4.85 A
I_o (limit) = 5 A, CR* mode: R = 3.473 Ω to 3.97 Ω
I_o undershoot = 500 mA, settling time = 7.52 ms

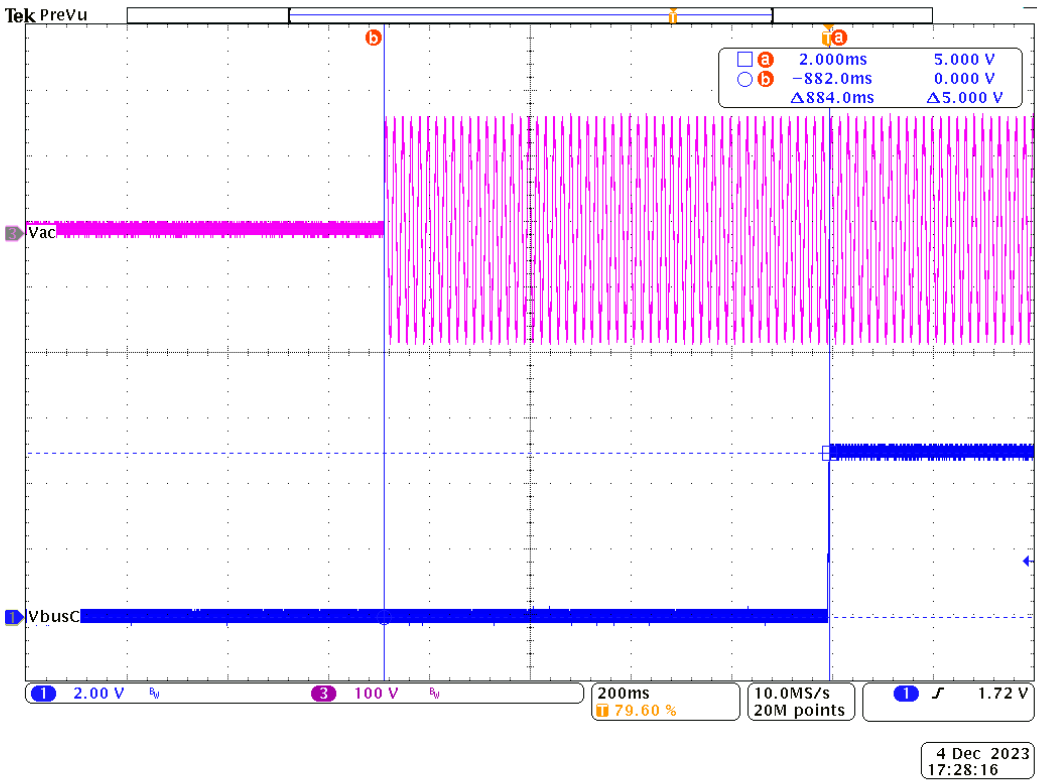
Figure 29 CV to CC region transition at V_{ac} = 230 V_{ac}, 50 Hz (CH1: V_{bus_C}, CH4: I_{out})

*Note: * **CR mode** is the mode the electronic load (E-load) should be set at. The resistance value mentioned is specific to E-loads, length of the cable used from E-load to the DUT end, and the length of Type-C cable.*

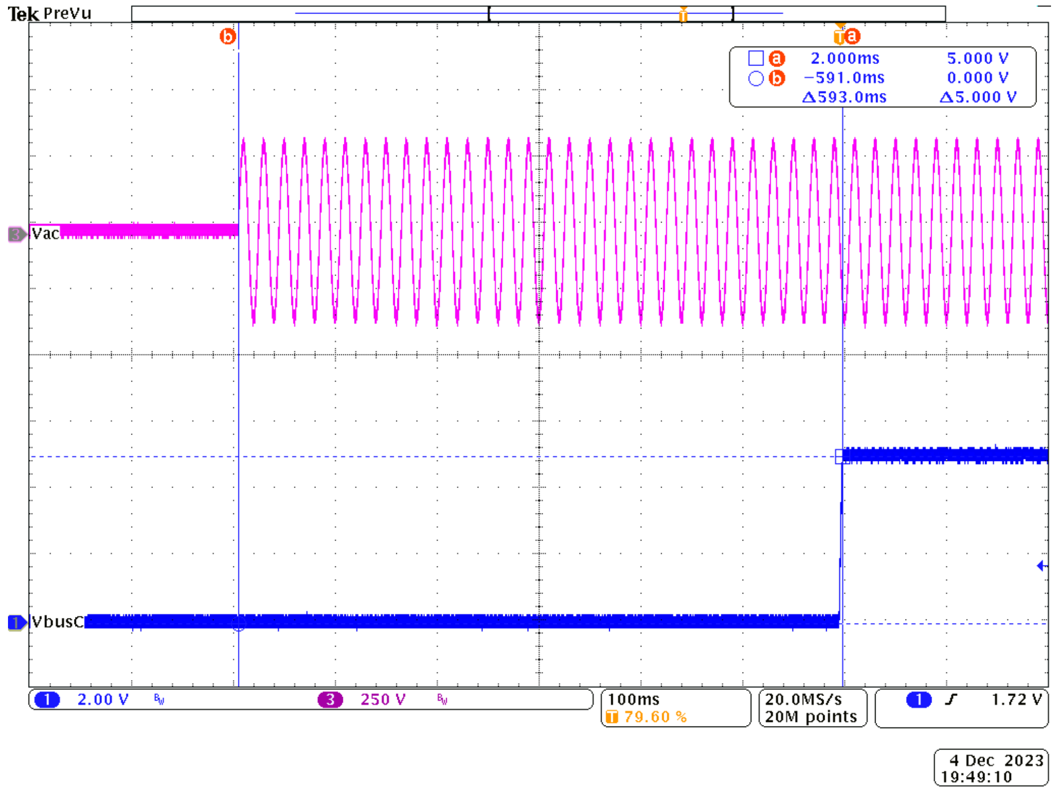
3.11 Start-up turn-on delay



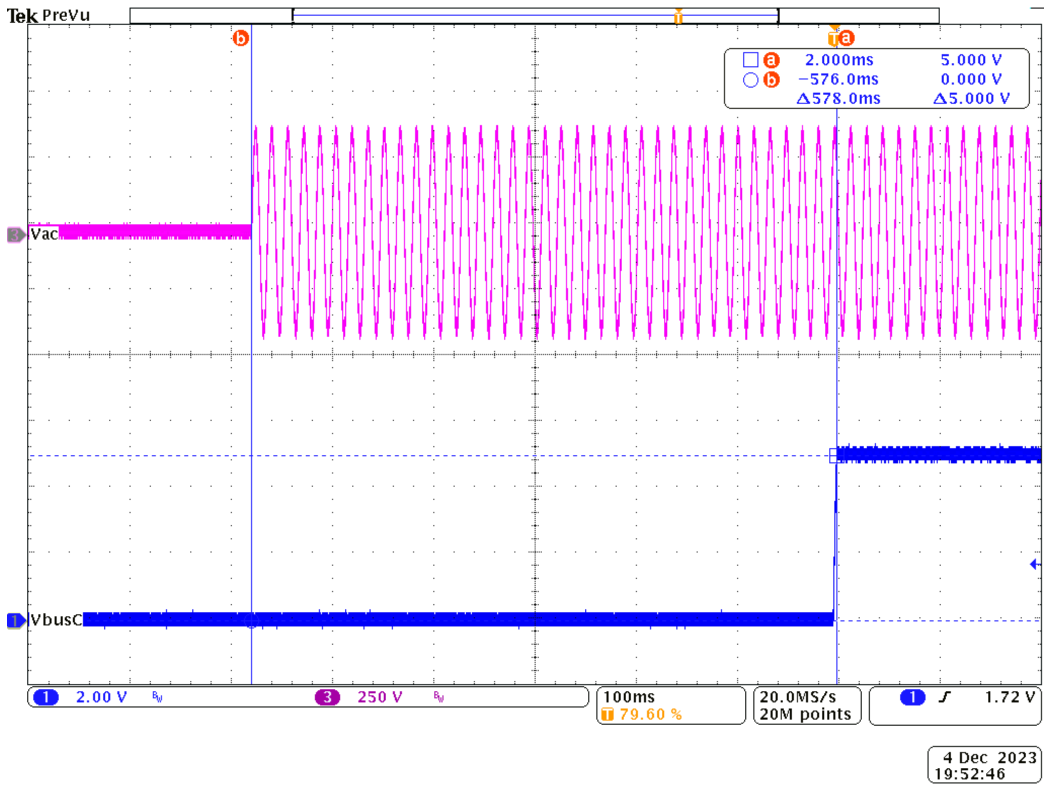
V_{out} = 5 V, I_{out} = 0 A, start-up turn-on delay time at 90 V_{ac}, 47 Hz = 1.16 s



V_{out} = 5 V, I_{out} = 0 A, start-up turn-on delay time at 115 V_{ac}, 60 Hz = 884 ms



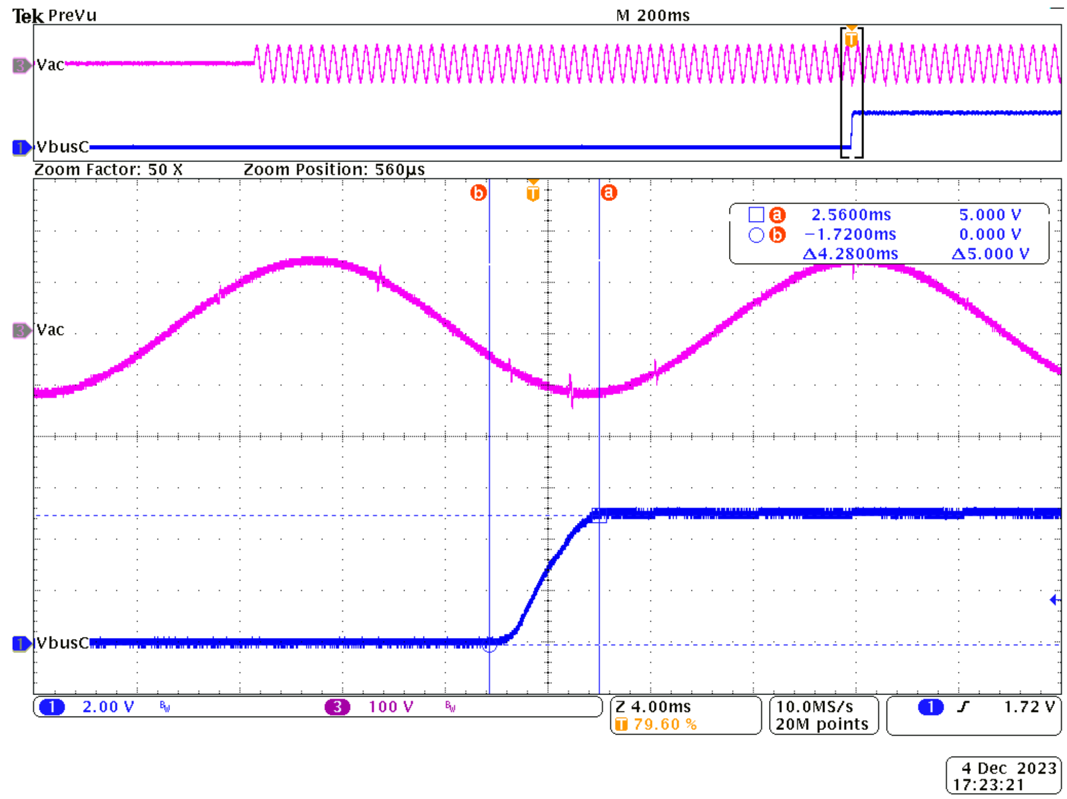
V_{out} = 5 V, I_{out} = 0 A, start-up turn-on delay time at 230 V_{ac}, 50 Hz = 593 ms



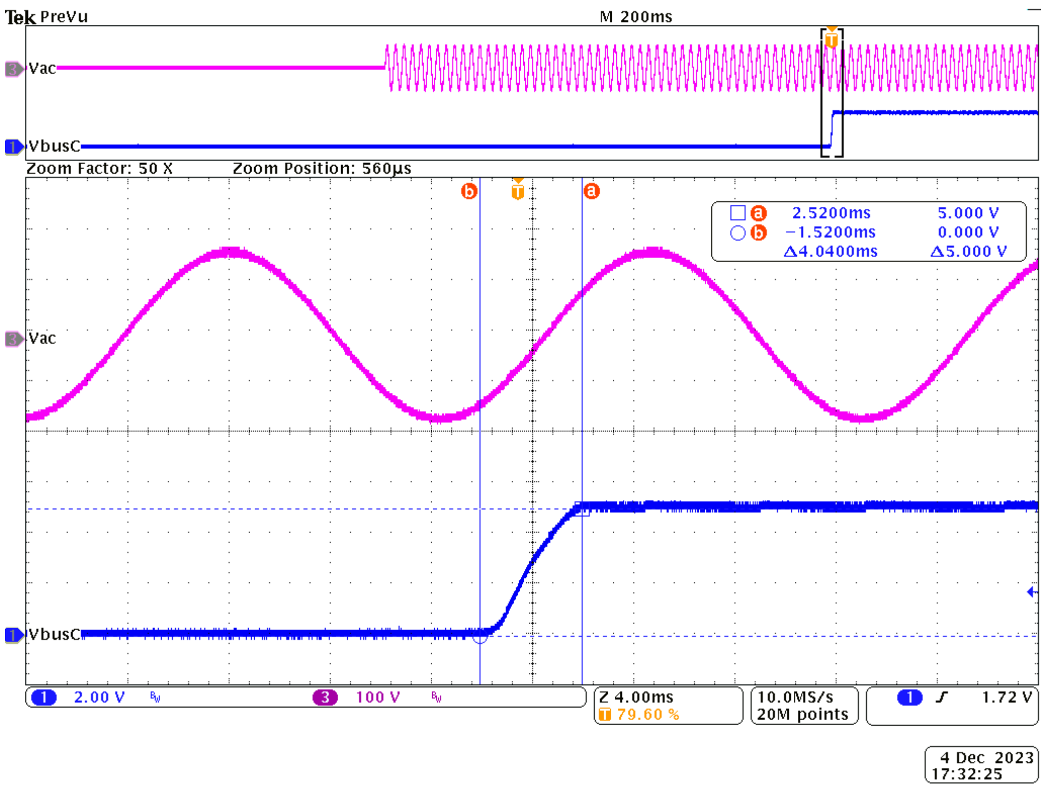
V_{out} = 5 V, I_{out} = 0 A, start-up turn-on delay time at 265 V_{ac}, 63 Hz = 578 ms

Figure 30 Start-up turn-on delay at various AC inputs (CH1: V_{bus_c}, CH3: V_{in_AC})

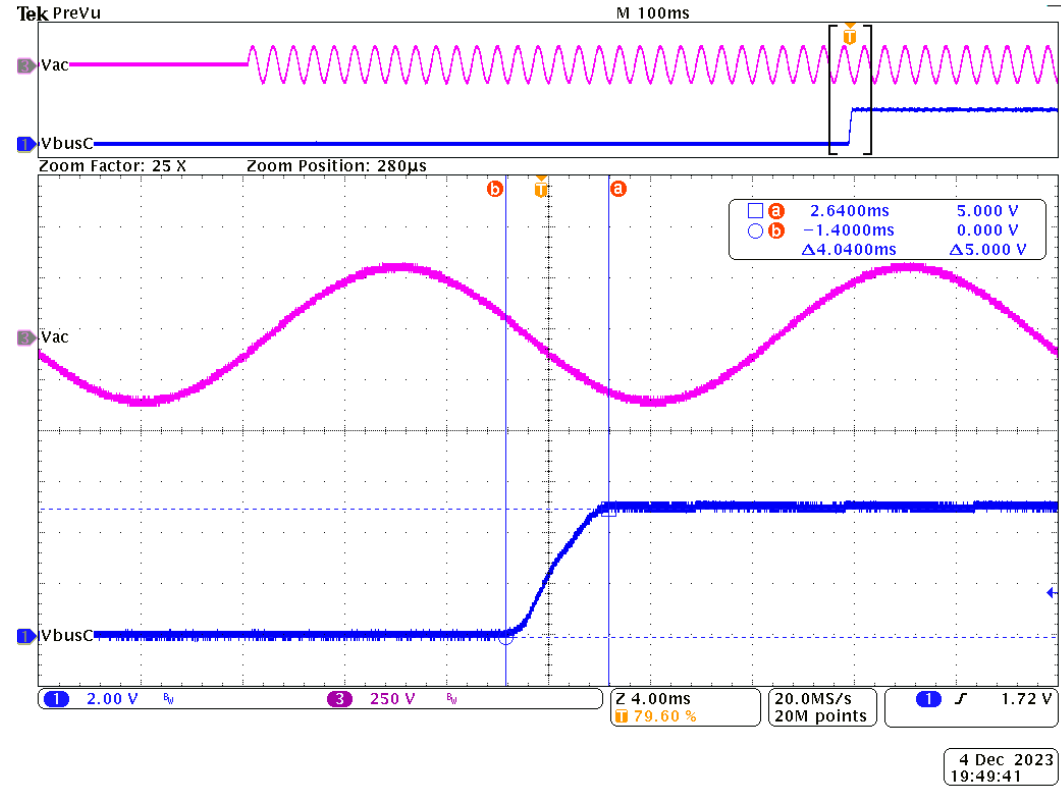
3.12 Start-up rise time



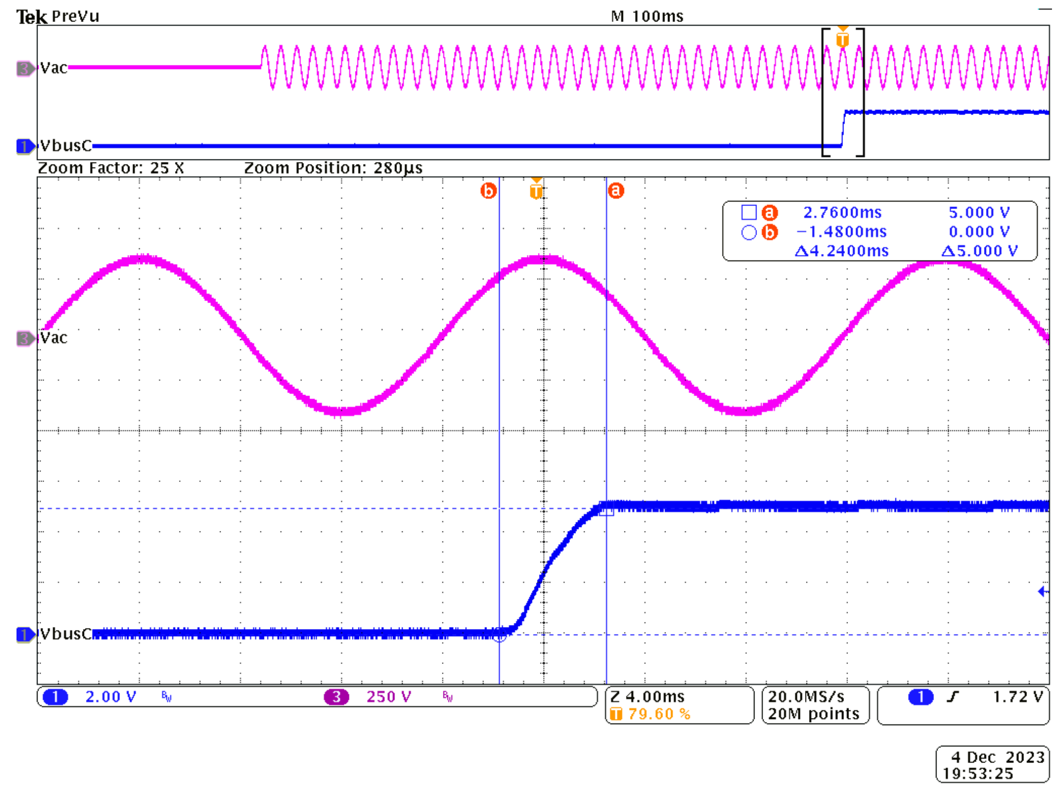
V_{out} = 5 V, I_{out} = 0 A, start-up rise time at 90 V_{ac}, 47 Hz = 4.28 ms



V_{out} = 5 V, I_{out} = 0 A, start-up rise time at 115 V_{ac}, 60 Hz = 4.04 ms



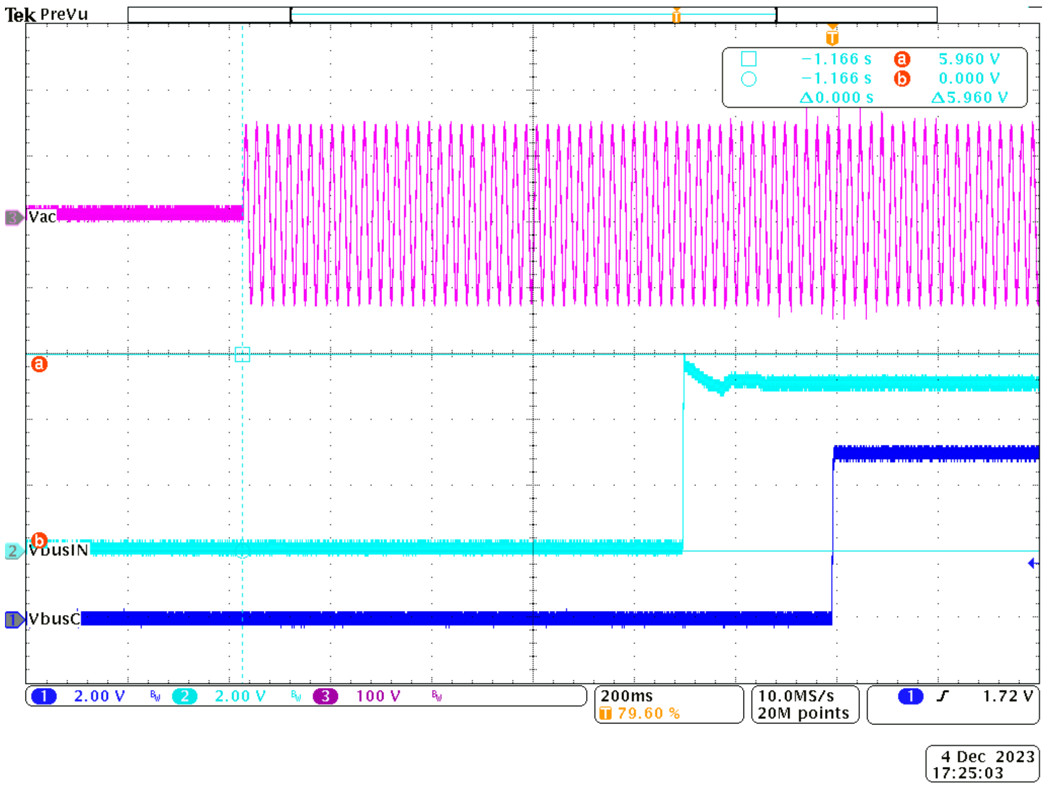
V_{out} = 5 V, I_{out} = 0A, start-up rise time at 230 V_{ac}, 50 Hz = 4.04 ms



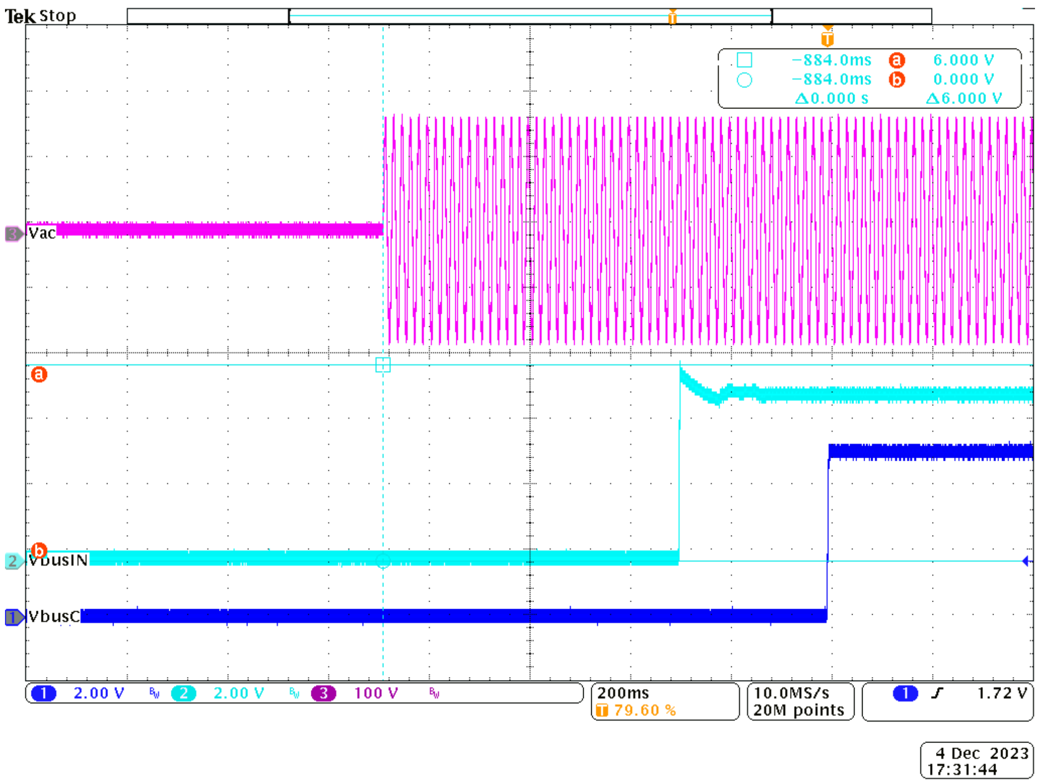
V_{out} = 5 V, I_{out} = 0A, start-up rise time at 265 V_{ac}, 63 Hz = 4.24 ms

Figure 31 Start-up rise-time at various AC inputs (CH1: Vbus_C, CH3: Vin_AC)

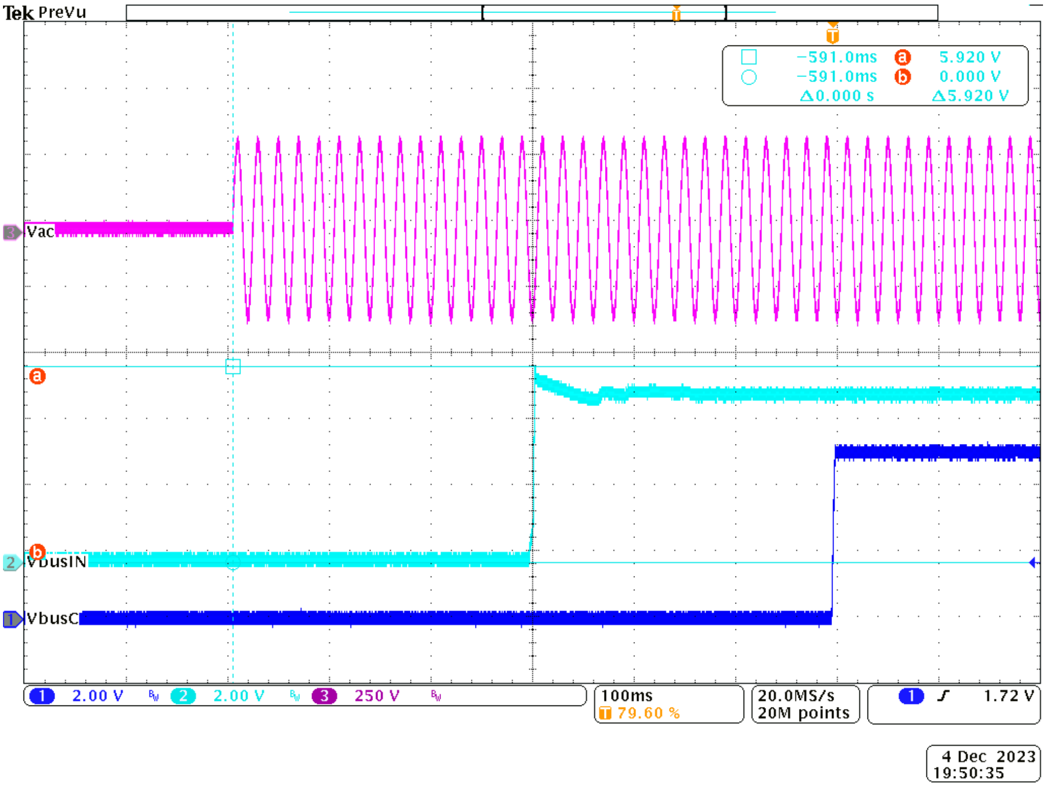
3.13 Startup V_{bus_in} overshoot



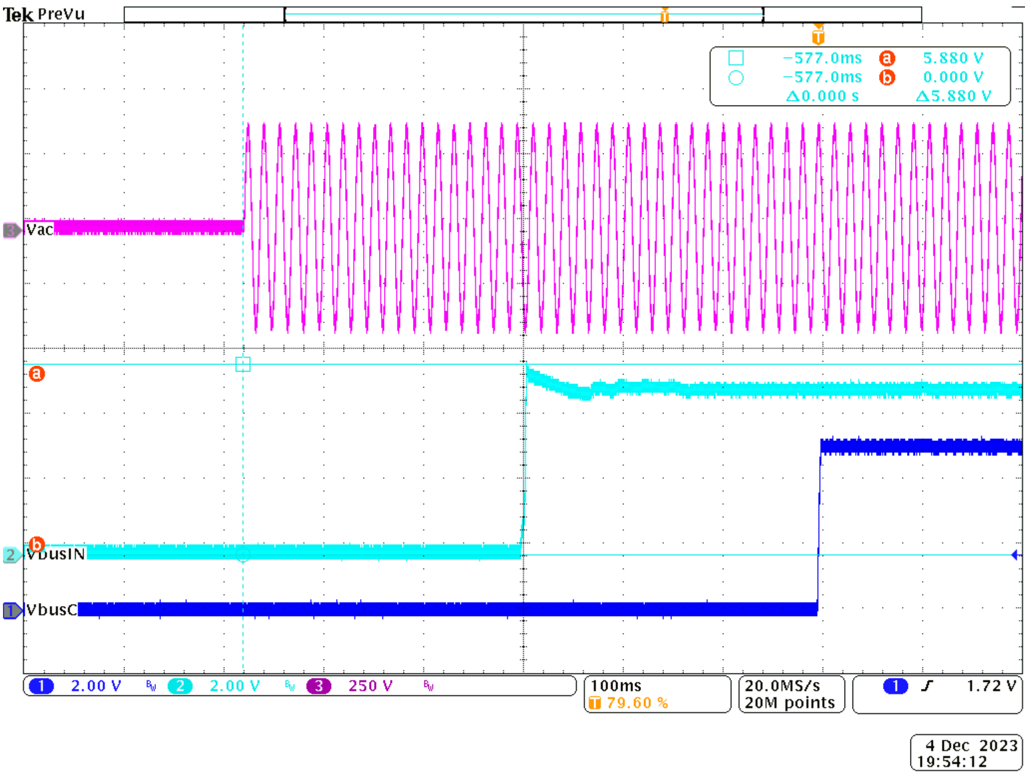
V_{out} = 5 V, I_{out} = 0 A, startup V_{bus_in} overshoot at 90 V_{ac}, 47 Hz = 5.96 V



V_{out} = 5 V, I_{out} = 0 A, startup V_{bus_in} overshoot at 115 V_{ac}, 60 Hz = 6 V



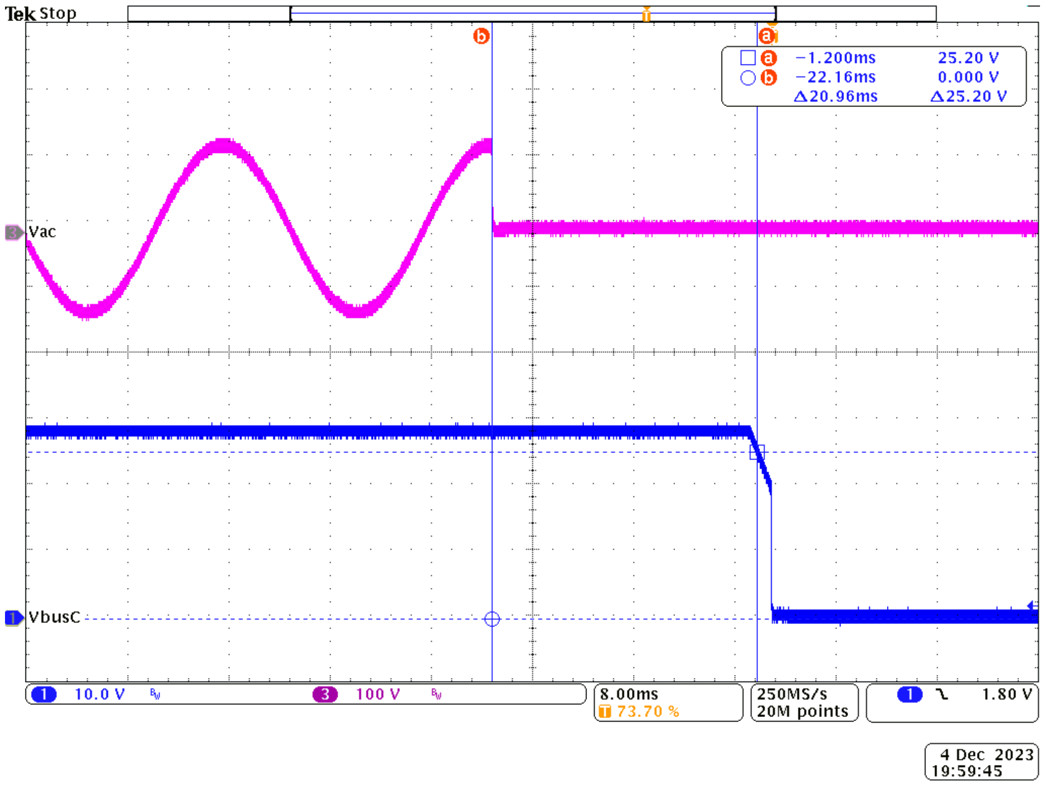
V_{out} = 5 V, I_{out} = 0 A, startup V_{bus_in} overshoot at 230 V_{ac}, 50 Hz = 5.92 V



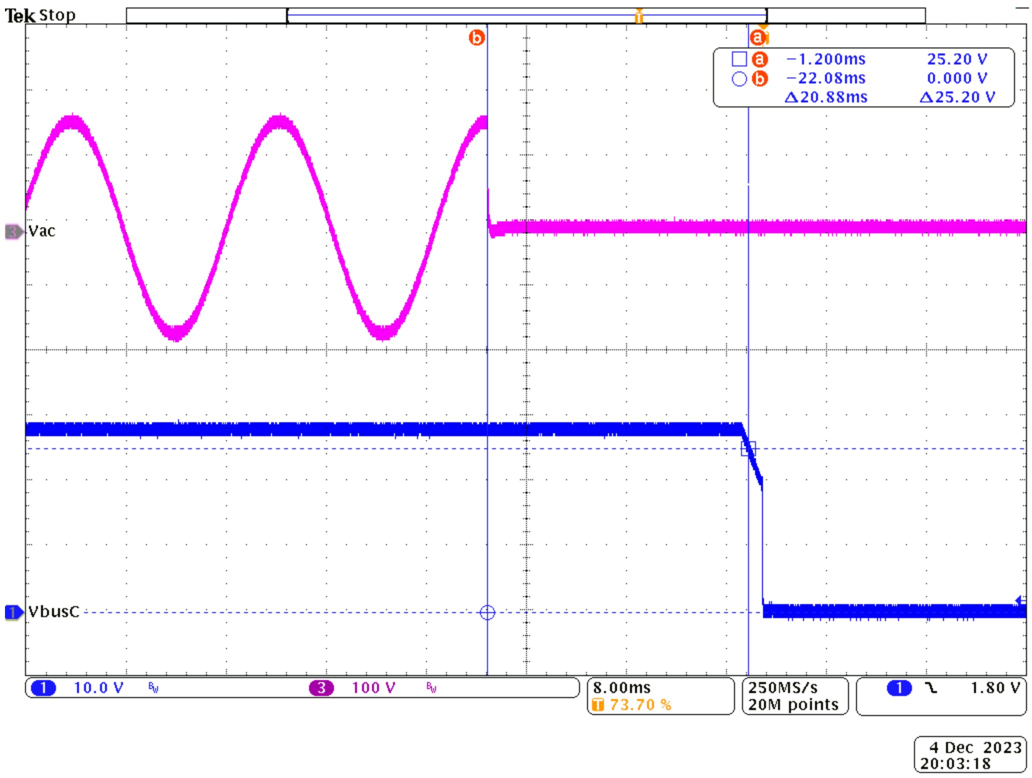
V_{out} = 5 V, I_{out} = 0 A, startup V_{bus_in} overshoot at 265 V_{ac}, 63 Hz = 5.88 V

Figure 32 Start-up V_{bus_in} overshoot at various AC inputs (CH1: V_{bus_c}, CH2: V_{bus_in}, CH3: V_{in_AC})

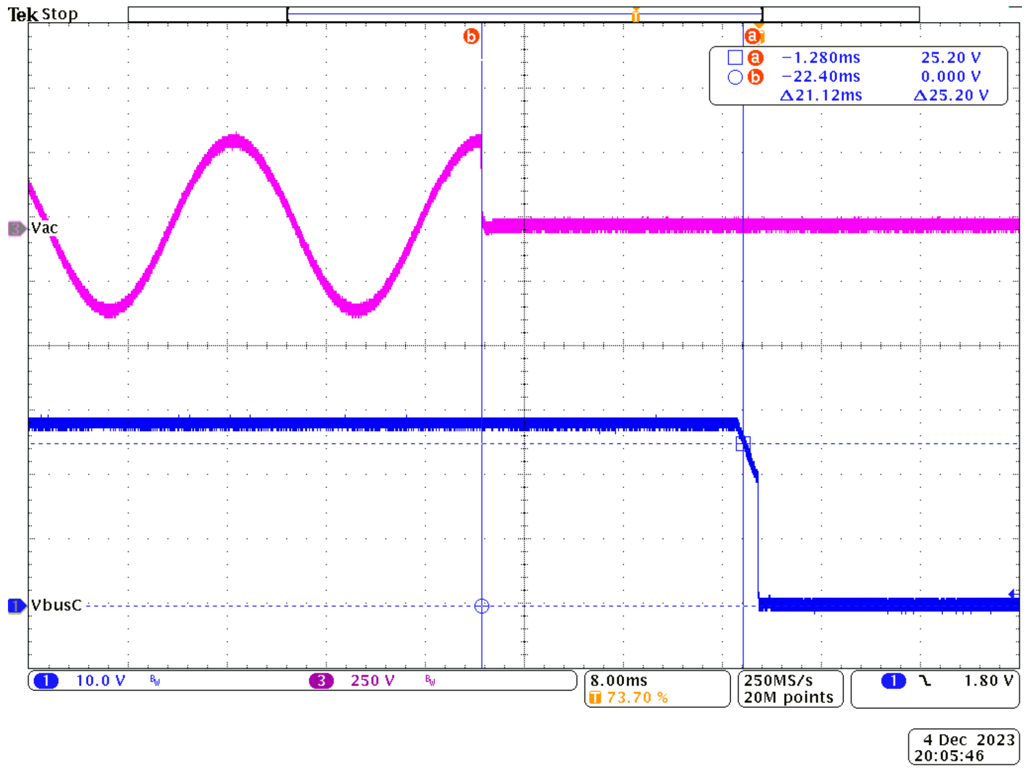
3.14 Hold-up time



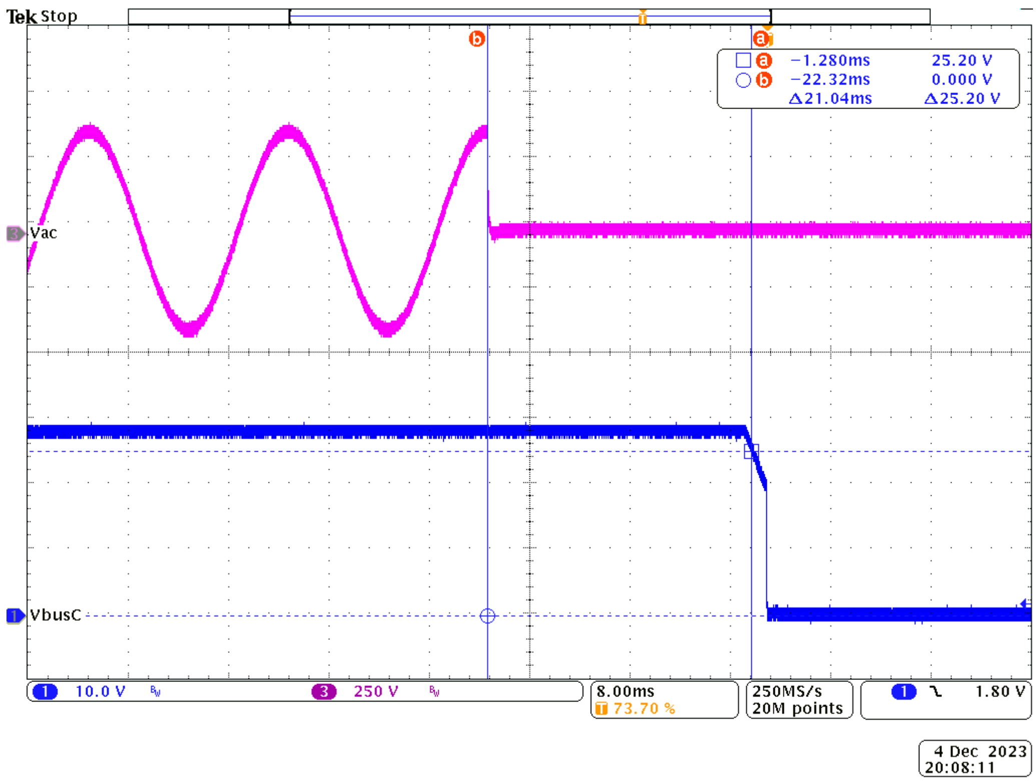
V_{out} = 28 V, I_{out} = 5 A, hold-up time at 90 V_{ac}, 47 Hz = 20.96 ms



V_{out} = 28 V, I_{out} = 5 A, hold-up time at 115 V_{ac}, 60 Hz = 20.88 ms



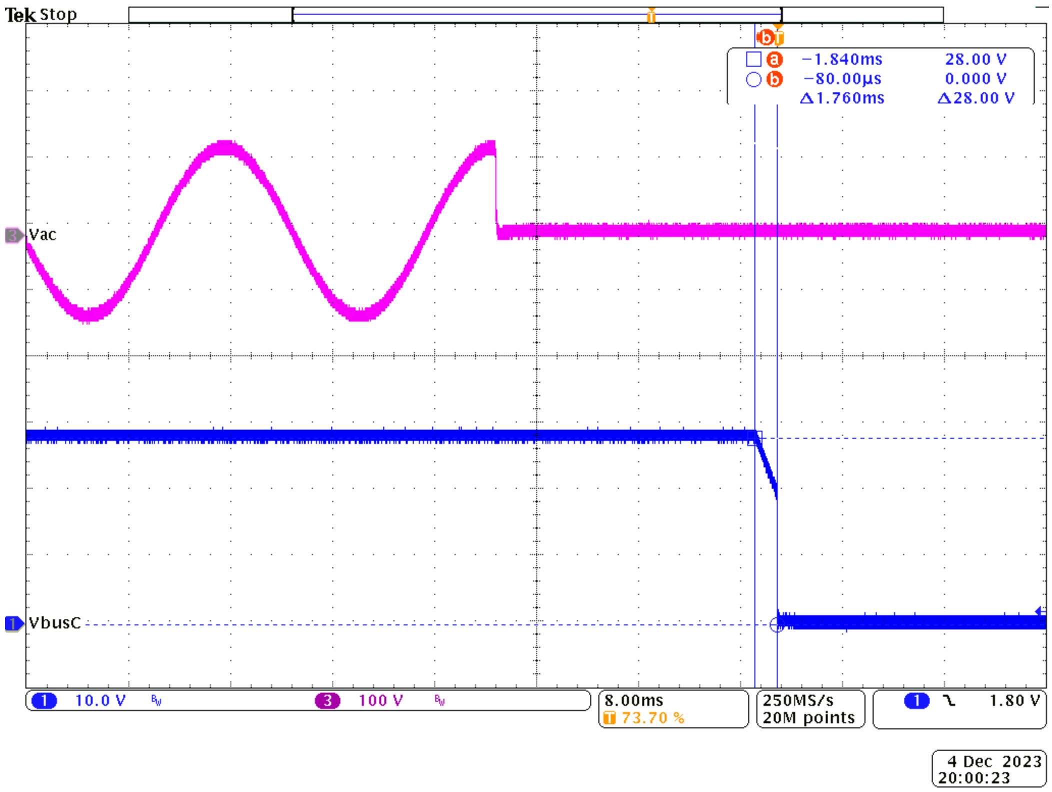
V_{out} = 28 V, I_{out} = 5 A, hold-up time at 230 V_{ac}, 50 Hz = 21.12 ms



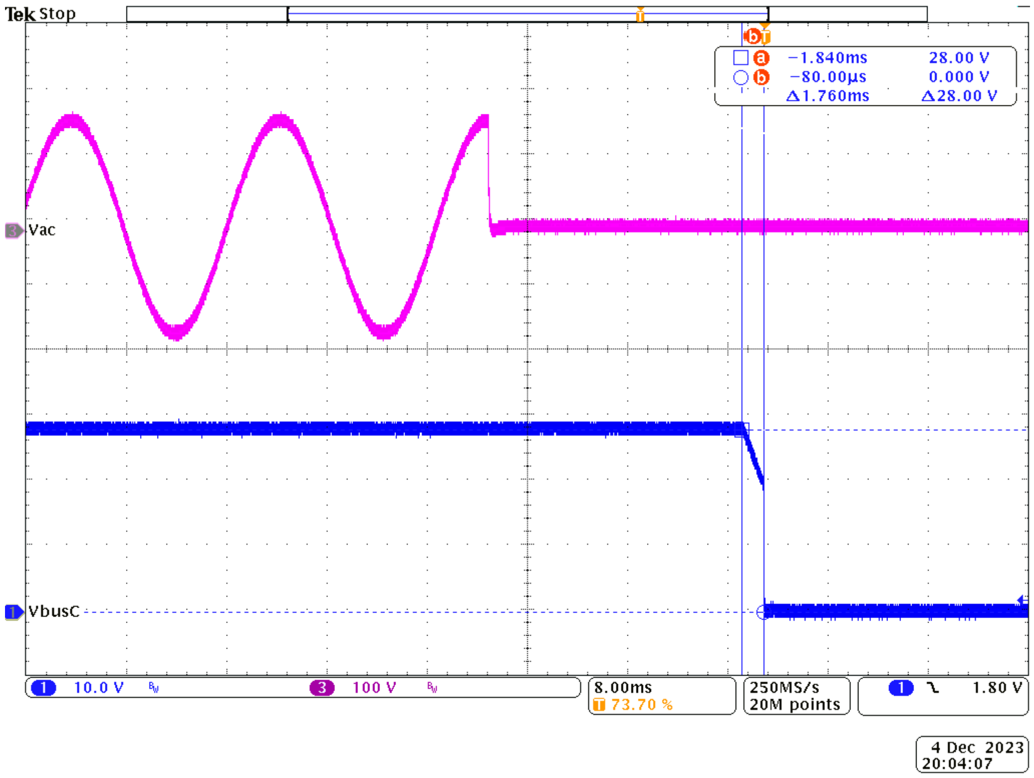
V_{out} = 28 V, I_{out} = 5 A, hold-up time at 265 V_{ac}, 63 Hz = 21.04 ms

Figure 33 Hold-up time at various AC inputs (CH1: V_{bus_c}, CH3: V_{in_AC})

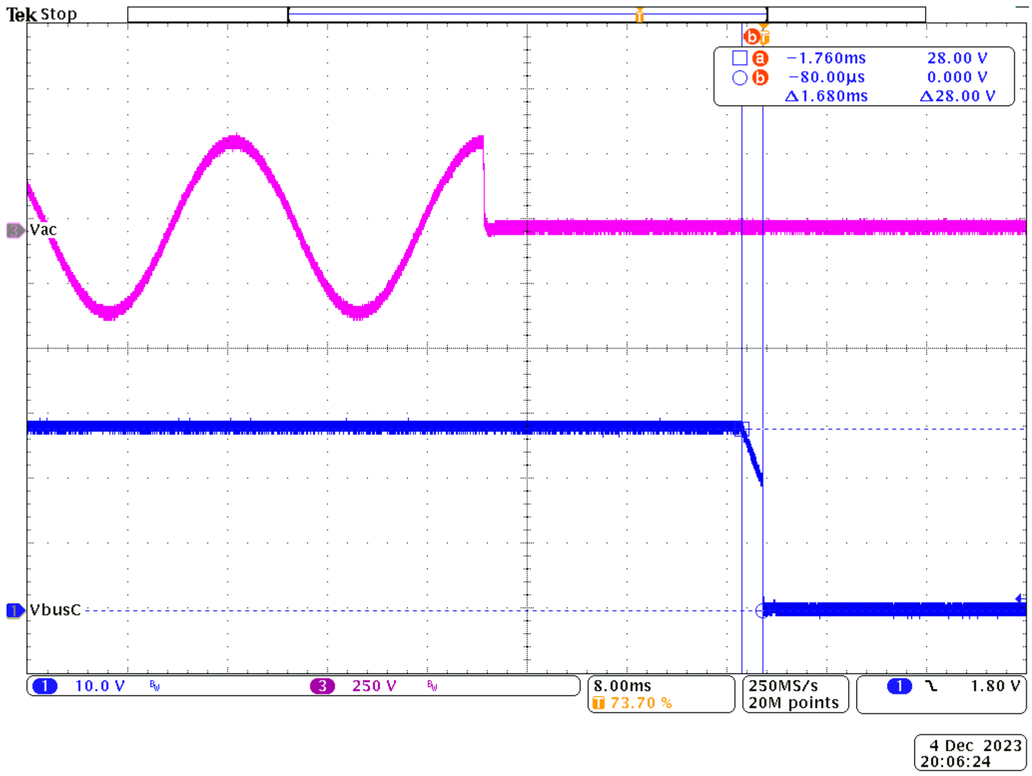
3.15 Shutdown fall time



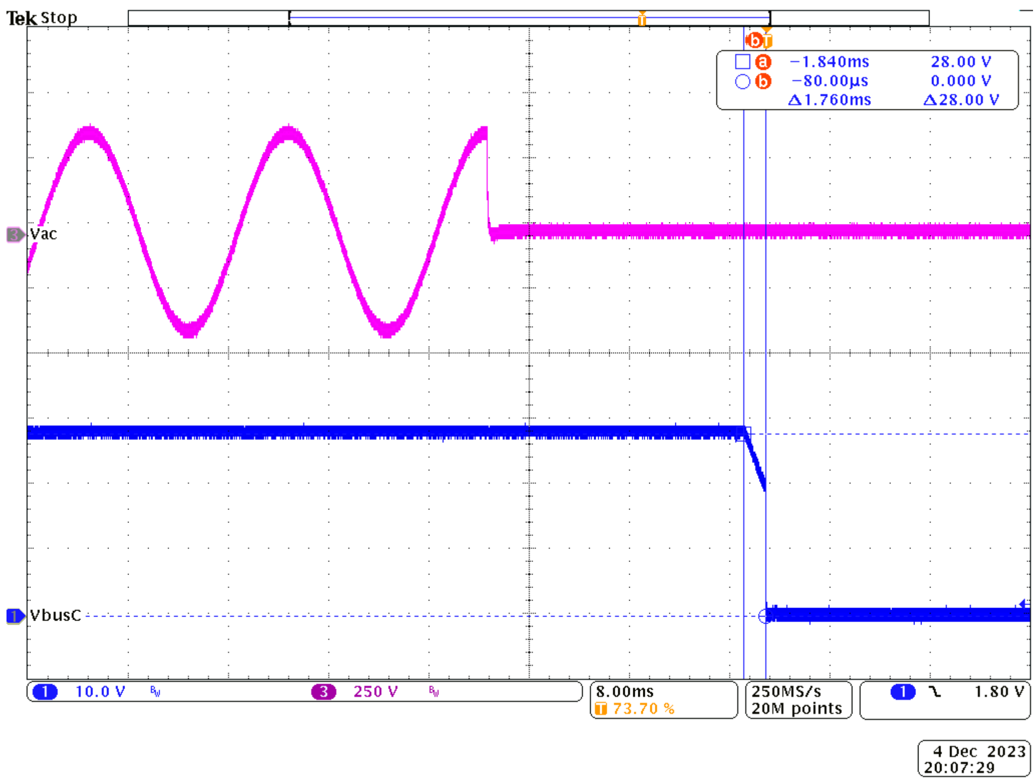
V_{out} = 28 V, I_{out} = 5 A, shutdown fall time at 90 V_{ac}, 47 Hz = 1.76 ms



V_{out} = 28 V, I_{out} = 5 A, shutdown fall time at 115 V_{ac}, 60 Hz = 1.76 ms



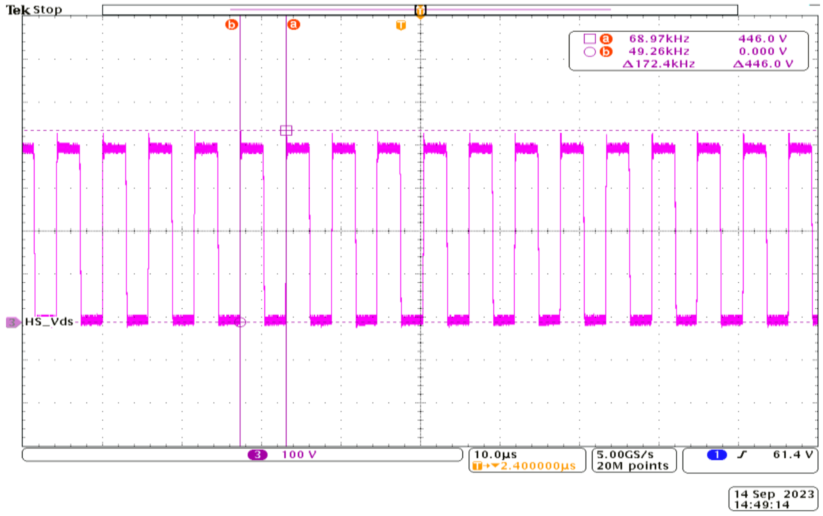
V_{out} = 28 V, I_{out} = 5 A, shutdown fall time at 230 V_{ac}, 50 Hz = 1.68 ms



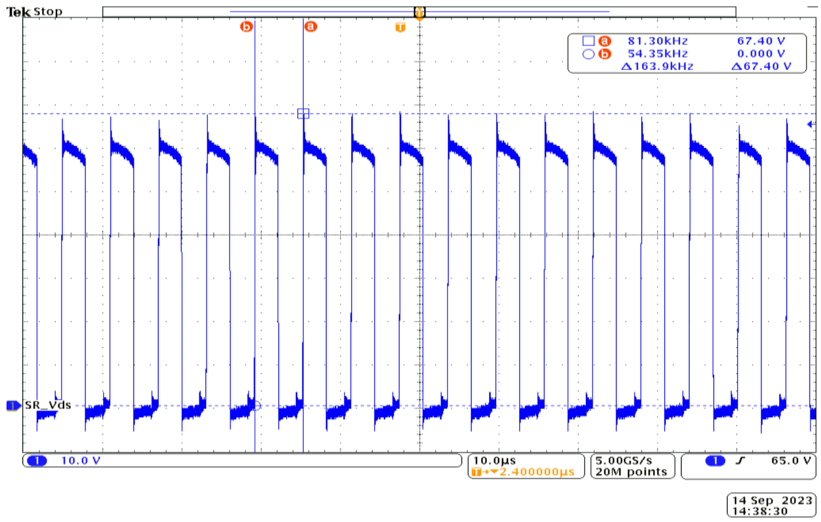
V_{out} = 28 V, I_{out} = 5 A, shutdown fall time at 265 V_{ac}, 63 Hz = 1.76 ms

Figure 34 Shutdown fall time at various AC inputs (CH1: V_{bus_C}, CH3: V_{in_AC})

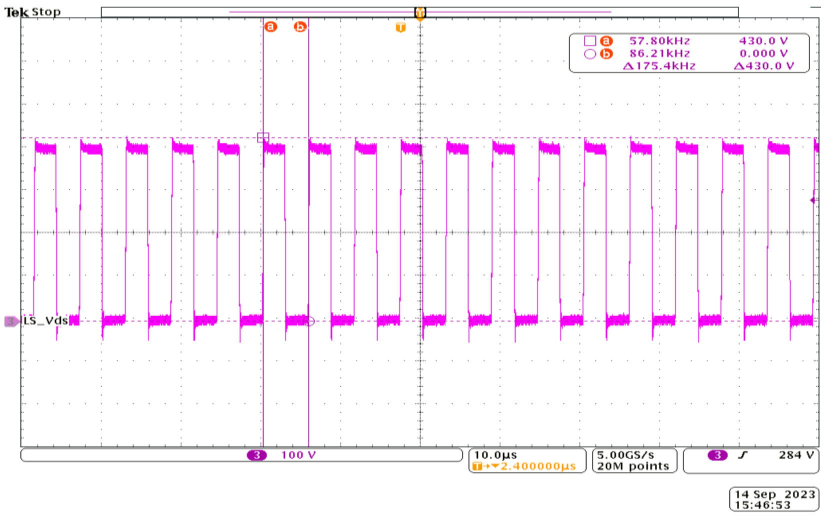
3.16 Switch voltage stress



V_{ds} of high-side primary FET = 446 V



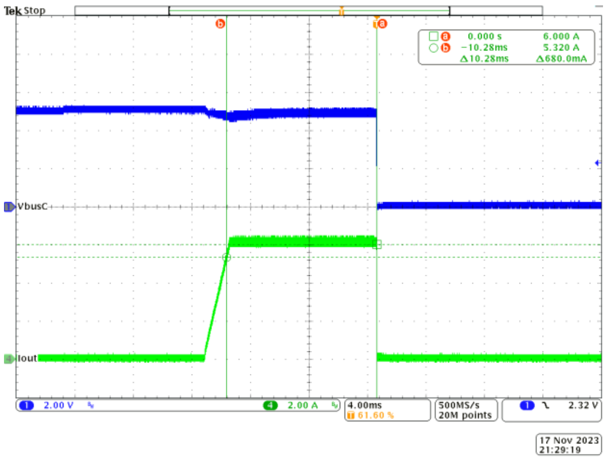
V_{ds} of SR secondary FET = 67.4 V



V_{ds} of low-side primary FET = 430 V

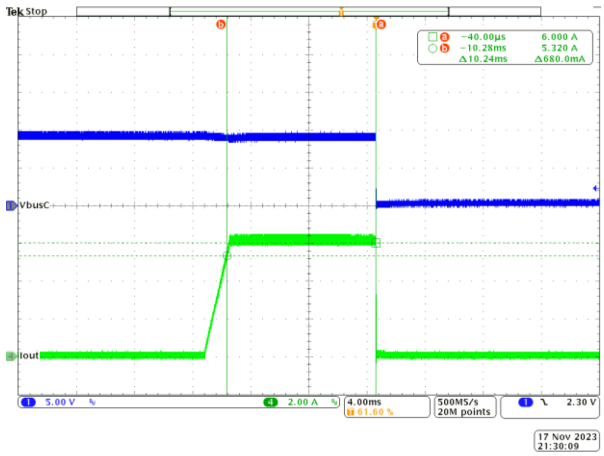
Figure 35 Drain-source voltage stress of different FETs at V_{in} = 265 V_{ac}/63 Hz, V_{out} = 28 V, I_{out} = 5 A

3.17 Overcurrent protection (OCP)



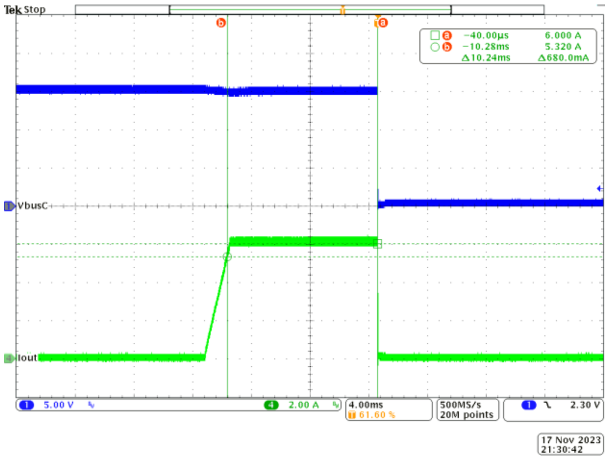
Fixed PDO: 5 V, 5 A

OCP trip = 5.32 A, OCP response time = 10.28 ms



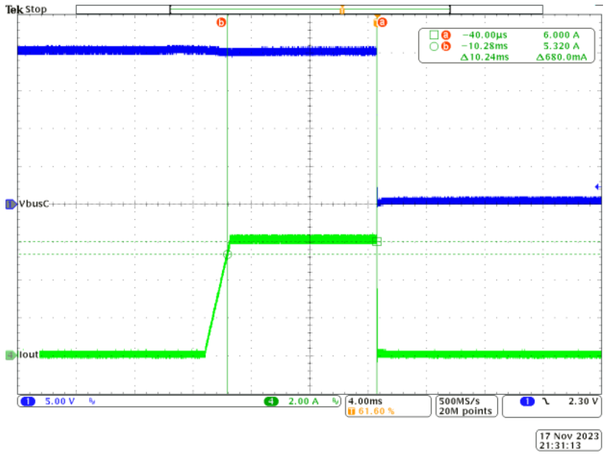
Fixed PDO: 9 V, 5 A

OCP trip = 5.33 A, OCP response time = 10.24 ms



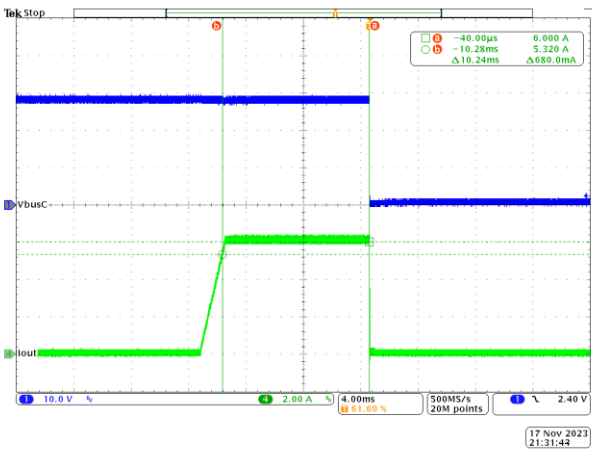
Fixed PDO: 15 V, 5 A

OCP trip = 5.32 A, OCP response time = 10.24 ms



Fixed PDO: 20 V, 5 A

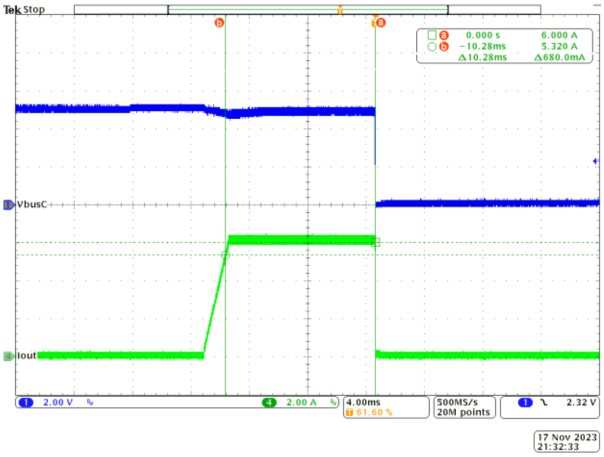
OCP trip = 5.31 A, OCP response time = 10.24 ms



Fixed PDO: 28 V, 5 A

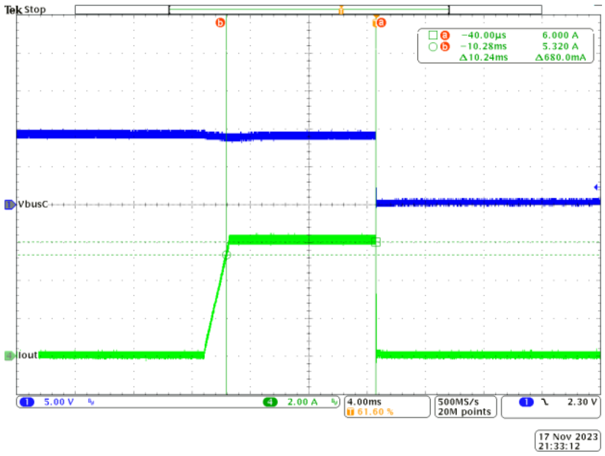
OCP trip = 5.31 A, OCP response time = 10.24 ms

Figure 36 Overcurrent protection trip point and response time at 115 V_{ac}, 60 Hz (CH1: V_{out}, CH4: I_{out})



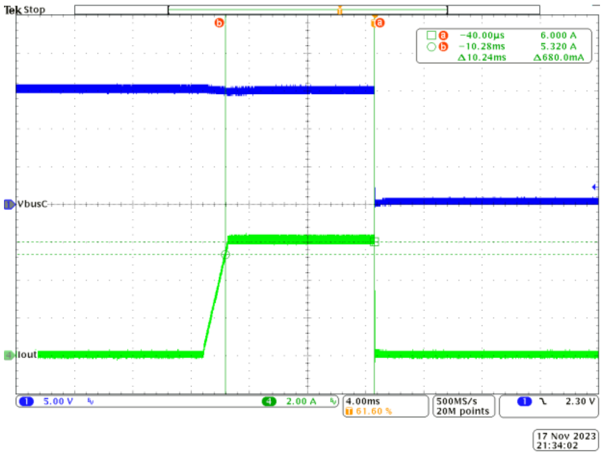
Fixed PDO: 5 V, 5 A

OCP trip = 5.31 A, OCP response time = 10.28 ms



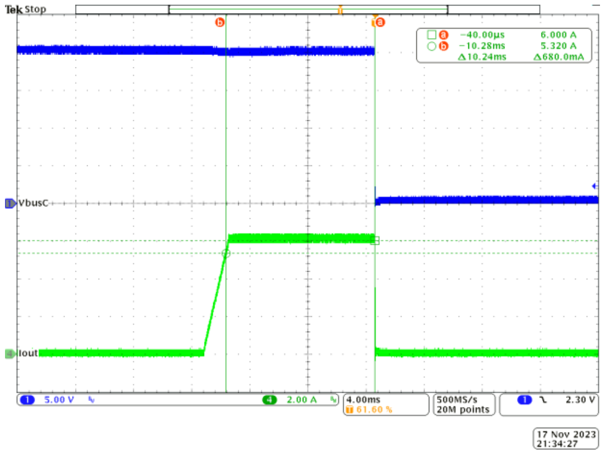
Fixed PDO: 9 V, 5 A

OCP trip = 5.32 A, OCP response time = 10.24 ms



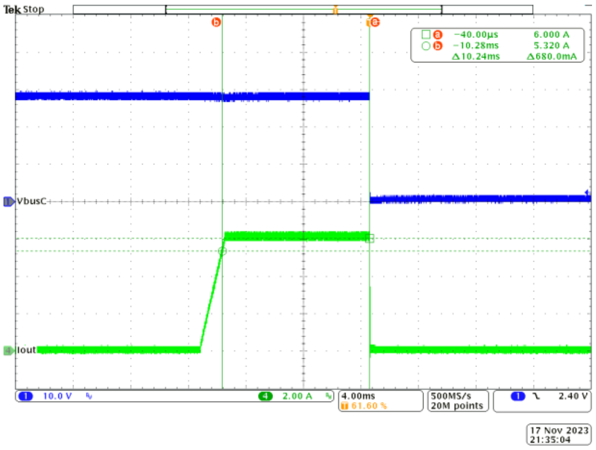
Fixed PDO: 15 V, 5 A

OCP trip = 5.32 A, OCP response time = 10.24 ms



Fixed PDO: 20 V, 5 A

OCP trip = 5.31 A, OCP response time = 10.24 ms

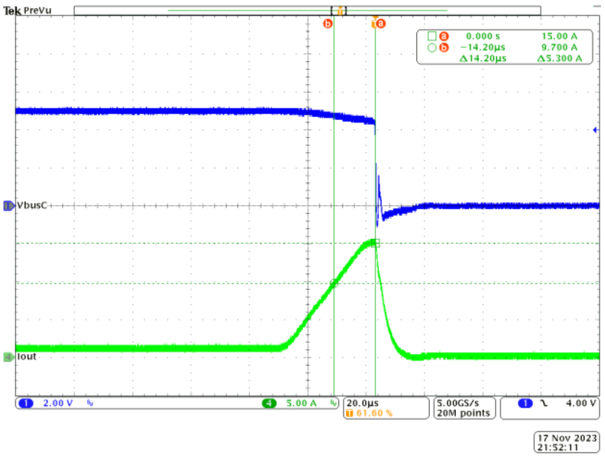


Fixed PDO: 28 V, 5 A

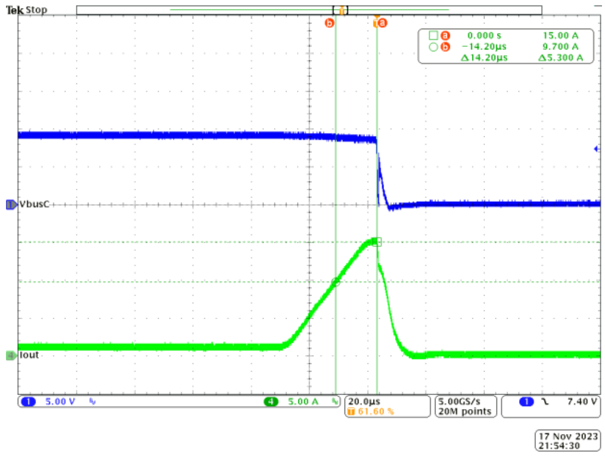
OCP trip = 5.31 A, OCP response time = 10.24 ms

Figure 37 Overcurrent protection trip point and response time at 230 V_{ac}, 50 Hz (CH1: V_{out}, CH4: I_{out})

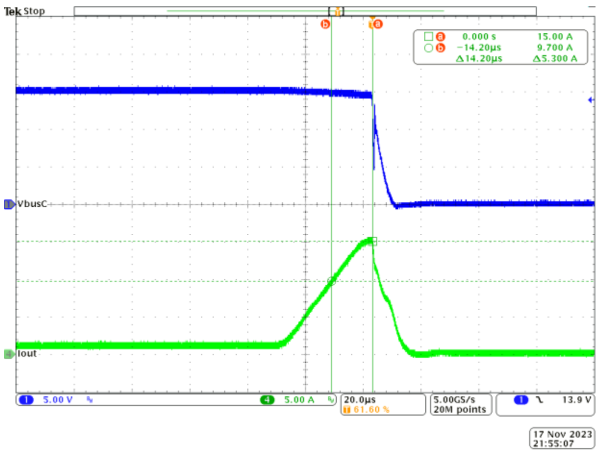
3.18 Short-circuit protection (SCP)



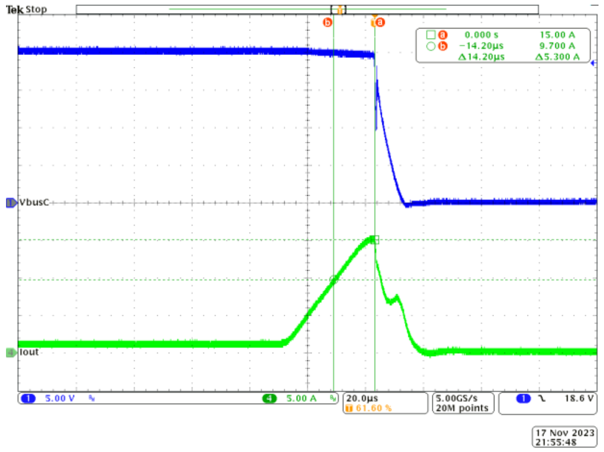
Fixed PDO: 5 V, 5 A
SCP trip = 9.7 A, SCP response time = 14.2 µs



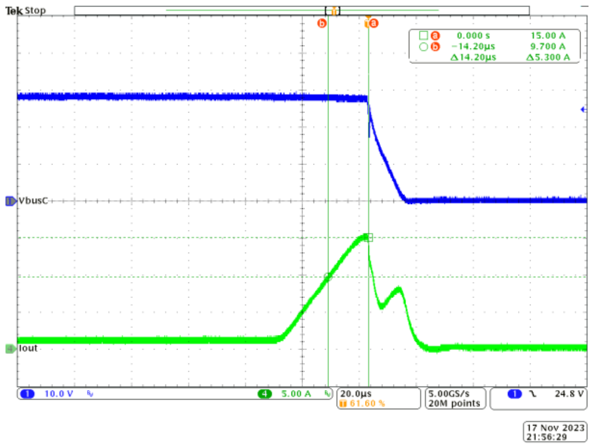
Fixed PDO: 9 V, 5 A
SCP trip = 9.7 A, SCP response time = 14.2 µs



Fixed PDO: 15 V, 5 A
SCP trip = 9.7 A, SCP response time = 14.2 µs

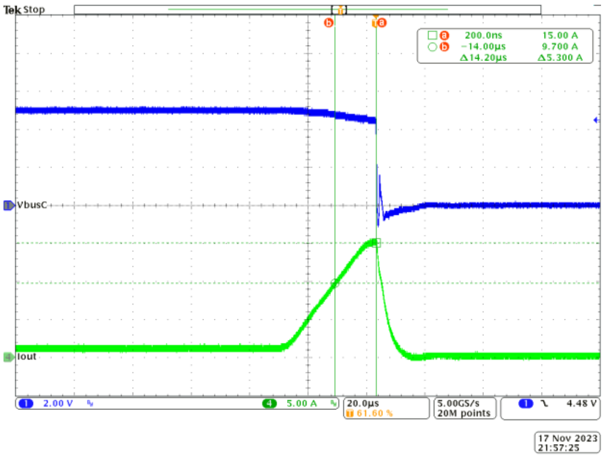


Fixed PDO: 20 V, 5 A
SCP trip = 9.7 A, SCP response time = 14.2 µs



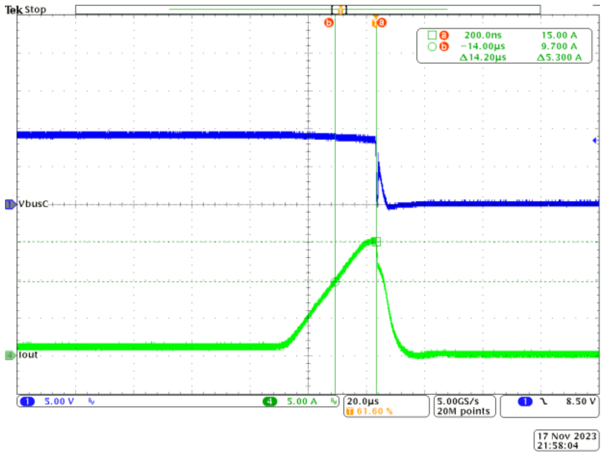
Fixed PDO: 28 V, 5 A
SCP trip = 9.7 A, SCP response time = 14.2 µs

Figure 38 Short-circuit protection trip point and response time at 115 V_{ac}, 60 Hz (CH1: V_{bus_c}, CH4: I_{out})



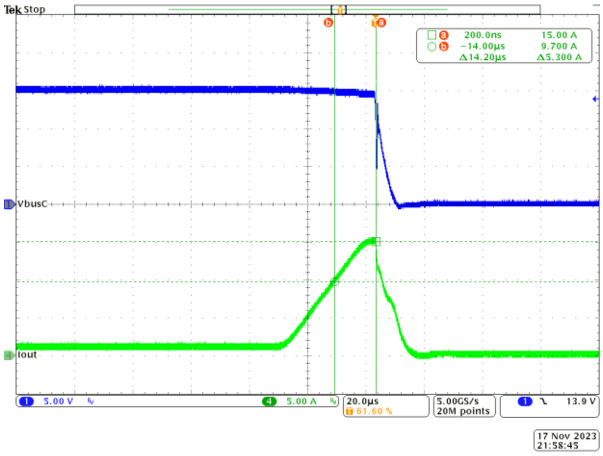
Fixed PDO: 5 V, 5 A

SCP trip = 9.7 A, SCP response time = 14.2 µs



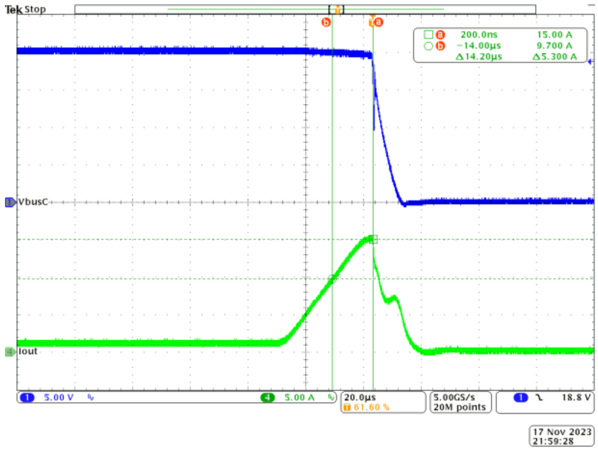
Fixed PDO: 9 V, 5 A

SCP trip = 9.7 A, SCP response time = 14.2 µs



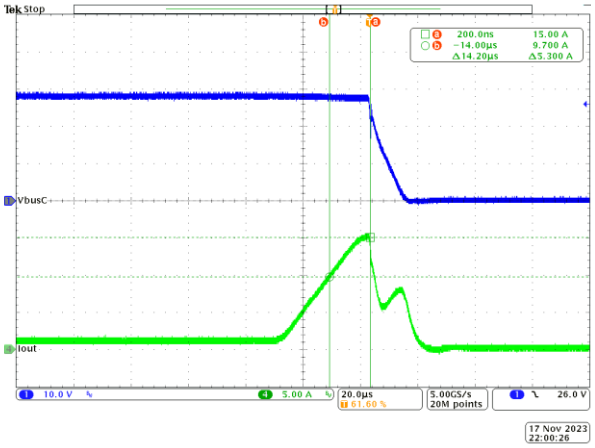
Fixed PDO: 15 V, 5 A

SCP trip = 9.7 A, SCP response time = 14.2 µs



Fixed PDO: 20 V, 5 A

SCP trip = 9.7 A, SCP response time = 14.2 µs



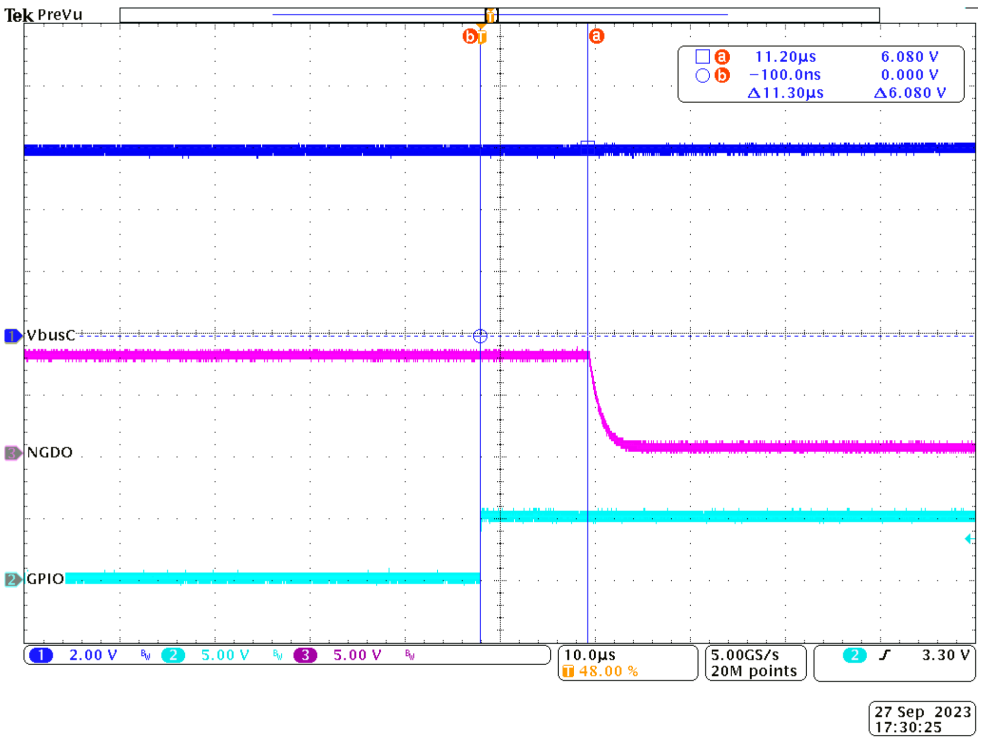
Fixed PDO: 28 V, 5 A

SCP trip = 9.7 A, SCP response time = 14.2 µs

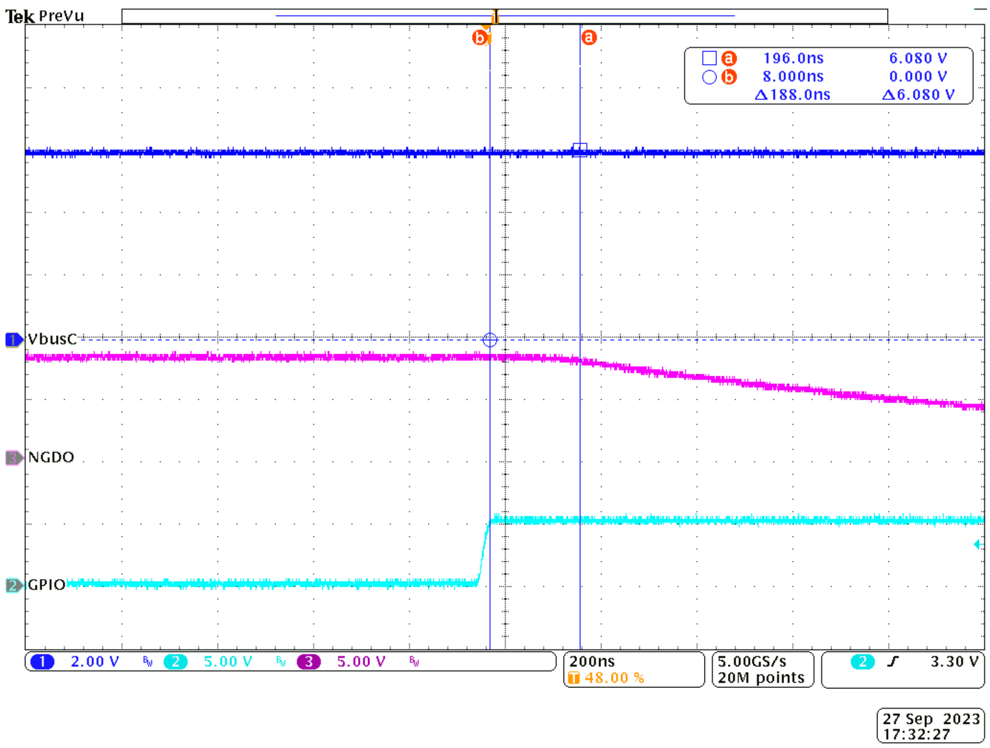
Figure 39 Short-circuit protection trip point and response time at 230 V_{ac}, 50 Hz (CH1: V_{bus_c}, CH4: I_{out})

3.19 Overvoltage protection (OVP)

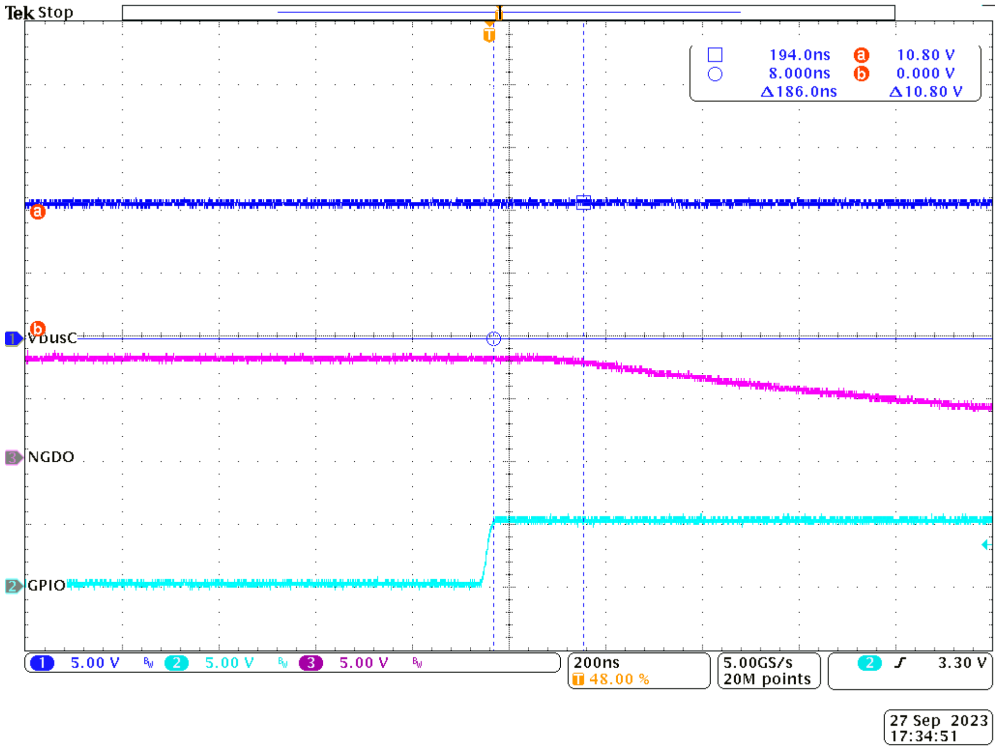
The overvoltage protection trip point and response time at 115 V_{ac}, 60 Hz is shown in Figure 40.



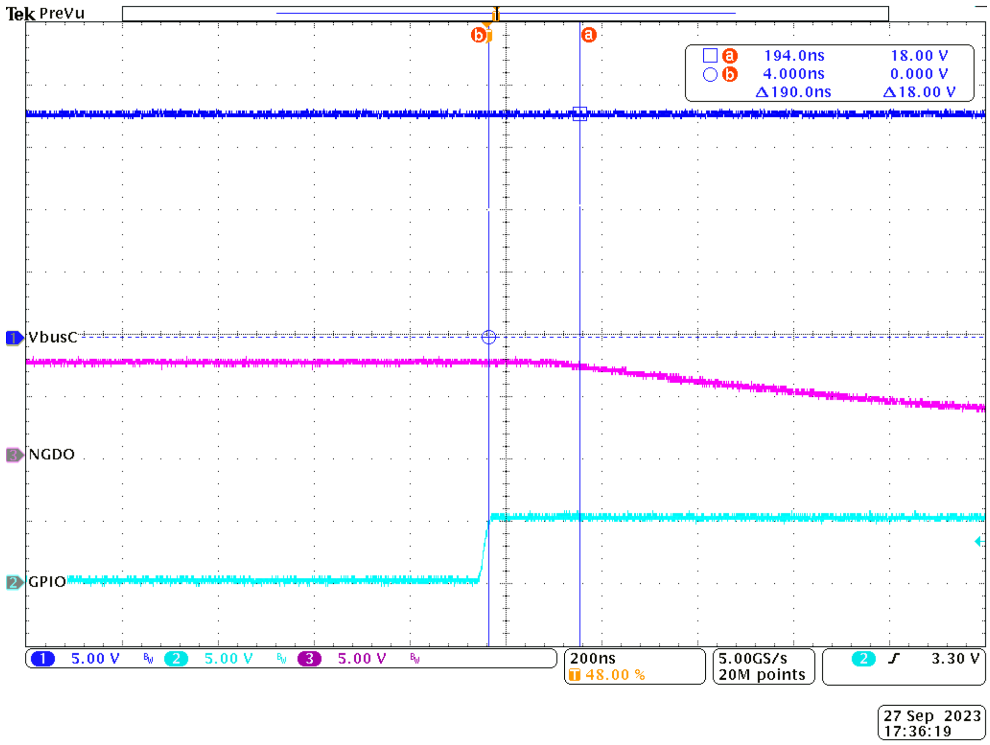
V_{out} = 3.3 V, OVP trip = 6.1 V, OVP response time = 11.3 µs



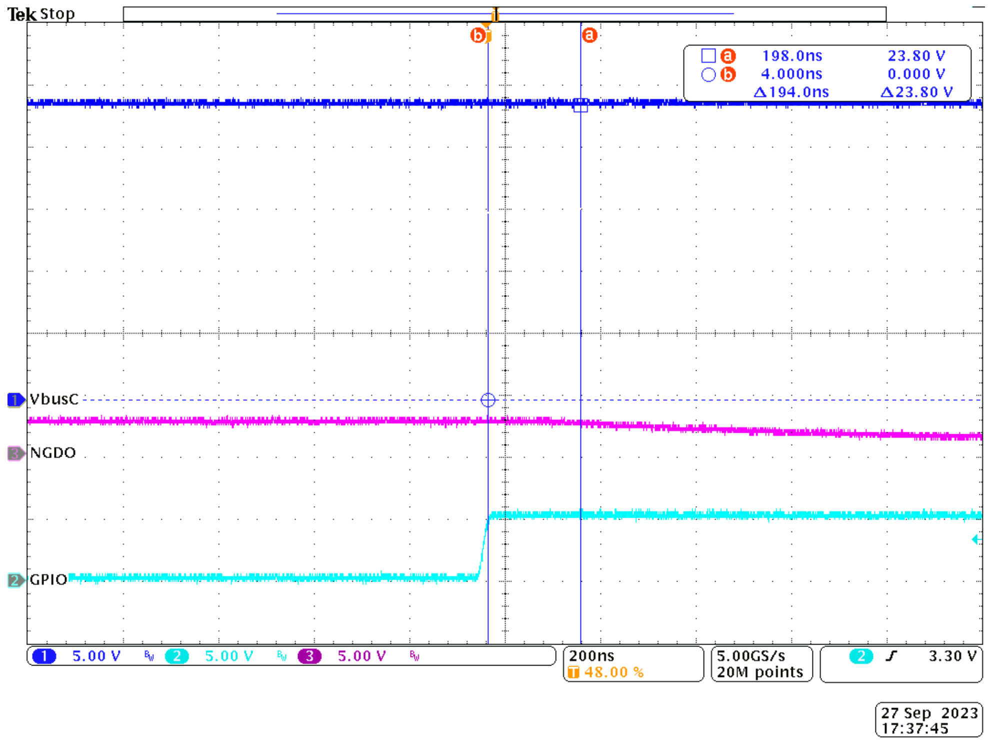
V_{out} = 5 V, OVP trip = 6.1 V, OVP response time = 188 ns



V_{out} = 9 V, OVP trip = 10.8 V, OVP response time = 186 ns



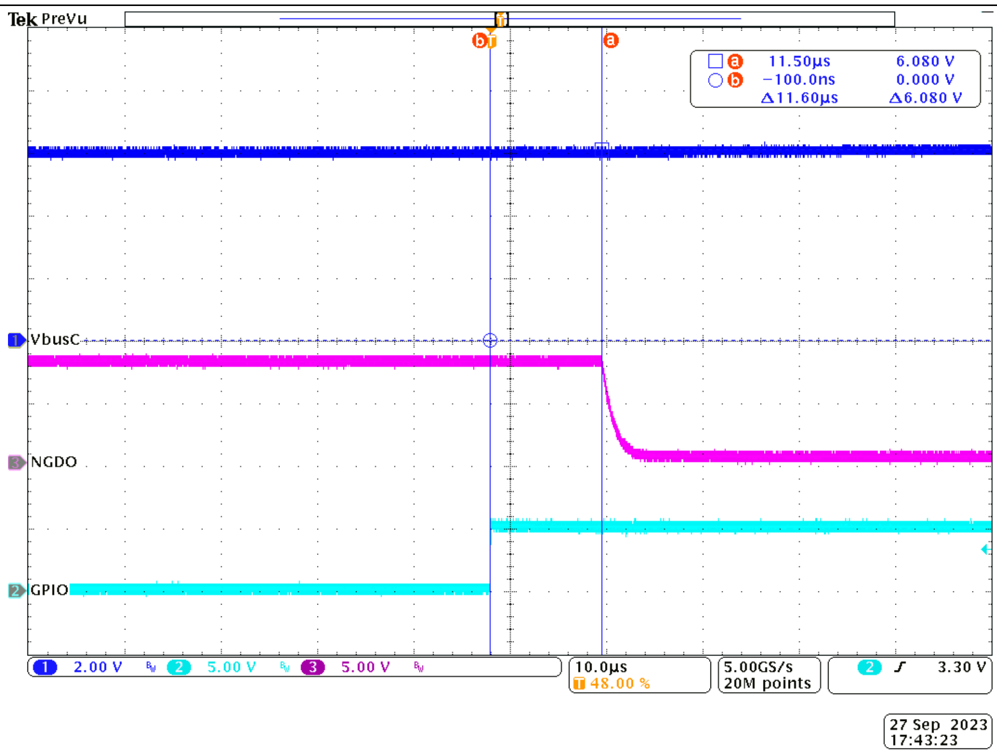
V_{out} = 15 V, OVP trip = 18 V, OVP response time = 190 ns



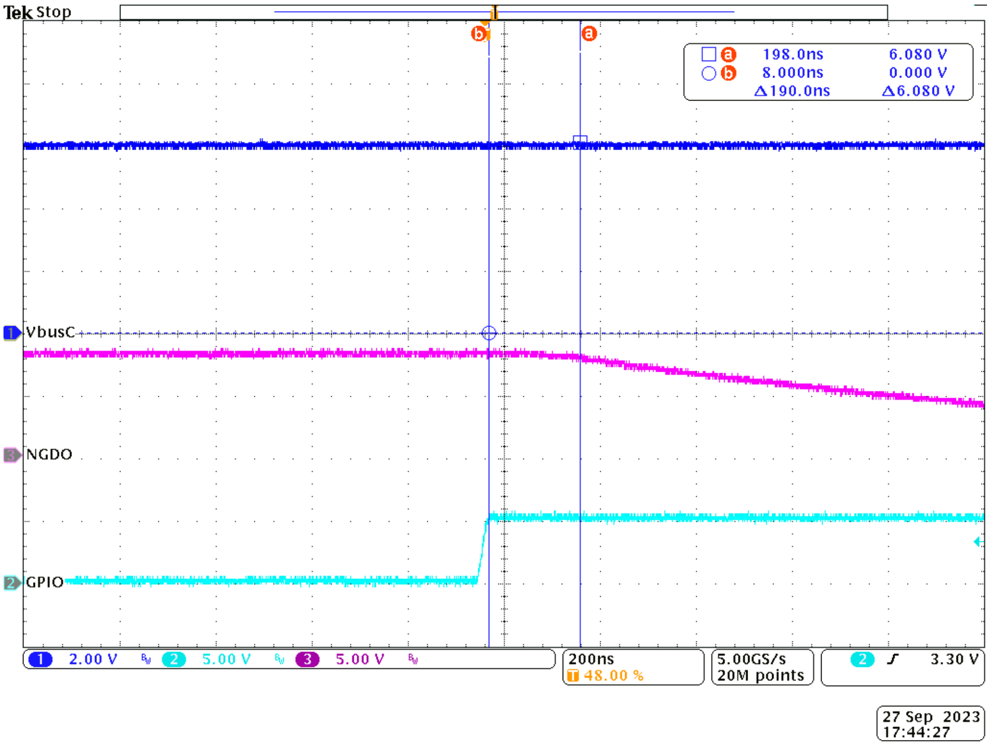
V_{out} = 20 V, OVP Trip = 23.8 V, OVP Response Time = 194 ns

Figure 40 Overvoltage protection trip point and response time at 115 V_{ac}, 60 Hz (CH1: V_{bus_c}, CH2: GPIO9, CH3: NDGO = Provider FET Q2 gate-source)

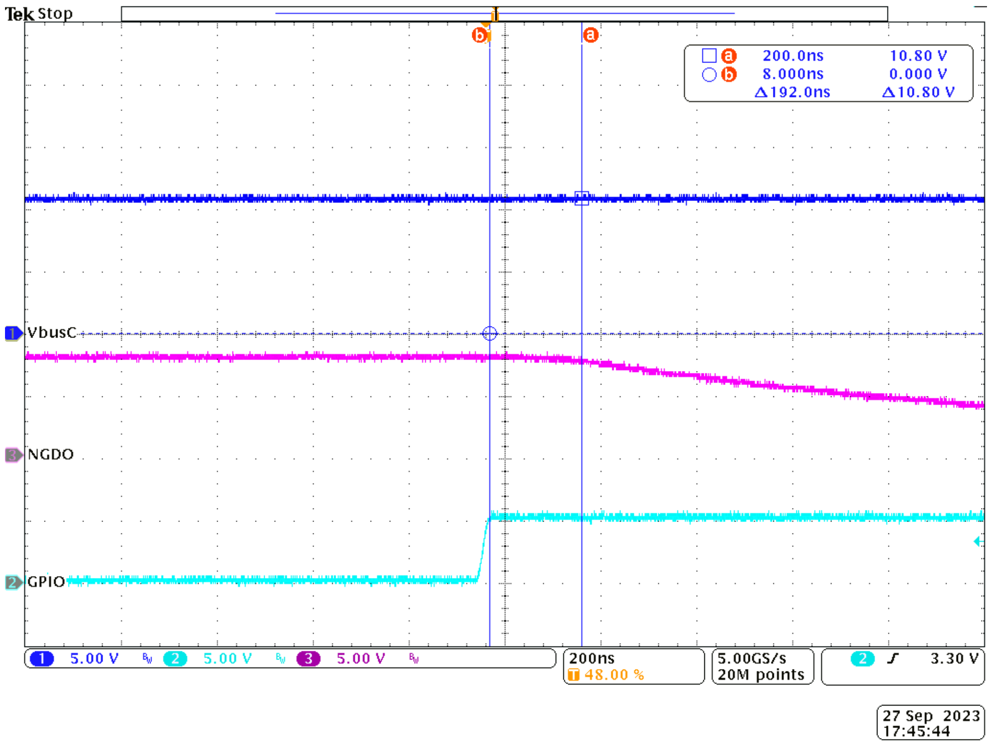
The overvoltage protection trip point and response time at 230 V_{ac}, 50 Hz is shown in Figure 41.



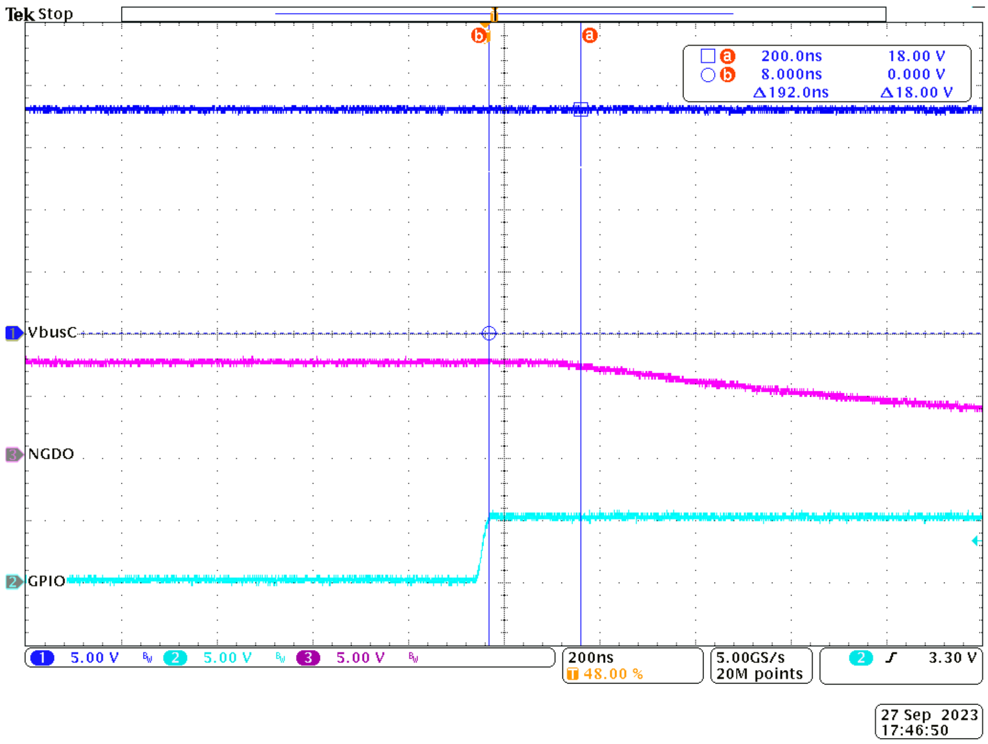
V_{out} = 3.3 V, OVP trip = 6.1 V, OVP response time = 11.6 µs



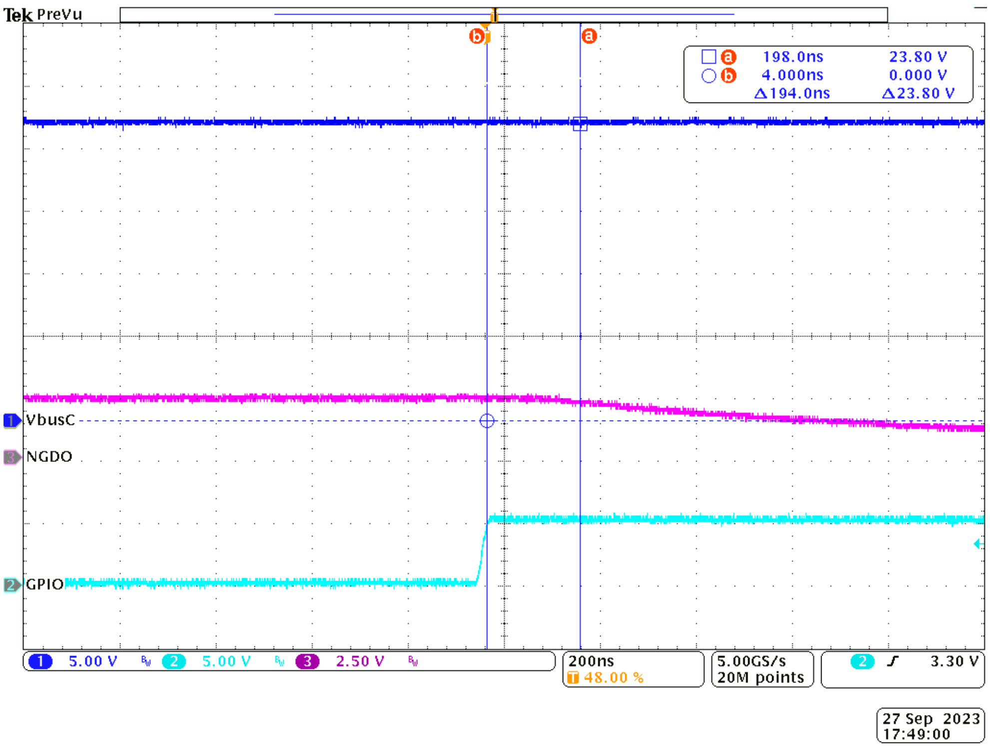
V_{out} = 5 V, OVP trip = 6.1 V, OVP response time = 190 ns



V_{out} = 9 V, OVP trip = 10.8 V, OVP response time = 192 ns



V_{out} = 15 V, OVP trip = 18 V, OVP response time = 192 ns

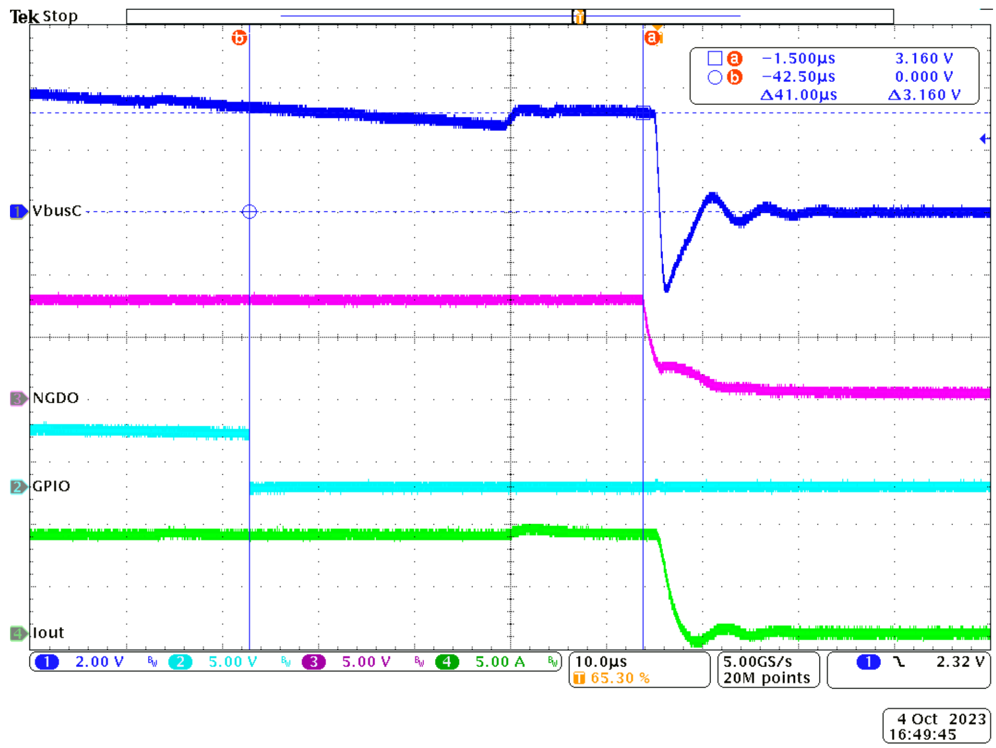


V_{out} = 20 V, OVP trip = 23.8 V, OVP response time = 194 ns

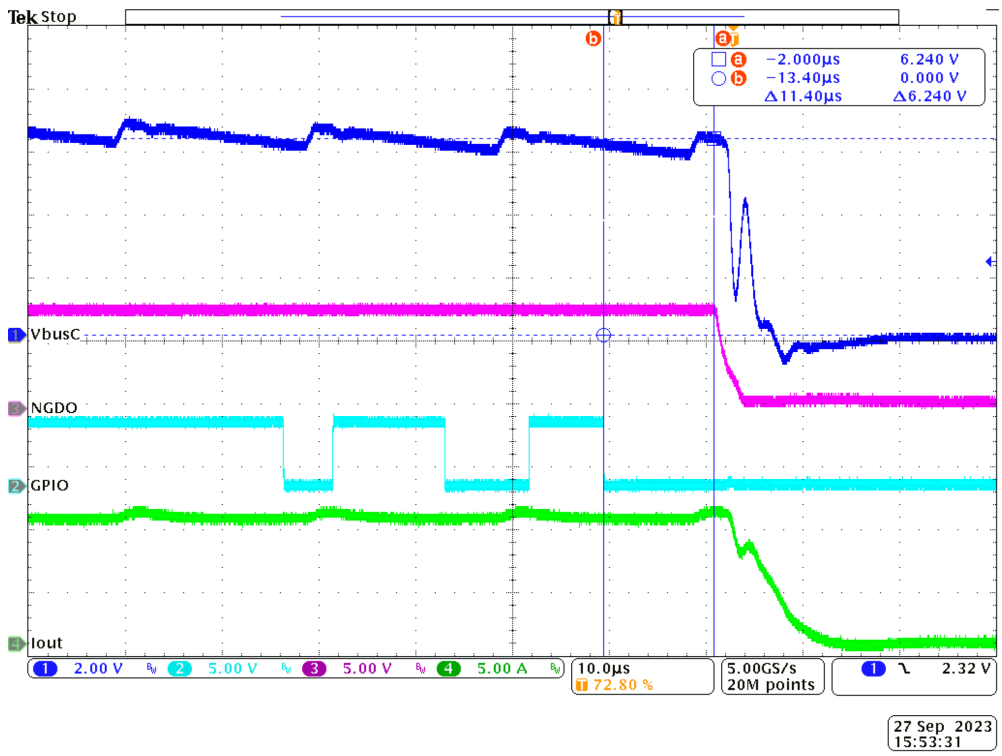
Figure 41 Overvoltage protection trip point and response time at 230 V_{ac}, 50 Hz (CH1: V_{bus_c}, CH2: GPIO9, CH3: NDGO = Provider FET Q2 gate-source)

3.20 Undervoltage protection (UVP)

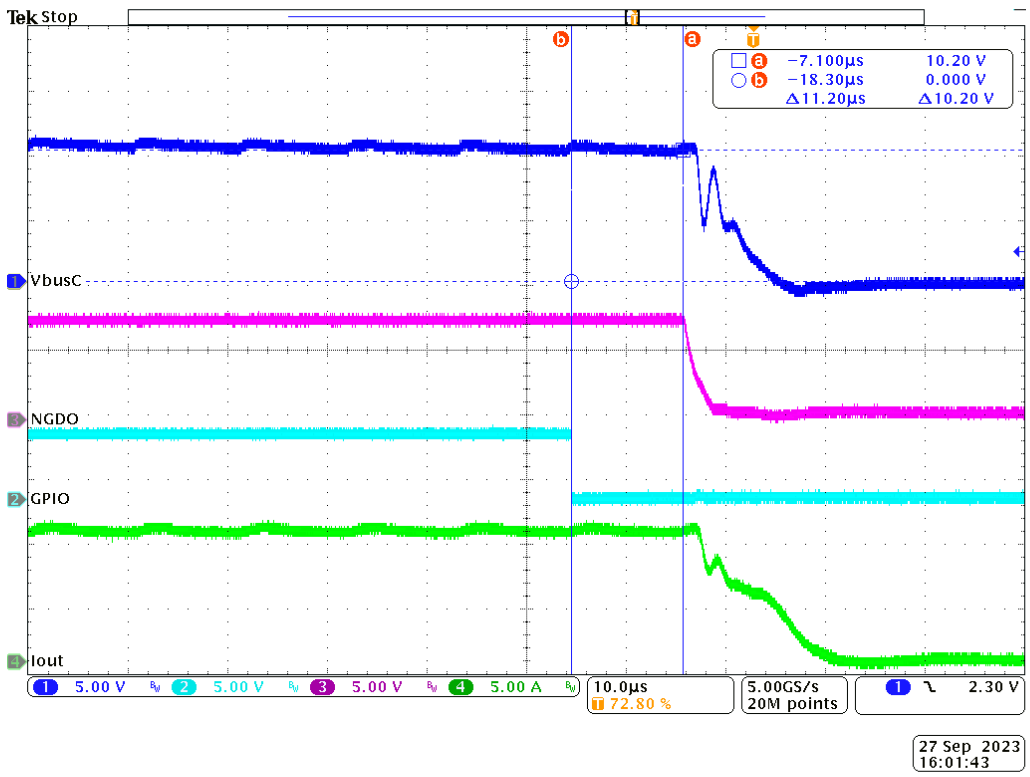
The undervoltage protection trip point and response time at 115 V_{ac}, 60 Hz is shown in Figure 42.



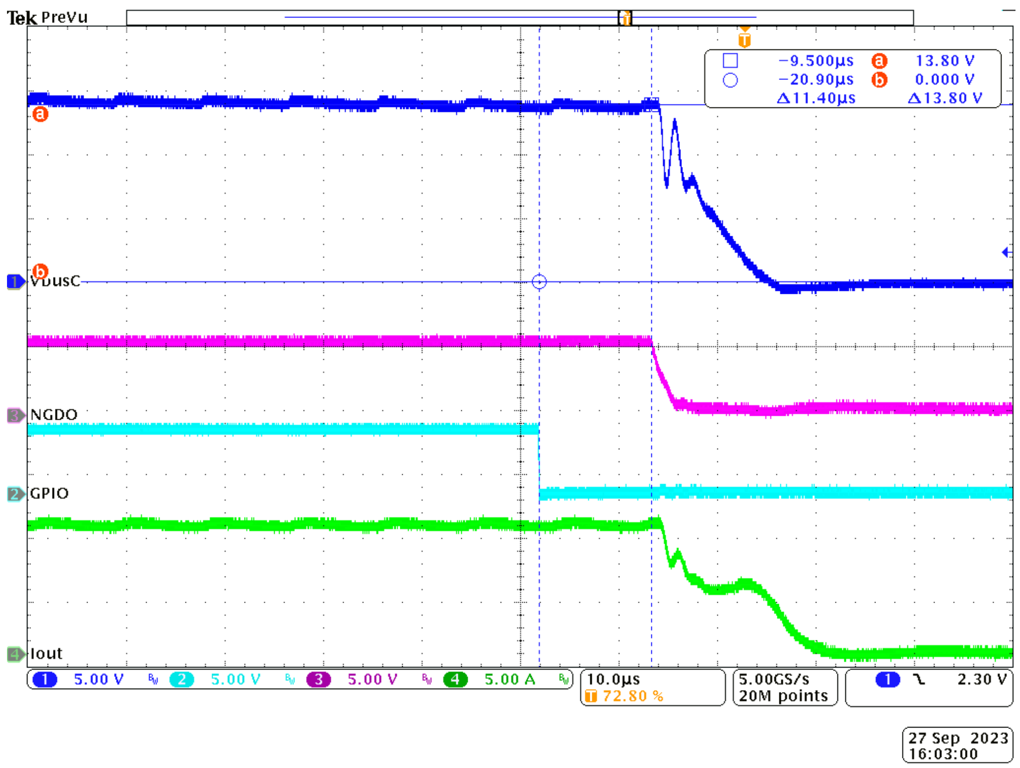
V_{out} = 5 V, UVP trip = 3.16 V, UVP response time = 41 µs



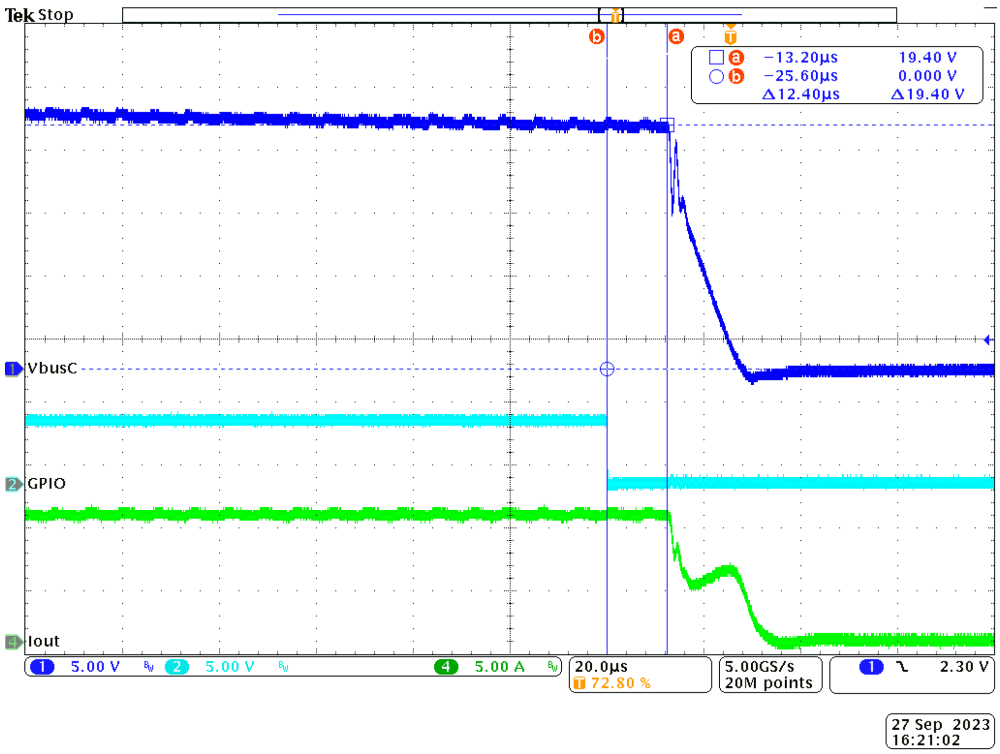
V_{out} = 9 V, UVP trip = 6.24 V, UVP response time = 11.4 µs



V_{out} = 15 V, UVP trip = 10.2 V, UVP response time = 11.2 µs



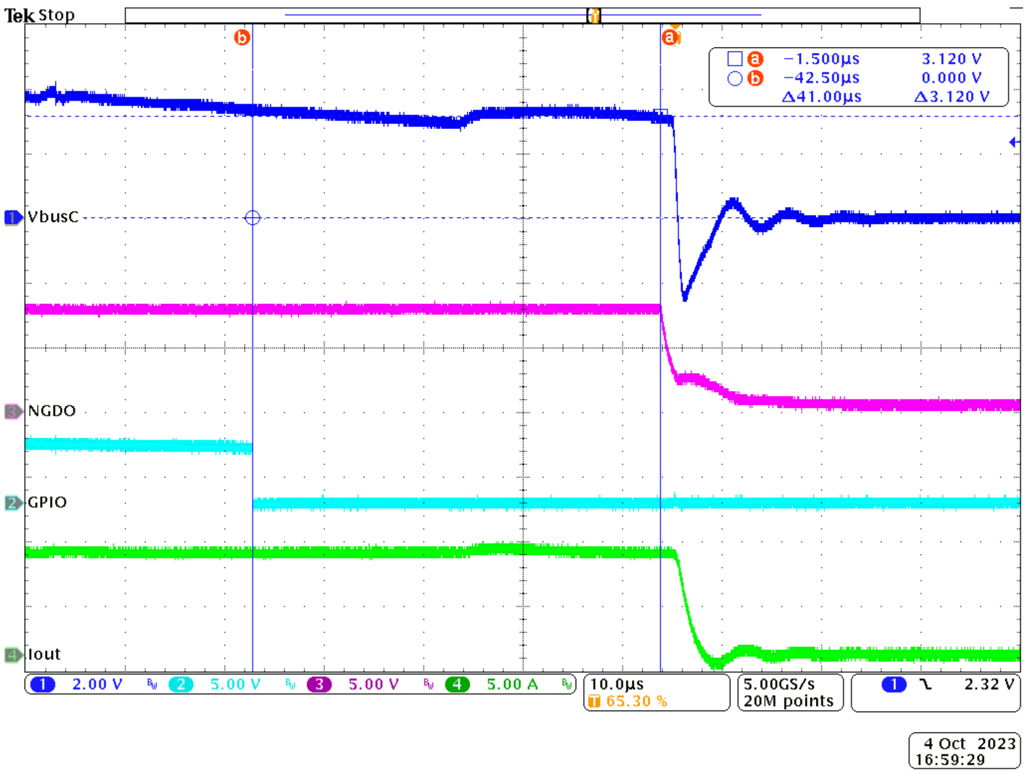
V_{out} = 20 V, UVP trip = 13.8 V, UVP response time = 11.4 µs



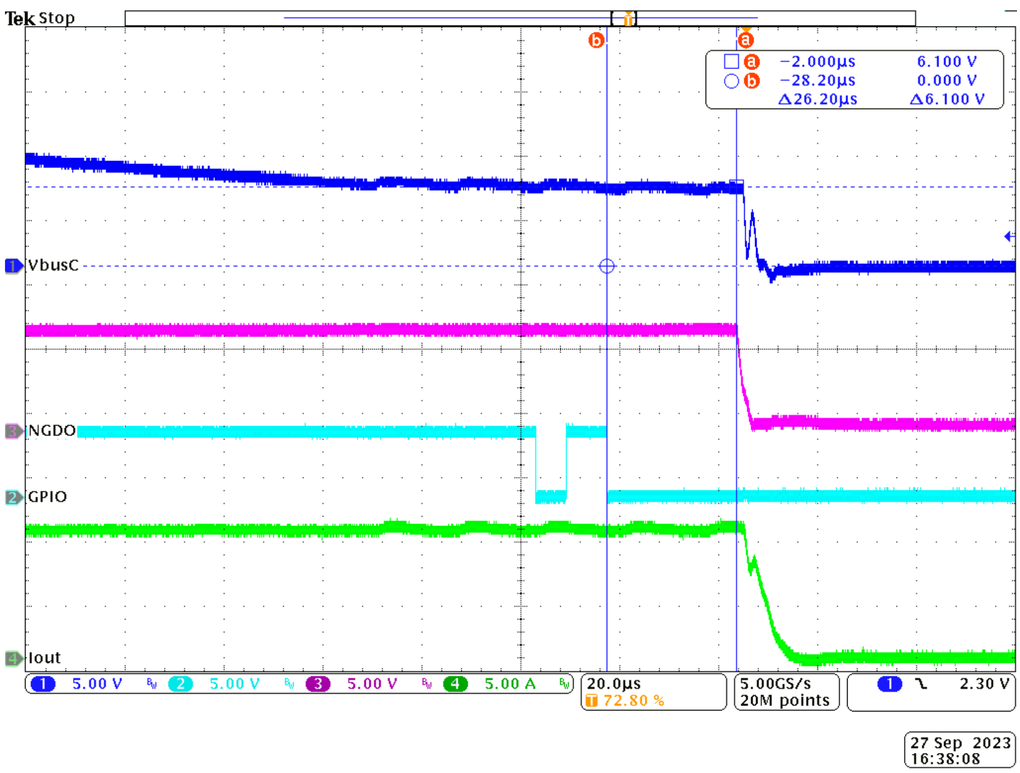
V_{out} = 28 V, UVP trip = 19.4 V, UVP response time = 12.4 µs

Figure 42 Undervoltage protection trip point and response time at 115 V_{ac}, 60 Hz (CH1: V_{bus_c}, CH2: GPIO9, CH3: NDGO = Provider FET Q2 gate-source, CH4: I_{out})

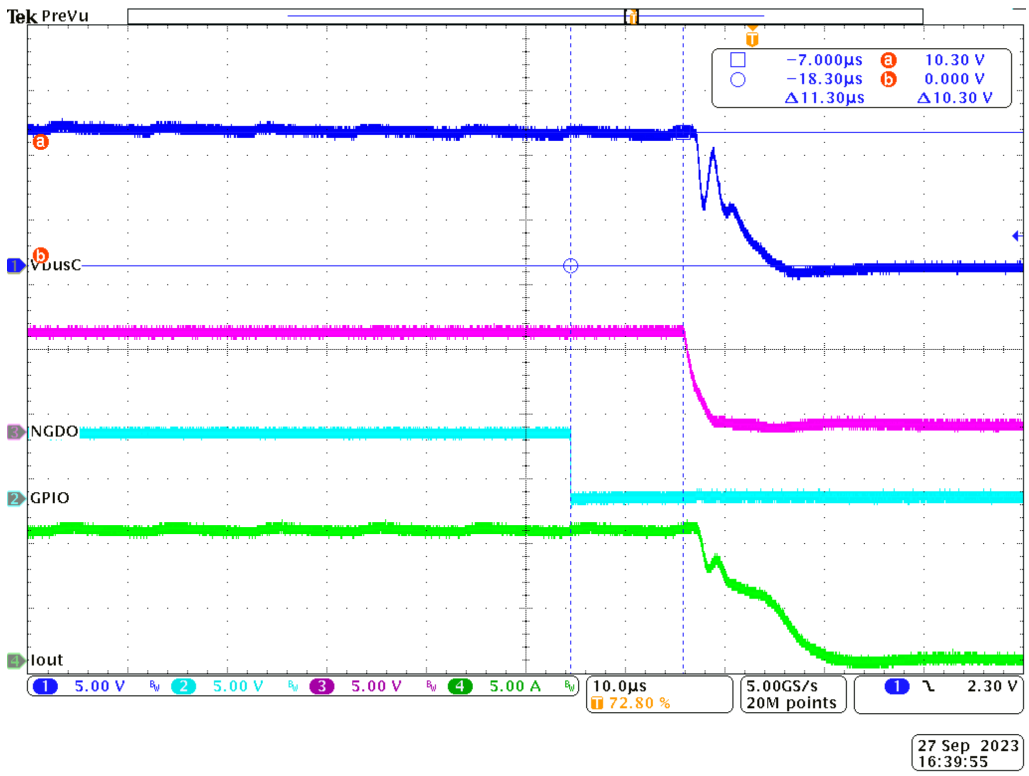
The undervoltage protection trip point and response time at 230 V_{ac}, 50 Hz is shown in Figure 43.



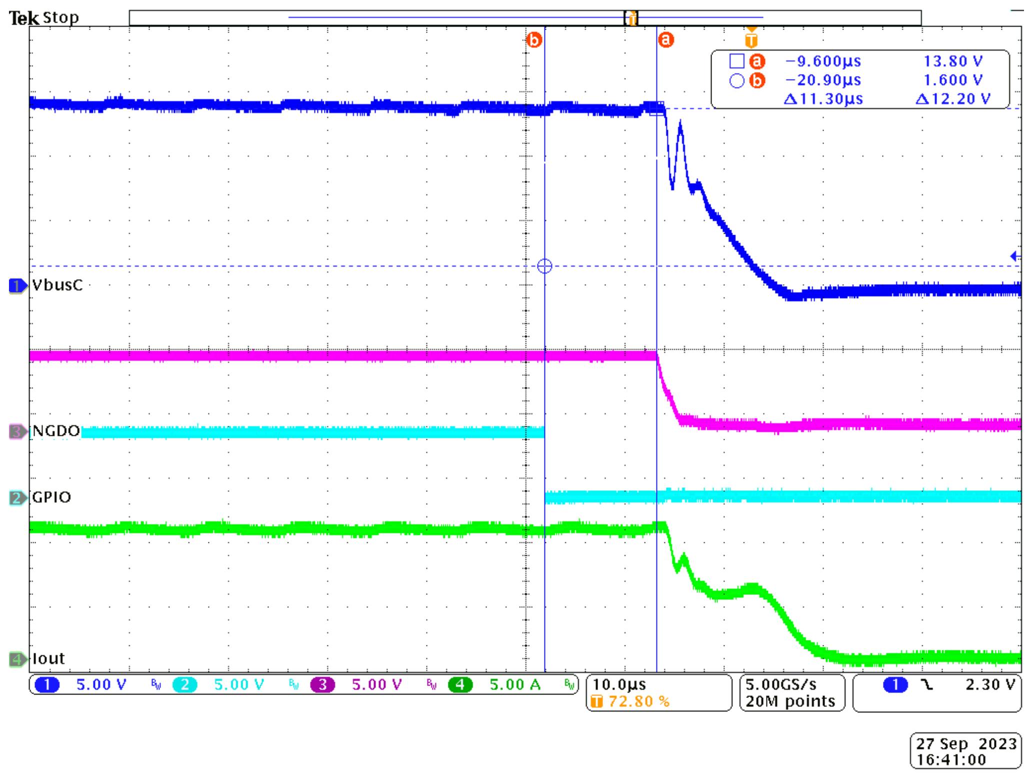
V_{out} = 5 V, UVP trip = 3.12 V, UVP response time = 41 µs



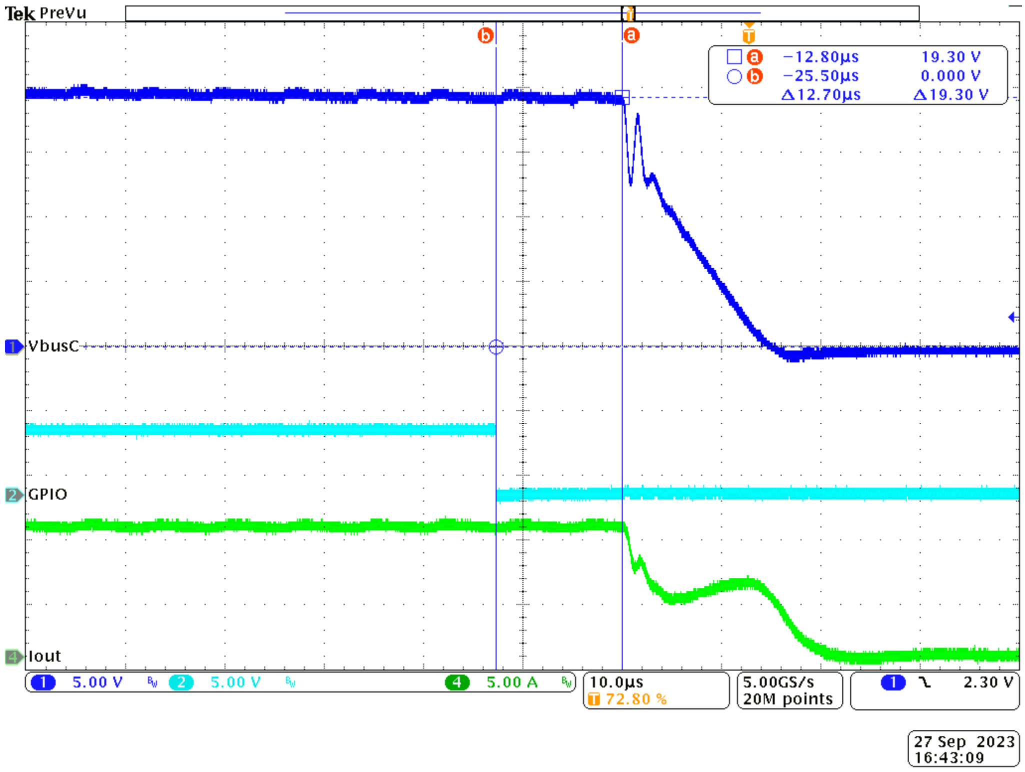
V_{out} = 9 V, UVP trip = 6.1 V, UVP response time = 26.2 µs



V_{out} = 15 V, UVP trip = 10.3 V, UVP response time = 11.3 µs



V_{out} = 20 V, UVP trip = 13.8 V, UVP response time = 11.3 µs



V_{out} = 28 V, UVP trip = 19.3 V, UVP response time = 12.7 µs

Figure 43 Undervoltage protection trip point and response time at 230 V_{ac}, 50 Hz (CH1: V_{bus_c}, CH2: GPIO9, CH3: NDGO = Provider FET Q2 gate-source, CH4: I_{out})

3.21 Thermal stress

- **Test condition**: V_{ac} = 90 V_{ac}/47 Hz, V_{out} = 28 V, I_{out} = 5 A
- **Ambient condition**: 23°C and in open-frame
- **Run time**: 60 minutes

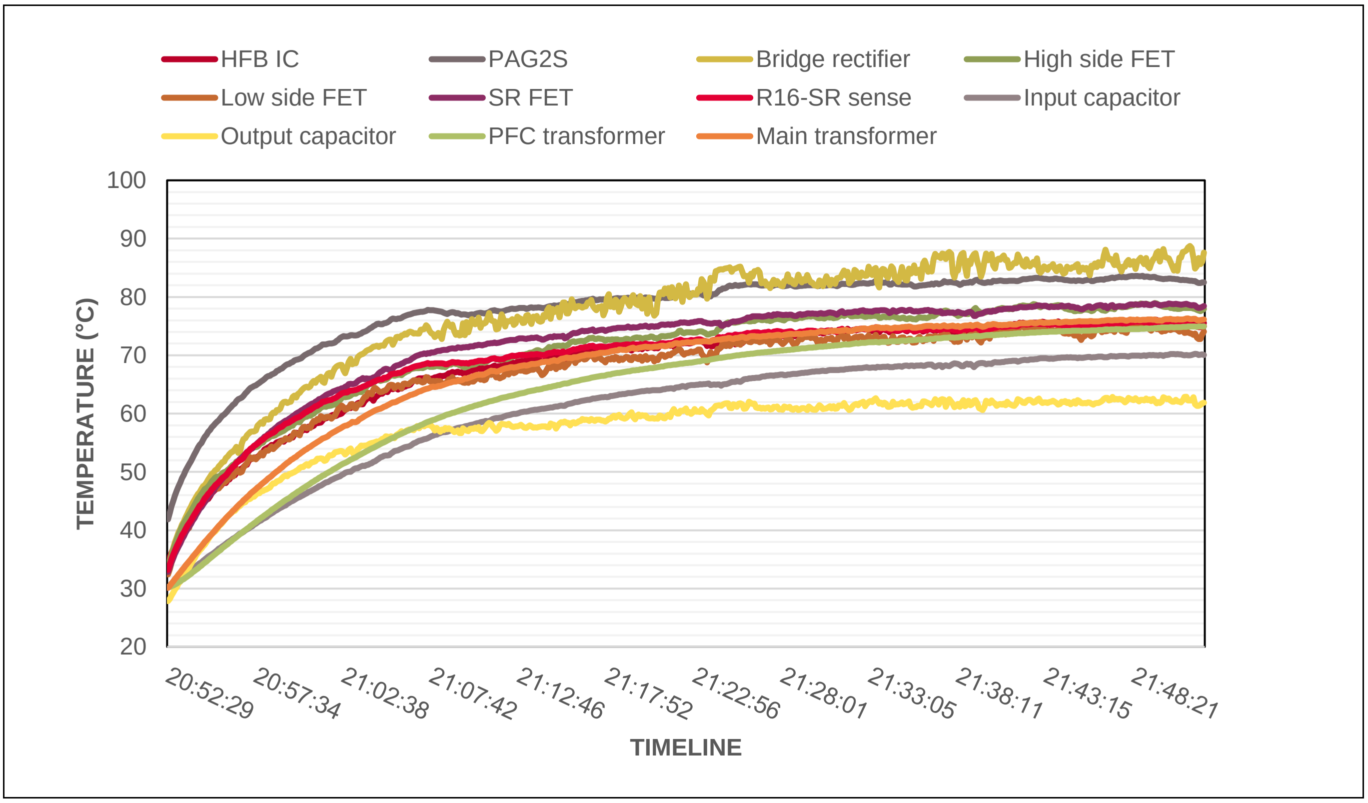


Figure 44 Thermal log with time (V_{ac} = 90 V_{ac}/47 Hz, V_{out} = 28 V, I_{out} = 5 A)

Table 9 Temperature measurements at 90 V_{ac} by the end of 60 minutes

S.No.	Measured key component	Temperature (°C) at 90 V_{ac}/47 Hz
1	XDPS2221 HFB IC (U200)	75.5
2	EZ-PD™ PAG2S (U1)	82.5
3	Bridge rectifier (D100)	87.6
4	High side MOSFET (Q300)	77.9
5	Low side MOSFET (Q301)	74.0
6	SR MOSFET (Q400)	78.4
7	SR sense (R16)	74.9
8	Input capacitor (C106)	70.1
9	Output capacitor (C219)	61.9
10	PFC transformer (T100)	74.9
11	Main transformer (T200)	76.2

- **Test condition**: V_{ac} = 265 V_{ac}/63 Hz, V_{out} = 28 V, I_{out} = 5 A
- **Ambient condition**: 23°C and in open-frame
- **Run time**: 60 minutes

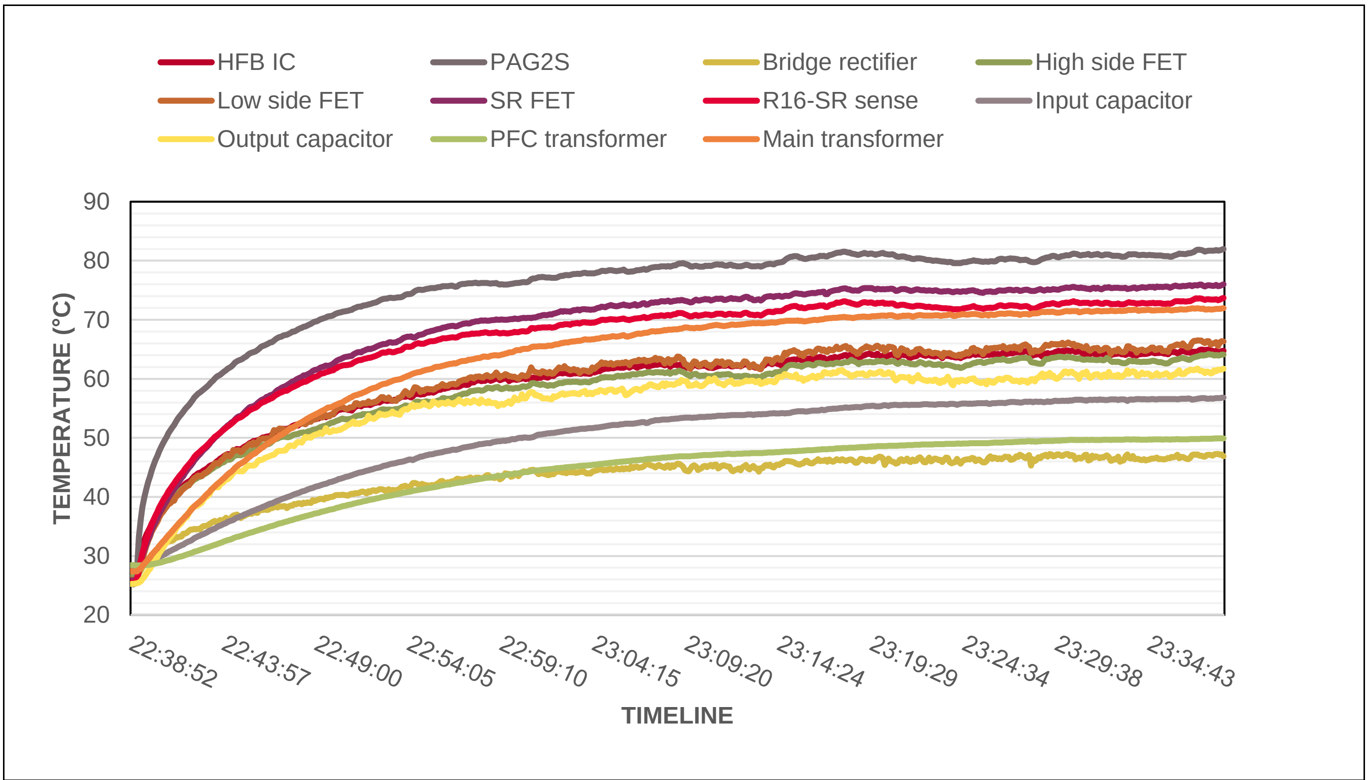
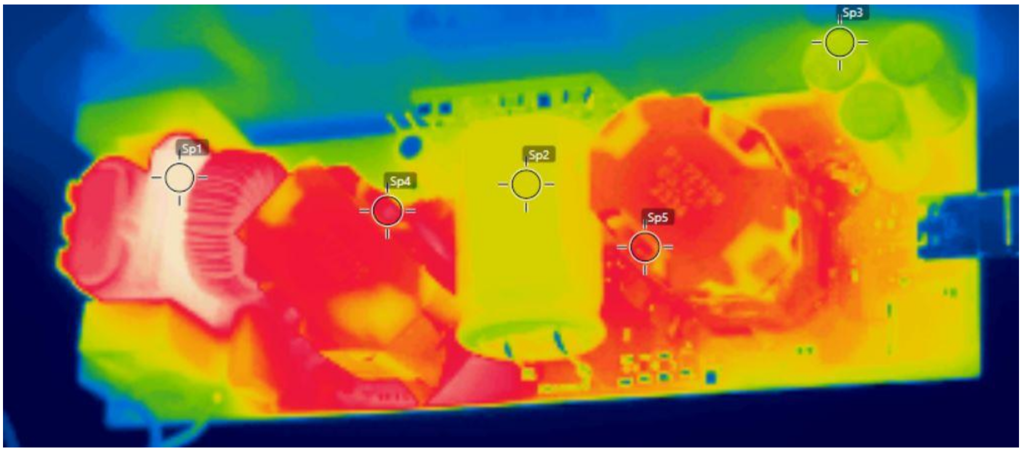


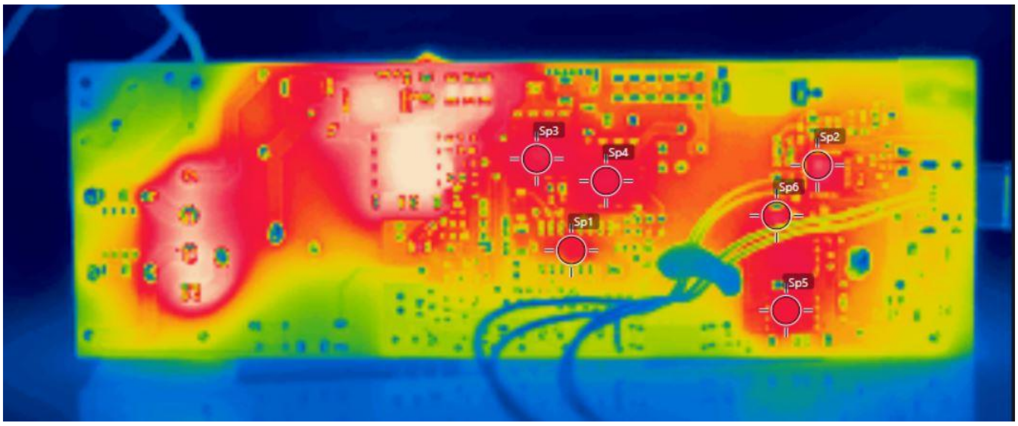
Figure 45 Thermal log with time (V_{ac} = 265 V_{ac}/63 Hz, V_{out} = 28 V, I_{out} = 5 A)

Table 10 Temperature measurements at 265 V_{ac} by the end of 60 minutes

S.No.	Measured key component	Temperature (°C) at 265 V_{ac}/63 Hz
1	XDPS2221 HFB IC (U200)	64.8
2	EZ-PD™ PAG2S (U1)	81.9
3	Bridge rectifier (D100)	46.8
4	High side MOSFET (Q300)	64.1
5	Low side MOSFET (Q301)	66.3
6	SR MOSFET (Q400)	76.0
7	SR sense (R16)	73.7
8	Input capacitor (C106)	56.8
9	Output capacitor (C219)	61.7
10	PFC transformer (T100)	49.9
11	Main transformer (T200)	71.9



Board top thermal image

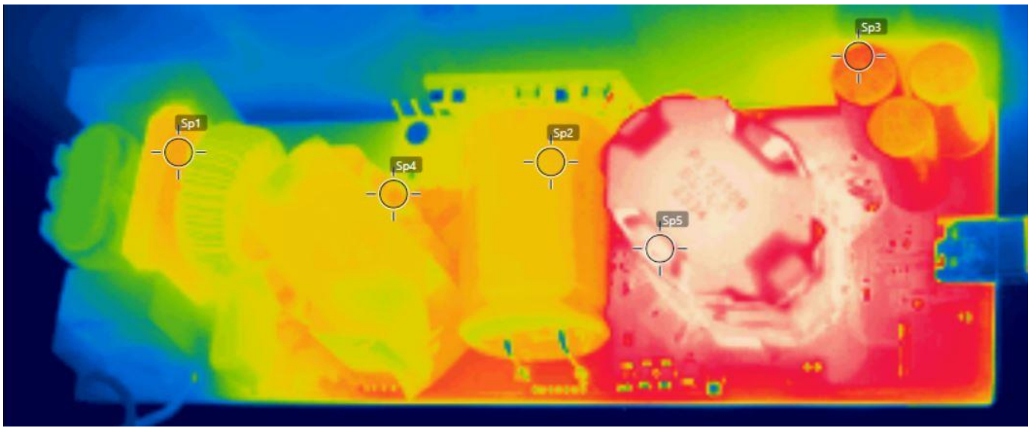


Board bottom thermal image

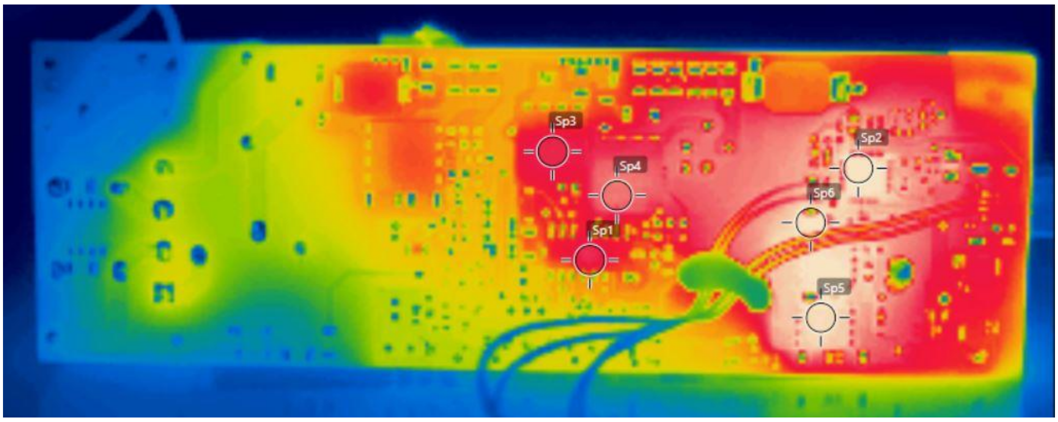
Figure 46 Thermal images after 60 minutes of run time (90 V_{ac}, 47 Hz, 28 V, 5 A)

Table 11 Component temperatures from thermal images at 90 V_{ac} by the end of 60 minutes

S.No.	Measured key component	Denotion on thermal image (Point: Top/bottom)	Temperature (°C) at 90 V_{ac}/47 Hz
1	XDPS2221 HFB IC (U200)	Sp1 – Bottom	87.1
2	EZ-PD™ PAG2S (U1)	Sp2 – Bottom	95.1
3	Bridge rectifier (D100)	Sp1 – Top	120.2
4	High side MOSFET (Q300)	Sp3 – Bottom	89.3
5	Low side MOSFET (Q301)	Sp4 – Bottom	89.1
6	SR MOSFET (Q400)	Sp5 – Bottom	86.9
7	SR sense (R16)	Sp6 – Bottom	90.7
8	Input capacitor (C106)	Sp2 – Top	67.9
9	Output capacitor (C219)	Sp3 – Top	64.8
10	PFC transformer core (T100)	Sp4 – Top	96.0
11	Main transformer core (T200)	Sp5 – Top	89.3



Board top thermal image



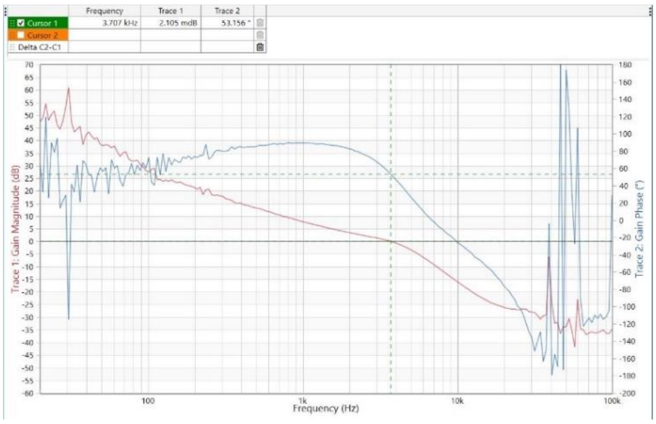
Board bottom thermal image

Figure 47 **Thermal images after 60 minutes of run time (265 V_{ac}, 63 Hz, 28 V, 5 A)**

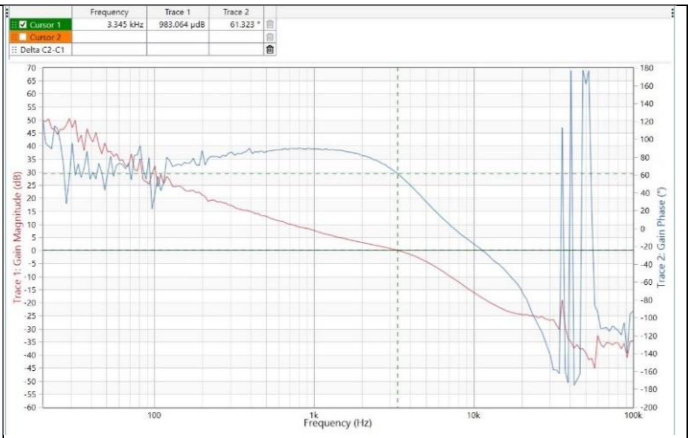
Table 12 **Component Temperatures from thermal images at 265 V_{ac} by end of 60 minutes**

S.No.	Measured key component	Denotion on thermal image (Point: Top/bottom)	Temperature (°C) at 265 V_{ac}/63 Hz
1	XDPS2221 HFB IC (U200)	Sp1 – Bottom	74.1
2	EZ-PD™ PAG2S (U1)	Sp2 – Bottom	93.5
3	Bridge rectifier (D100)	Sp1 – Top	58.3
4	High side MOSFET (Q300)	Sp3 – Bottom	73.8
5	Low side MOSFET (Q301)	Sp4 – Bottom	78.4
6	SR MOSFET (Q400)	Sp5 – Bottom	85.2
7	SR sense (R16)	Sp6 – Bottom	89.3
8	Input capacitor (C106)	Sp2 – Top	56.0
9	Output capacitor (C219)	Sp3 – Top	63.7
10	PFC transformer core (T100)	Sp4 – Top	59.0
11	Main transformer core (T200)	Sp5 – Top	86.5

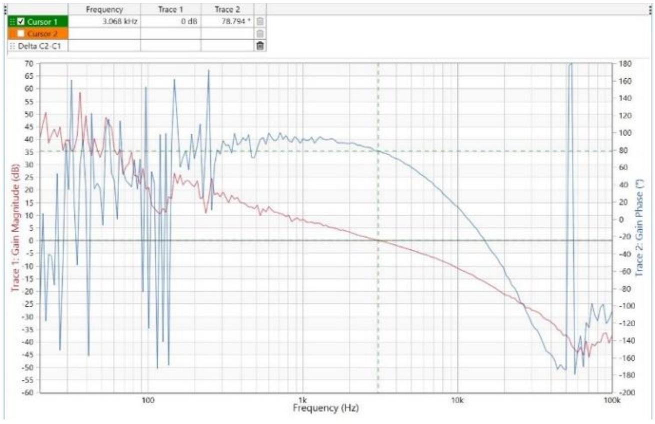
3.22 Bode stability



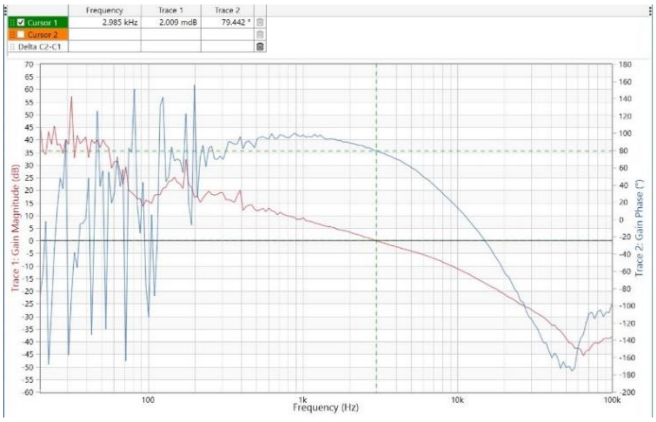
115 V_{ac}, 60 Hz
V_{out}: 5 V, I_{out}: 5 A
Bandwidth: 3.71 kHz
Phase Margin: 53.16 °



230 V_{ac}, 50 Hz
V_{out}: 5 V, I_{out}: 5 A
Bandwidth: 3.34 kHz
Phase Margin: 61.32 °



115 V_{ac}, 60 Hz
V_{out}: 28 V, I_{out}: 5 A
Bandwidth: 3.07 kHz
Phase Margin: 78.79 °



230 V_{ac}, 50 Hz
V_{out}: 28 V, I_{out}: 5 A
Bandwidth: 2.98 kHz
Phase Margin: 79.44 °

Figure 48 Detailed bode plots taken from OMICRON Bode network analyzer

Table 13 Tabular data of bode measurements

V_{ac}	V_{out}	I_{out}	Bandwidth	Phase margin
115 V_{ac}	3.3 V	5 A	2.74 kHz	64.79°
115 V_{ac}	5 V	5 A	3.32 kHz	57.40°
115 V_{ac}	5 V	5 A	3.55 kHz	60.06°
115 V_{ac}	15 V	5 A	2.55 kHz	78.04°
115 V_{ac}	20 V	5 A	2.76 kHz	80.02°
115 V_{ac}	28 V	5 A	2.72 kHz	79.31°
115 V_{ac}	3.3 V	1 A	3.47 kHz	12.19°
115 V_{ac}	5 V	1 A	2.65 kHz	30.56°
115 V_{ac}	5 V	1 A	2.95 kHz	30.10°
115 V_{ac}	15 V	1 A	2.68 kHz	40.85°
115 V_{ac}	20 V	1 A	3.05 kHz	59.76°
115 V_{ac}	28 V	1 A	3.11 kHz	61.92°
230 V_{ac}	3.3 V	5 A	2.63 kHz	63.42°
230 V_{ac}	5 V	5 A	2.85 kHz	65.19°
230 V_{ac}	5 V	5 A	2.82 kHz	68.10°
230 V_{ac}	15 V	5 A	3.78 kHz	57.88°
230 V_{ac}	20 V	5 A	3.53 kHz	66.22°
230 V_{ac}	28 V	5 A	2.79 kHz	78.41°
230 V_{ac}	3.3 V	1 A	2.66 kHz	20.51°
230 V_{ac}	5 V	1 A	2.41 kHz	30.19°
230 V_{ac}	5 V	1 A	2.71 kHz	31.31°
230 V_{ac}	15 V	1 A	2.69 kHz	43.66°
230 V_{ac}	20 V	1 A	2.95 kHz	60.59°
230 V_{ac}	28 V	1 A	3.09 kHz	62.70°

3.23 V_o steady state response with line transition

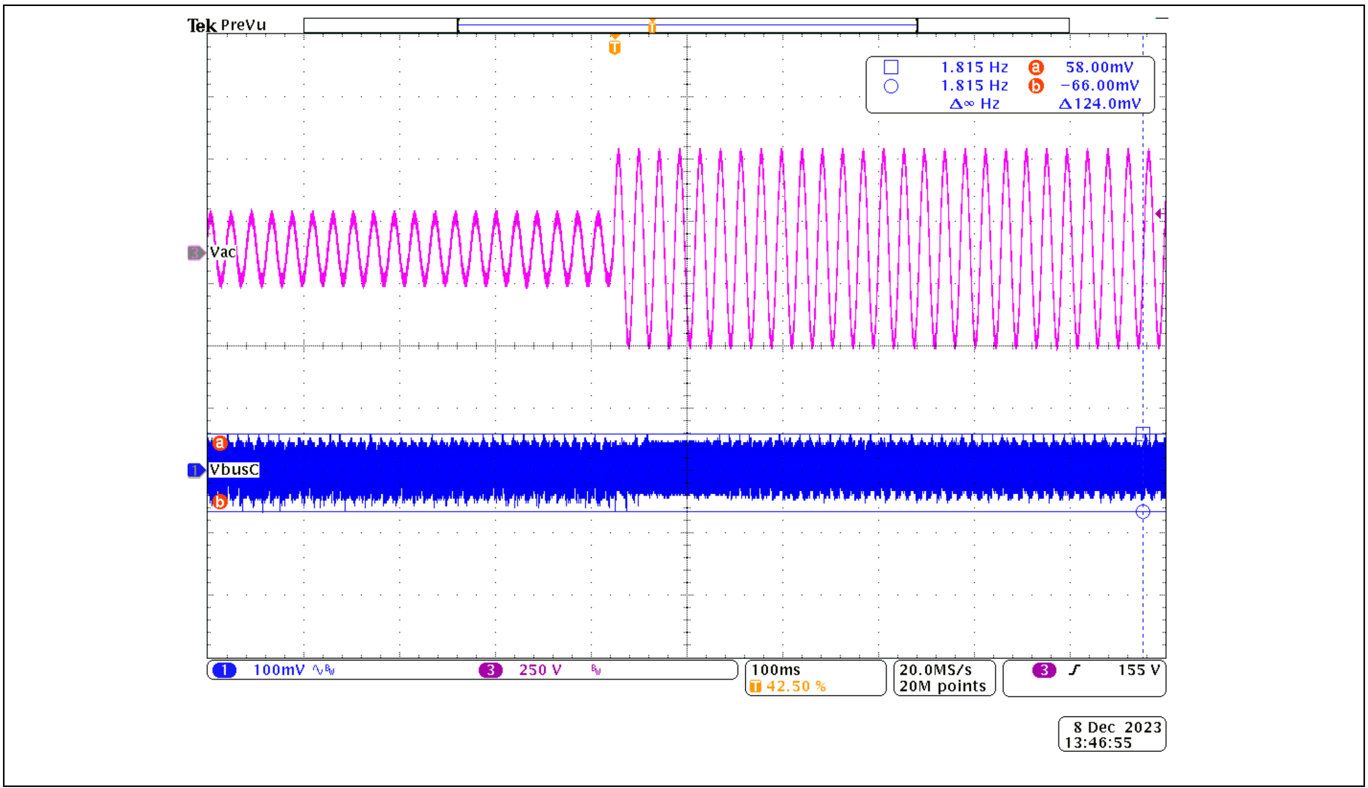


Figure 49 90 V_{ac}/47 Hz to 265 V_{ac}/47 Hz, 28 V, 5 A (CH1: V_{bus_C} – AC coupling, CH3: V_{ac})

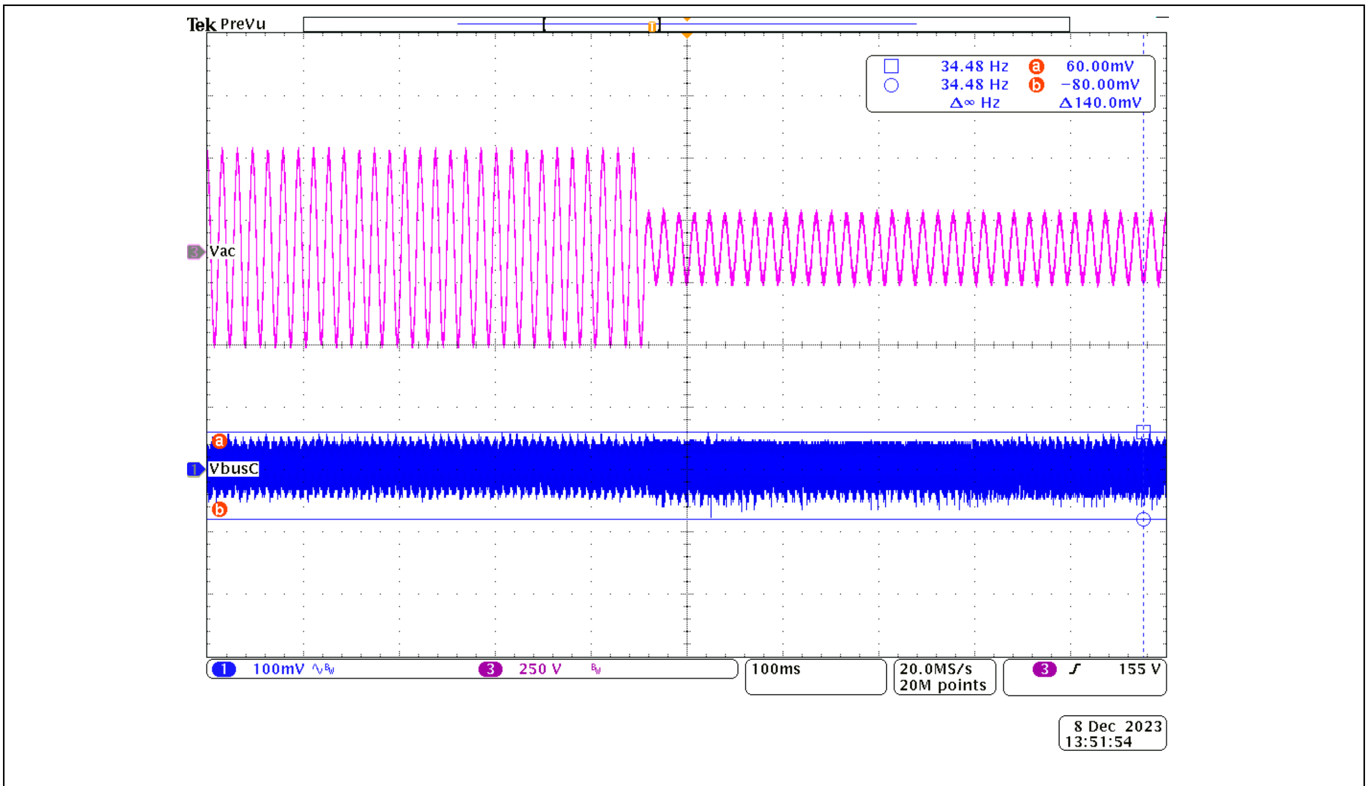


Figure 50 265 V_{ac}/63 Hz to 90 V_{ac}/63 Hz, 28 V, 5 A (CH1: V_{bus_C} – AC coupling, CH3: V_{ac})

3.24 Maximum input current in steady state

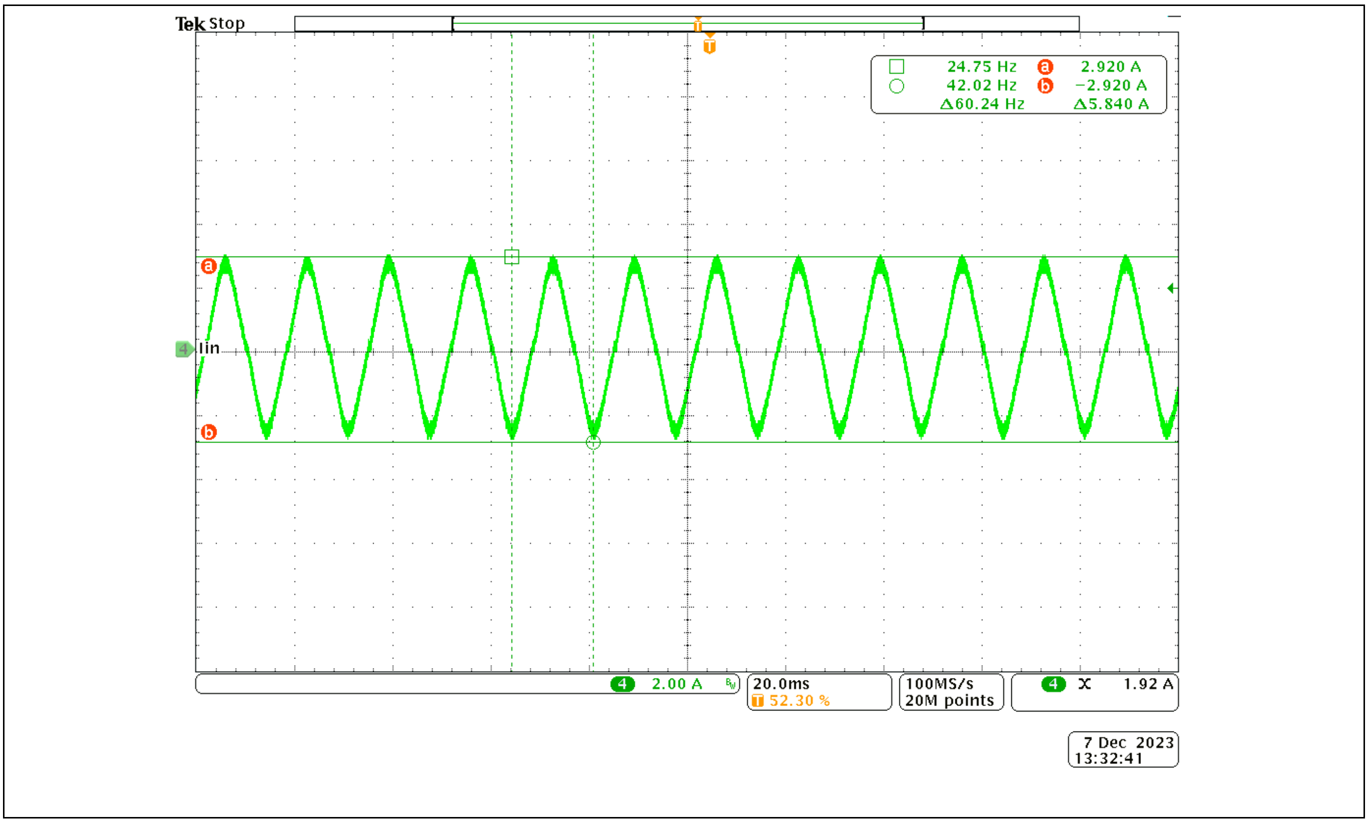


Figure 51 **Input peak current at 90 V_{ac}/60 Hz, 28 V, 5 A**

Table 14 **Input currents (RMS and peak) at 90 V_{ac}, 60 Hz, 28 V, 5 A load**

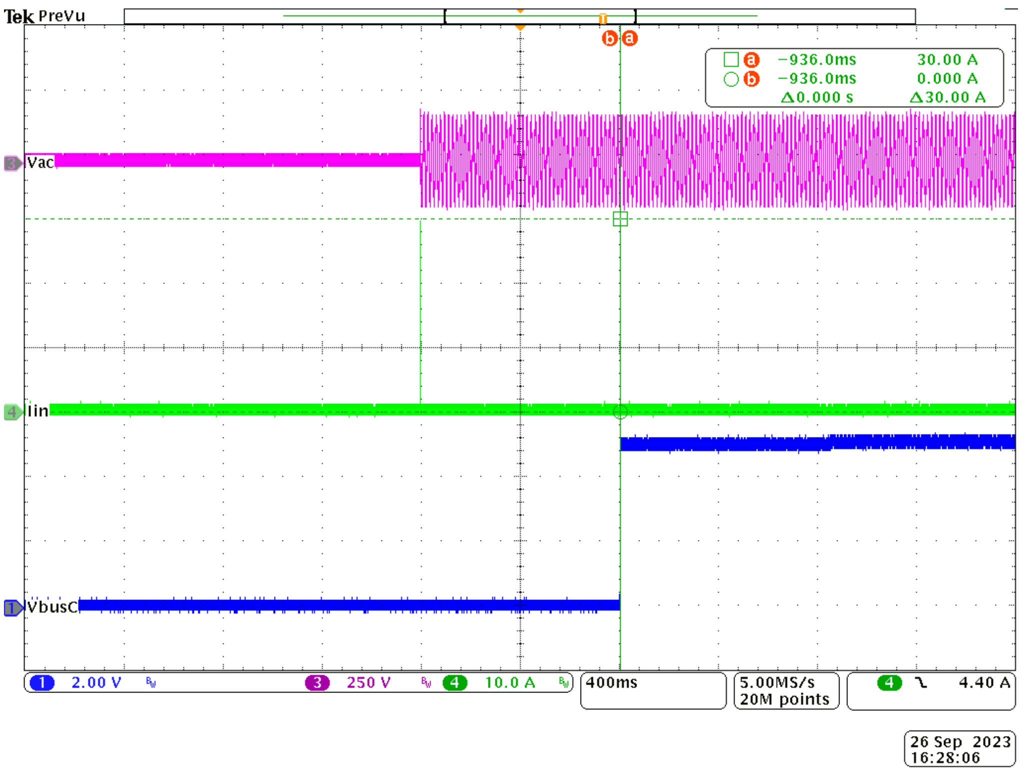
V_{out} = 28 V, I_{out} = 5 A	I_{rms} (from Power Meter)	I_{peak} (from waveform)
90 V_{ac}, 60 Hz	1.71 A	2.92 A

3.25 Brownout recovery

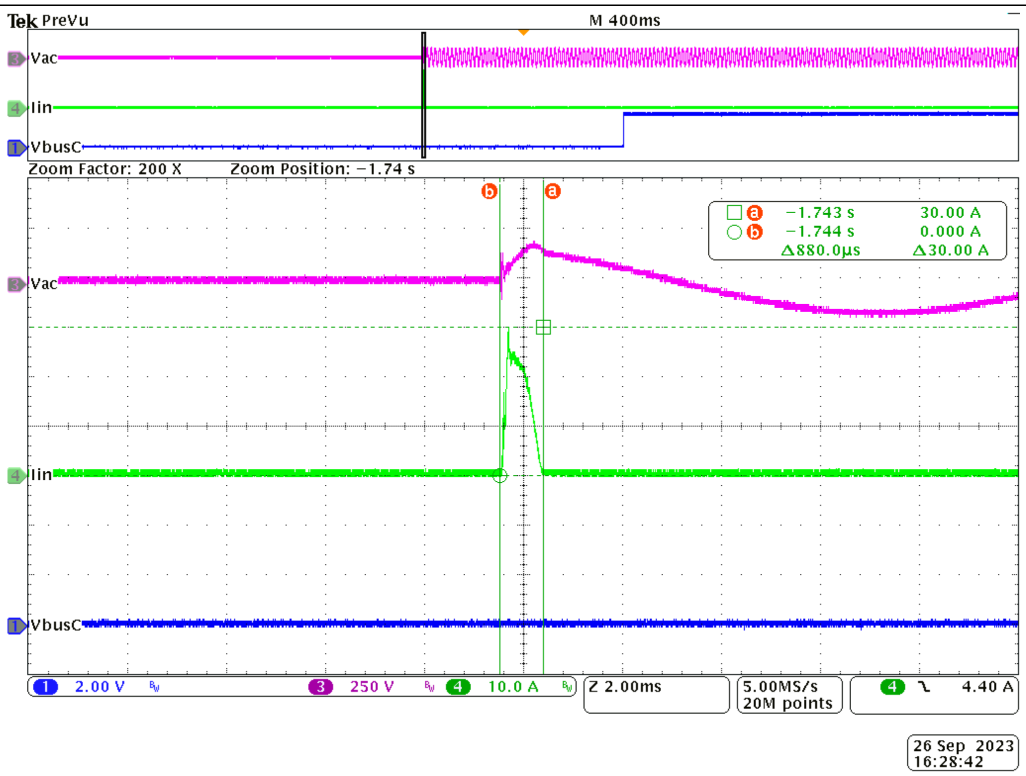
Table 15 **Brown-in and brownout data**

Test condition	Result
V_o = 5 V_{dc}, I_o= 0 A (no load)	UVLO falling at 67 V_{ac} and UVLO rising at 89 V_{ac}
V_o = 28 V_{dc}, I_o= 5 A (full power)	UVLO falling at 74 V_{ac} and UVLO rising at 89 V_{ac}

3.26 Inrush current at cold start



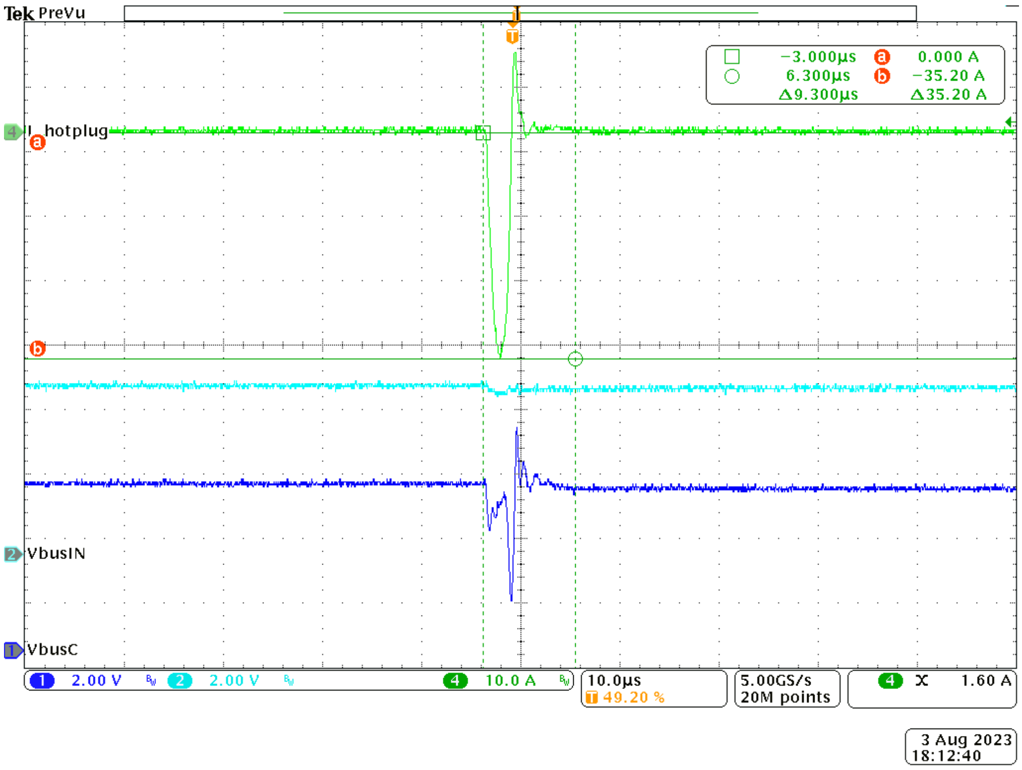
Cold start inrush current (30 A)



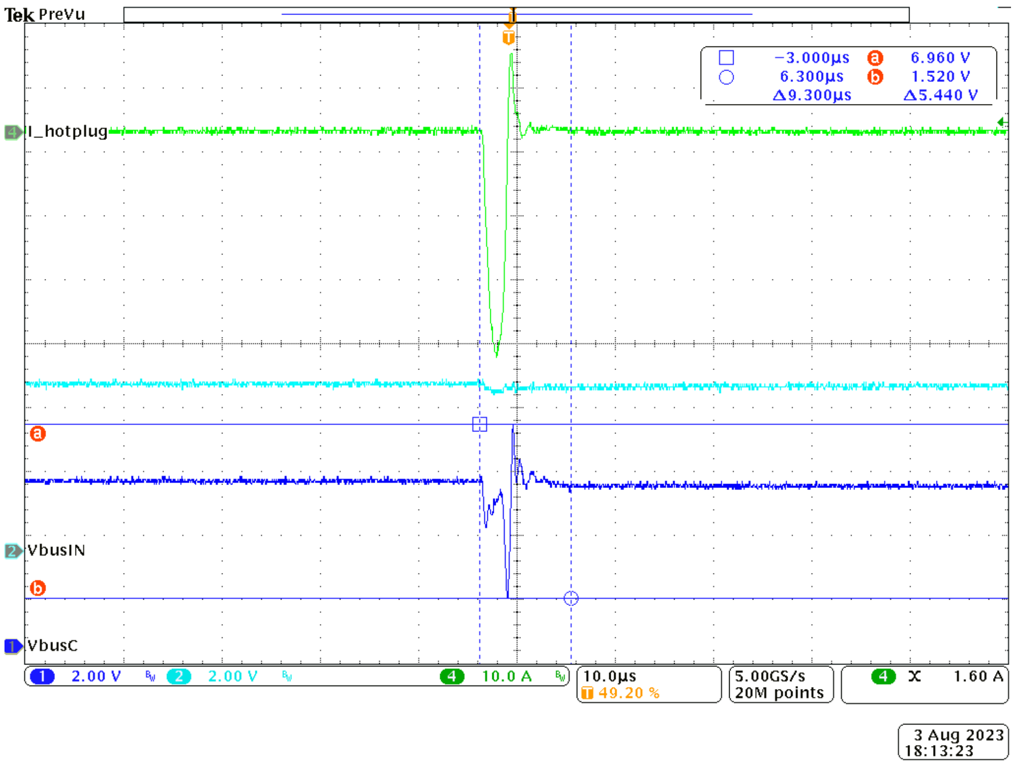
Zoomed in segment of cold start inrush current

Figure 52 Cold start at 115 V_{ac}, 60 Hz (CH2: V_{bus_in}, CH3: V_{ac}, CH4: $I_{in\text{-}peak}$)

3.27 V_o dynamic response on capacitive hotplug



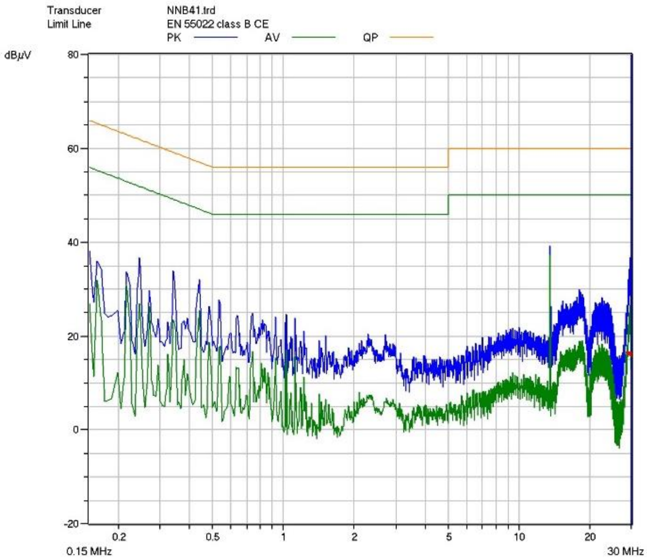
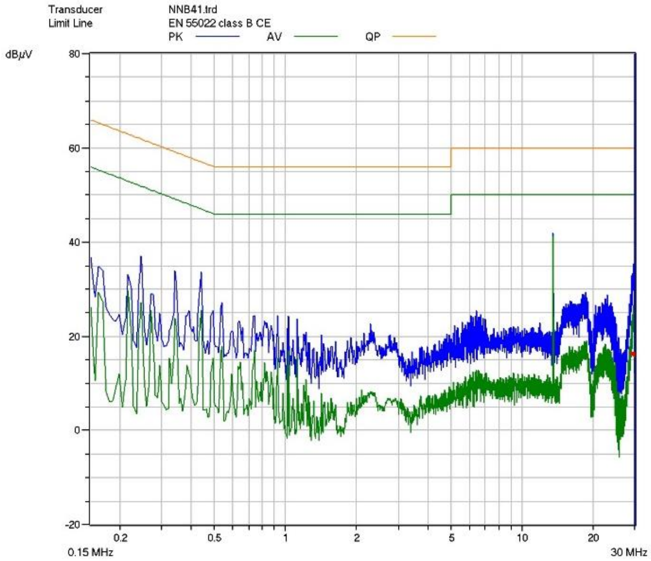
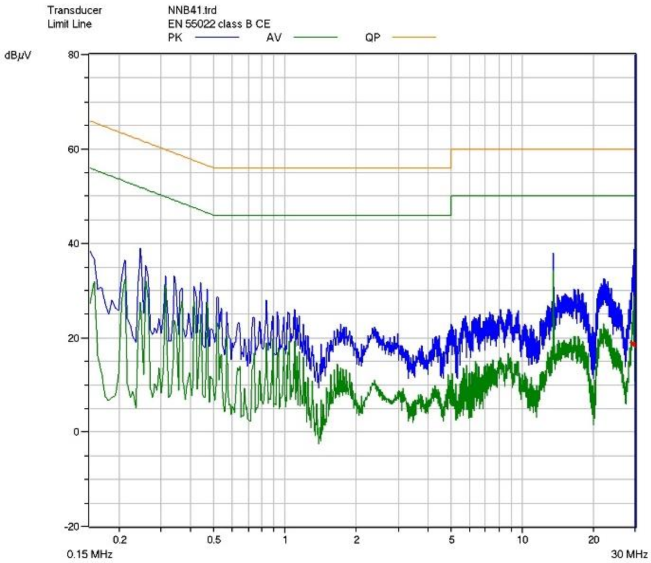
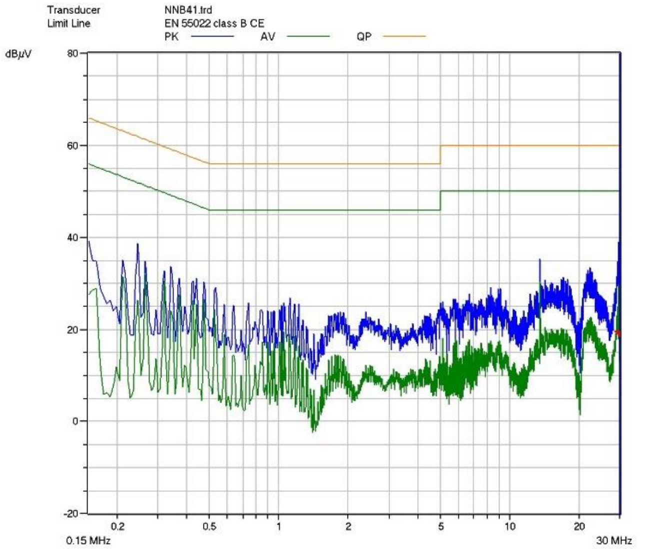
Capacitive hotplug, 10 µF MLCC used at V_{bus_c} board end



Capacitive hotplug showing V_{bus_c} droop

Figure 53 Capacitive hotplug at 115 V_{ac}/60 Hz, 5 V, 0 A (CH1: V_{bus_c}, CH2: V_{bus_in}, CH4: $I_{out\text{-}hotplug}$)

3.28 Conducted emissions EMI

V_{out}: 3.3 V, I_{out}: 5 A	
115 V_{ac}/60 Hz -- Line 21 dB QP margin at 13.5 MHz 	115 V_{ac}/60 Hz -- Neutral 18.5 dB QP margin at 13.6 MHz 
230 V_{ac}/50 Hz -- Line 21.6 dB QP margin at 243 kHz 	230 V_{ac}/50 Hz -- Neutral 21.5 dB QP margin at 29.5 MHz 

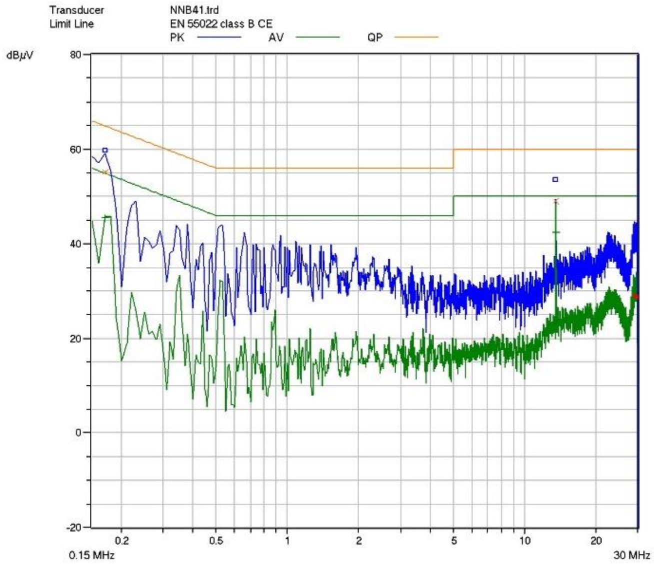
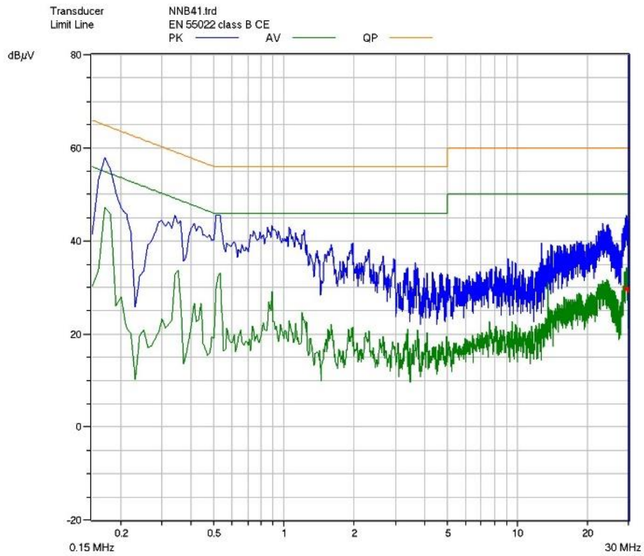
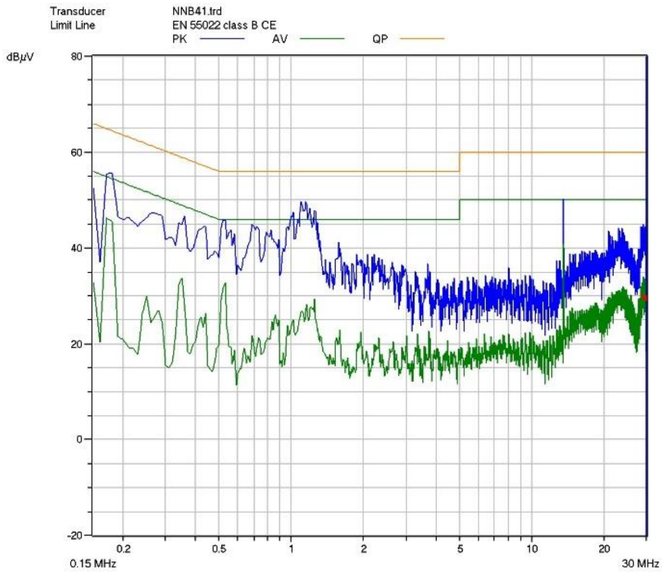
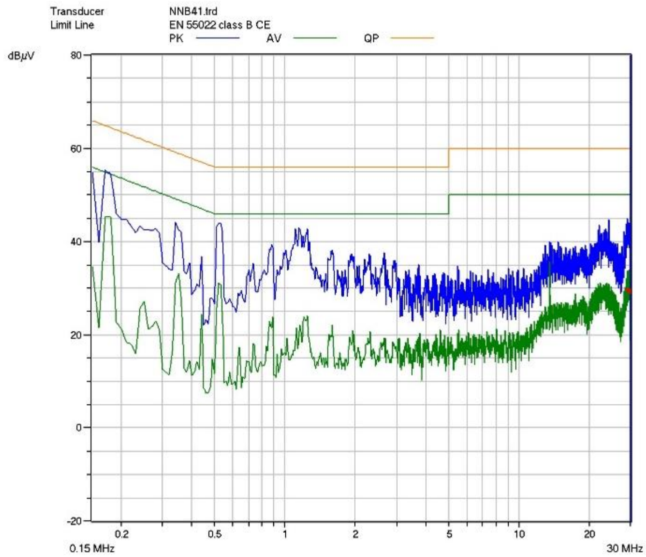
<table>
<tr><th colspan="2">V_{out}: 28 V, I_{out}: 5 A</th></tr>
<tr>
<td>115 V_{ac}/60 Hz -- Line
5.9 dB QP margin at 175 kHz

</td>
<td>115 V_{ac}/60 Hz -- Neutral
7.2 dB QP margin at 175 kHz

</td>
</tr>
<tr>
<td>230 V_{ac}/50 Hz -- Line
7.8 dB QP margin at 181 kHz

</td>
<td>230 V_{ac}/50 Hz -- Neutral
9.7 dB QP margin at 175 kHz

</td>
</tr>
</table>

Figure 54 Conducted emissions EMI test results

3.29 Hi-POT

Test conditions:

- Mode = ACW
- Voltage = 3 kV
- Timer = 2 s
- Hi-SET = 1 mA
- Lo-SET = 0 mA

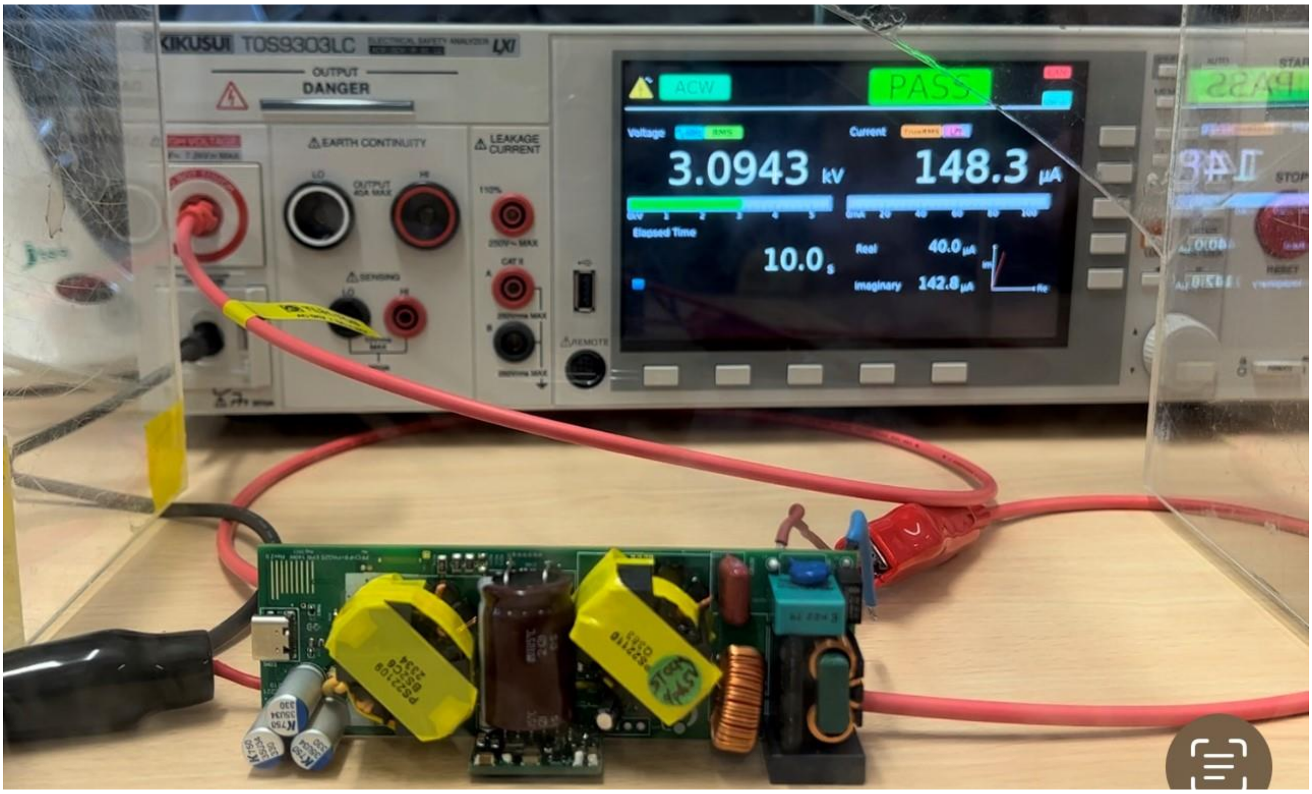


Figure 55 Hi-Pot test setup

Observations: Leakage current = 0.148 mA

4 USB PD source test results (using QuadraMAX)

4.1 Test setup

Figure 56 QuadraMAX test setup

- QuadDraw version: 0.9.8628
- QM#156 HWRev:1.4.4 FWST:0.1.1378 FWCCG1:0.11

4.2 Test results

Test input voltage conditions: 115 V_{ac}, 60 Hz and 230 V_{ac}, 50 Hz

Table 16 USB PD Source Test Results

Test	Description	Result
TD SPT.1	Load test	PASS
TD SPT.2	Capabilities test	PASS
TD SPT.3	Hard reset test	PASS
TD SPT.6	PPS voltage step test	PASS
TD SPT.7	PPS current limit test	PASS

5 Appendix

5.1 Schematics

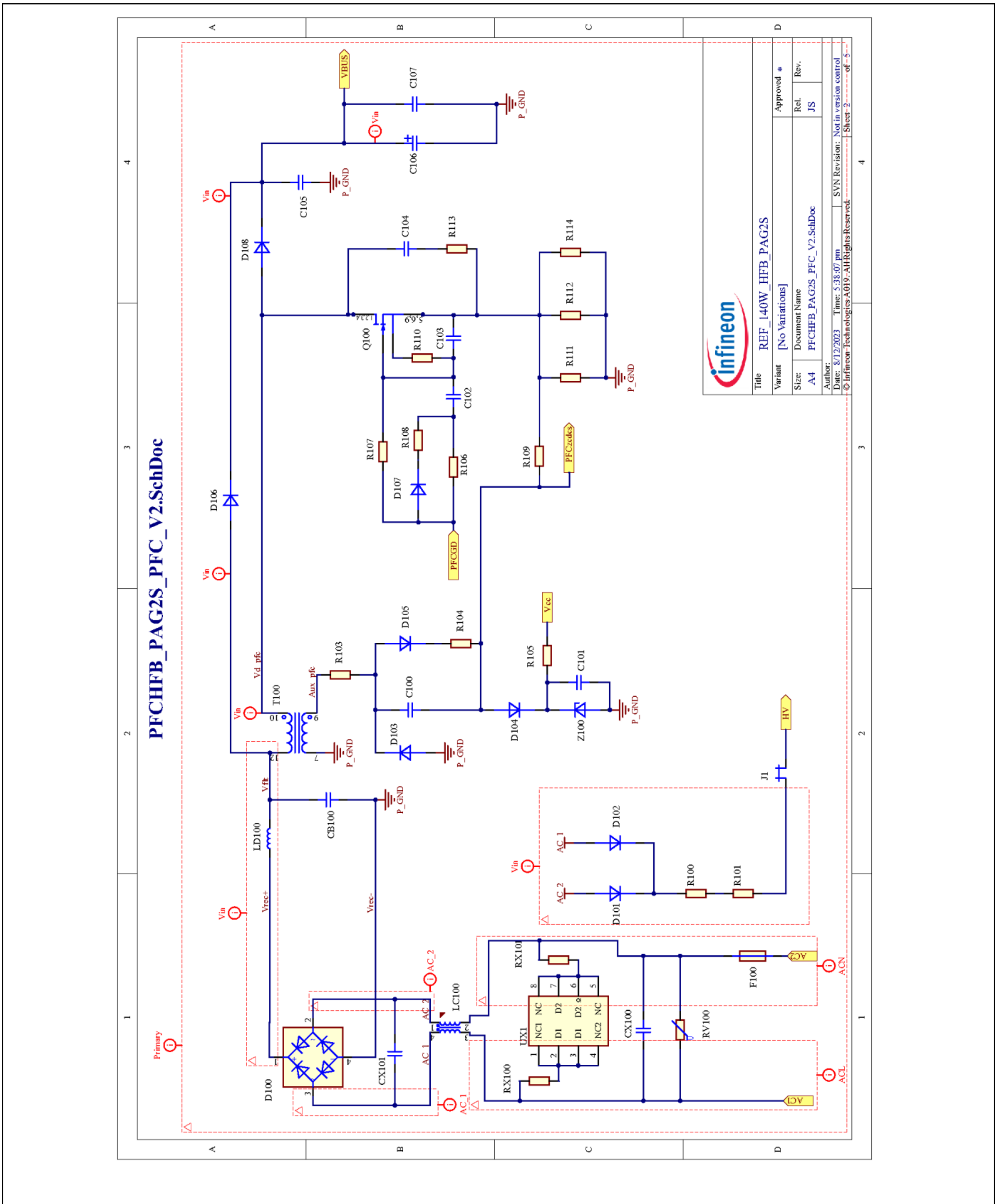


Figure 57 AC input and PFC stage circuit

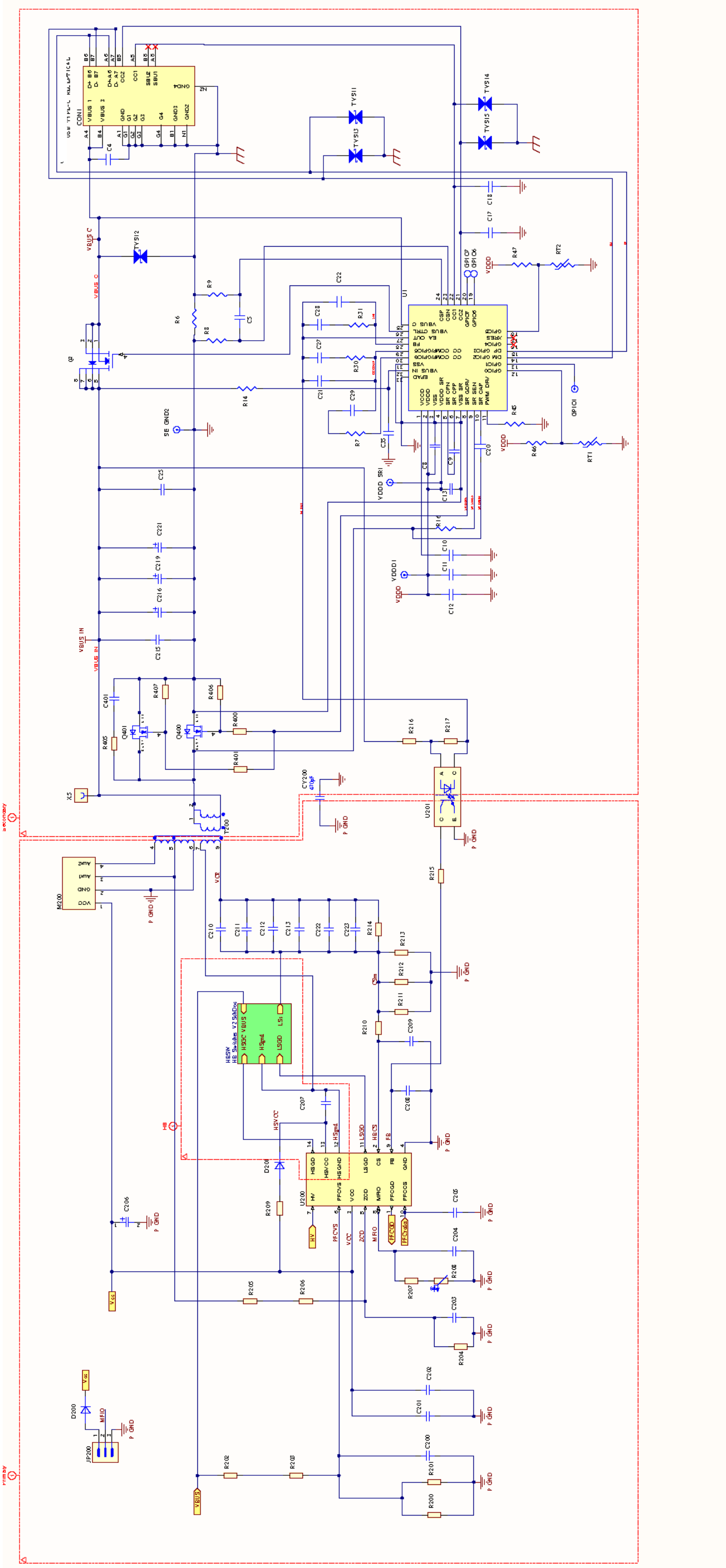


Figure 58 Primary and secondary circuit

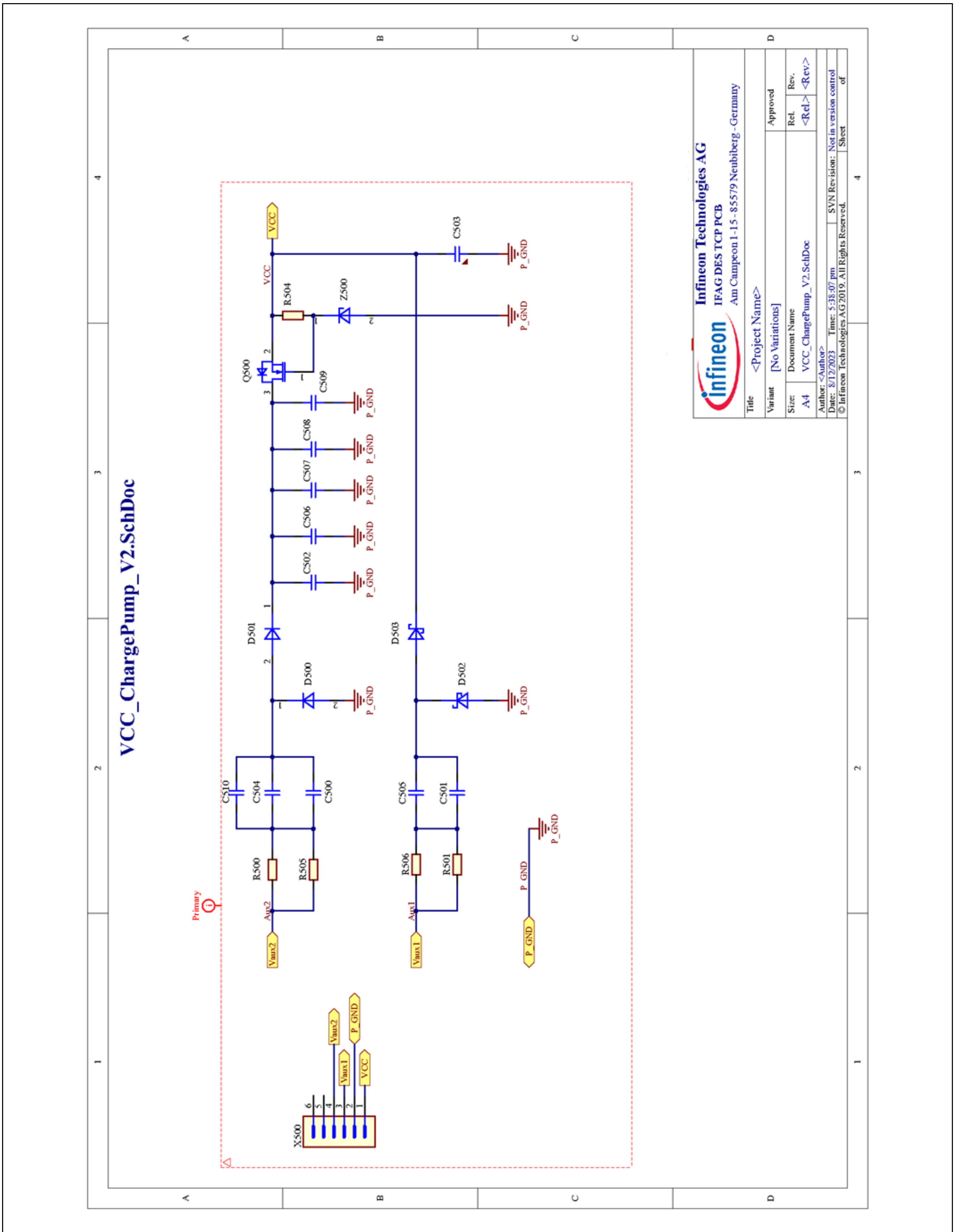


Figure 59 VCC charge pump circuit

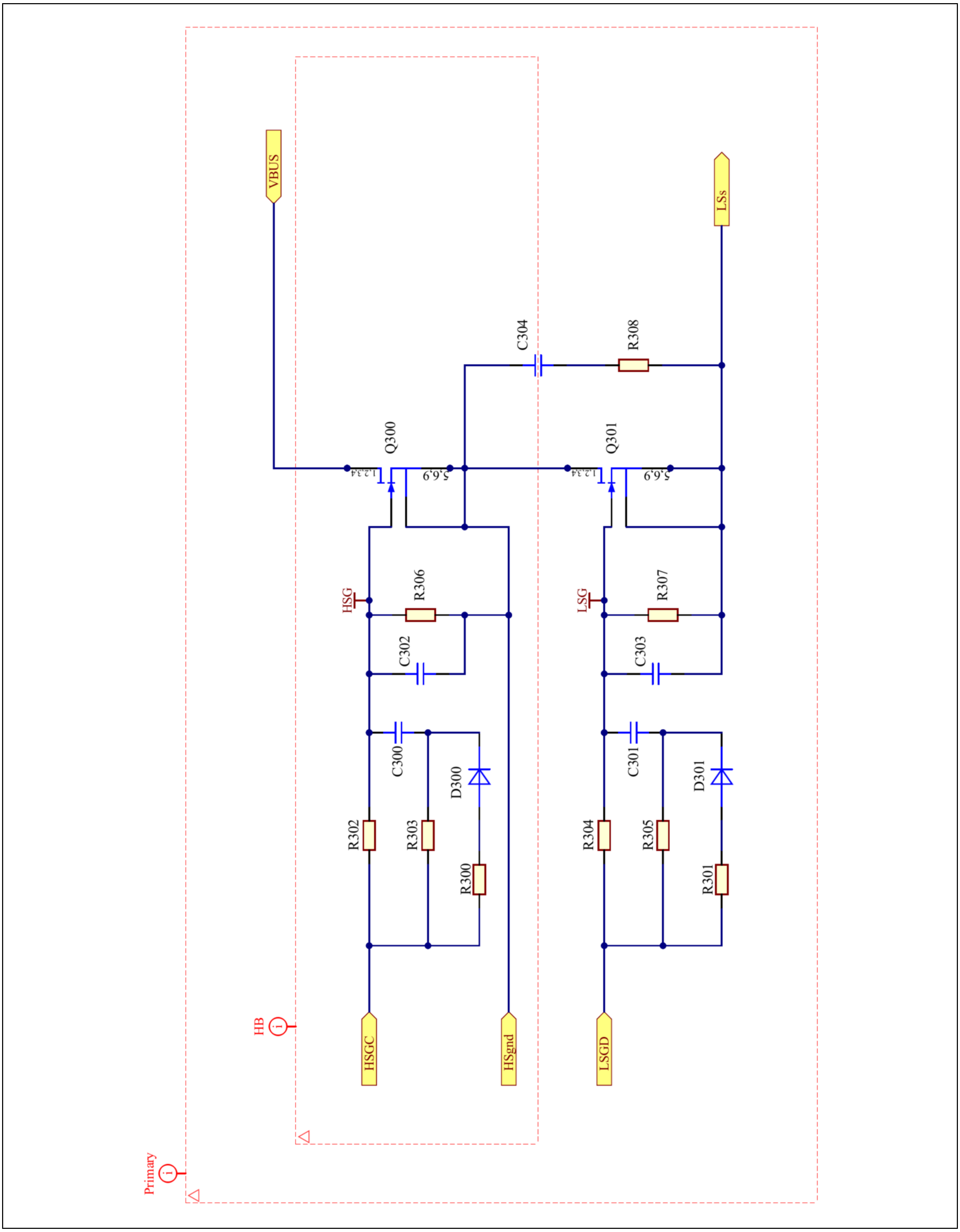


Figure 60 **Half-bridge switches**

5.2 Bill-of-materials (BOM)

Table 17 Bill-of-materials

S. No.	Qty	Designator	Value	Description	Manufacturer	MFG order number
1	1	C4	1 µF 50 V X5R 0603	CAP CER 1UF 50V X5R 0603	Murata Manufacturing Co., Ltd.	
2	3	C8, C9, C13	0.1 µF 16 V X7R 0603	CAP CER 0.1UF 16V X7R 0603		
3	2	C10, C12	0.1 µF 16 V X7R 0603	CAP CER 0.1UF 16V X7R 0603	KEMET Corporation, Murata Manufacturing Co., Ltd.	
4	1	C11	10 µF 10 V X5R 0805	CAP CER 10uF 10V X5R 0805	Murata Manufacturing Co., Ltd., Samsung Electro-Mechanics	
5	1	C35	10 µF 35 V X5R 0805	10uF 35V X5R 0805	TDK Corporation	C2012X5R1V106K125AC
6	2	C17, C18	390 pF 50 V C0G 0402	CAP CER 390PF 50V C0G 0402	Walsin Technology Corporation	
7	1	C20	10 pF 16 V C0G 0603	CAP CER 10PF 16V C0G/NP0 0603	Würth Elektronik	
8	1	C22	100 pF 25 V C0G 0402	CAP CER 100PF 25V C0G/NP0 0402	Murata Manufacturing Co., Ltd.	
9	1	C25	0.1 µF 50 V X7R 0805	CAP smd 0.1UF 50V X7R 0402		
10	1	C27	10 nF 16 V X7R	CAP CER16V X7R 0603	Murata Manufacturing Co., Ltd.	
11	1	C28	10 nF 25 V X5R 0603	CAP CER 25V X5R 0603	Murata Manufacturing Co., Ltd.	
12	1	C100	47 pF 50 V C0G 0603	CAP / CERA / 47pF / 50V / 10% / C0G (EIA) / NP0 / -55°C to 125°C / 0603(1608)	KEMET Corporation	C0603C470K5GACAUTO
13	1	C101	3.3 nF 25 V X7R 0603	CAP / CERA / 3.3nF / 25V / 5% / X7R (EIA) / 0603(1608)	Murata Manufacturing Co., Ltd.	GRM188R71E332JA01
14	3	C102, C300, C301	3.3 nF 25 V X7R 0603	CAP / CERA / 3.3nF / 25V / 5% / X7R (EIA) / -55Â°C to 125Â°C / 0603(1608) / SMD / -	Murata Manufacturing Co., Ltd.	GRM188R71E332JA01
15	2	C105, C107	100 nF 450 V X7R 1206	CAP / CERA / 100nF / 450V / 10% / X7R (EIA) / -55Â°C to 125Â°C / 3.20mm L X 1.60mm W X 1.80mm H / SMD / -	TDK Corporation	C3216X7R2W104K160AA
16	1	C106	82 µF 450 V 16x25/18x25	CAP / ELCO / 82uF / 450V / 20% / Aluminiumelectrolytic / -40Â°C to 105Â°C / 5.00mm C X 0.60mm W 12.50mm Dia X 27.00mm H / THT / -	UCC	EKXL451ELL820MM25S
17	1	C200	220 pF 50 V X7R 0603	CAP / CERA / 220pF / 50V / 5% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	Murata Manufacturing Co., Ltd.	GRM188R71H331JA01
18	2	C201, C207	100 nF 25 V X8L 0603	CAP / CERA / 100nF / 50V / 10% / X8L (EIA) / -55Â°C to 150Â°C / 0603(1608) / SMD / -	Murata Manufacturing Co., Ltd.	GCM188L81H104KA57
19	1	C202	1 µF 25 V X7R 0603	CAP / CERA / 1uF / 25V / 10% / X7R (EIA) / -55°C to 125°C / 0603(1608) / SMD / -	Murata Manufacturing Co., Ltd.	GRM188R71E105KA12
20	1	C203	10 pF 50 V X8G 0603	CAP / CERA / 10pF / 50V / 2.5% / X8G (Murata) / -55°C to 150°C / 0603(1608) / SMD / -	Murata Manufacturing Co., Ltd.	GCM1885G1H100RA16
21	1	C204	100 pF 50 V C0G 0603	CAP / CERA / 100pF / 50V / 5% / C0G (EIA) / NP0 / -55°C to 125°C / 0603(1608) / SMD / -	Murata Manufacturing Co., Ltd.	GCM1885C1H101JA16

S. No.	Qty	Designator	Value	Description	Manufacturer	MFG order number
22	1	C206	22 µF 25 V 5x12.5	CAP / ELCO / 22uF / 25V / 20% / Aluminiumelectrolytic / -40°C to 85°C / 2.00mm C X 0.50mm W 5.25mm Dia X 12.50mm H / THT / -	Nichicon Corporation	UVR1E220MDD
23	1	C208	150 pF 25 V C0G 0603	CAP / CERA / 150pF / 50V / 5% / C0G (EIA) / NP0 / -55°C to 125°C / 0603(1608) / SMD / -	Murata Manufacturing Co., Ltd.	GCM1885C1H151JA16
24	1	C209	22 pF 25 V C0G 0603	CAP / CERA / 22pF / 50V / 5% / C0G (EIA) / NP0 / -55°C to 125°C / 0603(1608) / SMD / -	Murata Manufacturing Co., Ltd.	GRM1885C1H220JA01
25	6	C210, C211, C212, C213, C222, C223	100 nF 250 V X7R 1206	CAP / CERA / 100nF / 250V / 10% / X7R (EIA) / -55°C to 125°C / 1206(3216) / SMD / -	Murata ManufacturingCo., Ltd.	GRM31BR72E683KW01
26	1	C215	22 µF 35 V X5R 1206	CAP / CERA / 22uF / 35V / 20% / X5R (EIA) / -55°C to 85°C / 1206(3216) / SMD / -	TDK Corporation	C3216X5R1V226M160AC
27	3	C216, C219, C221	330 µF/35 V/ W 8.0 mm, L 16.0 mm	CAP / ELCO / 330uF / 35V / 20% / - / -55°C to 105°C / 5.00mm C X 0.60mm W 8.00mm Dia X 18.00mm H / THT / -, CAP / ELCO / 330uF / 35V / 20% / Aluminiumelectrolytic / -55°C to 125°C / 8.00mm C X 0.60mm W 8.00mm Dia X 18.00mm H / - / -	KEMET Corporation	A750KW337M1VAAE020
28	1	CB100	Film capacitors 450 V_{dc} 0.47 µF 5% MPP L/S = 10 mm	Film Capacitors 450VDC 0.47uF 5% MPP L/S=10mm	Panasonic Corporation	667-ECW-FD2W474P1
29	1	CON1	Type-C connector	USB Connectors USB Type C,2.0, Rec, SMT, 0.95mmTH Shell Stakes,G/F,RA,Top Mnt,T&R	GCT	USB4105-GF-A
30	1	CX100	220 nF 310 V_{ac} X cap	Safety Capacitors 220nF 310Vac 13.0mm X 7.0mm X17mm	KEMET Corporation	F861AO224M310C
31	1	CX101	X2 cap 220 nF/275 V_{ac}	CAP / FILM / 275V / 10% / MKP (Metallized Polypropylene) 18.0mm L X 5.0mm T X 17.5mm H	KEMET Corporation	80-R463I32204002M
32	1	CY200	470 pF Y-cap SMD	CAP / CERA / 470pF / / 20% / E (JIS) / -40Â°C to 125Â°C / 5.10 mm Pitch, 2 pin, 8.00 mm L X 6.00 mm W X 2.50 mm H body / SMD / -	Murata Manufacturing Co., Ltd.	DK1B3EA471K86RBH01
33	1	D100	GBU8K SIP-4	BRIDGE RECT 1PHASE 800V 8A GBU	ON Semiconductor	GBU8K
34	2	D101, D102	US1MFA 700V SOD23-FL	Super Fast Surface Mount Rectifier VRMS 700V	ON Semiconductor	US1MFA
35	4	D103, D104, D105, D200	1N4148WS-7-F SOD323	Surface Mount Fast Switching Diode, 75V	Diodes Incorporated	1N4148WS-7-F
36	1	D106	RS3JB-13-F SMB	3.0A Surface Mount Fast Recovery Rectifier	Diodes Incorporated	RS3JB-13-F
37	1	D108	MUR560J 600V SMD	Ultrafast power diode	WeEn Semiconductors	MUR560J
38	1	D201	ES1JL SMA	1A, 400V Surface Mount Super Fast Rectifier, Low Power Loss, High Efficiency	Taiwan Semiconductor	ES1JL
39	1	F100	Box fuse 3.15 A/250 V	RES FUSE BRD MNT 3.15A 300VAC RADIAL/ 5.08mm C X 0.60mm W 8.35mm L X 4.00mm T X 8.10mm H / THT / -	Eaton Corporation	SS-5H-3.15A-APH
40	1	J1	Jumper wire (JL-1000-25-T) with plastic shealth	Through Hole Jumper, 25.4mm Pitch, 2 Pins, with plastic shealth	Samtec	JL-1000-25-T
41	1	M200	VCC CB Board		Intern	
42	1	R6	5 mΩ 1206	Current Sense Resistors - SMD +/-1% 1206 Metal Foil	Walsin Technology Corporation	WW12RR005FTL
43	2	R8, R9	0R 0402	RES 0 JUMPER 1/16W 0402,	Yageo Corporation, Vishay Dale	
44	3	R14, R104, R206	0R 0603	RES 1/16W 0603, RES / STD / 0R / -55°C to 155°C /	Yageo Corporation, Vishay Dale	CRCW06030000Z0EA
45	1	R16	12k 1% 1206	RES SMD 1% 1/4W 1206	Yageo Corporation	

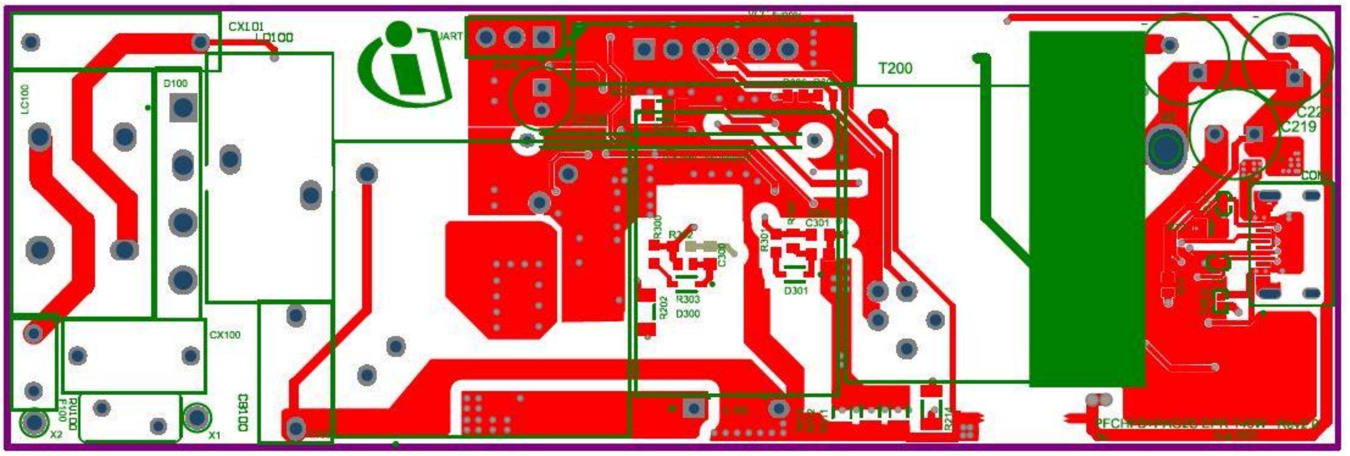
S. No.	Qty	Designator	Value	Description	Manufacturer	MFG order number
46	1	R30	40.2k 1% 0402	RES SMD 1% 1/16W 0402	Vishay Dale	
47	1	R31	4.7k 1% 0402	RES SMD 1% 1/10W 0402	Panasonic Corporation	
48	2	R46, R47	100k 1% 0402	RES SMD 1% 1/16W 0402	Vishay Dale	
49	1	R100	24k 1% 1206	RES / STD / 250mW / 1% / 100ppm/K / -55°C to 155°C / 1206 / SMD / -	Vishay Dale	CRCW120624K0FK
50	1	R101	27k 1% 1206	RES / STD / 250mW / 1% / 100ppm/K / -55°C to 155°C / 1206 / SMD / -	Vishay Dale	CRCW120627K0FK
51	1	R103	9.1k 1% 0805	RES / STD / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805 / SMD / -	Vishay Dale	CRCW08059K10FK
52	1	R105	47k 1% 0603	RES / STD / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay Dale	CRCW060347K0FK
53	1	R106	39R 0603	RES / VAR / 125mW / 1% / 25ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay Dale	CRCW060339R0FK
54	3	R107, R302, R304	1.5k 1% 0603	RES / 100mW / 1% / 100ppm/K / - / 0603(1608) / SMD / -	ROHM Semiconductors	MCR03EZPFX1501
55	1	R108	39R 1% 0603	RES / STD / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -, Standard Thick Film Chip Resistor	Vishay Dale	CRCW060339R0FK
56	2	R109, R205	18k 1% 0603	RES / STD / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay Dale	CRCW060318K0FK
57	1	R110	33k 1% 0603	RES / STD / 33k / 100mW / 1% / 100ppm/K / -55Â°C to 155Â°C / 603 / SMD / -	Yageo Corporation	RC0603FR-0733KL
58	3	R111, R112, R114	300mR 1% 1206	RES / STD / 300mR / 250mW / 1% / 600ppm/K / -55°C to 155°C / 1206(3216) / SMD / -	Walsin Technology Corporation	WW12PR300FTL
59	1	R200	750k 1% 0603	RES / STD / 750k / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay Dale	CRCW06031M50FK
60	1	R201	150k 1% 0603	RES / STD / 150k / 100mW / 1% / 100ppm/K / -55Â°C to 155Â°C / 0603 / SMD / -	Vishay Dale	CRCW060343K0FK
61	2	R202, R203	10M 1% 1206	RES / STD / 10MEG / 250mW / 1% / 100ppm/K / -55Â°C to 155Â°C / 1206 / SMD / -	Vishay Dale	CRCW12063M30FK
62	1	R204	6.8k 1% 0603	RES / STD / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay Dale	CRCW06037K50FK
63	1	R209	3.3R 1% 1206	RES / STD / 250mW / 1% / 100ppm/K / -55°C to 155°C / 1206(3216) / SMD / -	Vishay Dale	CRCW12063R30FK
64	1	R210	1k 1% 0603	RES / STD / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603 / SMD / -	Vishay Dale	CRCW06031K00FK
65	2	R211, R212	330mR 1% 1206	RES / STD / 500mW / 1% / 100ppm/K / -55Â°C to 155Â°C / 1206 / SMD / -	Bourns, Inc.	CRM1206-FX-R330 E LF
66	1	R214	4.7M 5% 1206	RES / STD / 330mW / 5% / 200ppm/K / -55Â°C to 155Â°C / 3.20mm L X 1.60mm W X 0.70mm H / SMD / -	KOA Speer Electronics Inc.	SG73P2BTTD475J
67	1	R215	100R 1% 0805	RES / STD / 125mW / 1% / 100ppm/K / -55°C to 155°C / 0805(2012) / SMD / -	Vishay Dale	CRCW0805100RFK
68	1	R216	1.1k 1% 0603	RES / STD / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay Dale	CRCW06031K10FK
69	1	R217	2.2k 1% 0603	RES / STD / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay Dale	CRCW06032K20FK
70	2	R303, R305	39R 1% 0603	RES / VAR / 125mW / 1% / 25ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay Dale	CRCW060339R0FK
71	2	R306, R307	22k 1% 0603	RES / STD / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Yageo Corporation	RC0603FR-0722KL

S. No.	Qty	Designator	Value	Description	Manufacturer	MFG order number
72	2	R400, R401	5.1R 1% 0603	RES / STD / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay Dale	CRCW060310K0FKEA
73	1	R406	10k 1% 0603	RES / STD / 100mW / 1% / 100ppm/K / -55°C to 155°C / 0603(1608) / SMD / -	Vishay Dale	CRCW060310K0FKEA
74	2	RT1, RT2	NTC 100K 0603	THERM NTC 4250K 0603	Murata Manufacturing Co., Ltd.	NCP21WF104J03RA
75	1	RV100	TVS 275VAC through hole		EPOCS Manufacturing Inc.	B72207S0271K101
76	2	RX100, RX101	1M 5% 1206	RES / STD / 250mW / 5% / 100ppm/K / -55Â°C to 155Â°C / 1206 / SMD / -	Yageo Corporation	RC1206JR-071ML
77	1	TVS12	ESD133C TVS ESD diode	break down 35V, maximum clamp 60V	SMC Diode Solutions	1655-ESD133CCT-ND
78	1	U201	TCLT1003 opto SMD	Optocoupler, Phototransistor Output	Vishay Dale	TCLT1003
79	1	Z100	2.7 V Zener SOD323	Voltage regulator diodes	Nexperia	BZX384-C2V7,115
80	4	C500, C501, C504, C505	470 nF/100 V/1206	CAP / CERA / 470nF / 100V / 10% / X7R (EIA) / -55°C to 125°C / 1206(3216) / SMD / -	CAPC3216X178N	AVX Corporation
81	1	C510	1 µF/100 V	CAP/Electrolytic CAP (solid cap)	Radial can	Würth Elektronik
82	4	C502, C506, C507, C508	4.7 µF/100 V/1206	CAP / CERA / 4.7uF / 100V / 10% / X7S (EIA) / -55°C to 125°C / 1206 (3216) / SMD / -	CAPC3216X190N-2	Murata Manufacturing Co., Ltd.
83	1	C503	3.3 µF/50 V/0805	10% / X5R (EIA) / -55°C to 85°C / 0805(2012) / SMD / -	CAPC2013X95N	TDK Corporation
84	2	D500, D501	SBR2M60S1FQ-7	SUPER BARRIER RECTIFIER/ /SOD-123F-2	SODFL3518X115N	Diodes Incorporated
85	2	D502, D503	PMEG4010BEA,115	Very low VF MEGA Schottky barrier rectifier	SOD2513X110N-1	Nexperia
86	1	Q500	BSS169	SIPMOS Small-Signal-Transistor	INF-PG-SOT23_N-0	Infineon Technologies
87	2	R500, R505	3.3R/1206	/ 250mW / 1% / 100ppm/K / -55°C to 155°C / 1206(3216) / SMD / -	RESC3216X60N	Vishay Dale
88	2	R501, R506	0R/1206	RES / STD / 0R / 250mW / 1% / 100ppm/K / -55°C to 155°C / 1206(3216) / SMD / -	RESC3216X60N	Vishay Dale
89	1	R504	47k/0603	RES / STD / 47k / 100mW / 1% / 100ppm/K / -55Â°C to 155Â°C / 0603 / SMD / -	RESC1609X50N	Vishay Dale
90	1	X500	10129379-906003BLF	Connector, THT, 6pins, 2.54mm pitch, Board-to-Board	CON-M-THT-10129379-906003BLF	Amphenol Corporation
91	1	Z500	Zener 11 V /SOD-123	Zener Voltage Regulators 500 mW SOD-123 Surface Mount	DIOMELF3515N-7	ON Semiconductor
92	1	T100	180 µH; 46:8 PFC choke	PFC choke, L:190uH, Np:Na = 46:9, RM10	Sumida Corporation	PS22-110
93	1	T200	PS22109 RM10	HFB transformer, Np:Ns:Na1:Na2 = 21:3:1:2, RM10, Lp: 230µH, Llk: 2.8µH, RM10	Sumida Corporation	PS22-109
94	4	TVS11, TVS13, TVS14, TVS15	ESD245-B1-W0201	ESD245-B1-W0201	Infineon Technologies	ESD245-B1-W0201
95	1	U1	CCGPAS213	EZ-PD™ PAG2S SR and USB-PD combo IC	Infineon Technologies	CCGPAS213-32LQXQ
96	1	U200	XDPS2221	XDP™ PFC and HFB combo IC	Infineon Technologies	XDPS2221-PG-DSO-14
97	1	LC100	12 mH CMC/2.5 A	IND / 50% / -40°C to 125°C / 100mR / THT / Inductor, THT, 4 pin, 22.00 mm L X 12.50 mm W X 20.00 mm H body / THT / -	ItaCoil	SCF1515050
98	1	LD100	300 µH D-choke	IND / STD / 300uH / 2.5A / 20% / -40°C to 105°C / 70mR / THT / Inductor, THT, 9 mm pitch, 2 pin, 22.00 mm L X 5.6 mm W / THT	Würth Elektronik	7447060
99	1	Q2	BSZ018N04LS	N-Channel 40 V 19A (Ta), 40A (Tc) - Surface Mount PG-TDSON-8 FL	Infineon Technologies	BSZ018N04LS
100	3	Q100, Q300, Q301	IGLD60R190D1 CoolGaN™	600V CoolGaN™ enhancement-mode Power Transistor / R_{DS_ON}:190mΩ / PG-LSON-8-1	Infineon Technologies	IGLD60R190D1

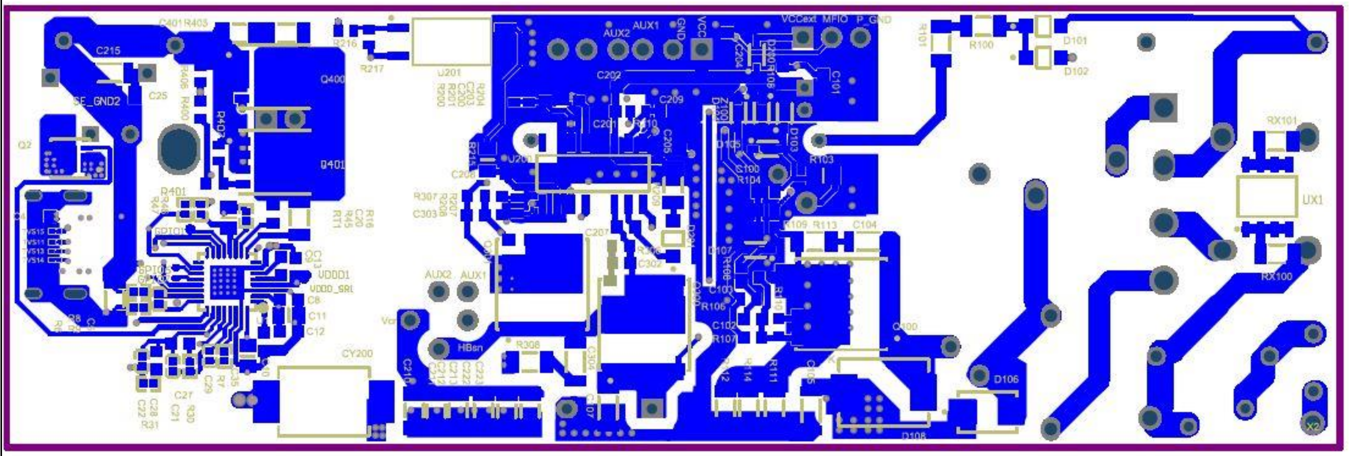
S. No.	Qty	Designator	Value	Description	Manufacturer	MFG order number
101	1	Q400	BSC070N10NS5 OptiMOS™	OptiMOS 5 Power-Transistor, 100V	Infineon Technologies	BSC070N10NS5
102	1	Q401	BSC070N10NS5 OptiMOS™	OptiMOS 5 Power-Transistor, 100V	Infineon Technologies	BSC070N10NS5

Total components (BOM count) = 152

5.3 PCB layout



Top view



Bottom view

Figure 61 Main board

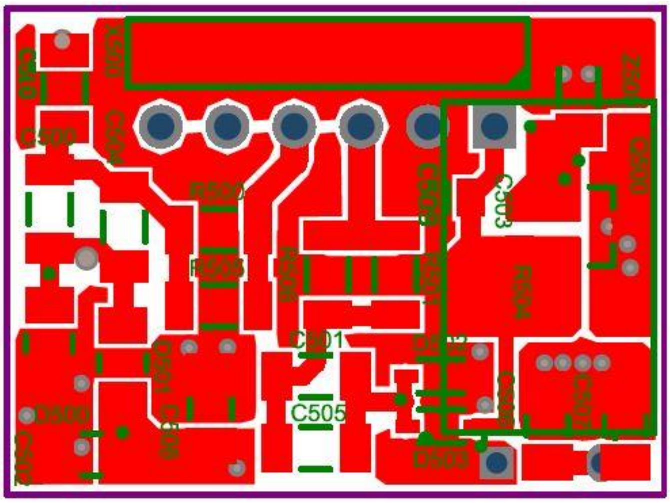
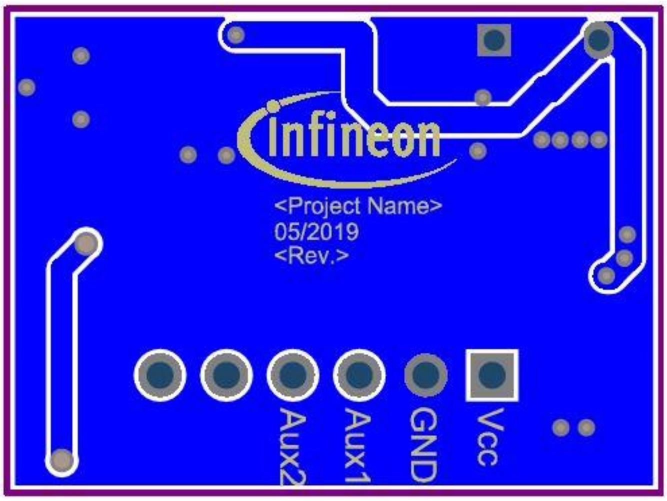
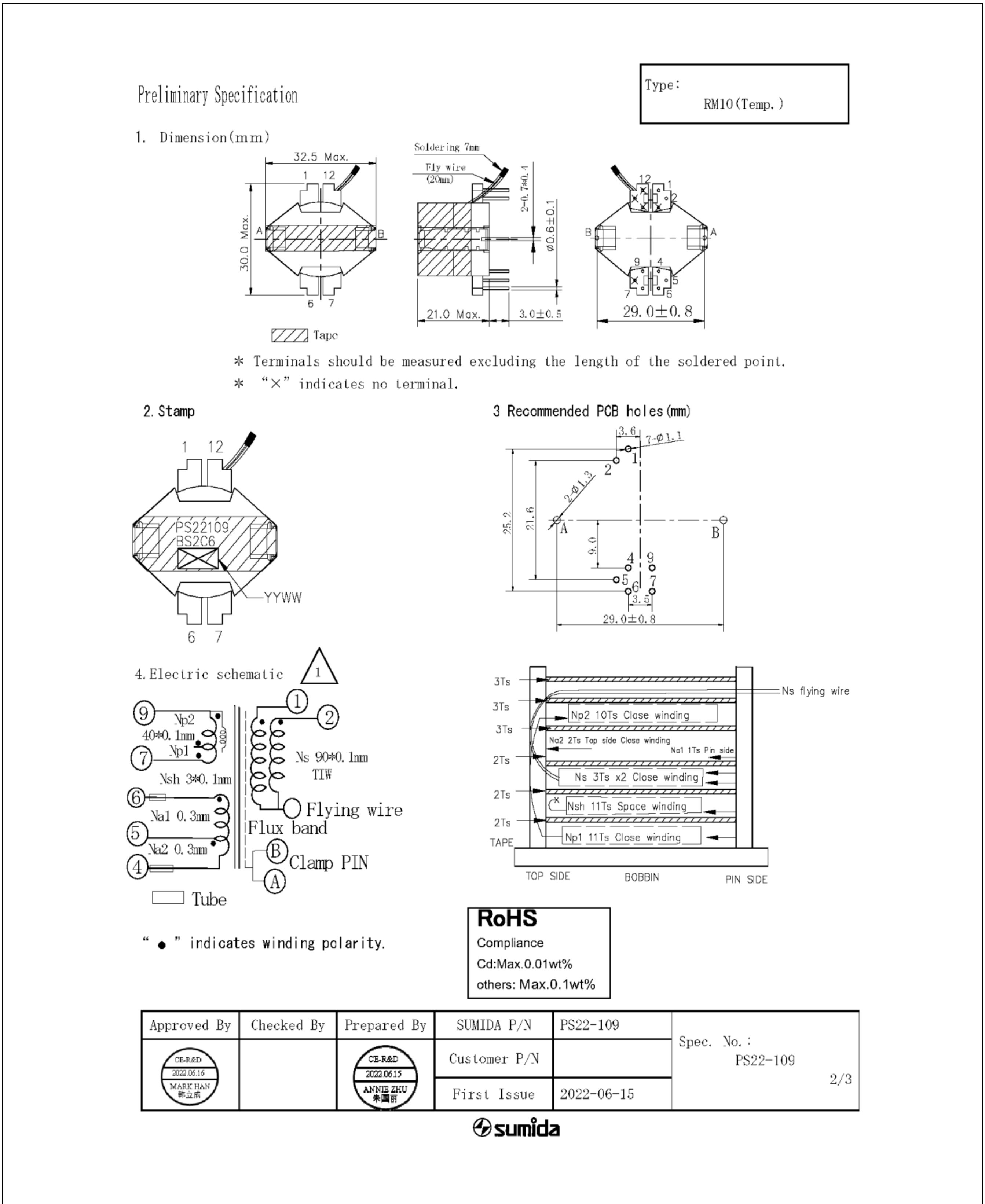
Top view	Bottom view
	

Figure 62 Daughter board

5.4 HFB main transformer specifications (T200 PS22-109 230 µH)



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 0A
Inductance drop	(9-7)	≦35% L0	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	E&B-XXXB (ϕ0.1*90 Triple insulated Litz wire)	E&B TECHNOLOGY CO LTD	E315265
		Litzwire	(ϕ0.10*40) MW75C or MW 79-C	EASEBOND ELECTRICAL MATERIAL (DONGGUAN) CO., LTD BAIYIN YIZHI CHANGTONG SUPER MICRO. WIRE CO., LTD	E173779 E363385
		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) ELECTIRC CO., LTD	E174837 E234896 E194410
④	Clip		Material SK7	PIN 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 63 RM10 transformer PS22-109 datasheet

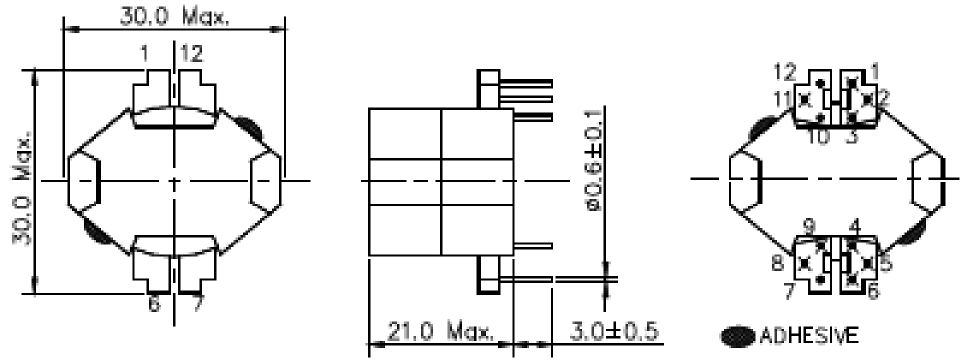
5.5 PFC choke transformer specifications (T100 PS22-110 190 µH)

Preliminary Specification

Type:
RM10(Temp.)

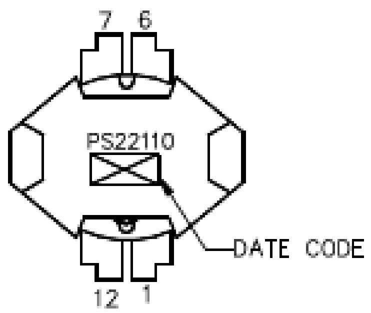
1. Appearance

1-1.Dimension(mm)

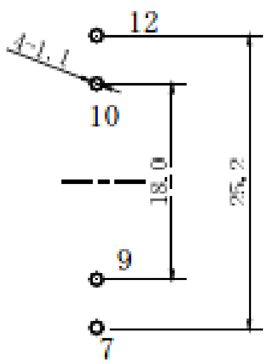


* Terminals should be measured excluding the length of the soldered point.
* "×" indicates no terminal.

1-2.Stamp



1-3 Recommended land patterns dimension



RoHS
Compliance
Cd:Max.0.01wt%
others: Max.0.1wt%

Approved By	Checked By	Prepared By	SUMIDA P/N	PS22-079	Spec. No.: PS22-110 2/3
(stamp)		(stamp)	Customer P/N		
			First Issue	2022-05-06	

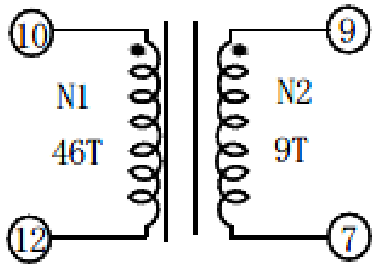
sumida

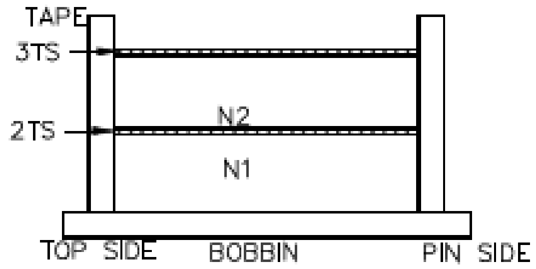
Preliminary Specification

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℃.

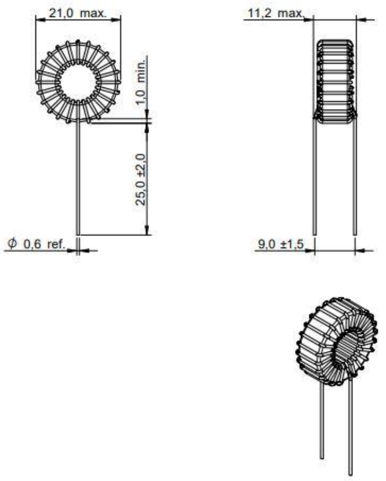
Note:	Spec. No.: PS22-110 3/3

Figure 64 **RM10 PFC choke transformer PS22-110 datasheet**

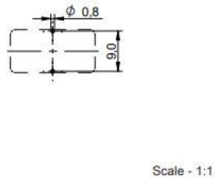
5.6 Differential mode inductor specifications (LD100)

Product description: Würth Electronik inductor 300 uH, 2.5 A, 150 mΩ; MPN: 7447060

Dimensions: [mm]



Recommended Hole Pattern: [mm]



Schematic:

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	10 kHz/ 5 mA	300	µH	±20%
Rated Current	I_R	ΔT = 40 K	2.5	A	max.
DC Resistance	R_{DC}	@ 20 °C	0.15	Ω	max.

Certification:

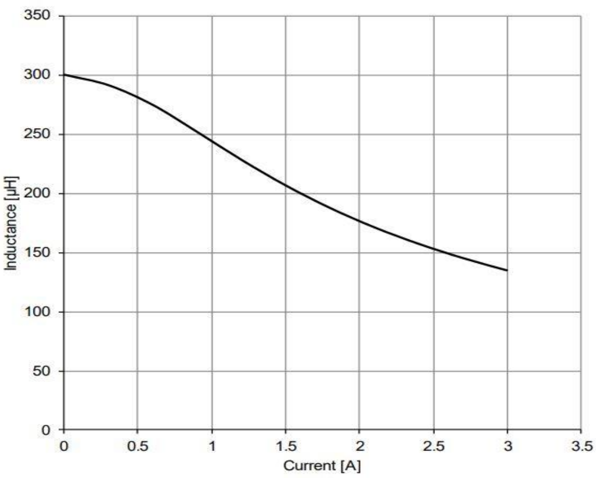
RoHS Approval	Compliant [2011/65/EU&2015/863]
REACh Approval	Conform or declared [(EC)1907/2006]
Halogen Free	Conform [JEDEC JS709B]
Halogen Free	Conform [IEC 61249-2-21]

General Properties:

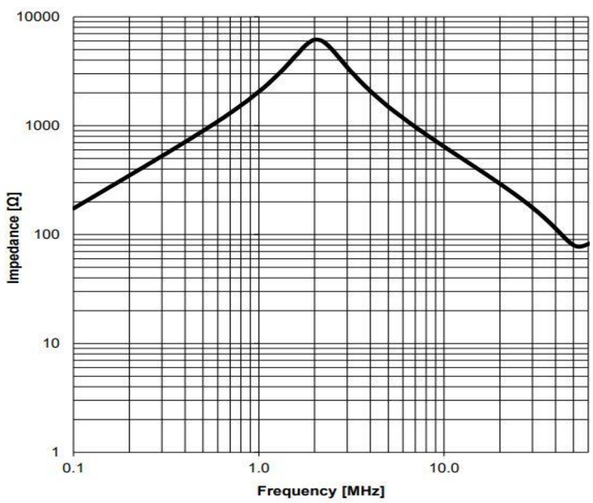
Ambient Temperature (referring to I_R)	-40 up to +65 °C
Operating Temperature	-40 up to +105 °C
Storage Conditions (in original packaging)	< 40 °C ; < 75 % RH
Moisture Sensitivity Level (MSL)	1

Test conditions of Electrical Properties: +20 °C, 33 % RH if not specified differently

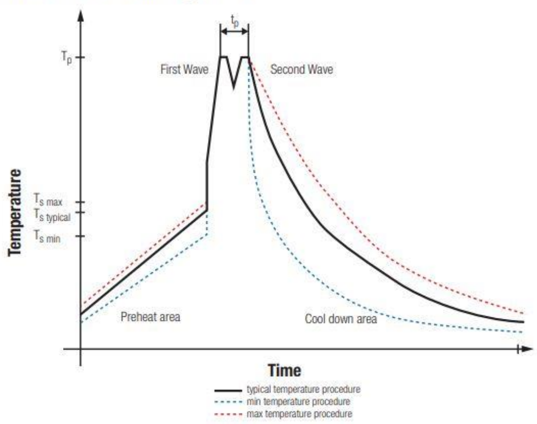
Typical Inductance vs. Current Characteristics:



Typical Impedance Characteristics:



Classification Wave Soldering Profile:



Classification Wave Soldering Profile:

Profile Feature		Pb-Free Assembly	Sn-Pb Assembly
Preheat Temperature Min	$T_{s\ min}$	100 °C	100 °C
Preheat Temperature Typical	$T_{s\ typical}$	120 °C	120 °C
Preheat Temperature Max	$T_{s\ max}$	130 °C	130 °C
Preheat Time t_s from $T_{s\ min}$ to $T_{s\ max}$	t_s	70 seconds	70 seconds
Ramp-up Rate	ΔT	150 °C max.	150 °C max.
Peak Temperature	T_p	250 °C - 260 °C	235 °C - 260 °C
Time of actual peak temperature	t_p	max. 10 seconds max. 5 seconds each wave	max. 10 seconds max. 5 seconds each wave
Ramp-down Rate, Min		~ 2 K/ second	~ 2 K/ second
Ramp-down Rate, Typical		~ 3.5 K/ second	~ 3.5 K/ second
Ramp-down Rate, Max		~ 5 K/ second	~ 5 K/ second
Time 25 °C to 25 °C		4 minutes	4 minutes

refer to EN61760-1:2006

Figure 65 Differential mode inductor datasheet

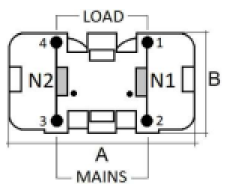
5.7 Common mode choke specifications (LC100)

Product description: ItaCoil Web CMC 12 mH, 2.36 A, 100 mΩ; MPN: SCF1515050

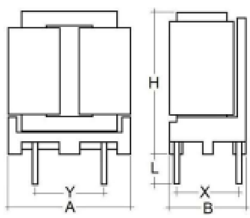
Code	Drawing	Minimum Inductance[1]	Stray Inductance typ[2]	Nominal Current[3]	Typical DCR[4]	Mains Rated Voltage	N1/N2 Dielectric strength
SCF1515037	A	2x7 mH	51 µH	3.02 A	58 mΩ	250V	1.5KV
SCF1515040	A	2x8 mH	63µH	2.25 A	93 mΩ	250V	1.5KV
SCF1515050	A	2x12 mH	89 µH	2.36 A	100 mΩ	250V	1.5KV
SCF1515069	A	2x21 mH	177 µH	1.26 A	298 mΩ	250V	1.5KV
SCF1520H100	B	2x36 mH	416 µH	1.12 A	428 mΩ	250V	1.5KV

Dimensions	mm
A max	22.0
B max	12.8
H max	20.4
X typ	7.5
Y typ	10.0
L min	2.5
D typ (Ø)	0.7

Layout (bottom view)

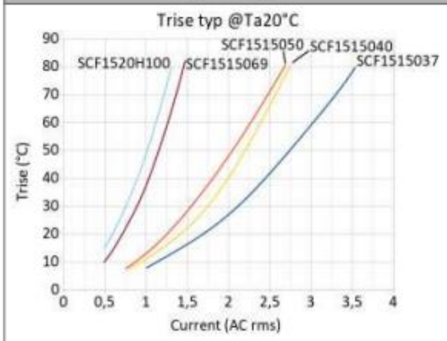


Drawing A

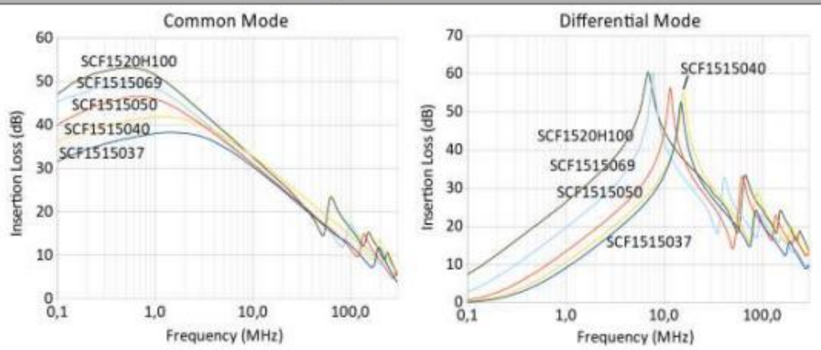


.stp file Download

Typical T_{rise}



Typical Insertion Loss



[1] *@ 10kHz - 1V*
[2] *@ 100kHz - 1V*
[3] *Max continuous current for 60° about temperature rise (@Ta 20°C). The temperature of the inductor should not exceed 100°C, T rise included.*
[4] *Referred to each winding @ Ta 20°C*

Figure 66 Common mode choke datasheet

5.8 EZ-PD™ Configuration utility

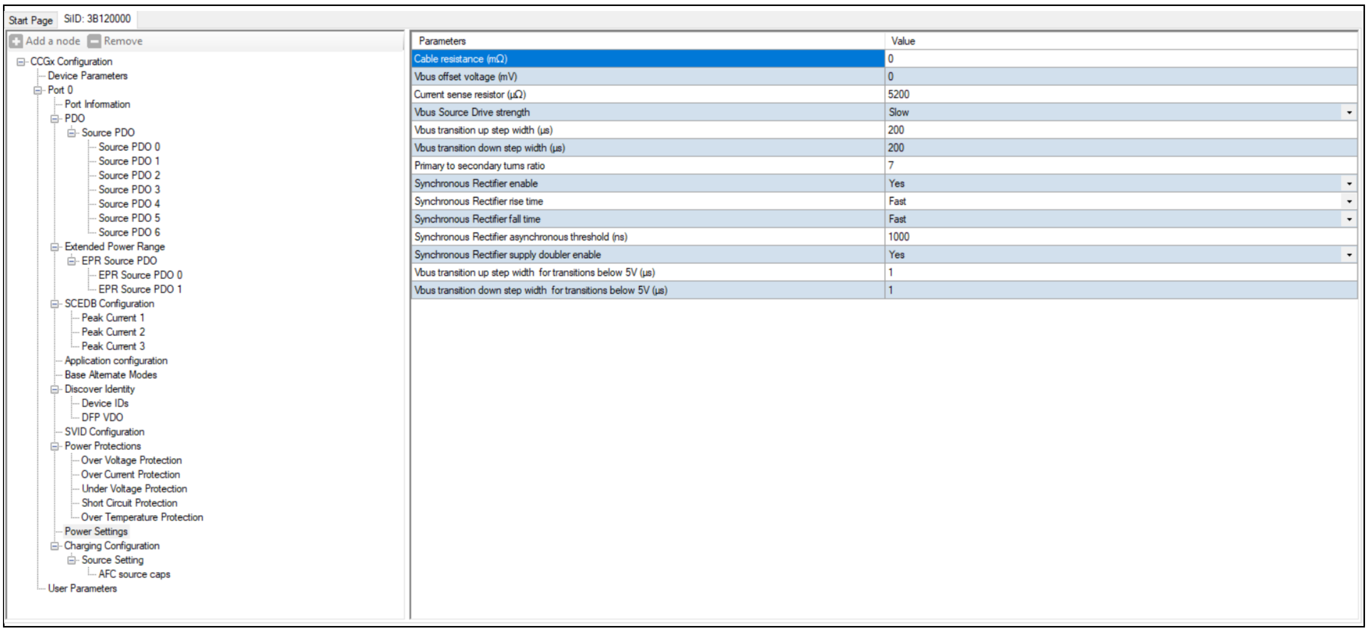


Figure 67 EZ-PD™ Configuration utility

The Infineon's EZ-PD™ PAG2S controller is a highly configurable and programmable solution. The chip can be configured using parameters stored in the internal flash memory. These parameters are to be chosen and programmed by Infineon's customers according to their use cases and requirements. The graphical user interface (GUI) of EZ-PD™ Configuration Utility allows users to intuitively select and configure the parameters for their application.

Table 18 lists the default configured values with respect to power settings and power protections.

Table 18 Default configuration values

Parameters	Values
Power settings	
Cable resistance (mΩ)	0
V_{bus} offset voltage (mV)	0
Current sense resistor (µΩ)	5200
V_{bus} source drive strength	Slow
V_{bus} transition up step width (µs)	200
V_{bus} transition down step width (µs)	200
Primary to secondary turns ratio	7
Synchronous rectifier enable	Yes
Synchronous rectifier rise time	Fast
Synchronous rectifier fall time	Fast
Synchronous rectifier async threshold (ns)	1000
Synchronous rectifier doubler enable	Yes
Power protections	

Parameters	Values
Overvoltage protection	
Enable	Yes
Mode	OVP using dedicated comparator
OVP threshold (%)	20
Debounce period (µs)	10
Retry count	2
Overcurrent protection	
OCP enable	Yes
OCP threshold (%)	20
Debounce period (ms)	10
Retry count	2
Undervoltage protection	
Enable	Yes
Mode	UVP using dedicated comparator
UVP threshold (%)	70
Debounce period (µs)	10
Retry count	2
Short-circuit protection	
Enable	Yes
Sense resistance (milli ohm)	0
SCP threshold (%)	40
Debounce period (µs)	10
Retry count	2
Over-temperature protection	
Enable	Yes
Thermistor type 1	NTC
Cutoff value 1	255
Restart value 1	909
Debounce period (ms)	10
Enable thermistor 2	Yes
Thermistor type 2	NTC
Cutoff value 2	255
Restart value 2	909

References

[1] USB Implementers Forum, Inc.: *Document library*

[2] USB Implementers Forum, Inc.: *USB Type-C and connector specification (release 2.2)*

[3] Infineon Technologies AG: *USB EZ-PD™ Configuration Utility*

[4] Infineon Technologies AG*: XDPS2221 PFC + hybrid flyback combo controller datasheet (revision 1.1), 2022-11-09*

[5] Infineon Technologies AG: *EZ-PD™ PAG2S integrated USB-PD and synchronous rectification controller, CYPAS213 datasheet (document number: 002-37178 Rev.*A), 2023-02-08*

Acronyms

Table 19 Abbreviations

Abbreviations	Description
CC-CV	constant current-constant voltage
CE	conducted emission
CH'x'	oscilloscope channel numbers
CR Mode	constant resistance mode in electronic load
DCM	discontinuous current mode
DP/DM	USB data positive/data negative lines
DUT/EUT	device under test/equipment under test
FET	MOSFET (metal oxide semiconductor field effect transistor)
GUI	graphical user interface
I_o/I_{OUT}	output current of the DUT
NGDO	NFET gate driver output
OCP	overcurrent protection
OVP	overvoltage protection
P-P	peak-to-peak
PAT	power adapter tester
PDO	power delivery output
PPS	programmable power supply
SCP	short-circuit protection
USB PD	Universal Serial Bus Power Delivery
V_{bus_C}/ V_{out}	output voltage of the DUT
V_{AC}/V_{in_AC}	input DC voltage to the DUT

Revision history

Document revision	Date	Description of changes
**	2023-12-13	Initial release
*A	2024-03-27	Updated metadata

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