

24 W, 12 V and 5 V SMPS reference board with CoolSET™ ICE5QR2280BG-1

REF_5QR2280BG-1_24W1

About this document

Scope and purpose

This document describes a universal input 24 W, 12 V and 5 V offline flyback converter using the CoolSET™ 5th Generation QR Plus ICE5QR2280BG-1 IC from Infineon, which offers high efficiency, low standby power with selectable entry and exit standby power options, a wider V_{CC} operating range with fast startup, robust line protection with input OVP, and brownout and various modes of protection for a highly reliable system.

This reference board is designed to evaluate the performance of the ICE5QR2280BG-1 CoolSET™ 5th Generation QR Plus ICE5QR2280BG-1 IC and its ease of use.

Intended audience

This document is intended for power supply design/application engineers, students, etc., who wish to design low-cost and highly reliable systems of offline SMPS as either auxiliary power supplies for white goods, PCs, servers and TVs, or enclosed adapters for gaming consoles.

CoolSET™

Infineon's CoolSET™ AC-DC integrated power stages in quasi-resonant switching scheme offers increased robustness and outstanding performance. This family offers superior energy efficiency, comprehensive protective features, and reduced system costs and is ideally suited for auxiliary power supply applications in a wide variety of potential applications such as:

- [SMPS](#)
- [Home appliances](#)
- [Server](#)
- [Telecom](#)

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24 W, 12 V and 5 V SMPS reference board with CoolSET™

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Introduction

1 Introduction

This document describes a 24 W, 12 V and 5 V reference board designed in a quasi-resonant flyback converter topology using the CoolSET™ 5th Generation QR Plus ICE5QR2280BG-1 IC.

With the CoolMOS™ integrated in this IC, it simplifies the design and layout of the PCB. The improved digital frequency reduction with proprietary QR operation offers lower EMI and higher efficiency for a wide AC range by reducing the switching frequency difference between low- and high-line. The active burst mode (ABM) power enables flexibility in standby power operation range selection, and QR operation during ABM. As a result, the system efficiency over the entire load range is significantly improved compared to a conventional free-running QR converter implemented with only maximum switching frequency limitation at light loads.

In addition, several adjustable protection functions have been implemented in ICE5QR2280BG-1 to protect the system and customize the IC for the chosen application. In case of failure modes, like brownout or line overvoltage, V_{CC} overvoltage and undervoltage, open control loop or overload, output overvoltage, overtemperature, V_{CC} short-to-ground, the device enters protection mode.

By means of the cycle-by-cycle peak current limitation (PCL), the dimensions of the transformer and the current rating of the secondary diode can both be optimized. Thus, a cost-effective solution can easily be achieved. The target applications of ICE5QR2280BG-1 are portable games controllers and DVD players, auxiliary power supply of white goods, PCs, printers, TVs, home theater/audio systems, etc.

This document contains the list of features, power supply specifications, schematics, bill of materials (BOM), and the transformer construction documentation. Typical operating characteristics such as performance curve and scope waveforms are shown at the end of the document.

24 W, 12 V and 5 V SMPS reference board with CoolSET™ ICE5QR2280BG-1

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Reference board

2 Reference board

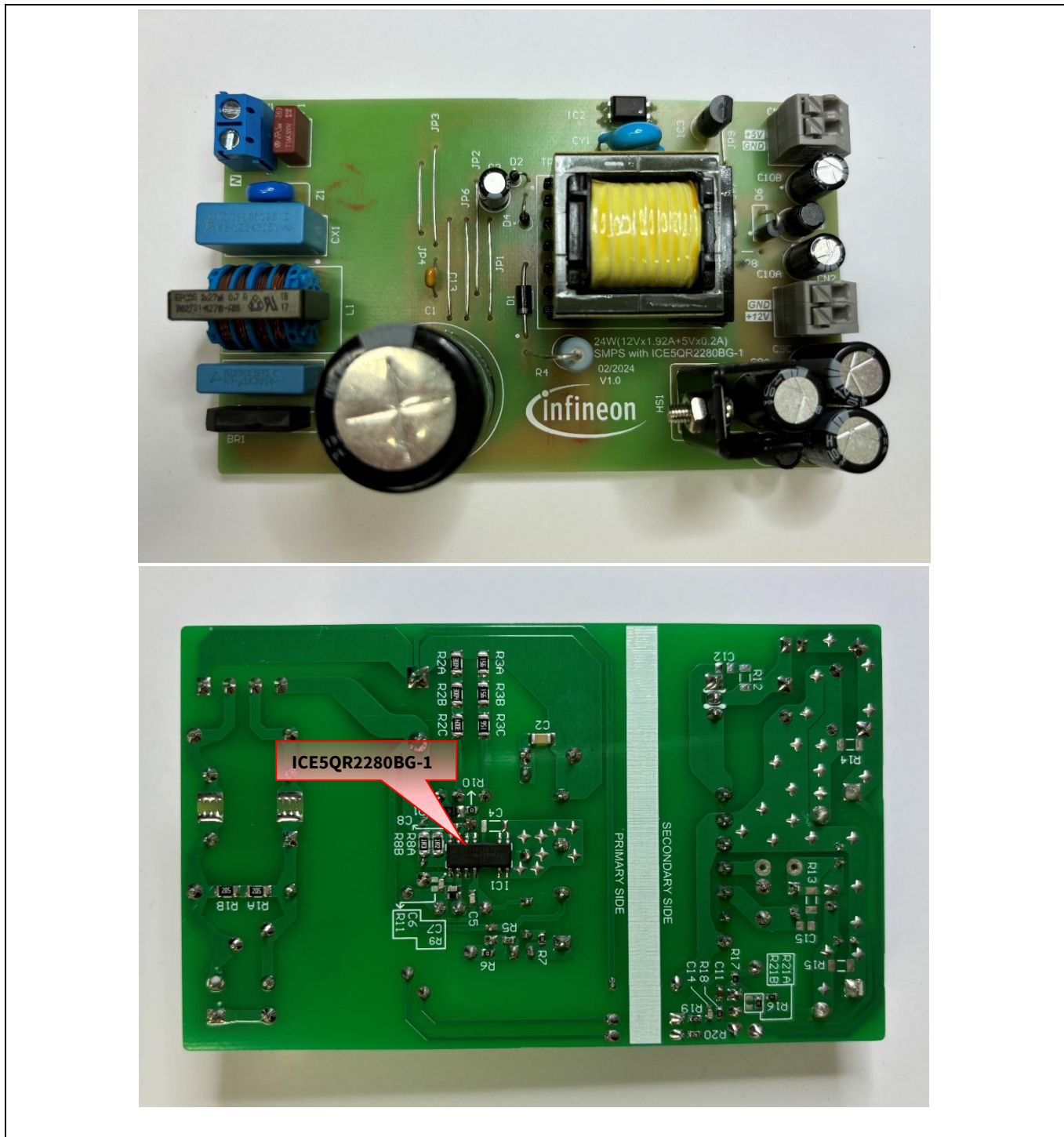


Figure 1 REF_5QR2280BG-1_24W1

3 Specifications of the reference board

Table 1 Specifications of REF_5QR2280BG-1_24W1

Input voltage and frequency	85 V AC (60 Hz) ~300 V AC (50 Hz)
Output voltage, current, and power	(12 V x 1.92 A) + (5 V x 0.2 A) = 24 W
Regulation	+5 V: < ±5% +12 V: < ±10%
Output ripple voltage (full load, 85 V AC ~ 300 V AC)	5 V _{ripple_p_p} < 100 mV 12 V _{ripple_p_p} < 200 mV
Active mode four-point average efficiency (25%, 50%, 75%, 100% load)	> 83% at 115 V AC and 230 V AC
No-load power consumption	< 100 mW at 230 V AC
Conducted emissions (EN 55022 Class B)	Pass with 6 dB margin for 115 V AC and 6 dB margin for 230 V AC
ESD immunity (EN 61000-4-2)	Special level (±14 kV for contact and ±14 kV air discharge)
Surge immunity (EN 61000-4-5)	Installation Class 4 (±2 kV for line-to-line and ±4 kV for line-to-earth)
Form factor case size (L x W x H)	(110 x 66 x 27) mm ³

Note that the reference board is designed for dual-output with cross-regulated loop feedback. It may not regulate properly if loading is applied only to a single output. If you want to evaluate for a single output (12 V only) condition, make the following changes on the board:

1. Remove D6, L3, C10A, C10B, and R16 to disable 5 V output.
2. Change R21A to 10 kΩ and R17 to 38 kΩ to disable 5 V feedback and enable 100% weighted factor on 12 V output.

Since the board (especially the transformer) is designed for dual output with optimized cross regulation, single output efficiency might not be optimized. This configuration is only for IC functional evaluation under single output condition.

24 W, 12 V and 5 V SMPS reference board with CoolSET™ ICE5QR2280BG-1

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Schematic

4 Schematic

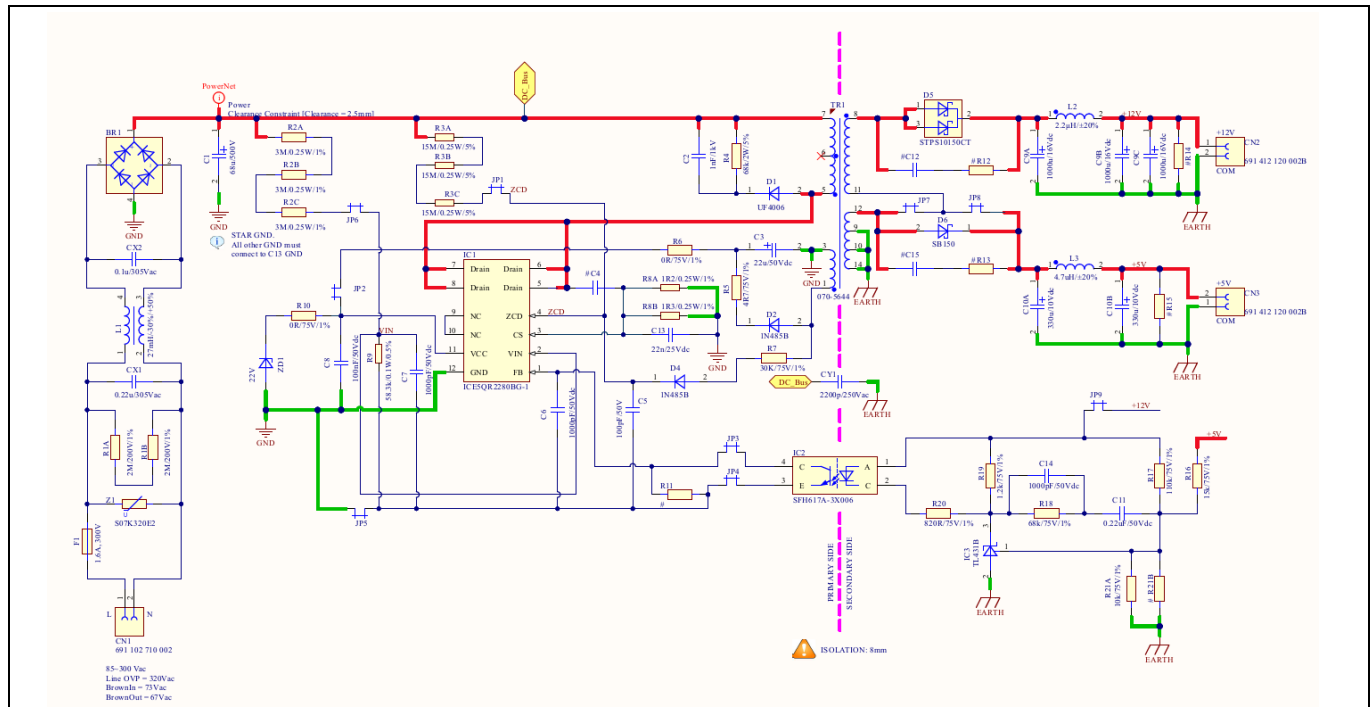


Figure 2 Schematic of REF_5QR2280BG-1_24W1

4.1 General guidelines for layout design of PCB:

- Star ground at the bulk capacitor (C1):** Connect all primary grounds to the ground of the bulk capacitor (C1) separately at one point. This reduces the switching noise going into the sensitive pins of the CoolSET™ device effectively. The primary star ground can be split into four groups as follows:
 - Combine the signal (all small-signal grounds connecting to the GND pin of the CoolSET™ device, such as filter capacitor grounds (C6, C7, C8, and optocoupler ground) and power grounds (CS resistors R8A and R8B).
 - V_{CC} ground includes the V_{CC} capacitor ground (C3) and the auxiliary winding ground (pin 3) of the power transformer.
 - EMI return ground, which includes Y capacitor (CY1).
 - DC ground from bridge rectifier (BR1).
- Filter capacitor close to the controller ground:** Place the filter capacitors (C6, C7, and C8) close to the controller ground and the controller pin to reduce the switching noise coupled into the controller.
- HV traces clearance:** To avoid arcing, space out the high-voltage traces far apart from the nearby traces.
 - 400 V traces (positive rail of bulk capacitor C1) to nearby trace:** > 2.0 mm
 - 600 V traces (drain voltage of CoolSET™ IC1) to nearby trace:** > 2.5 mm
- For better thermal performance, add a minimum copper area of 232 mm² at the drain pin on the PCB.
- To minimize the switching emissions, keep the following as small as possible:
 - Power-loop area (bulk capacitor C1)
 - Primary winding of the transformer TR1 (pins 7 and 5)
 - IC1 drain pin
 - IC1 CS pin
 - CS resistor R8A/R8B)

5 Bill of materials

Table 2 Bill of materials

No.	Designator	Description	Part Number	Manufacturer	Quantity
1	BR1	600 V/1 A	S1VBA60	Shindengen	1
2	CX1	0.22 μ F/305 V	B32922C3224	Epcos	1
3	CY1	2.2 nF/500 V	DE1E3RA222MA4BQ	Murata	1
4	C1	68 μ F/500 V	LGN2H680MELA25	Nichicon	1
5	C2	1 nF/1000 V	GRM31BR73A102KW0 1#	Murata	1
6	C3	22 μ F/50 V	50PX22MEFC5X11	Rubycon	1
7	C8	100 nF/50 V	GCM188R71H104KA5 7#	Murata	1
8	C6, C7, C14	1 nF/50 V	GRM1885C1H102JA0 1#	Murata	3
9	C5	100 pF/50 V	GCM1885C1H101JA1 6#	Murata	1
10	C9A, C9B, C9C	1000 μ F/16 V	16ZLH1000MEFC10X1 6	Rubycon	3
11	C10A, C10B	330 μ F/10 V	10ZLH330MEFC6.3X1 1	Rubycon	2
12	C11	220 nF/50 V	GRM188R71H224KAC 4#	Murata	1
13	C13	22 nF/25 V	K223K15X7RF5UL2	Murata	1
14	CN1 (L N)	Connector	691102710002	Würth Elektronik	1
15	CN2 (+12 V com), CN3 (+5 V com)	Connector	691 412 120 002B	Würth Elektronik	2
16	CX2	0.1 μ F/305 V	B329221C3104K	Epcos	1
17	D1	1 A/800 V	UF4006	–	1
18	D2,D4	0.2 A/200 V	1N485B	–	2
19	D5	10 A/150 V	STPS10150CT	STMicroelectronics	1
20	D6	1 A/45 V	SB150	Vishay	1
21	F1	1.6 A/300 V	36911600000	Littlefuse	1
22	IC1	ICE5QR2280BG -1	ICE5QR2280BG-1	Infineon	1
23	IC2	Optocoupler	SFH617A-3	–	1
24	IC3	Shunt regulator	TL431BVLPG	–	1
25	JP1,JP2,JP3,JP4,JP5,JP6, JP7,JP9	Jumper	–	–	8
26	L1	27 mH/0.7 A	B82731M2701A030	Epcos	1

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Bill of materials

No.	Designator	Description	Part Number	Manufacturer	Quantity
27	L2	2.2 uH/6.3A	744 746 2022	Würth Elektronik	3
28	L3	4.7 uH/4.2 A	744 746 2047	Würth Elektronik	2
29	R1A, R1B	2 MΩ/5%/200 V	RC1206JR-072ML	-	2
30	R2A, R2B, R2C	3 MΩ/0.25 W/1%	RC1206FR-073ML	-	3
31	R3A, R3B, R3C	15 MΩ/0.25 W/5%	RC1206JR-0715ML	-	3
32	R4	68 kΩ/2 W/500 V	MO2CT631R683J	KOA Speer	1
33	R5	4.7 Ω (0603)	-	-	1
34	R6, R10	0 Ω (0603)	-	-	2
35	R7	30 kΩ/±1% (0603)	-	-	1
36	R8A	1.2 R/0.25 W/±1%	ERJ8RQF1R2V	Panasonic	1
37	R8B	1.3 Ω / 0.25 W/ ±1%	ERJ8BQF1R3V	Panasonic	1
38	R9	58.3 kR/0.1 W/0.5%	RT0603DRE0758K3L	-	1
39	R16	15 kΩ (0603)	-	-	1
40	R17	110 kΩ (0603)	-	-	1
41	R18	68 kΩ (0603)	-	-	1
42	R19	1.2 kΩ (0603)	-	-	1
43	R20	820 Ω (0603)	-	-	1
44	R21A	10 kΩ (0603)	-	-	1
45	TR1	400 μH	750343101	Würth Elektronik	1
46	Z1	Varistor	B72207S2321K101	Epcos	1
47	ZD1	22 V Zener	MMSZ5251B-7-F	Diodes Incorporated	1
48	HS1	Heatsink	577202B00000G	AAVID	1

Circuit description

6 Circuit description

6.1 Line input

The AC-line input side comprises the input fuse (F1) as overcurrent protection. The choke (L1), X-capacitors (CX1 and CX2), and Y-capacitor (CY1) act as EMI suppressors. The sparking gap and varistor (Z1) absorb the HV stress during a lightning surge test. A rectified DC voltage (120~424 V DC) is obtained through the bridge rectifier (BR1) together with the bulk capacitor (C1).

6.2 Startup

To achieve fast and safe startup, ICE5QR2280BG-1 is implemented with a startup resistor and V_{CC} short-to-GND protection. When V_{VCC} reaches the turn-on voltage threshold (16 V), the IC begins with a soft start.

The soft start implemented in ICE5QR2280BG-1 is a digital time-based function. The preset soft-start time is 12 ms with four steps. If not limited by other functions, the peak voltage on the CS pin will increase incrementally from 0.3 V to 1 V. After the IC turns on, the V_{CC} voltage is supplied by auxiliary windings of the transformer. V_{CC} short-to-GND protection is implemented during the startup time.

6.3 Integrated MOSFET and PWM control

ICE5QR2280BG-1 comprises a power MOSFET and the proprietary novel QR controller, which enables higher average efficiency and low EMI. This integrated solution simplifies the circuit layout and reduces the cost of PCB manufacturing. The PWM switch-on is determined by the zero crossing detection input signal and the value of the up/down counter. The PWM switch-off is determined by the feedback signal VFB and the current sensing signal VCS. ICE5QR2280BG-1 also performs all necessary protection functions in the flyback converters. For more details, refer to the datasheet [\[1\]](#).

6.4 RCD clamper circuit

A clamper network (R4, C2, and D1) dissipates the energy of the leakage inductance and suppresses ringing on the SMPS transformer.

6.5 Output stage

There are two outputs on the secondary side (12 V and 5 V). The power is coupled out via Schottky diodes (D5 and D6). The capacitors (C9A and C10A) provide energy buffering followed by the L-C filters (L2-C9B, C9C and L3-C10B) to reduce the output ripple and prevent interference between SMPS switching frequency and line frequency. Storage capacitors (C9A and C10A) are designed to have the smallest possible internal resistance (ESR) to minimize the output voltage ripple caused by the triangular current.

6.6 Feedback loop

For feedback, the output is sensed by the voltage dividers (R16, R17, R21A, and R21B) and compared to the IC3 (TL431) internal reference voltage. C11, C14, and R18 comprise the compensation network. The output voltage of IC3 (TL431) is converted to the current signal via the optocoupler (IC2) and two resistors (R19 and R20) for regulation control.

Circuit description

6.7 Primary side peak-current control

The MOSFET drain-source current is sensed via the external resistors (R8A and R8B). Because ICE5QR2280BG-1 is a current mode controller, it would have a cycle-by-cycle primary current and feedback voltage control, which ensures the power of the converter is controlled in every switching cycle.

For a QR flyback converter, the maximum possible output power is increased when a constant current limit value is used for the entire line input voltage range. However, this is not desirable because this will increase the cost of the transformer and output diode in case of output over-power conditions.

Internal current limitation with line-dependent V_{CS} curve and the new proprietary QR switching, which reduces the switching frequency difference between the minimum and maximum line are implemented in ICE5QR2280BG-1. As a result, the maximum output power can be limited against the input voltage.

6.8 Digital frequency reduction

During normal operation, the switching frequency for ICE5QR2280BG-1 is digitally reduced with decreasing load. At light load conditions, the MOSFET will be turned on – not at the first minimum drain-source voltage time, but on the n th. The counter is within a range of 1 to 8 for low-line and 3 to 10 for high-line, which depends on the feedback voltage in a time base. The feedback voltage decreases when the output power requirement decreases, and vice versa. Therefore, the counter is set by the monitoring voltage VFB. The counter will be increased with low VFB and decreased with high VFB. The thresholds are preset inside the IC.

6.9 Active burst mode (ABM)

ABM entry and exit power (two levels) can be selected in ICE5QR2280BG-1 [1]. In light load conditions, the SMPS enters into ABM with QR switching. At this stage, the controller is always active but the V_{VCC} must be kept above the switch-off threshold. During ABM, the efficiency increases significantly; and it supports low ripple on V_{out} and fast response on load-jump.

For determination of entering ABM operation, three conditions apply:

- The feedback voltage is lower than the threshold of V_{FBEB} .
- The up/down counter is 8 for low-line and 10 for high-line.
- A certain blanking time ($t_{BEB} = 20$ ms).

Once all of these conditions are fulfilled, the ABM flip-flop is set and the controller enters ABM operation. This multi-condition determination for entering ABM operation prevents mis-triggering of entering ABM operation, so that the controller enters ABM operation only when the output power is really low during the preset blanking time.

During ABM, the maximum CS voltage is reduced from 1 V to 0.31/0.35 V to reduce the conduction loss and the audible noise. In ABM, the feedback voltage changes like a sawtooth between 2 V and 2.4 V.

The feedback voltage immediately increases if there is a sudden increment in the output load, as observed by one comparator. As the current limit is 31/35% during ABM, a certain load is needed so that the feedback voltage can exceed V_{FBLB} (2.75 V). After leaving ABM, maximum current can now be provided to stabilize V_{out} . In addition, the up/down counter will be set to '1' (low-line) or '3' (high-line) immediately after leaving ABM. This is helpful to decrease the output voltage undershoot.

7 Protection features

ICE5QR2280BG-1 provides comprehensive protection to ensure that the system is operating safely. When faults are found, the system enters protection mode and remains in this mode until the fault is removed, and then the system resumes normal operation. [Table 3](#) lists the protections and failure conditions.

Table 3 Protection functions of ICE5QR2280BG-1

Protection function	Failure condition	Protection mode
Line overvoltage	$V_{VIN} > V_{VIN_LOVP}$	Non-switch auto-restart
Brownout	$V_{VIN} < V_{VIN_BO}$	Non-switch auto-restart
V _{CC} overvoltage	$V_{VCC} > V_{VCC_OVP}$	Odd-skip auto-restart
V _{CC} undervoltage	$V_{VCC} < V_{VCC_OFF}$	Auto-restart
Overload	$V_{FB} > V_{FB_OLP}$ and lasts for 30 ms	Odd-skip auto-restart
Output overvoltage	$V_{ZCD} > V_{ZCD_OVP}$ and lasts for 10 consecutive pulses	Odd-skip auto-restart
Overtemperature (junction temperature of controller chip only)	$T_J > 140^\circ\text{C}$ with 40°C hysteresis to reset	Non-switch auto-restart
V _{CC} short-to-GND (V _{VCC} = 0 V, R _{StartUp} = 50 MΩ and V _{Drain} = 90 V)	$V_{VCC} < V_{VCC_SCP}$, I _{VCC_Charge} = I _{VCC_Charge1}	Cannot start up

8 PCB layout

8.1 Top side

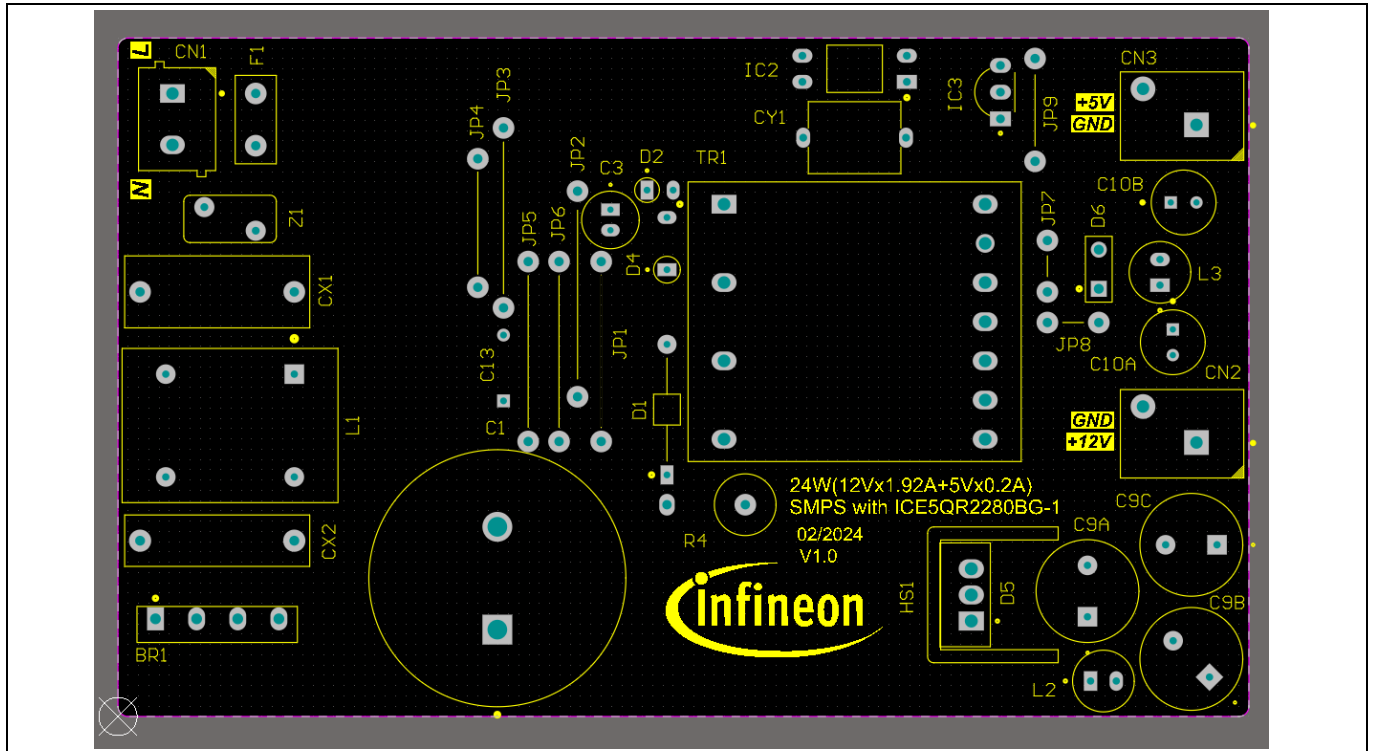


Figure 3 Top side component legend

8.2 Bottom side

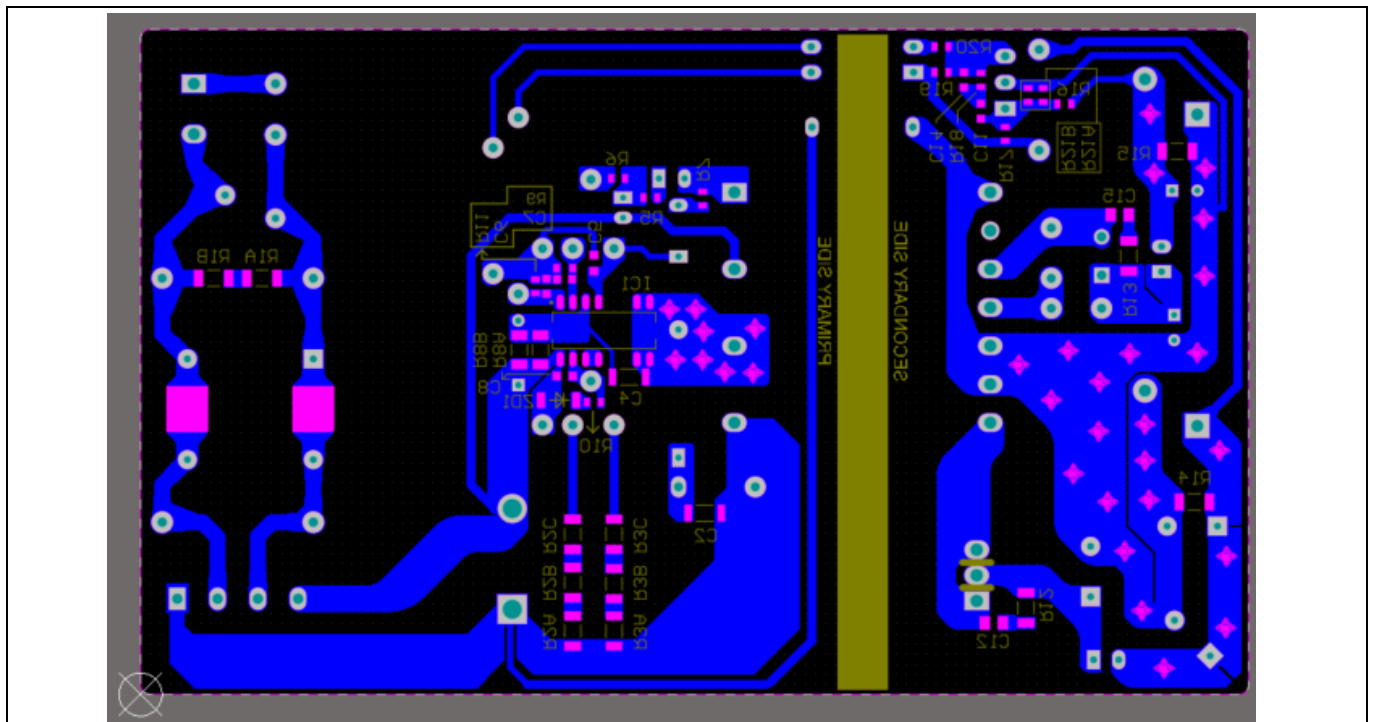


Figure 4 Bottom side copper and component legend

24 W, 12 V and 5 V SMPS reference board with CoolSET™

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Transformer construction

9 Transformer construction

Core and materials: EE25/13/7(EF25), TP4A (TDG)

Bobbin: 070-5644 (14-pin, THT, horizontal version)

Primary inductance: $L_p = 400 \mu\text{H}$ ($\pm 10\%$), measured between pin 5 and pin 7

Manufacturer and part number: Würth Elektronik Midcom (750343101)

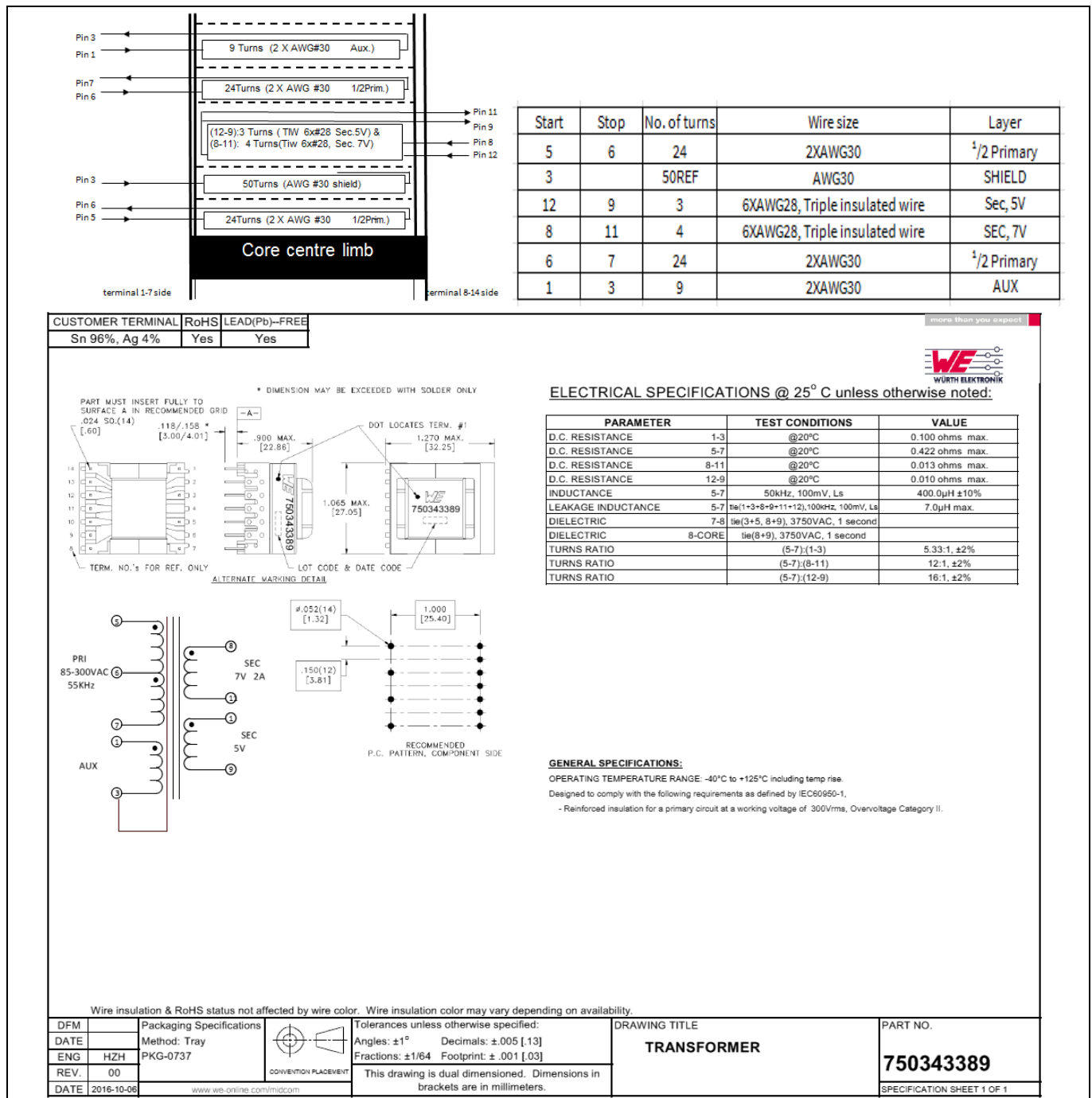


Figure 5 Transformer structure

Test results

10 Test results

10.1 Efficiency, regulation, and output ripple

Table 4 Efficiency, regulation, and output ripple

Input (V AC/H)	P _{in} (W)	V _{out1} (V DC)	I _{out1} (A)	V _{OutRPP1} (mV)	V _{out2} (V DC)	I _{out2} (A)	V _{OutRPP2} (mV)	P _{out} (W)	Efficiency η (%)	Average η (%)	OLP P _{in} (W)	OLP I _{out12V} (fixed 5 V at 0.2 A) (A)
85 V AC/ 60 Hz	0.033	11.83	0.000	48.0	4.96	0.000	10.9				38.40	2.61
	0.08	12.85	0.000	23.7	4.82	0.006	45.4	0.03				
	14.591	11.75	1.000	35.8	4.97	0.060	9.0	12.05	82.57			
	7.372	11.82	0.500	29.4	4.96	0.050	8.3	6.16	83.53			
	14.76	11.83	1.000	34.6	4.96	0.100	9.0	12.33	83.51			
	22.2	11.83	1.500	35.8	4.96	0.150	9.6	18.49	83.28	83.06		
28.99	11.85	1.920	47.4	4.96	0.200	12.2	23.74	81.90				
115 V AC/ 60 Hz	0.039	11.83	0.000	48.0	4.96	0.000	11.5				43.52	3.01
	0.085	12.85	0.000	23.7	4.83	0.006	47.4	0.03				
	14.282	11.73	1.000	36.5	4.97	0.060	9.6	12.03	84.22			
	7.364	11.81	0.500	28.8	4.96	0.050	9.0	6.15	83.56			
	14.694	11.82	1.000	41.0	4.96	0.100	9.0	12.32	83.82			
	22.15	11.82	1.500	43.5	4.96	0.150	9.6	18.47	83.40	83.66		
28.26	11.83	1.920	44.2	4.96	0.200	9.6	23.71	83.88				
230 V AC/ 50 Hz	0.067	11.83	0.000	51.8	4.96	0.000	14.7				45.48	3.16
	0.119	12.85	0.000	23.7	4.82	0.006	46.7	0.03				
	14.41	11.74	1.000	42.2	4.97	0.060	10.9	12.04	83.54			
	7.59	11.82	0.500	31.4	4.96	0.050	9.6	6.16	81.13			
	14.76	11.82	1.000	35.8	4.96	0.100	10.2	12.32	83.44			
	21.98	11.83	1.500	39.7	4.96	0.150	9.6	18.49	84.12	83.33		
28.03	11.84	1.920	46.1	4.96	0.200	10.9	23.72	84.64				
264 V AC/ 50 Hz	0.084	11.83	0.000	51.8	4.96	0.000	14.1				47.08	3.26
	0.136	12.85	0.000	26.2	4.82	0.006	54.0	0.03				
	14.63	11.73	1.000	38.1	4.97	0.060	14.0	12.03	82.22			
	7.74	11.82	0.500	31.4	4.96	0.050	13.0	6.16	79.56			
	14.89	11.83	1.000	42.2	4.96	0.100	10.2	12.33	82.78			
	22.18	11.82	1.500	47.4	4.96	0.150	9.6	18.47	83.29	82.40		
28.23	11.83	1.920	46.7	4.96	0.200	10.2	23.71	83.97				
300 V AC/ 50 Hz	0.103	11.83	0.000	53.2	4.96	0.000	13.4				48.43	3.36
	0.154	12.91	0.000	26.9	4.82	0.006	58.0	0.03				
	14.632	11.75	1.000	42.2	4.97	0.060	10.2	12.05	82.34			
	7.892	11.82	0.500	30.7	4.96	0.050	9.6	6.16	78.03			
	15.08	11.83	1.000	37.1	4.96	0.100	9.0	12.33	81.74			
	22.39	11.82	1.500	41.0	4.96	0.150	9.0	18.47	82.51	81.40		
28.45	11.83	1.920	41.6	4.96	0.200	9.6	23.71	83.32				

- **Minimum load condition:** 5 V at 6 mA
- **Typical load condition:** 5 V at 60 mA and 12 V at 1 A
- **Maximum load condition:** 5 V at 200 mA and 12 V at 1.92 A

Test results

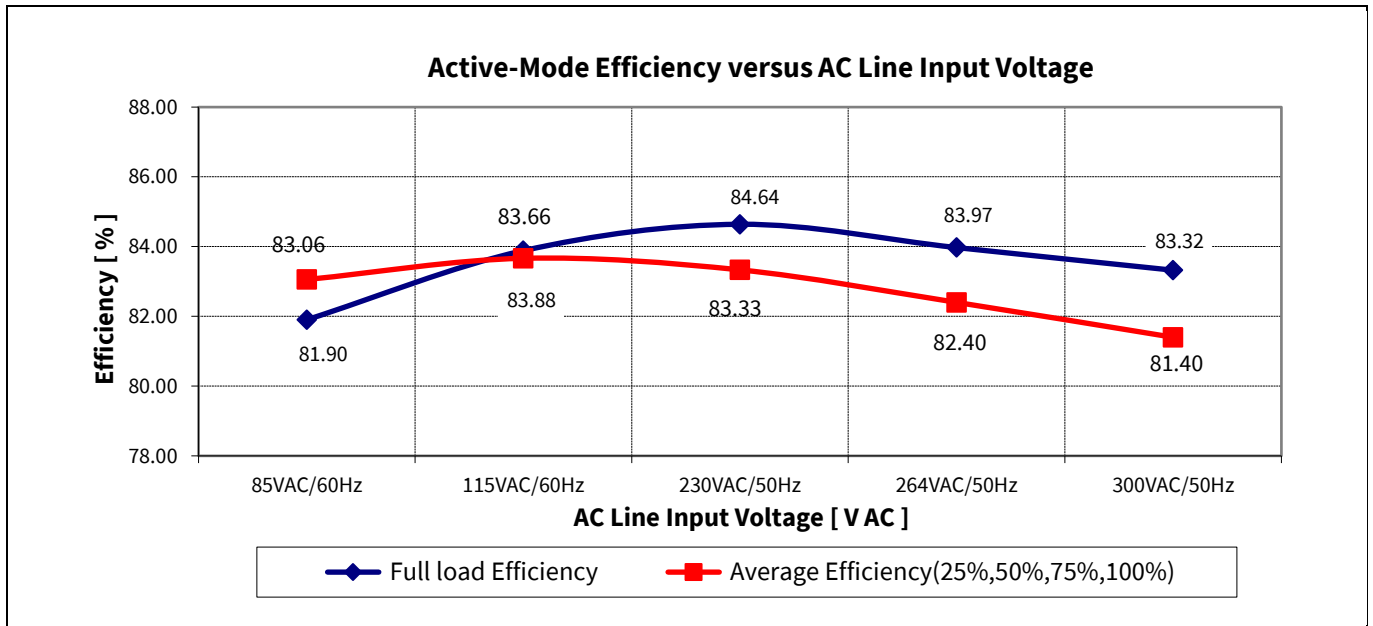


Figure 6 Efficiency vs. AC-line input voltage

10.2 Standby power

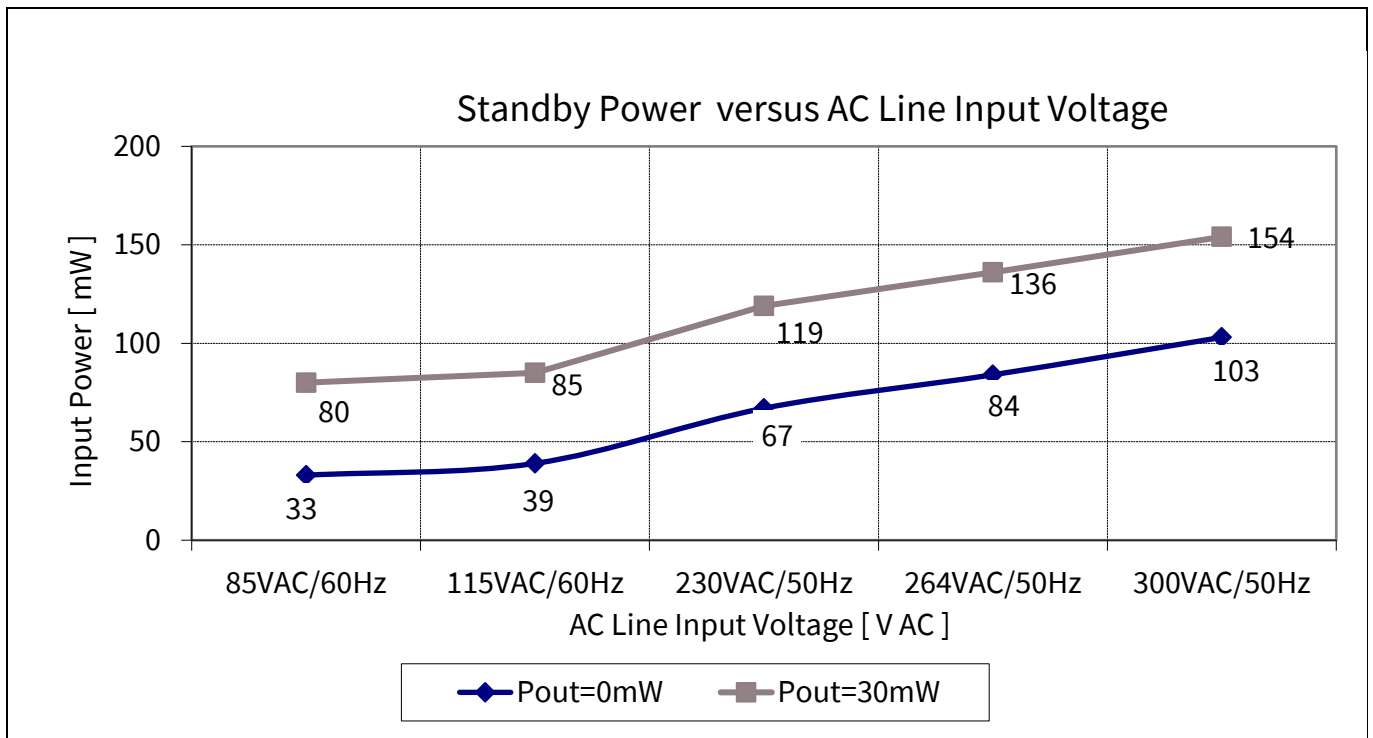


Figure 7 Standby power at no-load and 30 mW load vs. AC-line input voltage (measured by Yokogawa WT210 power meter – integration mode)

Test results

10.3 Line regulation

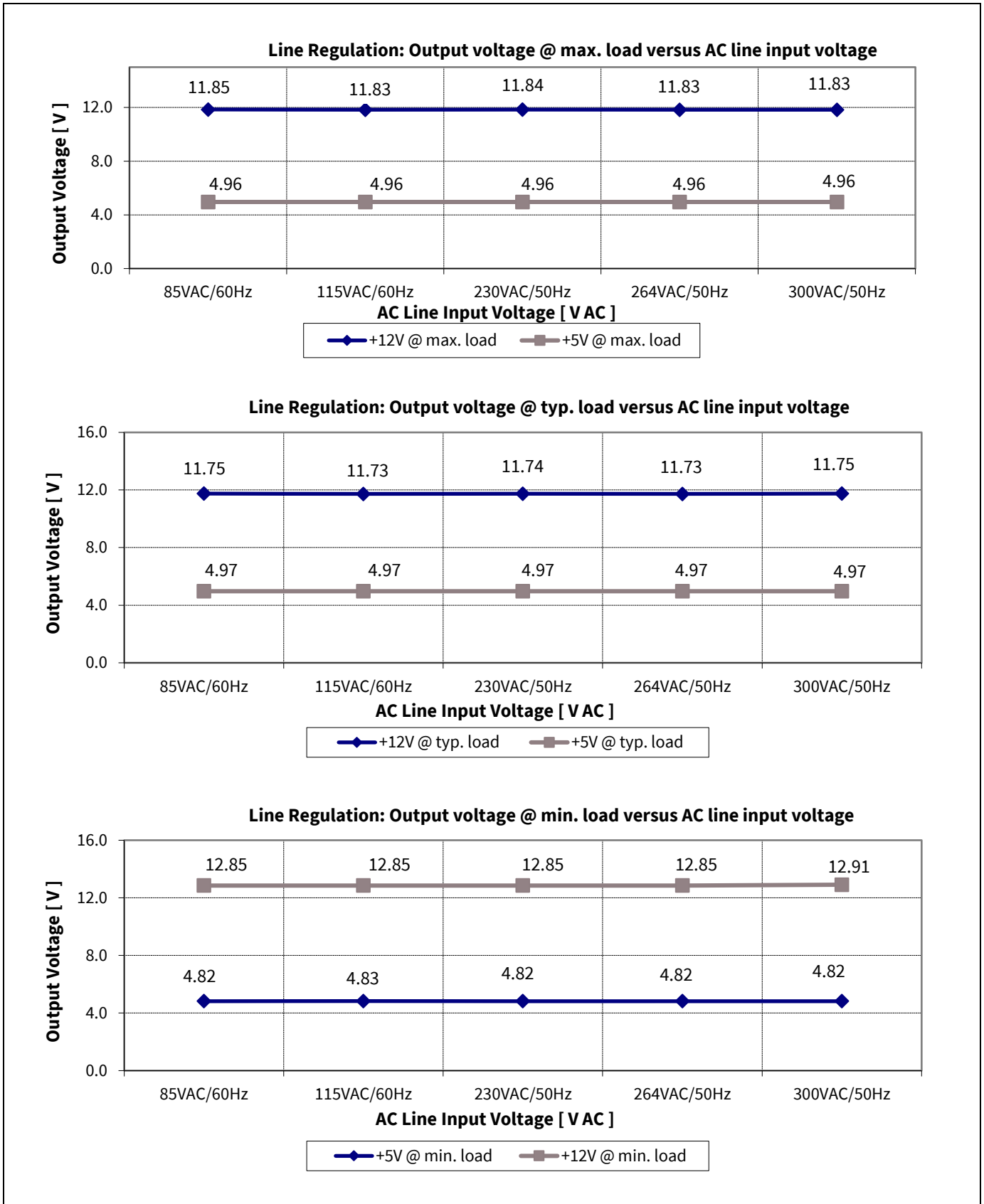


Figure 8 Line regulation V_{out} at full load vs. AC-line input voltage

Test results

10.4 Load regulation

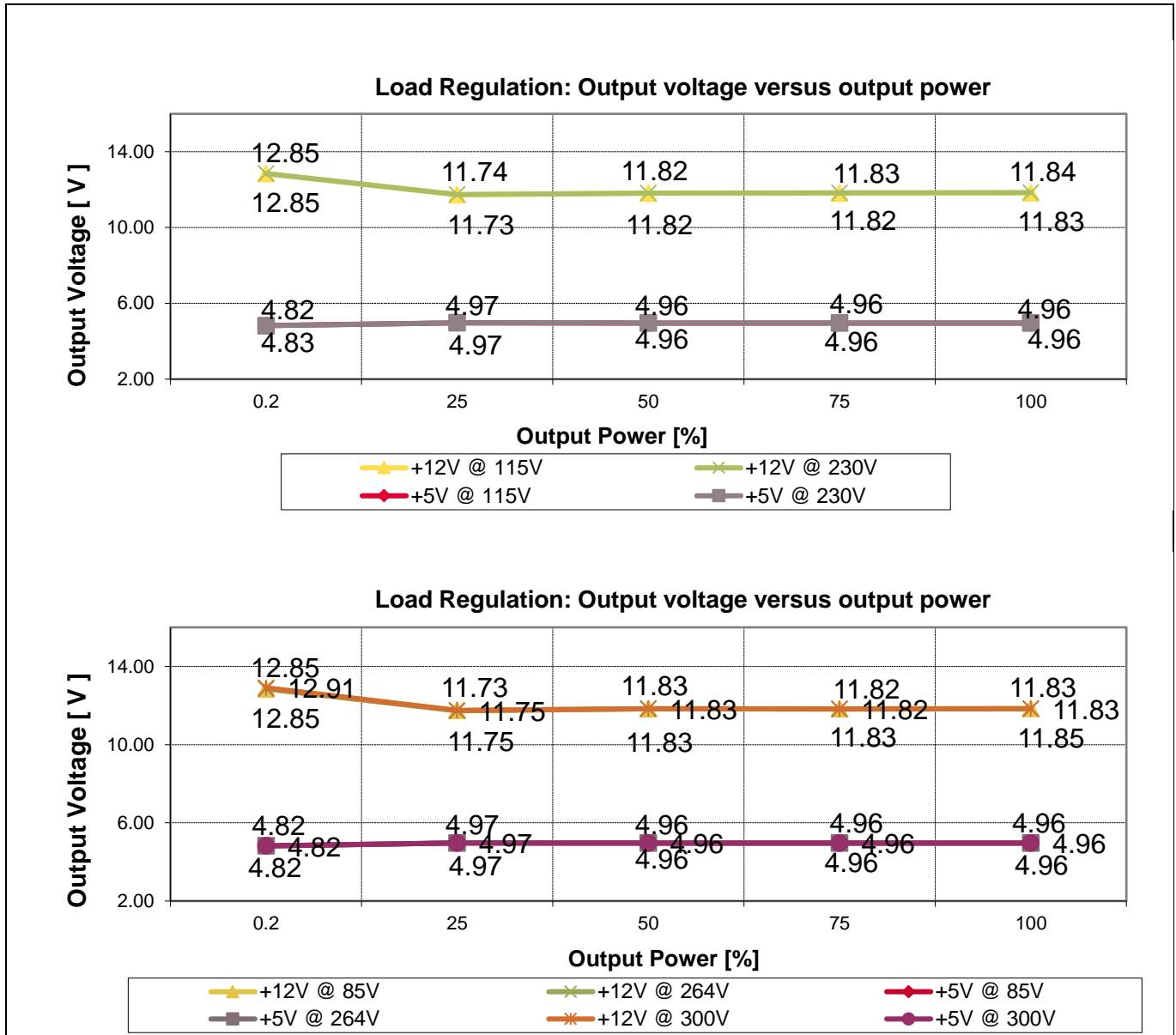


Figure 9 Load regulation V_{out} vs. output power

Test results

10.5 Maximum input power

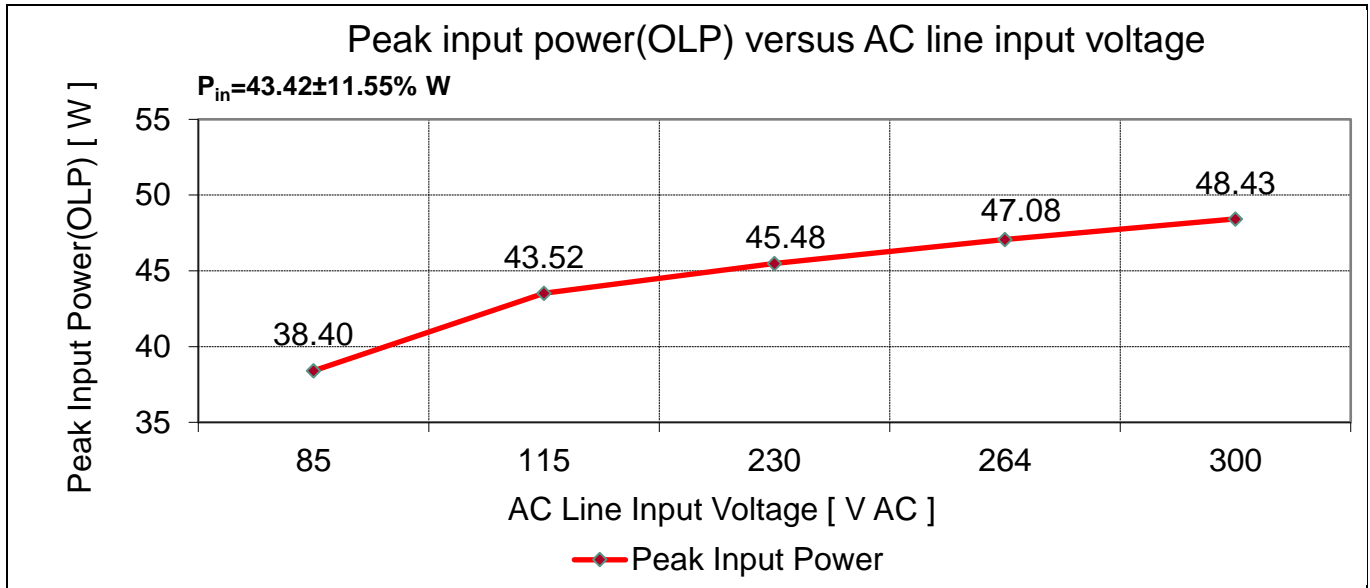


Figure 10 Maximum input power (before overload protection) vs. AC-line input voltage

10.6 ESD immunity (EN 61000-4-2)

Pass EN 61000-4-2 special level (± 14 kV for contact discharge and ± 16 kV air discharge).

10.7 Surge immunity (EN 61000-4-5)

Pass EN 61000-4-5 installation Class 4 (± 2 kV for line-to-line and ± 4 kV for line-to-earth)¹.

10.8 Conducted emissions (EN 55022 Class B)

The conducted EMI was measured by Schaffner (SMR4503) and followed the test standard of EN 55022 (CISPR 22) Class B. The reference board was set up at maximum load (24 W) with input voltage of 115 V AC and 230 V AC.

¹ PCB spark-gap distance needs to reduce to 0.5 mm and C1 change to 120 μ F.

Test results

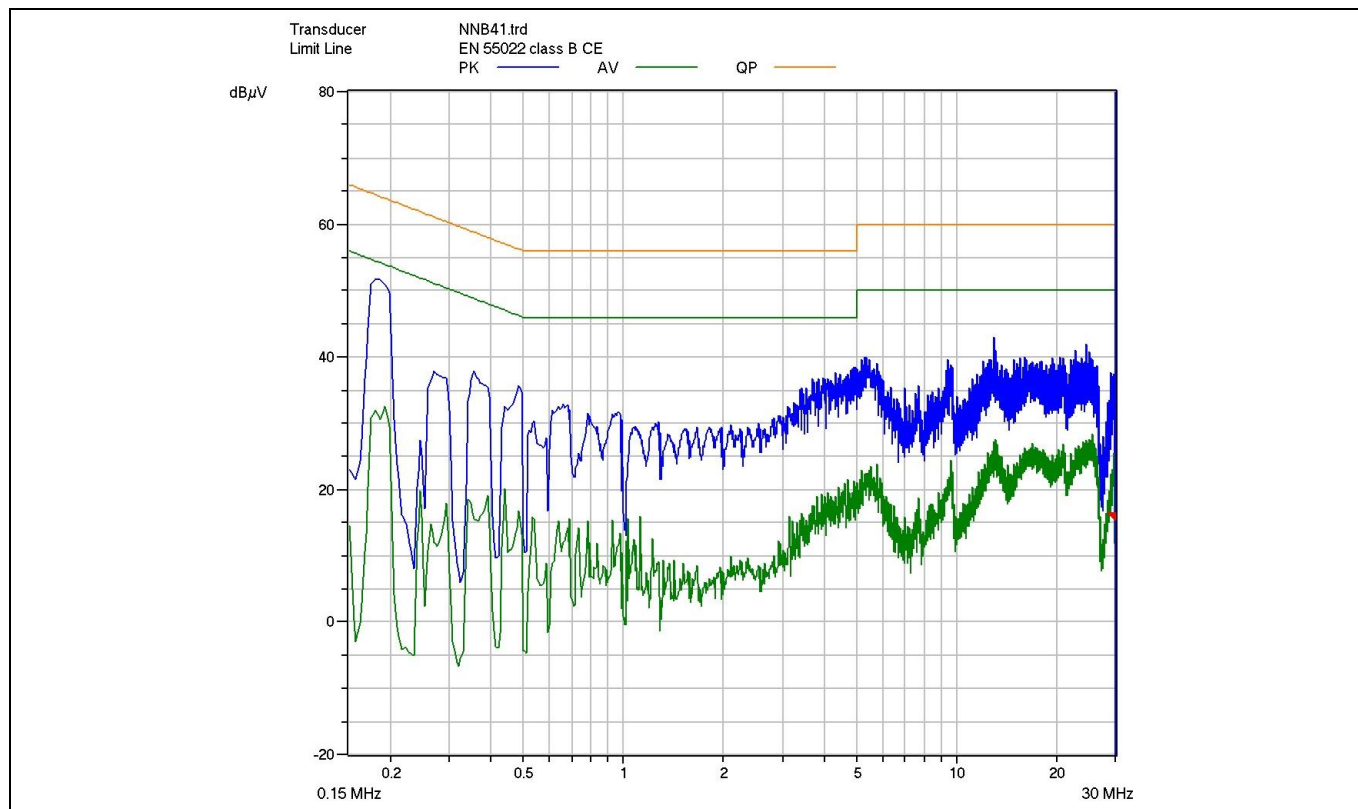


Figure 11 Conducted emissions (line) at 115 V AC and maximum load

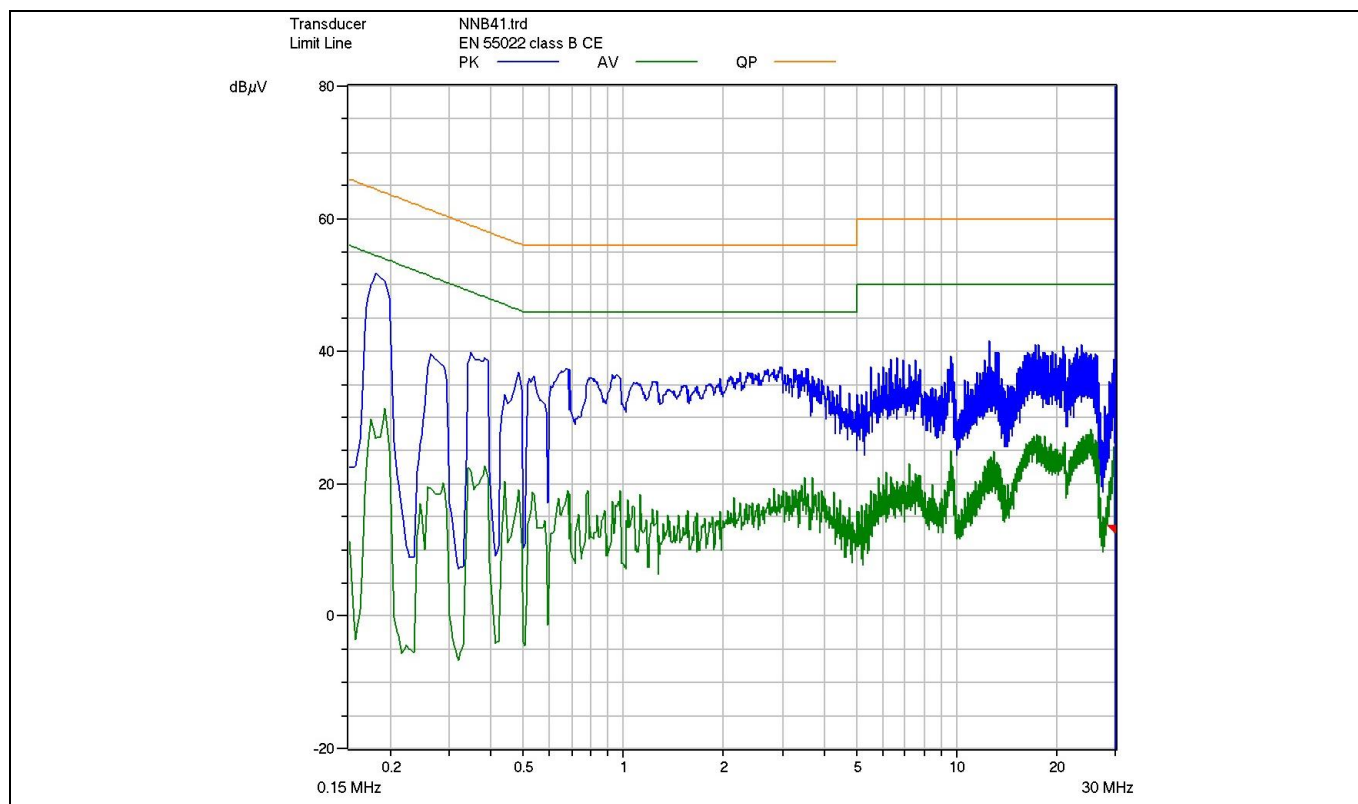


Figure 12 Conducted emissions (neutral) at 115 V AC and maximum load

Test results

Pass conducted emissions EN 55022 (CISPR 22) Class B with 10 dB margin for quasi-peak measurement at low-line (115 V AC).

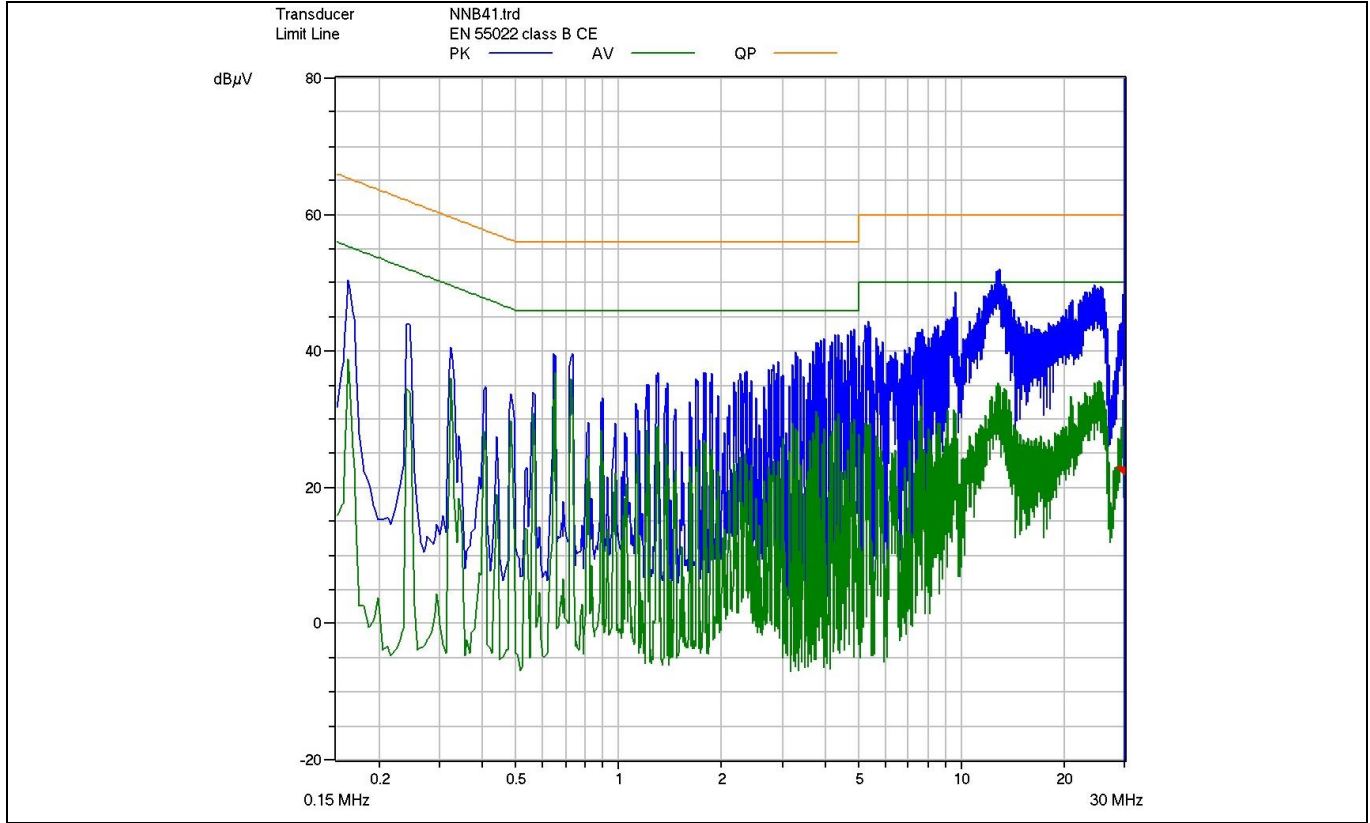


Figure 13 Conducted emissions (line) at 230 V AC and maximum load

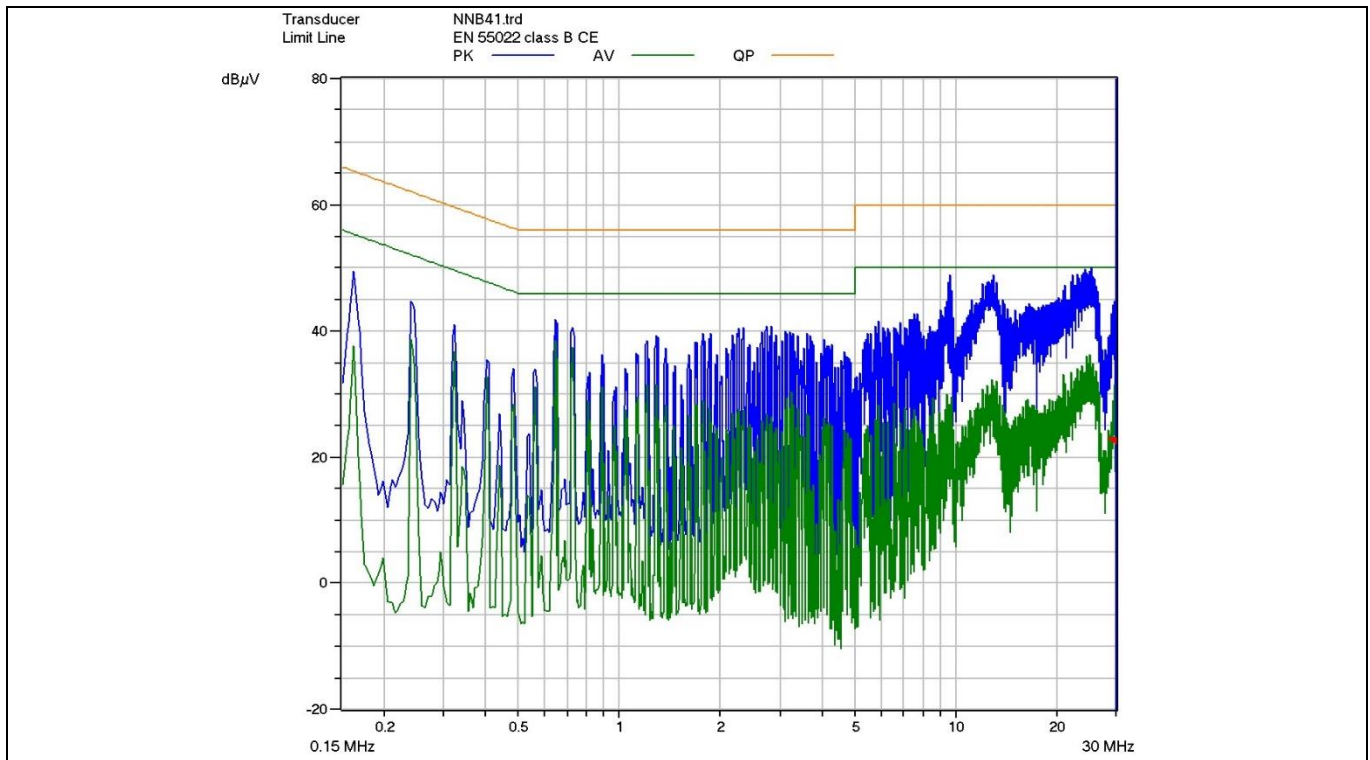


Figure 14 Conducted emissions (neutral) at 230 V AC and maximum load

24 W, 12 V and 5 V SMPS reference board with CoolSET™ ICE5QR2280BG-1

REF_5QR2280BG-1_24W1

Test results

Pass conducted emissions EN 55022 (CISPR 22) Class B with 6 dB margin for quasi-peak measurement at high-line (230 V AC).

10.9 Thermal measurement

The thermal test of the open-frame reference board was done using an infrared thermography camera (FLIR-T420) at an ambient temperature of 25°C. The measurements were taken after one hour running at full load condition.

Table 5 Hottest temperature of reference board

No.	Major component	85 V AC (°C)	300 V AC (°C)
1	TR1 (transformer)	58.1	64.1
2	D21 (secondary diode)	75.4	74.6
3	IC11 (ICE5QR2280BG-1)	86.2	90.6
4	L11 (choke)	62.2	35.2
5	Ambient	25.0	25.0

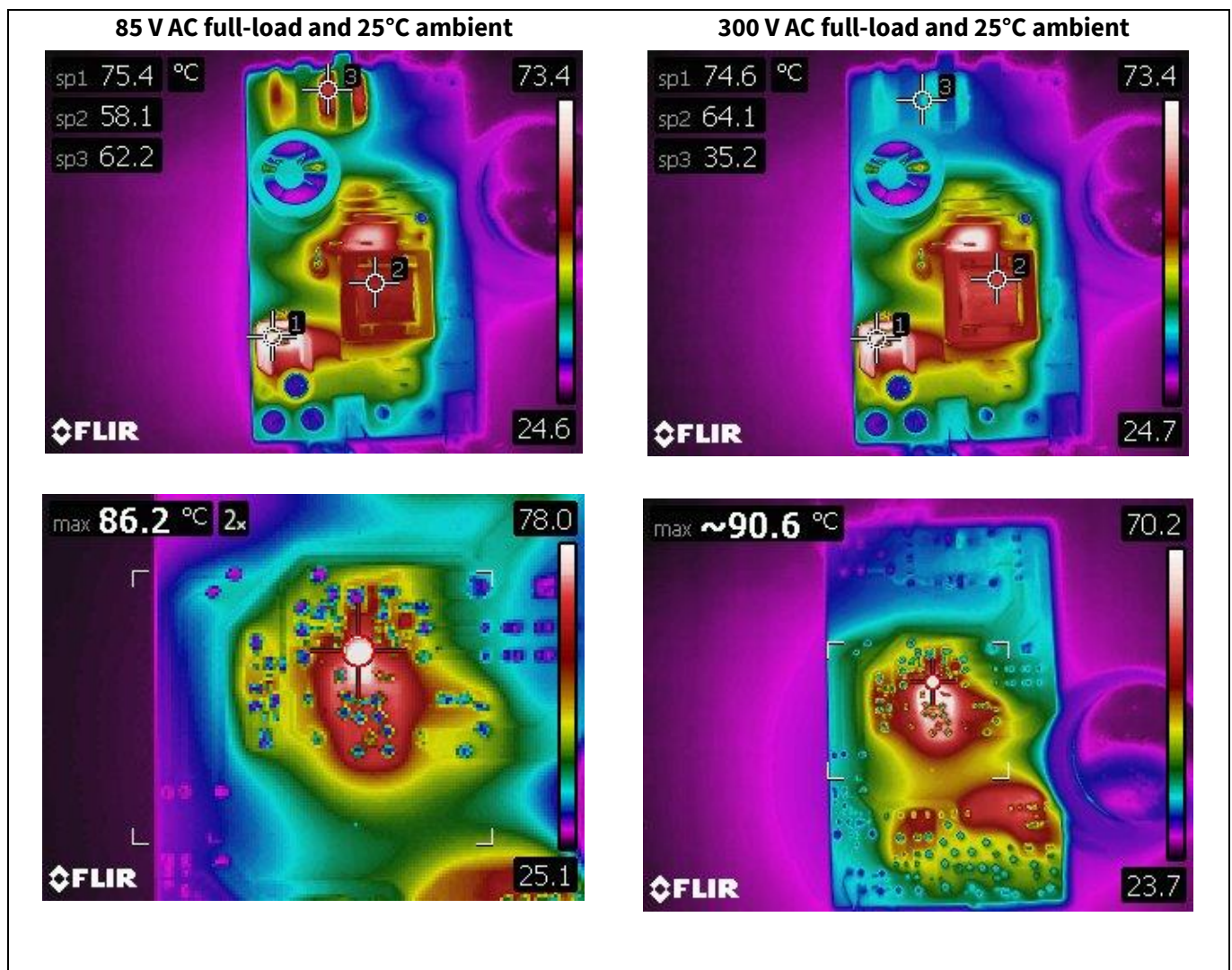


Figure 15 Infrared thermal image of REF_5QR2280BG-1_24W1

24 W, 12 V and 5 V SMPS reference board with CoolSET™ ICE5QR2280BG-1

REF_5QR2280BG-1_24W1

Waveforms and scope plots

11 Waveforms and scope plots

All waveforms and scope plots were recorded with a TELEDYNE LECROY 44Xi oscilloscope.

11.1 Start up at low/high AC-line input voltage with maximum load

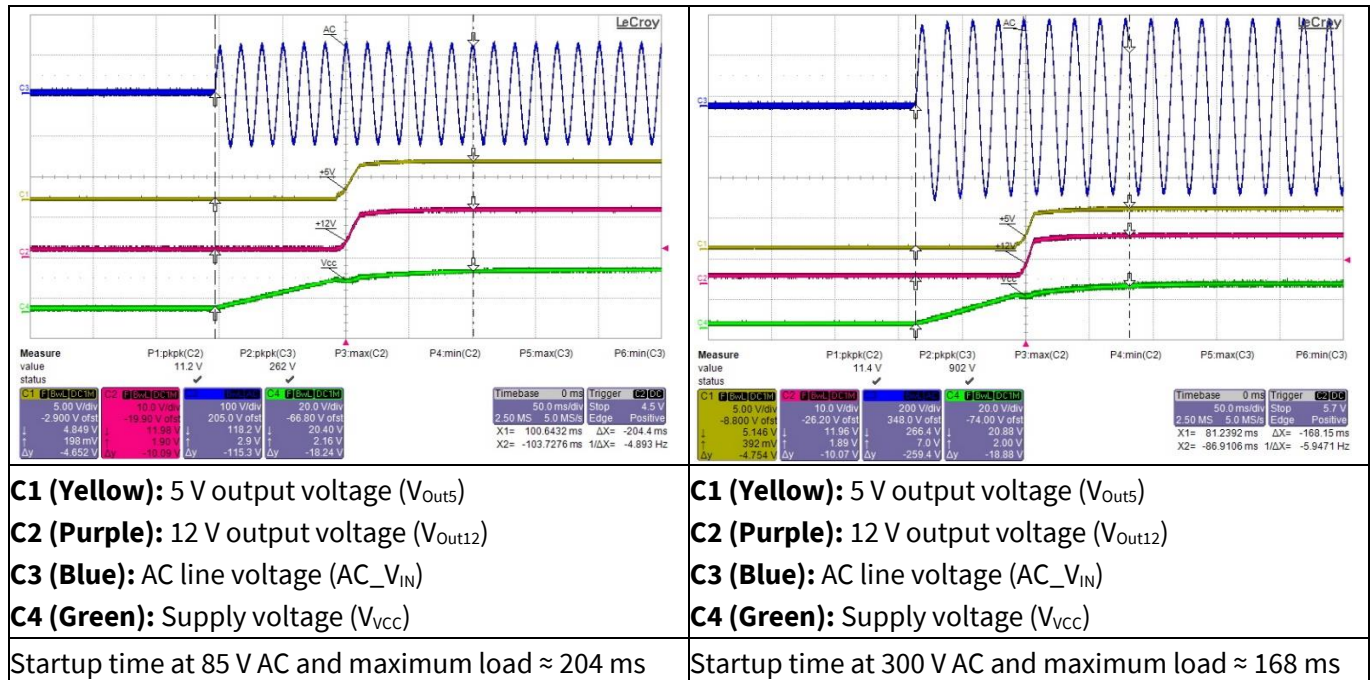


Figure 16 Start up

11.2 Soft start

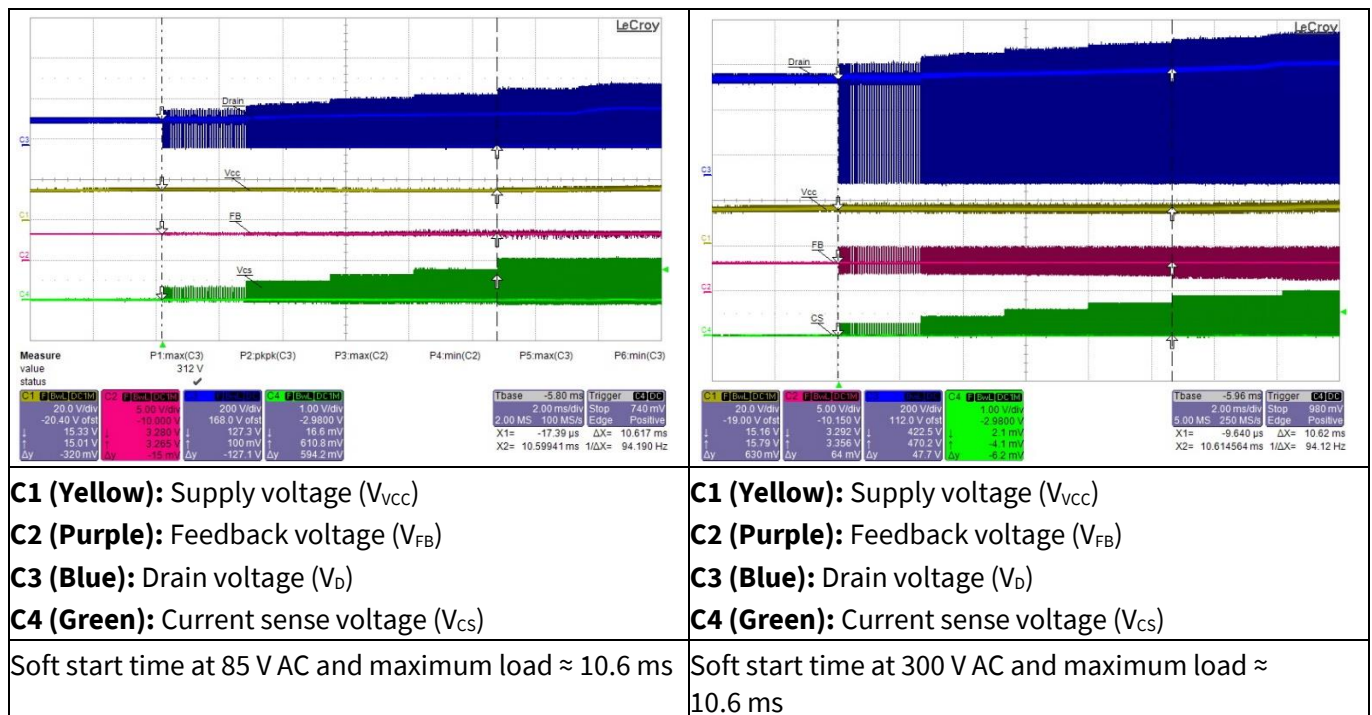


Figure 17 Soft start

24 W, 12 V and 5 V SMPS reference board with CoolSET™ ICE5QR2280BG-1

REF_5QR2280BG-1_24W1

Waveforms and scope plots

11.3 Drain and CS voltage at maximum load

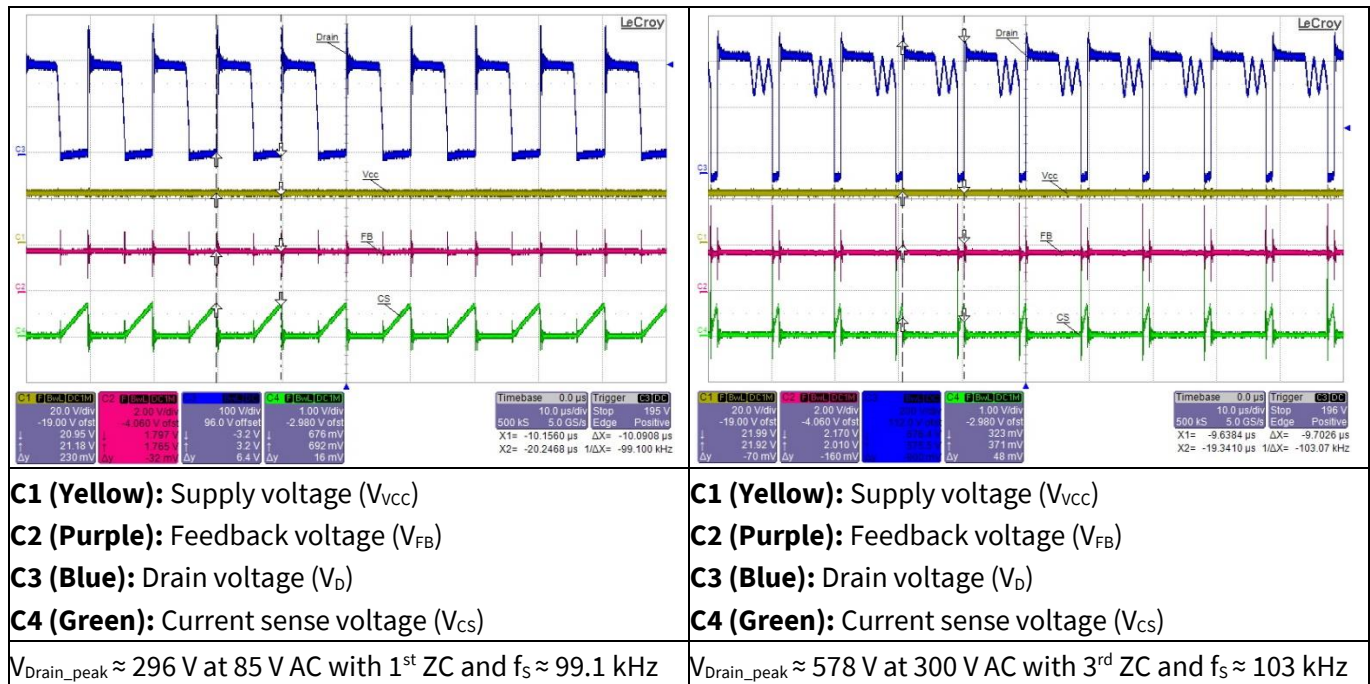


Figure 18 Drain and CS voltage at maximum load

11.4 Zero crossing point during normal operation

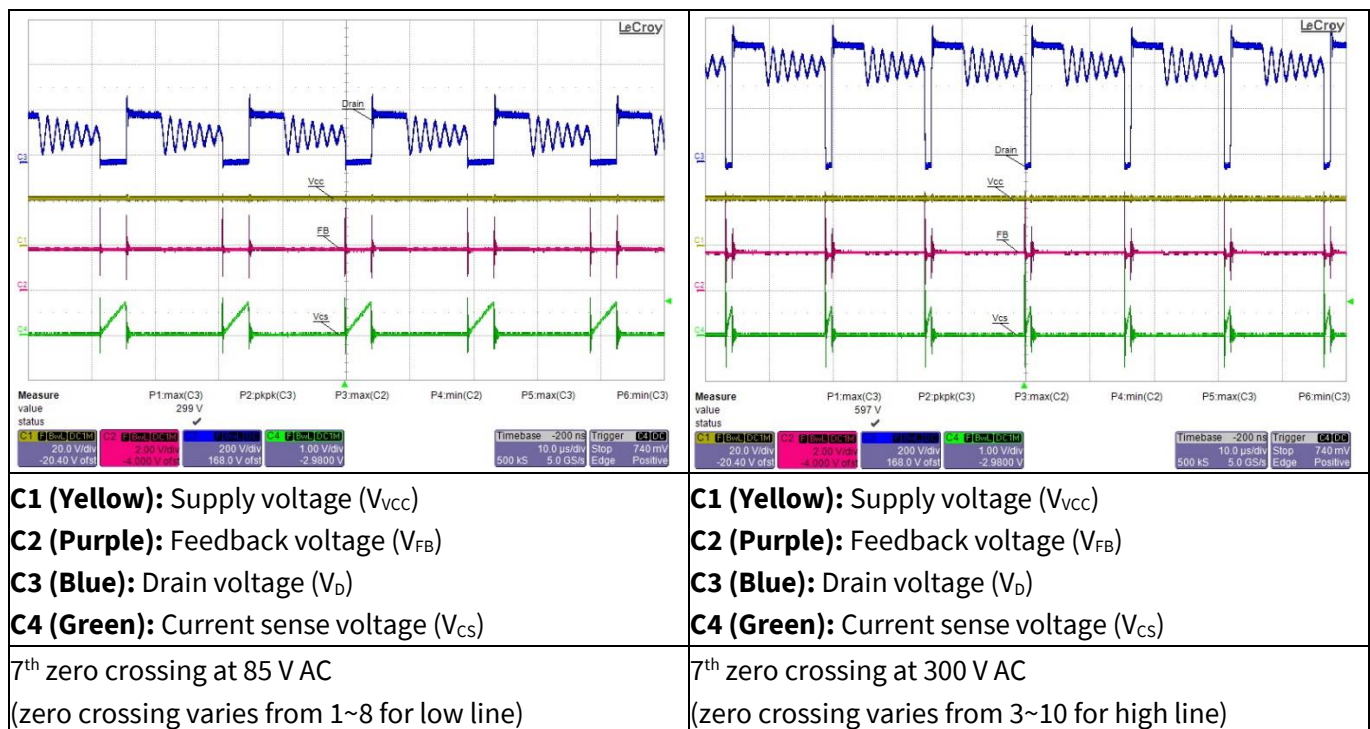


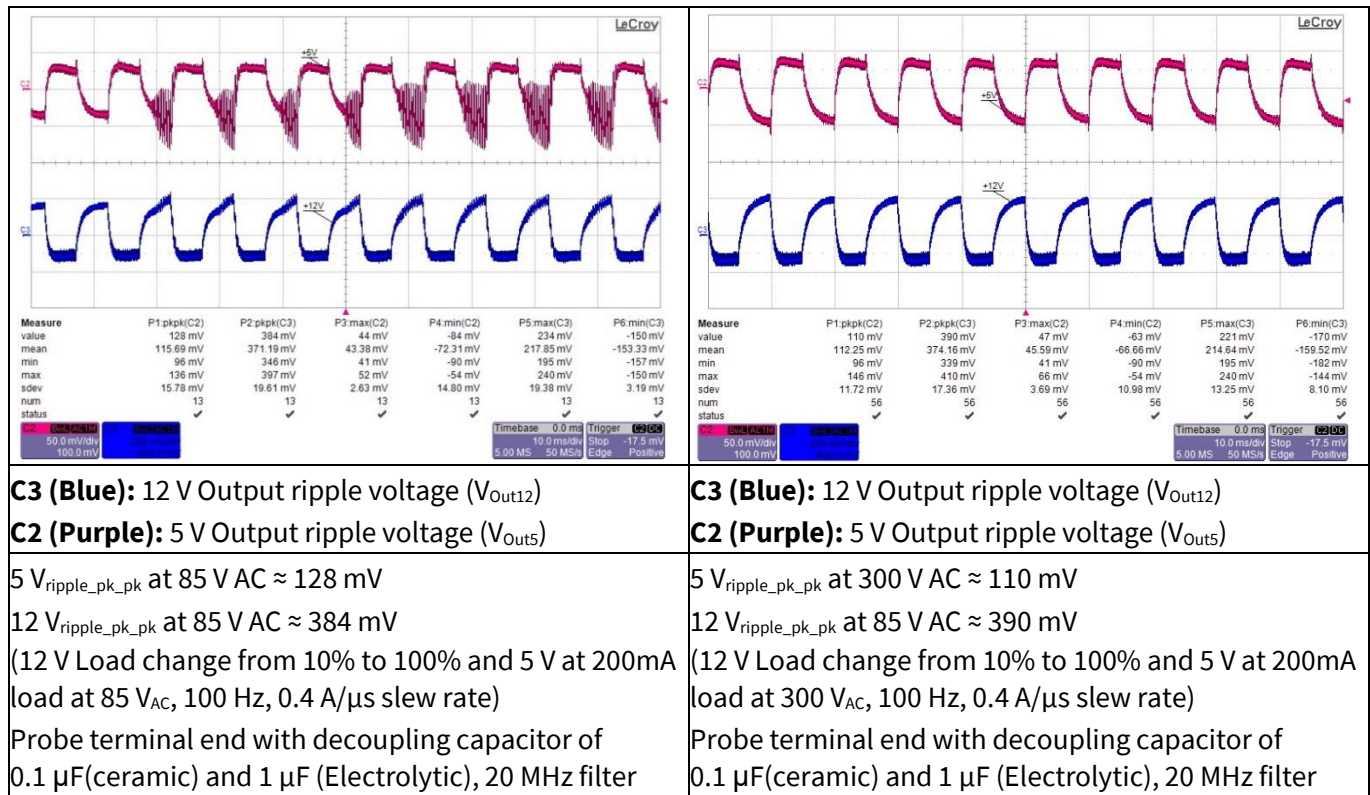
Figure 19 Zero crossing

24 W, 12 V and 5 V SMPS reference board with CoolSET™ ICE5QR2280BG-1

REF_5QR2280BG-1_24W1

Waveforms and scope plots

11.5 Load transient response (dynamic load from 10% to 100%)



C3 (Blue): 12 V Output ripple voltage (V_{Out12})

C2 (Purple): 5 V Output ripple voltage (V_{Out5})

5 V_{ripple_pk_pk} at 85 V AC \approx 128 mV

12 V_{ripple_pk_pk} at 85 V AC \approx 384 mV

(12 V Load change from 10% to 100% and 5 V at 200mA load at 85 V_{AC}, 100 Hz, 0.4 A/ μ s slew rate)

Probe terminal end with decoupling capacitor of 0.1 μ F(ceramic) and 1 μ F (Electrolytic), 20 MHz filter

C3 (Blue): 12 V Output ripple voltage (V_{Out12})

C2 (Purple): 5 V Output ripple voltage (V_{Out5})

5 V_{ripple_pk_pk} at 300 V AC \approx 110 mV

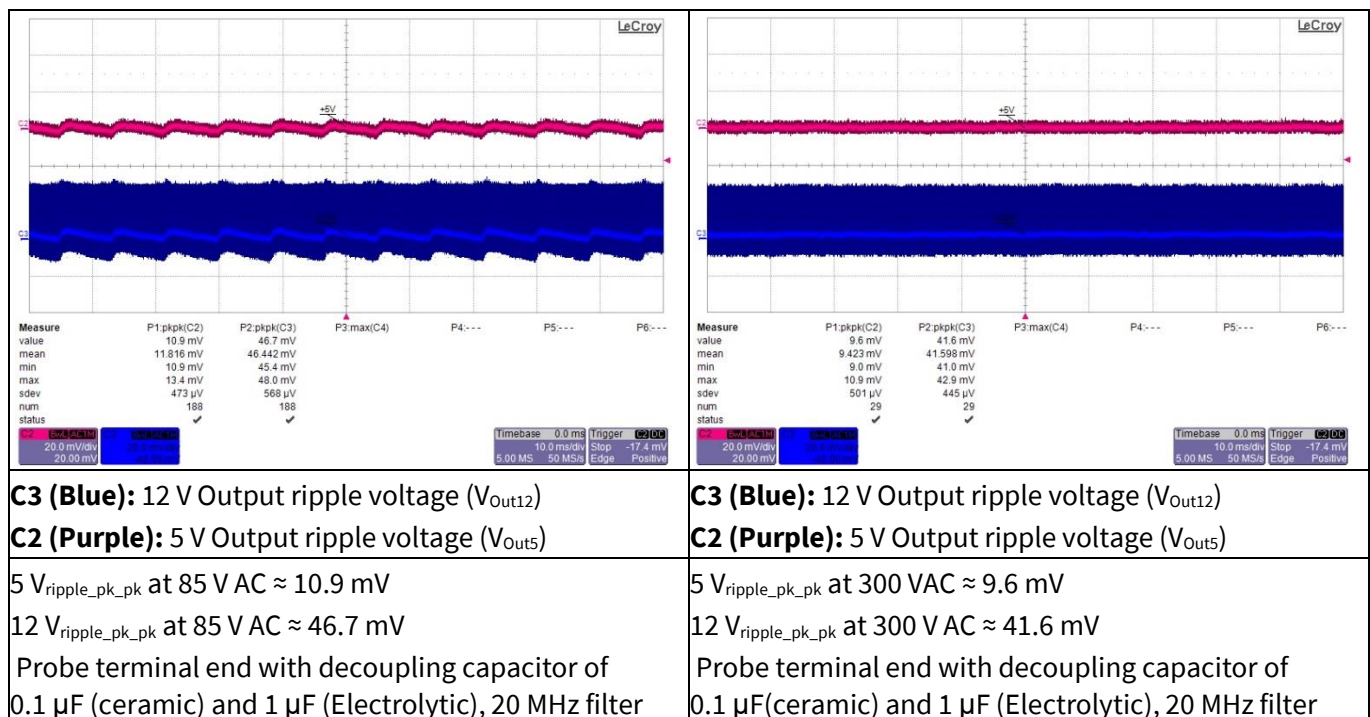
12 V_{ripple_pk_pk} at 85 V AC \approx 390 mV

(12 V Load change from 10% to 100% and 5 V at 200mA load at 300 V_{AC}, 100 Hz, 0.4 A/ μ s slew rate)

Probe terminal end with decoupling capacitor of 0.1 μ F(ceramic) and 1 μ F (Electrolytic), 20 MHz filter

Figure 20 Load transient response

11.6 Output ripple voltage at maximum load



C3 (Blue): 12 V Output ripple voltage (V_{Out12})

C2 (Purple): 5 V Output ripple voltage (V_{Out5})

5 V_{ripple_pk_pk} at 85 V AC \approx 10.9 mV

12 V_{ripple_pk_pk} at 85 V AC \approx 46.7 mV

Probe terminal end with decoupling capacitor of 0.1 μ F (ceramic) and 1 μ F (Electrolytic), 20 MHz filter

C3 (Blue): 12 V Output ripple voltage (V_{Out12})

C2 (Purple): 5 V Output ripple voltage (V_{Out5})

5 V_{ripple_pk_pk} at 300 V AC \approx 9.6 mV

12 V_{ripple_pk_pk} at 300 V AC \approx 41.6 mV

Probe terminal end with decoupling capacitor of 0.1 μ F(ceramic) and 1 μ F (Electrolytic), 20 MHz filter

Figure 21 Output ripple voltage at maximum load

24 W, 12 V and 5 V SMPS reference board with CoolSET™ ICE5QR2280BG-1

REF_5QR2280BG-1_24W1

Waveforms and scope plots

11.7 Output ripple voltage at ABM 1 W load

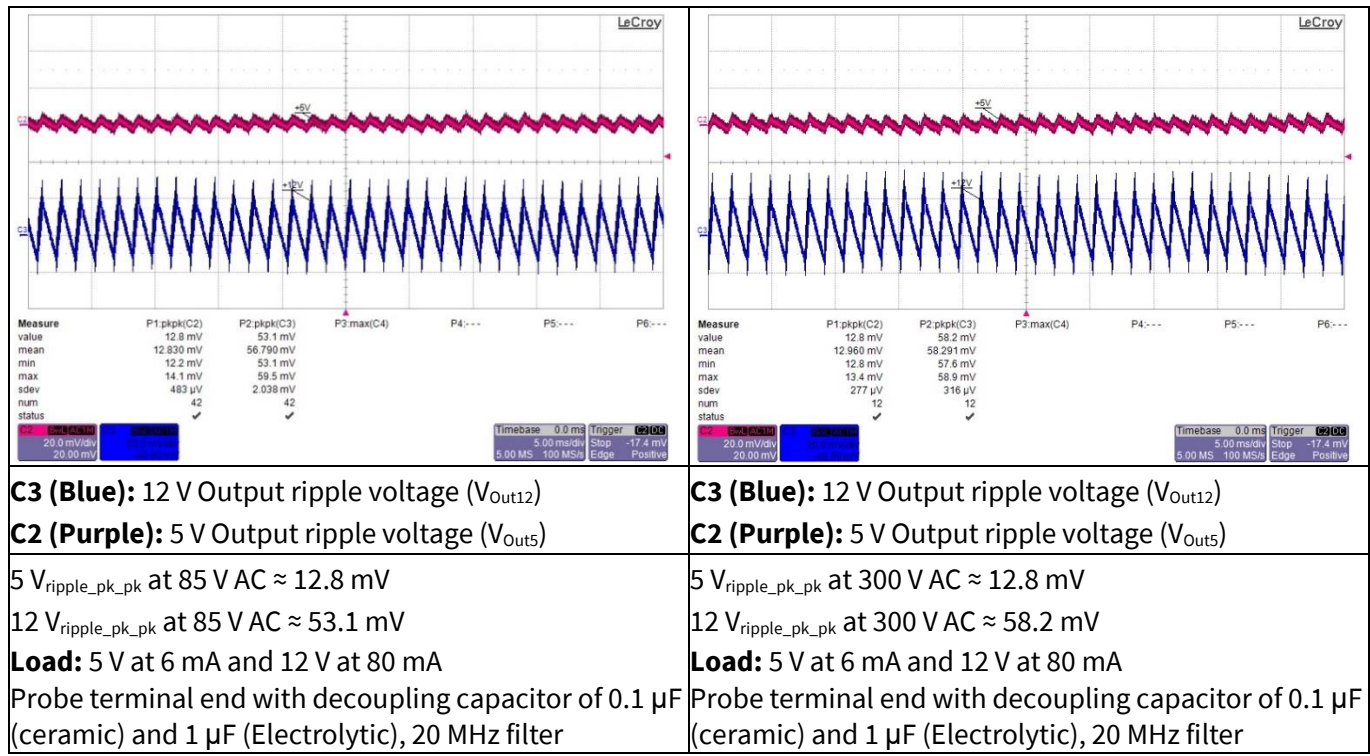


Figure 22 Output ripple voltage at ABM 1 W load

11.8 Entering ABM

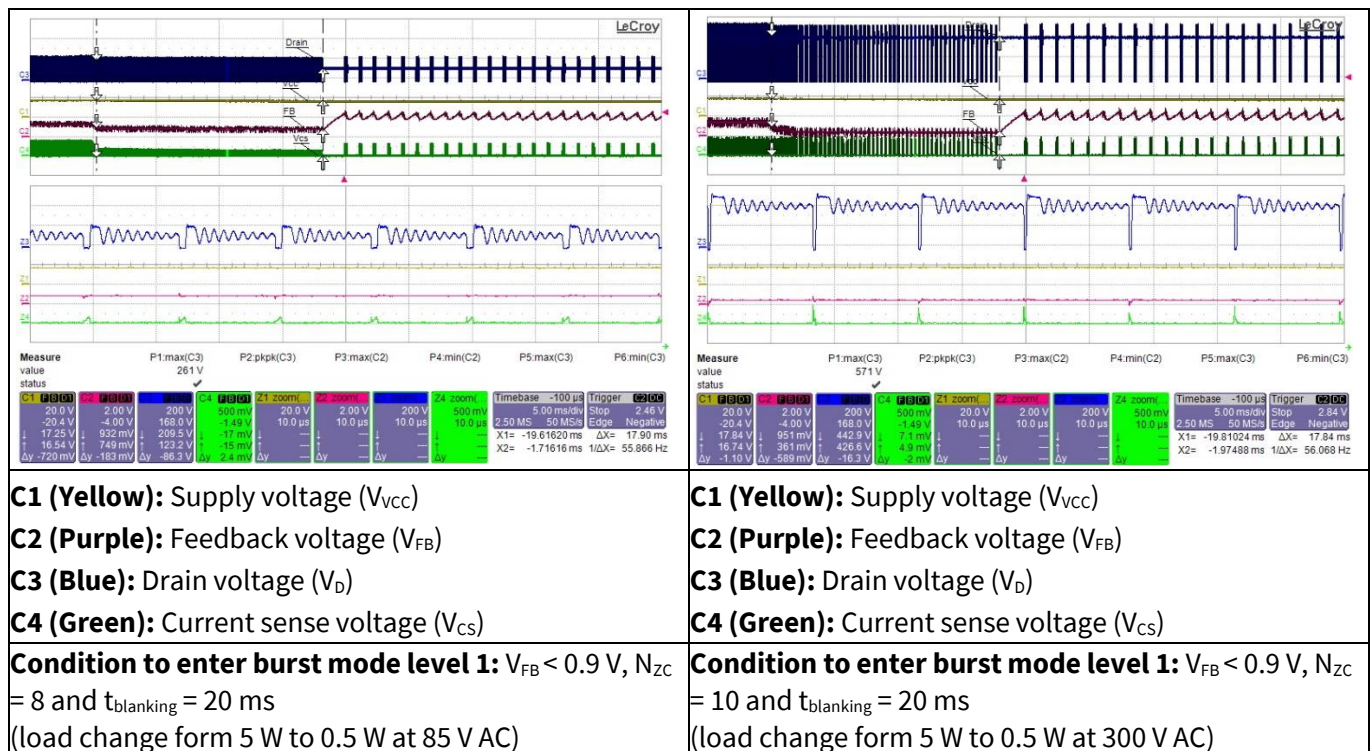


Figure 23 Entering ABM

24 W, 12 V and 5 V SMPS reference board with CoolSET™

ICE5QR2280BG-1

REF_5QR2280BG-1_24W1

Waveforms and scope plots

11.9 During ABM

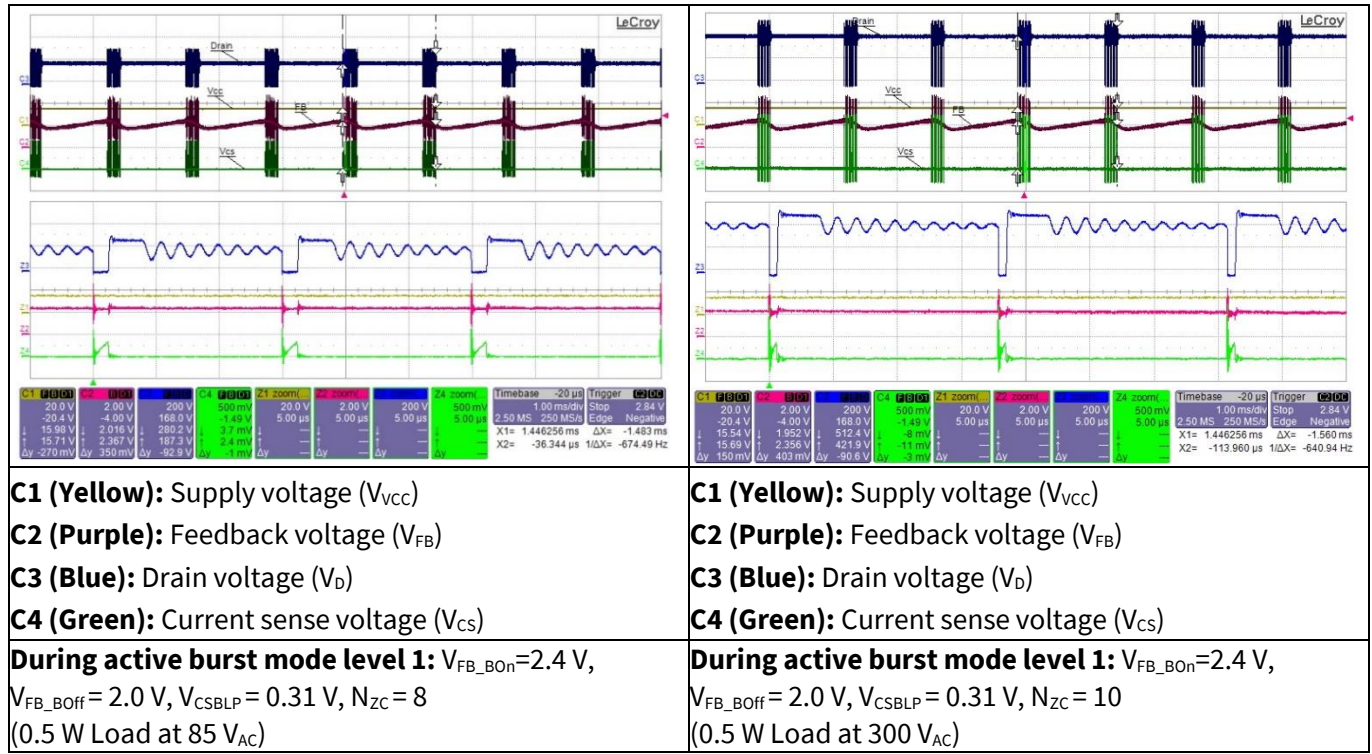


Figure 24 During ABM

11.10 Leaving ABM

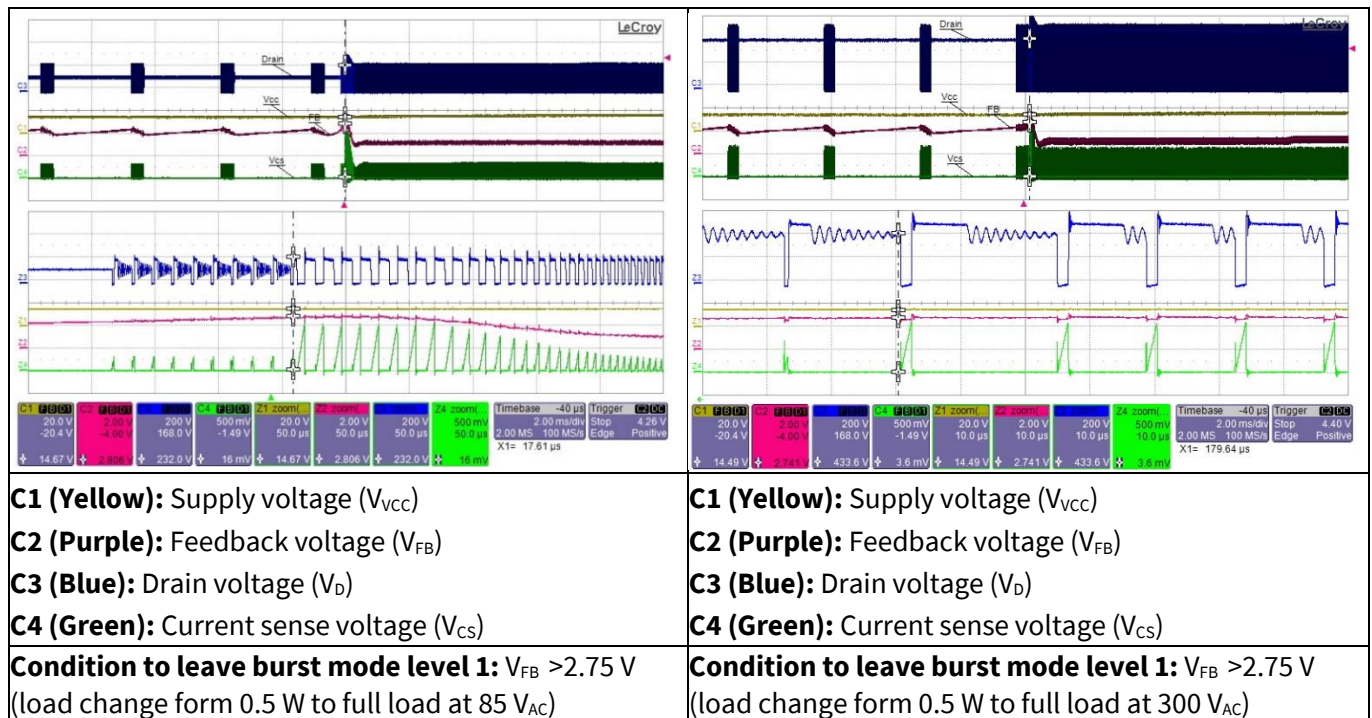


Figure 25 Leaving ABM

24 W, 12 V and 5 V SMPS reference board with CoolSET™ ICE5QR2280BG-1

REF_5QR2280BG-1_24W1

Waveforms and scope plots

11.11 Line OVP (non-switch auto-restart)

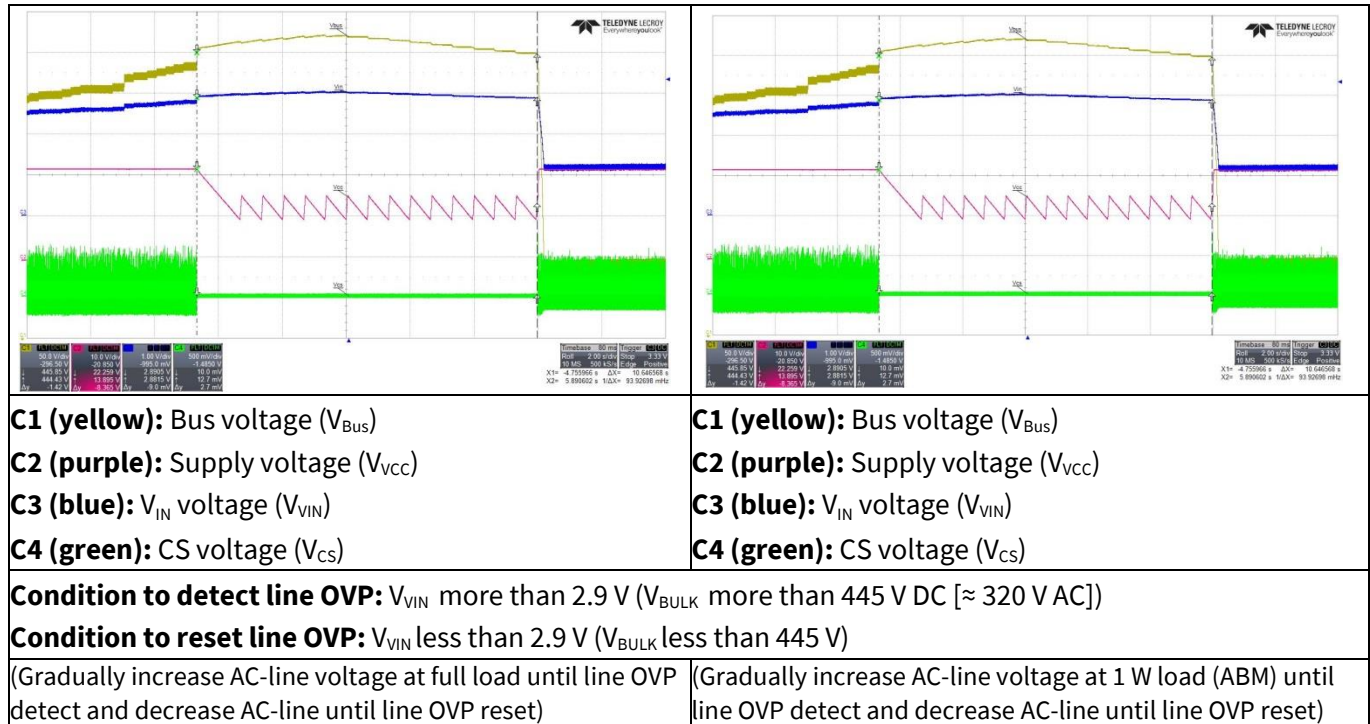


Figure 26 Line OVP

11.12 Brownout protection (non-switch auto-restart)

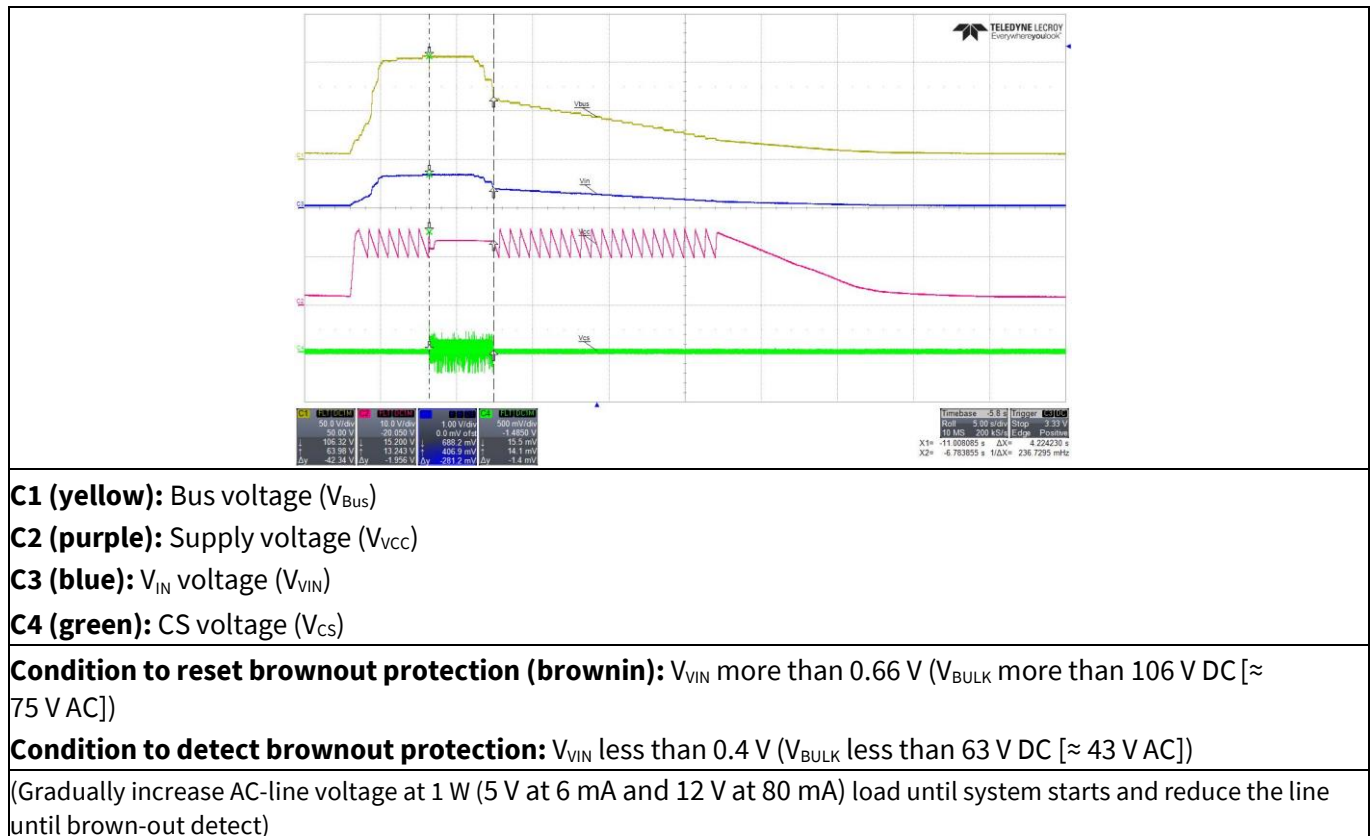
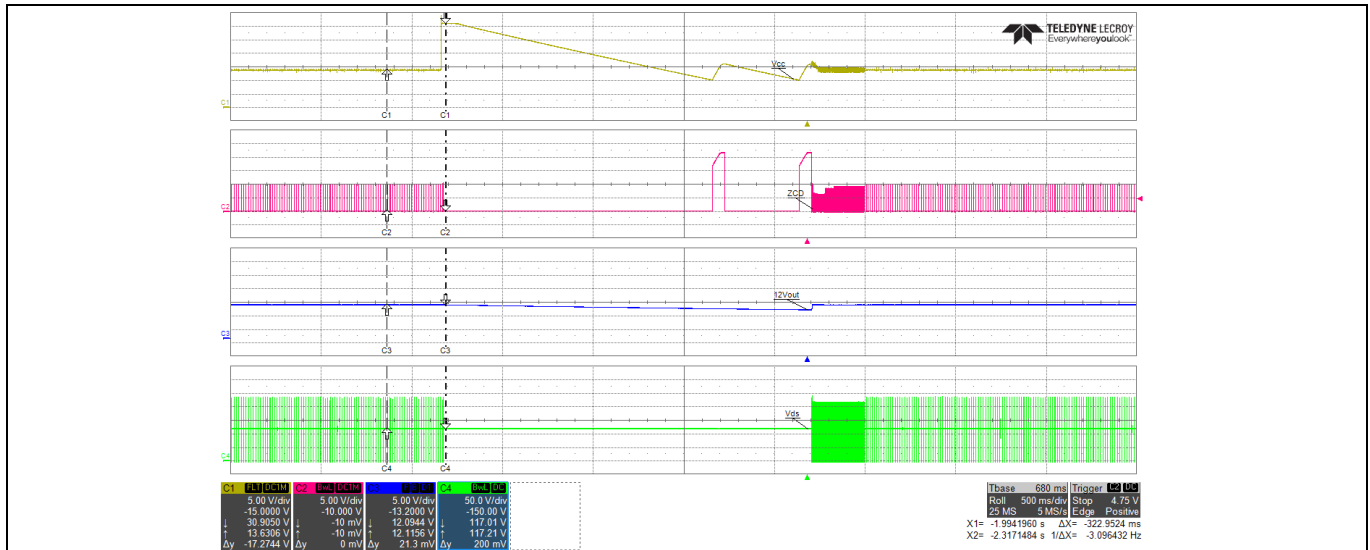


Figure 27 Brownout protection

11.13 V_{CC} OVP (odd-skip auto-restart)

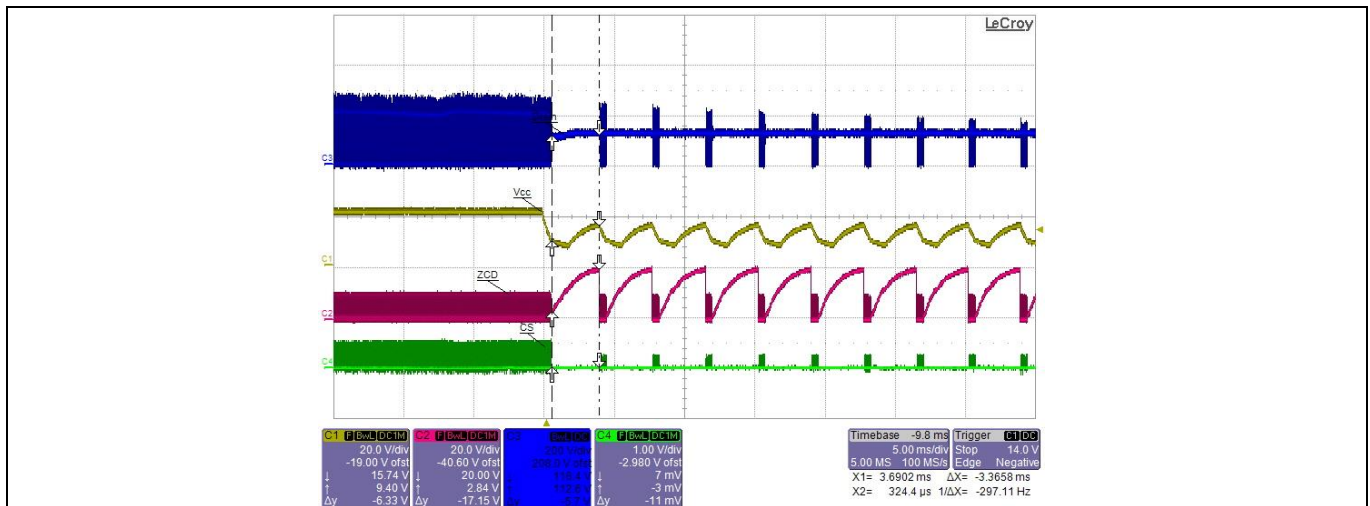


- C1 (yellow):** V_{CC} voltage (V_{CC})
- C2 (purple):** ZCD voltage (V_{ZCD})
- C3 (blue):** 12 V output voltage (V_{O12})
- C4 (green):** V_{DS} voltage (V_{DS})

Condition to enter V_{CC} OVP: V_{CC} more than 30.5 V
(at 85 V AC, no load. Apply externally a DC Pulse at V_{CC} pin > V_{VCC_OVP}.)

Figure 28 V_{CC} OVP

11.14 V_{CC} undervoltage protection (auto restart)



- C1 (Yellow):** Supply voltage (V_{CC})
- C2 (Purple):** Zero crossing detection voltage (V_{ZCD})
- C3 (Blue):** Drain voltage (V_D)
- C4 (Green):** Current sense voltage (V_{CS})

Condition to enter V_{CC} undervoltage protection: V_{CC} < 10 V
(Remove R6 during normal operation at 85 V_{AC})

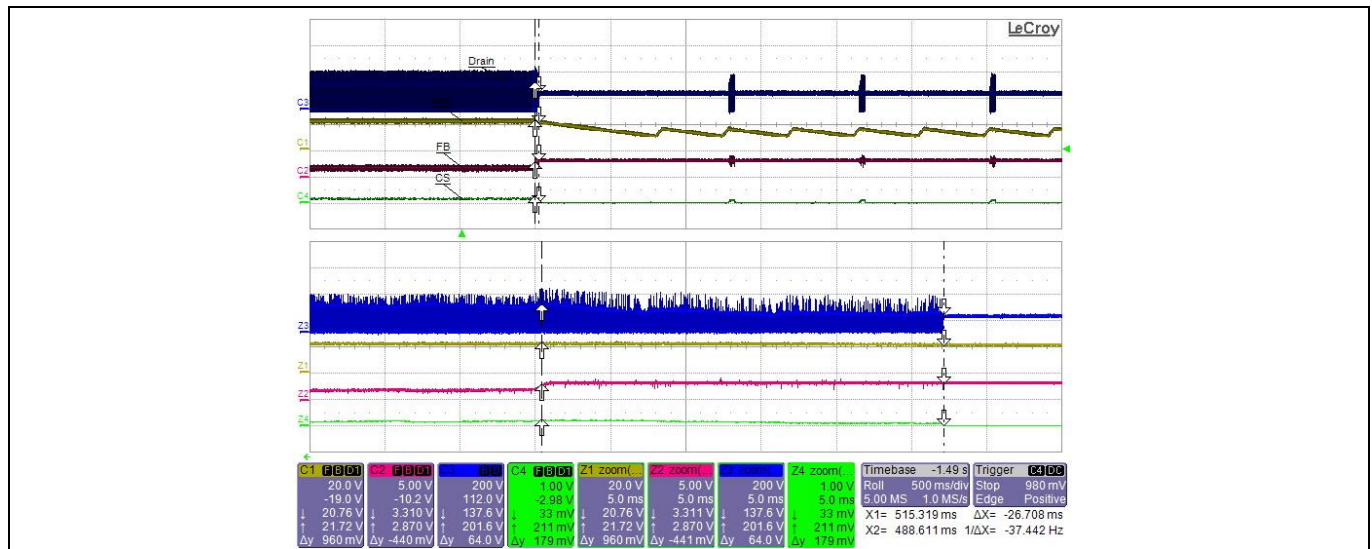
Figure 29 V_{CC} undervoltage protection

24 W, 12 V and 5 V SMPS reference board with CoolSET™ ICE5QR2280BG-1

REF_5QR2280BG-1_24W1

Waveforms and scope plots

11.15 Overload protection (odd-skip auto-restart)



C1 (Yellow): Supply voltage (V_{VCC})

C2 (Purple): Feedback voltage (V_{FB})

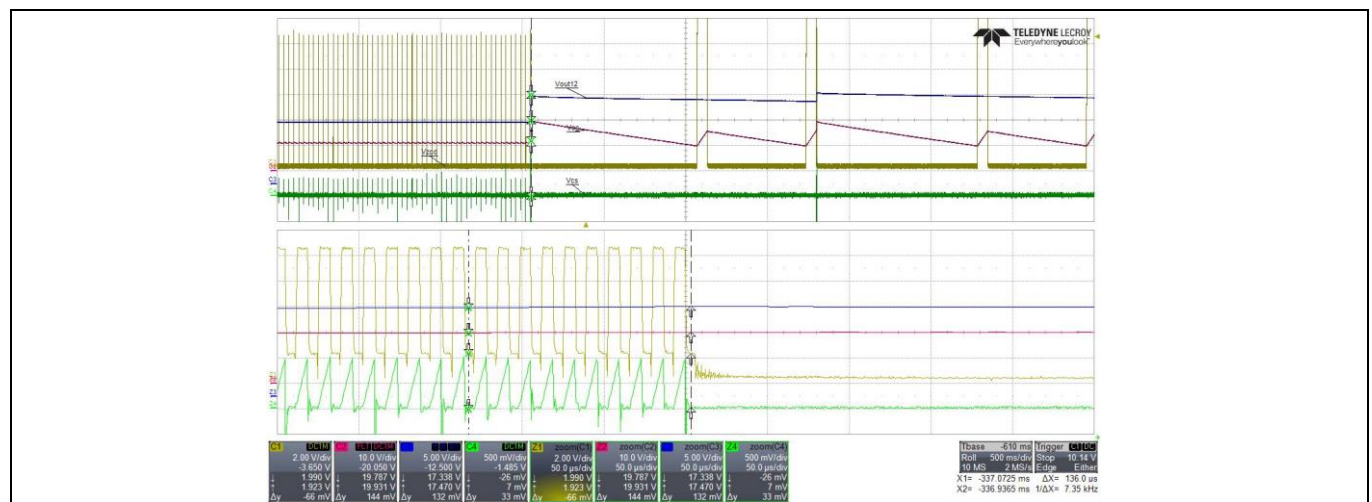
C3 (Blue): Drain voltage (V_D)

C4 (Green): Current sense voltage (V_{CS})

Condition to enter overload protection: $V_{FB} > 2.75\text{ V}$ and last for 30 ms blanking time
(12 V output load change from full load to short at 85 V AC)

Figure 30 OVP

11.16 Output OVP (odd-skip auto-restart)



C1 (yellow): ZCD voltage (V_{ZCD})

C2 (purple): Supply voltage (V_{VCC})

C3 (blue): 12 V output voltage (V_{O12})

C4 (green): CS voltage (V_{CS})

Condition to enter output OVP: V_{ZCD} more than 1.9 V
(85 V AC, short R26 during system operation at no load)

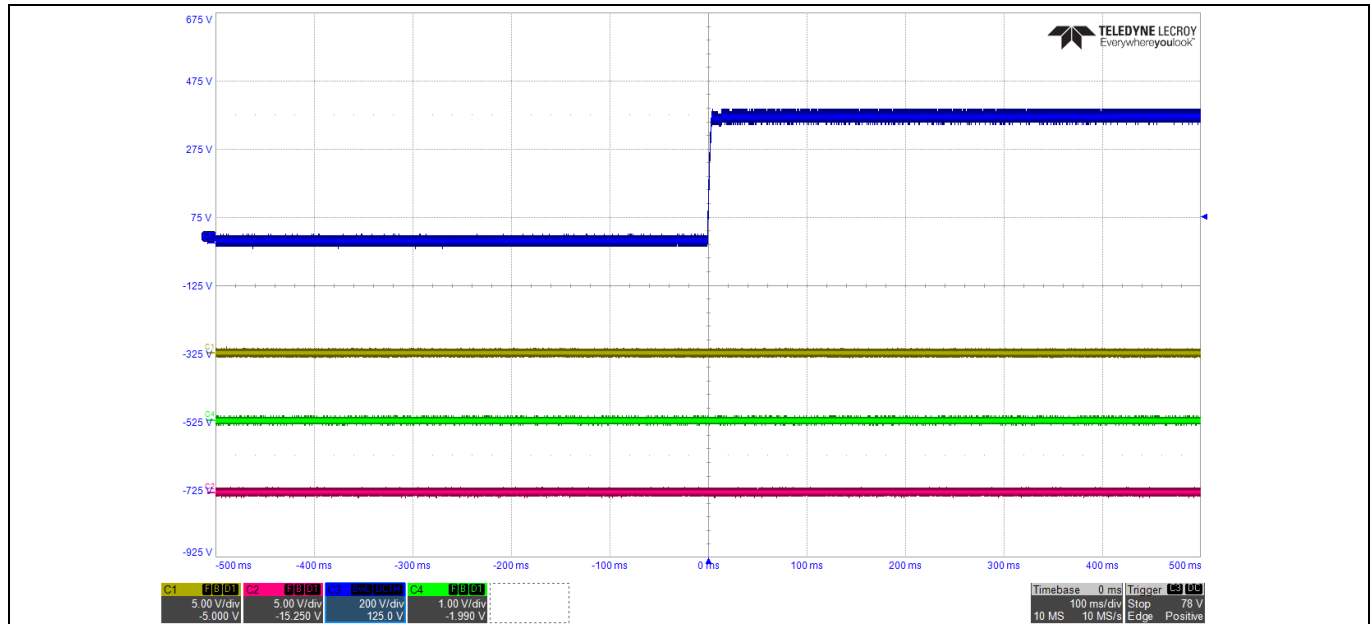
Figure 31 Output OVP

24 W, 12 V and 5 V SMPS reference board with CoolSET™ ICE5QR2280BG-1

REF_5QR2280BG-1_24W1

Waveforms and scope plots

11.17 V_{CC} short-to-GND protection



C1 (Yellow): V_{CC} voltage (V_{VCC})

C2 (Purple): Zero crossing detection voltage (V_{ZCD})

C3 (Blue): Drain voltage (V_D)

C4 (Green): Current sense voltage (V_{CS})

Condition to enter V_{CC} short to GND: If $V_{CC} < V_{VCC_SCP}$ $I_{VCC} = I_{VCC_Charge1}$

(Short V_{CC} pin to GND and measure the AC input current, $I_{in} \approx 24.4$ mA and input power is ≈ 40.2 mW at 264 V AC)

Figure 32 V_{CC} short-to-GND protection

References

12 References

- [1] Infineon Technologies AG: *ICE5QRxx80BG-1 datasheet*; [Available online](#)
- [2] Infineon Technologies AG: *CoolSET™ 5th Generation Quasi-Resonant Plus flyback design guide*; [Available online](#)
- [3] Infineon Technologies AG: *CoolSET™ 5th Generation Quasi-Resonant Plus calculation tool for flyback*; [Available online](#)

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Revision history

Revision history

Document revision	Date	Description of changes
V 1.0	2024-11-19	Initial release

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Edition 2024-11-19

Published by

Infineon Technologies AG

81726 Munich, Germany

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AN110939

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