

# 12W 12V SMPS Demo Board with ICE2QR4780G

## AN-DEMO-2QR4780G

### About this document

#### Scope and purpose

This document is an engineering report that describes universal input 12 W 12 V off-line flyback converter using Infineon Quasi-Resonant CoolSET™ ICE2QR4780G which offers high efficiency, very low standby power, wider  $V_{CC}$  operating range and various mode of protections for a high reliable system. This demonstrator board is designed for users who wish to evaluate the performance of ICE2QR4780G in ease of use.

#### Intended audience

This document is intended for power supply design/application engineer, students, etc.) who wish to design low cost and high reliable systems of off-line Switched Mode Power Supply (SMPS) for enclosed adapter, blu-ray/DVD player, set-top box, game console, smart meter, auxiliary power supply of white goods, PC, server, etc.

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**Abstract**

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**Abstract**

## **1 Abstract**

This application note is an engineering report of 12 W 12V demo board designed in a quasi resonant flyback converter topology using ICE2QR4780G Quasi-resonant CoolSET™. The target applications of ICE2QR4780G are set-top box, portable game controller, Blue-Ray/DVD player, netbook adapter and auxiliary power supply of PC, printer, TV, home theater/audio system, etc. With the CoolMOS™ integrated in this IC, it greatly simplifies the design and layout of the PCB. Due to valley switching, the turn on voltage is reduced and this offers higher conversion efficiency comparing to hard-switching flyback converter. With the DCM mode control, the reverse recovery problem of secondary rectify diode is relieved. And for its natural frequency jittering with line voltage, the EMI performance is better. Infineon's digital frequency reduction technology enables a quasi-resonant operation till very low load. As a result, the system efficiency, over the entire load range, is significantly improved compared to conventional free running quasi resonant converter implemented with only maximum switching frequency limitation at light load. In addition, numerous adjustable protection functions have been implemented in ICE2QR4780G to protect the system and customize the IC for the chosen application. In case of failure modes, like open control-loop/over load, output overvoltage, and transformer short winding, the device switches into Auto Restart Mode or Latch-off Mode. By means of the cycle-by-cycle peak current limitation plus foldback point correction, the dimension of the transformer and current rating of the secondary diode can both be optimized. Thus, a cost effective solution can be easily achieved



### 3 Specifications of Demonstrator Board

**Table 1 Specifications of DEMO-2QR4780G**

Input voltage and frequency	85 V <sub>AC</sub> (60 Hz) ~ 265 V <sub>AC</sub> (50Hz)
Output voltage, current and power	12 V, 1 A, 12 W
Dynamic load response (10% to 100% load, slew rate at 1.5 A/μs, 100 Hz)	±3% of nominal output voltage (V <sub>ripple_p-p</sub> < 200 mV)
Output ripple voltage (full load, 85 V <sub>AC</sub> ~ 265 V <sub>AC</sub> )	±1% of nominal output voltage (V <sub>ripple_p-p</sub> < 60 mV)
Active mode four point average efficiency (25%, 50%, 75%, 100% load) (EU CoC Version 5, Tier 1)	>86% at 115 V <sub>AC</sub> and >85% 230 V <sub>AC</sub>
10% load efficiency (EU CoC Version 5, Tier 1)	>83% at 115 V <sub>AC</sub> and >82% 230 V <sub>AC</sub>
No load power consumption (EU CoC Version 5, Tier 1)	< 50 mW at 265 V <sub>AC</sub>
Conducted emissions (EN55022 class B)	Pass with 10 dB margin for 115 V <sub>AC</sub> and 6 dB margin for 230 V <sub>AC</sub>
ESD immunity (EN61000-4-2)	Special Level (±16 kV for both contact and air discharge)
Surge immunity (EN61000-4-5)	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)	(98 x 44 x 24) mm <sup>3</sup>

**Circuit description**

## **4 Circuit description**

### **4.1 Line input**

The AC line input side comprises the input fuse F1 as over-current protection. The choke L11, X-capacitor C11 and Y-capacitor C12 act as EMI suppressors. Optional spark gap devices SA1, SA2 and varistor VAR can absorb high voltage stress during lightning surge test. A rectified DC voltage (120~374 V<sub>DC</sub>) is obtained through the bridge rectifier BR1 together with bulk capacitor C13.

### **4.2 Start up**

Since there is a built-in startup cell in the ICE2QR4780G, there is no need for external start up resistor, which can improve standby performance significantly.

When V<sub>VCC</sub> reaches the turn on voltage threshold 18V, the IC begins with a soft start. The soft-start implemented in ICE2QR4780G is a digital time-based function. The preset soft-start time is 12 ms with 4 steps. If not limited by other functions, the peak voltage on CS pin will increase step by step from 0.32 V to 1 V finally. After IC turns on, the V<sub>VCC</sub> voltage is supplied by auxiliary windings of the transformer.

### **4.3 Integrated MOSFET and PWM control**

ICE2QR4780G is comprised of a power MOSFET and the Quasi-Resonant controller; this integrated solution greatly simplifies the circuit layout and reduces the cost of PCB manufacturing. The PWM switch-on is determined by the zero-crossing input signal and the value of the up/down counter. The PWM switch-off is determined by the feedback signal V<sub>FB</sub> and the current sensing signal V<sub>CS</sub>. ICE2QR4780G also performs all necessary protection functions in flyback converters. Details about the information mentioned above are illustrated in the product datasheet.

### **4.4 RCD clamper circuit**

A clamper network (R11, C15 and D11) dissipates the energy of the leakage inductance and suppress ringing on the SMPS transformer.

### **4.5 Output stage**

On the secondary side, 12 V output, the power is coupled out via a schottky diode D21. The capacitor C22 provides energy buffering followed by the L-C filters L21 and C24 to reduce the output ripple and prevent interference between SMPS switching frequency and line frequency considerably. Storage capacitor C22 and C23 is designed to have an internal resistance (ESR) as small as possible. This is to minimize the output voltage ripple caused by the triangular current.

### **4.6 Feedback loop**

For feedback, the output is sensed by the voltage divider of R26 and R25 and compared to IC21 (TL431) internal reference voltage. C25, C26 and R24 comprise the compensation network. The output voltage of IC21 (TL431) is converted to the current signal via optocoupler IC12 and two resistors R22 and R23 for regulation control.



**Circuit description**

## **4.7 Primary side peak current control**

The MOSFET drain source current is sensed via external resistor R14 and R14A. Since ICE2QR4780G is a current mode controller, it would have a cycle-by-cycle primary current and feedback voltage control which can make sure the maximum power of the converter is controlled in every switching cycle.

For a Quasi-Resonant flyback converter, the maximum possible output power is increased when a constant current limit value is used for all the line input voltage range. This is usually not desired as this will increase additional cost on transformer and output diode in case of output over power conditions.

The internal foldback point correction is implemented to adjust the  $V_{CS}$  voltage limit according to the input line voltage. Here, the input line voltage is sensed using the current flowing out of ZC pin, during the MOSFET on-time. As the result, the maximum current limit will be lower at high input voltage and the maximum output power can be well limited versus the input voltage.

## **4.8 Digital frequency reduction**

During normal operation, the switching frequency for ICE2QR4780G is digitally reduced with decreasing load. At light load, the MOSFET will be turned on not at the first minimum drain-source voltage time, but on the nth. The counter is in range of 1 to 7, which depends on 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 monitoring voltage  $V_{FB}$ . The counter will be increased with low  $V_{FB}$  and decreased with high  $V_{FB}$ . The thresholds are preset inside the IC.

## **4.9 Active burst mode**

At light load condition, the SMPS enters into Active Burst Mode. At this stage, the controller is always active but the  $V_{VCC}$  must be kept above the switch off threshold. During active burst mode, the efficiency increase significantly and at the same time it supports low ripple on  $V_{out}$  and fast response on load jump.

For determination of entering Active Burst Mode operation, three conditions apply:

1. The feedback voltage is lower than the threshold of  $V_{FBEB}$  (1.25 V). Accordingly, the peak current sense voltage across the shunt resistor is 0.17;
2. The up/down counter is 7;
3. And a certain blanking time ( $t_{BEB}=24$  ms).

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

During active burst mode, the maximum current sense voltage is reduced from 1 V to 0.34 V so as to reduce the conduction loss and the audible noise. At the burst mode, the FB voltage is changing like a sawtooth between 3.0 V and 3.6 V.

The feedback voltage immediately increases if there is a high load jump. This is observed by one comparator. As the current limit is 34% during Active Burst Mode a certain load is needed so that feedback voltage can exceed  $V_{FBLB}$  (4.5 V). After leaving active burst mode, maximum current can now be provided to stabilize  $V_{out}$ . In addition, the up/down counter will be set to 1 immediately after leaving Active Burst Mode. This is helpful to decrease the output voltage undershoot.

**Protection features**

## **5 Protection features**

### **5.1 $V_{CC}$ over voltage and under voltage protection**

During normal operation, the  $V_{CC}$  voltage is continuously monitored. When the  $V_{CC}$  voltage increases up to  $V_{CC,OV}$  or  $V_{CC}$  voltage falls below the under voltage lock out level  $V_{CC,off}$ , the IC will enter into autorestart mode.

### **5.2 Over load/Open loop protection**

In case of open control loop, feedback voltage is pulled up with internally block. After a fixed blanking time, the IC enters into auto restart mode. In case of secondary short-circuit or overload, regulation voltage  $V_{FB}$  will also be pulled up, same protection is applied and IC will auto restart.

### **5.3 Over temperature protection**

The IC has a built-in over temperature protection function. When the controller's temperature reaches 140°C, the IC will shut down switch and enters into auto restart. This can protect power MOSFET from overheated.

### **5.4 Adjustable output overvoltage protection**

During off-time of the power switch, the voltage at the zero-crossing pin ZC is monitored for output overvoltage detection. If the voltage is higher than the preset threshold 3.7 V for a preset period 100  $\mu$ s, the IC is latched off.

### **5.5 Short winding protection**

The source current of the MOSFET is sensed via external resistor R14 and R14A. If the voltage at the current sensing pin is higher than the preset threshold  $V_{CSSW}$  of 1.68 V during the on-time of the power switch, the IC is latched off. This constitutes a short winding protection. To avoid an accidental latch off, a spike blanking time of 190 ns is integrated in the output of internal comparator.

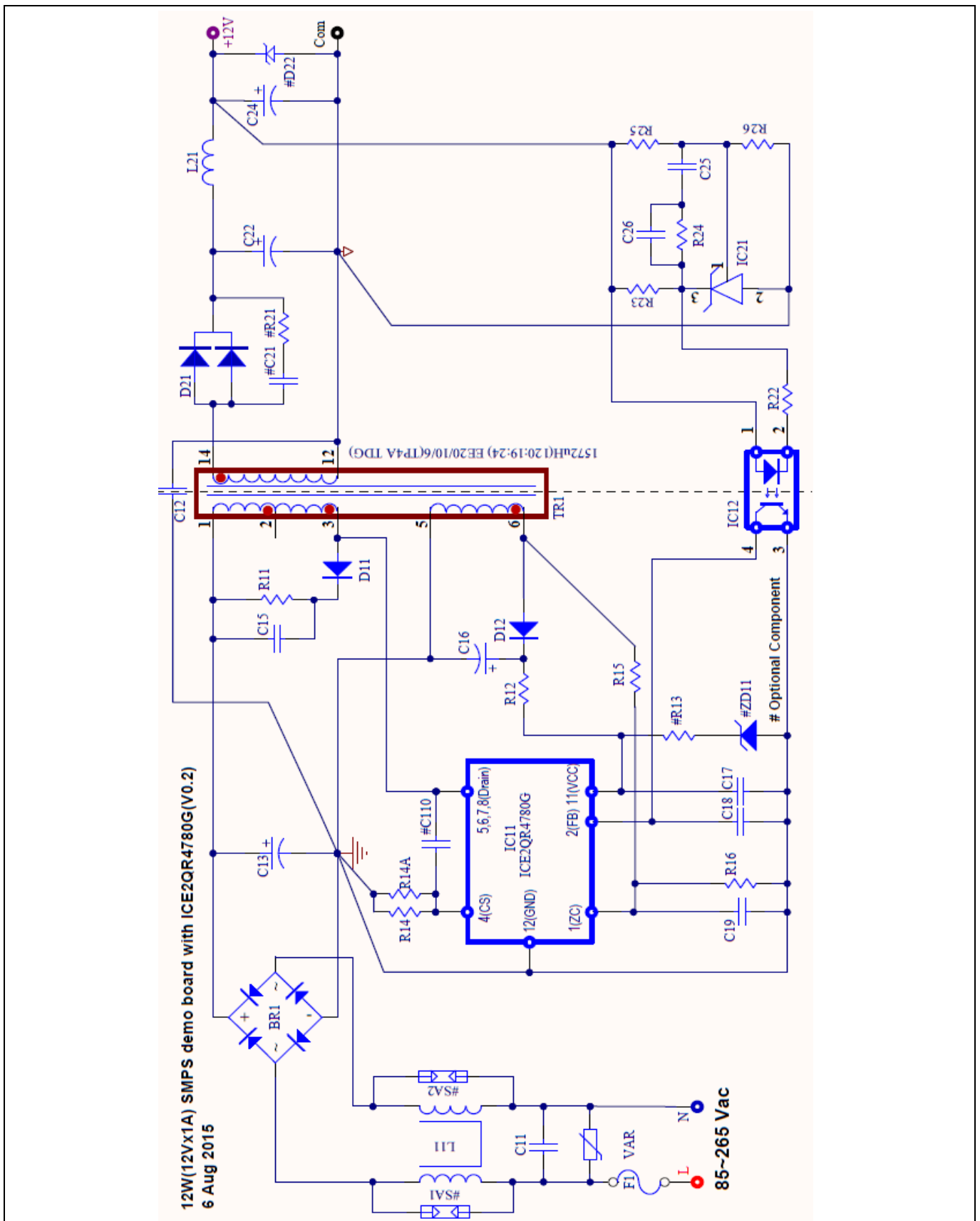
**Table 2 Protection function of ICE2QR4780G**

<b>Protection Function</b>	<b>Failure Condition</b>	<b>Protection Mode</b>
VCC Overvoltage	$V_{VCC} > 25 \text{ V}$ & last for 10 $\mu$ s (normal mode only)	Auto Restart
VCC Undervoltage/ Short Optocoupler	$V_{VCC} < 10.5 \text{ V}$	Auto Restart
Overload/Open Loop	$V_{FB} > 4.5 \text{ V}$ & last for 30 ms	Auto Restart
Over Temperature (Controller Junction)	$T_J > 140 \text{ }^\circ\text{C}$	Auto Restart
Output Overvoltage	$V_{ZCOVP} > 3.7 \text{ V}$ & last for 100 $\mu$ s	Latch
Short Winding	$V_{CSSW} > 1.68 \text{ V}$ & last for 190 ns	Latch



Circuit diagram

6 Circuit diagram



**Circuit diagram**

*Note: General guideline for layout design of Printed Circuit Board (PCB):*

1. *Star ground at bulk capacitor C13: all primary grounds should be connected to the ground of bulk capacitor C13 separately in one point. It can reduce the switching noise going into the sensitive pins of CoolSET™ device effectively. The primary star ground can be split into five groups as follows,*
  - i. *Signal ground includes all small signal grounds connecting to the CoolSET™ GND pin such as filter capacitor ground C17, C18, C19 and opto-coupler ground.*
  - ii. *VCC ground includes the VCC capacitor ground C16 and the auxiliary winding ground, pin 5 of the power transformer.*
  - iii. *Current Sense resistor ground includes current sense resistor R14 and R14A.*
  - iv. *EMI return ground includes Y capacitor C12.*
  - v. *DC ground from bridge rectifier, BR1*
2. *Filter capacitor close to the controller ground: Filter capacitors, C17, C18 and C19 should be placed as close to the controller ground and the controller pin as possible so as to reduce the switching noise coupled into the controller.*
3. *High voltage traces clearance: High voltage traces should keep enough spacing to the nearby traces. Otherwise, arcing would incur.*
  - i. *400 V traces (positive rail of bulk capacitor C13) to nearby trace: > 2.0 mm*
  - ii. *600V traces (drain voltage of CoolSET™ IC11) to nearby trace: > 2.5 mm*
4. *Recommended minimum 232mm<sup>2</sup> copper area at drain pin to add on PCB for better thermal performance.*
5. *Power loop area (bulk capacitor C13, primary winding of the transformer TR1 (Pin 1 and 3), IC11 Drain pin, IC11 CS pin and current sense resistor R14/R14A) should be as small as possible to minimize the switching emission.*



**Bill of material**

**8 Bill of material**

**Table 3 Bill of material (V0.2)**

No.	Designator	Description	Part Number	Manufacturer	Quantity
1	BR1	600V/1A	S1VBA60	Shindengen	1
2	C11	0.1μF/305V	B329221C3104K	Epcos	1
3	C12	2.2nF/250V	DE1E3KX222MA4BN01F	Murata	1
4	C13	33μF/450V	450BXC33MEFC16X25	Rubycon	1
5	C15	1nF/600V	GRM31A7U2J102JW31D9	Murata	1
6	C16	22μF/50V	50PX22MEFC5X11	Rubycon	1
7	C17	100nF/50V	GRM188R71H104KA93D	Murata	1
8	C18, C26	1nF/50V	GRM1885C1H102GA01D	Murata	2
9	C19	100pF/50V	GRM1885C1H101GA01D	Murata	1
10	C22	1000uF/16V	16ZLH1000MEFC10X16	Rubycon	1
11	C24	680uF/16V	16ZLH680MEFC8X16	Rubycon	1
12	C25	220nF/50V	GRM188R71H224KAC4D	Murata	1
13	D11	0.8A/600V	D1NK60	Shindengen	1
14	D12	0.5A/200V	GL34D		1
15	D21	30A/100V	STPS30M100SFP		1
16	F1	1.6A/300V	36911600000		1
17	HS1		577202B00000G		1
18	IC11	ICE2QR4780G	ICE2QR4780G	Infineon	1
19	IC12	SFH617A-3	SFH617A-3		1
20	IC21	TL431A	TL431A		1
21	L11	68mH/0.4A	B82731M2401A033	Epcos	1
22	L21	1uH/8A	744 746 201 0	Würth Electronics	1
23	R11	330K/2W/500V	MCF 2W 330K		1
24	R12	10Ω			1
25	R14, R14A	2.7R/ 0.33W/ ±1%	ERJ8BQF2R7V		2
26	R15	38kΩ/1%			1
27	R16	8.2kΩ/1%			1
28	R22	820Ω/5%			1
29	R23	1.2kΩ/5%			1
30	R24	68kΩ/1%			1
31	R25	38kΩ/1%			1
32	R26	10kΩ/1%			1
33	TR1	1572μH(120:19:24)	750342983	Würth Electronics	1
34	Test Point	ZC,FB,CS,Drain,Vcc,Gnd	5003		1
35	VAR	0.25W/300V	B72207S2301K101	Epcos	1
36	(L N), (+12V Com)	Connector	691102710002	Würth Electronics	2

Transformer construction

## 9 Transformer construction

Core and material: EE20/10/6(EF20), TP4A(TDG)

Bobbin: 070-5643 (14 Pin, THT, Horizontal Version)

Primary Inductance:  $L_p=1572 \mu\text{H}$  ( $\pm 10\%$ ), measured between pin 3 and pin 1

Manufacturer and part number: Wurth Electronics Midcom (750342983)

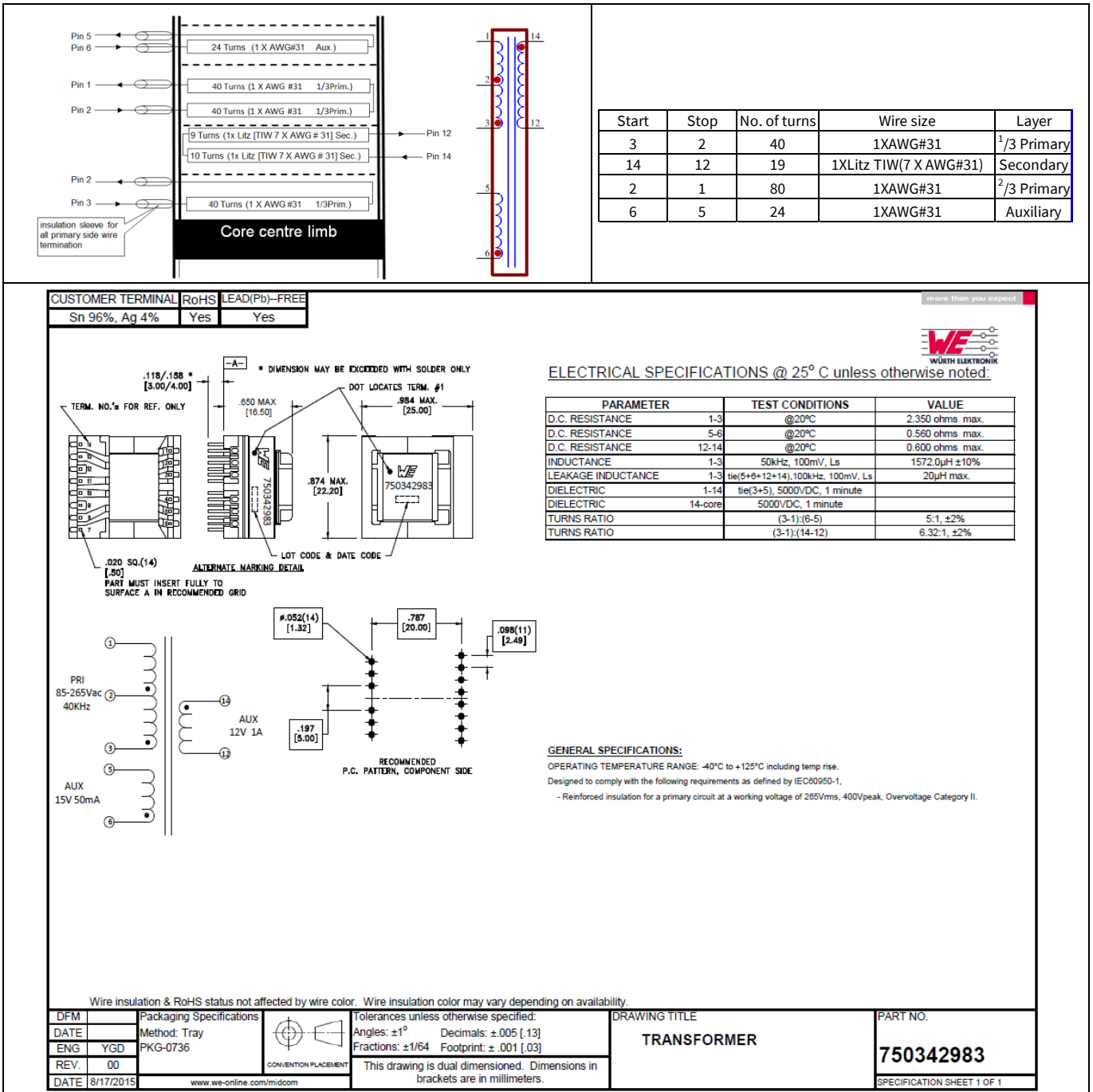


Figure 6 Transformer structure

Test results

## 10 Test results

### 10.1 Efficiency, regulation and output ripple

**Table 4 Efficiency, regulation & output ripple**

Input (V <sub>AC</sub> /Hz)	P <sub>in</sub> (W)	V <sub>out</sub> (V <sub>DC</sub> )	I <sub>out</sub> (A)	V <sub>OutRPP</sub> (mV)	P <sub>out</sub> (W)	Efficiency (η) (%)	Average η (%)	OLP P <sub>in</sub> (W)	OLP I <sub>out</sub> (A)
85 V <sub>AC</sub> /60 Hz	0.0333	12.07	0.00	40.13	/	/	/	17.10	1.18
	1.4500	12.07	0.10	47.64	1.21	83.24	/		
	3.5300	12.07	0.25	12.62	3.02	85.48	85.07		
	7.0300	12.07	0.50	15.47	6.04	85.85			
	10.5500	12.07	0.75	17.33	9.05	85.81			
	14.5200	12.07	1.00	28.36	12.07	83.13			
115 V <sub>AC</sub> /60 Hz	0.0334	12.07	0.00	39.96	/	/	/	16.70	1.19
	1.4500	12.07	0.10	48.93	1.21	83.24	/		
	3.5200	12.07	0.25	12.44	3.02	85.72	86.41		
	6.9600	12.07	0.50	14.44	6.04	86.71			
	10.4000	12.07	0.75	14.62	9.05	87.04			
	14.0100	12.07	1.00	17.60	12.07	86.15			
230 V <sub>AC</sub> /50 Hz	0.0363	12.07	0.00	41.91	/	/	/	16.80	1.21
	1.4700	12.07	0.10	51.24	1.21	82.11	/		
	3.6100	12.07	0.25	11.96	3.02	83.59	85.93		
	7.0000	12.07	0.50	13.38	6.04	86.21			
	10.4200	12.07	0.75	12.18	9.05	86.88			
	13.8700	12.07	1.00	12.36	12.07	87.02			
265V <sub>AC</sub> /50 Hz	0.0383	12.07	0.00	43.82	/	/	/	17.20	1.24
	1.4900	12.07	0.10	53.42	1.21	81.01	/		
	3.6700	12.07	0.25	11.73	3.02	82.22	85.16		
	7.0500	12.07	0.50	13.20	6.04	85.60			
	10.4900	12.07	0.75	12.27	9.05	86.30			
	13.9500	12.07	1.00	12.09	12.07	86.52			

Test results

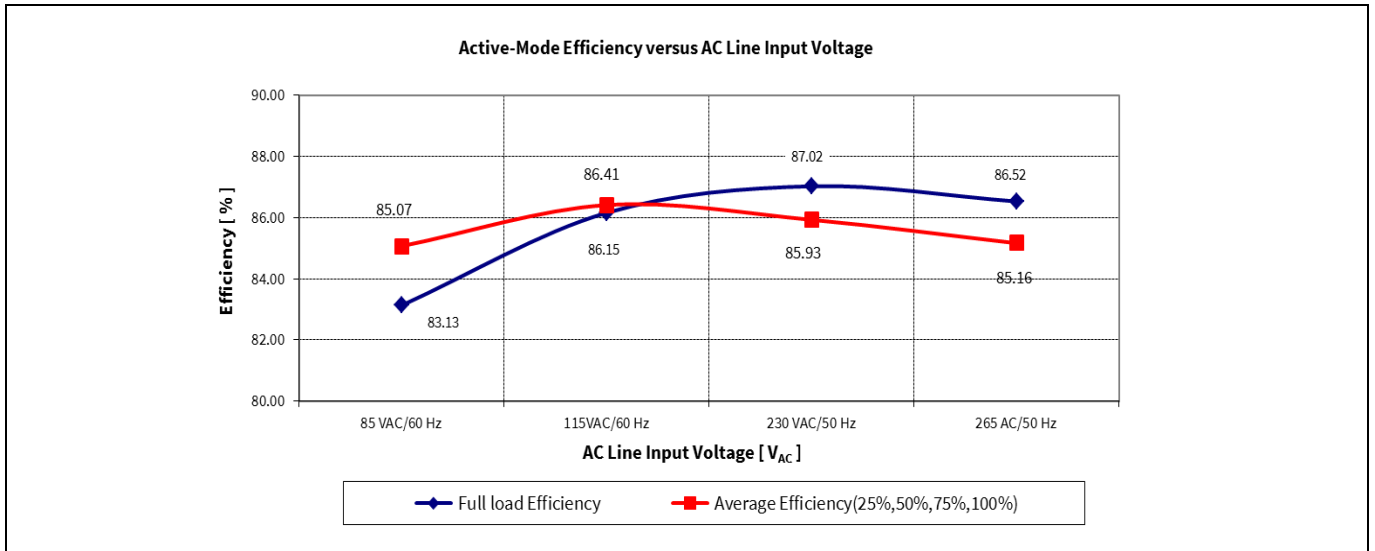


Figure 7 Efficiency vs AC line input voltage

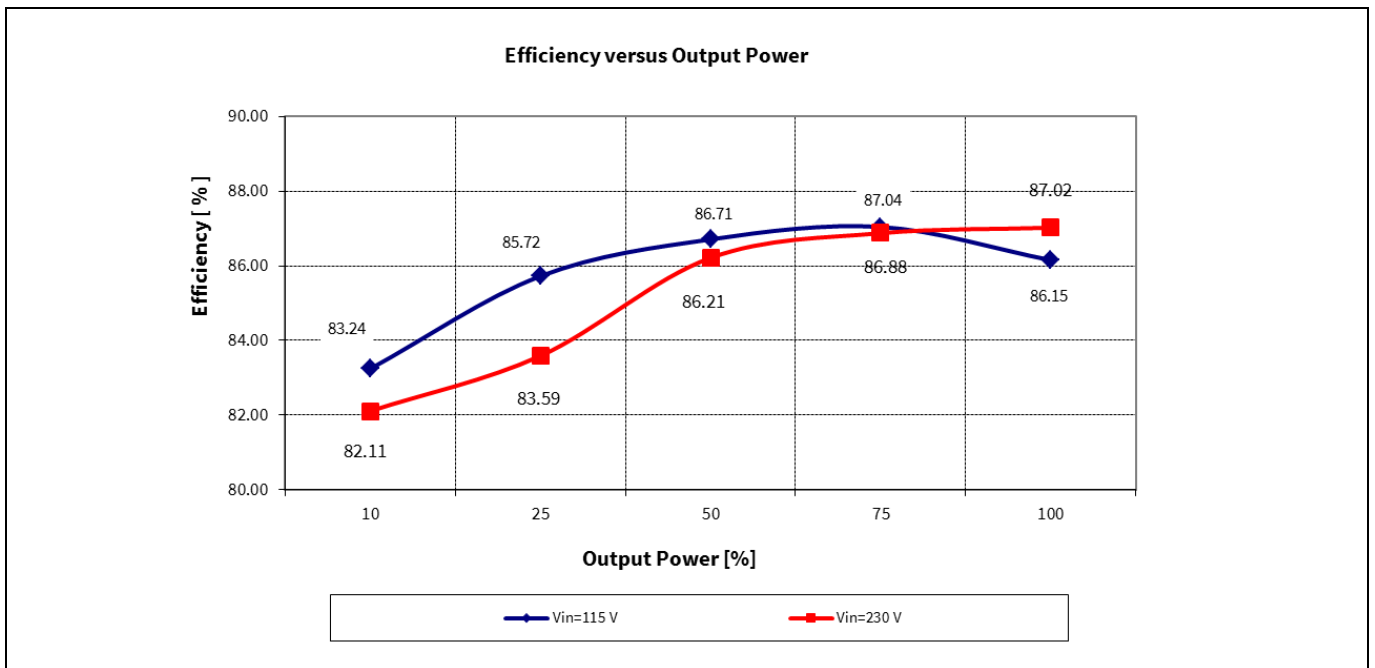


Figure 8 Efficiency vs output power at 115 V<sub>AC</sub> and 230 V<sub>AC</sub> line



Test results

### 10.2 Standby power

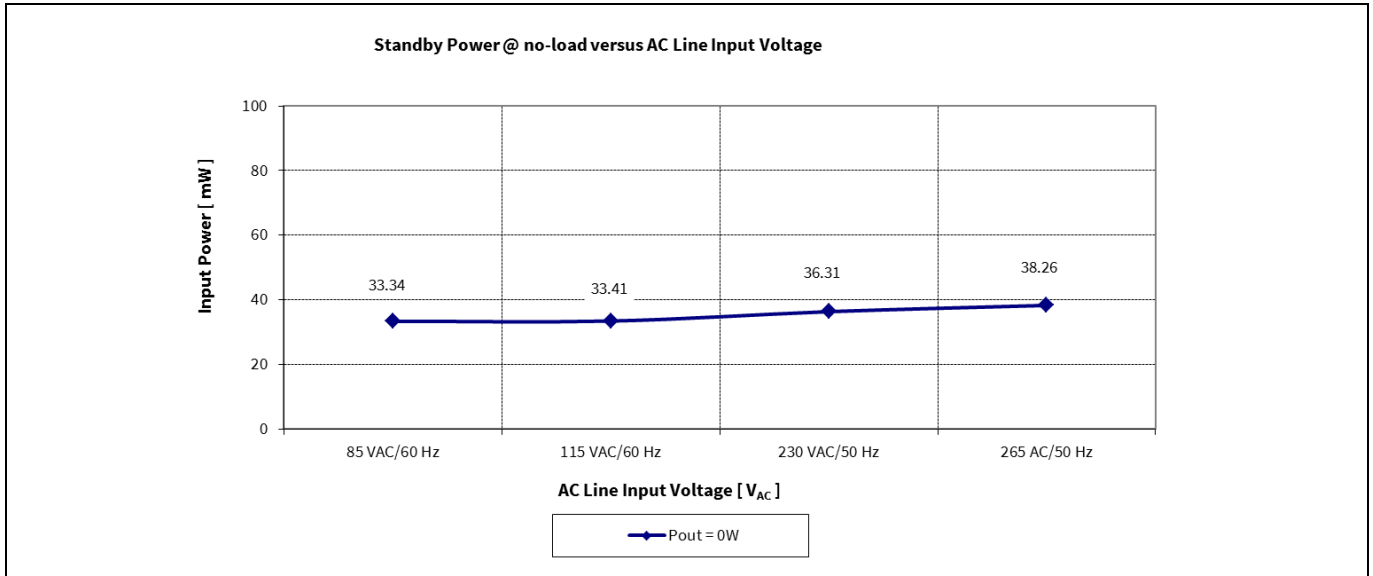


Figure 9 Standby power at no load vs AC line input voltage (measured by Yokogawa WT210 power meter - integration mode)

### 10.3 Line regulation

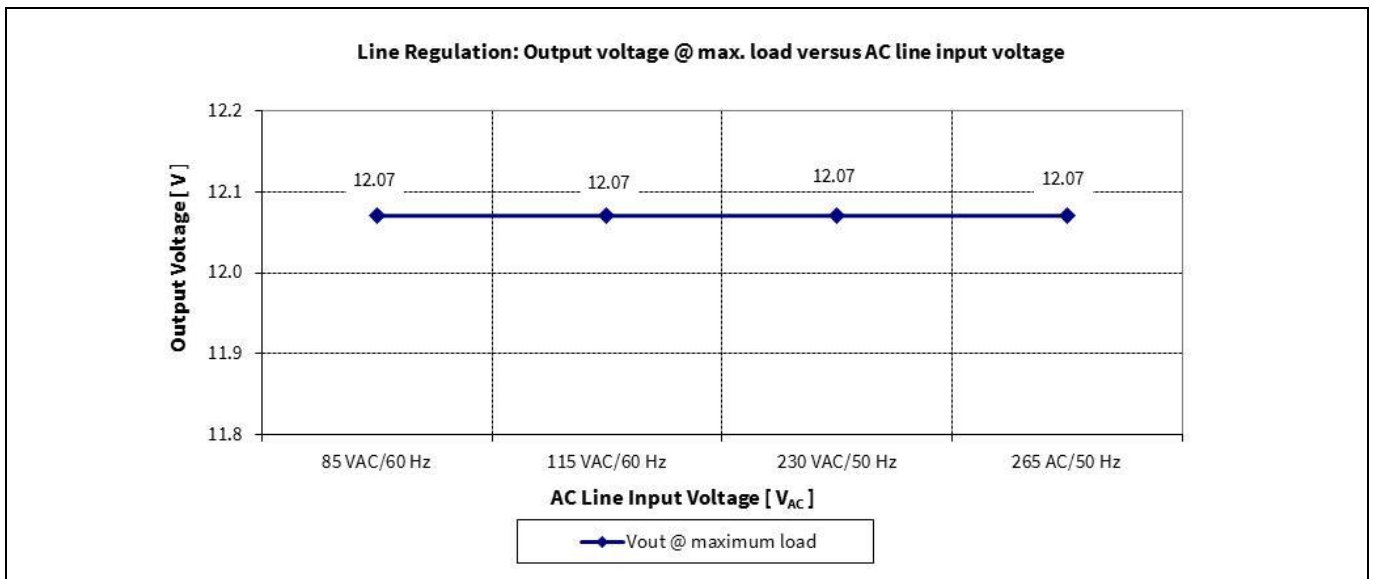


Figure 10 Line regulation Vout at full load vs AC line input voltage

Test results

### 10.4 Load regulation

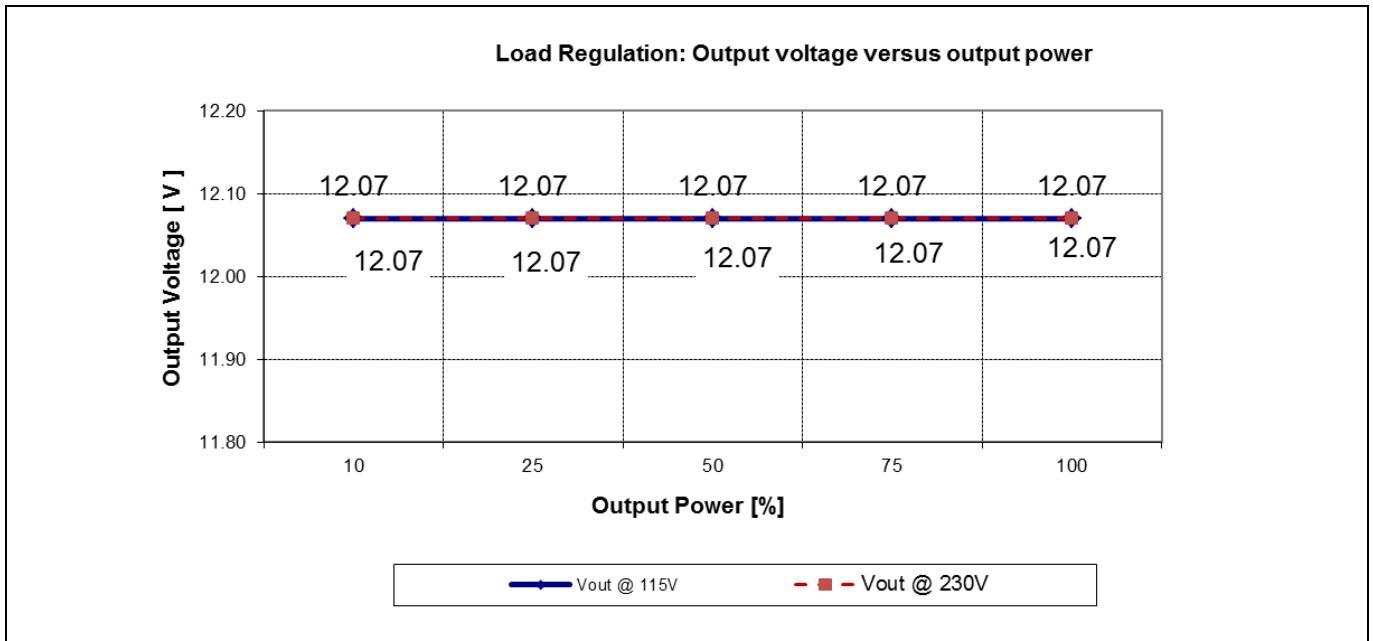


Figure 11 Load regulation  $V_{out}$  vs output power

### 10.5 Maximum input power

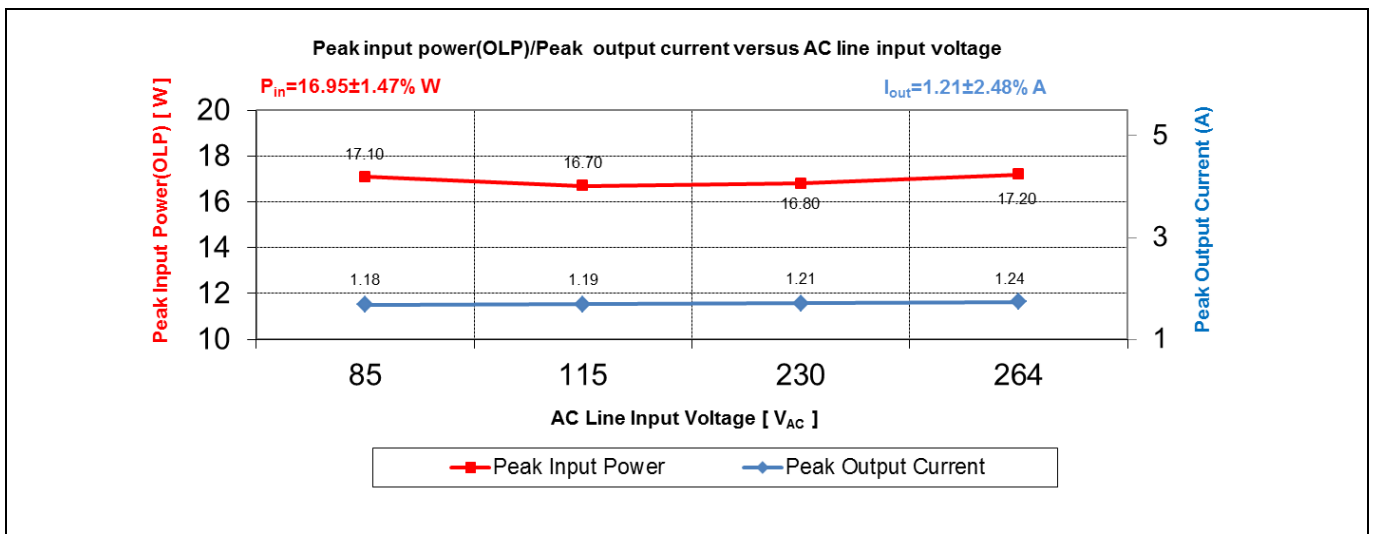


Figure 12 Maximum input power (before over-load protection) vs AC line input voltage

### 10.6 ESD immunity (EN61000-4-2)

Pass EN61000-4-2 Special Level ( $\pm 16$  kV for both contact and air discharge).

### 10.7 Surge immunity (EN61000-4-5)

Pass EN61000-4-5 Installation class 4 ( $\pm 2$  kV for line to line and  $\pm 4$  kV for line to earth).

Test results

### 10.8 Conducted emissions (EN55022 class B)

The conducted EMI was measured by Schaffner (SMR4503) and followed the test standard of EN55022 (CISPR 22) class B. The demo board was set up at maximum load (12 W) with input voltage of 115 V<sub>AC</sub> and 230 V<sub>AC</sub>.

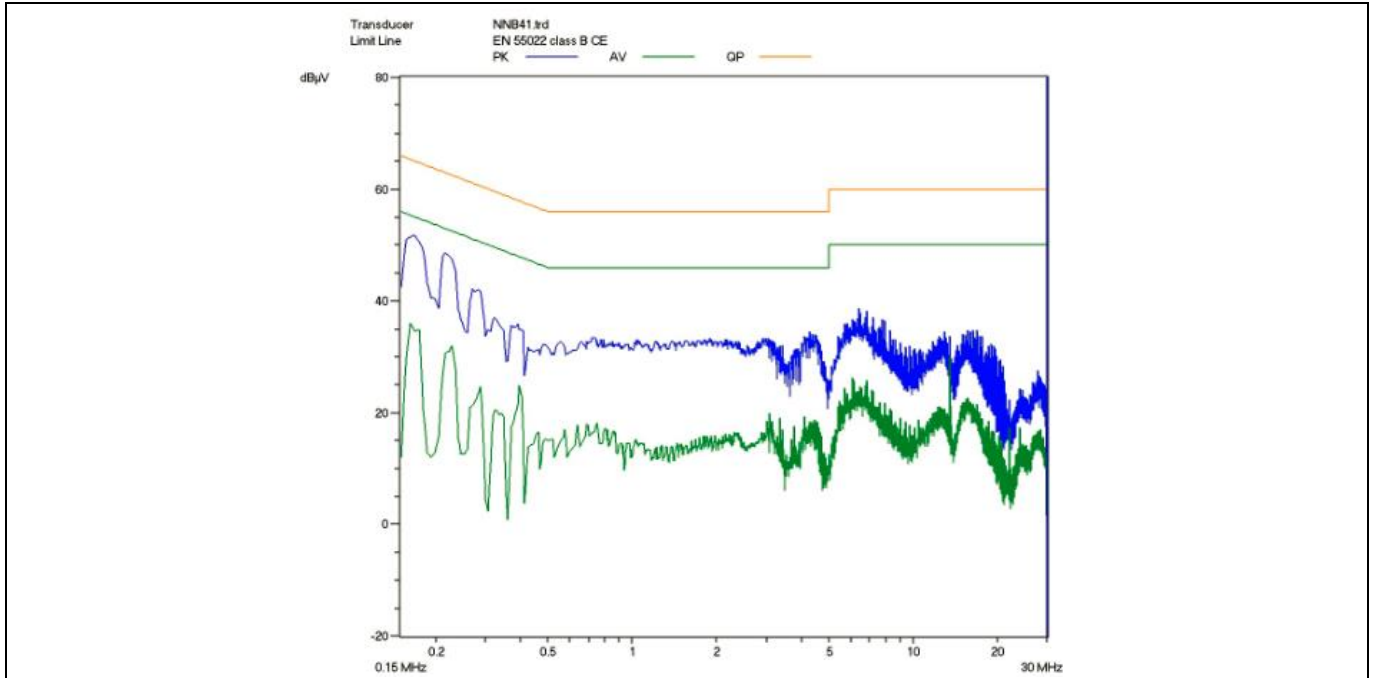


Figure 13 Conducted emissions(Line) at 115 V<sub>AC</sub> and maximum Load

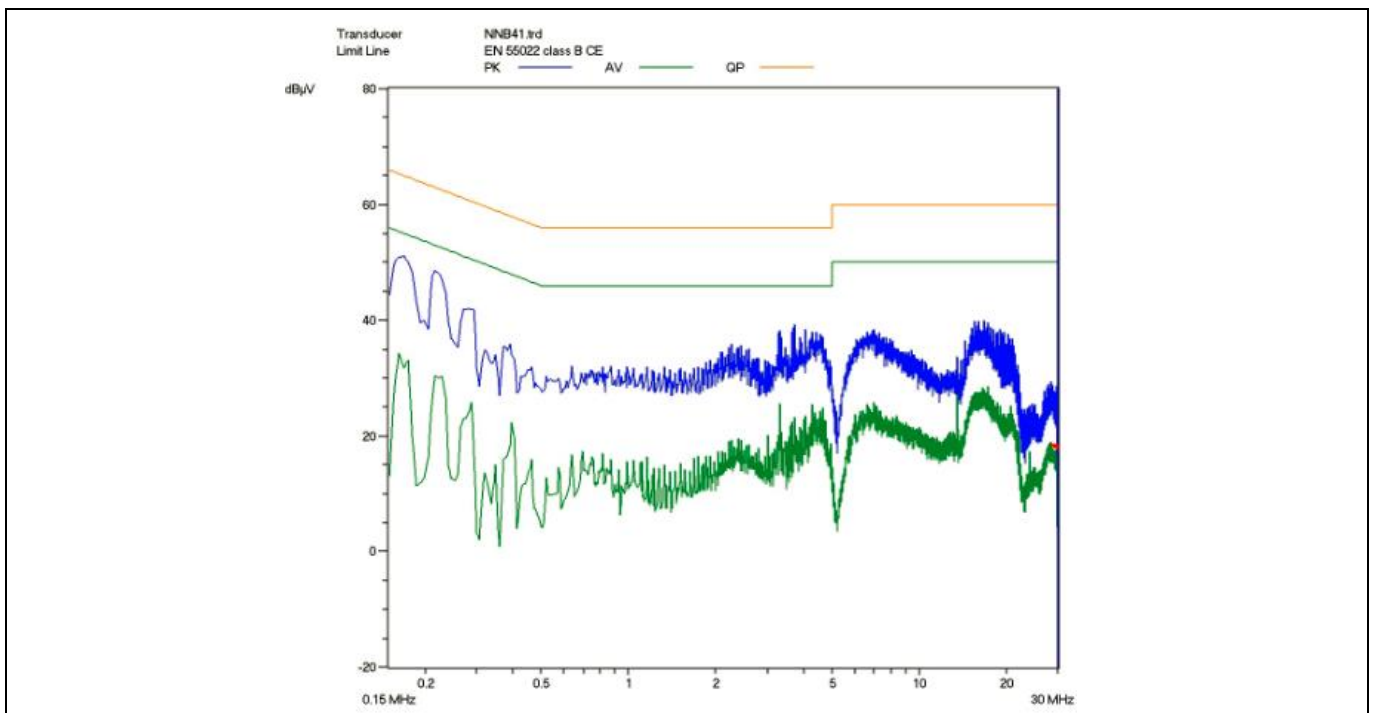


Figure 14 Conducted emissions(Neutral) at 115 V<sub>AC</sub> and maximum Load

Pass conducted emissions EN55022 (CISPR 22) class B with 10 dB margin for quasi peak limit at low line (115 V<sub>AC</sub>).

Test results

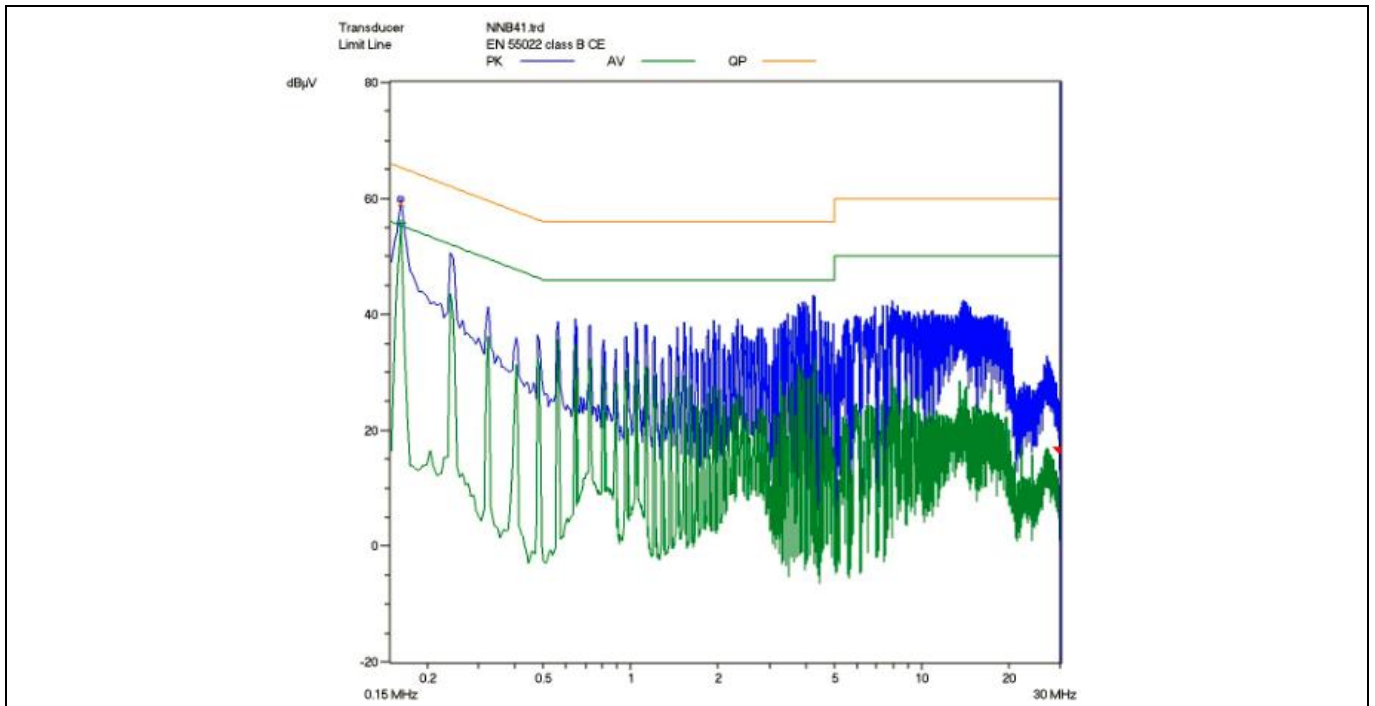


Figure 15 Conducted emissions(line) at 230 V<sub>AC</sub> and maximum Load

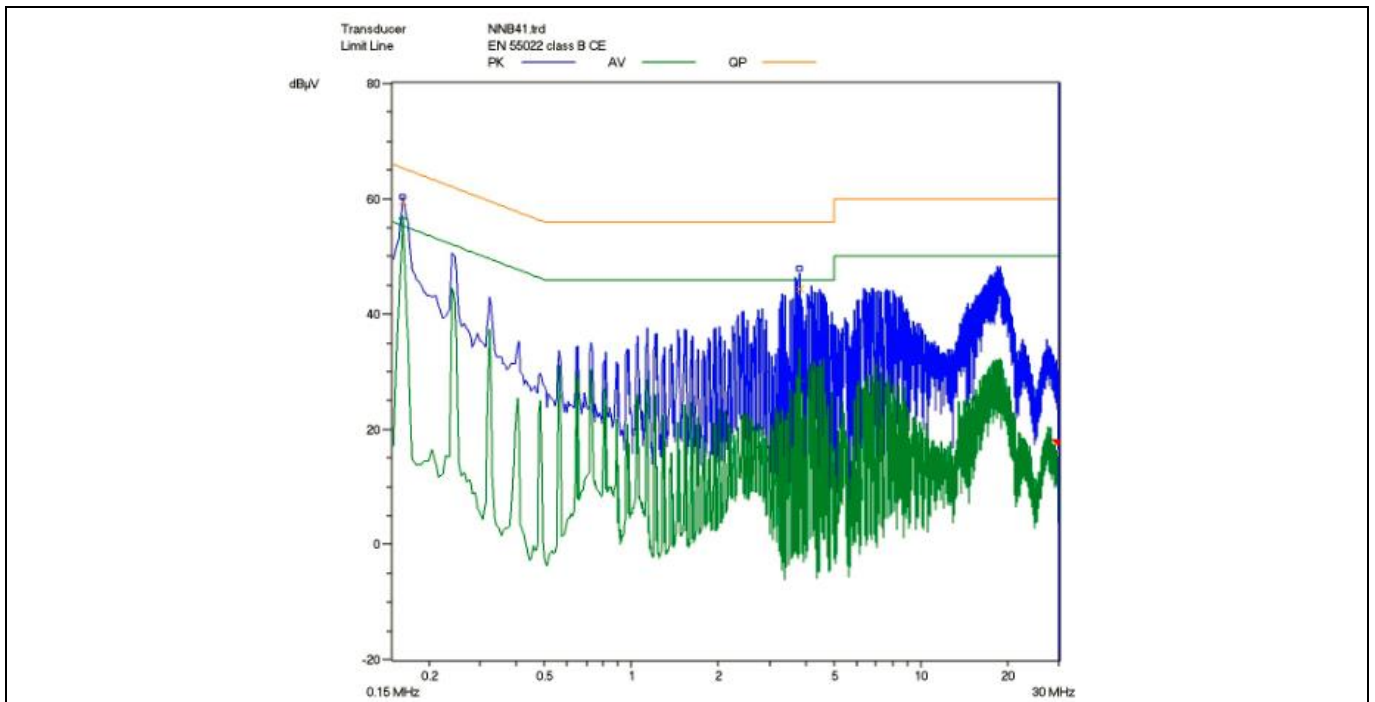


Figure 16 Conducted emissions(Neutral) at 230 V<sub>AC</sub> and maximum Load

Pass conducted emissions EN55022 (CISPR 22) class B with 6 dB margin for quasi peak limit at high line (230 V<sub>AC</sub>).

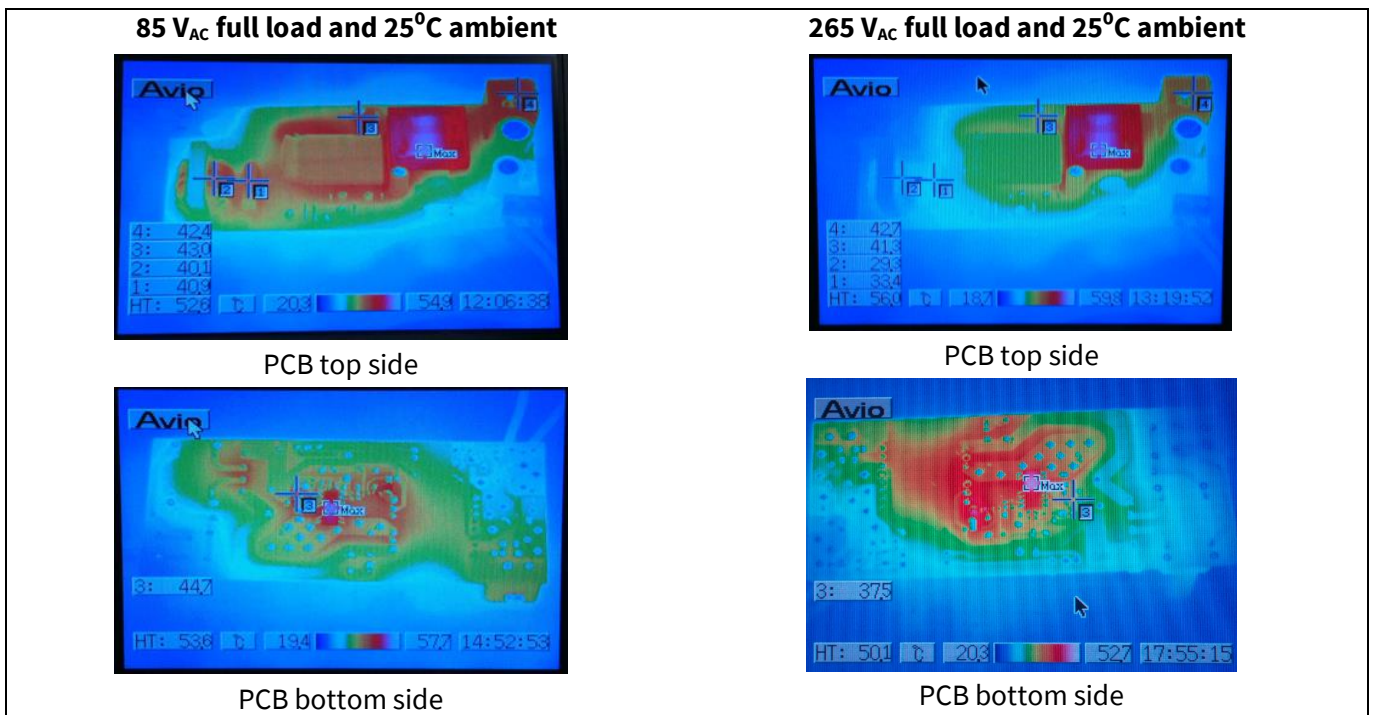
**Test results**

**10.9 Thermal measurement**

The thermal test of open frame demo board was done using an infrared thermography camera (TVS-500EX) at ambient temperature 25°C. The measurements were taken after two hours running at full load.

**Table 5 Hottest temperature of demo board**

No.	Major component	85 V <sub>AC</sub> (°C)	265 V <sub>AC</sub> (°C)
1	IC11 (ICE2QR4780G)	53.8	50.1
2	R14 (current sense resistor)	44.7	37.5
3	TR1 (transformer)	52.6	56.0
4	BR1 (bridge diode)	40.9	33.4
5	R11(clamper resistor)	43.0	41.3
6	L11 (choke)	40.1	29.3
7	D21 (Secondary diode)	42.4	42.7
8	Ambient	25	25



**Figure 17 Infrared thermal image of DEMO-2QR4780G**

Waveforms and scope plots

## 11 Waveforms and scope plots

All waveforms and scope plots were recorded with a TELEDYNELECROY 606Zi oscilloscope.

### 11.1 Startup at low/high AC line input voltage with maximum load

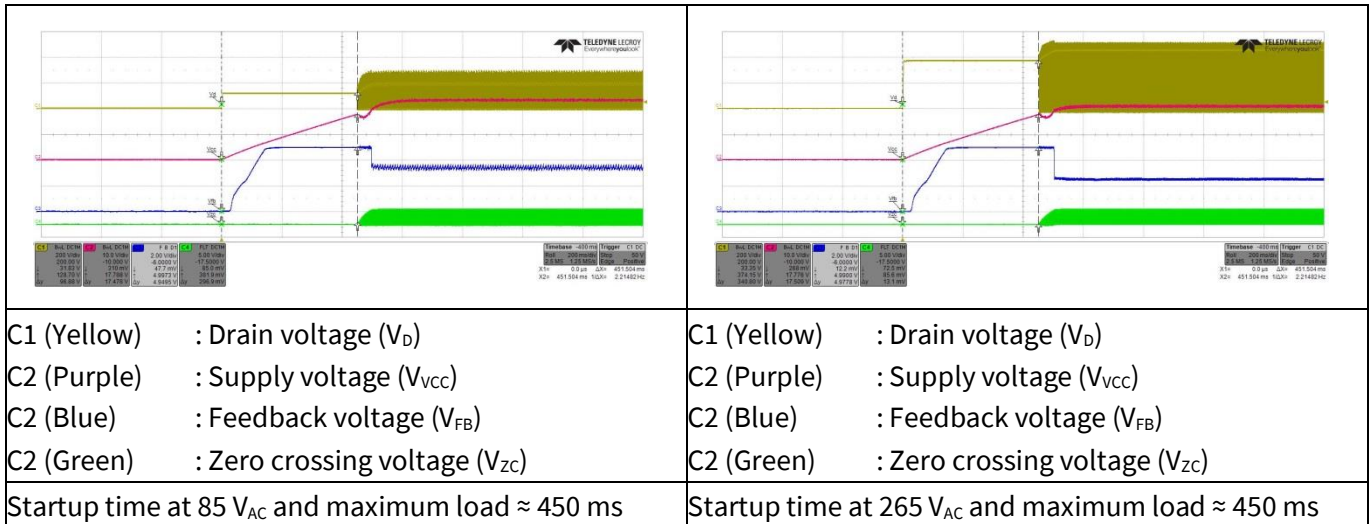


Figure 18 Startup

### 11.2 Soft start

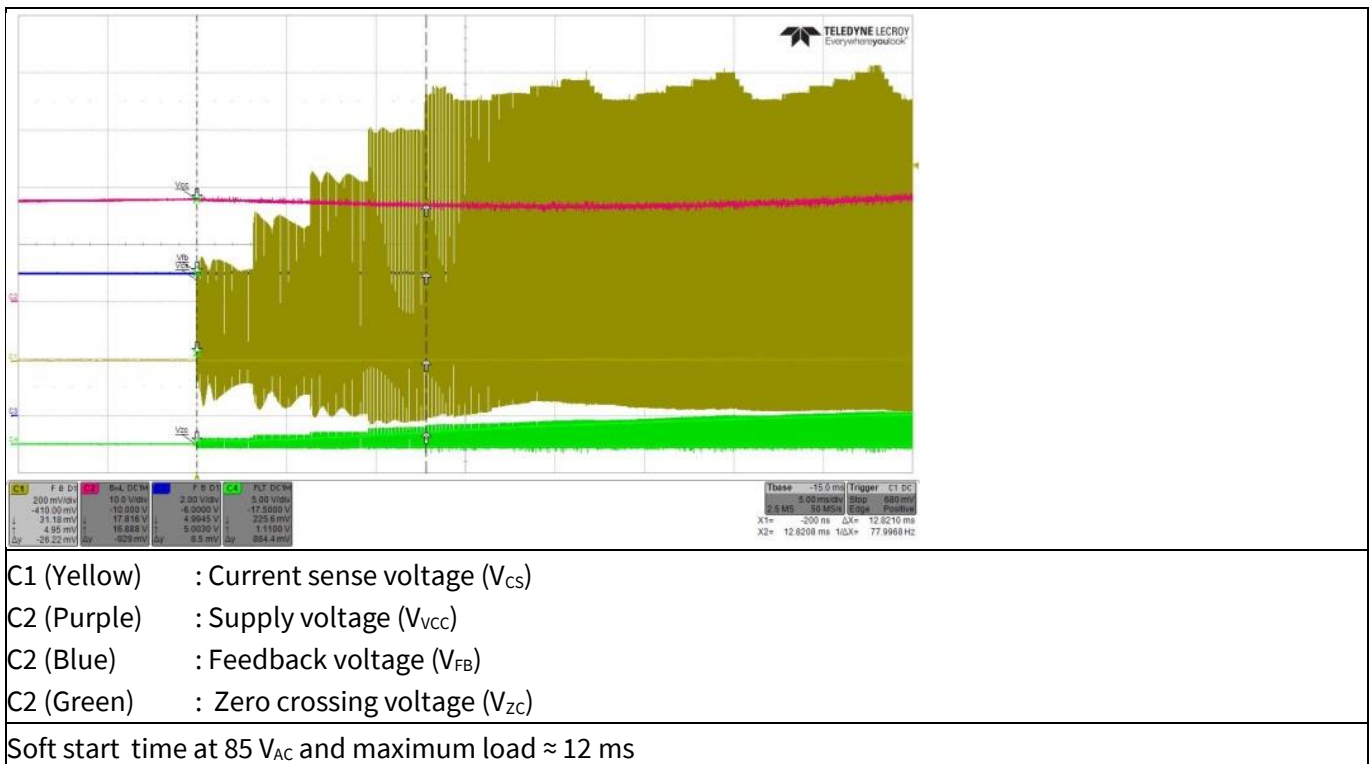
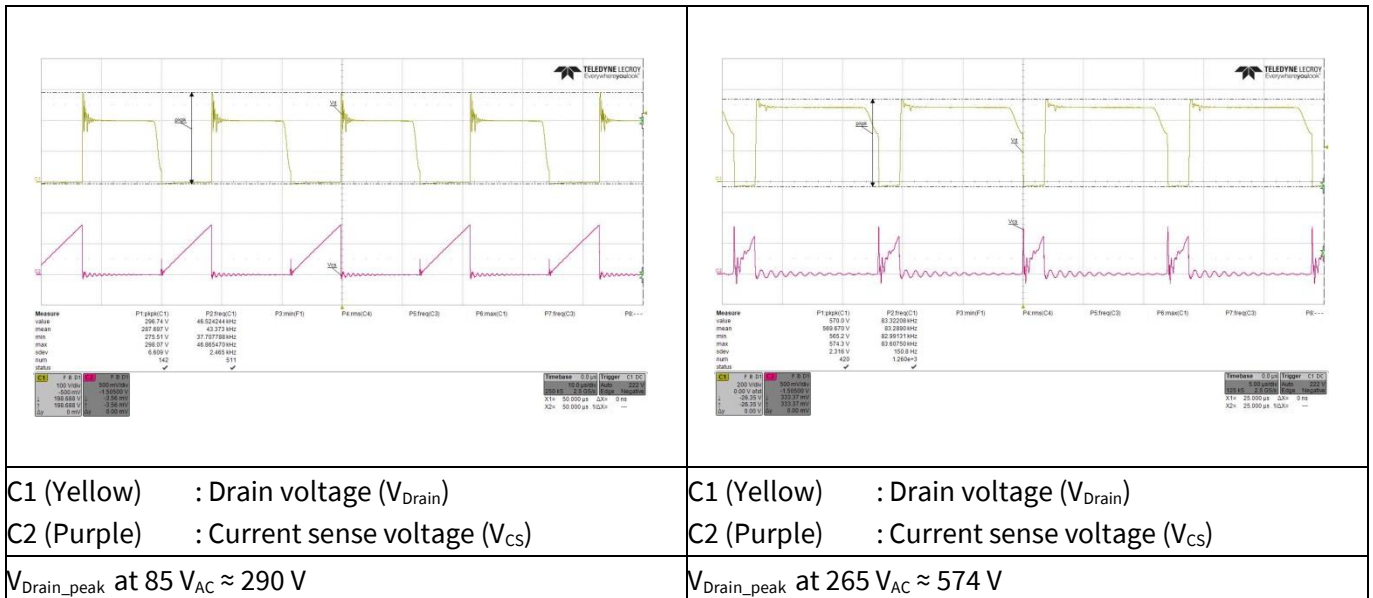


Figure 19 Soft start



Waveforms and scope plots

### 11.3 Drain and current sense voltage at maximum load



C1 (Yellow) : Drain voltage (V<sub>Drain</sub>)

C2 (Purple) : Current sense voltage (V<sub>CS</sub>)

V<sub>Drain\_peak</sub> at 85 V<sub>AC</sub> ≈ 290 V

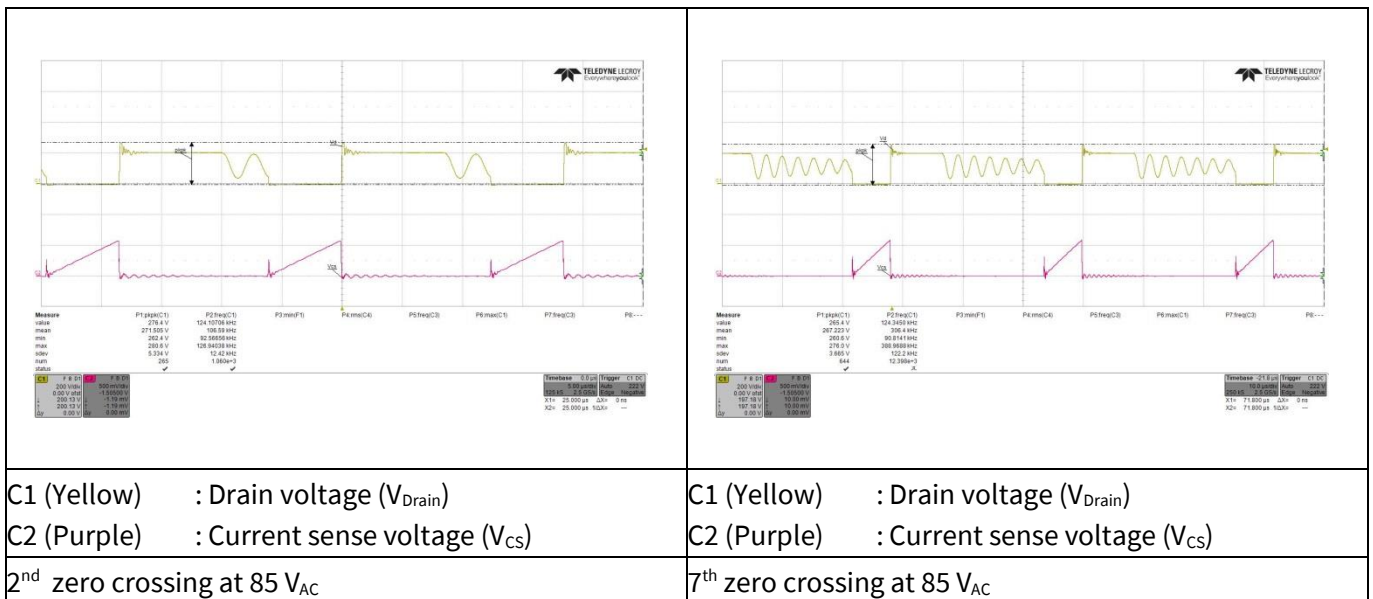
C1 (Yellow) : Drain voltage (V<sub>Drain</sub>)

C2 (Purple) : Current sense voltage (V<sub>CS</sub>)

V<sub>Drain\_peak</sub> at 265 V<sub>AC</sub> ≈ 574 V

Figure 20 Drain and current sense voltage at maximum load

### 11.4 Zero crossing point during normal operation



C1 (Yellow) : Drain voltage (V<sub>Drain</sub>)

C2 (Purple) : Current sense voltage (V<sub>CS</sub>)

2<sup>nd</sup> zero crossing at 85 V<sub>AC</sub>

C1 (Yellow) : Drain voltage (V<sub>Drain</sub>)

C2 (Purple) : Current sense voltage (V<sub>CS</sub>)

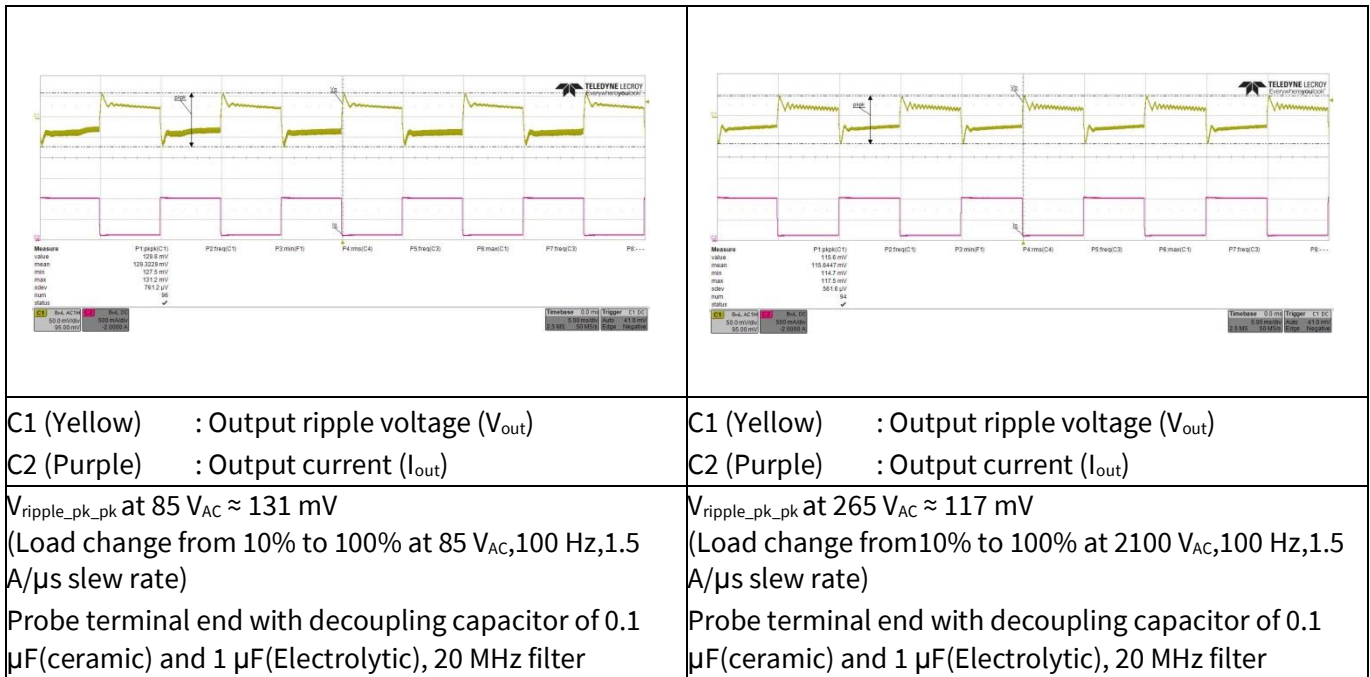
7<sup>th</sup> zero crossing at 85 V<sub>AC</sub>

Figure 1 Zero crossing



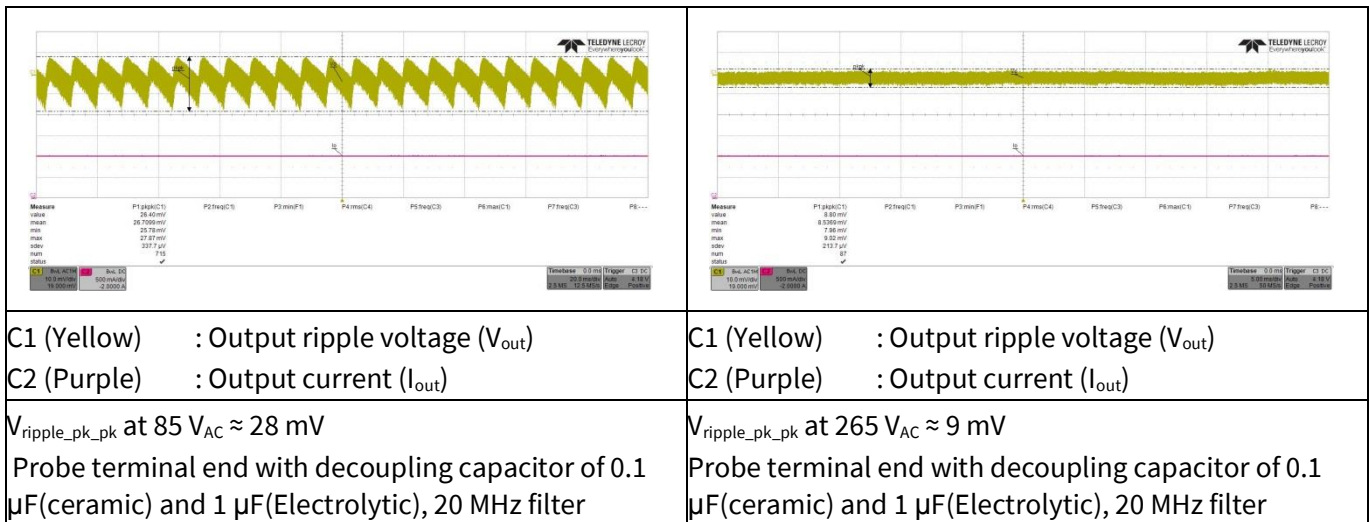
**Waveforms and scope plots**

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



**Figure 2 Load transient response**

**11.6 Output ripple voltage at maximum load**



**Figure 3 Output ripple voltage at maximum load**

Waveforms and scope plots

11.7 Output ripple voltage at burst mode 1 W load

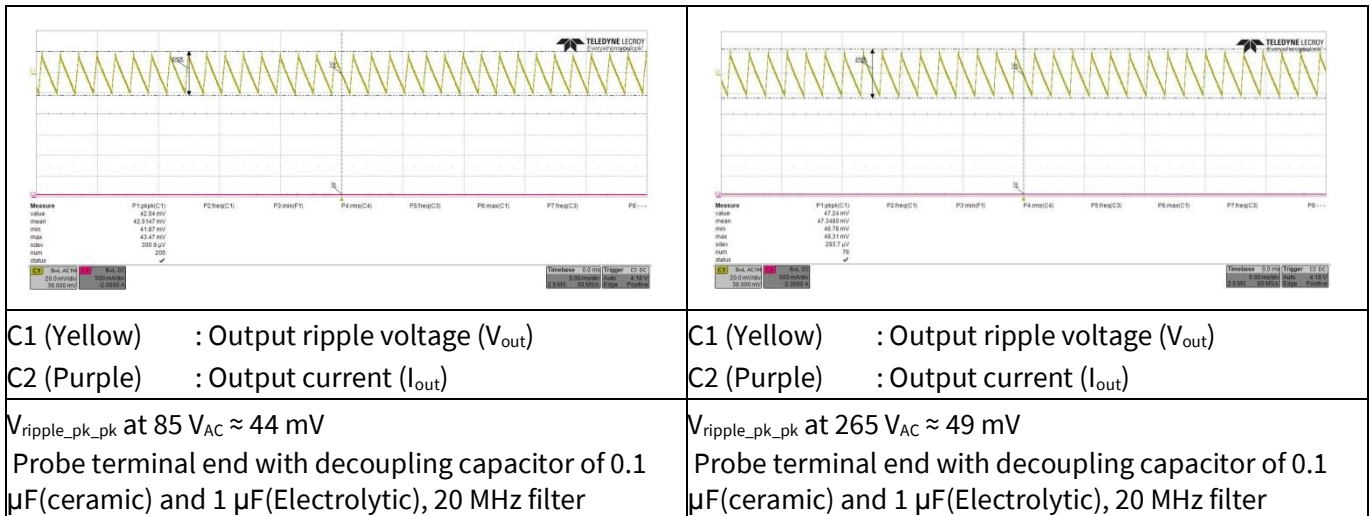


Figure 4 Output ripple voltage at burst mode 1 W load

11.8 Active burst mode

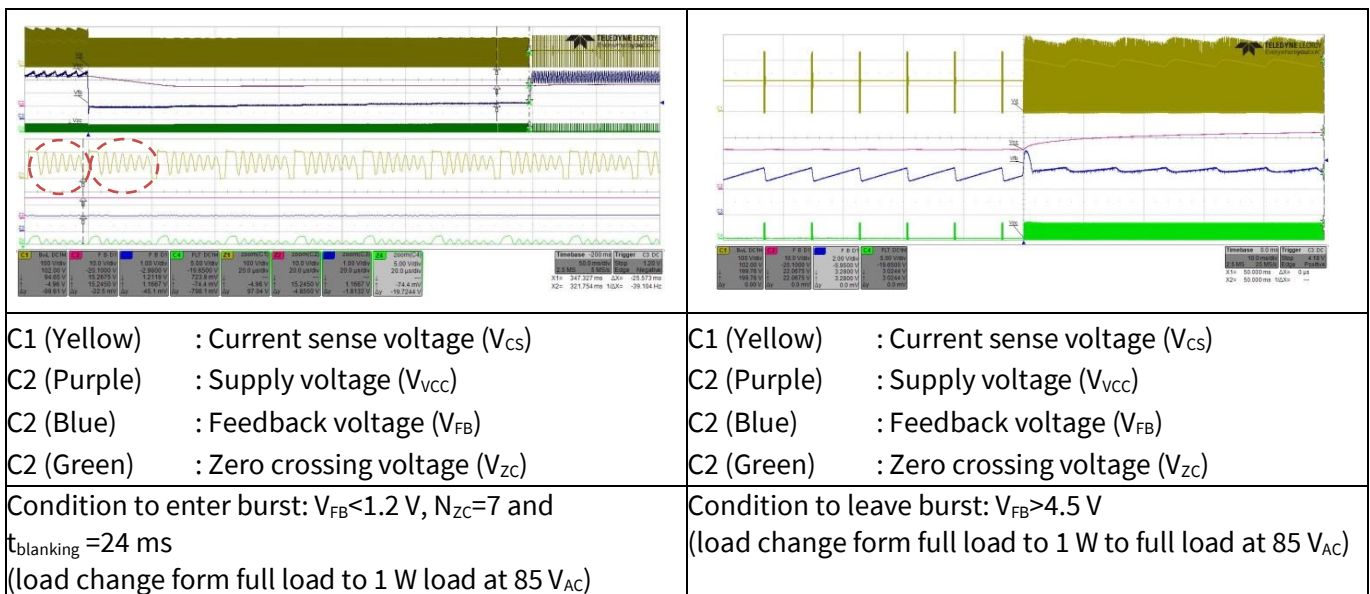


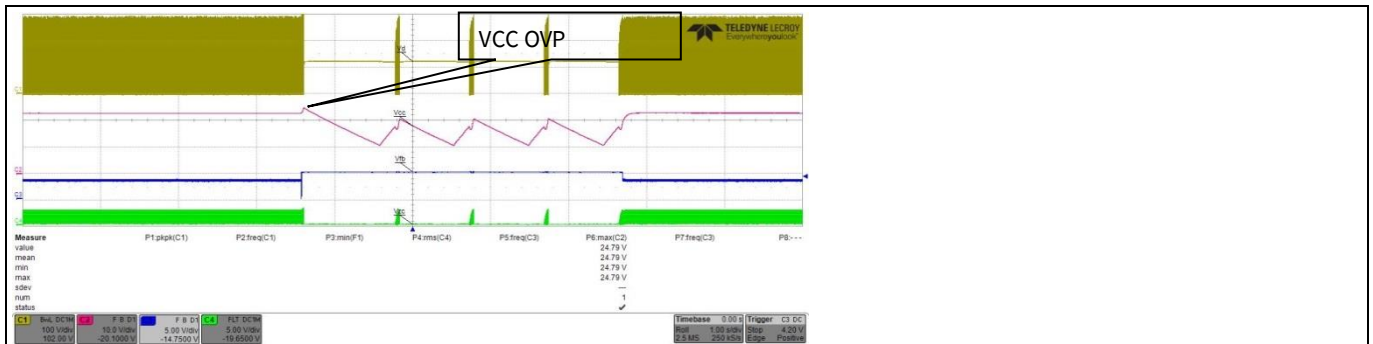
Figure 5 Active burst mode

# 12W 12V SMPS Demo Board with ICE2QR4780G

## AN-DEMO-2QR4780G

### Waveforms and scope plots

#### 11.9 VCC over voltage protection (Auto restart mode)



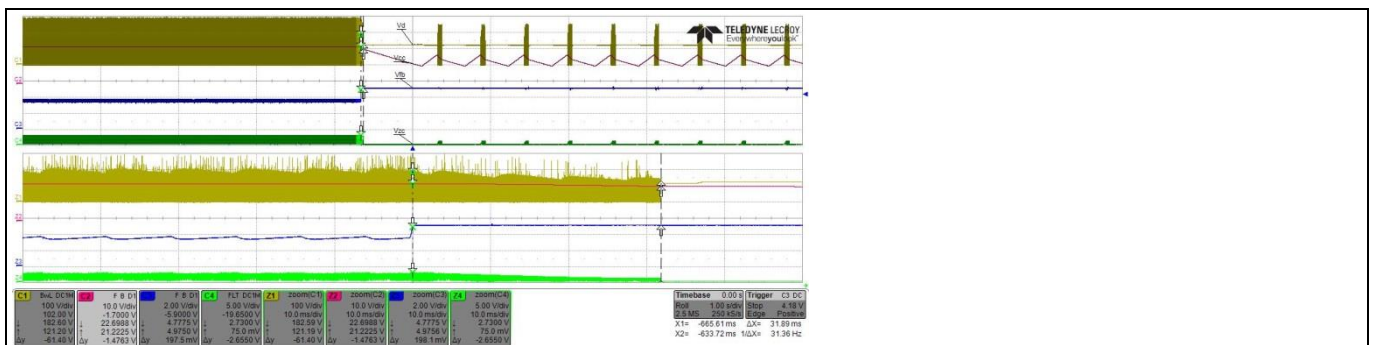
- C1 (Yellow) : Drain voltage ( $V_D$ )
- C2 (Purple) : Supply voltage ( $V_{VCC}$ )
- C2 (Blue) : Feedback voltage ( $V_{FB}$ )
- C2 (Green) : Zero crossing voltage ( $V_{ZC}$ )

Condition to enter  $V_{VCC}$  over voltage protection:  $V_{VCC} > 25V$

(85  $V_{AC}$ , short the diode of optocoupler(Pin 1 and 2 of IC12) during system operating at light load and release)

**Figure 6 Over load protection**

#### 11.10 Over load protection (Auto restart mode)



- C1 (Yellow) : Drain voltage ( $V_D$ )
- C2 (Purple) : Supply voltage ( $V_{VCC}$ )
- C2 (Blue) : Feedback voltage ( $V_{FB}$ )
- C2 (Green) : Zero crossing voltage ( $V_{ZC}$ )

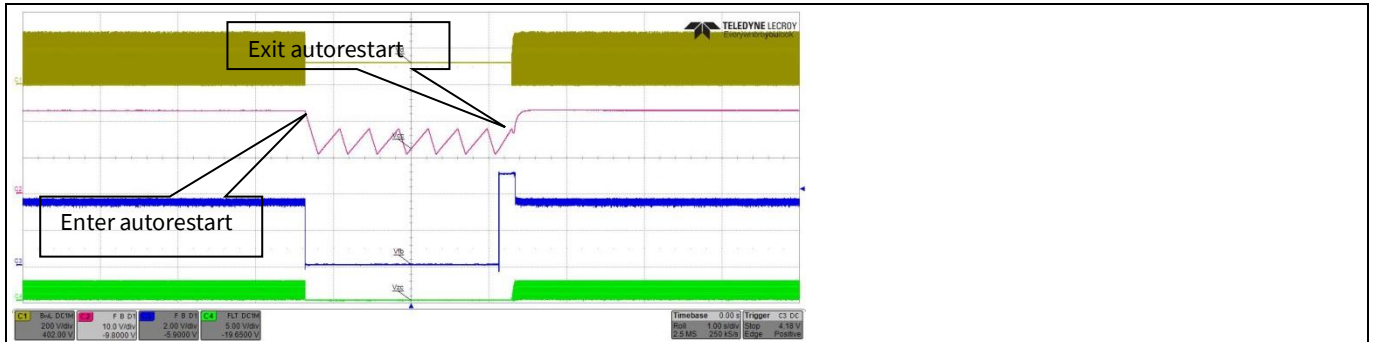
Condition to enter over load protection:  $V_{FB} > 4.5V$  & last for 40ms blanking time

(output load change from 2.33 A to 3.5 A at 85  $V_{AC}$ )

**Figure 7 Over load protection**

Waveforms and scope plots

**11.11 VCC under voltage/Short optocoupler protection (Auto restart mode)**

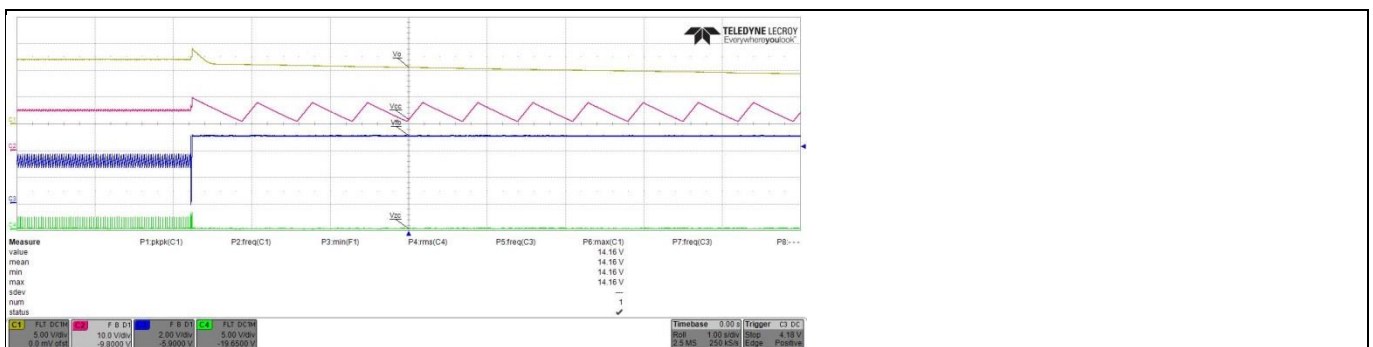


- C1 (Yellow) : Drain voltage ( $V_D$ )
- C2 (Purple) : Supply voltage ( $V_{VCC}$ )
- C2 (Blue) : Feedback voltage ( $V_{FB}$ )
- C2 (Green) : Zero crossing voltage ( $V_{ZC}$ )

Condition to enter VCC under voltage protection:  $V_{CC} < 10.5\text{ V}$   
(short the transistor of optocoupler(Pin 3 and 4 of IC12) during system operating at full load and release at  $85\text{ V}_{AC}$ )

**Figure 8 VCC under voltage/short optocoupler protection**

**11.12 Output overvoltage protection (Latch mode)**



- C1 (Yellow) : Output voltage ( $V_{out}$ )
- C2 (Purple) : Supply voltage ( $V_{VCC}$ )
- C2 (Blue) : Feedback voltage ( $V_{FB}$ )
- C2 (Green) : Zero crossing voltage ( $V_{ZC}$ )

Condition to enter external protection enable:  $V_{out} > 14\text{ V}$  ( $V_{ZC} > 3.7\text{ V}$ )  
( $85\text{ V}_{AC}$ , short R26 during while system operation at no load)

**Figure 9 External auto restart enable Output overvoltage protection**

References

## 12 References

- [1] [ICE2QR4780G datasheet, Infineon Technologies AG](#)
- [2] [AN-PS0025-CoolSET F3R DIP-8, DIP-7, DSO-16/12 new jitter version design guide-V2.2](#)

## Revision History

### Major changes since the last revision

Page or Reference	Description of change
--	First release.

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