44 W 12 V SMPS demo board with ICE5AR0680BZS

DEMO_5AR0680BZS_44W1

About this document

Scope and purpose

This document is an engineering report that describes a universal-input 44 W 12 V off-line flyback converter using the latest fifth-generation Infineon Fixed Frequency (FF) CoolSET™ ICE5AR0680BZS, which offers high-efficiency, low-standby power with selectable entry and exit standby power options, wide VCC operating range with fast start-up, and various modes of protection for a highly reliable system. This demo board is designed for users who wish to evaluate the performance of ICE5AR0680BZS in terms of optimized efficiency, thermal performance and EMI.

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 off-line SMPS, such as auxiliary power supplies for white goods, PCs, servers and TVs, or enclosed adapters for Blu-ray players, set-top boxes, games consoles, etc.

Table of contents

1 Abstract

This document is an engineering report for a 44 W 12 V demo board designed in an FF flyback converter topology using the fifth-generation FF CoolSET™ ICE5AR0680BZS. The demo board is operated in Continuous Conduction Mode (CCM) and is running at 100 kHz fixed switching frequency to optimize low-line full-load efficiency. The frequency reduction with soft gate driving and frequency jittering offers lower EMI and better efficiency between light load and 50% load. The selectable Active Burst Mode (ABM) enables ultra-low power consumption. In addition, numerous adjustable protection functions have been implemented in ICE5AR0680BZS to protect the system and customize the IC for the chosen application. In case of failure modes such as VCC Over Voltage (OV)/Under Voltage (UV), open control-loop or over-load, over-temperature, VCC short-to-GND and CS short-to-GND, the device enters protection mode. By means of the cycle-by-cycle Peak Current Limitation (PCL), the dimensions of the transformer and current rating of the secondary diode can both be optimized. In this way, a cost-effective solution can easily be achieved. The target applications of ICE5AR0680BZS are either auxiliary power supplies for white goods, PCs, servers and TVs, or enclosed adapters for Blu-ray players, set-top boxes, games consoles, etc.

2 Demo board

This document contains the list of features, the 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 report.

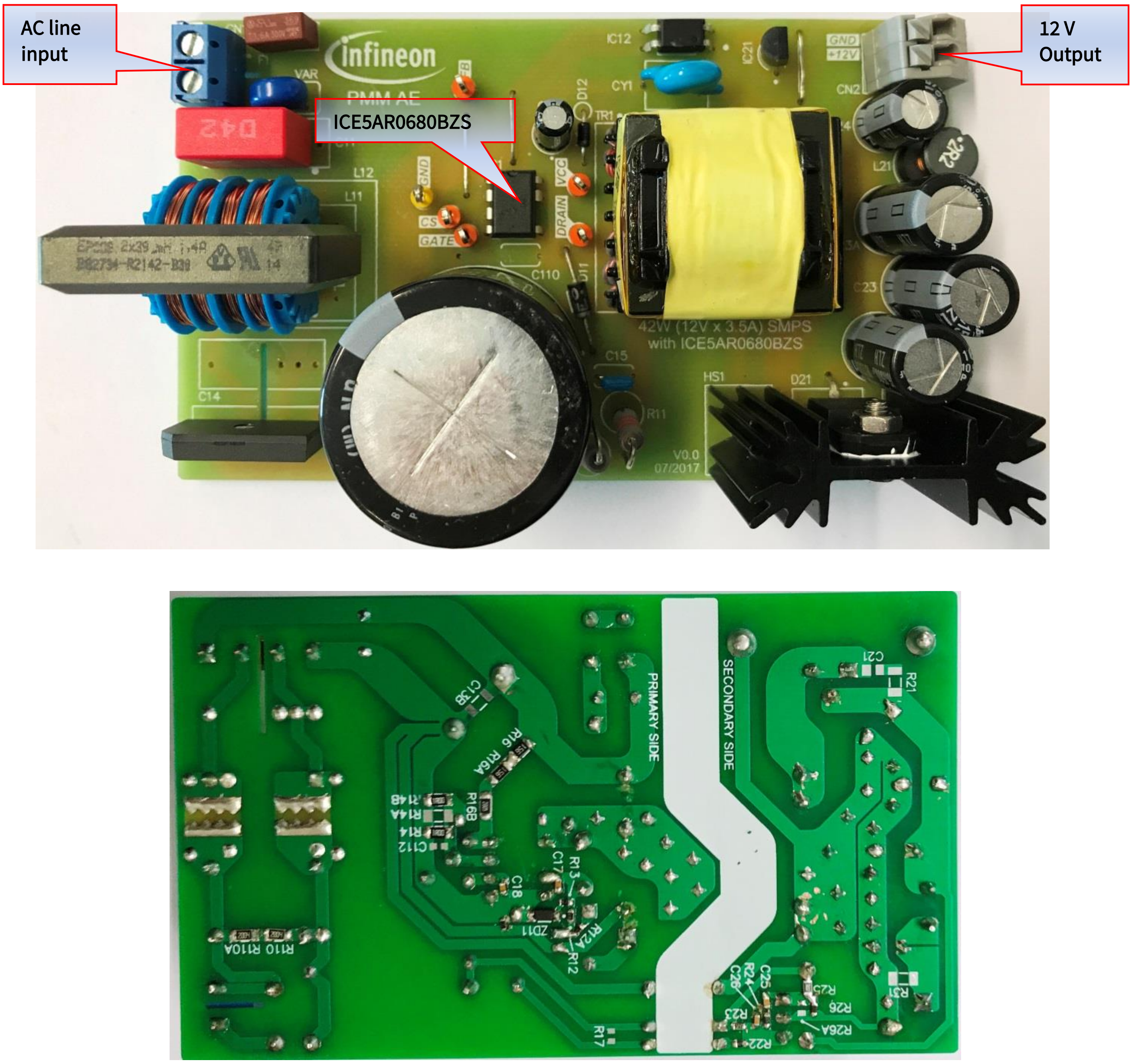


Figure 1 DEMO_5AR0680BZS_44W1

3 Specifications of the demo board

Table 1 Specifications of DEMO_5AR0680BZS_44W1

Input voltage and frequency	85 V AC (60 Hz) ~ 300 V AC (50 Hz)
Output voltage, current and power	12 V x 3.66 A = 44 W
Dynamic load response (12 V load change from 10% to 100%, slew rate at 0.4 A/µs, 100 Hz)	±3% of nominal output voltage
Output ripple voltage (full load, 85 V AC ~ 300 V AC)	12 $V_{ripple\_p\_p}$ < 100 mV
Active-mode four-point average efficiency (25%, 50%, 75%, 100% load)	> 87% at 115 V AC and 230 V AC
No-load power consumption	< 100 mW at 300 V AC
Conducted emissions (EN 55022 class B)	Pass with 8 dB margin for 115 V AC and 6 dB margin for 230 V AC
ESD immunity (EN 61000-4-2)	Level 4 for contact discharge and Level 3 for air discharge (±8 kV for both contact and 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)	(111 x 66 x 35) mm^3

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 CY1 act as EMI suppressors. Optional spark-gap devices SA1 and SA2 and varistor VAR can absorb HV stress during a lightning surge test. A rectified DC voltage (120 ~ 424 V DC) is obtained through the bridge rectifier BR1 together with bulk capacitor C13.

4.2 Start-up

To achieve fast and safe start-up, ICE5AR0680BZS is implemented with a start-up resistor and VCC short-to-GND protection. When V_{VCC} reaches the turn-on voltage threshold of 16 V, the IC begins with a soft-start. The soft-start implemented in ICE5AR0680BZS 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 in increments from 0.3 V to 0.8 V. After IC turn-on, the VCC voltage is supplied by auxiliary windings of the transformer. VCC short-to-GND protection is implemented during the start-up time.

4.3 Integrated CoolMOS™ with frequency-reduction controller

ICE5AR0680BZS comprises a CoolMOS™ and the frequency-reduction controller, which enables better efficiency between light load and 50% load. This integrated solution greatly simplifies the circuit layout and reduces the cost of PCB manufacturing. The new CoolSET™ can be operated in either Discontinuous Conduction Mode (DCM) or CCM with frequency-reduction mode. This demo board is designed to operate in CCM to increase efficiency under low-line full-load conditions. When the system is operating at maximum power, the controller will switch at the FF of 100 kHz. In order to achieve a better efficiency between light load and medium load, frequency reduction is implemented, and the reduction curve is shown in Figure 2. The V_{CS} is clamped by the current limitation threshold or by the PWM op-amp while the switching frequency is reduced. After the maximum frequency reduction, the minimum switching frequency is f_{OSC2_MIN} (43 kHz).

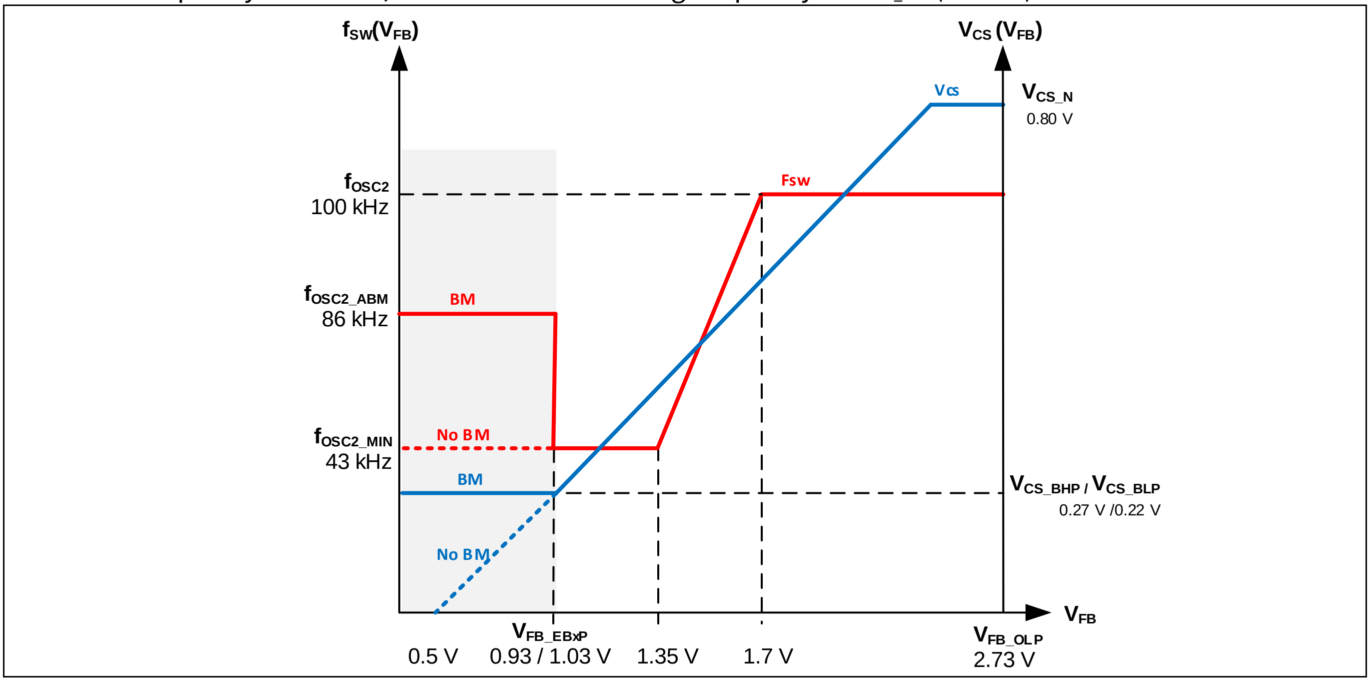


Figure 2 Frequency-reduction curve

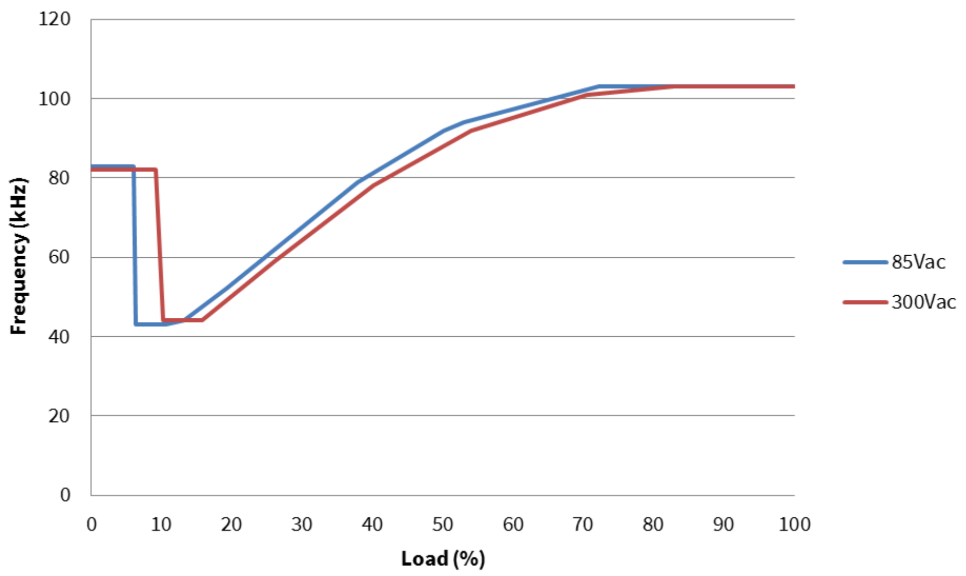


Figure 3 Frequency-reduction curve of DEMO_5AR0680BZS_44W1

The measured frequency-reduction curve of DEMO_5AR0680BZS_44W1 is shown in Figure 3.

4.4 Frequency jittering

The ICE5AR0680BZS has a frequency jittering feature to reduce the EMI noise. The jitter frequency is internally set at 100 kHz (±4 kHz), and the jitter period is 4 ms.

4.5 RCD clamper circuit

A clamper network (R11, R11A, C15 and D11) dissipates the energy of the leakage inductance and suppresses ringing on the SMPS transformer.

4.6 Output stage

There is a single output on the secondary side, 12 V. The power is coupled out via Schottky diode D21. The capacitors C22, C23 and C23A provide energy buffering followed by the L-C filters L21-C24 to reduce the output ripple and considerably reduce interference between SMPS switching frequency and line frequency. Storage capacitors C22, C23 and C23A are designed to have an internal resistance (ESR) as small as possible to minimize the output voltage ripple caused by the triangular current.

4.7 Feedback loop

For feedback (FB), the output is sensed by the voltage dividers 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.

4.8 ABM

ABM entry and exit power can be selected from three options, including no ABM. This demo board is set to option 3, and details are shown in the product datasheet. Under light-load conditions, the SMPS enters ABM. 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 at the same time it supports low ripple on V_{out} and fast response on load-jump.

In order to enter ABM operation, two conditions must apply:

1. The FB voltage must be lower than the threshold of V_{FB_EBXP}
2. A certain blanking time (t_{FB_BEB} = 36 ms) is required

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

During ABM, switching frequency is reduced to 86 kHz for level 2 and 3 selections and 43 kHz for level 1 (no ABM) to improve efficiency during standby power measurement. The maximum Current Sense (CS) voltage is reduced from V_{CS_N} to V_{CS_BXP} to reduce the conduction loss and the audible noise. During ABM, the FB voltage is changing like a sawtooth between $V_{FB\_Bon\_ISO}$ and $V_{FB\_Boff\_ISO}$.

The FB voltage immediately increases if there is a high load-jump. This is observed by one comparator. As the current limit is 27/33% during ABM a certain load is needed so that FB voltage can exceed V_{FB_LB} (2.75 V). After leaving ABM, maximum current can be provided to stabilize V_{out}.

5 Protection features

Protection is one of the major factors in determining whether the system is safe and robust – therefore sufficient protection is necessary. ICE5AR0680BZS provides comprehensive protection to ensure the system is operating safely. This includes VCC OV and UV, over-load, over-temperature (controller junction), CS short-to-GND and VCC short-to-GND. When those faults are found, the system will enter protection mode. Once the fault is removed, the system resumes normal operation. A list of protections and the failure conditions is shown in the table below.

Table 2 Protection functions of ICE5AR0680BZS

Protection function	Failure condition	Protection mode
VCC OV	$V_{VCC} > 25.5$ V	Odd-skip auto restart
VCC UV	$V_{VCC} < 10$ V	Auto restart
Over-load	$V_{FB} > 2.75$ V and lasts for 54 ms	Odd-skip auto restart
Over-temperature (junction temperature of controller chip only)	$T_J > 140$°C	Non-switch auto restart
CS short-to-GND	$V_{CS} < 0.1$ V, lasts for 0.4 µs and three consecutive pulses	Odd-skip auto restart
VCC short-to-GND ($V_{VCC} = 0$ V, start-up = 50 MΩ and V_{DRAIN} = 90 V)	$V_{VCC} < 1.1$ V, $I_{VCC\_Charge1} \approx -0.2$ mA	Cannot start up

6 Circuit diagram

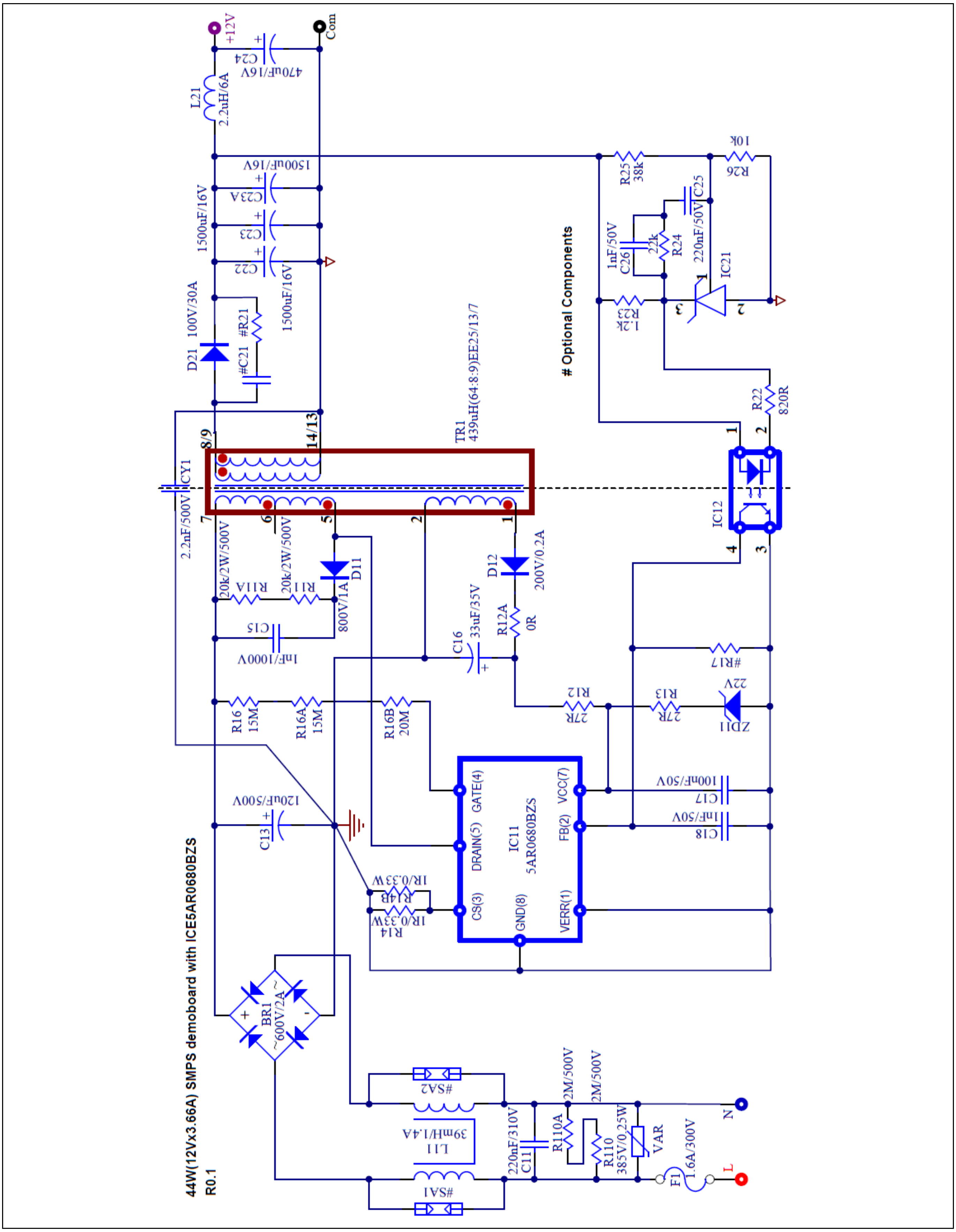


Figure 4 Schematic of DEMO_5AR0680BZS_44W1

7 PCB layout

7.1 Top side

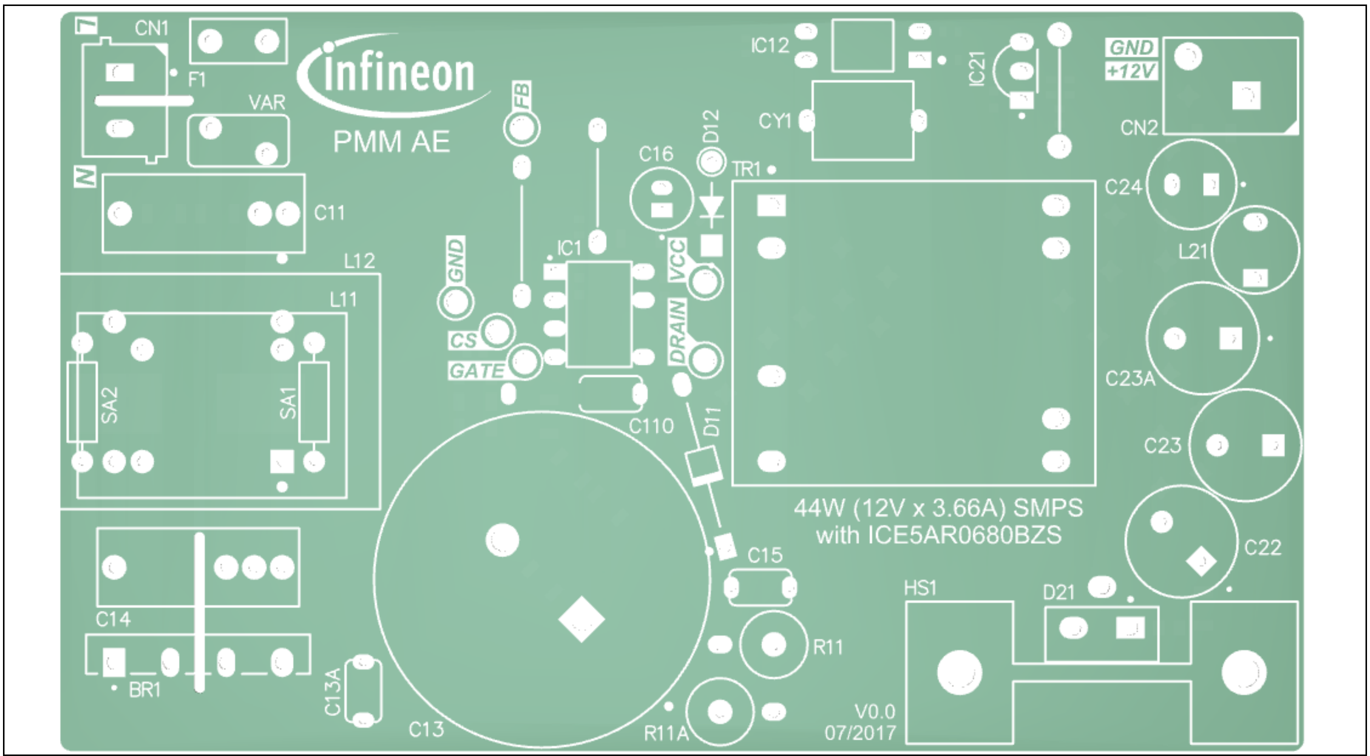


Figure 5 Top side component legend

7.2 Bottom side

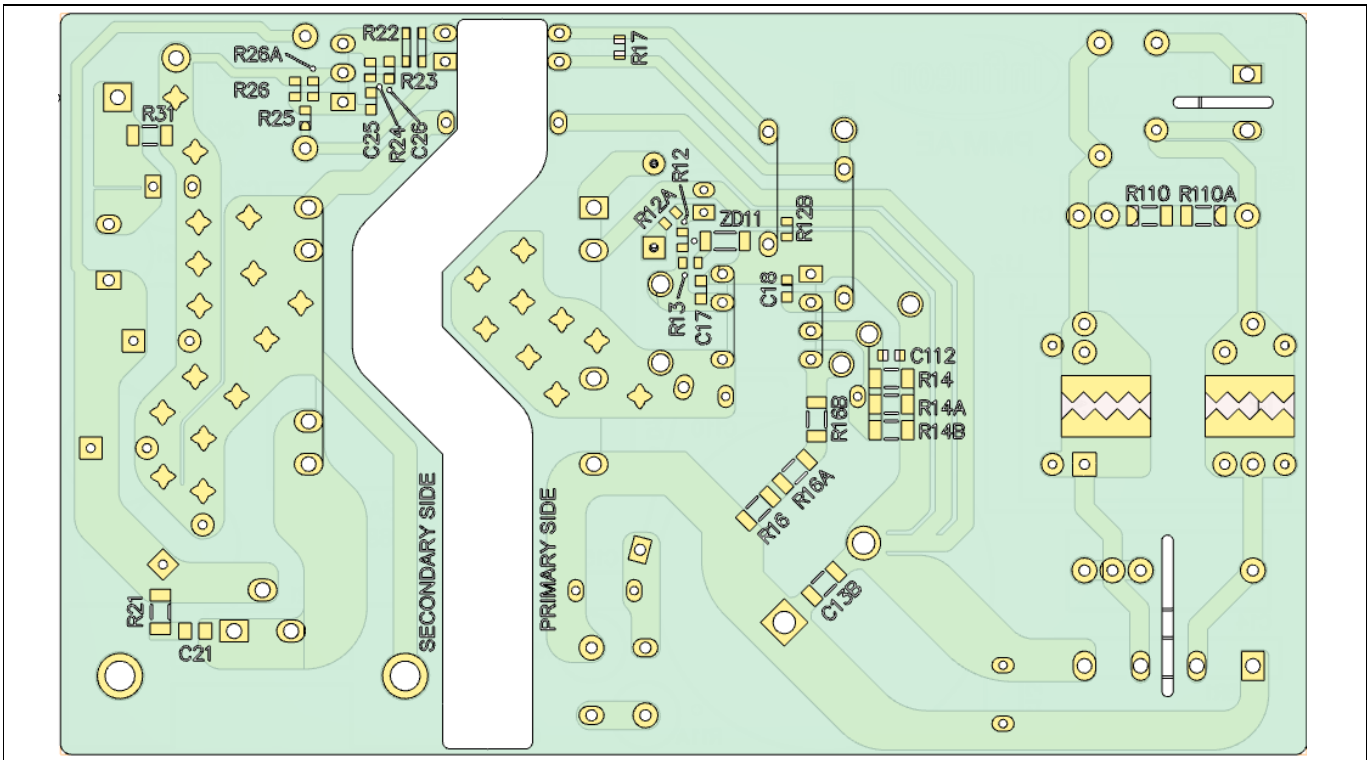


Figure 6 Bottom side copper and component legend

8 BOM

Table 3 BOM (R 0.1)

No.	Designator	Description	Part number	Manufacturer	Quantity
1	BR1	600 V/2 A	D2SB60A	Shindengen	1
2	C11	220 nF/310 V	890334024002	Wurth Electronics	1
3	CY1	2.2 nF/1000 V	DE1E3RA222MA4BQ	Murata	1
4	C13	120 uF/500 V	LGN2H121MELB30		1
5	C15	1 nF/1000 V	RDER7U3A102K2K1H03B	Murata	1
6	C16	33 uF/35 V	50PX33MEFC5X11	Rubycon	1
7	C17	100 nF/50 V	GRM188R71H104KA93D	Murata	1
8	C18, C26	1 nF/50 V	GRM1885C1H102GA01D	Murata	2
9	C22, C23, C23A	1500 uF/16 V	16ZLH1500MEFC10X20	Rubycon	3
10	C24	470 uF/16 V	16ZLH470MEFC8X11.5	Rubycon	1
11	C25	220 nF/50 V	GRM188R71H224KAC4D	Murata	1
12	D11	800 V/1 A	UF4006		1
13	D12	200 V/0.2 A	1N485B		1
14	D21	100 V/30 A	VF30100SG		1
15	F1	1.6 A/300 V	36911600000		1
16	FB @ pins 5 and 7 of TR1	Ferrite bead	B64290P0035X038	Epcos	2
17	HS21	Heatsink	513002B02500G		1
18	IC1	ICE5AR0680BZS	ICE5AR0680BZS	Infineon	1
19	IC12	Optocoupler	SFH617A-3		1
20	IC21	Shunt regulator	TL431BVLPG		1
21	JP11, JP12, J21	Jumper			3
22	L11	39 mH/1.4 A	B82734R2142B030	Epcos	1
23	L21	2.2 uH/6 A	744772022	Wurth Electronics	1
24	R11, R11A	33 k/2 W/500 V	PR02000203302JR500		2
25	R12, R13	27 R	0603 Resistor		2
26	R12A, R12B	0 R	0603 Resistor		2
27	R14, R14B	1 R/0.33 W	ERJ8BQF1R0 V		2
28	R16, R16A	15 M	1206 Resistor		2
29	R16B	20 M	1206 Resistor		1
30	R22	820 R	0603 Resistor		1
31	R23	1.2 k	0603 Resistor		1
32	R24	22 k	0603 Resistor		1
33	R25	38 k	0603 Resistor		1
34	R26	10 k	0603 Resistor		1
35	R110, R110A	2 M/500 V	1206 Resistor		2
36	TR1	439 uH(64:8:9)EE25/13/7	750343659(R00)	Wurth Electronics	1
37	Test point for FB, VCC, CS, DRAIN, GATE and GND	Test point	5010		6
38	VAR	385 V/0.25 W	B72207S0381K101	Epcos	1
39	CN1	Connector	691102710002	Wurth Electronics	1
40	CN2	Connector	691412120002B	Wurth Electronics	1
41	ZD11	22 V(SOD123)	MMSZ5251B-7-F		1

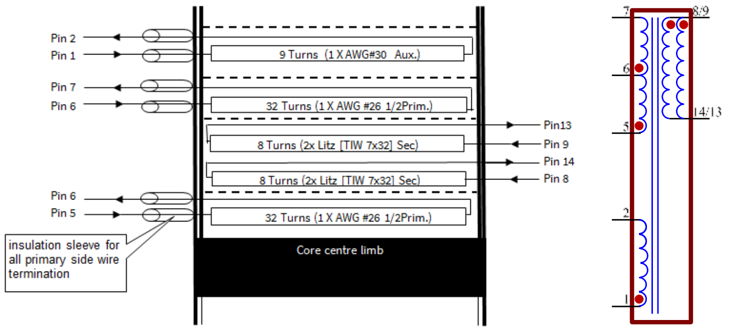
9 Transformer construction

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

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

Primary inductance: Lp = 439 µH (±10%), measured between pin 5 and pin 7

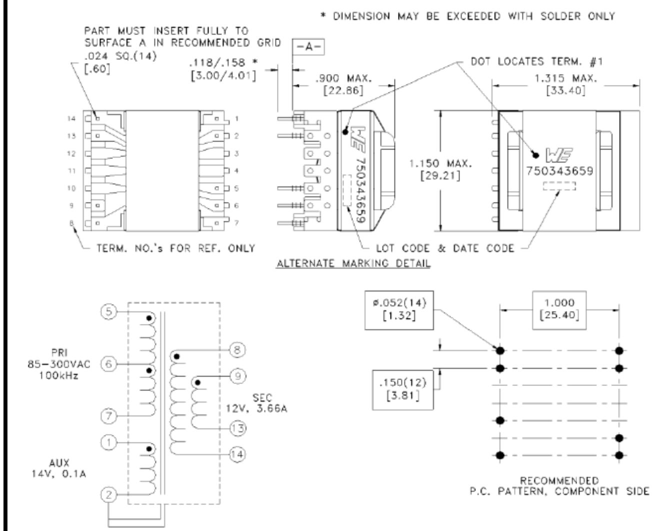
Manufacturer and part number: Wurth Electronics Midcom (750343659 R00)



Start	Stop	No. of turns	Wire size	Layer
5	6	32	1XAWG#26	1/2 Primary
8	14	8	2x Litz [TIW 7x32]	1/2 Secondary
9	13	8	2x Litz [TIW 7x32]	1/2 Secondary
6	7	32	1XAWG#26	1/2 Primary
1	2	9	1XAWG#30	Auxiliary

Horizontal and vertical external shields are added and tied to pin 2

CUSTOMER TERMINAL	RoHS	LEAD(Pb)--FREE
Sn 96%, Ag 4%	Yes	Yes



Application of the transformer allows for the leadwires between terminals 8&9 and 13&14 to solder bridge.

Customer to tie terminals 8+9 and 13+14 on PC board.

ELECTRICAL SPECIFICATIONS @ 25° C unless otherwise noted:

PARAMETER		TEST CONDITIONS	VALUE
D.C. RESISTANCE	5-7	@20ºC	0.470 ohms max.
D.C. RESISTANCE	8-14	tie(8+9,13+14), @20ºC	0.015 ohms max.
D.C. RESISTANCE	1-2	@20ºC	0.220 ohms max.
INDUCTANCE	5-7	100kHz, 100mV, Ls	439.00µH ±10%
LEAKAGE INDUCTANCE	5-7	tie(1+2+8+9+13+14),100kHz, 100mV, Ls	10.0µH max.
DIELECTRIC	7-14	tie(2+5, 8+9,13+14), 5000VDC, 1 second	
DIELECTRIC	1-7	625VAC, 1 second	
TURNS RATIO		(5-7):(8-14), tie(8+9,13+14)	8:1, ±2%
TURNS RATIO		(5-7):(1-2)	7.11:1, ±2%

GENERAL SPECIFICATIONS:

OPERATING TEMPERATURE RANGE: -40°C to +125°C including temp rise.

Wire insulation & RoHS status not affected by wire color. Wire insulation color may vary depending on availability.

DFM		Packaging Specifications	CONVENTION PLACEMENT	Tolerances unless otherwise specified:	DRAWING TITLE	PART NO.
DATE		Method: Tray		Angles: ±1° Decimals: ±.005 [.13]	TRANSFORMER	750343659
ENG	IYU	PKG-0737		Fractions: ±1/64 Footprint: ± .001 [.03]		
REV.	00			This drawing is dual dimensioned. Dimensions in brackets are in millimeters.		SPECIFICATION SHEET 1 OF 1
DATE	7/20/2017	www.we-online.com/midcom				

Figure 7 Transformer structure

10 Test results

10.1 Efficiency, regulation and output ripple

Table 4 Efficiency, regulation and output ripple

Input (V AC/Hz)	P_{in} (W)	V_{12} (V DC)	I_{12} (A)	V_{12RPP} (mV)	P_{out} (W)	Efficiency η (%)	Average η (%)	OLP P_{in} (W)	OLP I_{out12V} (A)
85 V AC/60 Hz	0.03614	12.04	0.000	58				60.80	4.20
	12.64	12.03	0.913	14	10.98	86.89	85.74		
	25.51	12.02	1.833	17	22.03	86.37			
	38.51	12.01	2.743	24	32.94	85.55			
	52.19	12.00	3.660	33	43.92	84.15			
115 V AC/60 Hz	0.03895	12.04	0.000	58				65.20	4.60
	12.56	12.03	0.913	14	10.98	87.45	87.07		
	25.18	12.02	1.833	16	22.03	87.50			
	37.81	12.01	2.743	20	32.94	87.13			
	50.95	12.00	3.660	22	43.92	86.20			
230 V AC/50 Hz	0.05925	12.04	0.000	61				71.50	5.10
	12.63	12.03	0.913	14	10.98	86.96	87.75		
	25.05	12.02	1.833	16	22.03	87.95			
	37.42	12.01	2.743	20	32.94	88.04			
	49.89	12.00	3.660	22	43.92	88.03			
265 V AC/50 Hz	0.06063	12.04	0.000	63				72.00	5.26
	12.69	12.03	0.913	13	10.98	86.55	87.39		
	25.18	12.02	1.833	16	22.03	87.50			
	37.54	12.01	2.743	20	32.94	87.76			
	50.05	12.00	3.660	22	43.92	87.75			
300 V AC/50 Hz	0.06563	12.04	0.000	63				72.70	5.31
	12.80	12.03	0.913	14	10.98	85.81	87.00		
	25.34	12.02	1.833	15	22.03	86.95			
	37.56	12.01	2.743	19	32.94	87.71			
	50.18	12.00	3.660	22	43.92	87.52			

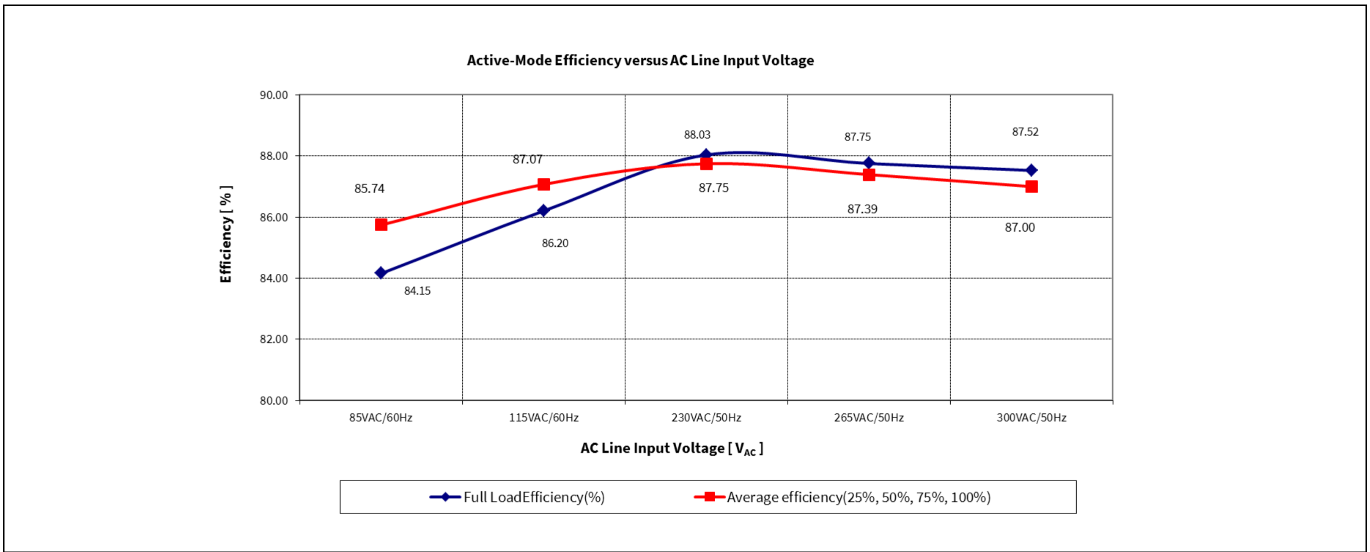


Figure 8 Efficiency vs AC-line input voltage

10.2 Standby power

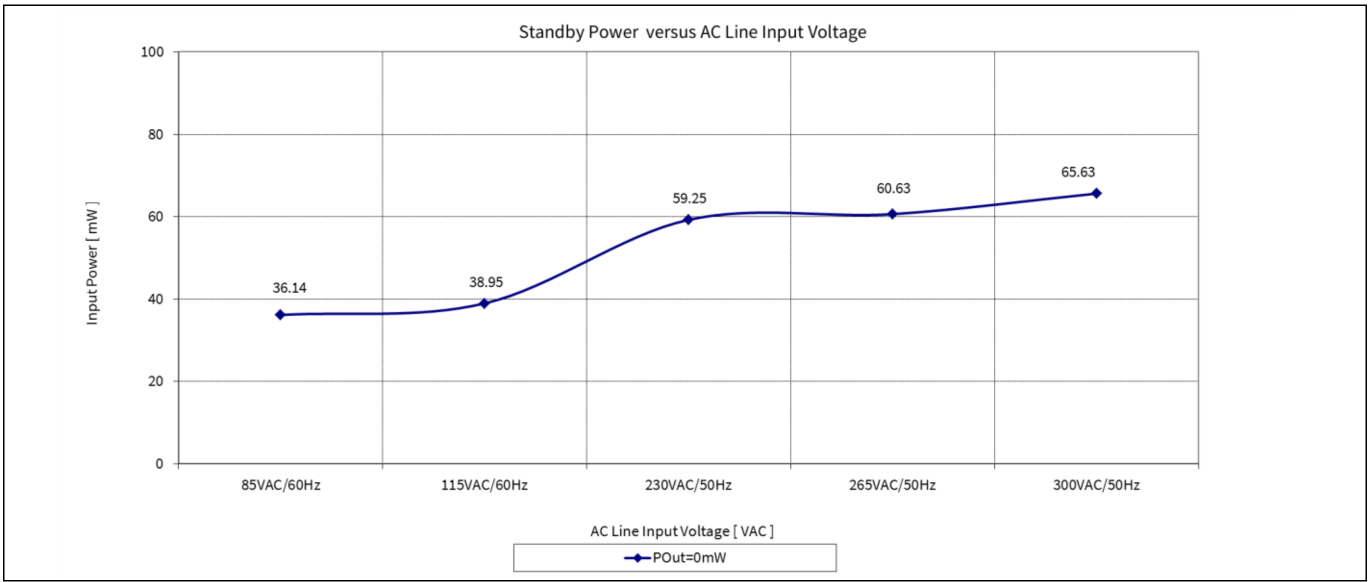


Figure 9 Standby power at no load vs AC-line input voltage (measured by Yokogawa WT210 power meter – integration mode)

10.3 Line regulation

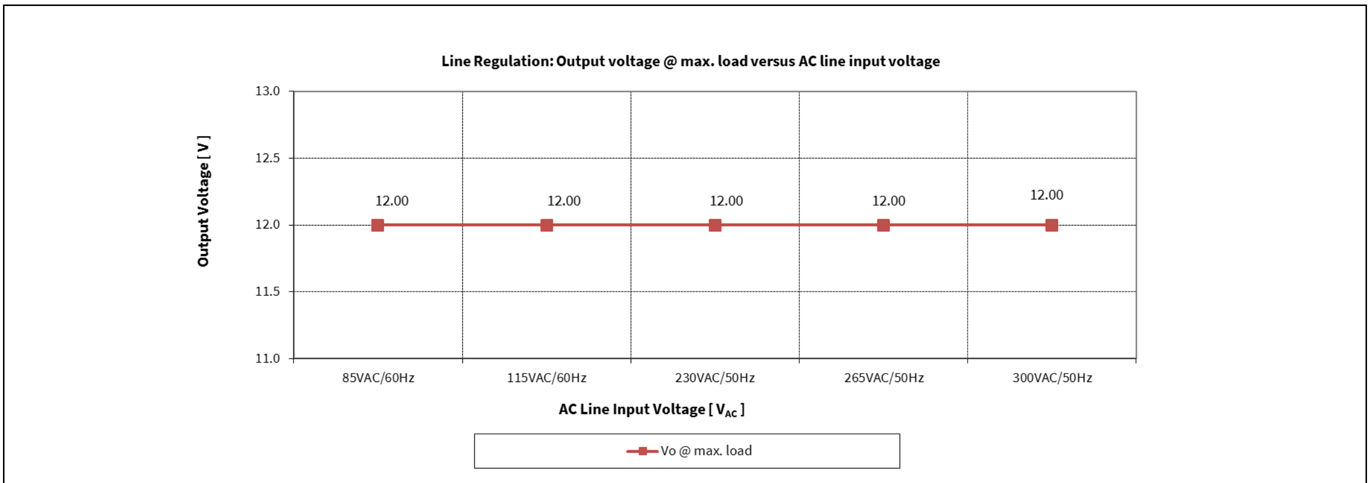


Figure 10 Line regulation V_{Out} at full load vs AC-line input voltage

10.4 Load regulation

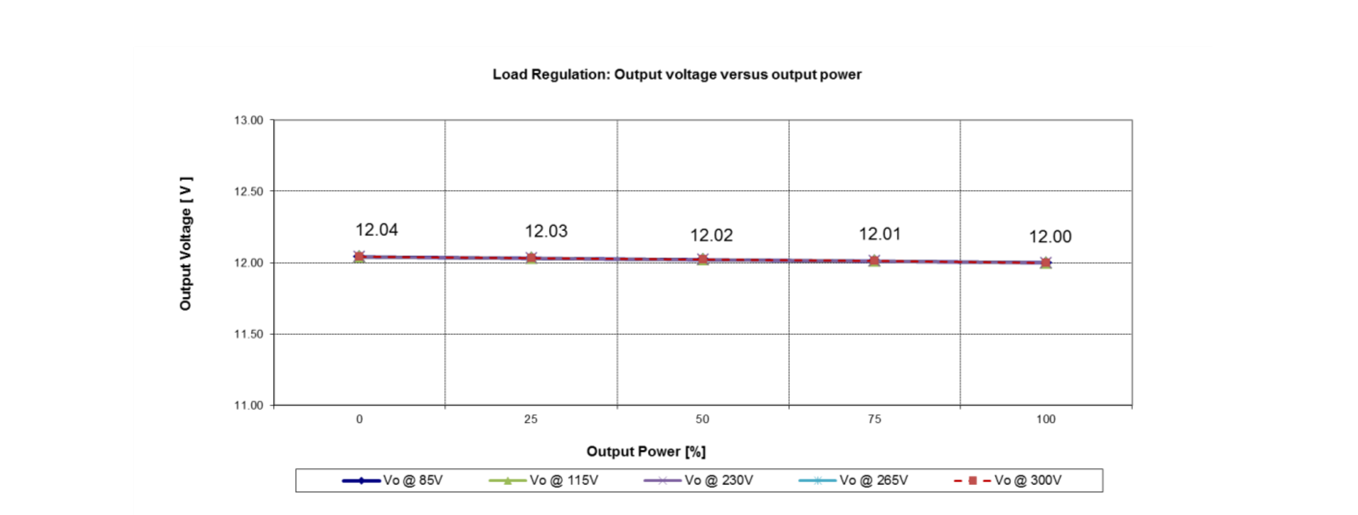


Figure 11 Load regulation V_{Out} vs output power

10.5 Maximum input power

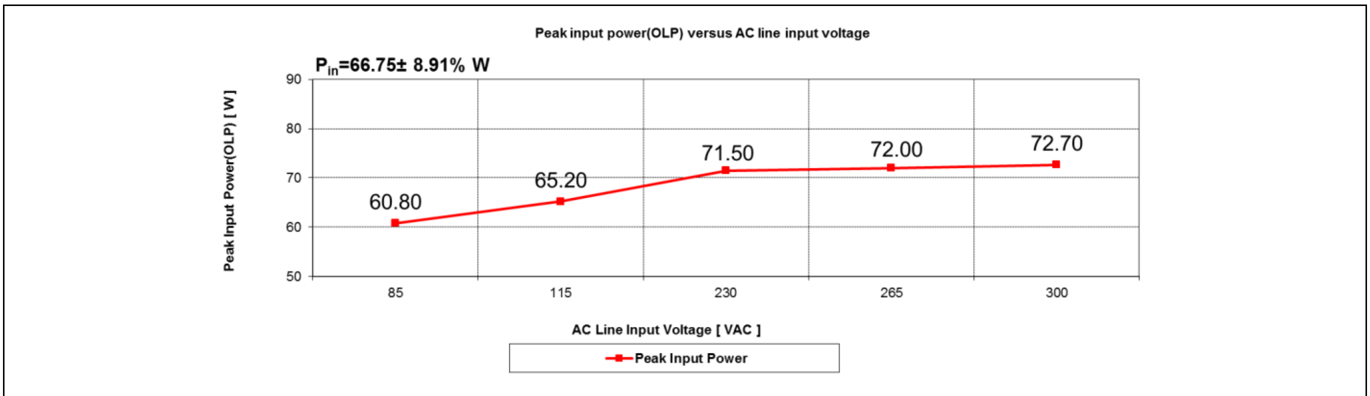


Figure 12 Maximum input power (before over-load protection) vs AC-line input voltage

10.6 ESD immunity (EN 61000-4-2)

Pass EN 61000-4-2 level 4 for contact discharge and level 3 for air discharge (±8 kV for both contact and air discharge).

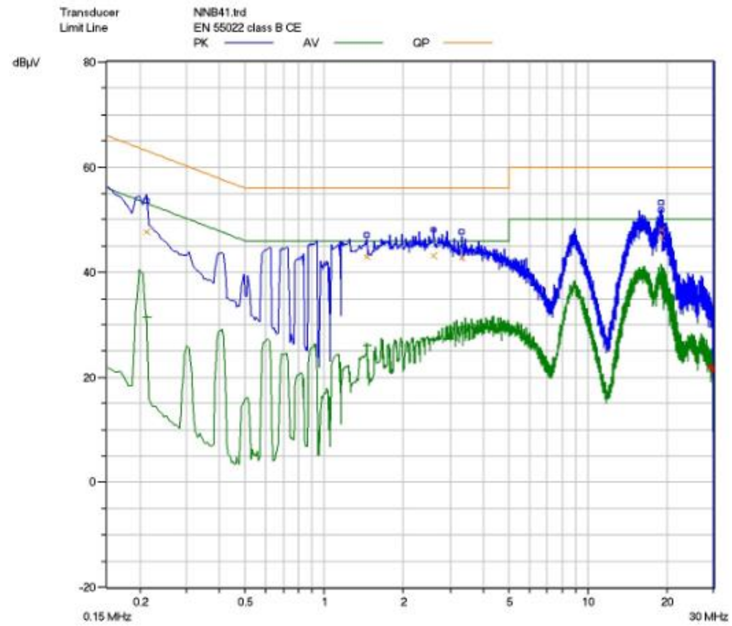
10.7 Surge immunity (EN 61000-4-5)

Pass EN61000-4-5 installation class 4 (±2 kV for line-to-line and ±4 kV for line-to-earth).

10.8 Conducted emissions (EN 55022 class B)

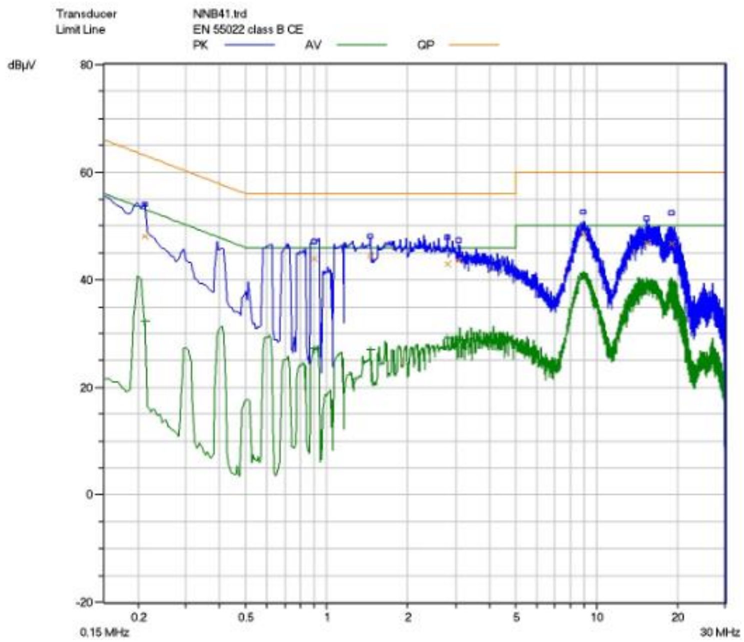
The conducted EMI was measured by Schaffner (SMR4503) and followed the test standard of EN 55022 (CISPR 22) class B. The demo board was set up at maximum load (44 W) with input voltage of 115 V AC and 230 V AC.

Pass conducted emissions EN 55022 (CISPR 22) class B with 8 dB margin for low-line (115 V AC) and 6 dB margin for high-line (230 V AC).



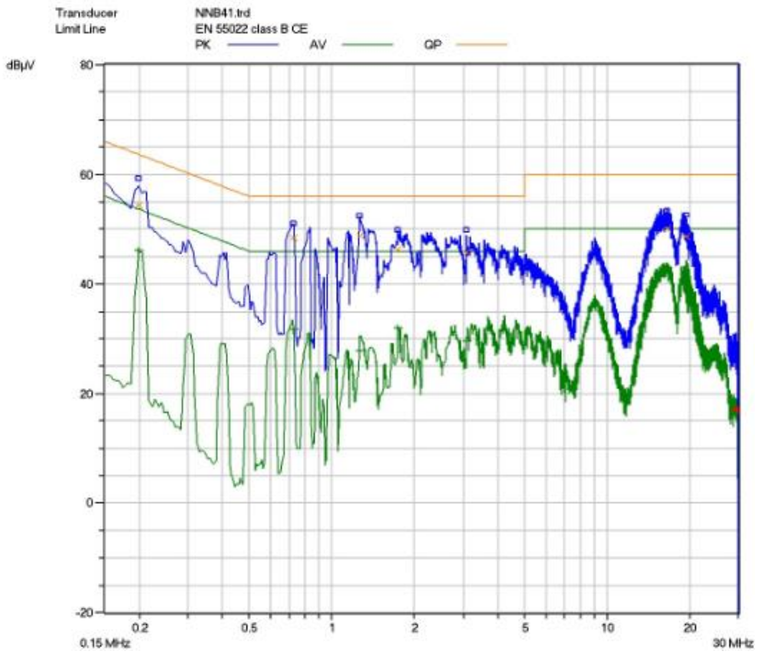
Frequency		Level Pk		Level AV		Level QP	Limit AV	Limit QP
0.2100	L	53.5	L	31.3	L	47.8	53.2	63.2
1.4520	L	47.1	L	26.1	L	43.1	46.0	56.0
2.5980	L	48.2	L	27.2	L	43.2	46.0	56.0
3.3200	L	47.6	L	29.7	L	42.8	46.0	56.0
18.9040	L	51.8	L	37.7	L	46.5	50.0	60.0
19.0720	L	53.2	L	39.7	L	48.1	50.0	60.0

Figure 13 Conducted emissions (line) at 115 V AC and maximum load



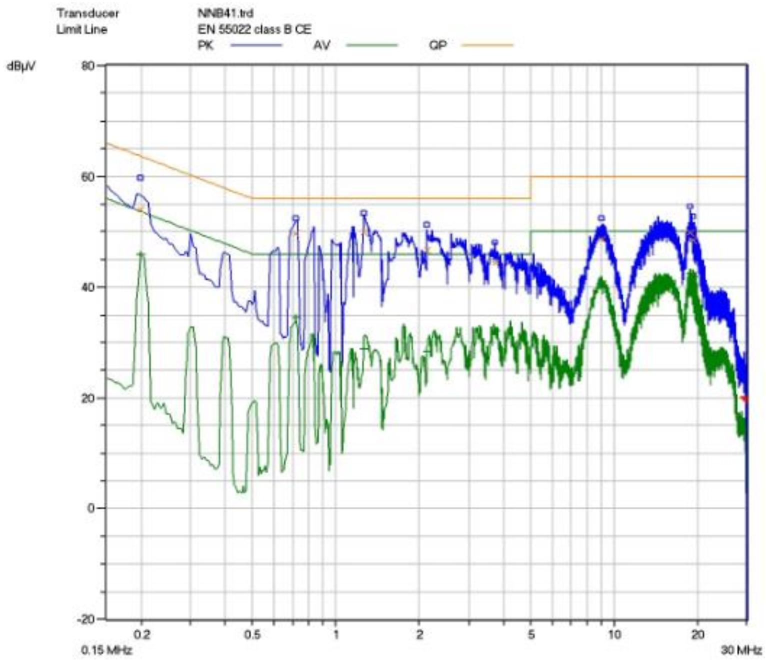
Frequency		Level Pk		Level AV		Level QP	Limit AV	Limit QP
0.2100	N	54.1	N	32.4	N	48.2	53.2	63.2
0.9000	N	47.2	N	27.2	N	44.0	46.0	56.0
1.4520	N	48.1	N	27.1	N	44.3	46.0	56.0
2.8080	N	48.0	N	29.3	N	43.1	46.0	56.0
3.0880	N	47.3	N	28.9	N	43.5	46.0	56.0
8.8880	N	52.6	N	41.1	N	48.5	50.0	60.0
15.3600	N	51.4	N	39.0	N	47.0	50.0	60.0
19.0240	N	52.4	N	39.0	N	46.7	50.0	60.0

Figure 14 Conducted emissions (neutral) at 115 V AC and maximum load



Frequency		Level Pk		Level AV		Level QP	Limit AV	Limit QP
0.1980	L	59.3	L	46.1	L	54.4	53.7	63.7
0.7260	L	51.1	L	31.7	L	48.6	46.0	56.0
1.2540	L	52.5	L	27.9	L	48.8	46.0	56.0
1.7400	L	50.0	L	32.0	L	46.4	46.0	56.0
3.0880	L	49.9	L	29.7	L	45.8	46.0	56.0
16.4640	L	53.5	L	43.0	L	50.0	50.0	60.0
19.4160	L	52.6	L	41.3	L	48.8	50.0	60.0

Figure 15 Conducted emissions (line) at 230 V AC and maximum load



Frequency		Level Pk		Level AV		Level QP	Limit AV	Limit QP
0.1980	N	59.8	N	46.0	N	54.0	53.7	63.7
0.7200	N	52.4	N	34.5	N	49.7	46.0	56.0
1.2540	N	53.5	N	28.7	N	50.0	46.0	56.0
2.1240	N	51.3	N	28.4	N	46.8	46.0	56.0
3.7360	N	48.1	N	32.2	N	44.5	46.0	56.0
9.0480	N	52.5	N	41.0	N	48.6	50.0	60.0
18.7360	N	54.5	N	42.4	N	49.8	50.0	60.0
19.2640	N	52.9	N	41.7	N	48.5	50.0	60.0

Figure 16 Conducted emissions (neutral) at 230 V AC and maximum load

10.9 Thermal measurement

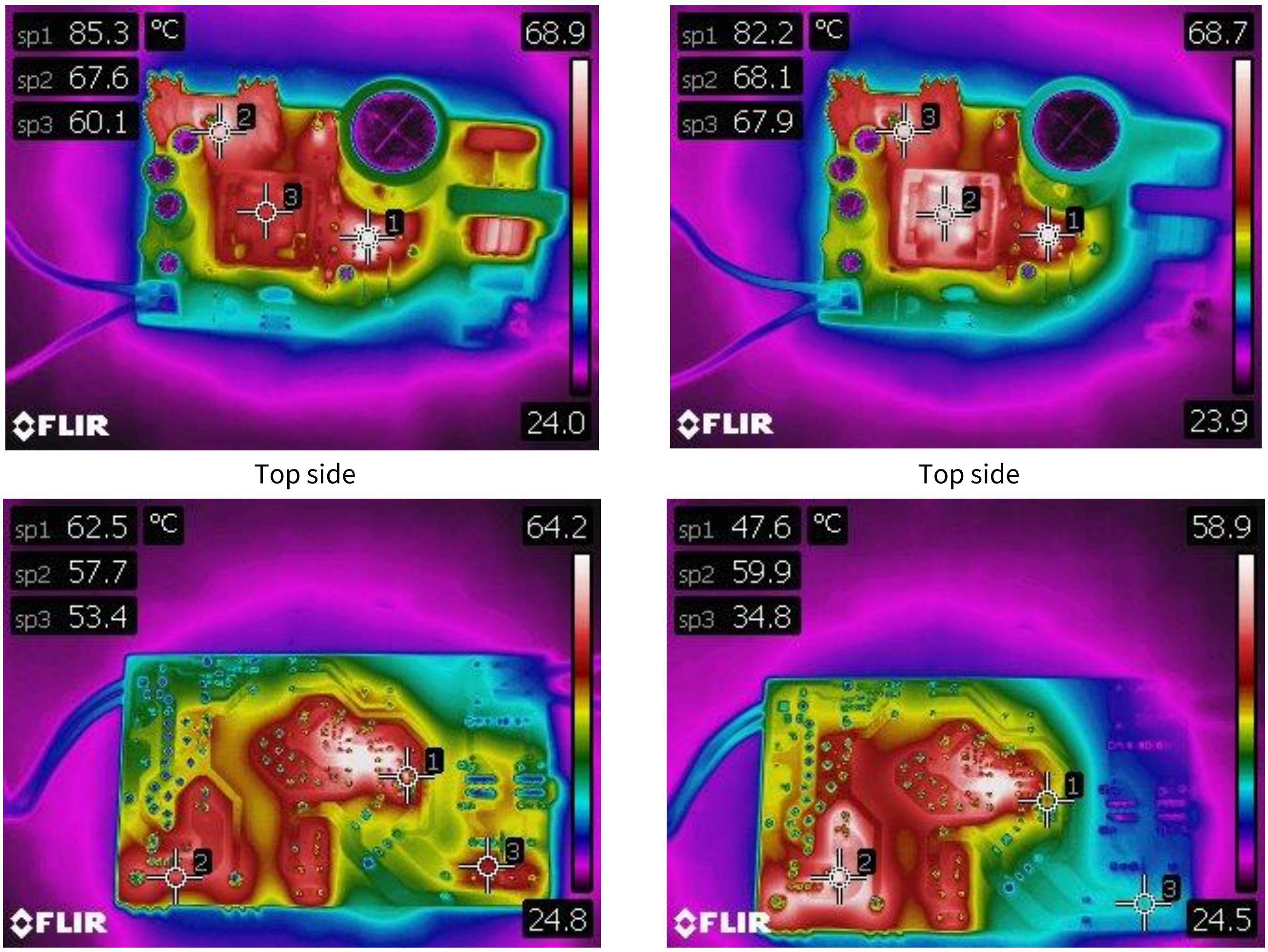
The thermal testing of the open-frame demo board was done using an infrared thermography camera (FLIR-T62101) at an ambient temperature of 25°C. The measurements were taken after one hour running at full load.

Table 5 Hottest temperature of demo board

No.	Major component	85 V AC (°C)	300 V AC (°C)
1	IC11 (ICE5AR0680BZS)	85.3	82.2
2	R14 (CS resistor)	62.5	47.6
3	TR1 (transformer)	60.1	68.1
4	BR1 (bridge diode)	61.7	36.0
5	R11 (clamper resistor)	67.6	64.0
6	L11 (choke)	68.3	35.0
7	D21 (secondary diode)	67.6	67.9
8	Ambient	25.0	25.0

85 V AC full load and 25°C ambient

300 V AC full load and 25°C ambient



Bottom side

Bottom side

Figure 17 Infrared thermal image of DEMO_5AR0680BZS_44W1

11 Waveforms and scope plots

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

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

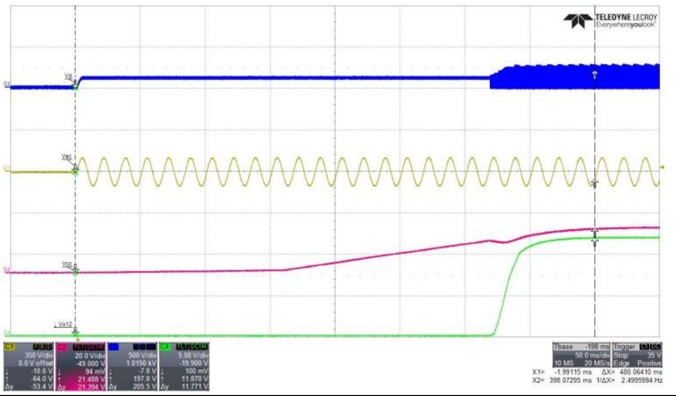
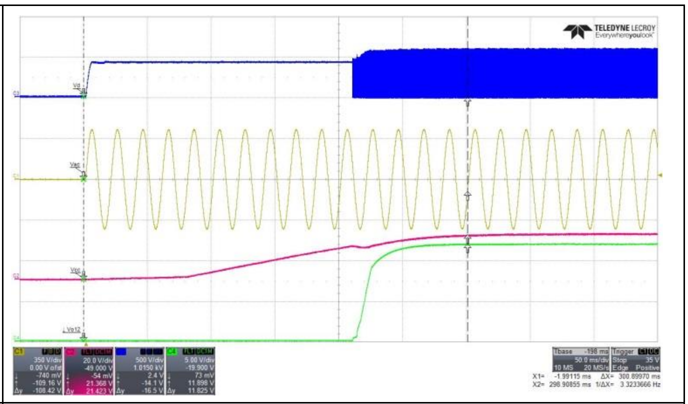
	
C1 (yellow) : AC-line voltage (V AC) C2 (purple) : Supply voltage (V_{VCC}) C3 (blue) : Drain voltage (V_D) C4 (green) : 12 V output voltage (V_{Out12})	C1 (yellow) : AC-line voltage (V AC) C2 (purple) : Supply voltage (V_{VCC}) C3 (blue) : Drain voltage (V_D) C4 (green) : 12 V output voltage (V_{Out12})
Start-up time at 85 V AC and maximum load ≈ 400 ms	Start-up time at 300 V AC and maximum load ≈ 300 ms

Figure 18 Start-up

11.2 Soft-start

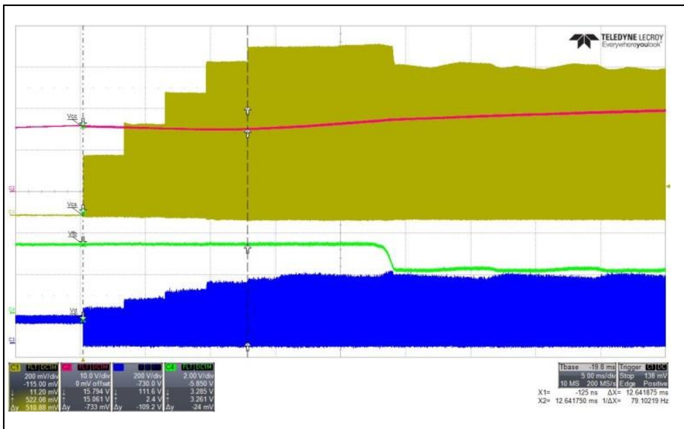
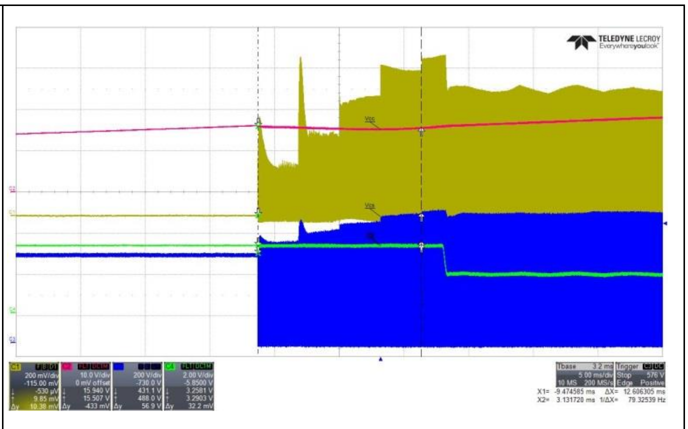
	
C1 (yellow) : CS voltage (V_{CS}) C2 (purple) : Supply voltage (V_{VCC}) C3 (blue) : Drain voltage (V_D) C4 (green) : FB voltage (V_{FB})	C1 (yellow) : CS voltage (V_{CS}) C2 (purple) : Supply voltage (V_{VCC}) C3 (blue) : Drain voltage (V_D) C4 (green) : FB voltage (V_{FB})
Soft-start time at 85 V AC and maximum load ≈ 12 ms	Soft-start time at 300 V AC and maximum load ≈ 12 ms

Figure 19 Soft-start

11.3 Drain and CS voltage at maximum load

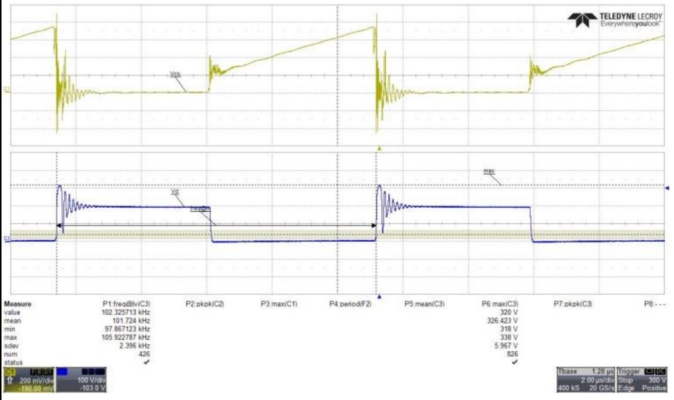
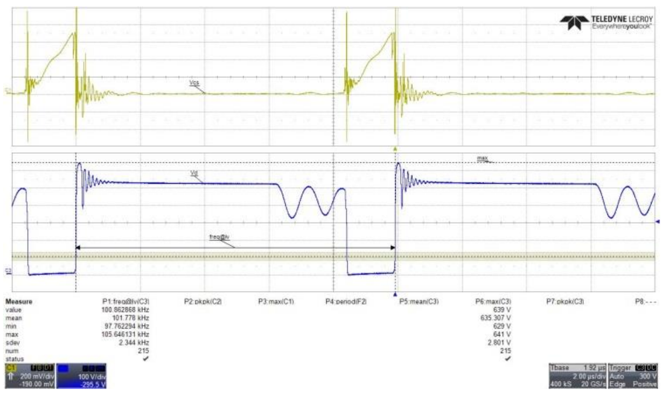
	
C1 (yellow) : CS voltage (V_{CS}) C3 (blue) : Drain voltage (V_D)	C1 (yellow) : CS voltage (V_{CS}) C3 (blue) : Drain voltage (V_D)
V_{Drain_peak} at 85 V AC ≈ 338 V	V_{Drain_peak} at 300 V AC ≈ 641 V

Figure 20 Drain and CS voltage at maximum load

11.4 Frequency jittering

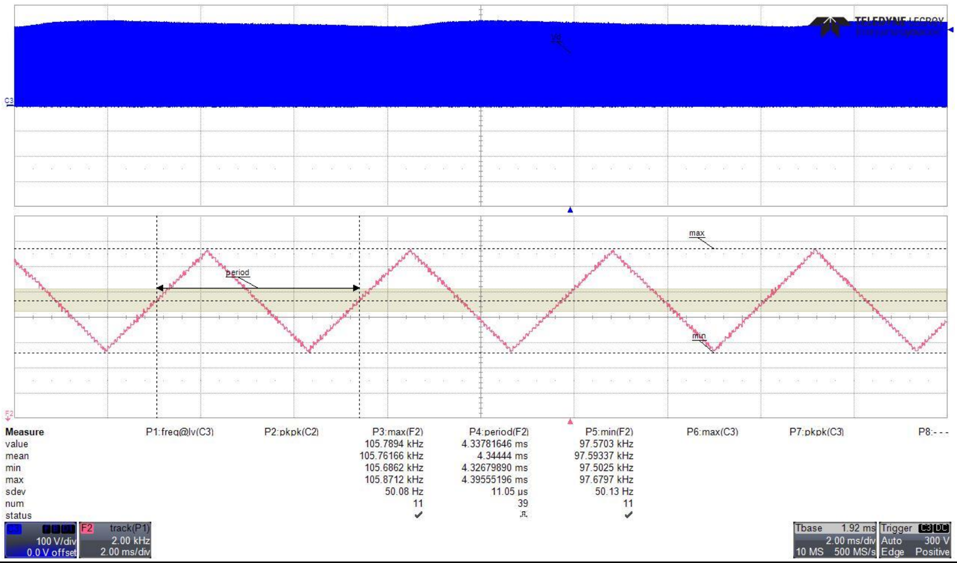

C3 (blue) : Drain voltage (V_D) F2 (purple) : Frequency track of drain
Frequency jittering at 85 V AC and maximum load is ≈ 97 kHz ~ 105 kHz, jitter period is ≈ 4.3 ms

Figure 21 Frequency jittering

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

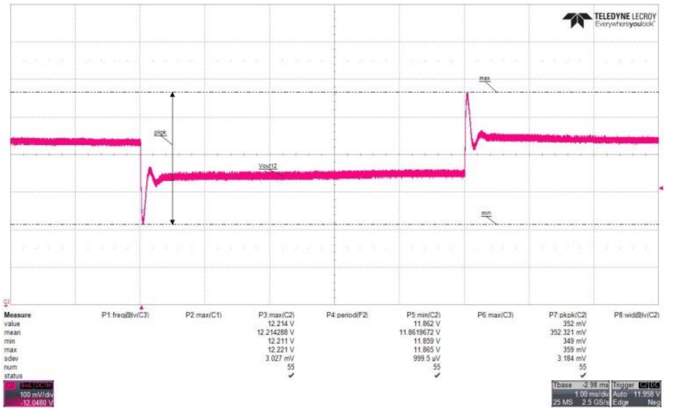
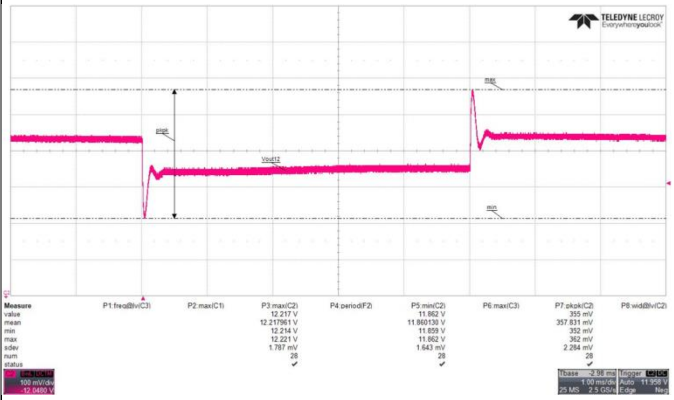
	
C2 (purple) : 12 V output ripple voltage (V_{Out12})	C2 (purple) : 12 V output ripple voltage (V_{Out12})
12 $V_{ripple\_pk\_pk}$ at 85 V AC ≈ 359 mV (85 V AC, 12 V load change from 10% to 100%, 100 Hz, 0.4 A/µs slew rate) Probe terminal end with decoupling capacitor of 0.1 µF (ceramic) and 1 µF (electrolytic), 20 MHz filter	12 $V_{ripple\_pk\_pk}$ at 85 V AC ≈ 362 mV (300 V AC, 12 V load change from 10% to 100%, 100 Hz, 0.4 A/µs slew rate) Probe terminal end with decoupling capacitor of 0.1 µF (ceramic) and 1 µF (electrolytic), 20 MHz filter

Figure 22 **Load transient response**

11.6 Output ripple voltage at maximum load

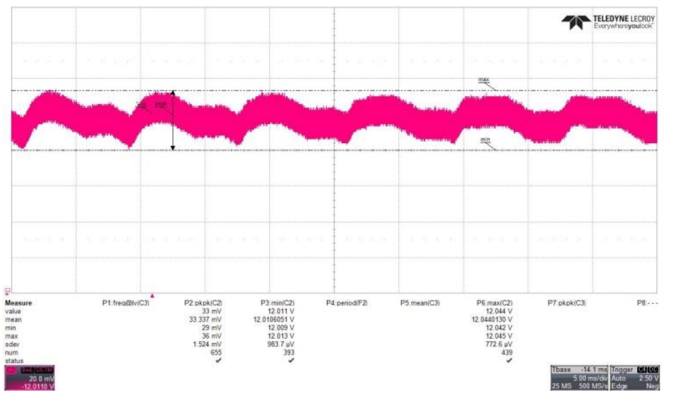
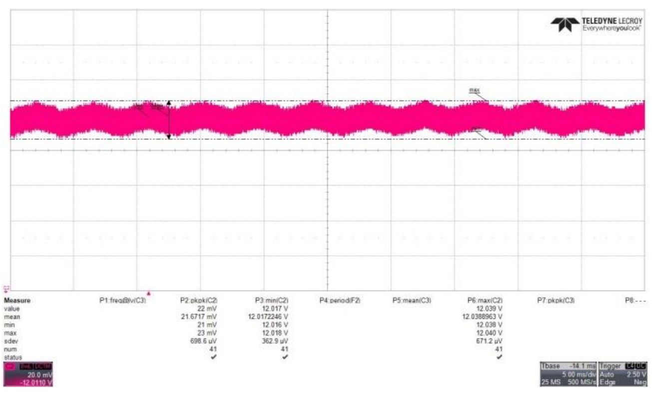
	
C2 (purple) : 12 V output ripple voltage (V_{Out12})	C2 (purple) : 12 V output ripple voltage (V_{Out12})
12 $V_{ripple\_pk\_pk}$ at 85 V AC ≈ 36 mV Probe terminal end with decoupling capacitor of 0.1 µF (ceramic) and 1 µF (electrolytic), 20 MHz filter	12 $V_{ripple\_pk\_pk}$ at 300 V AC ≈ 23 mV Probe terminal end with decoupling capacitor of 0.1 µF (ceramic) and 1 µF (electrolytic), 20 MHz filter

Figure 23 **Output ripple voltage at maximum load**

11.7 Output ripple voltage at ABM 1 W load

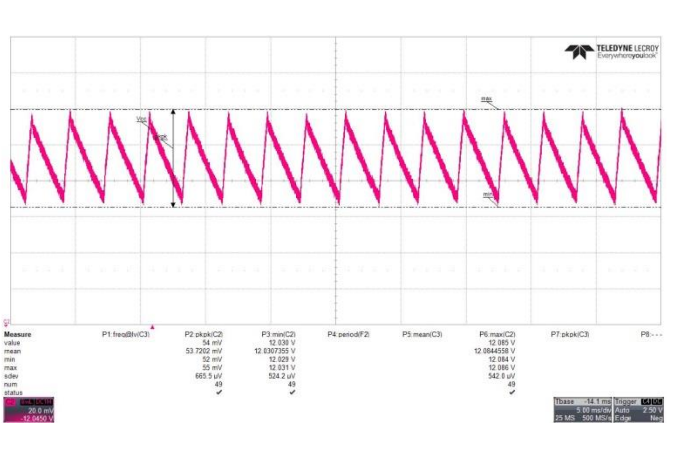
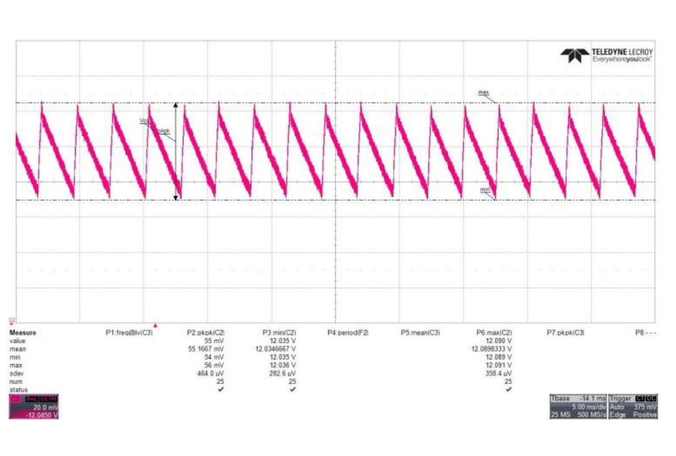
	
C2 (purple) : 12 V output ripple voltage (V_{Out12})	C2 (purple) : 12 V output ripple voltage (V_{Out12})
12 $V_{ripple\_pk\_pk}$ at 85 V AC ≈ 55 mV Load: 12 V at 83 mA Probe terminal end with decoupling capacitor of 0.1 µF (ceramic) and 1 µF (electrolytic), 20 MHz filter	12 $V_{ripple\_pk\_pk}$ at 300 V AC ≈ 56 mV Load: 12 V at 83 mA Probe terminal end with decoupling capacitor of 0.1 µF (ceramic) and 1 µF (electrolytic), 20 MHz filter

Figure 24 Output ripple voltage at ABM 1 W load

11.8 Entering ABM

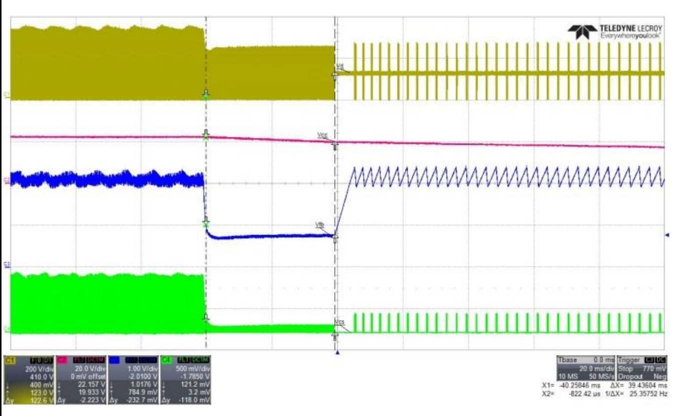
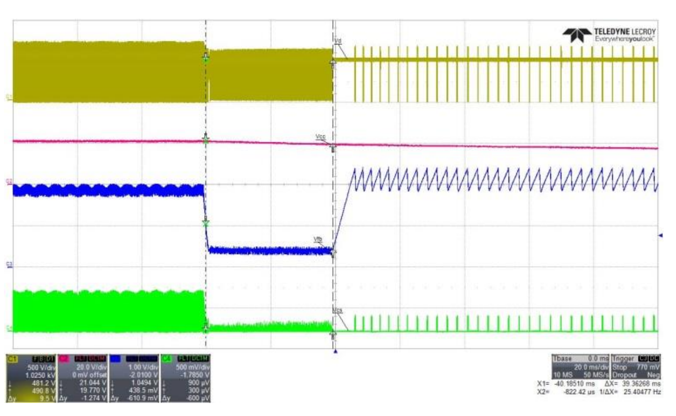
	
C1 (yellow) : Drain voltage (V_D) C2 (purple) : Supply voltage (V_{VCC}) C3 (blue) : FB voltage (V_{FB}) C4 (green) : CS voltage (V_{CS})	C1 (yellow) : Drain voltage (V_D) C2 (purple) : Supply voltage (V_{VCC}) C3 (blue) : FB voltage (V_{FB}) C4 (green) : CS voltage (V_{CS})
Condition to enter ABM level 1: V_{FB} < 1.05 V and $t_{blanking}$ = 36 ms (load change from full load to 1 W load at 85 V AC)	Condition to enter ABM level 1: V_{FB} < 1.05 V and $t_{blanking}$ = 36 ms (load change from full load to 1 W load at 300 V AC)

Figure 25 Entering ABM

11.9 During ABM

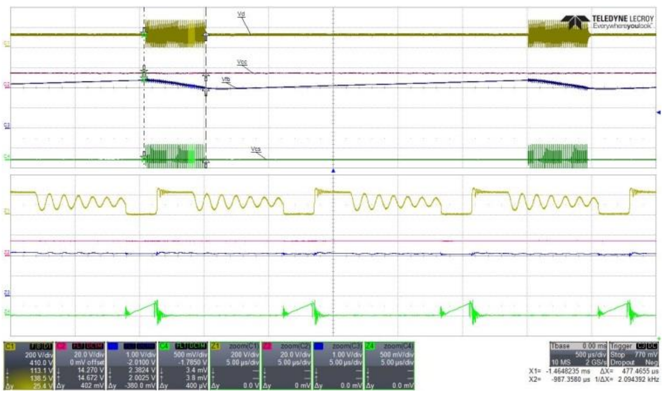
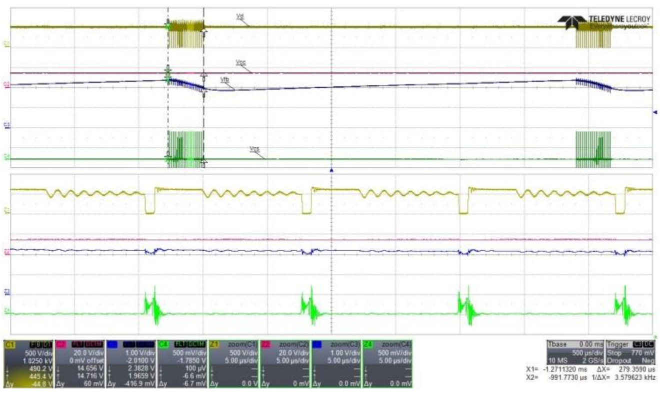
	
C1 (yellow) : Drain voltage (V_D) C2 (purple) : VIN voltage (V_{VIN}) C3 (blue) : FB voltage (V_{FB}) C4 (green) : CS voltage (V_{CS})	C1 (yellow) : Drain voltage (V_D) C2 (purple) : VIN voltage (V_{VIN}) C3 (blue) : FB voltage (V_{FB}) C4 (green) : CS voltage (V_{CS})
During ABM level 1: $V_{FB\_Bon\_ISO}$ = 2.4 V, $V_{FB\_BOff\_ISO}$ = 2.0 V, V_{CS_BHP} = 0.275 V (1 W load at 85 V AC)	During ABM level 1: $V_{FB\_Bon\_ISO}$ = 2.4 V, $V_{FB\_BOff\_ISO}$ = 2.0 V, V_{CS_BHP} = 0.275 V (1 W load at 300 V AC)

Figure 26 During ABM

11.10 Leaving ABM

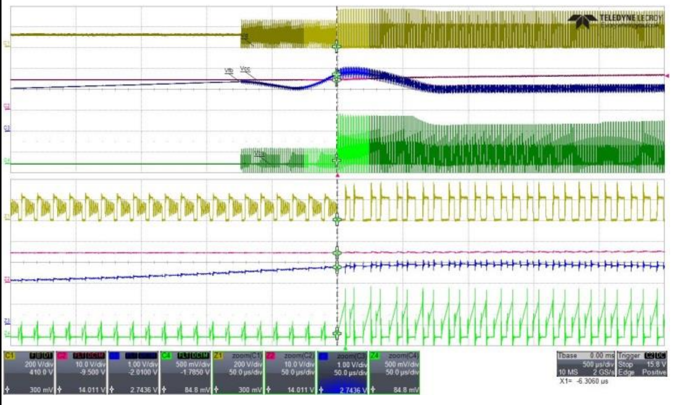
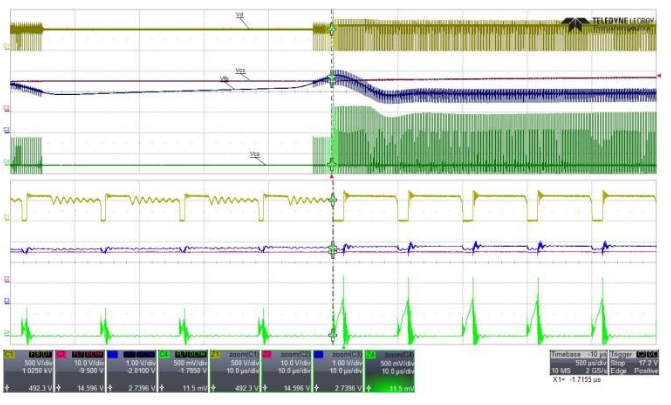
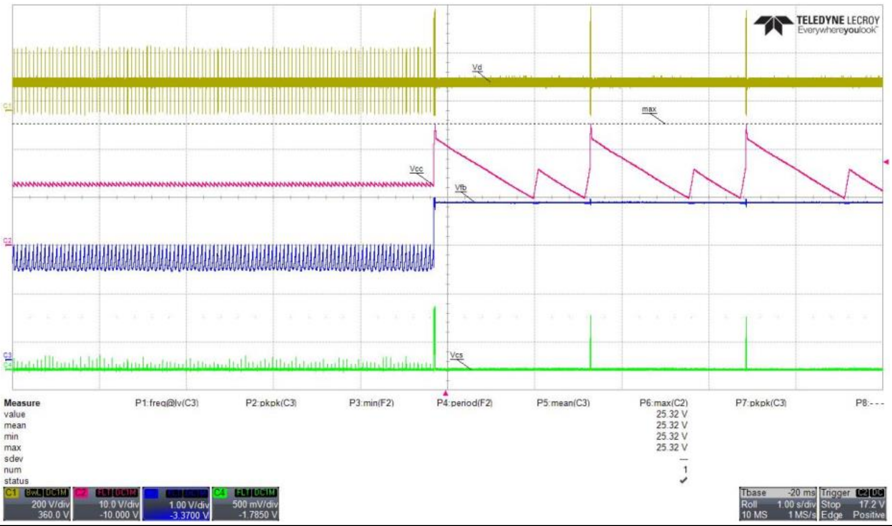
	
C1 (yellow) : Drain voltage (V_D) C2 (purple) : VIN voltage (V_{VIN}) C3 (blue) : FB voltage (V_{FB}) C4 (green) : CS voltage (V_{CS})	C1 (yellow) : Drain voltage (V_D) C2 (purple) : VIN voltage (V_{VIN}) C3 (blue) : FB voltage (V_{FB}) C4 (green) : CS voltage (V_{CS})
Condition to leave ABM level 3: V_{FB} > 2.75 V (load change from 1 W to full load at 85 V AC)	Condition to leave ABM level 3: V_{FB} > 2.75 V (load change from 1 W to full load at 300 V AC)

Figure 27 Leaving ABM

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

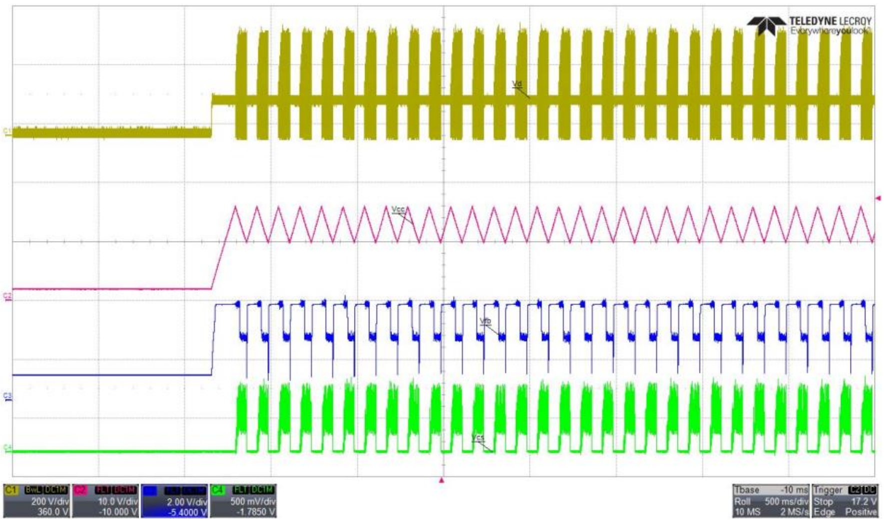


C1 (yellow) : Drain voltage (V_D)
C2 (purple) : Supply voltage (V_{VCC})
C3 (blue) : FB voltage (V_{FB})
C4 (green) : CS voltage (V_{CS})

Condition to enter V_{VCC} Over Voltage Protection (OVP): V_{VCC} > 25.5 V
(short R26 while system operating at 85 V AC and no load)

Figure 28 V_{CC} OVP

11.12 V_{CC} UVP (auto restart)



C1 (yellow) : Drain voltage (V_D)
C2 (purple) : Supply voltage (V_{VCC})
C3 (blue) : FB voltage (V_{FB})
C4 (green) : CS voltage (V_{CS})

Condition to enter VCC Under Voltage Protection (UVP): V_{CC} < 10 V
(remove R12A and power on the system with full load at 85 V AC)

Figure 29 V_{CC} UVP

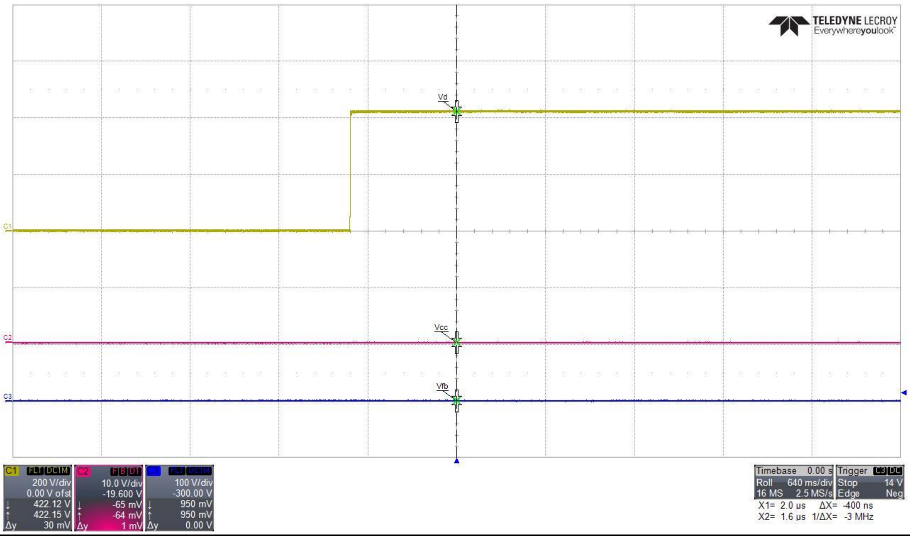
11.13 Over-load protection (odd-skip auto restart)

C1 (yellow)	: Drain voltage (V_D)
C2 (purple)	: Supply voltage (V_{VCC})
C3 (blue)	: FB voltage (V_{FB})
C4 (green)	: CS voltage (V_{CS})

Condition to enter over-load protection: V_{FB} > 2.75 V and lasts for 54 ms blanking time
(load change from full to short load at 85 V AC)

Figure 30 Over-load protection

11.14 V_{CC} short-to-GND protection



C1 (yellow)	: Drain voltage (V_D)
C2 (purple)	: VCC voltage (V_{VCC})
C3 (blue)	: FB voltage (V_{FB})

Condition to enter V_{CC} short-to-GND: if $V_{CC} < V_{VCC\_SCP} \rightarrow I_{VCC} = I_{VCC\_Charge1}$
(short VCC pin-to-GND and measure the current with multimeter before system start-up, I_{VCC} ≈ 500 µA and input power is ≈ 450 mW at 300 V AC)

Figure 31 V_{CC} short-to-GND protection

12 References

[1] ICE5xRxxxxBZS datasheet, Infineon Technologies AG

[2] 5th Generation Fixed-Frequency Design Guide

[3] Calculation Tool Fixed Frequency CoolSET™ Generation 5

Revision history

Document version	Date of release	Description of changes
V1.0	2017-09-18	First release

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