14 W 15 V and 5 V SMPS demo board with ICE5AR3995BZ

ER_DEMO_5AR3995BZ_14W1

About this document

Get exclusive information
Register product

Scope and purpose

This document is an engineering report that describes a universal-input 14 W 15 V and 5 V offline non-isolated flyback converter using the latest fifth-generation Infineon fixed-frequency (FF) CoolSET™ ICE5AR3995BZ, which offers high-efficiency, low-standby power with selectable entry and exit standby power options, wide V_{CC} operating range with fast start-up, and various protection modes for a highly reliable system. This demo board is designed for users who wish to evaluate the performance of ICE5AR3995BZ 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 for offline SMPS – either auxiliary power supplies for white goods, PCs, servers and TVs, or enclosed adapters for Blu-ray players, set-top boxes, game consoles, etc.

Table of contents

About this document **1**
Table of contents **1**
1 Abstract **3**
2 Demo board **4**
3 Specifications of the demo board **5**
4 Circuit description **6**
4.1 Input filtering 6
4.2 Start-up 6
4.3 Integrated CoolMOS™ with frequency reduction control 6
4.4 Frequency jittering 7
4.5 RCD clamper circuit 7
4.6 Output stage 7
4.7 Feedback loop 7
4.8 Active burst mode 7
5 Protection features **8**
6 Circuit diagram **9**
7 PCB layout **10**
7.1 Top side 10
7.2 Bottom side 10
8 Bill of materials **11**
9 Transformer construction **12**
10 Test results **13**
10.1 Efficiency and regulation 13

Table of contents

10.2 Efficiency curve 14
10.3 Standby power 14
10.4 Line regulation 15
10.5 Load regulation 15
10.6 Maximum input power 16
10.7 Surge immunity (EN 61000-4-5) 16
10.8 Conducted emissions (EN 55022 class B) 17
10.9 Thermal measurements 18
11 Waveforms and oscilloscope plots 19
11.1 Start-up at full load 19
11.2 Soft-start at full load 19
11.3 Drain and CS voltage at full load 20
11.4 Frequency jittering 20
11.5 Output ripple voltage at full load 21
11.6 Output ripple voltage at ABM 21
11.7 Entering ABM 22
11.8 During ABM 22
11.9 Leaving ABM 23
11.10 V_{CC} OV/UV protection 23
11.11 Overload protection 24
11.12 V_{CC} short-to-GND 24
12 Appendix A: Drop-in test for ICE5AR4770BZS and ICE5AR4780BZS 25
12.1 Full-load efficiency comparison 26
12.2 Standby power comparison 26
References 27
Revision history 28

1 Abstract

This document is an engineering report for a 14 W 15 V and 5 V demo board designed in a FF non-isolated flyback converter topology with primary-side feedback (FB) using the fifth-generation FF CoolSET™ ICE5AR3995BZ. The demo board is operated in discontinuous conduction mode (DCM) and is running at 100 kHz fixed switching frequency. The frequency reduction with soft gate driving and frequency jittering offers lower EMI and better efficiency between light load and 50 percent load. The selectable active burst mode (ABM) power enables ultralow power consumption. In addition, numerous adjustable protection functions have been implemented in ICE5AR3995BZ to protect the system and customize the IC for the chosen application. In case of failure modes, such as V_{CC} overvoltage (OV)/undervoltage (UV), open control-loop or overload, overtemperature, V_{CC} short-to-GND and current sense (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 the 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 ICE5AR3995BZ 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, power-supply specifications, circuit diagram, bill of materials (BOM) and transformer construction documentation of the DEMO_5AR3995BZ_14W1 demo board. Typical operating characteristics such as performance curve and oscilloscope waveforms are shown at the end of the document.

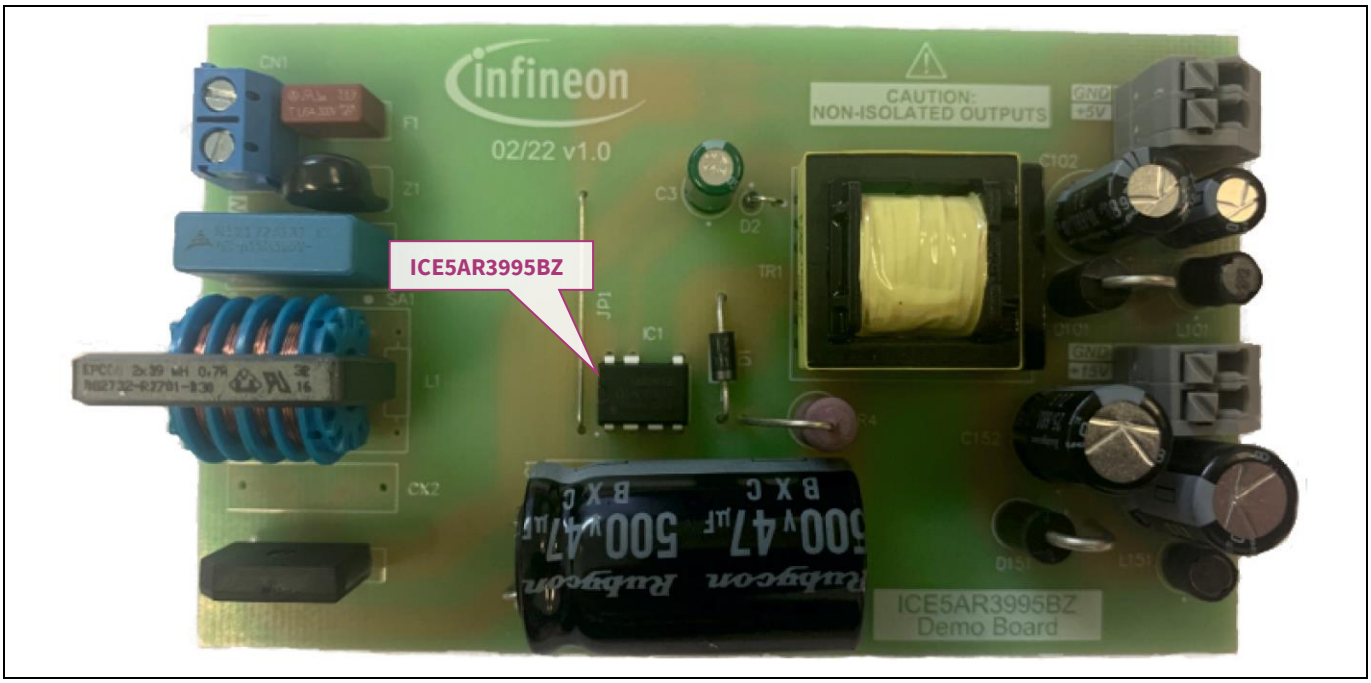


Figure 1 DEMO_5AR3995BZ_14W1

3 Specifications of the demo board

Table 1 Demo board specifications

Description	Symbol	Min.	Typ.	Max.	Units	Comments
Input						
Voltage	V_{IN}	85	–	300	V AC	Two wires (no P.E.)
Frequency	f_{LINE}	47	50/60	64	Hz	
No-load input power	P_{stby_NL}	–	–	100	mW	230 V AC
Output						
Output voltage 1	V_{OUT1}	–	15	–	V	±5 percent
Output current 1	I_{OUT1}		–	830	mA	
Output voltage ripple 1	$V_{RIPPLE1}$	–	–	150	mV	
Output voltage 2	V_{OUT2}	–	5	–	V	±5 percent
Output current 2	I_{OUT2}		–	400	mA	
Output voltage ripple 2	$V_{RIPPLE2}$		–	75	mV	
Output power	P_{OUT_Nom}	–	14.45		W	
Overcurrent protection (+15 V)	I_{OCP}	–	–	1250	mA	Full load on 5 V
Efficiency						
Average efficiency	η_{avg}	–	83	–	%	115 V AC/230 V AC
Environmental						
Conducted EMI			6		dB	Margin, CISPR 22 class B
Surge immunity						EN 61000-4-5
Differential mode			±2		kV	
PCBA dimension			110 x 66 x 27		mm^3	L x W x H

Note: This demo board is designed for dual-output with cross-regulated loop FB. It may not regulate properly if loading is only applied or heavily applied to any single output.

4 Circuit description

4.1 Input filtering

The AC-line input side comprises the input fuse F1 as overcurrent protection. The common-mode choke (CMC) L1 and X-capacitor CX1 act as EMI suppressors. Optional spark-gap devices SA1, SA2 and varistor Z1 can absorb high-voltage stress during lightning surge testing. A rectified DC voltage is obtained through the bridge rectifier BR1 together with bulk capacitor C1.

4.2 Start-up

To achieve fast and safe start-up, ICE5AR3995BZ is implemented with a high-resistance start-up resistor and V_{CC} short-to-GND protection. When V_{VCC} reaches the turn-on voltage threshold V_{CC_ON}, the IC begins with a soft-start. The soft-start implemented in ICE5AR3995BZ is a digital time-based function. The preset soft-start time is around 12 ms with four steps. If not limited by other functions, the peak voltage on the CS pin will increase incrementally to V_{CS_N}. After IC turn-on, the V_{CC} voltage is supplied by auxiliary windings of the transformer. V_{CC} short-to-GND protection is implemented during the start-up time.

4.3 Integrated CoolMOS™ with frequency reduction control

The integrated highly efficient CoolMOS™ and the frequency reduction control enable better efficiency from light load to full load. This integrated solution greatly simplifies the circuit layout and reduces the cost of PCB manufacturing. The new CoolSET™ can be operated in either DCM or continuous conduction mode (CCM) with frequency reduction mode. This demo board is designed to operate in DCM. When the system is operating at maximum load, the controller will switch at the fixed frequency of 100 kHz. In order to achieve 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).

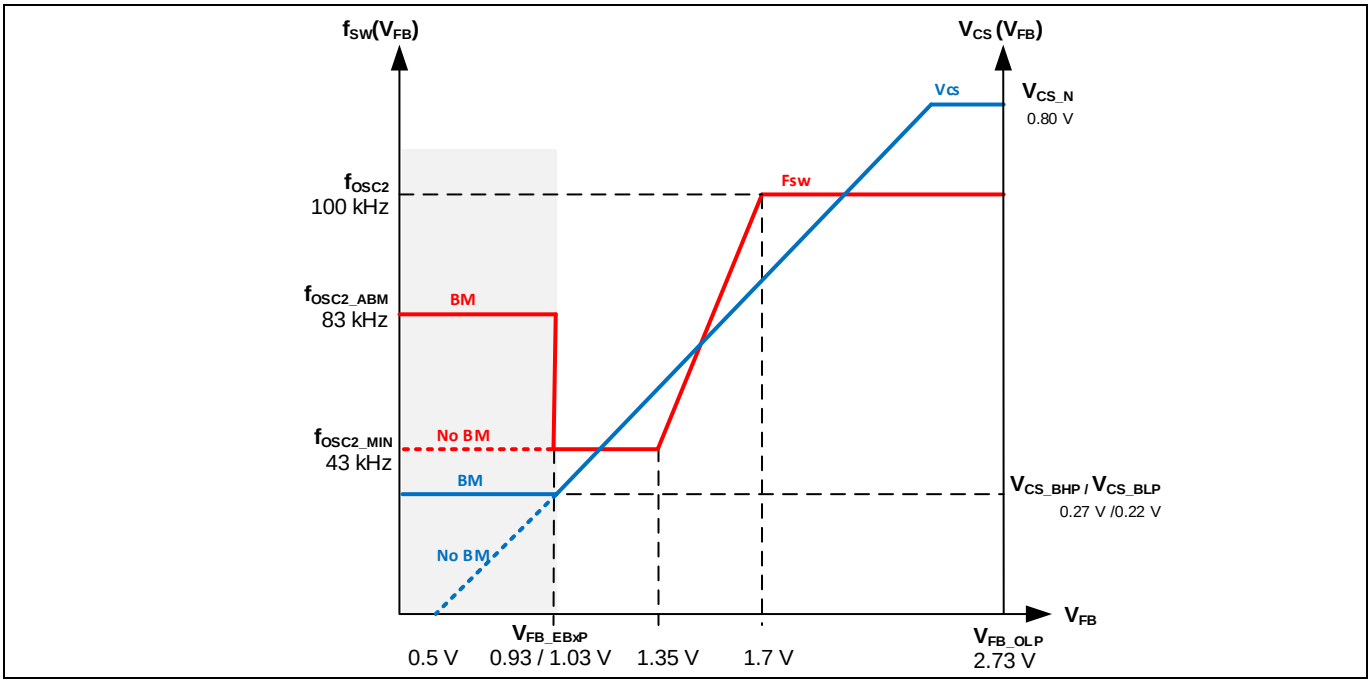


Figure 2 Frequency reduction curve (f_{OSC2})

4.4 Frequency jittering

The ICE5AR3995BZ has a frequency jittering feature to reduce the EMI noise. The jitter frequency is internally set at 100 kHz (±4 percent) and the jitter period is 4 ms.

4.5 RCD clamper circuit

A clamper network (R4, C2 and D1) dissipates the energy of the leakage inductance and suppresses ringing on the SMPS transformer. This is a dissipative circuit; therefore, R4 and C2 need to be fine-tuned depending on the voltage derating factor and efficiency requirement.

4.6 Output stage

There are two outputs in this converter, +15 V and +5 V. The power is coupled out via Schottky diodes D151 and D101. The capacitors C152 and C102 provide energy buffering followed by the L-C filters L151-C153 and L101-C103 to reduce the output voltage ripple and prevent interference between SMPS switching frequency and line frequency. Storage capacitors C152 and C102 are selected to have a very small ESR to minimize the output voltage ripple.

4.7 Feedback loop

The output voltage is sensed by the voltage divider of R11, R103 and R153 and compared to the internal reference voltage of ICE5AR3995BZ via the VERR pin, which is connected to the input of an integrated error amplifier internally. By connecting this pin, non-isolated application is achieved. The comparison voltage is converted to the current signal via IC internal integrated error amplifier to the FB pin for regulation control.

4.8 Active burst mode

ABM entry and exit power (three levels) can be selected in ICE5AR3995BZ. Details are illustrated in the product datasheet. At light-load condition, the SMPS enters ABM. At this stage, the controller is always active but the V_{VCC} must be kept above V_{VCC_OFF}. During ABM, the efficiency increases significantly and at the same time it supports low ripple on V_{OUT} and fast response on load-jump.

To enter ABM, two conditions must apply:

1. the FB voltage must be lower than the threshold of V_{FB_EBXP}
2. a certain blanking time must have elapsed (t_{FB_BEB} = 36 ms).

Once both of these conditions are fulfilled, the ABM flip-flop is set and the controller enters ABM operation. This dual-condition determination for entering ABM prevents mis-triggering, 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 V_{CS_N} to V_{CS_BXP} to reduce the conduction loss and the audible noise. In burst mode, the FB voltage is changing like a sawtooth between $V_{FB_Bon_NISO}$ and $V_{FB_Boff_NISO}$.

The FB voltage immediately increases if there is a sudden increment in output load. This is observed by one comparator. When FB voltage can exceed V_{FB_LB}, it will leave ABM and the PCL threshold voltage will return to V_{CS_N} immediately 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. ICE5AR3995BZ provides comprehensive protection to ensure the system is operating safely. Protections include V_{CC} OV and UV, overload, overtemperature (controller junction) and V_{CC} short-to-GND. When those faults are found, the system will enter protection mode until the fault is removed, and then resume normal operation. A list of protections and the failure conditions are shown in the table below.

Table 2 Protection features of ICE5AR3995BZ

Protection function	Failure condition	Protection mode
V_{CC} OV	V_{VCC} greater than V_{VCC_OVP}	Odd-skip auto restart
V_{CC} UV	V_{VCC} less than V_{VCCoff}	Auto restart
Overload	V_{FB} greater than V_{FB_OLP} and lasts for $t_{FB_OLP_B}$	Odd-skip auto restart
Overtemperature	T_J greater than 140°C (40°C hysteresis)	Non-switch auto restart
V_{CC} short-to-GND (V_{VCC} = 0 V, $R_{StartUp}$ = 50 MΩ and V_{DRAIN} = 90 V)	V_{VCC} less than V_{CC_SCP}, $I_{VCC_Charge1}$ ≈ -0.2 mA	Cannot start up

6 Circuit diagram

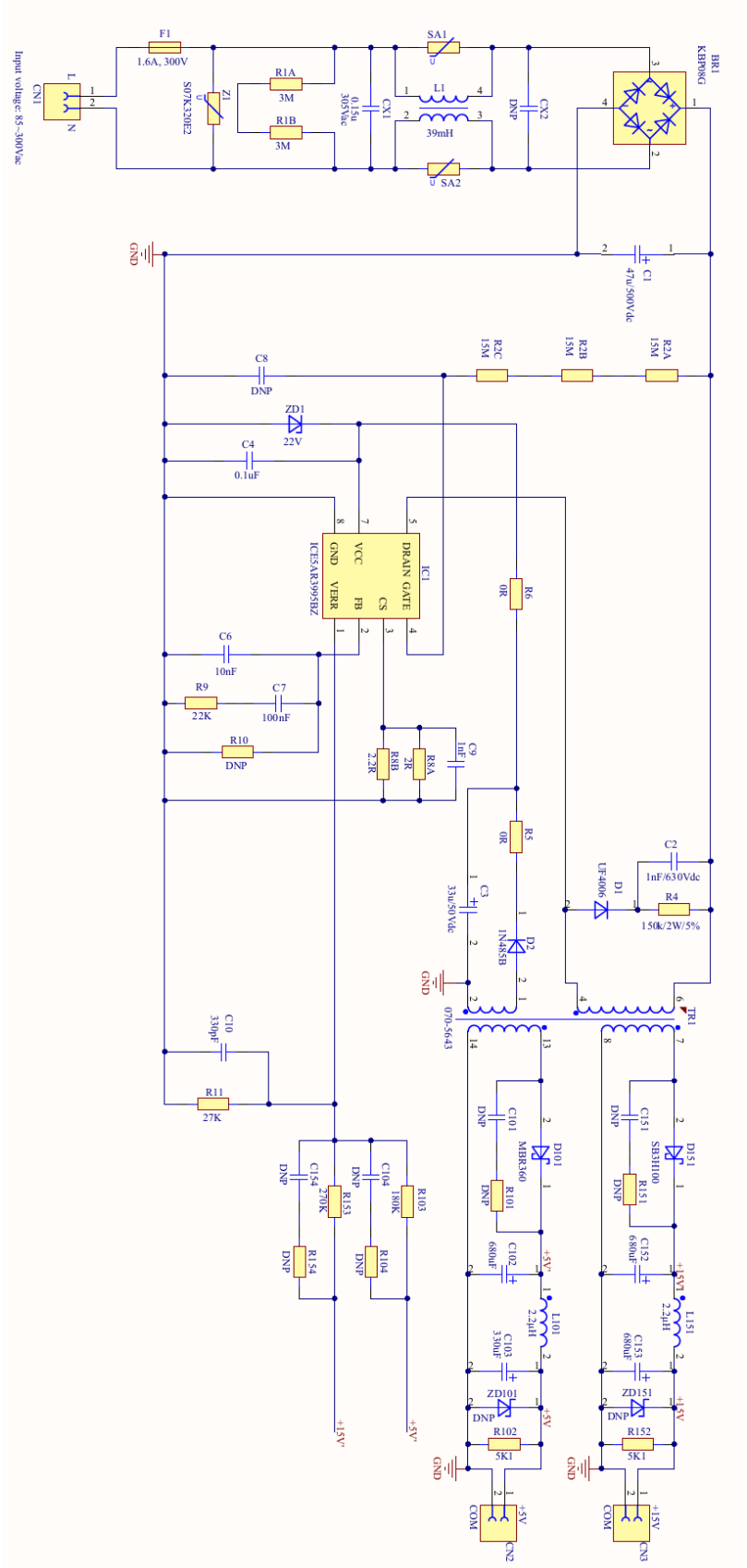


Figure 3 Schematic of DEMO_5AR3995BZ_14W1

7 PCB layout

7.1 Top side

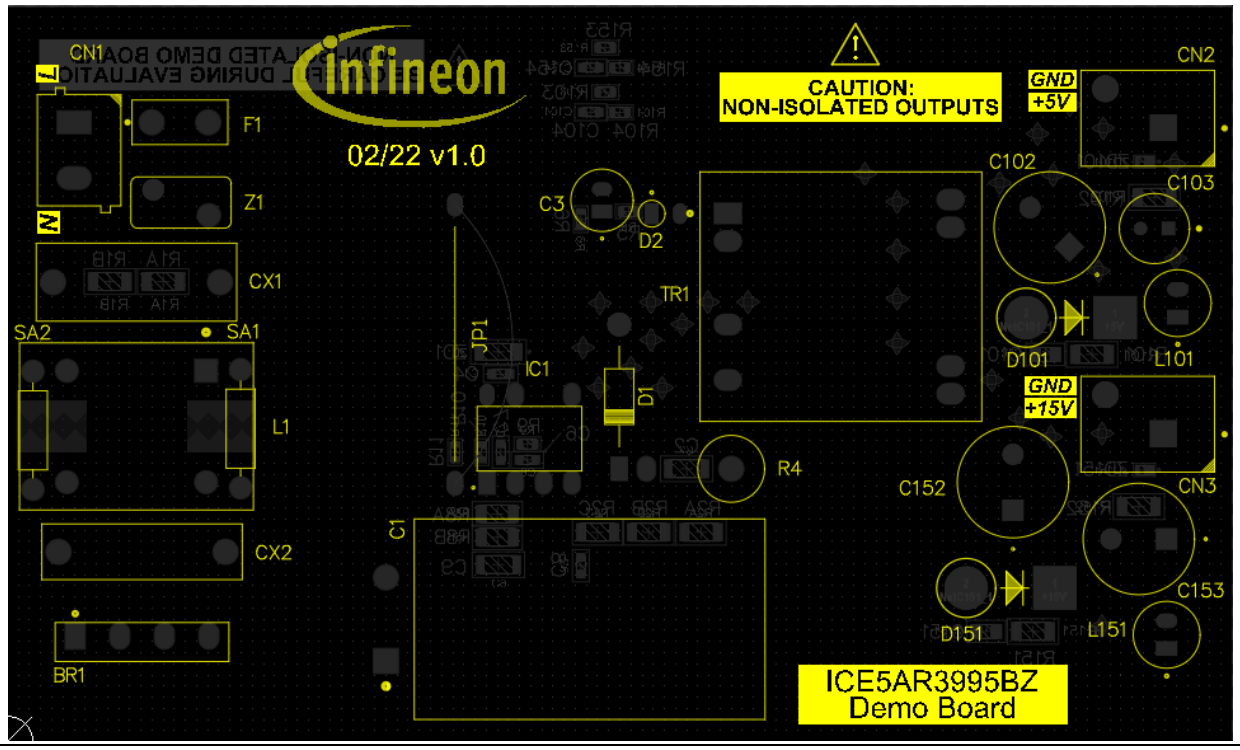


Figure 4 Top-side component legend

7.2 Bottom side

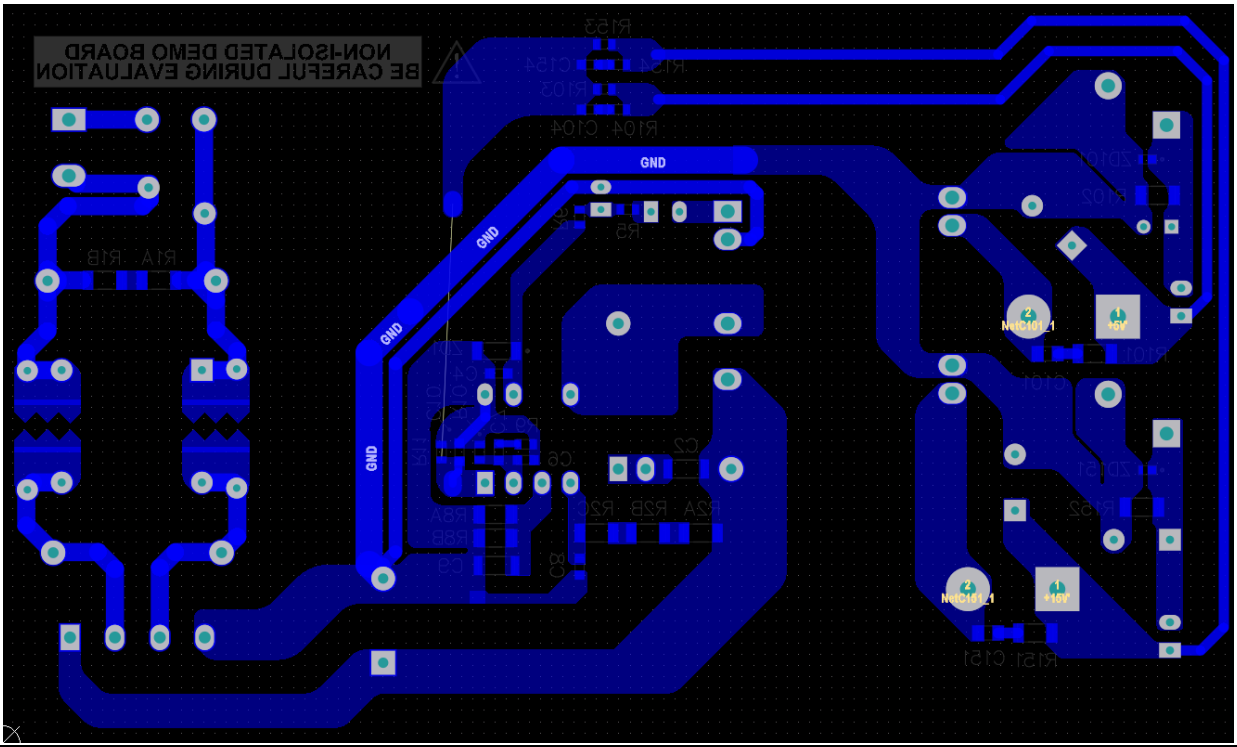


Figure 5 Bottom-side component legend

8 Bill of materials

Table 3 BOM

No.	Designator	Description	Manufacturer	Part number	Quantity
1	F1	Time-lag fuse 300 V 1.6 A	Littlefuse	36911600000	1
2	Z1	Varistor 0.3 W 320 V	Panasonic	ERZE07A511	1
3	BR1	Bridge diode 800 V 1.5 A	Diodes Incorporated	KBP08G	1
4	CX1	Film capacitor 0.15 µF 10% 310 V AC radial	EPCOS	B32932A3154K189	1
5	C1	Aluminum capacitor 47 µF 500 V radial	Rubycon	500BXC47MEFC18X31.5	1
6	C2	Ceramic capacitor 1000 pF 630 V U2J 1206	Murata	GRM31A7U2J102JW31D	1
7	C3	Aluminum capacitor 33 µF 20% 50 V radial	Rubycon	50PX33MEFC5X11	1
8	C4	Ceramic capacitor 0.1 µF 50 V X7R 0603			1
9	C6	Ceramic capacitor 10 nF 50 V X7R 0603			1
10	C7	Ceramic capacitor 100 nF 50 V X7R 0603			1
11	C9	Ceramic capacitor 1206 1 nF 25 V X7R 5%			1
12	C10	Ceramic capacitor 330 pF 50 V X7R 0603			1
13	C102	Aluminum capacitor 680 µF 20% 10 V radial	Rubycon	10ZL680MEFC8X16	1
14	C103	Aluminum capacitor 330 µF 20% 10 V radial	Rubycon	10ZLH330MEFC6.3X11	1
15	C152, C153	Aluminum capacitor 680 µF 20% 25 V radial	Rubycon	25ZLS680MEFC10X16	2
16	ZD1	Zener diode 22 V 500 mW 1206	Taiwan Semiconductor	BZS55B22 RXG	1
17	D1	General-purpose diode 800 V 1 A DO204AL	Vishay	UF4006-E3/54	1
18	D2	General-purpose diode 200 V 200 mA DO35	onsemi	1N485B	1
19	D151	Schottky diode 150 V 3 A DO201AD	STMicroelectronics	STPS3150	1
20	D101	Schottky diode 60 V 3 A DO201AD	onsemi	MBR360G	1
21	IC1	FF 950 V CoolSET™	Infineon	ICE5AR3995BZ	1
22	L1	CMC 39 mH 700 mA 2LN TH	EPCOS	B82732R2701B030	1
23	L101, L151	Fixed inductor 2.2 µH 6.3 A 20 MΩ TH	Würth Elektronik	7447462022	2
24	R1A, R1B	Resistor 3 mΩ 5% 1/4 W 1206			2
25	R2A, R2B, R2C	Resistor 15 mΩ 5% 1/4 W 1206	Yageo	RC1206JR-0715ML	3
26	R4	Resistor 150 kΩ 5% 2 W axial	Yageo	FMP200JR-52-150K	1
27	R5, R6	Resistor 0 Ω jumper 1/10 W 0603			2
28	R8A	Resistor 2 Ω 1% 1/4 W 1206			1
29	R8B	Resistor 2.2 Ω 1% 1/4 W 1206			1
30	R9	Resistor 22 kΩ 1% 1/10 W 0603			1
31	R11	Resistor 27 kΩ 1% 1/10 W 0603			1
32	R103	Resistor 180 kΩ 1% 1/10 W 0603			1
33	R153	Resistor 270 kΩ 1% 1/10 W 0603			1
34	R102, R152	Resistor 5.1 kΩ 5% 1/4 W 1206			2
35	T1	Transformer EE20_H rev 00	Würth Elektronik	750343698	1
36	CN1	Terminal blocks WR-TBL 300 V AC 15 A 2P straight	Würth Elektronik	691102710002	1
37	CN2, CN3	Terminal blocks WR-TBL two-position 3.5 mm 6 A 300 V	Würth Elektronik	691412120002B	2
38	JP1	Jumper			1
39	PCB	110 mm × 66 mm (L × W) single-layer 2 oz. FR-4			1

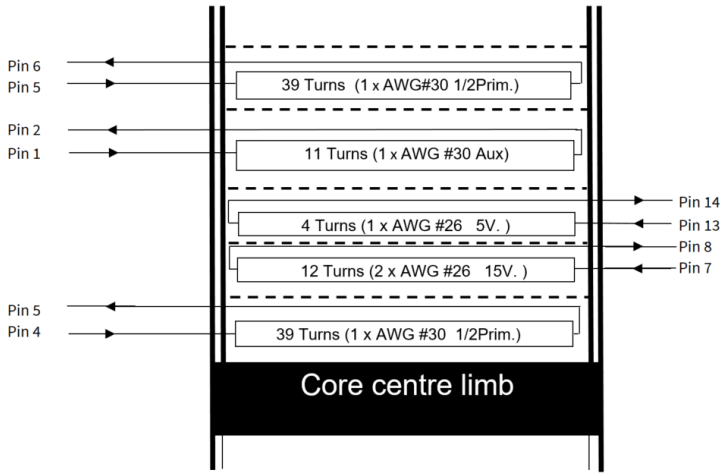
9 Transformer construction

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

Bobbin: 070-5643 (14-pin, THT, horizontal version)

Primary inductance: Lp = 550 µH (±10 percent), measured between pin 4 and pin 6

Manufacturer and part number: Wurth Electronics Midcom (750343698)



Start	Stop	No. of turns	Wire size	Layer
4	5	39	1 x AWG#30	1/2 Primary
7	8	12	2 x AWG #26	15V
13	14	4	1 x AWG #26	5V
1	2	11	1 x AWG#30	Auxiliary
5	6	39	1 x AWG#30	1/2 Primary

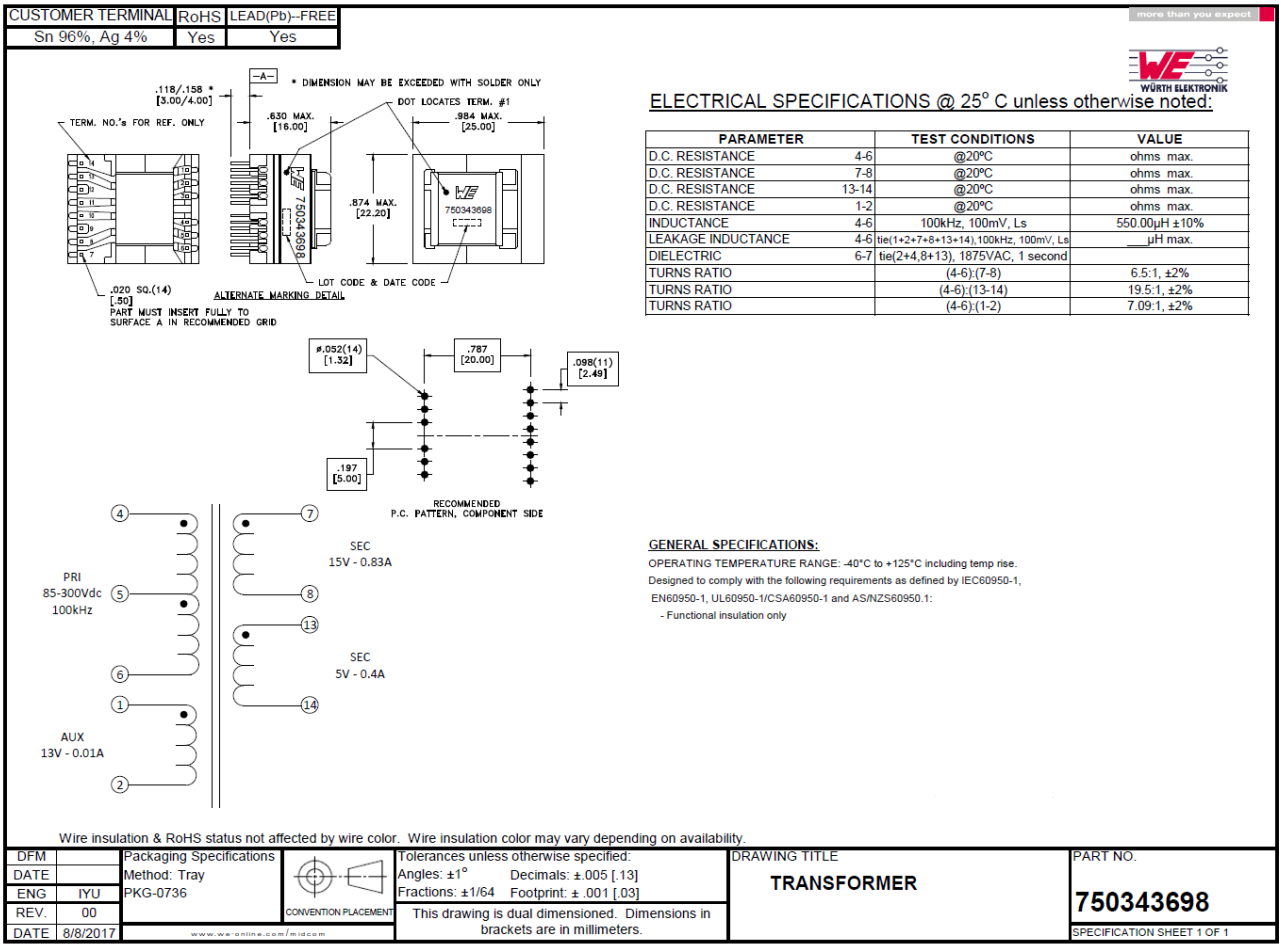


Figure 6 Transformer structure

10 Test results

10.1 Efficiency and regulation

Table 4 Electrical measurement

Input (V AC/Hz)	Load percentage	P_{IN} (W)	15 V DC (V)	I_{OUT_15V} (A)	5 V DC (V)	I_{OUT_5V} (A)	P_{OUT} (W)	Efficiency (%)	Average efficiency (%)	OLP pin (W)	OLP I_{OUT_15V} (fixed 5 V at 0.4 A) (A)
85 V AC/ 60 Hz	0	0.075	15.110	0.000	5.020	0.000				20.13	0.96
	25%	4.312	15.171	0.205	5.010	0.092	3.571	82.81	83.04		
	50%	8.696	15.187	0.414	4.993	0.197	7.271	83.61			
	75%	13.046	15.187	0.615	4.980	0.302	10.844	83.12			
	100%	17.520	15.187	0.825	4.973	0.392	14.473	82.61			
115 V AC/ 60 Hz	0	0.076	15.156	0.000	5.020	0.000	0.000			20.15	0.97
	25%	4.305	15.171	0.205	5.010	0.092	3.571	82.95	83.78		
	50%	8.651	15.187	0.414	4.993	0.197	7.271	84.05			
	75%	12.888	15.187	0.615	4.980	0.302	10.844	84.14			
	100%	17.235	15.187	0.825	4.973	0.392	14.473	83.97			
230 V AC/ 50 Hz	0	0.088	15.170	0.000	5.010	0.000				20.56	1.01
	25%	4.395	15.187	0.205	4.990	0.092	3.572	81.28	83.22		
	50%	8.735	15.187	0.414	4.990	0.197	7.270	83.23			
	75%	12.938	15.187	0.615	4.980	0.302	10.844	83.81			
	100%	17.120	15.187	0.825	4.973	0.392	14.473	84.54			
265 V AC/ 50 Hz	0	0.093	15.156	0.000	5.020	0.000				21.05	1.03
	25%	4.428	15.187	0.205	4.990	0.092	3.572	80.68	82.65		
	50%	8.810	15.187	0.414	4.990	0.197	7.270	82.52			
	75%	12.990	15.187	0.615	4.980	0.302	10.844	83.48			
	100%	17.245	15.187	0.825	4.970	0.392	14.471	83.92			
300 V AC/ 50 Hz	0	0.100	15.150	0.000	5.020	0.000				21.68	1.07
	25%	4.468	15.187	0.205	4.990	0.092	3.572	79.96	81.85		
	50%	8.951	15.187	0.414	4.990	0.197	7.270	81.22			
	75%	13.064	15.187	0.615	4.980	0.302	10.844	83.01			
	100%	17.387	15.187	0.825	4.970	0.392	14.471	83.23			

10.2 Efficiency curve

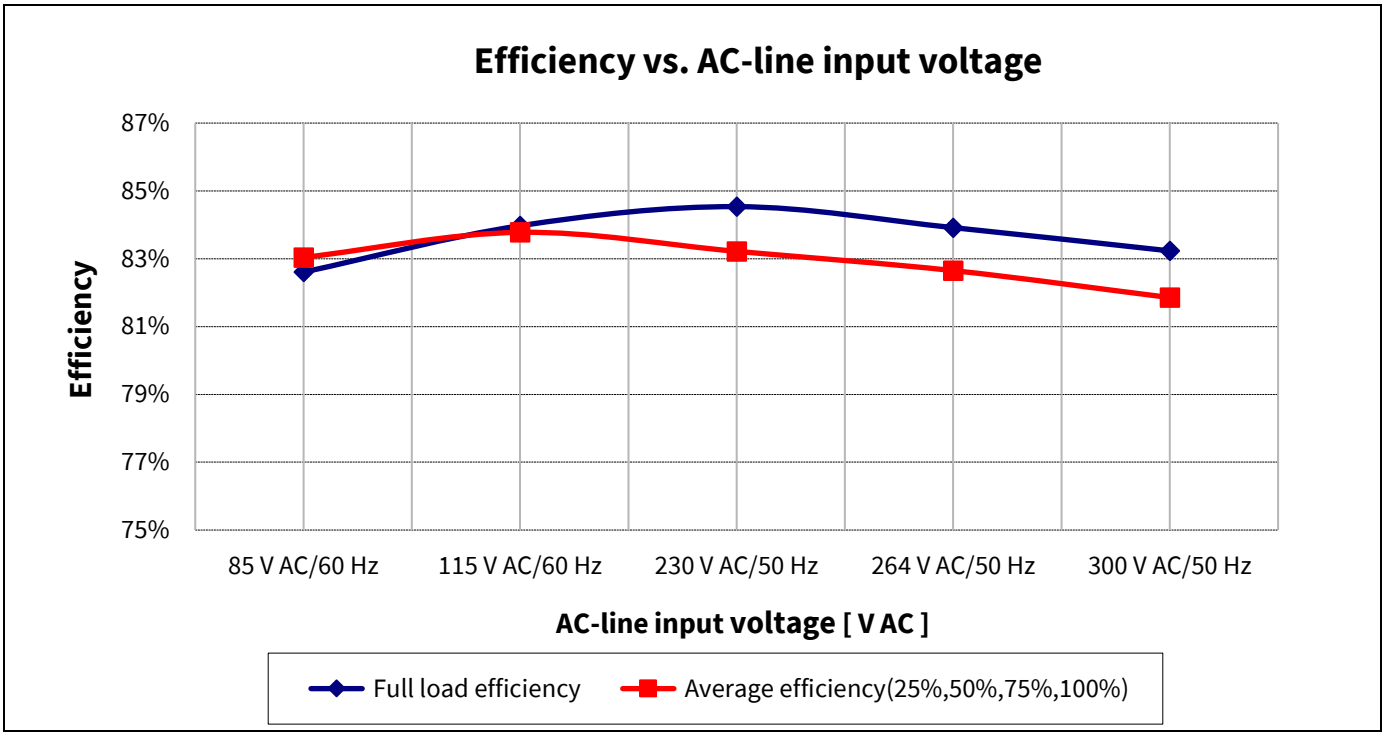


Figure 7 Efficiency vs. output load

10.3 Standby power

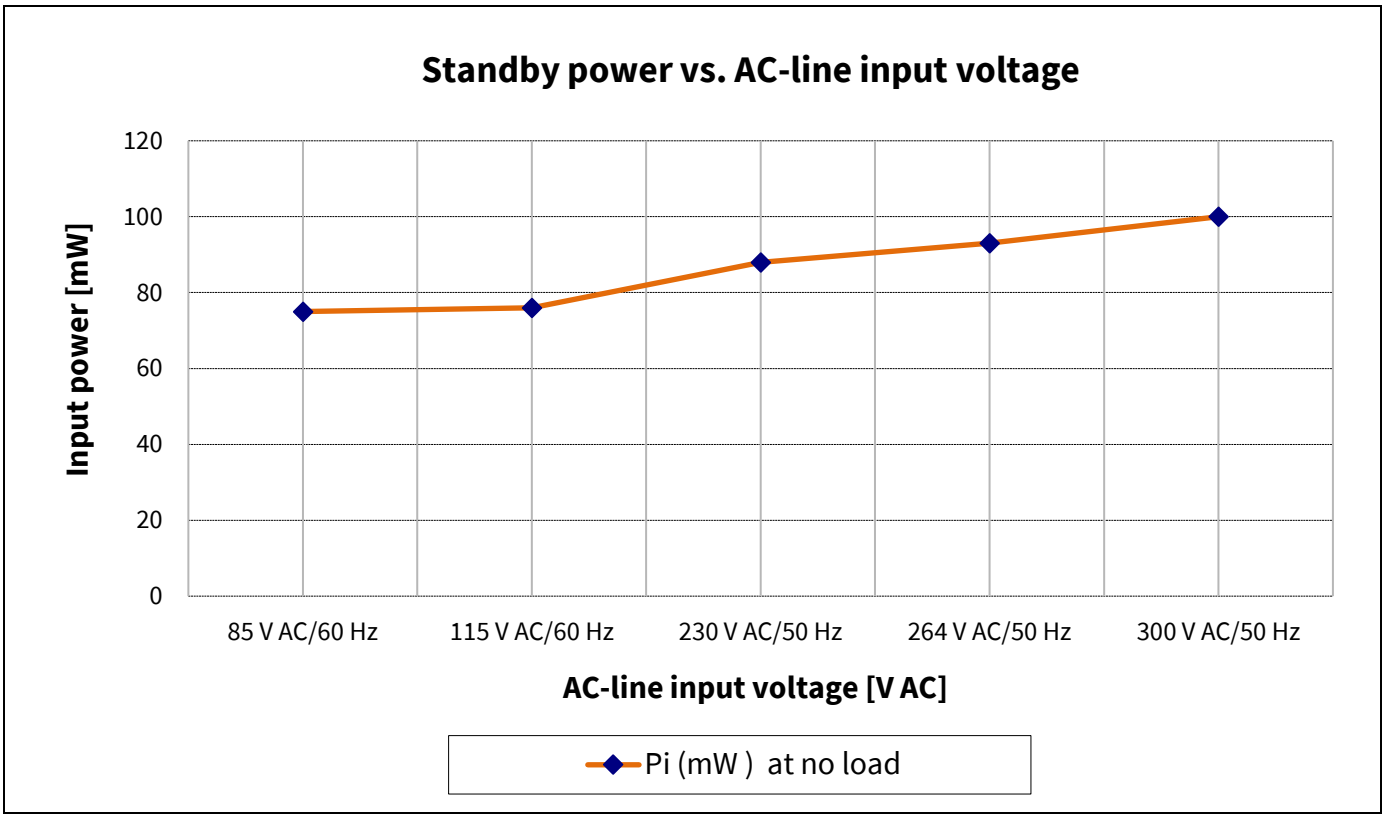


Figure 8 Standby power vs. AC-line input voltage

10.4 Line regulation

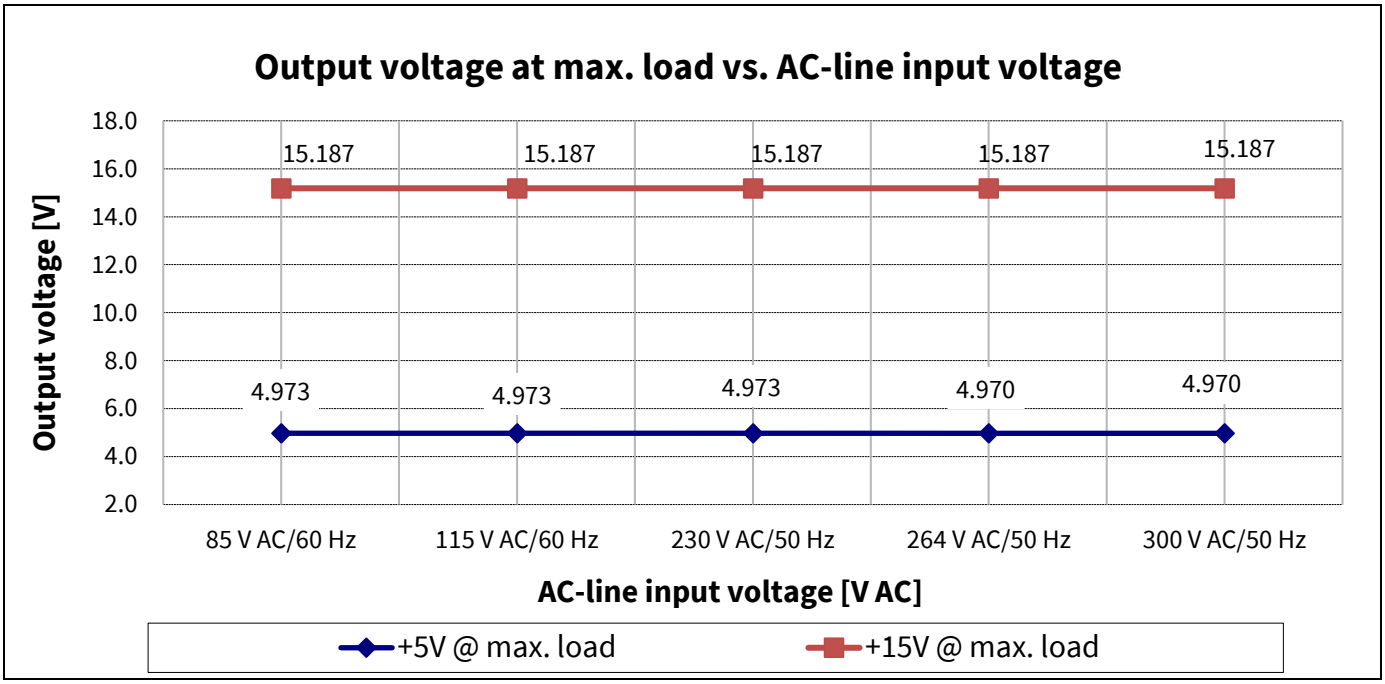


Figure 9 Output regulation at full load vs. AC-line input voltage

10.5 Load regulation

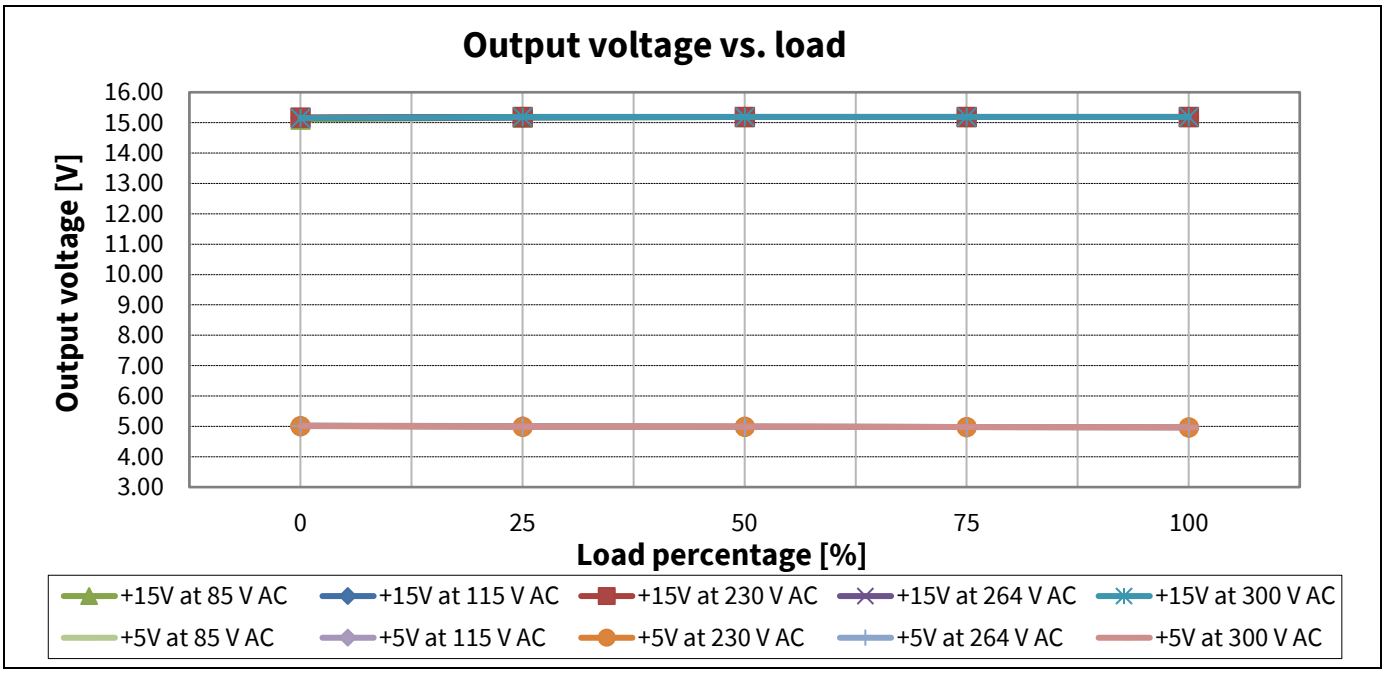


Figure 10 Output regulation vs. load

10.6 Maximum input power

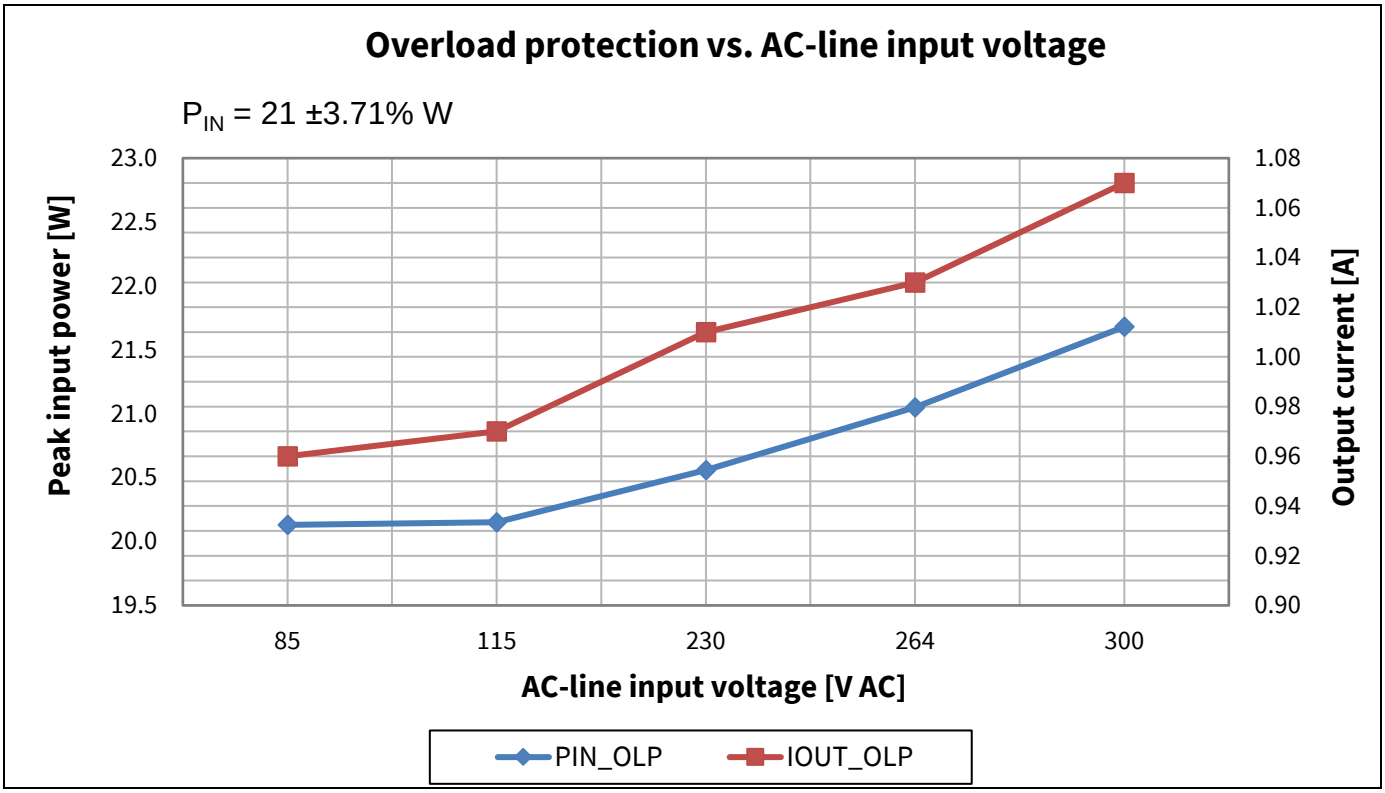


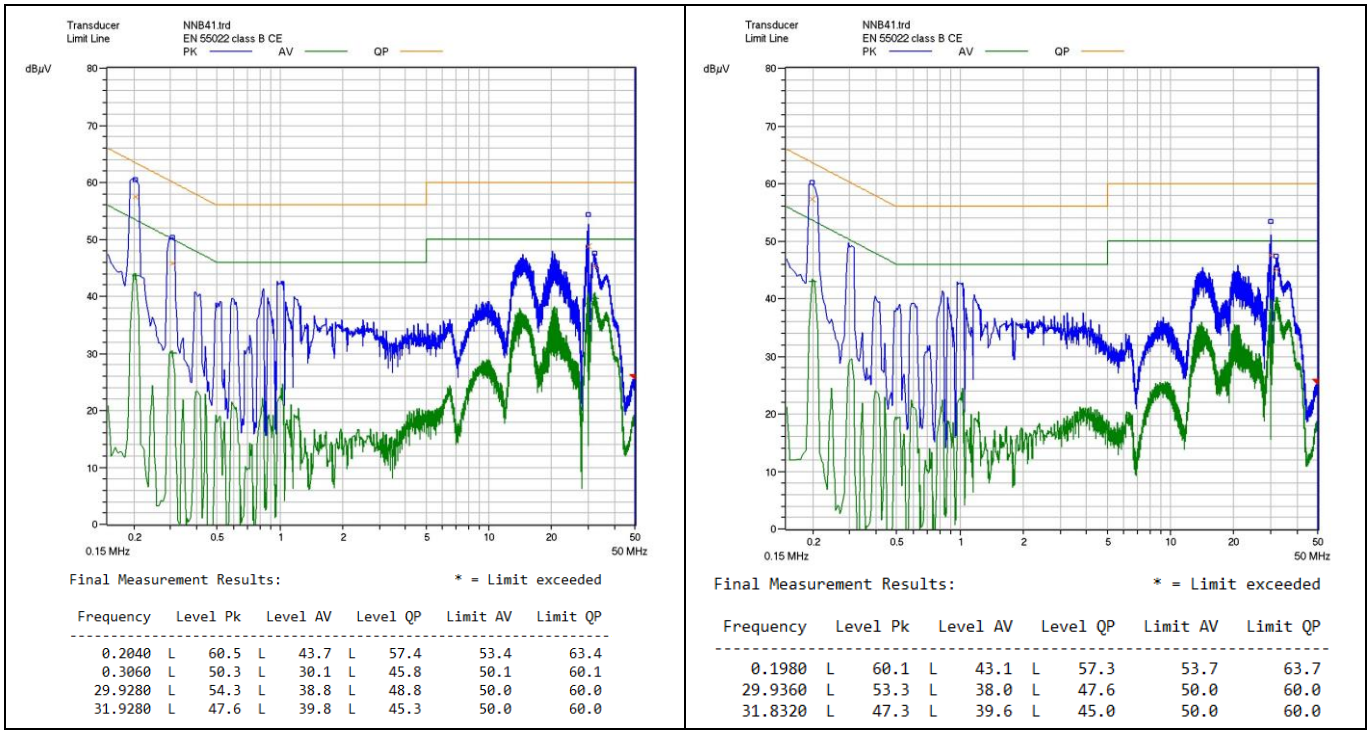
Figure 11 Maximum input power and output current (before overload protection) vs. AC-line input voltage

10.7 Surge immunity (EN 61000-4-5)

Pass EN 61000-4-5 installation class 4 (±2 kV for line-to-line).

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 tested at full resistive load with input voltage of 115 V AC and 230 V AC.



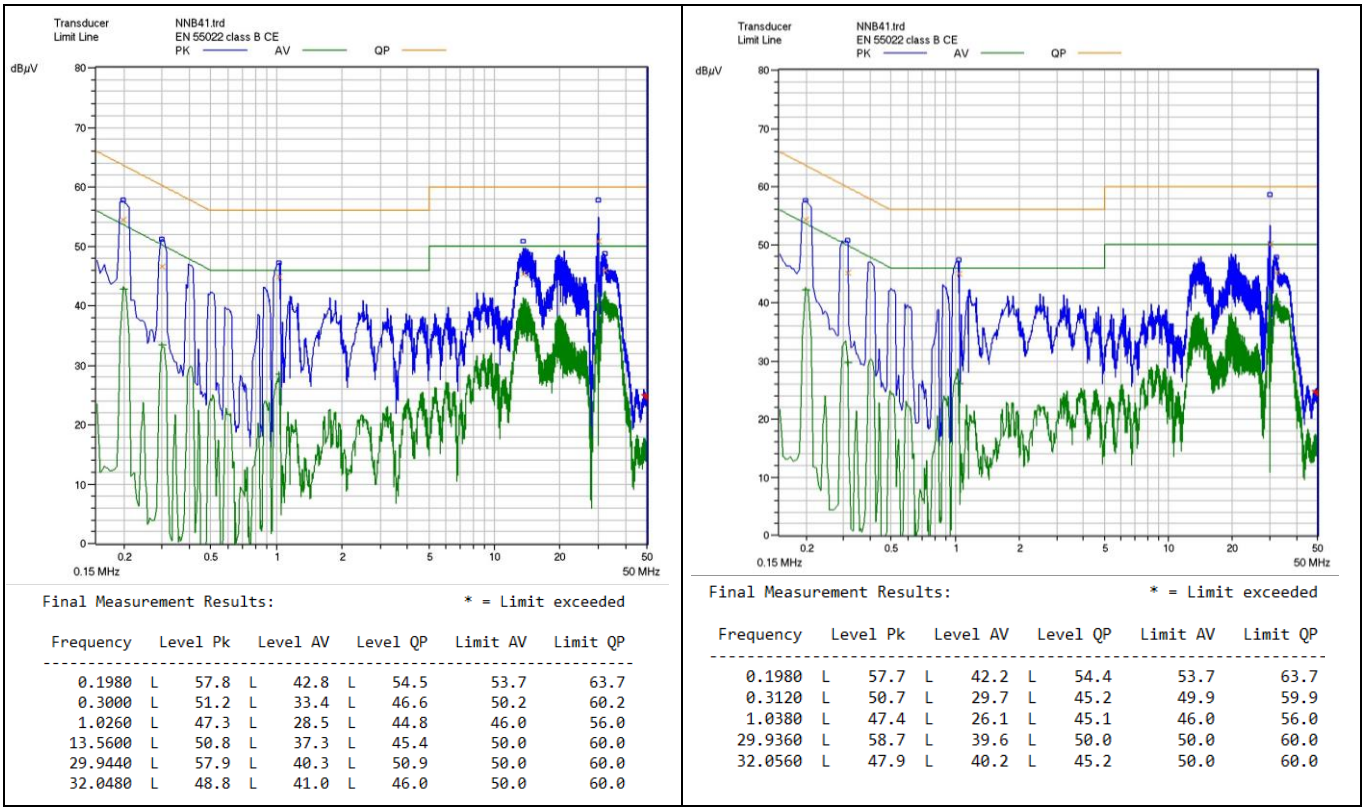
Final Measurement Results: * = Limit exceeded

Frequency		Level Pk		Level AV		Level QP	Limit AV	Limit QP
0.2040	L	60.5	L	43.7	L	57.4	53.4	63.4
0.3060	L	50.3	L	30.1	L	45.8	50.1	60.1
29.9280	L	54.3	L	38.8	L	48.8	50.0	60.0
31.9280	L	47.6	L	39.8	L	45.3	50.0	60.0

Final Measurement Results: * = Limit exceeded

Frequency		Level Pk		Level AV		Level QP	Limit AV	Limit QP
0.1980	L	60.1	L	43.1	L	57.3	53.7	63.7
29.9360	L	53.3	L	38.0	L	47.6	50.0	60.0
31.8320	L	47.3	L	39.6	L	45.0	50.0	60.0

Figure 12 Conducted emissions at 115 V AC and full load on line (left) and neutral (right)



Final Measurement Results: * = Limit exceeded

Frequency		Level Pk		Level AV		Level QP	Limit AV	Limit QP
0.1980	L	57.8	L	42.8	L	54.5	53.7	63.7
0.3000	L	51.2	L	33.4	L	46.6	50.2	60.2
1.0260	L	47.3	L	28.5	L	44.8	46.0	56.0
13.5600	L	50.8	L	37.3	L	45.4	50.0	60.0
29.9440	L	57.9	L	40.3	L	50.9	50.0	60.0
32.0480	L	48.8	L	41.0	L	46.0	50.0	60.0

Final Measurement Results: * = Limit exceeded

Frequency		Level Pk		Level AV		Level QP	Limit AV	Limit QP
0.1980	L	57.7	L	42.2	L	54.4	53.7	63.7
0.3120	L	50.7	L	29.7	L	45.2	49.9	59.9
1.0380	L	47.4	L	26.1	L	45.1	46.0	56.0
29.9360	L	58.7	L	39.6	L	50.0	50.0	60.0
32.0560	L	47.9	L	40.2	L	45.2	50.0	60.0

Figure 13 Conducted emissions at 230 V AC and full load on line (left) and neutral (right)

10.9 Thermal measurements

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 components on the demo board

No.	Components	Temperature at 85 V AC (°C)	Temperature at 300 V AC (°C)
1	D151 (15 V diode)	54.6	60.2
2	TR1 (transformer)	52.3	64.7
3	IC1 (ICE5AR3995BZ)	61.7	63.3

Top side – 85 V AC



Top side – 300 V AC



Figure 14 Infrared thermal image of DEMO_5AR3995BZ at full load

11 Waveforms and oscilloscope plots

All waveforms and scope plots were recorded with a Teledyne LeCroy 44Xi oscilloscope.

11.1 Start-up at full load

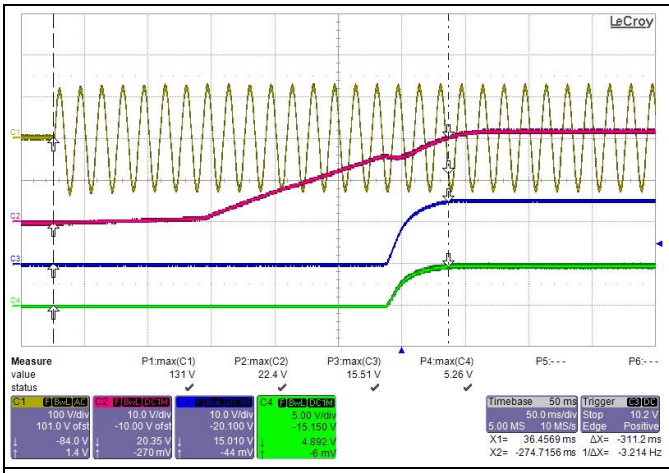
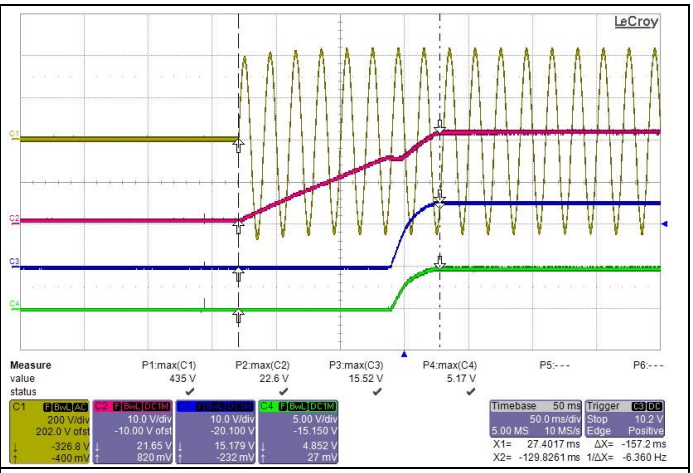
	
C1 (yellow) : AC-line voltage C2 (purple) : V_{CC} voltage C3 (blue) : +15 V output voltage C4 (green) : +5 V output voltage	C1 (yellow) : AC-line voltage C2 (purple) : V_{CC} voltage C3 (blue) : +15 V output voltage C4 (green) : +5 V output voltage
85 V AC start-up time at full load is around 311 ms	300 V AC start-up time at full load is around 157 ms

Figure 15 Start-up

11.2 Soft-start at full load

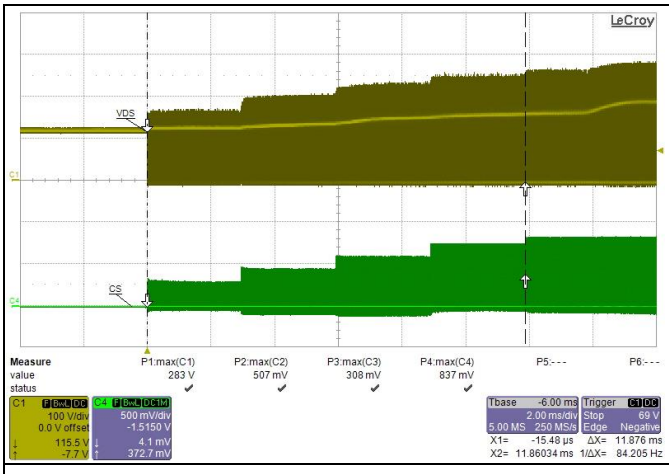
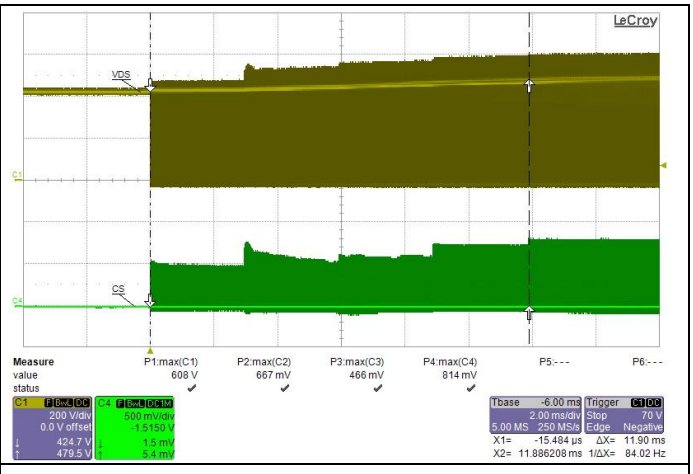
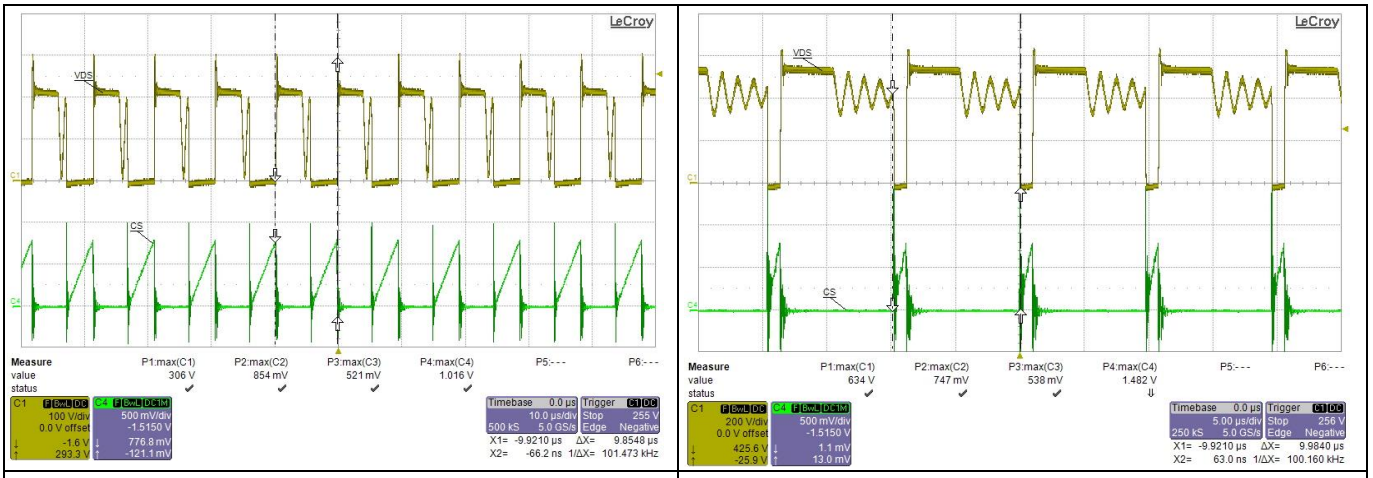
	
C1 (yellow) : Drain voltage C4 (green) : CS voltage	C1 (yellow) : Drain voltage C4 (green) : CS voltage
85 V AC soft-start time at full load is around 11.9 ms	300 V AC soft-start time at full load is around 11.9 ms

Figure 16 Soft-start

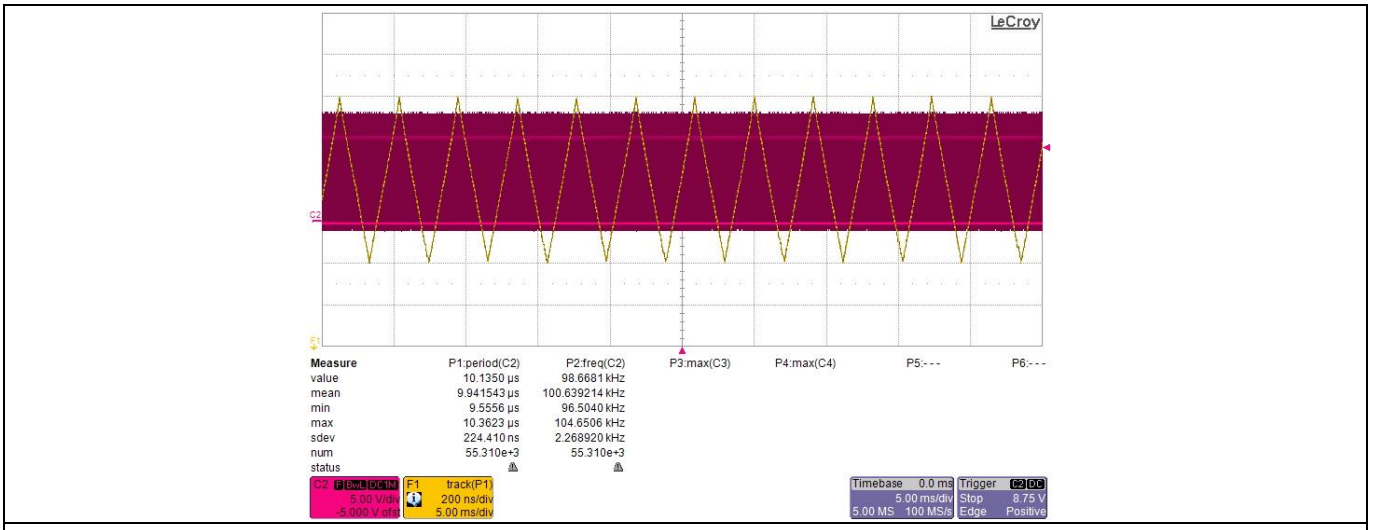
11.3 Drain and CS voltage at full load



C1 (yellow) : Drain voltage C4 (green) : CS voltage	C1 (yellow) : Drain voltage C4 (green) : CS voltage
85 V AC maximum drain voltage at full load is 306 V	300 V AC maximum drain voltage at full load is 634 V

Figure 17 Drain and CS voltage

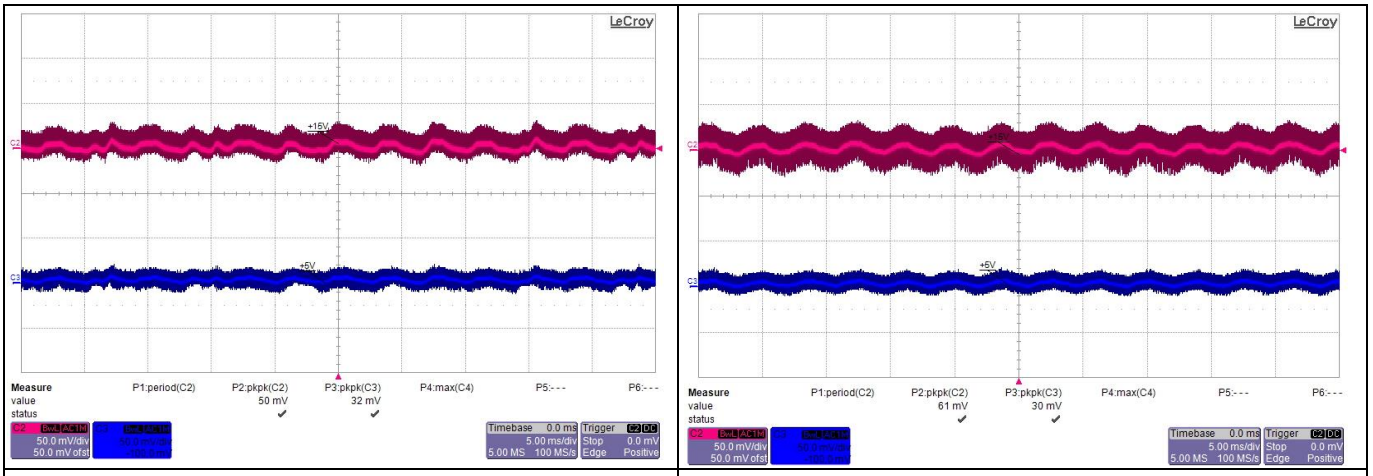
11.4 Frequency jittering



C2 (purple) : Gate voltage F1 (yellow) : Frequency track of gate voltage
85 V AC frequency jittering at full load is from ~96.5 kHz to ~104.6 kHz

Figure 18 Frequency jittering

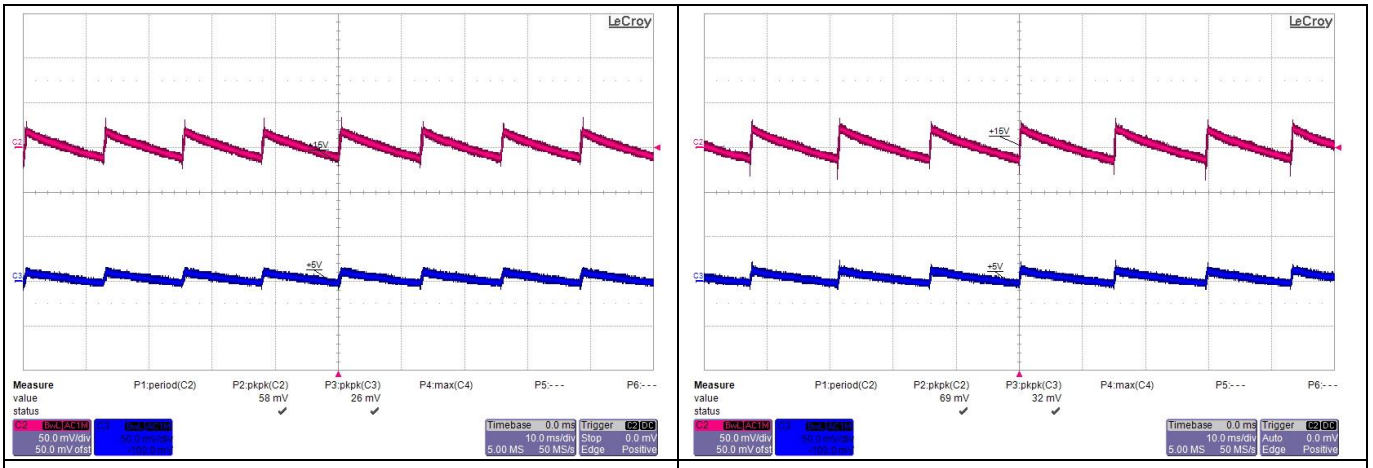
11.5 Output ripple voltage at full load



C2 (purple) : +15 V output voltage C3 (blue) : +5 V output voltage	C2 (purple) : +15 V output voltage C3 (blue) : +5 V output voltage
85 V AC +15 V output voltage $V_{ripple_pk_pk}$ is 50 mV 85 V AC +5 V output voltage $V_{ripple_pk_pk}$ is 32 mV	300 V AC +15 V output voltage $V_{ripple_pk_pk}$ is 61 mV 300 V AC +5 V output voltage $V_{ripple_pk_pk}$ is 30 mV

Figure 19 Output ripple voltage at full load. Probe terminals are decoupled with a 10 µF electrolytic capacitor and a 0.1 µF ceramic capacitor. Oscilloscope bandwidth is limited to 20 MHz.

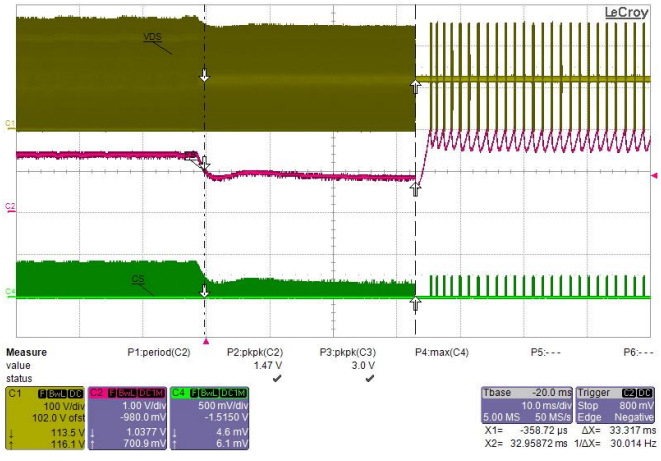
11.6 Output ripple voltage at ABM



C2 (purple) : +15 V output voltage C3 (blue) : +5 V output voltage	C2 (purple) : +15 V output voltage C3 (blue) : +5 V output voltage
85 V AC +15 V output voltage $V_{ripple_pk_pk}$ is 58 mV 85 V AC +5 V output voltage $V_{ripple_pk_pk}$ is 26 mV	300 V AC +15 V output voltage $V_{ripple_pk_pk}$ is 69 mV 300 V AC +5 V output voltage $V_{ripple_pk_pk}$ is 32 mV

Figure 20 Output ripple voltage at no load. Probe terminals are decoupled with a 10 µF electrolytic capacitor and a 0.1 µF ceramic capacitor. Oscilloscope bandwidth is limited to 20 MHz.

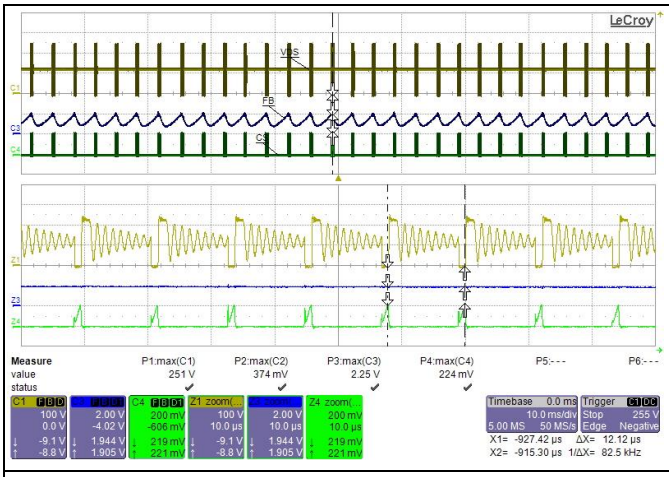
11.7 Entering ABM



C1 (yellow) : Drain voltage C2 (purple) : FB voltage C4 (green) : CS voltage	C1 (yellow) : Drain voltage C2 (purple) : FB voltage C4 (green) : CS voltage
85 V AC full load to 0.5 W load. Enter ABM at FB pin voltage less than 1.03 V (V_{FB_EBHP}) for more than 36 ms (t_{FB_BEB}).	300 V AC full load to 0.5 W load. Enter ABM at FB pin voltage less than 1.03 V (V_{FB_EBHP}) for more than 36 ms (t_{FB_BEB}).

Figure 21 Entering ABM

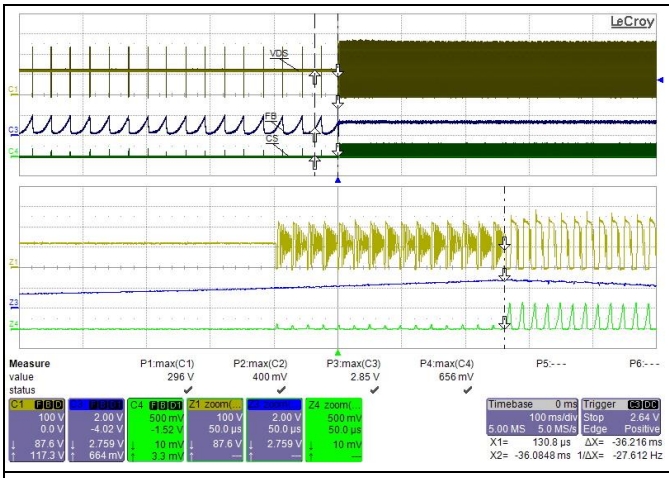
11.8 During ABM

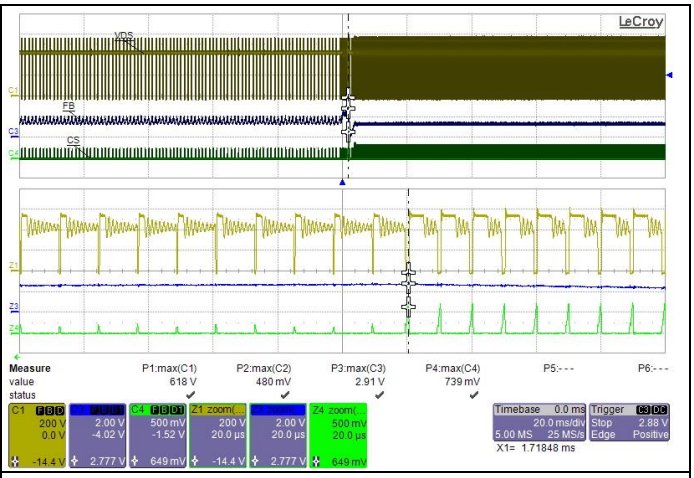


C1 (yellow) : Drain voltage C3 (blue) : FB voltage C4 (green) : CS voltage	C1 (yellow) : Drain voltage C3 (blue) : FB voltage C4 (green) : CS voltage
85 V AC at 0.5 W load. Burst on at FB voltage 1.95 V ($V_{FB_Bon_NISO}$) and burst off at 1.55 V ($V_{FB_BOff_NISO}$). CS voltage at 0.27 V (V_{CS_BHP}). Switching frequency at 86 kHz (f_{OSC2_ABM}).	300 V AC at 0.5 W load. Burst on at FB voltage 1.95 V ($V_{FB_Bon_NISO}$) and burst off at 1.55 V ($V_{FB_BOff_NISO}$). CS voltage at 0.27 V (V_{CS_BHP}). Switching frequency at 86 kHz (f_{OSC2_ABM}).

Figure 22 During ABM

11.9 Leaving ABM

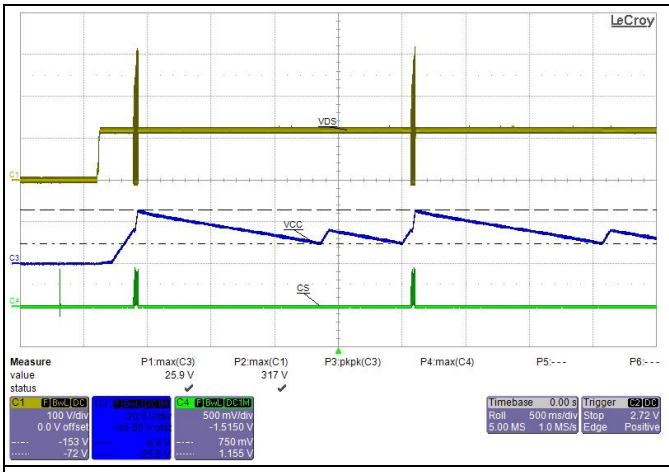


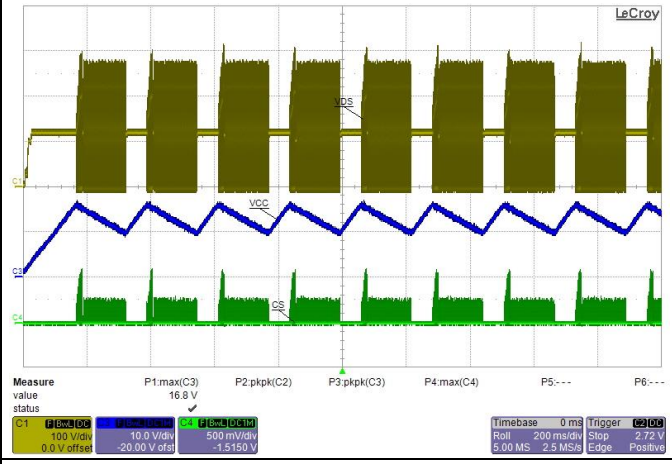


C1 (yellow) : Drain voltage C3 (blue) : FB voltage C4 (green) : CS voltage	C1 (yellow) : Drain voltage C3 (blue) : FB voltage C4 (green) : CS voltage
85 V AC at 0.5 W load to full load. Leave ABM at FB voltage more than 2.73 V (V_{FB_LB}).	300 V AC at 0.5 W load to full load. Leave ABM at FB voltage more than 2.73 V (V_{FB_LB}).

Figure 23 Leaving ABM

11.10 V_{CC} OV/UV protection

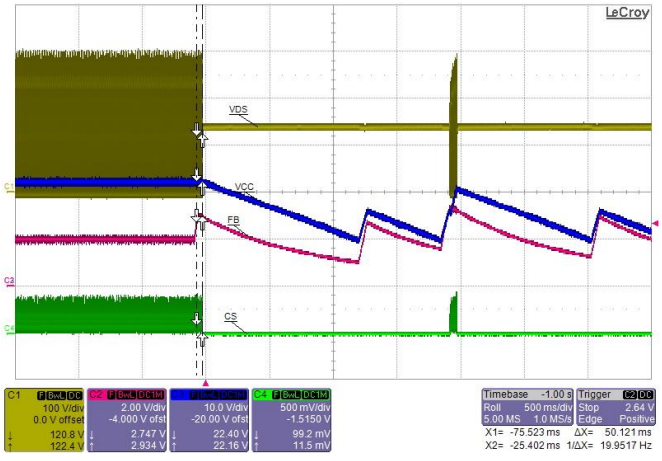


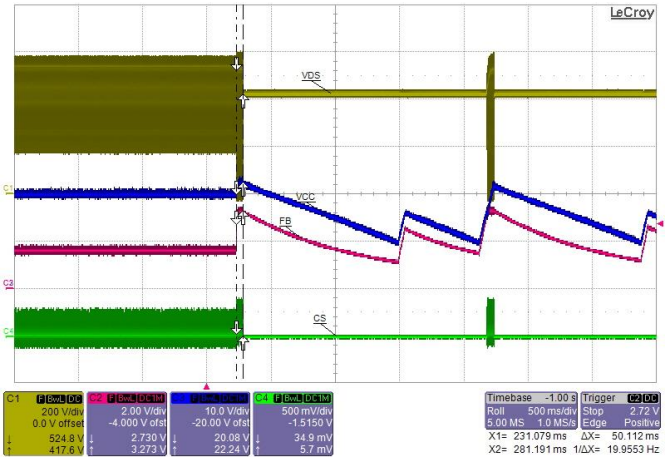


C1 (yellow) : Drain voltage C3 (blue) : V_{CC} voltage C4 (green) : CS voltage	C1 (yellow) : Drain voltage C3 (blue) : V_{CC} voltage C4 (green) : CS voltage
85 V AC at no load. Removed ZD1, R103 and R153. Trigger V_{CC} OV protection at V_{CC} voltage more than 25.5 V (V_{VCC_OVP}). Odd-skip auto restart mode.	85 V AC at full load. Removed R6. Trigger V_{CC} UV protection at V_{CC} voltage less than 10 V (V_{VCC_OFF}). Auto restart mode.

Figure 24 V_{CC} OV/UV protection

11.11 Overload protection

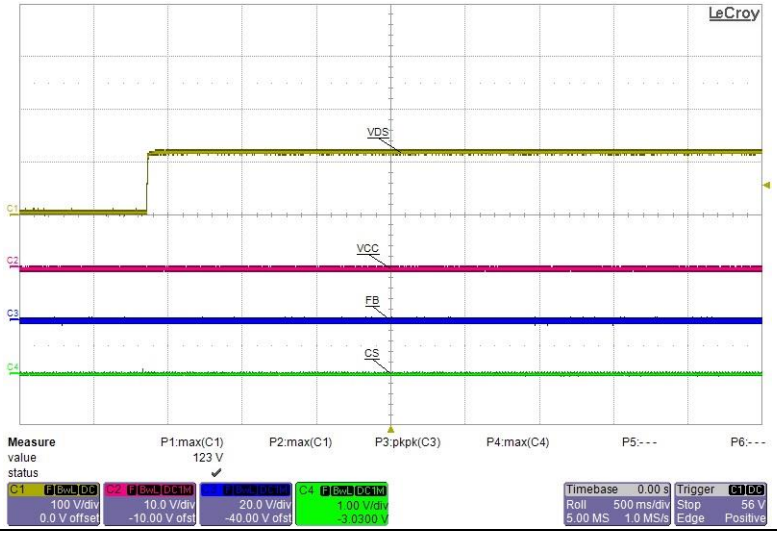




C1 (yellow) : Drain voltage C2 (purple) : FB voltage C3 (blue) : V_{CC} voltage C4 (green) : CS voltage	C1 (yellow) : Drain voltage C2 (purple) : FB voltage C3 (blue) : V_{CC} voltage C4 (green) : CS voltage
85 V AC at full load to overload. Trigger protection at FB pin voltage more than 2.73 V (V_{FB_OLP}) for more than 54 ms ($t_{FB_OLP_B}$). Odd-skip auto restart mode.	300 V AC at full load to overload. Trigger protection at FB pin voltage more than 2.73 V (V_{FB_OLP}) for more than 54 ms ($t_{FB_OLP_B}$). Odd-skip auto restart mode.

Figure 25 Overload protection

11.12 V_{CC} short-to-GND



C1 (yellow) : Drain voltage C2 (purple) : V_{CC} voltage C3 (blue) : FB voltage C4 (green) : CS voltage
Input 85 V AC. Short V_{CC} to ground, measured $I_{VCC_Charge1}$ = 268 µA. (V_{CC} charging current was measured with a digital multimeter.)

Figure 26 V_{CC} short-to-GND

12 Appendix A: Drop-in test for ICE5AR4770BZS and ICE5AR4780BZS

It is pin-to-pin compatible for CoolSET™ ICE5AR4770BZS, ICE5AR4780BZS and ICE5AR3995BZ. Here a drop-in test was conducted for the other two part numbers on DEMO_5AR3995BZ_14W1.

Table 6 Efficiency and standby power measurement

Part number	Input (V AC/Hz)	Load condition	P_{IN} (W)	V_{OUT1} (V)	I_{OUT1} (A)	V_{OUT2} (V)	I_{OUT2} (A)	P_{OUT} (W)	Efficiency (%)
ICE5AR4770BZS	85 V AC/60 Hz	0%	0.071	14.97	0.00	4.96	0.00	0.00	
		100%	17.65	15.03	0.82	4.92	0.39	14.30	81.03
	115 V AC/60 Hz	0%	0.073	14.97	0.00	4.96	0.00	0.00	
		100%	17.27	15.03	0.82	4.92	0.39	14.30	82.82
	230 V AC/50 Hz	0%	0.080	14.97	0.00	4.96	0.00	0.00	
		100%	17.00	15.03	0.82	4.92	0.39	14.30	84.13
	264 V AC/50 Hz	0%	0.085	14.97	0.00	4.96	0.00	0.00	
		100%	17.07	15.03	0.82	4.92	0.39	14.30	83.79
	300 V AC/50 Hz	0%	0.092	14.97	0.00	4.97	0.00	0.00	
		100%	17.21	15.03	0.82	4.92	0.39	14.30	83.11
ICE5AR4780BZS	85 V AC/60 Hz	0%	0.072	14.92	0.00	4.94	0.00	0.00	
		100%	17.56	14.97	0.82	4.89	0.39	14.24	81.10
	115 V AC/60 Hz	0%	0.073	14.92	0.00	4.94	0.00	0.00	
		100%	17.16	14.97	0.82	4.89	0.39	14.24	83.01
	230 V AC/50 Hz	0%	0.081	14.92	0.00	4.94	0.00	0.00	
		100%	16.95	14.97	0.82	4.89	0.39	14.24	84.03
	264 V AC/50 Hz	0%	0.085	14.92	0.00	4.94	0.00	0.00	
		100%	17.05	14.97	0.82	4.89	0.39	14.24	83.54
	300 V AC/50 Hz	0%	0.093	14.92	0.00	4.94	0.00	0.00	
		100%	17.16	14.97	0.82	4.89	0.39	14.24	82.99
ICE5AR3995BZ	85 V AC/60 Hz	0%	0.075	15.15	0.00	5.02	0.00	0.00	
		100%	17.52	15.19	0.82	4.97	0.39	14.47	82.61
	115 V AC/60 Hz	0%	0.077	15.16	0.00	5.02	0.00	0.00	
		100%	17.24	15.19	0.82	4.97	0.39	14.47	83.97
	230 V AC/50 Hz	0%	0.080	15.17	0.00	5.01	0.00	0.00	
		100%	17.12	15.19	0.82	4.97	0.39	14.47	84.54
	264 V AC/50 Hz	0%	0.085	15.16	0.00	5.02	0.00	0.00	
		100%	17.25	15.19	0.82	4.97	0.39	14.47	83.92
	300 V AC/50 Hz	0%	0.092	15.15	0.00	5.02	0.00	0.00	
		100%	17.39	15.19	0.82	4.97	0.39	14.47	83.23

Note: This is a drop-in test; no optimization was done on board for other devices.

12.1 Full-load efficiency comparison

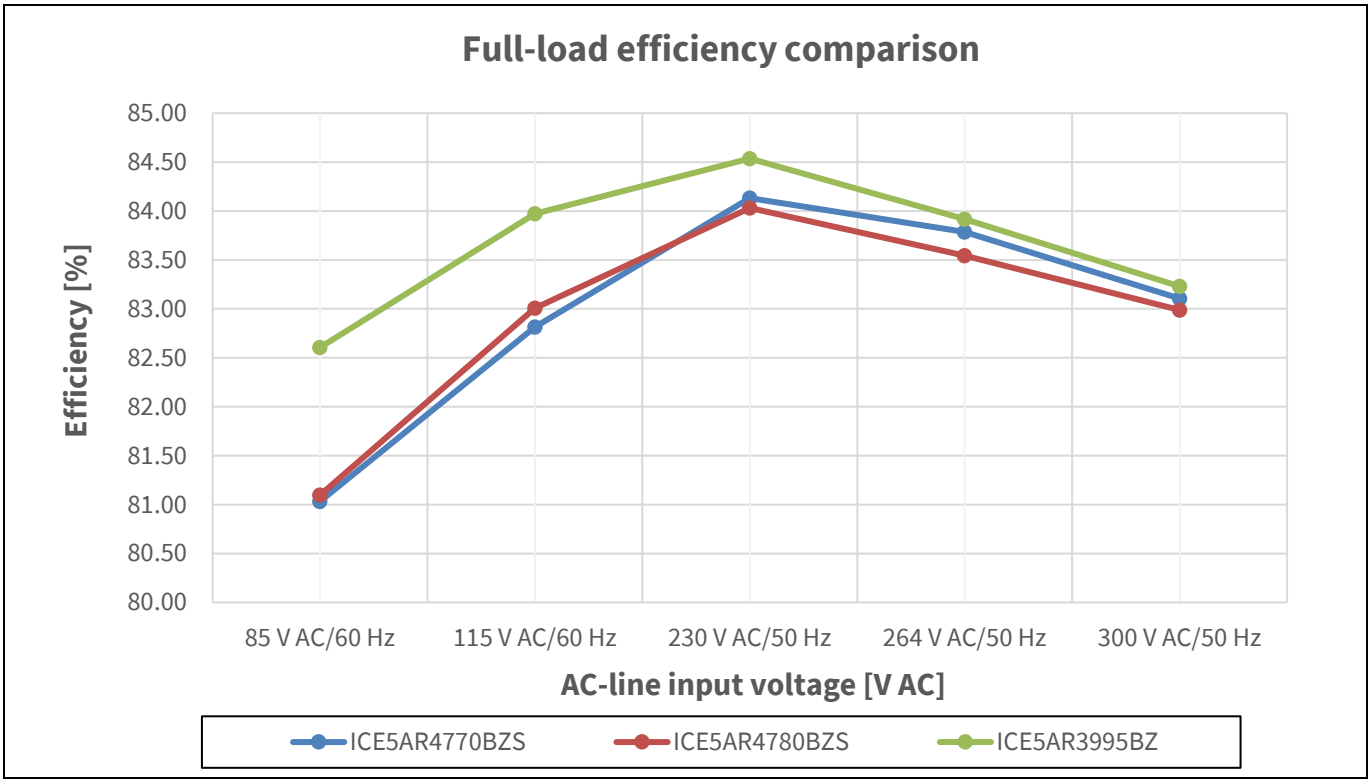


Figure 27 Full-load efficiency comparison

12.2 Standby power comparison

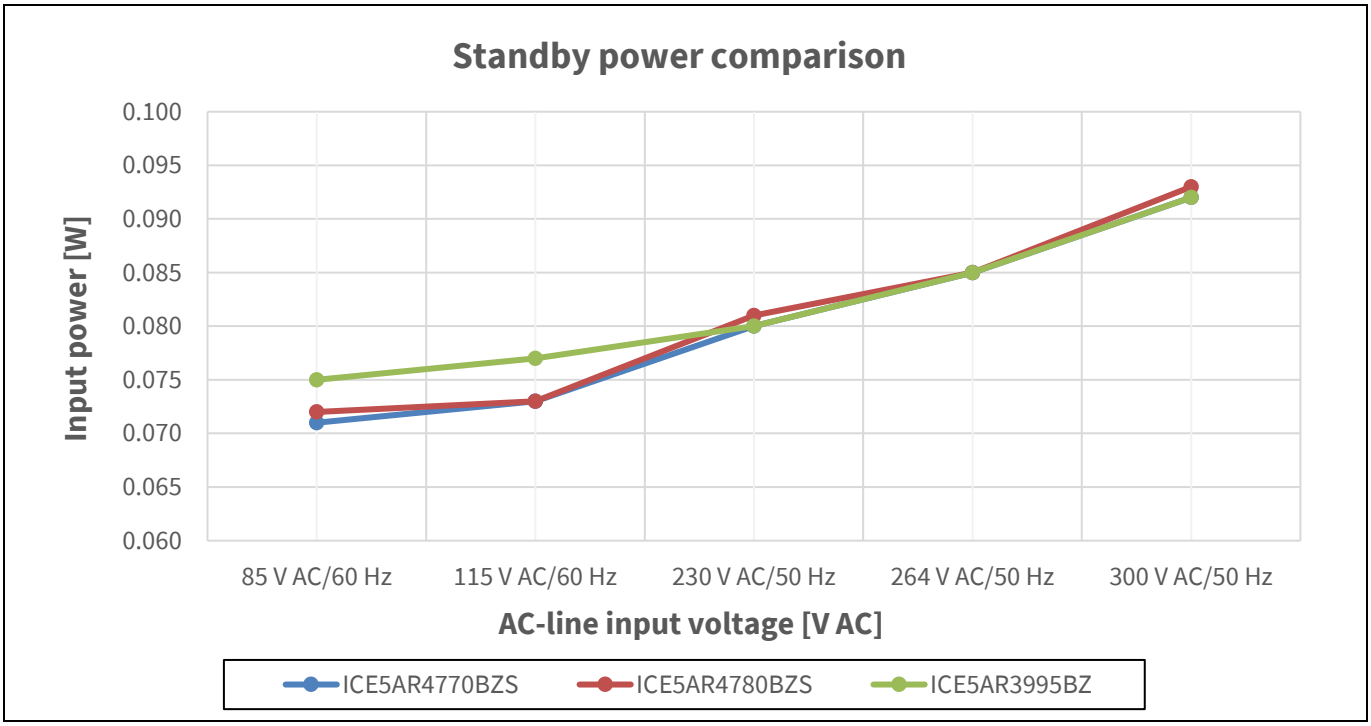


Figure 28 Standby power comparison

References

[1] Infineon Technologies AG: Fixed-frequency 800 V / 950 V CoolSET™ (V 1.1); 2022-07-19; **ICE5ARxxxxBZ Datasheet**

[2] Infineon Technologies AG: Fifth-Generation Fixed-Frequency Design Guide (V 1.0); 2019-07-24; **Fifth-Generation Fixed-Frequency Design Guide**

[3] Infineon Technologies AG: Calculation tool for fifth-generation fixed-frequency CoolSET™ (V 1.0); **Calculation tool**

Revision history

Document version	Date of release	Description of changes
V 1.0	2022-07-28	First release
V 1.1	2022-10-19	Table 4: units corrected

Trademarks
All referenced product or service names and trademarks are the property of their respective owners.

Edition 2022-10-19

Published by

Infineon Technologies AG

81726 Munich, Germany

© 2022 Infineon Technologies AG. All Rights Reserved.

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
ER_2203_PL21_2204_101057

IMPORTANT NOTICE

The information contained in this application note is given as a hint for the implementation of the product only and shall in no event be regarded as a description or warranty of a certain functionality, condition or quality of the product. Before implementation of the product, the recipient of this application note must verify any function and other technical information given herein in the real application. Infineon Technologies hereby disclaims any and all warranties and liabilities of any kind (including without limitation warranties of non-infringement of intellectual property rights of any third party) with respect to any and all information given in this application note.

The data contained in this document is exclusively intended for technically trained staff. It is the responsibility of customer's technical departments to evaluate the suitability of the product for the intended application and the completeness of the product information given in this document with respect to such application.

For further information on the product, technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies office (**www.infineon.com**).

WARNINGS

Due to technical requirements products may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by Infineon Technologies in a written document signed by authorized representatives of Infineon Technologies, Infineon Technologies' products may not be used in any applications where a failure of the product or any consequences of the use thereof can reasonably be expected to result in personal injury.