

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

About this document

Scope and purpose

This document describes a 15 W non-isolated auxiliary power supply for an outdoor air conditioner unit with the latest CoolSET™ 5th Generation Fixed Frequency Plus ICE5BR4780BZ-1 switching controller from Infineon. The power supply is designed with a universal input compatible with most geographic regions and three non-isolated outputs (12 V/800 mA, 15 V/150 mA, and 5 V/300 mA), where 15 V output and 5 V output are supported by a linear regulator from an 18 V source and an 8 V source respectively.

Highlights of the auxiliary power supply for “invertized” air conditioner units are:

- Tightly regulated output voltages, high efficiency under light-load conditions, and low standby power.
- Comprehensive CoolSET™ protection feature for a robust system.
- Auto-restart protection scheme to minimize interruption and enhance user-friendly experience.

Intended audience

This document is intended for power supply design engineers who want to design auxiliary power supplies for invertized air conditioner units that are efficient, reliable, and easy-to-design.

CoolSET™

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

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

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Introduction

1 Introduction

With the growing household trend for smart devices, the new generation of home appliances such as air conditioners are equipped with advanced features such as wireless control and monitoring capability, smart sensors, and touchscreen displays; transforming a static product into an interactive and intelligent home appliance, capable of adapting to the smart-home theme. To support this trend, Infineon has introduced the latest CoolSET™ 5th Generation Fixed Frequency Plus ICE5BR4780BZ-1 switching controller to address this need in an efficient and cost-effective manner.

An auxiliary switched-mode power supply (SMPS) is needed to power various modules and sensors, that typically operate from a stable DC voltage source. Infineon’s CoolSET™ switching controller as shown in [Figure 1](#), forms the heart of the system, providing necessary protection and AC-DC conversion from the mains to multiple regulated DC voltages to power the various blocks.

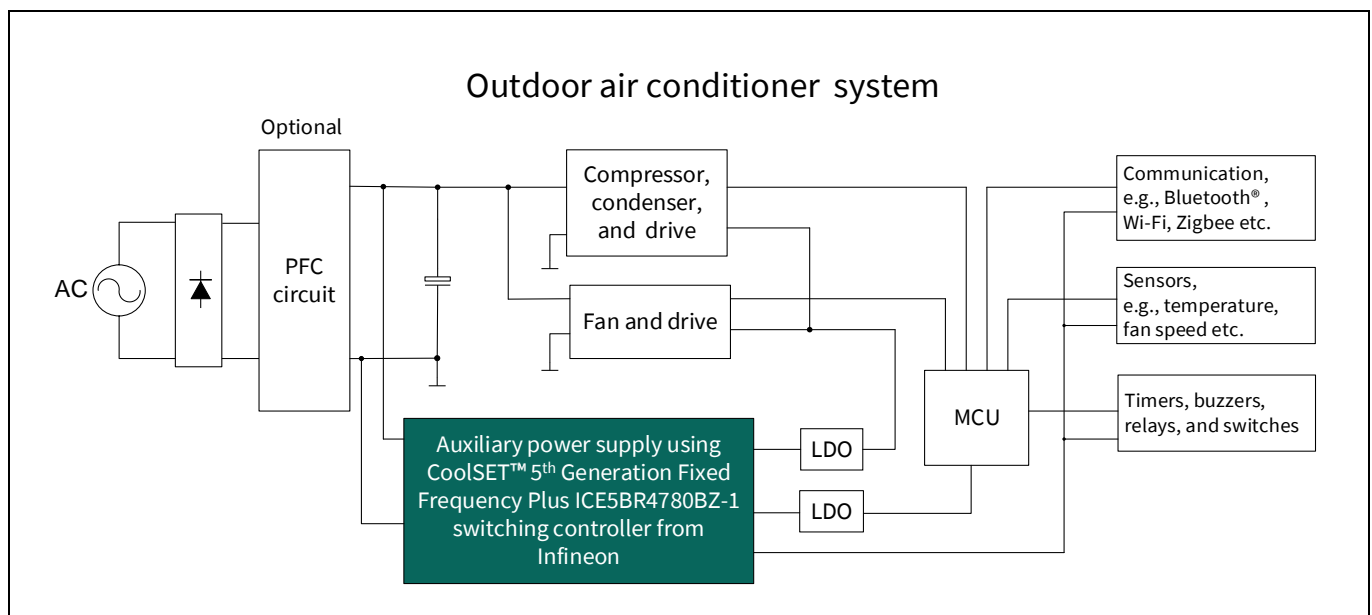


Figure 1 Simplified outdoor air conditioner system block diagram

The system requirements for an outdoor air conditioner and the corresponding Infineon solution is shown in [Table 1](#).

Table 1 System requirements and Infineon solutions

No.	System requirement for an invertized air conditioner	Infineon solution – ICE5BR4780BZ-1
1	High efficiency under light-load conditions and low standby power	Digital frequency reduction and active burst mode (ABM)
2	Robust system and protection features	Comprehensive CoolSET™ protection feature in DIP-7 package
3	Auto-restart protection scheme to minimize interruption and enhance end-user experience	All protections are in auto-restart

1.1 High efficiency under light-load conditions and low standby power

During typical air conditioning operation, the power requirement fluctuates according to various use cases. However, in most cases where room temperature is already stabilized, both indoor and outdoor air conditioner units reside in an idle state in which the loading towards the auxiliary power supply is low. It is crucial that the auxiliary power supply operates as efficiently as possible because it remains in this particular state for some time. Under light-load conditions, losses incurred by the power switch are usually dominated by the switching operation. The choice of switching scheme and frequency play a crucial role in ensuring high conversion efficiency.

In this reference design, ICE5BR4780BZ-1 is primarily chosen because of its frequency reduction switching scheme. Compared to a traditional fixed-frequency flyback, the CoolSET™ switching controller reduces its switching frequency from medium to light load, thereby minimizing switching losses. Therefore, an efficiency of more than 80 percent is achievable at 25 percent loading conditions and nominal input voltages.

1.2 Simplified circuitry with good integration of power and protection features

To minimize the complexity of the PCB layout and circuit design, the CoolSET™ switching controller is a highly integrated device with both a controller and a high voltage (HV) MOSFET integrated into a single and space-saving DIP-7 package. This certainly helps the designer to reduce the component count.

1.3 Auto-restart protection scheme

For an invertized air conditioner unit, it would be disturbing to both the end user and the manufacturer if the system were to halt and latch after protection. Accessibility of the input AC plug may also be difficult. Therefore, to minimize interruption and enhance end-user experience, the CoolSET™ switching controller implements an auto-restart mode for all fault protections.

1.4 Document structure

This document provides comprehensive design details including specifications, schematics, bill of materials (BOM), PCB layout, and transformer design. Additionally, it provides details on performance results pertaining to line/load regulation, efficiency, transient load, thermal conditions, conducted EMI scans etc.

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

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Reference board design

2 Reference board design



Figure 2 REF_5BR4780BZ-1_15W1

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1



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Power supply specifications

3 Power supply specifications

The following table shows the minimum acceptance performance of the design at 25°C ambient temperature. See Sections 9, 10, and 11 for details on actual performance measurements.

Table 2 Specifications of REF_5BR4780BZ-1_15W1

Description	Symbol	Min	Typ	Max	Unit	Notes/conditions
Input						
Voltage	V_{IN}	85	–	264	V AC	Two-wire (no P.E.)
Frequency	f_{LINE}	47	50/60	64	Hz	–
Output						
Output voltage 1	V_{O1}	–	12	–	V	±1 percent
Output current 1	I_{O1}	–	–	0.8	A	–
Output voltage ripple 1	V_{RPP1}	–	–	60	mV	–
Output voltage 2	V_{O2}	–	15	–	V	±1 percent
Output current 2	I_{O2}	–	–	0.15	A	–
Output voltage ripple 2	V_{RPP2}	–	–	50	mV	–
Output voltage 3	V_{O3}	–	5	–	V	±1 percent
Output current 3	I_{O3}	–	–	0.3	A	–
Output voltage ripple 3	V_{RPP3}	–	–	50	mV	–
Output power	P_{OUT}	–	13.35	–	W	–
Output overcurrent protection	I_{OCP}	–	–	1.2	A	12 V output
Start-up time	t_{start_up}	–	–	250	ms	–
Environmental						
Conducted EMI	–	8			dB	Margin, CISPR 22 Class B
Surge immunity						
Differential mode	–	±1			kV	EN 61000-4-5
PCBA dimension	–	80 x 57 x 26			mm	L x W x H

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

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Schematic

4 Schematic

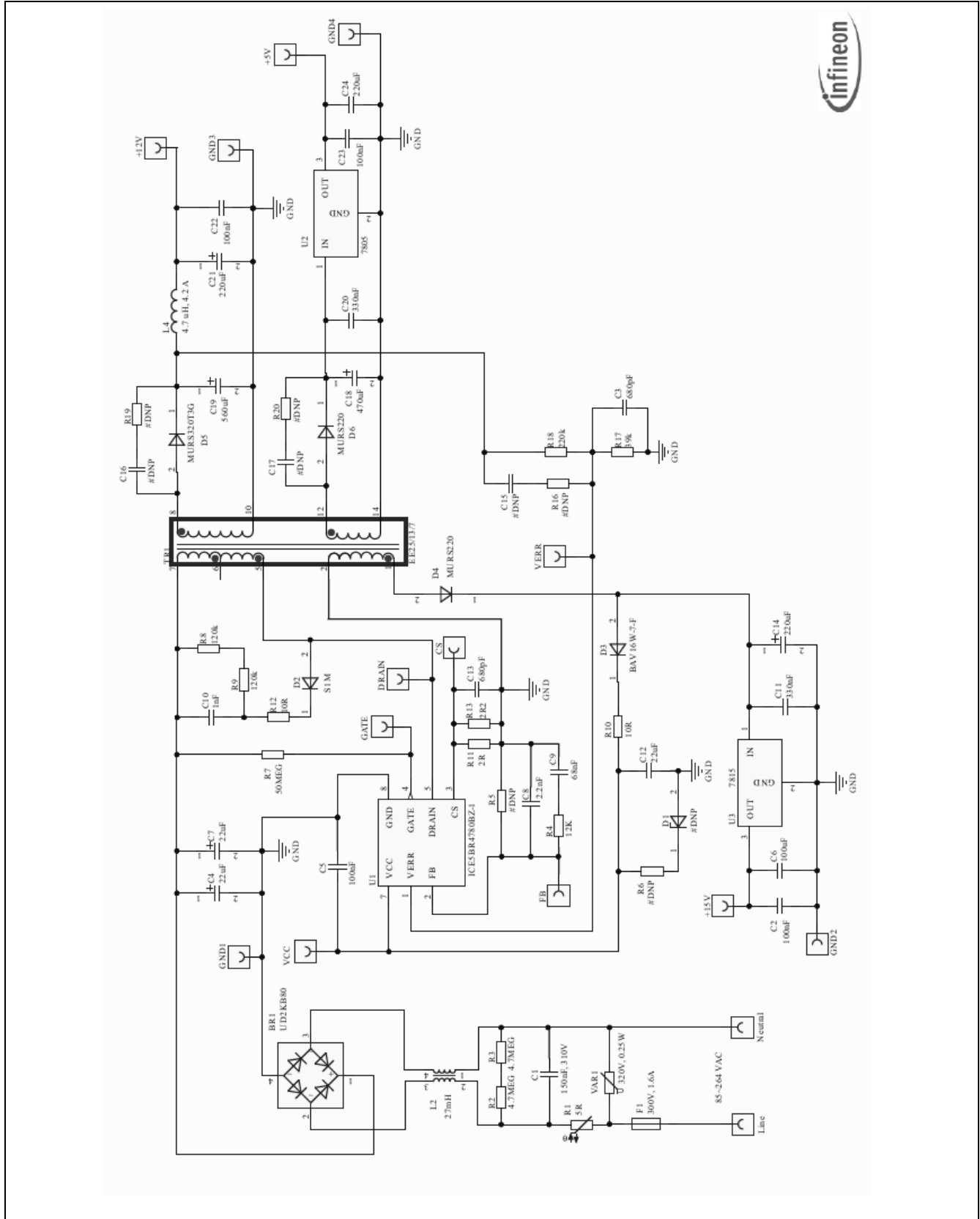


Figure 3 REF_5BR4780BZ-1_15W1

5 Circuit description

This section provides a brief description of the design circuit for the SMPS unit outlined by different functional blocks.

5.1 EMI filtering and line rectification

The input of the power supply unit is taken from the AC power grid, which is in the range of 85 V AC ~ 264 V AC. The fuse (F1) is directly connected to the input line to protect the system in case of excess current entering the system circuit due to any fault. The varistor (VAR1) is connected across the input to absorb excessive energy during line surge transient. The X-capacitor (C1) and common-mode choke (CMC) (L2) reduce the EMI noise. (R2 and R3) serve as the X-capacitor discharge resistor. Thermistor (R1) is in series with line to limit inrush current. The bridge rectifier (BR1) rectifies the AC input into DC voltage, filtered by the bulk capacitor (C4 and C7).

5.2 Flyback converter power stage

The flyback converter power stage consists of transformer (TR1), the CoolSET™ switching controller, secondary rectification diodes (D5 and D6), secondary output capacitors (C18 and C19), and an output filter inductor (L4).

When the primary HV MOSFET turns on, energy is stored in the transformer. When it turns off, the stored energy is discharged to the output capacitors and into the output load. Secondary winding is sandwiched between two layers of primary winding to reduce leakage inductance. This improves efficiency and reduces voltage spikes.

For the output rectification, lower forward voltage and ultra-fast recovery diodes can improve efficiency. Capacitor (C19) stores the energy needed during output load jumps. LC filter (L4/C21) reduces the high-frequency ripple voltage.

The 15 V output is from the 15 V low dropout (LDO) regulator (U3) with an input of 18 V. The 5 V output is from the 5 V LDO regulator (U2) with an input of 8 V. As such, these outputs would not be affected by cross regulation. However, its input should be maintained within the operating range of the LDO.

5.3 Control of the flyback converter

5.3.1 Current sensing (CS)

The ICE5BR4780BZ-1 is a current mode switching controller. The primary peak current is controlled cycle-by-cycle through the CS resistors (R11 and R13) which are connected across the CS pin (pin 3). Transformer saturation can be avoided through peak current limitation (PCL); and hence, the system is more protected and reliable.

5.3.2 Feedback and compensation network

Resistor (R17 and R18) comprises a voltage divider, which is used to sense the V_{OUT} and directly feedback output signals to the error amplifier pin (pin 1) of U1, as it is a non-isolated design. A type 2 compensation capacitor and resistor network (C8, C9, and R4) is connected between the FB pin (pin 2) and GND pin (pin 8) of the U1 to stabilize the system.

The FB pin of the ICE5BR4780BZ-1 switching controller is a multi-function pin, which is used to select the entry burst power level (three levels available) through the resistor at the FB pin (R5) and also the burst-on/burst-off sense input during active burst mode (ABM).

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Circuit description

5.4 Unique features

This section describes the CoolSET™ 5th Generation Fixed Frequency Plus ICE5BR4780BZ-1 switching controller to support the requirements of an invertized outdoor air conditioner auxiliary power system.

5.4.1 Fast self-start-up and sustaining of V_{CC}

The IC start-up uses a cascode structure integrated into the package to fast-charge the V_{CC} capacitor. Pull-up resistor (R7) is connected to the GATE pin (pin 4) to initiate the start-up phase. At first, *I*_{VCC_Charge1} is used to charge the V_{CC} capacitor from 0 V to V_{CC_SCP}. This is a protection feature which reduces power dissipation of the power MOSFET during V_{CC} short-to-GND condition. Thereafter, a much higher charging current of *I*_{VCC_Charge2} will charge the V_{CC} capacitor until the V_{CC_ON} is reached.

After start-up, the IC V_{CC} supply is sustained by the auxiliary winding of the transformer (TR1), which needs to support the V_{CC} to be above the undervoltage lockout (UVLO) voltage (10 V typ.). In this reference board, the V_{CC} supply is tapped from the 18 V winding.

5.4.2 CCM and DCM operation with frequency reduction

ICE5BR4780BZ-1 switching controller can be operated in either discontinuous conduction mode (DCM) or continuous conduction mode (CCM) with frequency-reduction features. This reference board is designed to operate in DCM at operating input voltage and load conditions. When the system is operating at high output load, the controller switches at a fixed frequency of 65 kHz. To achieve better efficiency between light load and medium load, frequency reduction is implemented as a function of V_{FB}, with a reduction curve as shown in Figure 4. Switching frequency will not reduce further once the minimum switching frequency of 28 kHz is reached.

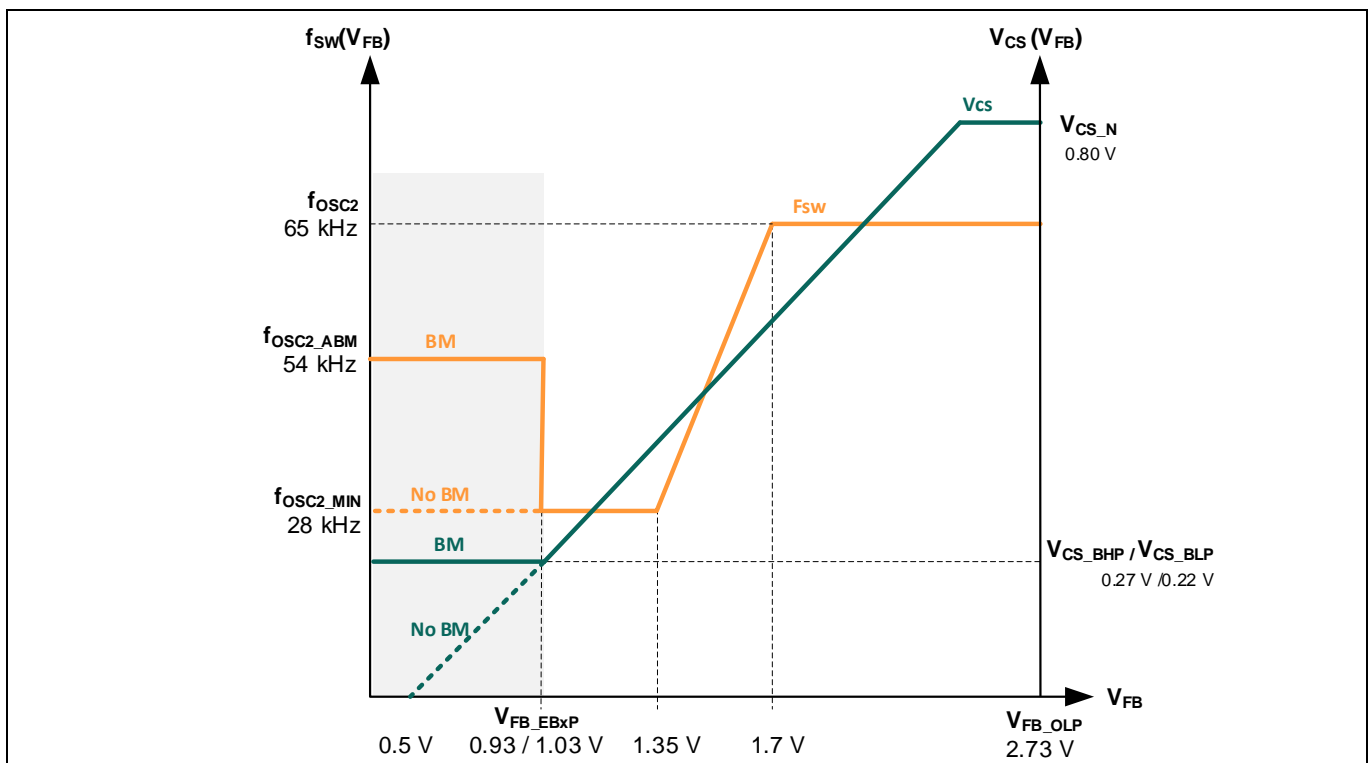


Figure 4 Frequency reduction curve

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Circuit description

5.4.3 Frequency jittering with modulated gate drive

ICE5BR4780BZ-1 switching controller has a frequency jittering feature with modulated gate drive to reduce the EMI noise. The jitter frequency is internally set at 65 kHz (± 4 kHz), and the jitter period is 4 ms.

5.4.4 System robustness and reliability through protection features

Protection is one of the major factors in determining whether the system is safe and robust. Therefore, sufficient protection is necessary. ICE5BR4780BZ-1 switching controller provides comprehensive protection to ensure the system is operating safely. Protections include V_{CC} overvoltage (OV) and undervoltage (UV), overload, overtemperature, and V_{CC} short-to-GND. When those faults are detected, the system enters protection mode until the fault is removed, and then resumes normal operation. The following table lists the protections and failure conditions.

Table 3 Protection functions of ICE5BR4780BZ-1

Protection function	Failure condition	Protection mode
V_{CC} OV	$V_{VCC} \geq V_{VCC_OVP}$	Extended cycle skip auto-restart
V_{CC} UV	$V_{VCC} \leq V_{VCC_off}$	Auto-restart
Overload	$V_{FB} \geq V_{FB_OLP}$ and lasts for $t_{FB_OLP_B}$	Extended cycle skip auto-restart
Over temperature	$T_J \geq 140^\circ\text{C}$ (40°C hysteresis)	Non-switch auto-restart
V_{CC} short-to-GND ($V_{VCC} = 0$ V, $R_{startup} = 50$ M Ω , $V_{DRAIN} = 90$ V)	$V_{VCC} \leq V_{VCC_SCP}$, $I_{VCC_charge1} \approx -0.2$ mA	Cannot start up

5.5 Clamper circuit

A clamper network consisting of a diode (D2), capacitor (C10), and resistors (R8, R9, and R12) are used to reduce the switching voltage spikes across the drain of the integrated HV MOSFET of the CoolSET™, which are generated by the leakage inductance of the transformer (TR1). This is a dissipative circuit; therefore, the selection of resistors (R8 and R9), and capacitor (C10) need to be fine-tuned depending on the voltage derating factor and efficiency requirement.

5.6 PCB design recommendations

Following are the recommendations for a good PCB design layout.

- The switching power loop needs to be as small as possible (see [Figure 5](#)). There are four power loops in the reference design; one on the HV side and three on the output side. The HV loop starts from the bulk capacitor (C7) positive terminal, the primary transformer winding, CoolSET™, CS resistors and back to the C7 negative terminal. The first output side loop (12 V output) starts at the transformer winding (pin 8), output diode (D5), output capacitor (C19) and back to pin 10 of TR1. The second output loop (8 V output) starts at the transformer winding (pin 12 of TR1), output diode (D6), output capacitor (C18) and back to pin 14 of TR1. The third output loop (18 V output) starts at the transformer winding (pin 2 of TR1), output diode (D4), output capacitor (C14) and back to pin 1 of TR1.

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Circuit description

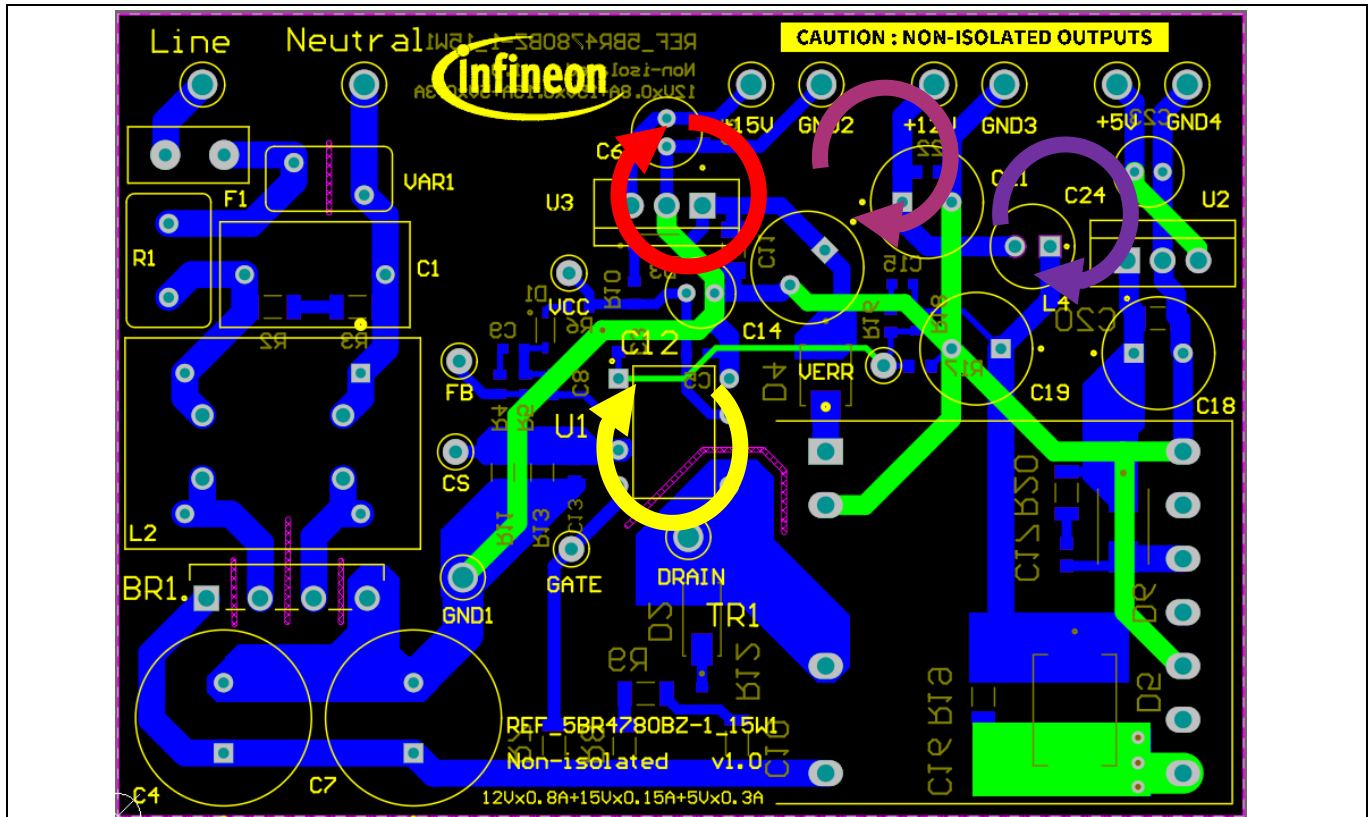


Figure 5 PCB layout recommendations

- Use the star ground connection to reduce high frequency (HF) noise coupling that affects the functional operation. The ground of the small-signal components must be connected directly to the IC ground.
- Separating the HV components and low voltage (LV) components, e.g., using a clamping circuit (C10, R8, R9, R12, and D2) can reduce the spark-over chance of the high energy surge during a lightning surge test.
- Make the PCB copper pour on the DRAIN pin of the MOSFET act as a heatsink.

5.7 EMI reduction tips

EMI compliance is always a challenge for the power supply designer. There are several critical points to consider in order to achieve a satisfactory EMI performance.

- A proper transformer design can significantly reduce EMI. Low leakage inductance can incur a low switching spike and HF noise. Interlaced winding technique is the most common practice to reduce leakage inductance. Winding shield, core shield, and whole transformer shield are also some of the techniques used to reduce EMI.
- Input CMC and X-capacitor greatly reduce EMI, but this is costly and impractical especially for low-power applications.
- Short-switching power-loop designs in the PCB can reduce radiated EMI due to the antenna effect (see Section 5.6).
- An output diode snubber circuit can reduce the HF noise.

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PCB layout

6 PCB layout

6.1 Top side

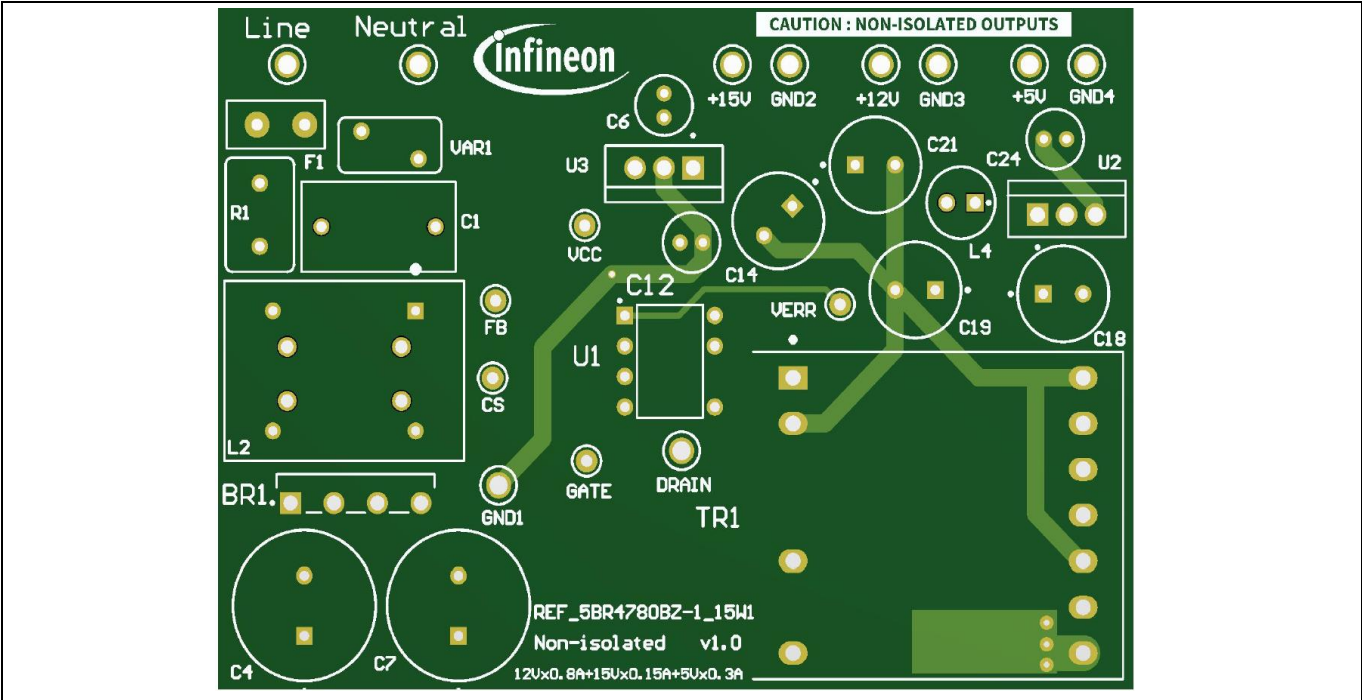


Figure 6 Top-side component legend

6.2 Bottom side

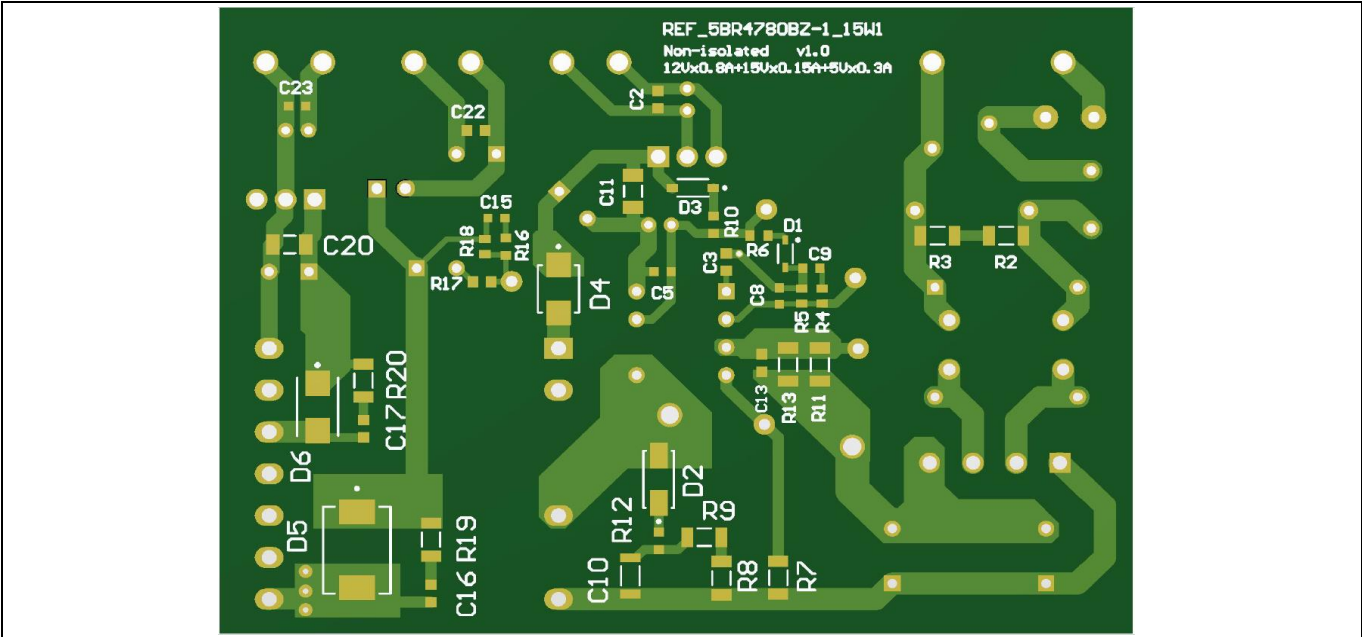


Figure 7 Bottom-side copper and component legend

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1



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Bill of materials

7 Bill of materials

Table 4 BOM

No	Designator	Description	Part number	Manufacturer	Qty
1	BR1	Bridge rectifier 2A 800 V	UD2KB80-7000	Shindengen	1
2	C1	Film capacitors, 150 nF, 310 V AC	890324023025	Würth Elektronik	1
3	C2, C5, C22, C23	MLCC - SMD/SMT 50 V .1 uF X7R 0603 10%	-	-	4
4	C4, C7	CAP ALUM 22 UF 20% 400 V RADIAL	EKXG401ELL220M K20S	UNITED CHEMI-CON	2
5	C6, C24	CAP ALUM 100 UF 20% 25 V RADIAL	25PX100MEFC5X11	Rubycon	2
6	C8	MLCC - SMD/SMT 0603 50 V 2200 pF 10%	-	-	1
7	C10	MLCC - SMD/SMT 500 V 1000 pF X7R 1206 10%	-	-	1
8	C9	MLCC - SMD/SMT 0603 50 V 68 nF 10%	-	-	1
9	C3, C13	MLCC - SMD/SMT 0603 50 V 680 pF 10%	-	-	2
10	C11, C20	MLCC - SMD/SMT 1206 50 V 330 nF 10%	-	-	2
11	C12	CAP ALUM 22 UF 20% 35 V RADIAL	UVR1V220MDD	Nichicon	1
12	C14, C21	CAP ALUM 220 UF 20% 35 V RADIAL	35ZLH220MEFCT7 8X11.5	Rubycon	2
13	C18	CAP ALUM 470 UF 20% 16 V RADIAL	UHE1C471MPD	Nichicon	1
14	C19	CAP ALUM 560 UF 20% 25 V RADIAL	25ZLJ560M8X20	Rubycon	1
15	D2	DIODE GEN PURP 1KV 1A SMA	S1M	-	1
16	D3	DIODE GEN PURP 100 V 150 MA SOD123	BAV16W-7-F	Diodes Incorporated	1
17	D4, D6	DIODE GEN PURP 200 V 2A SMB	MURS220T3G	ON Semiconductor	2
18	D5	DIODE GEN PURP 200 V 3A SMC	MURS320T3G	ON Semiconductor	1
19	F1	Time lag fuse, 300 V, 1.6A	36911600000	Littelfuse	1
20	L2	CMC 27 mH 900 mA 2LN TH	B82732R2901B030	TDK	1
21	L4	Inductor WE-TI, size 5075, 4.7 uH, 4.2 A	7447462047	Würth Elektronik	1
22	R1	ICL 5 OHM 20% 4.2 A 9.5 MM	B57235S0509M000	TDK Corporation	1
23	R2, R3	RES SMD 4.7M OHM 1% 1/4 W 1206	-	-	2
24	R4	RES SMD 12K OHM 1% 1/10 W 0603	-	-	1

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1



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Bill of materials

No	Designator	Description	Part number	Manufacturer	Qty
25	R7	RES SMD 50M OHM 1% 300 mW 1206	CRHA1206AF50M0 FKEF	Vishay	1
26	R8, R9	RES SMD 120K OHM 1% 1/4 W 1206	–	–	2
27	R10, R12	RES SMD 10 OHM 1% 1/10 W 0603	–	–	2
28	R11	RES SMD 2.0 OHM 1% 1/4 W 1206	–	–	1
29	R13	RES SMD 2.2 OHM 1% 1/4 W 1206	–	–	1
30	R17	RES 39K OHM 1% 1/10 W 0603	–	–	1
31	R18	RES 220K OHM 1% 1/10 W 0603	–	–	1
32	TR1	EE25/13/7	750344843	Würth Elektronik	1
33	U1	CoolSET™	ICE5BR4780BZ-1	Infineon	1
34	U2	IC REG LINEAR 5 V 1.5 A TO220AB	L7805CV	STMicroelectro nics	1
35	U3	IC REG LINEAR 15 V 1.5 A TO220AB	L7815CV	STMicroelectro nics	1
36	VAR1	S07K320E2/320 V AC/10%	B72207S2321K101	Epcos	1
37	+5V, +12V, +15V, DRAIN, Neutral	Test point THT, Red	5010	Keystone	5
38	GND1, GND2, GND3, GND4, Line	Test point THT, Black	5011	Keystone	5
39	CS, FB, GATE, VERR, VCC	Test point THT, White	5002	Keystone	5

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Transformer specification

8 Transformer specification

See [Appendix A](#) for the transformer specifications.

- **Core and material:** EE25/13/7, TP4A (TDG)
- **Würth Elektronik bobbin:** 070-6725 (14-pin, THT, horizontal version)
- **Primary inductance:** $L_p = 926 \mu\text{H}$ (± 10 percent), measured between pin 5 and pin 7
- **Manufacturer and part number:** Würth Elektronik (750344843) Rev.01

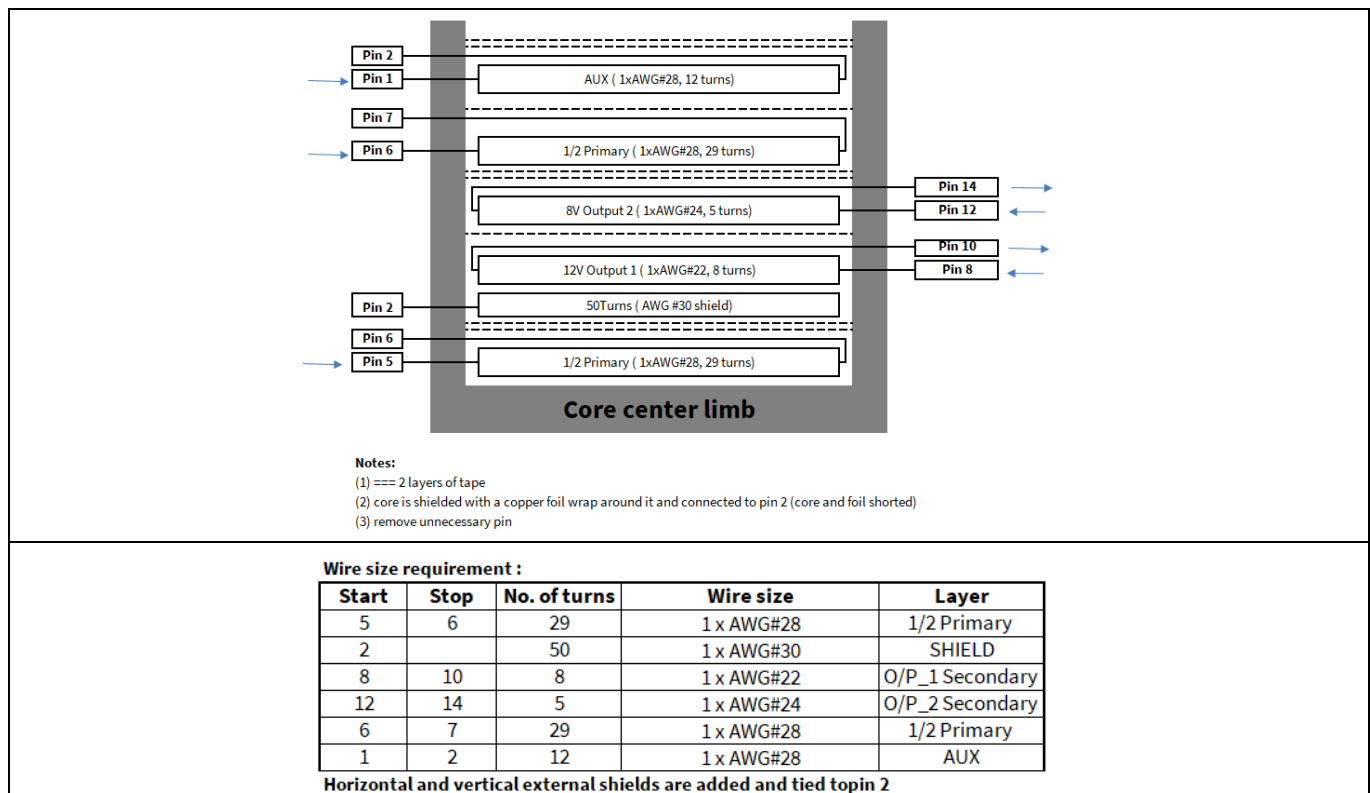


Figure 8 Transformer structure

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

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Measurement data and graphs

9 Measurement data and graphs

Table 5 Electrical measurements

Input (V AC/Hz)	P _{IN} (W)	V ₀₁ (V)	I ₀₁ (A)	V ₀₂ (V)	I ₀₂ (A)	V ₀₃ (V)	I ₀₃ (A)	P _{OUT} (W)	Efficiency (%)	Average efficiency (%)	OLP P _{IN} (W)	OLP I ₀₁ (A)
85 V AC/ 60 Hz	0.817	11.968	0.035	15.127	0.004	5.069	0.007	0.515			22.69	1.12
	4.366	11.984	0.194	15.117	0.038	5.067	0.075	3.279	75.11	75.58		
	8.728	11.984	0.395	15.105	0.079	5.066	0.150	6.687	76.61			
	13.060	11.984	0.596	15.100	0.108	5.065	0.223	9.903	75.83			
	17.743	11.984	0.794	15.087	0.149	5.064	0.298	13.269	74.79			
115 V AC/ 60 Hz	0.810	11.968	0.035	15.135	0.004	5.069	0.007	0.515			22.22	1.11
	4.345	11.984	0.194	15.117	0.038	5.067	0.075	3.279	75.47	76.84		
	8.665	11.984	0.395	15.105	0.079	5.066	0.150	6.687	77.17			
	12.770	11.984	0.596	15.100	0.108	5.065	0.223	9.903	77.55			
	17.193	11.984	0.794	15.087	0.149	5.064	0.298	13.269	77.18			
230 V AC/ 50 Hz	0.851	11.968	0.035	15.140	0.004	5.069	0.007	0.515			21.71	1.11
	4.417	11.984	0.194	15.132	0.038	5.068	0.075	3.280	74.26	76.64		
	8.703	11.984	0.395	15.127	0.079	5.067	0.150	6.689	76.86			
	12.749	11.984	0.596	15.097	0.108	5.065	0.223	9.902	77.67			
	17.060	11.984	0.794	15.090	0.149	5.064	0.298	13.270	77.78			
264 V AC/ 50 Hz	0.871	11.968	0.035	15.135	0.004	5.069	0.007	0.515			21.76	1.12
	4.496	11.984	0.194	15.130	0.038	5.068	0.075	3.280	72.95	75.91		
	8.763	11.984	0.395	15.130	0.079	5.067	0.150	6.689	76.33			
	12.880	11.984	0.596	15.095	0.108	5.065	0.223	9.902	76.88			
	17.130	11.984	0.794	15.090	0.149	5.064	0.298	13.270	77.47			

- Minimum load condition: 12 V/40 mA, 5 V/5 mA, 15 V/5 mA
- 25 percent load condition: 12 V/0.2 A, 5 V/75 mA, 15 V/38 mA
- 50 percent load condition: 12 V/0.4 A, 5 V/150 mA, 15 V/75 mA
- 75 percent load condition: 12 V/0.6 A, 5 V/225 mA, 15 V/113 mA
- 100 percent load condition: 12 V/0.8 A, 5 V/300 mA, 15 V/150 mA

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

Measurement data and graphs

Table 6 Efficiency and standby performance with a single output configuration

Input (V AC/Hz)	P _{IN} (W)	V _{o1} (V)	I _{o1} (A)	P _{OUT} (W)	Efficiency (%)	Average efficiency (%)
85 V AC/ 60 Hz	0.011	11.984	0.000	0.000		83.09
	1.101	11.984	0.075	0.899	81.63	
	2.813	11.984	0.194	2.325	82.65	
	5.642	11.984	0.395	4.734	83.90	
	8.581	11.968	0.596	7.133	83.12	
	11.495	11.968	0.794	9.503	82.67	
115 V AC/ 60 Hz	0.013	11.984	0.000	0.000		84.54
	1.089	11.984	0.075	0.899	82.53	
	2.741	11.984	0.194	2.325	84.82	
	5.568	11.984	0.395	4.734	85.02	
	8.451	11.968	0.596	7.133	84.40	
	11.322	11.968	0.794	9.503	83.93	
230 V AC/ 50 Hz	0.018	11.984	0.000	0.000		83.08
	1.176	11.984	0.075	0.899	76.43	
	2.833	11.984	0.194	2.325	82.06	
	5.711	11.984	0.395	4.734	82.89	
	8.567	11.968	0.596	7.133	83.26	
	11.300	11.968	0.794	9.503	84.09	
264 V AC/ 50 Hz	0.025	11.984	0.000	0.000		82.04
	1.218	11.984	0.075	0.899	73.79	
	2.876	11.984	0.194	2.325	80.84	
	5.781	11.968	0.395	4.727	81.77	
	8.640	11.968	0.596	7.133	82.56	
	11.448	11.968	0.794	9.503	83.01	

Note: Single-output (+12 V) configuration efficiency measurement is done by removing two LDO output circuits and connecting +12 V output directly to the V_{CC} circuit; the actual board comes with LDO circuits. The overall circuit is not optimized for single-output configuration; the above efficiency data is for illustration only.

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

Measurement data and graphs

9.1 Efficiency curve

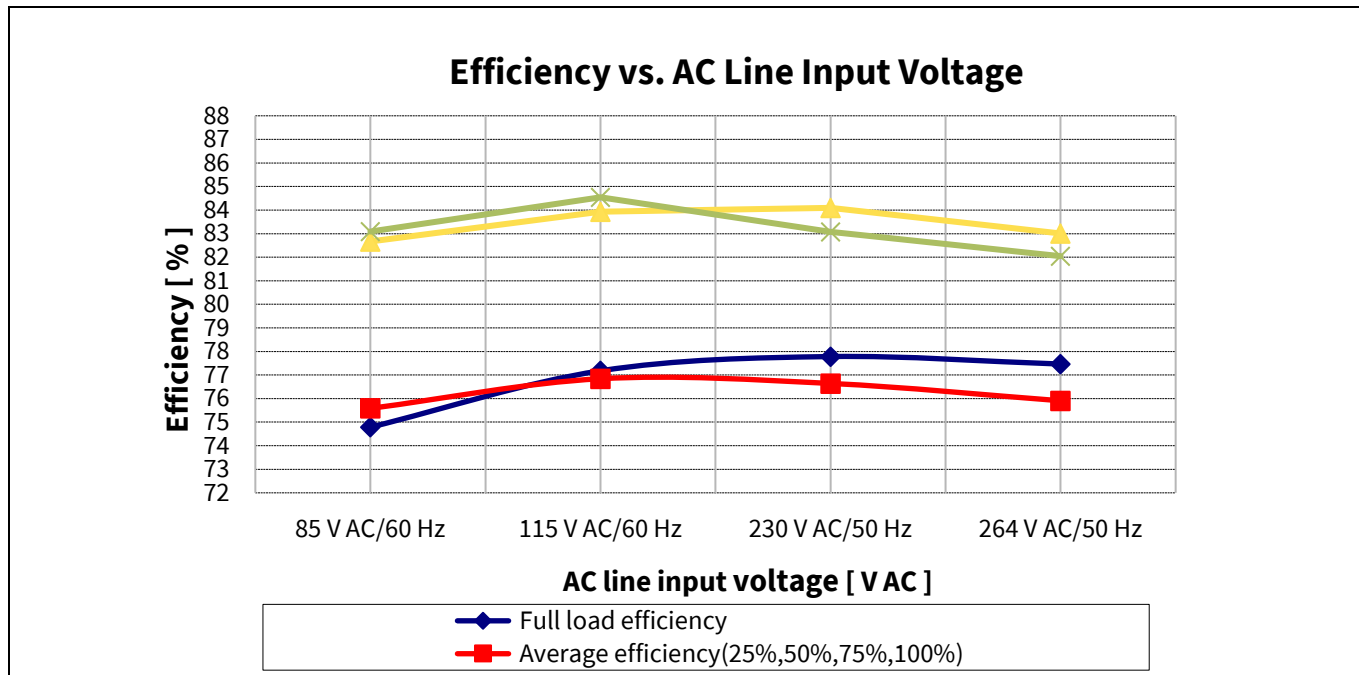


Figure 9 Efficiency vs. output load

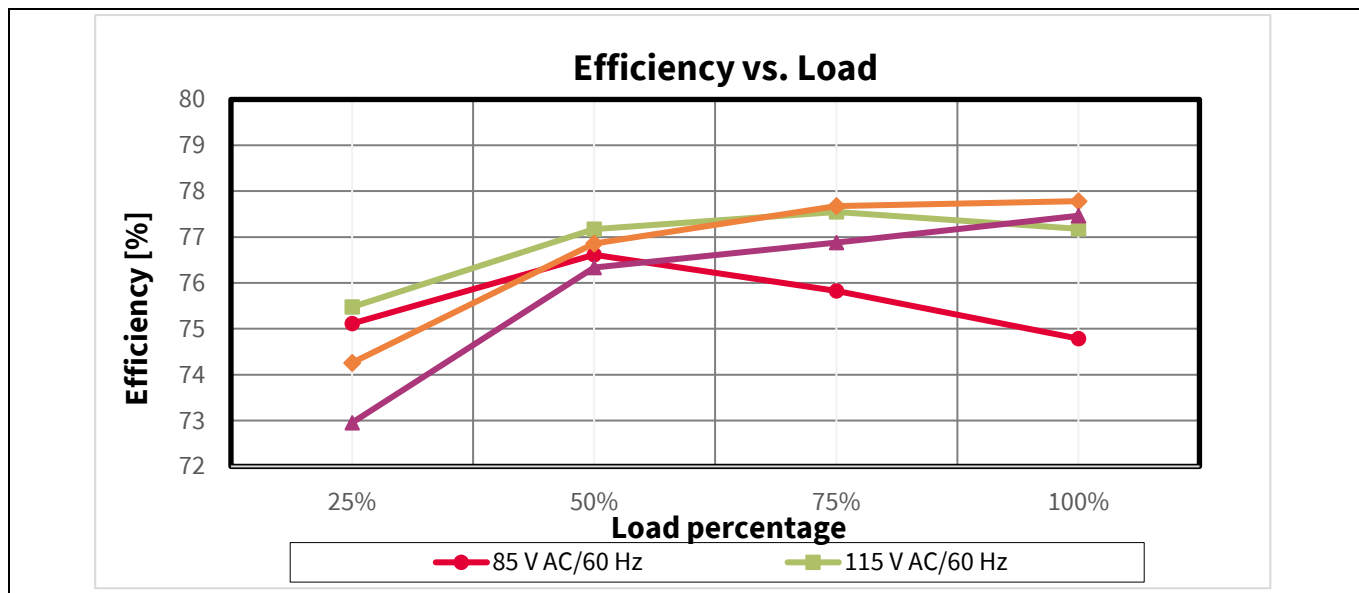


Figure 10 Efficiency vs. AC line input voltage

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

Measurement data and graphs

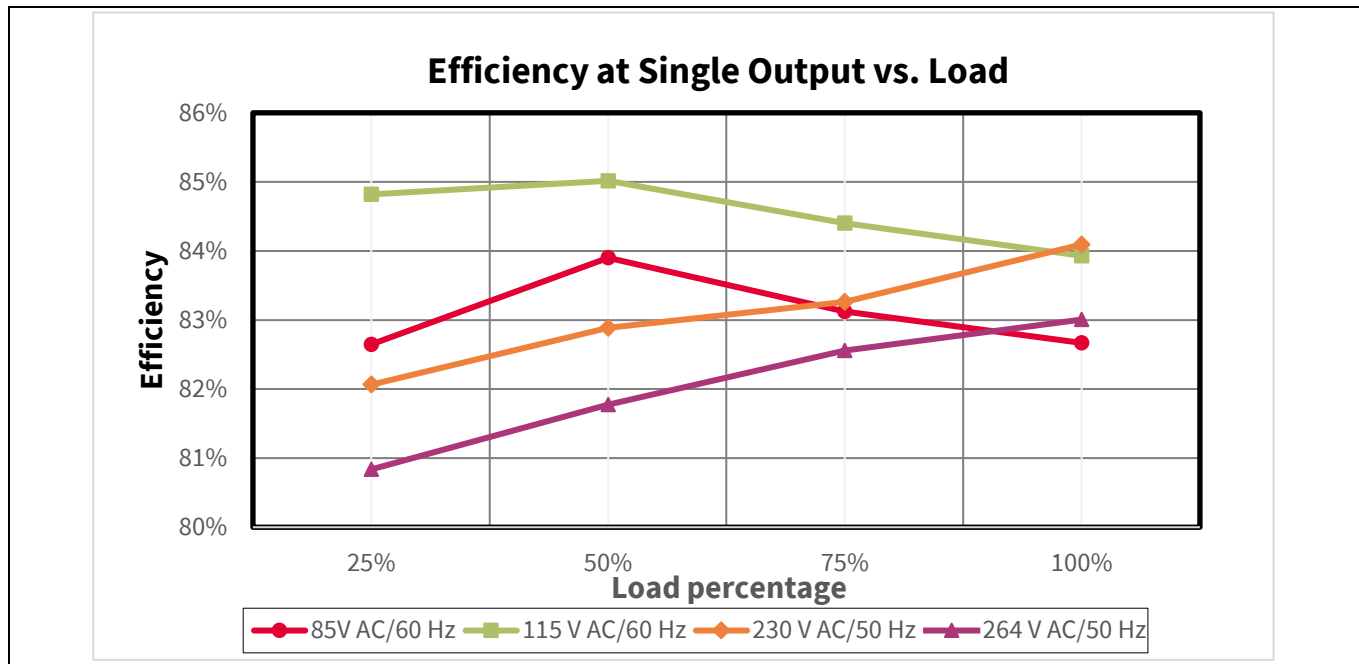


Figure 11 Efficiency at single output vs. AC line input voltage

9.2 Standby power

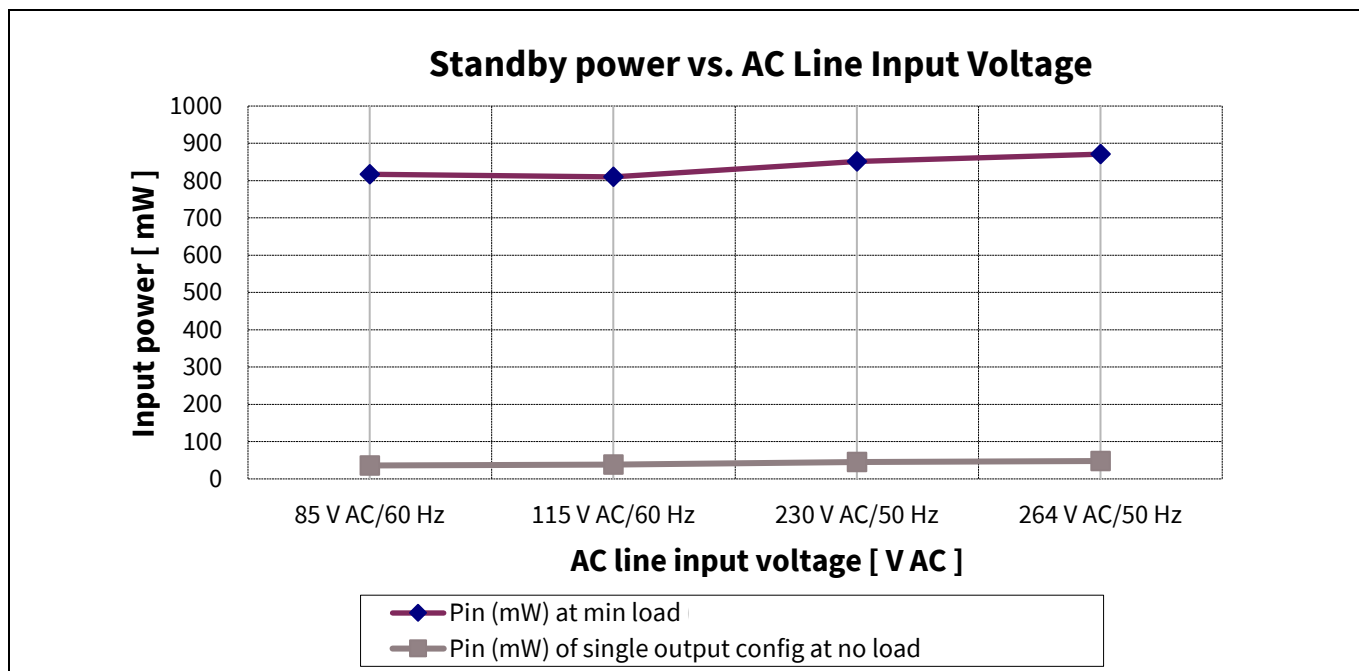


Figure 12 Standby power at minimum load vs. AC line input voltage

9.3 Line and load regulation

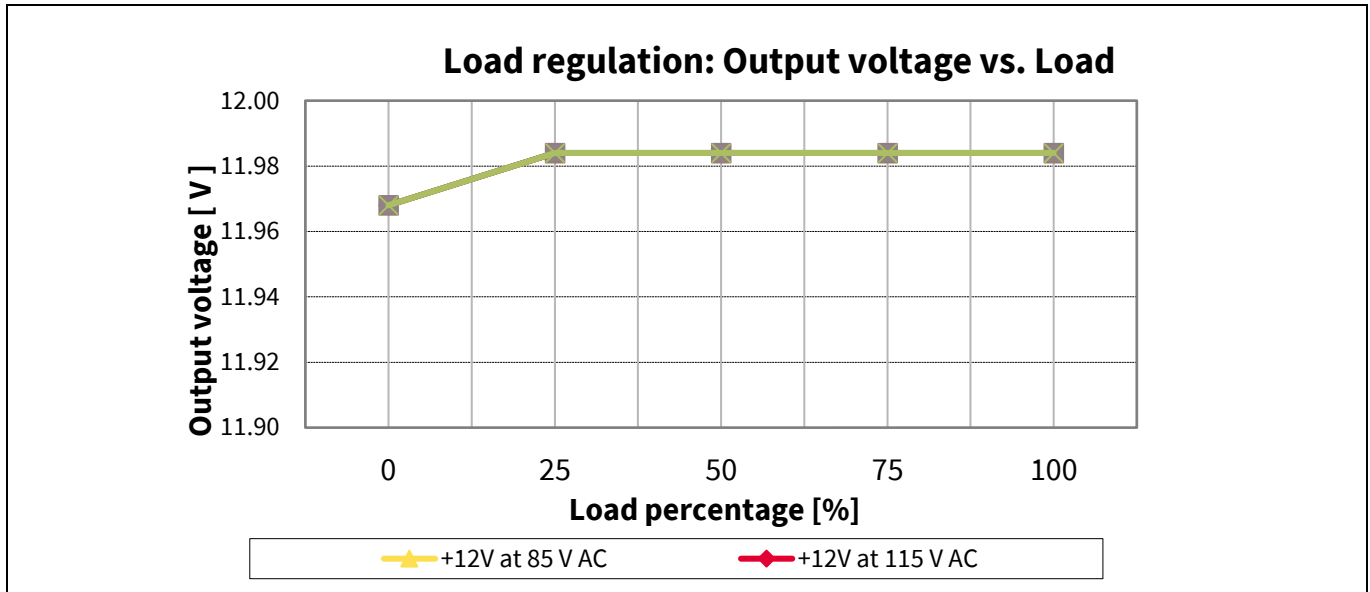


Figure 13 Output regulation vs. load at different AC line input voltages

9.4 Maximum input power

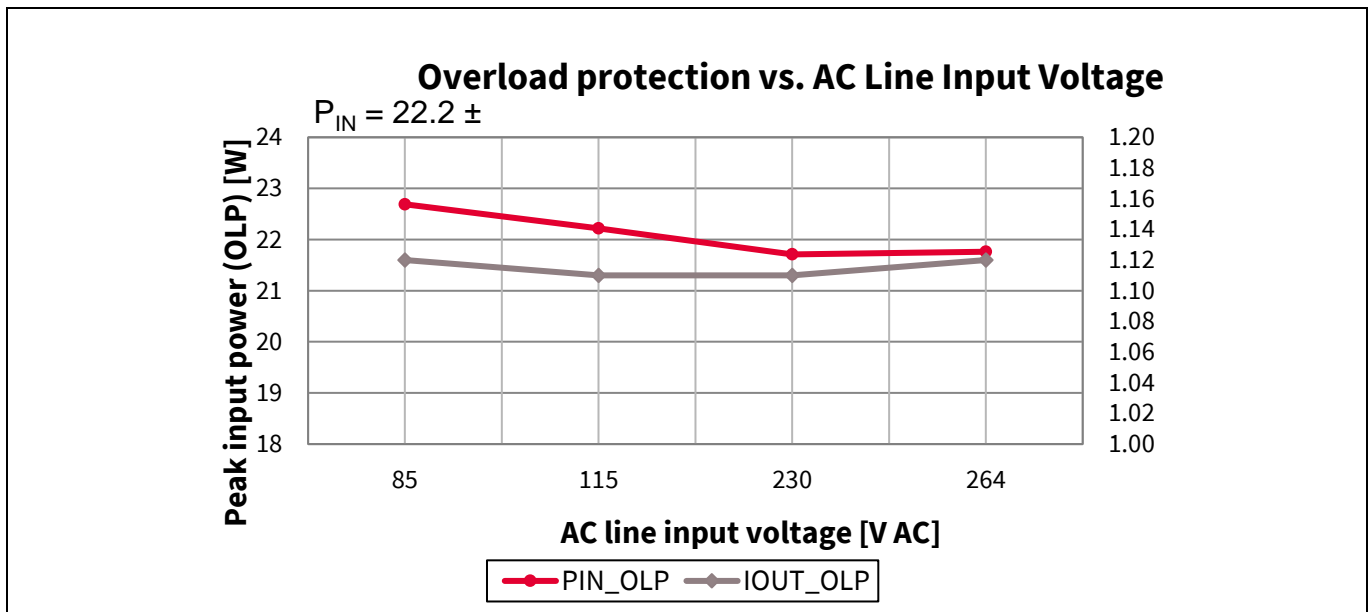


Figure 14 Maximum input power and output current (before overload protection) vs. AC line input voltage

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

Measurement data and graphs

9.5 Surge immunity (EN 61000-4-5)

The reference board is subjected to a surge immunity test (± 1 kV DM) according to EN 61000-4-5, at full load (resistive load). A test failure is defined as non-recoverable.

Table 7 System surge immunity test result

Description	Test	Level	Number of strikes				Test result
			0°	90°	180°	270°	
115/230 V AC	DM	± 1 kV	3	3	3	3	Pass

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Measurement data and graphs

9.6 Conducted emissions (EN 55022 Class B)

The conducted EMI is measured by Schaffner (SMR4503) and followed the test standard of EN 55022 (CISPR 22) Class B. The reference board is tested at full load (resistive load) at an input voltage of 115 V AC and 230 V AC.

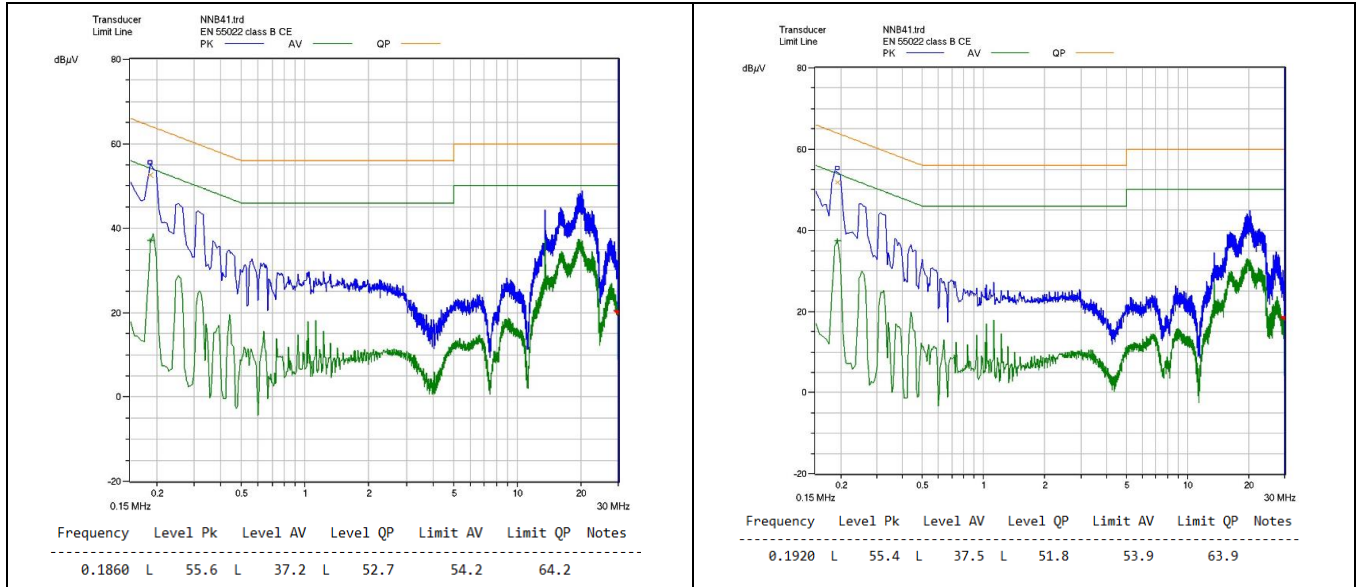


Figure 15 Conducted emissions at 115 V AC and full load on line (left) and neutral (right)

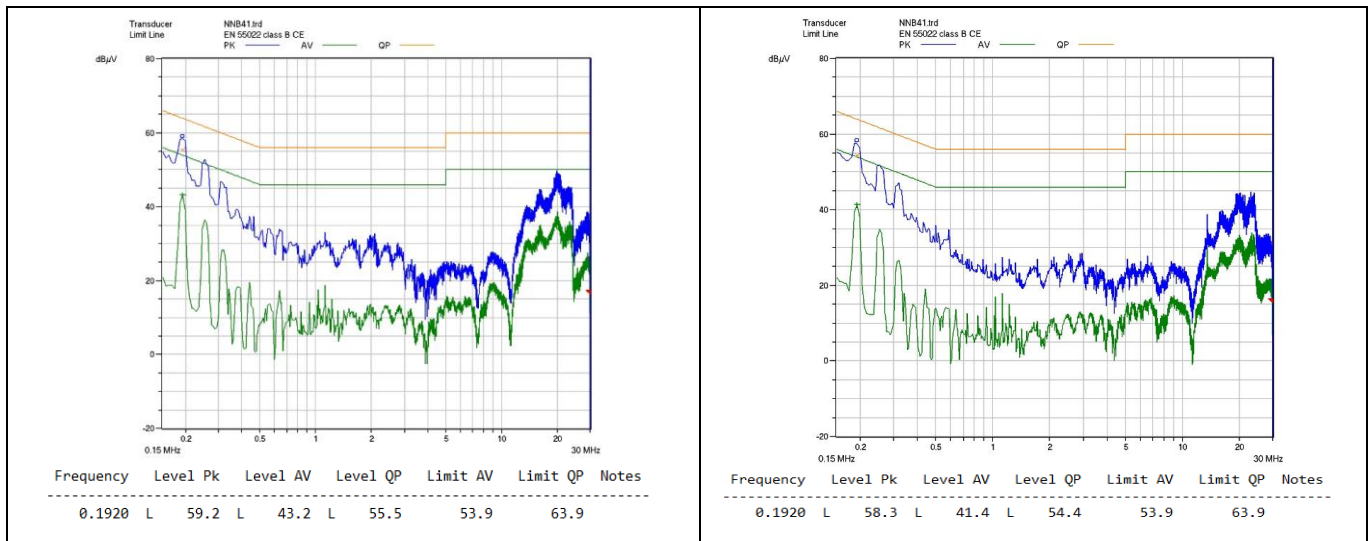


Figure 16 Conducted emissions at 230 V AC and full load on line (left) and neutral (right)

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

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Thermal measurement

10 Thermal measurement

The thermal testing of the components on the reference design board is done in an open-frame setup using an infrared thermography camera (FLIR-T62101) at an ambient temperature of 25°C taken after one hour running at full load.

Table 8 Thermal measurement of components (open frame)

No.	Component	Temperature at 85 V AC (°C)	Temperature at 264 V AC (°C)
1	ICE5BR4780BZ-1 (U1)	75.8	72.3
2	Transformer (TR1)	52	56.5
3	Bridge diode (BR1)	51.5	39.1
4	15 V output diode (D4)	62.3	62.1
5	12 V output diode (D5)	79.1	81.6
6	5 V output diode (D6)	67.6	69.8

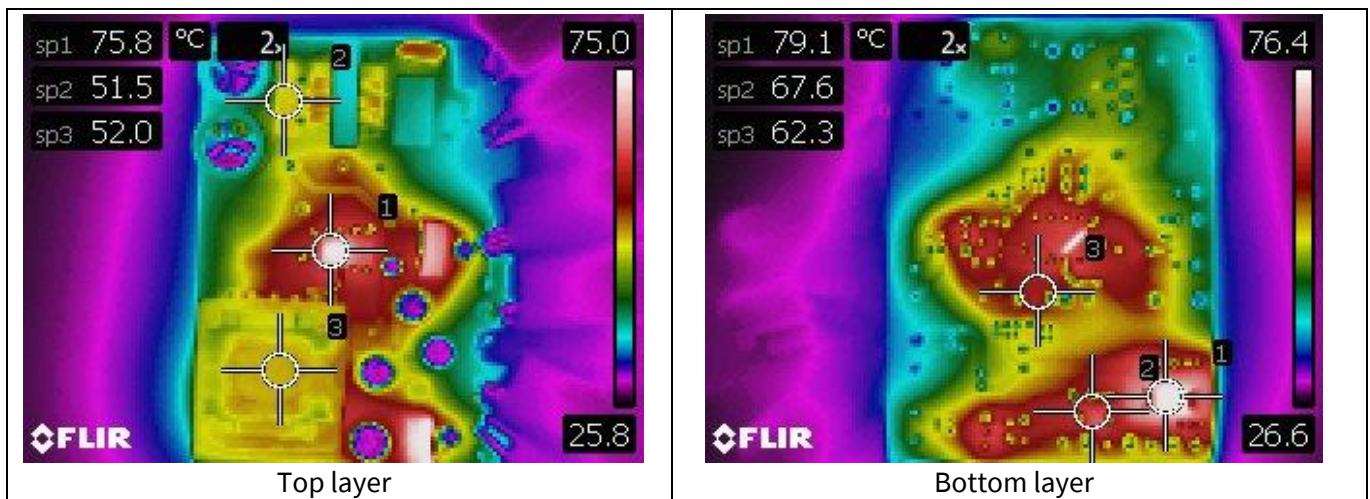


Figure 17 Infrared thermal image at 85 V AC input voltage

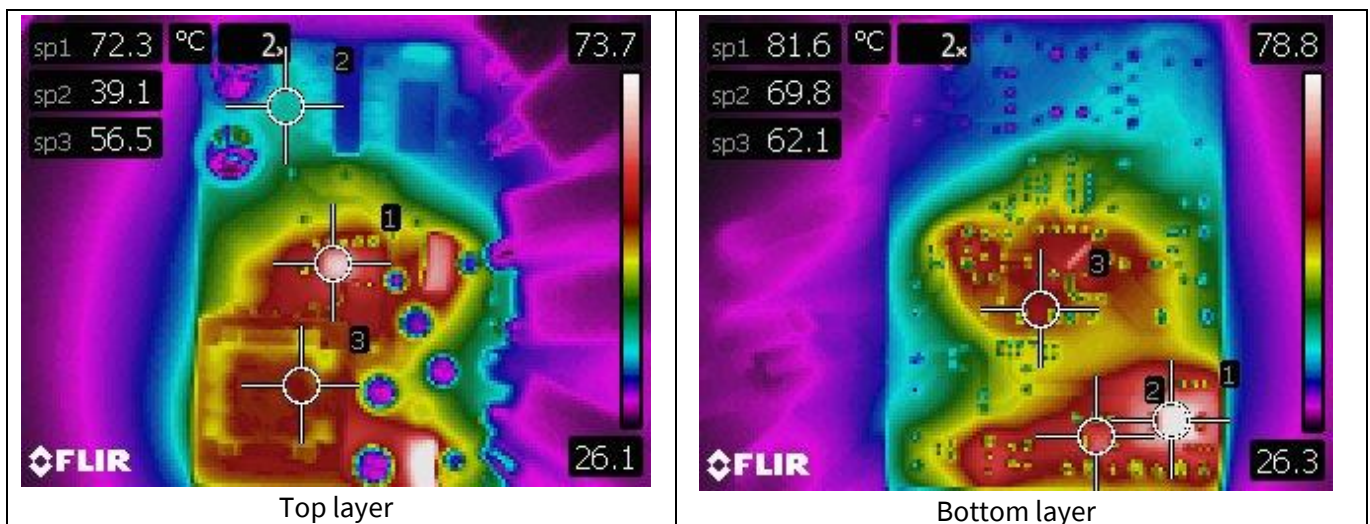


Figure 18 Infrared thermal image at 264 V AC input voltage

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

Thermal measurement

10.1 18 V rail regulation (LDO input)

As the 15 V output via LDO is derived from the 18 V rail of the transformer which is shared by the CoolSET™ switching controller V_{CC} , there are several design goals to achieve during normal operating conditions.

- Avoid V_{CC} UVLO (10 V typ.)
- Avoid V_{CC} OVP (25.5 V typ.)
- Meet the specification of the LDO: $(V_{OUT} + 1\sim 2\text{ V}) \leq V_{IN} \leq 30\text{ V}$; load dependent

From the chart and table below, the 18 V rail is operating between 18.52 V and 21.77 V under different load combinations and line conditions, which is well within the design objectives outlined above.

Table 9 +18 V rail line and load regulation

Conditions	12 V/40 mA 5 V/0 A 15 V/0 A (V)	12 V/40 mA 5 V/5 mA 15 V/5 mA (V)	12 V/0.8 A 5 V/5 mA 15 V/5 mA (V)	12 V/0.8 A 5 V/0.3 A 15 V/0.15 A (V)
85 V AC/60 Hz	18.74	18.57	21.77	18.67
115 V AC/60 Hz	18.73	18.53	21.76	18.67
230 V AC/50 Hz	18.74	18.53	21.39	18.65
264 V AC/50 Hz	18.74	18.52	21.46	18.66

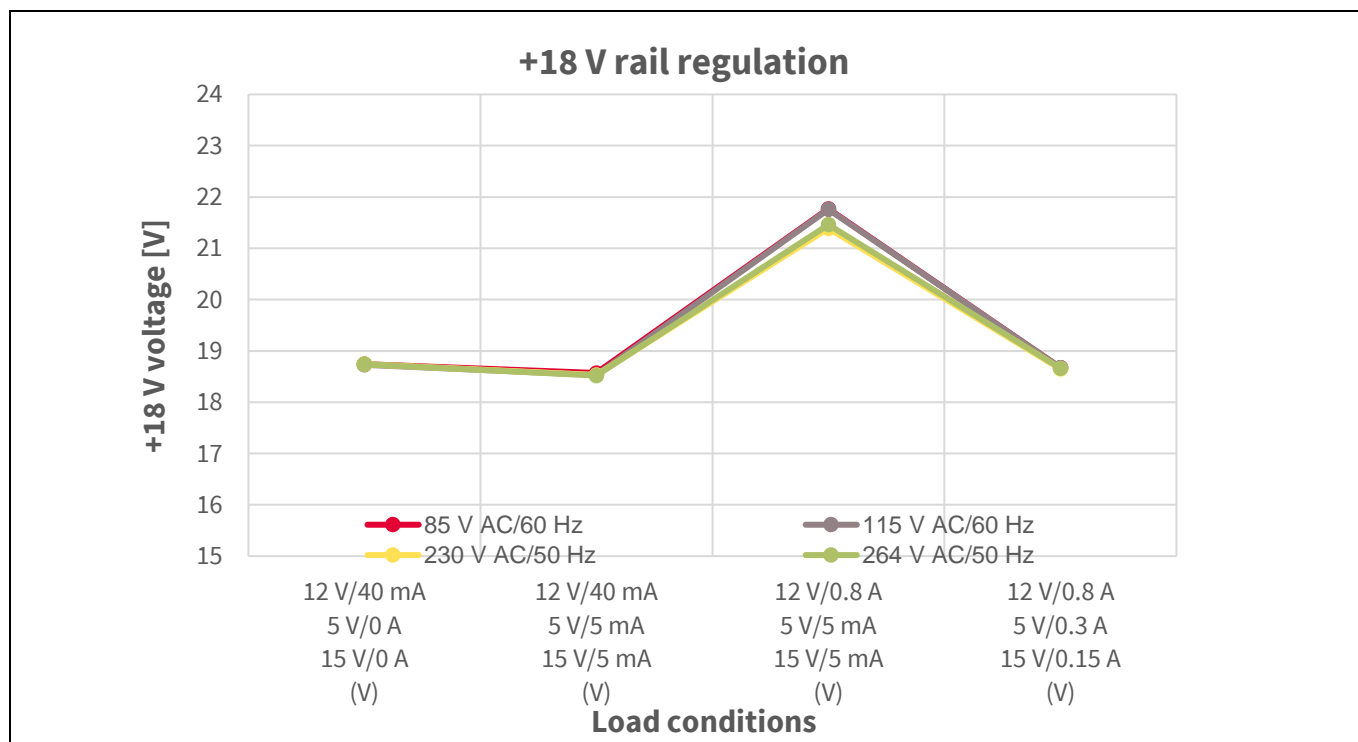


Figure 19 +18 V rail regulation

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

Waveforms and oscilloscope plots

11 Waveforms and oscilloscope plots

11.1 Start-up at full load

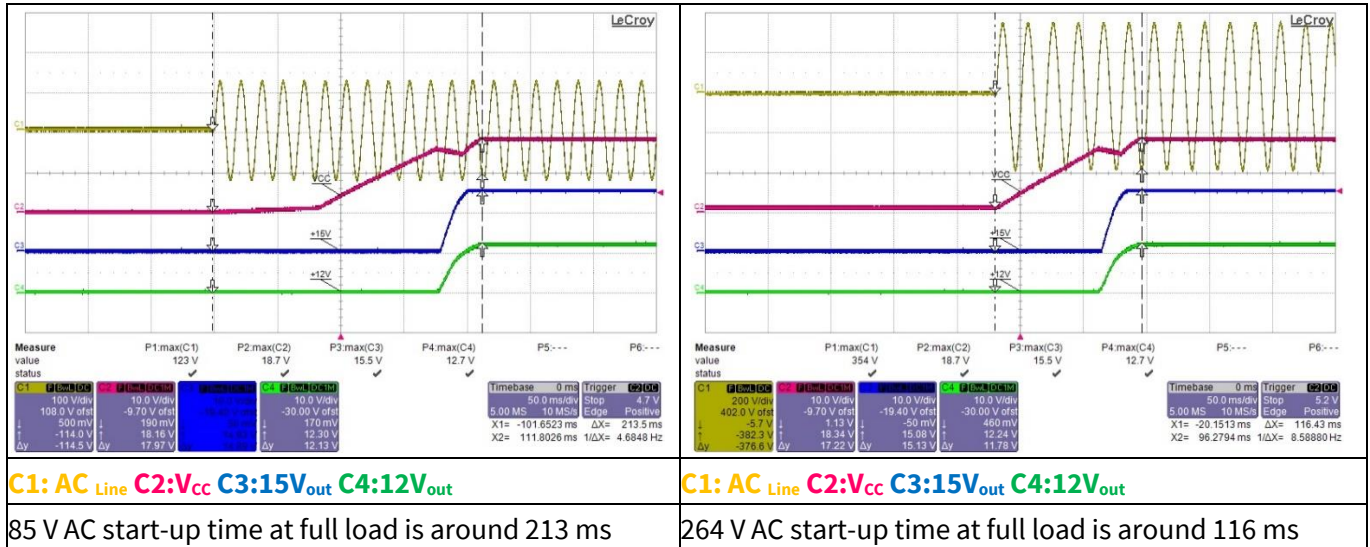


Figure 20 Start-up

11.2 Soft-start at full load

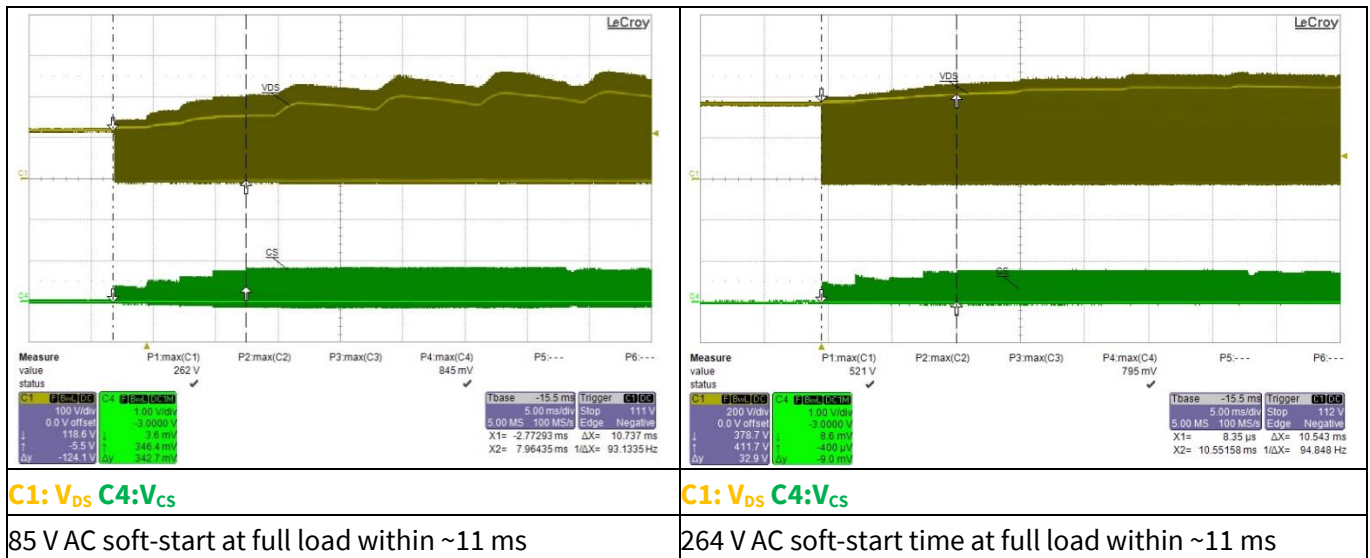


Figure 21 Soft-start

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

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Waveforms and oscilloscope plots

11.3 Drain and CS voltage at full load

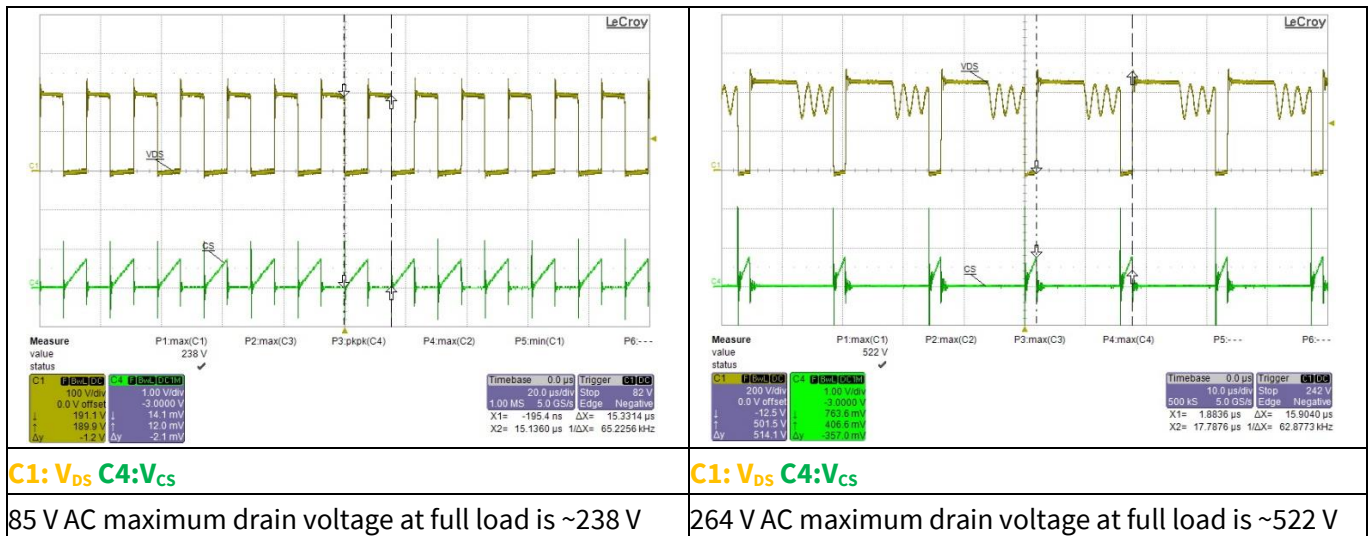


Figure 22 Drain and CS voltage

11.4 Frequency jittering and modulated gate drive

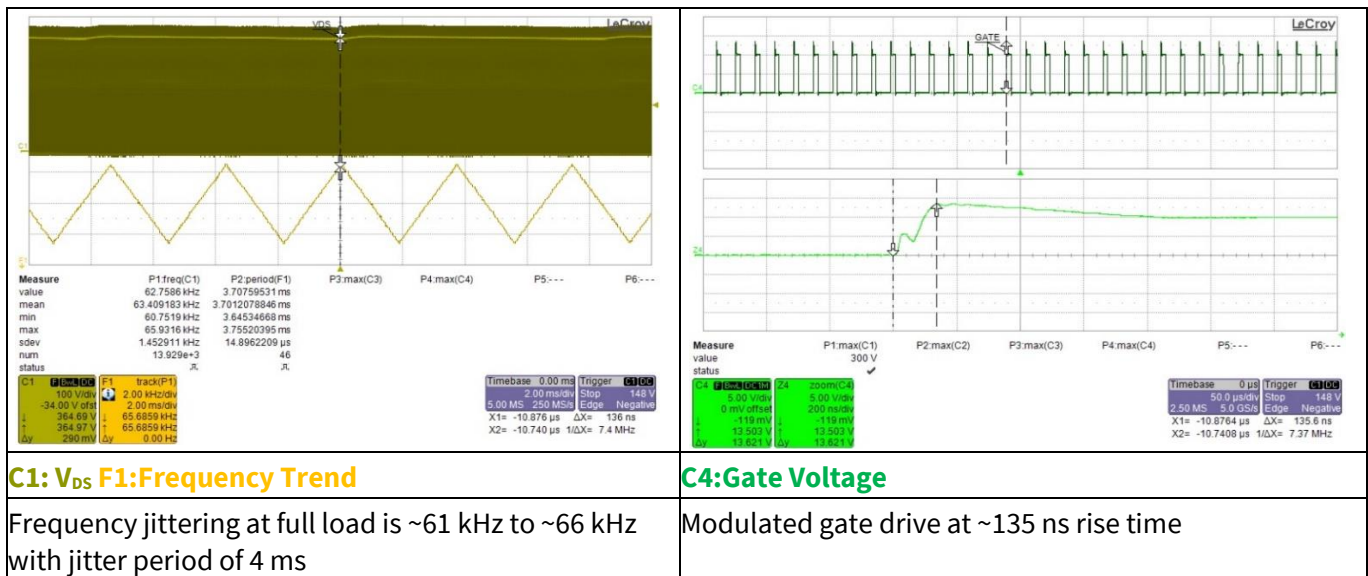


Figure 23 Frequency jittering and modulated gate drive

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

Waveforms and oscilloscope plots

11.5 Load-transient response

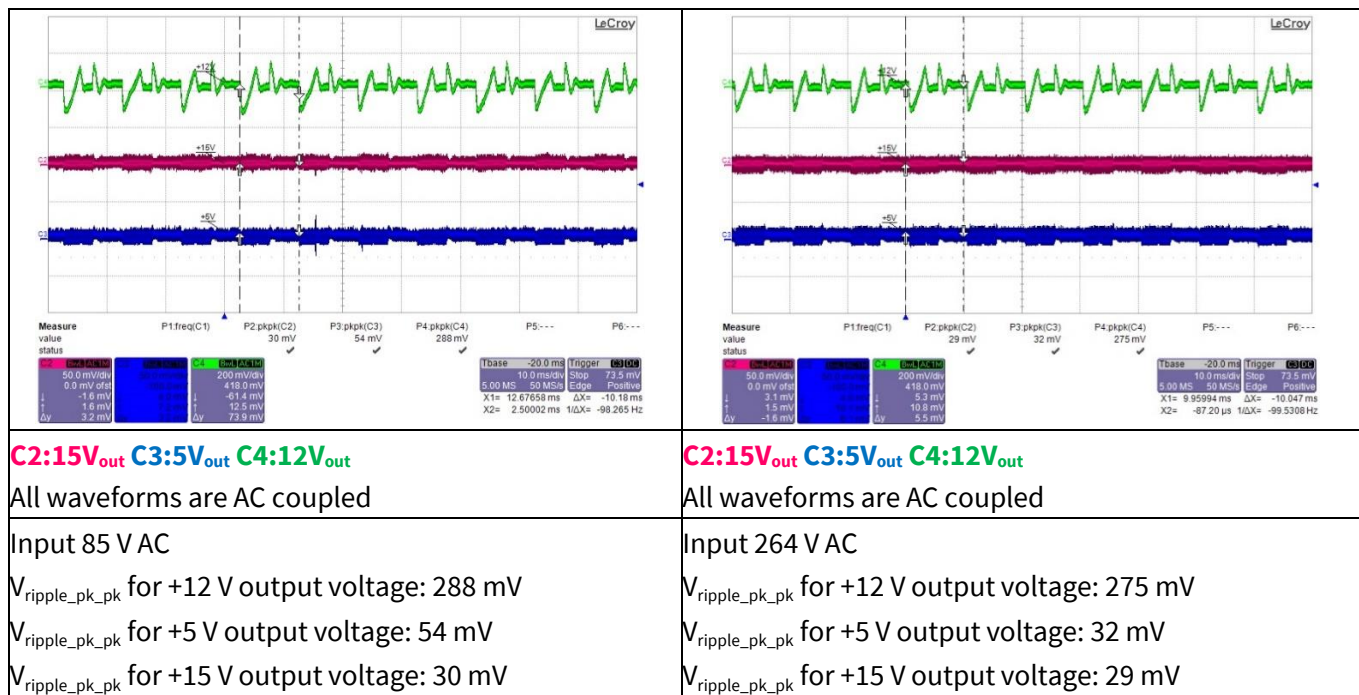


Figure 24 Load-transient response (+12 V output load change from 25 percent to 100 percent at 0.4 A/ μ s slew rate, 100 Hz, +15 V output and +5 V output load are fixed at full load; 20 MHz bandwidth and 10 μ F electrolytic capacitor in parallel with 0.1 μ F ceramic capacitor).

11.6 Output ripple voltage at full load

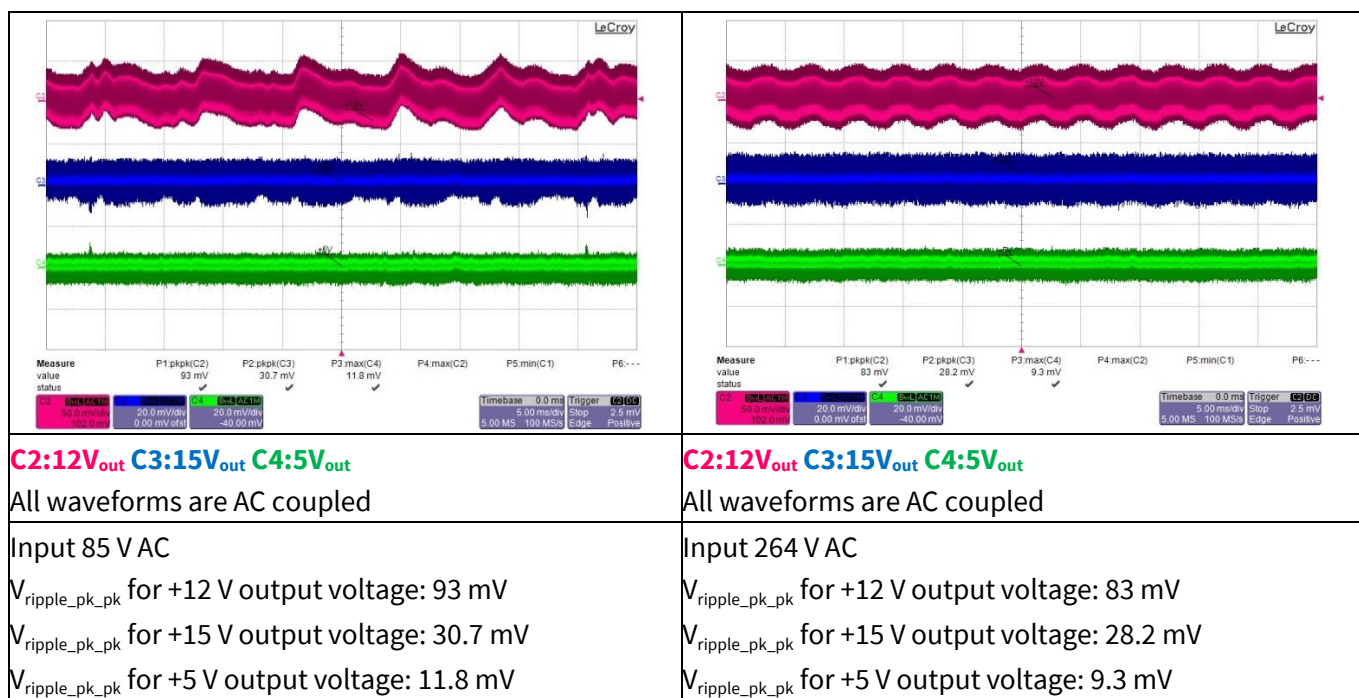


Figure 25 Output ripple voltage at full load. Probe terminals are decoupled with 10 μ F electrolytic and 0.1 μ F ceramic capacitors. Oscilloscope is a bandwidth filter limited to 20 MHz.

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

Waveforms and oscilloscope plots

11.7 Output ripple voltage at ABM (minimum load)

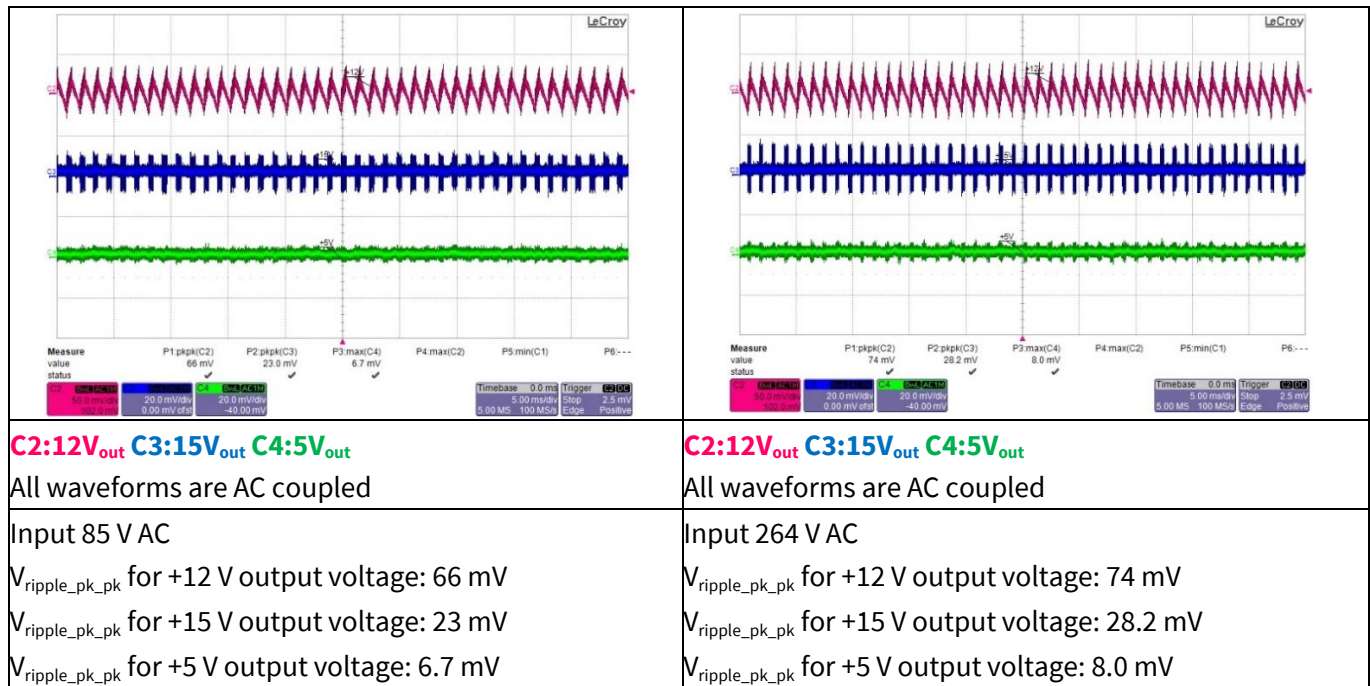


Figure 26 Output ripple voltage at minimum load. Probe terminals are decoupled with 10 μ F electrolytic and 0.1 μ F ceramic capacitors. Oscilloscope is bandwidth filter limited to 20 MHz.

11.8 Entering ABM

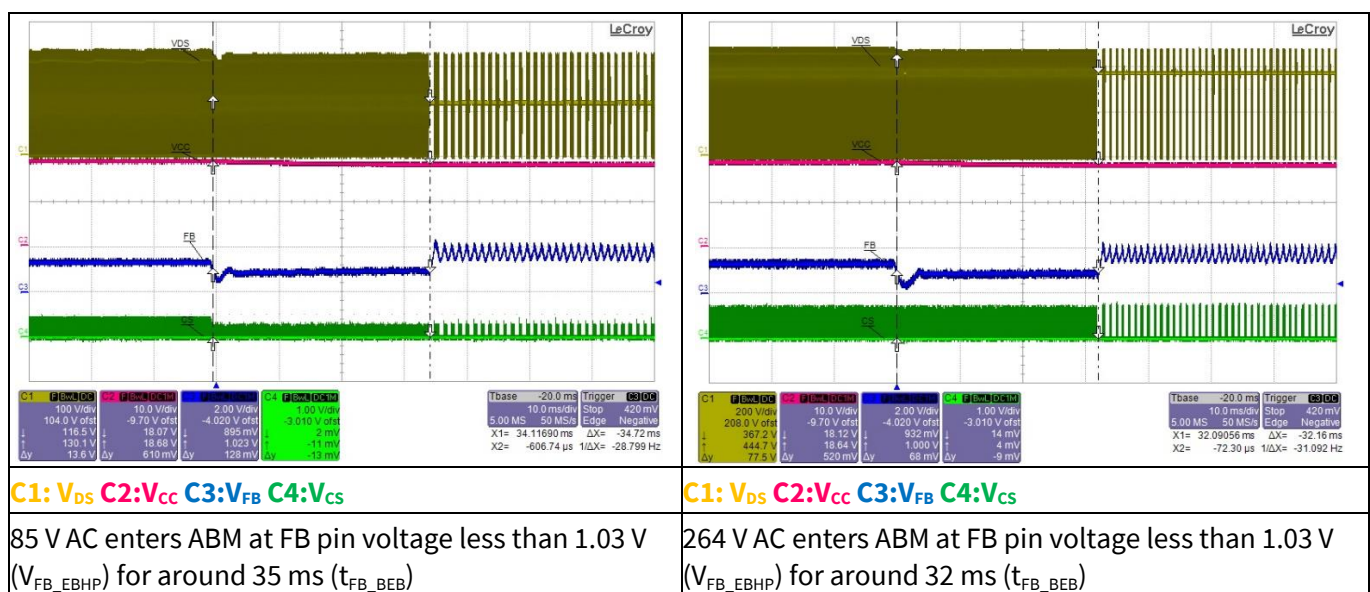


Figure 27 Entering ABM

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

Waveforms and oscilloscope plots

11.9 During ABM

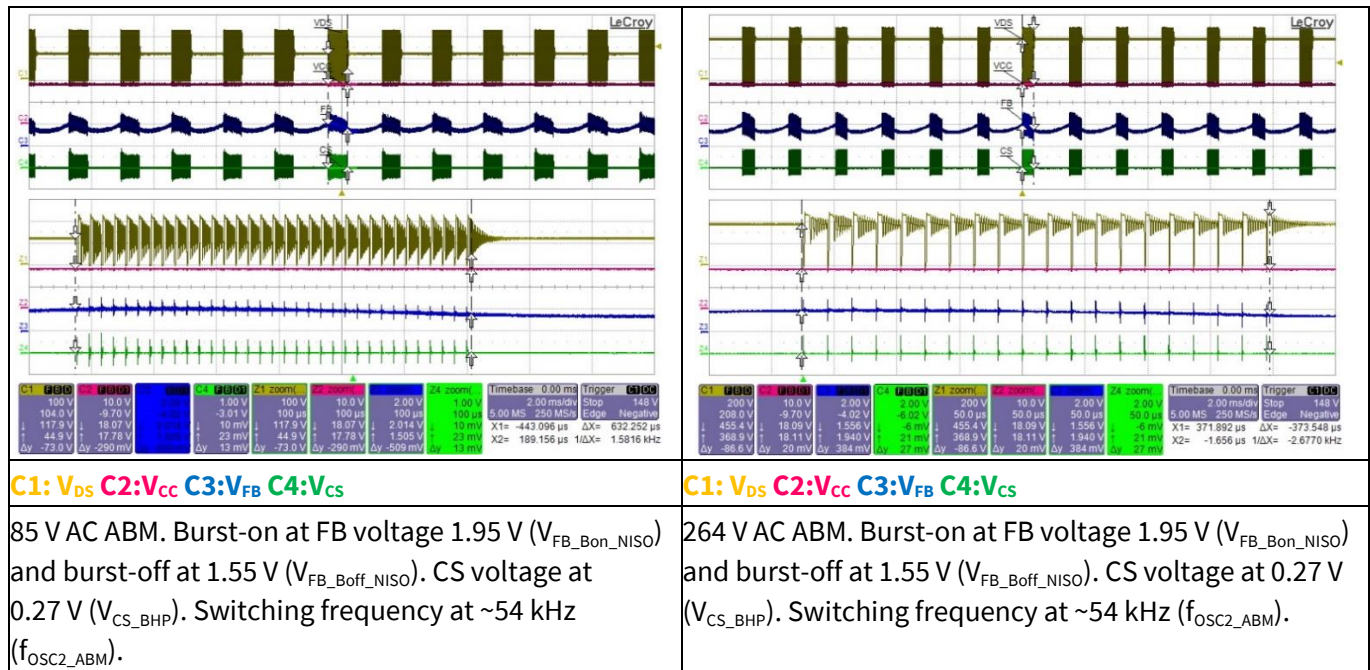


Figure 28 During ABM

11.10 Leaving ABM

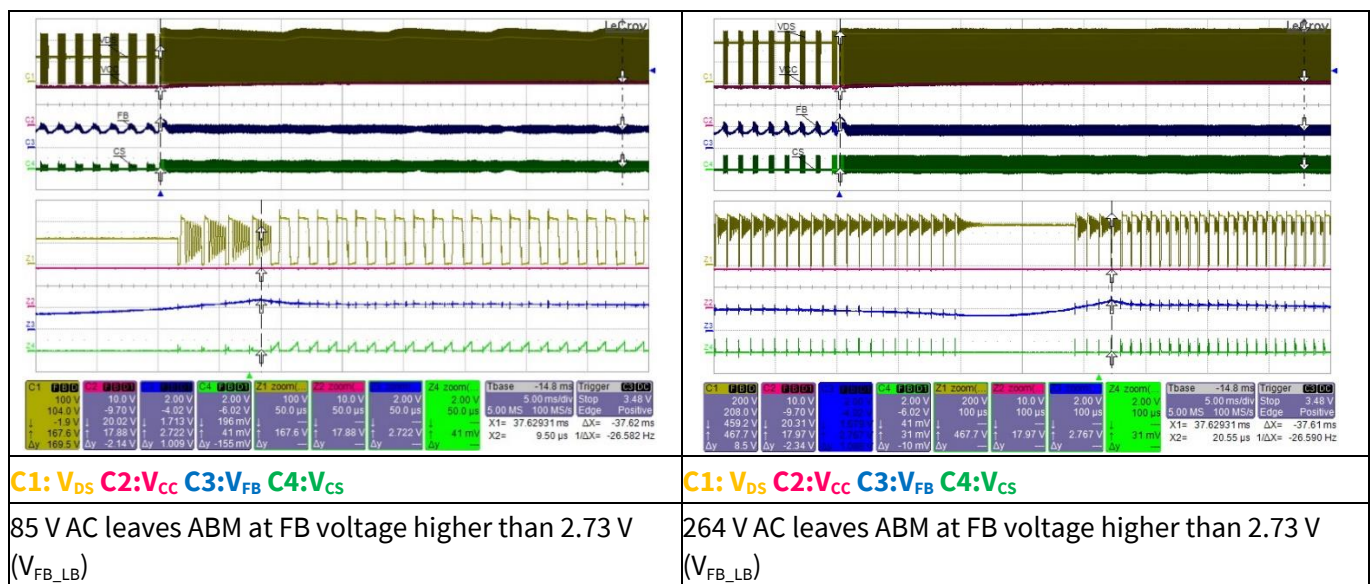


Figure 29 Leaving ABM

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

Waveforms and oscilloscope plots

11.11 V_{CC} OV/UV protection

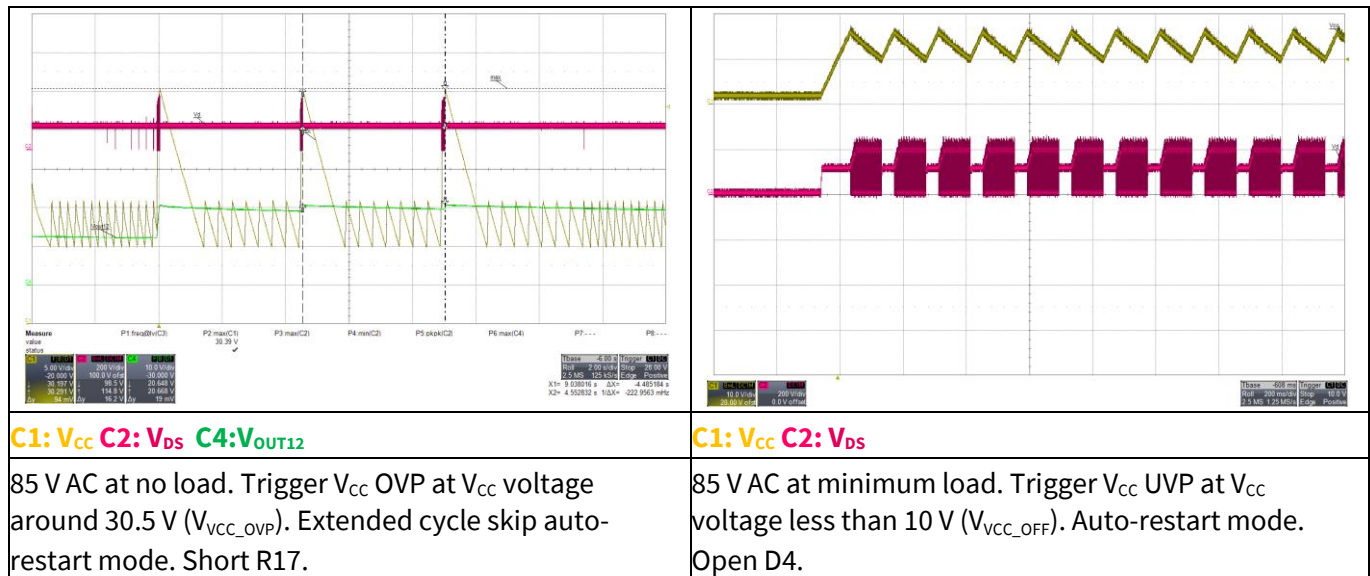


Figure 30 V_{CC} OV/UV protection

11.12 Overload protection

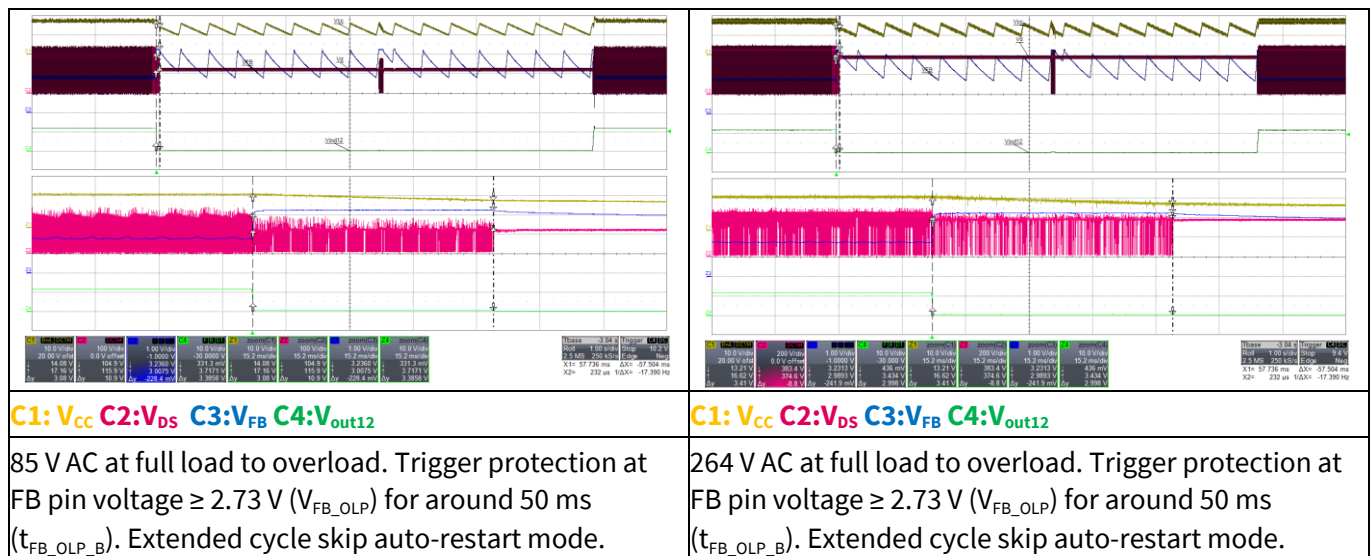


Figure 31 Overload protection

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

Appendix A: WE transformer specification

12 Appendix A: WE transformer specification

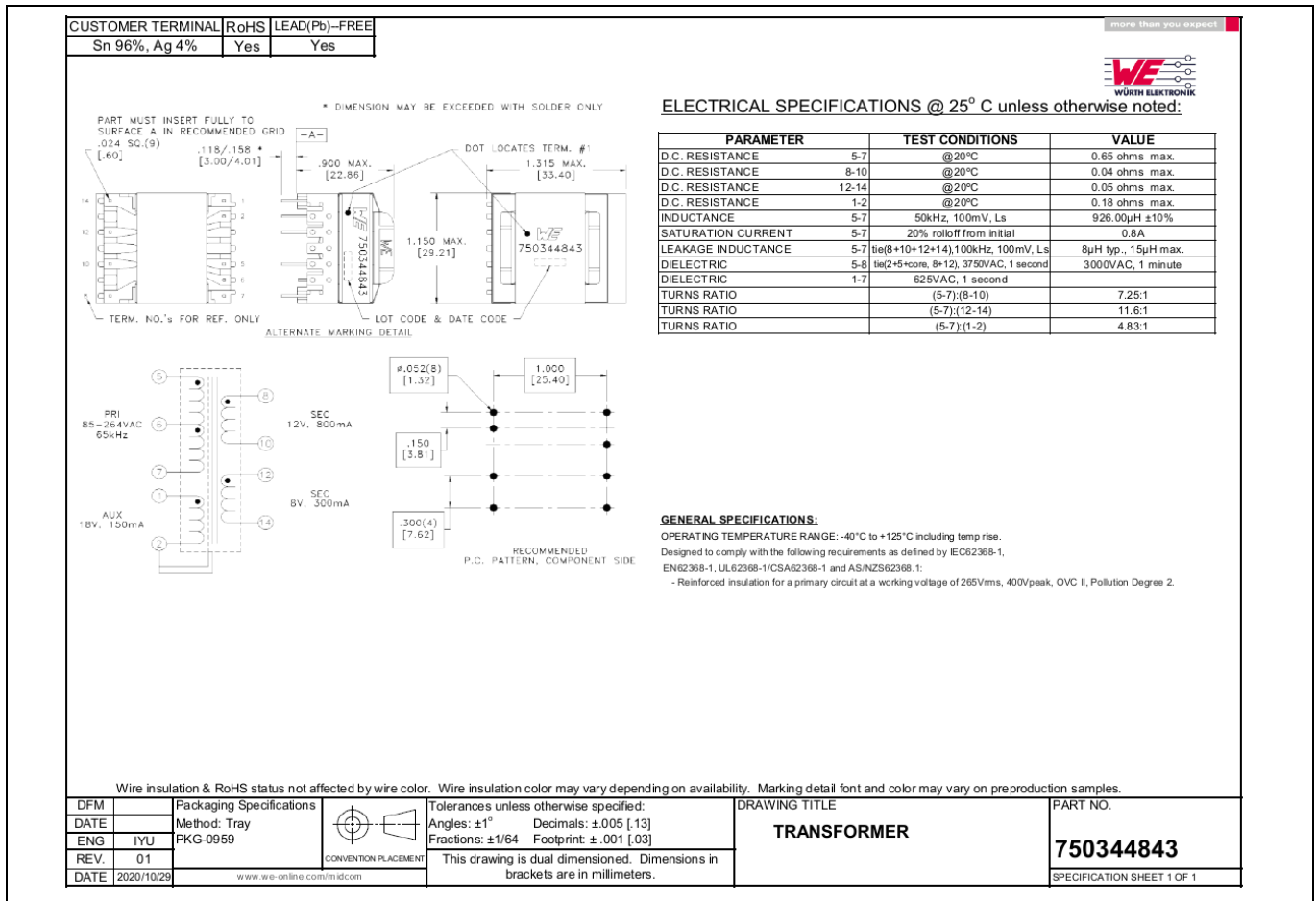


Figure 32 WE transformer specification

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1



REF_5BR4780BZ-1_15W1

References

References

- [1] Infineon Technologies AG: *ICE5xRxxxxBZx-1 datasheet*; [Available online](#)
- [2] Infineon Technologies AG: *CoolSET™ 5th Generation Fixed Frequency Plus flyback design guide*; [Available online](#)
- [3] Infineon Technologies AG: *CoolSET™ 5th Generation Fixed Frequency Plus calculation tool for flyback*; [Available online](#)

15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1

REF_5BR4780BZ-1_15W1

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15 W non-isolated auxiliary power supply for outdoor air conditioner using CoolSET™ ICE5BR4780BZ-1



REF_5BR4780BZ-1_15W1

Revision history

Revision history

Document revision	Date	Description of changes
V 1.0	2024-08-23	Initial release

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