# AC-DC universal input 45 W power supply using CoolSET™ SiP ICE184ZCM

## REF_45W1_ZVS_184ZCM

## About this document

### Scope and purpose

This application note describes a switched mode power supply (SMPS) using Infineon's latest CoolSET™ System in Package (SiP) ICE184ZCM. The power supply is designed to work with universal line alternating current (AC) input and has an isolated 12 V, 3.75 A output plus an additional non-isolated 15 V, 150 mA output.

### Intended audience

This document is intended for power supply design, application engineers, or others who want to design efficient and reliable auxiliary power supplies.

### Keypoints

- Overall high efficiency to meet energy efficiency requirements
- Zero-voltage switching (ZVS) technology to boost efficiency performance and lower the electro-magnetic interference (EMI)
- AC Zero-crossing detection signal sent to secondary side to synchronize and optimize system operation
- X-cap discharge function
- Ultra-low standby-power consumption (< 45 mW)
- Simplified circuitry with high-level integration of power control and protection features
- Auto-restart protection scheme to minimize interruption and enhance the end user experience

## About this product family

### Product family

Infineon's CoolSET™ AC-DC integrated power stages in fixed frequency and quasi-resonant switching schemes offer increased robustness and outstanding performance. This family offers superior energy efficiency, comprehensive protective features, and reduced system costs. The CoolSET™ controllers are ideally suited for auxiliary power supply applications.

### Target applications

- SMPS
- Home appliances
- Server power supply units
- Telecom AC-DC power conversion

# Table of contents

# 1      Introduction

This document describes a 12 V/3.75 A switched-mode power supply (SMPS) using Infineon's latest CoolSET™ SiP ICE184ZCM. The reference design demonstrates high power efficiency, low power consumption, and cost-effectiveness, made possible by the high-level integration capabilities of CoolSET™ SiP.

Table 1 lists the general system requirements for a power supply and the Infineon solution using ICE184ZCM.

**Table 1      General system requirements and reference design solution**

| S.No. | General system requirement | Reference design solution – ICE184ZCM |
|---|---|---|
| 1 | High efficiency to meet energy efficiency requirements | Primary zero voltage switching and secondary optimal synchronous rectifier (SR) control |
| 2 | Low standby power consumption to comply to latest energy conservation standards | Optimized low supply currents for hysteretic mode operation to reach lowest stand-by power < 30 mW |
| 3 | Simplified circuitry with high-level integration | Integrated primary 800 V MOSFET, primary and secondary controller, and communication in a DSO-27 package |
| 4 | Minimize interruption to enhance end user experience | All protections are defined to enter auto-restart mode |

# 2 Reference board

This document provides complete design details including power supply specifications, schematics, bill of materials, PCB layout, transformer specification, and performance data.



Top side of the board



Bottom side of the board
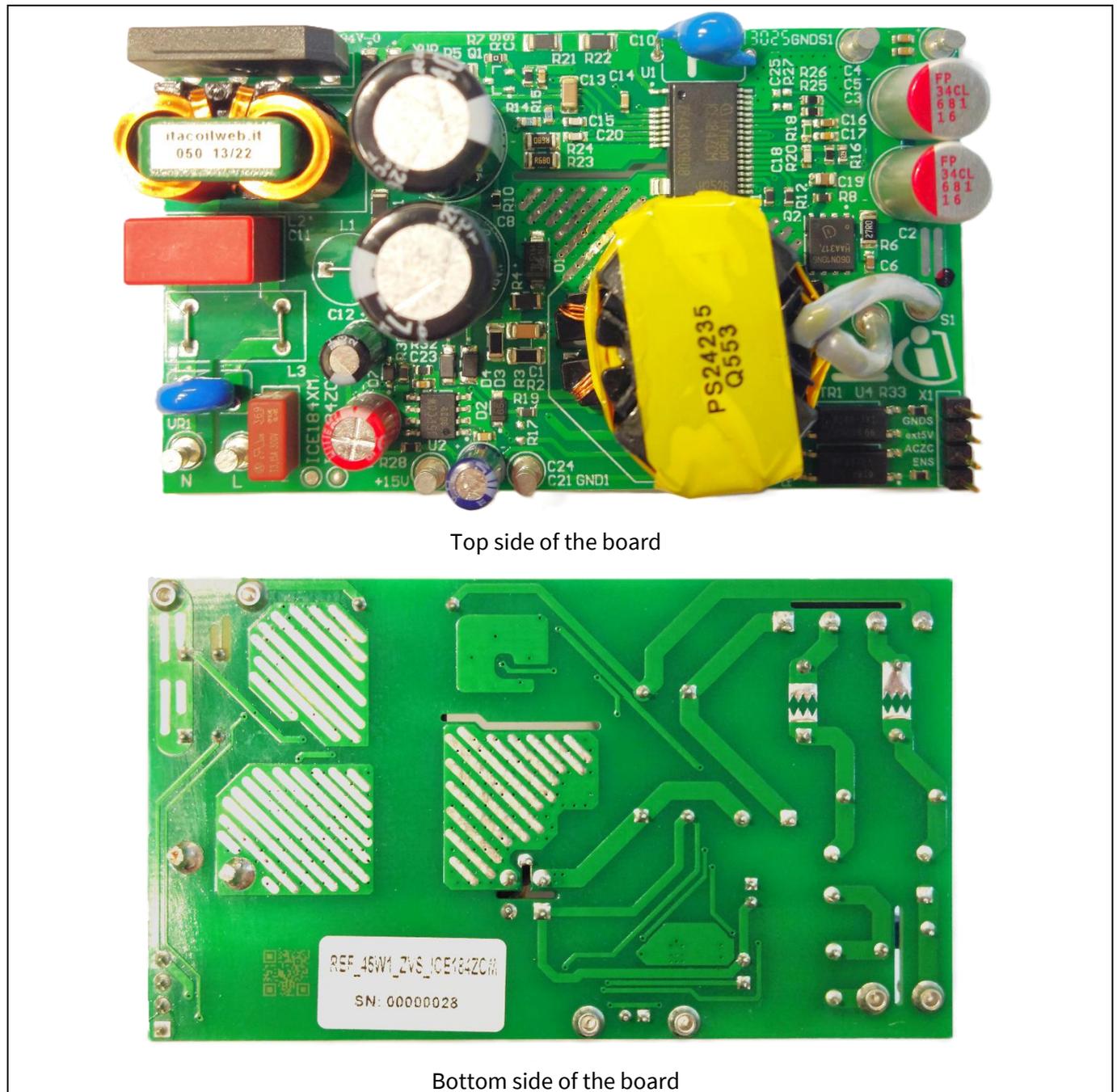
**Figure 1** **Reference board REF_45W1_ZVS_184ZCM**

# 3 Power supply specifications

The following table represents the minimum acceptance performance of the design. The actual performance is listed in the Measurement data and graphs section.

**Table 2** Specifications of REF_1_ZVS_184ZCM

| Description | Symbol | Min. | Typ. | Max. | Units | Comments |
|---|---|---|---|---|---|---|
| **Input** | | | | | | |
| Voltage | $V_{IN}$ | 90 | – | 264 | V AC | Live (L) and Neutral (N)/(no PE) |
| Frequency | $f_{LINE}$ | 47 | 50 | 64 | Hz | – |
| Line overvoltage | $V_{IN\_OVP}$ | – | 268 | – | V AC | – |
| **Output(12 V)** | | | | | | |
| Output voltage | $V_{OUT1}$ | – | 12 | – | V | ±1 percent (isolated) |
| Output current | $I_{OUT1}$ | – | 3.75 | – | A | – |
| Output voltage ripple | $V_{RIPPLE1}$ | – | – | 240 | mV | Peak to peak |
| Overcurrent protection | $I_{OCP}$ | – | – | 4.5 | A | Measured at 230 V AC |
| Total output power | $P_{OUT}$ | – | 45 | – | W | – |
| **Output(15 V)** | | | | | | |
| Output voltage | $V_{OUT2}$ | – | 15 | – | V | Non-isolated |
| Output current | $I_{OUT2}$ | – | 0.15 | – | A | – |
| Output power | $P_{OUT}$ | – | 2.25 | – | W | – |
| **Efficiency** | | | | | | |
| Maximum load efficiency | $\eta$ | – | 92.8 | – | % | Measured at 230 V AC, 45 W w/o LDO |
| **Environmental** | | | | | | |
| Conducted EMI | – | | 5 | | dB | Margin, CISPR 14 |
| **ESD** | | | | | | EN 61000-4-2 |
| Contact discharge | – | | ±8 | | kV | – |
| Air discharge | – | | ±15 | | kV | – |
| **Surge immunity** | | | | | | EN 61000-4-5 |
| Differential mode | – | | ±2 | | kV | – |
| Common mode | – | | ±4 | | kV | – |
| PCB size | – | | 87 × 50 | | mm$^2$ | L × W |
| Ambient temperature | Ta | – | – | 50 | °C | Convection cooling |

# 4 Circuit diagram
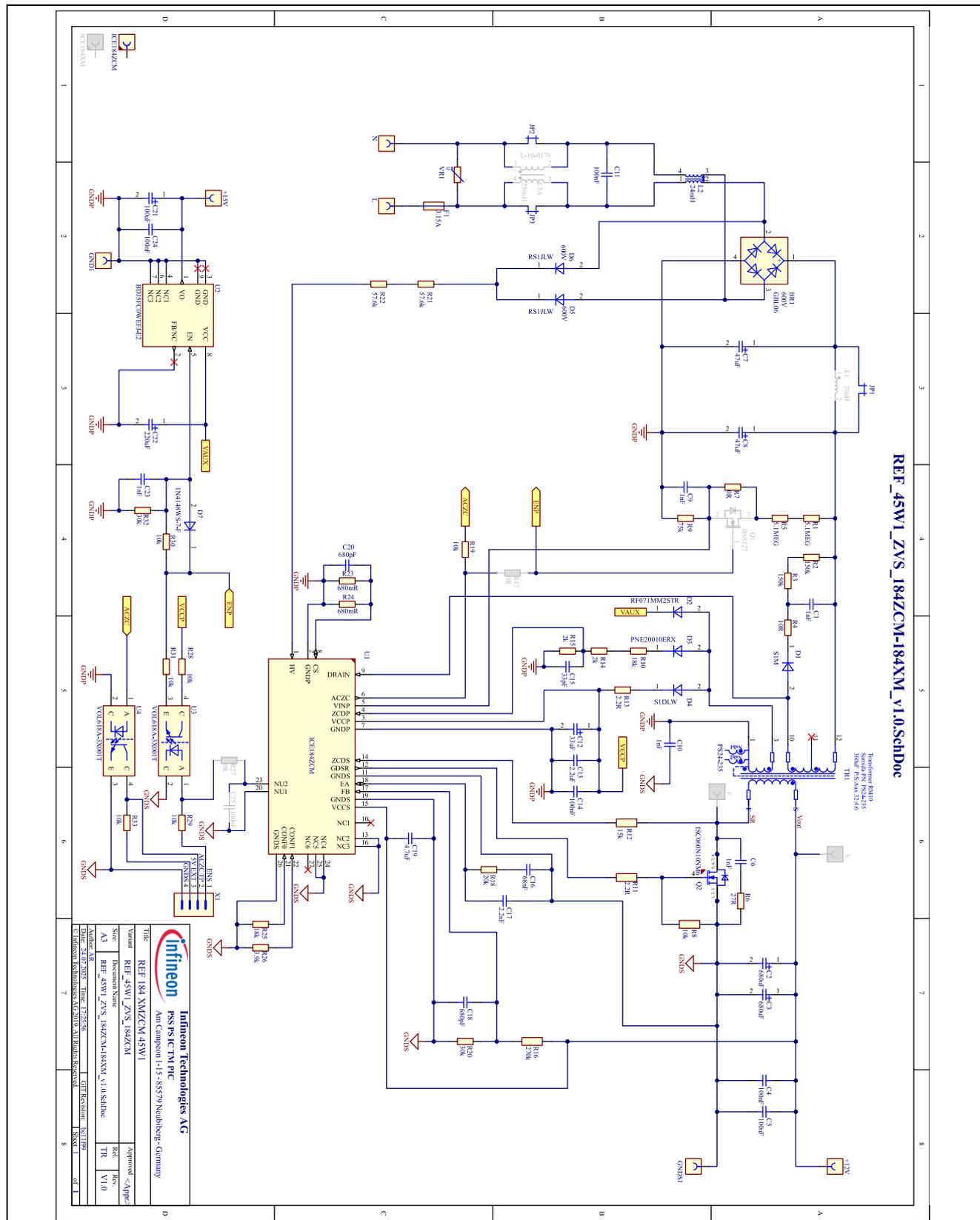


Figure 2    Schematic of REF_45W1_ZVS_184ZCM

# 5 Circuit description

This section briefly describes the reference design circuit by different functional blocks. For more information on the design procedure and component selection for the flyback circuitry, see the IC datasheet [1] and design guide [2].

## 5.1 EMI filtering and line rectification

- The input of the power supply is fed from AC power grid, which is the typical universal range 90 V AC ~ 264 V AC
- The slow blow F1 fuse is placed on the L terminal of the AC input to protect the system in case of excess current entering the system circuit due to a fault
- Following protection component is the varistor VR1, which is connected across L and N to protect the system in case of a line surge transient event
- The basic common noise filtering is made up from the common mode (CM) choke L2, and the X-capacitor C11
- There are some optional means to reduce the conducted EMI noise levels, by fitting L1 inductor (PI-filter with C7 and C8) and L3 high-frequency common-mode choke (HF CMC). These two components are not fitted and JP1, JP2, and JP3 wire jumpers are fitted on the current reference board to keep the cost and bill of materials (BOM) as low as possible
- The bridge rectifier BR1 rectifies the AC input into DC voltage, filtered by the bulk capacitors C7 and C8

## 5.2 CoolSET™ SiP power stage

The flyback converter power stage consists of:

- Power transformer
- Primary power MOSFET
- Secondary synchronous rectifier (SR) MOSFET
- Secondary output capacitors
- Filtering components

The primary-side and secondary side power management are separated for isolated power supply domains (VCCP, GNDP) and (VCCS, GNDS). CoolSET™ SiP ICE184ZCM controller IC provides reinforced and safe isolated communication between the primary and secondary sides.

### 5.2.1 CoolSET™ SiP primary side

CoolSET™ SiP ICE184ZCM integrates a 950 V startup cell and an 800 V CoolMOS™ MOSFET in the primary side. The IC is directly connected to the AC input voltage through the resistors R21 and R22 that are placed in series on the HV pin. This way, the VCCP pin capacitors C12, C13, and C14 will be charged when the reference board input is supplied with AC input voltage. The primary winding start pin of the transformer, TR1 pin 10 is connected to the drain of the CoolMOS™ MOSFET inside ICE184ZCM (U1 pin 9). When the integrated CoolMOS™ turns on, energy is stored in the transformer. When it turns off, the stored energy is released to the output capacitors C2, C3 and output loading through the output SR OptiMOS™ 6 power MOSFET Q2.

The resistors R1, R5, and R9 provide the divided voltage that is fed to controller pin VINP for the input overvoltage protection (OVP). The shunt resistors R23 and R24 serve as ICE184ZCM primary current sensing, to limit the peak current cycle by cycle.

**Circuit description**

A low-cost snubber consisting of the D1 diode, the R2, R3, R4 resistors, and the C1 capacitor is implemented to suppress the drain voltage spike that appears when the integrated CoolMOS™ power switch is turned off. This passive clamp helps to dissipate the energy stored in the transformer leakage inductance and reduces the drain-to-source voltage stress of the integrated power MOSFET.

## 5.2.2 CoolSET™ SiP secondary side

The start-up sequence is the following: the integrated high voltage startup cell is energizing the VCC supply capacitors and when the VCC voltage reaches the desired level, the IC starts switching the primary MOSFET to bring up the output voltage. When the output voltage reaches 95% of its regulation target, the secondary side of CoolSET™ SiP ICE184ZCM starts to take over the PWM control. The ICE184ZCM PWM control is based on sensing the reflected voltage from the primary side to the secondary side via the ZCDS pin, and on the error amplifier output EA voltage. ICE184ZCM integrated PWM and SR control ensures that the timing of the SR power switch (Q2) and the primary side power switch are well-synchronized, which avoids the cross conduction of the two switches and provides reliable and efficient synchronous rectification.

In addition, the current injection function via the SR power switch Q2 enables zero voltage switching operation on the primary-side

- Two external resistors, R25 and R26 are used to configure the IC with the transformer turns ratio and the desired preset of operation parameters
- The passive components C16, C17, and R18 are for the compensation network, used to stabilize the output voltage regulation
- The output filtering capacitors C2 and C3 are dimensioned to keep the output voltage ripple in the specified limits, working together with the ceramic capacitors C4 and C5 that are used to reduce the high frequency output voltage ripple

# 6 PCB layout

The REF_45W1_ZVS_184ZCM consists of a standard 2-layer 75 µm copper thickness PCB with only top-side components placement. The PCB layers are shown in the following figures.



**Figure 3      PCB top-side**



**Figure 4      PCB bottom-side**

**PCB layout**

A good PCB layout is crucial for a successful design. Following are some recommendations:

1. Minimize the loop with pulse shape current or voltage, such as the loop formed by the bus voltage source, primary winding, main power switch, and current sense resistor or the loop consisting of the secondary winding, SR switch, and output capacitor, or the loop of the $V_{CC}$ power supply

2. **Star connection of the primary side ground (GNDP) at the bulk capacitor**: All primary grounds should be connected to the ground of the bulk capacitors (C7 and C8) separately at one point. This can reduce the switching noise entering the sensitive pins of the CoolSET™ SiP device. The primary star ground can be split into four groups:
   – Combined signal (all small signal grounds connecting to the controller GNDP pin such as the filter capacitor C9, C15, and C20) and power ground (CS resistors R23 and R24)
   – $V_{CCP}$ ground includes the $V_{CCP}$ capacitors ground and the auxiliary winding ground, pin 1 of the power transformer
   – EMI return ground includes the Y capacitor for isolated flyback application
   – DC ground from the bridge rectifier BR1

3. CoolSET™ SiP primary side GNDP pin 2 and pin 7 are recommended to be jointly connected to a PCB copper plane, and then star connected to the bulk capacitor ground

4. CoolSET™ SiP secondary side GNDS pin 11, pin 19, and pin 26 are recommended to be jointly connected to a PCB copper plane, and then star connected to the SR MOSFET source pin

5. **Place the filter capacitors close to the controller ground (GNDP and GNDS)**: Filter capacitors should be placed as close to the controller ground and controller pin as possible to reduce the switching noise coupled into the controller

6. **High voltage (HV) trace clearance**: HV traces like startup, bulk capacitors + and primary switch drain traces should maintain sufficient spacing to the nearby traces — arcing may occur otherwise

7. Keep a minimum of 230 mm$^2$ copper area at both the primary drain pin and secondary GNDS for better thermal performance of the CoolSET™ SiP

8. SR drain copper plane surface area should be considered for a reasonable convection cooling capability

# 7 Bill of materials

**Table 3** **BOM**

| S.No. | Quantity | Designator | Description | Manufacturer | Part number |
|---|---|---|---|---|---|
| 1 | 6 | +12 V, +15 V, GND1, GNDS1, J1, J2 | Con 1502-2/CON-THT-TP-1502-2 | Keystone Electronics Corp. | 1502-2 |
| 2 | 1 | BR1 | Dio 600V/THT | Taiwan Semiconductor | GBL06 |
| 3 | 1 | C1 | Cap 1nF/1kV/ 1206/ X7R/10% | KEMET | C1206C102KDRACTU |
| 4 | 2 | C2, C3 | Cap 680uF/16V/ THT/Radial/ /20% | Nichicon | RNL1C681MDS1PX |
| 5 | 4 | C4, C5, C14, C24 | Cap 100nF/50V/ 0603/ X7R/10% | Würth Elektronik | 885012206095 |
| 6 | 1 | C6 | Cap 1nF/100V/ 0603/ X7R/10% | TDK Corporation | CGA3E2X7R2A102K080AA |
| 7 | 2 | C7, C8 | Cap 47uF/400V/ THT/Radial/ /20% | Rubycon | 400LXW47MEFR12.5X25 |
| 8 | 2 | C9, C23 | Cap 1nF/25V/ 0603/ X7R/10% | Würth Elektronik | 885012206059 |
| 9 | 1 | C10 | Cap 1nF/THT/Radial/ Y5V/20% | KEMET | C721U102MSVDBA7317 |
| 10 | 1 | C11 | Cap 100nF/630V/ THT/Radial/ /10% | Würth Elektronik | 890324023023CS |
| 11 | 1 | C12 | Cap 33uF/50V/THT/Radial/20% | KEMET | ESH336M050AC3AA |
| 12 | 1 | C13 | Cap 2.2uF/50V/1206/ X7R/10% | Murata | GCM31CR71H225KA55 |
| 13 | 1 | C15 | Cap 33pF/50V/0603/C0G/5% | Murata | GRM1885C1H330JA01 |
| 14 | 1 | C16 | Cap 68nF/ 25V/0603/X7R/10% | Murata | GCM188R71E683KA57 |
| 15 | 1 | C17 | Cap 2.2nF/ 25V/ 0603/ X7R/10% | Würth Elektronik | 885012206061 |
| 16 | 2 | C18, C20 | Cap 680pF/ 50V/ 0603/ X7R/5% | Murata | GRM188R71H681JA01 |
| 17 | 1 | C19 | Cap 4.7uF/ 25V/ 0805/ X7R/10% | Taiyo Yuden | TMK212AB7475KG-T |
| 18 | 1 | C21 | Cap 100uF/ 25V/ THT/Radial/ /20% | KEMET | ESK107M025AC3AA |
| 19 | 1 | C22 | Cap 220uF/ 25V/ THT/Radial/ /20% | Würth Elektronik | 860010473011 |

## Bill of materials

| S.No. | Quantity | Designator | Description | Manufacturer | Part number |
|-------|----------|------------|-------------|--------------|-------------|
| 20 | 1 | D1 | Dio 700 V/SMA (DO-214AC) | Taiwan Semiconductor | S1M |
| 21 | 1 | D2 | Dio 200 V/SOD-123 | ROHM Semiconductors | RF071MM2STR |
| 22 | 1 | D3 | Dio 200 V/CFP3 (SOD-123W) | Nexperia | PNE20010ERX |
| 23 | 1 | D4 | Dio 200 V/SOD-123W | Taiwan Semiconductor | S1DLW |
| 24 | 2 | D5, D6 | Dio 600 V/SOD-123W (CFP3) | Taiwan Semiconductor | RS1JLW |
| 25 | 1 | D7 | Dio 75 V/SOD-323 | Diodes Incorporated | 1N4148WS-7-F |
| 26 | 1 | F1 | Res 3.15 A/ 300 V/ THT/Radial | Littelfuse | 36913150000 |
| 27 | 3 | JP1, JP2, JP3 | JUMP-WIRE <= Ø0.9 mm | | |
| 28 | 1 | L2 | Ind 24 mH/THT | ITACOIL | SCF1515050 |
| 29 | 1 | Q2 | Tra ISC060N10NM6/ / PG-TDSON-8-36 | Infineon Technologies | ISC060N10NM6 |
| 30 | 2 | R1, R5 | Res 5.1MEG/ 200 V/ 1206/1% | Vishay | CRCW12065M10FK |
| 31 | 2 | R2, R3 | Res 150k/ 200 V/ 1206/1% | Vishay | CRCW1206150KFK |
| 32 | 1 | R4 | Res 10R/ 200 V/ 1206/ 1% | Vishay | RCS120610R0FKEA |
| 33 | 1 | R6 | Res 27R/ 200 V/ 1206/ 1% | Vishay | CRCW120627R0FK |
| 34 | 1 | R7 | Res 0R/ 75 V/ 0603/ 0R | YAGEO | RC0603JR-070RL |
| 35 | 7 | R8, R19, R28, R29, R30, R31, R33 | Res 10k/ 75 V/ 0603/ 1% | Vishay | CRCW060310K0FKEA |
| 36 | 1 | R9 | Res 75k/ 75 V/ 0603/ 1% | Vishay | CRCW060375K0FK |
| 37 | 2 | R10, R25 | Res 18k/ 75 V/ 0603/ 1% | Vishay | CRCW060318K0FK |
| 38 | 2 | R11, R13 | Res 2.2R/ 75 V/ 0603/ 1% | Vishay | CRCW06032R20FK |
| 39 | 1 | R12 | Res 15k/ 75 V/ 0603/ 1% | Vishay | CRCW060315K0FK |
| 40 | 2 | R14, R15 | Res 2k/ 75 V/ 0603/ 1% | KOA Speer Electronics Inc. | RK73H1JTTD2001F |
| 41 | 1 | R16 | Res 270k/ 75 V/ 0603/ 1% | Vishay | CRCW0603270KFK |
| 42 | 1 | R18 | Res 20k/ 75 V/ 0603/ 0.1% | Vishay | TNPW060320K0BY |
| 43 | 2 | R20, R32 | Res 30k/ 75 V/ 0603/ 1% | Vishay | CRCW060330K0FK |
| 44 | 2 | R21, R22 | Res 57.6k/ 200 V/ 1206/ 1% | Vishay | CRCW120657K6FK |
| 45 | 2 | R23, R24 | Res 680 mR/ 1206/ 1% | Bourns | CRM1206-FX-R680ELF |
| 46 | 1 | R26 | Res 3.9k/ 75V/ 0603/ 1% | Vishay | CRCW06033K90FK |
| 47 | 0 | TPZCM | Con testpad_1.50 mm/ SMD | – | testpad_1.50mm |
| 48 | 1 | TR1 | Tra PS24-235/ THT | Sumida | PS24-235 |

**REF_45W1_ZVS_184ZCM**

## Bill of materials

| S.No. | Quantity | Designator | Description | Manufacturer | Part number |
|-------|----------|------------|-------------|--------------|-------------|
| 49 | 1 | U1 | IC controller/IFX-PG-DSO-27N-V1 | Infineon Technologies | ICE184ZCM-V001 |
| 50 | 1 | U2 | Pow BDJ5FC0WEFJ-E2/ HTSOP-J8 | ROHM Semiconductors | BDJ5FC0WEFJ-E2 |
| 51 | 2 | U3, U4 | Opt VOL618A-3X001T/ LSOP-4 | Vishay | VOL618A-3X001T |
| 52 | 1 | VR1 | Res/ 320 V/ Radial type/ 10% | Epcos | B72207S2321K101 |
| 53 | 1 | X1 | Con TSW-104-07-L-S/ THT | Samtec | TSW-104-07-L-S |

# 8 Transformer specification

## 8.1 Electrical diagram and winding structure

The transformer used for this 45 W CoolSET™ SiP reference design is manufactured by Sumida and the part number is PS24-235. It is based on RM10 ferrite core, and the windings are fitted on a through-hole standard bobbin. The interleaved winding structure can be seen on the right side in Figure 5.
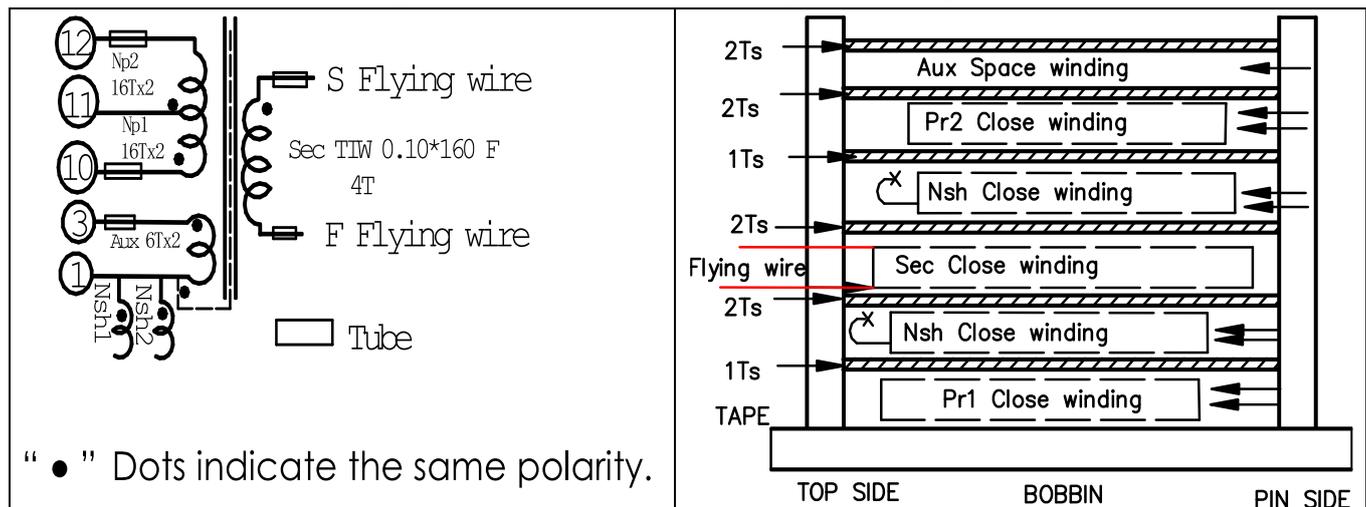


**Figure 5     Schematic and winding structure of PS24-235 transformer**

## 8.2 Electrical characteristics

2-2.Electrical characteristic (at 25℃, unless of otherwise specified)

| Items | Specification | Measuring conditions |
|---|---|---|
| Inductance        (10-12) | 360µH±10%   Within | 100kHz/0.1V |
| DCR               (10-12) | Max. 280mΩ | |
| DCR               (S Fly wire-F Fly wire) | Max. 4.5mΩ | |
| DCR                 (3-1) | Max. 130mΩ | |
| Hi top   (1,3,10,11,12)-(S Fly wire, F Fly wire) | AC 3000Vrms | 50/60Hz, 1mA, 2s |
| Hi top    (1,3)-(10,11,12) | AC 1000Vrms | 50/60Hz, 1mA, 2s |
| Turns ratio (10-12）:（S Fly wire-F Fly wire）:(1-3) | 32:4:6   ±3% | |

**Figure 6     Electrical characteristics of PS24-235 transformer**

# 9 Measurement data and graphs

All performance data is measured at room temperature Ta = 25°C, unless otherwise specifically mentioned.

## 9.1 Efficiency result

Measurements were performed at 25%, 50%, 75%, and 100% of the nominal load after 5 minutes of burn-in time.

**Table 4**      **Efficiency and four-point average efficiency**

| Input (V AC/Hz) | Load / % | $P_{IN}$ (W) | $V_{OUT}$ (V) | $I_{OUT}$ (A) | $P_{OUT}$ (W) | Efficiency (%) | Average efficiency (%) |
|---|---|---|---|---|---|---|---|
| 90 V AC/60 Hz | 100 | 49.62 | 12.03 | 3.75 | 45.20 | 91.09 | 91.54 |
| | 75 | 36.84 | 12.04 | 2.81 | 33.84 | 91.86 | |
| | 50 | 24.65 | 12.04 | 1.88 | 22.65 | 91.89 | |
| | 25 | 12.33 | 12.05 | 0.94 | 11.26 | 91.32 | |
| 115 V AC/60 Hz | 100 | 48.99 | 12.03 | 3.75 | 45.20 | 92.25 | 92.19 |
| | 75 | 36.55 | 12.03 | 2.81 | 33.84 | 92.57 | |
| | 50 | 24.49 | 12.04 | 1.88 | 2265 | 92.46 | |
| | 25 | 12.31 | 12.04 | 0.94 | 11.26 | 91.49 | |
| 230 V AC/50 Hz | 100 | 48.65 | 12.03 | 3.75 | 45.20 | 92.91 | 92.25 |
| | 75 | 36.42 | 12.04 | 2.81 | 33.84 | 92.92 | |
| | 50 | 24.51 | 12.04 | 1.88 | 22.65 | 92.41 | |
| | 25 | 12.40 | 12.05 | 0.94 | 11.26 | 90.78 | |
| 264 V AC/50 Hz | 100 | 48.65 | 12.03 | 3.75 | 45.20 | 92.90 | 92.05 |
| | 75 | 36.46 | 12.04 | 2.81 | 33.84 | 92.80 | |
| | 50 | 24.59 | 12.04 | 1.88 | 22.65 | 92.09 | |
| | 25 | 12.45 | 12.05 | 0.94 | 11.26 | 90.44 | |

**Measurement data and graphs**
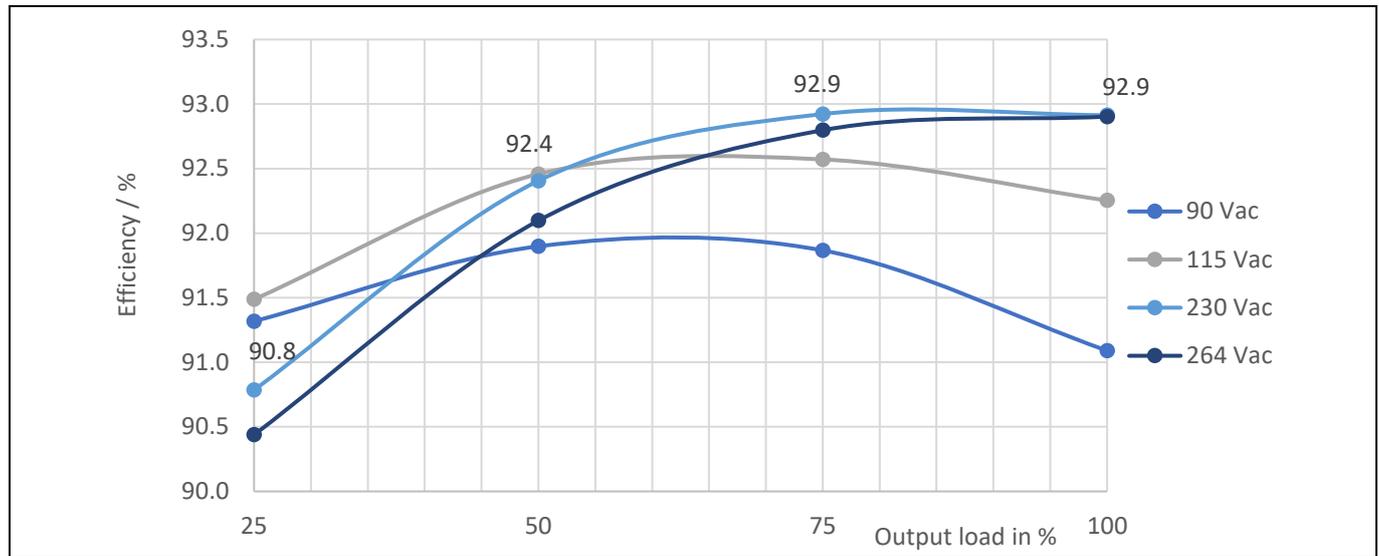


**Figure 7**       **Efficiency vs. load and AC line rms voltage**

## 9.2       Standby input power consumption

The standby power consumption is as low as 17 mW at low line input operating voltage 115 V AC, and increases to 36 mW at high line 230 V AC. Multiple measurements were performed, including the max. and min. of the input operating voltage, as shown below in Figure 8.
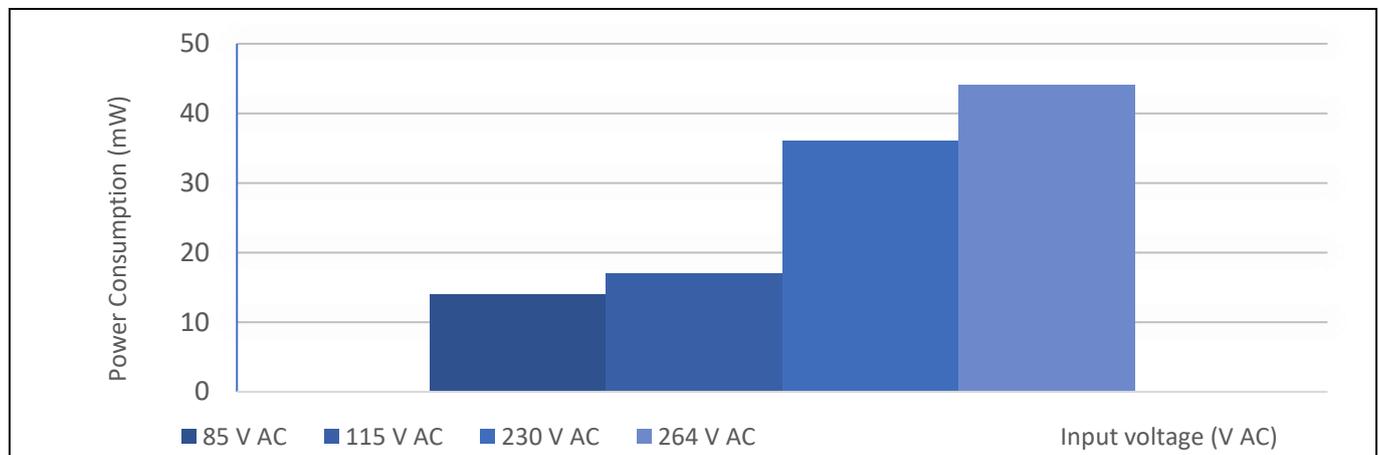


**Figure 8**       **Standby power consumption**

## 9.3       ESD immunity (EN 61000-4-2)

The reference board has successfully passed the system ESD test, according to EN 61000-4-2 level 3 (±8 kV contact and ±15 kV air discharge), as described in Table 5. The test was conducted with the system supplied with 230 V AC and a resistive load of 3.2 Ω was connected at the output, to deliver full power. A test failure was defined as non-recoverable.

**Table 5        System ESD test result**

| Description | ESD test | Level | Number of strikes | | Test result |
|---|---|---|---|---|---|
| | | | $V_{O1}$ | GNDS | |
| 230 V AC, 45 W | Contact | ±8 kV | 10 | 10 | Pass |
| | Air | ±15 kV | 10 | 10 | Pass |

## 9.4        Surge immunity (EN 61000-4-5)

The reference board was subjected to a surge immunity test according to EN 61000-4-5 level 4 (±2 kV DM and ±4 kV CM), as shown in Table 6. The test was conducted with the system supplied with 230 V AC and a resistive load of 3.2 Ω was connected at the output, to deliver full power. A test failure was defined as non-recoverable.

*Note:        The input line OVP was disabled to avoid triggering the protection while testing ±4 kV CM.*

**Table 6        System lightning surge immunity test result**

| Description | Test | Level | | Number of strikes | | | | Test result |
|---|---|---|---|---|---|---|---|---|
| | | | | 0° | 90° | 180° | 270° | |
| 230 V AC, 45 W | DM | ±2 kV | L → N | 3 | 3 | 3 | 3 | Pass |
| | CM | ±4 kV | L → G | 3 | 3 | 3 | 3 | Pass |
| | | ±4 kV | N → G | 3 | 3 | 3 | 3 | Pass |

## 9.5        Conducted emissions (EN 55014)

The conducted emissions test was performed at full output power following the test standard of EN 55014 (CISPR 14). The measurement was performed in phase and neutral configuration with a rated input voltage of 115 V AC/50 Hz and 230 V AC/50 Hz. The measurement equipment used for this emissions test was Rohde & Schwarz HM6050-2 and Tektronix RSA503A. A variable wire wound power resistor adjusted to 3.2 Ω was used as a load.

The results are shown in the plots below, from Figure 9 to Figure 12.

## Measurement data and graphs
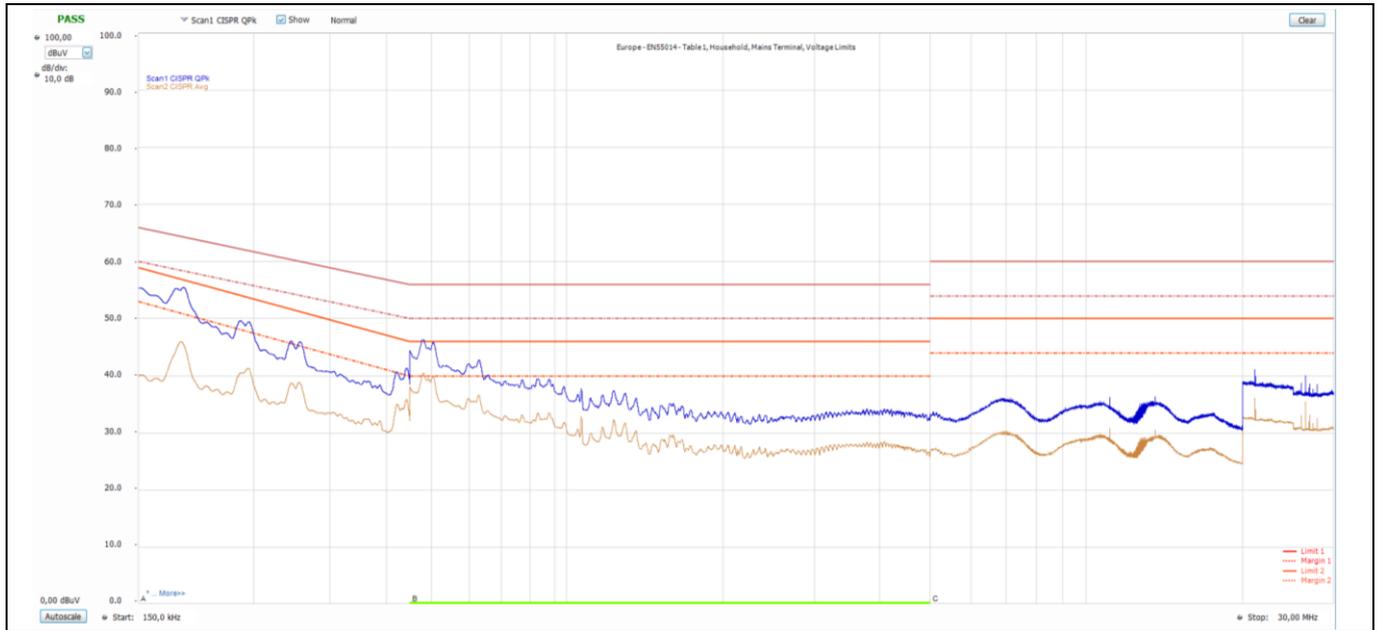


**Figure 9**　　　Conducted emissions – phase line (L) 230 V AC
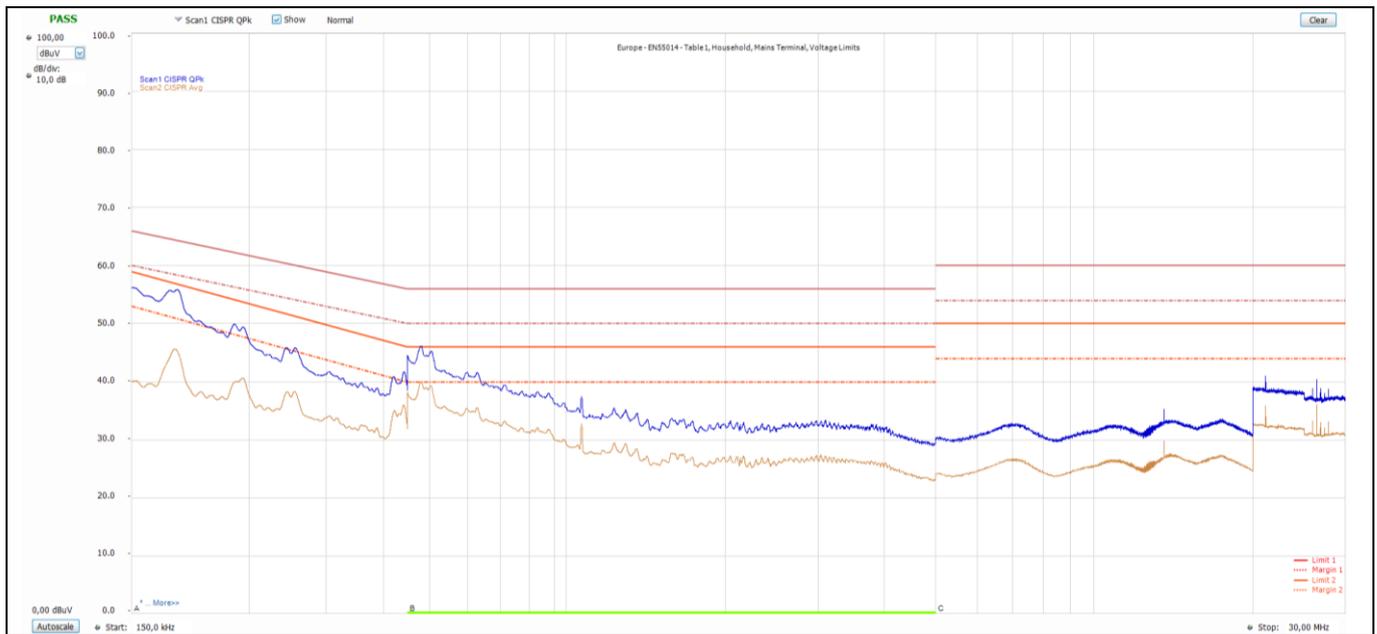


**Figure 10**　　　Conducted emissions – neutral line (N) 230 V AC

**Measurement data and graphs**
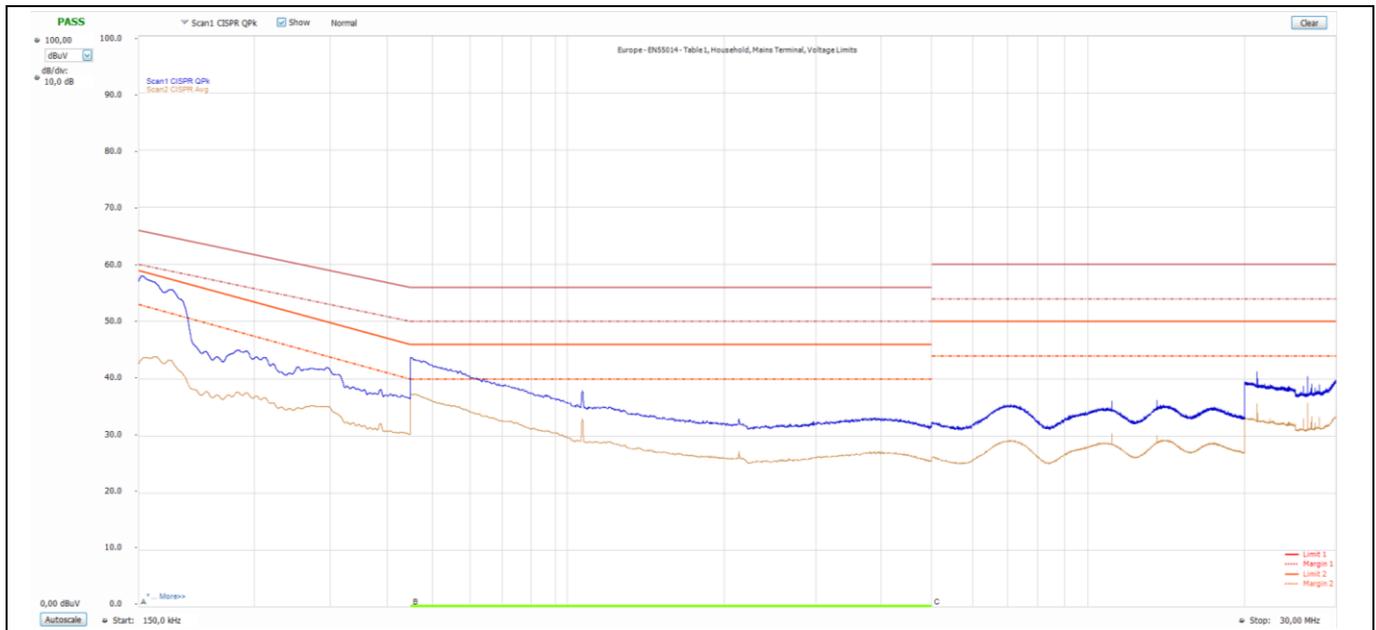


**Figure 11**     Conducted emissions – phase line (L) 115 V AC
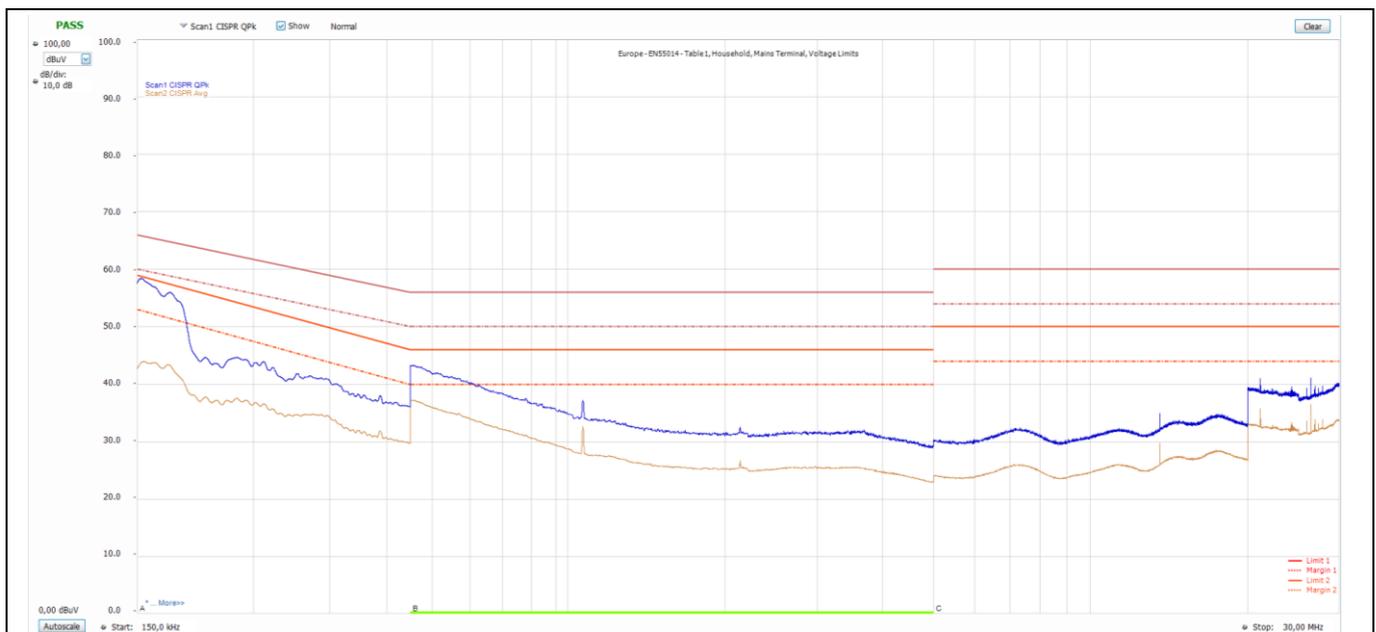


**Figure 12**     Conducted emissions – neutral line (N) 115 V AC

## 9.6     Thermal measurement

The thermal testing of the reference board was executed in open air without forced ventilation at an ambient temperature of 25°C. An infrared thermography camera (FLIR-T600) was used to capture the thermal reading of critical components. The measurements were taken in both cases of 90 V AC and 264 V AC with the maximum load of 45 W on 12 V output, plus the LDO maximum load of 2.25 W on 15 V non-insulated output and one hour warm-up time.

**Table 7    Component temperature at full load under $T_a$ = 25°C**

| IR image spot | Schematic identifier | Major component | Input voltage 90 V AC | Input voltage 264 V AC |
|---|---|---|---|---|
| | | | Temperature (°C) | Temperature (°C) |
| 1 | BR1 | Bridge rectifier | 69.6 | – |
| | R21, R22 | HV resistors | – | 81.8 |
| 2 | U1 | ICE184ZCM controller | 83.3 | 63.7 |
| 3 | Q2 | SR MOSFET | 57.6 | 59.7 |
| 4 | D1 | Primary snubber diode | 70.5 | 63.8 |
| 5 | TR1 | Transformer | 59.0 | 63.2 |
| 6 | U2 | LDO | 77.5 | 74.4 |

**Measurement data and graphs**



90 V AC maximum load and 25°C ambient

264 V AC maximum load and 25°C ambient
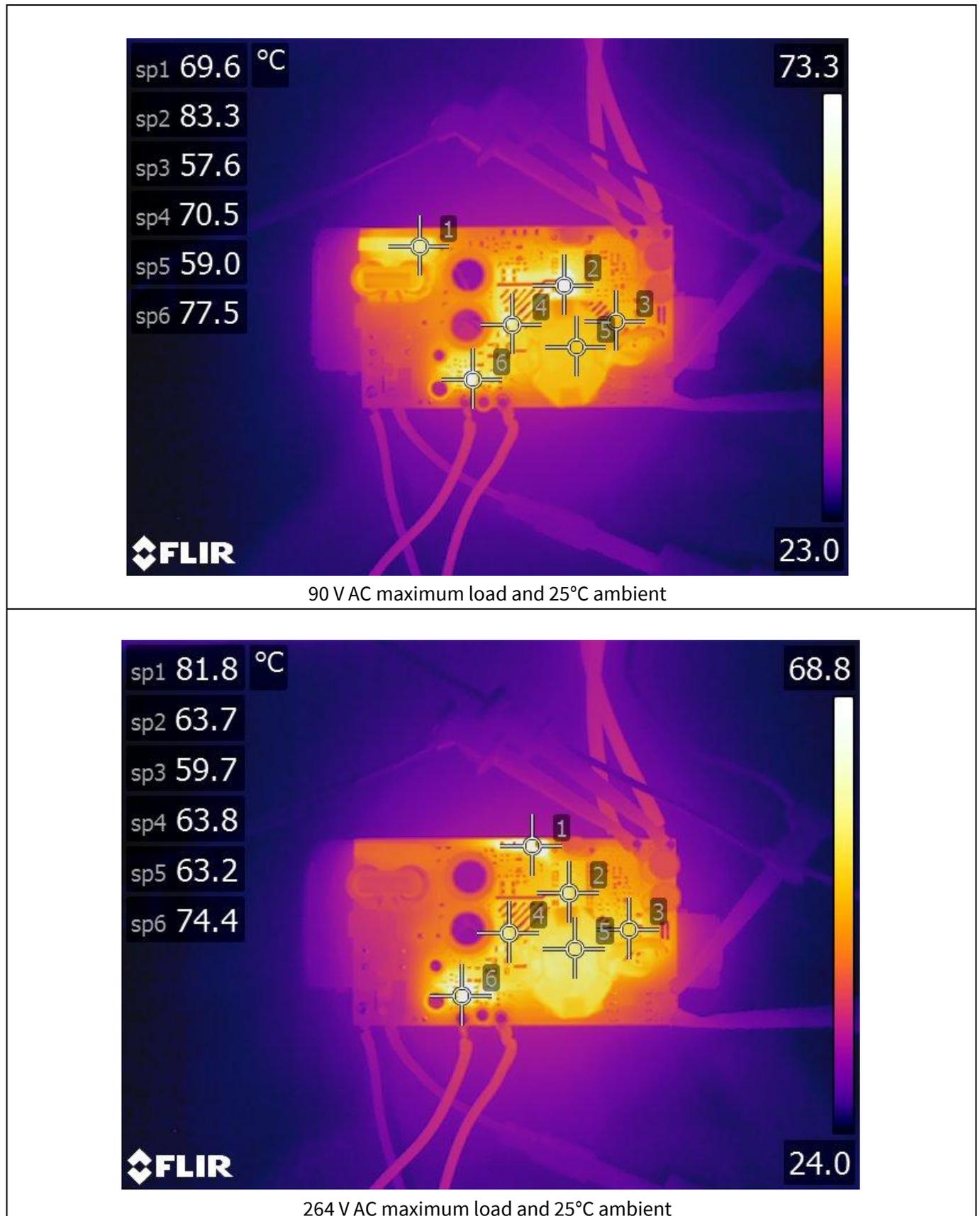
**Figure 13    Thermal image of REF_45W1_ZVS_184ZCM**

# 10 Waveforms and scope plots

The following waveforms and scope plots demonstrate the behavior of the reference board.

## 10.1 Startup at full load



| | |
|---|---|
| C1 (yellow)  : AC-line voltage<br>C2 (pink)     : +12 V output voltage<br>C3 (blue)     : +12 V output current | C1 (yellow)  : AC-line voltage<br>C2 (pink)     : +12 V output voltage<br>C3 (blue)     : +12 V output current |
| 115 V AC startup time at full load is around 1 s | 230 V AC startup time at full load is around 400 ms |
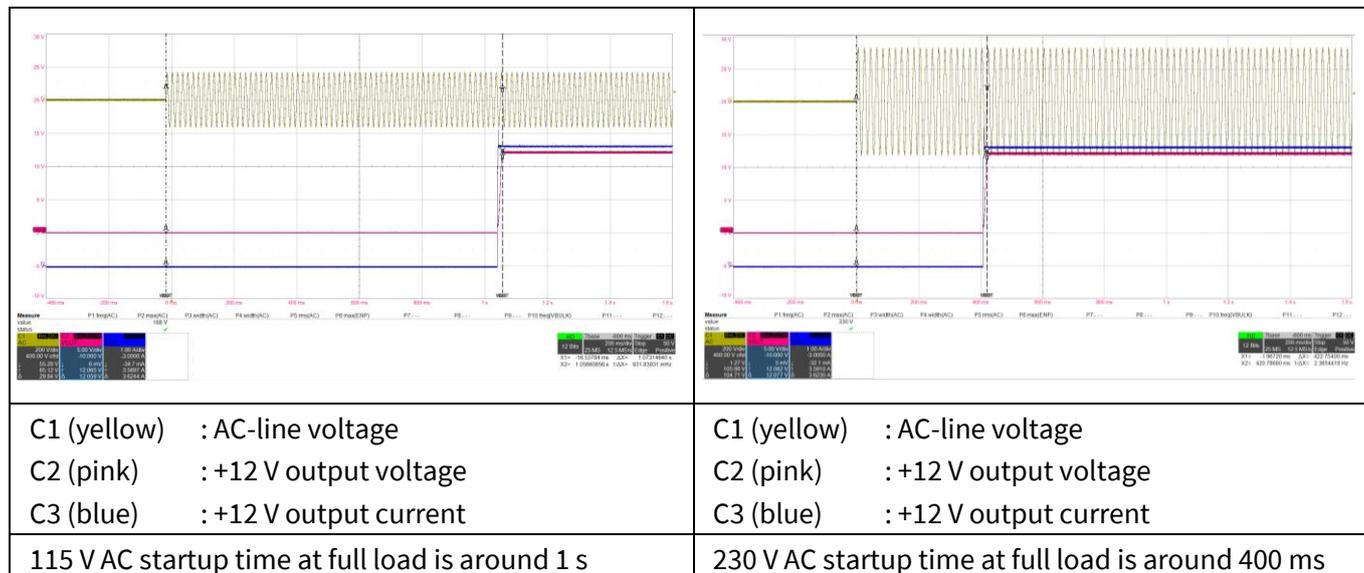
**Figure 14     Startup at full load**

## 10.2 Switching waveform at full load



| | |
|---|---|
| C1 (yellow)    : Drain voltage ($V_{DS}$)<br>C2 (pink)       : CS voltage ($V_{CS}$)<br>C3 (blue)       : SR gate voltage ($V_{GDSR}$) | C1 (yellow)    : Drain voltage ($V_{DS}$)<br>C2 (pink)       : CS voltage ($V_{CS}$)<br>C4 (blue)       : SR gate voltage ($V_{GDSR}$) |
| $V_{IN}$ = 90 V AC, full load 45 W; target valley number 1 (QR = 1 at low line) | $V_{IN}$ = 264 V AC, full load 45 W; target valley number 3 (QR = 3 at high line with ZVS switching) |
| CoolSET™ SiP ICE184ZCM operates in quasi-resonant valley switching mode at low line and achieves true ZVS at high line thanks to SR ZVS pulse for negative magnetizing current | |

**Figure 15     Switching waveform at full load**

## 10.3    SR FET voltage at full load



| C2 (pink)          : SR Drain voltage($V_{SR\_Drain}$) | C2 (pink)          : SR Drain voltage($V_{SR\_Drain}$) |
|---|---|
| $V_{IN}$ = 90 V AC, full load | $V_{IN}$ = 264 V AC, full load |
| Maximum Drain voltage is around 31 V | Maximum Drain voltage is around 63 V |
| The measured SR MOSFET voltage stress at 264 Vac input is much lower than its rating thanks to ZVS feature ||
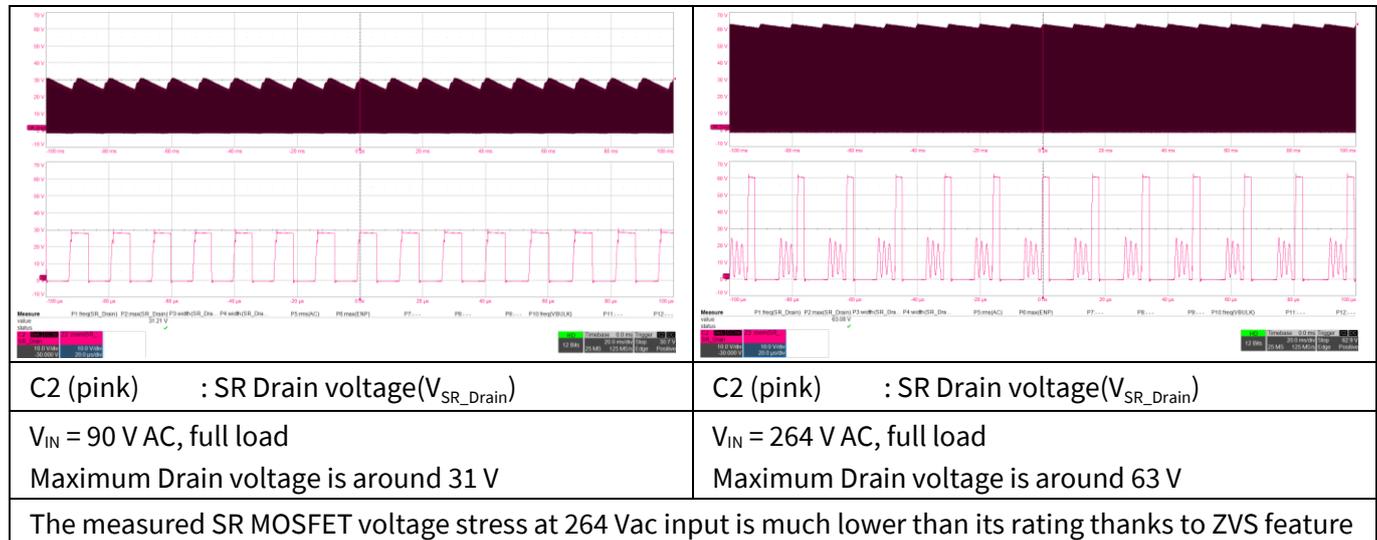
**Figure 16        SR FET voltage**

## 10.4    Output voltage ripple

The output voltage ripple was measured at 90 V AC and 264 V AC input and 45 W (full load) output, as shown in Figure 17. One 47 µF electrolytic capacitor in parallel with 0.1 µF ceramic capacitor is placed on the output for the ripple voltage reading. The oscilloscope probes were limited to 20 MHz bandwidth.



| C3 (blue)          : +12 V output ripple voltage | C3 (blue)          : +12 V output ripple voltage |
|---|---|
| $V_{IN}$ = 90 V AC, full load | $V_{IN}$ = 264 V AC, full load |
| $V_{ripple\_pk}$ for +12 V output voltage: 130 mV | $V_{ripple\_pk}$ for +12 V output voltage: 114 mV |
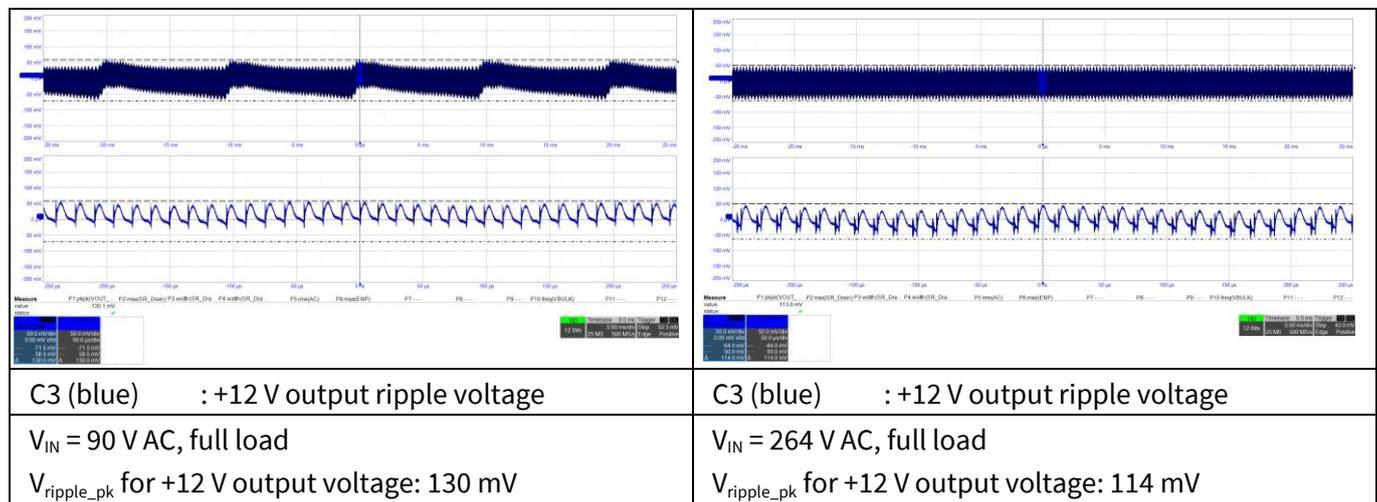
**Figure 17        Output voltage ripple at full load**

## 10.5 Load-transient response

The load-transient response of the system was tested at 90 V AC and 264 V AC input, as shown in Figure 18. The load-transient conditions are the following: +12 V output load change from 10% (0.375 A) to 100% (3.75 A) at 0.4 A/µs slew rate, 50 percent duty cycle and 100 Hz frequency. Oscilloscope probes were limited to 20 MHz bandwidth. One 47 µF electrolytic capacitor in parallel with 0.1 µF ceramic capacitor were placed on the output for the ripple voltage reading.

The yellow trace from bottom plot represents the output voltage ripple at 264 V AC input, and the blue trace overlapped under it represents the output voltage ripple at 85 V AC input. Small differences between the two results can be observed.



| C3 (blue)    : Load current | C3 (blue)    : Load current |
| C4 (green)    : +12 V output voltage ripple | C4 (green)    : +12 V output voltage ripple |
| --- | --- |
| VIN = 90 V AC<br>**Vripple_pk-pk: 514 mV**<br>Vripple_max: 233 mV<br>Vripple_min: -282 mV | VIN = 264 V AC<br>**Vripple_pk-pk: 565 mV**<br>Vripple_max: 236 mV<br>Vripple_min: -329 mV |
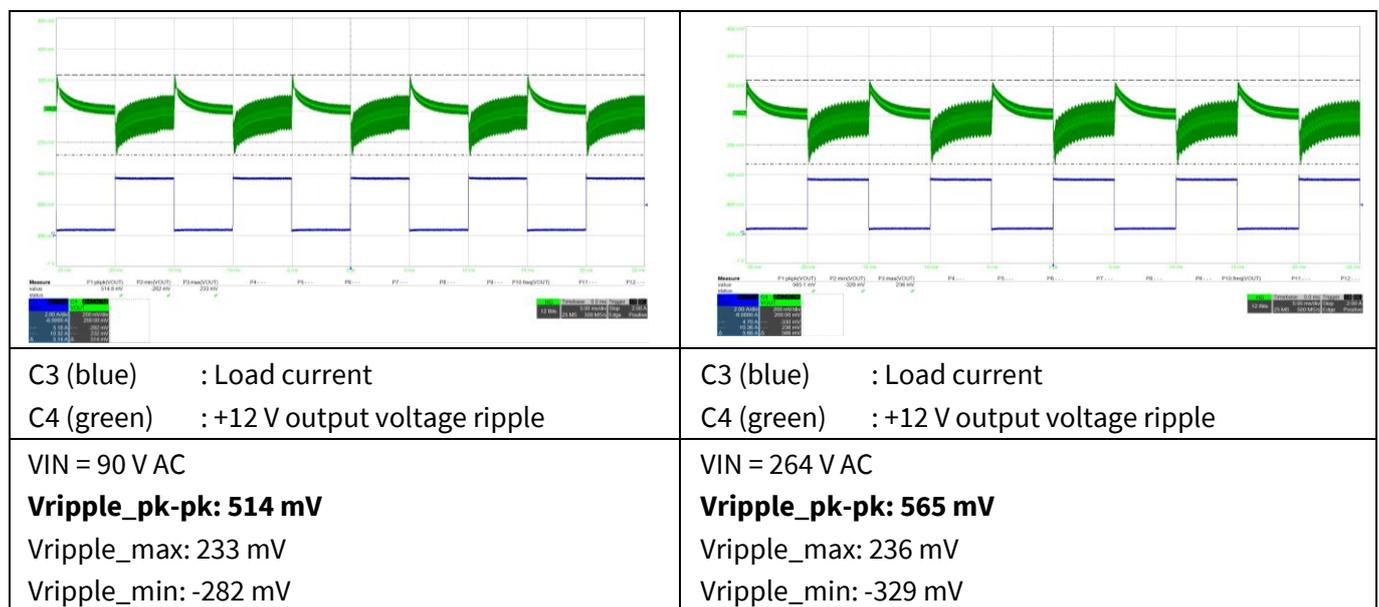
**Figure 18    Output voltage response at load-transient 10% - 100%**

## 10.6 AC zero-crossing detection

The AC zero-crossing detection signal is generated internally and the output is captured via ACZC pin, as shown in Figure 19.



| C1 (yellow)    : AC input voltage | C1 (yellow)    : AC input voltage |
| C8 (orange)    : ACZC signal | C8 (orange)    : ACZC signal |
| --- | --- |
| $V_{IN}$ = 90 V AC, full load | $V_{IN}$ = 264 V AC, full load |
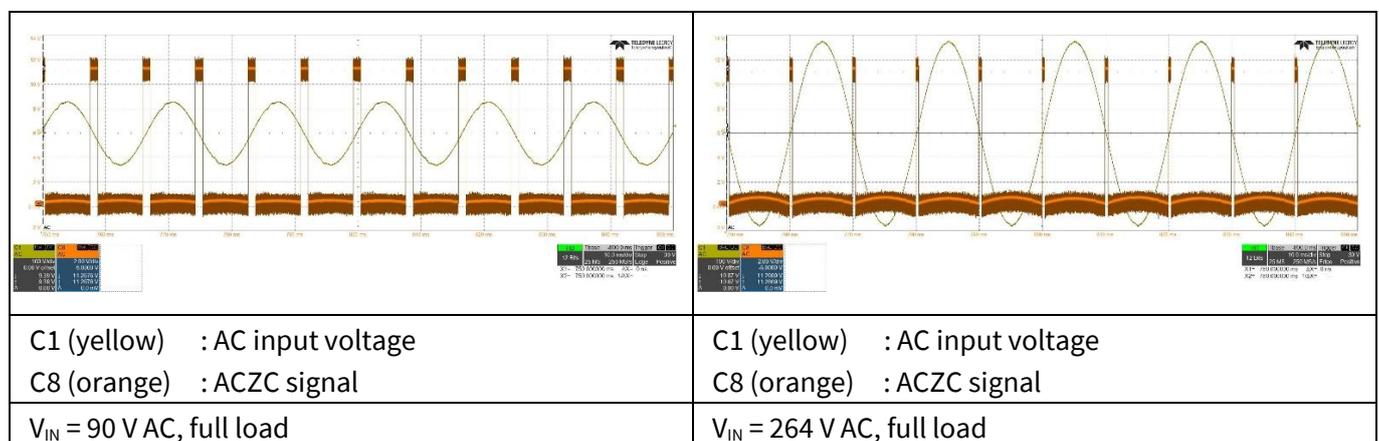
**Figure 19    ACZC - zero-crossing signal waveform**

## 10.7 X-cap discharge function

The integrated function of X-cap discharge is demonstrated by the oscilloscope captures shown in Figure 20.

| | |
|---|---|
|  |  |
| C1 (yellow)   : X-cap voltage | C1 (yellow)   : X-cap voltage |
| $V_{IN}$ = 90 V AC, full load | $V_{IN}$ = 264 V AC, full load |
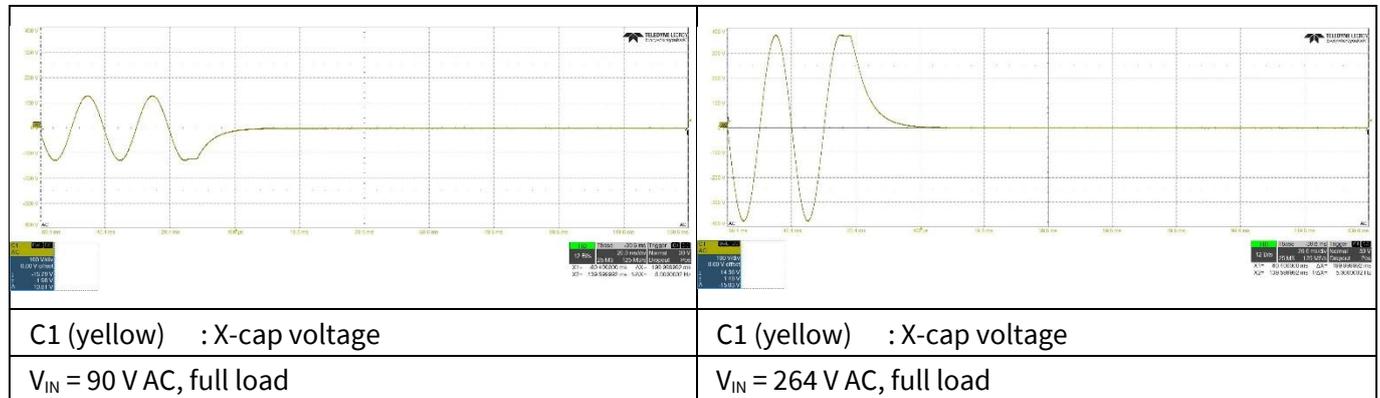
Figure 20     X-cap discharge after AC input off

# 11      Related resources

- AC-DC integrated power stage - CoolSET™
- Power Management ICs
- REF_45W1_ZVS_184ZCM

# References

[1]    Infineon Technologies AG: Datasheet - CoolSET™ SiP1LM; Available online

[2]    Infineon Technologies AG: Design guide - Design Guide for zero-voltage switching quasi-resonant flyback using CoolSET™ SiP; Available online

[3]    Infineon Technologies AG: Calculation tool: CoolSET™ SiP; Available online

## Revision history

| Document version | Date of release | Description of changes |
|---|---|---|
| V 1.0 | 2025-09-30 | Initial release |

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