

# 45 W 20 V adapter reference board

## with ICE2QS03G, IPA60R650CE, BAS21-03W and 2N7002

### About this document

#### Scope and purpose

This document is an engineering report that describes a 45 W 20 V adapter reference design board using a quasi-resonant PWM IC ICE2QS03G (DSO-8) with a CoolMOS™ IPA60R650CE (TO220FP). The reference adapter board is designed to fit a very small form factor while having high efficiency, low standby power and various modes of protection for a highly reliable system. The board passes EMI (both conducted and radiated), ESD immunity and surge immunity tests and can be used for production by customers after final verification with minor changes.

#### Intended audience

This document is intended for power supply designers, application engineers, students, etc., who wish to design a high efficiency, high reliability and very small form factor 45 W 20 V AC-DC adapter in a short period of time, using Infineon's CoolMOS™ CE series and quasi-resonant PWM IC ICE2QS03G.

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Abstract

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## Abstract

### 1 Abstract

This application note is an engineering report for a very small form factor reference design for a universal input 45 W 20 V adapter. The adapter uses **ICE2QS03G**, a second generation current mode control quasi-resonant flyback topology controller and **IPA60R650CE**, a **CE** series of high voltage power CoolMOS™ which is a price-performance optimized platform intended to target cost sensitive applications yet still meet the highest efficiency standards. The distinguishing features of this reference design are its very small form factor, best in class low standby power, high efficiency, good EMI performance and various modes of protection including a tailor-made brownout circuit for a highly reliable system.

## 2 Reference board

This document contains the list of features, the power supply specification, schematic, bill of material and the transformer construction documentation. Typical operating characteristics such as performance curve and scope waveforms are shown at the end of this report.

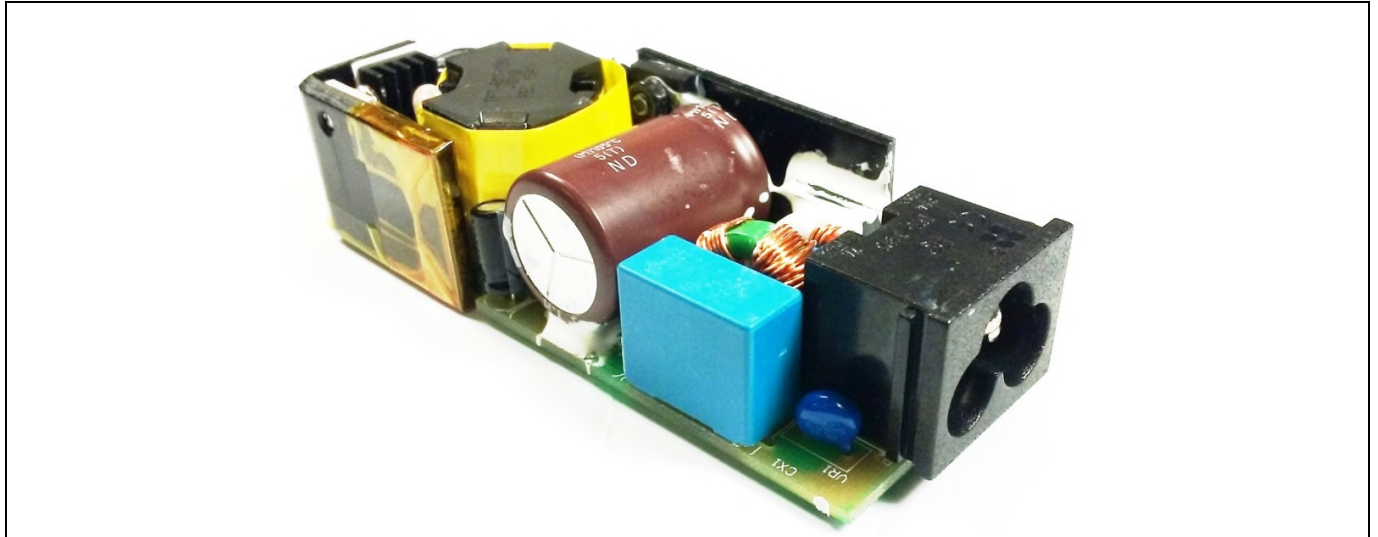


Figure 1 REF-45 W ADAPTER [PCBA dimensions L x W x H: 92 mm x 36mm x 22 mm]

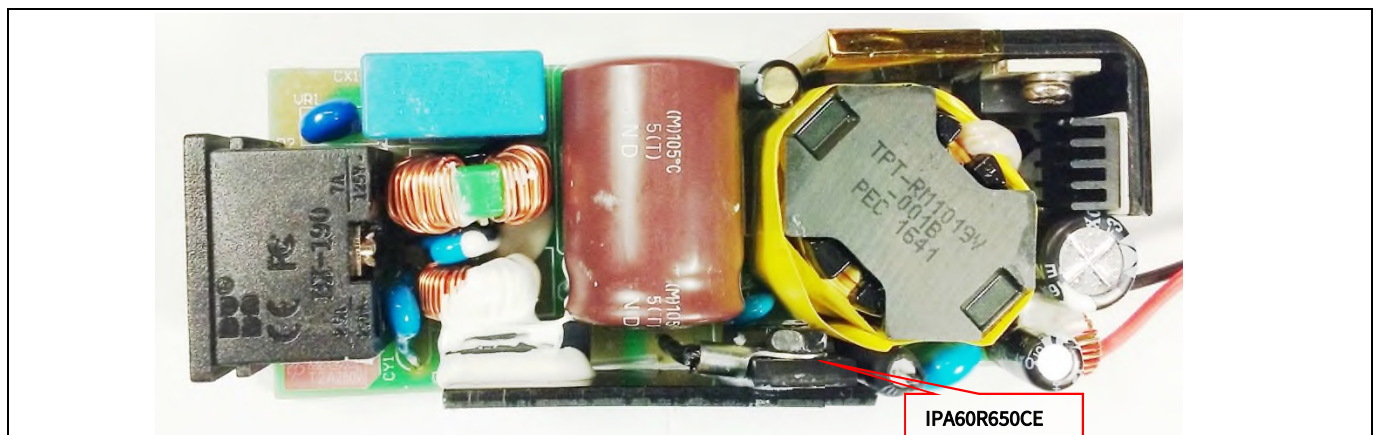


Figure 2 REF-45 W ADAPTER (top view)

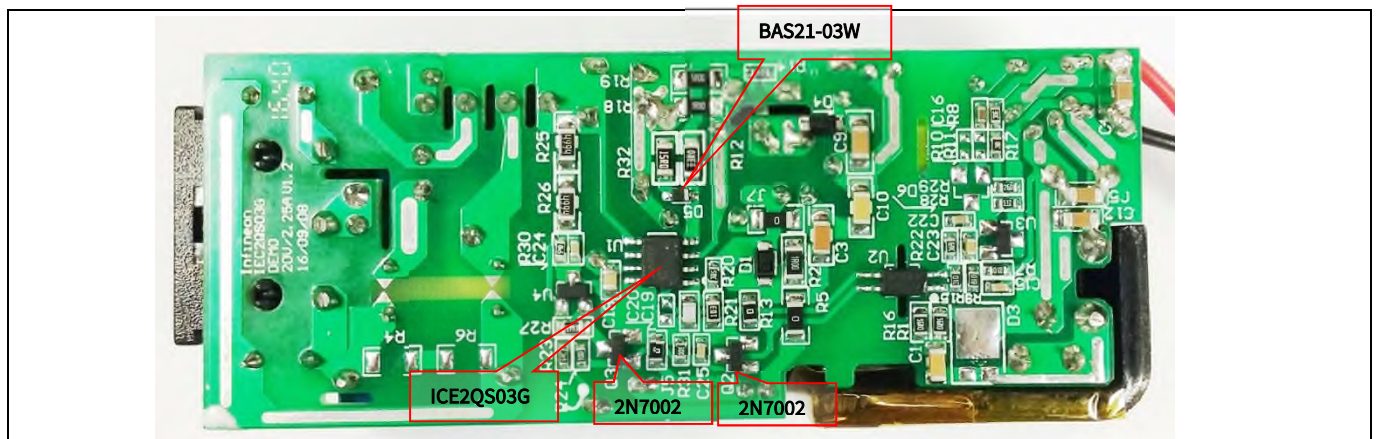


Figure 3 REF-45 W ADAPTER (bottom view)

### 3 Specification of reference board

**Table 1** Specification of REF-45W ADAPTER

|                                                                                                  |                                                                         |
|--------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Input voltage and frequency                                                                      | 90 V <sub>AC</sub> (60 Hz)~264 V <sub>AC</sub> (50 Hz)                  |
| Output voltage, current & power                                                                  | 20 V/2.25 A/45 W                                                        |
| Brownout detect/reset voltage at full load                                                       | 82/88 V <sub>AC</sub>                                                   |
| Output over voltage protection                                                                   | 21 ~ 25 V                                                               |
| Output over current protection                                                                   | 2.3 ~ 3.3 A                                                             |
| Active mode four point average efficiency<br>(25%,50%,75%,100% load) (EU CoC Version 5, Tier 2 ) | >88.9%                                                                  |
| No-load power consumption                                                                        | <100 mW                                                                 |
| Conducted emissions (EN55022 class B)                                                            | Pass with 8 dB margin for QP                                            |
| Radiated emissions (EN55022 class B)                                                             | Pass with 8 dB margin for QP                                            |
| ESD immunity (EN61000-4-2)                                                                       | Level 3 (±8 kV: contact discharge)                                      |
| Surge immunity (EN61000-4-5)                                                                     | Installation class 3 (2 kV: common mode and<br>1 kV: differential mode) |
| PCBA form factor (L x W x H)                                                                     | (92 x 36 x 22) mm                                                       |

## 4 Circuit description

### 4.1 Mains input rectification and filtering

The AC line input side includes an input fuse (F1) for over-current protection. The choke (L2), X-capacitors (CX1) and Y-capacitors (CY1, CY2 and CY3) act as EMI suppressors. The PCB spark gap and varistor (VR1) can absorb high voltage stress during a lightning surge test. After the bridge rectifier DB1 and the input bulk capacitor C11, a voltage of 90 to 373 V<sub>DC</sub> is present, depending on the input line voltage.

### 4.2 PWM control and switching MOSFET

The PWM pulse is generated by the quasi-resonant PWM current-mode controller **ICE2QS03G**. This PWM pulse drives the high voltage power MOSFETs, **IPA60R650CE** (CoolMOS™ CE). The CoolMOS™ CE provides all of the benefits of a fast switching SJ MOSFET while not sacrificing ease of use. It achieves extremely low conduction and switching losses and can make switching applications more efficient, more compact, lighter and cooler. The PWM switch-on is determined by the zero crossing signal and the value of the up/down counter. The PWM switch-off is determined by the feedback signal V<sub>FB</sub> and the current sensing signal V<sub>CS</sub>. The **ICE2QS03G** also provides all of the necessary protection functions for flyback converters. Full details are provided in the product datasheet.

### 4.3 Snubber network

A snubber network comprising R3, C9 and D4 dissipates the energy of the leakage inductance and suppresses ringing on the SMPS transformer. Due to the resonant capacitor (MOSFET's drain source capacitance), the overshoot is smaller than for a fixed frequency flyback converter. Thus, the snubber resistor can be increased to reduce the snubber loss.

### 4.4 Output stage

On the secondary side, for a 20 V output, the power is coupled via a Schottky diode (D2). Capacitor C7 provides energy buffering following the LC filter (L1, C8) to reduce the output ripple and prevent interference between the SMPS switching frequency and the line frequency considerably. Storage capacitor C7 is selected to have as low an internal resistance (ESR) as possible to minimize the output voltage ripple caused by the triangular current.

### 4.5 Feedback loop

For feedback, the output is sensed by the voltage divider comprising R8, R17, R28 and R29 and compared to U3 - the TL432 internal reference voltage. C22, C23 and R22 form the compensation network. The output voltage of U3, (TL432) is converted to the current signal via optocoupler U2 and 3 resistors (R7, R9 and R15) for regulation control.



## 5 Circuit operation

### 5.1 Startup operation

As there is a built-in startup cell in the **ICE2QS03G**, there is no need for an external start up resistor, which can improve standby performance significantly. When  $V_{CC}$  reaches the turn on voltage threshold of 18 V, the IC begins with a soft-start. The soft-start implemented in the **ICE2QS03G** is a digital time-based function. The preset soft-start time is 12 ms with 4 steps. If not limited by other functions, the peak voltage on the CS pin will increase step by step from 0.32 V to 1 V. After the IC turns on, the  $V_{CC}$  voltage is supplied by the auxiliary windings of the transformer.

### 5.2 Normal mode operation

The secondary output voltage is generated after startup with secondary regulation control provided by the TL432 and optocoupler. The compensation network (C22, C23 and R22) creates the error amplifier for the TL432. This circuitry allows the feedback to be precisely controlled with respect to any dynamically varying load conditions, therefore providing stable control.

### 5.3 Primary side peak current control

The MOSFET drain-source current is sensed via the external resistors R18 and R19. Since **ICE2QS03G** is a current mode controller, it has a cycle-by-cycle primary current and feedback voltage control that can ensure that the maximum power of the converter is controlled during every switching cycle.

### 5.4 Digital frequency reduction

During normal operation, the switching frequency of the **ICE2QS03G** is digitally reduced with decreasing load. At light load, the CoolMOS™ **IPA60R650CE** will be turned on the  $n$ th minimum drain-source voltage time where ' $n$ ' is in range 1 to 7, depending upon the feedback voltage. The feedback voltage decreases when the output power requirement decreases, and vice versa. Therefore, the counter is set by monitoring the feedback voltage,  $V_{FB}$ . The counter will be increased for low  $V_{FB}$  and decreased for high  $V_{FB}$ . The thresholds are preset inside the IC.

### 5.5 Burst mode operation

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

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

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

Once all of these conditions are fulfilled, the active burst mode flip-flop is set and the controller enters active burst mode operation. The multi-condition determination for entering active burst mode operation prevents mis-triggering, so that the controller only enters active burst mode operation when the output power is significantly low during the preset blanking time.

## **Circuit operation**

During active burst mode, the maximum current sense voltage is reduced from 1 V to 0.34 V so as to reduce the conduction loss and the audible noise. In active burst mode, the feedback voltage has a sawtooth waveform between 3.0 and 3.6 V.

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



## 6 Protection features

### 6.1 $V_{CC}$ over voltage and under voltage protection

During normal operation,  $V_{CC}$  is continuously monitored. When  $V_{CC}$  increases to  $V_{VCCOV}$  or  $V_{CC}$  falls below the under voltage lock out level  $V_{VCCoff}$ , the IC will enter auto restart mode.

### 6.2 Over load/open loop protection

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

### 6.3 Auto restart for over temperature protection

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

### 6.4 Adjustable output overvoltage protection

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

### 6.5 Short winding protection

The source current of the MOSFET is sensed via external resistors R18 and R19. If the voltage at the current sensing pin is higher than the preset threshold ( $V_{CSSW}$ ) of 1.68 V during the on-time of the power switch, the IC is latched off giving a short winding protection. To avoid an unintentional latch off, a spike blanking time of 190 ns is integrated in the output of internal comparator.

### 6.6 Foldback point protection

For a quasi-resonant flyback converter, the maximum possible output power is increased when a constant current limit value is used for all the mains input voltage range. This is usually not desired as this will increase the load on the transformer and output diode during output over power conditions.

Internal foldback protection is implemented to adjust the  $V_{CS}$  voltage limit according to the bus voltage. The input line voltage is sensed using the current flowing from the ZC pin, during the MOSFET on-time. As a result, the maximum current limit will be lower at high input voltage and the maximum output power can be limited in relation to the input voltage.

### 6.7 Line under voltage protection (brownout) by external circuit

When the AC line input voltage is lower than the specified voltage range, brownout mode is detected by sensing the voltage present on the REF pin ( $V_{REF\_TYP} = 2.5$  V) of U4 (ATL432) through the voltage divider resistors (R25, R26, R27 and R30 in Figure 4) via bulk capacitor, C11. Q2 acts as a switch to enter or exit brownout mode by controlling the FB pin voltage. Q3, together with R27, provides voltage hysteresis for the brownout circuit and U4 (ATL432) as a comparator. The system enters the brownout mode by controlling the FB pin voltage of U1 to 0 V, when the voltage level at  $V_{REF}$  drops to 2.5 V, the MOSFETs Q2 and Q3 are "ON" and  $V_{FB}$  drops to 0 V. The system is then in auto restart mode. Once the input voltage returns to the input voltage range,  $V_{REF}$  increases to

## Protection features

2.5 V. At the same time MOSFETs Q2 and Q3 are “OFF” and the brownout mode is released. After that, when  $V_{CC}$  reaches 18 V, the system resumes operation. The calculation for the brownout circuit is below.

$$V_{REF} = 2.5 \text{ V}$$

$$R25 = 4.99 \text{ M}\Omega \quad R26 = 4.99 \text{ M}\Omega \quad R30 = 357 \text{ k}\Omega \quad R27 = 499 \text{ k}\Omega$$

$$V_{Bulkcap\_brownout} = \frac{(R25 + R26 + R30) \cdot V_{REF}}{R30}$$

$$V_{Bulkcap\_brownout} = 72.38 \text{ V}$$

$$V_{Bulkcap\_brownin} = \frac{\left[ \left( \frac{R30 \cdot R27}{R30 + R27} \right) + R25 + R26 \right] \cdot V_{REF}}{\frac{R30 \cdot R27}{R30 + R27}}$$

$$V_{Bulkcap\_brownin} = 122.38 \text{ V}$$

Since there is AC ripples atop the DC voltage at the bulk capacitor C11, the calculated  $V_{Bulkcap\_brownout}$  refers to the ripple troughs and the  $V_{Bulkcap\_brownin}$  refers to the ripple crests.





Component list

## 9 Component list

Table 2 Bill of materials

| Item | Circuit code | Description         | Part value                                           | Supplier | Package / Footprint             | Qty |
|------|--------------|---------------------|------------------------------------------------------|----------|---------------------------------|-----|
| 1    | C1           | Output snubber cap. | 1 nF 630 V (1206)                                    |          | 1206                            | 1   |
| 2    | C2           | Vcc cap.            | 47 uF 35 V E-cap                                     |          | 5*10 mm, P=2.5 mm               | 1   |
| 3    | C3           | Filter cap.         | 100 nF 50 V (1206)                                   |          | 1206                            | 1   |
| 4    | C4           | Filter cap.         | 2.2 uF 50 V (1206)                                   |          | 1206                            | 1   |
| 5    | C5           | Filter cap.         | 2.2 uF 50 V (1206)                                   |          | 1206                            | 1   |
| 6    | C7           | Output Cap.         | 470 uF 35 V low ESR E-Cap                            |          | 10*16 mm, P=5.0 mm              | 1   |
| 7    | C8           | Output Cap.         | 100 uF 25 V low ESR E-Cap                            |          | 6.3*11 mm, P=5.0mm              | 1   |
| 8    | C9           | Clamper cap.        | 4.7 nF 630 V (1206)                                  |          | 1206                            | 1   |
| 9    | C10          | HV filter cap.      | 22 nF 630 V (1206)                                   |          | 1206                            | 1   |
| 10   | C11          | Input bulk cap.     | 82 uF 400 V E-Cap<br>(EKXG401ELL820MM25S)            |          | 18*25 mm. P=10mm                | 1   |
| 11   | C12          | Filter cap.         | 2.2 uF 50 V (1206)                                   |          | 1206                            | 1   |
| 12   | C15          | Filter cap.         | 1 nF 50 V (0603)                                     |          | 0603                            | 1   |
| 13   | C17          | HV Cds cap.         | 100 pF 1000 V                                        |          | 6*3 mm, P=4.0 mm                | 1   |
| 14   | C18          | Filter cap.         | 100 nF 50 V (0805)                                   |          | 0805                            | 1   |
| 15   | C22          | Filter cap.         | 22 nF 50 V (0603)                                    |          | 0603                            | 1   |
| 16   | C23          | Filter cap.         | 470 pF 50 V (0603)                                   |          | 0603                            | 1   |
| 17   | C24          | Filter cap.         | 100 nF 50 V (0603)                                   |          | 0603                            | 1   |
| 18   | C25          | Filter cap.         | 100 nF 50 V (0603)                                   |          | 0603                            | 1   |
| 19   | CX1          | X cap               | X2-Cap 0.33 uF 305 V <sub>AC</sub><br>(B32922D3334K) | EPCOS    | X2-cap, 8.5*14.5 mm,<br>P=15 mm | 1   |
| 20   | CY1          | Y cap               | Y2-Cap 220 pF 250 V <sub>AC</sub>                    |          | Y2-cap                          | 1   |
| 21   | CY2          | Y cap               | Y2-Cap 22 0pF 250 V <sub>AC</sub>                    |          | Y2-cap                          | 1   |
| 22   | CY3          | Y cap               | Y1-Cap 2.2 nF 250 V <sub>AC</sub>                    |          | Y1-cap                          | 1   |
| 23   | D1           | Signal diode        | 100 V 1 A diode (ES1001FL)                           |          | SOD-123                         | 1   |
| 24   | D2           | Output diode        | 100 V 20 A schottky diode(V20100C)                   |          | TO-220                          | 1   |
| 25   | D4           | Clamper diode       | 100 V 1 A diode (GS1010FL)                           |          | SOD-123                         | 1   |
| 26   | D5           | Signal diode        | 200 V 0.25 A diode (BAS21-03W)                       | Infineon | SOD323                          | 1   |
| 27   | DB1          | Input bridge diode  | 600 V 2 A bridge diode<br>(2KBP06M)                  |          |                                 | 1   |
| 28   | F1           | Fuse                | T 2 A 250 V TE5 fuse                                 |          | 8*4 mm, P=5 mm                  | 1   |
| 29   | HTSK1        | Heatsink for Q1     | 42 mm x 16 mm                                        |          |                                 | 1   |
| 30   | HTSK2        | Heatsink for D2     | 51 mm x 21 mm L-shape                                |          |                                 | 1   |
| 31   | J1           | Jumper              | L20 mm D0.6 mm                                       |          | axial                           | 1   |
| 32   | J2           | Jumper              | L23.7 mm D0.6 mm                                     |          | axial                           | 1   |
| 33   | J3           | Jumper              | L6.3 mm D0.6 mm                                      |          | axial                           | 1   |
| 34   | J4           | Jumper              | L18.5 mm D0.6 mm                                     |          | axial                           | 1   |
| 35   | J5           | Jumper              | 0R (0805)                                            |          | 0805                            | 1   |
| 36   | J6           | Jumper              | L10 mm D0.6 mm                                       |          | axial                           | 1   |

# 45 W 20 V adapter reference board with ICE2QS03G, IPA60R650CE, BAS21-03W and 2N7002



## Component list

|    |     |                    |                                  |          |                          |   |
|----|-----|--------------------|----------------------------------|----------|--------------------------|---|
| 37 | J7  | Jumper             | 0R (1206)                        |          | 1206                     | 1 |
| 38 | J8  | Jumper             | L6.5mm D0.6mm                    |          | axial                    | 1 |
| 39 | L1  | Output D-choke     | 4.7uH/5A (B32922D3334K )         | WURTH    | 6*8.5 mm, P=2.5 mm       | 1 |
| 40 | L2  | Input CMC          | 13 mH 1 A (GM-1495SH)            |          | 7*15*15mm, P=5 mm        | 1 |
| 41 | L3  | Output CMC         | 200 µH 1 A (GM-633-050)          |          | 4*8*8 mm, P=4 mm         | 1 |
| 42 | L4  | Input D-choke      | 43 µH 1 A 0.06 Ω (7447034)       | WURTH    | 6.5*13*13.5 mm, P=4.5 mm | 1 |
| 43 | P1  | Output wire        | 2 pcs φ0.6 mm                    |          |                          |   |
| 44 | P2  | Input 3 pin socket | Plum blossom socket (ST-A04)     |          |                          | 1 |
| 45 | PCB | PCB                | 88 mm x 35 mm FR1 1.6 mm thick   |          |                          | 1 |
| 46 | Q1  | Power MOSFET       | N MOS 600 V 0.65 Ω (IPA60R650CE) | Infineon | TO220FP                  | 1 |
| 47 | Q2  | Signal MOSFET      | N MOSFET 60 V 300 mA (2N7002)    | Infineon | SOT-23                   | 1 |
| 48 | Q3  | Signal MOSFET      | N MOSFET 60 V 300 mA (2N7002)    | Infineon | SOT-23                   | 1 |
| 49 | R1  | Resistor           | 56R (0805)                       |          | 0805                     | 1 |
| 50 | R2  | Resistor           | 1R (1206)                        |          | 1206                     | 1 |
| 51 | R3  | Clamper Resistor   | 82K 2W                           |          | axial                    | 1 |
| 52 | R5  | Resistor           | 0R (1206)                        |          | 1206                     | 1 |
| 53 | R7  | Resistor           | 1K (0603)                        |          | 0603                     | 1 |
| 54 | R8  | Resistor           | 20K (0603)                       |          | 0603                     | 1 |
| 55 | R9  | Resistor           | 1K (0603)                        |          | 0603                     | 1 |
| 56 | R12 | Resistor           | 33R (1206)                       |          | 1206                     | 1 |
| 57 | R13 | Resistor           | 0R (0805)                        |          | 0805                     | 1 |
| 58 | R14 | Resistor           | 10K (0603)                       |          | 0603                     | 1 |
| 59 | R15 | Resistor           | 10K (0603)                       |          | 0603                     | 1 |
| 60 | R16 | Resistor           | 56R (0805)                       |          | 0805                     | 1 |
| 61 | R17 | Resistor           | 15K (0603)                       |          | 0603                     | 1 |
| 62 | R18 | Resistor           | 1R (1206)                        |          | 1206                     | 1 |
| 63 | R19 | Resistor           | 1R (1206)                        |          | 1206                     | 1 |
| 64 | R20 | Resistor           | 39K2 (0603)                      |          | 0603                     | 1 |
| 65 | R21 | Resistor           | 10K (0603)                       |          | 0603                     | 1 |
| 66 | R22 | Resistor           | 51K (0603)                       |          | 0603                     | 1 |
| 67 | R23 | Resistor           | 51K (0603)                       |          | 0603                     | 1 |
| 68 | R24 | Resistor           | 200K (0603)                      |          | 0603                     | 1 |
| 69 | R25 | Resistor           | 4.99M (1206)                     |          | 1206                     | 1 |
| 70 | R26 | Resistor           | 4.99M (1206)                     |          | 1206                     | 1 |
| 71 | R27 | Resistor           | 499K ( 0603)                     |          | 0603                     | 1 |
| 72 | R28 | Resistor           | 5K1 (0603)                       |          | 0603                     | 1 |
| 73 | R29 | Resistor           | 182K (0603)                      |          | 0603                     | 1 |
| 74 | R30 | Resistor           | 357K (0603)                      |          | 0603                     | 1 |
| 75 | R31 | Resistor           | 200K (0603)                      |          | 0603                     | 1 |
| 76 | R32 | Resistor           | 15R (1206)                       |          | 1206                     | 1 |
| 77 | T1  | Power              | L <sub>p</sub> =650 µH, RM10 P47 |          | RM10                     | 1 |

## 45 W 20 V adapter reference board with ICE2QS03G, IPA60R650CE, BAS21-03W and 2N7002



### Component list

|    |             | Transformer         |                                         |          |        |   |
|----|-------------|---------------------|-----------------------------------------|----------|--------|---|
| 78 | U1          | PWM controller      | QR controller (ICE2QS03G)               | Infineon | SO-8   | 1 |
| 79 | U2          | Opto-coupler        | CTR 63% ~ 125% (VOS617A-2X001T)         |          | SOP4   | 1 |
| 80 | U3          | Error amplifier     | 2.5 V TL432 (TL432AIDBZR)               |          | SOT-23 | 1 |
| 81 | U4          | Error amplifier     | 2.5 V low current ATL432 (ATL432AIDBZR) |          | SOT-23 | 1 |
| 82 | VR1         | VDR                 | S05K075 (B72205S0271K101)               | EPCOS    | radial | 1 |
| 83 | Screw       | For HTSK1 and HTSK2 | M3 bolt and nut                         |          |        | 2 |
| 84 | Jumper wire | For HTSK1           | φ0.6mm with M3 crimp terminal           |          |        | 1 |



## Transformer construction

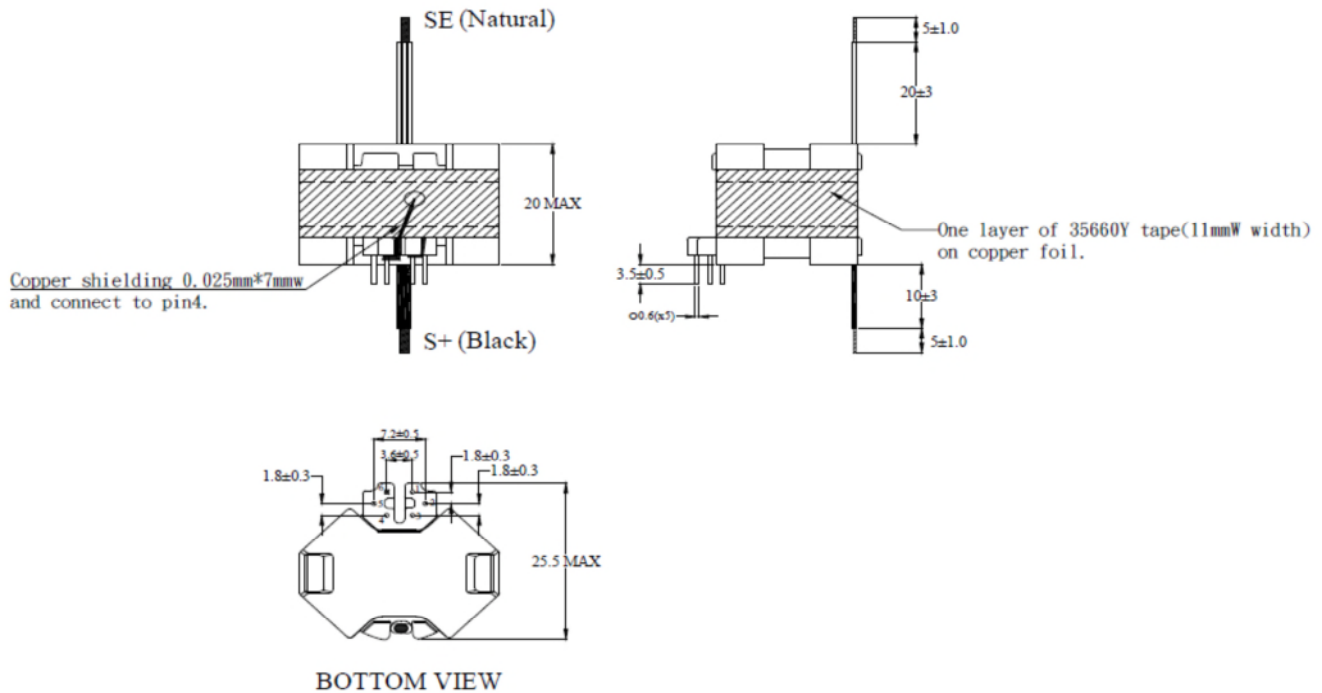
### 10 Transformer construction

Core and material: RM10 P47

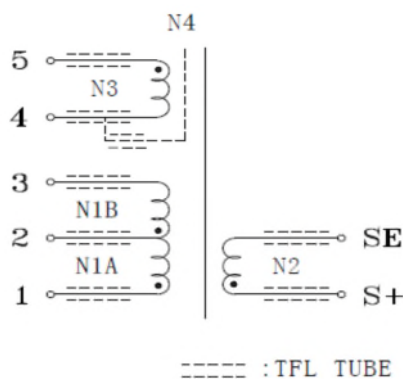
Primary inductance,  $L_p=650 \mu\text{H}$  ( $\pm 15 \mu\text{H}$ ), measured between pin 1 and pin 3

Leakage inductance,  $L_l=9.5 \mu\text{H}$  max measured between pin 1 and pin 3

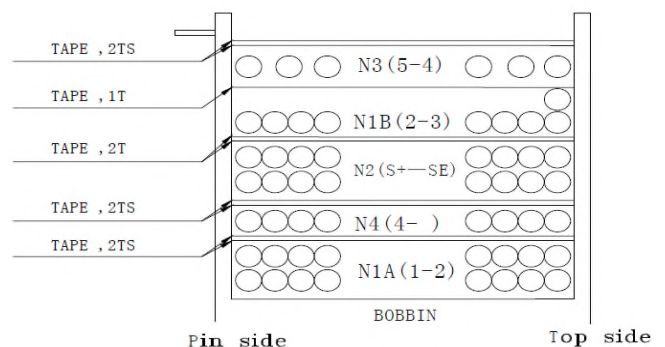
Physical Dimension :



Winding Spec. :



Winding Structure :



Winding Order :

|            |                 |       |                           |
|------------|-----------------|-------|---------------------------|
| N1A(1-2)   | :0.32 $\phi$ *2 | ,28TS | ,Close Wound              |
| N4 (4-)    | :0.32 $\phi$ *2 | ,14TS | ,Shield wind              |
| N2 (S+—SE) | :0.65 $\phi$ *3 | , 7TS | ,Close Wound ,Triple wire |
| N1B(2-3)   | :0.32 $\phi$ *2 | ,14TS | ,Close Wound              |
| N3 (5-4)   | :0.15 $\phi$    | , 6TS | ,Space Wound              |

Figure 7 Transformer structure

Test results

## 11 Test results

### 11.1 Efficiency, regulations and output ripple

Table 3 Efficiency, regulation & output ripple

| Input<br>(V <sub>AC</sub> /Hz) | P <sub>IN</sub> (W) | I <sub>OUT</sub> (A) | V <sub>OUT</sub> (V) | P <sub>OUT</sub> (W) | $\eta$ | Avg $\eta$ | OLP P <sub>IN</sub> (W) | OLP I <sub>OUT</sub> (A) |
|--------------------------------|---------------------|----------------------|----------------------|----------------------|--------|------------|-------------------------|--------------------------|
| 90 V <sub>AC</sub> /<br>60 Hz  | 50.25               | 2.26                 | 19.77                | 44.62                | 88.79% | 89.32%     | 57                      | 2.80                     |
|                                | 37.00               | 1.68                 | 19.79                | 33.26                | 89.88% |            |                         |                          |
|                                | 24.88               | 1.13                 | 19.80                | 22.37                | 89.92% |            |                         |                          |
|                                | 12.58               | 0.56                 | 19.81                | 11.16                | 88.69% |            |                         |                          |
|                                | 0.05                | 0.00                 | 19.82                | 0.00                 | -      | -          |                         |                          |
| 115 V <sub>AC</sub> /<br>60 Hz | 49.48               | 2.26                 | 19.80                | 44.67                | 90.29% | 90.05%     | 63                      | 3.00                     |
|                                | 36.68               | 1.68                 | 19.79                | 33.25                | 90.66% |            |                         |                          |
|                                | 24.77               | 1.13                 | 19.80                | 22.37                | 90.29% |            |                         |                          |
|                                | 12.54               | 0.56                 | 19.81                | 11.15                | 88.97% |            |                         |                          |
|                                | 0.05                | 0.00                 | 19.82                | 0.00                 | -      | -          |                         |                          |
| 230 V <sub>AC</sub> /<br>50 Hz | 49.26               | 2.26                 | 19.78                | 44.63                | 90.61% | 89.25%     | 65                      | 3.08                     |
|                                | 36.88               | 1.68                 | 19.79                | 33.25                | 90.18% |            |                         |                          |
|                                | 25.01               | 1.13                 | 19.80                | 22.36                | 89.40% |            |                         |                          |
|                                | 12.85               | 0.56                 | 19.81                | 11.16                | 86.82% |            |                         |                          |
|                                | 0.07                | 0.00                 | 19.82                | 0.00                 | -      | -          |                         |                          |
| 264 V <sub>AC</sub> /<br>50 Hz | 49.58               | 2.26                 | 19.78                | 44.63                | 90.03% | 88.42%     | 68                      | 3.10                     |
|                                | 37.16               | 1.68                 | 19.79                | 33.25                | 89.48% |            |                         |                          |
|                                | 25.24               | 1.13                 | 19.80                | 22.36                | 88.60% |            |                         |                          |
|                                | 13.04               | 0.56                 | 19.81                | 11.16                | 85.59% |            |                         |                          |
|                                | 0.08                | 0.00                 | 19.82                | 0.00                 | -      | -          |                         |                          |

Test results

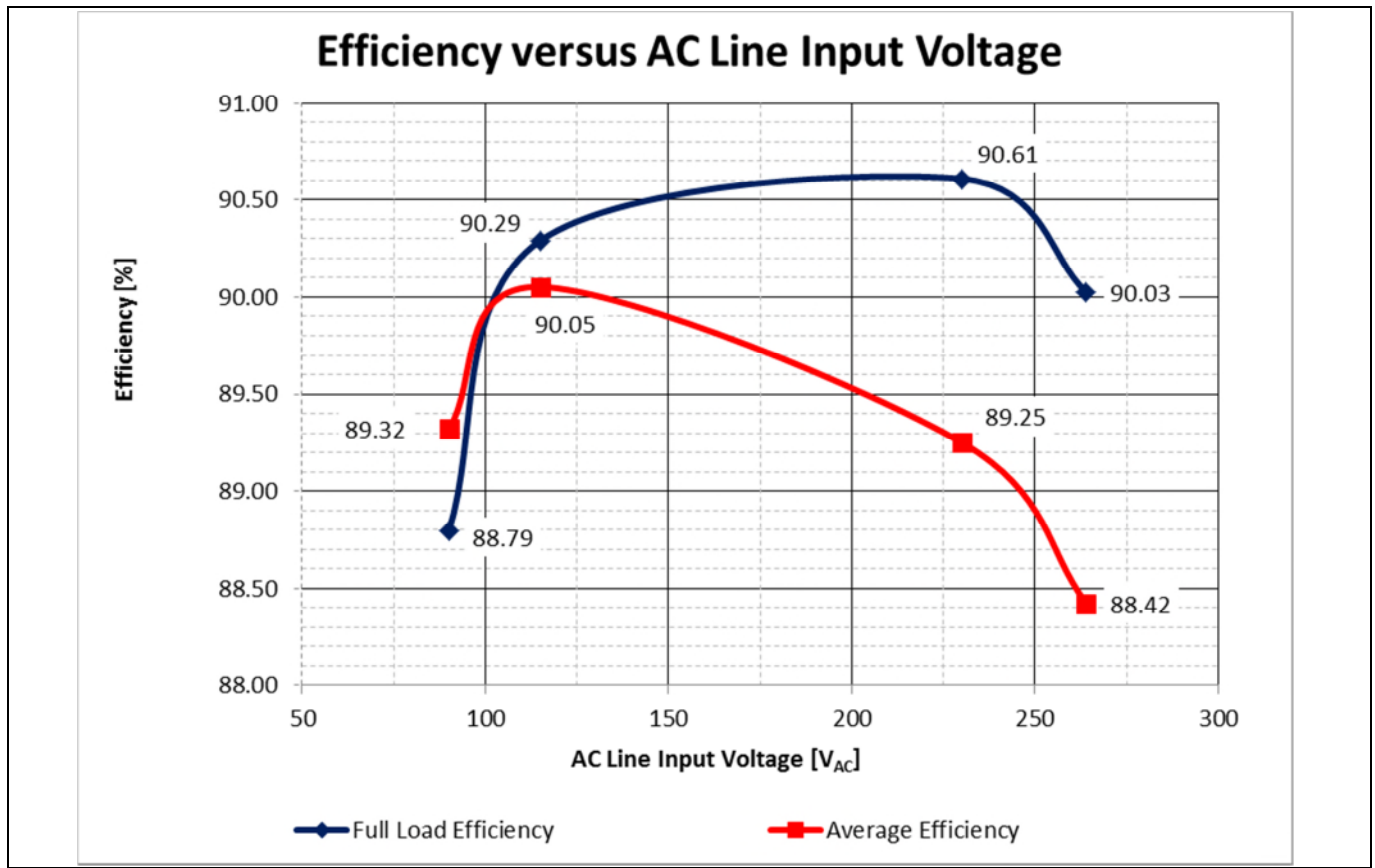


Figure 8 Efficiency vs AC line input voltage

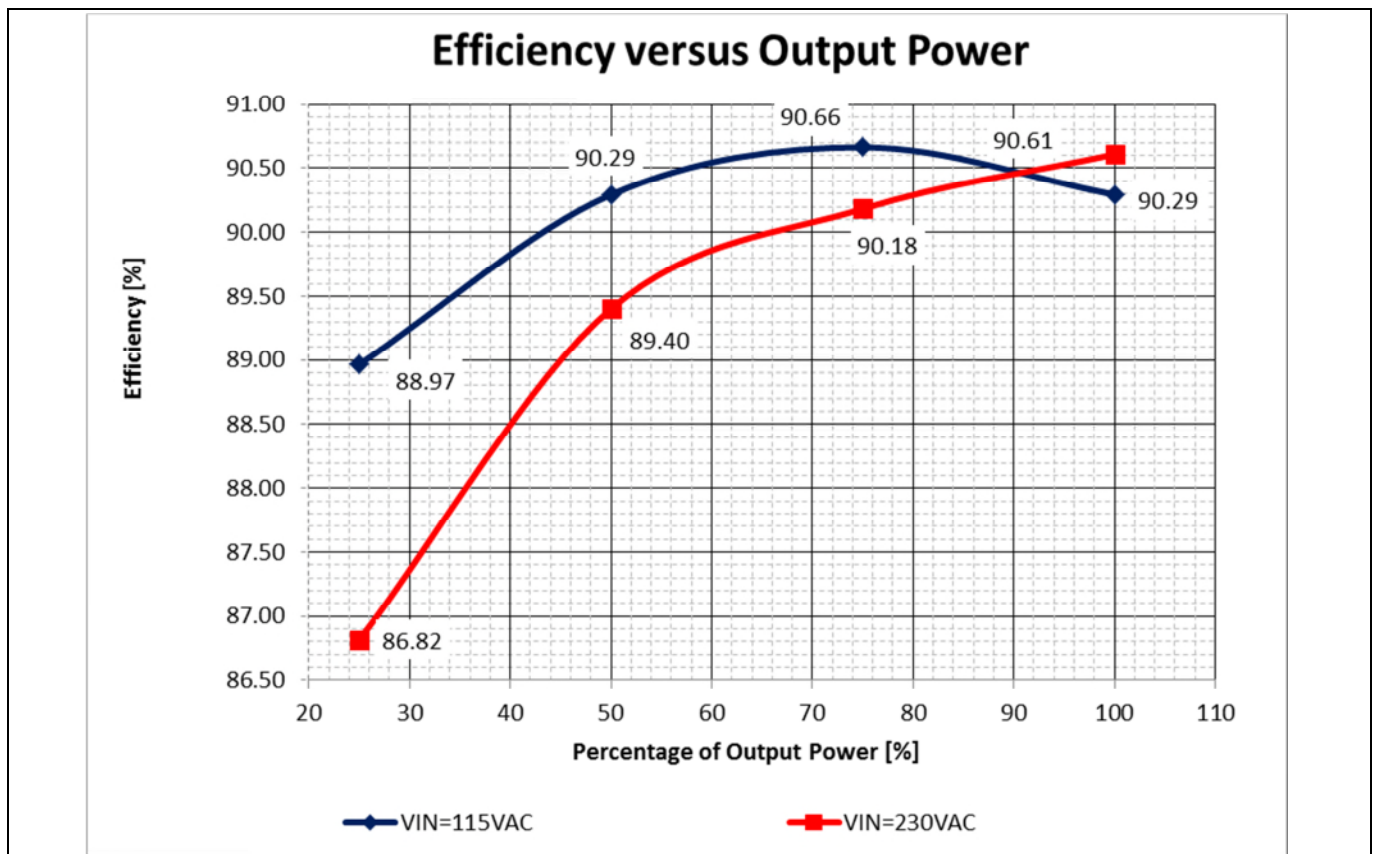


Figure 9 Efficiency vs output power at 115 V<sub>AC</sub> and 230 V<sub>AC</sub> line

## 11.2 Standby power

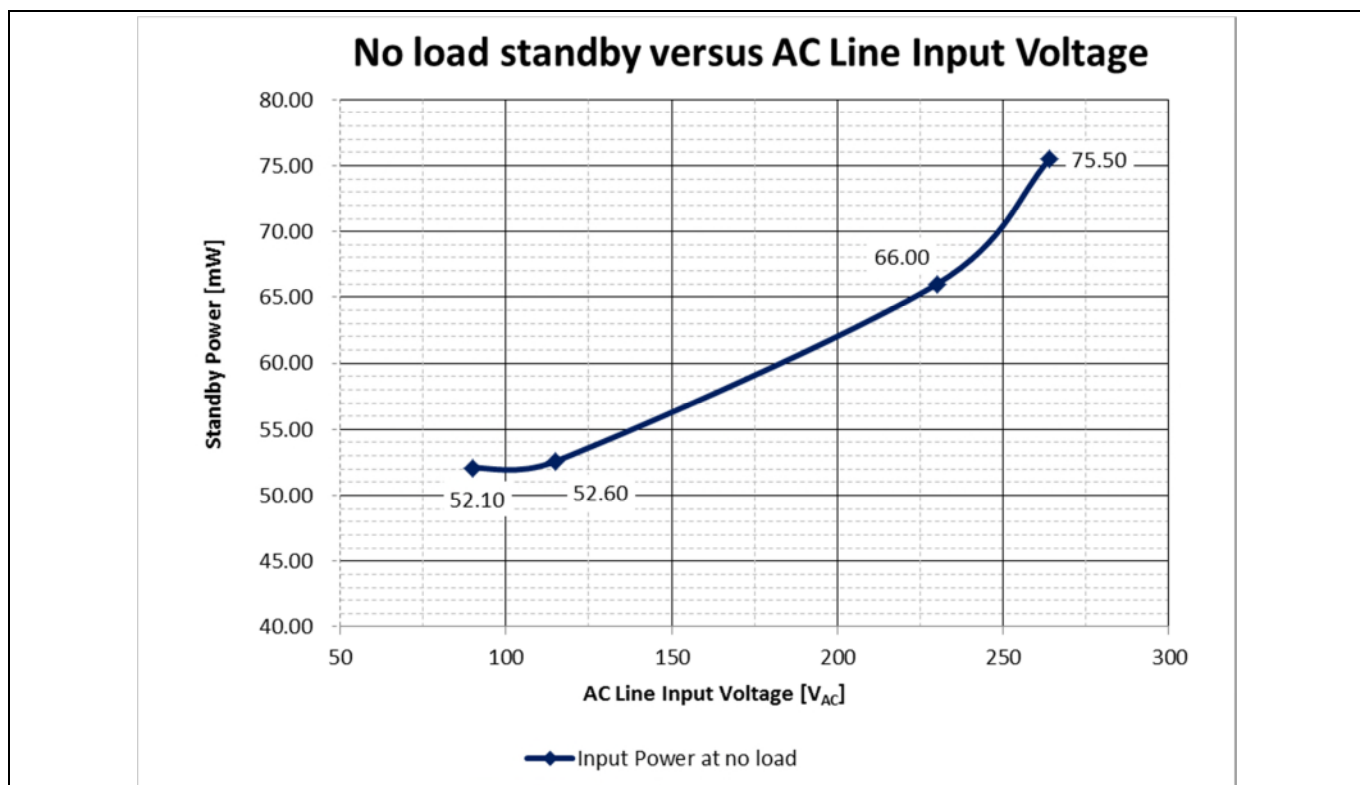


Figure 10 Standby power at no load vs AC line input voltage (measured by Yokogawa WT210 power meter - integration mode)

## 11.3 Line regulation

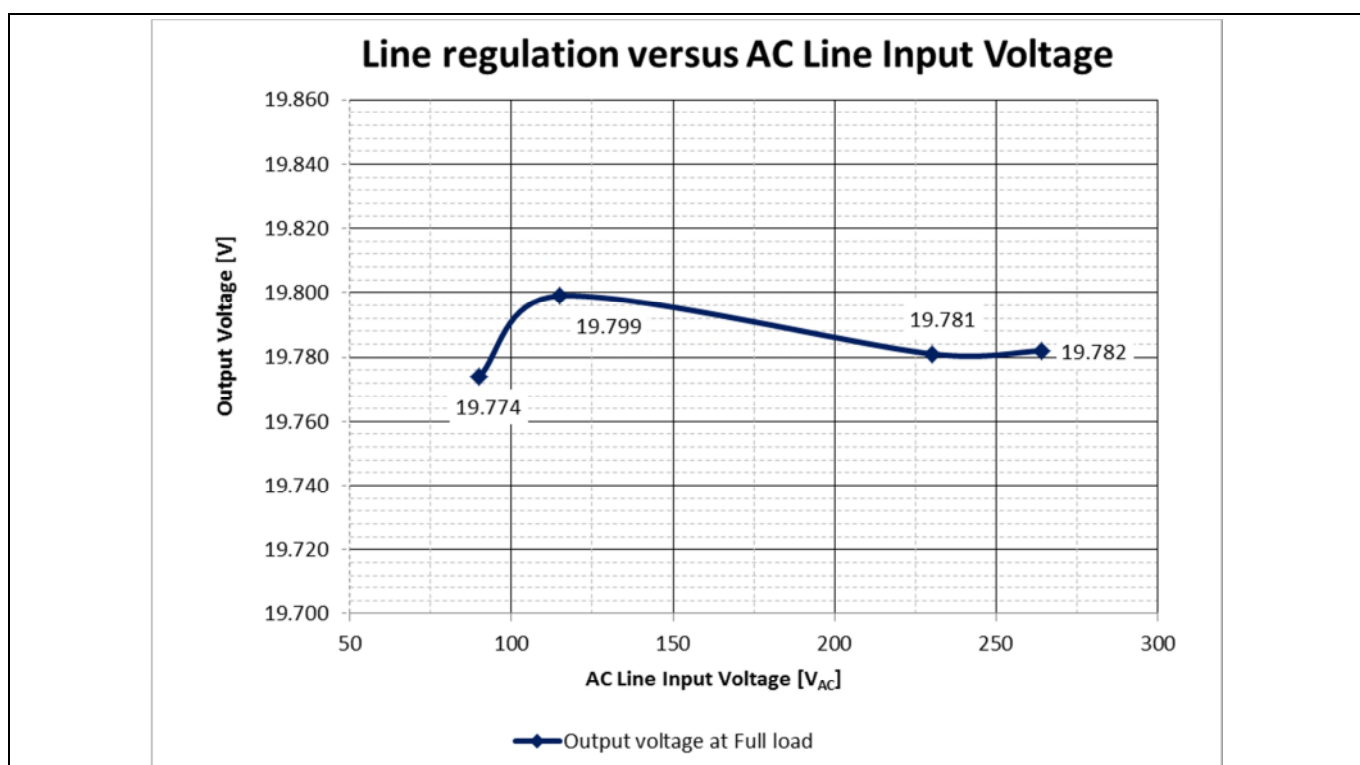


Figure 11 Line regulation  $V_{OUT}$  at full load vs AC line input voltage

## 11.4 Load regulation

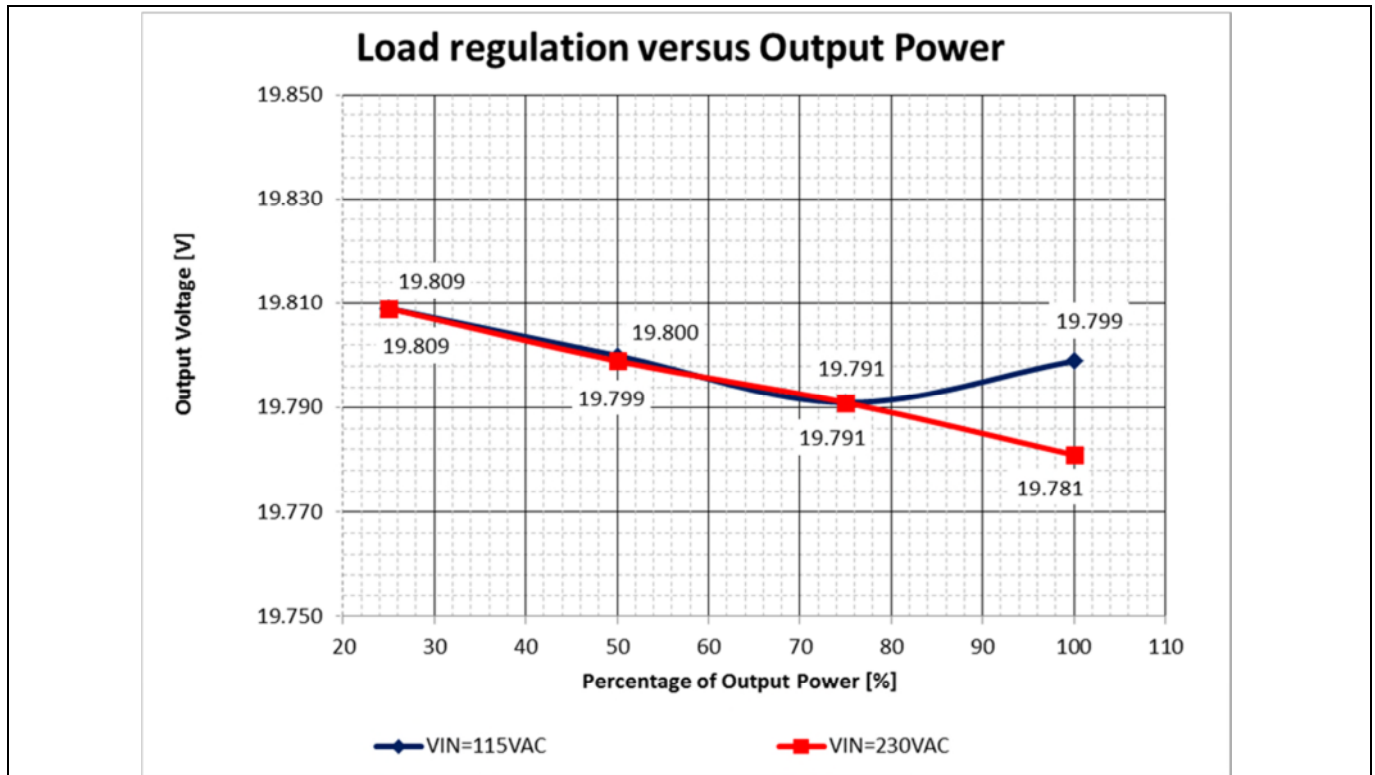


Figure 12 Load regulation  $V_{OUT}$  vs output power

## 11.5 Maximum output current / input power

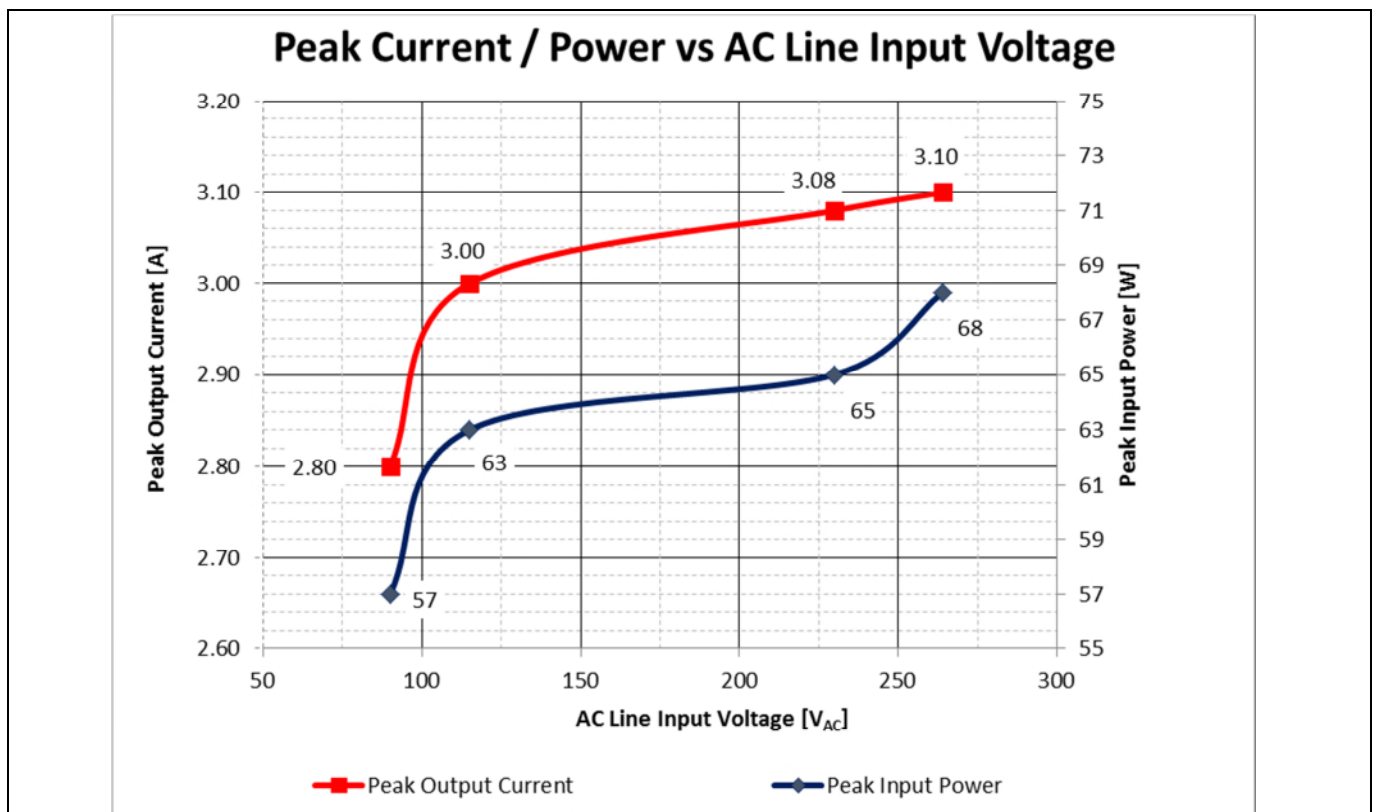


Figure 13 Maximum output current / input power vs AC line input voltage



## Test results

### 11.6 Conducted emissions (EN55022 class B)

The conducted EMI was measured by a certified laboratory (NTEK Testing Technologies Co., Ltd) and met EN55022 (CISPR 22) class B. The demo board was set up at full load (45 W) with an input voltage of 115 V<sub>AC</sub> and 230 V<sub>AC</sub>.

Pass conducted emissions EN55022 (CISPR 22) class B with 8 dB margin.

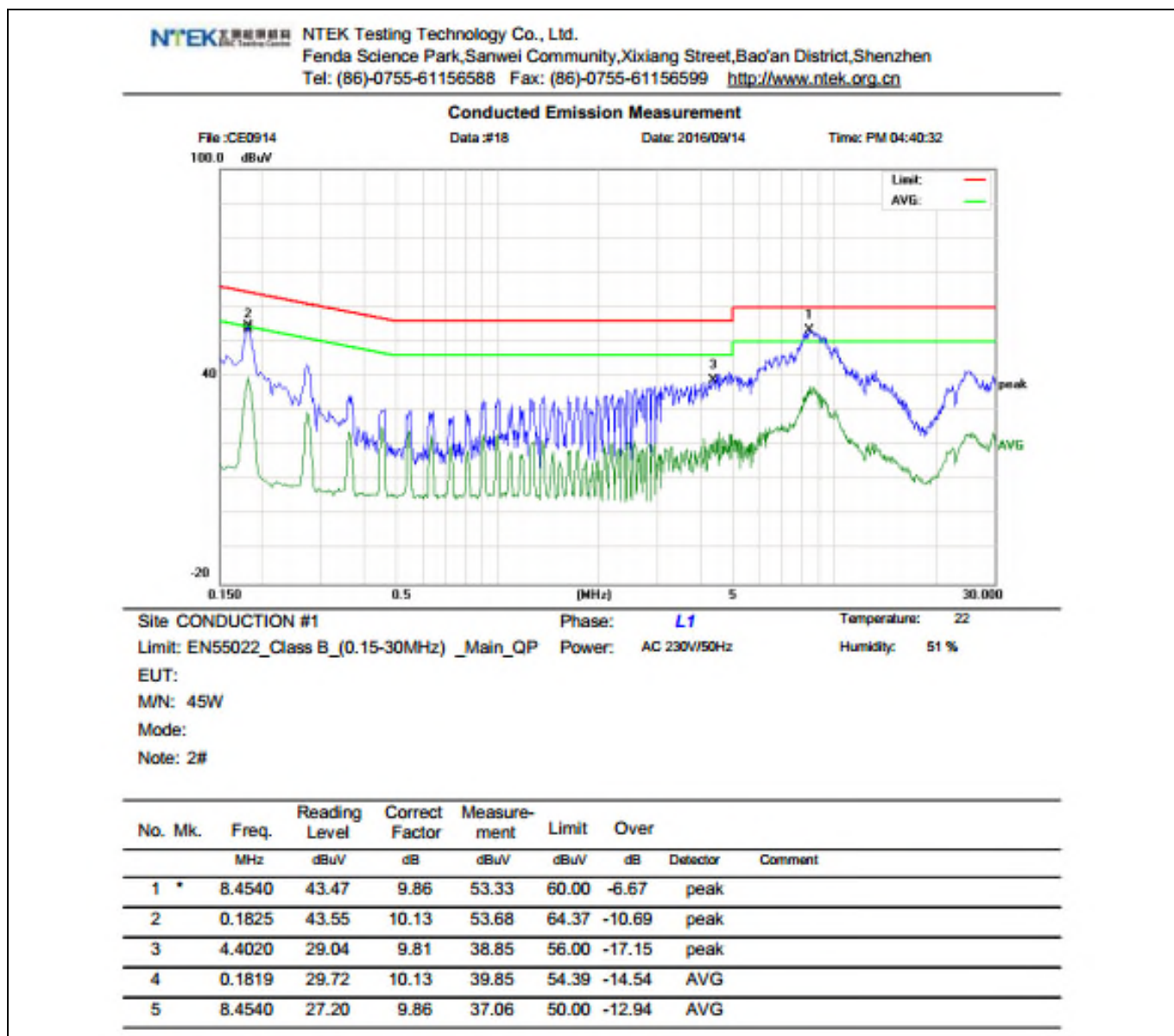


Figure 14 Conducted emissions (line) at 115 V<sub>AC</sub> and full load

# Test results

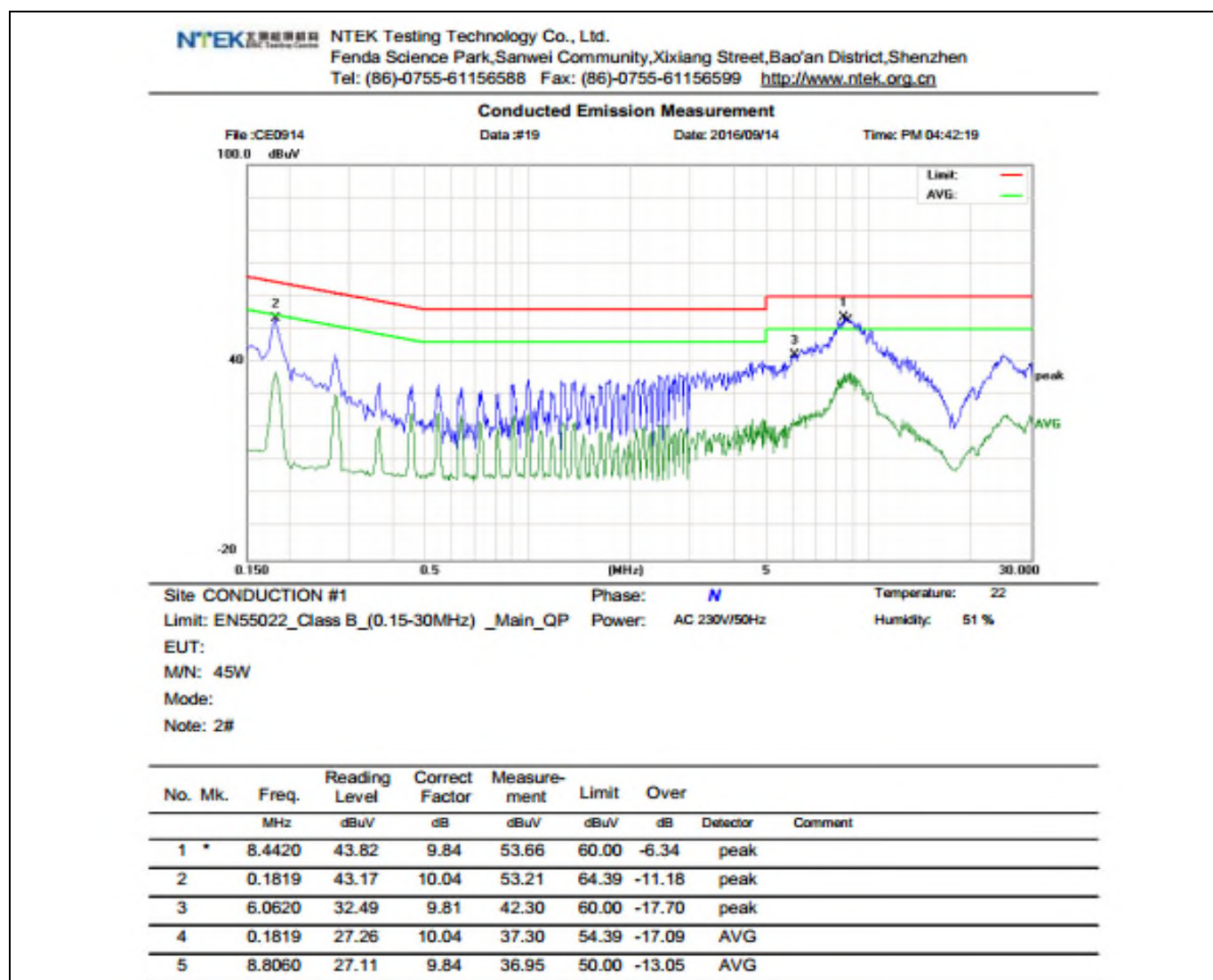


Figure 15 Conducted emissions (neutral) at 115 V<sub>AC</sub> and full load



# 45 W 20 V adapter reference board with ICE2QS03G, IPA60R650CE, BAS21-03W and 2N7002

## Test results

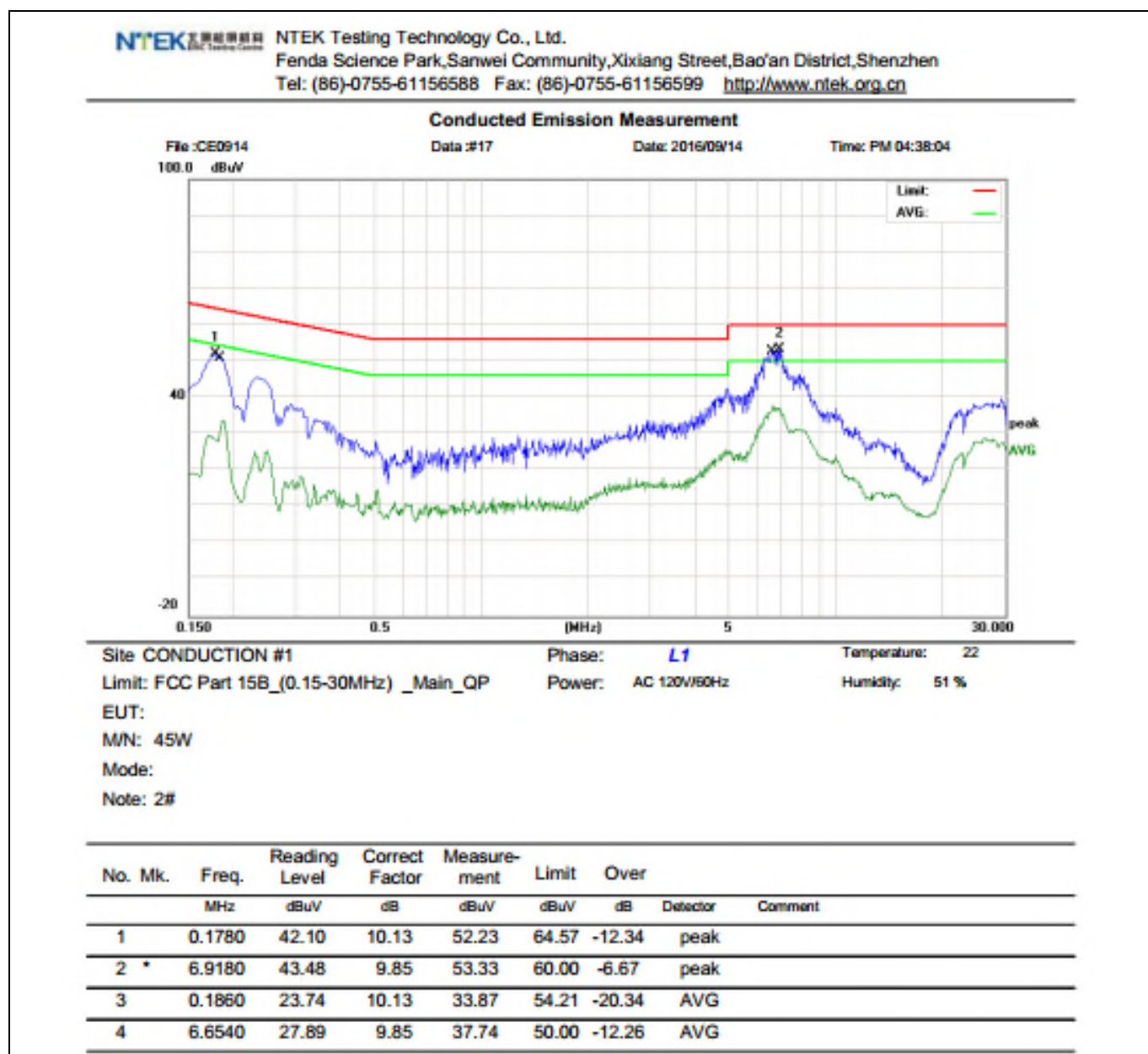


Figure 16 Conducted emissions (line) at 230 V<sub>AC</sub> and full load

# Test results

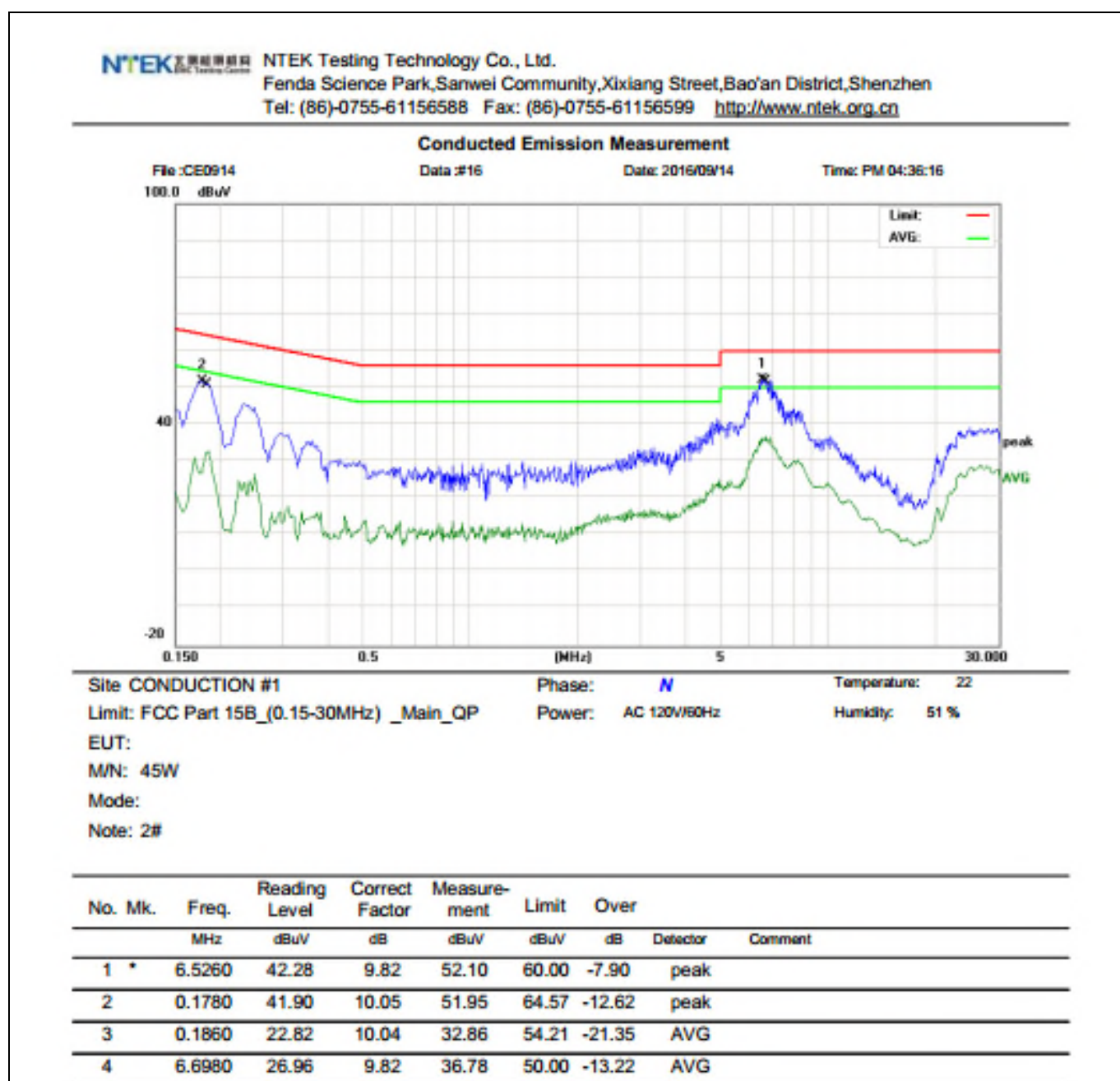


Figure 17 Conducted emissions (neutral) at 230 V<sub>AC</sub> and full load

# 45 W 20 V adapter reference board with ICE2QS03G, IPA60R650CE, BAS21-03W and 2N7002

## Test results

### 11.7 Radiated emissions (EN55022 class B)

The radiated EMI was measured by a certified laboratory (NTEK Testing Technologies Co., Ltd) and met EN55022 (CISPR 22) class B (230 V<sub>AC</sub>). The demo board was set up at full load (45 W) with an input voltage of 230 V<sub>AC</sub>.

Pass radiated emissions EN55022 (CISPR 22) class B with 8 dB margin.

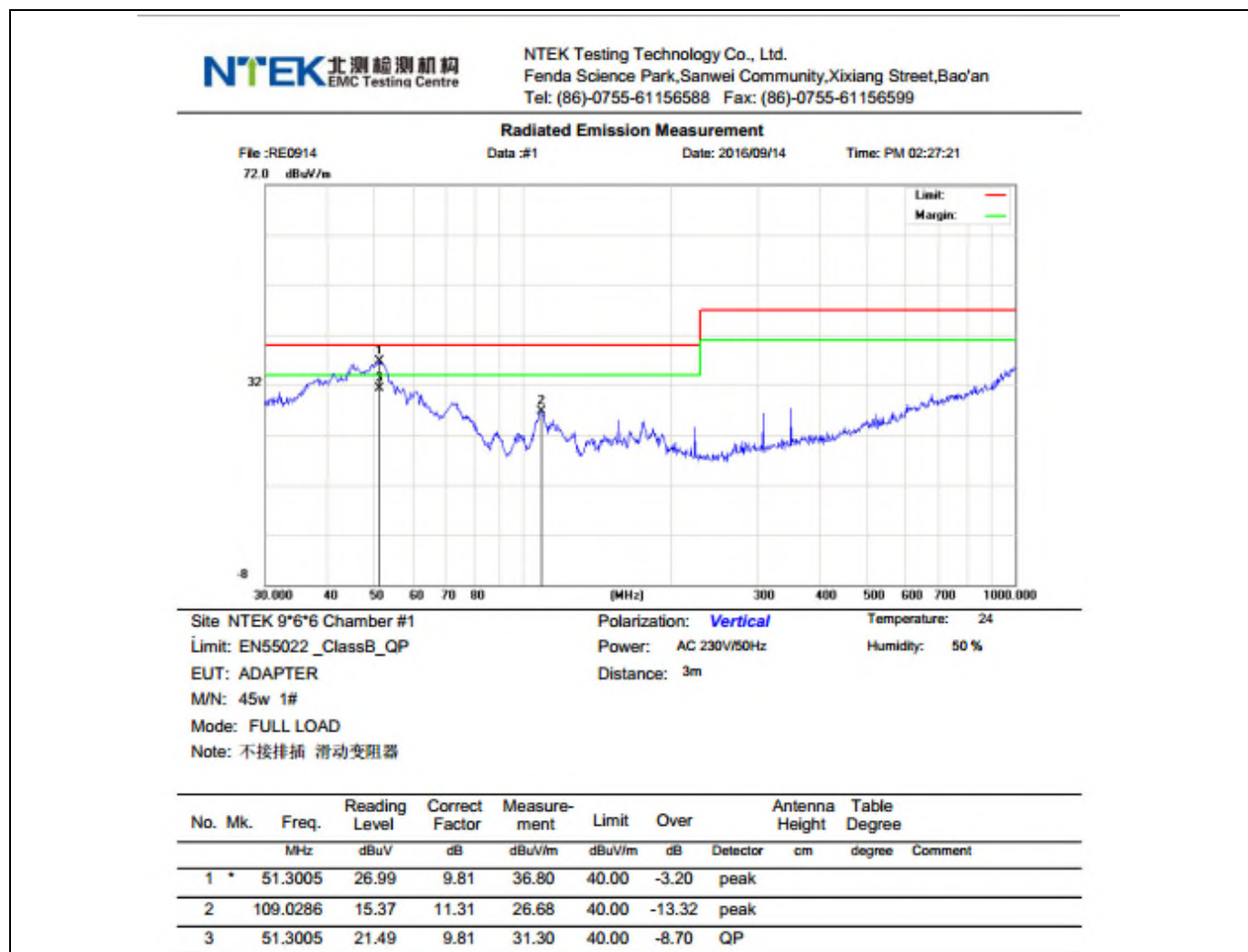


Figure 18 Radiated emissions (vertical) at 230 V<sub>AC</sub> and full load

# 45 W 20 V adapter reference board with ICE2QS03G, IPA60R650CE, BAS21-03W and 2N7002

## Test results

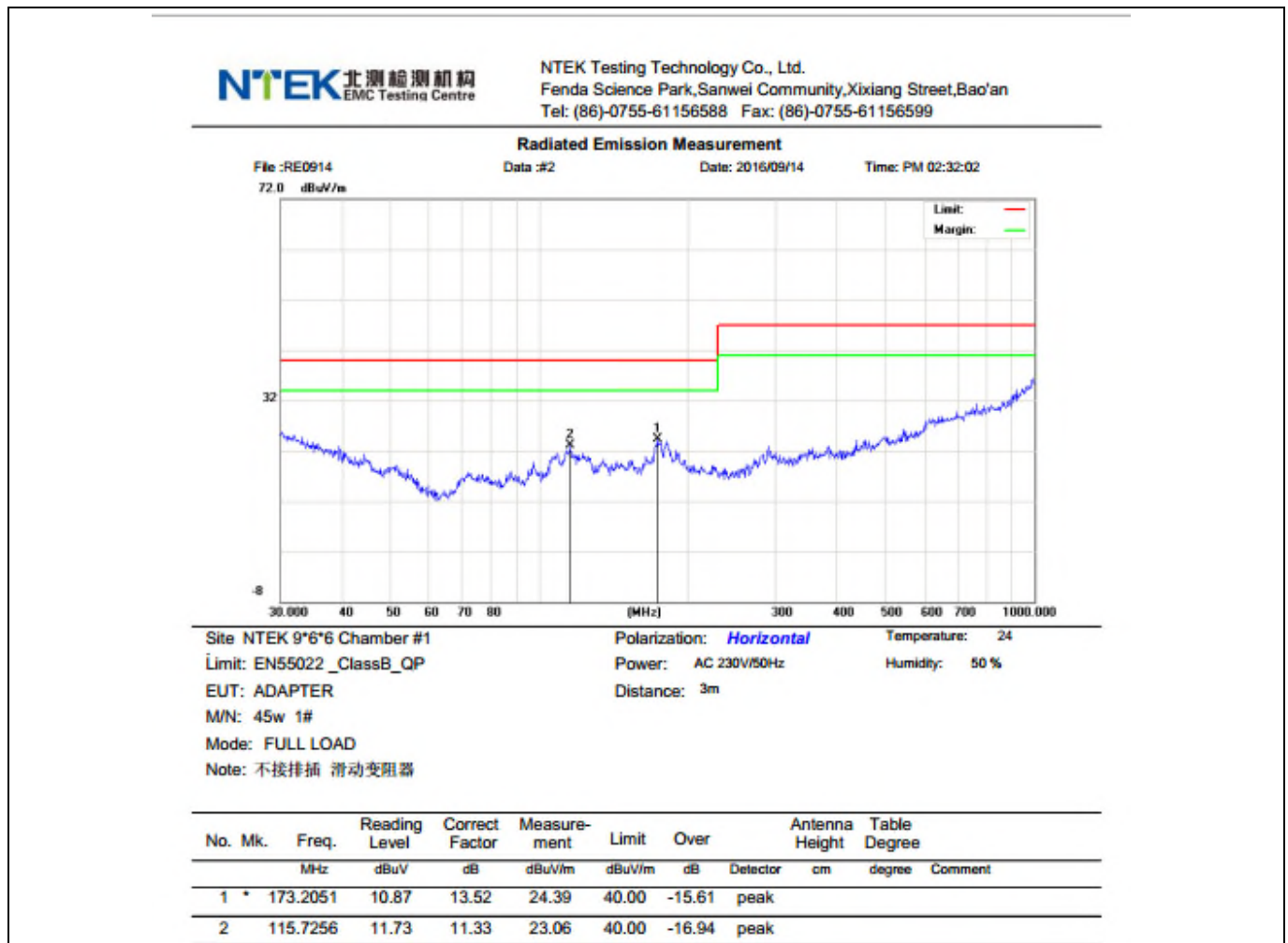


Figure 19 Radiated emissions (horizontal) at 230 V<sub>AC</sub> and full load



## Test results

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

The electrostatic discharge test was measured by a certified laboratory (NTEK Testing Technologies Co., Ltd) and met EN61000-4-2. The demo board was set up at full load (45 W) with an input voltage of 230 V<sub>AC</sub>.  
Pass EN61000-4-2 contact discharge  $\pm 8$  kV.

### 11.9 Surge immunity (IEC61000-4-5)

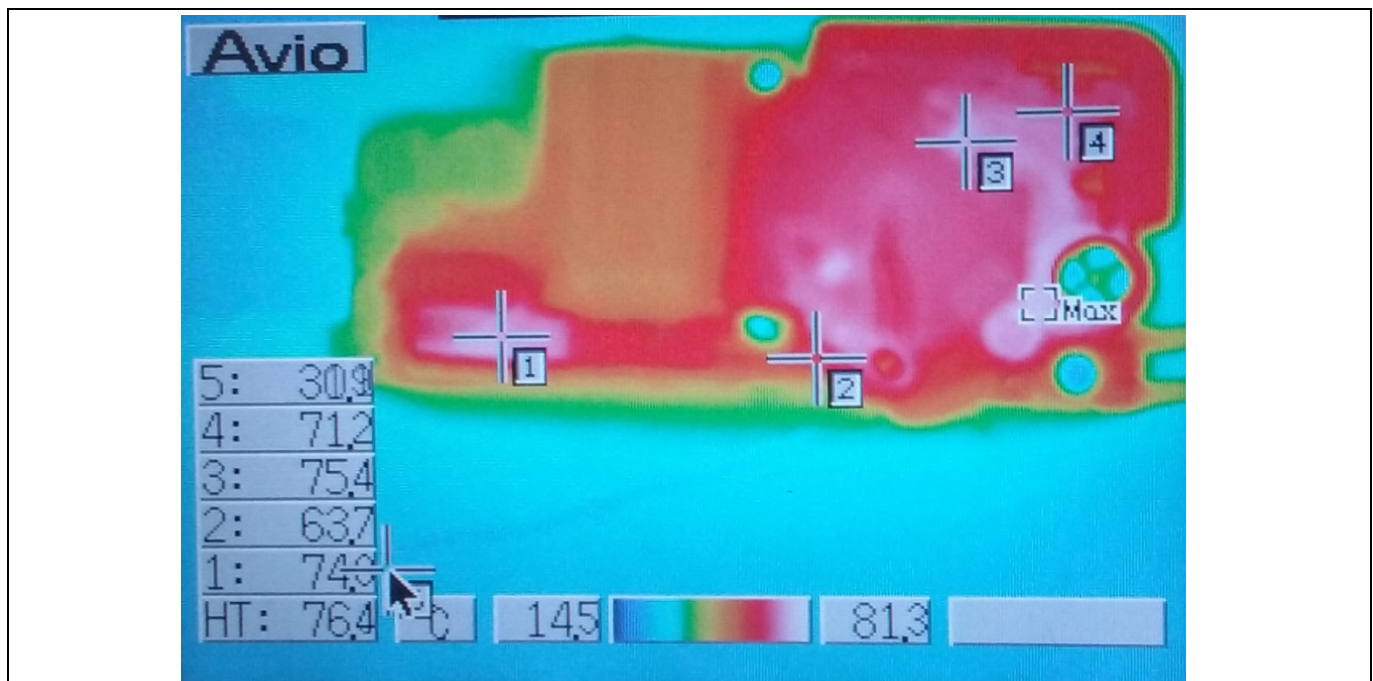
The surge immunity test was measured by a certified laboratory (NTEK Testing Technologies Co., Ltd) and met IEC61000-4-5. The demo board was set up at full load (45 W) with an input voltage of 230 V<sub>AC</sub>.  
Pass IEC61000-4-5 installation class 3; differential mode  $> \pm 1$  kV and common mode  $> \pm 2$  kV.

### 11.10 Thermal measurement

The reference adapter's open frame thermal test was performed with a thermal infrared camera (TVS-500EX) at an ambient temperature of 25°C. The thermal measurements were taken after one hour running at full load.

**Table 4 Thermal measurement of REF-45W ADAPTER**

| No. | Component            | 100 V <sub>AC</sub> & 45 W load (°C) |
|-----|----------------------|--------------------------------------|
| 1   | DB1 (Bridge diode)   | 74.0                                 |
| 2   | Q1 (Primary MOSFET)  | 63.7                                 |
| 3   | T1 (Transformer)     | 75.4                                 |
| 4   | D2 (Secondary diode) | 71.2                                 |
| 5   | Ambient              | 30.9                                 |



**Figure 20 Infrared thermal image of REF-45 W ADAPTER (PCB top side, 100 V<sub>AC</sub> & full load)**

## 12 Waveforms and scope plots

All waveforms and scope plots were recorded with a Lecroy Wavesurfer 24Xs-A.

### 12.1 Start up delay

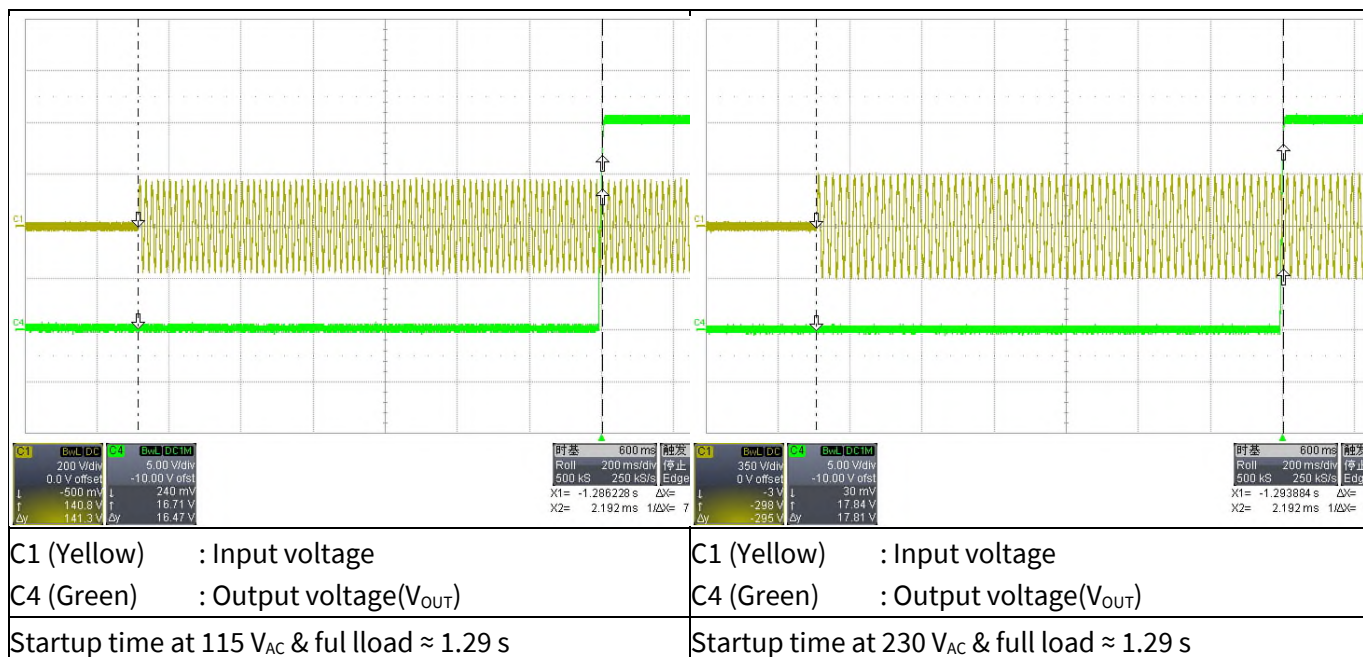


Figure 21 Start up delay

### 12.2 Output rise time

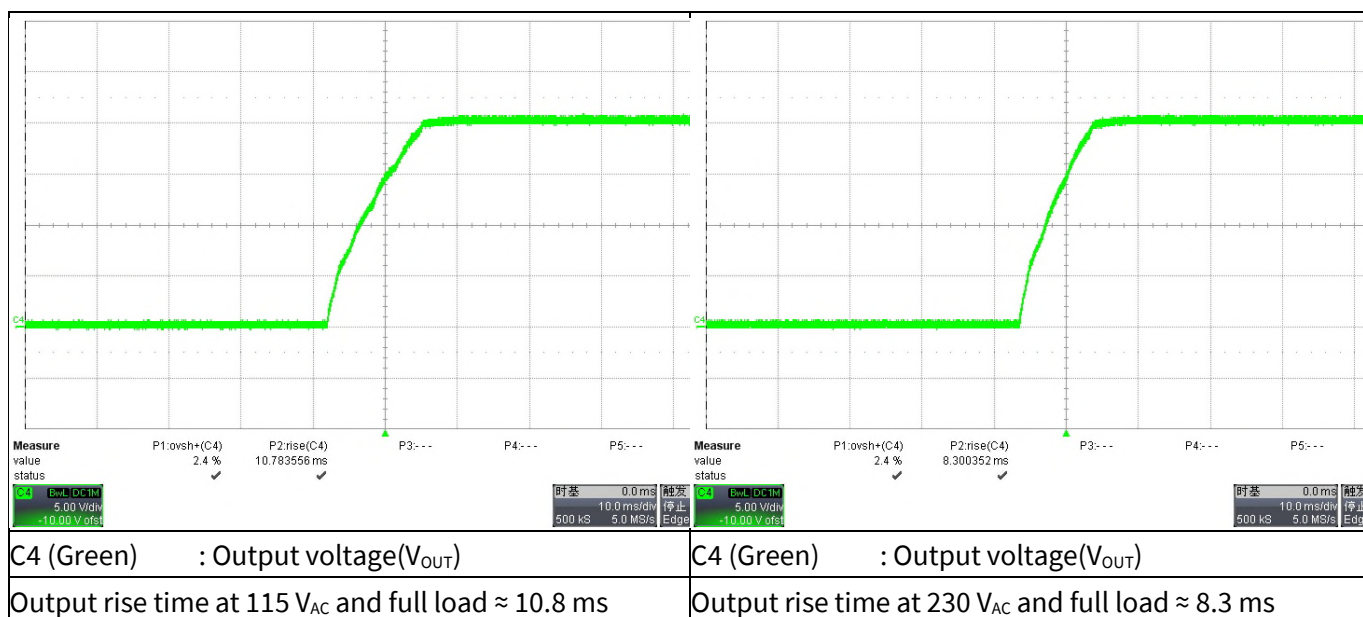


Figure 22 Output rise time



## Waveforms and scope plots

### 12.3 Voltage stress of main MOSFET and output diode at full load

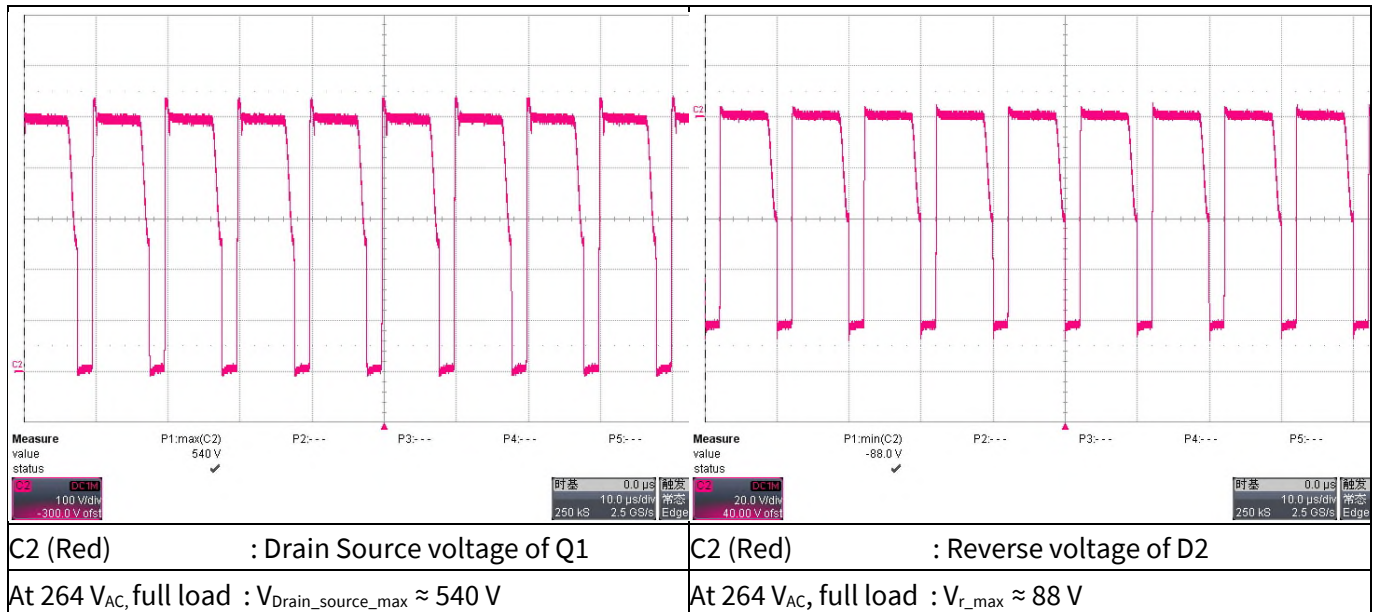


Figure 23 Drain and current sense voltage at full load

### 12.4 Load transient response (dynamic load)

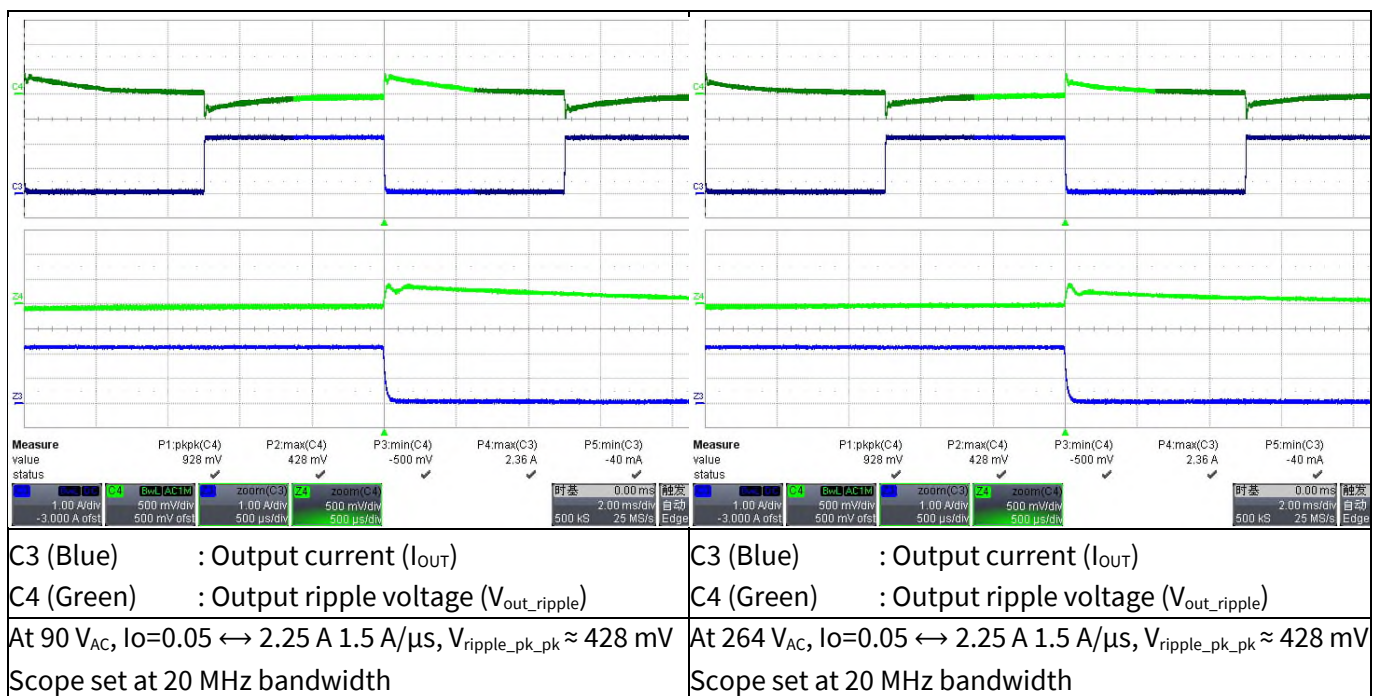


Figure 24 Load transient response

## Waveforms and scope plots

### 12.5 Output ripple voltage at full load

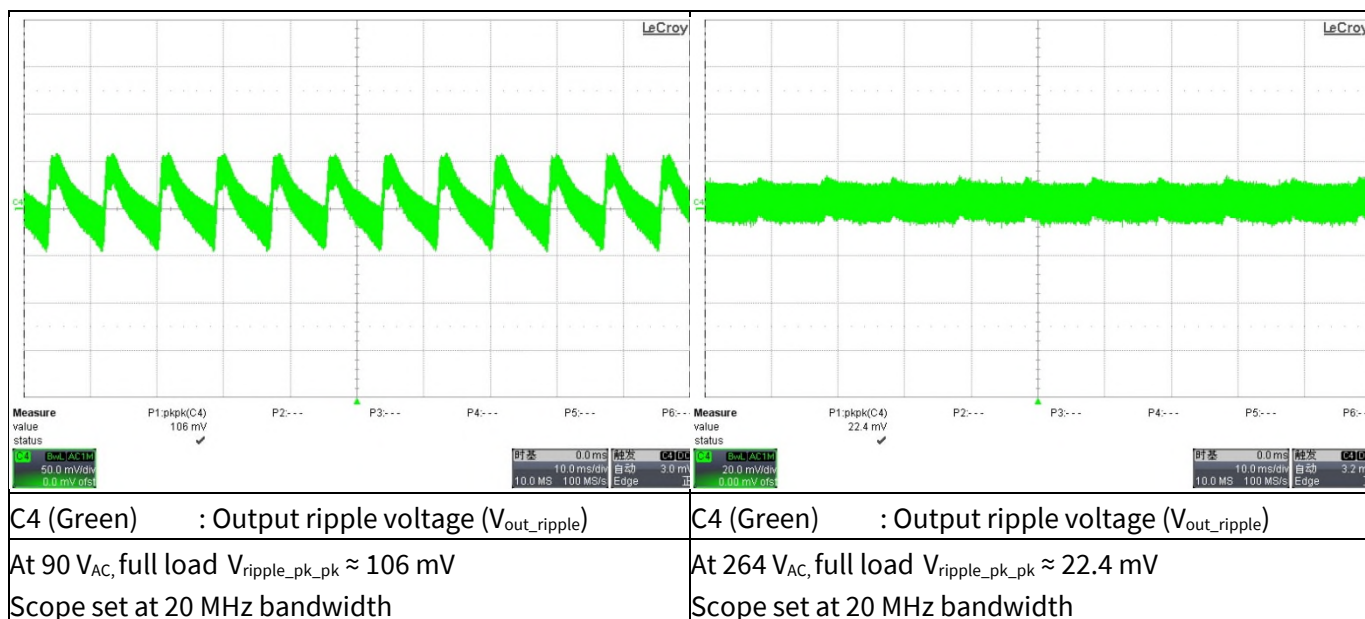


Figure 25 Output ripple voltage at full load

### 12.6 Output ripple voltage at no load (burst mode)

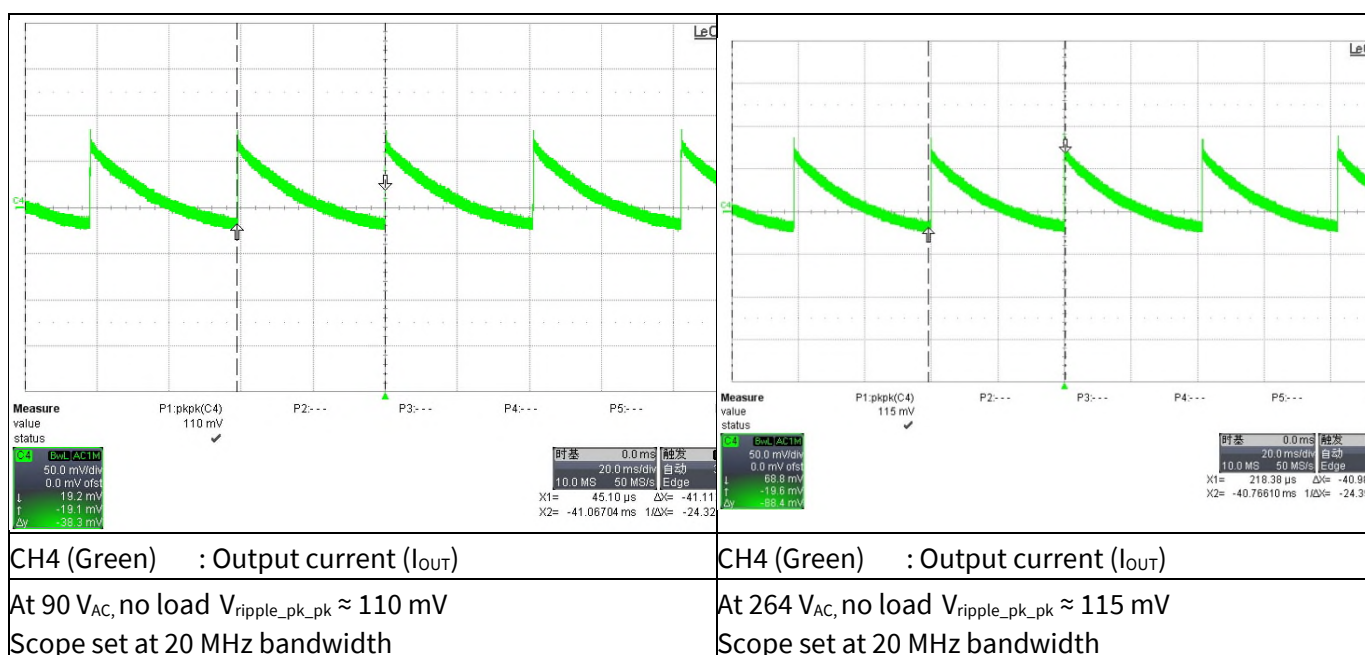


Figure 26 Output ripple voltage at no load (burst mode)

## Waveforms and scope plots

### 12.7 Active burst mode waveforms

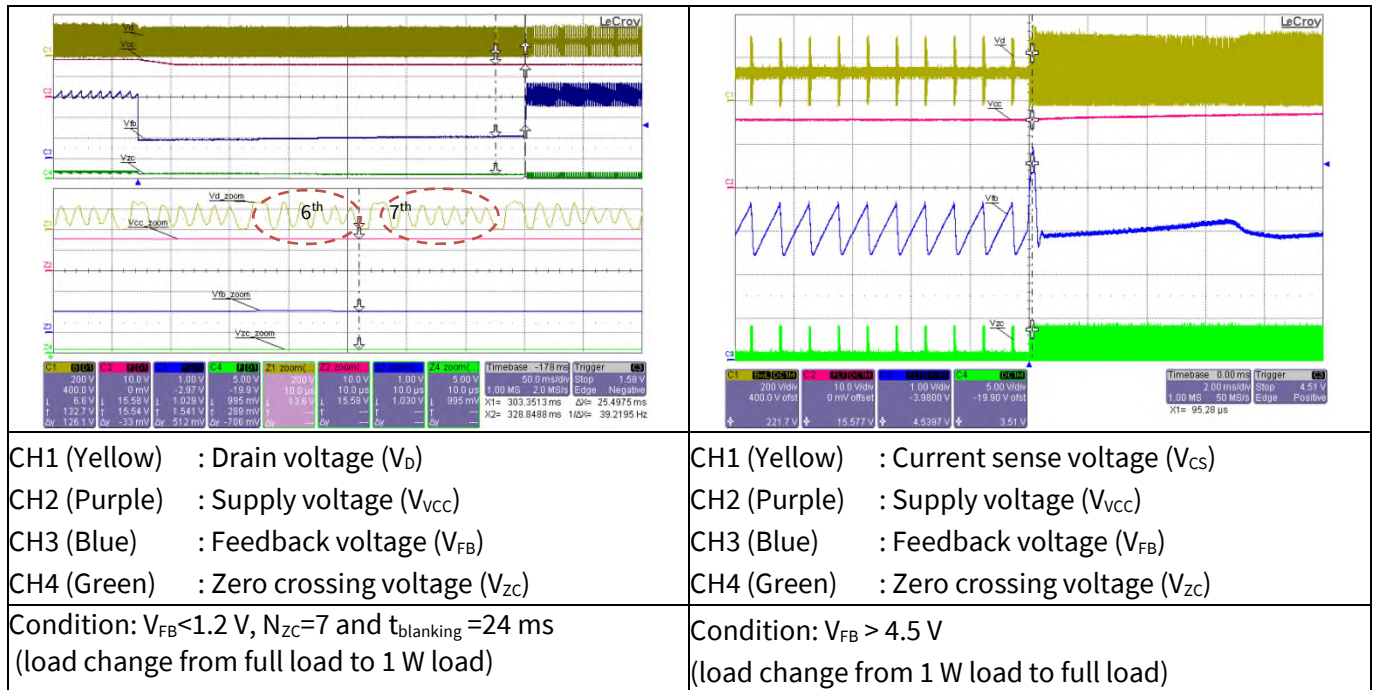


Figure 27 Active burst mode at 90 V<sub>AC</sub>

### 12.8 Over load protection (auto restart mode)

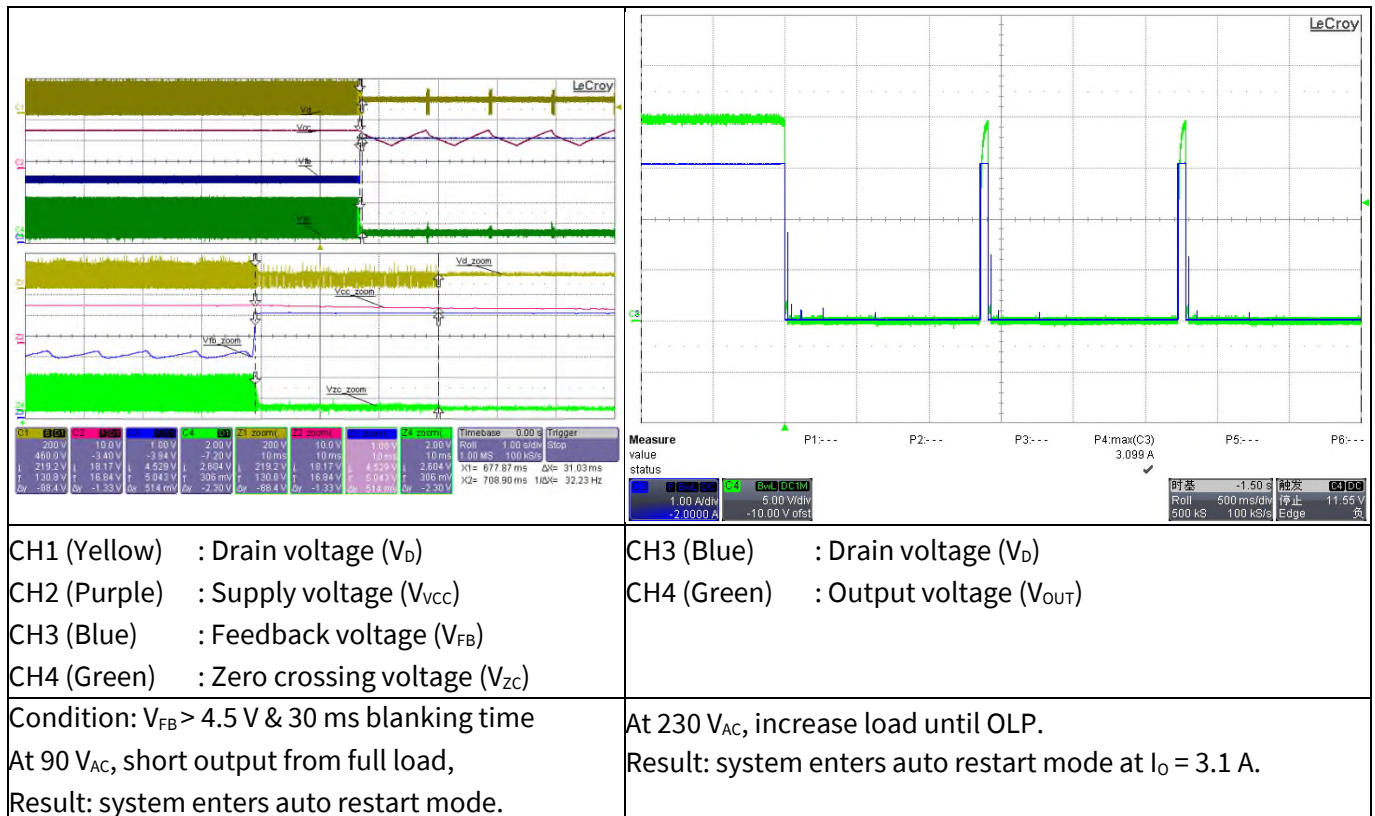


Figure 28 Over load protection



## 12.9 Output overvoltage protection (latched mode)

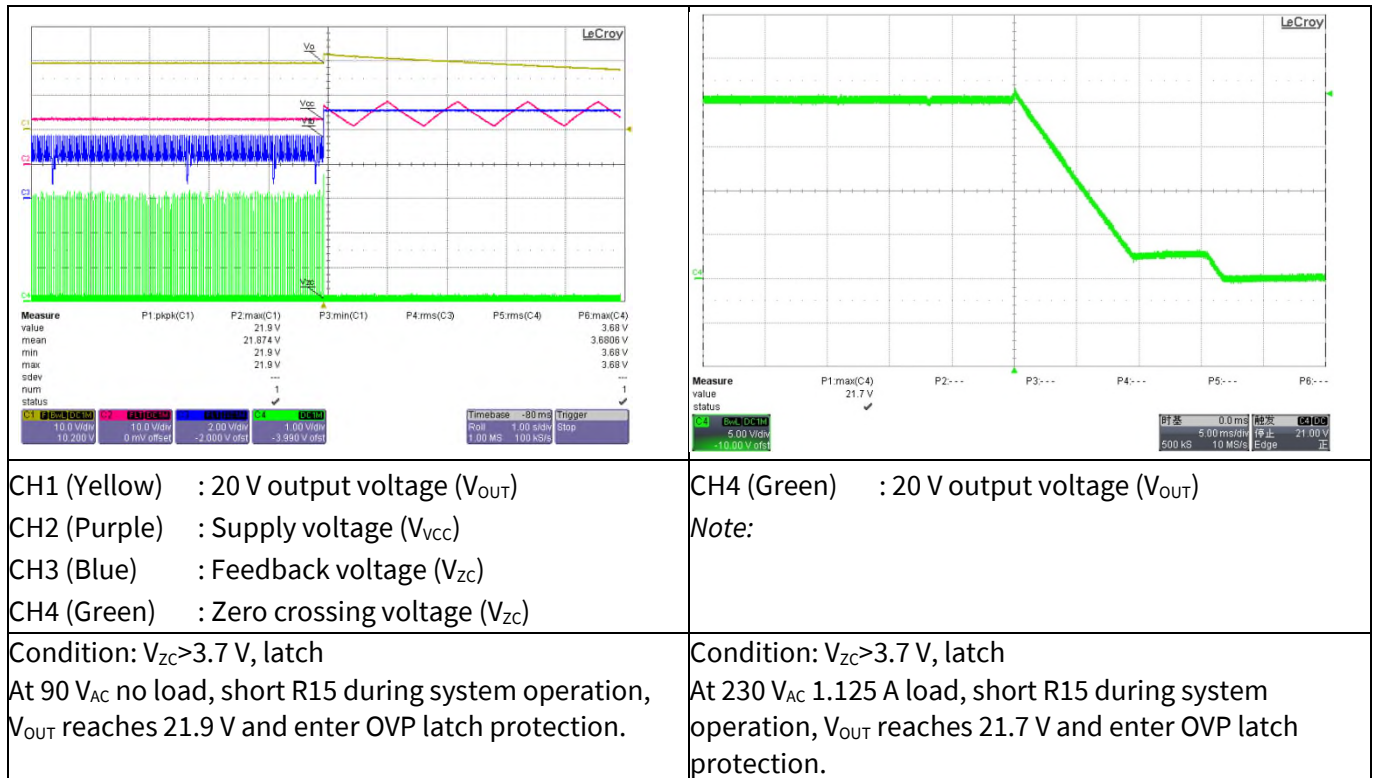


Figure 29 Output overvoltage protection

## 12.10 Brownin/brownout protection

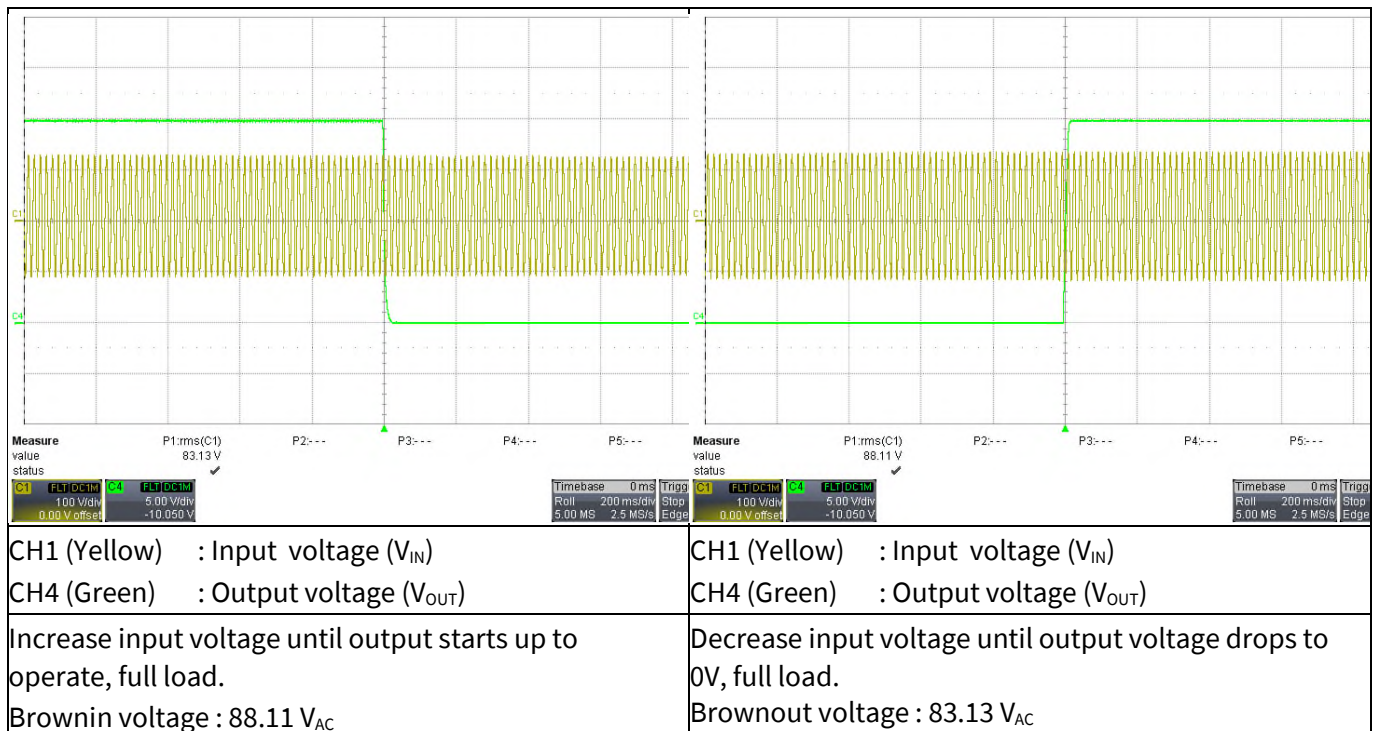


Figure 30 Brownin/brownout protection

## 13 References

- [1] [ICE2QS03G data sheet, Infineon Technologies AG](#)
- [2] [IPA60R650CE data sheet, 650V CoolMOS™ CE Power Transistor, Infineon Technologies AG](#)
- [3] [2N7002 data sheet, Infineon Technologies AG](#)
- [4] [BAS21-03W data sheet, Infineon Technologies AG](#)
- [5] [ICE2QS03G design guide. \[ANPS0027\]](#)

## Revision history

### Major changes since the last revision

| Page or reference | Description of change |
|-------------------|-----------------------|
| --                | First release         |
|                   |                       |
|                   |                       |

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AN\_REF\_201610\_PL21\_002

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**Адрес:** 198099, Санкт-Петербург,  
Промышленная ул, дом № 19, литера Н,  
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