# AN-REF-35W ADAPTER

## 35W 19V Adapter Reference Board with ICE2QS03G, IPD60R600P6 BAS21-03W & 2N7002

Application Note AN-REF-35W ADAPTER

V1.0, 2014-07-02

Power Management & Multimarket

**Edition 2014-07-02**
**Published by Infineon Technologies AG,**
**81726 Munich, Germany.**

## Revision History

**AN_201405_PL21_006**

**Major changes since previous revision**

| Date | Version | Changed By | Change Description |
|---|---|---|---|
| 2 Jul 2014 | 1.0 | Kyaw Zin Min | Release of final version |
| | | | |
| | | | |
| | | | |

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**ctdd@infineon.com**

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# 1 Abstract

This application note is an engineering report of a very small form factor reference design for universal input 35W 19V adapter. The adapter is using **ICE2QS03G**, a second generation current mode control quasi-resonant flyback topology controller and **IPD60R600P6**, a seventh generation of high voltage power CoolMOS™. The distinguishing features of this reference design are very small form factor, best in class low standby power, high efficiency, good EMI performance and various modes of protection for high 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 showed at the rear of the report.

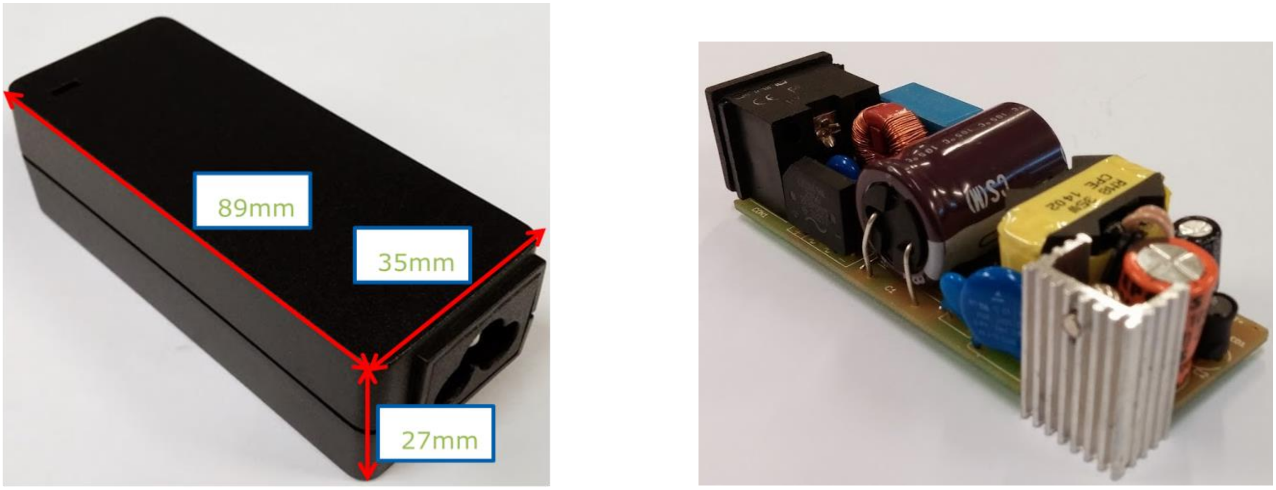



**Figure 1** – REF-ICE2QSO3G & IPD60R600P6 35W ADAPTER [Dimensions L x W x H: 89mm x 35mm x 27mm]


**Figure 2A** – REF-ICE2QSO3G & IPD60R600P6 35W ADAPTER (Top Side)

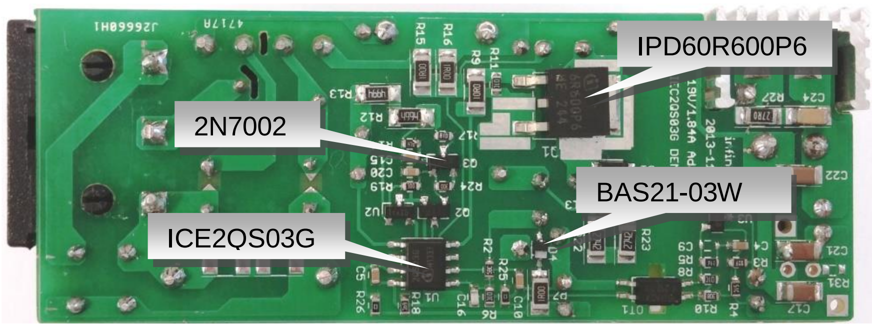



**Figure 2B** – REF-ICE2QSO3G & IPD60R600P6 35W ADAPTER (Bottom Side)

# 3 Technical specifications

| | |
|---|---|
| Input voltage | 90Vac~264Vac |
| Input frequency | 47~63Hz |
| Output voltage | 19V |
| Full load output current | 1.84A |
| Full load output power | 35W |
| Brownout detect/reset voltage @ full load | 80/87Vac |
| Output over voltage protection | 21~22V |
| Over current protection | 2.3~3.3A |
| No-load power consumption | <75mW (comply with EU CoC Version 5, Tier 2 and EPS of DOE USA) |
| Active mode four point average efficiency (25%,50%,75% & 100%load)<br><br>Active mode at 10% load efficiency | >88.22% (comply with EU CoC Version 5, Tier 2 and EPS of DOE USA)<br><br>>78.22% (comply with EU CoC Version 5, Tier 2) |
| Form factor case size (L x W x H) | (89 x 35 x 27) $mm^3$ |

# 4 List of features (ICE2QS03G)

| |
|---|
| Quasi resonant operation till very low load |
| Active burst mode operation at light/no load for low standby input power (< 100mW) |
| Digital frequency reduction with decreasing load |
| HV startup cell with constant charging current |
| Built-in digital soft-start |
| Foldback correction and cycle-by-cycle peak current limitation |
| Auto restart mode for VCC Overvoltage protection |
| Auto restart mode for VCC Undervoltage protection |
| Auto restart mode for Overload /Openloop protection |
| Auto restart mode for Over temperature protection |
| Latch-off mode for adjustable output overvoltage protection |
| Latch-off mode for Short Winding |

# 5 Circuit description

## 5.1 Mains Input Rectification and Filtering

The AC line input side comprises the input fuse F1 as over-current protection. The choke L2, X-capacitors C7 and Y-capacitor C11, C18 and C19 act as EMI suppressors. PCB spark gap and varistor VR1 can absorb high voltage stress during lightning surge test. After the bridge rectifier D3 and the input bulk capacitor C1, a voltage of 90 to 373 $V_{DC}$ is present which depends on input line voltage.

## 5.2 PWM Control and switching MOSFET

The PWM pulse is generated by the Quasi Resonant PWM current-mode Controller **ICE2QS03G** and this PWM pulse drives the high voltage power MOSFETs, **IPD60R600P6 (**CoolMOS™ **P6)**. P6 is Infineon's seventh generation of high voltage power MOSFETs designed according to the revolutionary Superjunction (SJ) principle. The new CoolMOS™ P6 series combines our experience as the leading SJ MOSFET supplier with innovation focusing on high efficiency solutions. The resulting P6 technology is tailored to provide high performance in hard & soft switching topologies while not sacrificing the ease of use. P6 achieves extremely low conduction and switching losses especially in light load condition enabling switching applications to work more efficient and be designed more compact, lighter and cooler. The PWM switch-on is determined by the zero-crossing input signal and the value of the up/down counter. The PWM switch-off is determined by the feedback signal $V_{FB}$ and the current sensing signal $V_{CS}$. **ICE2QS03G** also performs all necessary protection functions in flyback converters. Details about the information mentioned above are illustrated in the product datasheet.

## 5.3 Snubber Network

A snubber network R22, R23, C13 and D1 dissipate the energy of the leakage inductance and suppress ringing on the SMPS transformer. Due to the resonant capacitor (MOSFET's drain source capacitance), the overshoot is relatively smaller than fixed frequency flyback converter. Thus the snubber resistor can be used with a larger one which will reduce the snubber loss.

## 5.4 Output Stage

On the secondary side, 19V output, the power is coupled out via a schottky diode D2. The capacitors C2 provides energy buffering following with the LC filter L1 and C3 to reduce the output ripple and prevent interference between SMPS switching frequency and line frequency considerably. Storage capacitor C2 is designed to have an internal resistance (ESR) as small as possible. This is to minimize the output voltage ripple caused by the triangular current.

## 5.5 Feedback Loop

For feedback, the output is sensed by the voltage divider of R3 and R4 and compared to TL431 internal reference voltage. C4 and R5 comprise the compensation network. The output voltage of TL431 is converted to the current signal via optocoupler OT1 and two resistors R8 and R10 for regulation control.

# 6 Circuit Operation

## 6.1 Startup Operation

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

## 6.2 Normal Mode Operation

The secondary output voltage is built up after startup. The secondary regulation control is adopted with TL431 and optocoupler. The compensation network C4 and R5 constitutes the external circuitry of the error amplifier of TL431. This circuitry allows the feedback to be precisely controlled with respect to dynamically varying load conditions, therefore providing stable control.

## 6.3 Primary side peak current control

The MOSFET drain source current is sensed via external resistor R15 and R16. Since **ICE2QS03G** is a current mode controller, it would have a cycle-by-cycle primary current and feedback voltage control which can make sure the maximum power of the converter is controlled in every switching cycle.

## 6.4 Digital Frequency Reduction

During normal operation, the switching frequency for **ICE2QS03G** is digitally reduced with decreasing load. At light load, the CoolMOS™ **IPD60R600P6** will be turned on not at the first minimum drain-source voltage time, but on the nth. The counter is in range of 1 to 7, which depends on feedback voltage in a time-base. The feedback voltage decreases when the output power requirement decreases, and vice versa. Therefore, the counter is set by monitoring voltage $V_{FB}$. The counter will be increased with low $V_{FB}$ and decreased with high $V_{FB}$. The thresholds are preset inside the IC.

## 6.5 Burst Mode Operation

At light load condition, the SMPS enters into **Active Burst Mode**. At this stage, the controller is always active but the Vcc must be kept above the switch off threshold. During active burst mode, the efficiency increase significantly and at the same time it 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 is lower than the threshold of $V_{FBEB}$(1.219V). Accordingly, the peak current sense voltage across the shunt resistor is 0.1667;

2. The up/down counter is 7;

3. And a certain blanking time ($t_{BEB}$=24ms).

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

During active burst mode, the maximum current sense voltage is reduced from 1V to 0.34V so as to reduce the conduction loss and the audible noise. At the burst mode, the FB voltage is changing like a sawtooth between 3.0 and 3.6V.

The feedback voltage immediately increases if there is a high load jump. This is observed by one comparator. As the current limit is 34% during Active Burst Mode a certain load is needed so that feedback voltage can exceed VLB (4.19V). After leaving active burst mode, maximum current can now be provided to stabilize $V_O$. 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.

# 7 Protection Features

## 7.1 VCC over voltage and under voltage protection

During normal operation, the Vcc voltage is continuously monitored. When the Vcc voltage increases up to $V_{VCCOVP}$ or Vcc voltage falls below the under voltage lock out level $V_{VCCoff}$, the IC will enter into autorestart mode.

## 7.2 Over load/Open loop protection

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

## 7.3 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 switch and enters into auto restart. This can protect power MOSFET from overheated.

## 7.4 Adjustable output overvoltage protection

During 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 3.7V for a preset period 100µs, the IC is latched off.

## 7.5 Short winding protection

The source current of the MOSFET is sensed via external resistor R15 and R16. If the voltage at the current sensing pin is higher than the preset threshold $V_{CSSW}$ of 1.68V during the on-time of the power switch, the IC is latched off. This constitutes a short winding protection. To avoid an accidental latch off, a spike blanking time of 190ns is integrated in the output of internal comparator.

## 7.6 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 additional cost on transformer and output diode in case of output over power conditions.
The internal foldback protection is implemented to adjust the VCS voltage limit according to the bus voltage. Here, the input line voltage is sensed using the current flowing out of ZC pin, during the MOSFET on-time. As the result, the maximum current limit will be lower at high input voltage and the maximum output power can be well limited versus the input voltage.

## 7.7 AC line under voltage protection (Brownout mode) by external circuit

When the AC line input voltage is lower than the specified voltage range, brownout mode is detected by sensing the voltage level at U2 (TL431)'s REF pin ($V_{Ref\_Typ}$ =2.5V) through the voltage divider resistors (R12, R13, R14 and R17 in Fig.3) from bulk capacitor C1. Q2 acts as a switch to enter or leave brownout mode by controlling FB pin voltage. Q3 together with R17 act as voltage hysteresis for the brownout circuit and U2 (TL431) as a comparator. The system enters the brownout mode by controlling FB pin voltage of U1 to 0V (when the voltage level at $V_{Ref}$ drop down to 2.5V, then the MOSFET switch Q2 and Q3 on and $V_{FB}$ drop down to 0V). It is until the input level goes back to input voltage range, $V_{Ref}$ increase to 2.5V (then the switch Q2 and Q3 off) and the Vcc hits 18V, the brownout mode is released. The calculation for brownout circuit as below,

$$\mathrm{Vref} = 2.5\mathrm{V}$$

$$\mathrm{R12} = 4.99\mathrm{M\Omega} \qquad \mathrm{R13} = 4.99\mathrm{M\Omega} \qquad \mathrm{R14} = 301\mathrm{k\Omega} \qquad \mathrm{R17} = 681\mathrm{k\Omega}$$

$$\mathrm{Vbulkcap\_enterbrownout} = \frac{(\mathrm{R12} + \mathrm{R13} + \mathrm{R14}) \cdot \mathrm{Vref}}{\mathrm{R14}} \qquad \mathrm{Vbulkcap\_enterbrownout} = 85.39\mathrm{V}$$

$$\mathrm{Vbulkcap\_leavebrownout} = \frac{\left[\left(\frac{\mathrm{R14} \cdot \mathrm{R17}}{\mathrm{R14} + \mathrm{R17}}\right) + \mathrm{R12} + \mathrm{R13}\right] \cdot \mathrm{Vref}}{\left(\frac{\mathrm{R14} \cdot \mathrm{R17}}{\mathrm{R14} + \mathrm{R17}}\right)} \qquad \mathrm{Vbulkcap\_leavebrownout} = 122.028\mathrm{V}$$

# 8 Circuit diagram

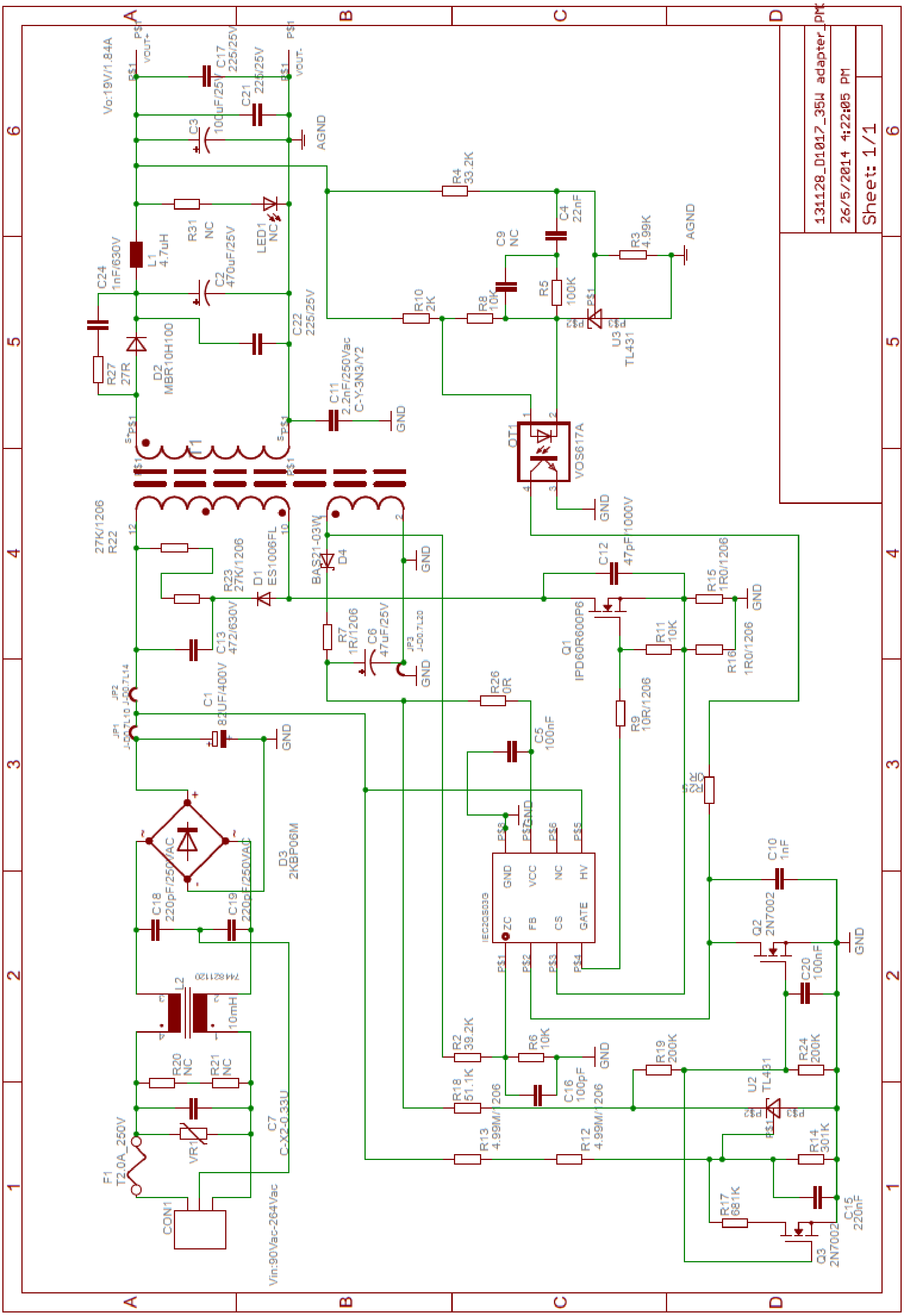


**Figure 3** – 35W 19V ICE2QSO3G power supply schematic

# 9 PCB layout

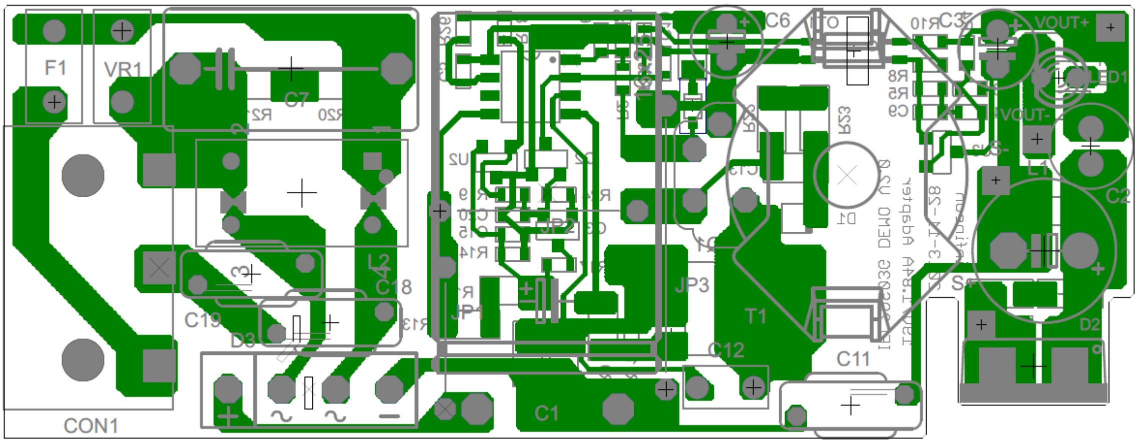



**Figure 4** – Bottom side copper and component legend

## 9.1 Top side

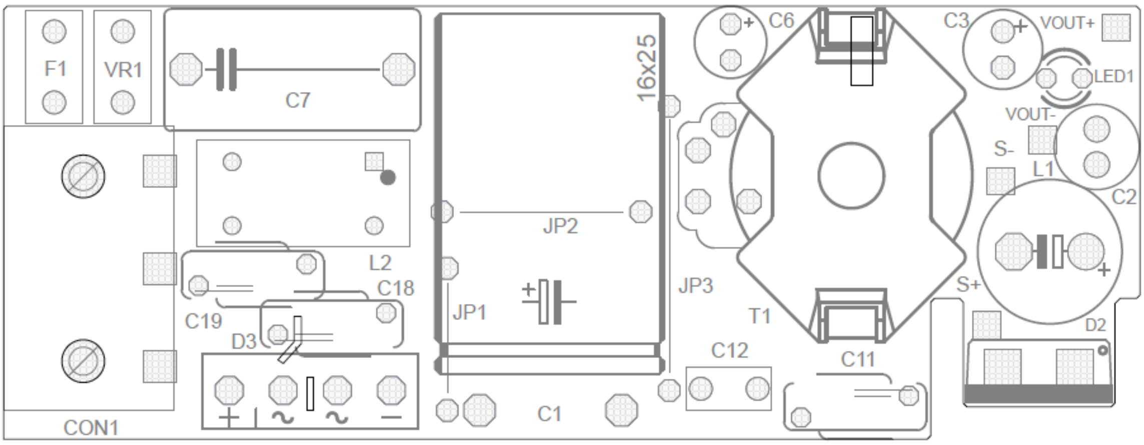



**Figure 5A** – Top side component legend

## 9.2 Bottom side

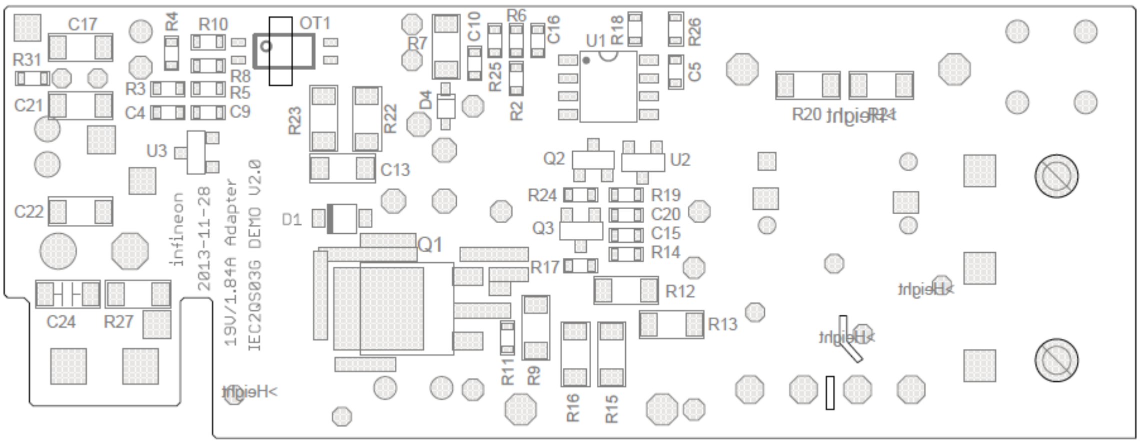



**Figure 5B** – Bottom side component legend

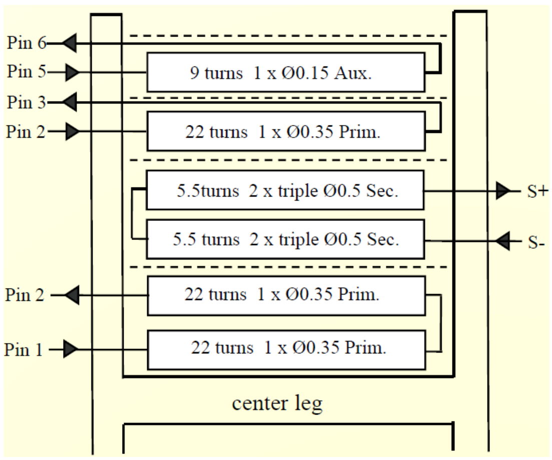
# 10 Component list

| No. | Reference | Part value | Supplier | Description | Package |
|---|---|---|---|---|---|
| 1 | C1 | E-CAP,82uF,400V,105℃ | | Electrolytic Cap | Φ18*25mm,P=10mm |
| 2 | C10 | 1nF/50V/X7R | MURATA | Chip Cap | 0603 |
| 3 | C11 | Y2 Cap,2.2nF/250Vac | | Ceramic Cap | 9*5mm,P=10mm |
| 4 | C12 | 47PF/1000V | | Chip Cap | 6*3mm P=4mm |
| 5 | C13 | 4.7nF/630V/X7R | MURATA | Chip Cap | 1206 |
| 6 | C15 | 220nF/16V/X7R | MURATA | Chip Cap | 0603 |
| 7 | C16 | 100pF/50V/X7R | MURATA | Chip Cap | 0603 |
| 8 | C17,C21,C22 | 2.2uF/25V/X7R | MURATA | Chip Cap | 1206 |
| 9 | C18,C19 | Y2 Cap,220pF/250Vac | | Ceramic Cap | 9*5mm,P=10mm |
| 10 | C2 | E-CAP,470uF,25V | EPCOS | Electrolytic Cap | Φ10*16mm,P=5.0mm |
| 11 | C24 | 1nF/630V/X7R | MURATA | Chip Cap | 1206 |
| 12 | C3 | E-CAP,100uF,25V | | Electrolytic Cap | Φ6.3*11.5mm,P=5.0mm |
| 13 | C4 | 22nF/X7R/50V | MURATA | Chip Cap | 0603 |
| 14 | C5,C20 | 100nF/X7R/50V | MURATA | Chip Cap | 0603 |
| 15 | C6 | 47uF/25V/105℃ | EPCOS | Electrolytic Cap | Φ5*10mm,P=2.5mm |
| 16 | C7 | X2 CAP,0.33uF,305VAC | EPCOS | X2 CAP | 6.0*12.0*13.0mm,P=10mm |
| 17 | C9 | NC | | Chip Cap | |
| 18 | D1 | ES1006FL | | Diode | SOD123 |
| 19 | D2 | 100V,10A,0.64V | | Diode | TO-220AC |
| 20 | D3 | 600V,2A,1.1V | | Bridge Rectifier | KBPM |
| 21 | D4 | 200V,250mA (**BAS21-03W**) | Infineon | Diode | SOD323 |
| 22 | F1 | T2.0A/250V | | Fuse | 8*4mm,P=5mm |
| 23 | JP1 | Φ0.6mm,L=10mm | | Jumper wire | |
| 24 | JP2 | Φ0.6mm,L=14mm | | Jumper wire | |
| 25 | JP3 | Φ0.6mm,L=20mm | | Jumper wire | |
| 26 | L1 | 4.7uH/4.2A, | Wurth | Inductance | Φ6*8.5mm,P=2.5mm |
| 27 | L2 | 10mH,350mohm,0.7A | Wurth | Inductance | 15mm*7.5mm*18mm |
| 28 | LED1 | NC | | LED | Φ3*mm,P=2.5mm |
| 29 | OT1 | PHOTOCOUPLER,VOS617A | | Optocoupler | |
| 30 | Q1 | N MOSFET,600V,0.6Ohm (**IPD60R600P6**) | Infineon | MOSFET | DPAK |
| 31 | Q2,Q3 | N MOSFET,60V,300mA,(**2N7002**) | Infineon | MOSFET | SOT23 |
| 32 | R3 | 4.99K/0603, ±1% | | Chip Resistor | 0603 |
| 33 | R10 | 2K/0603, ±1% | | Chip Resistor | 0603 |
| 34 | R12,R13 | 4.99M/1206, ±1% | | Chip Resistor | 1206 |
| 35 | R14 | 301K/0603, ±1% | | Chip Resistor | 0603 |
| 36 | R17 | 681K/0603, ±1% | | Chip Resistor | 0603 |
| 37 | R18 | 51.1K/0603, ±1% | | Chip Resistor | 0603 |
| 38 | R19,R24 | 200K/0603, ±1% | | Chip Resistor | 0603 |
| 39 | R2 | 39.2K/0603, ±1% | | Chip Resistor | 0603 |
| 40 | R20,R21,R31 | NC | | Chip Resistor | 0603 |
| 41 | R22,R23 | 27.4K/1206, ±1% | | Chip Resistor | 1206 |
| 42 | R25,R26 | 0/0603, ±1% | | Chip Resistor | 0603 |
| 43 | R27 | 27R/1206, ±1% | | Chip Resistor | 1206 |
| 44 | R4 | 33.2K/0603, ±1% | | Chip Resistor | 0603 |
| 45 | R5 | 100K/0603, ±1% | | Chip Resistor | 0603 |
| 46 | R6,R8,R11 | 10K/0603, ±1% | | Chip Resistor | 0603 |
| 47 | R7,R15,R16 | 1R0/1206, ±1% | | Chip Resistor | 1206 |

| | | | | | |
|---|---|---|---|---|---|
| 48 | R9 | 10R/1206, ±1% | | Chip Resistor | 1206 |
| 49 | T1 | RM-8 (N87) Lp=900 μH | EPCOS | Transformer | RM-8 |
| 50 | U1 | **ICE2QS03G** | Infineon | IC | SO-8 |
| 51 | U2,U3 | TL431 | | Regulator | SOT-23 |
| 52 | VR1 | S05K275, | EPCOS | Leaded varistors | 7*4.3mm,P=5mm |
| 53 | Heatsink | 22*15*10mm | | heatsink | |
| 54 | PCB | 80*30.5*1.6mm,one layer | | PCB | |
| 55 | Case | 89*35*27mm | | Case | |
| 56 | Connector input | The plum blossom socket,ST-A04 | | socket | |

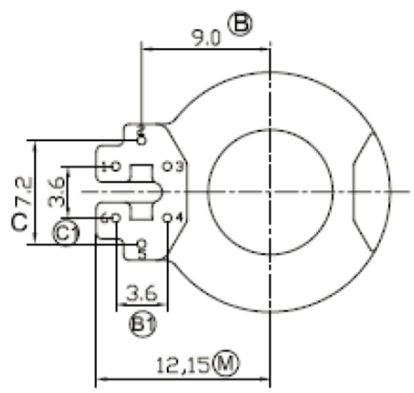
# 11 Transformer construction

Core and material: RM8 N87
Bobbin: RM8 with 6 pin
Primary Inductance, Lp=900 ±30 μH, measured between pin 1 and pin 3
Manufacturer and part number: EPCOS




1. S- in white teflon tube,S+ in black teflon tube
2. S- and S+ length 20mm,solder length 5mm
3. Cut pin 4 and pin 2
4. The outside of core need to parcel copper shield and connect pin 5

| Winding | Start | End | No.of Turns | Wire size | Layers | Method |
|---|---|---|---|---|---|---|
| N1 | 1 | 2 | 44 | 1 x Ø0.35 mm | 2/3 Primary | Tight |
| N2 | S- | S+ | 11 | 2 x triple Ø0.5 mm | Secondary | Tight |
| N3 | 2 | 3 | 22 | 1 x Ø0.35 mm | 1/3 Primary | Tight |
| N4 | 5 | 6 | 9 | 1 x Ø0.15 mm | Auxiliary | Tight |



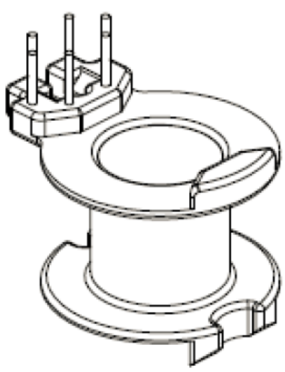



**Figure 6** – Transformer structure

# 12 Test results

## 12.1 Efficiency (without 0.11Ω cable)

| Vin(Vac) | Pin(W) | Vo(Vdc) | Io(A) | $V_{O\_ripple}$(mV) | Po(W) | η(%) | Average η (%) |
|---|---|---|---|---|---|---|---|
| 90 | 0.04360 | 19.03 | 0.000 | 96.40 | 0.00 | | |
| | 4.31000 | 19.04 | 0.184 | 15.00 | 3.50 | 81.28 | |
| | 9.92000 | 19.04 | 0.460 | 27.20 | 8.76 | 88.29 | 88.35 |
| | 19.82000 | 19.04 | 0.920 | 46.30 | 17.52 | 88.38 | |
| | 29.70000 | 19.04 | 1.380 | 34.60 | 26.28 | 88.47 | |
| | 39.71000 | 19.05 | 1.840 | 72.10 | 35.05 | 88.27 | |
| 115 | 0.04600 | 19.03 | 0.000 | 99.80 | 0.00 | 0.00 | |
| | 4.34000 | 19.04 | 0.184 | 15.80 | 3.50 | 80.72 | |
| | 9.90000 | 19.04 | 0.460 | 25.40 | 8.76 | 88.47 | 89.09 |
| | 19.66000 | 19.04 | 0.920 | 49.60 | 17.52 | 89.10 | |
| | 29.48000 | 19.04 | 1.380 | 33.50 | 26.28 | 89.13 | |
| | 39.10000 | 19.05 | 1.840 | 42.70 | 35.05 | 89.65 | |
| 230 | 0.05938 | 19.03 | 0.000 | 98.00 | 0.00 | 0.00 | |
| | 4.21000 | 19.04 | 0.184 | 144.10 | 3.50 | 83.22 | |
| | 10.12000 | 19.04 | 0.460 | 22.30 | 8.76 | 86.55 | 88.99 |
| | 19.64000 | 19.04 | 0.920 | 39.60 | 17.52 | 89.19 | |
| | 29.32000 | 19.04 | 1.380 | 29.60 | 26.28 | 89.62 | |
| | 38.68000 | 19.05 | 1.840 | 32.10 | 35.05 | 90.62 | |
| 264 | 0.06720 | 19.03 | 0.000 | 100.60 | 0.00 | 0.00 | |
| | 4.21000 | 19.04 | 0.184 | 131.90 | 3.50 | 83.22 | |
| | 10.24000 | 19.04 | 0.460 | 21.80 | 8.76 | 85.53 | 88.49 |
| | 19.74000 | 19.04 | 0.920 | 39.70 | 17.52 | 88.74 | |
| | 29.42000 | 19.04 | 1.380 | 36.80 | 26.28 | 89.31 | |
| | 38.79000 | 19.05 | 1.840 | 31.10 | 35.05 | 90.36 | |

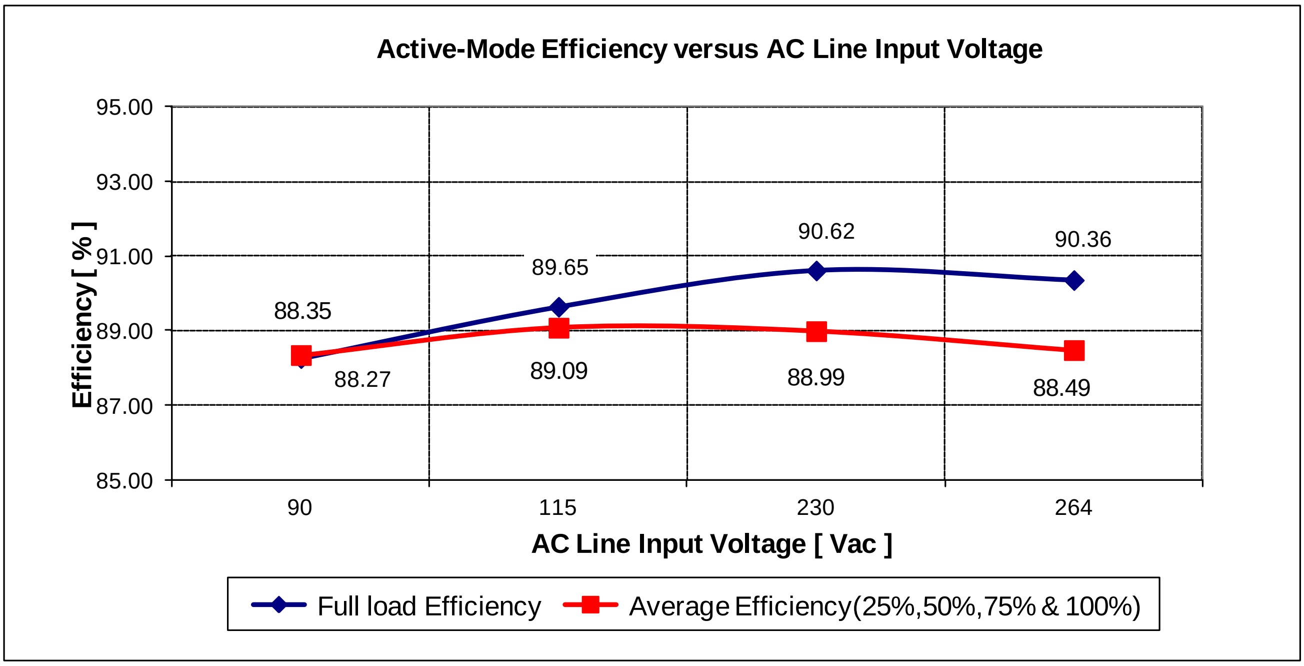



**Figure 7** – Efficiency vs AC line input voltage

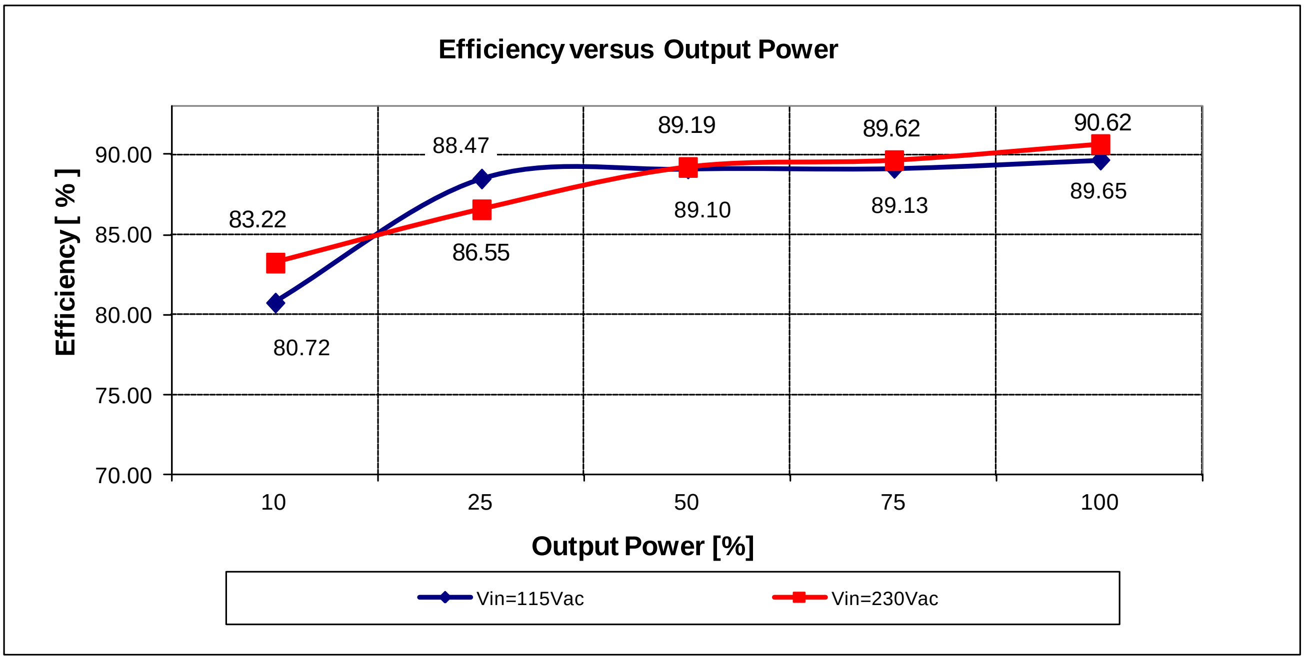



**Figure 8** – Efficiency vs output power @ low and high line

## 12.2 Input standby power

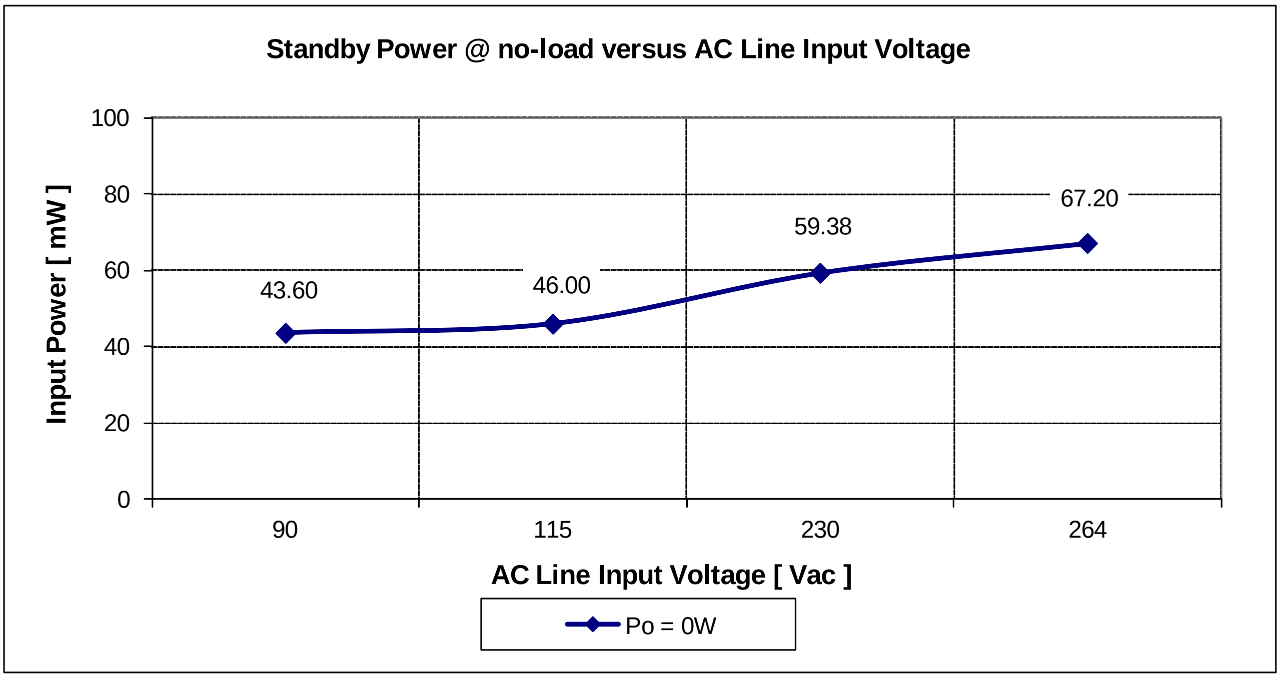



**Figure 9** – Input standby power @ no load vs AC line input voltage (measured by Yokogawa WT210 power meter - integration mode)

## 12.3 Line regulation

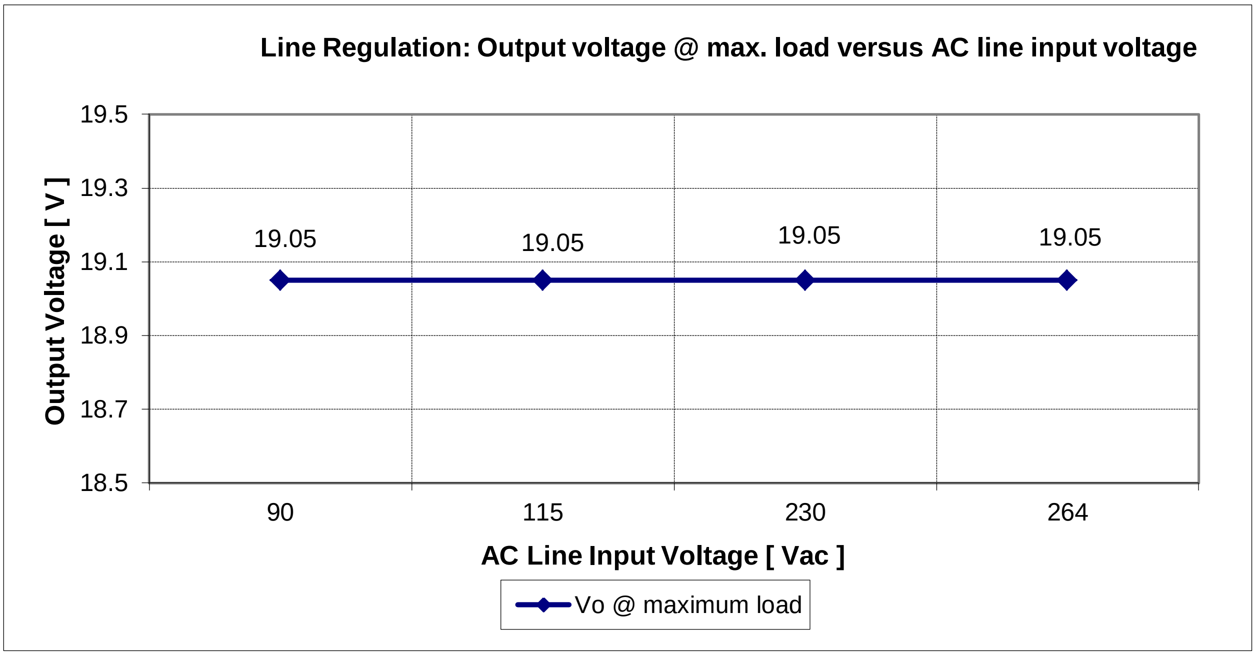



**Figure 10** – Line regulation Vo @ full load vs AC line input voltage

## 12.4 Load regulation

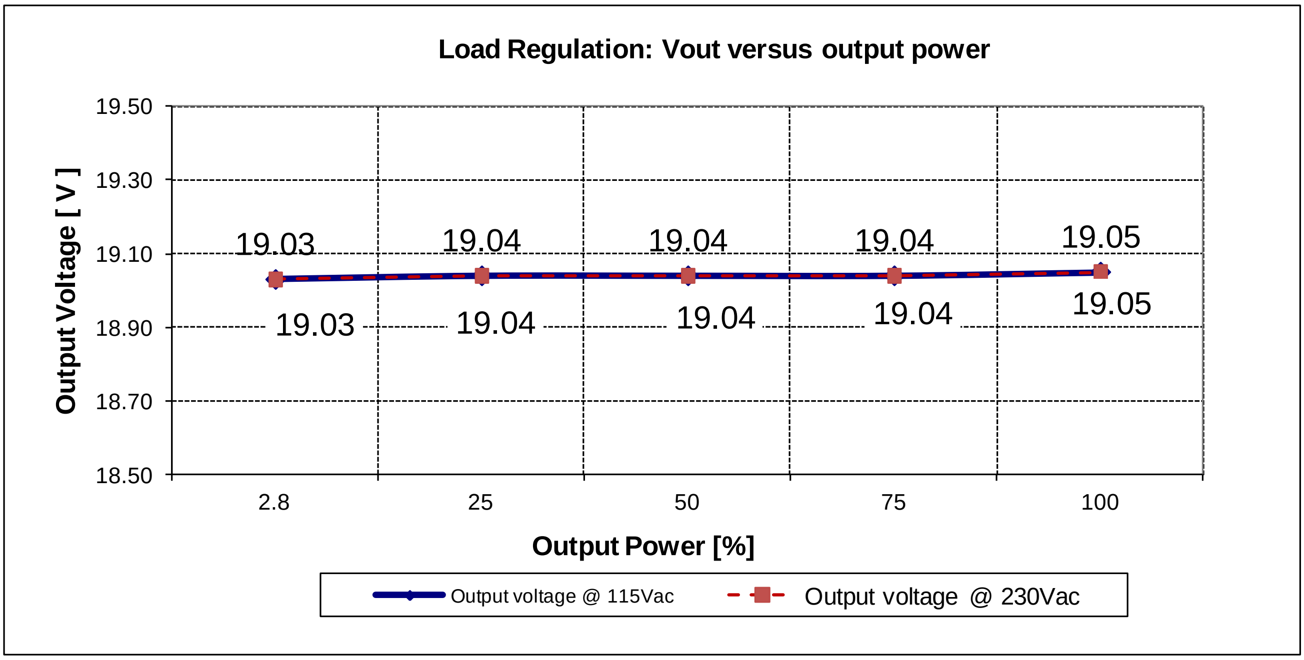



**Figure 11** – Load regulation Vo vs output power

## 12.5 Maximum power

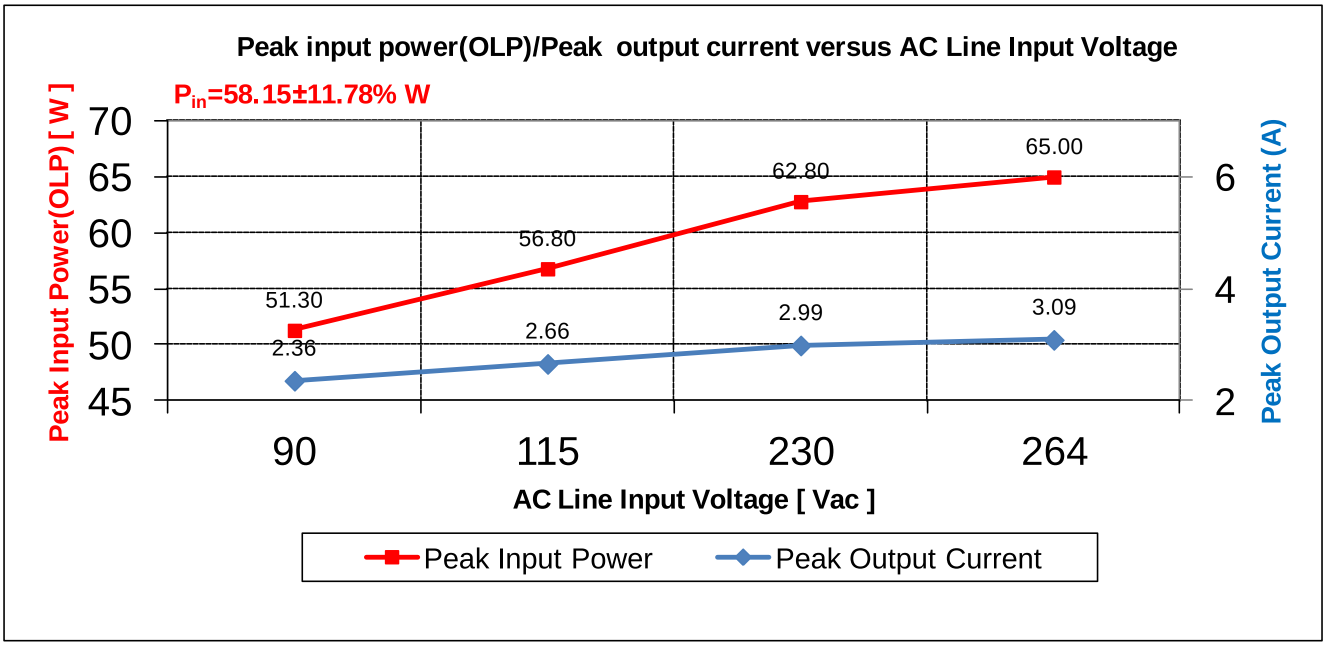



**Figure 12** – Maximum output power (before over-load protection) vs AC line input voltage

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

Pass EN61000-4-2 level 3 (±6kV) contact discharge

## 12.7 Electrical fast transient / Burst immunity (EN61000-4-4)

Pass EN61000-4-4 level 3 (±2kV)
(Note: output common is connected to ground during test)

## 12.8 Surge immunity (EN61000-4-5)

Pass EN61000-4-5 Installation class 3 (1kV: differential mode & 2kV: common mode)
(Note: output common is connected to ground during test)

## 12.9 Conducted emissions (EN55022 class B)

The conducted EMI was measured by Schaffner (SMR4503) and followed the test standard of EN55022 (CISPR 22) class B. The demo board was set up at maximum load (35W) with input voltage of 115Vac and 230Vac.

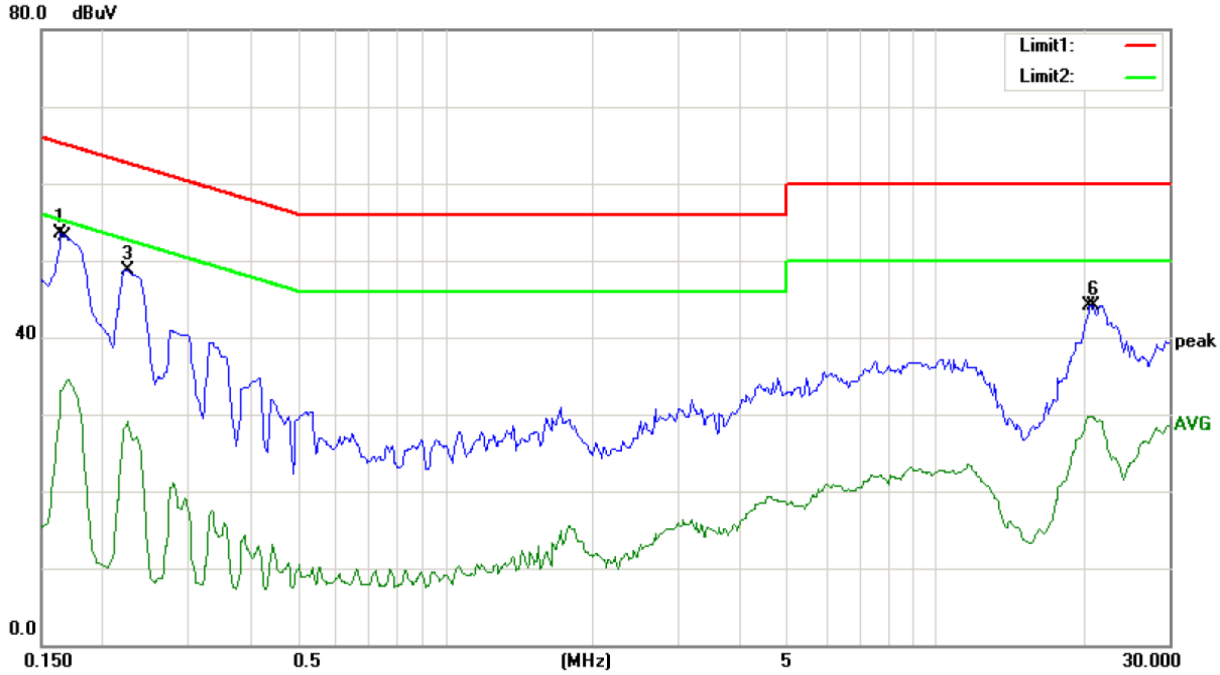



**Figure 13** – Max. Load (35W) with 115 Vac (Line)

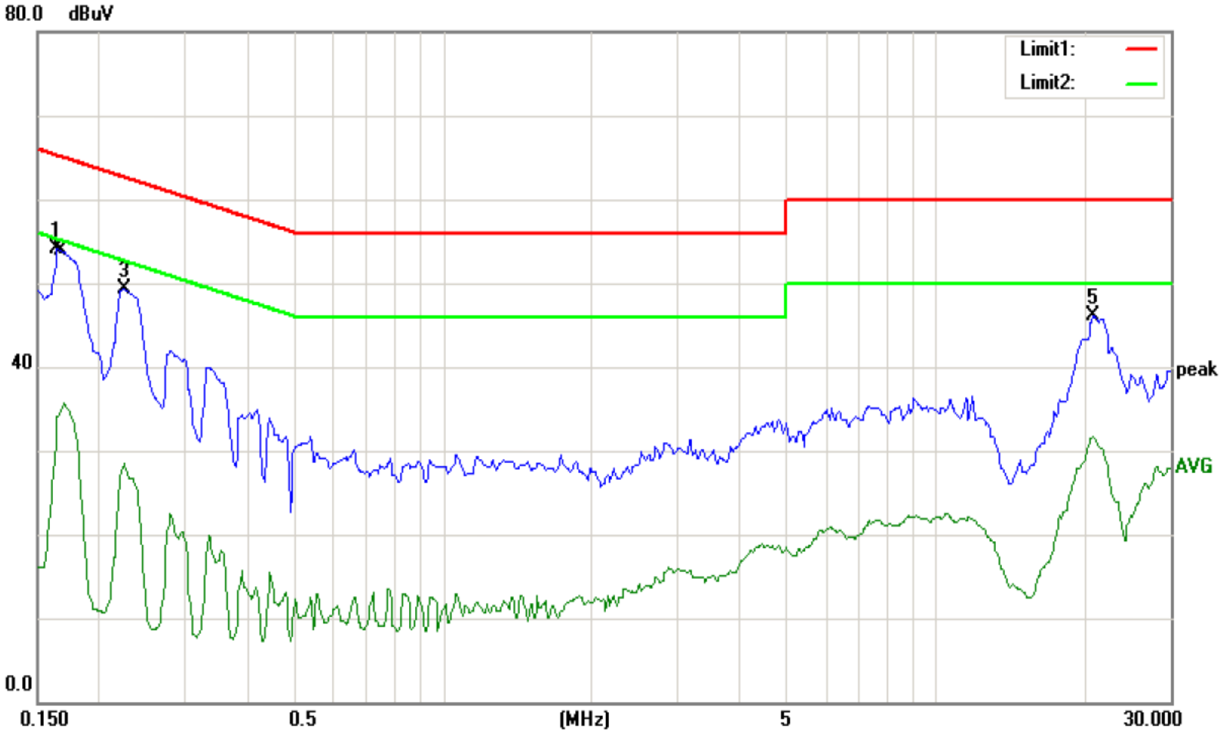



**Figure 14** – Max. Load (35W) with 115 Vac (Neutral)

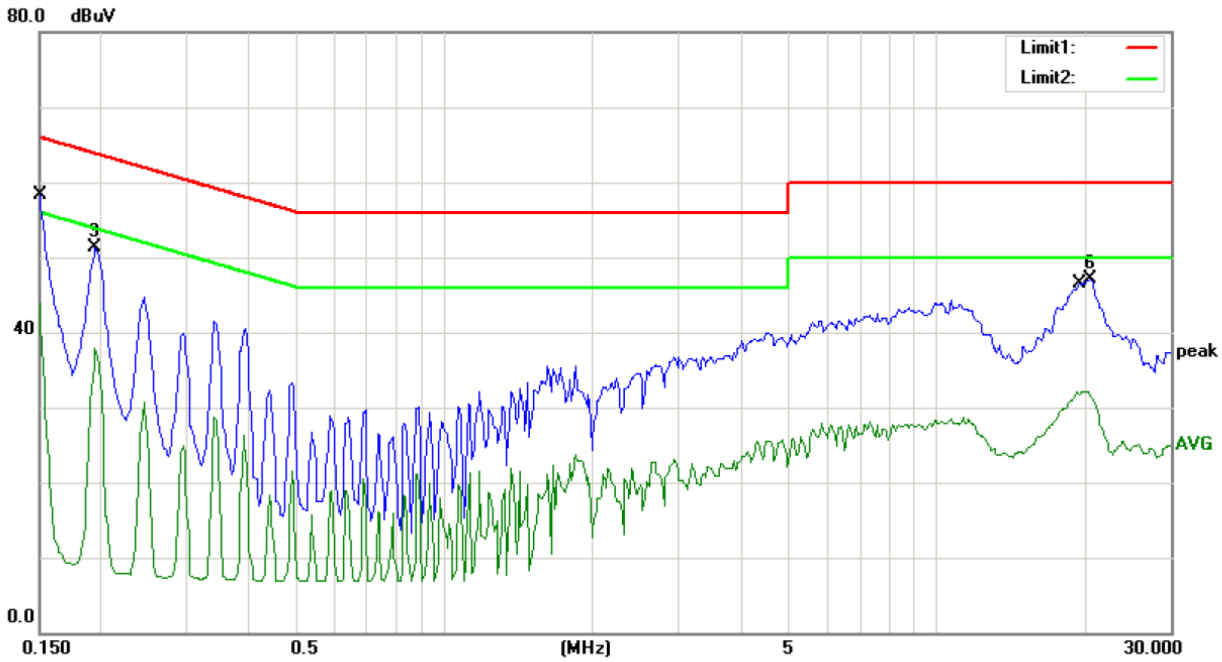



**Figure 15** – Max. Load (35W) with 230 Vac (Line)

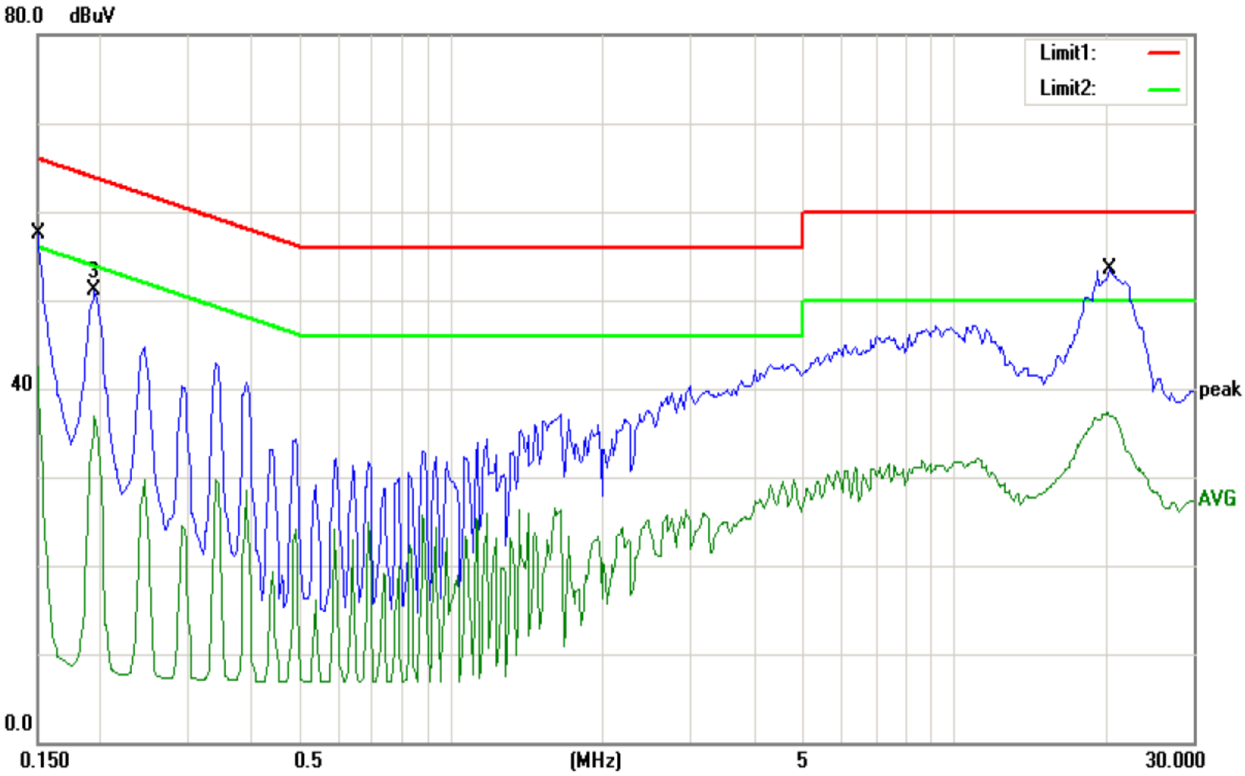


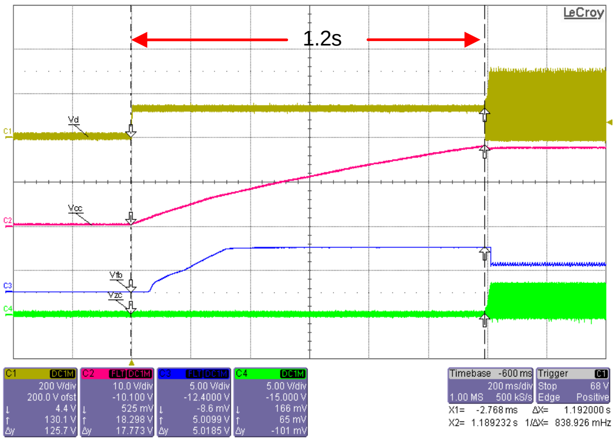

**Figure 16** – Max. Load (35W) with 230 Vac (Neutral)

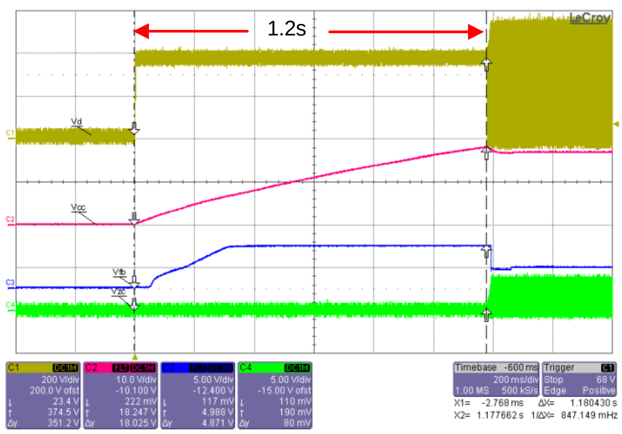
Pass EN55022 class B conducted emissions with > 10dB margin for QP.

# 13 Waveforms and scope plots

All waveforms and scope plots were recorded with a LeCroy 6050 oscilloscope

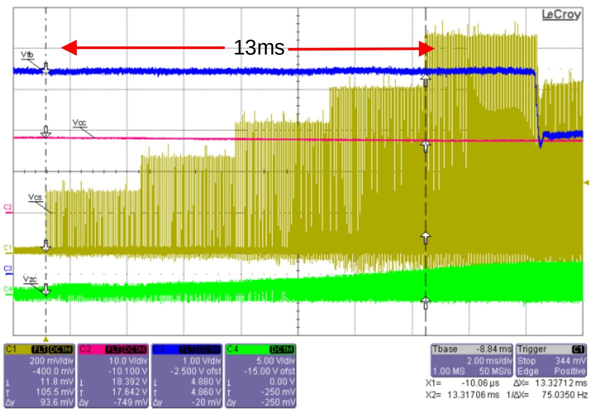
## 13.1 Start up at low/high AC line input voltage with maximum load



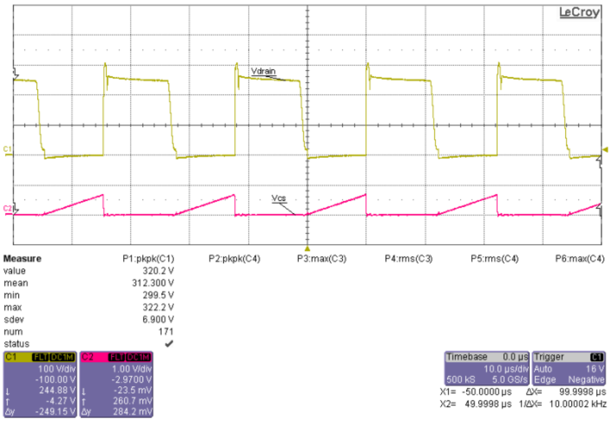

| | |
|---|---|
| Channel 1; C1 : Drain voltage ($V_{Drain}$)<br>Channel 2; C2 : Supply voltage ($V_{CC}$)<br>Channel 3; C3 : Feedback voltage ($V_{FB}$)<br>Channel 4; C4 : Zero crossing voltage ($V_{ZC}$) | Channel 1; C1 : Drain voltage ($V_{Drain}$)<br>Channel 2; C2 : Supply voltage ($V_{CC}$)<br>Channel 3; C3 : Feedback voltage ($V_{FB}$)<br>Channel 4; C4 : Zero crossing voltage ($V_{ZC}$) |
| Startup time = 1.2s | Startup time = 1.2s |
| **Figure 17** – Startup @ 90Vac & max. load | **Figure 18** – Startup @ 264Vac & max. load |

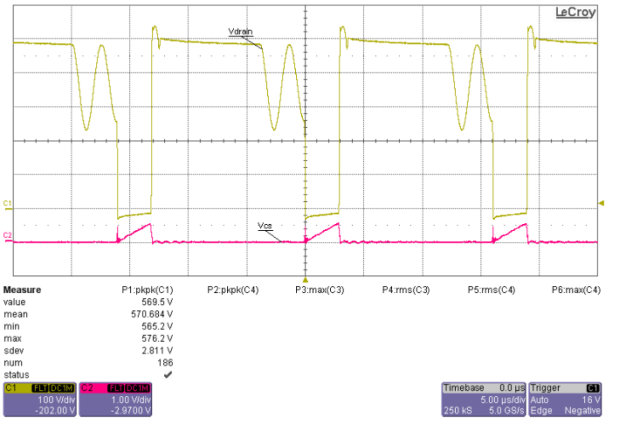
## 13.2 Soft start




| |
|---|
| Channel 1; C1 : Current sense voltage ($V_{CS}$)<br>Channel 2; C2 : Supply voltage ($V_{CC}$)<br>Channel 3; C3 : Feedback voltage ($V_{FB}$)<br>Channel 4; C4 : Zero crossing voltage ($V_{ZC}$) |
| Soft Star time = 13ms |
| **Figure 19** – Soft Start @ 90Vac & max. load |

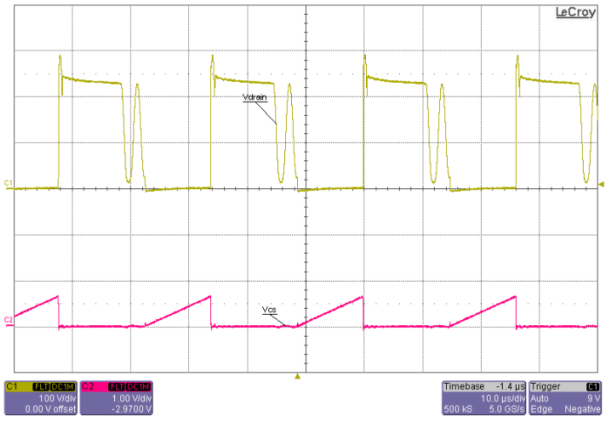
## 13.3 Drain voltage and current at maximum load

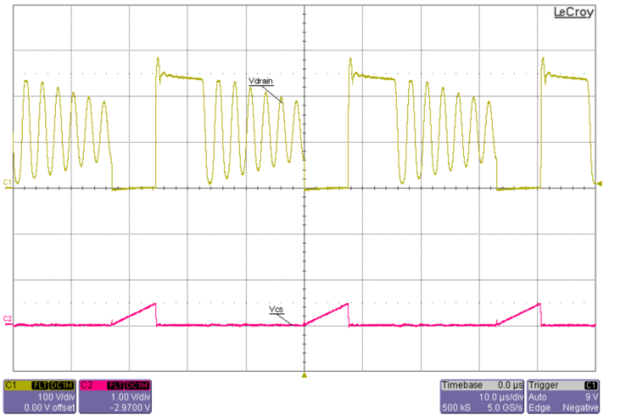



| | |
|---|---|
| Channel 1; C1 : Drain voltage ($V_{Drain}$)<br>Channel 2; C2 : Current sense voltage ($V_{CS}$) | Channel 1; C1 : Drain voltage ($V_{Drain}$)<br>Channel 2; C2 : Current sense voltage ($V_{CS}$) |
| $V_{Drain\_peak}$ = 322V | $V_{Drain\_peak}$ = 576V |
| **Figure 20** – Operation @ 90Vac and max. load | **Figure 21** – Operation @ 264Vac and max. load |

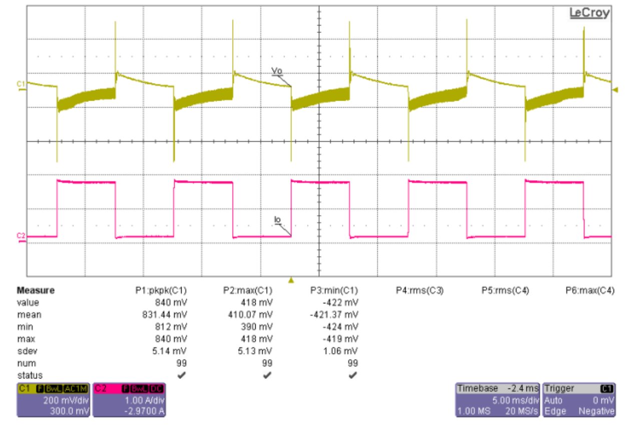
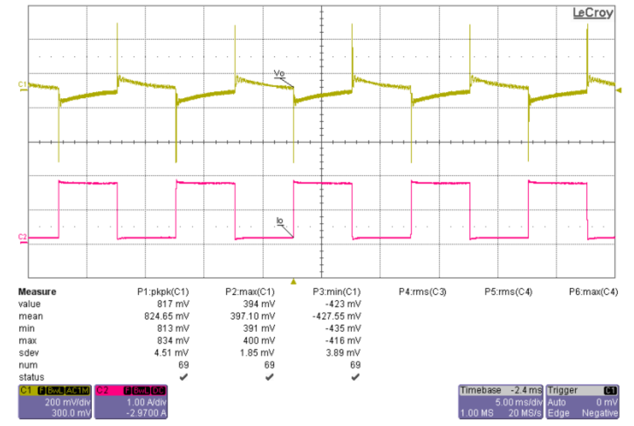
## 13.4 Zero crossing point during normal operation



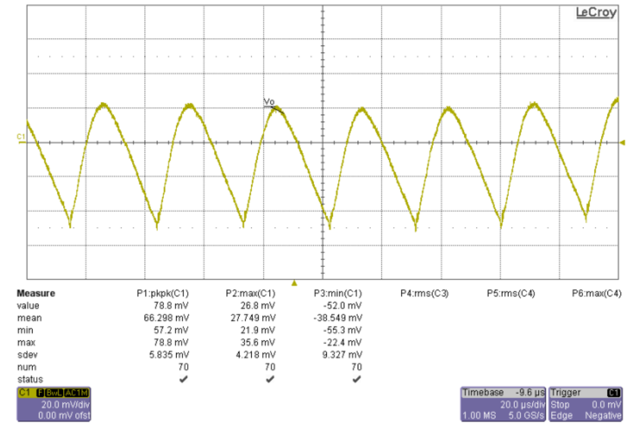
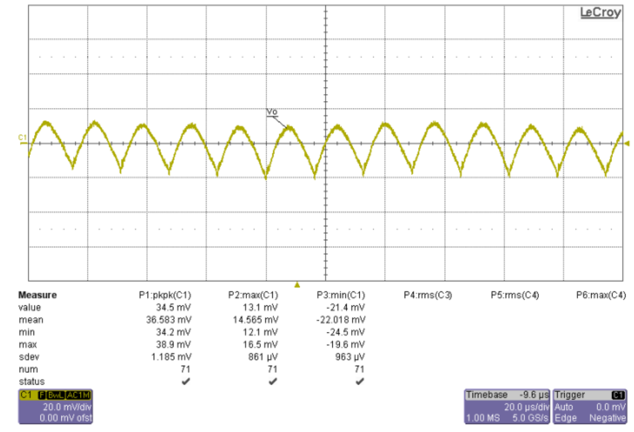




| | |
|---|---|
| Channel 1; C1 : Drain voltage ($V_{Drain}$)<br>Channel 2; C2 : Current sense voltage ($V_{CS}$) | Channel 1; C1 : Drain voltage ($V_{Drain}$)<br>Channel 2; C2 : Current sense voltage ($V_{CS}$) |
| **Figure 22** – Operation @ 90Vac and 2$^{nd}$ zero crossing | **Figure 23** – Operation @ 90Vac and 7$^{th}$ zero crossing |

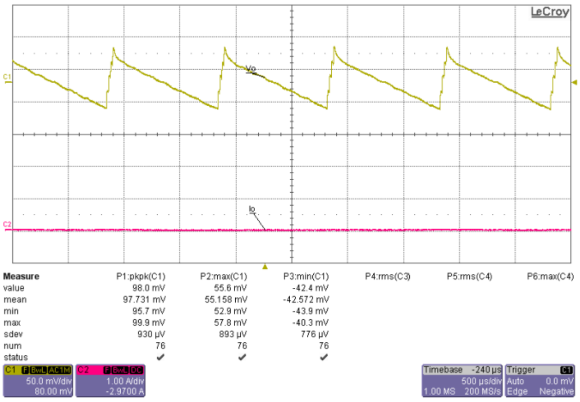
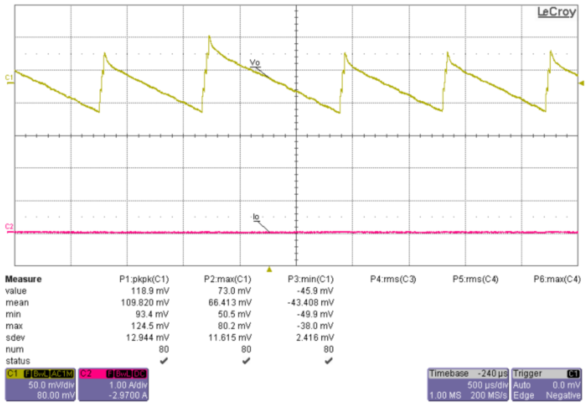
## 13.5 Load transient response (Dynamic load from 10% to 100%)

| | |
|---|---|
|  |  |
| Channel 1; C1 : Output ripple voltage (Vo)<br>Channel 2; C2 : Output current (Io) | Channel 1; C1 : Output ripple voltage (Vo)<br>Channel 2; C2 : Output current (Io) |
| $V_{ripple\_pk\_pk}$=840mV (Load change from10% to 100%,100Hz,0.4A/μS slew rate)<br>Probe terminal end with decoupling capacitor of 0.1μF(ceramic) & 1μF(Electrolytic), 20MHz filter | $V_{ripple\_pk\_pk}$=834mV (Load change from10% to 100%,100Hz,0.4A/μS slew rate)<br>Probe terminal end with decoupling capacitor of 0.1μF(ceramic) & 1μF(Electrolytic), 20MHz filter |
| **Figure 24** – Load transient response @ 90Vac | **Figure 25** – Load transient response @ 264Vac |

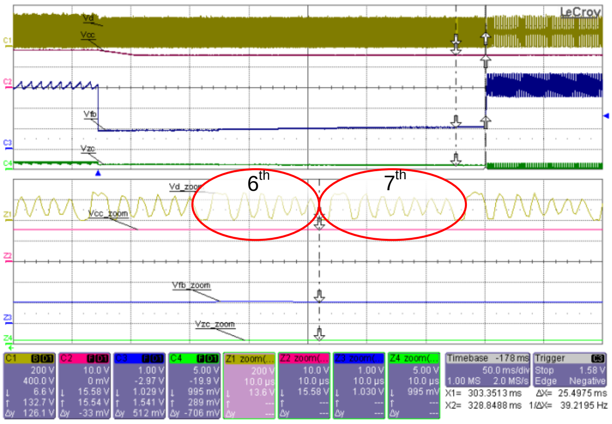
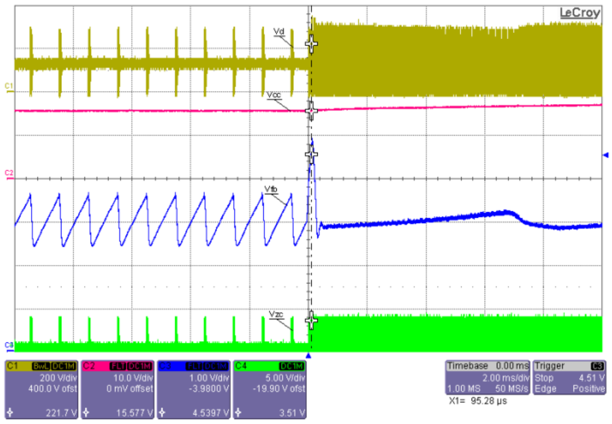
## 13.6 Output ripple voltage at maximum load

| | |
|---|---|
|  |  |
| Channel 1; C1 : Output ripple voltage (Vo) | Channel 1; C1 : Output ripple voltage (Vo) |
| $V_{ripple\_pk\_pk}$=78.8mV<br>Probe terminal end with decoupling capacitor of 0.1μF(ceramic) & 1μF(Electrolytic), 20MHz filter | $V_{ripple\_pk\_pk}$ = 38.9mV<br>Probe terminal end with decoupling capacitor of 0.1μF(ceramic) & 1μF(Electrolytic), 20MHz filter |
| **Figure 26** – AC output ripple @ 90Vac and max. load | **Figure 27** – AC output ripple @ 264Vac and max. load |

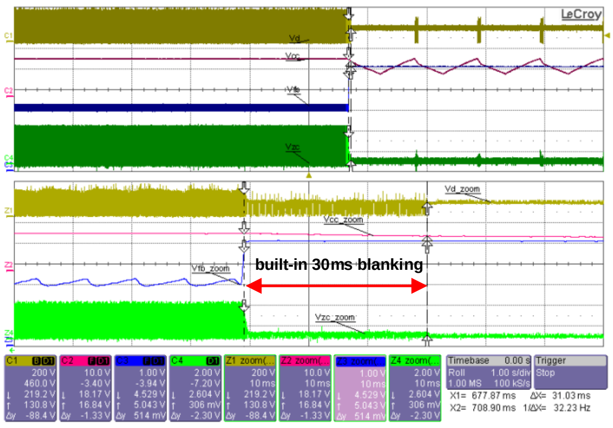
## 13.7 Output ripple voltage during burst mode at 1 W load

| | |
|---|---|
|  |  |
| Channel 1; C1 : Output ripple voltage (Vo) | Channel 1; C1 : Output ripple voltage (Vo) |
| $V_{ripple\_pk\_pk}$=99.9mV<br>Probe terminal end with decoupling capacitor of 0.1µF(ceramic) & 1µF(Electrolytic), 20MHz filter | $V_{ripple\_pk\_pk}$ = 124.5mV<br>Probe terminal end with decoupling capacitor of 0.1µF(ceramic) & 1µF(Electrolytic), 20MHz filter |
| **Figure 28** – AC output ripple @ 90Vac and 1W load | **Figure 29** – AC output ripple @ 264Vac and 1W load |

## 13.8 Active Burst mode operation

| | |
|---|---|
|  |  |
| Channel 1; C1 : Drain voltage ($V_{Drain}$)<br>Channel 2; C2 : Supply voltage ($V_{CC}$)<br>Channel 3; C3 : Feedback voltage ($V_{FB}$)<br>Channel 4; C4 : Zero crossing voltage ($V_{ZC}$) | Channel 1; C1 : Drain voltage ($V_{Drain}$)<br>Channel 2; C2 : Supply voltage ($V_{CC}$)<br>Channel 3; C3 : Feedback voltage ($V_{FB}$)<br>Channel 4; C4 : Zero crossing voltage ($V_{ZC}$) |
| Condition: $V_{FB}$<1.219V, $N_{ZC}$=7 and $t_{blanking}$ =25ms<br>(load change form full load to 1W load) | Condition: $V_{FB}$>4.19V<br>(load change from 1W to full load) |
| **Figure 30** – Entering active burst mode @ 90Vac | **Figure 31** – Leaving active burst mode @ 90Vac |

## 13.9 Over load protection (Auto restart mode)

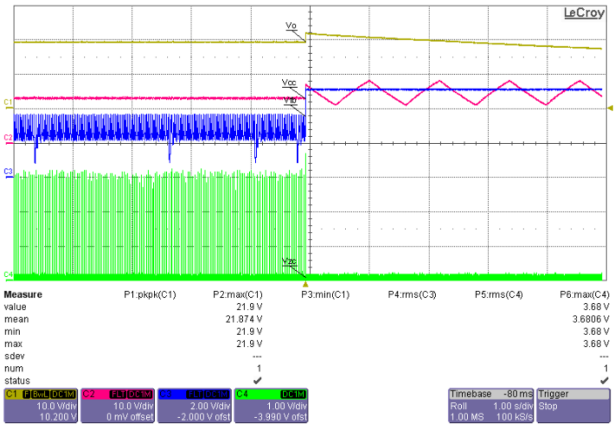



Channel 1; C1 : Drain voltage ($V_{Drain}$)
Channel 2; C2 : Supply voltage ($V_{CC}$)
Channel 3; C3 : Feedback voltage ($V_{FB}$)
Channel 4; C4 : Zero crossing voltage ($V_{ZC}$)

Over load protection with built-in 30ms blanking time
(output load change from full load to short load)

**Figure 32** – Over load protection with extended blanking time @ 90Vac)

## 13.10 Output overvoltage protection (Latched off mode)

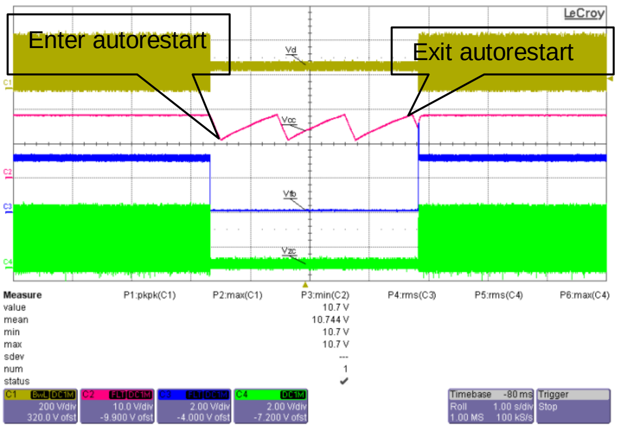



Channel 1; C1 : Output voltage (Vo)
Channel 2; C2 : Supply voltage ($V_{CC}$)
Channel 3; C3 : Feedback voltage ($V_{FB}$)
Channel 4; C4 : Zero crossing voltage ($V_{ZC}$)

Condition: $V_O$ >21.9V ($V_{ZC}$>3.7V)
(R10 disconnected during system operation at no load)

**Figure 33** – Output overvoltage protection @ 90Vac

## 13.11 $V_{CC}$ under voltage/Short optocoupler protection (Auto restart mode)

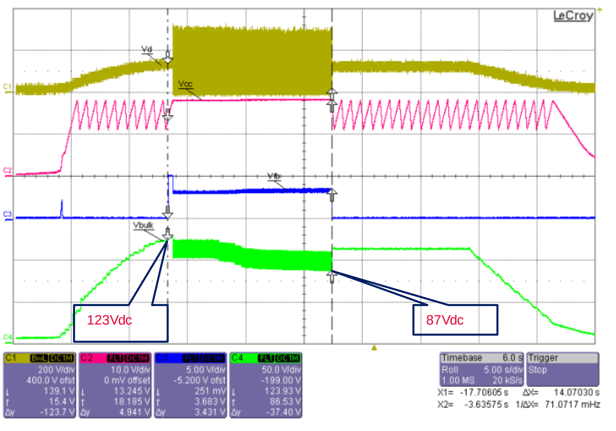
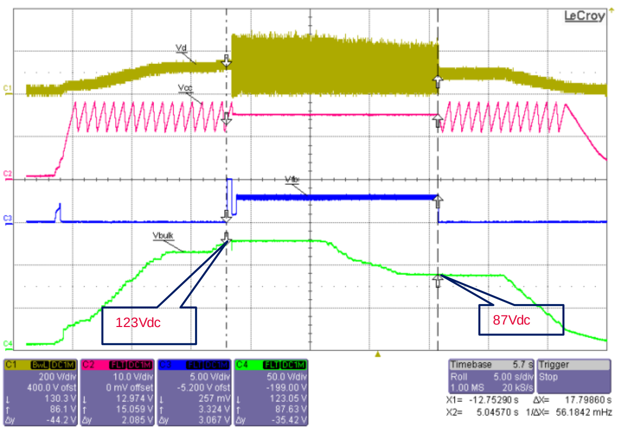



Channel 1; C1 : Drain voltage ($V_{Drain}$)
Channel 2; C2 : Supply voltage ($V_{CC}$)
Channel 3; C3 : Feedback voltage ($V_{FB}$)
Channel 4; C4 : Zero crossing voltage ($V_{ZC}$)

$V_{CC}$ under voltage/short optocoupler protection (short the transistor of optocoupler during system operating @ full load & release)

**Figure 34** – $V_{cc}$ under voltage/short optocoupler protection @ 90Vac

## 13.12 Brown out protection

| | |
|---|---|
| <br> | <br> |
| Channel 1; C1 : Drain voltage ($V_{Drain}$)<br>Channel 2; C2 : Supply voltage ($V_{CC}$)<br>Channel 3; C3 : Feedback voltage ($V_{FB}$)<br>Channel 4; C4 : Bulk voltage ($V_{Bulk}$) | Channel 1; C1 : Drain voltage ($V_{Drain}$)<br>Channel 2; C2 : Supply voltage ($V_{CC}$)<br>Channel 3; C3 : Feedback voltage ($V_{FB}$)<br>Channel 4; C4 : Bulk voltage ($V_{Bulk}$) |
| Brownout reset: $V_{bulk}$= 123Vdc(87Vac)<br>Brownout detect: $V_{bulk}$= 87Vdc(80Vac) | Brownout reset: $V_{bulk}$= 123Vdc(87Vac)<br>Brownout detect: $V_{bulk}$= 87Vdc(62Vac) |
| **Figure 35** – Brownout mode with max. load | **Figure 36** – Brownout mode with no load |

## 14 References

[1] ICE2QS03G data sheet, Infineon Technologies AG

[2] IPD60R600P6 data sheet, 600V CoolMOS™ P6 Power Transistor

[3] BAS21-03W data sheet, Infineon Technologies AG

[4] 2N7002 data sheet, Infineon Technologies AG

[5] Converter Design Using the Quasi-Resonant PWM Controller ICE2QS01, Infineon Technologies AG, 2006. [ANPS0003]

[6] Design tips for flyback converters using the Quasi-Resonant PWM controller ICE2QS01, Infineon Technologies, 2006. [ANPS0005]

[7] Determine the switching frequency of Quasi-Resonant flyback converters designed with ICE2QS01, Infineon Technologies, 2006. [ANPS0004]

[8] ICE2QS03G design guide. [ANPS0027]

[9] 36W Evaluation Board with Quasi-Resonant PWM Controller ICE2QS03G, 2011. [AN-PS0040]

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