Version 2.3, August 2002

# Design Note

## DN-EVALSF2-ICE2B765P-1

**CoolSET™**
**80W 24V Design Note for Adapter using ICE2B765P**

Author: Rainer Kling

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http://www.infineon.com/CoolSET

Power Management & Supply

Never stop thinking

# Table of Contents

# Introduction

## Application

This document is an engineering report that describes a universal input power supply designed in a typical off line flyback converter topology that utilizes the **ICE2B765P CoolSET™**. The application operates in discontinuous current mode using the frequency reduction during standby condition[1]. The board has one output voltage with secondary regulation.

This board demonstrates the basic performance features and the power capability of the latest CoolSET™ device ICE2B765P of the second generation of CoolSET™ in a TO220 package with extended creepage distance for higher electrical strength and isolated tab.

## CoolSET™

CoolSET™ is a current mode control IC and the power MOSFET CoolMOS™ within one standard package designed for low cost power supplies. CoolSET™ combines the superior technology of CoolMOS™ and the optimized technology of the control IC with enhanced protection features and improved standby power concept. The integrated propagation delay compensation (patented by Infineon Technologies) prevents a current overshoot, the result is a reduced electrical stress on the MOSFET, the transformer and the output diode. The 650V / 800V high avalanche rugged CoolMOS™ eliminates or reduces the need for a heatsink and permits a SMPS design with a simple RCD snubber and a low cost standard transformer design. The lowest area specific Rdson leads to a high efficiency and permits an operation at high ambient temperature. CoolSET™ permits always a safety operation during any error cases due to the integrated protection features.

**Figure 1**– EVALSF2-ICE2B765P

This document contains the power supply specification, schematic, bill of material and the transformer construction documentation. Typical operating characteristics are presented at the rear of the report and consist of performance curves and scope waveforms.
Note:
Design calculations for the components and the transformer were performed in accordance with the application note **"AN–SMPS–ICE2AXXX for OFF – Line Switch Mode Power Supplies"** and **FlyCal**, a EXCEL based design software according to the application note AN-SMPS-ICE2AXXX. The application note and FlyCal are available on the Internet: **www.Infineon.com/CoolSET**

[1] $P_{OUT}$ = 0W

## List of Features

| Feature |
|---|
| CoolSET™ Device **ICE2B765P** |
| External Sense |
| Adjustable Soft Start |
| Modulated Gatedrive |
| Over Load Protection with auto restart |
| Over Current Protection with auto restart |
| Over Temperature Shut Down with auto restart |
| Open Loop Protection with auto restart |
| Under Voltage Lock Out with auto restart |
| Drain Source Voltage 650V[2] |
| Frequency Reduction |
| Internal Leading Edge Blanking |
| 67 kHz operating frequency |
| TO220 ISODRAIN Package with isolated Tab |
| Standby Power according to European Commission |

**Table 1** – List of Features

## Power Supply Specification

| Description | Symbol | Min | Typ | Max | Units |
|---|---|---|---|---|---|
| **Input Section** | | | | | |
| Input Voltage | $V_{ACIN}$ | 85 | 115/230 | 270 | $V_{AC}$ |
| Line Regulation (85...270V) | | | < 1 | | % |
| Input Frequency | f | 47 | 50/60 | 64 | Hz |
| No Load Input Power (230$V_{AC}$) | | | < 0.9 | | W |
| **Output Section** | | | | | |
| Output Voltage | $V_{OUT}$ | 23.5 | 24 | 24.5 | $V_{DC}$ |
| AC Output Voltage Ripple (270$V_{AC}$) | $V_{Ripple}$ | | <0.1 | | $V_{P-P}$ |
| Output Current | $I_{OUT}$ | 3.25 | 3.3 | 3.35 | $A_{DC}$ |
| Output Power | $P_{OUT}$ | 0 | 80 | 85 | W |
| Peak Power | $P_{OUTmax}$ | | 95 | | W |
| Standby Power | | | < 1.0 | | W |
| Total Regulation | | | ±2 | | % |
| Load Regulation (10...100%) | | | < 1 | | % |
| Efficiency (85$V_{AC}$) @ nominal Load | $\eta$ | | 85 | | % |
| Efficiency (270$V_{AC}$) @ nominal Load | $\eta$ | | 90 | | % |
| **Environmental** | | | | | |
| Conducted EMI | | | | | EN55022B |
| Ambient Temperature | $T_A$ | 0 | 50 | 75 | °C |
| **Thermal Consideration @ $V_{ACIN}$ = 85V and Dmax = 69% (ΔT @ Ta = 25°C)** | | | | | |
| Transformer | | | 40 | | °C |
| CoolSET | | | 60 | | °C |
| Output Diode | | | 60 | | °C |
| Output Capacitors | | | 35 | | °C |

**Table 2** – Power Supply Specification

[2] $V_{DSBR}$ at Tj = 110°C

# Schematic

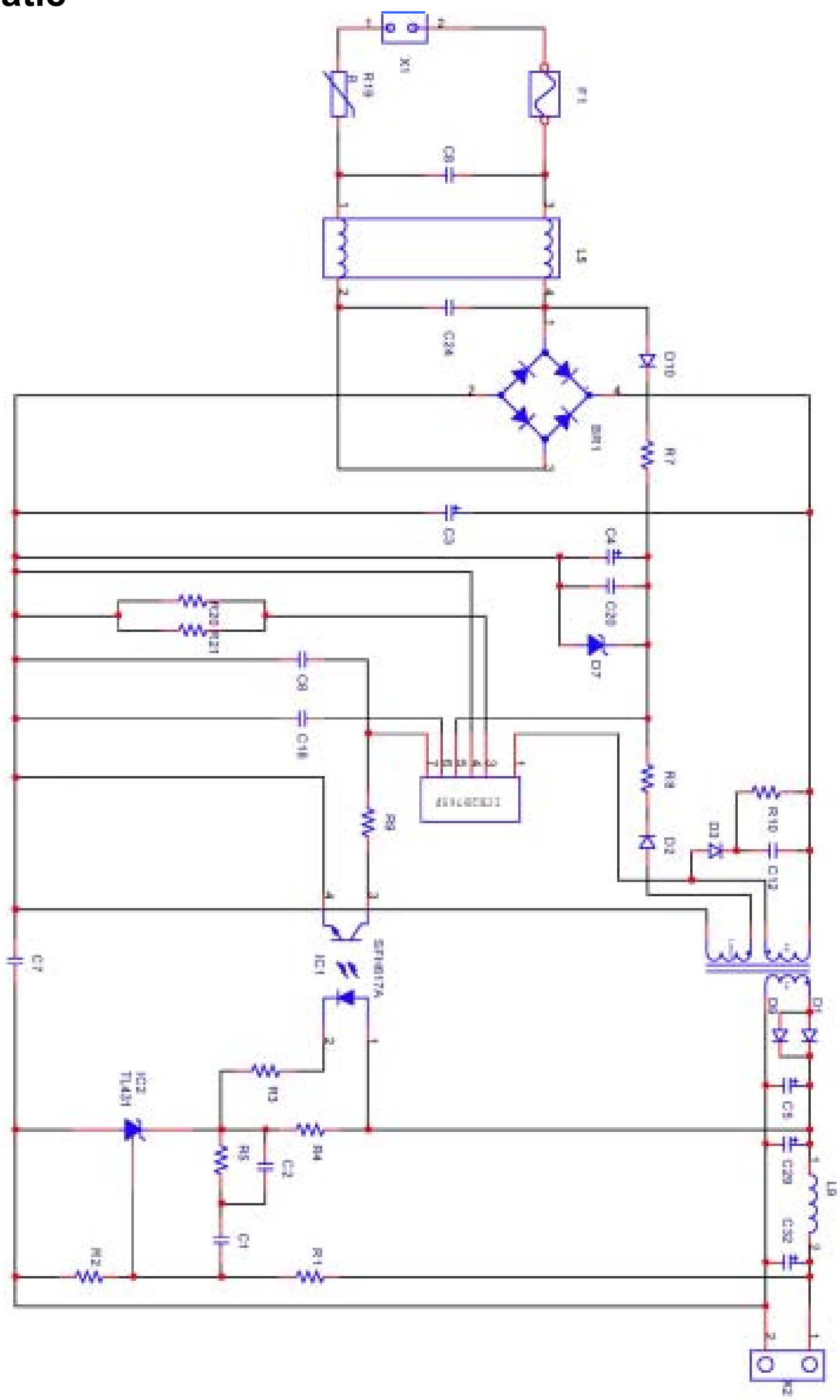

**Figure 2** Power Supply Schematic

## PCB Layout

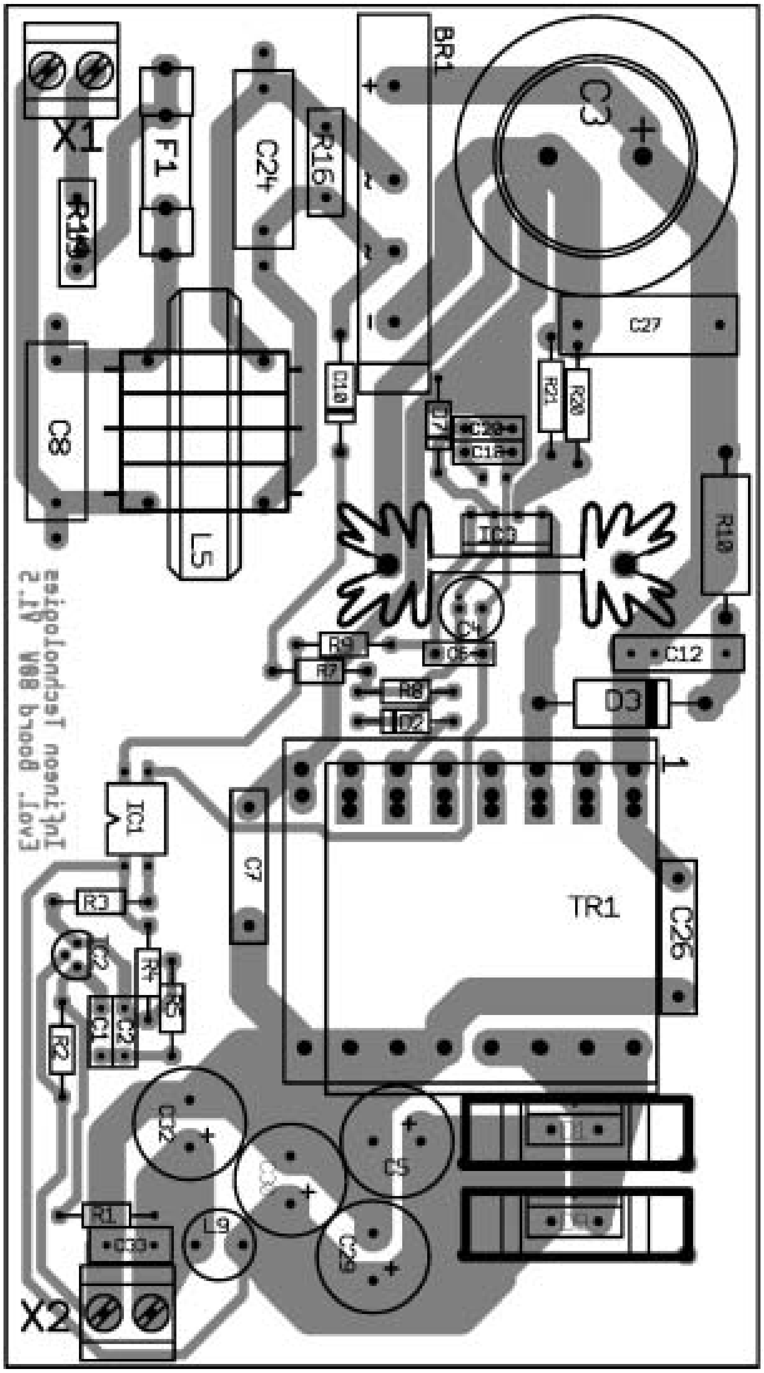


**Figure 3** Board Layout - Component Side

# Description

## Introduction

The **EVALSF2-ICE2B765P** demoboard is a low cost flyback switching power supply using the ICE2B765P integrated circuit from the *CoolSET™-F2* family. The circuit shown in Figure 2 details a 24V, 80W supply that operates from an line input voltage range of 85 to 265$V_{AC}$, suitable for applications requiring either an open frame supply or an enclosed adapter.

## Line Input

The AC line input side comprises of an input fuse F1 as line input over current protection as well as choke L5 and the X2 capacitors C8 and C24 as radio interference suppressors. R19 prevents the application against line shut on spikes. After the bridge rectifier BR1 and input capacitor C3, a voltage from 120 to 380 $V_{DC}$ is present. Only a 220µF input capacitor is required due to the wider duty cycle $DC_{MAX}$ of the ICE-F2-family.

## Startup

From the line input voltage, the current supply which is used to charge up the chip supply capacitor C4 is derived by using resistors R7 and rectifier diode D10. Because of the very low start up current of typically 27µA, a high-value resistor can be used to realize the startup.
Note:
Improve your standby power via increasing R7.

## Operation Mode

During operation, the $V_{CC}$ pin is supplied via a separate transformer winding with associated rectification D2 and buffering C4 and filter capacitor C20. Resistor R8 is used for current limiting during the charging of C4. In order not to exceed the maximum voltage at the $V_{CC}$ pin an external zener diode D7 limits this voltage. During light or no load condition the switching frequency is reduced down to 21kHz in order to reduce the switching losses without audible noise.
Note:
In order to improve the standby power, set the board in the burst mode during no load condition via increasing the chip supply resistor R8.

## Softstart

In order to minimize the electrical stress, a Soft-Start function is realized by an internal resistor and the adjustable external capacitor C18.

## Snubber Network

Due to the high avalanche rugged CoolMOS™ inside, a simple RCD snubber protection can be used. The network R10, C12 and D3 clamp the DRAIN voltage spike caused by transformer leakage inductance to a safe value below the drain source break down voltage $V_{DSBR}$ = 650V maximum.

## Limitation of primary current

The CoolMOS™ drain source current is sensed via external shunt resistors R20 and R21. An accurate value of the shunt improves the peak power limitation shown in the curve peak power limitation in the rear of this report and minimize the electrical stess on the MOSFET, the Transformer and the output rectifier.

## Output Voltage

Power is coupled out on the secondary side via a fast-acting diodes D1 and D9 with low forward voltage. Capacitors C5 and C29 performs energy buffering, a following LC - filter C32 and inductor L9 considerably reduces the output voltage ripple. Storage output capacitors C5 and C29 is designed to exhibit a very low ESR in order to minimize the output voltage ripple caused by the triangular current characteristic. The output voltage is set with resistors R1 and R2.

## Regulation

The output voltage is controlled using a type TL431 reference diode. This device incorporates the voltage reference as well as the error amplifier and a driver stage. Compensation network C1, C2, R1, R5 constitutes the external circuitry of the error amplifier of IC2. This circuitry allows the feedback to be precisely matched to dynamically varying load conditions, thereby providing stable control. The maximum current through the optocoupler diode and the voltage reference is set by using resistors R3, R4. Optocoupler IC1 is used for floating transmission of the control signal to the “Feedback” input via resistor R9 and capacitor C6 of the ICE2B765P control device. The optocoupler used meets DIN VDE 884 requirements for a wider creepage distance.

## EMI Behavior

In order to reduce the conducted EMI behavior, capacitor C7 is set in parallel to the transformer TR1.

Note:
The value should not exceeds 2.2nF in order to guarantee a safety off line switch mode power supply design.

# Bill of Material

**ICE2B765P Evaluation Board 24V/ 80W**

| Pos. | Part | Type | Number | Values | Note | Ordering Code |
|---|---|---|---|---|---|---|
| 1 | BR1 | B380 C5000 | 1 | | | |
| 2 | C1 [nF] | 470 | 1 | 50V | | |
| 3 | C2 [nF] | 0.15 | 1 | 50V | | |
| 4 | C3 [µF] | 220 | 1 | 385V | | |
| 5 | C4 [µF] | 22 | 1 | 25V | | |
| 6 | C5 [µF] | 1000 | 1 | 35V | Low ESR | |
| 7 | C6 [nF] | 2.2 | 1 | 50V | X7R | |
| 8 | C7 [nF] | 2.2 | 1 | 275V | Y1 Cap | |
| 9 | C8 [µF] | 0.22 | 1 | 275V | X2 Cap | |
| 10 | C12 [nF] | 4.7 | 1 | 400V | MKT | |
| 11 | C18 [nF] | 330 | 1 | 50V | X7R | |
| 12 | C20 [nF] | 100 | 1 | 50V | X7R | |
| 13 | C24 [µF] | 0.22 | 1 | 275V | X2 Cap | |
| 14 | C29 [µF] | 1000 | 1 | 35V | Low ESR | |
| 15 | C32 [µF] | 330 | 1 | 35V | Low ESR | |
| 16 | D1 | MUR1520 | 1 | 200V | | |
| 17 | D2 | 1N4148 | 1 | | | |
| 18 | D3 | 1N4937 | 1 | 200V | | |
| 19 | D7 | ZPD18 | 1 | 18V | | |
| 20 | D9 | MUR1520 | 1 | 200V | | |
| 21 | D10 | 1N4007 | 1 | | | |
| 22 | F1 | Microfuse | 1 | 3.15A | | |
| 23 | F1 | Clip for Fuse | 2 | | | |
| 24 | IC1 | SFH617A-3X016 | 1 | | | |
| 25 | IC2 | TL431CLP | 1 | | | |
| 26 | IC3 | ICE2B765P | 1 | | | |
| 27 | L9 [µH] | 1.0 | 1 | 6A | | |
| 28 | L5 [µH] | 2*27mH | 1 | 1.7A | | |
| 29 | R1 [kΩ] | 40.0 | 1 | 0.6W | 1% | |
| 30 | R2 [kΩ] | 4.7 | 1 | 0.6W | 1% | |
| 31 | R3 [kΩ] | 1.1 | 1 | 0.6W | | |
| 32 | R4 [kΩ] | 1.6 | 1 | 0.6W | | |
| 33 | R5 [kΩ] | 180.0 | 1 | 0.6W | | |
| 34 | R7 [kΩ] | 680 | 1 | 0.6W | | |
| 35 | R8 [Ω] | 7.5 | 1 | 0.6W | | |
| 36 | R9 [Ω] | 22.0 | 1 | 0.6W | | |
| 37 | R10 [kΩ] | 10.0 | 1 | 2W | | |
| 38 | R19 | NTC10 | 1 | | | |
| 39 | R20 [Ω] | 0.43 | 1 | 0.6W | 1% | |
| 40 | R21 [Ω] | 0.39 | 1 | 0.6W | 1% | |
| 41 | TR1 | ETD39/18/13 | 1 | 1mm | Gap | |
| 42 | Heatsink | | 1 | 11 k/W | | For ICE2B756P |
| 43 | Heatsink | | 2 | 18 k/W | | For Output Rectifiers |
| 44 | X1, X2 | Connector 2pol. | 2 | | | |

# Transformer Construction Documentation

Al-Value: **190** nH
Gap: **1** mm
Margin: **0** mm
Inductance: **1,49E-04** H
Leakage Ind.: **7,7E-06** H (5%)

| THOMSON MULTI MEDIA | SMT31 | 40335-xx |
|---|---|---|
| | SPF : G7183-00 | A |

## OUTPUT CHARACTERISTICS

| Pins | Value | Loads | Remarks |
|---|---|---|---|
| 16/15/14/13 - 12/11/10/9 | 24 V | 3.3A | |
| 6 - 8 | 13.5 V | / | VCC |
| 3 - 1 | | Ir | Primary |
| | | | |
| | | | |
| | | | |
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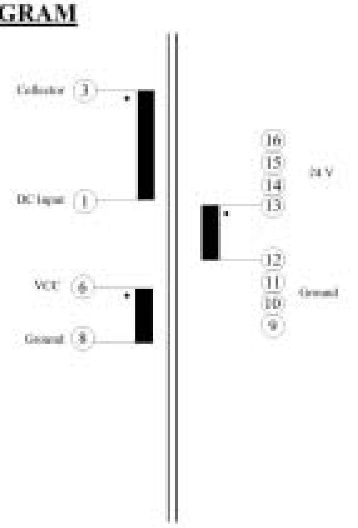
## CIRCUIT DIAGRAM

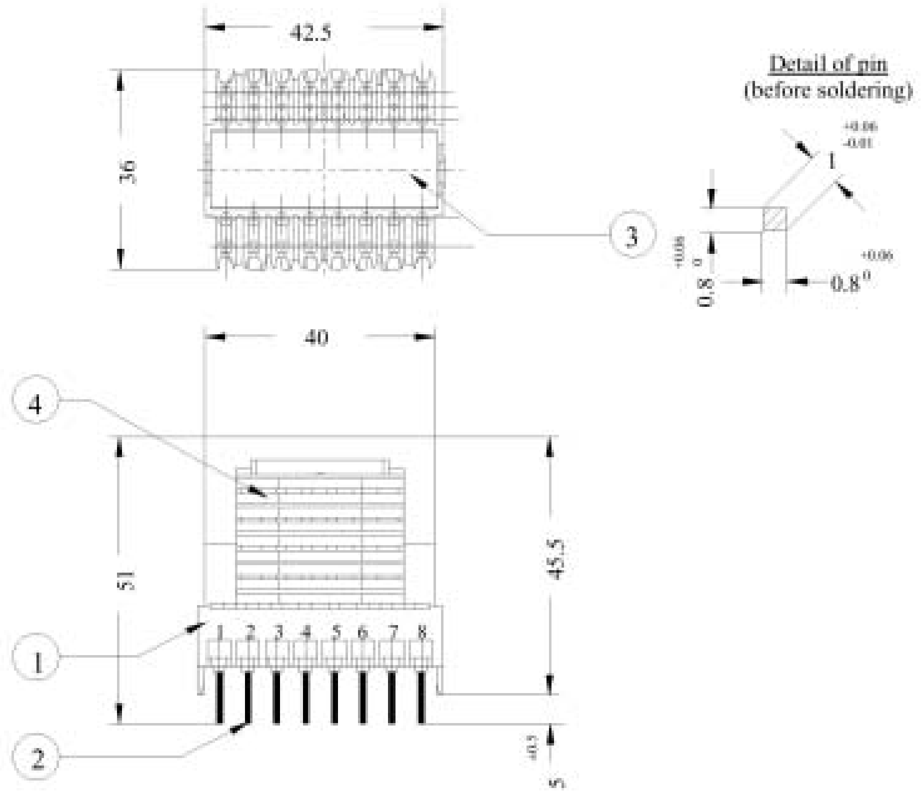



PRIMARY SIDE

| OREGA | PRODUCT SPECIFICATIONS | Page : | 3 |
|---|---|---|---|

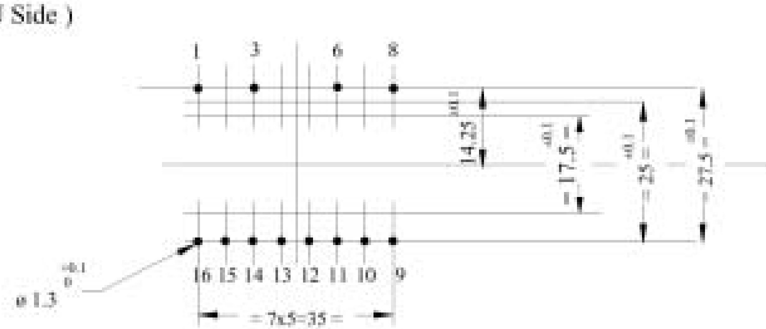
| THOMSON MULTIMEDIA | SMT31 | 40335-xx | |
|---|---|---|---|
| | SPF : | G7183-00 | A |

## MECHANICAL CHARACTERISTICS




## RECOMMENDED PUNCHING DIAGRAM

( CU Side )

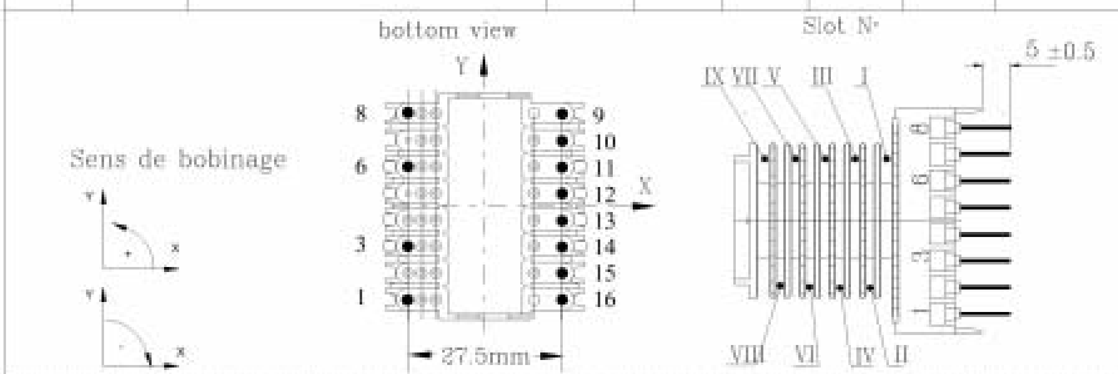



| OREGA | PRODUCT SPECIFICATIONS<br>R&D Dpt : Tél. : (33)03 84 64 54 00 - Fax (33)03 84 64 54 28 | Page : | 4 |
|---|---|---|---|

| | | |
|---|---|---|
| THOMSON MULTI MEDIA | SMT31 | 40335-xx |
| | SPF : G7183-00 | A |

## WINDING SPECIFICATION

| Slot N° | Winding N° | Voltage / Observations | Nr. of turns | Sense | ØWire (mm) | Start | End | Class of wire |
|---|---|---|---|---|---|---|---|---|
| I | 1 | Aux | 4 | + | 0.28 | 6 | 8 | Grade 2 |
| | 2 | Primary | 28 | + | 0.28 | 3 | 1 | Grade 2 |
| II | 3 | 24 V | 7 | + | 0.28 | 16 | 9 | Grade 2 |
| | 4 | 24 V | 7 | - | 0.28 | 9 | 16 | Grade 2 |
| | 5 | 24 V | 7 | + | 0.28 | 16 | 9 | Grade 2 |
| III | 6 | Primary | 28 | + | 0.28 | 3 | 1 | Grade 2 |
| IV | 7 | 24 V | 7 | + | 0.28 | 15 | 10 | Grade 2 |
| | 8 | 24 V | 7 | - | 0.28 | 10 | 15 | Grade 2 |
| | 9 | 24 V | 7 | + | 0.28 | 15 | 10 | Grade 2 |
| V | 10 | Primary | 28 | + | 0.28 | 3 | 1 | Grade 2 |
| VI | 11 | 24 V | 7 | + | 0.28 | 14 | 11 | Grade 2 |
| | 12 | 24 V | 7 | - | 0.28 | 11 | 14 | Grade 2 |
| | 13 | 24 V | 7 | + | 0.28 | 14 | 11 | Grade 2 |
| VII | 14 | Primary | 28 | + | 0.28 | 3 | 1 | Grade 2 |
| VIII | 15 | 24 V | 7 | + | 0.28 | 13 | 12 | Grade 2 |
| | 16 | 24 V | 7 | - | 0.28 | 12 | 13 | Grade 2 |
| | 17 | 24 V | 7 | + | 0.28 | 13 | 12 | Grade 2 |
| IX | 18 | Primary | 28 | + | 0.28 | 3 | 1 | Grade 2 |

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|---|---|---|---|
| OREGA | PRODUCT SPECIFICATIONS<br>R&D Dpt : Tél. : (33)03 84 64 54 00 - Fax (33)03 84 64 54 28 | Page : | 9 |

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# Performance Data

## Efficiency

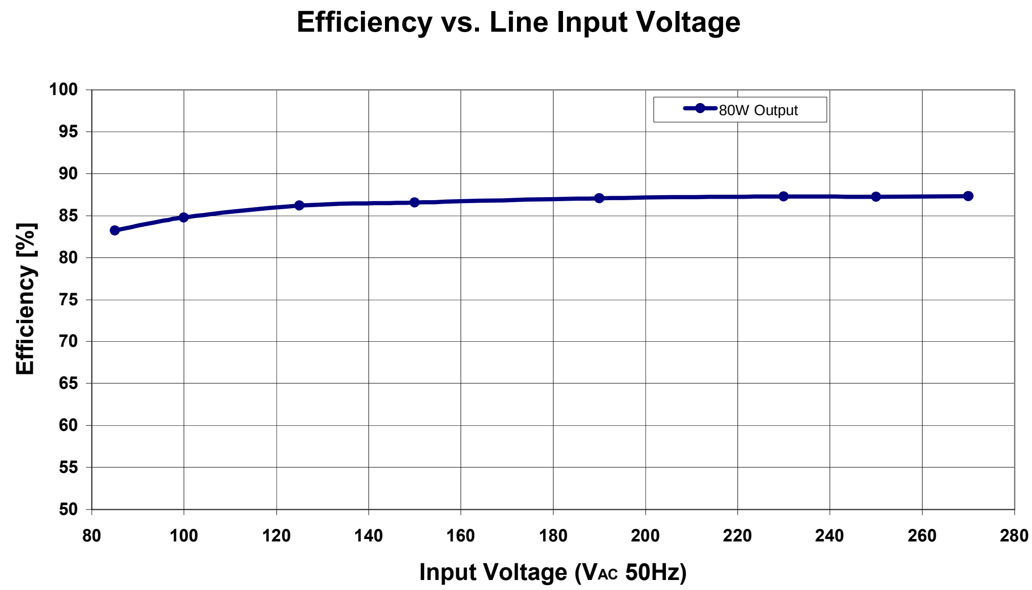


Figure 4 Efficiency vs. Line Input Voltage

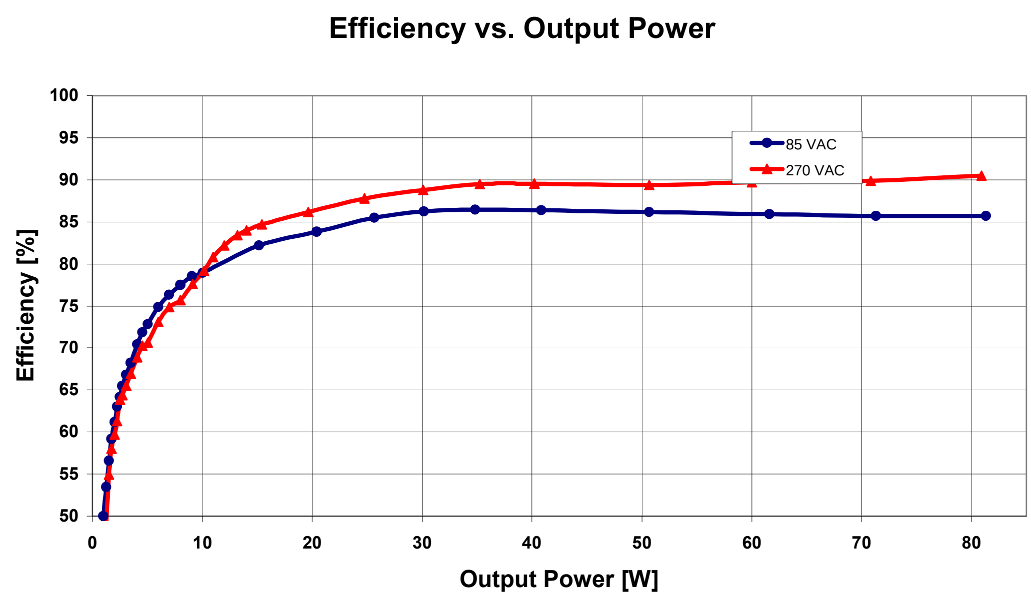


Figure 5 Efficiency vs. Output Power @ Low and High Line 50Hz

## No-Load Input Power (Standby)

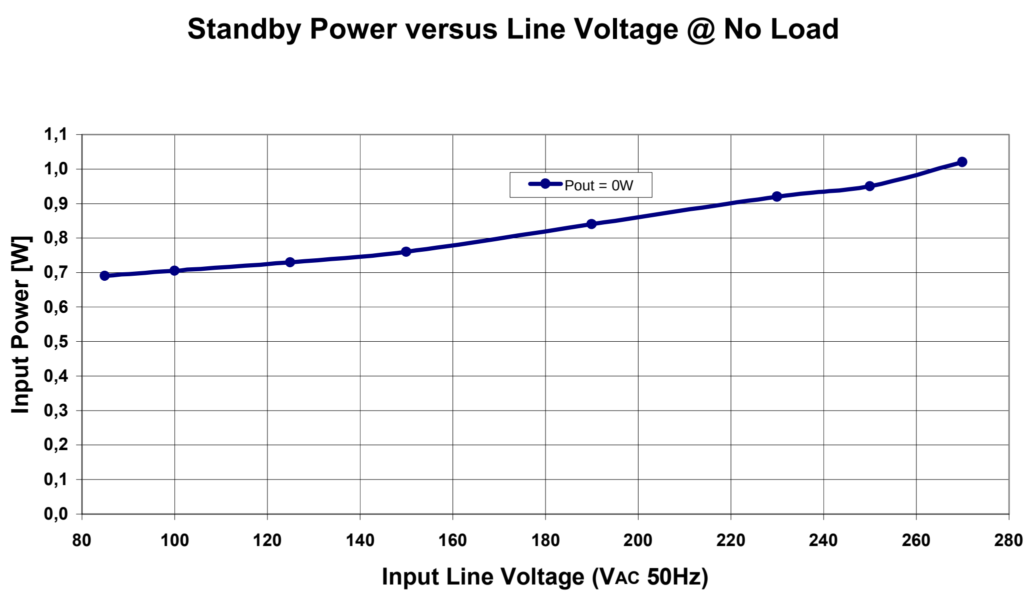


Figure 6 Standby Power vs. Line Input Voltage and No Load Condition (Pout = 0W)

## Regulation and Power Limiting

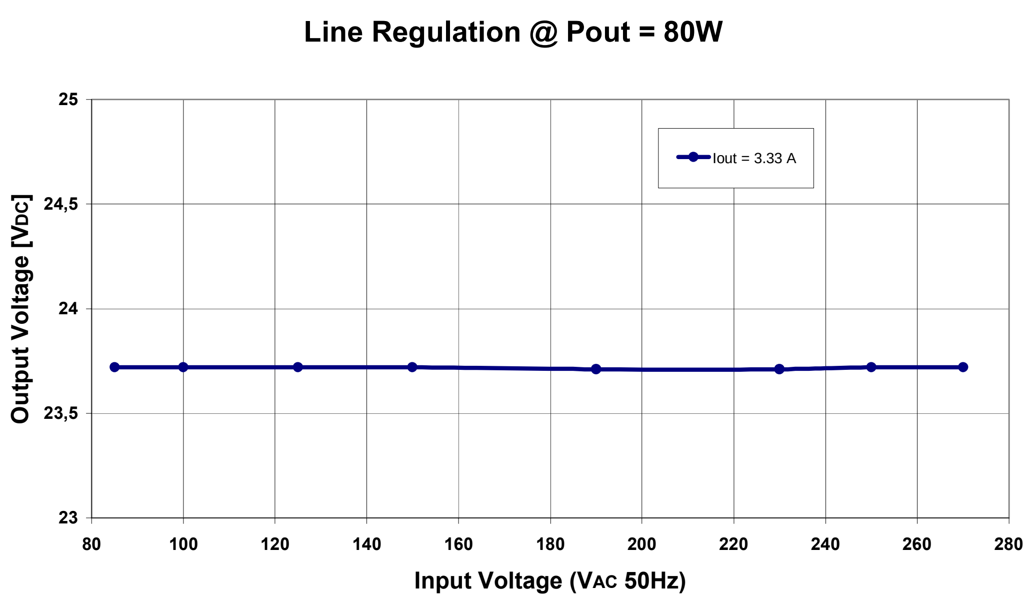


Figure 7 Regulation vs. Line Input Voltage

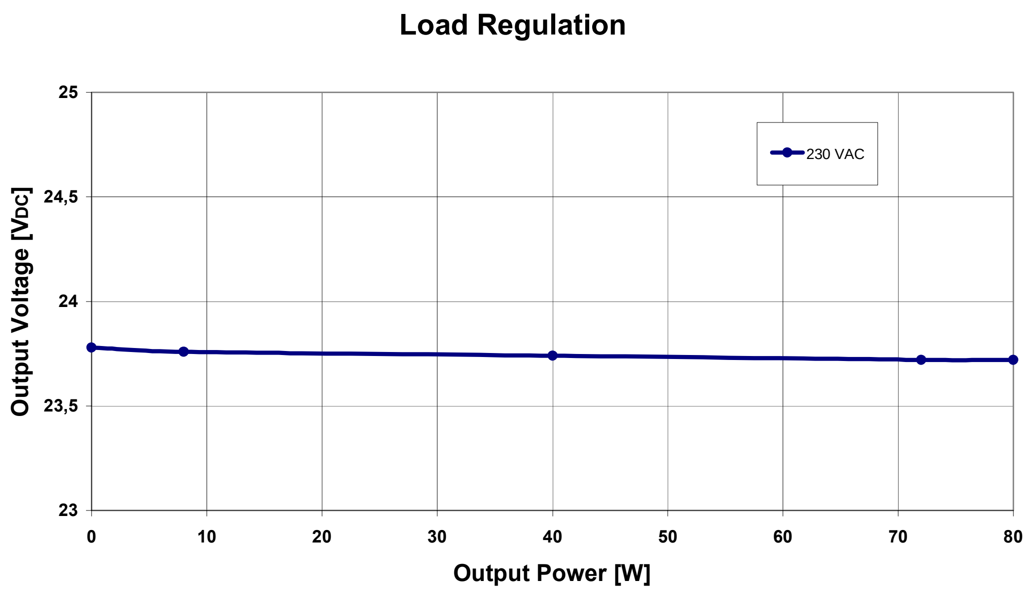


Figure 8 Regulation vs. Load

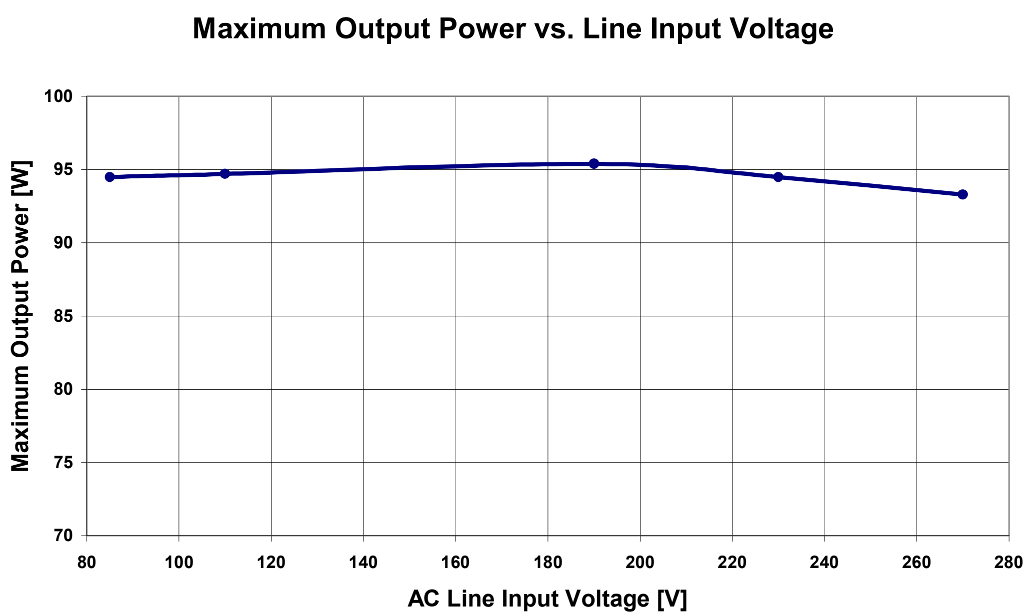


Figure 9 Peak Power (Over Current Shut Off Threshold) vs. Line Input Voltage

## Startup Curves (Low Line)

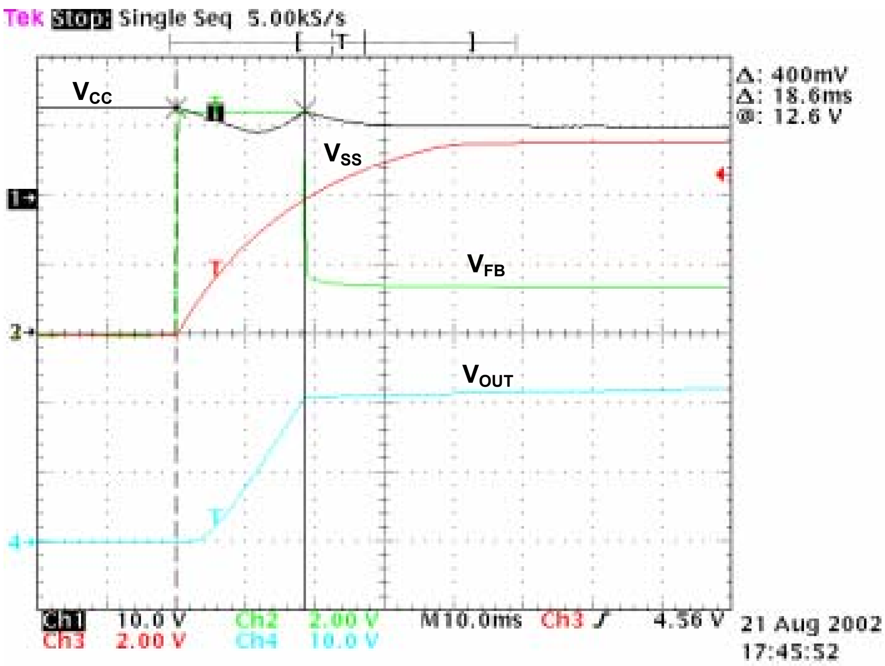


Figure 10 Startup $V_{ACIN}$ = 85V no Load Conditon ($P_{OUT}$ = 0W)

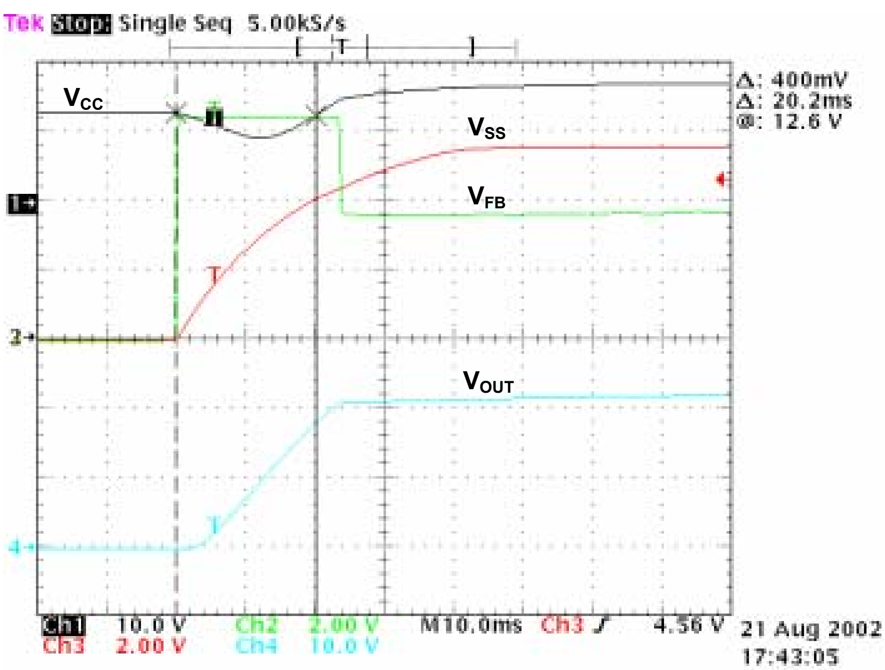


Figure 11 Startup @ Vacin = 85V and nominal Load ($P_{OUT}$ = 80W)

## Startup Curves (High Line)

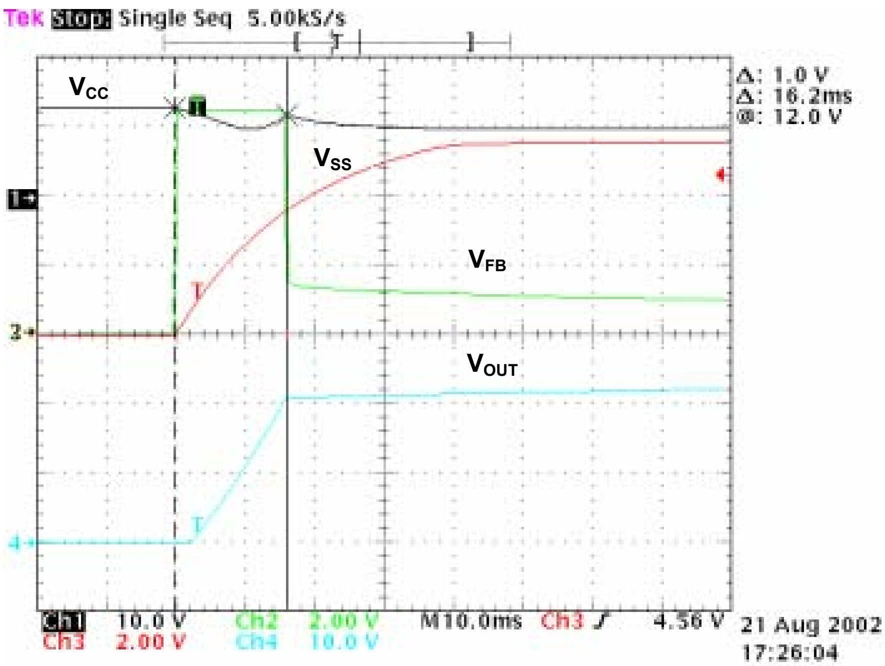


Figure 12 Startup @ 270$V_{ACIN}$ and no Load Condition ($P_{OUT}$ = 0W)

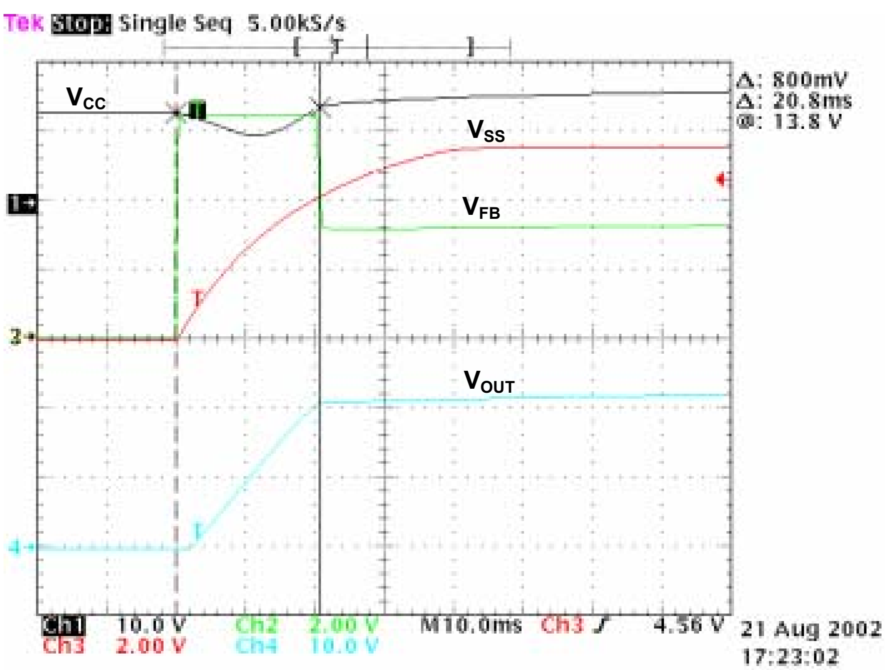


Figure 13 Startup @ Vacin = 270V and nominal Load ($P_{OUT}$ = 80W)

## Loadjump

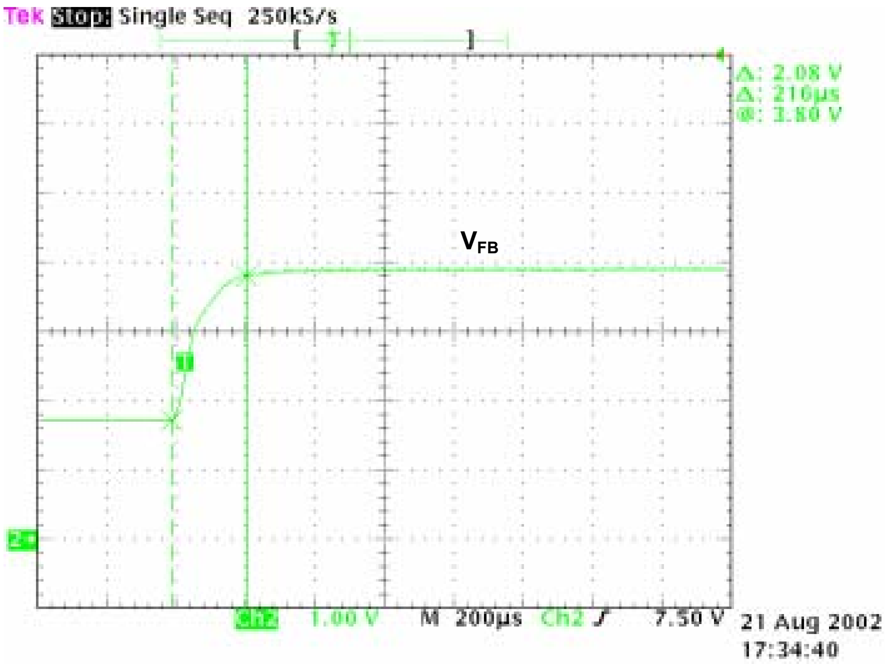


Figure 14 Loadjump form 10% up to 100% at $V_{ACIN}$ = 85V

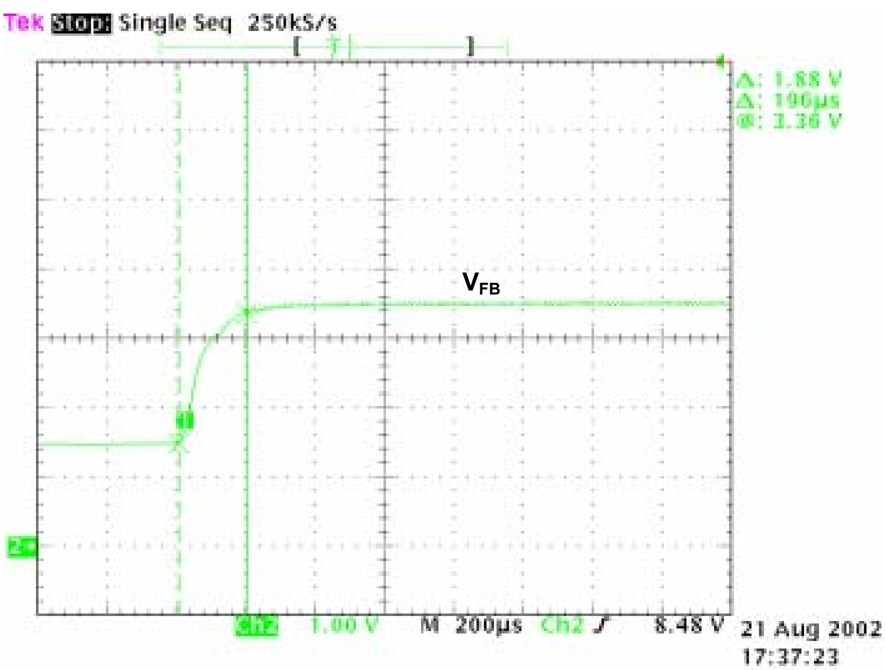


Figure 15 Loadjump form 10% up to 100% at $V_{ACIN}$ = 270V

## AC Output Voltage Ripple

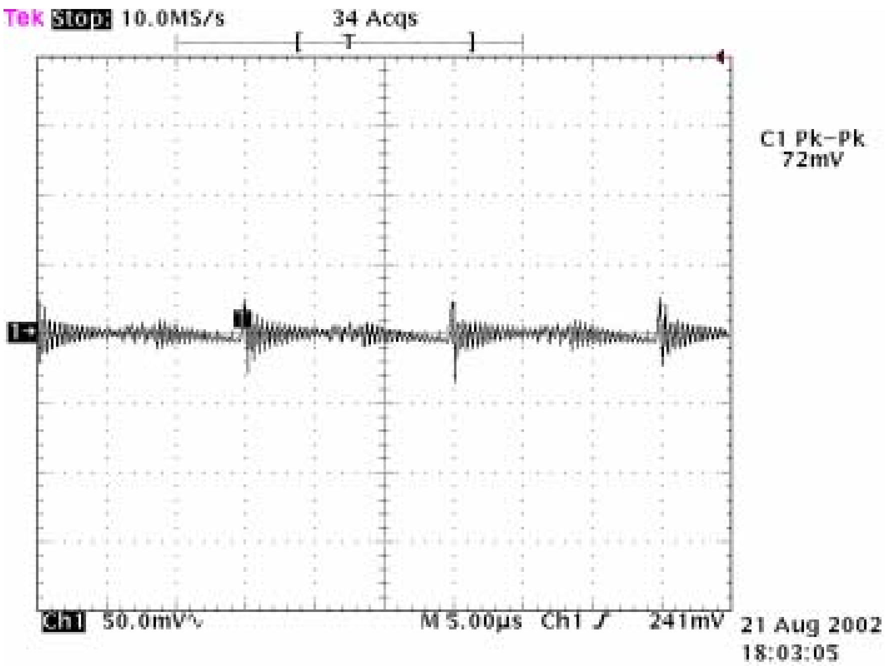


Figure 16 AC Output Voltage Ripple @ $V_{ACIN}$ = 85V

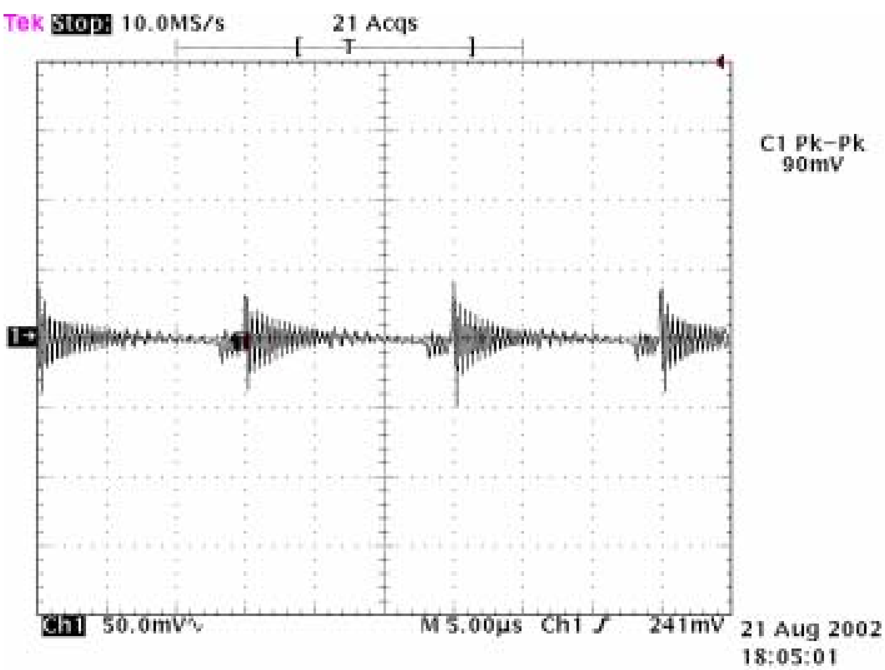


Figure 17 AC Output Voltage Ripple @ $V_{ACIN}$ = 270V

## Drain Source Voltage and Current

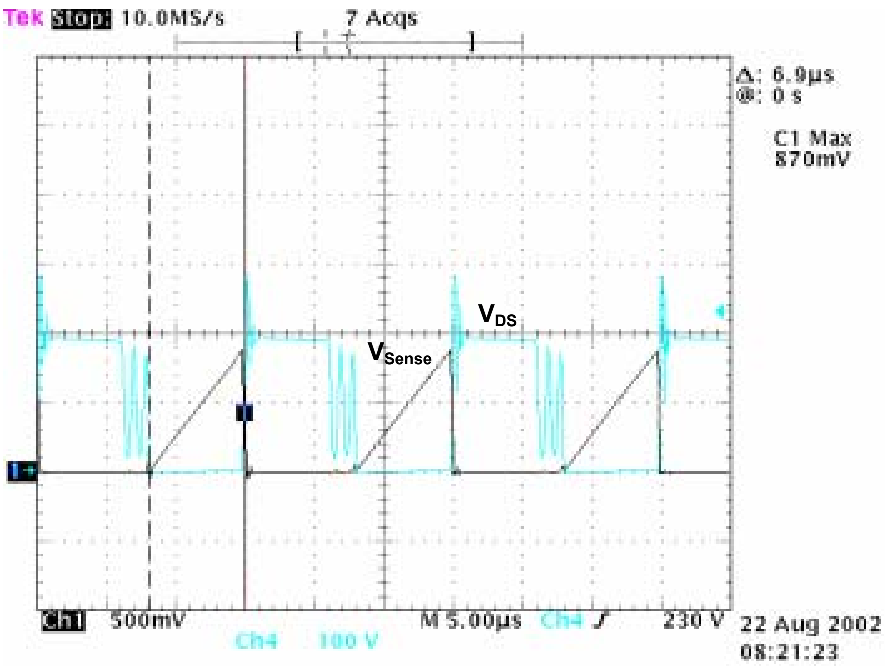


Figure 18 Drain Source Voltage and Current @ $V_{ACIN}$ = 85V

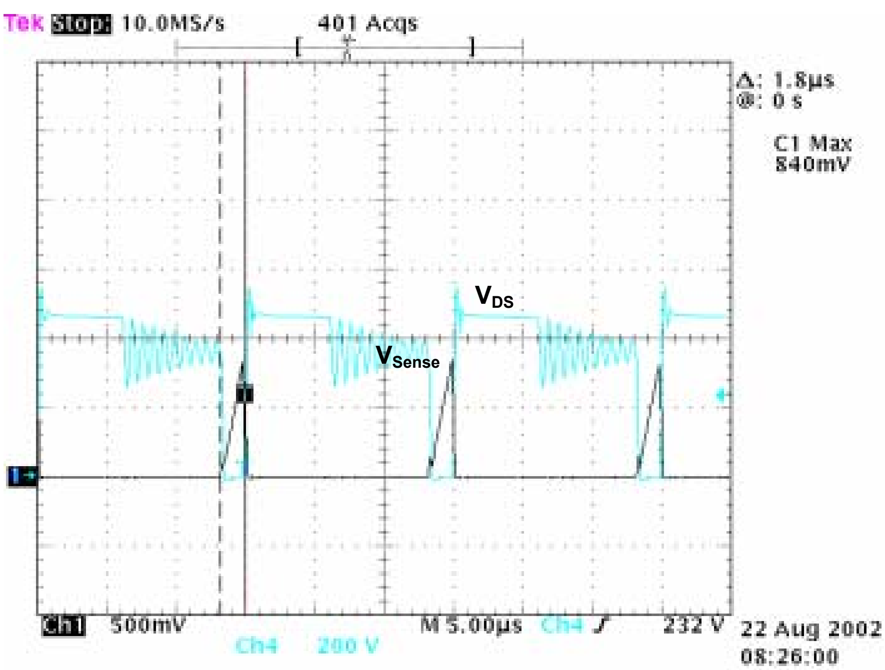


Figure 19 Drain Source Voltage and Current @ $V_{ACIN}$ = 85V

**Note:**

The built-in transformer does **not** comply with EN60950 safety requirements in respect of electrical isolation.

## *Change service*

| Issue status | Changes | | Date |
|---|---|---|---|
| 1.0 | First issue | | 02.05.2002 |
| 2.1 | BOM Update | | 02.08.2002 |
| 2.2 | Performance Data | | 27.08.2002 |
| 2.3 | BOM Update | | 08.11.2002 |

## References

[1] ICE2AXXX for OFF-Line Switch Mode Power Supplies
Application Note, Infineon Technologies

[2] CoolSET -II
Off-line SMPS Current Mode Controller with High Voltage CoolMOS on Board
Datasheet, Infineon Technologies

| Revision History | | |
|---|---|---|
| **Application Note AN-EVALSF2-ICE2B765P-01** | | |
| Actual Release: 2.3 Date: 2002-08-27 | Previous Release: V1.0 | |
| Page of actual Rel. | Page of prev. Rel. | Subjects changed since last release |
| -- | -- | See change service |
| | | |

For questions on technology, delivery and prices please contact the Infineon Technologies Offices in Germany or the Infineon Technologies Companies and Representatives worldwide: see the address list on the last page or our webpage at

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