

# Application Note

**AN-EVALSF2-ICE2A0565Z-2**

**CoolSET™**  
**10W 5.0V Evaluation Board with ICE2A0565Z**

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<http://www.infineon.com/CoolSET/>

Power Management & Supply



Never stop thinking

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## Introduction

### Application

This document is an engineering report that describes an universal input power supply designed in a typical off line flyback converter topology that utilizes the **ICE2A0565Z CoolSET™**. The application operates in discontinuous current mode using the **frequency reduction** during standby condition. The board has one output voltage with secondary regulation.

This board was designed to demonstrate the basic performance, the features and the power capability of the smallest CoolSET™ device ICE2A0565Z of the second generation of CoolSET™ in a DIP7 package with extended creepage distance for higher electrical strength.

### CoolSET™

CoolSET™ is a current mode PWM control IC and the power MOSFET CoolMOS™ within one package designed for low cost switch mode power supplies (SMPS). 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 heat sink and permits a SMPS design with a simply RCD snubber and a low cost standard transformer design. The lowest area specific  $R_{ds(on)}$  leads to a high efficiency and 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-ICE2A0565Z

This document contains the list of features, 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](http://www.infineon.com/CoolSET)

## List of Features

|                                                |
|------------------------------------------------|
| Feature                                        |
| CoolSET™ Device <b>ICE2A0565Z</b>              |
| External Sense                                 |
| Adjustable Soft start                          |
| Modulated Gate drive                           |
| 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 <sup>1</sup>         |
| Frequency Reduction                            |
| Internal Leading Edge Blanking                 |
| 100 kHz working frequency                      |
| DIP7 Package with extended Creepage Distance   |
| Standby Power according to European Commission |

**Table 1** – List of Features

## Power Supply Specification

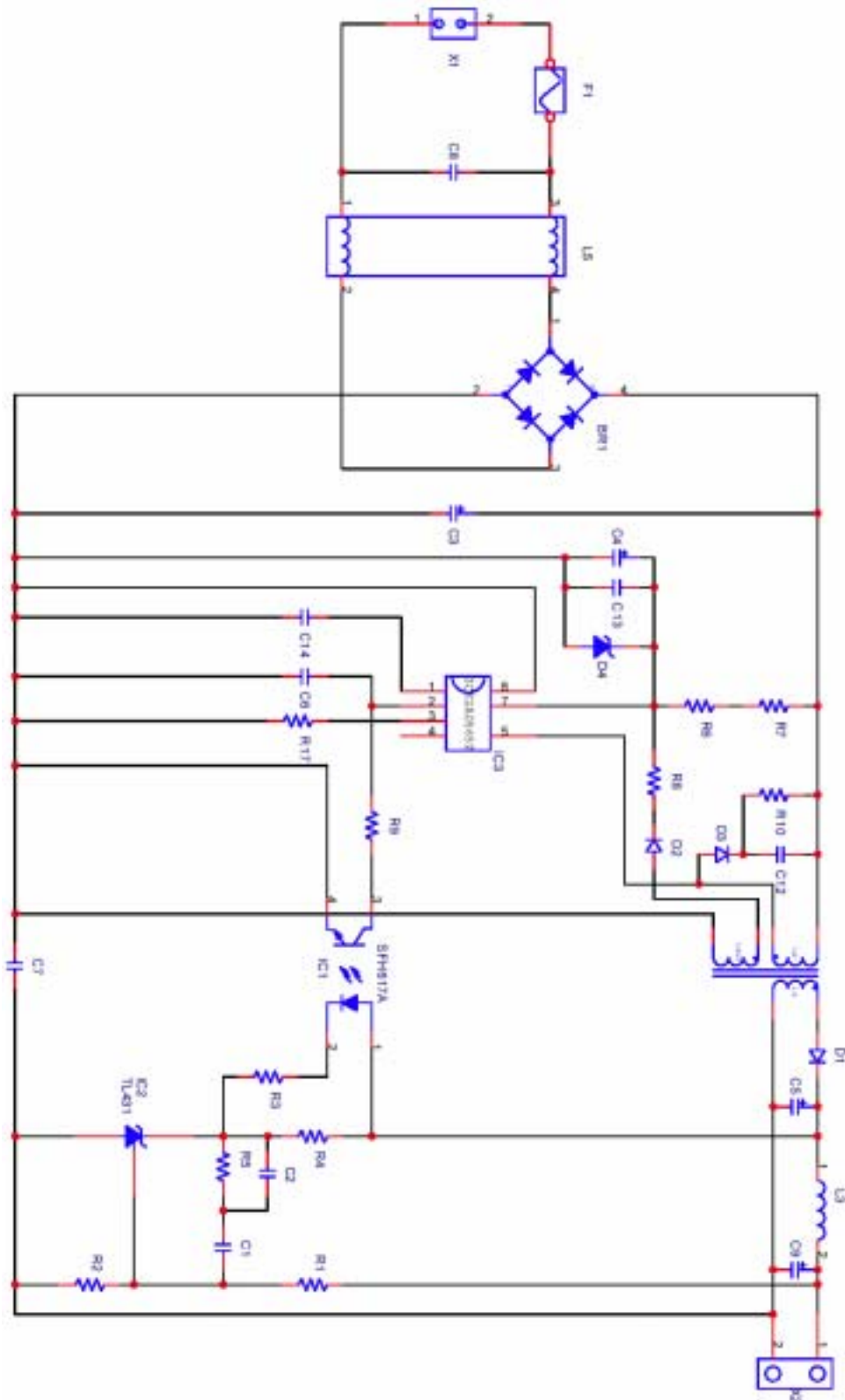
| Description                                            | Symbol       | Min  | Typ     | Max | Units             |
|--------------------------------------------------------|--------------|------|---------|-----|-------------------|
| <b>Input Section</b>                                   |              |      |         |     |                   |
| 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 (90V <sub>AC</sub> ) <sup>2</sup>  |              |      | 0.18    |     | W                 |
| No Load Input Power (230V <sub>AC</sub> ) <sup>2</sup> |              |      | 0.41    |     | W                 |
| <b>Output Section</b>                                  |              |      |         |     |                   |
| Output Voltage                                         | $V_{OUT}$    | 4.90 | 5.0     | 5.1 | $V_{DC}$          |
| AC Output Voltage Ripple                               | $V_{Ripple}$ |      | <50     |     | mV <sub>P-P</sub> |
| Output Current                                         | $I_{OUT}$    | 1.90 | 2.0     | 2.1 | $A_{DC}$          |
| Output Power Nominal                                   | $P_{OUT}$    |      | 10      |     | W                 |
| Peak Power                                             | $P_{OUTmax}$ |      | 16      |     | W                 |
| Total Regulation                                       |              |      | ±2      |     | %                 |
| Efficiency (90V <sub>AC</sub> )                        | $\eta$       |      | 78      |     | %                 |
| Efficiency (270V <sub>AC</sub> )                       | $\eta$       |      | 79      |     | %                 |
| <b>Environmental</b>                                   |              |      |         |     |                   |
| Conducted EMI                                          |              |      |         |     | EN55022B          |
| Ambient Temperature                                    | $T_A$        | 0    | 50      | 75  | °C                |
| <b>Thermal Consideration</b>                           |              |      |         |     |                   |
| Transformer                                            |              |      | 40      |     | °C                |
| CoolSET                                                |              |      | 60      |     | °C                |
| Output Diode                                           |              |      | 70      |     | °C                |
| Output Capacitors                                      |              |      | 20      |     | °C                |

**Table 2** – Power Supply Specification

<sup>1</sup>  $V_{DSBR}$  at  $T_j = 110^\circ\text{C}$

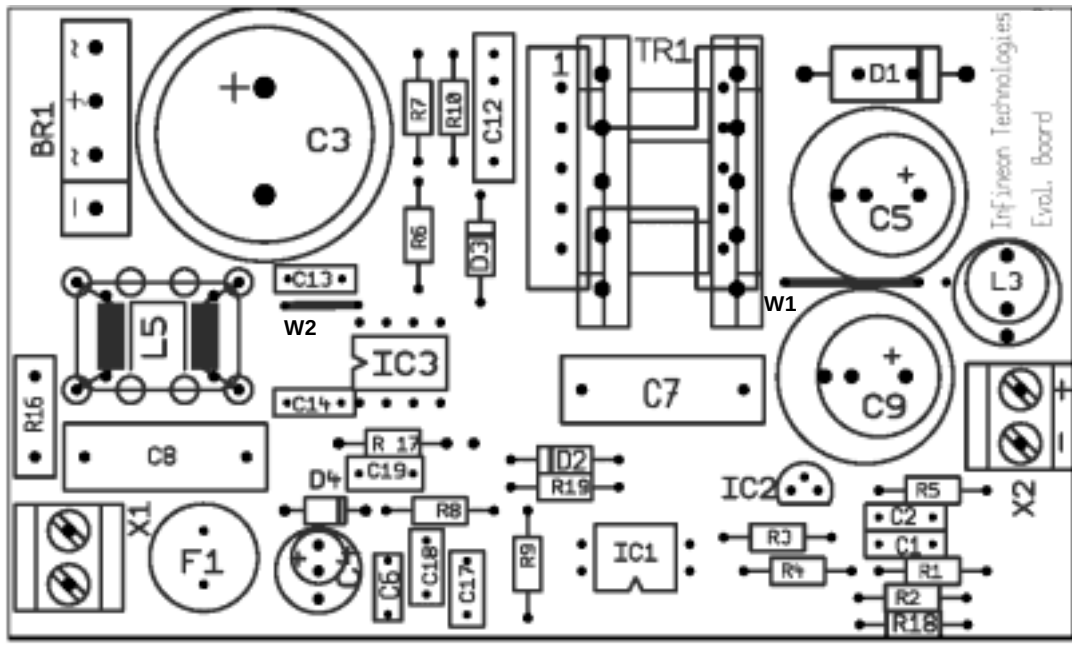
<sup>2</sup> Frequency Reduction Mode ( $f_{Standby} = 21\text{ kHz}$ ) and  $P_{OUT} = 0\text{ W}$

## Schematic



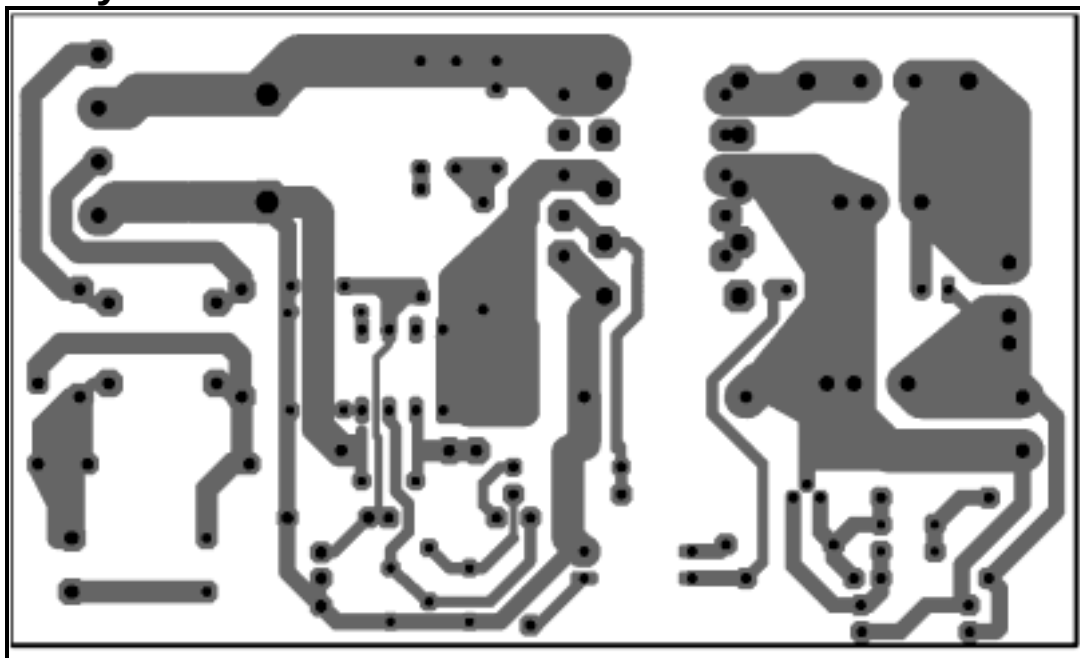
**Figure 2** 10W 5.0V ICE2A0565Z Power Supply Schematic

## PCB Component Legend



### Figure 3 Component Legend

## PCB Layout



**Figure 4** Board Layout - Component Side

## Description

### Introduction

The **EVALSF2-ICE2A0565Z** demoboard is a low cost off line flyback switch mode power supply (SMPS) using the ICE2A0565Z system IC from the *CoolSET™-F2* family. The circuit, shown in Figure 2, details a 5.0V, 10W power supply that operates from an AC line input voltage range of 85 to 265V<sub>AC</sub>, 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 capacitor C8 as radio interference suppressors. After the bridge rectifier BR1 and input capacitor C3, a voltage from 120 to 380 V<sub>DC</sub> is present. Due to the extended duty cycle  $D_{MAX}^3$  of the ICE-F2-family there is the possibility to replace the 47μF input capacitor with a 22μF (2.2μF/W)<sup>3</sup>.

### Startup

From this voltage, the chip starting the current supply is derived using resistors R6 and R7. Because of the very low start up current of typically 27μA, a high-value resistor can be used.

### Operation Mode

During operation, the V<sub>CC</sub> pin is supplied via a separate transformer winding with associated rectification D2 and buffering C4, C13. Resistor R8 is used for current limiting during the charging of C4. In order not to exceed the maximum voltage at V<sub>CC</sub> pin an external zener diode D4 limits this voltage. During light or no load condition, the switching frequency is automatically and continuously reduced down to 21kHz<sup>4</sup> in order to reduce the switching losses.

### Softstart

The Soft-Start function is realized by an internal resistor and the adjustable external capacitor C14.

### Snubber Network

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<sub>DSBR</sub> = 650V<sup>5</sup> maximum.

### Limitation of primary current

The CoolMOS™ drain source current is sensed via external shunt resistors R17. An accurate value of the shunt improves the peak power limitation shown in the curve peak power limitation in the rear of this report.

### Output Voltage

Power is coupled out on the secondary side via a fast-acting diode D1 with low forward voltage. Capacitor C5 performs energy buffering, a following LC - filter C9 and inductor L3 considerably reduces the output voltage ripple. Storage output capacitor C5 is designed to exhibit a very low ESR in order to minimize the output voltage ripple caused by the triangular 100kHz current characteristic. The output voltage is set with resistors R1 and R2.

### Regulation

The output voltage is controlled using a type TL431 reference diode (IC2). 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 ICE2A0565Z control device. The optocoupler used meets DIN VDE 884 requirements for a wider creepage distance.

<sup>3</sup> Slope Compensation is needed due to Current Mode Control and Dnom > 50% see description in the rear of the report

<sup>4</sup> Without audible noise

<sup>5</sup> V<sub>DSBR</sub> = 650V @ T<sub>j</sub> = 110°C

## Bill of Material

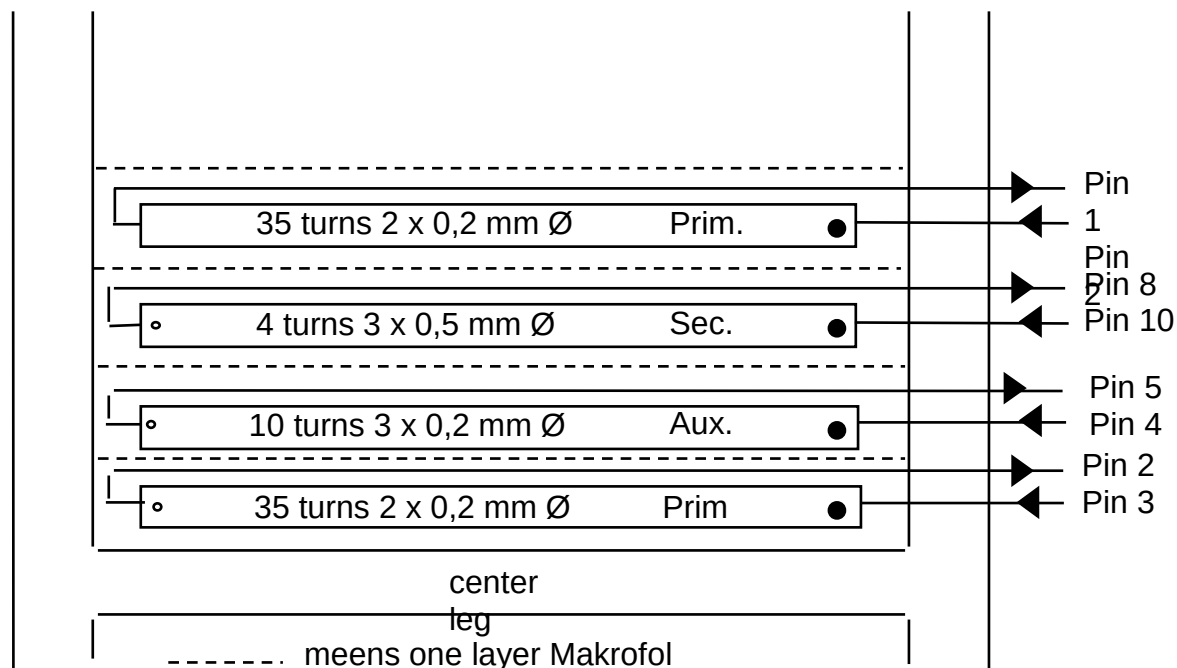
### ICE2A0565Z Evaluation Board 5.0V/ 10W

| Pos. | Part       | Type            | Number | Values | Others           |
|------|------------|-----------------|--------|--------|------------------|
| 1    | BR1        | B500 C1500      | 1      |        |                  |
| 2    | C1 [nF]    | 470             | 1      | 50V    | X7R              |
| 3    | C2 [nF]    | 10              | 1      | 50V    | X7R              |
| 4    | C3 [μF]    | 47              | 1      | 400V   | B43504-A9476-M   |
| 5    | C4 [μF]    | 22              | 1      | 63V    |                  |
| 6    | C5 [μF]    | 1000            | 1      | 25V    | Low ESR – B41886 |
| 7    | C6 [nF]    | 2.2             | 1      | 50V    | X7R              |
| 8    | C7 [nF]    | 2.2             | 1      | 250V   | Y1 Cap           |
| 9    | C8 [μF]    | 0.1             | 1      | 275V   | X2 Cap           |
| 10   | C9 [μF]    | 470             | 1      | 25V    | Low ESR – B41886 |
| 11   | C12 [nF]   | 1.0             | 1      | 400V   | MKT              |
| 12   | C13 [nF]   | 100             | 1      | 50V    | X7R              |
| 13   | C14 [nF]   | 100             | 1      | 50V    | X7R              |
| 14   | D1         | MUR540          | 1      | 400V   |                  |
| 15   | D2         | 1N4148          | 1      |        |                  |
| 16   | D3         | 1N4937          | 1      |        |                  |
| 17   | D4         | ZPD18           | 1      | 18V    |                  |
| 18   | F1         | Microfuse 3.15A | 1      | 3.15A  |                  |
| 19   | IC1        | SFH617A-3X016   | 1      |        |                  |
| 20   | IC2        | TL431CLP        | 1      |        |                  |
| 21   | IC3        | ICE2A0565Z      | 1      |        |                  |
| 22   | L3 [μH]    | 1.0             | 1      | 6A     | 262LYF-0074M     |
| 23   | L5 [μH]    | 2*27mH / 0.9A   | 1      | 0.9A   |                  |
| 24   | R1 [kOhm]  | 3.3             | 1      |        |                  |
| 25   | R2 [kOhm]  | 3.3             | 1      |        |                  |
| 26   | R3 [kOhm]  | 0,082           | 1      |        |                  |
| 27   | R4 [kOhm]  | 1.2             | 1      |        |                  |
| 28   | R5 [kOhm]  | 2,7             | 1      |        |                  |
| 29   | R6 [kOhm]  | 360             | 1      |        |                  |
| 30   | R7 [kOhm]  | 360             | 1      |        |                  |
| 31   | R8 [Ohm]   | 4.3             | 1      |        |                  |
| 32   | R9 [Ohm]   | 22              | 1      |        |                  |
| 33   | R10 [kOhm] | 100             | 1      |        |                  |
| 34   | R17 [Ohm]  | 1.1             | 1      |        | 1%               |
| 35   | TR1        | E20/10/6        | 1      | 0.50   | Mm               |
| 36   | W1         | Wire            | 1      |        |                  |
| 37   | W2         | Wire            | 1      |        |                  |
| 38   | X1         | Connector 2pol. | 1      |        |                  |
| 39   | X2         | Connector 2pol. | 1      |        |                  |

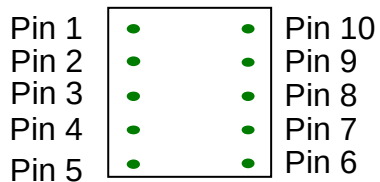


## Transformer Construction Documentation

Core Material: E20/10/6; N87  
Frequency: 100 kHz  
gap: 0.5mm  
Al = 103nH  
Lp = 503μH  
Coil former: horizontal version



Top view:



## Performance Data

### Efficiency

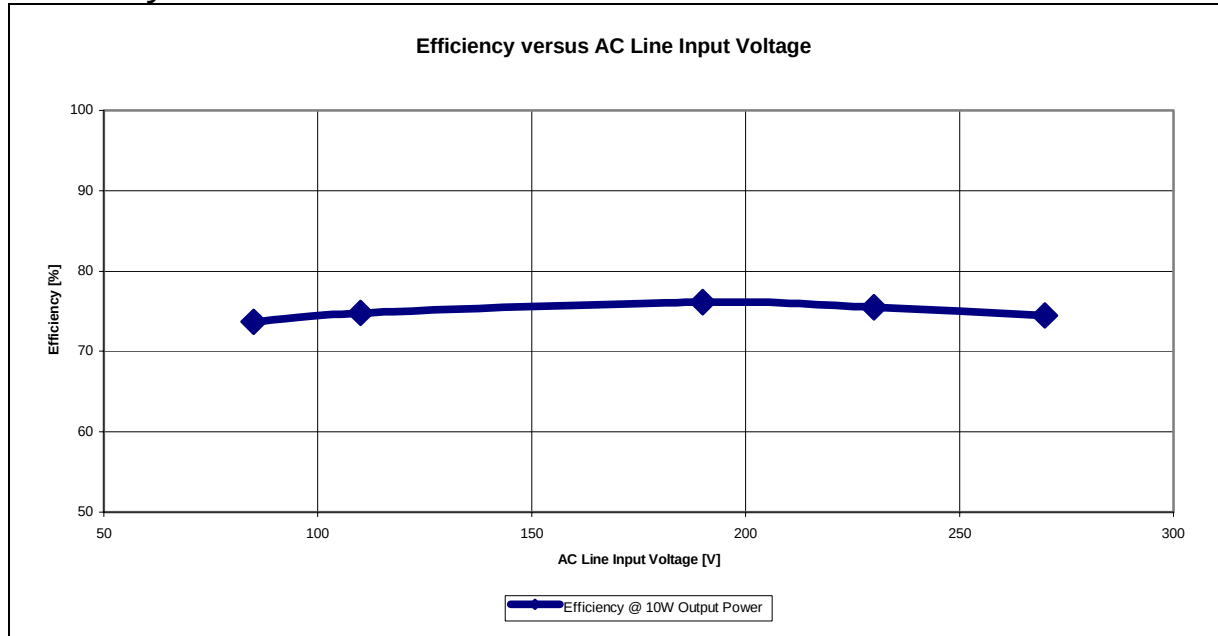


Figure 5 Efficiency vs. AC Line Input Voltage

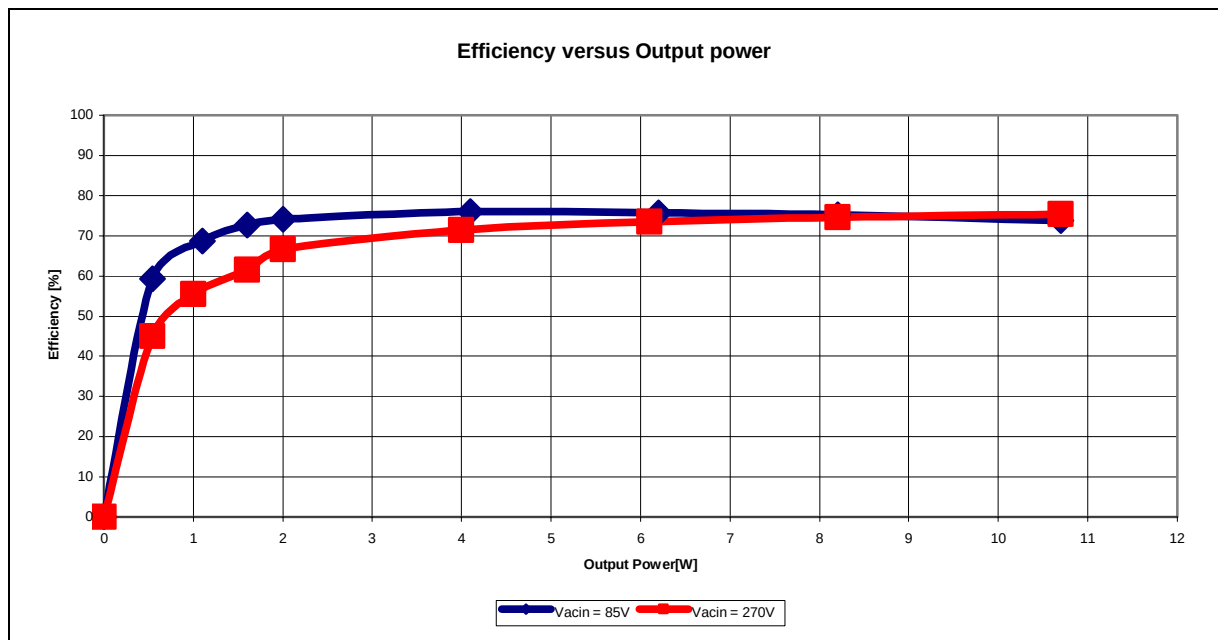


Figure 6 Efficiency vs. Output Power @ Low and High Line 50Hz

## No-Load Input Power (Standby)

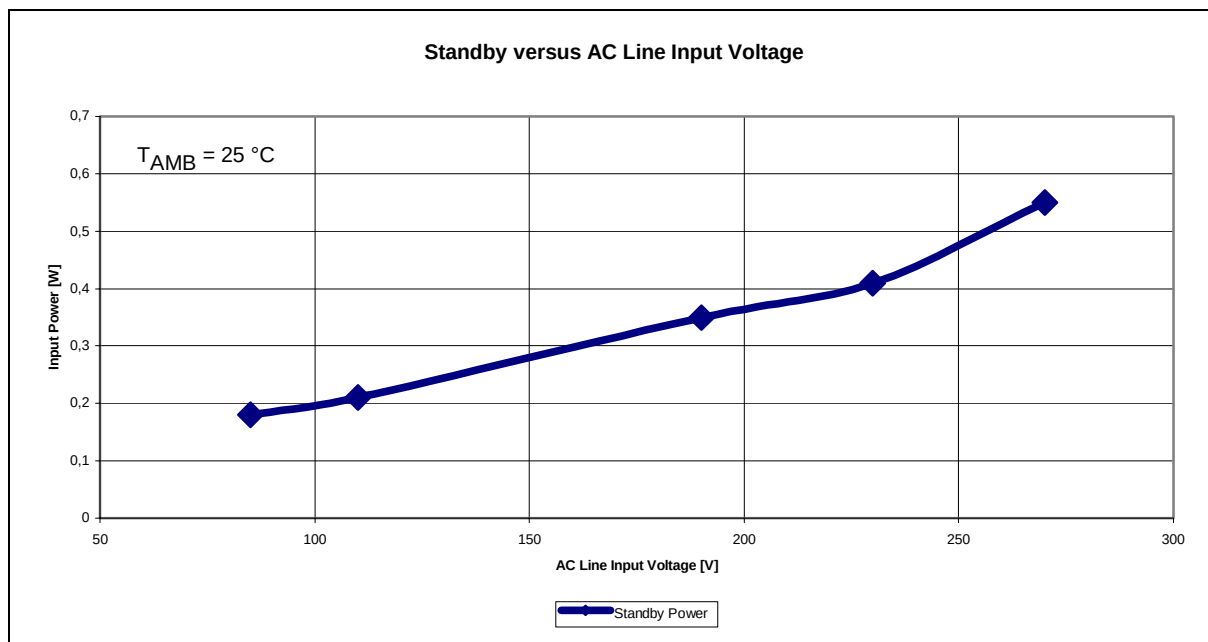


Figure 7 No Load Input Power (Standby) vs. AC Line Input Voltage @  $P_{out} = 0W$

## Regulation and Power Limiting

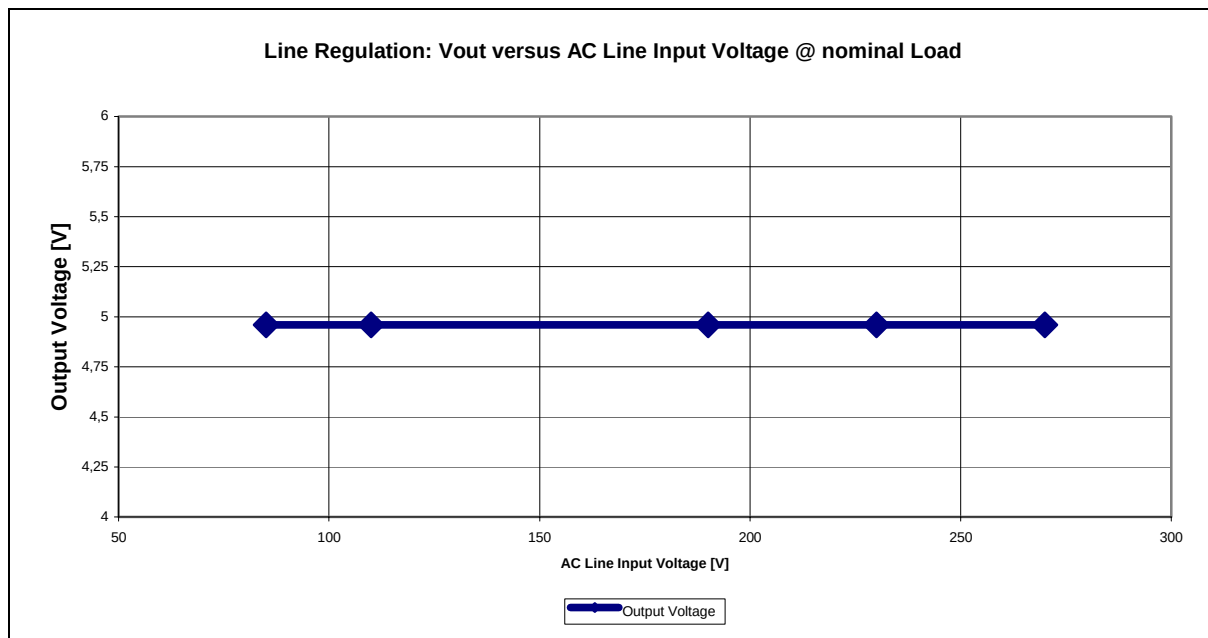
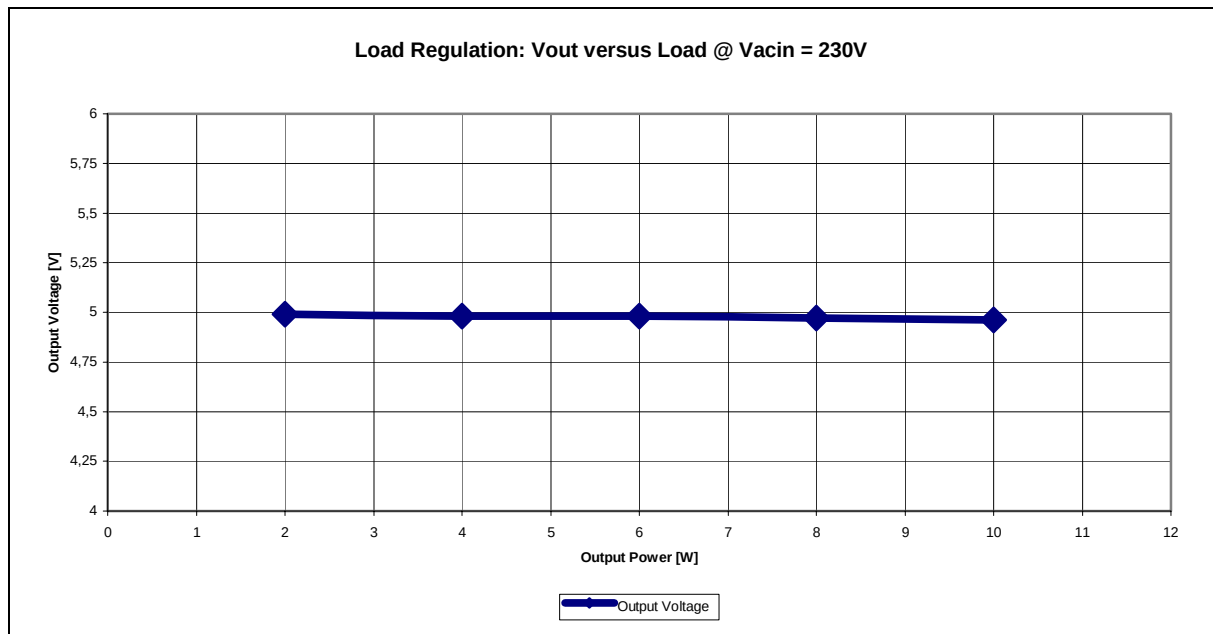
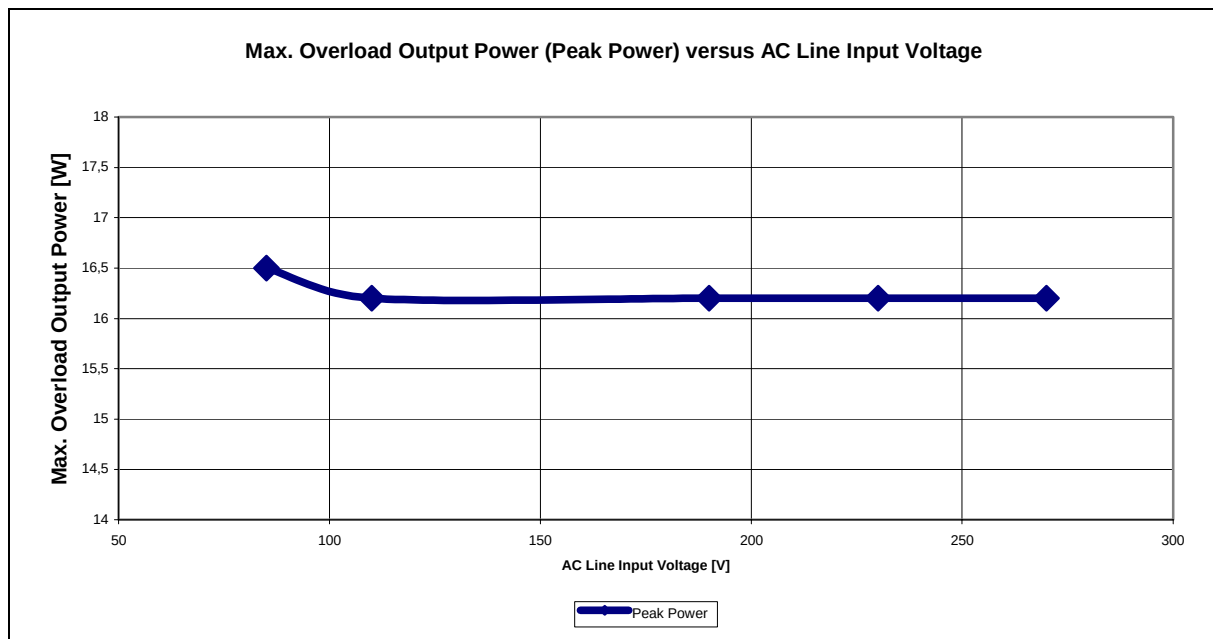


Figure 8 Line Regulation vs. AC Line Input Voltage



**Figure 9 Load Regulation**

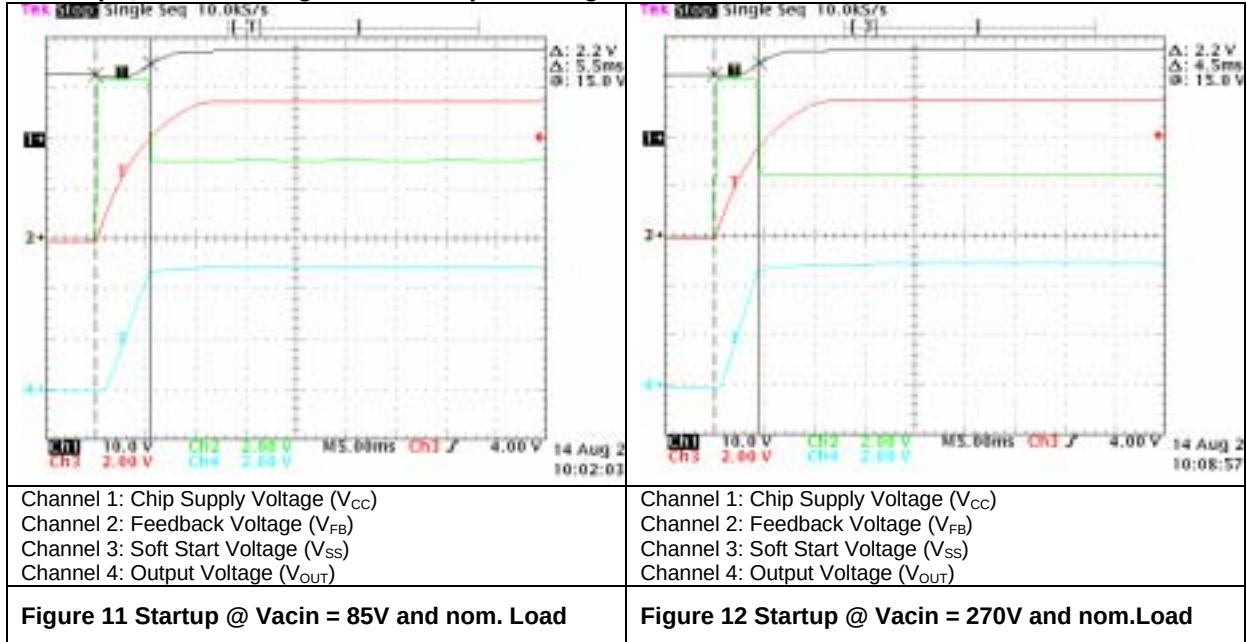


**Figure 10 Overload Output Power (Over Current Shut Off Threshold) vs. Line Input Voltage**

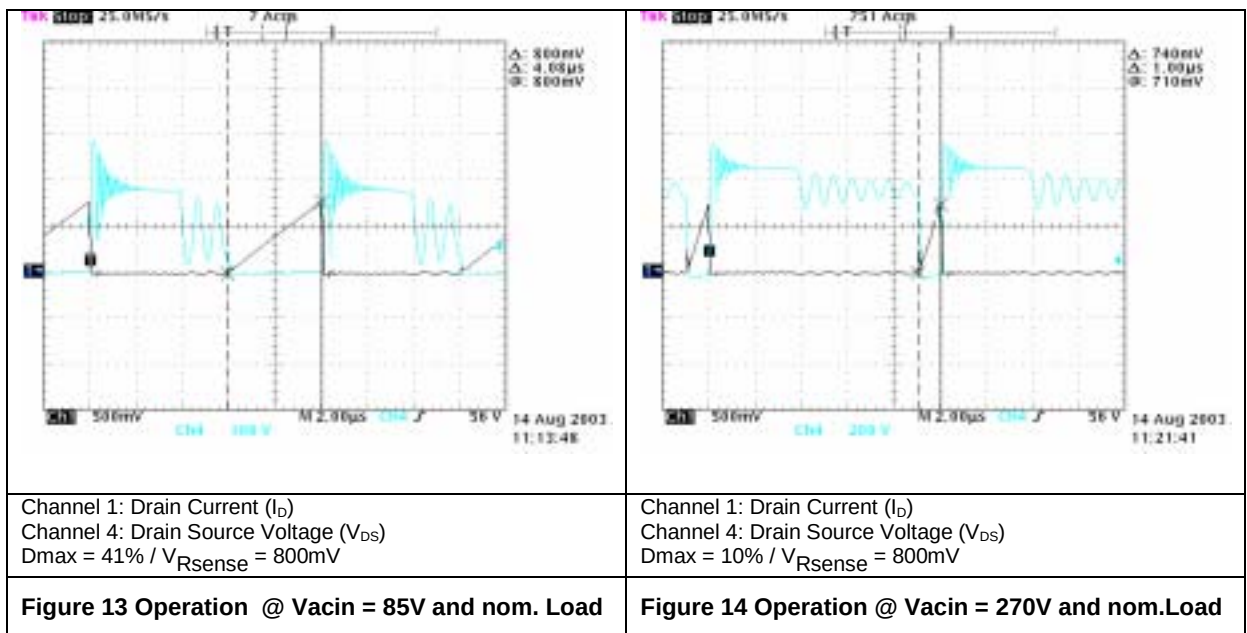
## Waveforms and Scope Plots

All waveforms and scope plots were recorded with a Tectronix TDS 745D

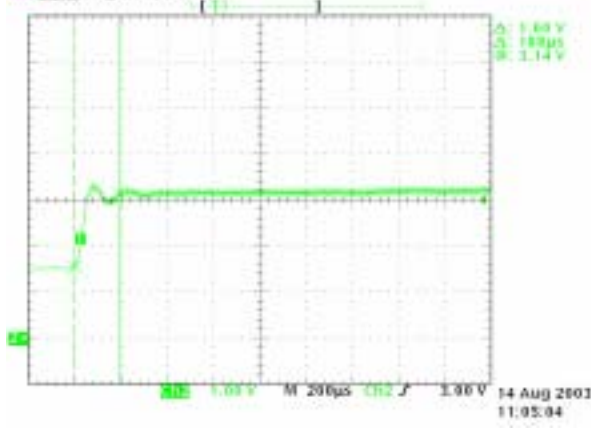
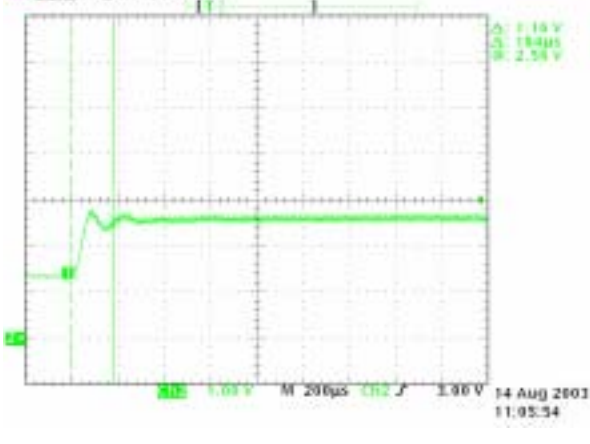
### Startup @ Low and High AC Line Input Voltage and Nominal Load



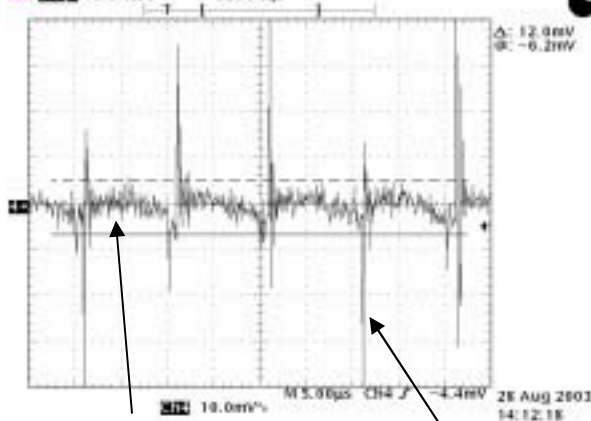
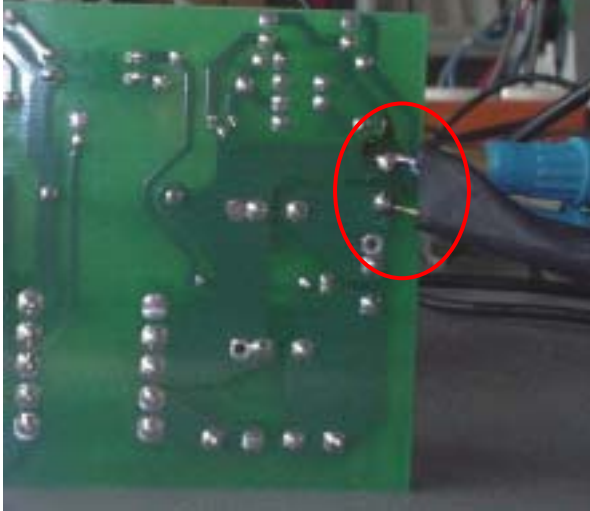
### Drain Source Voltage and Current During Normal Operation



## Load Transient Response (Loadjump from 10% Load until 100% Load)

|                                                                                   |                                                                                    |
|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
|  |  |
| Channel 2: Feedback Voltage ( $V_{FB}$ )                                          | Channel 2: Feedback Voltage ( $V_{FB}$ )                                           |
| Figure 15 Loadjump @ $V_{ACIN} = 85V$ and nom. Load                               | Figure 16 Loadjump @ $V_{ACIN} = 270V$ and nom. Load                               |

## AC Output Ripple during Nominal Load and Normal Operation

|                                                                                                                                                          |                                                                                                                                               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
|  <p>AC Output Voltage Ripple</p> <p>High Frequency Probe Coupling</p> |                                                           |
| Channel 1: AC Output Ripple ( $V_{ACOUT}$ )<br>$V_{ACOUTmax} = \pm 10mV$                                                                                 | Details of AC output voltage ripple measurements. The probe GND should be as short as possible to minimize the high frequency probe coupling. |
| Figure 17 AC Output Voltage Ripple at nom. Load                                                                                                          | Figure 18 AC Ripple Measurement Technique                                                                                                     |

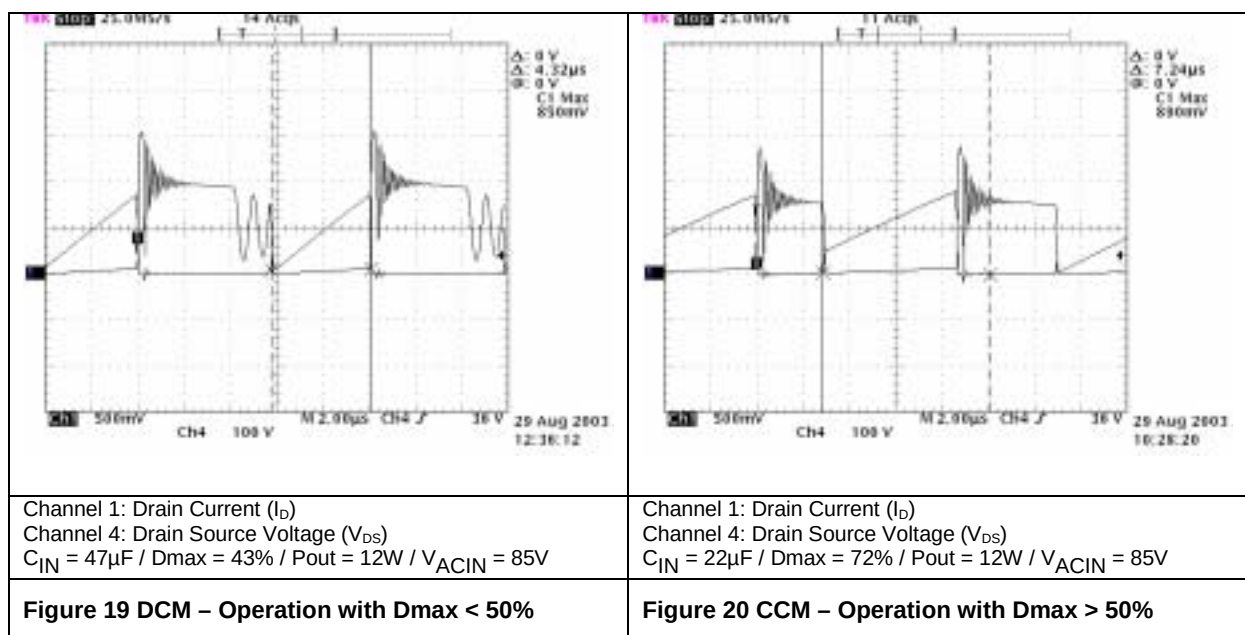
## Input Capacitor Improvement – Slope Compensation

### Input Capacitor Improvement

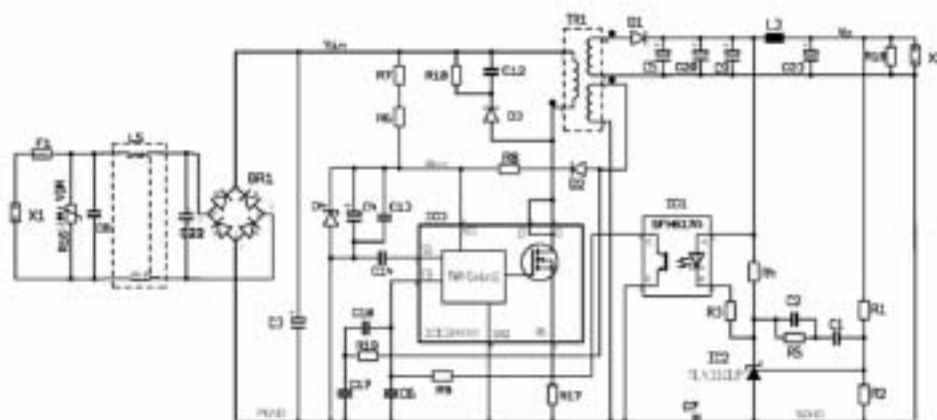
In case you are using a smaller input capacitor (22 $\mu$ F instead of 47 $\mu$ F), the maximum duty cycle increases. To make sure, that the board is not working in the continuous conduction mode, a different transformer is necessary; otherwise, you have to assemble slope compensation on board.

### Slope Compensation

Any kind of current mode controller needs to have slope compensation in case the application is designed for the continuous conduction mode (CCM) and the maximum duty cycle exceeds the 50% threshold. Below you see the impact on the system in case of an input capacitor reduction; with the 47 $\mu$ F bulk works the board in the discontinuous conduction mode (DCM) and a  $D_{max} < 50\%$ ; with the smaller 22 $\mu$ F bulk, the board is running in the continuous conduction mode (CCM) and  $D_{max} > 50\%$ .



To prevent an instability of the regulation loop, in case of CCM and  $D_{max} > 50\%$ , assemble just three more components (2 ceramic capacitors C17 / C18 and one resistor R19) as shown in the circuit diagram below.



**Figure 21 Circuit Diagram Switch Mode Power Supply with Slope Compensation**

More information regarding how to calculate the additional components, see in the application note AN\_SMPS\_ICE2XXXX – available on the internet: [www.infineon.com/CoolSET](http://www.infineon.com/CoolSET) CoolSET F2.

### 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 |
| 1.2          | Replace Device ICE2A165 with ICE2A0565Z                                                                                |  | Aug. 2002  |
| 2.0          | Update:<br>→ Board<br>→ BOM<br>→ Transformer construction<br>Additional:<br>→ Performance Data<br>→ Slope Compensation |  | Aug. 2003  |
|              |                                                                                                                        |  |            |



## 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-ICE2A0565Z-01 |                    |                                     |
| Actual Release: 2.0 Date: 2003-08-09      |                    | Previous Release: V1.0              |
| Page of actual Rel.                       | Page of prev. Rel. | Subjects changed since last release |
| --                                        | --                 | See change service                  |
|                                           |                    |                                     |