Version 3.0, Oct. 2003

Application Note

AN-EVALSF2-ICE2B765P2-3

CoolSET™
80W 24V Evaluation Board using ICE2B765P2

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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 a universal input power supply designed in a typical off line flyback converter topology that utilizes the **ICE2B765P2 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 F2 CoolSET™ device ICE2B765P2 of the second generation of CoolSET™ in a TO220 ISODRAIN 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, in combination with the adjustable soft start function, a reduced electrical stress on the MOSFET, the transformer and the output diode will be the effect. The 650V[2] / 800V[3] 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-ICE2B765P2

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 are performed in accordance with the application note **"AN–SMPS–ICE2AXXX for OFF – Line Switch Mode Power Supplies"** and **FlyCal**, an 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
2 At Tj = 110°C
3 At Tj = 25°C

List of Features

Feature
CoolSET™ Device **ICE2B765P2**
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[4]
Standby Mode: Frequency Reduction (f_{OSZ} = 21 kHz)
Internal Leading Edge Blanking
67 kHz operating frequency
TO220 ISODRAIN Package with isolated Tab
Standby Power according to international Standards

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 (230V_{AC})			0.58		W
Output Section					
Output Voltage	V_{OUT}	23.75	24	24.25	V_{DC}
AC Output Voltage Ripple	V_{Ripple}		< 0.05		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}		90		W
Total Regulation			±2		%
Load Regulation (10...100%)			< 1		%
Efficiency (85V_{AC}) @ nominal Load	η		83		%
Efficiency (270V_{AC}) @ nominal Load	η		89		%
Environmental					
Conducted EMI					EN55022B
Ambient Temperature	T_A	0	25	40	°C
Thermal Consideration @ V_{ACIN} = 85V and Dmax = 50% (ΔT @ Ta = 25°C)					
Transformer			65		°C
CoolSET			55		°C
Output Diode			65		°C
Output Capacitors			40		°C

Table 2 – Power Supply Specification

[4] V_{DSBR} at Tj = 110°C

Schematic

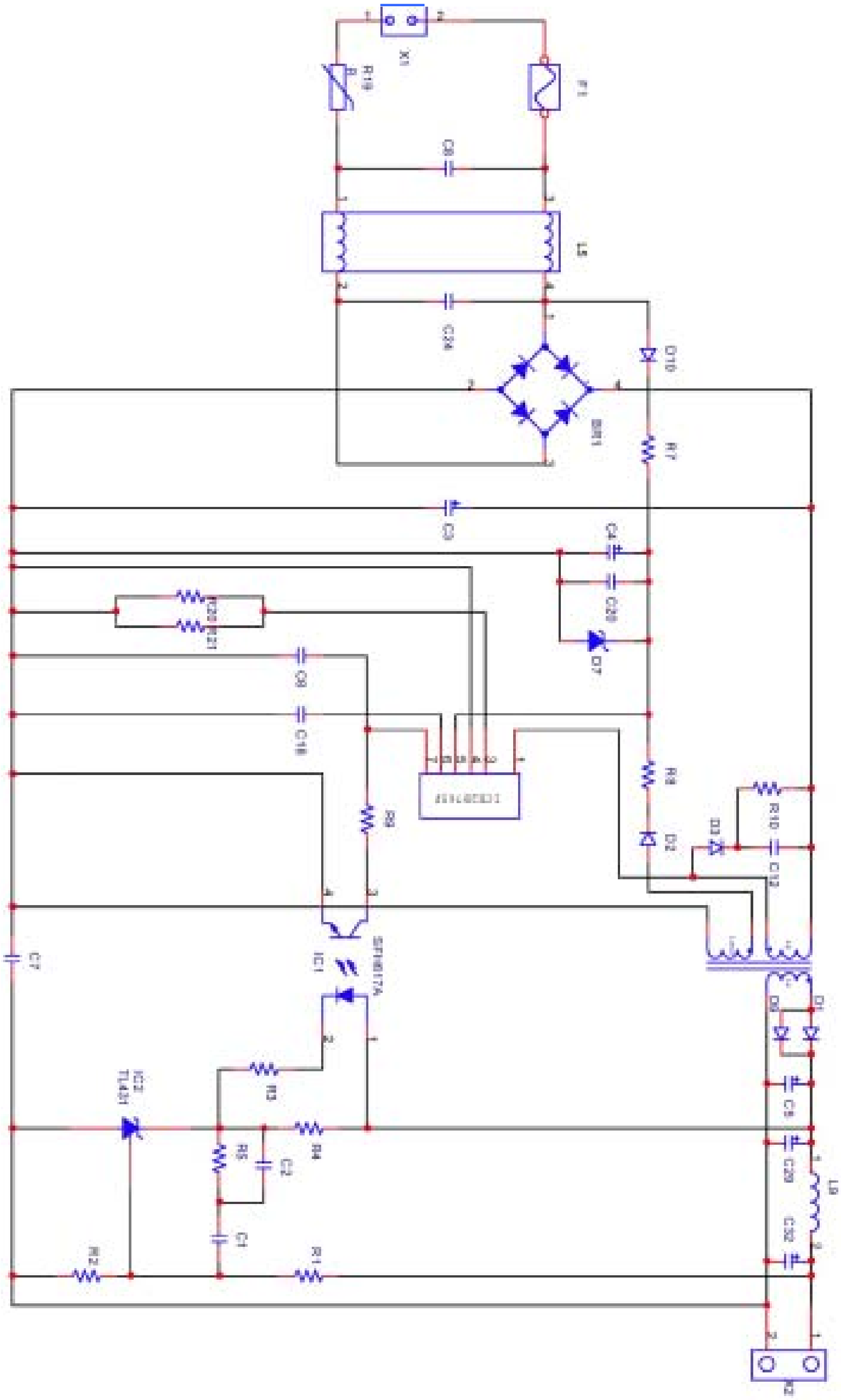


Figure 2 Power Supply Schematic

PCB Layout

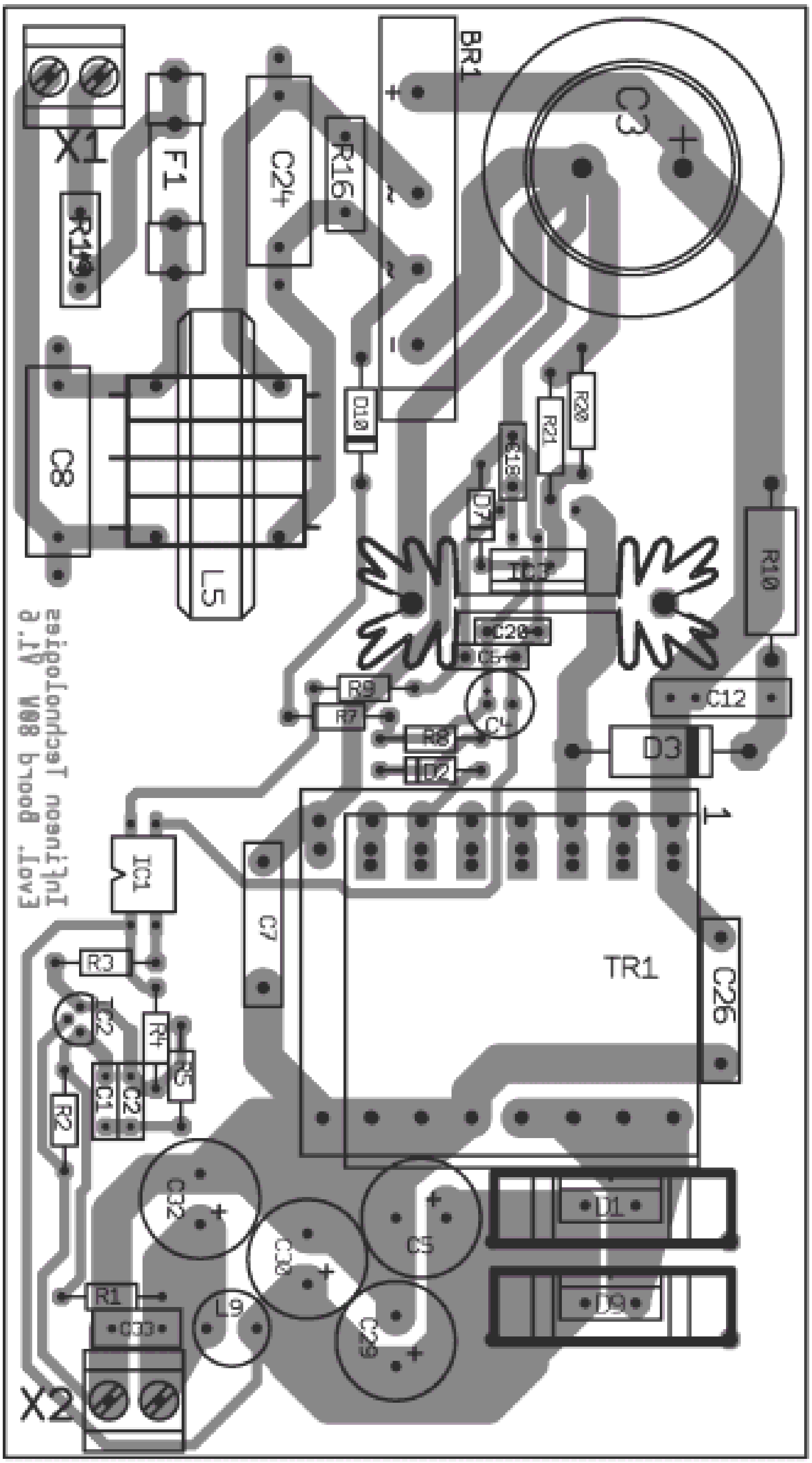


Figure 3 Board Layout - Component Side

Description

Introduction

The **EVALSF2-ICE2B765P2** demoboard is a low cost flyback switching power supply using the ICE2B765P2 integrated circuit from the *CoolSET™-F2* family. The circuit shown in Figure 2 details a 24V, 80W supply that operates from a line input voltage range of 85 up to 265V_{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 stress 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. The capacitor C33 lower the AC output ripple on the output voltage.

Regulation

The output voltage is controlled using a type TL431 (IC2) 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 ICE2B765P2 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, Y – 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

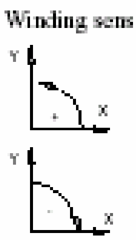
Pos.	Part	Type	Number	Values	Note	Ordering Code
1	BR1	B380 C5000-3300	1			DIOTEC B380C5000-3300
2	C1 [nF]	470	1	50V		EPCOS B37984M5474K
3	C2 [nF]	0.15	1	50V		EPCOS B37979G1151J
4	C3 [µF]	220	1	400V		EPCOS B43304B9227M
5	C4 [µF]	47	1	35V		EPCOS B41821A6476M
6	C5 [µF]	1000	1	35V		EPCOS B41886S7108M
7	C6 [nF]	2.2	1	50V	X7R	EPCOS B37979G5222J
8	C7 [nF]	2.2	1	250V	Y1 Cap	Röderste WKP2222MCPER
9	C8 [µF]	0.22	1	275V	X2 Cap	EPCOS B81130C1224M
10	C12 [nF]	2.2	1	400V	MKT	EPCOS B32520C6222K
11	C18 [nF]	330	1	50V	X7R	EPCOS B37984M5334K
12	C20 [nF]	100	1	50V	X7R	EPCOS B37987F5104K
13	C24 [µF]	0.22	1	275V	X2 Cap	EPCOS B81130C1224M
14	C29 [µF]	1000	1	35V	Low ESR	EPCOS B41886S7108M
15	C32 [µF]	220	1	35V	Low ESR	EPCOS B41859A7227M
16	C33 [nF]	470	1	50V		EPCOS B37984M5474K
17	D1	MUR1520	1	200V		ONS MUR1520
18	D2	1N4148	1			TELEFUNKEN 1N4148 TAP
19	D3	1N4937	1	200V		SETRON 1N4937
20	D7	ZPD18	1	18V		PHILIPS ZPD18
21	D9	MUR1520	1	200V		ONS MUR1520
22	D10	1N4007	1			DIOTEC 1N4007
23	F1	Microfuse	1	3.15A		SIBA SICH331
24	HS1	Heatsink	1			ASSMANN V-7477-X
25	HS2	Heatsink TO220	1			FISCHER FK224 MI P SIP
26	HS3	Heatsink TO220	1			FISCHER FK224 MI P SIP
27	IC1	SFH617A-3X006	1			VISHAY SFH617A-3X006
28	IC2	TL431CLP TO92	1			ONS TL431CLP TO92
29	IC3	ICE2B765P2	1			INFINEON
30	L9 [µH]	1.0	1	6A		WÜRTHEL 744772010
31	L5 [µH]	2*27mH	1	1.7A		EPCOS B82734R2172A30
32	R1 [kΩ]	40.0	1		1%	
33	R2 [kΩ]	4.7	1		1%	
34	R3 [kΩ]	1.1	1			
35	R4 [kΩ]	1.6	1			
36	R5 [kΩ]	180.0	1			
37	R7 [kΩ]	680	1			
38	R8 [Ω]	4.3	1			
39	R9 [Ω]	22.0	1			
40	R10 [kΩ]	33.0	1			
41	R19	NTC10	1			
42	R20 [Ω]	0.43	1		1%	
43	R21 [Ω]	0.39	1		1%	
44	TR1	SMT19	1	0.7mm Gap		OREGA
45	Haltefed.	For Heatsink	1			FISCHER THF104
46	W1	Wire	1			
47	X1, X2	Connector 2pol.	2			

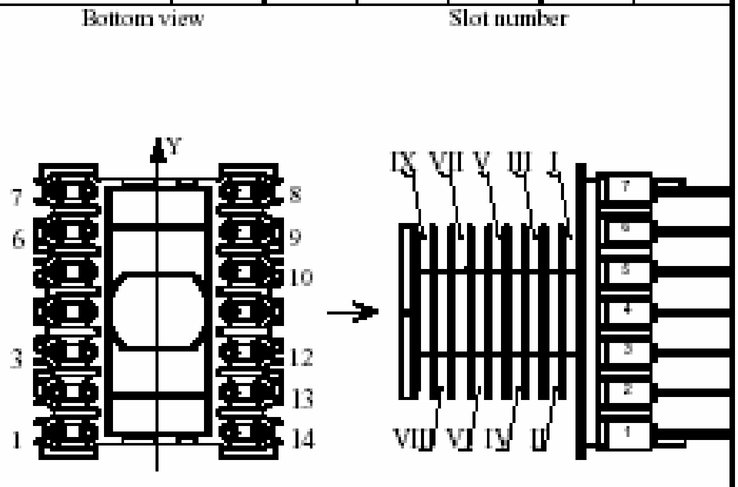
Transformer Construction Documentation

THOMSON	SMT 19	40346-XX
	SPF : Proposal	B

WINDING SPECIFICATION

N° Slot	N° Winding	Voltage / Observation	Nb de Turns	Sens	Ø wire (mm)	Start	Stop	Classe of wire
I	1	Aux	4	+	0.28	6	7	Grade 2
II	2	24v	7	+	0.28	14	10	Grade 2
	3	24v	7	-	0.28	10	14	Grade 2
	4	24v	7	+	0.28	14	10	Grade 2
III	5	Prim.	28	-	0.28	1	3	Grade 2
IV	6	24v	7	-	0.28	9	13	Grade 2
	7	24v	7	+	0.28	13	9	Grade 2
	8	24v	7	-	0.28	9	13	Grade 2
V	9	Prim.	28	+	0.28	3	1	Grade 2
VI	10	24v	7	+	0.28	12	8	Grade 2
	11	24v	7	-	0.28	8	12	Grade 2
	12	24v	7	+	0.28	12	8	Grade 2
VII	13	Prim.	28	-	0.28	1	3	Grade 2
VIII	14	24v	7	-	0.28	10	14	Grade 2
	15	24v	7	+	0.28	13	9	Grade 2
	16	24v	7	-	0.28	8	12	Grade 2
IX	17	Prim.	28	+	0.28	3	1	Grade 2
	18							Grade 2
	19							Grade 2





OREGA	PRODUCT SPECIFICATION R&D Dpt : Tel.:(33)03 84 64 54 00 - Fax (33)03 84 64 54 28	Page	1/5

Performance Data

Efficiency

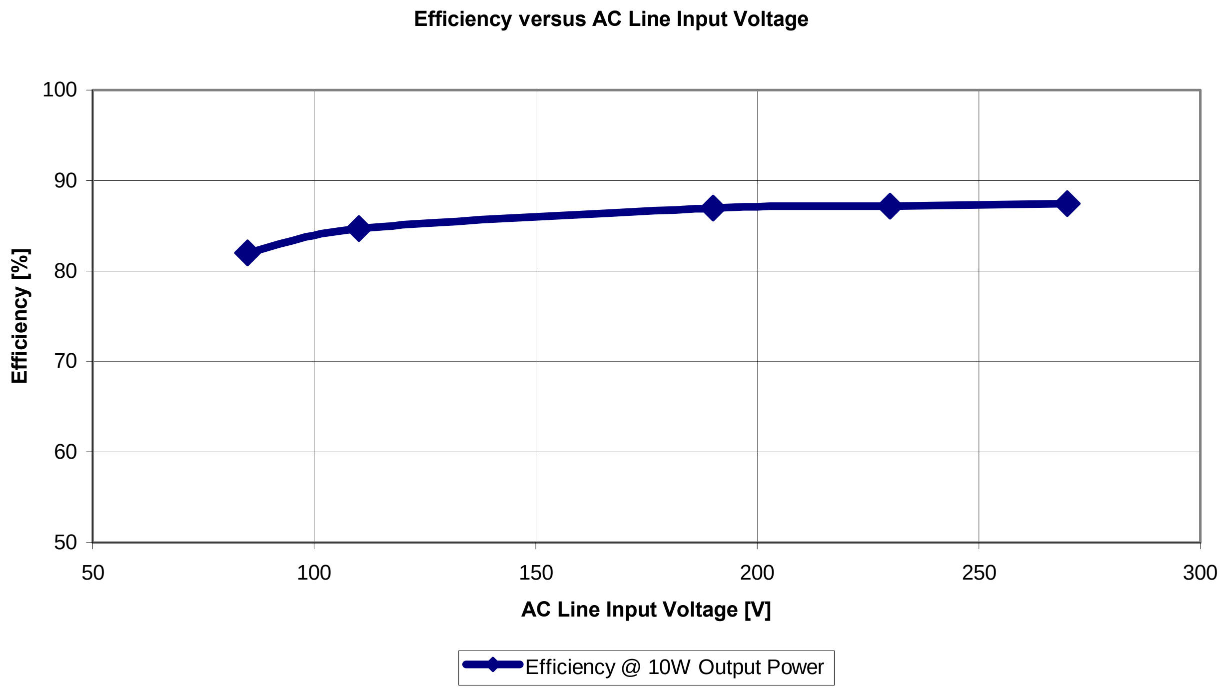


Figure 4 Efficiency vs. Line Input Voltage

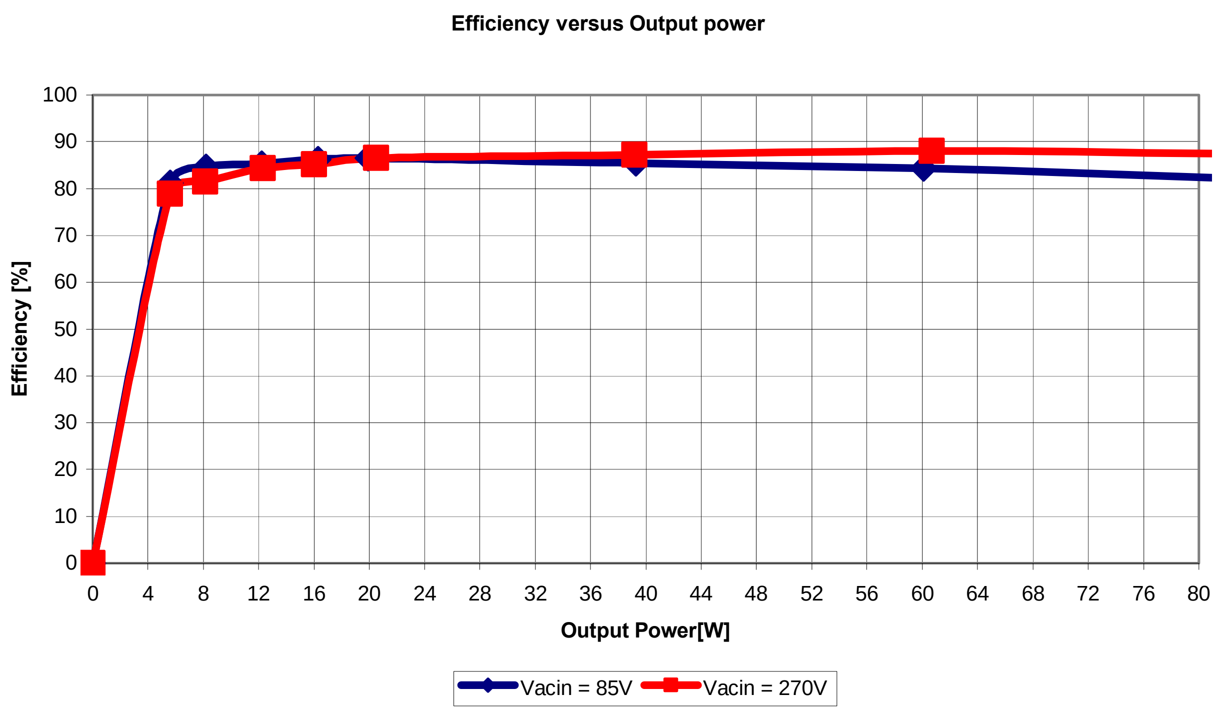


Figure 5 Efficiency vs. Output Power @ Low and High Line 50Hz

No-Load Input Power (Standby)

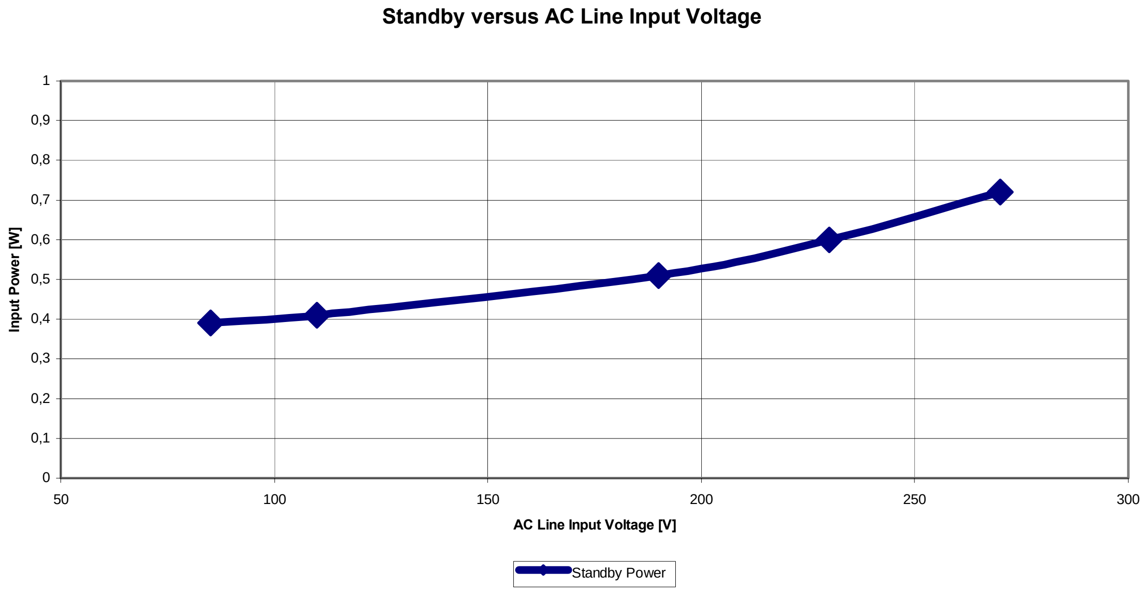


Figure 6 Standby Power vs. Line Input Voltage and No Load Condition (Pout = 0W)

Regulation and Power Limiting

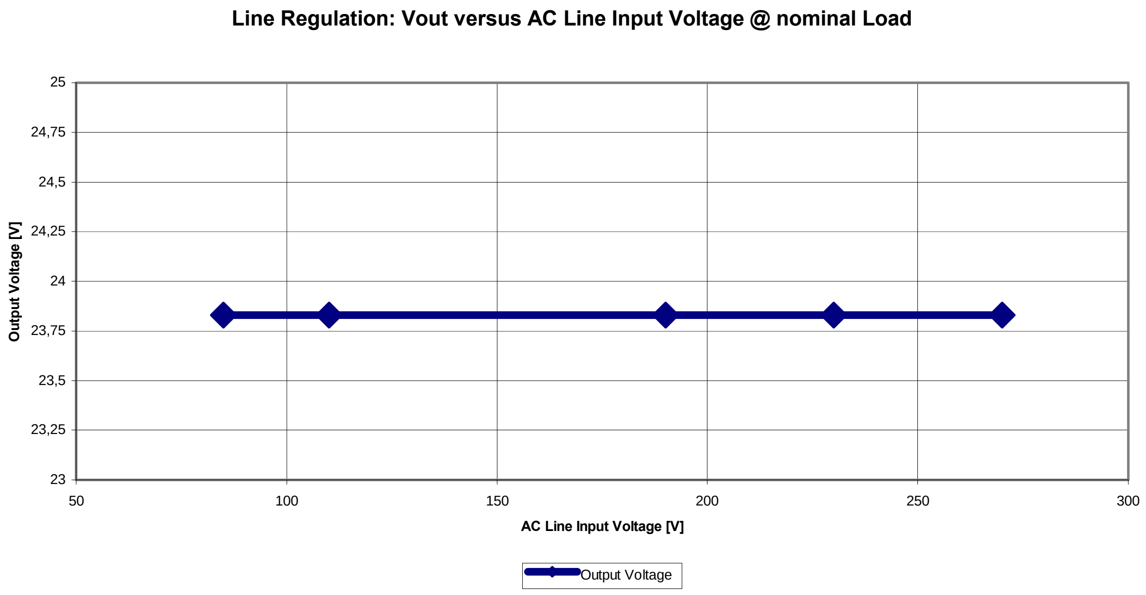


Figure 7 Output Voltage Regulation vs. Line Input Voltage

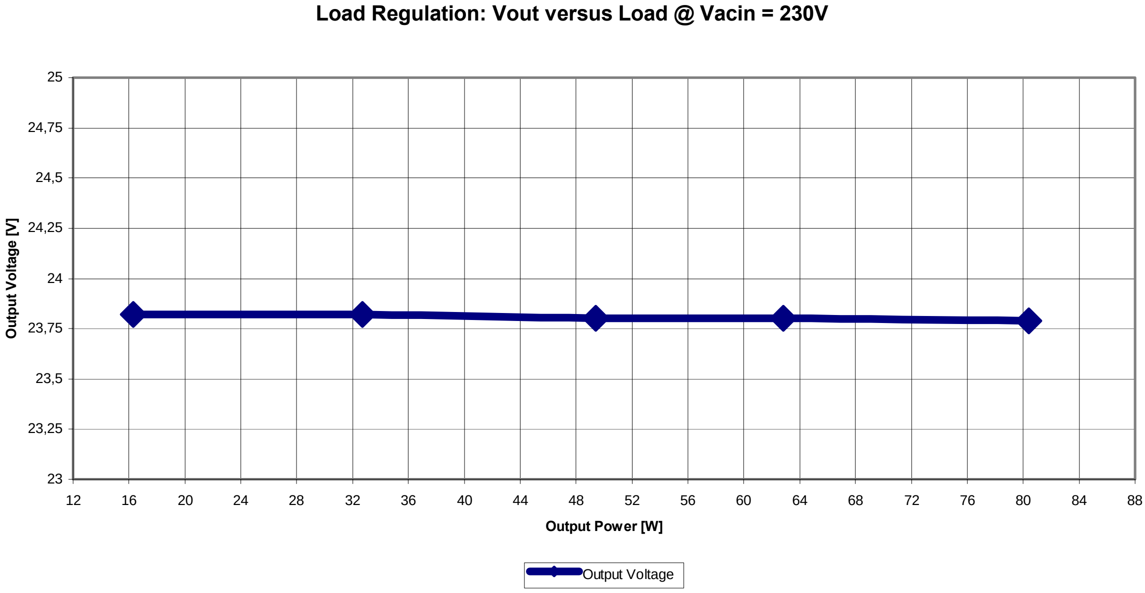


Figure 8 Output Voltage Regulation vs. Load

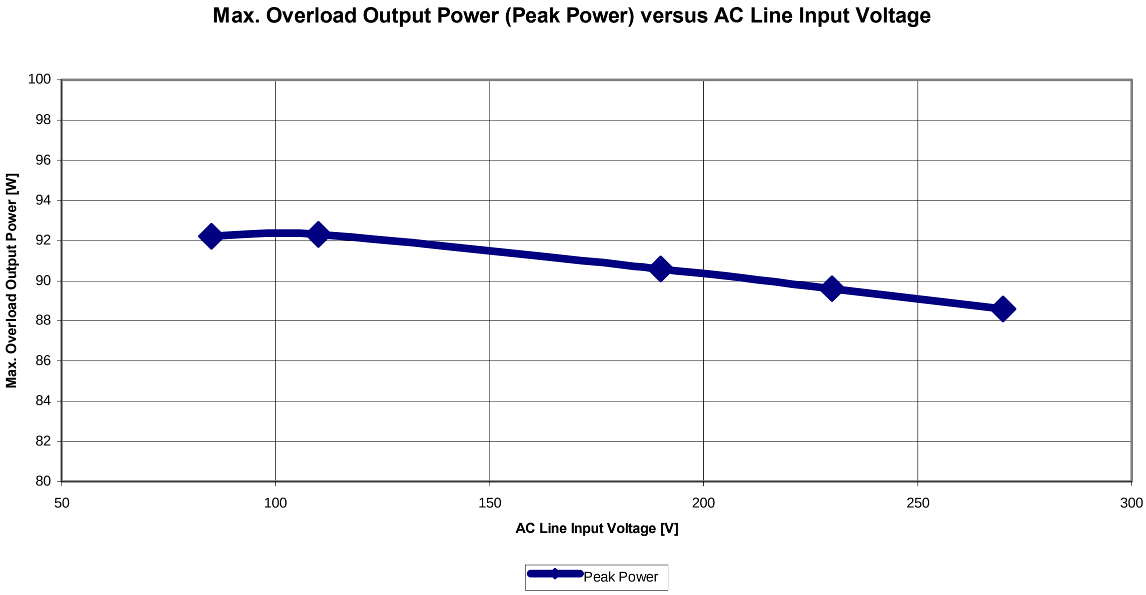
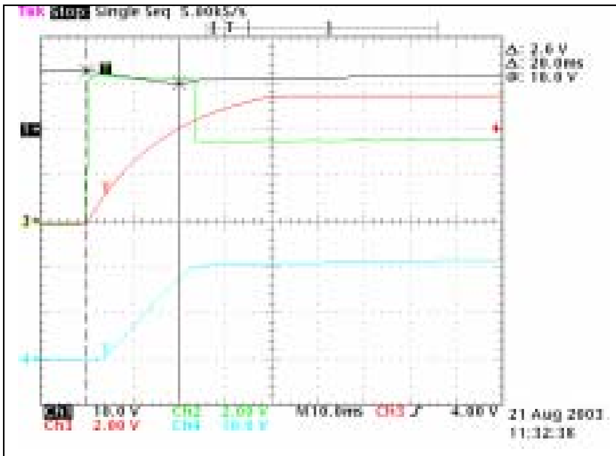


Figure 9 Peak Power (Over Current Shut Off Threshold) vs. Line Input Voltage

Waveforms and Scope Plots

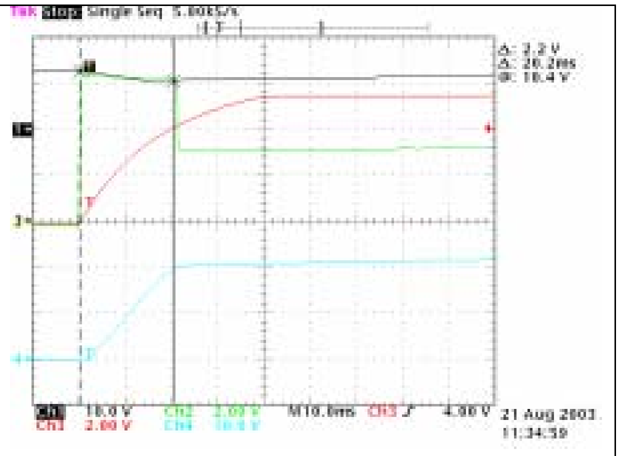
All waveforms and scope plots where recorded with a Tectronix TDS 745D

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



Channel 1: Chip Supply Voltage (V_{CC})
Channel 2: Feedback Voltage (V_{FB})
Channel 3: Soft Start Voltage (V_{SS})
Channel 4: Output Voltage (V_{OUT})

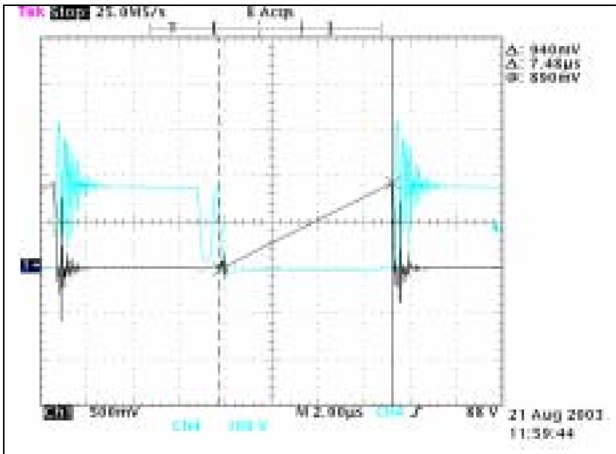
Figure 10 Startup @ Vacin = 85V and nom. Load



Channel 1: Chip Supply Voltage (V_{CC})
Channel 2: Feedback Voltage (V_{FB})
Channel 3: Soft Start Voltage (V_{SS})
Channel 4: Output Voltage (V_{OUT})

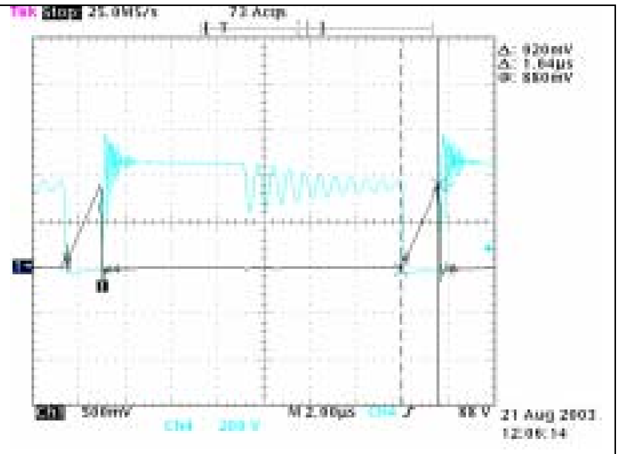
Figure 11 Startup @ Vacin = 270V and nom.Load

Drain Source Voltage and Current During Normal Operation



Channel 1: Drain Current (I_D)
Channel 4: Drain Source Voltage (V_{DS})
Dmax = 50% / V_{Rsense} = 890mV

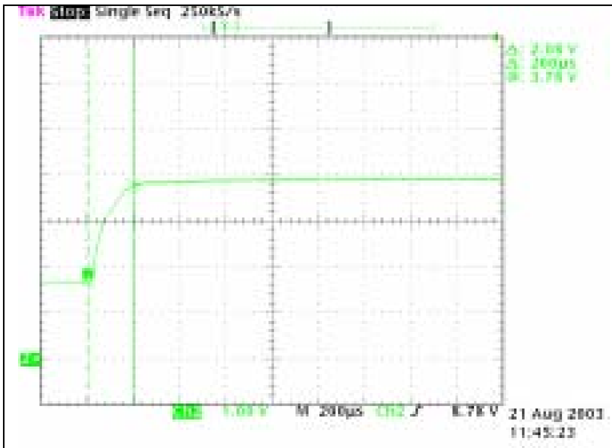
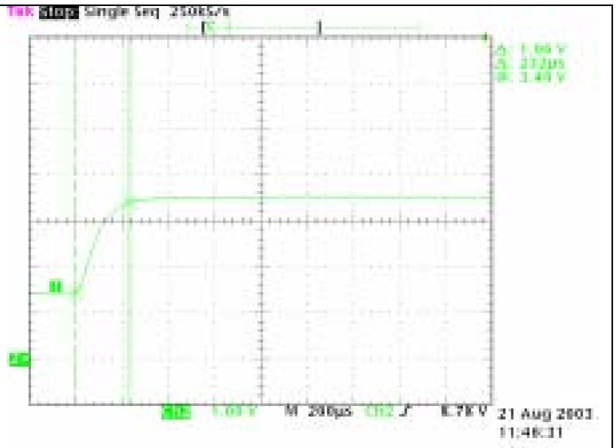
Figure 12 Operation @ Vacin = 85V and nom. Load



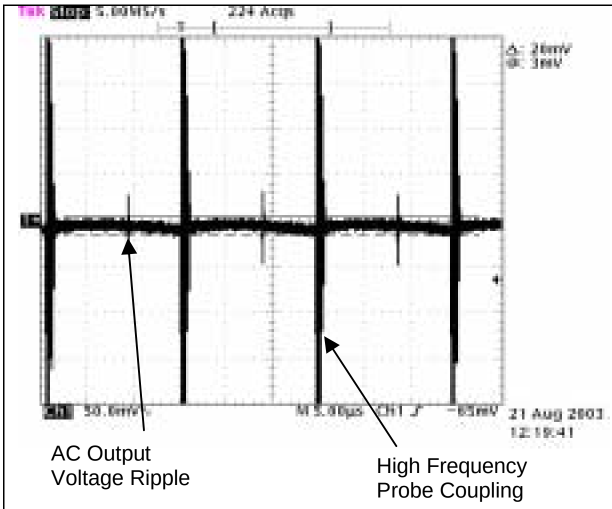
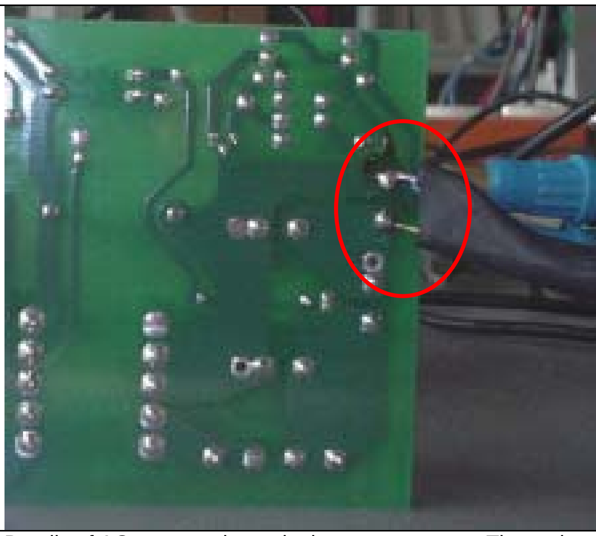
Channel 1: Drain Current (I_D)
Channel 4: Drain Source Voltage (V_{DS})
Dmax = 11% / V_{Rsense} = 880mV

Figure 13 Operation @ Vacin = 270V and nom.Load

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

	
Channel 2: Feedback Voltage (V_{FB})	Channel 2: Feedback Voltage (V_{FB})
Figure 14 Loadjump @ Vacin = 85V and nom. Load	**Figure 15 Loadjump @ Vacin = 270V and nom.Load**

AC Output Ripple during Nominal Load and Normal Operation

	
Channel 1: AC Output Ripple (V_{ACOUT}) $V_{ACOUTmax}$ = ± 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 16 AC Output Voltage Ripple at nom. Load	**Figure 17 AC Ripple Measurement Technique**

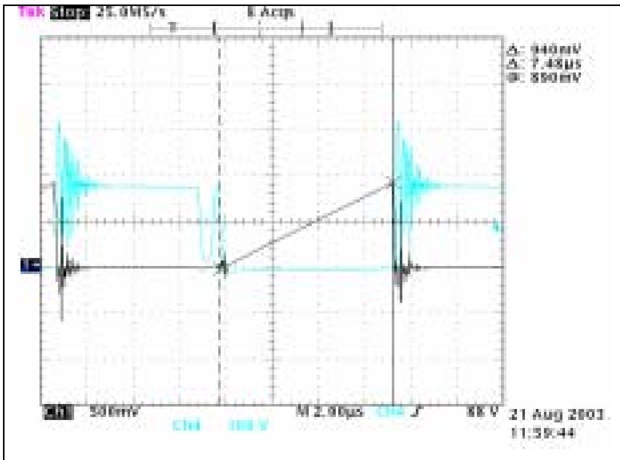
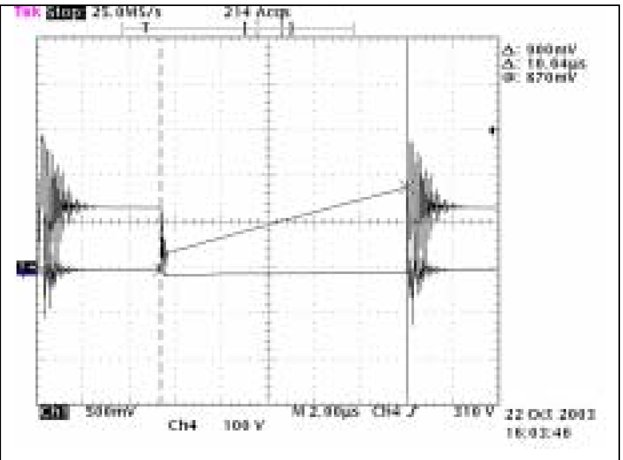
Input Capacitor Improvement – Slope Compensation

Input Capacitor Improvement

In case you are using a smaller input capacitor (100µF instead of 220µF), 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 220µF bulk works the board in the discontinuous conduction mode (DCM) and a D_{max} < 50% (Figure 18); with the smaller 100µF bulk (1.25µF/W), the board is running in the continuous conduction mode (CCM) and D_{max} > 50% (Figure 19).

	
Channel 1: Drain Current (I_D) Channel 4: Drain Source Voltage (V_{DS}) C_{IN} = 220µF / Dmax = 50% / Pout = 80W / V_{ACIN} = 85V	Channel 1: Drain Current (I_D) Channel 4: Drain Source Voltage (V_{DS}) C_{IN} = 100µF / Dmax = 71% / Pout = 80W / V_{ACIN} = 85V
Figure 18 DCM – Operation with Dmax < 50%	**Figure 19 CCM – Operation with Dmax > 50%**

To prevents 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.

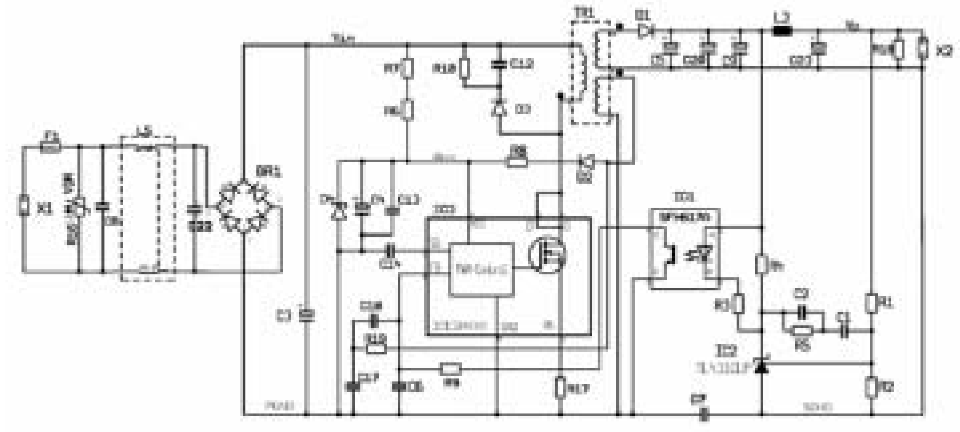


Figure 20 Circuit Diagram Switch Mode Power Supply with Slope Compensation

More information regarding how to calculate the components of the Slope Compensation see the application note AN_SMPS_16822CCM_V10. For the calculation of the additional components of a SMPS, see in the application note AN_SMPS_ICE2xXXX – available on the internet: 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
2.1	BOM Update		02.08.2002
2.2	Performance Data		27.08.2002
2.3	BOM Update		08.11.2002
3.0	Update: → Update Boardlayout → Update BOM → Different Transformer construction Additional: → Slope Compensation		Oct. 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-ICE2B765P2-3		
Actual Release: 3.0 Date: 2003-10-22		Previous Release: V2.3
Page of actual Rel.	Page of prev. Rel.	Subjects changed since last release
--	--	See change service