AN-EVALSF3-ICE3B0565J

12W 5.0V SMPS Evaluation Board with CoolSET^{TM} F3 ICE3B0565J

Power Management & Supply

Never stop thinking.

Edition 2005-09-26

Published by Infineon Technologies Asia Pacific,
168 Kallang Way,
349253 Singapore, Singapore

12W 5V Demoboard using ICE3B0565J on board

Revision History:	**2005-09**	V1.0
Previous Version:	none	

Page	Subjects (major changes since last revision)

12W 5.0V SMPS Evaluation Board with CoolSET^{TM} F3 ICE3B0565J:
License to Infineon Technologies Asia Pacific Pte Ltd ANP0065

Kok Siu Kam Eric
Jeoh Meng Kiat

We Listen to Your Comments
Any information within this document that you feel is wrong, unclear or missing at all?
Your feedback will help us to continuously improve the quality of this document.
Please send your proposal (including a reference to this document) to:
ap-lab.admin@infineon.com

Table of Contents **Page**

Abstract

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 ICE3B0565J CoolSET™[1]. The application operates in discontinuous current mode using the active burst mode during standby condition. The board has one output voltage with secondary regulation. It is especially suitable as an AC/DC power supply for LCD monitors, adapters for printer, notebook computers, DVD players and set-top boxes and auxiliary power for high power system. The ICE3B0565J is an enhanced version of the F3 CoolSET™. Besides having the basic features of the F3 CoolSET™ such as Active Burst Mode, adjustable blanking time, propagation delay compensation, etc., it also has the BiCMOS technology design and frequency jittering. It can further reduce the input Standby Power and at the same time achieve the low EMI performance.

1 Evaluation Board

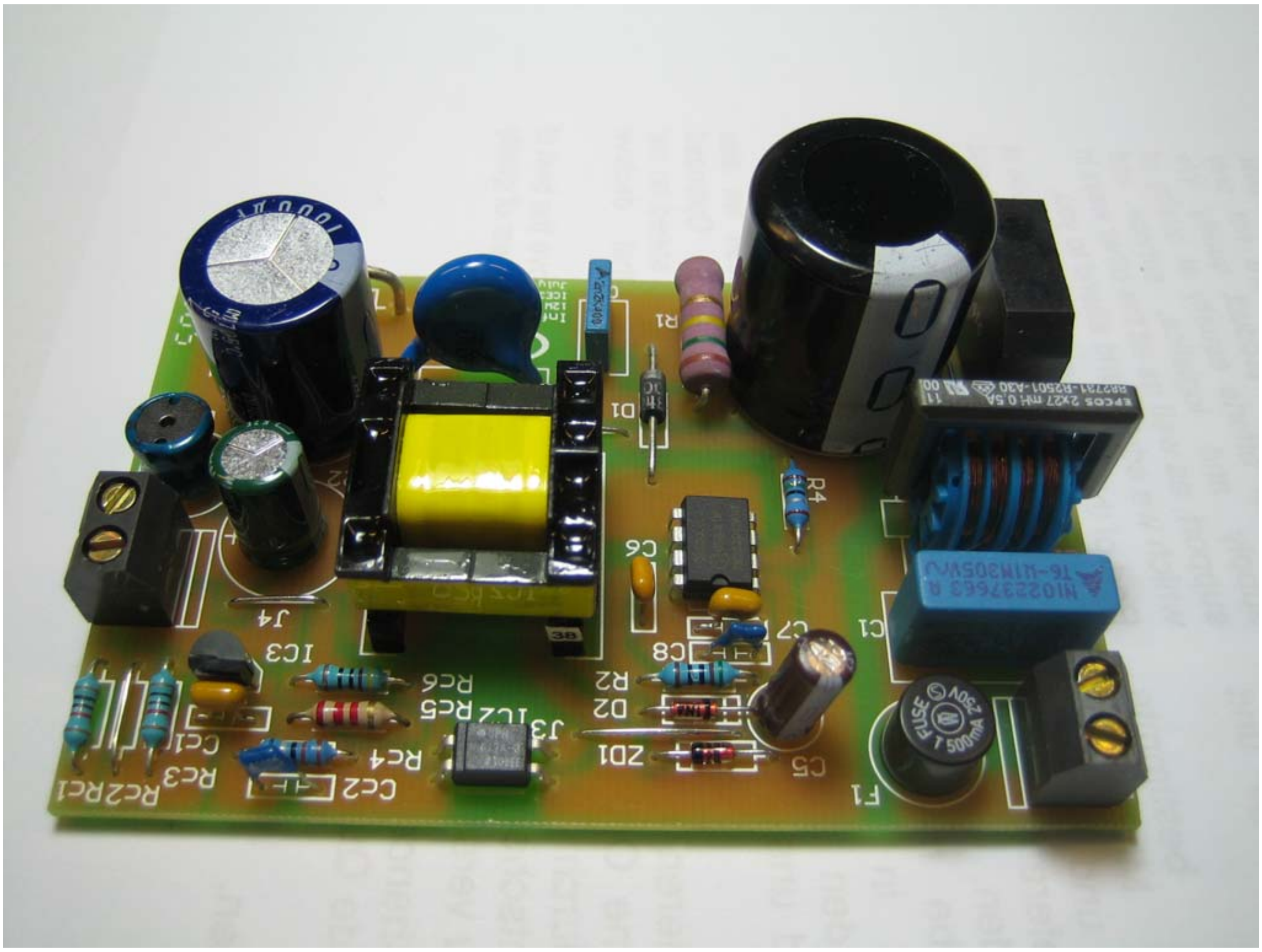


Figure 1 – EVALSF3-ICE3B0565J

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.

[1] 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).

2 List of Features

650V avalanche rugged CoolMOS™ with built in switchable Startup Cell
Active Burst Mode for lowest Standby Power @ light load controlled by Feedback signal
BiCMOS technology provide wide Vcc voltage range
Fast load jump response in Active Burst Mode
67kHz fixed switching frequency
Auto Restart Mode for Over temperature protection, Overvoltage protection, Overload protection, Open Loop protection and VCC Undervoltage protection
Blanking Window for short duration high current
User defined Soft Start
Max Duty Cycle 72%
Propagation delay compensation provide accurate primary current limit
Frequency jittering for low EMI

3 Technical Specifications

Input voltage	85VAC~265VAC
Input frequency	50Hz, 60Hz
Input Standby Power	< 100mV @ no load; < 0.8W @ 0.5W load
Output voltage and current	5V +/- 2%
Output current	2.4A
Output power	12W
Efficiency	>75% at full load
Output ripple voltage	< 50mVp-p (exclude high frequency spike)

4 Circuit Diagram

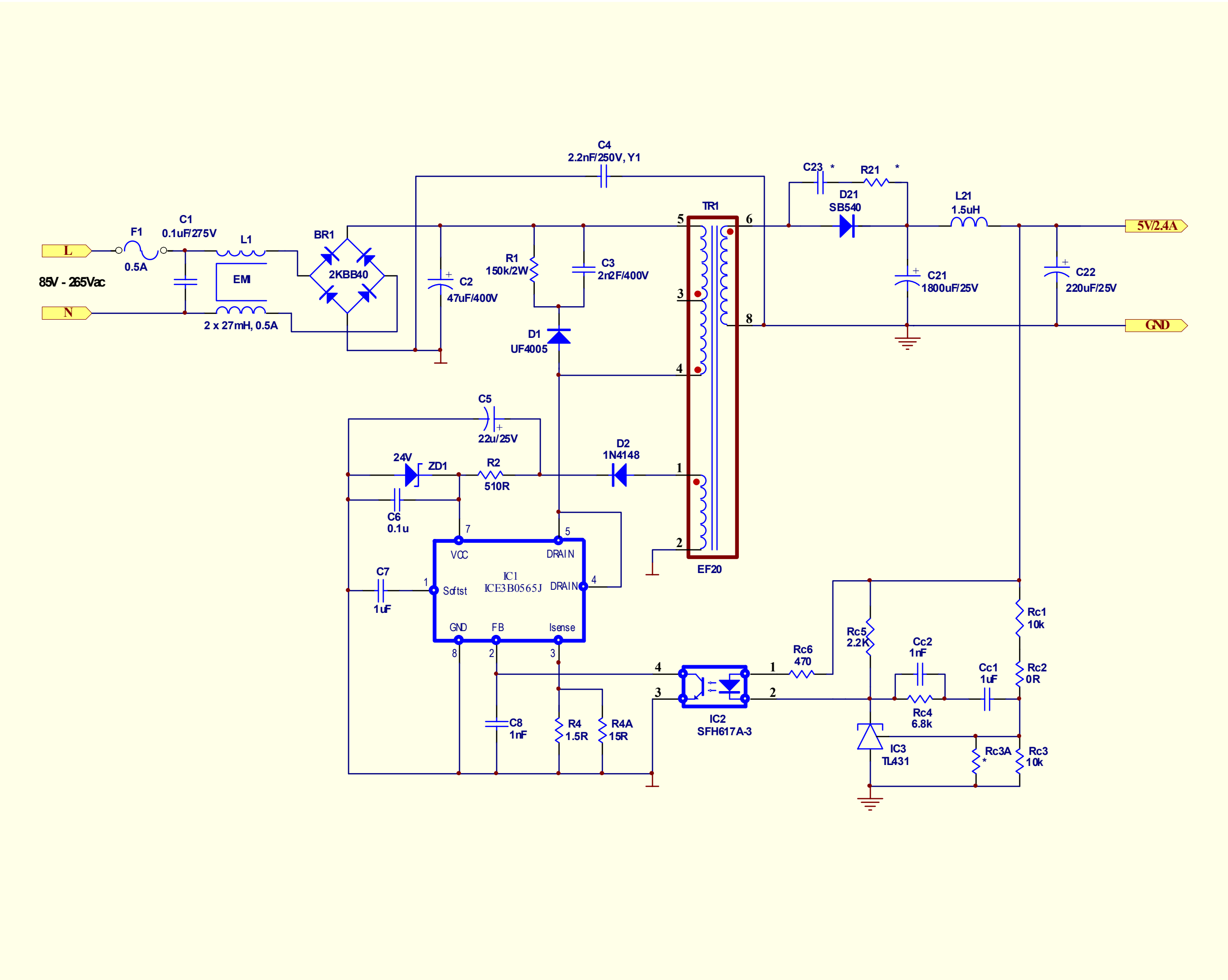


Figure 2 – 12W 5.0V ICE3B0565J power supply Schemetic

5 PCB Layout

5.1 Component side component legend

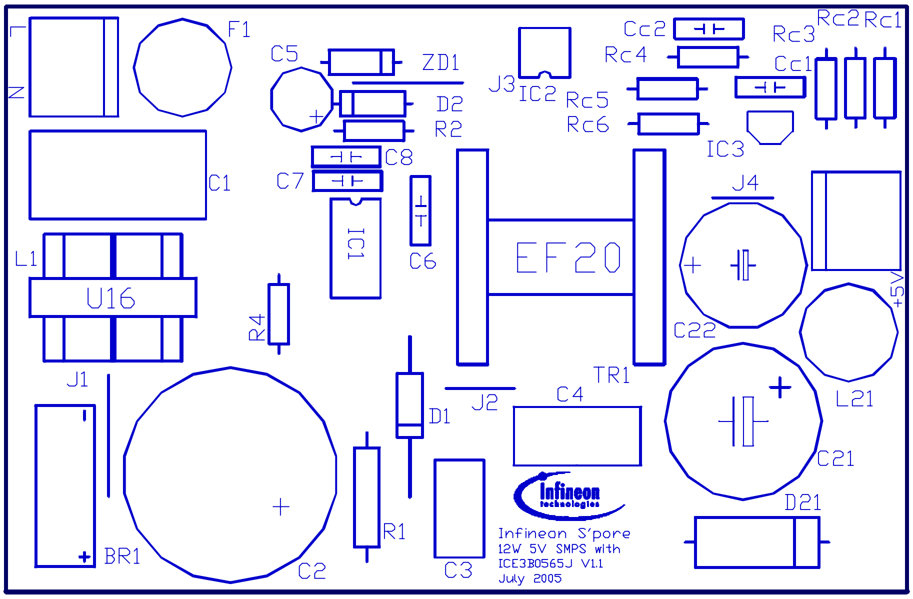


Figure 3 – Component side Component Legend – View from Component Side

5.2 Solder side copper & component legend

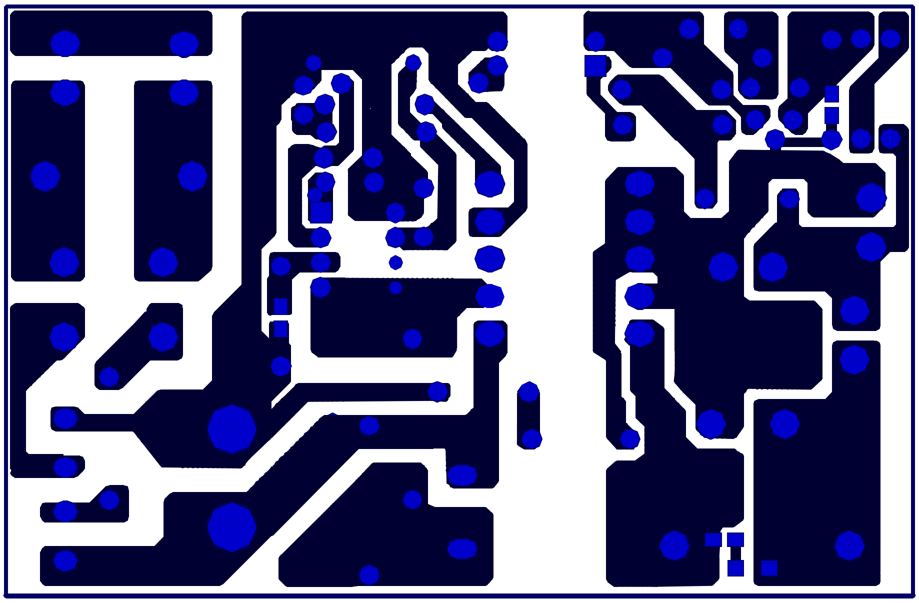


Figure 4 – Solder side copper – View from Component Side

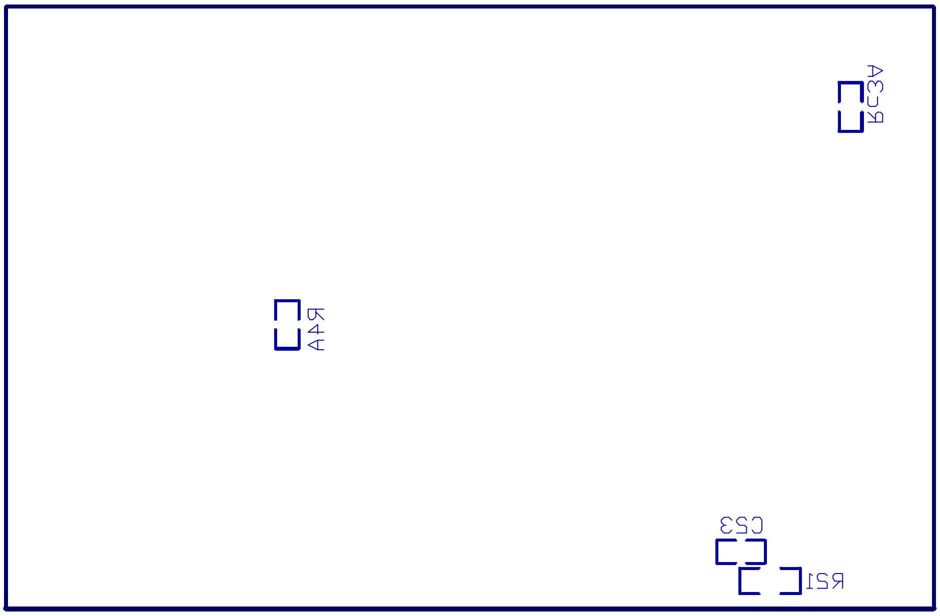


Figure 5 – Solder side component Legend – View from Component Side

6 Circuit Description

6.1 Introduction

The EVALSF3-ICE3B0565J demoboard is a low cost off line flyback switch mode power supply (SMPS) using the ICE3B0565J system IC from the CoolSET^{TM}-F3 family. The circuit, shown in Figure 2, details a 5.0V, 12W power supply that operates from an AC line input voltage range of 85Vac to 265Vac, suitable for applications requiring either an open frame supply or an enclosed adapter.

6.2 Line Input

The AC line input side comprises the input fuse F1 as over-current protection. The choke L1, X2-capacitors C1 and Y1-capacitor C4 act as radio interference suppressors. After the bridge rectifier BR1 and the input bulk capacitor C2, a voltage of 100 to 380 V_{DC} is present which depends on input voltage is available.

6.3 Start up

Since there is a built-in startup cell in the ICE3B0565J, there is no need for external start up resistor. The startup cell is connecting the drain pin of the IC. Once the voltage is built up at the Drain pin of the ICE3B0565J, the startup cell will charge up the Vcc capacitor C5 and C6. When the Vcc voltage exceeds the UVLO at 18V, the IC starts up. Then the Vcc voltage is bootstrapped by the auxiliary winding to sustain the operation.

6.4 Operation mode

During operation, the Vcc pin is supplied via a separate transformer winding with associated rectification D2 and buffering C5, C6. Resistor R2 is used for current limiting. In order not to exceed the maximum voltage at Vcc pin an external zener diode ZD1 limits this voltage.

6.5 Soft start

The Soft-Start function is realized by an internal resistor and the adjustable external capacitor C7.

6.6 Clamper circuit

The circuit R1, C3 and D1 clamp the DRAIN voltage spike caused by transformer leakage inductance to a safe value below the drain source break down voltage V_{DSBR} = 650V[1] maximum.

6.7 Limitation of primary current

The CoolMOS^{TM} drain source current is sensed via external shunt resistors R4 and R4A. An accurate value of the shunt improves the peak power limitation shown in the curve peak power limitation in the rear of this report.

6.8 Output Stage

On the secondary side the power is coupled out by a schottky diode D21. The capacitor C21 provides energy buffering following with the LC filter L21 and C22 to reduce the output voltage ripple considerably. Storage

[1] V_{DSBR} = 650V @ Tj = 110°C

capacitor C21 is selected to have an internal resistance as small as possible (ESR) to minimizes the output voltage ripple

6.9 Feedback and regulation

The output voltage is controlled using a type TL431 reference diode (IC3). This device incorporates the voltage reference as well as the error amplifier and a driver stage. Compensation network Cc1, Cc2, Rc1, Rc4 constitutes the external circuitry of the error amplifier of IC3. 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 Rc5 and Rc6. Optocoupler IC2 is used for floating transmission of the control signal to the “Feedback” input via capacitor C8 of the ICE3B0565J control device. The optocoupler used meets DIN VDE 884 requirements for a wider creepage distance.

6.10 Blanking Window for Load Jump / Active Burst Mode

In case of Load Jumps the Controller provides a Blanking Window before activating the Overvoltage Protection and entering the Auto Restart Mode. This time is generated by charging up the Soft Start capacitor from 3.4V to 4.0V. Within this time frame the voltage at Feedback pin can rise up above 4.5V, without switching off due to Overload Protection. During this operation the transferred power is limited to the maximum peak current defined by the value of the sense resistor. The same procedure happens to the external Soft Start capacitor if a low load condition is detected when V_{FB} is falling below 1.35V. Only after V_{SOFTS} has exceeded 4.0V and V_{FB} is still below 1.35V, Active Burst Mode is entered.

6.11 Active Burst Mode

At light load condition, the SMPS enters into Active Burst Mode. The controller is always active at this state. V_{CC} must therefore be above the switch off threshold V_{CCoff} = 10.5V. While supporting low ripple on V_{OUT} and fast response on load jump, efficiency also increased significantly during Active Burst Mode. When the voltage level at FB falls below 1.35V, capacitor C_7 at SOFTS pin is allowed to charge from the sawtooth voltage level at 3.2V ~ 3.6V in Normal Operating Mode. Active Burst Mode is entered if V_{SOFTS} exceeds 4.0V. A Blanking Window as mentioned earlier which can be adjusted by manipulating C_7, is generated to avoid a sudden entering of Burst Mode due to load jump.

During Active Burst Mode the current sense voltage limit at I_{CS} pin, V_{ICS}, is set to 0.32V to reduce the conduction losses. All the internal circuits are switched off except the reference and bias voltages to reduce the total V_{CC} current consumption to below 0.5mA. The FB voltage is changing like a sawtooth between 3.2 and 3.6V. To leave Burst Mode, FB voltage must exceed 4.5V. This resets the Active Burst Mode and turns the SMPS into Normal Operating Mode. Maximum current can now be provided to stabilize V_{OUT}.

6.12 Jitter mode

The soft start capacitor, C7 has 3 functions; control the soft start time, control the blanking time and control the period of the frequency jitter mode. Once the ICE3B0565J is startup, the SOFTS pin will run at a sawtooth voltage from 3.2V ~ 3.6V. This voltage controls the period of the jitter frequency. The jitter frequency is for ICE3B0565J is internally set at 67KHz +/-2.7KHz. This demo board has SOFTS capacitor of 1uF and the jitter period is around 3.2ms.

7 Component List

Items	Part	Type	Quantity
1	BR1	2KBB80R	1
2	C1	0.1uF/275V, X2 Capacitor	1
3	C2	47uF/400V	1
4	C3	2.2nF/400V	1
5	C4	2.2nF/250V, Y1 Capacitor	1
6	C5	22uF/35V	1
7	C6	100nF/50V	1
8	C7	1uF/50V	1
9	C8	1nF/50V	1
10	C21	1800uF/25V	1
11	C22	220uF/25V	1
12	C23	N.A.	0
13	Cc1	1uF/50V	1
14	Cc2	1nF/50V	1
15	D1	UF4005	1
16	D2	1N4148	1
17	D21	SB540	1
18	F1	0.5A/250V	1
19	IC1	ICE3B0565J	1
20	IC2	SFH617A-3	1
21	IC3	TL431CLP	1
22	J1, J2, J3, J4	Jumper	4
23	L1	2 x 27mH, 0.5A	1
24	L21	1.5uF	1
25	R1	150K , 2W , 5%	1
26	R2	510R , 0.25W, 5%	1
27	R4	1.5R 0.5W , 2%	1
28	R4A	15R , 0.1W , 5% (0805 SMD)	1
29	Rc1	10K , 0.25W , 1%	1
30	Rc2	0R	1
31	Rc3	10K, 0.25W , 1%	1
32	Rc3A	N.A.	0
33	Rc4	6.8K , 0.25W , 5%	1
34	Rc5	2.2K, 0.25W, 5%	1
35	Rc6	470, 0.25W , 5%	1
36	R21	N.A.	0
37	TR1	EF20 N87, Lp =830uH	1
38	ZD1	24V	1

8 Transformer Construction

Core and material : EF20/10/6, N87

Bobbin: Horizontal Version

Primary Inductance, Lp=830µH, measured between pin 4 and pin 5 (Gapped to Inductance)

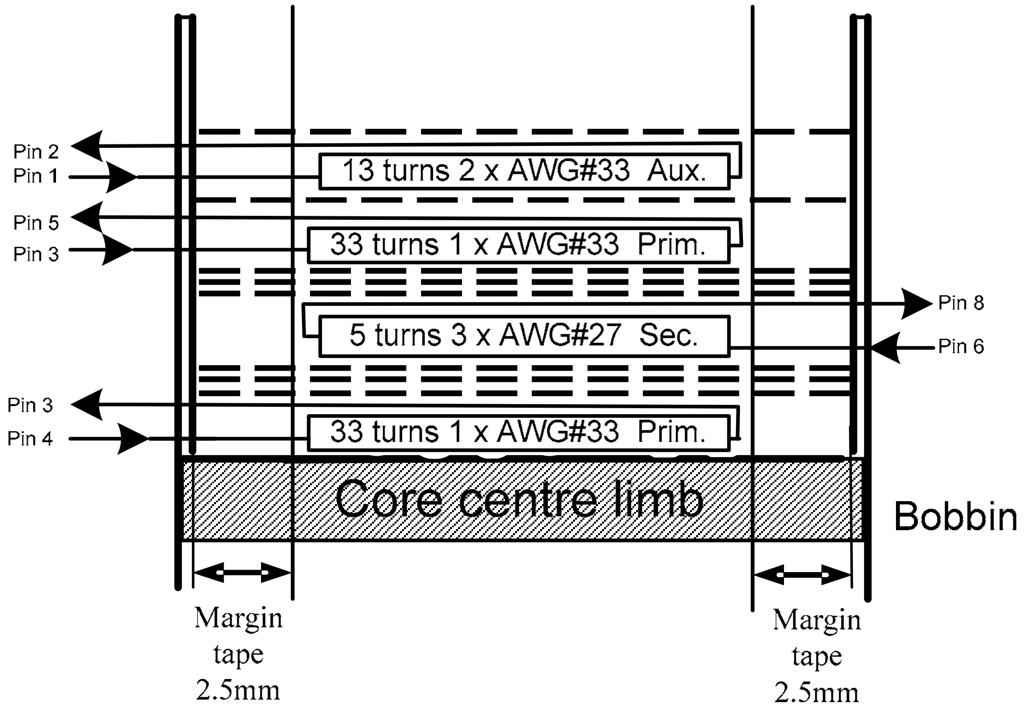


Figure 6 – Transformer structure

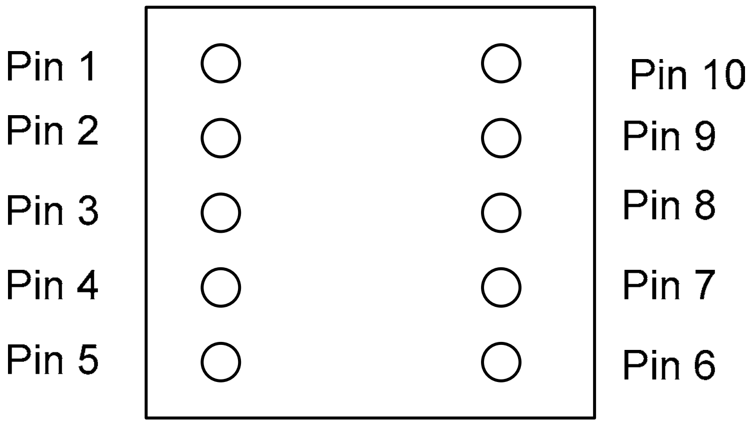


Figure 7 – Transformer complete – top view

9 Test Results

9.1 Efficiency

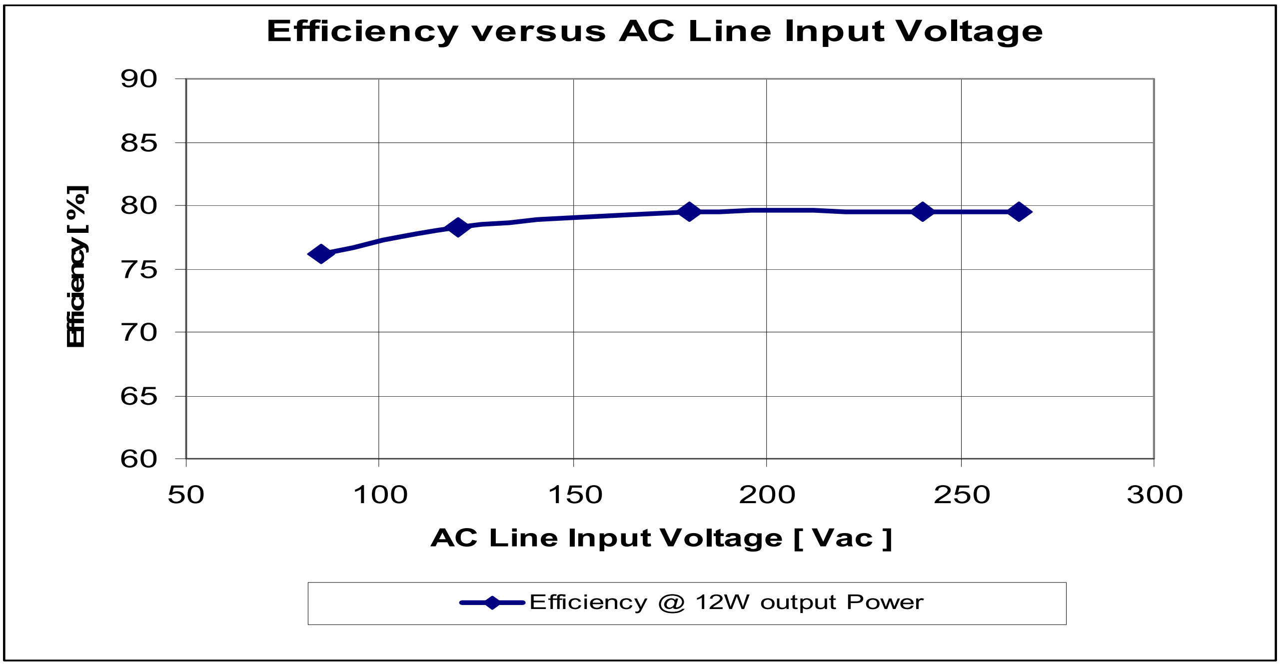


Figure 8 – Efficiency vs. AC Line Input Voltage

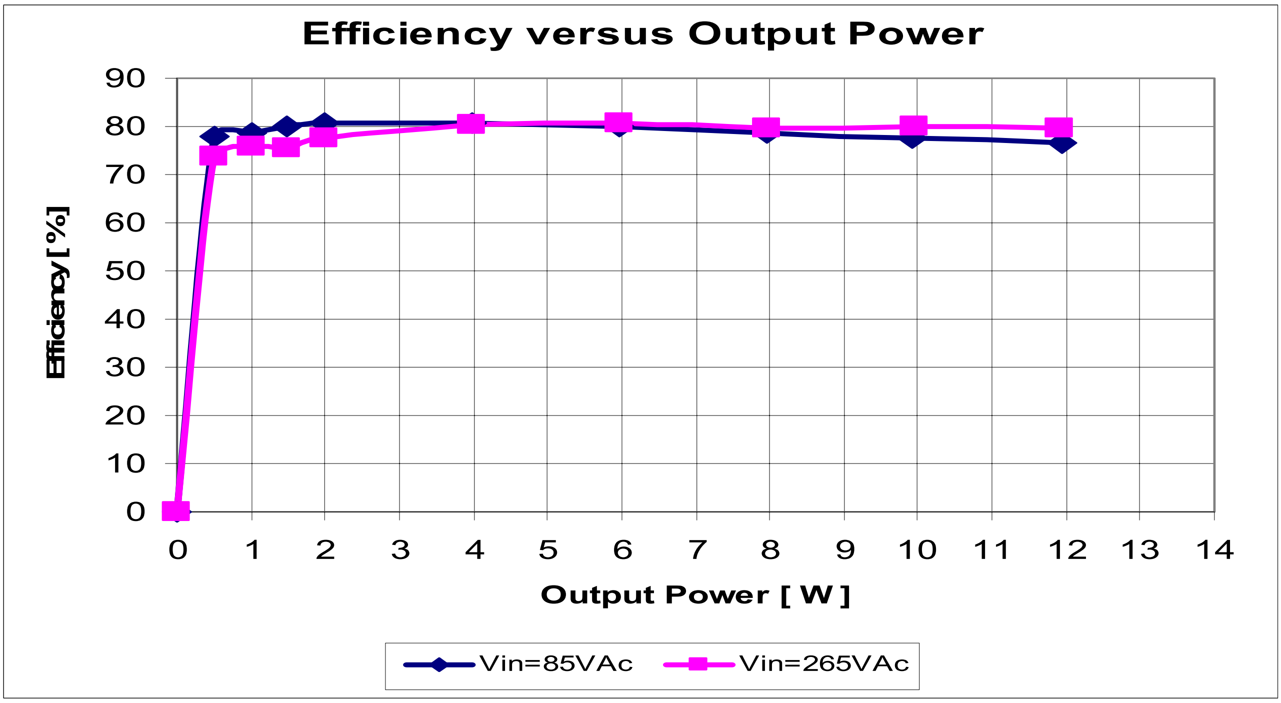


Figure 9 – Efficiency vs. Output Power @ Low and High Line 50Hz

9.2 Input Standby Power

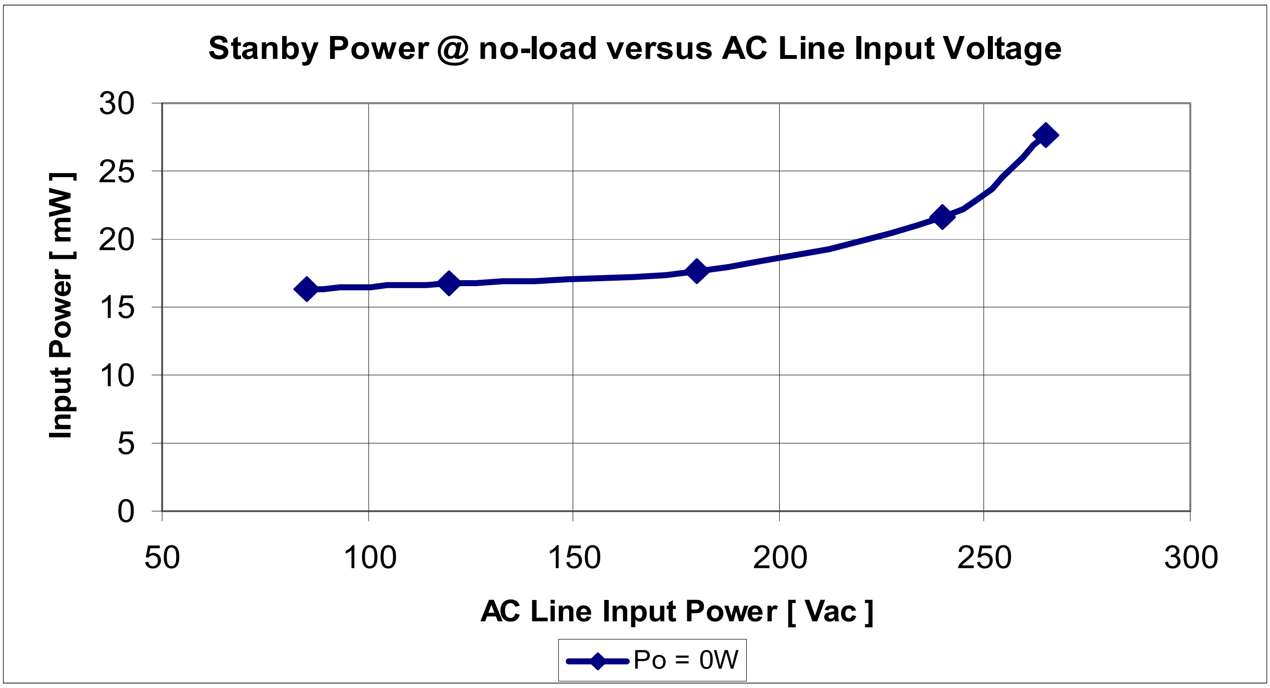


Figure 10 – Input Standby Power @ no load vs. AC Line Input Voltage

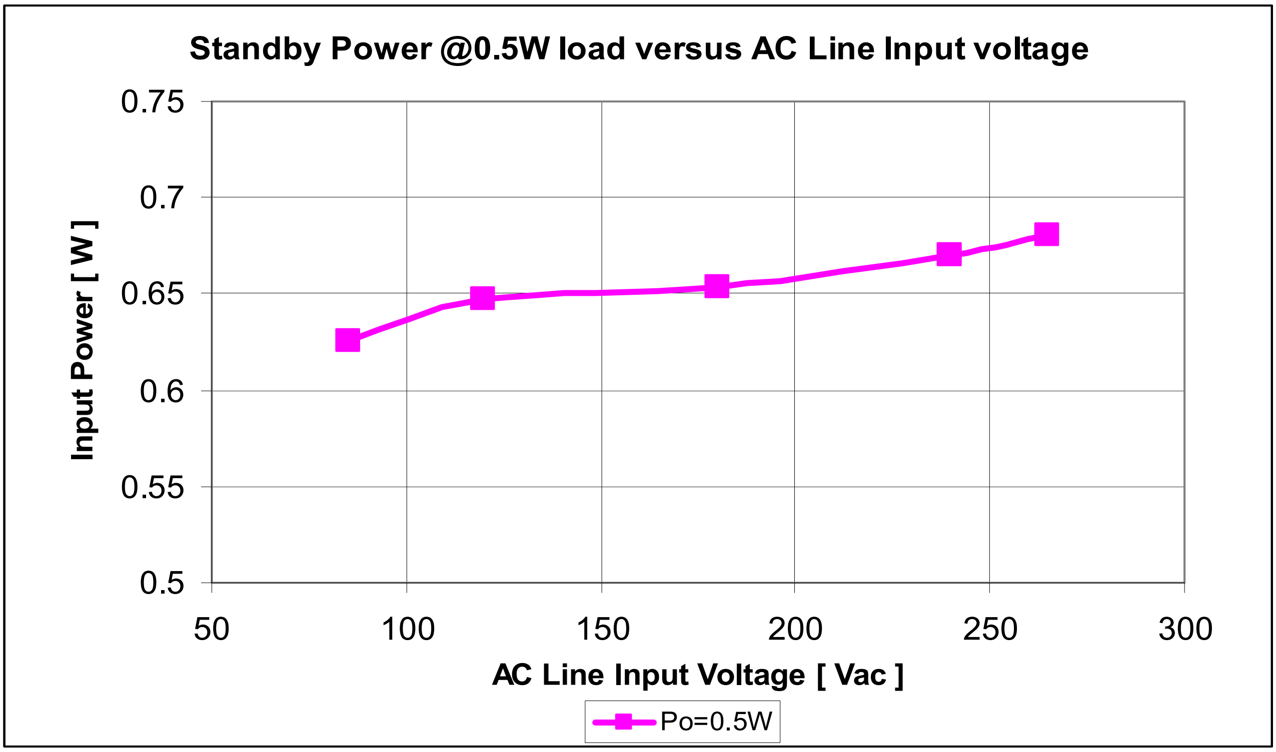


Figure 11 – Input Standby Power @ 0.5W load vs. AC Line Input Voltage

9.3 Line Regulation

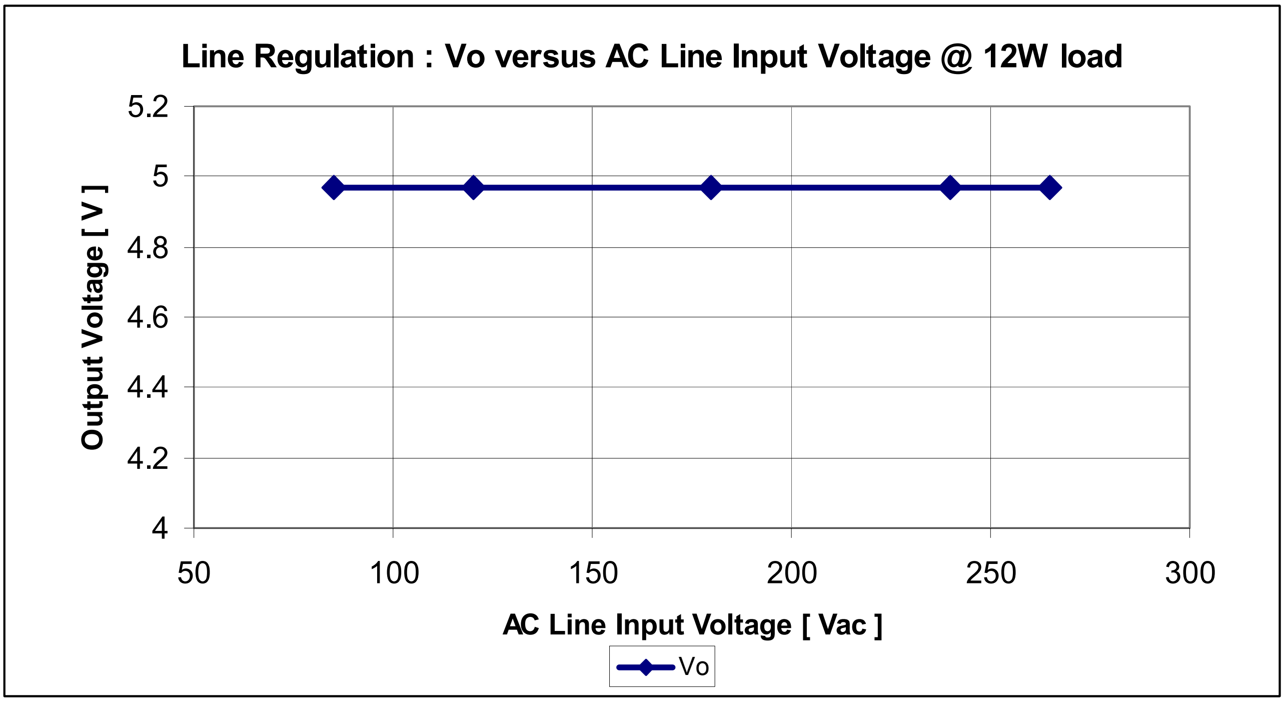


Figure 12 – Line Regulation vs. AC Line Input Voltage

9.4 Load Regulation

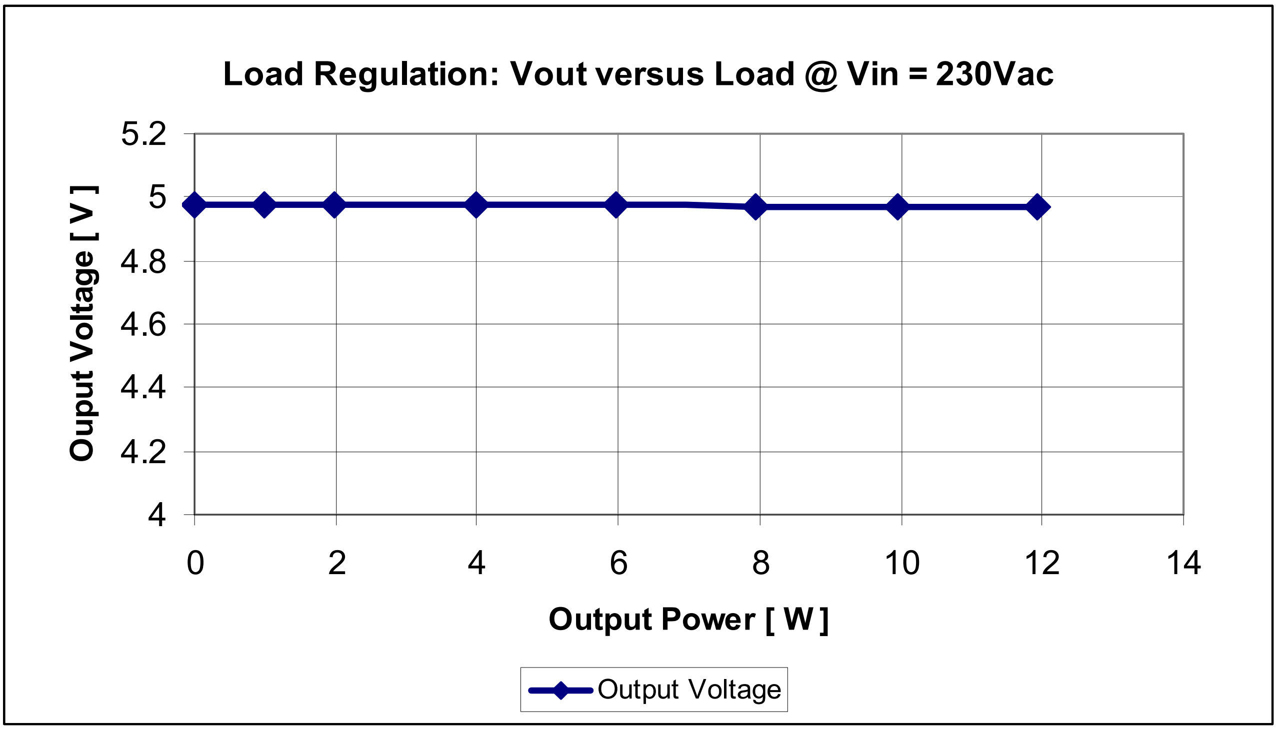


Figure 13 – Load Regulation vs. AC Line Input Voltage

9.5 Max. Overload Output Power

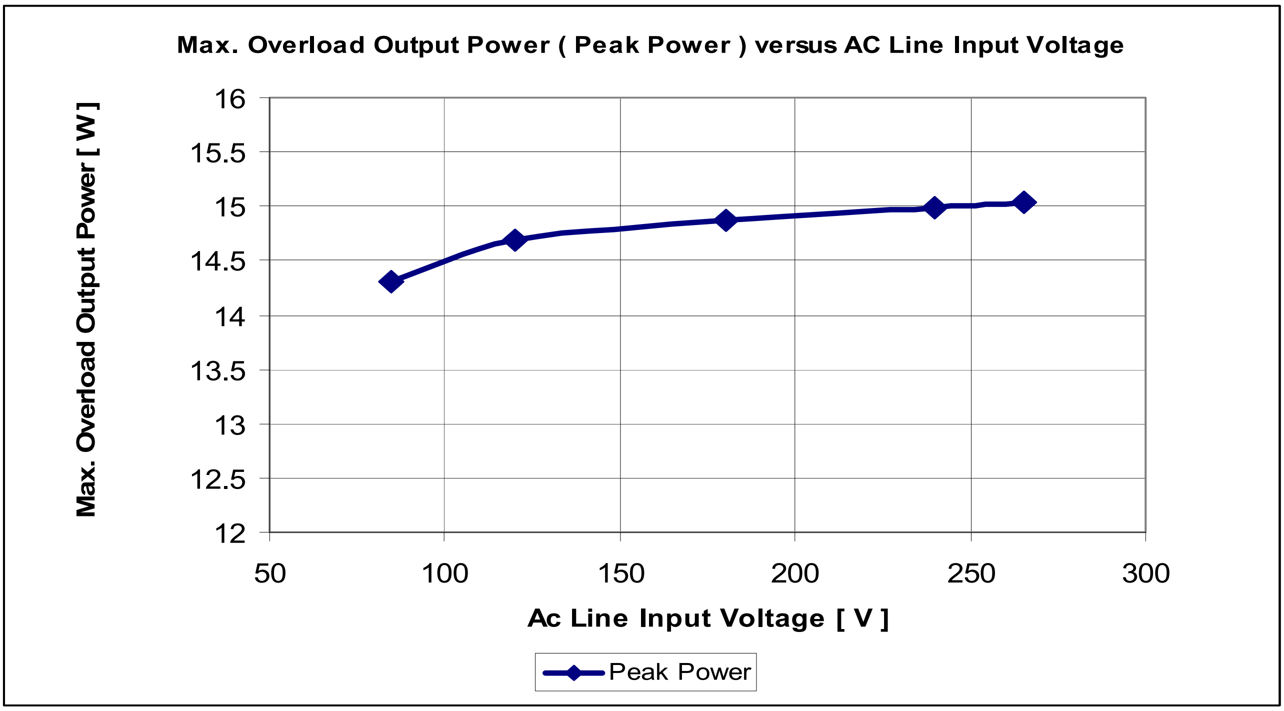
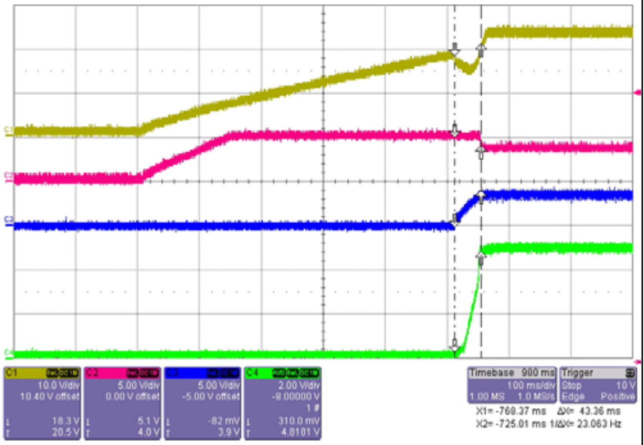
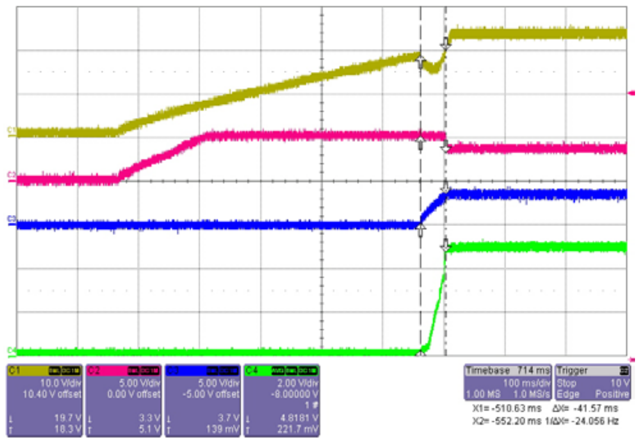


Figure 14 – Overload Output Power (Over Current Shut Off Threshold) vs. AC Line Input Voltage

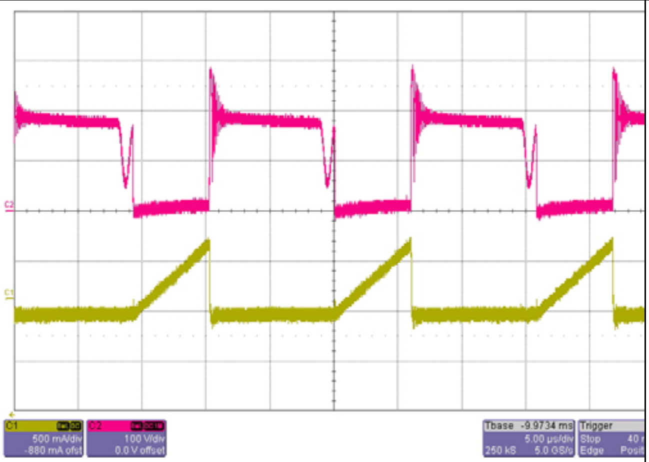
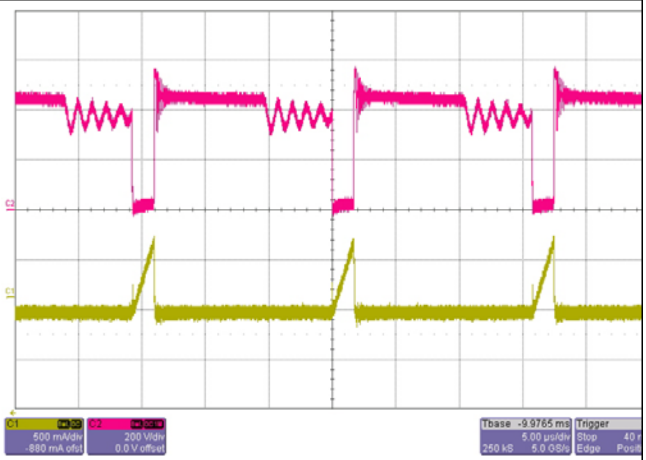
10 Waveforms and Scope Plots

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

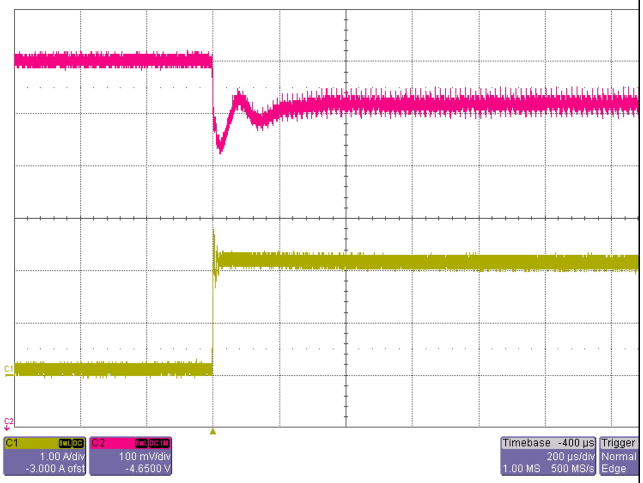
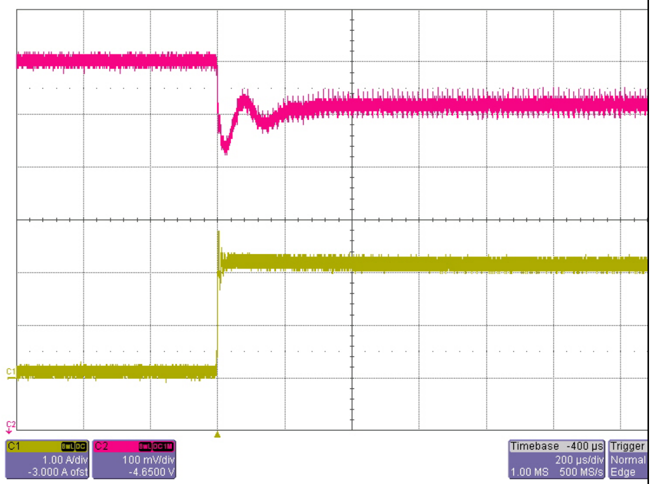
10.1 Startup @ Low and High AC Line Input Voltage and 12W load

	
Channel 1; C1 : IC Supply Voltage (Vcc) Channel 2; C2 : Feedback voltage (V_{FB}) Channel 3; C3 : Soft Start Voltage (V_{SOFTS}) Channel 4; C4 : Output Voltage (Vo)	Channel 1; C1 : IC Supply Voltage (Vcc) Channel 2; C2 : Feedback voltage (V_{FB}) Channel 3; C3 : Soft Start Voltage (V_{SOFTS}) Channel 4; C4 : Output Voltage (Vo)
Startup time = 0.56s, Soft start time = 43.3ms	Startup time = 0.55s, Soft start time = 41.5ms
Figure 15 – Startup @ Vin=85Vac and 12W load	**Figure 16** – Startup @ Vin=265Vac and 12W load

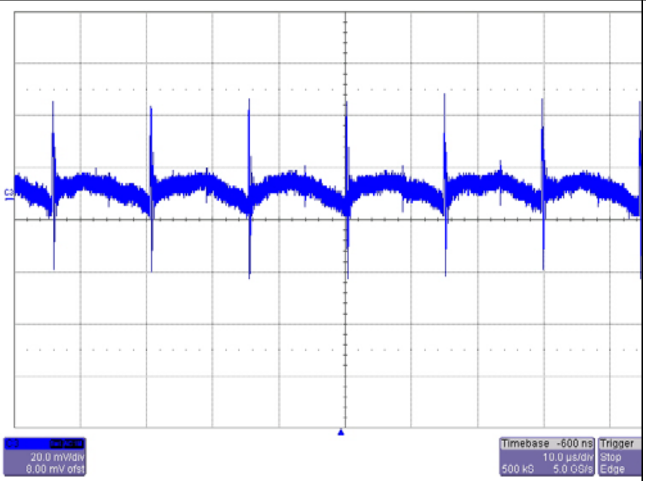
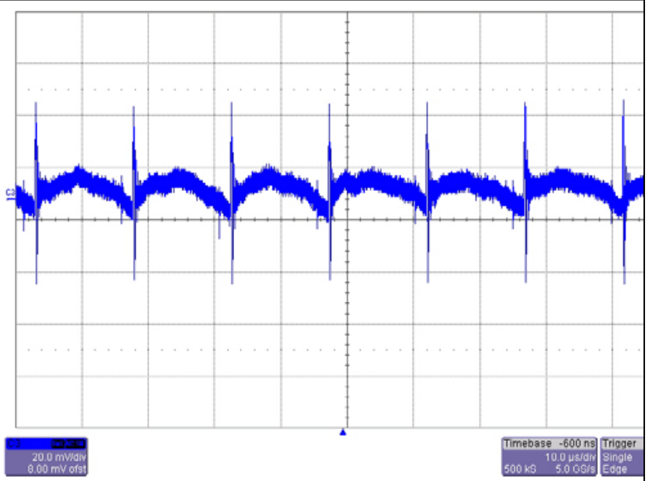
10.2 Drain Source Voltage and Current During 12W load Operation

	
Channel 1; C1 : Drain Source Current (I_{DS}) Channel 2; C2 : Drain Source Voltage (V_{DS})	Channel 1; C1 : Drain Source Current (I_{DS}) Channel 2; C2 : Drain Source Voltage (V_{DS})
Duty cycle = 40%	Duty cycle = 10.8%
Figure 17 – Operation @ Vin = 85Vac and 12W load	**Figure 18**–Operation @ Vin = 265Vac and 12W load

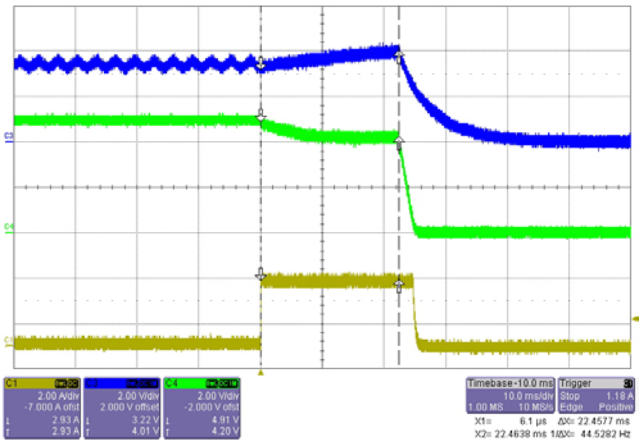
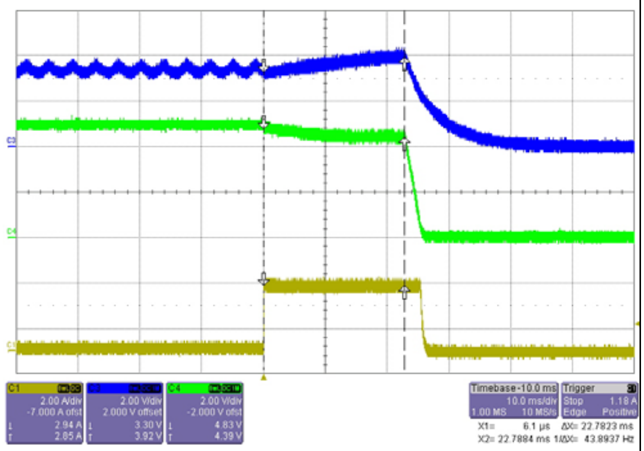
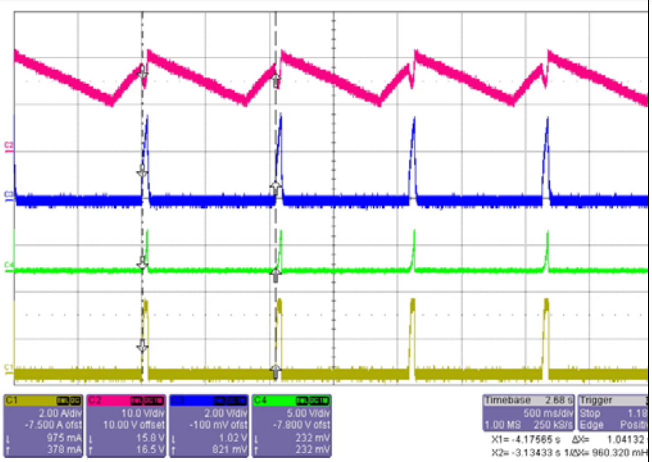
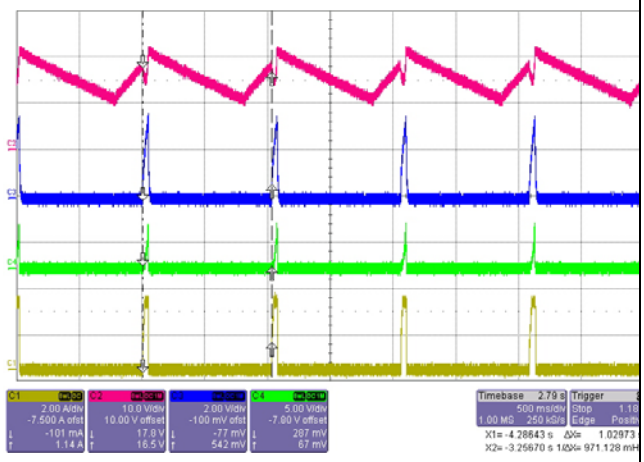
10.3 Load Transient Response (Load jump from 10% to 100% Load)

	
Channel 1; C1 : Output Current (Io) Channel 2; C2 : Output Voltage (Vo)	Channel 1; C1 : Output Current (Io) Channel 2; C2 : Output Voltage (Vo)
Current step slew rate = 0.4A/us	Current step slew rate = 0.4A/us
Figure 19– Loadjump @ Vin=85Vac from 1.2W to 12W load	**Figure 20** – Loadjump @ Vin=265Vac from 1.2W to 12W load

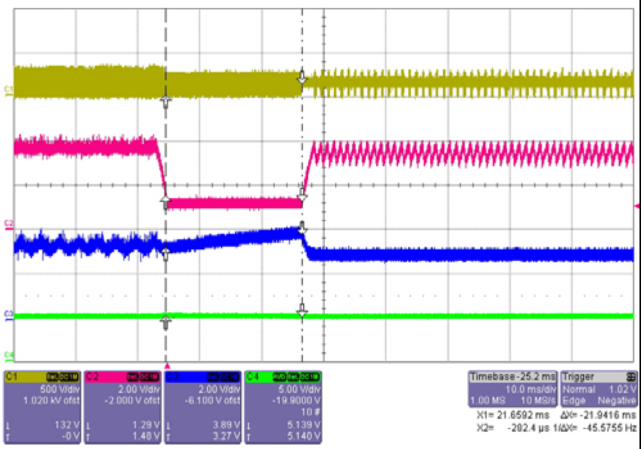
10.4 AC Output Ripple during 12W

	
Channel 3; C3 : Output Ripple Voltage (Vo_ripple)	Channel 3; C3 : Output Ripple Voltage (Vo_ripple)
Vo_ripple = +/-10mV (exclude high frequency ripple) Terminal with decoupling capacitor of 0.1uF + 10uF	Vo_ripple = +/-10mV (exclude high frequency ripple) Terminal with decoupling capacitor of 0.1uF + 10uF
Figure 21 – AC output ripple @ Vin=85Vac and 12W load	**Figure 22** – AC output ripple @ Vin=265Vac and 12W load

10.5 Blanking window for over power protection

	
Channel 1; C1 : Output current (I_O) Channel 3; C3 : Soft Start Voltage (V_{SOFTS}) Channel 4; C4 : Output Voltage (Vo)	Channel 1; C1 : Output current (I_O) Channel 3; C3 : Soft Start Voltage (V_{SOFTS}) Channel 4; C4 : Output Voltage (Vo)
Blanking time to enter auto-restart mode : 22.4ms	Blanking time to enter auto-restart mode : 22.7ms
Figure 23 – Over Power protection @ Vin=85Vac and output power step from 1.2W to 16W load	**Figure 24** – Over Power protection @ Vin=265Vac and output power step from 1.2W to 16W load
	
Channel 1; C1 : Output current (I_O) Channel 2; C2 : Vcc Voltage (V_{CC}) Channel 3; C3 : Soft Start Voltage (V_{SOFTS}) Channel 4; C4 : Output Voltage (Vo)	Channel 1; C1 : Output current (I_O) Channel 2; C2 : Vcc Voltage (V_{CC}) Channel 3; C3 : Soft Start Voltage (V_{SOFTS}) Channel 4; C4 : Output Voltage (Vo)
Burst period at auto-restart mode : 1.04 s	Burst period at auto-restart mode : 1.04 s
Figure 25 – Auto-restart mode under Over Power protection @ Vin=85Vac	**Figure 26** – Auto-restart mode under Over Power protection @ Vin=265Vac

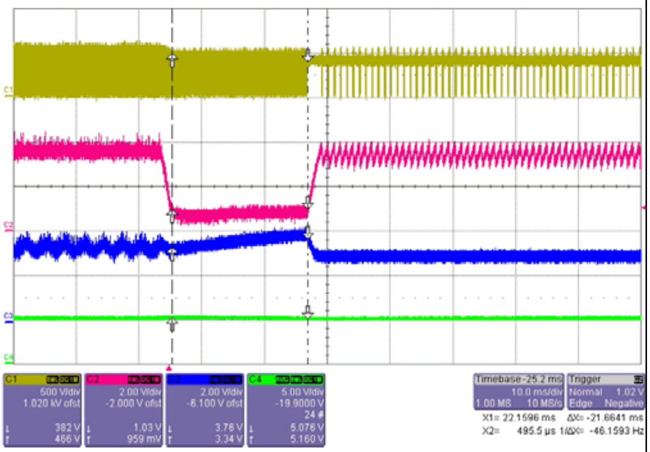
10.6 Active Burst Mode @ 0.5W load



Channel 1; C1 : Drain Source Voltage (V_{DS})
Channel 2; C2 : Feedback voltage (V_{FB})
Channel 3; C3 : Soft Start Voltage (V_{SOFTS})
Channel 4; C4 : Output Voltage (Vo)

Blanking time to enter burst mode : 21.9ms

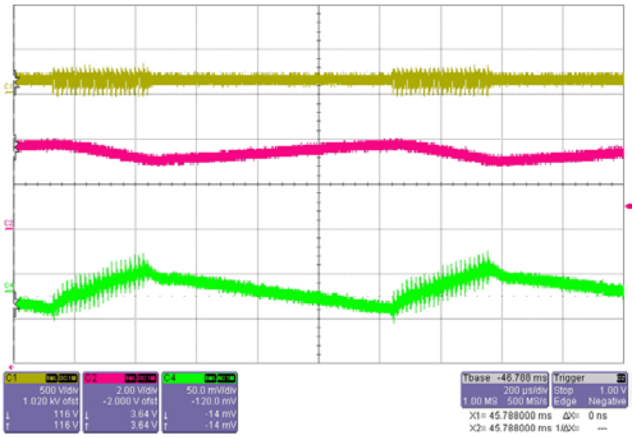
Figure 27 – Active burst mode @ Vin=85Vac and 0.5W load



Channel 1; C1 : Drain Source Voltage (V_{DS})
Channel 2; C2 : Feedback voltage (V_{FB})
Channel 3; C3 : Soft Start Voltage (V_{SOFTS})
Channel 4; C4 : Output Voltage (Vo)

Blanking time to enter burst mode : 21.6ms

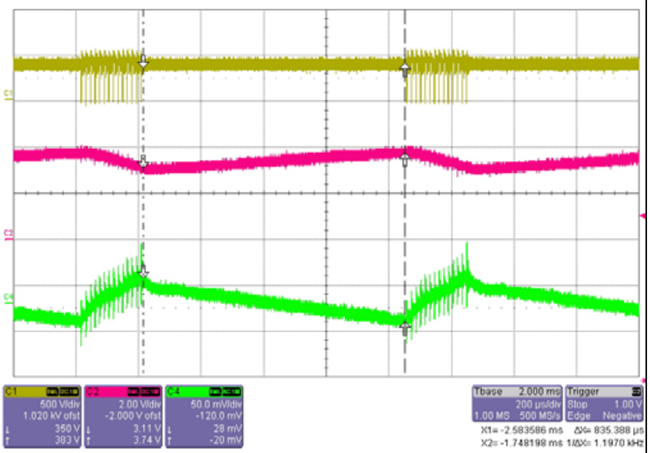
Figure 28 – Active burst mode @ Vin=265Vac and 0.5W load



Channel 1; C1 : Drain Source Voltage (V_{DS})
Channel 2; C2 : Feedback voltage (V_{FB})
Channel 4; C4 : Output Voltage (Vo)

Output ripple : app. 60mV

Figure 29 – Output ripple at active burst mode @ Vin=85Vac and 0.5W load

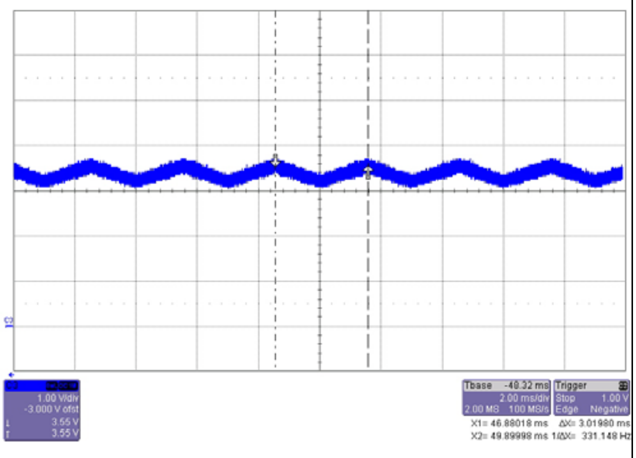
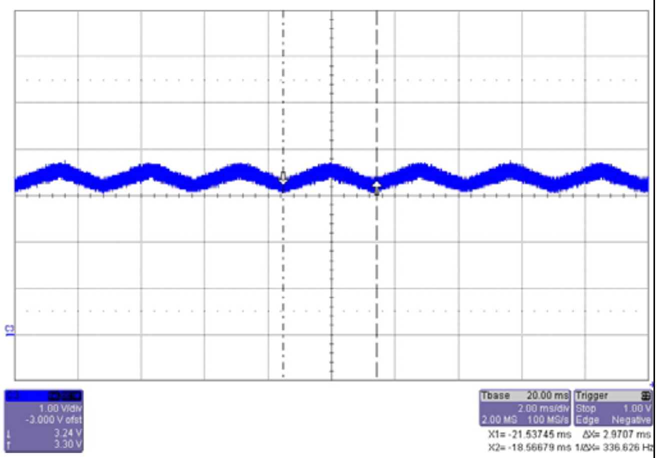
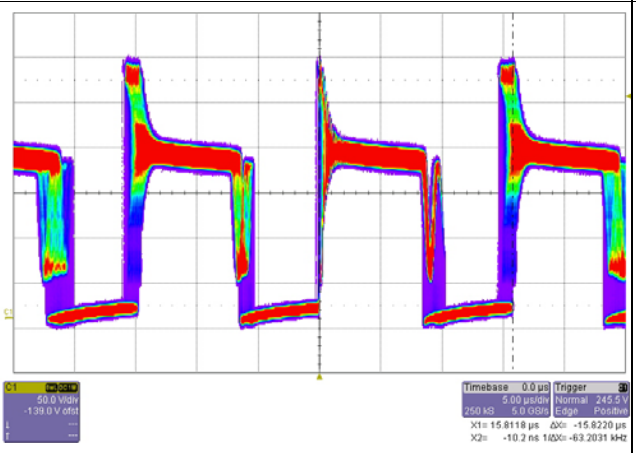
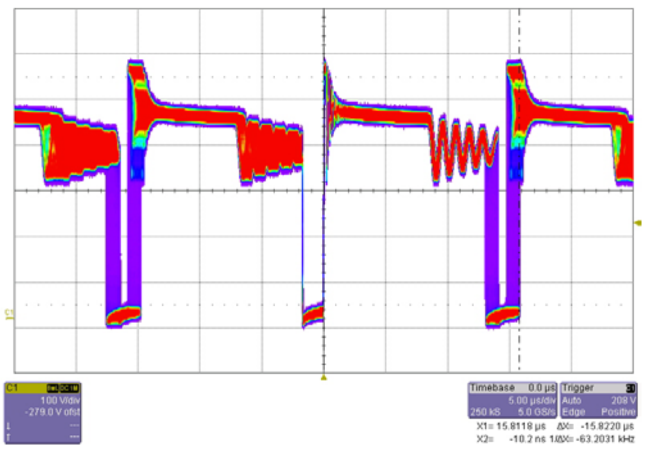


Channel 1; C1 : Drain Source Voltage (V_{DS})
Channel 2; C2 : Feedback voltage (V_{FB})
Channel 4; C4 : Output Voltage (Vo)

Output ripple : app. 70mV

Figure 30 – Output ripple at active burst mode @ Vin=265Vac and 0.5W load

10.7 Frequency Jittering

	
Channel 3; C3 : Soft Start Voltage (V_{SOFTS})	Channel 3; C3 : Soft Start Voltage (V_{SOFTS})
Frquency Jitter period : app. 3.02ms	Frquency Jitter period : app. 2.97ms
Figure 31 – Frequency Jitter period shown in SOFTS pin @ Vin=85Vac and 12W load	**Figure 32** – Frequency Jitter period shown in SOFTS pin @ Vin=265Vac and 12W load
	
Channel 1; C1 : Drain Source Voltage (V_{DS})	Channel 1; C1 : Drain Source Voltage (V_{DS})
Frequency changing from 63.2kHz ~ 68.9KHz	Frequency changing from 63.2kHz ~ 68.9KHz
Figure 33 – Frequency change shown at V_{DS} @ Vin=85Vac and 12W load	**Figure 34** – Frequency change shown at V_{DS} @ Vin=265Vac and 12W load

10.8 Slope compensation

This demo board is designed in Discontinuous Conduction Mode (DCM) operation. If the application is designed in Condtinous Condiction Mode (CCM) operation where the maximum duty cycle exceeds the 50% threshold, it needs to add the slope compensation network. Otherwise, the circuitry will be unstable. In this case, three more components (2 ceramic capacitors C17 / C18 and one resistor R19) is needed to add as shown in the circuit diagram below.

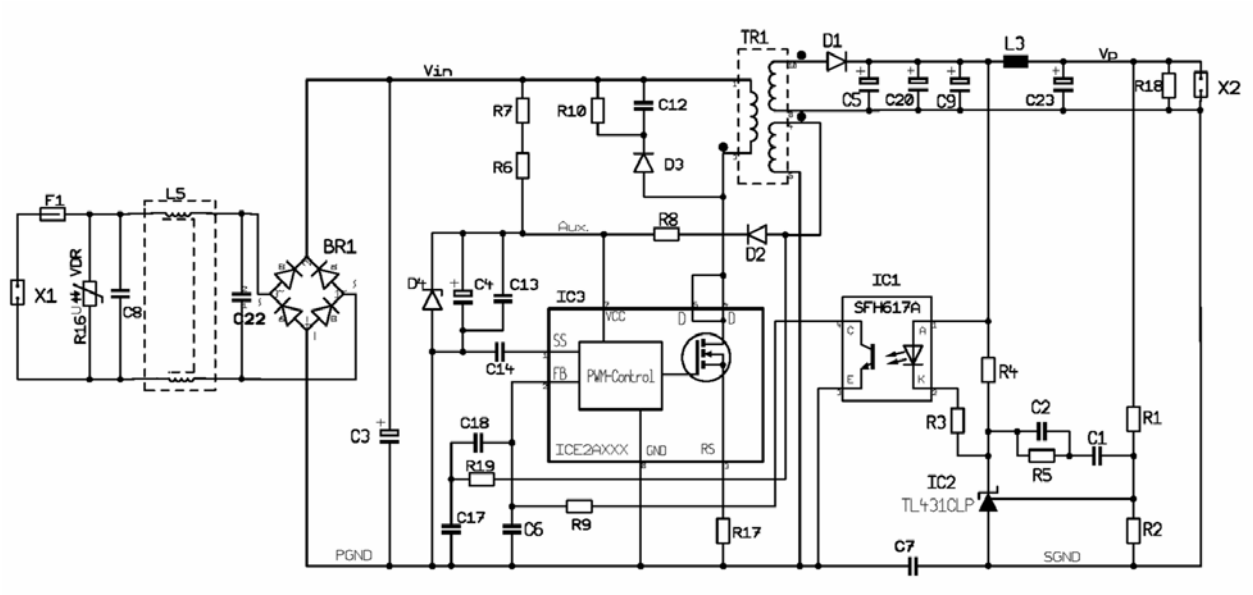


Figure 33 – Circuit Diagram Switch Mode Power Supply with Slope Compensation

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 CoolSET F2.

References

[1] Infineon Technologies, Datasheet
CoolSET™ - F3 (Jitter Version) ICE3B0365J / ICE3B0565J
OFF-Line SMPS Current Mode Controller with integrated 650V
Startup Cell/Depl-CoolMOS™

[2] Infineon Technologies, Application Note
AN-SMPS-ICE2xXXX-1
CoolSET™
ICE2xXXX for OFF-Line Switch Mode Power Supply (SMPS)

[3] Infineon Technologies, Application Note
AN-SMPS-ICE3DS01-1
CoolSET™
ICE3DS01 Current Mode Controller for OFF–Line Switch Mode
Power Supply (SMPS)

[3] APEB Power Management Chapter September, Article
60W SMPS design achieving <100mW standby power