AN-EVAL3AR2280JZ

20W 5V SMPS Evaluation Board with CoolSET® F3R80 ICE3AR2280JZ

Power Management & Supply

Never stop thinking.

Edition 2010-08-11

Published by Infineon Technologies Asia Pacific,
8 Kallang Sector,
349282 Singapore

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20W 5V Demoboard using ICE3AR2280JZ on board

Revision History:	**2010-08** V1.1
Previous Version:	1.0
Page	Subjects (major changes since last revision)
1, 6, 8	Change demo board name to EVAL3AR2280JZ

20W 5V SMPS Evaluation Board with CoolSET®F3R80 ICE3AR2280JZ:
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1 Abstract

This document is an engineering report of an universal input 20W 5V off-line flyback converter power supply utilizing IFX F3R80 CoolSET® ICE3AR2280JZ. The application demo board is operated in Discontinuous Conduction Mode (DCM) and is running at 100 kHz switching frequency. It has a single output voltage with secondary side control regulation. It is especially suitable for small power supply such as DVD player, set-top box, game console, charger and auxiliary power of high power system, etc. The ICE3AR2280JZ is the latest version of the CoolSET®. Besides having the basic features of the F3R CoolSET® such as Active Burst Mode, propagation delay compensation, soft gate drive, auto restart protection for major faults (Vcc over voltage, Vcc under voltage, over temperature, over-load, open loop and short opto-coupler), it also has the BiCMOS technology design, selectable entry and exit burst mode level, adjustable brownout feature, built-in soft start time, built-in and extendable blanking time, frequency jitter feature and external auto-restart enable, etc. The particular features need to be stressed are the best-in-class low standby power and the good EMI performance.

2 Evaluation board

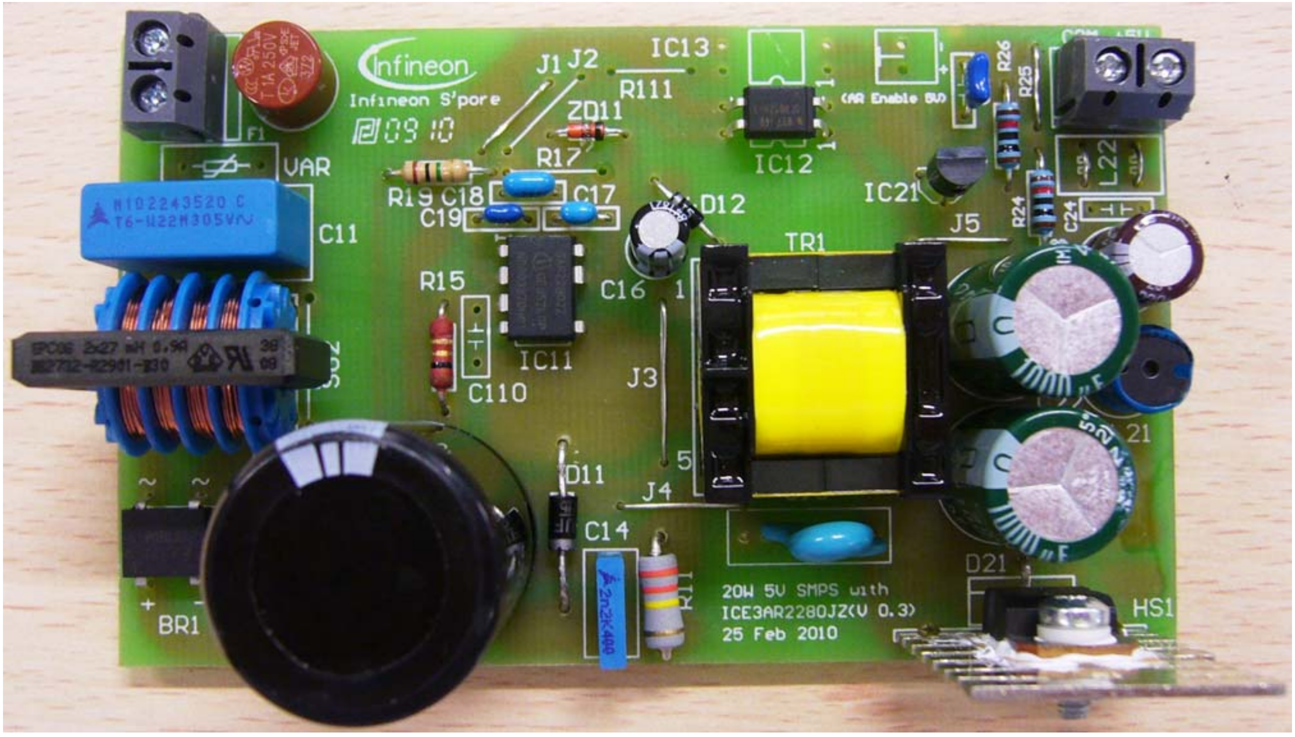


Figure 1 – EVAL3AR2280JZ

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.

3 List of features

800V avalanche rugged CoolMOS® with Startup Cell
Active Burst Mode for lowest Standby Power
Selectable entry and exit burst mode level
100kHz internally fixed switching frequency with jittering feature
Auto Restart Protection for Over load, Open Loop, VCC Under voltage & Over voltage and Over temperature
External auto-restart enable pin
Over temperature protection with 50°C hysteresis
Built-in 10ms Soft Start
Built-in 20ms and extendable blanking time for short duration peak power
Propagation delay compensation for both maximum load and burst mode
Adjustable brownout feature
Overall tolerance of Current Limiting < ±5%
BiCMOS technology for low power consumption and wide VCC voltage range
Soft gate drive with 50Ω turn on resistor

4 Technical specifications

Input voltage	85Vac~282Vac
Brownout detect/reset voltage	75/85Vac
Input frequency	50/60Hz
Input Standby Power	< 100mW @ no load
Output voltage	5V +/- 1%
Output current	4A
Output power	20W
Acitve mode average efficiency	>75%
Output ripple voltage	< 50mVp-p

5 Circuit description

5.1 Introduction

The EVAL3AR2280JZ demo board is a low cost off-line flyback switch mode power supply (SMPS) using the ICE3AR2280JZ integrated power IC from the CoolSET®-F3R80 family. The circuit, shown in Figure 3, details a 5V, 20W power supply that operates from an AC line input voltage range of 85Vac to 282Vac and brownout detect/reset voltage is 75/85Vac, suitable for applications in enclosed adapter or open frame auxiliary power supply for different system such as PC, server, DVD, LED TV, Set-top box, etc.

5.2 Line input

The AC line input side comprises the input fuse F1 as over-current protection. The choke L11, X1-capacitor C11, and Y1-capacitor C15 act as EMI suppressors. Optional spark gap device SG1, SG2 and varistor VAR can absorb high voltage stress during lightning surge test. After the bridge rectifier BR1 and the input bulk capacitor C13, a voltage of 120 to 400 V_{DC} is present which depends on input voltage.

5.3 Start up

Since there is a built-in startup cell in the ICE3AR2280JZ, there is no need for external start up resistors. The startup cell is connecting the drain pin of the IC. Once the voltage is built up at the Drain pin of the ICE3AR2280JZ, the startup cell will charge up the Vcc capacitor C16 and C17. When the Vcc voltage exceeds the UVLO at 17V, the IC starts up. Then the Vcc voltage is bootstrapped by the auxiliary winding to sustain the operation.

5.4 Operation mode

During operation, the Vcc pin is supplied via a separate transformer winding with associated rectification D12 and buffering C16, C17. In order not to exceed the maximum voltage at Vcc pin, an external zener diode ZD11 and resistor R14 can be added.

5.5 Soft start

The Soft-Start is a built-in function and is set at 10ms.

5.6 RCD clamper circuit

While turns off the CoolMOS®, the clamper circuit R11, C14 and D11 absorbs the current caused by transformer leakage inductance once the voltage exceeds clamp capacitor voltage. Finally drain-source voltage of CoolMOS® is lower than maximum break down voltage ($V_{(BR)DSS}$ = 800V) of CoolMOS®.

5.7 Peak current control of primary current

The CoolMOS® drain source current is sensed via external shunt resistors R15 and R16 which determine the tolerance of the current limit control. Since ICE3AR2280JZ is a current mode controller, it would have a cycle-by-cycle primary current and feedback voltage control and can make sure the maximum power of the converter is controlled in every switching cycle. Besides, the patented propagation delay compensation is implemented to ensure the maximum input power can be controlled in an even tighter manner thoughout the wide range input voltage. The demo board shows approximately. +/-3.86% (refer to Figure 14).

5.8 Output stage

On the secondary side the power is coupled out by a schottky diode D21. The capacitor C21 & C22 provide energy buffering following with the LC filter L21 and C23 to reduce the output voltage ripple considerably. Storage capacitors C21 & C22 are selected to have a very small internal resistance (ESR) to minimize the output voltage ripple. The optional common mode choke L22 and ceramic capacitor C24 are added to suppress the high voltage electrostatic static charge during ESD test.

5.9 Feedback and burst entry/exit control

FBB pin has 2 features; functions of output voltage feedback and burst entry control.

The output voltage is controlled by using a TL431 (IC21) which incorporates the voltage reference as well as the error amplifier and a driver stage. Compensation network C26, C27, R23, R24, R25, R26 and R27 constitutes the external circuitry of the error amplifier of IC21. This circuitry allows the feedback to be precisely matched to dynamically varying load conditions and provides stable control. The maximum current through the optocoupler diode and the voltage reference is set by using resistors R21 and R22. Optocoupler IC12 is used for floating transmission of the control signal to the “Feedback” input of the ICE3AR2280JZ. The capacitor C19 at the FBB pin acts 2 functions; filter the noise from going to the pin and setting for the selection of the burst entry control (explained below). The optocoupler used meets DIN VDE 884 requirements for a wider creepage distance.

C19 capacitor is also used to select the entry and exit burst level. The IC would generate the charge and discharge current to the FBB pin and then detect the number of count for the charge and discharge cycle during the 1st 1ms of IC start up (Vcc > 17V). Based on the detected number of count, the entry and exit burst level are set. The below table is the recommended capacitance range for the entry and exit level with the C_{FB} (C19) capacitor.

C_{FB}	Corresponding no. of counts	Entry level		Exit level	
		% of P_{in_max}	V_{FB_burst}	% of P_{in_max}	V_{csth_burst}
≥ 6.8nF	≤ 7	10%	1.6V	20%	0.45V
1nF~2.2nF	8 ~ 39	6.67%	1.42V	13.30%	0.37V
220pF~470pF	40 ~ 91	4.38%	1.27V	9.60%	0.31V
≤100pF	≥ 92	0	never	0	always

5.10 Blanking window for load jump

In case of load jumps the controller provides a blanking window before activating the Over Load Protection and entering the Auto Restart Mode. There are 2 modes for the blanking time setting; basic mode and the extendable mode. If there is no capacitor added to the BBA pin, it would fall into the basic mode; i.e. the blanking time is set at 20ms. If a longer blanking time is required, a capacitor, C_{BK} (C18) can be added to BBA pin to extend it. The extended blanking time can be achieved by the lead time of 256 times of charging and discharging of C_{BK} capacitor, which is generated by the controller. Thus the overall blanking time is the addition of 20ms and the extended time. For example, C_{BK} (C18) = 0.22uF, I_{chg_EB} (internal charging current) = 720uA

$$t_{blanking} = Basic + Extended = 20ms + \left\{ 256 \times \left(\left(\frac{(4.5-0.9)\times C_{BK}}{I_{chg\_EB}} \right) + \left(C_{BK} \times 500 \times \ln(\frac{4.5}{0.9}) \right) \right) \right\} = 346.9ms$$

Since the BBA pin is multi-function pin, extended blanking time can be changed if the brownout resistor R110 (28kΩ) is added to the system, new I_{chg_EB}‘ and overall blanking time can be calculated as follows,

$$I_{chg\_EB}' = 720\mu A - \frac{(4.5+0.9)}{2 * R_{BO2}} = 623.6\mu A$$

$$t_{blanking\_R_{BO2}} = 20ms + \left\{ 256 \times \left(\left(\frac{(4.5-0.9)\times C_{BK}}{I_{chg\_EB}'} \right) + \left(C_{BK} \times 500 \times \ln(\frac{4.5}{0.9}) \right) \right) \right\} = 390.4ms$$

Note: A filter capacitor (e.g. 100pF (min. value)) may be needed to add to the BBA pin if the noise cannot be avoided to enter that pin in the physical PCB layout. Otherwise, some protection features may be mis-triggered and the system may not be working properly.

5.11 Brownout mode

When the AC line input voltage is lower than the input voltage range, brownout mode is detected by sensing the voltage level at BBA pin through the resistors divider from the bulk capacitor. Once the voltage level at BBA pin falls below 0.9V, the controller stops switching and enters into brownout mode. It is until the input level goes back to input voltage range and the Vcc hits 17V, the brownout mode is released. Brownout sensing resistor R_{BO1} and R_{BO2} can be calculated as below.

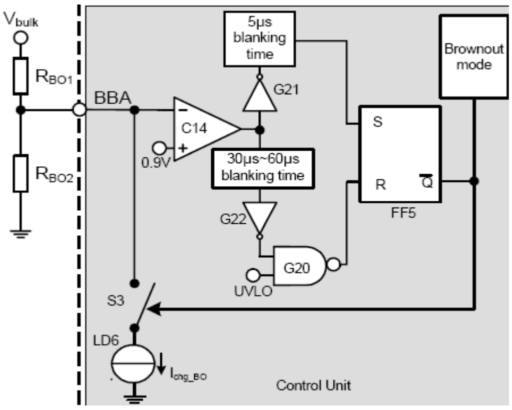


Figure 2 – Brownout detection circuit

$$R_{BO1} = \frac{V_{BO\_hys}}{I_{chg\_BO}} \quad ; \qquad R_{BO2} = \frac{V_{BO\_ref} \times R_{BO1}}{V_{BO\_L} - V_{BO\_ref}}$$

where V_{BO_hys}: input brownout hysteresis voltage
I_{chg_BO} = 10μA: charging current for brownout
V_{BO_ref} = 0.9V: brownout reference voltage for IC
V_{BO_L}: input brownout voltage (low point)
R_{BO1} and R_{BO2}: resistors divider from input voltage to BBA pin

For example, if brownout release voltage is 85Vac and entry voltage is 75Vac and assuming there is a ripple voltage of 14Vdc at the bulk capacitor before entering brownout at full load.

$$V_{BO\_H} = 85 \times \sqrt{2} = 120Vdc \qquad V_{BO\_L} = 75 \times \sqrt{2} - 14 = 92Vdc$$

$$V_{BO\_hys} = V_{BO\_H} - V_{BO\_L} = 28Vdc$$

$$R_{BO1} = \frac{V_{BO\_hys}}{I_{chg\_BO}} = 2.8M\Omega$$

$$R_{BO2} = \frac{V_{BO\_ref} \times R_{BO1}}{V_{BO\_L} - V_{BO\_ref}} = 28k\Omega$$

Note: The above calculation assumes the tapping point (bulk capacitor) has a 14Vdc ripple voltage at full load when entering brownout mode. If there is no ripple voltage at light load, the enter brownout point will be lower, 65Vac. Besides that the low side brownout voltage V_{BO_L} added with the ripple voltage at the tapping point should always be lower than the high side brownout voltage (V_{BO_H}); V_{BO_H} > V_{BO_L} + ripple voltage. Otherwise, the brownout feature cannot work properly. In short, when there is a high load running in system before entering brownout, the input ripple voltage will increase and the brownout voltage will increase (V_{BO_L} = V_{BO_L}+ ripple voltage) at the same time. If the V_{BO_hys} is set too small and is close to the ripple voltage, then the brownout feature cannot work properly (V_{BO_L} = V_{BO_H}).
If the brownout feature is not needed, it needs to tie the BBA pin to the Vcc pin through a current limiting resistor (R17), 500kΩ~1MΩ. The BBA pin cannot be in floating condition. If the brownout feature is disabled with a tie up resistor, there is a limitation of the capacitor C_{BK} (C18) at the BBA pin. It is as below.

	Vcc tie up resistor	C_{BK_max}
1	500kΩ	0.47µF
2	1MΩ	0.22µF

5.12 Active burst mode

At light load condition, the SMPS enters into Active Burst Mode. For this 800V CoolSET, the enter/exit burst mode level is selected by a FB capacitor (refer to section 5.9). The light load condition is actually reflected to the FB voltage level for the DCM operation; i.e. FB voltage drops according to how light the load is. With the selectable feature, the enter burst mode level, V_{FB_burst} is determined by the capacitor at FB capacitor. After entering burst mode, the controller is always active and thus the V_{CC} must always be kept above the switch off threshold V_{CCoff} ≥ 10.5V. During the active burst mode, the efficiency maintains in a very high level and at the same time it supports low ripple on V_{OUT} and fast response on load jump. To avoid mis-triggering of the burst mode, there is a 20ms internal blanking time. Once the FB voltage drops below V_{FB_burst}, the internal blanking timer starts to count. When it reaches the built-in 20ms blanking time, it then enters Active Burst Mode.

During Active Burst Mode the current sense voltage limit is reduced from 1V to V_{csth_burst} so as to reduce the conduction losses and audible noise. All the internal circuits are switched off except the reference and bias voltages to reduce the total V_{CC} current consumption to below 0.62mA. At burst mode, the FB voltage is changing like a sawtooth between 3.2 and 3.5V. To leave Burst Mode, FB voltage must exceed 4V. It will reset the Active Burst Mode and turn the SMPS into Normal Operating Mode. Maximum current can then be provided to stabilize V_{OUT}.

5.13 Jitter mode, soft gate drive and the 50Ω gate turn on resistor

In order to obtain better EMI performance, the ICE3AR2280JZ is implemented with frequency jittering, soft gate drive and 50Ω gate turn on resistor.

The jitter frequency is internally set at 100 kHz (+/-4 kHz) and the jitter period is set at 4ms.

5.14 Protection modes

Protection is one of the major factors to determine whether the system is safe and robust. Therefore sufficient protection is necessary. ICE3AR2280JZ provides two kinds of protection mode; odd skip auto restart mode and non switch auto restart mode.
In odd skip auto restart mode, there is no detect of fault and no switching pulse for the odd number restart cycle. At the even number of restart cycle, the fault detects and soft start switching pulses maintained. If the fault persists, it would continue the auto-restart mode. However, if the fault is removed, it can release to normal operation only at the even number auto restart cycle.
Non switch auto restart mode is similar to odd skip auto restart mode except the start up switching pulses are also suppressed at the even number of the restart cycle. The detection of fault still remains at the even number of the restart cycle. When the fault is removed, the IC will resume to normal operation at the even number of the restart cycle.

The main purpose of the odd skip auto restart is to extend the restart time such that the power loss during auto restart protection can be reduced when a small Vcc capacitor is used. A list of protections and the failure conditions are shown in the following table.

Protection functions	Failure condition	Protection Modes
V_{CC} overvoltage(1)	V_{CC} > 20.5V & V_{FBB} > 4.5V & during soft start period	Odd skip auto restart
V_{CC} overvoltage(2)	V_{CC} > 25.5V	Odd skip auto restart
Over load	V_{FBB} > 4.5V, after blanking time	Odd skip auto restart
Open loop	-> Overload	Odd skip auto restart
V_{CC} under voltage	V_{CC} < 10.5V	Non switch auto restart
short optocoupler	-> V_{CC} Undervoltage	Non switch auto restart
Over temperature	T_J > 130°C (recovered with 50°C hysteresis)	Non switch Auto restart
External protection enable	V_{BBA} < 0.4V	Non switch auto restart

6 Circuit diagram

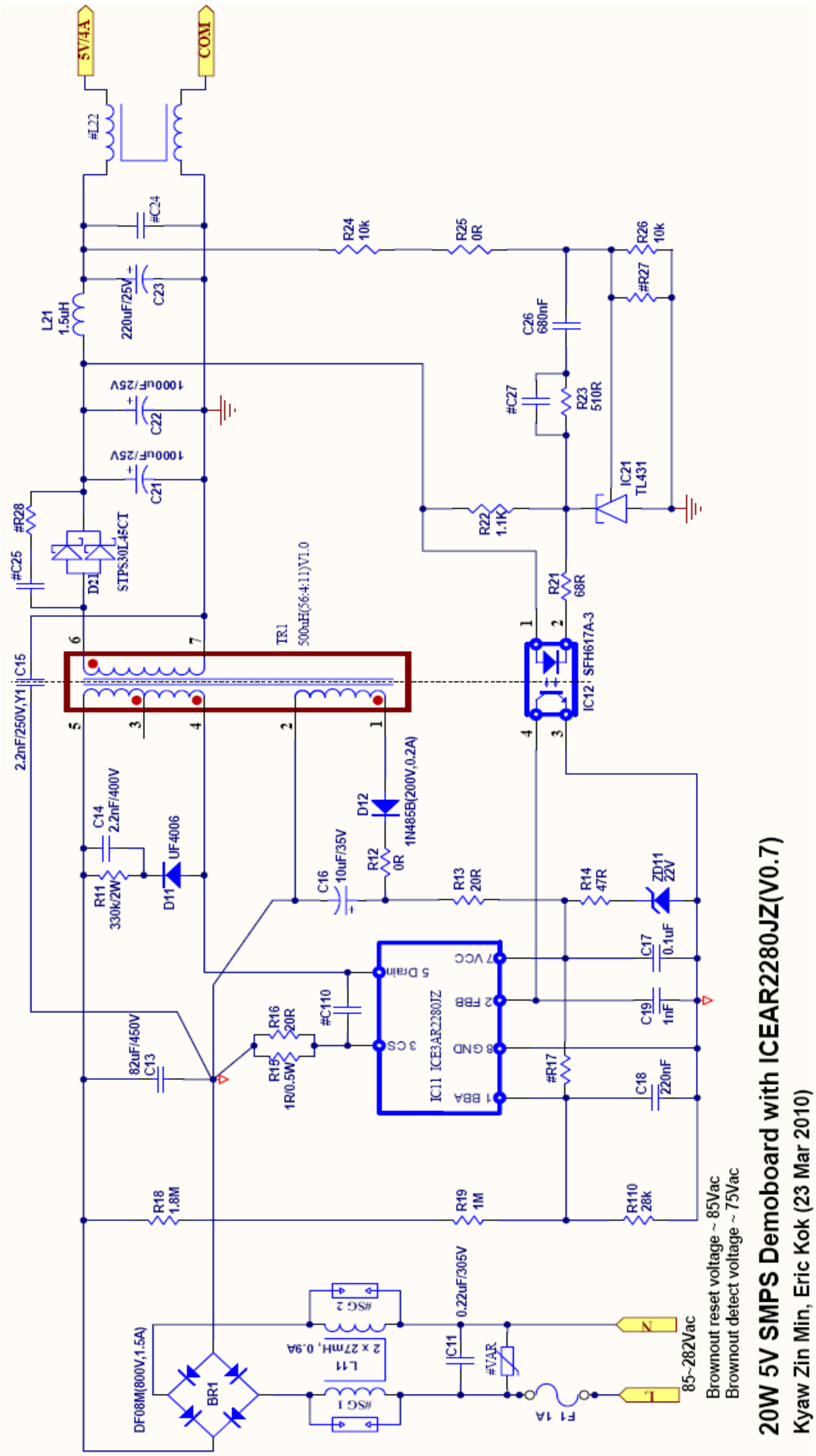


Figure 3 – 20W 5V ICE3AR2280JZ power supply schematic

N.B. : In order to get the optimized performance of the CoolSET®, the grounding of the PCB layout must be connected very carefully. From the circuit diagram above, it indicates that the grounding for the CoolSET® can be split into several groups; signal ground, Vcc ground, Current sense resistor ground and EMI return ground. All the split grounds should be connected to the bulk capacitor ground separately.

- Signal ground includes all small signal grounds connecting to the CoolSET® GND pin such as filter capacitor ground, C17, C18, C19 and opto-coupler ground.
- Vcc ground includes the Vcc capacitor ground, C16 and the auxiliary winding ground, pin 2 of the power transformer.
- Current Sense resistor ground includes current sense resistor R15 and R16.
- EMI return ground includes Y capacitor, C15.

7 PCB layout

7.1 Top side

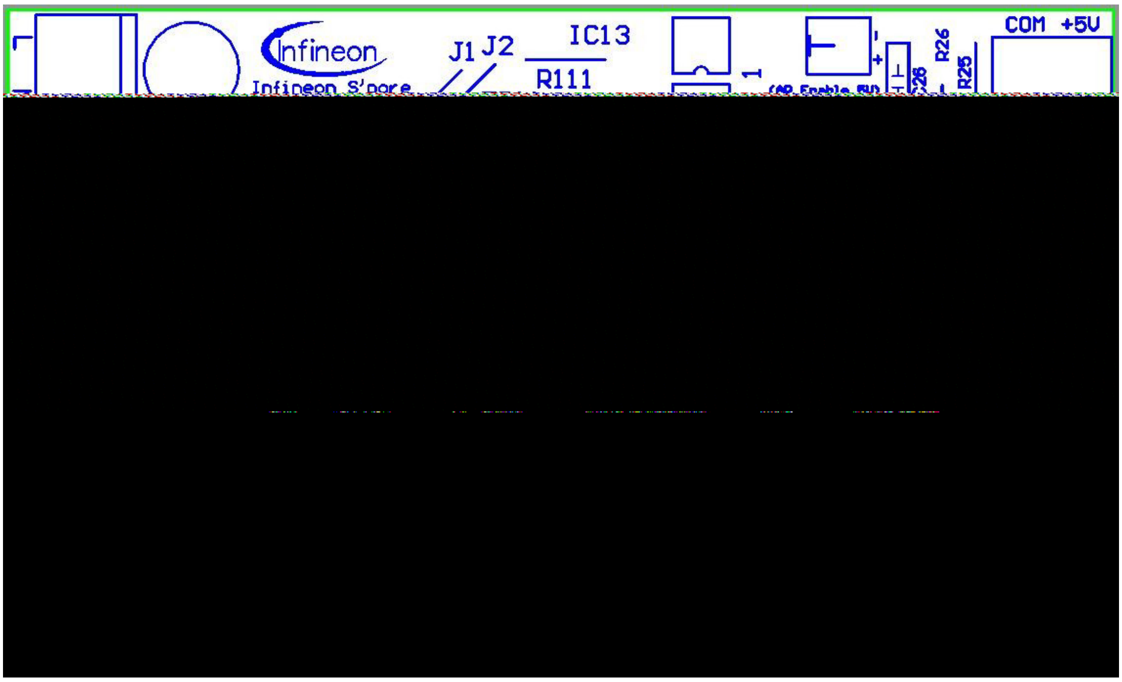


Figure 4 – Top side component legend

7.2 Bottom side

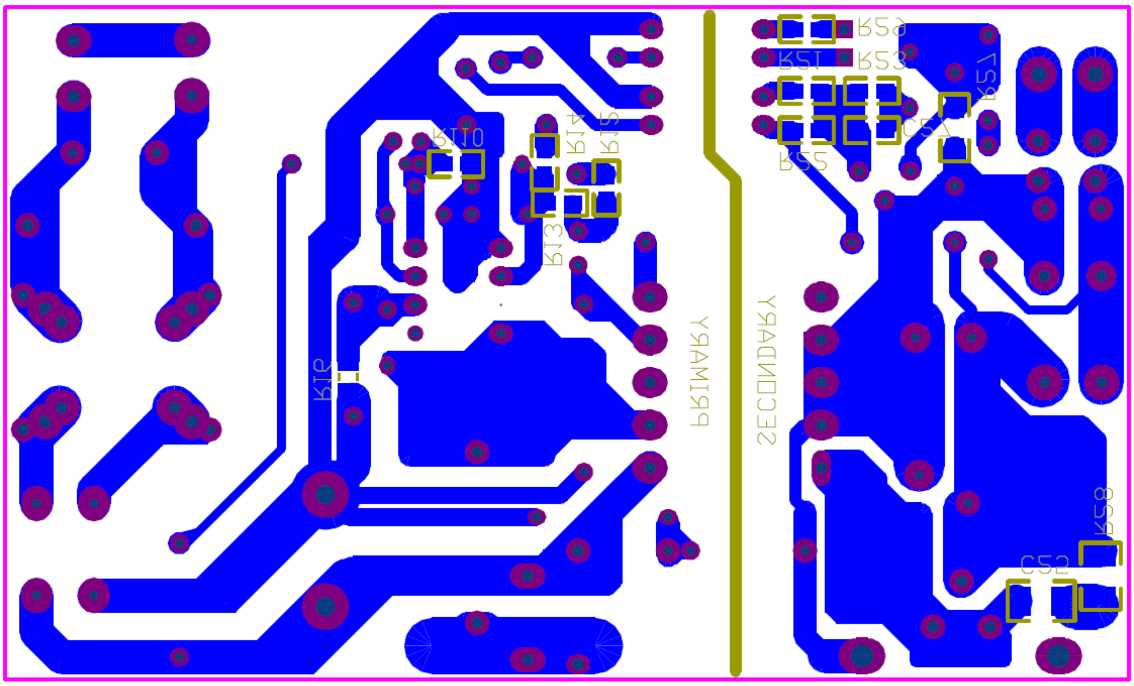


Figure 5 – Bottom side copper & component legend

8 Component list

No	Designator	Component description	Part No.	Manufacturer
1	BR1	DF08M(800V,1.5A)		
2	C11	0.22uF/305V	B32922C3224K000	EPCOS
3	C13	82uF/450V	B43504A5826M000	EPCOS
4	C14	2.2nF/400V		
5	C15	2.2nF/250V,Y1	DE1E3KX222MA4BL01	MURATA
6	C16	10uF/35V	B41821A6106M000	EPCOS
7	C17	0.1uF	RPER71H104K2K1A03B	MURATA
8	C18	220nF	RPER71H224K2K1C03B	MURATA
9	C19	1nF	RPE5C1H102J2K1A03B	MURATA
10	C21, C22	1000uF/25V		
11	C23	220uF/25V		
12	C26	680nF		
13	D11	UF4006	UF4006	VISHAY
14	D12	1N485B(200V,0.2A)		
15	D21	STPS30L45CT		
16	F1	1A		
17	IC11	ICE3AR2280JZ	ICE3AR2280JZ	INFINEON
18	IC12	SFH617A-3		
19	IC21	TL431		
20	J1,J3,J4,J5,R25,L22	Jumper		
21	L11	2 x 27mH, 0.9A	B82732F2901B001	EPCOS
22	L21	1.5uH		
23	R11	330k(2W,5%)		
24	R12	0R(SMD 0805)		
25	R13	20R(SMD 0805)		
26	R14	47R(SMD 0805)		
27	R15	1R(0.5W,1%)		
28	R16	20R(SMD 1206)		
29	R18	1.8M		
30	R19	1M		
31	R21	68R(SMD 0805)		
32	R22	1.1K(SMD 0805)		
33	R23	510R(SMD 0805)		
34	R24, R26	10k		
35	R110	28k(SMD 0805)		
36	TR1	500uH(56:4:11)V1.0	B662061110T001	EPCOS
37	ZD11	22V		

9 Transformer construction

Core: E20/10/6, N87(EPCOS)
Bobbin: Horizontal Version
Primary Inductance, Lp=500µH, measured between pin 4 and pin 5 (Gapped to inductance)

Transformer structure:

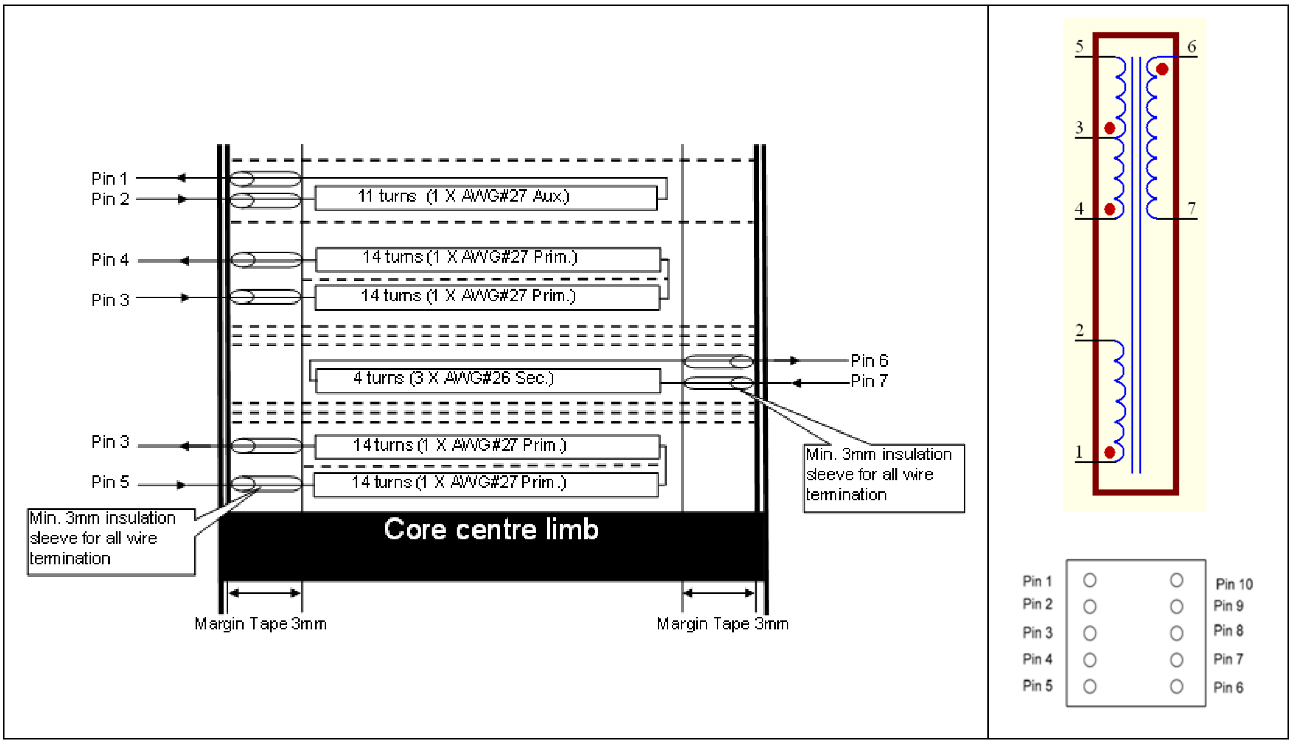


Figure 6 – Transformer structure and top view of transformer complete

Wire size requirement:

Start	Stop	No. of turns	Wire size	Layer
2	1	11	1XAWG#27	Auxiliary
3	4	28	1XAWG#27	$^{1}/_{2}$ Primary
7	6	4	3XAWG#26	Secondary
5	3	28	1XAWG#27	$^{1}/_{2}$ Primary

10 Test results

10.1 Efficiency

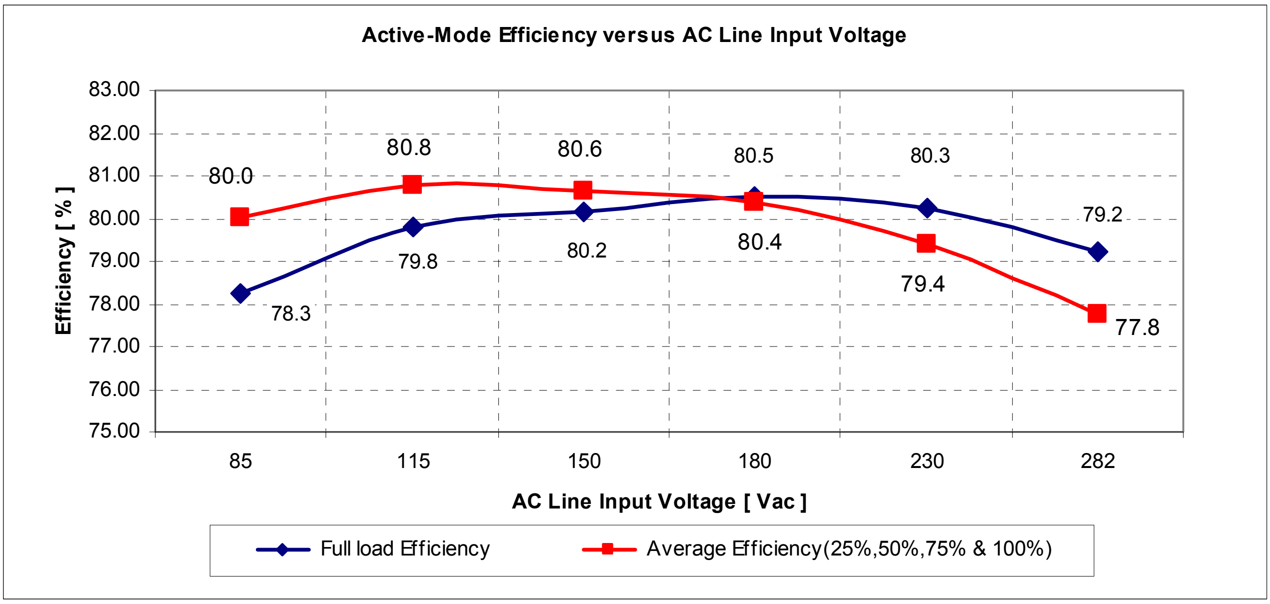


Figure 7 – Efficiency vs. AC line input voltage

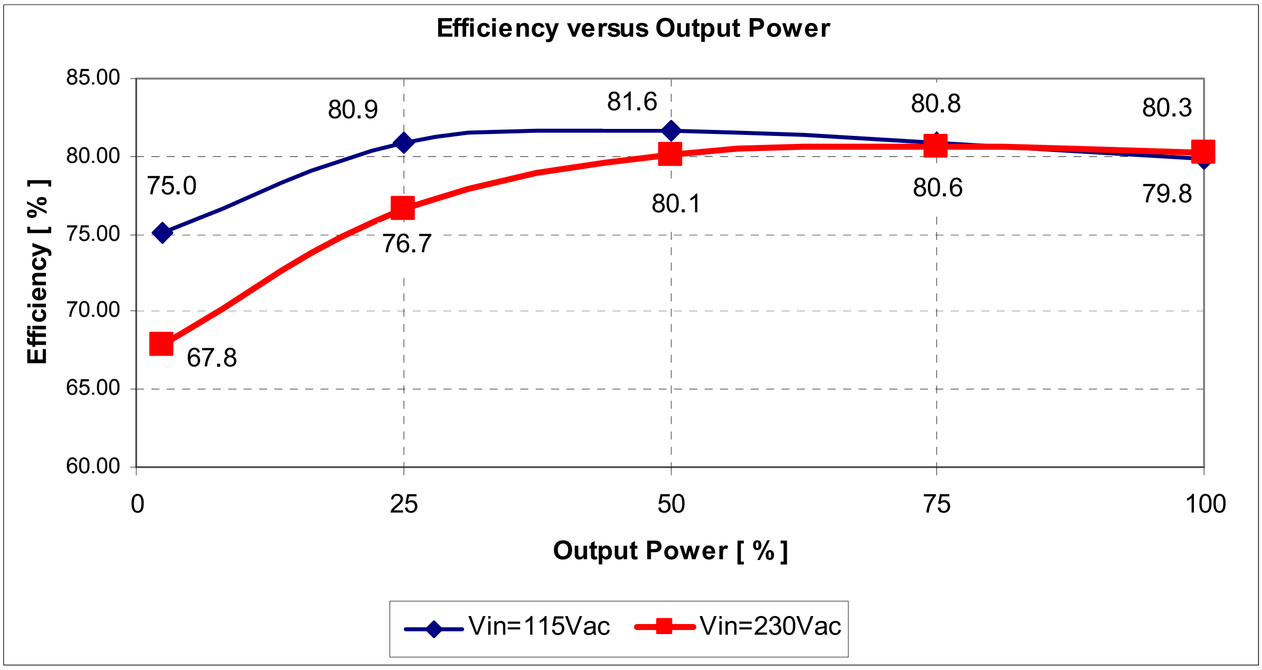


Figure 8 – Efficiency vs. output power @ low and high line

10.2 Input standby power

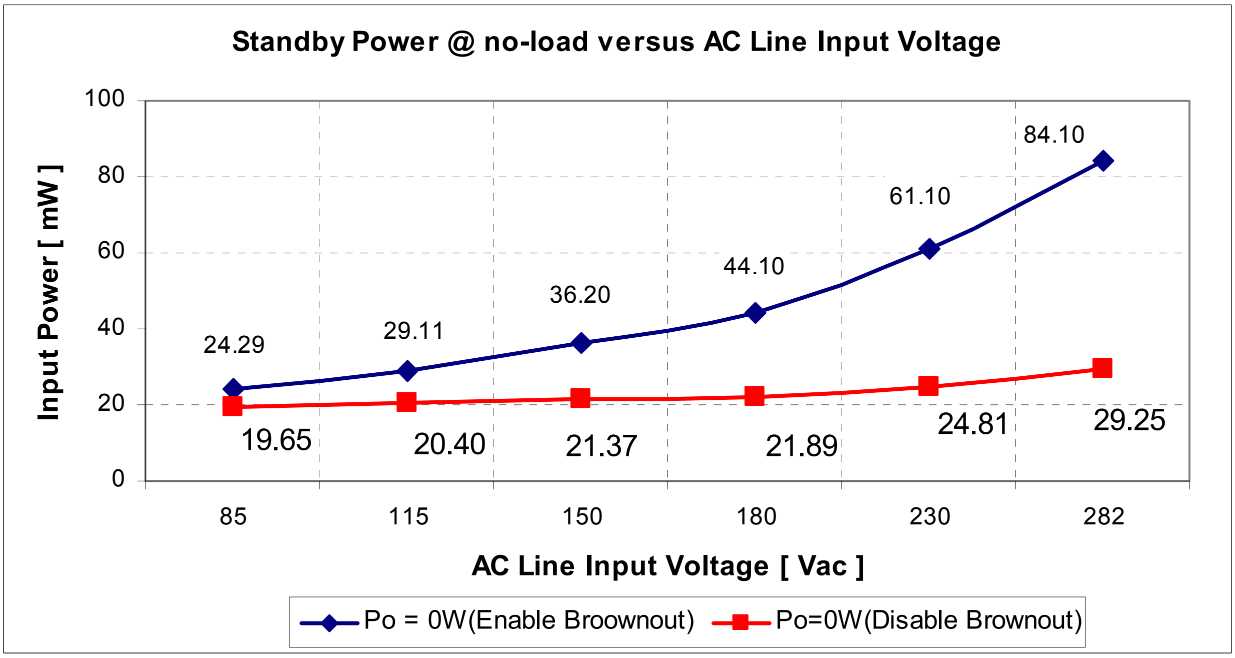


Figure 9 – Input standby power @ no load vs. AC line input voltage (measured by Yokogawa WT210 power meter - integration mode)

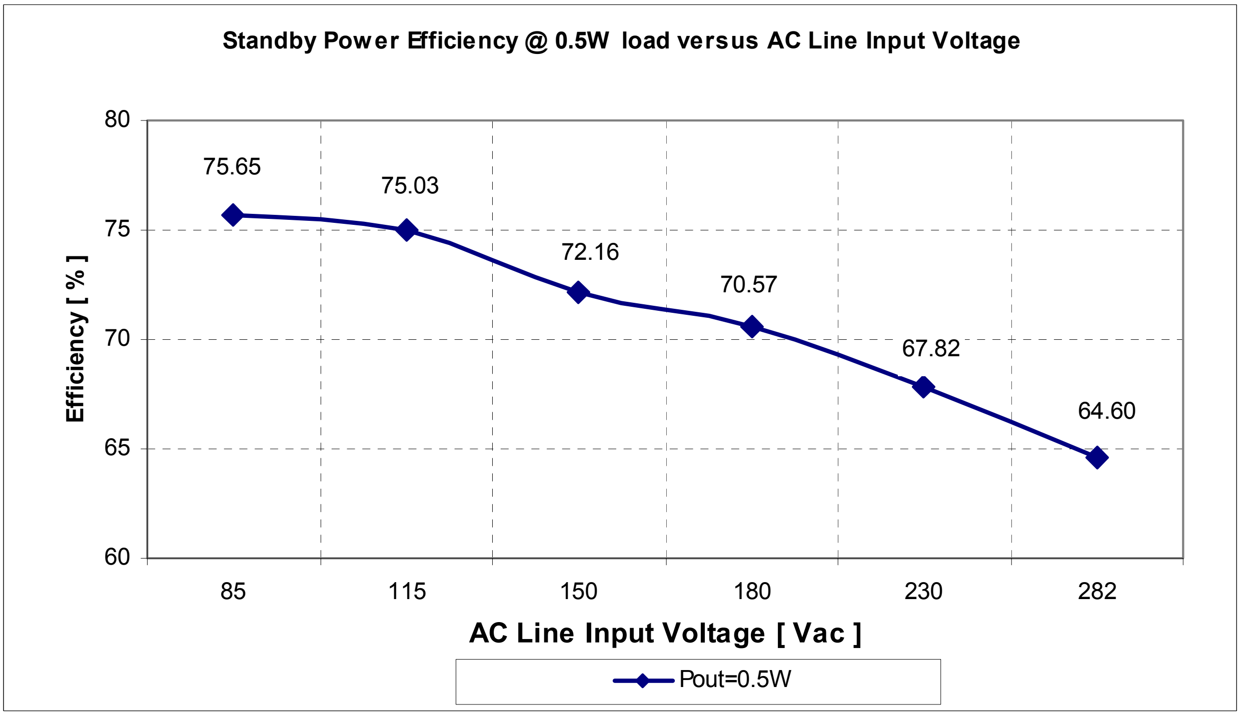


Figure 10 – Input standby power @ 0.5W vs. AC line input voltage (measured by Yokogawa WT210 power meter - integration mode)

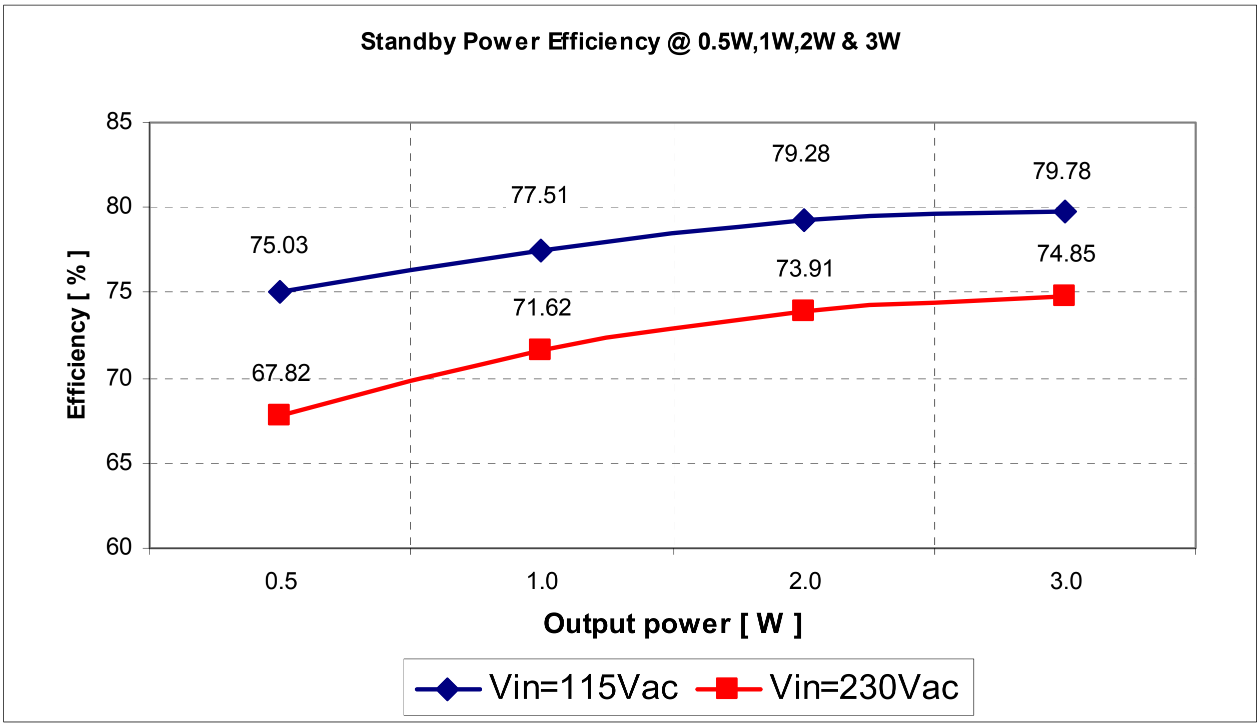


Figure 11 – Input standby power efficiency vs. light output power

10.3 Line regulation

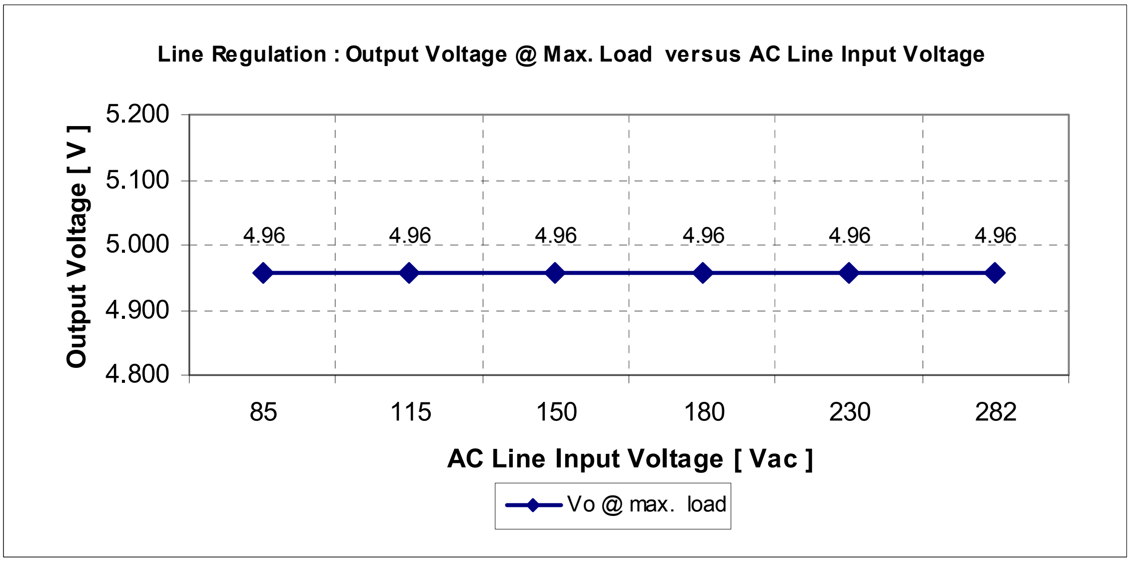


Figure 12 – Line regulation Vo @ full load vs. AC line input voltage

10.4 Load regulation

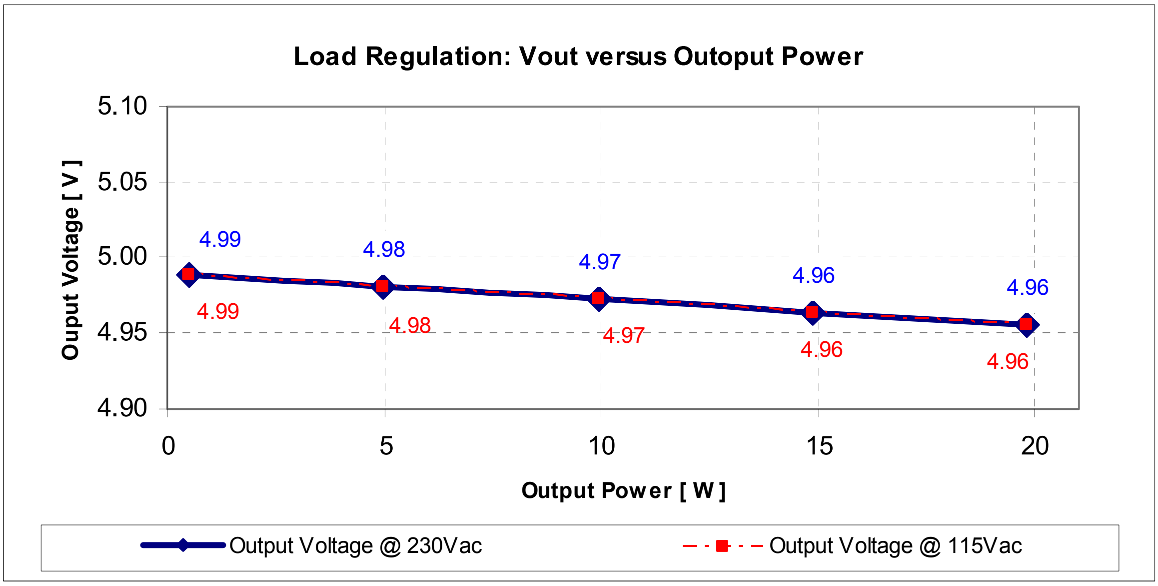


Figure 13 – Load regulation Vout vs. output power

10.5 Max. output power

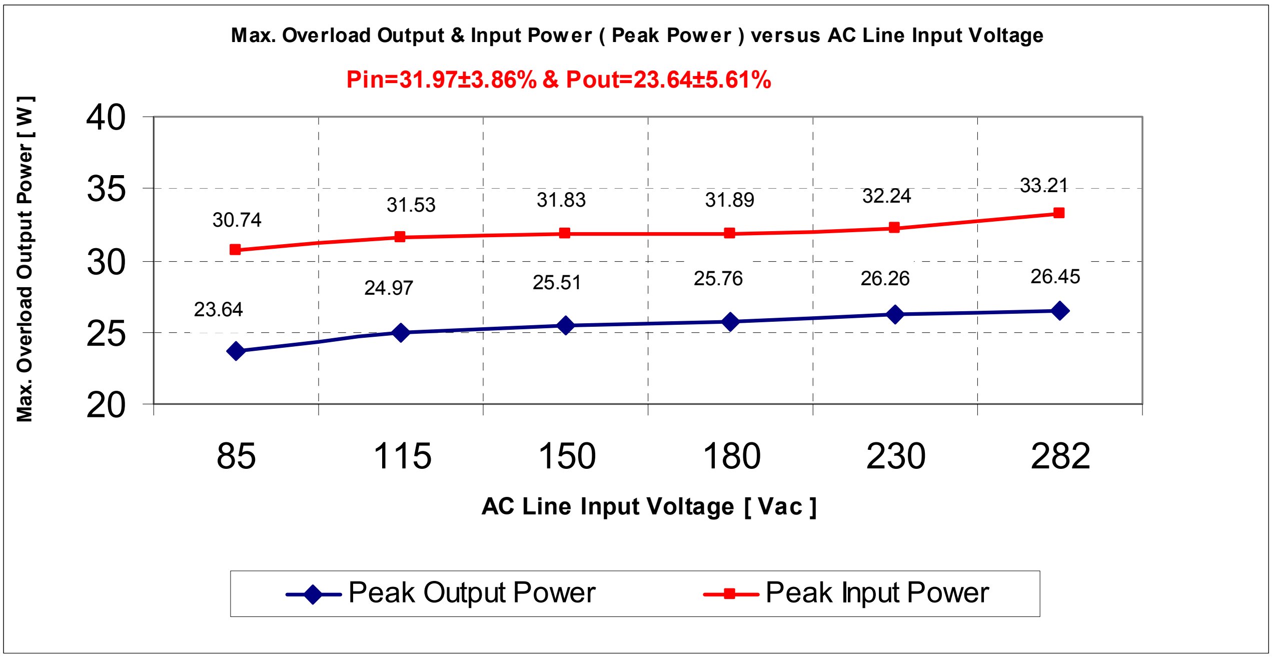


Figure 14 – Max. output power (before over-load protection) vs. AC line input voltage

10.6 ESD test

Pass* (EN61000-4-2): 20kV for contact discharge.

*Add L22 and C24

10.7 Lightning surge test

Pass* (EN61000-4-5) 6kV for line to earth

*Add SG1 & SG2 (DSP-301N-S00B)

10.8 Conducted EMI

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 (20W) with input voltage of 115Vac and 230Vac.

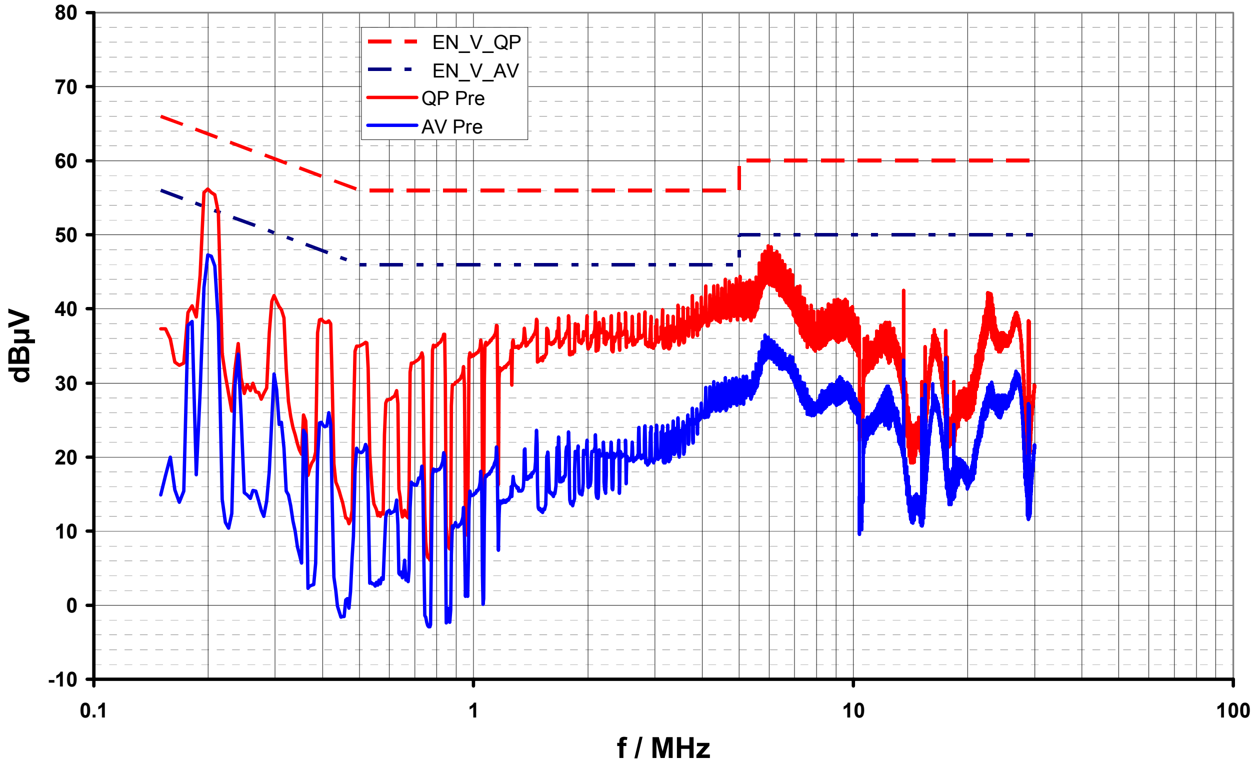


Figure 15 – Max. Load (20W) with 115 Vac (Line)

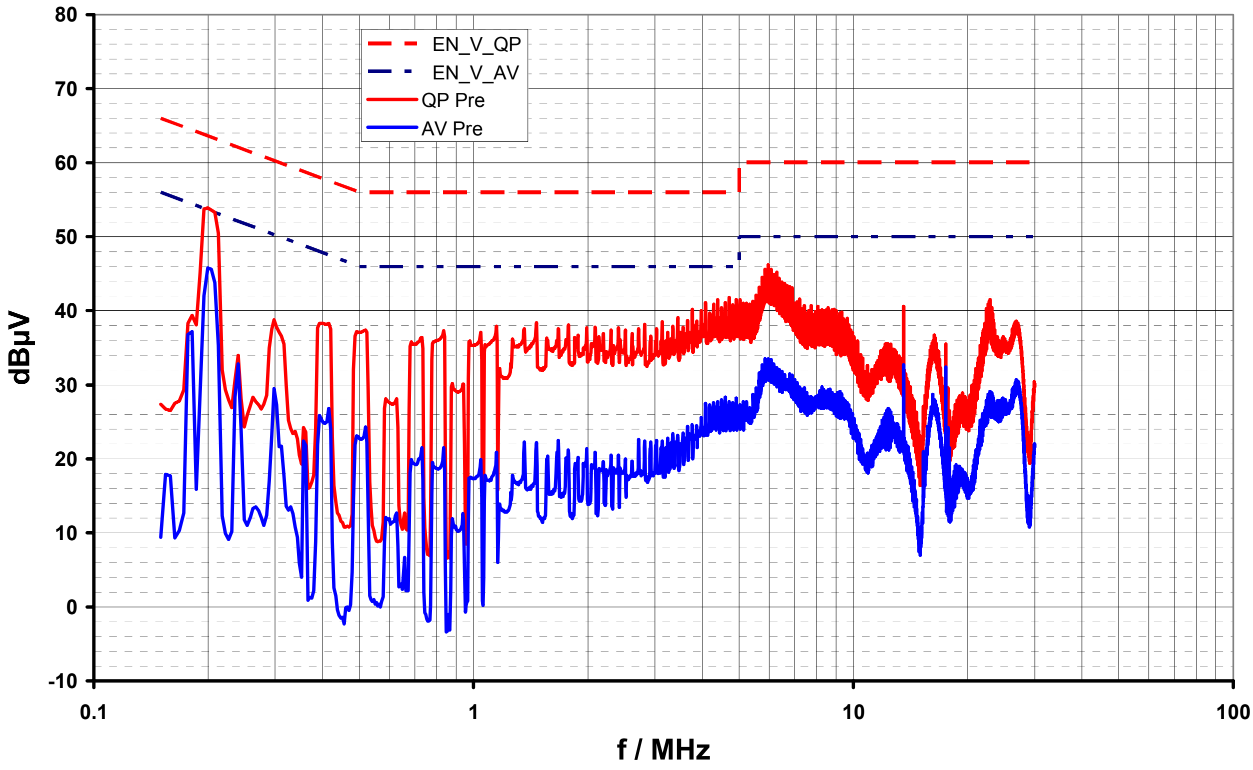


Figure 16 – Max. Load (20W) with 115 Vac (Neutral)

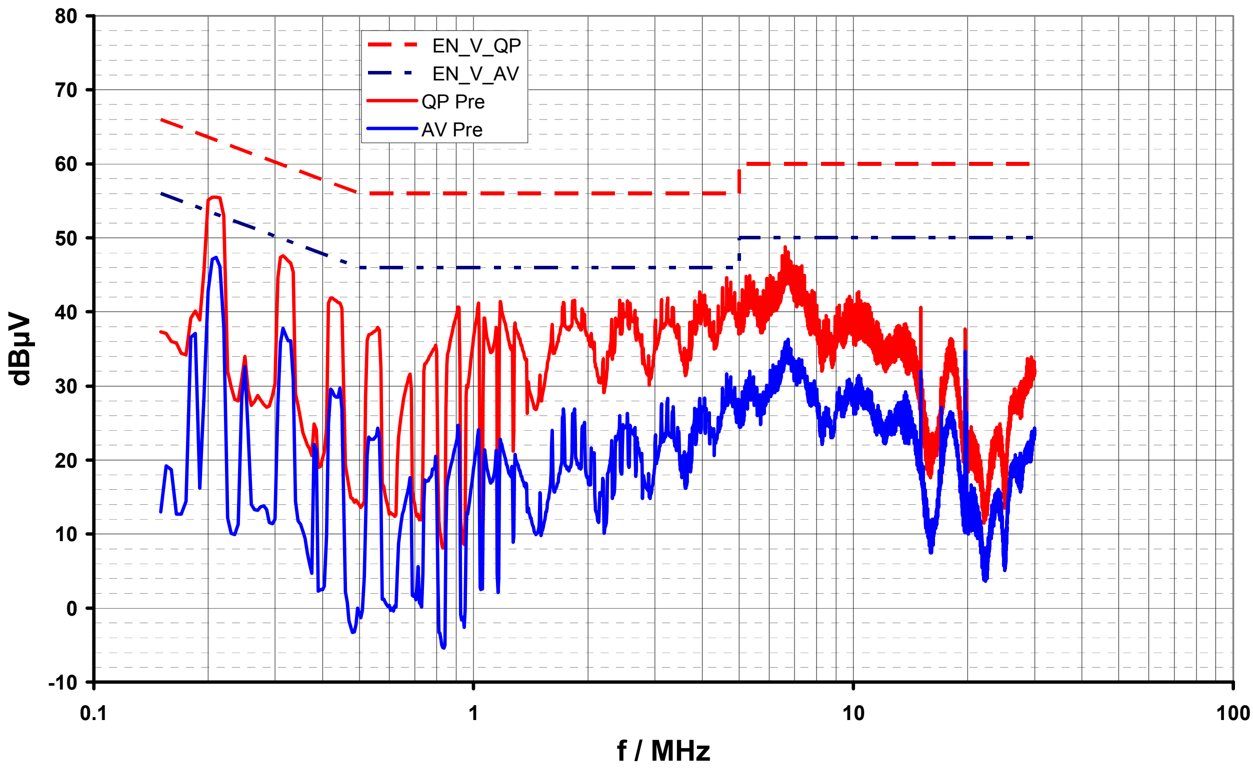


Figure 17 – Max. Load (20W) with 230 Vac (Line)

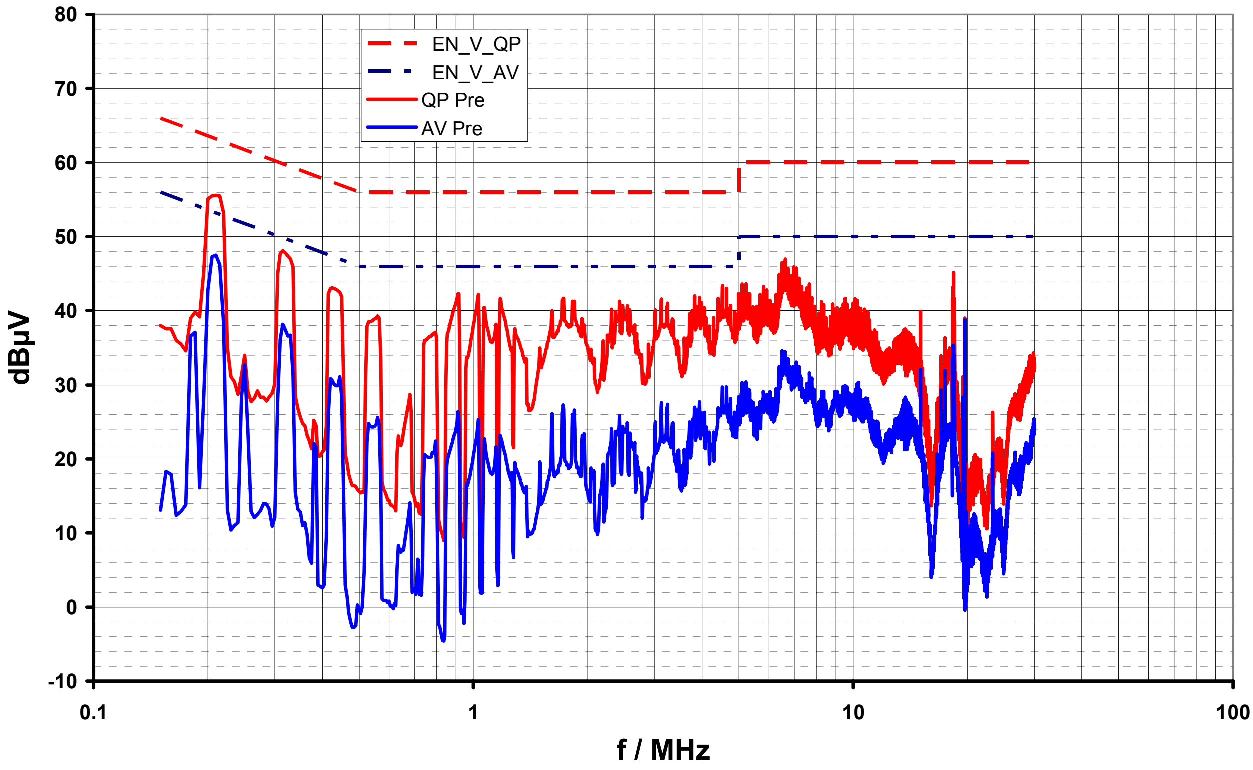


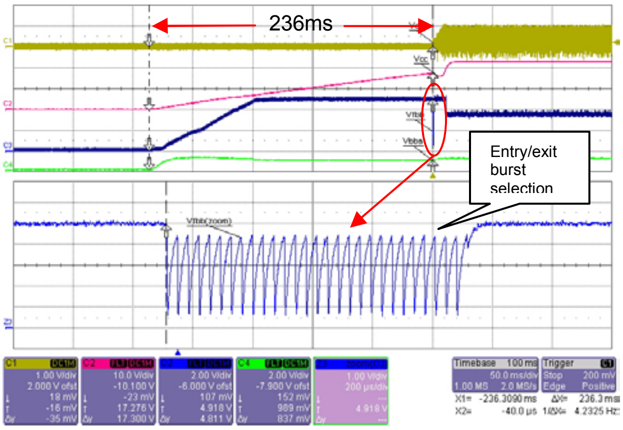
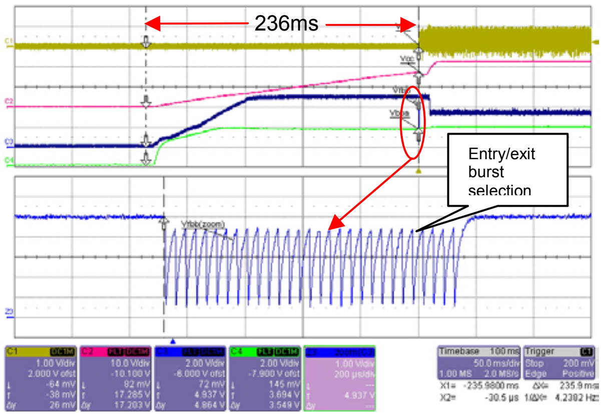
Figure 18 – Max. Load (20W) with 230 Vac (Neutral)

Pass conducted EMI EN55022 (CISPR 22) class B with > 8dB margin.

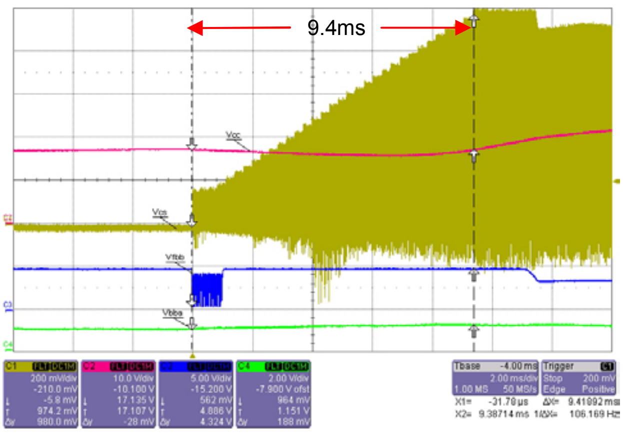
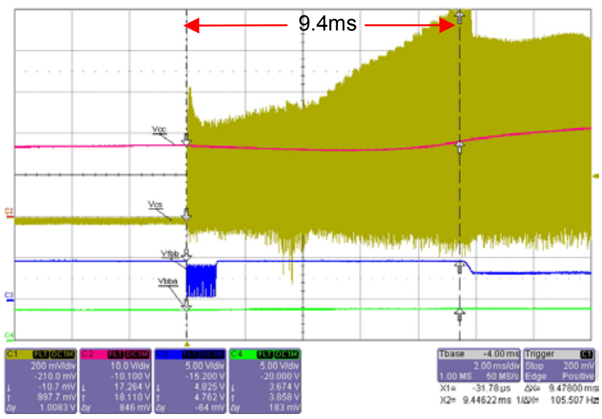
11 Waveforms and scope plots

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

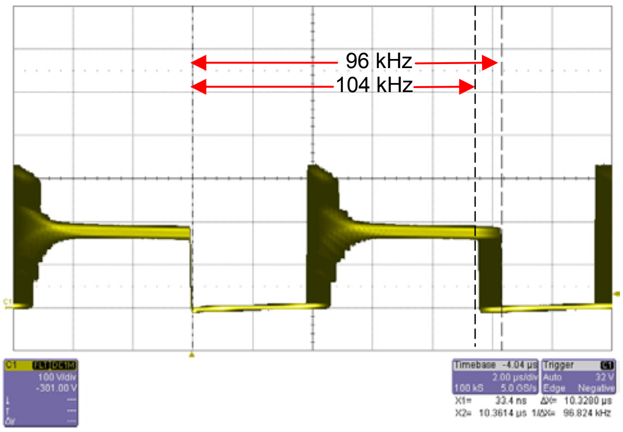
11.1 Start up at low and high AC line input voltage and max. load

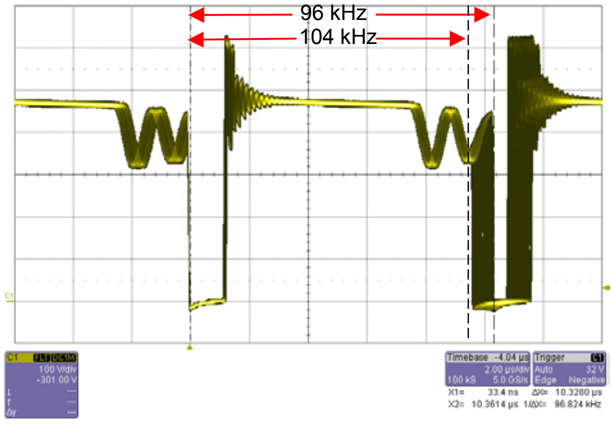
	
Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})	Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})
Startup time = 236ms	Startup time = 236ms
Figure 19 – Startup @ 85Vac & max. load	**Figure 20** – Startup @ 282Vac & max. load

11.2 Soft start at low and high AC line input voltage and max. load

	
Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})	Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})
Soft Star time = 9.4ms(32 steps)	Soft Star time = 9.4ms(32 steps)
Figure 21 – Soft Start @ 85Vac & max. load	**Figure 22**– Soft Start @ 282Vac & max. load

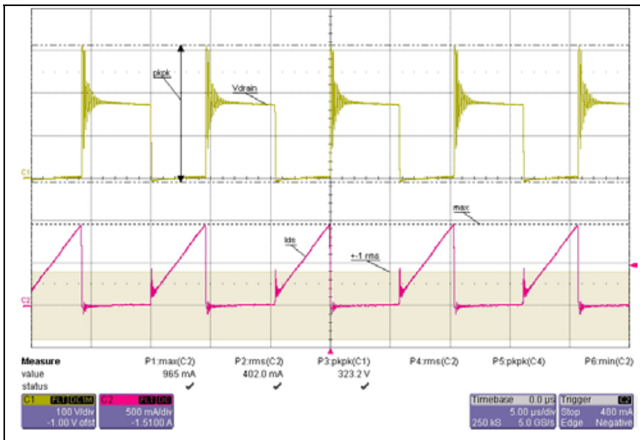
11.3 Frequency jittering

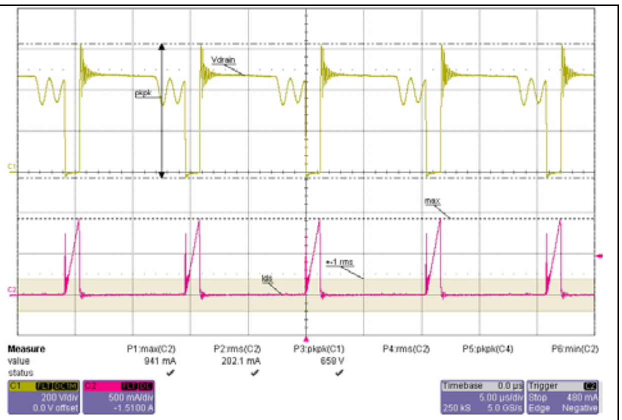




Channel 1; C1 : Drain voltage (V_{Drain})	Channel 1; C1 : Drain voltage (V_{Drain})
Frequency jittering from 96 kHz ~ 104 kHz, Jitter period is set at 4ms internally	Frequency jittering from 96kHz ~ 104 kHz, Jitter period is set at 4ms internally
Figure 23 – Frequency jittering @ 85Vac and max. load	**Figure 24** – Frequency jittering @ 282Vac and max. load

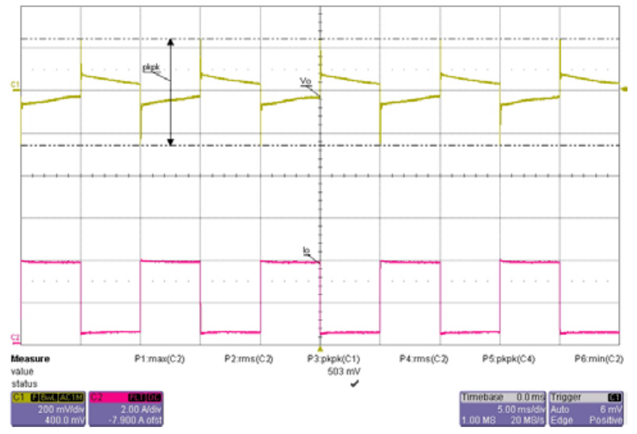
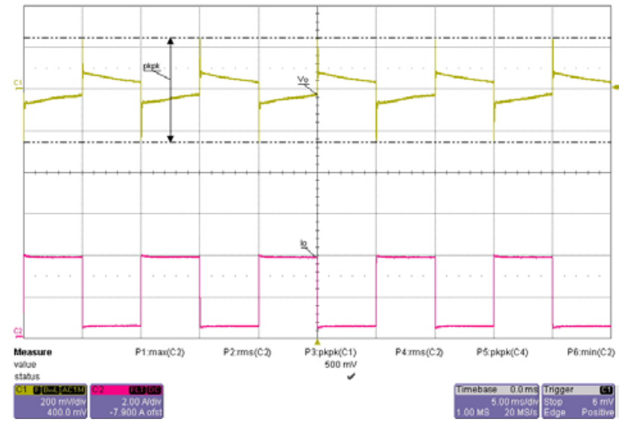
11.4 Drain to source voltage and Current at max. load



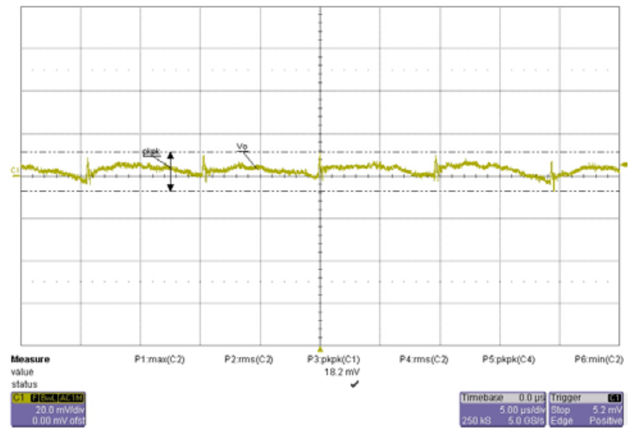
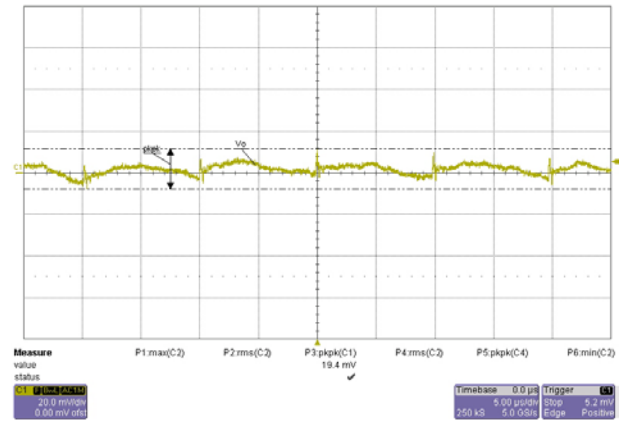


Channel 1; C1 : Drain voltage (V_{Drain}) Channel 2; C2 : Drain current (I_{DS})	Channel 1; C1 : Drain voltage (V_{Drain}) Channel 2; C2 : Drain current (I_{DS})
Duty cycle = 41%, V_{Drain_peak} = 323V	Duty cycle = 11%, V_{Drain_peak} = 658V
Figure 25 – Operation @ 85Vac and max. load	**Figure 26** – Operation @ 282Vac and max. load

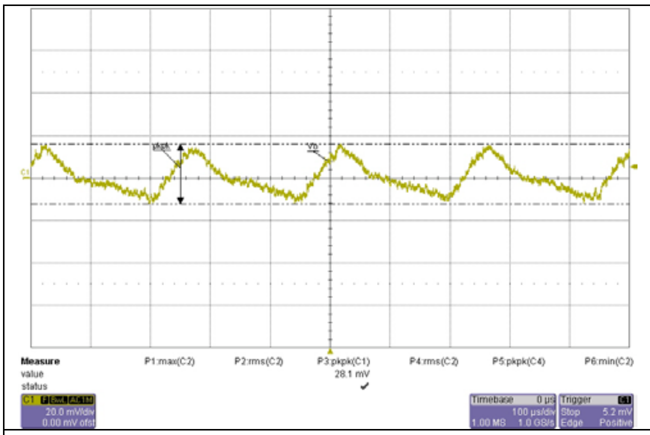
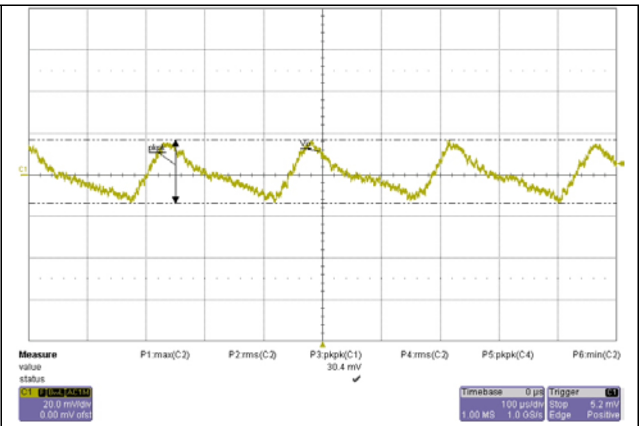
11.5 Load transient response (Dynamic load from 10% to 100%)

	
Channel 1; C1 : Output ripple voltage (Vo) Channel 2; C2 : Output current (Io)	Channel 1; C1 : Output ripple voltage (Vo) Channel 2; C2 : Output current (Io)
$V_{ripple\_pk\_pk}$=500mV (Load change from10% to 100%,100Hz,0.4A/μS slew rate)	$V_{ripple\_pk\_pk}$=500mV (Load change from10% to 100%,100Hz,0.4A/μS slew rate
Figure 27 – Load transient response @ 85Vac	**Figure 28** – Load transient response @ 282Vac

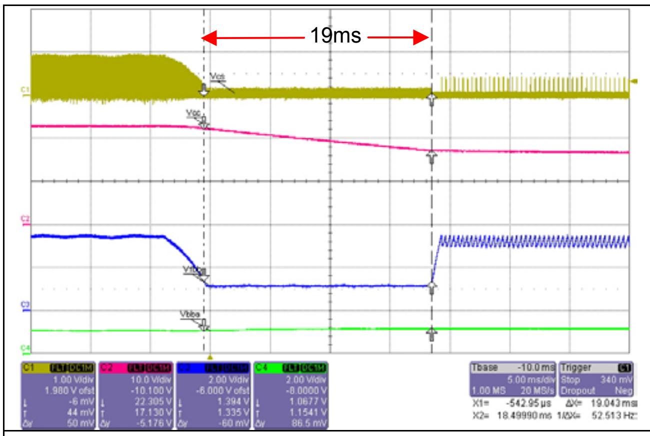
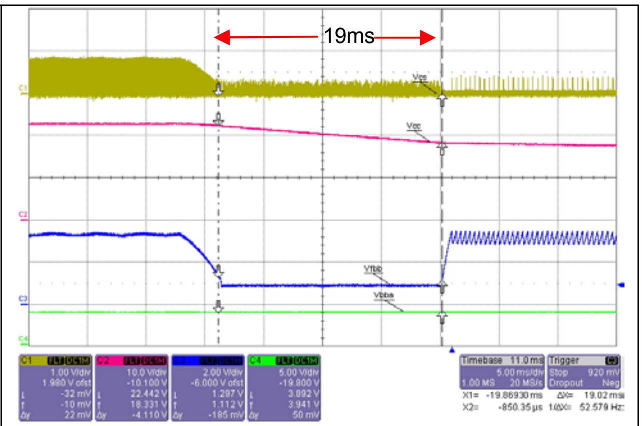
11.6 Output ripple voltage at max. load

	
Channel 1; C1 : Output ripple voltage (Vo)	Channel 1; C1 : Output ripple voltage (Vo)
$V_{ripple\_pk\_pk}$=18mV Probe terminal end with decoupling capacitor of 0.1uF(ceramic) & 1uF(Electrolytic), 20MHz filter	$V_{ripple\_pk\_pk}$ = 19mV Probe terminal end with decoupling capacitor of 0.1uF(ceramic) & 1uF(Electrolytic), 20MHz filter
Figure 29 – AC output ripple @ 85Vac and max. load	**Figure 30** – AC output ripple @ 282Vac and max. load

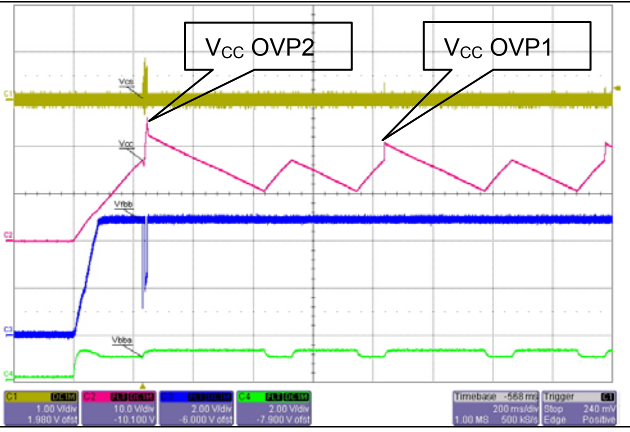
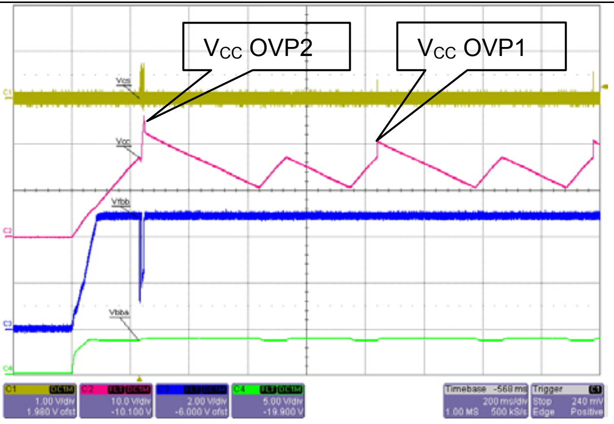
11.7 Output ripple voltage during burst mode at 1 W load

	
Channel 1; C1 : Output ripple voltage (Vo)	Channel 1; C1 : Output ripple voltage (Vo)
$V_{ripple\_pk\_pk}$=28mV Probe terminal end with decoupling capacitor of 0.1uF(ceramic) & 1uF(Electrolytic), 20MHz filter	$V_{ripple\_pk\_pk}$ = 30mV Probe terminal end with decoupling capacitor of 0.1uF(ceramic) & 1uF(Electrolytic), 20MHz filter
Figure 31 – AC output ripple @ 85Vac and 1W load	**Figure 32** – AC output ripple @ 282Vac and 1W load

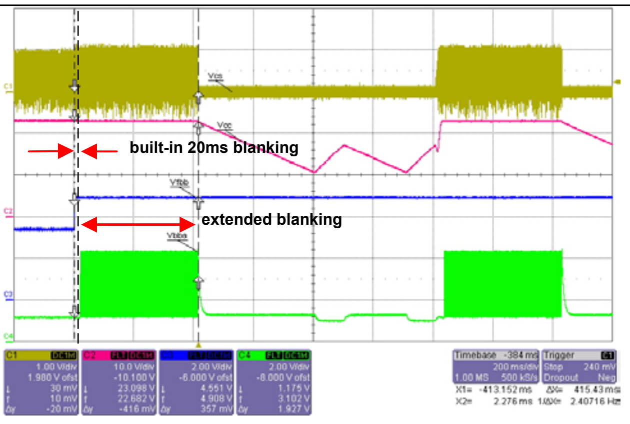
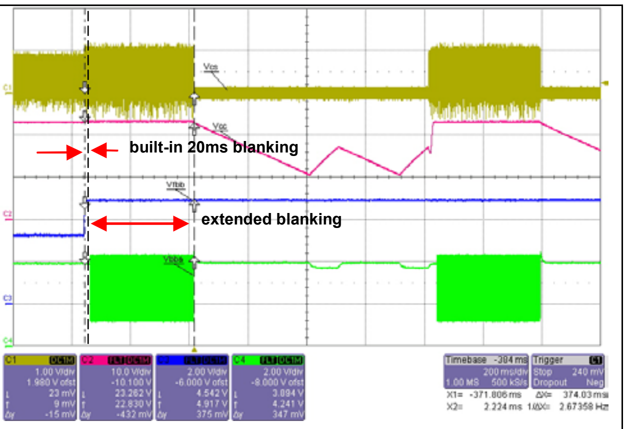
11.8 Entering active burst mode

	
Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})	Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})
Blanking time to enter burst mode : 19ms (load step down from 4A to 0.2A)	Blanking time to enter burst mode : 19ms (load step down from 4A to 0.2A)
Figure 33 – Active burst mode @ 85Vac	**Figure 34** – Active burst mode @ 282Vac

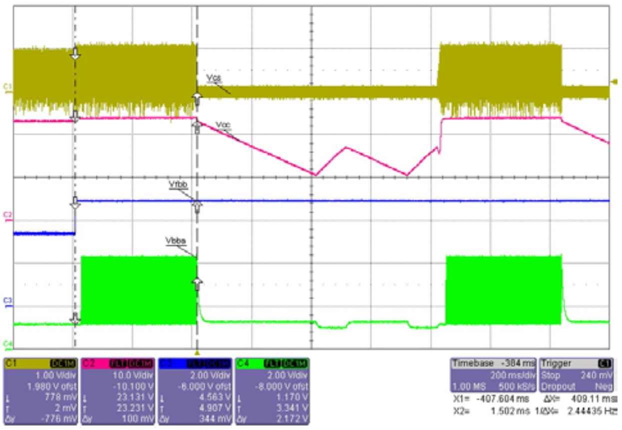
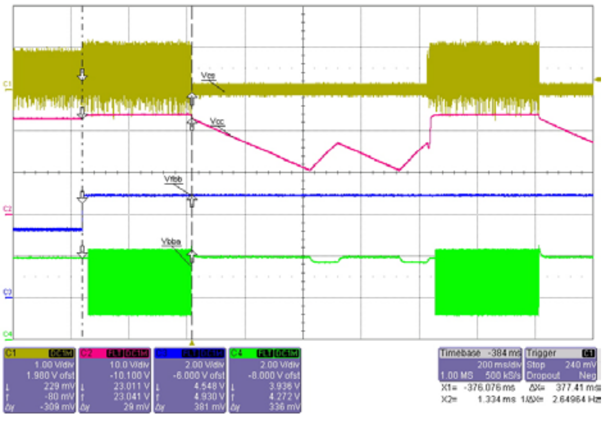
11.9 Vcc over voltage protection (Odd skip auto restart mode)

	
Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})	Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})
VCC OVP2 first & follows VCC OVP1 (R24 disconnected before system start up with no load)	VCC OVP2 first & follows VCC OVP1 (R24 disconnected before system start up with no load)
Figure 35 – Vcc overvoltage protection @ 85Vac	**Figure 36** – Vcc overvoltage protection @ 282Vac

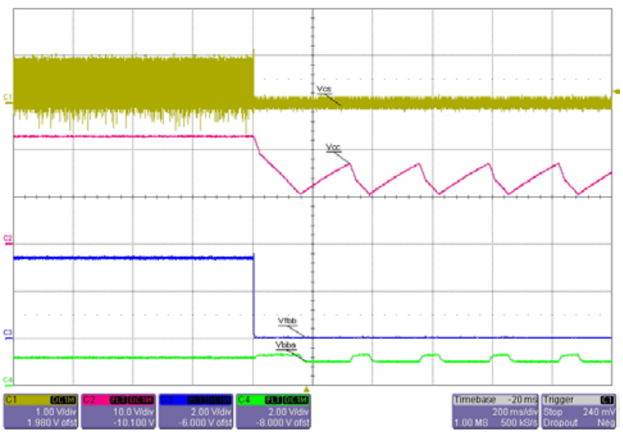
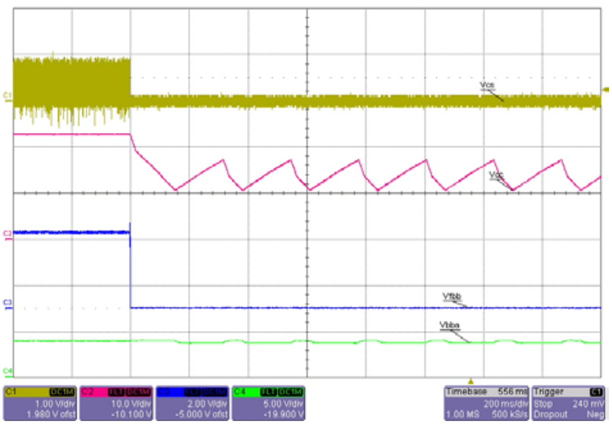
11.10 Over load protection (Odd skip auto restart mode)

	
Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})	Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})
Over load protection with (built-in+extended) blanking time = 415ms (output load change from 4A to 6A)	Over load protection with (built-in+extended) blanking time = 364ms (output load change from 4A to 6A)
Figure 37 – Over load protection with extended blanking time @ 85Vac)	**Figure 38** – Over load protection with extended blanking time @ 282Vac)

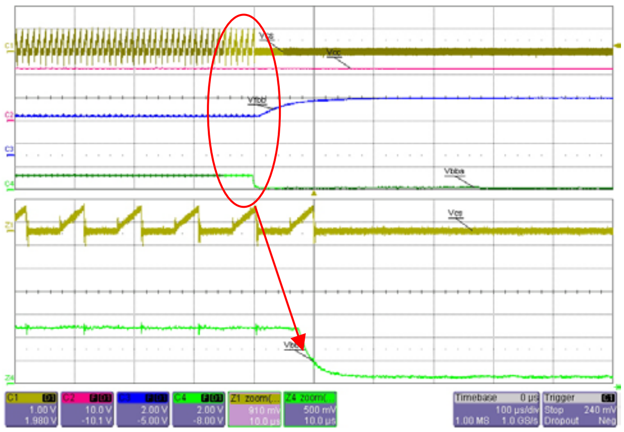
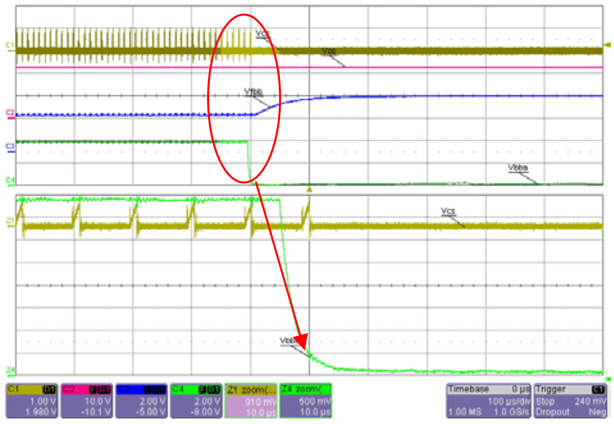
11.11 Open loop protection (Odd skip auto restart mode)

	
Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})	Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})
Open loop protection (R24 disconnected during system operation at max. load) – over load protection	Open loop protection (R24 disconnected during system operation at max. load) – over load protection
Figure 39 – Open loop protection @ 85Vac	**Figure 40** – Open loop protection @ 282Vac

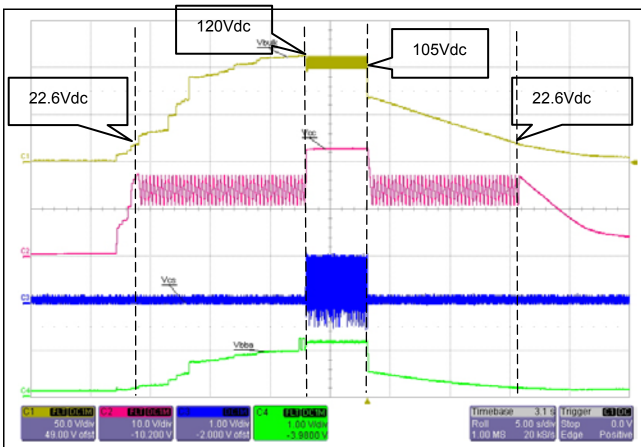
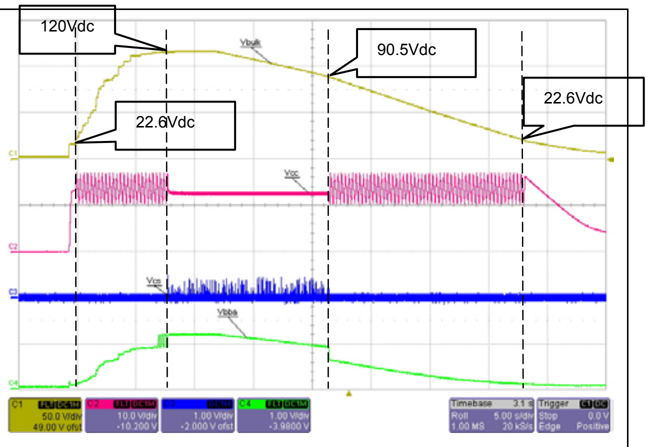
11.12 V_{CC} under voltage/Short optocoupler protection (Non switch auto restart mode)

	
Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA})	Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA}
V_{CC} under voltage/short optocoupler protection (short the transistor of optocoupler during system operating @ full load)	V_{CC} under voltage/short optocoupler protection (short the transistor of optocoupler during system operating @ full load)
Figure 41 – V_{cc} under voltage/short optocoupler protection @ 85Vac	**Figure 42** – V_{cc} under voltage/short optocoupler protection @ 282Vac

11.13 External protection enable (Non switch auto restart mode)

	
Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA}	Channel 1; C1 : Current sense voltage (V_{CS}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Feedback voltage (V_{FBB}) Channel 4; C4 : BBA voltage (V_{BBA}
External protection enable (short BBA pin to Gnd by 10Ω resistor)	External protection enable (short BBA pin to Gnd by 10Ω resistor)
Figure 43 – External protection enable @ 85Vac	**Figure 44**– External protection enable @ 282Vac

11.14 Brownout mode

	
Channel 1; C1 : Bulk voltage(V_{bulk}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Current sense voltage (V_{CS}) Channel 4; C4 : BBA voltage (V_{BBA})	Channel 1; C1 : Bulk voltage(V_{bulk}) Channel 2; C2 : Supply voltage (V_{CC}) Channel 3; C3 : Current sense voltage (V_{CS}) Channel 4; C4 : BBA voltage (V_{BBA})
IC on & 1st detect brownout: V_{bulk}= 22.6Vdc (16Vac) Brownout reset: V_{bulk}= 120Vdc (85Vac) Brownout triggered: V_{bulk}= 105Vdc (74Vac) IC off: V_{bulk}= 22.6Vdc (16Vac)	IC on & 1st detect brownout:V_{bulk}= 22.6Vdc (16Vac) Brownout reset: V_{bulk}= 120Vdc (85Vac) Brownout triggered: V_{bulk}= 90.5Vdc (64Vac) IC off: V_{bulk}= 22.6Vdc (16Vac)
Figure 45 – Brownout mode with max. load	**Figure 46** – Brownout mode with no load

12 Appendix

12.1 Slope compensation for CCM operation

This demo board is designed in Discontinuous Conduction Mode (DCM) operation. If the application is designed in Continuous Conduction 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.

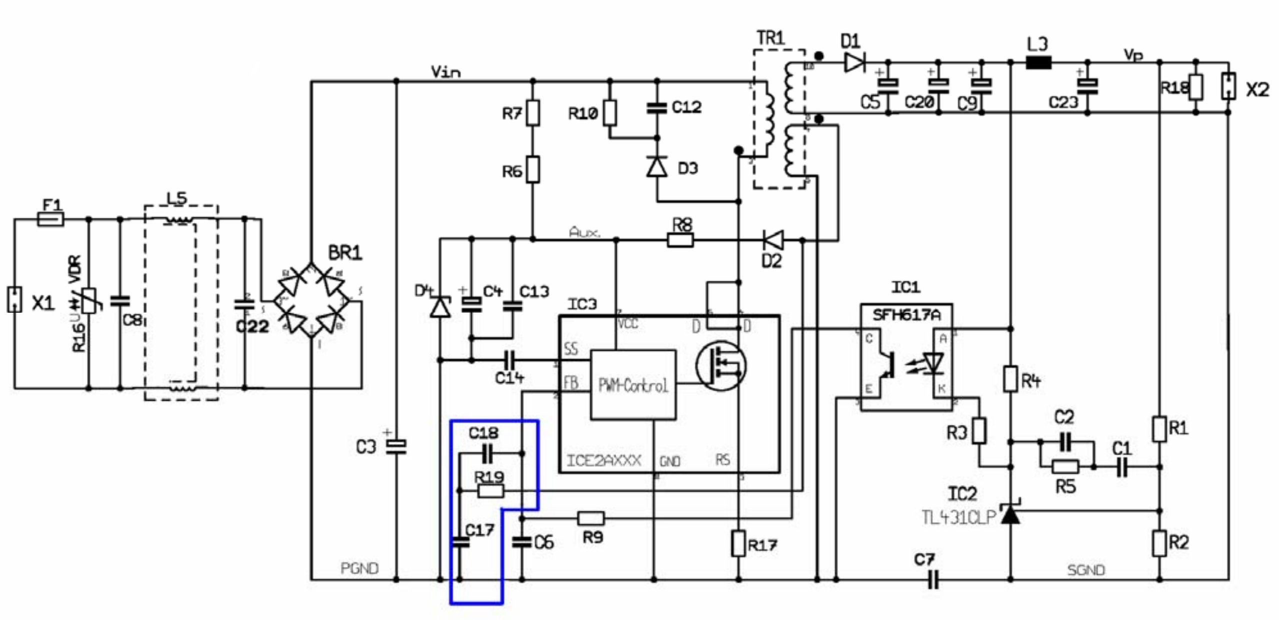


Figure 47 – Circuit Diagram Switch Mode Power Supply with Slope Compensation

More information regarding how to calculate the additional components, see application note AN_SMPS_ICE2xXXX – available on the internet: www.infineon.com (directory : Home > Power Semiconductors > Integrated Power ICs > **CoolSET® F2**)

13 References

[1] Infineon Technologies, Datasheet "CoolSET®-F3R80 ICE3AR2280JZ Off-Line SMPS Current Mode Controller with integrated 800V CoolMOS® and Startup cell(brownout & Frequency Jitter) in DIP-7"

[2] Kyaw Zin Min, Kok Siu Kam Eric, Infineon Technologies, Design Guide "ICE3ARxx80JZ CoolSET® F3R80 (DIP-7) brownout & frequency jitter version Design Guide"

[3] Harald Zoellinger, Rainer Kling, Infineon Technologies, Application Note "AN-SMPS-ICE2xXXX-1, CoolSET® ICE2xXXXX for Off-Line Switching Mode Power supply (SMPS)"