AN4583
Application note

Cable set-top box SMPS adaptor using VIPER27

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Introduction

Abstract: a set-top box (STB) is a cable box, placed in the consumer's house, that has the ability to receive commands from the cable company. Such commands would enable the box to decode a particular channel, such that only the customer, who subscribes to a channel, will receive that channel. This application note describes the design for the SMPS adaptor using the ST's innovative off-line integrated flyback controller VIPER27. The typical power requirement is within 8 to 10W in wide range for the cable set-top application. The VIPER27LN device has an integrated high-performance low voltage PWM controller chip and an 800 V avalanche rugged power MOSFET in the same package. The device is suitable for the isolated flyback converter mainly off-line power supplies.
The burst mode operation and device very low consumption help to meet the standby energy saving regulation. Advance frequency jittering reduces the EMI filter cost. Brown-out function protects the switch mode power supply when the rectified input voltage is below the nominal minimum level specified for the system. The high voltage start-up circuit is embedded in the device.

Figure 1. SMPS adaptor

Some of the common applications which can be covered with the device are listed below:

- SMPS for set-top boxes, DVD players and recorders, white goods
- Auxiliary power supply for consumer and home equipments
- ATX auxiliary power supply
- Low / medium power AC-DC adapters.

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1 Brief description of VIPER27

The device is an off-line converter with an 800 V rugged power section, a PWM control, two levels of overcurrent protection, overvoltage and overload protections, hysteretic thermal protection, the soft-start and safe auto restart after any fault condition removal. The burst mode operation and device's very low consumption help to meet the standby energy saving regulations.

Advance frequency jittering reduces the EMI filter cost. Brown-out function protects the switch mode power supply when the rectified input voltage level is below the normal minimum level specified for the system. The high voltage start-up circuit is embedded in the device.

Features

- 800 V avalanche rugged power section
- PWM operation with frequency jittering for low EMI
- Operating frequency:
  - 60 kHz for L type
  - 115 kHz for H type
- Standby power < 50 mW at 265 V_{AC}
- Limiting current with adjustable set point
- Adjustable and accurate overvoltage protection
- On-board soft-start
- Safe auto restart after a fault condition
- Hysteretic thermal shutdown

Figure 2. Typical topology

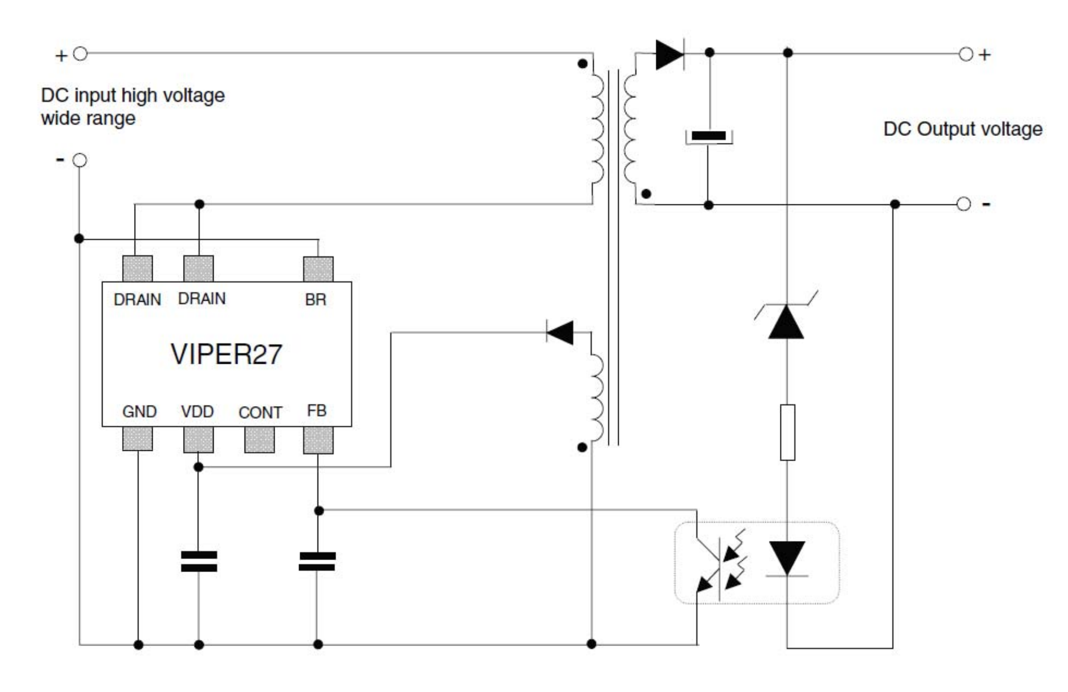
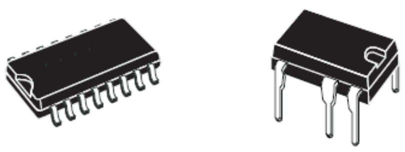


Figure 3. Package of VIPER27



SO16 narrow **DIP-7**

A typical output power table is shown below.

Table 1. Typical output power

Part number	230 V_{AC}		85-265 V_{AC}	
	Adapter[(1)]	Open frame[(2)]	Adapter[(1)]	Open frame[(2)]
VIPER27	13 W	16 W	10 W	12 W

1. Typical continuous power in non ventilated enclosed adapter measured at 50 °C ambient.
2. Maximum practical continuous power in an open frame design at 50 °C ambient, with adequate heat sinking.

Table 2. Basic specifications of adaptor

Parameters	Limits
Rated voltage range	90 - 265 V_{AC}
Nominal operating voltage range	100 - 320 V_{AC}
Input supply frequency (f_L)	47 - 63 Hz
Input / output isolation	Yes, > 2.7 KV
Application	Set-top box SMPS/adaptor
Output voltage tolerance	12 V ± 0.2 V
Nominal output current	1 Amp
Total output power	12 W
Active mode efficiency	> 80%
Active mode at 10% load efficiency	> 70%
Output voltage ripple	< 50m Vp-p
Maximum ambient temperature	50 °C
Protections	Overload, short-circuit, thermal shutdown

2 Schematic and description

The schematic of the power supply is shown in *Figure 4*. The input section is comprised of the fuse F1, NTC, capacitor C4 and the common mode inductor L1. L1, C4 are used to take care of conducted emissions. The MOV1 is placed after the inductor, in this way surge energy is also limited up to some extent by the L1 and then the MOV does its function. The bulk capacitor C3 after bridge rectification provides also the additional path to absorb energy and helpful in the surge immunity in addition to the filtration purpose[a].

Then the transformer T1 and the VIPer U1 are configured in typical isolated flyback topology. The RCD clamp is made up with the R2, C1 and D2 which clamps the off-state leakage spikes across the MOSFET device.

The integrated MOSFET of the device is 800 V avalanche rugged, which provides extra room to take care of wide mains operating condition. Normally the power supply is intended to use for the wide mains operation which has maximum working voltage 265 V_{AC}, but with 800 V the device one can easily achieve the high mains line operation, provided there is enough voltage withstanding capability of the bulk capacitor voltage after rectification. Just an example: the power supply can even cater line to line voltage 440 V_{AC} using the C3 as two bulk 400 WV capacitors in series. With suitable designing of the transformer and the turn ratio considering the 90 - 440 V_{AC} operation, the off-state stress can be maintained within 800 V.

There are other features of the device - by using the functionality of the BR and CONT pins are described as below:

BR: input voltage information is provided to the BR pin by using the resistor divider network from rectified bus voltage and can detect the brown-out threshold to turn off the device. The resistor divider network R4, R5 and R7 is programmed to achieve brown-out protection.

If the function is not required, we can disable by grounding the BR pin using the R7 as the 0E resistor. This will also reduce the power consumption and no load losses in addition to reduce the component counts otherwise one can easily program the values of the R4, R5 and R7 for desired mains under the voltage shutdown. The C10 helps to reduce the noise pick-up at the BR pin (refer to the VIPER27 datasheet for more details).

CONT: with the CONT pin, one can impose a limit on the peak drain current (Idlim can be programmed using the R9). Not using this resistor will limit the peak current to its internal maximum Idlim value. An another feature is to have protection in case output overvoltage (output OVP protection), which can be sensed using the auxiliary winding which is used for VCC biasing (refer to the VIPER27 datasheet for more details).

With these features of the VIPer™ Plus family from the STMicroelectronics designer can make the system more reliable and robust.

The device is biased using the auxiliary winding and using the D3, R3 and C9. The C2 helps for noise reduction and enhances also the ESD immunity.

a. The inrush is also reduced by the common mode inductor L1. So one can also remove the NTC as it consumes some power and reduces the efficiency of converter.

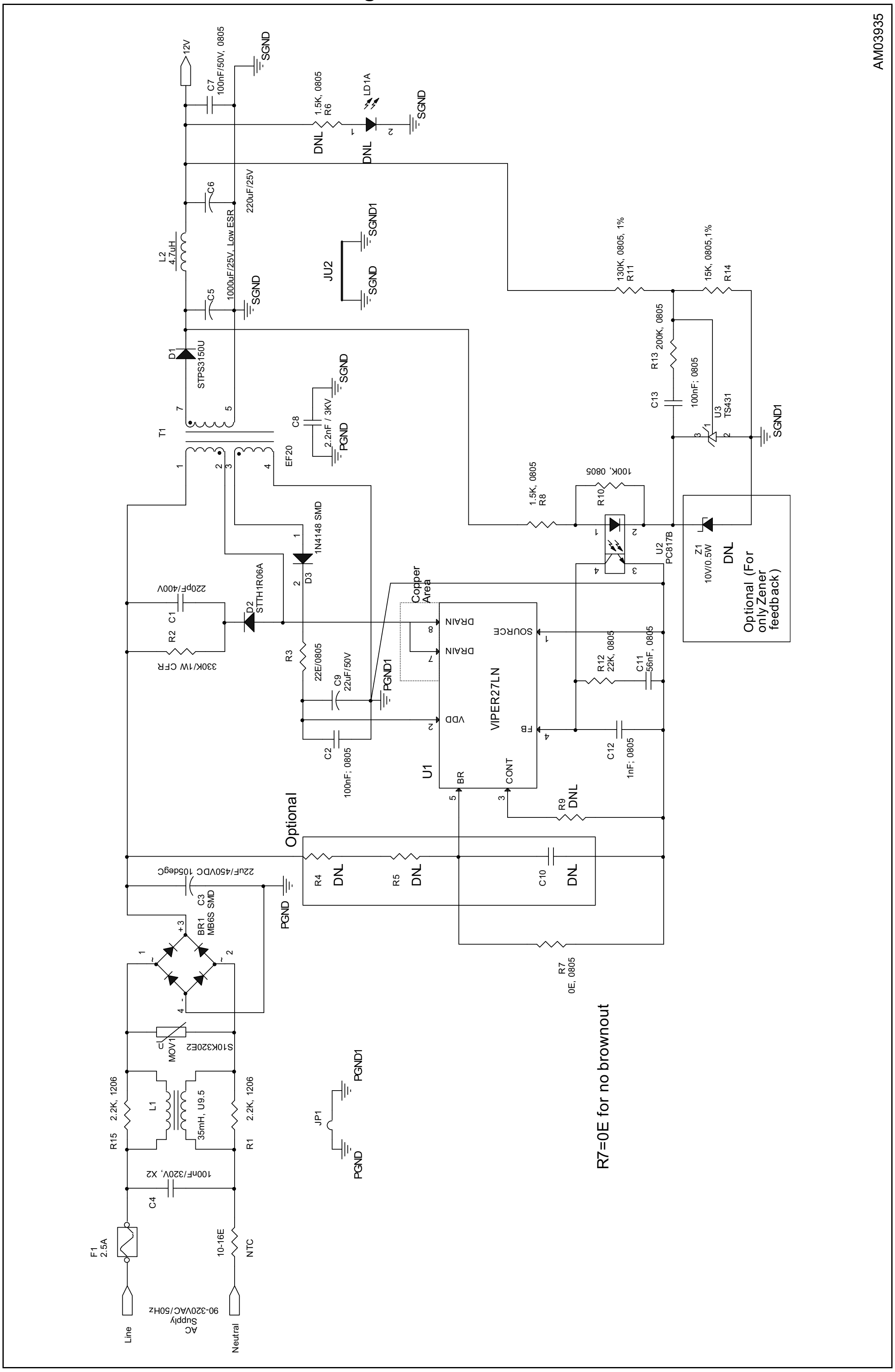
The C11, C12 and R12 comprise of the type - II compensation network for feedback loop stability (for more details, refer to the VIPER27 datasheet). The device is configured with the secondary side regulation using the U2, U3: the optocoupler and the TS431 standard secondary side feedback network. The R11 and R14 are programmed for 12 V output by fixing 1.25 V reference to the TS431.

There is also the option to make the loop regulated by using the simple Zener diode, Z1 and eliminating all other parts: U3, R11, R13, R14 and C13 to bring the system solution cost down. In the board, the option to place the Zener diode is also provided in case one doesn't want to use TS431 based feedback design. This simple scheme is also fine as long as there is no stringent requirement of transient specifications. The power supply is tested in both condition with or without the TS431, however the performance is shown with standard TS431 configuration.

The used transformer is the EE19 profile, which is suitable to provide the power requirements for cable set box requirements. Of course the board is tested in a fully enclosed frame with an output of 12 W power. This is explained further and shown the thermal performance. In the board, there is also kept the option to mount the EE20 profile core and the board can easily accommodate the EE20 transformer as well if the EE19 is not the customer's choice.

Output rectification is achieved using the ST Schottky rectifier STPS3150U in the SMD package along with the low ESR capacitor C5 for filtering function. The L2 and C6 comprise the post LC filter to reduce the switching noise to a very low level as desired in set-top box requirements.

Figure 4. Schematic



3 Bill of material

Table 3. Bill of material

S. no.	Reference	Part value and description	Manufacturer	Manufacturer part no.	Package	Qty.
1	BR1	Bridge rectifier, MB6S	Vishay Semiconductor	MB6S-E3/45	SMD	1
2	C1	Capacitor disc type, 220 pF/400 V			TH	1
3	C2, C13, C7	Capacitor, 100 nF/50 V			SMD, 0805	3
4	C3	Capacitor electrolytic, 22 µF/450 V	Panasonic	EEUEE2W220S	TH	1
5	C4	Capacitor 100 nF/ 320 V, X2 type			TH(1)	1
6	C5	Capacitor electrolytic, 1000 µF/25 V, low ESR, 105 °C	Rubycon	25ZL1000MEFC12.5X20	TH	1
7	C6	Capacitor electrolytic, 220 µF/25 V	Rubycon	25YXH220MEFC8X11.5	TH	1
8	C8	Capacitor, 2.2 nF/ 250 V X1/Y1 type	Murata	DE2E3KY222MA2BM01	TH	1
9	C9	Capacitor electrolytic, 22 µF/35V	Panasonic	EEUFC1V220	TH	1
10	C11	Capacitor, 56 nF/25 V			SMD, 0805	1
11	C12	Capacitor, 1 nF/25 V			SMD, 0805	1
12	D1	Schottky diode, STPS3150U	STMicroelectronics		SMA	1
13	D2	Ultrafast diode, STTH1R06A	STMicroelectronics		SMD	1
14	D3	Schottky diode, 1N4148	STMicroelectronics		SMD	1
15	LD1A	LED red, 3 mm			TH	1
16	L1	Common mode line inductor, 35 mH			TH	1
17	L2	Filter inductor, 4.7 µH			TH, drum type	1
18	MOV1	MOV, S10K320E2			10 mm	1
19	R1, R15	Resistor, 2.2 KΩ			SMD 1206	2
20	R2	Resistor CFR 330 KΩ/ 1 W CFR			TH	1
21	R3	Resistor, 22E			SMD, 0805	1
22	R6, R8	Resistor, 1.5 KΩ			SMD, 0805	2

Table 3. Bill of material (continued)

S. no.	Reference	Part value and description	Manufacturer	Manufacturer part no.	Package	Qty.
23	R7	Resistor, 0E			SMD, 0805	1
24	R10	Resistor, 100 KΩ			SMD, 0805	1
25	R11	Resistor, 130 KΩ, 1%			SMD, 0805	1
26	R12	Resistor, 22 KΩ			SMD, 0805	1
27	R13	Resistor, 200 KΩ			SMD, 0805	1
28	R14	Resistor, 15 KΩ, 1%			SMD, 0805	1
29	T1	Transformer, EE19			TH, 7 pins	1
30	U1	VIPer27LN	STMicroelectronics		DIP-7	1
31	U2	Optocoupler, PC817A/B			DIP4	1
32	U3	TS431	STMicroelectronics		TO-92	1
33	NTC	NTC 10-16E at 25 °C(2)				1
34	F1	Fuse 2.5 A/250 V_{AC}	Cooper Bussmann	SS-5H-2-5A-BK	TH	1

1. “TH” stands for a through hole package.
2. Optional, not mounted on board.

4 Transformer specification

4.1 General description and characteristics

- Transformer type: closed
- Coil former: vertical type, 4 + 3 pins, two slots
- Max. temperature rise: 45 °C
- Max. operating ambient temperature: 60 °C
- Mains insulation: in accordance with EN60950

4.2 Electrical characteristics

- Converter topology: fixed frequency flyback
- Core type: EE19-N67 or equivalent
- Min. operating frequency: 60 kHz
- Typical operating frequency: 60 kHz
- Primary inductance: 1400 µH ± 10% at 10 kHz - 0.25 V (measured between pins 2 - 1)
- Auxiliary inductance: 43 µH ± 15% at 10 kHz - 0.25 V (measured between pins 3 - 4)
- Secondary inductance: 28 µH ± 20% at 10 kHz - 0.25 V (measured between pins 7 - 5)
- Leakage inductance : 17 µH ± 10% at 50 kHz - 0.25 V (measured between pins 2 - 1 with secondary winding 7 - 5 shorted)
- Primary (2 - 1) - secondary (8 - 5) turn ratio: 6.3:1
- Primary (2 - 1) - auxiliary turn ratio: 8:1
- Dielectric strength between primary (2 - 1) - secondary (7 - 5): 2.5 KV, 5 mA, 1 min.

Figure 5. Picture of transformer

Table 4. Winding details

Winding name	Pins (start - stop)	Wire	Method
Np	2 - 1	1UEW 0.30 mm x 1	Solenoid (split halves)
Naux	3 - 4	1UEW 0.12 m x 1	Spread
Ns	7 - 5	1UEW 0.60 mm x 1	Solenoid

Transformer part number: RDTS - 1907.

Manufacturer: GSP Electronics Pvt. Ltd., Noida, India.

E-mail: sales@gspelectronics.com; info@gspelectronics.com.

5 Performance test results

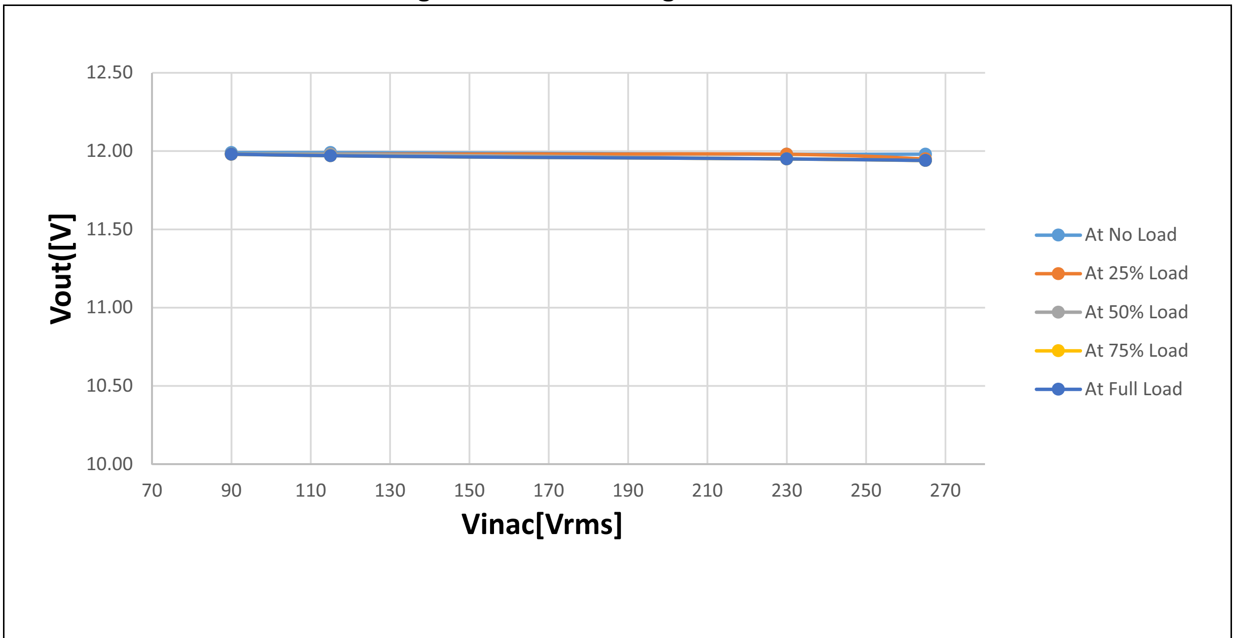
5.1 Output regulation test

The output voltage of the board is measured in different line and load conditions (see *Table 5*). The output voltage is practically not affected by the line condition. The Vcc voltage is also measured to verify that it is inside the operating range of the device.

Table 5. Output voltage and VDD line-load regulation

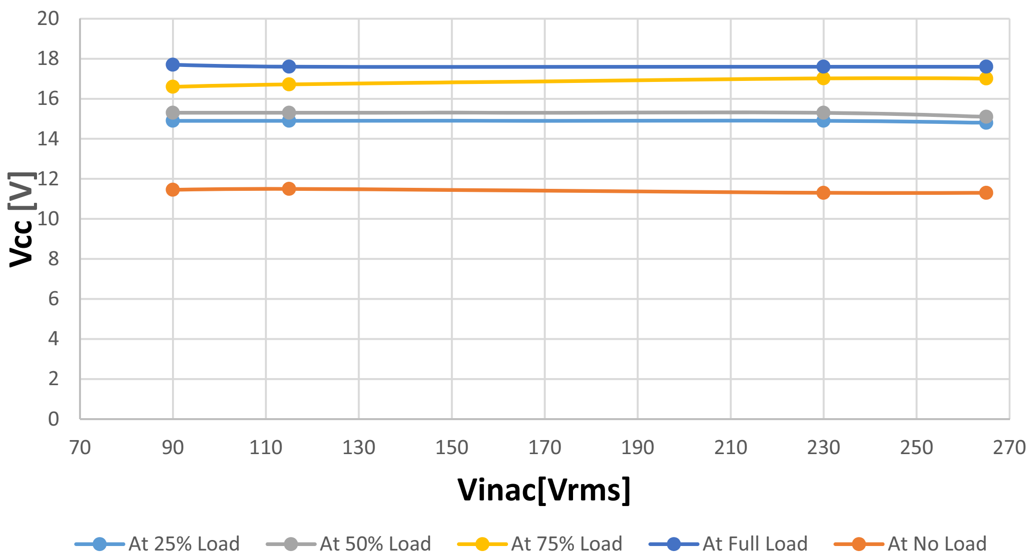
Vinac (Vrms)	No load		25% load		50% load		75% load		100% load	
	Vout (V)	Vcc (V)	Vout (V)	Vcc (V)	Vout (V)	Vcc (V)	Vout (V)	Vcc (V)	Vout (V)	Vcc (V)
90	11.99	11.45	11.98	14.90	11.98	15.30	11.98	16.60	11.98	17.70
115	11.99	11.50	11.98	14.90	11.98	15.30	11.97	16.72	11.97	17.60
230	11.98	11.30	11.98	14.90	11.95	15.30	11.95	17.02	11.95	17.60
265	11.98	11.30	11.95	14.80	11.94	15.10	11.94	17.01	11.94	17.60

Figure 6. Line load regulation curve



Looking to *Figure 6*, the output voltage is tightly regulated for wide mains variation at different load conditions.

Figure 7. Vcc variations for line and load changes



5.2 Efficiency test results

The efficiency of the converter is measured in different load and line voltage conditions. The measurements are taken at 25%, 50%, 75% and the full load for different input voltages and the efficiency at the 10% load and the measurement falls under limits of the “EC CoC version 5 Tier2” requirements as shown in *Table 8*, *Table 9* and *Table 10*.

Table 6. Energy efficiency criteria for standard models - average efficiency - Tier2

Nameplate output power (Pno)	Minimum average efficiency (expressed as a decimal)
0 to ≤ 1 watt	≥ 0.5 * Pno + 0.169
> 1 to ≤ 49 watts	≥ [0.071 * ln (Pno)] - 0.00115 * Pno + 0.67
> 49 watts	≥ 0.890

Table 7. Energy efficiency criteria for standard models - efficiency at 10% load - Tier2

Nameplate output power (Pno)	Minimum average efficiency (expressed as a decimal)
0 to ≤ 1 watt	≥ 0.5 * Pno + 0.06
> 1 to ≤ 49 watts	≥ [0.071 * ln (Pno)] - 0.00115 * Pno + 0.57
> 49 watts	≥ 0.790

Table 8. Average efficiency at 115 V_{AC}

% load	I_{OUT} (A)	V_{OUT} (V)	P_{IN} (W)	P_{OUT} (W)	Efficiency (%)
25%	0.25	11.98	3.612	2.995	**82.92**
50%	0.50	11.98	7.140	5.990	**83.89**
75%	0.75	11.97	10.750	8.978	**83.51**
100%	1.00	11.97	14.430	11.970	**82.95**
Average efficiency					**83.32**
EC Coc version 5 Tier2 - minimum average efficiency					**83.26**

Table 9. Average efficiency at 230 V_{AC}

% load	I_{OUT} (A)	V_{OUT} (V)	P_{IN} (W)	P_{OUT} (W)	Efficiency (%)
25%	0.25	11.96	3.696	2.990	**80.90**
50%	0.50	11.95	7.148	5.975	**83.59**
75%	0.75	11.95	10.630	8.963	**84.31**
100%	1.00	11.95	14.130	11.950	**84.57**
Average efficiency					**83.34**
EC Coc version 5 Tier2 - minimum average efficiency					**83.26**

Table 10. Average efficiency at 10% of the max. output load

V_{IN} [V_{AC}]	I_{OUT} (A)	V_{OUT} (V)	P_{IN} (W)	P_{OUT} (W)	Efficiency [%]
115	0.10	11.99	1.517	1.199	**79.04**
230	0.10	11.98	1.633	1.198	**73.36**
EC Coc version 5 Tier2 - minimum efficiency at 10% load					**73.26**

Figure 8. Efficiency at 115 V_{AC} and 230 V_{AC}

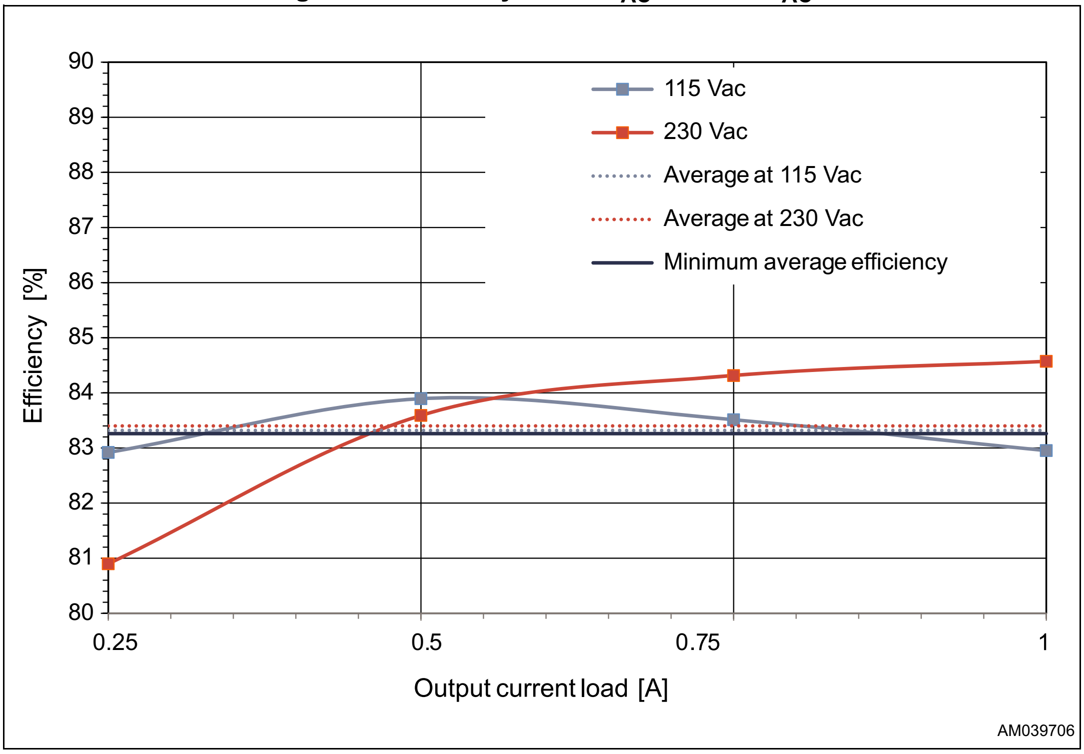


Table 11. Active mode efficiency

		Efficiency [%]				Average efficiency
		0.25 A	**0.50 A**	**0.75 A**	**1 A**	
V_{IN} [V_{AC}]	90	82.83	83.01	82.28	80.73	**82.21**
	115	82.92	83.89	83.51	82.95	**83.32**
	150	83.03	84.13	84.38	84.18	**83.93**
	180	82.46	84.07	84.46	84.57	**83.89**
	230	80.90	83.59	84.31	84.57	**83.34**
	265	79.69	82.97	83.93	84.32	**82.73**

Figure 9. Efficiency at different line and load conditions

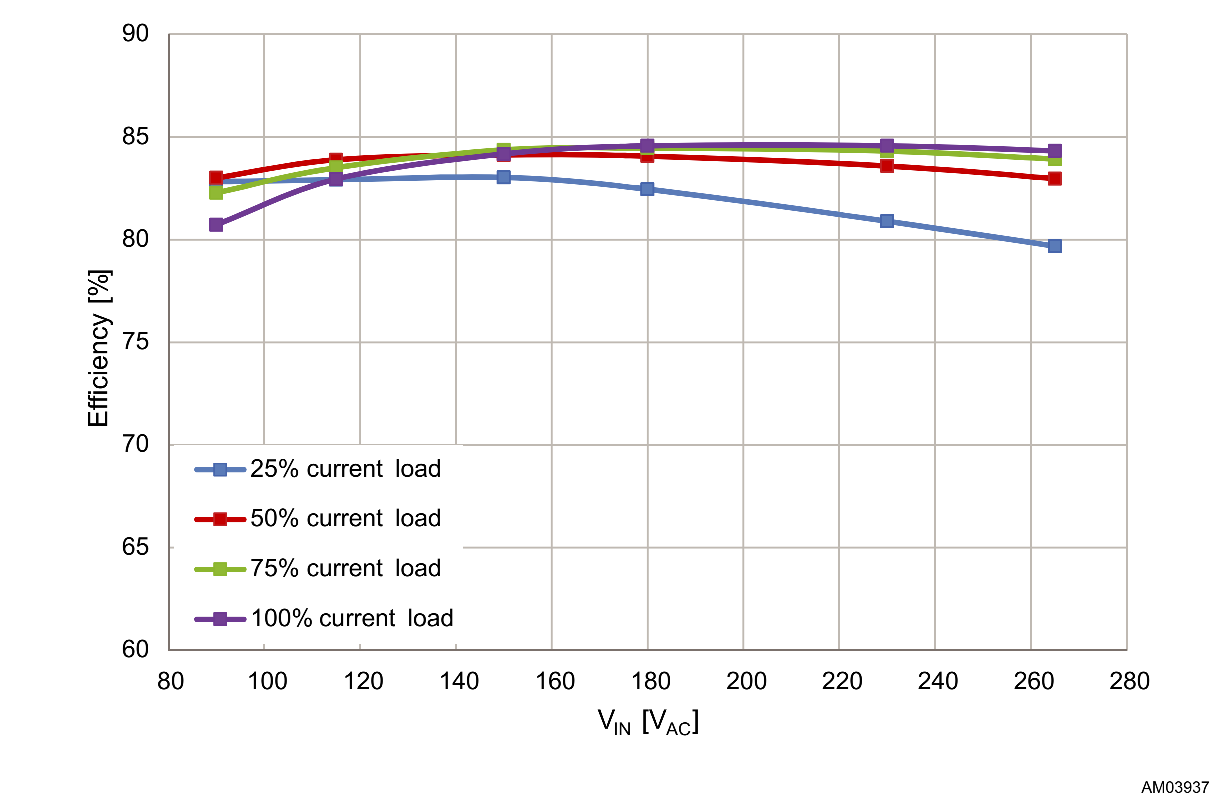
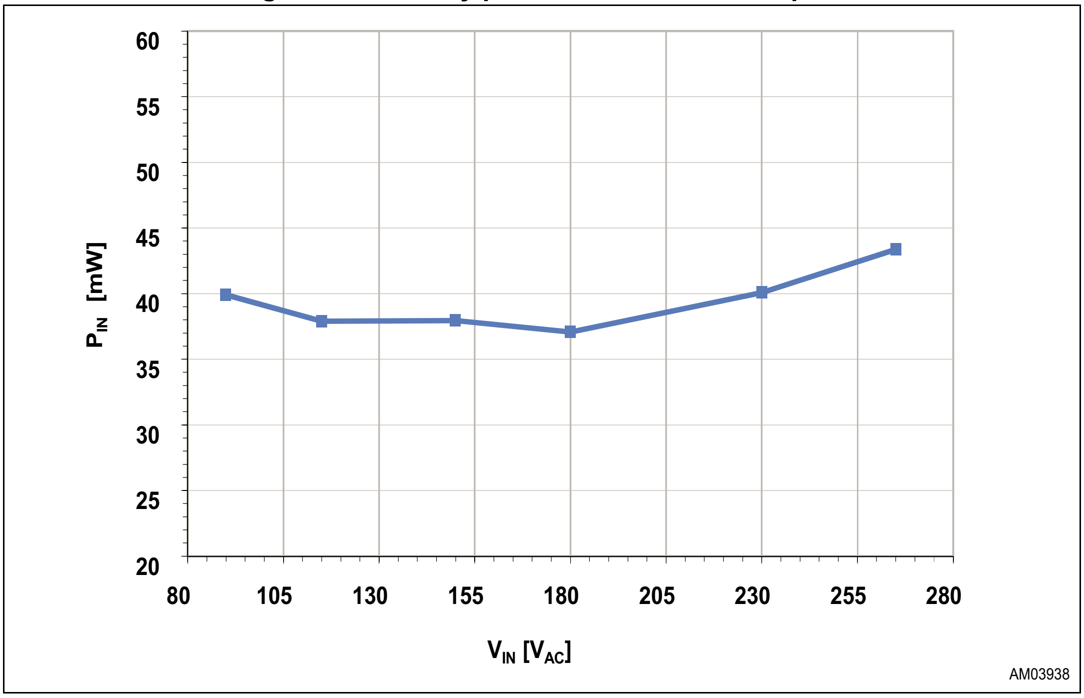


Table 12. Consumptions at no load

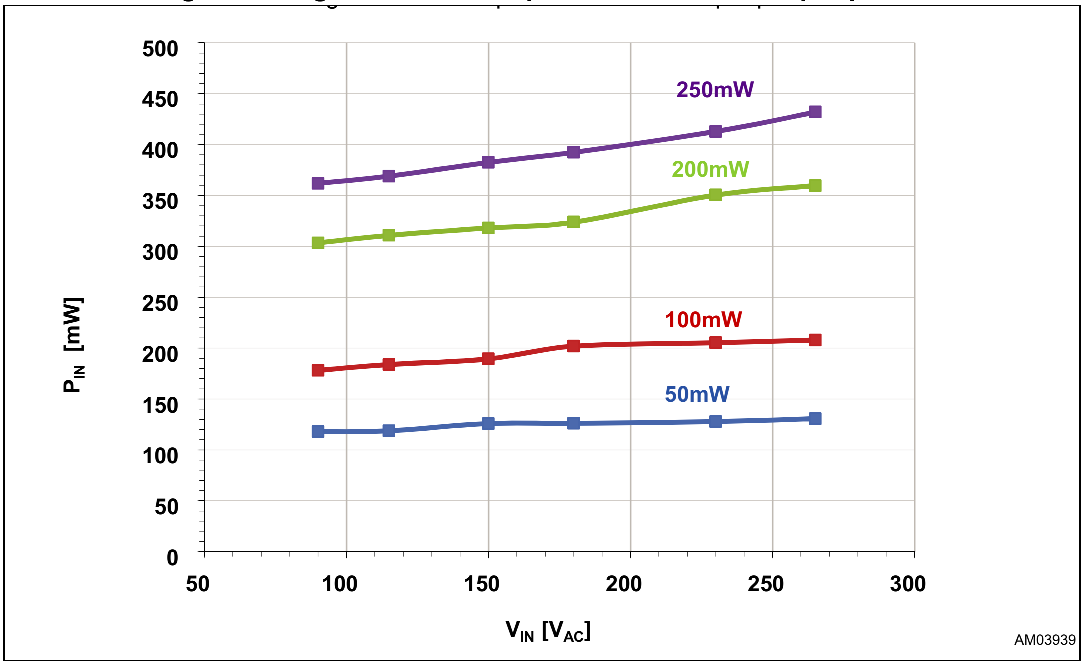
	P_{IN} [mW]	P_{OUT} [mW]
90	39.91	0
115	37.90	
150	37.96	
180	37.07	
230	40.09	
265	43.38	

Figure 10. Standby power at different line inputs



To be complying with the EuP Lot 6, the EPS requires efficiency higher than 50% when the output load is 250 mW.

Figure 11. Light load consumptions at different output power



From efficiency analysis, the results are very close to the limits as per Tier2 although the power supply satisfies the requirement of cable Set top box applications and is targeted mainly for cable set top box application in India.

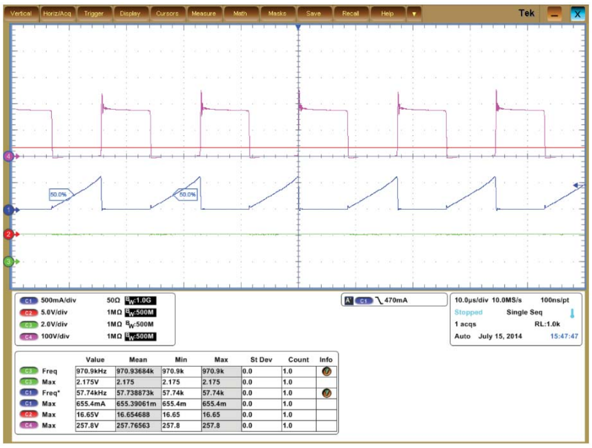
6 Functional check

The converter is operated at different mains conditions (refer from *Figure 12* to *Figure 17*), starting from 90 to 320 V_{AC} and the drain switching waveform and drain current waveforms are captured at each line voltage at full load conditions.

6.1 Steady state waveforms

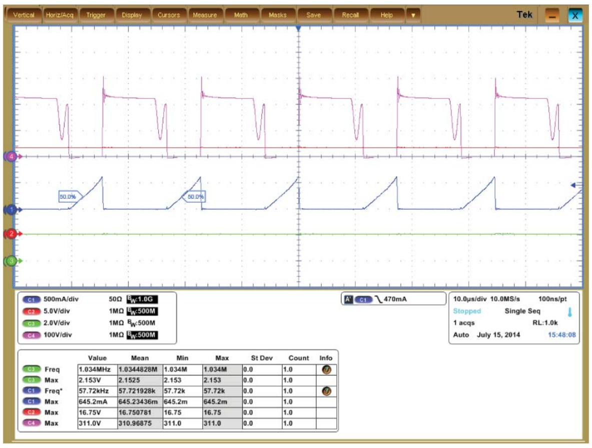
The typical operating waveforms are captured for wide mains variation input at full loaded conditions.

Figure 12. Waveform at 90 V_{AC}



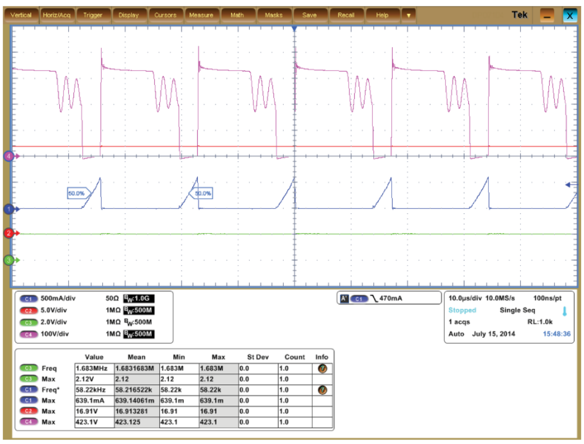
CH1: drain current; CH2: Vcc voltage;
CH3: FB signal; CH4: drain-source voltage

Figure 13. Waveform at 115 V_{AC}



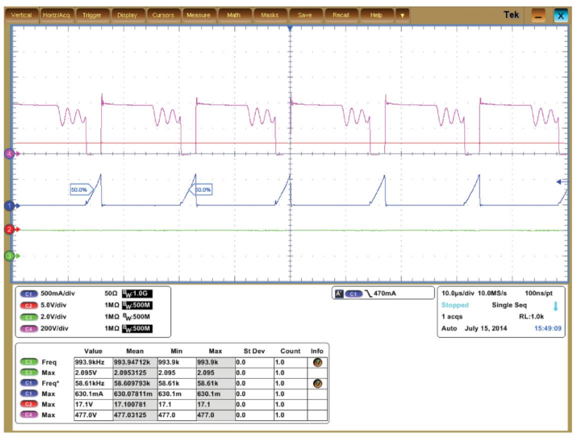
CH1: drain current; CH2: Vcc voltage;
CH3: FB signal; CH4: drain-source voltage

Figure 14. Waveform at 190 V_{AC}



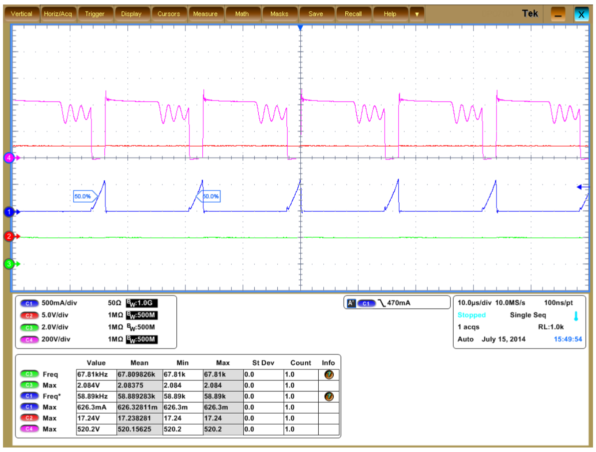
CH1: drain current; CH2: Vcc voltage;
CH3: FB signal; CH4: drain-source voltage

Figure 15. Waveform at 230 V_{AC}



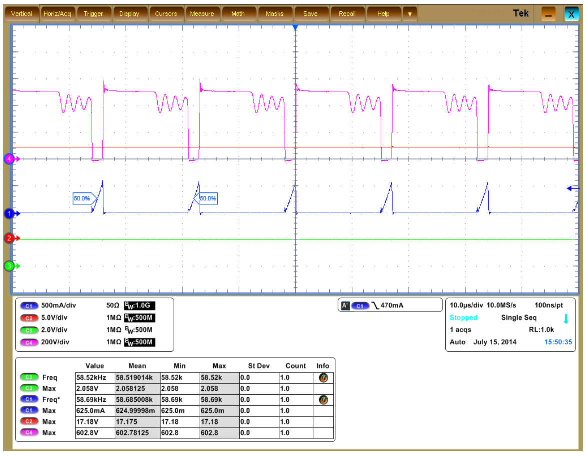
CH1: drain current; CH2: Vcc voltage;
CH3: FB signal; CH4: drain-source voltage

Figure 16. Waveform at 265 V_{AC}



CH1: drain current; CH2: Vcc voltage; CH3: FB signal; CH4: drain-source voltage

Figure 17. Waveform at 320 V_{AC}

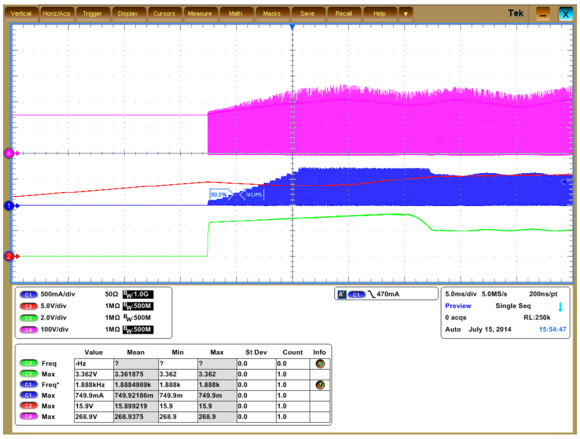


CH1: drain current; CH2: Vcc voltage; CH3: FB signal; CH4: drain-source voltage

6.2 Transient/start-up waveforms

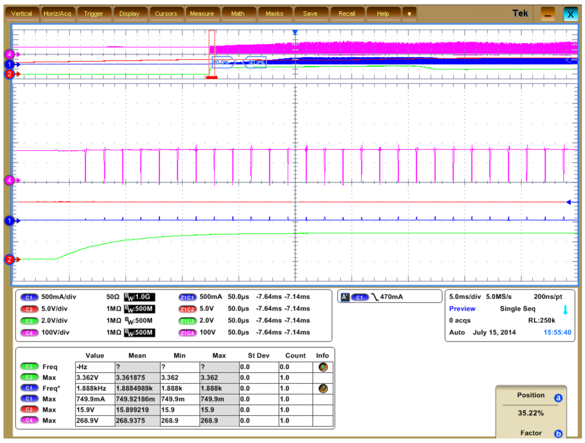
In this section, both the primary current as well as voltage stress on the MOSFET are captured at extreme mains conditions 90 V_{AC} and 265 V_{AC} at full loaded conditions. Following waveforms are analyzed from *Figure 18* to *Figure 24*.

Figure 18. Waveform of start-up at 90 V_{AC}



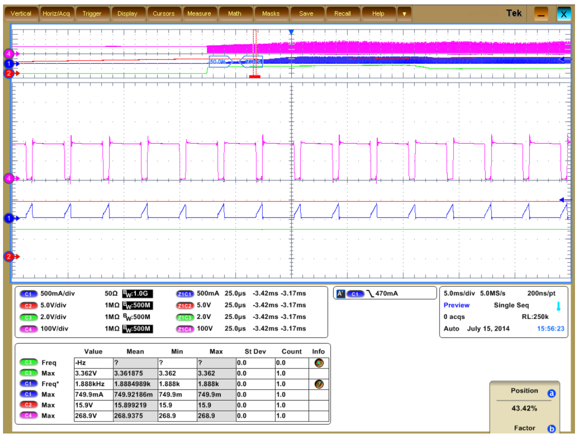
CH1: drain current; CH2: Vcc voltage; CH3: FB signal; CH4: drain-source voltage

Figure 19. Waveform of start-up at 90 V_{AC} (zoom view 1)



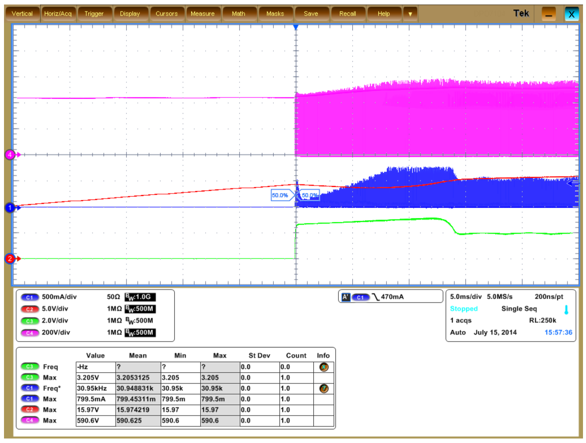
CH1: drain current; CH2: Vcc voltage; CH3: FB signal; CH4: drain-source voltage

Figure 20. Waveform of start-up at 90 V_{AC} (zoom view 2)



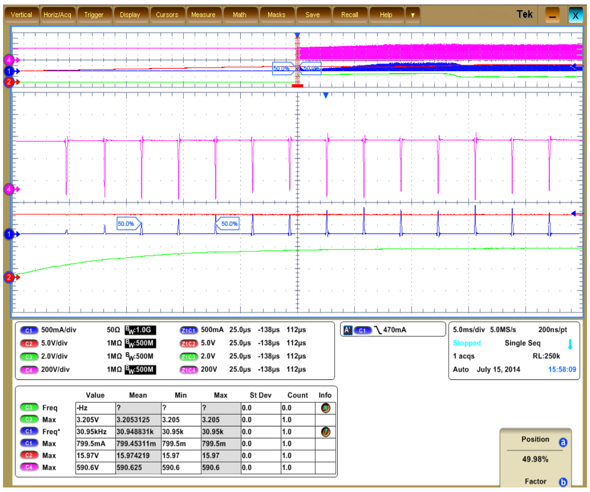
CH1: drain current; CH2: Vcc voltage;
CH3: FB signal; CH4: drain-source voltage

Figure 21. Waveform of start-up at 265 V_{AC}



CH1: drain current; CH2: Vcc voltage;
CH3: FB signal; CH4: drain-source voltage

Figure 22. Waveform of start-up at 265 V_{AC} (zoom view 1)

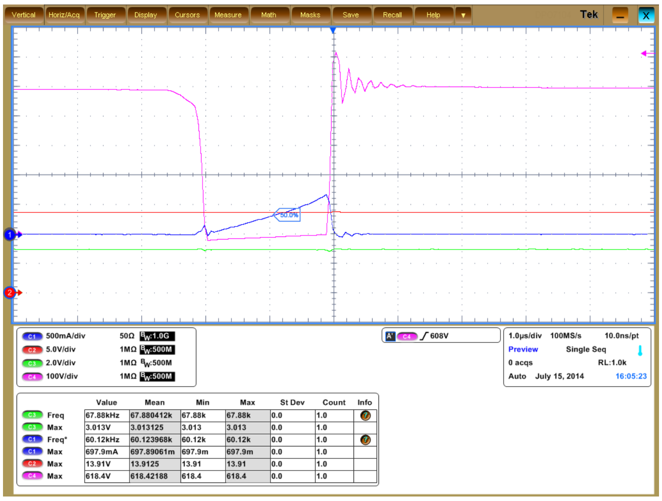


CH1: drain current; CH2: Vcc voltage;
CH3: FB signal; CH4: drain-source voltage

Figure 23. Waveform of start-up at 265 V_{AC} (zoom view 2)

CH1: drain current; CH2: Vcc voltage;
CH3: FB signal; CH4: drain-source voltage

Figure 24. Waveforms of drain-source at 320 V_{AC} start-up condition



CH1: drain current; CH2: Vcc voltage; CH3: FB signal; CH4: drain-source voltage

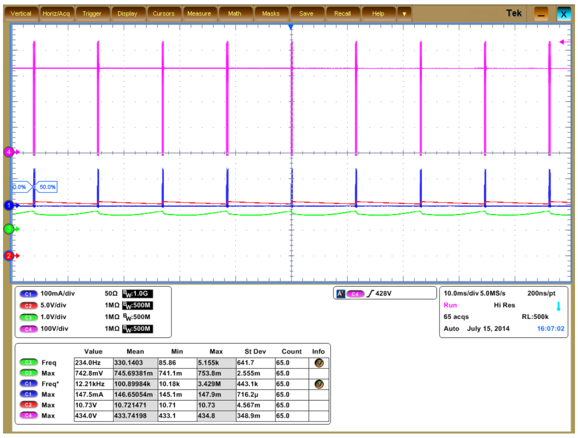
Looking into above waveforms, the duty cycle is progressively increased which is the inherent property of VIPer Plus devices to maintain the soft-start feature and to protect the converter from excessive stress and avoiding the saturation in magnetic (if any) that may arise due to uncontrolled duties at the start-up. In any case, no abnormal behavior in terms of saturation effect observed in the transformer at various peak detections.

Referring to *Figure 24*, the drain source start-up instants are captured at 320 V_{AC} at full loaded condition. It is found that the maximum off-state stress on the MOSFET is 618 V, means at worst start-up condition, the device has enough margin of around 800 - 618 = 182 Volts. This indicates that the converter could be even operated at higher line voltages, provided the bulk capacitor and other rectifiers are rated accordingly. In addition, since the VIPer Plus has an avalanche rugged MOSFET which gives extra protections against spikes, that may happen due to improper transformer leakages and other abnormal conditions if the stress voltage exceeds 800 V.

7 Burst mode operation

During no load condition, the device enters into the burst mode and the input power consumption drops to minimum level. The corresponding switching waveforms are displayed in *Figure 25*.

Figure 25. Waveforms at no load condition, 230 V_{AC}

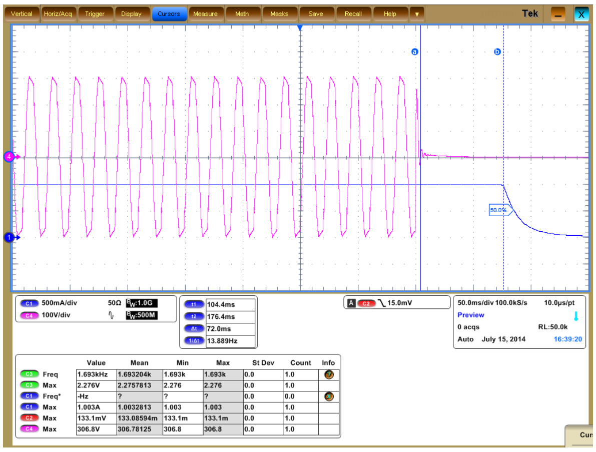


CH1: drain current; CH2: Vcc voltage;
CH3: FB signal; CH4: drain-source voltage

8 Hold-up test

The mains input is interrupted at loaded conditions to see the hold-up capability of the SMPS. Referring to the waveform in *Figure 26*, the converter is able to deliver the load in case there is missing of about 4 cycles of the 50 Hz mains supply at 230 V_{AC}.

Figure 26. Hold-up test at 230 V_{AC} input voltage, at full load

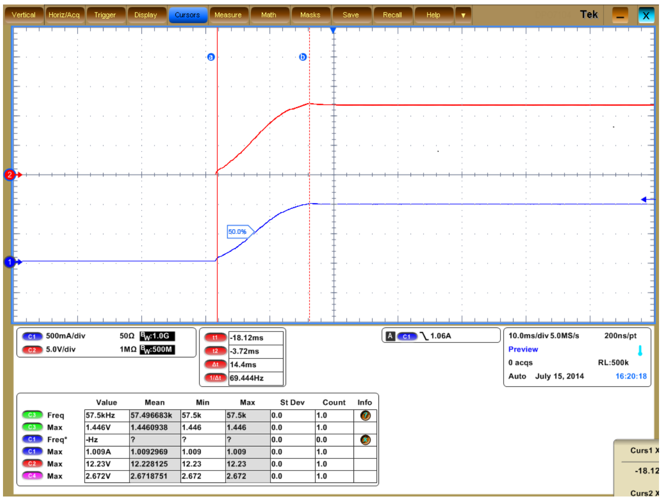


CH1: load current; CH4: mains input voltage

9 Soft-start test

The output voltage start-up behavior is captured at full load condition as shown in *Figure 27*.

Figure 27. Output soft-start at full load



CH1: load current; CH2:ouput voltage

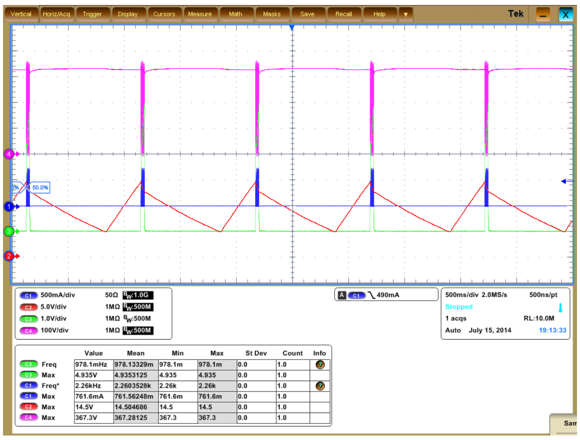
10 Short-circuit test

The VIPerX7 family has several protections, one of them prevents converter damage in case of the overload or output short-circuit. If the load power demand increases, the output voltage decreases and the feedback loop reacts by increasing the voltage on the feedback pin. The increase of the feedback pin voltage leads to the PWM current set point increase which increases the power delivered to the output until this power equals the load power. If the load power demand exceeds the converter's power capability (which can be adjusted using RLIM), the voltage on the feedback pin continuously rises, but the power delivered no longer increases. When the feedback pin voltage exceeds VFBlin (3.5 V typ.), VIPER27L logic assumes that it is a warning for an overload event. Before shutting down the system, the device waits for a period of time set by the capacitor present on the feedback pin. In fact if the voltage on the feedback pin exceeds VFBlin, the internal pull-up is disconnected and the pin starts sourcing a 3 μA typ current that charges the capacitor connected to it. As the voltage on the feedback pin reaches the V_{FBOLP} threshold (4.8 V typ.), the VIPER27L stops switching and is not allowed to switch again until the VDD voltage goes below $V_{DD(RESTART)}$ (4.5 V typ.) and rises again up to V_{DDON} (14 V typ.).

The following waveforms show the behavior of the converter when the output is shorted.

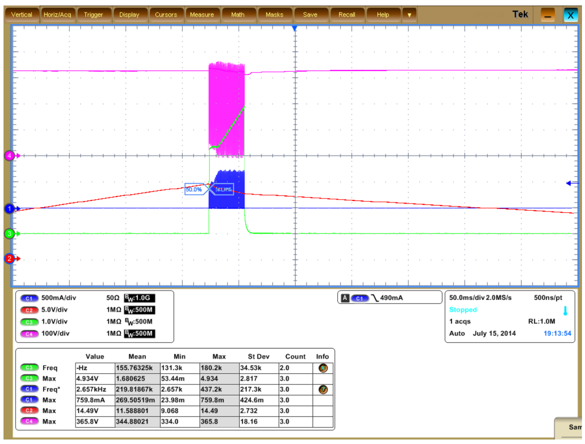
The converter is powered up at 230 V_{AC} and output terminals are short-circuited. The device enters into the hiccup mode, reducing the input power throughput from the mains. Refer to short-circuit behavior as shown in *Figure 28* and *Figure 29*.

Figure 28. Output short-circuit behavior at 230 V_{AC}



CH1: drain current; CH2: Vcc voltage; CH3: FB signal; CH4: drain-source voltage

Figure 29. Output short-circuit behavior at 230 V_{AC} (single burst)

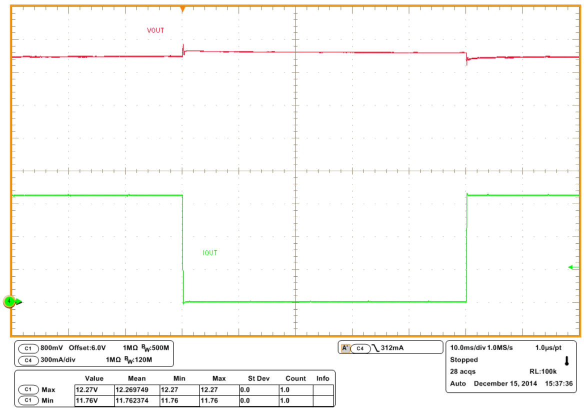


CH1: drain current; CH2: Vcc voltage; CH3: FB signal; CH4: drain-source voltage

11 Transient load test

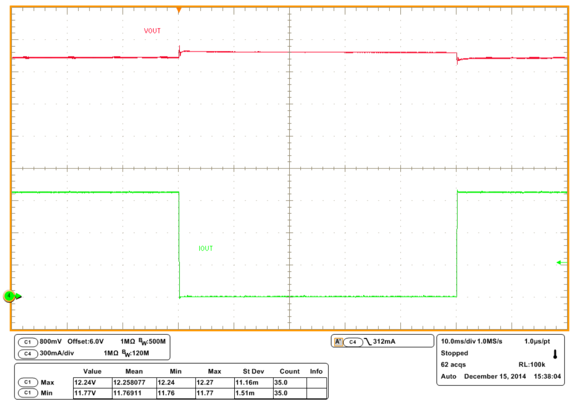
The converter is powered at 115 and 230 V_{AC} at step load condition, i.e.: a sudden full load is applied at output of the converter and removed to observe the undershoot and overshoot in output voltage of the converter. The dynamic performance of the converter is analyzed as shown in *Figure 30* and *Figure 31* at 115 V_{AC} and 230 V_{AC} respectively. There is the negligible overshoot and undershoot observed in output and it shows good stable design of the converter feedback loop.

Figure 30. Output transient response at 115 V_{AC}



CH1: output voltage; CH4: load current

Figure 31. Output transient response at 230 V_{AC}



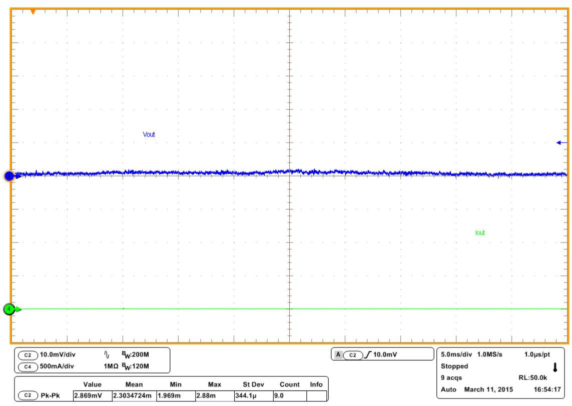
CH1: output voltage; CH4: load current

12 Output voltage ripple

The peak-to-peak high frequency switching output voltage ripples are measured at output terminals at no load as well as full load conditions. The ripple waveforms are captured at different line conditions - 115 V_{AC} and 230 V_{AC}, as displayed from *Figure 32* to *Figure 35*.

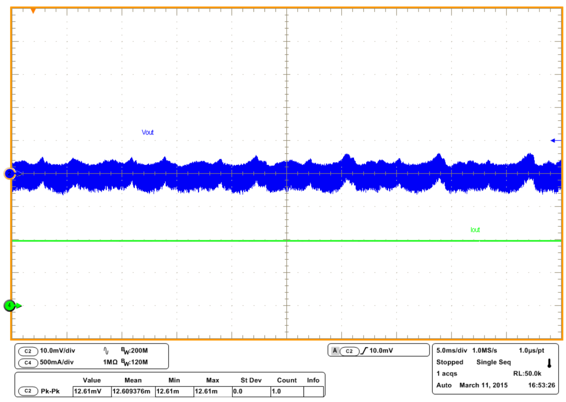
The peak-to-peak ripple voltage is approximately 25 - 35 mV at full load condition.

Figure 32. Output voltage ripple at 115 V_{AC}, no load



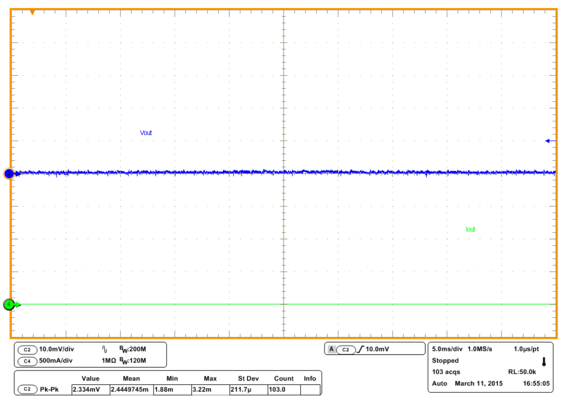
CH1: load current; CH2: output voltage ripple

Figure 33. Output voltage ripple at 115 V_{AC}, full load



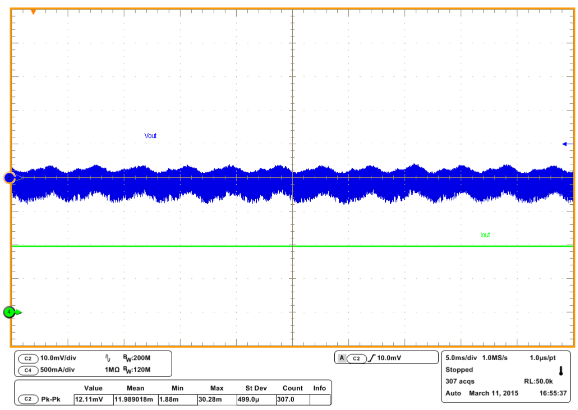
CH1: load current; CH2: output voltage ripple

Figure 34. Output voltage ripple at 230 V_{AC}, no load



CH1: load current; CH2: output voltage ripple

Figure 35. Output voltage ripple at 230 V_{AC}, full load



CH1: load current; CH2: output voltage ripple

13 Thermal test

The converter is kept on at the full load in a fully enclosed form at 90 V_{AC} and 230 V_{AC} and at an ambient of 40 °C, following are the temperature readings for critical components noted in stabilized condition:

Table 13. Temperature measurements

Sr. no.	Part and location of sensor	Temperature at 90 V_{AC}	Temperature at 230 V_{AC}
1	U1, VIPER27 case temperature	101.5 °C	72.8 °C
2	T1, transformer coil temperature	91.4 °C	82.1 °C
3	T1, transformer core temperature	87.0 °C	81.5 °C
4	C3, bulk capacitor body	59.2 °C	44.5 °C
5	D1, output Schottky rectifier	107.8 °C	100.2 °C

14 EMI pre-compliance test

A pre-compliance test for EN55022 (Class B) European normative[b] was also performed and the results are shown in *Figure 36* and *Figure 37*.

Figure 36. EMI results at 115 V_{AC} mains input

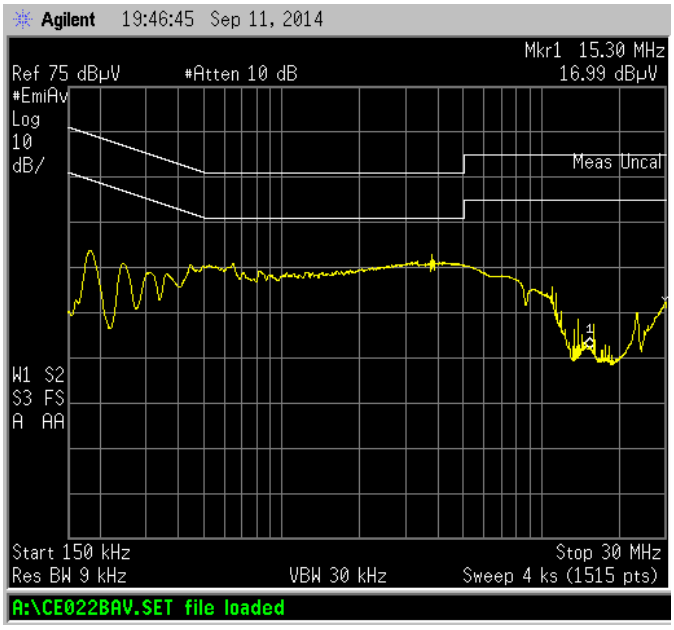
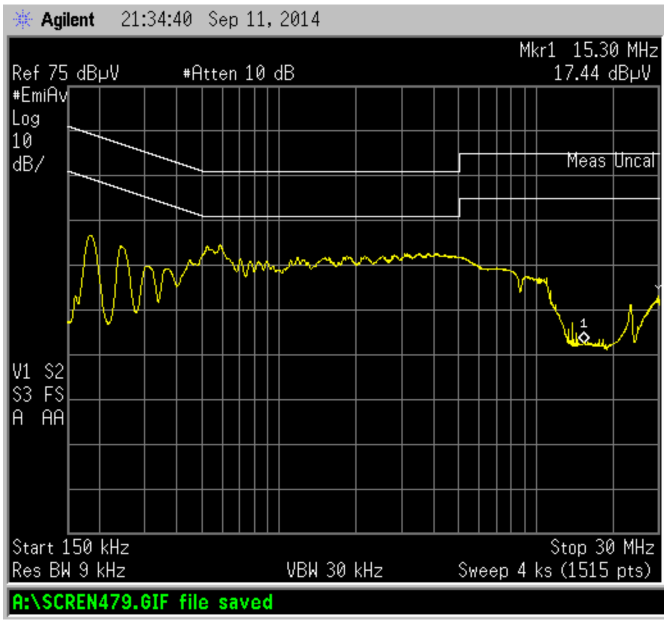


Figure 37. EMI results at 230 V_{AC} mains input



b. Using an average measurement method.

15 Printed circuit board

Figure 38. PCB top view

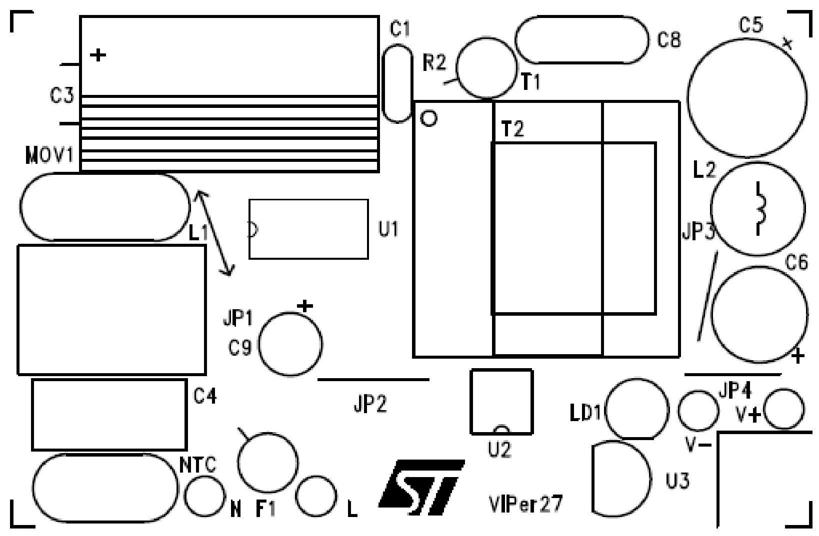


Figure 39. PCB solder side bottom view

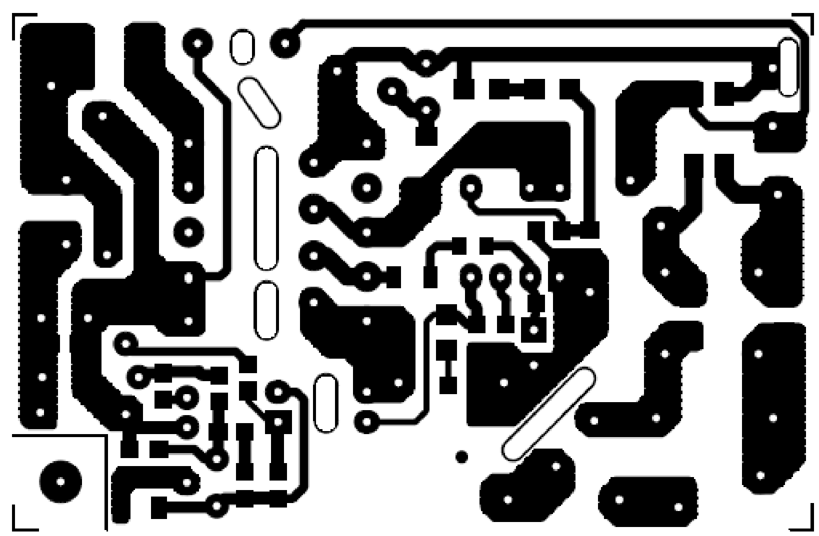
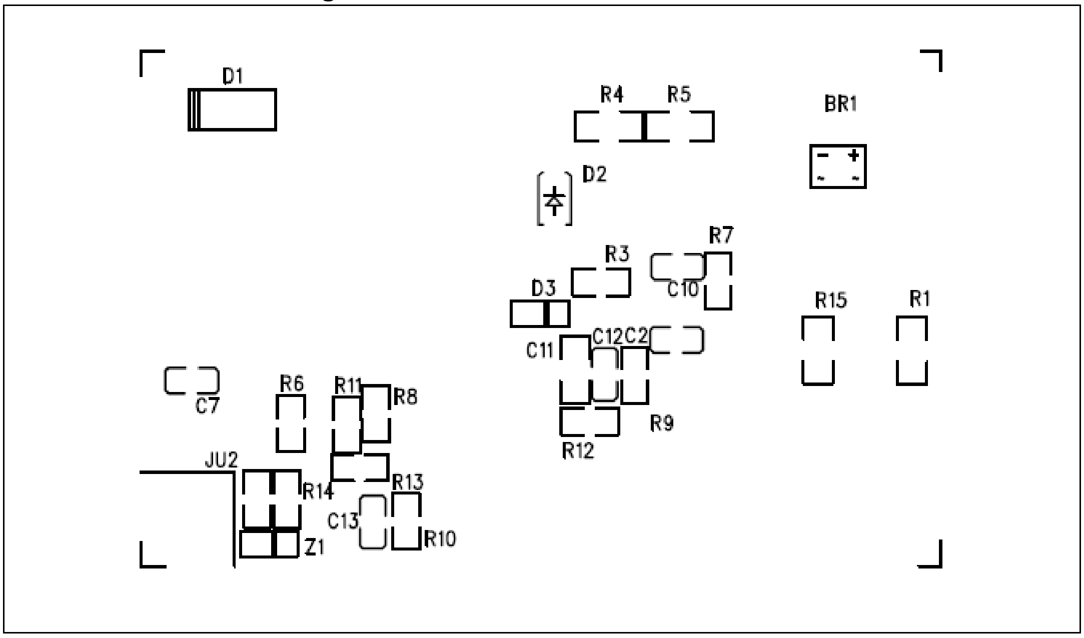


Figure 40. PCB silkscreen bottom view



16 Reference

VIPER27L datasheet (VIPER27 - “Off-line high voltage converters”).

17 Revision history

Table 14. Document revision history

Date	Revision	Changes
25-Aug-2015	1	Initial release.