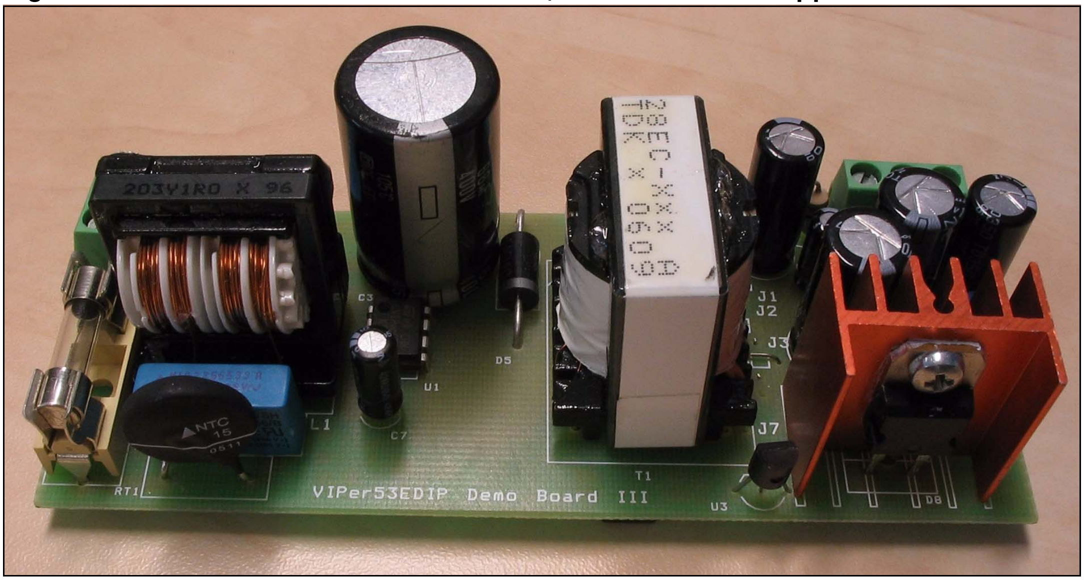
AN2426
Application note

Auxiliary power supply with VIPer53EDIP

1 Introduction

This document describes the reference design of the 25W Switch Mode Power Supply which is dedicated to industrial or white goods applications. The board accepts wide range input voltages (90 to 265Vrms) and delivers 2 or 3 output voltages depending on the version. Two types of power supply are available: negative output or positive output voltage. The actual version depends the way the components are assembled on the secondary side and on the configuration of jumpers. On the primary side, the PCB and transformer are the same for both versions. More information is available in *Chapter 3*. The Switch mode power supply is based on the VIPer53E. The VIPer53E combines in the same package an enhanced current mode PWM controller with a high voltage MDMesh Power Mosfet. High efficiency and low standby consumption are the main characteristics of this board. Such features, coupled with minimal part requirements and global low cost in addition to, makes it an ideal solution for powering industrial or consumer equipment, meeting worldwide standards.

Figure 1. STEVAL-ISA023V1 demo board, described in this application note



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2 Main characteristics

The main characteristics of the SMPS are listed below:

- Input voltage: Vin: 90-265Vrms
- Frequency 45-66Hz
- Output voltages are given in *Table 1*, and *2*:
- Standby consumption: <1 Watt
- Short circuit protection: on all outputs with auto-restart at short removal
- EMI according to:EN55022 Class B.

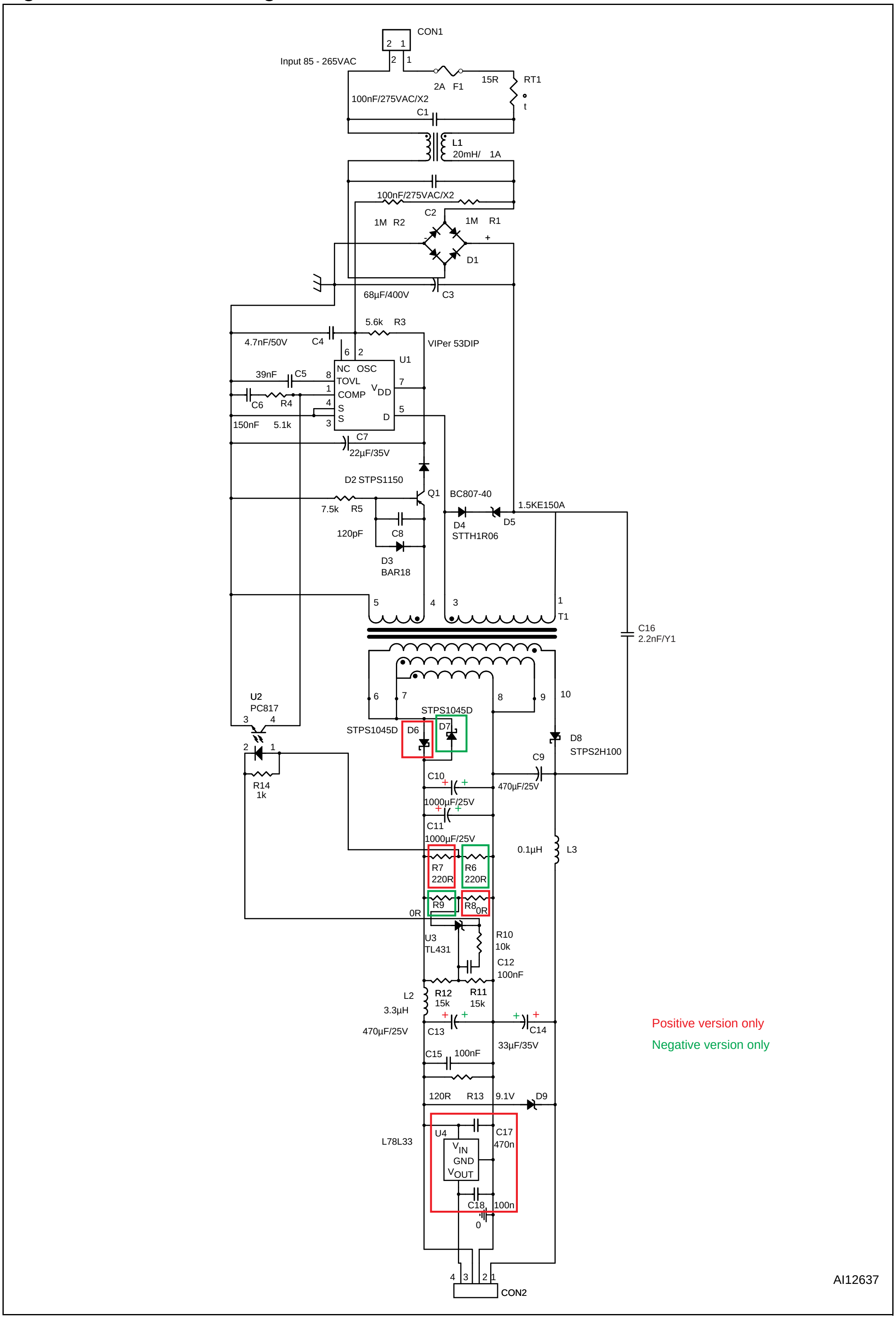
Table 1. Output voltages, positive version

V_{OUT}	I_{OUT}	P_{MAX}	Stability
3.3V	100mA	330mW	2%
5V	3A	15W	5%
12V	0.8A	9.6W	15%
P_{OUT} = 24.93W			

Table 2. Output voltages, negative version

V_{OUT}	I_{OUT}	P_{MAX}	Stability
–5V	3A	15W	5%
–12V	0.8A	9.6W	15%
P_{OUT} = 24.6W			

Figure 2. Electrical diagram



3 Circuit description

The converter topology of this SMPS is the fly-back, working in continuous and discontinuous conduction mode. The core of this design is the primary controller VIPer53EDIP, integrating the controller and a Power Mosfet in a single, standard DIP-8 package. The device integrates all the functions needed to control and protect a power supply, giving a modern, compact and cheap solution to SMPS designs. If an SMT mounting is required, a PowerSO-10 version is also available (VIPer53ESP).

The operating frequency of the circuit (~60kHz) has been chosen in order to obtain a compromise between the transformer size and the input filter complexity. Frequency modulation has been implemented on the input of VIPer53E to reduce electromagnetic interferences on the SMPS. Thus, the EMI input filter can be a simple LC-filter consists of CMC and two X2 capacitors, for differential and common mode noise. The input of SMPS is protected against inrush peak current by an NTC. In case any catastrophic failures a standard 5 x 20mm fuse disconnects the SMPS from mains. The transformer reflected voltage is ~73V, which provides enough room for the leakage inductance voltage spike and leaves enough margin of reliability. The D4 diode and the D5 transil, clamp the leakage inductance voltage spike, assuring reliable operation of the Viper53EDIP.

The transformer is manufactured by TDK, and designed according to the safety standard EN60950. It has two secondary windings, which provide 5 and 12V or –5 and –12V, and an additional winding which provides the supply voltage for the VIPer53EDIP.

This power supply can generate positive or negative output voltages depending on the configuration of the jumpers. Jumpers J1, J2, J5 and J7 have to be assembled for the positive version of the power supply, whilst jumpers J3, J4, J6 and J8 have to be assembled for the negative version. It is also mandatory to change polarity of the output electrolytic capacitors: C9, C10, C11, C13 and C14. Diode D6 is found on the secondary side of the positive power supply, whilst diode D7 is found on the negative side. The polarization of the diode D8 has to be also changed. The positive power supply can generate a voltage of 3.3V from the linear regulator U4.

The output rectifiers have been chosen in accordance with the maximum reverse voltage and their power dissipation. The 5V and –5V rectifier is a Schottky barrier, type STPS1045D0. It is assembled in an axial TO220 package. The 12V and –12V rectifier is a Schottky barrier, type STPS2H100. It is assembled in an SMD package. This rectifier has low forward voltage drop, therefore it improves efficiency as it has a lower power dissipation in comparison with a standard type. A small LC filter has been added on both outputs in order to filter the high frequency ripple without increasing the output capacitors size or quality. Output voltage regulation is performed by secondary feedback, which monitors the 5V output. The feedback network is a classical one, which uses a TL431 and optocoupler. It assures the required insulation between the primary and secondary sides. The opto-transistor drives the COMP pin of the Viper53EDIP, directly. Capacitor C6 and resistor R4 are parts of the compensation loop filtering the high frequency noise.

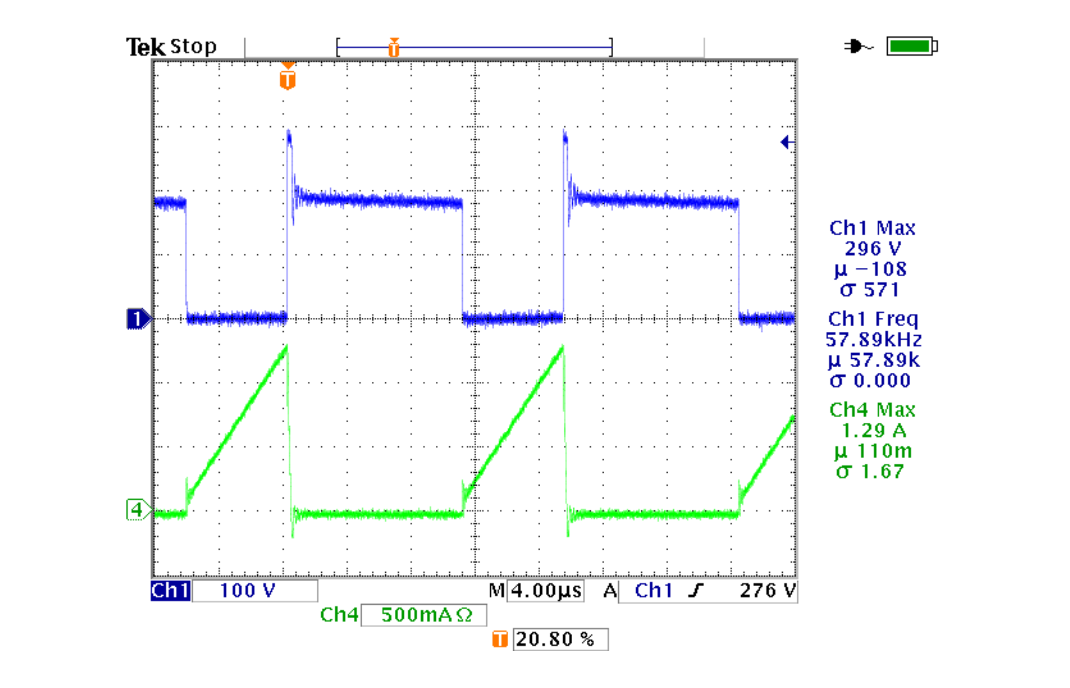
The VIPer53EDIP is activated at start-up by an internal current source, charging capacitor C7 from the DC bus via the Drain pin. As a result of this circuit, the start-up time is short and independent from the mains voltage input. During normal operation the device is powered by the transformer via the LEB circuit (Q1, C8, D3 and R5) and the D2 diode. The LEB circuit filters leakage inductance spikes, i.e. it blanks the spike appearing at the leading edges of the voltage which are generated by the self-supply winding. These spikes, which are due to inductance leakage from the transformer, are the major cause of raised V_{CC}

voltages at high load. This circuit also helps to keep the max V_{CC} voltage under control if the transformer has a high leakage inductance across the auxiliary.

The switching frequency is selected by resistor R3 and capacitor C4. Capacitor C5 provides a delay to the current protection intervention, the so called TOVL function.

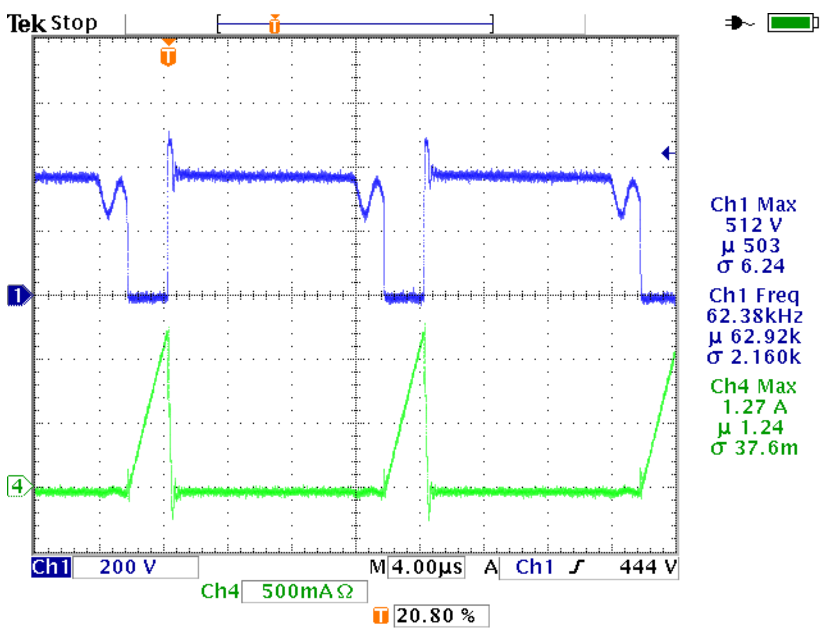
Figure 3, *Figure 4* and *Figure 5* show the drain voltage and current at nominal mains voltage input during normal operation at full load. Clearly the current peak is below the maximum current peak defined in the VIPer53 datasheet. The drain voltage rise time is around 120ns. *Figure 3* shows the drain peak voltage at full load and maximum mains voltage input. The measured voltage of 564V, assures reliable operation of the Viper53 MOSFET with a good margin of the maximum break down voltage BV_{DSS} (620V).

Figure 3. Drain voltage and current at V_{IN} = 90VAC - 50Hz and full load



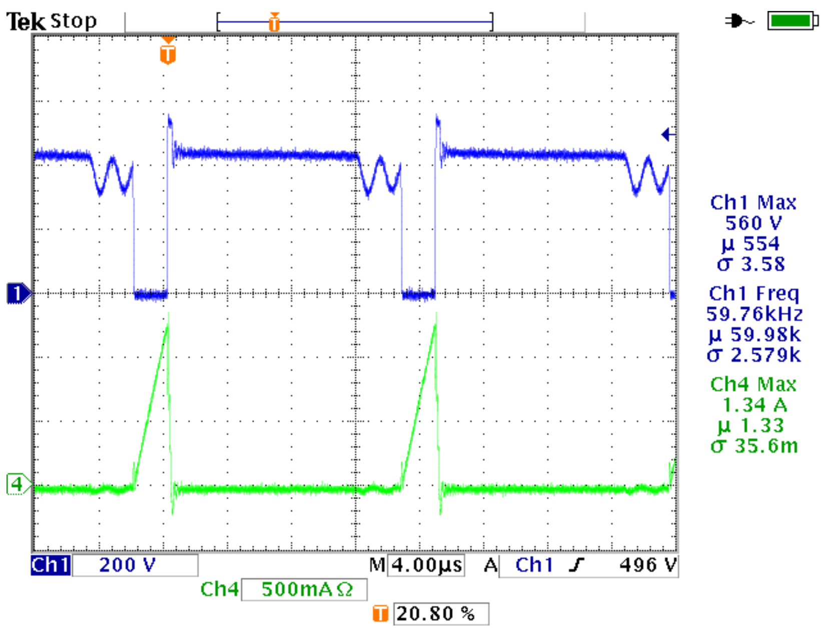
Ch1: VPIN5 (Drain) Ch4: IPIN5 (Drain current)

Figure 4. Drain voltage and current at V_{IN} = 230VAC - 50Hz and full load



Ch1: VPIN5 (Drain) Ch4: IPIN5 (Drain current)

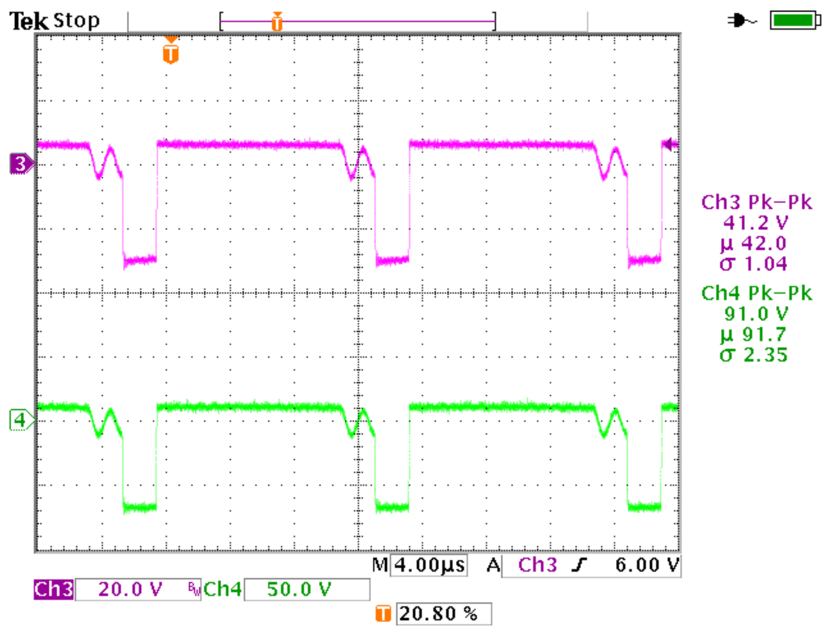
Figure 5. Drain voltage and current at V_{IN} = 265VAC - 50Hz and full load



Ch1: VPIN5 (Drain) Ch4: IPIN5 (Drain current)

The *Figure 6* shows the maximum PIV of rectifiers. They have been measured during 'worst case scenario'. The margin, with respect to the maximum voltage sustained by each diode, assure a safe operating conditions for these devices.

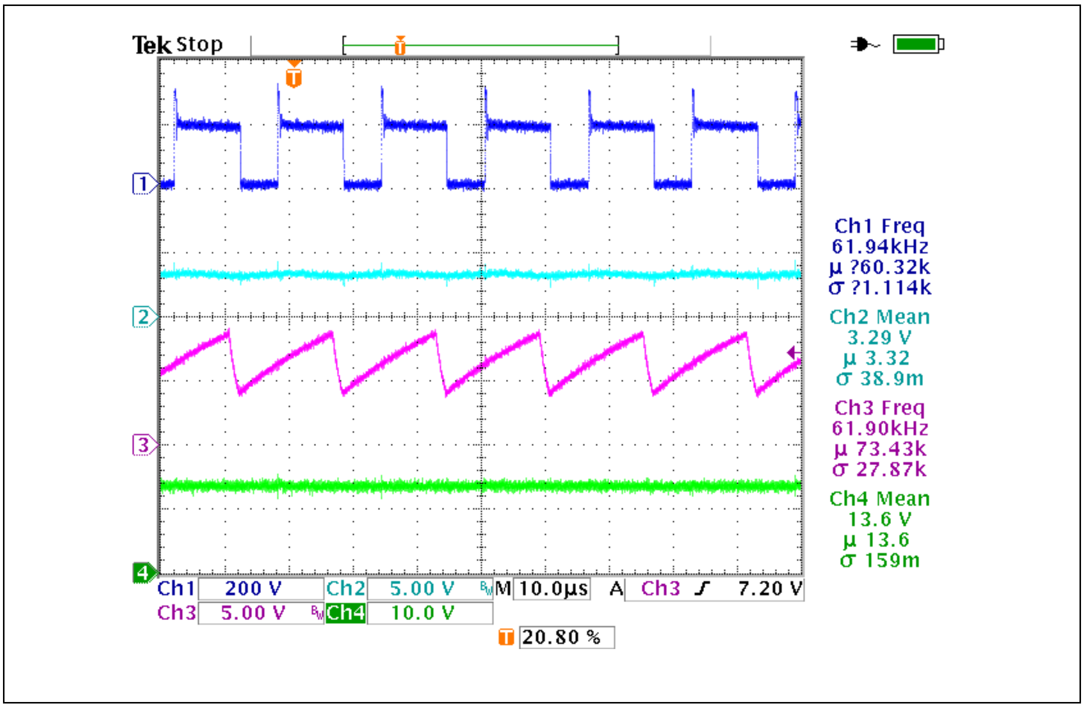
Figure 6. Diodes voltages at V_{IN} = 265VAC - 50Hz and full load



Ch3: +5V Diode: Anode voltage Ch4: +12V Diode: Anode voltage

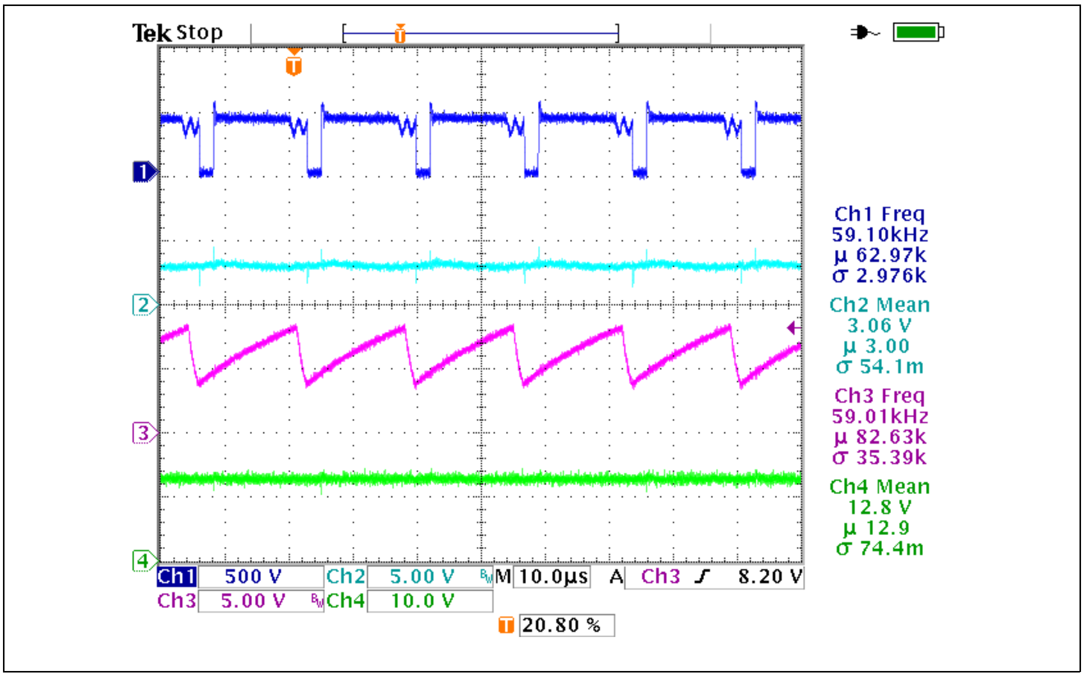
Signals measured on the VIPer53E are shown in *Figure 7* and *Figure 8*, the most salient controller IC signals are shown. In both figures, clean waveforms, free of hard spikes and noise that could affect correct operation of SMPS, are distinguishable.

Figure 7. Drain-source and V_{DD} voltage and current at V_{IN} = 90VAC - 50Hz and full load



Ch1: VPIN5 (Drain) Ch2: VPIN1 (Comp) Ch3: VPIN2 (Osc) Ch4: VPIN7 (V_{DD})

Figure 8. Drain-source and V_{DD} voltage and current at V_{IN} = 265VAC - 50Hz and full load



Ch1: VPIN5 (Drain) Ch2: VPIN1 (Comp) Ch3: VPIN2 (Osc) Ch4: VPIN7 (V_{DD})

4 Cross regulation and stand by

The following tables show the output voltages for both positive and negative version of power supplies, in addition to the overall efficiency of the converter measured at different input voltages. All the output voltages have been measured on the output connector. It should be noted that the 5V output is regulated. The 12V output is influenced by load of 5V branch. If the 5V voltage branch is not loaded typically the voltage on the 12V branch fall rapidly down.

Positive version of power supply

Table 3. Output voltages at V_{IN} 90VAC, 12V / 0.8A

3.3V		5V		12V		P_{OUT} [W]	P_{IN} [W]	Efficiency [%]
Voltage [V]	Current [A]	Voltage [V]	Current [A]	Voltage [V]	Current [A]			
3.28	0.1	4.95	0.5	11.00	0.8	11.60	15.30	75.80
3.28	0.1	4.95	1.0	11.13	0.8	14.17	18.70	75.70
3.28	0.1	4.94	1.5	11.23	0.8	16.71	22.00	75.90
3.28	0.1	4.93	2.0	11.31	0.8	19.22	25.50	75.40
3.28	0.1	4.92	2.5	11.39	0.8	21.73	29.00	74.90
3.28	0.1	4.91	3.0	11.47	0.8	24.23	32.50	74.50

Table 4. Output voltages at V_{IN} 230VAC, 12V / 0.8A

3.3V		5V		12V		P_{OUT} [W]	P_{IN} [W]	Efficiency [%]
Voltage [V]	Current [A]	Voltage [V]	Current [A]	Voltage [V]	Current [A]			
3.28	0.1	4.95	0.5	10.97	0.8	11.58	15.20	76.20
3.28	0.1	4.95	1.0	11.12	0.8	14.16	18.40	76.90
3.28	0.1	4.94	1.5	11.21	0.8	16.70	21.50	77.60
3.28	0.1	4.93	2.0	11.28	0.8	19.20	24.80	77.40
3.28	0.1	4.92	2.5	11.35	0.8	21.70	27.90	77.70
3.28	0.1	4.91	3.0	11.42	0.8	24.19	31.20	77.50

Table 5. Output voltages at V_{IN} 90VAC, 5V / 3A

3.3V		5V		12V		P_{OUT} [W]	P_{IN} [W]	Efficiency [%]
Voltage [V]	Current [A]	Voltage [V]	Current [A]	Voltage [V]	Current [A]			
3.28	0.1	4.91	3.0	12.25	0.2	17.50	23.80	73.50
3.28	0.1	4.91	3.0	11.74	0.4	19.75	26.60	74.20
3.28	0.1	4.91	3.0	11.56	0.6	21.98	29.60	74.20
3.28	0.1	4.91	3.0	11.46	0.8	24.21	32.50	74.50

Table 6. Output voltages at V_{IN} 230VAC, 5V / 3A

3.3V		5V		12V		P_{OUT} [W]	P_{IN} [W]	Efficiency [%]
Voltage [V]	Current [A]	Voltage [V]	Current [A]	Voltage [V]	Current [A]			
3.28	0.1	4.91	3.0	12.22	0.2	17.49	23.10	75.70
3.28	0.1	4.91	3.0	11.71	0.4	19.73	25.80	76.50
3.28	0.1	4.91	3.0	11.52	0.6	21.96	28.40	77.30
3.28	0.1	4.91	3.0	11.41	0.8	24.17	31.10	77.70

Negative version of power supply

Table 7. Output voltages at V_{IN} 90VAC, –12V / 0.8A

–5V		–12V		P_{OUT} [W]	P_{IN} [W]	Efficiency [%]
Voltage [V]	Current [A]	Voltage [V]	Current [A]			
–4.98	0.5	–10.97	0.8	11.30	14.50	77.70
–4.97	1.0	–11.16	0.8	13.90	18.00	77.20
–4.96	1.5	–11.27	0.8	16.40	21.50	76.50
–4.95	2.0	–11.36	0.8	19.00	25.10	75.60
–4.95	2.5	–11.45	0.8	21.50	28.60	75.20
–4.94	3.0	–11.54	0.8	24.00	32.20	74.60

Table 8. Output voltages at V_{IN} 230VAC, –12V / 0.8A

–5V		–12V		P_{OUT} [W]	P_{IN} [W]	Efficiency [%]
Voltage [V]	Current [A]	Voltage [V]	Current [A]			
–4.98	0.5	–10.97	0.8	11.30	14.50	77.70
–4.97	1.0	–11.12	0.8	13.90	17.80	77.90
–4.96	1.5	–11.24	0.8	16.40	21.00	78.20
–4.95	2.0	–11.33	0.8	19.00	24.30	78.00
–4.94	2.5	–11.41	0.8	21.50	27.40	78.40
–4.93	3.0	–11.48	0.8	24.00	30.70	78.10

Table 9. Output voltages at V_{IN} 90VAC, –5V / 3A

–5V		–12V		P_{OUT} [W]	P_{IN} [W]	Efficiency [%]
Voltage [V]	Current [A]	Voltage [V]	Current [A]			
–4.93	3.0	–12.35	0.2	17.30	23.40	73.80
–4.93	3.0	–11.82	0.4	19.50	26.30	74.20
–4.93	3.0	–11.61	0.6	21.70	29.10	74.80
–4.93	3.0	–11.51	0.8	24.00	32.00	75.00

Table 10. Output voltages at V_{IN} 230VAC, –5V / 3A

–5V		–12V		P_{OUT} [W]	P_{IN} [W]	Efficiency [%]
Voltage [V]	Current [A]	Voltage [V]	Current [A]			
–4.93	3.0	–12.28	0.2	17.30	22.70	76.00
–4.93	3.0	–11.77	0.4	19.50	25.30	77.00
–4.93	3.0	–11.58	0.6	21.70	28.00	77.60
–4.93	3.0	–11.46	0.8	24.00	30.70	78.00

5 Functional checking

5.1 Stand by

The consumption reduction is requested at low load or stand by mode. This request is completely fulfill thanks burst mode of operation implemented in the VIPer53. When the VIPer53 detects a light load, it operates automatically in burst mode. VIPer53 monitors the voltage on pin 1 (Comp) and if this voltage remains lower than 0.5V the device stops switching cycles. It starts switching cycles again as soon as the voltage on pin 1 increases to greater than 0.5V. In this way, the output voltage is always under control and the device is ready to start. *Figure 9* shows power consumptions of positive and negative version of power supplies during stand-by. *Figure 10* shows the main waveforms in stand-by operation.

Figure 9. Power consumption during stand by

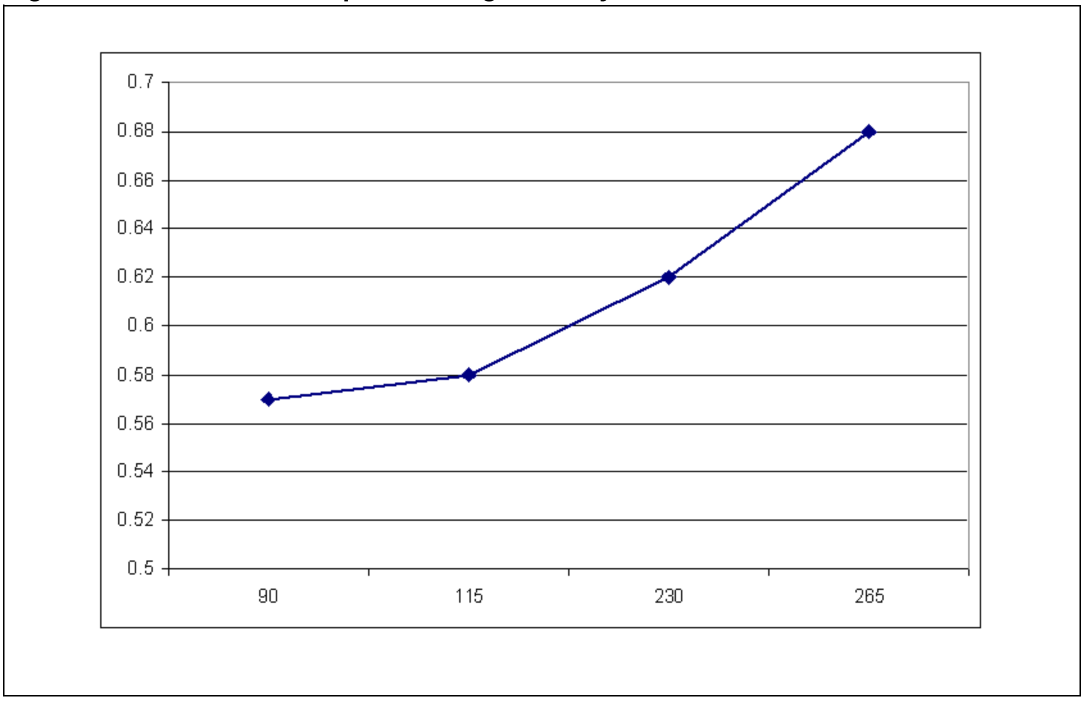
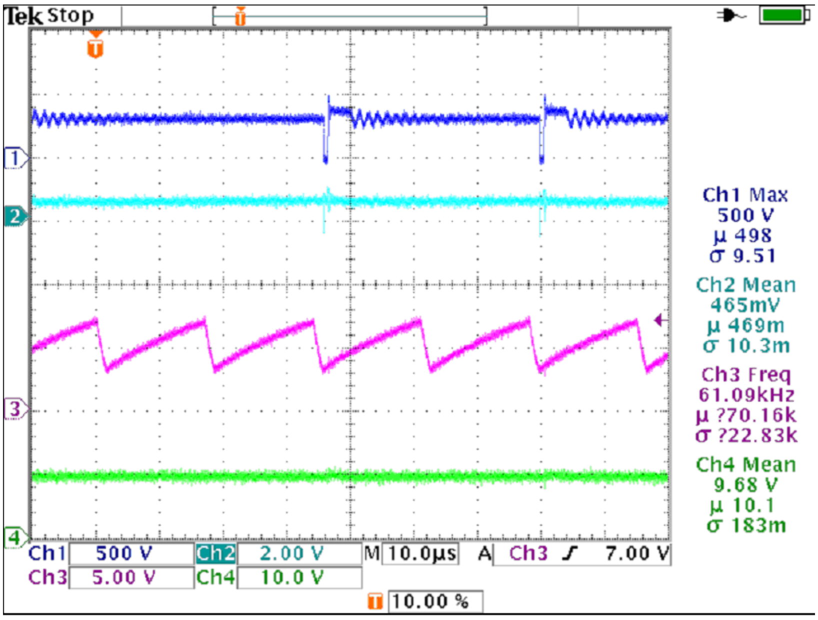


Figure 10. Device voltages in stand by operation



Ch1: VPIN5 (Drain) Ch3: VPIN2 (Osc) Ch2: VPIN1 (Comp) Ch4: VPIN7 (V_{DD})

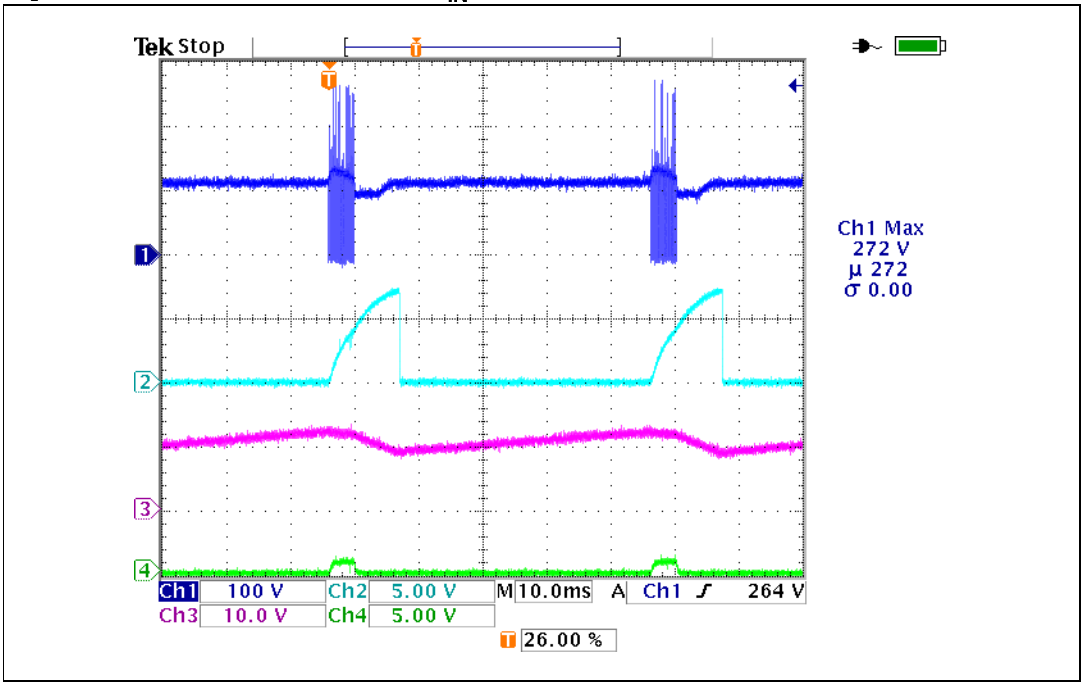
5.2 Short-circuit tests

The VIPer53 contains two overload protections. The first one is undervoltage detection on the V_{DD} pin. The second one depends on the voltage on the COMP pin connected to the optocoupler. This protection protects the power supply also against the feedback loop disconnection. When V_{COMP} goes above 4.4 V, the capacitor connected on the TOVL pin begins to charge. When reaching typically 4 V (V_{OVLth}), the internal mosfet driver is disabled and the device stops switching. This state is latched thanks to the regulation loop which maintains the COMP pin voltage above the $V_{COMPovl}$ threshold. Since the V_{DD} pin doesn't receive any more energy from the auxiliary winding, its voltage drops down until it reaches V_{DDoff} and the device is reset. If V_{COMP} goes below the OVL threshold till the TOVL pin does not reach the V_{OVLth} level, normal operation conditions are resumed. It is important to note that the maximum Peak Drain Current value to consider for design purposes is the I_{DMAX}, also called Drain Current Capability. The I_{DMAX} is the maximum Drain Current that does not trigger overload protection and defines the maximum power output that the power supply can deliver.

All tests have been performed at minimum, nominal and maximum input voltage. Short circuit tests have been also made for negative version of power supply and are shown in *Figure 11*, *Figure 12*, *Figure 13*, *Figure 14*, and *Figure 15*. Only the most significant positive power supply images are shown (figures *11* to *15*).

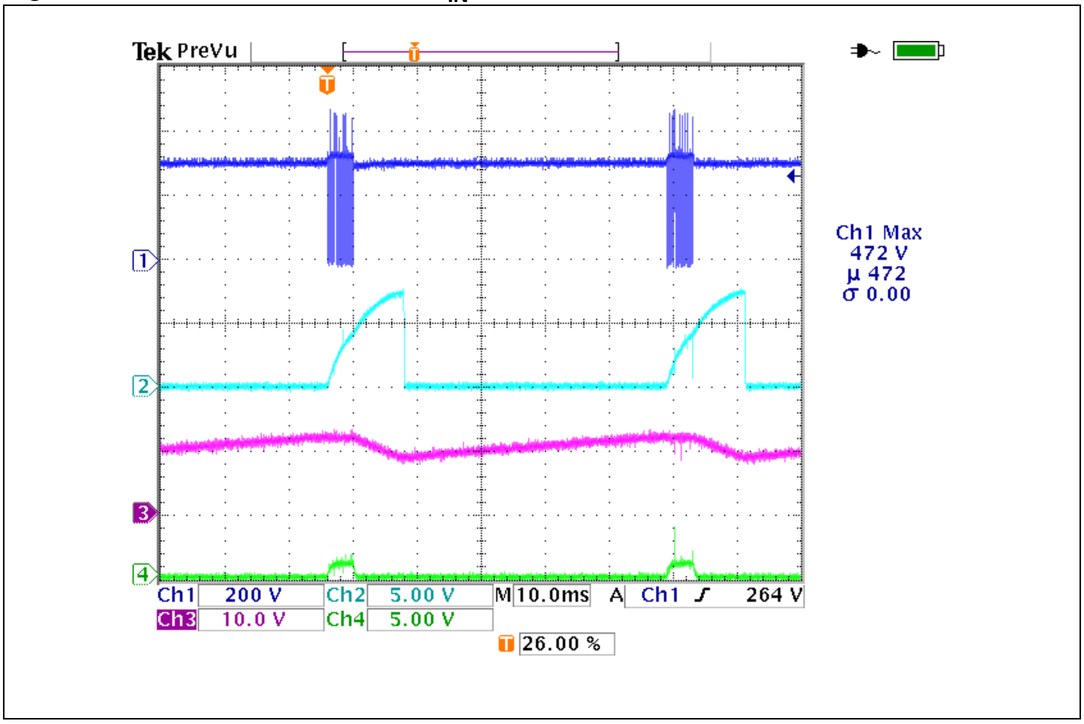
When a short occurs the controller enters hiccup mode, and works only for a short period as shown in figures *11* to *15*. This behavior limits the average power dissipation of all devices, preventing dangerous overheating and catastrophic failure of the SMPS.

Figure 11. Short circuit on 5V at V_{IN} = 90VAC



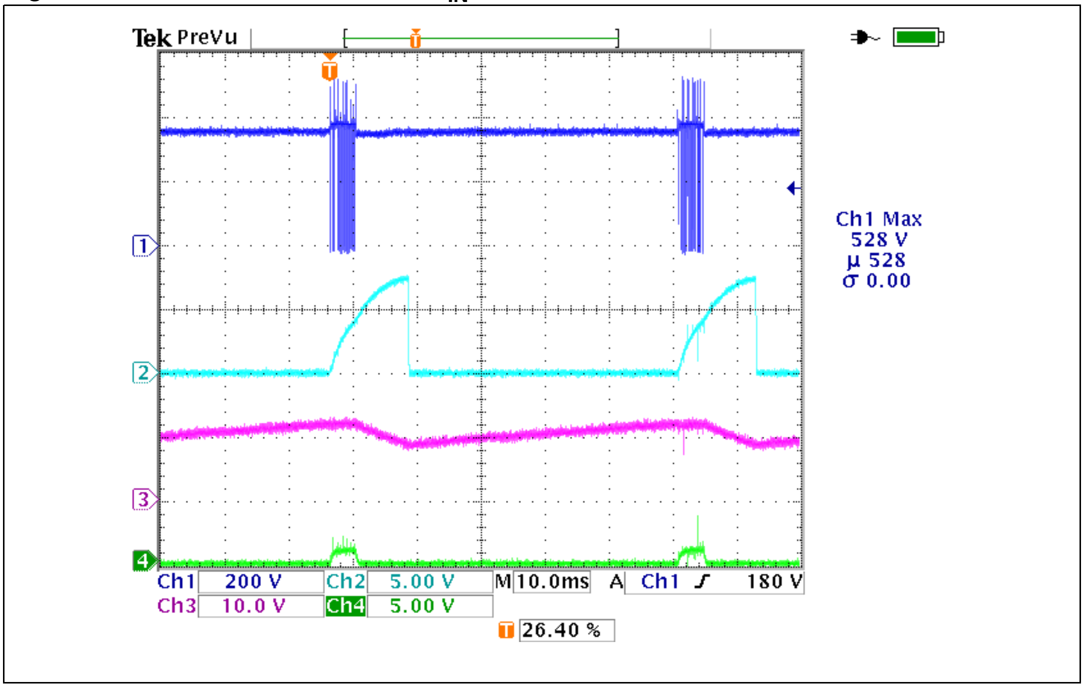
Ch1: VPIN5 (Drain) Ch2: VPIN1 (Tovl) Ch3: VPIN7 (V_{DD}) Ch4: 5V output

Figure 12. Short circuit on 5V at V_{IN} = 230VAC



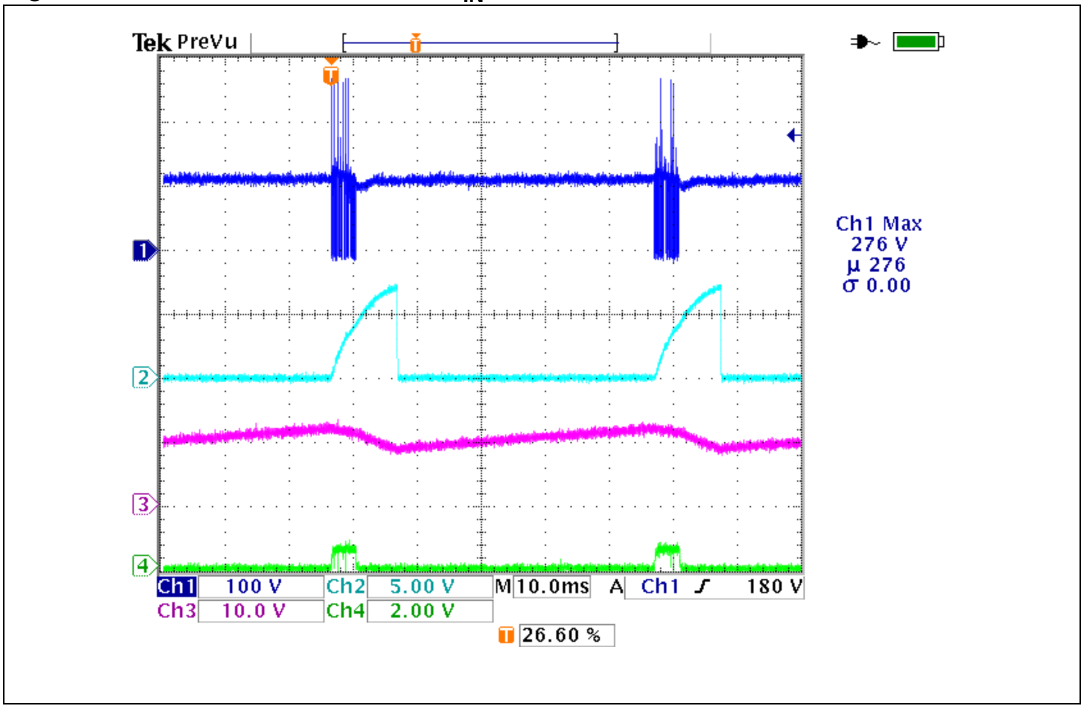
Ch1: VPIN5 (Drain) Ch2: VPIN1 (Tovl) Ch3: VPIN7 (V_{DD}) Ch4: 5V output

Figure 13. Short circuit on 5V at V_{IN} = 265VAC



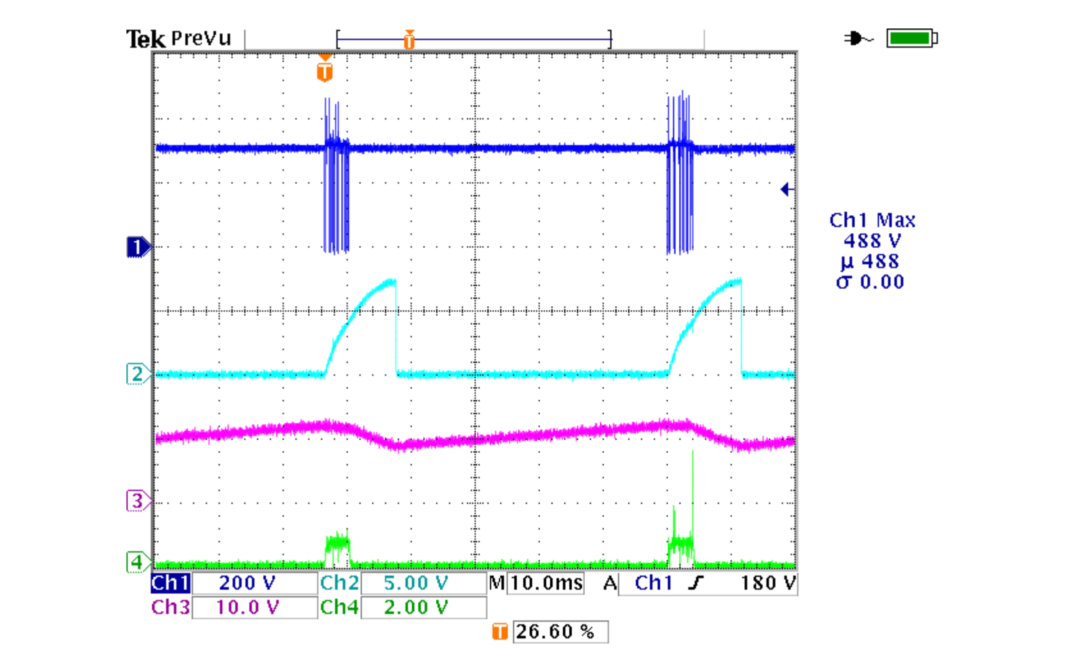
Ch1: VPIN5 (Drain) Ch2: VPIN1 (Tovl) Ch3: VPIN7 (V_{DD}) Ch4: 5V output

Figure 14. Short circuit on 12V at V_{IN} = 90VAC



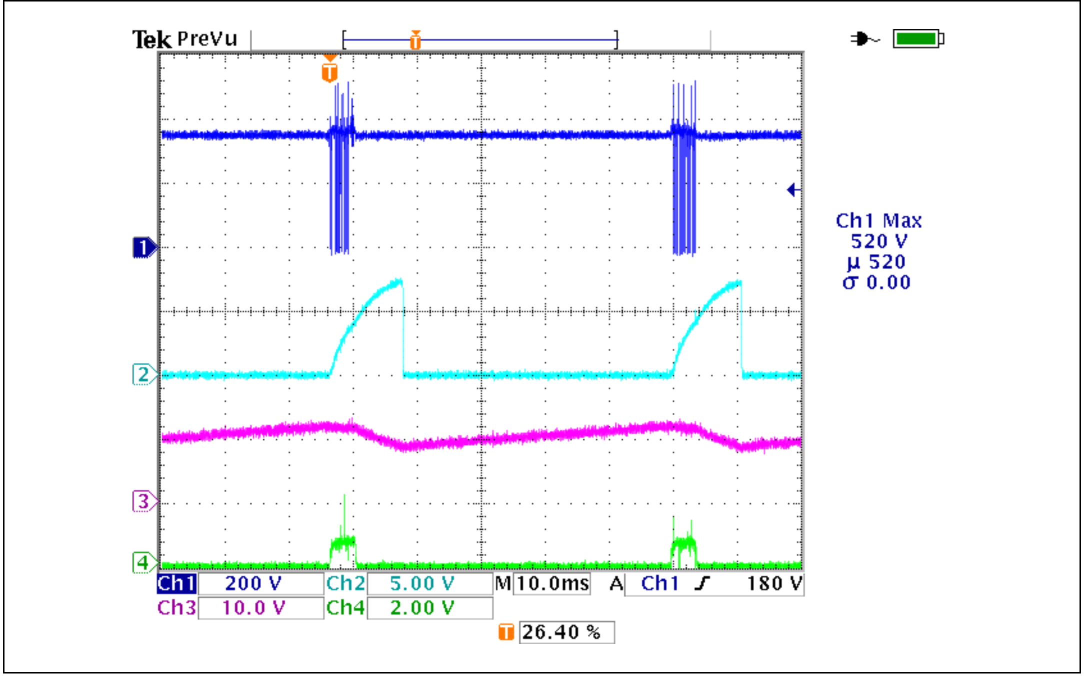
Ch1: VPIN5 (Drain) Ch2: VPIN1 (Tovl) Ch3: VPIN7 (V_{DD}) Ch4: 12V output

Figure 15. Short circuit on 12V at V_{IN} = 230VAC



Ch1: VPIN5 (Drain) Ch2: VPIN1 (Tovl) Ch3: VPIN7 (V_{DD}) Ch4: 12V output

Figure 16. Short circuit on 12V at V_{IN} = 265VAC



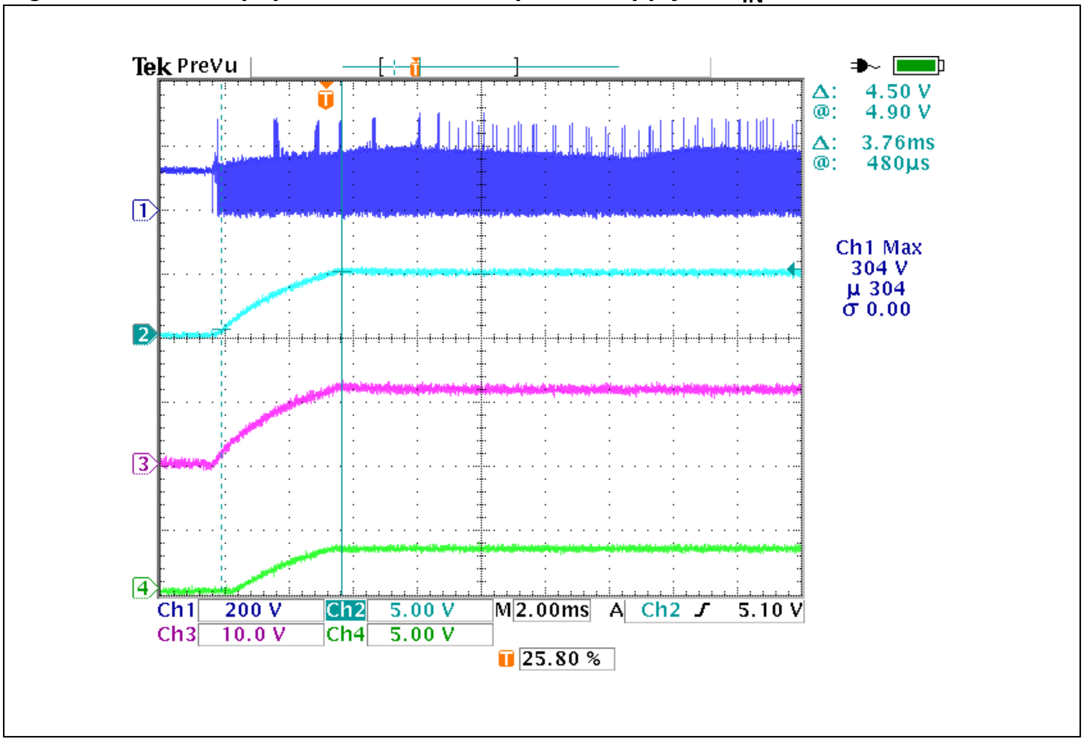
Ch1: VPIN5 (Drain) Ch2: VPIN1 (Tovl) Ch3: VPIN7 (V_{DD}) Ch4: 5V output

5.3 Start-up behavior at full load

The figures *17*, *18*, *19* and *20* display the rising slopes of output voltages. The measurements were perform at full load and for different input voltages (90VAC and 230VAC). As shown in figures *17* to *20*, rising time is monotonic and it is almost constant over all the mains input ranges. No overshoot or abnormal behavior is apparent.

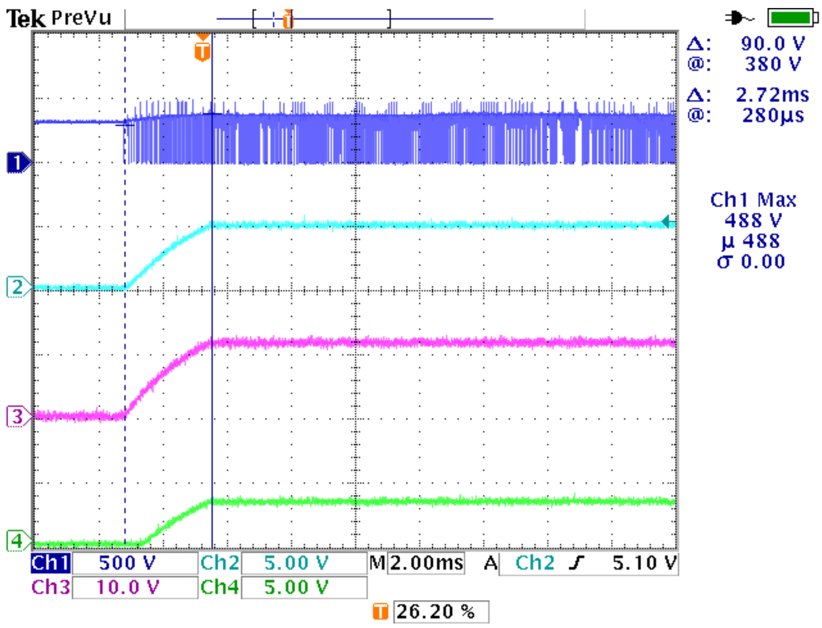
Positive version of power supply

Figure 17. Start-up, positive version of power supply at V_{IN} = 90VAC



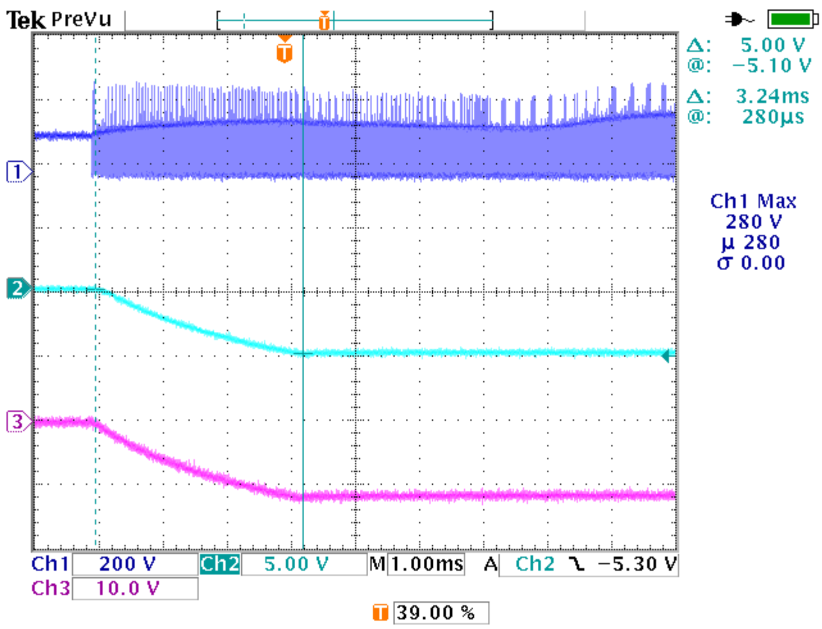
Ch1: VPIN5 (Drain) Ch2: 5V level Ch3: 12V level Ch4: 3.3V level

Figure 18. Start-up, positive version of power supply at V_{IN} = 230VAC



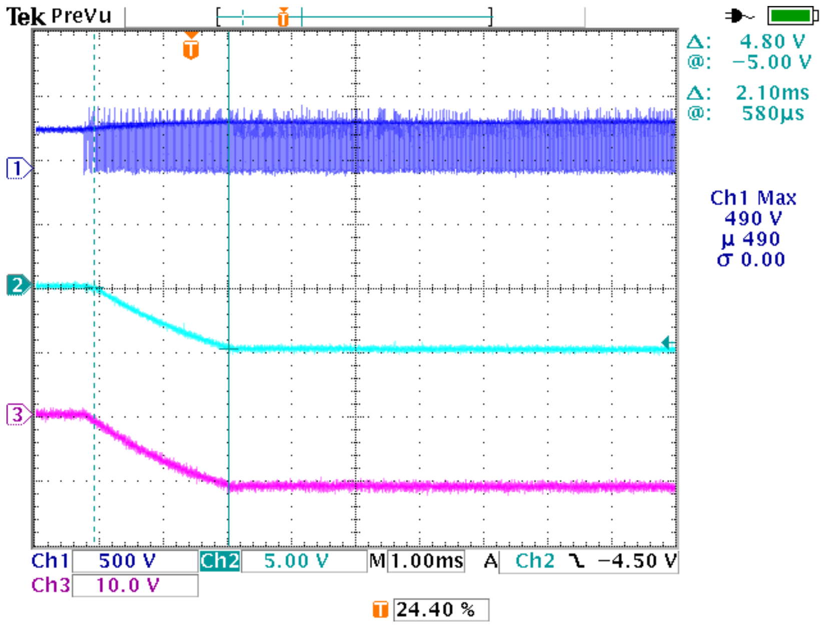
Ch1: VPIN5 (Drain) Ch2: 5V level Ch3: 12V level Ch4: 3.3V level

Figure 19. Start-up, negative version of power supply at V_{IN} = 90VAC



Ch1: VPIN5 (Drain) Ch2: –5V level Ch3: –12V level

Figure 20. Start-up, negative version of power supply at V_{IN} = 230VAC



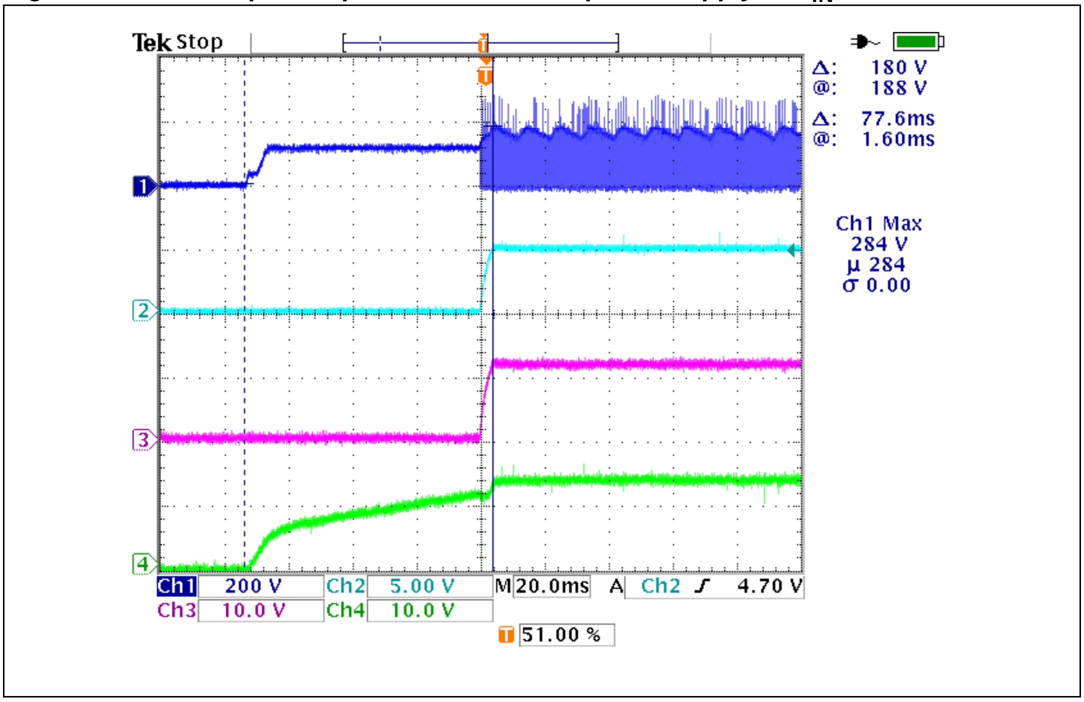
Ch1: VPIN5 (Drain) Ch2: –5V level Ch3: –12V level

5.4 Wake-up time

The wake-up time is the time needed for the power supply to deliver the nominal output voltages once it has been plugged-in the mains. During wake up time the external capacitor on the V_{DD} pin is charged at about 9mA. When V_{DDoff} is reached, the charging current is reduced down to I_{DDch2} which is about 0.6mA. This lower current leads to a slope change on the V_{DD} rise.

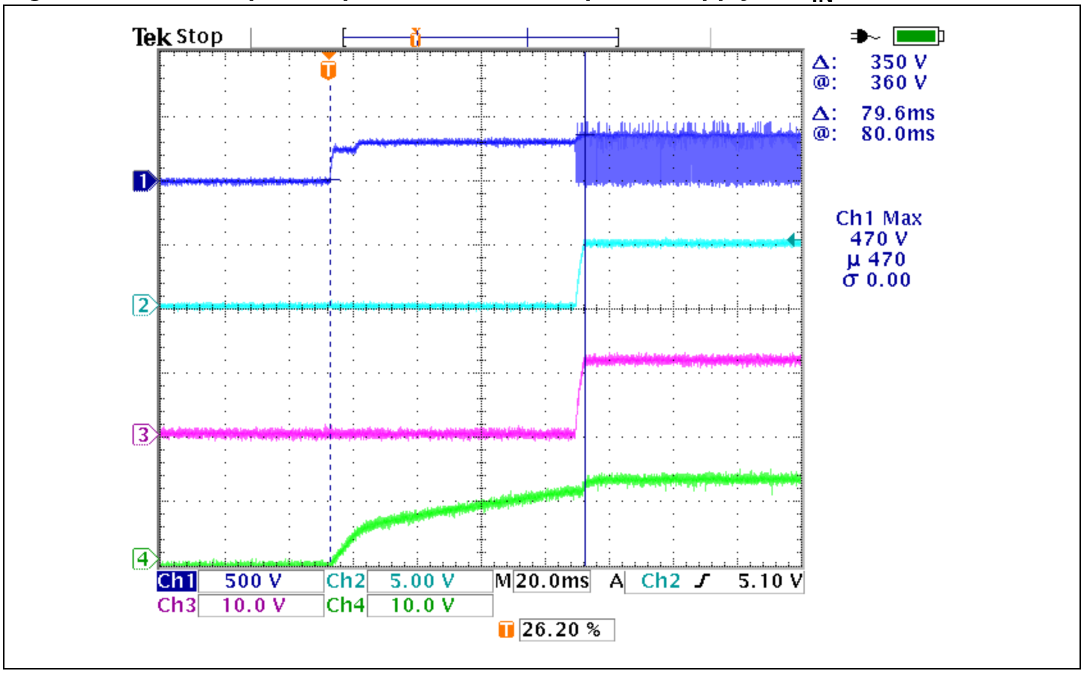
Figures 21 to 24 show the wake up time of the power supply. It is clear that no overshoot, undershoot or loss of control occurs during the power supply wake up time.

Figure 21. Wake-up time, positive version of power supply at V_{IN} = 90VAC



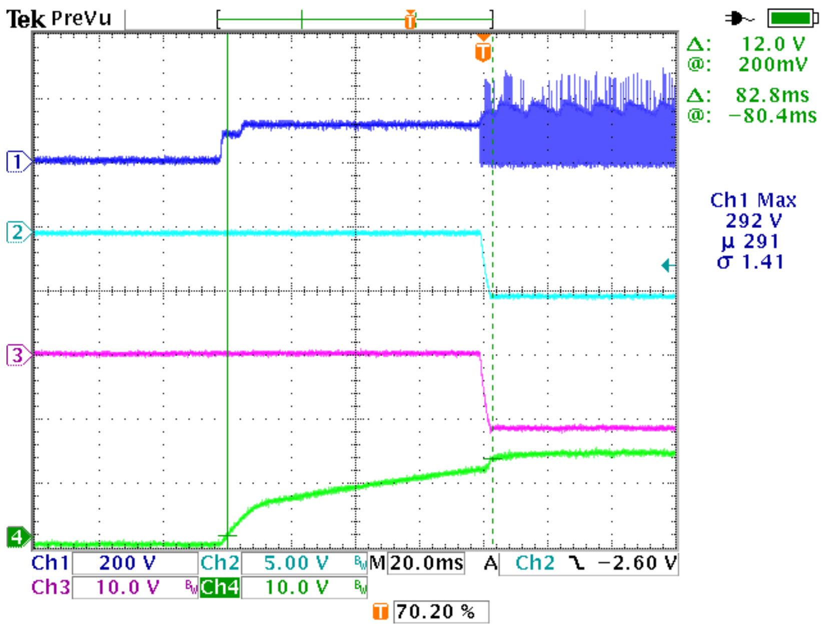
Ch1: VPIN5 (Drain) Ch2: 5V level Ch3: 12V level Ch4: VPIN7 (V_{DD})

Figure 22. Wake-up time, positive version of power supply at V_{IN} = 230VAC



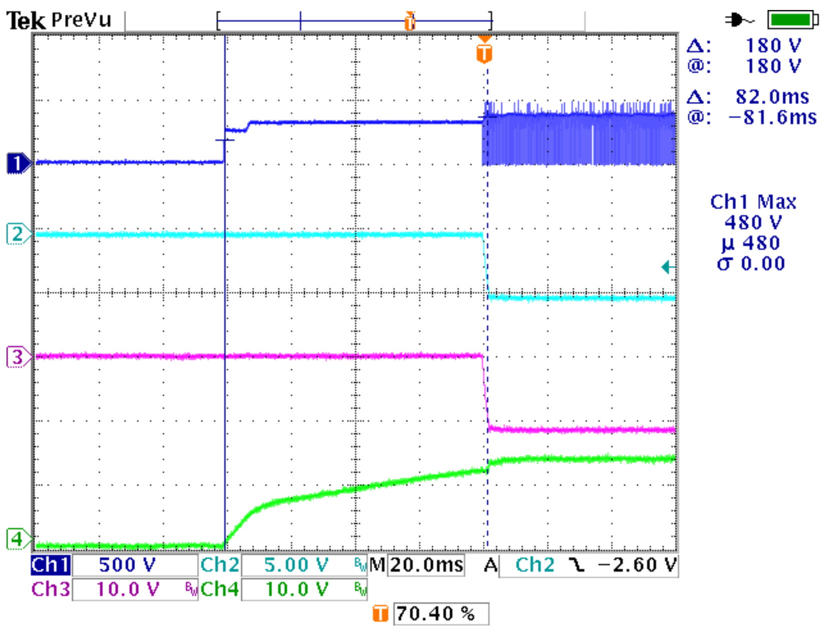
Ch1: VPIN5 (Drain) Ch2: 5V level Ch3: 12V level Ch4: VPIN7 (V_{DD})

Figure 23. Wake-up time, negative version of power supply at V_{IN} = 90VAC



Ch1: VPIN5 (Drain) Ch2: –5V level Ch3: –12V level Ch4: VPIN7 (V_{DD})

Figure 24. Wake-up time, negative version of power supply at V_{IN} = 230VAC

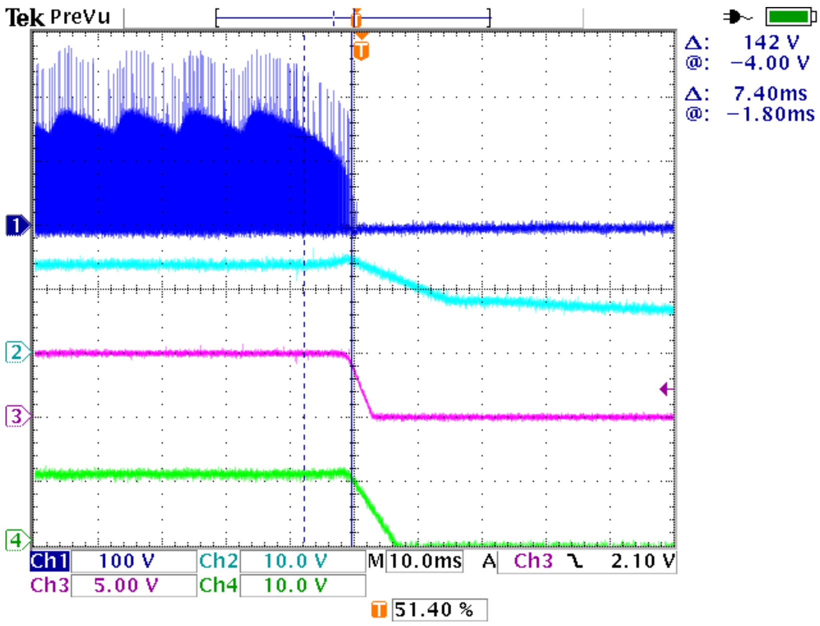


Ch1: VPIN5 (Drain) Ch2: –5V level Ch3: –12V level Ch4: VPIN7 (V_{DD})

5.5 Power down

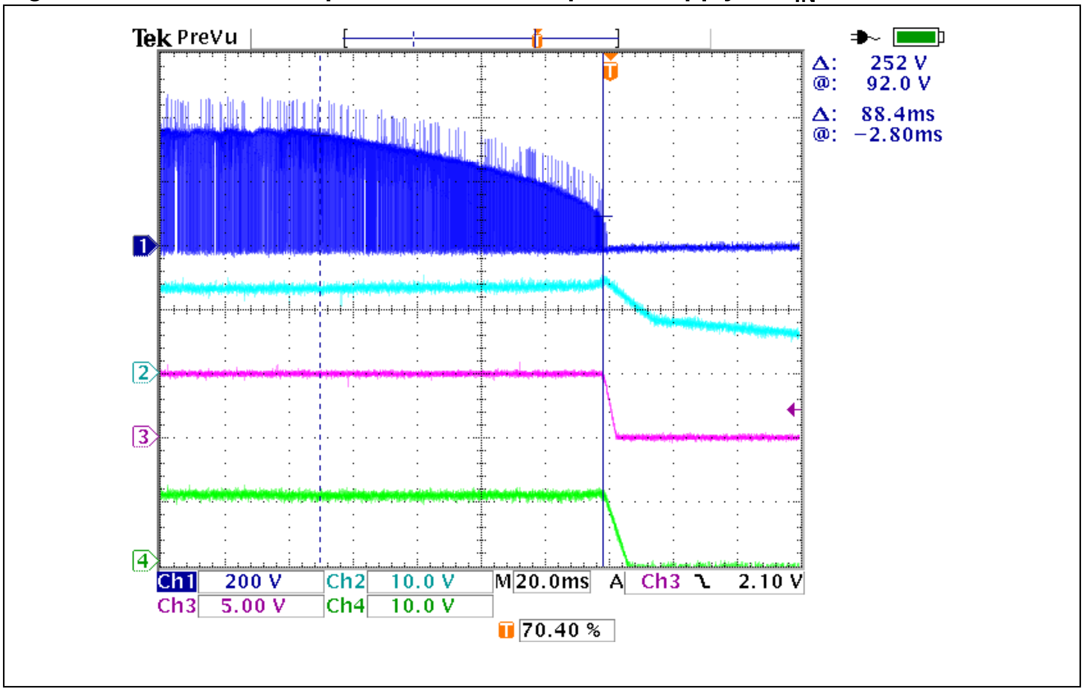
Figures 25 to 28 present the output voltages at converter switch off. All voltages fall at the same time, because the converter doesn't deliver any more energy. However, the slopes are individually driven by the output capacitors and the output current.

Figure 25. Power down, positive version of power supply at V_{IN} = 90VAC



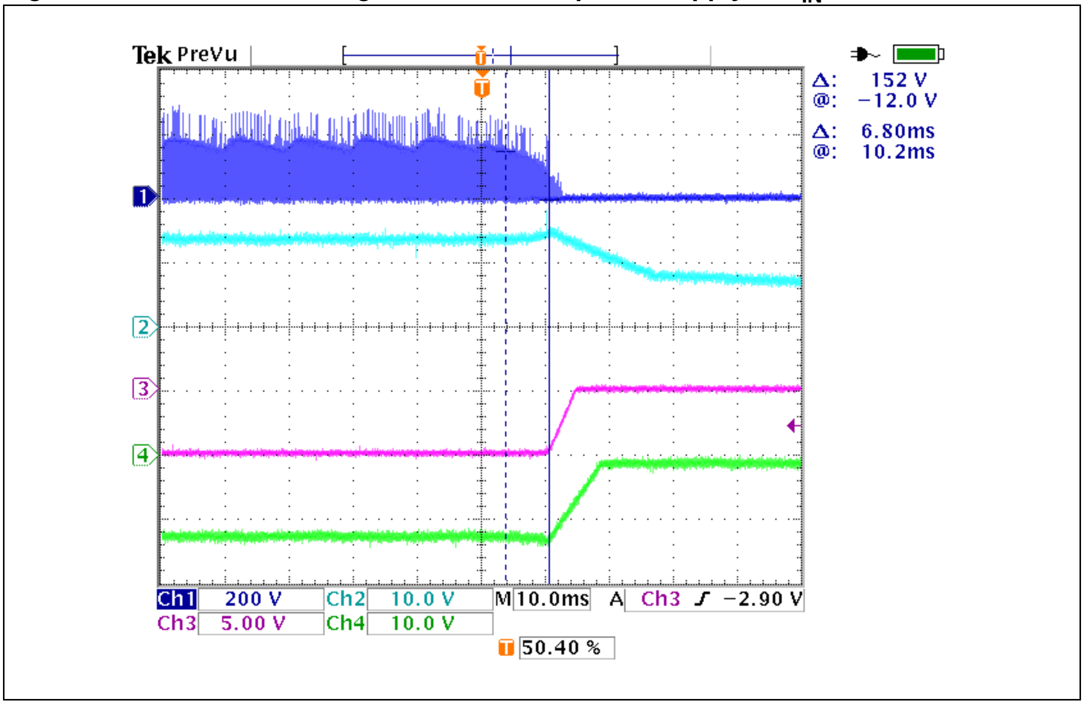
Ch1: VPIN5 (Drain) Ch2: VPIN7 (V_{DD}) Ch3: 5V level Ch4: 12V level

Figure 26. Power down, positive version of power supply at V_{IN} = 230VAC



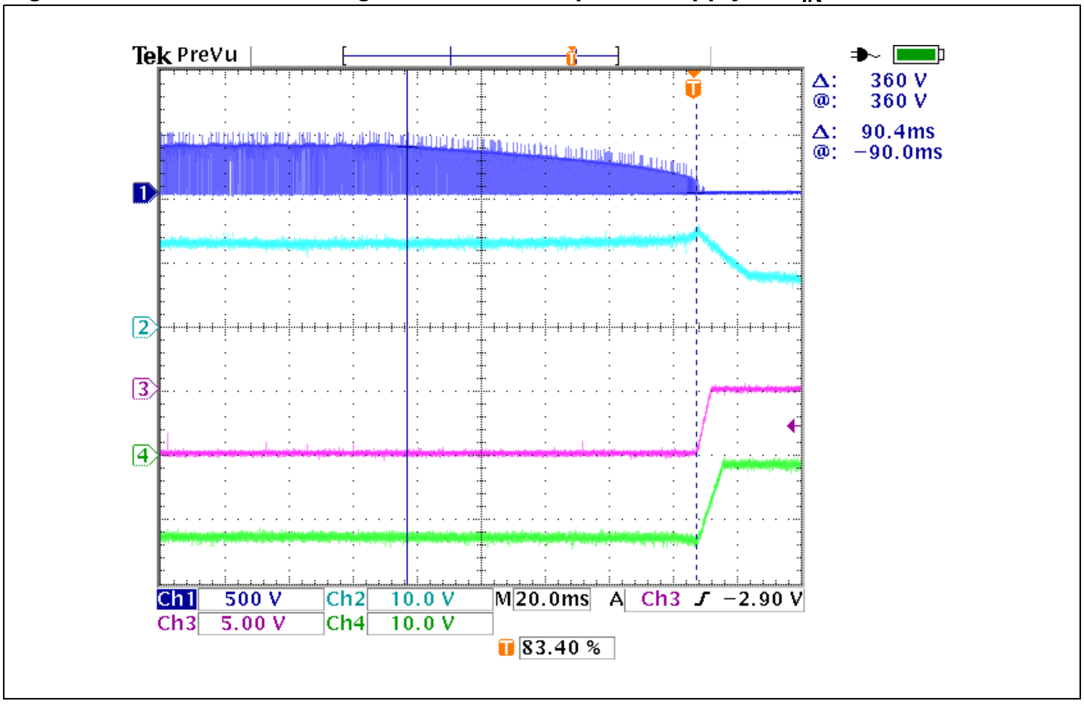
Ch1: VPIN5 (Drain) Ch2: VPIN7 (V_{DD}) Ch3: 5V level Ch4: 12V level

Figure 27. Power down, negative version of power supply at V_{IN} = 90VAC



Ch1: VPIN5 (Drain) Ch2: VPIN7 (V_{DD}) Ch3: –5V level Ch4: –12V level

Figure 28. Power down, negative version of power supply at V_{IN} = 230VAC



Ch1: VPIN5 (Drain) Ch2: VPIN7 (V_{DD}) Ch3: –5V level Ch4: –12V level

5.6 Overvoltage protection

The open-loop fault is a very dangerous, event which could happen as a result of feedback circuitry failure. If this occurs, the SMPS output voltages can rise causing the rectifiers and output capacitors to be overstressed, destroyed or even catch fire. However, this depends on the load of each output and the transformer coupling between the windings. The safety rules requests that the SMPS has to have suitable protection against such risks. The Viper53 has an integrated overvoltage comparator. The non inverting pin of the overvoltage comparator is connected to the V_{DD} pin. If the V_{DD} voltage reaches the V_{DD}ovp the Viper53EDIP stops operations.

The SMPS has been tested with opening the feedback loop. Measured data are shown in tables *11* and *12*.

Table 11. Output voltages with open feedback loop - positive version of power supply

V_{IN} 230VAC 50Hz	Stand by	Full load
3.3V	3.30V	3.28V
5.0V	8.29V	5.88V
12.0V	18.18V	13.71V

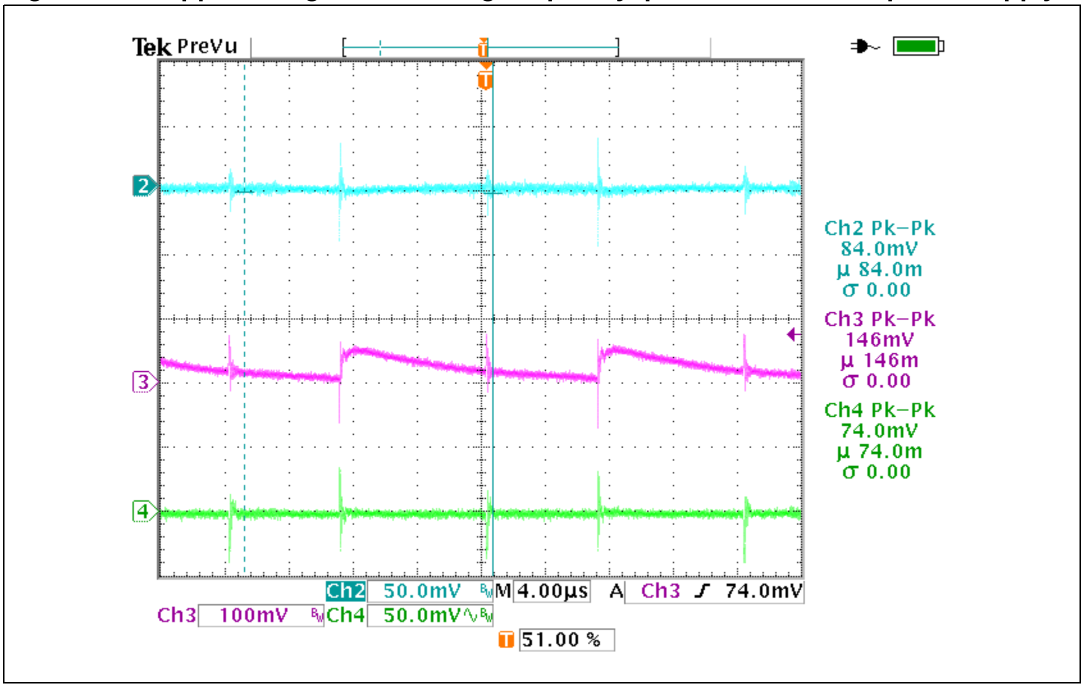
Table 12. Output voltages with open feedback loop - negative version of power supply

V_{IN} 230VAC 50Hz	Stand by	Full load
–5.0V	–8.47V	–6.06V
–12.0V	–18.35V	–14.22V

5.7 Output ripple voltage at full load

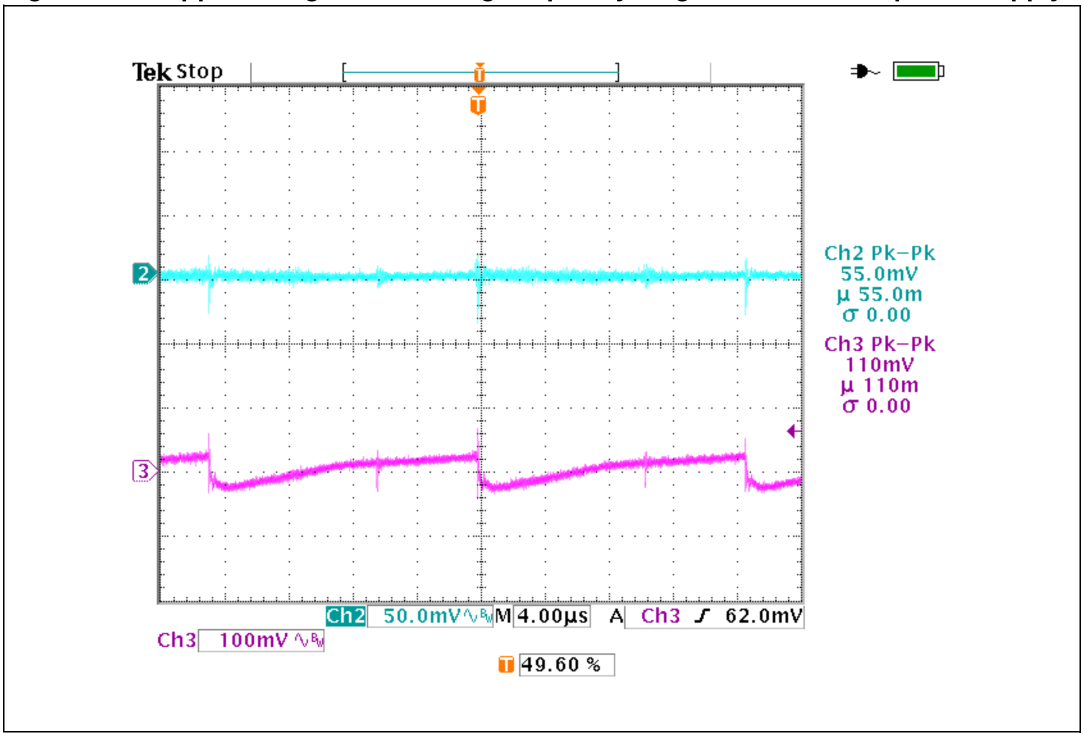
Figures *29* and *30* present the ripple voltage at switching frequency measured at 90VAC on the input. As shown, ripple voltage spikes are in line with power-supply specifications mainly thanks LC filters added on the outputs of positive and negative version of power supplies.

Figure 29. Ripple voltage at switching frequency, positive version of power supply



Ch2: 5V level Ch3: 12V level Ch4: 3.3V level

Figure 30. Ripple voltage at switching frequency, negative version of power supply



Ch2–5V level Ch3: –12V level

6 Conducted noise measurements

The following figures display the conducted noise measurements at full load when a mains voltage of 230VAC was applied on the input. The measurement was made in accordance with EN55022 CLASS B using Peak and Average detection. The diagrams clearly indicate a good margin of all measurements with respect to their limits.

Figure 31. Conducted noise measurements Phase A - positive version of power supply, peak detection

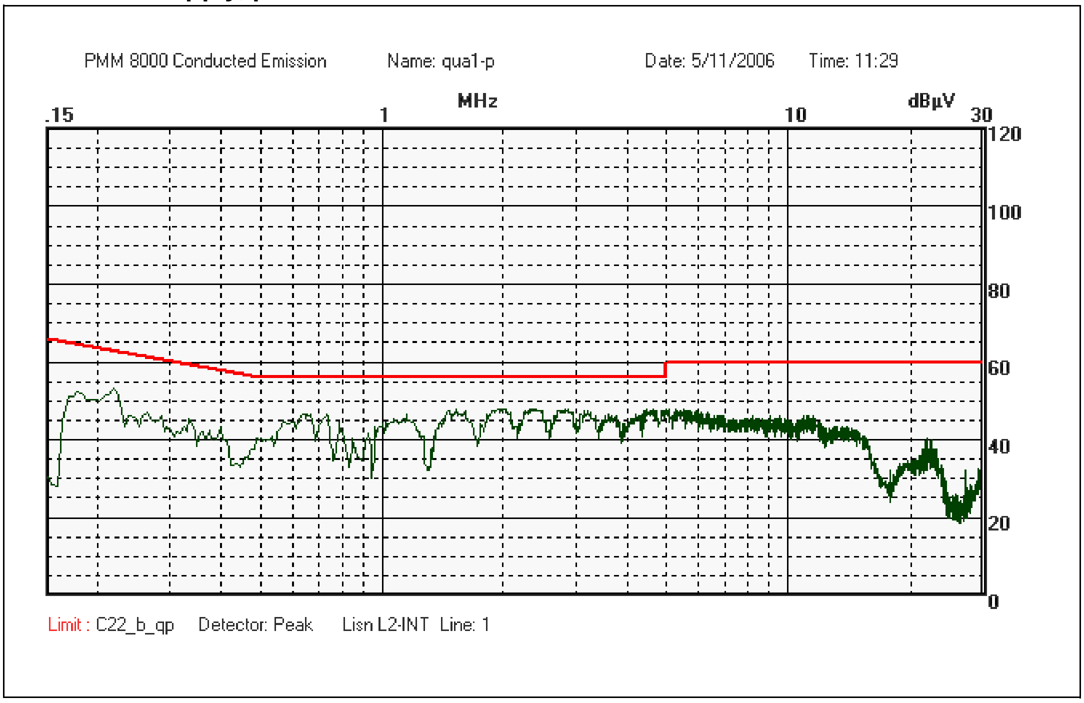


Figure 32. Conducted noise measurements Phase B - positive version of power supply, peak detection

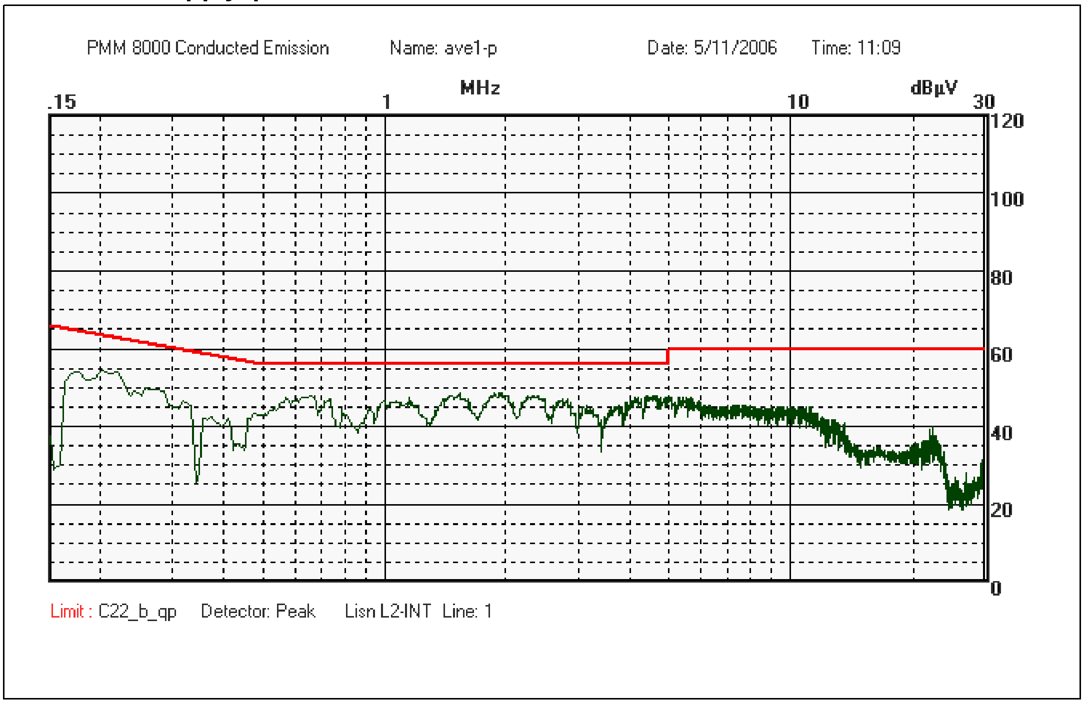


Figure 33. Conducted noise measurements Phase A - positive version of power supply, AVG detection

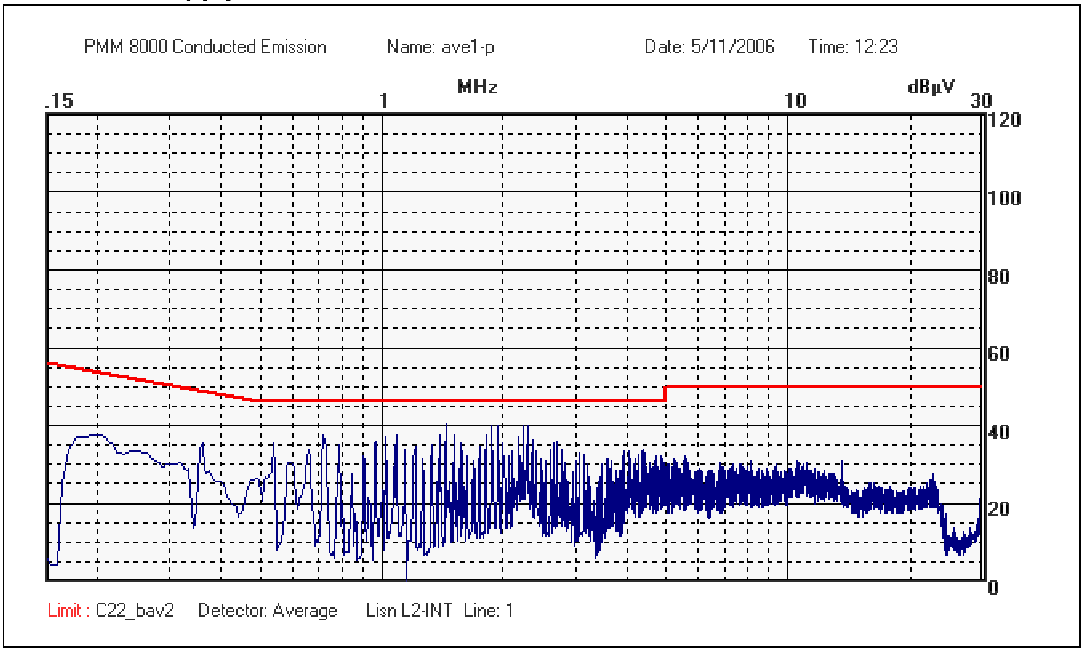


Figure 34. Conducted noise measurements Phase B - positive version of power supply, AVG detection

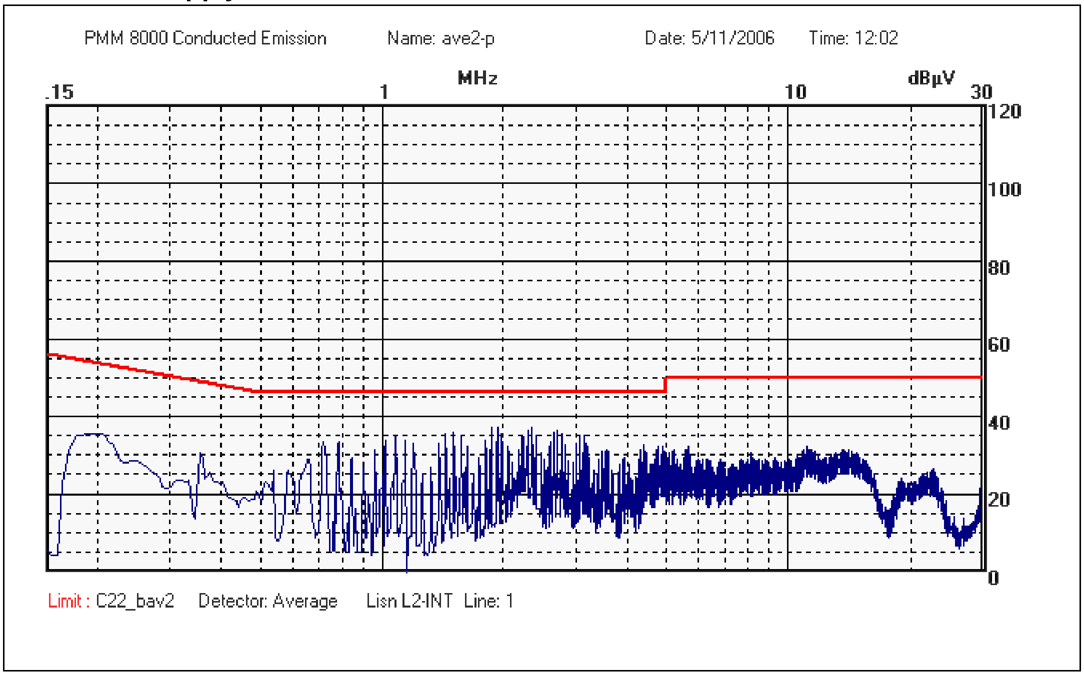


Figure 35. Conducted noise measurements Phase A - negative version of power supply, peak detection

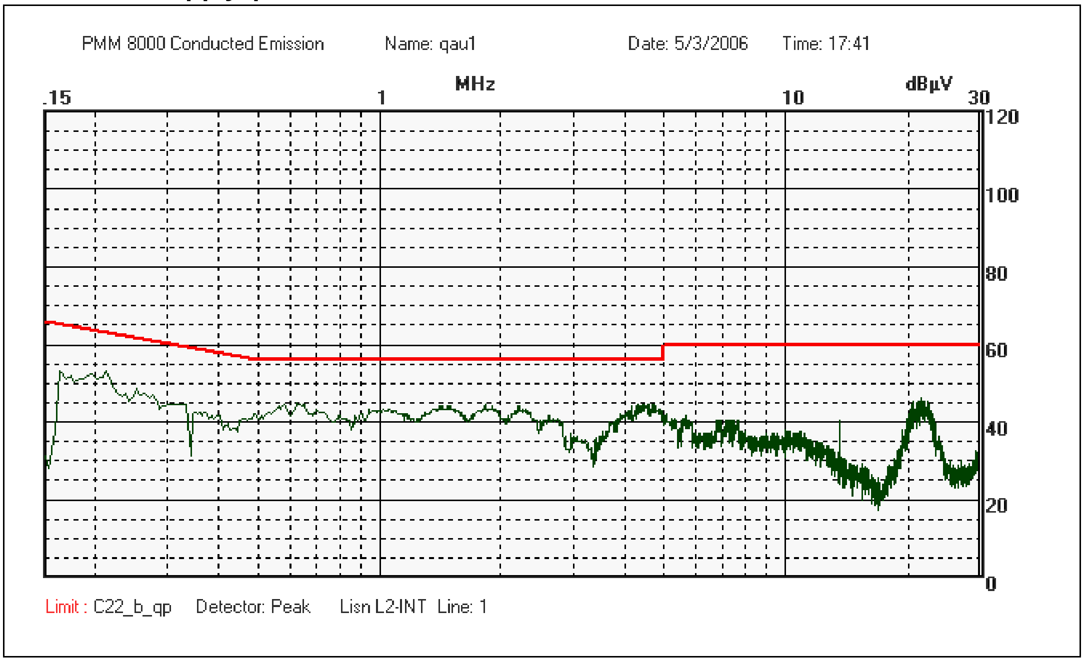


Figure 36. Conducted noise measurements Phase B - negative version of power supply, peak detection

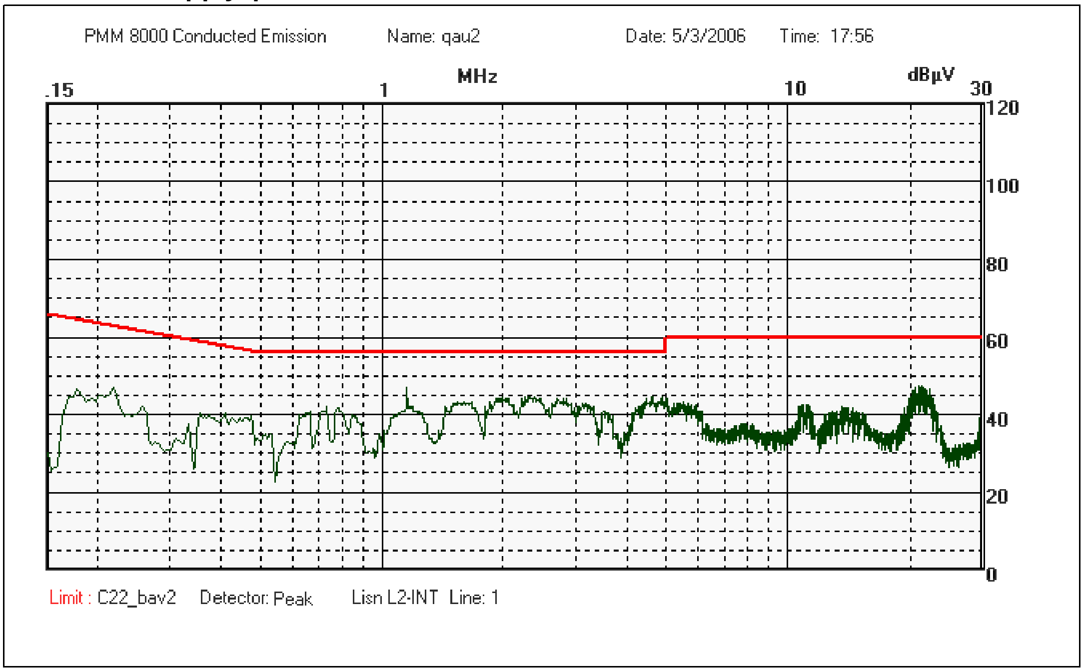


Figure 37. Conducted noise measurements Phase A - negative version of power supply, AVG detection

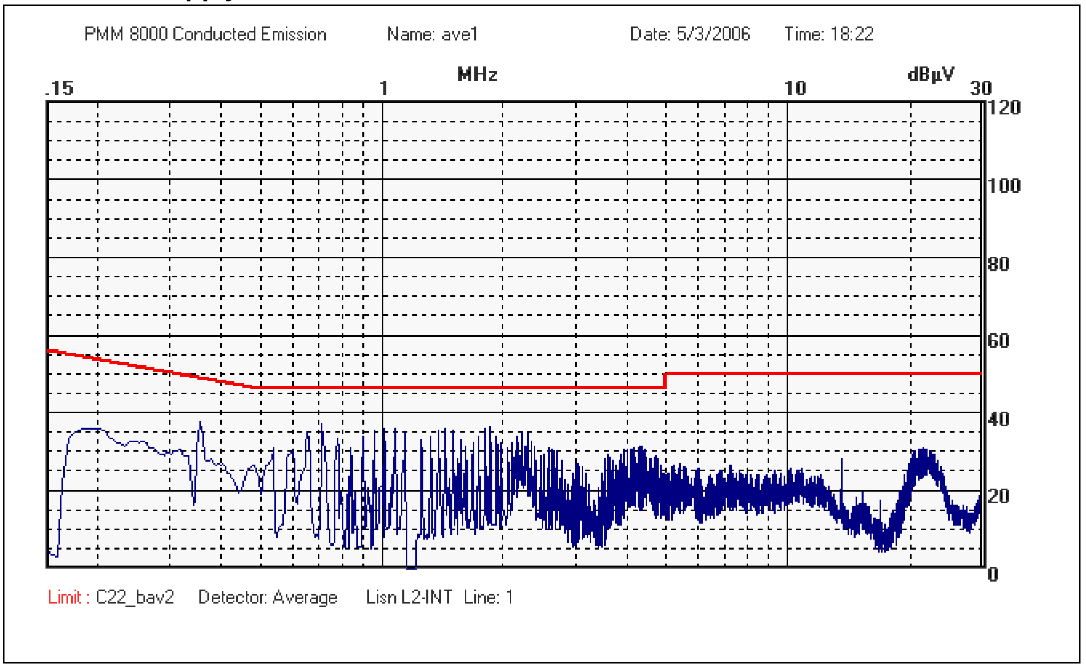
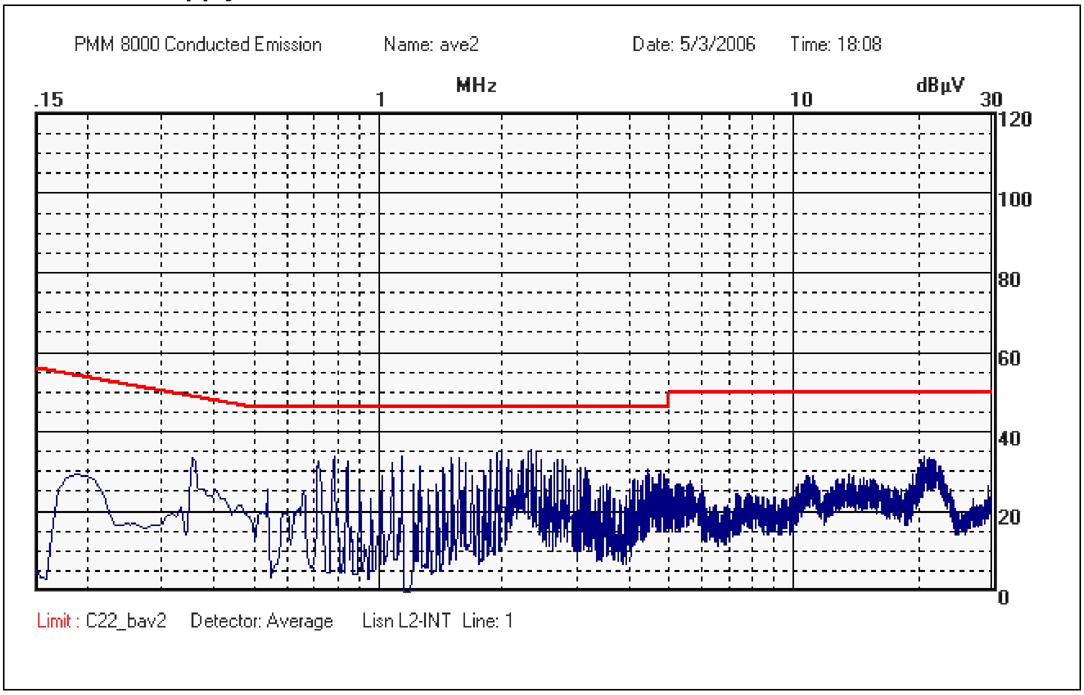


Figure 38. Conducted noise measurements Phase B - negative version of power supply, AVG detection



7 Part list

Table 13. Bill of material (Part 1 of 3)

Item	Part	Value	Description	Size	Assembly	Manufacturer	Order code	Version
1	R1	1M/5%	Resistor	1206	SMD	General		
2	R2	1M/5%	Resistor	1206	SMD	General		
3	R3	5k6/5%	Resistor	0805	SMD	General		
4	R4	5k1/5%	Resistor	0805	SMD	General		
5	R5	7k5/5%	Resistor	0805	SMD	General		
6	R6	220R/5%	Resistor	0805	SMD	General		Negative
7	R7	220R/5%	Resistor	0805	SMD	General		Positive
8	R8	0R	Resistor	1206	SMD	General		Positive
9	R9	0R	Resistor	0805	SMD	General		Negative
10	R10	10k/5%	Resistor	0805	SMD	General		
11	R11	15k/5%	Resistor	0805	SMD	General		
12	R12	15k/5%	Resistor	0805	SMD	General		
13	R13	150R	Resistor	1206	SMD	General		
14	R14	1k/5%	Resistor	0805	SMD	General		
15	RT1	15R	NTC resistor	D15 x 7.5	TH	Epcos	B57237S0150M 000	
16	F1	2A/T	Fuse	5 x 20	TH	General		
17	C1	100nF/275VAC	X2 capacitor	18 x 6	TH	Epcos	B32922A210M	
18	C2	100nF/275VAC	X2 capacitor	18 x 6	TH	Epcos	B32922A210M	
19	C3	68µF/400V	Electrolytic capacitor	D18 x 7.5	TH	Panasonic	EEUED2G680	
20	C4	4.7nF/50V	Ceramic capacitor, X7R	0805	SMD	General		
21	C5	39nF/50V	Ceramic capacitor, X7R	0805	SMD	General		
22	C6	150nF/16V	Ceramic capacitor, X7R	0805	SMD	General		
23	C7	22µF/35V	Electrolytic capacitor	D5 x 7.5	TH	Jamicon	SKR220M1ED11	
24	C8	120pF/50V	Ceramic capacitor, X7R	0805	SMD	General		
25	C9	470µF/25V	Electrolytic capacitor	D8 x 3.5	TH	Rubycon	25ZL470M8X20	
26	C10	1000µF/25V	Electrolytic capacitor	D10 x 5	TH	Rubycon	25ZL1000M12.5 X20	

Table 14. Bill of material (Part 2 of 3)

Item	Part	Value	Description	Size	Assembly	Manufacturer	Order code	Version
27	C11	1000µF/25V	Electrolytic capacitor	D10 x 5	TH	Rubycon	25ZL1000M12.5X20	
28	C12	100nF/50V	Ceramic capacitor, X7R	0805	SMD	General		
29	C13	470µF/25V	Electrolytic capacitor	D8 x 3.5	TH	Rubycon	25ZL470M8X20	
30	C14	33µF/35V	Electrolytic capacitor	D5 x 2	TH	Rubycon	35ZL33M5X11	
31	C15	100nF/50V	Ceramic capacitor, X7R	0805	SMD	General		
32	C16	2.2nF	Ceramic capacitor Y1	12 x 10 RM10	TH	Murata	DE1E3KX222MA5B	
33	C17	470nF/16V	Ceramic capacitor, X7R	0805	SMD	General		Positive
34	C18	100nF/50V	Ceramic capacitor, X7R	0805	SMD	General		Positive
35	L1	20mH/1A	CMC coil	24 x 19	TH	TDK	HF2430-203Y1R0-T01	
36	L2	3.3µH/3.8A	Inductor	D8.5 x 5	TH	TDK	TSL0808 - 3R3M3R8-PF	
37	L3	0.1µH/ 1.6A	Inductor	D4	TH	Fastron	SMCC-R10M	
38	D1	B250C1000SMD	Rectified bridge, 800V, 1A	DB-1S	SMD	General		
39	D2	STPS1150	Schottky diode, 150V, 1A	DO214AC	SMD	ST	STPS1150A	
40	D3	BAR18	Schottky diode, 80V, 70mA	SOT23	SMD	ST	BAR18	
41	D4	STTH1R06A	Ultrafast, 600V, 1A	DO214AC	SMD	ST	STTH1R06A	
42	D5	1.5KE150A	Transil	DO201	TH	ST	1.5KE150A	
43	D6	STPS1045D	Schottky diode, 45V, 10A	TO220AC	TH	ST	STPS1045D	Positive
44	D7	STPS1045D	Schottky diode, 45V, 10A	TO220AC	TH	ST	STPS1045D	Negative
44	D8	STPS2H100U	Schottky diode, 100V, 2A	SMB	SMD	ST	STPS2H100U	
45	D9	ZMM9.1V/2%	Zener diode	SOD80	SMD	General		
46	U1	VIPer53EDIP	PWW controller with MOSFET	DIP-8	TH	ST	VIPer53EDIP	
47	U2	PC817	Opto coupler	SO 4	SMD	General		

Table 15. Bill of material (Part 3 of 3)

Item	Part	Value	Description	Size	Assembly	Manufacturer	Order code	Version
48	U3	TL431	Voltage reference	TO 92	TH	ST	TL1431CZ/CZT/CZ-AP	
49	U4	L78L33	Linear regulator	TO92	TH	ST	L78L33CZ	Positive
50	Q1	BC807-40	NPN transistor	SOT23	SMD	ST	BC807-40	
51	T1	EER28	Transformer		TH	TDK	SRW28EC-X64V015	
52	H1		Heatsink 25 x 23 x16				GM code: V7142B	
	J1		Jumper					Positive
	J2		Jumper					Positive
	J3		Jumper					Negative
	J4		Jumper					Negative
	J5		Jumper					Positive
	J6		Jumper					Negative
	J7		Jumper					Positive
	J8		Jumper					Negative

8 PCB layout

Figure 39. Silk screen - top side

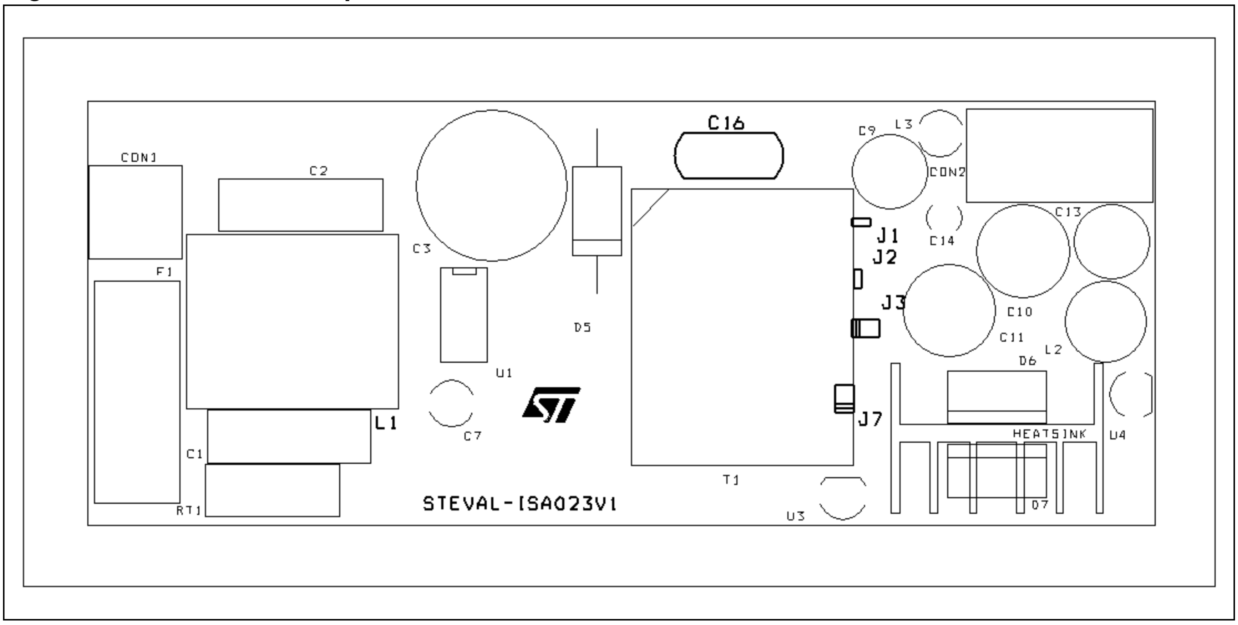


Figure 40. Silk screen - bottom side

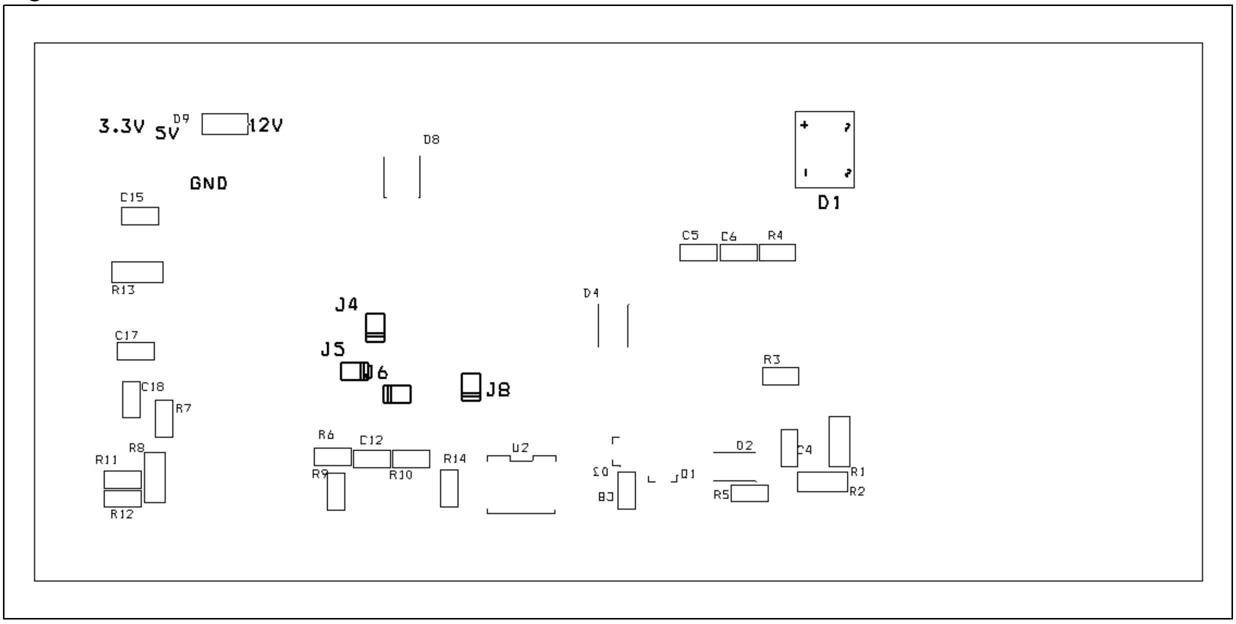
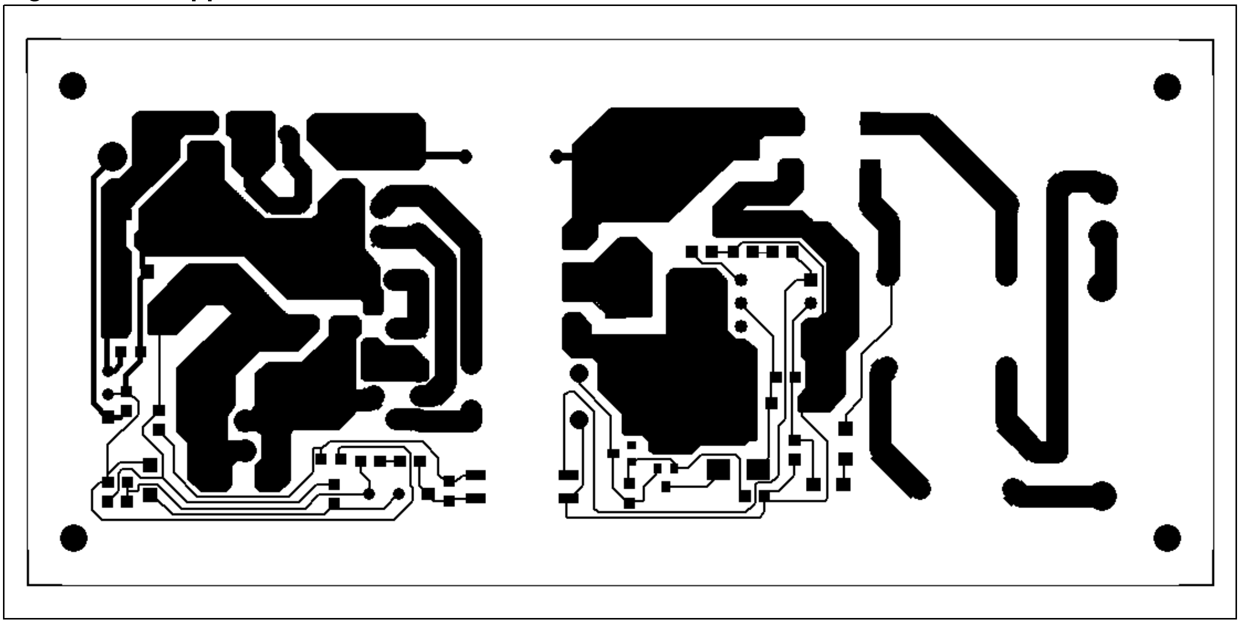


Figure 41. Copper tracks - bottom side



9 Transformer specification

- Application type: Consumer, Home Appliance
- Transformer type: Open
- Coil former: Vertical type 5 + 5 pins
- Maximum temperature rise: 45°C
- Maximum operating ambient temperature: 60°C
- Main insulation: Acc with EN60065.

9.1 Electrical characteristics:

- Converter topology: Flyback, CCM/DCM Mode
- Core type: EER28 - PC40 or equivalent
- Typical operating frequency: 60kHz
- Primary inductance: 600µH ±10% at 10kHz - 1V [a]
- Leakage inductance: 32µH MAX at 10kHz - 1V [b]
- Maximum peak primary current: 1.4 Apk
- RMS primary current: 0.45 ARMS.

a. Measured between pins 1-3

b. Measured between pins 1-3 with all secondary windings shorted.

Figure 42. Transformer layout

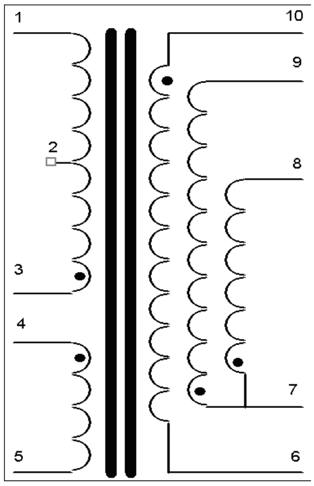


Figure 43. Dimension and appearance of transformer

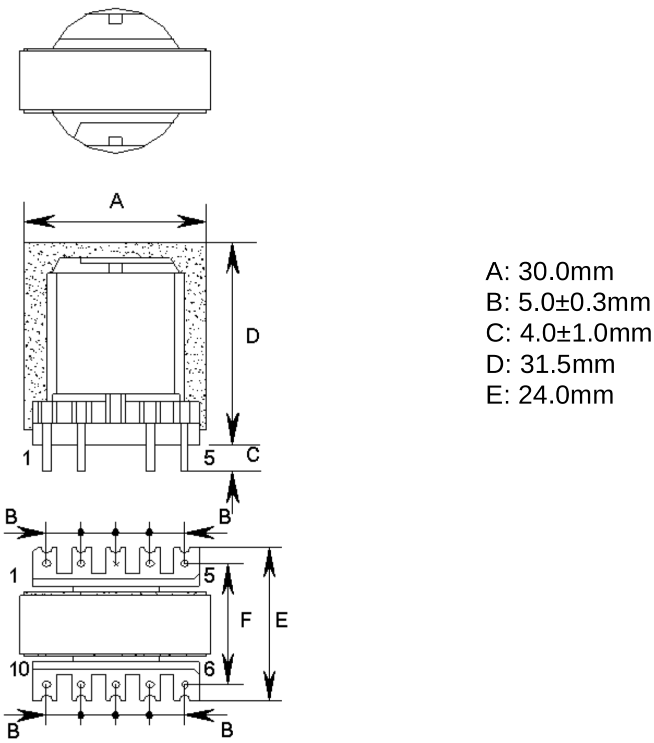
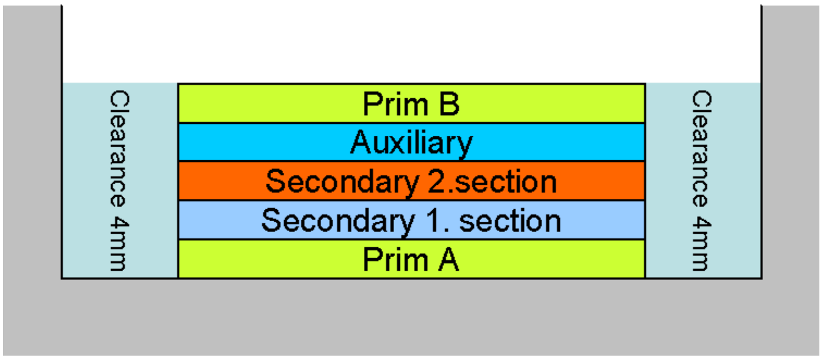


Table 16. Winding characteristics of transformer

Pins	Winding	RMS current	Number of turns
3-2	Primary -A	0.45A	35
7-8.9	Secondary 1.section	3.92A	6
6-10	Secondary 2.section	2.75A	7
4-5	Auxiliary	0.05A	14
2-1	Primary-B	0.45A	35

Figure 44. Winding position of transformer



9.2 Manufacturer

TDK Electronics Europe -Germany

Transformer P/N: SRW28EC-X64V015.

10 Revision history

Table 17. Document revision history

Date	Revision	Changes
11-Jan-2007	1	Initial release.