AN2929
Application note

Wide range [90 V - 265 V] input, 5 V - 12 W output VIPER27LN demonstration board with improved standby performance

Introduction

In consumer applications such as LCD or plasma TVs, some models of DVD recorders, set-top boxes with hard disk, as well as desktop computers, the power supply often includes two modules: the main power supply that provides most of the power and is off when the application is in standby mode and the auxiliary power supply that provides energy for specific peripherals such as USB ports, remote receivers, and modems.

The auxiliary power supply is also on when the application is in standby mode and it is often required that its input power be as low as possible. The demonstration board presented in this application note meets the specification of a wide range of auxiliary power supplies for these applications and is optimized for very low standby consumption, helping to meet the most stringent energy-saving requirements.

Figure 1. VIPER27LN demonstration board

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1 Board description

1.1 Electrical specifications

The electrical specifications of the VIPER27LN demonstration board are listed in *Table 1*.

Table 1. Electrical specifications

Symbol	Parameter	Value	Unit
V_{IN}	Input voltage range	[90V_{RMS}; 265V_{RMS}]	V
V_{OUT}	Output voltage	5	V
I_{OUT}	Max output current	2.4	A
Δ_{VOUT_LF}	Precision of output regulation	±5%	
Δ_{VOUT_HF}	High-frequency output voltage ripple	50	mV
T_A	Max ambient operating temperature	60	°C

1.2 Schematic and bill of material

The schematic of the board is shown in *Figure 2*. *Table 2* gives the list of components (bill of material).

Figure 2. Schematic

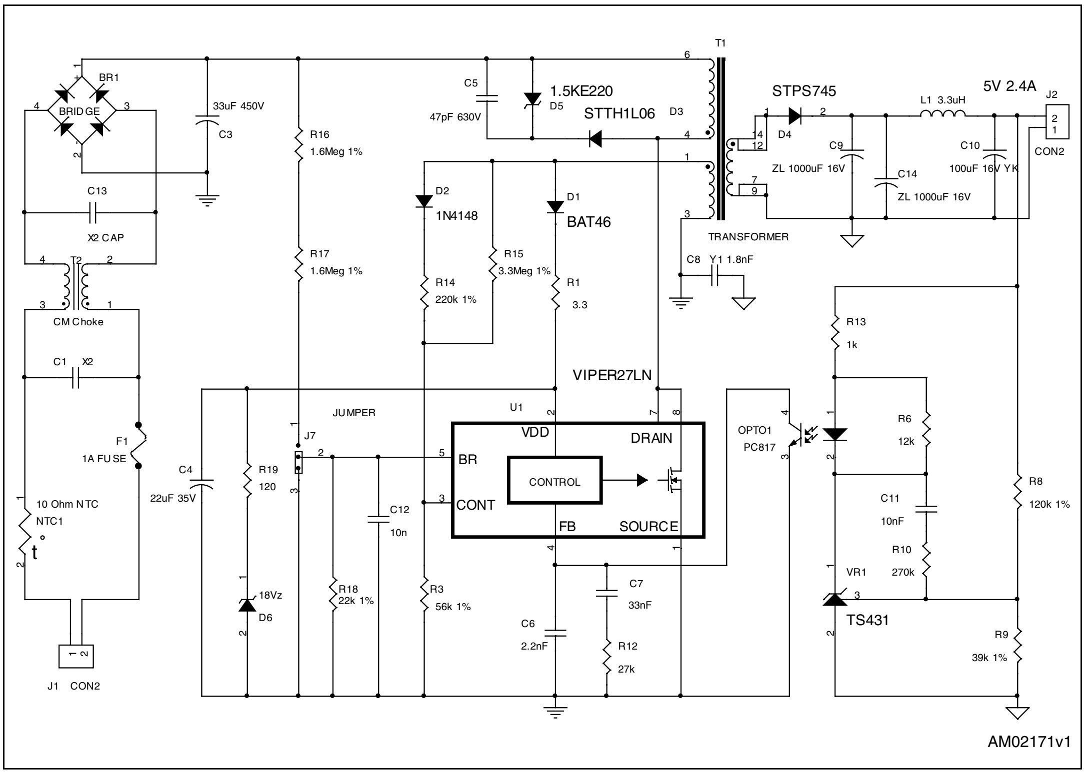


Table 2. **Bill of material**

Reference	Part	Description	Manufacturer
BR1	DF06M	600 V 1 A diodes bridge	Fairchild \ General Semiconductor
C1, C13		22 nF X2 capacitor	Evox Rifa
C3		450 V 33 µF electrolytic capacitor	
C4		35 V 22 µF electrolytic capacitor	
C5	Not mounted	Not mounted	
C6		25 V ceramic capacitor	
C7		25 V ceramic capacitor	
C8		Y1 2.2 nF capacitor	
C9, C14	16 V ZL 1000 µF 10X20	1000 µF 16 V electrolytic capacitor	Rubycon
C10	16 V 100 µF YK	100 µF 16 V YK rubycon	Rubycon
C11, C12	10 nF	25 V ceramic capacitor	
D1	BAT46	Diode	STMicroelectronics
D2	1N4148	Diode	
D3	STTH1L06	Diode	STMicroelectronics
D4	STPS745	Diode	STMicroelectronics
D5	1.5KE250	Transil	STMicroelectronics
D6	BZX79-C18	Zener diode	NXP
F1	TR5 250 V 1 A	Fuse	
L1		3.3uH	
NTC1	B57236S160M	16 Ω NTC	EPCOS
OPTO1	PC817	Opto coupler	Sharp
R1		3.3 Ω axial resistor	
R16, R17		1600 kΩ 1% axial resistor	
R3		56 kΩ 1% axial resistor	
R6		12 kΩ axial resistor	
R8		120 kΩ 1% axial resistor	
R9		39 kΩ 1% resistor	
R10		270 kΩ axial resistor	
R14		220 kΩ 1% axial resistor	
R12		27 kΩ axial resistor	
R13		1 kΩ axial resistor	
R19		120 Ω axial resistor	
R20		Heatsink	

Table 2. Bill of material (continued)

Reference	Part	Description	Manufacturer
T1	750871111	Switch-mode power transformer	Würth Elektronik
T2	BU15-4530R4BL	Common-mode choke	Coilcraft
U1	VIPER27LN	Offline high-voltage converters	STMicroelectronics
VR1	TS431AIZ-AP	Voltage reference	STMicroelectronics

1.3 Transformer

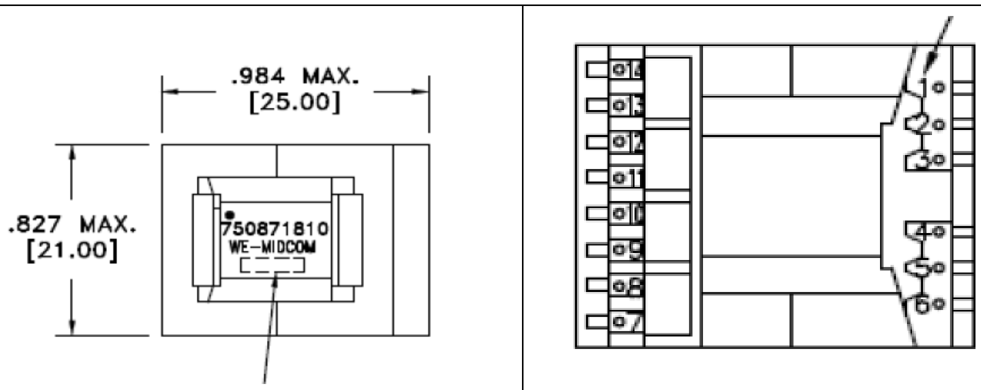
The transformer characteristics are listed in the table below.

Table 3. Transformer characteristics

Properties	Test condition	Value
Manufacturer		Würth Elektronik
Part number		750871111
Primary inductance	Measured at 10 kHz 0.1 V	1.7 mH ± 10%
Leakage inductance	Measured at 100 kHz 0.1 V	60 µH
Primary-to-secondary turn ratio (6 - 4)/(7, 9 – 12, 14)	Measured at 10 kHz 0.1 V	13.5 ± 3%
Primary-to-auxiliary turn ratio (6 - 4)/(3 - 1)	Measured at 10k Hz 0.1 V	5.19 ± 3%
Insulation	Primary to secondary	4 kV

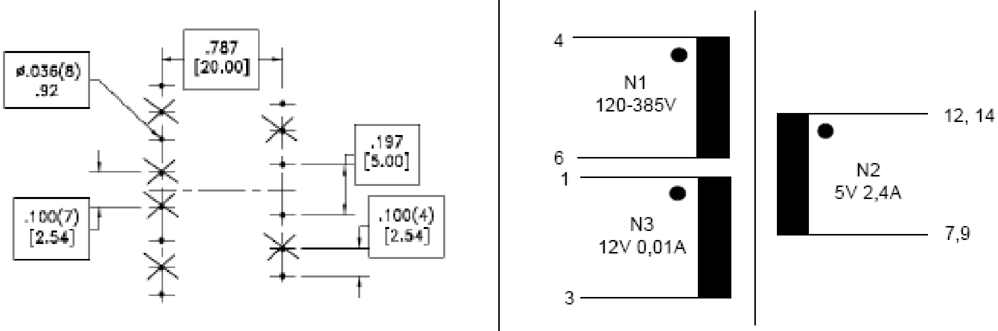
The figures below show the size and pin distances (inches and [mm]) of the transformer.

Figure 3. Transformer size



(a) Top view (b) Bottom view

Figure 4. Transformer size and pin diagram [inches (mm)]



(a) Pins distances (b) Electrical diagram

2 Testing the board

2.1 Typical board waveforms

Drain voltage and current waveforms were captured for the two nominal input voltages and for the minimum and the maximum voltage of the converter's input operating range.

Figure 5 and *Figure 6* show the drain current and the drain voltage waveforms at the nominal input voltages of 115 V_{AC} and 230 V_{AC} when the load is the maximum (2.4 A). *Figure 7* and *Figure 8* show the same waveforms for the same load condition, but for the minimum (90 V_{AC}) and the maximum (265 V_{AC}) input voltages.

The converter is designed to operate in continuous conduction mode (in full-load condition) at low line. CCM (continuous conduction mode) allows reducing the root mean square current values at the primary side in the power switch inside the VIPER27LN and at the secondary side in the output diode (D4) and in the output capacitors (C9 and C14). Reducing RMS currents means reducing the power dissipation (mainly in the VIPER27LN) and the stress on these components.

Figure 5. Drain current and voltage at full load 115 V_{AC}

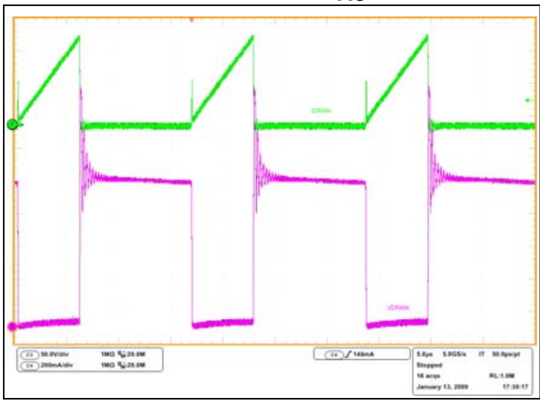


Figure 6. Drain current and voltage at full load 230 V_{AC}

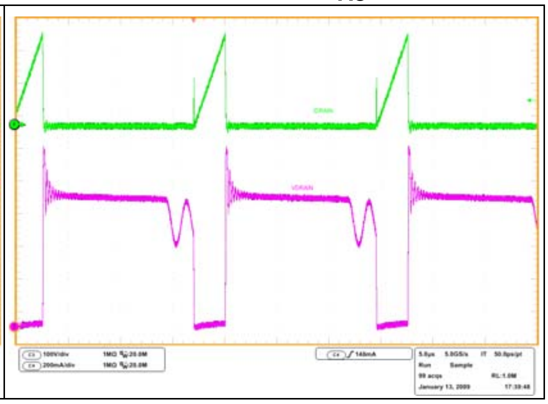


Figure 7. Drain current and voltage at full load 90 V_{AC}

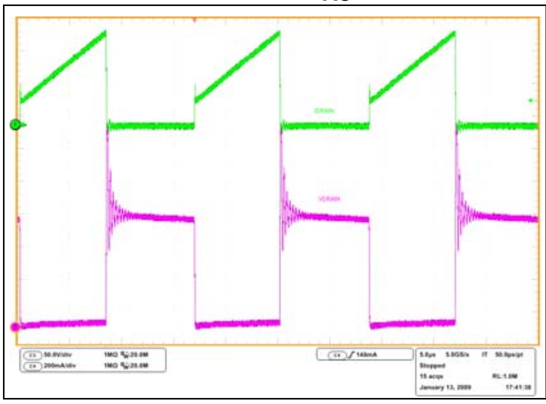
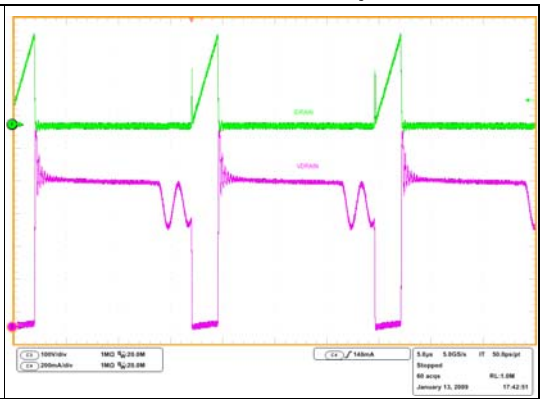


Figure 8. Drain current and voltage at full load 265 V_{AC}



2.2 Precision of the regulation and output voltage ripple

The output voltage of the board was measured in different line and load conditions (see *Table 4*). The output voltage is practically not affected by the line condition. The V_{DD} voltage was also measured to verify that it is inside the operating range of the device.

Table 4. Output voltage and V_{DD} line-load regulation

V_{INAC} (V)	No load		Half load		Full load	
	V_{OUT} (V)	V_{DD} (v)	V_{OUT} (V)	V_{DD} (V)	V_{OUT} (V)	V_{DD} (V)
90	5.05	9.79	5.05	18.9	5.04	19.8
115	5.05	9.71	5.05	18.9	5.04	19.7
230	5.05	9.37	5.05	18.8	5.04	19.6
265	5.05	9.22	5.05	18.8	5.04	19.6

In a dual-output flyback converter, when just one output is regulated, the unregulated output does not rigorously respect the turn ratio. The unregulated output voltage value depends not only on the turn ratio but also, approximately, from the output current ratio (output current of the regulated output divided by the output current of the unregulated output).

As confirmed from the results in *Table 4*, the V_{DD} voltage (unregulated auxiliary output) increases as the load on the regulated output increases. In order to avoid that the V_{DD} voltage exceeds its operating range, an external clamp was used (D6, R19). See schematic in *Figure 2*.

The ripple at the switching frequency superimposed at the output voltage was also measured and the results are given in *Table 5*. The board is provided with an LC filter for cleaner output voltage. The high-frequency voltage ripple across capacitor C9 (V_{OUT_FLY}), which is the output capacitor of the flyback converter before the LC filter, was also measured to verify the effectiveness of the LC filter and to provide complete results.

Table 5. Output voltage ripple

V_{INAC} (V_{RMS})	Half load		Full load	
	V_{OUT} (mV)	V_{OUT_FLY} (mV)	V_{OUT} (mV)	V_{OUT_FLY} (mV)
90	25	275	40	172
115	26	275	37	201
230	26	273	36	194
265	25	272	36	195

The waveforms of the two voltages (V_{OUT} and V_{OUT_FLY}) are shown in the figures below.

Figure 9. Output voltage ripple 115 V_{INAC} full load

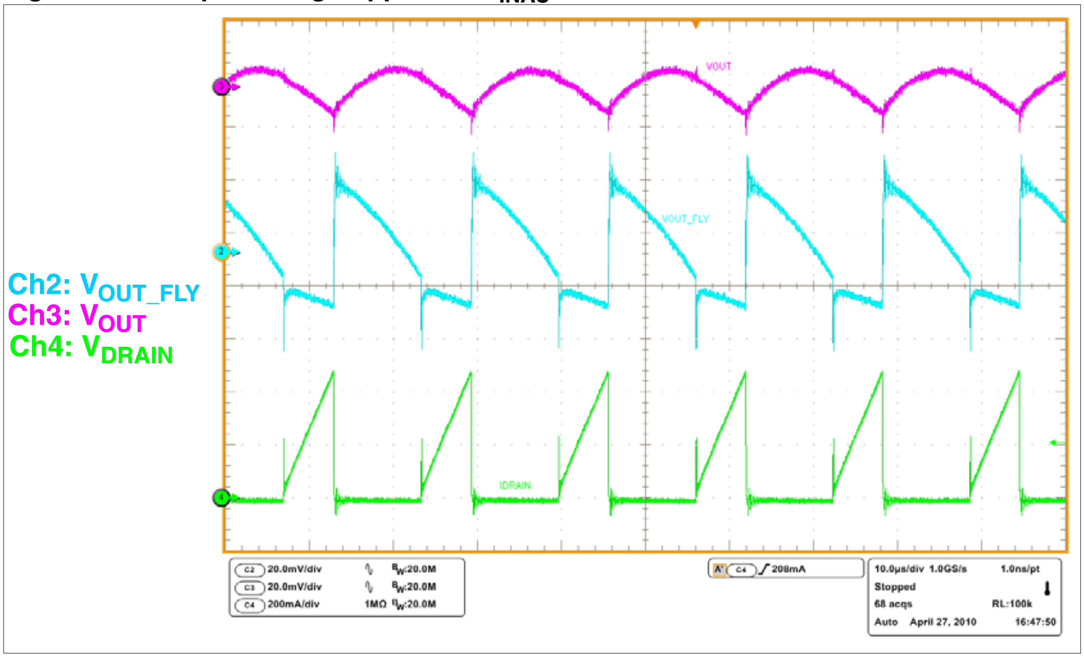
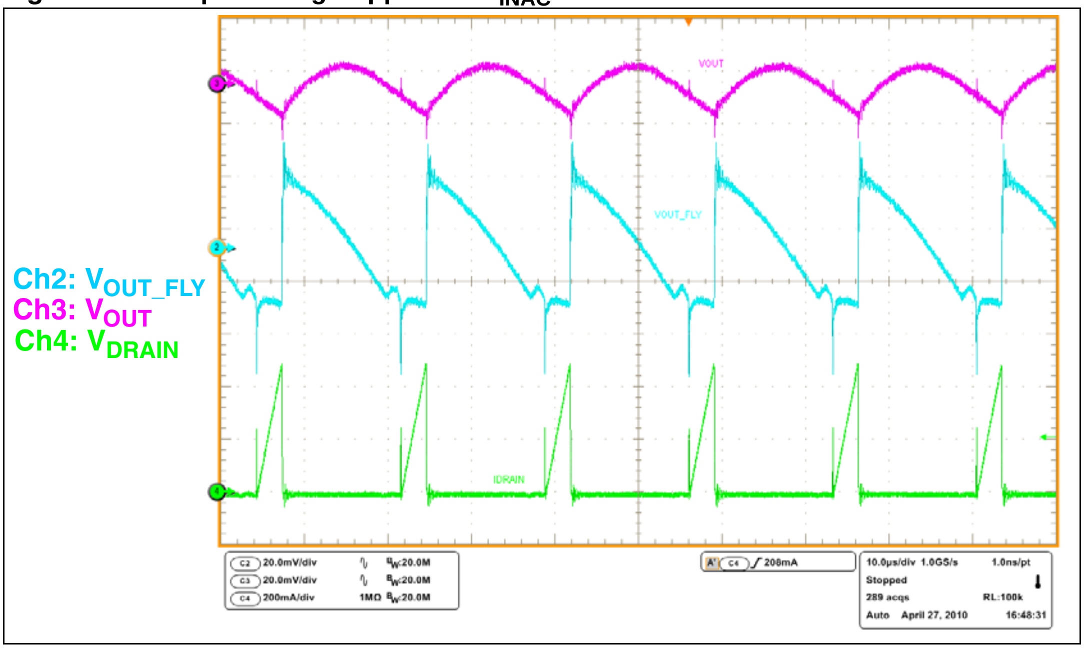


Figure 10. Output voltage ripple 230 V_{INAC} full load



When the device is working in burst mode, a lower frequency ripple is present. In this mode of operation the converter does not supply continuous power to its output. It alternates periods when the power MOSFET is kept off and no power is processed by the converter, and periods when the power MOSFET is switching and power flows towards the converter output. Even if no load is present at the output of the converter, during no switching periods, the output capacitors are discharged by their leakage currents and by the currents needed to supply the circuitry of the feedback loop present at the secondary side. During the switching period the output capacitance is recharged. The figures below show the output voltage and the feedback voltage when the converter is not loaded. In *Figure 11* the converter is supplied with 115 V_{AC} and with 230 V_{AC} in *Figure 12*.

Figure 11. Output voltage ripple 115 V_{INAC} at no load (burst mode)

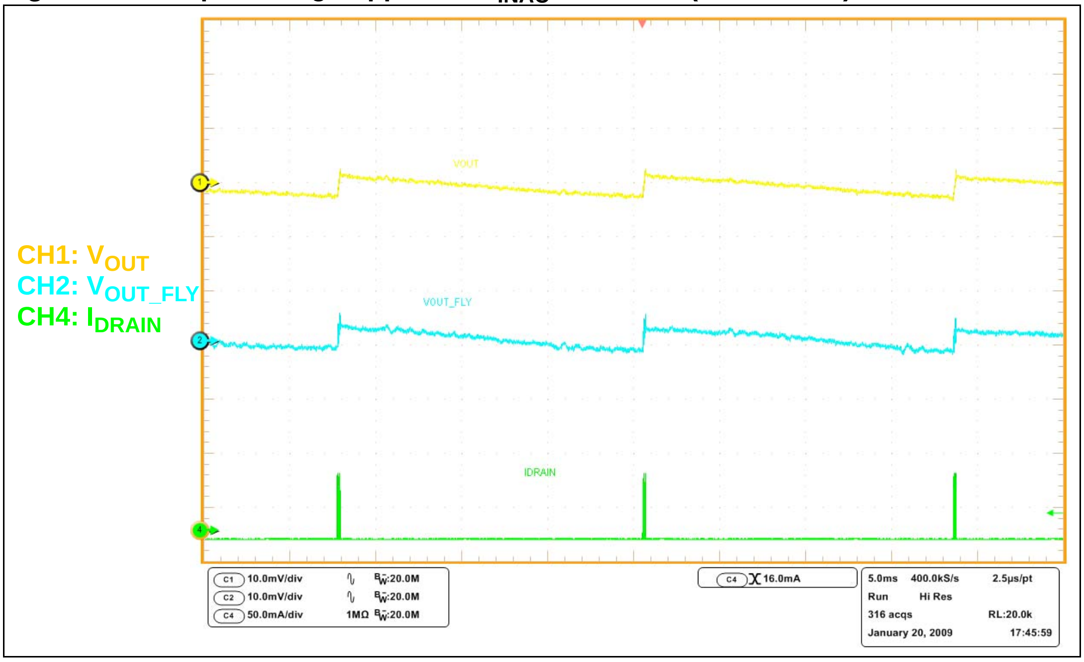


Figure 12. Output voltage ripple 230 V_{INAC} 50 mA at no load (burst mode)

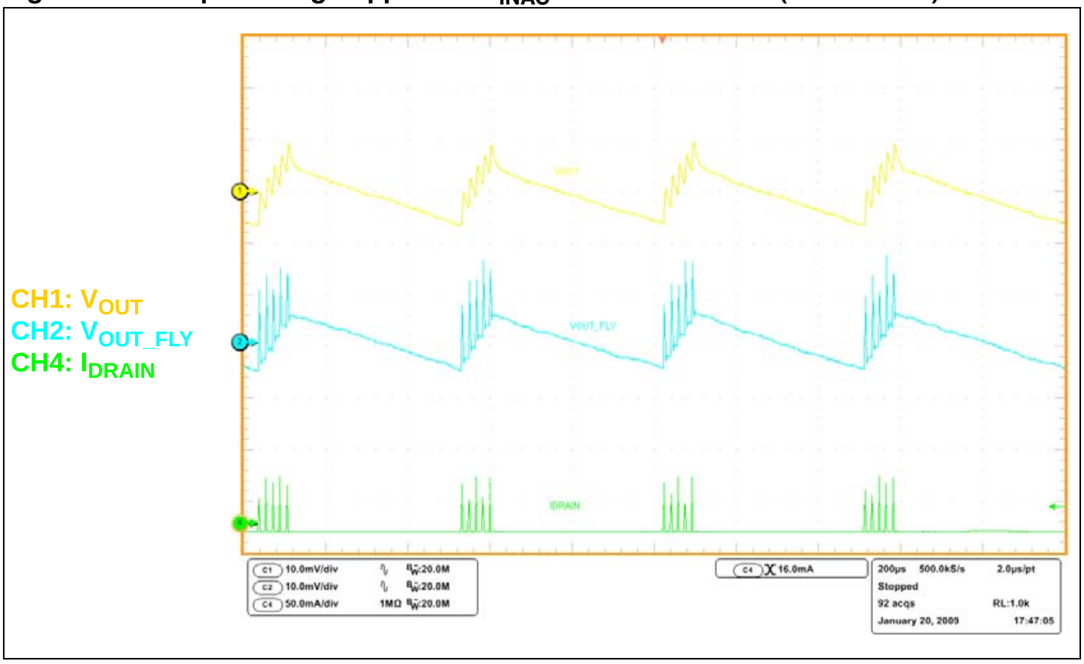


Table 6 shows the measured value of the burst mode related ripple measured in different operating conditions. The measured ripple in burst mode operation is very low and always below 25 mV.

Table 6. Burst mode related output voltage ripple

V_{IN}	No load (mV)	25 mA load (mV)	50 mA load (mV)
90	5.1	13.5	14.5
115	5.2	14.5	15.5
230	5.4	15.4	16.9
265	5.7	15.8	18

2.3 Efficiency

The efficiency of the converter was measured in different load and line voltage conditions. According to the ENERGY STAR® average active mode testing efficiency method, the measurements were done with full load and with 75%, 50%, and 25% of the full load for different input voltages, see *Table 7*.

Table 7. Efficiency

V_{INAC} (V_{RMS})	Efficiency (%)			
	Full load (2.4 A)	75% load (1.8 A)	50% load (1.2 A)	25% load (0.6 A)
90	72.46	75.34	78.503	79.841
115	74.96	76.95	79.634	80.395
230	77.70	79.04	80.690	79.990
265	77.80	78.97	80.264	78.287

The results were plotted in the following figures for better visibility. *Figure 13* shows the efficiency versus V_{IN} for the four different load values and *Figure 14* shows the efficiency versus load for different input voltages.

Figure 13. Efficiency vs. V_{IN}

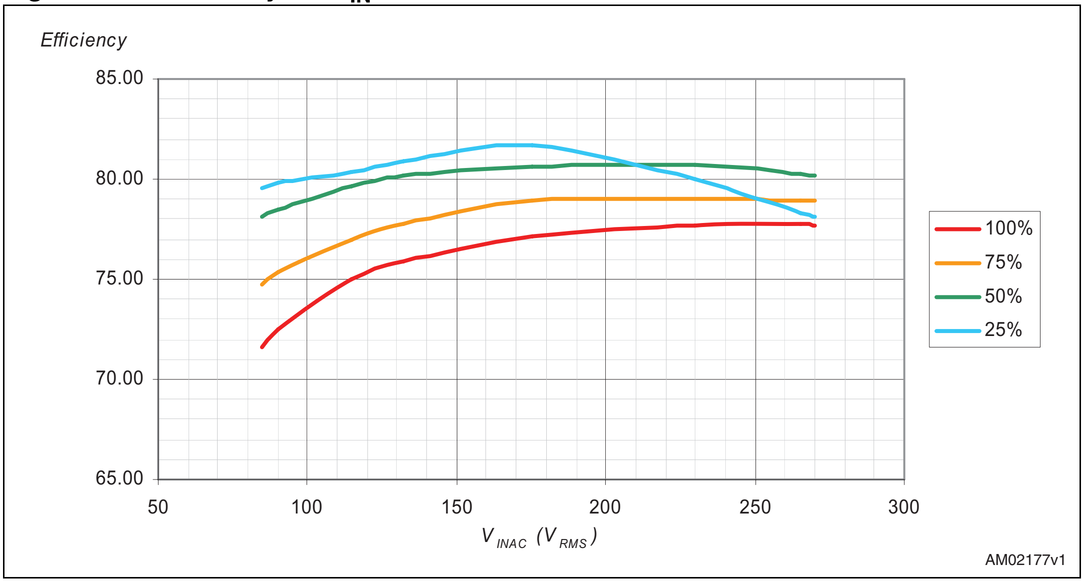
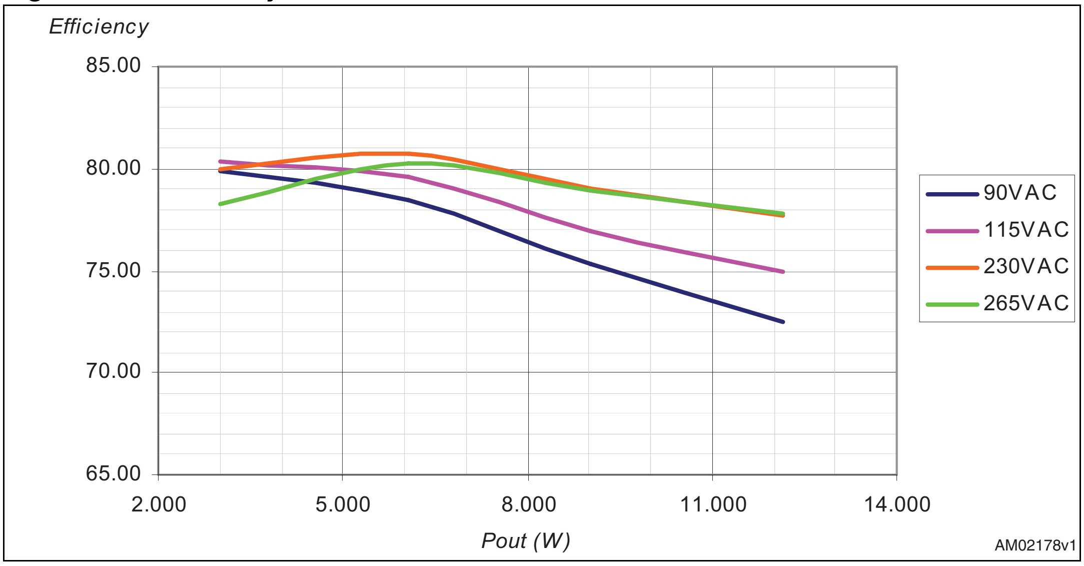


Figure 14. Efficiency vs. load



The active mode efficiency is defined as the average of the efficiencies measured at 25%, 50% and 75% of maximum load and the maximum load itself. Table 8 gives the active mode efficiencies calculated from the Table 7 measured values. For clarity the values from Table 8 are plotted in Figure 15. Figure 16 shows the averaged (average was done considering the efficiency at different input voltage) value of the efficiency versus load.

Table 8. Active mode efficiencies

V_{INAC} (V_{RMS})	Efficiency (%)
90	76.54
115	77.98
230	79.35
265	78.83

Figure 15. Active mode efficiency vs. V_{IN}

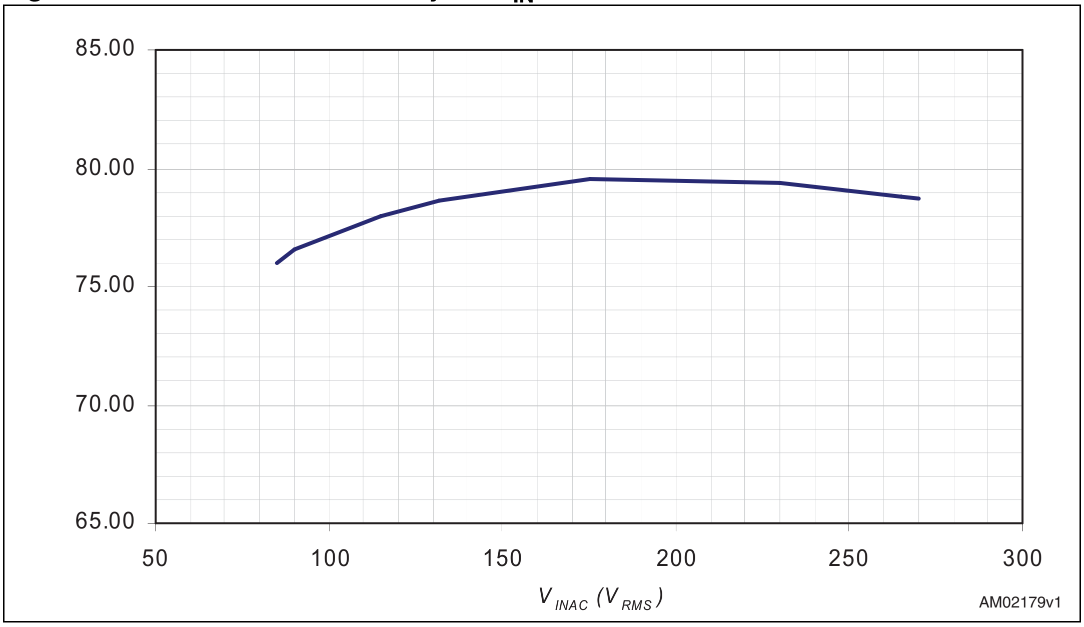
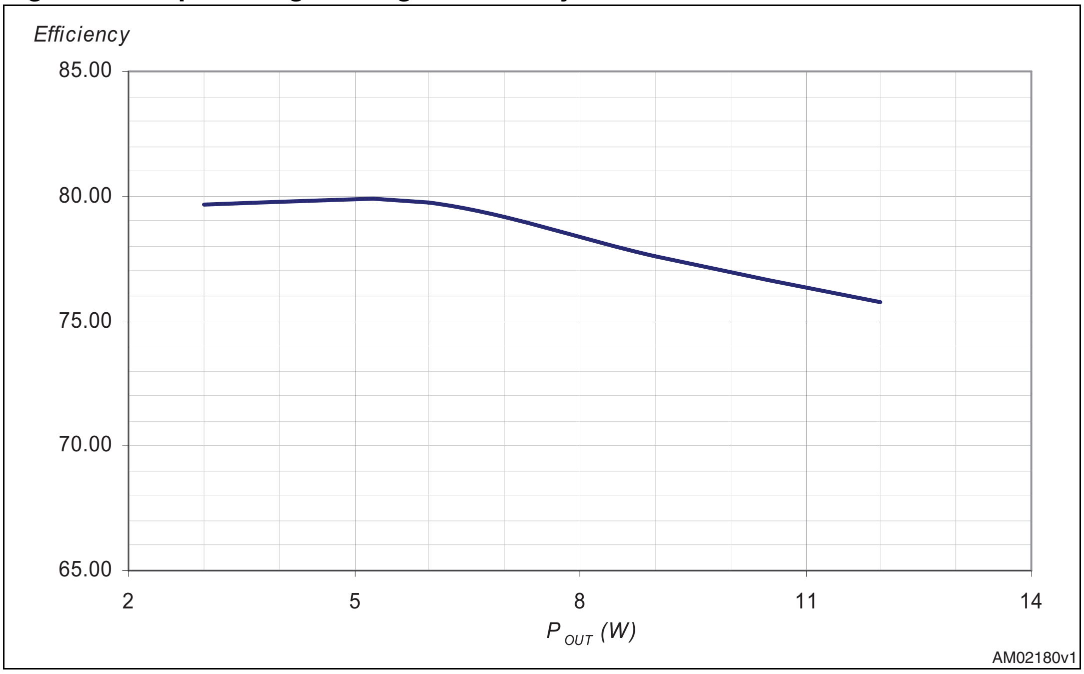


Table 9. Line voltage averaged efficiency vs. load

Load (% of full load)	Efficiency (%)
100	79.39
75	79.85
50	78.67
25	75.56

Figure 16. Input voltage averaged efficiency vs. load



In the version 2.0 of the ENERGY STAR® program requirement for single voltage external AC-DC power supplies (see *Section 4: References*), the power supplies are divided in two categories: low-voltage power supplies and standard power supplies with respect to the nameplate output voltage and current. An external power supply, in order to be considered a low-voltage power supply, needs to have a nameplate output voltage lower than 6 V and a nameplate output current greater than or equal to 550 mA.

The tables below give the EPA energy efficiency criteria for AC-DC power supplies in active mode for standard models and for low-voltage models, respectively.

Table 10. Energy efficiency criteria for standard models

Nameplate output power (P_{no})	Minimum average efficiency in active mode (expressed as a decimal)
0 W < P_{no} ≤ 1 W	= 0.48 * P_{no} + 0.140
1 W < P_{no} ≤ 49 W	= [0.0626 * ln (P_{no})] + 0.622
P_{no} > 49 W	= 0.870

Table 11. Energy efficiency criteria for low-voltage models

Nameplate output power (P_{no})	Minimum average efficiency in active mode (expressed as a decimal)
0 W < P_{no} ≤ 1 W	= 0.497 * P_{no} + 0.067
1 W < P_{no} ≤ 49 W	= [0.075 * ln (P_{no})] + 0.561
P_{no} > 49 W	= 0.860

Figure 17. ENERGY STAR® efficiency criteria

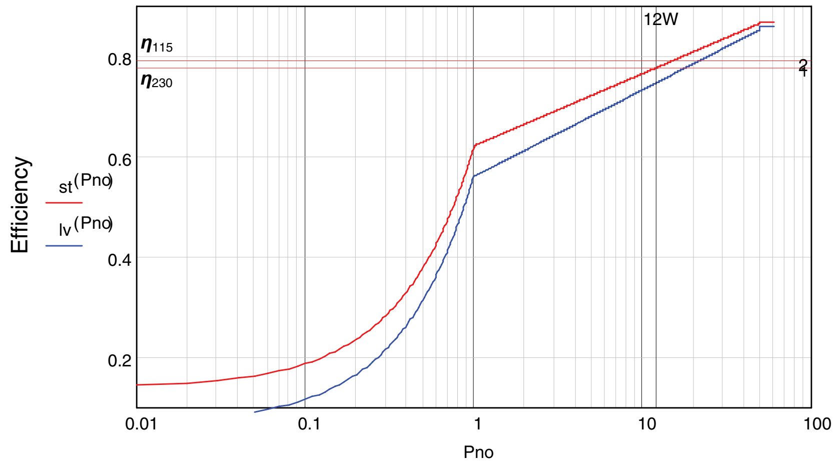


Figure 17 shows the efficiency criteria where the red line is the criteria for the standard model and the blue line is the criteria for the low-voltage model. The P_{NO} axe is in logarithmic scale.

The power supply presented belongs to the low-voltage power supply category and, in order to be compliant with ENERGY STAR® requirements, needs to have efficiency higher than 74.7%. For all the considered input voltages, the efficiency results (see *Table 8*) are higher than the recommended value.

2.4 Light-load performance

The input power of the converter was measured in no load condition, with brownout protection disabled (see *Section 2.8*) for different input voltages and the results are given in *Table 12*.

Table 12. No-load input power (no brownout)

V_{INAC} (V_{RMS})	Pin (mW)	f_{SW_AVG} (kHz)
90	15	0.590
115	16	0.558
230	24	0.434
265	29	0.401

In version 2.0 of the ENERGY STAR® program the power consumption of the power supply when it is not loaded is also considered. The criteria for compliance are given in the table below.

Table 13. Energy consumption criteria for no load

Nameplate output power (P_{no})	Maximum power in no load for AC-DC EPS
0 W < P_{no} ≤ 50 W	< 0.3 W
50 W < P_{no} < 250 W	< 0.5 W

The performance of the VIPER27LN board is much better than required. The power consumption is about twelve times lower than the ENERGY STAR® limit. Even if the results seem to be disproportionally better than the requirements, it is worth mentioning that often AC-DC adapter or battery charger manufacturers have very strict requirements concerning no-load consumption and if the converter is used as an auxiliary power supply, the line filter of the entire power supply is much bigger and considerably increases the standby consumption.

Even if the ENERGY STAR® program does not have other requirements regarding light-load performance, in order to give complete information we have provided the input power and efficiency of the demonstration board in two other low-load cases also. *Table 14* and *Table 15* show the performances when the output load is 25 mW and 50 mW respectively.

Table 14. Low-load performance P_{OUT} = 25 mW

V_{IN_AC}	P_{OUT} (mW)	P_{IN} (mW)	Eff. (%)	P_{IN}-P_{OUT} (mW)	f_{SW_AVG} (kHz)
90	25.760	48	53.22	22.640	2.017
115	26.760	49	54.95	21.940	1.886
230	25.760	61	41.95	35.640	1.461
265	25.760	67	38.74	40.740	1.355

Table 15. Low-load performance P_{OUT} = 50 mW

V_{IN_AC}	P_{OUT} (mW)	P_{IN} (mW)	Eff. (%)	P_{IN}-P_{OUT} (mW)	f_{SW_AVG} (kHz)
90	51.510	80	64.39	28.490	3.407
115	51.510	82	62.82	30.490	3.177
230	51.510	98	52.56	46.490	2.435
265	51.510	104	49.53	52.490	2.284

The input power and the average switching frequency versus the input voltage for different load conditions are shown in the following figures.

Figure 18. Input power vs. input voltage for different loads

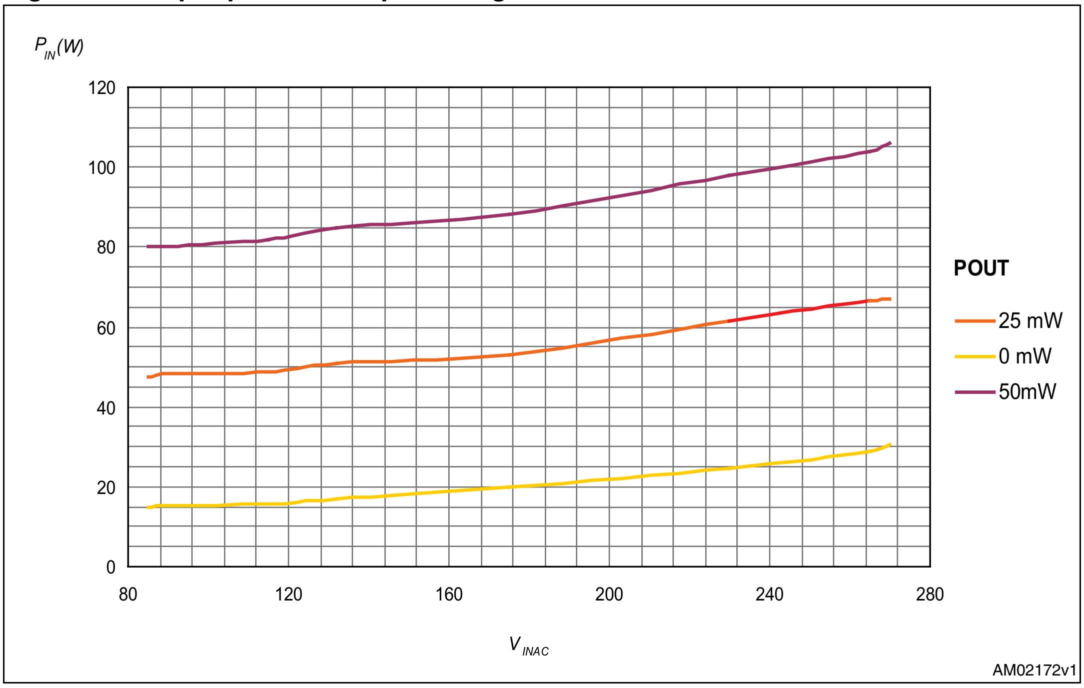
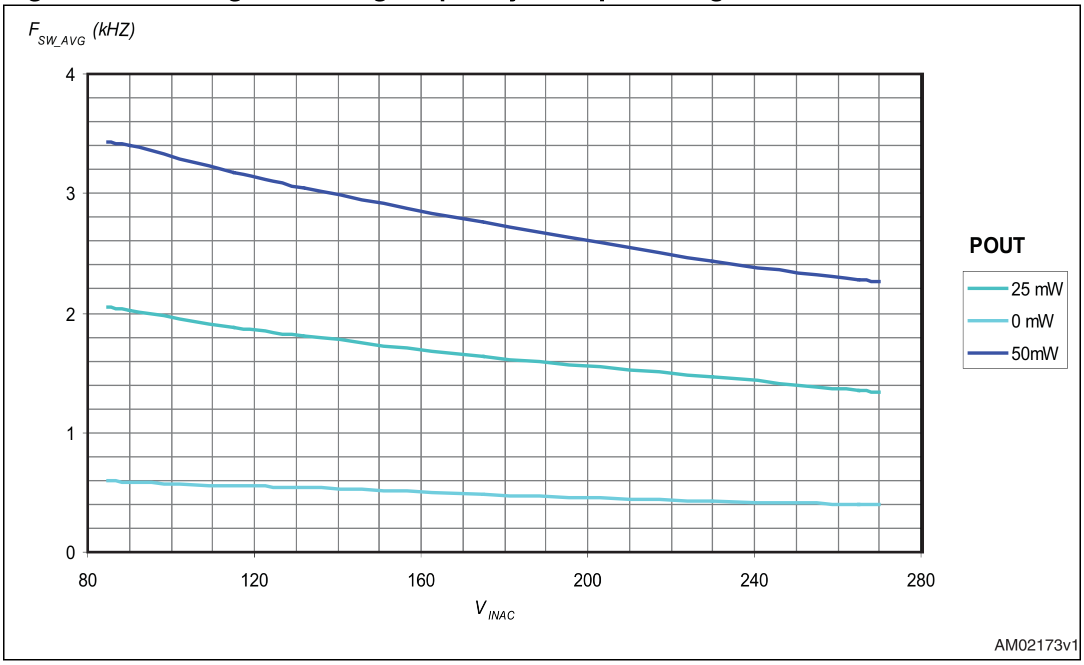


Figure 19. Average switching frequency vs. input voltage

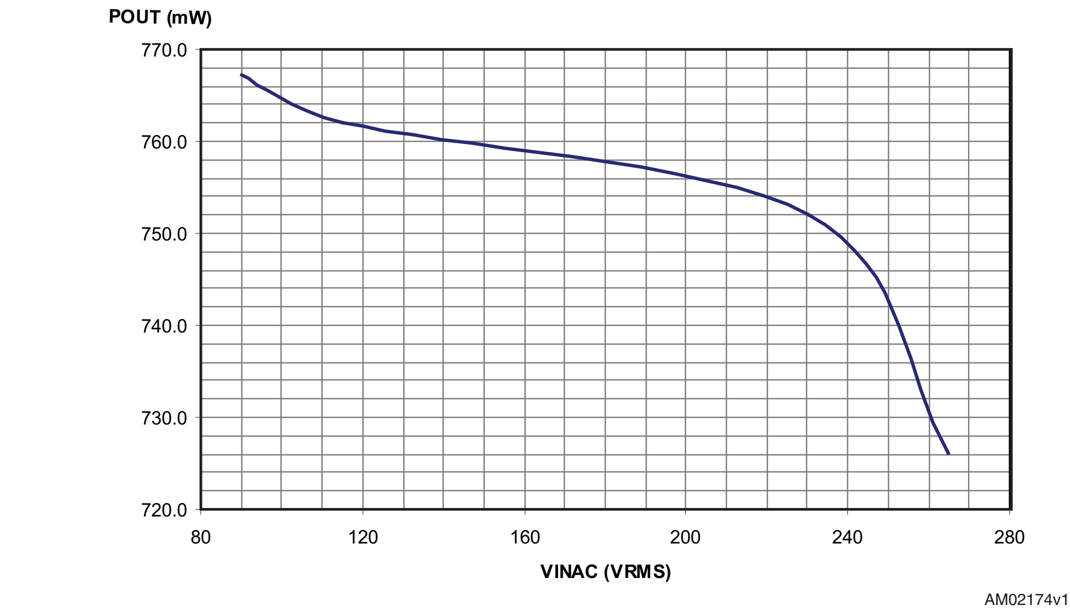


Depending on the equipment supplied, we can have several criteria to measure the standby or light-load performance of a converter. One criterion is the measure of the output power when the input power is equal to one watt. *Table 16* gives the output power needed to have 1 W of input power in different line conditions and *Figure 20* illustrates this.

Table 16. Output power when the input power is 1 W

V_{IN} (V_{RMS})	P_{IN} (mW)	P_{OUT} (mW)	Efficiency (%)	Pin-Pout (mW)
90	1000	767.1	76.71	232.853
115	1000	762.1	76.21	237.910
230	1000	752.0	75.20	248.024
265	1000	726.2	72.62	273.815

Figure 20. Output power vs. input voltage with input power of 1 W



If brownout protection is required, for the same load condition the input power increases. The brownout external circuit (R16, R17 and R18 see schematic in *Figure 2*) is connected in parallel with a bulk capacitor (C3 in the schematic) and some power is dissipated on it according to the voltage across the bulk capacitor. The following formula gives the additional power dissipation in the brownout circuit:

Equation 1

$$P_{BR\_LOSS} = \frac{V^2_{BULK\_RMS}}{(R16 + R17 + R18)}$$

In light-load condition the voltage across bulk capacitor can be considered constant and equal to the peak of the AC input voltage. Considering the worst case of maximum input voltage, the dissipation in the brownout circuit is:

Equation 2

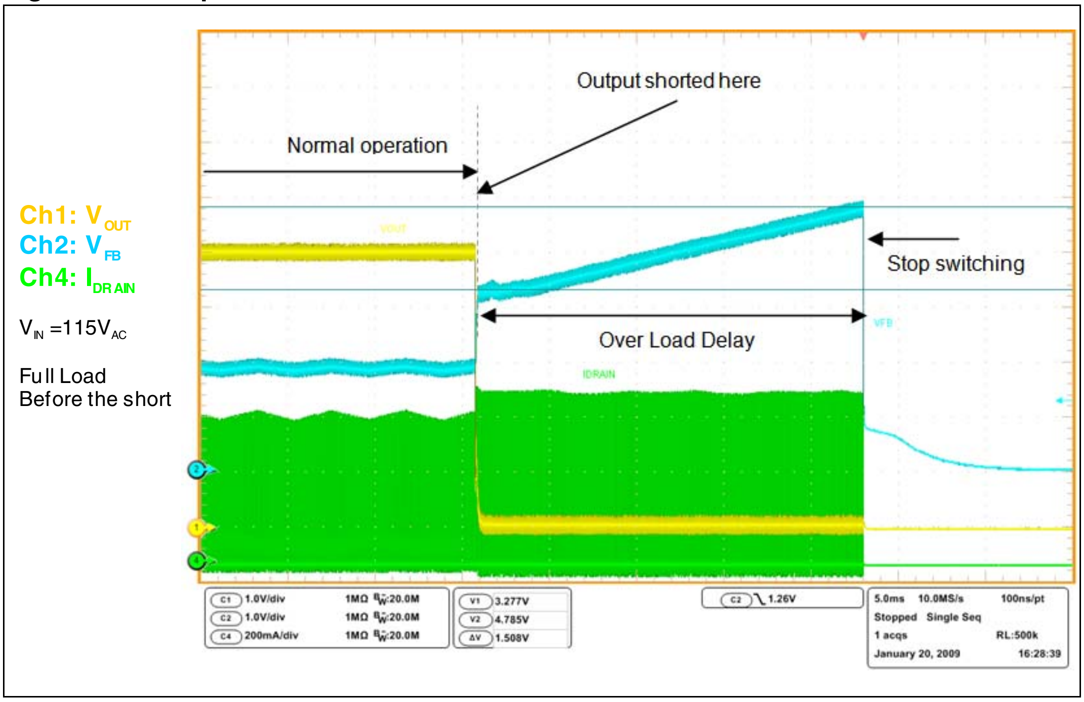
$$P_{BR\_LOSS} = \frac{V^2_{ACMAX\_PK}}{(R16 + R17 + R18)} = \frac{(\sqrt{2} \cdot 265 \cdot V)^2}{3222 \cdot k\Omega} \cong 43mW$$

2.5 Overload protection

The VIPER27LN has several protections, one of which prevents converter damage in case of 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 R_{LIM}), the voltage on feedback pin continuously rises but the power delivered no longer increases. When the feedback pin voltage exceeds V_{FB_lin} (3.3 V typ.), VIPER27LN 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 V_{FB_lin}, the internal pull-up is disconnected and the pin starts sourcing a 3 A current that charges the capacitor connected to it. As the voltage on the feedback pin reaches the V_{FB_olp} threshold (4.8 V typ.), VIPER27LN stops switching and is not allowed to switch again until the V_{DD} voltage goes below $V_{DD\_RESTART}$ (4.5 V typ.) and rises again up to V_{DD_ON} (14 V typ.).

The following waveform shows the behavior of the converter when the output is shorted.

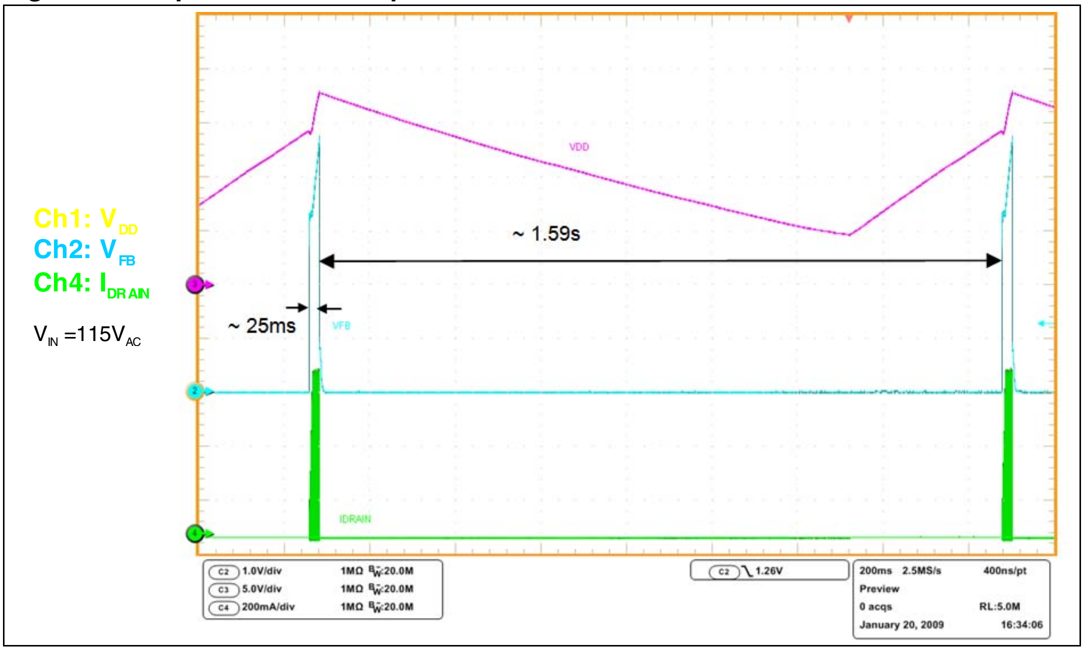
Figure 21. Output short-circuit



If the short-circuit is not removed, the system starts to work in auto-restart mode. The behavior, when a short-circuit is permanently applied on the output, is a short period of time where the MOSFET is switching and the converter tries to deliver to the output as much power as it can, and a longer period where the device is not switching and no power is processed.

The duty cycle of power delivery is very low (around 1.55%) so the average power throughput is also very low (see the figure below).

Figure 22. Operation with output shorted

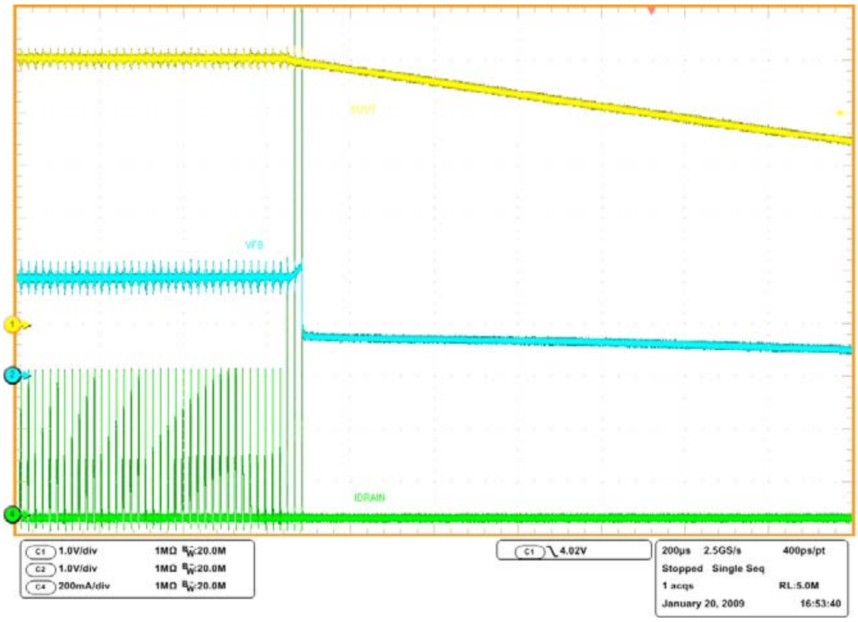


2.6 Secondary winding short-circuit protection

The VIPER27LN is provided with an adjustable first level of primary overcurrent limitation that switches off the power MOSFET if this level is exceeded. This limitation acts cycle by cycle and its main purpose is to limit the maximum deliverable output power. A second level of primary overcurrent protection is also present and in this case it is not adjustable, it is fixed to 1 A (typical value). If the drain current exceeds this 2nd OCP (second overcurrent protection) threshold, the device enters a warning state. The next cycle the MOSFET is switched on, and if again the second level of overcurrent protection is exceeded, the device assumes that a secondary winding short-circuit or a hard saturation of the transformer is happening and stops the entire operation. In order to re-enable the operation, the V_{DD} voltage has to be recycled which means that V_{DD} has to go down to $V_{DD\_RESTART}$, then rise up to V_{DD_ON}. When the VIPER27LN is switched on again (V_{DD} equals V_{DD_ON}), the MOSFET can start to switch again. If the cause of the 2nd overcurrent protection activation is not removed, the device goes in auto-restart mode.

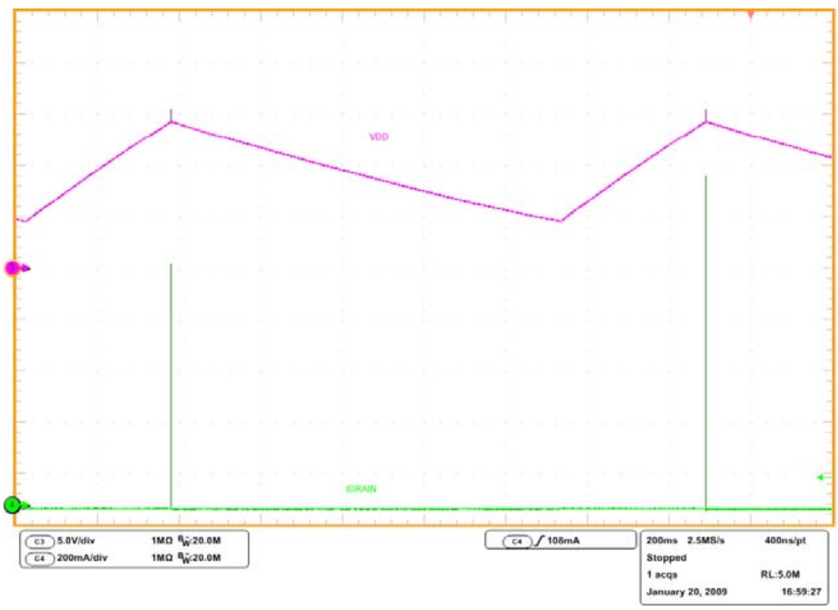
This protection was tested on the present board. The secondary winding of the transformer was shorted, in different operating conditions. The following figures show the behavior of the system during these tests.

Figure 23. 2^{nd} OCP tripping



In *Figure 23* when the board was working in full-load condition with an input voltage of 115 V_{AC}, the secondary winding was shorted. The short on the secondary winding leads to a high drain current. After two switching cycles, the system stops and continuous running with high currents in the primary as well as in the secondary windings and through the power section of the VIPER27LN is avoided. *Figure 24* shows the situation when a permanent short-circuit is applied on the secondary windings. Most of the time the power section of the VIPER27LN is off, eliminating any risk of overheating.

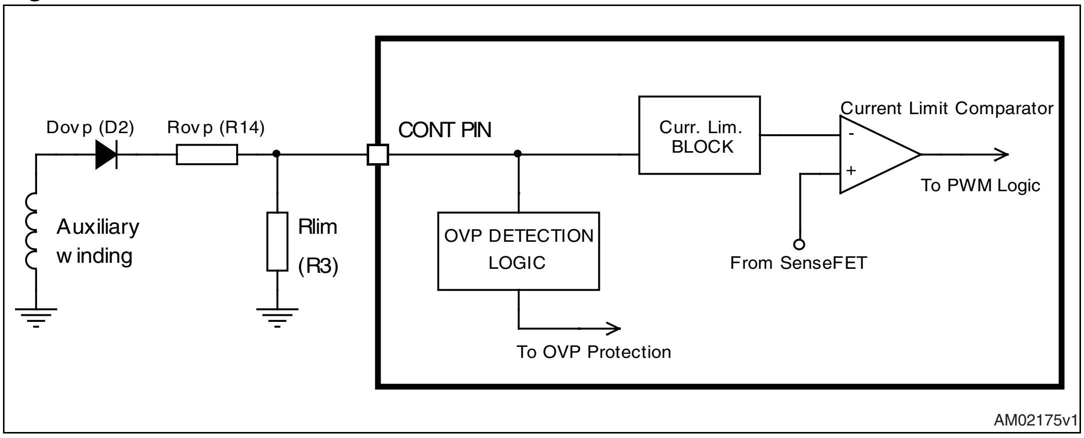
Figure 24. Operating with secondary winding shorted - restart mode



2.7 Output overvoltage protection

An output overvoltage protection is implemented by monitoring the voltage across the auxiliary winding during the MOSFET off-time, through the D2 diode and the resistor divider R3 and R14 (see schematic of *Figure 2*) connected to the CONT pin of the VIPER27LN. If the voltage on the pin exceeds the V_{OVP} thresholds (3 V typ.), an overvoltage event is assumed and the power section is no longer allowed to switch on. To re-enable operation, the V_{DD} voltage has to be recycled. In order to provide high noise immunity and avoid that spikes erroneously trip the protection, a digital filter was implemented so the CONT pin has to sense a voltage higher than V_{OVP} for four consecutive cycles before stopping operation.

Figure 25. OVP circuit



The value of the output voltage when the protection has to be tripped can be set by properly selecting the resistor divider R3 and R14. R3 is selected according to the maximum power that the converter has to provide to the output, and R14 is selected according to *Equation 3:*

Equation 3

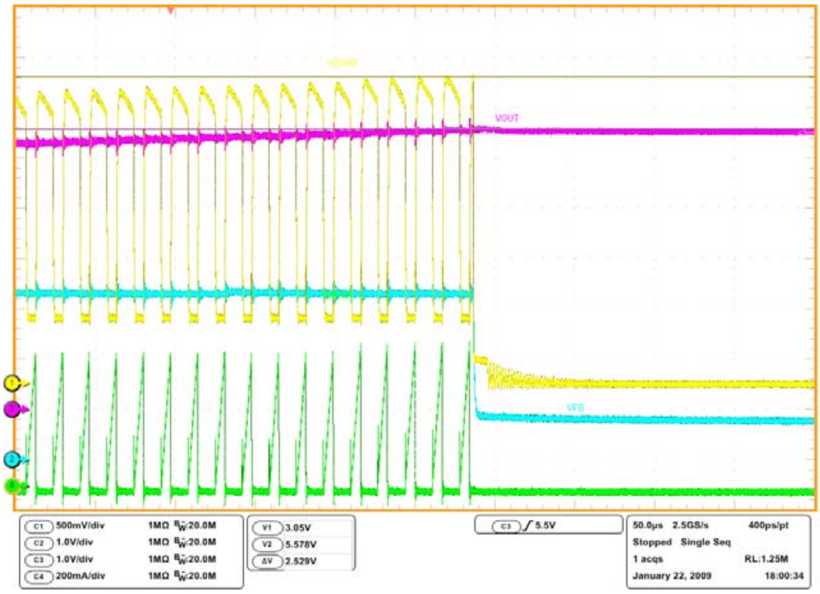
$$R_{OVP\_(R14)} = \frac{R_{LIM\_(R3)}}{V_{OVP}} \cdot \left(\frac{N_{AUX}}{N_s} \cdot V_{OUT\_OVP} - V_{drop\_D_{ovp\_(D2)}} - V_{OVP} \right)$$

The protection was tested by disconnecting the opto-coupler from the feedback pin and applying a minimum load to the converter. In this way the converter operates in open loop and delivers the maximum power that it can to the output. The excess of power with respect to the load charges the output capacitance, increasing the output voltage since the OVP is tripped and the converter stops working.

In *Figure 26* it is possible to see that the output voltage increases and, as it reaches the value of 5.58 V, the converter stops switching. In the same figure the CONT pin voltage (Ch1, yellow waveform) is shown. The crest value of the CONT pin voltage tracks the output voltage.

Figure 26. OVP

Ch1: V_{CONT}
Ch2: V_{FB}
Ch3: V_{OUT}
Working condition:
input voltage: $115V_{AC}$
No load
Feedback pin: disconnected.



The test was performed in different line and load conditions, to check the dependence of the output voltage value, when the protection is activated, on the converter's input voltage and load.

The results are shown in *Table 17*.

Table 17. Input and output load

V_{IN} (V_{RMS})	V_{OUT_OVP} (V)				
	Load				
	No load	25% (0.6 A)	50% (1.2 A)	75% (1.8 A)	100% (2.4 A)
90	5.56	5.50	5.46	5.45	5.45
115	5.56	5.51	5.49	5.48	5.46
230	5.59	5.55	5.52	5.53	5.53
265	5.59	5.54	5.54	5.53	5.53

The variation with load and line condition is very low ([5.45 V; 5.59 V], ΔV_{OUT_OVP} = 140 mV), less than 3%. Considering a precision of the OVP threshold on the CONT pin of 10% ([2.7 V; 3.3 V]), using as R_{OVP} and R_{LIM} 1% precision resistance and with a turn ratio between the secondary and auxiliary windings that has a precision of 5%, it is possible to fix the output overvoltage 20%, 25% higher than the nameplate output voltage of the converter, without risk of undesired protection tripping due to the spread in the values of the components (R3 and R14), of the transformer parameter (turn ratio) and of the VIPER27LN parameter (V_{OVP}).

It is possible to not implement this protection if it is not necessary, by not mounting diode D2 and resistor R14, thus reducing the number of components.

2.8 Brownout protection

The brownout protection is basically an unlatched device shutdown functionality whose typical use is to sense flyback converter input undervoltage. The VIPER27LN has a pin (BR, pin 5) dedicated to this function that must be connected to the DC HV bus. If the protection is not required, it can be disabled by connecting the pin to ground. In the present converter the brownout protection is implemented but can be disabled by changing the setting of jumper J7 (see schematic in *Figure 2*). The settings of jumper J7 are shown in *Figure 27* and *Figure 28*. The shutdown of the converter is accomplished by means of an internal comparator internally referenced to 450 mV (typ, V_{BRth}) that disables the PWM if the voltage applied to the BR pin is below the internal reference, as shown in *Figure 29*. The PWM operation is re-enabled as the BR pin voltage is more than 450 mV plus 50 mV of voltage hysteresis that ensures noise immunity. The brownout comparator is also provided with current hysteresis. An internal current generator is ON as long as the voltage applied to the brownout pin is below 450 mV and is OFF if the voltage exceeds 450 mv plus the voltage hysteresis.

Figure 27. Jumper J7 setting, brownout disabled

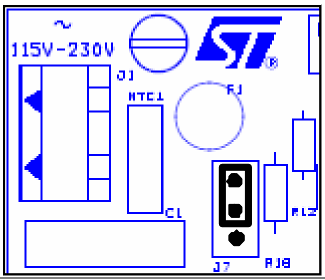


Figure 28. Jumper J7 setting, brownout enabled

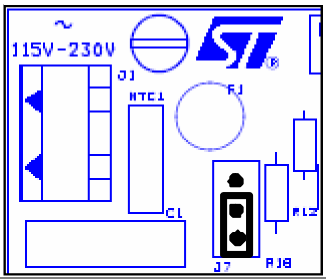
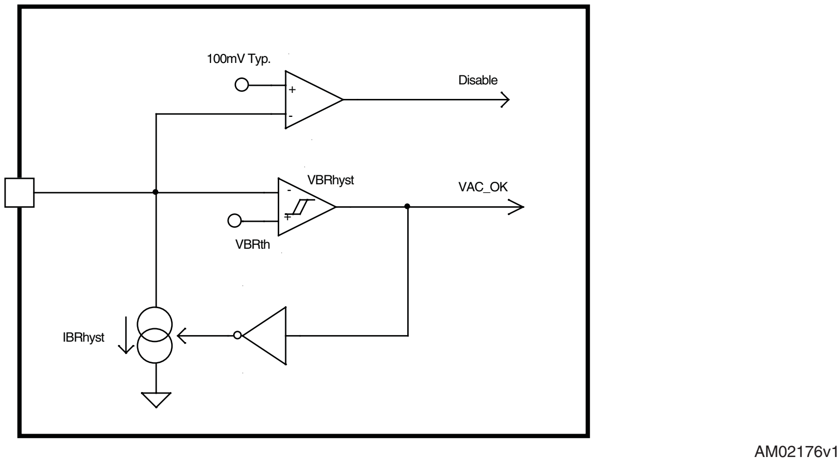


Figure 29. Brownout protection



The current hysteresis provides an additional degree of freedom. It is possible to set the ON threshold and the OFF threshold for the flyback input voltage separately by properly choosing the resistors of the external divider. The following relationships can be established for the ON (V_{IN_ON}) and OFF (V_{IN_OFF}) thresholds of the input voltage:

Equation 4

$$V_{IN\_OFF} = V_{BRth} \cdot \left(\frac{R_H + R_L}{R_L} \right)$$

Equation 5

$$V_{IN\_ON} = (V_{BRth} + V_{BRhyst}) \cdot \left(\frac{R_H + R_L}{R_L} \right) + R_H \cdot I_{BRhyst}$$

where I_{BRhyst} = 8.5 µA (typ.) is the current hysteresis, V_{BRhyst} = 50 mV (typ.) is the voltage hysteresis and V_{BRth} = 450 mV (typ.) is the brownout comparator internal reference.

One purpose of this protection is to stop operation of the converter when the line voltage is too low, avoiding an excessive root mean square current value flowing inside the main switch and consequently its overheating. Another purpose is to avoid a false restart of the converter and then having a monotonic decay to zero of the output voltage when the converter itself is unplugged from the mains. A typical situation, in most cases for converters designed for the European range (230 V_{AC}), could be a converter that, when unplugged, shuts down due to the overload protection (due to the low input voltage the converter is not able to supply the full power), but the voltage on the bulk capacitor is higher than $V_{DRAIN\ RESTART}$ so the device restarts and the output voltage rises again. This situation could be dangerous for some loads, and in many applications it is better to avoid it.

The following figures show how the brownout protection works in the VIPER27LN board when used. *Figure 30* shows the behavior of the board when the input voltage is changed from 90 V_{AC} to 75 V_{AC} with a full load applied. The system stops switching and the output load, no longer supplied, decays monotonically to zero.

Figure 30. Input AC voltage steps from 90 V_{AC} to 75 V_{AC}

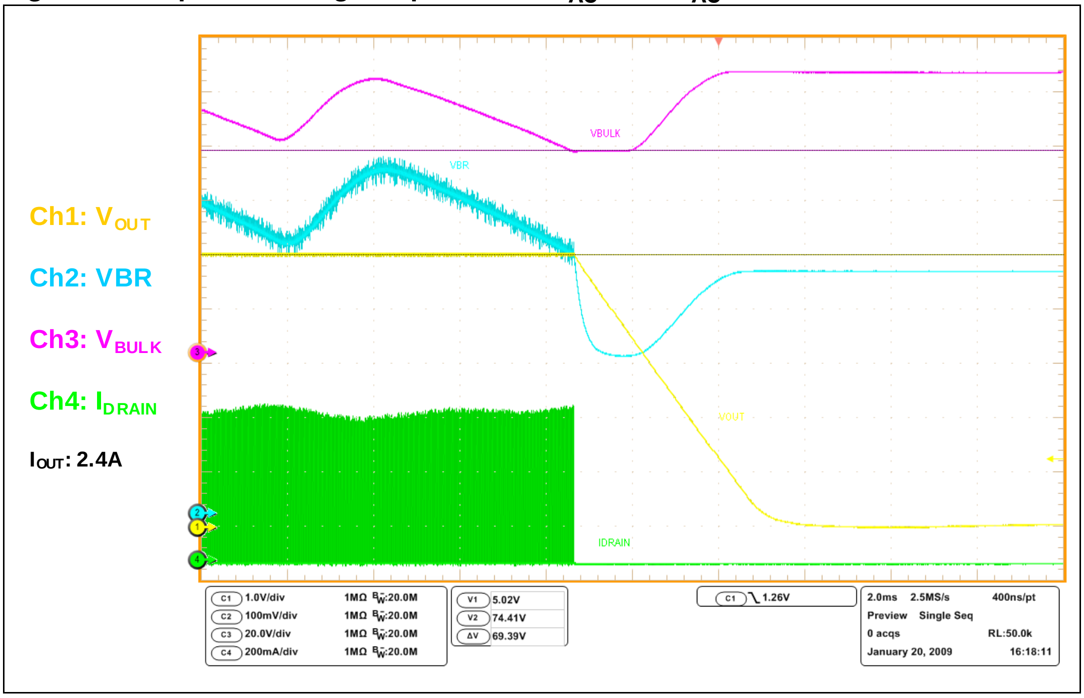
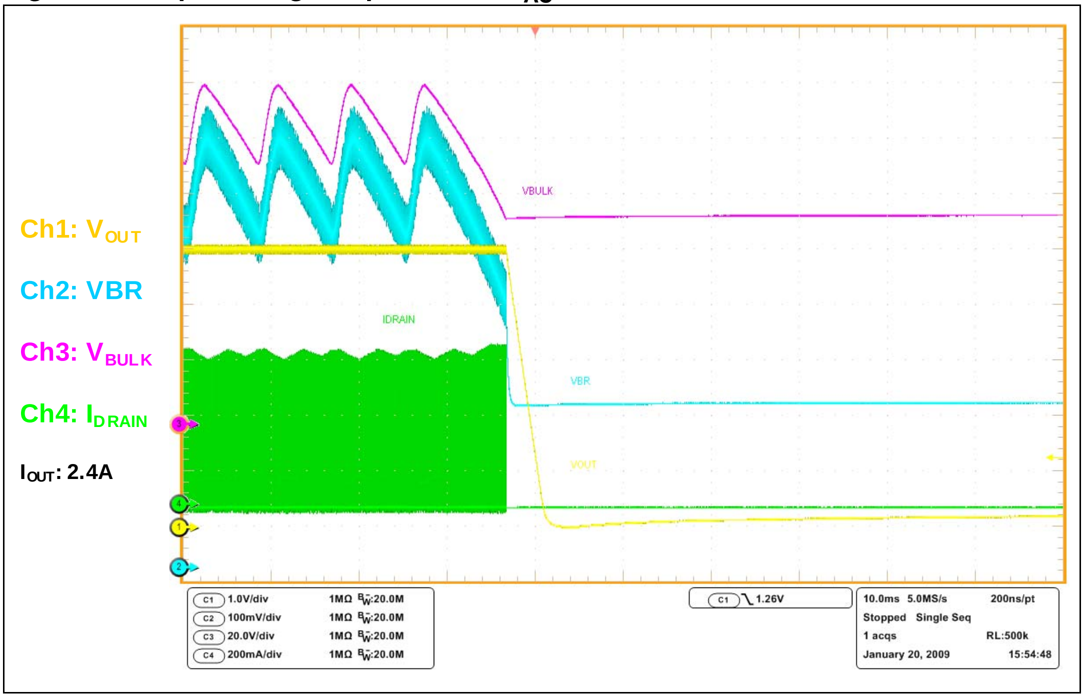


Figure 31. Input voltage steps from 90 V_{AC} to 0



2.9 EMI measurements

A pre-compliance test for EN55022 (Class B) European normative was also performed and the results are shown in the two figures below.

Figure 32. 115 V_{AC}

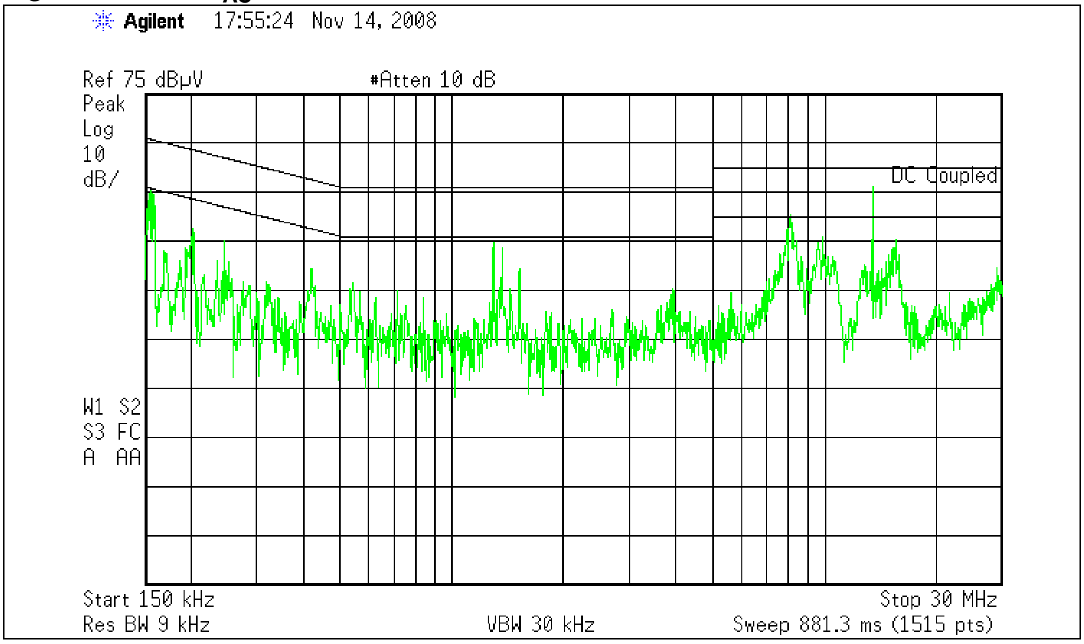
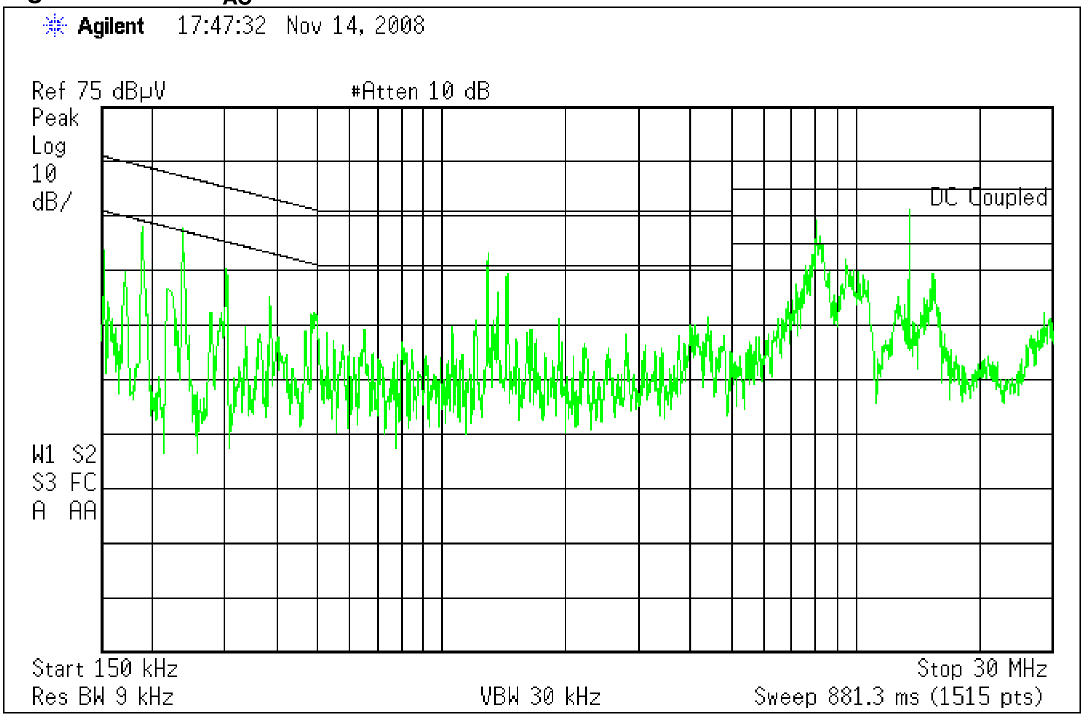


Figure 33. 230 V_{AC}



3 Conclusion

The presented flyback converter is suitable for different applications and can be used as an external adapter or as an auxiliary power supply in consumer products. Special attention was given to low-load performance and the bench results are good with very low input power in light-load condition. The efficiency was compared to the requirements of the ENERGY STAR® program (version 2.0) for external AC/DC adapters with very good results in that the measured active mode efficiency was always higher than the minimum required.

4 References

[1] ENERGY STAR® program requirements for single voltage external AC-DC adapter (Version 2.0)

[2] VIPER27 datasheets

5 Revision history

Table 18. Document revision history

Date	Revision	Changes
07-May-2010	1	Initial release
06-Apr-2011	2	Modified: *Table 2: Bill of material*