AN2063
Application note

VIPower™: low consumption standby power with the VIPerx2A family

Introduction

The new regulation on the power supply standby consumption for the battery charger is more and more stringent. Thanks to the VIPerx2A family low power consumption, a battery charger can be built in standby mode with no-load of 100 mW. This charger solution with the VIPer12A-E is presented in *Table 1*.

Some general features:

- Ultra low standby power dissipation
- Burst mode operation in standby
- 72% typical efficiency
- Current mode controller
- Output short-circuit protection
- Thermal shutdown protection

Table 1. Operation conditions

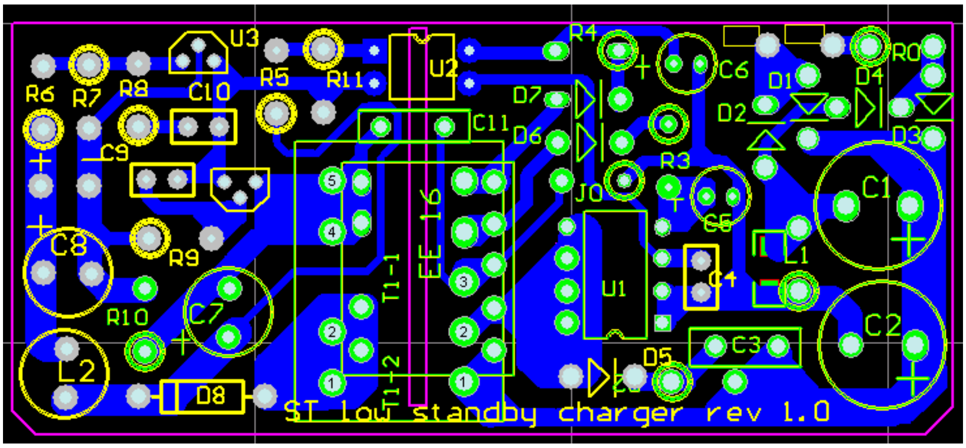
Parameters	Limits
Input voltage range	90 to 264 VAC
Input frequency range	50 to 60 Hz
Output voltage	5 V
Output current	800 mA
Output power	4 W
Efficiency	72% typical
Line regulation	0.5%
Load regulation	1%
Output ripple	30 mVpp
Safety	Short-circuit protection

Contents

1 Description

The VIPer12A-E is a high voltage integrated circuit intended to be used as a primary side switch on the offline power supply, in a monolithic structure housed in DIP8 or SO-8 package. It includes a PWM driver, a power MOSFET with 730 V breakdown voltage, a start-up circuit and several protection circuits. It minimizes the count of external parts, reduces the product size and power consumption. This application note describes the results obtained when the VIPer12A-E is used in mobile charger applications.

Figure 1. Evaluation board bottom foil (not in scale)

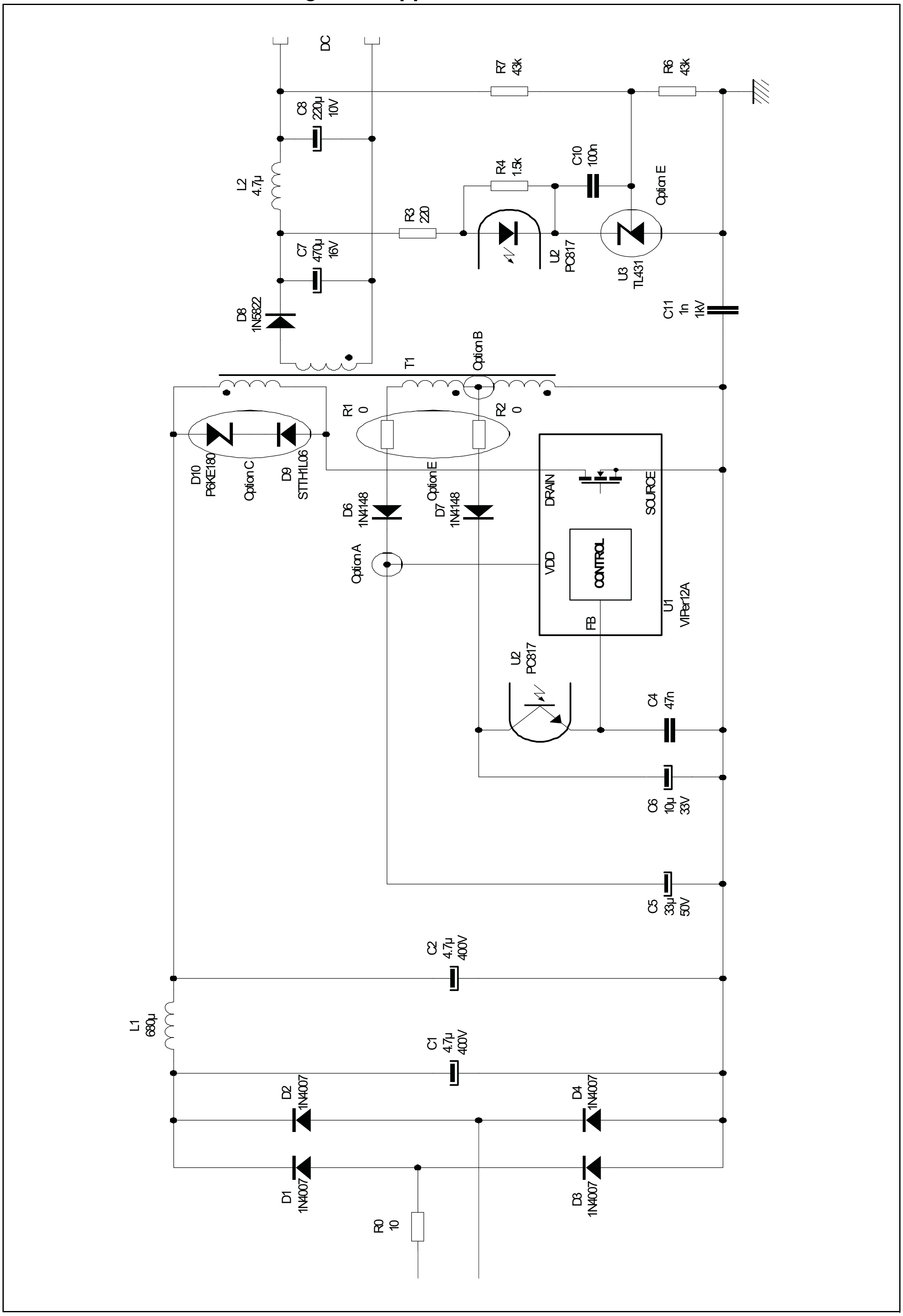


2 General circuit description

This board is a flyback regulator, delivering 0.8 A to 5 V. The AC input is rectified and filtered by the diodes D1, D2, D3, D4, the bulk capacitor C1, and C2 to generate the high voltage DC bus applied to the primary winding of the transformer, TR1. C1, L1, and C2 provide EMI filtering for the circuit. D9 and D10 form the snubber circuit, which reduces the leakage spike and voltage ringing on the drain pin of the VIPer12A-E.

The output voltage is regulated by a TL431 (U3) via an optocoupler (U2) to the feedback pin. The output voltage ripple is controlled by the capacitor, C7, with an additional LC PI filter configuration made up of L2 and C8. The output voltages can be modified by changing the transformer turn ratio and modifying the R6 and R7 resistance values in the feedback loop.

Figure 2. Application schematic



3 Charger application

3.1 Schematic general description

As the total input power dissipation at no-load condition of this solution is less than 0.1 W, the power losses of each component have to be saved. Below the major approaches adopted in this evaluation board.

3.2 Solutions for energy saving

1. Losses of the VIPer12A-E controller.

The power losses of the VIPer12A-E control part can be calculated by below formula:

$P_{viper} = V_{dd} * I_{dd1}$

where:

- V_{dd} is the supply voltage of the VIPer12A-E control part (range: 9 V-38 V)

- I_{dd1} is the operation current of the VIPer12A-E control part (typical value: 4.5 mA)

V_{dd} is set by considering two operative conditions; if the VIPer12A-E power has to be saved, the V_{dd} value has to be lowered and, at the same time the V_{dd} has to be higher than 10 V, which is the required normal operation value of the VIPer12A-E (with 1 V margin).

V_{dd} value (10 V) fixes the suitable turn ratio between secondary and auxiliary winding.

2. Optimized voltage source for optocoupler.

In a flyback topology, the voltage source of the optocoupler primary side is normally connected to the V_{dd} of the IC directly, but in this board, in order to save energy, another winding is inserted in the transformer to supply the optocoupler; the voltage supplied by this winding is lower than the V_{dd} value (typical value 3 V).

3. Snubber circuit configuration.

An RCD clamp is a popular cheap solution, however it dissipates power even at no-load condition, in fact there is a reflected voltage across the clamp resistor all the time. The power losses on the resistor can be calculated as follows:

$$P_R = \frac{V_R^2}{R_{min}} + \frac{1}{2} \cdot L_{LK} \cdot I_{lim}^2 \cdot f_{sw}$$

where V_R is the reflected voltage; R_{min} is the resistor value; L_{LK} is the leakage inductance; I_{lim} is the peak current limitation value of the VIPer12A-E and f_{sw} is the switching frequency.

As at no-load condition, the energy $½*L_{LK}*I_{lim}*f_{sw}$ can be neglected, then the RCD losses could be considered as:

$P_R=V_R*V_R/R_{min}$

in this case with V_R=70 V, R_{min}=82 kΩ, P_R is around 60 mW.

This 60 mW power at no-load condition can be saved using the transil clamp to replace the RCD configuration in the snubber circuit.

4. Optional for the voltage reference devices (TS431 or TL431 or Zener)

The TS431, the TL431 and the Zener can be used as voltage regulators. The TS431 shows the low minimum operation current with the typical value of 150 A. This feature is quite useful, because the biasing resistor can be removed without any voltage regulation performance loss. With this device, the power losses can be saved on the biasing resistor with typical value of 5-8 mW.

The TL431 is a cost-effective solution for the constant voltage. The weakness of this device, in this special application, is its operation current higher than 1 mA. In order to get good voltage regulation performance at full load condition, a biasing resistor is very important, but this leads to an additional power loss.

If the requirement of the output voltage performance is not so tight, a Zener can be used as voltage reference. The standby power in no-load condition is lower than 0.1 W with the 3 optional solutions of voltage reference above. The best solution depends on customers' requests.

5. The short-circuit of resistors for current limitation on the auxiliary windings.

3.3 Performance results

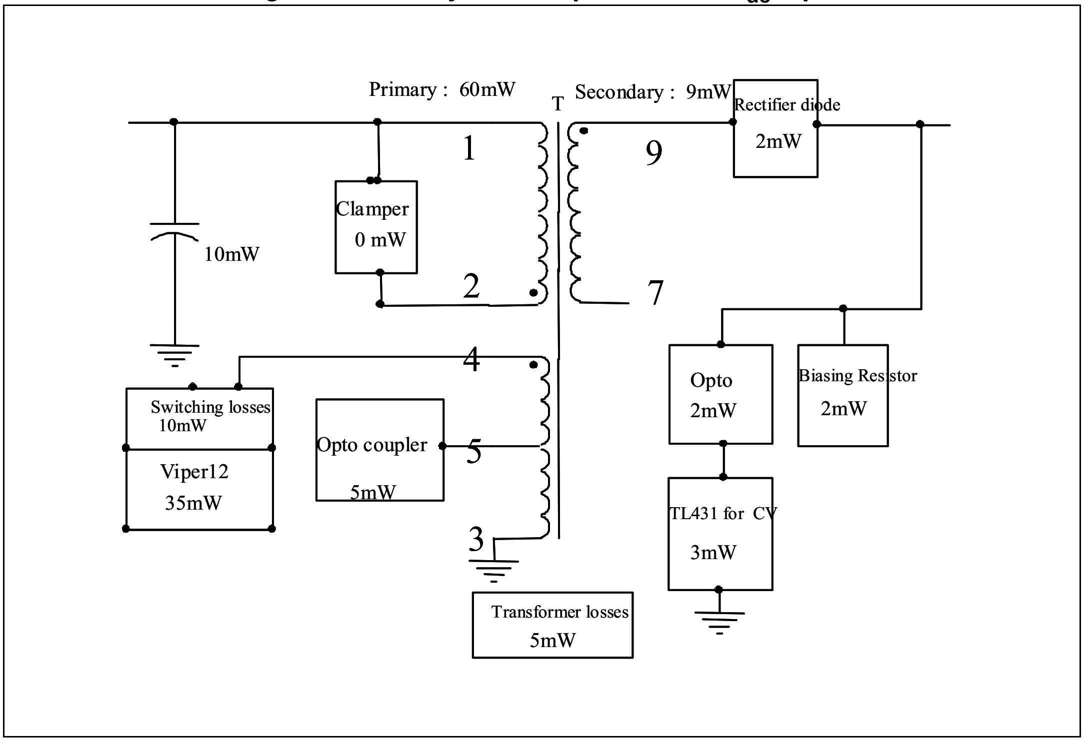
3.3.1 Input power consumption at no-load condition

Table 2. Standby power

Input power consumption		
V_{IN}	**I_{IN}**	**P_{IN}**
100 V_{dc}	505 µA	50.5 mW
300 V_{dc}	252 µA	75.6 mW
380 V_{dc}	215 µA/203 µA	81.7 mW/77.2 mW

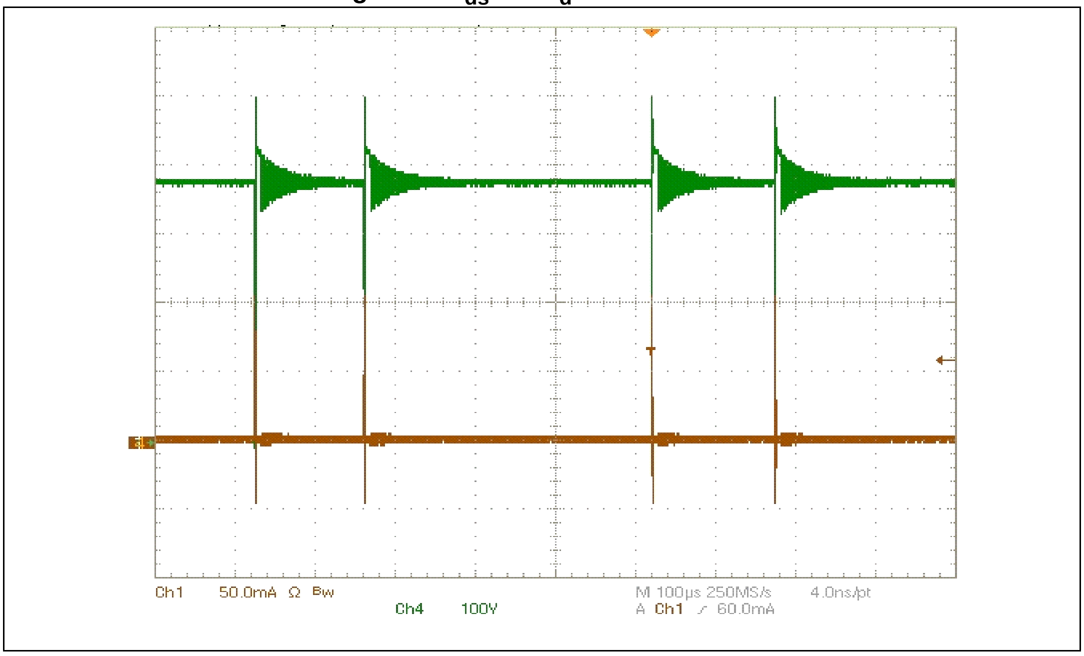
As shown in *Table 1*, the standby power is measured at DC voltage input in order to have more precision in the input power data. At the high line input of 380 V_{dc} input, this board standby power is around 82 mW (with theTL431).

Figure 3. Standby consumption at 380 V_{dc} input



3.3.2 Standby operation

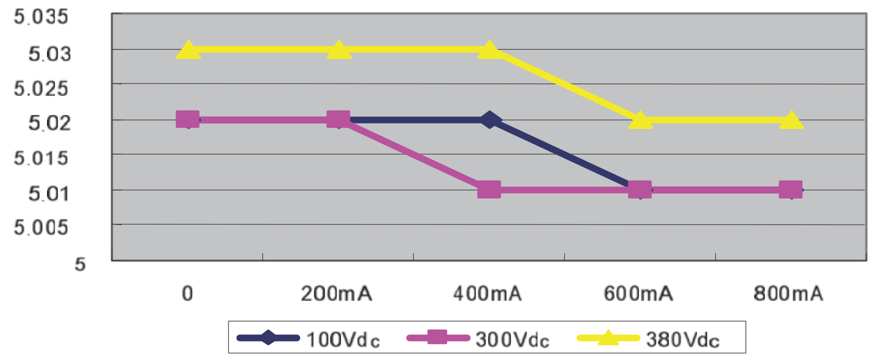
Figure 4. V_{ds} and I_d at burst mode



When no-load is applied to the secondary side, the VIPer12A-E works in burst mode by skipping some switching cycles and this behavior is shown in *Figure 4*. Thanks to this feature, the VIPer12A-E can save a lot of the switching losses reducing the standby power consumption.

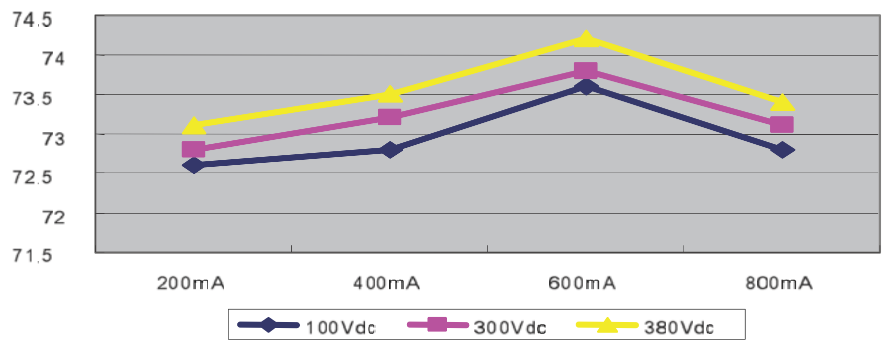
3.3.3 Load, line regulation and efficiency

Figure 5. Load regulation



The output load changes from 0 A to full load 0.8 A while the line input voltage is set as 100 V_{dc}, 300 V_{dc}, 380 V_{dc}. The board has a load, line regulation lower than 1%.

Figure 6. System efficiency



The measurements are based on input voltage of 100 V_{dc},300 V_{dc}, 380 V_{dc}. The typical efficiency measured is about 73%. *Figure 6* shows the efficiency measured when I_{OUT} is set at different values from 200 mA to maximum value of 800 mA.

3.3.4 Load transient

Figure 7. V_{ds} and I_d at V_{IN}=100 V_{dc}, P_{OUT}=4 W - 50 mV/division

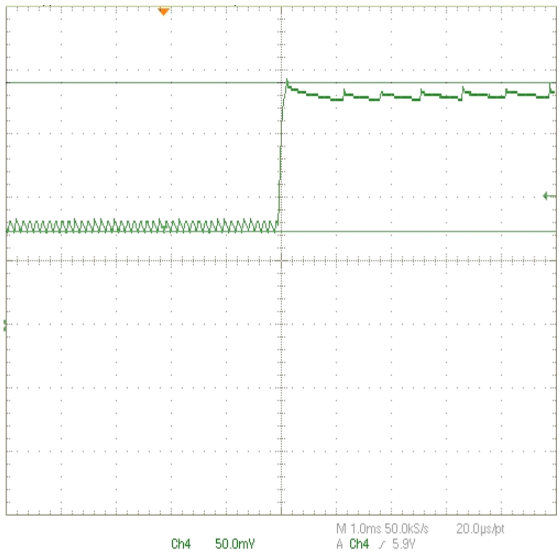
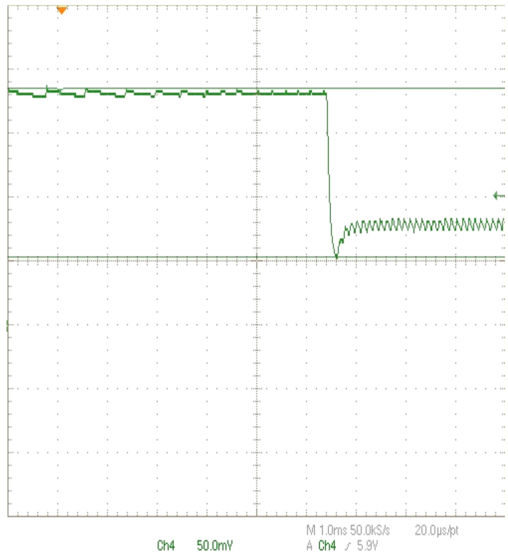


Figure 8. V_{ds} and I_d at V_{IN}=380 V_{dc}, P_{OUT}=4 W - 50 mV/division



As shown in *Figure 7* and *Figure 8* the maximum overshoot and undershoot value of the output voltage is less than 150 mV at transient tests.

3.3.5 Switching waveforms of normal operation at full load

Figure 9. V_{ds} and I_d at V_{IN}=100 V_{dc}, P_{OUT}=4 W

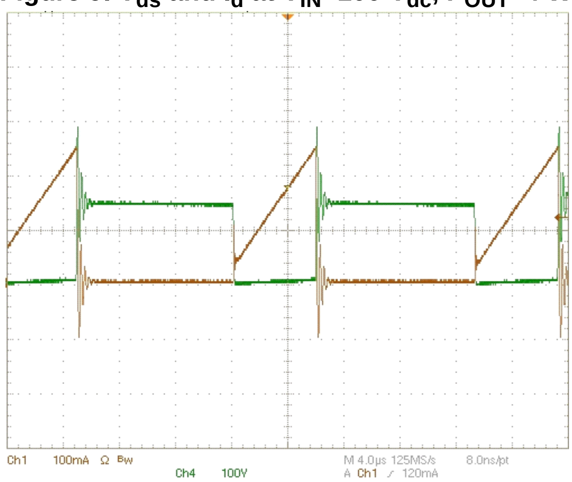


Figure 10. V_{ds} and I_d at V_{IN}=380 V_{dc}, P_{OUT}=4 W

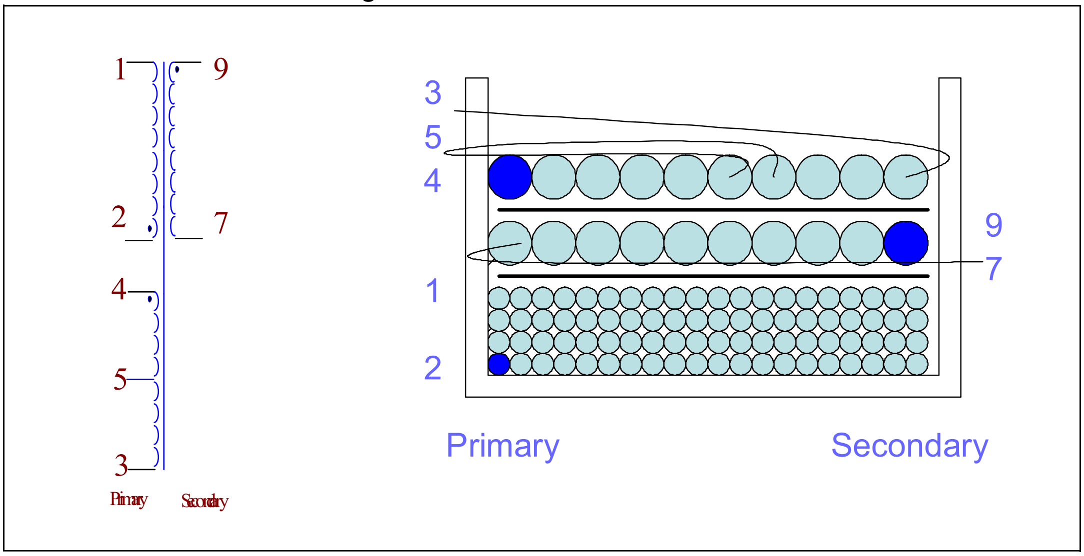
Figure 8 and *Figure 9* show the drain voltage and drain current during normal operation at full load. The power supply operates in the continuous current mode at low line and in discontinue current mode at high line input as seen from the waveforms.

4 Transformer specification

Table 3. Transformer characteristics

Winding description	Symbol	Number turns	Wire size	Start pin	End pin	Remarks
Primary	P1	145	0.19 mm	2	1	EE-16; Lp = 2.5 mH at 1 V, 1 kHz
Secondary	S1	11	0.50 mm	9	7	Tipple isolated wire
Auxiliary1	A1	16	0.10 mm	4	5	
Auxiliary2	A2	15	0.10 mm	5	3	

Figure 11. Transformer structure



5 Bill of material

Table 4. Bill of material

Symbol	Part list description	Note
C1,C2	Elect Cap 4.7 µF/400 V	
C4	47 nF/25 V	
C5	Elect cap 33 µF/25 V	
C6	Elect cap 10 µF/6.3 V	
C7	Elect cap 470 µF/16 V	
C8	Elect cap 220 µF/10 V	
C10	Film 100 nF/50 V	
C11	Y cap 1 nF/1 KV	
R0	10 Ω	Fuse
R1,R2	0 Ω	
R3	220 Ω	
R4	1.5 KΩ	TL431:1.5 K/TS431: remove
R6	43 KΩ	
R7	43 KΩ/130 KΩ	TL431:43 K/TS431: 130 K
D1,D2,D3,D4	1N4007	
D6,D7	1N4148	
D8	1N5822	
D9	STTH1L06	
D10	P6KE180	
L1	680 µH	
L2	4.7 µH	
T1	2.7 mH EE-16 vertical	
U1	VIPer12A-E	
U2	PC817	
U3	TL431/TS431	

6 Conclusions

When the board works in standby, it consumes less than 0.1 W meeting the “Blue Angel” norm. The total power consumption measured at 100 V_{dc} input with zero load on output is approximately 50 mW, while at 380 V_{dc} input this value is about 80 mW.

This unit operates in burst mode when the output load is reduced to zero and normal operation is resumed automatically when the power gets back to a level higher than the standby power. The output voltage remains regulated even when the board works in burst mode.

7 Revision history

Table 5. Document revision history

Date	Revision	Changes
10-Nov-2014	2	Content reworked to improve readability, no technical changes.