# AN2063
# APPLICATION NOTE

## VIPower: LOW CONSUMPTION STAND-BY POWER WITH VIPerX2A FAMILY

**GENERAL FEATURES**

- ULTRA LOW STANDBY POWER DISSIPATION
- BURST MODE OPERATION IN STAND-BY
- 72% TYPICAL EFFICIENCY
- CURRENT MODE CONTROLLER
- OUTPUT SHORT CIRCUIT PROTECTION
- THERMAL SHUT DOWN PROTECTION

### 1. INTRODUCTION

The new regulations on the power supply stand-by consumption for the battery charger are becoming more stringent. Thanks to VIPerX2A family low power consumption, it is possible to build a battery charger with a power consumption in stand-by mode with no-load of 100mW.

In table 1 this charger solution with VIPer12A is presented.

**Table 1: Operation conditions**

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

### 2. VIPer12A DESCRIPTION

VIPer12A is a high voltage integrated circuits intended to be used on off line power supply as a primary side switch. in a monolithic structure housed in DIP-8 or SO-8 package it includes a PWM driver, a Power MOSFET with 730V breakdown voltage, a start-up circuit and several protection circuit. It takes advantage from minimizing the external part count, reducing the products size and power consumption. The application note describes the results obtained when VIPer12A is used in mobile charger application.

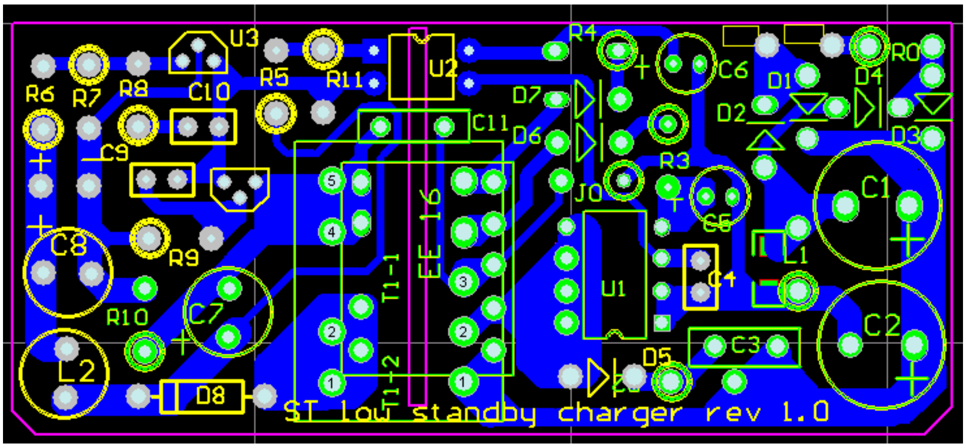
## 3. PCB LAY-OUT

The layout of the switching power supply is very important in order to minimize noise and interference. The high switching current loop areas should be kept as small as possible to reduce the radiated electromagnetic emissions. Figure 1 shows the board layout.

In order to meet safety agencies' requirements, there needs to be an adequate clearance of about 6mm between the high and low voltage sides of the circuit.

The power grounds need to be separated from the small signal grounds. The current in the power ground changes very quickly in time; resulting in large transient that induces voltage shifts, which in turn can disturb critical, sensitive small signal currents. Any disturbance or shift of ground in the small signal ground will upset critical reference paths. Therefore, poor grounding routing can manifest itself as poor load regulation, or excessive switching noises on the output.

**Figure 1: Demo board bottom foil (not in scale)**

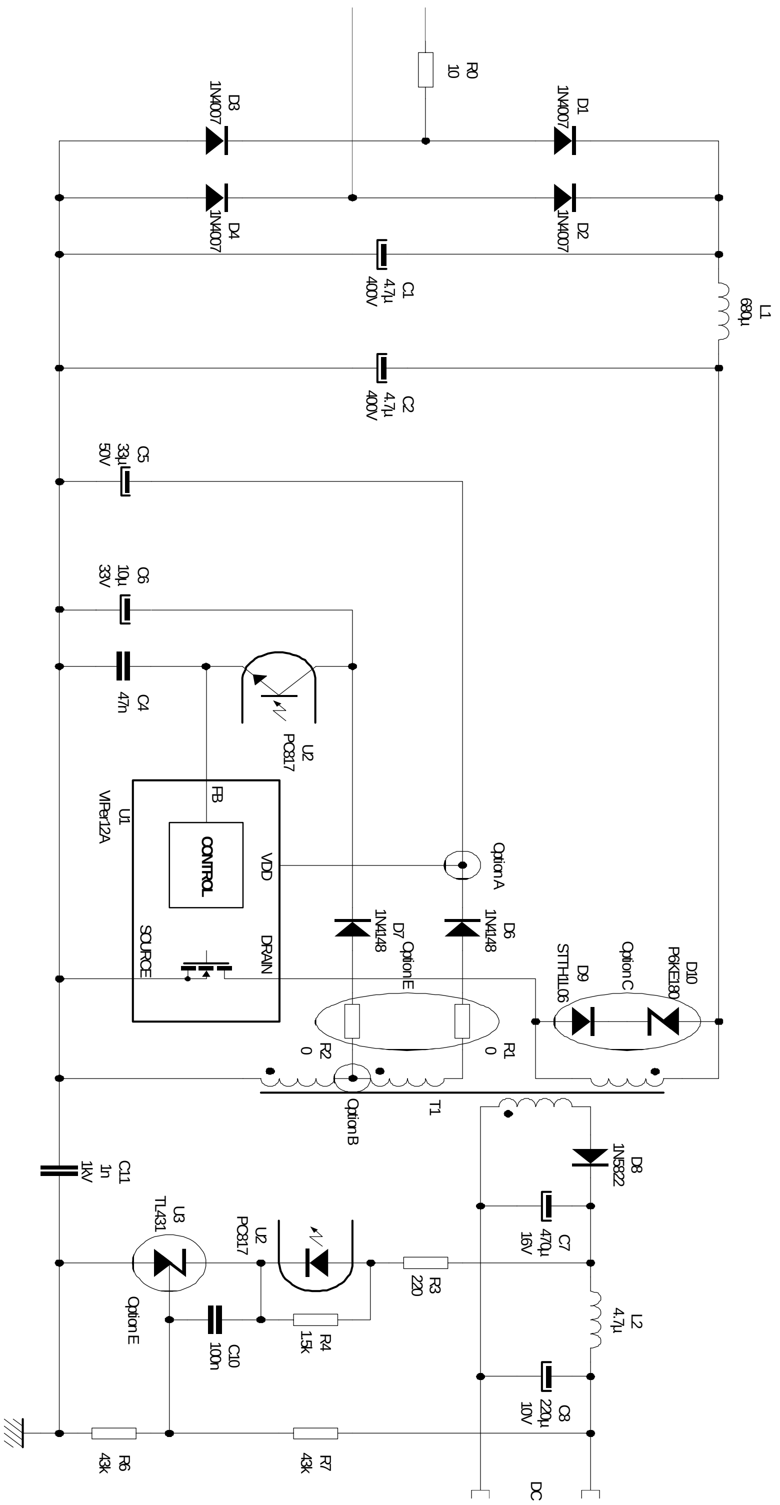



## 4. GENERAL CIRCUIT DESCRIPTION

This board is a fly-back regulator delivering 0.8A at 5V. The AC input is rectified and filtered by the diode 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, D10 form the snubber circuit needed to reduce the leakage spike and voltage ringing on the drain pin of VIPer12A.

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

**Figure 2: Application schematic**



## 5. CHARGER APPLICATION

### 5.1 Schematic general description

As the total input power dissipation at no load condition of this solution is less than 0.1W, we have to put our attention to save the power losses of each component as much as possible. Below we will introduce details for the major approaches which we adopt in this demo board.

### 5.2 Solutions for energy saving

(A) Losses of VIPer12A controller.

As on this demo board, the power losses of the control part of VIPer12A can be calculated by formula (1).

$P_{viper} = V_{dd} * I_{dd1}$ (1)

Shown in datasheet:

Where:

- $V_{dd}$ is the supply voltage of the control part of VIPer12A (range:9V-38V)
- $I_{dd1}$ is the operation current of the control part of VIPer12A (typical value: 4.5mA)

The $V_{dd}$ is set by considering two operative conditions; if we want to save the power of VIPer12A, we must lower the $V_{dd}$ value as much as possible, and at the same time guarantee the $V_{dd}$ higher than 10V which the required normal operation value of VIPer12A (with 1V margin).

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

(B) Optimized voltage source for optocoupler.

In a fly-back topology, the voltage source of 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 for supplying the optocoupler; the voltage supplied with this winding is lower than the $V_{dd}$ value (typical value 3V).

(C) Snubber circuit configuration.

An RCD clamp is a popular cheap solution, however it dissipates power even at no load condition: there is at least a reflected voltage across the clamp resistor at all times. The power losses on resistor can be calculated using the formula below:

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

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 VIPer12A and $f_{sw}$ is the switching frequency.

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

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

In this case with $V_R$=70V, $R_{min}$=82KΩ, $P_R$ is around 60mW

It is possible to save this 60mW power at no load condition using the transil clamp to replace the RCD configuration in the snubber circuit.

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

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

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

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

(E) Short circuit the resistors for current limitation on the auxiliary windings which for $V_{dd}$ of VIPer12A and voltage source for optocoupler primary side.

### 5.3 Performance Results

#### 5.3.1 Input power consumption at no load condition

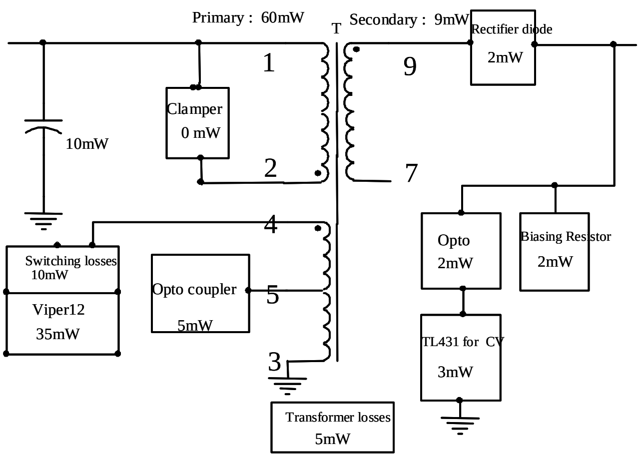
**Table 2. Stand-by power**

| Input Power Consumption | | |
|---|---|---|
| $V_{IN}$ | $I_{IN}$ | $P_{IN}$ |
| 100Vdc | 505µA | 50.5mW |
| 300Vdc | 252µA | 75.6mW |
| 380Vdc | 215µA/203µA | 81.7mW/77.2mW |

Note 1: TL431: 81.7mW; TS431: 77.2mW

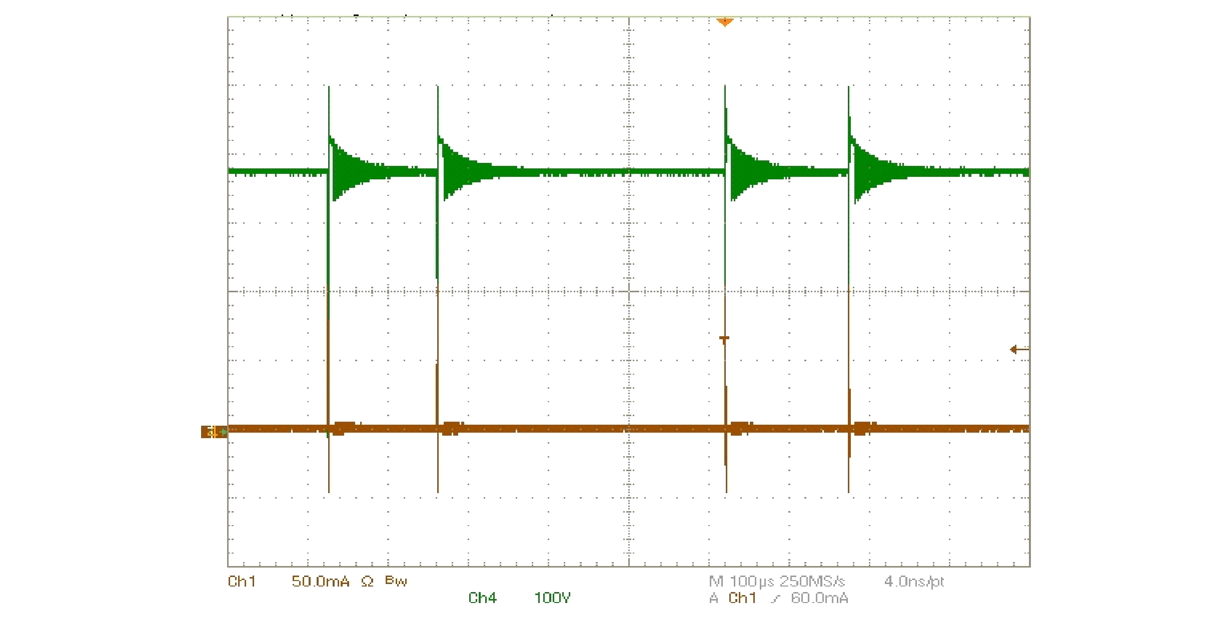
As shown in table 1, the stand-by power is measured at DC voltage input in order to have more precision in the input power data. At the high line input of 380Vdc input, this demo board standby power is around 82mW (with TL431).

**Figure 2. Stand-by consumption at 380Vdc input**



### 5.3.2 Stand-by operation

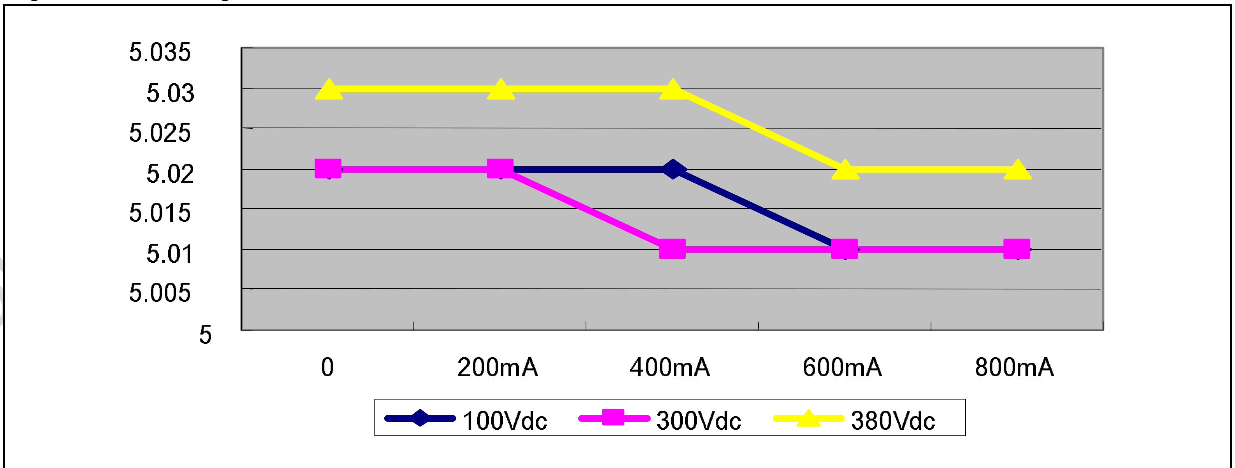
**Figure 3. $V_{ds}$ & $I_d$ at burst mode**




When no load is applied on secondary side, VIPer12A works in burst mode by skipping some switching cycles and this behavior is shown in figure 3. Thanks to this feature, VIPer12A can save a lot of the switching losses reducing the standby power consumption

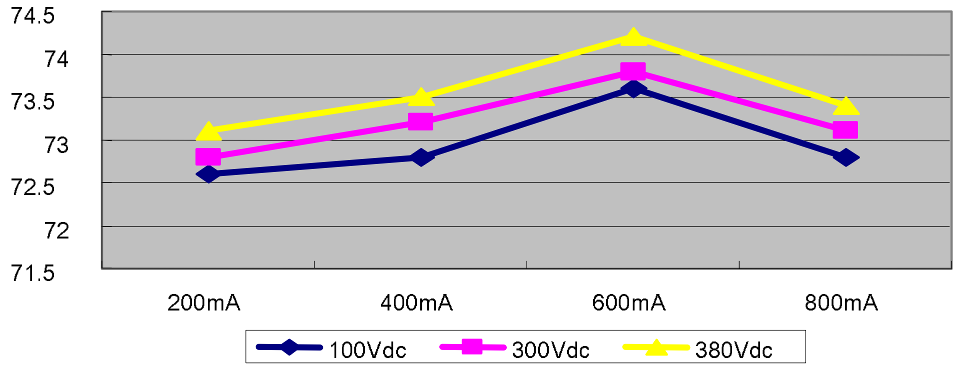
### 5.3.3 Load, Line regulation & Efficiency

**Figure 4. Load regulation**




The output load is changed from 0A to full load 0.8A while the line input voltage is set as 100Vdc, 300Vdc, 380Vdc. The board has a load, line regulation of lower than 1%.

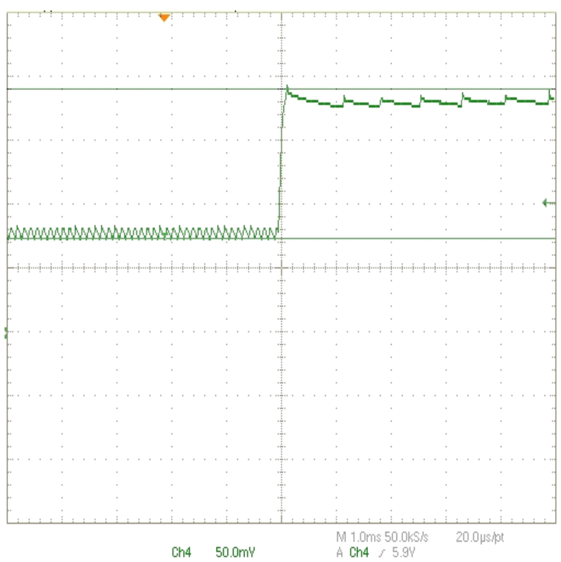
**Figure 5. System Efficiency**




The measurements are taken at an input voltage of 100Vdc,300Vdc, 380Vdc The typical efficiency measured is about 73%. Figure 5 shows the efficiency measured when $I_{OUT}$ is set at different values from 200mA to maximum value of 800mA.

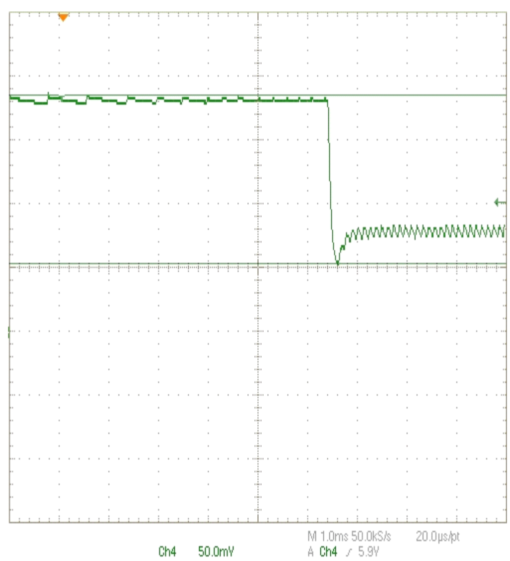
### 5.3.4 Load transient

**Figure 6a: Max load → No load**




(50mV / division)

**Figure 6b: No load → Max load**




(50mV / division)

As shown in the figures 6a, 6b the maximum overshoot and undershoot value of output voltage are less than 150mV at transient tests.

### 5.3.5 Switching Waveforms of normal operation at full load

**Figure 7: $V_{ds}$ & $I_d$ at $V_{IN}$=100Vdc, $P_{OUT}$=4W**

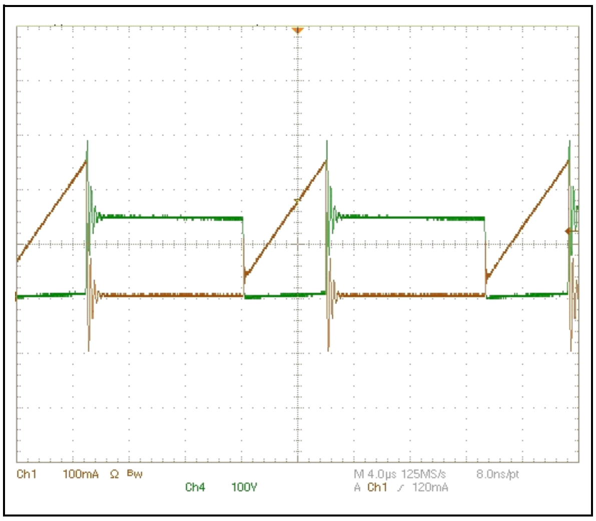
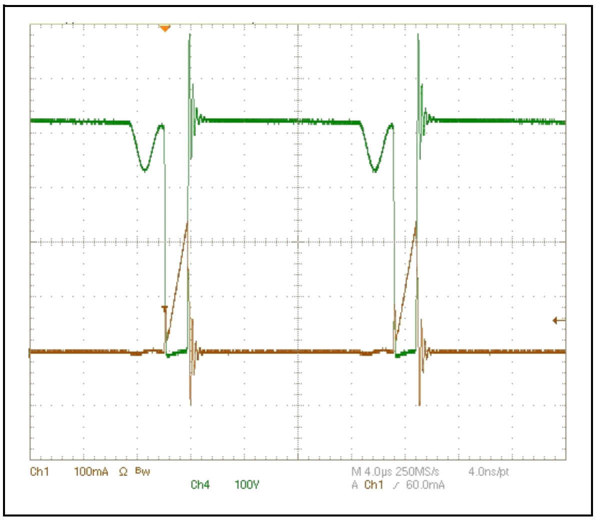



**Figure 8: $V_{ds}$ & $I_d$ at $V_{IN}$=380Vdc, $P_{OUT}$=4W**



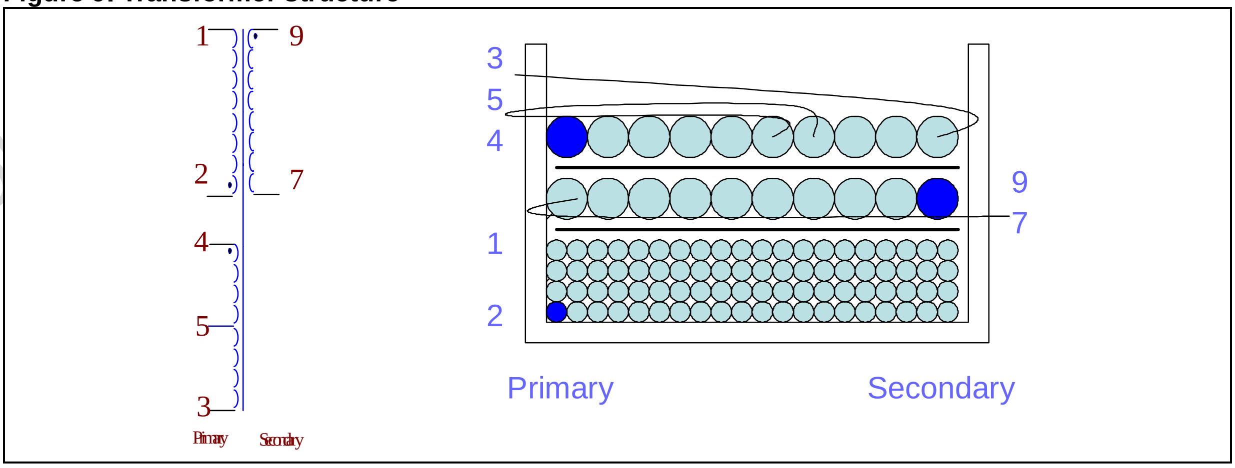

Figures 7 and 8 show the drain voltage and drain current during normal operation at full load. The power supply operates in the continuous current mode at low line and in discontinue current mode at high line input as seen from the waveforms

## 6. TRANSFORMER SPECIFICATION

**Table 3.**

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

**Figure 9. Transformer structure**



## 7. BILL OF MATERIALS

**Table 4. Component list**

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

## 8. CONCLUSIONS

When the board works in standby, it consumes less than 0.1W meeting the "Blue Angel" Norm. The total power consumption measured at 100Vdc input with zero load at output is approximately 50mW, while at 380Vdc input this value is about 80mW.

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 operates in burst mode.