AN2042
APPLICATION NOTE

VIPower: DIMMABLE DRIVER FOR HIGH BRIGHTNESS LEDS WITH VIPer22A

1. ABSTRACT

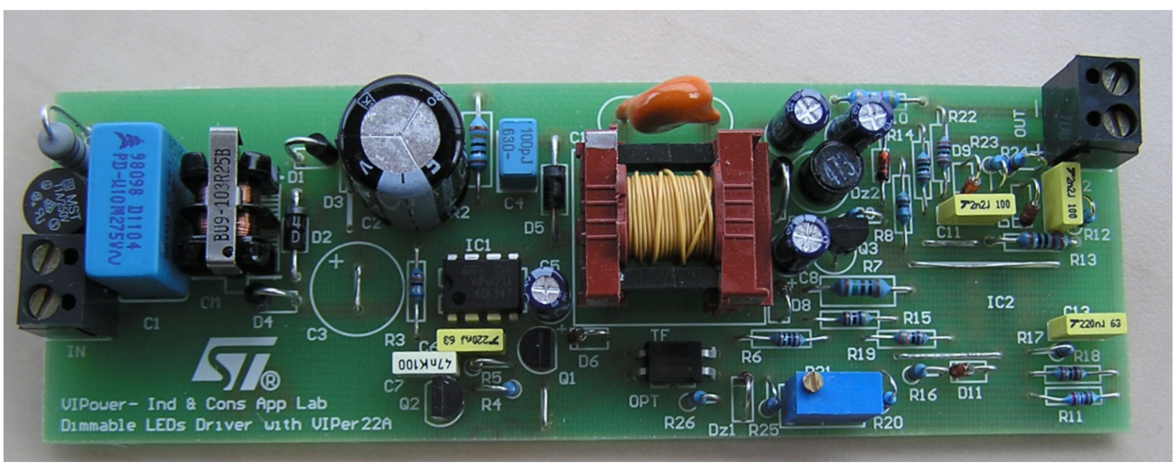
This application note introduces an innovative solution to drive high brightness 1W LEDs (Light Emitting Diode), using VIPer22A in flyback configuration with output current control.

The power supply is able to drive an array of 1 to 8 LEDs in European range, i.e. 185-265VAC with no modifications. By means of an input voltage doubler, it is possible to use the same VIPer device also in U.S. input voltage range, guaranteeing the specs. A new control technique is used to adjust the duty cycle of the output current, in order to dim the luminosity of the LEDs down to 10% of the maximum value (patent pending by STMicroelectronics).

The proposed driver can be suitably used in applications such as landscape lighting, street lighting, car parks, bollards, garden lighting, large area displays and so on.

Also domestic applications such as room lighting, decorative fixtures and architectural lighting can benefit from the advantage of this dimmable light source.

Figure 1. 10W Dimmable LEDs Driver board layout



2. INTRODUCTION

Incandescent lights are basically electric space heaters that give off light as a by-product. They are very inefficient, wasting most of the power they consume as heat.

An innovative light source is represented by LED technology, with very low power consumption and virtually no heating effect, making LEDs ideal for several domestic and commercial applications.

The long lifetime characteristic of LEDs means savings on maintenance costs. Unlike traditional light sources, LEDs are not subject to sudden failure or burnout. Since LED based light sources last at least 10 times longer than a normal light source (up to 10 years or 100.000 hours for the higher quality products), it is possible to reduce or eliminate the maintenance ongoing costs.

This can be useful in many critical applications where the location makes replacement difficult (radio tower, aircraft warning lights, bridge and tunnel lights…) or in applications where a failure of the light source is not acceptable (emergency exit lights, back up lighting, security lighting…).

LED lighting technology features many advantages compared to conventional lighting:

- Higher energy efficiency, in terms of lumens per watt;
- Direct light beam for increasing system performance;
- Dynamic color control technology;
- Full dimmable without color variation;
- No mercury and no UV or heat in light beam;
- Low voltage operation, suitable for safety purpose in SELV systems.

The most important limitation for using high brightness LEDs is the manufacturing cost, which is still relatively high.

In table 1 a comparison between traditional light sources and a typical commercial LED is shown.

Table 1. Performance of typical light sources compared with White Luxeon LEDs

Lighting source	Luminous efficiency (lm/W)	Lifetime (hours)	Theoretical optical power (min and max)
Incandescent bulbs	18 ÷ 25	1000 – 2000	15 – 1000W
Halogen lamps	15 – 25	2000 – 5000	5 – 2000W
Fluorescent lamps	60 – 110	14000 – 20000	4 – 60W
Mercury lamps	15 – 60	12000 – 24000	50 – 1000W
LEDs (White Luxeon)	**25**	**100000**	**0.7 – 5W**

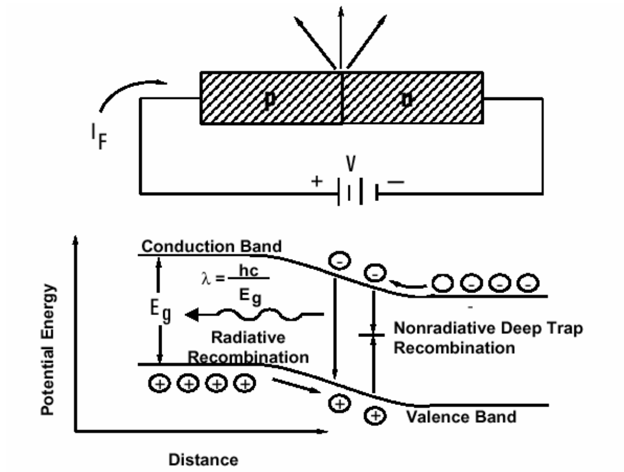
3. LIGHT EMITTING DIODE AND COLOUR VISION

Light-emitting diodes (LEDs) used for illumination are solid-state devices that produce light by passing electric current across layers of semiconductor chips that are housed in a reflector, which in turn is encased in an epoxy lens. The semiconductor material determines the wavelength and subsequent color of the light. The lens converts the LED into a multidirectional or unidirectional light source based on specification.

The first generation of LED was based on Gallium Arsenide (GaAs), Gallium Arsenide Phosphide (GaAsP), Gallium Phosphide (GaP) technology, but thanks to the growth of solid state technology, new structures have been introduced based on Aluminum Indium Gallium Phosphide (AlInGaP), Indium Gallium Nitride (InGaN) or Gallium Aluminum Arsenide (AlGaAs), mainly for the high brightness LEDs branch.

In figure 2 the basic LED structure and the energy bands are shown.

Figure 2. Light emitting diode structure

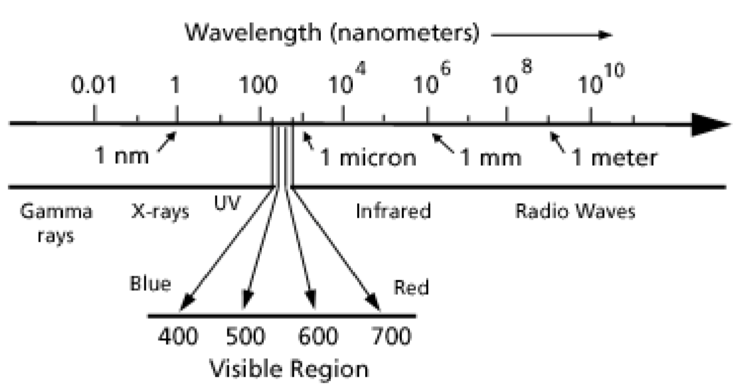


The junction in an LED is forward biased and when electrons cross the junction from the n to the p type material, the electron-hole recombination results in a process called electroluminescence: when the applied voltage drives the electrons and holes into the active region between the n-type and p-type material, the energy can be converted into infrared or visible photons. This implies that the electron-hole pair drops into a stabler bound state, releasing energy on the order of electron volts by emission of a photon of energy, according to (1).

$$E_g = h_c \cdot \upsilon = \frac{h_c}{\lambda} \quad (1)$$

The human eye is excited in response to electromagnetic radiations with wavelengths in a tight range of the electromagnetic spectrum, as shown in figure 3, from 400 nm to 700 nm which corresponds to extreme red and violet respectively.

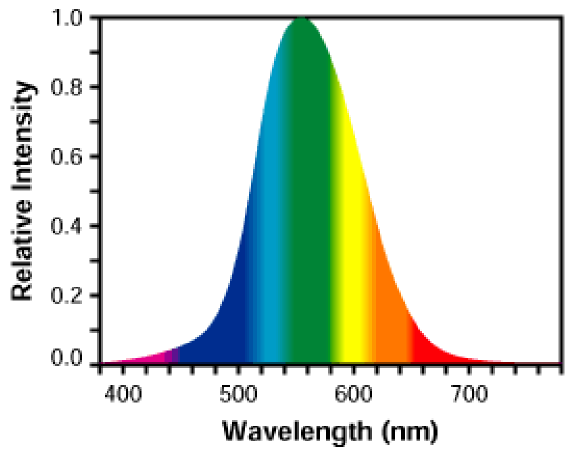
Figure 3. The electromagnetic spectrum and visible region of light



The red extreme of the visible spectrum, 700nm, requires an energy release of 1.77eV to provide the quantum energy of the photon. At the other extreme, 400nm in the violet, 3.1eV is required.

The human vision efficacy is not constant in the entire visible region, but decreases near the edges, as shown in figure 4 featuring a peak value for a wavelength of 555nm (green-yellow).

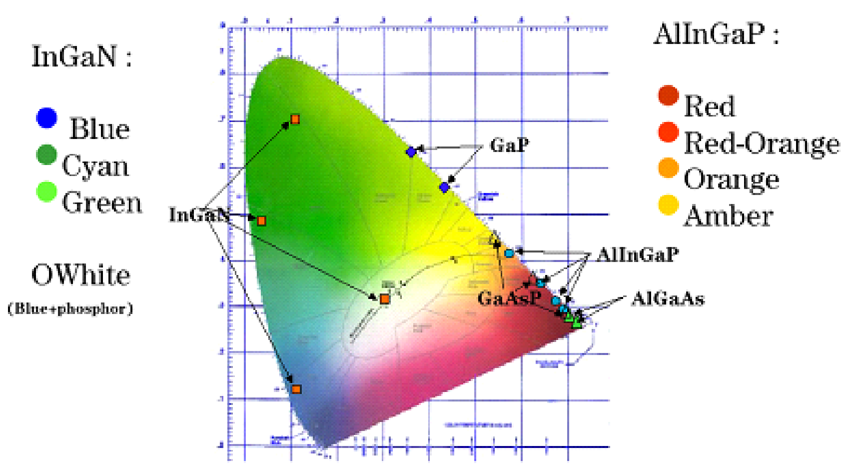
Figure 4. Human relative vision curve



Wavelength can be defined in terms of dominant wavelength and x-y chromaticity coordinates, which define the color as perceived by the human eye. The dominant wavelength is derived from the C.I.E. (Commission Internationale de l'Eclairage - International Commission on Illumination) Chromaticity Diagram, as shown in figure 5. This is an international standard for primary colors established in 1931.

Based on the fact that the human eye is able to separately sense three different portions of the spectrum (we identify these peak sensitivities as red, green and blue), the eyes response is best described in terms of such primary colors. All the other colors are defined as weighted sum of them.

Figure 5. C.I.E. chromaticity diagram



4. COMMERCIAL LEDs

In the last years, light emitting diodes can be chosen from a wide variety of products designed to meet specific needs to provide more efficient, longer life time alternatives to traditional incandescent lamps.

They are manufactured of GaN and related compounds of AlGaN and InGaN due to the wide bandgap, which allows emission of light ranging from the red to the ultraviolet (UV) wavelength. Blue and green LEDs are of special interest and are being used in a wide range of applications from outdoor video displays to automotive and cell phone backlights. LEDs for solid-state white lighting offer high efficiency, long lifetime and a high degree of design flexibility for a variety of lighting applications.

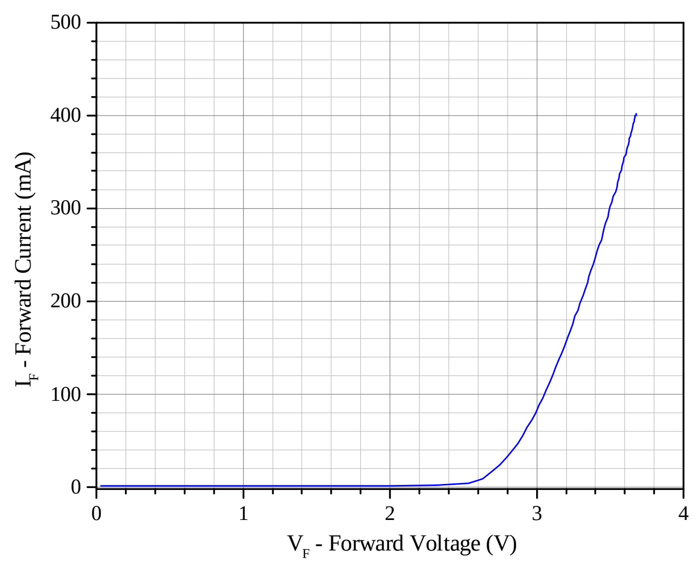
Thanks to new solid state technology, it now delivers from 25 to more then 120 lm/W in white and comparable light output in other colors.

In table 2 are listed the main specifications for typical commercial high efficiency LEDs are listed, while figure 6 shows a typical V-I characteristic for a high efficiency LED.

Table 2. Typical characteristic for commercial LEDs (from Luxeon).

COLOR	Operating Voltage (V)	Operative Forward Current (mA)	Dominant wavelength/ Color temperature	Typical Luminous Flux (lm)
White	3.42	350	5500K	18
Blue	3.42	350	470nm	5
Cyan	3.42	350	505nm	30
Green	3.42	350	530nm	25
Amber	2.85	350	590nm	20
Red	2.85	350	625nm	25

Figure 6. Forward current vs. Forward Voltage in a typical commercial LEDs



5. NEW DIMMING TECHNIQUE

Nowadays, thanks to the growth of process, packaging and thermal transfer technologies, light output continues to evolve. This involves especially the InGaN technology, which produces light output across blue, cyan, green and white, with high reliability and efficiency.

The wavelength of the light emitted is strongly dependent on the forward current driven through the device and in order to avoid shifts in color the dimming strategies have to be chosen carefully.

The most common method of dimming a LED is by varying either forward current or voltage across it.

Unfortunately, due to the characteristics of InGaN, varying current or voltage will shift the wavelength. This effect is proportional to the wavelength, with the longer wavelengths undergoing the strongest shift variation versus current.

In many applications this effect cannot be accepted and, employing a PWM technique, it is possible to dim a LED in the right manner, without wavelength shift.

The LED is switched on and off at constant forward current (I_F) by varying the duty cycle, as shown in figure 7.

If the PWM frequency is higher than 100Hz, the human eyes cannot perceive the single pulses, but they integrate and interpret those pulses as brightness, which can be changed linearly by varying the duty cycle linearly, with no wavelength shift. Figure 8 shows the brightness variation versus duty cycle.

Figure 7. PWM technique for dimming

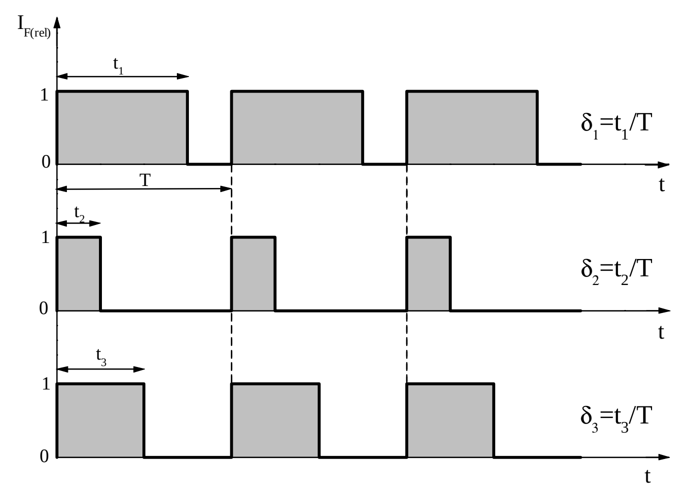
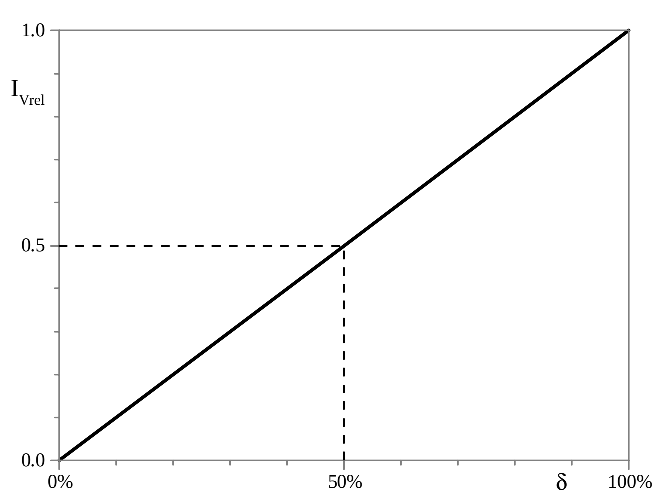


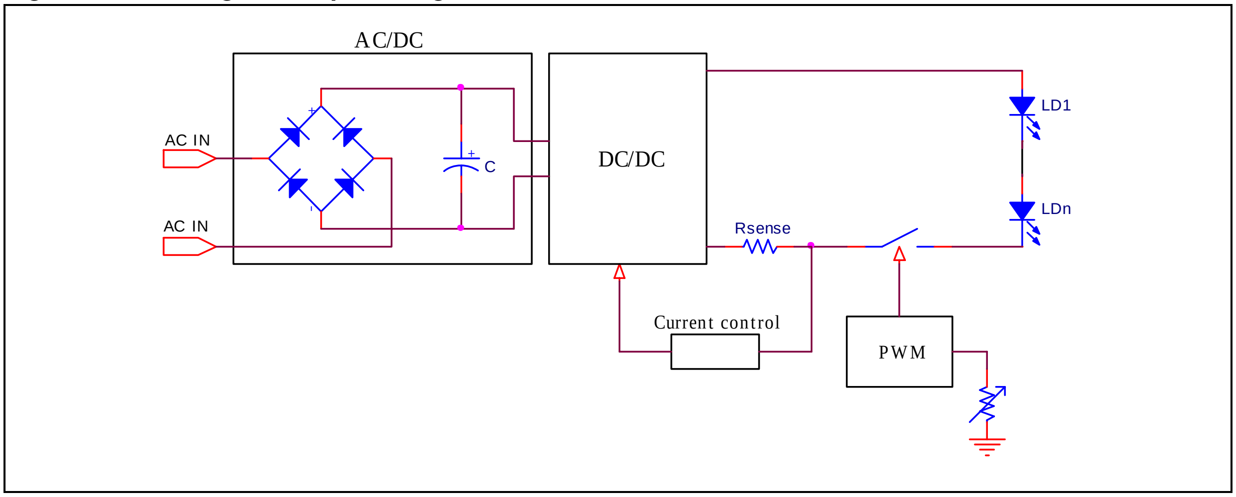
Figure 8. Brightness variation versus duty cycle



As shown in figure 9, the most common method to dim LEDs consists in a series connection of a power switch which is controlled by PWM.

Due to the relatively high operative forward current, the switch has to be selected carefully in order to handle the conduction losses.

Figure 9. Dimming technique using series switch



To overcome this problem, a patented solution has been implemented, which allows to eliminate the series switch, with a considerable improvement in terms of efficiency.

The new technique consists in a double control loop: a current and a voltage control loops. The first one drives the LEDs with constant current when the maximum luminosity is required. During the dimming operation, the current control loop will still limit the maximum output current, while the voltage loop will maintain the output voltage below the threshold voltage of the LEDs array. Also disconnecting the LEDs, the maximum output voltage will be limited by the voltage loop. In figure 10 and figure 11 the block diagram of the new dimming technique and the temporal diagrams are respectively shown. Thanks to the absence of the power switch, it is possible to have a more efficient and cheaper solution.

Figure 10. Dimming technique using the new methodology.

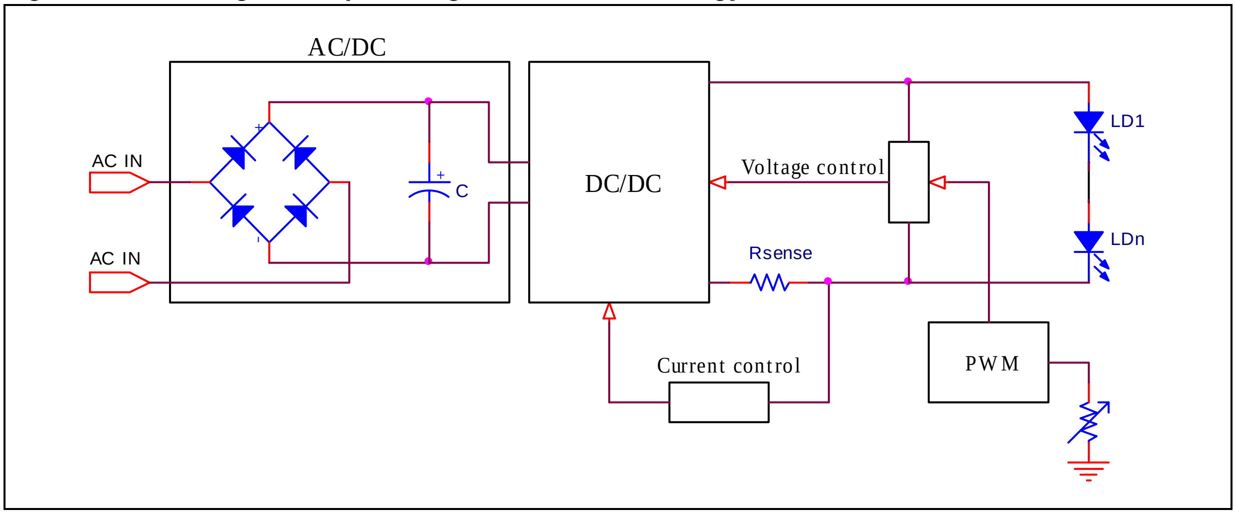
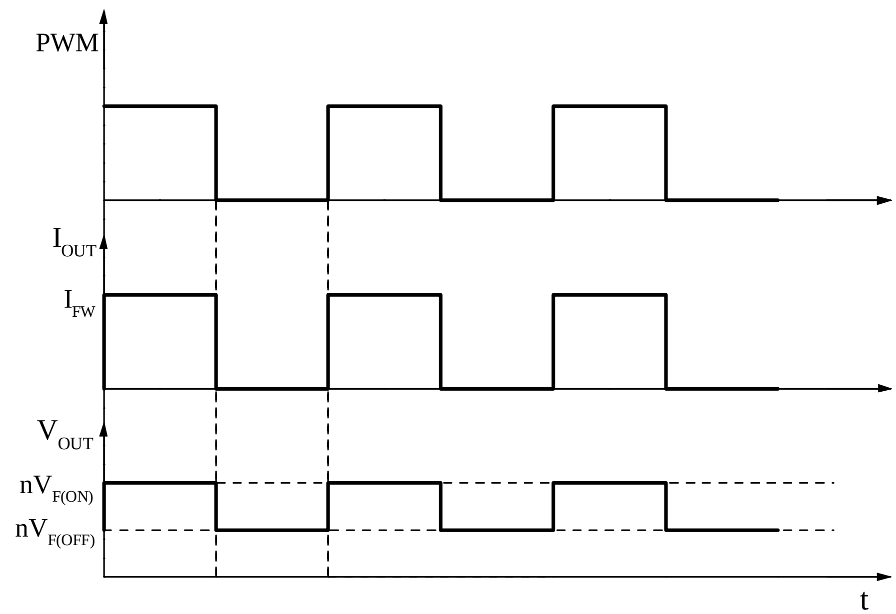


Figure 11. New dimming technique: typical waveforms



6. APPLICATION DESCRIPTION

The proposed converter is based on VIPer22A, a smart power with a current mode PWM controller, start-up circuit and protections integrated in the same monolithic chip, using STMicroelectronics VIPower M0 Technology. The power stage consists in a vertical Power MOSFET with 730V breakdown voltage and 0.7A typical peak drain current.

The application consists in an isolated constant current power supply, intended to supply an array of eight high efficiency LEDs, as shown in figure 12.

The board has been designed referenced to the specifications listed in table 3. It is important to highlight that the converter works in single range, but both U.S. and European range can be selected, with only a few modifications in the input section.

Table 3. SMPS Specifications

Selectable Input Voltage Range	$85V_{AC}$÷$135V_{AC}$ or $185V_{AC}$÷$265V_{AC}$
Nominal Output Voltage Range	3.5V÷28V
Maximum Output Voltage at Open Load	32V
Output Current	350mA
Dimming Range	0%÷90%
EMI Standard	EN55015:2000

In the input stage, an EMI filter is implemented (C_1, CM, C_2) for both differential and common mode noise, in order to fit the EN55015:2000 standard (limits for electrical lighting and similar equipment). The input resistor R_1, limits the inrush current of the capacitors at plug-in and a standard fuse is also introduced to prevent catastrophic failure.

The clamping network (R_2-C_4-D_5), limits the peak of the leakage inductance voltage spike, assuring reliable operation of the VIPer22A.

The auxiliary winding on the primary side, is connected in forward mode, since the output voltage ranges from 3.5V to 28V and the voltage on VDD pin varies from 17V to 24V.

A brown-out circuit (R_3, R_4, R_5, Q_1, Q_2 and C_7) is implemented in order to avoid the flickering of the LEDs during switch off. The values of R_3, R_4 and R_5 are chosen in order to get the given thresholds, while C_7 stabilizes the voltage on the base of Q_1.

The output filter selection is a very critical point to consider during the design. Since LEDs are switched on and off during the dimming phase the value of the output capacitor has to be as low as possible. Therefore, in order to avoid exceeding the maximum output current ripple, care must be paid to design the right LC post filter.

6.1. Dimming Control Circuit

The current loop is controlled by the second operational amplifier of TSM104W and the sense resistor R10. The voltage threshold is generated by means of a resistor bridge (R_{12}, R_{13} and R_{14}) connected to the 2.5V internal voltage reference V_{REF}. The resistors of the bridge should be 1% precision in order to get the best precision on the regulation.

The current control equations are given by (2) and (3).

$$V_{(Iout)} = \frac{V_{REF} \cdot R_{14}}{R_{12} + R_{13} + R_{14}} \qquad (2)$$

$$I_{OUT} = V_{(Iout)} \cdot R_{10} \qquad (3)$$

The sense resistor R_{10}, is chosen taking into account the maximum dissipation during full load.

The voltage loop is controlled by the third operational amplifier and the voltage divider R_8 and R_9 directly connected to the output. The values are chosen according the equations (4) and (5).

$$V_{Oref} = \frac{V_{REF} \cdot (R_{13} + R_{14})}{R_{12} + R_{13} + R_{14}} \qquad (4)$$

$$V_{Oref} = \frac{V_{OUT(MAX)} \cdot R_9}{R_8 + R_9} \qquad (5)$$

Where $V_{OUT(MAX)}$ is the maximum acceptable output voltage, when the LEDs array is disconnected.

The transistor Q_3, connected to the dimming control section, is ON during normal operation.

The feedback to the primary side is achieved thanks to the diodes D9 and D10, which decouple the two loops and drive the optocoupler OPT. The legs R_{23}-C_{11} and R_{24}-C_{12} are connected for feedback stabilization.

The zener diode D_{Z2} is connected at the non-inverting input of the voltage control operational amplifier in order to clamp the maximum voltage on the pin in any operative condition.

The PWM control is realized using the first operational amplifier to generate a sawtooth waveforms at 270Hz (given by the leg R_{19}-C_{13}), which is compared with a variable voltage (set by the potentiometer R21): the generated signal will drive the NPN transistor Q_3.

When the transistor is "ON", the SMPS works in "current control" mode limiting the max output current while, when the transistor is "OFF", it works in "voltage control" mode, regulating the output voltage below the LEDs threshold and consequently switching them off.

During the dimming operation, the transistor Q_3 is switched off and the voltage on pin 11 of IC2 is pulled up and limited to V_{DZ1}. Consequently, the VIPer stops switching and the output current falls to zero, while the output voltage decrease down to V_{OUT}=n · $V_{F(OFF)}$, where n is the number of LEDs and $V_{F(OFF)}$ is the threshold voltage. Further decrease of the output voltage is not possible because of the high output impedance. Doing so, the output voltage never falls to zero, resulting in a big improvement in the dynamic behavior of the dimming function, with a slight impact on the efficiency (P_{DISS}=V_{OUT}-V_{DZ2})/R_8).

In open load condition, the maximum voltage is regulated by R_8, R_9 and D_{Z2} according to the reference voltage given by (5).

Figure 12. Converter schematic for European input voltage range

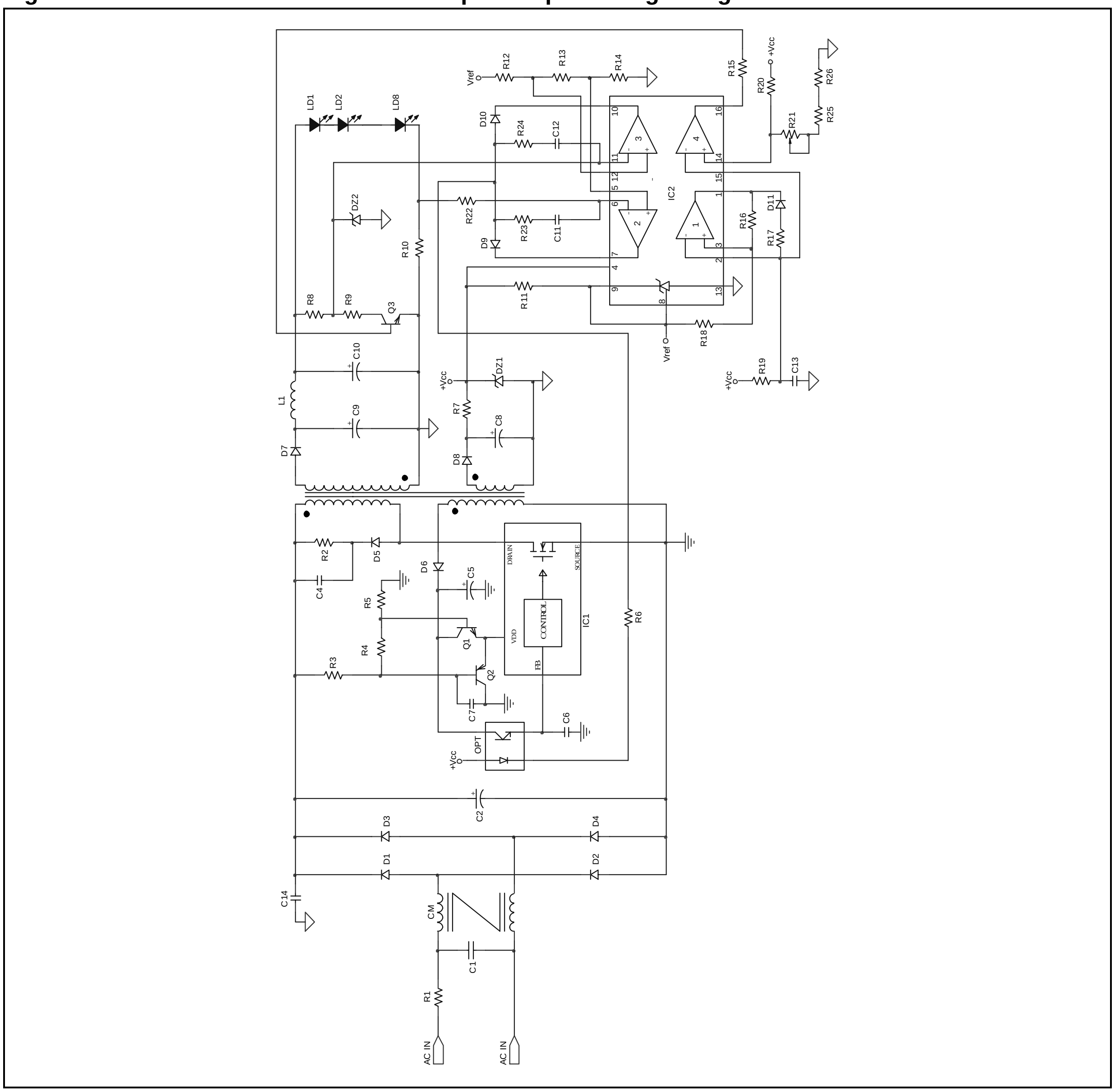


Table 4. Component list

Reference	Description	Note
Fs	1A-250V	Fuse
R_1	10Ω, 1/2W	Metallic Oxide Resistor – No flammable
R_2	1MΩ, 1/2W	
R_3	560kΩ, 1/4W	
R_4	12kΩ, 1/4W	
R_5	24kΩ, 1/4W	
R_6	1kΩ, 1/4W	
R_7	150Ω, 1/2W	
R_8	5.6kΩ, 1/4W	
R_9	220Ω, 1/4W	
R_{10}	0.47Ω, 1/4W	Sense Resistor
R_{11}	2.7kΩ, 1/4W	
R_{12}	12kΩ, 1/4W	
R_{13}	10kΩ, 1/4W	
R_{14}	1.5kΩ, 1/4W	
R_{15}	4.7kΩ, 1/4W	
R_{16}, R_{18}, R_{22}	22kΩ, 1/4W	
R_{17}	100Ω, 1/4W	
R_{19}	33kΩ, 1/4W	
R_{20}	15kΩ, 1/4W	
R_{21}	20kΩ, 1/4W	Potentiometer
R_{23}, R_{24}	220kΩ, 1/4W	
R_{25}	1.2kΩ, 1/4W	
R_{26}	6.8kΩ, 1/4W	
C_1	100nF, 275V	X2 Capacitor
C_2	10µF, 400V	Electrolytic Capacitor
C_4	100pF, 630V	Polypropylene Capacitor
C_5	33µF, 25V	Electrolytic Capacitor
C_6, C_{13}	220nF	Polyester Capacitor
C_7	47nF	Polyester Capacitor
C_8	33µF, 16V	Electrolytic Capacitor
C_9	1µF, 50V	Electrolytic Capacitor
C_{10}	3.3µF, 50V	Electrolytic Capacitor
C_{11}, C_{12}	2.2nF	Polyester Capacitor
C_{14}	2.2nF, 250V	Y1 Capacitor
D_1, D_2, D_3, D_4	1N4007	
D_5	**STMicroelectronics STTH1R06**	
D_6, D_8, D_9, D_{10}, D_{11}	1N4148	
D_7	**STMicroelectronics STTH102**	
D_{Z1}, D_{Z2}	Zener Diode 5.1V, 1/4W	
Q_1, Q_3	**STMicroelectronics BC337**	NPN transistor

Table 4. Component list (continued)

Q_2	**STMicroelectronics BC327**	PNP transistor
L_1	47µH	Radial Power Inductor
TF	TDK SRW16ES-ExxH003	
CM	Coilcraft BU9-103R25B	2X10mH Common Mode Choke
OPT	SFH610A	
IC_1	**STMicroelectronics VIPer22ADIP**	
IC_2	**STMicroelectronics TSM104**	

6.2. Transformer Specifications

The transformer has four windings, included two auxiliaries. One is used to supply the VIPer and the other one to supply the TSM104 and the dimming control circuit on the secondary side.

Since the output voltage is variable between 3.5V (with 1 LED) and 28V (with 8 LEDs), the two auxiliary windings are coupled in forward mode to the primary winding.

In order to limit the reflected voltage to a maximum value (100V), the primary-to-secondary turn's ratio has been set according to the maximum count of LEDs.

The transformer characteristics are listed in table 5 and the winding arrangement as well as the mechanical specifications are shown in figure 13.

Figure 13. Transformer features: (a) schematic, (b) mechanical characteristics and (c) pinout

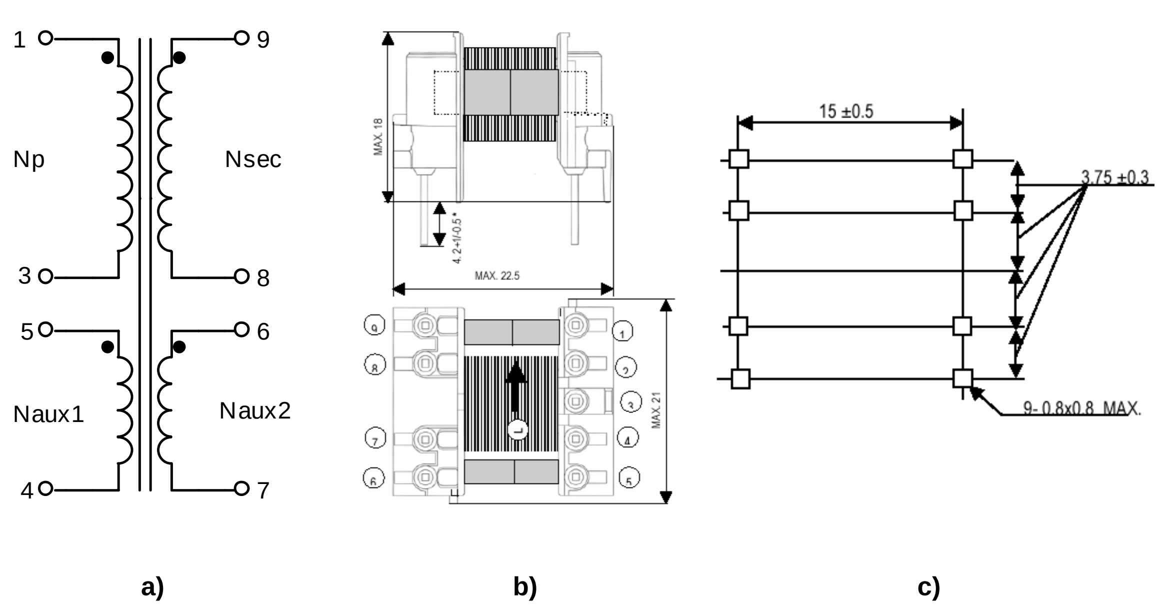


Table 5. Transformer specifications

Ferrite	PC40EF16
Core Geometry	E16
Primary Inductance	2.0mH±12%
Leakage Inductance	60µH max
N_P	135 turns – AWG 35
N_{AUX1}	9 turns – AWG 35
N_{AUX2}	5 turns – AWG 29
N_{SEC}	36 turns – AWG 29

7. EXPERIMENTAL RESULTS

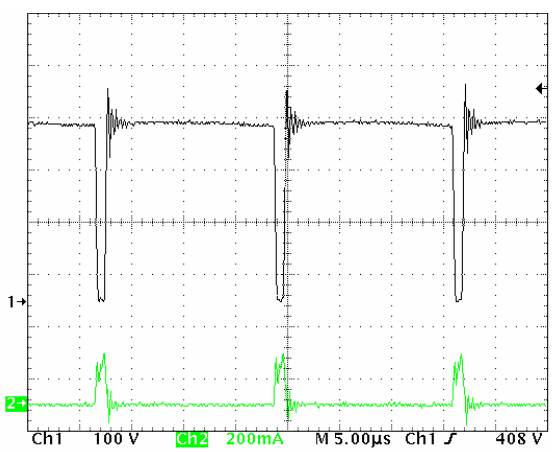
In this section typical waveforms are given under several load conditions. In figures 14a and 14b the drain-source voltage and the drain current at minimum load (1 LEDs) and full load (8 LEDs), at nominal input voltage (230VAC) are shown, respectively. In figure 14a the output current ripple is shown, which is fixed to about 20% IOUT, in order to keep the output filter small and improve the output dynamic behavior.

In figures 15 to 17 the output current and drain-source voltage are shown during dimming operations. It is important to point out that the driver is able to dim the LEDs array down to 10% of its maximum luminosity.

In figures 18 and 19 typical waveforms of the dimming control section, as introduced in 6.1, are shown: the sawtooth waveform, VSAW, defines the dimming frequency while varying the reference voltage, VREF, by means of the potentiometer R21, it is possible to change the PWM duty-cycle and consequently the LEDs luminosity. It is important to point out that the output voltage never goes to zero, but is always above a minimum value depending on the number of LEDs in the array.

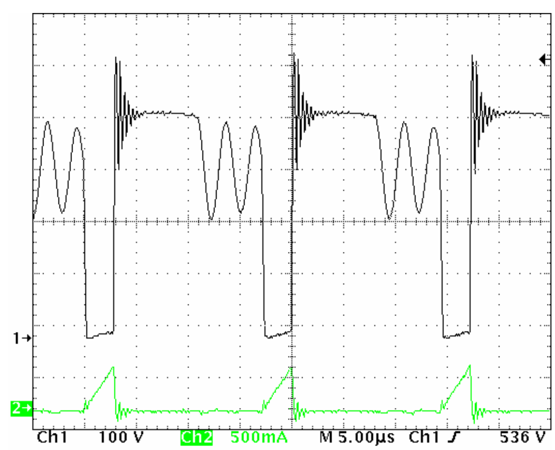
Finally, figure 20 shows the drain voltage and output voltage in open load condition with 1 or 8 LEDs connected respectively. Under this condition the output voltage is limited to about 33V both in steady state and dimming operation.

Figure 14. V_{DS} and I_D at $230V_{AC}$: a) 1 LED and b) 8 LEDs



Ch1 Freq – 58.18kHz
Ch2 Max – 196mA

a)



Ch1 Freq – 58.18kHz
Ch2 Max – 196mA

b)

Figure 15. Typical waveforms: a) Drain voltage and output current ripple at 230V_{AC} and b) Startup at 265V_{AC}

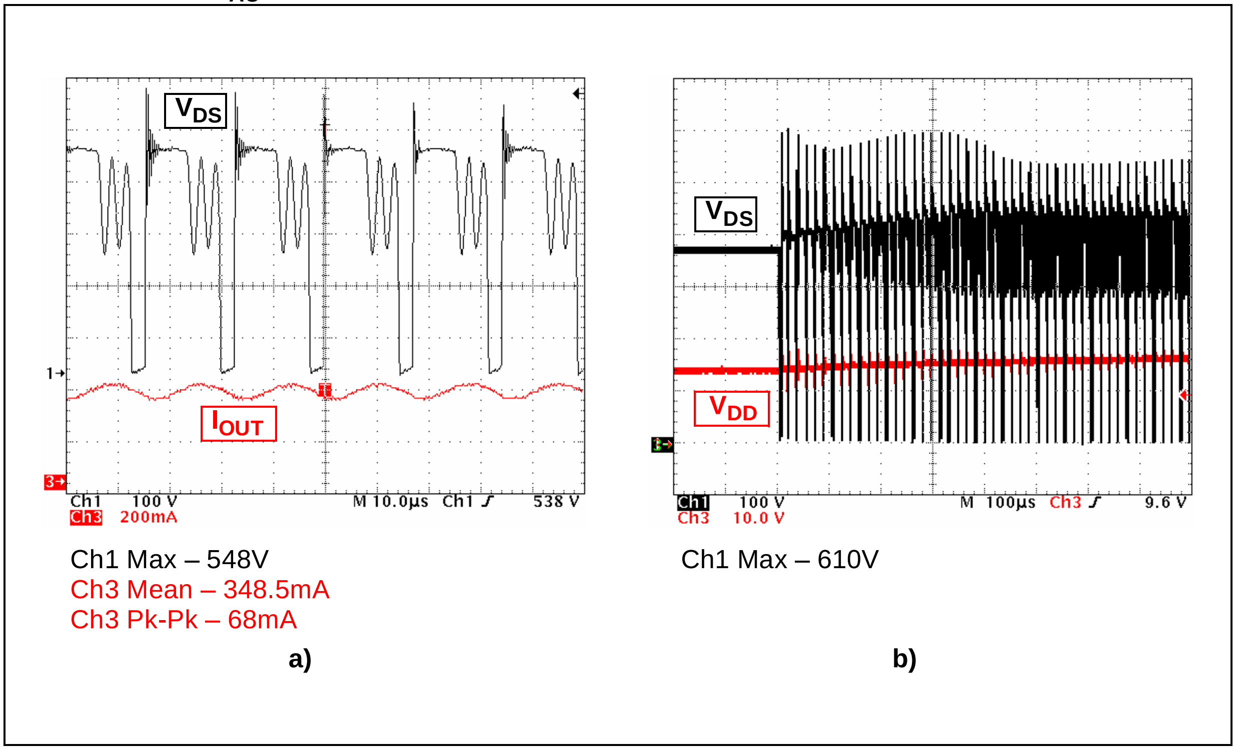


Figure 16. Drain voltage V_{DS} and Output current I_{OUT}: a) 1 LED and b) 8 LEDs

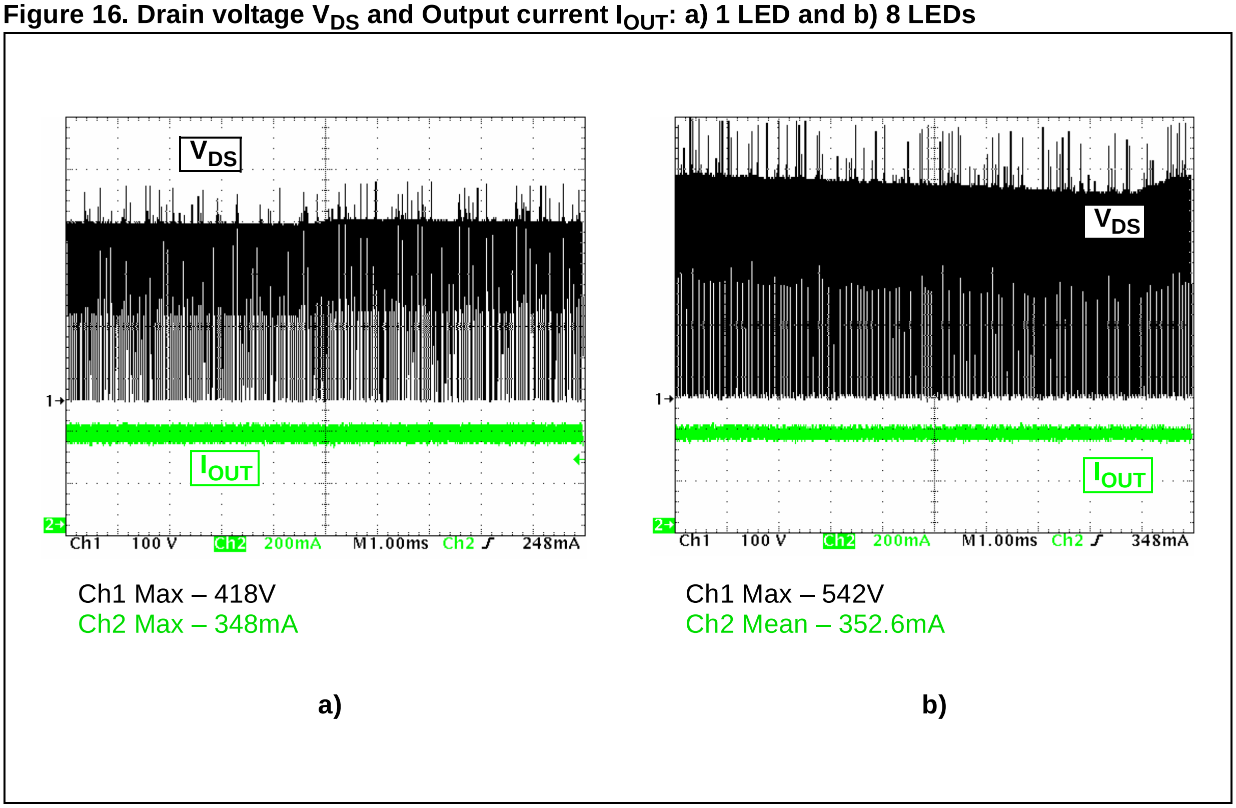
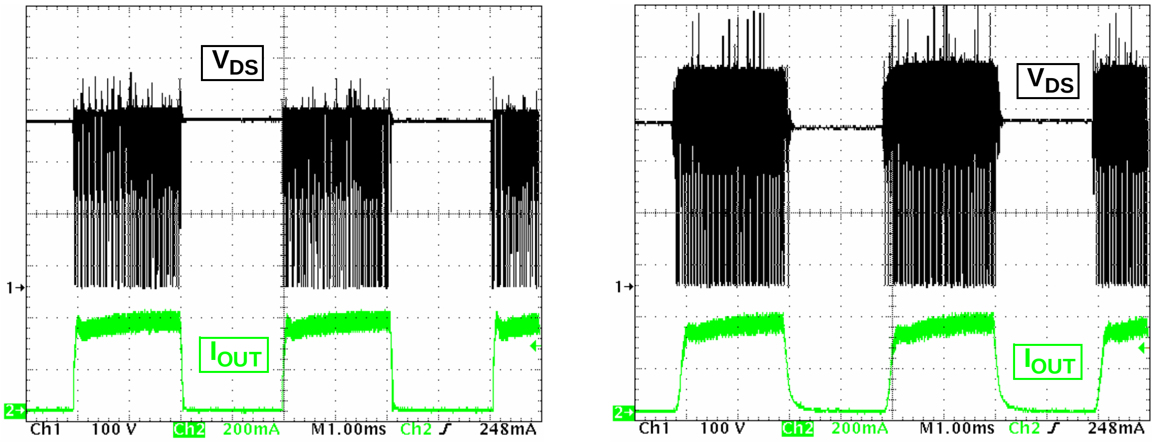


Figure 17. Drain voltage V_{DS} and Output current I_{OUT} at 50% dimming: a) 1 LED and b) 8 LEDs



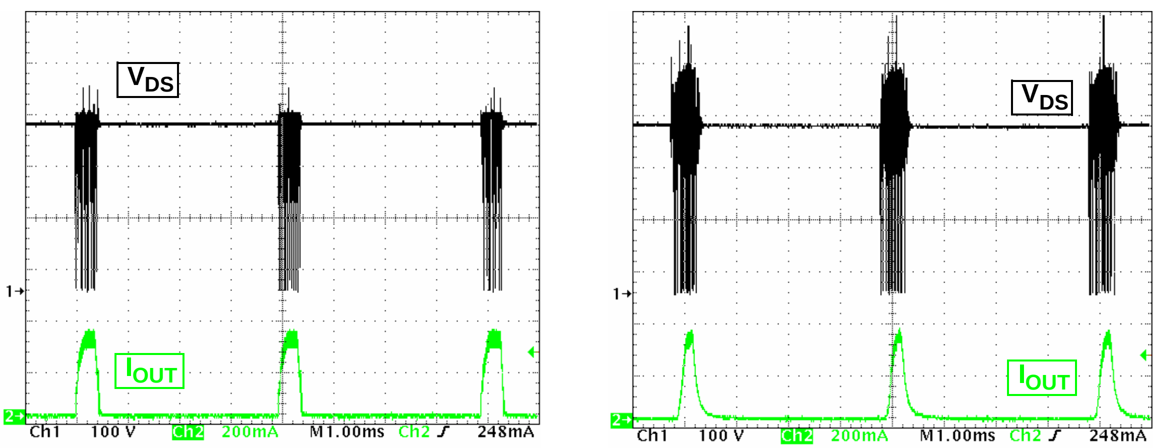
Ch2 Mean – 170.6mA
Ch2 Duty – 51.63%
Ch2 Freq – 246Hz

a)

Ch2 Mean – 171.1mA
Ch2 Duty – 50.52%
Ch2 Freq – 245Hz

b)

Figure 18. Drain voltage V_{DS} and Output current I_{OUT} at 10% dimming: a) 1 LED and b) 8 LEDs



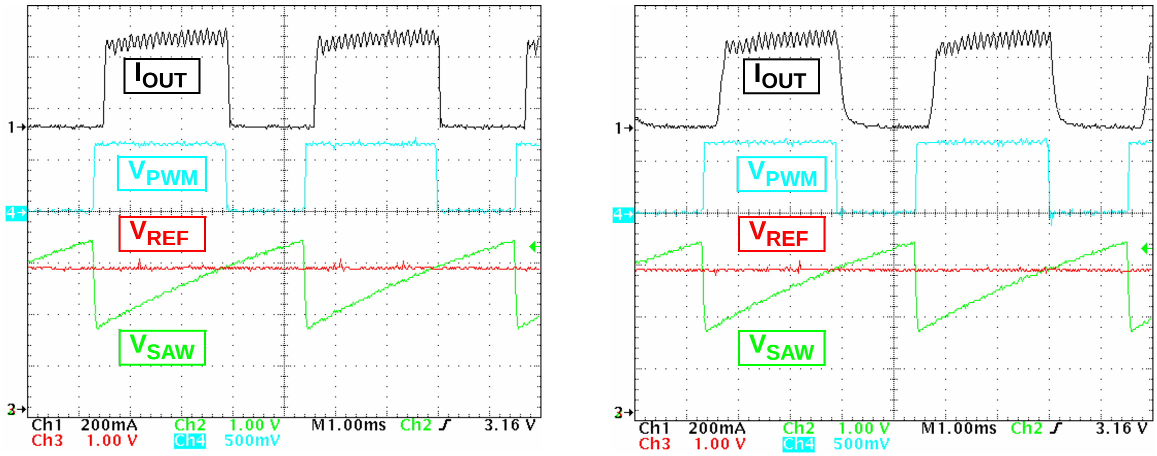
Ch2 Mean – 33.9mA
Ch2 Duty – 10.18%
Ch2 Freq – 252Hz

a)

Ch2 Mean – 31.5mA
Ch2 Duty – 8.8%
Ch2 Freq – 249Hz

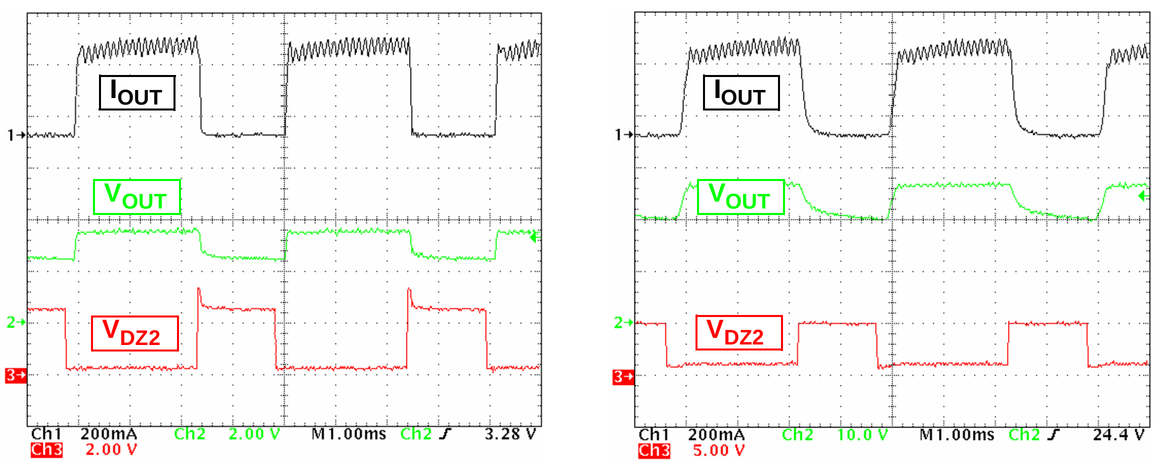
b)

Figure 19. Control signals at 230VAC: a) 1 LED and b) 8 LEDs



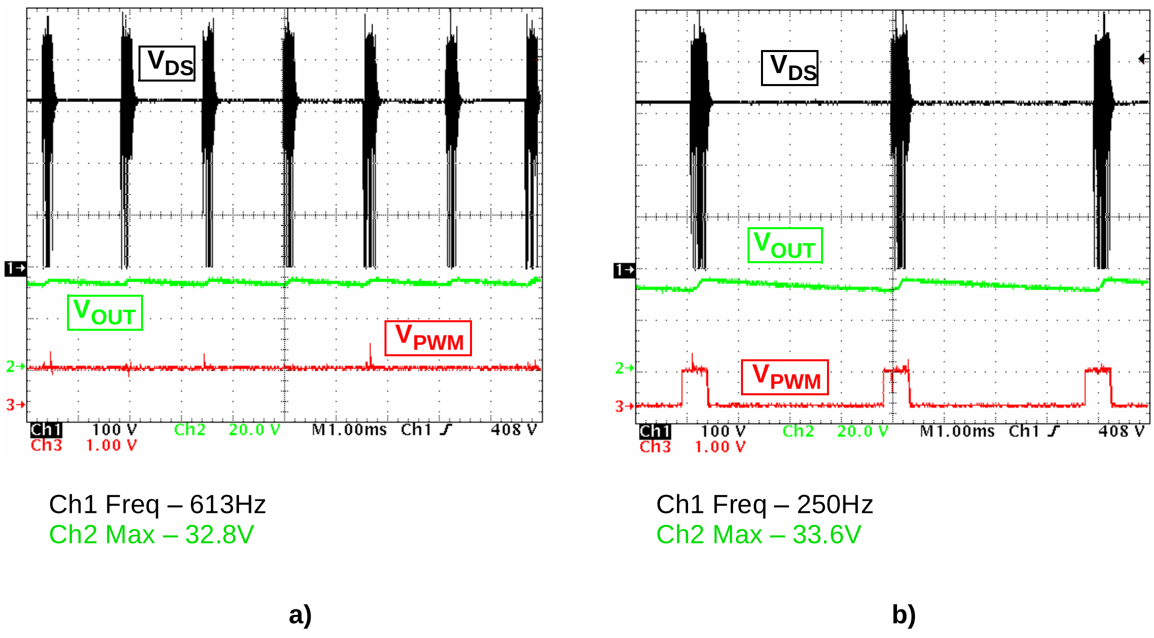
a)	b)
Ch2 Mean – 33.9mA	Ch2 Mean – 31.5mA
Ch2 Duty – 10.18%	Ch2 Duty – 8.8%
Ch2 Freq – 252Hz	Ch2 Freq – 249Hz

Figure 20. Control Stage at 230VAC: a) 1 LED and b) 8 LEDs



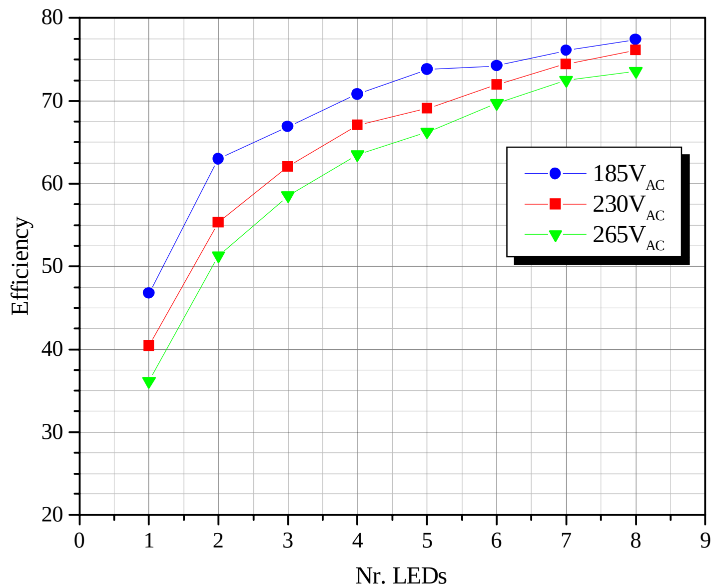
a)	b)
Ch1 Mean – 200mA	Ch1 Mean – 197.4mA
Ch2 Max – 3.48V	Ch2 Max – 26.6V
Ch2 Min – 2.44V	Ch2 Min – 20.2V

Figure 21. Open Load condition at 230VAC: a) no dimming and b) minimum dimming



The efficiency of the system, one of the key parameters of the application, has been measured in the whole input voltage range varying the number of LEDs from 1 to 8, and the experimental results are shown in figure 22.

Figure 22. Efficiency



8. LAYOUT CONSIDERATIONS

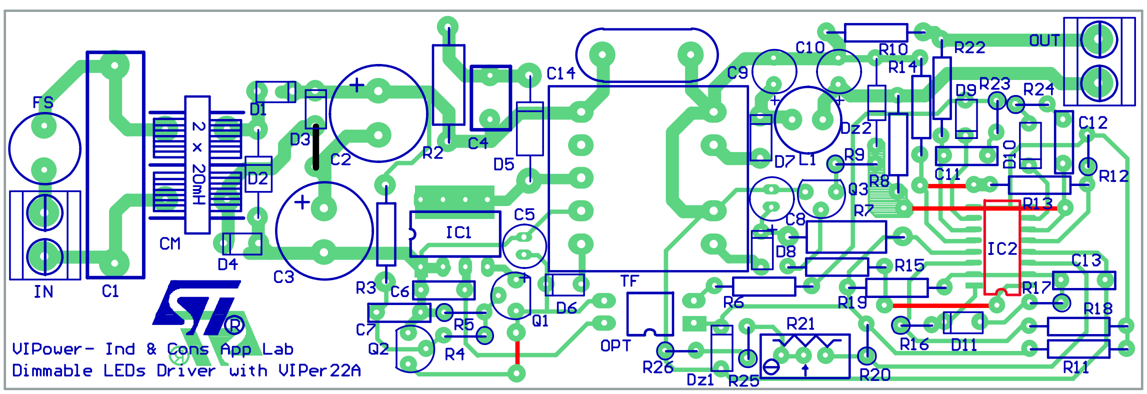
As any switched mode power supply, for proper operations, basic rules have to be taken into account in order to optimize the current path, especially in the routing of high current path. In fact, since EMI issues are also related to layout, the current loop area has to be minimized.

In addition to this, in order to avoid any noise interference between the control section and the power section, the control ground paths have to be kept separated from each other. All the high current traces have to be as short and wide as possible, in order to minimize the resistive and inductive effect.

A particular care has to be taken regarding the optimal routing of the input EMI filter path and the correct placement of any single component.

A final consideration regards the thermal management: a copper area has to be provided on the VIPer drain, in order to reduce the thermal resistance R_{th} and consequently keep the device temperature reasonably low. All the aforementioned considerations have been taken into account in the lab prototype, as shown in figure 23.

Figure 23. PCB Layout (Not in scale)



9. EMI MEASUREMENTS

Conducted EMI measurements have been performed according to EN55015:2000, the specific European standard on electrical lighting and similar equipment, using a 50 LISN and a spectrum analyzer with peak detector.

The results are shown in figures 24 and 25, for Line 1 and Line 2 respectively, under full load condition at nominal input voltage, i.e. 230VAC. The emissions level are well below the Quasi Peak limit although the measurements have been performed using the Peak detector, conforming the conducted EMI compliance of the system.

Figure 24. Conducted emissions at full load: line 1 emissions

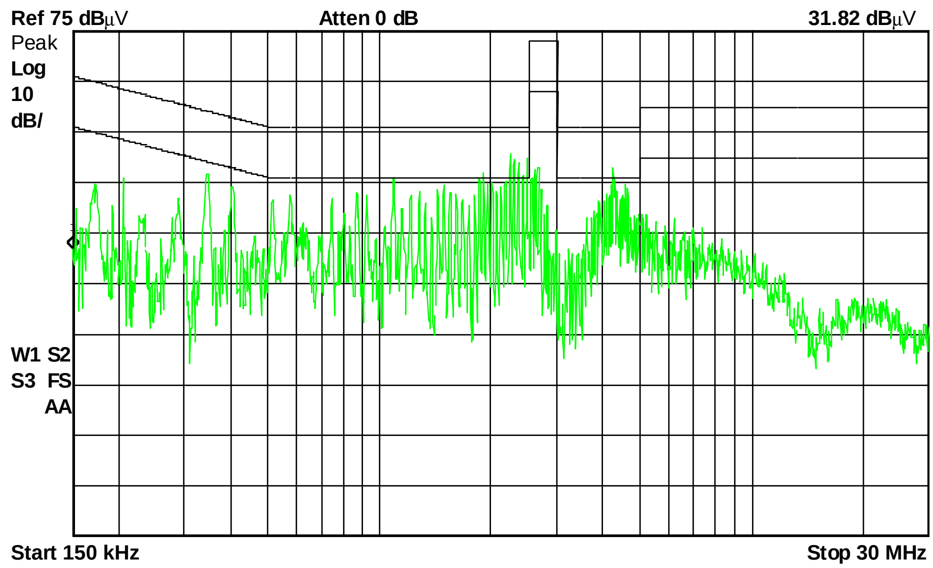
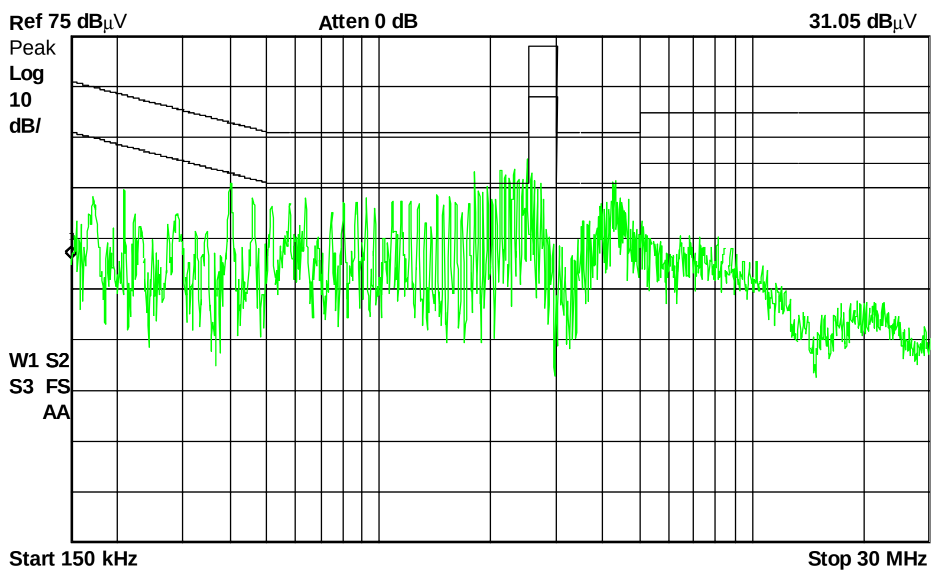


Figure 25. Conducted emissions at full load: line 2 emissions

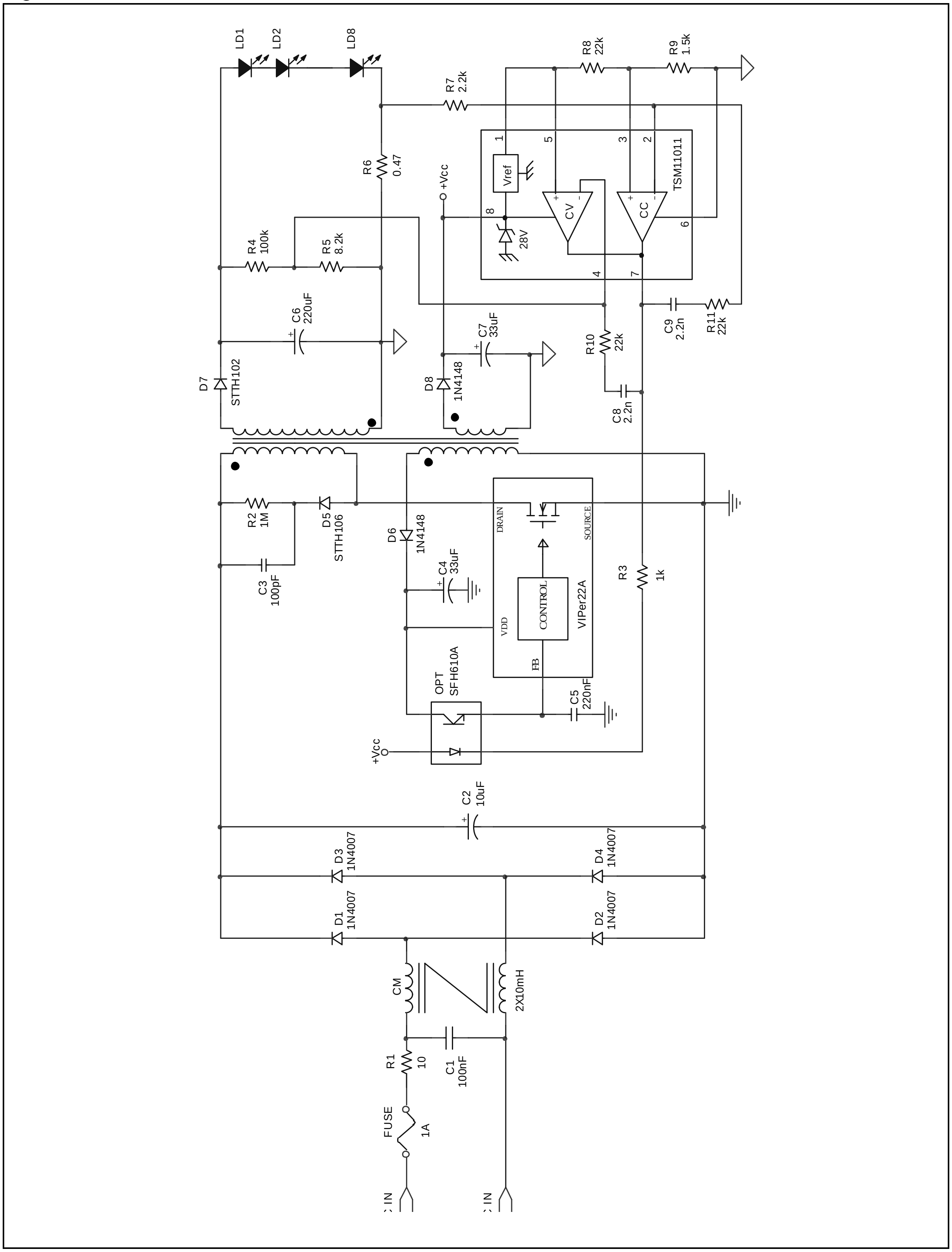


10. NON DIMMABLE VERSION

A lower cost solution is introduced as shown in Fig. 26, if the dimming function is not required. In this case the TSM104 used for the dimming control is replaced by the simpler TSM1011 and the brown-out circuit is not necessary anymore during the switch off of the circuit. No other changes need to be introduced neither the transformer specifications nor the voltage and current thresholds have to be changed.

The dimming control section is eliminated and the TSM104 is replaced by the simplest TSM1011. Moreover, the brownout circuit is not necessary during the switch off. The same rules to design to define the transformer specifications and voltage and current thresholds are still valid.

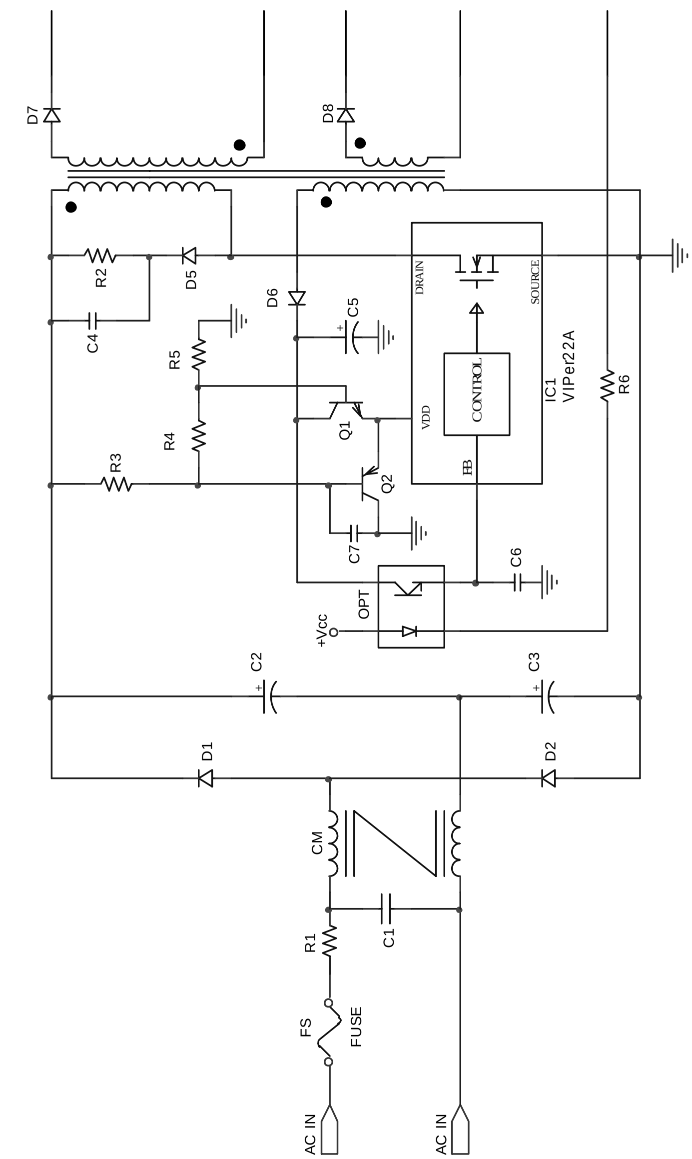
Figure 26. Non dimmable solution



11. INPUT SECTION ARRANGEMENT FOR U.S. MARKET

The proposed system has been designed for the European voltage range, i.e. 187-264VAC, but by means of a voltage doubler, consisting of D_1-D_2 and C_2-C_3, it can also be used with the U.S. voltage range, i.e. 88-132VAC. The only modification needed is related to the input capacitor C_2 which has to be replaced by two capacitors C_2 and C_3 with half the value of the European voltage range, connected as shown in figure 27.

Figure 27. Application circuit for U.S. input voltage range: changes on the input section



12. CONCLUSIONS

In this document an innovative solution for driving High Efficiency LEDs has been introduced.

The power converter is based on a Flyback topology with the smart power VIPer22A. It is able to drive with no circuital modifications 1 to 8 LEDs array and to perform an optimal dimming function by means of a patented PWM technique. A simplified version of the system has also been introduced in order to address the low end applications which do not require the dimming function.

A lab prototype has been developed and fully tested under several conditions, confirming the suitability of the proposed approach to such an emerging application.

The reference board will be available at stock through the Order Code: **STDIMLED22-EVAL1**.

REVISION HISTORY

Table 6. Revision History

Date	Revision	Description of Changes
Oct. 2004	1	- First Issue.
Feb. 2005	2	- Fig. 1 changed. - Bill of Materials modified.