Wide Range Constant Current LED Driver with High Power Factor, Low THD and Low Standby Power Consumption

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ABSTRACT

This article presents a high power factor, low THD (total harmonic distortion) constant current LED driver, which operates with universal input voltage range (90Vac-300Vac), in constant current mode (0.7A) for a wide LED voltage range (60V-105V). STMicroelectronic's design is suitable for 50W-80W LED driver, mainly addressing outdoor and street lighting applications. The power factor and the standby power (no load) consumption meet the energy targets set by EnergyStar and EU Ecodesign standards. Input Current Harmonic Distortion is well kept below 10% at full load thanks to a THD enhancer. The converter efficiency reaches 90% for most of the input voltage range. All protection features like LED open and short are present in the proposed solution. The board is compact in size so as to fit into existing commercially available LED extrusions for LED streetlights.

INTRODUCTION

Among the three major sectors of the LED lighting market (general illumination, backlighting and automotive), general lighting is the one posing the biggest technical challenges to LED driver designers. AC line powered LED drivers, which must comply with class C harmonic emission limits of the IEC61000-3-2, are more and more often specified to meet some emerging targets of THD of the input current. Other technical challenges may come from the requirement of LED drivers that are specified for a rated output current and for a range of output voltages, to power different types and lengths of LED strings or to regulate the LED current over the VLED spread of production and temperature. In order to address these two main challenges of THD reduction and current regulation over a wide LED voltage range, a solution using a single stage single switch in quasi-resonant mode is proposed. The proposed STEVAL-ILL085V1 solution is developed for a wide range of output voltage starting from 60V to 105V. With this solution, it is possible to get higher lumens using the same LED driver operated at a wide range of LED voltage rather than cascaded LED drivers, which add driver stages, increased cost, and decreased conversion efficiency. Figure1 shows the LED driver board developed and tested, which suits a 50W to 80W range without compromising with high power factor (HPF), THD, high efficiency, good current regulation (CR), and low current ripple. Dimming features have been implemented additionally, with the capability to add remote dimming and remote power-on/power-off.

Fig.1 STEVAL-ILL085V1 Evaluation Board

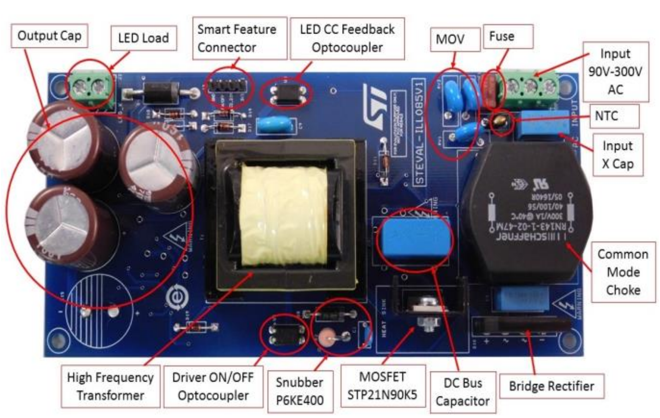
SYSTEM ARCHITECTURE

The single stage single switch LED driver consists of a HPF flyback converter with primary side voltage regulation (PSR) and secondary side current regulation. The flyback converter operates in quasi-resonant mode in order to achieve the best trade-off among EMI conducted emission, input current form factor, and near-zero voltage switching, which results in a high conversion efficiency. Due to the implemented THD optimizer circuit, the proposed solution overcomes the HPF QR flyback converters inherent distortion of the input current.

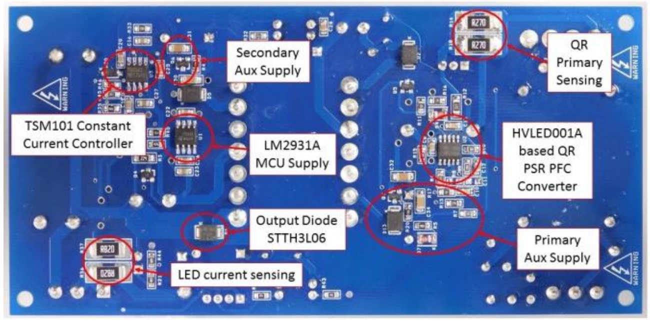
On the primary side, the flyback converter is controlled by the **HVLED001A,** an enhanced peak current mode controller for offline LED lighting applications. The device embeds advanced features to control either the output voltage or the output current precisely and reliably using a reduced number of passive components. Startup and light load conditions are managed by dedicated operating schemes to improve the quality of the regulation of the output variable in the final application. The embedded high voltage start-up circuit is 800V rated, suitable for extra wide AC input voltage range up to 305 Vac. Abnormal conditions such as output short-circuit, input overvoltage/under voltage, and circuit failures like open loop and overcurrent of the main switch are effectively controlled.

The HVLED001A provides the PWM duty cycle to drive the **STP21N90K5** N-channel 900 V, 0.25 Ohm typ., very high voltage super junction technology MDmesh K5 Power MOSFET, in TO-220 package, as the primary switch. The device features drastic reduction in on-resistance and ultra-low gate charge for applications that require superior power density and high efficiency.

On the secondary side, the converter includes the **STTH1L06** and **STTH3L06** ultrafast high voltage diodes for the secondary rectification as well as the **TSM101** to implement the current control loop and to limit the output voltage in case of an LED open event. A post regulation with **LM2931** is used to get supply voltage of any additional MCU and connectivity modules or ICs for remote control.



(a) Top view board major components



(b) Bottom view board major components
Fig.2 STEVAL-ILL085V1 Evaluation Board with Components

Figure 2 shows the hardware of the STEVAL-ILL085V1 LED driver both for the top side (a) and for the bottom side (b).

HARDWARE TEST RESULTS

In this section, test results are detailed. In general, test results are good and match requirements set by regulatory bodies.

Syetem Level Test Reults

Figure 3 shows the system level test results of the STEVAL-ILL085V1. Figure 3 (a) shows driver efficiency—more than 87% for entire line (90Vac-300Vac) and load (60Vdc-105Vdc) variation. Figure 3 (b) shows the current regulation (CR) of the LED—less than 1% for universal input and wide load variation.

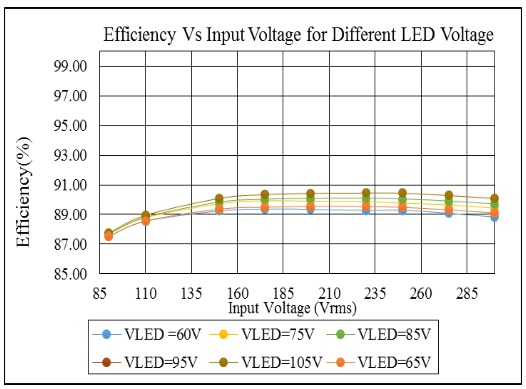


Fig.3 (a) AC-DC LED driver efficiency plot for different LED loads

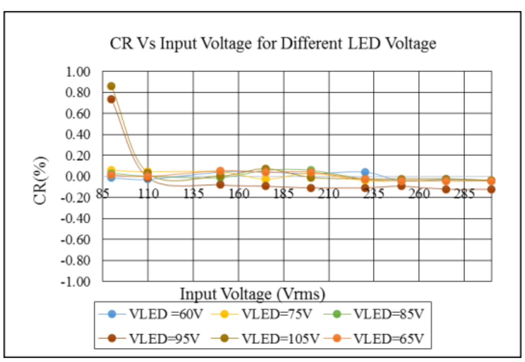


Fig3 (b) AC-DC LED driver current regulation for plot
Fig. 3 Efficiency and current regulation plot of proposed LED driver

Input Current THD and PF

Figure 4 plots the input current THD (a) and PF (b) measured for universal input voltage and different LED loads. The THD measured is well below 10% at the full load condition and below 15% for all load conditions. The power factor is more than 0.95 at all load and line conditions.

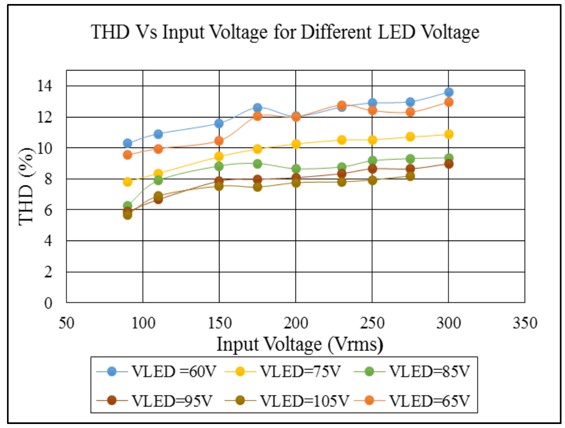


Fig.4 (a) Current THD at different line and LED loads

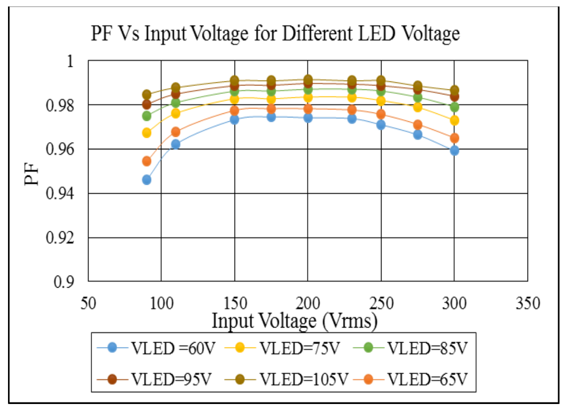


Fig.4 (b) PF at different line and LED loads
Fig.4 Proposed LED driver power quality parameters

Switching Mode of Operation

The LED driver power converter is working in quasi-resonant (QR) mode in order to achieve a higher efficiency than a fixed frequency discontinuous current mode flyback topology would. The zero crossing current detection is predicted by the ZCD pin. Figure 5 shows the test results of switching performance at different line and loads.

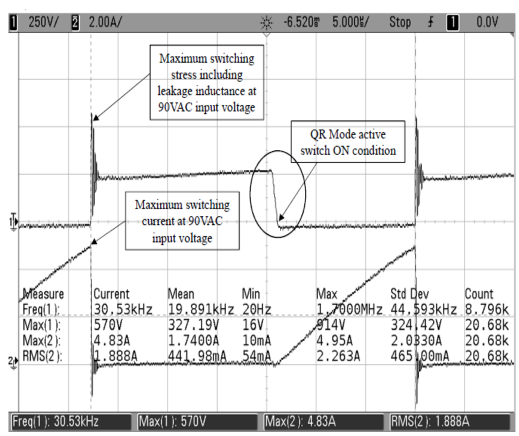


Fig.5 (a) Switching performance at 90Vac and full load

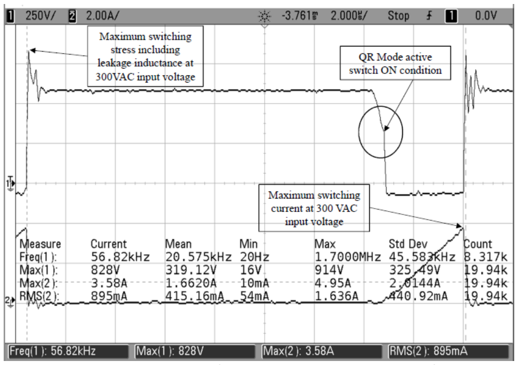


Fig.5 (b) Switching performance at 300Vac and full load

Fig.5 Switching operation expended

(CH1: Q1 drain voltage, Scale: 250V/div. CH2: Q1 current; Scale: 2A/div)

LED Driver Protection Features

The proposed LED driver is protected from LED load open as well as well as short circuit. Figure 6 shows the test results in the fault condition of LED open (a) and short circuit (b). In both conditions, the power converter is stable and stops switching activity whenever a fault occurs at the load side.

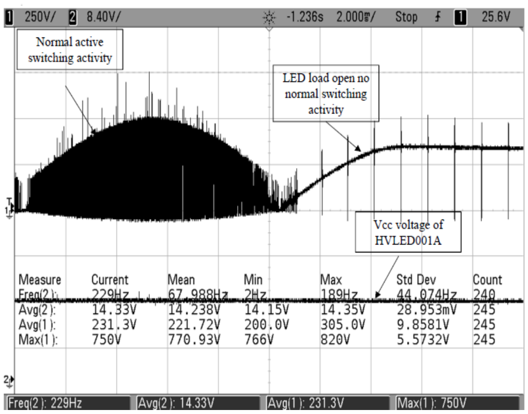


Fig.6 (a) LED open fault condition (Scale: 2ms/div)

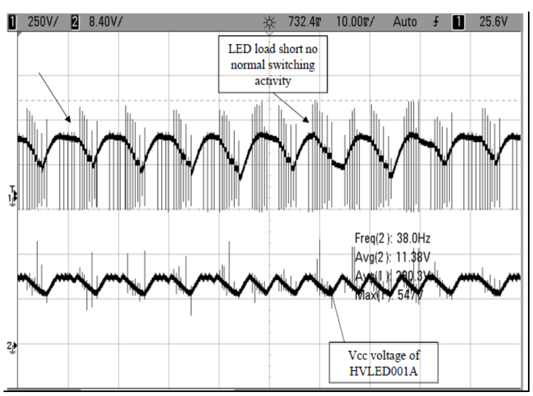


Fig.6 (b) LED short fault condition

(CH1: Q1 drain voltage, Scale: 250V/div. CH2: Vcc voltage; 8.4V/div)

Fig.6 LED driver fault condition test results

Standby Power Consumption of the LED Driver

The standby consumption is less than 500mW. Figure 7 shows the test result in standby condition. In this condition, the LED driver is OFF using CTRL pin low of HVLED001A.

Fig.7 Standby power consumption of LED driver

Smart Features Test Results of the LED Driver

The driver supports LED dimming as well as ON/OFF control. Figure 8 shows the LED current as well as LED driver output power at different PWM (%), with the almost linear relationship relative to the PWM applied signal. The applied frequency of the PWM signal is 500Hz.

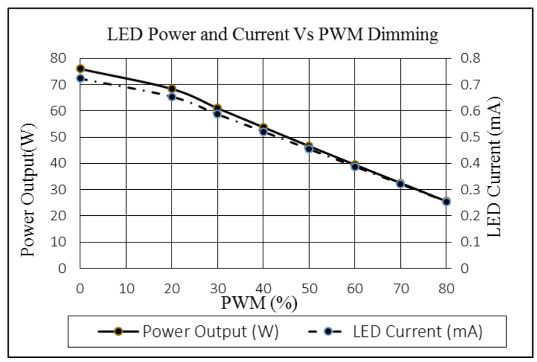


Fig.8 LED dimming plot

CONCLUSION

The presented LED driver regulates LED current with high accuracy and high efficiency over an extra wide input voltage range and a wide set of output voltage values. Even by means of an extremely popular and very cost effective topology, i.e. high power factor quasi resonant flyback, ST's proposed solution based on HVLED001A and STP21N90K5 meets the emerging THD targets (<10% at full power) that are becoming a market requirement for some geographical areas and that are typically very difficult to achieve. The standby consumption is not compromised by the THD performance, making the presented solution a good candidate to achieve more aggressive targets that, reasonably, will be issued by new regulations in the coming years.