DN0044
Design note

DESIGNS from our LABS

STEVAL-LLL006V1: Smart LED Driver using 6LoWPAN Mesh Network for Outdoor Street lighting

Designs from our labs describe tested circuit designs from ST labs which provide optimized solutions for specific applications. For more information or support, visit www.st.com

By Aman Jha

Main components	
HVLED001A	Offline Quai Resonant PFC Controller
STP21N90K5	N-Channel MOSFET
TSM101	Constant voltage constant current controller
LDF33DT	Low dropout regulator
STPS1H100	Schottky diode
STTH3L06, STTH1L06	Ultrafast diodes
STM32L071	Microcontroller Unit
SPSGRFC	SubGHz module
VIPer012LS	Low voltage energy saving fixed frequency high voltage converter
SMA188A, P6KE400A	Transient voltage surge suppressor

Introduction

This design note describes the main characteristics of an 80W constant current smart LED driver which works on 6LoWPAN mesh networking. The power supply capable to drive LED voltage of very wide range (60V-110V) as well as wide input range (90V-300VAC) with very high displacement power factor and very low input current distortion power factor. The 6LoWPAN mesh network is implemented to control light remotely using microcontroller and SubGHz wireless module. The standby consumption of power supply is less than 500mW.

Specification

- Wide input voltage range: 90Vac to 300 Vac (47-63 Hz)
- Output voltage: 60VDC -110VDC, 700mA, ± 5 % current regulation
- Overall efficiency at full load: above 90%.
- Efficiency > 90%; Power Factor > 0.95, Input Current THD < 15%
- OFF/ON and secondary PWM dimming
- Standby consumption <0.5W
- Mesh networking using 6LoWPAN network
- LED Open circuit, short circuit and thermal fold back protection

Design Architecture

The design architecture of smart lighting for proposed solution is shown in Figure 1. The power management LED driver is communicated via microcontroller unit (MCU) though wireless connectivity module. The LED driver in connection with MCU and SubGHz module will act as a standalone smart light which is also known as a lighting node. The communication of lighting node from the external world is through gateway which is known data communication unit (DCU). The DCU work as an interface from internet of things (IOT) cloud server or any input to control lighting note remotely. The STEVAL-LLL006V1 board is developed to keep in mind for communicating with DCU and act according to input from the user. STEVAL-LLL006V1 board is working as a lighting node having all smart features like ON/OFF, dimming and 6LoWPAN mesh networking features for connected smart lighting. The board is capable to provide high power quality features as well as protection and EnergyStar capability for today's needs.

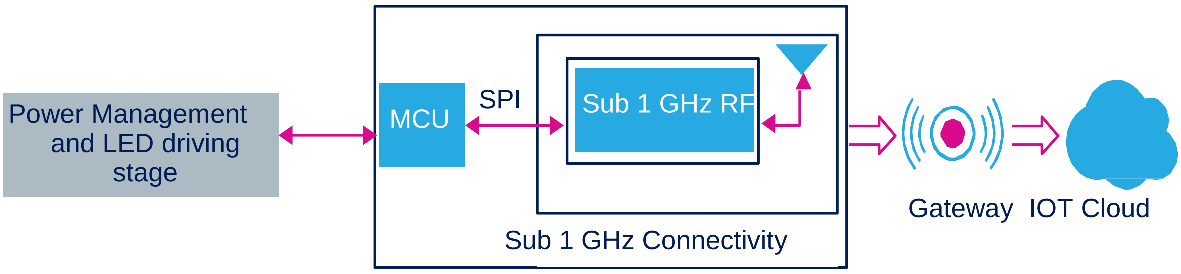


Figure 1. Architecture of Smart Street Lighting System for STEVAL-LLL006V1

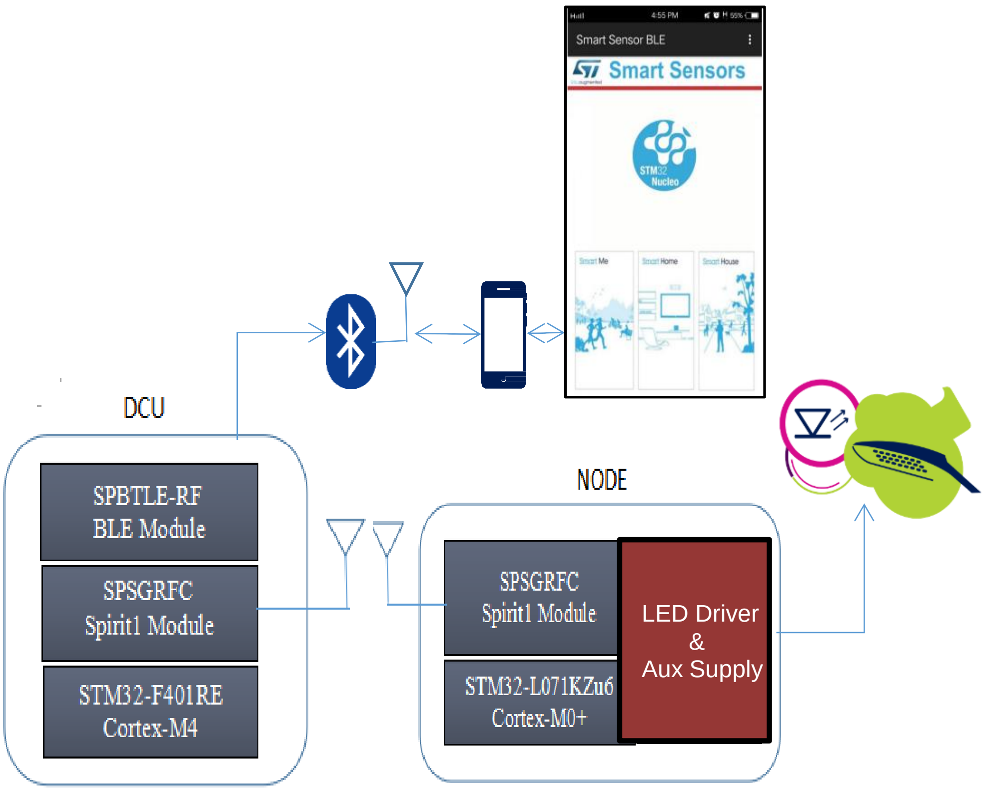


Fig.2 STEVAL-LLL006V1 Signal Flow Diagram

In order to demonstrating capability of proposed smart LED driver, DCU and mobile application is developed. The Bluetooth is used for mobile application to communicate with DCU. The DCU is made using one unit of each Nucleo-F401RE, X-Nucleo-IDS01A4 and X-Nucelo-IDB05A1 which communicate with mobile application and STEVAL-LLL00V1 board. The lighting nodes are connected each other in 6LoWPAN mesh networking using STM32L071 MCU and SPSGRFC wireless module. Figure 2 shows the complete signal flow diagram of proposed smart LED driver unit.

Circuit description

The STEVAL-LLL006V1 evaluation board is a smart off-line LED driver which works on 6LoWPAN mesh networking. The smartness of LED driver featured with a microcontroller (STM32-L071) and a connectivity module (SPSGRFC) to manage wireless communication along with LED brightness control. This microcontroller and connectivity module power is supplied by offline isolated VIPER012LS based AC-DC converter in integration with low dropout regulator. The driver supports LED dimming as well as ON/OFF control. Basically, the driver is regulating LED current through dimming for reducing power consumption.

Figure 1. STEEVAL-LLL006V1: Smart LED Driver using 6LoWPAN Mesh Network for Outdoor Street lighting

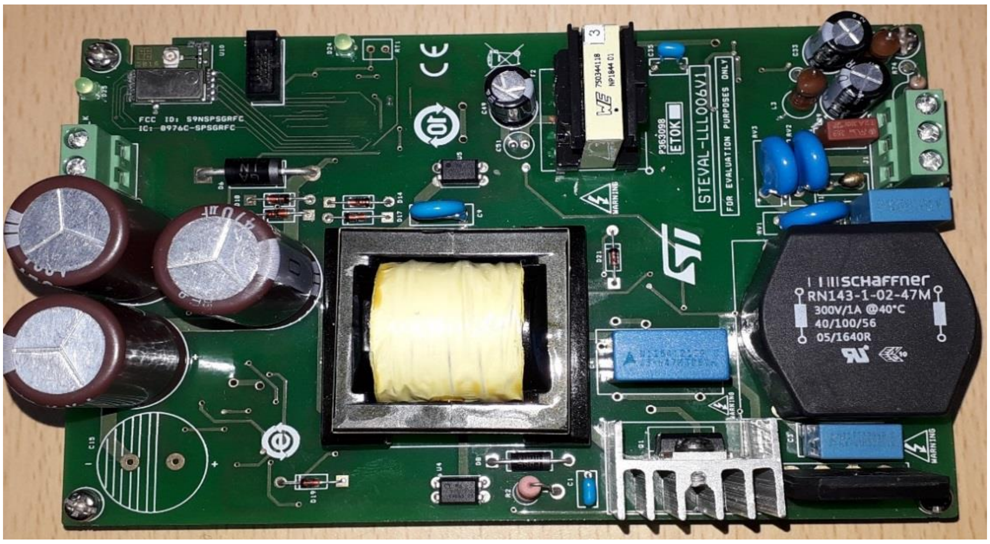
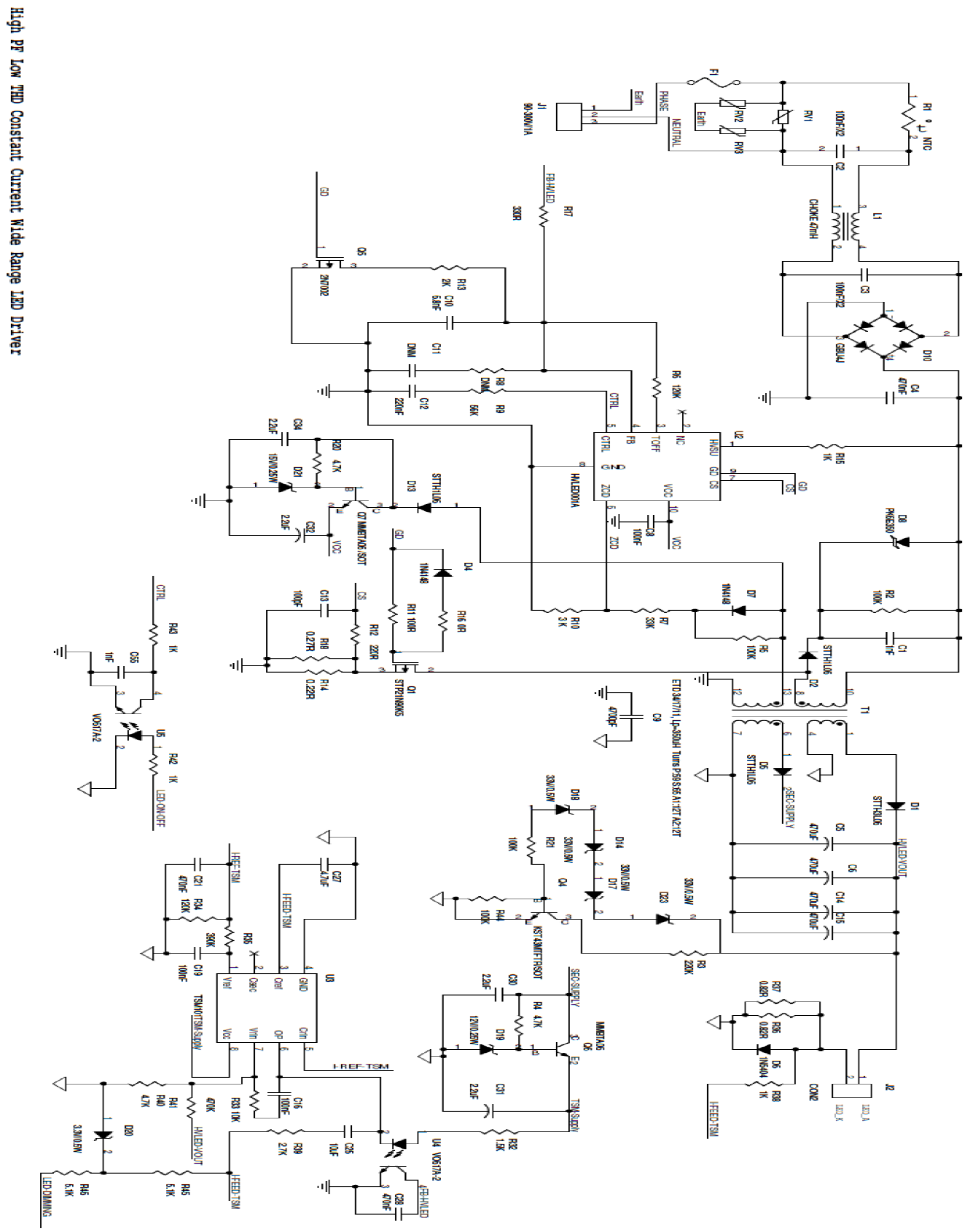
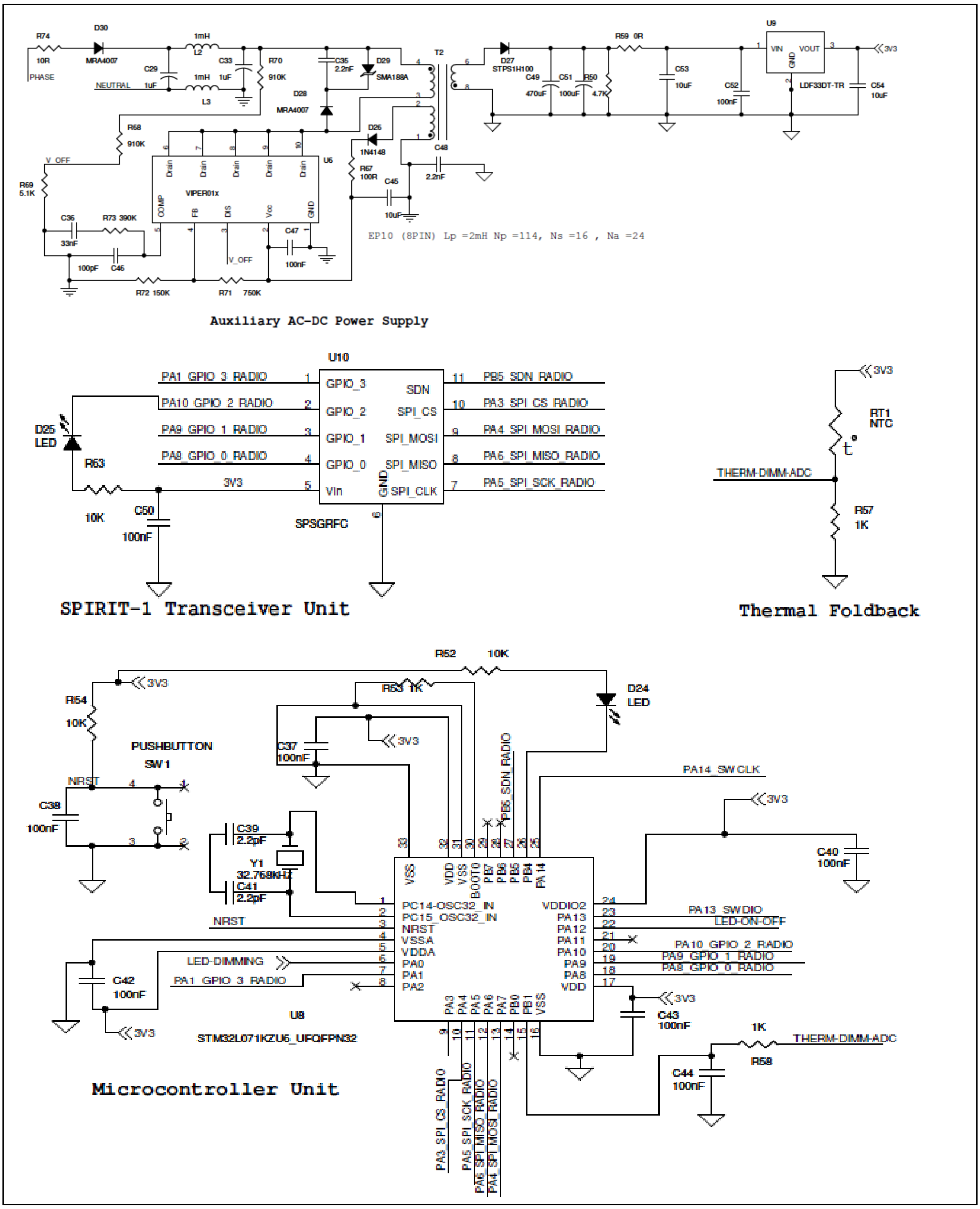


Figure 2. Circuit diagram





SYSTEM LEVEL SMART LED DRIVER PERFORMANCE

Figure 3 shows the graph for overall efficiency measurements for LED driver at entire input voltage variation and different output LED voltage setting. As per measurement efficiency is more than 87% for entire line and load variation. The LED current regulation (CR) is shown in Figure 4. The measurement shows; CR is less than ±0.3% for entire line and load variation.

Figure 5 shows the graph for input current total harmonic distortion (THD) for entire input voltage variation and different output LED voltage setting. As per measurement THD is less than 15% for entire line and load variation. The displacement power factor (PF) is shown in Figure 6. The measurement shows; PF is more than 0.93 for entire line and load variation.

Figure 3. Graph of efficiency measurements

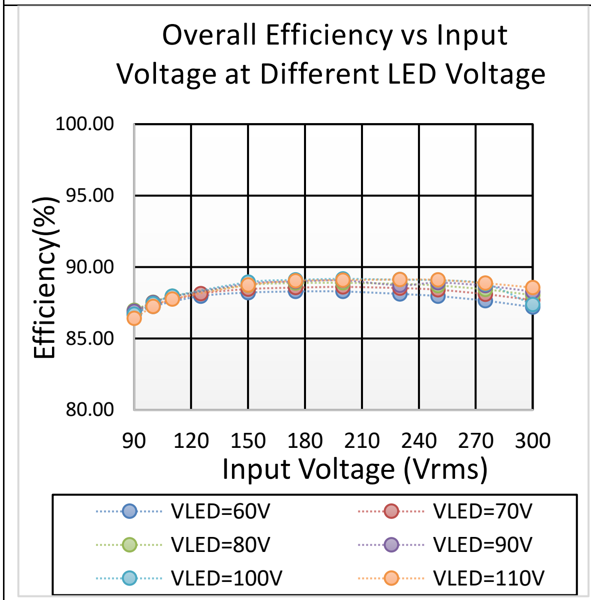


Figure 4. Graph of LED current regulation (CR)

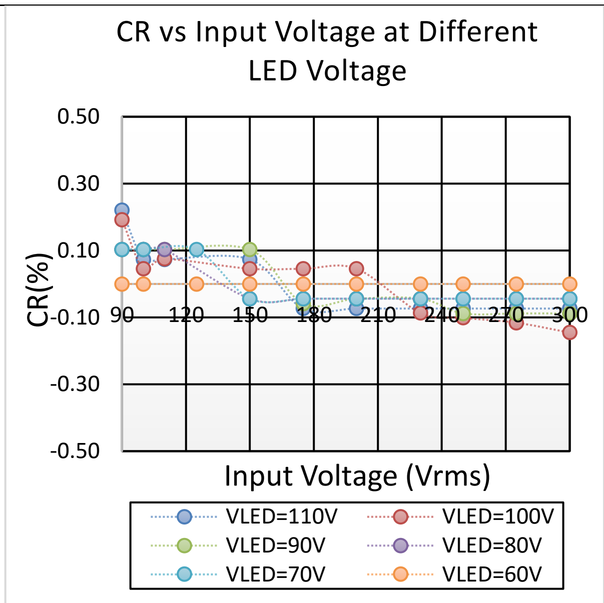


Figure 5. Graph of input current total harmonic distortion (THD) measurements

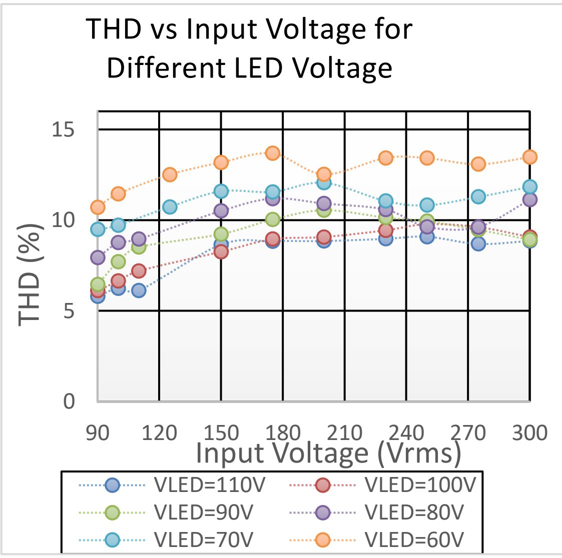
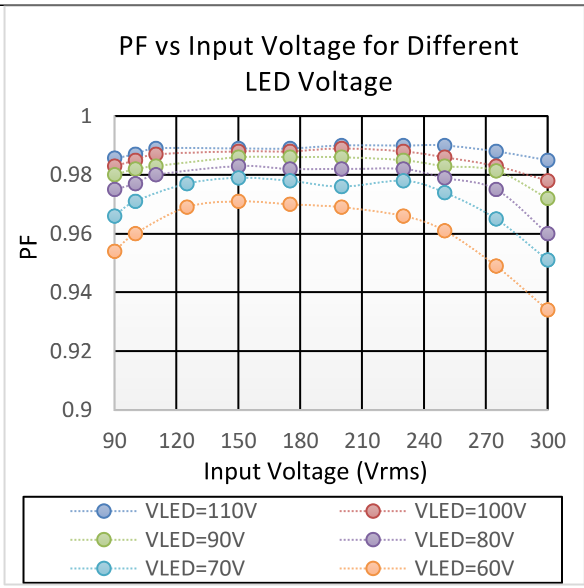


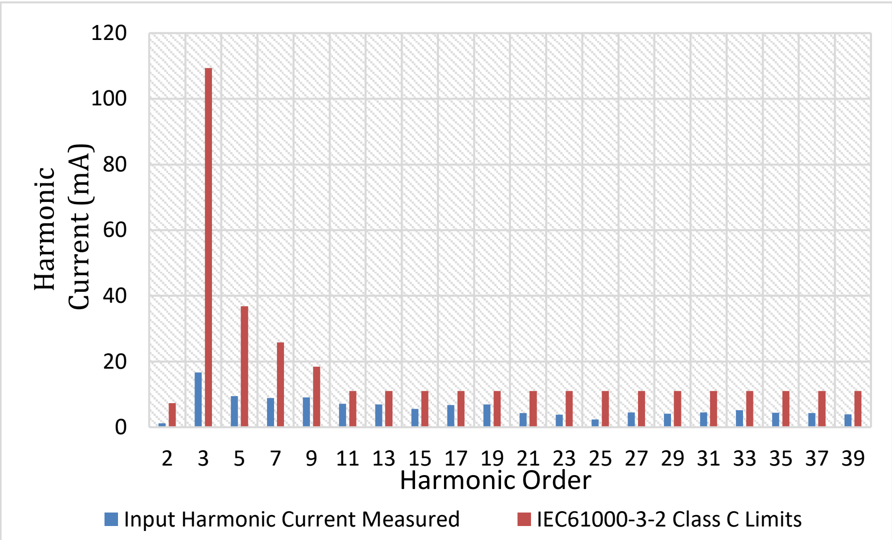
Figure 6. Graph of input displacement power factor (PF) measurements



Harmonic content measurement

The board has been tested according to the IEC61000-3-2 Class-C which is applicable for lighting loads. The measured input current THD and power factor are more 0.97 and less than 15% for entire line and load variations.

Figure 7: EN61000-3-2 Class C at 230Vac– 50 Hz, full load



THD = 8.5% - PF = 0.988; Input Current =368.5mA; LED Load =110V/700mA

Switching Mode Waveforms

The steady state switching waveforms at line frequency and switching states are given in Figure 8 to Figure 13 at different input voltages 230V, 300V and 90V AC input voltage and full LED load 110V/0.7A. The test results shows the converter is stable and working in quasi-resonant mode for wide range inputs, constant current and all power components are well within the optimum rating.

Figure 8: Switching plot 230 Vac – 50 Hz - Full load

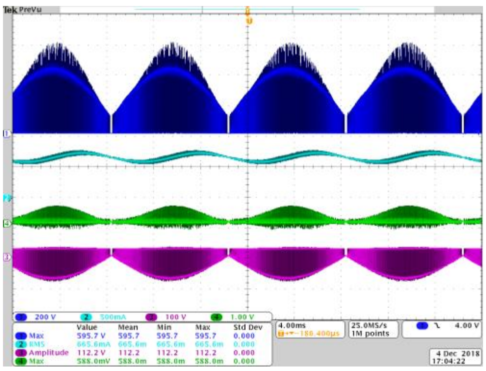


Figure 9: Switching plot 230 Vac – 50 Hz - Full load

CH1: MOSFET Drain ;CH2:LED Current;CH3: Peak Current Sense;CH4: Auxiliary Diode Voltage

Figure 10: Switching plot 300 Vac – 50 Hz - Full load

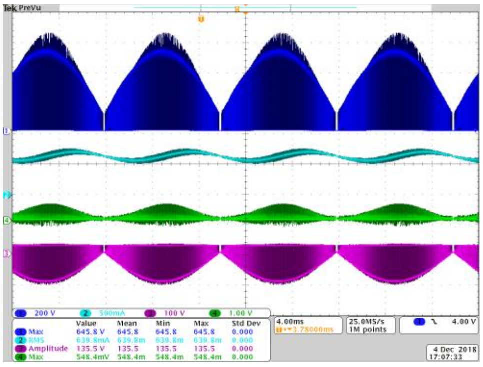
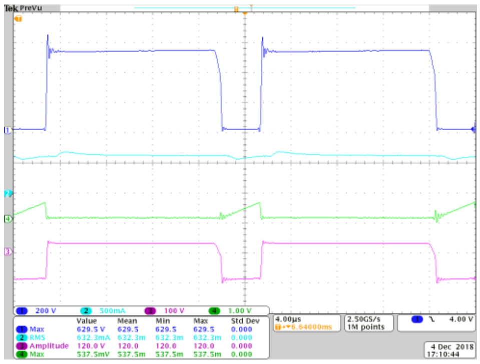


Figure 11: Switching plot 230 Vac – 50 Hz - Full load



CH1: MOSFET Drain ;CH2:LED Current;CH3: Peak Current Sense;CH4: Auxiliary Diode Voltage

Figure 12: Switching plot 90 Vac – 50 Hz - Full load

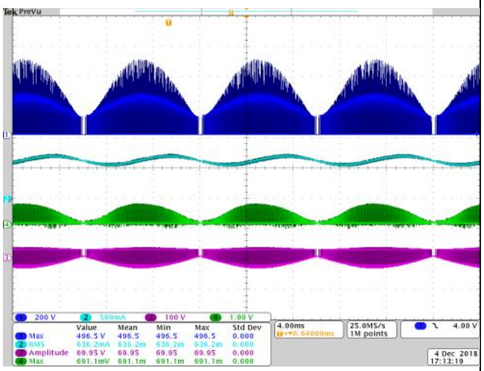
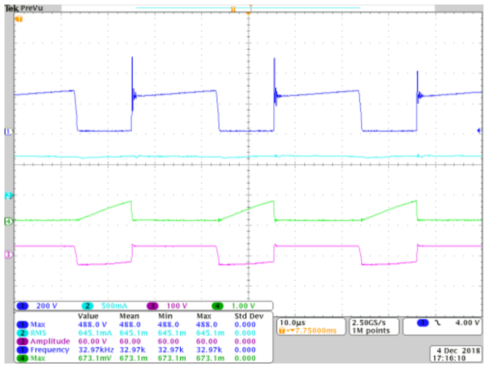


Figure 13: Switching plot 90 Vac – 50 Hz - Full load



CH1: MOSFET Drain ;CH2:LED Current;CH3: Peak Current Sense;CH4: Auxiliary Diode Voltage

Protection and Smart Lighting Features

The LED driver is well protected for open as well as short circuit condition. Figure 14 shows the LED open condition waveforms at full load and Figure 15 shows the LED short condition.

Figure 14: LED open condition

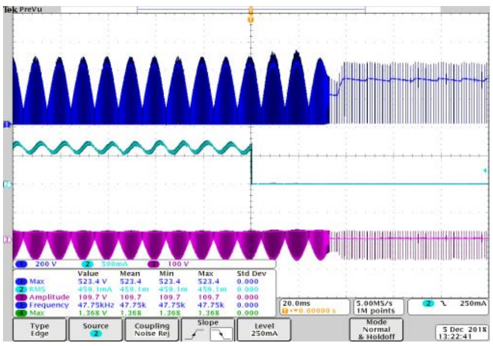
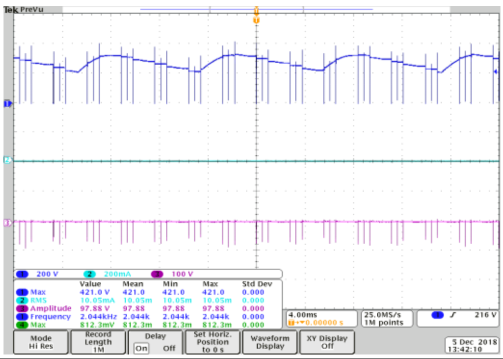


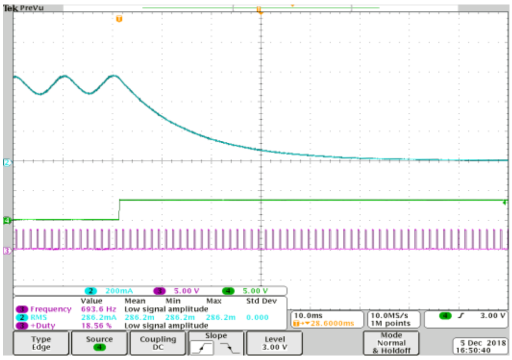
Figure 15 : LED short condition



CH1: MOSFET Drain ;CH2:LED Current; CH4: Auxiliary Diode Voltage

Figure 16 shows the smart features of power supply. The dimming as well as ON/OFF signal coming as per user input to SPSGRFC and control signal generated by STM32L071 microcontroller unit (MCU). The standby power consumption of board is 0.36 W at nominal input voltage. It is recorded in Figure 17. The dimming capability of LED driver is shown in Figure 18 and 19.

Figure 16: LED ON/OFF condition and dimming at full load



CH2:LED Current;CH3: Dimming signal;CH4: ON/OFF Signal

Figure 17: Standby consumption at full load condition

Standby consumption 0.36W at full load and LED ON/OFF signal high

Figure 18: LED Current Linearity at different LED Voltage and Dimming Value

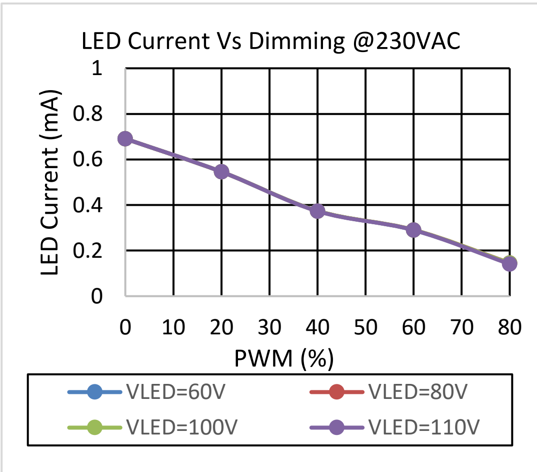
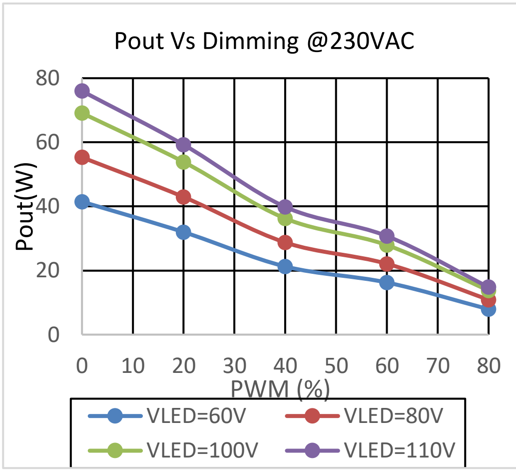
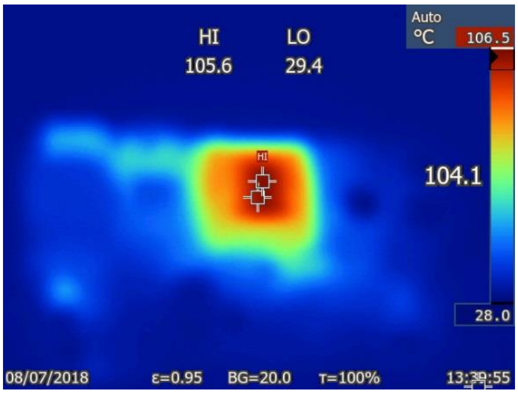
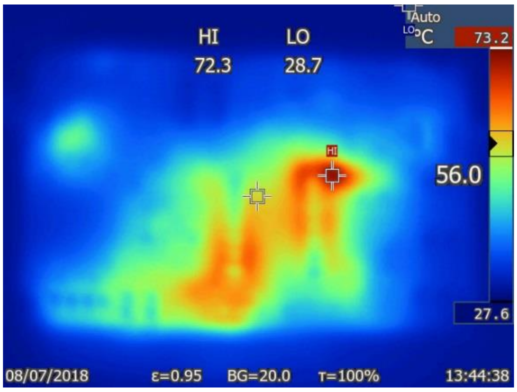


Figure 19: Output Power at different LED Voltage and Dimming Value



Thermal map

In order to check the design reliability, a thermal mapping by means of an IR camera was done. Below, the thermal graph of the power supply at full load and nominal input voltage. As per measurement the maximum temperature recorded for transformer which around 100 ^{0}C which is ok for such type of design requirement. The other parts are well within the thermal limits as per measurement.

Figure 4: Thermal map at 230 Vac – 50 Hz - Full load : Top View	Figure 5: Thermal map at 230 Vac – 50 Hz - Full load : Bottom View
	

Transformer Design

The complete details of flyback transformer for HVLED001A and VIPER012LS are given in Figure 27 and 28 respectively.

Figure 6. High Power Flyback Transformer for HVLED001A (Wurtz Part No. 750343544,Rev01)

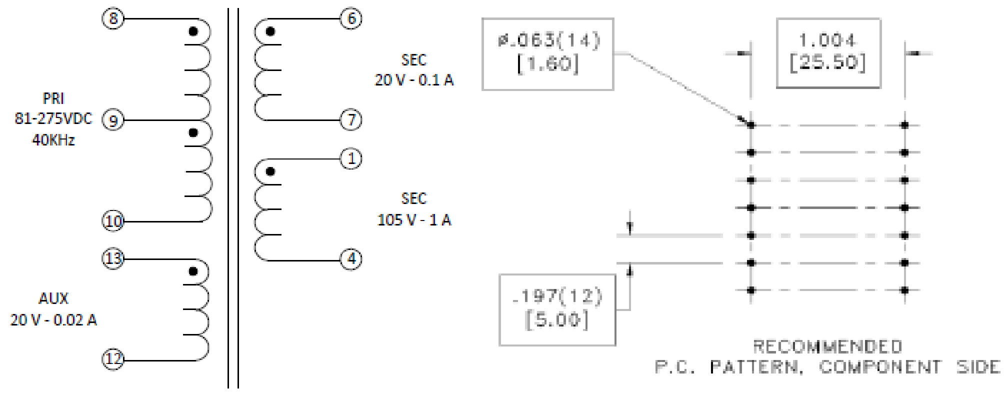
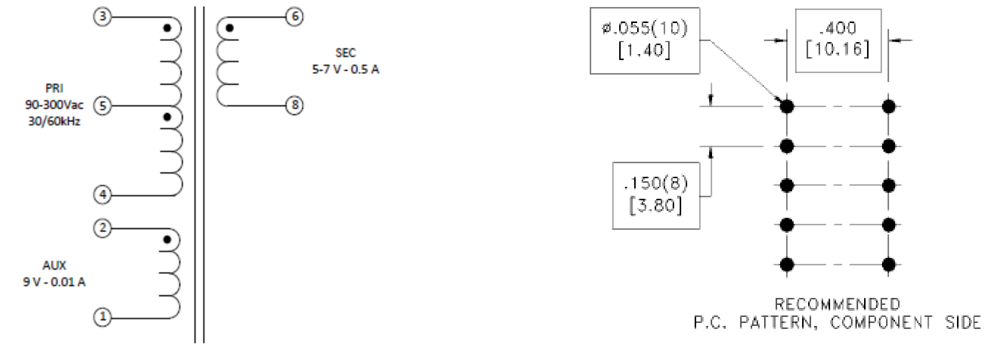


Figure 28: High Frequency Power Supply Transformer for VIPER012LS (Wurtz Part No. 750344118,Rev01)



Support material

Documentation

Revision history

Date	Version	Changes
03-Dec-2018	1	Initial release