Application Report

SLVA663–June 2014

Low Cost, Single Inductor Non-Isolated AC/DC LED Driver Design using TPS92314A

Abhijeet Godbole, Bharat Agrawal, TM Leung

Lighting Power Products

ABSTRACT

The control principle of the TPS92310/11/12/14 is to provide constant current line and load regulation for primary-side sensing flyback configurations operating in critical conduction mode (CRM), removing the opto-coupler used for secondary-side feedback.

The new application circuit uses a single inductor rather than a bulky transformer, saving board space and BOM cost while still meeting the standard performance specifications of an LED driver.

This application report describes how to design a non-isolated AC/DC buck LED driver with an integrated PFC control using the TPS92314A from Texas Instruments. This application report includes schematics, switch node waveforms and test results to help the user better understand how to retain a very tight line and load regulation when applying the IC as a buck regulator with the help of external add-on circuitry that modifies the control equation of the TPS92314A. In this way, tighter line and load regulation specifications required by certain applications can be met.

Contents

1 Design Specifications:

Table 1. Design Specifications

Input Voltage Range (Vin)	Universal, 90V-276V AC RMS
Output Voltage (Vout)	29V
Load Current (Iout)	230mA
Power Factor	Greater than 0.9 in Vin range
Current Total Harmonic Distortion (ITHD)	Less than 25% at 220V AC RMS
Output Short Circuit Protection	Yes
Output Open Circuit Protection	Yes

2 Application Schematic: Single Inductor, Non-Isolated AC/DC LED Bulb Design

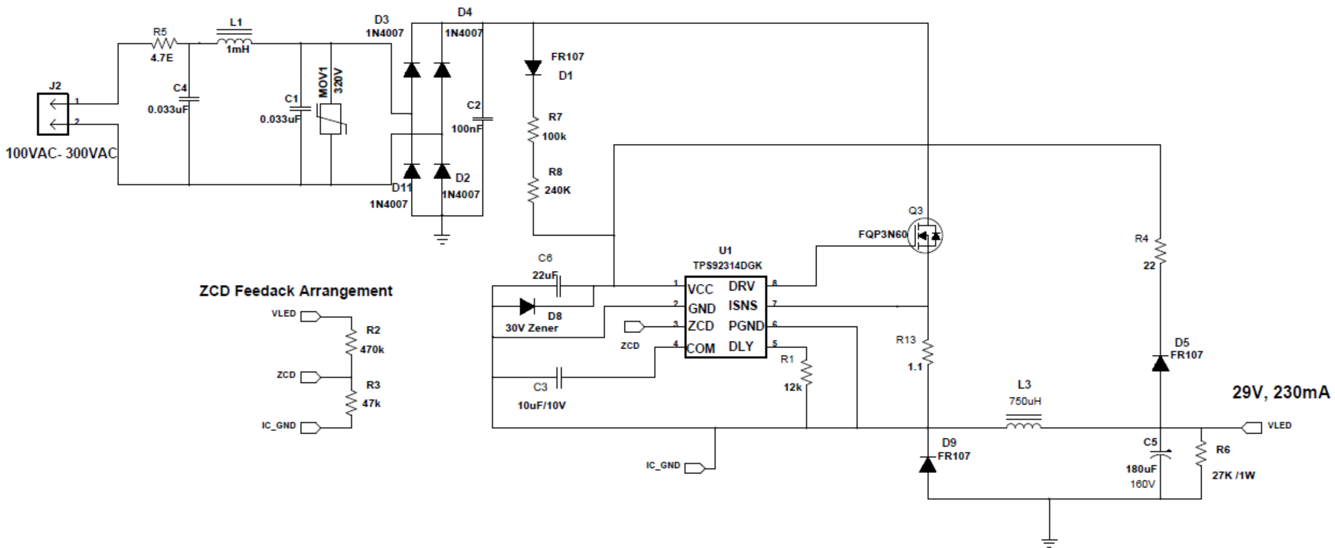

Figure 1. TPS92314 based non isolated, single inductor LED driver for 7W application

3 Principles of Operation

The TPS92314A is an off-line AC/DC controller specifically designed to drive high power LEDs for lighting applications. With advanced features such as constant on-time control (for high Power Factor at input) and quasi-resonant switching (for high efficiency and reduced EMI signature), this controller can be used as a high-side switching buck controller to regulate the amount of energy being stored in the inductor. The need for an auxiliary winding, required in non-isolated designs to provide a DC supply to a controller, is eliminated with the use of energy from an output capacitor through a forward diode. This makes a small solution size, low cost and high efficiency possible, some of the key requirements for a residential bulb design.

See Figure 1 for a reference schematic describing key components in this buck design. The input AC voltage is rectified using a full bridge rectifier to obtain a unidirectional AC bus. This rectified voltage follows the AC input sine wave, due to the presence of a small 100nF input capacitor after the bridge required to obtain a high Power Factor. This rectified AC is connected to a drain of the High-Side switching MOSFET Q3, whose source is connected to the freewheeling diode D8 and inductor L3 to output capacitor C5. The TPS92314A switcher (U1) is referenced to switching node SW (which is IC_GND in Figure 1).

The TPS92314 will not turn on unless the rectified input AC voltage is greater than the LED forward voltage, and there is no current drawn from the input source. This conduction time delay can be given by:

$$\Delta T = \text{Sine(Inverse)} \frac{\text{VLED}}{\sqrt{2} \times \text{Vac}} \quad (1)$$

As the TPS92314 operates in critical conduction mode, the inductor peak current is twice the input peak current. The desired value of inductance can be calculated as per the following equation:

$$L = \frac{\left[1.41 \times \text{VAC} - \text{VLED}\right] \times \text{Ton}}{\Delta I_{PEAK}} \quad (2)$$

Since the TPS92314A implements a critical conduction mode, the next ON cycle initiates only after the inductor current ramps down to zero. VLED voltage is fed back as supply to the TPS92314 through the diode and current limiting resistor (D5 and R4), because VLED is referenced to the input bridge ground. This enables the use of a single inductor and eliminates the need for bias winding. The use of a single inductor reduces overall system cost and solution size, but matches the necessary performance specifications listed in the next section.

4 Experimental Results and Performance Characteristics

4.1 Switch Node Waveform at VAC = 110V

- Channel 1 (Inductor Switch node)
- Channel 2 (Inductor Peak current)
- Channel 3 (Output LED current)

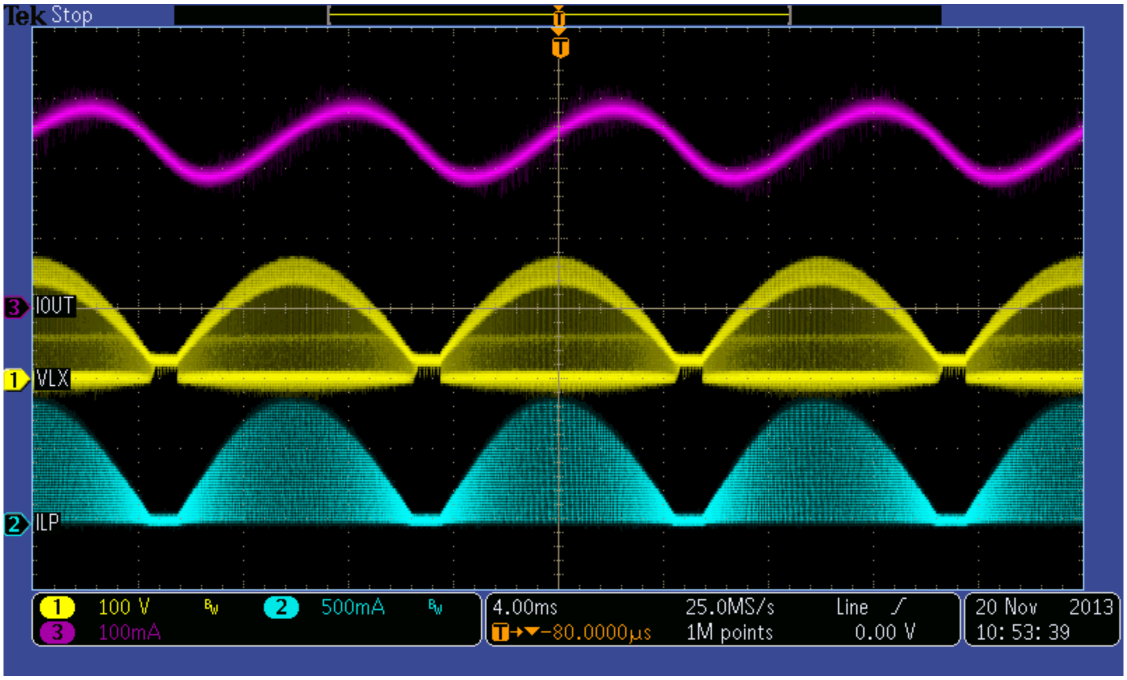

Figure 2. Switch Node Waveform

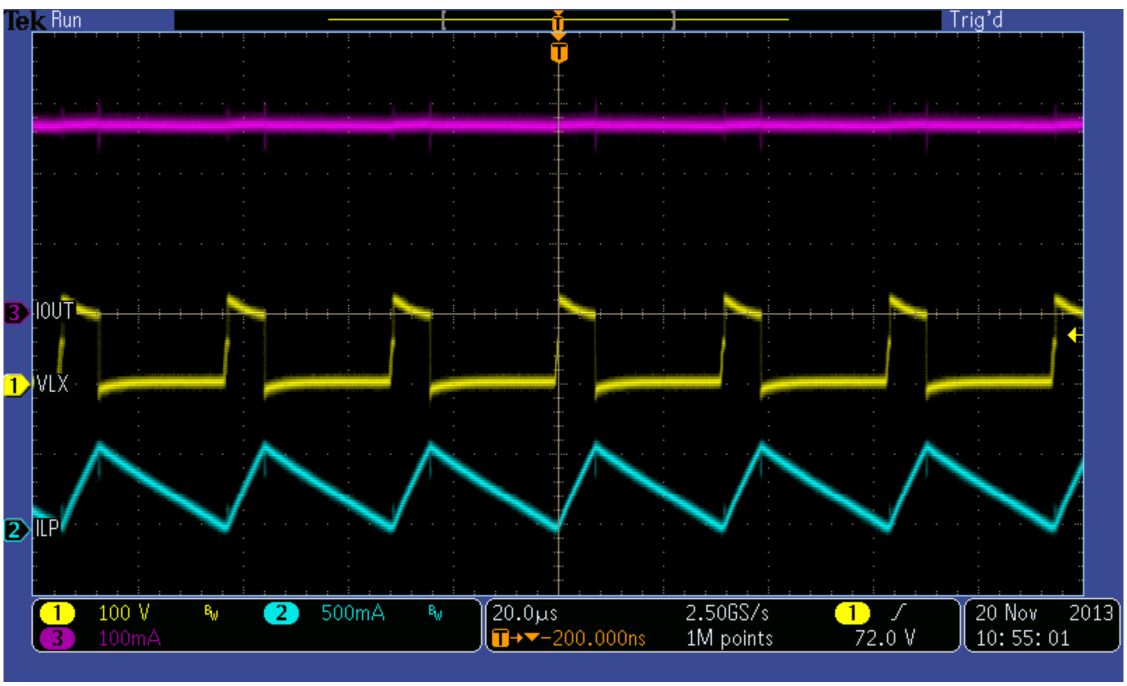

Figure 3. Switch Node Waveform

4.2 Switch Node Waveform at VAC = 220V

- Channel 1 (Inductor Switch node)
- Channel 2 (Inductor Peak current)
- Channel 3 (Output LED current)

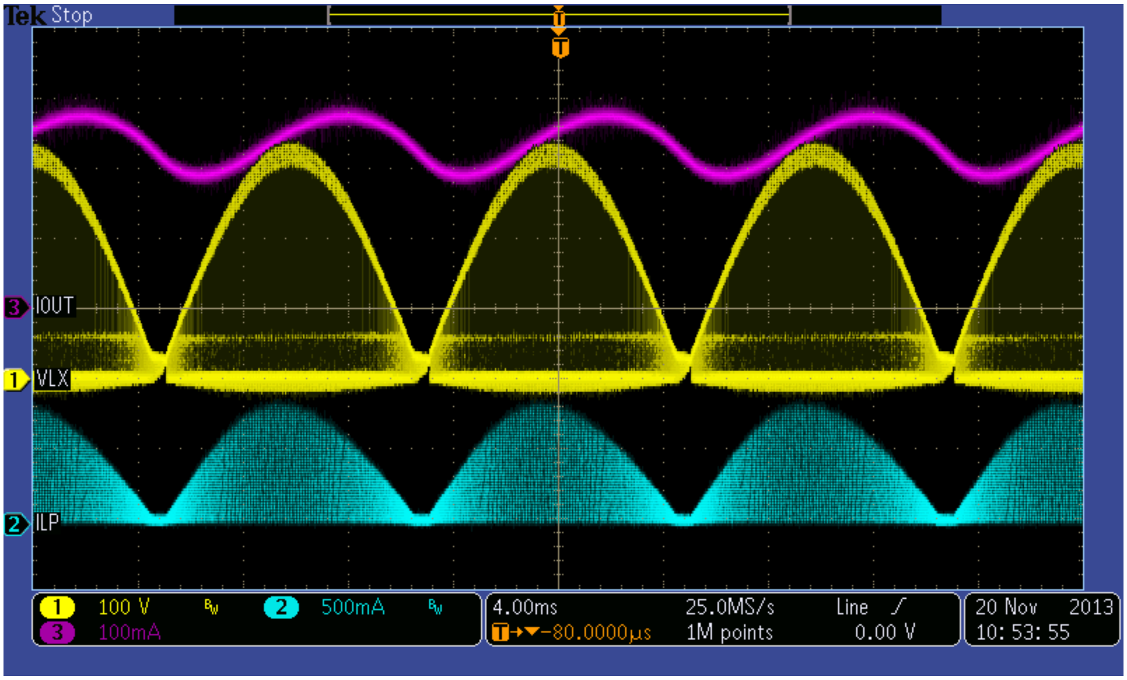

Figure 4. Switch Node Waveform

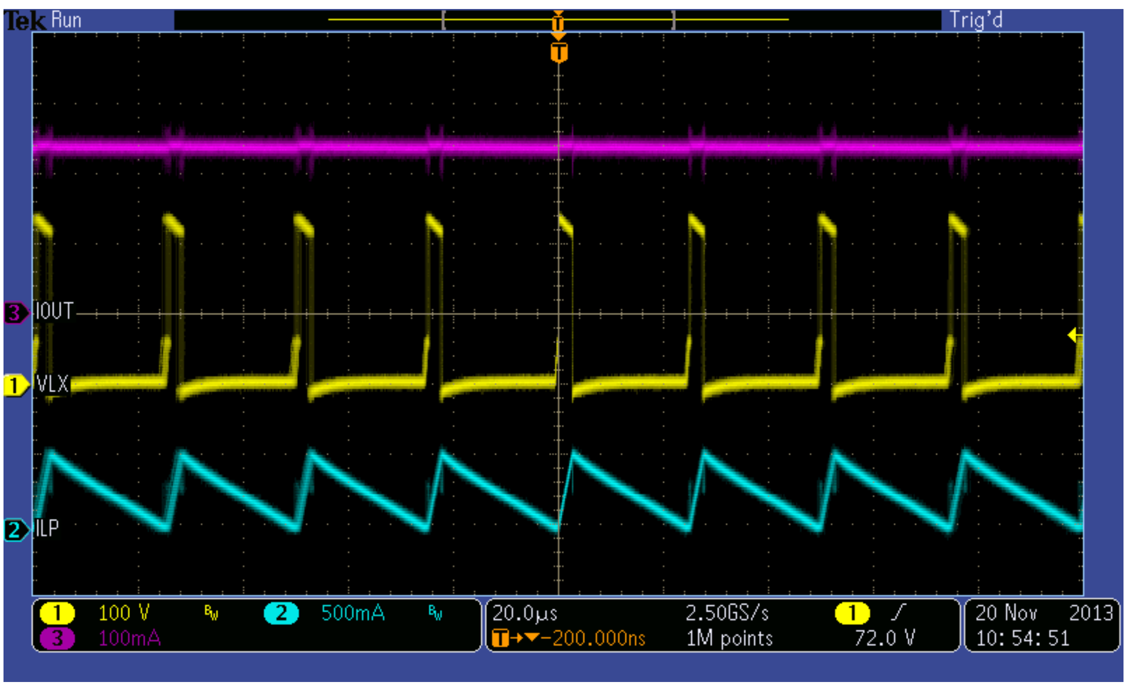

Figure 5. Switch Node Waveform

4.3 Output Current Variation with Respect to Input Voltage

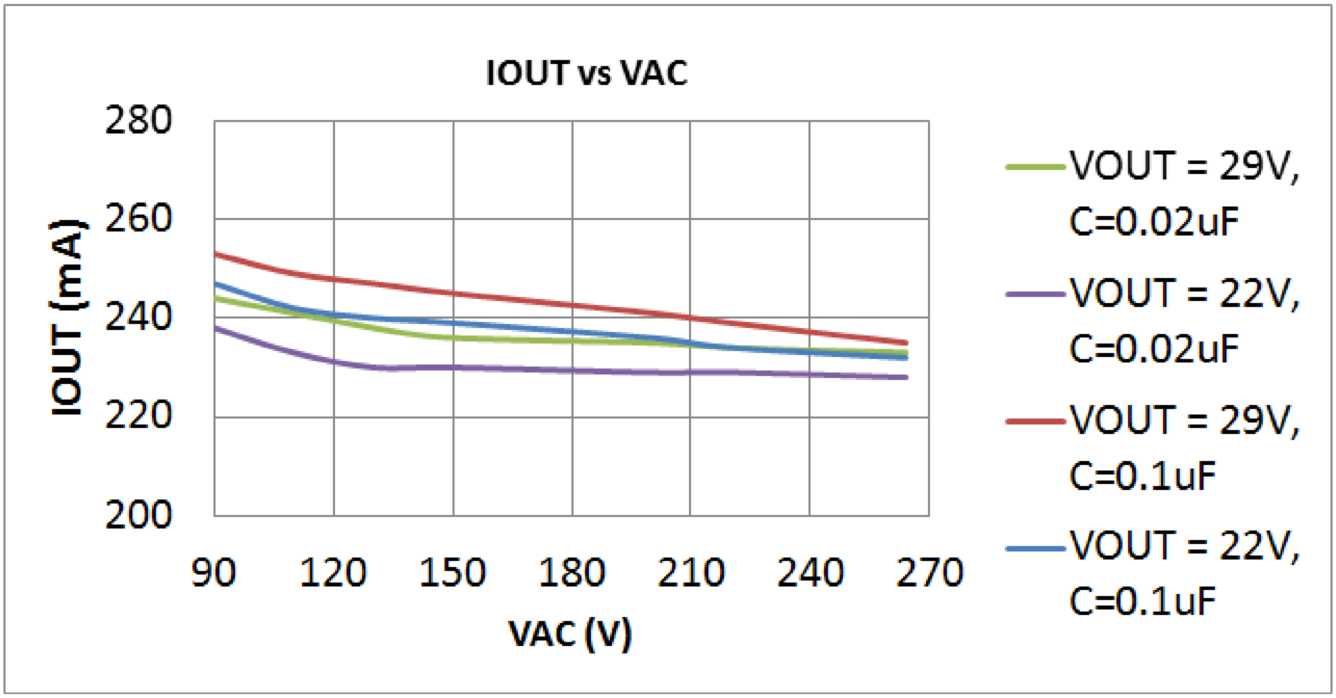

Figure 6. Output Current Variation with Respect to Input Voltage

4.4 Power Factor Variation with Respect to Input Voltage

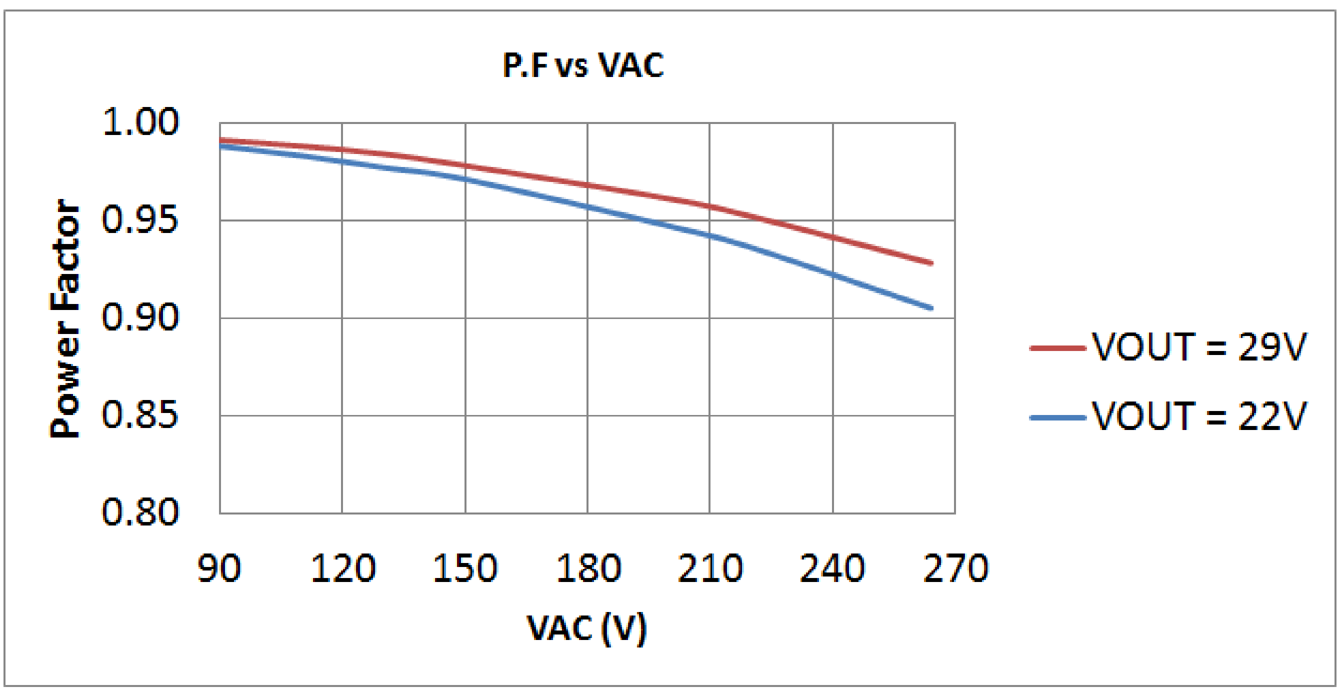

Figure 7. Power Factor Variation with Respect to Input Voltage

4.5 Detailed Test Results for 7W Design

Table 2. Performance Characteristics of Single Inductor, Non Isolated Design Based on TPS92314

Input Voltage (VAC)	90	110	130	150	200	220	260
Input Current (mA)	91.1	72.8	61.2	52.7	40.1	36.9	31.4
Input Power (W)	8.2	8.01	7.95	7.9	8.02	8.12	8.29
Output Current (mA)	244	241	238	236	235	234	233
Output Voltage (V)	29.04	29.02	28.9	28.86	28.8	28.8	28.78
Efficiency (%)	86.4	87.3	86.5	86.2	84.4	83.0	80.9
Power Factor	0.991	0.988	0.984	0.978	0.961	0.952	0.928

5 External Add On Circuit to Meet Tighter Line and Load Regulation Specification

In general fly-back convertor at CRM operation, the output current is as follows:

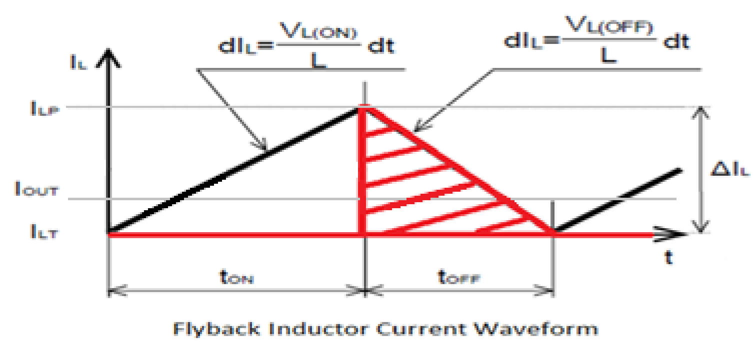

Figure 8. Output Current in Flyback at Critical Conduction Mode

In buck convertor, the output current is as follows:

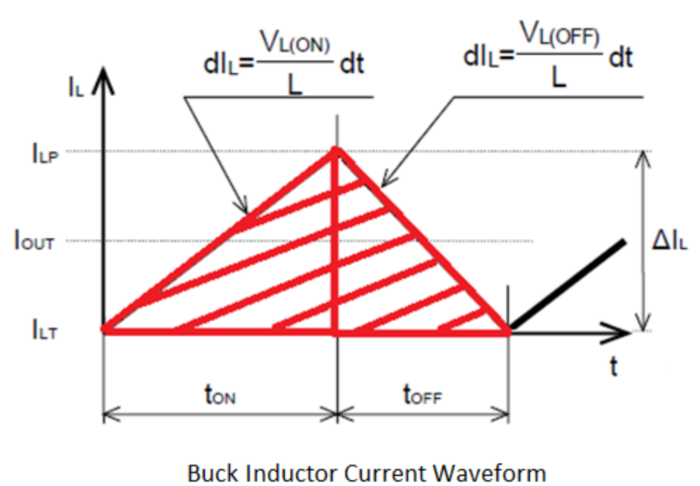

Figure 9. Inductor Current Waveform in Buck Converter at Critical Conduction Mode

In comparing fly-back and buck convertor current waveforms, fly-back output current is observed at tOFF time only due to the flyback action of the transformer. In buck convertor, the output current is observed during tON + tOFF time. For waveforms for both topologies, the tOFF time inductor current is the same at CRM operation. Thus after blanking time, the inductor current at ON time tON in both flyback and buck convertor will be at the same level.

A modified, non-isolated buck LED driver with the TPS92314 controller is as follows:

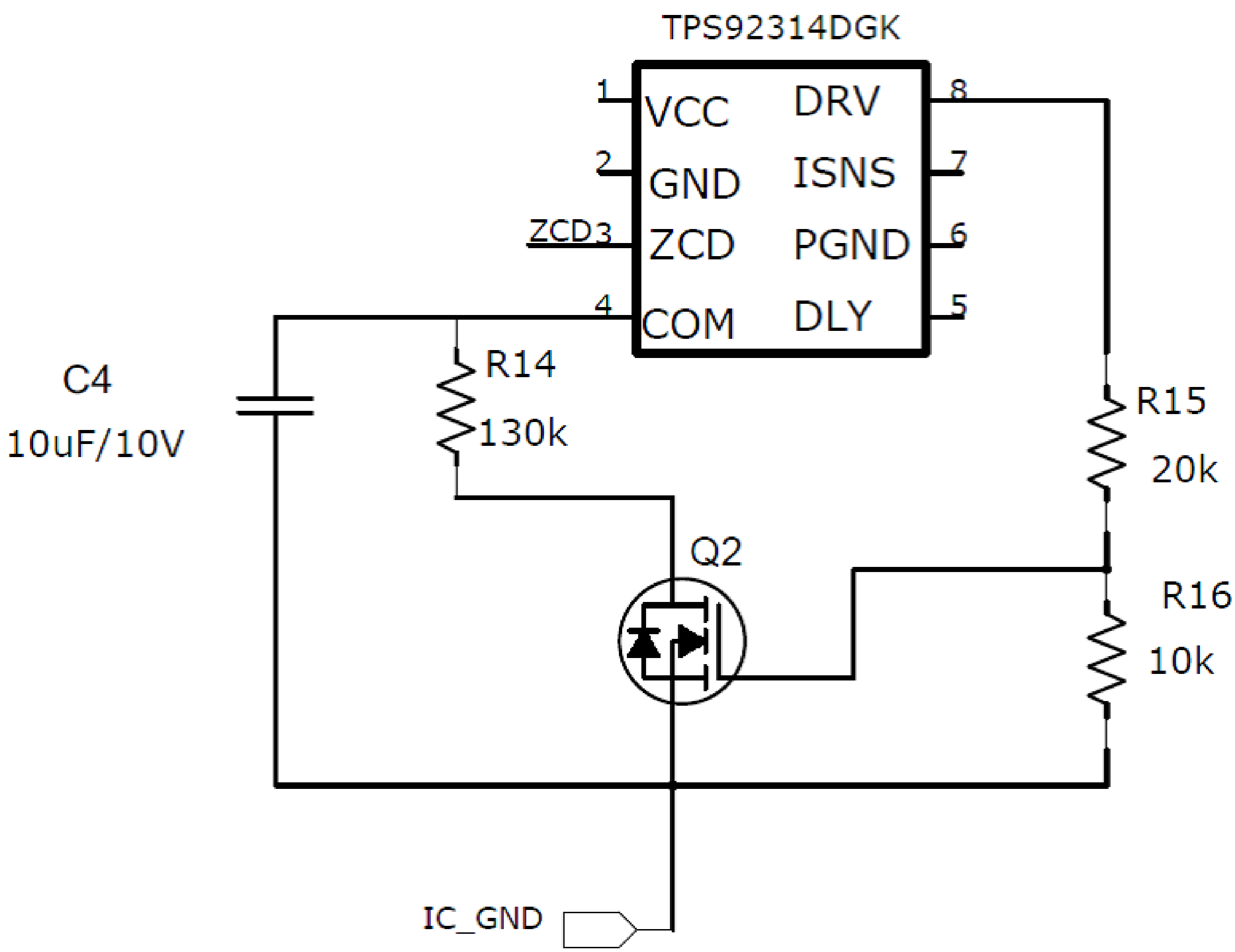

Figure 10. External Add On Circuit to meet Tighter Line and Load Regulation Specifications

This implementation meets tighter line and load regulation specifications for a non-isolated buck application with the TPS92314 controller by drawing the internal reference current when the gate driver is turned on (TON time) through small signal MOSFET Q2. The blanking timer appears to blank the input current at TON time in CRM buck operation. The user can meet the line regulation specifications by modifying the discharge current through small signal MOSFET Q2. Theoretically, if the discharge current is same as the compensation pin internal reference current (27uA), a controller output current can be controlled with the same level.

In Figure 10, the COMP voltage VCOMP is dependent on the TON time and is nearly constant in close loop operation. MOSFET Q2 is driven through the resistor divider from the gate drive pin (pin 8 of TPS92314) R15 and R16. The value of resistor R14 can be calculated as:

$$\frac{\left(V_{COMP} - V_{DS(ON)Q2}\right)}{R14} = 27\mu A \quad (3)$$

The value of resistor R14 is application-dependent and can be tweaked to set the desired current drawn from the compensation pin capacitor and meet required line regulation.

Though this circuit achieves good line and load regulation, the circuit affects the power factor. Use of this circuit is a tradeoff between performance specifications and varies from application to application.

6 Conclusion

A detailed application report with test results is presented for a 7W single inductor, non-isolated AC/DC LED driver based on the TPS92314A off-line primary side switching AC/DC controller from Texas Instruments. Use of the single inductor helps to reduce complexity, solution size and overall system cost. The inductor meets all the necessary performance specifications such as power factor (>0.9), protection features (Open LED, Output Short Circuit), and efficiency of up to 88% for an 8W application.

7 References

1. TPS92314A Off-Line Primary Side Sensing Controller with PFC in 8-SOIC datasheet
2. SLVA057: Understanding Buck Power Stage sin Switchmode Power Supplies application report

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265