

Driving Higher Levels of Efficiency in Lighting through Primary Side Regulation

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Abstract

Global attention continues to focus on the methods for achieving low power consumption and high efficiency. Lighting represents nearly 20% of the worldwide consumption of electrical resources and advancements in lighting can have a tremendous impact. LED solid state lighting (SSL) is environmentally friendly for the global environment. It has a smart form factor, long life, high conversion efficiency, and substantially reduces power consumption up to 80 or 90 percent compared to traditional incandescent lighting. LED drivers play an important role in LED SSLs, as these drivers provide accurate current to maintain a stable brightness. However, the traditional approach of the LED driver used a secondary feedback circuitry for driving LED's voltage and current. This secondary feedback circuit increases the cost and size. This article shows a patented technology "Primary Side Regulation" (PSR). This PSR controller precisely regulates the voltage and current of the LED driver in the primary side of the transformer without the need for secondary feedback circuitry. It includes a frequency hopping technique to reduce EMI and a green mode function to reduce standby power losses. With this approach, a PSR charger can achieve a smaller form factor, lower standby power and higher efficiency compared with conventional designs, such as Ringing Chock Converter (RCC) and traditional PWM.

An Overview of LED Lighting

Because of energy demand imbalance, the cost of energy rising and the environmental concerns, technologies that can conserve power and be green are increasingly important. Power losses in lighting represent can be as much as 20 percent and recouping this wasted energy through innovative techniques can have a strong impact on energy-savings. Energy-efficient regulations are becoming more pervasive. In the US, there is ENERGY STAR[®], but Australia, European Union and California have also announced that they will gradually phase out tradition lighting solutions.

Light Emitting Diode (LED) is actually the same as a rectifier diode as it has unilateral conduction. Compared with traditional lighting technologies, LED kind of Solid State Lighting(SSL), transferring the electrical energy to light by the semiconductor. The advantages of LED lighting comparing to traditional lighting technologies are as shown below: (The advantages lists below)

1. Drive by DC voltage and have high-brightness even during low-voltage, low current conditions. This solution can achieve 80% energy savings compare to other lighting sources in the same lighting illumination application. The lifetime of high brightness LEDs can be as much as 60,000~100,000 hours compared to 1000 hours of an incandescent bulb and the LEDs offer fast reaction speed (100ns ~ 1ns).
2. Good monochromatic, common colors are red, green, yellow and orange. Color can be changed through changing the current, and there are no ultraviolet and infrared in optical spectrum compared with traditional mercury cold cathode fluorescent lamps (CCFL) that contain less harmful mercury metal elements, recyclables and offer better environmental benefits.

3. The LED offers small size, anti-vibration and excellent impact resistance, and offer the added advantage of making them into various shapes in lamps.

Compare with LEDs, spiral energy saving bulbs, and T5 fluorescent lamps, incandescent lamp illumination efficiency was only 12lm/W, life time less than 2000 hours. Spiral energy saving light bulbs illumination efficiency was 60lm/W, with a lifetime of approximately 8000 hours. T5 lamp illumination efficiency was 96lm/W, life time with approximately 10,000 hours. The 5mm white LED illumination efficiency was 20 ~ 28lm/W, with a life time of approximately 100,000 hours. LEDs clearly have a longer lifespan and more attractive features compare with traditional lighting applications. High-Brightness Light Emitting Diode (HBLED) is a high-power, high-brightness LED. With its longer life-time, small size and flexible design, HBLEDs are already being adopted as an alternative to traditional incandescent and halogen products. HBLED applications are commonly used in the following applications:

1. Screen display and traffic lights: Variety of billboards, sports scoreboard and traffic signals.
2. Vehicle lights: dashboard indicator, audio and external LED brake lights, taillights, side light, etc.
3. Backlight: mobile phones, digital cameras and notebook computers backlight.
4. Landscape lighting, architectural lighting, decorative lights, street lighting and residential lighting.

As a new type of LED light source green products, these are bound to be the next trend in the development of the next generation.

A High Brightness LED Driver using a Primary Side Regulation Controller

LED lighting has many advantages as described above but without the correct voltage and precise current, these devices cannot only decrease the lifetime but also increase power losses and heat consumption and ultimately, causing irreparable damage to the LED. Consider the physical property of LED like general diode in that it has a sharp V-I curve. The LED operating voltage is quite sensitive to operating current and impact HB-LED unit lifetime in case of changing widely. Therefore, LED current is very important to lighting illumination. For this reason, the PSR with outstanding constant current technology is important and instrumental for the longevity of the HB-LED unit. Non-isolated Buck converters or isolate Flyback converters are commonly used in LED drivers.

An offline constant output current LED driver can be implemented using an isolated flyback converter with secondary circuit to achieved output current regulation as shown in Figure 1 for conventional LED control circuit. The LED current is measured through a current-sense resistor R_o from the secondary side and provides the necessary feedback information through an optocoupler. The optocoupler forms isolation for primary and secondary side and couples the feedback signal to the PWM controller at the primary side. To achieve better output regulation, the PWM controller receives the feedback signal from secondary site through the optocoupler to decide the MOSFET duty cycle. This approach provides precise current control but the drawback is higher device count is needed, which means more board space is required, higher cost and lower reliability. Meanwhile, the current-sense resistor R_o will also increase the power losses and decrease the efficiency of the power supply for constant current regulation. Recently, efficiency and power saving requirements are becoming more and more important for LED drivers. Smaller size is also needed for LED applications. Hence, the conventional circuit will no longer meet this requirement. This article provides a method using primary side control that can reduce device counts and provide better efficiency.

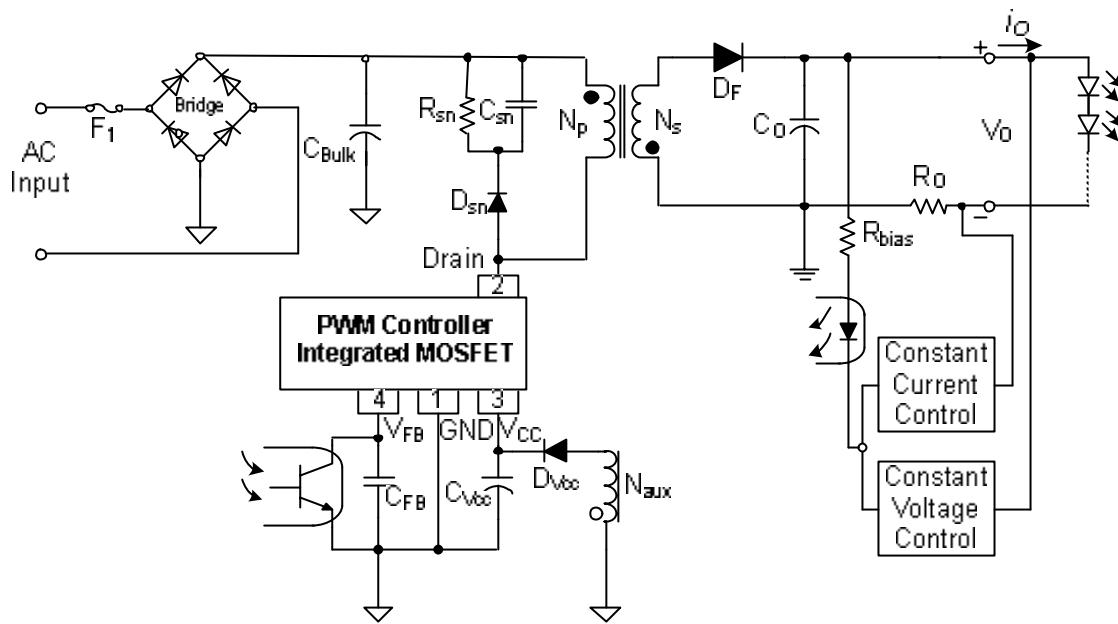


Figure 1. Conventional Secondary Side Regulation Flyback Converter for LED drive

The Primary Side regulation (PSR) technique can be an optimal solution to minimize the costs for offline LED drivers and provides precise current control without using an optocoupler at secondary site. The concept of PSR uses an innovative method to detect the output information by auxiliary winding without feedback circuit and takes the place of optocoupler form secondary site as shown in Figure 2. Figure 2 shows the basic circuit diagram of a flyback converter using a primary side controller and its principal operation waveforms.

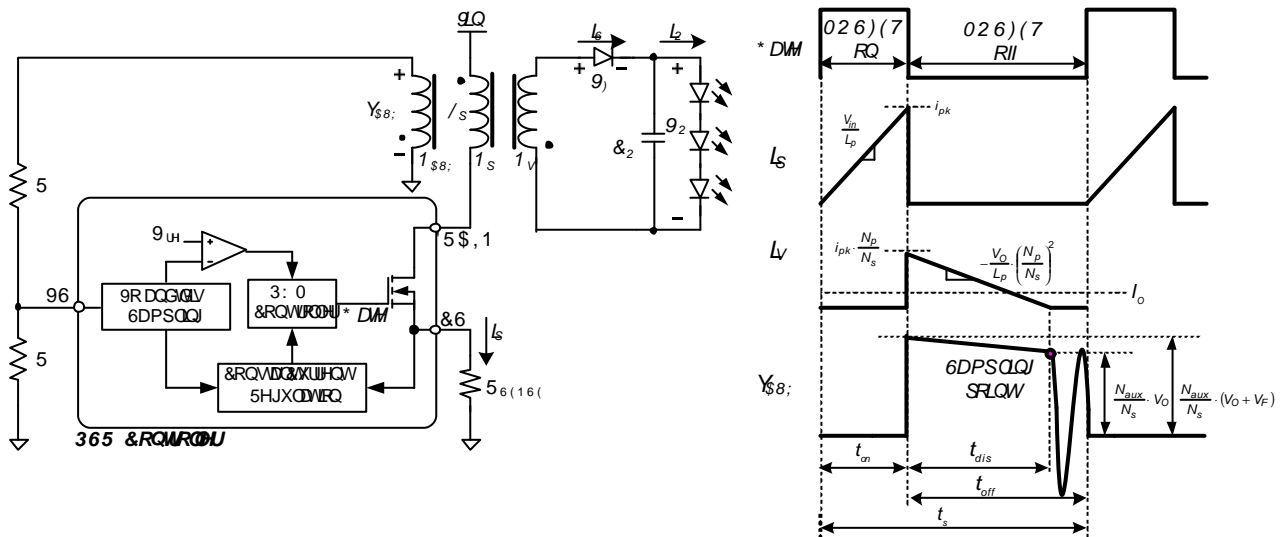


Figure 2. basic circuit diagram of Flyback Converter using Primary Side Controller and its waveforms

When the PSR controller turns on the MOSFET, the transformer current i_p will increase linearly from zero to i_{pk} as Equation (1). During the turn-on period the energy is stored in the transformer. When the MOSFET turns off (t_{off}), the energy stored in transformer will deliver to the output of the power converter through the output rectifier. During this period, the output voltage V_o and diode forward voltage V_f will be reflected to the auxiliary winding N_{AUX} , the voltage on the auxiliary winding N_{AUX} can be expressed by Equation (2). A proprietary sampling technology is applied to sample the

reflected voltage. The correlated output voltage information can be obtained because the forward voltage of the output rectifier becomes a constant. After that, the sampled voltage compares with a precise reference voltage to develop a voltage loop for determining the on-time of the MOSFET and regulating an accurate constant output voltage.

$$i_{pk} = \frac{V_{IN}}{L_p} \times t_{on} \quad (1)$$

$$V_{AUX} = \frac{N_{AUX}}{N_s} \times (V_O + V_F) \quad (2)$$

where L_p is the primary winding inductance of the transformer; V_{IN} is the input voltage of the transformer; t_{on} is the on time period of the MOSFET; N_{AUX}/N_s is the turn ratio of the auxiliary winding and secondary output winding; V_O is the output voltage; the V_F is the forward voltage of the output rectifier.

This sampling approach also duplicates a discharge time (t_{dis}) of the transformer as shown in Figure 2, the output current I_O is related to secondary side current of the transformer. It can be calculated by the signal i_{pk} , t_{dis} as Equation (3). The PSR controller uses this result to determine the on-time of the MOSFET and regulate a constant output current. The current-sense resistor R_{SENSE} is utilized to adjust the value of the output current.

$$I_O = \frac{1}{2t_s} \left(i_{pk} \times \frac{N_p}{N_s} \times t_{dis} \right) = \frac{1}{2t_s} \left[\frac{V_{CS}}{R_{SENSE}} \times \frac{N_p}{N_s} \times t_{dis} \right] \quad (3)$$

where t_s is the switching period of the PSR controller; N_p/N_s is the turn ratio of the primary winding and secondary output winding; R_{SENSE} is the sense resistance for converting the switching current of the transformer to a voltage V_{CS} .

Implementing a HB LED Driver by Using a PSR controller

Implementing a HB LED driver to drive three HB LEDs in a series so that the output specification is 12V/0.35A. By using the PSR controller FSEZ1016A that integrates a PSR controller and a 600V/1A MOSFET will help to reduce external components, PCB size, reduce power losses and signal noise on the MOSFET's driver circuit and will also reduce interference. To minimize standby power losses, the proprietary green-mode function provides off-time modulation to decrease the PWM frequency linearly at light-load and no load conditions to easily meet the most of green requirements. The built-in frequency hopping function further improves EMI performance.

The experiment shows constant current (CC) regulation can achieve 1.8% with fold-back voltage 4V as shown in Figure 3 and suitable for widely VDD range and the CC capability is relative with output voltage. The efficiency was 77.66% at 115Vac input and 77.40% at 230Vac input, max no load power saving 0.115W. By using FSEZ1016A, a lighting solution can be implemented with fewest external components and minimize cost.

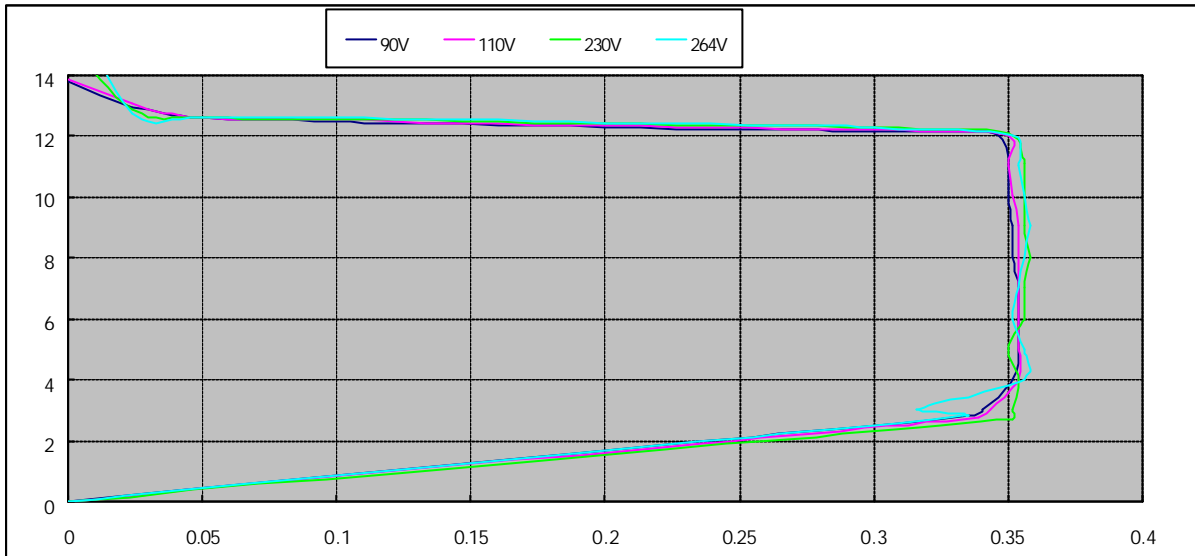


Figure 3. V-I curve by Using PSR controller

Conclusion

As there is a stronger focus on creating energy-efficient electronics, innovative techniques will be needed in lighting applications to replace traditional incandescent and halogen products. The advantages of HBLEDs are smaller size, high illumination, longer lifetime and environmental protection. All of these advantages will be instrumental factors why these products will gradually replace conventional lighting products. For provide better capability of HBLED, control circuits must using constant current for the LED driver. This article shows a patented "Primary Side Regulation" (PSR) technology. The PSR controller precisely regulates the voltage and the current for LED Driver in the primary side of the transformer without secondary feedback circuitry provides small size, longer life and environment protect product. The experiment shows PSR can provides constant current (CC) regulation 1.8%, efficiency 77.66% at 115Vac input and 77.40% at 230Vac, and input, max no load power saving 0.115W. By using this PSR technique can be an optimal solution to minimize the cost for offline LED drivers.