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Simple, Yet Versatile Flybacks Present Low-Cost Driver Solutions For LED Lighting

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The evolution of LED lighting is being driven not only by the ongoing development of LEDs but also by the development of the electronics to produce the required driving voltage and current. Electronic converters driving LED lights, ranging from light-bulb replacements to office and street lighting, differ widely among the variety of competing products in the market. Many semiconductor manufacturers offer different solutions giving a wide choice to producers of LED light fixtures.

Most LED light fixtures continue to drive the LEDs with current-regulated dc by means of an LED driver circuit consisting of an ac-dc switching converter since this is the ideal way to supply LEDs. Alternative ac LED solutions also exist where multiple LED die are packaged together and connected with some simple integrated electronics to produce an LED module capable of being driven directly from an ac supply. Among dc solutions there are also several variations of isolated and nonisolated converters. Isolation is often preferred because it simplifies fixture design, avoiding the need for mechanical safety isolation to prevent access to LEDs and heat sinks that produce hazardous voltages without isolation.

The simple, single-stage flyback converter is a basic platform used in many LED drivers because of its simplicity and low component count. It meets many of the common application requirements for isolation, input voltage range, power factor, THD and operating life. And with the addition of a few components, the LED driver becomes dimmable using an analog control voltage.

This article describes two isolated LED driver designs based on the one-stage flyback converter. The first design is non-dimmable; the second is dimmable. The operation of these circuits, their typical performance capabilities and ranges of operation, and important design considerations are explained.

A Non-dimmable, Isolated LED Driver For Offline Operation

Fig. 1 represents an isolated ac-dc constant-current converter based on a one-stage flyback circuit capable of operating over a wide input-voltage range, typically 90 to 305 Vac.

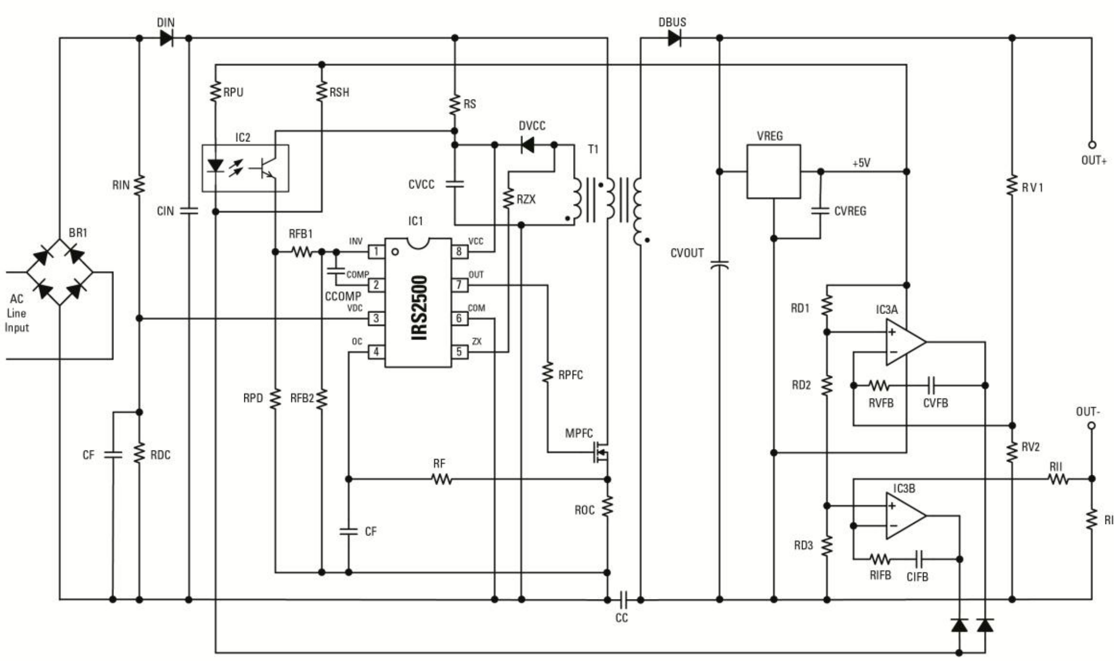

Fig. 1. Because of its simplicity and low cost, one-stage flyback circuits like the one shown here are popular for implementing isolated non-dimmable LED drivers.

The circuit uses a switched-mode controller at the primary and voltage- and current-sensing circuitry at the secondary with an optoisolator to transfer the feedback error signal to the control IC. This closes the loop and in turn regulates the LED current. In order to achieve high power factor, the loop response must be slow rolling off the current regulator gain well below line frequency as in a standard boost power-factor front-end circuit.

The one-stage flyback converter can operate over a range of power from under 10 W up to 100 W and also has the ability to achieve a power factor >0.95 and line current THD <20% without the need for additional circuitry. This is done by eliminating the bulk storage capacitor from the dc bus at the primary, leaving a full-wave-rectified voltage. On the down side, however, an electrolytic capacitor is necessary at the output to filter low-frequency current ripple.

Temperature derating is necessary to extend the life of electrolytic capacitors to meet the requirements for the application. A relatively large output current ripple can usually be tolerated in order to minimize the size of the electrolytic capacitor required at the output. Several parallel capacitors are often used in place of one large one to minimize the component height.

Flyback converter efficiency ranges from 75% at low power levels to close to 90% at higher power levels. At power levels above 100 W alternative circuit topologies offer better efficiency and power density. The efficiency limitation arises from the flyback converter being a derivative of the boost converter, which stores and releases energy in the inductor during each switching cycle rather than transferring power directly during the on period. In many LED lighting applications, the tradeoff between cost and performance favors the flyback circuit.

A Dimmable Version

Dimming can be implemented in the flyback LED driver with some additional circuitry. The simplest control method is 0- to 10-V control, which is widely used in commercial and industrial lighting. Since the circuit is already isolated, the dimming control circuitry can be combined with the current regulation circuitry based around op amp IC3B and referenced to the output 0-V return, making implementation easy. Fig. 2 shows a simple voltage-controlled current source can be used to inject an offset into the current feedback circuit causing the regulation threshold to be reduced and therefore the LED current to be regulated at a reduced level.

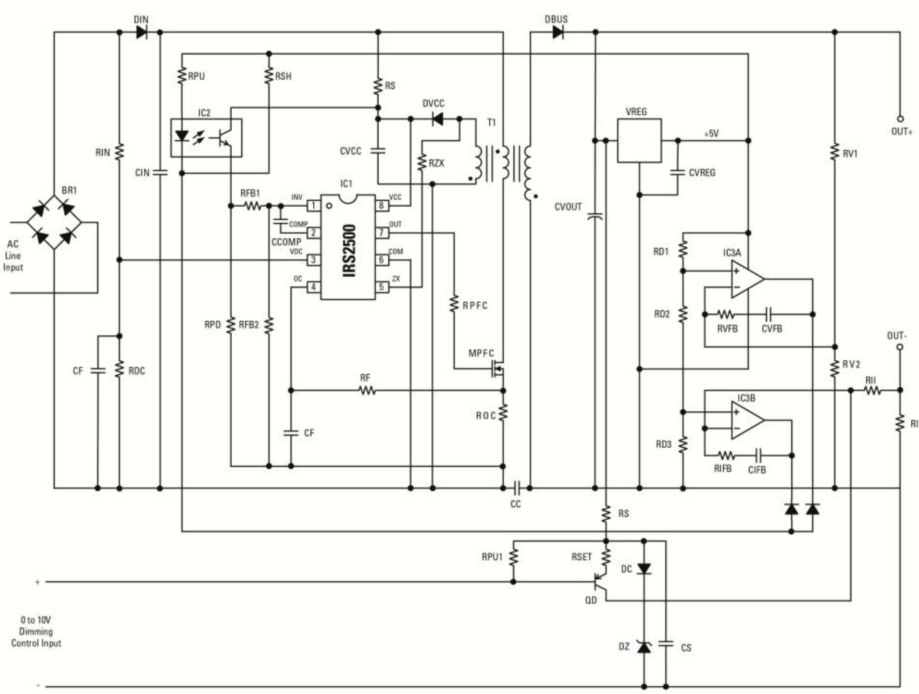

Fig. 2. With the addition of a few components, the one-stage flyback becomes a dimmable isolated LED driver, with dimming controlled by a 0- to 10-Vdc control signal. The additional dimming components inject an offset into the current feedback circuit, reducing the regulation threshold, which in turn causes the LED current to be regulated at a reduced level.

In this circuit, a 10.6-V dc supply is derived from the output via a simple resistor RS and clamp made up of diodes DC and DZ. This works if the LED output voltage exceeds 10 V, otherwise an additional winding would be needed on the inductor.

When there is no dimming-control input connected, RPU1 pulls up on the base of QD and no current is supplied from the collector. The 0- to 10-V dimming controls are always current sinking so that as the voltage is reduced the QD base voltage is also reduced. The emitter voltage is fixed at approximately 0.6 V above the base voltage creating a variable voltage drop across RSET, which increases as the control input is reduced.

Sizing RSET determines the amount of current injected from the collector into the current regulator input. This current is set to reduce the LED current to zero when the control input is 1 V, which occurs when the injected current multiplied by RI produces a voltage equal to the current reference voltage across RD3. Using this method, the output current-to-control voltage characteristic is very linear as shown in Fig. 3.

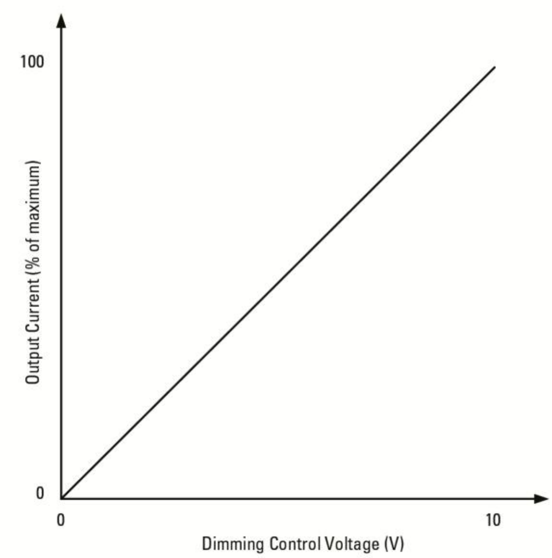

Fig. 3. Dimming characteristic of LED driver circuit shown in Fig. 2.

Output overvoltage protection is very important in flyback converters. That's because, when an open-circuit condition occurs, the output voltage can rise to a very high level and damage the components on the circuit's secondary side including the inductor. Op amp IC3A realizes this function with its output being OR'd with the output of op amp IC3B so voltage and current are both limited.

It is also possible to use the same circuit as a constant-voltage supply. This type of supply is not commonly used with LEDs because of the very steep V-I characteristic and tolerance of these devices. The 0- to 10-V dimming method described would not work in the case of a constant-voltage driver.

About The Author

Peter Green received a BSc degree in electrical engineering from Queen Mary College, University of London in 1985. Since then he has worked in product design and development for commercial and military companies in the power supply and lighting industries in the UK. He is a member of the Institution of Engineering and Technology and a Chartered Engineer. In 2001 he relocated to California to join the Lighting Design Center at International Rectifier where he has worked on new lighting ASIC definition and design, as well as application support. Peter is currently managing LED systems and applications. Peter has previously presented at APEC, PCIM and many other conferences and has several patents related to lighting electronics.

For further reading on the design of LED drivers, see the How2Power Design Guide, select the Advanced Search option, go to Search by Popular Topics and select "LED Lighting" in the Popular Topics category.