Inductor selection for LED driver designs

Overview

Light Emitting Diodes (LEDs) are semiconductor devices that contain no moving parts. This makes LEDs very reliable in demanding applications with high vibration and shock. These properties, along with high efficiency, long life, and brightness also make LEDs very attractive in lighting applications. The typical operating life of an LED is one hundred thousand (100,000) hours. LEDs are available in a wide range of colors and have superior brightness to traditional lighting making them ideal for a variety of applications such as backlighting, instrument panel, liquid crystal display, automobile lighting and general illumination.

The LED needs to be properly driven to ensure optimal performance and long life. Designing and implementing an effective driver with suitable topology is the key to successful LED lighting circuits. The topologies used in present day LED drivers are:

- Buck
- Flyback
- SEPIC
- Forward
- Buck-Boost

Each topology is selected according to the required power level and cost. Semiconductor companies have developed Integrated Circuits (ICs) to drive LEDs.

Controlling the current is the most important consideration in designing circuits that drive LEDs. Increasing current will result in higher intensity/brighter lighting, but with considerably reduced LED life.

Low wattage LEDs can be driven directly from the IC and higher power LED drivers using Pulse Width Modulation (PWM).

Most LED driver circuits need an inductor or transformer to drive the LED. Eaton has a large selection of inductors and transformers in various sizes, inductance values and current ratings to satisfy any particular LED driver circuit requirement.

Typical circuits for LED driver applications

Buck Circuit:
A buck circuit regulates input DC voltage down to a desired DC voltage (Figure 1). Buck circuits generally require one inductor. The following part number families are typical Eaton inductors used in buck circuits.

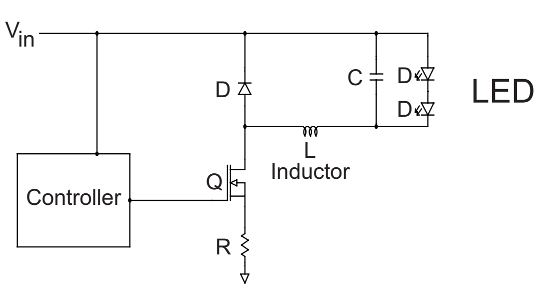

Figure 1. Buck circuit

MPI40xxV2 family
DR family: DR1030, DR1040, DR1050, DR73, DR74, DR124, DR125, DR127
LDS family: LDS0705
SD family: SD3114, SD3118, SD10, SD12, SD14, SD18, SD20, SD25, SD52, SD53, SD6020, SD6030, SD7030, SD8328, SD8350
Uni-Pac family: UP2.8B, UP0.4C, UP2UC, UP1B, UP2B, UP3B, UP4B
LD family: LD1, LD2

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Typical circuits for LED driver applications

Buck-Boost

The Buck-Boost circuit generates an output voltage that is either higher or lower than the input voltage. The polarity of the output is opposite to that of the input (Figure 2). Buck-Boost circuits generally require one inductor. The following part number families are typical Eaton inductors used in Buck-Boost circuits.

DR family: DR1030, DR1040, DR1050, DR73, DR74, DR124, DR125, DR127
LDS family: LDS0705
MPI40xxV2 family
SD family: SD3114, SD3118, SD3812, SD10, SD12, SD14, SD18, SD20, SD25, SD52, SD53, SD6020, SD6030, SD7030, SD8328, SD8350
Uni-Pac family: UP2.8B, UP0.4C, UP2UC, UP1B, UP2B, UP3B, UP4B
LD family: LD1, LD2

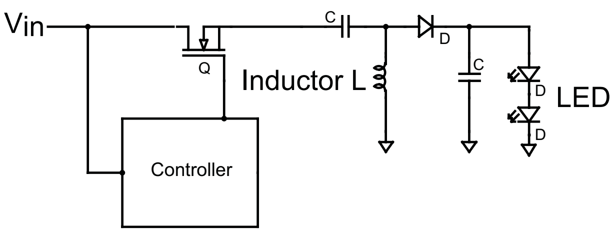

Figure 2. Buck-Boost circuit

Single Ended Primary Inductance Converter (SEPIC) circuit

The SEPIC circuit is a popular Buck-Boost topology that allows the output voltage to be higher or lower than the input voltage. The SEPIC output polarity is the same as the input (Figure 3). SEPIC circuits generally require two identical inductors that can be individual inductors or a dual-winding inductor. Dual winding inductors that are bifilar wound are preferred because the technique uses less space, reduces leakage inductance, and increases the coupling of the windings which results in overall increased circuit efficiency. The following part number families are typical Eaton inductors used in SEPIC circuits.

DRQ family: DRQ73, DRQ74, DRQ125, DRQ127
SDQ family: SDQ12, SDQ25

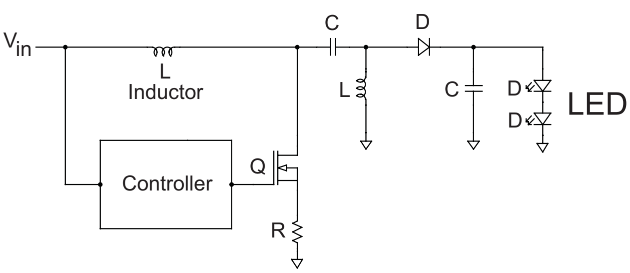

Figure 3. SEPIC circuit

Boost Circuits

Boost circuits are power converters with an output DC voltage greater than its input DC voltage (Figure 4). Boost circuits generally require one inductor. The following part number families are typical Eaton inductors used in boost circuits.

MPI40xxV2 family
DR family: DR1030, DR1040, DR1050, DR73, DR74, DR124, DR125, DR127
LDS family: LDS0705
SD family: SD3114, SD3118, SD10, SD12, SD14, SD18, SD20, SD25, SD52, SD53, SD6020, SD6030, SD7030, SD8328, SD8350
Uni-Pac family: UP2.8B, UP0.4C, UP2UC, UP1B, UP2B, UP3B, UP4B
LD family: LD1, LD2

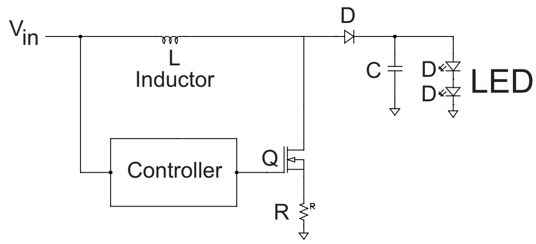

Figure 4. Boost circuit

Flyback Circuits

The Flyback transformer combines isolation, energy storage, and voltage scaling. The flyback allows multiple output voltages as well as can provide plus and minus outputs by using tapped windings (Figure 5).
Flyback circuits require a custom-designed flyback transformer. Eaton designs and makes custom and semi-custom transformers to match flyback circuit design requirements.

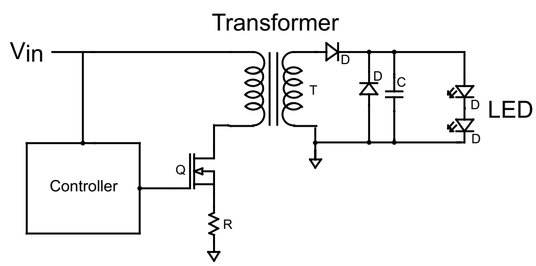

Figure 5. Flyback circuit

Forward Circuits

The Forward transformer only provides isolation and voltage scaling. The Forward allows multiple output voltages as well as can provide plus and minus outputs by using tapped windings. A separate energy storage device (inductor) is needed (Figure 6). Forward circuits require a custom-designed forward transformer and an output inductor.
Eaton designs and makes custom and semi-custom transformers to match forward circuit design requirements as well as has a number of output inductor offerings.

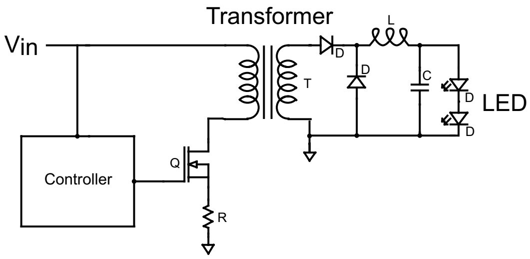

Figure 6. Forward circuit

Inductor selection and design process

Inductors are energy storage devices. Energy is stored in the inductor during the ON time and delivered to the LED during the OFF time.

The rule of thumb to design the inductor is to set the peak-to-peak ripple current in the inductor to 30 percent of the nominal LED current. It is a good practice to calculate the total volt drop across the LED string.

For example:
An LED string consist of five LEDs with each having a forward voltage drop of 3.0 volts resulting in a total LED voltage of 15 volts. Inductance value is calculated using formulas below.

$$D = \frac{V_{led}}{V_{in}} \qquad T_{on} = \frac{V_{led}}{V_{in} * F_{osc}}$$

$$T_{on} = \frac{D}{F_{osc}} \qquad L = \frac{(V_{in} - V_{led}) * T_{on}}{(0.3 * I_{led})}$$

D = Duty Cycle

Fosc = Frequency

I = Current

L = Inductance in Henries (H)

T = Time ON

V = Voltage

Total inductor current is the sum of the required LED current plus half the ripple current.

The inductance value and the maximum current requirement lead us to the selection of the correct Eaton part number from the catalog. The saturation current is also taken into consideration when selecting the inductor. The DC resistance of the inductor is another important parameter. Lower DC resistance will yield better efficiency.

Care must be taken to implement the power factor correction for circuits on the offline LED application circuits. This will give a leg up on passing the AC line harmonic limits of EN61000-3-2 standard for Class C equipment.

Design guide for SEPIC topology and inductor selection

D = Duty Cycle

f = Frequency

Iin = Input Current

Iout = Output Current

Vin = Voltage In

Vout = Voltage Out

$$D_{\max} = \frac{V_{out}}{V_{out} + V_{in(\min)}} \qquad D_{\min} = \frac{V_{out}}{V_{out} + V_{in(\max)}}$$

$$L \geq \frac{V_{in(\max)} \times D_{\min}}{f \times I_{out(\min)} \left(\frac{V_{out}}{V_{in(\max)}} + 1 \right)}$$

$$I_{in(\max)} = \frac{I_{out(\max)} \times D_{\max}}{1 - D_{\max}}$$

$$RMS_{ripplecurrent} = \sqrt{I_{out}\max^2 \times D\max + I_{in}\max^2 \times (1 - D\max)}$$

The calculated inductor value and the Irms current enable the engineer to select the correct inductor. For SEPIC application, the dual inductor must be bifiliar wound on a single core. This will reduce the leakage inductance. This in turn reduces the losses and improves efficiency.

Inductor parametric search engine: tools.eatonelectronics.com/tools/parametric-search
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Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
www.eaton.com/electronics

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