

Driving LEDs - A Fresh Look

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It is a well established fact in the solid state lighting industry that LEDs are constant current devices. This is because light output (luminous flux) is more or less linearly proportional to forward drive current over a given operating range. The overwhelming majority of driver topologies deliver a tightly regulated constant current in order to deliver a given number of lumens. The forward voltage of the LED can vary over a broad range, therefore, the amount of power delivered to the LED will fluctuate accordingly because power is voltage multiplied by current ($P_{LED} = V_{LED} * I_{LED}$). Furthermore, the brightness of LEDs typically varies, from lot to lot, more than forward voltage, implying that luminous efficacy is the main variable with respect to manufacturing output. For example, two LEDs (let's call them LED1 and LED2) driven at identical forward currents of 350 mA may have forward voltages of 2.8 V and 3.0 V, and luminous flux outputs of 105 lm and 120 lm, respectively. Consequently, LED2 is more efficient at 114 lm/W while LED1 is capable of 107 lm/W. Due to the variance of multiple critical parameters, LEDs are typically binned at production. For example, LEDs may be binned according to any combination of forward voltage, luminous flux, correlated color temperature (CCT) for white LEDs, dominant wavelength for color LEDs, etc. LED cost is proportional to the number of bins required per the application and can increase LED cost by as much as 30 percent depending on the supplier. Therefore, an interesting and important question worth examining is: which type of bin is most important? The answer lies in how the LEDs are being driven. This short article will use a few examples to illustrate the key relevant points.

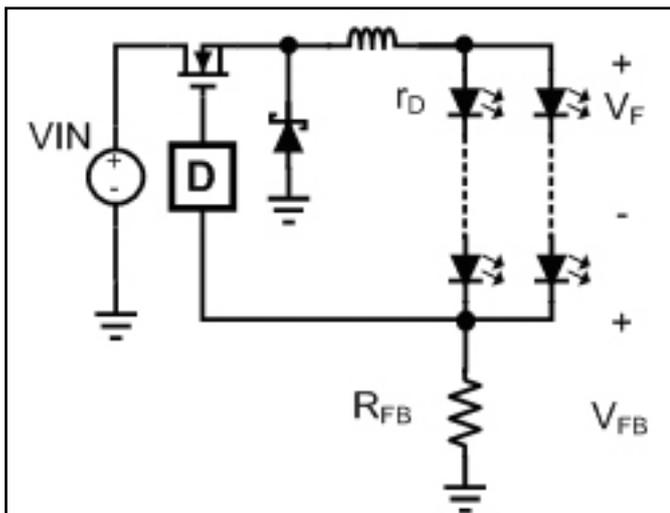


Figure 1. National Semiconductor's LM3406 buck regulator driving series-parallel LED combination with constant current.

The first example will use a traditional buck regulator since it is the most common DC/DC conversion topology and is even

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becoming popular in direct AC/DC LED drivers as well. The buck is the most common topology because of the ease in which it delivers a constant current to the LED stack. As shown in Figure 1, the inductor current and the LED current have the same continuous average value, so the output capacitor can be greatly reduced if not eliminated. At switching frequencies that typically range from 200 kHz to 1 MHz or more, the inductor creates a high output impedance and this is the closest that a switching regulator can come to being an ideal current source.

The first major decision relates to the driver's compliance voltage. If it is desired to remain in the class 2, low voltage category in galvanically isolated AC/DC applications, or your driver simply lacks enough compliance voltage to run the entire LED stack in series, a series-parallel combination may be implemented, also as shown in Figure 1. In this case, the LEDs should likely be binned for forward voltage since today's LEDs have a very low AC or dynamic impedance when driven at typical current levels of several hundred milliamps or more. Another, and perhaps simpler way of saying this is that an LED's forward current varies significantly with only minor variations in forward voltage. When driven in any parallel combination, LEDs are forced to run at identical forward voltages by definition. If not binned for forward voltage, the current in each LED will vary significantly and consequently, so will its lumen output, which is undesirable. Even when binned for forward voltage, acceptable current matching over operating points and lifetime may not result. The forward voltage of binned LEDs are matched only at a particular rated current; deviation from that rated current will result in an unmatched forward operating characteristic whose mismatch will be proportional to the difference in operating current and rated current. Finally, as LEDs age over time, their forward voltage changes and these changes are not guaranteed to match. A much better option would be to run multiple independent channels using a multitude of options including multiple buck regulators or dynamically controlled linear regulators.

The next major element to consider relates to the control input of the converter. As discussed previously, the majority of LED drivers control or regulate the current, but should they? The example of a flyback regulator, as shown in Figure 2, is commonly implemented in small, low cost, relatively efficient (80 percent+), isolated AC/DC converters for direct LED drive. As a side note, flyback regulators also offer the potential for buck-boost operation as well as power factor correction, all of which are increasingly important considerations in LED drivers. The topics discussed and conclusions drawn can be similarly applied to other LED drive topologies. For this example, five LEDs of both type LED1 and LED2, with luminous efficacies of 107 lm/W and 114 lm/W, respectively, are used in Figure 2 below.

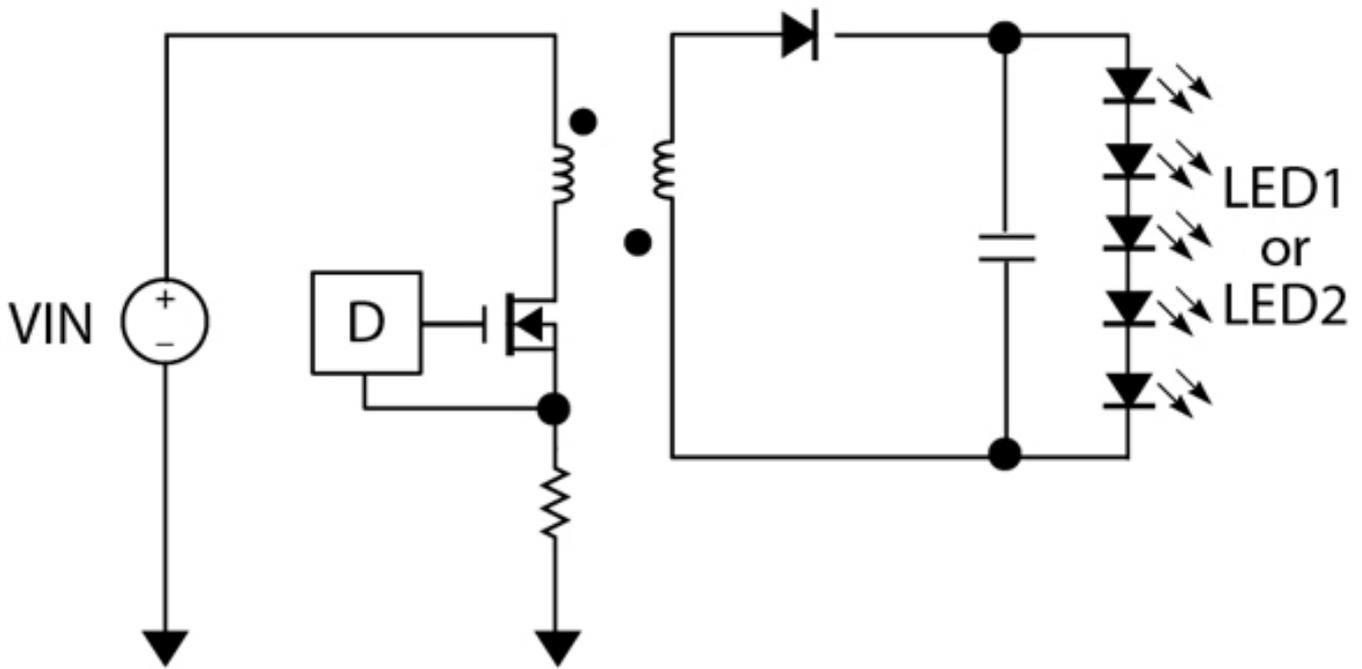


Figure 2. National Semiconductor’s LM3445 flyback regulator in constant power operation.

If the five LEDs are driven with a constant current of 350 mA, the following system performance characteristics will result:

	Total Stack Voltage (V)	Total Stack Power (W)	Total Luminous Flux (lm)
LED1 Stack	14	4.90	524
LED2 Stack	15	5.25	599

Taking the more efficient stack (LED2) as the reference, a difference of 12.4 percent in total luminous flux would result. If, however, the LEDs were to be driven with a constant power of 5 W instead of a constant current of 350 mA, the following system characteristics would result:

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	Total Stack Power (W)	Stack Current (mA)	Total Luminous Flux (lm)
LED1 Stack	5	357	536
LED2 Stack	5	333	571

As can be seen in the table, a difference of only 6.1 percent in total luminous flux results, providing a significant improvement over the constant current drive method.

Another advantage of driving a constant power is with respect to total luminous flux versus temperature. As LEDs heat up, their forward voltage drops, as does their flux output. While lumen output is typically quoted in LED datasheets at 25°C, actual junction temperatures in practice are typically closer to 85°C or higher. At these elevated temperatures, luminous flux is typically reduced by 10 to 15 percent. Driving the LEDs with a constant power will increase the current slightly to accommodate this drop because the LED stack voltage is also dropping with increased temperature. This effect becomes more prominent the hotter the LEDs are permitted to operate.

Driving LEDs with a constant power instead of a constant current introduces other new elements that need to be considered, e.g., shorted output protection. The fact is, most regulators and especially LED drivers provide for over-current protection, thereby addressing this concern.

In summary, designing your power supply before choosing the arrangement of LEDs will give you greater flexibility of the LED driver design and increases optimization to meet the demands of performance, cost and LED binning. While constant current topologies dominate the LED driver landscape, constant power operation should be given a closer look, especially when multiple forward voltage bins or increased flux consistency over temperature are important.

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