A guide to selecting power supplies for LED lighting applications

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Thanks to their energy savings, long service life, durability and design flexibility they offer, light emitting diodes (LEDs) are rapidly replacing incandescent and fluorescent technologies in both indoor and outdoor luminaires. But choosing the right LED is only part of the design equation. In order for your solid-state lighting design to realize its full efficiency, durability, and longevity, you'll need to choose a power supply with characteristics which closely match the requirements of your application and the LEDs you're using. This brief tutorial offers some helpful pointers on what you'll need to consider during the selection process.

Start with the basics

LEDs begin to produce light once their supply voltage is equal to or greater than the diode's forward voltage drop (typically in the region of 2-3V). The current required for full brightness varies from device to device but is typically 350mA for a 1W LED (usually the smallest size used in lighting applications). But unlike incandescent bulbs, LEDs are non-linear devices. This means that once the supply voltage exceeds the diode's forward voltage, the current they pass increases exponentially as a function of supply voltage. Without some sort of current regulation, the LED chip will become an expensive, one-shot solid-state flash bulb.

To prevent this inconvenient behavior, the power source therefore must provide a suitable voltage at the appropriate current. The simplest way to achieve this would be to select a power supply with an output voltage above the forward voltage of the chosen LED and to limit the current to the maximum specified by the LED manufacturer using a current limit resistor. The down-side of this approach is that one of the main benefits of LED lighting – that of high efficiency, is compromised by the power dissipated by the current limiting device.

A further problem with this approach is that the LED junction temperature affects its forward voltage. As a power supply’s output voltage is fixed, this in-turn means that the voltage across the current limiting device changes and hence the current will change too. The changing current will affect the amount of light being emitted and decrease the reliability of the LED. The best approach is to drive the LED from a constant current source. This allows the current to be set to the maximum specified by the LED manufacture to achieve greatest efficiency and reliability, or to achieve the exact brightness required and also to remove the effects of junction temperature as the LED or ambient temperature changes.

One of the benefits of using LEDs in lighting applications is the ease of varying the brightness of the light. This can be achieved by varying the current through the LED which proportionally varies the amount of light emitted, however, running the LED with less than its maximum current reduces the efficiency and may result in slight changes in colour. A better way is therefore to pulse the current
between zero and maximum to vary the average light emitted. As long as this is done at a high enough frequency to avoid the pulsing being seen as flicker by the human eye this is the optimum way to achieve dimming. Pulsing of the current will usually be done at a fixed frequency with the ratio of zero to full current being changed. This is the pulse width modulation (PWM) method.

**Selecting a power supply**
The type of power supply selected for a lighting application will be based on several factors. First, consider the environment your application will be operating in. Is the application for indoor or outdoor use? Does the power supply need to be water-proof or have any special IP rating? Will the power supply be able to use conduction cooling or only convection cooling?

Next, define the overall power requirements. A single luminaire may only require a small power source but a complex system may need ones supplying hundreds of Watts. Also, will other features be required? For example, will the power supply be required to work in simple constant voltage mode or constant current mode, and will your application need to be dimmable?

**Rules & regulations matter**
Then it's time to think about regulations. Will the overall system need to operate within certain harmonic current limits? Will it need to conform to the safety standard for lighting or will an ITE power supply be adequate? And, in these energy-aware times, how efficient does the power supply need to be to meet local or regional standards.

Equally important, will your product be sold in places where utilities offer rebates or other subsidies for products which meet a particular level of efficiency and power factor correction? It's also important to know whether the standards your design will need to comply with include any requirements for how much power the supply draws when the lamps are turned off.

**Safety standards**
There are various standards that apply to lighting systems. Internationally there is IEC61347 Part 1\(^{(1)}\) of which covers the general safety requirements of lamp control gear and Part 2 Section 13\(^{(2)}\) which is applicable to power sources for LED modules, the US have UL8750\(^{(3)}\) and Europe has EN61347 following the IEC format of section naming.

**Harmonic currents**
A lighting application will generally require the harmonic current emissions to meet the requirements of EN61000-3-2\(^{(4)}\) and the class of equipment which covers lighting is class C. Within this class there are one set of limits for above 25W active input power and another set for 25W and below. However, the standard specifically only mentions discharge lighting for 25W and below.

To meet the limits for above 25W will generally require power factor correction and, as the limits are calculated as a percentage of the fundamental rather than as an absolute value of Amps, it may be better to use a power source designed specifically for lighting applications rather than an ITE type power supply. However, an ITE power supply will probably meet the limits as long as the lighting load is above 40-50% of the power supply’s full load rating.

An example of an power supply series specifically designed for LED lighting applications is the IP67-rated DLE series from XP Power. The range comprises 15, 25, 35 and 60 Watt models and complies with safety specifications EN61347 and UL8750.
LED configurations
Some lighting applications may use just a single LED. The power used by this will typically be around 1W as the forward voltage is in the range of 2-3V and forward current around 350mA. Although this will produce a bright source of light, it is more probable that LEDs will be used in an array of some kind within a luminaire or group of luminaires to produce a brighter and more even light source. The LEDs will be generally arranged in one of four types of configuration. Placing the LEDs in series, parallel or a matrix (combination of series and parallel) configurations enables them to be driven from a single power source. The fourth configuration utilises multiple channels which require multiple power sources.

Series configuration

In this configuration the individual LEDs are arranged in series. This gives the advantage that the
same current flows through each of them resulting in the same brightness of light given off. Another advantage that if one LED fails in short circuit, the other LEDs are unaffected and hence still lit. A disadvantage is that if one LED fails in open circuit, then current flow is interrupted and all the other LEDs turn off. A further disadvantage is that if many LEDs are needed to produce the amount of light required then the total sum of the forward voltages can necessitate the use of a power source with quite a high output voltage.

Parallel configuration

Figure 3 – LEDs connected in parallel

When connected in parallel the LEDs may still be arranged in two or more strings of LEDs in series. The advantage is that for the same number of LEDs i.e. the same brightness, the power source could have a lower output voltage as the number of LEDs in each string can be reduced. Another advantage is that if one of the LEDs becomes open circuit in one string then the other strings are unaffected and the luminaire will still produce light albeit at a reduced brightness. The disadvantage is that the current in each string cannot be precisely controlled from a single power source due to the slightly different forward voltages present in each string and so a current balancing device in each string may be needed which could reduce the overall efficiency.

Matrix Configuration

Figure 4 – LEDs connected in a matrix configuration

In a matrix layout, the LEDs can be arranged in a similar manner to that of parallel configuration but there are links between each LED form string to string. The big advantage of this configuration is that if a single LED becomes open circuit, there is still a path for current to flow through all the other LEDs in that string and so light output is hardly diminished. The main disadvantage is that it is more difficult to control the current in each string as a current balancing device cannot be used.
This means that the LEDs used must have a closely match forward voltage which could add to the cost.

**Multiple channel configuration**

![Figure 5 - LEDs connect by the multiple channel method](image)

Using this approach, the LEDs are arranged in series in multiple strings arrangements similar to the parallel and matrix configurations. This has the benefit that the total string voltage can be reduced for any given brightness required and as each string is fed from an individual power source the failure of any one string will not affect the other strings in any way. A disadvantage is that the power source will be more costly as each string has an individual output however it does allow for more flexibility in applications where the brightness of one string needs to differ from the others or where individual string dimming is required.

**References**

1. IEC61347 Part 1 – an overview of the standard is available at this link [http://www.ieCEE.org/ctl/equipment/pdf/lite/IEC%2061347%20Part%201%202007%202007_06_04.PDF](http://www.ieCEE.org/ctl/equipment/pdf/lite/IEC%2061347%20Part%201%202007%202007_06_04.PDF)

2. IEC61347 Part 2, section 13 – an overview of the standard is available at this link [http://www.ieCEE.org/ctl/equipment/pdf/lite/LITE%2061347%20Part%202%20Section%2013%202008%202009_05_18.PDF](http://www.ieCEE.org/ctl/equipment/pdf/lite/LITE%2061347%20Part%202%20Section%2013%202008%202009_05_18.PDF)
