

WHAT IS THE PROBLEM WITH DIMMING LEDs?

White LEDs are revolutionising general lighting markets, but dimming them can cause problems.

By James Hunt



LEDs have been developed to provide a genuine and affordable alternative to conventional white-light lamps, especially taking into account the total cost of ownership, which will usually easily offset the relatively high initial cost. So successful have LEDs become that LED lighting is genuinely revolutionising the general lighting sector. LEDs are even starting to find their way into homes, despite the still comparatively high initial cost.

LEDs can be designed to produce bright, uniform light, and have many advantages, including relatively high energy efficiency, long life, good

reliability and well-directed light output. They are also unaffected by extremely low temperatures and are virtually unbreakable. LEDs can be designed into buildings, structures and materials in ways that are impossible with conventional lighting and can therefore provide more freedom in the design of luminaires, which can be made to look sleek, modern and unobtrusive.

Another advantage is that, because individual LEDs are almost a point-light source, light control is simple, and well-designed LED lighting luminaires – which have special optics – can use virtually all of the light emitted. The high optical

efficiency of LED luminaires means that they can achieve the designed illumination for less initial flux (light) than would be needed from a conventional light source (e.g. a fluorescent lamp). Compared with equivalent fluorescents, good-quality LED luminaires will usually make significant energy and cost savings over the life of the installation.

But there is one aspect that is still problematic – dimming. People dim lights for comfort, or to set a scene, but there is also evidence that dim illumination can improve creative performance. A study carried out by researchers from the University of

Stuttgart and Hohenheim indicated that dim lighting “elicits a feeling of freedom, self-determination, and reduced inhibition” – all factors conducive to innovative thinking.

Then there is the possibility of energy-saving, though dimming certain types of older lamp can actually reduce luminous efficacy, of which more later.

Clearly dimming is an important requirement and if the LED is to realise its full market potential then we need to be able to dim LEDs with relative ease. We’re not there yet, and providing ‘dimming capability’ is one of the most common problems faced by an



LED lighting techniques can vary colour and dimming for mood enhancement in a hotel lobby



Flicker – This is an irritating phenomenon. Modern LED drivers typically use pulse-width modulation (PWM) to regulate power, which is a form of fast switching to achieve perceived dimming. To avoid perceptible flicker, the driver output frequency should be at least 120Hz. However, low resolution (the number of bits used to represent values) digital electronics can produce a flicker effect at the lowest settings, but the latest drivers (employing resolutions of 12 bits or higher) avoid this problem.

Colour temperature – When dimming incandescent lamps, the lower filament temperature causes a colour shift from white through yellow to orange/red. Dimming a CFL brings similar results, but much less pronounced. For white LEDs, the light does not shift to red when dimmed; some can even appear more blue, but in any case, colour temperature compensation to obtain the required colour effect may be possible as white light, or other colours, can be produced by mixing red, green and blue LEDs. Of course, the LED lighting system concerned has to be designed to allow this. >

electrician when installing LEDs. The root cause of this problem is that the electronic control gear driving the LEDs is often incompatible with dimmers designed for older lamp types, still in place. To take an example, an LED driver directly connected to a line-voltage incandescent dimmer may not receive sufficient power to operate at lower dimming levels. It may also be damaged by current spikes.

Dimmers used with the now withdrawn incandescent lamps regulate the amount of power to the lamp filament using phase control techniques that incandescent lamps could handle reliably. People didn't

notice the inherent flicker because it was too fast.

These characteristics, however, become important when used with compact fluorescent lamps (CFLs) and LEDs. Certain LED lighting products can be used with line-voltage dimmers, but dimmer and LED driver electronics must be carefully matched. However, because already-installed dimmers may vary widely, an LED fixture cannot be guaranteed to automatically work with all dimmers.

The answer is to use dedicated LED dimmers. These typically incorporate low-voltage (LV) controls connected separately to the electronic driver to which full

AC power is supplied. This allows the electronic controls to operate at all times, in turn enabling LEDs to be uniformly dimmed to around 5 per cent or lower. However, there is a drawback, as this arrangement may need extra LV wiring for retrofit applications, which can increase the installation cost.

If not properly selected and installed, dimming attempts can give LED lighting a bad name. The solution lies in a proper understanding of the issues.

Dimming issues

Important LED dimming parameters include flicker, colour temperature and efficiency changes.

**An office using LED
downlighting. A
study has indicated
that dim light can
help creativity.**



█ Luminous efficiency is significantly reduced for dimmed incandescent lamps. CFL efficacy is much less affected by dimming, but the luminous efficacy of the latest LEDs can actually improve when dimmed, along with lumen maintenance and longevity. For example, reducing the light output of an LED by two-thirds reduces the current consumption from 525mA to 75mA, in turn reducing the overall energy consumption by 90 per cent.

In general, dimming causes LEDs to experience a similar shift in spectral power distribution as an incandescent lamp, but if coloured LEDs in an array are used to produce the white light, the different spectral shifts among the different colours, particularly with red and yellow LEDs, may adversely affect the overall quality of the white light produced.

When fluorescent lighting is dimmed, the lamp life can be reduced; this does not occur with LED dimming. Instead, dimming LEDs can lengthen the useful life of the LEDs, because the process typically reduces the light source operating temperatures.

How to dim LED lighting

Dimming is achieved by reducing the voltage into, and luminance out of, a light source. LED drivers having a dimming capability can now dim the LED light output over the full range from 100 per cent to 5 per cent, or even zero. Such drivers work by reducing the forward current, by PWM, or via more sophisticated methods. In practice, commercial LED drivers generally use one of two methods to dim mixed-colour RGB (red, green and blue) and phosphor-converted high-power white LEDs.

The first is continuous current-reduction (CCR) – also called ‘analogue dimming’ – which decreases the forward current supplied to the

LED, in turn proportionally lowering the light output level, so the current flows continuously at a set level for a given lumen output.

The second is PWM dimming, in which the frequency could range from a hundred modulations each second to as high as hundreds of thousands of modulations per second, so that flicker is unnoticeable. PWM dimming has the advantage of being less susceptible to colour changes in the LED with varying brightness levels. This is because the LED essentially runs at a constant current when it is on and at no current when it is off. However, this advantage comes at the expense of extra logic to create the PWM waveforms.

Both techniques control the time-averaged LED drive current through the LED (or LED lighting cluster or string), which is proportional to the light output, but the two have their own advantages and disadvantages. Both dimming methods – which are sometimes used together – provide small chromaticity shifts for white LED lighting, with PWM being slightly better than the CCR. Note that mixed-colour (RGB) systems may have the disadvantage of large chromaticity shifts, regardless of the dimming scheme used. Note also that the 1-10V, DMX and DALI technical lighting digital control standards are all compatible with CCR and PWM dimming.

PWM dimming – advantages

█ **PWM drivers only run the LEDs at the rated current level or zero, preventing colour and efficiency characteristics from changing as the load is dimmed. The same colour temperature is maintained throughout the dimming range – there is minimal colour shift. This is a significant advantage.**

- █ **PWM provides a wide dimming range.**
- █ **PWM drivers provide a precise output, since the LEDs are always on at the rated current (or zero), so the relationship between light output and duty cycle is linear.**

PWM dimming – disadvantages

- █ **PWM drivers can suffer performance loss if mounted remotely from the light source, because the capacitance and inductance of lengthy cable runs interfere with the fast rise and fall times needed for precision control.**
- █ **PWM operating frequency must be high to avoid flicker; however, higher-frequency power supplies are typically more complex and expensive, especially for low light levels.**
- █ **PWM operation may cause electromagnetic interference (EMI) – this may limit the applications.**
- █ **PWM dimming is typically suitable for LED lighting that must be dimmed below 40 per cent while still maintaining a consistent colour temperature. It is also suitable for colour mixing applications.**

CCR dimming – advantages

- █ **CCR dimming is simple, requires the least control overhead, and is generally more efficient than PWM dimming because of the lower forward**

voltage of the LEDs at lower drive currents.

- █ **CCR dimming with a Class 2 power supply provides greater voltage than PWM.**
- █ **In contrast to PWM, CCR dimming doesn't need a complex and expensive higher-frequency power supply.**
- █ **CCR dimming, unlike PWM, avoids the risk of potentially damaging EMI.**
- █ **CCR current can in some cases be controlled via amplifier gain, and feedback allows current and thermal foldback for LED protection. Thermal foldback limits the LED temperature to protect against failure by reducing the LED current as the ambient temperature increases. This decreases the current until the LED junction temperature returns to a safe operating temperature, providing greater reliability, and a longer working life.**
- █ **CCR dimmers can be mounted remotely from the LED light source without significant performance loss.**

CCR dimming – disadvantages

- █ **CCR dimming needs the analogue voltage to be generated using a separate voltage reference, typically using a digital-to-analogue converter or the output of an RC filter on a square wave input signal. Both approaches can increase costs**
- █ **CCR dimming can vary**

the colour temperature with the LED current. For certain applications – e.g. in retail outlets – this is unacceptable.

CCR dimming is best suited to those applications where there are long cable runs between the driver and the light engine (a combination of one or more LED modules together with the associated electronic control gear (ECG), also known as an LED driver). An LED module contains one or more LEDs, together with further components, but excluding the ECG.

CCR dimming is also suitable for applications where high-performance dimming is essential, and where there are EMI restrictions. CCR is also suitable for lighting systems

needing a higher rated output voltage than the PWM voltage level.

LEDs and dimming for emergency lighting

UK legislation demands reliable, good quality emergency lighting to ensure that people can see and that escape routes are properly identified and illuminated.

Today's high-quality technologically-rich emergency lighting products and systems, such as LED lighting and drivers, allow fire safety legislation requirements to be met, while simultaneously helping to save money longer term and adding to versatility.

There are two main choices for emergency lighting systems. These are the self-contained type having an on board battery in the

luminaire, and luminaires that are slaves to a central emergency power system (CPS) in which the batteries are located away from the emergency luminaires. CPS and/or central battery systems are mainly used in medium or large installations where there are many emergency luminaires, or high ambient temperatures, as well as a need for central control.

Integrated CPS systems combined with mains dimmed controlled luminaires is a technology that has evolved to provide still greater benefits for building owners and end-users. Such systems include low-energy LED-based emergency lighting (either self-contained non-maintained, or with central battery systems)

combining lighting controls and emergency functions into a single system. Such integrated systems can provide very high design flexibility and save installation time, energy consumption and money, while allowing the creation of a very stylish, unified and yet distinctive architectural appearance.

As LED dimming techniques are further developed and widely used, leading to lower first costs, fully integrated LED dimming controls will become more common in many applications, including new build homes. However, developments are also aimed at designing LED lighting products that can be used with existing dimmers to allow for more retrofitting to existing homes. ✱



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