Driver design to increase control system compatibility and performance in LED lighting.

Research indicates that various issues such as flickering, dead travel and ghosting occur when LEDs are used with incompatible dimmers or home automation systems. This paper investigates the reasons for poor dimming performance and outlines the benefits of LED driver design for dimmer and home automation system compatibility.

The Transforming Nature of LED Lighting

With the introduction of LEDs, the requirements for how power is delivered to light sources has changed. Due to the low power and highly sensitive design of LEDs, electronic transformers are required to alter the mains power supply. These electronic transformers differ from the heavier magnetic low-voltage transformers previously required for halogen lamps.

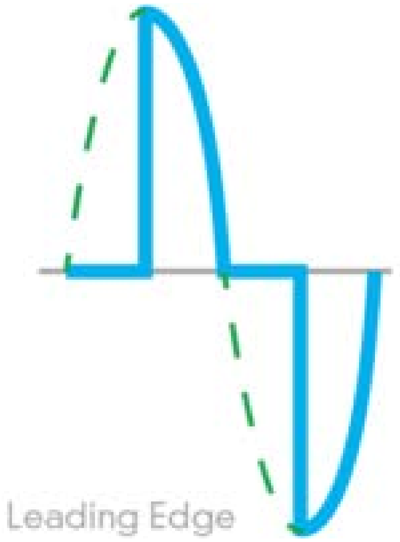
LED transformers, otherwise known as drivers, can be classified into two major groups; single-stage and multiple-stage topologies. Single-stage designs are usually smaller, cheaper and have a shorter lifetime than multiple-stage designs (Almeida et al, 2015).

In conjunction with these two different topologies, not all LED lamps have drivers designed for dimming. Attempting to dim a non-dimmable LED will result in incompatibility issues and erratic behaviour. Dimmable LED lamps are generally only compatible with certain specified dimming techniques. The main dimmers used are leading edge, trailing edge, and universal dimmers. Other dimming methods can be used, such as Pulse Width Modulation (PWM), 0-10V, DALI, and DMX.

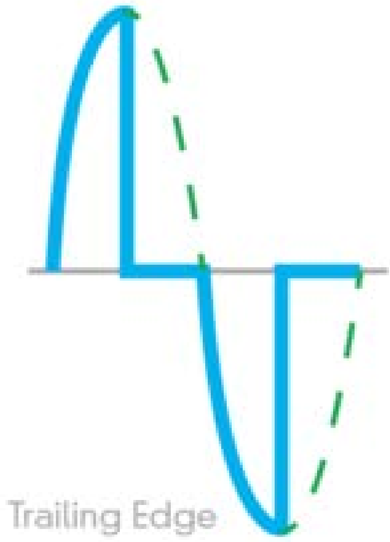
Dimmers: How They Work

Dimmers are used to change the appearance of a space and how it is experienced. The most common dimming method is triac dimming, where the sine wave of the mains power supply is modified to reduce the total output power.

Leading edge dimming is the most popular form of triac dimming available to consumers, due to its relative maturity and lower cost compared to trailing edge and universal dimming. Leading edge dimmers work by altering the voltage and current delivered by delaying the turn on at the start of the sine wave. This form of dimming works well on resistive loads, such as incandescent lights, but poses a problem for most LED drivers as it does not correct for changes in power factor.



Trailing edge dimming is a relatively new form of triac dimming designed to work better with LED drivers. It works in the opposite manner to leading edge dimmers, by adjusting the turn off point at the end of the sine wave.



Universal dimming is the newest form of TRIAC dimming. It combines both leading and trailing edge dimming into one module. Universal dimmers have the ability to detect the type of load attached and choose the dimming mode most suited to the load.

Most home automation systems on the market still use leading edge dimmers as their main dimmer module, although universal dimmers are becoming more readily available.

Issues with Dimming

LEDs often perform undesirably when used in conjunction with a dimmer. This incompatibility can be attributed to three main variables:

1. The characteristics of the LED driver
2. The characteristics of the dimmer
3. The number and type of light sources on the circuit

Due to a lack of standardised testing procedures and no standard definition for a dimmable LED driver, it is difficult to predict the performance of a circuit without testing. Additional issues are introduced through legacy wiring and variations in the mains power supply.

Incompatibility of LEDs and dimmers can result in the following issues (DOE, 2012):

- Flickering: Light source intermittently turns on and off
- Dead travel: Adjusting of the dimmer does not correspondingly change the light level
- Ghosting: Light source exhibits a dim glow when it should be off
- Pop-on: Dimming level needs to be raised to a certain point before turning on the LED
- Popcorning: Multiple lights on the circuit turn on a different times
- Audible noise: LED driver or dimmer produce a hum when in operation
- Permanent failure: Inoperable failure of the LED driver or dimmer

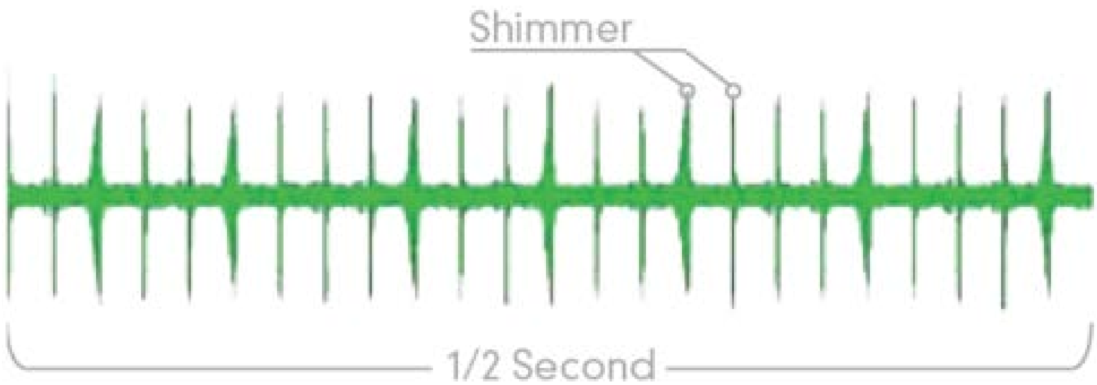
Flickering: Why it Occurs and How to Prevent it

Flickering occurs in all LEDs with electronic drivers using PWM to reduce the voltage going to the LED. This is due to the power supply turning the LED on and off at such a high frequency that it cannot be seen. According to the IES (Illuminating Engineering Society) two types of measures are commonly used; Flicker Index (FI) and Percent Flicker (PF). The prefered measure by lighting designers is Flicker Index. FI measures the relative cyclic variation of the output from different sources.

When used in conjunction with a dimmer, LEDs may display flickering that is visible to the human eye. There are 6 main reasons why this occurs (Philips, 2012)

1. Mains supply instability
2. Noise on the mains supply or dimming system
3. Dimming system not loaded correctly
4. Too many or too few LED lamps are being used per lighting control channel
5. LED driver design
6. Dimmer level set too low

Unlike incandescent lamps, LEDs respond very quickly to changes to its electrical current. During times of instability from the mains power supply, incandescents could use the high thermal mass of the filaments to mask any changes in voltage. Conversely, the fast response time of LEDs can lead them to exhibit a shimmer unless the driver used has additional filtering capabilities.(Ethan Biery, 2014)



When used with leading edge dimmers, LEDs do not provide enough draw current for correct operation due to their low power nature. This is called incorrect latching and can produce a constant flicker. To mitigate this, drivers need to be designed with the highest minimum current draw dimmer in mind. Other corrective measures can be used such as using an Active Load Device/Light Dimmer Filter Module. These devices limit the amount of peak current when the dimmer is first turned on, as well as reducing the magnitude of subsequent current oscillations. If the peak current is sufficiently reduced, the dimmer should be able to latch onto the LED load correctly and prevent any flickering.

If flickering is occurring on trailing edge dimmers, it is generally because there are too many LEDs on a single dimmer. The extra load on the dimmer creates a large amount of slow voltage decay. This decay can affect how the driver recognises the phase angle creating flickering, dead travel and poor minimum light levels.

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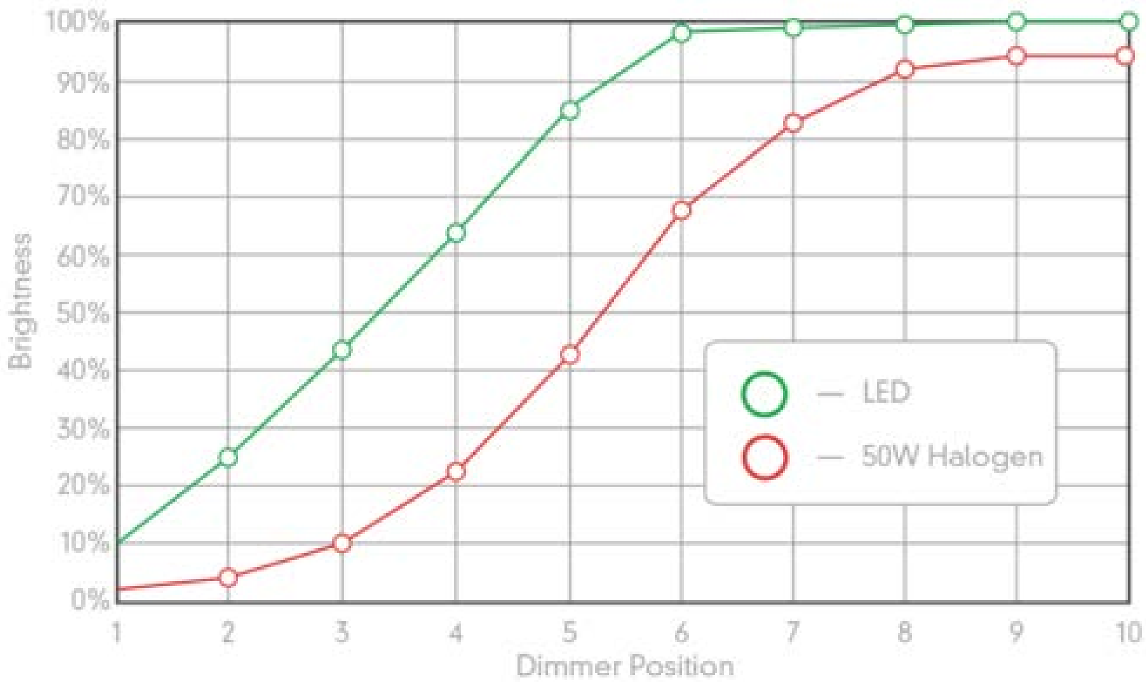
To mitigate the likelihood of flicker some manufacturers are switching to drivers with digital control. Digital drivers are capable of detecting the dimmer type and phase to dynamically adjust driver characteristics accordingly. This prevents flicker, increases the amount of LED load able to be placed on a driver and enables the full dimming range (0-100%).

Dimming Curve Differences

When installing LED lamps into legacy home automation systems, pre-set scenes will require adjustments due to LED lamps exhibiting a differed dimming curve. In this case, the most common issue experienced is that the new LED is unable to match the same minimum or maximum dimming level as the previous fitting. This is due to the firing angles of the dimmer being within the firing angles of the power supply. If the firing angles of the dimmer are outside the firing angles of the power supply, dead travel will be experienced on the circuit (Thornton. T, 2013).

The figure below shows a dimming curve example of a LED that exhibits dead travel.



It should also be noted that if LEDs with different transformers are mixed, the dimming of all lights may not track together.

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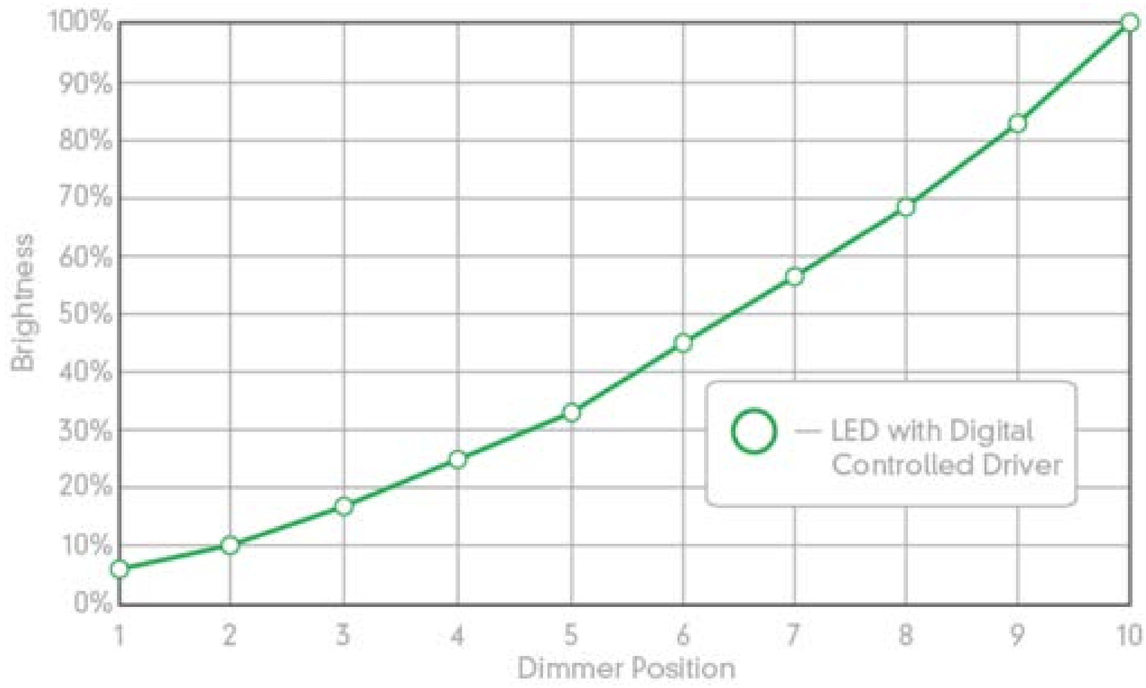


Failure Rate of Drivers on Dimmers and Home Automation Systems

The driver is the most common point of failure for any LED light. A survey of 5,400 LED luminaires showed that approximately 59% of all catastrophic failures are due to the LED driver (Almeida, 2015). This is mostly due to the driver containing components with an incompatible lifespan. Cheap electrolytic components allow for a low-cost driver with comparable dimming performances, but with drastically reduced lifespans of approximately 10,000 hours. Complex multistage drivers with digital control offer better dimming performance due to the use of components with higher heat resistance, longer lifespan and non short-circuit failure modes. When designed correctly, LED drivers should have a lifespan of over 100,000 hours (Almeida, 2015).

Audible noise should not be produced on electronic circuits. Drivers and dimmers may produce noise if its components are working outside their nominal range. Whilst audible noise created from the vibration of components poses no immediate risk of failure, it is a sign of incompatibility between the driver and dimmer, and over a period of time will eventually lead to failure before the product's estimated life span (Kiwi Electronics, 2007).

Over the past decade, the Australian lighting market has seen an influx of LEDs direct from China for residential and commercial new builds. In addition to the fact that the majority of these lights are incompatible with triac dimming systems, failure rates are high because the drivers because the drivers have not been designed to handle Australia's unstable power supply. Currently, the general failure rate of LED drivers is 0.02% (40/2000).

Brightgreen Gen3 Drivers

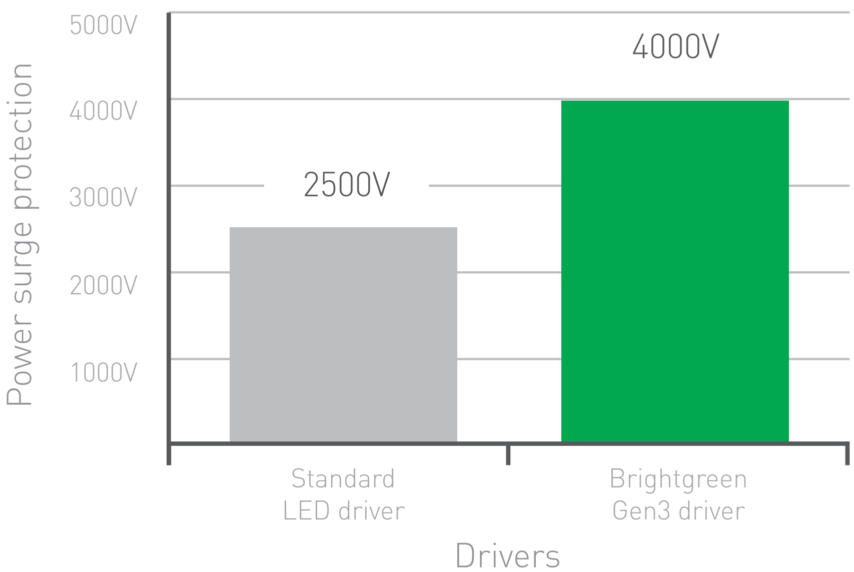
Through Brightgreen's custom driver design and quality control methods, a driver failure rate of 0.0005% (1/2000) has been achieved, establishing Brightgreen as a market leader in both quality and LED dimming performance.

The new Gen3 driver has been designed and tested to work on the majority of leading, trailing and universal dimmers available in Australia. Through utilising digital control IC in multiple stage topologies, the driver removes the low frequency component of AV voltage in power mains supply. This improves dimming performance, eliminating troubleshooting due to flicker and diver failure.

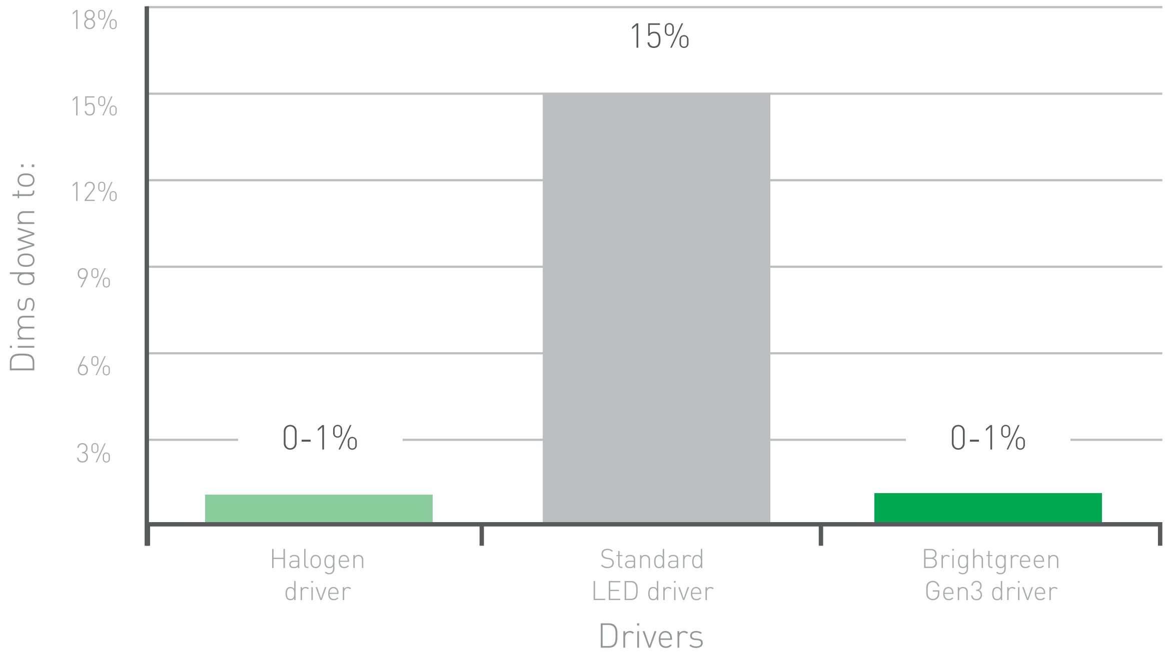
The Brightgreen Gen3 driver has specifically designed for compatibility with all major home automation system to ensure smooth, flicker-free performance and longevity.

A common cause of LED driver failure, particularly in Australia, is that the majority of imparted LEDs are designed for more stable power supplies.

Gen3 drivers offer power surge protection and are designed to handle spikes within the Australian power mains.



The Gen3 driver has been engineered to out perform other low-energy LED technologies; and offer the same deep dimming provided by less efficient, outdated halogens.



Bibliography

Almeida. P, Camponogara. D, Braga. H, Dalla Costa. M, Alonso. J, (2015) Matching LED and Driver Life Spans, IEEE

Biery. E, (2014), Challenges of Dimming LED Loads on ELV and MLV Transformers, Lutron

Brodrick. J, (2012), The LED Dimming Dilemma, Electrical Construction & Maintanence, http://ecmweb.com/lighting-amp-control/led-dimming-dilemma

Dimming Electronic Transformers Explained, (2007), KIWI Electronics

LED Dimming Control and Load Compatibility, (2012), Philips
http://www.lighting.philips.com/pwc_li/main/subsites/dynalite/library_support/assets/led_lamp_compatibility.pdf

Liao. A, (2014), LEDs: A Deep Dive in Dimming,
http://www.archlighting.com/technology/leds-a-deep-dive-in-dimming_o

Lin. M and Chen. C, (2012), IEEE, VOL.27, No.11

Poplawski. M, (2012), LED Dimming: What you need to know, DOE

Thornton. T, (2013), Improve phase-cut dimming performance in LED luminaires, LED Magazine,
http://www.ledsmagazine.com/articles/print/volume-10/issue-12/features/improve-phase-cut-dimming-performance-in-led-luminaires-magazine.html

Weir. B, (2012), The Subtle Circuitry Behind LED Lighting, IEEE