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White paper

Flicker performance in LED lighting

Introduction

A major issue plaguing the LED lighting industry today is flicker, which is defined as “variations of luminance in time” in *The Lighting Handbook,* published by the Illuminating Engineering Society of North America (IESNA). Flicker may be inherent to the design of a luminaire but can also be introduced by external factors. This white paper focuses on (undesirable) flicker that may be introduced when a luminaire is dimmed; flicker generated from line noise or transients is not addressed. Especially in LED applications, the choice of an LED driver can have a direct impact on the flicker performance of a luminaire.

Figure 1 – Flicker made visible with RouLED demo

There are two primary types of flicker: visible and invisible. Visible flicker is consciously observed by humans and is typically considered objectionable except in some special applications like stroboscopic lights. Invisible flicker is not consciously perceived but may still have biological or even health effects on humans, including:

- Neurological problems, including epileptic seizure
- Headaches, fatigue, blurred vision, eyestrain and migraines
- Increased autistic behaviours, especially in children

Flicker can also cause problems that are not health related such as:

- Reduced visual task performance
- Apparent slowing or stopping of motion (stroboscopic effect)
- Distraction
- Unstable light output in video applications

In the past, when fluorescent lights used inductive ballasts, flicker was also an issue. This was solved with the introduction of electronic ballasts. In addition to that, fluorescent and incandescent lamps are slow by nature – when the lamp is switched off it takes a while before it stops glowing. Due to this slow nature, flicker is less apparent. LEDs however, are fast: an LED stops emitting light virtually immediately after the current is switched off. The same is true for the traditional way of dimming of LEDs with *pulse width modulation* or PWM, as PWM essentially switches the current *on* and *off* very fast.

Flicker percentage and flicker frequency

Invisible flicker is primarily generated by a dimming method called PWM (*pulse width modulation*). PWM cycles the LED from maximum electric current to zero current and repeats it at a fixed rate. This PWM signal is generated by the LED driver.

The amount of flicker can be quantified with a metric called flicker percentage, which is a measure for the amount of flicker at a given frequency – a smaller flicker percentage means less flicker.

Flicker percentage or %flicker can be calculated with the following formula:

$$\%flicker = 100 \cdot \frac{A - B}{A + B}$$

where *A* represents maximum light output and *B* minimum light output; see figure 2.

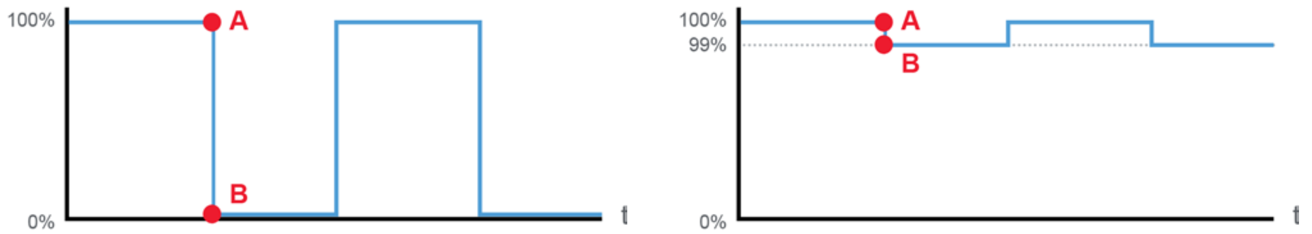

Figure 2 – %Flicker

Note that low %flicker alone does not guarantee high quality lighting. Flicker frequency also plays an important role in lighting quality. Flicker frequency is the rate at which the light output fluctuates in time and is related to the speed at which the PWM takes place. In figure 3 two different frequencies are shown. The left graph shows a low frequency of 100 Hz, so the light cycles between on and off 100 times per second. The right graph shows a higher frequency of 1250 Hz where the light cycles between on and off 1250 times per second.

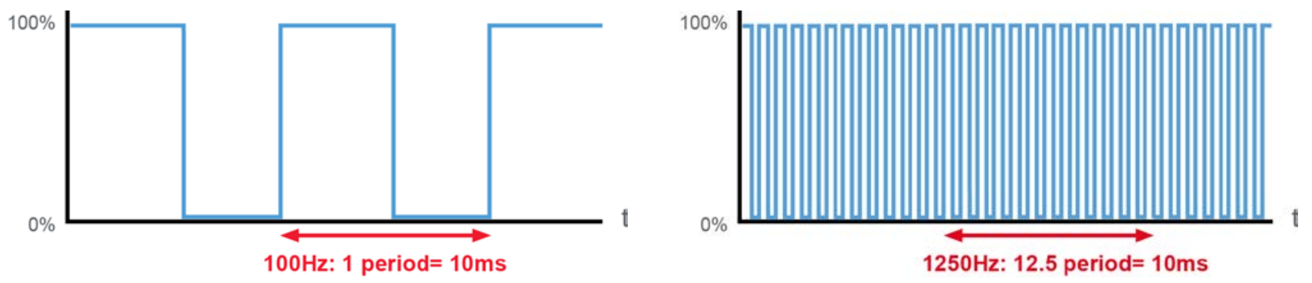

Figure 3 – Frequency

IEEE P1789 standard

eldoLED believes the IEEE P1789 standard and the diagram associated with it (figure 4) are great tools to compare drivers with regard to flicker. We suggest the following recommended practice to the specification community for specifying LED drivers:

> "*LED drivers shall conform to IEEE P1789 standards. Alternatively, manufacturers must demonstrate conformance with product literature and testing which demonstrates this performance. Systems that do not meet IEEE P1789 will not be considered.*"

eldoLED communicates measurements on the amount of flicker with its drivers. These measurements are taken according to '*IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers*' (IEEE P1789).

Figure 4 shows %flicker vs. flicker frequency of the eldoLED SOLOdrive 360/A. At different dimming levels all frequency components in the light output are measured. These frequency components are plotted in a graph (the dots in figure 4). In the green area, there is no observable effect. In the yellow area there is low risk. For instance, the red highlighted dot in figure 4 indicates a 300 Hz frequency in the measured light with a %flicker of 2. Since this frequency component is in the green area of the graph there will be no observable effect. All other measured components – the blue dots – are also in the green area and they too will have no observable effect.

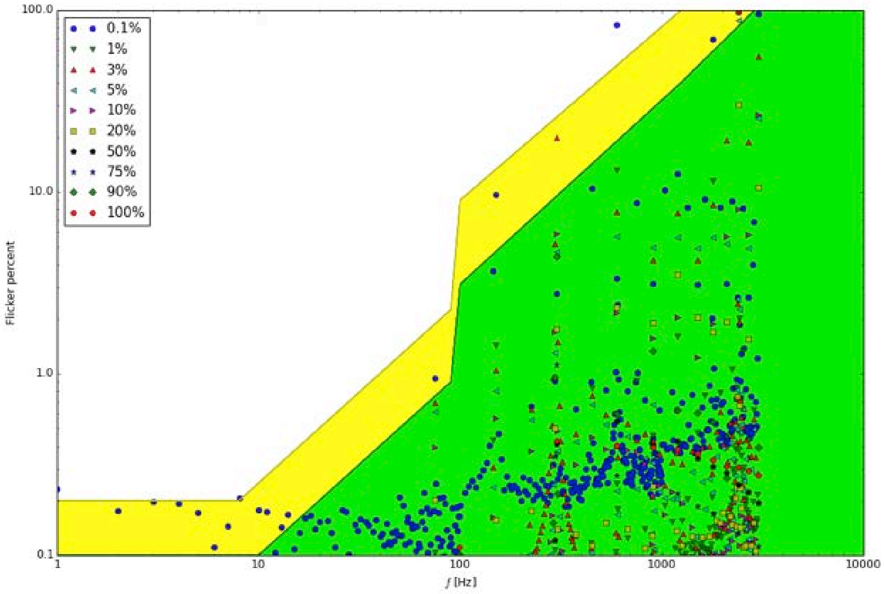

Figure 4 – %flicker vs. Flicker frequency

Applications where flicker can be an issue

Offices *Industrial spaces* *Hospitals* *Classrooms*

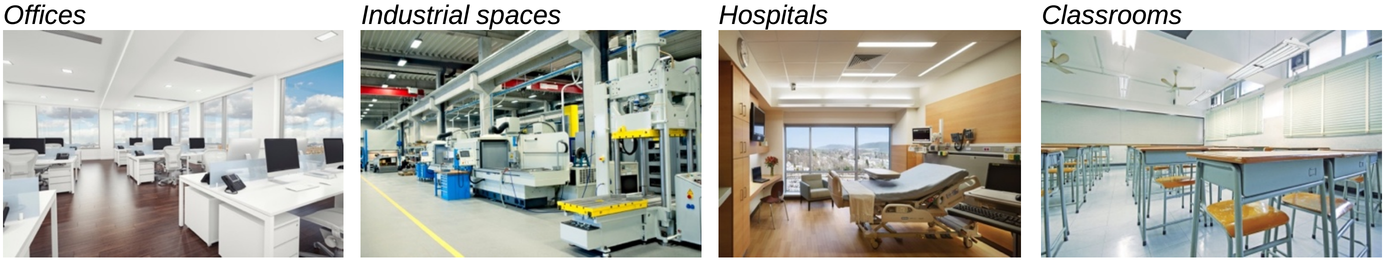

Figure 5 – Applications where flicker can be an issue

Above are some examples of applications where flicker can cause problems or can be inconvenient. In environments where people are exposed to light during several hours or even days, flicker can cause health issues such as those mentioned in the introduction on page 1. Especially children can be more susceptible to flicker induced effects. And in industrial environments, flicker can cause performance issues. For instance, a lathe or a table saw in a workshop can appear to rotate slowly or even stand still.

Flicker for safety and flicker for fun

Flicker is not always an issue and sometimes flicker is even used on purpose. Visible flicker can be used for attention or fun instead of being prevented. Cyclists and runners sometimes use a flashing rear light. And in discotheques flicker is used for the stroboscopic effect where dancers appear to move slowly.

Figure 6 – Flicker for safety and flicker for fun

Hybrid HydraDrive

An LED system is made up of a controller or dimmer, an LED driver and a luminaire with LEDs. Figure 7 shows a typical LED system. To achieve natural control of the LED and no objectionable flicker, it is important to ensure that these three components are compatible and especially that the right LED driver is selected.

Figure 7 – LED system

Choosing a driver with the right dimming method can help to minimise flicker and to reduce the risk of adverse health effects associated with LED dimming.

Figure 8 shows three dimming methods:

- Pulse width modulation (PWM) which switches the LED on and off repeatedly in a high frequency
- Constant current reduction (CCR): the LED is dimmed by reducing the electric current
- eldoLED's Hybrid HydraDrive: uses a reduced current in combination with a variable frequency to achieve natural dimming to dark and to optimise flicker performance.

Table 1 shows the benefits and limitations of these three dimming methods. As you can see, all three methods have their advantages, but only Hybrid HydraDrive can smoothly dim to dark without undesirable flicker. Hybrid HydraDrive reduces %flicker and uses a high and variable modulation frequency to ensure that our drivers operate in the green or yellow area in figure 4. eldoLED drivers support a variety of controls: 0–10 V / 1–10 V, DALI and DMX/RDM.

Figure 8 – LED dimming methods

Pulse Width Modulation	Constant Current Reduction	Hybrid HydraDrive
× Potentially undesirable flicker, depending on frequency	✓ No flicker	✓ No health issues caused by flicker
✓ Good dimming regulations at low levels	× Poor dimming regulation at deep dimming levels	✓ Best dimming regulation all the way to 0.1%

Table 1 – Benefits and limitations of various dimming methods

Recommendations

Choose the right driver: dimming is controlled by the driver, therefore choosing the right driver is crucial to get the required light effect. Drivers that use *pulse width modulation* potentially can introduce undesirable flicker. Drivers using *constant current reduction* will not introduce flicker but have poor dimming regulation at deep dimming levels.

Specifiers:

- Evaluate products in person and learn to test for flicker.
- Only choose LED drivers that conform to IEEE P1789 standard.
- Alternatively, ask manufacturers to:
    - demonstrate conformance with product literature;
    - present tests that demonstrate driver performance.

Manufacturers:

- Be proactive and test for flicker – test over the full dimming range in 1% increments.
- Demand drivers that produce less flicker, and that modulate current at high frequencies.
- Avoid PWM dimming unless combined with other techniques like reducing current.
- Publish flicker metrics including %flicker, modulation frequencies and the IEEE P1789 graph.

References

- The Lighting Handbook – Illuminating Engineering Society of North America (IESNA)
- IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers (IEEE P1789) – IEEE
- 2011 IES flicker paper – M. Poplawski and N. Miller
- FLICKER: Understanding the New IEEE Recommended Practice (LightFair 2015) – N. Miller and B. Lehman

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