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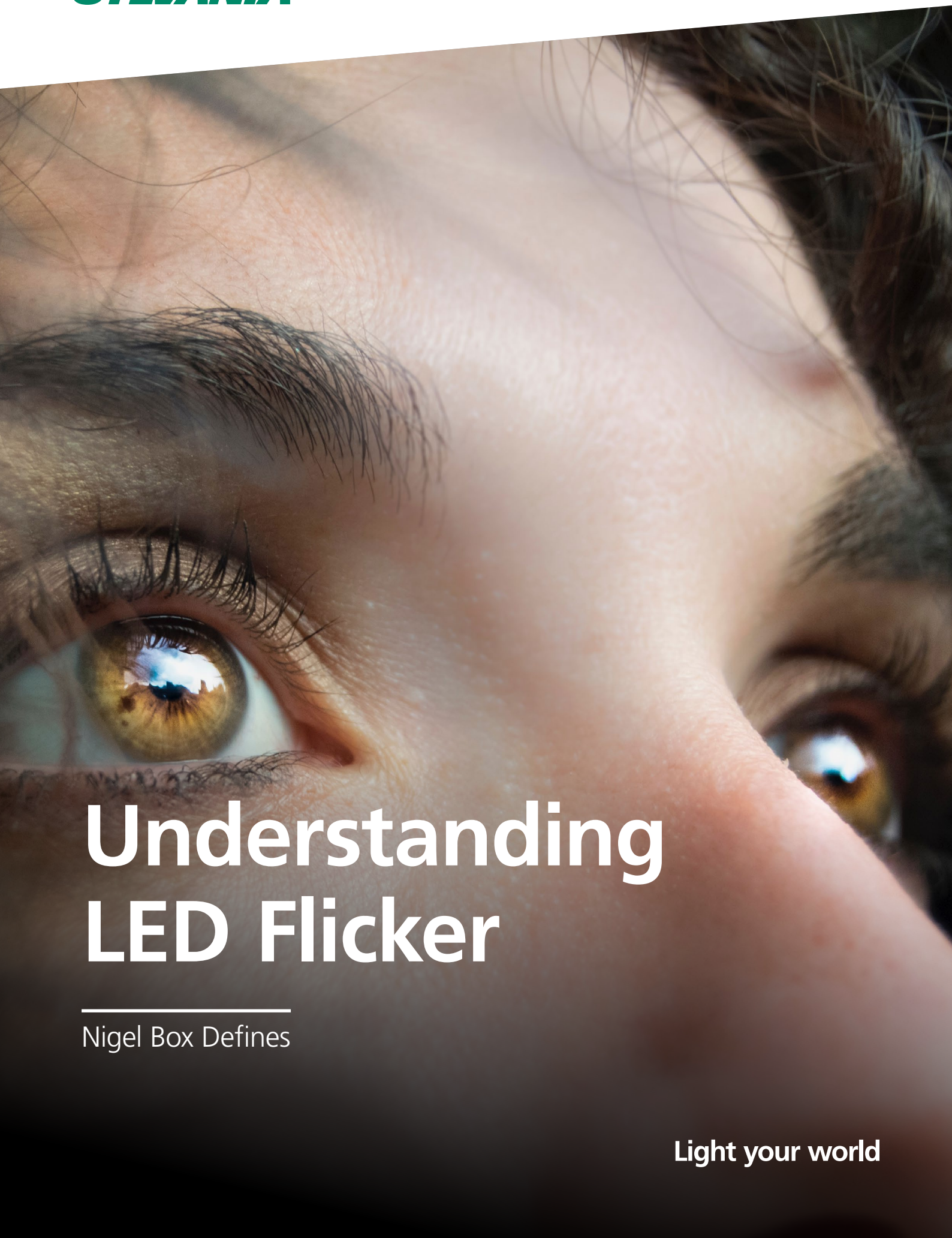

Understanding LED Flicker

Nigel Box Defines

Light your world

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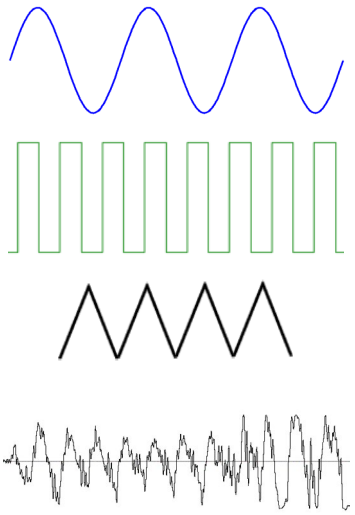
What is Optical Flicker?

Official definition:

"Variations in luminance over time"



It generally refers to direct flicker from a light source surface

It assumes a static observer

Perception and acceptability depend on frequency and waveform

There is low human perceptibility above c.100 Hz

It does not apply to intentional modulation (flashing indicators, beacons, etc)

Unofficial definition:

"Anything unpleasant that is related to variations in luminance over time"

It could refer to:

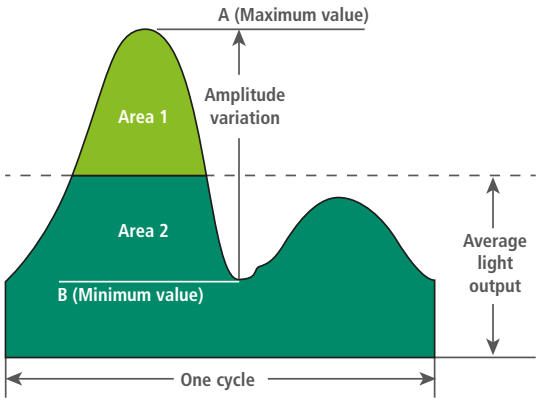
+ True light source flicker
+ Stroboscopic effects (indirectly perceived flicker)
+ Temporal lighting artefacts (undesired changes in visual perception induced by a light stimulus whose luminance or spectral distribution fluctuates with time, for an observer in a certain environment)

Metrics

Percent Flicker (Modulation)

This metric is only focused on the relative change in the modulation.

Percent flicker = $100\% * \frac{\text{Maximum} - \text{Minimum}}{\text{Maximum} + \text{Minimum}} = 100\% * \frac{A - B}{A + B}$



+ A product that drops to zero output at any point in the waveform has 100% flicker
+ Ignores frequency and waveform
+ Commonly used

Flicker Index

This metric considers waveform and is based upon the area above and below the average light output.

Percent flicker = $\frac{Area\ 1}{Area\ 1 + Area\ 2}$

+ This metric still ignores the influence of frequency
+ It is not so easy to calculate
+ Is not so commonly used

Causes of Optical Flicker

The main causes are electrical power variations.

+ Input voltage variations will cause LEDs to draw more or less current
+ These variations cause the LEDs to become more or less bright
+ It is nearly impossible to remove all voltage variations
+ With LEDs, the relationship between their brightness and the voltage or current is not entirely linear, but it is linked (see later).

Electrical distortion in →  → **Optical distortion out** → 

Why is this a problem once more?

A long time ago, fluorescent lamp circuits with magnetic ballasts had around 100Hz or 120Hz light output frequency, which could be perceived by humans.

Then we switched to the use of high frequency electronic ballasts and the problem disappeared.

LEDs use power supplies that convert AC to DC.

+ High quality drivers tend to be larger, more complex and more costly
+ The trend has been towards smaller, simpler drivers in order to reduce cost and size
+ What is the optimum solution?

Perception

Viewing angle: Centre-of-field vision can be different from peripheral vision

Moving objects: Stroboscopic effects may be perceived.
Speed of eye movement may have an influence.

Individual sensitivity: Some people are more sensitive to flicker than others

Light sources

Line (mains) frequency:

+ Can add a 100Hz or 120Hz component
+ This is a low enough frequency to cause problems

Light source response time:

+ Incandescent sources have a slow response time
+ LEDs have a fast response time

Phosphor persistency:

+ Tends to smooth out flicker somewhat

Power supply (driver) design

Drivers with DC output:

+ Increasing the power smoothing reduces flicker
+ Increases driver complexity, size and cost

AC drivers:

+ Many AC drivers have suffered from little or no power smoothing, leading to substantial flicker.
+ Newer designs improve on this and flicker is reduced, but still not as low as a quality DC driver.

PWM (pulse width modulation) dimmable drivers:

+ The waveform tends to introduce flicker, but this can be taken out of the range of human and device* detection by choosing a sufficiently high modulation frequency.
(*Smart phone cameras, videos, CCTV, etc)

Standards for Maximum Optical Flicker?

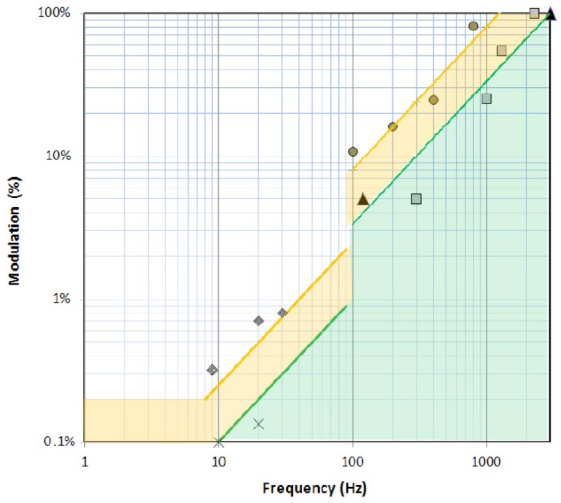
Aside from in California, there are no specific limits set on optical flicker, so far.

However, there are some loose definitions in the market which describe 'low flicker' as less than 30% flicker, some adding that this is at frequencies below 200Hz. However, such levels of flicker are perceptible to humans and definitely to electronic devices such as smart phones and video cameras.

IEEE Std 1789-2015

"IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers"

Diagram shows: Low-Risk Level and no observable effect level (NOEL)



+ Modulation (%) is defined as the difference between maximum and minimum luminance divided by the sum of maximum and minimum luminance (multiplied by 100)
+ The no-effect region is shown in green and the low-risk region includes any of the shaded region (green or orange).
+ The upper limit of the low-risk region is the line Modulation (%) < 0.08×Frequency and corresponds to a factor of about 2.5 above the NOEL. Below 90 Hz, the low-risk region satisfies Modulation (%) < 0.025×Frequency and the NOEL can be taken a factor of 2.5 below that to become Modulation (%) < 0.01×Frequency. The conservativeness of the regions may be determined by further research, but based on the available data, the shaded regions contain the low-risk region.

What can we do, practically?

+ We can measure optical flicker
+ We can measure LED driver output current ripple

The two are linked to a certain degree.

A low-ripple driver will produce low optical flicker.

Experience tells us that we might expect a slightly lower flicker percentage than the declared driver output current ripple percentage, below 120Hz.

Setting basic standards

As a general 'rule of thumb', it is recommended to specify LED drivers with **<5%** output current ripple, for specification-grade luminaires.

These products may be considered 'flicker-free' or having 'very low flicker'.

This is considered a good solution for the majority of indoor applications, including retail, office and education. For specific applications, where TV is used, then even lower ripple drivers can be specified on a project-by-project basis.

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