LED-Drivers and Quality of Light

LED Event 2016 | 540L | PB

Light is OSRAM

OSRAM

Agenda
Light Modulation and Relevant Frequency Bands

1. Introduction: Temporal Light Artefacts (TLA)
2. Visible Light Flicker (0 Hz...80 Hz) 
3. Stroboscopic Effects (80 Hz….2 kHz) 
4. Camera Applications (25 Hz....10 kHz) 
5. Barcode Scanners (10 kHz….100 kHz) 

Temporal Light Artefacts (TLA)

Formally, TLAs are described as undesired effects in the visual perception of an observer within an environment.

The term ‘flicker’ refers to unacceptable light variation that is directly perceived by an average (or normal) observer.

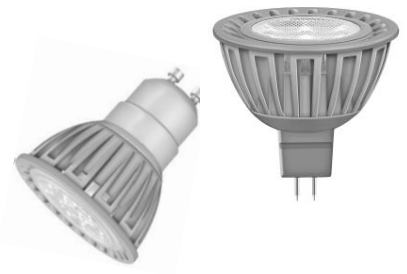
‘Stroboscopic effect’ is an effect which may become visible for an average observer when a moving or rotating object is illuminated.

Lighting products that exhibit flicker or stroboscopic effect are considered not good quality lighting.

Temporal Light Artefacts
Flicker - Terminology

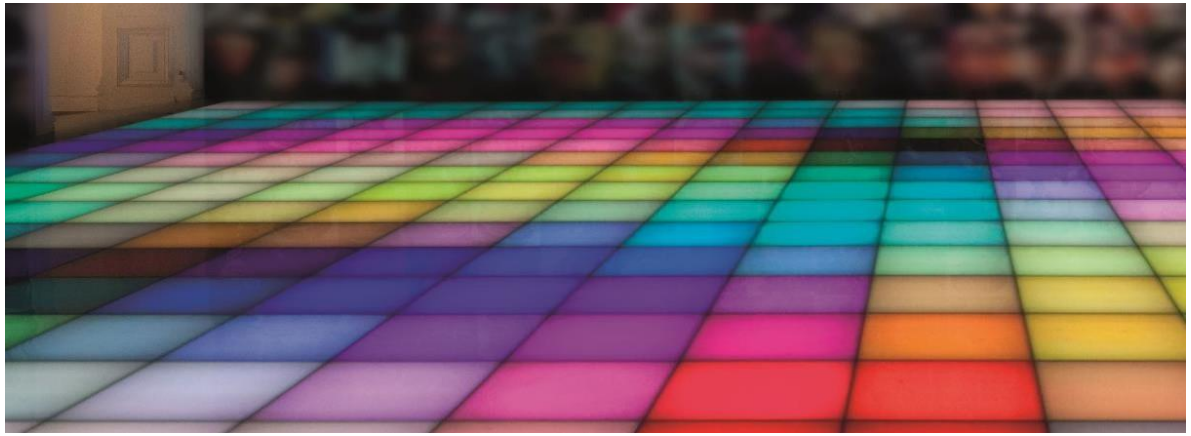
Flicker, flutter, shimmer

- (Repetitive) change in magnitude over time, or modulation, of the luminous flux of a light source
- Light source modulation



Visible, invisible, perceptible, detectable (sensation)

- Sensation: External conditions are detected; neurons respond
- Visible flicker = Luminous modulation is sensed and perceived
- Invisible flicker = Luminous modulation is sensed, but not perceived



Flicker - Terminology

Stroboscopic vs. Phantom array effects

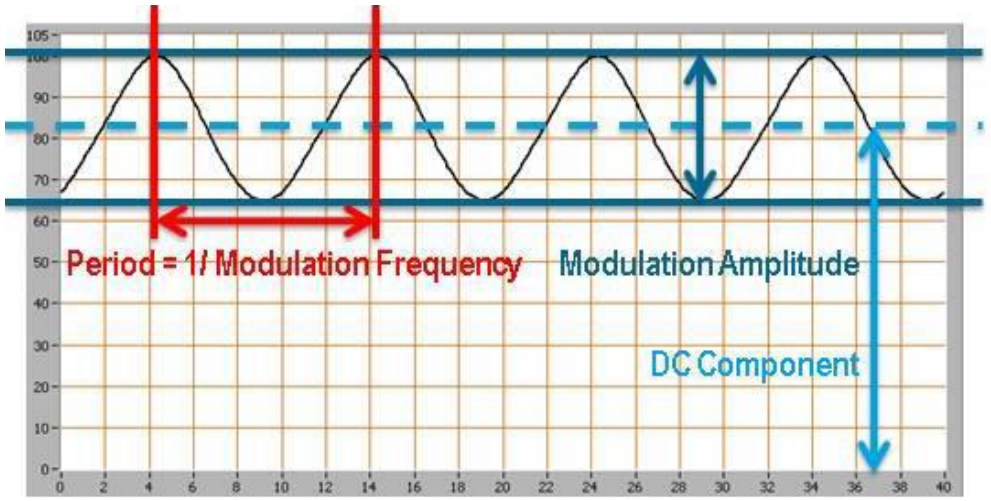
- Stroboscopic effect: Luminous flux modulation made perceptible by the motion of objects, when the observer's eye is still

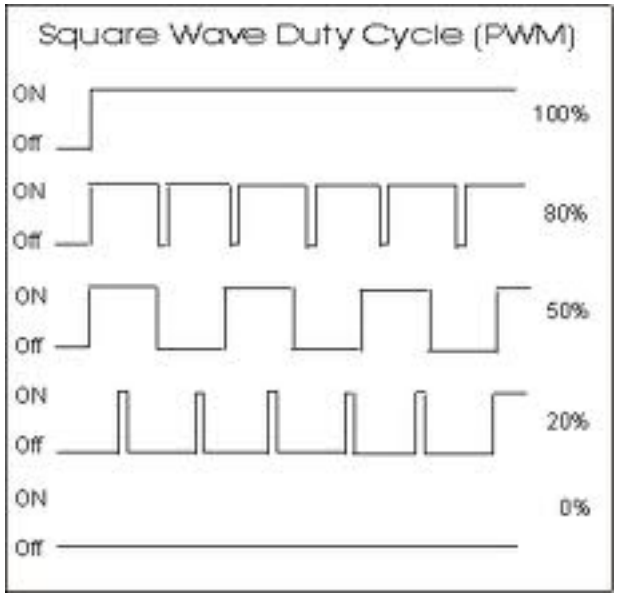
- Phantom array effect: Luminous flux modulation made perceptible by the motion of the observer's eye, when the light source is still

Flicker Factors

Flicker factors for both Visible and Invisible Flicker

- Modulation Frequency
- Modulation Amplitude
- DC Component
- Duty Cycle





What determines flicker in LED sources?

- LED flicker and dimming performance depends on (**quality of**) the LED driver
- LED flicker is not only depending from the LED driver (combination driver-module)
- Dimmers and other electronics can induce or increase flicker

Products more likely to flicker:

- AC LEDs
- DC LEDs with **simple / inexpensive** drivers (e.g., inadequate capacitors)
- Integral lamp LEDs on some electronic transformers
- LEDs dimmed with phase cut dimmers (triac, e.g.)
- LEDs with **Pulse Width Modulation (PWM) drivers**

Application:
Where Flicker Matters

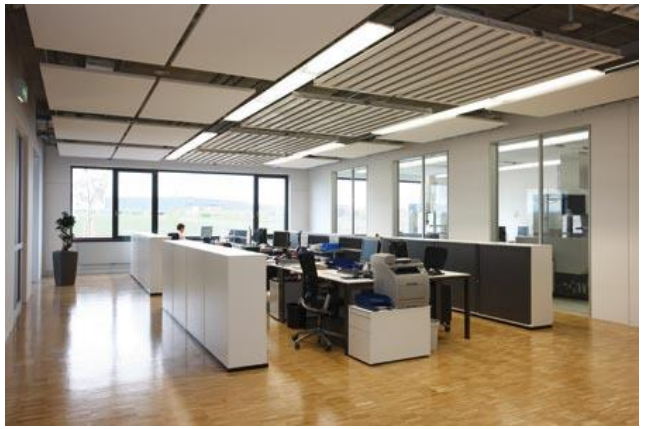
Task lighting

Hospitals / Clinics

Classroom lighting

Industrial spaces

General lighting



Office lighting

Application:
Where flicker is less important

Roadways parking lots

Accent lighting on Artwork

Very low intensity holiday lighting

Sports and industrial lighting on 3-phase electrical system lighting

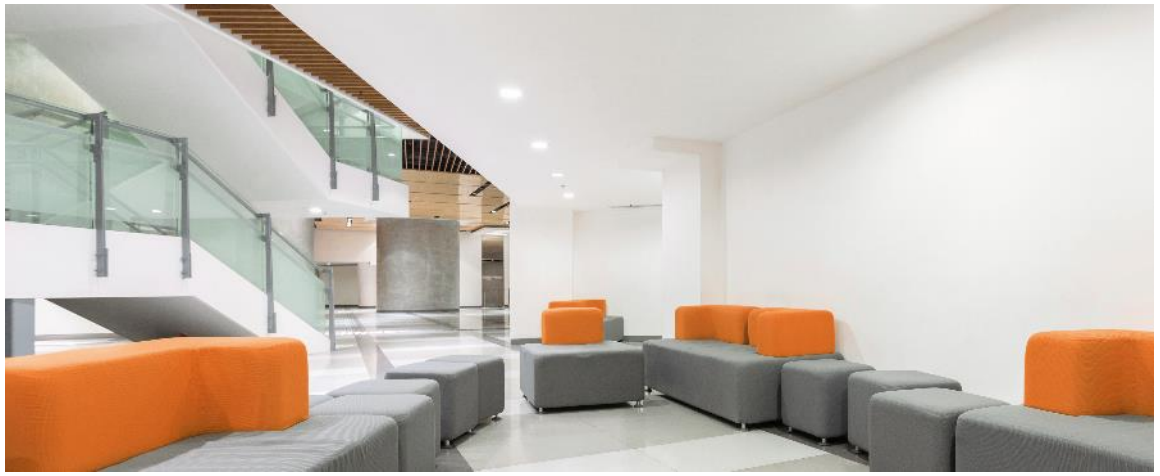
Application:
Where flicker might be an advantage

Warning lights

Discotheques

Use for very short duration recommended
Avoid the epilepsy frequencies

Light Modulation and Relevant Frequency Bands



Visible Light Flicker (0 Hz…80 Hz)

The OSRAM used measurement method (Kelly-metric <0.003) and qualification for visible light flicker is equivalent and even more strict compared to a $\mathbf{P_{st}^{LM}}$ flicker-measurement-metric acc. DTR – IEC/TR 61547-1

Stroboscopic Effects (80 Hz…2 kHz)

The SVM – Method (Stroboscopic Value Measurement) and the related limits are not finally defined. Therefore the low frequency measurement method (100 Hz) is still the dominant criteria to rate stroboscopic effects.

Light Modulation and Relevant Frequency Bands

Cameras (25 Hz...10 kHz)

Modern cameras (like in mobile phones or semi professional surveillance cameras) use exposure times that could lead to brightness modulation in the video streams or pictures in case of certain light modulation in the range of 25 Hz to 10 kHz.

Barcode Scanners (10 kHz…100 kHz)

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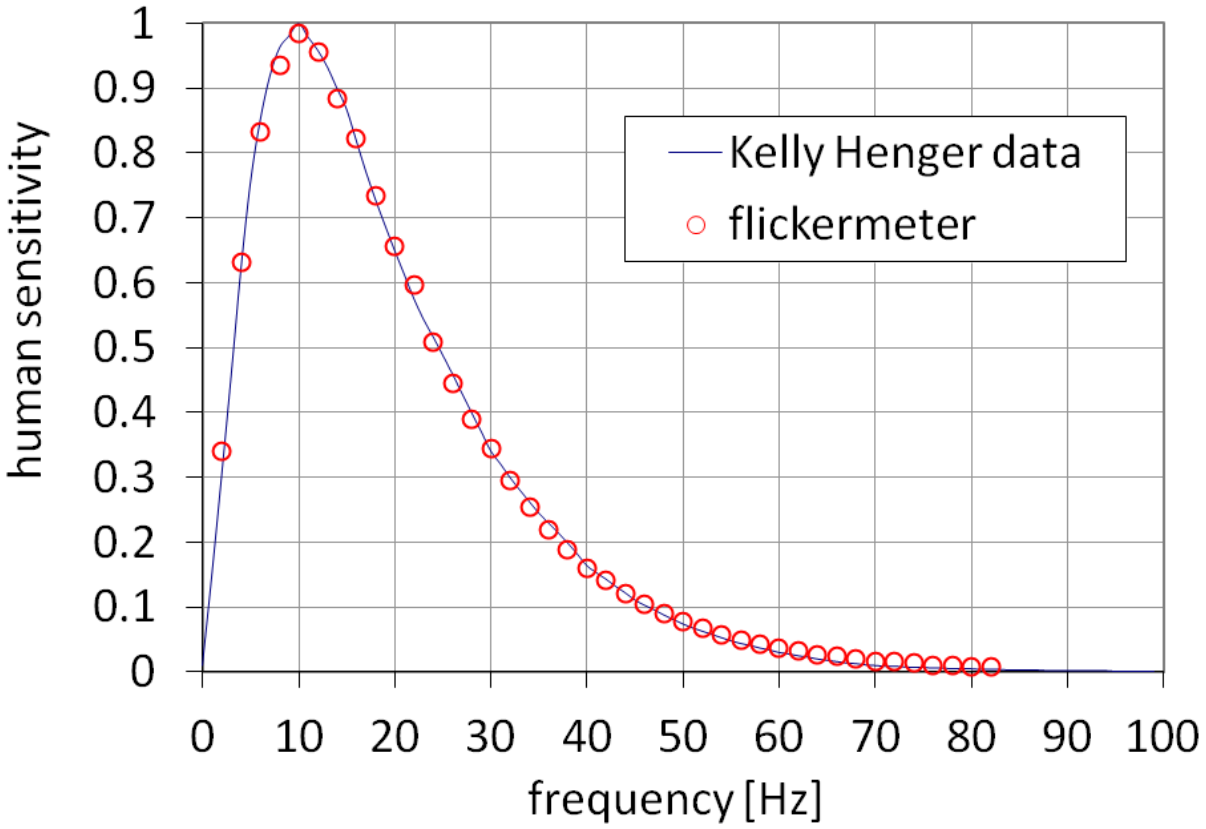
Visible Light Flicker

Measurement according to Kelly-Metric (0…80 Hz)



The perceived **visible light flicker** is the accumulation of **spectrally resolved Light Levels**, weighted by **Kernel Function**

$$FV[S] = \frac{1}{A}\sqrt{\sum_k \mathcal{K}^2(f_k)\ b_{f_k}^2}$$

The visible light flicker (**Kelly-metric <0.003**) is equivalent and even more strict compared to a $\mathbf{P_{st}^{LM}}$ flicker-measurement-metric acc. DTR – IEC/TR 61547-1

Threshold Level *)
$FV_{Th} \leq 0.003 = 0.3\%$

*) suggested in literature: U. Henger: Investigations for the development of measurement equipment to determine the flicker factor.
7 th Lichttechn. Gemeinschaftstag. Pp. 251-256 Baden b. Wien, May 13-16, 1986

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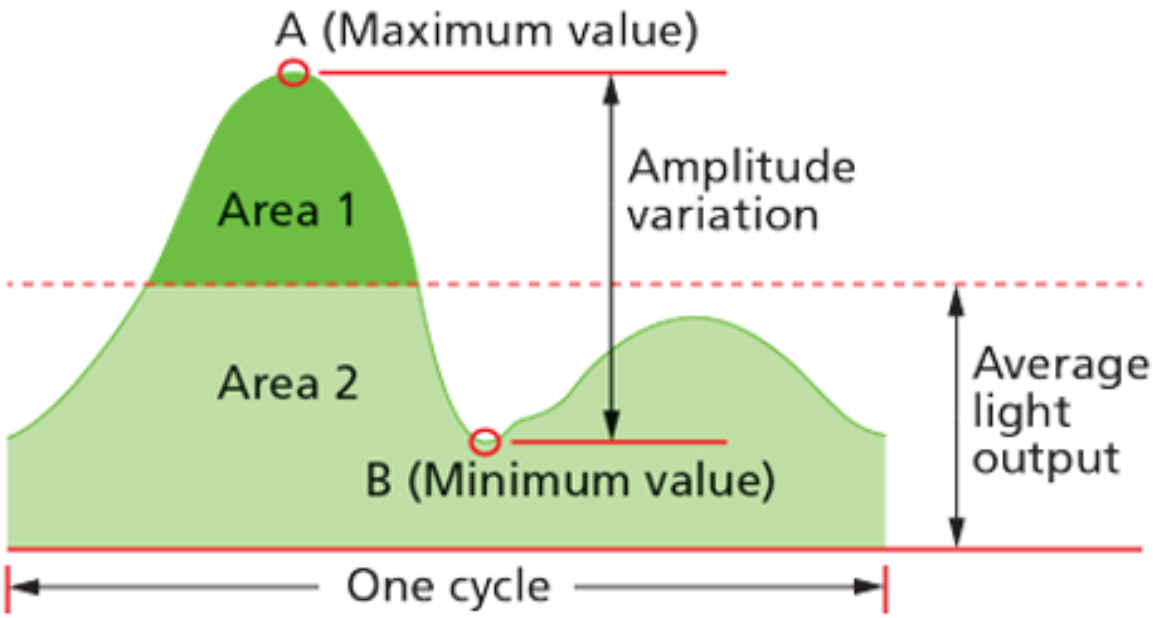
Stroboscopic Effects

Measurement for Light Modulation/Ripple current



The **most common** definition for the light modulation is:

$$\text{Light modulation} = \frac{\phi\ \text{max} - \phi\ \text{min}}{\phi\ \text{max} + \phi\ \text{min}}$$

(where Φ is luminous flux)

As well called MD:
Modulation **D**epth = **Percent Flicker**

Modulation depth sometimes called modulation

Stroboscopic Effects

Modulation (100 Hz) of different electronic driver technologies

Fluorescent lamp ECG: QUICKTRONIC		LED driver: OPTOTRONIC	
QTI DALI/QTI…DIM	< 10%	OTi DALI	1…3% SELV, 1…10% non-isolated
QTP OPTIMAL	< 10%	OTi	< 10%
QT FIT	< 10%	OT FIT	5%
Magnetic gear	25…35%	OTe	20…35%

*Strongly depends on the LED module

In practice, many drivers **deliver a high content of 100-Hz modulation**. The table shows a comparison of traditional control gears with the new LED drivers.

Compared to traditional fluorescent light sources, **LEDs instantaneously translate their operating current** into light, **without much smoothing effects**. Already minor imperfections of the driver can lead to a low quality of light.

The light modulation depth can be measured by measuring of the current modulation depth.

Ripple current ~ light modulation

Stroboscopic Effects

Measurement for Light Modulation/Ripple current

The light modulation depth is equivalent (nearly the same value) to the modulation depth of the driver output current.

$$\text{Light modulation} = \frac{\phi\,\text{max} - \phi\,\text{min}}{\phi\,\text{max} + \phi\,\text{min}} \quad \Rightarrow \quad \text{LF ripple current} = \frac{I_{LFmax} - I_{LFmin}}{I_{LFmax} + I_{LFmin}}$$

(where Φ is luminous flux)

LF = Low Frequency (<2 kHz)

As well called MD: Modulation **D**epth = **Percent Flicker**

In general, the relevance of light modulation decreases towards higher frequencies.
Frequencies **above 2.0 kHz** are usually regarded as **uncritical in typical lighting applications, while 100 Hz are of high importance**.

Currently, various organizations such as CIE, IEEE or NEMA are discussing very diverse metrics (P_{st}^{LM}, SVM, Flicker index, MD). **Current discussions in CIE, ZVEI and Lighting Europe indicate a preference for the P_{st}^{LM} and SVM metrics**.

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Camera – Application (smartphone and surveillance cameras)

CCD and CMOS sensors with rolling shutter or global shutter technology

- Rolling frame technology is key to image distortion, used in most common applications
- Affected frequency band **25 Hz … 10 kHz**
- Severity of image distortion depends on illumination, camera settings, scene and viewer awareness

Limit for modulation depends also on illumination, camera settings, scene and viewer awareness

OSRAM-recommendation*: MD < 10 %
Camera proof / Camera-friendly

10 % modulation depth

20 % modulation depth

* For indoor application

Impact on human beings: Low light modulation has a positive impact and influence on human well being

Using ECGs and LED-Drivers with **Low light modulation has an positive impact on the working environment**. In general, heavy flickering at low frequencies should be avoided. It is known that a small subgroup of epilepsy patients is light-sensitive and reacts to flickering light. By increasing the frequency of light modulation, the risk of these reactions decreases dramatically. According to scientific publications, **above 70 Hz, no reaction of epilepsy patients to flicker in general lighting application has been noted.**

Even at **frequencies up to 400 Hz** negative effects on human well being can not be fully ruled out.

In this frequency range scientific experts suggest to minimize light modulation depths.

No study has shown **adverse effects** at modulation frequencies **above 400 Hz**.

Hybrid-Dimming in office applications (AM/PWM (460 Hz) - Dimming)

Office Application with daylight

	LED-Light		
	AM-Dimming	**PWM-Dimming**	**Dimming**
Dimming level	**> 20 %** AM-Dimming	**< 20 %** PWM (460 Hz)	**1 % …5 %** PWM (460 Hz)
Driver Modulation	5-10 %	100%	100%
Daylight Share	> 2%	> 80%	99%
System Modulation	**5-10 %**	**20 %**	**< 5 %**

Benefit:
Stable color quality dimming with moderate light modulation

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Thank you.

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