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1. About this document

Temporal Light Artifacts (TLA) is a term for undesired light artefacts such as flicker or stroboscopic effects. TLA are physically caused and occur in all illuminants to some extent.

The measurement of TLA is difficult. But new, improved measurement methods (PstLM and SVM metric) now make it possible to make comprehensible and comparable statements about the light quality of individual devices.

This text explains the causes of TLA and provides an overview of the TLA measurement methods used at TRIDONIC.

2. What are TLA?

The umbrella organisation of the European lighting industry defines in its position paper "Position Paper on Flicker and Stroboscopic Effect" as follows:

"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."

Simply put, TLA are unwanted brightness fluctuations of an electric illuminant.

3. How do TLA arise?

TLA are no product-specific problem. They always arise when a luminaire is operated with mains voltage (AC).

Different light sources reproduce the fluctuations of the luminous flux with different intensity. The reason for this are differences in design and construction.

- _ Since incandescent light bulbs are directly operated via mains voltage and without an upstream control gear, fluctuations of luminous flux occur with double mains frequency.
However, these fluctuations are mitigated because the filament has an inherent inertance. Because of this, the filament keeps glowing at the moment of the zero-crossing of the mains voltage.
- _ LEDs emit light precisely following the voltage. But LEDs always have an upstream control gear which provides DC with a superimposed alternating component of both low frequency (twice the mains frequency) and high-frequency (operating frequency of the control gear). The low frequency content is relevant for TLA.

4. What are the negative consequences of TLA?

TLA have different negative consequences:

- _ Flicker in the visible range:
Visible TLA are perceived as disturbing.
- _ Impaired health:
TLA can incite stress symptoms. Headaches or fatigue can occur in rare cases in humans. In some cases, TLA can cause epileptic seizures. In animal breeding, TLA can cause reduced growth. The symptoms in humans are independent from whether or not TLA are perceived consciously.
- _ Image distortions in cameras:
Strip-shaped image errors for some camera models (digital cameras, film cameras, security/surveillance cameras, webcams, sports cameras, high-speed cameras, systems for visual inspection)
- _ Malfunctions in devices:
It is possible that switching operations which are the cause for TLA also cause interferences in other technical devices. This includes bar code readers, pulse oximeters, sensors, optical measuring devices, photocells, etc.
- _ Dangers in jobs with rotating machines:
The strobe effect distorts the perception of rotating parts. This increases the risk of accidents at work.

5. What were the difficulties of measuring TLA?

The older measurement methods, modulation depth and flicker-index, were only of limited relevance for the assessments of TLA because of the following reasons:

- _ Important influencing factors on the human perception like e.g. mixed modulation frequencies, special curve shape, pulse duty factor of the modulation are considered insufficiently
- _ The procedures work without specifying the modulation frequency and are therefore not meaningful.
- _ The procedure is limited to short review periods.
- _ Data that was measured at different frequencies, cannot be directly compared (such a comparison would be possible only with the help of a frequency-dependent conversion)

Developing improved measurement methods was difficult because of the following reasons:

- _ Interaction of different components:
The evaluation of individual components is often only possible in combination with other system components. In the interaction between LED modules and control gear, TLA depend on the operating point and to some degree also on the differential resistance of the LED module.
- _ Influence of different application conditions:
Different application conditions (work environment, hazards, etc.) require different limits. These have to be defined separately.

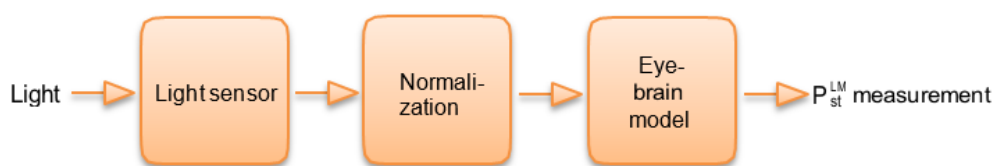
The result was a situation characterized by measurement methods that were not fully suitable, a lack of standardization and limits.

6. Which new and improved measurement methods have been developed recently?

6.1. PstLM measuring procedure

The goal of this measurement procedure (PstLM comes from "short-term light modulation") is to measure visible flicker caused by light modulation in the frequency range between 0.3 Hz and 80 Hz.

The details are described in IEC/TR 61547-1 and IEC 61000-4-15.



The above image shows a block diagram of a flicker metre, which works according to the PstLM measuring procedure. A reliable assessment of low-frequency flicker phenomena takes about about 1 minute with this method.

6.1.1. Light sensor

The first block contains the light sensor. The light sensor converts the measured light signal into an electrical signal that is proportional to this.

6.1.2. Standardization

This block scales the input signal in such a way that the amplitude of the output signal is independent from the absolute light level (e.g. illuminance). To do this, the input signal is standardized to the average value (DC portion) of the input signal .

6.1.3. Eye-brain model

This block evaluates the signal with a so-called "eye brain model", which reproduces the frequency-dependent flicker perception of an average person. The output of this block corresponds to the PstLM value.

6.1.4. Limit value for PstLM

Limit values have not been finalized, so far. But a limit of $P_{stLM} \leq 1$ is considered very likely.

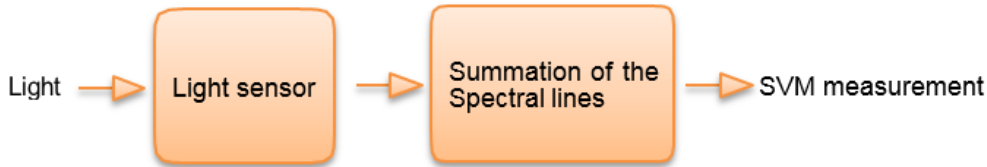
This limit was determined on the basis of a representative test group and represents the average visibility limit for visible flicker (criterion of IEC/EN 61000-3-3).

What this limit value does not determine, is a more accurate classification of values for different application conditions.

6.2. SVM measuring method

The goal of the SVM measuring method (SVM from "Stroboscopic visibility measure") is to asses the strobe effect which can occur in conjunction with moving objects and a light modulation in the frequency range from 80 Hz to 2,000 Hz.

The below image shows a block diagram of a flicker metre which works according to the SVM measuring method. A signal duration of at least 1 second is required for the calculation of the value of the SVM.



6.2.1. Light sensor

The first block contains the light sensor. The light sensor converts the measured light signal into an electrical signal that is proportional to this.

6.2.2. Summation of the spectral lines

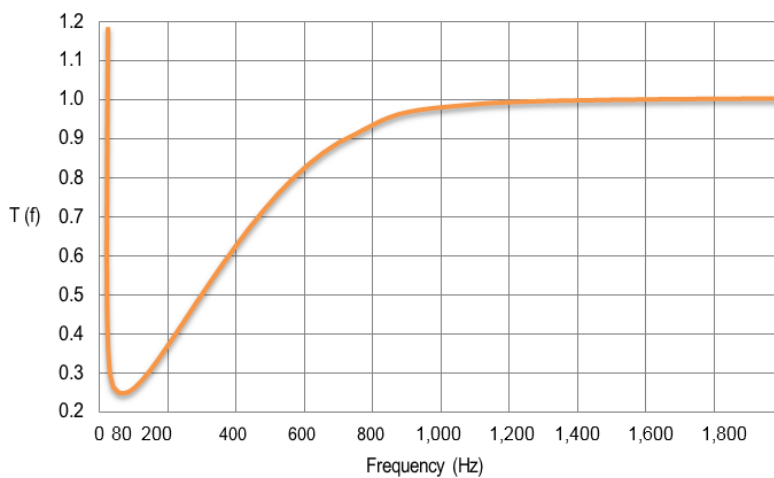
In this block, the SVM value is calculated. This is done through a summation of the frequency components of the input signal according to the following formula:

$$SVM = \sqrt[3,7]{\sum_{i=1}^{N(\leq 2kHz)} \left(\frac{C_i}{T_i}\right)^{3,7}}$$

The normalized frequency components of the signal (C_i) are weighted and summed up via T_i according to the human perception.

T_i in the formula represents the visibility limit for the strobe effect for a sinusoidal signal with the frequency of the i -th frequency component.

The frequency-dependent sensitivity curve $T(f)$ is shown in the image below. The output signal of the summation block corresponds to the SVM value.



6.2.3. limits for SVM

Useful application-specific limits are still being discussed at the moment. But a limit of SVM = 0.4 is very likely.

This value of SVM = 0.4 represents the visibility limit of test persons who focus on the assessment of the strobe effect under laboratory conditions. The real acceptance limit can greatly depend on application conditions.

7. What about the availability of appropriate measuring devices?

The first commercially available measuring instruments are now available on the market. Tridonic already has the necessary equipment.

For future products, measurements are taken as standard. For existing products, measurements can be made upon request.

8. How far is the development of appropriate acceptance criteria?

As regards acceptance conditions and acceptance criteria only general instructions exist.

The acceptance criteria depend on both the visibility and the relevance or risk in the respective application. For general applications (e.g. domestic lounges, offices), the limits $P_{stLM} \leq 1.0$ and SVM=0,4 can be a good reference value.

With regard to the further development and definition of limit values, further experience has to be gained over the next few years.

9. References

- _ LightingEurope, Position Paper on Flicker and Stroboscopic Effect:
<https://lightingeurope.org/position-papers/119-lightingeurope-position-paper-on-flicker-and-stroboscopic-effect>

- _ ZVEI, Temporal Light Artefacts - TLA:
<https://www.zvei.org/en/association/division/lighting-division/temporal-light-artefacts-tla/>

- _ IEC/TR 61547-1, Equipment for general lighting purposes - EMC immunity requirements - Part 1: An objective light flickermeter and voltage fluctuation immunity test method

- _ IEC 61000-4-15, Electromagnetic compatibility (EMC) - Part 4-15: Testing and measurement techniques - Flickermeter - Functional and design specifications

- _ IEC/EN 61000-3-3, Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection