Driving the Flicker-Free Effect

unios®

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Introduction

With the increasing demand for energy efficient lighting, the lighting industry has progressed towards solid-state lighting (SSL). In recent years inorganic light-emitting diodes (LEDs) have become the most preferred solid-state lighting option.

BENEFITS OF LEDS INCLUDE LONGER LIFE, energy savings, improved durability, less frequent maintenance and significantly less electricity usage to provide the equivalent amount of light compared to traditional light sources. Another key advantage of light emitting diodes is fast response time to energization, providing light almost instantaneously. Due to the fast response time, poor performing drivers with unstable outputs leads to creation of temporal light artefacts (TLA)[1].

The International Commission on Illumination (CIE) defines temporal light artefacts as the "change in visual perception, induced by a light stimulus, the luminance or spectral distribution of which fluctuates with time, for human observers in a specified environment" [2]. In other words, temporal light artefacts are the visual effects that change the way that we see our surroundings, triggered by a light source. Temporal light artefacts are divided into three different categories: flicker, stroboscopic effect and phantom array.

Flicker

Flicker is the perception of visual fluctuations in intensity and unsteadiness in the presence of a light stimulus, that is seen by a static observer within a static environment. Flicker that is visible to the human eye will operate at a frequency of up to 80Hz.

Stroboscopic Effect

The stroboscopic effect refers to the phenomenon that occurs when there is a change in perception of motion, caused by a light stimulus that is seen by a static observer within a dynamic environment. The stroboscopic effect will typically occur within a frequency range of between 80Hz-2kHz.

Phantom Array

Phantom array, also known as the ghosting effect, occurs when there is a change in perception of shapes and spatial positions of objects. The phenomenon is caused by a light stimulus in combination with rapid eye movements (saccades) of an observer in a static environment. Similar to the stroboscopic effect, the phantom effect will also occur between 80Hz-2kHz.

Why is it important?

The diverse applications of LED lighting have proven to be a popular lighting solution and are being used in almost every application. Therefore, it is becoming increasingly important for LEDs to be able to operate as intended in all environmental conditions and absent of the negative effects of TLAs.

THIS PAPER WILL INVESTIGATE THE implications of temporal light artefact from a more technical perspective.

Temporal light artefacts have the potential to affect all those within the illuminated space. While some TLAs will cause some minor irritations, some may cause serious implications for certain individuals. The degree to which a person is affected by temporal light artefacts is highly dependent on the individual's eye adaptation and sensitivity to light. TLAs are usually quite apparent when visible, however, when it is not visible to the human eye, it can unknowingly cause negative effects for those who are exposed to these lighting conditions.

TLAs have the potential to cause health implications, create safety hazards and interfere with electronic imaging devices.

Health Implications

Flicker is the primary type of light stimulus that has health implications. Flicker is important as it occurs in all light sources. This temporal light artefact can be categorised into three types, determined by a person's ability to detect (sense) and perceive the flicker. The IEEE [3] defines the categories as follows:

- ***Visible flicker:*** The luminous modulation is sensed and consciously perceived.
- ***Sensation:*** The eye/brain/neurological system detects the modulation of light output over time in the external conditions, and neurons respond.
- ***Invisible flicker:*** The luminous modulation is sensed, but not consciously perceived.

The average human eye can detect light flicker at frequencies below 60Hz and is most sensitive around 15Hz, as indicated in Figure 1. An average person will generally not see light flicker between 60Hz-90Hz and is known as the critical flicker fusion frequency (CFF)[3]. When light flickers at a rate that is beyond the CFF, the output appears to be continuous to the human eye and is known as invisible flicker. Even though the human eye cannot detect the invisible flicker, flickering is still present and can cause mild to severe health related issues.

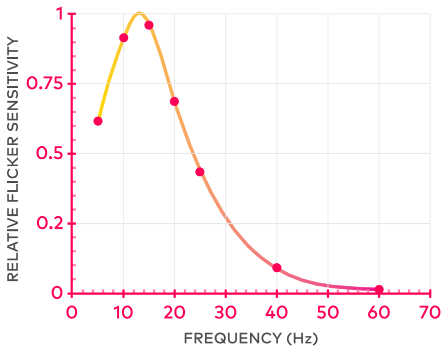


Figure 1: Relative flicker sensitivity in respect to frequency [7]

Photosensitive epilepsy

A photosensitive epileptic patient is highly sensitive to light flicker. Wilkins et al. [4] and Harding and Jeavons [5] investigated and discovered a strong relationship between the responses of photosensitive epilepsy patients and flicker frequencies. Figure 2 indicates that up to 70Hz will induce a response in photosensitive epilepsy patients, where 15-20Hz will have the greatest chance of an epileptic patient to experience seizures.

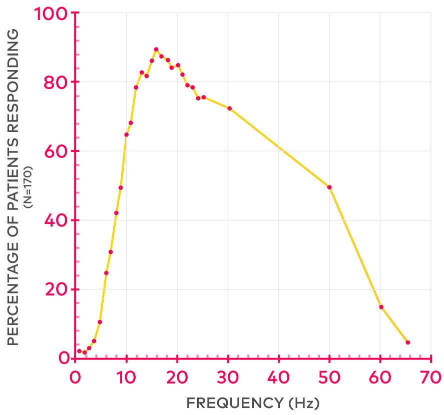


Figure 2: Percentage of photosensitive epilepsy patients responding to flicker at varying frequencies [4]

Autism

The average person is unlikely to see flickering at frequencies above 60Hz, however an exception to this is people with Autism Spectrum Disorders (ASD). People with ASD are extremely sensitive to light and can sense and visualise flickering at 60Hz [3]. Fenton and Penney [6] conducted a study with five autistic and five intellectually disabled children, which investigated the effects of fluorescent lighting with varying frequencies. From the study, it found that autistic children are more likely to be affected by the flickering of light with greater frequencies. Signs and symptoms of patients with ASD that are being affected by lights include: repetitive behaviours, poor eye contact or eye movement, increased anxiety and can lead to social problems [7].

Other Health Implications

Varying from person to person, exposure to flicker may cause additional health implications. A study conducted by Debney [8] found that 25% to 50% of migraine sufferers identified flicker as a trigger for migraines. Numerous studies have confirmed that exposure to flicker within offices, doubles the average incidence of headaches[9]. Previous studies have also found that exposure to flicker can cause eye strain, malaise, nausea, reduced visual performance, panic attacks, anxiety and general discomfort.

Safety Hazards

The stroboscopic effect is the change in perception of motion, caused by a light stimulus that is seen by a static observer within a dynamic environment. In other words, the stroboscopic effect creates an optical illusion which causes moving objects to appear stationary, change in speed, forward or backward motion. This effect is most prevalent in industrial settings where rotating machines are in common use. Therefore, becoming highly hazardous to the operator of high-speed rotary machinery.

The stroboscopic effect can be seen within the frequency range of 80Hz to 2kHz .[10] The visibility of the stroboscopic effect is dependent on both the frequency of the light and the speed of the rotating object. By increasing the speed of the object, visibility is decreased and vice versa when decreasing the speed of the moving object.[11]

Electronic Devices

Temporal light artefacts not only affect the vision and health of the people, but it also interferes with electronic imaging devices. The most common imaging device would be digital cameras. All digital cameras contain an electronic component called an image sensor, a device that converts real-life images to digital pictures. An interesting fact about digital cameras is that the operating mechanism is very similar to the human eye. Both camera and the human eye take light waves that are projected by objects and converts them into the form of an image. Since the human eye can detect the effects of temporal light artefacts, it is not surprising that cameras will also experience these effects.

The most obvious effect that cameras can pick up, occurs when there is flicker present. When the camera's shutter speed is not in sync with the flicker frequency, the camera will either be able to capture flicker or a phenomenon known as the "rolling band" or "rolling bars" effect. In photos, the rolling bars will create dark or discoloured stripes across the image, as seen in Figure 3. When recorded, the rolling band will have dark horizontal bands that will continuously oscillate between the top to the bottom of the recorded video.

Figure 3: Example of the rolling band effect.

This becomes highly problematic for companies that using equipment such as barcode scanners and image-based testing equipment. The presence of flicker will most likely reduce the efficiency and the ability to for this equipment to operate as intended.

Videographers will immensely benefit from flicker-free lighting. Although the professional videographers will most likely have flicker-free functions built-into their cameras, it can be quite tedious to constantly alter camera settings to eliminate these issues. In addition to videographers, video editors will also benefit from flicker-free lighting. In the event that videographers have picked up flicker or rolling bands in their recorded videos, it becomes a time-consuming and or costly process to remove these effects from the video.

When flicker is present in video conference calls, it becomes rather distracting and has been noted to cause headaches to attendees. Temporal light artefacts in conjunction with imaging devices have the potential to ruin once in a lifetime moments. For example, weddings, high-speed sporting events and precious moments of a child.

The severity of these effects will be highly dependent on the camera and its image sensor. A high-quality camera will most likely avoid these effects. However, if the camera unfortunately picks up these TLAs, it is important to provide flicker-free lighting to the surrounding environments in order to eliminate these effects.

Exceptions

Although temporal light artefacts are generally undesirable, there are some situations where the effects are purposely used. These applications use temporal light artefacts for the purpose of controlling the atmosphere and as a form of communication. Examples include warning lights on emergency vehicles, theatrics, night clubs, decorative lighting, pedestrian crossing lights and any other form of signalling lights. Temporal light artefacts are great for these purposes however for general lighting it is highly undesirable.

Causes of Temporal Light Artefacts

Power distribution through lighting systems is typically in the form of Alternating Current (AC) power which means a frequency-varying voltage. This supply waveform is defined by its amplitude, DC offset component, duty cycle and frequency. All of these can contribute towards the presence of TLAs.

Total Harmonic Distortion

TOTAL HARMONIC DISTORTION (THD) is a measure that compares the summation of all harmonic components of voltage or current waveforms with their respective fundamental signal. The equation for total harmonic distortion within a voltage signal is shown below. Where V_1 represents the fundamental frequency and V_n represents the n^{th} harmonic component of a signal.

$$THD = \frac{\sqrt{(V_2^2 + V_3^2 + V_4^2 + \ldots + V_n^2)}}{V_1} \times 100\%$$

Equation 1: Mathematical expression of total harmonic distortion

Total harmonic distortion essentially determines the quality of a signal. The greater the THD value, the greater the distortion of the signal. An ideal sinusoidal signal would not have any harmonics present and therefore it is undesirable to have any distortions caused by harmonics. However this is inevitable in real life and harmonics will always be present.

Causes of Harmonics

Harmonics are produced when supplying power to non-linear loads. The impedance of non-linear loads changes when a voltage is applied to the system [12]. The load will draw non-sinusoidal current from sinusoidal voltage sources, in the process producing undesirable harmonics. As most electronic devices are considered as non-linear loads, the existence of harmonics is becoming an increasing issue. Common non-linear loads include inverters, DC converters, switch-mode power supplies, and AC to DC drivers [12]; which are present in all household electrical goods.

Effects of Harmonics

Power supplies that supply excessive amounts of harmonics, have the potential to create some detrimental effects to electrical components. It will cause "increased transformer, capacitor, motor or generator heating, misoperation of electronic equipment, incorrect readings on meters, misoperation of protective relays, interference with telephone circuits" [12].

As a result, harmonics will reduce the overall lifetime of the electrical device and in the event of a large electrical surge, this will instantly destroy the electronic component.

LEDs and LED drivers are no exception and will experience the effects of harmonics. All drivers will experience harmonic waveforms; however, some LED drivers may output excessive harmonic waveforms more than others. Since LED drivers provide power to an LED luminaire, the luminaire will also be affected by harmonics; resulting in a poor performing luminaire.

Modulation

Example of Modulation: Ripple Injection

Ripple injection is a technique known as modulation and is commonly used by electricity distributors to control the switching of off-peak loads. During off-peak periods, electricity distributors will send a ripple signal along the power lines which will activate off-peak loads such as off-peak hot water systems and street lighting [13]. Injecting a ripple signal along power lines allows for one-way communication without additional communication infrastructure.

Switching of an off-peak load is highly dependent on the magnitude of the ripple signal. If the ripple signal is too low, it may not activate the load and if the signal is too high, this will cause implications to any electrical equipment connected to mains power. Implications that clients will typically experience include flickering of lights and audible noise.

What is Modulation?

Modulation is the process of combining a message signal with a specifically altered carrier signal. This process is primarily used within communications and has several benefits, which include transmitting low frequencies over larger distances and reducing signal interference. There are three fundamental types of modulation: amplitude modulation, frequency modulation and phase modulation. Modulation can be thought of as a method of coding messages, where it can be decoded with a reverse process called demodulation.

To determine how much a modulated signal varies from an unmodulated signal, a measure known as modulation index is used. Amplitude modulation, frequency modulation and phase modulation are defined by the following equations.

$$\text{Amplitude Modulation Index } (M_a) = \frac{\text{Modulation Amplitude } (A_m)}{\text{Carrier Amplitude } (A_c)}$$

Equation 2: Amplitude Modulation Index

$$\text{Frequency Modulation Index } (M_f) = \frac{\text{Peak Frequency Deviation } (\Delta f)}{\text{Peak Frequency of Modulating Signal } (F_m)}$$

Equation 3: Frequency Modulation Index

$$\text{Phase Modulation Index } (M_p) = \text{Peak Phase Deviation } (\Delta\theta)$$

Equation 4: Phase Modulation Index

Modulation, THD and Flicker Sensitivity

Although there are three primary modulation methods, studies have shown that amplitude modulation is the primary variable that can influence the total harmonic distortion[14], [15]. Based on these findings, by increasing the amplitude modulation index the total harmonic distortion is decreased [14], [15].

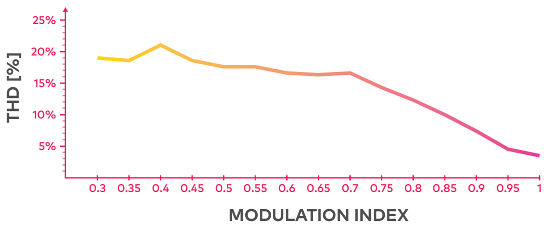


Figure 4: The effects of THD with varying amplitude modulation index [15]

Total harmonic distortion greatly influences the performance of electrical components, including LEDs and LED drivers. This would signify that modulation indirectly affects flickering of LEDs, as modulation affects THD and THD has the potential to cause misoperation of electrical components.

ASSIST [16] investigated the average modulation threshold needed to detect flicker as a function of frequency for a group of 10 subjects viewing an A-lamp-sized light source. The results from this study is shown in Figure 5 and provides a great baseline when designing LED drivers. Modulations and frequency pairings beyond the threshold would exhibit flicker which is highly undesirable.

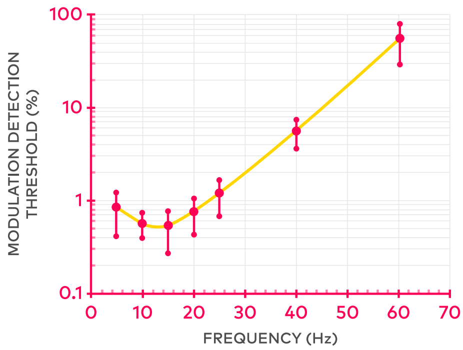


Figure 5: Average modulation threshold in percent to detect flicker as a function of frequency [16]

Electronic LED Drivers

LED drivers need to convert the AC supply voltage into a fixed non-frequency-varying DC output to drive the LED devices. In practice, it is very difficult to get an ideal or perfect DC output from an AC input. Typically, there will be a small amount of modulation on the output. There are two major contributors: driver design and input noise.

Driver Design

The basic topology of an electronic LED driver is shown in the block diagram below. An electronic driver takes the AC voltage input, rectifies it, and then uses a bulk capacitor to smooth out the peaks to produce an intermediary DC voltage. A digital controller then switches the DC supply though a transformer (or inductor) to produce the required output DC supply. This switching mechanism is where the commonly used “switchmode supply” name comes from. The digital controller uses feedback mechanisms to vary the switching duty cycle to control output voltage or current as required.

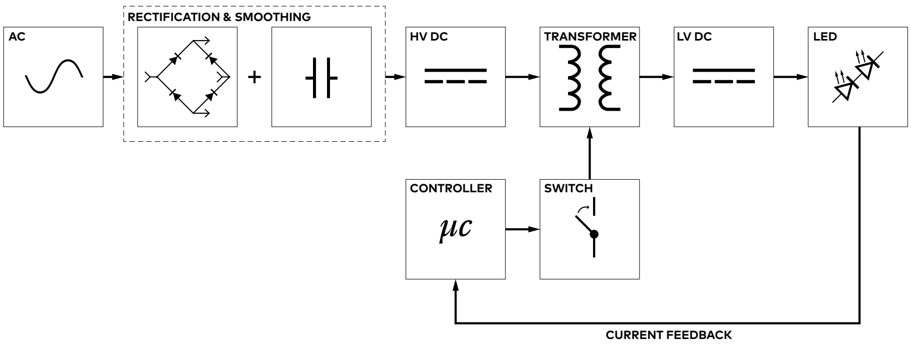


Figure 6: Basic topology of an electronic LED driver.

Modern controllers typically use a fixed switching frequency in the low-to-mid kHz range (50-200kHz) which is outside the visible and invisible TLA range. However, poor design or faults can lead to oscillation in the fixed switching frequency which can present TLA issues.

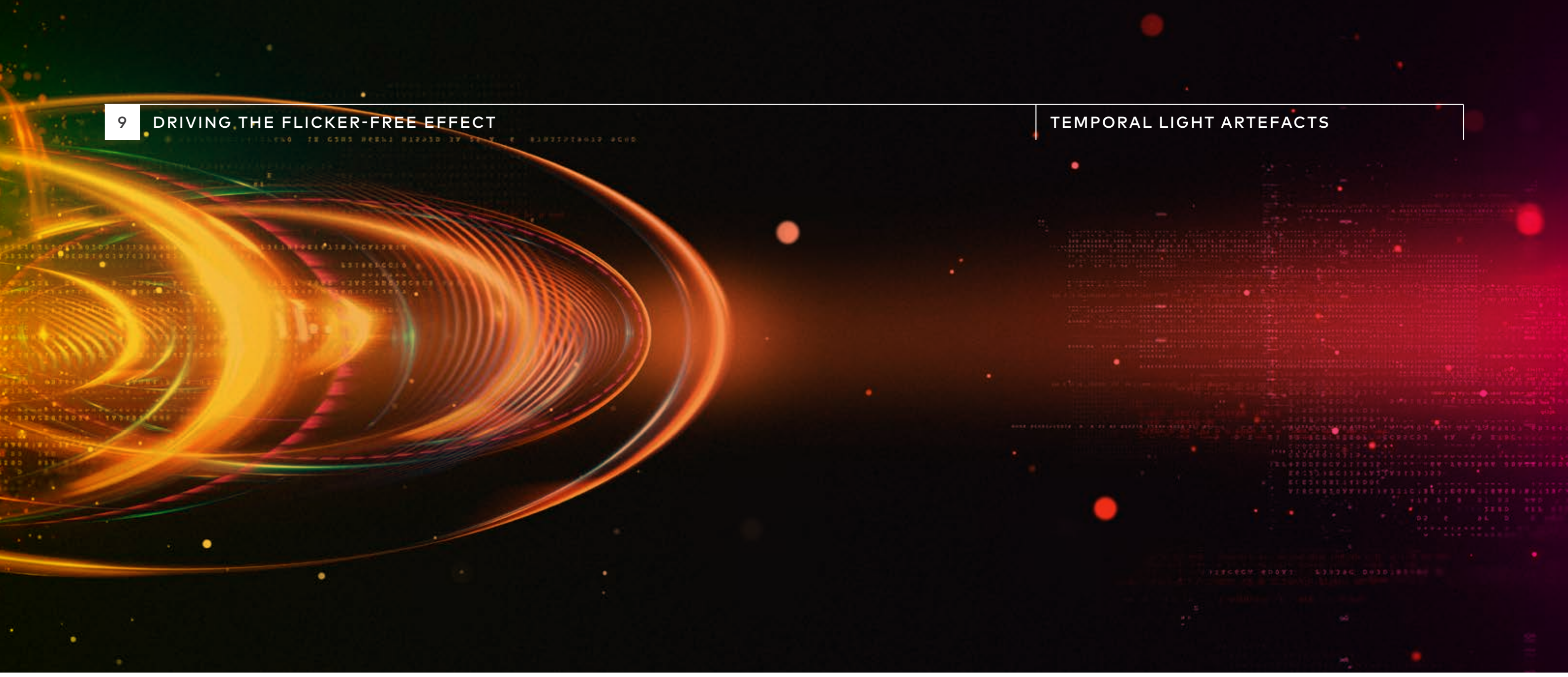
Some barebones low-cost LED designs are driverless (or non-electronic) and run straight from AC mains voltage with only a bridge rectifier and capacitor. The LED units are designed to run from what is essentially the intermediary DC voltage that would be in an electronic driver. These suffer immensely from TLA in the 100 to 120Hz range (or 2x the fundamental mains supply frequency). However, due to the frequency, the TLA effects are not usually visibly noticeable to the human eye., but the effects still have an impact.

Intelligent driver designs minimise both output noise and emitted harmonics into the supply through more advanced control strategies and switching techniques.

Input Noise

Input noise, in the form of modulation, harmonics and the like, can be coupled to the output of the driver. The internal control feedback loop response time and compensation characteristics determine the driver’s ability to deal with changes to the supply voltage. A digital controller must sense the output supply and determine any required changes to the switching control to achieve the desired output on the next cycle through small corrections. If the voltage unexpectedly changes before the next cycle, the new switching control settings will not achieve the desired output.

Input noise is reduced within the driver through input filtering, where included in the design. More advanced filtering techniques can remove a higher spectrum of noise giving a more stable intermediary DC voltage to drive the LED units with.



Quantifying Temporal Light Artefacts

As flicker is present to some degree in all types of artificial lighting, it is important to be able to quantify the effects of temporal light effects within an area. Although there are existing measures used to identify flicker, there are several limitations and therefore requires alternative measures that can account for the limitations.

Existing Metrics

PERCENT FLICKER (MODULATION DEPTH) and flicker index are the two most commonly used metrics to determine the extent of flicker. Although these two metrics are a good indicator of flicker, these existing measures fail to identify the distinction between flicker and the stroboscopic effect [17]. While also failing to address human perception due to the frequency of the flicker.

Percent Flicker (Modulation Depth)

Ideally, all light sources should have a percent flicker of 0%, which would provide a constant light source. A typical magnetically ballasted fluorescent light will have a Percent Flicker of 40%.

Percent flicker measures flicker and uses the maximum and minimum amplitude values to determine the degree of flicker. It considers the signals' average waveform and peak-to-peak amplitudes. This is defined in the following equation and corresponds to Figure 7.

$$\text{Percent Flicker} = 100\% \times \frac{A - B}{A + B}$$

The major disadvantage of this metric is that there is no accountability for the signal's shape, duty cycle or frequency [18].

Flicker Index

Similar to percent flicker, ideal light sources should have a flicker index of 0. Most magnetically ballasted fluorescent lights will have a flicker index of 0.15.

The flicker index calculates flicker based on the ratio between the area above the average signal amplitude with the total signal area. This metric considers the average, peak-to-peak amplitude, shape and duty cycle. The flicker index is defined mathematically in the equation below and can be visualised in Figure 7.

$$\text{Flicker Index} = \frac{\text{Area 1}}{\text{Area 1} + \text{Area 2}}$$

The main disadvantage of the flicker index is that it does not take frequency into consideration [18].

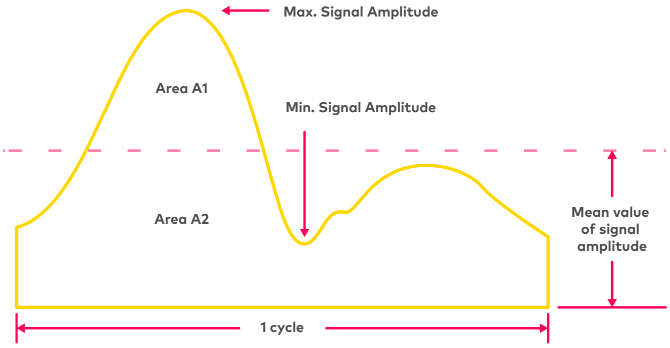


Figure 7: Example of Percent Flicker and Flicker Index Metrics

New Metrics

Due to the limitations of the existing metrics, new metrics have been developed to consider each of the temporal light artefacts. The German Electrical and Electronic Manufacturers' Association (ZVEI – Zentralverband Elektrotechnik- und Elektronikindustrie e. V.) has conducted a thorough investigation into the various newly developed TLA metrics.

Perception of Short Term Light Modulation (P_{st}^{LM})

The perception of short-term light modulation (P_{st}^{LM}) measuring method, or commonly referred to as the “Flickermeter”, is a relatively new metric that is currently being applied in industry. P_{st}^{LM} can predict the visibility of flicker when light modulation occurs between the frequency range of 0.4Hz to 80Hz, requiring up to 1 minute to generate a value [19]. This process of obtaining P_{st}^{LM} is depicted in Figure 8. This process involves passing light through a light sensor which then collects and converts the data in the form of an electrical signal. The signal then undergoes a signal processing phase that obtains the illuminance of the light source and then uses an eye-brain models to “generates a signal frequency-based flicker perception of an average person” [19], which finally outputs a P_{st}^{LM} value.

Figure 8: Block diagram of P_{st}^{LM} [19]

Dubois [20] states that 50% of people will see flicker and find irritable when the P_{st}^{LM} value is less than 1, any value greater than 1 may be visible, but not irritable.

$$P_{st}^{LM} = \begin{cases} <1 & \text{flicker may be visible but it is not irritable} \\ >1 & \text{flicker is visible and irritable to at least 50\% of people} \end{cases}$$

Limitations of P_{st}^{LM} include underpredicting the visibility of non-periodic (aperiodic) flicker, its complexity and the predictions are limited to frequencies of up to 80Hz [20].

Flicker Visibility Measure (FVM)

Flicker Visibility Measure is a metric used to determine the visibility of flicker within lighting. FVM measures the effects of both frequency and shape of periodic waveforms. By using Equation 5, it transforms the waveform into its respective frequency components, which then produces a single value that determines the flicker visibility.

$$FVM = \sum_{m=1}^{\infty}\left(\left|\frac{C_m}{T_m}\right|^{n}\right)^{1/n} \begin{cases} >1 & \textit{visible} \\ =1 & \textit{just visible} \\ <1 & \textit{not visible} \end{cases}$$

Equation 5: Flicker Visibility Measure

The limitations of FVM is the inability to determine aperiodic signals and this is crucial to be able to do so, as input signals are not always periodical[20].

Flicker Visibility Measure in Time Domain (FVM_t)

The Flicker Visibility Measure in time domain (FVM_t), is a newly proposed metric developed by Philips to overcome the limitation of FVM[20]. FVM_t can predict the visibility of both periodic and aperiodic flicker. The formula for FVM_t is shown in Equation 6.

$$FVM_t = 733 \times \sqrt[4]{\frac{\sqrt{\Sigma(r_1 - \overline{r}_1)^2}^{\,4}}{2.55} + \sqrt{\Sigma r_2^{\,2}}^{\,4}} \begin{cases} <1 & \textit{flicker is visible with the probability smaller than 0.1} \\ >1 & \textit{flicker is visible with the probability larger than 0.1} \end{cases}$$

Equation 6:Flicker Visibility Measure in Time Domain

The key advantage of FVM_t is the ability to predict the visibility of simple transient light effects, which encompasses single increase, decrease and pulses[20]. The main limitation of FVM_t is the inability to predict complex transient light effects which involve double pulses and changes in frequencies[20]. Dubois [20] conducted a direct comparison between P_{st}^{LM} and FVM_t, which concluded that P_{st}^{LM} significantly underpredicts the visibility of aperiodic flicker and FVM_t is not only easier to implement, but it also has greater prediction accuracy.

Stroboscopic Visibility Measure (SVM)

The Stroboscopic Visibility Measure (SVM) is a metric designed to measure the stroboscopic effects of light modulations within the frequency range of 80Hz to 2kHz[19]. The block diagram created by ZVEI[19] and shown in Figure 9, provides a visual representation of the SVM calculation process. On average this method takes approximately 1 second to complete[19].

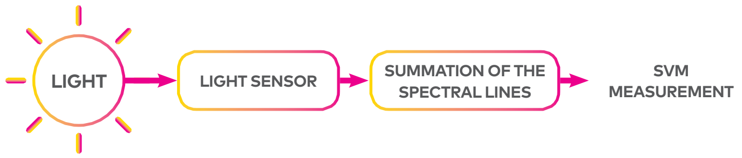


Figure 9: Block Diagram of Stroboscopic Visibility Measure[19]

Identical to the P_{st}^{LM} metric, the light source is passed through a light sensor which is then converted into an electrical signal. The SVM value is then produced after the the summation of all spectral lines, using Equation 7. As SVM is a relatively new metric, the SVM thresholds have yet been defined and require on going test to determine ideal operating conditions in respect to SVM values[19].

$$SVM = \sqrt[3.7]{\sum_{i=1}^{N(\leq 2kHz)}\left(\frac{C_i}{T_i}\right)^{3.7}}$$

Equation 7: The formula used to calculate the Stroboscopic Visibility Measure [19]

The main limitation of this metric includes the inability to differentiate an individual's sensitivity to seeing the stroboscopic effect. As SVM is a relatively new metric, the threshold values are still to be defined completely. However, early results have shown SVM = 1 represents the visibility threshold of people evaluating stroboscopic effects under laboratory conditions[19].

Standards

To ensure that LED lighting does not induce temporal light artefacts and cause negative health effects, the IEEE standards committee has developed IEEE PAR1789: Recommending practices for modulating current in High Brightness LEDs for mitigating health risks to viewers. By conducting a risk assessment on the health effects of temporal light artefacts, this identifies the maximum threshold for human exposure.

The chart shown in Figure 10 indicates the range at which the frequency and modulation percentage will be low health risk or have no observable health effects on people. Based on this information IEEE [3] has provided a recommended operating area for LEDs as shown in Figure 11. Between 10Hz to 90Hz the modulation percentage should be below 0.025*frequency and above 90Hz the modulation percentage should be below 0.08*frequency. If the frequency of the light is undeterminable, then the flicker percentage shall not exceed 10% [21].

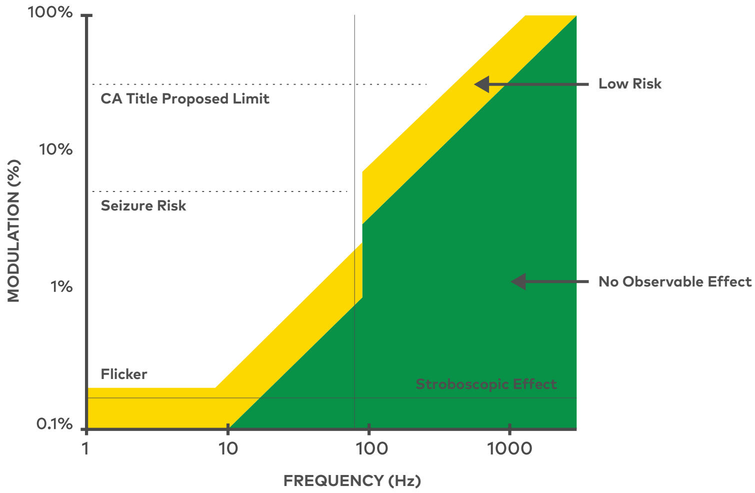


Figure 10: The observable health effects with varying modulation percentages [3]

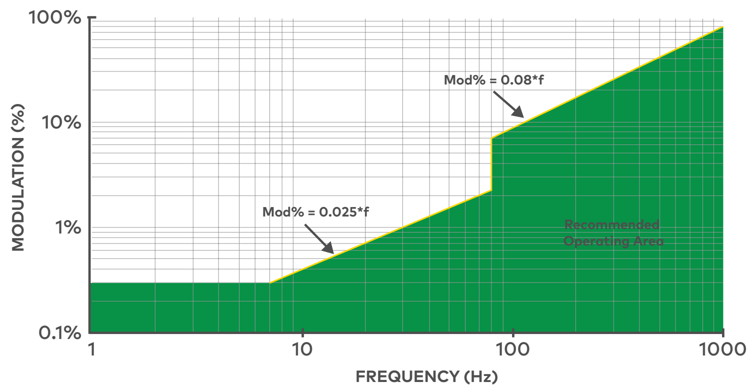


Figure 11: Recommended operating area for LEDs [3]

Conclusion

LEDs are becoming the go to illuminating solution for the lighting industry. With an increase in popularity, it is crucial for LEDs to provide constant light without the negative effects of temporal lighting artefacts when undesired.

TRADITIONAL LED DRIVERS HAVE THE potential to cause temporal light artefacts such as flickering, stroboscopic effect or phantom array. Both short term and long-term exposure to temporal light artefacts has a significant impact on the health of humans. Negative health effects differ from person to person, with some experiencing less severe eye-strain and headaches, to serious epileptic seizures and evidence of aggravating autistic conditions. Not only does temporal light artefacts cause health concerns to humans, it becomes a safety hazard for those operating high-speed rotary machinery and a nuisance for imaging devices.

Through investigation, the primary cause behind temporal light artefacts are due to total harmonic distortion and modulation. To quantify the effects of flickering and the stroboscopic effect several new metrics have been developed, as it was found that the existing measures were insufficient at addressing human perception due to the frequency of flicker.

The two recommended metrics for measuring the effects of flickering and the stroboscopic effect is the Flicker Visibility Measure in time domain (FVM_t) and the Stroboscopic Visibility Measure (SVM). Since these two measures are relatively new, further research is required to determine the minimum threshold of FVM_t and SVM, to minimise the TLA effects.

The IEEE committee has created IEEE PAR1789: Recommending practices for modulating current in High Brightness LEDs for mitigating health risks to viewers. The standard states and identifies the optimal operating conditions of which LED lights should operate in. Abiding with this standard, Unios has announced the release of the new G2 Driver that will address the issues with temporal light artefacts. By redesigning the existing driver to include a harmonic filter, it reduces the total harmonic distortion and thus significantly reduces flicker and any potential strobing effects. In addition to the flicker-free feature, a higher power factor correction improves the overall power consumption and reduces electricity costs.

Unios G2 Phase-Cut Driver

To overcome issues concerning the flicker and stroboscopic effect, Unios has developed the G2 Phase-Cut Driver.

UNIOS' REDESIGNED DRIVER FEATURES A TWO-STAGE topology including active filtering and advanced switchmode control:

- Reduced in-rush current at start up and when using leading edge dimming resulting in less audible hum
- Active input filter reduces typical total harmonic distortion produced by the driver to approximately 6%
- Active filtering to reduced coupled modulation to output
- An extended lifetime of 50,000 hours
- Exceeds all current flicker and stroboscopic standards
- Increased power factor rated at >0.9 for full range voltage (typically performing at 0.95), Resulting in an increase in cabling efficiency and potentially reducing electricity costs
- Sleek new case with improved noise reduction and superior heat dissipation through the use of fully potted internals.

Figure 12: Unios G2 Phase-Cut Driver

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