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INNOVATING THE FUTURE

Optical Flicker in Lighting

LED Lighting inherently flickers, however, products that remove flicker offer optimal light output

Flicker Fundamentals

Optical flicker is defined as variations in luminance (brightness) over time, and generally refers to direct flicker from the surface of a light source. This differs from electrical flicker, which is associated with perception of voltage changes on a 60W incandescent lamp.[1]

Flicker typically brings to mind visibly perceptible blinking, flashing, or strobing effects. This is true when the frequency of the flicker is below 90Hz. Above this visual perception frequency and up to 2000Hz, non-visible flicker still may have effects on physiology and cognition, as discussed below.

Other definitions surrounding what is described as variations in luminance over time can be:

- **True Light Source Flicker** – visibly perceptible light flicker.
- **Stroboscopic Effects** (indirectly perceived flicker) – caused by light source flicker combined with relative movement of the viewed object. For example, moving a ruler back and forth quickly across a desk will create the appearance of multiple versions of the object under flickering light.
- **Temporal Lighting Artifacts** – "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."[4]

General Definitions and Metrics

Flicker is dependent on the changing brightness, and not on the type of light source. Frequency and amplitude of modulation, spectral variation, adaptation luminance, contrast, size of retinal area being stimulated and distance to a source and its location in the visual field are all factors that help us characterize flicker. All light sources can flicker, and most modern products have the ability to remove flicker.

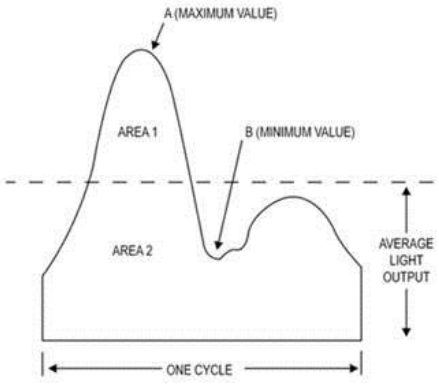
Percent Flicker is an Illuminating Engineering Society (IES) defined metric, based on the relative change in the light modulation. It does not account for frequency and waveform.

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

Flicker Index is an IES defined metric, considers waveform indirectly, and is based on the areas above and below the average light output, but also is independent of frequency.

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

Flicker Perception considers waveform and frequency, and provides a probability of a waveform being detected directly.



Why Light Sources Produce Flicker

The most common cause of flicker is fluctuation in the power source of a light. In incandescent lamps, this was the natural fluctuations of the AC grid that was "filtered" only by the heat storage of a filament, resulting in 6-11% flicker. Early magnetic ballasted fluorescent lights had extremely high flicker, 80-100%. The same fluorescent lamps operating on modern electronic ballasts typically achieve flicker below 20%, and as low as <1%.

LEDs are perfectly capable of achieving zero flicker. However, the power supplies (drivers) that convert AC power to DC may have a ripple effect on the DC, resulting in flicker. How much flicker is present depends almost entirely on the driver design of the manufacturer. Even products that use LEDs for backlighting and not for ambient light have the potential to flicker, such as smart-phone devices, televisions, and computers.

One contributor to flicker is the addition of dimming. Some dimming sources, particularly phase-cut dimmers, operate by chopping up the input voltage of a lamp or driver, and can result in higher flicker when the light is dimmed from when it is full brightness. Again, the driver plays a large role.

Standards that Guide Flicker in Lighting

IEEE 1789

The Institute of Electrical and Electronics Engineers (IEEE) evaluated studies surrounding flicker and wrote recommended standards. Although updated in 2015, there is no test method included to adequately evaluate flicker rates.[5]

Industry Awareness of Need for Updates and New Standards

Underwriters Laboratories (UL) offers a program for lighting manufacturers to verify percent-flicker on their products as a way to verify to California Standards (Title 24 JA-8). The National Electrical Manufacturers Association (NEMA) has a working group to create TLA measurement procedures that include frequency and waveform effects.

Flicker in LED products is becoming a growing issue, and while some manufacturers are taking their own stand and removing flicker on a basis of responsibility and integrity, the lack of standards and no requirement to report flicker allows flicker to remain a present in our lighting.

Biological Effects of Flicker

The human visual system is sensitive to approximately 50Hz and below, although this may range from person to person. Although some light sources will flicker faster than we can perceive, our nervous system will still respond to this modulation in light.[5]

Visual Sensitivity

Frequencies in the range of 100Hz – 120Hz (above visible threshold) have been demonstrated to cause headache and eyestrain. The sensitivity to flicker in this range and above is a spectrum, and the effects on the population are not quantified. However, studies have shown that performance on tasks decreases with long exposure to frequencies in this range.[6] Persons on the autism spectrum are typically hypersensitive to visual stimuli, and are especially susceptible to encountering issues with flicker in lighting.[5]

Photosensitive Epilepsy

One in four-thousand people are affected by photosensitive epilepsy. Short exposure to 3Hz – 70Hz (visible modulation) may cause seizures in sensitive people.[5]

Frequencies between 120Hz and 40,000Hz can have chromatic effects, and may possibly affect neural and behavioral outcomes, although this range has not been as well characterized as below 120Hz.[7]

Electronic and Mechanical Issues With Flicker

Barcode Scanners

The sensor of a barcode scanner emits light on a high frequency light carrier to operate, which functions to generate contrast between black and white. The typically infrared signal from a barcode scanner has to reach the barcode and bounce back to the receiver for the scanner to work properly. If a room's light source is flickering at a frequency similar to the barcode scanners' carrier, the scanner will not function.

Video and Photo Equipment

Modern camera devices have shutter speeds that are fast enough to catch moving objects and show extremely high resolution of objects. If the lights in a room are flickering faster than the shutter speed or video scan rate, banding lines or "aliasing" show up in the image, and exposure can be ruined in photos.

Investment to Remove Flicker in LED Lighting

Removal of the output ripple of a driver is not automatic. Additional circuitry must be introduced to regulate this to stable, direct current.

The cost of flicker removal is not substantial. The removal of the flicker represents a loss of efficiency, commonly around 5%. However, the additional cost of the product and the reduction of lamp efficiency is arguably much less than the loss of productivity associated with headache and eye strain.

Eliminating flicker from lighting can greatly improve the learning environments of students with hypersensitivity to light and sound such as students with Autism Spectrum Disorder.

Measuring Flicker

With your Smart Phone

Current smart phone devices, that have 240 frames per second capability, have incredibly high-quality cameras. Holding your phone camera up to a television or computer monitor, or even your light source, can show banding. A slow-motion video will make a scene with a flickering light source appear like a strobe light at a disco as the lights appear to flash on and off.

With an Oscilloscope and Photocell

A more traditional and quantitative approach to measuring flicker is using an oscilloscope. By collecting light input in real time with a connected photocell, an oscilloscope can detect the waveform of the light pattern, and provide the information needed to calculate flicker index or percent-flicker.

Conclusion

Not all LEDs are created equal. While the industry continues to study and standardize flicker, many manufacturers continue to make products that have substantially greater flicker than the lights they were meant to replace. While these products may have lower initial cost, it shows insensitivity to the health and well-being of those operating under the lights every day.

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