Flicker

What is flicker?

Flicker is defined as the variation of light output over time and occurs in every light source, at varying degrees, usually as their power is drawn from an AC source (frequency of 50Hz in the UK). Modulation in light output can be caused by the light source itself. This is known as *photometric flicker* and varies with each technology, for example, an incandescent bulb does not appear to flicker due to its inefficient thermal persistence keeping the filament hot, masking the switch in direction of the current [1]. In contrast to this, an LED responds instantaneously to changes in the power supply so any effect of photometric flicker is obscured by *electrical flicker* such as noise on the AC distribution lines or dimming an LED using pulse width modulation [2].

Measuring flicker

There are a couple of metrics that are commonly used to quantify the extent of flicker in a light source, namely *percent flicker* and *flicker index*, defined by the US IESNA organisation. Percent flicker describes the modulation in light output using the maximum and minimum intensity values and has a scale from 0 – 100%. Flicker index considers the shape of the waveform relative to the average light intensity and has a scale of 0 – 1.0. Figure 1 illustrates the values used in the below equations.

$$Flicker\ index = \frac{Area\ 1}{(Area\ 1 + Area\ 2)}$$

$$Percent\ flicker\ (\%) = \frac{100 \times (Max - Min)}{(Max + Min)}$$

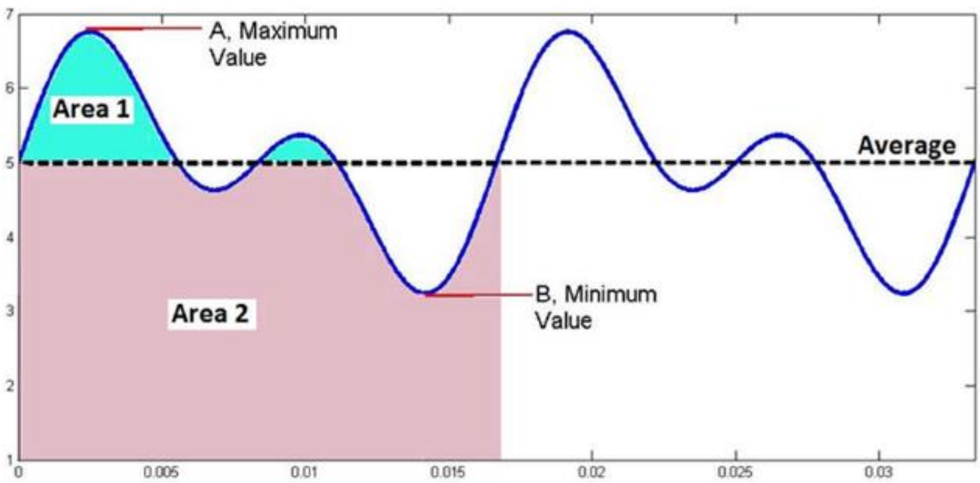

Figure 1 – Illustrating calculation of the flicker metrics [3]

Flicker needs to be measured using instrumentation which incorporate filters that scale the detector response to that of the standard CIE luminous efficiency function.

Flicker and health

Although every light source flickers to some extent, it is not always visible. Flicker is typically periodic, and whether the flicker is visible or not to the human eye depends on a few characteristics of the waveform including the amplitude modulation, dc component (average value), shape of the waveform and the frequency. It also depends on the sensitivity of the individual observer, the contrast between the light source and background, and the position of the light on the retina.

When describing flicker as 'visible' it means that the observer is consciously aware of, and senses, the modulation of light output. This usually occurs when the frequency of the modulation is less than 60Hz. When 'invisible' the observer can still sense the flicker, but is not consciously aware of it. This effect can occur anywhere between 60-100Hz depending on the light source and the individual and is called the *critical flicker fusion frequency* (CFF) [3, 4]. If someone senses flicker in an external source, even when not consciously, the neurological system responds. This can cause headaches, general malaise, eye strain, fatigue, migraines, and in some cases, may aggravate autistic behaviour and cause photosensitive epileptic seizures (500,000 people have epilepsy in UK, 5% of that number have photosensitive epilepsy and are most sensitive between 3 – 70Hz) [5].

As well as the responses of the neurological system, flicker also poses a threat in industrial settings. The *stroboscopic effect* is an illusion that occurs when a moving object appears to be moving at a different speed, in an opposite direction or even stationary when illuminated intermittently. This can happen if the frequency of flicker in a light source is a multiple of the frequency of a moving object and can increase the risk of accidents in workplaces that use moving machinery.

LED flicker

Flicker was initially an issue for lighting manufacturers and engineers when fluorescent lighting replaced incandescent bulbs [6]. The flicker in these instances was found to be caused by the magnetic ballasts that were being used to limit the current in the tube. These were replaced with high frequency alternatives so that the flicker was no longer perceived by human observers.

Flicker has become a problem again now that LED lighting has become more prevalent. As mentioned earlier, LEDs have no persistence. This means when powered directly from an AC mains source they switch on and off 50 times a second which is seen by human observers. To stop this from happening, modern LED installations use transformers that convert AC to DC. This doubles the frequency to 100Hz - a value that is unlikely to be perceived [7].

The flicker in LEDs is known to become particularly bad when connected to a domestic dimmer switch, sometimes making flicker perceivable in LED sources that would be flicker-free otherwise. Analogue dimming of an LED, when the drive current is reduced linearly (50% current = 50% light output etc), can cause changes

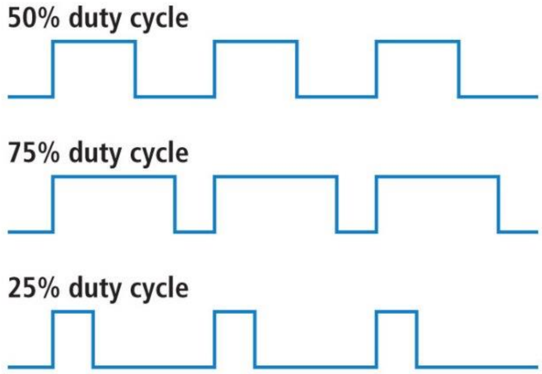

Figure 2 - Pulse width modulation (PWM) waveform [13]

in its colour temperature. To avoid this change, LEDs are dimmed using pulse width modulation (PWM). This stops the change in colour temperature as the LED is always operating at maximum current when ON. The *duty cycle* is used to describe the time the LED is ON. With this technique, 50% light output is achieved by having the LED driven by pulses that have equal time ON as they have OFF (see 50% duty cycle in Figure 2). A human observer sees the average light output over time as long as the switching frequency is high. If the LEDs are dimmed, the frequency of the flashes decreases, causing visible flicker.

Recently, the Institute of Electrical and Electronics Engineers (IEEE) has published recommendations on how to reduce or eliminate flicker in LED lighting. This working standard: IEEE 1789-2015 "Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers" discusses the biological risks associated with flicker and suggests ways in which it can be avoided [3]. Suggested in this document are calculations that can be done to find the maximum percent flicker (modulation (%)) that will either lower the risk of biological effects, or prevent them completely ('No observable effect level' or NOEL). These values are displayed on the graph in Figure 3.

Frequency above 90Hz:

Low risk max modulation < 0.08 x Frequency

NOEL < 0.0333 x Frequency

Frequency below 90Hz:

Low risk max modulation < 0.025 x Frequency

NOEL < 0.01 x Frequency

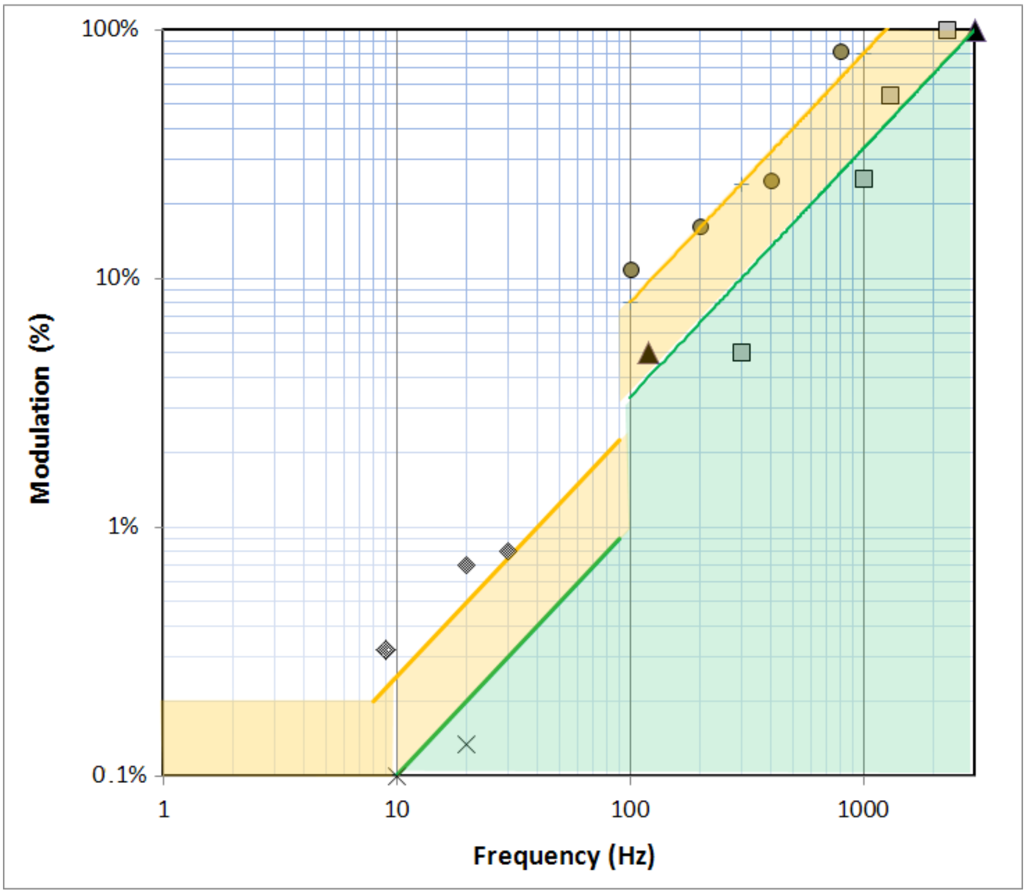

Figure 3 - Graph showing low risk (yellow) and NOEL (green) modulation percentage against frequency [3]. The data points on this graph relate to data from research into visible flicker (diamonds [8, 9]), stroboscopic effects (squares [10] and circles [11]) and phantom arrays (triangles [12])

Further reading

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