

Understanding Stroboscopic Effects (Flicker)

Flicker of a light is the rapid variation in output of a lamp over time, and can be characterized by its (dominant) frequency and modulation depth (the variation between the maximum and minimum intensity).

Whether flicker is directly visible depends largely on the dominant frequency. When the frequency is relative low below 90Hz - or 90 modulations per second - flicker is visible for most people under most conditions. At higher frequencies, flicker may no longer be directly visible but can be detected with fast eye or head movements or by moving objects quickly. This phenomenon is also known as the stroboscopic effect.

Sunlight has no flicker, and incandescent and halogen lights have minimal flicker because they are thermal radiators and have a relatively long persistence (due to the thermal capacity of the tungsten filament). Gas discharge lamps such as fluorescent lights and solid state light sources such as LEDs and lasers have no or very short persistence by nature, which means that their ballasts and drivers need to supply a stable or high frequency power to the lamp to avoid flicker.

Fluorescent lamps for example, had flicker when mostly line frequency magnetic ballasts were used. Studies involving these kind of ballasts showed a doubling incidence of headaches with office workers, triggering of migraines in people sensitive to it (about 10% of the people), and impairment of performance. Even worse, with aging of the lamps AC polarity dependent fluctuation could start to occur in the 20-70 Hz frequency ranges, which can induce epileptic seizures! With the introduction of electronic ballasts for fluorescent lights most of the flicker problems were eliminated.

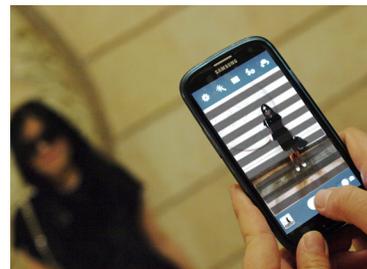
Flicker problems started to emerge again with LED lights, mainly driven by the need to lower the cost and size of LED lamps. Cost and size can be reduced by only minimally processing the AC signal, which directly exposes users to double line frequency flicker similar to that caused by magnetic ballasts for fluorescents. And the problems get even worse when LED lights are dimmed — directly visible flicker can occur depending on dimmer-lamp (in)compatibility.

Even at higher frequencies (up to 2 kHz) flicker can induce eyestrain and fatigue due to eye movements or 'saccades'.

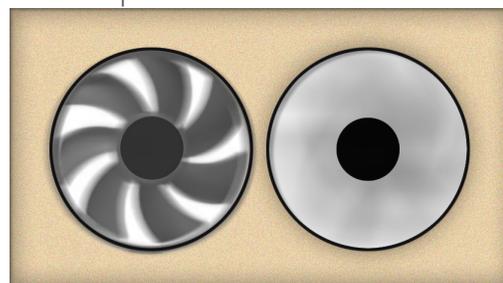
A saccade (/si'ka:d/ se-KAHD, French for jerk) is a quick, simultaneous movement of both eyes between two phases of fixation in the same direction.

These are needed to see or else our vision would start to fade. We are normally not aware of these saccades as our brain filters these out and provides a stable view of our environment. However, when lights flicker the image processors in our brain start to get confused, resulting in eyestrain and fatigue. This is a subliminal, unconscious effect, and we normally don't associate these problems with flickering lights.

An additional problem that is associated with flicker is banding which can occur when taking photos or recording video. When modulation interferes with the frame rate of the camera, dark bands can occur. This can be especially problematic when video systems are depended upon for security and safety reasons, or for example in video conference rooms.



Lastly, flicker in a light source may cause rotating objects to stand still or move at much slower speeds. This can result in hazardous situations when objects may seem safe to touch because they appear to move slowly but in fact have high speeds which can cause injuries. A related effect is ghosting, where fast moving objects no longer appear to moving continuously but are observed in discrete steps.



Circular Fan Demonstration - Notice the "ghosting" on the left as the fan spins. The fan to the right representing Xicato XIM does not show ghosting.

Lighting Flicker & Ghosting Health Risks



How to avoid flicker problems? How do you know if LED lights flicker or not? And how does flicker increase when the lights are dimmed?

First you need to realize that you can not tell if lights flicker by looking at them. If you can see flicker you are already far into the danger zone: when flicker can be seen, there is a risk of epileptic seizures! And as with fluorescent lights the real problem is not with the light itself but with the LED driver. It can be tested using a flicker wheel, although this is somewhat of a subjective test but at least this can be used as a good 'sanity check'. Measuring flicker requires a photodetector and an oscilloscope and can be fairly easily measured by the manufacturer and independent testing labs. Easy to use and good quality tools for use in the field do not really exist yet.

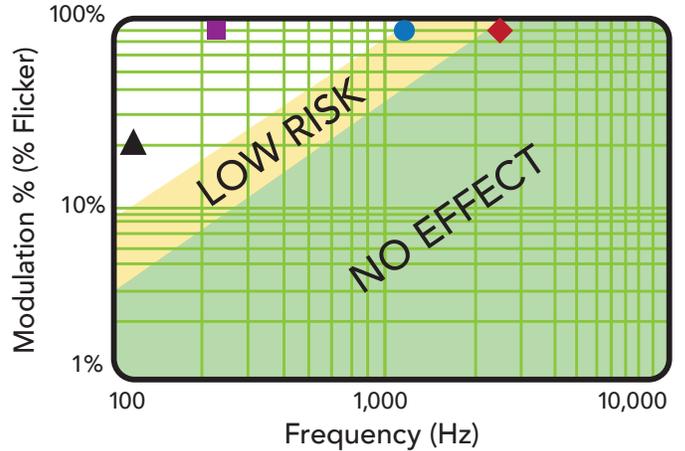


Xicato Flicker Wheel is available. Please contact us for your complimentary tool. marketing@xicato.com

Fortunately, standards have been developed, based on published studies and research, such as the article from September 2014 by Brad Lehman and Arnold J. Wilkens in the IEEE Power Electronics Magazine titled: 'Designing to Mitigate the Effects of Flicker in LED Lighting'. These investigations resulted in IEEE Std 1789-2015: "Recommended Practice for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers". This standard allows lighting designers and specifiers to specify a requirement for low flicker. For details please see the standard.

As a simple means for determining risks associated to flicker, you can use the following formula:

$$FR = 40 \times M(\%)/f$$



- Recommended Low Risk Minimum (1250Hz)
- ◆ Xicato XIM at 1% Dim Level (2500 Hz)
- "Quality" Dimming Driver at 5% Dim Level
- ▲ "Mainstream" Dimming Driver at 20% Dim Level

Above: IEEE 1789 risk zones showing various typical solutions
Below: More typical examples

FR	< 1	1 - 3	> 3
Risk level	None	Low	Substantial Risk: Should be avoided

Dim Level	Xicato XIM			LED Driver	
	100% to 20%	20% to 1.2%	1.2% to 0.5%	100%	99% to 5%
Frequency	Constant	≥ 3000 Hz	≥ 2500 Hz	200 Hz	200 Hz
Modulation Depth	0%	100%	100%	0%	25%
FR	0	1.33	1.60	0	20
Risk level	None	Low	Low	None	High
IEEE Flicker Risk Zone	None	No Effect	Low	No Effect	High

Dim Level	Good Retrofit Lamp		Poor Retrofit Lamp	
	100%	10%	100%	10%
Frequency	120 Hz	120 Hz	120 Hz	120 Hz
Modulation Depth	25%	25%	100%	100%
FR	8.3	8.3	33.3	33.3
Risk level	High	High	High	High
IEEE Flicker Risk Zone	High	High	High	High

In conclusion, it is important to note that it is the LED driver that determines the characteristics of the light with respect to flicker. Depending on how dimming is implemented, the risks associated to flicker can be high.

With XIM, Xicato has found a way to deliver a solution that not only dims very well but also is low in risk for negative effects associated with flickering lights.