

Email received on February 3, 2010 from Victor Zwanenberg.

Sir,

In line with your request for comments in your letter date 22 January 2010, some comments on LED operating frequency. I have some (6 years) expertise in the field of dimmable LED lamps and did several investigation in relation with visible flicker from LED lamps under both dimmed and undimmed conditions.

In my opinion, visibility of modulation of LED light depends on the current through the device and the decay time of the phosphors in 'white' LEDs. LED's without phosphor can be modulated in light output with a bandwidth >100KHertz. The decay time of current phosphors on white LED's is much smaller than the time constant of human eye detection.

For perception of flicker, two parameters are of importance: The modulation frequency/dutycycle and the modulation depth. There is a transitional field between these parameters where visibility of flicker is highly arbitrary. As example: Using a LED driven in PWM mode at a frequency of 150Hz with full current modulation at a dutycycle of 10%, flicker will be visible. Using a LED driven in constant current mode with a current ripple of 20% at 100 Hertz, flicker will not be visible. The frequency of variation for which the human observer is most susceptible is around 10 Hertz. The variation causes severe stress and might induce epileptic attack.

Visibility of flicker is, as previously stated, highly arbitrary and depends on surrounding conditions, like ambient light level, angle of view over which light variation is seen, color of the light, age of the observer, duration of the exposure, and application. In practice, using task lighting or office lighting using full modulation with a suggested frequency of 120 Hertz, severe fatigue will occur with most people. This will in turn result in head-aches and rejection/replacement of the lamps. An early test at the local counsel of Hoogeveen (Netherlands) shows such an effect. The motivation why 120 Hertz is proposed by some manufacturers is, that energy storage to bridge the ripple caused by the mains input waveform is no longer required in full. This saves cost, saves space, and will make lifetime of electronics less critical since electrolytic capacitors can be avoided. However, when these products are mass-introduced into the market as replacement for existing lamp technologies, they will be rejected by the public because of perceived poor quality of light. This will hamper LED reputation and stalls further market introduction. It is fully feasible to design LED lamps using electrolytic capacitors and high lifetime, and the cost adding factor is in fact marginal in comparison to current end product costs. Deep modulation of light level will also cause motion artifacts on moving or dynamic objects, so unsuitable for area's with movement. As third factor, deep modulation will cause inter-modulation of light level when using a digital camera: recordings on these camera's will show slow but deep change in light level.

I would propose a more balanced specification of light level variation than based upon frequency only:

- At full current modulation (0-100%) modulation frequency must be 200Hz or larger.
- Between 200 and 120 Hertz modulation frequency, the ripple in light level must be within a bandwidth of +40%/-40% of the average value of light level.
- At 120 Hertz modulation frequency, the ripple in light level must be within a bandwidth of +30%/-30% of the average value of light level.
- Between 120 and 95 Hertz modulation frequency, the ripple in light level must be within a bandwidth of +20%/-20% of the average value of light level.
- Modulation frequencies between 95 Hertz and 1 Hertz are not allowed.

Light level in above proposal is expressed in Lux.

I hope this information will be helpful to set up a specification that better meets various market interests,

With regards,

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