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2016 Building Standards Update

Comments submitted by AccurIC Ltd, via Docket number 14-BSTD-01

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Background:

AccurIC Ltd is a UK-based innovative start-up, in the area of LED lighting. It holds patents in the area of LED driver technology and is actively engaged, through its CEO, Dave Bannister, in the Institution of Electrical and Electronic Engineers (IEEE) Standards Association (SA) process in drafting recommended practices for the reduction of flicker in LED lighting. As such, AccurIC Ltd applauds the efforts of the California Energy Commission in seeking to address this as well as associated issues, such as dimming and Power Factor, as part of its process of updating the Building Energy Efficiency Standards for the State of California. It also therefore, welcomes the opportunity to comment on those proposed updates that relate to lighting. In doing so, however, AccurIC Ltd wishes to make clear that the comments offered herein reflect the views and opinions of the Company itself and do not purport to represent any official position of the IEEE. That said, the data and peer-reviewed research on which these comments are based are also the data and peer-reviewed research on which the draft recommendations of the IEEE PAR1789 Working Group are based and the recommended performance figures quoted in the main body of this submission are taken directly from the draft recommendations of the Working Group.

The general thrust of our comments concerns the various performance criteria that collectively define 'quality' in high-efficacy lighting in general and LED lighting in particular. It is therefore perhaps useful, before making our comments, to define what AccurIC regard as high quality. The definition of a high-quality light-source, which has driven the development of our technology is a one capable of achieving:

Dimming down to below 1% and preferably down to 0.1%

A peak-to-peak current ripple (at 100-120 Hz) of less than 0.1% and maintaining less than 0.2% peak-to-peak ripple at all dimming points – thereby ensuring that flicker percentage (Michaelson Contrast) remains below 0.1% throughout the dimming-range

Power Factor greater than 0.9

Driver Efficiency greater than 90% at full load and greater than 80% at all dimming points

High driver MTBF – due at least in part, to high driver efficiency

Technologies that enable this level of performance, across all power-ranges and applications (including light bulbs, commercial lighting systems, street lighting and tunnel lighting) are due to become available within the timescale of the recommended standards emerging from the CASE process – namely, by 2016. We appreciate that setting standards by reference to the very best emerging technologies might be seen as unnecessarily restricting supply. However, as our following comments indicate, there is now a significant body of peer-reviewed research that indicates a clear need to reduce photometric flicker from light sources, including high-efficacy sources such as LED. Furthermore, the evidence strongly indicates that these levels of flicker should be in the single digits percent at low frequencies and should apply at all dimmer-settings. Using the same data, the research also leads directly to the conclusion that Pulse-Width Modulation (PWM) – often used to produce dimming – should be restricted to frequencies above 1.25 KHz and preferably above 3 KHz.

Comments:

We wholeheartedly support the assertion made in the CASE document entitled *Residential Lighting* and dated September 2014, that 'If JA8 compliant products such as LED, provide high quality illumination that customers expect, it is unlikely that they will revert to less efficient technologies'. This assertion is very-much in line with the growing commentary within the lighting industry press, around the importance of quality in determining the long-term acceptance of high-efficacy technologies, such as LED. It is in support of this assertion and the clear aim that lies behind it – namely, of improving such quality – that we offer what we hope the Commission will see as constructive input, aimed at ensuring that by 2016, the quality of LED and other high-efficacy lighting technologies is sufficient to achieve this goal. Within the wide definition of 'quality' it is becoming clear that issues around photometric flicker and dimmability are becoming increasingly important in influencing customer experience and therefore customer acceptance of LED lighting.

In that context, we further support the Commission's aim of encouraging the reduction of flicker from high efficacy light sources, including LED, to at least a level that is similar to incandescent sources, and to ensure that such low-flicker performance is maintained throughout the dimming-range of the lighting fixture. It is therefore important to bear in mind that incandescent bulbs typically give a flicker percentage (aka modulation depth, or Michaelson Contrast) of around 8% at the second harmonic of the mains frequency. It would

therefore seem rational to use this figure as a guide in defining what would be regarded as acceptable for LED lighting, within the proposed low-pass filtered frequency band DC to 200 Hz. We appreciate, however, that the performance of an incumbent technology cannot be the sole basis on which to establish acceptable performance limits for a replacement technology. After all, it may be the case that the performance of the incumbent technology (in this case, incandescent bulbs) exceeds that which users would find acceptable. Guidance must also be sought, therefore, from research.

The CASE report, on pages 17 to 18, reviews the latest relevant research (LRC 2012 and Lehman et al, 2014). In particular, it overlays the maximum flicker level proposed in Appendix JA8 of the CASE report (namely, 30% for frequencies less than 200 Hz) and comments:

'This region of frequencies and amplitude modulation is detectable by at least 80% of the population and the stroboscopic effects are considered very unacceptable'.

We respectfully suggest that reducing the effected population to something (just) below 80% and increasing the average acceptability level amongst the population as a whole to something (just) above 'very unacceptable' would not do justice to the Commissions' stated and laudable aims. Furthermore, the results given in both research documents cited, support very strongly the assertion that the level of flicker provided by the average incandescent 60W bulb (around 8%) is indeed a very good guide to what is borderline-acceptable for a replacement technology, such as LED. This level of flicker for frequencies up to 200 Hz lies in a region of the LRC data that corresponds to 'somewhat acceptable' and detectable by around 40% of the population. Similarly, 8% flicker at frequencies up to 200 Hz sits within the low-risk region of the data presented by Lehman et al. By contrast, as is clearly shown in the CASE document, the level of flicker suggested by JA8 (30%) sits firmly in the high risk region.

Turning to the draft recommendations of IEEE PAR1789, the recommended maximum level of flicker at 120 Hz (twice US mains frequency) is 10%. This maximum level is recommended in view of the fact that it sits at the boundary between Low risk and High risk of detection of stroboscopic effects. Furthermore, this level should be achieved under all operating conditions, including dimmed operation.

The frequency 120 Hz is chosen, as it corresponds to the dominant frequency component produced by the first operation of an LED driver – namely, the full-wave rectification of the incoming mains at 60Hz. It therefore represents the strongest flicker component present within an LED lighting fixture at frequencies below 200 Hz.

As indicated above, alongside the issue of flicker, lies the often-associated issue of dimming. The two are often connected in people's minds by the fact that the action of dimming – for instance, by use of a phase-cutting dimmer – can give rise to flickering during deep-dimming, due to interactions between the dimmer-switch and the light source. However, there are other effects that cause flicker to increase (again at twice mains frequency) as a light source, such as an LED, driven by a driver circuit, is dimmed. Chief amongst these is a drop in the efficiency of the driver when deeply dimmed. However, whatever the cause within a given

fixture, it is clearly important to establish a maximum flicker level at frequencies below 200 Hz that applies throughout the dimming range.

To that end, the CASE document and its appendix JA8, proposes that the maximum level of flicker to be set in the 2016 standard should apply both to full brightness and a dimming level that corresponds to 'dimmed operation'. In proposing this, however, an inconsistency seems to have arisen in the choice of dimming level to which the maximum flicker level should apply. Whilst the document proposes that high-efficacy lighting fixtures should be dimmable down to 10%, the same document proposes that the maximum flicker percentage should apply at both full-brightness and 20% dimmed. We strongly suggest that in order to establish consistency in the resulting 2016 standard that the flicker criterion should at least apply down to the 10% dimming level.

Alongside this, on the issue of dimming performance itself, we wish to point out that, due to the response of the eye, 10% dimmed (light output being 90% down on full brightness) corresponds to a perceived brightness level of 32% (light output is perceived as being down by only 68%). We therefore suggest that in order for the minimally-acceptable dimming performance to correspond to a perceived dimming level of 10%, the minimally-acceptable dimming depth for a high-efficacy light source should be 1%. In our submission, in an era which will see lighting controls and daylight harvesting methods increasingly used in residential and commercial buildings, such a minimally acceptable deep dimming capability will be seen as a "must have" rather than simply as a desirable feature.

On page 15 of the CASE document, it is clearly indicated that the 2008 Title 24 development process took on-board comments from LED manufacturers concerning the use of Pulse-Width Modulation (PWM) to affect dimming. PWM applies a 100% modulation – thereby giving rise to 100% flicker. It was stated at the time that such modulation 'did not result in perceptible flicker because this amplitude modulation was occurring at very high frequencies'.

There has been much work done since, in investigating the effect of PWM, with a view to establishing a minimum frequency, above which PWM-based dimming can be applied to a light-source, such as LED, without giving rise to perceptible and unacceptable flicker effects – including stroboscopic effects. Indeed, the main body of work in this area has been based on the very research that the Commission rightly cites within the CASE document – LRC 2012 and Lehman et al, 2014. Based on these, together with the draft recommendations of IEEE Working Group PAR1789, a frequency of 1.25 KHz is established as the minimum frequency for PWM dimming. This is established in part, by observing that in Lehman et al, this is the frequency at which 100% modulation falls on the boundary between Low Risk and High Risk operation.

This criterion could and should, in our view, be added to the Commission's Title 24 recommendations by increasing the upper frequency of the highest frequency filtered data to be submitted by manufacturers, from the currently-proposed 1,000Hz to 1,250 Hz and testing for any 100% modulation below that frequency.

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Before summarising our submission, we would like to point out that both the maximum flicker level and minimum PWM frequency cited herein – namely, 10% and 1.25 KHz respectively – are those that are judged by the authors of the draft IEEE PAR1789 recommendations as applying to circumstances where it is desired to limit the possible adverse biological effects of flicker. In order to operate with no effect of flicker – biological, or merely distracting – more stringent limits are proposed. These are less than 4% flicker at 120 Hz and no PWM below 3 KHz.

Summary:

Given the clear purpose of the California Title 24 standards process, namely to define minimum acceptable standards that will facilitate public acceptance of high-efficacy indoor lighting technology, we strongly suggest, on the basis of the available evidence, including peer-reviewed research, that:

1. The maximum flicker percentage, for frequencies up to 200 Hz, be reduced from the currently-proposed 30%, to 10%
2. This maximum flicker percentage be applied both in the undimmed condition and at 10% dimmed
3. There be an additional criterion relating to Pulse-Width Modulation, namely that it should not be used in a high-efficacy light source at any frequency below 1,250 Hz

Yours faithfully,

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