

Energy Efficiency & Renewable Energy

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## FLICKER: Understanding the New IEEE Recommended Practice



#### LightFair 2015 – DOE SSL Program Booth 1875

May 2015

Pacific Northwest National Laboratory Brad Lehman Department of Electrical and Computer Engineering Northeastern University Chair, IEEE Standards PAR1789 Group (LED Lighting)

#### Flicker, flutter, shimmer

- Repetitive change in magnitude over time, or modulation, of the luminous flux of a light source
- Light source modulation
- Visible, invisible, perceptible, detectable (sensation)
  - Sensation: External conditions are detected; neurons respond
  - Visible flicker = Luminous modulation is sensed and perceived
  - Invisible flicker = Luminous modulation is sensed, but not perceived









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## **Flicker - Terminology**

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# Stroboscopic vs. Phantom array effects

- Stroboscopic effect: Luminous flux modulation made perceptible by the motion of objects, when the observer's eye is still
- Phantom array effect:
  Luminous flux modulation made perceptible by the motion of the observer's eye, when the light source is still







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- Neurological problems, including epileptic seizure
- Headaches, fatigue, blurred vision, eyestrain
- Migraines
- Reduced visual task performance
- Increased autistic behaviors, especially in children
- Apparent slowing or stopping of motion (stroboscopic effect)
- Distraction



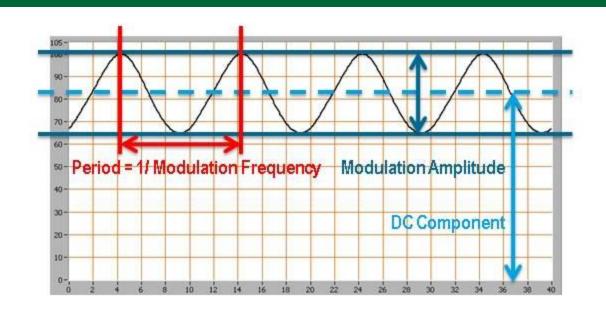
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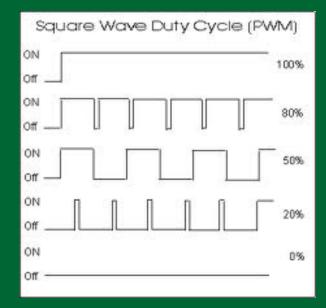
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- Duration of exposure (longer is worse)
- Area of the retina receiving stimulation (greater is worse)
- Location in visual field (central is worse because it projects to a greater area of the visual cortex, even though flicker is less noticeable)
- Brightness of the flash (higher luminances are worse; scotopic luminances produce low risk, high mesopic and photopic luminances produce higher risk)
- Contrast of the flash with the surround luminance (higher is worse)
- Color contrast of flash (deep red is worse)

Flicker factors for both Visible and Invisible Flicker

- Modulation Frequency
- Modulation Amplitude
- DC Component
- Duty Cycle





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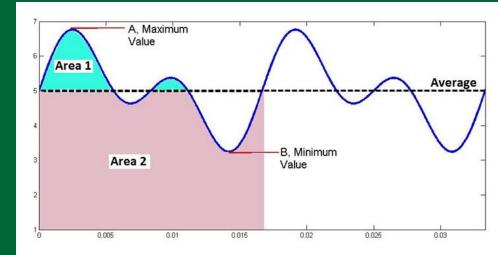
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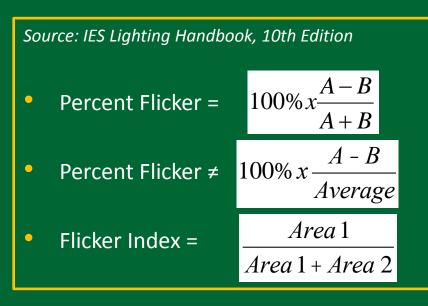
## **Flicker - Metrics**

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IESNA has defined two metrics for flicker:

- Percent flicker
  - 0-100% scale
  - Older, but more well-known and more commonly used
  - Accounts for average, peak-topeak amplitude
  - Does not account for shape, duty cycle, frequency
- Flicker index
  - 0-1.0 scale
  - Newer, but less well-known and rarely used
  - Accounts for average, peak-topeak amplitude, shape, duty cycle
  - Does not account for frequency





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#### (THE SUSPENSE KILLER)

Here's the equation:

## Max % Flicker ≤ Flicker Frequency x 0.08

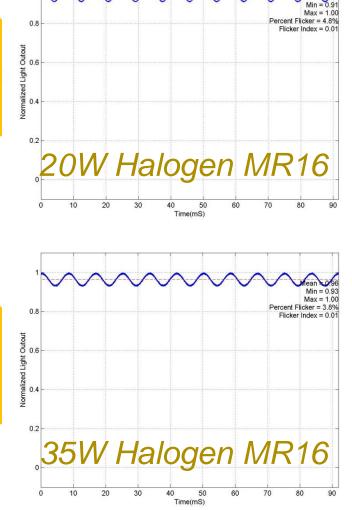
### Incandescent, Halogen, Metal Halide

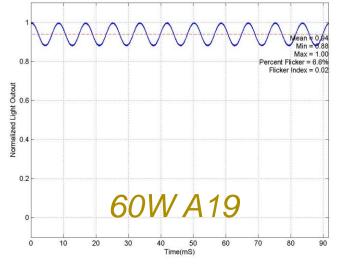
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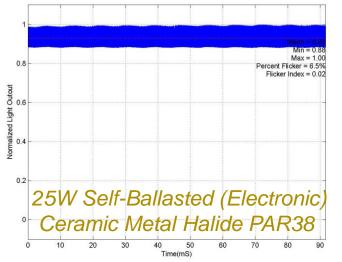






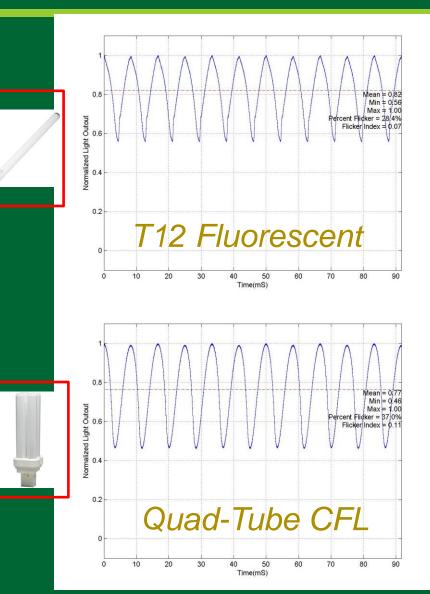


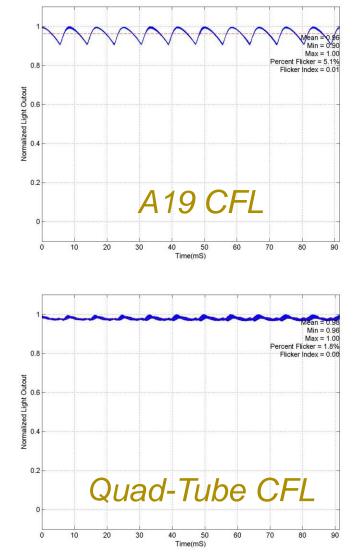




### **Fluorescent**

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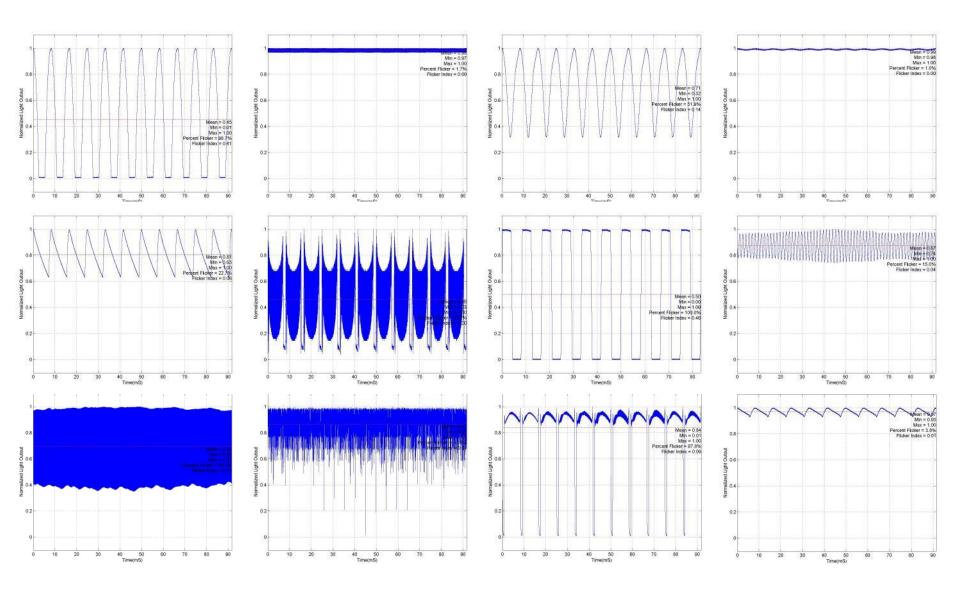




**Magnetically-ballasted** 

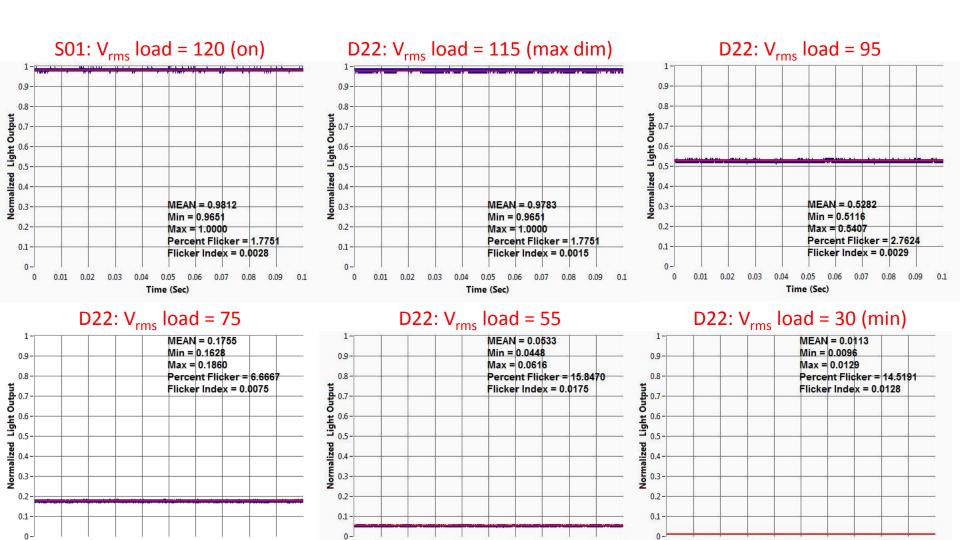
**Electronically-ballasted** 

## Flicker in early LED products (some lamps/luminaires)





#### Effect of Dimming - LED lamp A controlled by phase-cut dimmer



0 0.01 0.02

0.03 0.04 0.05 0.06 0.07

Time (Sec)

0.08 0.09 0.1 0.01 0.02

0

0.03 0.04 0.05 0.06

Time (Sec)

0.07

0.08 0.09 0.1 0 0.01 0.02

0.05 Time (Sec)

0.04

0.03

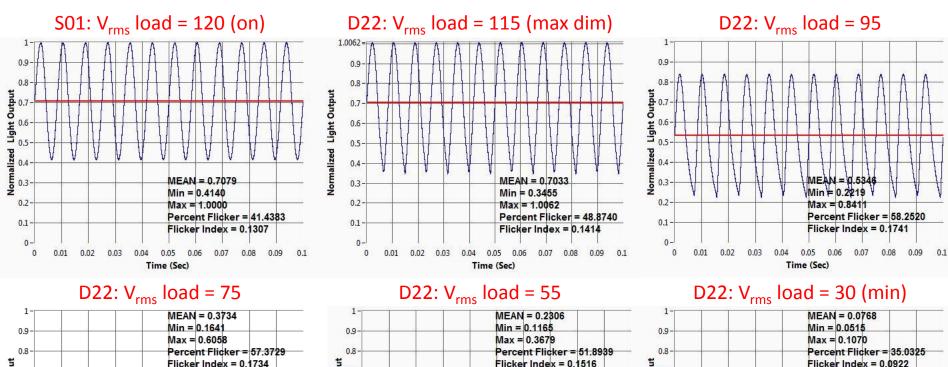


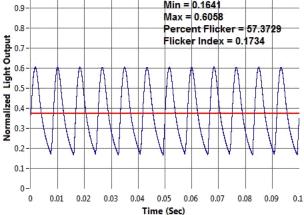
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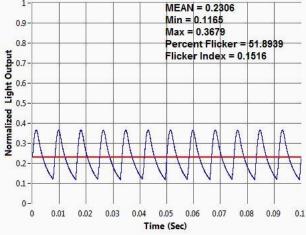
0.1

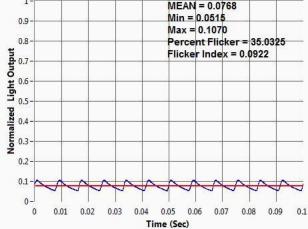
0.06 0.07

#### LED lamp B controlled by phase-cut dimmer



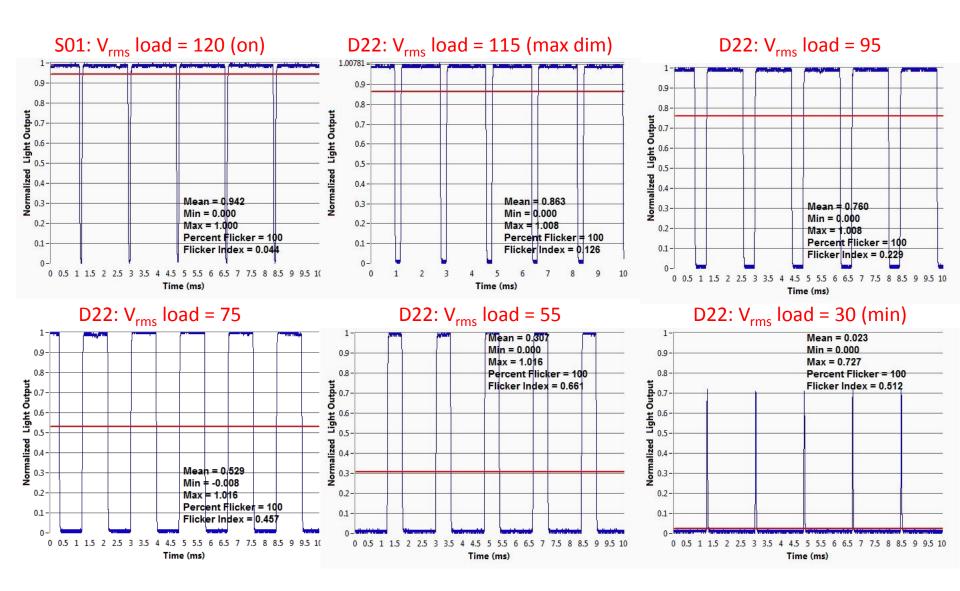






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#### LED downlight controlled by phase-cut dimmer





## What determines flicker in LED sources?

- LED flicker and dimming performance depends on the LED driver
- Dimmers and other electronics can induce or increase flicker

Products more likely to flicker:

- AC LEDs
- DC LEDs with simple/inexpensive drivers (e.g., inadequate capacitors)
- Integral lamp LEDs on some electronic transformers
- LEDs dimmed with phase cut dimmers (triac, e.g.)
- LEDs with Pulse Width Modulation (PWM) drivers







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### How can you tell if a product flickers?

- Flicker waveforms not available from cut sheets yet
- See the product in person, with the same driver/transformer/dimming setting of final installation
- Try a flicker wheel or a spinning top
- Sometimes a digital camera picks up flicker
- Wave your fingers in the light or scan your eyes side to side; look for phantom array effect
- Can't we get a reliable metric???





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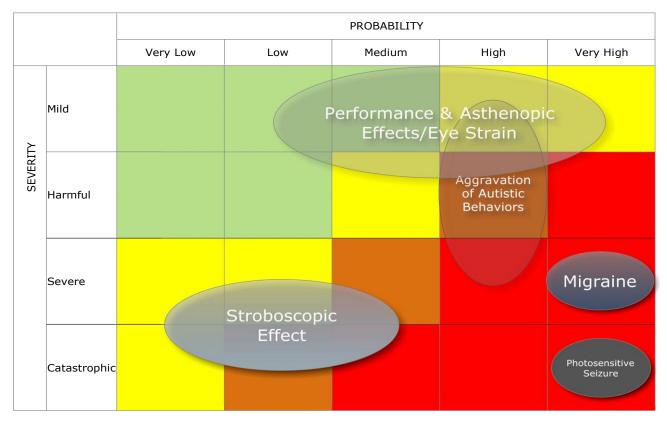
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## **IEEE PAR1789 Recommended Practice**

- IEEE PAR1789 committee formed in 2008 to research issue, evaluate risk of flicker from SSL, and develop recommended practice. (Brad Lehman, chair.)
- Developed Risk Assessment procedure and published document in 2012.

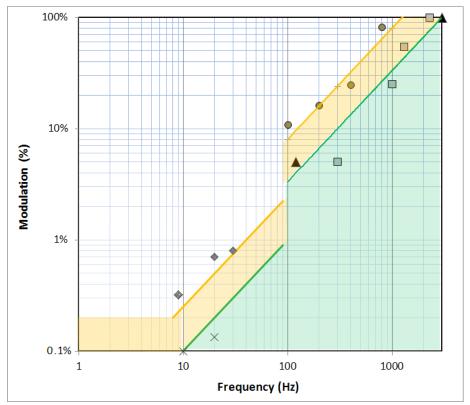




## **IEEE PAR1789 Recommended Practice**

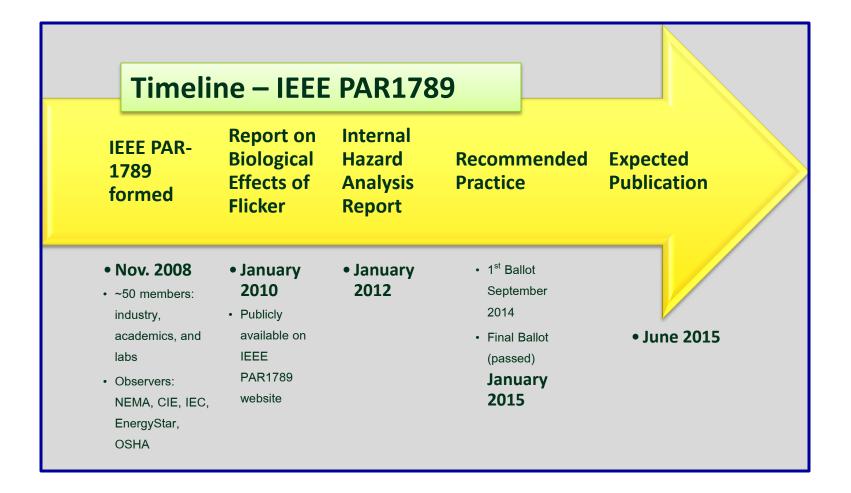
## Methodology for developing recommendations

- Plotted data from multiple studies based on risk level, probability of exposure, and severity of exposure
- Characterized data reliability (from opinion to solid data)
- Plotted % Flicker (modulation) and frequency for no effect level (green) and low risk level (yellow).
- Lehman and Wilkins authored article, "Designing to Mitigate the Effects of Flicker in LED Lighting"
  - IEEE Power Electronics Magazine, Sep 2014
- IEEE PAR1789 committee Recommended Practice written, debated, reviewed, and documented. Recently passed by committee and IEEE Board. Likely to be published in June 2015.





## **IEEE Recommended Practice**





## How to apply IEEE PAR1789 Recommended Practice

- Test to determine the flicker frequency in Hz of the SSL product (it must be ≥100 Hz)
- Test to determine the % Flicker of the SSL product
- Multiply the frequency by 0.08 and round up to the nearest whole number to get the max Allowable % Flicker
- If % Flicker of the SSL product is LOWER than the Allowable Flicker, then the product is acceptable for all but the most unusually sensitive individuals.
- If frequency is difficult to determine, % Flicker shall not exceed 10%.

Example: At 120 Hz frequency, max allowable % flicker is 10%. At 1250 Hz or higher, 100% flicker is allowed.



## Managing Risk: Recommendations

#### Utilities and energy efficiency organizations

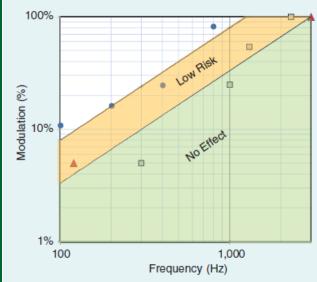
Require flicker documentation for EE programs

#### Manufacturers:

- Be proactive now. Test for flicker. Test over dimming range. (Flicker meters are coming out of the woodwork!)
- Demand drivers that produce less flicker, or higher frequency
- Avoid PWM dimming unless combined with other techniques
- Publish flicker waveforms and flicker metrics

#### **Specifiers**

- Avoid products more likely to produce flicker
- See products in person. Learn to test for flicker.
- Specify products where
  - Flicker Freq ≥ 100 Hz
  - % Flicker  $\leq$  Flicker Freq x 0.08 (normal populations), or
  - % Flicker ≤ Flicker Freq x 0.0333 (special populations)



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#### **Application - Where Flicker Matters**



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**General lighting** 

#### Hospitals/clinics

Classrooms



Task lighting







Offices

## **Where Flicker Matters**



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TV studios/videoconferencing (Anywhere video cameras are used)

## Where flicker is less important



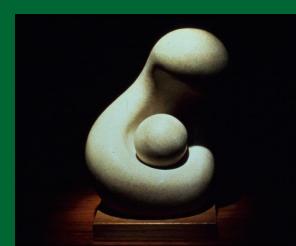
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#### Roadways/parking lots



# Sports and industrial lighting on 3-phase electrical system



Accent lighting on artwork?



Very low intensity holiday lighting?

# Where flicker might be an advanta

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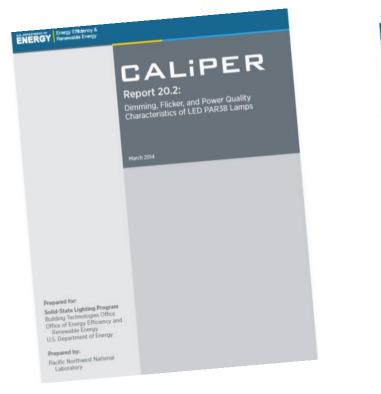


#### Discotheques

#### Warning lights

(Just please avoid the epilepsy frequencies and use for very short duration)

#### In July, Google "IEEE PAR1789 Recommended Practice for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers"



#### **DOE CALIPER Report 20.2**

Emergy Eliclency A Building Technologies Office SOLID-STATE LIGHTING TECHNOLOGY FACT SHEET

#### Flicker

The advancement of commercially available LED products is reopening discussions on how the performance of light sources should be evaluated. This includes questions about the necessity of characterizing light sources for flicker, the (potentially visible) temporal variation of emitted light. While conventional light sources operating on alternating current (AC) modulate light output, the variety and severity of modulation seen with LED products-from good to poor-has sparked new interest in quantifying and understanding its impact.

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LED flicker characteristics are primarily a function of the LED LED finder characteristics use primindly. A function of the LED draw. Duffrest current architectures present different uses of performance two-defies for a draw the decay our whole we can de-sample, a low correspondence to small integral lange may first a finalization in add-off barriers the disks and power factor. Durantizes and 15 marrier on bounder or induce to de-monstration and 15 marrier on bounder or induce to deforce a fundamental trade-off between flicket and power factor. Domining an LED source can increase or induce flicker, most orbidy when plaze-cut controls are used and/or pulse-width modulation (FWM) is employed within the driver to reduce the average light output from the LED source.

#### Why Flicker Matters

Photometric flicker from magnetically-ballacted fluorescent, rmoonsetur manar from magnetically-ballasted mosercer, metal halade, and high-pressure softim hangs has been a con-cern of the lighting community because of the potential human impacts, which range from distriction or mild annovance to impacts, which range trees ostraction or mind anony net vo neurological problems. The effects of flicker are dependent on the light modulation characteristics of the given source, the ient light conditions, the sensitivity of the individuals using

#### **DOE Flicker Fact Sheet**

have not.

the space, and the tasks performed. Low-frequency flicker can

ent clowing or stopping of moving machinery in an industrial When discussing the potential human impacts of flicker, if is When discussing the potential human impacts of fucase, it is important to understand the difference between semiation and perception. Semiation is the physiological detection of external sectors and the sector of external sectors of external sectors and the sector of external sectors and the sectors sectors are set of the sectors are set of

conditions that can lead to a nervous system response, while

perception is do protects by which the brain interpretent, second information. Some ansates of information is not percent, and togen array more to our exercitly and each of default exercitly and the second second second second second second second and the second second second second second second second and the second second second second second second second into the second se

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