U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FLICKER:

Understanding the New IEEE Recommended Practice

LightFair 2015 – DOE SSL Program Booth 1875

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Flicker - Terminology

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

Flicker - Terminology

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

Potential flicker-induced impairments

- 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

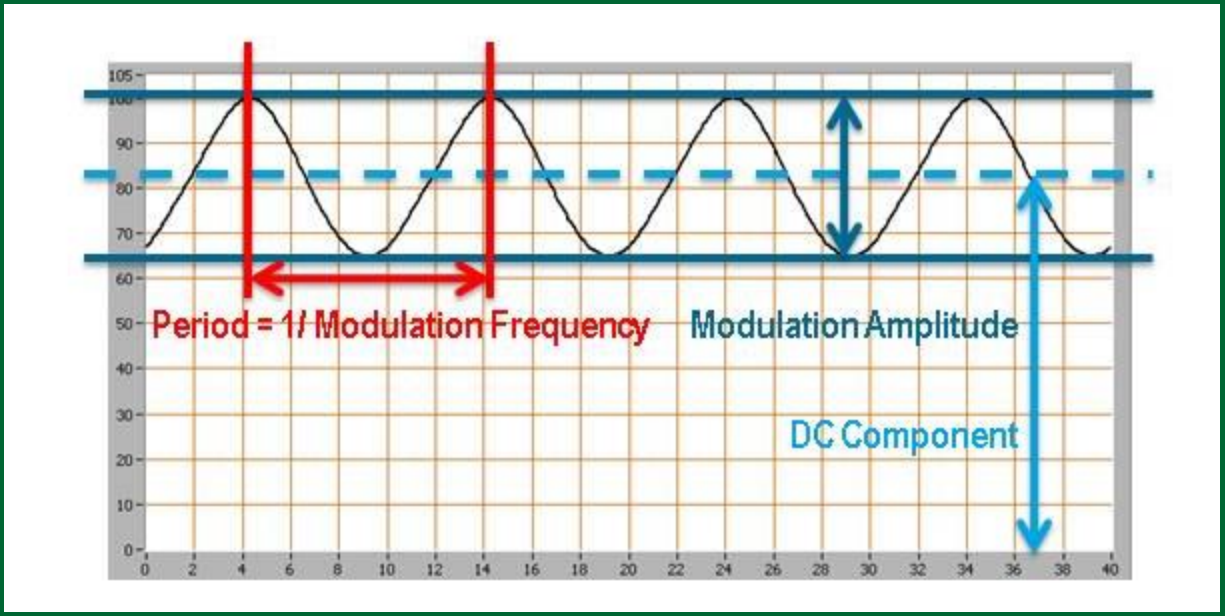
What makes flicker worse

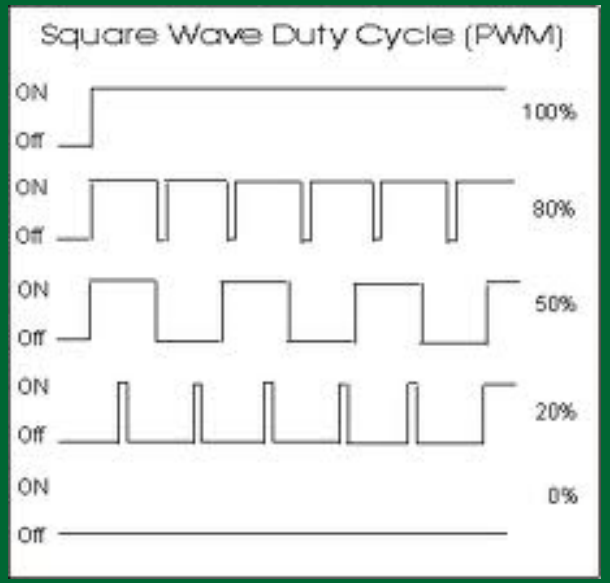
- Duration of exposure (longer is worse)
- Area of the retina receiving stimulation (greater is worse)
- Location in visual field (central is worse because it projects to a greater area of the visual cortex, even though flicker is less noticeable)
- Brightness of the flash (higher luminances are worse; 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

Flicker factors for both Visible and Invisible Flicker

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



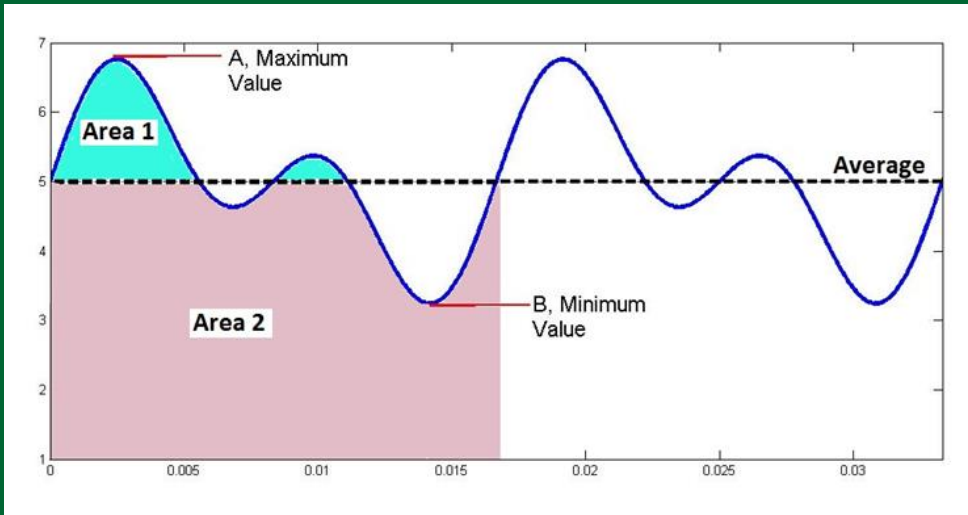


Flicker - Metrics

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-to-peak 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-to-peak amplitude, shape, duty cycle
  - Does not account for frequency



Source: IES Lighting Handbook, 10th Edition

- Percent Flicker = $100\% x \frac{A-B}{A+B}$
- Percent Flicker ≠ $100\% x \frac{A - B}{Average}$
- Flicker Index = $\frac{Area\,1}{Area\,1 + Area\,2}$

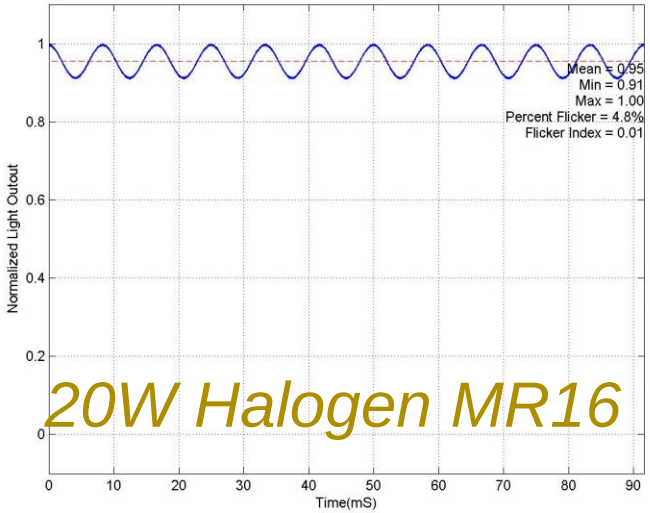
Flicker – Applied Metrics

(The SUSPENSE KILLER)

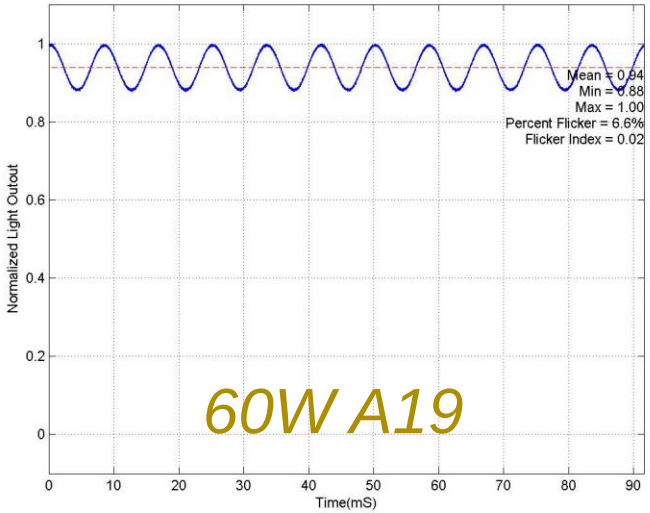
Here's the equation:

Max % Flicker ≤ Flicker Frequency x 0.08

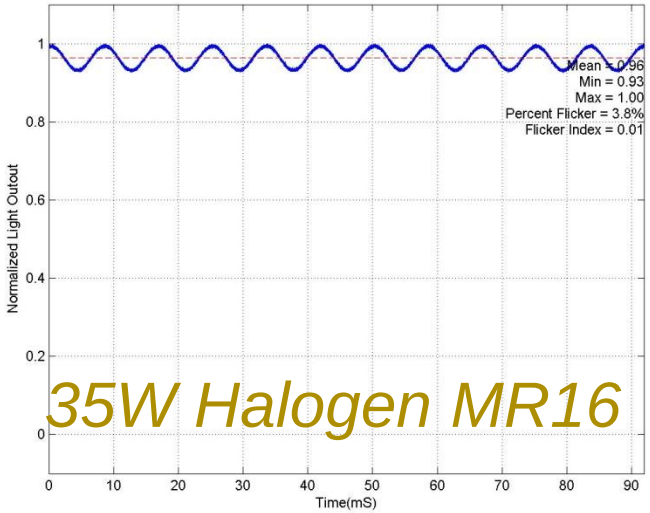
Incandescent, Halogen, Metal Halide



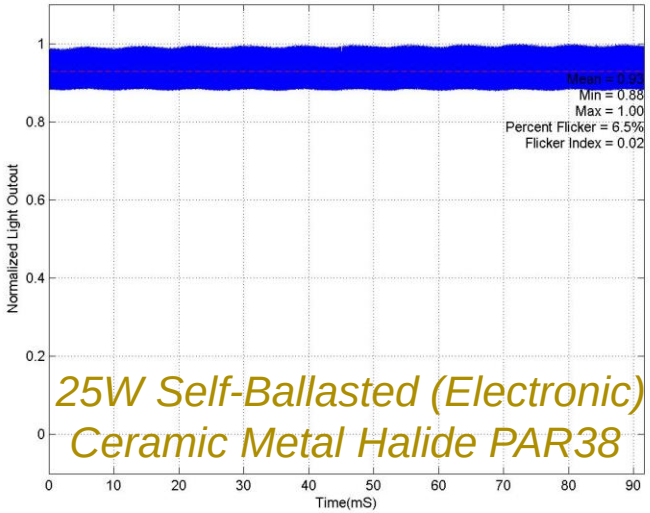
20W Halogen MR16



60W A19

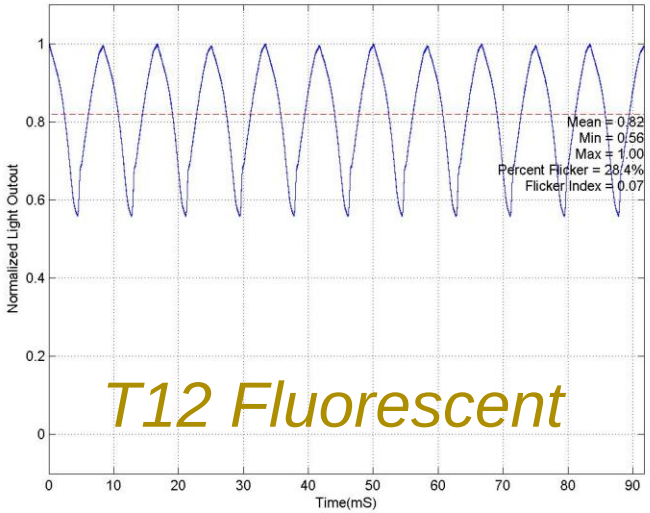


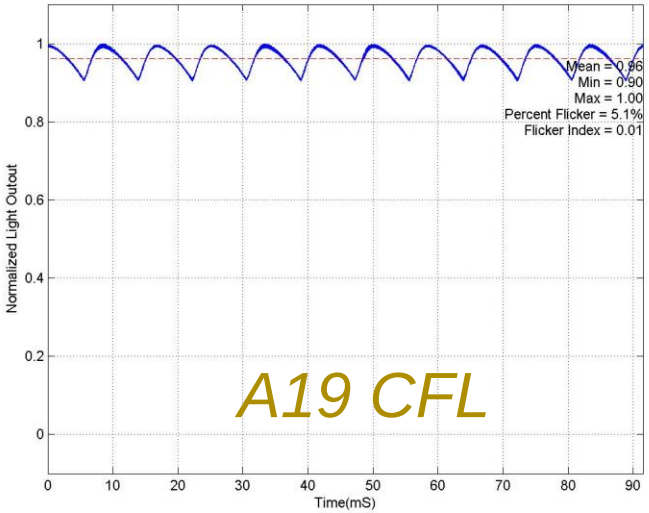
35W Halogen MR16

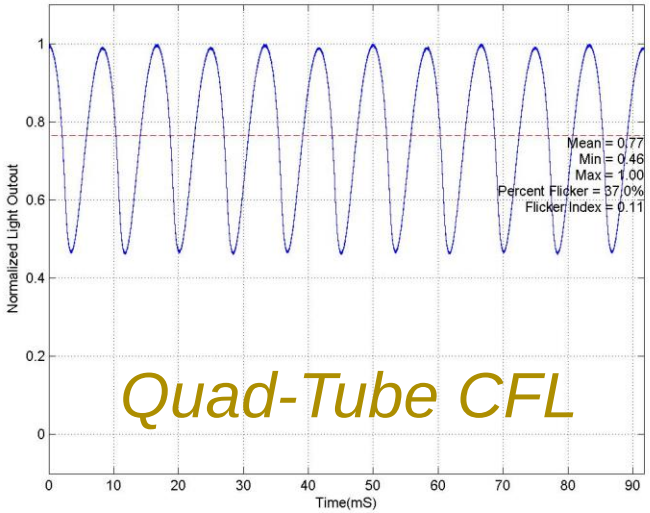


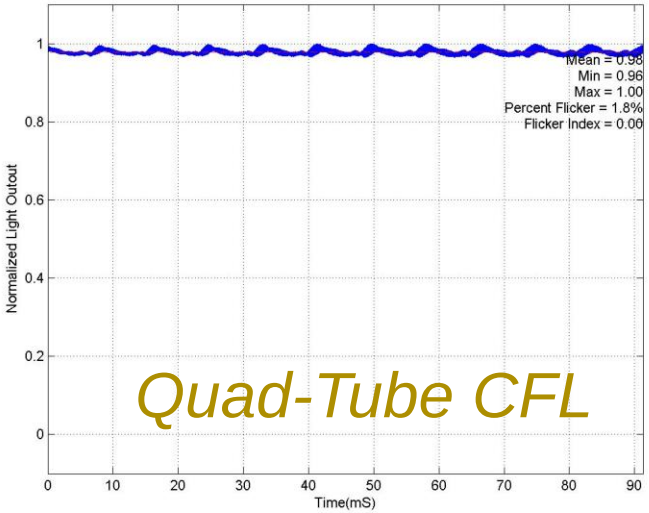
25W Self-Ballasted (Electronic) Ceramic Metal Halide PAR38

Fluorescent



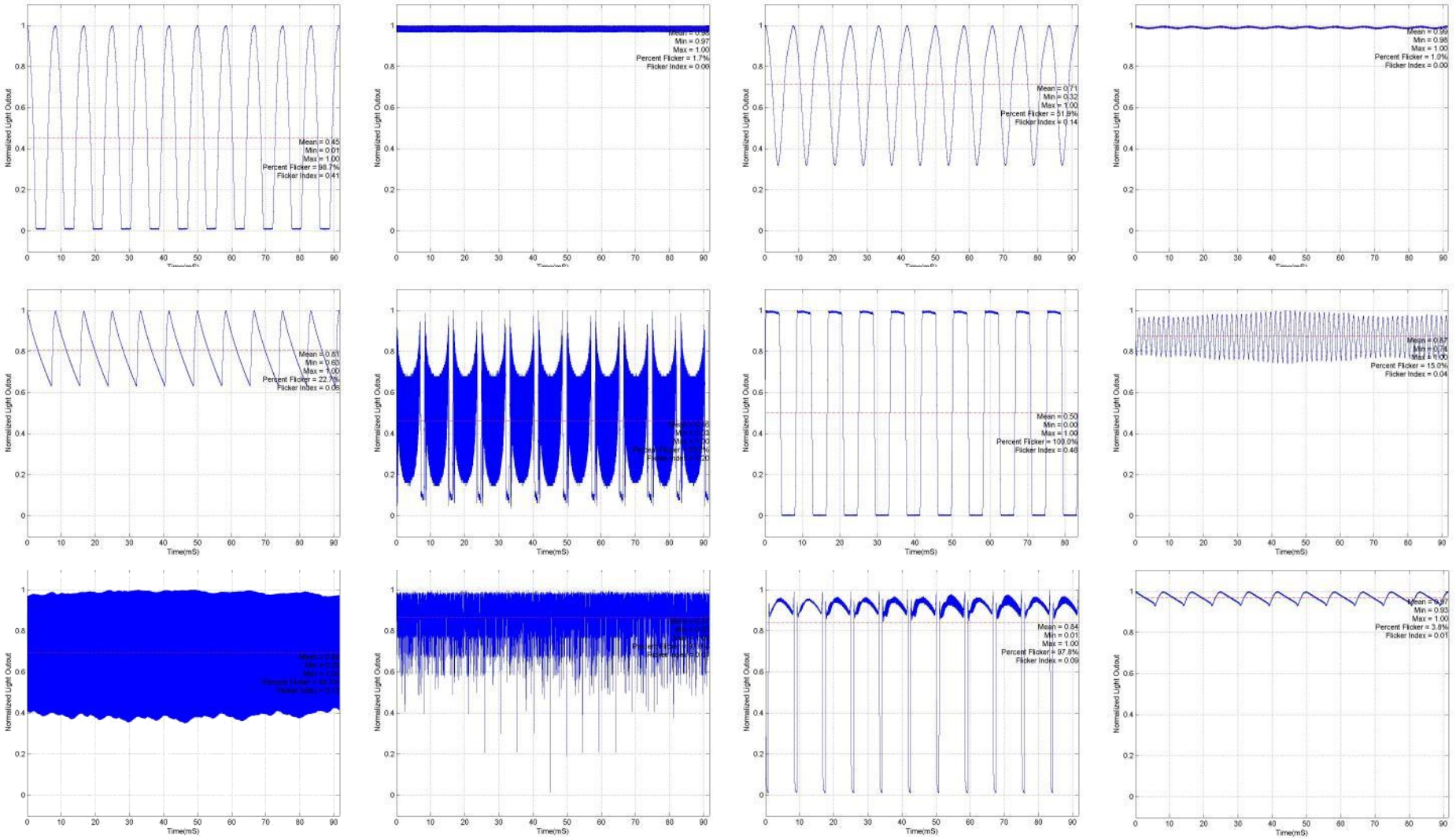






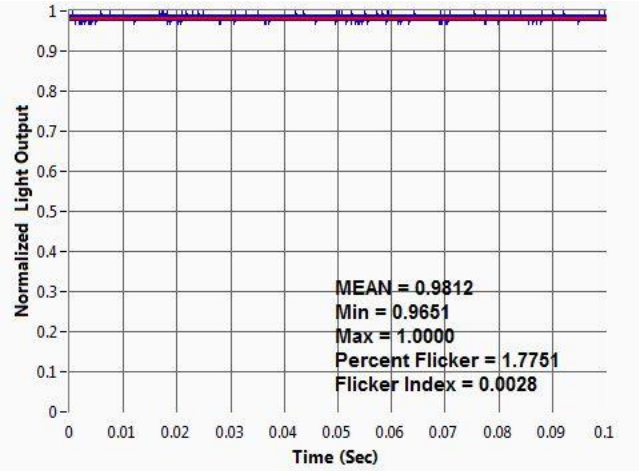
Magnetically-ballasted **Electronically-ballasted**

Flicker in early LED products (some lamps/luminaires)

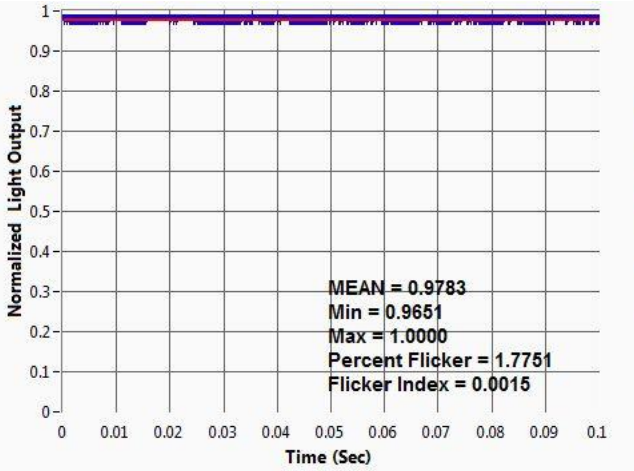


Effect of Dimming - LED lamp A controlled by phase-cut dimmer

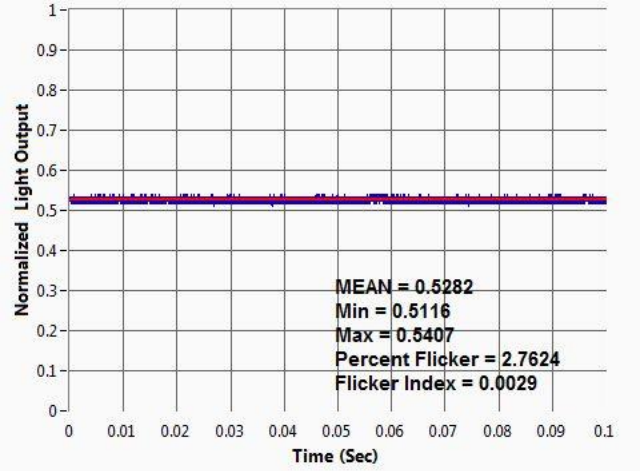
S01: V_{rms} load = 120 (on)



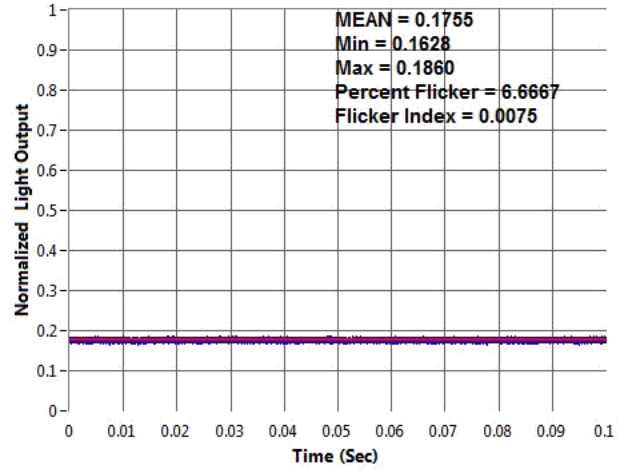
D22: V_{rms} load = 115 (max dim)



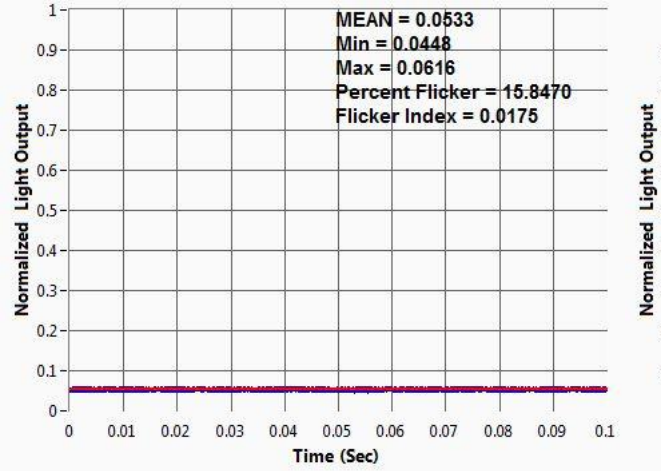
D22: V_{rms} load = 95



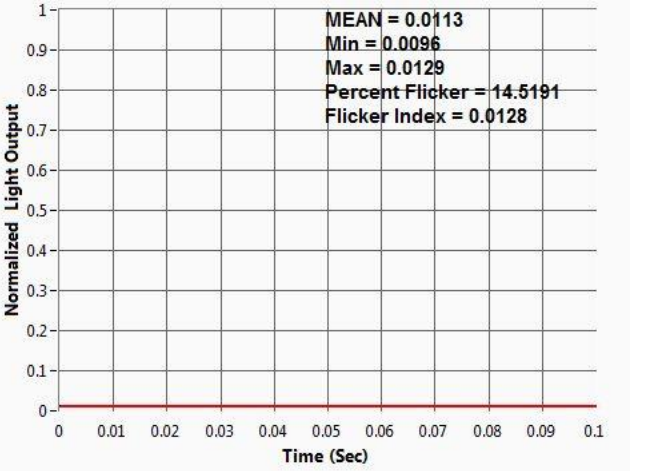
D22: V_{rms} load = 75



D22: V_{rms} load = 55

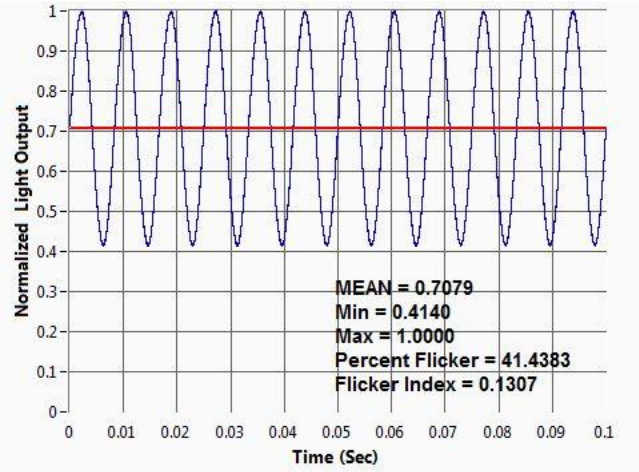


D22: V_{rms} load = 30 (min)

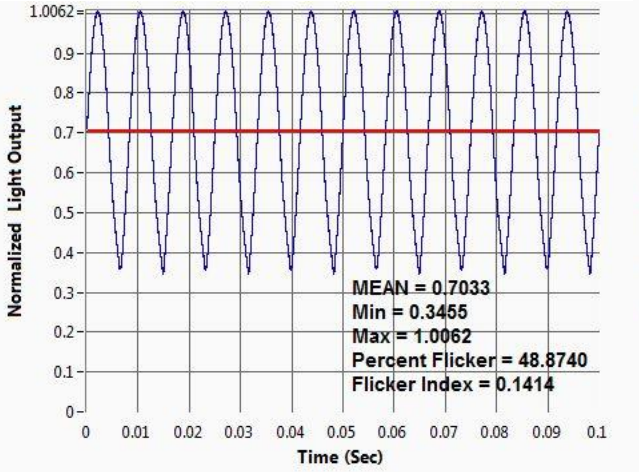


LED lamp B controlled by phase-cut dimmer

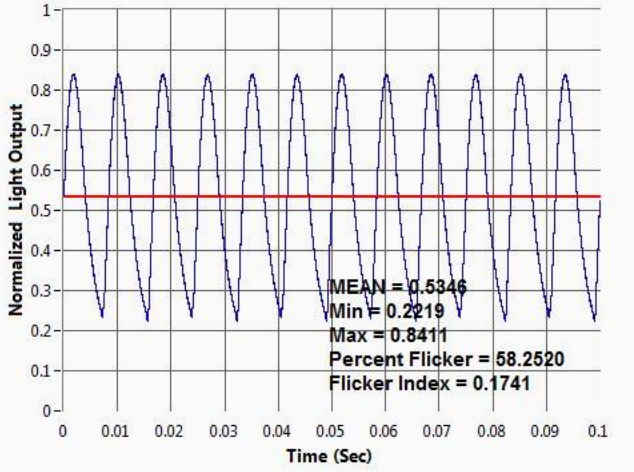
S01: V_{rms} load = 120 (on)



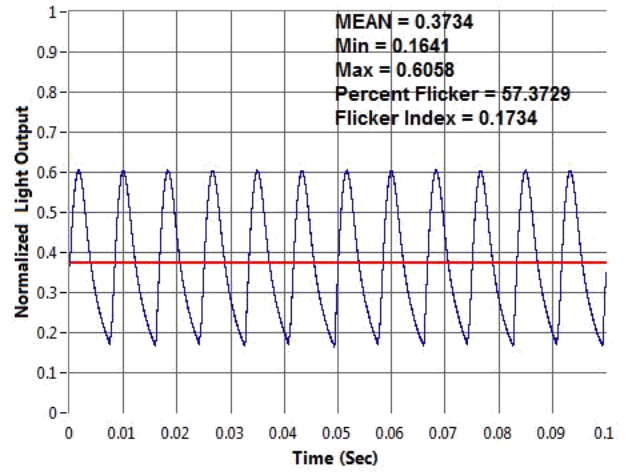
D22: V_{rms} load = 115 (max dim)



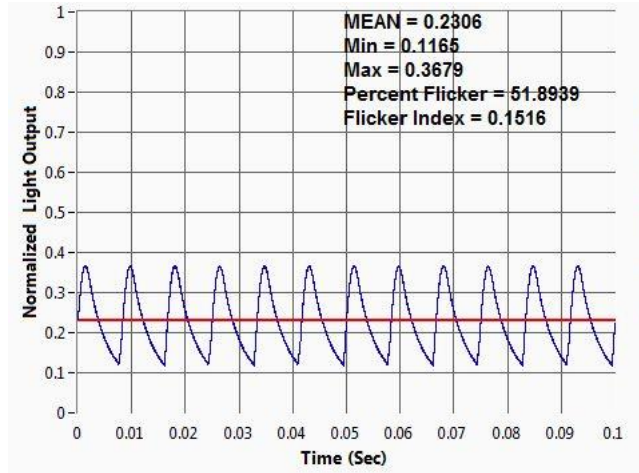
D22: V_{rms} load = 95



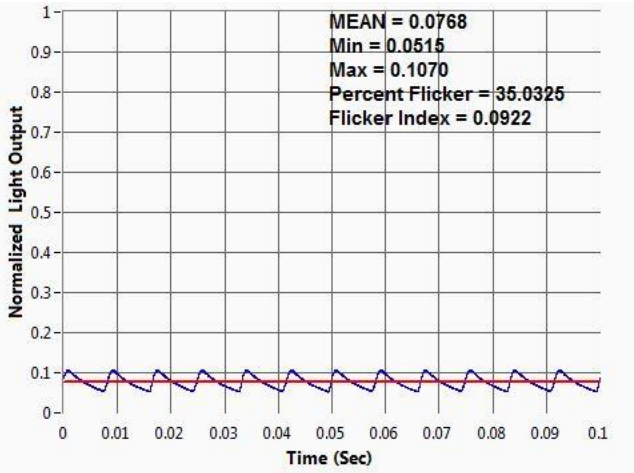
D22: V_{rms} load = 75



D22: V_{rms} load = 55

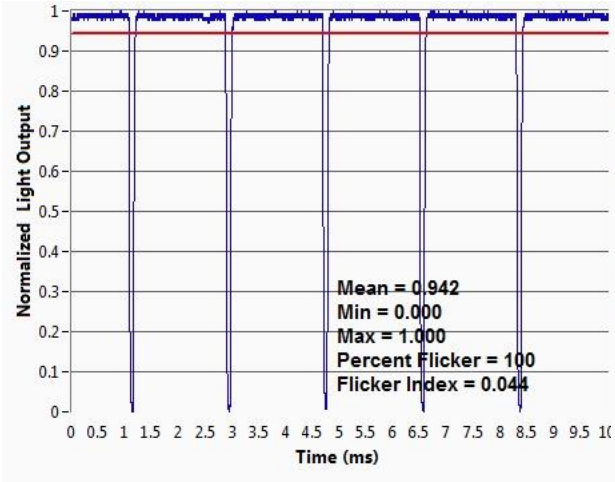


D22: V_{rms} load = 30 (min)

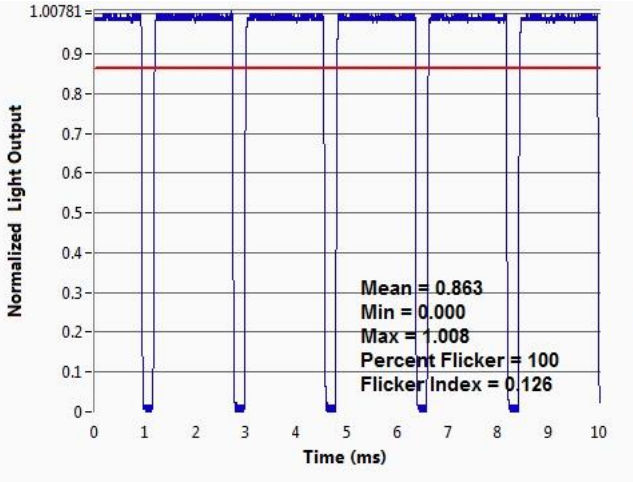


LED downlight controlled by phase-cut dimmer

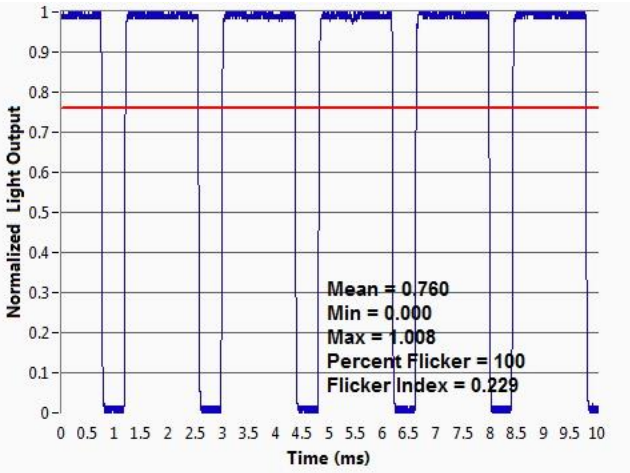
S01: V_{rms} load = 120 (on)



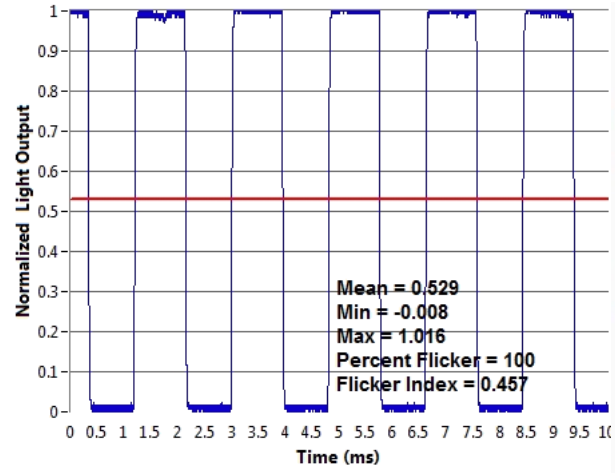
D22: V_{rms} load = 115 (max dim)



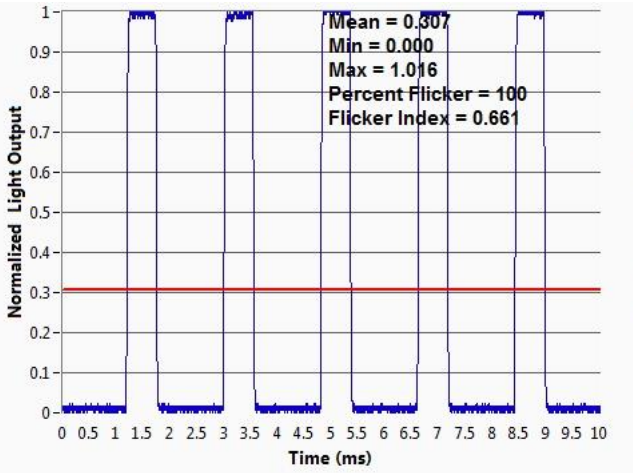
D22: V_{rms} load = 95



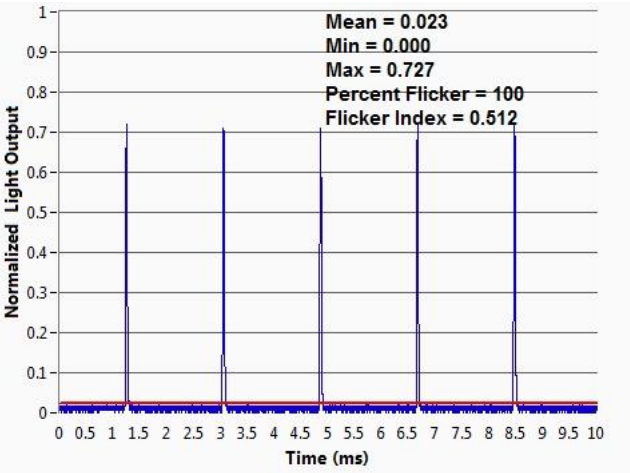
D22: V_{rms} load = 75



D22: V_{rms} load = 55



D22: V_{rms} load = 30 (min)



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

How can you tell if a product flickers?

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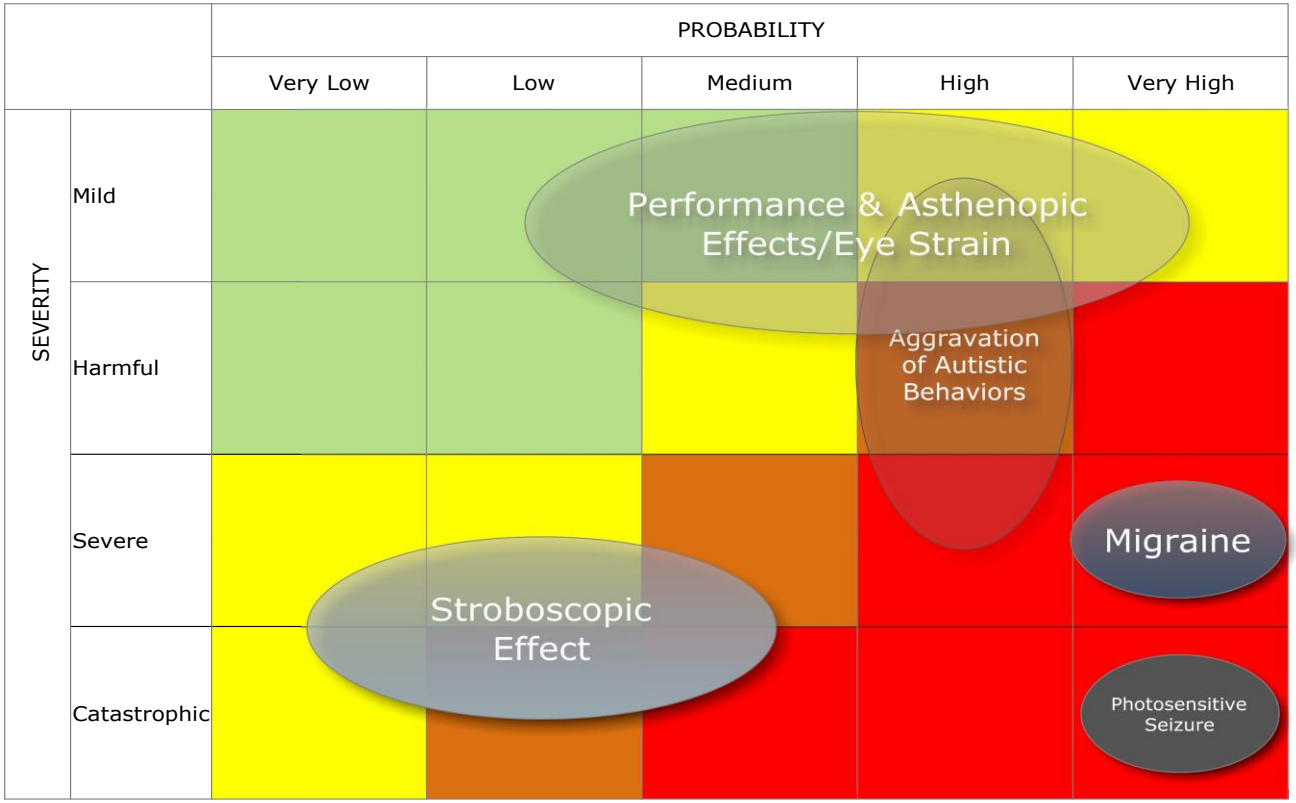
- Flicker waveforms not available from cut sheets yet
- See the product in person, with the same driver/transformer/dimming setting of final installation
- Try a flicker wheel or a spinning top
- Sometimes a digital camera picks up flicker
- Wave your fingers in the light or scan your eyes side to side;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

No flicker

Flicker

IEEE PAR1789 Recommended Practice

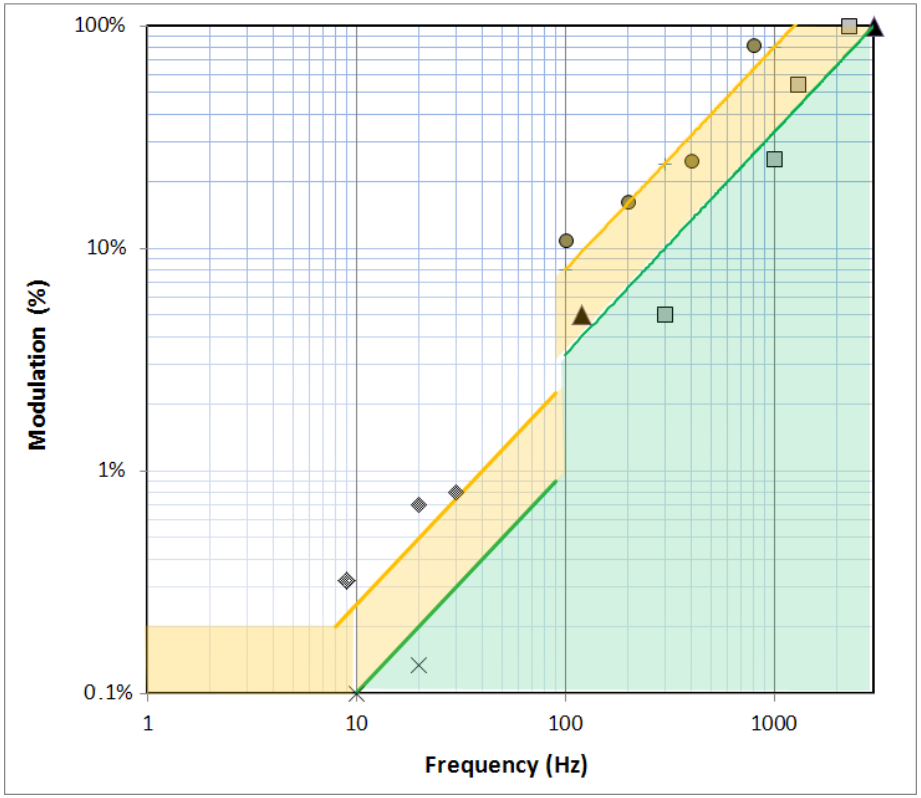
- IEEE PAR1789 committee formed in 2008 to research issue, evaluate risk of flicker from SSL, and develop recommended practice. (Brad Lehman, chair.)
- Developed Risk Assessment procedure and published document in 2012.



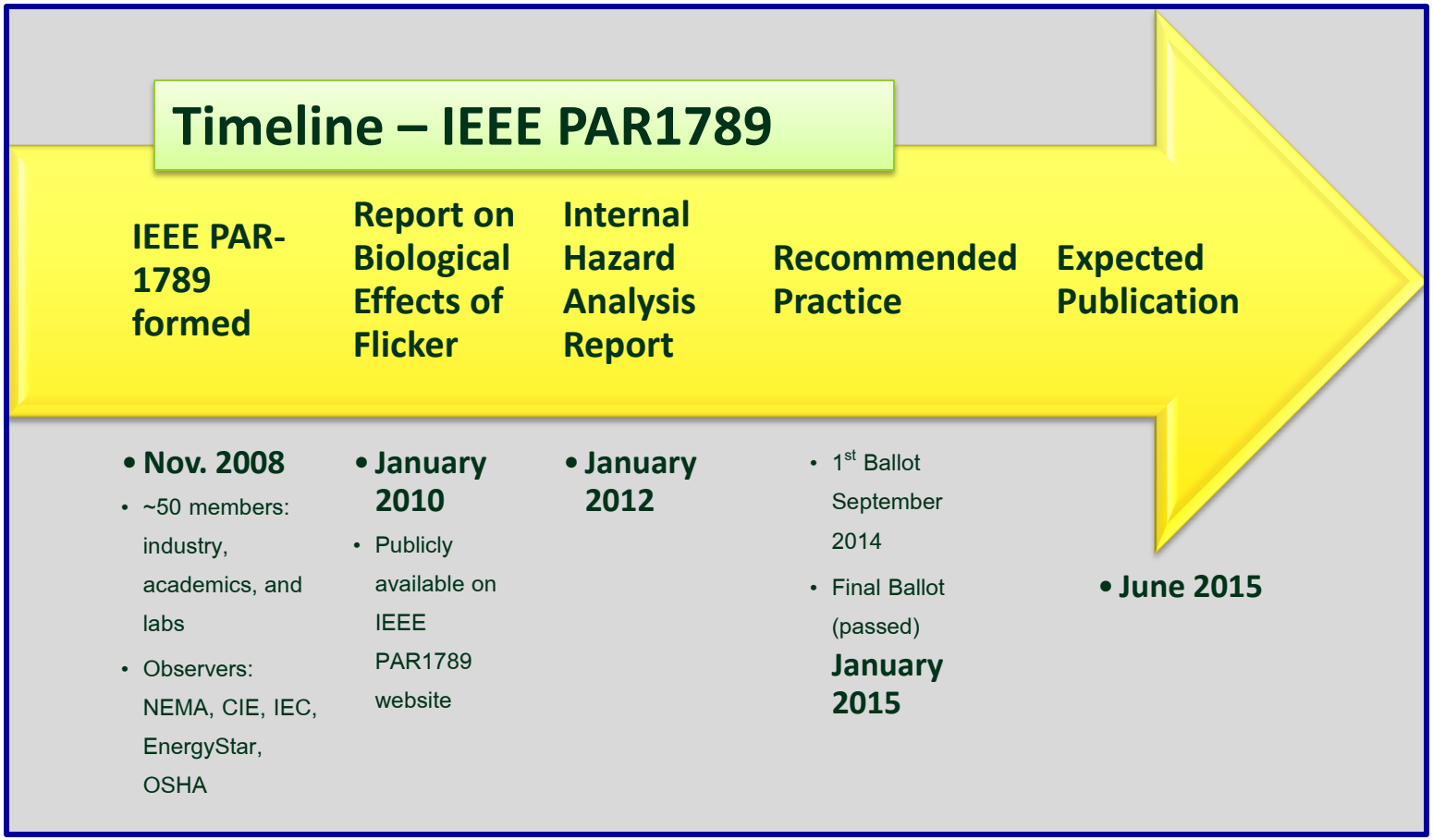
IEEE PAR1789 Recommended Practice

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

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Utilities and energy efficiency organizations

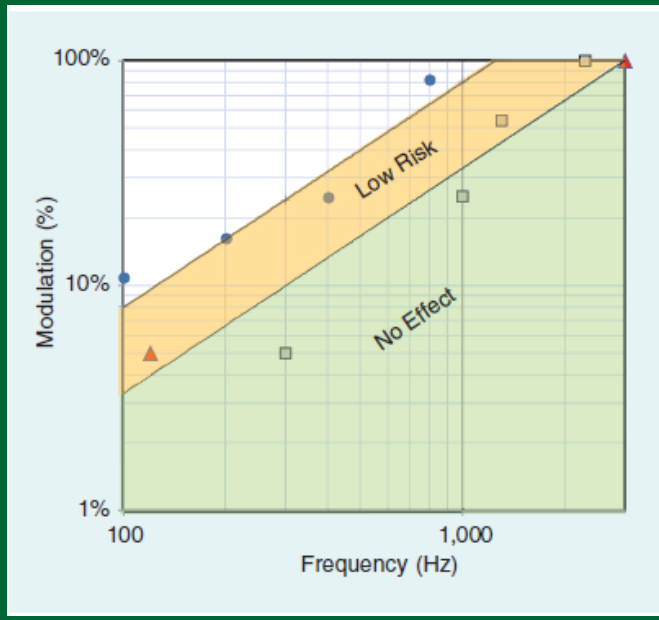
- Require flicker documentation for EE programs

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 ≤ Flicker Freq x 0.08 (normal populations), or
  - % Flicker ≤ Flicker Freq x 0.0333 (special populations)



Application - Where Flicker Matters

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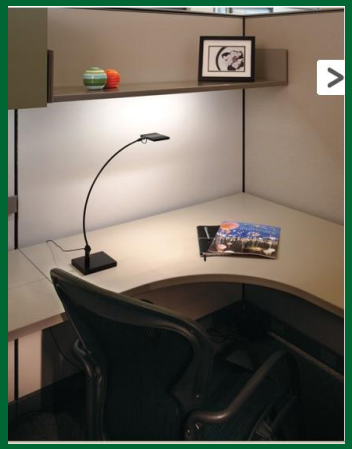
General lighting

Hospitals/clinics

Classrooms



Task lighting

Industrial spaces

Offices

Where Flicker Matters

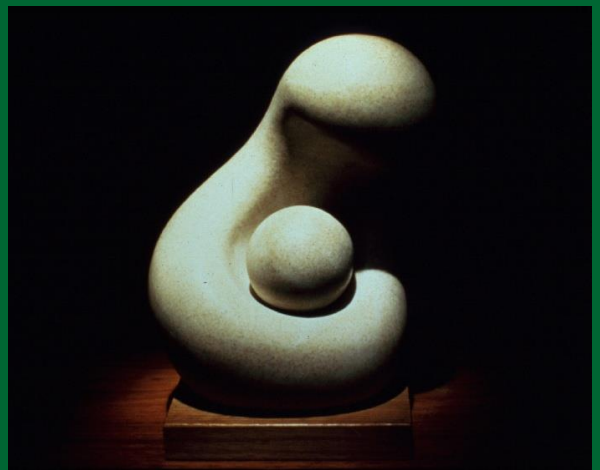
TV studios/videoconferencing

(Anywhere video cameras are used)

Where flicker is less important

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 advantage

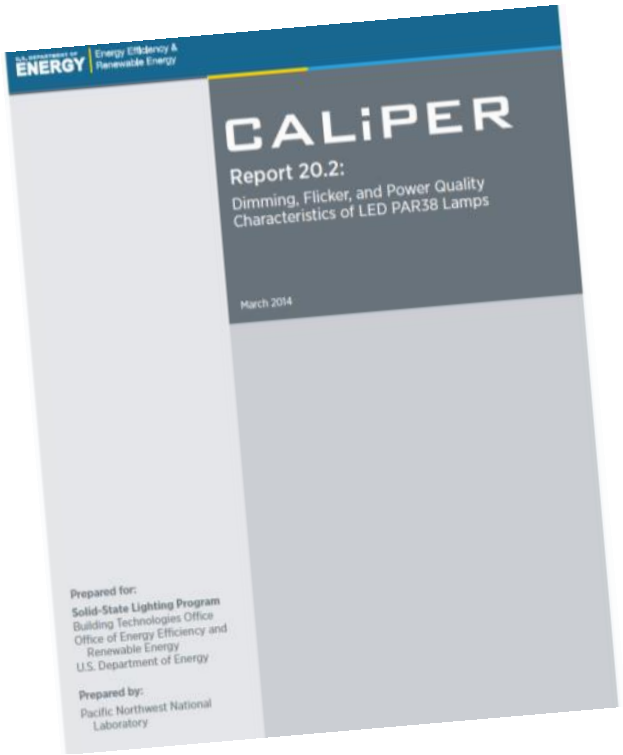
Warning lights

Discotheques

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

Resources (and thanks for listening!)

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

DOE Flicker Fact Sheet

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