

The Evaluation of Flicker in LED Luminaires

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Flicker – Introduction

- Flicker is the periodic change in the instantaneous light output of a light source.
- In most conventional light sources driven by line current, the frequency of the flicker is two times the frequency of the line current.
- The increased use of high frequency electronic ballasts has greatly decreased the amount of flicker present in the indoor environment.

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Why is flicker a problem?

1) People are noticing it...

- People have their own ways of looking for it.
- Flicker Fusion Frequency in humans is $\sim 16\text{Hz}$
- Fast movement causes flicker to become more obvious – The stroboscopic effect, Phantom arrays, Ghost images.

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Why is flicker a problem?

2) It has an effect on people...

- They don't necessarily notice the flicker
- Migraines – Wilkins, et al, 1988 study linking headaches and eyestrain to flicker.
- Nausea (motion sickness)
- Women more sensitive to flicker than men, younger people more than older. (Rubenstein, 1992)

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Why is flicker a problem?

3) Certain applications may be more sensitive...

- Roadway
- Sports lighting
- Lighting for video applications
- Industrial Applications

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Why is flicker a problem?

4) It contributes to the general perception of the technology...

- If most LEDs exhibit flicker, the public will most likely decide that all LEDs flicker.
- Energy Star requirements currently only address flicker by the frequency of the drive current.
- Energy Star Requirements for Solid State Luminaires (DOE) version 1.1 =>120Hz
- Energy Star RLF version 4.3 =>120Hz

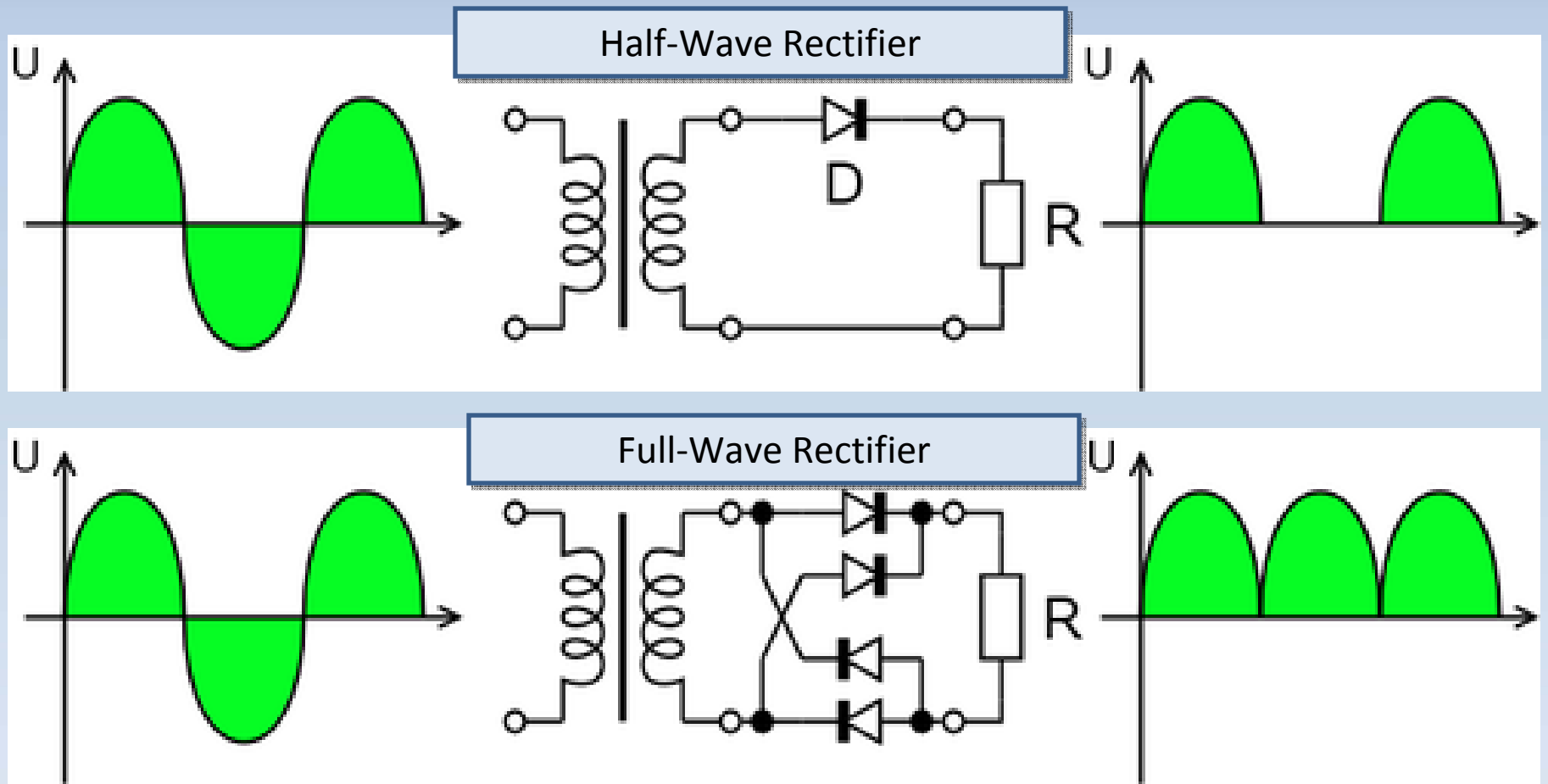
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Why does flicker exist in LED Luminaires?

- \$\$ - DC Power Supply Design (ripple on DC)
- High switching speed of LEDs
- Duty Cycle variations to control power
- \$\$ and efficiency – in some cases, LEDs could be used as the diodes in the rectifier circuit.

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Why does flicker exist in LED Luminaires?



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What about Conventional Sources?

- Yes, there is flicker associated with conventional sources and there has been much study on its effects.
- High Frequency Ballasts (~20kHz)
- Persistence of phosphor in fluorescent lamps
- Flicker of conventional sources does not typically drop to 0 intensity within a waveform

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Metrics for flicker measurement

P_{ST} and P_{LT} – (short term and long term flicker)

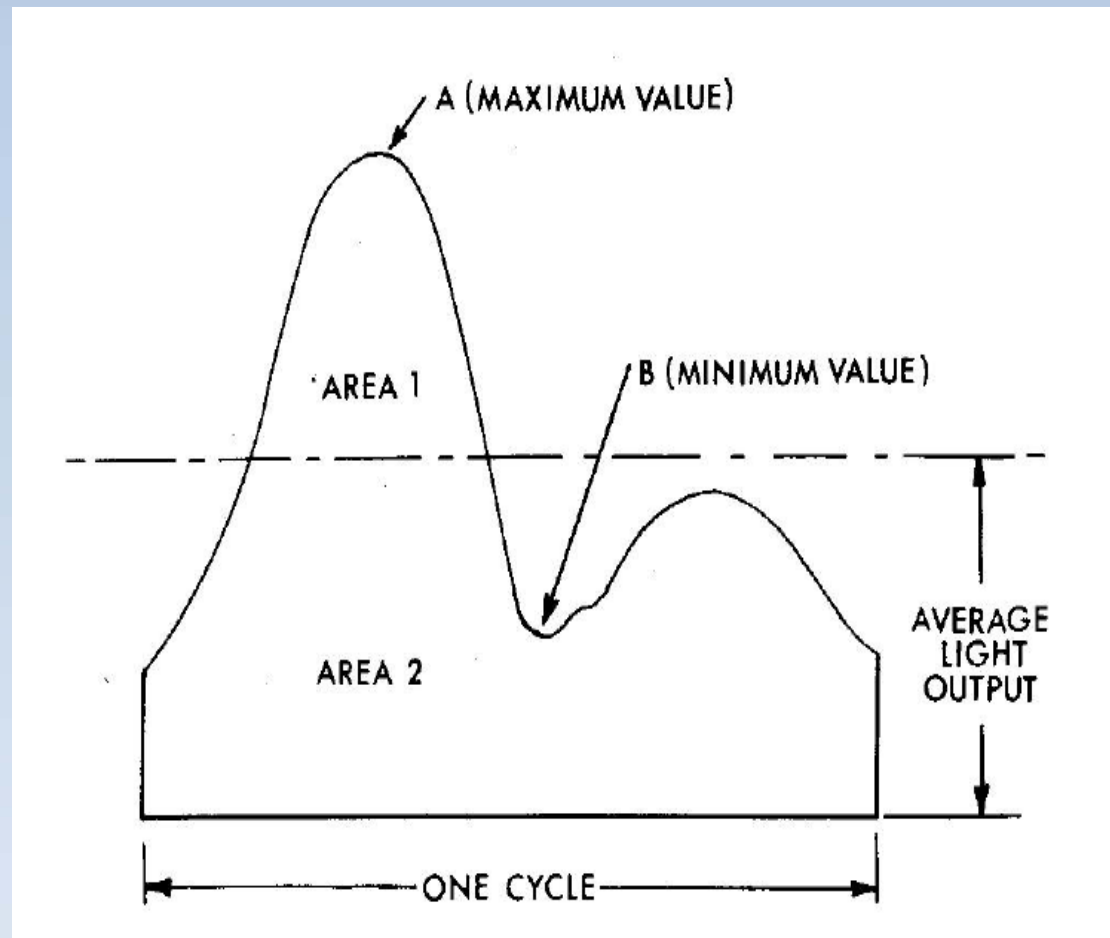
- Described in IEC 61000-4-15
- Uses a “flickermeter” (described in the standard)
- Generally for measurement of sub-harmonic changes in the AC waveform
- A $P_{ST} > 1.0$ is considered unacceptable flicker (found annoying)

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Metrics for flicker measurement

Percent Flicker

- Percent Flicker = $100 * (A - B) / (A + B)$



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Metrics for flicker measurement

Percent Flicker

- Described in early versions of the IESNA Handbook
- Percent modulation of the intensity waveform
- Range is from 0% to 100%
- 0% is a pure DC waveform
- 100% would occur when the range extends to 0 light output at any time during the waveform
- Does not include information about the duty cycle

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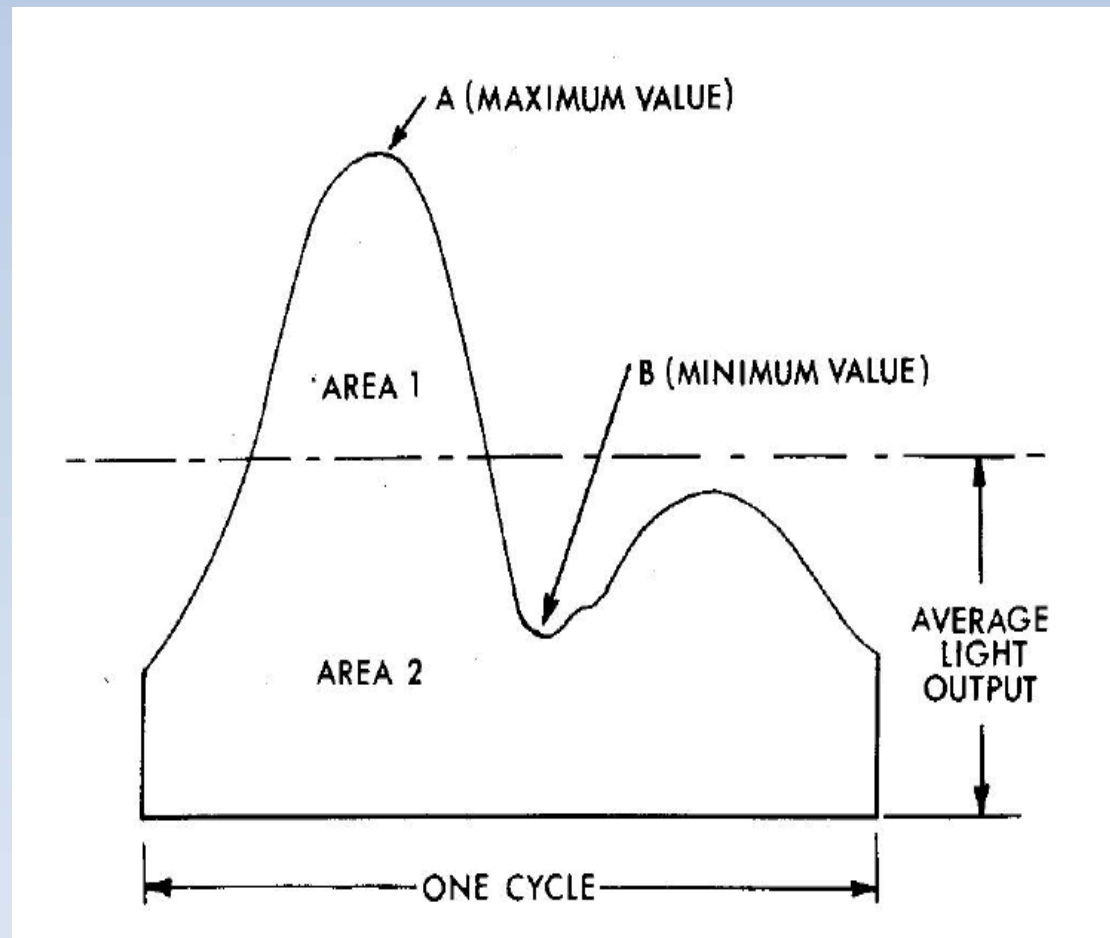
Metrics for flicker measurement

Flicker Index

- Flicker Index =

Area 1

Area 1 + Area 2



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Metrics for flicker measurement

Flicker Index

- Relates the area under the curve above the average light intensity to the area under the curve below the average light intensity
- Range is from 0 to 1.0
- 0 is a pure DC waveform
- 1.0 can only occur with the most dramatic changes in light output
- Includes the effects of duty cycle

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Metrics for flicker measurement

Flicker Index

Vs

Percent Flicker

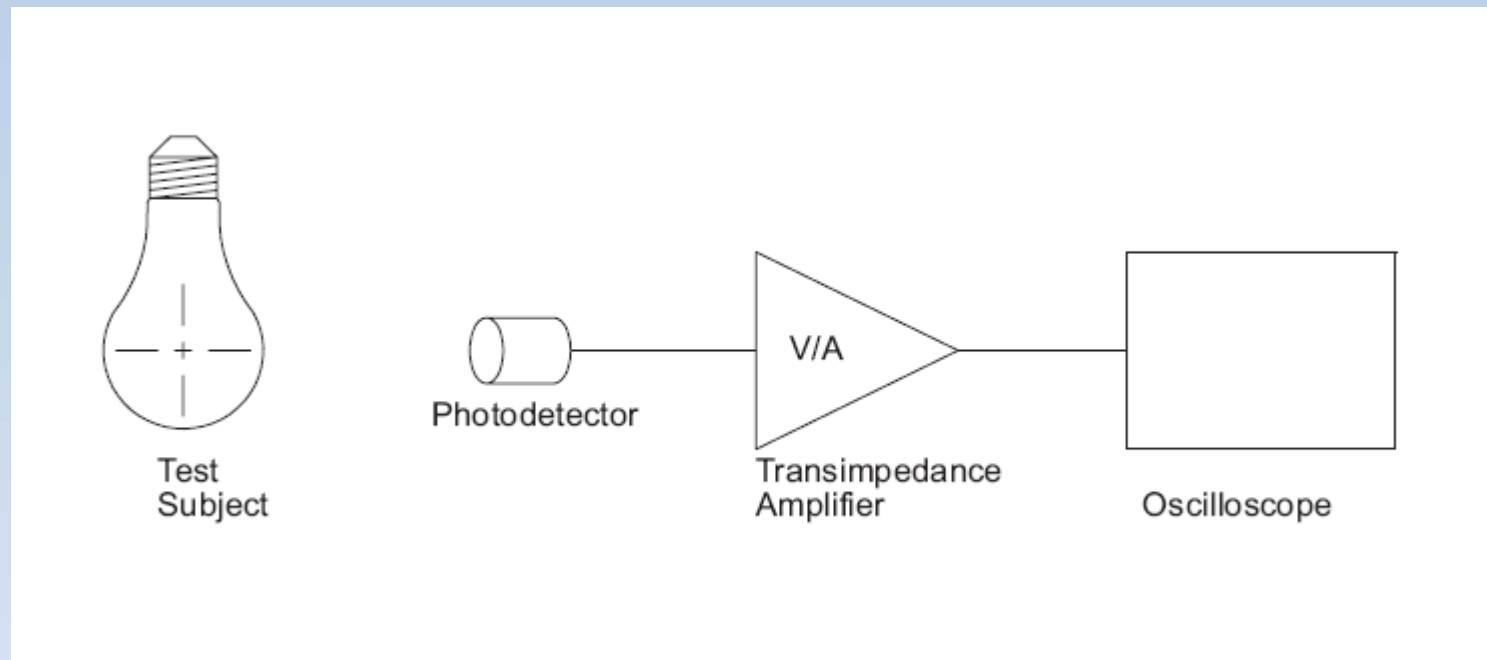
(from IESNA Handbook
Reference Volume
1981)

Fig. 8-38. Flicker Index and Per Cent Flicker Values for "White" Fluorescent Lamps

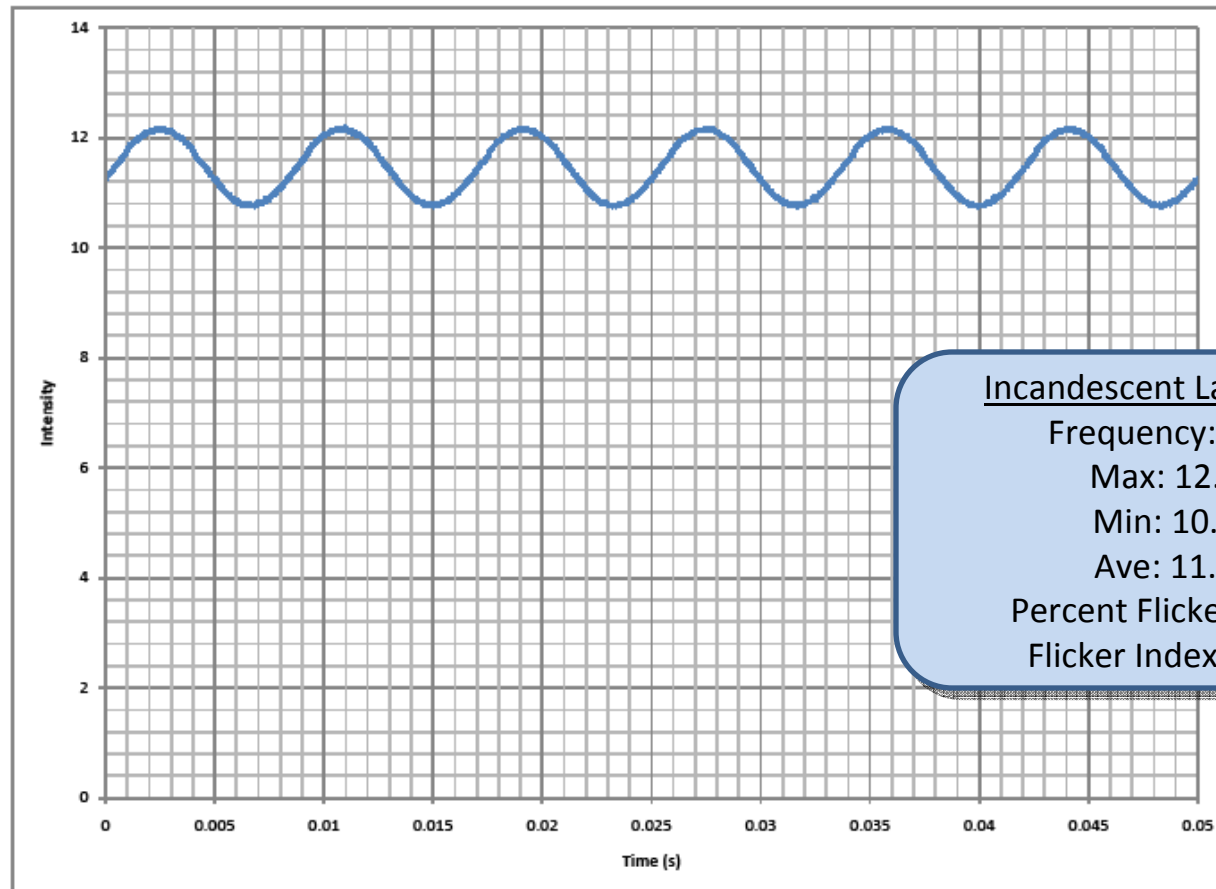
	Single Lamp		2-Lamp Lead-Lag Instant Start		2-Lamp Lead-Lag Preheat Switch Start	
	Flicker Index	Per Cent Flicker	Flicker Index	Per Cent Flicker	Flicker Index	Per Cent Flicker
Cool white	.079	34	.071	26	.056	16
Deluxe cool white	.078	34	.075	27	.046	14
Warm white	.048	20	.044	16	.029	10
Deluxe warm white	.049	20	.043	16	.030	10
Daylight	.119	50	.107	41	.075	24
White	.058	25	.054	20	.042	12

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Block Diagram of Test Setup



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Incandescent Lamp (60Hz)

Frequency: 120Hz

Max: 12.180

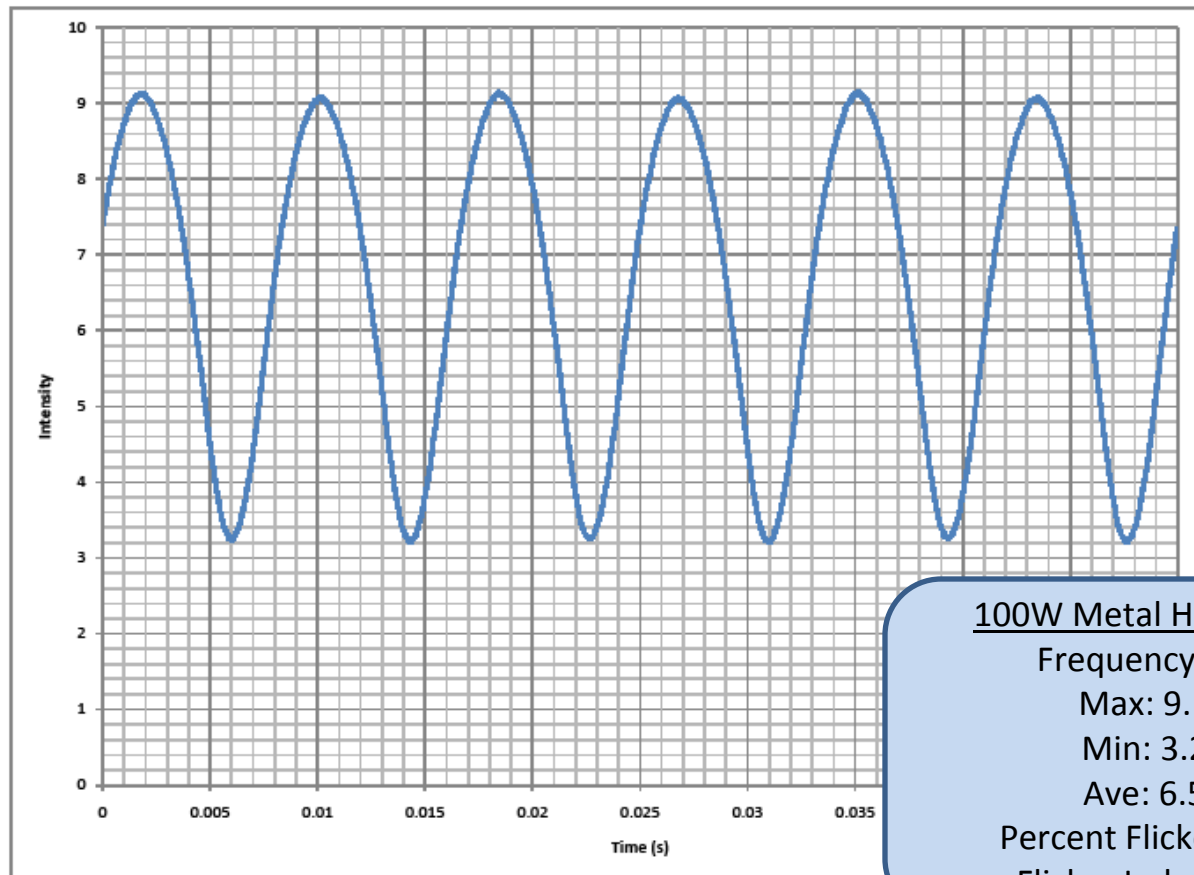
Min: 10.745

Ave: 11.460

Percent Flicker: 6.2594

Flicker Index: 0.0194

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100W Metal Halide (clear)

Frequency: 120Hz

Max: 9.1472

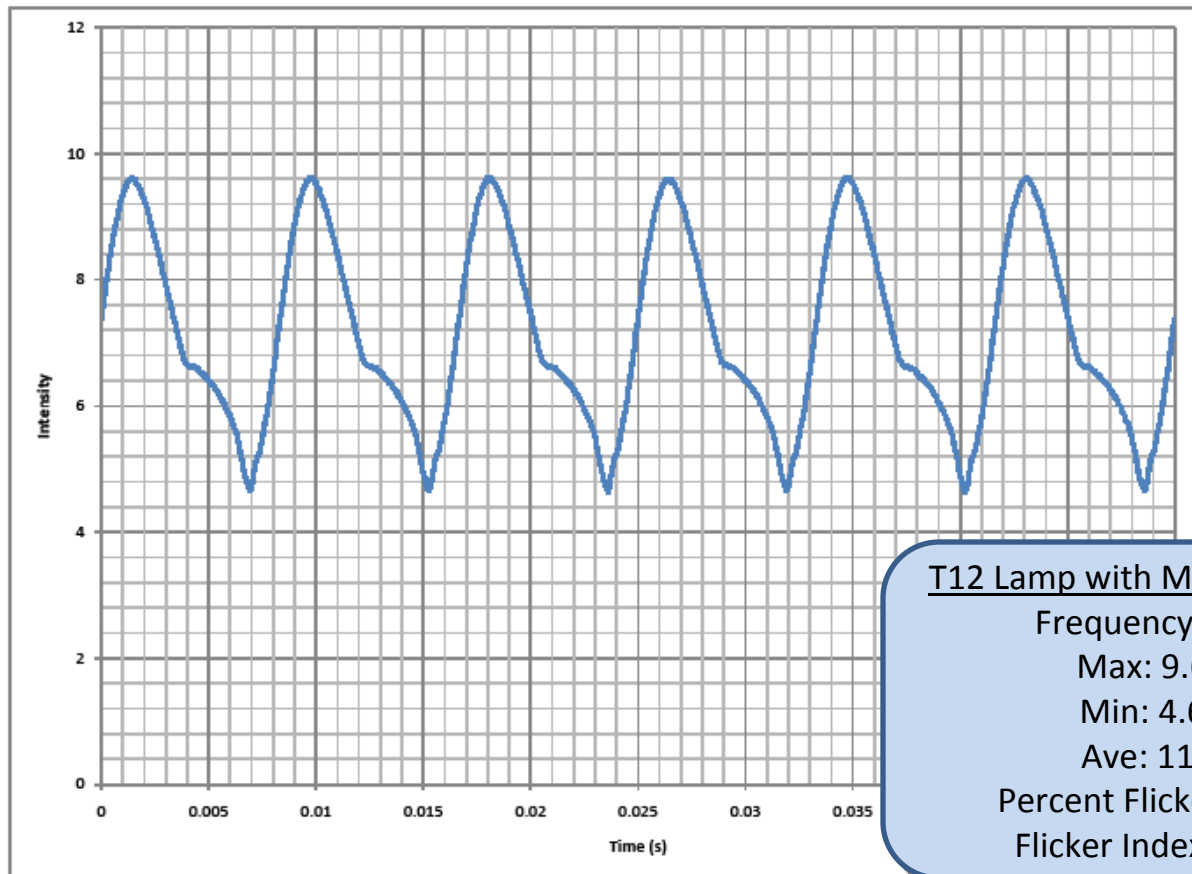
Min: 3.2066

Ave: 6.5147

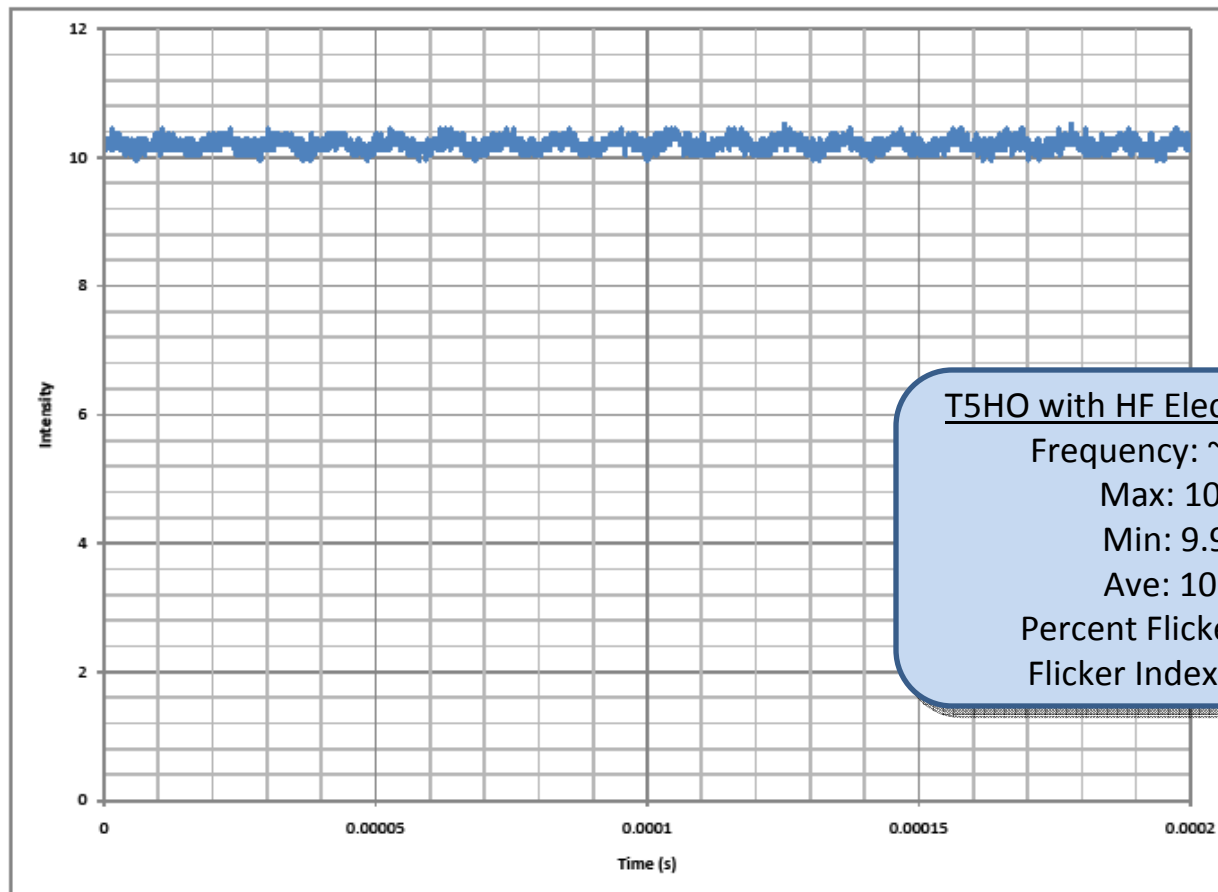
Percent Flicker: 48.088

Flicker Index: 0.1398

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T5HO with HF Electronic Ballast

Frequency: ~100kHz

Max: 10.52

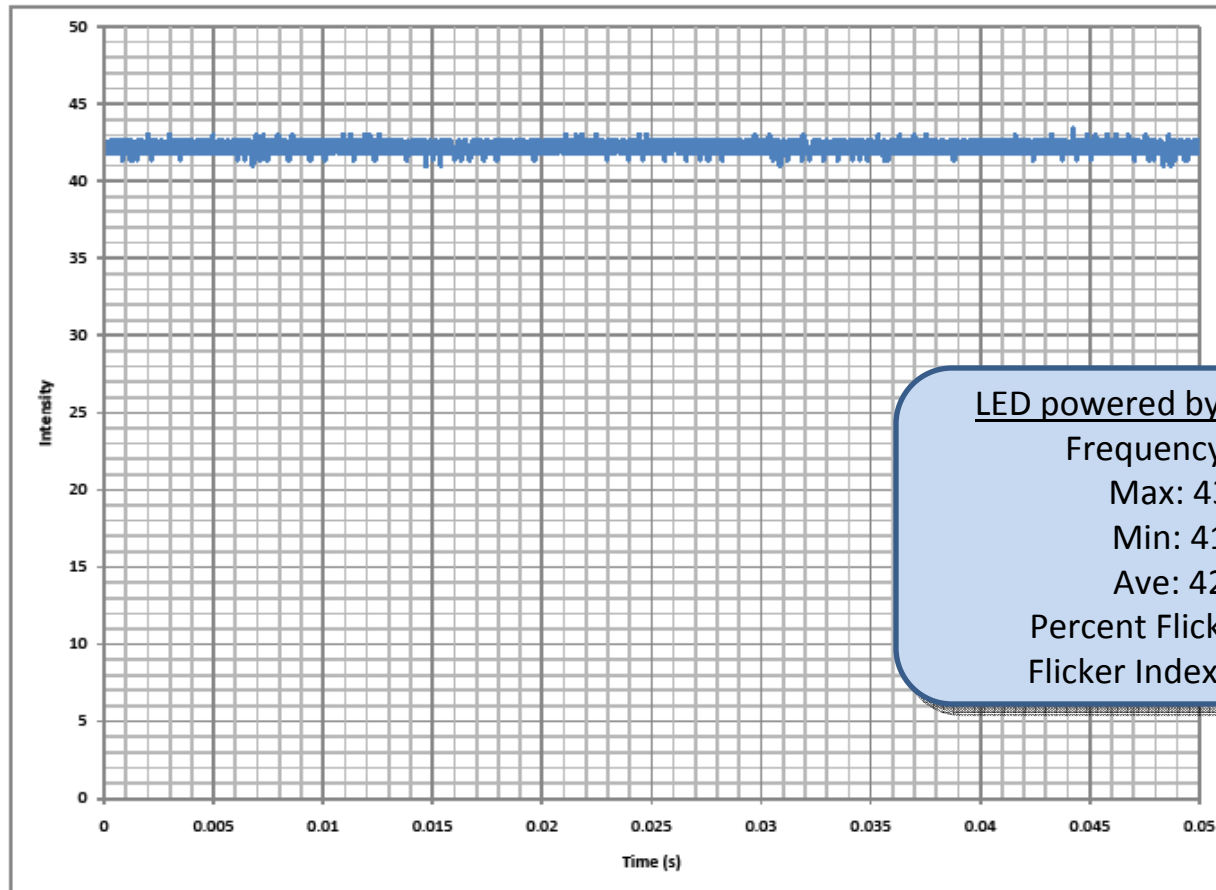
Min: 9.960

Ave: 10.20

Percent Flicker: 2.734

Flicker Index: 0.0036

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LED powered by DC current

Frequency: N/A

Max: 43.4

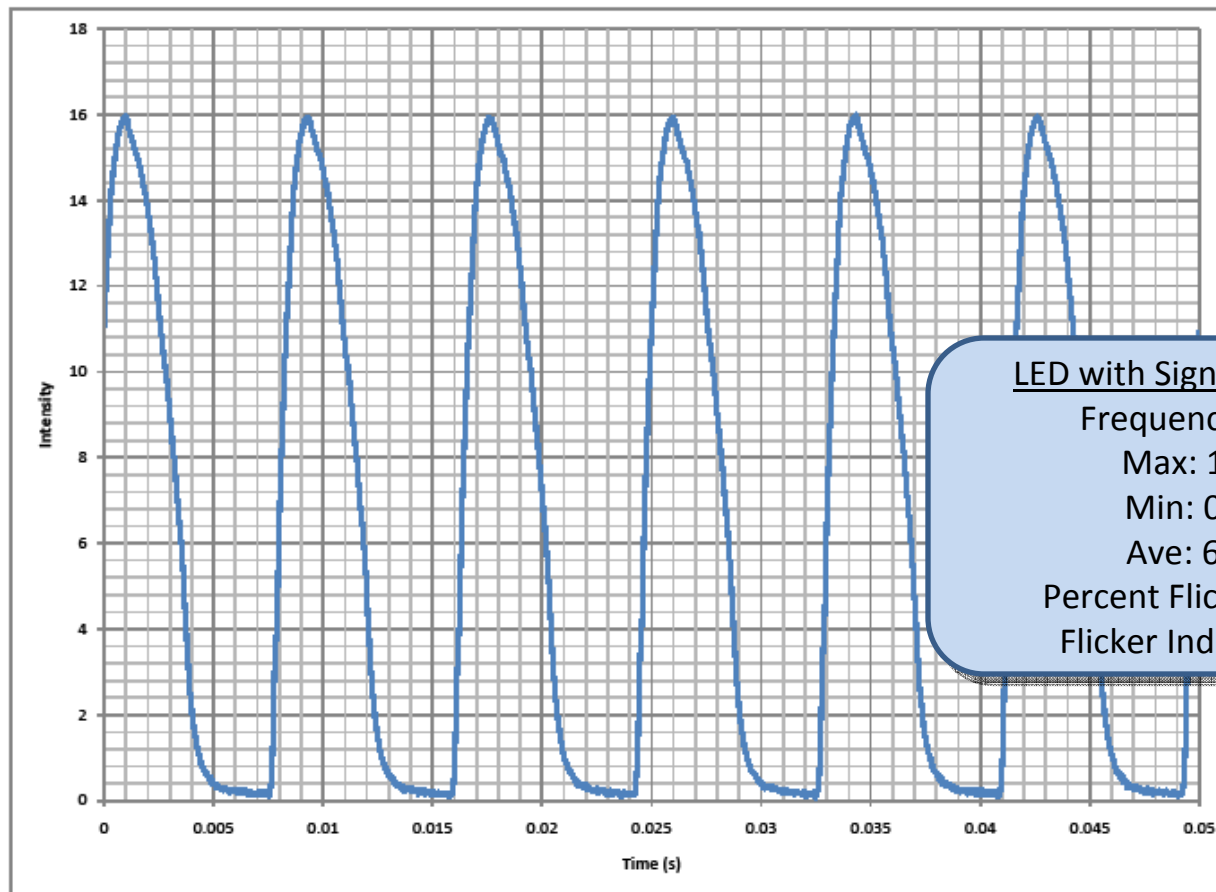
Min: 41.0

Ave: 42.2

Percent Flicker: 2.84

Flicker Index: 0.0037

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LED with Significant Flicker

Frequency: 120Hz

Max: 15.996

Min: 0.0555

Ave: 6.3026

Percent Flicker: 99.309

Flicker Index: 0.4498

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	Max	Min	Ave	% Flicker	Flicker Index
Incandescent	12.180	10.745	11.460	6.2594	0.0194
100W MH	9.1472	3.2066	6.5147	48.088	0.1398
T12 Magnetic	9.6281	4.6256	7.1565	35.096	0.0897
T5HO Elec	10.52	9.960	10.20	2.734	0.0036
LED at DC	43.4	41.0	42.2	2.84	0.0037
LED w/ Flicker	15.996	0.0555	6.3026	99.309	0.4498

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Conclusions

- Flicker Frequency alone is an inadequate measure of flicker.
- More studies will be needed to develop appropriate thresholds for flicker metrics.
- Flicker from LED luminaires can be much more significant than flicker from conventional sources.
- The Flicker Index metric is a useful tool for evaluating both the percent modulation and duty cycle of flicker in all types of light sources.

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Thank You!

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