Measuring and Assessing Light Source Flicker

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ENERGY STAR® Lighting Webinar Series
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Lighting Research Center

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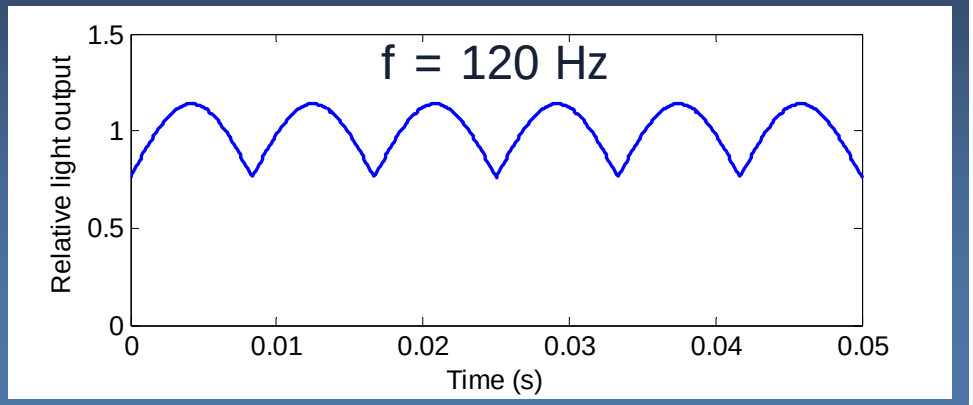
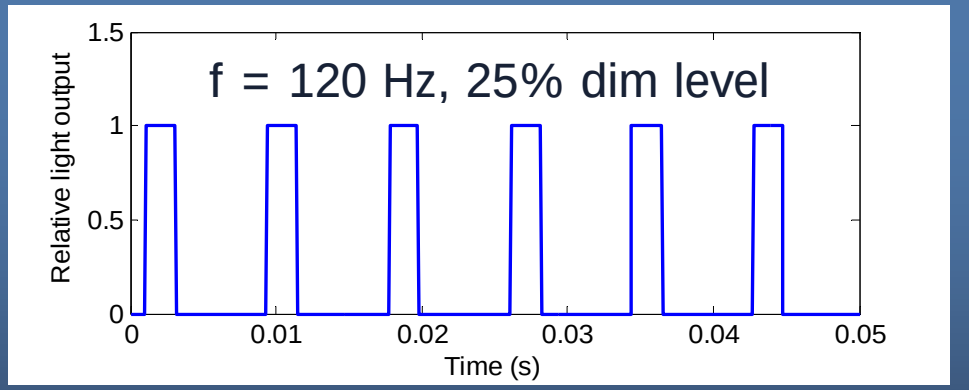
What is flicker?

- Rapid fluctuation of light output over time
  - Unintentional result from operating on 50/60 Hz line power
  - Can be intentional to control light output
    - For example, pulse width modulation (PWM)





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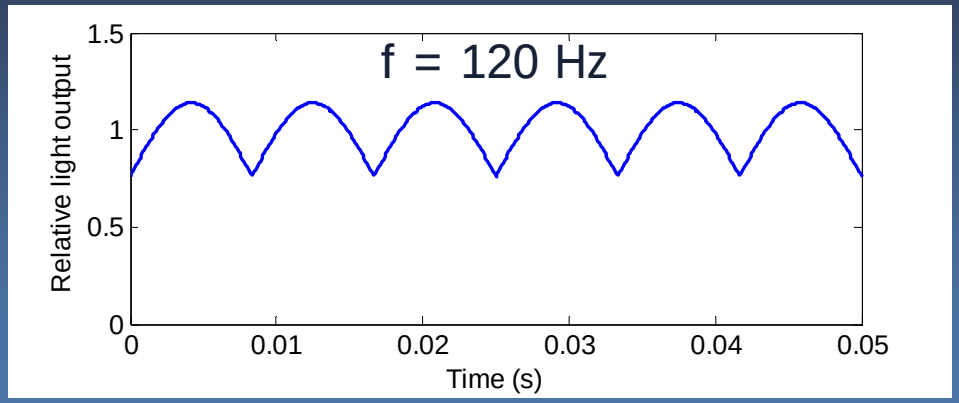
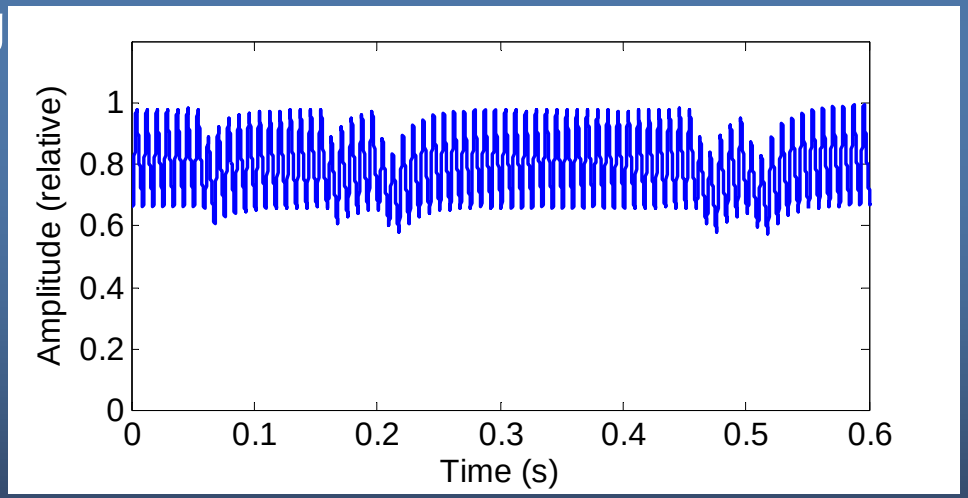
Types of flicker

- Periodic
  - Often intentional, e.g. PWM
  - Consequence of ac power
- Non-periodic
  - Unintentional
  - Often the result of something not working properly
    - End of life
    - Driver/dimmer/lamp incompatibility
    - Power line disturbances





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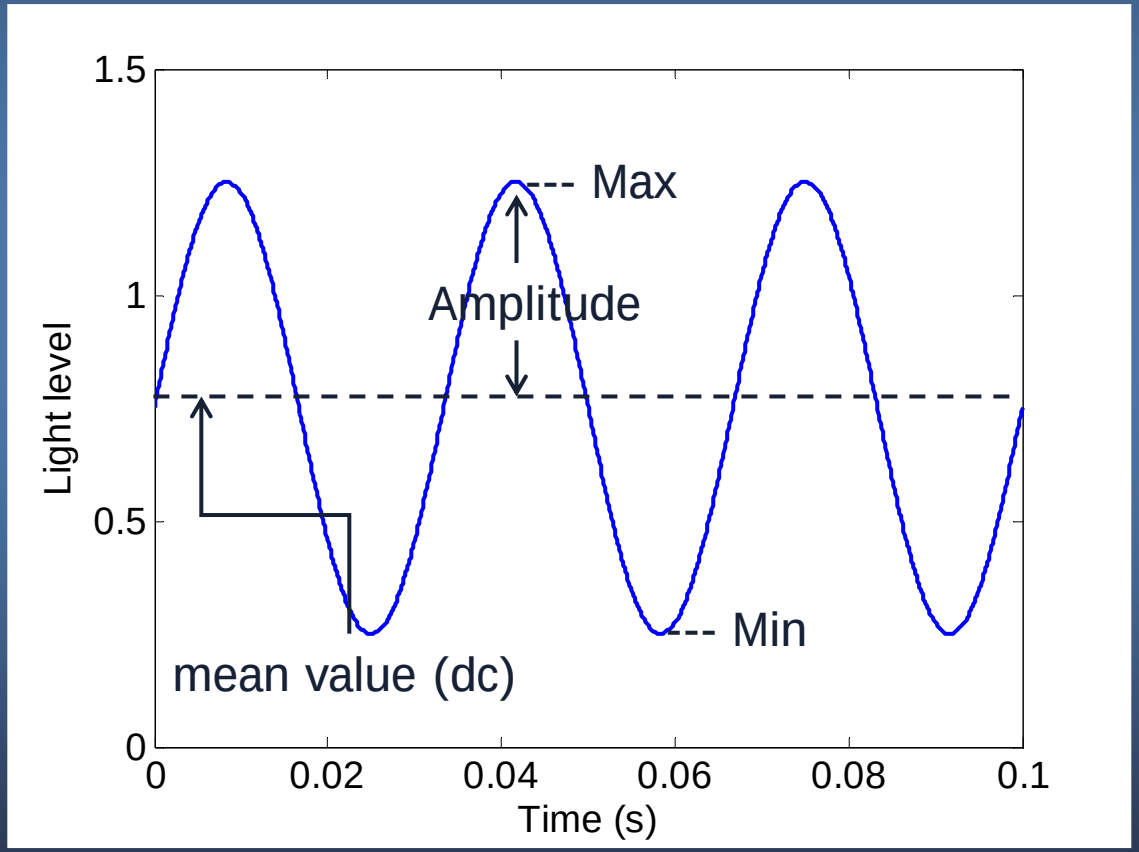
Measuring flicker

$$\text{Percent Flicker} = \frac{(max - min)}{(max + min)}$$

For sinusoidal wave shapes:

$$\text{Percent Flicker} = \frac{Amplitude}{dc}$$

Percent flicker provides no information about the frequency or wave shape.



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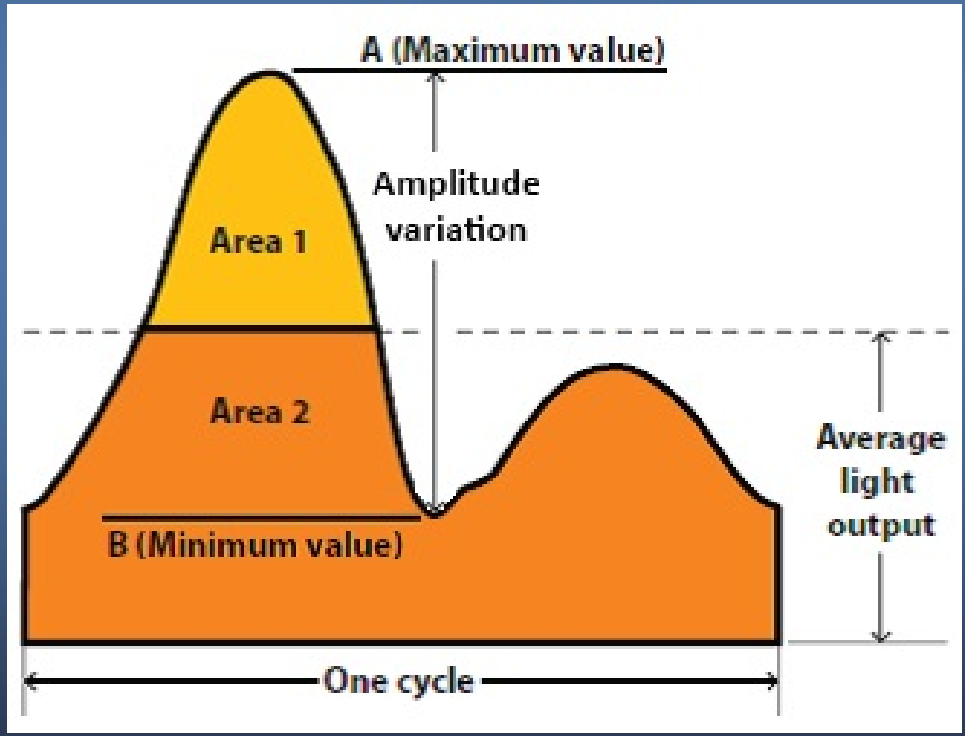
Measuring flicker

$$\text{Flicker Index} = \frac{Area\ 1}{Area\ 1 + Area\ 2}$$

Flicker index depends on both modulation depth (percent flicker) and wave shape

Works well for specific types of flicker, e.g. 60 Hz, periodic



Adapted from IES Lighting Handbook, 9th Edition

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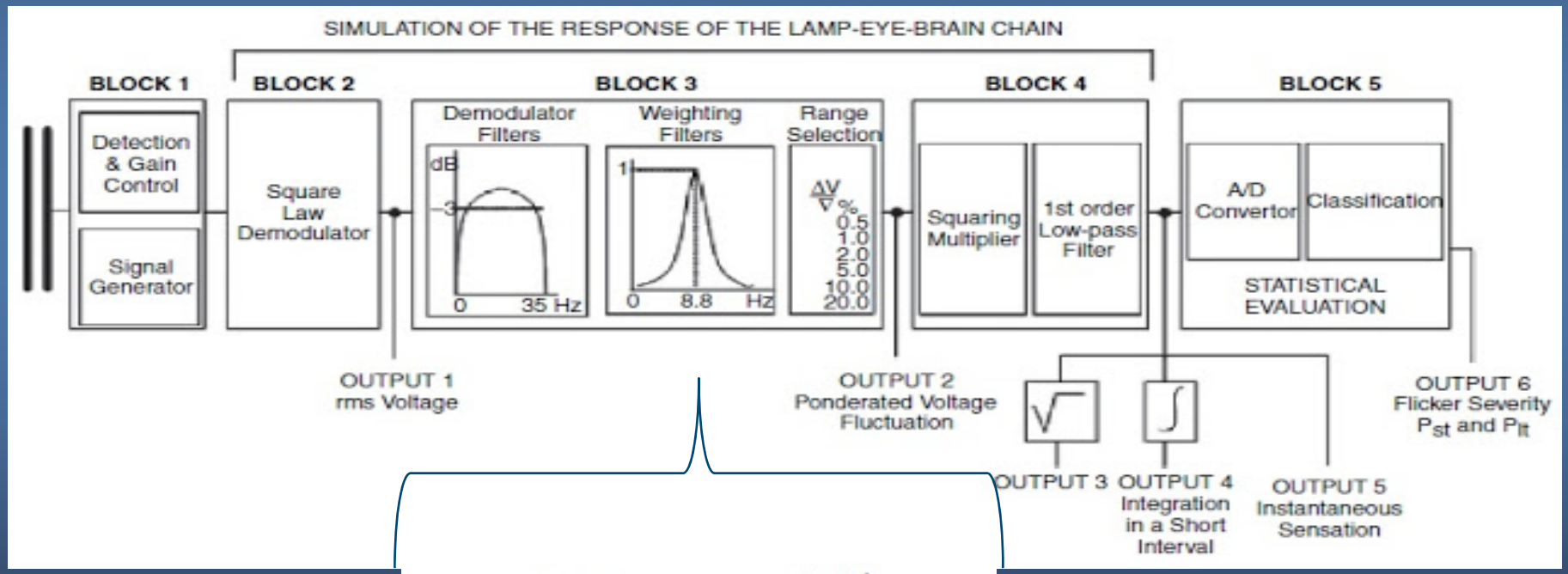
Measuring flicker

- IEC Flicker Meter
  - Flicker from incandescent lamps due to powerline disturbances
  - Could be simplified when measuring light output directly



$$F(s) = \frac{k\omega_1 s}{s^2 + 2\lambda s + \omega_1^2} \times \frac{1 + s/\omega_2}{(1 + s/\omega_3)(1 + s/\omega_4)}$$

IEC 61000-4-15:2010

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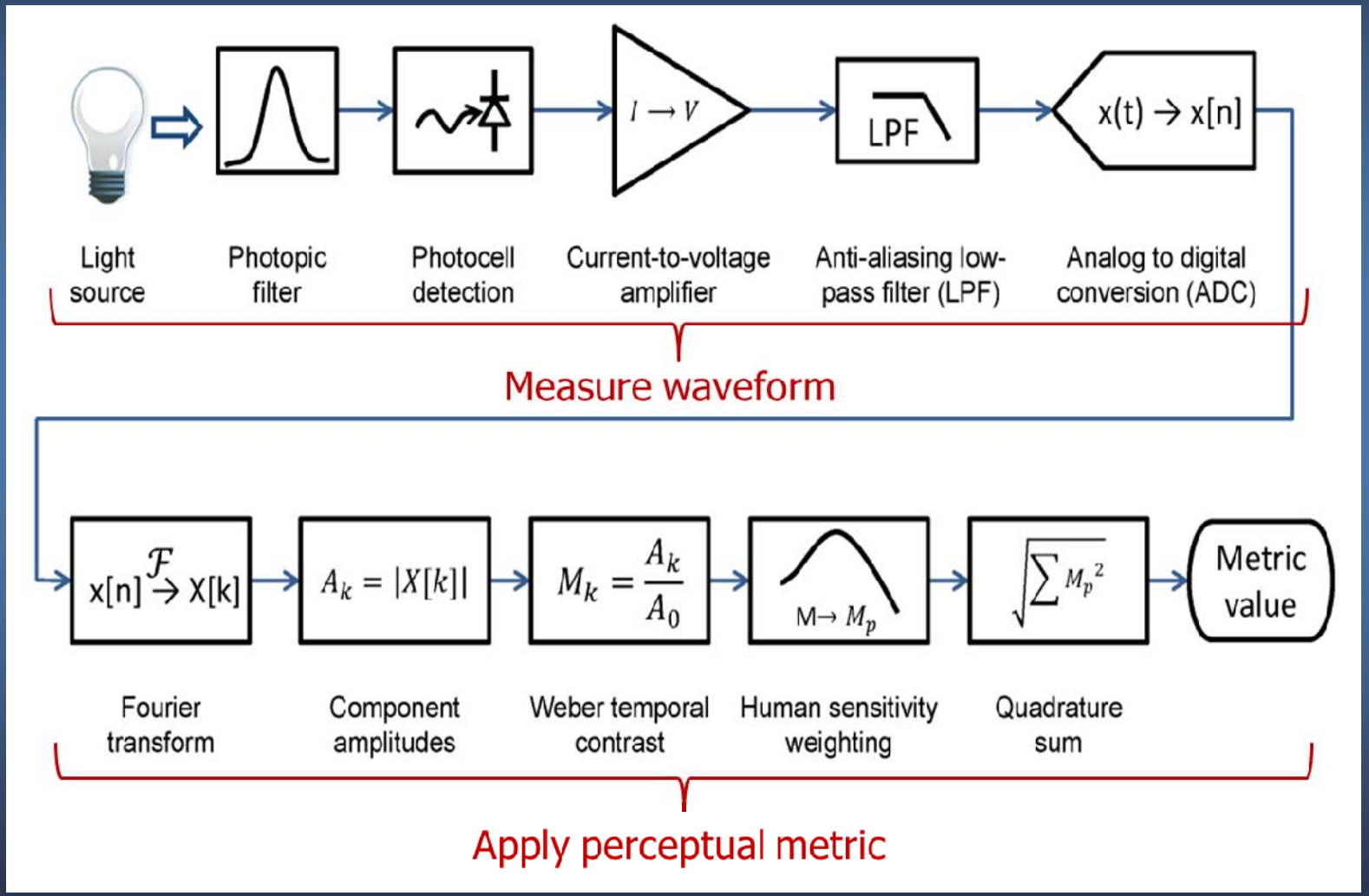
ASSIST Flicker Metric



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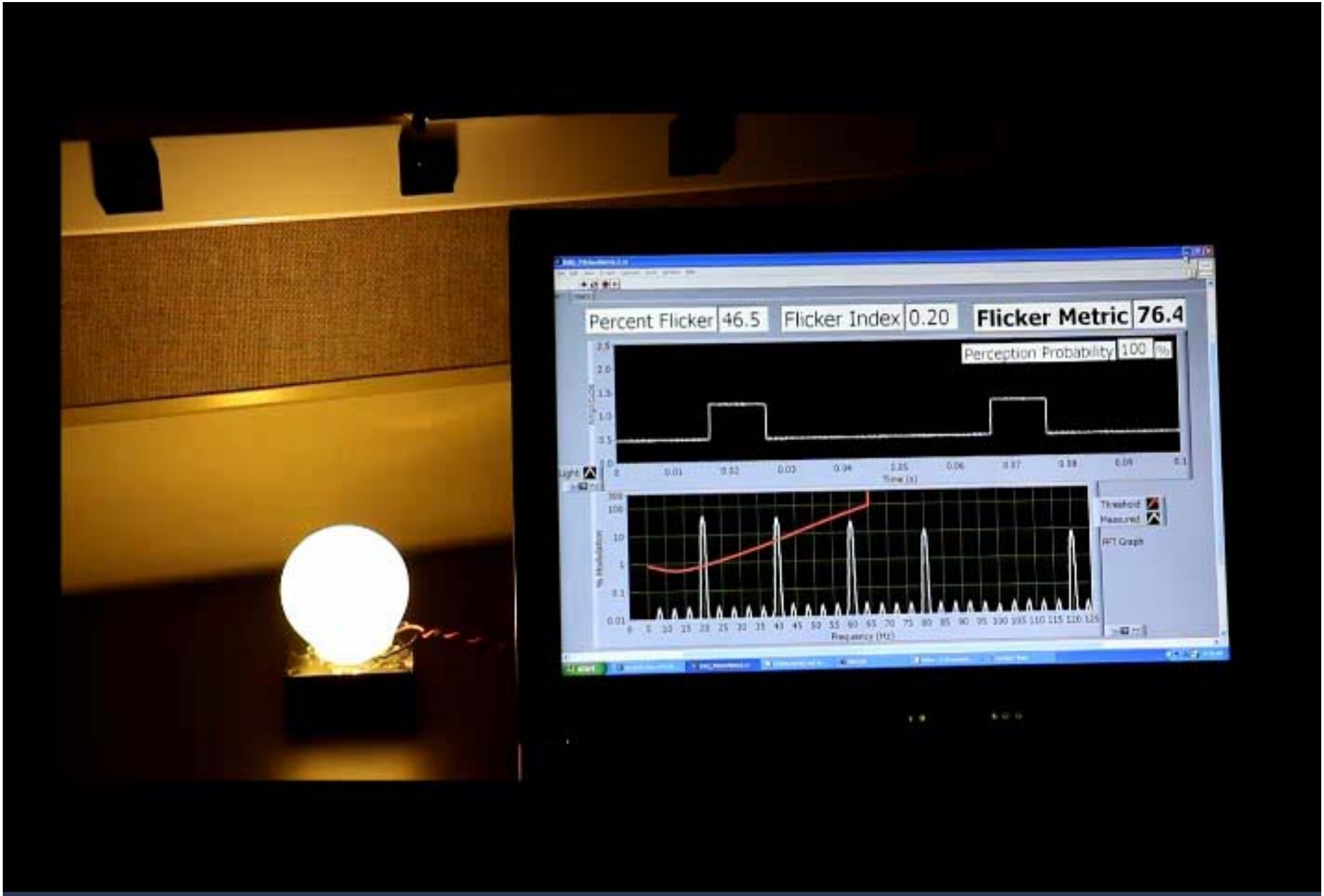

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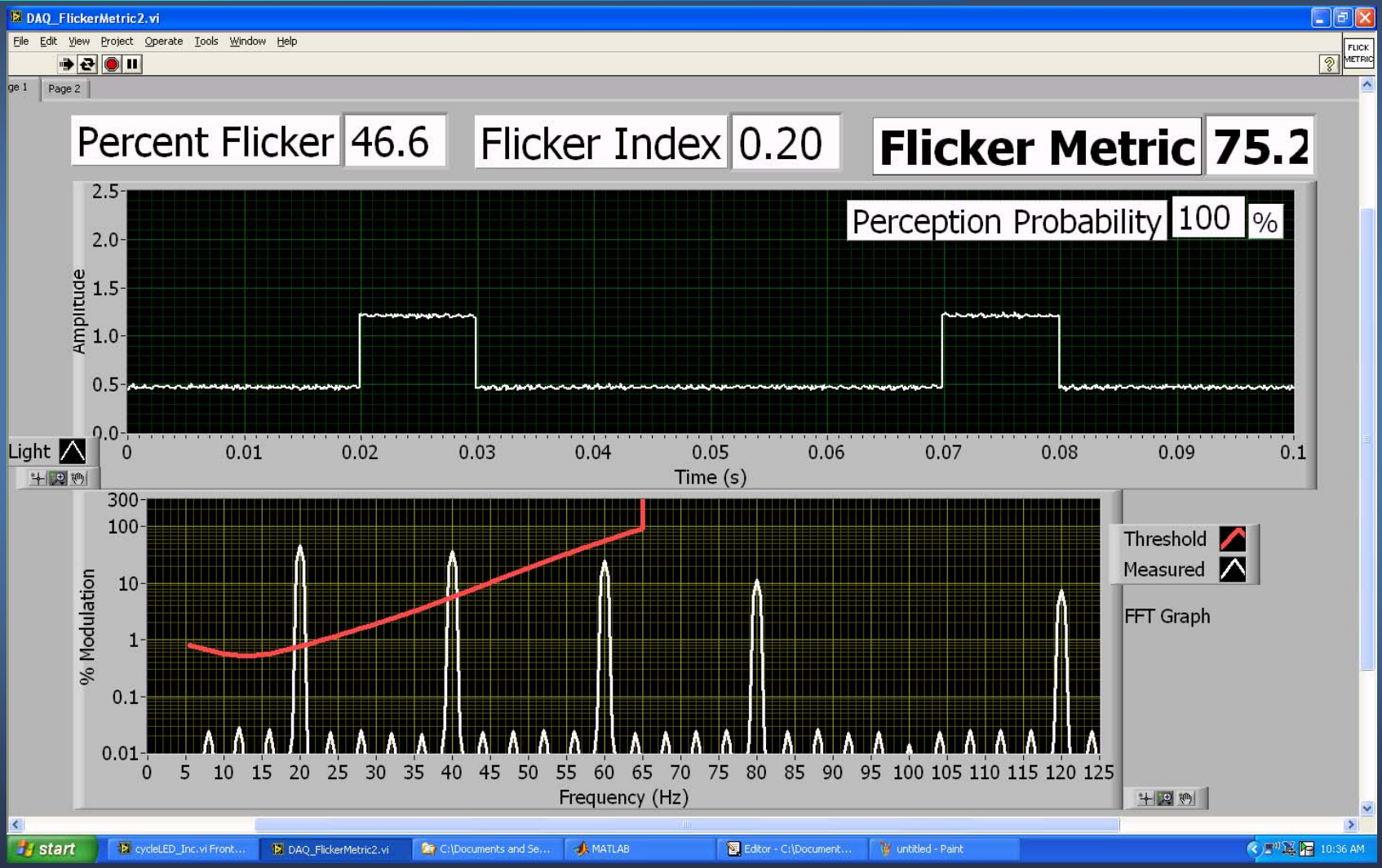
Periodic Flicker waveform: Obvious flicker



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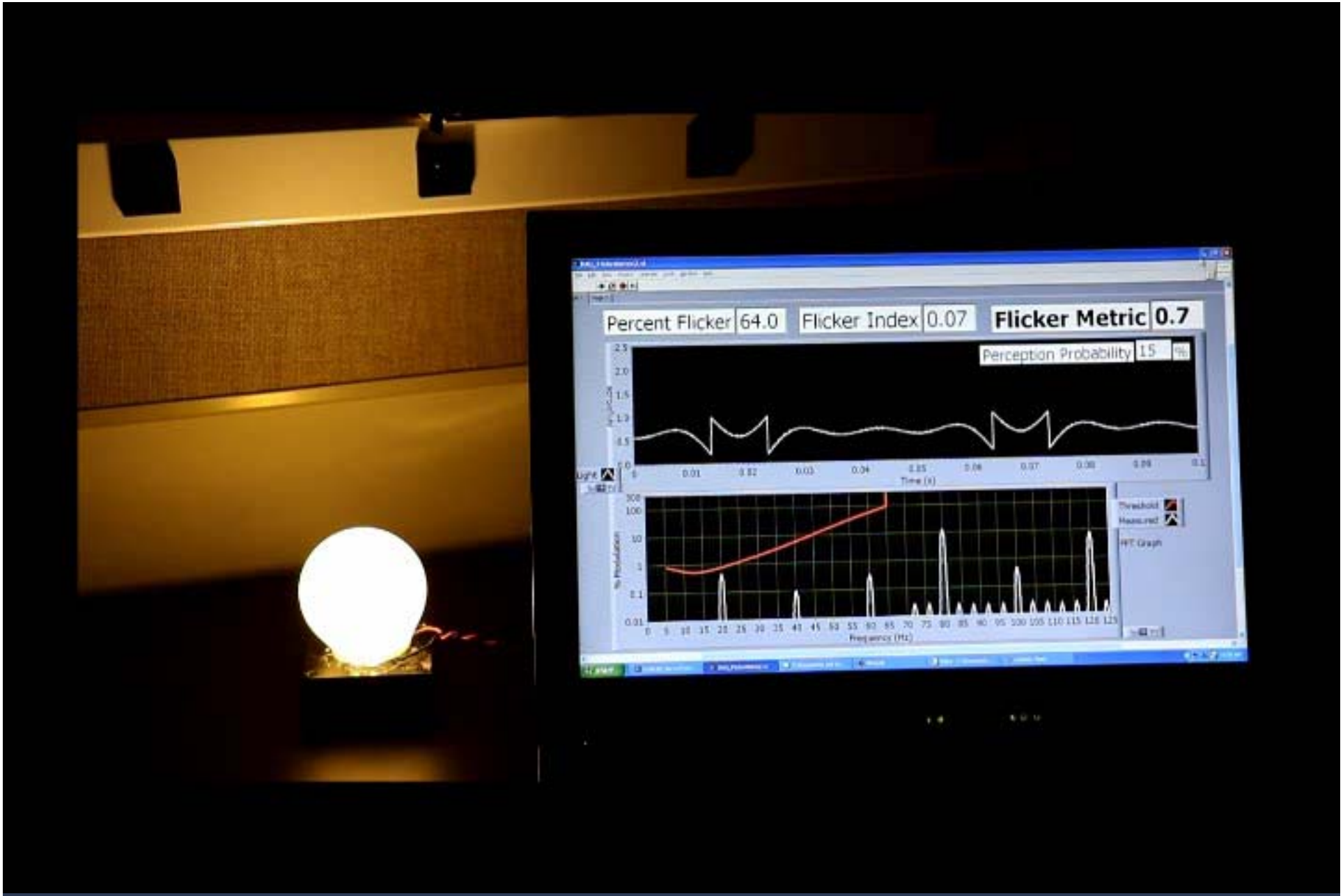

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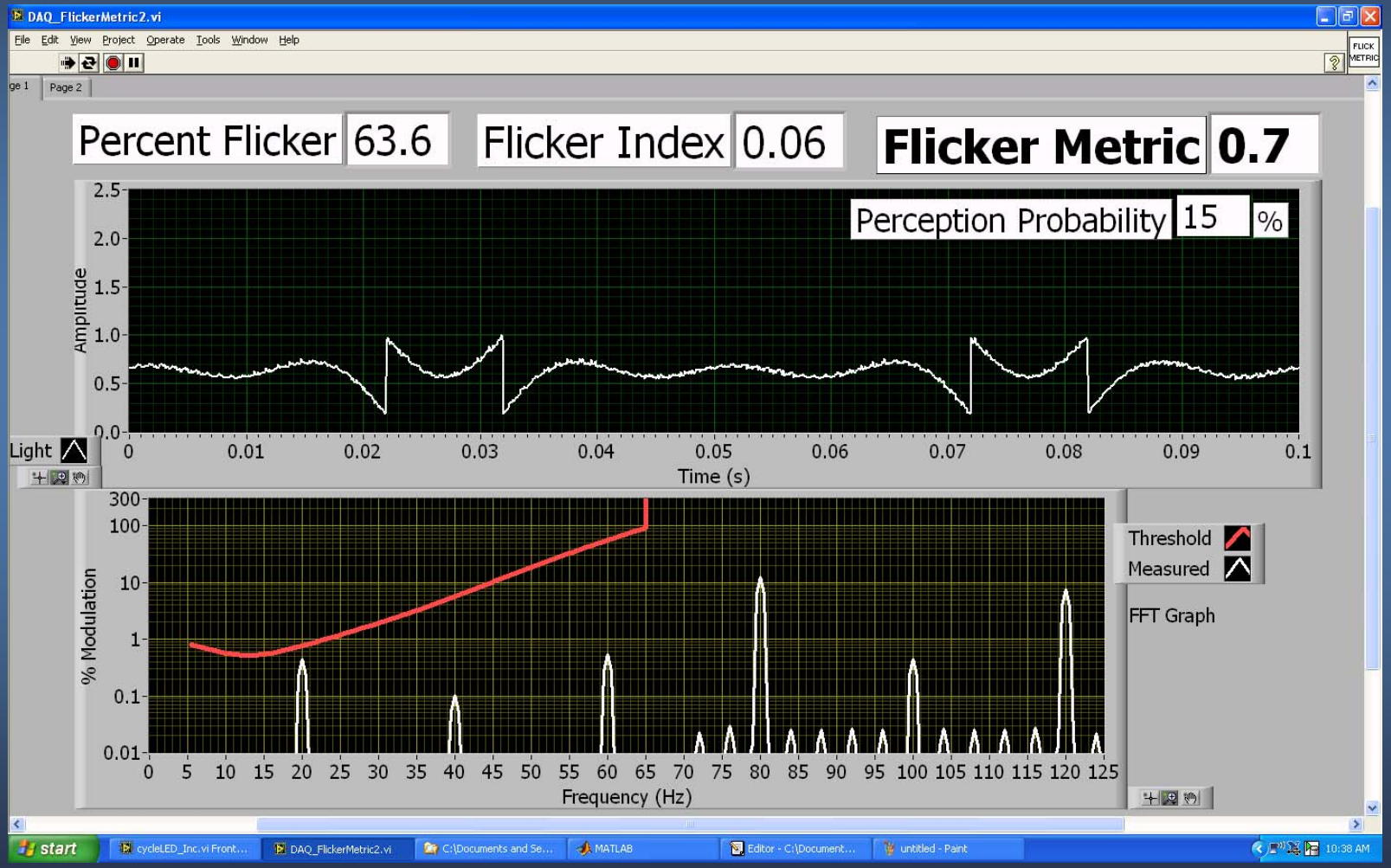
Periodic flicker waveform: No flicker



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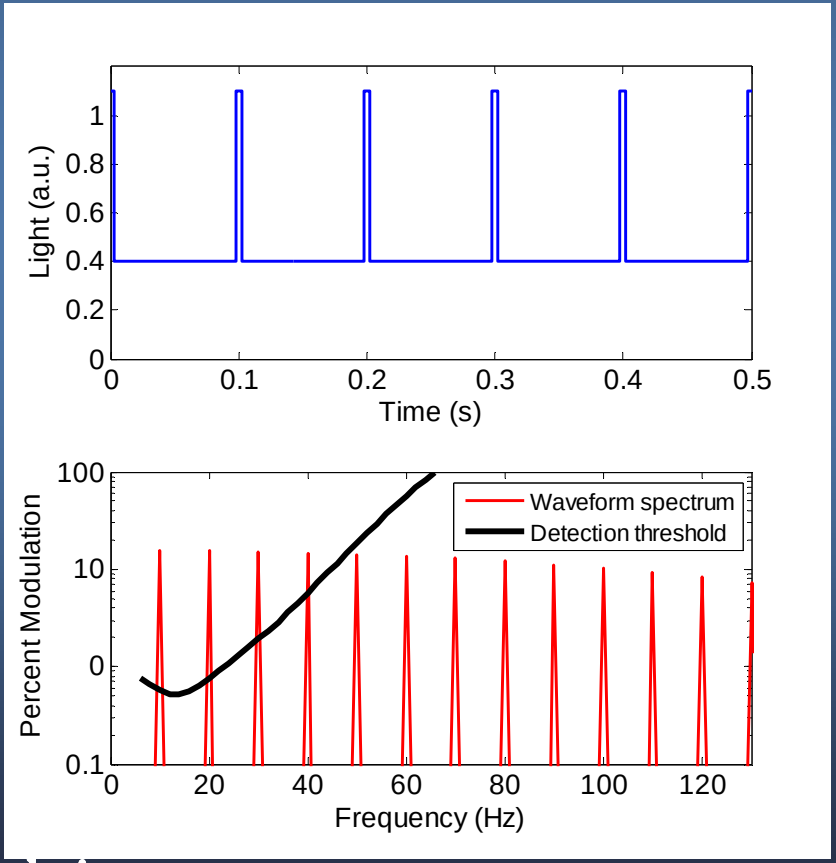
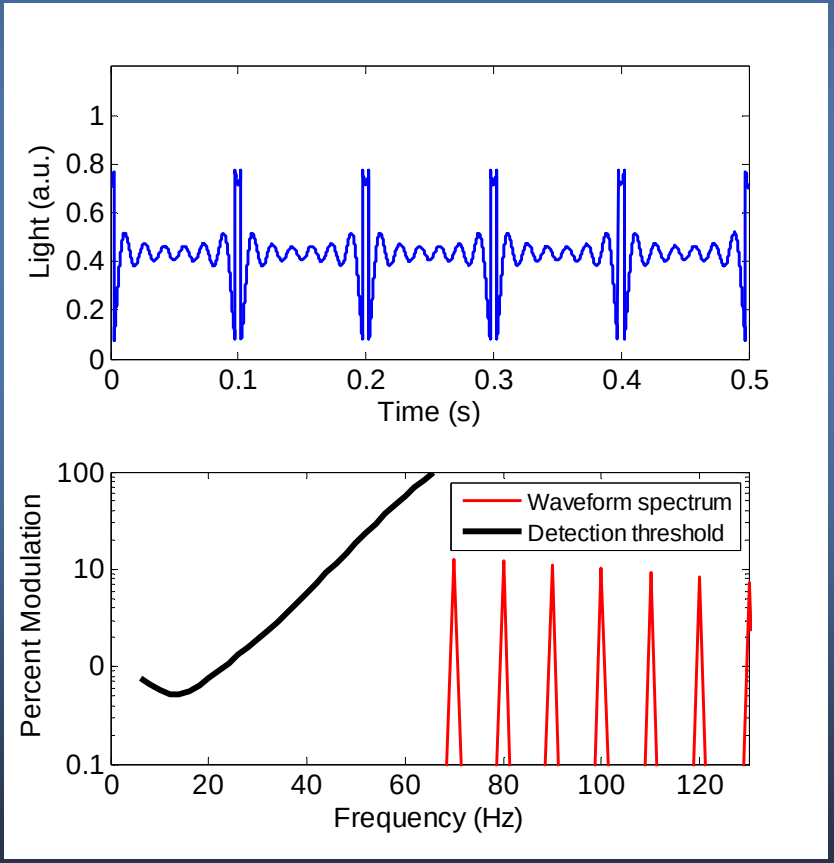
An example for metric comparison

Visible flicker				No Visible flicker
	47	← Percent Flicker →	76	
	0.075	← Flicker Index →	0.073	
	35	← Flicker Metric →	0.3	





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Testing LED screw-base lamps with dimmers

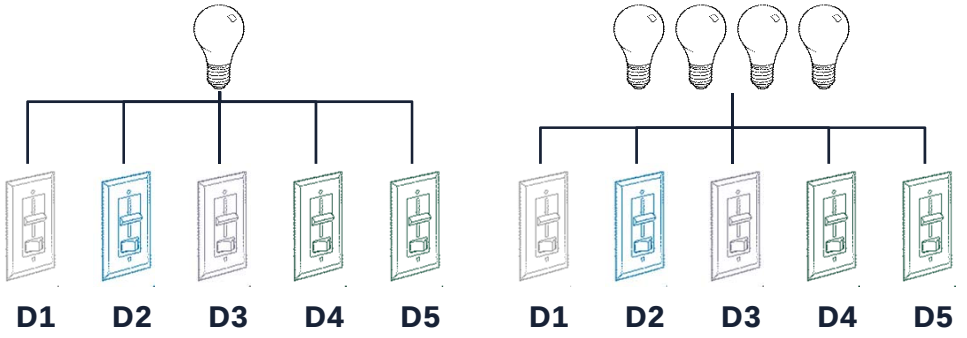
Test conditions

- 20 lamp types
- 5 dimmer types
- 21 tests per lamp
  - 10 measurements / condition
  - 4200 waveforms acquired
    - 20 lamps x 21 tests x 10 repetitions

Measurements

- Percent Flicker
- Flicker Index
- ASSIST Flicker Metric

Test condition	4-lamp	1-lamp	4-lamp
Bypass	1		
DIM at MAX		5	5
DIM at min		5	5
Total	**21**		



	Did not observe flicker
	Perceived minimal flicker, undecided
	Definitely see flicker

		Flicker observations									
		1-LAMP					4-LAMP				
Lamp ID		D1	D2	D3	D4	D5	D1	D2	D3	D4	D5
1	Bypass										
	Dim at MAX										
	Dim at MIN										

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Testing procedure

- Stabilize with dimmer bypassed according to IES LM79-08
  - Light output and power variation < 0.5% over 30 minutes
  - Ambient temperature 25° ±1° C
  - Record maximum light output (MLO)
- Connect dimmer and test at maximum and minimum dimmer settings
  - Minimum setting 20% of MLO, or as specified by manufacturer if lower
  - Stabilize to < 0.5% variation over 2.25 minutes

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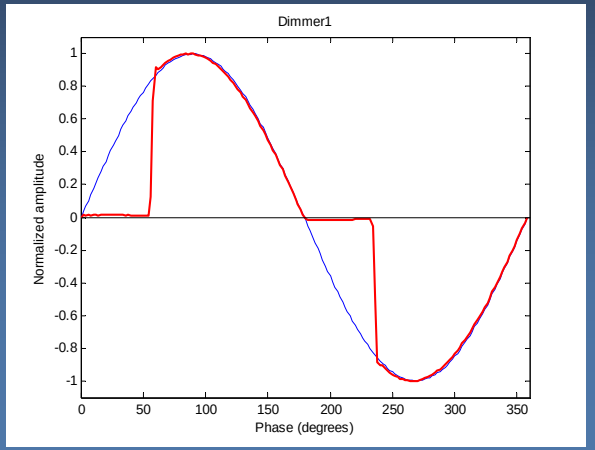
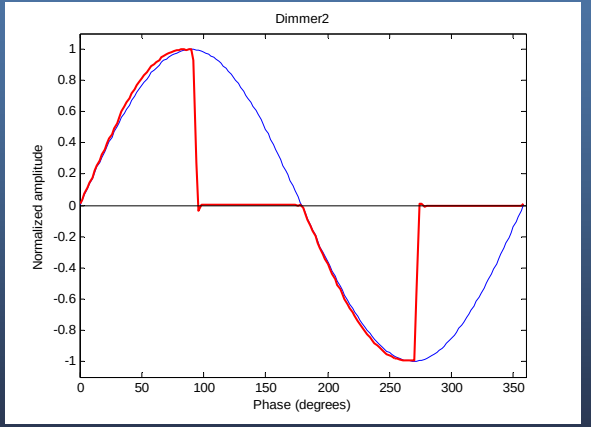
Dimmers used

- 5 Different dimmer types
  - Forward phase, incandescent, magnetic low voltage (2 models)
  - Forward phase, incandescent, CFL and LED (2 models)
  - Reverse phase: electronic low voltage (1 model)

Forward phase



Reverse phase



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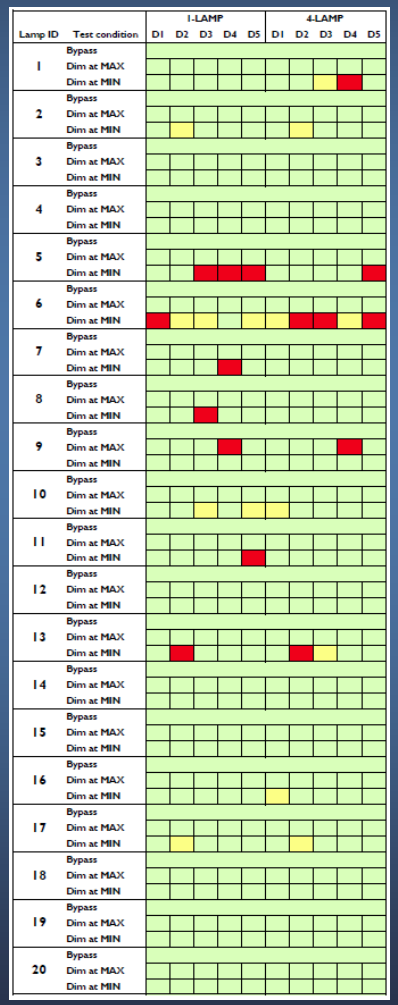
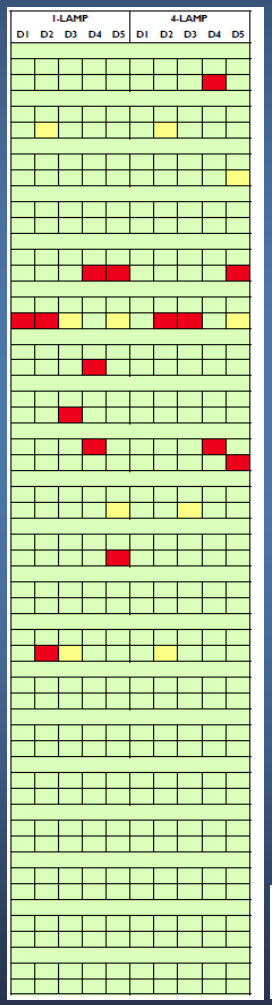
Results: Flicker during dimming

Observed



Flicker Metric



Test condition	Observed	Correctly predicted	Accuracy of prediction
Did not observe flicker	387	386	99.7%
Undecided	15	6	40%
Definitely see flicker	18	14	88%

	Did not observe flicker
	Perceived minimal flicker, undecided
	Definitely see flicker

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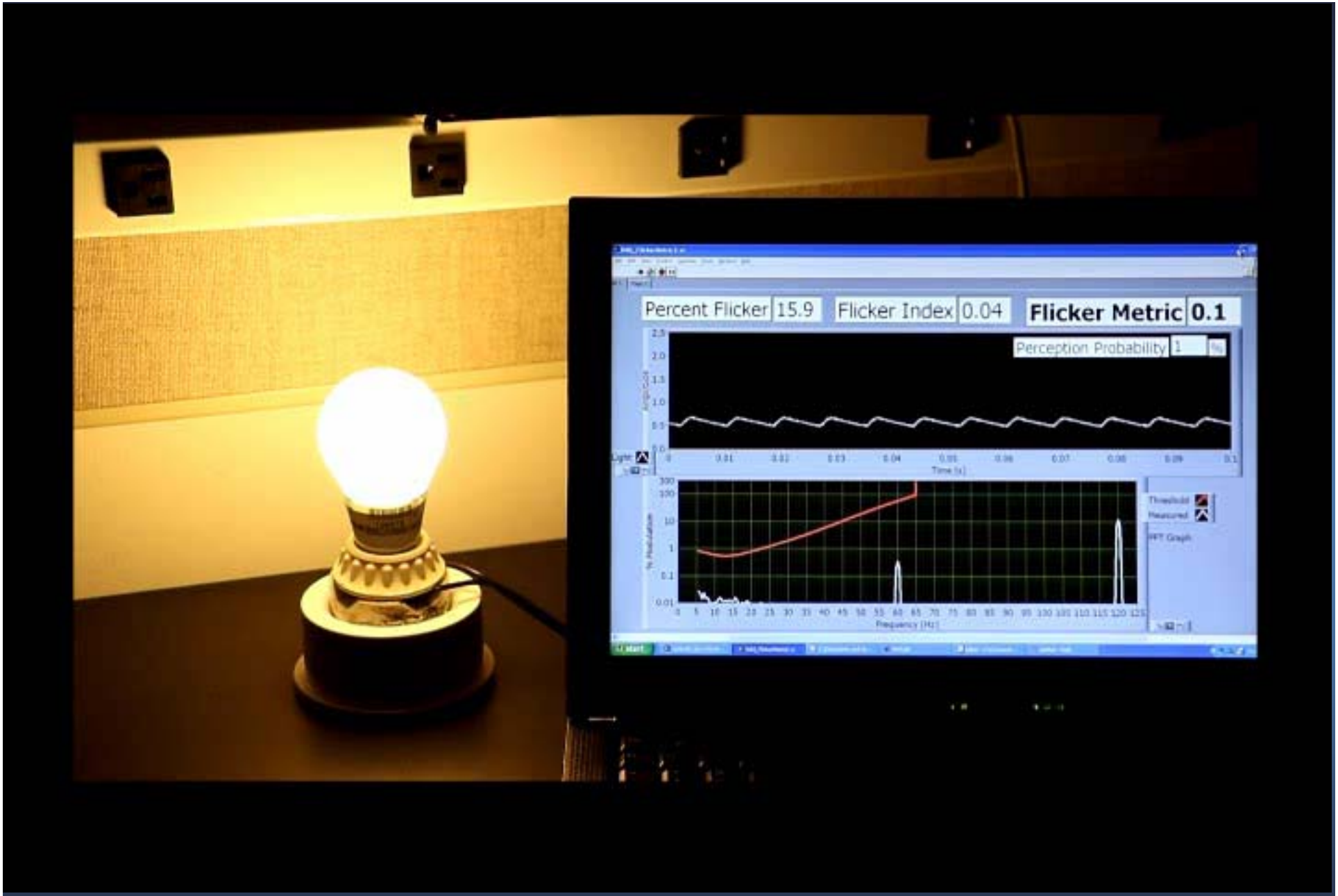

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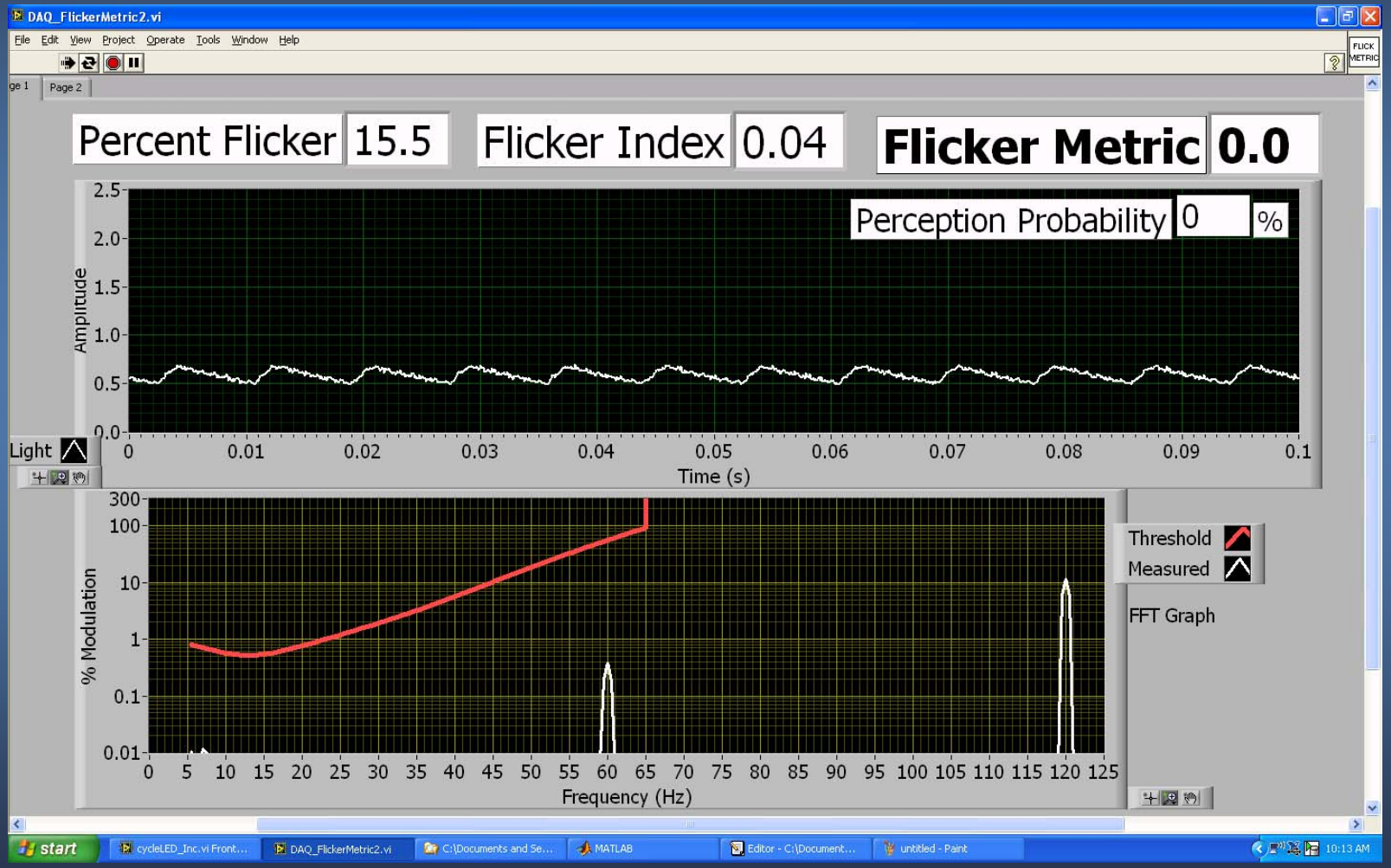
LED A-lamp on dimmer: No Flicker



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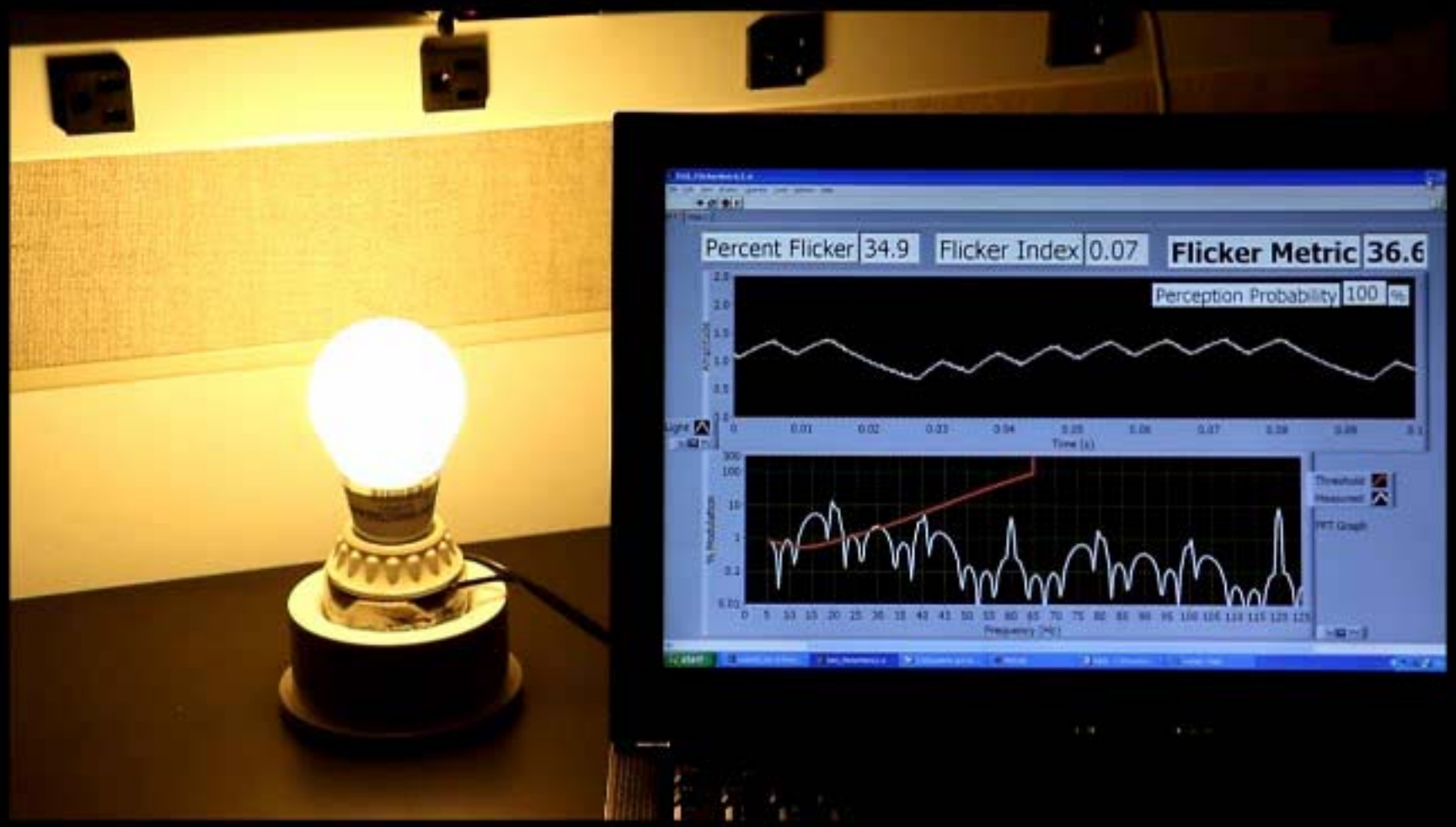

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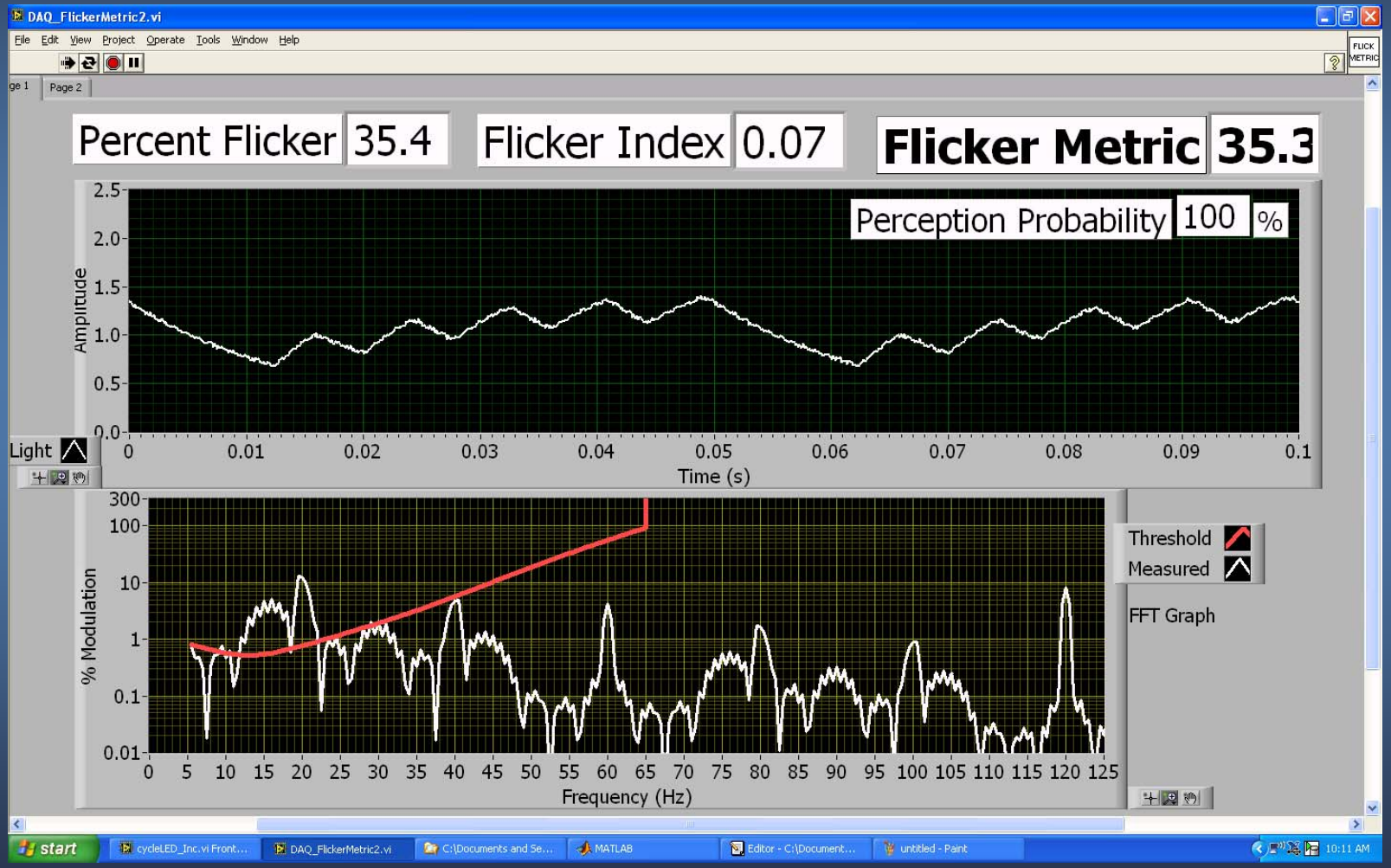
LED A-lamp on dimmer: Obvious Flicker



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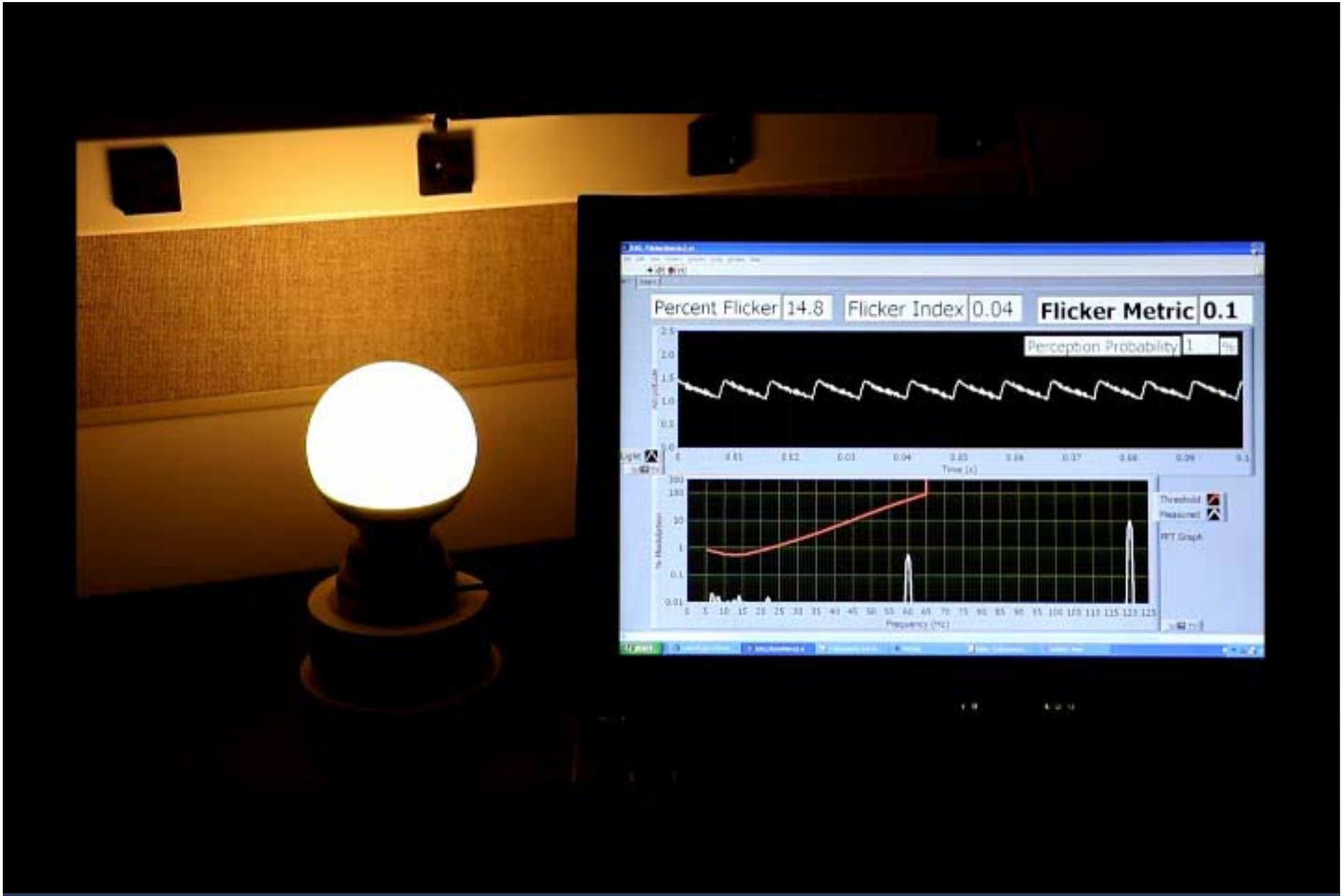

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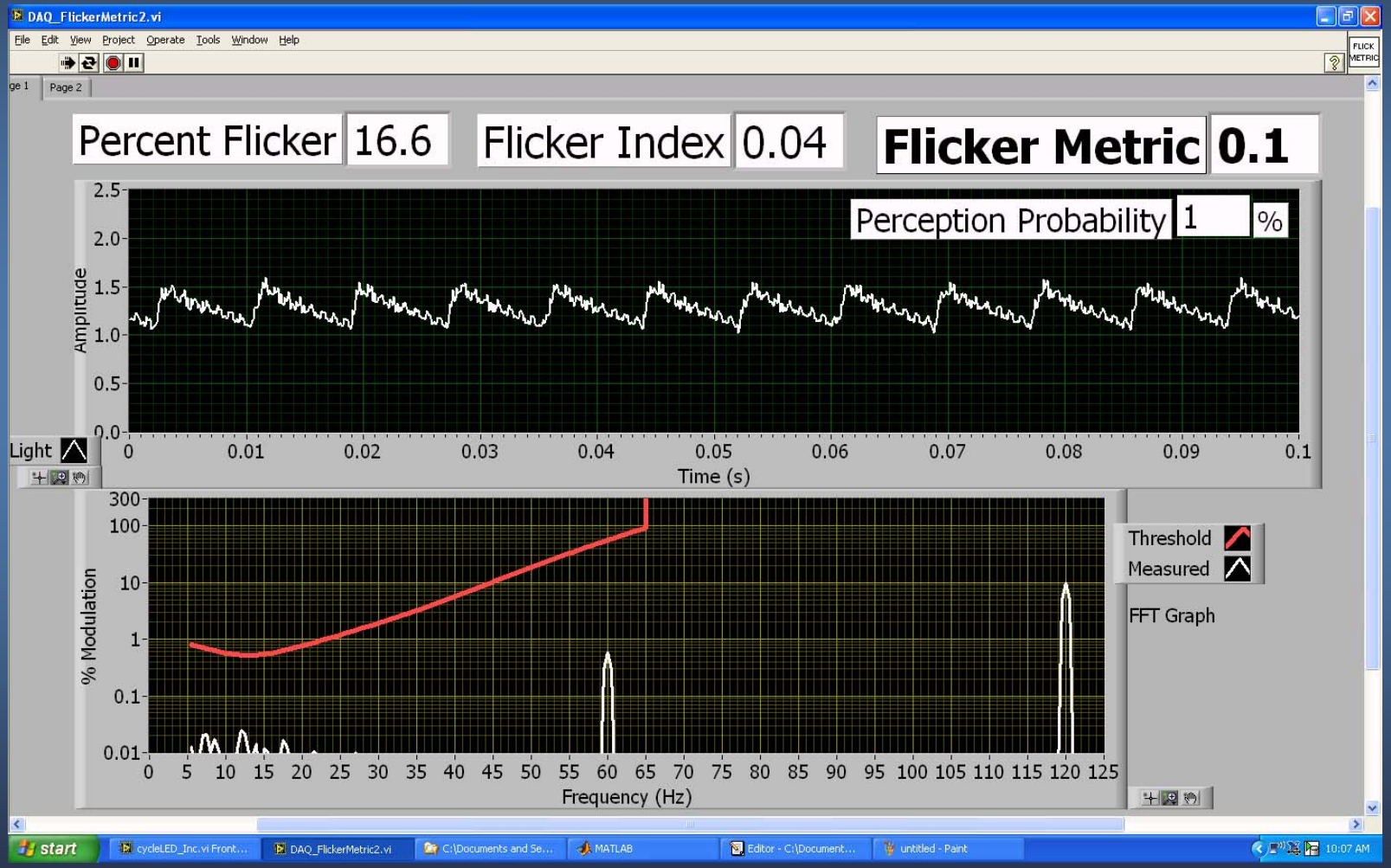
LED A-lamp on dimmer: No Flicker



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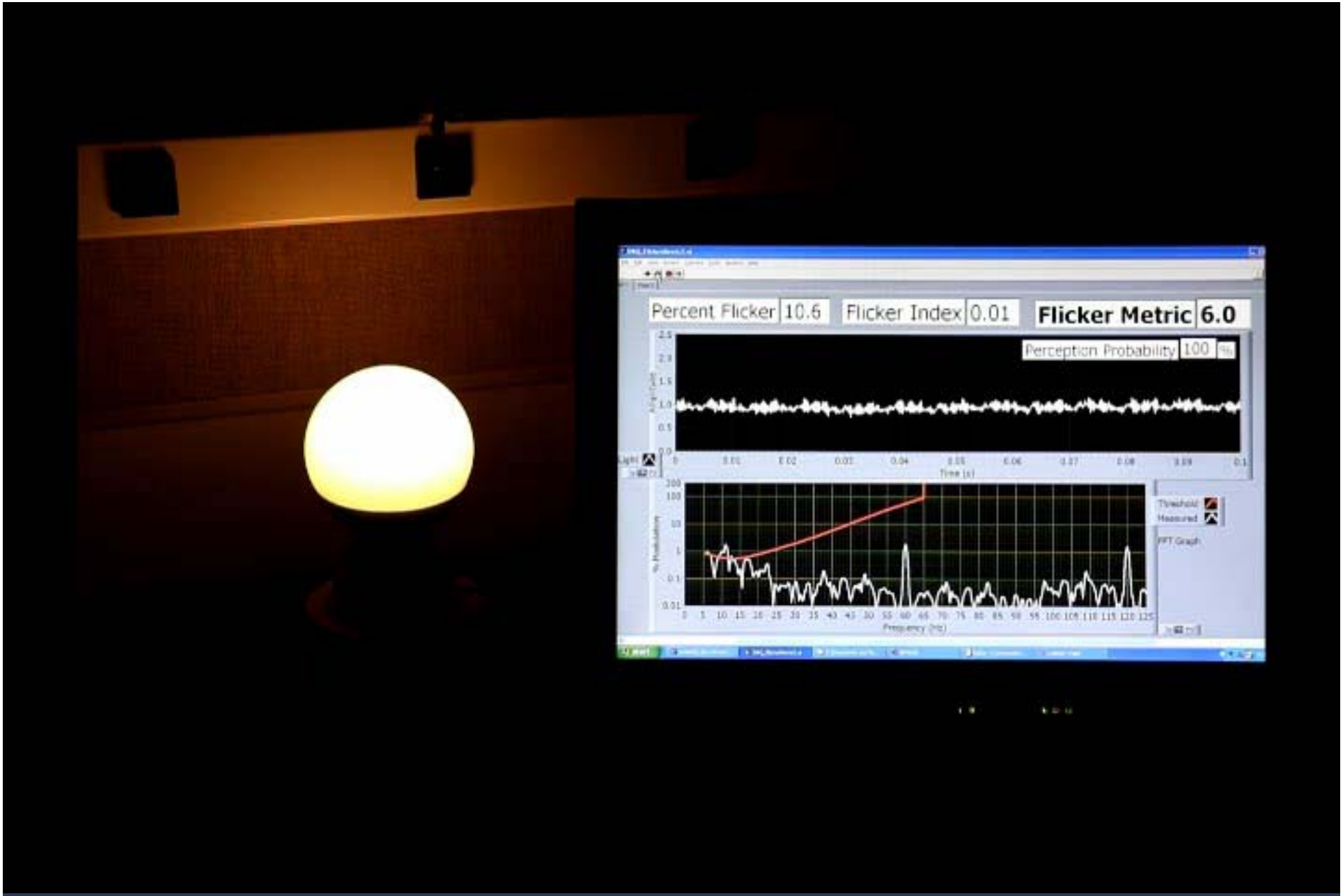

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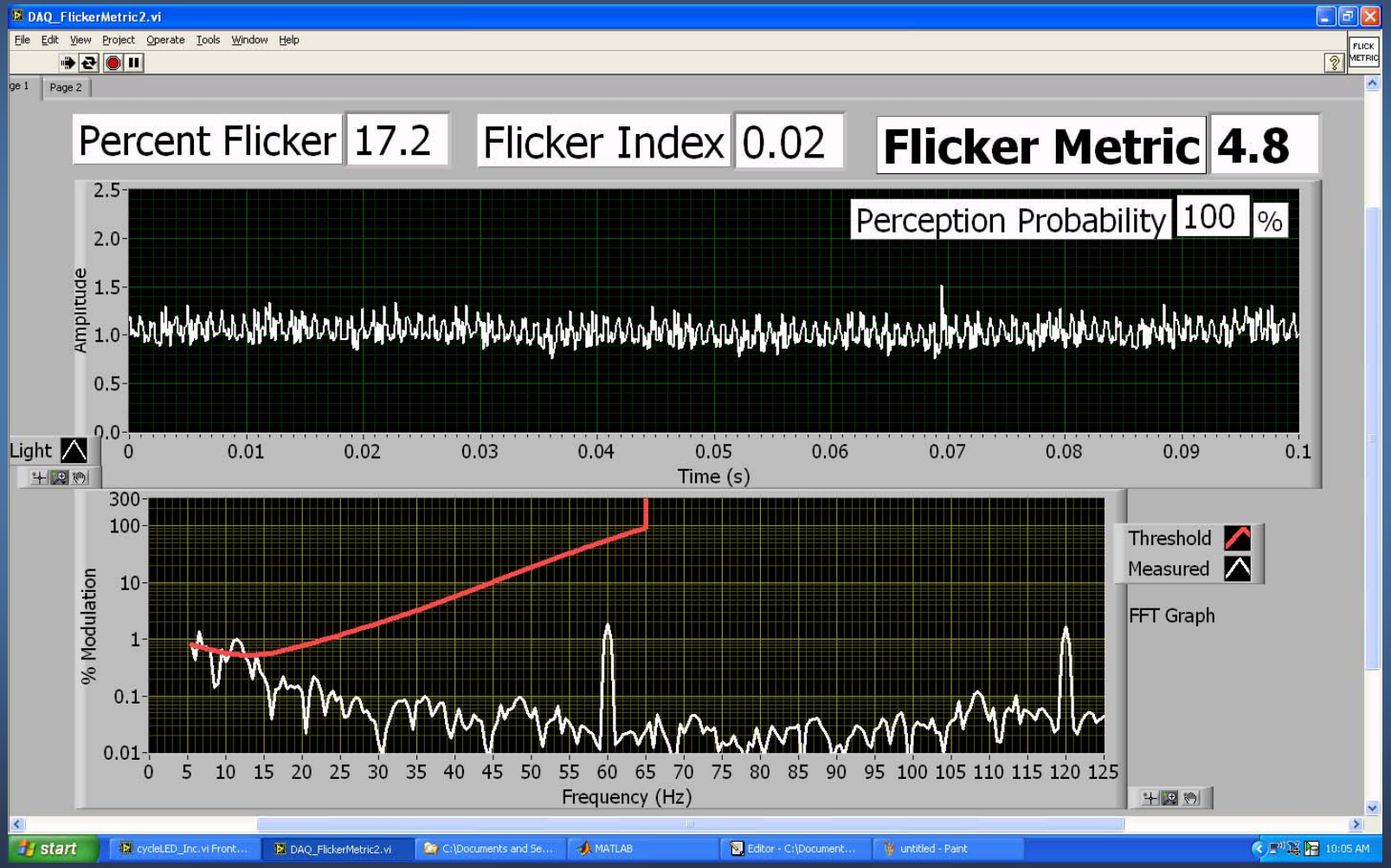
LED A-lamp on dimmer: Noticeable Flicker



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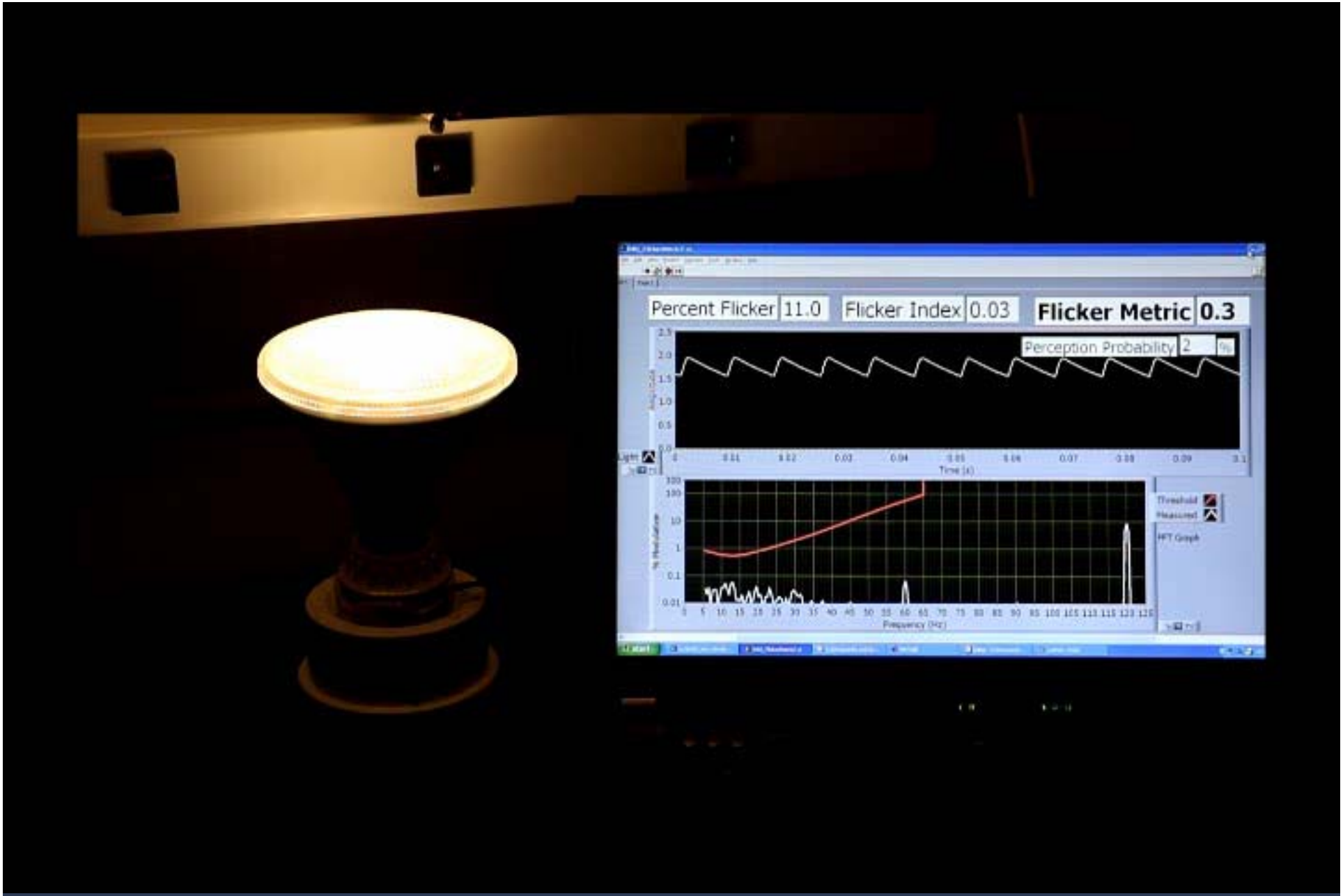

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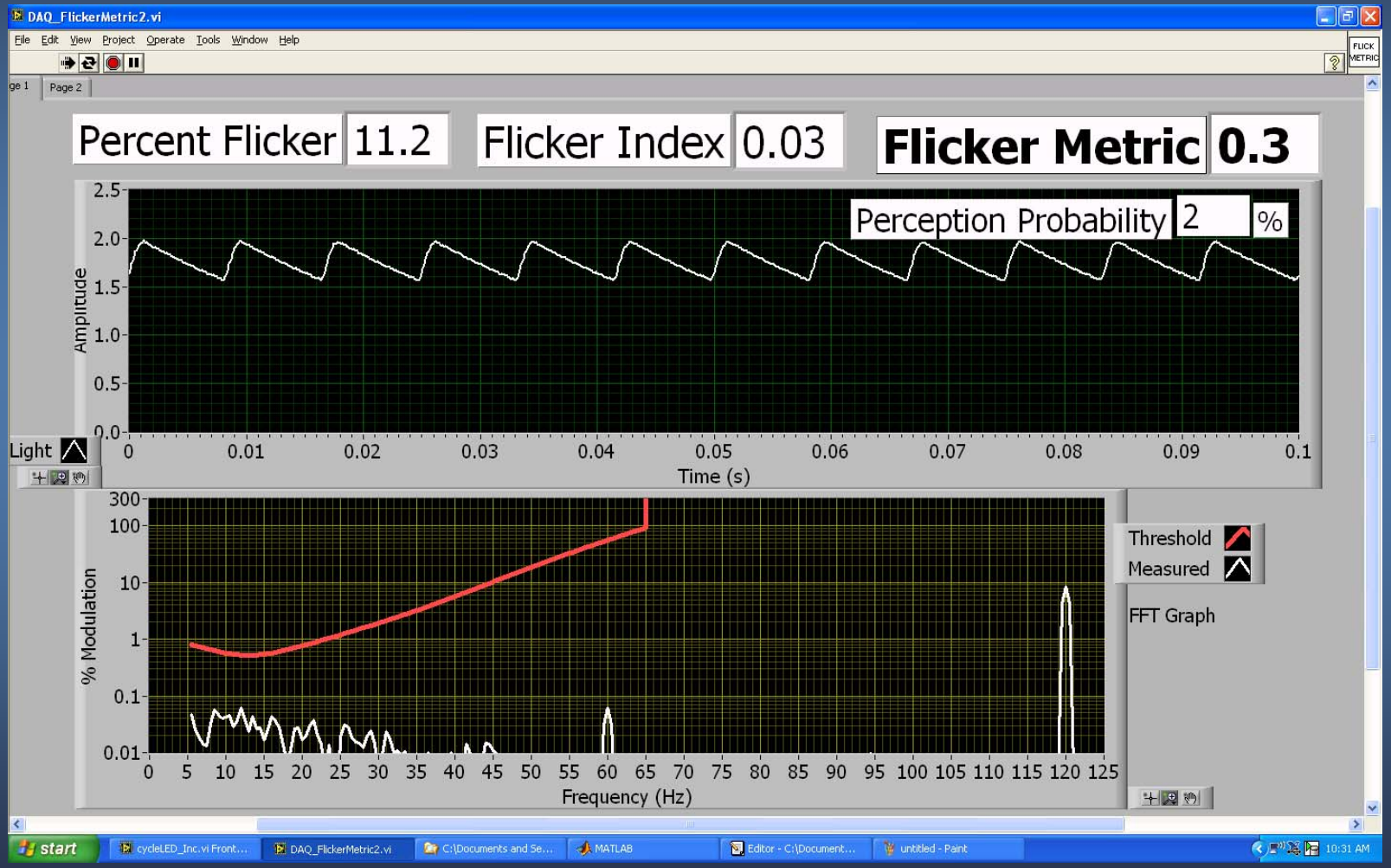
LED A-lamp on dimmer: No Flicker



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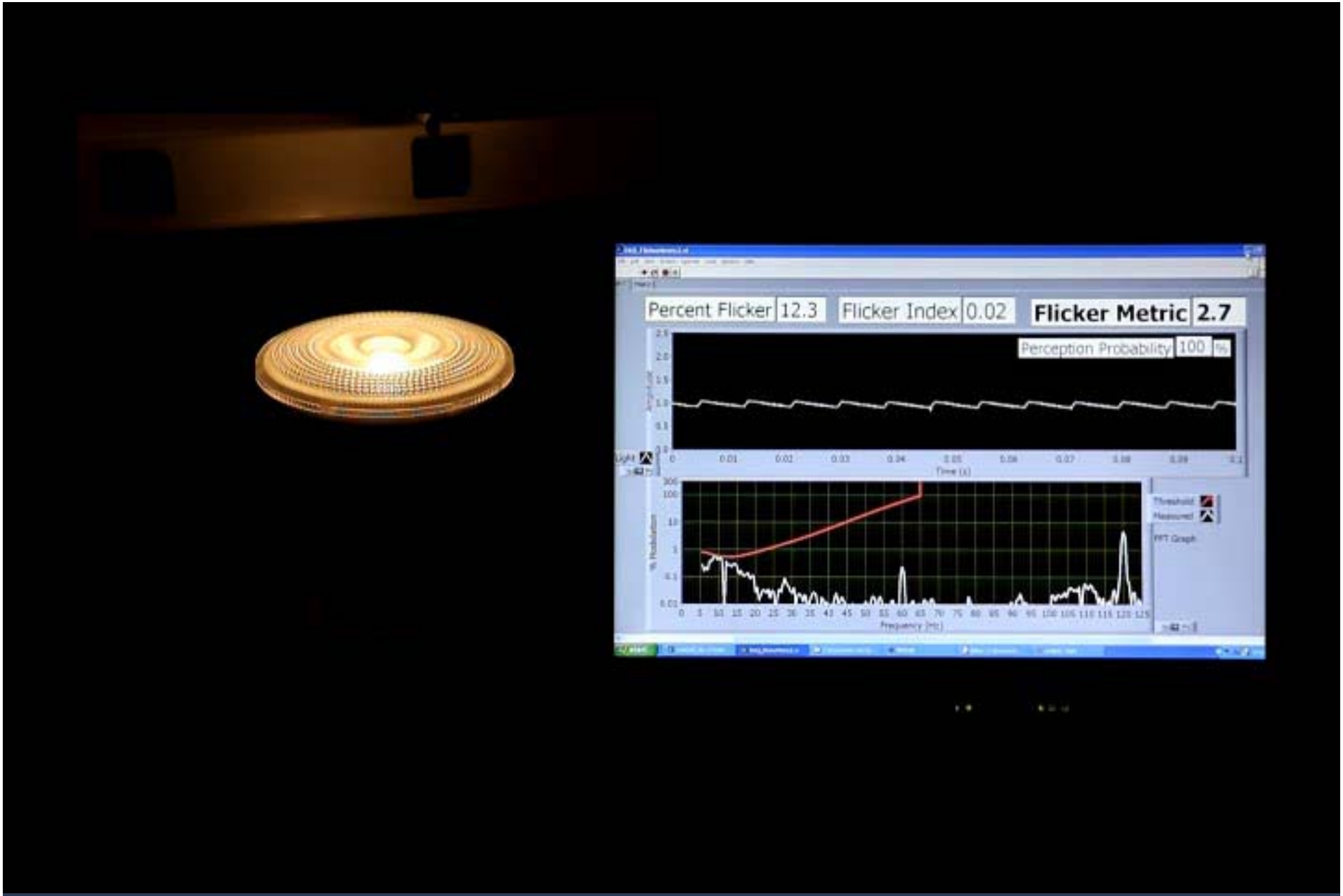

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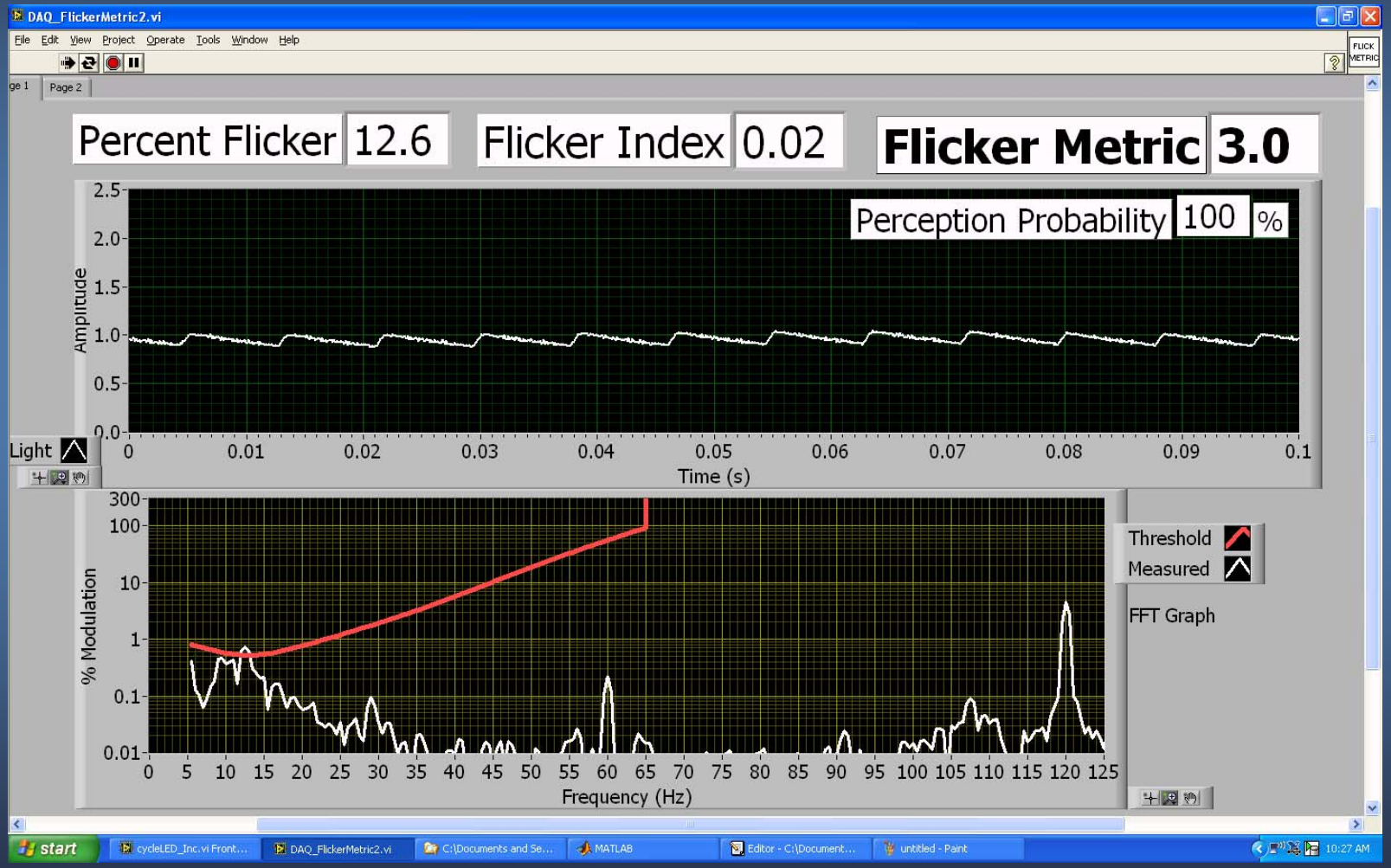
LED A-lamp on dimmer: Noticeable Flicker



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Test methodology comments

- A bandwidth requirement is needed for measuring light output waveforms. "Less than 5% attenuation (-26 dB) from dc to 500 Hz."
- An amplitude resolution requirement is needed. "Must resolve < 0.1% change in light level."
- Some lamp/dimmer combinations would not stabilize when dimmed; output and power input would oscillate. Used steady-state criterion.
- Test time dominated by stabilization
  - Ranged from 2 to 5+ hours per lamp tested on 5 dimmers
- A 5% light output tolerance at 20% (or less) is difficult and sometimes impossible to achieve. Requires a stability of 0.25% of full scale.
  - Express all light output tolerances a percentage of maximum light output
- Sample more waveforms spaced over longer time interval in order to catch the transient, stochastic nature of flicker for some products

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Thank You!

- For more information visit http://www.lrc.rpi.edu/programs/solidstate/assist/flicker.asp

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