ENERGY STAR® Method of Measurement for Light Source Flicker

1 OVERVIEW

This document provides the method of measurement for light source flicker. This test can be performed concurrently with the ENERGY STAR Light Output on a Dimmer testing.

2 APPLICABILITY

This method of measurement applies to all products covered in the scope of the Lamps, Luminaires, and Ceiling Fans specifications that are marketed as dimmable.

3 DEFINITIONS

Unless otherwise specified, all terms used in this document are consistent with the definitions in the ENERGY STAR Eligibility Criteria for Lamps.

Baseline Light Output: The baseline light output (BLO) refers to the stabilized light output of the UUT operating without a dimmer in the circuit.

Fundamental Frequency: The lowest frequency component of a periodic waveform.

Maximum Control Position: The setting on the dimmer or control device intended to achieve the maximum light output during operation.

Maximum Light Output: The maximum light output (MaxLO) refers to the light output of the UUT when operating with a dimmer in the circuit with the control at the maximum position.

Minimum Control Position: The setting on the dimmer or control device intended to achieve the minimum light output during operation.

Minimum Dimming Level Claimed: The minimum light output level of a UUT when operated with a dimmer in the circuit, as declared by the manufacturer. Typically expressed as a percentage.

Minimum Light Output: The minimum light output (MinLO) refers to the light output of the UUT when operating with a dimmer in the circuit. For the purposes of this testing:

- If no minimum dimming level is claimed, MinLO shall be set at 20% of MaxLO.
- If minimum dimming level claimed: MinLO shall be set at the claimed percentage of MaxLO.

Unit Under Test: The unit under test (UUT) refers to the specific sample being tested.

4 METHODS OF MEASUREMENT AND REFERENCE DOCUMENTS

4.1 Methods or Measurement and Reference Documents

A) IES LM-66-14: 2014. Approved Method for Electrical and Photometric Measurements of Single-Ended Compact Fluorescent Lamps, Illuminating Engineering Society, New York.

B) IES LM-79-08: 2008. Approved Method for Electrical and Photometric Measurements of Solid-State Lighting Products, Illuminating Engineering Society, New York.

C) IES LM-54-12: 2012. IES Guide to Lamp Seasoning, Illuminating Engineering Society, New York.

D) IES RP-16-10: 2010. Nomenclature and Definitions for Illuminating Engineering, Illuminating Engineering Society, New York.

E) ASSIST recommends…Recommended Metric for Assessing the Direct Perception of Light Source Flicker, Volume 11, Issue 3 (ASSIST 2015).

5 TEST SETUP

5.1 General

The test requires multiple relative light output waveform measurements of the UUT. Absolute or relative photometry methods may be used provided that the waveform measurements are representative of the total light output (in all directions) of the UUT. Integrating spheres are ideal for obtaining light measurements that are representative of the total light output, but other geometries are acceptable depending on the spatial-temporal output uniformity of the UUT. For example, an integrating box enclosure may be acceptable for many products, and for diffuse globe products no integrating enclosure may be needed. If no integrating enclosure is used, the representative waveform assumption shall be verified by recording several waveform measurements for different orientation changes of the setup around the UUT and all need to show no significant changes in waveform shape.

Measurements of the relative light output waveforms are used to calculate three metrics: Percent Flicker, Flicker Index and the ASSIST Flicker Metric (M_P). Different temporal bandwidth and dynamic range requirements for these metrics will likely require different instrumentation for capturing the corresponding waveforms, or at least different instrument settings.

5.2 Test Setup and Instrumentation

A. Waveform capture equipment

1. Waveform digitizer (e.g., oscilloscope) with the following requirements:

Table 1. Waveform digitizer requirements

Characteristic	**For Percent Flicker and Flicker Index**	**For ASSIST Flicker Metric (M_P)**
Temporal bandwidth (-3 dB rolloff frequency)	0 to ≥ 1 MHz	0 to ≥ 500 Hz
Dynamic range of waveform amplitude	≥ 100:1 (40 dB)	≥ 1000:1 (60 dB)
Sampling rate	≥ 5 MSa/s	≥ 10 kSa/s
Record length	0.1 s (≥ 500 kSa)	2 s (≥20 kSa)

Note – Many 8-bit oscilloscopes satisfy the requirements for measuring Percent Flicker and Flicker Index, but fail to meet the dynamic range requirements for the ASSIST Flicker Metric signal acquisition. At least 12-bit analog-to-digital conversion (ADC) is likely required to meet the dynamic range requirements for calculating the ASSIST Flicker Metric (M_P).

2. Appropriate photodetection, amplification and signal conditioning are needed to ensure that the temporal bandwidth and dynamic range requirements listed above apply for detection and are maintained throughout the analog signal chain.
3. The photodetector shall be corrected to closely fit the Commission Internationale de l'Eclairage (CIE) spectral luminous efficiency curve ($V\lambda$). The f_1' figure of merit shall be less than 5% ($f_1' < 5\%$). The photodetector's speed of response shall meet or exceed the temporal bandwidth requirements in Table 1.
4. A photodetector amplifier, typically a transimpedance amplifier (current-to-voltage), is required to obtain a linear voltage response from the photodetector and is useful for improving or maintaining the temporal bandwidth of the detector.

5. An anti-aliasing filter is required. This is a low pass filter with a frequency response that satisfies the sampling theorem for alias-free waveform digitization. The response of this low pass filter shall be less than 0.1% (-60 dB) at the sampling rate frequency of the waveform digitizer. The in-band response of this filter shall be 1 ± 0.1% (±0.01 dB). The in-band frequency range is 0 (dc) to 100 Hz for determining the ASSIST Flicker Metric and 0 (dc) to 100 kHz for Percent Flicker and Flicker Index.

B) Stray light: The testing conditions shall ensure that the light measured comes only from the UUT and is representative of the total light output of the product. When the UUT is not powered, the detector output should read zero to within noise and resolution limits.

C) Lamp Seasoning and Preburning: Prior to the first readings, compact fluorescent lamps (CFLs) shall be seasoned for 100 hours in accordance with IES LM-54-12. CFLs shall be preburned in accordance with IES LM-66-14. LED lamps shall not be seasoned.

D) Input Power for Measurements: The power requirements shall be per IES LM-66-14 or LM-79-08 as applicable.

Note: When selecting a power supply for use with integrated lamps, it is necessary to include an appropriate power factor when specifying the Volt-Amp rating of the power supply.

E) Ambient Temperature: Testing shall take place in an ambient temperature of 25°C ± 5°C. Drafts shall be minimized.

F) Power Meter: Power meters shall be capable of measuring to the appropriate requirements of IES LM-66-14 and/or IES LM-79-08 as applicable.

G) Environmental Conditions: The test environment shall be clean and free from large amounts of dust and moisture.

H) Sample Selection: Samples shall be representative of the manufacturer's typical product. The samples shall be clean and thoroughly inspected before testing. Any flaws or inconsistencies in the samples shall be noted. The samples used for flicker testing shall be the same samples used for the ENERGY STAR Light Output on a Dimmer testing and can be the same samples used for other testing.

6 GUIDANCE FOR IMPLEMENTING THE TEST PROCEDURE FOR LIGHT SOURCE FLICKER

6.1 Photometric Measurements

A. The UUT, photodetector, and enclosure (if applicable) shall remain stationary and have no vibrations or movement of any kind during the measurement recording periods.

B. Ensure that the waveform digitizer receives the appropriate voltage range from the photodetector/amplifier by adjusting the amplifier gain, or repositioning the photodetector if necessary. This is needed to preserve the dynamic range (specifically the amplitude resolution) of the waveform digitizer as applied to the specific waveform being measured.

C. Ensure that the photodetector receives light only produced by the UUT.

D. Check dark reading and adjust offsets as needed to ensure that the recorded zero-level (dc) is accurate.

6.2 Lamp Transfer for CFLs

A. Care shall be exercised to maintain lamp orientation and avoid shaking or bumping the lamp during the transfer from the seasoning area.

6.3 Low Voltage Lamps:

A. Lamps designed for operation on low voltage transformers shall be operated on a compatible transformer specified or supplied by the lamp manufacturer.

B. Electrical measurements shall characterize the lamp only and must not include external control gear.

6.4 Measurement sampling:

A. Two light output waveforms shall be collected per measurement sample:

1. One at the full bandwidth of 0 to 1 MHz for a duration of 0.1 seconds (to calculate Flicker Index and Percent Flicker); and
2. Another at a reduced bandwidth of 0 to 500 Hz for a duration of 2 seconds (to calculate the ASSIST Flicker Metric).

B. At least 10 measurement samples shall be collected per UUT operating condition. The time interval between each repeated sample shall be greater than 5 seconds. The reported values of Percent Flicker, Flicker Index, and ASSIST Flicker Metric shall be the highest value measured.

C. Data recording: The following data shall be collected at each measurement point:

1. Waveform amplitude values for each of the 10 measurement samples for both the full-bandwidth and reduced-bandwidth measurements (at least 20 recorded waveforms)
2. Sampling rates of the full-bandwidth and reduced-bandwidth waveforms
3. Measurement bandwidths
4. Ambient temperature
5. Input voltage (rms), current (rms), and power

7 TEST PROCEDURE FOR LIGHT SOURCE FLICKER

<u>Steps 1-6 are for measuring light source flicker at BLO:</u>

1. Install the UUT in the test environment without a dimmer in the circuit.
2. Set power supply to rated voltage and frequency of the UUT. If a range is specified, test the sample at the midpoint of the range.
3. Apply rated voltage/frequency to the UUT.
4. Allow the UUT to stabilize per IES LM-66-14 or IES-LM-79-08 as applicable. If the UUT has been stabilized for measurements previously and the stabilization time recorded, the UUT may be considered stabilized after operating for this period of time.
5. Record light output, electrical parameters, and waveform readings per sections 6.4.B and 6.4.C from measurement equipment.
6. Percent Flicker, Flicker Index, and ASSIST Flicker Metric (M_p) may be calculated now or at any later time from the saved waveforms. These measurements correspond to the BLO condition.

<u>Steps 7-12 for measuring light source flicker at MaxLO:</u>

Products marketed as dimmable that are designed for phase cut dimming operation (i.e., alterations to the line voltage to the UUT) must be tested with a minimum of 5 dimmers from at least 2 different manufacturers.

Note – A test setup that includes transfer switches to quickly install a dimmer into the test circuit as well as means to enable hot switching between dimmers may be utilized to reduce stabilization times. A test setup that includes means to measure light source flicker at maximum light output (MaxLO) for all five dimmers, and then measure light source flicker at minimum light output (MinLO) for all five dimmers may be utilized to further reduce stabilization times by incurring only one max-to-min stabilization cycle.

Products compatible with a non-phase cut control device (i.e., a dimmer that does not alter the line voltage to the UUT, such as wireless controls), shall be tested with the control device(s) and application(s) specified by the partner.

7. Install dimmer into the test circuit.
8. Apply rated voltage/frequency to the dimmer or control device.
9. Adjust dimmer to the maximum control position.
10. Allow UUT to stabilize. Verify stabilization by taking light output measurements (time-averaged readings over at least one power line cycle) every minute until three consecutive measurements are no more than 0.5% apart. This light output stabilization criterion assumes that the lamp continues to be thermally stable after the conclusion of the BLO test.

    Note – To accommodate dimmer/UUT combinations that do not reach the required stabilization criterion, if the UUT has been stabilized for measurements previously (e.g., during BLO measurements) and the stabilization time recorded, the UUT may be considered stabilized after operating for this period of time.
11. Record light output, electrical parameters, and waveform readings per sections 6.4.B and 6.4.C from measurement equipment.
12. Percent Flicker, Flicker Index, and ASSIST Flicker Metric (M_P) may be calculated now or at any later time from the saved waveforms. These measurements correspond to the MaxLO condition.

<u>Steps 13-15 are for measuring light source flicker at MinLO:</u>

13. Adjust dimmer so that the light output is the lower of:
    a. (20% of the MaxLO) ± 5%.
    b. (The minimum dimming level claimed as percentage of the MaxLO) ± 5%.

    <u>For example</u>: A UUT with a MaxLO of 1,000 lumens and a minimum claimed dimming level of 20% should be adjusted to a light output level that is between 190 and 210 lumens.

    For cases where the minimum light output is greater than 20% of the MaxLO (*e.g., at the minimum control position the minimum light output of a UUT with a MaxLO of 1,000 lumens is 250 lumens*), measurements shall be taken at the minimum light output and the UUT/dimmer combination shall be identified as not meeting the ENERGY STAR minimum light output requirement.

    For cases where the minimum light output is greater than the claimed minimum dimming level (*e.g., at the minimum control position the minimum light output of a UUT with minimum claimed dimming level of 10% and a MaxLO of 1,000 lumens is 150 lumens*), measurements shall be taken the minimum light output and the UUT/dimmer combination should be identified as not meeting the manufacturer performance claims.

14. Allow the UUT to stabilize. Verify stabilization by taking light output measurements (time-averaged readings over at least one power line cycle) every minute until three consecutive measurements are no more than 5% apart.

    Note – To accommodate dimmer/UUT combinations that do not reach the required stabilization, if the UUT has been stabilized for measurements previously and the stabilization time recorded, the UUT may be considered stabilized after operating for this period of time.

15. Verify that the UUT light output is still within the range as determined in step 13.

    a) If not, repeat steps 13 and 14.

    b) If light output is within range, record light output, electrical parameters, and waveform readings per sections 6.4.B and 6.4.C from measurement equipment. Percent Flicker, Flicker Index, and ASSIST Flicker Metric (M_P) may be calculated now or at any later time from the saved waveforms. These measurements correspond to the MinLO condition.

Repeat steps 7-15 for each dimmer to be tested.

8 WAVEFORM CALCULATIONS

8.1 Percent flicker

Percent flicker is calculated according to equation 1.

$$\text{Percent flicker} = \frac{\max(\Phi(n)) - \min(\Phi(\text{n}))}{(\max(\Phi(\text{n})) + \min(\Phi(\text{n})))}(100\%)$$

Equation 1

Where Φ(n) is the digitally sampled waveform. The functions max() and min() return the maximum value and minimum value of the waveform, respectively.

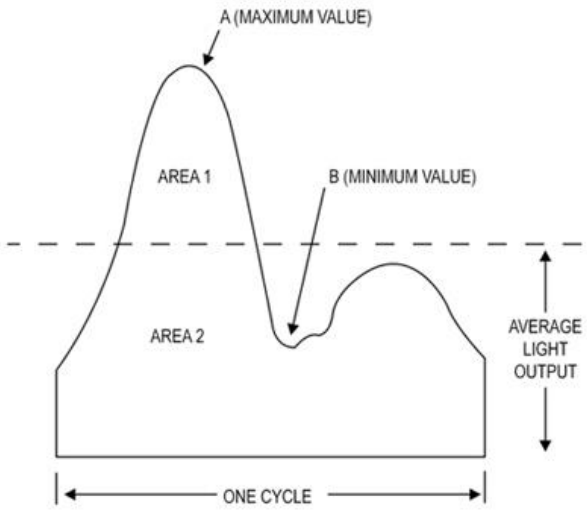
8.2 Flicker Index

Flicker Index is calculated according to equation 2.

$$\text{Flicker Index} = \frac{\sum_i \max\left[\left(\Phi_i - \overline{\Phi}\right), 0\right]}{\sum_i \Phi_i}$$

Equation 2

Where $\overline{\Phi}$ is the average or dc value of the waveform: $\overline{\Phi} = (\sum_i \Phi_i)/N$, where *N* is the total number of sample values in the waveform, and *i* is the index of each value. The max() function returns the maximum value of the two comma-separated arguments. A graphical representation of Flicker Index is shown below.



Flicker Index = Area 1/ (Area 1+ Area 2)

8.3 ASSIST Flicker Metric

The ASSIST Flicker Metric is documented at the ASSIST website (see section 4.1 E).

9 TEST REPORT

Light Source Flicker report data shall include the following test information and be submitted on the ENERGY STAR Dimming Data Sheet:

A) Manufacturer's name and product identification for the UUT and dimmers tested

B) Name and location of testing facility

C) Test date

D) Lamp base orientation (if applicable)

E) Input voltage (V)

F) Input voltage frequency (Hz)

G) Fundamental frequency (lowest frequency component), Percent Flicker, Flicker Index, and ASSIST Flicker Metric (M_P) at BLO

H) Electrical measurements, light output reading, Percent Flicker, Flicker Index, and ASSIST Flicker Metric (M_P) at MaxLO for each dimmer tested

I) Electrical measurements, light output reading, Percent Flicker, Flicker Index, and ASSIST Flicker Metric (M_P) at MinLO for each dimmer tested

J) Stabilization time and stabilization method used

K) Digitized photometric waveform data of the full-bandwidth and reduced-bandwidth measurements that resulted in the highest values of Flicker Index and ASSIST Flicker Metric, respectively, as well as an image of the full-bandwidth photometric amplitude waveform plotted over a 100 ms time interval.