

SEMI D86-0524

TEST METHOD OF FLICKER NUISANCE FOR WIDE-VISUAL-FIELD DISPLAYS

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1 Purpose

1.1 This Test Method aims to elucidate the measures of flicker nuisance from playing motion pictures on wide-visual-field displays, such as large-size curved displays, near-eye displays or flexible displays etc. The Test Method proposes an objective detection algorithm and presents resultant examples on assessing flickering light from display applications. Finally, the Test Method reveals that the 90th percentile of magnitude spectrum is a proper measure of discomfort flicker for wide-visual-field displays.

1.2 The impact of flicker has been shown to induce migraines and headaches, photosensitive epilepsy, and even increased autistic behaviors in certain people. Reduced task performance, stroboscopic, or phantom array motion effects, distraction, and annoyance are other possible consequences¹.

1.3 Frequency, modulation depth, and waveform have been shown to affect visual flicker sensitivity and are known to be dependent upon duration and visual factors or a kind of tasks. Nowadays, there are many metrics for flicker visibility included the contrast method, JEITA flicker value, IDMS flicker visibility, percentage flicker, flicker index, detection of stroboscopic effect, and acceptability of stroboscopic effect, etc. In addition, IEC 61000-4-15:2010 and ΔV_{10} are standards well known for evaluation of the severity of voltage flicker. However, all of them only apply for regular waveforms or known fundamental frequency of luminance fluctuation.

1.4 On the other hand, the brightness fluctuation from motion pictures typically is depended on video contents consisted of temporal and spatial domain. To the best of our knowledge, very little work has been performed to evaluate such kind of flicker effect in the lighting or display research fields.

2 Scope

2.1 The goal is to rank the flicker nuisance on high dynamic range luminance using standard operators designed for playing video on wide-visual-field displays. When doing so, not only temporal incoherence of the minimum, maximum or average scene luminance leads to flicker, but also spatial incoherence of luminance distributions induces the disturbing flicker. This is reported by two experiments².

2.1.1 The first assumption is that flicker is sufficiently well detected by computing the luminance of a pixel and comparing it to the luminance of the previous frames. In this Test Method, it can be considered that there were total of all pixels' light-emitting individually on and off dependent on the contents of motion pictures frame by frame.

2.1.2 The second assumption is that people are more sensitive to flicker in horizontal direction due to binocular vision. Therefore, the Test Method deals with the objective flicker calculation row-by-row along the vertical direction of a frame. The Test Method will demonstrate the flowchart of the flicker detection algorithm.

2.2 This Test Method proposes a flicker nuisance model for evaluating the wide-visual-field displays.

¹ Poplawski, M.E. and Miller, N.M. "Flicker in Solid-State Lighting: Measurement Techniques, and Proposed Reporting and Application Criteria." Proceedings of CIE Centenary Conference "Towards a New Century of Light", Paris, France (2013): pp. 188-202.

² Guthrie, B., Kopf, S., Eble, M., and Effelsberg, W. "Flicker Reduction in Tone Mapped High Dynamic Range Video." Proc. SPIE 7866, Color Imaging XVI: Displaying, Processing, Hardcopy, and Applications, 78660C, 2011.

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3 Limitations

3.1 This Standard is applicable to regular or free forms of flexible displays or LED displays for vehicles or billboard and signage applications. However, the Test Method does not address on the reflective or transparent displays.

4 Referenced Standards and Documents

*CIE® Standards*³

CIE 015:2018 — Colorimetry, 4th Edition

4.1 *IEC® Standards*⁴

IEC 61000-4-15:2010 — Electromagnetic Compatibility (EMC) – Part 4-15: Testing and Measurement Techniques – Flickermeter – Functional and Design Specifications

4.2 *ISO® Standards*⁵

ISO 20677:2019 — Image Technology Colour Management – Extensions to Architecture, Profile Format and Data Structure

ISO 9241-305:2008 — Ergonomics of Human-System Interaction – Part 305: Optical Laboratory Test Methods for Electronic Visual Displays

ISO 9241-307:2008 — Ergonomics of Human-System Interaction – Part 307: Analysis and Compliance Test Methods for Electronic Visual Displays

4.3 *SID Standards*⁶

IDMS v1.03 — Information Display Measurement Standard, Clause 10.5

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 Definitions

5.1.1 *color characterization model* — colorimetric characterization is an essential factor toward accurate color reproduction or management for imaging applications, which establishes the transformation from digital inputs of a device to the device-independent CIE tristimulus values *XYZ*.

5.1.2 *Imaging Luminance Measurement Device (ILMD)* — a device to use a digital camera or an array sensor for measurement of the photometric unit, luminance (cd/m²), in a particular direction at a solid angle from a surface.

5.1.3 *region of interest (ROI)* — are samples within a data set identified for a particular purpose. In computer vision and optical character recognition, the ROI defines the borders of an object under consideration.

5.1.4 *visual angle* — the angle subtended at the nodal point of the eye's crystalline lens by a visual stimulus, determined jointly by the size of the stimulus and its distance from the observer, usually stated in degrees of arc.

5.1.5 *visual field* — the number of degrees of visual angle during stable fixation of the eyes.

³ CIE Central Bureau, Babenbergerstraße 9/9A, 1010 Vienna, AUSTRIA, Tel: +43 1 714 31 87, <https://cie.co.at/>

⁴ International Electrotechnical Commission, 3 rue de Varembe, Case Postale 131, CH-1211 Geneva 20, Switzerland; Telephone: +41.22.919.02.11, <http://www.iec.ch>. IEC trademark is owned by International Electrotechnical Commission.

⁵ International Organization for Standardization, ISO Central Secretariat, Chemin de Blandonnet 8, CP 401-1214 Vernier, Geneva, Switzerland; Telephone: +41.22.749.01.11, Fax: +41.22.733.34.30, <http://www.iso.org>. ISO trademark is owned by International Organization for Standardization.

⁶ Society for Information Display, 1475 S. Bascom Ave. # 114 Campbell, CA 95008-4006 USA; Telephone: (408) 879-3901, <https://www.sid.org/>

6 Summary of Test Method

6.1 Figure 1 demonstrates the overall flowchart of the flickering nuisance computation. The key procedures include device color characterization, two-dimension discrete Fourier transform and clarification of the 90th percentile of fast Fourier transform (FFT) magnitude spectrum.

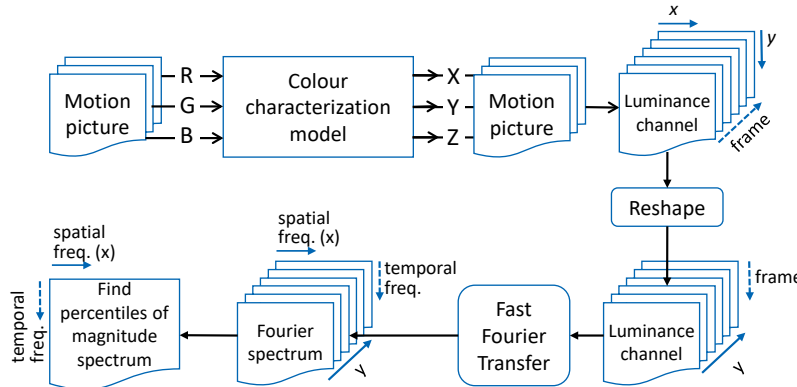


Figure 1
Flowchart of the Flicker Nuisance Computation

6.2 In this Test Method, the color characterization model consisted of a 3×3 matrix for the primary transformation and three 1024-levels one-dimensional lookup tables used to describe the electro-optical transfer function of color channels.

6.2.1 Based on the developed model, luminance of each pixel of a sequence of frames was calculated. Then we calculated the average luminance for each frame of the motion picture. The relative average luminance of pixels along vertical direction for each column frame-by-frame is shown. The alternative of measuring the pixel-wise luminance of the under-test-display is by an Imaging Luminance Measurement Device (ILMD).

6.3 After rearranging the resultants of color characterization, the standard two-dimension discrete Fourier transform computed with a FFT algorithm is performed.

6.3.1 Given an FFT chain, this Test Method calculates the cumulative distribution of the frequency spectrum, and outputs the frequency value which corresponds to the desired percentile. For example, to find the frequency at which 90% of FFT magnitude spectrum lies below that frequency, the 90-percentile means the value of fraction should be 0.9.

6.3.2 The 90-percentile or 95-percentile is often used as a measure of spectral roll-off. This Test Method applies the 90th percentile of the spectral energy for each video to predict the subjective flicker nuisance.

6.4 The wide-visual-field or field of view (FOV) is larger than 10 degrees. This Test Method addresses that human vision arising from images falling beyond the parafoveally area of the retina immediately surrounding the fovea around 8 degrees of the visual field. Under photopic adaptation conditions, the fovea central has the highest sensitivity. The perifoveal region is characterized by a decreasing sensitivity beginning at the fovea and ending approximately at 10 degrees eccentricity⁷. Under scotopic adaptation, the most sensitive part of the retina lies at approximately 10 degrees to 20 degrees horizontal eccentricity on the temporal side.

6.5 Dark or dim viewing condition. The background illumination shall be less than 20 cd/m^2 when dimension of device under test (DUT) is turned off. If a different illuminance or ambient illumination condition is used, it shall be noted on the report.

⁷ Strasburger, Hans; Rentschler, Ingo; Jüttner, Martin, "Peripheral vision and pattern recognition: a review". *Journal of Vision*. 11 (5): pp 1–82 (2011).

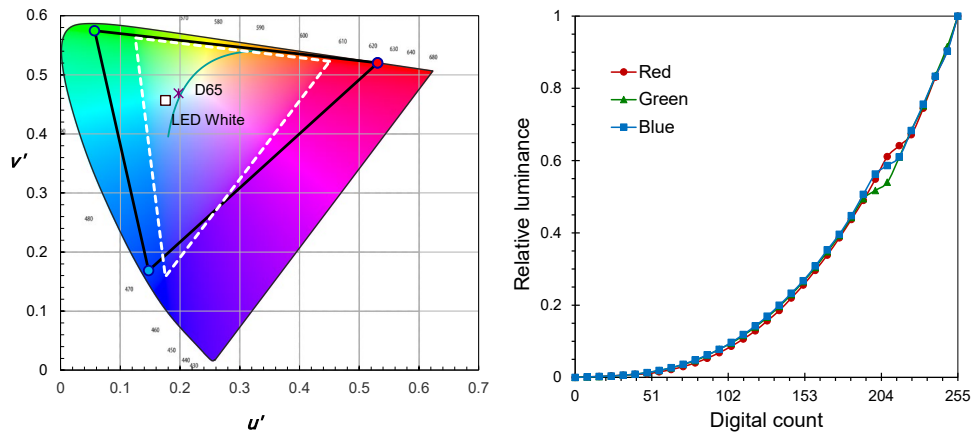
7 Calculations

7.1 Device Color Characterization

7.1.1 The color characterization model consisted of a 3×3 matrix for the primary transformation and three 1024-levels one-dimensional lookup tables (LUTs) used to describe the electro-optical transfer function (EOTF) of color channels for RGB display. Figure 2 illustrates an example of the chromaticity coordinates and the EOTFs of primaries. The primary transform matrix for the colorimetric characterization of this display was derived from the direct colorimetric measurements of the three full on primary colors as shown in Figure 2(a). The transform matrix is given in Equation 1. The EOTF is used to describe the relationship between the input signal and the luminance produced by the color channel of display. The three LUTs can be constructed via cubic spline interpolation on the 33-level radiometric scalar data shown in Figure 4(b).

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} X_r & X_g & X_b \\ Y_r & Y_g & Y_b \\ Z_r & Z_g & Z_b \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

7.1.2 Based on the developed characterization model of the display, the luminance of each pixel of a sequence of frames is calculated. Then this Test Method calculates the average luminance for a frame during playing the video and finds the maximum or peak luminance as well. The maximum luminance should be noted on the report. Figure 3 illustrates an example of the relative average luminance of pixels along vertical direction for each column frame-by-frame.



#1 (a) chromaticity coordinates of primaries, (b) measured data for three EOTFs

Figure 2
Color Characteristics of the RGB Wide-Visual-Field Displays

7.1.3 To perform the color characterization model, ICC profile of the device is an alternative approach in color management. Every device that captures or displays color can be profiled. Profiles describe the color attributes of a particular device or viewing requirement by defining a mapping between the device source or target color space and a profile connection space (PCS). This PCS could be CIEXYZ. The device ICC profile is adopted in the demonstration code in Appendix 1.

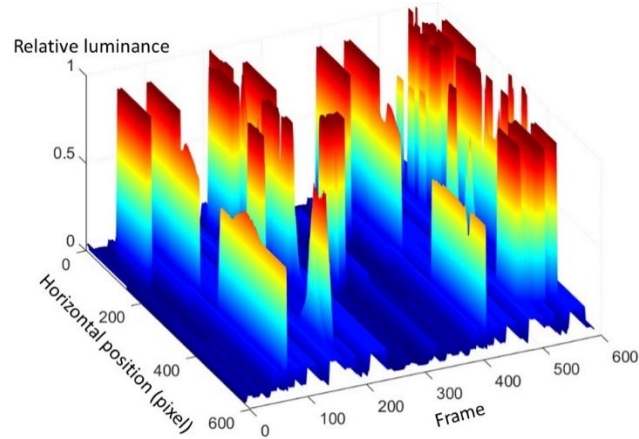


Figure 3
An Example of the Relative Average Luminance Distribution in a Row of the Measured Video

7.2 Calculation of Visual Field for the ROI

7.2.1 The DUT is one of important factors. To calculate the active area of display, the elevation view is defined as shown in Figure 4, such as concave, freeform, cylinder, tiled, round scrolling POP displays, etc. The front view of a display shows the width (W) and height (H) dimension.

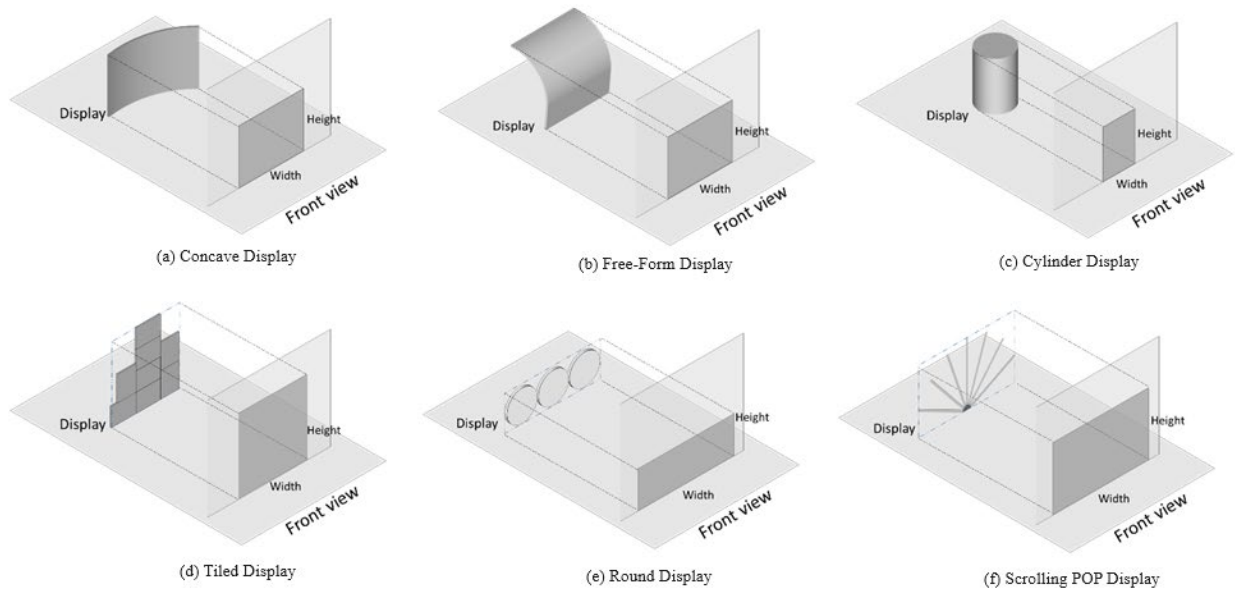


Figure 4
Elevation View of DUTs with Multiview Projection

7.2.2 The viewing distance D is between the center of DUT and the observer or ILMD as shown in Figure 5. In this method the measurement device ILMD is setup at the viewer's eye position. The measuring distance should be noted on the report.