Background Statement for SEMI Draft Document 4672
New Standard: DEFINITION OF MEASUREMENT INDEX (VCT) FOR MURA IN FPD IMAGE QUALITY INSPECTION

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Background
Specific definitions and quantifications of Mura are not consistent for many FPD manufacturers. Though there are standards for quantification of Mura, they are only used for limited types of Mura and are not practical in real varied cases. Currently it is still difficult to implement instruments to replace human inspectors for Mura inspections of LCDs. Therefore, it is necessary to standardize the classification of Mura for LCD.

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Review Information
Responses to this ballot will be reviewed by the Mura Task Force. This ballot will be adjudicated by the Taiwan FPD Metrology committee at its meeting at the SEMI Taiwan office in Hsinchu on 29 September 2009.
SEMI Draft Document 4672
New Standard: DEFINITION OF MEASUREMENT INDEX (VCT) FOR MURA IN FPD IMAGE QUALITY INSPECTION

1 Purpose
1.1 Specific definitions and quantifications of Mura are not consistent for many FPD manufacturers. Though there are standards for quantification of Mura, they are only used for limited types of Mura and are not practical in real varied cases. Currently it is still difficult to implement instruments to replace human inspectors for Mura inspections of LCDs. Therefore, it is necessary to standardize the classification of Mura for LCD.

2 Scope
2.1 This document will focus on the definition of Measurement Index (VCT) for Mura in FPD Image Quality Inspection.

NOTICE: This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

3 Limitations
3.1 This document is focused on grayish Mura.

4 Referenced Standards and Documents
4.1 SEMI Standards
SEMI D31 — Definition of Measurement Index (SEMU) for Luminance Mura in FPD Image Quality Inspection
SEMI D41 — Measurement Method of SEMI Mura in FPD Image Quality Inspection
4.2 ISO Standards
ISO 13406-2:2001 — Ergonomic requirements for work with visual displays based on flat panels – Part 2: Ergonomic requirements for flat panel display

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

5 Terminology
5.1 Abbreviations and Acronyms
5.1.1 JND — Just Noticeable Difference
5.1.2 VA — Visual Angle
5.1.3 VCT — Visual Contrast Threshold
5.2 Definitions
5.2.1 Mura — a display defect characterized by low contrast and unclear boundaries.
5.2.2 VA — used to describe Mura size in degrees.
5.2.2.1 VA can be calculated by the following equation:

\[
S = \tan\left(\frac{VA}{2}\right) \times 2D
\]  

(1)

Where S is the distance between object and edge, VA is visual angle and D is viewing distance.

5.2.3 VCT — the contrast of Mura at JND=1 (correction rate of 75%).

\[
VCT(\%) = \left|\frac{L_{mura} - L_b}{L_b}\right| \times 100\%
\]  

(2)

Where \(L_{mura}\) and \(L_b\) represent luminance of Mura and background respectively.
5.2.4 The relationship between Mura size (VA) and the VCT under different Mura positions can be illustrated as regression equations below (refer to Related Information 1):

\[
\begin{align*}
VCT_{\text{center}}(\%) &= 0.48/VA + 0.71 \\
VCT_{\text{edge}}(\%) &= 0.61/VA + 0.78 \\
VCT_{\text{corner}}(\%) &= 1.23/VA + 0.76
\end{align*}
\]

where:

- \( VCT_{\text{center}} \) = visual contrast threshold of center Mura
- \( VCT_{\text{edge}} \) = visual contrast threshold of edge Mura
- \( VCT_{\text{corner}} \) = visual contrast threshold of corner Mura

6 Related Documents

6.1 ISO Standard\(^1\)

ISO 13406-2:2001 — Ergonomic requirements for work with visual displays based on flat panels – Part 2: Ergonomic requirements for flat panel display


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\(^1\) International Organization for Standardization, ISO Central Secretariat, 1 rue de Varembe, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30; [http://www.iso.ch](http://www.iso.ch)
RELATED INFORMATION 1
EXPERIMENT OVERVIEW FOR MEASUREMENT OF VCT (VISUAL CONTRAST THRESHOLD) FOR MURA

R1-1 Purpose
R1-1.1 The experiment was designed to determine the relationship between the Mura size and visual contrast threshold (VCT) under different Mura positions.

R1-2 Experimental Method
R1-2.1 Experimental Equipment
R1-2.2 A 3840 × 2400 pixel TFT-LCD was utilized in the experiment. A 17 inch diagonal rectangular area was used to show the test pattern which was reworked to display 7140 gradations in a 0.79 cd/m² – 244.8 cd/m² range by using halftoning method.
R1-2.2.1 The illuminance of the experimental room was (110 ± 10) lx. The observers were in a fixed position at a 30 cm viewing distance, and the viewing angle was normal to the center of the LCD by using a chin rest.
R1-2.2.2 There were five levels of Mura size (2.386 mm², 23.569 mm², 187.185 mm², 567.984 mm² and 1721.093 mm² which corresponds to the visual angles (VA) of 0.33°, 1.04°, 2.84°, 5.13° and 8.92°, respectively), and three positions (Figure 1). The background luminance of the Mura was 23.86 cd/m².

R1-2.3 Subjects
R1-2.3.1 There were 31 subjects in total (17 males, 14 females, ages from 20 to 40 years). The subjects had no eye disease and passed the eye sensitivity tests for the experiment. All subjects were novices who had no experience with luminance Mura evaluations.

R1-2.4 Experimental Procedure
R1-2.4.1 2AFC (2-alternative forced-choice) and QUEST methods were applied to the experiments. The Mura stimuli appeared randomly and the subjects were told the position of Mura stimuli in each experimental trial. Subjects had to judge if the Mura appeared in the first or second frame. If subjects did not detect Mura stimuli, they had to guess and make a choice.

R1-3 Experimental Results
R1-3.1 The VCT is defined as equation (R1-1):

\[ VCT(\%) = \left( \frac{L_{mura} - L_b}{L_b} \right) \times 100\% \]  (R1-1)
Where $L_{mura}$ and $L_b$ represent luminance of Mura and background respectively. The experimental results and the fitting curves are shown in figure 2. The horizontal axis is $1/VA$ and the vertical axis is VCT. The results showed that VCT was significantly affected by Mura size (visual angle) and position.

$$
R^2 = 0.981
$$

$$
R^2 = 0.982
$$

$$
R^2 = 0.999
$$

![Figure 2](image)

Relation Between VA and the VCT Under Different Mura Positions

R1-3.1.1 The relationship between VA and the VCT under different Mura positions can be illustrated by the linear regression results as below:

$$
VCT_{center} (\%) = 0.48/VA + 0.71 \quad (R1-2)
$$

$$
VCT_{edge} (\%) = 0.61/VA + 0.78 \quad (R1-3)
$$

$$
VCT_{corner} (\%) = 1.23/VA + 0.76 \quad (R1-4)
$$

where:

- $VCT_{center}$ = visual contrast threshold of center Mura
- $VCT_{edge}$ = visual contrast threshold of edge Mura
- $VCT_{corner}$ = visual contrast threshold of corner Mura

According to equations (R1-2–R1-4), if Mura size and Mura position are known, VCT can be determined.

R1-3.2 Ergonomic Unit Transformation of VCT

R1-3.2.1 Sensitivity (dB) is often used to represent the visual contrast in ergonomic field. The translation function of sensitivity and VCT (%) is shown as equation (R1-5):

$$
\text{Sensitivity (dB)} = -20 \times \log\left(\frac{100}{VCT(\%)}\right) \quad (R1-5)
$$
R1-3.3 Definition of Edge/Corner Region
R1-3.3.1 Edge region is defined as a position near one side of panel within a specific range.
R1-3.3.2 Corner region is defined as a position near two sides of panel within a specific range.
R1-3.4 Range Discussion of Edge/Corner Region
R1-3.4.1 According to the results of subjective test, the average standard deviation among 31 subjects is 2.45 dB. If the sensitivity difference among center, edge and corner is smaller than 2.45 dB, the border effect will not be obvious. The sensitivity differences between different VAs and positions are listed in Table 1.

<table>
<thead>
<tr>
<th>VA (degree)</th>
<th>Center (dB)</th>
<th>Edge (dB)</th>
<th>Corner (dB)</th>
<th>Max-Min (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>−41.51</td>
<td>−45.98</td>
<td>−45.98</td>
<td>4.47</td>
</tr>
<tr>
<td>2</td>
<td>−39.55</td>
<td>−40.71</td>
<td>−42.77</td>
<td>3.21</td>
</tr>
<tr>
<td>3</td>
<td>−38.79</td>
<td>−39.85</td>
<td>−41.36</td>
<td>2.57</td>
</tr>
<tr>
<td>4</td>
<td>−38.38</td>
<td>−39.39</td>
<td>−40.57</td>
<td>2.19</td>
</tr>
<tr>
<td>5</td>
<td>−38.13</td>
<td>−39.10</td>
<td>−40.05</td>
<td>1.93</td>
</tr>
<tr>
<td>6</td>
<td>−37.95</td>
<td>−38.91</td>
<td>−39.69</td>
<td>1.74</td>
</tr>
<tr>
<td>7</td>
<td>−37.83</td>
<td>−38.76</td>
<td>−39.42</td>
<td>1.60</td>
</tr>
<tr>
<td>8</td>
<td>−37.73</td>
<td>−38.65</td>
<td>−39.22</td>
<td>1.49</td>
</tr>
<tr>
<td>9</td>
<td>−37.65</td>
<td>−38.57</td>
<td>−39.05</td>
<td>1.40</td>
</tr>
</tbody>
</table>

R1-3.4.2 The value $4^\circ$ of VA is a good integer threshold because the sensitivity difference is just under the standard deviation of subjects.
R1-3.4.3 VA can be calculated by the following equation:

$$S = \tan\left(\frac{VA}{2}\right) \times 2D \quad (R1-6)$$

Where $S$ is the distance between object and edge, $VA$ is visual angle and $D$ is viewing distance.
R1-3.4.4 Mura inspection is always performed within short viewing distance (e.g., 30 cm or 50 cm, which depends on different inspection rules in each company), but not in normal watching distance (e.g., 3Height or 1.5Diagonal). VCT is affected by VA and D, but is independent of panel size. The value of VA and S at typical inspection distances are listed in Table 2. This table can be used as a quick reference.

<table>
<thead>
<tr>
<th>$D$ (cm)</th>
<th>$VA$</th>
<th>$S$ (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>$4^\circ$</td>
<td>2.10</td>
</tr>
<tr>
<td>50</td>
<td>$4^\circ$</td>
<td>3.49</td>
</tr>
</tbody>
</table>
R1-4  Referenced Documents


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