Background Statement for SEMI Draft Document 4723A
NEW STANDARD: MEASUREMENT METHOD FOR THE COLOR BREAKUP OF FIELD SEQUENTIAL COLOR DISPLAY

Note: This background statement is not part of the balloted item. It is provided solely to assist the recipient in reaching an informed decision based on the rationale of the activity that preceded the creation of this document.

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Background
There are so many technique reports that talk about how to reduce the phenomenon of color breakup, but only a few methods were proposed to measure the degree of CBU. We would like to propose a list of measurement methods that could be used to measure the degree of color breakup in the field sequential display.

Ballot 4723 failed at previous technical meeting in March 11, 2011 due to persuasive rejects. The document is revised (4723A) and is approved for reballot in cycle 4-11 for review at the next meeting.

The results of this ballot will be adjudicated at the Taiwan Flat Panel Display Committee meeting scheduled on July 27, 2011 in Hsinchu. Check www.semi.org/standards for latest schedule

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1 Purpose

1.1 Field sequential color technique in the flat panel display has become more and more important. The effect of color breakup (CBU) occurs in the panels in which the field sequential technique is used. There are still no adaptive measurement standards to quantify the quality of color breakup. To standardize the classification of color breakup for flat panel displays is necessary.

2 Scope

2.1 This standard is to design and implement the measurement method of color breakup. This standard is applicable to the color breakup phenomenon on the field sequential color display. The testing method proposed in this standard includes dynamic CBU and static CBU. The correct testing method setting shall be used to measure the dynamic or static CBU.

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3 Limitations

3.1 These methods are applied to field sequential color displays.

4 Referenced Standards and Documents

4.1 SEMI Standard

SEMI D58 – Terminology and Test Pattern for the Color Breakup of Field Sequential Color Display

4.2 ISO/CIE Standard


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

5 Terminology

5.1 Abbreviations and Acronyms

5.1.1 CBU – Color Breakup

5.1.2 CBI – Color Breakup Index

5.1.3 Cpd – Cycle per degree

5.1.4 f – frame rate

5.1.5 FSD – Field Sequential Display

5.1.6 ppf – pixel per frame

5.1.7 SS – scroll speed

5.1.8 ST – seen-threshold

5.2 Definitions

5.2.1 CBIij – The color breakup index of color transition pattern with color i to color j. Color i and color j could be white(W), black(K), red(R), green(G), blue(B), cyan(C), magenta(M), and yellow(Y).
5.2.2 frame rate – The number of frames per second are shown on a display.

5.2.3 Resolution – The number of pixels on each screen line.

6 Apparatus

6.1 Color Camera System – A devise used for measuring and recording the color picture onto the storage media. The exposure time shall be longer enough to capture completely a frame time of sequential display.

6.1.1 Parallel Trajectory System – A color camera with a stage that moves in the parallel trajectory

6.1.2 Rotation Pursuit System – A color camera on the synchronizing and rotational stage

6.2 High Speed Camera System – A device used for recording fast moving objects as a photographic image onto the storage media, recording typically over 1000 frames per second. A problem for high speed cameras is the needed very bright light for a signal image, so the user should deal with the problem when capture the color breakup image.

6.2.1 Parallel Trajectory System – A high speed camera with a stage that moves in the parallel trajectory

6.2.2 Rotation Pursuit System – A high speed camera on the synchronizing and rotational stage

6.3 Software Implementation for Quantitative Visual Analysis

7 Procedure

7.1 Measuring Conditions

7.1.1 Environment conditions

7.1.1.1 In order to obtain accurate measured data, the following environment conditions are required.

- Temperature: 25±5 °C
- Humidity: 25-85 %RH
- Air flow: no wind
- Dark room: the illuminance < 1 lx

7.1.2 Measuring Distance

7.1.2.1 Measuring distance is 3H (where H is the height of the measured display device).

7.1.3 Viewing Direction

7.1.3.1 The basic viewing direction of this test is perpendicular angle.

7.1.4 Warm-up time

7.1.4.1 The display must be warmed up for a minimum of 30 minutes. Longer warm-up times are encouraged to the point that the display exhibits less than 5% drift per 5 minutes. Special situations arise where either a longer or shorter warm-up is required. In such a case deviations must be reported to all interested parties.

7.2 Testing Pattern

7.2.1 A proposed testing pattern is a checker board pattern. Even in the same color transition pair, the CBU phenomena are different in the different color transitions (i.e., black to white vs. white to black) of the same color transition pair. For this reason, we the testing pattern as 2x2 checker board pattern. Then the two different color breakups could be captured at the same time. There are 6 primary colors, name Red (R), Green (G), Blue (B), Cyan (C), Magenta (M), and Yellow (Y), and 2 achromatic colors, name white (W) and black (K), were used to form a testing pattern. Since the opposite color transition could make the serious problem of color breakup, 8 color transition pairs are selected to be the testing pattern. White and Black color transition pairs are shown in Figure 1. Red and Cyan color transition pairs are shown in Figure 2. Green and Magenta color transition pairs are shown in Figure 3. Blue and Yellow color transition pairs are shown in Figure 4.
Figure 1  
The CBU Measurement Checker Board Test Pattern 1

Figure 2  
The CBU Measurement Checker Board Test Pattern 2

Figure 3  
The CBU Measurement Checker Board Test Pattern 3
NOTE 1: Testing patterns are not limited.

7.3 Testing Method

7.3.1 Structure

7.3.1.1 The setting of color breakup measurement structure is shown on Figure 5. A rotating or linear moving capture system is used to capture the color breakup phenomenon. A pattern generator is used to present the testing pattern on the field sequential display (FSD).

7.3.2 Scroll Speed

7.3.2.1 Eye saccade is the major reason why we can see the color breakup phenomenon. A saccade is a fast movement of an eye. The peak angular speed of the eye during a saccade reaches up to 100°/sec when we focus on a target[11.1][11.2]. The scroll speed (SS) of CBU measurement can be calculated using Equation 1.

\[
SS = \frac{100 \cdot D \cdot \tan\left(\frac{\pi}{180}\right) \cdot Resolution}{\text{frame rate} \cdot W}
\]  

(1)
7.3.3 For Dynamic CBU

7.3.3.1 The measurement pattern is shown on the FSD and moves from left to right at the specified scroll-speed (SS). In the parallel trajectory system, the capture system moves from left to right at the same specified SS. In the rotation pursuit system, the capture system tracks the scrolling test pattern at the same specified SS. When the capture system arrives the center position of FSD, the capture system takes a picture of color breakup. A triggering signal is used or created to synchronize the camera's view with the motion speed. Figure 6 is a demonstration of dynamic CBU measurement. The detail processes are shown as the following steps.

7.3.3.1.1 Show the measurement pattern on the FSD and scrolling the measurement pattern by the SS.

7.3.3.1.2 Move or rotate the capture system using the same SS to pursuit the center of the measurement pattern.

7.3.3.1.3 When the capture system arrives the center of the FSD, the capture system takes a picture.

![Figure 6](image.png)

The Demonstration of Measurement for Dynamic CBU

7.3.4 For Static CBU

7.3.4.1 The measurement pattern is shown on the FSD without any scrolling setting. In the parallel trajectory system, the capture system moves from left to right at the specified SS. In the rotation pursuit system, the capture system tracks the scrolling test pattern at the specified SS. When the capture system arrives the center position of FSD, the capture system takes a picture of color breakup. A triggering signal is used or created to synchronize the camera's view with the motion speed. Figure 7 is a demonstration of dynamic CBU measurement. The detail processes are shown as the following steps.

7.3.4.1.1 Show the measurement pattern on the FSD.

7.3.4.1.2 Move or rotate the capture system by the specified SS.

7.3.4.1.3 When the capture system arrives the center of the FSD, the capture system takes a picture.
8 Calculations

The flowchart of the CBU measurement method is shown in Figure 8.

8.1 Color Space Transformation

8.1.1 The RGB color channel of the captured color breakup image will be converted to L*u*v* uniform color space.

8.2 K-means Clustering

8.2.1 According to the two colors in the test pattern, the breakup colors are calculated by a simple mathematical method. According to the luminance steps of the captured image to decide the number of breakup colors. Then the K-means clustering method was proposed to calculate the noticeable color in the color breakup area. For example, if there are seven noticeable colors, such as seven yellow squares in Iteration 1 of Figure 9. Then the k-means clustering algorithm was proposed to detect the seven major colors in the captured image. After some iteration times, the seven noticeable colors were calculated. Figure 9 is an example of a clustering process. Two colors in the test pattern must be two of the noticeable colors; the other five extra noticeable colors are breakup color appearing in the area of edge boundary. The lower right image of Figure 9 is the clustering result of dynamic CBU and the yellow squares are the seven noticeable colors.
8.3 Human Sensitivity

8.3.1 After these noticeable colors were computed by the clustering method, the number of each cluster group was counted. Since the color breakup phenomenon must be seen by the human eye, the pixel number of each noticeable color was the major important factor of color breakup measurement. The chromatic contrast sensitivity function (CSF) was considered to calculate the sensitive of these noticeable colors. It is important to note that the chromatic CSF filter behaves as a low-pass filter. The highest available spatial frequency is 18 cycle-per-degree [11.3][11.4]. In digital image applications, cycles-per-degree is a function of both addressability and viewing distance. This calculation is shown in Equation 2.

\[
Cpd = \frac{\text{Resolution}}{W} \times \frac{180}{\pi} \times \tan^{-1}\left(\frac{1}{D}\right)
\]

The value of pixel number in the highest available spatial frequency could be calculated using Equation 3. This value is called seen-threshold (ST). If the pixels of these three noticeable colors were too less to be seen (smaller than the value of highest sensitive frequency), these noticeable colors should be discarded.

8.4 Color Breakup Index

8.4.1 If the displays do not have the phenomenon of color breakup, the transition of two colors shall align the ideal transition line, such as the blue points in each iteration image of Figure 6. The color distance, D, between the ideal transition line and the noticeable color was used to present the level of color breakup. The three dimensional color space (L*, u*, and v*) was used to calculate the distance, so that the equation of distance is as follows Equation 4.

\[
D = \sqrt{(L_{\text{Notice}} - L_{\text{Ideal}})^2 + (u_{\text{Notice}} - u_{\text{Ideal}})^2 + (v_{\text{Notice}} - v_{\text{Ideal}})^2}
\]

When the pixels number of each extra noticeable color larger than ST, these noticeable colors were used to compute the color breakup index (CBI), as shown in Equation 5. Where the Size is the pixels number of each cluster group. As mention above, if the size is larger than ST, the size of noticeable color was used to be the weighing value to calculate the final color breakup index. On the other hand, if the size of noticeable color is smaller than ST, the weighing value of the noticeable color is setting to 0.

\[
CBI = \sum \omega_i D_i, \quad \omega_i = \begin{cases} \text{Size}_i, & \text{if } \text{Size}_i > ST \\ 0, & \text{if } \text{Size}_i \leq ST \end{cases}
\]
9 Report

9.1 Report the related scroll-speed, \( sp \) (ppf), the information of frame rate, \( f \) (Hz), and the following data:

9.1.1 The color breakup index for all transitions, their average, their standard deviation, and their minimum and maximum;

9.1.2 Report the color breakup index of 8 color pairs as shown in Table 1.

Table 1: \( CBI_{WK}, CBI_{KW}, CBI_{RC}, CBI_{CR}, CBI_{GM}, CBI_{MG}, CBI_{BY}, \) and \( CBI_{YB} \)

<table>
<thead>
<tr>
<th>Scroll speed (ppf)</th>
<th>( CBI_{WK} )</th>
<th>( CBI_{RC} )</th>
<th>( CBI_{GM} )</th>
<th>( CBI_{YB} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( CBI_{WK} )</td>
<td>( CBI_{CR} )</td>
<td>( CBI_{MG} )</td>
<td>( CBI_{YB} )</td>
<td></td>
</tr>
</tbody>
</table>

NOTE 2: Because sufficient research has not yet been done to determine which analysis results are most important to characterizing the motion blur, it is necessary to report all the above parameters. It is anticipated that fewer parameters will be identified in the future whereby the analysis and reporting load will be reduced.

10 Summary of Test Method

10.1 The image processing technique was presented to analyze the color combination of the image which has the CBU. The k-means clustering method and the concept of color distance were used to form a color breakup index. We convert RGB color space to \( L^*u^*v^* \) color space, and then use the k-means clustering method to detect the \( n \) major noticeable colors in the color breakup area. These colors will be considered the size of the appeared area to be the weighting value of each noticeable color. Finally, for each noticeable color, the color distance from the noticeable color to the ideal transition color and the weighting factor were used to calculate the color breakup index (CBI).

11 Related Documents


RELATED INFORMATION 1
AN EXAMPLE OF COLOR BREAKUP MEASUREMENT RESULTS OF FIELD SEQUENTIAL COLOR DISPLAY

NOTICE: This related information is not an official part of SEMI (doc#) and was derived from (origin of information). This related information was approved for publication by ballot on (date of approval).

R1-1 Purpose
R1-1.1 The experiment was designed to measure the color breakup index in the field sequential color displays.

R1-2 Experimental Method
R1-2.1 Experimental Equipment
R1-2.2 A field sequential color display was utilized in the experiment.
R1-2.2.1 The illuminance of the experimental room was a dark room.
R1-2.2.2 There are four test patterns used, those were white black color pair, red cyan color pair, green magenta color pair, and blue yellow color pair.
R1-2.3 Capture System
R1-2.3.1 The 3CCD color camera was used to capture the images.
R1-2.3.2 The rotation motor was used to move the color camera.
R1-2.4 Experimental Setup
R1-2.4.1 Width of FSD: 15 cm
R1-2.4.2 Resolution of FSD: 320 pixel
R1-2.4.3 Distance between FSD and capture system: 26 cm
R1-2.5 Experimental Procedure
R1-2.5.1 Test patterns were shown on the test display statically.
R1-2.5.2 The moving speed of the capture system was related to the scroll speeds of test display. The scroll speed was calculated as 16 ppf (pixel per frame) using Equation 1.

\[
SS' = \frac{100 \cdot D \cdot \tan\left(\frac{\pi}{180}\right) \cdot \text{Resolution}}{\text{Frame rate} \cdot W} = \frac{100 \cdot 26 \cdot 0.0175 \cdot 320}{60 \cdot 15} = 16.1
\]

(R1-1)

R1-3 Experimental Results
R1-3.1 Capture Images
Figure R1-1
An Example of Capture Image and its Area of White and Black Color Transition Pattern

Figure R1-2
Figure R1-3An Example of Capture Image and its Area of Red and Cyan Color Transition

Figure R1-4
An Example of Capture Image and its Area of Green and Magenta Color Transition Pattern

Figure R1-5
An Example of Capture Image and its Area of Blue and Yellow Color Transition Pattern
**R1-4 Experimental Report**

R1-4.1 Scroll-speed: 16 ppf

R1-4.2 Frame rate: 180 Hz

R1-4.3 Average: 167.25, Standard deviation: 55.80

R1-4.4 Minimum: 98.56, Maximum: 265.37

**Table R1-1 Color Breakup Index**

<table>
<thead>
<tr>
<th></th>
<th>CBIKW</th>
<th>CBIKC</th>
<th>CBIKM</th>
<th>CBIKY</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 ppf</td>
<td>216.75</td>
<td>183.57</td>
<td>101.32</td>
<td>149.60</td>
</tr>
<tr>
<td></td>
<td>CBIWK</td>
<td>CBIKC</td>
<td>CBIKM</td>
<td>CBIKY</td>
</tr>
<tr>
<td>16 ppf</td>
<td>265.37</td>
<td>159.84</td>
<td>98.56</td>
<td>162.97</td>
</tr>
</tbody>
</table>

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