Background Statement for SEMI Draft Document 4724A
New Standard: MEASUREMENT METHOD OF LED LIGHT BAR FOR LIQUID CRYSTAL DISPLAYS

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.

Note: Recipients of this document are invited to submit, with their comments, notification of any relevant patented technology or copyrighted items of which they are aware and to provide supporting documentation. In this context, “patented technology” is defined as technology for which a patent has issued or has been applied for. In the latter case, only publicly available information on the contents of the patent application is to be provided.

Background Statement:
With increasing use of LED light bar as a light source for liquid crystal displays, there are requests for electro-optical and mechanical performances to be evaluated. However, they have not been standardized so far.

This proposed standard is developed to solve this problem and to provide relevant test methods of LED light bar for LCD backlight units.

The results of this ballot will be discussed at the next Taiwan LED Backlight TF meeting scheduled on September 23, 2010.

If you have any questions, please contact to the LED Backlight Task Force co-leaders:
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SEM I Draft Document 4724A
NEW STANDARD: MEASUREMENT METHOD OF LED LIGHT BAR FOR LIQUID CRYSTAL DISPLAYS

1 Purpose
1.1 This measurement standard defines measurement methods for various characteristics of light emitting diode (LED) light bar for liquid crystal displays (LCDs). This standard will be helpful to unify methodologies used for measurement of LED light bar quality, which can improve LED backlight unit standard reproduction characteristics or fidelity to original design rule.

2 Scope
2.1 This standard is a generic specification for electro-optical and mechanical measurement methods of LED light bar for Liquid Crystal Displays (LCDs).
2.2 This standard is only for common types of LED light bar of the edge (or side) type backlight unit and general purpose for methodology. The types of LED on the LED light bar cover both side-view and top-view surface mount device (SMD) LEDs.
2.3 The standard includes practical methodologies of flux, intensity, color, and geometric specification measurements. These optical performances apply to practical operational conditions such as an extended source, rather than a multi-point-source.

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 Referenced Standards and Documents
3.1 SEMI Standard
SEMI D36 — Terminology for LCD Backlight Unit
3.2 CIE Standard
CIE 15:2004 3rd edition — Colorimetry
CIE 84:1989 — The Measurement of Luminous Flux

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

4 Terminology
4.1 Abbreviations and Acronyms
4.1.1 LED — light emitting diode
4.1.2 LGP — light guide plate
4.1.3 PCB — printed circuit board
4.1.4 SMD — surface mount device
4.1.5 CRM — certified reference material

4.2 Optical/Mechanical Definitions
4.2.1 edge (or side) type LED backlight unit — a backlight unit with one or more LED light bars coupled with one or more edges of the LGP of backlight unit. Light emits originally from the edge (rather than from bottom to top) of LGP (shown in Figure 1).
4.2.2 LED light bar — a strip light source with multiple LEDs (SMD or other package type LED) mounted along on a strip PCB. In general, all the LEDs emit the chief optical radiation in the same direction.
4.2.3 top-view SMD LED — a SMD LED whose (optical radiation) emitting surface is parallel to the PCB surface (shown in Figure 2).

1 International Commission On Illusion, http://www.cie.co.at/cie/
4.2.4 **side-view SMD LED** — a SMD LED whose (optical radiation) emitting surface is normal to the PCB surface (shown in Figure 3).

![Figure 1](image1)

**Figure 1**
Structure of the Edge Type LED Backlight Unit Showing the Coordinate System for the Left Edge LED Light Bar, and the Light Bar May be Populated with either Top-view or Side-view SMD LEDs

![Figure 2](image2)

**Figure 2**
Cross Section of Top-view SMD LED Coupling with a Light Guide Plate

![Figure 3](image3)

**Figure 3**
Cross Section of Side-view SMD LED, Optical Radiation Axis is Z-axis

4.2.5 **alignment mark** — an auxiliary mark used to indicate the LED specific mounting position on the PCB (shown in Figure 4).

4.2.6 **specific origin** — a center coordinate (x-y plane) for the official designed mounting position of LED on the PCB. The specific origin of the ith LED is denoted as \( O_i(x_i, y_i) \). The specific origins of all LED can refer to their alignment marks on the PCB.

**NOTE 1:** For testers that intend to get the absolute coordinate, in general the global coordinate origin (0,0) is recommended to be the center of the left-most alignment mark.

4.2.7 **major axis** — an axis \( \hat{x}_{major} \) with direction defined by PCB alignment from left to right or through each alignment mark centers of all LEDs (shown in Figure 4).

4.3 **Measurement Definitions**

4.3.1 **Mechanical Characteristic Measurement Parameter**
4.3.1.1 **mechanical origin** — a center coordinate (x-y plane) of the emitting surface feature of a LED used as the reference for the mounting position of a LED on the PCB. The mechanical origin coordinate for i\(^{th}\) LED is denoted as \(O_{m,i}(x_{m,i}, y_{m,i})\) (shown in Figure 4) (i is the ordinal number of LED).

4.3.1.2 **optical origin** — a center-of-gravity coordinate (x-y plane) of the optical radiation on the emitting surface of a LED used as the reference for the mounting position of a LED on the PCB. The optical origin coordinate for i\(^{th}\) LED is denoted as \(O_{o,i}(x_{o,i}, y_{o,i})\) (shown in Figure 5).

4.3.1.3 **mechanical origin deviation** — an x-y plane distance between each mechanical origin and the relative LED specific origin. It is used as the reference for mounting axis of a LED. The mechanical origin deviation for i\(^{th}\) LED is denoted as \(d_{m,i}(x_{m,i}, y_{m,i})\).

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**Figure 4**

Diagram of Major Axis of LED Light Bar (Image of Unlighted LED Light Bar), Mechanical Axis, Mechanical Origins, Alignment Marks

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**Figure 5**

Diagram of Luminance Spatial Distribution (Image of Lighted LED Light Bar), Global Coordinate Origin (Black Dot), Optical Origins (Red Dot), and Optical Axis of i\(^{th}\) LED

**NOTE:** The Lower Diagram is an Exaggerated Drawing for Demonstrating the Deviation of Optical Origin and Optical Axis from Specific Origin (Black Cross Mark), and Major Axis.
4.3.1.4 optical origin deviation — an x-y plane distance between each optical origin and the relative LED specific origin. It is used as the reference of the accuracy of LED radiation distribution. The optical origin deviation for i-th LED is denoted as $d_{o,i} (x_{o,i}, y_{o,i})$.

4.3.1.5 optical x-axis — an axis through optical origin with maximum light spread, direction followed PCB major axis from left to right. It is used as the reference of the LED radiation distribution. The optical x-axis for i-th LED is denoted as $\hat{x}_{o,i}$ (shown in Figure 5).

4.3.1.6 optical x-axis deviation — the angle between each optical x-axis and the major axis of LED light bar. It is used as the reference for the accuracy of LED radiation distribution. It is denoted as $\Delta \theta(\hat{x}_{o,i}, \hat{x}_{major})$ or $\Delta \theta_{o,i}$ for i-th LED.

4.3.1.7 mechanical x-axis — an axis along the longer LED edge, direction following the PCB major axis from left to right. It is denoted as $\hat{x}_{m,i}$ for i-th LED.

4.3.1.8 mechanical x-axis deviation — the angle between each mechanical x-axis and the major axis of LED light bar. It is denoted as $\Delta \theta(\hat{x}_{m,i}, \hat{x}_{major})$ or $\Delta \theta_{m,i}$ for i-th LED.

4.3.2 Optical Characteristic Measurement Parameter

4.3.2.1 partial luminous flux — the amount of luminous flux under a certain solid angle of each LED in a forward direction over the specific origin.

4.3.2.2 total luminous flux — the total luminous flux in $4\pi$ solid angle of a LED light bar.

4.3.2.3 forward $2\pi$ luminous flux — the amount of luminous flux in $2\pi$ solid angle of each LED in forwards direction over the specific origin.

4.3.2.4 partial/forward $2\pi$ luminous flux uniformity — the minimum and maximum ratio of partial/forward $2\pi$ luminous flux among LEDs of the LED light bar.

4.3.2.5 luminous intensity — the partial flux divided by the relative solid angle, or the illuminance divide by the square of the measurement distance (under certain illumination area with certain measurement distance for each single SMD LED of LED light bar over its specific or mechanical origin position). The measurement report shall illustrate the measurement condition.

4.3.2.6 luminous intensity uniformity — the minimum and maximum ratio of average intensity among LEDs of the LED light bar (measurement report shall illustrate the measurement condition).

4.3.2.7 color — the chromaticity coordinate of single LED or LED light bar under the measurement condition of partial, total, or $2\pi$ luminance flux, or average intensity. The measurement report shall illustrate the measurement condition.

4.3.2.8 color non-uniformity — the maximum color difference, (i.e., the maximum Euclidean distance $\Delta u'v'$ or $\Delta xy$ in CIE 1976 ($u'v'$) or CIE 1931 (x,y) color space respectively) between any two LEDs of the light bar. The measurement report shall illustrate the measurement condition.

5 Set-up

5.1 All tests and measurements shall be carried out in rooms with illuminance under 10 lux. All tests and measurements shall be carried out in ambient temperature ($25 \pm 3)^{\circ}C$, relative humidity ($60 \pm 20)$ RH.

5.2 LEDs shall be driven from constant current switching regulators. The variation of driving current should be within $\pm0.5\%$ for during of measurement period. As an alternative, testers should make sure that the driving current variation does not cause more measurement uncertainty than what is required.

5.3 Warm-up Time

5.3.1 Warm-up time is the period from power-on to reach light intensity or its color to stability (or some other optical parameters with which testers may be concerned).

5.3.2 Specify the typical warm-up curve (e.g., relative intensity and chromaticity vs. light-on period shown in Figure 6) for each type LED light bar.

5.3.3 Specify the warm-up time for each type of optical characteristics measurement.

5.3.4 Specify the variation of intensity or color (or some optical parameters with which testers may be concerned) for during of measurement period. (In the case of Figure 6, the warm-up time is set to be 180 seconds (3 minutes)
for the intensity/intensity uniformity measurement, with intensity variation less than 0.3% during the measurement period of 2 minutes.)

![Diagram](image)

**Figure 6**
The Typical Warm-up Curve of Relative Average Intensity vs. Light-on Time of SMD LED for LED Light Bar

5.4 The optical axis of the optical measurement device should be perpendicular to the LED light bar under test. The uncertainty in axis alignment is specified to be ±0.3° as a goal. As an alternative, testers should make sure that the alignment error does not cause more measurement uncertainty than what is required.

5.5 The uncertainty in locating measurement position of the optical measurement device should be relatively within ±3% of the single LED diagonal. As an alternative, testers should make sure that the location error does not cause more measurement uncertainty than what is required.

### 6 Measurement Method

6.1 **Mechanical Characteristic Measurement Method**

6.1.1 **Mechanical Origin** — Measure the feature (in general, rectangular) of the emitting surface for each LED in x-y plane. Then determine the geometric center coordinates relative to the LED feature. The mechanical origin coordinates $O_{m,i}(x_{m,i}, y_{m,i})$ for $i^{th}$ LED are defined as those coordinates.

6.1.2 **Optical Origin** — Measure the luminance spatial distribution $L(x, y)$ in x-y plane while the LED light is on. Then calculate the gravity center coordinates of each LED according to the luminance spatial distribution itself. The optical origin coordinates $O_{o,i}(x_{o,i}, y_{o,i})$ for $i^{th}$ LED are defined as those coordinates. They are calculated by the Equation 1, and $L(x, y)$ is the luminance spatial distribution of $i^{th}$ LED (see Appendix 1 for Measurement example).

$$\begin{align*}
    x_{o,i} &= \frac{\int x \cdot L_i(x, y) \cdot dx}{\int L_i(x, y) \cdot dx}, \\
    y_{o,i} &= \frac{\int y \cdot L_i(x, y) \cdot dy}{\int L_i(x, y) \cdot dy}.
\end{align*} \quad (1)$$

To achieve the measurement, a digital image-type instrument or a photometer may be used, the luminance spatial distribution of $i^{th}$ LED is denoted as $L_{j,i}(x, y)$. Then the Equation 1 approximates to the Equation 2:

$$\begin{align*}
    x_{o,i} &= \frac{\sum x_{j,i} \cdot L_{j,i}}{\sum L_{j,i}}, \\
    y_{o,i} &= \frac{\sum y_{j,i} \cdot L_{j,i}}{\sum L_{j,i}}.
\end{align*} \quad (2)$$

For $j=1..m$, $m$ is the total sampling number of area of interested. The area of interested is the area which luminance is greater than some ratio of maximum luminance for each LED.

**NOTE 2:** For testers that intend to avoid cross talk with nearby LEDs or including too much background noise, in general the ratio of maximum luminance is recommended to be 1/10.

6.1.3 **Mechanical Origin Deviation** — Calculate the distance between each mechanical origin $O_{m,i}(x_{m,i}, y_{m,i})$ and the relative LED specific origin $O_i(x_i, y_i)$. (The specific origin $O_i(x_i, y_i)$ of $i^{th}$ LED is official data, or the specific distance from the center coordinate of the relative alignment mark. It can be measured by mechanical or optical type instruments.) The mechanical origin deviations $d_{m,i}(x,y)$ of $i^{th}$ LED is defined as that distance. It is calculated by Equation 3:
6.1.4 Optical Origin Deviation — Calculate the distance between each optical origin \( O_o,i(x_{o,i}, y_{o,i}) \) and the relative LED specific origin \( O_i(x_i, y_i) \). The optical origin deviations \( d_{o,i}(x,y) \) of \( i \)th LED is calculated by Equation 4.

\[
d_{o,i}(x,y) = \sqrt{(x_{o,i} - x)^2 + (y_{o,i} - y)^2}.
\]  

6.1.5 Optical X-axis — Measure the luminance spatial distribution \( L(x,y) \) in x-y plane while the LED light is on. Find the optical origin \( O_{o,i}(x_{o,i}, y_{o,i}) \) of \( i \)th LED inside the some ratio of maximum luminance area. Then find the longest line segment passing through the optical origin within this area. The optical axis for \( i \)th LED is along this line segment, and its direction follows the PCB major axis from left to right. This axis is assigned as the optical x-axis of \( i \)th LED. It is denoted by \( \hat{x}_{o,i} \).

NOTE 3: For testers who intend to avoid cross talk with nearby LEDs or including too much background noise, in general the ratio of maximum luminance is recommended to be 1/10. (see Appendix 1 for measurement example). 

6.1.6 Optical X-axis Deviation — Calculate the angle between the optical x-axis \( \hat{x}_{o,i} \) of \( i \)th LED and the major axis \( \hat{x}_{major} \) of LED light bar. This angle is the optical x-axis deviation \( \Delta \theta_{o,i} \) of \( i \)th LED. \( (\Delta \theta_{o,i} \leq 90^\circ) \)

6.1.7 Mechanical X-axis — Measure the feature (in general, rectangular shape) of the emitting surface for each LED on the PCB in the x-y plane. Determine the longer edge of this contour of the \( i \)th LED. This longer edge is assigned as the mechanical x-axis for \( i \)th LED. It is denoted by \( \hat{x}_{m,i} \).

6.1.8 Mechanical X-axis Deviation — Calculate the angle between the mechanical x-axis \( \hat{x}_{m,i} \) of \( i \)th LED and the major axis \( \hat{x}_{major} \) of LED light bar. This angle is the mechanical x-axis deviation \( \Delta \theta_{m,i} \) of \( i \)th LED. \( (\Delta \theta_{m,i} \leq 90^\circ) \)

6.2 Optical Characteristic Measurement Method

6.2.1 Partial Luminous Flux — Measure the total amount luminous flux under the certain solid angle for each LED. The measurement setup conditions are shown in Figure 7. An integrated sphere is over its specific or mechanical origin (coordinate) of each LED. The distance between the LED front surface and the open port of the integrated sphere is \( d \). The diameter of the open port is \( D \). In order to avoid the measurement variation caused by heat, the measurement is conducted by switching on either an individual LED or the smallest single driving unit in the light bar. If the individual LED cannot be driven, some baffles shall be used to avoid stray light from adjacent LEDs. Each partial luminous flux is determined by a photometer. The photometer can be a cosine-corrected photometer or a spectral radiometer. If a cosine-corrected photometer is used, it shall be calibrated by spectral mismatch correction. The measurement system shall be calibrated with a partial luminous flux LED CRM (Certificate Reference Material) regardless of the kind of photometer used. The partial luminous flux of \( i \)th LED denotes as \( \Phi_{p,i} \).

6.2.2 Total Luminous Flux — Measure the total luminance flux of \( 4\pi \) solid angle of a light bar. The measurement is conducted by switching on a whole LED light bar. One of the possible measurement setup conditions is shown in Figure 7.
Figure 8. The LED light bar is located at the center of the integrated sphere. It is recommended that the sphere diameter should be twice the length of the LED light bar at least, and the reflectance of the sphere wall and the baffle should be higher than 90%. The baffle is placed at a distance equal to about 1/6 of the sphere diameter (or 1/4, if the LED light bar is short compared to the sphere diameter) away from the detector. It should be big enough to avoid the light source directly illuminating detector while being as small as possible. The total luminous flux is determined by a photometer. The photometer can be a cosine-corrected photometer or a spectral radiometer. If a cosine-corrected photometer is used, it shall be calibrated by spectral mismatch correction. The measurement system shall be calibrated with a total luminous flux LED CRM regardless of the kind of setup condition or photometer used. The total luminous flux of a LED light bar is denoted by $\Phi_t$.

![Figure 8](image)

**Figure 8**
Setup Condition for Total Luminous Flux Measurement

6.2.3 *Forward $2\pi$ Luminous Flux* — Measure the amount of luminous flux under the forward $2\pi$ solid angle of each LED. The measurement setup conditions are shown in Figure 9. An integrated sphere is attached to the PCB front surface over its specific or mechanical origin (coordinate) of each LED. The diameter of the open port is just suited to the LED size. In order to avoid the measurement variation caused by heat, the measurement is conducted by switching on either an individual LED or the smallest single driving unit in the light bar. Each $2\pi$ luminous flux is determined by a photometer. The photometer can be a cosine-corrected photometer or a spectral radiometer. If a cosine-corrected photometer is used, it shall be calibrated by spectral mismatch correction. The measurement system shall be calibrated with a $2\pi$ luminous flux LED CRM regardless of the kind of photometer used. The forward $2\pi$ luminous flux of $i^{th}$ LED is denoted by $\Phi_{h,i}$.

![Figure 9](image)

**Figure 9**
Setup Condition for Forward $2\pi$ Partial Luminous Flux Measurement

6.2.4 *Luminous Flux Uniformity* — Determine the maximum and minimum of the partial (or $2\pi$) luminous flux for all LEDs on the LED light bar. The luminous flux uniformity $U_p$ (or $U_h$ for forward $2\pi$ luminous flux) is defined by Equation 5 (or Equation 6).
\[ U_p = \frac{\text{Min}(\Phi_{p,i})}{\text{Max}(\Phi_{p,i})}, \quad \text{for } i=1..n, \text{ n is the number of LED on LED light bar,} \quad (5) \]

or

\[ U_h = \frac{\text{Min}(\Phi_{h,i})}{\text{Max}(\Phi_{h,i})}, \quad \text{for } i=1..n, \text{ n is the number of LED on LED light bar.} \quad (6) \]

### 6.2.5 Luminous Intensity —
Measure the partial luminous flux for each LED with a certain solid angle of each LED. The luminous intensity is defined as the ratio of partial luminous flux to the relative solid angle. Or measure the average illuminance within a certain illumination area with a certain measurement distance for each single LED over its specific or mechanical origin position. The luminous intensity also can be defined as the average illuminance divided by the square of the measurement distance. The luminous intensity of the \(i^{th}\) LED denotes as \(I_{v,i}\) (measurement report shall illustrate the measurement condition). In order to avoid the measurement variation caused by heat, the measurement is conducted by switching on either an individual LED or the smallest single driving unit in the light bar. If the individual LED cannot be driven, some baffles shall be used to avoid stray light from adjacent LEDs.

### 6.2.6 Luminous Intensity Uniformity —
Determine the maximum and minimum of the luminous intensity for all LEDs on the LED light bar. The luminous intensity uniformity \(U_v\) is defined by Equation 7.

\[ U_v = \frac{\text{Max}(I_{v,i})}{\text{Min}(I_{v,i})}, \quad \text{for } i=1..n, \text{ n is the number of LED on LED light bar.} \quad (7) \]

### 6.2.7 Color —
Measure the chromaticity coordinate for each LED. In order to avoid the measurement variation caused by heat, the measurement is conducted by switching on either an individual LED or the smallest single driving unit in the light bar. The measurement setup condition is the same as partial luminous flux, luminous flux, or luminous intensity conditions. If the individual LED cannot be driven, some baffles shall be used to avoid stray light from adjacent LEDs. Or measure the chromaticity coordinate for the whole LED light bar under the measurement setup condition of total flux. The chromaticity coordinate is determined by a photometer. The photometer can be a colorimeter or a spectral radiometer. A colorimeter shows the measurement result of chromaticity coordinate in CIE 1931 \((x,y)\) or CIE 1976 \((u',v')\) color space. A spectral radiometer shows the result of spectral power distribution which can be calculated into the chromaticity coordinates. If a colorimeter is used, it shall be calibrated by spectral mismatch correction. The measurement system shall be calibrated with a color LED CRM for using any kind of photometer. (The measurement report shall be noted with measurement setup condition which is used.)

### 6.2.8 Color Non-uniformity —
Determine the maximum of the color difference between any two LEDs on the light bar. The color non-uniformity is defined by Equation 8 (or Equation 9).

\[ \Delta u'v' = \text{Max}(\sqrt{(u_j - u_k)^2 + (v_j - v_k)^2}), \quad (8) \]

or

\[ \Delta xy = \text{Max}(\sqrt{(x_j - x_k)^2 + (y_j - y_k)^2}). \quad (9) \]

For \(j\) and \(k\) =1..n, \(n\) is the number of LED on LED light bar. (The measurement report shall include the measurement setup conditions used.)

**NOTE 4:** It is recommended the \(\Delta u'v'\) being the priority.

### 7 Report

7.1 Report the following general information:

7.1.1 Date, time of test,

7.1.2 Identification of operator,

7.1.3 LED light bar information (identification of model number, serial number, LED type, global coordinate origin location, LED light bar size, LED number, LED size, left-most LED center location, left-most alignment mark center location, LED pitch, etc.),

7.1.4 Set-up condition (Identification of ambient temperature, humidity, driving current, etc.).
7.2 Report the following mechanical characteristic measurement results and the analysis information:
7.2.1 Mechanical origins, mechanical origin deviations (including specific origins) for each LED,
7.2.2 Mechanical x-axis angles, mechanical x-axis deviation (identification of major axis angle) for each LED,
7.2.3 Ratio of maximum luminance to determine the area of interest for calculating optical origins and optical axis,
7.2.4 Optical origins, optical origin deviation (including specific origins) for each LED,
7.2.5 Optical x-axis angles, optical x-axis deviation (identification of major axis angle) for each LED.
7.3 Report the following optical characteristic measurement results and the measurement conditions:
7.3.1 Partial luminous flux
7.3.1.1 Partial luminous flux, chromaticity coordinates (under partial luminous flux measurement condition) for each LED,
7.3.1.2 Partial luminous flux uniformity, color non-uniformity for this LED light bar,
7.3.1.3 Specification of measurement conditions, including measurement location, light measurement equipment, working distance, diameter of open port of integrated spherical sphere, solid angle, warm-up time, variation of partial luminous flux for during of measurement period.
7.3.2 Forward 2 \( \pi \) luminous flux
7.3.2.1 Forward 2 \( \pi \) luminous flux, chromaticity coordinates (under forward 2 \( \pi \) luminous flux measurement condition) for each LED,
7.3.2.2 Forward 2 \( \pi \) luminous flux uniformity, color non-uniformity for this LED light bar,
7.3.2.3 Specification of measurement conditions, including measurement location, light measurement equipment, warm-up time, variation of forward 2 \( \pi \) luminous flux for during of measurement period.
7.3.3 Luminous intensity
7.3.3.1 Luminous intensity, chromaticity coordinates (under luminous intensity measurement condition) for each LED,
7.3.3.2 Luminous intensity uniformity, color non-uniformity for this LED light bar,
7.3.3.3 Specification of measurement conditions, including measurement location, light measurement equipment, working distance, solid angle, warm-up time, variation of luminous intensity for during of measurement period.
7.3.4 Total flux
7.3.4.1 Total flux, chromaticity coordinates (under total flux measurement condition) for the whole LED light bar,
7.3.4.2 Specification of measurement conditions, including light measurement equipment, integrated sphere diameter, CRM description, warm-up time, variation of total flux for during of measurement period.
7.4 Report tables
7.4.1 General Information is provided in Table 1.

### Table 1  Report Sample of General Information

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7.4.2 Mechanical Characteristic Measurement Report is provided in Table 2.
7.4.3 Optical Characteristics Measurement Report - Partial Luminous Flux is provided in Table 3.
7.4.4 Optical Characteristics Measurement Report - Forward $2\pi$ Luminous Flux is provided in Table 4.
7.4.5 Optical Characteristics Measurement Report - Luminous Intensity is provided in Table 5.
7.4.6 Optical Characteristics Measurement Report - Total Luminous Flux is provided in Table 6.

### Table 2 Report Sample of Mechanical Characteristic Measurement Data

<table>
<thead>
<tr>
<th>Mechanical Characteristic Measurement Report</th>
<th>Mechanical Origin Deviation $d_{m,i}(x_i, y_i) = \sqrt{(x_{m,i} - x_i)^2 + (y_{m,i} - y_i)^2}$</th>
<th>Unit : mm</th>
<th>Unlighted LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED #</td>
<td>Mechanical Origin Specific Origin</td>
<td>Mechanical Origin Deviation $d_{m,i}$</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$O_{m,1}(x_{m,1}, y_{m,1})$</td>
<td>$x_1$, $y_1$</td>
<td>$d_{m,1}$</td>
</tr>
<tr>
<td>2</td>
<td>$O_{m,2}(x_{m,2}, y_{m,2})$</td>
<td>$x_2$, $y_2$</td>
<td>$d_{m,2}$</td>
</tr>
<tr>
<td>3</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

#### Mechanical X-axis Deviation $\Delta \theta_{n,i} = \theta(\hat{x}_{m,i}, \hat{x}_{n,i})$ | Unit: degree | Unlighted LED |
| LED # | Mechanical X-axis Angle $\theta(\hat{x}_{m,i})$ | Major Axis Angle $\theta(\hat{x}_{n,i})$ | Mechanical X-axis Deviation $\Delta \theta_{n,i}$ |
| 1 | $\theta(\hat{x}_{m,1})$ | $\theta(\hat{x}_{n,1})$ | $\Delta \theta_{n,1}$ |
| 2 | $\theta(\hat{x}_{m,2})$ | $\theta(\hat{x}_{n,2})$ | $\Delta \theta_{n,2}$ |
| 3 | ... | ... | ... |

#### Optical Origin Deviation $d_{o,i}(x_i, y_i) = \sqrt{(x_{o,i} - x_i)^2 + (y_{o,i} - y_i)^2}$ | Unit : mm | Lighted LED | Area of interested-ratio of max luminance |
| LED # | Optical Origin Specific Origin | Optical Origin Deviation $d_{o,i}$ |
| 1 | $O_{o,1}(x_{o,1}, y_{o,1})$ | $x_1$, $y_1$ | $d_{o,1}$ |
| 2 | $O_{o,2}(x_{o,2}, y_{o,2})$ | $x_2$, $y_2$ | $d_{o,2}$ |
| 3 | ... | ... | ... |

#### Optical X-axis Deviation $\Delta \theta_{o,i} = \theta(\hat{x}_{o,i}, \hat{x}_{n,i})$ | Unit: degree | Light LED | Area of interested-ratio of max luminance |
| LED # | Optical X-axis Angle $\theta(\hat{x}_{o,i})$ | Major Axis Angle $\theta(\hat{x}_{n,i})$ | Optical X-axis Deviation $\Delta \theta_{o,i}$ |
| 1 | $\theta(\hat{x}_{o,1})$ | $\theta(\hat{x}_{n,1})$ | $\Delta \theta_{o,1}$ |
| 2 | $\theta(\hat{x}_{o,2})$ | $\theta(\hat{x}_{n,2})$ | $\Delta \theta_{o,2}$ |
| 3 | ... | ... | ... |

### Table 3 Report Sample of Optical Characteristic Data under Partial Luminous Flux Measurement Conditions

| Optical Characteristic Measurement Report - Partial Luminous Flux Summary |
|---------------------------------------------|-------------------------------------------------|----------|---------------|
| Partial Luminous Flux Uniformity $U_p = \frac{\min(\Phi_{o,i})}{\max(\Phi_{o,i})}$ | Color Non-uniformity $\Delta u'v' = \max(|u_i' - u_i'|^2 + |v_i' - v_i'|^2)$ | $\Delta uv = \max(|x_i - x_i'|^2 + |y_i - y_i'|^2)$ |
| LED # | Partial Luminous Flux $\Phi_{o,i}$ | Color (Chromaticity Coordinate) | Measurement Condition |
| 1 | $\Phi_{o,1}$ | $(u_i', v_i')/(x_i, y_i)$ | □ specific origin |
| 2 | $\Phi_{o,2}$ | $(u_i', v_i')/(x_i, y_i)$ | □ mechanical origin |
| 3 | ... | ... | ... |

<table>
<thead>
<tr>
<th>Measurement Location</th>
<th>□ specific origin</th>
<th>□ mechanical origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working Distance $d$</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>Diameter of Open Port $D$</td>
<td>mm</td>
<td>Solid Angle $sr$</td>
</tr>
<tr>
<td>Warm-up Time $t$</td>
<td>sec</td>
<td>Variation $%$</td>
</tr>
</tbody>
</table>
Table 4 Report Sample of Optical Characteristic Data under Forward $2\pi$ Luminous Flux Measurement Conditions

<table>
<thead>
<tr>
<th>LED #</th>
<th>Forward $2\pi$ Luminous Flux Uniformity</th>
<th>Color (Chromaticity Coordinate)</th>
<th>Measurement Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$U_i = \frac{\text{Min}(\Phi_{i,1})}{\text{Max}(\Phi_{i,1})}$</td>
<td>$u_i, v_i, x_i, y_i$</td>
<td>□ specific origin □ mechanical origin</td>
</tr>
<tr>
<td>1</td>
<td>$\Phi_{i,1}$</td>
<td>$(u_i, v_i)/x_i, y_i$</td>
<td>Light Measurement Equipment</td>
</tr>
<tr>
<td>2</td>
<td>$\Phi_{i,2}$</td>
<td>$(u_i, v_i)/x_i, y_i$</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>Warm-up Time: sec, Variation: %</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>% Measured Period: sec, %</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5 Report Sample of Optical Characteristic Data under Luminous Intensity Measurement Conditions

<table>
<thead>
<tr>
<th>LED #</th>
<th>Luminous Intensity Uniformity</th>
<th>Color (Chromaticity Coordinate)</th>
<th>Measurement Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$U_i = \frac{\text{Min}(I_{i,1})}{\text{Max}(I_{i,1})}$</td>
<td>$u_i, v_i, x_i, y_i$</td>
<td>□ specific origin □ mechanical origin</td>
</tr>
<tr>
<td>1</td>
<td>$I_{i,1}$</td>
<td>$(u_i, v_i)/x_i, y_i$</td>
<td>Light Measurement Equipment</td>
</tr>
<tr>
<td>2</td>
<td>$I_{i,2}$</td>
<td>$(u_i, v_i)/x_i, y_i$</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>Working Distance: mm, Solid Angle: sr</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>Warm-up Time: sec, Variation: %</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>% Measured Period: sec, %</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6 Report Sample of Optical Characteristic Data under Total Flux Measurement Conditions

<table>
<thead>
<tr>
<th>Total Flux</th>
<th>Color (Chromaticity Coordinate)</th>
<th>Measurement Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit: lm</td>
<td>$\Phi_t$</td>
<td>CRM description</td>
</tr>
<tr>
<td>$u_t, v_t, x_t, y_t$</td>
<td>Light Measurement Equipment</td>
<td></td>
</tr>
<tr>
<td>Integrated Sphere Diameter: $m$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm-up Time: sec, Variation: %</td>
<td>Measured Period: sec, %</td>
<td></td>
</tr>
</tbody>
</table>

NOTE 5: The measurement parameters showed in the reports will depend on the actual demand.
APPENDIX 1
OPTICAL ORIGIN AND OPTICAL X-AXIS MEASUREMENT EXAMPLE

A1-1 Set-up
A1-1.1 Set the optical axis of an image type photometer to lie along a perpendicular axis to the LED light bar which is being tested.
A1-1.2 Set the location of the image type photometer over the specific origin position of the LED which is being tested.
A1-1.3 Set the constant current switching regulators to drive the LED light bar. Set the driving current of each LED to be 20 mA.
A1-1.4 Set the warm-up time to be 180 seconds (3 minutes) for the luminance spatial distribution measurement, with intensity variation less than 0.1% during the measurement period of 1 minute.

A1-2 Measurement Procedure
A1-2.1 Optical Origin Measurement Procedure
A1-2.1.1 Measure the luminance spatial distribution $L(x,y)$ in x-y plane while the LED light is on. $(x, y)$ coordinate is the pixel number in x-axis and y-axis of the image type photometer, and shown as Figure A1-1.

![Diagram of Luminance Spatial Distribution of LED Light Bar (Partial Image)](image1)

Figure A1-1
Diagram of Luminance Spatial Distribution of LED Light Bar (Partial Image)

A1-2.1.2 Find the pixel coordinates and the value of the maximum luminance for each LED in the $L(x, y)$ map. (in this case $L_{max}(318,489) = 4056.79$ counts, the center LED image shown as following figures)
A1-2.1.3 Circle the area in which the pixel value is greater than 1/10 of the maximum luminance for each LED. In this case the threshold value is 405.7 counts, shown as Figure A1-2.

![Diagram of the Maximum Luminance Position, the Contour of the Area to Calculate the Gravity Center, and the Optical Origin (Gravity Center) of ith LED](image2)

Figure A1-2
Diagram of the Maximum Luminance Position, the Contour of the Area to Calculate the Gravity Center, and the Optical Origin (Gravity Center) of ith LED

A1-2.1.4 Calculate the gravity center coordinates of each LED within the area in which the pixel value is greater than 1/10 of the maximum luminance. This coordinate is assigned as the optical origin coordinate $O_{oi}(x_{oi}, y_{oi})$ for ith LED. They are calculated by the Equation A1-1, and $L_i(x,y)$ is the luminance spatial distribution of ith LED.
For \( j = 1..m \), \( m \) is the total sampling number of area of interested. The area of interested is the area which luminance is greater than \( 1/10 \) of maximum luminance for \( i \)th LED. In this case, the \( O_{o,i}(x_{o,i}, y_{o,i}) = (35.221, 0.410) \) (the coordinate transfer to real dimensional scale in mm, (0,0) is the 1st alignment mark center).

A1-2.2 Optical X-axis Measurement Procedure

A1-2.2.1 Measure the luminance spatial distribution \( L(x,y) \) (as Figure A1-3), and calculate the optical origin. \( O_{o,i}(x_{o,i}, y_{o,i}) \) for \( i \)th LED (the same as § A1-2.1, optical origin measurement procedure above). The red square represents the position of maximum luminance, and the green square represents the position of optical origin in the Figure A1-3.

A1-2.2.2 Contour the area with greater than \( 1/10 \) of maximum luminance, and the red contour line represents it in the Figure A1-3.

A1-2.2.3 Then find the longest line segment (i.e., most pixel numbers) passing through the optical origin within this area, and set the direction following the PCB major axis. The purple line is the \( i \)th optical x-axis in the Figure A1-3.

### Figure A1-3

Diagram of the Maximum Luminance Position (Red Square), the Optical Origin(Green Square), the Contour (Red Line) of the Area to Determine the Optical X-axis, and the Optical X-axis (Purple Line) of \( i \)th LED

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