Light Emitting Diode

# Nichia E11A and E17A Series Discrete Color LEDs

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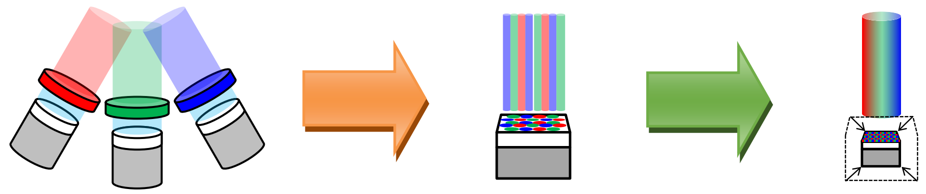
The Nichia part numbers NFSxE11A-V1, NCSxE17A, NCSxE17A-V1, and NCSxE17A-V1L1 within this document are merely Nichia's part numbers for those Nichia products and are not related nor bear resemblance to any other company's product that might bear a trademark.

# 1. Overview

In recent years, color LEDs have started to be used in various types of lighting fixtures in the lighting industry. Before color LEDs, floodlights and stage lighting luminaires used white halogen lamps and color filters (i.e. filters that are colored red, green, or blue, etc.) to create colors (see Figure 1). With this method, a color filter was needed for each color to create the required colors. Additionally, two or more luminaires were required to create intermediate colors. With color LEDs, a single luminaire can create any color[1] without external parts and seamlessly change between colors. Color LEDs have greatly expanded the range of color effects far beyond that of conventional lighting fixtures. Color LEDs have various other advantages compared to halogen lamps; for example, reducing the size and weight of a luminaire, energy saving, improving the maintainability of the luminaire due to the long life of the LEDs.

Nichia offers discrete color LEDs[2] for general lighting to meet the needs of its customers. Especially, with the NFSxE11A-V1, NCSxE17A, NCSxE17A-V1, and NCSxE17A-V1L1 LEDs[3] (hereinafter referred to as “Nichia E11A and E17A Series LEDs”), the size of a luminaire can be further reduced, and a uniform color can be achieved on the illuminated surface since they are very small. This application note provides the features and the handling precautions for the Nichia E11A and E17A Series LEDs.



White light + Color filters    Luminaire using color LEDs    Smaller luminaire using color LEDs[4]

Figure 1. Reference Image of Full-color Luminaires

# 2. Full-color Luminaires

## 2.1. Full-color Luminaires Using LEDs

This section provides examples of full-color luminaires that use color LEDs.

### 2.1.1. Floodlights

Floodlights are used to decoratively illuminate constructions (i.e. a building, bridge, etc.) and landscapes (see Figure 2). Floodlights should have high luminous flux and high luminous intensity to illuminate objects in the distance clearly. With a programmed control, floodlights can be operated to emit a single-colored light, create tunable/gradient colors, and/or flash the light, etc. to provide eye-catching illumination.

Figure 2. Example of a Floodlight Illuminating a Building with a Colored Light

[1] Any color can be created by adjusting the intensities of three or more colors (i.e. usually primary colors). Generally, the additive primary colors are used for general lighting and PC monitors and those are RGB (i.e. red, green, and blue). Regarding how to create required colors, refer to the application note: Design Considerations for Full-Color Luminaires Using Discrete Color LEDs.
[2] The LEDs that emit a single color (i.e. red, blue, etc.); LEDs that emit white light are not included.
[3] The character “x” in the part numbers described herein refers to the color of the emitted light; each color will have a unique character.
[4] This illustration is only a reference image of a full-color luminaire. How the luminaire operates is different than what is shown here.

### 2.1.2. Stage Lighting Luminaires

Stage lighting luminaires are available in a variety of types (e.g. hanging from the ceiling, floor recessed, etc.) to illuminate the stage from many different directions. The greatest advantage that can be achieved by using LEDs for stage lighting is the installation flexibility of the luminaires; luminaires that use LEDs are easier to install and they can be installed in a wider variety of locations than traditional luminaires since the luminaire size and weight can be reduced when using LEDs as the light source.

Additionally, full-color luminaires using LEDs can provide a more even color without casting multiple shadows on the stage since the required color is created inside the luminaire. For comparison, when using the traditional method of creating an intermediate color (i.e. overlapping the colors emitted from multiple luminaires with color filters on the illuminated surface to create a new color), the individual colors may be seen where the colors do not fully overlap (i.e. the outlines of each light).

### 2.1.3. Other Luminaires that use LEDs

As discussed above, LEDs increase the design flexibility for luminaires. Full-color tuning is now possible for a wider variety of locations and for various purposes/situations with luminaires that use LEDs. Nichia expects that full-color luminaires using LEDs will become more widely used in residential homes in the future.

## 2.2. How to Change Colors with Full-color Luminaires

In a full-color luminaire, a required color is created by changing the brightness of each primary color (i.e. RGB); a luminaire needs to be able to control three or more channels simultaneously for full-color tuning[5]. This section discusses some of the communication methods generally used to control the brightness and colors of a luminaire.

### 2.2.1. Infrared Communication

The infrared communication is mainly used for general lighting for residential homes. A luminaire using this communication method has an infrared receiving sensor on it. The brightness and colors are controlled with an infrared remote controller supplied with the luminaire. With this communication method, each luminaire needs a corresponding remote controller; therefore, this method is not suitable for situations where controlling multiple luminaires at once or a more complicated program control (e.g. automatic timing control) are needed.

### 2.2.2. Digital Addressable Lighting Interface (DALI)

DALI is an international standard for digital lighting control that was developed mainly by European luminaire manufacturers. Since DALI is a standard, DALI compliant products are interoperable between manufacturers; this applies not only to luminaires, but also when connecting devices like sensors and switches to a DALI control system.

[5] Generally, three primary colors (i.e. RGB) are used for full-color tuning; these three colors need to be controlled separately.

As shown in Figure 3, one device (i.e. DALI controller) can control up to sixty-four devices (i.e. luminaires). Each luminaire has its own unique address and it allows for the luminaires to be controlled individually or arranged into groups (sixteen groups maximum) to be controlled together. In addition, a DALI system is a two-way communication system; it can monitor the state of the luminaires (e.g. on or off), the power consumed, etc. and control the luminaires automatically based on the feedback provided. This feature makes DALI suitable to control multiple luminaires in a large-scale lighting system (e.g. office building) together with a single communication system.

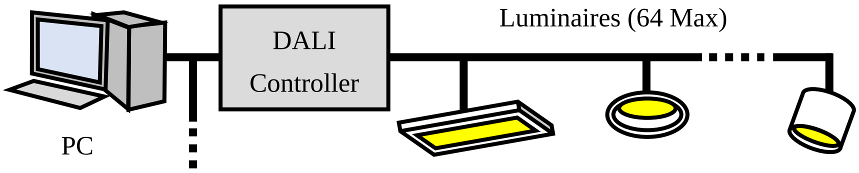



Figure 3. Illustrated Image of a DALI Control System

### 2.2.3. DMX512 and DMX512-A

DMX512 was originally established by the United States Institute for Theatre Technology (USITT) for controlling stage lighting dimmers and effects. It was revised to be DMX512-A and approved by the American National Standards Institute (ANSI). Since the digital signal transmission method in DMX512 and DMX512-A is simpler than the other standards and the cables used to connect the devices are robust, it can offer stable communication even in severe environments. The DMX controller and its controlled devices are connected in a daisy chain; see Figure 4. Up to 512 channels can be used with a single DMX controller and 8 bits (i.e. 256 levels of control are available) per channel. In addition to dimming the light, it is also possible to control the devices mechanically (e.g. panning, tilting, etc.). In most applications, once a starting address is configured for each device, corresponding addresses (i.e. channels) are automatically assigned per control.

DMX512 and DMX512-A systems are usually not used for general lighting for residential homes. They are widely used for full-color luminaires such as floodlights and stage lighting luminaires to provide eye-catching illumination.

It should be noted that the DMX512 system is not a two-way communication system; if a problem (e.g. a data reception failure, an electrical connection failure in a connected device) occurs, the system cannot detect it and therefore a DMX512 system it is not recommended for safety-critical applications such as a fireworks ignition system. Two-way communication is available with DMX512-A (i.e. Remote Device Management, RDM).

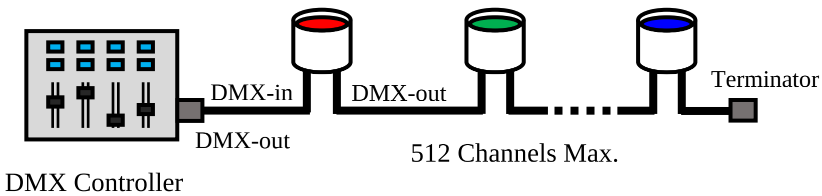



Figure 4. Illustrated Image of a DMX512/DMX512-A System

# 3. Specifications and Color Options for the Nichia E11A and E17A Series LEDs

### 3.1 Outline Dimensions

Figures 5 and 6 show the outline dimensions for the Nichia E11A and E17A series discrete color LEDs respectively. Since the LEDs in these series are smaller than existing LEDs that have an equivalent output power, the size of a luminaire can be reduced.

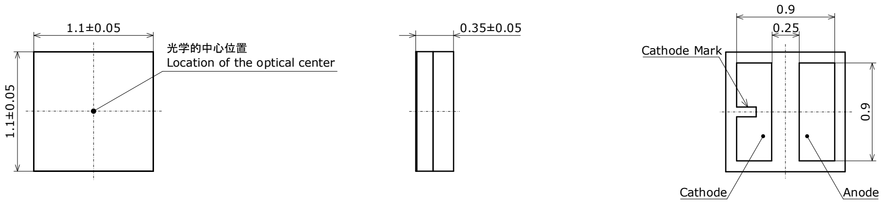



Figure 5. Outline Dimensions for the Nichia E11A Series LEDs

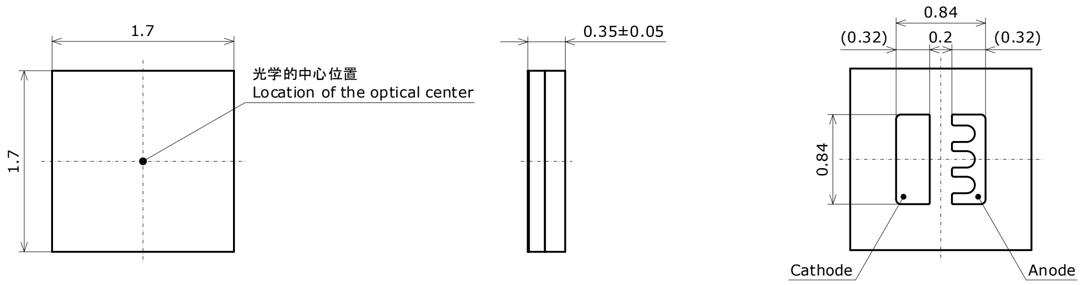
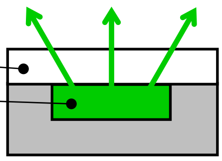
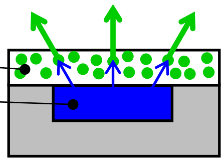



Figure 6. Outline Dimensions for the Nichia E17A Series LEDs

### 3.2 How the Nichia E11A and E17A Series LEDs Create Colors

There are two ways to create a colored light for the Nichia E11A and E17A series LEDs. One of them is to use an LED chip that emits the required color; no phosphor is used for this method. The other one is to use a colored phosphor with the LED chip; the phosphor is excited by the light emitted from the chip and emits the required color. Table 1 provides the difference in the LED structure for these two methods and their advantages/disadvantages.

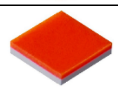
Table 1. Two Methods to Create a Colored Light (e.g. Green Light)

| | Method Using a Chip of the Required Color (No Phosphor Used) | Method Using a Colored Phosphor |
|---|---|---|
| Structure | Clear Resin<br>Green LED Chip  | Green Phosphor<br>Blue LED Chip  |
| Advantage | Since the required color can be created with the chip itself, the LEDs have a high color purity and a wide color tuning range (i.e. gamut). | Since all of the colors use a blue chip, the difference in the forward voltage between the colors can be reduced with this method. See section 4.2. |
| Disadvantage | The characteristics of the LEDs vary depending on the color of the chip; the difference in the forward voltage needs to be considered when designing the circuit for a color tunable luminaire. See section 4.2. | The brightness and/or color of the LED may change since the LED may be affected by the color of the light emitted from an adjacent LED. See section 4.4. |

### 3.3. Part Numbers and Characteristics of the Nichia E11A and E17A Series LEDs

Table 2 shows the characteristics of each LED in the Nichia E11A and E17A Series; the white LEDs are not included.
Figure 7 shows the wavelengths of the Nichia E11A and E17A Series LEDs.
Figure 8 shows the chromaticity of the Nichia E11A and E17A Series LEDs.

Table 2. Characteristics of the Nichia E11A and E17A Series LEDs (i.e. Typical Characteristics at $T_C$=25°C)[6,7]

| Series Name and Sorting Current | Appearance | Emitted Color | Method to Create a Color | Part Number | Forward Voltage, $V_F$ (V) | Luminous Flux, $\varphi_v$ (lm) |
|---|---|---|---|---|---|---|
| E11A-V1 ($I_F$=65mA) |  | Blue | Chip | NFSBE11A-V1L1 | 2.83 | 9.5 |
| |  | Green | Phosphor | NFSGE11A-V1 | 2.8 | 41.9 |
| |  | Brilliant Red | Phosphor | NFSRE11A-V1 | 2.8 | 11.5 |
| |  | Red | Phosphor | NFSRE11A-V1 | 2.8 | 6.5 |
| E17A-V1 ($I_F$=350mA) |  | Royal Blue | Chip | NCSCE17A | 3.00 | 18 |
| |  | Blue | Chip | NCSBE17A | 3.00 | 42 |
| |  | Azure | Phosphor | NCSEE17A | 3.00 | 132 |
| | | | | NCSEE17A-V1 | 2.95 | 137 |
| |  | Bluish Green | Chip | NCSEE17A-V1L1 | 2.60 | 126 |
| |  | Green | Phosphor | NCSGE17A | 3.00 | 208 |
| | | | | NCSGE17A-V1 | 2.95 | 221 |
| |  | Green | Chip | NCSGE17A-V1L1 | 2.55 | 175 |
| |  | Lime | Phosphor | NCSGE17A | 3.00 | 212 |
| | | | | NCSGE17A-V1 | 2.95 | 225 |
| |  | Amber | Phosphor | NCSAE17A | 3.00 | 124 |
| | | | | NCSAE17A-V1 | 2.95 | 131 |
| |  | Brilliant Red | Phosphor | NCSRE17A | 3.00 | 58 |
| | | | | NCSRE17A-V1 | 2.95 | 60 |
| |  | Red | Phosphor | NCSRE17A | 3.00 | 31 |
| | | | | NCSRE17A-V1 | 2.95 | 32 |
| |  | Deep Red | Phosphor | NCSRE17A-V1 | 2.95 | 24 |

[6] There are more color variations in the Nichia E11A and E17A series. For further information, contact a local Nichia sales representative.
[7] The forward voltage and luminous flux are measured at the sorting current applicable for each series.

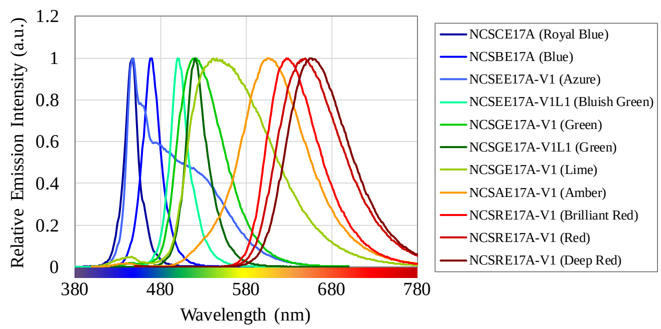



Figure 7. Wavelength[8]

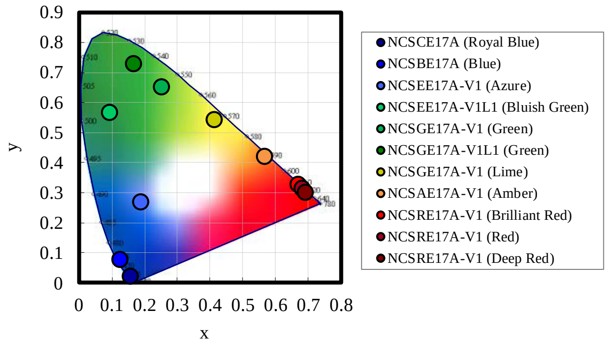


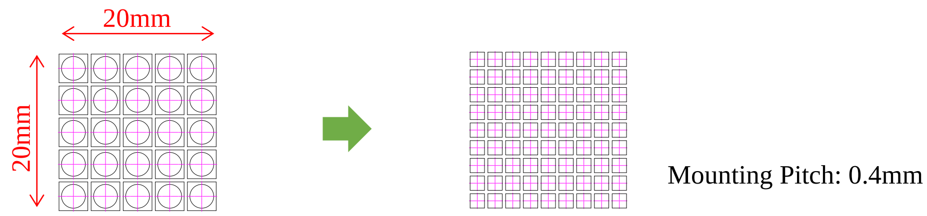

Figure 8. Chromaticity Coordinates[8]

## 4. Features of the Nichia E11A and E17A Series LEDs

This section provides the key features of the Nichia E11A and E17A Series LEDs.

### 4.1. High Light Output and Small Emitting Area

The most remarkable feature of the Nichia E11A and E17A Series LEDs is their very compact package size. For example, while the rated power consumption of both the Nichia E17A and 19B-V1 Series LEDs are the same, more than three times as many E17A Series LEDs can fit in the same area (see Figure 9). This allows the E17A Series LEDs to have a light output per area that is significantly greater than that of the 19B-V1 Series LEDs[9].




The 19B-V1 Series LEDs: 25 LEDs    The E17A Series LEDs: 81 LEDs

Figure 9. Number of 19B-V1 and E17A Series LEDs that can be Mounted in the Same Area

If the light output required for the chosen luminaire using the E17A Series LEDs is the same as the luminaire using the 19B-V1 Series LEDs, the area of the total emitting surface can be greatly reduced. A smaller total emitting surface has advantages when optical components (e.g. lens, reflector) are used with the LEDs in the luminaire. For example, when the light is collimated to produce a parallel light (e.g. a floodlight), the smaller the total emitting surface is, the narrower the beam angle will be (see Figure 10), and if the beam angle and the luminous intensity required for the luminaire are the same as when using the Nichia 19B-V1 Series LEDs, the size of the optical components can be reduced.

However, the heat dissipation needs to be taken into consideration when designing the chosen luminaire using the Nichia E17A Series LEDs since the power dissipation will be in a smaller area compared to the 19B-V1 Series LEDs. Ensure that the absolute maximum rated junction temperature is not exceeded for any of the LEDs in the luminaire; note that the junction temperature of the LEDs mounted in the middle of the PCB tends to be higher than the other LEDs.

8 The information for the Nichia E11A series LEDs is not shown here.
9 The difference in the light output per area between the Nichia E17A and 19B-V1 series LEDs varies depending on the emitted color.

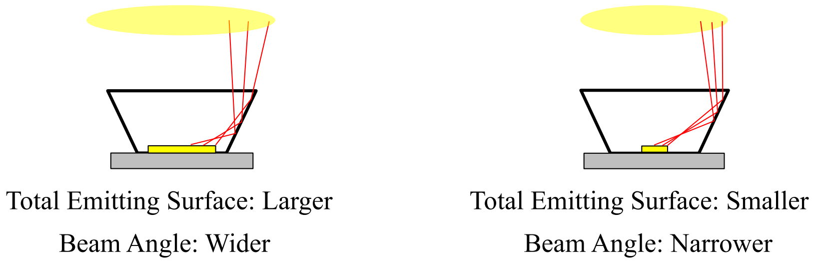



Figure 10. Difference in the Beam Angle Depending on the Size of the Total Emitting Surface

### 4.2. Same Forward Voltage for Most Colors

Since the forward voltage of an LED greatly varies depending on emitted color of the chip, power loss/heat generation may occur in the circuit for a color tunable luminaire due to the difference in the forward voltage. For the Nichia E11A or E17A series, all the LEDs that use a phosphor to create a colored light have the same forward voltage; they can reduce the power loss/heat generation.
Figure 11 shows a circuit that has three LEDs with different forward voltages; it explains how power loss occurs due to the forward voltage difference.

The voltage applied to Constant Current Circuit R1 in Circuit 1 is calculated by subtracting the forward voltage of LED 1 from the input voltage Vin: 4V - 2.5V = 1.5V. If the current of 100mA flows through LED 1, the same amount of current flows to Constant Current Circuit R1; the electric power consumed in R1 is calculated as 1.5V × 100mA = 0.15W. These calculations also apply to Circuits 2 and 3: as done for R1, if the current of 100mA flows to Constant Current Circuits R2 and R3, the electric power consumed in R2 is 0.05W and that in R3 is 0.1W. The power that is consumed in R1, R2, and R3 is the energy that becomes heat, etc. instead of being converted into light; the power loss of the luminaire is calculated as the sum of the consumed power in R1, R2, and R3: 0.15W + 0.05W + 0.1W = 0.3W.

Next, assume a case where the difference in the forward voltage between the LEDs in the circuit is greater. If the forward voltage for Circuit 1 is changed from 2.5V to 2.0V, the electric power consumed in R1 will increase from 0.15W to 0.2W. As a result, the power loss of the luminaire will increase from 0.3W to 0.35W. This means that the greater the difference in the forward voltage between the LEDs is, the power loss in a circuit with a lower operating voltage will be greater, causing the luminaire efficacy to decrease and the heat generated in Constant Current Circuits to increase.

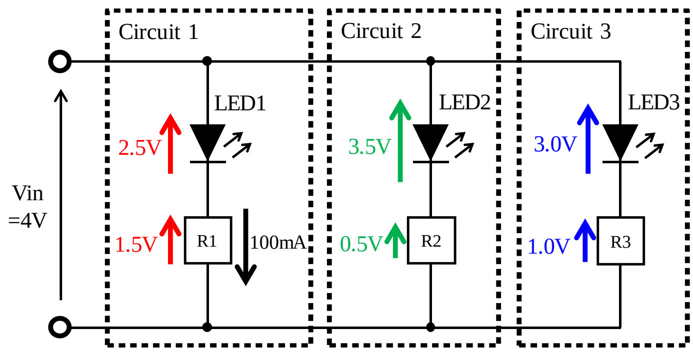



Figure 11. Example Circuit for a Color Tunable Luminaire

### 4.3. Temperature Characteristics of Red LEDs

When the LED temperature (i.e. the junction temperature) is increased, the luminous flux is reduced in most cases: generally, this reduction in the luminous flux is greater for a red LED chip than LED chips of another color. When using an LED that has a red chip there is a concern that the designed value of the luminous flux may not be obtained due to this temperature characteristic, causing color tunable luminaires that use this type of LED to not create the required colors.
The Nichia E11A and E17A Series LEDs use a blue LED chip for the red LEDs. Blue LED chips have more stable temperature characteristics than red chips; using the E11A or E17A Series LEDs offers the following advantages for luminaires: the reduction in the luminous flux due to an increase of the junction temperature is smaller, and the color shift is smaller.

### 4.4. Optical Effects Caused by Adjacent LEDs

When LEDs are mounted with a small pitch, the light emitted from an LED may interfere with an adjacent LED resulting in optical effects on both of the LEDs (i.e. a reduction in the luminous flux, color shift, etc.). This issue is likely to occur especially for the Nichia E11A and E17A Series LEDs due to their structure; the resulting effect will be more serious for the LEDs within the series that use a phosphor to create a colored light. Refer to Figure 12 for how an adjacent LED may affect the luminous flux/color of the LEDs that contain a phosphor.
For the LEDs that do not contain a phosphor, the light emitted from an LED will hit the substrate and/or the chip of an adjacent LED causing the light to be reflected or absorbed by the adjacent LED (or transmitted through the resin of the adjacent LED). It may result in a reduction in the luminous flux of the LED. However, for LEDs that do not contain a phosphor, a color shift is less likely to occur as there is no phosphor that could be excited by the adjacent LED.
For the LEDs that contain phosphor, the light emitted from an LED will hit the phosphor layer of an adjacent LED causing the phosphor to be excited and emit a low light; it may result in a color shift of the luminaire using these LEDs. Since most types of phosphors are excited by light whose wavelength is shorter than that of the color of the light the phosphor emits, the color shift may be more likely to occur when a blue LED is illuminated. This means the possibility for a color shift to occur will depend on the combination of LEDs and LED pitch used for the luminaire. Nichia performed evaluations on how much color shift would occur for different mounting conditions. This section provides the evaluation results.

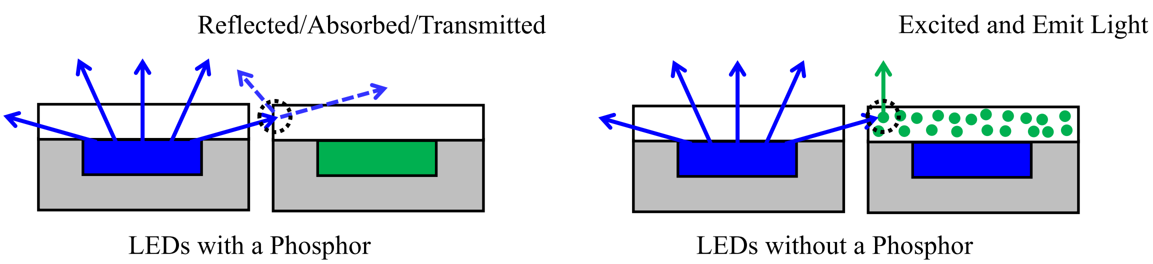



Figure 12. How an Adjacent LED Affects the Luminous Flux/Color

### 4.4.1. Evaluation Method

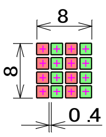
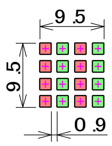
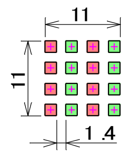
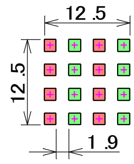
Evaluated LEDs:

R: NCSRE17A (Red)
G: NCSGE17A (Green)
B: NCSCE17A (Royal Blue)
A: NCSAE17A (Amber)
W: NCSWE17A (Cool White, Rank: sm50/R70)
L: NCSLE17A (Warm White, Rank: sm30/R9050)
All combinations using two colors from the above list were evaluated.

LED Pitch:

The evaluated LEDs were mounted with four different pitches between 0.4mm and 1.9mm. See Table 3.

Table 3. How the Evaluated LEDs were Mounted

| | LED Pitch | | | |
|---|---|---|---|---|
| | 0.4mm | 0.9mm | 1.4mm | 1.9mm |
| ■: Color No.1<br>■: Color No.2 |  |  |  |  |

Operating Current:

The evaluated LEDs were operated at the sorting current of 350mA in pulse mode[10] to reduce the effect of the self-heating of the LEDs on the evaluations.

Evaluation Method:

For each evaluated PCB with the evaluated LEDs mounted per condition, only the LEDs of Color No. 1 were illuminated (i.e. the adjacent LEDs of Color No. 2 were not illuminated); the chromaticity was measured with an integrating sphere.
The obtained chromaticity coordinates were compared to the average chromaticity coordinates of the LEDs that were measured before the LEDs were mounted on the PCB to verify the amount of the color shift.

[10] For more information on the operation in pulse mode, refer to the applicable specification.

### 4.4.2. Evaluation Results

Figures 13-18 show the evaluation results.

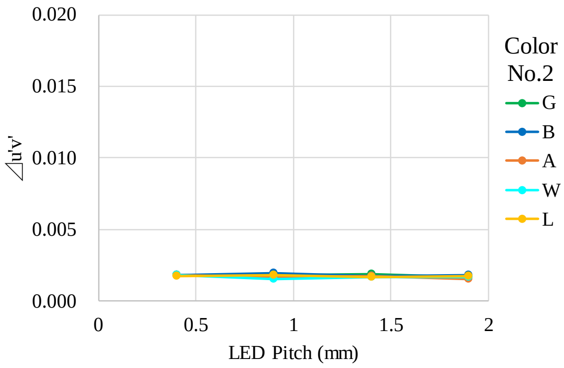



Figure 13. Color No. 1: Red

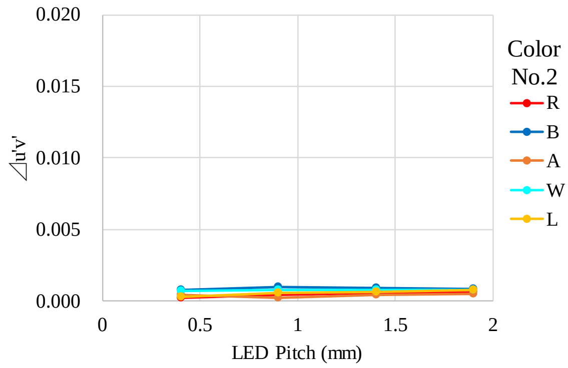



Figure 14. Color No. 1: Green

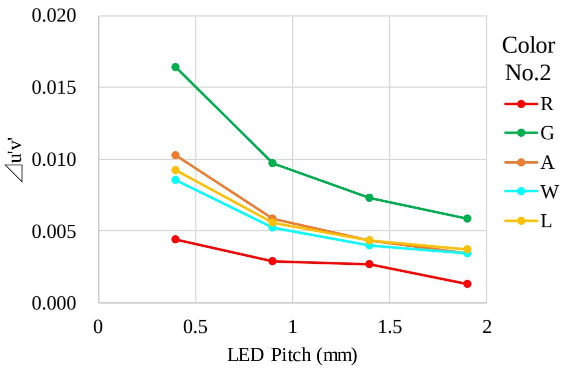



Figure 15. Color No. 1: Royal Blue

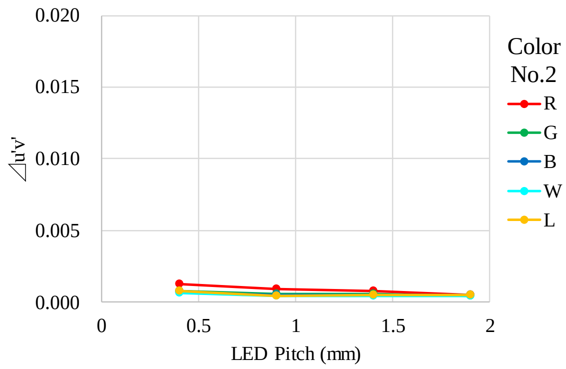



Figure 16. Color No. 1: Amber

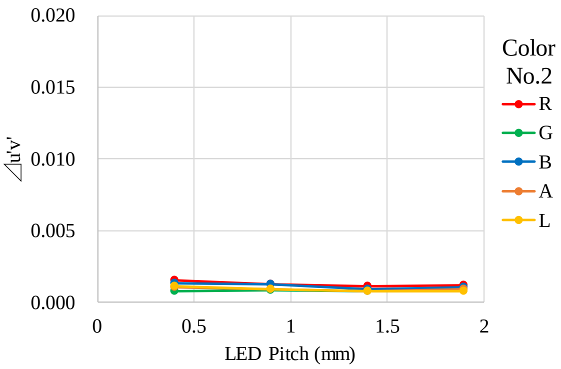



Figure 17. Color No. 1: Cool White

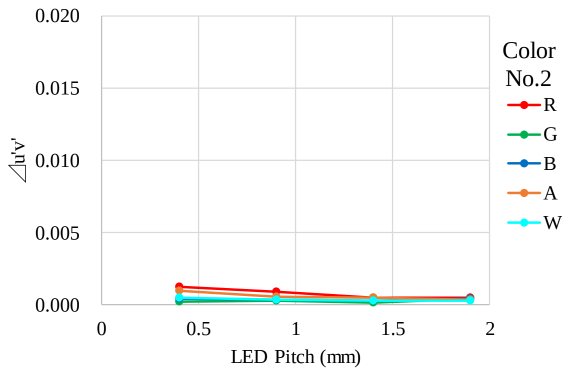



Figure 18. Color No. 1: Warm White

Evaluation Results and Conclusion:

- When the illuminated LEDs (i.e. Color No. 1) were not royal blue, the color shift that occurred was very small.
- When the illuminated LEDs were royal blue (see Figure 15), color shift occurred. The amount of the color shift depended on the color of the adjacent LEDs (i.e. Color No. 2). The smaller the LED pitch was, the greater the color shift was since the adjacent LEDs received more light from the illuminated LEDs when these LEDs were mounted with a smaller pitch.
- When the illuminated LEDs were royal blue (see Figure 15) and the adjacent LEDs were green, the greatest color shift occurred among all the color combinations. It is considered that the green light is more likely to cause a color shift since the green wavelength is close to the peak response wavelength of the human eye and the green light has a higher luminous flux. Contrary to the green light, the red light does not cause a great color shift since its luminous flux is lower.

These results indicate that the color shift is likely to occur when blue LEDs and LEDs of other colors are mounted next to each other. Nichia recommends selecting a color combination that does not cause a great color shift when mounted next to each other, mounting the LEDs in a greater pitch, etc.

### 4.5. Color Uniformity on the Illuminated Surface

An LED-based high-power luminaire (e.g. floodlight) uses an optical component (e.g. lens, reflector) for each of the LEDs. The reason for this is that if the light directivities of all the LEDs are controlled together using only one optical component, the optical component would be very large since there would be many LEDs mounted in the luminaire to obtain a high power, resulting in a large emitting surface; the size of the luminaire can be reduced by controlling the light directivity of each LED independently. However, this method has disadvantages for color-tunable luminaires including that the individual colors may be seen at the outlines of each light since the colors are mixed on the illuminated surface to create a required color, and the colors emitted from the LEDs that are mounted in the edges of the PCB may not be mixed in the created color on the illuminated surface and be seen as they are.

With the Nichia E11A or E17A Series LEDs, the sizes of the optical component and the luminaire can be reduced even when the light directivities of all the LEDs are controlled with one optical component since the package of the LEDs is very compact resulting in the area of the emitting surface of the luminaire to be greatly reduced. In addition, for the luminaires using these series of LEDs with one optical component, the color can be more uniform on the illuminated surface since the colors are mixed on the emitting surface.
Nichia performed evaluations on the color uniformity on the illuminated surface with the E17A Series LEDs mounted on a PCB with a small pitch to create colored lights, using one reflector to collimate the lights. This section provides the evaluation results.

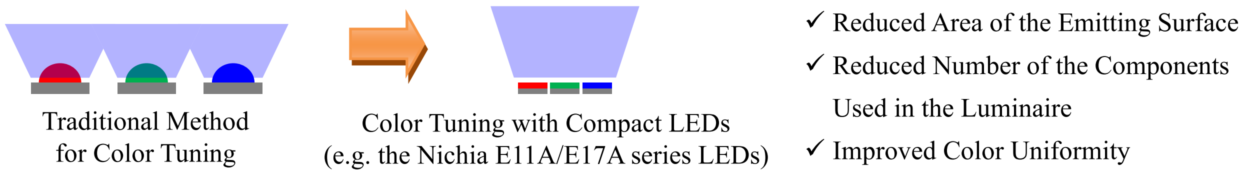



Figure 19. Reference Image of Color Tuning using the Nichia E11A or E17A Series LEDs

### 4.5.1. Evaluation Conditions

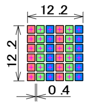
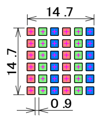
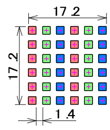
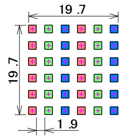
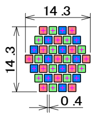
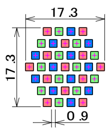
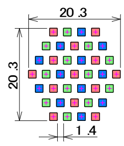
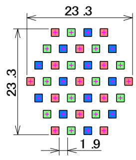
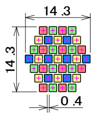
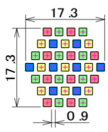
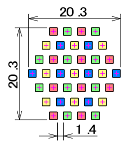
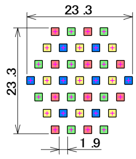
Evaluated LEDs:

R: NCSRE17A (Red), G: NCSGE17A (Green), B: NCSCE17A (Royal Blue), W: NCSWE17A (Cool White,5000K)

LED Pitch, Configuration, and Color Combination:

The LEDs were mounted with three different configurations and color combinations, and with four different pitches between 0.4mm and 1.9mm. See Table 4.

Table 4. How the Evaluated LEDs were Mounted

| Configuration | LED Pitch | | | |
|---|---|---|---|---|
| | 0.4mm | 0.9mm | 1.4mm | 1.9mm |
| Configuration 1:<br>R: 12 LEDs<br>G: 12 LEDs<br>B: 12 LEDs |  |  |  |  |
| Configuration 2:<br>R: 13 LEDs<br>G: 12 LEDs<br>B: 12 LEDs |  |  |  |  |
| Configuration 3:<br>R: 10 LEDs<br>G: 10 LEDs<br>B: 8 LEDs<br>W: 9 LEDs |  |  |  |  |

Configuration 1: Each of the red (R), green (G), and royal blue (B) LEDs were mounted in a line. This simple way of mounting the LEDs would make designing the wiring pattern for the PCB easier.

Configuration 2: The red, green, and royal blue LEDs were mounted in a manner where the same color LEDs were not next to each other.

Configuration 3: The red, green, royal blue, and cool white (W) LEDs were mounted in a manner where the same color LEDs were not next to each other. Using white LEDs with the red, green, and royal blue LEDs enhances the expression of pale colors (i.e. pastel colors).

Evaluated Reflector:

A reflector whose half-power beamwidth was approximately 10° was used to achieve a narrow directivity. Figure 20 shows the approximate outline dimensions of the evaluated reflector.

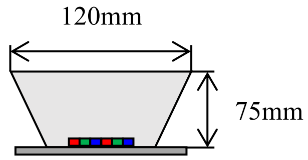



Figure 20. Evaluated Reflector

Created Colors:

Table 5 shows the created colors that were evaluated. The brightness and chromaticity of each created color were controlled to be the same for all the evaluated PCBs by adjusting the current that flowed through each LED.

Table 5. Created Colors

| Configuration | Created Colors | Note |
|---|---|---|
| Configuration 1 & 2 (R, G, and B) | 5000K | The red, green, and royal blue LEDs were illuminated to achieve a color temperature of 5000K. |
| | 3000K | The red, green, and royal blue LEDs were illuminated to achieve a color temperature of 3000K. |
| | Red (R) | Only the red LEDs were illuminated. |
| | Green (G) | Only the green LEDs were illuminated. |
| | Royal Blue (B) | Only the royal blue LEDs were illuminated. |
| | Yellow (Y) | The red and green LEDs were illuminated. |
| | Magenta (M) | The red and royal blue LEDs were illuminated. |
| | Cyan (C) | The green and royal blue LEDs were illuminated. |
| Configuration 3 (R, G, B, and W) | Cool White (W) | Only the cool white (5000K) LEDs were illuminated. |
| | Red (R)+ Cool White (W) | The red and cool white LEDs were illuminated. |
| | Green (G)+ Cool White (W) | The green and cool white LEDs were illuminated. |
| | Royal Blue (B)+ Cool White (W) | The royal blue and cool white LEDs were illuminated. |
| | Yellow (Y)+ Cool White (W) | The red, green, and cool white LEDs were illuminated. |
| | Magenta (M)+ Cool White (W) | The red, royal blue, and cool white LEDs were illuminated. |
| | Cyan (C)+ Cool White (W) | The green, royal blue, and cool white LEDs were illuminated. |

Evaluation Method:

For each evaluated PCB, the light was emitted on a white wall that is three meters away from the PCB (i.e. the illuminated surface). The color uniformity of each of the created colors (see Table 5) was evaluated on the illuminated surface.

### 4.5.2. Evaluation Results

Tables 6-8 show pictures of the illuminated surfaces for Configurations 1-3.

Table 6. Illuminated Surfaces for Configuration 1

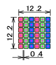
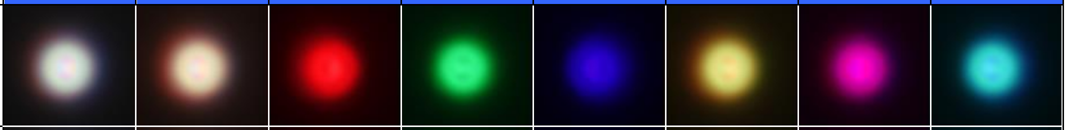
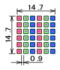
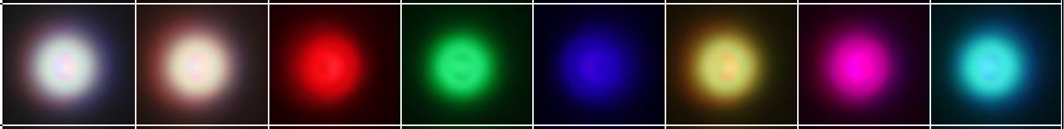
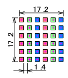
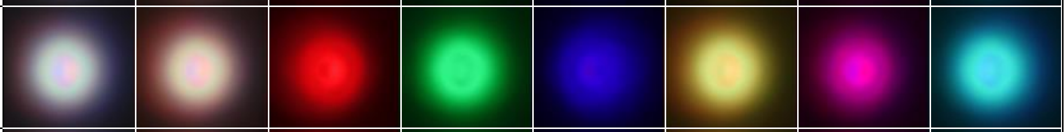
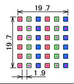
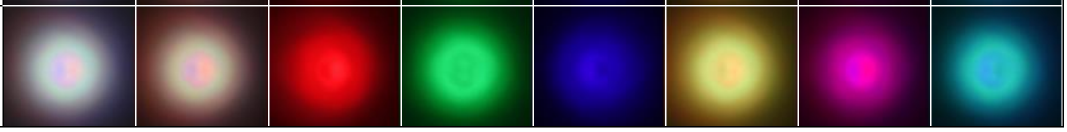
| | 5000K | 3000K | R | G | B | Y | M | C |
|---|---|---|---|---|---|---|---|---|
| 0.4mm  |  | | | | | | | |
| 0.9mm  |  | | | | | | | |
| 1.4mm  |  | | | | | | | |
| 1.9mm  |  | | | | | | | |

Table 7. Illuminated Surfaces for Configuration 2

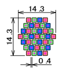
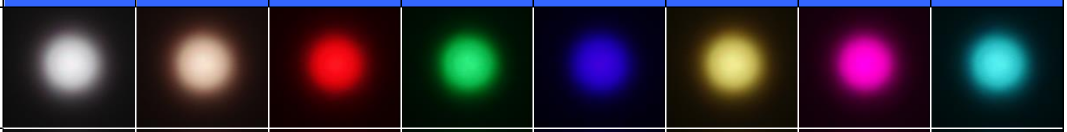
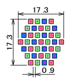
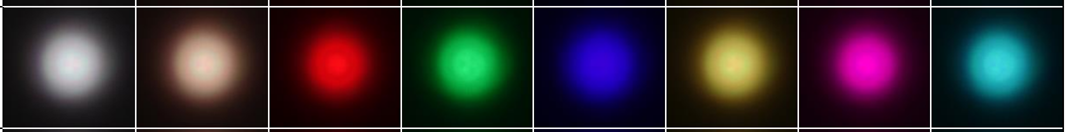
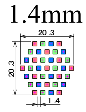
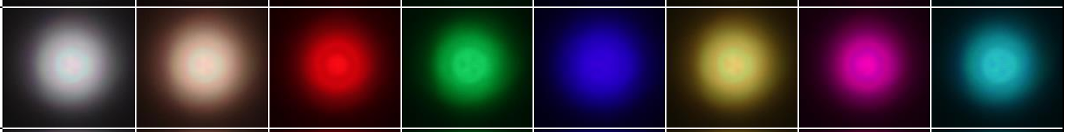
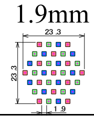
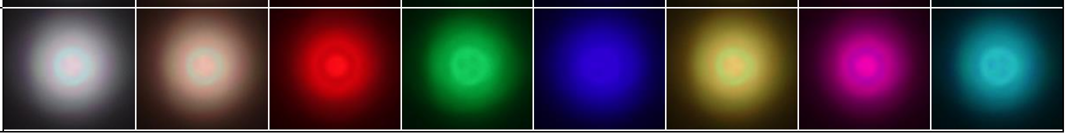
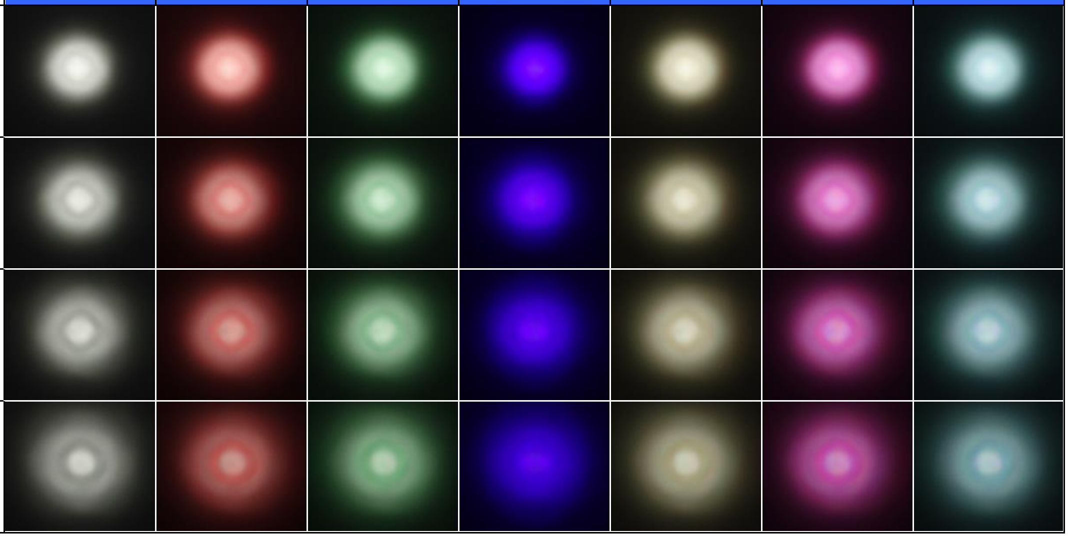
| | 5000K | 3000K | R | G | B | Y | M | C |
|---|---|---|---|---|---|---|---|---|
| 0.4mm  |  | | | | | | | |
| 0.9mm  |  | | | | | | | |
| 1.4mm  |  | | | | | | | |
| 1.9mm  |  | | | | | | | |

Table 8. Illuminated Surfaces for Configuration 3

| | W | R+W | G+W | B+W | Y+W | M+W | C+W |
|---|---|---|---|---|---|---|---|
| 0.4mm | | | | | | | |
| 0.9mm | | | | | | | |
| 1.4mm | | | | | | | |
| 1.9mm | | | | | | | |



Evaluation Results:

- For Configuration 1 (see Table 6), the colors did not mix well to create a uniform color when different color LEDs were illuminated. The luminance was also not uniform when only one color group of LEDs was illuminated.
- For Configuration 2 (see Table 7), the color uniformity was much better than Configuration 1. However, the larger the LED pitch was, the worse the color uniformity was.
- For Configuration 3 (see Table 8), the luminance was less uniform compared to Configurations 1 and 2. The reason is that more LEDs were left unilluminated for Configuration 3 than for Configurations 1 and 2.

The uniformity of the color and luminance can be improved by arranging the LEDs in a manner that ensures the colors are mixed evenly on the emitting surface (i.e. Configuration 2).
If the LEDs are not mounted in an equal blend of colors (i.e. Configuration 1), the color uniformity will be lower since the colors emitted from the LEDs are not mixed well either on the emitting surface or the illuminated surface.
The uniformity of the color and luminance can be improved even more by using a diffuser in addition to the optimum arrangement of the LEDs described above; with a diffuser, the colors are mixed near the emitting surface to achieve better color and luminance uniformity (see Figure 21). Note that the luminous flux and luminous intensity may be reduced when using a diffuser.


Figure 21. Reference Images of the Emission with/without a Diffuser and Picture of the Emitting Surfaces

## 5. Assembly Precautions

One of the features of the Nichia E11A and E17A Series LEDs is their compact package size; this feature can be utilized most when the LEDs are mounted with a small pitch to reduce the emitting area as much as possible. However, Nichia recommends an LED pitch of ≥0.4mm with consideration of various factors including the dimensional tolerances and deviations of the LEDs and other components, tilting/floating of the LED after reflow soldering, etc. in addition to the placement accuracy of a typical pick-and-place machine (i.e. chip mounter). If the LEDs are being used in a high-density application, perform a sufficient verification to ensure that there are no issues with the chosen conditions/environments before use.

For more information about assembly precautions, refer to the applicable specification and the application notes: Assembly Precautions for the Nichia E11 Series LEDs and Assembly Precautions for the Nichia NCSxE17A or NVSxE21A Series LEDs.

## 6. General Cautions/Suggestions for Using the LEDs

When designing luminaires using the Nichia E11A or E17A Series LEDs, the following must be considered:

- The absolute maximum rated forward current must not be exceeded for any of the LEDs in the luminaire under any circumstances. Note that the absolute maximum rated forward current may be different depending on the color of the emitted light.
- The absolute maximum rated junction temperature must not be exceeded for any of the LEDs in the luminaire under any circumstances. Note that when the LEDs are mounted with a small pitch, the junction temperature of the LEDs mounted in the middle of the PCB tends to be higher than the other LEDs since heat will be concentrated in a small area.
- Each LED has its own current and temperature characteristics; the measured values of luminous flux/chromaticity may be different from the designed values when the LEDs are operated in luminaires.
- Depending on the design of the luminaire, the color of the light may not be uniform on the illuminated surface (i.e. the emitted colors from the LEDs are not mixed and there are different color patches on the illuminated surface). Perform sufficient verification to ensure that there are no issues with the chosen luminaire before use.

## 7. Summary

Nichia makes no guarantee that customers will see the same results for their chosen application described in this application note; sufficient verification must be done prior to use to ensure there are no issues for the chosen application.

## Disclaimer



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