Light Emitting Diode

Thermal Design Considerations for the Nichia NCSxE17A Discrete Color LEDs

Table of Contents

The Nichia part numbers NCSRE17A, NCSGE17A, NCSBE17A, NCSCE17A, NCSAE17A, NCSWE17A, and NCSxE17A 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.

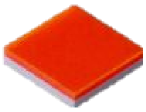
1. Overview

Thermal design is very important for LEDs since it determines the optical and electrical characteristics (e.g. luminous flux, forward voltage, etc.) of the LEDs and it even largely affects the reliability (lifetime) of the LEDs. When performing a thermal evaluation, customers must check how high the junction temperature of the LED will be when the LED is operated in the conditions/environments in which the LED will actually be used.
This application note provides cautions/suggestions for the thermal design of the chosen application using the Nichia NCSxE17A discrete color and white LEDs to ensure that the luminous flux required for the chosen application is obtained.

2. Applicable Part Numbers

This application note applies to the Nichia discrete color and white LEDs (hereinafter referred to as "NCSxE17A LEDs"). See Table 1 below.

Table 1. Applicable Part Numbers and Descriptions

Part Number	Emitted Color	Appearance[1]	Maximum Forward Currrent	Maximum Junction Temperature	Thermal Resistance (typ., max)[2]
NCSRE17A	Red (With Phosphor)		700mA	135°C	0.5°C/W, 1.0°C/W
NCSRE17A	Brilliant Red (With Phosphor)		700mA	135°C	0.5°C/W, 1.0°C/W
NCSGE17A	Green (With Phosphor)		550mA	135°C	0.5°C/W, 1.0°C/W
NCSGE17A	Lime (With Phosphor)		700mA	135°C	0.5°C/W, 1.0°C/W
NCSCE17A	Royal Blue (Without Phosphor)		700mA	135°C	0.5°C/W, 1.0°C/W
NCSBE17A	Blue (Without Phosphor)		700mA	135°C	0.8°C/W, 1.6°C/W
NCSAE17A	Amber (With Phosphor)		700mA	135°C	0.5°C/W, 1.0°C/W
NCSWE17A	White (With Phosphor)		700mA	135°C	0.5°C/W, 1.0°C/W

[1] Outline dimensions for all LEDs listed above (NCSxE17A LEDs): 1.7mm × 1.7mm
[2] The thermal resistance ($R_{\theta JC}$) represents the resistance value from the LED chip to the LED electrode.

Since the chip of the NCSBE17A LED has different characteristics from those of the other NCSxE17A LEDs, the thermal resistance is higher than the other LEDs.

3. Thermal Design

3.1 Thermal Resistance Model and Descriptions of the Terms

Figure 1 shows a cross-sectional view of a NCSxE17A LED mounted on an aluminum PCB with heat dissipation using a heatsink and Figure 2 shows a simplified thermal resistance model for these LEDs.

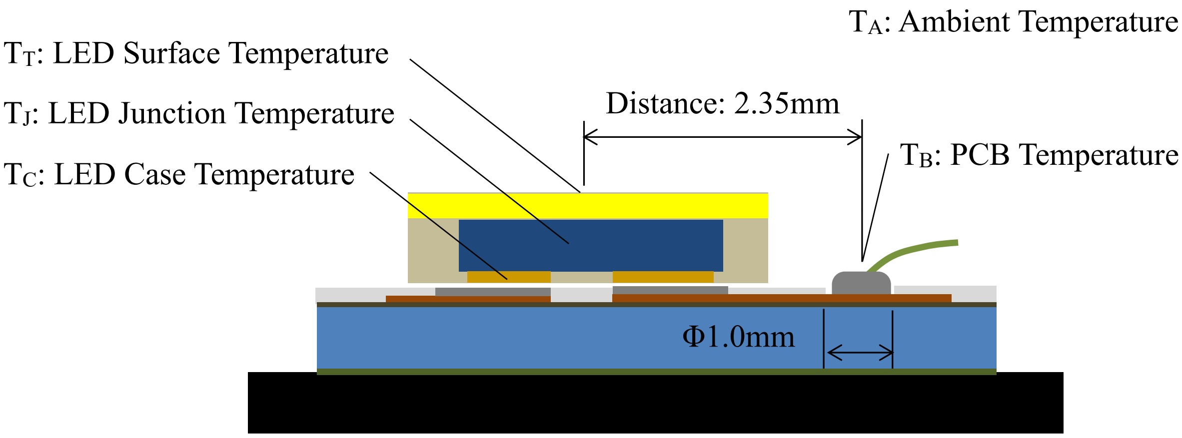


Figure 1. Cross-sectional View of a NCSxE17A LED

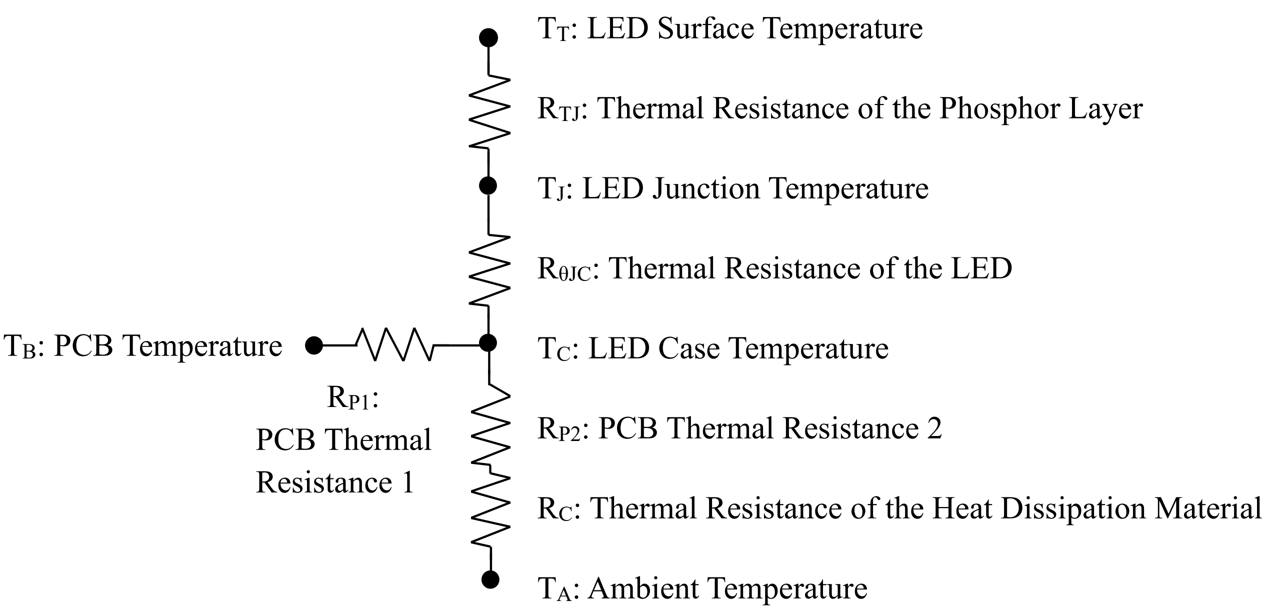


Figure 2. Simplified Thermal Resistance Model

Table 2. Terms, Descriptions, and Main Precautions

Term	Symbol	Description and Main Precautions
LED Surface Temperature	T_T	Temperature of the emitting surface of the LED. Nichia recommends that this temperature is 150°C or less.
LED Junction Temperature	T_J	Temperature of the LED chip. The maximum junction temperature of the NCSxE17A LEDs is 135°C. To achieve longer reliability, ensure that the LEDs are operated at a junction temperature of 100°C or less.
Thermal Resistance of the LED	$R_{\theta JC}$	Thermal resistance from the LED chip to the LED electrode of the LED. The $R_{\theta JC}$ is obtained according to the measurement/calculation methods detailed in JESD 51-1 standard. The maximum thermal resistance of the NCSxE17A LEDs is 1.6°C/W, which is very low.
LED Case Temperature	T_C	Temperature of the electrode of the LED. The T_C is used in a thermal simulation; it cannot be measured once the LED is soldered to the PCB.
PCB Temperature	T_B	PCB surface temperature near the side of the LED package. For the NCSxE17A LEDs, since it is difficult to measure the temperature at the soldered area directly, the measurement should be conducted at T_B point shown in Figure 1.
PCB Thermal Resistance 1	R_{P1}	Thermal resistance from the T_C point of the LED to the T_B measurement point on the PCB. The value of the R_{P1} varies depending on the soldering pad pattern for the LEDs, the copper area and heat dissipation performance of the aluminum PCB, heatsink, the operating temperature, etc.
Thermal Resistance of from the LED to the PCB	$R_{\theta JB}$	Thermal resistance from the LED chip to the T_B measurement point on the PCB. This thermal resistance value can be obtained by using the following equation: $R_{\theta JB} = R_{\theta JC} + R_{P1}$.
PCB Thermal Resistance 2	R_{P2}	Combined thermal resistance of an aluminum PCB in the vertical direction from the soldered area towards the heatsink. The thermal resistance of an aluminum PCB varies significantly depending on the properties of the insulating layer (thermal conductivity, thickness). Take this into consideration when selecting materials. The thermal resistance of an aluminum PCB can be obtained by using the following equation: Thermal resistance = Thickness of the insulating layer / (Thermal conductivity of the insulating layer × Its area)
Thermal Resistance of Thermal Dissipation Material	R_C	Combined thermal resistance of a thermal sheet, thermal grease, heatsink, etc.
Ambient Temperature	T_A	Ambient temperature of the LED assembled in the chosen application.

3.2 Materials for PCBs

Since the electrodes of the NCSxE17A LEDs are very small, the heat dissipation of the PCB used is important. When the chosen application requires a large electric power, Nichia recommends using an aluminum PCB with a high thermal conductivity instead of using a glass resin substrate (FR4), a glass composite substrate (CEM3), or an aluminum PCB with a low thermal conductivity. For reference, Figures 3 and 4 show the thermal simulations when an LED is mounted on aluminum PCBs with low and high thermal conductivity.

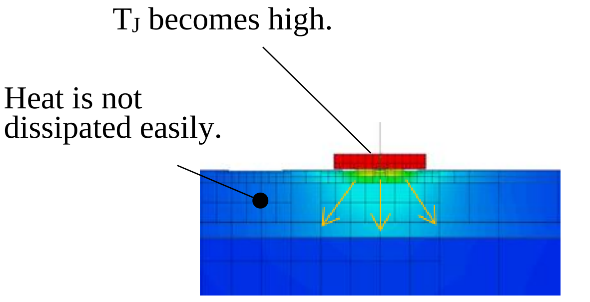


Figure 3. Aluminum PCB with a Low Thermal Conductivity

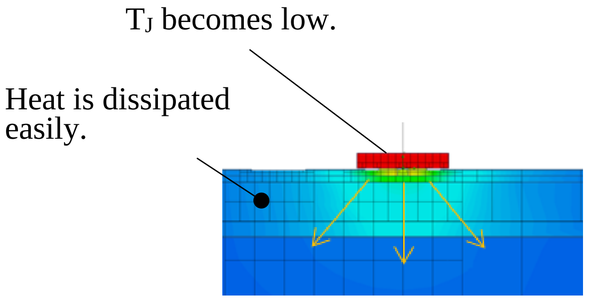


Figure 4. Aluminum PCB with a High Thermal Conductivity

When an LED is mounted on an aluminum PCB with a low thermal conductivity, the heat dissipation becomes insufficient, resulting in a high junction temperature, whereas when an LED is mounted on an aluminum PCB with a high thermal conductivity, the heat generated from the LED can dissipate efficiently, resulting in a low junction temperature.

3.3 Recommended Soldering Pad Pattern

Figure 5 shows the recommended soldering pad pattern for the NCSxE17A LEDs. There are two types of solder pad patterns: Solder Mask Defined (SMD) and Non-Solder Mask Defined (NSMD). Table 3 provides the comparison between SMD and NSMD. Select a soldering pad pattern that is appropriate for the chosen application.

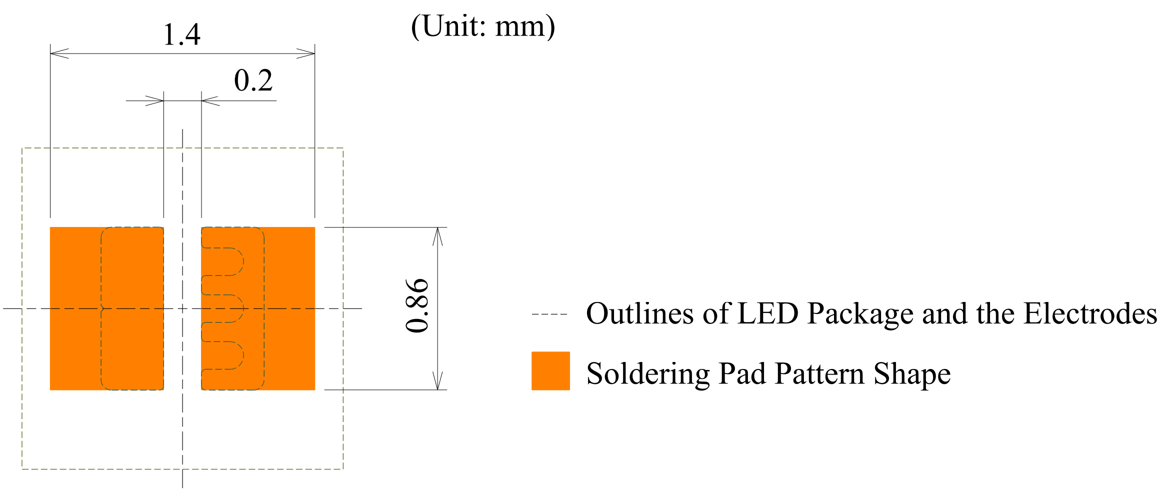
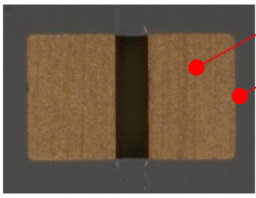
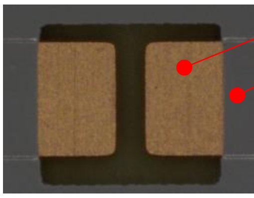


Figure 5. Recommended Soldering Pad Pattern

Table 3. Comparison between SMD and NSMD

Solder Pad Pattern	SMD	NSMD
Pattern Design Method	The shape and location of the soldering pad pattern are defined by the aperture and location of the solder resist.	The shape and location of the soldering pad pattern are defined by the shape and location of the copper layer, not by those of the solder resist.
Appearance	 Copper Layer Solder Resist	 Copper Layer Solder Resist
Placement Accuracy	If the coating accuracy of the solder resist is poor, the shape and location of the soldering pad pattern can differ from the intended design dimensions (it may have effects on the placement accuracy).	Even if the coating accuracy of the solder resist is poor, the shape and location of the soldering pad pattern will be the same as the intended design dimensions (it may have less of an effect on the placement accuracy).
Heat Dissipation Performance	Good heat dissipation performance due to a large copper layer area.	Limited heat dissipation performance due to a small copper layer area.
Intended Purpose	High heat dissipation performance	High density assembly

Nichia measured the thermal resistance values of the NCSxE17A LEDs using the following parameters: the thermal conductivity rate of the insulating layer of an aluminum PCB and the length of the soldering pad pattern. The evaluation results are shown in Section 4.

4. Thermal Resistance

Nichia measured the thermal resistance ($R_{\theta JB}$) of the NCSxE17A LEDs using the following parameters: the thermal conductivity rate of the insulating layer of an aluminum PCB and the length of the soldering pad pattern. The $R_{\theta JB}$ was obtained in accordance with the measurement method detailed in JESD 51-1 standard.

4.1 Evaluated LEDs

Table 4. Evaluated LEDs

Part Number	Emitted Color	Color Rank/ Color Rendering Index	Forward Current
NCSRE17A	Red	Rp	350mA, 700mA
NCSRE17A	Brilliant Red	R021	350mA, 700mA
NCSGE17A	Green	G013	350mA, 550mA
NCSGE17A	Lime	G014	350mA, 700mA
NCSCE17A	Royal Blue	V2	350mA, 700mA
NCSBE17A	Blue	W011	350mA, 700mA
NCSAE17A	Amber	Lea	350mA, 700mA
NCSWE17A	White	sm507, R70	350mA, 700mA

4.2 Specifications of the PCBs used for the Evaluations

Nichia used four different types of aluminum PCBs with insulating layers whose thermal conductivity ranged from 1.8/m·K to 5.7/m·K. The specifications of the PCBs are shown in Table 5.

Table 5. Specifications of the PCBs

Aluminum PCB[3]	Unit	NRA-ES1	NRA-E (3.0)	NRA-E (6.5)	NRA-H6
Thermal Conductivity Rate of the Insulating Layer[4]	W/m·K	1.8	2.7	4.5	5.7
Thickness of the Insulting Layer	µm	120	120	120	120
Thickness of the Copper Layer[5]	µm	35	35	35	35
Thickness of the Aluminum Layer	mm	1	1	1	1

[3] The aluminum PCBs are manufactured by NIPPON RIKA INDUSTRIES CORPORATION.

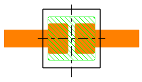
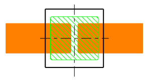
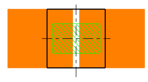
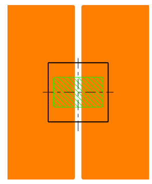
[4] The thermal conductivities of the insulating layers are the values stated in the aluminum PCB manufacture's data sheet, these are not guaranteed values.

[5] The thickness of the copper layer largely affects the heat dissipation performance. In the evaluations, the PCBs whose copper layer was a thickness of 35µm were used with consideration of the minimum clearance between the copper layers.

4.3 Length of the Soldering Pad Pattern

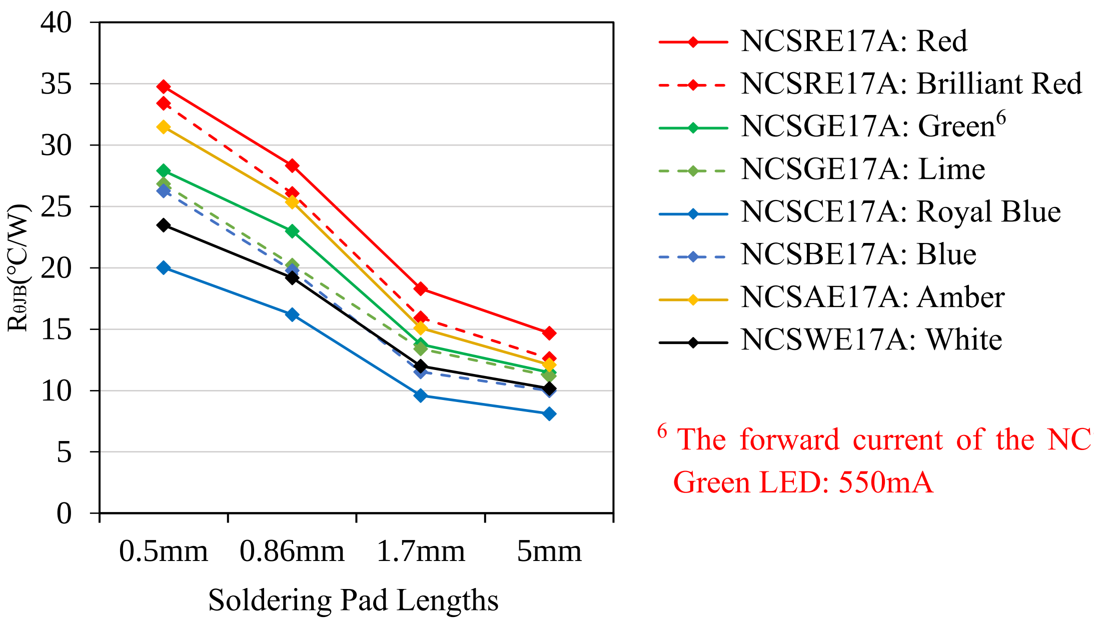
Nichia used PCBs with four different lengths: the minimum (0.5mm), the same as the electrode length (0.86mm), the same as the length of the LED package (1.7mm), and the maximum (5mm).

Table 6. Soldering Pad Lengths

Length of Soldering Pad Pattern	0.5mm	0.86mm	1.7mm	5mm
Solder Pad Pattern	NSMD	NSMD	SMD	SMD
Pattern Image				

4.4 Thermal Resistance Measurement Results

Figure 6 shows the thermal resistance ($R_{\theta JB}$) of the LEDs on aluminum PCBs (thermal conductivity of the insulating layer: 1.8W/m·K) at I_F=700mA[6] with different lengths for the soldering pad pattern.

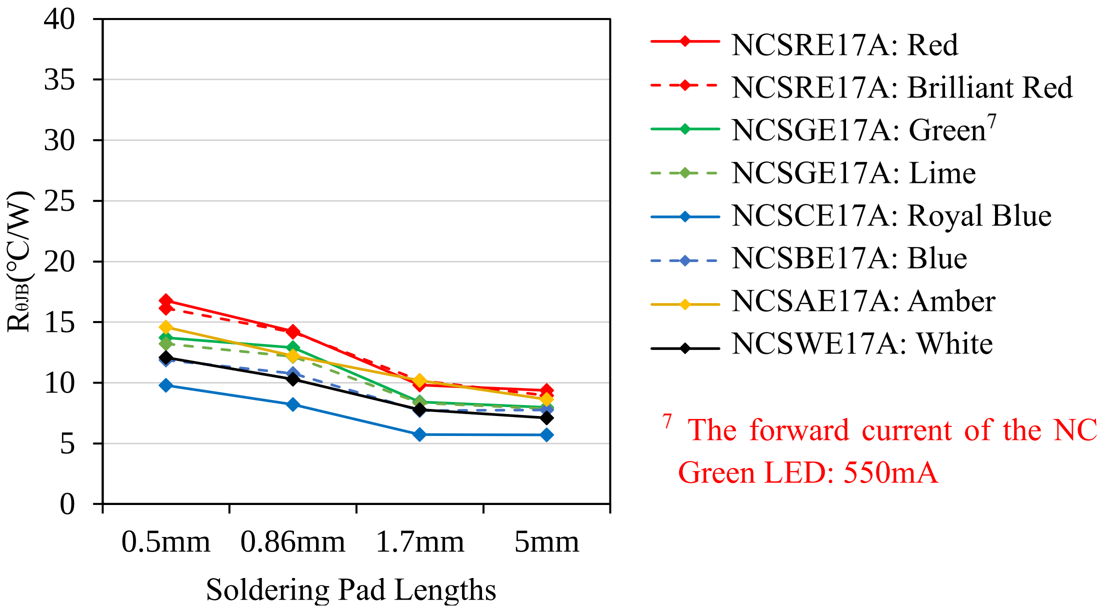


[6] The forward current of the NCSGE17A Green LED: 550mA

Figure 6. Thermal Resistance ($R_{\theta JB}$) of the NCSxE17A LEDs on Aluminum PCBs (Thermal Conductivity of the Insulating Layer: 1.8W/m·K) at I_F=700mA[6]

In this evaluation, the NCSRE17A LED (Red) showed the highest thermal resistance and the NCSCE17A LED (Royal Blue) showed the lowest thermal resistance.
As the soldering pad pattern area becomes larger, the thermal resistance of the LEDs tends to decrease; thus, it is important to design the soldering pad pattern area as large as possible when designing the PCB traces.

Figure 7 shows the thermal resistance ($R_{\theta JB}$) of the LEDs on aluminum PCBs (thermal conductivity of the insulating layer: 5.7W/ m·K) at I_F=700mA[7] with different lengths for the soldering pad pattern.



[7] The forward current of the NCSGE17A Green LED: 550mA

Figure 7. Thermal Resistance ($R_{\theta JB}$) of the NCSxE17A LEDs on Aluminum PCBs
(Thermal Conductivity of the Insulating Layer: 5.7W/m·K) at I_F=700mA[7]

When the thermal conductivity of the insulating layer used in the aluminum PCBs was changed from 1.8W/m·K to 5.7W/m·K, the thermal resistance of all the NCSxE17A LEDs decreased.
By comparing the thermal resistance values between Figures 6 and 7 at those different thermal conductivities (1.8W/m·K and 5.7W/m·K), the difference in the thermal resistance due to the different length of the soldering pad pattern with the thermal conductivity of 5.7W/m·K is smaller than that with the thermal conductivity of 1.8W/m·K. This indicates that PCBs with a high thermal conductivity are suitable to use when it is not possible to make the soldering pad pattern area larger.

Table 7 provides the evaluation results of thermal resistance ($R_{\theta JB}$) of the NCSxE17A LEDs under different parameters.

LEDs on the Aluminum PCBs with an Insulating Layer
whose Thermal Conductivity is 1.8W/m･K

Length of the Soldering Pad Pattern	0.5mm	0.86mm	1.7mm	5mm	0.5mm	0.86mm	1.7mm	5mm
Forward Current	350mA				700mA [8] The current applied to NCSGE17A Green LED is 550mA.			
NCSRE17A Red	29.4	24.1	15.3	11.8	34.8	28.3	18.3	14.7
NCSRE17A Brilliant Red	27.5	21.9	13.7	10.1	33.4	26.1	15.9	12.6
NCSCE17A Royal Blue	14.7	11.3	6.9	5.5	20.0	16.2	9.6	8.1
NCSBE17A Blue	22.9	17.0	10.0	9.2	26.3	19.8	11.5	10.0
NCSGE17A Green[8]	24.4	21.7	12.1	10.1	27.9	23.0	13.8	11.5
NCSGE17A Lime	24.0	18.6	12.7	10.7	26.9	20.2	13.4	11.2
NCSAE17A Amber	25.7	20.8	12.9	10.0	31.5	25.4	15.1	12.1
NCSWE17A White	20.2	17.1	10.1	8.9	23.5	19.2	12.0	10.2

LEDs on the Aluminum PCBs with an Insulating Layer
whose Thermal Conductivity is 2.7W/m･K

Length of the Soldering Pad Pattern	0.5mm	0.86mm	1.7mm	5mm	0.5mm	0.86mm	1.7mm	5mm
Forward Current	350mA				700mA [9] The current applied to NCSGE17A Green LED is 550mA.			
NCSRE17A Red	26.0	20.5	13.4	10.8	29.1	23.8	15.3	12.4
NCSRE17A Brilliant Red	23.8	19.9	12.1	10.3	28.0	23.0	14.5	12.3
NCSCE17A Royal Blue	11.5	10.0	8.0	5.7	15.6	13.2	9.1	6.7
NCSBE17A Blue	19.6	15.8	8.9	8.4	19.5	16.9	10.1	9.6
NCSGE17A Green[9]	22.3	18.4	12.0	9.6	24.8	20.8	12.9	10.6
NCSGE17A Lime	19.6	16.6	11.1	9.4	22.4	18.3	12.2	10.2
NCSAE17A Amber	24.4	19.6	11.7	10.8	26.8	22.0	13.4	11.4
NCSWE17A White	19.3	16.3	10.1	8.9	21.5	17.8	11.3	9.3

LEDs on the Aluminum PCBs with an Insulating Layer
whose Thermal Conductivity is 4.5W/m・K

Length of the Soldering Pad Pattern	0.5mm	0.86mm	1.7mm	5mm	0.5mm	0.86mm	1.7mm	5mm
Forward Current	350mA				700mA [10] The current applied to NCSGE17A Green LED is 550mA.			
NCSRE17A Red	17.5	15.7	9.6	9.0	19.2	17.6	11.2	10.3
NCSRE17A Brilliant Red	17.2	15.1	9.1	8.3	20.5	17.9	10.6	10.0
NCSCE17A Royal Blue	8.4	7.8	4.7	3.9	11.0	10.4	6.4	5.7
NCSBE17A Blue	16.1	13.2	8.7	7.9	15.7	13.5	9.0	8.1
NCSGE17A Green[10]	15.0	13.1	8.8	8.3	17.2	15.6	10.0	9.0
NCSGE17A Lime	14.8	13.3	8.8	7.6	16.6	14.6	9.7	8.8
NCSAE17A Amber	15.5	13.9	8.9	8.0	18.3	16.3	10.6	9.8
NCSWE17A White	14.2	11.7	8.0	6.3	15.1	13.3	8.9	8.6

LEDs on the Aluminum PCBs with an Insulating Layer
whose Thermal Conductivity is 5.7W/m・K

Length of the Soldering Pad Pattern	0.5mm	0.86mm	1.7mm	5mm	0.5mm	0.86mm	1.7mm	5mm
Forward Current	350mA				700mA [11] The current applied to NCSGE17A Green LED is 550mA.			
NCSRE17A Red	15.1	13.2	8.3	7.7	16.8	14.2	9.8	9.4
NCSRE17A Brilliant Red	13.5	11.8	8.3	7.3	16.1	14.2	10.2	8.9
NCSCE17A Royal Blue	7.4	6.5	4.7	4.8	9.8	8.2	5.7	5.7
NCSBE17A Blue	10.1	8.9	6.7	7.0	11.9	10.8	7.7	7.8
NCSGE17A Green[11]	12.5	11.6	7.5	6.3	13.7	12.9	8.4	8.0
NCSGE17A Lime	11.6	10.1	7.2	6.9	13.2	12.2	8.3	7.9
NCSAE17A Amber	13.4	10.9	8.4	6.7	14.6	12.2	10.2	8.6
NCSWE17A White	10.3	9.0	7.0	6.1	12.1	10.3	7.8	7.1

Light Emitting Diode

5. LED Junction Temperature

5.1 How to Calculate the LED Junction Temperature

The junction temperature of the NCSxE17A LEDs is obtained by using Equation 1 below:

$$\boxed{\text{Equation 1: } T_J = T_B + R_{\theta JB} \times W}$$

T_J: LED Junction Temperature (°C)
T_B: PCB Temperature (°C)
$R_{\theta JB}$: Thermal resistance from the LED chip to the T_B measurement point (°C/W)
W: Input Power ($I_F \times V_F$) (W)
I_F=Forward Current (A), V_F=Forward Voltage (V)

As explained in Section 4, the thermal resistance ($R_{\theta JB}$) varies significantly depending on the specifications of the aluminum PCB on which the LED is mounted.
For the thermal resistances required for calculating the approximate LED junction temperatures, refer to Table 7 in Section 4.

Note that the thermal resistance values detailed in this application note are ones obtained under Nichia's evaluation conditions and these values can differ depending on the other components used in the chosen application, the operating condition, and the environment where the chosen application is used.

If customers need help checking the thermal resistance of the LED on the PCB and the junction temperature of the LED once it has been assembled in the chosen application, contact a local Nichia sales representative.

5.2 LED Maximum Junction Temperature

The maximum junction temperature of the NCSxE17A LEDs is 135°C. To achieve longer reliability (to avoid a decrease in the luminous flux and significant color shift), ensure that the LED is operated at a junction temperature of 100°C or less.
When the LED case temperature is high, a decrease in the bonding strength and solder cracks are more likely to occur.
For reference, a "LED Case Temperature vs. Allowable Forward Current" graph provided in the "DERATING CHARACTERISTICS" section of the specifications for a NCSxE17A LED is shown in Figure 8. In Nichia's specifications, the maximum case temperature is set as 100°C.

The junction temperature of the NCSRE17A LED shown in Figure 8 is obtained by using Equation 2 below:

$$\text{Equation 2: } T_J = T_C + R_{\theta JC} \times W$$

T_J: LED Junction Temperature (°C)
T_C: Case Temperature (°C)
$R_{\theta JC}$: Thermal resistance from the LED chip to the T_C point (°C/W)
W: Input power [$I_F \times V_F$] (W)

When the case temperature of the NCSRE17A LED is 100°C, the LED junction temperature is approx. 102.1 °C.

$$100°C + 1.0°C/W \times (0.7A \times 3V) = 102.1°C$$

Example of NCSRE17A Red LED

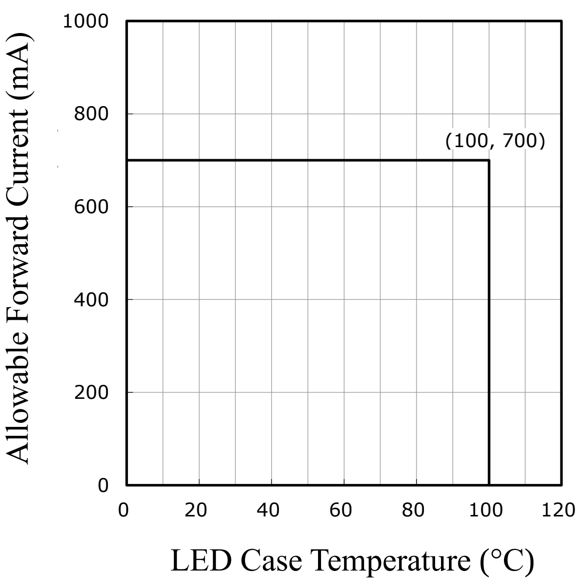


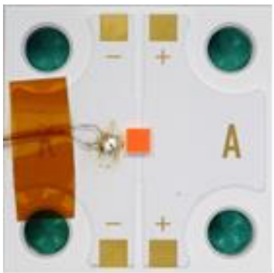
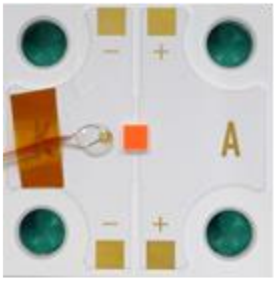
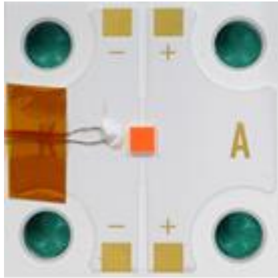
Figure 8. LED Case Temperature vs. Allowable Forward Current

5.3 PCB Temperature (T_B) Measurement

The appropriate sensor position for a thermocouple is as close as possible to the LED on the PCB. Nichia recommends placing the temperature measurement point (diameter: 1.0mm) 2.35mm from the center of the LED. Nichia also recommends attaching the thermocouple to the PCB by soldering in a standard manner; however, when the PCB has an excellent heat dissipation performance, the solder cannot melt which makes it difficult to attach the thermocouple by using solder.

In some cases, soldering the thermocouple is not possible for some light fixtures; for these cases, the thermocouple should be attached by another method. Note that measurement errors occur with any thermocouple attachment method; sufficient evaluations must be done prior to use.
Table 8 provides examples of how thermocouples are attached to the PCBs for reference.

Table 8. Examples of How Thermocouples are Attached to PCBs

Attachment Method	Soldering (Recommended)	Using Adhesive	Using Silicone Curing Agent
Appearance			
Material Name	Thread Solder: M705	Cemedine Super X2	Thermal Silicone
Composition	Sn-3.0Ag-0.5Cu	Acrylic-modified silicone polymer	SVC-22
Manufacturer	Senju Metal Industry Co., Ltd.	CEMEDINE Co., Ltd.	Sunhayato Corporation
Precaution	Avoid applying solder flux to the emitting surface of the LED. (Adhesion to the emitting surface may increase the LED junction temperature.)	Apply the appropriate amount of the adhesive. (An excess amount of adhesive may affect the amount of light emitted from the LED, leading to large measurement errors from the thermocouple.)	Apply the appropriate amount of the silicone curing agent. (An excess amount of silicone curing agent may affect the amount of light emitted from the LED and the heat dissipation performance, leading to large measurement errors from the thermocouple.)

6. Thermal Evaluations

Infrared thermography is an effective method to evaluate the temperatures of an LED-mounted PCB. The LED junction temperature cannot be measured by infrared thermography; however, the LED surface temperature and the temperature distribution over the entire surface of the PBC can be obtained by infrared thermography.

6.1 Examples of Thermal Evaluations of LED-mounted PCBs

Tables 9 and 10 show examples of the thermal evaluations for the four LEDs (Part No. NCSRE17A, NCSGE17A, NCSCE17A, and NCSWE17A) arranged in a square on the PCB. In these evaluations, comparisons were made between LED-mounted PCBs with different PCB trace widths.

Table 9. Specifications of an LED-mounted PCB (NSMD)

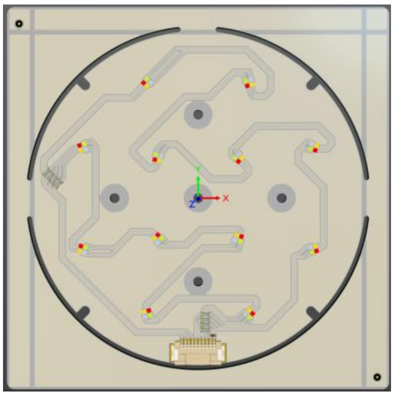
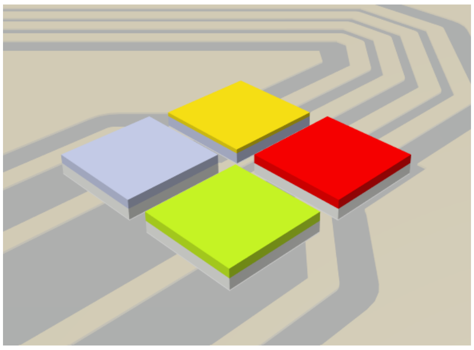
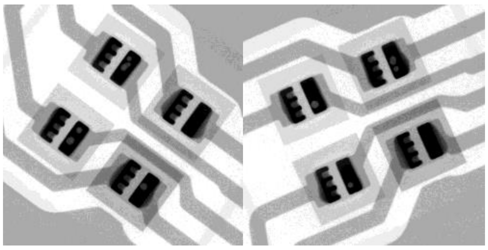
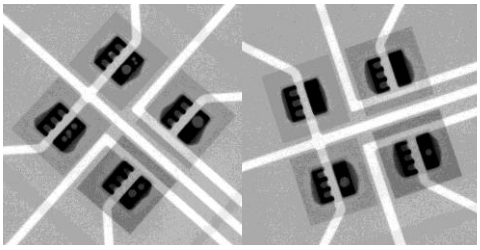
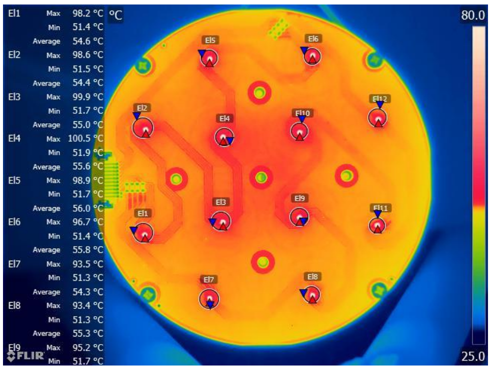
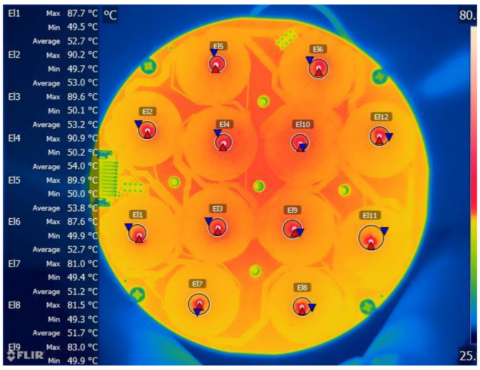
LED-mounted PCB	LED Placement Configuration
	 Clearance between LEDs: 0.4mm
Outline of the Aluminum PCB: - Diameter: 140mm - Thickness: 1.0mm	12 NCSRE17A LEDs and 12 NCSGE17A LEDs
Insulating Layer: - Thermal Conductivity: 2.1W/m･K - Thickness: 120µm	12 NCSCE17A LEDs and 12 NCSWE17A LEDs
Copper Layer: - Thickness: 35µm	Circuit Configuration: 4 circuits (2 arrays connected in parallel, each with 6 LEDs connected in series)

Table 10. Thermal Evaluation Results of the LED-mounted PCBs

PCB Trace Width	0.4mm and 0.5mm (NSMD)	1.7mm (SMD)
X-ray Image of the Circuit Pattern		
Temperature Measurement by Thermography Measurement Conditions: Emissivity: 0.95 Reflection Temperature: 20°C		
Operated LEDs	NCSRE17A LEDs (discrete color)	NCSRE17A LEDs (discrete color)
Forward Current	350mA per LED	350mA per LED
LED Surface Temperature	96.3°C (Average)	85.6°C (Average)
Evaluation Result	The surface temperature of the LEDs on the NSMD pads is higher than that on the SMD pads. The temperauture of the PCB traces connected between the LEDs is high.	The surface temperature of the LEDs on the SMD pads is lower than on the NSMD pads by 10.6°C.

6.2 LED Surface Temperature

Since the NCSRE17A, NCSGE17A, NCSAE17A, and NCSWE17A LEDs have a phosphor layer above the LED chip, the LED surface temperature tends to be higher than the LED junction temperature. Most of the heat is generated in the LED junction area; however, heat is also generated in the phosphor layer due to the Stokes' loss in the wavelength conversion. The phosphor layer of these LEDs is very thin and is located far from the heat dissipation path of the LED chip, leading to the poor heat dissipation. Refer to Figure 9 for a schematic diagram of how the heat generated flows within these LEDs.

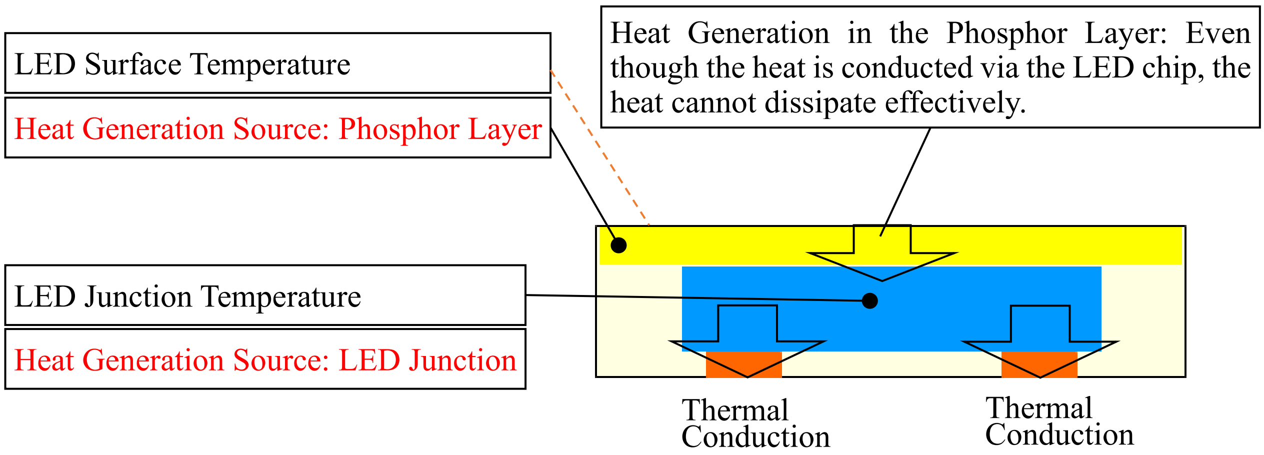


Figure 9. Heat Generation in the NCSRE17A, NCSGE17A, NCSAE17, and NCSWE17A LEDs

On the other hand, since the NCSCE17A and NCSBE17A LEDs do not have phosphor layers, the temperature difference between the LED surface and the LED junction is not large. Refer to Figure 10 for a schematic diagram of how the heat generated flows within those LEDs.

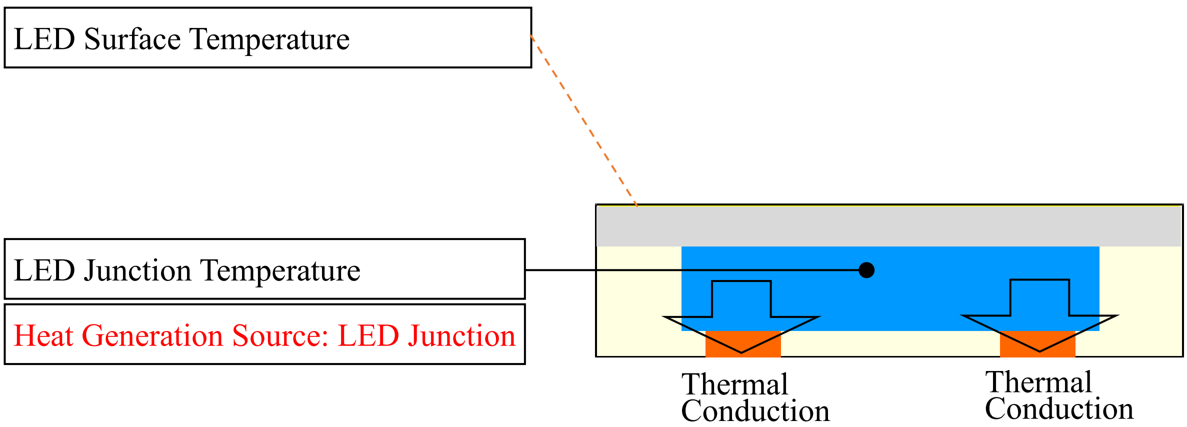


Figure 10. Heat Generation in the NCSCE17A and NCSBE17A LEDs

Figure 11 shows the temperature difference between the LED surface and the LED junction at different forward currents.

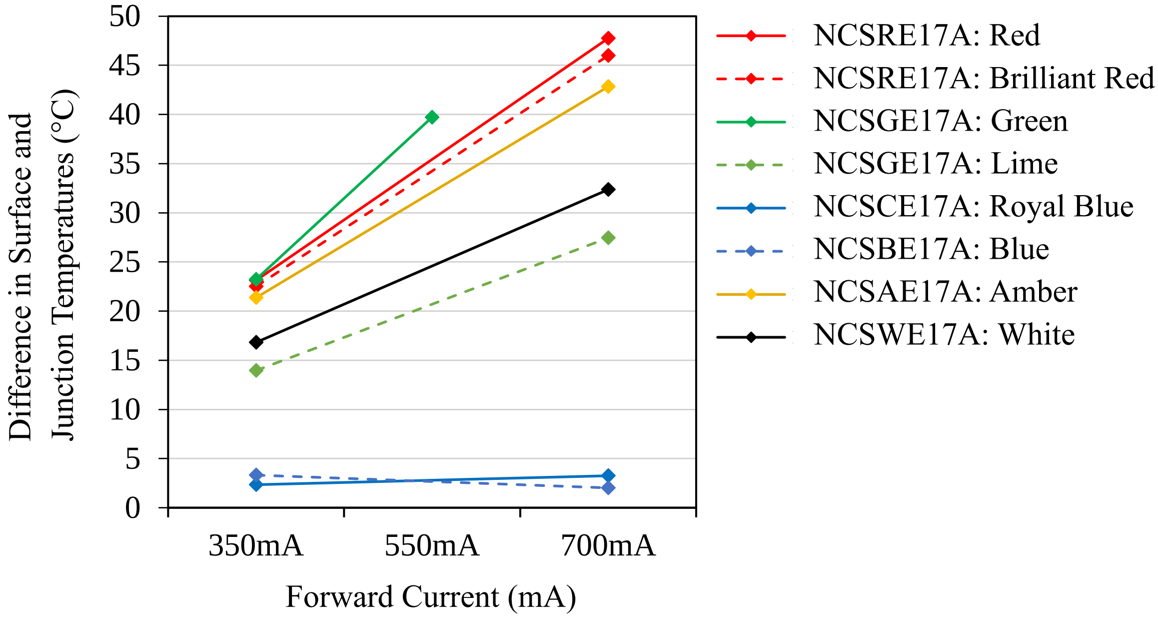


Figure 11. Relationship between the LED Surface and Junction Temperature Differences

For the NCSRE17A, NCSGE17A, NCSAE17A, and NCSWE17A LEDs that have the phosphor layer, the temperature difference between LED surface and the LED junction tends to become larger as the forward current increases.
Whereas for the NCSCE17A and NCSBE17A LEDs that do not have the phosphor layer, the temperature difference between LED surface and the LED junction is not large even when the forward current increases.

Note that the temperature difference between the LED surface and the LED junction shown in Figure 11 is an evaluation result of the LEDs without optical components (e.g. lens or reflector). The surface temperature of the LED assembled in a chosen application may increase due to other factors. The chosen application must be designed with sufficient margins to ensure the heat is dissipated properly.

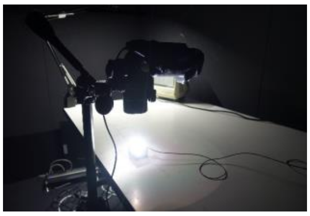
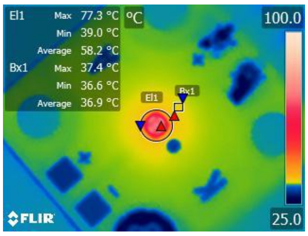
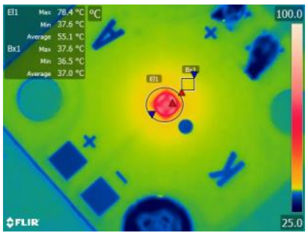
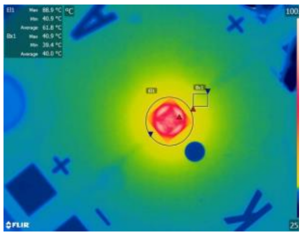
6.3 Precautions for Thermography Measurement

Infrared thermography measurements will contain errors due to the measurement equipment, measurement conditions, measurement environment, etc. When using measurement values obtained through infrared thermography for the thermal design, the chosen application must be designed with sufficient margins to ensure the heat is dissipated properly.

When using a close-up lens in the infrared thermography measurement, ensure that there is sufficient distance between the close-up lens and the LED-mounted PCB. When performing thermal measurements for LEDs with high light output, the measurement errors may be large due to effects of the light emitted from the LED (see Table 11).

Nichia recommends that the LED surface temperature is 150°C or less. When the LED surface temperature is high, it indicates that the LED has been operated under significant severe conditions; ensure that the PCB used, the shape of the soldering pad pattern, the performance of the heatsink, and the value of the forward current are appropriate for the chosen application.
Note that the LED surface temperature becomes even higher than the LED junction temperature during operation. When using optical components (e.g. lens or reflector) with a low heat resistance temperature, ensure that the appropriate clearance is provided between the optical component and the LED and that the heat resistance temperature of the optical component used must not be exceeded.

Table 11. Evaluation Results at I_F=700mA (NCSWE17A LEDs)

Lens Type	Standard Lens	Close-up Lens 1	Close-up Lens 2
Measurement Environment			
Measurement Distance	220mm	100mm	50mm
Magnification	2.0	1.4	1.0
Thermography Image			
LED Surface Temperature	77.3°C	78.4°C	88.9°C
PCB Temperature	37.4°C	37.6°C	40.9°C
Note	-	-	The LED surface temperatures and the PCB temperature increased due to reflected light (radiant heat).

7. Summary

This application note explains important information and precautions for the thermal design of the NCSxE17A LEDs. Select suitable PCB materials and thermal management materials for these LEDs and perform sufficient thermal evaluations prior to use to ensure there are no issues for the chosen application.

Disclaimer

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