Light Emitting Diode

How to Calculate the Junction Temperature for the Nichia 121, 131, or 170 Series LEDs

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The “Nichia 121, 131, or 170” collectively refers to Nichia part numbers listed in the table in Section 2 Applicable Part Numbers. These Nichia part numbers 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

When designing applications using LEDs, it is necessary to consider the heat generated from the LEDs during operation. The junction temperature (T_J) of the LED is an important aspect to be considered in selecting the operating conditions of the application. If the absolute maximum rating T_J is exceeded even for a short period of time, it may cause an adverse effect on the performance of the LED; in the worst case, it could cause the LED not to illuminate. Note that the LED must be operated to ensure that the absolute maximum rating T_J is not exceeded. To prevent the T_J from exceeding the absolute maximum rating T_J, it is necessary to know how high the T_J will be when the LED is operated in the conditions/environments in which the LED will actually be used.
This application note provides how to estimate the T_J by measuring the temperature at the measurement point Nichia specifies with a thermocouple.

2. Applicable Part Numbers

This application note applies to the LEDs listed in Table 1.

Table 1. Applicable Part Numbers

Series Name	Nichia 121 Series				Nichia 131 / 170 Series[1]		
Part Number[2]	NC2W121x	NC3W121x	NC4W121x	NC5W121x	NCSx131x NCSx170x	NC2x131x NC2x170x	NJSx170x
Example Appearance							
Outline Dimensions (mm)	3.1×2.6 ×0.75	3.1×3.75 ×0.75	3.1×4.9 ×0.75	3.1×6.05 ×0.75	1.8×1.45 ×0.75	3.0×1.6 ×0.75	1.6×1.2 ×0.75

[1] The electrode pattern on the back of the package for the Nichia 131 Series and Nichia 170 Series is different.

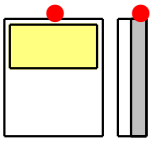
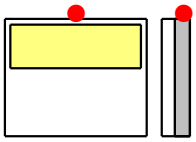
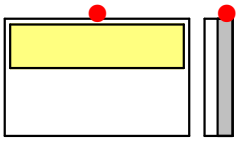
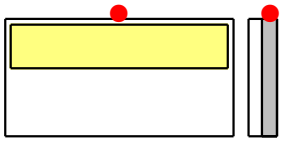
[2] The x represents a letter that follows the alphanumeric code of the same LED type.
(e.g.: NCSx170x → NCSW170D, NCSW170F, NCSY170F, NCSA170G, NCSW170G, NCSW170G-SA, etc.)

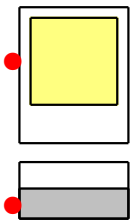
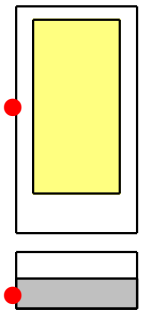
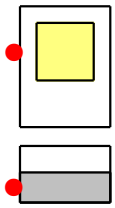
3. T_{MP} Measurement

The T_J estimation can be calculated by measuring the temperature of the LED (T_{MP}) at the measurement point Nichia specifies once the LED has been attached to a PCB. The measuring current should be the maximum operating current (I_F) that will be applied to the LED under the conditions in which the LED will actually be used. See Table 2 for the T_{MP} measurement point.

Table 2. T_{MP} Measurement Point

● : T_{MP} Measurement Point

Part Number	NC2W121x	NC3W121x	NC4W121x	NC5W121x
T_{MP} Measurement Point				

Part Number	NCSx131x / NCSx170x	NC2x131x / NC2x170x	NJSx170x
T_{MP} Measurement Point			

To measure the T_{MP}, securely attach the temperature sensing part on the tip of the thermocouple to the side of the ceramic substrate of the LED with adhesive as shown in Figure 1.

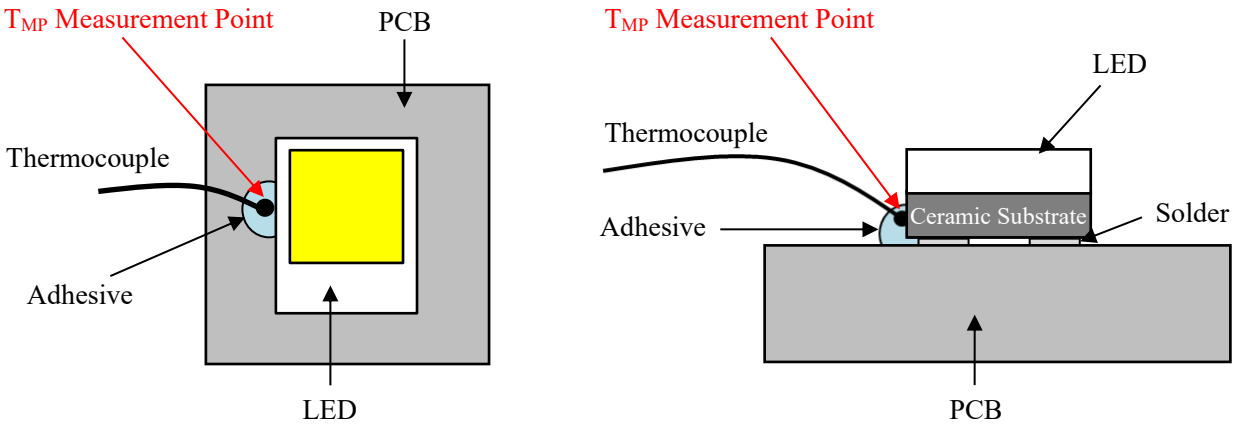


Figure 1. How to Measure the T_{MP}

4. How to Calculate the Junction Temperature (T_J)

When the product using the LED is operated, the T_J can be calculated with Equation 1 below.

Equation 1: $\mathbf{T_J = T_{MP} + R_{\theta JMP} \times W}$

T_J: Junction Temperature (˚C)
T_{MP}: Measurement Point Temperature (˚C)
$R_{\theta JMP}$: Thermal Resistance from the Chip to the T_{MP} Measurement Point (˚C/W)
W: Input Power ($I_F \times V_F$) (W)
I_F=Forward Current (A), V_F=Forward Voltage (V)

The $R_{\theta JMP}$ value may be different depending on the part number. For the $R_{\theta JMP}$ value of each part number, refer to the annex: Thermal Resistance Values of the Nichia 121, 131, or 170 Series LEDs. For the LEDs whose $R_{\theta JMP}$ values are not listed in this annex, contact a local Nichia sales representative.

5. Calculation Example of the Junction Temperature (T_J)

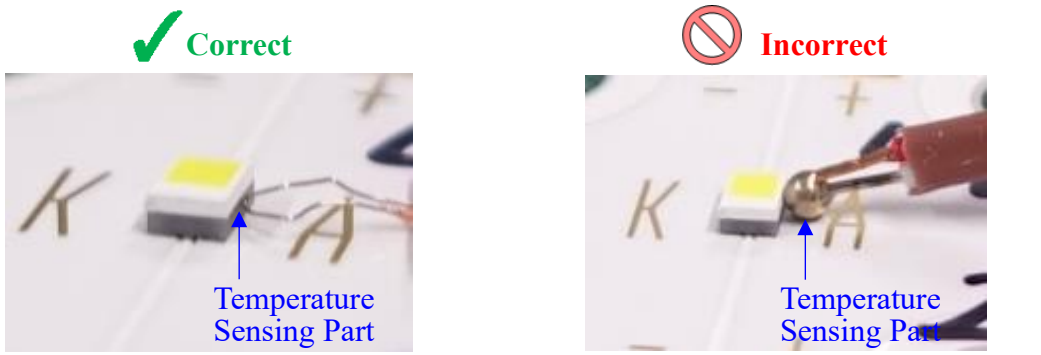
This section provides an example of the T_J calculation using the measured T_{MP}.

Example: The NCSW170F LED is operated at an input power of 3.2W.
The measured T_{MP} is 50˚C.

The $R_{\theta JMP}$ value of the NCSW170F LED is 4.8˚C/W (refer to the annex: Thermal Resistance Values of the Nichia 121, 131, or 170 Series LEDs).
Using Equation 1 ($T_J = T_{MP} + R_{\theta JMP} \times W$), the following calculation is obtained:
$T_J = 50(˚C) + 4.8(˚C/W) \times 3.2(W) = \underline{65.4(˚C)}$

6. Considerations and Suggestions when Using a Thermocouple

It is recommended to use a thermocouple with wires that are as thin as possible. If the wires are too thick, they may create thermal paths causing measurement errors.
If the temperature sensing part on the tip of the thermocouple is too large, the temperature sensing part may not be properly attached to the T_{MP} measurement point on the ceramic substrate of the LED as shown in Figure 2; if the temperature sensing part does not properly contact the ceramic substrate and/or is in contact with another component other than the ceramic substrate, it may affect the measurement accuracy.



The wires are thin.
The temperature sensing part contacts the T_{MP} measurement point.

The wires are thick.
The temperature sensing part is too large.

Figure 2. Examples of Correct/Incorrect Thermocouples
(Before adhesive is applied)

The temperature sensing part of a thermocouple is at the base of the bonding/contacting area of the wires. Figure 3 (b) shows a thermocouple twisted near the base. With this type of thermocouple, perform the temperature measurement at the base of the twisted part, not at the tip of the thermocouple. With a thermocouple whose temperature sensing part is not at the tip, the T_{MP} measurement may be lower than the actual T_{MP} even when the tip is in contact with the T_{MP} measurement point; ensure that the temperature sensing part is attached to contact the T_{MP} measurement point.

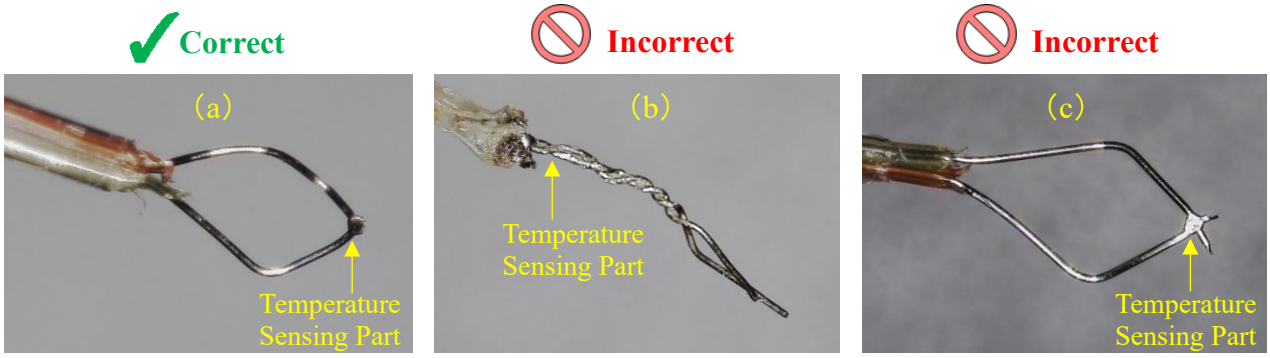


Figure 3. Temperature Sensing Part of Thermocouples

Do not apply an excess amount of adhesive when attaching the thermocouple to the LED; if adhesive adheres to the emitting surface of the LED, it may affect the measurement accuracy.

7. T_{MP} Measurement Considerations

Even under the same operating conditions, the T_J of the LED may vary depending on the heat dissipation conditions around the LED. The T_{MP} should be measured once the saturation temperature at the junction has been reached while ensuring that the LED is incorporated in the chosen application at the finished product level and in a manner that takes into consideration the conditions/environments in which the LED will actually be used, oriented the way it will actually be used, and the LED is operated at the maximum possible ambient temperature after aging.
Taking into consideration the possibility of measurement variations it is recommended that the evaluation is performed with more than one LED. The more measurements that are used in the evaluation, the easier it will be to judge the accuracy of the T_{MP} measurement.

8. Summary

In this application note, Nichia has provided how to calculate the estimated value of the T_J for the LED mounted on a PCB using the thermal resistance $R_{\theta JMP}$ and the measured T_{MP}. To estimate the T_J more accurately, perform the evaluation as per the precautions/suggestions provided herein regarding how to attach the thermocouple to the ceramic substrate of the LED and the T_{MP} measurement conditions/environments.
Additionally, ensure that the chosen design has a sufficient margin to not exceed the absolute maximum rating T_J by taking into consideration the heat dissipating conditions (i.e. the material, design, etc. of the components used with the LED, mounting conditions of the LED, etc.) and the variation of the heat dissipation performance of each individual component.

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