Light Emitting Diode

# Thermal Design - Selecting an Appropriate Heatsink for the COB-Z Series LEDs

Table of contents



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## 1. Overview

In recent years, many luminaire designers have started to use COB LEDs in their applications and COB LED-based luminaires have become available on the market. When designing a COB LED-based luminaire, one of the key requirements is to understand the thermal management of COB LEDs.

COB LEDs can produce high-power outputs and are designed to have multiple LED die assembled close to each other in a single COB LED, causing heat to concentrate in a narrow area. If COB LEDs become excessively hot during operation, it will cause the luminous flux to decrease (i.e. temperature characteristics of COB LEDs) and/or shorten the lifetime. To avoid the performance/reliability degradation, proper thermal management of COB LEDs will be required, especially for the heatsink as it will play the primary role in dissipating the heat of the COB LED.

Nichia performed evaluations of heatsinks with an emphasis on the relationship between the volume of a heatsink and the heat dissipation performance of the heatsink (i.e. junction temperature of the COB LED). This application note provides information and data from the evaluations to select an appropriate heatsink for the COB-Z series LEDs.

## 2. Evaluation Objectives

The evaluations were performed to determine:
1. the change in the junction temperature ($T_J$) depending on the volume of the heatsink when the COB LEDs were operated in a constant current mode,
2. the heatsink volume required to ensure that the absolute maximum junction temperature ($T_{JMax}$) is not exceeded.

## 3. Evaluation Method

A COB LED was secured to an evaluation heatsink via COB LED holders and screws. Then, the assembly was installed in an enclosure[1] with no ventilation and operated at the sorting/absolute maximum current of the COB LED (i.e. the constant current). Once the saturation temperature at the junction had been reached, the temperature at the $T_C$ measurement point (i.e. $T_C$) was measured to calculate the $T_J$. For the part numbers and specifications of the evaluated COB LEDs, refer to Table 1 below. For the evaluation environment and the specifications of the assembly components except for the COB LEDs, refer to Figure 1 below. For the position of the $T_C$ measurement point, refer to Figure 2 below.

Note:
1 Enclosure size (mm): L=350 x W=350 x H=350

Table 1. Specifications of the evaluated COB LEDs

| Part Number | $I_F$ [mA] | | $V_F$ [V] | $T_{Jmax}$ [°C] |
|---|---|---|---|---|
| | Sorting Current | Max. Rating Current | Typ. | |
| NJCxS024Z | 500 | 1000 | 35.8 | 150 |
| NVCxL024Z | 1200 | 2200 | 35.4 | |
| NVExJ048Z | 1800 | 3300 | 47.2 | |

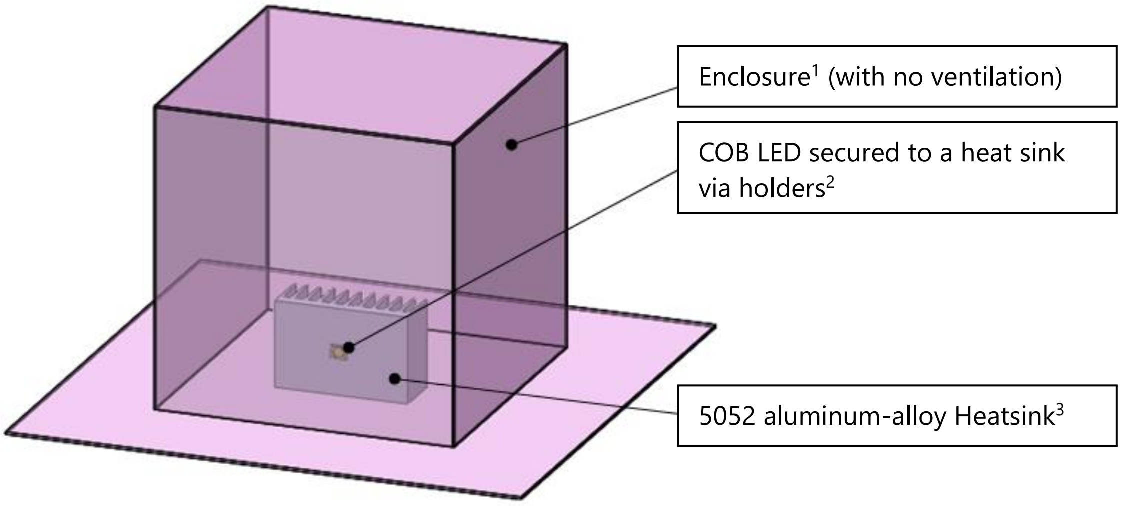



Figure 1. Evaluation environment

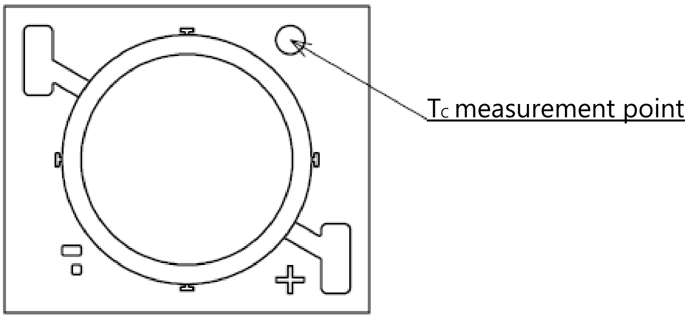



Figure 2. Position of the $T_C$ measurement point

Note:

[2] Thermal grease was used between the COB LED and the heatsink.

[3] Different volumes of heatsinks were used

Light Emitting Diode

# 4. Evaluation Results

## 4.1 The NJCxS024Z COB LEDs

4.1.1 Change in the $T_J$ depending on the volume of the heatsink

Refer to Figure 3 for the change in the $T_J$ vs. the volume of the heatsink when operated at:

- IF = 500mA (i.e. the sorting current), which is equivalent to 17W
- IF = 1000mA (i.e. the absolute maximum rating current), which is equivalent to 36W

4.1.2 Minimum volume to ensure that the $T_{JMax}$ is not exceeded

If the COB LEDs are operated at IF = 1000mA, a heatsink with a volume more than 50cm$^3$ is required to ensure that $T_J$ does not exceed 150°C (i.e. $T_{JMax}$).

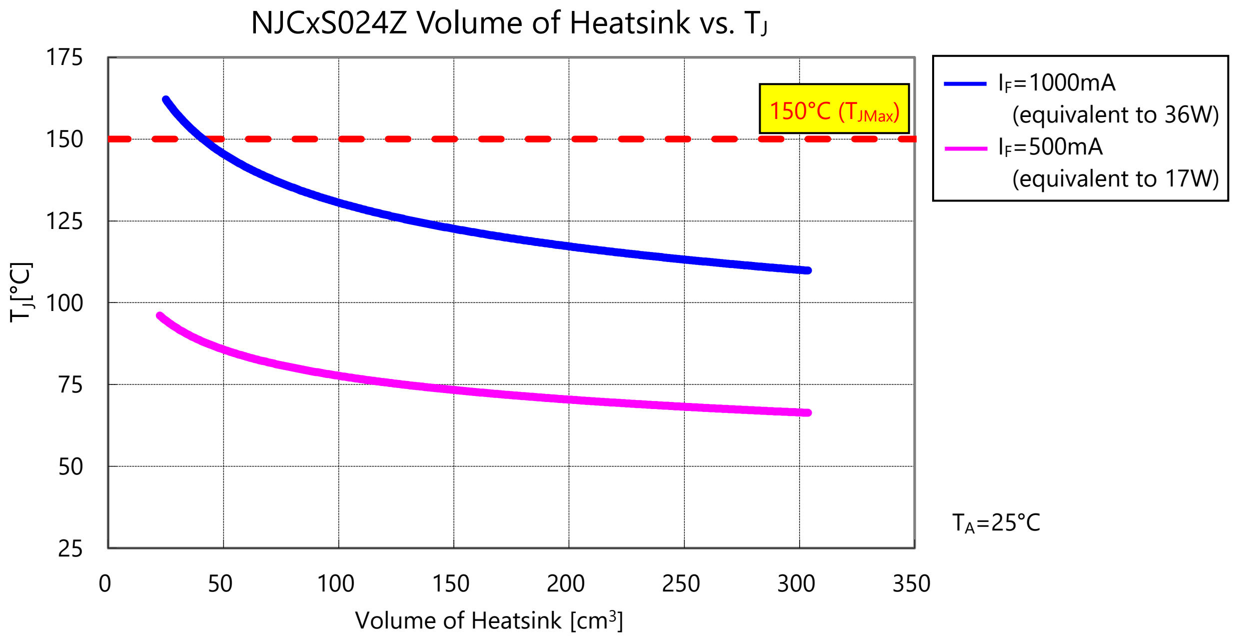



Figure 3. Evaluation Result for the NJCxS024Z COB LEDs

## 4.2 The NVCxL024Z COB LEDs

4.2.1 Change in the $T_J$ depending on the volume of the heatsink

Refer to Figure 4 for the change in the $T_J$ vs. the volume of the heatsink when operated at:
- $I_F$ = 1200mA (i.e. the sorting current), which is equivalent to 41W
- $I_F$ = 2200mA (i.e. the absolute maximum rating current), which is equivalent to 75W

4.2.2 Minimum volume to ensure that the $T_{JMax}$ is not exceeded

If the COB LEDs are operated at $I_F$ = 2200mA, a heatsink with a volume more than 1100cm$^3$ is required to ensure that $T_J$ does not exceed 150°C (i.e. $T_{JMax}$).

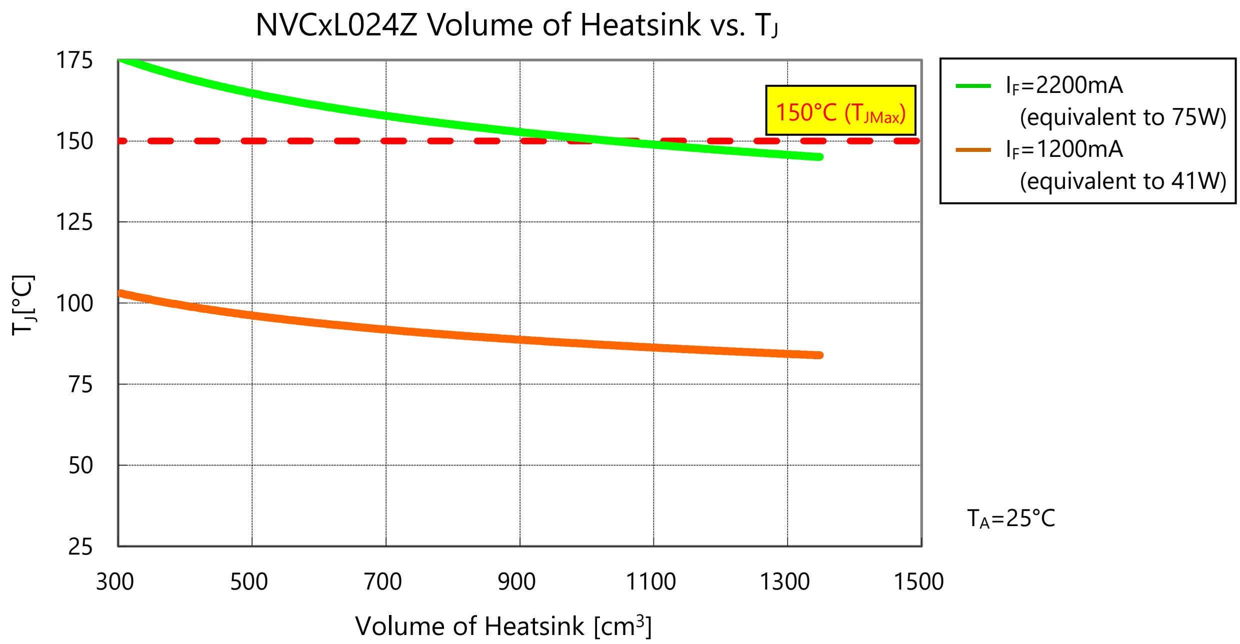



Figure 4. Evaluation Result for the NVCxL024Z COB LEDs

## 4.3 The NVExJ048Z COB LEDs

### 4.3.1 Change in the $T_J$ depending on the volume of the heatsink

Refer to Figure 5 for the change in the $T_J$ vs. the volume of the heatsink when operated at:

- $I_F$ = 1800mA (i.e. the sorting current), which is equivalent to 81W
- $I_F$ = 3300mA (i.e. the absolute maximum rating current), which is equivalent to 150W

### 4.3.2 Minimum volume to ensure that the $T_{JMax}$ is not exceeded

As shown in Figure 5 below, when the COB LEDs were operated at $I_F$ = 3300mA, increasing the volume of the heatsink did not have a significant effect on reducing the $T_J$. Since there are cases where this approach is not effective, alternative solutions (e.g. use with cooling fans, heatsink with heat pipes, etc.) may be required to ensure that the $T_J$ does not exceed 150°C (i.e. $T_{JMax}$). The following section discusses the effectiveness of heatsinks with heat pipes as a solution to the issue.

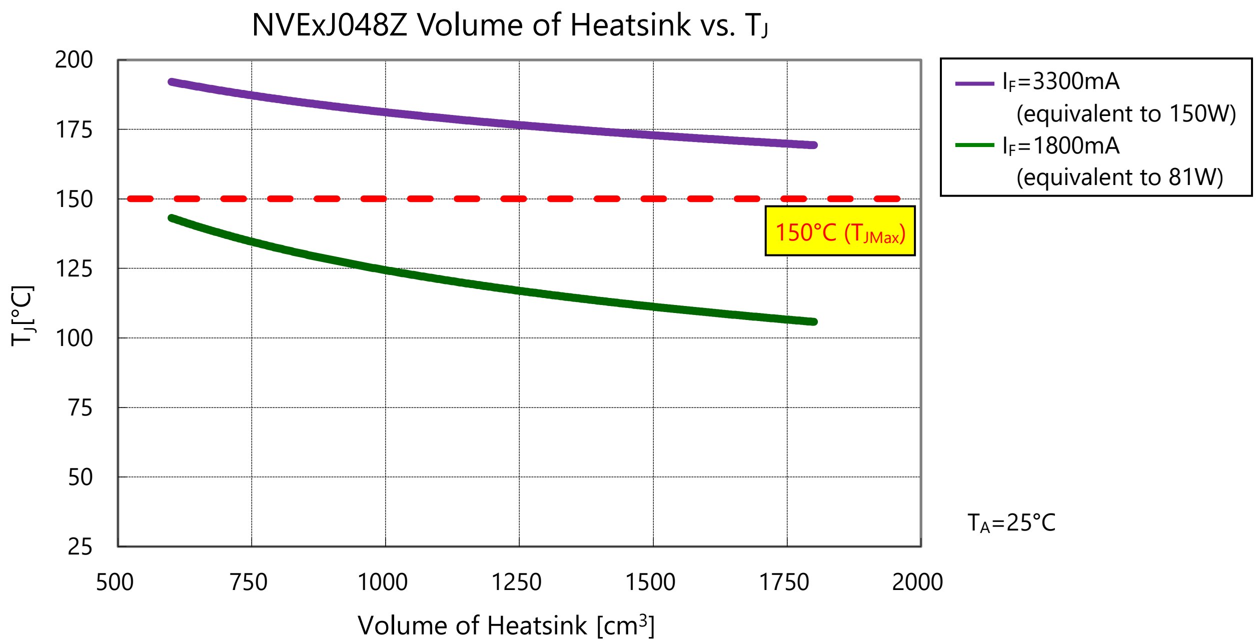


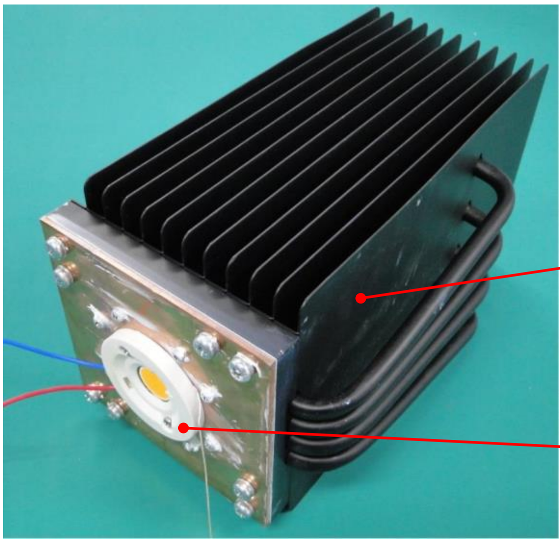

Figure 5. Evaluation Result for the NVExJ048Z COB LEDs

## 4.4 Evaluation using a Heatsink with Heat Pipes

Nichia performed an evaluation to determine the effectiveness of heatsinks with heat pipes in dissipating heat from the COB LED, especially in cases where increasing the volume of the heat sink is not sufficient (e.g. driving the NVCxL024Z/ NVExJ048Z COB LEDs at high wattages).
Refer to 4.4.1 for the evaluation method and conditions used and 4.4.2 for the results.

### 4.4.1 Evaluation Method/Conditions

A COB LED was secured to a heatsink with heat pipes via a COB LED holder and screws. Thermal grease was used between the COB LED and the heatsink. Then, the assembly was installed in an enclosure with no ventilation and operated at the absolute maximum current of the COB LED (i.e. the constant current). Once the saturation temperature at the junction had been reached, the temperature at the $T_C$ measurement point (i.e. $T_C$) was measured to calculate the $T_J$.



| | |
|---|---|
| LED Part No. | NVCxL024Z, NVExJ048Z |
| LED/Heatsink Orientation | See the image to the left. |
| Cooling Method | Natural cooling (No ventilation openings/gaps within the enclosure) |
| Ambient Temp. | 25°C |
| Heatsink with Heat Pipes | HYC200 manufactured by Furukawa Electric Co., Ltd.<br>143 x 130 x 220 [mm]<br>Aluminum, Copper |
| Holder | Manufactured by TE Connectivity Ltd. |
| Screws | M3 pan-head screws tightened with a torque of 0.5N·m (without washers) |
| Thermal Grease | SPG-30B manufactured by Fuji Polymer Industries Co., Ltd.<br>Conductivity: 3.1W/m·K |

Figure 6. Conditions of the evaluation using a heatsink with heat pipes

4.4.2 Evaluation Results

As shown in Table 2 below, Nichia verified that when the NVCxL024Z COB LEDs and the NVExJ048Z COB LEDs were operated at the absolute maximum rating currents while being cooled by the heatsink with heat pipes, the $T_J$ did not exceed the $T_{JMax}$.
If these COB LEDs or similar/successor COB LEDs are designed into a high-wattage application, determine the appropriate thermal solution (e.g. use with cooling fans, heatsink with heat pipes, etc.) for the application and perform a sufficient verification to ensure that there are no issues with the thermal design since the COB LED can produce a significant amount of heat.

Table 2. Specifications for the evaluated COB LEDs and evaluation results

| Evaluation LED | $I_F$ [mA] | $T_J$[4] [°C] | $T_{JMax}$ [°C] |
|---|---|---|---|
| NVCxL024Z | 2200mA (i.e. absolute maximum rating current) | 117 | 150 |
| NVExJ048Z | 3300mA (i.e. absolute maximum rating current) | 128 | |

## 5. Summary

Since the volume of the heat sink has an effect on the $T_J$ for COB LEDs, it is very important to choose a heatsink of sufficient volume to improve the performance and the reliability of the chosen application.

To optimize the thermal design of the chosen application, it is critical to determine the $T_J$ when the assembly/system and the COB LED are being operated. Since this $T_J$ can vary depending on the heatsink being used and Nichia COB LEDs have different thermal resistances (i.e. $R_{\theta JC}$), an actual measured $T_C$ should be used to calculate the $T_J$.

To maximize the heat dissipation for a chosen heatsink, the luminaire designer should also consider how the COB LED is attached to the heatsink to ensure sufficient adhesion (e.g. determining the correct tightening torque, thermal interface material [TIM], and the amount of the TIM, etc.). For more details, refer to Nichia's application note entitled Heat dissipation performance according to the adhesion strength of COB and housing.

Note:

4 The $T_J$ when the saturation temperature at the junction had been reached. These $T_J$ are calculated values.

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NICHIA CORPORATION
491 Oka, Kaminaka-Cho, Anan-Shi, TOKUSHIMA 774-8601, JAPAN
http://www.nichia.co.jp
Phone: +81-884-22-2311 Fax: +81-884-21-0148