Light Emitting Diode

Heat Dissipation Performance of the Nichia NVSxx19C Series LEDs

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The Nichia part numbers NVSx119C and NVSx219C 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

Nichia's NVSxx19C series LEDs offer two different types of electrode designs: LEDs with one cathode and one anode electrode (i.e. NVSx119C) and LEDs with an electrically isolated die heat sink in addition to these two electrodes (i.e. NVSx219C). The thermal resistances ($R_{\theta JS}$) from the LED die to the T_S measurement point are the same for both of those types. However, the difference in the design of the LED (i.e. electrodes/heat sink pad on the back of the LED package) and/or the soldering pad pattern of the printed circuit board (PCB) may cause the thermal path to change causing a difference in the heat dissipation.

Nichia presumes that the NVSxx19C series LEDs will be used for applications that are operated at high currents. When the LED is operated at a high current, it produces a large amount of heat; if this causes the LED temperature (T_J) to increase, it may cause issues (e.g. reduction in the luminous flux according to the LED temperature characteristics). Ensure that when designing the PCB and the luminaire, there are no issues with the thermal designs for the chosen application.

This application note provides the results of the evaluation of the heat dissipation capabilities of the NVSxx19C series LEDs as a discrete part (i.e. a single LED is soldered to a PCB) with an emphasis on the difference in the LED electrode configuration between the NVSx219C and NVSx119C LEDs.

2. Difference in the Electrode Configurations

As mentioned in the Overview, there is a difference in the electrode configuration between these models: the NVSx219C LEDs have a die heat sink that is electrically isolated from both the anode electrode and cathode electrode and the NVSx119C LEDs do not have a die heat sink. This is the only difference that exists between these models, the other parts/materials used are the same.
Refer to Figure 1 for the common appearance of the NVSxx19C series LEDs, and Figures 2 and 3 for the electrode configurations of the NVSx119C and NVSx219C LEDs.

Figure 1. Appearance of the NVSxx19C series LEDs

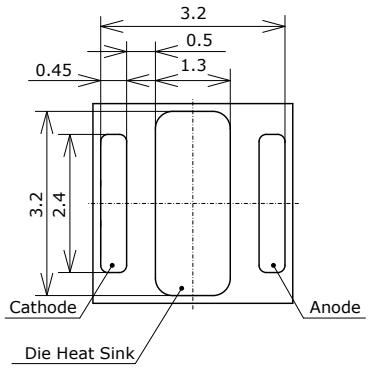


Figure 2. Electrode Configuration of the NVSx219C LEDs

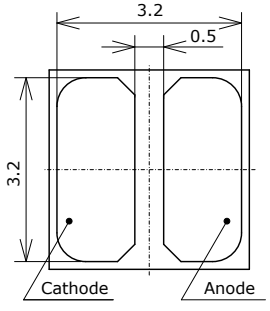


Figure 3. Electrode Configuration of the NVSx119C LEDs

When the LED is operated, it produces heat at the LED die. This heat is conducted to the LED ceramic substrate and then to the PCB (i.e. the copper layer) via the electrodes, spreading over the PCB. For the NVSx219C LEDs, heat is conducted to the PCB (i.e. the copper layer) via the cathode electrode, die heat sink, and anode electrode; for the NVSx119C LEDs, it is conducted via the cathode and anode electrodes.
Refer to Figure 4 for the NVSx219C LEDs' thermal path from the LED die to the PCB and Figure 5 for the NVSx119C LEDs' thermal path.

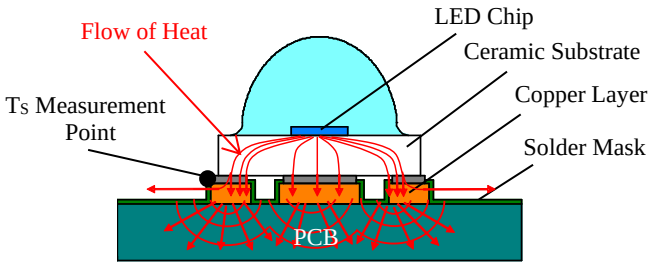


Figure 4. Thermal Path of the NVSx219C LEDs

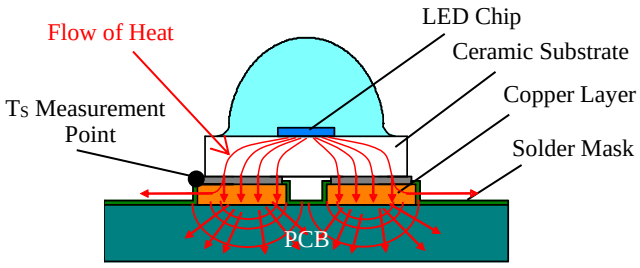


Figure 5. Thermal Path of the NVSx119C LEDs

3. Evaluation of the Heat Dissipation Capabilities

3.1 Evaluation Method/Conditions

To verify the effect of the difference in the electrode design on the heat dissipation capability, Nichia has measured the junction temperatures and thermal resistances of the NVSxx19C Series LEDs (i.e. NVSx119C and NVSx219C) using two different types of PCBs: FR-4 glass epoxy PCBs and aluminum core PCBs. These PCBs were designed to have copper layers with the same total area, though different pattern designs.

For the NVSx219C LEDs, three different copper layer pattern designs were used to determine whether this difference has an effect on the heat dissipation:

Copper Layer Pattern 1: The copper area that the die heat sink is soldered to is significantly larger than the other two copper areas (i.e. copper area that the anode/cathode electrodes are soldered to).

Copper Layer Pattern 2: All the three copper areas that the anode/cathode electrodes and die heat sink are soldered to have approximately the same area.

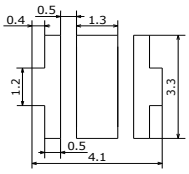
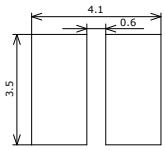
Copper Layer Pattern 3: The copper areas that the anode/cathode electrodes are soldered to have approximately the same area. The die heat sink is designed to be soldered to the same copper area with the cathode electrode.

For the NVSx119C LEDs, a copper layer pattern design was used:

Copper Layer Pattern 4: The copper areas that the anode/cathode electrodes are soldered to have approximately the same area.

Refer to Table 1 for the e Soldering Pad Patterns, Table 2 for the copper layer patterns of the FR-4 PCBs used, and Table 3 for the copper layer patterns of the aluminum core PCBs on Page 5.

Table 1. Soldering Pad Patterns

Part Number	NVSx219C	NVSx119C
Soldering Pad Patterns		

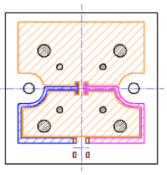
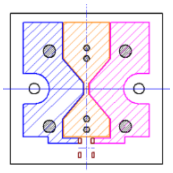
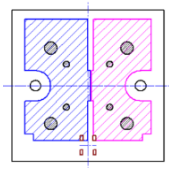
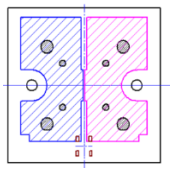
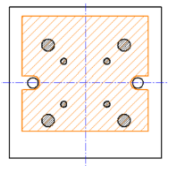
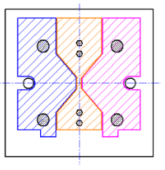
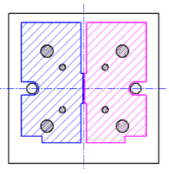
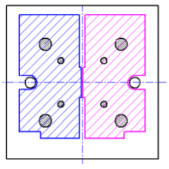
: Copper are that the cathode electrode is soldered to

: Copper area that the die heat sink is soldered to

: Copper area that the anode electrode is soldered to

: Through hole

Table 2. FR-4 Glass Epoxy PCB Copper Layer Patterns

Item		NVSx219C			NVSx119C
		Pattern 1[1]	Pattern 2[2]	Pattern 3[3]	Pattern 4[4]
Copper Layer Pattern	Top of the PCB				
	Back of the PCB				
PCB Dimensions		50mm×50mm×t1.6			
Copper Layer Thickness		70μm			
Top of the PCB Copper Layer Area[mm²]	Die Heat Sink	1247	406		
	Anode	67	488	655	691
	Cathode	67	488	728	691
	Subtotal	1381	1382	1383	1381
Back of the PCB Copper Layer Area[mm²]	Die Heat Sink	1464	406		
	Anode		529	732	732
	Cathode		529	732	732
	Subtotal	1464	1464	1464	1464
Total[mm²]		2845	2847	2847	2846

Notes:

1: The copper area that the die heat sink is soldered to is significantly larger than the other two copper areas (i.e. copper area that the anode/cathode electrodes are soldered to).

2: All the three copper areas that the anode/cathode electrodes and die heat sink are soldered to have approximately the same area.

3: The copper areas that the anode/cathode electrodes are soldered to have approximately the same area. The heat sink is designed to be soldered to the same copper area with the cathode electrode.

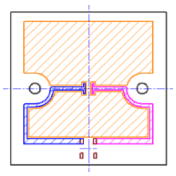
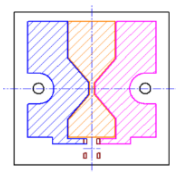
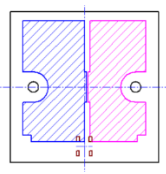
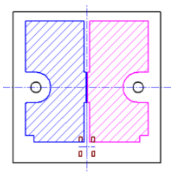
4: The copper areas that the anode/cathode electrodes are soldered to have approximately the same area.

: Copper are that the cathode electrode is soldered to

: Copper area that the die heat sink is soldered to

: Copper area that the anode electrode is soldered to

Table 3. Aluminum Core PCB Copper Layer Patterns

Item		NVSx219C			NVSx119C
		Pattern 1[1]	Pattern 2[2]	Pattern 3[3]	Pattern 4[4]
Copper Layer Pattern	Top of the PCB				
PCB Dimensions		50mm×50mm×t1.7			
Copper Layer Thickness		70μm			
Insulating Layer's Thermal Conductivity		4.5W/m･K			
Copper Layer Area[mm^2]	Die Heat Sink	1312	412		
	Anode	67	518	688	723
	Cathode	67	518	761	723
Total[mm^2]		1446	1448	1448	1447

Notes:

1: The copper area that the die heat sink is soldered to is significantly larger than the other two copper areas (i.e. copper area that the anode/cathode electrodes are soldered to).

2: All the three copper areas that the anode/cathode electrodes and die heat sink are soldered to have approximately the same area.

3: The copper areas that the anode/cathode electrodes are soldered to have approximately the same area. The heat sink is designed to be soldered to the same copper area with the cathode electrode.

4: The copper areas that the anode/cathode electrodes are soldered to have approximately the same area.

3.2 Evaluation Results

3.2.1 Heat Dissipation Capabilities of the LEDs when soldered to the FR-4 Glass Epoxy PCBs

The evaluation verified that when the NVSx119C LEDs and NVSx219C LEDs were soldered to the FR-4 glass epoxy PCBs, the NVSx119C LEDs achieved the lowest values in both thermal resistance and junction temperature (i.e. Copper Layer Pattern 4); this leads to the conclusion that the NVSx119C LEDs could have better heat dissipation than NVSx219C LEDs.

For the evaluation results of the NVSx219 LEDs alone, the LEDs had better heat dissipation when used with Copper Layer Patterns 2 and 3 than Copper Layer Pattern 1.
Refer to Table 4, Figures 6 and 7 below for more details on the evaluation results.

Table 4. Evaluation Results for the Heat Dissipation Capabilities

I_F=1800mA, T_A=25°C

Conditions	NVSx219C			NVSx119C
	Pattern 1[1]	Pattern 2[2]	Pattern 3[3]	Pattern 4[4]
Thermal Resistance ($R_{\theta JA}$) [°C/W]	33.8	25.4	25.3	23.9
Junction Temperature (T_J) [°C]	206.6	160.3	159.4	153.1

*The absolute maximum junction temperature of the NVSxx19C series LEDs (i.e. NVSx119C and NVSx219C) is 150°C. Ensure that when using the LEDs, the absolute maximum junction temperature is not exceeded. The data above should be used for reference purpose only.

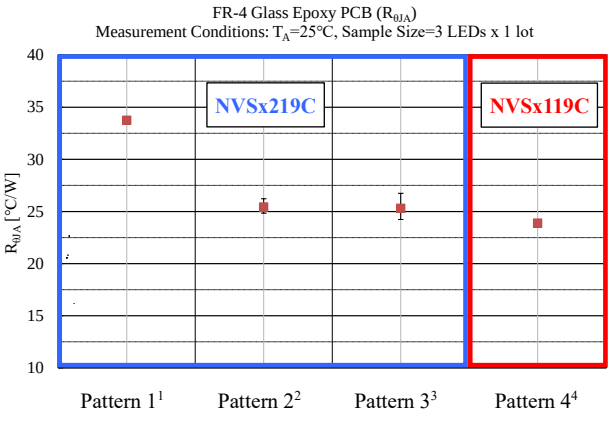


Figure 6. Evaluation Results for the Thermal Resistance ($R_{\theta JA}$)

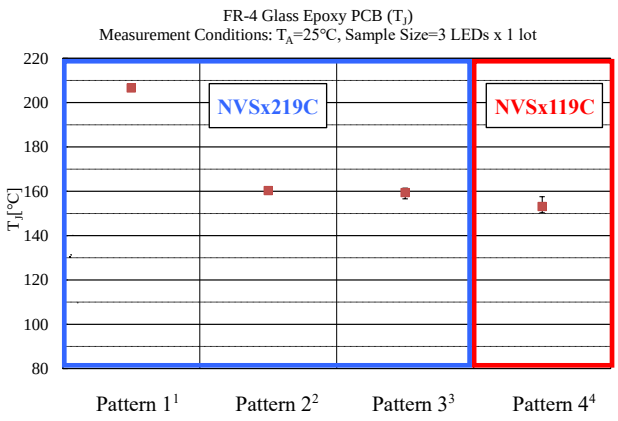


Figure 7. Evaluation Results for the Junction Temperature (T_J)

Notes:

1: The copper area that the die heat sink is soldered to is significantly larger than the other two copper areas (i.e. copper area that the anode/cathode electrodes are soldered to).

2: All the three copper areas that the anode/cathode electrodes and die heat sink are soldered to have approximately the same area.

3: The copper areas that the anode/cathode electrodes are soldered to have approximately the same area. The heat sink is designed to be soldered to the same copper area with the cathode electrode.

4: The copper areas that the anode/cathode electrodes are soldered to have approximately the same area.

3.2.2 Heat Dissipation Capabilities of the LEDs when soldered to the Aluminum Core PCBs

The evaluation with the aluminum core PCBs verified that the NVSx119C LEDs and NVSx219C LEDs have very similar heat dissipation.
Refer to Table 5 and Figures 8 and 9 below for more details on the evaluation results.

Table 5. Evaluation Results for the Heat Dissipation Capabilities

I_F=1800mA, T_A=25°C

Conditions	NVSx219C			NVSx119C
	Pattern 1[1]	Pattern 2[2]	Pattern 3[3]	Pattern 4[4]
Thermal Resistance ($R_{\theta JA}$) [°C/W]	14.1	14.4	13.9	13.8
Junction Temperature (T_J) [°C]	102.2	103.2	101.3	101.2

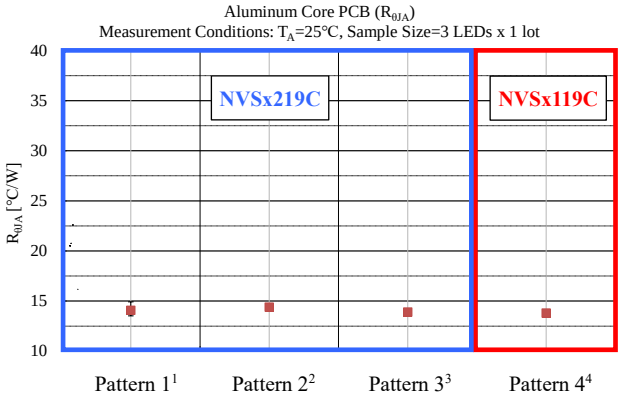


Figure 8. Evaluation Results for the Thermal Resistance ($R_{\theta JA}$)

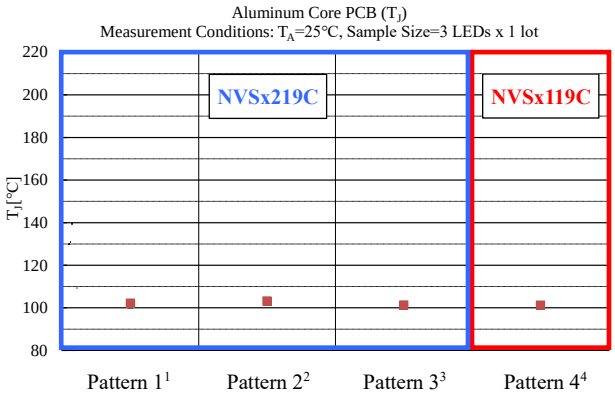


Figure 9. Evaluation Results for the Junction Temperature (T_J)

Notes:

1: The copper area that the die heat sink is soldered to is significantly larger than the other two copper areas (i.e. copper area that the anode/cathode electrodes are soldered to).

2: All the three copper areas that the anode/cathode electrodes and die heat sink are soldered to have approximately the same area.

3: The copper areas that the anode/cathode electrodes are soldered to have approximately the same area. The heat sink is designed to be soldered to the same copper area with the cathode electrode.

4: The copper areas that the anode/cathode electrodes are soldered to have approximately the same area.

4. Summary

Based on the evaluation results above, Nichia has concluded that:

1. When the NVSx119C/NVSx219C LEDs are soldered to an FR-4 glass epoxy PCB and operated, the NVSx119C LEDs achieve better dissipation than the NVSx219C.
2. When these LEDs are soldered to an aluminum core PCB and operated, no significant difference is observed in the heat dissipation.

The NVSx119C LEDs have electrodes larger than the total area of the electrodes/die heat sink of the NVSx219C LEDs. These electrodes will be an advantage in dissipating the heat from the LED to the PCB. However, if sufficient heat dissipation has been achieved (e.g. using an aluminum core PCB with the LEDs), the difference will be less apparent. Additionally, these evaluations were performed by using test PCBs with one LED per board; the data may change depending on the PCB layout and/or operating conditions. Use the data/information provided in this application note for reference purposes only.

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