Thermal Design Guide for the Nichia NVSU233C(U405) or NVSU233C-D4 (U365, U385, U395, U405) LEDs

Light Emitting Diode

Table of contents

The Nichia part numbers NVSU233B, NVSU233C and NVSU233C-D4 within this document are merely Nichia's part numbers for these Nichia products and are not related nor bear any resemblance to any other company's product that might bear a trademark.

SP-QR-C2-220655-2
Nov. 24, 2022

1. Overview

The light output of LEDs decreases due to the effect of heat generation. When LEDs are operated above the maximum LED junction temperature (T_{JMAX}), the reliability will drop significantly. In order to use the NVSU233C and NVSU233C-D4 LED with high performance and high reliability, it is important to design the heat dissipation so that the junction temperature (T_J) does not exceed the T_{JMAX} of 130°C.
This application note covers the effect on the T_J when a board with one LED is driven with two different heat dissipation configurations. This information can be used as a reference for thermal design.

2. T_J Measurement Method

The following equation can be used to calculate the T_J.

$$T_J = T_S + R_{\theta JS} \times W$$

- T_J : LED Junction Temperature (°C)
- T_S : Soldering Temperature (°C)
- $R_{\theta JS}$: Thermal Resistance from Junction to T_S Measurement Point (°C/W)
- W : Input Power (W) = I_F(A)×V_F(V)

The specifications of the NVSU233C and NVSU233C-D4 are as follows:

Symbol	Condition	NVSU233C-D4						NVSU233C NVSU233C-D4	
		U365		U385		U395		U405	
		Typ	Max	Typ	Max	Typ	Max	Typ	Max
$R_{\theta JS}$ (°C/W)	-	3.9	5.7	3.9	5.7	3.9	5.7	3.9	5.7
V_F (V)	I_F=1000mA	3.85	-	3.70	-	3.65	-	3.60	-

Absolute Maximum Ratings (T_S=25°C):

I_{FMAX} (mA)	1400
I_{FPMAX} (mA)	2000
T_{opr} (°C)	-10～85
T_{JMAX} (°C)	130

- I_F : Forward Current (mA)
- I_{FP} : Pulse Forward Current (mA)
- I_{FP} conditions : pulse width ≤10ms and duty cycle ≤10%
- T_{opr} : Operating Temperature (°C)

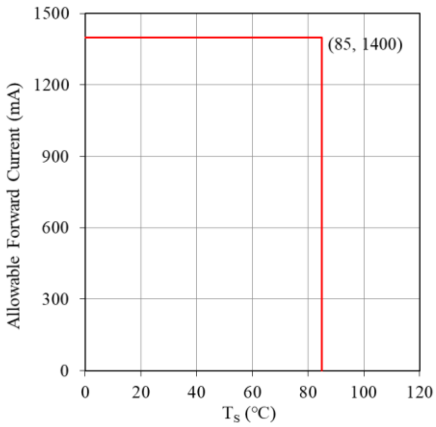


Figure 1. T_S vs Allowable Forward Current

3. T_S Measurement Point

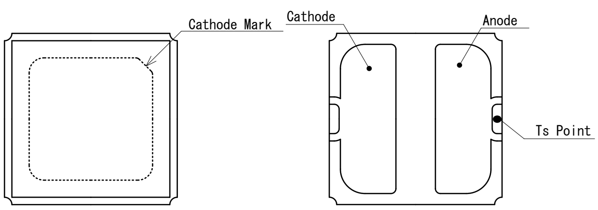


Figure 2. T_S Measurement point (NVSU233C)

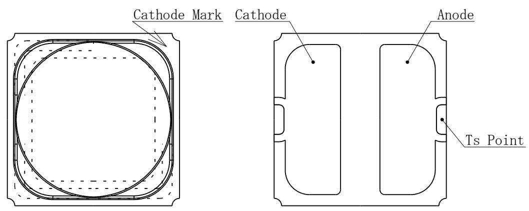


Figure 3. T_S Measurement point (NVSU233C-D4)

4. Heat Dissipation Configuration and T_J Measurement Results

The T_J was confirmed when one LED was mounted on the board and it was driven with two different heat dissipation configurations.

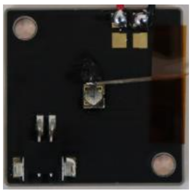
Heat dissipation configuration 4-1, One LED on the board + Heatsink A

The specification of the board is as follows:

Thickness(mm)			Outline dimensions (mm)
Copper foil	Insulation layer	Copper base	
0.105	0.120	1.5	30 × 30

The thermal conductivity of the copper foil and copper base is 390W/m·K and that of the insulation layer is 4.5W/m·K.

Picture 1. Board appearance (NVSU233C)



Picture 2. Board appearance (NVSU233C-D4)

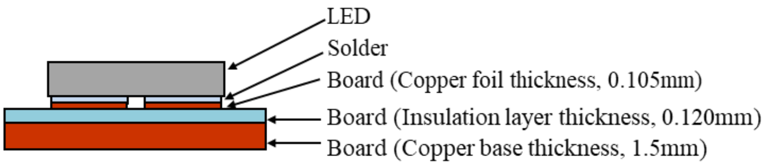


Figure 4. Structure of the board + LED

The specification of heatsink A is as follows:

Heatsink A			Fin			Thermal resistance (°C/W)
Material	Size (mm)	Thickness of the base Material (mm)	Number of fins	Size (mm)	Arrangement	
Al	50 × 38 × t25	5	8	1 × 38	8 × 1	5.70

Thermal conductivity of thermal grease is 5.3W/m·K.

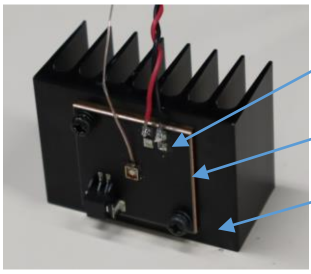
The results of the evaluation with heatsink A are shown below:[1]

T_A (°C)	Part number	Wavelength Rank	I_F (A)	V_F (V)	W (W)	T_S (°C)	T_J (°C)
25	NVSU233C-D4	U365	1.0	3.7	3.7	55	76
			1.4	3.8	5.3	67	97
		U385	1.0	3.5	3.5	49	69
			1.4	3.6	5.0	60	89
		U395	1.0	3.5	3.5	50	70
			1.4	3.6	5.0	61	90
	NVSU233C NVSU233C-D4	U405	1.0	3.6	3.6	45	66
			1.4	3.8	5.3	55	85

With heat dissipation configuration 4-1 using the U385 rank, there was enough margin to not exceed the T_{JMAX} even when 1.4A was applied. The shorter the wavelength, the tighter the heat dissipation, the results for the other wavelengths showed even greater margins for the heat dissipation.

Nichia performed another evaluation where the size of the heatsink was increased.

[1] NVSU233C and NVSU233C-D4 (U385, U395) are based on the data of similar products NVSU233B (U385, U395).



Picture 3. Evaluated light source 4-1 (NVSU233C)

Heat dissipation configuration 4-2, One LED on the board + Heatsink B

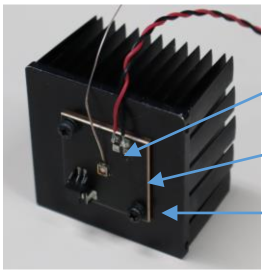
The specification of heatsink B is as follows:

Heatsink B			Fin			Thermal resistance (°C/W)
Material	Size (mm)	Thickness of the base Material (mm)	Number of fins	Size (mm)	Arrangement	
Al	53 × 53 × t35	4	64	0.8 × 9	13 × 5	4.25

Thermal conductivity of thermal grease is 5.3W/m·K.

The results of the evaluation with heatsink B are shown below:[1]

T_A (°C)	Part number	Wavelength Rank	I_F (A)	V_F (V)	W (W)	T_S (°C)	T_J (°C)
25	NVSU233C-D4	U365	1.0	3.7	3.7	49	70
			1.4	3.8	5.3	59	89
		U385	1.0	3.6	3.6	44	65
			1.4	3.7	5.2	53	83
		U395	1.0	3.5	3.5	47	67
			1.4	3.6	5.0	57	86
	NVSU233C NVSU233C-D4	U405	1.0	3.6	3.6	42	63
			1.4	3.8	5.3	50	80



Picture 4. Evaluated light source 4-2 (NVSU233C)

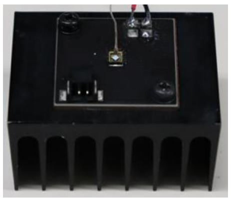
By increasing the size of the heatsink from A to B, the heat dissipation performance was improved and the T_J was further lowered.

5. Design Considerations

The performance of naturally air-cooled heatsinks varies depending on the orientation of the fins of the heatsink. Since the T_S will increase when warm air accumulates, it is important that the air movement is not obstructed. At Nichia, the fins are placed to face vertically to allow warm air to escape from the top (See Figure 5).

When designing the system, pay attention to the orientation of the fins when installing the heatsink.

Picture 5.
Fins facing vertical
(Nichia uses this orientation)



Picture 6.
Fins facing down
(This orientation obstructs the air flow)

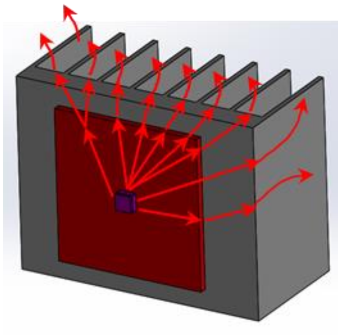


Figure 5.
Image of the heat path when fins are facing vertical

6. Summary

On a board with one LED, there was sufficient margin to stay under the T_{JMAX}, even with an air-cooling heat dissipation configuration using only a heatsink. Additionally, a larger heatsink size resulted in an even lower T_J.

For high-density mounting using multiple LEDs, heat interference occurs between adjacent LEDs, resulting in poor heat dissipation. Make sure that the pitch width is sufficient, increase the heatsink size, or attach a fan to the heatsink, etc. and check that it is sufficiently cooled before use.

The absolute maximum ratings for the NVSU233C and NVSU233C-D4 LED per the Nichia specification:

I_F=1.4A, T_{JMAX}=130°C

Nichia will not guarantee the LEDs if used above these ratings.

Disclaimer

This application note is a controlled document of Nichia Corporation (Nichia) published to provide technical information/data for reference purposes only. By using this application note, the user agrees to the following:

- This application note has been prepared solely for reference on the subject matters incorporated within it and Nichia makes no guarantee that customers will see the same results for their chosen application.
- The information/data contained herein are only typical examples of performances and/or applications for the product. Nichia does not provide any guarantees or grant any license under or immunity from any intellectual property rights or other rights held by Nichia or third parties.
- Nichia makes no representation or warranty, express or implied, as to the accuracy, completeness or usefulness of any information contained herein. In addition, Nichia shall not be liable for any damages or losses arising out of exploiting, using, or downloading or otherwise this document, or any other acts associated with this document.
- The content of this application note may be changed without any prior or subsequent notice.
- Copyrights and all other rights regarding the content of this document are reserved by Nichia or the right holders who have permitted Nichia to use the content. Without prior written consent of Nichia, republication, reproduction, and/or redistribution of the content of this document in any form or by any means, whether in whole or in part, including modifications or derivative works hereof, is strictly prohibited.

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

SP-QR-C2-220655-2
Nov. 24, 2022