



# Thermal Design Guide for the Nichia NCSU03xD (U365, U385, U405) LEDs

Light Emitting Diode

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### 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 NCSU03xD 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) =  $I_F(A) \times V_F(V)$

The specifications of the NCSU03xD are as follows:

Symbol	Condition	NCSU033D		NCSU034D		NCSU035D	
		U365		U385		U405	
		Typ	Max	Typ	Max	Typ	Max
$R_{\theta JS}$ (°C/W)	-	4.1	5.0	4.1	5.0	4.1	5.0
$V_F$ (V)	$I_F=500mA$	3.65	-	3.50	-	3.35	-

Absolute Maximum Ratings ( $T_S=25^\circ C$ ):

$I_{FMAX}$ (mA)	700
$I_{FPMAX}$ (mA)	1000
$T_{opr}$ (°C)	-10~85
$T_{JMAX}$ (°C)	130

$I_F$ : Forward Current (mA)

$I_{FP}$ : Pulse Forward Current (mA)

$I_{FP}$  conditions : pulse width  $\leq 10ms$  and duty cycle  $\leq 10\%$

$T_{opr}$ : Operating Temperature (°C)

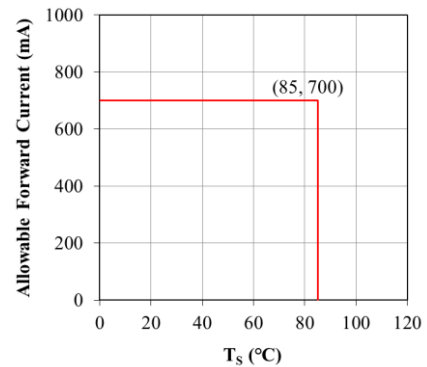


Figure 1.  $T_S$  vs Allowable Forward Current

### 3. $T_S$ Measurement Point

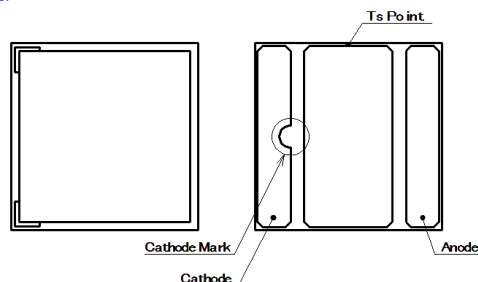


Figure 2.  $T_S$  Measurement point

This document contains tentative information, Nichia may change the contents without notice.

### 4. Heat Dissipation Configuration and T<sub>J</sub> Measurement Results

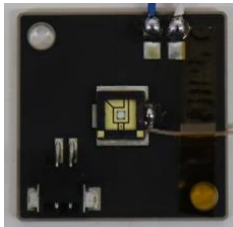
The T<sub>J</sub> was confirmed when one LED was mounted on the board and it was driven with two different heat dissipation configurations.

#### 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

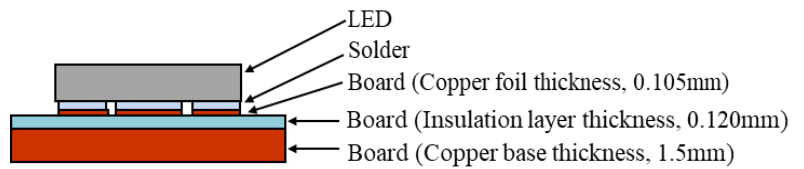


Figure 3. Structure of the board + LED

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

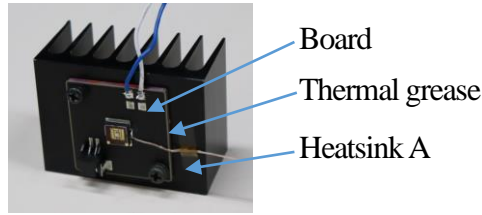
Thermal conductivity of thermal grease is 5.3W/m·K.

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

T <sub>A</sub> (°C)	Part number	Wavelength Rank	I <sub>F</sub> (A)	V <sub>F</sub> (V)	W (W)	T <sub>S</sub> (°C)	T <sub>J</sub> (°C)
25	NCSU033D	U365	0.5	3.7	1.9	34	43
			0.7	3.9	2.7	38	52
	NCSU034D	U385	0.5	3.6	1.8	32	41
			0.7	3.8	2.7	36	49
	NCSU035D	U405	0.5	3.4	1.7	32	41
			0.7	3.6	2.5	35	48

With heat dissipation configuration 4-1 using the U365 rank, there was enough margin to not exceed the T<sub>JMAX</sub> even when 0.7A 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.



Picture 2. Evaluated light source 4-1

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

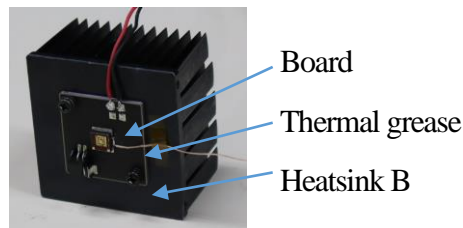
The specification of heatsink B is as follows:

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:

T <sub>A</sub> (°C)	Part number	Wavelength Rank	I <sub>F</sub> (A)	V <sub>F</sub> (V)	W (W)	T <sub>S</sub> (°C)	T <sub>J</sub> (°C)
25	NCSU033D	U365	0.5	3.7	1.9	33	42
			0.7	3.9	2.7	36	50
	NCSU034D	U385	0.5	3.6	1.8	31	40
			0.7	3.8	2.7	34	47
	NCSU035D	U405	0.5	3.4	1.7	29	38
			0.7	3.6	2.5	32	45



Picture 3. Evaluated light source 4-2

By increasing the size of the heatsink from A to B, the heat dissipation performance was improved and the T<sub>J</sub> was further lowered.

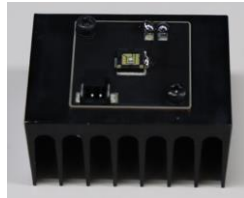
## 5. Design Considerations

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 4).

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



Picture 4.  
Fins facing vertical  
(Nichia uses this orientation)



Picture 5.  
Fins facing down  
(This orientation obstructs the air flow)

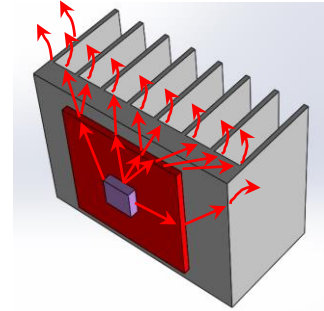


Figure 4.  
Image of the heat path when fins are facing vertical

## 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 NCSU03xD LED per the Nichia specification:

$$I_F=0.7A, T_{JMAX}=130^{\circ}C$$

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

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