UV

Light Emitting Diode

Thermal Design Considerations for the SMD Type UV LEDs

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NVSU233Cx and NCSU434D refer to Nichia 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.

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1. Overview

LEDs generate heat during operation which causes a decrease in the light output. Also, if the applicable absolute maximum junction temperature (T_{Jmax}) is exceeded during operation, it will have a significant effect on the reliability of the LEDs. To achieve high performance and high reliability, it is important to design the thermal management of the chosen application in a manner that ensures the junction temperature (T_J) will not exceed the applicable T_{Jmax}.
Nichia performed evaluations for how the T_J of Nichia UV LEDs varies when they are used with different heatsinks; for the evaluation, the NVSU233Cx UV LEDs and the NCSU434D UV LEDs were used to represent the UV-A, UV-B, and UV-C LEDs respectively. This application note provides the evaluation results. The results should be taken into consideration when designing the thermal management of the chosen application.

2. Evaluation for the UV-A LEDs (Evaluated UV LED: NVSU233Cx)

2.1 How to Calculate the Junction Temperature (T_J)

It is possible to estimate the junction temperature (T_J) by using the following equation:

Equation 1: $T_J = T_S + R_{\theta JS} \times W$

T_J: UV 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 ($I_F \times V_F$) (W)

I_F=Forward Current (A), V_F =Forward Voltage (V)

See below for the specifications of the evaluated UV LEDs.

UV LED Part No. and Wavelength Ranks		NVSU233C and NVSU233C-D4							
		U365		U385		U395		U405	
Characteristics	Conditions	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	-

Sufficient margins/tolerances can be achieved by using the maximum $R_{\theta JS}$ value for the calculation.

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)

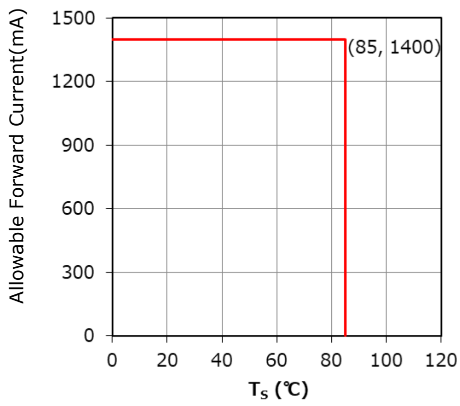


Figure 1. Solder Joint Temperature vs Allowable Forward Current

2.2 T_S Measurement Point

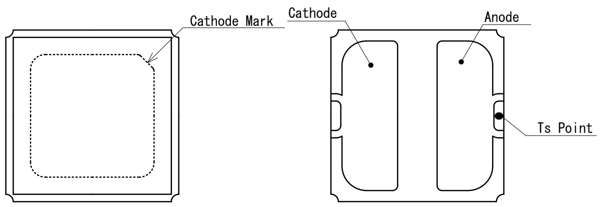


Figure 2. T_S Measurement Point for the NVSU233C UV LED

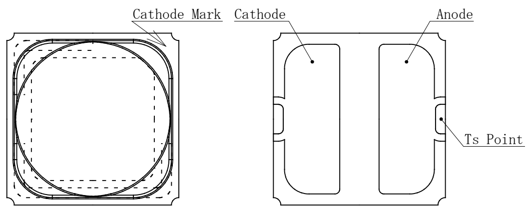


Figure 3. T_S Measurement Point for the NVSU233C-D4 UV LED

2.3 Evaluated Heat Dissipation Structure and Measurement Results for the T_J

One UV LED was mounted on a PCB and operated with two different heat dissipation structures. The T_J was measured for both heat dissipation structures.

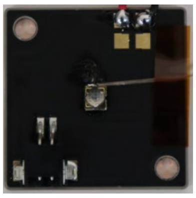
2.3.1 Evaluated Heat Dissipation Structure: One LED Mounted on a PCB + Heatsink A

See below for the detailed specifications of the evaluation PCB and heatsink.

Copper Layer (mm)	Insulating Layer (mm)	Base Metal (Copper) (mm)	Outline Dimensions (mm)
0.105	0.120	1.5	30 × 30

The thermal conductivity of the copper layer and the base metal (copper) is 390W/m·K, and the thermal conductivity of the insulating layer is 4.5W/m·K.

Picture 1.
The NVSU233C UV LED on the PCB



Picture 2.
The NVSU233C-D4 UV LED on the PCB

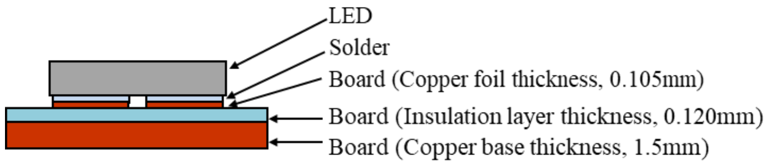


Figure 4. Configuration of the Mounted UV LED and the PCB

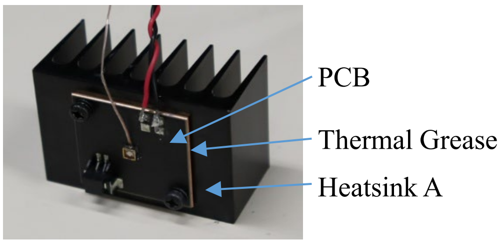
See below for for the detailed specifications of Heatsink A.

Heatsink Type	Material	Outline Dimensions (mm)	Base Thickness (mm)	Fins			Thermal Resistance (°C/W)
				# of Fins	Outline Dimensions (mm)	Arrangement	
A	Aluminum	50 × 38 × t25	5	8	1 × 38	8 Fins × 1 Row	5.7

Thermal conductivity of the thermal grease: 5.3W/m·K

The table below provides the measurement results obtained with the heat dissipation structure detailed above.

T_A (ºC)	Evaluated LED	Wavelength Rank	I_F (A)	V_F (V)	W (W)	T_S (ºC)	T_J (ºC)
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



Picture 3. Evaluated Structure and Orientation of the PCB (Mounted UV LED: NVSU233C)

Based on the evaluation results, this heat dissipation structure had sufficient margins/tolerances (i.e. the T_{Jmax} was not exceeded) even when a current of 1.4A was applied to the UV LED with the shortest wavelength rank, U365. Since LEDs with shorter wavelengths generate more heat, the margins/tolerances will be even greater for the UV LEDs of other wavelength ranks.
The next section shows an evaluation with a different-sized heatsink.

2.3.2 Evaluated Heat Dissipation Structure: One LED Mounted on a PCB + Heatsink B

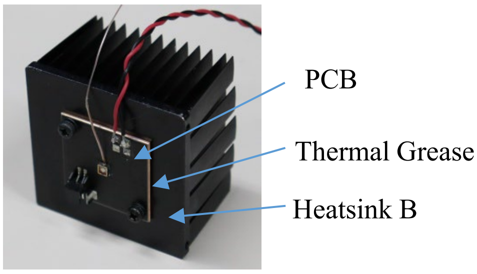
See below for for the detailed specifications of Heatsink B.

Heatsink Type	Material	Outline Dimensions (mm)	Base Thickness (mm)	Fins			Thermal Resistance (°C/W)
				# of Fins	Outline Dimensions (mm)	Arrangement	
B	Aluminum	53 × 53 × t35	4	65	0.8 × 9	13 Fins × 5 Rows	4.25

Thermal conductivity of the thermal grease: 5.3W/m·K

The table below provides the measurement results obtained with the heat dissipation structure detailed above.

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



Picture 4. Evaluated Structure and Orientation of the PCB (Mounted UV LED: NVSU233C)

The results show that by increasing the size of the heatsink (i.e. changing the heatsink used from Heatsink A to Heatsink B), the heat dissipation performance improved and lowered the T_J.

3. Evaluation for the UV-C LEDs (Evaluated UV LED: NCSU434D in Rank U280)

3.1 How to Calculate the Junction Temperature (T_J)

It is possible to estimate the junction temperature (T_J) by using the following equation:

Equation 1: $T_J = T_S + R_{\theta JS} \times W$

T_J: UV 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 ($I_F \times V_F$) (W)

I_F=Forward Current (A), V_F =Forward Voltage (V)

See below for the specifications of the evaluated UV LEDs.

UV LED Part No. and Wavelength Ranks		NCSU434D	
		U280	
Characteristics	Conditions	Typ.	Max.
$R_{\theta JS}$ (°C/W)	-	10.2	11.0
V_F (V)	I_F=350mA	5.2	-

Sufficient margins/tolerances can be achieved by using the maximum $R_{\theta JS}$ value for the calculation.

Absolute Maximum Ratings (T_S=25°C)

I_{Fmax} (mA)	700
I_{FPmax} (mA)	500
I_{FPmax} (mA)	700
T_{opr} (°C)	-40~100
T_{Jmax} (°C)	110

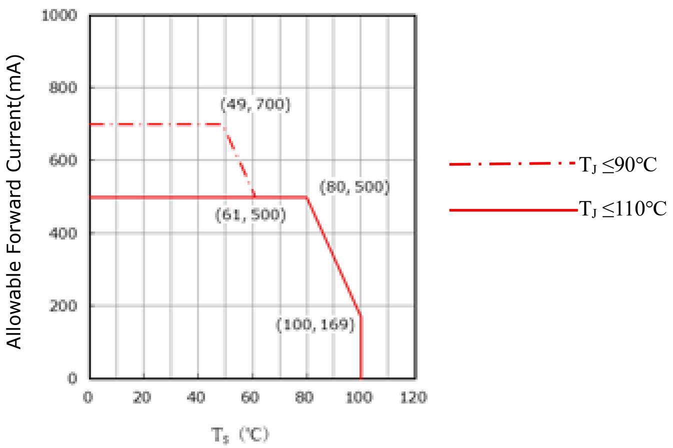


Figure 5. Solder Joint Temperature vs Allowable Forward Current

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)

3.2 T_S Measurement Point

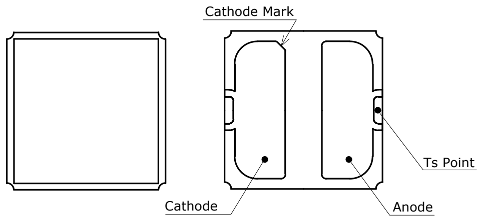


Figure 6. T_S Measurement Point for the NCSU434D UV LED

3.3 Evaluated Heat Dissipation Structure and Measurement Results for the T_J

One UV LED was mounted on a PCB and operated with two different heat dissipation structures. The T_J was measured for both heat dissipation structures.

3.3.1 Evaluated Heat Dissipation Structure: One LED Mounted on a PCB + Heatsink A

See below for the detailed specifications of the evaluation PCB and heatsink.

Copper Layer (mm)	Insulating Layer (mm)	Base Metal (Copper) (mm)	Outline Dimensions (mm)
0.105	0.120	1.5	30 × 30

The thermal conductivity of the copper layer and the base metal (copper) is 390W/m·K, and the thermal conductivity of the insulating layer is 4.5W/m·K.

Picture 5 The NCSU434D UV LED on the PCB

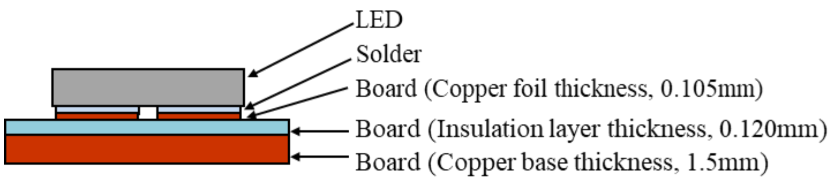


Figure 7. Configuration of the Mounted UV LED and the PCB

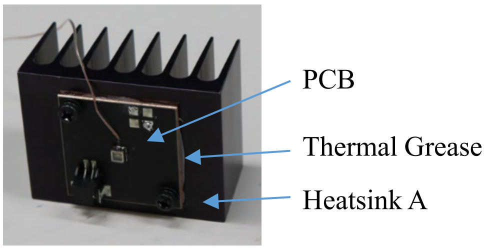
See below for the detailed specifications of Heatsink A.

Heatsink Type	Material	Outline Dimensions (mm)	Base Thickness (mm)	Fins			Thermal Resistance (°C/W)
				# of Fins	Outline Dimensions (mm)	Arrangement	
A	Aluminum	50 × 38 × t25	5	8	1 × 38	8 Fins × 1 Row	5.7

Thermal conductivity of the thermal grease: 5.3W/m·K

The table below provides the measurement results obtained with the heat dissipation structure detailed above.

T_A (°C)	Evaluated LED	Wavelength Rank	I_F (A)	V_F (V)	W (W)	T_S (°C)	T_J (°C)
25	NCSU434D	U280	0.35	5.2	1.8	41	61
			0.50	5.4	2.7	48	78
			0.70	5.7	4	57	101



Picture 6. Evaluated Structure and Orientation of the PCB (Mounted UV LED: NCSU434D)

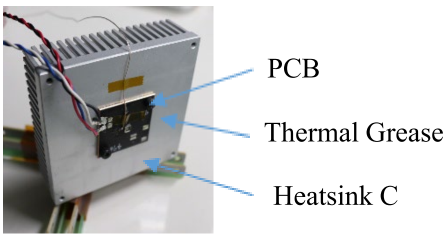
Based on the evaluation results, this heat dissipation structure had sufficient margins/tolerances (i.e. the T_{Jmax} was not exceeded) when currents of 0.35A and 0.5A were applied to the UV LEDs. However, when a current of 0.7A was applied, the T_S was as high as 57°C and the T_J exceeded the T_{Jmax} of 90°C. Nichia performed an evaluation with a larger heatsink to see the temperature rise; the results are shown in the next section.

3.3.2 Evaluated Heat Dissipation Structure: One LED Mounted on a PCB + Heatsink C

See below for for the detailed specifications of Heatsink C.

Heatsink Type	Material	Outline Dimensions (mm)	Base Thickness (mm)	Fins			Thermal Resistance (°C/W)
				# of Fins	Outline Dimensions (mm)	Arrangement	
A	Aluminum	80 × 80 × t25	7	400	2 × 2	20 Fins × 20 Row	1.06

Thermal conductivity of the thermal grease: 5.3W/m·K



Picture 7. Evaluated Structure and Orientation of the PCB (Mounted UV LED: NCSU434D)

The table below provides the measurement results obtained with the heat dissipation structure detailed above.

T_A (ºC)	Evaluated LED	Wavelength Rank	I_F (A)	V_F (V)	W (W)	T_S (ºC)	T_J (ºC)
25	NCSU434D	U280	0.35	5.2	1.8	35	55
			0.50	5.4	2.7	39	69
			0.70	5.7	4	45	89

The results show that by increasing the size of the heatsink (i.e. changing the heatsink used from Heatsink A to Heatsink C), the heat dissipation performance improved. Even when a current of 0.7A was applied, the T_S was as low as 45°C and the T_J was 89°C, which was lower than the T_{Jmax} (i.e. 90°C).

4. Design Considerations

The heat dissipation performance of passive heatsinks (i.e. heatsinks without a fan) varies depending on the installation orientation of the fins. It is important that smooth airflow is facilitated since the T_S will rise if warmed air remains trapped in the heatsink. For the evaluations described above, Nichia installed heatsinks with the fins in a vertical orientation to ensure that the warmed air was discharged from the top of the heatsinks (see Figure 8). When designing a chosen application, ensure that the heatsink is installed with the fins in an appropriate orientation.

Picture 8. Fins are Vertical (Nichia’s Evaluation Condition).

Picture 9: Fins Point Downward (Airflow is Blocked).

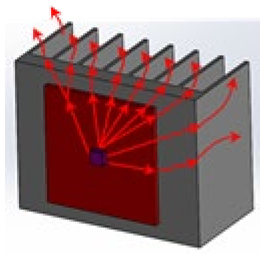


Figure 8. Reference Image of Heat Dissipation Path When the Fins are Vertical.

5. Summary

When only one UV LED is mounted on a PCB, a passive heatsink can be used. Verify that there are sufficient margins/tolerances so that the T_{Jmax} will not be exceeded with a chosen heatsink. A larger heatsink can result in a lower T_J.
If multiple UV LEDs are mounted on a PCB with a small mounting pitch, thermal interference occurs between adjacent LEDs resulting in insufficient heat dissipation. Ensure that the cooling performance of the chosen heat dissipation structure is appropriate; examples of measures that can be taken are a larger mounting pitch, a larger heatsink, an active heatsink (i.e. a heatsink with a fan), etc.

This application note has provided cautions/suggestions for the thermal design of the chosen application using the NVSU233Cx or NCSU434D UV LEDs showing the evaluation results. However, the results are examples for reference purposes only and may be different depending on the UV LED part number and/or the chosen operating conditions/environment. Sufficient verification must be done prior to use to ensure there are no issues for the chosen application based on the information provided in the most recent applicable specification.

Note:
For the NVSU233Cx UV LEDs, the absolute maximum forward current (I_F) is 1.4A and the absolute maximum junction temperature (T_{Jmax}) is 130°C. For the NCSU434D UV LEDs, the T_{Jmax} is 110°C when I_F=0.5A, and 90°C when I_F=0.7A. Nichia will not guarantee the reliability of the UV LEDs if they are used under conditions exceeding these values.

Disclaimer

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