Light Emitting Diode

Assembly and Handling Precautions for the Nichia 321 Series LEDs

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NCSW321x, NC2W321x, NC3W321x, NC4W321x, and NC5W321x 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.

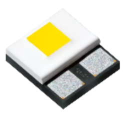
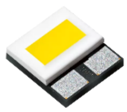
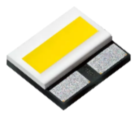
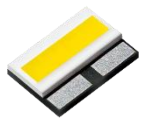
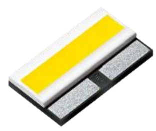
1. Overview

When handling LEDs, care should be taken to ensure that they are handled in a proper manner; if LEDs are improperly handled, it may cause damage to the LEDs and/or an adverse effect on their performance.
The Nichia 321 series LEDs use submounts and are specially designed to be mounted without soldering. The structure of this LED allows it to be directly attached to a heatsink/housing to achieve efficient thermal dissipation. These LEDs need to be handled and assembled in a proper manner to obtain excellent heat dissipation.
This application note provides the assembly and handling precautions for the Nichia 321 series LEDs.

2. Applicable Part Numbers

This application note applies to the LEDs shown in Table 1.

Table 1. Applicable LED Part/Series Numbers

Category	Nichia 321 Series				
Part Number	NCSW321x	NC2W321x	NC3W321x	NC4W321x	NC5W321x
Appearance					
Package Size (mm)	3.05×2.8×0.75	3.5×3.2×0.75	3.5×4.0×0.75	3.5×5.1×0.75	3.5×6.1×0.75

The x represents a letter that follows the alphanumeric code of the same LED type (e.g.: NC2W321x → NC2W321B, NC2W321F, etc. NCxW321F → NCSW321F, NC2W321F, NC3W321F etc.).

3. Storage

3.1 Storage Conditions

If the LED absorbs moisture and is exposed to heat during the LED mounting process, it may cause the moisture to vaporize and the package to expand and the resulting pressure may cause internal delamination. To minimize moisture absorption in storage/transit, moisture-proof aluminum bags are used for the LEDs with a silica gel packet to absorb any air moisture in the bag.
Table 2 provides the required storage conditions before and after opening the moisture-proof aluminum bag.

Table 2. Storage Time and Baking Conditions

Conditions		Temperature	Humidity	Time
Storage	Before Opening the Moisture-proof Aluminum Bag	≤30°C	≤90%RH	Within 1 Year from Delivery Date
	After Opening the Moisture-proof Aluminum Bag	≤30°C	≤70%RH	≤168 hours
Baking		65±5°C	-	≥24 hours

Once the moisture-proof aluminum bag is opened, ensure that soldering is completed within the storage times detailed in the applicable specification. To store any remaining unused LEDs, use a hermetically-sealed container with silica gel desiccants. Nichia recommends placing them back to the original moisture-proof bag used for shipment and reseal it.

If the "After Opening" storage time has been exceeded or any pink silica gel beads are found, ensure that the LEDs are baked before use. Baking should only be done once.

These LEDs have aluminum-plated electrodes. If the LEDs are exposed to a corrosive environment, it may cause the plated surface to tarnish causing issues (i.e. electric connection failures).

3.2 Deformation of the Embossed Carrier Tape

Do not store the LEDs in a manner where excessive external force may be applied to the reel (e.g. the reel is stored using a vacuum seal, heavy objects are stacked onto the reel, etc.) since it may cause the embossed carrier tape to deform; see Figure 1. If the embossed carrier tape deforms, the LEDs inside the pockets of the embossed carrier tape may tilt, causing damage to the LEDs and/or pick-up errors.

Before Opening the Bag with a Reel in it

Squashed Reel as a Result of Vacuum Sealing

Tilted LED in Pocket

Figure 1. Vacuum Storage and Deformation of the Embossed Carrier Tape

3.3 Storage Environment

To avoid condensation, the LEDs must not be stored in areas where temperature and humidity fluctuate greatly. Also, ensure that the LEDs are not exposed to direct sunlight and/or an environment over a long period of time where the temperature is higher than normal room temperature, and are not stored in a dusty environment.

4. Design Consideration

4.1 Absolute Maximum Ratings

Absolute maximum ratings of the LEDs are the maximum values that must not be exceeded even for a short period of time. It must be ensured that the absolute maximum ratings are taken into consideration when designing a system/application using the LED and will not be exceeded in the conditions/environments in which the LED will actually be used even for a short period of time.
For the absolute maximum rating values for the LED, refer to the applicable specification.

4.2 Circuit Design Considerations

The circuit must be designed to ensure that the absolute maximum ratings are not exceeded for each LED. The LEDs should be operated at a constant current per LED. In the case of operating at a constant voltage, Circuit B is recommended. If Circuit A is used, it may cause the currents flowing through the LEDs to vary due to the variation in the forward voltage characteristics of the LEDs on the circuit.

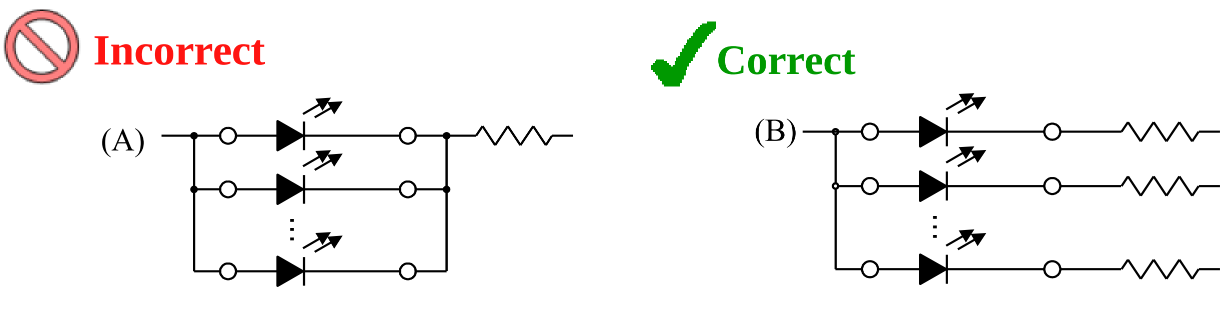


Figure 2. Examples of a Parallel Circuit

4.3 Operating Current

These LEDs are designed to be operated at a forward current. To stabilize the LED characteristics while in use, Nichia recommends that the LEDs are operated at currents ≥10% of the sorting current. For the sorting current for the LED, refer to the applicable specification.

4.4 Precautions for when the LED is Off

Ensure that no voltage is applied to the LED in the forward/reverse direction while the LED is off. If the LEDs are used in an environment where reverse voltages are applied to the LED continuously, it may cause electrochemical migration to occur causing the LED to be damaged.

4.5 Volatile Organic Compounds (VOCs)

Materials present around the LEDs (e.g. housing, gasket/seal, adhesive, secondary lens, lens cover, grease, etc.) may contain volatile organic compounds (VOCs); the VOCs that have been released from them may penetrate the encapsulating resin of the LED. If the LEDs are being used in a hermetically/near-hermetically sealed environment, VOCs can discolor after being exposed to heat and/or photon energy and it may greatly reduce the LED light output and/or cause color shift (see Figure 6). Perform a light-up test, sufficient verifications etc. of the chosen application prior to use to ensure that the expected performance is maintained.
Ventilating the environment may improve the reduction in light output and/or color shift that may occur due to VOCs.

4.6 Corrosive Gases

To prevent substances/gases from affecting the plated surfaces of the LEDs, ensure that the parts/materials used around the LEDs (e.g. gasket/seal, adhesive, etc.) in the same assembly/system do not release corrosive gases (i.e. the parts/materials do not contain sulfur, halogens, etc.). If the plating becomes contaminated, it may cause issues (e.g. electrical connection failures). If a gasket/seal is used, silicone rubber gaskets/seals are recommended; ensure that this use of silicone does not result in issues (e.g. electrical connection failures) caused by low molecular weight volatile siloxane.
Perform a light-up test, sufficient verifications etc. of the chosen application prior to use to ensure that the expected performance is maintained.

4.7 Precautions for Environmental Conditions

Ensure that transient excessive voltages (e.g. lightning surge) are not applied to the LEDs. If the LEDs are used for outdoor applications, ensure that necessary measures are taken (e.g. protecting the LEDs from water/salt damage and high humidity).

5. Handling Precautions

5.1 Areas where Contamination Must be Avoided

Avoid contamination of the LEDs, especially the surfaces of the electrodes and the light emitting areas (see Figure 3) and keep them clean. If the LED surfaces are contaminated, the optical characteristics and/or reliability may be affected.

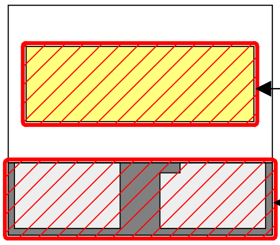


Figure 3. Areas where Contamination Must be Avoided

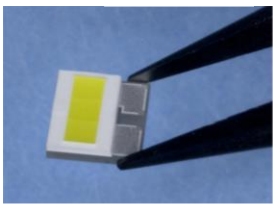
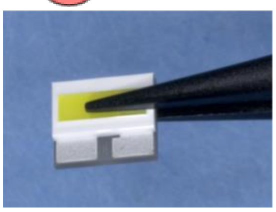
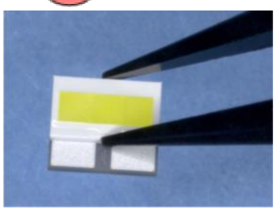
5.2 Handling with Bare Hands

Do not handle the LEDs with bare hands. This may contaminate the LED surface and have an effect on the optical characteristics and/or reliability.

5.3 Handling with Tweezers

Ensure that when handling the LEDs with tweezers, excessive force is not applied to the LED. Otherwise, it may cause damage to the light emitting area, the electrodes and/or the silicone resin (e.g. cut, scratch, chip, crack, etc.) and have an effect on the optical characteristics and/or the reliability.

Table 3. Correct/Incorrect Examples of Handling the LEDs

Correct Examples	Incorrect Examples		
(A) Correct 	(B) Incorrect 	(C) Incorrect 	(D) Incorrect 

For the LEDs with ceramic substrates, grab/hold the LEDs by the sides of the substrate. See the Correct Examples in Table 3. Do not apply excessive force to the emitting area, the electrodes and/or the silicone resin as shown by the Incorrect Examples in Table 3.

5.4 Other Precautions

Do not drop the LEDs; this may cause issues (e.g. crack, chip, and/or deformation of the LED, and/or cut, scratch, etc. on the emitting area) causing the optical characteristics and/or the reliability to be adversely affected.

6. Precautions for Mounting the LEDs

6.1 LED Mounting

The LEDs are designed to be directly attached to a heatsink/housing with an adhesive; no soldering is required.

Nichia recommends using an adhesive with a high thermal conductivity when mounting the LED. If an adhesive with a poor thermal conductivity is used, the optical characteristics and/or reliability of the LED may decrease due to insufficient heat dissipation while the LED is operated. The recommended thermal conductivity of an adhesive used with the LEDs is 3W/m･K or higher. As stated in Sections 4.5 and 4.6, ensure that the adhesives used with the LEDs do not contain substances that have adverse effects on the LEDs.
When selecting an adhesive, perform a light-up test, sufficient verifications etc. of the chosen application prior to use to ensure that the expected performance is maintained.

6.2 Pick-and-Place Nozzle

When using a pick-and-place machine, select a pick-and-place nozzle that is appropriate for the 321 series LEDs. The nozzle is placed onto the emitting surface[1] and it suctions the surface to pick up the LED. If the size, shape, or material of the nozzle tip is not appropriate for the LED, this may damage the LED (i.e. scratch, chip, crack, etc.), affecting the optical characteristics and/or the reliability.

When setting the LED pick-up position, ensure that the center of the nozzle and the center of the emitting area of the LED are aligned. Do not apply excessive force to the emitting area when picking up the LED. If the nozzle does not pick up the LED at the center of the emitting area, and/or if excessive force is applied to the LED, this may damage the LEDs (i.e. scratch, chip, crack, etc.), affecting the optical characteristics and/or the reliability.

Table 4 shows examples of the pick-and-place nozzles that are appropriate for the 321 series LEDs.

[1] The material of the emitting area: Ceramics for the NCxW321F LEDs and hard glass for the NCxW321B LEDs.

Table 4. Examples of the Pick-and-Place Nozzles that are Appropriate for the 321 Series LEDs

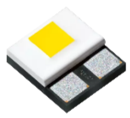
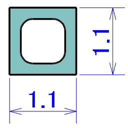
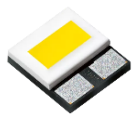
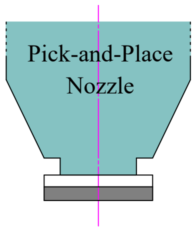
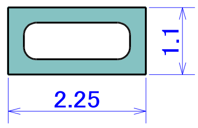
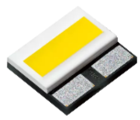
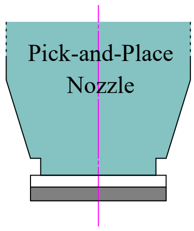
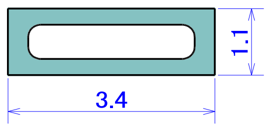
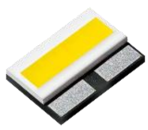
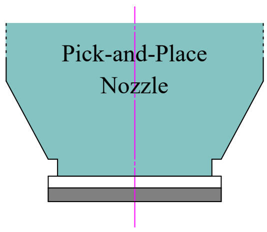
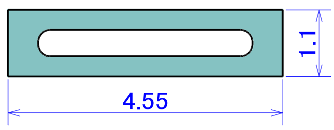
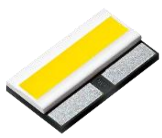
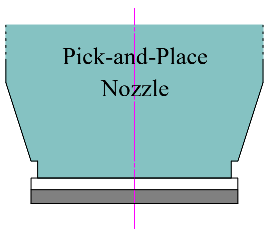
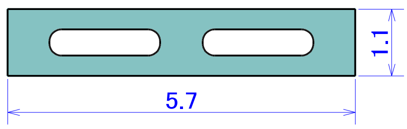
Part Number	Appearance (Dimensions of the Emitting Area: mm)	Cross-sectional view of the Nozzle when the LED is picked up	Example of the Shape of the Nozzle Tip (mm)
NCSW321x	 (1.15×1.15)		
NC2W321x	 (1.15×2.3)		
NC3W321x	 (1.15×3.45)		
NC4W321x	 (1.15×4.6)		
NC5W321x	 (1.15×5.75)		

Figure 4 shows examples of LED pick-up positions for the NC3W321 series LEDs.

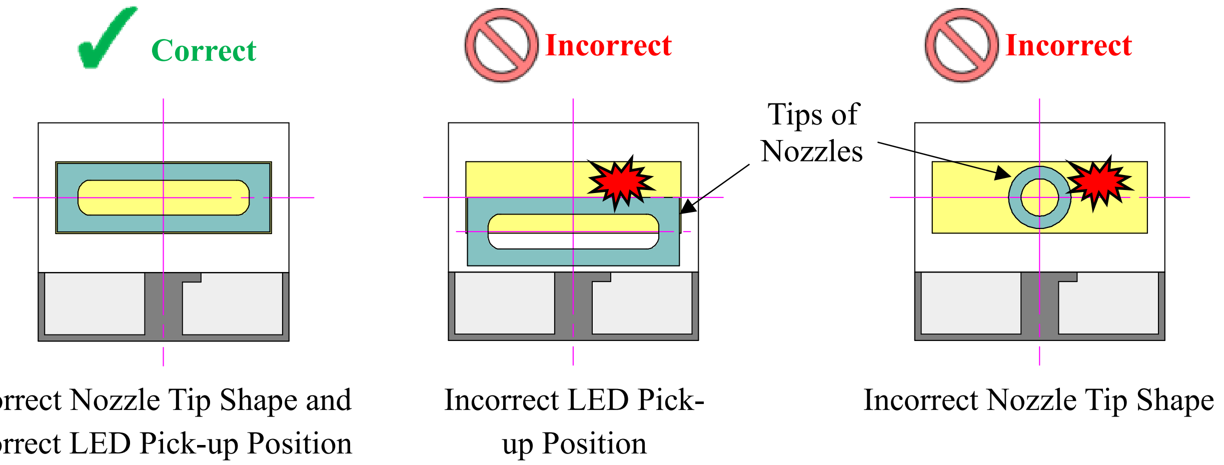


Figure 4. Examples of LED Pick-up Positions for the NC3W321 Series LEDs

6.3 Electrical Connection

The Nichia 321 series LEDs have aluminum-plated electrodes and are designed to have an electrical connection by bonding aluminum ribbons including aluminum wires. Materials other than aluminum such as gold wires are not suitable for these LEDs. To ensure an effective electrical connection, the surfaces of the electrodes should be free from contamination.
When an aluminum ribbon is bonded to the LED, ensure the loop shape/shadow of the aluminum ribbon or light reflected from the ribbon does not affect the LED optical design.
An electrical connection created by clamping the LED electrodes with a contact terminal such as a spring plate is not recommended because the input voltage may become unstable.

6.4 Bonding Conditions

A wedge bonding machine is used to bond an aluminum ribbon onto the surface of the LED electrode. In this bonding method, ultrasonic waves and loads are applied to the aluminum ribbon by using the wedge tool. The ultrasonic output power, the load applied, and the duration will affect the bonding strength.
The shear test and pull test shown in Figure 5 are used to evaluate the bonding strength. Based on the resulting strength value and failure mode etc., select the setting conditions that are suitable for the ribbon bonding.

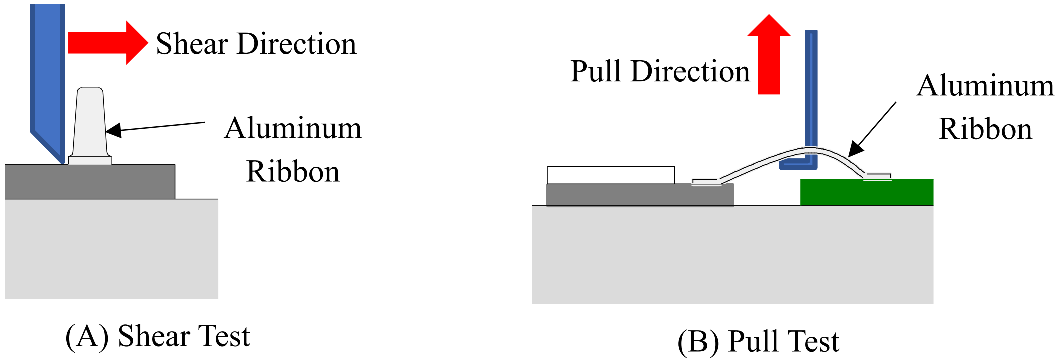


Figure 5. Evaluation Methods for the Ribbon Bonding Strength

Note that there is the mutual dependence between the ultrasonic output and load, and the combination of these setting values has a significant effect on the bonding strength. Figure 6 shows how the shear strength varies depending on the ultrasonic output and load.

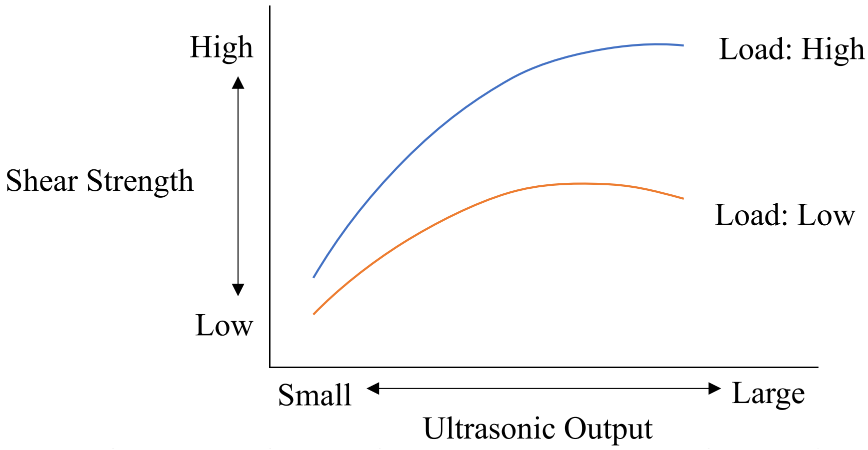


Figure 6. An Example of the Mutual Dependence between the Ultrasonic Output and Load

6.5 Precautions after LED Mounting

Do not stack assembled components together. Otherwise, it may cause damage to the emitting area, the resins, and/or the aluminum ribbons (e.g. scratch, chip, crack, deformation, cut, etc.) and have an effect on the optical characteristics and/or the reliability.

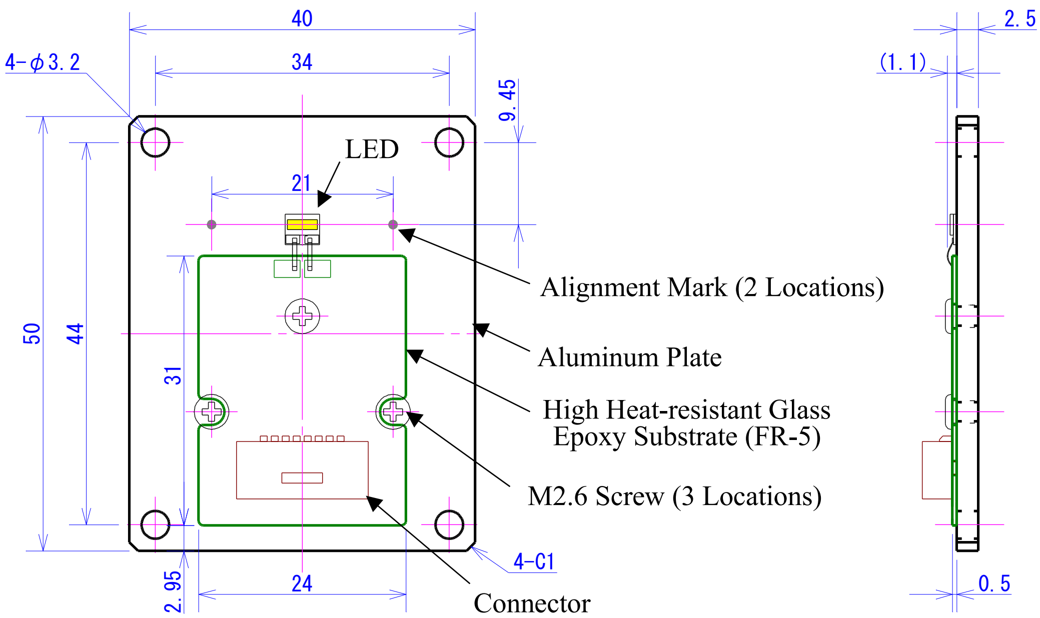
Light Emitting Diode

7. Examples of Modules assembled with the Nichia 321 Series LEDs

Nichia prepared the module shown below and performed various evaluations to measure the characteristics at the module level.

7.1 Structure/Dimensions of the Module used for the Evaluations

Figure 7 shows the structure/dimensions of the module used for the evaluations of the Nichia 321 series LEDs. In this module, a high heat-resistant glass epoxy substrate (FR-5: 31mm [L] × 24mm [W] × 0.5mm [H]) is fixed on an aluminum plate (50mm [L] × 40mm [W] × 2.5mm [H]) at three locations with M2.6 screws and the LED is mounted on the aluminum plate by using a high thermal conductivity adhesive. An aluminum ribbon (0.5mm [W] × 0.1mm [H]) is used to create an electrical connection between the LED and the glass epoxy substrate.



[Aluminum Plate]
Surface Finishing: Anodic oxide coating (Black)
Surface Roughness: Ra=0.3μm

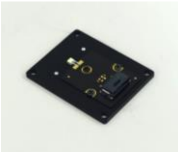
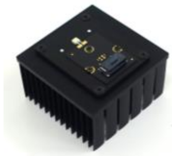
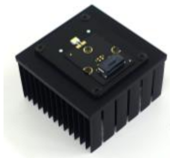
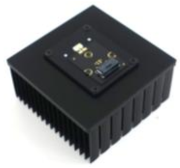
Figure 7. Structure/Dimensions of the Module Used for the Evaluations

7.2 Characteristics of the Nichia 321 Series LEDs at the Module Level

Nichia evaluated the optical and thermal characteristics of the LEDs at the module level with heatsinks. The module is fixed to the heatsink at four locations with M3 screws, not with a heat-dissipating material such as thermal grease.

Table 5 shows the evaluation results at T_J =25°C when the LED was operated at 1000mA (sorting current) in pulse mode.

Table 5. Characteristics of the Nichia 321 Series LEDs at the Module Level with Different Heatsinks

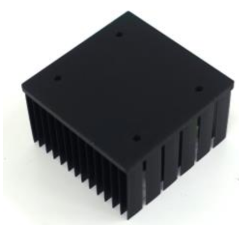
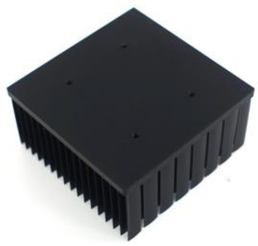
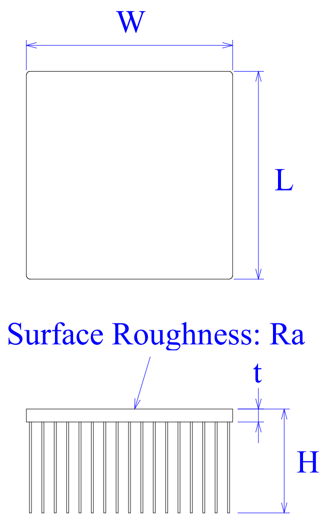
LED Part Number	NCSW321F	NC2W321F	NC3W321F	NC4W321F	NC5W321F
Color Rank	sw57	sw57	sw57	sw57	sw57
Appearance of the Module					
Heatsink[2]	None	Heatsink A	Heatsink A	Heatsink B	Heatsink B
Operating Current (mA)	1000 (Sorting Current)	1000 (Sorting Current)	1000 (Sorting Current)	1000 (Sorting Current)	1000 (Sorting Current)
T_J (°C)	25	25	25	25	25
Voltage (V)[3]	3.3	6.4	9.6	12.8	16.1
Input Power (W)[3]	3.3	6.4	9.6	12.8	16.1
Luminous Flux (lm)[3,4]	(393)	(812)	(1232)	(1587)	(2033)

[2] Refer to Table 6 for the details of the heatsinks used.

[3] The values are the averages of the measured values of three LEDs.

[4] The values in parentheses are for reference purposes.

Table 6. Heatsinks Used for the Evaluations

		Heatsink A	Heatsink B	Note
Appearance				
Size (mm)	W×L×H	60×60×35	80×80×40	
	t	4	5	
Surface Roughness (µm)	Ra	1.6	1.6	
Thermal Resistance (°C/W)[5]		(3.7)	(2.2)	
Material		Aluminum	Aluminum	
Surface Finishing		Anodic oxide coating (Black)	Anodic oxide coating (Black)	

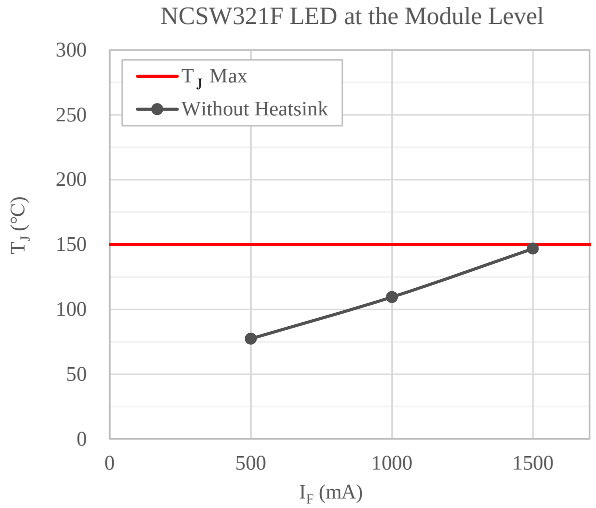
[5] The values in parentheses are for reference purposes.

Figure 8 shows the junction temperatures (T_J) of the Nichia 321 series LEDs at the module level at different operating currents. The junction temperature (T_J) was measured when the saturation temperature at the junction was reached under the ambient temperature (T_A) of 50°C. This measurement was performed with the LED's emitting surface upward.

The chosen application must be designed to ensure that the maximum junction temperature (T_J Max) of 150°C is not exceeded.

The T_J estimation of the LED at the module level can be calculated by using the temperature of the LED (T_{MP}) at the measurement point Nichia specifies, the thermal resistance ($R_{\theta JMP}$) from the LED chip to the T_{MP} measurement point, and the input power (W).

For the details of the T_J calculation, refer to the application notes "How to Calculate the Junction Temperature for the Nichia 321 Series LEDs" and "Thermal Resistance Values of the Nichia 321 Series LEDs".



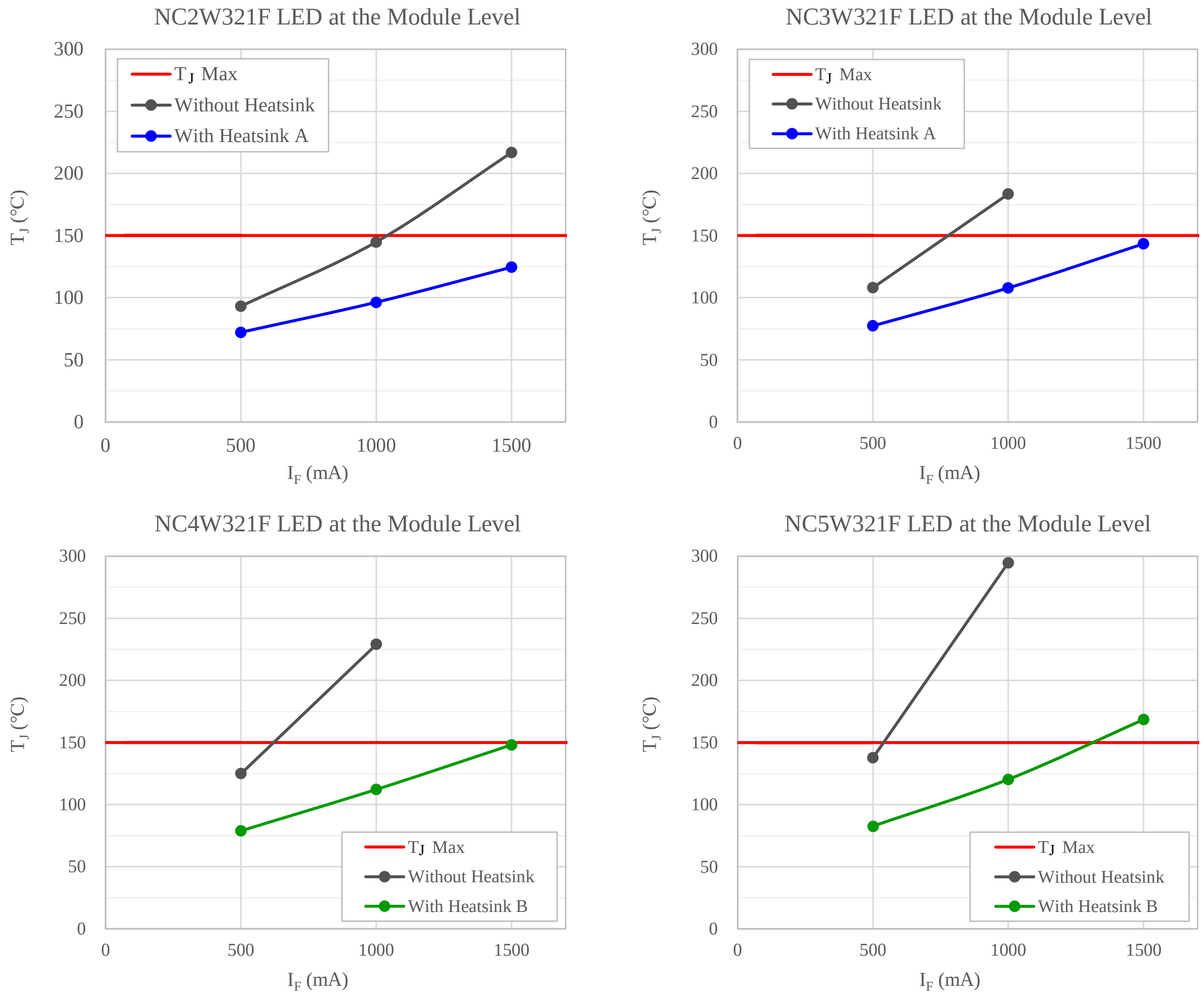


Figure 8. Relationship between the Operating Current and the Junction Temperature (T_A=50°C)

7.3 Placement Accuracy of the Nichia 321 Series LEDs

When designing the chosen application, the accuracy of the distance between the reference point (the optical component position) and the center of the LED emitting surface is important; however, the required accuracy varies depending on the application. For reference when designing the chosen application, Nichia evaluated the placement accuracy of the mounted LEDs based on the alignment marks on the evaluation module.

Figure 9 shows the evaluation of the LED placement accuracy. In the evaluations, one hundred NC3W321F LEDs were used and the target LED placement position was defined as the midpoint of the line connecting the two alignment marks on the aluminum plate. After a high thermal conductivity adhesive was applied to the aluminum plate, the pick-and-place machine placed the LED in place where the center of the emitting surface is aligned with the target LED placement position.
After the LED placement was completed, Nichia evaluated the placement accuracy (the amount of the deviation between the center of the LED emitting surface and the target LED placement position in the x and y directions is described as ⊿x and ⊿y, respectively). Nichia also evaluated the placement accuracy in the angular direction (the amount of the deviation between the center line of the emitting surface in the x direction and the line connecting the 2 alignment marks is described as ⊿θ).

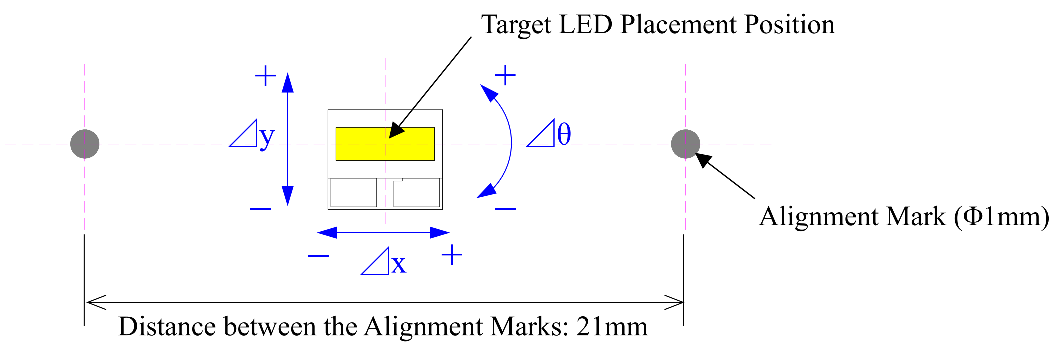


Figure 9. LED Placement Accuracy Evaluation

The evaluation results are shown in Table 7 and Figure 10. At an average value of ±3σ, the deviations from the target LED placement position in the x and y directions are both within ±15μm and the deviation in the angular direction is within ±0.1°.

Table 7. Evaluation Results of the LED Placement Accuracy (For Reference)

	LED Placement Accuracy		
	Deviations in x and y Directions (µm)		Deviation in the Angular Direction (°)
	⊿x	⊿y	⊿θ
Average	-0.9	3.5	0.03
σ	3.6	3.9	0.02
Average -3σ	-12	-8	-0.03
Average +3σ	10	15	0.09
Min.	-12	-4	-0.02
Max.	6	15	0.08

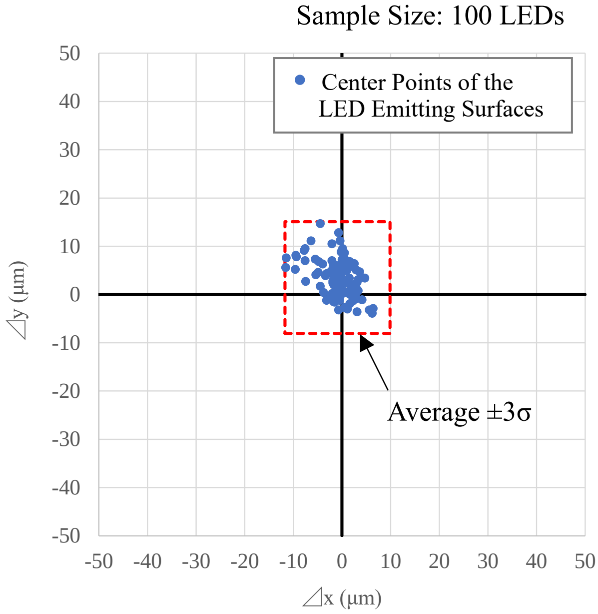


Figure 10. Distribution of the Center Points of the LED Emitting Surfaces (For Reference)

8. Thermal Management

When designing the chosen application using the LED, it is necessary to consider the heat generated from the LED during operation. The increase in the junction temperature (T_J) of the LED while in operation varies depending on the thermal resistances of the heatsink and housing, the thermal conductivity of the adhesive used, and how the adhesive is applied etc. Ensure that when using the LED for the chosen application, heat is not concentrated in an area and properly managed in the application and the Absolute Maximum Junction Temperature (T_J) is not exceeded under any circumstances.

The operating current should be determined by considering the temperature conditions surrounding the LED (i.e. T_A). Ensure that when operating the LED, proper measures are taken to dissipate the heat.

9. Electrostatic Discharge (ESD)

9.1 Measures against ESD

The Nichia 321 series LEDs are sensitive to transient excessive voltages (e.g. ESD, lightning surge). If this excessive voltage occurs in the circuit, it may cause the LEDs to be damaged causing issues (e.g. the LEDs to become dimmer or not to illuminate [i.e. catastrophic failure]).
Ensure that when handling the Nichia 321 series LEDs, necessary measures are taken to protect them from an ESD discharge. The following examples are recommended measures to eliminate the charge:

- Grounded wrist strap, ESD footwear, clothes, and floors
- Grounded workstation equipment and tools
- ESD table/shelf mat made of conductive materials

Ensure that all necessary measures are taken to prevent the LED modules from being exposed to transient excessive voltages (e.g. ESD, lightning surge):

- tools, jigs, and machines that are used are properly grounded
- appropriate ESD materials/equipment are used in the work area
- the system/assembly is designed to provide ESD protection for the LED modules

9.2 Measures for when the Tool/Equipment Used is an Insulator

If the tool/equipment used is an insulator (e.g. glass cover, plastic, etc.), ensure that necessary measures have been taken to protect the LED from transient excessive voltages (e.g. ESD). The following examples are recommended measures to eliminate the charge:

- Dissipating static charge with conductive materials
- Preventing charge generation with moisture
- Neutralizing the charge with ionizers

9.3 Identifying ESD Damaged LEDs

To detect if an LED was damaged by transient excess voltages (i.e. an ESD event during the system's assembly process), perform a characteristics inspection (e.g. forward voltage measurement, light-up test) at low current (≤1mA). If the LED was damaged by transient excess voltages (e.g. ESD), it would cause the Forward Voltage (V_F) to decrease, the LED not to illuminate at a low current, etc.
For the failure criteria for the LED, refer to the applicable specification; the failure criteria for the V_F at the forward current of 0.5mA is specified.

10. Cleaning

Do not clean and/or wipe the emitting surface of the LED. If an area of the LED other than the emitting surface is contaminated (e.g. dust/dirt), use a cloth, swab, etc. soaked with a small amount of isopropyl alcohol (IPA) and wipe the LED with it in a manner that does not touch the emitting surface. If another solvent is used, it may cause the LED package/resin to be damaged causing the optical characteristics and/or the reliability to be affected; ensure that sufficient verification is performed prior to use.
Do not clean the LED with an ultrasonic cleaner. This may cause the optical characteristics and/or the reliability to be affected.

11. Eye Safety

There may be two important international specifications that should be noted for safe use of the LEDs: IEC 62471:2006 Photobiological safety of lamps and lamp systems and IEC 60825-1:2001 (i.e. Edition 1.2) Safety of Laser Products - Part 1: Equipment Classification and Requirements. Ensure that when using the LEDs, there are no issues with the following points:

- LEDs have been removed from the scope of IEC 60825-1 since IEC 60825-1:2007 (i.e. Edition 2.0) was published. However, depending on the country/region, there are cases where the requirements of the IEC 60825-1:2001 specifications or equivalent must be adhered to.
- LEDs have been included in the scope of IEC 62471:2006 since the release of the specification in 2006.
- Most Nichia LEDs will be classified as the Exempt Group or Risk Group 1 according to IEC 62471:2006. However, in the case of high-power LEDs containing blue wavelengths in the emission spectrum, there are LEDs that will be classified as Risk Group 2 depending on the characteristics (e.g. radiation flux, emission spectrum, directivity, etc.)
- If the LED is used in a manner that produces an increased output or with an optic to collimate the light from the LED, it may cause damage to the human eye.

If an LED is operated in a manner that emits a flashing light, it may cause health issues (e.g. visual stimuli causing eye discomfort). The system should be designed to ensure that there are no harmful effects on the human body.

12. Summary

The LEDs need to be handled and assembled in a proper manner to obtain the required characteristics and the reliability. Follow the cautions/suggestions detailed in this application note and the applicable specification for the LED to ensure that the LED is used properly.
In addition, when selecting the parts/materials to be used with the LED, effects of VOCs and corrosive gases from the parts/materials (e.g. sulfur, halogens, etc.) must be carefully considered and sufficient verifications with the conditions/environments in which the chosen application containing the LED will actually be used must be performed to ensure that the characteristics and/or the reliability for the LED are not adversely affected.

Light Emitting Diode

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