PART NO. NVCUQ096A
- Built-in ESD Protection Device
- RoHS Compliant
SPECIFICATIONS

(1) Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Absolute Maximum Rating</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward Current</td>
<td>$I_{F}$</td>
<td>8.8</td>
<td>A</td>
</tr>
<tr>
<td>Allowable Reverse Current</td>
<td>$I_{R}$</td>
<td>85</td>
<td>mA</td>
</tr>
<tr>
<td>Power Dissipation</td>
<td>$P_{D}$</td>
<td>427</td>
<td>W</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>$T_{opr}$</td>
<td>0~85</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>$T_{stg}$</td>
<td>-40~100</td>
<td>°C</td>
</tr>
<tr>
<td>Junction Temperature</td>
<td>$T_{J}$</td>
<td>130</td>
<td>°C</td>
</tr>
</tbody>
</table>

* Absolute Maximum Ratings at $T_{tn}=25^\circ$C.
* The operating Temperature range is the range of Thermistor temperatures ($T_{Th}$).
* Do not operate the LEDs in environments where temperature and humidity fluctuate greatly (i.e. causing condensation to form).

(2) Initial Electrical/Optical Characteristics

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Condition</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>U365</td>
<td>Forward Voltage</td>
<td>$V_{P}$</td>
<td>$I_{F}=8A$</td>
<td>46.3</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Radiant Flux</td>
<td>$\Phi_e$</td>
<td>$I_{F}=8A$</td>
<td>135</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td>Peak Wavelength</td>
<td>$\lambda_p$</td>
<td>$I_{F}=8A$</td>
<td>365</td>
<td>nm</td>
</tr>
<tr>
<td>U385</td>
<td>Forward Voltage</td>
<td>$V_{P}$</td>
<td>$I_{F}=8A$</td>
<td>44.8</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Radiant Flux</td>
<td>$\Phi_e$</td>
<td>$I_{F}=8A$</td>
<td>165</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td>Peak Wavelength</td>
<td>$\lambda_p$</td>
<td>$I_{F}=8A$</td>
<td>385</td>
<td>nm</td>
</tr>
<tr>
<td>U395</td>
<td>Forward Voltage</td>
<td>$V_{P}$</td>
<td>$I_{F}=8A$</td>
<td>44.1</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Radiant Flux</td>
<td>$\Phi_e$</td>
<td>$I_{F}=8A$</td>
<td>157</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td>Peak Wavelength</td>
<td>$\lambda_p$</td>
<td>$I_{F}=8A$</td>
<td>395</td>
<td>nm</td>
</tr>
<tr>
<td>Spectrum Half Width</td>
<td>$\Delta \lambda$</td>
<td>$I_{F}=8A$</td>
<td>12</td>
<td>-</td>
<td>nm</td>
</tr>
<tr>
<td>Thermal Resistance</td>
<td>$R_{θJC}$</td>
<td>-</td>
<td>0.026</td>
<td>0.030</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

* Characteristics at $T_{tn}=25^\circ$C.
* Radiant Flux value as per CIE 127:2007 standard.
* $R_{θJC}$ is the thermal resistance from the junction to the $T_C$ measurement point. (Heat sink used: Copper, t=1.5mm, Thermal grease used: 4.3W/m·K, t=0.1mm)
* It is recommended to operate the LEDs at a current greater than 10% of the sorting current to stabilize the LED characteristics.
### RANKS

<table>
<thead>
<tr>
<th>Item</th>
<th>Rank</th>
<th>Min</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward Voltage</td>
<td>B480</td>
<td>48.0</td>
<td>48.5</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>B475</td>
<td>47.5</td>
<td>48.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B470</td>
<td>47.0</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B465</td>
<td>46.5</td>
<td>47.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B460</td>
<td>46.0</td>
<td>46.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B455</td>
<td>45.5</td>
<td>46.0</td>
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<tr>
<td></td>
<td>B450</td>
<td>45.0</td>
<td>45.5</td>
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<tr>
<td></td>
<td>B445</td>
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<td></td>
<td>B440</td>
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<td></td>
<td>B435</td>
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<td></td>
<td>B430</td>
<td>43.0</td>
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<td></td>
<td>B425</td>
<td>42.5</td>
<td>43.0</td>
<td></td>
</tr>
<tr>
<td>Radiant Flux</td>
<td>Pw175h</td>
<td>175.7</td>
<td>193.3</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td>Pw159h</td>
<td>159.7</td>
<td>175.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pw145b</td>
<td>145.2</td>
<td>159.7</td>
<td></td>
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<tr>
<td></td>
<td>Pw132</td>
<td>132.0</td>
<td>145.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pw120</td>
<td>120.0</td>
<td>132.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pw109a</td>
<td>109.1</td>
<td>120.0</td>
<td></td>
</tr>
<tr>
<td>Peak Wavelength</td>
<td>U395</td>
<td>390</td>
<td>400</td>
<td>nm</td>
</tr>
<tr>
<td></td>
<td>U385</td>
<td>380</td>
<td>390</td>
<td></td>
</tr>
<tr>
<td></td>
<td>U365</td>
<td>360</td>
<td>370</td>
<td></td>
</tr>
</tbody>
</table>

* Ranking at $T_{Th}=25^\circ C$.
* Forward Voltage Tolerance: ±0.35V
* Radiant Flux Tolerance: ±6%
* Peak Wavelength Tolerance: ±3nm
* LEDs from the above ranks will be shipped. The rank combination ratio per shipment will be decided by Nichia.

#### Forward Voltage Ranks by Peak Wavelength

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranking by Peak Wavelength</td>
<td>U365</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U385</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>U395</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Radiant Flux Ranks by Peak Wavelength

<table>
<thead>
<tr>
<th>Ranking by Radiant Flux</th>
<th>Pw109a</th>
<th>Pw120</th>
<th>Pw132</th>
<th>Pw145b</th>
<th>Pw159h</th>
<th>Pw175h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranking by Peak Wavelength</td>
<td>U365</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U385</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U395</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>
OUTLINE DIMENSIONS

<table>
<thead>
<tr>
<th>項目 Item</th>
<th>内容 Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>基板材料 Substrate Materials</td>
<td>窒化アルミニウム Aluminum Nitride</td>
</tr>
<tr>
<td>カバー材料 Cover Materials</td>
<td>硬質ガラス Hard Glass</td>
</tr>
<tr>
<td>コネクター Connector</td>
<td>Hirose Electric DF65-4P-1.7V(21) DF65-6P-1.7V(21)</td>
</tr>
<tr>
<td>質量 Weight</td>
<td>4.5g(TYP)</td>
</tr>
</tbody>
</table>

* 本製品はRoHS指令に適合しております。This product complies with RoHS Directive.

* 括弧で囲まれた寸法は参考値です。The dimension(s) in parentheses are for reference purposes.

* 本製品ははんだ付けに非対応です。はんだ付けでの使用をしないで下さい。This product is non-soldering-compliant. Do not solder this product.

* 製品と筐体間の接続には放熱グリスなど低熱抵抗の放熱材料を用いることを推奨します。When attaching the LEDs to the heat sink, etc., Nichia recommends using a thermal interface material that has a low thermal resistance (i.e. thermal grease).
TRAY DIMENSIONS

* 数量は1トレイにつき6個入ります。
  Tray Size: 6pcs
* 寸法は参考です。
  All dimensions shown are for reference only and are not guaranteed.

 количество

数量は1トレイにつき6個入ります。
Tray Size: 6pcs
* 寸法は参考です。
All dimensions shown are for reference only and are not guaranteed.
Trays are shipped with desiccants in heat-sealed moisture-proof bags.

Moisture-proof bags are packed in cardboard boxes. PS boxes are packed in cardboard boxes with corrugated partitions. They are shipped in cardboard boxes to protect them from external forces during transportation.

- **UV LED**
  - “UV LEDs emit light in the ultraviolet region (UV light).”
  - “UV light is invisible and may be harmful to the human eye.”
  - “Do not expose the eyes directly to the UV light. Wear appropriate protective gear when handling.”
  - “Use appropriate warning signs/labels on devices using the UV LEDs.”

* Part No. Nxxxxxxx
* No. STS-DA7-12138C

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* Products shipped on trays are packed in a moisture-proof bag.
  - They are shipped in cardboard boxes to protect them from external forces during transportation.
  - Do not drop or expose the box to external forces as it may damage the products.
  - Do not expose to water. The box is not water-resistant.

---

* Warning and Explanatory Labels 警告ラベル

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* For details, see "LOT NUMBERING CODE" in this document.
LOT NUMBERING CODE

Lot Number is presented by using the following alphanumeric code.

YMxxxx - RRR

Y - Year

<table>
<thead>
<tr>
<th>Year</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>I</td>
</tr>
<tr>
<td>2019</td>
<td>J</td>
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<tr>
<td>2020</td>
<td>K</td>
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<tr>
<td>2021</td>
<td>L</td>
</tr>
<tr>
<td>2022</td>
<td>M</td>
</tr>
<tr>
<td>2023</td>
<td>N</td>
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</table>

M - Month

<table>
<thead>
<tr>
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<th>M</th>
<th>Month</th>
<th>M</th>
</tr>
</thead>
<tbody>
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<td>7</td>
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</tr>
<tr>
<td>2</td>
<td>2</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>10</td>
<td>A</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>11</td>
<td>B</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>12</td>
<td>C</td>
</tr>
</tbody>
</table>

xxxx-Nichia’s Product Number

RRR-Ranking by Wavelength, Ranking by Radiant Flux, Ranking by Forward Voltage
DERATING CHARACTERISTICS

* $R_{\text{BTH}}$の算出は注意事項熱の発生を参照して下さい。
For calculation of $R_{\text{BTH}}$, see the "Thermal Management" of this specification.

サーミスタ温度・許容順電流特性
Thermistor Temperature vs Allowable Forward Current

<table>
<thead>
<tr>
<th>Thermistor Temperature(°C)</th>
<th>Allowable Forward Current (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>8.80</td>
</tr>
<tr>
<td>68</td>
<td>8.80</td>
</tr>
<tr>
<td>85</td>
<td>8.80</td>
</tr>
<tr>
<td>85</td>
<td>5.20</td>
</tr>
<tr>
<td>85</td>
<td>2.60</td>
</tr>
</tbody>
</table>

$R_{\text{BTH}} = 0.059\,\text{°C/W}$
$R_{\text{BTH}} = 0.1\,\text{°C/W}$
$R_{\text{BTH}} = 0.2\,\text{°C/W}$

For calculation of $R_{\text{BTH}}$, see the "Thermal Management" of this specification.
OPTICAL CHARACTERISTICS

* 本特性は参考です。
All characteristics shown are for reference only and are not guaranteed.

The graphs above show the characteristics for U365x LEDs of this product.

* 本特性はピーク波長ランクU365xに対応しています。
The graphs above show the characteristics for U365x LEDs of this product.
**Optical Characteristics**

*本特性は参考です。
All characteristics shown are for reference only and are not guaranteed.

* 本特性はピーク波長ランクU385xに対応しています。
The graphs above show the characteristics for U385x LEDs of this product.
OPTICAL CHARACTERISTICS

* 本特性は参考です。
All characteristics shown are for reference only and are not guaranteed.

The graphs above show the characteristics for U395x LEDs of this product.

* 本特性はピーク波長ランクU395xに対応しています。
The graphs above show the characteristics for U395x LEDs of this product.
* 本特性は参考です。
All characteristics shown are for reference only and are not guaranteed.

* 本特性はピーク波長ランクU365xに対応しています。
The graphs above show the characteristics for U365x LEDs of this product.
FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

All characteristics shown are for reference only and are not guaranteed.

- 本特性は参考です。 The graphs above show the characteristics for U385x LEDs of this product.
FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

* 本特性は参考です。
All characteristics shown are for reference only and are not guaranteed.

顺電流−順電圧特性
Forward Voltage vs Forward Current

T_A = 25°C

順電圧 Forward Voltage(V)

周囲温度−順電圧特性
Ambient Temperature vs Forward Voltage

L_F = 8A

順電圧 Forward Voltage(V)

順電流−相対放射束特性
Forward Current vs Relative Radiant Flux

T_A = 25°C

相対放射束 Relative Radiant Flux(a.u.)

周囲温度−相対放射束特性
Ambient Temperature vs Relative Radiant Flux

L_F = 8A

相対放射束 Relative Radiant Flux(a.u.)

* 本特性はピーク波長ランクU395xに対応しています。
The graphs above show the characteristics for U395x LEDs of this product.
FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

* 本特性は参考です。 All characteristics shown are for reference only and are not guaranteed.

The graphs above show the characteristics for U365x LEDs of this product.
FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

* All characteristics shown are for reference only and are not guaranteed.

The graphs above show the characteristics for U385x LEDs of this product.

* The graphs above show the characteristics for U385x LEDs of this product.
FORWARD CURRENT CHARACTERISTICS / TEMPERATURE CHARACTERISTICS

* 本特性は参考です。All characteristics shown are for reference only and are not guaranteed.

The graphs above show the characteristics for U395x LEDs of this product.
## RELIABILITY

### (1) Tests and Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Reference Standard</th>
<th>Test Conditions</th>
<th>Test Duration</th>
<th>Failure Criteria #</th>
<th>Units Failed/Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Shock (Air to Air)</td>
<td>JEITA ED-4701 200 201</td>
<td>-40°C to 100°C, 15min dwell</td>
<td>100cycles</td>
<td>#1</td>
<td>0/2</td>
</tr>
<tr>
<td>High Temperature Storage</td>
<td>JEITA ED-4701 200 201</td>
<td>T_a=100°C</td>
<td>1000hours</td>
<td>#1</td>
<td>0/2</td>
</tr>
<tr>
<td>Low Temperature Storage</td>
<td>JEITA ED-4701 200 202</td>
<td>T_a=-40°C</td>
<td>1000hours</td>
<td>#1</td>
<td>0/2</td>
</tr>
<tr>
<td>Room Temperature Operating Life</td>
<td>JEITA ED-4701 200 202</td>
<td>T_a=25°C, T_w=30°C, I_f=8.8A</td>
<td>1000hours</td>
<td>#1</td>
<td>0/2</td>
</tr>
<tr>
<td>Vibration</td>
<td>JEITA ED-4701 400 403</td>
<td>200m/s², 100<del>2000</del>100Hz, 4cycles, 4min, each X, Y, Z</td>
<td>48minutes</td>
<td>#1</td>
<td>0/2</td>
</tr>
<tr>
<td>Electrostatic Discharges</td>
<td>JEITA ED-4701 300 304</td>
<td>HBM, 2kV, 1.5kΩ, 100pF, 3pulses, alternately positive or negative</td>
<td></td>
<td>#1</td>
<td>0/2</td>
</tr>
</tbody>
</table>

**NOTES:**
1) $R_{\theta JTH} \approx 0.052^\circ C/W$
2) $T_w =$ Cooling Water Temperature: °C
3) Measurements are performed after allowing the LEDs to return to room temperature.

### (2) Failure Criteria

<table>
<thead>
<tr>
<th>Criteria #</th>
<th>Items</th>
<th>Conditions</th>
<th>Failure Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Forward Voltage($V_f$)</td>
<td>I_f=8A</td>
<td>$&gt;$Initial value $\times 1.1$</td>
</tr>
<tr>
<td></td>
<td>Radiant Flux($\Phi_e$)</td>
<td>I_f=8A</td>
<td>$&lt;$Initial value $\times 0.7$</td>
</tr>
</tbody>
</table>
CAUTIONS

(1) Storage

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Temperature</th>
<th>Humidity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Opening Aluminum Bag</td>
<td>≤30°C</td>
<td>≤90%RH</td>
<td>Within 1 Year from Delivery Date</td>
</tr>
<tr>
<td>After Opening Aluminum Bag</td>
<td>≤30°C</td>
<td>≤70%RH</td>
<td>≤168 hours</td>
</tr>
</tbody>
</table>

- After opening the moisture-proof aluminum bag, the LEDs should be installed into an end product immediately. If a PCB is used to mount the LEDs before installing into an end product, these processes must be completed within the range of the conditions stated above. Unused remaining LEDs should be stored with silica gel desiccants in a hermetically sealed container, preferably the original moisture-proof bags for storage and resealing this bag.
- This LED has gold-plated parts; if the LEDs are exposed to a corrosive environment, it may cause the plated surface to tarnish causing issues. Ensure that when storing LEDs, a hermetically sealed container is used. Nichia recommends placing them back to the original moisture-proof bag and reseal it.
- To prevent substances/gases from affecting the plated surface, ensure that the parts/materials used with the LEDs in the same assembly/system do not contain sulfur (e.g. gasket/seal, adhesive, etc.). If the plating is contaminated, it may cause issues (e.g. electric 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.
- To avoid condensation, the LEDs must not be stored in areas where temperature and humidity fluctuate greatly.
- Do not store the LEDs in a dusty environment.
- Do not expose the LEDs to direct sunlight and/or an environment over a long period of time where the temperature is higher than normal room temperature.

(2) Directions for Use

- Nichia recommends designing the circuit to ensure that each LED is driven by a separate power supply.
- If two or more LEDs are connected in parallel, the current will be split between them (i.e. current division); this 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, and in some cases, excessive current (i.e. exceeding the Absolute Maximum Rating). 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 issues (i.e. a variation in the current flowing through the LEDs).

(A) ![Circuit A](image)

(B) ![Circuit B](image)

- This LED is designed to be operated at a forward current. 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. When not in use for a long period of time, the system’s power should be turned off to ensure that there are no issues/damage.
- To stabilize the LED characteristics while in use, Nichia recommends that the LEDs are operated at currents ≥ 10% of the sorting current.
- Ensure that transient excessive voltages (e.g. lighting 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).
- Although this LED is specifically designed to emit invisible light, a small amount of light in the visible region exists in the emission spectrum. Ensure that when using the LEDs for sensors, verification is performed to ensure that the emission spectrum is fit for the intended use.
- If this product is stored and/or used constantly under high humidity conditions, it may accelerate the deterioration of the die; this may cause the radiant flux to decrease. If the LEDs are stored and/or used under these conditions, sufficient verification must be done prior to use to ensure there are no issues for the chosen application.
- Do not design this LED into applications where condensation may occur. If the LEDs are stored/operated in these environments, it may cause issues (e.g. current leaks that cause the radiant flux to decrease).
(3) Handling Precautions

● Do not handle the LEDs with bare hands as it will contaminate the LED surface and may affect the optical characteristics: it might cause the LED to be deformed and/or the wire to break, which will cause the LED not to illuminate. The lead could also cause an injury.

● Ensure that when handling the LEDs with tweezers, excessive force is not applied to the LED. Otherwise, it may cause damage to the lens and/or the substrate (e.g. cut, scratch, chip, crack, delamination, and deformation) and the wire to break causing a catastrophic failure (i.e. the LED not to illuminate).

● Dropping may cause damage to the LED (e.g. deformation).

● Do not stack the LEDs on top of one another, regardless of whether the LEDs are attached to heat sinks or not. Otherwise, it may cause damage to the lens and the substrate (e.g. cut, scratch, chip, crack, delamination, and deformation) and the wire to break causing a catastrophic failure (i.e. the LED not to illuminate).

(4) Design Consideration

● Volatile organic compounds that have been released from materials present around the LEDs (e.g. housing, gasket/seal, adhesive, secondary lens, lens cover, thermal grease, etc.) may adhere to the LED glass cover and other areas (e.g. package). If the LEDs are being used in a hermetically sealed environment, these volatile compounds can discolor after being exposed to heat and/or photon energy and it may greatly reduce the LED light output. In this case, ventilating the environment may improve the reduction in light output. Perform a light-up test of the chosen application for optical evaluation to ensure that there are no issues.

● When attaching the LEDs to the heat sink, etc., Nichia recommends using a thermal interface material that has a low thermal resistance (i.e. thermal grease).

(5) Electrostatic Discharge (ESD)

● This LED is sensitive to transient excessive voltages (e.g. ESD, lightning surge). If this excessive voltage occurs in the circuit, it may cause the LED to be damaged causing issues (e.g. the LED to have a reduction in the radiant flux or not to illuminate [i.e. catastrophic failure]).

Ensure that when handling the 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 LEDs 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 LEDs

● 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

● 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) at low current (≤8mA).

Failure Criteria: $V_F<24.0V$ at $I_F=4.0mA$

If the LED is damaged by transient excess voltages (e.g. ESD), it will cause the Forward Voltage ($V_F$) to decrease.
(6) Thermal Management

- When designing, the derating characteristics (i.e. Thermistor Temperature vs. Allowable Forward Current) must be considered. The increase in the temperature of an LED while in operation may vary depending on the heat sink's thermal resistance and the density of LEDs in the system/assembly. Ensure that when using the LEDs for the chosen application, heat is not concentrated in an area and properly managed in the system/assembly to ensure the derating characteristics during actual use.
- Use the thermistor temperature ($T_{\text{TH}}$) to determine the operating current for the chosen application and optimize the thermal design (e.g. selecting a proper heat sink, thermal interface material, etc.) accordingly.
- The following two equations can be used to calculate the LED junction temperature:
  
  $1) \ T_J = T_{\text{TH}} + R_{\theta JTH} \cdot W$  
  $2) \ T_J = T_C + R_{\theta JC} \cdot W$

  *$T_J$=LED Junction Temperature: °C  
  $T_{\text{TH}}$=Thermistor Temperature: °C  
  $T_C$=Case Temperature (back surface of LED): °C  
  $R_{\theta JTH}$=Thermal Resistance from Junction to $T_{\text{TH}}$ Measurement Point: °C/W  
  $R_{\theta JC}$=Thermal Resistance from Junction to $T_C$ Measurement Point: °C/W  
  $W$=Input Power ($I_F \times V_F$): W

- Once the LEDs have been attached to a heat sink, it is difficult to measure $T_C$ due to the location of the $T_C$ measurement point. Refer to the relevant application notes for a method of determining the $T_J$ by measuring $T_{\text{TH}}$. To access the application notes, go to the Technical Suggestions And Recommendations section of Nichia’s website.
- Refer to the relevant application notes for detailed information (e.g. how to handle the COB LEDs, the effect of adhesion strength between the COB and the heat sink, thermal design considerations, etc.). To access the application notes, go to the Technical Suggestions And Recommendations section of Nichia’s website. Note that the application notes may be updated, revised, modified and supplemented without notice.
- To determine the thermal resistance ($R_{\theta TH}$), use the following data/equation.

```
y = 0.03 e^{5.34 \times x}
```

- A mount of Change in Temperature of Thermistor ($T_{\text{TH}}$) /Input Power (°C/W)
(7) Cleaning
● Do not wipe/clean the LEDs with any type of material (e.g. dry/wet cloth) or solvent (e.g. benzene, thinner, etc.). Cleaning can cause pressure leading to damage to the top surface (e.g. lens, electrode, connecting device, etc.) that may cause issues (e.g. the LED not to illuminate [i.e. catastrophic failure]).
● If an LED is contaminated (e.g. dust/dirt), use a cloth soaked with isopropyl alcohol (IPA). Ensure that the cloth is firmly squeezed before wiping the LED.

(8) 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.
● This LED emits light in the ultraviolet (UV) region. The UV light from an LED while in operation is intense and harmful; if human eyes are exposed to this light, it may cause damage to them. Do not look directly or indirectly (e.g. through an optic) at the UV light. Ensure that if there is a possibility that the UV light reflects off objects and enters the eyes, appropriate protection gear (e.g. goggles) is used to prevent the eyes from being exposed to the light.
● Ensure that appropriate warning signs/labels are provided both on each of the systems/applications using the UV LEDs, in all necessary documents (e.g. specification, manual, catalogs, etc.), and on the packaging materials.
(9) Miscellaneous

- Nichia warrants that the discrete LEDs will meet the requirements/criteria as detailed in the Reliability section within this specification. If the LEDs are used under conditions/environments deviating from or inconsistent with those described in this specification, the resulting damage and/or injuries will not be covered by this warranty.

- Nichia warrants that the discrete LEDs manufactured and/or supplied by Nichia will meet the requirements/criteria as detailed in the Reliability section within this specification; it is the customer’s responsibility to perform sufficient verification prior to use to ensure that the lifetime and other quality characteristics required for the intended use are met.

- The applicable warranty period is one year from the date that the LED is delivered. In the case of any incident that appears to be in breach of this warranty, the local Nichia sales representative should be notified to discuss instructions on how to proceed while ensuring that the LED in question is not disassembled or removed from the PCB if it has been attached to the PCB. If a breach of this warranty is proved, Nichia will provide the replacement for the non-conforming LED or an equivalent item at Nichia’s discretion. FOREGOING ARE THE EXCLUSIVE REMEDIES AVAILABLE TO THE CUSTOMER IN RESPECT OF THE BREACH OF THE WARRANTY CONTAINED HEREIN, AND IN NO EVENT SHALL NICHIA BE RESPONSIBLE FOR ANY INDIRECT, INCIDENTAL OR CONSEQUENTIAL LOSSES AND/OR EXPENSES (INCLUDING LOSS OF PROFIT) THAT MAY BE SUFFERED BY THE CUSTOMER ARISING OUT OF A BREACH OF THE WARRANTY.

- Nichia DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

- This LED is intended to be used for general lighting, household appliances, electronic devices (e.g. mobile communication devices); it is not designed or manufactured for use in applications that require safety critical functions (e.g. aircraft, automobiles, combustion equipment, life support systems, nuclear reactor control system, safety devices, spacecraft, submarine repeaters, traffic control equipment, trains, vessels, etc.). If the LEDs are planned to be used for these applications, unless otherwise detailed in the specification, Nichia will neither guarantee that the LED is fit for that purpose nor be responsible for any resulting property damage, injuries and/or loss of life/health. This LED does not comply with IATF 16949 and is not intended for automotive applications.

- The customer will not reverse engineer, disassemble or otherwise attempt to extract knowledge/design information from the LED.

- All copyrights and other intellectual property rights in this specification in any form are reserved by Nichia or the right holders who have granted Nichia permission to use the content. Without prior written permission from Nichia, no part of this specification may be reproduced in any form or by any means.

- Both the customer and Nichia will agree on the official specifications for the supplied LEDs before any programs are officially launched. Without this agreement in writing (i.e. Customer Specific Specification), changes to the content of this specification may occur without notice (e.g. changes to the foregoing specifications and appearance, discontinuation of the LEDs, etc.).
Assembly and Handling Precautions for the NVCUQ048/072/96A(-D4) UV LEDs

Fifth Edition
July 24, 2019

UV LED Development Group, UV Project
Optoelectronic Products BU.
Nichia Corporation

The Nichia part numbers NVCUQ048A/-D4, NVCUQ072A/-D4, and NVCUQ096A/-D4 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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## Revision History

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<td>Jul. 14, 2018</td>
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<td>Nov. 16, 2018</td>
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<td>- Created the “Evaluation for Applying Thermal Grease” section.</td>
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<td>- Created the “Recommended Screw Tightening Order” section.</td>
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<td>- Created the “Precautions When Using UV LEDs in a Parallel Circuit” section.</td>
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<td>- Created the “Peak Irradiance Measurement of a UV Irradiator – Results (U385)” section to add the measurement results for U385 NVCUQ096A-D4 UV LEDs.</td>
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<td>- Created the “How to Calculate the Junction Temperature (Tj) Using the RθJTH” section.</td>
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<td>- Created the “Derating Characteristics” section.</td>
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<td>- Edited the “Peak Irradiance Measurement of a UV Irradiator” sections to include the measurement results for U365 and U385 NVCUQ096A UV LEDs.</td>
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<td>- Added specific information about the NVCUQ048A/-D4 UV LEDs to the related sections (Pages 9 through 11).</td>
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<td>- Added information/data for the NVCUQ048A/072A(-D4) UV LEDs to the “Peak Irradiance Measurement of a UV Irradiator/Results” sections.</td>
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Key Features

Overview
The UV LEDs use a newer LED package technology that integrates multiple bare LED die in a single package. For most conventional LEDs, it is necessary to solder LEDs to PCBs before attaching LED assemblies to heatsinks. However, since these UV LEDs are designed to be directly attached to heatsinks, neither soldering nor PCBs is required. Additionally, light sources using these UV LEDs require fewer UV LEDs to produce the same amount of output as those using conventional UV LEDs due to the mechanical feature of these UV LEDs (i.e. being multi-chip packaged). This enables the light source size to be reduced.

This application note provides general technical information on how to use/handle the UV LEDs.

Basic structure of the UV LEDs
Refer to Figure 1 and Figure 2 for the basic structure of the NVCUQ096A/-D4 UV LEDs. The NVCUQ072A/-D4 and NVCUQ048A/-D4 UV LEDs use the same design and parts/materials (e.g. LED die, ceramic substrate, thermistor, connecting device, etc.) to those used in the NVCUQ096A/-D4; however, they have a smaller number of LED die (i.e. 96 LED die for the NVCUQ096A/-D4 UV LEDs, 72 LED die for the NVCUQ072A/-D4, and 48 LED die for the NVCUQ048A/-D4). For more details on the similarities and differences between these LEDs, refer to the specifications/drawings.

![Figure 1. Basic structure of an NVCUQ096A UV LED](image1)

![Figure 2. Basic structure of an NVCUQ096A-D4 UV LED](image2)
• When designing, the derating characteristics (i.e. Thermistor Temperature \( T_{TH} \) vs. Allowable Forward Current \( I_F \)) must be considered. For the derating characteristics of the UV LEDs, refer to Figures 9, 10, and 11 on Page 10.

• Use the thermistor temperature \( T_{TH} \) to determine the operating current for the chosen application and optimize the thermal design (e.g. selecting a proper heatsink, thermal interface material, etc.) accordingly. For information on how to determine the \( T_{TH} \), refer to Pages 6 to 8.

• Since the absolute maximum junction temperature must not be exceeded under any circumstances, consider the operating conditions/environment that both the system/assembly and the UV LEDs are exposed to when calculating the junction temperature for the chosen application. For information on how to calculate the \( T_J \), refer to Pages 9 and 10.

Figure 3. Temperature positions for \( T_J \) and \( T_{TH} \)
Thermistor Characteristics – $R_{\theta JTH}$ vs. $T_{TH}$

Table 1. Thermistor’s resistance ($R_{\theta JTH}$) vs. temperature ($T_{TH}$) data

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</tr>
</tbody>
</table>

Note:
1. Thermal resistance: $R_{\theta JTH} =$ Thermal resistance from Junction to $T_{TH}$.
2. The B constant is a value representing the $R_{\theta JTH}$ vs. $T_{TH}$ relationship of a thermistor and can be calculated using $R_{\theta JTH}$ values at two given ambient temperatures.

Figure 4. $R_{\theta JTH}$ vs. $T_{TH}$
How to Determine the Thermistor Temperature \( (T_{TH}) \)

There are several methods to determine the \( T_{TH} \). For example,

1. Measuring the resistance value of the thermistor \( (R_2) \) using a multi-meter.
2. Applying a very low pulse current to the thermistor to measure the voltage \( (V_2) \) and calculate the resistance \( (R_2) \).
3. Using a voltage divider circuit energized by a constant voltage power supply and measuring the voltage drop across the thermistor \( (V_2) \) to calculate the \( T_{TH} \).

There are disadvantages to the first two methods: Once the UV LEDs are assembled in a system, it may be difficult or impossible to measure the \( R_2 \) with a multi-meter. Power supplies capable of delivering very low currents are generally expensive. The third method requires neither a multi-meter nor a special low current power supply; it uses a voltage divider circuit instead. Since it is the most useful and practical method, Nichia recommends using the third method and provides the details on how to calculate the \( T_{TH} \) using the third method on the next page.

Definitions of the Symbols used for the Third Method:

- \( V \): Voltage set for the constant voltage power supply defined by \( V = V_1 + V_2 \) (Unit: V)
  - E.g. 5V switch mode power supply (SMPS) manufactured by Cosel USA, Inc.
- \( I \): Current flowing through the circuit defined by \( I = I_1 = I_2 \) (Unit: A)
- \( R \): Combined resistance of the circuit defined by \( R = R_1 + R_2 \) (Unit: \( \Omega \))
- \( V_1 \): Voltage drop across the resistor (Unit: V)
- \( I_1 \): Current flowing through the resistor (Unit: A)
- \( R_1 \): Resistance of the resistor (Unit: \( \Omega \))
  - NOTE: Select a resistor that will ensure that the power consumed by the thermistor is \( \leq 0.3 \text{mW} \). Otherwise, the thermistor produces heat and will adversely affect the calculation result of the \( T_J \).
- \( V_2 \): Voltage drop across the thermistor (i.e. the voltage meter connected with the thermistor in parallel). (Unit: V)
  - NOTE: Measure this value for the chosen application.
- \( I_2 \): Current flowing through the thermistor (Unit: A)
- \( R_2 \): Resistance of the thermistor (Unit: \( \Omega \))
  - NOTE: The NVCUQ096A-D4 UV LEDs have a thermistor with a resistance of 10k\( \Omega \) (typ.)
- \( \delta \): Dissipation constant of the thermistor \( \geq 0.3 \) (Unit: mW/\( ^\circ \text{C} \))
How to Calculate the $T_{TH}$ Using the Voltage Drop Across the Thermistor

Example of calculating the $T_{TH}$

Calculating the $R_2$ using the measured $V_2$. For the definition of the symbols, refer to Page 7.

1. Before applying current to the UV LED, measure the $T_n$ and the $V_2$ and calculate the $R_2$ using equation (2) below (i.e. Ohm’s law).

   $$R_2 = \frac{(V_2 \times R_1)}{(V - V_2)}$$

2. Substitute the $R_2$, $T_n$, and B constant$_{(25-50^\circ C)}$ into equation (3) and solve for $R_{25}$. For the B constant$_{(25-50^\circ C)}$, see page 6.

   $$B\ \text{Constant} = \ln \left( \frac{R_2/R_{25}}{1/T_n - 1/T_{25}} \right)$$

3. Calculate the difference between the calculated $R_{25}$ and the typical $R_{25}$ in Table 1 on page 6 (i.e. 10kΩ) and use this value to draw an offset characteristics curve for the thermistor$^3$.

4. Apply the chosen current to the UV LED and measure the $V_2$ to calculate the $R_2$. Use this value and the offset characteristic curve to determine the $T_{TH}$.

Definitions of the Symbols:

- $R_{25}$: Thermistor Resistance ($R_2$) at $T_A=25^\circ C$
- $T_n$: Ambient temperature of $n^\circ C$ in Kelvin (i.e. $K=n+273.15$)
- $T_{25}$: Absolute temperature of $25^\circ C$ in Kelvin (i.e. $K=25+273.15$)

Figure 6. Example of offset thermistor Characteristic ($R_{BTH}$ vs. $T_{TH}$) curves

Note:

$^3$ This is required to determine an accurate $T_J$ for the chosen application since the characteristics of thermistors can vary for each individual thermistor.
How to Calculate the Junction Temperature (T_J) Using the R_ΘJC

Once the UV LEDs have been attached to a heatsink, it is difficult to measure T_C due to the location of the T_C measurement point. When calculating the junction temperature (T_J) using the R_ΘJC, the temperature of the heatsink (T_M)\(^4\) should be used. Note that this T_J calculation method may require simulation runs using material properties (e.g. thermal conductivity, etc.) of components being used with the UV LEDs in addition to the R_ΘJC values shown below. If this method is not convenient for the chosen application, refer to the method on the next page.

\[ T_J = \text{LED Junction Temperature: } ^\circ\text{C} \]
\[ R_{\ThetaJC} = \text{Thermal resistance from junction to } T_C \]
\[ T_C = \text{Measurement Point: } ^\circ\text{C/W} \]
\[ R_{CMP} = \text{Thermal Resistance of the Heatsink: } ^\circ\text{C/W} \]
\[ T_{MP} = \text{Temperature of the Heatsink} \]

**Figure 7. Cross-sectional diagram of the UV LEDs attached on a heatsink**

**Figure 8. Schematic diagram of the thermal resistance of the UV LEDs when soldered to a heatsink**

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Thermal Resistance</th>
<th>Typical</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>NVCUQ096A/-D4</td>
<td>R_ΘJC</td>
<td>0.026</td>
<td>0.030</td>
<td>°C/W</td>
</tr>
<tr>
<td>NVCUQ072A/-D4</td>
<td></td>
<td>0.030</td>
<td>0.038</td>
<td></td>
</tr>
<tr>
<td>NVCUQ048A/-D4</td>
<td></td>
<td>0.040</td>
<td>0.052</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. R_ΘJC values of the UV LEDs**

**Equation (4)\(^7,8\):**

\[ T_J (^\circ\text{C}) = T_{MP} (^\circ\text{C}) + R_{ΘJMP} (^\circ\text{C/W}) \times \text{Input Power (W)} \]

**Note:**

\(^4\) For water cooling, use the set temperature of the cooling water (i.e. T_W) as the T_M; for air cooling, measure the temperature of the heatsink and use that measurement as the T_M. For information on how to measure the heatsink, consult appropriate literature (e.g. manufacturer’s technical document) or contact the manufacturer directly.

\(^5\) The T_C measurement point is on the back of the ceramic substrate. For more details, see the specification for each UV LED.

\(^6\) If the actual R_M in the chosen system/assembly is not available, consult appropriate literature (e.g. manufacturer’s technical document) or contact the manufacturer directly.

\(^7\) \(R_{ΘJMP} = R_{ΘJC} + R_{CMP}\)

\(^8\) Input Power: \(W = V_F + I_F\)
How to Calculate the Junction Temperature (T_J) Using the R_θJTH

The UV LEDs have thermistors that can be used as temperature sensors. To determine the T_J of the UV LEDs, first measure the temperature of the thermistor (T_{TH}) and it will be possible to calculate the thermal resistance (R_θJTH) with the following data/equations (i.e. equations [5] through [7]) shown in Figures 9 through 11. Then, use all these values (i.e. T_{TH} and R_θJTH), the input power (W), and equation (8) below to calculate the T_J.

Equation (8)^7,8: \[ T_J (°C) = T_{TH} (°C) + R_\theta JTH (°C/W) \times \text{Input Power (W)} \]

Note:
^9 Change in the temperature of the thermistor (T_{TH}): \( \Delta T_{TH} \) = The change in T_{TH} once the T_{TH} has stabilized.
Derating Characteristics

When designing, the derating characteristics (i.e. Thermistor Temperature [$T_{TH}$] vs. Allowable Forward Current [$I_F$]) must be considered. The increase in the temperature of an LED while in operation may vary depending on the heatsink’s thermal resistance and the density of LEDs in the system/assembly. Ensure that when using the LEDs for the chosen application, heat is not concentrated in an area and properly managed in the system/assembly to ensure the derating characteristics during actual use.

Figure 12. Derating characteristics (i.e. $T_{TH}$ vs. allowable $I_F$) for the NVCUQ096A/-D4 UV LEDs

Figure 13. Derating characteristics (i.e. $T_{TH}$ vs. allowable $I_F$) for the NVCUQ072A/-D4 UV LEDs

Figure 14. Derating characteristics (i.e. $T_{TH}$ vs. allowable $I_F$) for the NVCUQ048A/-D4 UV LEDs
Precautions Against Condensation

- When using the UV LEDs, do not design them into applications where condensation may occur. If the UV LEDs are stored/operated in these environments, it may cause issues (e.g. current leaks that cause the radiant flux to decrease).

- Cautions for use with a water cooling system:
  If the water temperature is lower than the ambient temperature, it may cause condensation on both the outer and inner surfaces of the UV LED and its surrounding surfaces. Adjust the water temperature to suit the operating environment (i.e. temperature and humidity) to prevent condensation from occurring.

- Example:
  The water jacket surrounding the assembly/system may be covered with dew when used under the following conditions:

  Water temperature: \( \leq 26^\circ C \)
  Ambient temperature \( (T_A) \): \( 30^\circ C \)
  Relative humidity (RH): \( 80\% \)

  Note:
  \(^{10}\) The actual amount of water vapor in the air (i.e. absolute humidity) can be calculated to be 24g/m\(^3\) with the \( T_A \) and RH values.

  Figure 15. Saturated vapor density
Cautions/Suggestions for Attaching the UV LEDs to a Heatsink

• If there are issues with the contact surface of the heatsink (i.e. uneven surface, hole/recess, burr/flash, etc.), it may significantly reduce the thermal conductivity.

• If there are issues with the thermal interface material (e.g. insufficient coverage, excessive thickness, etc.), it may cause heat not to sufficiently transfer to the heatsink and in some cases, damage to the UV LEDs. Additionally, excessively thick thermal films/sheets are more likely to lead to assembly issues (e.g. damage to the ceramic substrate) when excessive pressure is applied to the UV LEDs. Nichia recommends using thermal grease.

• If the heatsink has a foreign material and/or burr/flash on the contact surface as indicated in Figure 16-I and Figure 16-J, there is a possibility that the UV LED may be damaged when attaching it to this heatsink, even if the tightening torque is below the range indicated on Page 17.

• For more issues with the heatsink/thermal interface material, refer to Figures 16-A through 16-J below.

Figure 16. Correct/incorrect application of thermal grease between the UV LED and heatsink
How to Apply Thermal Grease

• Ensure that thermal grease is applied evenly and in an adequate amount (see Correct example in Figure 18 below).
  ◦ If the amount is too low – especially if it does not fully cover the back side of the emission area of the UV LEDs (see Incorrect example in Figure 18 below), heat from the UV LED die may not be efficiently dissipated.
  ◦ If the amount is too high, the excess thermal grease may contaminate the UV LED’s top surface causing the output power to decrease.

![Figure 17. Stencil mask aperture pattern](image)

![Correct example](image)

![Incorrect example](image)

Figure 18. Thermal grease applied to the back of the UV LEDs

• To determine the procedure/conditions for applying the thermal grease (e.g. stencil design, volume, etc.), perform sufficient verification on the chosen system fully assembled with all parts/materials properly in place. If the thermal grease has been applied incorrectly, it may significantly affect the amount of change in the resistance value of the thermistor (i.e. the relationship of the input current vs. thermistor’s resistance); check the thermistor’s resistance against the design value when operating the UV LEDs at the chosen input current. Additionally, if the chosen design uses multiple UV LEDs on a heatsink, ensure that there is no significant difference in temperature between the UV LEDs.

**Recommended resistance value:** ≥ 3kΩ at $T_A \leq 60^\circ$C

**Recommended temperature range:** ≤ 10°C

Note:

11 The thermal grease stencil mask is designed and used only for Nichia’s evaluation of the NVCUQ096A/-D4, NVCUQ072A/-D4, and NVCUQ048A/-D4 UV LEDs. The specifications for the thermal grease/stencil mask are provided for reference purposes only.
Example of a UV LED Failure Caused by Thermal Grease

Nichia has observed a UV LED failure during a developmental reliability test caused by improper application of thermal grease.

**Test Conditions:**
- P/N: NVCUQ096A, Wavelength rank: U365, Operating conditions: \( T_A = 25^\circ C, T_W^{12} = 30^\circ C, I_F = 8.8A^{13} \)

**Failure Description/Findings:**
- After 100 hours of operation, a UV LED failed to illuminate and the ceramic package was damaged in the lower half of the emission area (see Figure 19 below). Further observation revealed that the thermal grease was uneven/inconsistent in thickness in this area (see Figure 20 below).

**Conclusion:**
- The UV LED failure was caused by improper application of thermal grease. This caused the UV LED to become extremely hot causing the ceramic package to be damaged and the UV LED not to illuminate.

Nichia has performed an evaluation to determine whether the thermistor temperature \( T_{TH} \) can be used as an effective indicator for the issue. Refer to the next page for details.

---

**Note:**
12 \( T_W \) = Temperature of the water in the water-cooled chiller used in the evaluation.
13 The absolute maximum current value for the NVCUQ096A/-D4 UV LEDs.

---

Figure 19. UV LED after operating the UV LED

The red lines indicate damage to the ceramic substrate

Figure 20. UV LED before operating the UV LED

The area highlighted in a blue box indicates where thermal grease was uneven/inconsistent in thickness
Evaluation for Temperature Distributions

To determine if the thermistor temperature \( T_{TH} \) represents how evenly or unevenly applied the thermal grease is, Nichia has performed an evaluation under the following conditions. To verify the \( T_{TH} \), a thermal imaging camera was used.

**Evaluation Conditions:**
- P/N: NVCUQ096A, Wavelength rank: U365, Operating conditions: \( T_A=25^°C \), \( T_W=25^°C \), \( I_F=8A \)

**Evaluation Results:**
- When an uneven application of thermal grease occurred only in the upper half of the emission area, the \( T_{TH} \) was very similar to the \( T_{TH} \) for the UV LED with an even application (i.e. \( T_{TH}=46^°C \)). See Figures 21 through 23 below.
- However, the thermal imaging camera showed that the first UV LED (i.e. with an uneven application of thermal grease) had a temperature difference of approx. 60°C between the upper and lower half area.

**Conclusions/Recommendations:**
- If an uneven application of thermal grease occurs in areas away from the thermistor position, it will not be detected by the thermistor.
- Sufficient verification should be performed (e.g. using a thermal imaging camera) to ensure an even and consistent application of thermal grease.

---

**Figure 21.** Thermal grease applied with an appropriate stencil mask (upper) and a thermal image of this UV LED in operation (lower)

- Virtually no difference in the temperature between the upper and lower emission area.
- \( T_{TH} \approx 46°C \)

**Figure 22.** Thermal grease applied only in the lower half of the emission area (upper) and a thermal image of this UV LED in operation (lower)

- Difference in the temperature between the upper and lower emission area \( \approx 60°C \).
- \( T_{TH} \approx 46°C \)

**Figure 23.** Thermal grease applied only in the upper half of the emission area (upper) and a thermal image of this UV LED in operation (lower)

- Difference in the temperature between the upper and lower emission area \( \approx 50°C \).
- \( T_{TH} \approx 95°C \)

---
Recommended Tightening Torques

Nichia has performed a tightening torque test for the UV LEDs and confirmed that there are no issues with the following conditions:

- **Recommended screw:** M3 steel pan-head screw
- **Recommended tightening torque range:** 0.25 to 0.60N·m

### Table 3. Results of a tightening torque test

<table>
<thead>
<tr>
<th>Appearance</th>
<th>Thermal Interface Material</th>
<th>Tightening Torque (N·m)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Grease</td>
<td></td>
<td>30cN·m (0.30N·m)</td>
<td>No issue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35cN·m (0.35N·m)</td>
<td>No issue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40cN·m (0.40N·m)</td>
<td>No issue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45cN·m (0.45N·m)</td>
<td>No issue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50cN·m (0.50N·m)</td>
<td>No issue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55cN·m (0.55N·m)</td>
<td>No issue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60cN·m (0.60N·m)</td>
<td>No issue</td>
</tr>
</tbody>
</table>

### Table 4. Tightening torques by screw type

<table>
<thead>
<tr>
<th>Material</th>
<th>Strength Grade</th>
<th>Type of Head</th>
<th>M2</th>
<th>M2.6</th>
<th>M3</th>
<th>M4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>4.6</td>
<td>Pan-head</td>
<td>0.12</td>
<td>0.25</td>
<td>0.43</td>
<td>0.98</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>A2 - 50</td>
<td>Pan-head</td>
<td>0.11</td>
<td>0.22</td>
<td>0.37</td>
<td>0.87</td>
</tr>
<tr>
<td>Brace</td>
<td>—</td>
<td>Pan-head</td>
<td>0.09</td>
<td>0.18</td>
<td>0.28</td>
<td>0.74</td>
</tr>
</tbody>
</table>

**Cautions/Suggestions:**

- Use the test results/data presented above for reference purposes only. Nichia strongly recommends performing a verification to ensure the optimal tightening torque for the chosen application.
  - If the tightening torque is too low, it may cause issues with heat dissipation.
  - If the tightening torque is too high, it may cause the ceramic substrate to be damaged.
  - The optimal tightening torque varies depending on the material of the screw being used.

**Note:**

14 The tightening torque values are only typical values and are not the specification values for the indicated screws.
Recommended Screw Tightening Order

- The diameter of the reference screw hole (i.e. screw hole circled in red in Figure 25 below) is designed to be smaller than those of the other holes (i.e. screw holes circled in light blue in Figure 25 below) to ensure that the reference screw is easy to identify.

**Screw hole diameters:**
- Reference screw hole: $\phi$ 3.2cm
- Screw holes: $\phi$ 3.6cm

- The screw holes are designed with a larger tolerance for easy insertion when attaching the UV LEDs to a heatsink and the aligning holes for the assembly. However, if the first screw is tightened in one of the three larger screw holes before the screw is tightened in the reference screw hole, it may cause the UV LED to move resulting in a misalignment between the reference screw hole and the hole in the heatsink; in some cases, this could cause the ceramic substrate to be damaged (see Figure 24 below). Ensure that when attaching the UV LEDs to a heatsink, tighten the screw in the reference screw hole first.

- Nichia recommends tightening the screws in the order indicated by the arrows in Figure 25.

*Figure 24. Example of damage to the ceramic substrate*

*Figure 25. Screw hole positions*
Precautions for Using Washers/Spring Washers

When tightening a screw with a washer/spring lock washer (a.k.a. split washer, spring lock washer), ensure that it does not damage the ceramic substrate.

Nichia has performed an evaluation test and confirmed that:
- if a M3 screw is secured using both a spring washer and washer, it does not damage the ceramic substrate.
- if the washer diameter is \( \varnothing 7 \) mm, it can touch the solder joints of the connecting device.

Based on reports from customers, Nichia is aware that:
- if a screw is secured only using a spring washer without a washer under it, it can damage the ceramic substrate.

Cautions/Suggestions:
- **Washer size:**
  - If the washer touches the solder joints of the connecting device, it may cause serious injury or death (e.g. electrical shock). Nichia has confirmed that washers with a diameter of \( \varnothing 6 \) mm did not cause this issue.

- **Use of spring washers:**
  - Spring washers are shaped like a spiral and one of the edges is raised to create resistance to rotation. This may cause excessive force on the ceramic substrate when a washer is not used with the spring washer. Ensure that spring washers are used properly with washers.

Figure 26. Example of using a spring washer and \( \varnothing 6 \) mm washer

Figure 27. Example of using a spring washer and \( \varnothing 7 \) mm washer

Figure 28. Example of using a spring washer without a washer

The \( \varnothing 7 \) mm washer is in contact with the solder joints of the connecting device.
Assembly/Handling Precautions for the NVCUQ048A/072A/096A(-D4) UV LEDs

Assembly Precautions
- Ensure that the nozzle does not come in contact with the lens when it picks up the UV LED. If this occurs, it may cause damage to the lens (e.g. cuts, scratches, chips, cracks, delamination, and deformation) and the wire to break causing a catastrophic failure (i.e. the UV LED not to illuminate).
- The nozzle should only touch the ceramic substrate to hold the UV LED.

Handling Precautions with Tweezers
- Nichia recommends using special tweezers (e.g. vacuum tweezers) to handle the UV LEDs. However, use care to ensure:
  - the tweezers do not touch the lens,
  - excessive force is not applied to the UV LED.
- Otherwise, it may cause damage to the lens and/or the ceramic substrate (e.g. cuts, scratches, chips, cracks, delamination, and deformation) and the wire to break causing a catastrophic failure (i.e. the UV LED not to illuminate).

Handling Precautions with Bare hands
- Do not handle the UV LEDs with bare hands:
  - this may contaminate the UV LED surface and have an effect on the optical characteristics,
  - the lens may cause injuries since the edges are sharp.
- Dropping may cause damage to the lens, ceramic substrate, and in some cases the internal wires causing a catastrophic failure (i.e. the UV LED not to illuminate).

Handling Precautions with Tweezers
- Nichia recommends using special tweezers (e.g. vacuum tweezers) to handle the UV LEDs. However, use care to ensure:
  - the tweezers do not touch the lens,
  - excessive force is not applied to the UV LED.

Handling Precautions with Bare hands
- Do not handle the UV LEDs with bare hands:
  - this may contaminate the UV LED surface and have an effect on the optical characteristics,
  - the lens may cause injuries since the edges are sharp.
- Dropping may cause damage to the lens, ceramic substrate, and in some cases the internal wires causing a catastrophic failure (i.e. the UV LED not to illuminate).

Miscellaneous
- Do not stack the UV LEDs on top of one another, regardless of whether the UV LEDs are attached to heatsinks or not. Otherwise, it may cause damage to the lens and the ceramic substrate (e.g. cuts, scratches, chips, cracks, delamination, and deformation) and the wire to break causing a catastrophic failure (i.e. the UV LED not to illuminate).

CAUTION: Do not allow the nozzle to touch the lens.
CAUTION: Ensure that the tweezers do not damage the LED (e.g. lens).
CAUTION: Do not handle the UV LEDs with bare hands.
CAUTION: Do not drop. Handle with care.
CAUTION: Do not stack the UV LEDs on top each other.
How to Insert/Remove a Socket Connector

Inserting a socket connector

1. Place the socket connector on the connecting device for initial positioning.

2. Push down the socket connector until it is inserted correctly.

3. If the socket connector is successfully inserted, a click is heard.

Removing the socket connector

1. Hold the protruding edge portion indicated to the left (i.e. lever).

2. Pull it up to disengage the snap-fits closer to the lever side.

3. Pull it up further until the reinforced snap-fits are fully disengaged.

Cautions when removing the socket connector:

- Do not pull the cables as it may damage the socket connector, the header, and/or the UV LED.
- Do not remove the socket connector from the cable side as it will not disengage the snap-fits. Doing so may damage the socket connector, the header and/or the UV LED.

Note:

15 P/N: DF65-4P/6P manufactured by Hirose Electric Co. Ltd.
Precautions When Using UV LEDs in a Parallel Circuit

- Nichia performed a simulation with the following conditions and method to determine the effect of connecting the UV LEDs in parallel (i.e. current divider circuit).

- **Simulated Conditions:**
  - Part Number: NVCUQ096A
  - Wavelength rank: U365
  - Junction temp.: $T_J=25^\circ C$, $85^\circ C$, $130^\circ C$
  - Input current: $I_F=16A$ (i.e. $I_F=8A^{16}$ for each LED, both driven by a power supply)

- **Simulation Method:**
  - Two UV LEDs$^{17}$ were connected in parallel and driven by a power supply at $I_F=16A$ to calculate the difference in current between the two UV LEDs.

- **Simulation Result:**
  - When the UV LED with a forward voltage ($V_F$) of 44V was connected with another with a 1V higher $V_F$ in parallel, the current was split between them (i.e. current division) and the current flowing through the first one (i.e. due to its lower $V_F$) exceeded the absolute maximum rating (i.e. 8.8A).

- **Cautions/Suggestions:**
  - Nichia recommends designing the circuit to ensure that each UV LED is driven by a separate power supply.
  - If the chosen application uses the UV LEDs in a parallel circuit, sufficient verification should be performed to ensure that there are no issues (e.g. exceeding the absolute maximum current due to parallel connection as shown above). If technical assistance is required or specific issues arise during verification, contact a local sales representative.
  - This simulation and its results are for reference purposes only.

---

**Note:**

$^{16}$ $I_F=8A$ is the sorting current of the NVCUQ096A UV LEDs.

$^{17}$ The $V_F$ of one of these UV LEDs was set as 44V and the $V_F$ of the other one was set as 44V to 46V. The $V_F$ value 44V was used as a reference to calculate the difference in current between the two UV LEDs.
Peak Irradiance Measurement of a UV Irradiator (NVCUQ096A/-D4)

- Nichia performed a measurement of a UV irradiator using the NVCUQ096A-D4 UV LEDs. For the details of the measurement conditions and the internal circuit diagram, refer to the following information. For the measurement results, refer to Pages 24 through 27.

![Figure 32. Measured UV irradiator](image)

**UV Irradiator Specifications:**
- Number or units: 4 UV irradiators
- Size of the emitting area: 20 x 100mm

Unit 1: 4 NVCUQ096A (U365) LEDs, Radiant flux: Avg. 144W
Unit 2: 4 NVCUQ096A (U385) LEDs, Radiant flux: Avg. 160W
Unit 3: 4 NVCUQ096A-D4 (U365) LEDs, Radiant flux: Avg. 128W
Unit 4: 4 NVCUQ096A-D4 (U385) LEDs, Radiant flux: Avg. 155W

**Water Cooling System Specifications:**
- Copper heatsink: HS-C120 (manufactured by Kawaso Texcel Co., Ltd.)
- Thermal grease: TC-5622 (manufactured by Dow Corning Toray Co., Ltd.)
- Tube Diameter: 10mm (inner), 12mm (outer)
- Chiller: PCU-1610R (manufactured by Apiste Corporation)

**Note:**
- Each UV LED has two internal circuits; each internal circuit has four arrays connected in parallel, each with 12 LED die connected in series.
- Each unit was assembled with 4 UV LEDs from the same wavelength rank.
- Size of the area highlighted by the dashed red box in Figure 30.
- Values measured at $T_A=25^\circ C$, $I_0=8A$.
- Chilled water temperature $T_W=25^\circ C$, water flow rate=5L/min.
Peak Irradiance Measurement of a UV Irradiator - Results (Unit 1)

- The following results shown in Figure 34 below were obtained from the measurement of a UV irradiator using U365 NVCUQ096A UV LEDs\textsuperscript{23}. For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 5. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 23. For information on how to calculate the $T_J$, see Pages 9 and 10.

Table 5. Current vs. temperature ($T_{TH}/T_J$) data

<table>
<thead>
<tr>
<th>Current per LED Die\textsuperscript{24} [mA]</th>
<th>Thermistor Temp.\textsuperscript{25} [$^\circ$C]</th>
<th>Junction Temp.\textsuperscript{25} [$^\circ$C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 [mA]</td>
<td>30.7</td>
<td>34.2</td>
</tr>
<tr>
<td>500 [mA]</td>
<td>37.1</td>
<td>44.6</td>
</tr>
<tr>
<td>1000 [mA]</td>
<td>51.6</td>
<td>67.6</td>
</tr>
</tbody>
</table>

\textsuperscript{23} The measurement was performed with the UV Power Puck® II (manufactured by Electronic Instrumentation & Technology, Inc.).

\textsuperscript{24} The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same $V_F$.

\textsuperscript{25} Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.
Peak Irradiance Measurement of a UV Irradiator - Results (Unit 2)

- The following results shown in Figure 36 below were obtained from the measurement of a UV irradiator using U385 NVCUQ096A UV LEDs. For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 6. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 23. For information on how to calculate the $T_J$, see Pages 9 and 10.

Table 6. Current vs. temperature ($T_{TH}/T_J$) data

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>250 mA per die</td>
<td>29.8 °C</td>
<td>33.1 °C</td>
</tr>
<tr>
<td>500 mA per die</td>
<td>35.2 °C</td>
<td>42.1 °C</td>
</tr>
<tr>
<td>1000 mA per die</td>
<td>47.6 °C</td>
<td>62.3 °C</td>
</tr>
</tbody>
</table>

Figure 36. Peak irradiance vs. working distance by Current

Figure 37. Definition for the working distance (WD)

Note:

26 The measurement was performed with the UV Power Puck® II (manufactured by Electronic Instrumentation & Technology, Inc.).
27 The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same $V_F$.
28 Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.
Peak Irradiance Measurement of a UV Irradiator - Results (Unit 3)

- The following results shown in Figure 38 below were obtained from the measurement of a UV irradiator using U365 NVCUQ096A-D4 UV LEDs. For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 7. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 23. For information on how to calculate the $T_J$, see Pages 9 and 10.

<table>
<thead>
<tr>
<th>Current per LED Die $^\text{30}$ [mA]</th>
<th>Thermistor Temp. $^\text{31}$ [$^\circ$C]</th>
<th>Junction Temp. $^\text{31}$ [$^\circ$C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>29.2</td>
<td>32.8</td>
</tr>
<tr>
<td>500</td>
<td>35.9</td>
<td>43.5</td>
</tr>
<tr>
<td>1000</td>
<td>50.4</td>
<td>66.6</td>
</tr>
</tbody>
</table>

Table 7. Current vs. temperature ($T_{TH}/T_J$) data

- The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same $V_F$.
- Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.

Note:

29 The measurement was performed with the UV Power Puck® II (manufactured by Electronic Instrumentation & Technology, Inc.). Since the measurement equipment is only capable of reading up to 20W/cm$^2$, the measurement results shown in Figure 38 include both data based on actual readings (i.e. solid line) and estimated readings (i.e. dashed line).
30 The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same $V_F$.
31 Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.
The following results shown in Figure 40 below were obtained from the measurement of a UV irradiator using U385 NVCUQ096A-D4 UV LEDs. For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 8. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 23. For information on how to calculate the $T_J$, see Pages 9 and 10.

Note:
32 The measurement was performed with the UV Power Puck® II (manufactured by Electronic Instrumentation & Technology, Inc.). Since the measurement equipment is only capable of reading up to 20W/cm², the measurement results shown in Figure 40 include both data based on actual readings (i.e. solid line) and estimated readings (i.e. dashed line).
33 The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same $V_F$.
34 Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.
Peak Irradiance Measurement of a UV Irradiator (NVCUQ072A/-D4)

- Nichia performed a measurement of a UV irradiator using the NVCUQ072A-D4 UV LEDs. For the details of the measurement conditions and the internal circuit diagram, refer to the following information. For the measurement results, refer to Pages 29 through 32.

![Figure 42. Measured UV irradiator](image)

![Figure 43. UV LED’s internal circuit diagram](image)

**UV Irradiator Specifications:**
- Number or units: 4 UV irradiators
- Size of the emitting area: 20 x 100mm

<table>
<thead>
<tr>
<th>Unit</th>
<th>Number of LEDs</th>
<th>Radiant flux</th>
<th>Avg. value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>4 NVCUQ072A (U365) LEDs</td>
<td>103W</td>
<td>103W</td>
</tr>
<tr>
<td>6</td>
<td>4 NVCUQ072A (U385) LEDs</td>
<td>128W</td>
<td>128W</td>
</tr>
<tr>
<td>7</td>
<td>4 NVCUQ072A-D4 (U365) LEDs</td>
<td>93W</td>
<td>93W</td>
</tr>
<tr>
<td>8</td>
<td>4 NVCUQ072A-D4 (U385) LEDs</td>
<td>109W</td>
<td>109W</td>
</tr>
</tbody>
</table>

**Water Cooling System Specifications:**
- Copper heatsink: HS-C120 (manufactured by Kawaso Texcel Co., Ltd.)
- Thermal grease: TC-5622 (manufactured by Dow Corning Toray Co., Ltd.)
- Tube Diameter: 10mm (inner), 12mm (outer)
- Chiller: PCU-1610R (manufactured by Apiste Corporation)

**Note:**
35 Each UV LED has two internal circuits; each internal circuit has three arrays connected in parallel, each with 12 LED die connected in series.
36 Each unit was assembled with 4 UV LEDs from the same wavelength rank.
37 Size of the area highlighted by the dashed red box in Figure 30.
38 Values measured at $T_A=25^\circ C$, $I_F=6A$.
39 Chilled water temperature $T_W=25^\circ C$, water flow rate=5L/min.
Peak Irradiance Measurement of a UV Irradiator - Results (Unit 5)

• The following results shown in Figure 44 below were obtained from the measurement of a UV irradiator using U365 NVCUQ072A UV LEDs\textsuperscript{40}. For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 9. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 28. For information on how to calculate the $T_J$, see Pages 9 and 10.

![Figure 44. Peak irradiance vs. working distance by Current\textsuperscript{35}](image)

Table 9. Current vs. temperature ($T_{TH}/T_J$) data

<table>
<thead>
<tr>
<th>Current per LED Die\textsuperscript{41} [mA]</th>
<th>Thermistor Temp.\textsuperscript{42} [$^\circ$C]</th>
<th>Junction Temp.\textsuperscript{42} [$^\circ$C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>28.0</td>
<td>33.1</td>
</tr>
<tr>
<td>500</td>
<td>31.6</td>
<td>42.3</td>
</tr>
<tr>
<td>1000</td>
<td>39.8</td>
<td>62.6</td>
</tr>
</tbody>
</table>

![Figure 45. Definition for the working distance (WD)](image)

Note:

\textsuperscript{40} The measurement was performed with the UV Power Puck\textsuperscript{®} II (manufactured by Electronic Instrumentation & Technology, Inc.).

\textsuperscript{41} The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same $V_F$.

\textsuperscript{42} Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.
Peak Irradiance Measurement of a UV Irradiator - Results (Unit 6)

- The following results shown in Figure 46 below were obtained from the measurement of a UV irradiator using U385 NVCUQ072A UV LEDs\(^{43}\). For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 10. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 28. For information on how to calculate the \(T_J\), see Pages 9 and 10.

![Figure 46. Peak irradiance vs. working distance by Current\(^{38}\)](image)

<table>
<thead>
<tr>
<th>Working Distance (mm)</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Irradiance (W/cm(^2))</td>
<td>40</td>
<td>35</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

- The measurement was performed with the UV Power Puck\(^{\circledR}\) II (manufactured by Electronic Instrumentation & Technology, Inc.).

- The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same \(V_F\).

- Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.

**Table 10. Current vs. temperature \((T_{TH}/T_J)\) data**

<table>
<thead>
<tr>
<th>Current per LED Die(^{44}) [mA]</th>
<th>Thermistor Temp(^{45}) [°C]</th>
<th>Junction Temp.(^{45}) [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>27.5</td>
<td>32.3</td>
</tr>
<tr>
<td>500</td>
<td>30.6</td>
<td>40.7</td>
</tr>
<tr>
<td>1000</td>
<td>37.9</td>
<td>59.6</td>
</tr>
</tbody>
</table>

**Figure 47. Definition for the working distance (WD)**

WD=0mm was set at the same level as the UV LED assembly (i.e. heatsink) surface.

\(^{43}\) The measurement was performed with the UV Power Puck\(^{\circledR}\) II (manufactured by Electronic Instrumentation & Technology, Inc.).

\(^{44}\) The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same \(V_F\).

\(^{45}\) Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.
Peak Irradiance Measurement of a UV Irradiator - Results (Unit 7)

The following results shown in Figure 48 below were obtained from the measurement of a UV irradiator using U365 NVCUQ072A-D4 UV LEDs\(^ {46}\). For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 11. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 28. For information on how to calculate the \( T_J \), see Pages 9 and 10.

Table 11. Current vs. temperature (\( T_{TH}/T_J \)) data

<table>
<thead>
<tr>
<th>Current per LED Die(^ {47}) [mA]</th>
<th>Thermistor Temp.(^ {48}) [°C]</th>
<th>Junction Temp.(^ {48}) [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>28.5</td>
<td>33.8</td>
</tr>
<tr>
<td>500</td>
<td>32.4</td>
<td>43.3</td>
</tr>
<tr>
<td>1000</td>
<td>41.4</td>
<td>64.7</td>
</tr>
</tbody>
</table>

Figure 48. Peak irradiance vs. working distance by Current\(^ {41}\)

Figure 49. Definition for the working distance (WD)

Note:

\(^ {46}\) The measurement was performed with the UV Power Puck® II (manufactured by Electronic Instrumentation & Technology, Inc.). Since the measurement equipment is only capable of reading up to 20W/cm\(^2\), the measurement results shown in Figure 48 include both data based on actual readings (i.e. solid line) and estimated readings (i.e. dashed line).

\(^ {47}\) The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same \( V_F \).

\(^ {48}\) Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.
Peak Irradiance Measurement of a UV Irradiator - Results (Unit 8)

- The following results shown in Figure 50 below were obtained from the measurement of a UV irradiator using U385 NVCUQ072A-D4 UV LEDs\(^{49}\). For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 12. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 28. For information on how to calculate the \(T_J\), see Pages 9 and 10.

### Table 12. Current vs. temperature (\(T_{TH}/T_J\)) data

<table>
<thead>
<tr>
<th>Current per LED Die (^{50}) [mA]</th>
<th>Thermistor Temp. (^{51}) [°C]</th>
<th>Junction Temp. (^{51}) [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>28.1</td>
<td>33.1</td>
</tr>
<tr>
<td>500</td>
<td>31.6</td>
<td>42.1</td>
</tr>
<tr>
<td>1000</td>
<td>39.7</td>
<td>61.8</td>
</tr>
</tbody>
</table>

**Figure 50. Peak irradiance vs. working distance by Current\(^{44}\)**

**Figure 51. Definition for the working distance (WD)**

---

**Note:**

\(^{49}\) The measurement was performed with the UV Power Puck® II (manufactured by Electronic Instrumentation & Technology, Inc.). Since the measurement equipment is only capable of reading up to 20W/cm\(^2\), the measurement results shown in Figure 50 include both data based on actual readings (i.e. solid line) and estimated readings (i.e. dashed line).

\(^{50}\) The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same \(V_F\).

\(^{51}\) Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.
Peak Irradiance Measurement of a UV Irradiator (NVCUQ048A/-D4)

- Nichia performed a measurement of a UV irradiator using the NVCUQ048A-D4 UV LEDs. For the details of the measurement conditions and the internal circuit diagram, refer to the following information. For the measurement results, refer to Pages 34 through 37.

![Figure 52. Measured UV irradiator](image)

**Figure 52. Measured UV irradiator**

**UV Irradiator Specifications:**
- Number of units: 4 UV irradiators
- Size of the emitting area: 20 x 100mm

<table>
<thead>
<tr>
<th>Unit</th>
<th>Description</th>
<th>Radiant Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>4 NVCUQ048A (U365) LEDs</td>
<td>Avg. 68W</td>
</tr>
<tr>
<td>10</td>
<td>4 NVCUQ048A (U385) LEDs</td>
<td>Avg. 79W</td>
</tr>
<tr>
<td>11</td>
<td>4 NVCUQ048A-D4 (U365) LEDs</td>
<td>Avg. 62W</td>
</tr>
<tr>
<td>12</td>
<td>4 NVCUQ048A-D4 (U385) LEDs</td>
<td>Avg. 72W</td>
</tr>
</tbody>
</table>

**Water Cooling System Specifications:**
- Copper heatsink: HS-C120 (manufactured by Kawaso Texcel Co., Ltd.)
- Thermal grease: TC-5622 (manufactured by Dow Corning Toray Co., Ltd.)
- Tube Diameter: 10mm (inner), 12mm (outer)
- Chiller: PCU-1610R (manufactured by Apiste Corporation)

**Note:**
- Each UV LED has two internal circuits; each internal circuit has two arrays connected in parallel, each with 12 LED die connected in series.
- Each unit was assembled with 4 UV LEDs from the same wavelength rank.
- Size of the area highlighted by the dashed red box in Figure 30.
- Values measured at $T_A=25^\circ\text{C}$, $I_L=4\text{A}$.
- Chilled water temperature $T_W=25^\circ\text{C}$, water flow rate=5L/min.
Peak Irradiance Measurement of a UV Irradiator - Results (Unit 9)

- The following results shown in Figure 54 below were obtained from the measurement of a UV irradiator using U365 NVCUQ048A UV LEDs\textsuperscript{57}. For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 13. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 33. For information on how to calculate the $T_J$, see Pages 9 and 10.

![Graph showing peak irradiance vs. working distance by Current](image)

**Figure 54. Peak irradiance vs. working distance by Current\textsuperscript{52}**

**Table 13. Current vs. temperature ($T_{TH}/T_J$) data**

<table>
<thead>
<tr>
<th>Current per LED Die\textsuperscript{58} [mA]</th>
<th>Thermistor Temp.\textsuperscript{59} [$°C$]</th>
<th>Junction Temp.\textsuperscript{59} [$°C$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>26.4</td>
<td>30.8</td>
</tr>
<tr>
<td>500</td>
<td>29.1</td>
<td>38.5</td>
</tr>
<tr>
<td>1000</td>
<td>34.2</td>
<td>54.1</td>
</tr>
</tbody>
</table>

**Figure 55. Definition for the working distance (WD)**

**Note:**

\textsuperscript{57} The measurement was performed with the UV Power Puck\textsuperscript{®} II (manufactured by Electronic Instrumentation & Technology, Inc.).

\textsuperscript{58} The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same $V_F$.

\textsuperscript{59} Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.
Peak Irradiance Measurement of a UV Irradiator - Results (Unit 10)

- The following results shown in Figure 56 below were obtained from the measurement of a UV irradiator using U385 NVCUQ048A UV LEDs\textsuperscript{60}. For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 14. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 33. For information on how to calculate the $T_J$, see Pages 9 and 10.

![Graph showing peak irradiance vs. working distance by Current](image_url)

Table 14. Current vs. temperature ($T_{TH}/T_J$) data

<table>
<thead>
<tr>
<th>Current per LED Die\textsuperscript{61} [mA]</th>
<th>Thermistor Temp.\textsuperscript{62} [°C]</th>
<th>Junction Temp.\textsuperscript{62} [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>26.4</td>
<td>30.7</td>
</tr>
<tr>
<td>500</td>
<td>28.3</td>
<td>37.2</td>
</tr>
<tr>
<td>1000</td>
<td>32.7</td>
<td>51.8</td>
</tr>
</tbody>
</table>

Note:

\textsuperscript{60} The measurement was performed with the UV Power Puck® II (manufactured by Electronic Instrumentation & Technology, Inc.).

\textsuperscript{61} The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same $V_F$.

\textsuperscript{62} Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.
Peak Irradiance Measurement of a UV Irradiator - Results (Unit 11)

The following results shown in Figure 58 below were obtained from the measurement of a UV irradiator using U365 NVCU048A-D4 UV LEDs\(^{63}\). For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 15. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 33. For information on how to calculate the \(T_J\), see Pages 9 and 10.

<table>
<thead>
<tr>
<th>Current per LED Die ([\text{mA}])</th>
<th>Thermistor Temp. ([\text{°C}])</th>
<th>Junction Temp. ([\text{°C}])</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>27.1</td>
<td>31.6</td>
</tr>
<tr>
<td>500</td>
<td>29.3</td>
<td>38.7</td>
</tr>
<tr>
<td>1000</td>
<td>34.6</td>
<td>54.6</td>
</tr>
</tbody>
</table>

Table 15. Current vs. temperature \(\left(\frac{T_{TH}}{T_J}\right)\) data

Note:

\(^{63}\) The measurement was performed with the UV Power Puck® II (manufactured by Electronic Instrumentation & Technology, Inc.).

\(^{64}\) The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same \(V_F\).

\(^{65}\) Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.
The following results shown in Figure 60 below were obtained from the measurement of a UV irradiator using U385 NVCU048A-D4 UV LEDs. For the temperature data of the UV irradiator with the heat dissipation conditions used, refer to Table 16. For the details of the UV irradiator specifications and heat dissipation conditions used in the measurement, see Page 33. For information on how to calculate the T_J, see Pages 9 and 10.

Table 16. Current vs. temperature (T_TH/T_J) data

<table>
<thead>
<tr>
<th>Current per LED Die [mA]</th>
<th>Thermistor Temp. [°C]</th>
<th>Junction Temp. [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>26.8</td>
<td>31.2</td>
</tr>
<tr>
<td>500</td>
<td>28.9</td>
<td>38.0</td>
</tr>
<tr>
<td>1000</td>
<td>33.9</td>
<td>53.3</td>
</tr>
</tbody>
</table>

Figure 60. Peak irradiance vs. working distance by Current

Figure 61. Definition for the working distance (WD)

Note:

66 The measurement was performed with the UV Power Puck® II (manufactured by Electronic Instrumentation & Technology, Inc.).
67 The current values per LED die were calculated based on the current value input to the measured UV LEDs assuming the UV LED consists only of LED die with the same V_F.
68 Both the thermistor temperatures and the junction temperatures are average values of the four UV LEDs used in the measured UV irradiator.