NUD4001, NSVD4001

High Current LED Driver

This device is designed to replace discrete solutions for driving LEDs in low voltage AC–DC applications 5.0 V, 12 V or 24 V. An external resistor allows the circuit designer to set the drive current for different LED arrays. This discrete integration technology eliminates individual components by combining them into a single package, which results in a significant reduction of both system cost and board space. The device is a small surface mount package (SO–8).

Features
- Supplies Constant LED Current for Varying Input Voltages
- External Resistor Allows Designer to Set Current – up to 500 mA
- Offered in Surface Mount Package Technology (SO–8)
- AEC–Q101 Qualified and PPAP Capable
- NSV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements
- Pb–Free Package is Available

Benefits
- Maintains a Constant Light Output During Battery Drain
- One Device can be used for Many Different LED Products
- Reduces Board Space and Component Count
- Simplifies Circuit and System Designs

Typical Applications
- Portables: For Battery Back–up Applications, also Simple Ni–CAD Battery Charging
- Industrial: Low Voltage Lighting Applications and Small Appliances
- Automotive: Tail Lights, Directional Lights, Back–up Light, Dome Light

PIN FUNCTION DESCRIPTION

<table>
<thead>
<tr>
<th>Pin</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vin</td>
<td>Positive input voltage to the device</td>
</tr>
<tr>
<td>2</td>
<td>Boost</td>
<td>This pin may be used to drive an external transistor as described in the App Note AND8198/D.</td>
</tr>
<tr>
<td>3</td>
<td>Rext</td>
<td>An external resistor between Rext and Vin pins sets different current levels for different application needs</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>5, 6, 7, 8</td>
<td>Iout</td>
<td>The LEDs are connected from these pins to ground</td>
</tr>
</tbody>
</table>

MARKING DIAGRAM

ORDERING INFORMATION

<table>
<thead>
<tr>
<th>Device</th>
<th>Package</th>
<th>Shipping¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUD4001DR2</td>
<td>SO–8</td>
<td>2500 / Tape &amp; Reel</td>
</tr>
<tr>
<td>NUD4001DR2G</td>
<td>SO–8 (Pb–Free)</td>
<td>2500 / Tape &amp; Reel</td>
</tr>
<tr>
<td>NSVD4001DR2G</td>
<td>SO–8 (Pb–Free)</td>
<td>2500 / Tape &amp; Reel</td>
</tr>
</tbody>
</table>

¹For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.
MAXIMUM RATINGS ($T_A = 25^\circ C$ unless otherwise noted)

<table>
<thead>
<tr>
<th>Rating</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Input Voltage</td>
<td>$V_{\text{in}}$</td>
<td>30</td>
<td>V</td>
</tr>
<tr>
<td>Non-repetitive Peak Input Voltage ($t \leq 1.0 \text{ ms}$)</td>
<td>$V_{\text{p}}$</td>
<td>60</td>
<td>V</td>
</tr>
<tr>
<td>Output Current (For $V_{\text{drop}} \leq 2.2 \text{ V}$) (Note 1)</td>
<td>$I_{\text{out}}$</td>
<td>500</td>
<td>mA</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>$V_{\text{out}}$</td>
<td>28</td>
<td>V</td>
</tr>
<tr>
<td>Human Body Model (HBM)</td>
<td>ESD</td>
<td>1000</td>
<td>V</td>
</tr>
</tbody>
</table>

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. $V_{\text{drop}} = V_{\text{in}} - 0.7 \text{ V} - V_{\text{LEDs}}$.

THERMAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Ambient Temperature</td>
<td>$T_A$</td>
<td>–40 to +125</td>
<td>°C</td>
</tr>
<tr>
<td>Maximum Junction Temperature</td>
<td>$T_J$</td>
<td>150</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>$T_{\text{STG}}$</td>
<td>–55 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>Total Power Dissipation (Note 2)</td>
<td>$P_D$</td>
<td>1.13</td>
<td>W</td>
</tr>
<tr>
<td>Derating above 25°C (Figure 3)</td>
<td></td>
<td>9.0</td>
<td>mW/°C</td>
</tr>
<tr>
<td>Thermal Resistance, Junction–to–Ambient (Note 2)</td>
<td>$R_{\text{JA}}$</td>
<td>110</td>
<td>°C/W</td>
</tr>
<tr>
<td>Thermal Resistance, Junction–to–Lead (Note 2)</td>
<td>$R_{\text{JL}}$</td>
<td>77</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

2. Mounted on FR–4 board, 2 in sq pad, 2 oz coverage.

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ C$ unless otherwise noted)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Current1 (For $V_{\text{in}} = 12 \text{ V}$, $R_{\text{ext}} = 2.0 \Omega$, $V_{\text{LEDs}} = 10 \text{ V}$)</td>
<td>$I_{\text{out1}}$</td>
<td>305</td>
<td>325</td>
<td>345</td>
<td>mA</td>
</tr>
<tr>
<td>Output Current2 (For $V_{\text{in}} = 30 \text{ V}$, $R_{\text{ext}} = 7.0 \Omega$, $V_{\text{LEDs}} = 24 \text{ V}$)</td>
<td>$I_{\text{out2}}$</td>
<td>95</td>
<td>105</td>
<td>115</td>
<td>mA</td>
</tr>
<tr>
<td>Bias Current (For $V_{\text{in}} = 12 \text{ V}$, $R_{\text{ext}} = \text{Open}$, $V_{\text{LEDs}} = 10 \text{ V}$)</td>
<td>$I_{\text{Bias}}$</td>
<td>–</td>
<td>5.0</td>
<td>8.0</td>
<td>mA</td>
</tr>
<tr>
<td>Voltage Overhead (Note 3)</td>
<td>$V_{\text{over}}$</td>
<td>1.4</td>
<td>–</td>
<td>–</td>
<td>V</td>
</tr>
</tbody>
</table>

3. $V_{\text{over}} = V_{\text{in}} - V_{\text{LEDs}}$. 

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TYPICAL PERFORMANCE CURVES

(T\textsubscript{A} = 25°C unless otherwise noted)

Figure 1. Output Current (I\textsubscript{OUT}) vs. External Resistor (R\textsubscript{ext})

Figure 2. V\textsubscript{sense} vs. Junction Temperature

Figure 3. Total Power Dissipation (P\textsubscript{D}) vs. Ambient Temperature (T\textsubscript{A})

Figure 4. Internal Circuit Power Dissipation vs. Input Voltage

Figure 5. Current Regulation vs. Junction Temperature
Design Guide

1. Define LED’s current:
   a. \( I_{\text{LED}} = 350 \text{ mA} \)

2. Calculate Resistor Value for \( R_{\text{ext}} \):
   a. \( R_{\text{ext}} = \frac{V_{\text{sense}} \text{ (see Figure 2)}}{I_{\text{LED}}} \)
   b. \( R_{\text{ext}} = 0.7 \text{ (Tj } = 25 \text{ °C)} / 0.350 = 2.0 \text{ }\Omega \)

3. Define \( V_{\text{in}} \):
   a. Per example in Figure 6, \( V_{\text{in}} = 12 \text{ V} \)

4. Define \( V_{\text{LED}} @ I_{\text{LED}} \) per LED supplier’s data sheet:
   a. Per example in Figure 6, \( V_{\text{LED}} = 3.5 \text{ V } + 3.5 \text{ V } + 3.5 \text{ V } = 10.5 \text{ V} \)

5. Calculate \( V_{\text{drop}} \) across the NUD4001 device:
   a. \( V_{\text{drop}} = V_{\text{in}} - V_{\text{sense}} - V_{\text{LED}} \)
   b. \( V_{\text{drop}} = 12 \text{ V } - 0.7 \text{ V (Tj } = 25 \text{ °C)} - 10.5 \text{ V} \)
   c. \( V_{\text{drop}} = 0.8 \text{ V} \)

6. Calculate Power Dissipation on the NUD4001 device’s driver:
   a. \( P_{D_{\text{driver}}} = V_{\text{drop}} \times I_{\text{out}} \)
   b. \( P_{D_{\text{driver}}} = 0.8 \text{ V } \times 0.350 \text{ A} \)
   c. \( P_{D_{\text{driver}}} = 0.280 \text{ Watts} \)

7. Establish Power Dissipation on the NUD4001 device’s control circuit per Figure 4:
   a. \( P_{D_{\text{control}}} = \) Figure 4, for 12 V input voltage
   b. \( P_{D_{\text{control}}} = 0.055 \text{ W} \)

8. Calculate Total Power Dissipation on the device:
   a. \( P_{D_{\text{total}}} = P_{D_{\text{driver}}} + P_{D_{\text{control}}} \)
   b. \( P_{D_{\text{total}}} = 0.280 \text{ W } + 0.055 \text{ W } = 0.335 \text{ W} \)

9. If \( P_{D_{\text{total}}} > 1.13 \text{ W} \) (or derated value per Figure 3), then select the most appropriate recourse and repeat steps 1 through 8:
   a. Reduce \( V_{\text{in}} \)
   b. Reconfigure LED array to reduce \( V_{\text{drop}} \)
   c. Reduce \( I_{\text{out}} \) by increasing \( R_{\text{ext}} \)
   d. Use external resistors or parallel device’s configuration (see application note AND8156)

10. Calculate the junction temperature using the thermal information on Page 7 and refer to Figure 5 to check the output current drop due to the calculated junction temperature. If desired, compensate it by adjusting the value of \( R_{\text{ext}} \).
Figure 7. Stop light automotive circuit using the NUD4001 device to drive one high current LED (550 mA).

Figure 8. Dome light automotive circuit using the NUD4001 device to drive one LED (220 mA).
Figure 9. NUD4001 Device Configuration for PWM

Figure 10. 12 Vac landscape lighting application circuit using the NUD4001 device to drive three 350 mA LEDs.
NUD4001, NSVD4001 Power Dissipation

The power dissipation of the SO−8 is a function of the pad size. This can vary from the minimum pad size for soldering to a pad size given for maximum power dissipation. Power dissipation for a surface mount device is determined by $T_{J\text{max}}$, the maximum rated junction temperature of the die, $R_{\theta JA}$, the thermal resistance from the device junction to ambient, and the operating temperature, $T_A$. Using the values provided on the data sheet for the SO−8 package, $P_D$ can be calculated as follows:

$$P_D = \frac{T_{J\text{max}} - T_A}{R_{\theta JA}}$$

The values for the equation are found in the maximum ratings table on the data sheet. Substituting these values into the equation for an ambient temperature $T_A$ of 25°C, one can calculate the power dissipation of the device which in this case is 1.13 W.

$$P_D = \frac{150^\circ C - 25^\circ C}{110^\circ C} = 1.13 \text{ W}$$

The 110°C/W for the SO−8 package assumes the use of a FR−4 copper board with an area of 2 square inches with 2 oz coverage to achieve a power dissipation of 1.13 W. There are other alternatives to achieving higher dissipation from the SOIC package. One of them is to increase the copper area to reduce the thermal resistance. Figure 11 shows how the thermal resistance changes for different copper areas. Another alternative would be to use a ceramic substrate or an aluminum core board such as Thermal Clad®. Using a board material such as Thermal Clad or an aluminum core board, the power dissipation can be even doubled using the same footprint.

![Figure 11. $\theta JA$ versus Board Area](image)

![Figure 12. Transient Thermal Response](image)

Thermal Clad is a registered trademark of the Bergquist Company.

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NOTES:
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. 751−01 THRU 751−06 ARE OBSOLETE. NEW STANDARD IS 751−07.

<table>
<thead>
<tr>
<th>DIM</th>
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</thead>
<tbody>
<tr>
<td>MILIAMETERS</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
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<td>M</td>
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<tr>
<td>N</td>
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<tr>
<td>S</td>
</tr>
</tbody>
</table>

*This information is generic. Please refer to device data sheet for actual part marking. Pb−Free indicator, “G” or microdot “•”, may or may not be present. Some products may not follow the Generic Marking.
### STYLE 1: PIN 1. EMITTER
1. DRAIN
2. SOURCE
3. GROUND
4. SOURCE
5. DRAIN
6. SOURCE
7. BASE
8. EMITTER

### STYLE 2: PIN 1. COLLECTOR, DIE, #1
1. DRAIN, #1
2. SOURCE, #1
3. SOURCE, #2
4. SOURCE, #3
5. SOURCE, #4
6. SOURCE, #5
7. SOURCE, #6
8. SOURCE, #7

### STYLE 3: PIN 1. DRAIN
1. DRAIN
2. DRAIN
3. DRAIN
4. DRAIN
5. DRAIN
6. DRAIN
7. DRAIN
8. DRAIN

### STYLE 4: PIN 1. ANODE
1. ANODE
2. ANODE
3. ANODE
4. ANODE
5. ANODE
6. ANODE
7. ANODE
8. COMMON CATHODE

### STYLE 5: PIN 1. DRAIN
1. DRAIN
2. DRAIN
3. DRAIN
4. DRAIN
5. DRAIN
6. DRAIN
7. DRAIN
8. DRAIN

### STYLE 6: PIN 1. SOURCE
1. SOURCE
2. SOURCE
3. SOURCE
4. SOURCE
5. SOURCE
6. SOURCE
7. SOURCE
8. SOURCE

### STYLE 7: PIN 1. COLLECTOR, DIE, #1
1. COLLECTOR, DIE, #1
2. COLLECTOR, DIE, #2
3. COLLECTOR, DIE, #3
4. COLLECTOR, DIE, #4
5. COLLECTOR, DIE, #5
6. COLLECTOR, DIE, #6
7. COLLECTOR, DIE, #7
8. COLLECTOR, DIE, #8

### STYLE 8: PIN 1. INPUT
1. INPUT
2. INPUT
3. INPUT
4. INPUT
5. INPUT
6. INPUT
7. INPUT
8. INPUT

### STYLE 9: PIN 1. EMITTER, COMMON
1. EMITTER, COMMON
2. COLLECTOR, DIE, #1
3. COLLECTOR, DIE, #2
4. COLLECTOR, DIE, #3
5. COLLECTOR, DIE, #4
6. BASE, #1
7. BASE, #2
8. EMITTER, DIE #1

### STYLE 10: PIN 1. GROUND
1. GROUND
2. GROUND
3. GROUND
4. GROUND
5. GROUND
6. GROUND
7. GROUND
8. GROUND

### STYLE 11: PIN 1. SOURCE
1. SOURCE
2. SOURCE
3. SOURCE
4. SOURCE
5. SOURCE
6. SOURCE
7. SOURCE
8. SOURCE

### STYLE 12: PIN 1. ANODE
1. ANODE
2. ANODE
3. ANODE
4. ANODE
5. ANODE
6. ANODE
7. ANODE
8. ANODE

### STYLE 13: PIN 1. N.C.
1. N.C.
2. SOURCE
3. SOURCE
4. SOURCE
5. SOURCE
6. SOURCE
7. SOURCE
8. SOURCE

### STYLE 14: PIN 1. N-SOURCE
1. N-SOURCE
2. N-SOURCE
3. N-SOURCE
4. N-SOURCE
5. N-SOURCE
6. N-SOURCE
7. N-SOURCE
8. N-SOURCE

### STYLE 15: PIN 1. ANODE
1. ANODE
2. ANODE
3. ANODE
4. ANODE
5. ANODE
6. ANODE
7. ANODE
8. ANODE

### STYLE 16: PIN 1. SOURCE (N)
1. SOURCE (N)
2. SOURCE (P)
3. SOURCE (P)
4. SOURCE (P)
5. SOURCE (P)
6. SOURCE (P)
7. SOURCE (P)
8. SOURCE (P)

### STYLE 17: PIN 1. VCC
1. VCC
2. VCC
3. VCC
4. VCC
5. VCC
6. VCC
7. VCC
8. VCC

### STYLE 18: PIN 1. LINE 1 IN
1. LINE 1 IN
2. LINE 1 IN
3. LINE 1 IN
4. LINE 1 IN
5. LINE 1 IN
6. LINE 1 IN
7. LINE 1 IN
8. LINE 1 IN

### STYLE 19: PIN 1. BASE
1. BASE
2. BASE
3. BASE
4. BASE
5. BASE
6. BASE
7. BASE
8. BASE

### STYLE 20: PIN 1. GND
1. GND
2. GND
3. GND
4. GND
5. GND
6. GND
7. GND
8. GND

### STYLE 21: PIN 1. CATHODE 1
1. CATHODE 1
2. CATHODE 1
3. CATHODE 1
4. CATHODE 1
5. CATHODE 1
6. CATHODE 1
7. CATHODE 1
8. CATHODE 1

### STYLE 22: PIN 1. I/O LINE 4
1. I/O LINE 4
2. I/O LINE 4
3. I/O LINE 4
4. I/O LINE 4
5. I/O LINE 4
6. I/O LINE 4
7. I/O LINE 4
8. I/O LINE 4

### STYLE 23: PIN 1. LINE 1 OUT
1. LINE 1 OUT
2. LINE 1 OUT
3. LINE 1 OUT
4. LINE 1 OUT
5. LINE 1 OUT
6. LINE 1 OUT
7. LINE 1 OUT
8. LINE 1 OUT

### STYLE 24: PIN 1. OVP
1. OVP
2. OVP
3. OVP
4. OVP
5. OVP
6. OVP
7. OVP
8. OVP

### STYLE 25: PIN 1. VIN
1. VIN
2. VIN
3. VIN
4. VIN
5. VIN
6. VIN
7. VIN
8. VIN

### STYLE 26: PIN 1. SW_TO_GND
1. SW_TO_GND
2. SW_TO_GND
3. SW_TO_GND
4. SW_TO_GND
5. SW_TO_GND
6. SW_TO_GND
7. SW_TO_GND
8. SW_TO_GND

### STYLE 27: PIN 1. ILIMIT
1. ILIMIT
2. ILIMIT
3. ILIMIT
4. ILIMIT
5. ILIMIT
6. ILIMIT
7. ILIMIT
8. ILIMIT