

# NUD4011

## Low Current LED Driver

This device is designed to replace discrete solutions for driving LEDs in AC/DC high voltage applications (up to 200 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 70 mA
- Offered in Surface Mount Package Technology (SO-8)
- 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: General Lighting Applications and Small Appliances
- Automotive: Tail Lights, Directional Lights, Back-up Light, Dome Light

### PIN FUNCTION DESCRIPTION

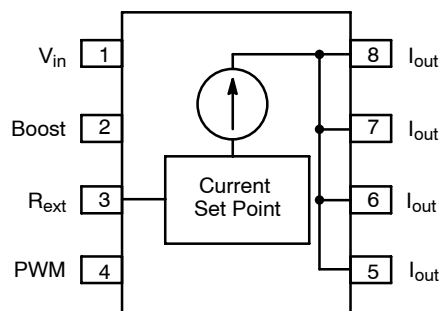
Pin	Symbol	Description
1	$V_{in}$	Positive input voltage to the device
2	Boost	This pin may be used to drive an external transistor as described in the App Note AND8198/D.
3	$R_{ext}$	An external resistor between $R_{ext}$ and $V_{in}$ pins sets different current levels for different application needs
4	PWM	For high voltage applications (higher than 48 V), pin 4 is connected to the LEDs array. For low voltage applications (lower than 48 V), pin 4 is connected to ground.
5, 6, 7, 8	$I_{out}$	The LEDs are connected from these pins to ground



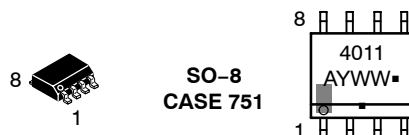
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### PIN CONFIGURATION AND SCHEMATIC



### MARKING DIAGRAM



A = Assembly Location  
 Y = Year  
 WW = Work Week  
 ■ = Pb-Free Package  
 (Note: Microdot may be in either location)

### ORDERING INFORMATION

Device	Package	Shipping <sup>†</sup>
NUD4011DR2	SO-8	2500 / Tape & Reel
NUD4011DR2G	SO-8 (Pb-Free)	2500 / Tape & Reel

<sup>†</sup>For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specification Brochure, BRD8011/D.

# NUD4011

## MAXIMUM RATINGS ( $T_A = 25^\circ\text{C}$ unless otherwise noted)

Rating	Symbol	Value	Unit
Input Voltage	$V_{in}$	200	V
Output Current (For $V_{drop} \leq 16\text{ V}$ ) (Note 1)	$I_{out}$	70	mA
Output Voltage	$V_{out}$	198	V
Human Body Model (HBM)	ESD	500	V

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

## THERMAL CHARACTERISTICS

Characteristic	Symbol	Value	Unit
Operating Ambient Temperature	$T_A$	-40 to +125	$^\circ\text{C}$
Maximum Junction Temperature	$T_J$	150	$^\circ\text{C}$
Storage Temperature	$T_{STG}$	-55 to +150	$^\circ\text{C}$
Total Power Dissipation (Note 2) Derating above $25^\circ\text{C}$ (Figure 3)	$P_D$	1.13 9.0	W mW/ $^\circ\text{C}$
Thermal Resistance, Junction-to-Ambient (Note 2)	$R_{\theta JA}$	110	$^\circ\text{C/W}$
Thermal Resistance, Junction-to-Lead (Note 2)	$R_{\theta JL}$	77	$^\circ\text{C/W}$

2. Mounted on FR-4 board, 2 in sq pad, 1 oz coverage.

## ELECTRICAL CHARACTERISTICS ( $T_A = 25^\circ\text{C}$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Output Current1 (Note 3) ( $V_{in} = 120\text{ Vdc}$ , $R_{ext} = 24\ \Omega$ , $V_{LEDs} = 90\text{ V}$ )	$I_{out1}$	26.0	27.5	29.5	mA
Output Current2 (Note 3) ( $V_{in} = 200\text{ Vdc}$ , $R_{ext} = 68\ \Omega$ , $V_{LEDs} = 120\text{ V}$ )	$I_{out2}$	11.5	14.0	15.5	mA
Bias Current ( $V_{in} = 120\text{ Vdc}$ , $R_{ext} = \text{Open}$ , $R_{shunt} = 80\text{ k}\Omega$ )	$I_{Bias}$	-	1.1	2.0	mA
Voltage Overhead (Note 4)	$V_{over}$	5.0	-	-	V

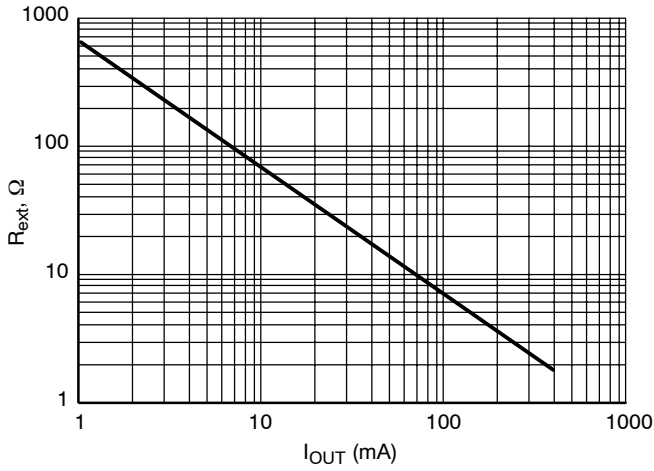
3. Device's pin 4 connected to the LEDs array (as shown in Figure 5).

4.  $V_{over} = V_{in} - V_{LEDs}$ .

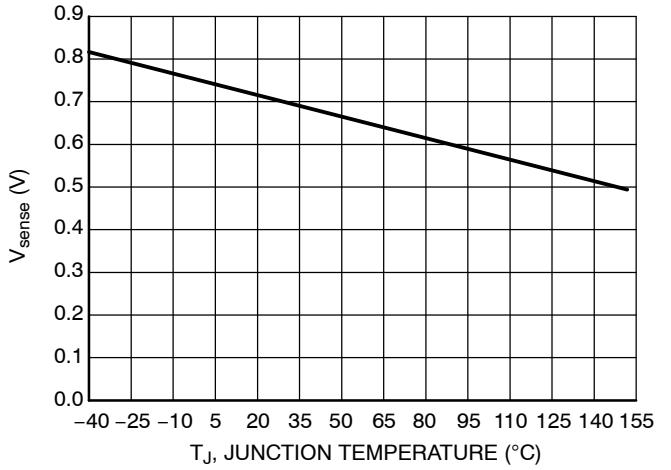
# NUD4011

## TYPICAL PERFORMANCE CURVES

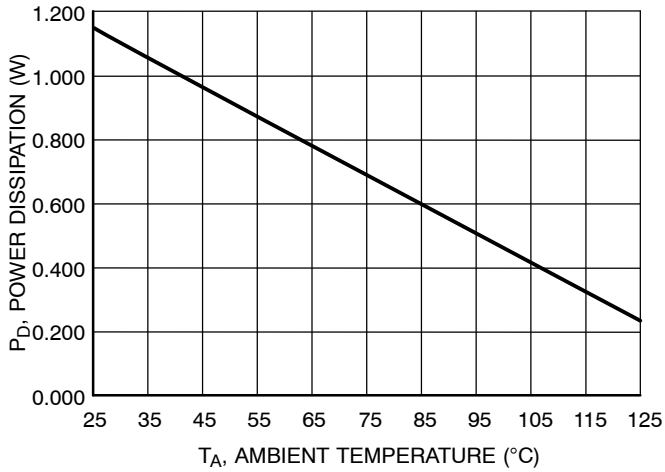
( $T_A = 25^\circ\text{C}$  unless otherwise noted)



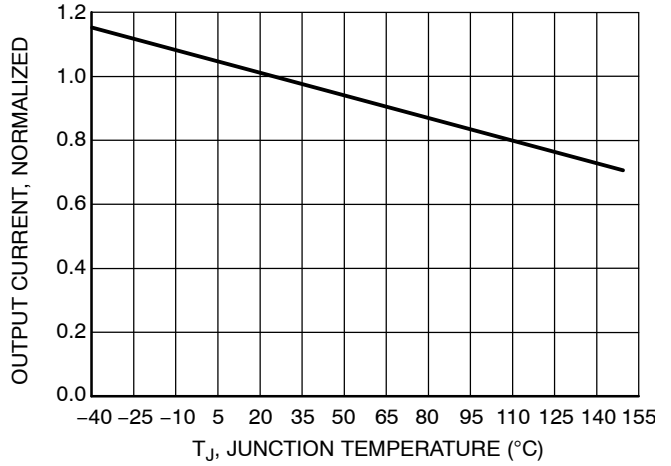
**Figure 1. Output Current ( $I_{OUT}$ ) vs. External Resistor ( $R_{ext}$ )**



**Figure 2.  $V_{sense}$  vs. Junction Temperature**



**Figure 3. Total Power Dissipation ( $P_D$ ) vs. Ambient Temperature ( $T_A$ )**



**Figure 4. Current Regulation vs. Junction Temperature**

APPLICATION INFORMATION

Design Guide for DC Applications

1. Define LED's current:
  - a.  $I_{LED} = 30 \text{ mA}$
2. Calculate Resistor Value for  $R_{ext}$ :
  - a.  $R_{ext} = V_{sense} / I_{LED}$  (see Figure 2)
  - b.  $R_{ext} = 0.7(T_J = 25 \text{ }^\circ\text{C}) / 0.030 = 24 \text{ } \Omega$
3. Define  $V_{in}$ :
  - a. Per example in Figure 5,  $V_{in} = 120 \text{ Vdc}$
4. Define  $V_{LED} @ I_{LED}$  per LED supplier's data sheet: per example in Figure 5,
  - a.  $V_{LED} = 3.0 \text{ V}$  (30 LEDs in series)
  - b.  $V_{LEDs} = 90 \text{ V}$
5. Calculate  $V_{drop}$  across the NUD4001 device:
  - a.  $V_{drop} = V_{in} - V_{sense} - V_{LEDs}$
  - b.  $V_{drop} = 120 \text{ V} - 0.7 \text{ V} - 90 \text{ V}$
  - c.  $V_{drop} = 29.3 \text{ V}$
6. Calculate Power Dissipation on the NUD4001 device's driver:
  - a.  $P_{D\_driver} = V_{drop} * I_{out}$
  - b.  $P_{D\_driver} = 29.3 \text{ V} \times 0.030 \text{ A}$
  - c.  $P_{D\_driver} = 0.879 \text{ W}$
7. Establish Power Dissipation on the NUD4001 device's control circuit per below formula:
  - a.  $P_{D\_control} = (V_{in} - 1.4 - V_{LEDs})^2 / 20,000$
  - b.  $P_{D\_control} = 0.040 \text{ W}$
8. Calculate Total Power Dissipation on the device:
  - a.  $P_{D\_total} = P_{D\_driver} + P_{D\_control}$
  - b.  $P_{D\_total} = 0.879 \text{ W} + 0.040 \text{ W} = 0.919 \text{ W}$
9. If  $P_{D\_total} > 1.13 \text{ W}$  (or derated value per Figure 3), then select the most appropriate recourse and repeat steps 1–8:
  - a. Reduce  $V_{in}$
  - b. Reconfigure LED array to reduce  $V_{drop}$
  - c. Reduce  $I_{out}$  by increasing  $R_{ext}$
  - d. Use external resistors or parallel device's configuration
10. Calculate the junction temperature using the thermal information on Page 8 and refer to Figure 4 to check the output current drop due to the calculated junction temperature. If desired, compensate it by adjusting the value of  $R_{ext}$ .

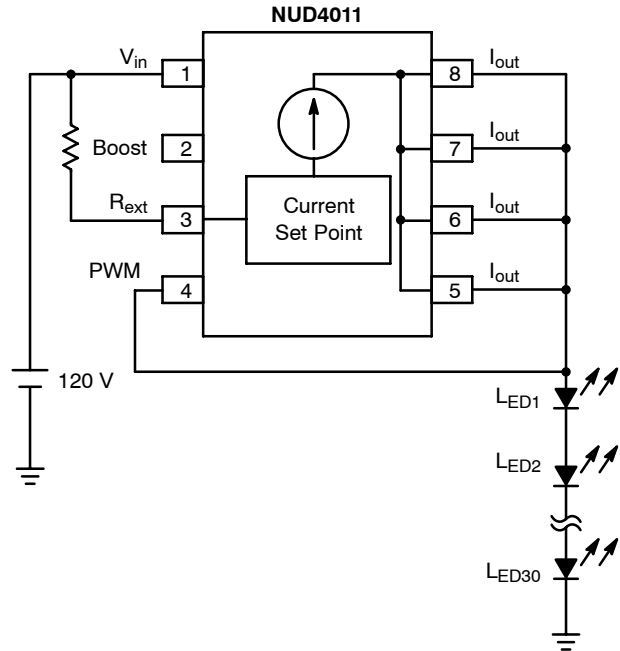


Figure 5. 120 V Application (Series LED's Array)

APPLICATION INFORMATION (continued)

Design Guide for AC Applications

1. Define LED's current:
  - a.  $I_{LED} = 30 \text{ mA}$
2. Define  $V_{in}$ :
  - a. Per example in Figure 5,  $V_{in} = 120 \text{ Vac}$
3. Define  $V_{LED} @ I_{LED}$  per LED supplier's data sheet:
  - a. Per example in Figure 6,
 
$$V_{LED} = 3.0 \text{ V (30 LEDs in series)}$$

$$V_{LEDs} = 90 \text{ V}$$
4. Calculate Resistor Value for  $R_{ext}$ :
 

The calculation of the  $R_{ext}$  for AC applications is totally different than for DC. This is because current conduction only occurs during the time that the ac cycles' amplitude is higher than  $V_{LEDs}$ . Therefore  $R_{ext}$  calculation is now dependent on the peak current value and the conduction time.

  - a. Calculate  $\theta$  for  $V_{LEDs} = 90 \text{ V}$ :
 
$$V = V_{peak} \times \text{Sin } \theta$$

$$90 \text{ V} = (120 \times \sqrt{2}) \times \text{Sin } \theta$$

$$\theta = 32.027^\circ$$
  - b. Calculate conduction time for  $\theta = 32.027^\circ$ . For a sinusoidal waveform  $V_{peak}$  happens at  $\theta = 90^\circ$ . This translates to 4.165 ms in time for a 60 Hz frequency, therefore 32.027° is 1.48 ms and finally:
 
$$\text{Conduction time} = (4.165 \text{ ms} - 1.48 \text{ ms}) \times 2$$

$$= 5.37 \text{ ms}$$
  - c. Calculate the  $I_{peak}$  needed for  $I_{(avg)} = 30 \text{ mA}$   
 Since a full bridge rectifier is being used (per Figure 6), the frequency of the voltage signal applied to the NUD4011 device is now 120 Hz. To simplify the calculation, it is assumed that the 120 Hz waveform is square shaped so that the following formula can be used:
 
$$I_{(avg)} = I_{peak} \times \text{duty cycle};$$
 If 8.33 ms is 100% duty cycle, then 5.37 ms is 64.46%, then:
 
$$I_{peak} = I_{(avg)} / \text{duty cycle}$$

$$I_{peak} = 30 \text{ mA} / 0.645 = 46 \text{ mA}$$
  - d. Calculate  $R_{ext}$ 

$$R_{ext} = 0.7 \text{ V} / I_{peak}$$

$$R_{ext} = 15.21 \Omega$$
5. Calculate  $V_{drop}$  across the NUD4011 device:
  - a.  $V_{drop} = V_{in} - V_{sense} - V_{LEDs}$
  - b.  $V_{drop} = 120 \text{ V} - 0.7 \text{ V} - 90 \text{ V}$
  - c.  $V_{drop} = 29.3 \text{ V}$

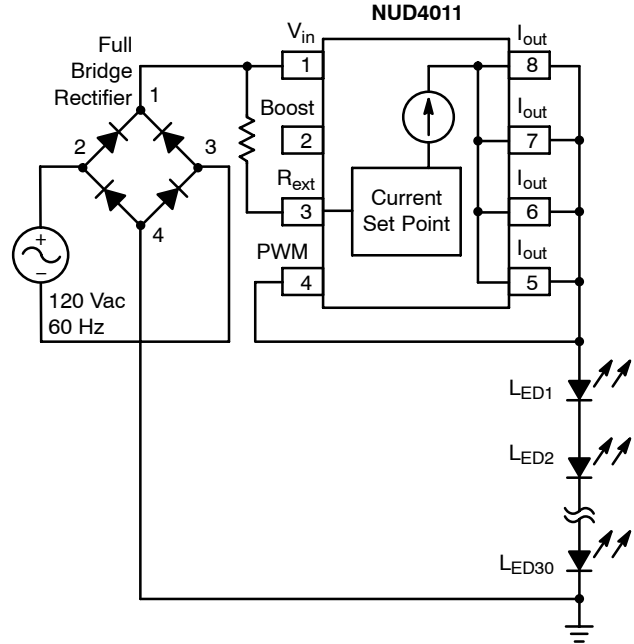


Figure 6. 120 Vac Application (Series LED's array)

6. Calculate Power Dissipation on the NUD4011 device's driver:
  - a.  $P_{D\_driver} = V_{drop} * I_{(avg)}$
  - b.  $P_{D\_driver} = 29.3 \text{ V} \times 0.030 \text{ A}$
  - c.  $P_{D\_driver} = 0.879 \text{ W}$
7. Establish Power Dissipation on the NUD4011 device's control circuit per below formula:
  - a.  $P_{D\_control} = (V_{in} - 1.4 - V_{LEDs})^2 / 20,000$
  - b.  $P_{D\_control} = 0.040 \text{ W}$
8. Calculate Total Power Dissipation on the device:
  - a.  $P_{D\_total} = P_{D\_driver} + P_{D\_control}$
  - b.  $P_{D\_total} = 0.879 \text{ W} + 0.040 \text{ W} = 0.919 \text{ W}$
9. If  $P_{D\_total} > 1.13 \text{ W}$  (or derated value per Figure 3), then select the most appropriate recourse and repeat steps 1-8:
  - a. Reduce  $V_{in}$
  - b. Reconfigure LED array to reduce  $V_{drop}$
  - c. Reduce  $I_{out}$  by increasing  $R_{ext}$
  - d. Use external resistors or parallel device's configuration
10. Calculate the junction temperature using the thermal information on Page 8 and refer to Figure 4 to check the output current drop due to the calculated junction temperature. If desired, compensate it by adjusting the value of  $R_{ext}$ .

# NUD4011

## TYPICAL APPLICATION CIRCUITS

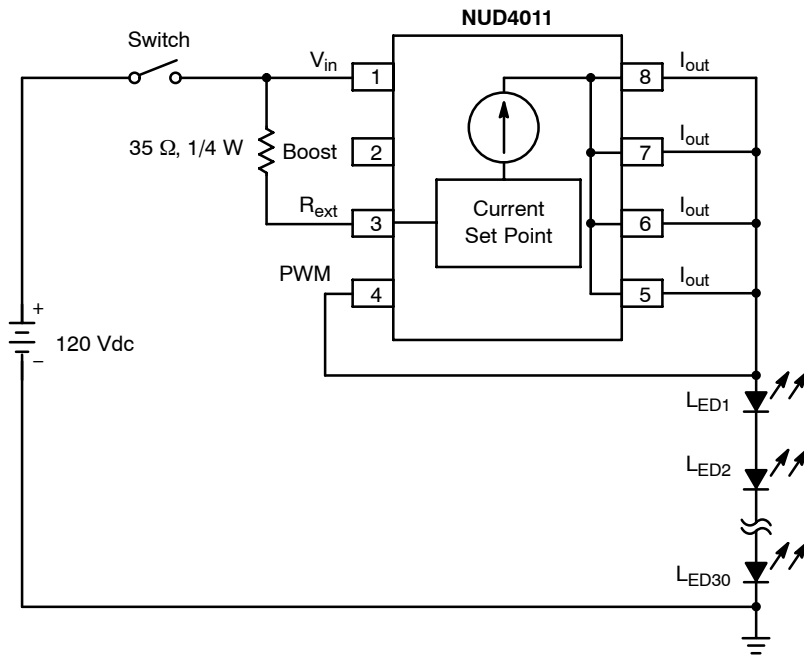


Figure 7. 120 Vdc Application Circuit for a Series Array of 30 LEDs (3.0 V, 20 mA)

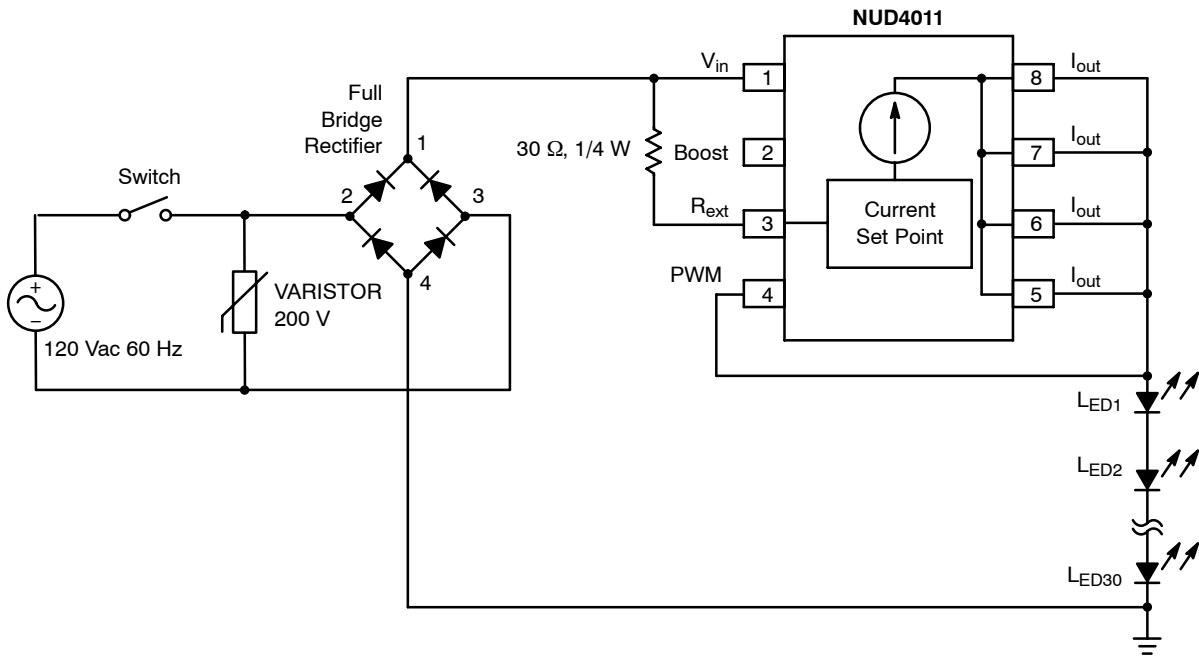


Figure 8. 120 Vac Application Circuit for a Series Array of 30 LEDs (3.0 V, 20 mA)

# NUD4011

## TYPICAL APPLICATION CIRCUITS (continued)

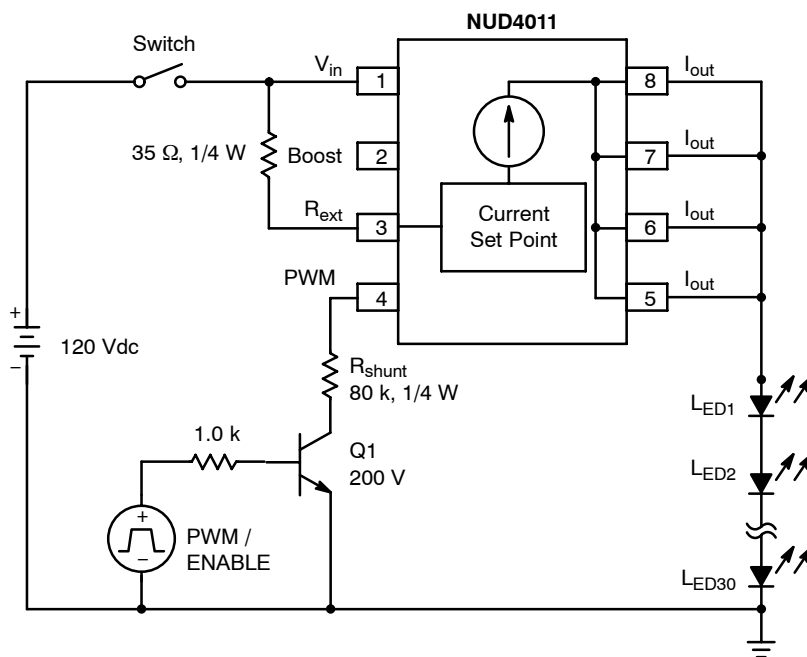


Figure 9. 120 Vdc Application with PWM / Enable Function, 30 LEDs in Series (3.0 V, 20 mA)

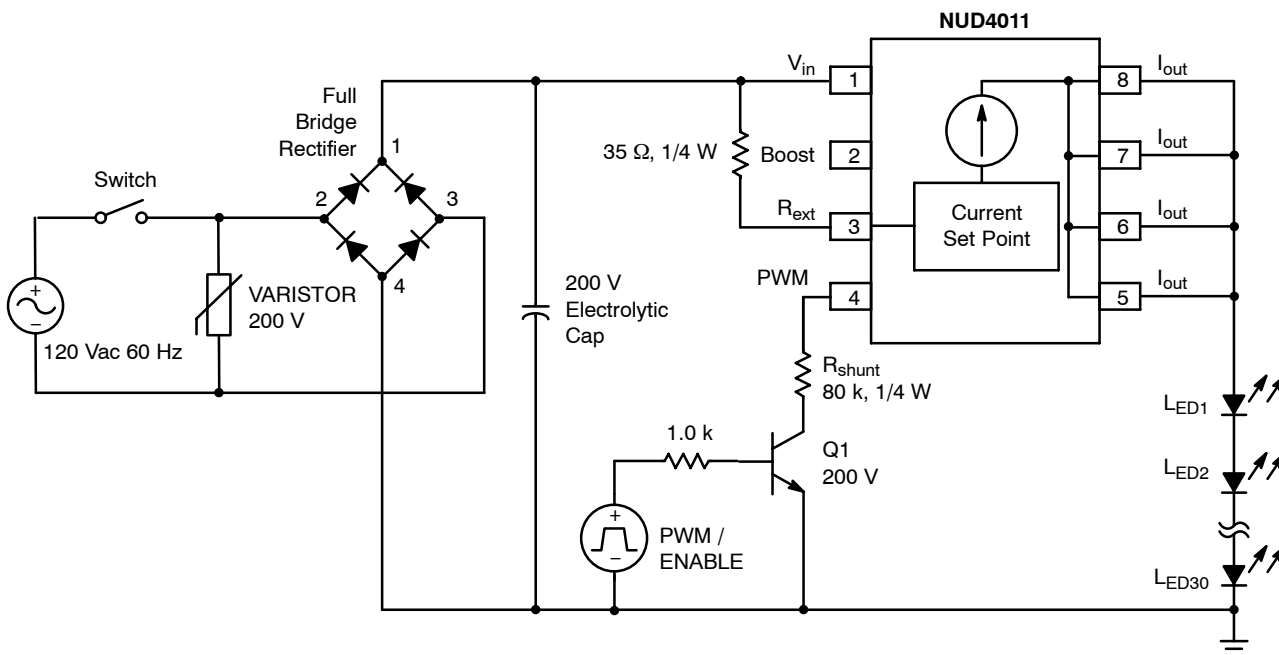


Figure 10. 120 Vac Application with PWM / Enable Function, 30 LEDs in Series (3.0 V, 20 mA)

THERMAL INFORMATION

NUD4011 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  $T_{J(max)}$ , 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:

$$P_D = \frac{T_{Jmax} - T_A}{R_{\theta JA}}$$

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.

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

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.

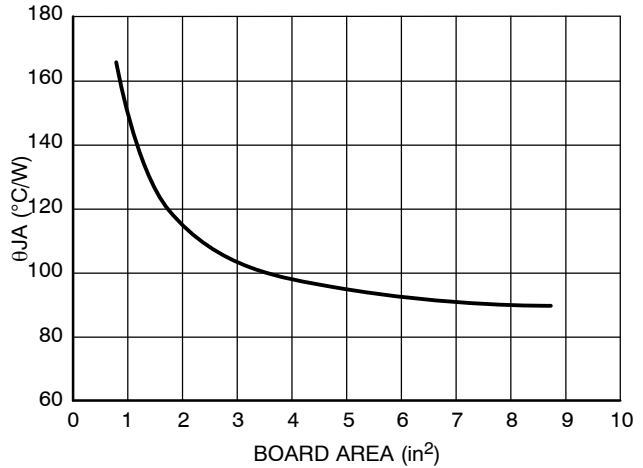


Figure 11. θJA versus Board Area

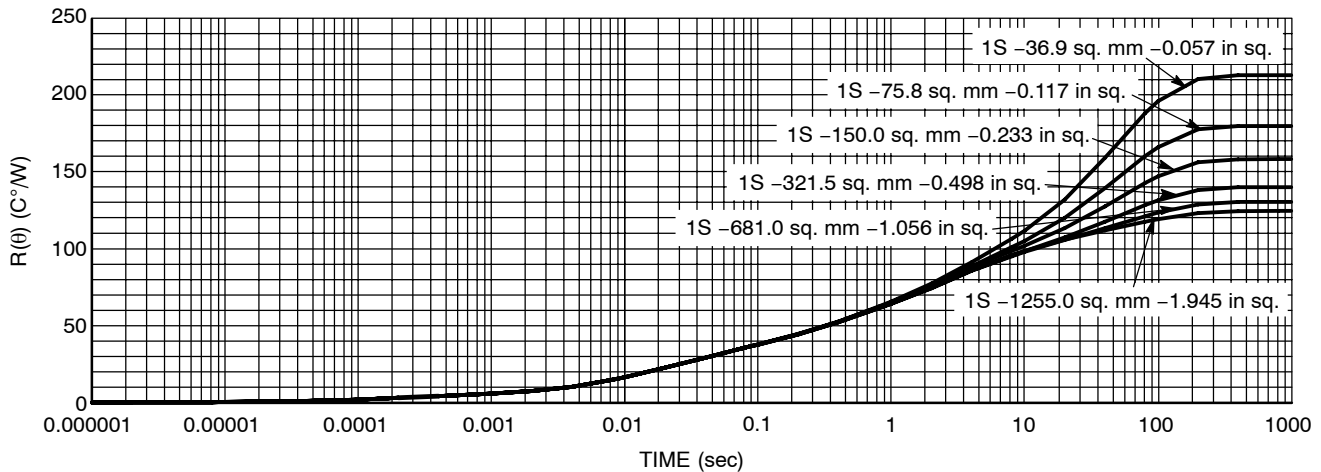


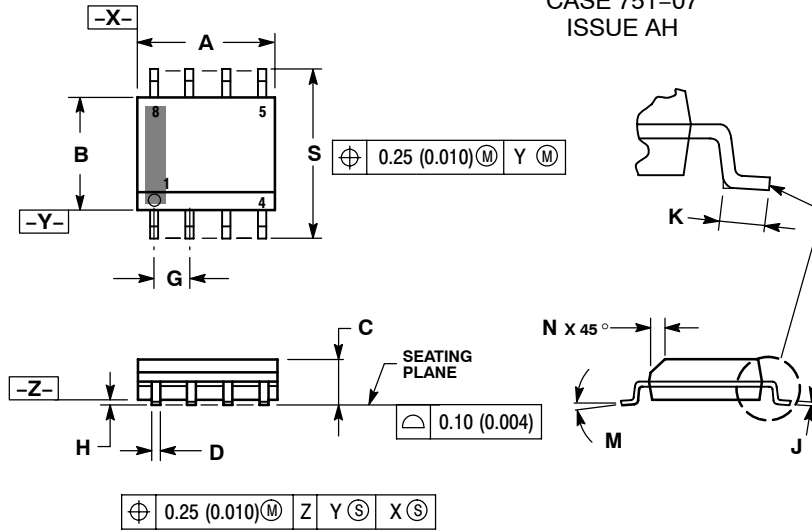
Figure 12. Transient Thermal Response



# NUD4011

## PACKAGE DIMENSIONS

### SOIC-8 NB CASE 751-07 ISSUE AH

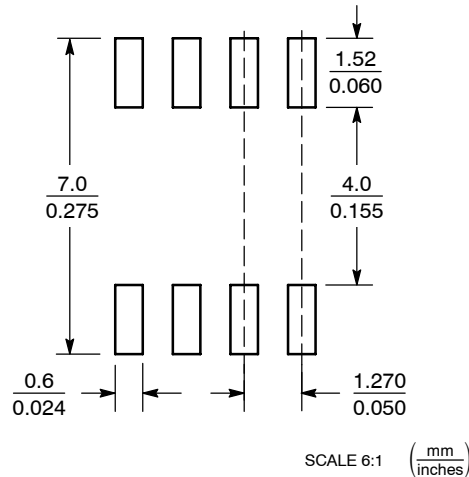


#### NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
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.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.197
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.053	0.069
D	0.33	0.51	0.013	0.020
G	1.27 BSC		0.050 BSC	
H	0.10	0.25	0.004	0.010
J	0.19	0.25	0.007	0.010
K	0.40	1.27	0.016	0.050
M	0°	8°	0°	8°
N	0.25	0.50	0.010	0.020
S	5.80	6.20	0.228	0.244

### SOLDERING FOOTPRINT\*



\*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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