NUD4021, NUD4022, NUD4023

Advance Information

Switching LED Current Source

This integrated Switching LED Driver provides a regulated dc current to an LED powered from a standard automotive 12 V system. It is a low cost switching device which utilizes a minimal of external components that can be used to power high intensity LEDs for a number of applications.

The NUD4021 is recommended for currents of 50 mA to 400 mA, while the NUD4022/NUD4023 is recommended for currents of 300 mA to 2.0 A.

Features

- High Power Conversion Efficiency
- Output Current in Excess of 1.0 A
- Thermal Protection
- Adjustable LED Current
- 80 V Rating for Automotive Immunity
- Internal SENSEFET™ for Lossless Current Sensing
- Automotive Compliant

Typical Applications

- Automotive LED Lighting
- 12 V Current Source

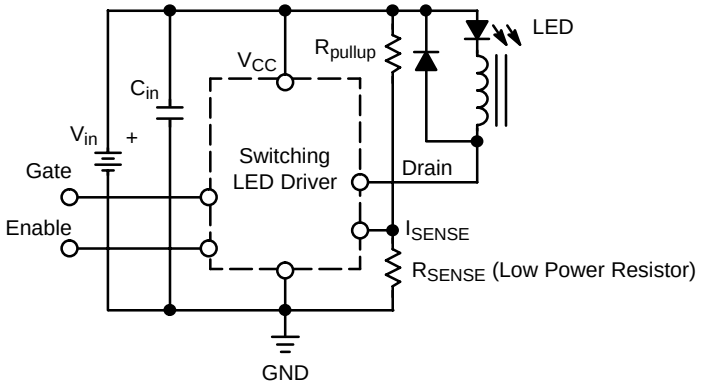

Figure 1. Typical System Schematic

This document contains information on a new product. Specifications and information herein are subject to change without notice.

ON Semiconductor®

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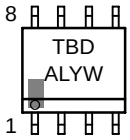
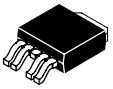
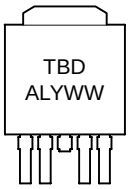
MARKING DIAGRAMs & PIN ASSIGNMENTS

SO−8
CASE 751





DPAK 5
CASE 175AA



TBD = Specific Device Code
A = Assembly Location
L = Wafer Lot
Y = Year
W, WW = Work Week

ORDERING INFORMATION

Device	Package	Shipping
NUD4021	SO−8	TBD
NUD4022	DPAK	TBD
NUD4023	DPAK	TBD

FUNCTIONAL PIN DESCRIPTION

Pin 4021	Pin 4022	Pin 4023	Function	Description
4	5	5	V_{CC}	Input voltage to the LED driver. This voltage is compatible with a 12 V automotive electrical system.
8	3	3	Drain	This is the drain of the internal power FET which conducts pulsed current through the LEDs that are connected in series to it.
3	4	4	I_{SENSE}	The output of the SENSEFET. A resistor from this pin to ground converts the drain current (divided by the sense ratio) to a voltage.
1	N/C	2	Enable	This pin is in a high state for operation and in a low state for shutdown, which turns off the power FET.
5,6,7	1	1	Ground	The reference node to this chip, also the source of the power FET.
2	2	N/C	Gate	This pin is the gate of the power MOSFET. A capacitor can be added to ground to reduce the switching speed of the MOSFET.

MAXIMUM RATINGS

Symbol	Rating		Value	Unit
V_{CC}	Input Voltage, Operating (Vcc to Ground) V_{CC} pin connected directly to the input voltage V_{CC} pin connected through a 10k resistor		 24 80	V
V_{DD}	Drain Voltage, Operating (Drain to Ground) Transient (300 ms) Steady−State		 100 80	V
V_{EN}	Enable Voltage, Operating (Enable to ground)		12	V
I_{Davg}	Drain Current, Continuous (Note 1)	SO−8 DPAK	0.4 2.0	A
I_{Dpk}	Drain Current, Peak	SO−8 DPAK	1.5 4.0	A
E_{LD}	Load Dump Pulse, Drain−to−Source. (Note 3), (Note 4) (R_{SOURCE}=0.5 Ω, t=300 ms), (Vcc pin tied to Vbat, Enable open, L=330 μH, R_{sense}=1.2 Ω)		60	V
Rev−Bat	Reverse Battery, Drain−to−Source, (Vcc pin tied to Vbat) (A diode in series with Vcc is required to protect the LED Load)		−14	V
Dual−Volt	Dual Voltage Jump Start, 2 minutes (Drain−to−Source), (Note 4) (Vcc pin tied to Vbat, Enable open, L=330 μH, R_{sense}=1.2 Ω)		24	V
ESD	Human Body Model (HBM) According to EIA/JESD22/A114 Specification		TBD	V

Maximum ratings are those values beyond which device damage can occur. Maximum ratings applied to the device are individual stress limit values (not normal operating conditions) and are not valid simultaneously. If these limits are exceeded, device functional operation is not implied, damage may occur and reliability may be affected.

THERMAL CHARACTERISTICS

Symbol	Rating		Value	Unit
T_J	Operating Temperature Range		−40 to 150	°C
T_J	Non−Operating Temperature Range		−55 to 175	°C
T_L	Lead Temperature, Soldering (1/8” from case for 10 sec)		260	°C
P_D	Total Power Dissipation (T_A = 25°C), (Note 1) Derated above 25°C	SO−8 DPAK SO−8 DPAK	1.13 2.4 9.0 19.0	W mW/°C
$R_{\theta JA}$	Thermal Resistance Junction−to−Ambient, (Note 1)	SO−8 DPAK	110 52	°C/W
$R_{\theta JL}$	Thermal Resistance Junction−to−Lead, (Note 1)	SO−8 DPAK	77 4.7	°C/W

1. Mounted on FR4 Board, 1 in sq pad, 1 oz coverage.

ELECTRICAL CHARACTERISTICS (V_{CC} = 12 V, T_J = 25°C, unless otherwise noted)

Symbol	Characteristics		Min	Typ	Max	Unit
POWER FET						
V_{BRDSS}	Drain−to−Source Breakdown Voltage (Gate pin tied to ground, I_D = 1 mA)		80	−	−	V
I_{DSS}	Drain−to−Source Leakage Current (Gate pin tied to ground, V_{DS} = 80 V)		−	−	10	μA
V_{SD}	Source−Drain Body Diode (Forward On−Voltage)		−	1.1	−	V
RDS_{ON}	ON Resistance					mΩ
	(I_D = 100 mA, Enable open, Isense tied to ground)	SO−8	2500	3000	3500	
	(I_D = 1.0 A, Enable open, Isense tied to ground)	DPAK	375	450	525	
CURRENT REGULATION						
I_{LED}	LED Current Regulation					mA
	(V_{LED}=3.5 V, R_{sense}=1.2 Ω, C_{in}=100 μF, L=330 μH, R_{pullup}=1.1 kΩ)	SO−8	297	330	363	
	(V_{LED}=3.5 V, R_{sense}=TBD, C_{in}=100 μF, L=TBD, R_{pullup}=TBD)	DPAK	630	700	770	
t_{Offmax}	Maximum Off Time		−	TBD	−	μs
t_{Offmin}	Minimum Off Time		−	TBD	−	μs
THERMAL SHUTDOWN						
T_{SD}	Thermal Limit Shutdown Temperature, (Note 2)		−	150	−	°C
T_{hyst}	Thermal Hysteresis		−	30	−	°C
ENABLE/PWM						
V_{ENhigh}	Logic Level High, (Turn−on)		2.1	−	−	V
V_{ENlow}	Logic Level Low, (Turn−off)		−	−	1.9	V
f_{PWM}	PWM Frequency, (Note 2)		−	100	−	Hz
R_{pullup}	Internal Pull up Resistance, (Terminated to a 7.7 V source)		400	500	600	kΩ
BIAS SUPPLY (V_{CC})						
I_{BIAS}	Bias Current (Vcc=12 V, Enable & Gate open, I_{sense}=1.2 Ω, No Load)		−	1.0	−	mA
V_{min}	Minimum Operating Voltage		8.0	−	−	V

2. Verified by design.
3. Non−repetitive load dump pulse per Figure 3.
4. Tested with a Load = One LED (Vf = 3.5 V, If = 0.350 mA).

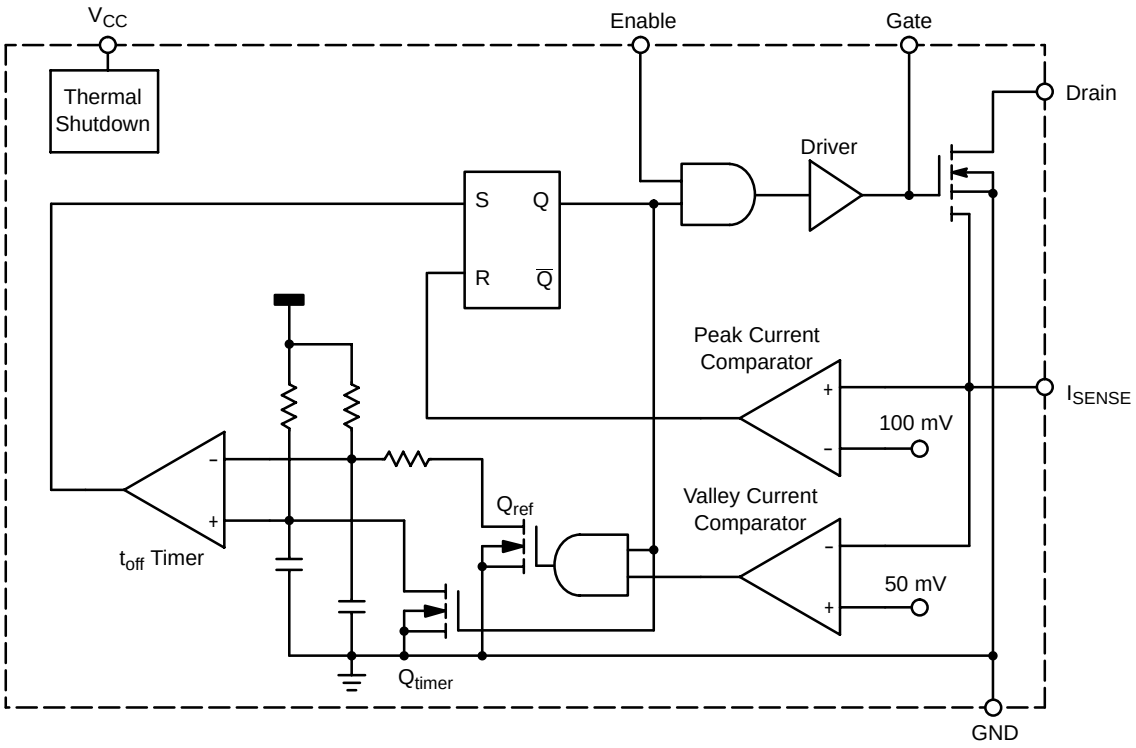


Figure 2. Simplified Block Diagram

Load Dump Pulse Not Suppressed:
V_r = 13.5 V Nominal ±10%
V_S = 60 V Nominal ±10%
T = 300 ms Nominal ±10%
t_r = 1 − 10 ms ±10%

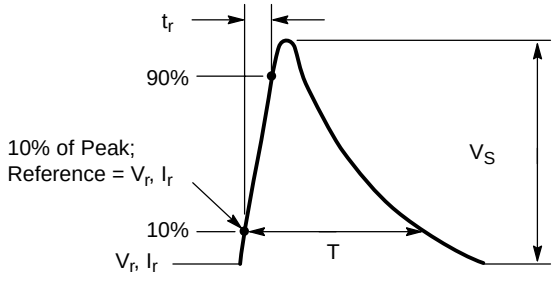


Figure 3. Load Dump Waveform Definition

TYPICAL PERFORMANCE CURVES

(T_J = 25°C unless otherwise specified)

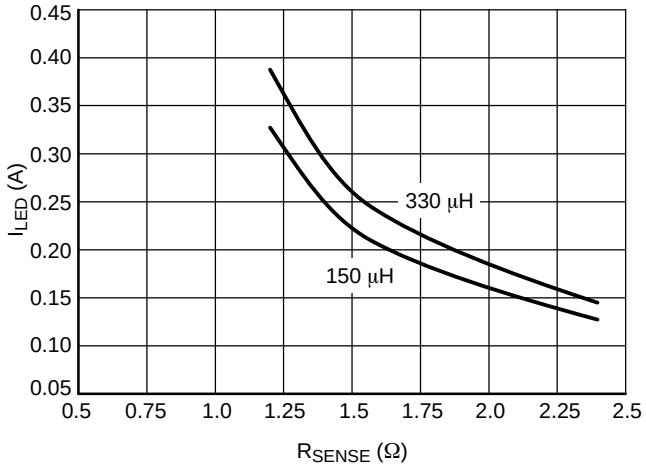


Figure 4. NUD4021, LED Current Adjustment (Vcc = 12 V, V_{LED} = 3.5 V, R_{pullup} = 1.1 kΩ, C_{in} = 100 μF)

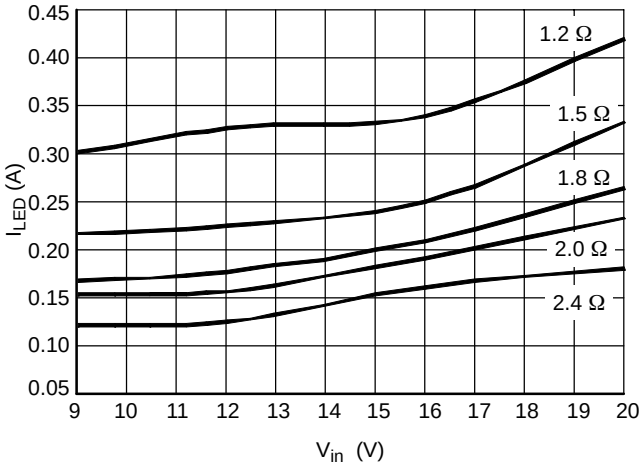


Figure 5. NUD4021, Line Regulation for different LED Currents (V_{LED} = 3.5 V, R_{pullup} = 1.1 kΩ, C_{in} = 100 μF, L = 150 μH)

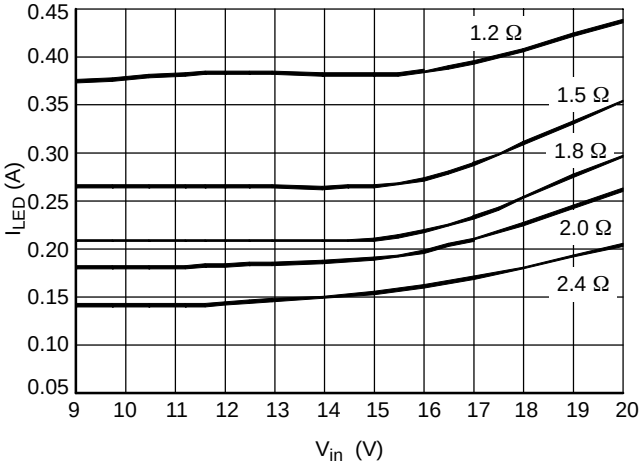


Figure 6. NUD4021, Line Regulation for different LED Currents (V_{LED} = 3.5 V, R_{pullup} = 1.1 kΩ, C_{in} = 100 μF, L = 330 μH)

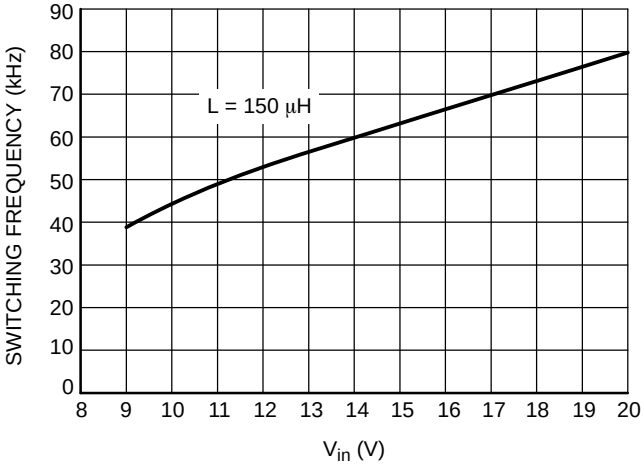


Figure 7. NUD4021, Switching Frequency Variation versus Input Voltage (V_{LED} = 3.5 V, R_{sense} = 1.2 Ω, R_{pullup} = 1.1 kΩ, C_{in} = 100 μF)

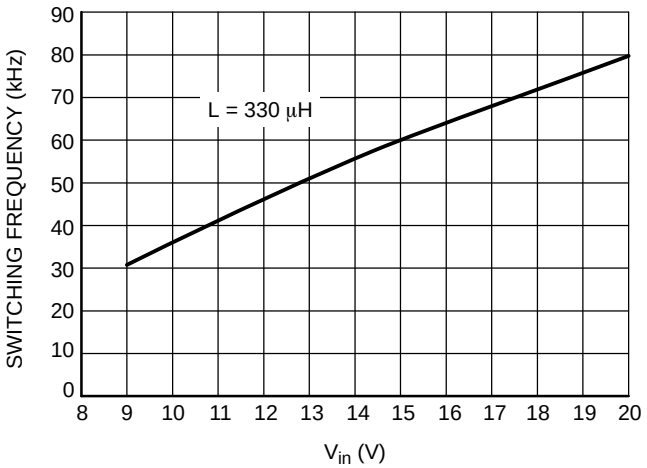


Figure 8. NUD4021, Switching Frequency Variation versus Input Voltage (V_{LED} = 3.5 V, R_{sense} = 1.2 Ω, R_{pullup} = 1.1 kΩ, C_{in} = 100 μF)

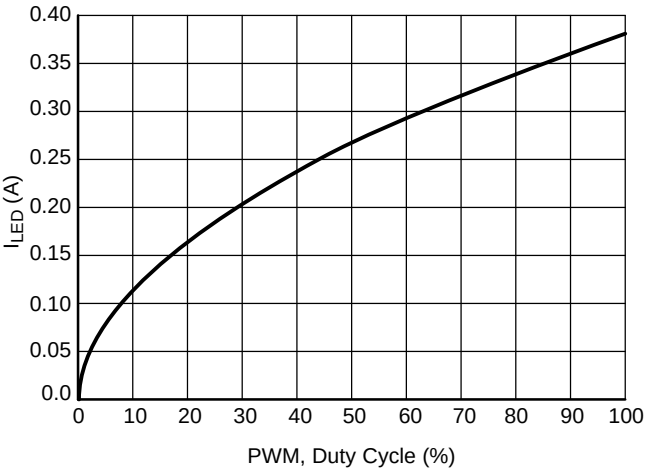


Figure 9. NUD4021, Dimming Performance(V_{LED} = 3.5 V, R_{sense} = 1.2 Ω, R_{pullup} = 1.1 kΩ, C_{in} = 100 μF, L = 330 μH, f_{PWM} = 100 Hz)

TYPICAL PERFORMANCE CURVES

(T_J = 25°C unless otherwise specified)

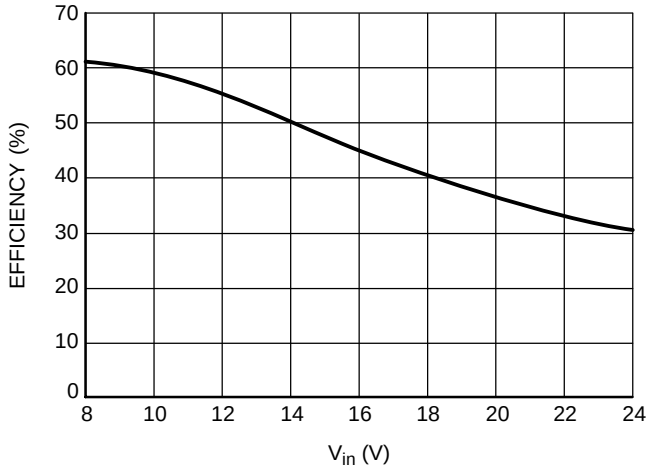


Figure 10. NUD4021, System Efficiency versus Input Voltage (V_{LED} = 3.5 V, R_{sense} = 1.2 Ω, R_{pullup} = 1.1 kΩ, C_{in} = 100 μF, L = 330 μH, Diode MBRA160T3)

TYPICAL APPLICATION CIRCUITS AND OPERATION WAVEFORMS

(T_J = 25°C unless otherwise specified)

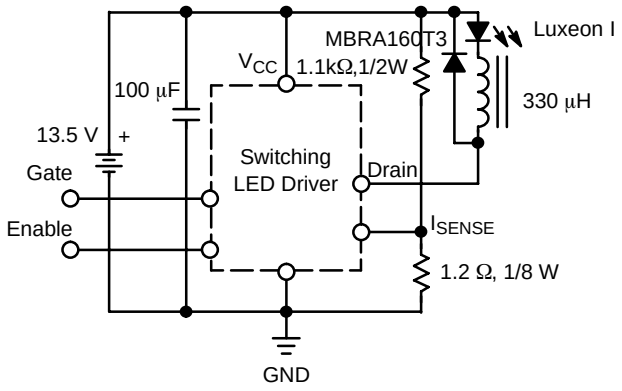


Figure 11. NUD4021, Typical Application Circuit to Drive one LED (Luxeon I, V_F = 3.5 V, I_F = 0.350 mA)

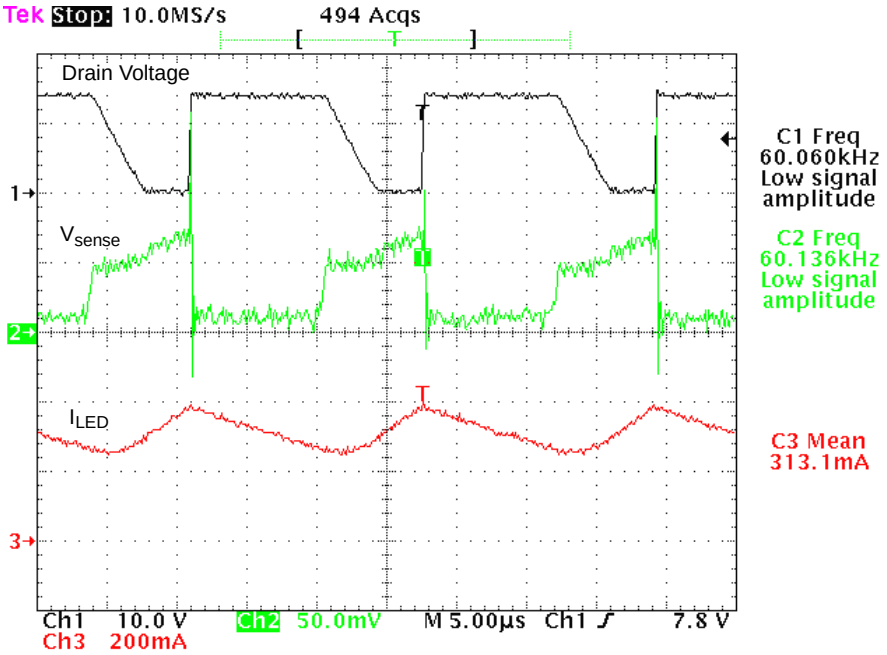


Figure 12. NUD4021, Typical Operation Waveforms (Vcc = 13.5 V, V_{LED} = 3.5 V, R_{sense} = 1.2 Ω, R_{pullup} = 1.1 kΩ, C_{in} = 100 μF, L = 330 μH)

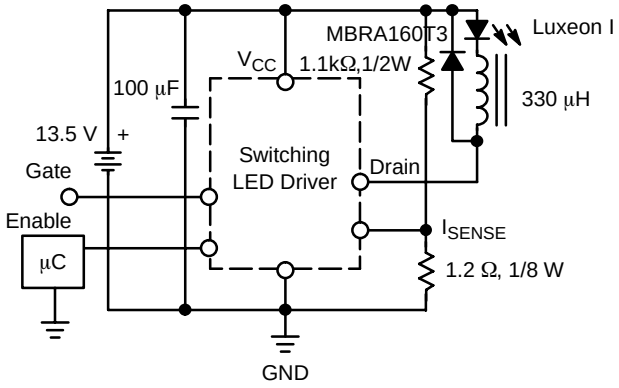


Figure 13. NUD4021, Typical Application Circuit for Dimming (Load = One LED, V_F = 3.5 V, I_F = 0.350 mA)

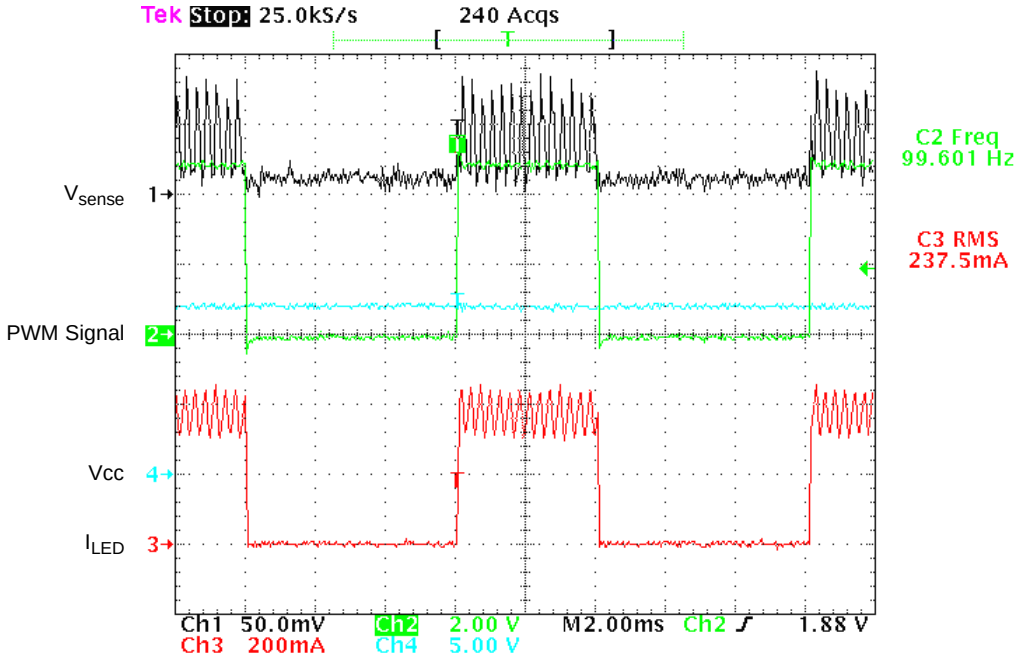


Figure 14. NUD4021, Typical Operation Waveforms (Vcc = 13.5 V, V_{LED} = 3.5 V, R_{sense} = 1.2 Ω, R_{pullup} = 1.1 kΩ, C_{in} = 100 μF, L = 330 μH)

DEVICE THEORY

Theory of Operation

This switching power supply is comprised of an inverted buck regulator controlled by a current mode, hysteretic control circuit. The buck regulator operates exactly like a conventional buck regulator except the power device placement has been inverted to allow for a low side power FET.

Referring to Figure 1, when the SENSEFET is conducting, current flows through the inductor and the LED. When the SENSEFET shuts off, current continues to flow through the inductor and LED, but is diverted through the diode. This operation keeps the current in the LED continuous with a continuous current ramp that varies from the peak current level to 50% of the peak current level.

The control circuit hysterectically controls the current. Figure 2 illustrates the operation of this circuit. When the SENSEFET is conducting, the current in the inductor ramps up. This current is sensed by the sense resistor that is connected from I_{sense} to ground. The SENSEFET diverts a small fraction of its drain current through the Isense terminal, so that a low power resistor is able to sense currents up to 2 amps.

When the voltage on the I_{sense} pin reaches 100 mV, the peak current comparator switches to its high state and sets the Q output of the flip−flop low, which turns off the power FET.

A conventional hysteretic controller would monitor the load current and turn the switch back on when the current reaches its minimum level; 50% in this case. Due to the topology and the fact that the current is being sensed by the FET, once the FET turns off, the current information is no longer available to the control circuit, so a proprietary timer circuit is used to determine the off time.

There are two RC networks in this timer. The one connected to the non−inverting input is a short time constant circuit (approx 10 μs) that determines the off time of the switch. When the power switch is on, Qtimer is also conducting and keeps the timing capacitor discharged. When the switch turns off, Qtimer does also and the timing cap charges until it reaches the reference voltage at the inverting input.

The correct off time is essential to keep the valley current at 50% of the peak current. To achieve this, the valley current comparator sends a correction signal to the reference voltage circuit. This circuit uses a resistor and capacitor, similar to the timer circuit, but has a much slower time constant (approx 100 μs).

Any time the switch is on and the valley current is less than 50% of the peak current (less than 50 mV on the input of the valley current comparator), the comparator will turn of Qref which will reduce the voltage on the reference capacitor. The resistor connected to the drain of Qref is much smaller than the one that charges the reference capacitor, so only a small pulse is required to reduce the reference voltage, but that voltage will increase very slowly when no pulse is present.

The reference signal will be adjusted to a level that keeps the valley current at 50% of the peak current, thereby minimizing the error pulses from the valley current comparator.

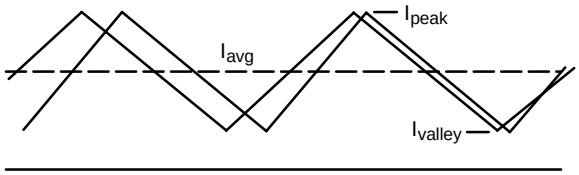


Figure 15. Typical Current Waveforms

The current waveshape is triangular, and the peak and valley currents are controlled. The average value for a triangular waveshape is halfway between the peak and valley, so even with changes in duty cycle due to input voltage variations or load changes, the average current will remain constant.

Inductor Calculation

These first engineering samples do not represent the final performance of the NUD4021 device since design changes are to be made. Therefore the inductor calculation is yet to be defined based on the new silicon. For suggested inductor values please refer to Figures 4, 5, 6 and 7 of the datasheet.

Pull−up Resistor

For these engineering samples, the 1.1 kΩ pull−up resistor connected from I_{sense} to V_{CC} is necessary to improve the LED current regulation. Its main purpose is to provide an offset to the current limit circuit so that the regulation is improved. This pull−up resistor may not be necessary for the next silicon design.

Enable

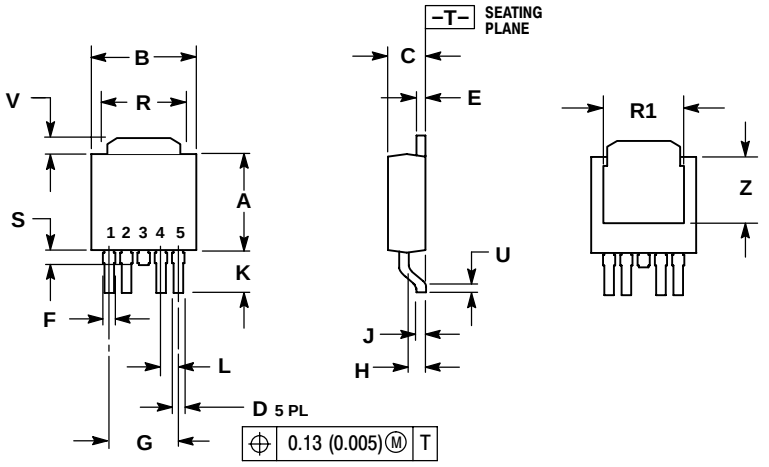
The device's enable can be used for two different functions: enable/disable and dimming. The enable circuit has an internal pull up resistor of 500 kΩ that is terminated to a 7.7V internal source. So if the enable pin is left open, the device will be enabled automatically. If logic gates are used, the device will be enabled when the voltage at the enable pin is higher than 1.5 V and will be disabled for voltages lower than 1.4 V. For dimming purposes, a PWM signal can be connected to the enable pin, and it is recommended that the frequency of the PWM signal is not higher than 500 Hz.

Cgate

The option for a gate capacitor (Cgate) is built in the NUD4021 device and was originally intended to slow down the switching speed of the internal SENSEFET to minimize EMI issues. However for these engineering samples, it is not necessary to use any gate capacitors because the turn−on time of the SENSEFET is already quite slow, and therefore the addition of a gate capacitor may cause malfunction on the device due to the slow switching speed.

PACKAGE DIMENSIONS

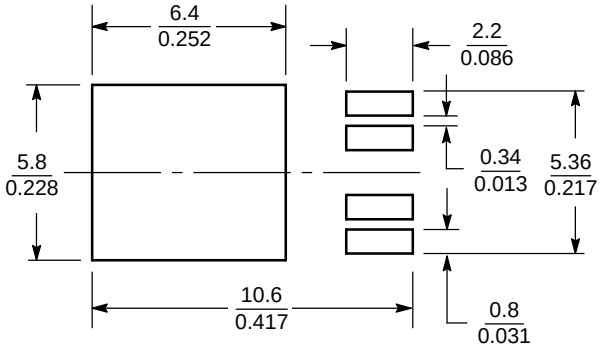
DPAK 5, CENTER LEAD CROP
CASE 175AA−01
ISSUE A



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.235	0.245	5.97	6.22
B	0.250	0.265	6.35	6.73
C	0.086	0.094	2.19	2.38
D	0.020	0.028	0.51	0.71
E	0.018	0.023	0.46	0.58
F	0.024	0.032	0.61	0.81
G	0.180 BSC		4.56 BSC	
H	0.034	0.040	0.87	1.01
J	0.018	0.023	0.46	0.58
K	0.102	0.114	2.60	2.89
L	0.045 BSC		1.14 BSC	
R	0.170	0.190	4.32	4.83
R1	0.185	0.210	4.70	5.33
S	0.025	0.040	0.63	1.01
U	0.020	−−−	0.51	−−−
V	0.035	0.050	0.89	1.27
Z	0.155	0.170	3.93	4.32

SOLDERING FOOTPRINT*

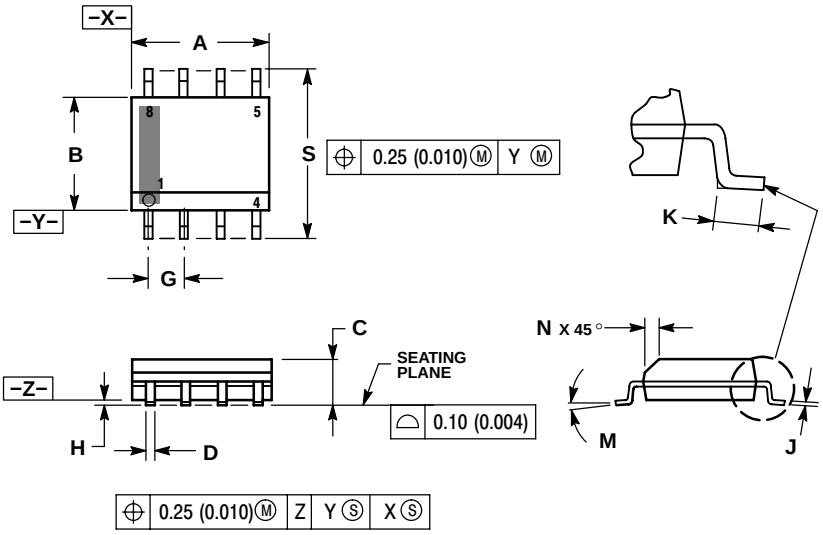


SCALE 4:1 $\left(\frac{\text{mm}}{\text{inches}}\right)$

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

PACKAGE DIMENSIONS

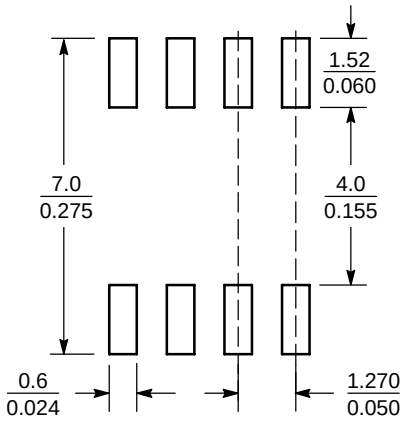
SOIC−8 NB
CASE 751−07
ISSUE AG



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.

	MILLIMETERS		INCHES	
DIM	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*



SCALE 6:1 (mm / inches)

*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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