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AND8234/D

NUD4001 Dimming Ability Demonstration Board

Prepared by: Fionn Sheerin
ON Semiconductor

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APPLICATION NOTE

General Description

The NUD4001 produces a constant current to power LEDs, using an external resistor to determine the current level. This works well for applications which require a constant brightness from the LEDs (on or off). In applications which require the LED to dim, or to operate at moderate intensities, a pulse width modulated signal can be used to vary the intensity of the LED by switching it on and off at high frequencies (greater than 100 Hz). This turns out to be a very straightforward circuit, requiring few components and giving a full dimming range from completely off to completely on.

The NUD4001 dimming demonstration board demonstrates this circuit. It can be built with an external transistor to handle voltages up to 18 V (instead of 6 V), and it can use either a single LED on the board or it can connect to an external LED. It can also be built without the dimming circuit, providing a constant output current without the dimming ability.

Features:

- Adjustable LED brightness
- Constant LED current when LED is on
- Minimal external circuit requirements

NUD4001 Overview

The high current LED driver (NUD4001) uses an external resistor to determine the output current. The resistor is connected between the first and third pins of the device, and the output current is:

$$I_{out} = \frac{0.7\ V}{R_{ext}}$$

The LED driver also has an input voltage (Pin 1), and a ground (Pin 4, see Figure 2). If the ground pin is disconnected, then the device stops functioning. The circuit used in the dimming demonstration board takes advantage of this requirement to switch the device on and off.

The dimming demonstration board features an external transistor in parallel with the NUD4001, which decreases the power dissipated in the LED driver, allowing larger currents and higher input voltages (see AND8197/D, NUD4001 LED Driver Demonstration Boards).

Basic Circuit Operation

The dimming demonstration board runs on 6 VDC without the external transistor, or up to 18 VDC with the external transistor (at 350 mA output current). This input can be applied either to the test points labeled “VDC“, or using a DC supply connected to the 2.1 mm power jack (labeled “CON1”). The board has two possible LED configurations, one with an LED, and one with a connector to drive a load not on the demo board. If the connector is used to drive an LED in parallel with the LED on the board, the two LEDs must have the same voltage drop (or else they will not share the current evenly), and the current limit resistor on the LED driver needs to be adjusted to supply the proper current to the parallel LEDs. When running, the potentiometer can be used to adjust the duty cycle of the timer circuit, which turns the LED drivers on and off; which reduces the average current through the LEDs. The circuit also contains one jumper, in series with the load, which may be used to connect an ammeter in series with the load to monitor the current regulation.

Power Consumption and Voltage Constraints

Ignoring power dissipation, the board can operate at any voltage between 6 V and 18 V, provided the input voltage is at least 1.4 V higher than the total V_f of the LED load. However, with this board design, the LED driver cannot dissipate more than 1.1 W of power without the external transistor. Using the external transistor, the drive current will flow primarily through the external transistor, which has a maximum power dissipation of 5.3 W (at an ambient temperature of 25°C, with the heatsink on this particular board). The power dissipated in the LED driver can be easily calculated by subtracting the V_f of the load from the input voltage, to get the voltage across the driving circuit, and then multiplying by the load current.

$$P = (V_{in} - V_{LED}) \cdot I_{LED}$$

For this board, the power must remain below 1.1 W without the external transistor, and below 5.3 W with the external transistor. If, for example, this board is built with the external transistor, connected to one LED with a 2.9 V V_f, driving a current of 350 mA, then the circuit could

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operate between 6 V and 18 V ((5.3 W / 0.35 A) + 2.9 V = 18 V). Alternatively, if the circuit were built without the external transistor, driving 3 LEDs in series, each with a 3.2 V V_f, at 300 mA, then the circuit could operate between 11 V and 13.2 V ((1.1 W / 0.3 A) + 3 * 3.2 V = 13.2 V). Due to the voltage requirements of the timer chip, however, the input voltage must always be between 6 V and 18 V, regardless of the power dissipation.

Circuit Details

The dimming application demonstration board uses an ON Semiconductor MC1455 timer chip (which is identical to a 555 timer chip) to generate a PWM signal which is connected to an NPN bipolar transistor base. This connects or disconnects the ground pin on the current driver to ground. When the timer output is low, the NPN transistor disconnects the LED driver from ground, and when the timer output is high the NPN transistor restores the ground connection, allowing the LED driver to turn on again (see Figure 1 for schematic, see Figure 4 for output waveforms).

In addition, the timer output also charges and discharges a capacitor connected to the input on the timer (C2), so it triggers itself and alternates states. The charge and discharge path of the trigger capacitor go through diodes (D1 and D2), to ensure that the charge and discharge times are different, and through opposite ends of a potentiometer (P1), which can be used to adjust the duty cycle. When the timer input is low, and the output is high, the input capacitor charges through one diode, and through one side of the potentiometer, until the input rises high enough to change the output. When the output is low, and the input is high, the input capacitor discharges through the other side of the potentiometer and a separate diode, allowing the potentiometer to control the duty cycle. When the potentiometer is set at one end, the timer output is almost constantly at one voltage, while a median setting on the potentiometer creates more balanced duty cycle. This signal is then sent through a simple RC filter (R2 and C1), which imposes a maximum switching frequency (approximately 1 kHz), but prevents the current driver from turning on during the fast switches at the highest and lowest possible duty cycles. The duty cycle of the timer controls how much time the LED current driver spends on, so it directly scales the apparent intensity of the LED. A 50% duty cycle only appears about half as bright as a 100% duty cycle. Because of the RC filter, a 0% duty cycle is completely off, and a 100% duty cycle is completely on. In addition, the timer chip is operating at a frequency of about 500 Hz, so the LED does not appear to be flashing on and off. This frequency can be adjusted using the capacitor on the input of the timer chip (C2), and the frequency could be reduced to make the LED flash visibly if desired. The timer frequency could be set to any value below the cutoff frequency of the RC filter (1 kHz). Finally, a shunt resistor (500 kΩ) is used in parallel with the load. This shunts charge when the circuit is off, to prevent the LED load from glowing faintly.

Alternate Board Configurations

The dimming demonstration board can be built in a number of configurations. The board can be built with or without the external transistor, which determines affects the maximum power consumption in the LED driver circuit. The board can also be built without the dimming function, if the pads of J2 are shorted to permanently connect the ground pin of the NUD4001 to ground, bypassing the PWM circuit (which can then be left off the board entirely, see Figures 6 and 7 for pictures of example board configurations). It can also be built with an LED soldered directly onto the board, or with a connector to drive an external load (note that if an LED is connected directly to the board, it should be attached to the board with thermal epoxy to dissipate the heat in the LED).

Circuit Testing

The circuit can be tested to verify that it works correctly. The jumper at J1 can be replaced by a wire clipped on to the jumper terminals, and the current through the wire can then be measured with a current probe. This is the current flowing through the LED, and except for small changes caused by temperature variations in the NUD4001, this current should remain constant (see Figure 6 for the V_{in}/I_{out} regulation curves).

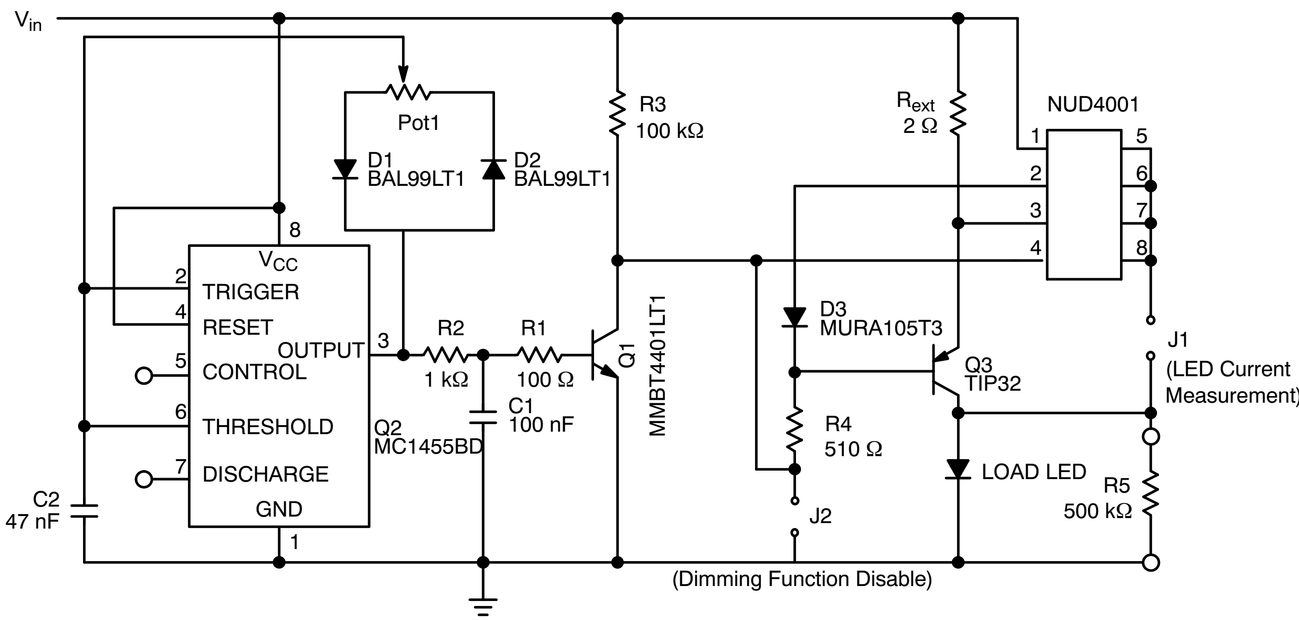


Figure 1. PWM Circuit Diagram

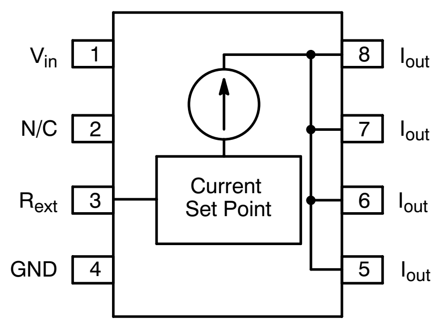
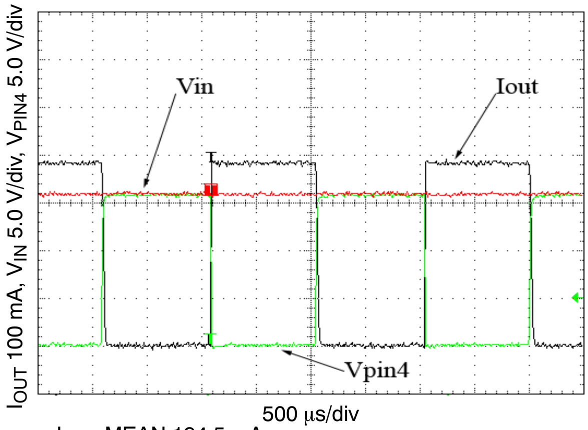


Figure 2. Pinout for NUD4001

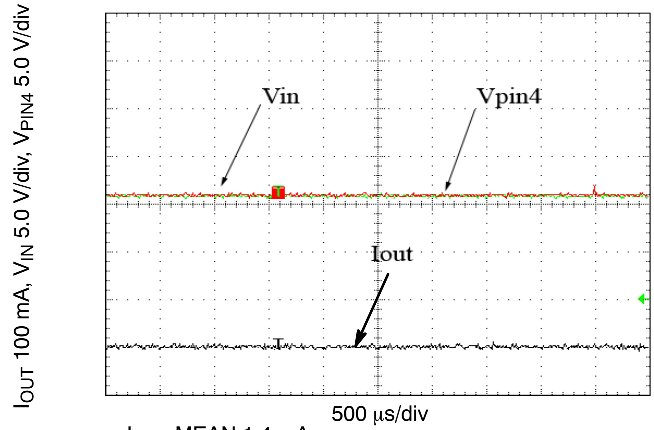
Table 1. BILL OF MATERIALS

Man. Part #	Manufacturer	Description	Quantity	Location
NUD4001	ON Semiconductor	High Current LED Driver	1	LED Driver
		2 Ω Resistor (1206)	2	R_{ext}
		500 kΩ Resistor (0805)	1	R5
PJ-102A	CUI Inc	Power Connector	1	CON1
535676-5	TYCO	Output Connector	1	CON2
		Jumpers	1	J1
1211	Keystone	Test Points	2	+VDC-
SJ-5003	3M	Rubber Feet	3	
Optional Dimming Circuit				
MMBT4401LT1	ON Semiconductor	NPN Transistor	1	Q1
MC1455BD	ON Semiconductor	Timing Chip	1	Q2
BAL99LT1	ON Semiconductor	Small Signal Diodes	2	D1, D2
C2012X7R1H104K	TDK	100 nF Capacitor	1	C1
C3216X7R2E473M	TDK	47 nF Capacitor	1	C2
		100 Ω Resistor (0805)	1	R1
		1 kΩ Resistor (0805)	1	R2
		100 kΩ Resistor (0805)	1	R3
EVU-F3AF30850	Panasonic	50 kΩ Potentiometer	1	Pot1
Optional External Transistor				
MUR105T3	ON Semiconductor	Rectifier	1	D3
		510 Ω Resistor (1206)	1	R4
TIP32C	ON Semiconductor	PNP Power Transistor	1	Q3
6022pb	AVVID	Heatsink	1	Q3
Optional Onboard LED				
LXHL-MW1D	Lumileds	High Current LED	1	LED



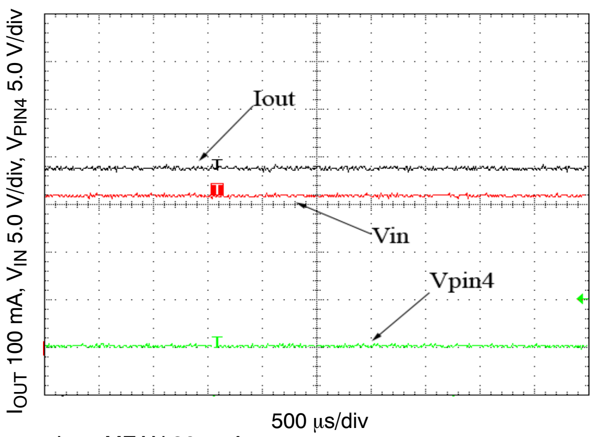
I_{OUT} MEAN 194.5 mA
DUTY CYCLE 49.66%

Figure 3. Circuit Behavior at ∼50% Duty Cycle



I_{OUT} MEAN 1.4 mA

Figure 4. Circuit Behavior at 0% Duty Cycle



I_{OUT} MEAN 367 mA

Figure 5. Circuit Behavior at 100% Duty Cycle

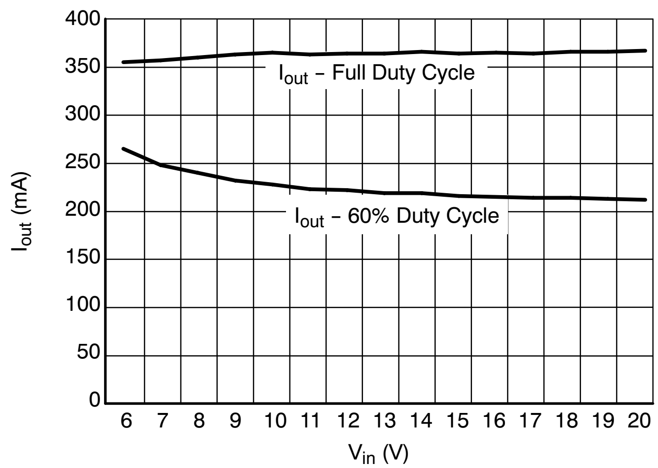


Figure 6. Output Current Regulation at 100% and 60% Duty Cycles

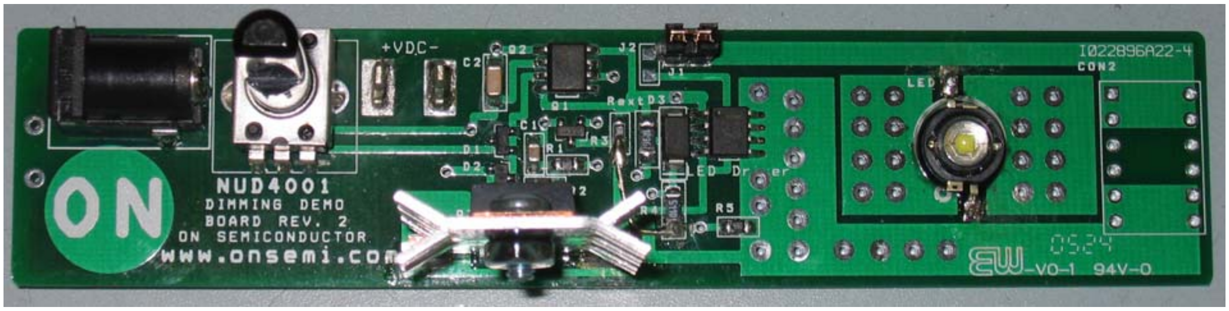


Figure 7. Demonstration Board Built with the Dimming Circuit, the External Transistor, and an Onboard LED

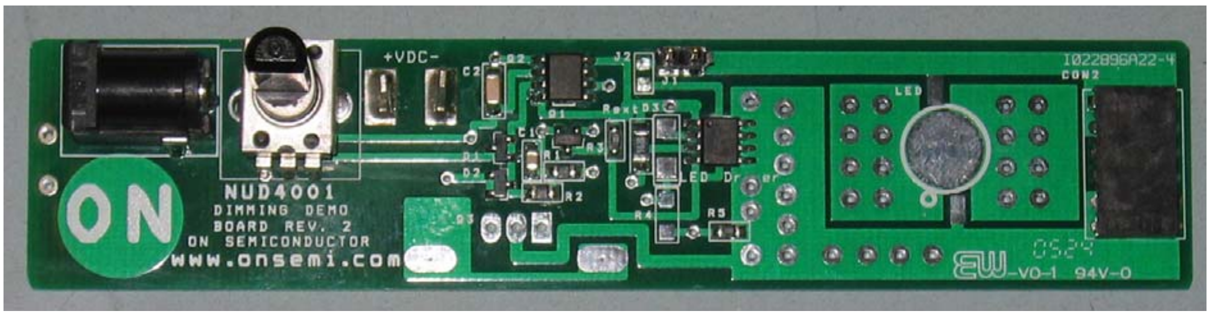


Figure 8. Demonstration Board Built with the Dimming Circuit, Without the External Transistor, and Without the Onboard LED

Table 2. MANUFACTURER CONTACTS

Manufacturer	Contact Information
ON Semiconductor	www.onsemi.com
TDK	(847) 803-6100
Lumileds	www.lumileds.com
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3M	www.3m.com
Panasonic	www.panasonic.com

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