Keywords: backlight LED driver, cree , nichia, ledtronics, Toyoda, agilent, xlamp, ostar led, high-power led, buck boost led driver, constant current, general lighting led driver, HB LED, HB LED driver, HB LEDs, HB-LED, white led lighting, white leds , luxeon star, hbled driver

Nov 04, 2005

APPLICATION NOTE 3639

Design of a Nonisolated, Flyback LED Driver Circuit

Abstract: This app note provides a simple circuit to drive high brightness LEDs. It requires minimum external components and it provides both linear and PWM dimming. Ideal for Osram, Lumileds, Cree, and Nichia LEDs.

General Description

Flyback LED drivers are versatile because they can be used for applications that have input voltages above or below the required output voltages. Furthermore, when flyback circuits are designed to operate in the discontinuous inductor current mode, they lend themselves to a simple circuit configuration that keeps the LED current constant without using additional control loops. The circuit described in this application note is designed around the highly integrated MAX16802 PWM LED driver IC.

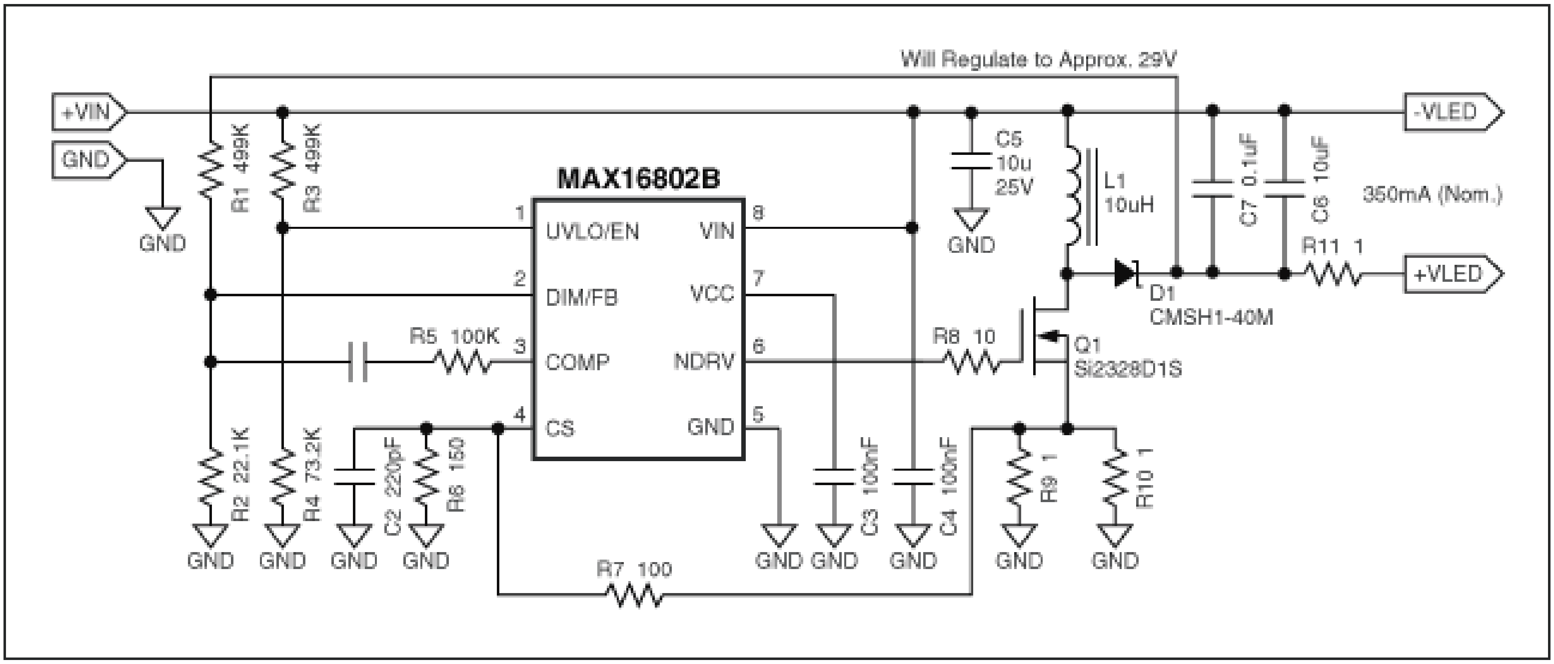
Applications

LED Track Lighting
General LED Lighting Applications

Features

- 10.8V to 24V Input-Voltage Range
- Powers a Single 3.3V LED with 350mA (typ). (For Other LED Configurations, Please Follow Design Procedure.)
- 29V (typ) Maximum Open-Circuit Anode-Terminal-to-Ground Voltage
- 262kHz Switching Frequency
- Cycle-by-Cycle Current Limit
- ON/OFF Control Input
- Allows Implementation of Low-Frequency PWM Dimming
- Circuit Can Be Scaled to Accommodate Several Series- or Parallel-Connected LED Configurations

Typical Application Circuit



Caution: Avoid applying power to the circuit with the $+V_{LED}$ and $-V_{LED}$ terminals not connected to an LED.

Component List

Designation	Qty.	Description
C1	1	1nF ±10%, 50V X7R ceramic capacitor (0603) TDK C1608X7R1H102K
C2	1	220pF ±10%, 50V X7R ceramic capacitor (0603) TDK C1608X7R1H221K
C3, C4, C7	3	0.1µF ±10%, 50V X7R ceramic capacitor (0603) TDK C1608X7R1H104
C5	1	10µF ±10%, 25V X7R ceramic capacitor (1206) TDK
C6	1	10µF ±10%, 16V X7R ceramic capacitor (1206) TDK C3216X7R1C475K
D1	1	40V, 1A Schottky diode (SMA) CMSH1-40M Central Semiconductor
L1	1	10µH inductor Coilcraft DO3308P-103
Q1	1	40V, 0.045W MOSFET Vishay Si2328DS
R1, R3	2	499kΩ ±1% resistor (0603)
R2	1	22.1kΩ ±1% resistor (0603)
R4	1	73.2kΩ ±1% resistor (0603)
R5	1	100kΩ ±5% resistor (0603)
R6	1	150Ω ±1% resistor (0603)
R7	1	100Ω ±1% resistor (0603)
R8	1	10Ω ±5% resistor (0603)
R9, R10	2	1Ω ±1% resistor (0805)
R11	1	1Ω ±1% resistor (0805)
U1	1	PWM IC Maxim: MAX16802AEUA (8-pin µMAX®)

Circuit Topology

Open-loop, nonisolated, flyback LED drivers are very versatile and simple to use. They offer a series of advantages that make them especially attractive. Some of these advantages are:

- No explicit control loop is required for LED current regulation
- Low EMI emissions as a result of discontinuous inductor current conduction
- No diode reverse recovery losses
- Low switch turn ON losses
- Simple circuit and design procedure
- Can accommodate LED voltages that are higher or lower than the input voltage
- Wide input-voltage operating range
- Relatively easy to apply a dimming PWM signal

Simplicity, however, comes at the expense of:

- LED current is dependent on component tolerances, such as the inductor and current-sense comparator propagation delays
- Discontinuous inductor current operation makes this topology more suitable for lower power applications

Design Procedure

The critical parameter is the LED current. High-brightness LEDs operate with several hundred mA. For LED longevity, this current must be kept constant; the power source essentially has to be a current driver. There are several ways of accomplishing this. One simple and low-cost way is to use a dedicated current-mode PWM controller IC, such as the MAX16802. The benefits of this device are:

- High integration—minimal external parts required
- High 262kHz switching frequency
- Very small, 8-pin µMAX package
- Small current-sense threshold for low losses
- Relatively accurate oscillator frequency reduces LED current variation
- On-board voltage feedback amplifier can be used to limit output open terminal voltage

The given LED parameters are:

$$I_{LED} = 350mA$$
$$V_{LED} = 3.3V$$
$$V_{in\min} = 10.8V$$
$$V_{in\max} = 24V$$

Step 1: Calculate the approximate optimum ON duty cycle required at minimum input voltage:

$$d_{on} = \frac{V_{LED} + R_b \cdot I_{LED} + V_D}{V_{in\min} + V_{LED} + R_b \cdot I_{LED} + V}$$

where R_b is the ballast resistor, same as R11 in the application schematic, set at 1Ω in this application. V_D is the forward drop of the rectifying diode D1.

Inserting known values in the above yields:

$$d_{on} = 0.291$$

Step 2: Calculate the approximate required peak inductor current:

$$I_p = \frac{k_f \cdot 2 \cdot I_{LED}}{1 - d_{on}}$$

where k_f is a noncritical "fudge factor," set at 1.1 for this example.

Inserting known values in the above yields:

$$I_p = 1.058A$$

Step 3: Calculate the approximate required inductor value and choose the closest standard value smaller than the calculated value:

$$L = \frac{d_{on} \cdot V_{in\min}}{f \cdot I_p}$$

where L is L1 in the application schematic, and f is the switching frequency, equal to 262kHz.

Inserting known values in the above yields:

$$L = 10.566\mu H$$

The closest standard value lower than the above is 10µH.

Step 4: Power transferred to the output circuit by the flyback process is:

$$P_{in} = \frac{1}{2} \cdot L \cdot I_p^2 \cdot f$$

Power consumed by the output circuit is:

$$P_{out} = V_{LED} \cdot I_{LED} + V_D \cdot I_{LED} + R_b \cdot I_{LED}^2$$

Conservation of power requires that the above two equations be equated and solved for a more precise value of the required peak inductor current:

$$I_p = \sqrt{\frac{2 \cdot I_{LED} \cdot (R_b \cdot I_{LED} + V_{LED} + V_D)}{L \cdot f}}$$

where L is the actual standard inductor value chosen.

Inserting known values in the above yields:

$$I_p = 1.037A$$

Step 5: Calculate the value of the current-sense resistor(s) consisting of the parallel combination of R9 and R10 and the sensed voltage divider resistor values (if necessary), consisting of R6 and R7.

The current-limit threshold of the MAX16802 is 291mV. Thus, the values of R9, R10, R6, and R7 are chosen to produce the inductor peak current calculated in Step 4.

This is done, and the values that yield 350mA at 12V are shown in the application schematic. Due to parasitics, the resistor values (R7) might need some tweaking to get the desired current.

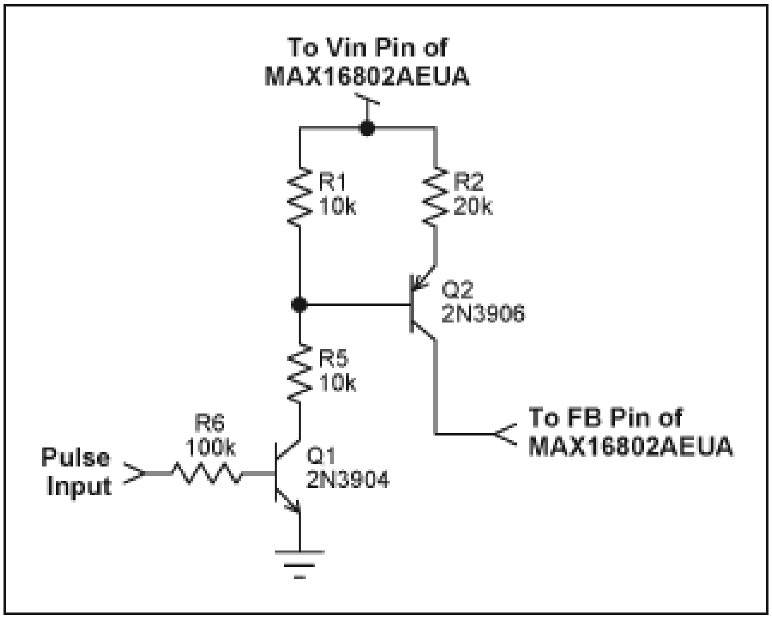
Step 6: Components R1 and R2 are optional. They are used to regulate the $+V_{LED}$ node to 29V. This is useful if the output terminals are accidentally open circuited. Without the voltage feedback provided by the above components, the output terminal voltage will most likely reach destructive levels.

Components C1 and R5 are also optional and are used to stabilize the voltage feedback loop. For this type of application, these components can be left out.

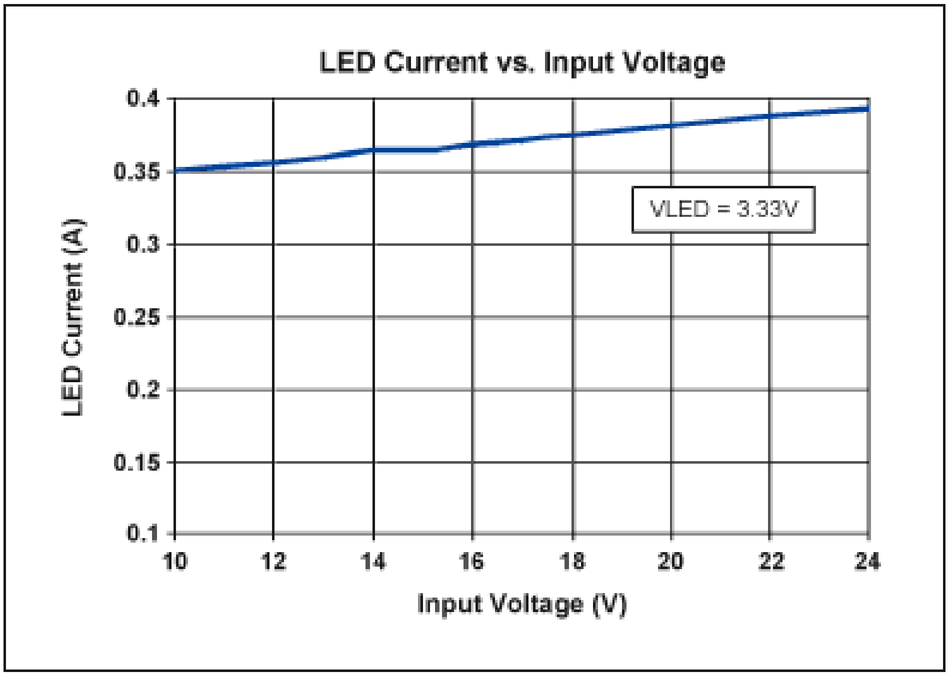
Low-Frequency PWM Dimming

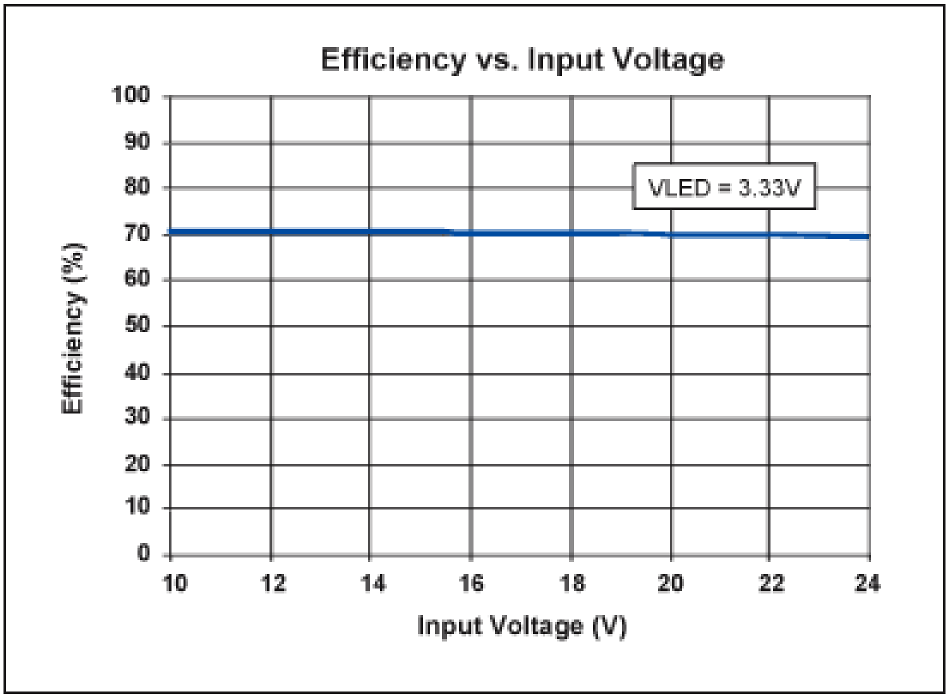
The best method for controlling the brightness level of an LED light source is by low-frequency PWM pulsing of the LED current. In this method, the LED current is pulsed at varying duty cycles while keeping the absolute amplitude of the current constant. In this way, the light wavelength emanating from the device is unchanged throughout the dimming range.

Use the circuit below to accomplish PWM dimming.

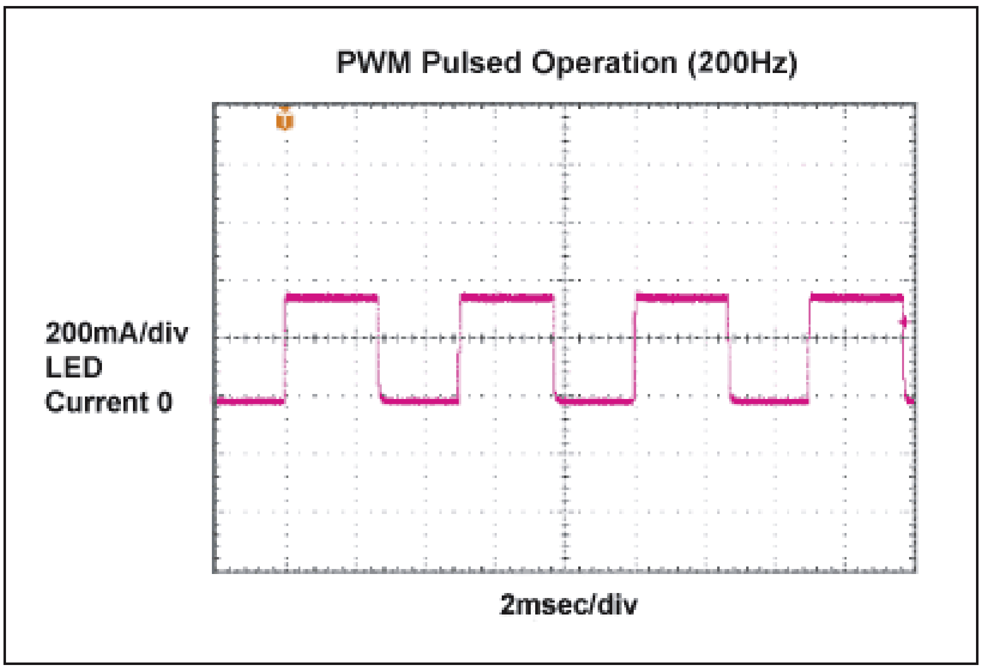


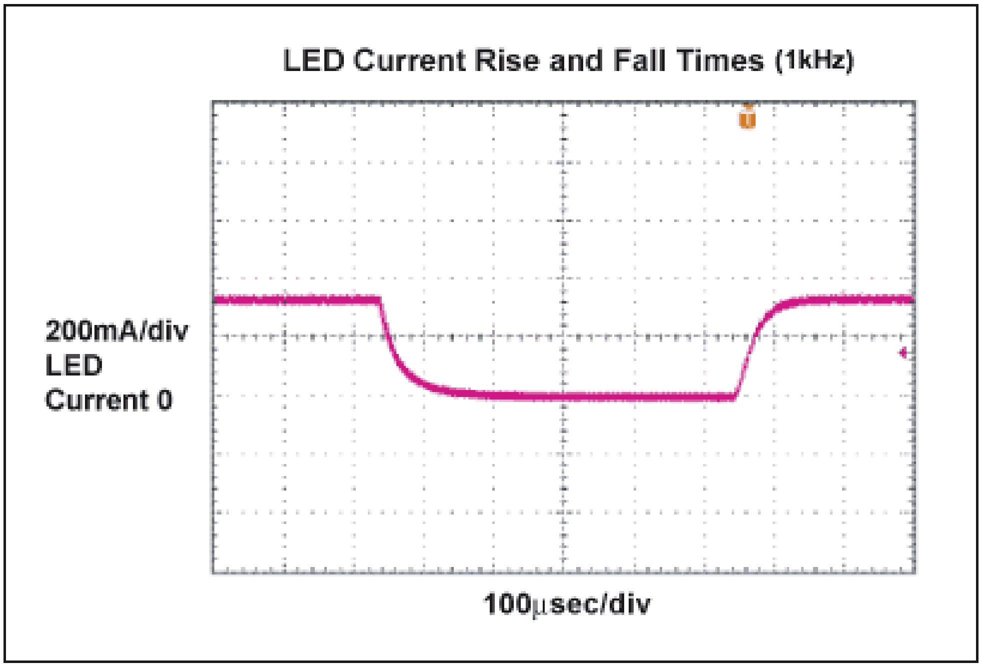
Performance Curves





Printed Circuit Board





µMAX is a registered trademark of Maxim Integrated Products, Inc.

Application Note 3639: www.maxim-ic.com/an3639

More Information
For technical support: www.maxim-ic.com/support
For samples: www.maxim-ic.com/samples
Other questions and comments: www.maxim-ic.com/contact

Automatic Updates
Would you like to be automatically notified when new application notes are published in your areas of interest? Sign up for EE-Mail™.

Related Parts

MAX16801A: QuickView -- Full (PDF) Data Sheet -- Free Samples
MAX16801B: QuickView -- Full (PDF) Data Sheet -- Free Samples
MAX16802A: QuickView -- Full (PDF) Data Sheet -- Free Samples
MAX16802B: QuickView -- Full (PDF) Data Sheet -- Free Samples

AN3639, AN 3639, APP3639, Appnote3639, Appnote 3639