AN-1250 Inductive Based Switching Regulator Circuits Provide High Efficiency White LED Drives

ABSTRACT

White LEDs are quickly becoming the light of choice for backlighting of small color displays because of their falling costs, longer life, and smaller size. The problem this presents is that the white LED has a high voltage drop (3.1 V to 4.0 V depending on manufacturer) as compared to the monochrome displays' green LED with a voltage drop of 1.8 V to 2.7 V. Whereas the green LED can be powered directly from the commonly used Li-Ion battery, with a linear regulator, and a ballast resistor, the white LED used for backlight or frontlight purposes will requires the battery voltage be boosted.

Contents

List of Figures

1 Introduction

TI has many solutions for driving LEDs including switched capacitor converters and inductive based switching regulators. This application note will describe some methods of driving white LEDs using inductive based switching regulators and some of the benefits of each. The main areas of concern for most designers of portable equipment are efficiency, size, cost, functionality, and LED current matching. Balancing these competing demands will help designers make the right choice for his or her application.

2 The Switching Regulator

A boost switching regulator set up as a constant current source can drive several white LEDs in series, keeping brightness constant even over a wide variation in supply voltage.

Figure 1, Figure 2 and Figure 3 show some designs using the LM2622 PWM boost regulator and the LM2704 PFM boost regulator.

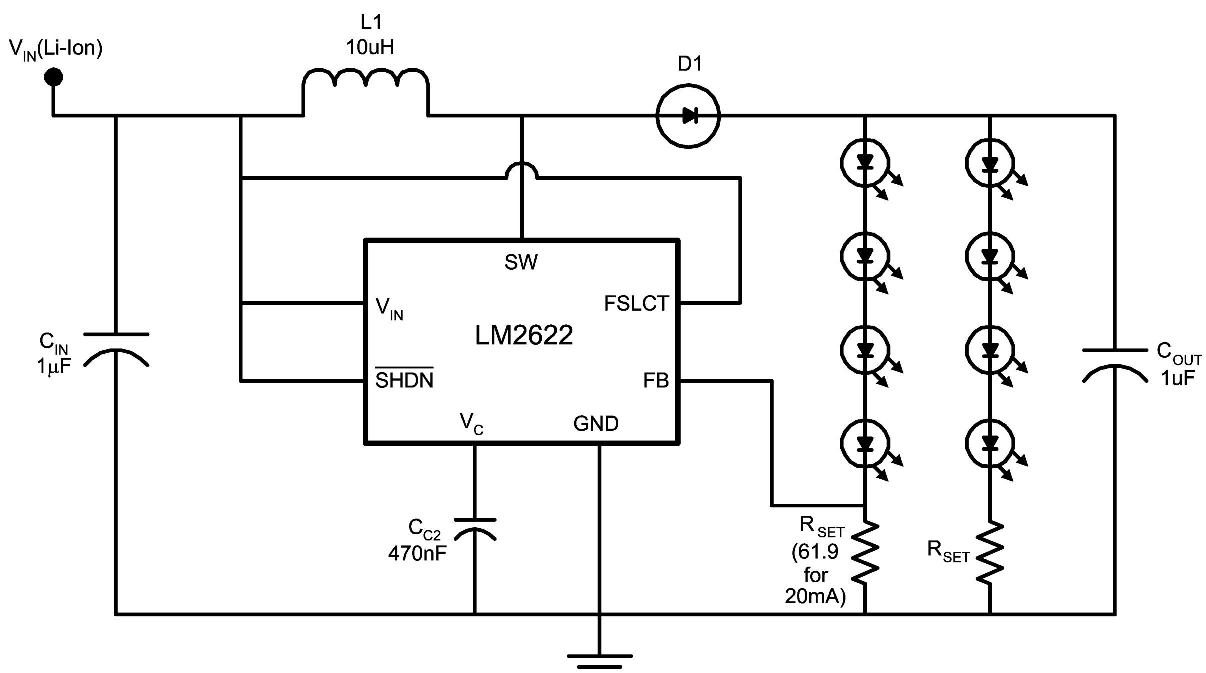

Figure 1. Basic LED Driver for Two to Eight LEDs at up to 30 mA Each

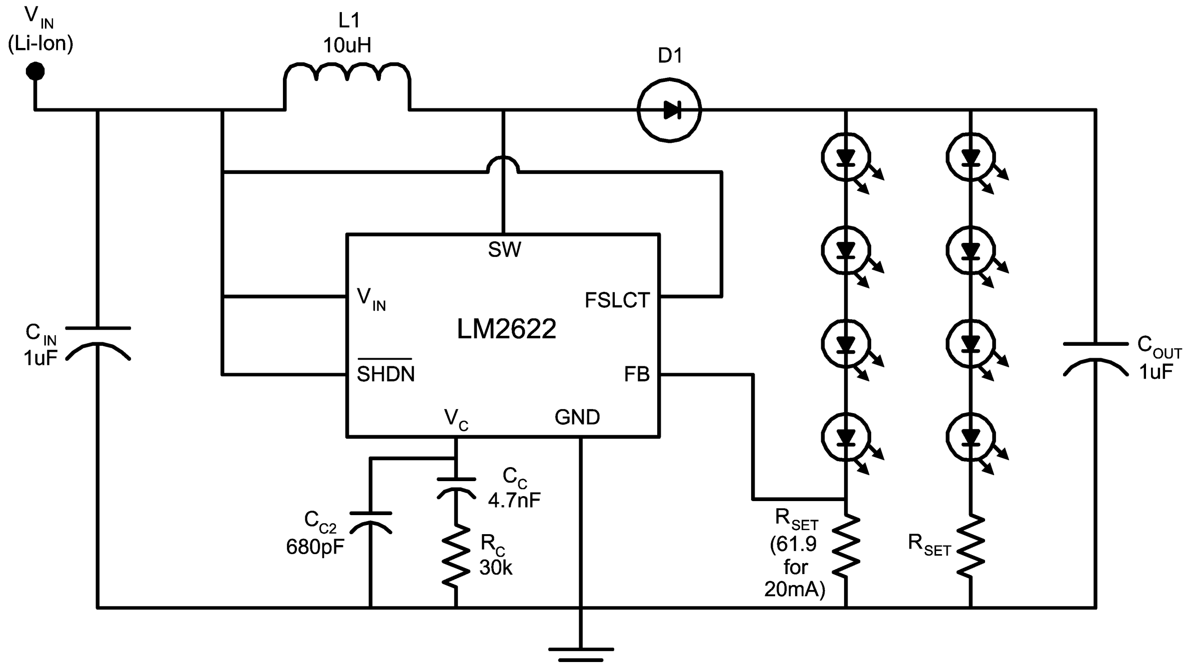

Figure 2. LED Driver With Improved Compensation for Faster Setup

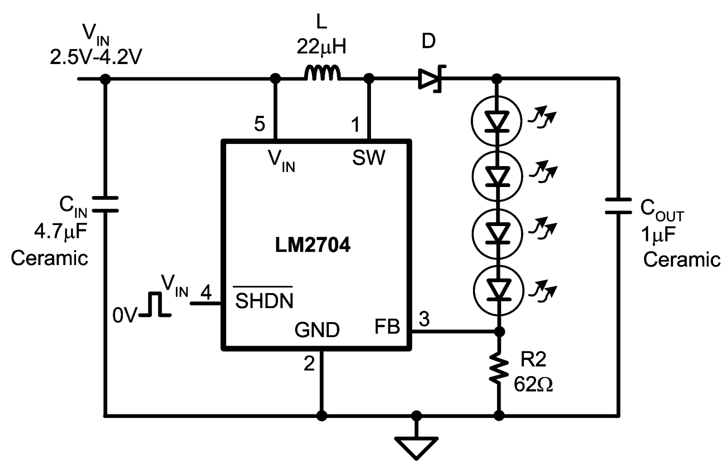

Figure 3. High-Efficiency LED Driver With Low Components Count Drives Two to Eight LEDs at up to 20 mA Each

Figure 1 is capable of driving 2 to 8 white LEDs at up to 30 mA each. When using four or fewer, the second string of LEDs (not connected to the FB pin) is eliminated. The desired LED current is set using the equation:

$$I_D = (1.26V/R_{SET}) \qquad (1)$$

When all of the LEDs are in series with each other (using up to four), there is perfect current matching through each.

When a second string of LEDs is added, it too will have perfect current matching through its LEDs, but not with the first string of LEDs. The current matching between the two strings will depend on how well the LED forward voltages match. Probability works to your advantage because the sum of four LEDs VF tend to balance widely varying VF in individual LEDs.

An inductive switching regulator also has a relatively high efficiency of typically 70% to 85% over the Li-Ion input voltage range (see Figure 5 for actual LM2622 measurements). However, higher efficiency comes at the expense of using an inductor for energy storage versus switched capacitor solutions that use only capacitors. The circuit in Figure 1 is best suited for static LED currents so dimming via a pulse width modulated (PWM) (square wave at the shutdown pin) signal is not recommended. This is due to the slow startup time of the circuit, which does not allow a sufficiently fast PWM signal to eliminate visible blinking. Figure 1 is a reduced component count version of Figure 2 at the expense of functionality.

Figure 2 is identical in description to Figure 1, with the only difference being a change in how it is compensated. This requires an extra capacitor and resistor on the VC pin, but provides a faster startup time. The brightness of the LEDs can now be controlled using a PWM signal on the shutdown (SHDN) pin. This signal can be anywhere from 60Hz to 200Hz and the brightness is controlled by the duty cycle of the PWM signal (50% duty cycle equals approximately 50% LED current).

Figure 3 shows the LM2704 pulse frequency modulated (PFM) regulator. The LM2704 circuit has the same benefits of current matching and high efficiency as the LM2622 circuit but with a few advantages. Since it is a PFM architecture, it has a slightly better efficiency than the LM2622. It is also more inherently stable, which means a lower component count since the compensation R's and C's are no longer required. The LM2704 circuit is also physically smaller since it comes in a SOT-23 package versus the MSOP package of the LM2622. The costs of these advantages are a lower current output and a larger input capacitor. The LM2704 is only capable of driving up to 8 LEDs at 20 mA each, but this is plenty for most applications. PFM circuits are also more susceptible to noise and require more energy storage at the input. This requires the use of a large input capacitor relative to the PWM architecture.

In conclusion, the switching regulator approach is desirable for applications that require two to eight LEDs, the highest efficiency, basic brightness functionality, and precise current matching.

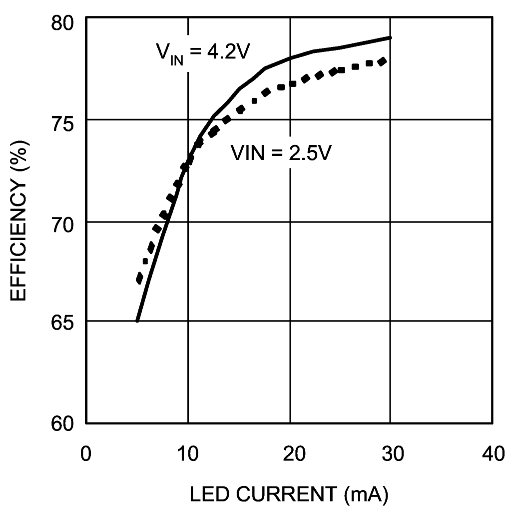

Figure 4. LM2622 Efficiency (4 LEDs)

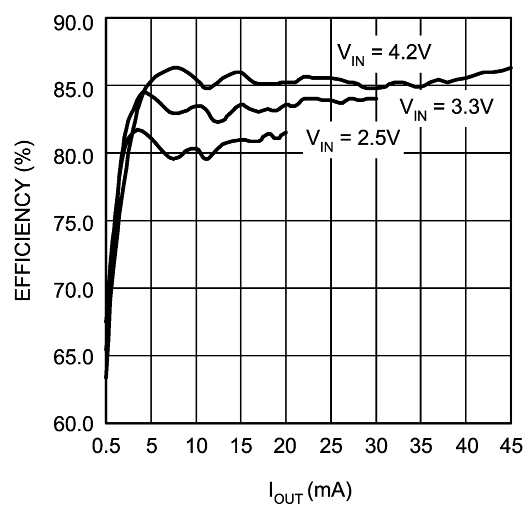

Figure 5. LM2704 Efficiency (4 LEDs)

IMPORTANT NOTICE