Application Brief

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

Application Brief 110

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Since the conception of cellular phones, PDAs, and handheld computers, there has been a continuing push for more useful and dynamic displays. One of the more drastic changes in miniature display technology has emerged due to the availability of Internet content, pictures, and videos on ever-shrinking personal devices. The promise of more content and functionality has caused a migration towards higher resolution color displays. However, this presents some added design issues as a color LCD display requires white backlighting as opposed to the more standard green. The current options are using a Cold Cathode Fluorescent Lamp (CCFL), an electroluminescent backlight, or newer white LEDs. White LEDs are quickly becoming the light of choice because of their falling costs, longer life, and smaller size. The problem this presents is that the white LED has a high voltage drop (3.1V to 4.0V depending on manufacturer) as compared to the green LED with a voltage drop of 1.8V to 2.7V. Whereas the green LED can be powered directly from the commonly used Li-Ion battery, a linear regulator, and a ballast resistor, the white LED used for backlight or frontlight purposes will require the battery voltage be boosted.

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.

The Switching Regulator

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

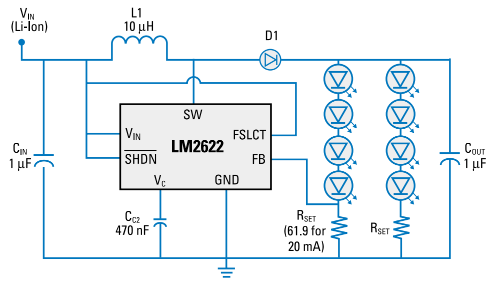
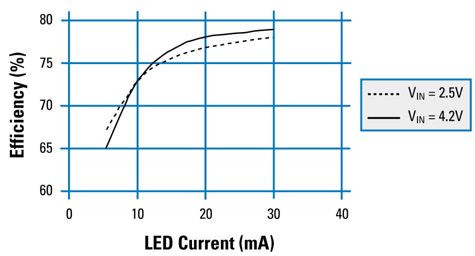


Figure 1: Basic LED Driver For Two To Eight LEDs At Up To 30 mA Each

Figure 1 The LM2622 is capable of driving two to eight 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:

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

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 V_F tend to balance widely varying V_F in individual LEDs.



Graph 1: LM2622 Efficiency (Four LEDs)

An inductive switching regulator also has a relatively high efficiency of typically 70% to 85% over the Li-Ion input voltage range *(see Graph 1 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 of *Figure 1* is best suited for static LED currents so dimming via a PWM (Pulse Width Modulated) 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.

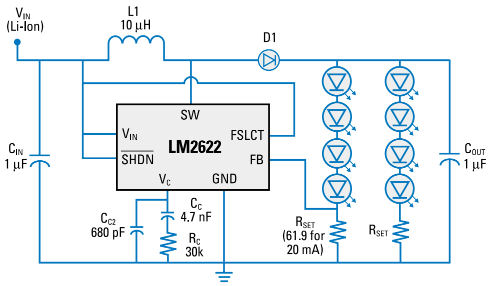


Figure 2: LED Driver With Improved Compensation For Faster Startup

Figure 2 The circuitry port 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 V_C 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 60 Hz to 200 Hz and the brightness is controlled by the duty cycle of the PWM signal (50% duty cycle equals approximately 50% LED current).

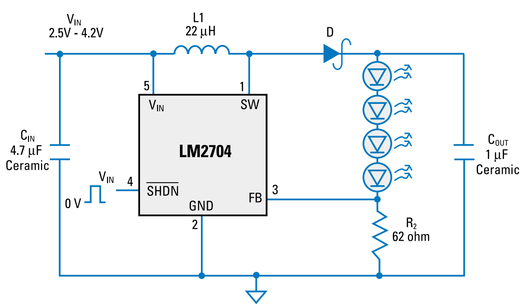
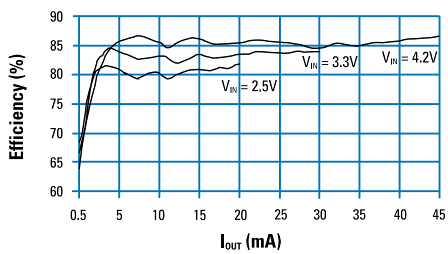


Figure 3: High-Efficiency LED Driver With Low Componets Count Drives Two To Eight LEDs At Up To 20 mA Each

Figure 3 shows the LM2704 PFM (Pulse Frequency Modulated) 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 *(see Graph 2)*. 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 eight 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.



Graph 2: LM2704 Efficiency (Four LEDs)

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