Application Brief

Switched Capacitor Circuits Provide Efficient and Functional White-LED Drive

Application Brief 109

Clinton Jensen

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. This presents some added design issues, however, 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 with a linear regulator and a ballast resistor, the white-LED used for backlight or frontlight purposes will require the battery voltage be boosted.

National has many solutions for driving LEDs including switched capacitor converters and inductive-based switching regulators. This application note will describe some different switched capacitor methods of driving white-LEDs and 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 Switched Capacitor Voltage Regulator

One method of driving white-LEDs is to use a switched capacitor DC/DC buck-boost converter with a regulated output voltage. *Figure 1* shows an example of this using the LM3354 buck-boost switched capacitor DC/DC converter. The output is a regulated 4.1V.

This circuit is capable of supplying 90 mA at 4.1V output (see the LM3355 for up to 50 mA output current). The number of LEDs that may be driven depends on the LED current desired in each. The current is set using the equation:

$$I_D = (4.1V - V_F)/R_{SET}$$

where V_F is the forward voltage drop of the LED chosen. As the LEDs are in parallel, the current matching is not perfect. The current matching will depend on how well the forward voltage drop of each LED matches. This circuit is smaller than a switching regulator solution yet still maintains an average efficiency of about 70% (actual efficiency to LEDs, some power is dissipated by the ballast resistors) over the Li-Ion input voltage range.

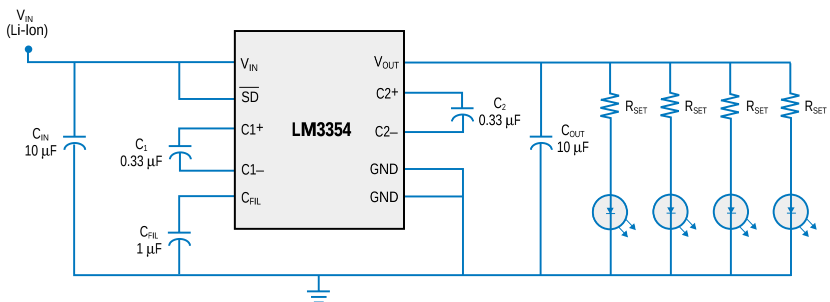

Figure 1: Switched Capacitor Voltage Regulator

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The brightness of the LEDs in this circuit may be controlled using a 60 Hz to 200 Hz PWM signal on the shutdown (SD) pin.

The switched capacitor voltage regulator approach is desirable for applications requiring one to ten LEDs, high efficiency, brightness control functionality, lower cost and small solution size. However, this solution suffers from poor brightness matching due to varying LED currents.

The Switched Capacitor Current Regulator

The second method presented here is a switched capacitor current regulator. Current regulation is achieved by using a switched capacitor boost circuit to drive a set of current sources. *Figure 2* shows the LM2792 switched capacitor LED driver.

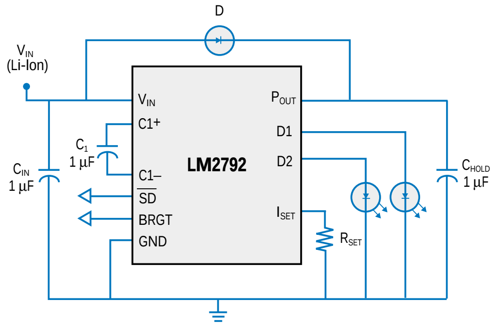
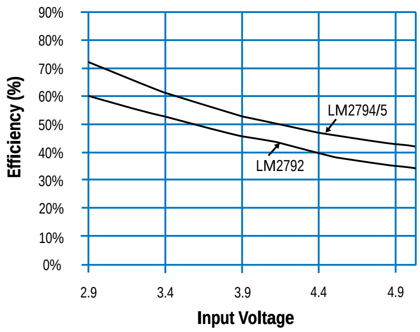


Figure 2: Switched Capacitor Current Regulator

This circuit uses a switched capacitor doubler (2X) circuit to power the current sources. It is capable of driving one to two LEDs at up to 32 mA total (16 mA each LED when using two). The current is set using the resistor R_{SET} and the BRGT pin (refer to the datasheet for a description on setting current using R_{SET} and the BRGT pin). Because current sources are used, the LED current matching is exceptional, within one percent. This circuit yields a smaller solution size than the voltage regulator yet it provides more functionality, although at the cost of a significantly lower efficiency. The brightness can be controlled one of two ways. A PWM signal between 100 Hz and 1 kHz may be used at the shutdown (SD) pin as in the previous two examples. An analog voltage can be applied to the BRGT pin as well. This provides the ability to control the brightness with much better linearity. The BRGT pin also allows a variety of lighting patterns and effects since a continuous analog waveform of any desired shape can be used for controlling LED brightness.

For driving up to four LEDs the LM2794 or LM2795 may be used. These circuits are similar to the LM2792 in that they have all the same functionality. The difference is that a three halves (3/2X) charge pump is used to power the current sources. This provides higher efficiency *(see Graph 1)* since the current sources will have a reduced voltage drop across the transistors. They are capable of supplying a total of 60 mA for up to four LEDs. The LM2794 and LM2795 also do not require the diode D shown in the LM2792 schematic. The only other difference is that where the LM2792 requires some signal at the BRGT pin to set the LED current, the LM2794 and LM2795 LED currents can be set using only R_{SET} if desired. The only difference between the LM2794 and LM2795 is the polarity of the shutdown pin to make it easier for designers to incorporate into existing systems. The switched capacitor current regulator approach is desirable for circuits requiring one to four LEDs, precise current matching, small solution size, lowest cost, and the highest functionality and control.



Graph 1: Comparison Of LM2792 and LM2794/5 Efficiency

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National Semiconductor
2900 Semiconductor Dr.
PO Box 58090
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