White LED Driver Minimizes Space, Maximizes Efficiency and Flexibility

by Steven Martin

Introduction

White LEDs are the LCD backlight of choice for portable equipment due to their small profile, exceptional ruggedness and high luminosity. Li-Ion batteries, also rugged and small, are the popular power choice for the same portable equipment. The white LEDs have a nominal forward voltage between 3V and 4V and a Li-Ion battery has a nominal voltage of 3.6V, thus requiring circuitry to step-up the Li-Ion battery's voltage. The problem is, stepping up tends to reduce efficiency, which in turn reduces battery life. The LTC3205 solves this problem by powering up in *direct-connect* mode rather than step up mode. Once powered up, it uses a dropout detector for each white LED to determine if any are running out of drive. As the first white LED just begins to lose current, the chip automatically engages a very powerful 2:3 mode step-up charge-pump. Including 9 precision LED current sources in all, the LTC3205 has enough LED pins and sufficient strength to power a 4-LED main display, a 2-LED sub display and a 3-LED RED, GREEN and BLUE "happy-light".

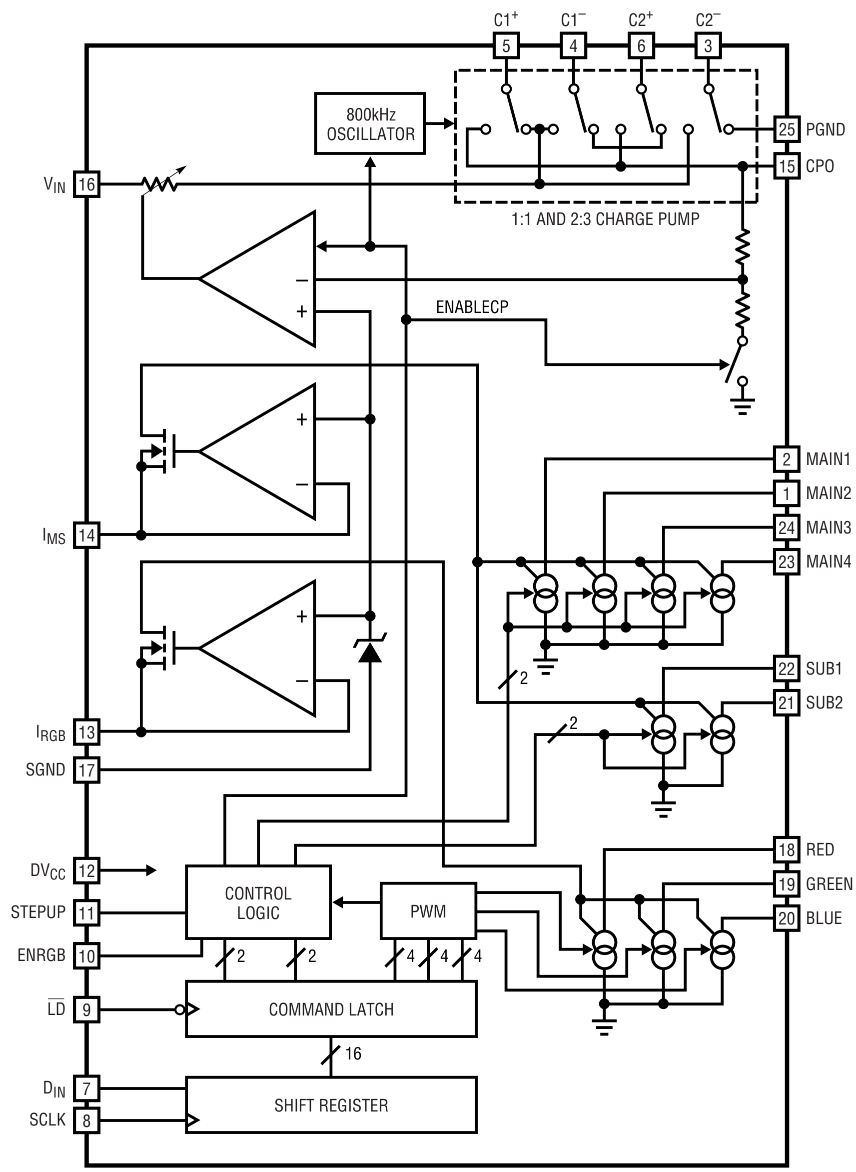

Figure 1. Block diagram of the LTC3205

Figure 1 shows the block diagram of the LTC3205. The chip is controlled by a simple 3-wire serial interface. The 16-bit register provides two control bits for the main display and two control bits for the sub display, giving exponentially-spaced brightness control for each. The remaining 12 bits are divided among the RED, GREEN and BLUE outputs giving 16 shades for each LED and a total of 4096 total colors for the happy light. The RGB LEDs are pulse-width modulated for brightness control while the white LED currents are linearly controlled. A separate logic reference pin (DVCC) allows logic levels from a microcontroller to be supplied at virtually any voltage above or below the battery voltage.

When powered from a Li-Ion battery, the power management section of the LTC3205 connects the LEDs (via the CPO pin) to the battery. Its 2:3 charge-pump only soft-starts when a main or sub display LED has insufficient drive or when the RGB current sources are used. The fractional-ratio charge-pump ensures that the efficiency is high even when the device is in charge-pump mode. The patented constant frequency architecture keeps input noise to a minimum by regulating current on both charge-pump phases.

Two precision servo amplifiers provide inputs to set the reference currents for the LEDs. The main/sub displays and the RGB display are controlled independently for maximum flexibility.

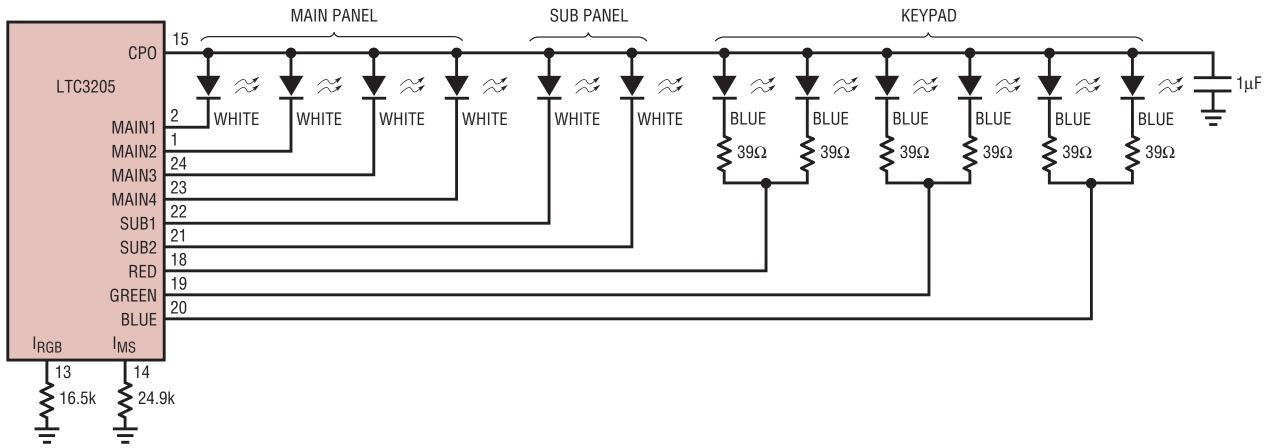

Figure 2. 8-LED keyboard display

Flexibility Limited only by Imagination

Because there are so many white LED applications, it's important to arrange each circuit for optimum performance. Given that the LTC3205 has four individual settings for its main display, four individual settings for its sub display and 16 individual settings for each of its color LED pins, the applications it can serve are virtually unlimited.

The LTC3205's primary application provides regulated currents to a 3- or 4-LED main display, a 1- or 2-LED sub display and 4096 colors to an RGB display. Nevertheless, it is possible to arrange the LTC3205 to provide power to an 8-LED keyboard display as shown in Figure 2. Alternatively, it can be used to power a 4-LED camera light as shown in Figure 3.

Brightness control can be achieved in a number of ways for each of the displays. The RGB display has 16 built in settings per LED. No external hardware or signals are required. The main and sub displays have four settings each, but these can be easily multiplied by adding a digital control signal to switch a reference resistor in or out as shown in Figure 4. With techniques like this, the number of brightness settings can be increased rapidly to 7 or 13 for the main and sub displays. Brightness can also be controlled by analog means as shown in Figure 5.

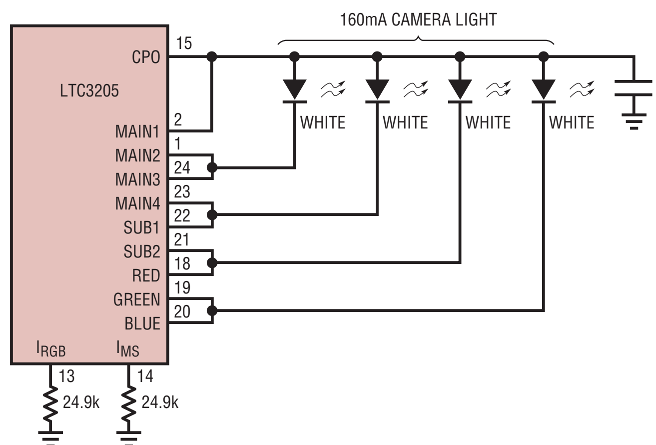

Figure 3. 4-LED camera light

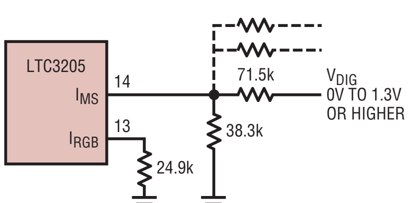

Figure 4. Alternative digital brightness control

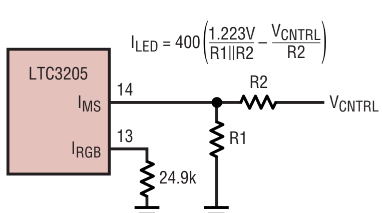

Figure 5. Alternative analog brightness control

Efficiency

Because the LTC3205 only enables its charge-pump as needed, it spends the majority of each battery cycle in direct-connect mode. Since the LED voltages are so close to the battery voltage, true efficiency ($P_{LED}/P_{BATTERY}$) is maximized, as is battery life. Figure 6 shows an example of achievable efficiency as a function of battery voltage for a 4-LED application running at 15mA per LED.

To achieve this high level of efficiency, the LED current sources are designed to deliver accurate current with as little as 120mV of compliance voltage. Furthermore, the 0.8Ω pass switch in direct-connect mode drops only 48mV with 60mA of display power.

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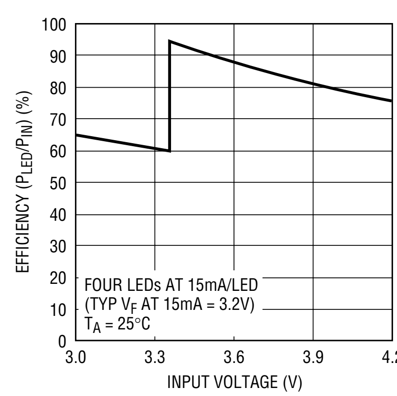

Figure 6. 4-LED main panel efficiency vs battery voltage

such that the desired output voltages ramp characteristic is achieved. The gate pullup currents are controlled via the FB^+ and FB^- pins.

Figure 4 shows coincident tracking for a system operating with +12V and –12V supplies as per the circuit in Figure 2. The circuit in Figure 2 is easily converted to work with –5V and +12V supplies by simply changing R3, R9 and R11 to 12.4kΩ. The new coincident tracking behavior is shown in Figure 5. Ratiometric tracking is sometimes preferable, especially in signal processing applications. Figure 6 shows this mode of operation, obtained by changing only R3 and R11 to 12.4kΩ. Note that in this case the supply ramps are made to start and finish at the same time.

Short-Circuit Protection

Current limiting provides protection for the output MOSFET devices. The current limit for either supply is set by sense resistors R_S^+ and R_S^- (Figure 2). The voltage across the sense resistor is regulated by the current limit circuitry to 50mV for conditions where foldback current limiting is not enabled. The TIMER pin provides a means for setting the maximum time the LT4220 is allowed to operate in current limit. Whenever the current limit circuitry becomes active, by either the positive or negative sense amplifier operating in current limit, a pull-up current source of 60uA is connected to the TIMER pin and the voltage rises with a slope of $dV/dt = 60\mu A/C_{TIMER}$. If the overload is removed, a small 3µA pulldown current slowly discharges the timer pin. If the timer succeeds in charging to a 1.24V threshold, an internal fault latch is set and the $\overline{FAULT}$ pin is pulled low. Both MOSFETs are quickly turned off while the TIMER pin is slowly discharged to ground.

The power dissipation will be high in the output MOSFET devices when the output is shorted with zero ohms. To prevent excessive power dissipation in these pass transistors the current limit on each supply is reduced as the output voltage falls. This characteristic, commonly referred to as “current foldback”, reduces the fault current as the output voltage drops and reaches the lowest level into the short. The foldback current limiting reduces short circuit MOSFET dissipation by a factor of 2.5. The FB± pins effectively measure the MOSFET V_{DS} voltage and control the appropriate current limit sense amplifier input offset to provide the foldback current limit.

Automatic Restart

Normally the LT4220 latches off in the presence of a fault. Nevertheless, by removing R15 in Figure 2, you can connect the $\overline{FAULT}$ and ON^+ together to enable automatic restart. $\overline{FAULT}$ pulls the ON^+ pin low allowing an automatic restart to be initiated once the TIMER pin ramps below 0.5V.

Conclusion

The LT4220 combines all of the functions necessary for split supply Hot Swap control in one small 16-lead SSOP plastic package. This device is adaptable to applications covering a wide range of positive and negative supply voltages, ramping profiles, capacitance and load currents, including optical/laser, audio and ECL systems.

LTC6903/LTC6904, continued from page 9

Conclusion

Though crystal based oscillators have dominated the timing and clocking market for many years, the LTC6903 (I^2C) and LTC6904 (SPI) offer solutions that are smaller, more flexible, more robust and lower power. Selecting a frequency from the 1kHz–68MHz frequency range is simple through the serial ports, and both devices operate over a wide range of supply voltages.

LTC3205, continued from page 23

Both of these features are required to keep the LTC3205 in direct-connect mode as long as possible.

Conclusion

The LTC3205, designed specifically for portable backlighting applications, provides all of the necessary current regulation, power circuitry and control logic to deliver efficient and accurate power to a large number of LEDs in a portable product. To further reduce board level complexity, it uses only four 0603 sized ceramic capacitors keeping the total solution height under 1mm. A straightforward serial interface reduces the number of wires needed to control all of the LEDs. Given its feature set, the LTC3205 packs an amazing amount of backlighting horsepower, flexibility and performance into a very small 4mm × 4mm footprint.