Tiny Device Drives 20 White LEDs from a Single Cell Li-Ion Battery

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Introduction

White LEDs are gaining popularity as the backlighting source for the LCD displays used in handheld devices, mainly due to their improved efficiency and shrinking costs. White LEDs are also making inroads into the larger LCD displays used in automotive instrument panels and car radios. The LT3466 simplifies the task of fitting the LED driver circuitry into the latest devices by providing a dual high efficiency, constant current white LED driver in a space-saving 3mm × 3mm DFN package. The LT3466 is designed to drive up to 20 white LEDs from a single cell Li-Ion battery input with greater than 80% efficiency. It also provides space- and component-savings with integrated Schottky diodes and internal compensation.

About the LT3466

Figure 1 shows a block diagram of the LT3466 with its two independent, but identical, step-up converters capable of driving asymmetric LED strings. The step-up converters are designed to drive the series connected LEDs with a constant current, thus ensuring uniform brightness and eliminating the need for ballast resistors. LT3466 incorporates internal 44V power switches and Schottky diodes. Switch current limit is guaranteed to be greater than 320mA over the full operating temperature range. A low, 200mV, high accuracy (±4%) reference voltage is provided to program the LED current.

The step-up converters use a current mode topology to provide excellent line and load transient response. Internal feedback loop compensation of LT3466 allows the use of small ceramic capacitors at the output. The built-in over-voltage protection circuit clamps the output of either converter to 42V if the LED string connected to that output fails open-circuited. Internal soft-start is provided for each step-up converter, thus minimizing inrush current during start-up.

The switching frequency of LT3466 can be programmed over a 200kHz

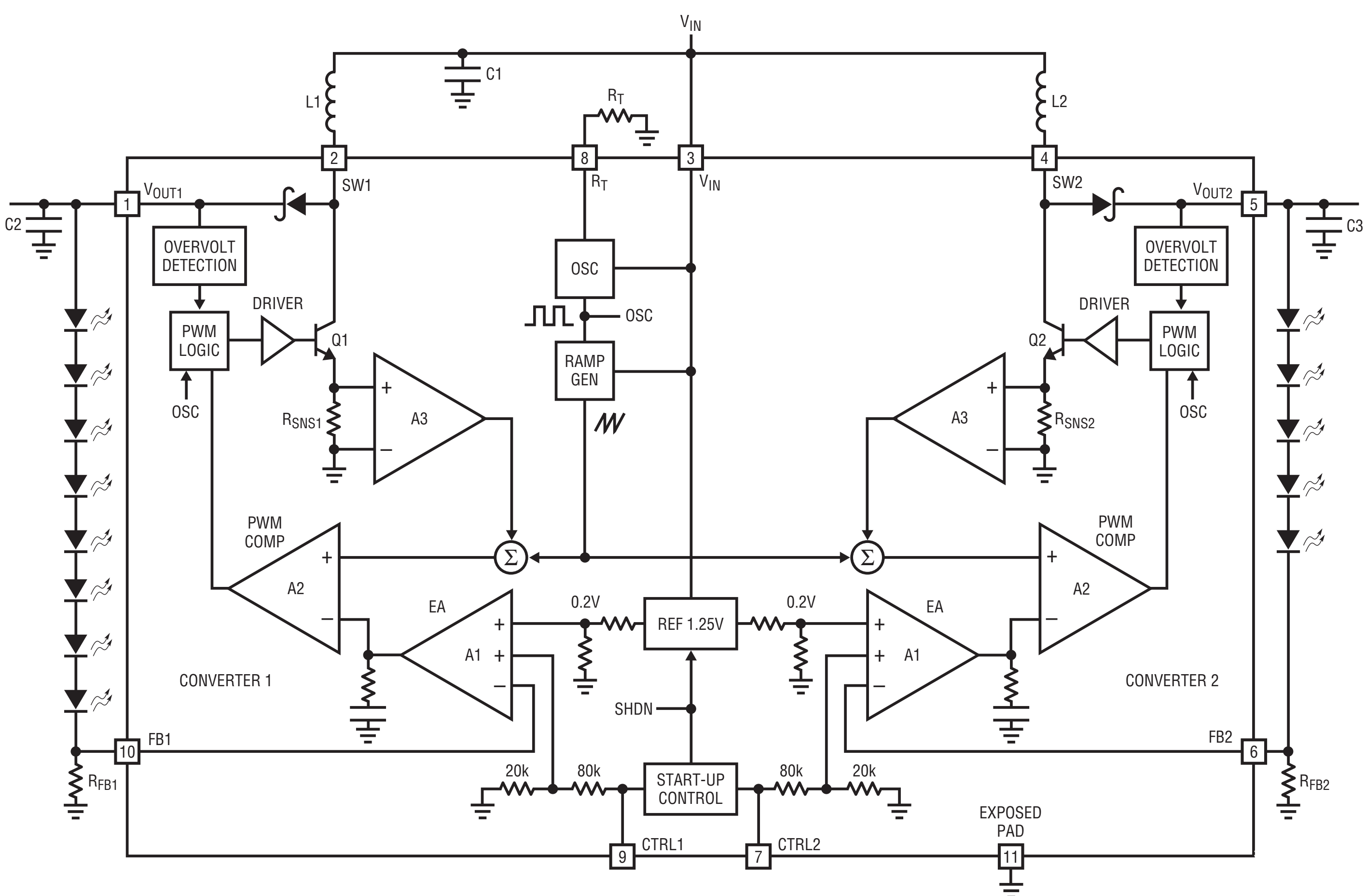

Figure 1. LT3466 block diagram

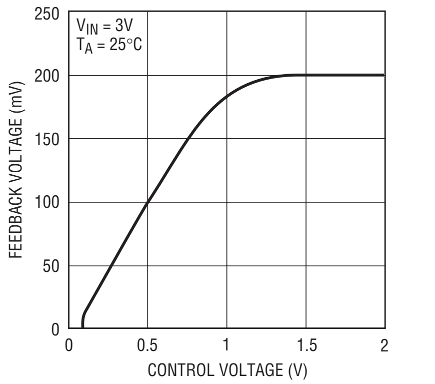

Figure 2. Correlation of feedback voltage (V_{FB}) to control voltage. The current (dimming) in the LED string is given by $I_{LED} = V_{FB}/R_{FB}$.

to 2MHz range by means of a single resistor from the R_T pin to ground. The LT3466 operates from a wide 2.7V to 24V input voltage range, making it suitable for a wide range of applications.

The device features independent shutdown and dimming control of the two LED strings. The current in each LED string can be shut off by pulling the respective control (CTRL1 or CTRL2) pin voltage below 50mV. Dimming for each LED string is achieved by applying a DC voltage to its respective control pin. When both CTRL1 and CTRL2 pin voltages are pulled below 50mV, the device enters total shutdown.The dimming feature for the LT3466 can be best understood by referring to the block diagram in Figure 1. The amplifier A1 (present in both converters) has two noninverting inputs and a single inverting input. An internal 200mV (±4%) reference voltage is connected to one of its noninverting inputs. An input voltage equal to 0.2 • V_{CTRL} is connected to the second noninverting input of A1. The inverting input of A1 is connected to the cathode of the lowest LED in the string and the feedback resistor.

The LED current in each string is given by:

$$I_{LED} = \frac{V_{FB}}{R_{FB}}$$

Thus, a linear change in the feedback voltage results in a linear change in the LED current. The amplifier A1 regulates the feedback pin voltage as a function of the control voltage as given by:

$$V_{FB} = 0.2 \bullet V_{CTRL}\text{ , When } 0.2V < V_{CTRL} < 1V$$

$$V_{FB} = 0.2V\text{ , When } V_{CTRL} > 1.6V$$

As the voltage at the control pin is ramped from 0.2V to 1.6V, the respective feedback pin voltage changes from 40mV to 200mV. When the control voltage is taken above 1.6V, it does not affect the feedback pin voltage. Figure 2 shows the correlation between the feedback voltage and the control pin voltage.

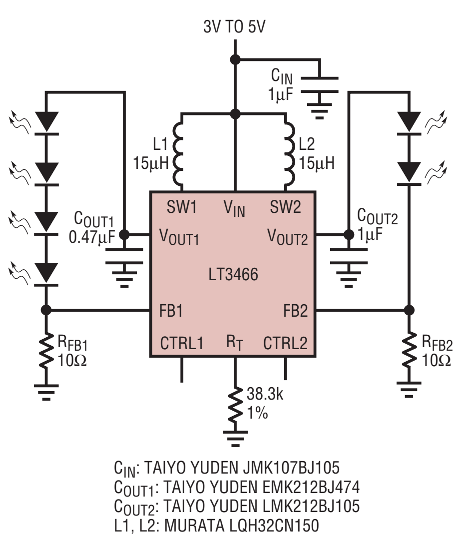

Figure 3. Low profile (max height < 1.7mm), single cell Li-Ion powered, six (4/2) white LED driver circuit

Main and Sub-Display Backlighting for Cell Phones

A typical application of the LT3466 is as a driver for dual backlights in a cell phone. Present day, flip style cell phones typically use four white LEDs (with the phone open) for backlighting the main display and two white LEDs (with the phone closed) for a sub-display. Each of the backlights requires independent dimming and shutdown control. Figure 3 shows a Li-Ion battery powered 6-LED (4-LED main and 2-LED sub) backlight system. LT3466 allows for independent dimming control of the main and sub display via the CTRL1 and CTRL2 pins.

Board real estate is at a premium in cell phones and the circuit shown in Figure 3 minimizes the number of external components and provides a complete system solution with maximum component height under 1.7mm. The LT3466 is designed to run at a 1.25MHz switching frequency via the selection of the R_T resistor. The choice of high 1.25MHz switching frequency allows the use of space saving low-profile inductors and tiny 0805 size ceramic capacitors, while maintaining high system efficiency. Figure 4 shows the efficiency of the circuit. The typical efficiency at 3.6V input supply is 81% with both the LED strings being run at 20mA.

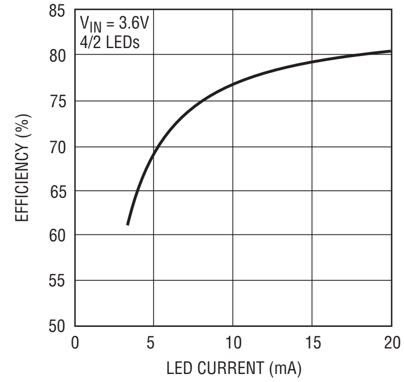

Figure 4. Efficiency for Figure 3's circuit

Figure 5 shows the transient response of the circuit to a step in the current of the 4-LED string from 10mA to 20mA. The inductor current transition is smooth and has a well-defined steady state ripple, which results in a lower output voltage ripple. This reduces the size and cost of the output filter capacitor and allows the use of a small 0.47µF (16V, X7R dielectric) 0805 case size ceramic output capacitor.

Single Cell Li-Ion-Powered, 20-White-LED Driver Circuit Using all Ceramic Capacitors

Large color LCD displays used in present day GPS systems and other handheld devices may require up to 20 white LEDs for backlighting while

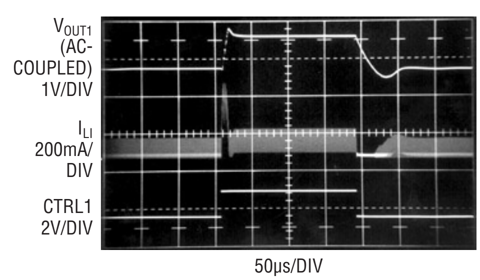

Figure 5. Transient response for Figure 3's circuit. Current in the 4-LED string is stepped from 10mA to 20mA

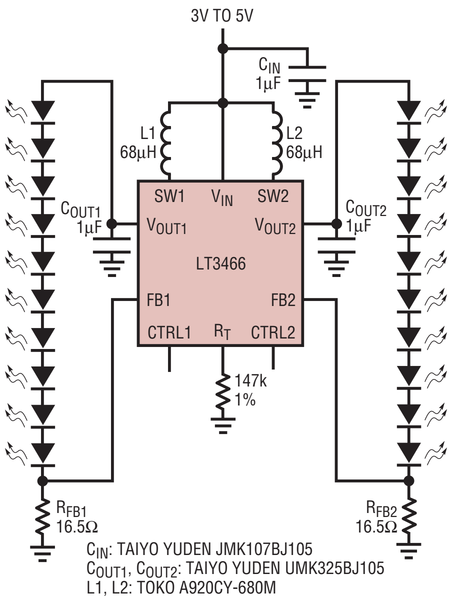

Figure 6. High efficiency, single cell Li-Ion powered twenty (10/10) white LED circuit uses all ceramic capacitors

running off a single Li-Ion cell. The LT3466, with its internal 44V power switches and Schottky diodes, is well suited to drive up to ten white LEDs in series at each output. In order to drive ten white LEDs in series, the converter needs to generate up to a 40V output voltage (the forward voltage drop of a white LED being 3V to 4V). Figure 6 shows 20 white LEDs powered by single cell Li-Ion battery.

To drive ten LEDs per output from a single Li-Ion cell, the converter must run at a high duty cycle of 94%

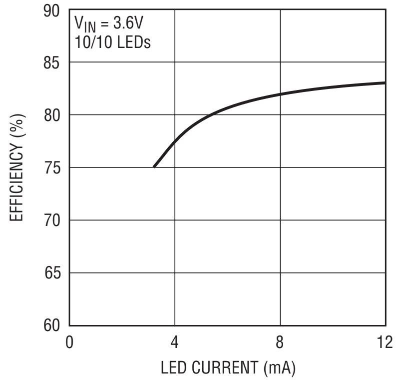

Figure 7. Efficiency for Figure 6's circuit

(typical). The unique architecture of LT3466 allows it to achieve high duty cycles by switching at a lower frequency. In the circuit shown in Figure 6, the LT3466 is designed to run at a switching frequency of 350kHz. The circuit of Figure 6 uses low profile inductors and all ceramic capacitors. Figure 7 shows the efficiency vs LED current for the circuit. The typical efficiency at 3.6V input supply is 83% with both the LED strings being run at 12mA.

If either of the 10-LED strings must be run at greater than 12mA, then it is necessary to power the LT3466 with a higher input supply voltage. The LT3466 is capable of driving 20 white LEDs at 20mA when powered from two Li-Ion cells connected in series. Consult the LT3466 data sheet for more details on the application circuit.

Lighting up Automotive Instrument Panels: A 50-White-LED Driver Operates from a 12V Supply

The LT3466's wide input voltage range makes it ideal for automotive applications. White LEDs are commonly used for providing the backlight for automotive instrument panels and car radio displays. In these applications, the white LEDs must be powered by a constant current to guarantee consistent light intensity and uniform brightness. Figure 8 shows the LT3466 powering 50 (two banks of 25) white LEDs from a 12V input supply. The circuit is configured as a voltage tripler to produce output voltages in excess of 90V. This allows a string of 25 LEDs to be connected at each output, resulting in constant current and uniform brightness.

In Figure 8, the LT3466 is configured to operate at a 2MHz switching frequency by the choice of the 20.5kΩ R_T resistor. This ensures that the radiated switching noise falls outside the AM radio band. High switching frequency also allows the use of low-profile inductors and surface mount ceramic capacitors. Figure 9 shows the efficiency for the circuit. In this application, LT3466 delivers 2.4W output power with 83% efficiency. The thermally enhanced 3mm × 3mm DFN packaging (with exposed pad) of the

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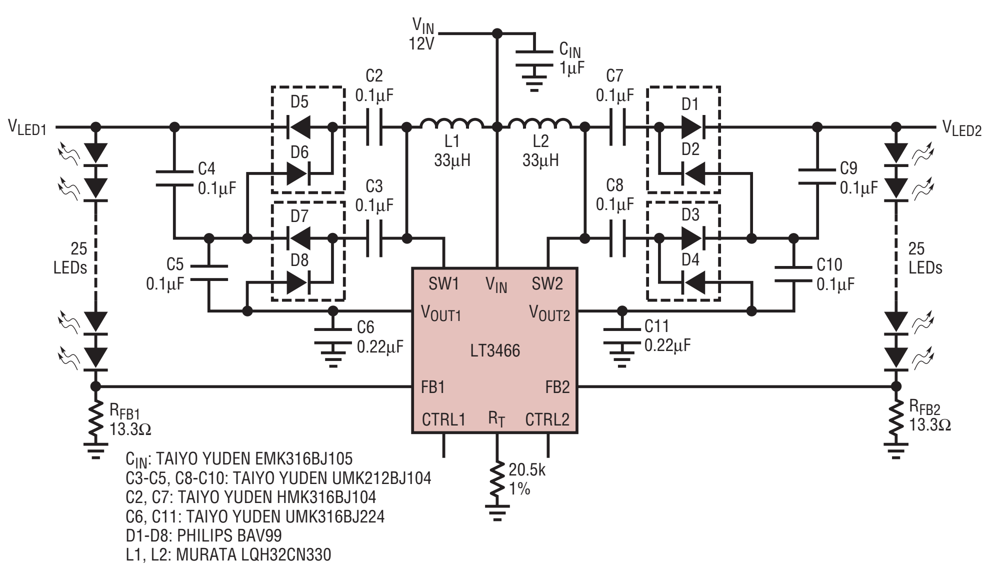

Figure 8. 50 white LEDs powered by a 12V input using low profile surface-mount components

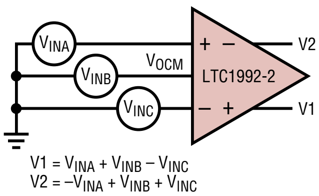

Figure 4. Easy arithmetic processing of single-ended signals

namic and has extremes that are 50% of the input swing (V_{INCM} is ±2.5V in the Figure 3 example). The V_{ICM} equation above is used with both the upper and lower dynamic V_{INCM} values to verify single-ended operability.

Common-Mode Input Range Extension

The configurable-gain LTC1992 makes it possible to extend input common-mode capability to well outside the supply range by selecting gain below unity and/or introducing common-mode shunt-resistors (see R_S in Figure 6). The drawback to the shunt-resistor method is that component tolerances of R_G and R_S become magnified by approximately the gain of the circuit, leading to reduced CMRR performance for a given resistor tolerance. For

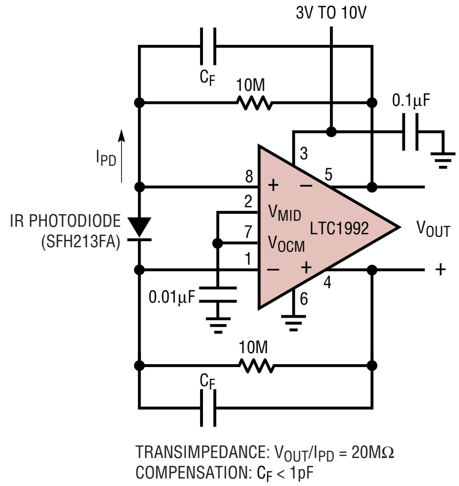

Figure 5. Fully differential transimpedance amplifier topology

low-gain operation, common-mode extension to beyond 35V is realizable with the use of high-accuracy resistor networks.

Conclusion

The LTC1992 family of differential amplifiers offers easy-to-use building blocks that provide simple, minimum component-count solutions for a wide range of applications, including convenient methods of transforming signals

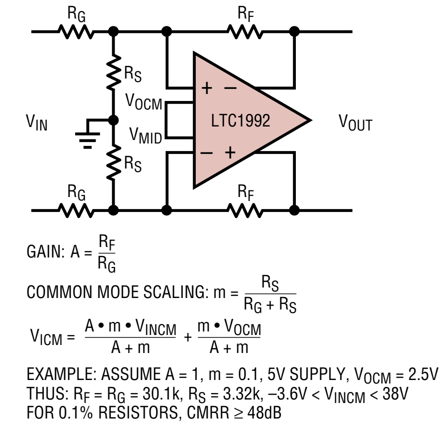

Figure 6. Extending input common-mode range

to/from differential form, providing component-free gain, or generating DC level-shifting functions. The versions that include on-chip precision resistors save space and reduce costs by eliminating expensive precision resistor networks. The configurable-gain LTC1992 saves cost by allowing single-supply applications to support input signal swings that exceed the supply-voltage window without additional design complexity.

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LT3466 enables it to drive as many as 50 white LEDs from a 12V input supply. Figure 10 shows the switching waveforms for the circuit.

Conclusion

The LT3466 is a dual white LED driver designed to drive up to 20 white LEDs from a single Li-Ion input. Integrated power switches, Schottky diodes, and availability in a space-saving (3mm × 3mm) DFN package make LT3466 an excellent fit for handheld applications. The wide operating voltage range and high frequency capability of the LT3466 enables it to meet the backlighting needs for automotive

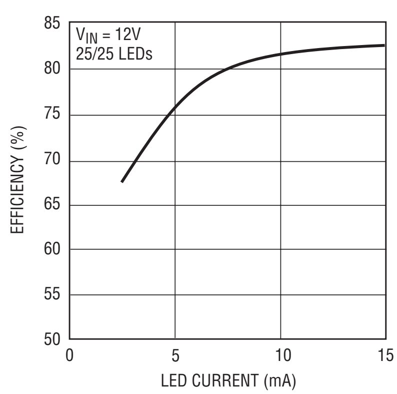

Figure 9. Efficiency for Figure 8's circuit

instrument panels and car radio displays as well. Features like internal soft-start, open LED protection and internal loop compensation reduce the

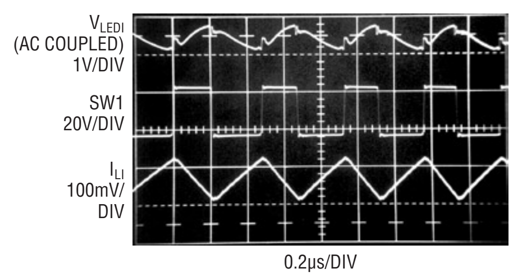

Figure 10. Switching waveforms for Figure 8's Circuit. Each set of 25 white LEDs driven at 15mA

number of external components, thus reducing the overall cost and size of the white LED driver circuit.

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