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Make a White-LED Torch Using a Buck Converter

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APPLICATION NOTE

Introduction

Very popular in portable backlight applications, the white LED finds more and more derivatives on adjacent market. Its small package size and light efficient conversion contribute to replace standard illumination solution. White LED considerably improves their technologies in the last years and where a DC−DC boost or buck−boost converter was required for a given illumination, you can now place a DC−DC buck converter.

Higher current with lower forward voltages and you can now address flashlights, head−mounted lighting, bicycle lighting, solar−powered lighting, torch and other battery−powered lighting applications.

This application note will detail the method of making White LED torch application using NCP1529.

NCP1529 integrated circuit is a high frequency stand alone DC to DC buck converter. Designed for portable markets, it is able to supply voltages from 0.9 V to 3.3 V by an external resistor divider and to provide up to 1 A. Based on current mode architecture, its large bandwidth fills fast transient requirements of handled devices. Additional features include integrated soft−start, cycle−by−cycle current limiting and thermal shutdown protection.

Application Objective

Knowing that light intensity of a White LED depends on its forward current, not on its forward voltage; the main objective of this application is to regulate a constant current with a converter typically used to regulate a constant voltage. The proposal must be both accurate and energy efficient and must be able to support low frequency dimming (below 10 Hz) for distress alert application and PWM medium frequency dimming (from 100 Hz to 1 kHz) to adjust light intensity.

This application note will take the example of regulating a constant current of 800 mA through a single die LED. Input voltage range can be based on standard 5 V rails or battery cells arrangement which does not exceed maximum rating of the NCP1529.

The NCP1529 − DC−DC buck converter housed in UDFN−6 package − is selected for its high power conversion and high thermal dissipation capabilities. Moreover, loop control which allows 100 % duty cycle operation extends play time when battery voltage is closed to forward voltage.

The White LED of interest selected for this demonstration is the CREE XP−G which delivers unprecedented levels of light output and efficacy for a single die LED. At 800 mA forward current, following figure shows that forward voltage is below 3.25 V.

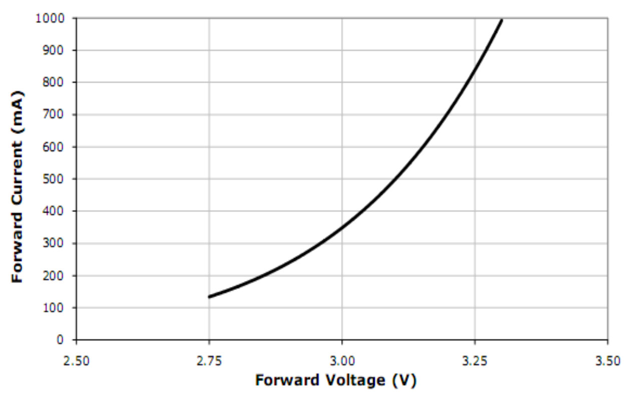

Figure 1. Shows CREE XP−G Forward Voltage Characteristics

Making a Schematic

Most of the DC−DC step down converters regulate a constant voltage using a divider network set to provide a given feedback voltage at 500 mV or 600 mV. The NCP1529 reference voltage is 600 mV.

Reducing this voltage to 80 mV for instance will considerably increase play time of your torch and improve system efficiency.

A simple and low cost solution could be to reduce feedback network using an additional resistor as shown in Figure 2.

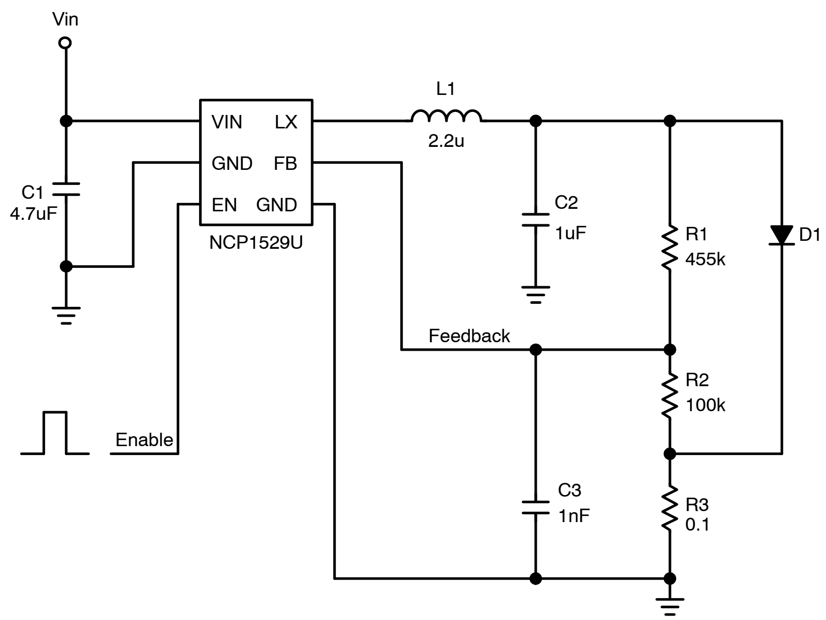

Figure 2. Presents a Simple Solution to Reduce Current Sense Voltage

To get 800 mA through the White LED implies R3 = 0.1 Ω. The resistor bridge R1 and R2 is given by:

$$R1/R2 = (Vf + 80\ mV) / 600\ mV - 1 \quad \text{(eq. 1)}$$

Having R2 = 100 kΩ leads to R1 = 455 kΩ

This equation puts forward that NCP1529 is still used as voltage regulator. Consequently light intensity will vary upon the forward voltage of the LED and this parameter is generally subject to a large deviation. At the end, system engineer will observe a light intensity differences from one torch to another one.

A method to regulate a constant current uses the benefits of current mirror with a high divider ratio. Two additional PNP bipolar transistors are required for the proposal shown in Figure 3. Bipolar used for mirroring are usually paired on the same die for maximum matching and proposed as a single solution.

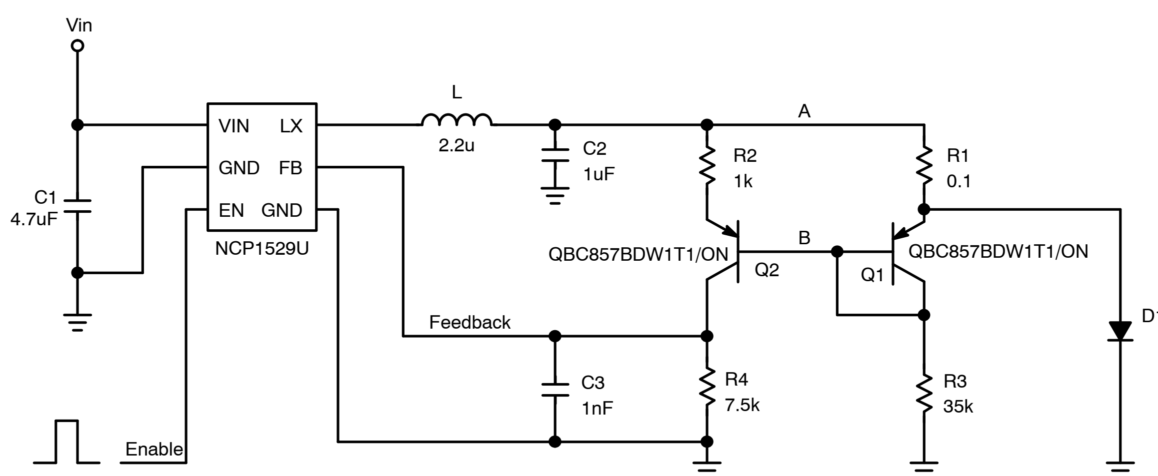

Figure 3. Regulates the Forward Current of the LED

In that example, the current flowing R3 can be considered as negligible. R1 is the sense resistor used to regulate the 800 mA of interest, e.g. I1. The voltage drop across Q1 is Vbe1. Q1 is diode connected and sets Vbe2 for transistor Q2. Because Q1 and Q2 are matched and their β_0 agreed, Vbe2 = Vbe1. The node law leads to write the equation between nodes A and B:

$$R2 \times I2 = R1 \times I1 \quad \text{(eq. 2)}$$

I2 is the current flowing transistor Q2, this current is given by the 600 mV reference voltage.

$$I2 = Feedback / R4 \quad \text{(eq. 3)}$$

Finally, the equation given by the mirror is:

$$I1 = Feedback \times R2 / (R1 \times R4) \quad \text{(eq. 4)}$$

Normally the complete equation without the assumption on R3 is:

$$I1 = Feedback \times R2 / (R1 \times R4) - I3 \quad \text{(eq. 5)}$$

Most of the design engineers will be satisfied by this proposal both accurate and efficient. Compensate the current flowing R3 is also possible but require two additional NPN paired bipolar transistor as pictures by Figure 4.

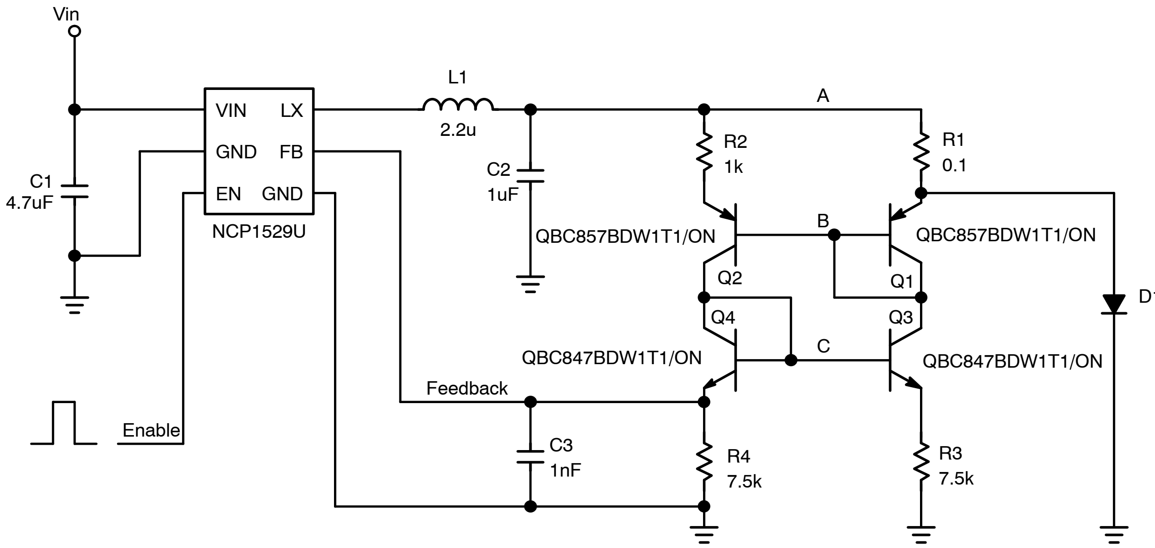

Figure 4. Eliminates the Current Mismatch Due to R3

The difference with previous proposal is to compensate current flowing R3. In that case, the complete equation is:

$$I1 = Feedback \times R2 / (R1 \times R4) \quad \text{(eq. 6)}$$

This schematic will serve as reference for the rest the application note.

Dimming

Schematic of Figure 4 provides good results on system accuracy (LED current is 800 mA as expected), on loop stability and control and on use of dimming from 0% to 100%. It is recommended to apply a dimming signal on EN pin below 1 kHz in order to minimize soft start over the dimming period and keep the benefit of system accuracy.

Figures from 5 to 7 illustrate dimming examples at 200 Hz from 10% to 90%.

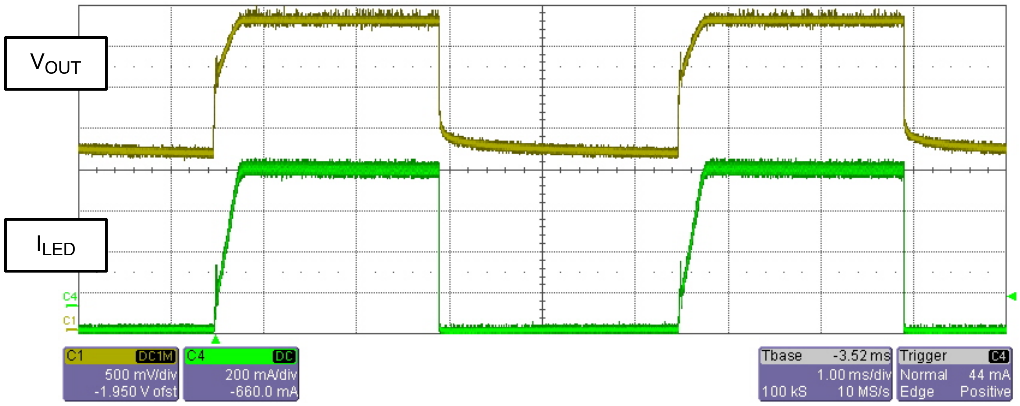

Figure 5. Is 50% at 200 Hz Dimming on EN Pin

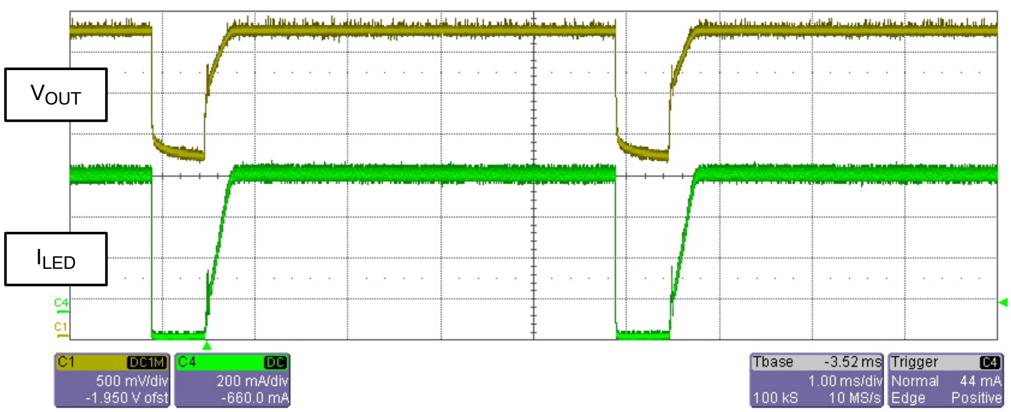

Figure 6. Is 90% at 200 Hz Dimming on EN Pin

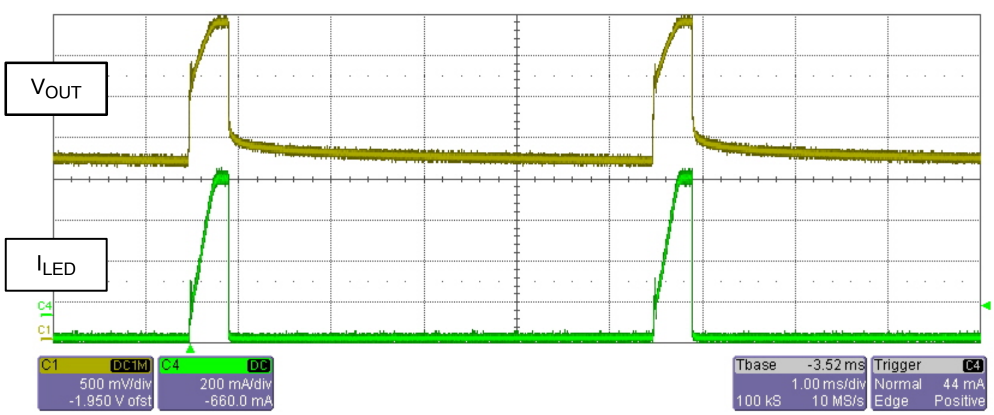

Figure 7. Is 10% at 200 Hz Dimming on EN Pin

The soft start phase can be adjusted by C3 capacitor. A lower capacitor will decrease soft start time but will increase inrush current. Due to the integrated peak current protection which can protect the device and the application if peak inductor current is higher than 1.6 A. A larger capacitor will increase soft start time but will reduce dimming accuracy as detailed before.

Removing the output capacitor C2

Figure 8 pictures main operating signals when the device is supplied from a 5 V rail. To regulate the White LED forward current at 800 mA, the DC to DC converter regulates an output voltage at 3.43 V. This voltage includes the forward voltage of the White LED plus the sense voltage through R1.

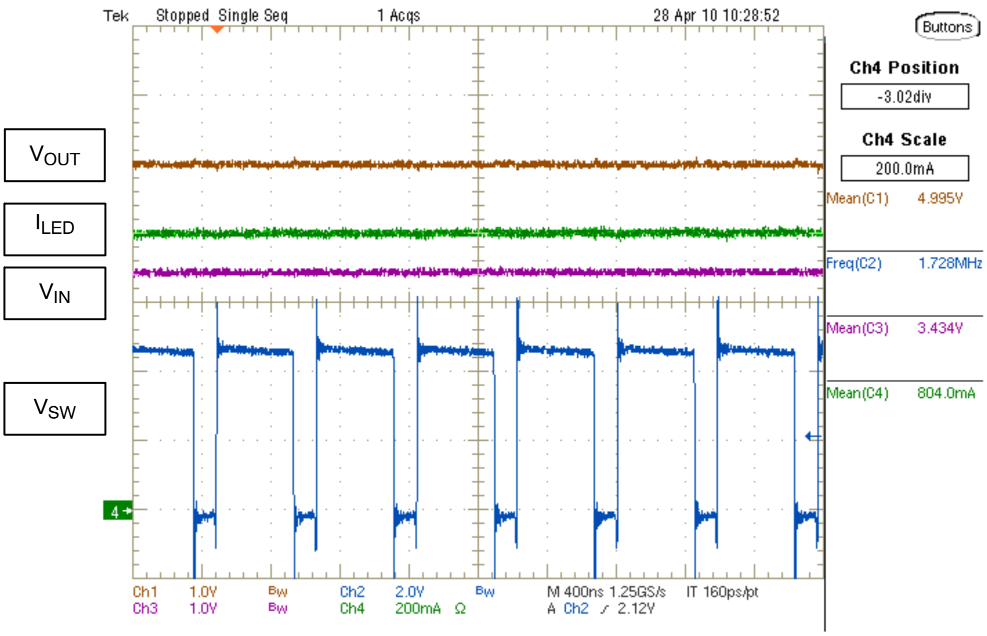

Figure 8. Zoom on Main Operating Signals

The simplest approach of the output capacitor on a high frequency switching step down converter is to form with the associated inductor a L−C filter. Its principle characteristics allow recovering a DC voltage from a square signal which operates from V_{IN} to GND.

Because the main criteria in this application is the forward current, not the output voltage; we can remove the output capacitor, save one external component and lose the benefit of having a DC voltage at the output. In that case, forward current becomes a triangular signal which operates at NCP1529 switching frequency of 1.7 MHz: too fast to be visible.

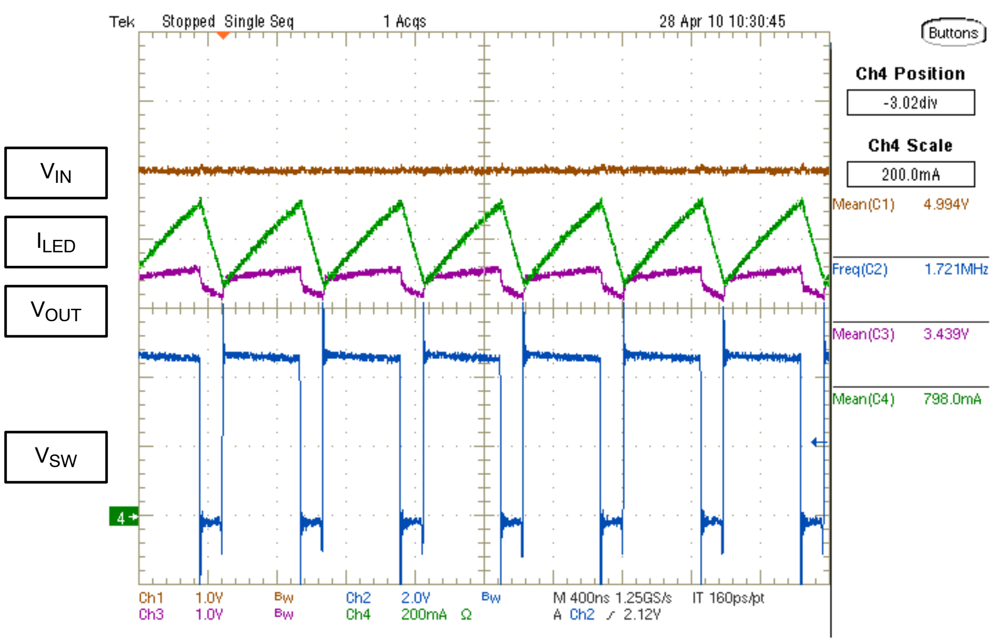

Figure 9. Presents Main Operating Signal Without Output Capacitor C2

Demonstration Board Overview

A dedicated demonstration board is available upon demand. This board is valid for both schematics of Figure 4. and 5. Three high current White LED footprints are proposed:

- Phillips LUXEON® Rebels series
- OSRAM Golden DRAGON Plus series
- Cree XLamp™ XP series

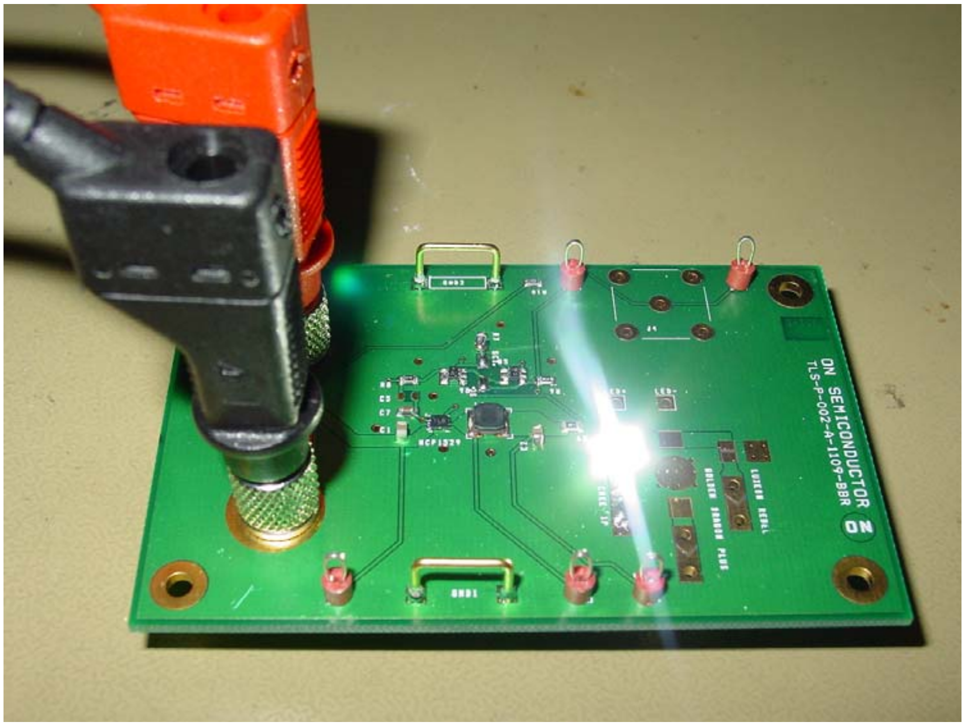

Figure 10. Is NCP1529 Torch Application Demonstration Board

The board is ideal for test purpose providing a dazzling amount of light. Knowing that the application will be optimized with a metallic cavity, we can imagine without difficulty end result of this power efficient DC to Light conversion using NCP1529.

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