

NCP1421/2 Reference Designs for High-Power White LED Flash Applications

Prepared by: Jim Hill
ON Semiconductor

Abstract

The attached design illustrates how the NCP1421/2 boost converters can be configured as a current regulator for biasing high current white LED's. Typical boost converters, such as these, have a reference voltage of 1.2 V. Since this is a current sourcing application, the more straightforward approach of directly sensing the boost converter's reference voltage (V_{ref}), which is 1.2 V, across a sense resistor would dissipate too much power at the currents required to drive high-power White LED's. Also, the lot-to-lot forward voltage variation is too high to simply regulate at a fixed voltage with a current limiting resistor. Therefore, this paper describes a technique that reduces both the power loss in the sense resistor and the lot-to-lot variation effect of the LED. This applications shows two implementations of this concept. Figure 1 shows a simple boost converter configured at various current levels and uses the Lumileds LXHL-WW06 white LED. Figure 5 shows a circuit that switches between a low current for focus lighting and high current for the flash and uses the Lumileds LXCL-PWF1 white LED.

Overview

The NCP1421 and NCP1422 are monolithic boost converter IC's uniquely suited to power higher current portable applications (600 – 800 mA maximum). Their high switching frequency (up to 1.2 MHz) allows for a low



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profile, small sized inductor and output capacitor to be used. Also an integrated disconnect switch provides "true cutoff" by isolating the output from the battery during shutdown. The NCP1421 comes in the 3x5 mm Micro-8 package, and the NCP1422 comes in the 3x3 mm DFN package. Because of these features the NCP1421/2 are well suited to provide current regulation for biasing high current white LED's in portable flash applications. Figure 1 illustrates this circuit.

In summary the reference voltage is split between the current sense resistor, R4, and a divided down voltage from the white LED with resistors R2 and R3. This helps remove some of the dependence of the NCP1421/2's output voltage, and thus current, on the LED's forward voltage, V_F . This also helps prevent lot-to-lot V_F variation affecting the LED brightness.

Figure 1 shows a typical circuit which, with the Bill of Materials shown in Table 1, can provide LED currents of 200, 600 and 800 mA. The 200 mA design uses the NCP1422 because of its smaller footprint, and the 600 mA and 800 mA designs use the NCP1421 and NCP1422 respectively to showcase the load current limits of each device.

The higher currents (600 and 800 mA) assume that the LED will be pulsed and not run at steady state. 50 ms pulses on the LBI/EN were used in the analysis of these circuits. The NCP1421/2 takes 1.5 ms (nominal) to turn on after the LBI/EN pin is driven high.

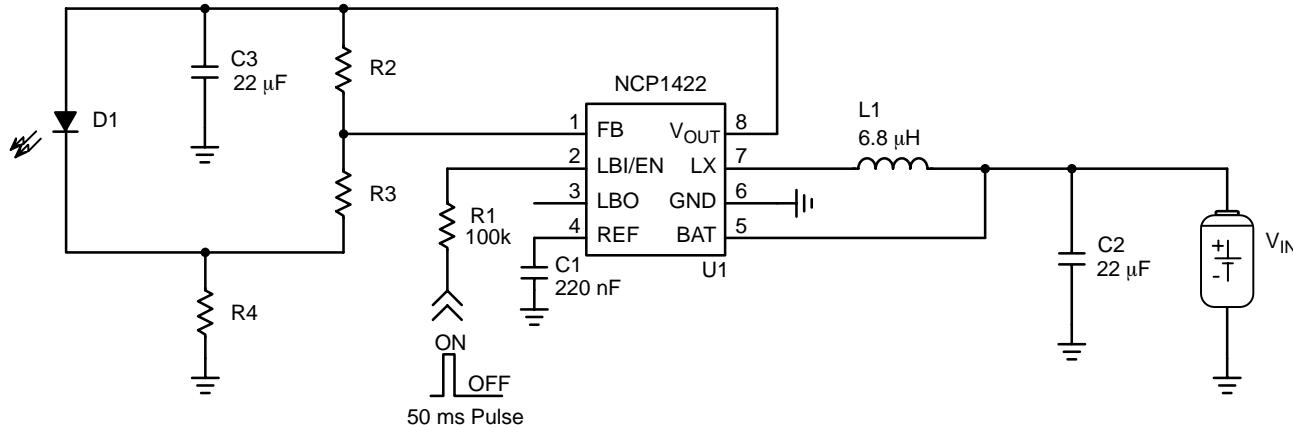


Figure 1. NCP1422 Configured to Drive High Current White LED

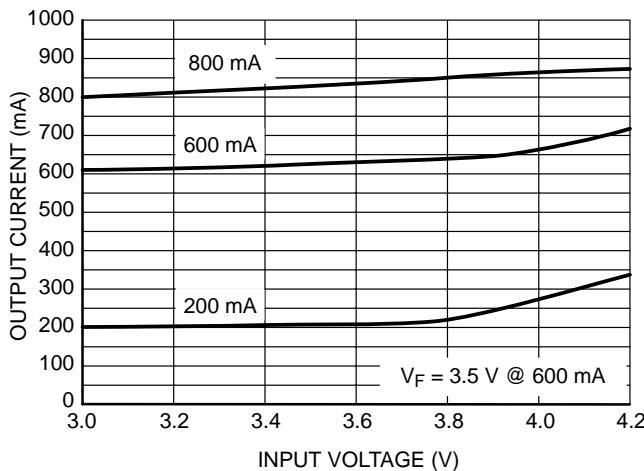


Figure 2. Output Current vs. Input Voltage

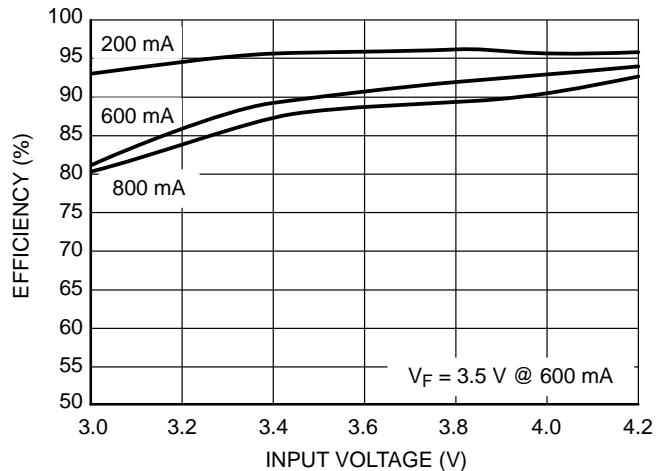


Figure 3. Converter Efficiency vs. Input Voltage

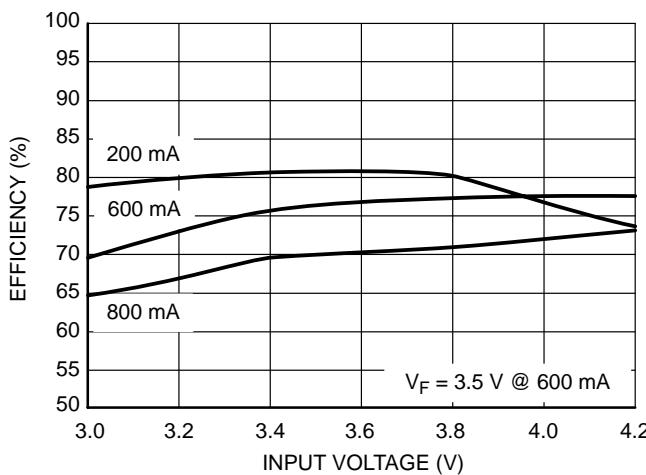


Figure 4. Electrical to Optical Efficiency vs. Input Voltage

Design Steps

The following steps show how to determine the critical components for this circuit. (R_2, R_3, R_4, L_1) This shows the 600 mA version as an example:

Step 1: Let LED current = $I_D = 600 \text{ mA}$

Step 2: From the LED datasheet, let $V_F = 3.5 \text{ V}$ (Find value of V_F at 600 mA).

Step 3: Let $R_3 = 100 \text{ k}\Omega$

Step 4: Let $V_{R4} = 0.5 * V_{ref}$ which is 0.6 V. This places equal dependence on V_F variation and tolerance of the reference and R_4 . One could increase the output voltage by making the voltage across R_4 (V_{R4}) larger or decrease power dissipation in R_4 by lowering V_{R4} .

Step 5: For $I_D = 600 \text{ mA}$ and $V_{R4} = 0.6 \text{ V}$, $R_4 = 1.0 \Omega$.

Step 6: Now, V_{R4} plus the divided voltage off of the LED must equal 1.2 V, and that is 0.6 V

Step 7: So, $R_2 = (V_F/(V_{ref} - V_{R4})) * R_3 - R_3 = (3.5/0.6) * 100 \text{ k}\Omega - 100 \text{ k}\Omega = 483 \text{ k}\Omega$

Step 8: Then choose a standard value of R_2 which is close to the above calculated value. Choose $R_2 = 475 \text{ k}\Omega$.

Step 9: Pick input voltage range. These circuits assume a one-cell Li-ion battery pack or a 3-cell NiMH pack so the

input voltage is assumed to be 3.6 V and has been optimized around this point.

Step 10: Determine output voltage. Output voltage will be $V_F + V_{R4} = 4.1 \text{ V}$. One can use the 3.6 V as V_{in} chosen above because this circuit decreases LED current as V_F increases from the designed value. This is shown by the following equation: $I_D = 1/R_4 * (V_{ref} - V_F * (R_3/R_2 + R_3))$. Conversely it increases current as V_F decreases from the designed value, but then the difference between V_{in} and V_{out} is less, so the peak current is reduced.

Step 11: Use the NCP1421 or NCP1422 datasheet to determine the appropriate L_1 , C_1 , and C_2 . For this application, 6.8 μH , 22 μF , and 22 μF were found to work well over the load and line range.

Step 12: Determine the inductor saturation current. For this circuit $V_{in} \text{ min} = 3 \text{ V}$: $I_{Lavg} = I_{out} / (1-D)$ where $D = (1-V_{in}/V_{out})$. Therefore $I_{Lavg} = 600 \text{ mA} / (1 - (1 - V_{in}/V_{out})) = 840 \text{ mA}$

Step 13: Add 20% margin to this I_{Lavg} and pick an inductor with an $I_{sat} > 1.0 \text{ A}$.

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Finally, Figure 5 shows a Focus/Flash application where the NCP1422 drives one LED at 200 and 600 mA. An external MOSFET changes the R4 resistance to vary the LED current. 50 ms pulses were used for this design.

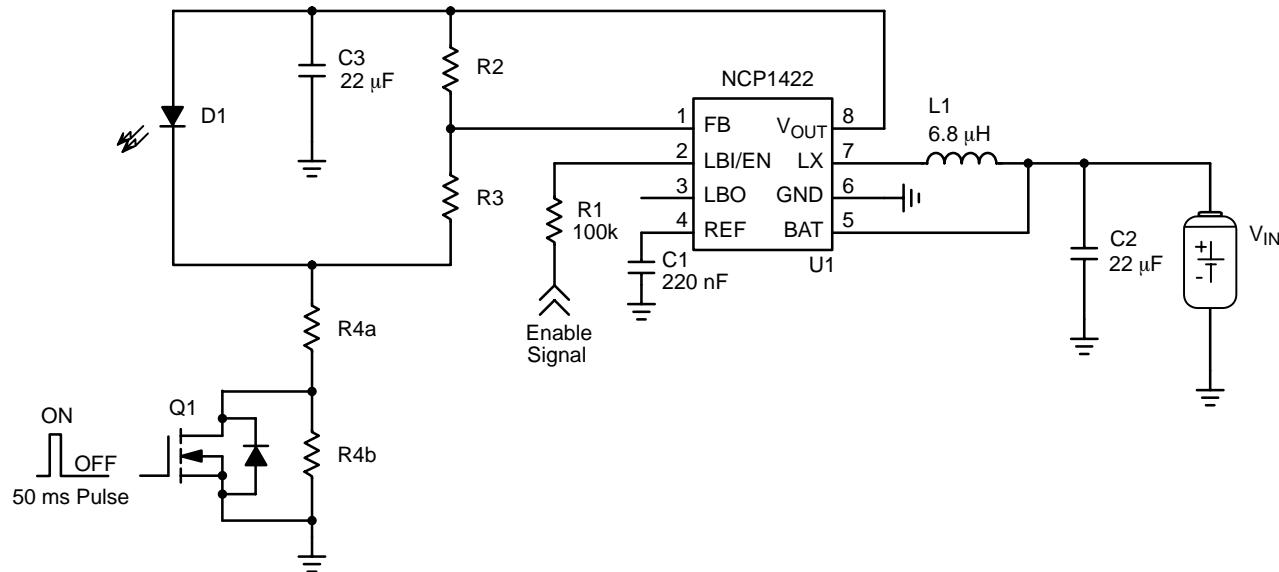


Figure 5. 200/600 mA Focus/Flash Application

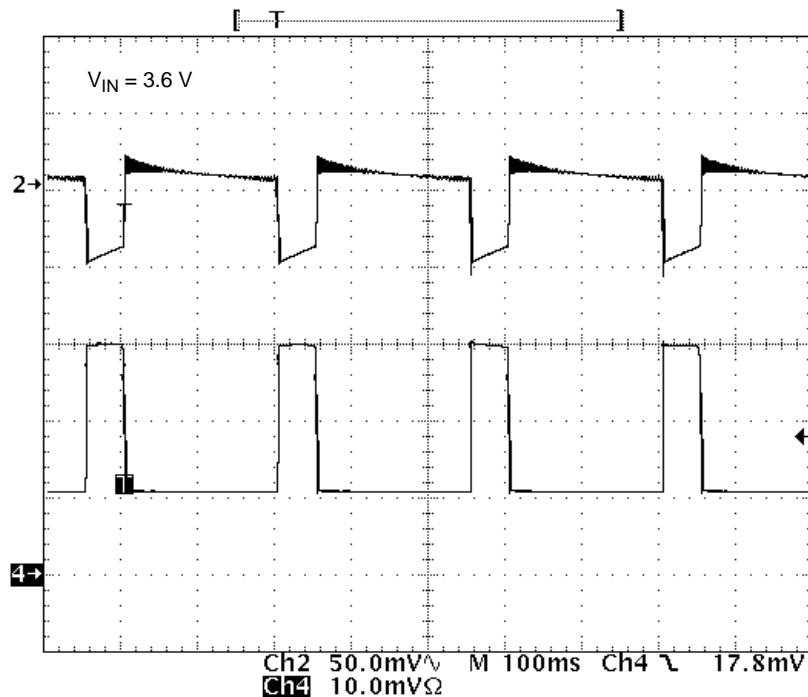


Figure 6. LED Current and V_{in} Ripple Voltage with 200/600 mA Focus/Flash Pulse
(CH2 = V_{in} , ac-coupled @ 50 mV/div; CH4 = I_{LED} @ 200 mA/div)

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Table 1. Bill of Materials for Figure 1

| Ref | Part Number | Description | PCB Footprint | Manufacturer |
|----------------------|------------------|----------------------------------|----------------------|------------------|
| 200 mA Design | | | | |
| U1 | NCP1422MNR2 | NCP1422 Boost Converter | DFN-10 (3 x 3 mm) | ON Semiconductor |
| D1 | LXHL-WW06 | White LED | | Lumileds |
| L1 | VLP5610T-6R8 | 6.8 μ H Inductor | (5.6 x 5.0 x 1.0 mm) | TDK |
| R1 | CRCW0402104.... | 100 k Ω | 0402 | Vishay |
| R2 | CRCW04025603.... | 560 k Ω | 0402 | Vishay |
| R3 | CRCW04021503.... | 150 k Ω | 0402 | Vishay |
| R4 | DCRCW12062R70... | 2.7 Ω | 1206 | Vishay |
| C1 | C1608X5R1A224K | 220 nF | 0603 | TDK |
| C2 | C2012X5R0J226M | 22 μ F / 6.3 V (X5R Ceramic) | 0805 | TDK |
| C3 | C2012X5R0J226M | 22 μ F / 6.3 V (X5R Ceramic) | 0805 | TDK |
| 600 mA Design | | | | |
| U1 | NCP1421DMR2 | NCP1421 Boost Converter | Micro-8 (3 x 5 mm) | ON Semiconductor |
| D1 | LXHL-WW06 | White LED | | Lumileds |
| L1 | VLP6214T-6R8 | 6.8 μ H Inductor | (6.2 x 5.8 x 1.4 mm) | TDK / Coilcraft |
| R1 | CRCW0402104.... | 100 k Ω | 0402 | Vishay |
| R2 | CRCW04025603.... | 475 k Ω | 0402 | Vishay |
| R3 | CRCW04021503.... | 100 k Ω | 0402 | Vishay |
| R4 | CRCW12061R00... | 1.0 Ω | 1206 | Vishay |
| C1 | C1608X5R1A224K | 220 nF | 0603 | TDK |
| C2 | C2012X5R0J226M | 22 μ F / 6.3 V (X5R Ceramic) | 0805 | TDK |
| C3 | C2012X5R0J226M | 22 μ F / 6.3 V (X5R Ceramic) | 0805 | TDK |
| 800 mA Design | | | | |
| U1 | NCP1422DMR2 | NCP1422 Boost Converter | DFN-10 (3 x 3 mm) | ON Semiconductor |
| D1 | LXHL-WW06 | White LED | | Lumileds |
| L1 | VLP6214T-6R8 | 6.8 μ H Inductor | (6.2 x 5.8 x 1.4 mm) | TDK |
| R1 | CRCW0402104.... | 100 k Ω | 0402 | Vishay |
| R2 | CRCW04025603.... | 750 k Ω | 0402 | Vishay |
| R3 | CRCW04021503.... | 150 k Ω | 0402 | Vishay |
| R4 | CRCW12061R50...* | 0.75 Ω | 1206 | Vishay |
| C1 | C1608X5R1A224K | 220 nF | 0603 | TDK |
| C2 | C2012X5R0J226M | 22 μ F / 6.3 V (X5R Ceramic) | 0805 | TDK |
| C3 | C2012X5R0J226M | 22 μ F / 6.3 V (X5R Ceramic) | 0805 | TDK |

*2 – 1.5 Ω resistors were used in parallel.

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Table 2. Bill of Materials for Figure 5

| 200/600 mA Design | | | | |
|-------------------|------------------|----------------------------------|------------------------|------------------|
| U1 | NCP1422MNR2 | NCP1422 Boost Converter | DFN-10 (3 x 3 mm) | ON Semiconductor |
| D1 | LXCL-PWF1 | White LED | (1.64 x 2.04 x 0.9 mm) | Lumileds |
| Q1 | NTJS3157N | N-Channel MOSFET | SC-88 | ON Semiconductor |
| L1 | VLP5610-6R8 | 6.8 μ H Inductor | (5.6 x 5.0 x 1.0 mm) | TDK |
| R1 | CRCW0402104.... | 100 k Ω | 0402 | Vishay |
| R2 | CRCW04025603.... | 475 k Ω | 0402 | Vishay |
| R3 | CRCW04021503.... | 100 k Ω | 0402 | Vishay |
| R4a | CRCW12062R00...* | 1.0 Ω | 1206 | Vishay |
| R4b | CRCW12062R00... | 2.0 Ω | 1206 | Vishay |
| C1 | C1608X5R1A224K | 220 nF | 0603 | TDK |
| C2 | C2012X5R0J226M | 22 μ F / 6.3 V (X5R Ceramic) | 0805 | TDK |
| C3 | C2012X5R0J226M | 22 μ F / 6.3 V (X5R Ceramic) | 0805 | TDK |

*2 – 2.0 Ω resistors were used in parallel.

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Телефон: +7 495 668-12-70 (многоканальный)

Факс: +7 495 668-12-70 (доб.304)

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