AND8126/D

NCP5008/NCP5009 Compensation Methods

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APPLICATION NOTE

ABSTRACT

The NCP5008 and NCP5009 are high efficiency boost converters operating in current loop control mode to drive Light Emitting Diode (LED). These products are dedicated to supply any LEDs for any portable application. A digital programming current level allows the user to set 8 different levels of brightness intensity. The photo sense input is an innovative function: it adapts the brightness backlight in function of the ambient light in order to save the battery lifetime duration. The devices are designed to operate in open−loop configuration to enable the digital and the photo−sensebrightness control.

This application note describes alternate application schematics to increase the output current accuracy.

INTRODUCTION

This manual describes several possible applications built around the NCP5008 and NCP5009. We thank you for choosing an ON Semiconductor part, and we hope this guide will help you to benefit from these devices' advanced features. Please use the NCP5009 data sheet as a reference source. For an up−to−date document, refer to the NCP5009 data sheet which is available on our web page: http://www.onsemi.com/home.

Among the electrical parameters, the power supply must be capable to yield 200 mA minimum continuous DC current to operate the system properly. Peak current up to 300 mA can be developed when the driver operates at full power.

GENERAL DESCRIPTION

As opposed to classical Boost DC−DC converter, which operates in closed loop mode, the NCP5009 is operating in open−loop mode to avoid the need for a sense resistor in series with the white LEDs. This feature significantly simplifies the implementation when the LED network and the driver are located on separate boards because only one connection is required. The second advantage is that the current flowing through the photo sensor can be easily subtracted from the DC reference current. The external reference current is generated by connecting a resistor between the Iref pin and the ground. It can be internally modified by a digital programming word or by the current flowing through the photo sensor. The modified current is used to control the inductor's current peak value.

The consequence of open−loop operation, is that the current actually flowing through the LED is indirectly controlled, leading to lower accuracy as opposed to closed loop operation. The main cause of variation is the power supply, because the amount of energy stored in the inductor is proportional to it. This may be an issue when the device is supplied from a nonconstant DC source, such as a battery.
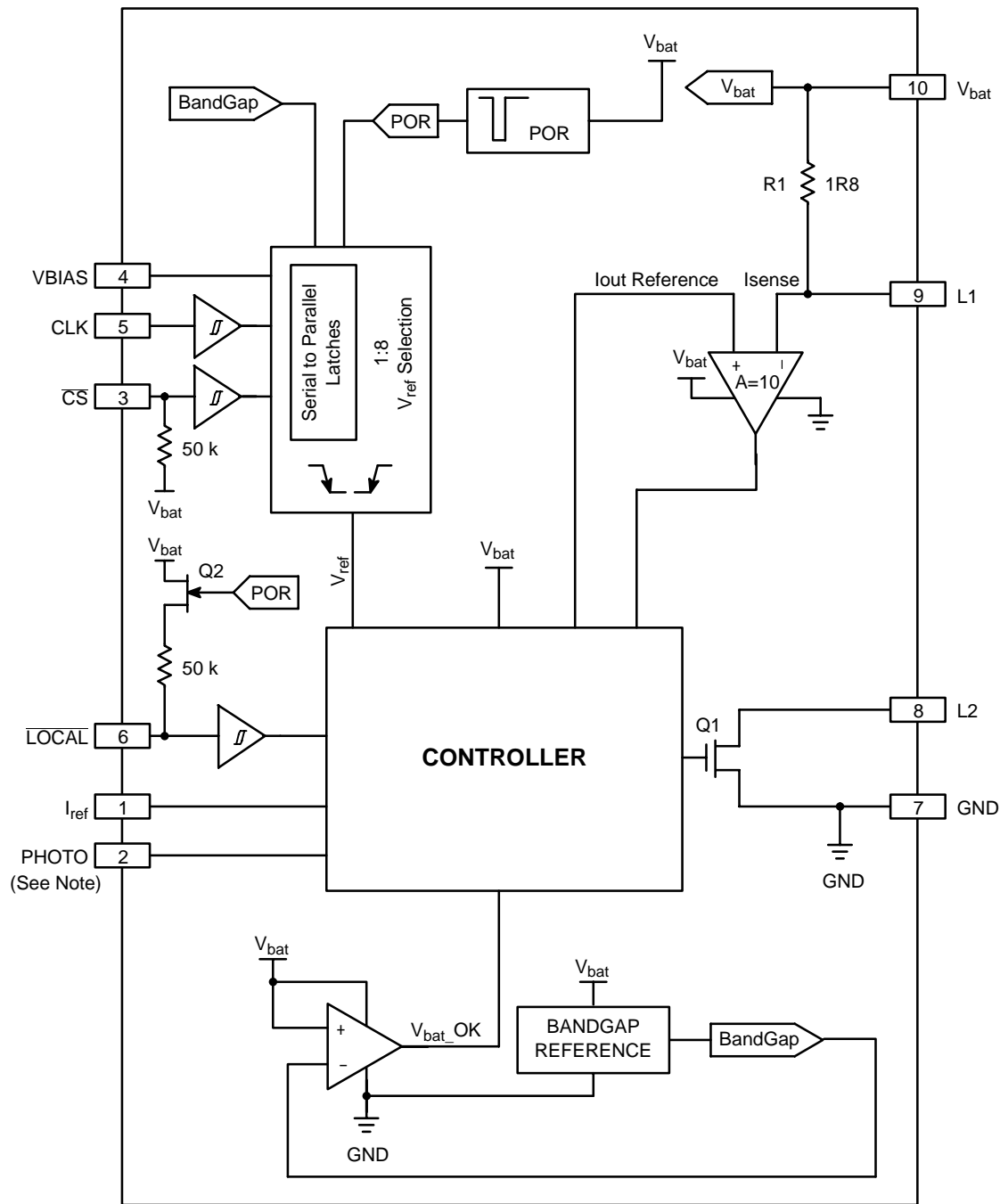
Figure 1.

This behavior can be explained in detail by reviewing the Boost converter operation. The NCP5008 has been modelized in the following schematic by an ideal switch.
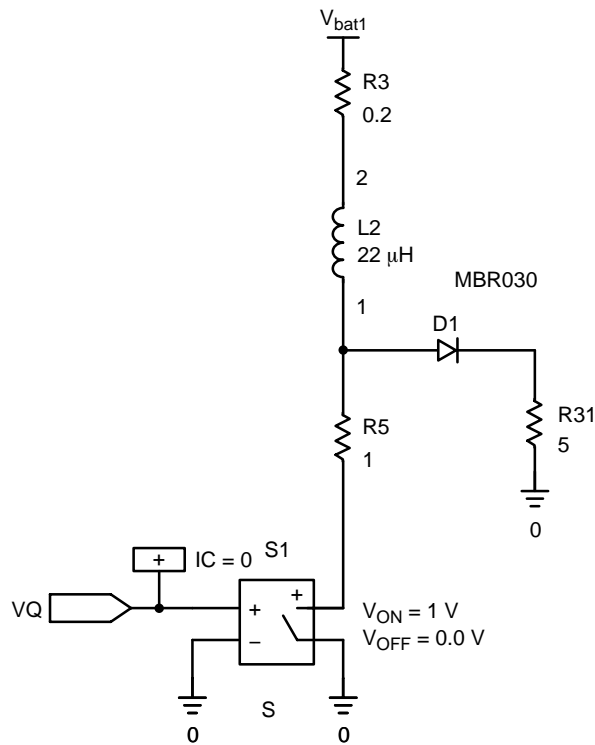

Figure 2. Typical Boost Topology Converter

NCP5008/9 constantly monitors the current flowing through the inductor. In order to achieve maximum efficiency, NCP5008/9 particularly controls the inductor peak current, and constantly switches the inductor charge and discharge between two boundaries Ipeak and Ivalley.
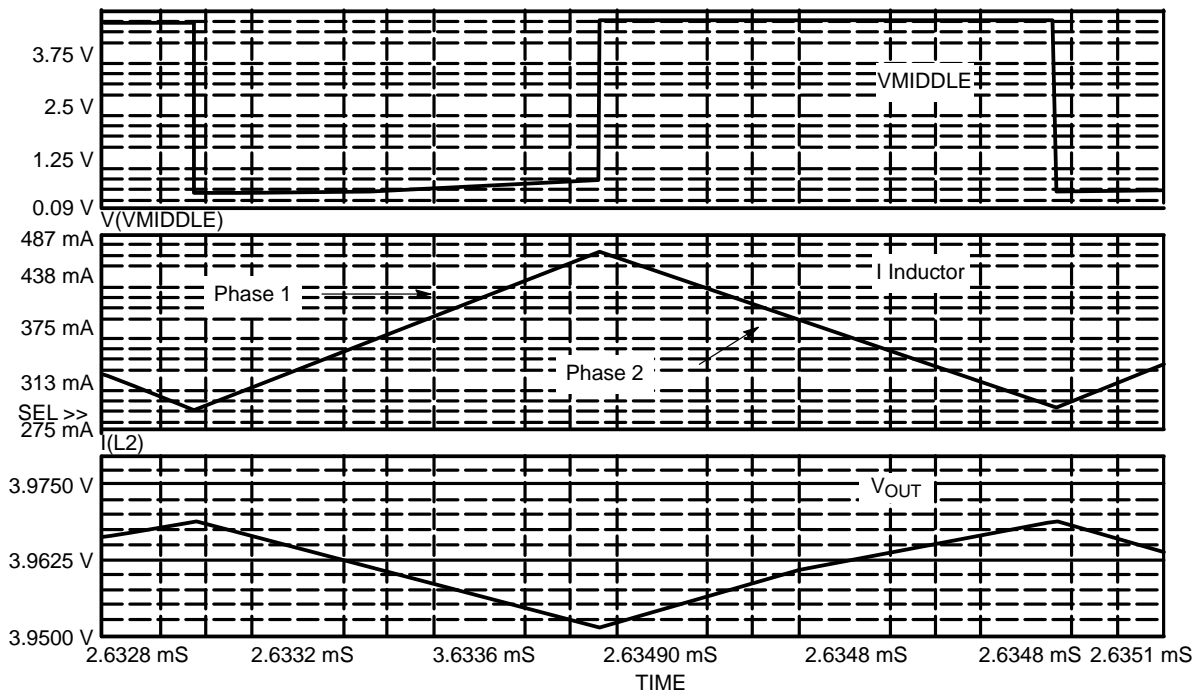

Figure 3. Typical Current/Voltage Diagrams (Spice Simulation)

The basic operation of the boost converter can be divided in two phases:

1. Phase 1

Switch S1 is ON (see Figure 2). Therefore, the input voltage Vin is applied across the inductor L1. Inductor current linearly ramps up from its original value Imin (say 0 A) to the peak value Ipk (when the switch turns off). During this period, energy is stored in the core material as per following equation:

$$\text{Energy} = 0.5 * L * (\text{Ipk–Imin})^2 \qquad \text{(eq. 1)}$$

And

$$\frac{dI}{dt} = \frac{Vbat}{L} \qquad \text{(eq. 2)}$$

2. Phase 2

Switch S1 is OFF (see Figure 2). Since the inductor current must not be discontinuous, the inductor voltage **flies back**. Rectifier diode D1 now turns on, and energy from the inductor is transferred to the output reservoir capacitor C1. As the inductor voltage flies back above the input voltage, the output voltage is then higher than the input voltage such as:

$$\frac{dI}{dt} = \frac{(Vout–Vbat)}{L} \qquad \text{(eq. 3)}$$

From equations 1, 2, and 3, it is obvious that overall output power (and thus average output current) is directly linked to the battery voltage Vbat. Consequently, any battery voltage variation will be noticeable on the output current.

How to Compensate Battery Variation

NCP5008/9 derives the peak current (which determines the ON time of the inductor) from the external resistor Rref (between pin 1 and ground). Following diagram depicts internal blocks.
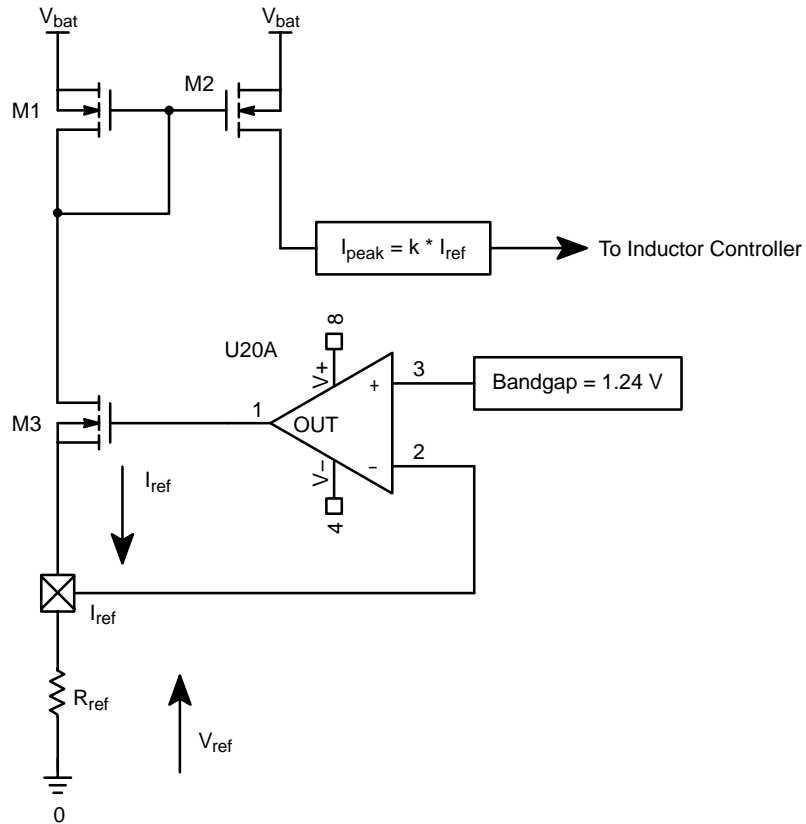

Figure 4.

Since

$$\text{Ipeak} = k * \text{Iref} \qquad \text{(eq. 4)}$$

And

$$\text{Iref} = \frac{Vref}{Rref} = \frac{1.24}{Rref} \qquad \text{(eq. 5)}$$

It appears that when the battery voltage varies, the peak current threshold remains the same. Hence, the output current will vary along with the battery voltage: the more Vbat is high, the more current we will have on the output.

Compensating the battery variation means that when Vbat is increasing, we need to decrease the Iref (thus decreasing Ipeak) and conversely, when Vbat is decreasing, we need to increase Iref.
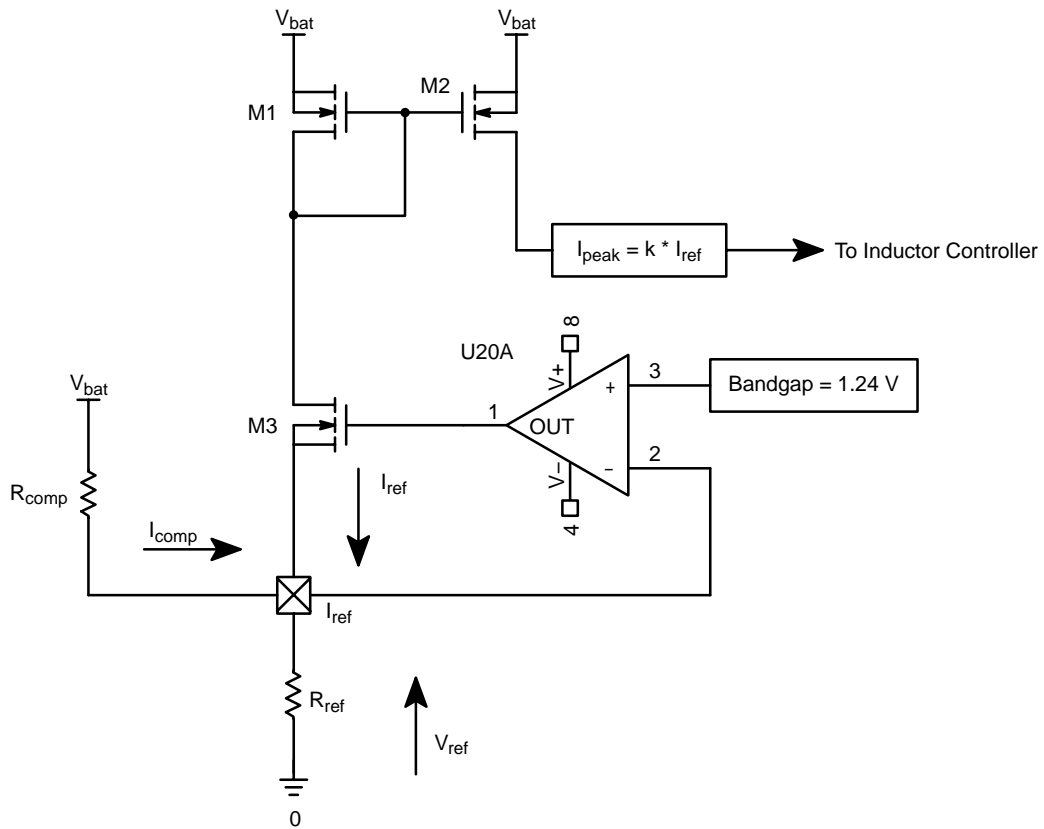
Figure 5.

With such compensation circuitry, we now have:

$$\frac{V_{ref}}{R_{ref}} = I_{ref} + \frac{V_{bat} - V_{ref}}{R_{comp}} \qquad \text{(eq. 6)}$$

A little of calculation and we find:

$$\Delta I_{ref} = -\frac{\Delta V_{bat}}{R_{comp}} \qquad \text{(eq. 7)}$$

Negative sign means that when Vbat is decreasing, compensated current is positive: that's exactly what we want. This compensation method has been applied to the NCP5009 for several output current values.

Experimental Results

Open Loop Operation

The following curves are based on experimental results at ambient temperature. A resistive divider has been used to set the reference current. It has been connected between Vbat and the CS input to prevent a DC current to flow when the circuit is disabled. The open−loop operation is necessary to allow the Photo−transistor dimming (NCP5009 only) and the digital control.
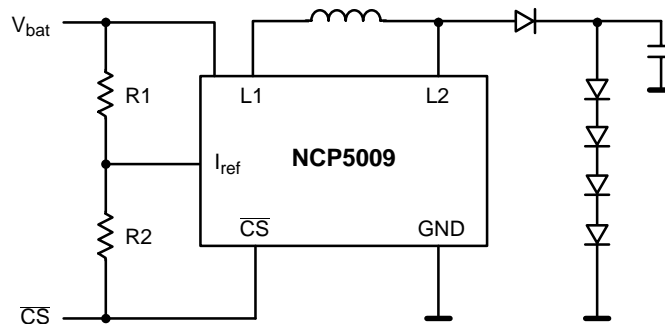
Figure 6. Compensation Schematic
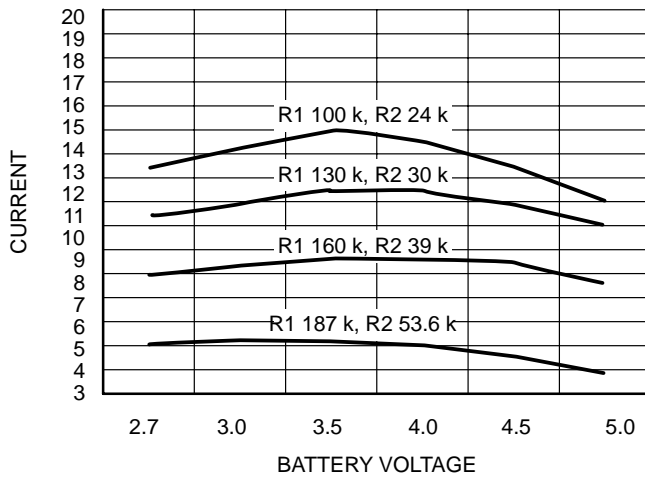
Figure 7. Output Current with Four White LEDs as a Function of Battery Voltage
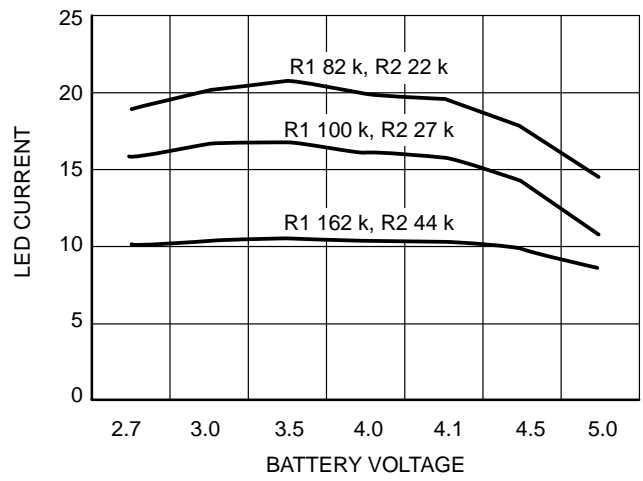
Figure 8. Output Current as a Function of Battery Voltage with Three LEDs

The ratio between R1 and R2 can be modified to reduce the variation on a given battery voltage range. The chosen values are corresponding to 2.7 V to 4.1 V range.

Closed Loop Operation

When high accuracy is requested, the compensation method previously described, is not sufficient to reduce the current variations. The Iref pin is a true current input. This means it is equivalent to a voltage generator having zero output resistor. An additional transistor has been used to increase the open−loop gain, and reduce the error voltage.
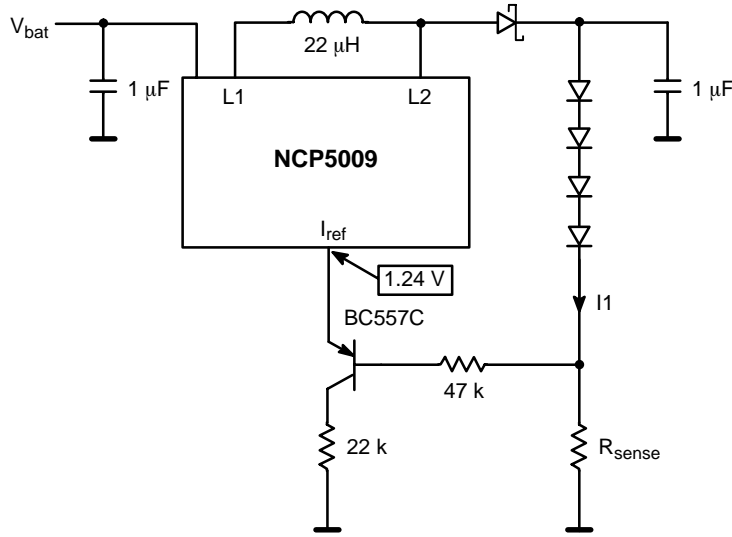
Figure 9. Closed Loop Compensation
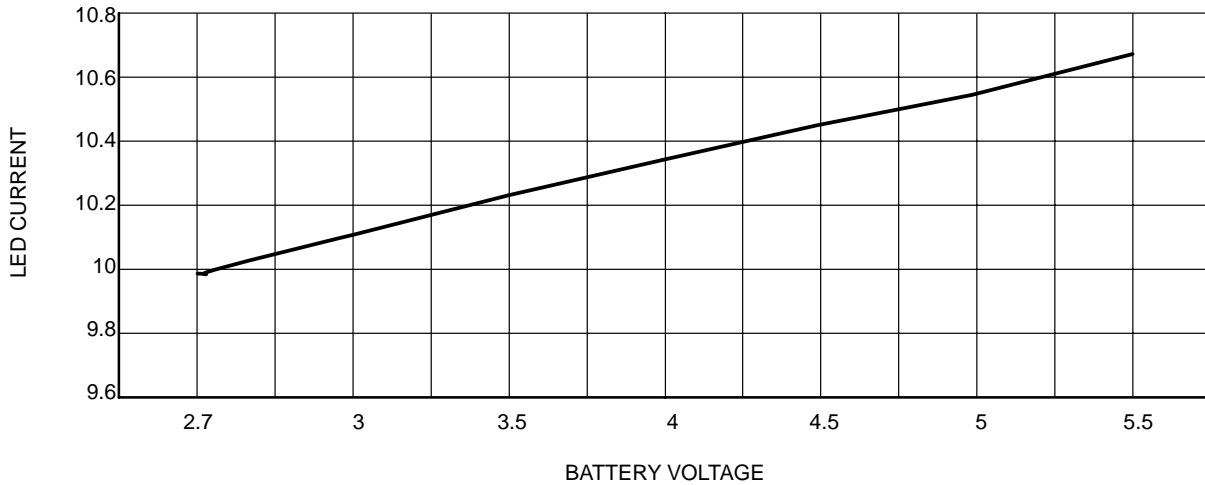
Figure 10.

LED current adjust is quite straightforward. It is only imposed by the sense resistor value. Sixty−eight ohm resistor has been used to get the above curve. The 47 k resistor prevents high current to flow from Iref pin to ground at circuit start−up. This would results in very high peak current and over−heating. The BC557C PNP transistor is recommended because it exhibits high Beta for collector current values.

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