Optimized Control Schemes Improve LED Driver Performance

This application note describes recent trends in the electronic component power management industry, in particular an optimized high-brightness LED (HB LED) driver, the Allegro™ A6210 device, which provides an advanced form of power management.

Introduction

High Brightness (HB) LEDs are being widely adopted into luminaires used in the General Lighting Market where there are a myriad of possibilities; commercial/ retail downlighting, industrial, architectural, external and emergency back-up lighting to name a few. In the strive for more lumens in these applications, the HB LED Driver requirements are becoming more onerous as HB LED currents increase. In many applications, the typical HB LED currents range from 350 mA up to 1 A, however, some of the latest HB LEDs require anything up to 3 A.

In addition to the higher current requirements, efficiency improvements are becoming mandatory through Energy Star standards. Size is often important and of course cost as always is critical. To address all these requirements requires Driver solutions that utilize innovative switching architectures.

Limitations of currently available HB LED Driver Solutions

The majority of HB LED Driver solutions available on the market today are based on standard voltage regulator architectures that already exist. Whilst these architectures deliver a solution, they are far from optimum. Refer to figure 1 below for a typical solution, which is based on a fixed frequency current mode control buck converter.

The control schemes are overly complex with two loops: an outer-loop to regulate the current control (set by R3) and an inner-loop to provide the peak current control. This control technique typically requires external compensation components (R2 & C5) as well as having the additional overhead in the silicon which impacts the solution cost. An output capacitor (C3) is often required, not necessarily to reduce the current ripple through the LED, but simply to ensure the control loop is stabilized correctly. With a carefully considered control loop, this output capacitor can be omitted.

Another problem with these control solutions is that brightness control is difficult to achieve. Most solutions rely on pulse width modulating (PWM) the enable pin (EN). To avoid the effects of flicker, PWM frequencies in excess of 200 Hz are generally used. To achieve a good dynamic range for brightness control, requires the ability to modulate to

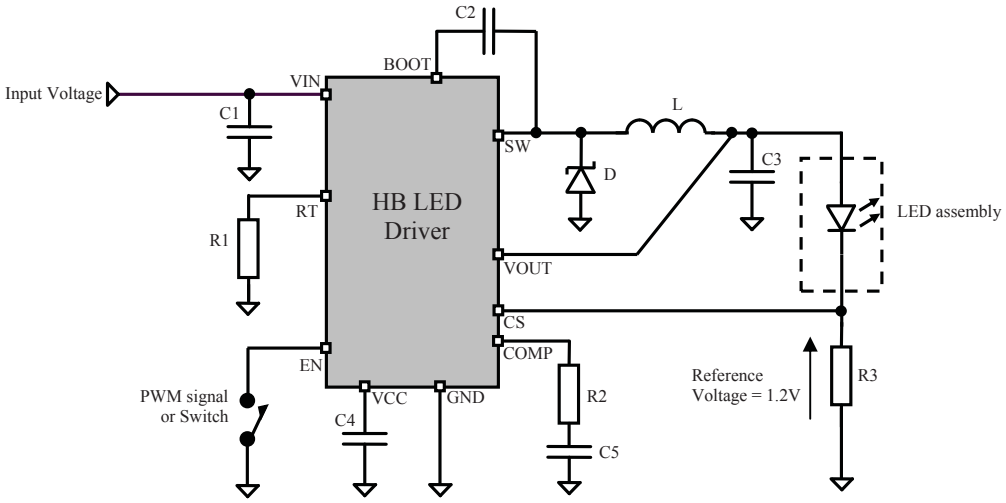

Figure 1

duty cycles as low as 10%. With a 200 Hz signal, this means the Driver has to support the ability to turn on and off in a period of: 10/100 × 1/200 = 0.5 ms. Most solutions have an inherent soft-start feature that is in the region of several milliseconds, severely restricting the dynamic control range.

The sense voltage (refer to figure 2) can be as high as 1.2 V which has a large impact on the power dissipation. For example, when driving a single HB LED with a V_f of 3.5 V, the efficiency drops by 34% before you even consider any of the other losses. Note also that this loss occurs across the full switching period.

Many vendors claim short-circuit and open LED protection. Whilst these are key protection features in boost or buck-boost derived topologies, they are completely unnecessary in buck-derived topologies.

An optimum HB LED Driver Solution

The Allegro A6210 is a solution that has been specifically designed and optimized for driving HB LEDs. This solution addresses the challenges and requirements for a HB LED Driver solution by: delivering high efficiency, simplified control scheme, rapid start-up for good dynamic brightness control and minimal external components.

Figure 2 illustrates the simplicity of the Allegro A6210 solution where the component count amounts to only two resistors, two capacitors, one Schottky diode and the power inductor.

One of the things to note, is that no output capacitor is required. The first reason is because the peak-to-peak current ripple can be as low as 10% of the maximum HB LED current through careful selection of the inductor value and switching frequency. This more than meets the majority of HB LED lighting applications. Secondly, there is no outer-loop requiring stabilization.

The control architecture deploys a simple inner-loop that controls the current by sensing the voltage developed across the sense resistor (R2) during the recirculation diode (D) conduction phase. No outer-loop is required, simplifying the design and removing the need for external compensation components. A further advantage of this scheme is that the start-up restrictions of the more traditional control schemes are largely removed as the requirement for soft-start disappears.

The plots shown in figure 3 illustrates the rapid start-up performance using the circuit configuration of figure 2. In this particular application, the input voltage is 42V, the LED assembly has seven 1.4 A HB LEDs connected in series producing 24 V and the switching frequency is 1 MHz.

It can be seen that the start-up time to reach the target current is 7 µs. When the A6210 is commanded off (immediately after reaching the target current), the current decays as a function of the voltage across the LED assembly and inversely as a function of the inductor value.

The A6210 is designed to operate at switching frequencies of up to 2 MHz allowing the use of low value inductors with physi-

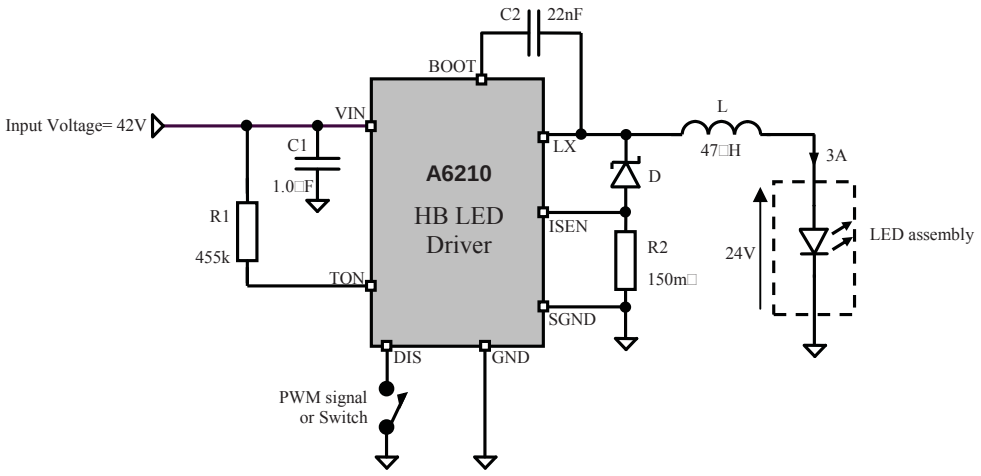

Figure 2

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cally small footprints. Figure 4 illustrates the main switching voltage waveform on the LX pin as well as the current through the LED assembly.

The A6210 is designed for very high efficiencies. A reference voltage of only 183 mV is used, making it amongst the lowest in the market. Furthermore, the loss contribution from the reference only occurs during the recirculation diode conduction phase and not across the full switching period.

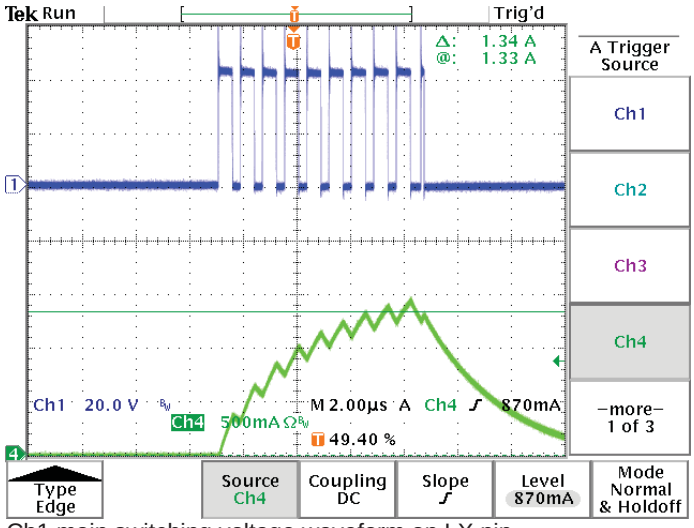
The series switching MOSFET has been specifically optimized to minimize the power loss contributions from both the static and switching losses. Many vendors claim their integrated MOSFETs are low impedance, but neglect the effects of switching losses which can be considerable, especially at high switching frequencies and/or high input voltages.

In the above example, an efficiency of 90.5% was achieved.

Conclusion

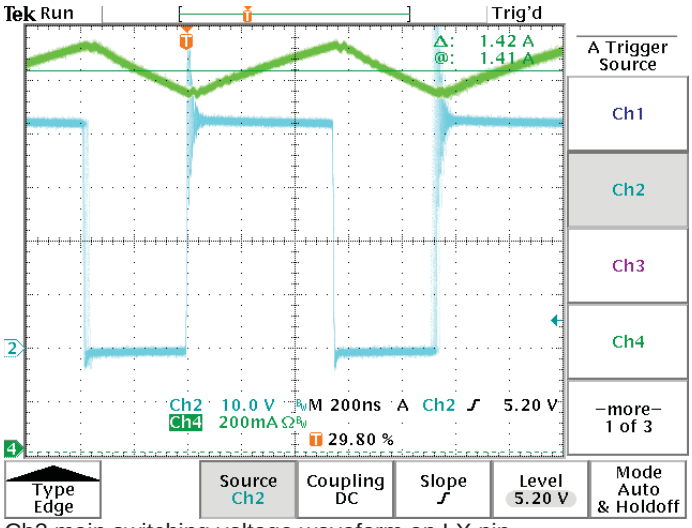
The Allegro A6210 addresses the requirements for current and future HB LED based luminaires.

To aid the design-in phase of the A6210, a simple spreadsheet is available for download from the Allegro website: www.allegromicro.com. From a simple 'black box' specification, the component selection is made along with an efficiency estimator.



Ch1 main switching voltage waveform on LX pin.
Ch4 HB LED current.

Figure 3



Ch2 main switching voltage waveform on LX pin.
Ch4 HB LED current.

Figure 4

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