Analysis and Experiment of Peak Current Controlled Buck LED Driver

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Abstract

Realistic amounts of time delay are found to have significant effects on the average output LED current and on the critical inductor value at the boundary between the two conduction modes. Especially, the time delay can provide an accurate LED current for the peak current controlled (PCC) buck converter with a wide input voltage. Experimental results are presented for the PCC buck LED driver with constant-frequency controller.

1. Introduction

Modeling of current mode controlled converters has been focused on multi-loop regulators with output voltage feedback. In multi-loop regulators, a current controlled power stage inside the conventional outputer voltage feedback loop constitutes a multi-loop feedback. The outer voltage feedback loop provides the regulated output voltage of converters.

However, LEDs require a stabilized output current. The purpose of this paper is to investigate the time-delay effects on the average output current and the critical inductor value at the boundary between the continuous and discontinuous conduction modes of the peak current controlled (PCC) buck LED driver without the outer voltage feedback loop. One new result of the analysis in the paper [1] by the authors is that the average output current of the PCC buck LED driver is insensitive to the input voltage variations if realistic amounts of time delay of 0.4-0.6 μs exist in the control circuit, which is different from the analytical result of [2]-[3], where the time delay is assumed to be zero.

Due to the time delay at turn off, the peak inductor current has an overshoot over the peak current control input. This overshoot of the peak inductor current results in the increase of the average output current and the reduction of the critical inductor value at the boundary between the two conduction modes in the PCC buck converter. The performance of the PCC buck LED driver is confirmed through the experimental results.

2. Analysis and Experimental result for PCC buck LED driver

The average output LED current of the PCC buck LED driver is

$$I_{LED} = I_{avg} = \frac{V_c}{R_s} + \frac{(V_i - V_o)}{L} T_{df} - \frac{V_o (V_i - V_o)}{2 f_s L V_i} . \quad (1)$$

The critical inductor value of the PCC buck LED driver at the boundary between the two conduction modes is

$$L_c = (T_s - \frac{V_i}{V_o} T_{df}) \frac{V_o (V_i - V_o)}{V_i} \frac{R_s}{V_c} . \quad (2)$$

For performance evaluations, a prototype converter has been constructed as shown in Fig. 1. The constant switching frequency is 58.8 kHz. The control IC is CS3842, where no compensation slope is used. The peak control input V_c / R_s is 390 mA. S is IRF 840 and D is DSEI12-06A. Here, we use pure-white LEDs, Z-POWER w42182, which has a typical current of 350 mA . This LED forward voltage varies from 2.9V to 3.8V, for a nominal of 3.25 V [4].

With four LEDs connected in series, which provides a typical loading voltage of approximately (3.25V X 4 LEDs in series) 13 V, the measured LED currents are shown in Fig. 2. As the input voltage increases, the average LED current doesn't decrease in this figure. This experimental result is different from the previous analytical results [2]-[3], where the time delay is not considered. Due to the time delay in the control circuit, the average LED current is insensitive to the input voltage variations in the PCC buck converter. Fig. 3 shows the measured LED current waveforms at a typical output voltage of approximately (3.25V X 3 LEDs in series) 9.75V, which means the output voltage variation of about 25 % compared to the output voltage of 13 V in Fig. 2. This experimental result shows that the average LED current of the PCC buck converter doesn't vary significantly due to the change of the LED forward voltage. From Figs. 2-3, it can be said that the PCC bck converter is excellent for LED drivers in wide input voltage applications.

The start-up transient responses are shown in Fig. 4. The LED current is well limited below the peak current as expected. Fig. 5 shows the simulated critical inductor values of the PCC buck converter at the boundary between two conduction modes, the simulated data are obtained from PSPICE simulation.

3. Conclusion

The average output current of the PCC buck converter maintains relatively at a constant level as the input voltage varies if a realistic amount of time delay exists in the control circuit. Because the current overshoot by the time delay compensates for the average output current reduction from increasing the input voltage. Thus the peak current controlled buck converter is most suitable for the power LED driver, especially in wide input voltage applications.

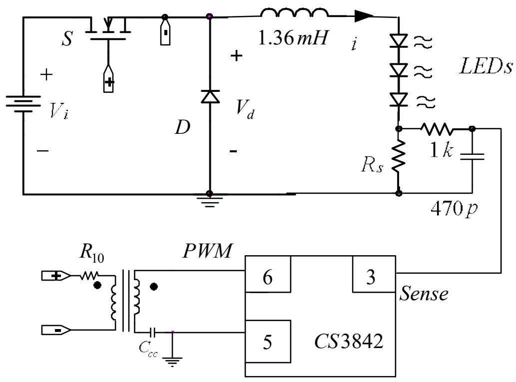
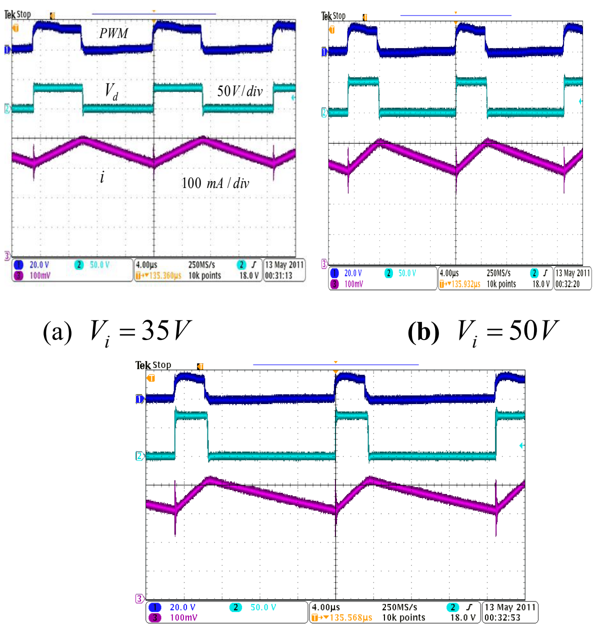


Fig. 1 Experimental peak current controlled buck LED driver ($f_s = 58.8\,kHz$, $V_c / R_s = 390\ mA$)



(a) $V_i = 35V$ (b) $V_i = 50V$

(c) $V_i = 70V$

Fig. 2 LED current waveforms as a function of the input voltage ($V_o \approx 13\ V$, $V_c / R_s = 390\ mA$)

References

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[2] O. Ronat, P. Green and S. Ragona, " Accurate current control to drive high power LED strings, " IEEE APEC, 2006, pp. 376-380.

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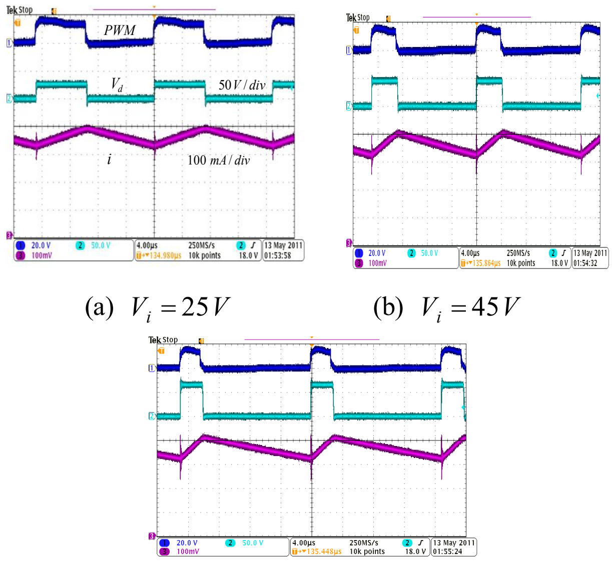
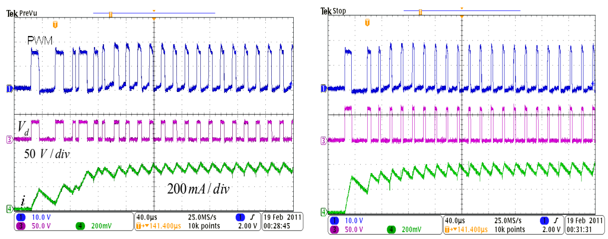
[4] Datasheet, "Z-power LED Series– Technical Datasheet for X4218X ", Seoul Semiconductor Co., LTD, 2007.



(a) $V_i = 25V$ (b) $V_i = 45V$

(c) $V_i = 65V$

Fig. 3 LED current waveforms when the output voltage is varied ($V_o \approx 9.75V$, $V_c / R_s = 390mA$)



(a) $V_i = 35\ V$ (b) $V_i = 65\ V$

Fig. 4. Start-up transient responses of Fig. 1 ($V_o \approx 13\ V$, $V_c / R_s = 390\ mA$)

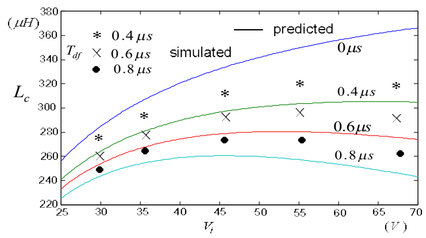


Fig. 5 Simulated critical inductor values of the PCC buck converter ($V_o = 10\ V$, $V_c / R_s = 390\ mA$)