

A Flicker-Free LED Driver with Two Parallel Inverted Buck Topology

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ABSTRACT: This paper deals with a two parallel inverted buck converter to decrease the light flicker in the lighting applications. One inverted buck converter is used for storing energy and for power factor correction (PFC). The other inverted buck converter is used to reduce the light flicker in LEDs and to maintain a constant brightness by regulating the LED current. Instead of using electrolytic capacitor as storage capacitor, film capacitors can be used. Hence the size of storage capacitor can be reduced. Here the converters are designed in such a way to achieve a high power factor of 0.90 and low LED (load) current ripple.

KEYWORDS: Inverted buck, Flicker, Power factor correction, Light-emitting diodes (LEDs), Current ripple.

I. INTRODUCTION

A light-emitting diode (LED) is a two-lead semiconductor light source. In many lighting applications the incandescent and fluorescent lamps are replaced by light-emitting diodes(LEDs) because of their wide range of color, long life, high luminous efficacy and are environment friendly [1]. There are two types of off-line LED driver such as single-stage LED driver and two-stage LED driver. The single-stage off-line LED driver topology is more compatible because of its simplicity. Drawback of this topology is that it exhibits light flicker and produce a large LED current ripple. Two-stage LED driver have a PFC stage to achieve a high power factor. The main drawback of this type is that the life time of electrolytic capacitor, used as a storage capacitor is very less and hence the overall life time of LED is reduced [2]. Odd harmonic signals such as third and fifth harmonics or third harmonics only can be injected to the input current to reduce the input current pulsation and hence to reduce the LED current ripple and to achieve high power factor. The control is difficult and cannot be suitable for high power applications [3]. Another method to reduce the output current ripple is the feed-forward control scheme, where the switching frequency is modulated and the electrolytic capacitors can be replaced [4]. To eliminate the electrolytic capacitor, high voltage driving of LEDs is used. It requires the use of simple PFC pre-regulators as single-stage LED drivers. This method provides a good overall efficiency but flickering is the disadvantage [5].

To mitigate these entire problems two parallel inverted buck converter with an AC-DC LED driver can be used. Here one inverted buck converter is used to store energy and to achieve power factor correction. The other inverted buck converter will regulate the LED current to reduce the light flicker. Hence the LED current will maintain constant brightness. Film capacitors are used as the storage capacitors in order to improve the life time of the LED driver. Paper is organized as follows. Section II deals with the operating principle of the LED driver, and the simulink model and results are given in Section III. Section IV presents conclusion.

II. OPERATION PRINCIPLE

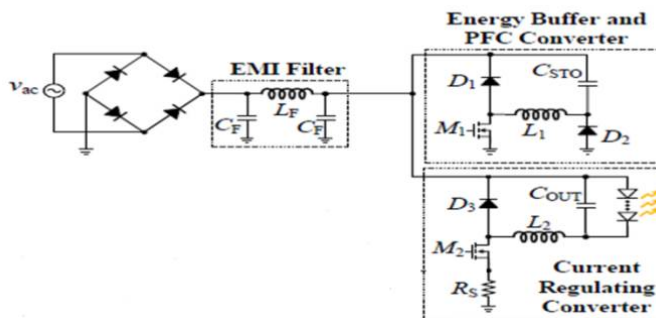


Fig. 1: AC-DC LED driver with two parallel inverted buck topology

Figure 1 shows the LED driver with two parallel inverted buck converter. It consists of a full bridge rectifier, an EMI filter, two parallel inverted buck converter. The upper inverted buck converter consists of a MOSFET switch M_1 , D_1 , L_1 , D_2 , C_{STO} (storage capacitor). The storage capacitor will store the energy which is fed as input. It will help to buffer the instantaneous power difference between the input and output power and hence power factor correction can be achieved. So this converter is labelled as PFC converter. The lower inverted buck converter consists of M_2 (MOSFET), D_3 , L_2 , C_{OUT} , and a sensing resistor R_s . This converter regulates the LED current to maintain a constant brightness in the LEDs and hence to avoid flicker.

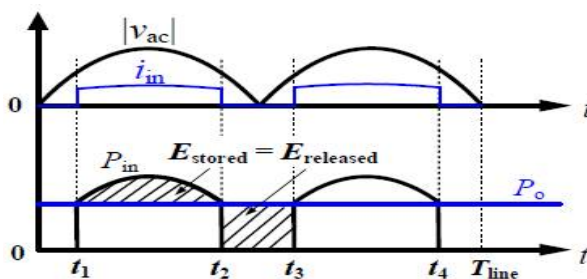


Fig.2:Energy flow concept

The input voltage and current waveform is as shown. From time t_1 to t_2 energy is stored in the capacitor and from t_2 to t_3 , stored energy is released to the LEDs. Hence energy stored is equal to the energy released. Therefore LED will get a constant output current. Output power P_o is constant.

Mode 1

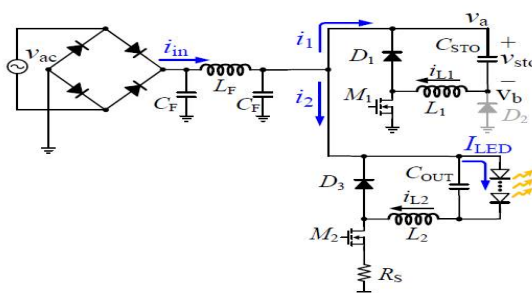


Fig. 3: Operating Mode 1

In this mode of operation, ac input source is given to both the buck converters. So the input current is the sum of currents flowing through both converters. Input supply voltage is greater than storage capacitor voltage. The current will flow through capacitor and it gets charged, when the switch M_1 is ON. At that time the diode D_2 is reverse biased. When the switch M_1 is OFF, inductor will change the polarity and hence the diode D_1 will conduct. The upper inverted buck converter operates in DCM to achieve high power factor. The storage capacitor voltage increases until it reaches the second mode of operation. The lower converter will provide a constant brightness to the LED. This converter operates in CCM to reduce the output voltage ripple. Diode D_2 is always off in this mode. Average current flowing into the regulating converter in one switching cycle is

$$i_{2AVG}(t) = \frac{P_o}{V_m |\sin \omega t|} \tag{1}$$

The average current flowing into the upper converter is expressed as

$$i_{1AVG}(t) = \frac{D^2}{2L_1 f_{sw}} (V_m |\sin \omega t| - v_{sto}(t)) \tag{2}$$

Figure 3 shows the theoretical voltage and current waveforms. i_{1AVG} is proportional to the voltage difference between the input voltage and the output voltage. i_{2AVG} is inversely proportional to the input voltage. i_{in} is the sum of i_1 and i_2 .

$$i_{in}(t) = \frac{D^2}{2L_1 f_{sw}} (V_m |\sin \omega t| - v_{sto}(t)) + \frac{P_o}{V_m |\sin \omega t|} \tag{3}$$

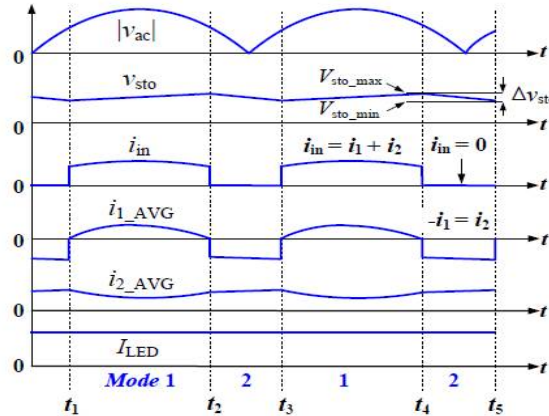


Fig.4: Voltage and Current Waveforms

Mode 2

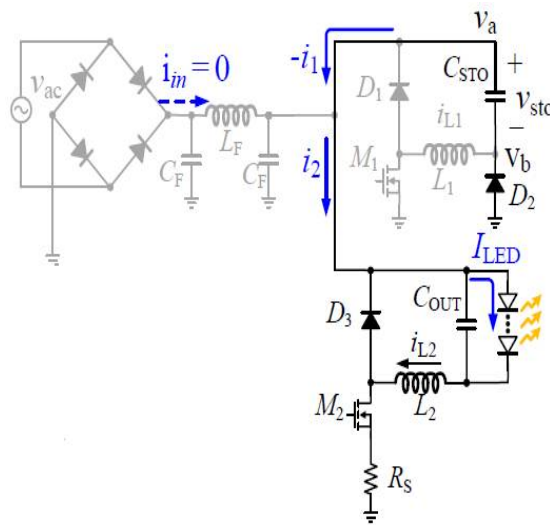


Figure.5: Operating Mode 2

In this mode full bridge rectifier is OFF and the energy stored in the capacitor is fed to the current regulating converter. When M_2 is ON, D_2 turns ON and hence LEDs gets energy from the storage capacitor. If the input voltage is greater than v_{sto} then the full bridge rectifier will turn ON and D_2 turns OFF. Regulating converter will supply dc current to LED during two modes.

III. SIMULINK MODEL AND RESULTS

Simulation is done in MATLAB software. LED is represented by an equivalent resistor in the simulink model. The voltage and current rating of LED is 3.7V and 0.35A. So the equivalent resistance for 14 LED (15W) is 148Ω. Output voltage is regulated using PI controller with k_p as 1 and k_i as 0.9. The load (LED) current is obtained as 0.35A. Output voltage (LED) is obtained as 51.8V. Switching pulse are given to M_1 if and only if $v_{ac} > v_{sto}$.

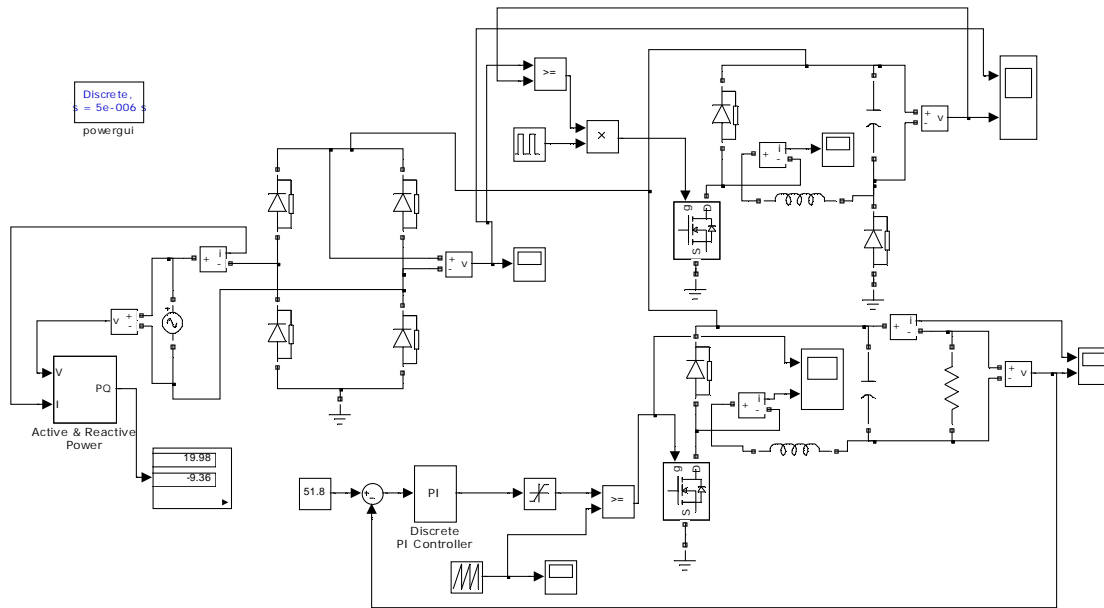


Fig.6: Simulink model of the LED driver

Output waveforms

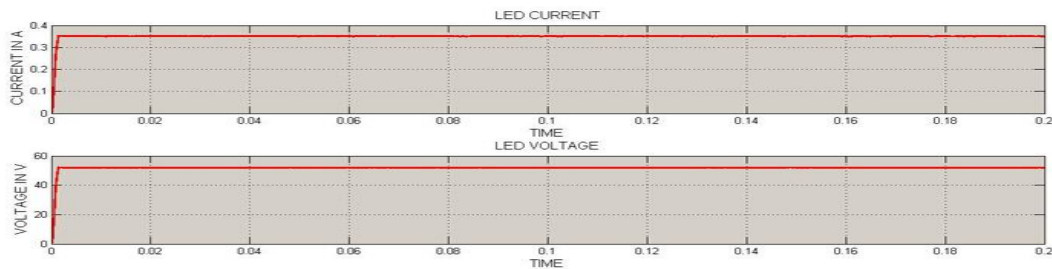


Fig.7: Waveform of the output current and voltage

IV. CONCLUSION

LED driver without flicker is simulated with the help of MATLAB software. Power factor correction is performed by the upper converter and the lower converter regulates the LED current. By using this topology high power factor (0.90) and low LED current ripple is achieved. Efficiency is also increased.

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