# ANALYSIS OF THE INTEGRATED DOUBLE BUCK BOOST CONVERTER FOR POWER-LED LAMPS

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**ABSTRACT**

*The IDBB converter features just one controlled switch and two inductors and is able to supply a solid-state lamp from the mains providing high power factor and good efficiency. And with a careful design of the converter the filter capacitances can be made small enough so that film capacitors may be used. Thus the converter mean time between failures can be made as high as that of the solid-state lamp. The integrated double buck–boost (IDBB) converter will power-LED lamps from the ac mains providing high power factor, low LED current ripple and high efficiency. The operation of the converter is equivalent to two buck–boost converters in cascade, in which the controlled switch is shared by the two stages.*

## I INTRODUCTION

Generally, white power LEDs are becoming an attractive light source, owing to their high reliability, long life, high color rendering index, and small size. In addition, there are commercially available units that can reach light efficacies as high as 100 lm/W [2]. All these features make white LEDs a good candidate to override fluorescent and other discharge lamps in many applications, including street lighting, automotive lighting, decorative applications, and household appliances [3]–[8]. However, powers LEDs are still far from being a panacea since they suffer from several drawbacks. First, due to their nearly constant-voltage behavior, they cannot be supplied.

In this paper, a novel converter such as based on integrated double buck–boost (IDBB) converter is proposed to supply power LED lamps from the ac mains, providing high power factor (PF), low LED current ripple, and high efficiency. The structure of IDBB converter is obtained by cascaded connection of two buck-boost converters, in which the controlled switch is shared by the two stages. Thus, the proposed IDBB converter includes two inductors, two capacitors, three diodes, and one ground-referenced controlled switch, featuring affordable low cost and good reliability for this kind of applications.

## II IDBB CONVERTER

Switch mode dc-to-dc converters are used to convert the unregulated dc input into a controlled dc output at a desired voltage level. Buck (step down) converter and the Boost (step up) converters are basic converter topologies. The buck, boost and buck-boost converters all transferred energy between input and output using the inductor, analysis is based of voltage balance across the inductor. The CUK converter uses capacitive energy transfer and analysis is based on current balance of the capacitor. The CUK converter is derived from DUALITY principle on the buck-boost converter. Forward converter is another popular switched mode power supply (SMPS) circuit that is used for producing isolated and controlled dc voltage from the unregulated dc input supply. As in the case of fly-back converter the input dc supply is often derived after rectifying (and little filtering) of the utility ac voltage. The forward converter, when compared with the fly-back circuit, is generally more energy efficient and is used for applications requiring little higher power output. In this paper, a novel converter such as based on integrated double buck–boost (IDBB) converter is proposed to supply power LED lamps from the ac mains, providing high power factor (PF), low LED current ripple, and high efficiency.

Fig. 1 shows the electric diagram of the IDBB converter. As explained in the introduction, the converter behaves as two buck–boost converters in cascade. The input buck–boost converter is made up by Li, D1, CB, and M1, and the output buck–boost converter comprises LO, D2, D3, CO, and M1. The reversing polarity produced by the first converter in the capacitor CB is corrected by the second converter, given a positive output voltage with respect to ground. This simplifies the measurement of the load current for closed-loop operation, thus reducing sensing circuitry and cost.

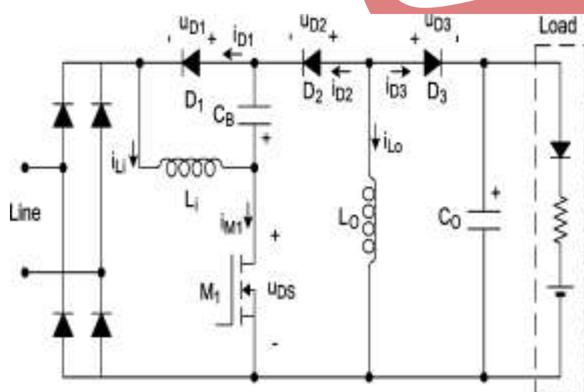


**Fig 1: Circuit Diagram for IDBB converter**

By operating the input inductor $L_i$ in discontinuous conduction mode (DCM), the average current through the line will be proportional to the line voltage, therefore providing a near-unity PF. On the other hand, the output inductance $L_O$ can be operated either in continuous conduction mode (CCM) or DCM. The operation in DCM has the advantage of providing a bus voltage across $C_B$ independent of the duty cycle and output power. However, it presents the disadvantage of requiring a higher value of the output capacitance to achieve low current ripple through the load.

Moreover, with a careful design of the converter, the bus capacitor can also be made low enough to be implemented with film technology, thus avoiding the low-life-rating electrolytic capacitors in the whole converter. This implies the design of the converter so that it operates with a duty cycle lower than 0.5. In this manner, the output converter voltage ratio will be lower than one, thus reducing the low-frequency voltage ripple in the same amount.

## III ANALYSIS OF THE OFFLINE IDBB CONVERTER

In this, the IDBB converter is analyzed when operated from the main voltage, achieving a near-unity input PF and a low-ripple current through the Power-LED load.

### 3.1 Line Current and Input Power

The input current ig corresponds to the current through the inductance Li during the time interval 0 − DTS , where D is the transistor duty cycle and TS is the transistor switching period. This current is modulated by the rectified line voltage, as shown in Fig. 3. Thus, the value of the input current averaged at line frequency can be calculated as follows:

$$i_g = \frac{1}{T_s}\frac{1}{2} i_{g\_peak} DT_s = \frac{D^2 V_g}{2 L_i f_s} \sin w_L t \qquad (1)$$

Where ig_peak is the instantaneous peak current in each switch-ing period, fS is the switching frequency, Vg is the peak line voltage, and ωL is the line angular frequency. As can be seen in (1), the averaged input current is a sinusoidal waveform that

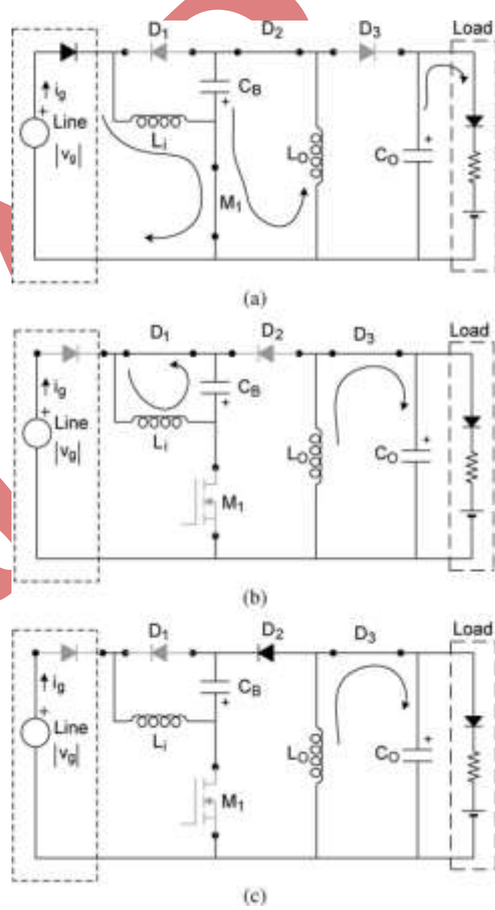


**Fig: 2 IDBB Converter of Interval**

Equivalent circuits for the operation of the IDBB converter as in figure 2 is explained in modes of operation. i.e. (a) Interval I: 0 < t < DTS. (b) Interval II: DTS < t < DTS + t1. (c) Interval III: DTS + t1 < t < TS.

will provide an input PF close to unity once filtered by the input electromagnetic interference (EMI) filter.

The mean input power Pg can now be calculated, taking into account that both input waveforms will be sinusoidal

$$P_g = \frac{1}{2} V_g i_{gpeak} = \frac{D^2 V_g^2}{4 L_i f_s} \qquad (2)$$

Where ig peak is the peak value of the averaged input current.

### 3.2 Output and Bus Voltages

The output voltage VO for the ideal converter can be obtained by equaling input and output powers. The output power is obtained as follows:

$$P_0 = \frac{V^2{}_0}{R} \qquad (3)$$

with R being the static equivalent resistance of the LED load, which can be obtained by the ratio between the dc values of LED voltage (VLED) and current (ILED) at each operating point

$$R = \frac{V_{LED}}{I_{LED}} = \frac{V_\gamma + R_\gamma I_{LED}}{I_{LED}} = \frac{V\gamma}{I_{LED}} + R_\gamma \qquad (4)$$

as

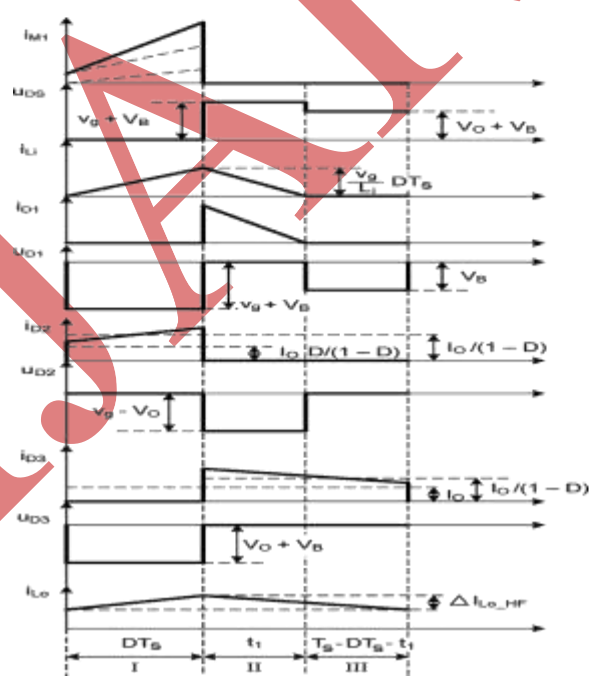


**Fig: 3 IDBB Converter Switching Period Wave forms**

Main waveforms of the IDBB converter within a high-frequency switching period around the peak line voltage. Then, assuming 100% efficiency, by equaling (2) and (3), the output voltage is finally obtained

$$V_0 = \frac{DV_g}{2\sqrt{K}} \tag{5}$$

Since the output stage corresponds to a buck–boost converter operating in CCM, the bus voltage VB can be calculated by using the voltage conversion ratio for this converter.

## IV SIMULATION DIAGRAM AND RESULTS

The Integrated Double Buck-Boost Converter was simulated using MATLAB/SIMULINK and the resulting waveforms are as shown below. A simulation prototype for a street lighting application has been developed using MATLAB/SIMULINK. The lamp is formed by 60 LW W5SG power LEDs by Osram in a series array.

The load rating current is 350 mA, with an output power of 70Wand a total luminous flux of 1500 lm. The load was tested at the laboratory, obtaining the following model parameters: Vγ = 170 V and Rγ = 87Ω. The equivalent load resistance at nominal power is R = 570 Ω. The selected switching frequency is 50 kHz. The line voltage is 230 Vrms with a 50-Hz line frequency. The converter must admit at least 10% line voltage variation, assuring constant current through the load. The switching frequency is assumed to be 50 KHz. The output voltage obtained to be 200 V.

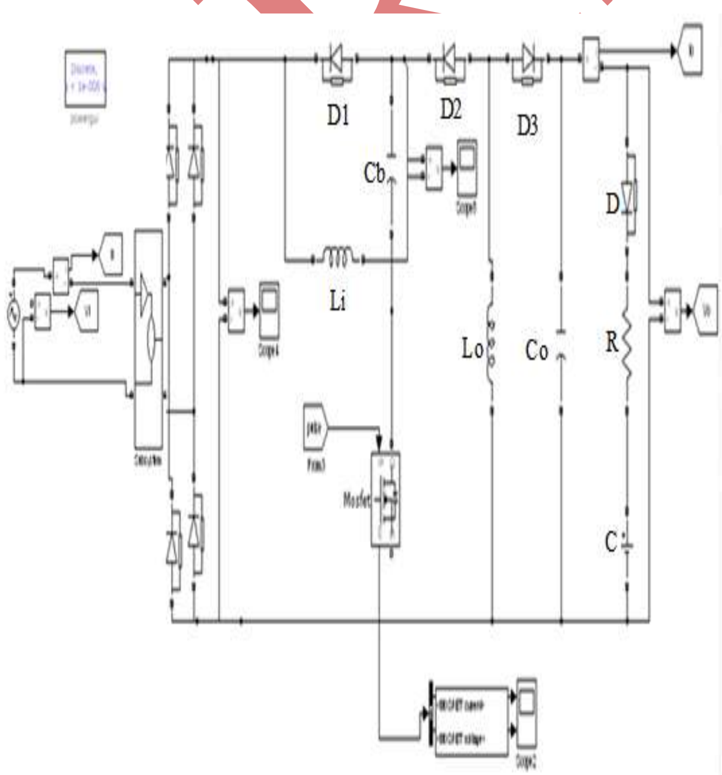


**Fig 4: Schematic Diagram of the Simulation Diagram**

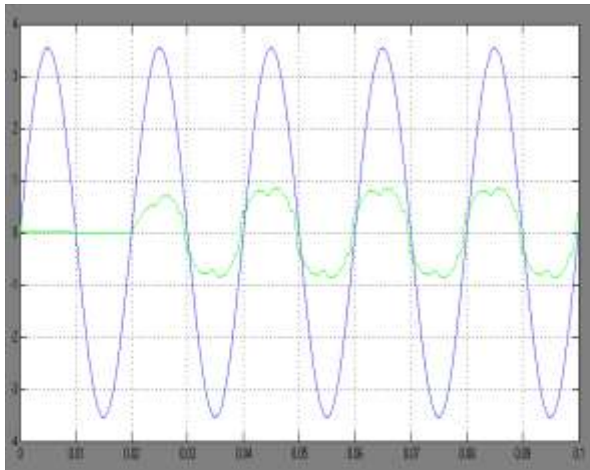

**Fig 5: Simulation Result**

The above wave form shows the input voltage and current waveform for IDBB converter.

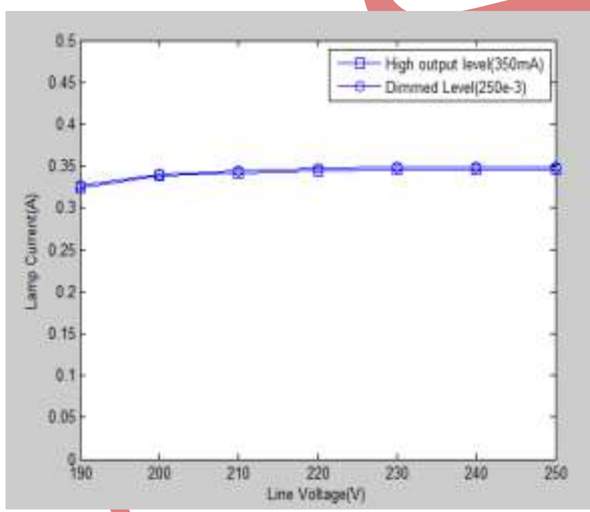


**Fig 6(a) Measured lamp current as a function of the input voltage at closed loop operation**

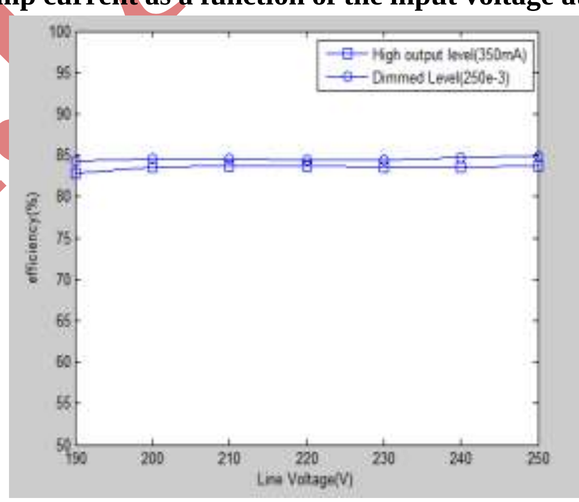


**Fig 6(b) Measured converter efficiency as a function of the input voltage.**

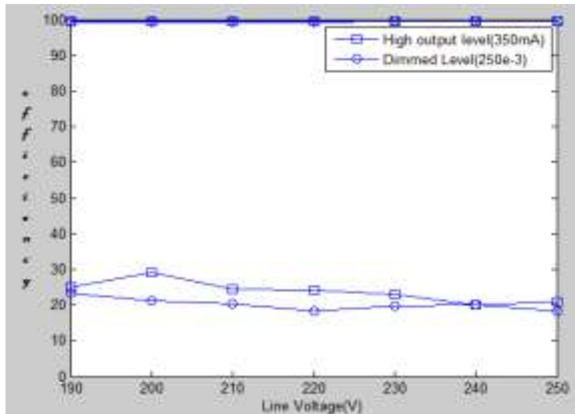


**Fig 6(c) Measured PF and THD of the input current as a function of the line voltage**.

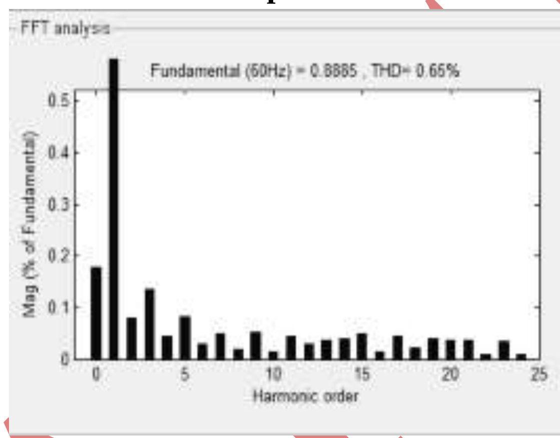


**Fig 7: Measurement of THD**

## V CONCLUSION

An IDBB converter has been investigated in this paper as a solution to implement a high-power-factor offline power supply for LED lighting applications. The topology features two buck–boost converters in cascade but using only one controlled switch. By operating the input converter in DCM, a high input PF can be obtained. On the other hand, the operation of the second stage in CCM assures a low-ripple current through the LED load without using a very high output capacitance. In this way, the converter can be implemented using only film capacitors, avoiding the use of electrolytic capacitors and increasing the converter mean time between failures.

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