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ANALYSIS & DESIGN OF INTEGRATED DOUBLE BUCK BOOST CONVERTER FOR POWER LED LAMPS

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Abstract
In this paper, an integrated double buck boost converter which act as a LED driver is presented. Here a 70 W IDBB converter is analyzed and designed which is fed from a 230 V/ 50 Hz ac supply and is used mainly for street lighting.

Introduction
LED is a passive element which is comes under the category of optoelectronic. The basic working principle of LED lamps is electroluminescence. There are many applications for white power LEDs which is used in home appliances, street light and even in decoration [1]. The LED runs in constant current mode. Normally high brightness LED is comes under the range of 350 mA [2]. These have a temperature range of 2800K to 3500K for this. Due to their high color rendering index and good reliability it is necessary to take more care about the selection of LED. There have many selection criteria for power LED lamps such as color of LED, color temperature, luminous flux and voltage and current [3]. It is not possible to connect a LED directly from the ac or dc supply. This is because of their constant voltage behavior. For meeting the maximum efficiency for the LED, they need to operate under certain conditions which are not possible in all circumstances. That's why it is very important to control a LED in a proper way.

This paper introduce integrated double buck boost converter (IDBB) which is work as a LED driver. Switching mode voltage regulator (pre-regulator with multiple current regulators), non – isolated buck converter, and series input –connected converter cells are also used as a LED driver [4]. LED driver is a circuit which converts ac input voltage to constant dc voltage/currant. This driver is same as that of ballast in LED system. In this paper, the proposed converter can manage the fluctuations in both input and load. There are two stages: first one is full output level and the second one is dimming level. By controlling the control circuit within the IDBB it is possible to reduce the forward current through LED. This converter operation is similar to that of conventional buck boost converter. Here two buck boost converter is connected in cascade.

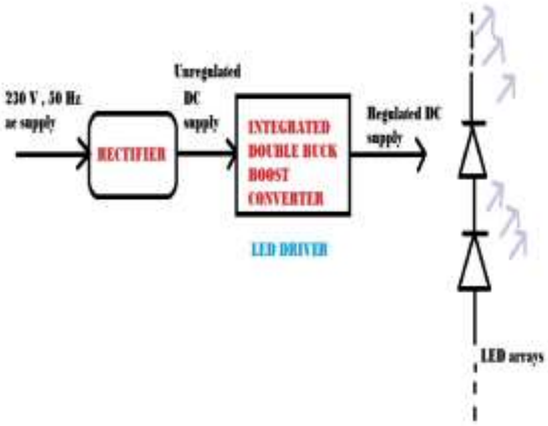

Fig. 1. Overall view

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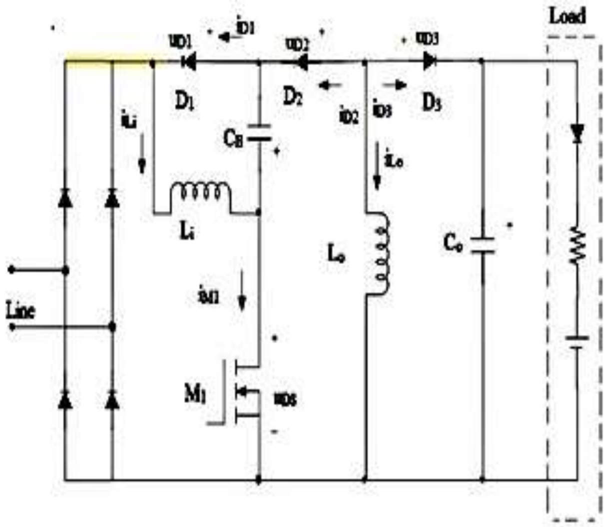

Fig. 2. IDBB converter

Integrated double buck boost converter

The electrical diagram of IDBB converter can see in fig.2 and the equivalent circuit can see in fig.3. This converter operation is somewhat similar to that of normal buck boost operation. Here, two buck boost converters are connected in cascade. One acts as an input converter and other acts as an output converter. The input converter includes L_i, D_1, C_B, M_1 and the output buck boost converter consists of L_o, D_2 , D_3, C_o and M_1. The capacitor in the input converter has reverse polarity which is corrected by the second buck boost converter, and this will provide a positive output voltage. This will make the IDBB to reduce the circuitry of sensing and cost.

Here the input inductor L_i is in discontinuous conduction mode and the output inductor is in continuous conduction mode. The main advantage of putting the input inductor in DCM is I_{av} passing through the line will be directly proportional to the V_g , which is capable of providing nearly unity power factor. By operating the output inductor in DCM, the input capacitor (C_B) voltage independent of the output power and duty cycle. But when we design like this, for attaining low ripple current through the load it will direct to a high value of output capacitance. To avoid this problem the output inductance operates in CCM.

Analysis of IDBB

The IDBB converter is supplied from a 230V , 50Hz ac supply which is capable of providing near unity PF in input. The ripple current across the power LED also low in this case. Assuming a sinusoidal voltage is flowing across through the line.

$$V_g(t) = V_g \sin \omega_L t$$

To find line current and input power

Through L_i the input current i_g is flowing in time interval of 0 – DT_s . Here the switching period of transistor is T_s , and the duty cycle of the transistor is D.

$$< i_g > = \frac{1}{T_s}\frac{1}{2}\, i_{g\_peak} DT = \frac{D^2}{2}\frac{V_g}{L_i f_s} \sin \omega_L t \quad (1)$$

$$P_g = \frac{1}{2} V_g < i_g >_{peak} = \frac{D^2}{4}\frac{V_g{}^2}{L_i f_s} \quad (2)$$

To find the output voltage and bus voltage

$$P_o = \frac{V_o{}^2}{R} \quad (3)$$

When equating the input and output power the output voltage V_o can be obtained. Consider the converter have 100% efficiency,

$$V_o = \frac{DV_g}{2\sqrt{K}} \quad (4)$$

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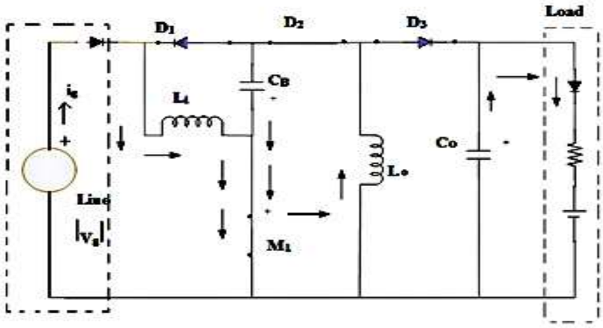
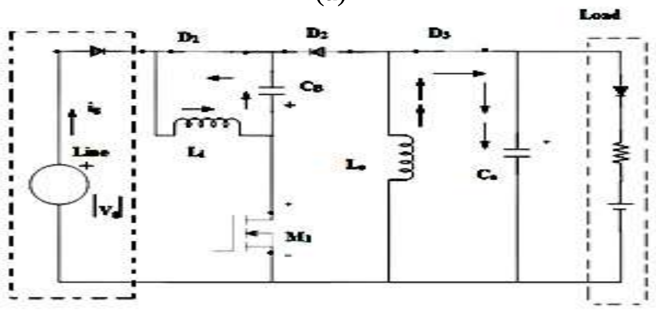
The bus voltage of the IDBB in which the output stage is in CCM is,

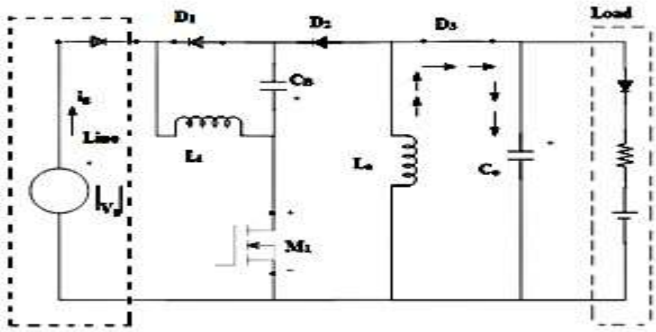
$$V_B = \frac{1-D}{D} V_o = \frac{(1-D)V_g}{2\sqrt{K}} \qquad (5)$$



(a)



(b)



(c)

Fig. 3. Equivalent circuit of IDBB

When duty cycle increases, the output voltages increases but the bus voltage decreases in the quantity.

$$V_B + V_o = \frac{V_g}{2\sqrt{K}} \qquad (6)$$

To find limit duty cycle , D_{limit}

In order to maintain high input power factor the input stage is in DCM in any load condition.

$$D_{limit} = \frac{1}{1+\frac{V_g}{V_B}} \qquad (7)$$

To find reactive elements

By assuming 100% efficiency, for a particular P_o the input inductance L_i can be calculated as,

$$L_i = \frac{D^2 V_g^2}{4 P_o f_s} \qquad (8)$$

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Specification of converter

With an output of 70W the load current rating is 350 mA. The equivalent LED load resistance at 70 W output power is, R = 577Ω The line frequency is 50Hz. The IDBB allow ±10% voltage regulation in line, to make constant current through the load. The Li is calculated by selecting 40% duty cycle. The peak to peak maximum bus voltage is selected as 5% , approximately 12Vpp. The Lo is calculated for 50% current ripple and Co for 2% current ripple.

Table.1. Specification of idbb

parameters	*specifications*
Duty Cycle, D	40%
Switching frequency, f_s	50KHz
V_o(output voltage)	200 V (for 100% efficiency)
K (non-dimensional factor)	0.103
V_B(bus voltage)	300 V
$V_B + V_O$	500 V
D_{limit}	0.480
L_i(input inductance)	100 m H
$i_{D1-peak}$	2.166 A
i_{D1}	0.469 A
C_B(input capacitance)	80 µF
L_o(output inductance)	7.0 mH
C_o(output capacitance)	40µF

The Lo is calculated for 50% current ripple and Co for 2% current ripple.

Results

The input current is sinusoidal and the measured power factor is 0.98. The average voltage is 197.9V for 84% efficiency and the average current is 0.346m A nearly 350 m A. So that, the output power is approximately 70 W. The lamp voltage has a ripple value 10Vpp and the lamp current have a ripple value 120 m AVpo . The efficiency of the converter lies in between the range of 84% - 85%.

Comparision with buck boost converter

This paper compares the effect of both integrated double buck boost converter and buck boost converter. The analysis is done by taking same input and same load in both converters. The buck boost converter which is feeding from a 230 Vrms, 50Hz ac supply. The switching frequency is 50 K Hz and the duty cycle is taken as 40% same as in IDBB. Then analyzed the output voltage, by checking with different duty cycle ratios.

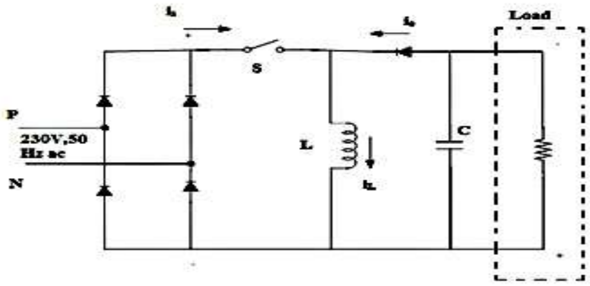

Fig. 4. Buck boost converter

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Inductance and capacitance

The inductance and capacitance of the conventional buck boost converter is given by,

$$L = \frac{(1-D)R}{2f} \quad (7)$$

$$C = \frac{D}{2fR} \quad (8)$$

output power and power factor

$$P_o = \frac{{V_o}^2}{R} \quad (9)$$

$$\text{Power factor} = \frac{P_{real}}{P_{apparent}} \quad (10)$$

$$\text{Efficiency} = \frac{output\ power}{input\ power} \quad (11)$$

Design of buck boost converter

The buck boost converter is supplied from a 230V, 50Hz ac supply with same load that used in IDBB. The switching frequency is 50 KHz and the line frequency is 50Hz. For a 40% duty cycle the output voltage is 114.9 V. The efficiency at this case is 61% and this is very low compared to IDBB. The power factor of buck boost converter is 0.54. The power factor is also poor in buck boost converter compared to IDBB. The inductor value as per the design is 3.46mH and the capacitor value is 23 nF.

Table.2 output voltage variation with duty cycle

Duty cycle (%)	Output voltage(V)
20	66.63
40	114.9
60	445
90	685

Simulation circuits & results

For idbb converter

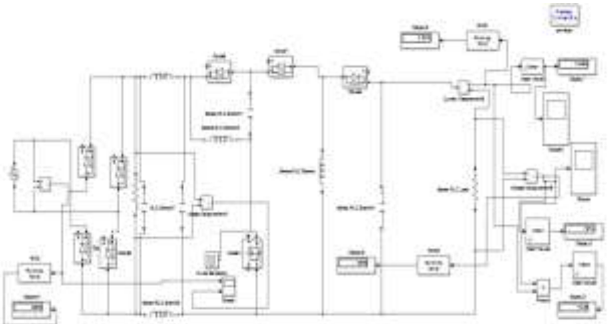
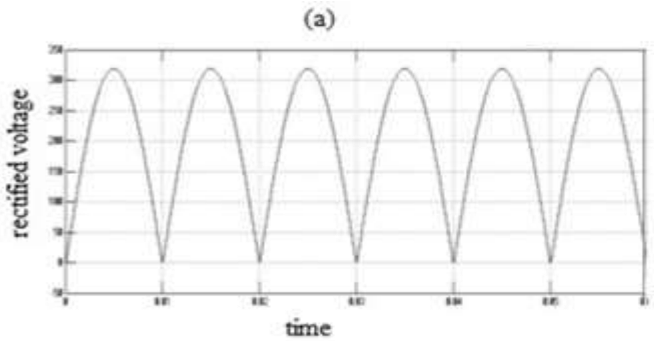


Fig. 5. Simulation of IDBB



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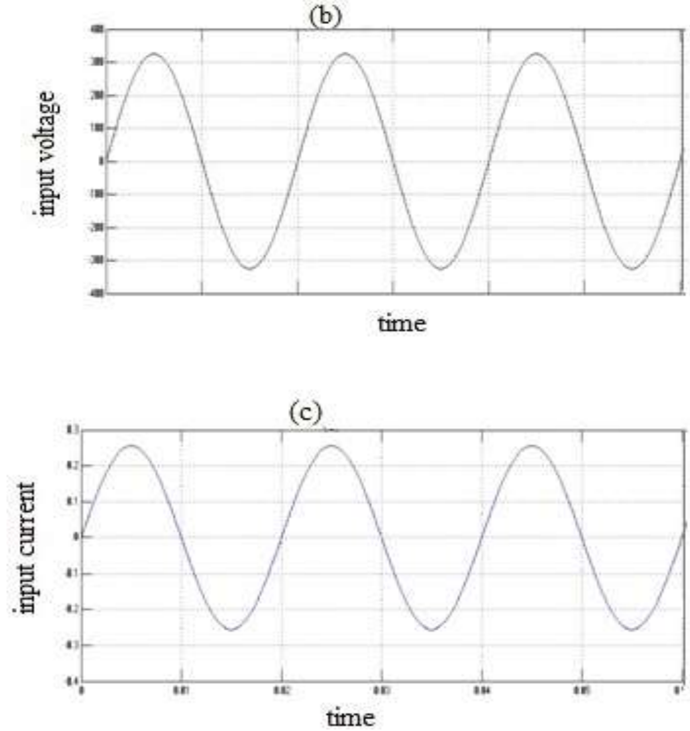

Fig. 6. Waveform of rectified voltage (a), input voltage (b), input current(c)

The input current and the input voltage are proportional. So, can see a power factor approximately unity.

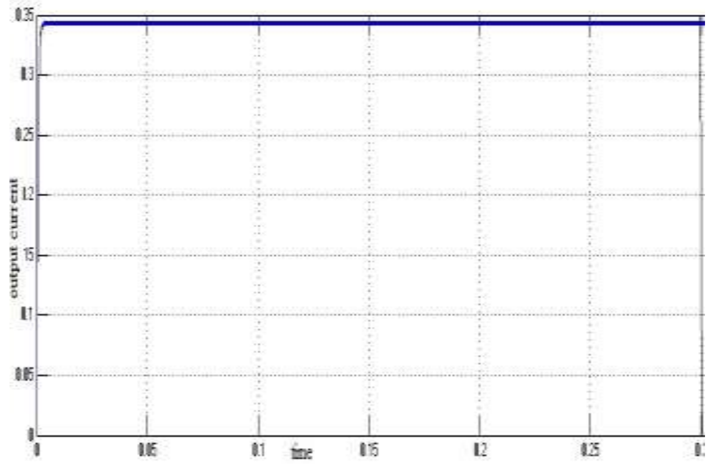

Fig. 7. Waveform of output current

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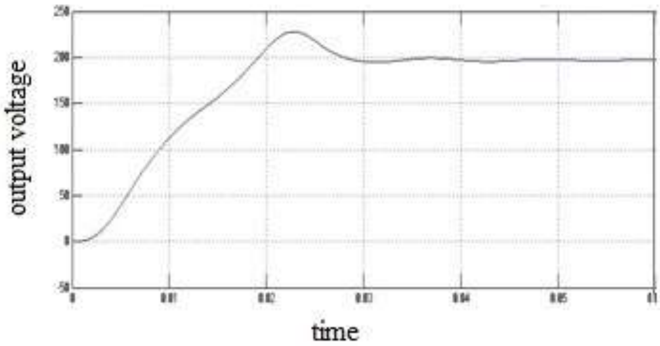

Fig. 8. Waveform of output voltage

For buck boost converter

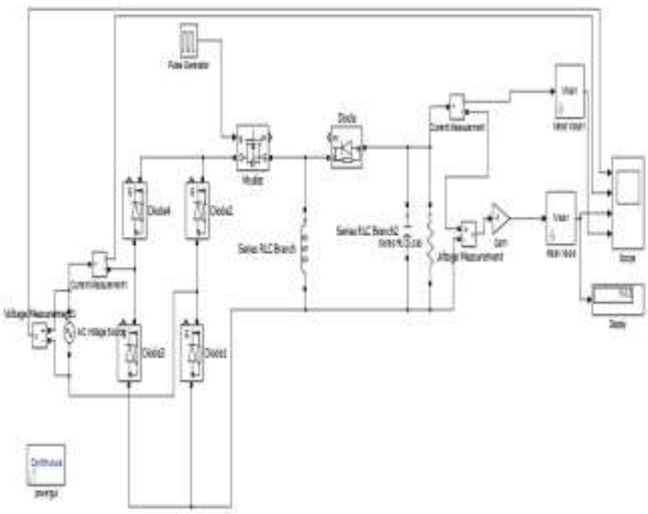

Fig. 9. Simulation of buck boost converter

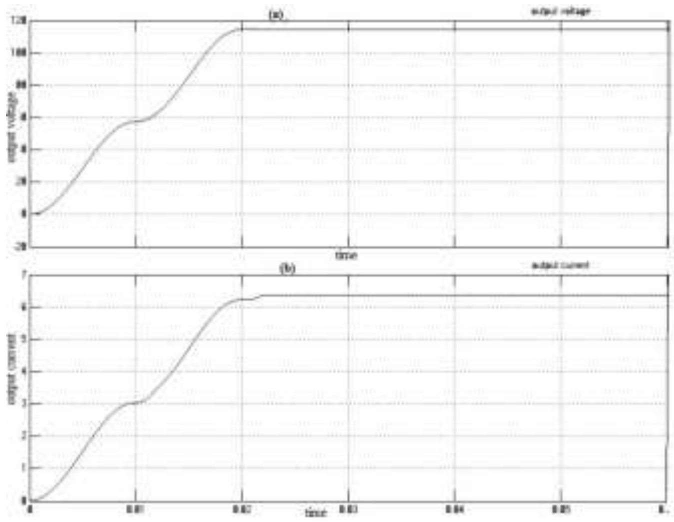

Fig. 10. Waveform of (B) output current and (A) voltage at D=40% .

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Conclusion

This paper analyzed and designed a IDBB converter in which it is able to provide high power factor supply to lighting application for power LED. Here two buck boost converters are connected in cascade with one controlled switch. Input converter operates in DCM, to deliver high input power factor. The second converter is in CCM to reduce the ripple current in LED.

The IDBB is supplied from a 230V, 50Hz ac supply able to provide high power factor, low cost and better efficiency. This converter is mainly for street lightening applications. There are two level of LED light: first is for full output level in which the lamp is providing with a current of 350 m A and supplied an output power of 70 W. This paper analyzed and designed for 70W output power. This is mainly for peak time where a full output level is needed. The second one is in dimming level have an output power of 50W at 250mA. This is mainly for spare time where high power is not required. By controlling the IDBB converter, these can be easily achieved.

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