International Journal of Electrical and Electronic Engineering & Telecommunications

ISSN 2319 – 2518 www.ijeetc.com
Special Issue, Vol. 1, No. 1, March 2015
National Level Technical Conference P&E- BiDD-2015

Research Paper

DYNAMIC CONTROL OF INTERLEAVED BOOST CONVERTER FOR AUTOMOTIVE LED LIGHTING APPLICATION

Ajith P[1]* and H Umesh Prabhu[1]

*Corresponding Author: **Ajith P,** ✉ ajithpaul90@gmail.com

DC-DC converters are widely used in Industrial, Commercial and Non Renewable energy applications and also especially in Switch Mode Power Supplies. This paper presents with the design and implementation of interleaved DC-DC Boostconverter with PI controller. The interleaved concept is used to meet the increased demands and also a low current ripple in source current due to this reducing the size of the filter component in input and output. To control the current flow at the output side of interleaved boost converter closed loop control method is used. There are different types of closed loop methods are available. In this paper, we use PI controller to control the current flow in the load. Advantages of interleaving such as higher efficiency, reduced input current ripple are also realized in boost topology.

Keywords: DC-DC converter, PI controller, Interleaved boost converter

INTRODUCTION

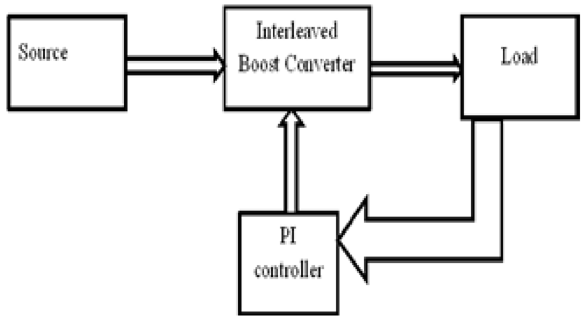
Interleaved Boost Converter has been widely used in electric vehicles, photo voltaic generation and power factor correction due to its high power density and fast dynamic response. There are ripple in the input current due to inductor of boost converter which can be minimized by using two phase interleaved boost converter. In two phase interleaved boost converter two boost converters operate in 180° out of phase. The input current is the sum of two inductor currents. As the inductor's ripple currents are out of phase they cancel each other out and reduce input ripple current that the boost converter cause. This paper introduces interleaved boost converter using PI controller which provides higher power factor and also provides better control.

Our system can be used to supply constant stepped up voltage to dc loads using DC-DC converter. In a boost converter, the average voltage is greater than the input voltage. A boost converter is called step up converter. Interleaved boost converter can minimize

[1] Department of EEE, St. Joseph's College of Engineering, Chennai, India.

switching loss by adopting a resonant soft-switching method. Since, the interleaved method distributes the input current according to each phase; it can decrease the current rating of the switching device. Also, it can reduce the input current ripple, output voltage, and size of the passive components.

Figure 1: Block Diagram

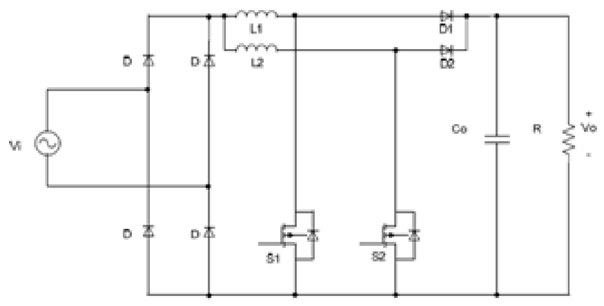


A boost converter is a power converter with an output DC voltage greater than its input DC voltage. In this case, interleaved boost converter is used where twice the value of input voltage is got as output from the converter. Load may be battery or any DC supply unit. Even AC supply unit can be used with inverter (DC to AC) block should be used

TWO PHASE INTERLEAVED BOOST CONVERTOR

The two phase interleaved boost converter is shownin Figure 2. There are two parallel converter channels in the circuit. The first channel is composed of inductorL1, Switch S1, and Diode D1, whereas the second channel consists of L2, S2 and D2. The two converter channels are essentially connected in parallel but operate in an interleaved mode. They share the same filter capacitor C at the output. It is assumed that the parameters of the two channels are identical.

Figure 2: Two Phase Interleaved Boost Converter



With the interleaving design, the gating signals S1(vg1) and S2(vg2) for switch S1 and S2 are identical but shifted by 360°/2=180°, where 2 is the no. of converters which are connected in parallel. The total input current I_{in}, which is the sum of the two inductor currents iL_1 and iL_2.

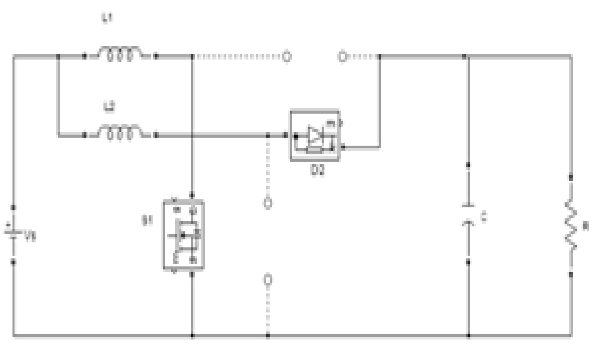
MODES OF OPERATION

The switching period is subdivided into two modes. The main equivalent circuits for the operation modes are shown below.

Mode 1

At t_0S_1 turns ON and switch S_2 turns OFF. During this period, the inductor L_1 linearly charged by the input voltage. Due to this I_{l1} current in the inductor get increases linearly.

Figure 3: Equivalent Circuit During Mode 1 Operation

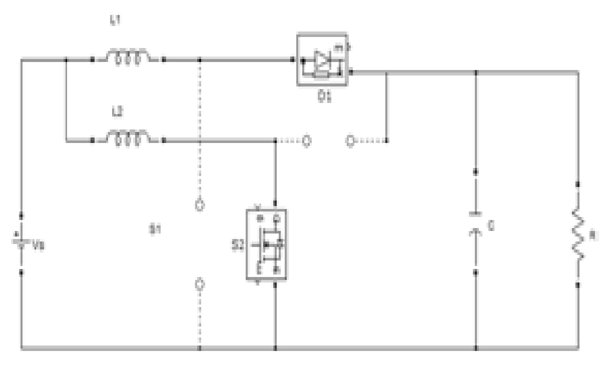


Due to reverse bias condition D_1 maintains OFF stage, because of the voltage stress across the diode is equal to the output voltage. Meanwhile the energy stored in the inductor L_2 gets transferred to load R.

Mode 2

At $t_1 S_2$ turns ON and switch S_1 turns OFF. During this period, the inductor L_2 linearly charged by the input voltage. Due to this I_{l2} increases linearly.

Figure 4: Equivalent Circuit During Mode 2 Operation



Due to reverse bias condition D_2 maintains OFF stage, because of the voltage stress across the diode is equal to the output voltage. Meanwhile the energy stored in the inductor L_1 gets transferred to load R.

TRANSFER FUNCTION OF INTERLEAVED BOOST CONVERTER

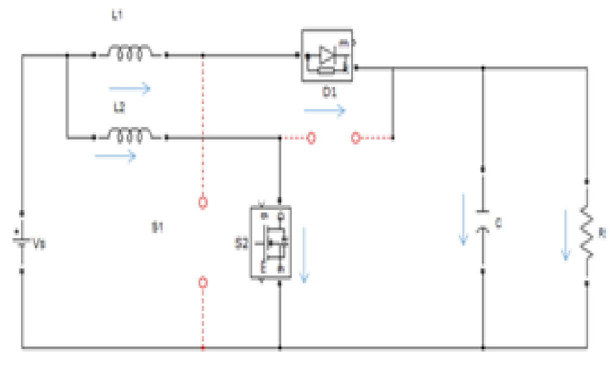
Consider the mode 2 circuit operation and according to the current flow in the mode 2 operation the corresponding equation are written as

$$V_s = L_2.di_2/dt \qquad ...(1)$$

$$V_s = L1.di2/dt + 1/c \int (i_2 - i_3).dt \qquad ...(2)$$

$$0 = 1/c \int (i_3 - i_2).\mathrm{dt} + \mathrm{R}.i_3 \qquad ...(3)$$

Figure 5: Equivalent Circuit During Mode 2 Operation



By taking laplace transform and solving the above equation we get the transfer function as

$$Tf = \frac{\mathrm{Vs}/(1-\mathrm{D})2.[(1-\mathrm{S}).(\mathrm{L}/\mathrm{R}(1-\mathrm{D})2)}{S.\frac{L}{R(1-D)2} + S^2\frac{LC}{(1-D)2} + 1}$$

The above transfer function can be obtained by solving the laplace transform equation by equating the equation.

DESIGN OF PI CONTROLLER

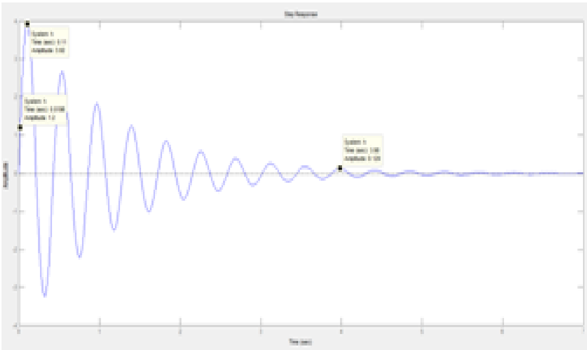
The PI control settings proportional gain (*Kp*) and integral time (*Ti*) are designed using Ziegler – Nichols tuning method by applying the step test to the transfer function of IBC.

The transfer function of the two phase interleaved boost converter is obtained by average state space method.

$$Tf = \frac{.00595 - .00595S}{5.136 * 10^{-7}S^2 + 1.24 * 10^{-4}S + 1}$$

The controller attempts to minimize the error by adjusting the process control inputs. The PID controller involves three separate constant parameters, and is accordingly sometimes called three term control proportional, integral and derivative values. It is denoted by *P*, *I* and *D*. Among these where *P* depends on the present error, *I* depends on the accumulation

Figure 6: Step Response of Inter Leaved Boost Converter



of past error and *D* depends on the prediction of the past future errors. PID control represents a significant advancement in the controls industry. It is a very effective technique for providing precise control. Although PID control is a relatively complex feature

The above waveform shows the step response obtained by the LTI viewer. Usingzeiger Nicholas tuning method the K_p and K_i values can be find. Using the formula shown in the below table the K_p and T_i values can be calculated.

Table 1: Zeigler Nichols Method

Type of Controller	K_p	T_i	T_d
P	$\frac{T}{L}$	∞	0
PI	$0.9\frac{T}{L}$	$\frac{L}{0.3}$	0
PID	$1.2\frac{T}{L}$	$2L$	$0.5L$

SIMULATION RESULTS

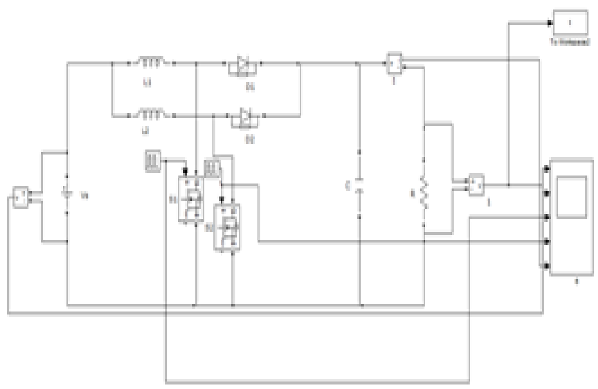
The MATLAB/SIMULINK model of interleaved boost converter is depicted in Figure 7 and the parameters of IBC are given in the Table 2.

Figure 8 shows the open loop simulation of interleaved boost converter. Here the

Table 2: Parameters of IBC

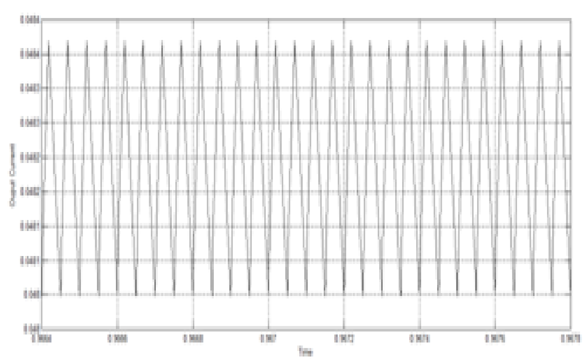
S. No.	Parameters	Values
1.	Input Voltage	12 V
2.	Output Voltage	24 V
3.	Inductor (L_1, L_2)	0.015 H
4.	Capacitor	10 µF
5.	Switching Frequency (f_s)	25 KHZ
6.	Resistive Load	1200 Ω

Figure 7: Simulink Model of Open Loop IBC



MOSFET switch is turned ON using pulse generator with 50% duty ratio and the output Current is obtained.

Figure 8: Output Current Waveform of IBC



In the open loop simulation of Interleaved Boost converter the output current cannot be controlled. Here the duty ratio is obtained by comparing actual and the reference voltages

Figure 9: Output Voltage Waveform of IBC

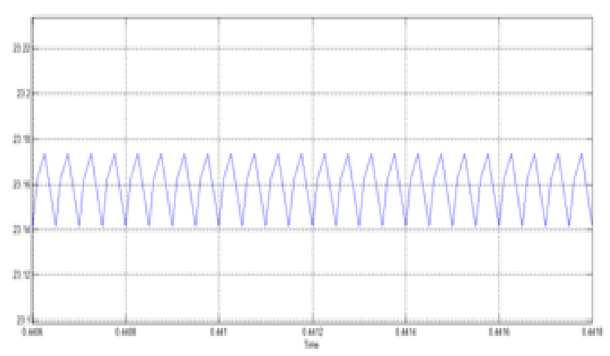
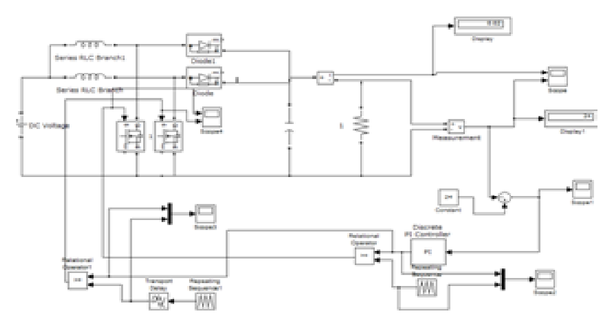


Figure 10: Simulink Model of Closed Loop IBC



through PI controller fed to the switch. The output has lot of ripples and settles very slow.

The above diagram shows the closed loop simulation of Interleaved Boost converter. Here the output voltage is measured and it is compared with the constant value and the error is given to the PI controller. The output of the PI controller is compared with the reference triangular pulse and it is given to the switches as a gating pulse.Depend upon the desired output the gating pulse given to the switches can be varied.

Figure 11 showsthe closed loop simulation of Interleaved Boost Converter with PI controller. Here the actual output is compared with the reference voltage to get an error and the change in error is fed as input to PI controller to control the flow of output current to the load. The controller output provides the desired duty ratio to switch the MOSFET. The output voltage has small overshoot and it settles very fast.

Figure 11: Output Curretnt Waveform of IBC with PI Control

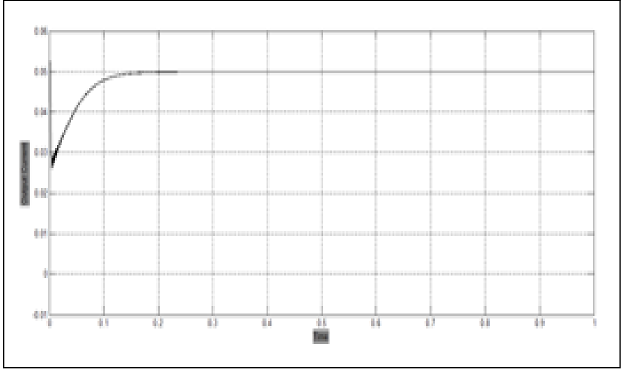


Figure 12: Gate Pulses for Switch S1

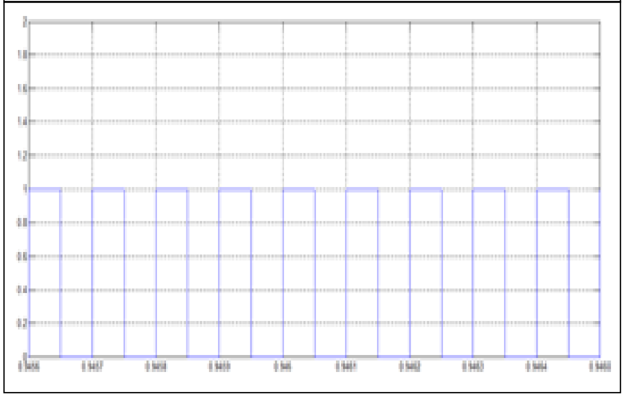


Figure 13: Gate Pulses for Switch S2

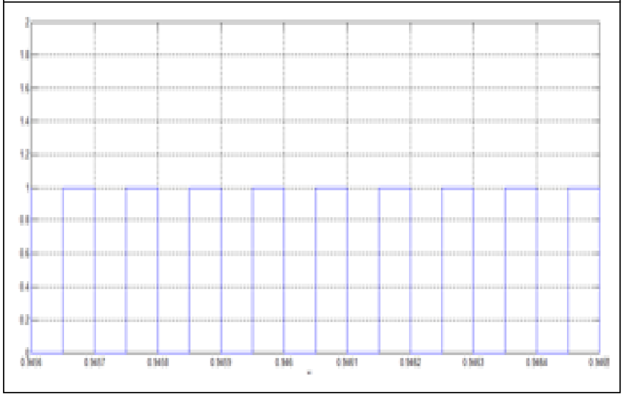
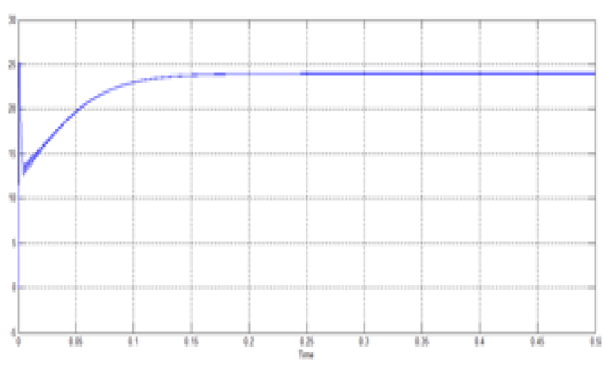


Figure 14: Output Voltage Waveform of IBC with PI Control



CONCLUSON

The above simulation diagram shows the output current waveform In this initially the oscillations are produced and settles at less than 0.2 ms. For automotive LED lighting load the intensity of the light depend upon the flow of current. So to vary the intensity of the light the current flow can be varied. This can be achieved through closed loop control of the interleaved boost converter. Tuning is adjustment of control parameters to the optimum values for the desired control response.

REFERENCES

1. Chuang Y-C, Ke Y-L, Chuang H-S and He C-C (2010), "Single-Stage Power Factor-Correction Circuit with Flyback Converter to Drive LEDs for Lighting Applications", in *Proc. IEEE Ind. Appl. Soc. Annu. Meeting*, pp. 1-9.
2. "Electromagnetic Compatibility (EMC): Part 3", *International Standard IEC*, 61000-3-2, 2001.
3. Gacio D, Alonso J M, Calleja A J, Garcia J and Secades M R (2011), "A Universal-Input Single-Stage High-Power-Factor Power Supply for HBLEDs Based on Integrated Buck-Flyback Converter", *IEEE Trans. Ind. Electron.*, Vol. 58, No. 2, pp. 589-599.
4. Hsieh Y-C, Chen M-R and Cheng H-L (2011), "An Interleaved Flyback Converter Featured with Zero-Voltage Transition", *IEEE Trans. Power Electron.*, Vol. 26, No. 1, pp. 79-84.
5. Hwu K I and Yau Y T (2009), "An Interleaved AC-DC Converter Based on Current Tracking", *IEEE Trans. Ind. Electron.*, Vol. 56, No. 5, pp. 1456-1463.
6. Liu K-H and Lin Y-L (1989), "Current Waveform Distortion in Power Converters", in Proc. IEEE Power Electron. Spec. Conf., pp. 825-829.
7. Pires V F and Silva J F (2011), "Single-Stage Double-Buck Topologies with High Power Factor", *J. Power Electron.*, Vol. 11, No. 5, pp. 655-661.
8. Redl R and Balogh L (1995), "Design Considerations for Single-Stage Isolated Power-Factor-Corrected Power Supplies with Fast Regulation of the Output Voltage", in Proc. IEEE Appl. Power Electron. Conf., Vol. 1, pp. 454-458.
9. Tao F and Lee F C (2000), "An Interleaved Single-Stage Power-Factor-Correction Electronic Ballast", in Proc. IEEE Appl. Power Electron. Conf., Vol. 1, pp. 617-623.
10. Villarejo J A, Sebastian J, Soto F and de Jodar E (2007), "Optimizing the Design of Single-Stage Power-Factor Ccorrectors", *IEEE Trans. Ind. Electron.*, Vol. 54, No. 3, pp. 1472-1482.