I J C T A, 9(16), 2016, pp. 8333-8339

DC-DC Double PWM Converter for Dimmable LED Lighting

Pavankumar, Rohit Shinde and R. Gunabalan*

ABSTRACT

A simplebuck-boost converter topologywith a dimming feature using double PWM technique is presented for automotive lighting applications. The power circuit is simple and cost effective.The buck-boost converter hassingle controlled switch and four energy storing devices to perform bothoperations. The design of output filter capacitor is made small to use film capacitor in order to increase the life time of LED driver circuit. Simulation is performed in matlab-simulink for a power rating of 10W LED array load with an input voltage of 24V DCand the performance of the converter is presented under normal LED lighting and dimming conditions to prove the effectiveness of the control technique.

Keywords: Automotive lighting, buck-boost converter, LED lamp, PWM method

1. INTRODUCTION

The light emitting diode (LED) lamps are more efficient and give maximum illumination and they replace the inefficient automotive lighting. They are compact in size, more reliable and highly efficient.For LEDs, the electrons and holes recombination produces photons in terms of light and causes increase in junctiontemperature which degrades in luminous flux of LEDs.The operational lives of LED bulbs clearly distinguish them from ordinary bulbs. LEDs are current driven devices and to maintain the current constant, theLED driver circuits are intended to work in continuous conduction mode[1].

Dimming of LEDs is adopted by varying the current through them. The life time of dimmable bulbs can be 100,000 hours. The brightness of the LED can be tuned by varying theon and off time of LED current [2]. There are different methodologies are existing in literatures for LED dimming. PWM dimming circuits are employed to avoid flicker and colour shift in LED lighting with a low frequency range of 100 Hz to 200 Hz.Digital dimming using low frequency pulse width modulation to avoid chromaticity shift problem was studied and experimentally verified for a frequency of 200 Hz [3]. The light intensity of the LED is comparative to its average current. A double PWM (DPWM) low frequency gate driver circuit was adopted to regulate the average current and its amplitude to stop the LED lighting from color swing [4]. Simple fly-back converter was employed in discontinuous conduction mode with high efficiency to drive a LED load of 45 W.

An integrated double buck-boost (IDBB) converter LED driver circuit was presented in [5] for street lighting applications. Single stage parallel connected constant voltage and constant current driver circuit in which linear dimming control was applied for LED streetlighting applications [6]. Three dimming levels were realized with reduced power loss and good efficiency (>90%).Dimmable valley fill sepicLED driver was developed for low power applications using IC 555 timer in astable mode with one cycle control [7]. PWM control was usedwithin a duty cycle range of 5% to 95% to vary the brightness of the LED lamps.

PWM dimming with frequencies above the audible range for illumination control was designed and tested in order to avoid the audible noise. A shunt switch was connected across the LED string to vary the

* School of Electrical Engineering VIT University Chennai, *Email: gunabalanr@yahoo.co.in*

average current [8]. Dimming linearity was maintained for a range of 20% to 80% of its maximum brightness. A low frequency PWM control was employed to dim the LEDs with high line input power factor and reduced input current total harmonic distortion [9]. A buck-boost converter and a buck converter were integrated and operated in discontinuous and continuous conduction mode respectively. Dimming control was performed by varying the duty cycle of the low frequency signal which is used to control the active switch in the buck converter.

Non-linear closed loop control was used in [10] for dimming and colour control of LED lamps. Average current mode controlled inverse buck dimmable LED driver with an integrated current control technique was implemented with a power efficiency of 98.16% and a dimming range of 5 % to 95 % [11].In this proposed work, double PWM technique is incorporated with modified IDBB converter to enable dimming featurewithout flickering and colour shift and also for better efficiency and low LED current ripple.

2. DOUBLE PWM TECHNIQUE WITH MODIFIED IDBB CONVERTER

The block diagram of IDBB converter is depicted in Figure 1. The converter contains three diodes, two capacitors, two inductors and one controlled switch. This converter is connected to the battery of automotive vehicle or the battery of the solar LED lighting for greater efficiency and low LED current ripple.

In the power circuit diagram of modified IDBB converter shown in Figure 2, the capacitor C_B and diode D_1 are interchanged as compared to the IDBB converter discussed in [5]. The input inductor L_i is functioned

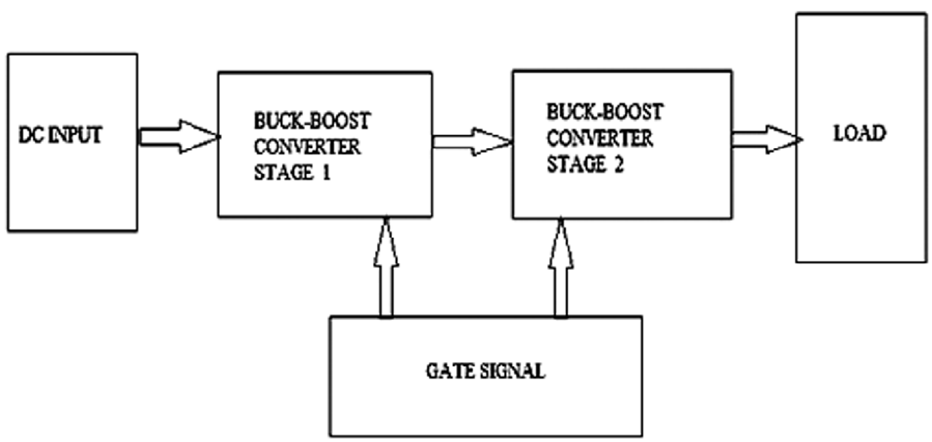


Figure 1: Block diagram of IDBB Converter

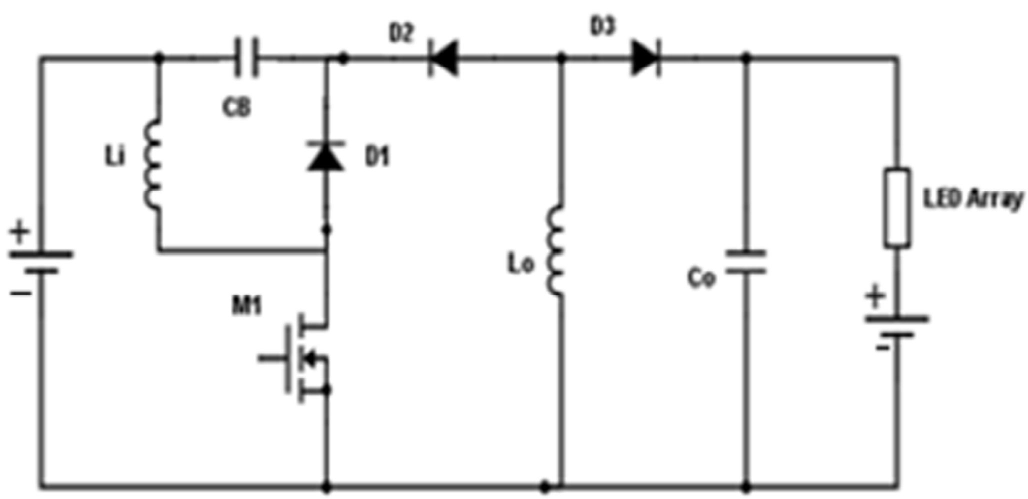


Figure 2: Power circuit diagram for modified IDBB converter

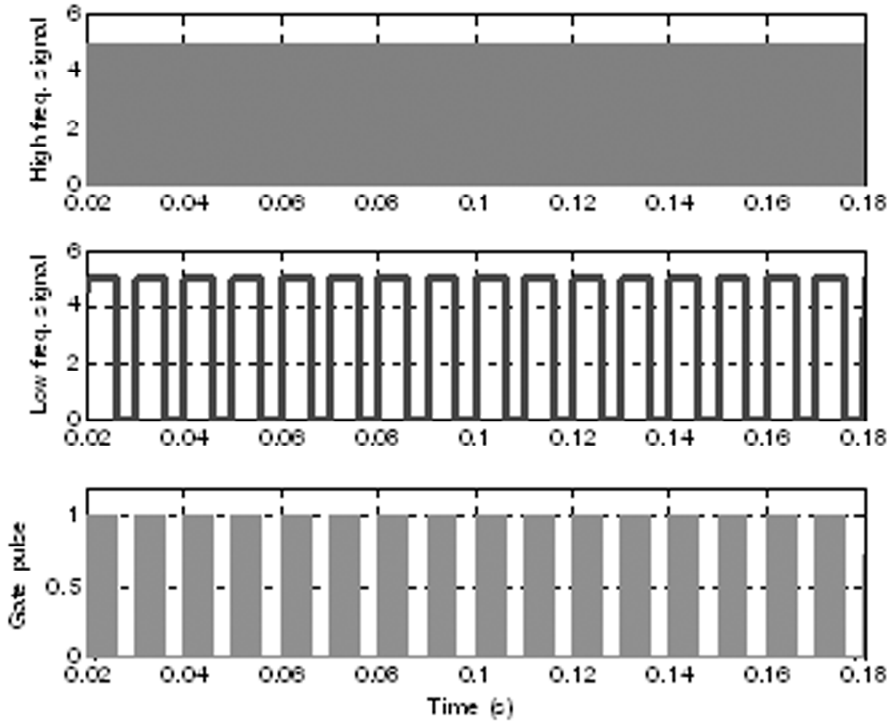


Figure 3: Double pulse width modulation control signal

in continuous conduction mode in normal operating condition and discontinuous conduction mode during dimming. In the same way, the output inductance L_o can also be operated in continuous and discontinuous conduction mode respectively during normal mode and dimming. The converter is operated with constant output voltage and current to minimize the low frequency voltage and current ripple under normal lighting conditions. Double pulse width modulation technique is employed to operate the LED lighting in dimming by mixing a high and low frequency signals.

The luminosity of the LED is approximately proportional to the average current and dimming can be achieved by adjusting the duty ratio of the control signal. But there might be a current deviation in LED which may cause color swing. To prevent the color shift, PWM for low frequency can be used andDPWM is used to regulate the amplitude of the pulse current and pulse average synchronously. Figure 3 reflects the DPWM control pulse pattern. High frequency signal is combined with the low frequency signal to obtain discontinuous conduction. Consequently the LED is driven through a pulsed current.

3. DESIGN OF MODIFIED IDBB CONVERTER

Theanalysis of IDBB converter was explained in detail [5] when operated from the main voltage. The converter components are designed for offline automotive lighting applications for a power rating of 10 W and it is operated from the battery voltage. The design analysis presented in [4] is reproduced for easy understanding.

The input and output power is given by the following terms for the IDBB converter:

$$P_{in} = V_b \ I_{in} \tag{1}$$

$$P_0 = V_o \ I_o \tag{2}$$

The output voltage is calculated from the given formula,

$$V_0 = \frac{DV_b}{2\sqrt{K}} \tag{3}$$

where K is non-dimensional factor is given by,

$$K = \frac{f_s L_i}{R} \tag{4}$$

The input inductance is calculated by,

$$L_i = \frac{D^2 V_b^2}{4 P_o f_s} \tag{5}$$

The bus voltage V_B is calculated when the converter is operated in continuous conduction mode [11],

$$V_B = \frac{(1-D)}{D} V_o \tag{6}$$

The output capacitor (C_o) and output inductor(L_o)are expressed using the following standard equations [11]:

$$L_0 = \frac{D V_B}{0.5 \Delta I_{L0} f_s} \tag{7}$$

$$C_o = \frac{D I_o}{\Delta V_0 f_s} \tag{8}$$

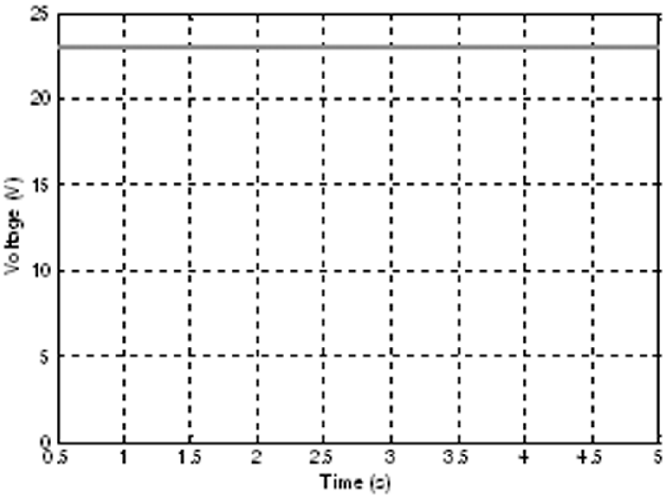
where ΔI_{L0} and ΔV_0 are the high frequency peak to peak current and voltage ripple respectively.

4. SIMULATION RESULTS AND DISCUSSIONS

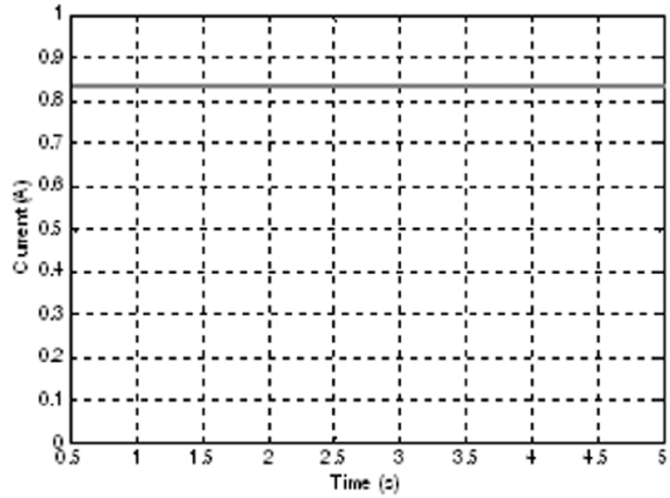
Themodified IDBB converter is designed for a power rating of 10 W and simulated in matlab-simulink. The Converter supplied by input supply voltage V_{dc} = 24V drawn from the battery whereas the output voltage is V_0 = 24Vfor a duty cycle of 0.423 and the output current is I_o = 0.35A to serve 10W power to the load of LED array.Duty cycle of the high frequency signal is 0.423, and the switching frequency is 50kHz. The input inductorcurrent I_{Li} = 0.8A and the output inductor current I_{LO} = -0.8A. The desired parameters and their ratings for modeling the converter in the software environment are given in Table.1. Simulation is done in Simulink to illustrate the performance of the converter and results are presented for different operating conditions. Figure 4 shows the simulations waveforms of the LED driver circuit for a rated load current of 350 mA. The internal resistance and voltage of the LED array is 9 Ù and 17.5 V respectively. The duty cycle of the power electronic switch is limited to 0.423 to operate it in continuous conduction mode with a switching frequency of 50 kHz. The voltages across the capacitors, currents through the inductors are illustrated in Figure 4. It shows that the current is continuous in both the inductors with minimum current ripples.

Table 1
Parameters for modified IDBB converter

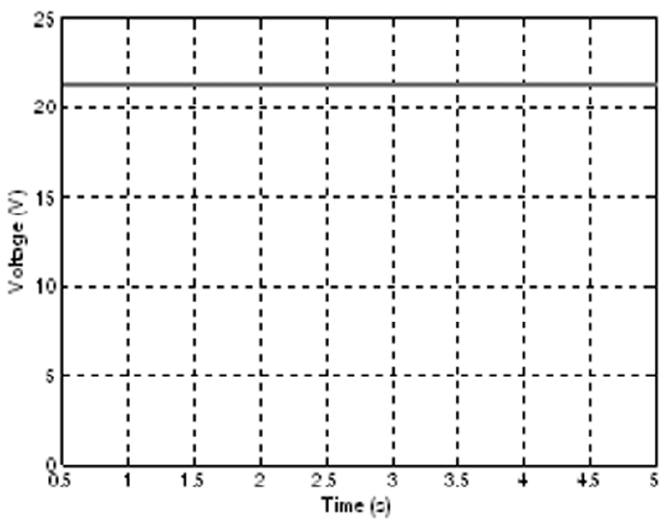
Input inductance (Li)	12µH
Output inductance (Lo)	2.8mH
Input capacitance (C_B)	41.75µF
Output capacitance (Co)	74µF
Output power	10W
Output current	350 mA



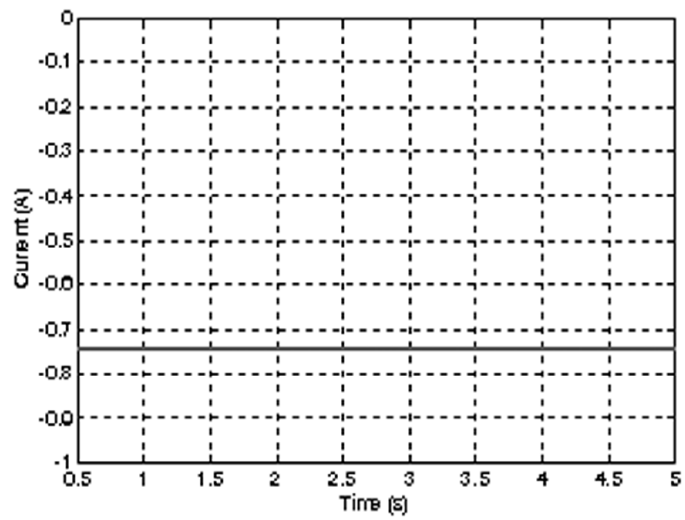
(a) Input capacitor voltage



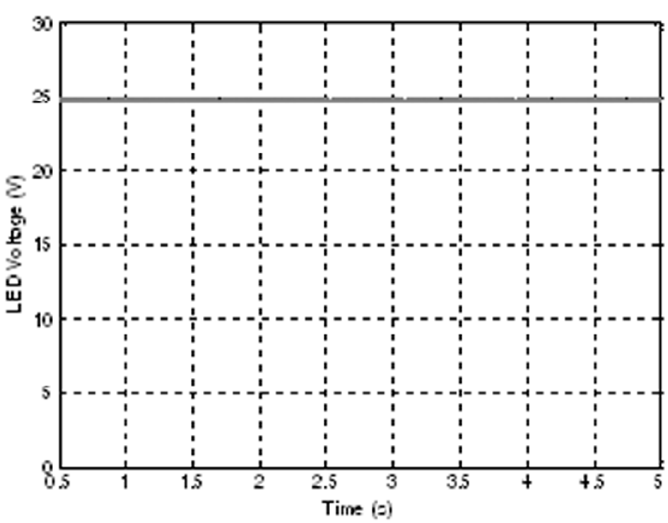
(b) Input inductor current



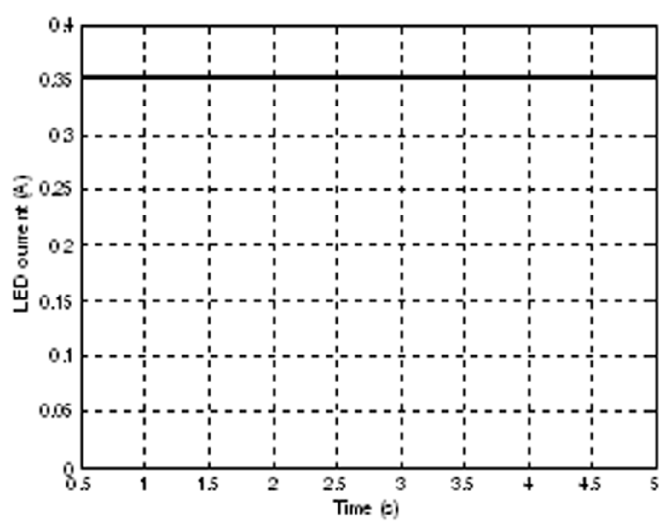
(c) Output capacitor voltage



(d) Output inductor current

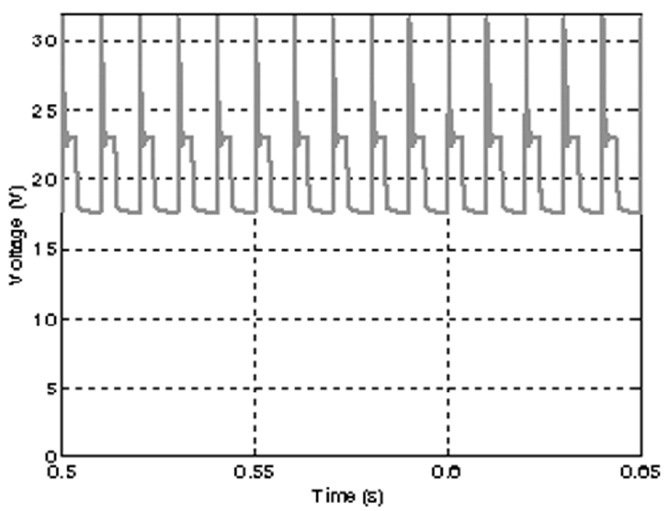


(e) LED voltage

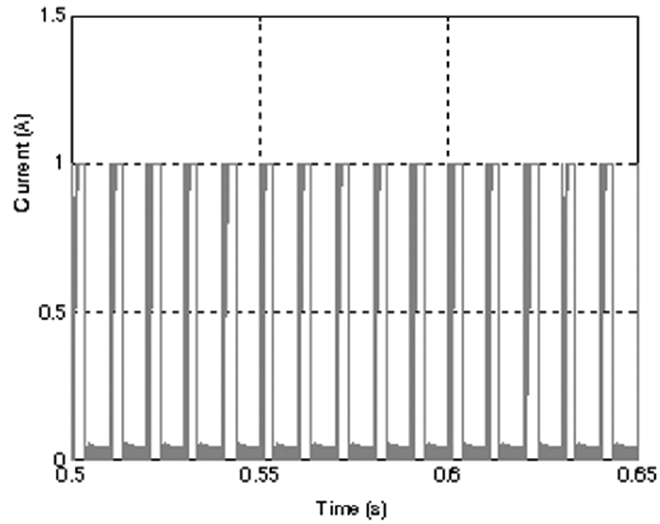


(f) LED current

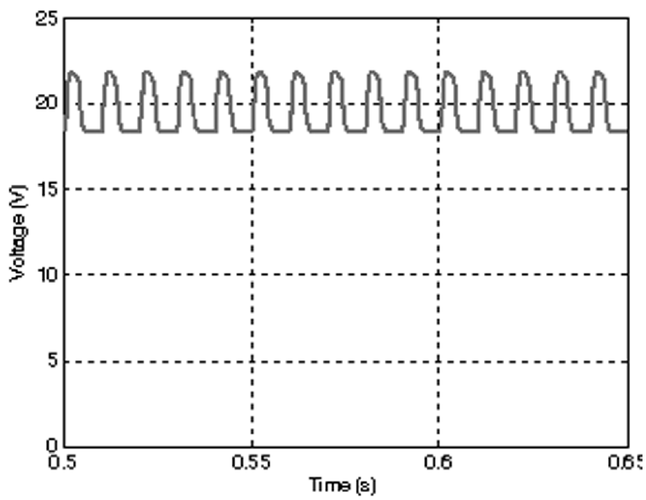
Figure 4: Simulation results in normal LED lighting



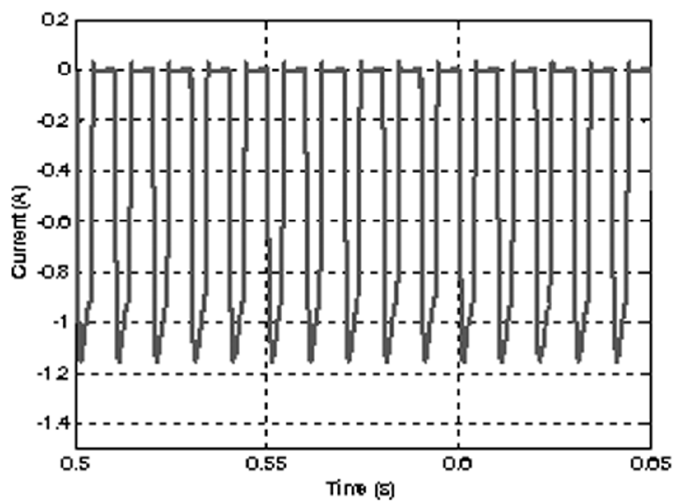
(a) Input capacitor voltage



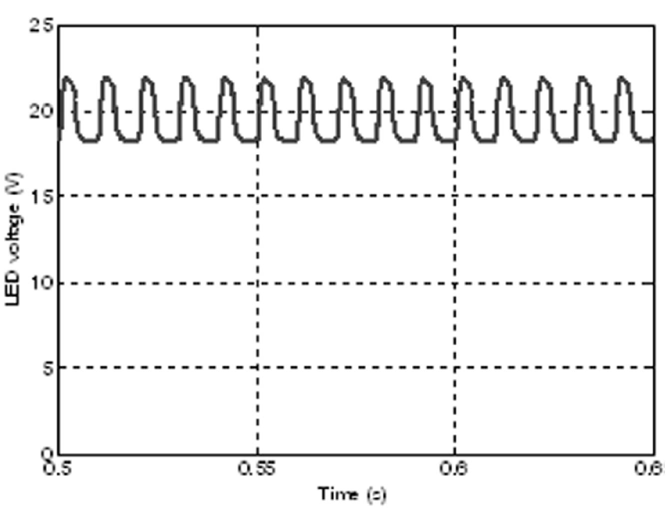
(b) Input inductor current



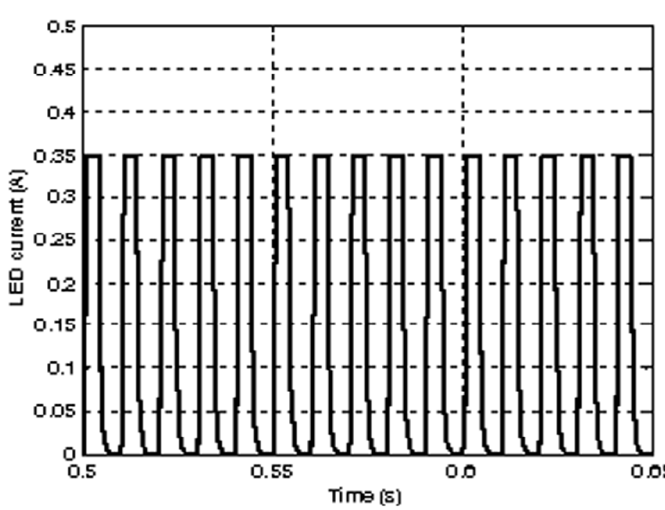
(c) Output capacitor voltage



(d) Output inductor current



(e) LED voltage



(f) LED current

Figure 5: Simulation results in dimmable LED lighting

For dimming applications, the high frequency signal is mixed with the 100 Hz low frequency signal using DPWM technique to eliminate colour shift and flicker. Figure 5 shows the waveforms obtained in dimmable LED lighting with capacitor voltages and inductor currents. The pulse width of the low frequency signal is varied keeping constant pulse width of the high frequency signal. The waveforms are obtained for half the rated LED current (178 mA) and the load voltage is 19.55 V. Figure 5 (e) and 5 (f) show the LED voltage and current waveforms respectively. The converter is operated in discontinuous conduction mode for light dimming.

5. CONCLUSION

The performance of the modified IDBB converter with dimming feature by applying DPWM was designed and simulated in matlab-simulinkenvironment. The low frequency PWM eliminates the flicker and colour shift. The designed model is verified for 10W LED array load. The life time of the driver circuit can be increased if film capacitors are used instead of electrolytic capacitors for implementation.It is cheap in cost for decorative lighting, street lighting, auto-motive lighting, traffic lighting and household appliances.

REFERENCES

[1] Q. Hu, R. Zane, “LED driver circuit with series-input-connected converter cells operating in continuous conduction mode,” IEEE Trans. Power Electron., vol. 25, no. 3, March 2010, pp. 574-582.

[2] B. Lehman and A. J. Wilkins, “Designing to mitigate the effects of flicker in LED lighting reducing risks to health and safety”, IEEE Power Electron., magazine, vol. 1, no. 3, Sept. 2014, pp. 18-26.

[3] C.L. Ko, T. J. Liang, K. H. Chen and J. F. Chen, “Design and implementation of high frequency AC-LED driver with digital dimming”, In: Proc. IEEEInternational Symposium on Circuits and Systems, 2010, pp. 3713-3716.

[4] C. S. Moo, Y. J. Chen and W. C. Yang, “An efficient driver for dimmable LED lighting”, IEEE Trans. Power Electron., vol. 27, no. 11, Nov. 2012, pp. 4613-4618.

[5] J. M. Alonso, J.Vina, D. G. Vaquero, G. Martinez, and R. Osorio, “Analysis and design of the integrated double buck–boost converter as a high-power-factor driver for power-LED lamps,” IEEE Trans. Ind. Electron., vol. 59, no. 4, pp. 1689–1697, April 2012.

[6] G. C. Jane, C. C. Su, H. J. Chiu and Y. K. Lo, “High-efficiency LED driver for street light applications”,In: Proc. IEEE International Conference on Renewable Energy Research and Applicationms and Applicatioystce nnai, TamilNadu, INDIAs, Nagasaki, Japan, 2012, pp. 1-5

[7] S. Hariprasath and R. Balamurugan, “A valley-fill sepic-derived power factor correction topology for LED lighting applications using one cycle control technique”, In: Proc. IEEE International Conference on Computer Communication and Informatics. Coimbatore, India 2013, pp. 1-4.

[8] M. Kumar, L. Parsa, “Dual-purpose offline LED driver for illumination and visible light communication”, IEEE Trans. Ind. Appl., vol. 51, no. 1, Jan./Feb. 2015, pp. 406 - 419.

[9] Y. N. Chang, H. L. Cheng, C. A. Cheng, C. H. Chang and Y. H. Lin, “An LFPWM dimmed LED driver featuring high power factor”, In: proc. IEEE International Conference on Industrial Technology, Seville, Spain 2015, pp. 914-919.

[10] A.T.L. Lee, H. Chen, S. C. Tan and S. Y. Hui, “Precise dimming and colour control of LED systems based on colour mixing”, IEEE Trans. on Power Electron., vol. 31, no. 1, Jan. 2016, pp. 65-80.

[11] B. M. Lim, Y. H. Ko, Y. S. Jang and O. H. Kwan, “A 200 V 98.16%- efficiency buck LED driver using integrated current control to improve current accuracy for large scale single string LED backlighting applications”, IEEE Trans. Power Electron., vol. 31, no. 9, Sept. 2016, pp. 6416-6427.

[12] M. H. Rashid, Ed., Power Electronics Handbook. Amsterdam, The Netherlands: Elsevier, 2007.