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Two Input Buck-Boost Integrated Soft-Switched Ripple Free LED Driver with Reduced Voltage Stress

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Abstract: In this research paper, a two input buck-boost integrated light emitting diode (LED) driver using full bridge is proposed. Two different input dc voltages are connected in anti-series across full bridge. Due to this, voltage stress across each semi-conductor switch is low. An LC resonant circuit in full bridge converter is used to achieve soft-switching. Thus, proposed ripple free LED driver energy efficiency is improved due to low switching transition power. Further, the current in LC series circuit is completely decided by difference in two input voltages. LED lamp is powered by using interleaved inductor configuration, which reduces the ripple in lamp current. This feature helps its suitability in future dc-grid lighting applications. Modified buck-boost configuration is used at the input side for constant lamp current regulation. Proposed converter steady-state operation is performed using numerical simulations. A 36 W experimental prototype is also made to verify the simulation results.

***Keywords**: experimental, simulation, interleaved, efficiency, configuration*

1. Introduction

In lighting industry, LED lighting systems are replacing traditional lighting sources due to their high luminous efficiency and long operating life [1]. Most of the lighting applications like street lighting, indoor lighting, outdoor sports lighting, transportation lighting etc., are occupied by LED lighting systems with vast variety of power and voltage ratings [2].

LEDs are non-linear dc operated semi-conductor devices. Thus their *v-i* characteristics demand constant current regulated sources, which are also called as LED driver circuits. To improve power density of LED drivers, switched mode circuits are preferred [3-5]. Several switched mode AC-DC driver circuits are presented in literature, which include single power conversion stage topologies [6], and multi stage topologies [7-8]. The life of AC-DC LED drivers is affected with the use of electrolytic capacitors. Thus topologies without electrolytic capacitors are also available with certain circuit complexities [9-11].

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Attempts have been increasing rapidly in establishing dc grid system. This is evident with ongoing research of applications of power electronic systems with renewable energy sources. With dc power distribution, most of the dc equivalent power loads are supplied with high energy efficiency due to the absence of AC-DC power conversion stage. Hence applications like LED systems can be available with more efficiency, reliability and compactness compared with ac operated systems. LED drivers powered from dc sources for different lighting applications are proposed [12-19]. Requirements of each lighting application are different. However, high efficiency, regulation of LED current, compactness, multiple lamp requirement, dimming capability etc., are some of the essential features of LED systems with dc power sources. Soft-switching feature further improves the power density of driver circuit for LED lighting application.

For low voltage DC-Grid lighting applications, zero voltage switched full-bridge LED driver is presented [12]. For lamp current regulation, input voltage using symmetric voltage cancellation method is adopted. Low device current stress, low power dissipation, low component count and PWM dimming feature are addressed. A high power input controlled driver circuit for street light LED application is proposed [13]. Low current stress, ZVS, high efficiency, dimming control and constant peak current regulation in LED lamps are the key features. In [14], a full bridge based LED driver with soft-switching feature for future dc-grid applications is given. Ripple current in inductors is used to obtain ZVS and total power dissipation in the converter is less due to low conduction and switching losses. The article in [15] proposes a full bridge zero voltage switched LED driver with low conduction losses, less conversion power, current regulation and dimming control. In this driver multiple LED lamps can be powered. However independent control of lamps is not addressed. A reduced switch current LED driver topology to supply three lamps is presented [16]. In this, power is processed only to power two lamps, peak to peak ripple current in interleaved inductors is used for ZVS and lamp current regulation is achieved using modified buck-boost converter. In [17], an asymmetrical duty cycle controlled resonant converter for multiple LED lighting loads is proposed with independent illumination control, zero voltage switching and high efficiency. However device current stress and ZVS transitions are not uniform. The work in [18] presents a CLLC based resonant LED driver. It features inherent constant output, wide input and output voltage range, and continuous input dc current. An LCLC resonant LED converter for lighting applications is presented [19]. An auxiliary switch is used for regulation, PWM dimming and open-load protection. It provides soft-switching transitions for wide input and output voltages.

In this research work, an LED driver with two different input voltages using full bridge configuration is presented. The difference in two output voltages is the input voltage to full bridge. Thus the devices in full bridge experience less voltage during non-conducting state. Further, LC resonant circuit is connected to the output of full bridge and it produces a resonant current which helps in achieving zero voltage switching transition. An interleaved concept is used to supply a ripple free current through LED lamp. In this configuration, input voltage with lesser magnitude is modulated to control the current in lamp. The organization of the paper is as follows, description of proposed configuration is given section 2. Working principle and mathematical analysis are presented in section 3, followed by design procedure in section 4. The results and discussions are presented in section 5. Finally, the conclusions are presented in section 6.

2. Description of Proposed Configuration

The proposed two input ripple free LED driver using full bridge is shown in Figure 1. Leg-1 of full bridge consists two power MOSFETs (S_1 & S_2) and leg-2 consists of two power MOSFETs (S_3 & S_4). Each MOSFET switch is represented with an intrinsic body diode and output capacitance. Midpoint of leg-1 is represented as *A* and midpoint of leg-2 is represented as *B*. Series connection of inductor (L_r) and capacitor (C_r) is connected between terminal *A* and *B*. Output voltage of full bridge is represented as v_{AB}. Two different input dc voltages (V_{dc1} & V_{dc2}) are connected across full bridge in anti-series with midpoint terminal '*O*'. Inductor L_{i1} is connected between midpoint of leg-1 and positive terminal of LED lamp. Similarly, inductor L_{i2} is connected between midpoint of leg-2 and positive terminal of LED lamp. Midpoint of two input voltages is connected to negative terminal of lamp. Due to the currents in inductor L_{i1} and L_{i2}, ripple free output current (i_0) flows through lamp. And lamp output voltage (V_0) is also constant without any ripple voltage. V_{Li1} & V_{Li2} are the voltages across inductor L_{i1} and L_{i2} respectively. The sign on V_{Li1} & V_{Li2} decides charging and discharging in L_{i1} & L_{i2} respectively. In proposed configuration, input voltage (V_{dc2}) is modulated for regulating lamp current using modified conventional buck-boost. It generates a controllable voltage V_{CBB} using V_{BB} as input voltage. Controllable voltage V_{CBB} compensates the variations in (V_{dc1} & V_{BB}). Gate voltages for switches and the operating waveforms of the proposed LED driver are shown in Figure 2.

3. Principle of Operation and Analysis

A. Principle of Operation

Gate voltages for S_1 to S_4 and the operating waveforms of the proposed ripple free two input LED driver are shown in Figure 2. Devices in full bridge (S_1 & S_4) and (S_2 & S_3) are conducted complimentarily with equal duty ratio. Switching period (*T*) is divided into four modes and duty ratio (D) of each switch in full bridge is equal.

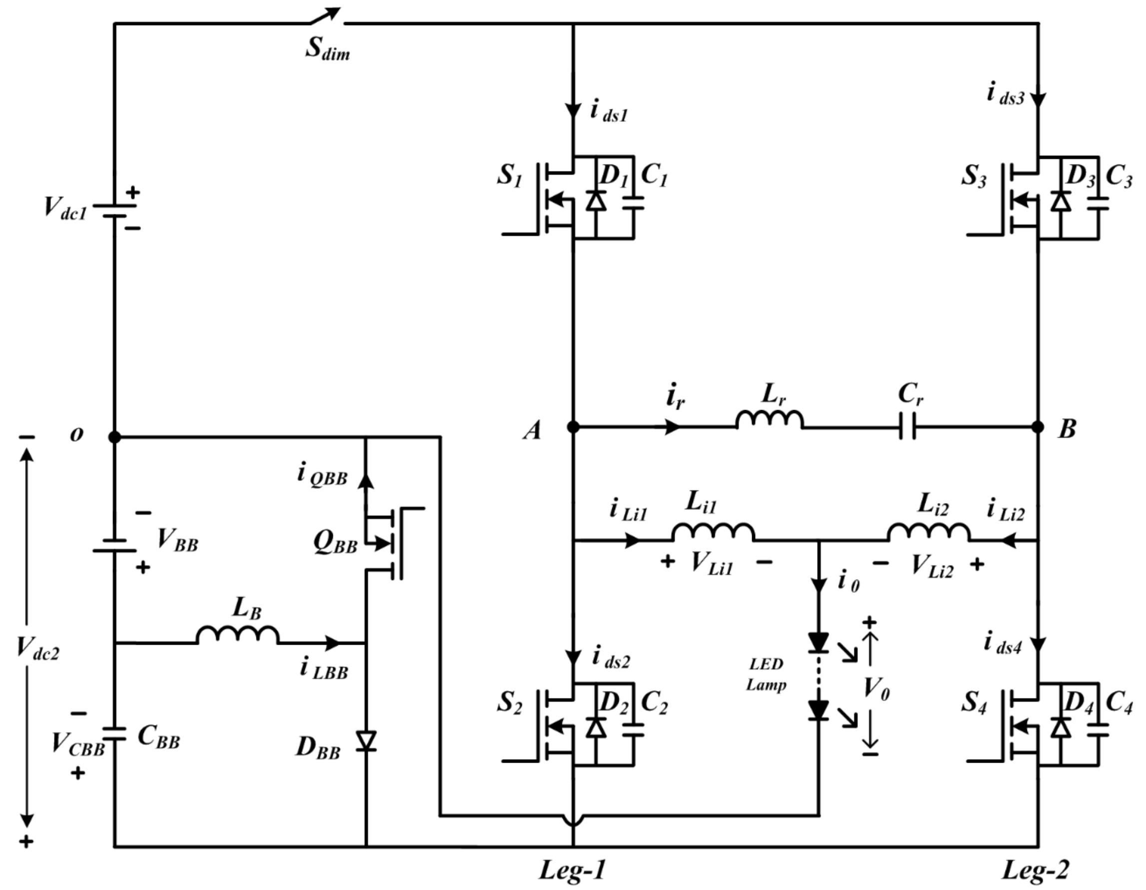


Fig 2. Circuit diagram of proposed two input full-bridge LED driver

3.1 Mode-1 ($t_0 - t_1$)

At time $t = t_0$, switches S_1 & S_4 are turned on using gate voltages (v_{g1} & v_{g4}). The operative circuit is shown in Figure 3 (a). From $t_0 - t_1$, switches S_1 & S_4 are in conduction. The output voltage (v_{AB}) of full bridge is $+(V_{dc1} - V_{dc2})$. Thus, resonant current flows i_r through S_1 & S_4. In this mode, voltage across L_{i1} is $V_{dc1} - V_0$ which is positive, hence inductor L_{i1} stores energy linearly through S_1. Simultaneously, voltage across L_{i2} is $V_{dc2} - V_0$ which is negative, hence i_{Li2} decreases linearly through S_4. In leg-1, switch S_1 conducts the sum of resonant current i_r and i_{Li1}. Similarly, in leg-2, switch S_4 conducts the difference of resonant current i_r and i_{Li2}. Further voltage across S_2 & S_3 is $(V_{dc1} - V_{dc2})$. Hence voltage stress of devices is reduced. This mode ends at $t = t_1$.

The equations in this mode are expressed as follows.

$$v_{Li1} = V_{dc1} - V_0 \tag{1}$$

$$v_{Li2} = V_{dc2} - V_0 \tag{2}$$

The current through L_{i1} and L_{i2} are obtained as

$$i_{Li1}(t) = i_{Li1}(t_0) + \frac{V_{dc1} - V_0}{L_{i1}'}(t - t_0) \tag{3}$$

$$i_{Li2}(t) = i_{Li2}(t_0) + \frac{V_{dc2} - V_0}{L_{i2}'}(t - t_0) \tag{4}$$

Where $i_{Li1}(t_0)$ & $i_{Li2}(t_0)$ are the initial currents in inductors L_{i1} and L_{42} respectively at time $t = t_0$. From Eqn. (3) to Eqn. (4) the ripple current in L_{i1} and L_{i2} are calculated as

$$\Delta i_{Li1} = i_{Li1}(t_1) - i_{Li1}(t_0) = \frac{V_{dc1} - V_0}{L_{i1}} DT \tag{5}$$

$$\Delta i_{Li2} = i_{Li2}(t_1) - i_{Li2}(t_0) = \frac{V_{dc2} - V_0}{L_{i2}} DT \tag{6}$$

During $t_1 - t_0$, voltage (v_{AB}) across resonant circuit components L_r and C_r is $+(V_{dc1} - V_{dc2})$. The current through it is expressed as

$$i_r(t) = \frac{v_{AB}}{Z_0}\sin\omega_0(t-t_0) + i_r(t_0)$$

$$= +(V_{dc1} - V_{dc2})\sqrt{\frac{C_r}{L_r}}\sin\omega_0(t-t_0) + i_r(t_0)$$

$$t_0 \le t < t_1 \qquad (7)$$

Where Z_0 = Characteristic Impedance = $\sqrt{\frac{L_r}{C_r}}$;

$$\omega_0 = \frac{1}{\sqrt{L_r C_r}} = \text{Resonant Frequency}$$

3.2 Mode-1I ($t_1 - t_2$)

At $t = t_1$, devices S_1 and S_4 are turned off with zero voltage. The operative circuit in this mode is shown in Figure 3(b). The switches S_2 & S_3 remain in off state and their drain to source capacitances C_2 and C_3 are charged to $(V_{dc1} - V_{dc2})$. During this interval $t_1 - t_2$, in leg-1, the drain to source capacitances C_1 is charged from zero to $(V_{dc1} - V_{dc2})$ using the current $(i_r+i_{Li1})/2$. Simultaneously, output capacitance C_2 is discharged by $(i_r+i_{Li1})/2$ from $(V_{dc1} - V_{dc2})$ to zero. In leg-2, C_3 is discharged by currents $(i_r-i_{Li2})/2$ from $(V_{dc1} - V_{dc2})$ to zero and C_4 is charged by $(i_r-i_{Li2})/2$ from $(V_{dc1} - V_{dc2})$ to zero respectively. When body diodes of S_2 and S_3 are forward biased, gate voltages (v_{g2} & v_{g3}) will be given to switches S_2 and S_3 for zero voltage switching. This mode ends at $t = t_2$. Since the duration of dead times in bridge configurations are in nano seconds, the currents through switch output capacitances are considered to be constant. Thus the expressions for (C_1 - C_4) are given as

$$C_1 = C_2 = \frac{(i_r + i_{Li1})}{2(V_{dc1} - V_{dc2})}(t_2 - t_1) = \frac{(i_r + i_{Li2})t_{d1}}{2(V_{dc1} - V_{dc2})} \qquad (8)$$

$$C_3 = C_4 = \frac{(i_r - i_{Li2})}{2(V_{dc1} - V_{dc2})}(t_2 - t_1) = \frac{(i_r - i_{Li2})t_{d1}}{2(V_{dc1} - V_{dc2})} \qquad (9)$$

In order to ensure ZVS, (C_1 - C_4) should be less than the values obtained from Eqn. (8) and (9), respectively.

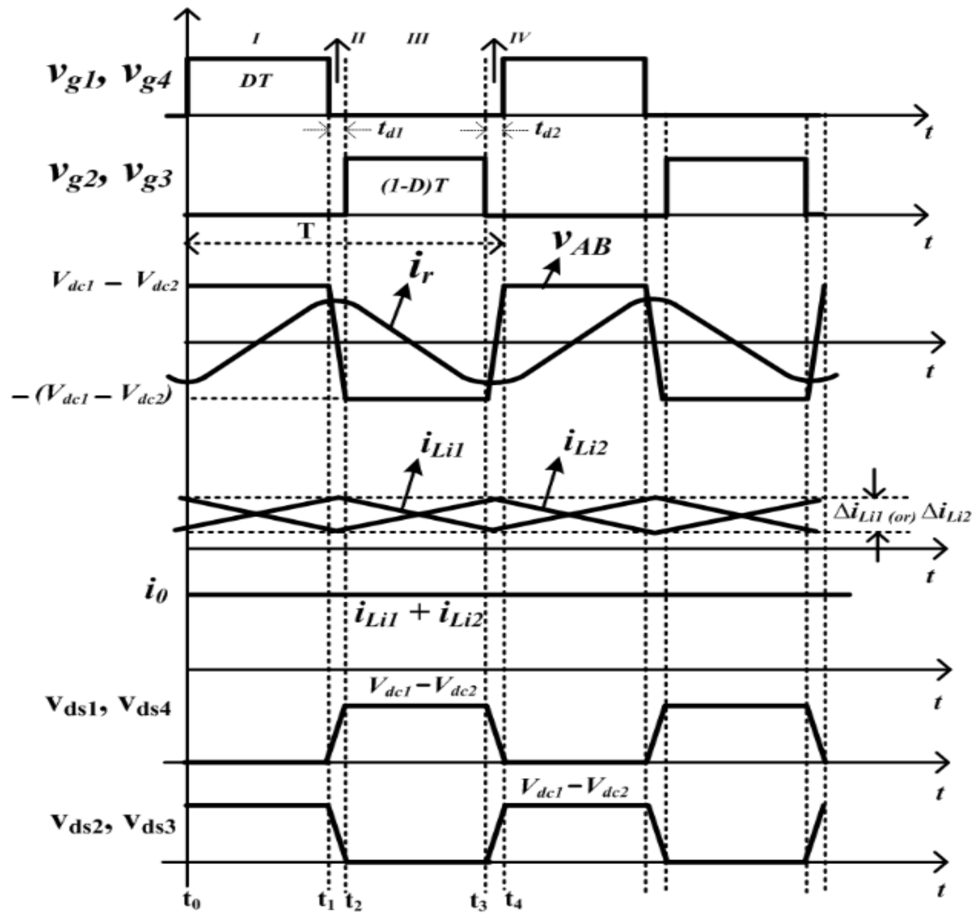
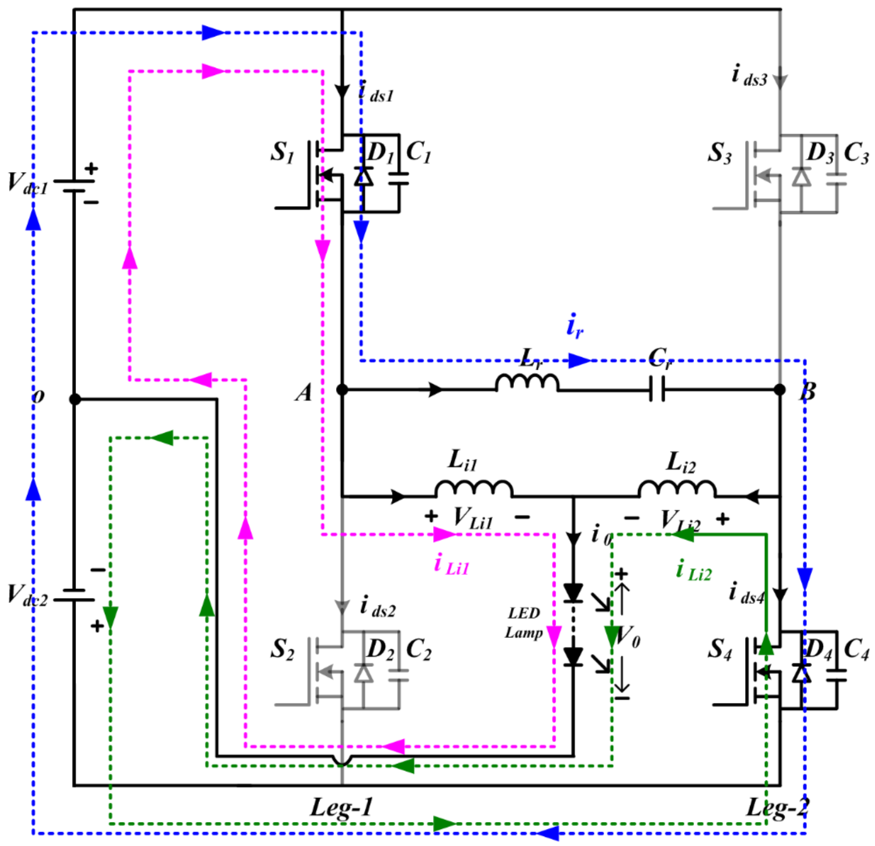
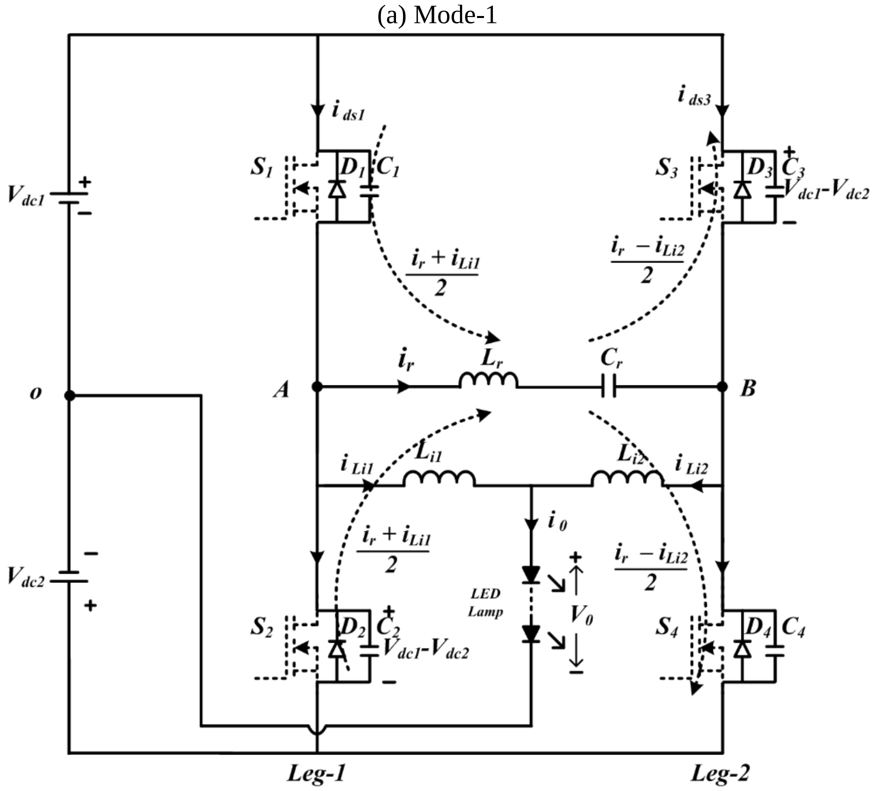


Fig 2. Operating waveforms

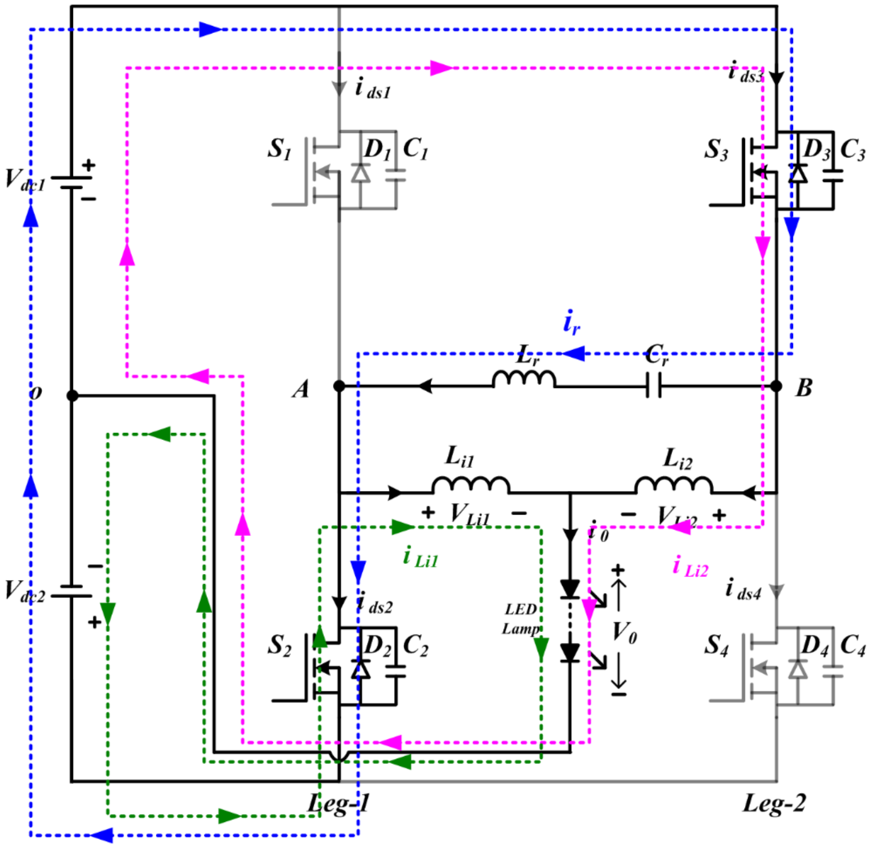


(a) Mode-1

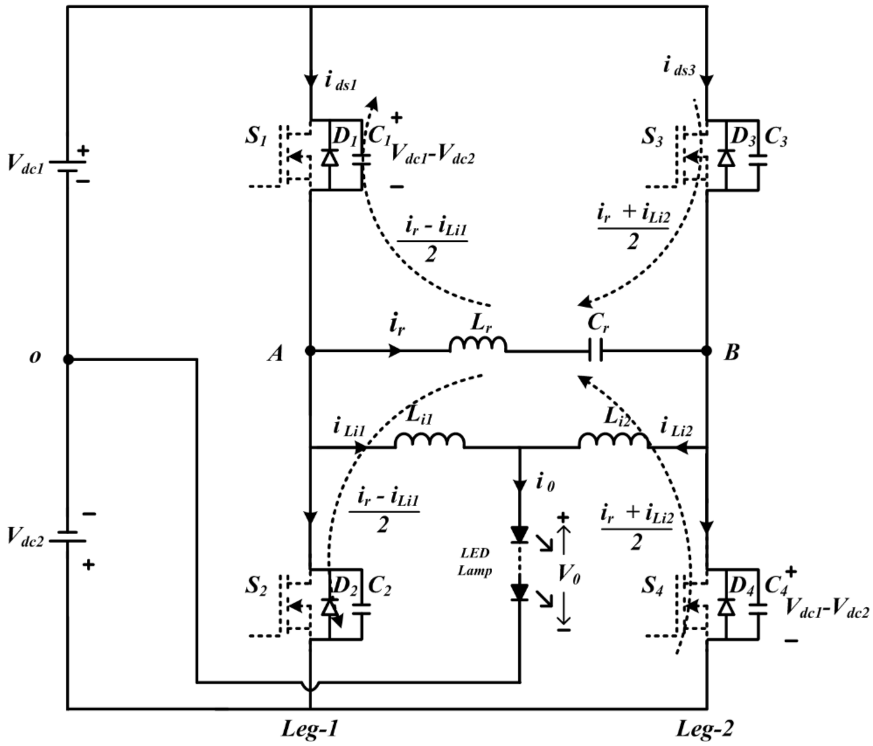


(b) Mode-2

Fig 3. Operative equivalent circuits



(a) Mode-3



(b) Mode-4

Fig 4. Operative equivalent circuits.

3.3 Mode-III ($t_2 - t_3$)

At time $t = t_2$, switches S_2 & S_3 are turned on using gate voltages (v_{g2} & v_{g3}) at zero voltage. The operative circuit with current direction is shown in Figure 4 (a). From $t_2 - t_3$, switches S_2 & S_3 are in conduction. The output voltage (v_{AB}) of full bridge is

$-(V_{dc1}-V_{dc2})$. Thus, resonant current flows i_r through S_2 & S_3. In this mode, voltage across L_{i1} is $V_{dc2}-V_0$ which is negative, hence i_{Li1} decreases linearly through S_2. At the same time, voltage across L_{i2} is $V_{dc1}-V_0$ which is positive, hence i_{Li2} increases linearly through S_3. In leg-1, switch S_2 conducts the difference of resonant current i_r and i_{Li1}. Similarly, in leg-2, switch S_4 conducts the sum of resonant current i_r and i_{Li2}. Further voltage across S_1 & S_4 is $(V_{dc1}-V_{dc2})$. Hence voltage stress of devices is reduced. This mode ends at $t = t_3$.

The key equations of the proposed LED driver are expressed as follows.

$$v_{Li1} = V_{dc2} - V_0 \tag{10}$$

$$v_{Li2} = V_{dc1} - V_0 \tag{11}$$

The current through L_{i1} and L_{i2} are obtained as

$$i_{Li1}(t) = i_{Li1}(t_2) + \frac{V_{dc2}-V_0}{L_{i1}'}(t-t_2) \tag{12}$$

$$i_{Li2}(t) = i_{Li2}(t_2) + \frac{V_{dc1}-V_0}{L_{i2}'}(t-t_2) \tag{13}$$

Where $i_{Li1}(t_2)$ & $i_{Li2}(t_2)$ are the initial currents in inductors L_{i1} and L_{i2} respectively at time $t = t_2$. From Eqn. (12) to Eqn. (13) the ripple current in L_{i1} and L_{i2} are calculated as

$$\Delta i_{Li1} = i_{Li1}(t_3) - i_{Li1}(t_2) = \frac{V_{dc2}-V_0}{L_{i1}}(1-D)T \tag{14}$$

$$\Delta i_{Li2} = i_{Li2}(t_3) - i_{Li2}(t_2) = \frac{V_{dc1}-V_0}{L_{i2}}(1-D)T \tag{15}$$

During $t_2 - t_3$, voltage (v_{AB}) across resonant circuit components L_r and C_r is $-(V_{dc1}-V_{dc2})$. The current through it is expressed as

$$i_r(t) = \frac{v_{AB}}{Z_0}\sin\omega_0(t-t_2) + i_r(t_2)$$
$$= -(V_{dc1}-V_{dc2})\sqrt{\frac{C_r}{L_r}}\sin\omega_0(t-t_2) + i_r(t_2)$$
$$t_2 \le t < t_3 \tag{16}$$

3.4 Mode-4 ($t_3 - t_4$)

During t_3 to t_4, switches (S_2 & S_3) and (S_1 & S_4) experience ON to OFF and OFF to ON switching transitions at zero voltage respectively. The operation of this interval is similar to that of mode-2. This mode ends at $t = t_4$. Switch output capacitances ($C_1 - C_4$) are expressed as

$$C_1 = C_2 = \frac{(i_r - i_{Li1})}{2(V_{dc1}-V_{dc2})}(t_4-t_3) = \frac{(i_r - i_{Li1})t_{d2}}{2(V_{dc1}-V_{dc2})} \tag{17}$$

$$C_3 = C_4 = \frac{(i_r + i_{Li2})}{2(V_{dc1}-V_{dc2})}(t_4-t_3) = \frac{(i_r + i_{Li2})t_{d2}}{2(V_{dc1}-V_{dc2})} \tag{18}$$

B. Analysis

The following assumptions are made to provide the analysis:

(i) The proposed configuration is operating in steady state

(ii) LED lamp voltage V_0 is constant

(iii) The converter components are ideal

(iv) Input dc voltage V_{dc1} is greater than V_{dc2}

(v) Input dc voltage V_{dc2} is less than V_{01} & V_{02}

The switches in full bridge are conducted with equal ON and OFF time duration at fixed frequency. The relation between output voltage of lamp and input voltages (V_{dc1} & V_{dc2}) is obtained from mode-1 and mode-3 by neglecting the dead times. When switches S_1 and S_4 are ON, LED lamp and L_{i1} are powered from input voltage (V_{dc1}). At the same time, inductor L_{i2} releases its stored energy through lamp. When switches S_2 and S_3 are ON, LED lamp and L_{i2} are powered from input voltage (V_{dc1}). At the same time, inductor L_{i1} releases its stored energy through lamp.. In order to make the analysis simple, ON time duration (DT) of each switch is approximately equal to its OFF time duration $(1 - D)T$. By applying volt-sec balance in inductor L_{i1} and L_{i2} the output voltage V_0 is obtained as

$$V_0 = D(V_{dc1}-V_{dc2}) + V_{dc2} \tag{19}$$

4. Design Procedure

In the proposed LED driver, equivalent circuit [21] of an LED is required to select the parameters related LED lamp. In this research work, TMX HP 3WLEDs are used. The v-i characteristics of TMX HP 3WLED are shown in Figure 5. From the characteristics, it is found that cut-in voltage (Vth) of LED is 2.3 V. An operating voltage of 3.25 V and current of 510 mA is chosen for LED lamp. There are two parallel strings and in each string 11 LEDs are connected in series. Therefore LED lamp is operated at 35.7 V, 1.02 A and 36 W. And, the cut-in voltage of lamp is obtained as 25.3 V. It is observed that output voltage (V_0) of lamp is obtained as 35.7 V and output current (i_0) as 1.02 A.

In output expression of V_0, V_{dc2} is in series with $D(V_{dc1} - V_{dc2})$. LED lamp current is zero below cut-in voltage. Therefore V_{dc2} is selected as 24 V. Remaining 11.75 V is supplied through full bridge converter.

Referring equation (19), input voltage V_{dc1} is given by

$$V_{dc1} = \frac{V_0 - V_{dc2}}{D} + V_{dc2} \qquad (20)$$

With a duty ratio (D) of 0.5, V_{dc2} of 24 V and a V_0 of 35.75 V, the input voltage (V_{dc1}) is calculated by

$$V_{dc1} = \frac{35.75 - 24}{0.5} + 24 \cong 48V$$

From equation (19), input voltage across the full bridge is calculated as

$$V_{dc1} - V_{dc2} = \frac{11.75}{0.5} \cong 24V$$

To calculate L_{i1} and L_{i2} values, switching period, Δi_{Li1} and Δi_{Li2} must be chosen. L_{i1} and L_{i2} supplies half of the lamp current magnitude, that is, 1.02 A. Thus a ripple current magnitude of 1.02 A can be allowed. With V_{dc1} of 48 V, V_{dc2} of 24 V, V_0 of 35.75 V, D of 0.5, switching period T of 10 µs, and the current ripple Δi_{Li1} or Δi_{Li2} of 0.6 A, from equation (5), the inductor L_{i1} is calculated as

Similarly, from equation (6), the inductor L_{i2} is

$$L_{i1} = \frac{(48 - 35.75)}{(0.6)} \cdot (0.5) \cdot 10 \cdot 10^{-6} \cong 102 \mu\text{H}$$

calculated as

The proposed LED driver is a full bridge based configuration. In one

$$L_{i2} = \frac{(24 - 35.75)}{(0.6)} \cdot (0.5) \cdot 10 \cdot 10^{-6} \cong 102 \mu\text{H}$$

switching period, switches are not conducting during t_{d1} and t_{d2} interval. However, switch output capacitances ($C_1 - C_4$) allow currents in these dead time intervals. And, the currents through ($C_1 - C_4$) help to achieve zero-voltage switching transitions in switches ($S_1 - S_4$) in full bridge. To obtain significant lagging current magnitude during dead time interval, an LC series resonant circuit is connected at the output full bridge. Hence a resonant frequency of LC circuit is selected as 79.62 kHz and it is given by

$$f_r = \frac{1}{2\pi\sqrt{L_r C_r}} \qquad (21)$$

The value of capacitance (C_r) is selected as 47 nF. From equation (21), L_r is calculated as 85 uH.

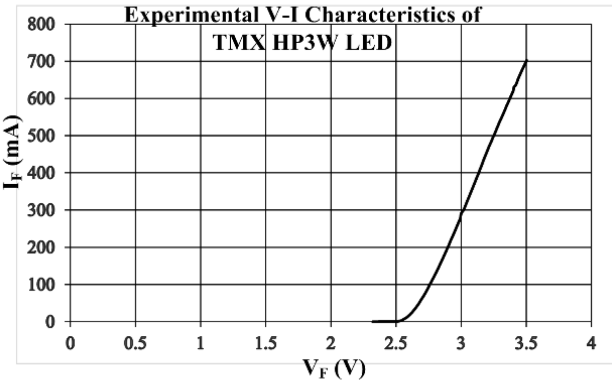


Fig 5 v-i characteristics of TMX HP 3WLED

Table 1 Parameters of the proposed LED driver

DC input voltage, V_{dc1}	48 V
DC input voltage, V_{dc2}	24 V
Switching frequency, f_s	100 kHz
Resonant frequency, f_0	79.62 kHz
Resonant inductor, L_r	85 µH
Resonant capacitor C_r	47 nF
Inductor, $L_{i1,i2}$	102 µH

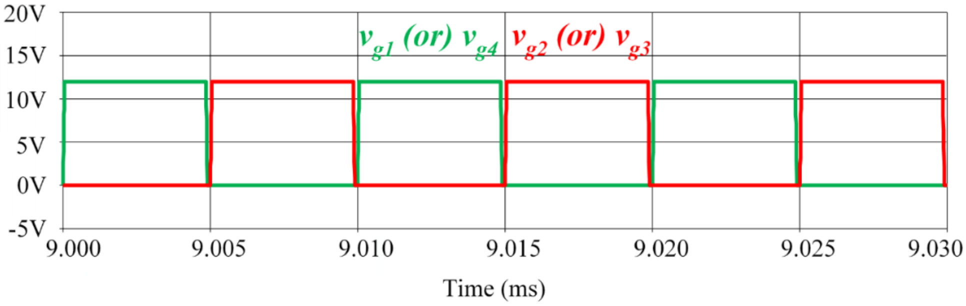
Lamp voltage, V_0	35.75 V
Current in lamp, i_0	1.02 A
P_0	36 W
Switching devices used	IRF 640N

5. Simulation Results

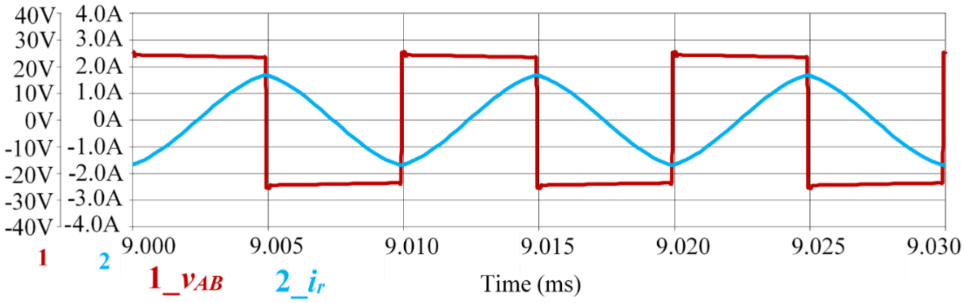
The proposed two input ripple free full bridge LED driver is simulated using OrCAD PSpice environment. LED lamp voltage, current and power ratings and component values are presented in Table. I. The proposed configuration is designed to power one LED lamp of 36 W. It is verified using OrCAD PSpice simulation software. At rated illumination, gate voltages of switches in full bridge, voltage across series LC circuit, and resonant current are shown in Figure 7. It is observed that full bridge devices are operated with constant duty ratio, $\pm(V_{01} - V_{02})$ voltage is appeared across resonant LC circuit and consequently resonant current flows. In Figure 8, simulated waveforms of voltage and current in LED lamp, current in interleaved inductors and LED lamp and voltage across interleaved inductors are given. Voltage and current waveforms are at selected values with no ripple. Current through interleaved inductors (i_{Li1} & i_{Li2}) indicate that i_0 is the sum of i_{Li1} & i_{Li2}. And, voltage across interleaved inductors (v_{Li1} & v_{Li2}) are also very low. To understand zero voltage switching feature in the proposed topology, gate voltages and voltage across switches in leg-1 are shown in Figure 9. Devices in leg-1 ON to OFF and OFF to ON transitions are completed within the dead time. Thus voltage across S_1 increases from zero to $(V_{dc1} - V_{dc2})$ and voltage across S_2 decreases from $(V_{dc1} - V_{dc2})$ to zero between the dead time in v_{g1} and v_{g2}. At selected lamp rating, the energy efficiency of the proposed converter is calculated to be 91.84%.

In the proposed configuration, pulse width modulation (PWM) dimming operation is implemented. To achieve PWM dimming, a switch, S_{dim} is placed in series with input voltage, V_{dc1}. It operates at low frequency (50 Hz). Different dimming operations are obtained by changing the duty ratio of S_{dim}. Figure 10 shows waveforms LED lamp voltage and current at 80%, 60% and 40% dimming respectively. These waveforms clearly show that when S_{dim} is conducting, LED lamp voltage and current at selected value. And, when S_{dim} is OFF, lamp do not conduct. At various dimming levels, energy efficiency curve of the converter is shown in Figure 10(d) and high efficiency is obtained at all the dimming operations.

To incorporate regulation of lamp current in the proposed configuration, modified form of conventional buck-boost converter is used. To maintain output voltage at 35.75 V, V_{dc1} is calculated as 48 V and V_{dc2} is calculated as 24 V from design analysis. At rated voltage levels, buck-boost converter is given with input voltage V_{BB} = 12 V and it produces a controlled voltage V_{CBB} = 12 V. The gate voltage of switch (Q_{BB}), current in inductor (L_{BB}) and voltage across C_{BB} in buck-boost converter are shown in Figure 11 (a). It is observed that Q_{BB} is operated at 100 kHz, i_{LBB} is continuous and V_{CBB} is 12 V. At these voltage levels, the energy efficiency of converter is calculated to be 91.84%. A variation of $\pm 5\%$ in V_{dc1} and V_{BB} is also verified. Figure 11 (b) shows the waveforms at V_{dc1} = 50.4 V, V_{BB} = 12.6 V and V_{CBB} = 8.5 V. An efficiency of 92.46% is observed at -5% variation in V_{dc1} and V_{BB}. Figure 11 (c) shows the waveforms V_{dc1} = 45.6 V, V_{BB} = 11.4 V and V_{CBB} = 14.5 V. At these levels, an efficiency of 90.76% is observed.

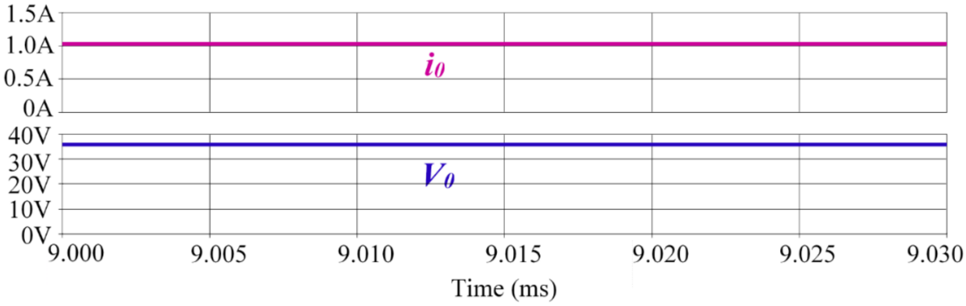


(a)

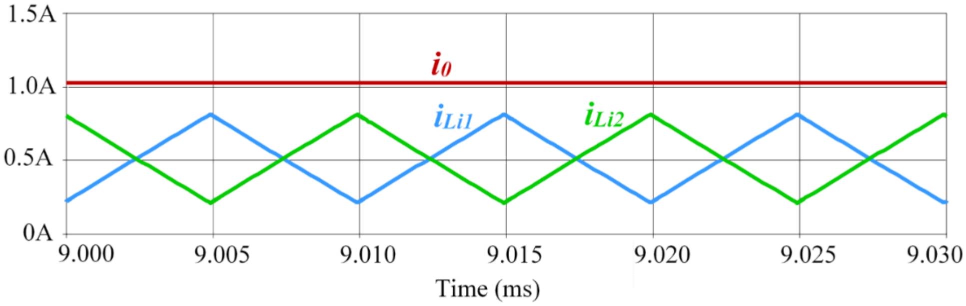


(b)

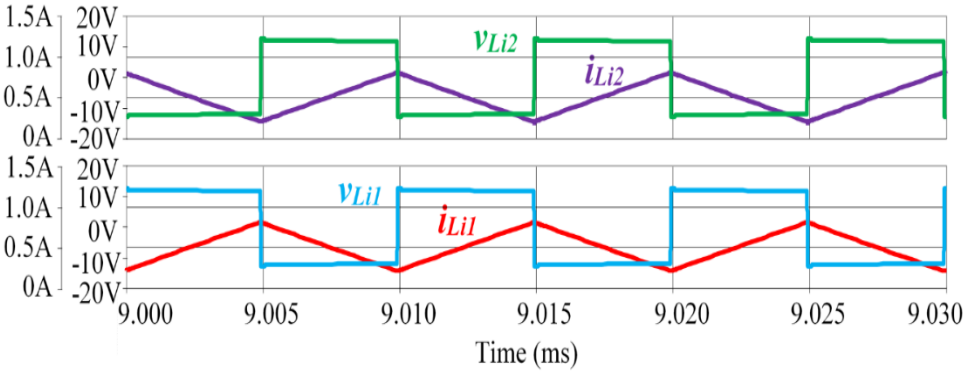
Fig 7. Simulation waveforms. (a) $v_{g1} - v_{g4}$. (b) v_{AB} and i_r



(a)

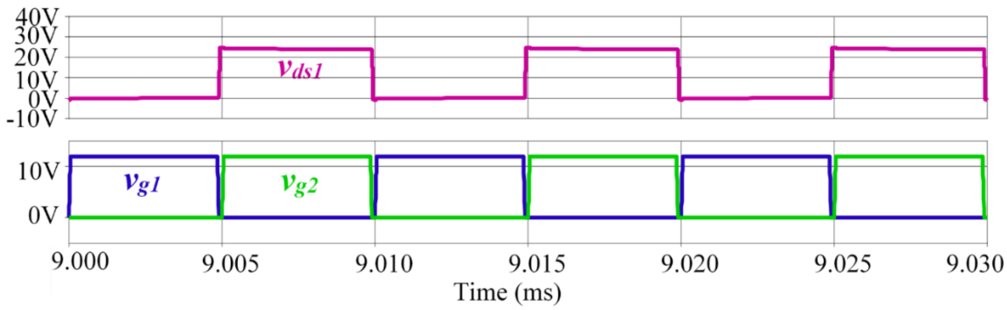


(b)

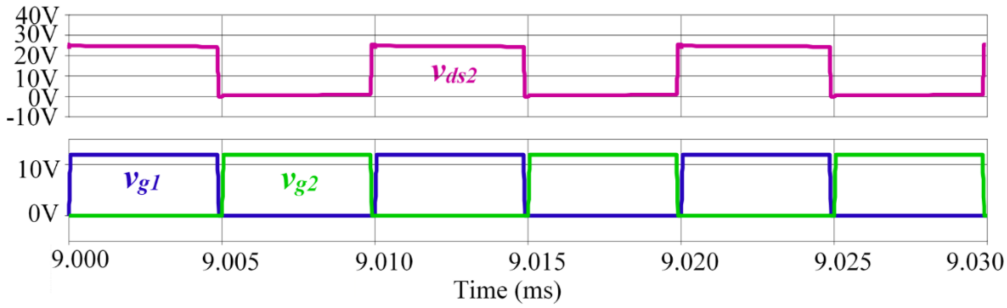


(c)

Fig 8. (a) Voltage and current in LED lamp, (b) Current in interleaved inductors and LED lamp, (c) Voltage across interleaved inductors with currents.

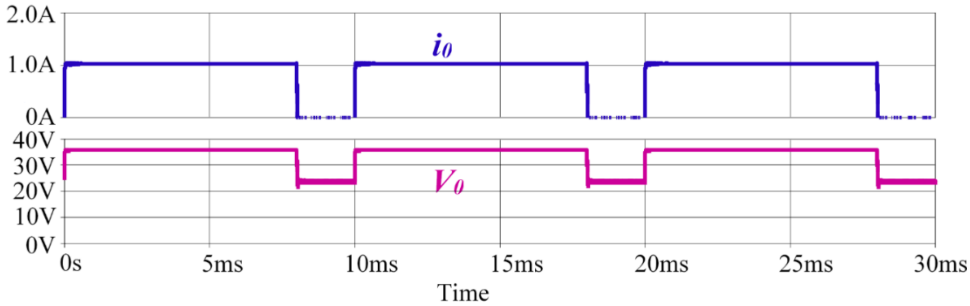


(a) Gate voltages (v_{g1} & v_{g1}) and voltage across S_1

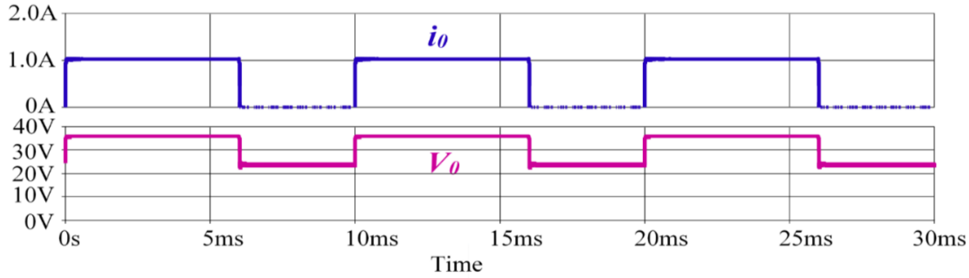


(b) Gate voltages (v_{g1} & v_{g1}) and voltage across S_1

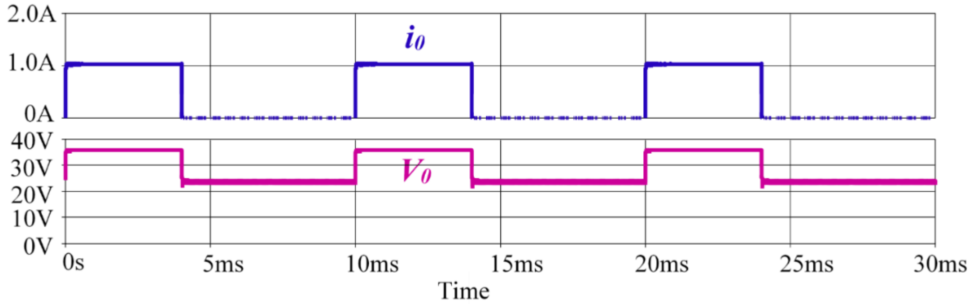
Fig 9. Switching waveforms



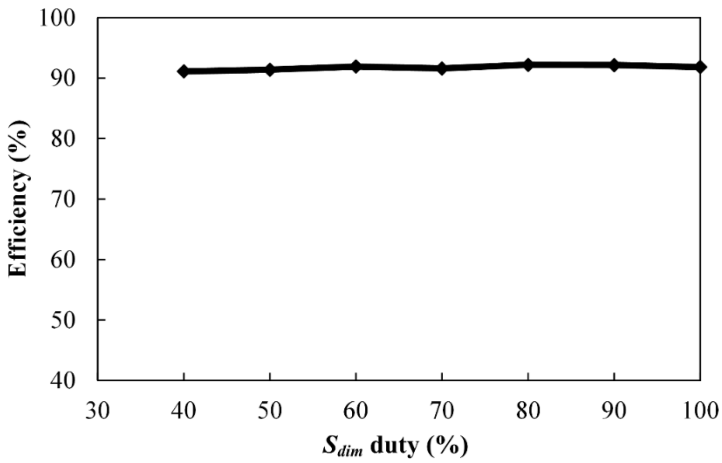
(a) V_0 and i_0 at 80% dimming



(b) V_0 and i_0 at 60% dimming

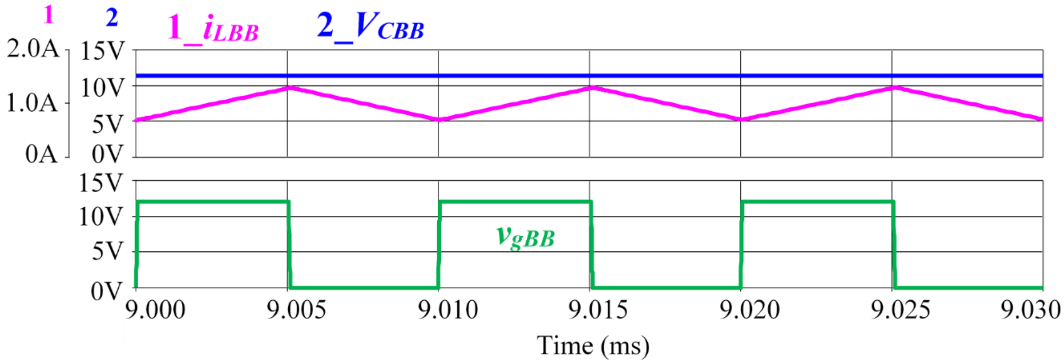


(c) V_0 and i_0 at 40% dimming

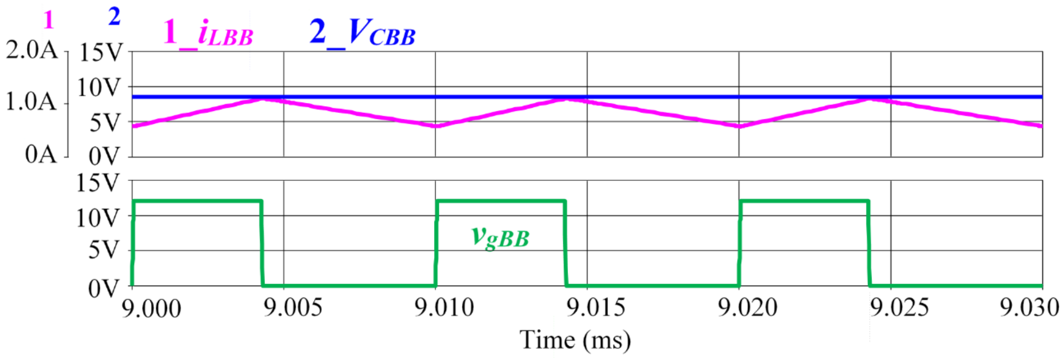


(d) Efficiency curve

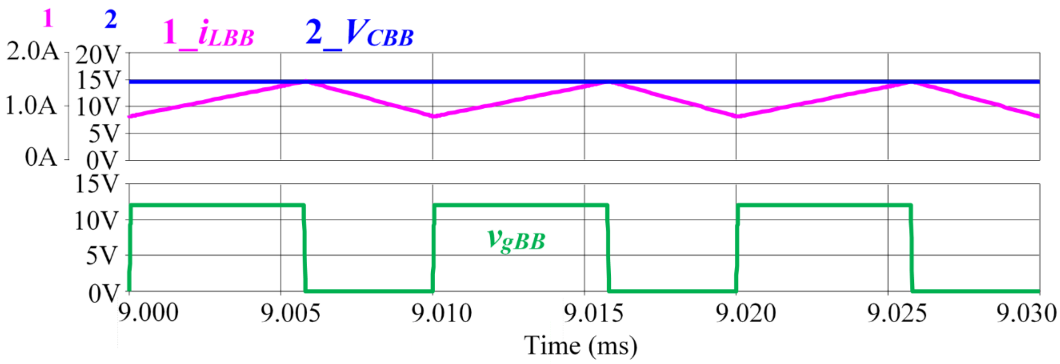
Fig 10. Dimming waveforms



(a) At V_{dc1} = 48 V and V_{BB} = 12 V



(b) At V_{dc1} = 50.4 V and V_{BB} = 12.6 V



(c) At V_{dc1} = 45.6 V and V_{BB} = 11.4 V

Fig 11. Waveforms of buck-boost converter at different input voltage levels.

6. Conclusion

In this paper, a full bridge converter with reduced voltage stress to supply a ripple free current through LED lamp is proposed. Steady state operating modes, analysis, design procedure, simulation and experimental results are presented in detail. The main advantages of proposed configuration are: 1) Reduced voltage stress of full bridge devices, 2) Ripple free lamp current, 3) Zero-voltage switching, 4) High conversion efficiency, 5) Input regulation for constant light output, 6) Can power multiple LED lamps. The voltage stress of full bridge switches depends on the magnitude of anti-series lamp voltages. Modified conventional buck-boost converter is used to maintain input voltage constant for lamp current regulation. A 36 W experimental prototype is also made to verify the simulation results. This topology may suitable for future dc-grid lighting applications.

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