BOOST INVERTER INTENDED AS A SOLUTION TO DRIVE A HID LAMP

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Abstract – Actual solutions to drive a high intensity discharge (HID) lamp from a battery power source implies in a double stage conversion system. The reason is that the output voltage must be boosted and inverted. The topology presented in this paper appears as a good solution to drive HID lamps in a single stage, improving the whole overall efficiency, reducing the number of switches and as a result reducing the cost. A microcontroller based system was implemented to confirm the theoretical analysis and simulations curves. Simulations and experimental results were performed and are presented in this paper.

KEYWORDS

Boost Inverter, Xenon lamp, HID ballast

I. INTRODUCTION

The automotive HID lamp is metal halide type. The xenon lamp term is frequently used to designate it because the xenon gas fill the arc tube to facilitate the ignition process. Its good color rendering, high efficiency and long life justify a growing in its usage [1]. However, the complexity of the electronic ballast design and the price of the complete lighting system, explain the small number of automobile manufactures whose employ this technology. The way to reduce the price is design a low cost ballast. Some electronic ballast used in this application were already developed. Nevertheless, almost all these ballast perform the conversion in two stages. Therefore, the solution presented in this paper shows that it is possible to reduce the electronic ballast cost reducing the conversion stages from two to only one.

Some problems appear when this kind of load must be drove. Two phenomenon have particular importance: the acoustic resonance and the cataphoresis. Acoustic resonance apperars when the HID lamp is drove from 1kHz to 1MHz current. If this phenomenon occurs, the electric arc becomes unstable and may extinguish. The cataphoresis is a not equal electrodes consummation when a continuous current is applied to the lamp. To avoid the acoustic resonance and cataphoresis, a symmetrical voltage of low frequency is imposed to the lamp [2-5].

One of the advantages of this kind of lamp is the possibility to reduce the automotive headlamps. This fact improves the designer's freedom to create new headlamps styles.

II. BOOST INVERTER

The voltage source inverter converts a continuous power source to an alternated power source. Therefore, the output voltage has a lower level than the input voltage. The general used solution is a dc-dc boost converter followed by a voltage inverter. The boost inverter may be an alternative solution. Fig. 1 shows the referred topology. This converter was first studied as an alternative to drive ac motors and UPS systems [6]. The proposed application is to drive HID lamps focused in the metal halide automotive lamp.

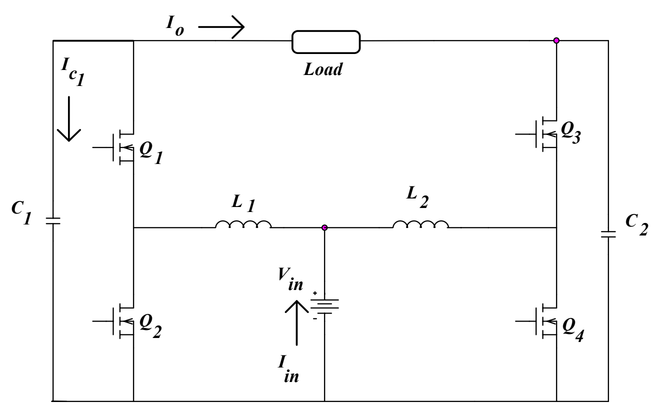

Fig 1 – Boost inverter topology.

The converter duty cycle (D) is defined by (1). The switches are drove complementary. The dc-ac converter was derived from the basic dc-dc boost converter[6]. The Boost inverter is composed of two independent converters. The inductor L_1, switches Q_1 and Q_2 and capacitor C_1 form the convert A. The inductor L_2, switches Q_3 and Q_4 and capacitor C_2 form the convert B. The voltage gain is computed using (2), where the output voltage V_o is the difference between V_1 (voltage over capacitor C_1) and V_2 (voltage over capacitor C_2).

$$D = \frac{t_{cond}(Q_{2,}Q_3)}{T_s} \quad (1)$$

$$q = \frac{V_O}{V_{IN}} = \frac{2D-1}{D(1-D)} \quad (2)$$

Fig. 2 shows the voltage gain characteristic. As can be seen, the output voltage depends only of the duty cycle and can be as high as eight times the input voltage for 0,1<D<0,9.

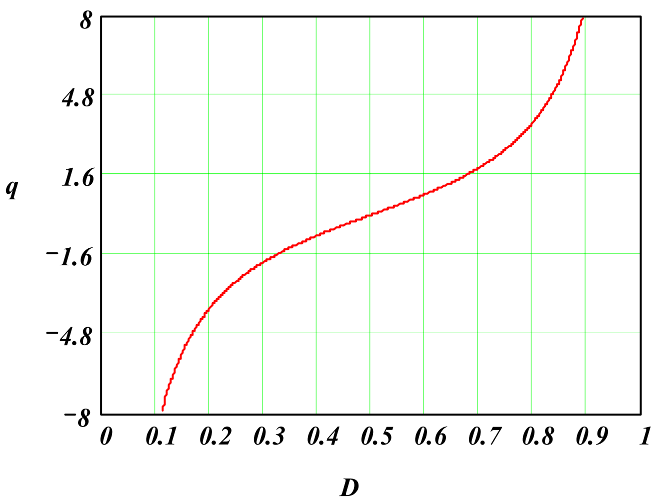

Fig. 2 – Gain voltage characteristic.

The passives components are calculated using (3) and (4).

$$L_1 = \frac{V_{IN} D_{MAX}}{\Delta I f_S} \quad (3)$$

$$C_1 = \frac{(I_{IN} - I_O)(1 - D_{MAX})}{\Delta V_C f_S} \quad (4)$$

III. Simulation Results

Using the ORCAD circuit simulation software, some curves were plotted in order to describe the power stage of the converter. The simulations were performed following the specifications bellow and using the calculated components listed.

Specifications:

V_{IN}= +12V
V_O = ±85V
P_O=35W
F_S=50kHz
ΔI=40%
ΔV_c=10%
D_{MAX}=0,9

components:

L_1=L_2=132µH
C_1=C_2=854nF

Fig. 3 shows the output voltage and the capacitors voltage. It is possible to verify the fast capacitors discharge and slow capacitors charge. This topology characteristic turn each load voltage transition from one polarity to another not so fast as desired. A voltage degree is assumed in the load voltage waveform. This fact maybe critical and the lamp may extinguish. Fig. 4 shows the inductor current and the load voltage ripple. Fig. 5 shows the switch commutation of Q_2 and the voltage over Q_1. In switch Q_2 commutation, the turn on is soft.

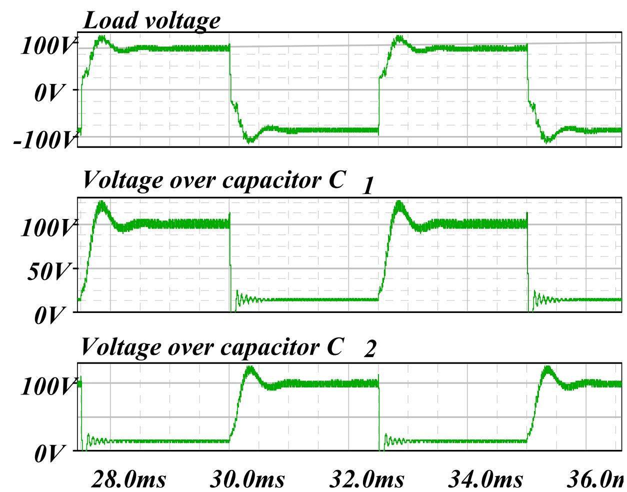

Fig. 3 – Output voltage and capacitors voltage.

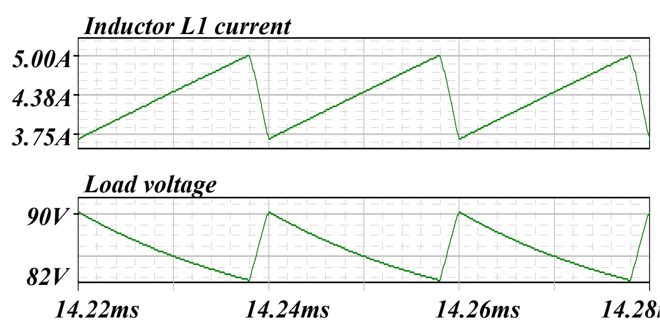

Fig. 4 – Inductor current and load voltage.

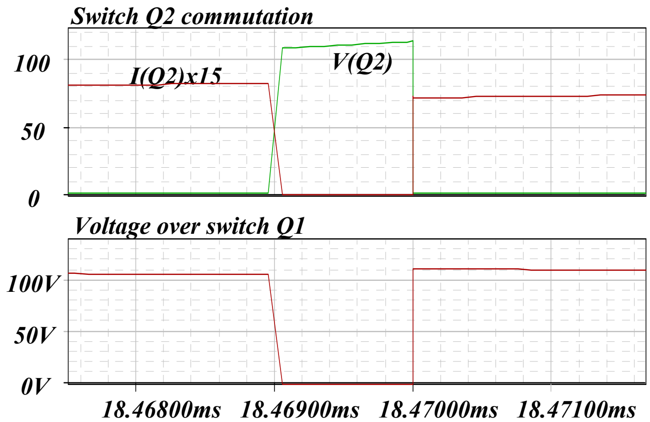

Fig. 5 – Switches voltages and commutation of Q_2.

IV. Power stage and driver circuits

A prototype was implemented to verify the practical operation. The drive signals were generated using a *Microchip Pic 16F873* microcontroller. This microcontroller has 8K flash program memory, high performance RISC CPU, PWM module, 10 bit analog to digital converter and others. Fig. 6 shows the complete circuit schematic. The Bridge mosfet are IRFP460A type, the Mosfet M5 is the IRF840, inductors L_1 and L_2 are 150μH, capacitors C_1 and C_2 are 3.2μF.

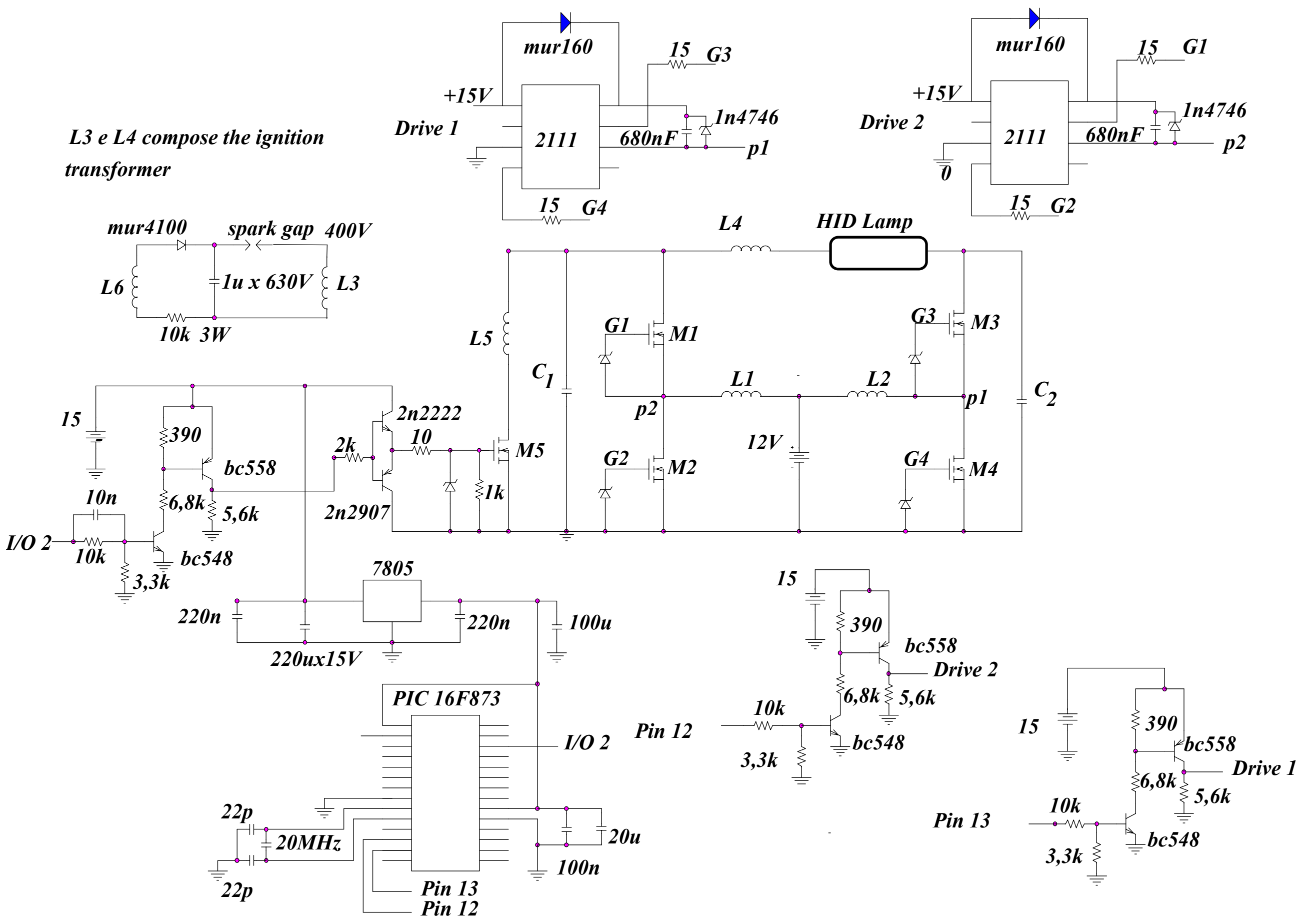

Fig. 6 – Complete implemented circuit.

V. Experimental results

This section presents practical results which illustrate the performance of the proposed system. A resistive load with the same impedance of the xenon HID automotive lamp in steady state was used to obtain the waveforms shown in Fig. 7 and Fig. 8. Fig. 7 shows the load voltage, current and power with a modulation able to generate alternate signals. Fig. 8 shows the L_1 inductor current in 50kHz. Fig. 9 is a measure of takeover current, the current right after the breakdown voltage is applied to the HID lamp. Fig. 10 shows the voltage and current in the lamp, drove with continuous current.

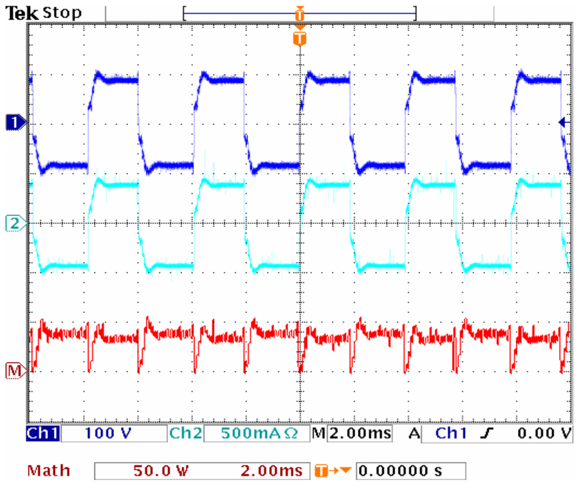

Fig. 7 – Prototype experimental results (I :0.5A/div.;V:100V/div; P:50W/div.;t:2ms/div.).

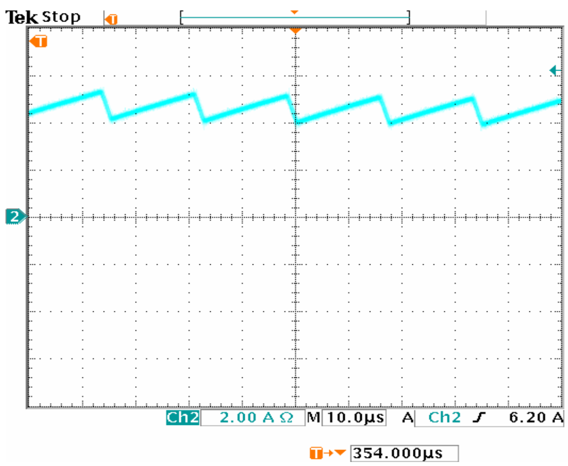

Fig. 8 – Inductor L_1 current (I :2A/div.;t:10µs/div.).

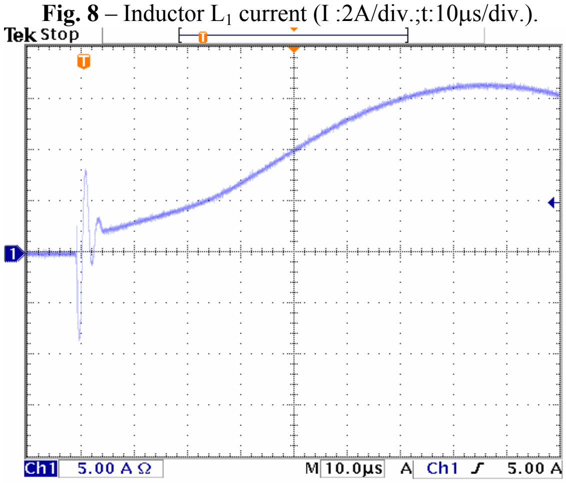

Fig. 9 – Takeover current (I :5A/div.;t:10µs/div.).

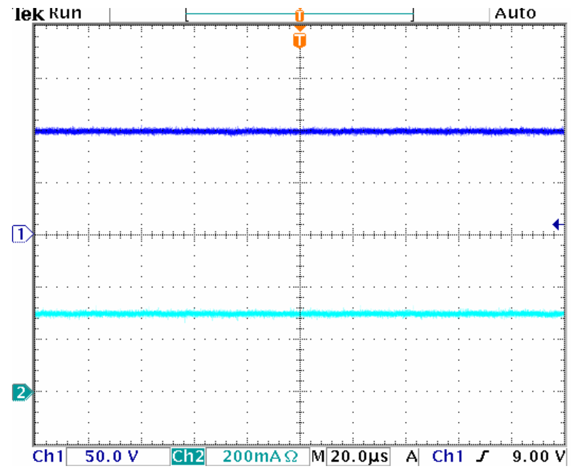

Fig. 10 – Lamp under steady state (I :0.2A/div.;V:50V/div;t:20µs/div.).

VI. CONCLUSION

The mathematical analysis, simulation and practical experimentation show that it is possible to use this structure to drive a HID lamp. Using an appropriated control circuit and a good power stage design, the efficiency can be improved.

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