BUCK-BOOST PUSH-PULL ELECTRONIC BALLAST

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***Abstract* – This paper proposes a high power factor electronic ballast that supplies two tubular fluorescent lamps. Two converters operating in a cascade mode form it. The first one is a buck-boost converter operating in a discontinuous conduction mode and the second one is a push-pull converter that provides the high frequency to the load. Experimental results were obtained for two 40W fluorescent lamps operating at 50kHz switching frequency and 110 V_{RMS} line voltage.**

I. INTRODUCTION

A great amount of produced electric energy in worldwide is consumed as artificial illumination, and any improvement in the efficiency of illumination is desirable [1]. These systems when using fluorescent lamps reduce the consumption of electric energy when compared to incandescent lamps, because the former present more efficiency (lm/W) [2].

In recent years several topologies were developed improving the performance of fluorescent lamps when they are supplied for electronic systems instead of electromagnetic systems.

The integrated converters becoming more attractive in industry, since they have light weight, lower flicker level, high power factor and high efficiency, if compared to conventional electromagnetic ballasts [3].

The proposed topology may achieve near unity power factor, and high frequency lamp current through an integration of two converters.

Unit power factor is guaranteed by a buck-boost converter operating in a discontinuous conduction mode. The buck-boost topology in discontinuous conduction mode assures high power factor maintaining relatively low voltage stress across the switches when compared with boost power factor correction topology [4].

The high frequency to supply the lamp is made through a push -pull converter.

This Paper is organized as follows. In section II, the proposed topology is shown. In section III the operational principle are described. In section IV the relevant equations are shown. In section V the experimental results are shown to demonstrate the performance of the proposed topology. Section VI presents a conclusion of the electronic ballast proposed.

II. PROPOSED TOPOLOGY

Figure 1 shows the basic circuit configuration of the proposed topology. It includes an input rectified line voltage V_{in}, a buck-boost converter circuit formed by a buck-boost inductor $L_{Buck\text{-}Boost}$, power switch S_1, high frequency diode D_6, capacitor C_{out} and two fluorescent lamps, $Lamp_1$ and $Lamp_2$.

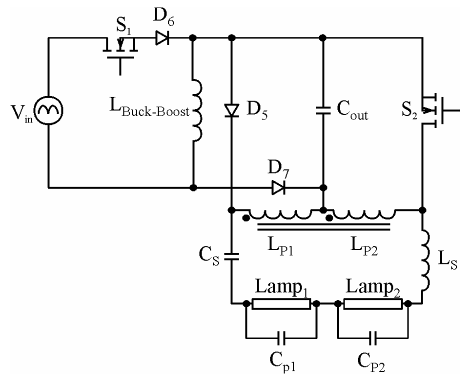


Fig.1 Proposed Topology

The Push-Pull converter is formed by push-pull inductors L_{p1}, L_{p2}, diode D_5 and switch S_2.

An EMI input filter and a LCC resonant filter to supply the lamps formed by L_{out} inductor, C_s series capacitor, C_{p1} and C_{p2} parallel capacitors are employed.

III. OPERATIONAL PRINCIPLES

The behavior of the proposed topology could be analyzed in two sections. The first one is the low frequency in the line side, and the second one is the high frequency stage in the load side. The first one will not be considered because of its simplicity.

The high frequency section could be analyzed in three operational stages shown in figs. 3(a), (b) and (c), respectively.

1) *First Stage*

In this stage switches S_1 and S_2 are closed and the diode D_5 is reverse biased. The input voltage V_{in} provides energy to the buck-boost inductor $L_{buck\text{-}boost}$, and the voltage in the capacitor C_{out} is applied to LP_2 windings that reflected to LP_1 windings applied $2.V_{cout}$ to the load. The simplification of this stage is shown in fig 4(a).

2) *Second Stage*

In this stage switches S_1 and S_2 are opened and the diode D_5 is forward biased by push-pull energy. Then the buck-boost stored energy is transferred to output capacitor C_{out}. The voltage applied to the load is the inverse in relation to the first stage. The simplification of this stage is shown in fig 4(b).

3) Third Stage

When the buck-boost and the magnetizing push-pull energy is zero, the LCC resonant filter supplies the lamp. The simplification of this stage is shown in fig 4(c).

IV. ELECTRONIC BALLASTS DESIGN PROCEDURE

The design of this topology is made for two tubular 40 W fluorescent lamps. The input line 110 VRMS, 60 Hz, and switching frequency of 50 kHz. The main equations are shown as following.

1) Series-Parallel Resonant Filter Design

The LCC series parallel resonant filter is one of the simplest and more commonly used resonant circuits suitable for driving fluorescent lamps. The filter components are calculated according to [5] using (1) and (2), through the θ phase angle or arg(z) in Fig. 2.

$$C_p = \sqrt{\frac{[1+(\tan(\theta))^2]\,.\,P}{\omega^2.\,R\,.V_{ac}^{\;2}} - \frac{1}{\omega^2.\,R^2}} \qquad (1)$$

Where:

$C_P(\theta)$	parallel capacitor resonant
θ	filter current phase angle
P	lamp power
ω	angular switching frequency
f_s	switching frequency
R	lamp equivalent resistance
V_{ac}	rms voltage of the fundamental component
C_s	series capacitor resonant

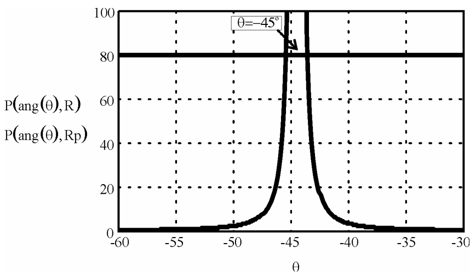


Fig. 2. Power in the Lamp versus Filter Current Phase Angle

2) Converter Design

The relevant equations of the converter are given by:

- S_1 maximal duty-cycle

$$\alpha = \frac{V_p}{Vc}; \qquad D_{\max} = \frac{1}{1+\alpha};$$

- output average current of Buck-Boost converter

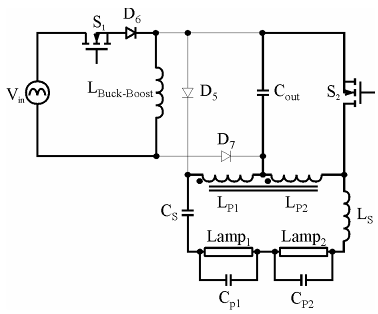
$$i_0 = \frac{\alpha \cdot D_{\max}^{\;2} \cdot \pi}{2};$$

- $L_{\text{Buck-Boost max.}}$ inductance

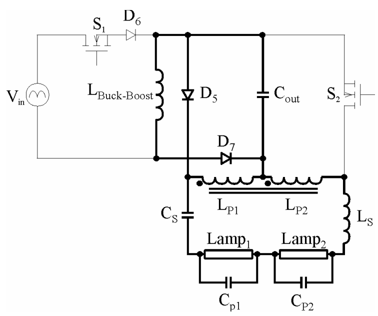
$$L_{buck-Boost\,\max} = \frac{\alpha \cdot V_P \cdot \pi \cdot D_{\max}^{\;2}}{4 \cdot \pi \cdot f_S \cdot i_o};$$

Where:

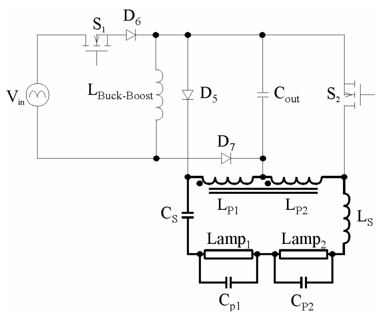
V_P	input peak voltage
V_c	C_{out} voltage
D_{max}	maximal duty cycle
i_o	output average current



(a) First Stage



(b) Second Stage



(c) Third Stage

Fig.3 Operational Stages

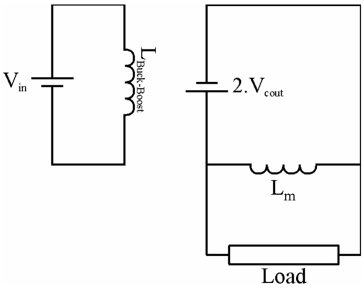
3) Push-Pull Design

The core is determined by expression

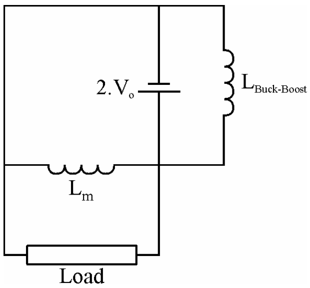
$$Ae \cdot Aw = \frac{1{,}5 \cdot P_{o,\max} \cdot 10^4}{K_P \cdot K_W \cdot J \cdot f_S \cdot \Delta B};$$

The number of turns for two windings is defined by

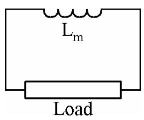
$$n = \frac{V_{Cout}}{2 \cdot A_e \cdot \Delta B \cdot f_S};$$



(a) First Simplified Stage



(b) Second Simplified Stage



(c) Third Simplified Stage

Fig.4.Simplified Operational Stages

V. EXPERIMENTAL RESULTS

In order to verify the feasibility of the proposed topology some experimental results are shown in fig.5.

The main ratings are as follows:

- Supply voltage: V_{in}= 110 V RMS, 60 Hz
- Output power: P_o= 80W
- Switching frequency: f_s= 50 kHz

The values of the components topology are described in table 1.

TABLE 1
Summarized Parameters

Resonant Filter		Input Filter		Converters	
C_s	330 nF	L_{in}	1.4 mH	S_1, S_2	Mosfet IRF 840
C_{p1}, C_{p2}	8.2 nF	C_{in}	680 nF/250 V	$L_{BUCK\text{-}BOOST}$	270 µH
L_s	1.4 mH			L_{p1}, L_{p2}	1.6mH
				C_{out}	100 µF 250 V

Figure 5(a) shows line voltage and current. These illustrations show the high power factor of this electronic ballast topology. Figure 5(b) show the buck-boost inductor current in low frequency. Figure 5(c) show high frequency buck-boost inductor current. Figure 5(d) and 5(e) show the voltage and current in the switches S_1 and S_2 respectively. Figure 5(f) show the diode voltage and current. The C_{out} voltage is shown in figure 5(g) and the high frequency fluorescent lamp voltage and current is shown in figure 5(h).

Ballast characteristics obtained though experimental results are summarized in table 2.

TABLE 2
Experimental Results

Power Factor	0,99
Total Harmonic Distortion	8,88 %
Current crest Factor	1,78

VI. CONCLUSION

This paper introduces new high power factor electronic ballast based on a integration of two converters.

The first one is a buck-boost converter operating in a discontinuous conduction mode. This operation mode allows the input current to follow sinusoidal waveform of the input voltage, achieving high power factor. The second one is a push-pull converter that provides the high frequency to the load.

The improvement of a buck-boost converter allows a low voltage stress across the switches, when compared with a boost converter operating in the same model. Then this topology has the advantage to be supplied in a higher voltage V_{in}, what is not possible in topologies that use a boost converter.

The simulation and experimental results was obtained for two 40W fluorescent lamps and validate the new electronic ballast proposed.

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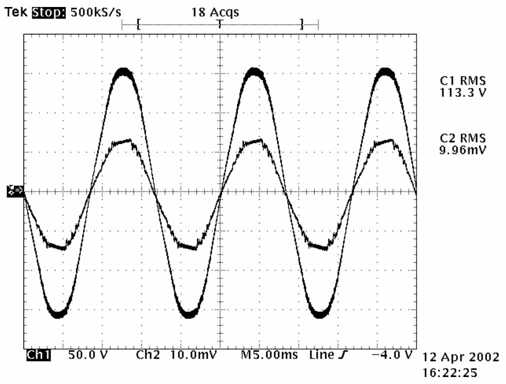
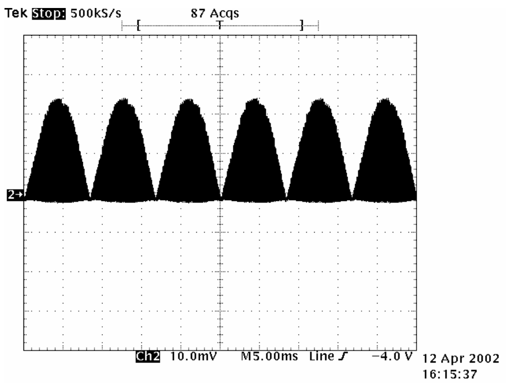
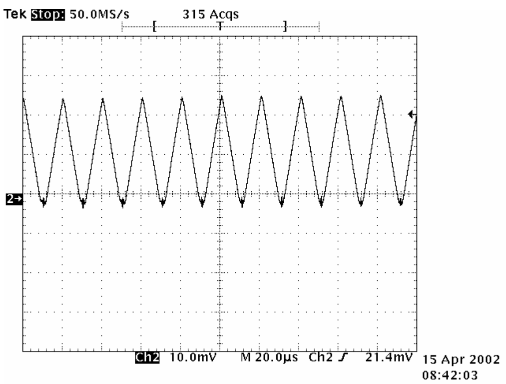


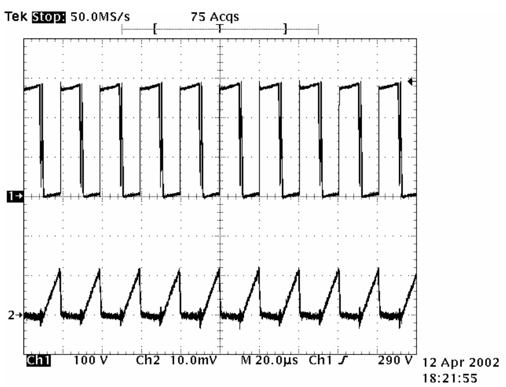
(a) Input Voltage (50V/div) and Current (1A/div), 5ms



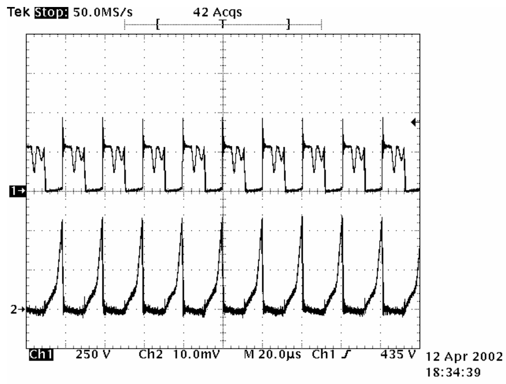
(b) Low Frequency Buck-Boost Inductor Current 2A/div, 5ms



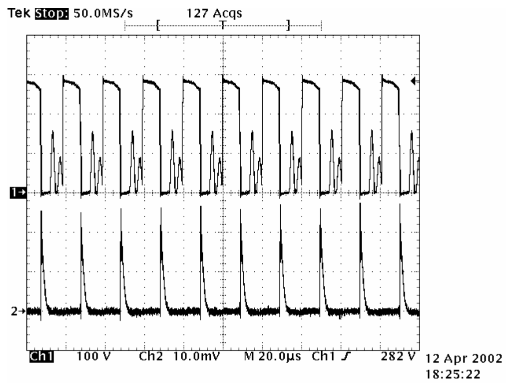
(c) High Frequency Buck-Boost Inductor Current 2A/div, 20µs



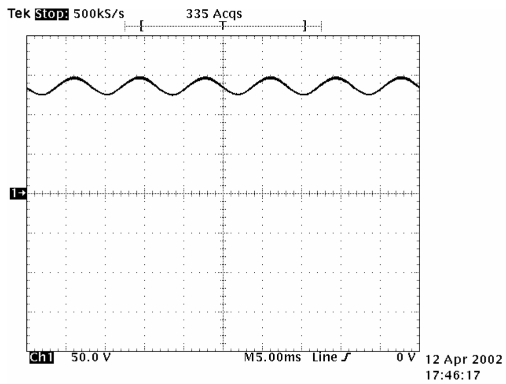
(d) Power Switch S_1 Voltage (100V/div) and Current (5A/div), 20µs



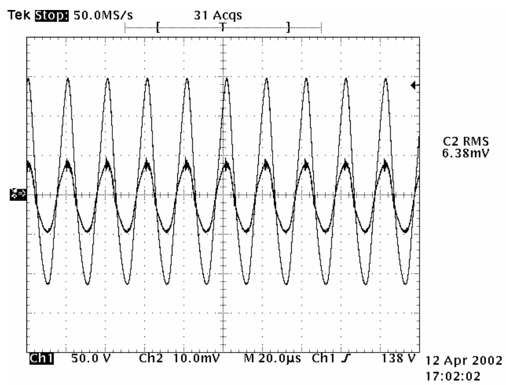
(e) Power Switch S_2 Voltage (100V/div) and Current (2A/div), 20µs



(f) D_5 Diode Voltage (100V/div) and Current (2A/div), 20µs



(g) C_{out} Capacitor Voltage, 50V/div, 5ms



(h) Lamp Voltage (50V/div) and Current (500mA/div), 20µs

Fig. 5 - Buck-Boost Push-Pull Electronic Ballast Experimental Results