A HIGH POWER FACTOR SYMMETRICAL SWITCHED POWER SUPPLY RESULTING FROM THE COMBINATION OF A BOOST CONVERTER AND TWO FORWARD TOPOLOGIES

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***Abstract* ¾ This paper proposes a pre-regulator Boost converter applied to a dc/dc converter in order to provide power factor correction. The combination of both stages results in a symmetrical switched power supply, which is composed of two symmetrical stages that operate at 100kHz, as the individual output voltages are equal to $+200V_{dc}$ and $-200V_{dc}$, the total output voltage is $400V_{dc}$ and the total output power is 500W. The power factor correction IC UC3854 is employed in the control strategy of the Boost stage.**

KEYWORDS

SMPS, power factor correction, UC3854.

I. INTRODUCTION

Power supplies have been intensively used in several types of electronic loads e.g. computers and telecommunication equipments, for they provide the necessary voltages to the accurate operation of electronic circuits. As they have become more sophisticated [1] [2], their weight and size have decreased significantly, increasing the functionality and the efficiency. Generally, such equipments use ac voltages as primary power supplies, which must be converted to dc voltages, since most of the systems require high quality dc power.

Linear power supplies are adequate for low power applications, but are uneconomical and inefficient as more power is demanded. Then, the use of switched-mode power supplies (SMPS) is prominent, because they provide multiple output dc voltages, constant switching frequency and reduced size and weight when compared to linear power supplies. However, the input stages in the switched-mode power supplies are well known to be harmonic sources. Recently, there has been great interest about the reduction of the input current harmonic content and power factor correction (PFC) [3]. Moreover, in many single-phase applications, mainly in power supplies, the power levels can reach several kilowatts and, in some cases, the input voltage can be quite high as well. For such types of application, the conventional Boost PFC converter has been widely used due to the dc voltage gain characteristics, lower inductor size and weight, and reduced losses in the power devices, which will affect cost, efficiency, and power density [4] [5] [6]. This converter is perfect for pre-regulator applications, but it presents commutation and conduction losses, bringing reduction in the overall efficiency.

This paper presents the application of a Boost converter as a pre-regulator in order to provide power factor correction in a dc/dc converter, where the combination of both stages results in a symmetrical switched power supply, composed of two symmetrical units that operate at 100kHz. The output voltages of the units are equal to $+200V_{dc}$ and $-200V_{dc}$, the total output voltage is $400V_{dc}$, and the total output power is 500W, as UC3854 power factor correction IC is employed in the Boost stage control strategy.

II. THE PROPOSED SYMMETRICAL SWITCHED POWER SUPPLY

The Boost PFC stage and the dc/dc stages are shown in Figures I and II, respectively. The dc/dc converters consist of two Forward topologies that provide output voltages equal to $+200V_{dc}$ and $-200V_{dc}$, and can be associated so that the total output voltage is equal to $400V_{dc}$. A high power factor is obtained by employing the average current control waveshaping technique using UC3854 IC.

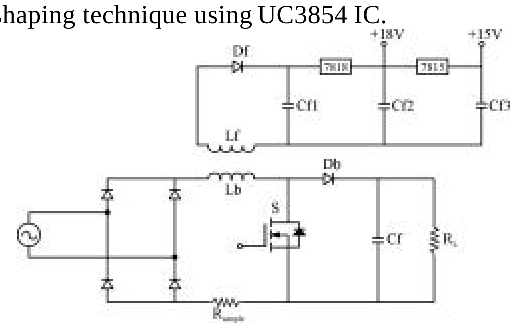
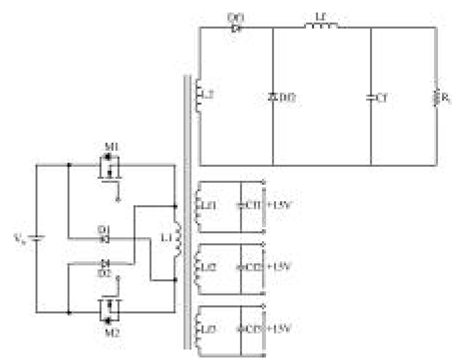
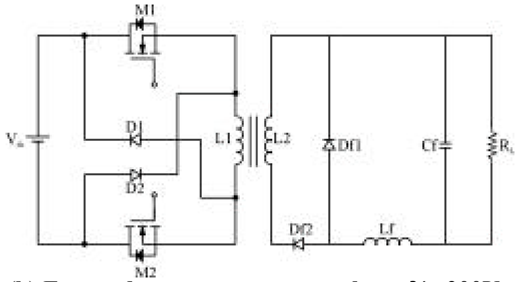


FIGURE I
Boost converter



(a) Forward converter: output voltage ¾ $+200V_{dc}$



(b) Forward converter: output voltage ¾ -200V_{dc}

FIGURE II
Dc/dc Forward converters

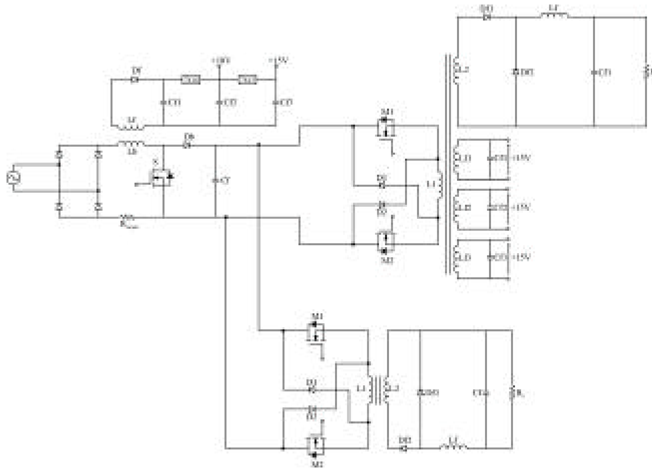


FIGURE III
Proposed switched power supply

The association of the stages shown in Figures I and II results in the proposed switched power supply presented in Figure III.

III. CONTROL STRATEGY

The Boost stage operates with constant switching frequency and high power factor, using the average current mode control [8] (Figure IV), which eliminates many serious problems, such as poor noise immunity, a need for slope compensation, and peak-to-average current errors which the inherently low current loop gain can not correct [7].

The block diagram of the control circuit of the Boost power stage is shown in Figure V. The input current and line voltage samples are obtained from sensors *Rshu* and *Rt1*/*Rt2*, as the voltage sample is rectified in the precision rectifier block. The PI controller is implemented to provide the control signal (*Vc*), which is multiplied by the reference voltage (*Vin*(*ref*)). Then, this signal is added to the sawtooth signal, what generates the reference current signal (*Iref*). Drive signals are provided comparing the current feedback signal, obtained in sensor *Rshu*, to the reference current signal. In this case, this process is implemented by UC3854.

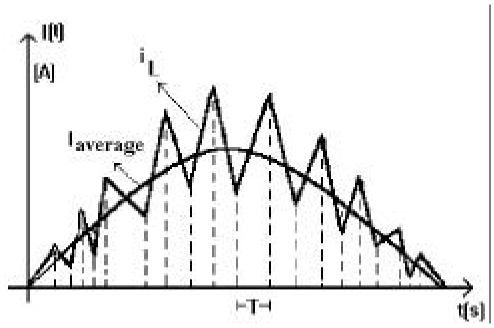


FIGURE IV
Principle of the average current mode control

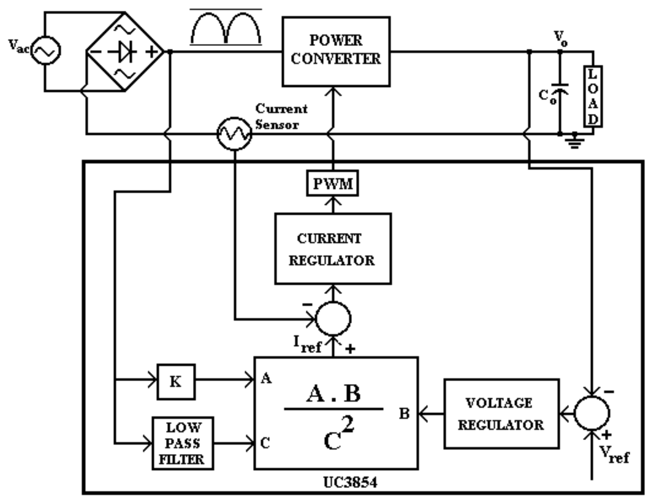


FIGURE V
Control strategy applied to the Boost converter

IV. SIMULATION AND EXPERIMENTAL RESULTS

Simulation tests were performed for the proposed SMPS as the following parameter set shown in Table I was employed. All switches and diodes are considered as ideal devices.

TABLE I
Parameter set used in simulation tests

Parameter	Value
V_{in}	127/220V_{ac}
Lb	600 H
Lf	30 H
Lf1, *Lf2*, *Lf3*	50 H
L1	730 H
L2	310 H
Cf	330 F
Cf1, *Cf2*	10 F
f_s	100kHz
V_{o1}	+200V_{dc}
V_{o2}	-200V_{dc}
P_o	500W
I_o	1.5A

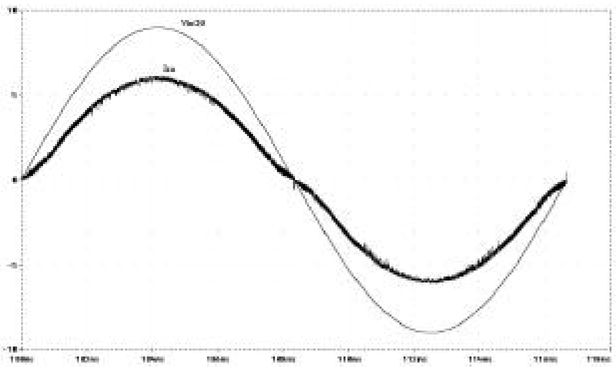


FIGURE VI
Simulation results: input voltage and input current at nominal load

Furthermore, a prototype was built using the same parameter set presented in Table I. The switches used in the prototype are MOSFETs IRFP460 and the diodes are MUR1650.

Figure VI shows simulation results regarding the input voltage (V_{in}=220V_{ac}) and input current, where the power factor correction is focused. As it can be noticed, the power factor is almost unity i.e. 0.998 at nominal load.

Figure VII presents the ac input voltage and the gate signal in switch S waveforms obtained experimentally.

Figures VIII and IX evidence the power factor correction when the input voltage is 127V_{ac} and 220V_{ac}, respectively, and also the harmonic content of the input voltage and input current.

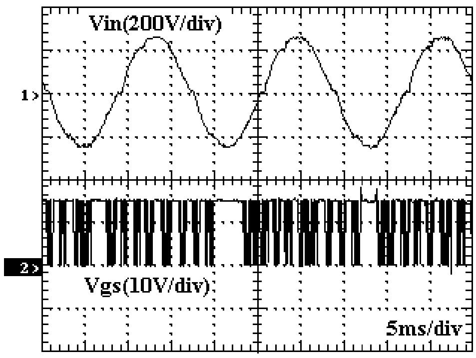
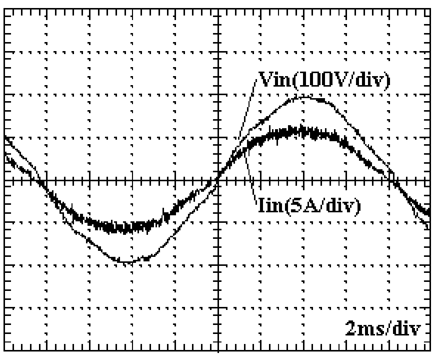
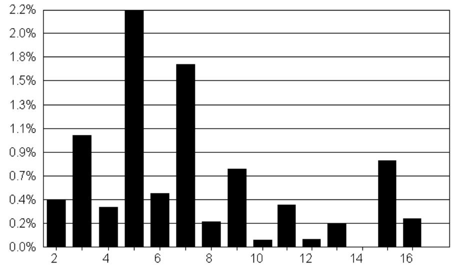


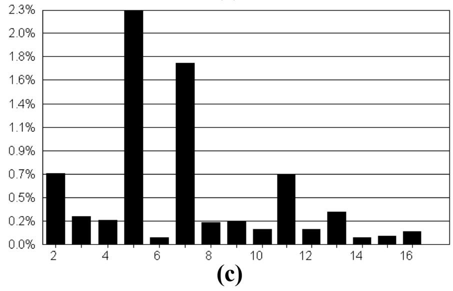
FIGURE VII
Experimental results: input voltage and gate signal in switch *S*



(a)

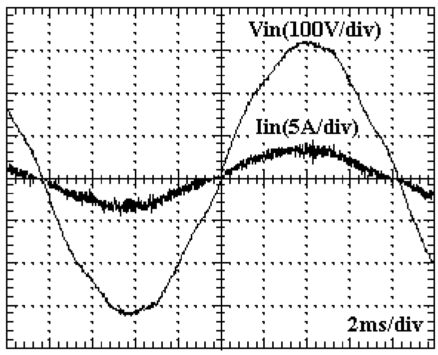


(b)

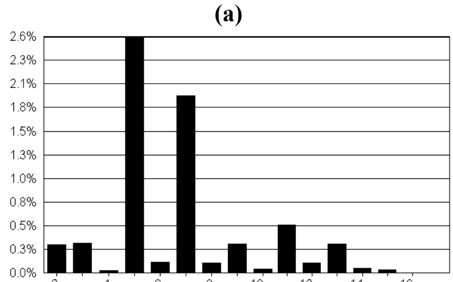


(c)

FIGURE VIII
Experimental results: V_{in}=127V_{ac}
(a) Input voltage and input current;
(b) Harmonic content of the input voltage;
(c) Harmonic content of the input current;



(a)



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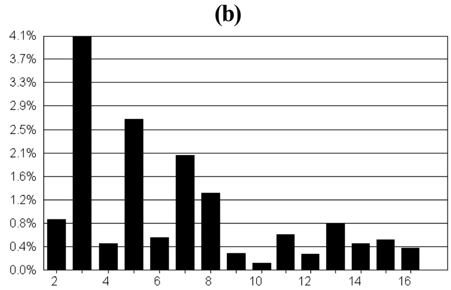

(c)

FIGURE IX
Experimental results: V_{in}=220V_{ac}
(a) Input voltage and input current;
(b) Harmonic content of the input voltage;
(c) Harmonic content of the input current;

TABLE II
Measured results – V_{in}=127V_{ac}

Parameter	Value
V_{in}	127V_{ac}
I_{in}	4.56A
Input power factor	0.990
Input power	570W
THD_V	3.11%
THD_I	3.33%

TABLE III
Measured results – V_{in}=220V_{ac}

Parameter	Value
V_{in}	220V_{ac}
I_{in}	2.36A
Input power factor	0.993
Input power	523W
THD_V	3.34%
THD_I	5.79%

Tables II and III show some relevant experimental results obtained when the input voltage is 127V_{ac} and 220V_{ac}, respectively. One can see that the input power factor is almost unity, and that the voltage and current total harmonic distortion rates are relatively low.

Additional tests were carried out in order to evaluate the dynamics of the converter, when the input voltage is 220V_{ac}. Fig. X shows the output voltage control performance with and without load. Fig. XI shows the output current control performance when a short circuit in the output side of the power supply occurs.

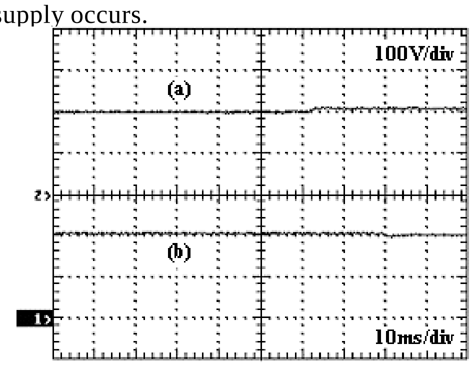

FIGURE X
Output voltage control response
(a) Positive load step;
(b) Negative load step.

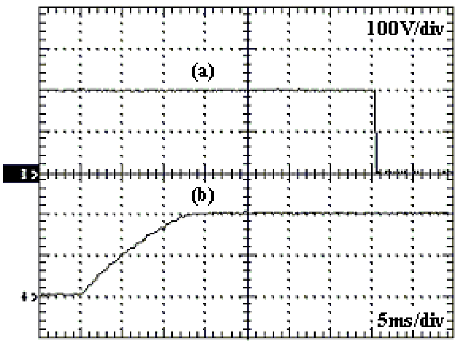

FIGURE XI
Output current control response
(a) Beginning of the fault;
(b) End of the fault.

V. CONCLUSION

This paper reports results concerning the development of a symmetrical switched power supply using the PFC ac/dc Boost converter. It has been demonstrated that the use of the average current waveshaping control technique implies a highly efficient power factor correction, allowing a good performance in high frequencies. The presented SMPS employs two Forward structures as dc/dc stages, so that an output voltage equal to 400V_{dc} can be achieved. The current and voltage total harmonic distortion rates obtained experimentally are considered low, and an almost unity input power factor is achieved.

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