Analysis Of One Soft Switch PFC Boost Converter Using Analogical And Digital Control Circuits

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Abstract - This work presents a comparison between analogical and digital (PIC16c73a) control types applied to a Boost converter with a non dissipative snubber. Both control types use the bang-bang hysteresis current waveshaping control technique in order to achieve a quasi unity-power factor.

INTRODUCTION

One of the most interesting areas for researchers in power electronics is the use of microprocessor circuits replacing the existent analogical circuits used in the converters control.

Due to the increasing progress in the microprocessor circuitry, there are high technology components available nowadays that are perfectly suitable to the converters control. The employment of such components reduces the number of electronic devices, implying high switching frequencies, and limiting the converter operation to the designer’s wish.

One of the most pertinent demands regarding equipments that use one or more active switches, done by utilities and power quality committees is the fact that these equipments introduce a high harmonic content in the power system and thus they should meet the existent standards related to power factor and harmonic distortion.

Several authors worldwide have presented a lot of control strategies [1] and [2] in order to meet the international standards. Some of them employ the analogical control [3] and other ones employ the digital control [4].

Another important factor to be noticed is the reduction of electromagnetic interference levels (EMI). A simple way of solving this problem is the use of switching techniques that employ null current and/or null voltage [5] and [6]. These techniques increase the converters efficiency and switches utility life.

This work presents a PWM Boost converter with non-dissipative commutation [6] using both analogical and digital control types and applying the control strategy by current imposition called HYSTERESIS "BANG-BANG" [2]. It also seeks a simple comparison between the analogical and digital control types, contributing to the development of works related the use of microprocessors in the converters control.

PRE REGULATOR BOOST CONVERTER

Fig. 1 shows the simplified schematic circuit of the proposed non-dissipative snubber associated to a Boost Converter. This converter operates without commutation losses.

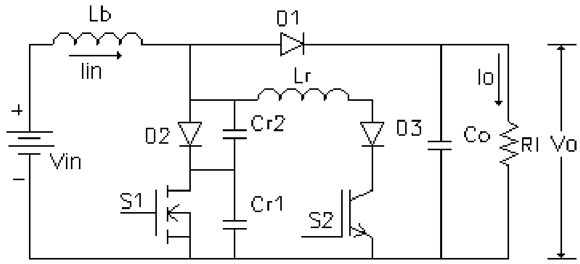


Fig. 1 - Boost converter associated to a non-dissipative snubber.

Switches S1 and S2 commutate softly. Switch S1 commutates in a ZVS way and switch S2 commutates in a ZCS way.

PRINCIPLE OF OPERATION

According to the [6], one can obtain the waveforms shown in Fig. 2.

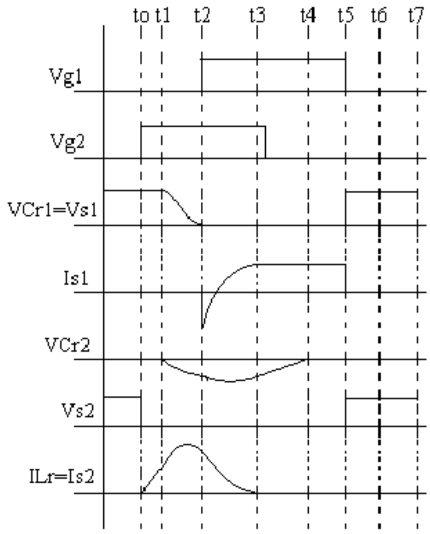


Fig. 2 - Theoretical waveforms for the Boost Converter associated to a non-dissipative snubber.

The transfer function between Vo and Vin is given by [6]:

$$G = \frac{Vo}{Vin} = \frac{1}{1 - \left\{ D + \frac{K1}{2p}\left[Arc\cos\left(-\frac{1}{X} \right) + \frac{X+1}{Xa} + \frac{a}{2} \right] \right\}} \qquad (1)$$

Where:

f_s = switching frequency;
f_0 = resonant frequency;
D = duty cycle;

$$a = \frac{Iin}{Vo}\sqrt{\frac{L_R}{C_R}} \qquad (2)$$

$$K1 = \frac{f_s}{f_0} \qquad (3)$$

Control Strategy

The control circuit block diagram and the power stage are shown in Fig. 3, and that one employing the digital control circuit is shown in Fig. 4. This converter operates with constant switching frequency and high power factor, using a Bang-Bang current control strategy.

The input current and line voltage samples are obtained from Rshu and Rt1 / Rt2 sensors. The voltage sample is rectified in the Accuracy Rectifier block.

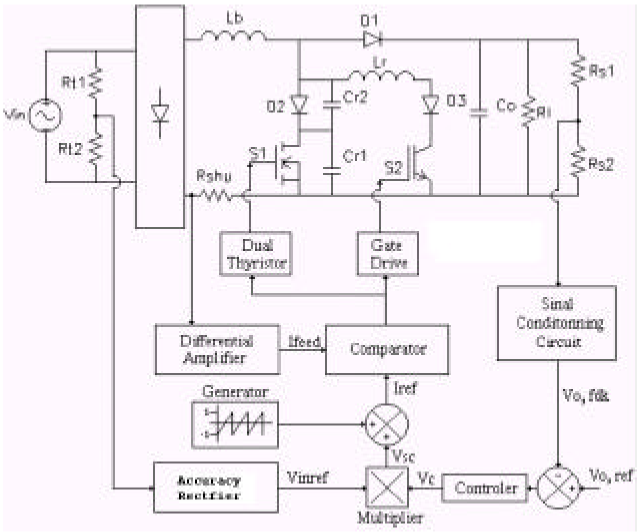


Fig. 3 - Boost Converter associated to a non-dissipative snubber and the analogical control circuit.

The PI controller is implemented to provide the control signal (Vc) which is multiplied for the control (Vsc). Then this signal is added to the sawtooth signal generating the reference current signal (Iref). The drive signals are obtained by comparing the current feedback signal, generated in the sensor Rshu, with the reference current signal.

The signal obtained from the comparator block output drives the auxiliary switch S2 directly. The same signal will drive switch S1, but only when the zero voltage transition on the switch is satisfied.

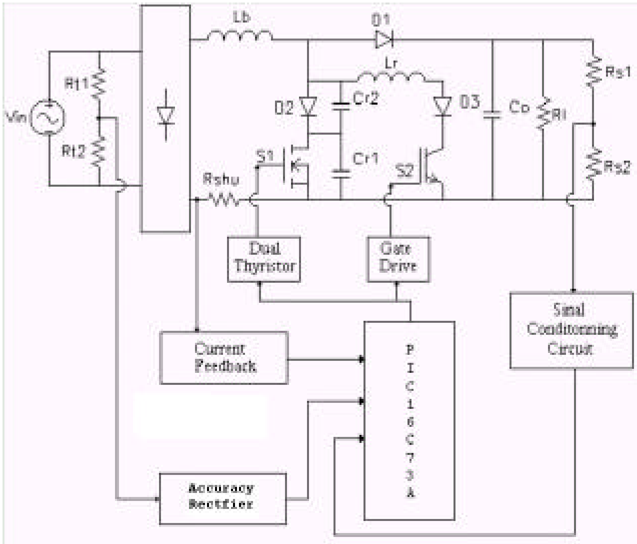


Fig. 4 - Boost Converter associated to a non-dissipative snubber and the digital control circuit.

In order to establish a more accurate comparison between the analogical and digital control types, an algorithm with the same features as those presented above was implemented and then applied to microcontroller PIC16c73a.

The algorithm that applies the hysteresis “bang-bang” control strategy follows the flow chart shown in Fig. 5. The called stage of "Start" is characterized by the declaration of the variables. In the stage, which is called "Read Vin", happens the reading of the A/D channel corresponding to the input voltage. In the stage, which is called "Read Iin", happens the reading of the A/D channel corresponding to the input current. However, the conversion time is very lingering (16μs each) the reload of the output voltage was not used.

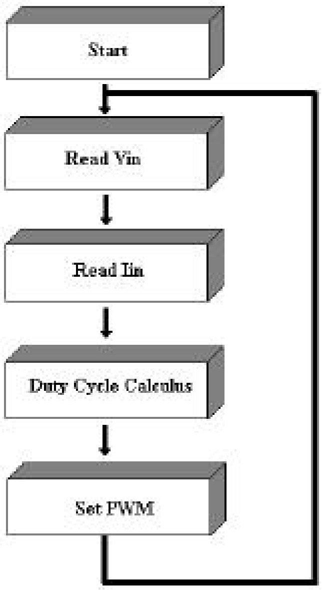


Fig. 5 – Flow chart representation of the employed algorithm.

In the stage called "Duty Cycle calculus" is used a mathematical algorithm that corresponds to the analogical control. In the last stage happens the configuration of the PIC’s PWM channels.

The Fig. 6 shows the total time diagram. It is observed that for reach 100Kz the strategy uses one update of the pulse width after 5 (five) Duty Cycle.

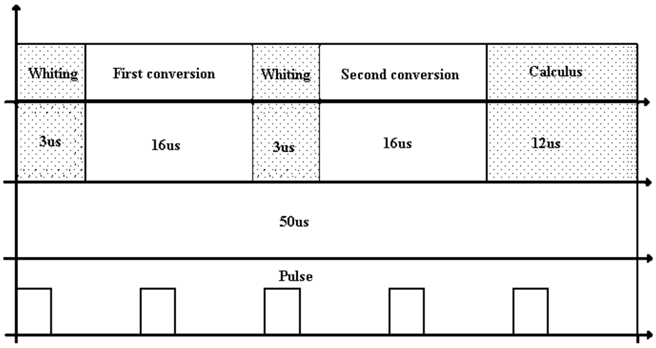


Fig. 6 – Total time diagram.

SIMULATION AND EXPERIMENTAL RESULTS

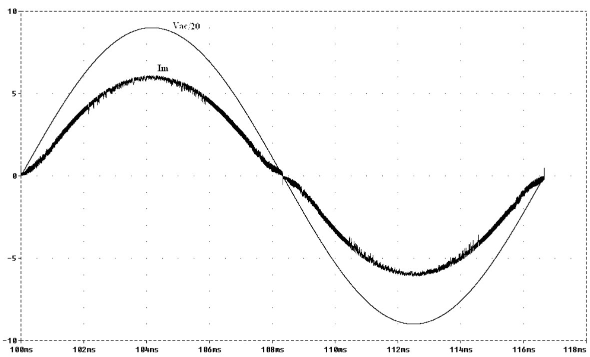
The Boost converter associated to a non-dissipative snubber and the control circuit was analyzed by simulation using PSpice software with the following parameter set.

S1 = IRFP460 (Mosfet);	S2 = Ideal;
D1 and D2 = MUR1560;	D3 = Ideal;
Cr1 = 10nF;	Cr2 = 27nF;
Lr = 2.5μH;	Co = 680μF;
Lb = 1.5mH;	Vin = ~115V;
f_s = 100kHz;	P_0 = 600W.

A Boost converter prototype associated to a non-dissipative snubber, using the analogical and digital control circuits was built using the following parameter set.

S1 = IRFP460 (Mosfet);	Cr1 = 10nF;
S2 = IRGBC20F (Igbt);	Cr2 = 27nF;
D1, D2 and D3 = MUR1560;	Lr = 2.5μH;
Co = 680μF;	Lb = 1.5mH.
Vin = ~115 V;	f_S = 100kHz;
P_0 = 600 W.	

Figs. 7, 8, 9, 10 and 11 show the simulation and experimental results. As it can be seen the switches commutation occurs without losses and the power factor is almost unity. Fig. 7 shows the power factor correction, under rated load condition. The value obtained for the analogical control was 0.998 and that one for the digital control was 0.990.



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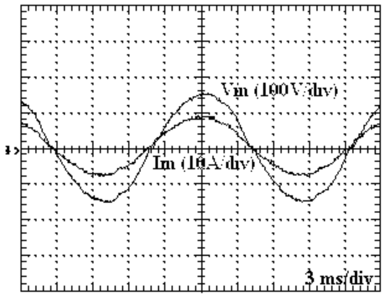

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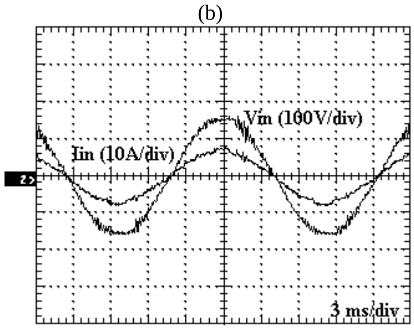
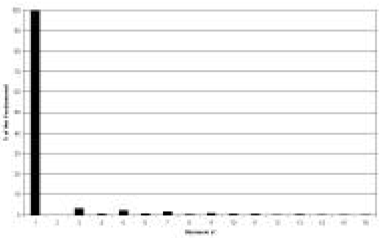


(c)

Fig. 7 - Input voltage and current under rated load condition:
a) simulated results;
b) experimental results using analogical control;
c) experimental results using digital control.

The obtained current and voltage THD (total harmonic distortion) values are relatively low, as it can be seen in Fig. 8 and Fig. 9. The current THD value was calculated in both simulation and experimental analysis, while the voltage THD value was calculated just for the prototypes.



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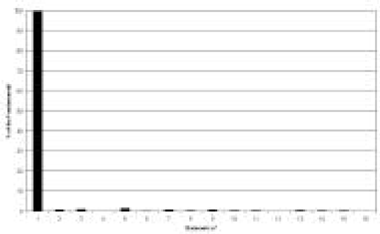

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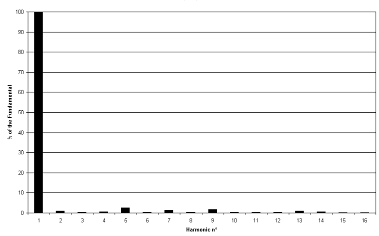

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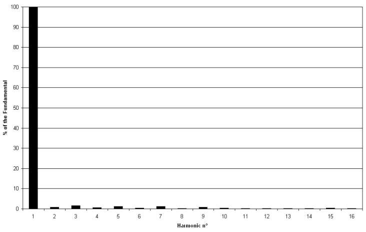
Fig. 8 - Harmonic Content of the Input Current:
a) simulation results;
b) experimental results using analogical control;
c) experimental results using digital control.



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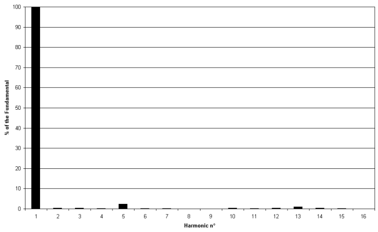
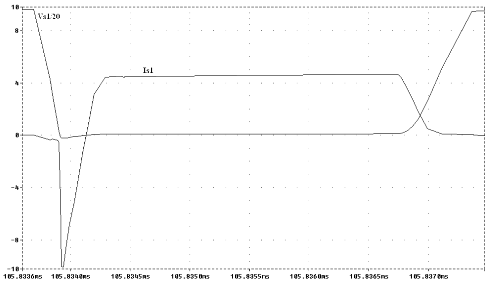


(b)

Fig. 9 - Harmonic Content of the Input Voltage:
a) experimental results using analogical control;
b) experimental results using digital control.

The current THD value obtained in the simulation was 4.85%. The current and voltage THD values obtained for the prototype employing the analogical control were 2.84% and 2.83% respectively. The current and voltage THD values obtained for the prototype employing the digital control were 5.09% and 2.84% respectively.



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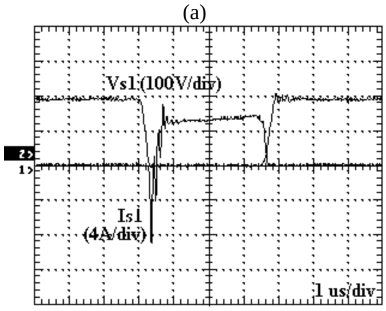

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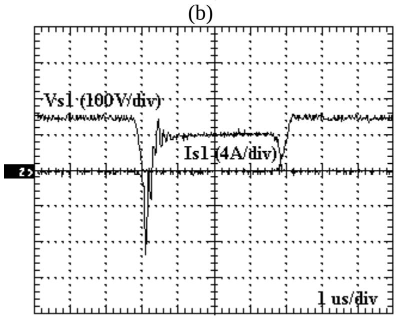
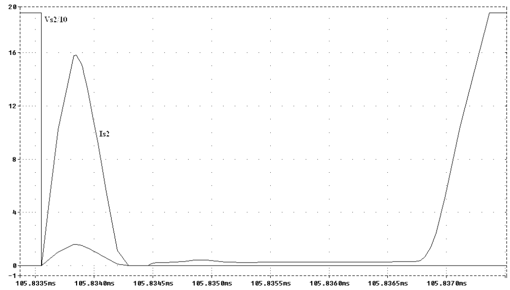


(c)

Fig. 10 - Switch S_1 waveforms:
a) simulation results under rated load condition;
b) experimental results using analogical control;
c) experimental results using digital control.

Fig. 10 shows the commutation in the main switch S1. One can notice that it does not present current and/or voltage stresses, as well as the commutations are non-dissipatives.



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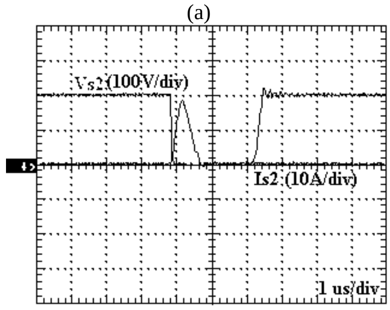

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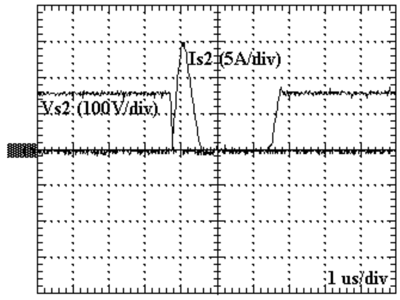

(c)

Fig. 11 - Switch S_2 waveforms:
a) simulation results under rated load condition;
b) experimental results using analogical control;
c) for experimental results using digital control.

Fig. 11 shows the commutation in the auxiliary switch S2. One can see that it does not present current and/or voltage stresses, as well as the commutations are non-dissipatives.

CONCLUSION

The analogical control applied to the Boost converter with non-dissipative commutation presented a high power factor (0.998) and low harmonic distortion (ITHD = 2.84% and VTHD = 2.83%). Some drawbacks of the analogical control are as follows: the control circuit complexity, problems with the gain adjustment and the increased number of components implying larger cost and weight. Its main advantage is related to the response speed of the control circuit.

The digital control applied to the Boost converter with non-dissipative commutation presented a high power factor (0.990) and low harmonic distortion (ITHD = 5.09% and VTHD = 2.84%). A digital control disadvantage is that the necessity of A/D converters reducing its dynamic response.

Its main advantage in the reduced number of components and the system flexibility.

As the digital control brings a reduction in the number of components, the complexity factor is concerned directly to the microcontroller programming. It is also a more versatile control and can be updated and modified in order to assist new demands that may appear. However, the control response speed is limited as a function of the number of A/D converters existent in PICs.

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