International Journal of Electrical and Power Engineering 1 (1): 99-103, 2007

A Novel Microcontroller Based Power Factor Correction (PFC) Boost Converter with EMI Filter

[1]P. Ram Mohan, [2]M. Vijaya Kumar, [3]S. Rama Reddy and [4]O.V. Raghava Reddy
[1]G. Pulla Reddy Engineering College, Kurnool, Andhra Pradesh, India
[2]JNTU College of Engineering Anantapur, Andhra Pradesh, India
[3]Jerusalem College of Engineering Chennai, Tamil Nadu, India
[4]Scientist, ISRO Satellite Center, Bangalore, Karnataka, India

Abstract: This study deals with the simulation and implementation of Power Factor Correction (PFC) boost converter along with Electro Magnetic Interference (EMI) filter. The boost converter of PFC Circuit is analyzed, designed and then simulated for resistive load. Near unity power factor is obtained by using PFC Boost Converter with EMI Filter. The laboratory model is implemented and the experimental results are obtained. These experimental results are correlated with the simulation results.

Key words: Power factor correction, electro magnetic interference, diode, rectifier, boost converter

INTRODUCTION

Electro-magnetic pollution of the power line introduced by power electronic systems include harmonic distortion due to nonlinear loads, typically, rectifiers[1]. So, various types of single phase PFC converter circuits to improve the ac current waveform have been developed and used[2-5]. The PFC converter is constructed by a boost chopper circuit with a switching device in the dc side of the diode bridge rectifier circuit. Good characteristics such as a sinusoidal current waveform in phase with the ac line voltage and the constant dc voltage can be obtained from the PFC converter.

Electro Magnetic Interference is related with the disturbance caused due to electro magnetic waves to the operation of any electronic circuit. Because of rapid change in voltages and currents within a switching converter, power electronic equipment is a source of electro magnetic interference with other equipment as well as with its own proper operation. So, Electro Magnetic Interference Filter (EMI Filter) has to be used at the input of PFC converter. Literature[6] deals with design of Boost Power Factor Correction Converter using genetic algorithms. Conducted EMI analysis of boost PFC Converter is presented in[7]. A method for EMI study in PFC rectifier is given by Ohnishi[8]. EMI considerations in Power Electronic Converters is given by Evans[9]. Concept of inductor design is presented in[10] and soft switching techniques in PWM converters are given by Busquets-Monge[11]. In the literature mentioned above, the hardware details of boost converter are not furnished. In this study, the hardware details are presented.

Power factor correction boost converter: The thyristor for PFC converter with different firing angles will give less output power, more harmonics and less power factor as compared with Diode rectifier. Hence, the diode rectifier is used as a dc input source to the Boost converter as shown in Fig. 1.

Figure 2 shows the boost converter where the output voltage is greater than the input voltage. Boost converter is also called as step-up converter. A large inductor in series with the source voltage is essential. When the switch is on, the input current flows through the inductor and switch and the inductor stores the energy during this period. When the switch is off, the inductor current cannot die down instantaneously, this current is forced to flow through the diode and the load during this off period. As the current tends to decrease, polarity of the emf induced in L_b is reversed. As a result, voltage across the load is the sum of supply voltage and inductor voltage and it is greater than the supply voltage.

The voltage impressed across the inductor during on-period is V_d. During this period, the current rises linearly from a minimum level I_1 to a maximum level I_2. Therefore the voltage across inductor is,

$$V_L = V_d \quad (1)$$

Also,
$$V_L = L\,(I_2 - I_1) / T_{on} = L\,(\Delta I) / T_{on} \quad (2)$$

From (1) and (2),

$$T_{on} = L\,(\Delta I) / V_d \quad (3)$$

Corresponding Author: P. Ram Mohan, G. Pulla Reddy Engineering College, Kurnool, Andhra Pradesh, India

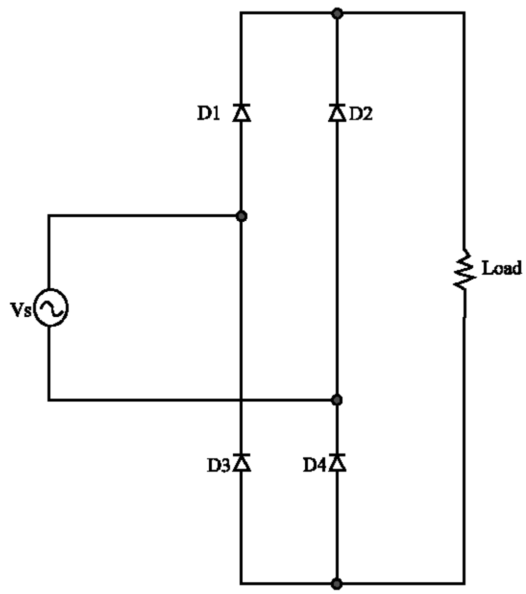

Fig. 1: Diode rectifier

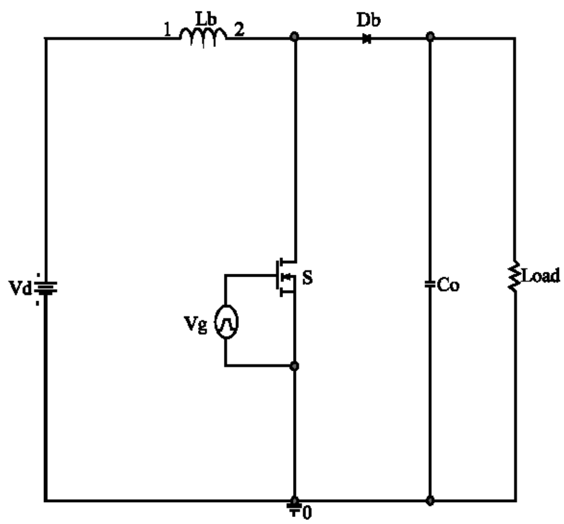

Fig. 2: Boost converter

The voltage impressed across the inductor during off period is ($V_o - V_d$) and the current drops linearly from the maximum level I_2 to the minimum level I_1. Therefore the voltage across the inductor is,

$$V_L = (V_0 - V_d) \tag{4}$$

Also, $$V_L = L\,(I_2 - I_1) / T_{off} = L\,(\Delta I) / T_{off} \tag{5}$$

From (4) and (5),

$$T_{off} = L\,(\Delta I) / (V_0 - V_d) \tag{6}$$

From (3), $$L\,(\Delta I) = T_{on} * V_d \tag{7}$$

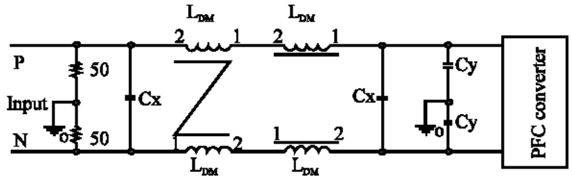

Fig. 3: EMI filter for the PFC circuit

From (6), $$L\,(\Delta I) = T_{off} * (V_0 - V_d) \tag{8}$$

From (7) and (8)

$$T_{on} * V_d = T_{off} * (V_0 - V_d)$$

Or $$V_0 = (T_{on} + T_{off}) * V_d / T_{off}$$

Or $$V_0 = T * V_d / T_{off}$$

Or $$V_0 = V_d / (1 - \alpha) \tag{9}$$

Where α = delay angle of the boost converter. As firing angle increases from 0 to 1, the output voltage will be from V_d to infinity. Hence, the output voltage is boosted.

Electro magnetic interference filter: The electro magnetic interference is transmitted in two forms: radiation and conduction. The switching converters supplied by the power lines generate conducted noise into the power lines that is usually several orders of magnitude higher than the radiated noise into free space. Metal cabinets used for housing power converters reduce the radiated component of the electromagnetic interference.

Conducted noise consists of two categories commonly known as the differential mode and the common mode. The differential mode noise is a current or a voltage measured between the lines of the source, that is line-to-line voltage. The common mode noise is a voltage or a current measured between the power lines and ground, that is line-to-ground voltage. An EMI filter is needed to reduce the differential mode and common mode noises. The filter comprises of inductors and capacitors as shown in Fig. 3.

RESULTS AND DISCUSSION

The PFC Boost Converter with EMI Filter is simulated using ORCAD PSPICE software. The simulated waveforms of output voltage, input voltage and input current are shown in Fig. 4. The simulation results coincide with the results given in the literature.

Experimental results: The boost converter with EMI Filter is fabricated and tested with R-load. The control circuit is shown in Fig. 5. The control pulses are generated

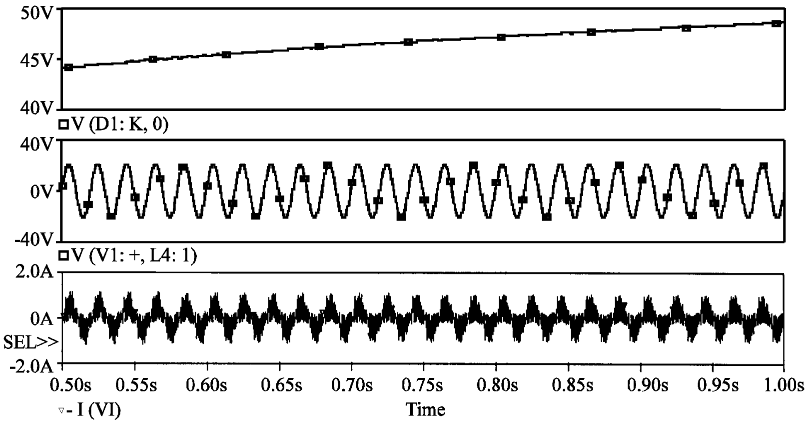

Fig. 4: Output voltage, input voltage and input current waveforms PFC boost converter with EMI filter

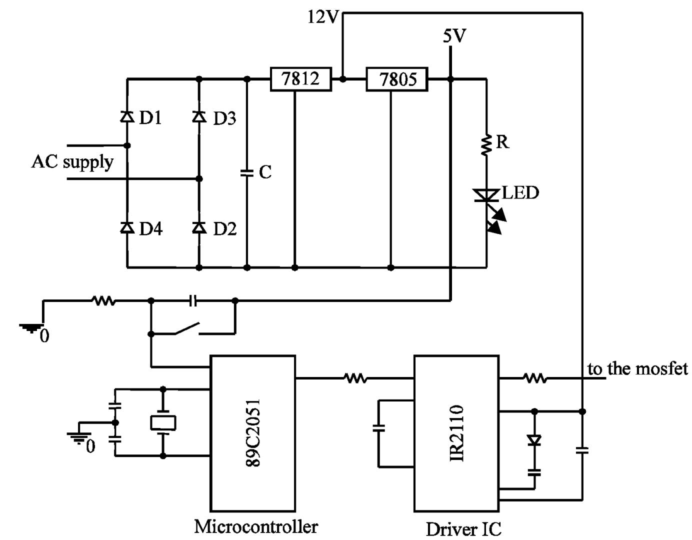

Fig. 5: Control circuit

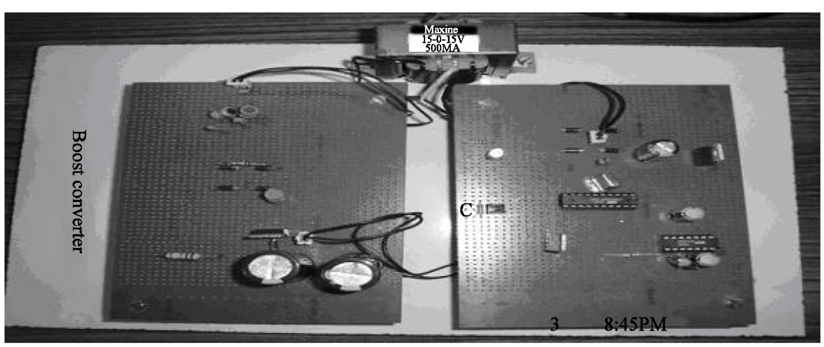

Fig. 6: Top view of hardware circuit

using the Micro Controller 89C2051. These pulses are amplified to 10V using the driver IC IR2110. The output of this chip is applied to the gate of the MOSFET.

The experimental set up is done for 15V AC Supply. The results were obtained and they are presented here. The top view of hardware circuit is shown in Fig. 6. The

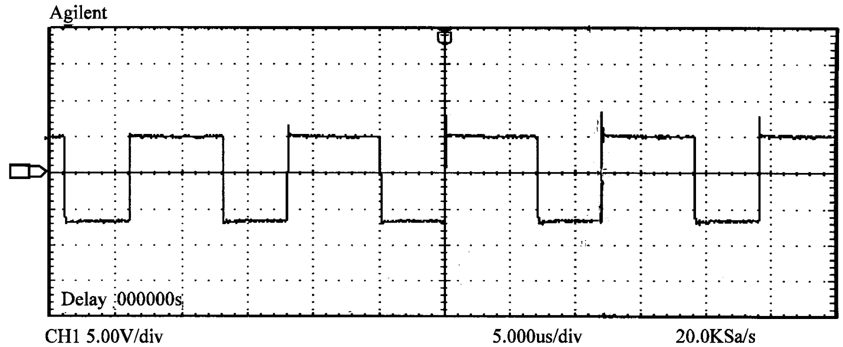

Fig. 7a: Driving Pulses to MOSFET

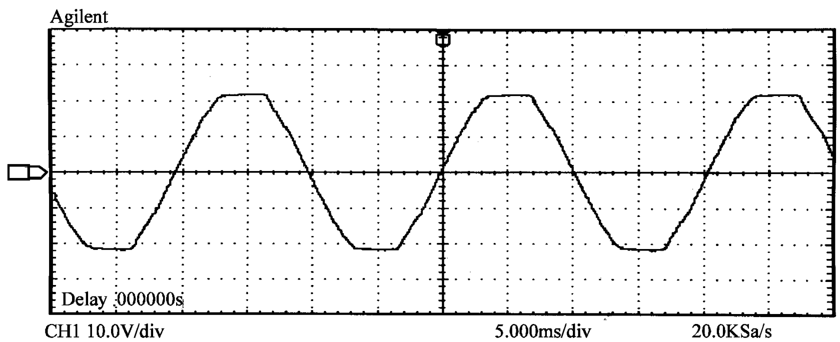

Fig. 7b: Input supply voltage

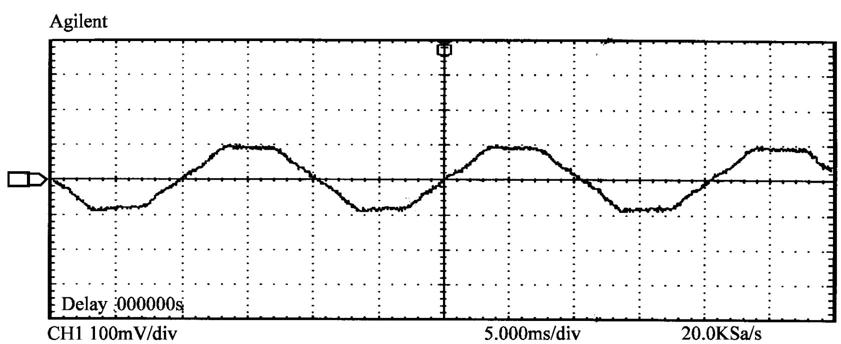

Fig. 7c: Input supply current

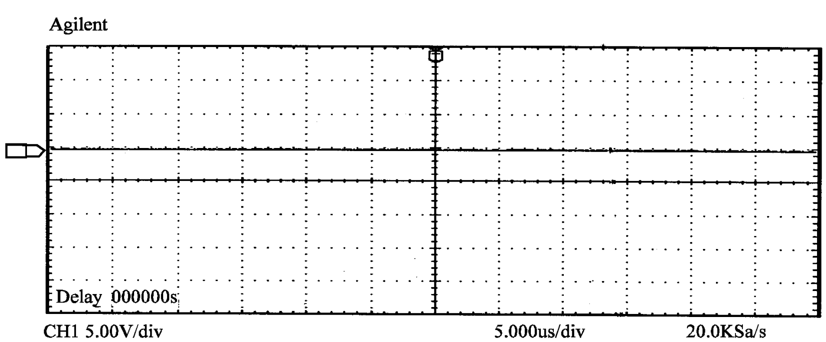

Fig. 7d: DC output voltage

oscillogram for driving pulses is shown in Fig. 7a. The oscillogram for AC input voltage to the power circuit is shown in Fig. 7b. The oscillogram for AC input current is shown in Fig. 7c. The output of the boost converter is shown in Fig. 7d.

CONCLUSION

The Boost Converter is analyzed. The Power Factor Correction (PFC) boost converter along with Electro Magnetic Interference (EMI) filter is simulated for resistive load. From the simulation results, it can be seen that the best power factor can be obtained by using PFC Boost Converter along with EMI Filter. The simulation studies prove that the PFC boost converter with EMI filter is a viable alternative for power factor improvement. The laboratory model for PFC boost converter with EMI filter is implemented. The circuit is tested with resistive load. The experimental results are presented in this paper. The experimental results closely agree with the simulation results.

REFERENCES

1. Chew, W., P. Evans and W. Heffernan, 1991. Inductor design concepts for high frequency applications, EPE FIRENZE, pp: 1.019-1.024.
2. Guichao Hua and F.C. Lee, 1993. Soft switching techniques in PWM converters, IEEE IECON, pp: 637-643.
3. Zhang, A.W., M.T. Zhang and F.C. Lee *et al*., 1997. Conducted EMI analysis of a boost PFC Circuit, Proc. IEEE Applied Power Electronics Conf., APEC-1997, pp: 223-229.
4. Crebier, J.C., M. Brunello and J.P. Ferrieux, 1999. A new method for EMI study in PFC rectifiers, Proc. IEEE Power Electronics Spec. Conf., PESC-1999, pp: 855-860.
5. Rossetto, L., P. Tenti and A. Zucato, 1999. Electromagnetic Compatibility issue in industrial equipment, IEEE Ind. Applications. Mag., pp: 34-36.
6. Qian, J. and F.C. Lee, 2000. Charge pump power factor correction technologies part I and part II, IEEE Trans. Power Electronics, pp: 121-139.
7. Ohnishi, T. and M. Hojo, 2000. Single phase PFC converter with switching pulse free chopper, Proc. IPEC-2000, Tokyo, Japan, pp: 1796-1801.
8. Ohnishi, T., 2000. Binary controlled single phase PFC rectifier, Proc. IECON-2000, Nagoya, Japan, pp: 2666-2671.
9. Evans, P. and W. Heffernan, 2001. Electromagnetic considerations in power electronic converters, Proc. IEEE, pp: 864-875.
10. Ohnishi, T. and M. Hojo, 2002. Single phase PFC converter constructed by ac line voltage waveform detection, Proc. SPC-2002, pp: 7-11.
11. Busquets-Monge, S. and G. Soremekun *et al*., 2002. Design of a boost power factor correction converter using genetic algorithms, proc. IEEE Applied Power Electronics Conf. (APEC-2002), pp: 1177-1182.