FPGA Implementation of Neuro-Fuzzy based Buck Boost Converter

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***Abstract*—The DC-DC power converters are widely used. However, the controller design for DC- DC power converters cannot easily design if load is dynamics vary widely. Therefore a Field Programmable Gate Array (FPGA) is proposed to build a neuro fuzzy system for controlling a nonlinear buck boost converter. A Very High speed integrated circuit Hardware Description Language (VHDL) has been used to implement the proposed controller. The main purpose behind implementation of the NF controller in VHDL is to minimize the hardware implementation cost of the generic NF controller for use in industrial applications. Quartus II Software has been used as programming environment to type and synthesis the VHDL codes that described the neuro- fuzzy controller and to generate a configuration file which is used to program the FPGA board.**

***Keywords*—Buck-Boost converter, FPGA, Neuro- Fuzzy Control, VHDL**

I. INTRODUCTION

This paper aims to establish the superior performance of neuro fuzzy controllers at various operating points of the buck & boost converters. The basic concept of Neuro-Fuzzy control method is first to use structure-learning algorithm to find appropriate Fuzzy logic rules and then use parameter-learning algorithm to fine-tune the membership function and other parameters. The proposed controller reveals that it is adaptive for all operating conditions. Simulation results are shown and settling time and peak overshoot have been used to measure the performance.

Traditional frequency domain methods for design of controllers for power converters are based on small signal model of the converter. The small signal model of the converter has restricted validity and changes due to changes in operating point. Also the models are not sufficient to represent systems with strong non- linearity. A state space averaged model of the classical Buck boost DC/DC converters suffers from the well known problem of Right-Half-Plane zero in its control to output transfer function under continuous conduction mode. There are two possible routes to achieve fast dynamic response. One way is to develop a more accurate non-linear model of the converter based on which the controller is designed. The other way is the artificial intelligence way of using human experience in decision-making. Among the various techniques of artificial intelligence, the most popular and widely used technique in control systems is the fuzzy logic. Such an intelligent controller designed may even work well with a system with an approximate model.[1]

The requirement for short time-to-market has made FPGA devices very popular for the implementation of general purpose electronic devices. Modern FPGA architectures offer the advantage of partial reconfiguration, which allows an algorithm to be partially mapped into a small and fixed FPGA device that can be reconfigured at run time, as the mapped application changes its requirements. Such a feature can be beneficial for modern control applications that may require the change of coefficients, models and control laws with respect to external conditions. The proposed solution is both technically advanced and cost effective, offering flexibility, modularity and efficiency, without performance reduction[2]

II. LITERATURE SURVEY

The paper they presented adaptive neuro-fuzzy inference system modified for efficient HW/SW implementation. The design of pipelined architecture suitable for online parameter adaptation two different on-chip approaches are

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presented: a high-performance parallel architecture for offline training and a and a pipelined architecture suitable for online parameter adaptation[3]. The paper presented Controller design, the voltage output DC-DC Converter Buck Boost Converter pursues performance improves during the admittance process[4]. The paper presented modelling variable DC output voltage using MATLAB fuzzy logic controller for Buck boost converter and developed Hardware of fuzzy logic controller for variable output voltage DC-DC Buck boost converter[5]. The paper presented Sliding Mode Control (SMC) and Fuzzy Sliding Mode Control (FSMC) for Buck, Boost and Buck-Boost converters are proposed, tested and compared . SMC is suitable for switched mode DC-DC converters.[6]

III. Proposed Work

Figure1 shows the proposed hardware behavior of Neuro fuzzy logic control that will be design in VHDL language & implement on Quartus II Altera FPGA board. First, the trained data is generated with the help of Matlab software for the input of Neuro-Fuzzy controller. Then VHDL codes are simulated in ModelSim. After this NF is Synthesis in Quartus. Then NF Code are downloaded from the host computer into the FPGA board using a USB cable. Then, Edge connector is used to interface the board (NF controller) with model of the buck boost converter. The FPGA board generates the digital inputs to the NF controller. The NF controller generates a suitable digital control signal based on the rules that were stored in the FPGA chip. The digital control signal generate pulse waveform which will be applied as an input to the buck boost converter. At the same time buck boost converter also get DC input supply. Thus at the output we get DC output.

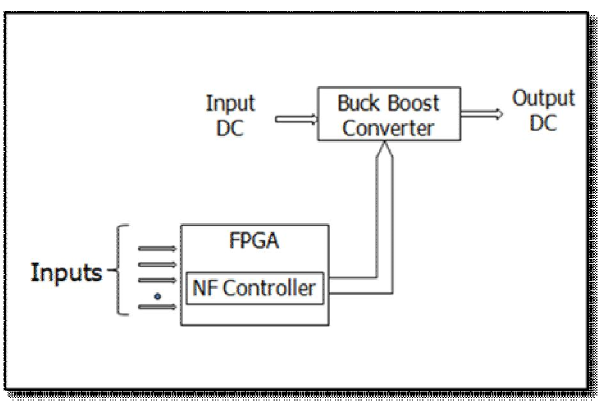

Figure 1 Block Diagram of project Block Diagram

IV. Methodology

A. Linearized Model for Buck Boost Converter

A Buck-Boost converter is a type of switched mode power supply that combines the principles of the Buck Converter and the Boost converter in a single circuit. [7][8].

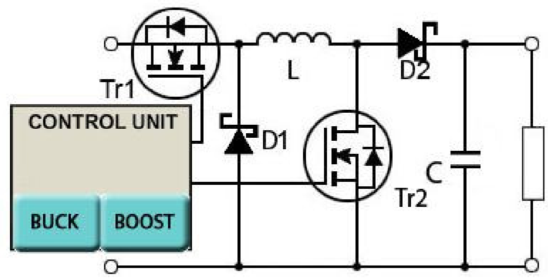

Figure 2: Buck Boost Converter Model

Operation as a Buck Converter

In this mode Tr2 is turned off, and Tr1 is switched on and off by a high frequency square wave from the control unit. When the gate of Tr1 is high, current flows though L, charging its magnetic field, charging C and supplying the load. The Schottky diode D1 is turned off due to the positive voltage on its cathode.

Operation as a Boost Converter

In Boost Converter mode, Tr1 is turned on continually and the high frequency square wave applied to Tr2 gate. During the on periods when Tr2 is conducting, the input current flows through the inductor L and via Tr2. Whilst this is happening D2 cannot conduct. For the duration of the on period, the load is being supplied entirely by the charge on the capacitor C, built up on previous oscillator cycles.

MODES OF OPERATION:

Continuous conduction mode

The switching results in a cyclic current increase and decrease in the inductor.value by using defuzzification scheme. All rules in this architecture are evaluated in parallel to generate the final output fuzzy set, which is then defuzzified to get the crisp output value.[9]

The neural network mechanism (embedded inside the Altera™ FPGA) initially acquires the sampled training data relayed from the Matlab.[10][11]

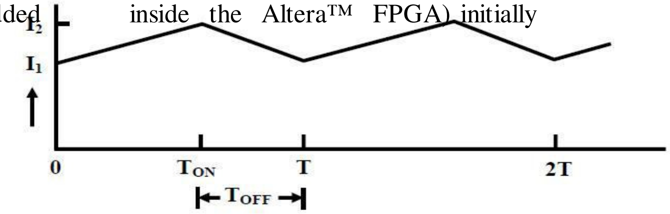

Figure 3 Current through the Inductor

The input and output voltages are related by the following equation:

$$V_{out} = -\frac{d}{1-d} \times V_{in}$$

Discontinuous conduction mode:

If the current does go to zero at any time, then the conduction is said to be discontinuous

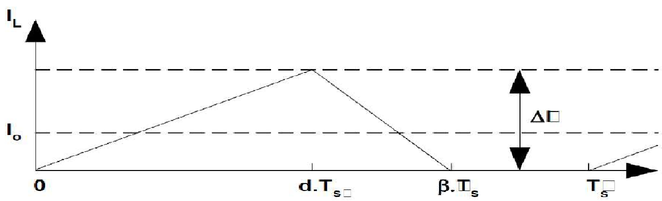

Figure 4 Discontinuous conduction mode current waveform

B. Neuro-Fuzzy Controller For Proposed System

We consider a multi-input, single-output dynamic system whose states at any instant can be defined by “n” variables X1, X2,...,Xn. The control action that derives the system to a desired state can be described by a well known concept of “if-then” rules, where input variables are first transformed into their respective linguistic variables, also called fuzzification. Then, conjunction of these rules,called inferencing process, determines the linguistic value for the output. This linguistic value of the output also called fuzzified output is then converted to a crisp

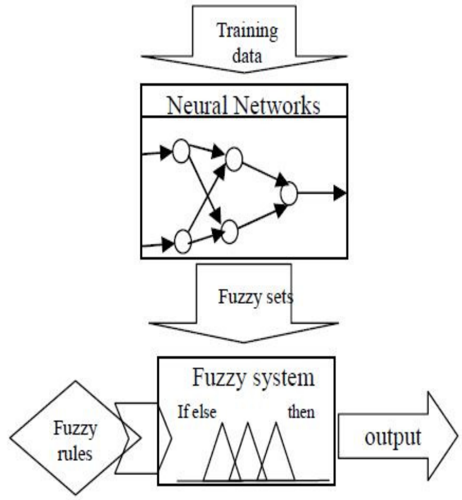

Figure 5 Neuro-fuzzy algorithm used features MF of the fuzzy system that are predetermined by the neural network

V. RESULTS & DISCUSSION

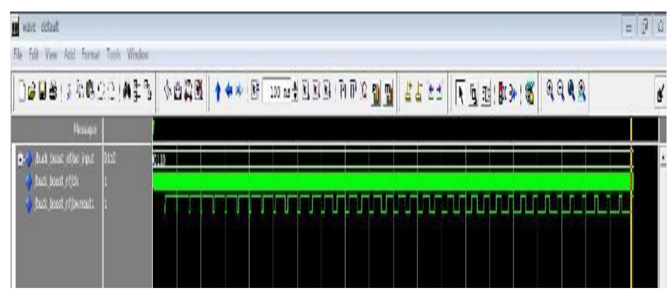

Figure 6: waveform of pwm

A PWM waveform is a sequence of pulses with fixed frequency but varying pulse widths. In this Buck Boost Converter, pwm is Control signal which have to generate . Here only one pwm waveform is

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given but we have to generate several pwm waveform to apply this project.

Flow Status	Successful - Sun Nov 16 12:49:32 2014
Quartus II Version	9.1 Build 222 10/21/2009 SJ Web Edition
Revision Name	buck_boost_nf
Top-level Entity Name	buck_boost_nf
Family	Cyclone II
Device	EP2C20F484C7
Timing Models	Final
Met timing requirements	Yes
Total logic elements	225 / 18,752 (1 %)
Total combinational functions	225 / 18,752 (1 %)
Dedicated logic registers	35 / 18,752 (< 1 %)
Total registers	35
Total pins	7 / 315 (2 %)
Total virtual pins	0
Total memory bits	0 / 239,616 (0 %)
Embedded Multiplier 9-bit elements	0 / 52 (0 %)
Total PLLs	0 / 4 (0 %)

Figure 7 Flow summary of Project Report

In this Altera board there are total number of pins are 315 and out of that we are using only 7 pins.

Observation Table

Parameter	Input Voltage	Output voltage
Buck mode	5 V	4.4 V
Boost mode	5 V	113 V

PowerPlay Power Analyzer Status	Successful - Sun Nov 16 12:49:32 2014
Quartus II Version	9.1 Build 222 10/21/2009 SJ Web Edition
Revision Name	buck_boost_nf
Top-level Entity Name	buck_boost_nf
Family	Cyclone II
Device	EP2C20F484C7
Power Models	Final
Total Thermal Power Dissipation	67.49 mW
Core Dynamic Thermal Power Dissipation	0.00 mW
Core Static Thermal Power Dissipation	47.35 mW
I/O Thermal Power Dissipation	20.14 mW
Power Estimation Confidence	Low: user provided insufficient toggle rate data

Figure 8 Power Play Power Analyzer Project Report

Experimental Setup of Project

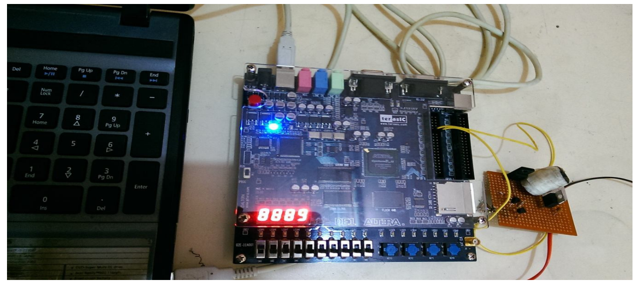

Figure 9 Experimental Setup of Project

In this we can see Laptop from which we are mounting programming on Altera Cyclone II Board usingg USB connector and Buck Boost Cirtcuit model.

CONCLUSION

We concluded that the Neuro Fuzzy Buck Boost Converter has been designed in VHDL and implemented on the Quartus Altera Cyclone II device. The Controller is running absolutely fine at a clock frequency of 50 MHz. According to the simulation results, pwm waveform is generated properly. The operation of Buck Boost converter for different values of duty cycle was observed.

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