FPGA CONTROLLED BUCK CONVERTER

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Abstract : ***This paper presents FPGA controlled buck converter using PWM signal. Buck converters are widely used in various types of electrical equipment. The control of a buck converter is essentially important. There are many power converter control methods like linear control, fuzzy logic and predictive control. Each of these has its advantages and disadvantages. One of the most commonly used techniques of linear control is PID control because of its simplicity in design, implementation and understanding of operation. In this paper, for the software simulation the control is implemented by the use of linear-PID controller and for the hardware module, the control is implemented using PWM signal generated by FPGA.***

Key words:FPGA,PID Controller,PWM signal

I. INTRODUCTION

A buck converter [1],[8](step-down converter) is a dc-dc power converter, which steps down voltage (while stepping up current) from its input to its output (load). Buck Converter protects the circuits from voltage surges. Switching converters such as buck converters provide much greater power efficiency than linear regulators, which are simpler circuits which lowers voltage by dissipating power as heat, but do not step up output current. Buck converter is a class of switched-mode power supply (SMPS) typically containing at least two semiconductor devices (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such converter's output (load-side filter) and input (supply-side filter).

II PROPOSED PID CONTROL METHOD FOR SOFTWARE SIMULATION

PID control[2],[7] is one of the oldest and classical control technique used for DC-DC converters. It uses one of its families of controllers including P, PD, PI and PID controller. These different combinations will gives us various ways to regulate dc power supply in these converters. Due to the various advantages of PID, is widely used for industrial applications in the area of power electronics.

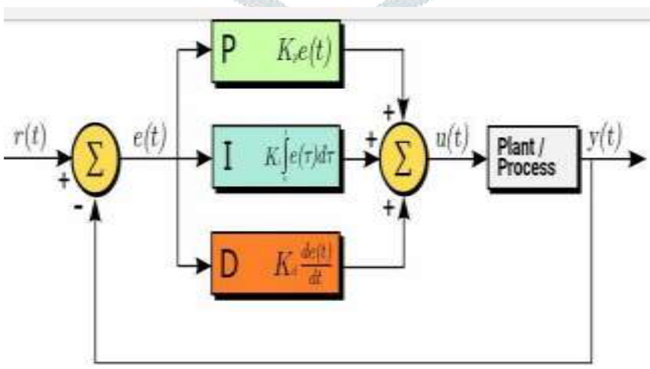


Figure 1 PID Controller

$r(t)$ is the desired process value or set point (SP), and $y(t)$ is the measured process value (PV). Term **P** is proportional to the current value of the SP − PV error $e(t)$. Term **I** accounts for past values of the SP − PV error and integrates them over time to produce the **I** term. Term **D** is a best estimate of the future trend of the SP − PV error, based on its current rate of change. It is sometimes called "anticipatory control".

III VERIFICATION BY MATLAB SIMULATION

Simulation is done in Simulink. The simulated model is shown in Figure.

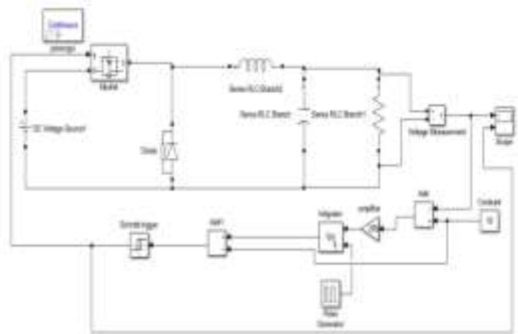


Figure 2 Simulated Model

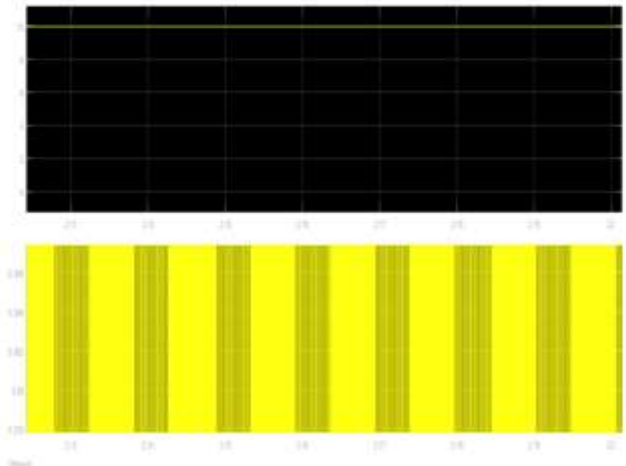
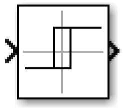


Figure 3 Simulation Output

IV COMPONENTS USED:

- Dc voltage source
- MOSFET
- Diode
- Series rlc branch[R,L,C]
- Voltmeter
- Scope
- Constant
- Adder
- amplifier
- PID controller
- Pulse generator
- Schmitt trigger

Schmitt Triggger

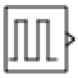


- The output for the Relay block switches between two specified values. When the relay is on, it remains on until the input drops below the value of the Switch off point parameter. When the relay is off, it remains off until the input exceeds the value of the Switch on point parameter. The block accepts one input and generates one output.

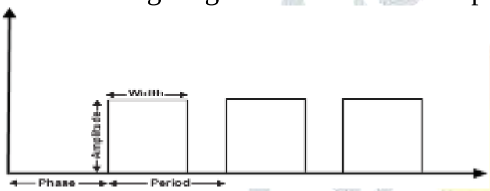
- PID tuning is the process[5] of finding the values of proportional, integral, and derivative gains of a PID controller to achieve desired performance and meet design requirements.

- Amplifier:
  Use the amplifier object to create an amplifier element. An amplifier is a 2-port RF circuit object. This element can be used in the rfbudget object and the circuit object.
  Syntax
  amp = amplifier
  Amp = amplifier (Name, Value)

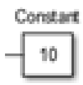
- Pulse generator:



The Pulse Generator block generates square wave Pulses at regular intervals. The block waveform parameters, Amplitude, Pulse Width, Period, and Phase delay, determine the shape of the output waveform. The following diagram shows how each parameter affects the waveform.

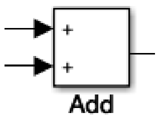


- Constant:



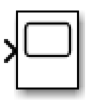
To create named constants as part of a class or package in MATLAB versions 7.6 and above.

- Adder:



The Sum block performs addition or subtraction on its inputs. The Add, Subtract, Sum of Elements, and Sum blocks are identical blocks. This block can add or subtract scalar, vector, or matrix inputs. It can also collapse the elements of a signal and perform a summation.

- Scope



Display signals generated during simulation.

V HARDWARE IMPLEMENTATION

FPGA DISCRIPTION:

Figure 4 Spartan 6 kit

Field programmable gate arrays[3] (FPGAs) are digital integrated circuits (ICs) that contain configurable (programmable) blocks of logic along with configurable interconnects between these blocks. Design engineers can configure, or program, such devices to perform a tremendous variety of tasks.

The "field programmable" portion of the FPGA's name refers to the fact that its programming takes place "in the field". This mean that FPGAs are configured in the laboratory, or it may refer to modifying the function of a device resident in an electronic system that has already been deployed in the outside world. If a device is capable of being programmed while remaining resident in a higher-level system, it is referred to as being in-system programmable.

VI PWM GENERATION:

The generation of PWM wave form using FPGA is shown below.

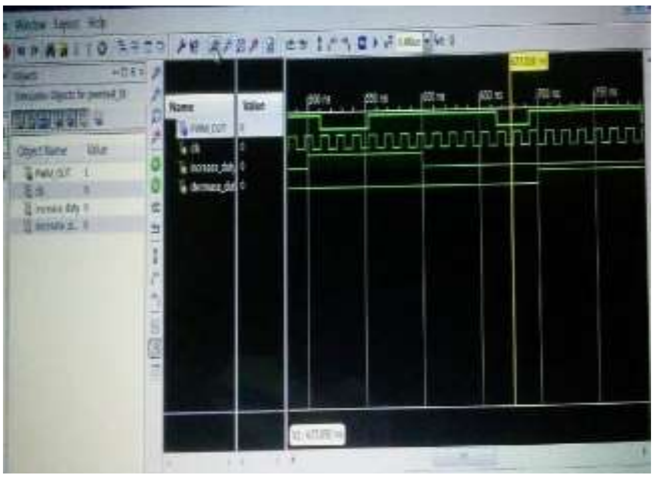


Figure 5 PWM signal generation using FPGA

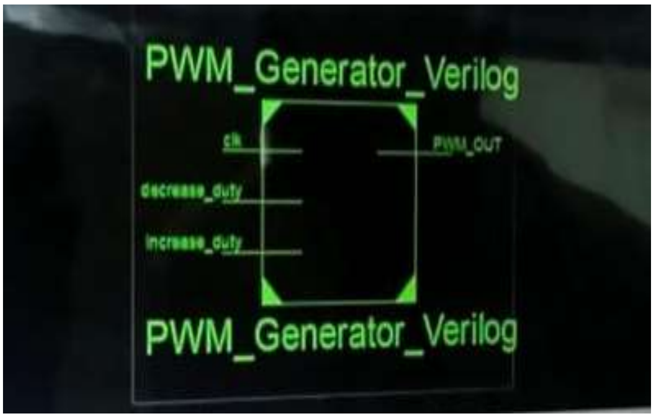


Figure 6 Simulation PWM schematic

The PWM signal[4],[6] is generated by varying duty cycle for the input clock signal. The duty cycle can be varied by varying the on period and off period of the clock signal .

VII PROPOSED CIRCUIT DIAGRAM

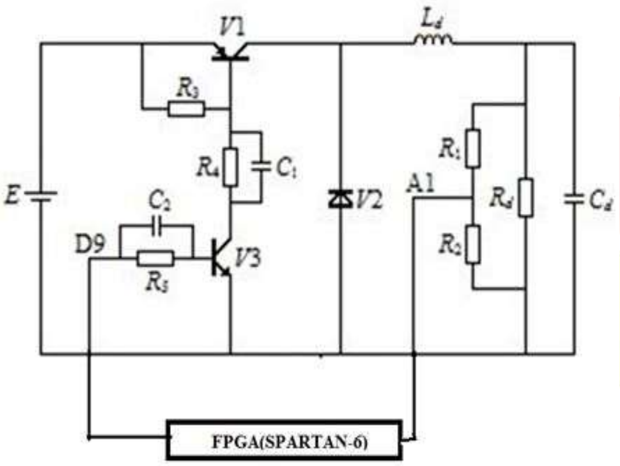


Figure 7 Proposed DC-DC Buck Converter

Physical realization[9] of the buck converter is shown in Figure. The basic circuit of the converter consists of a power supply E, switches V1 and V3, output filter Ld, Cd and load Rd. In the drive unit transistor V3 drives controlled switch V1. Resistors R4 and R5 are used for current adjustment. Capacitors C1 and C2 and resistor R3 are used to improve switching characteristics. As a control device FPGA (SPARTAN6) is used.

Table :1 LIST OF COMPONENTS

Component	Value	Component	Value
E	20 V	C_1	5,6 nF
$U_d(0)$	13,2 V	C_2	2,2 nF
$I_d(0)$	0,34 A	C_d	100 µF
$d = U_d(0)/E$	0,66	L_d	2,17 mH
R_1	470 kΩ	$V1$	MJE1501G
R_2	100 kΩ	$V3$	BC107B
R_3	27 Ω	$V2$	1N5408
R_4	220 Ω	FPGA	SPARTAN 6
R_5	1 kΩ		
R_6	39 Ω		

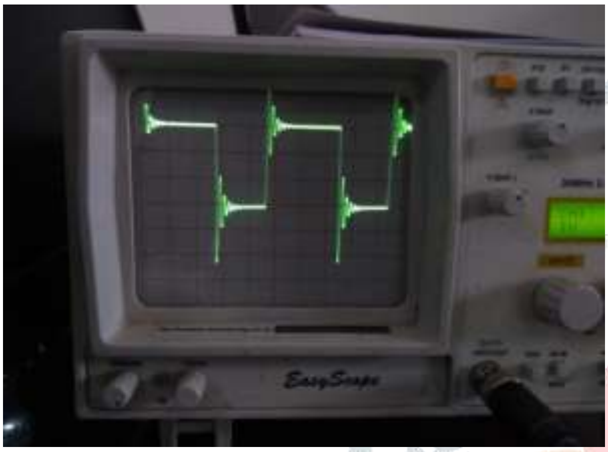


Figure 8 PWM Wave form from Hardware Circuit

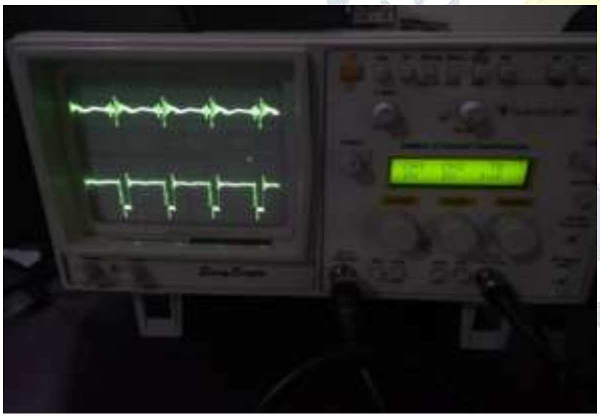


Figure 9 PWM output with Output Voltage

VIII CONCLUSION

The buck converter controlled by FPGA using Spartan 6 kit for the generation of PWM signal is designed and the output is verified. In software simulation, the converter control is implemented by PID controller. The software simulation output and the hardware output is compared for 50% duty cycle. The ripple at the the output waveform is reduced by the efficient design of filter.

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