

# **DIGITAL SIMULATION ZERO VOLTAGE SWITCHING DC TO DC CONVERTOR USING SIMULINK**

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## **ABSTRACT**

The primary task of power electronics is to process and control the flow of electric energy by supplying voltages and currents in a form that is optimally suited for user loads. Modern power electronic converters are involved in a very broad spectrum of applications like switched-mode power supplies, active power filters, electrical-machine-motion-control, renewable energy conversion systems distributed power generation, flexible AC transmission systems, and vehicular technology, etc. Power electronic converters can be found wherever there is a need to modify the electrical energy form with classical electronics in which electrical currents and voltage are used to carry information, whereas with power electronics, they carry power. Some examples of uses for power electronic systems are DC/DC converters used in many mobile devices, such as cell phones or PDAs, and AC/DC converters in computers and televisions. Large scale

power electronics are used to control hundreds of megawatt of power flow across our nation. The design of power electronic converter circuit with the use of closed loop scheme needs modeling and then simulating the converter using the modeled equations. This can easily be done with the help of state equations and MATLAB/SIMULINK as a tool for simulation of those state equations. This paper underlines the simulation using simulink for DC to DC converters.

Keywords - Converters, MATLAB, Simulink, System Modeling

## **INTRODUCTION**

Controller design for any system needs knowledge about system behavior. Usually this involves a mathematical description of the relation among inputs to the process, state variables, and output. This description in the form of mathematical equations which describe behavior of the system (process) is called model of the system. This paper describes an efficient method to learn, analyze and simulation of power electronic converters, using system level nonlinear, and switched state- space models. The MATLAB/SIMULINK software package can be advantageously used to simulate power converters. This study aims at development of the models for all basic converters and studying its open loop response, so these models can be used in case of design of any close loop scheme. Also as a complete exercise a closed scheme case has been studied using cascaded control for a boost converter.

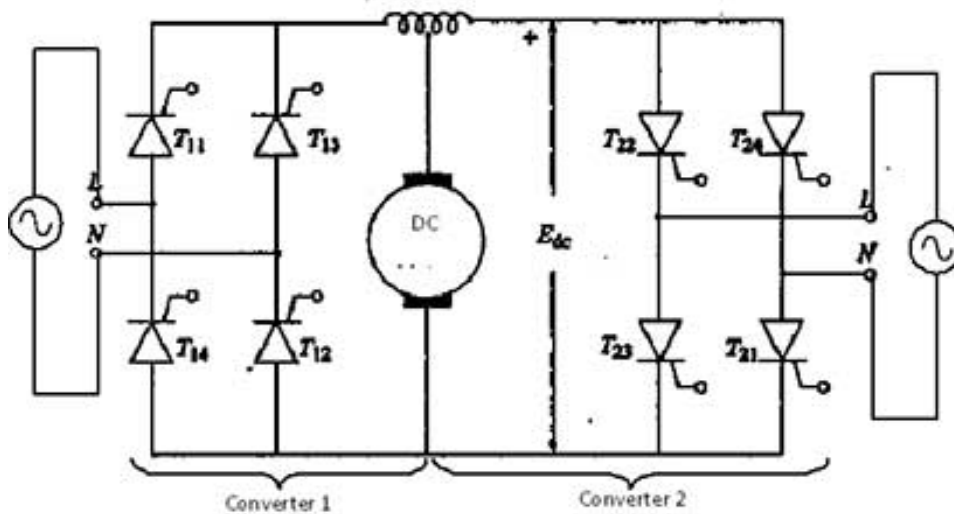
Dual converter is a combination of a rectifier and inverter in which the conversion of A.C to D.C happens and followed by D.C to A.C where load lies in between. A dual converter can be of a single phase or a three phase. A dual converter consists of two bridges consisting of thyristors in which one for rectifying purpose where alternating current is

converted to direct current which can be given to load. Other bridge of thyristors is used for converting D.C to A.C.

### DC-DC Switching Converter

System modeling is probably the most important phase in any form of system control design work. The choice of a circuit model depends upon the objectives of the simulation. If the goal is to predict the behavior of a circuit before it is built. A good system model provides a designer with valuable information about the system dynamics. Due to the difficulty involved in solving general nonlinear equations, all the governing equations will be put together in block diagram form and then simulated using Matlab's Simulink program. Simulink will solve these nonlinear equations numerically, and provide a simulated response of the system dynamics.

### Single Phase Converters



### Modeling Procedure

To obtain a nonlinear model for power electronic circuits, one needs to apply Kirchhoff's circuit laws. To avoid the use of complex mathematics, the electrical and semiconductor

devices must be represented as ideal components (zero ON voltages, zero OFF currents, zero switching times). Therefore, auxiliary binary variables can be used to determine the state of the switches. It must be ensure that the equations obtained by the use of Kirchhoff's laws should include all the permissible states due to power semiconductor devices being ON or OFF.

The steps to obtain a system-level modeling and simulation of power electronic converters are listed below.

1) Determine the state variables of the power circuit in order to write its switched state-space model, e.g., inductor current and capacitor voltage.

2) Assign integer variables to the power semiconductor (or to each switching cell) ON and OFF states.

3) Determine the conditions governing the states of the power semiconductors or the switching cell.

4) Assume the main operating modes of the converter (continuous or discontinuous conduction or both) or the modes needed to describe all the possible circuit operational modes. Then, apply Kirchhoff's laws and combine all the required stages into a switched state-space model, which is the desired system-level model.

5) Write this model in the integral form, or transform the differential form to include the semiconductors logical variables in the control vector: the converter will be represented by a set of nonlinear differential equations.

6) Implement the derived equations with "SIMULINK" blocks (open loop system simulation is then possible to check the obtained model).

7) Use the obtained switched space-state model to design linear or nonlinear controllers for the power converter.

8) Perform closed-loop simulations and evaluate converter performance.

9) The algorithm for solving the differential equations and the step size should be chosen before running any simulation. The two last steps are to obtain closed-loop simulations .

## Simulation of DC-DC Converters

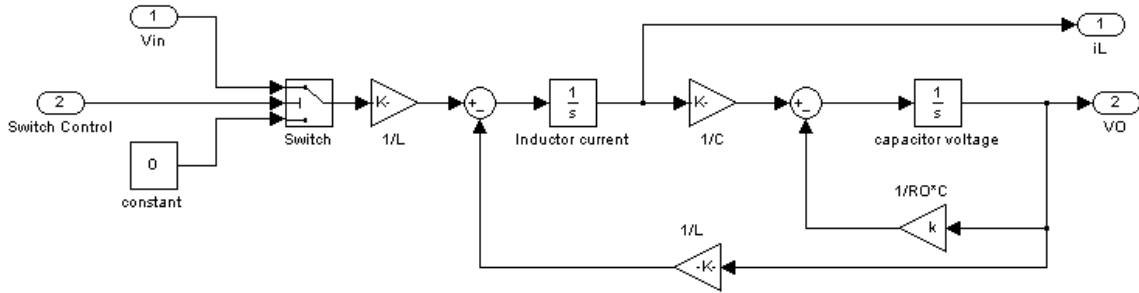
### Buck Converter Modeling

The buck converter with ideal switching devices will be considered here which is operating with the switching period of  $T$  and duty cycle  $D$ . The state equations corresponding to the converter in continuous conduction mode (CCM) can be easily understood by applying Kirchhoff's voltage law on the loop containing the inductor and Kirchhoff's current law on the node with the capacitor branch connected to it. When the ideal switch is ON, the dynamics of the inductor current  $i_L(t)$  and the capacitor voltage  $v_C(t)$  are given by,

$$\begin{cases} \frac{di_L}{dt} = \frac{1}{L}(V_m - v_o) \\ \frac{dv_o}{dt} = \frac{1}{C}(i_L - \frac{v_o}{R}) \end{cases}, \quad 0 < t < dT, \quad Q:ON$$

and when the switch is OFF are presented by,

$$\begin{cases} \frac{di_L}{dt} = \frac{1}{L}(-v_o) \\ \frac{dv_o}{dt} = \frac{1}{C}(i_L - \frac{v_o}{R}) \end{cases}, \quad dT < t < T, \quad Q:OFF$$



**Fig 1 Open-loop modeling of Buck DC-DC converters**

These equations are implemented in Simulink as shown in Fig. 2 using multipliers, summing blocks, and gain blocks, and subsequently fed into two integrators to obtain the states  $i_L(t)$  and  $v_C(t)$  .

### Boost Converter Modeling

The boost converter with a switching period of  $T$  and a duty cycle of  $D$  is given. Again, assuming continuous conduction mode of operation, the state space equations when the main switch is ON

$$\begin{cases} \frac{di_L}{dt} = \frac{1}{L}(V_{in}) \\ \frac{dv_o}{dt} = \frac{1}{C}(-\frac{v_o}{R}) \end{cases}, \quad 0 < t < dT, \quad Q: ON$$

and when the switch is OFF

$$\begin{cases} \frac{di_L}{dt} = \frac{1}{L}(V_{in} - v_o) \\ \frac{dv_o}{dt} = \frac{1}{C}(i_L - \frac{v_o}{R}) \end{cases}, \quad dT < t < T, \quad Q: OFF$$

### Simulation Closed-Loop of DC-DC Converters Using Cascaded Control

The simulation model for cascaded control of DC-DC switching converters is build using the specific steps. The DC-DC buck, boost, buck-boost, and Cuk converters was previously designed, and simulated on digital computer using Matlab package with the parameters given in Table 1, and Table 2.

Table 1 Buck, Boost, and Buck-Boost converters parameters					
$V_{in}$	$L$	$C$	$R$	$f$	$V_o$
24, 10, 24V Respectively	69 <i>mH</i>	22 0 $\mu F$	13 $\Omega$	10 0 <i>KHz</i>	12, 20, - 24V Respectively

Table 2 Cuk converter parameters							
$V_{in}$	$L_1$	$L_2$	$C_1$	$C_2$	$f$	$R$	$V_o$
24 V	69 <i>mH</i>	19 <i>mH</i>	47 $\mu F$	22 0 $\mu F$	10 0 <i>KHz</i>	1 5 $\Omega$	31. 8 V

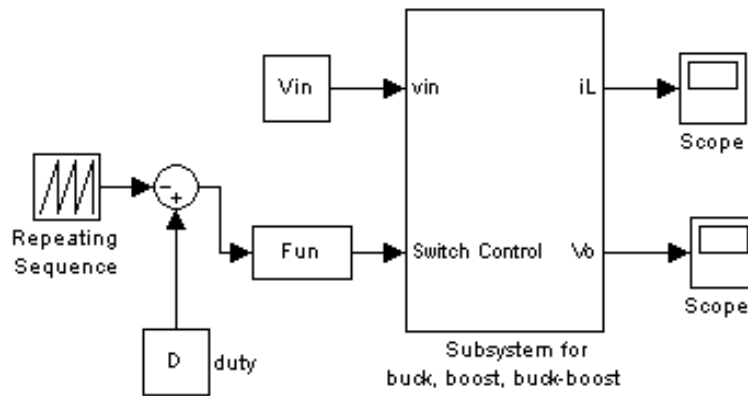
Here the output voltage rises up to 21.3V (6.5%) for the step variation of load from 10 $\Omega$  to 13 $\Omega$  (30%). The output voltage resumes its reference value (of 20V) within 15ms after the transient variation of load. As per fig 12(b), for a step change at the input voltage from 10V to 18 V (80%) (at 0.5 Sec instant), a satisfactory performance is obtained in the output voltage which has a rise up to 22.8V (14%), but it is quickly dropped to its set value (20V) within 16 ms. Simulation results verify that the control scheme in this section gives stable operation of the power supply. The output voltage and inductor current can return to the steady state even when it is affected by line and load variation.

#### Applications of single phase dual converter

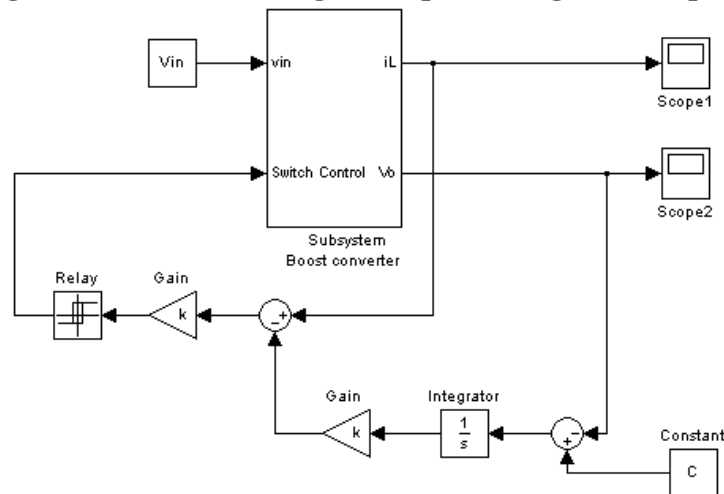
- Speed control and direction control in dc motors.
- Speed control and polarity control of dc motor using single phase dual converter
- A single phase dual converter can be used in controlling speed and direction of rotation interfacing with microcontroller, combination of four SCR's is placed

either side of motor and motor is load. These thyristors can be triggered through an optocoupler which is connected to a port of microcontroller.

- Rotation of motor can be initialized using optocoupler by setting a set of thyristor to trigger which is placed at one side and change in direction of motor can be achieved by triggering another set of thyristor Variation in speed of motor can be achieved by delayed firing angle of SCR.

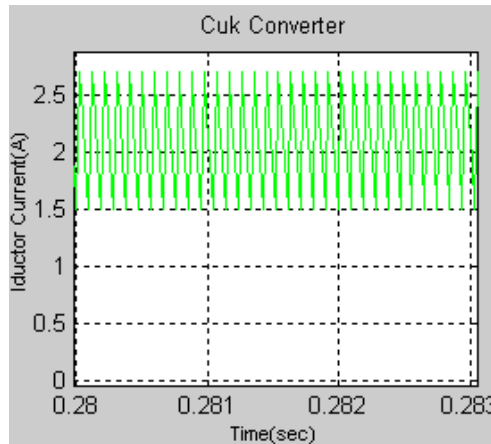


**Fig.2 Simulink block diagram representing close loop**



**Fig. 3 Subsystem for Cuk converters**





## CONCLUSIONS

This paper analysis nonlinear, switched, state-space models for buck, boost, buck-boost, and Cuk converters. The simulation environment MATLAB/SIMULINK is quite suitable to design the modeling circuit, and to learn the dynamic behavior of different converter structures in open loop. The simulation model in MATLAB/SIMULINK for the boost converter is build for close loop. The simulation results obtained, show that the output voltage and inductor current can return to steady state even when it is affected by input voltage and load variation, with a very small over shoot and settling time.

## REFERENCES

- [1] J.Mahdavi, A.Emadi, H.A.Toliyat, Application of State Space Averaging Method to Sliding Mode Control of PWM DC/DC Converters, IEEE Industry Applications Society October 1997.
- [2] Vitor Femao Pires, Jose Fernando A. Silva, Teaching Nonlinear Modeling, Simulation, and Control of Electronic Power Converters Using MATLAB/SIMULINK, IEEE Transactions on Education, vol. 45, no. 3, August 2002.

[3] Juing-Huei Su, Jiann-Jong Chen, Dong-Shiuh Wu, Learning Feedback Controller Design of Switching Converters Via MATLAB/SIMULINK, IEEE Transactions on Education, vol. 45, November 2002.

[4] Daniel Logue, Philip. T. Krein, Simulation of Electric Machinery and Power Electronics Interfacing Using MATLAB/SIMULINK, in 7<sup>th</sup> Workshop Computer in Power Electronics, 2000,pp. 34-39.

[5] N. Mohan, T. Undeland, W. Robbins, Power Electronics Converters, Applications and Design, ISBN 9814-12-692-6.