

Circuit Averaging for Boost Converter Involving Generation of Pseudo-Random Carrier Modulation via PSIM

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Abstract: - The paper reflects the approach towards the understanding of the circuit averaging method used for the power converters. Various software simulation packages are available for the purpose to be served such as MATLAB (Simulink), LTspice, PSIM (power electronics, motor drives, and dynamic system simulation) etc. A mathematical analysis is done for modeling the Boost converter (Step-Up) ideally as well as practically. An implementation of the Pseudo-random carrier modulation scheme is worked on the software package PSIM. Semiconductor devices used in power electronics systems(PES) increases the effects of audible switching noise, electromagnetic interference etc, which is one of the major concern while designing the power converters.

Keywords: - Boost converter, system modeling, MATLAB (Simulink), LTspice, Pseudo-random carrier.

I. INTRODUCTION

In power electronics Boost converter is the basic topology under DC–DC converter, whose behavior serves to convert a DC input voltage to a Higher DC output voltage, which has been widely used in engineering. It is an important step for designing of a Boost converter is to model and analyze this converter according to the real requirements. Many appropriate models have been made by researchers to establish and explore the corresponding analysis method. Up to now, a few good models have been proposed to describe the Boost converter, and a few good analysis methods have been explored to investigate the dynamic behavior.[1] For example, under the assumption that the switching frequency is much higher than its characteristic frequency, the averaged model, which is used to derive the small signal model, can be obtained by averaging the circuit variable within each switching cycle to describe the dynamic behavior of the Boost converter in the low frequency region.[1-2] Controller design for any system needs knowledge of system behavior. Usually involves a mathematical description of the relation established for inputs to the process, state variables, and output. When system is described in the form of mathematical equations which gives an insight 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 Averaged models. The MATLAB (Simulink), LTspice, PSIM software packages are used to simulate power converters. Our study aims at development of the model for basic converters and studying its open loop behavior, so this model can be used in case of design of any closed loop system. The averaged model can be obtained by using the state-space averaging[2] or the circuit averaging technique.[3] Since the circuit averaging technique, whose advantages are its simplicity and clearer insight into the converter behavior, is applied to derive the transfer functions of the open-loop Boost converter operating in the either continuous conduction mode (CCM) or Discontinuous conduction mode(DCM) of operation .

II. BOOST CONVERTER MODELING

In system control design, system modeling is probably the most important phase in any form of work. The simulation objectives depend on the circuit model. If the goal is to predict the behavior of a circuit before it is built. A designer needs to have good system model information to know the system dynamics. Due to the difficulty involved in solving general nonlinear equations due to presence of nonlinear semiconductor devices, all the governing equations will be put together in a block diagram form and then simulated using LTspice program. LTspice will solve these nonlinear equations numerically, and provide a simulated response of the system dynamics.

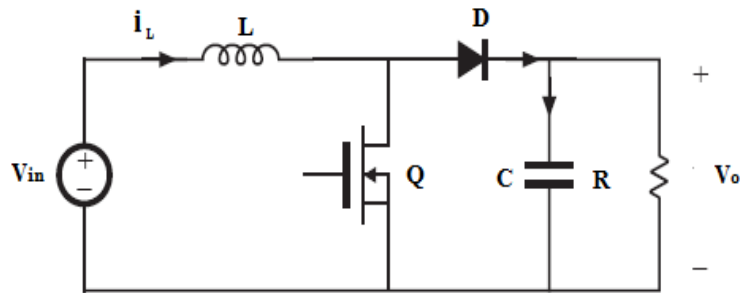


Fig. no.1. Schematic diagram of a boost converter.

The boost converter of Fig. no. 1 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 are shown by,

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

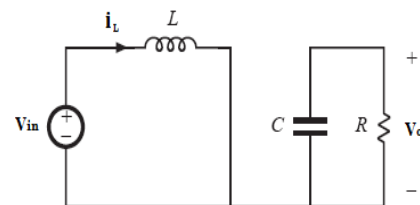


Fig. no.2. when Switch is ON

and when the switch is OFF

$$\begin{cases} \frac{di_L}{dt} = \frac{1}{L}(V_{in} - v_o) \\ \frac{dv_o}{dt} = \frac{1}{C}(i_L - \frac{v_o}{R}) \end{cases}, \quad dT < t < T, \quad Q: OFF \quad (2)$$

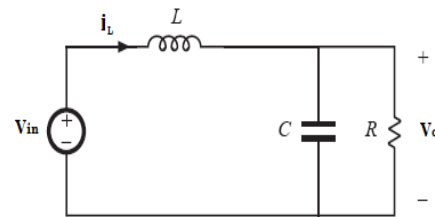


Fig. no. 3. when Switch is OFF

III. RULES AND CIRCUIT AVERAGING

There are three important RULES in learning power electronics converters [4]:

- Inductor Volt-sec balance.
- Capacitor charge balance.
- Small ripple Approximation.

Under steady-state conditions power converter output response is periodic in nature and hence rather applying Fourier analyses to the output waveforms. It is best suited that we should apply these rules in steps so as we can easily apply our conventional KVL and KCL rules in a simpler manner.

1. Inductor volt-sec balance:

$$\langle V_L \rangle = \frac{1}{T} \int_0^T v_L(t) dt$$

2. Capacitor charge balance:

$$\langle i_c \rangle = \frac{1}{T} \int_0^T i_c(t) dt$$

3. Small ripple approximation:

In a well versed designed power converter, the output voltage ripple is small. Therefore we can easily neglect the ripple from output voltage.

$$v_o(t) = V + v_{ripple}(t) \quad (3)$$

$$\| v_{ripple} \| \ll V \quad (4)$$

$$v \approx V \quad (5)$$

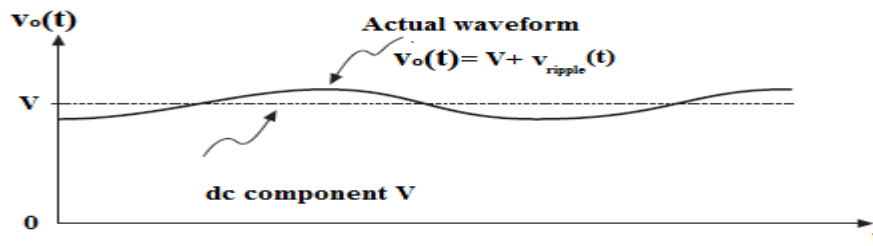


Fig. no.4. Small ripple approximation.

4. Averaging of the boost converter obtained in two states of switch Q:
 So to make our implementation easy and simpler we take an average of the equations sets 1 and 2 with respect to the duty ratio d .

$$L \frac{di_L}{dt} = v_{in} - (1 - d)v_o \tag{6}$$

$$C \frac{dv_o}{dt} = (1 - d)i_L - \frac{v_o}{R} \tag{7}$$

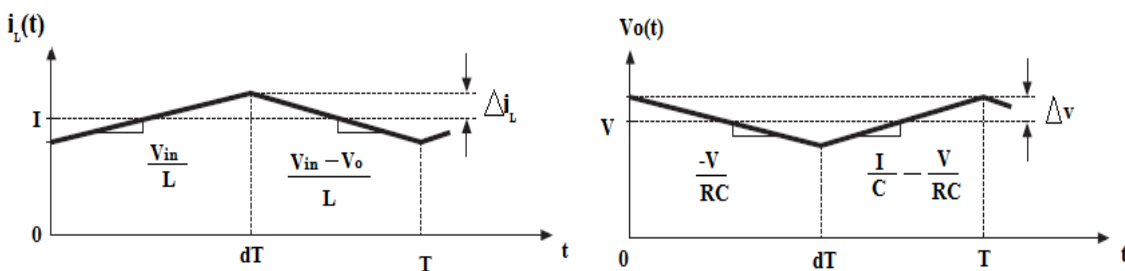


Fig. no.5 Behavior of inductor current and output voltage switch Q changes its ON state to OFF state.

Hence, we are able to predict the response of the boost converter on the above basis in a simpler manner. Averaged switched model has been made in LTspice for analysis of the converter ratio which gives relationship between output voltage and input voltage. (here switch is the averaged model of the semiconductor devices)

$$k = \frac{V_o}{V_{in}} = \frac{1}{1-d} \tag{8}$$

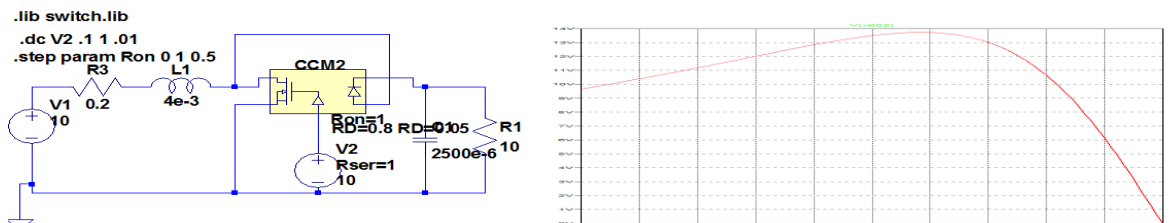


Fig. no.6 Converter ratio K changes as duty ratio changes with respect to $V_{in}=10v, R=10, C=2.5mh, L=4mh$.

IV. GENERATION OF PSEUDO-RANDOM CARRIER

Generating of pseudorandom carrier[6] is simple task as proposed in our previous work using MATLAB(Simulink). Similarly we have tried to achieve the Pseudorandom carrier waveform using some Analog to Digital converter, D-Flip-Flops and using some digital logic gates. By sensing the output voltage ripple, Analog to digital converter generates corresponding bits which are shifted and XOR-ed using a digital logic according to desired frequency so that multiplexer can be controlled to generate Pseudorandom carrier via PSIM.

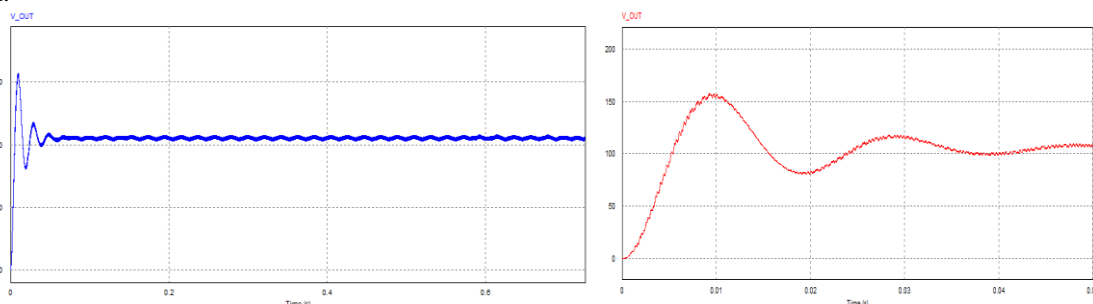


Fig. no.7 Steady-state and transient analysis of a boost converter using Pseudorandom carrier and DC-signal as reference.

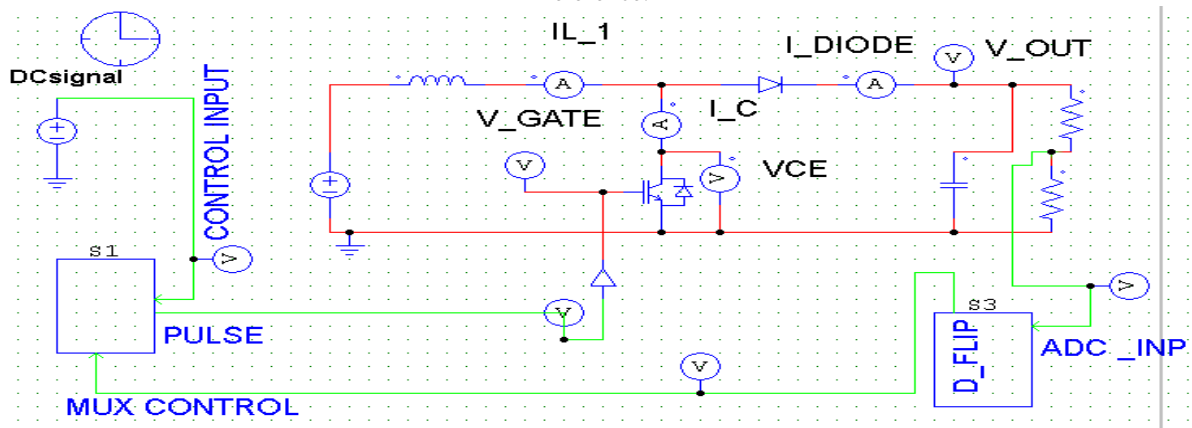


Fig. no.8. Implemented open loop boost converter using PSIM.

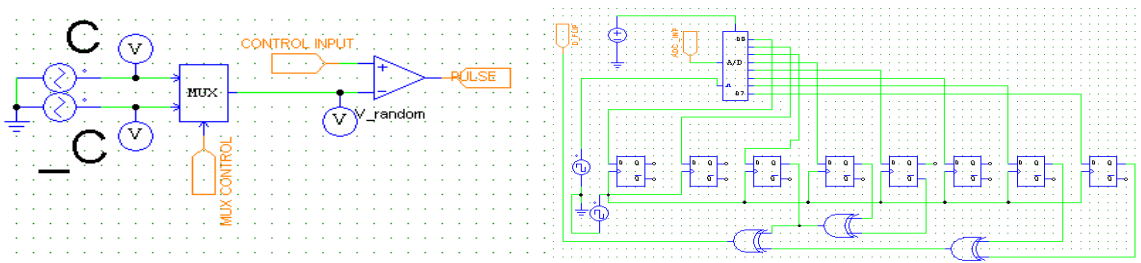


Fig. no.9. Internal block S1 and S3 for implementation of PSEUDO-RANDOM-CARRIER.

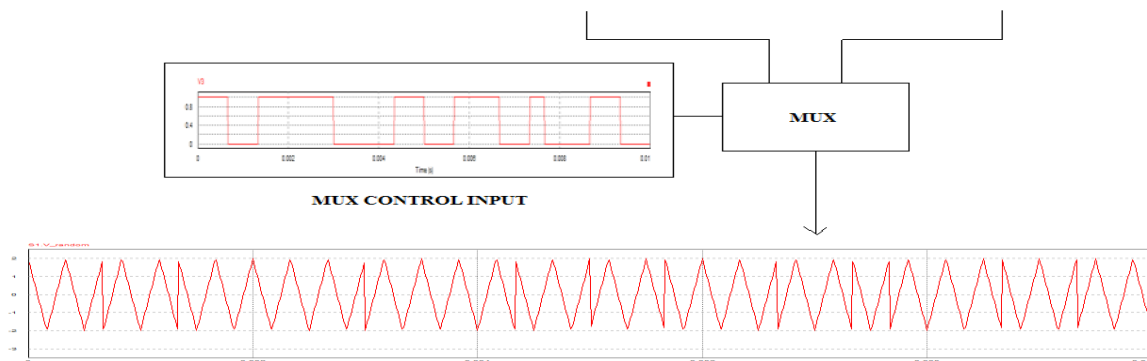
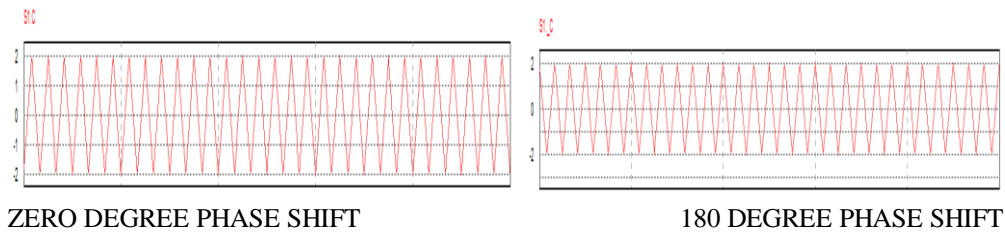


Fig. no.10 Generated Pseudo-random Carrier using PSIM.

V. CONCLUSION

The average model of method of Boost converter is simpler to take up learning in power converter field .our study can further be taken up for example to study the average model of the basic non-ideal converter. And we improve the model by using the duty ratio constraint; derive the open-loop transfer function and closed-loop transfer function of the model. Finally it can be examined under the different simulation tools available. In future a hardware implementation of Pseudo-random carrier waveform will be implemented using various function generator integrated circuits.

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