

# Open Loop Modeling of Different DC-DC Converter

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**Abstract**— Design of different DC-DC converters circuit with the help of close loop control scheme requires and modeled equations are used to simulate the converter in MATLAB. State equations are used in the close loop control. In this paper all the non-isolated converters like buck, boost, buck-boost are used and shows total harmonic distortion (THD).

**Keywords**- Open Loop Control Scheme, DC-DC Converter, Cascade control ,MATLAB/SIMULINK.

## 1. INTRODUCTION

This paper explains an efficient method to analysis and simulation of DC-DC converters, using switched state- space models and system level nonlinear. The MATLAB/SIMULINK software can be advantageously used to simulate DC-DC converters. The modeling of all the DC-DC converter and open loop control schemes developed and the close loop control for boost converter using cascaded control has been studied.

## 2. MODELING PROCEDURE

Kirchhoff's circuit laws are used to obtain a nonlinear model of power electronics circuits. The complexity are reduced by using ideal component. So auxiliary binary variables can be used to determine the state of the switches.

Some steps for obtaining the modeling and simulation of DC-DC converter are as follow.

1. Obtain the state variables of the circuit in order to write its switched state-space model as capacitor voltage and inductor current.

2. Integer variable can be assigned to the semiconductor device ON and OFF states.

3. Obtain the conditions of the semiconductors devices.

4. Assume the main operating modes of the converter in continuous or discontinuous conduction or. Then, apply KVL and KCL and combine all the required stages into a switched state-space model.

5) This model must be write in the integral form normally.

6) "SIMULINK" is used to derive the equations and open loop system simulation is then possible to check the obtained model.

7) Space-state model is used to design linear or nonlinear controllers for any DC-DC converter.

8) The last steps are to obtain closed-loop simulations [1].

## 3. SIMULATION OF DC-DC CONVERTER WITH OPEN LOOP MODELING

### A. Buck converter modeling

Buck converter with mosfet switching device which is operating with the switching period of T and duty cycle D Figure1 [5]. The state equations corresponding to the converter in continuous conduction mode (CCM) can be understood by using Kirchhoff's voltage(KVL) law on the loop containing the inductor and Kirchhoff's current(KCL) law on the node with the capacitor branch connected to it. When ideal switch is ON, Dynamics of the inductor current  $I_L(t)$  and capacitor voltage  $V_C(t)$  are given by the following equations

$$dI_L/dt = 1/L_1(V_{in}-V_o), 0 < t < dT, Q:ON$$

$$dV_o/dt = 1/C_1(I_L-V_o/R_1)$$

and when switch is OFF, the equation will be

$$dI_L/dt = 1/L_1(-V_o), dT < t < T, Q:OFF$$

$$dV_o/dt = 1/C_1(I_L-V_o/R_1)$$

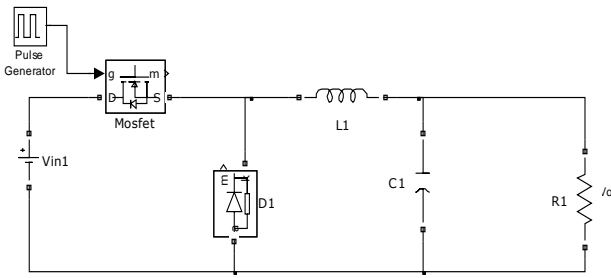


Fig. 1. Buck converter

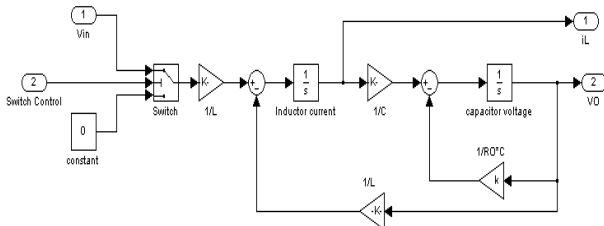


Fig. 2. Open Loop modeling of buck converter

These equations can be implemented in MATLAB/SIMULINK shown in Fig. 2 by using summing blocks, multiplier blocks and gain blocks and fed towards two integrators for obtain the states  $I_{L1}(t)$  and  $V_{C3}(t)$  [1]-[4].

**B. Boost Converter Modeling**

Boost converter in Fig. 3 with duty cycle of D and total switching period of T is given. We have to assume continuous conduction mode(CCM) of operation, so the state-space equations when the mosfet switch is ON are shown by following equations [5].

$$dI_{L2}/dt = 1/L2(V_{in}), 0 < t < dT, Q:ON$$

$$dV_o/dt = 1/C2(-V_o/R2)$$

and when the switch is OFF

$$dI_{L2}/dt = 1/L2(V_{in}-V_o), dT < t < T, Q:OFF$$

$$dV_o/dt = 1/C2(I_{L2}-V_o/R2)$$

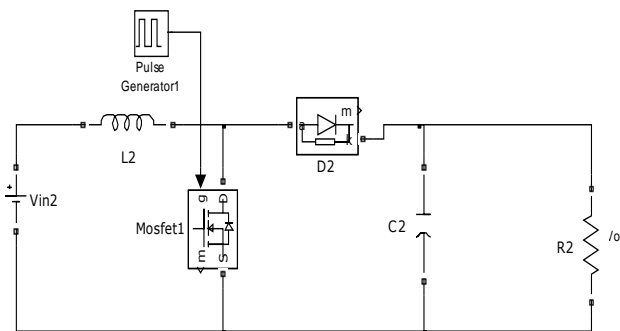


Fig. 3. Boost Converter

These equations can be implemented in MATLAB using summing blocks, multiplier block, gain blocks fed towards two integrators for obtain the states  $I_{L2}(t)$  and  $V_{C2}(t)$  [1]-[4].

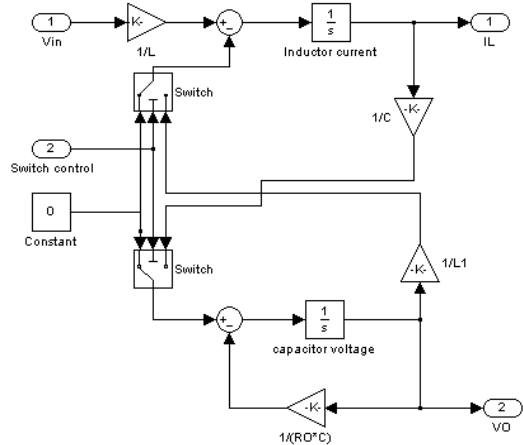


Fig. 4. Open-loop of Buck-Boost DC-DC Converters

**C. Buck-Boost Converter Modeling**

DC-DC buck-boost converter is shown in fig. 5. The switching period is T and the duty cycle is D. we have to assume CCM of the circuit operation, when the mosfet switch is ON, so the state-space equations are given by following equations [5].

$$dI_{L3}/dt = 1/L3(V_{in}), 0 < t < dT, Q:ON$$

$$dV_o/dt = 1/C3(-V_o/R3)$$

and when the switch is OFF

$$dI_{L3}/dt = 1/L3(V_o), dT < t < T, Q:OFF$$

$$dV_o/dt = 1/C3(-I_{L3}-V_o/R3)$$

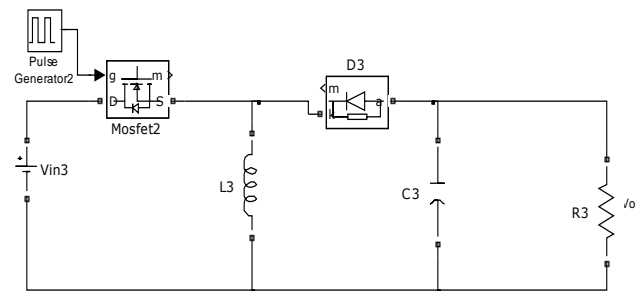


Fig. 5. DC-DC Buck-Boost Converter

These equations can be implemented in MATLAB/SIMULINK shown in Fig. 6 with the help of summing blocks, multiplier block and gain blocks, and fed towards two integrators to obtain the states  $I_{L3}(t)$  and  $V_{C3}(t)$  [1]-[4].

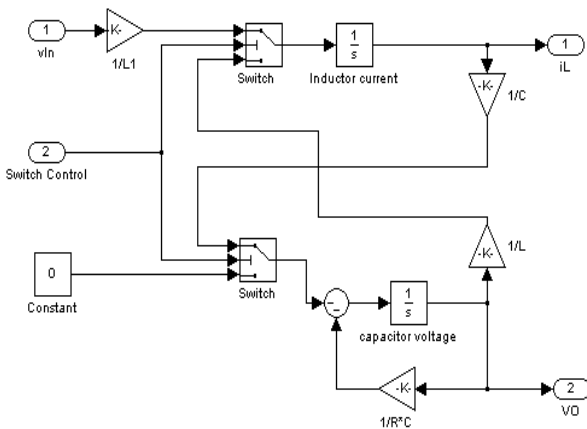


Fig. 6. open loop of buck-boost converter

**D. Subsystems**

All of the DC-DC converter models represent subsystems within the simulation. These blocks have been developed so they can be interconnected in a consistent and simple manner for the construction of complex systems. Relevant parameters can be set by double-clicking a mouse then entering the appropriate values in the resulting dialog window [2].

The PWM signal to control the mosfet switch can be built into the masked subsystem Fig. 7. For each converter to verify it's working in open loop control system trigger pulses have been derived using a duty cycle block and repeating sequence generator.

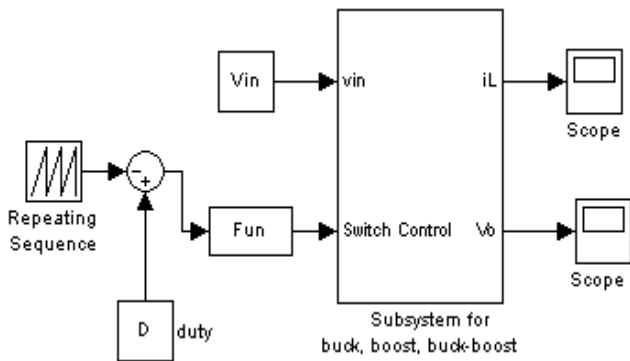


Fig.. 7. Buck, Boost and Buck-Boost converters with Subsystem

**4. CLOSE LOOP BOOST CONVERTER BY USING CASCADE CONTROL**

Cascaded control of DC-DC switching converters is build using simulation as shown in Fig.8. The DC-DC buck, boost and buck-boost converters were simulated by using MATLAB/SIMULINK with parameters shown in Table 1. The total harmonics distortion for open loop control simulation of all DC-DC converters are shown in Fig. 9. (1, 2, and 3).

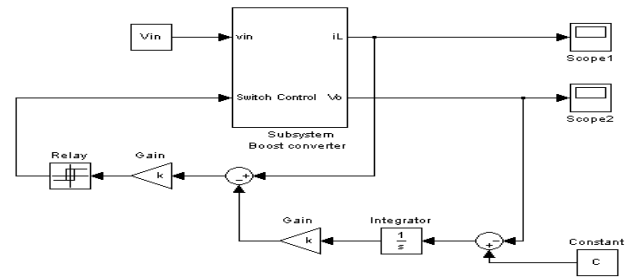


Fig. 8. Simulink of close loop Scheme of Boost converter using cascaded control

I. Table

| I. Table Buck, Boost and Buck-Boost converter parameters |           |          |          |         |                           |
|--|-----------|----------|----------|---------|---------------------------|
| Vin  | R1,R2, R3 | L1,L2,L3 | C1,C2,C3 | f       | Vo                        |
| 24.V,11V, 25V respectively                               | 14Ω       | 70 mH    | 222μF    | 120 KHz | 15V,25V, 34V respectively |

Close loop with cascade control for a boost converter shown in figure and the output voltage for boost converter increases up to 26.5V for the variation of load from 11Ω to 14Ω. The output voltage resumes reference value of 27.8V within 17ms after the transient variation. According to Fig. 8 the change in input 11V to 19V. The satisfactory condition is obtained in the output voltage which is rise up to 24.8V but it is suddenly fall to its reference value of 22V within 18ms so the close loop boost converter using cascade control gives stable operation of the power supply.

**5. RESULTS**

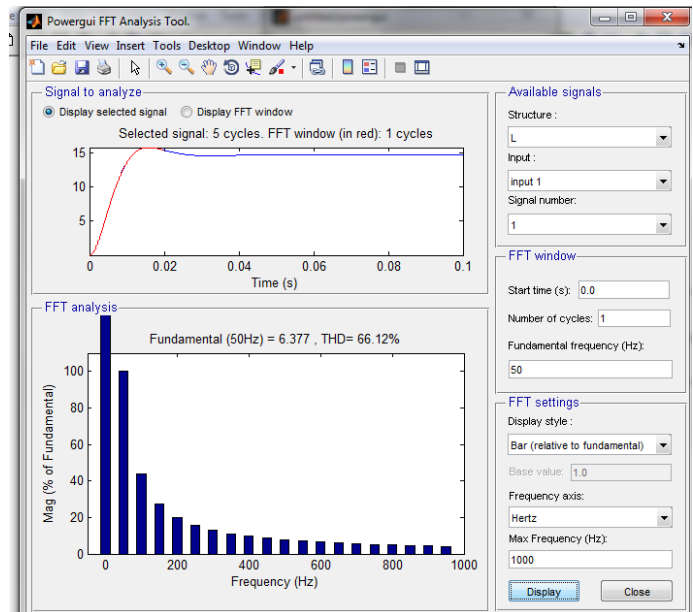


Fig. 1 Buck converter (THD= 66.12%)

7. REFERENCE

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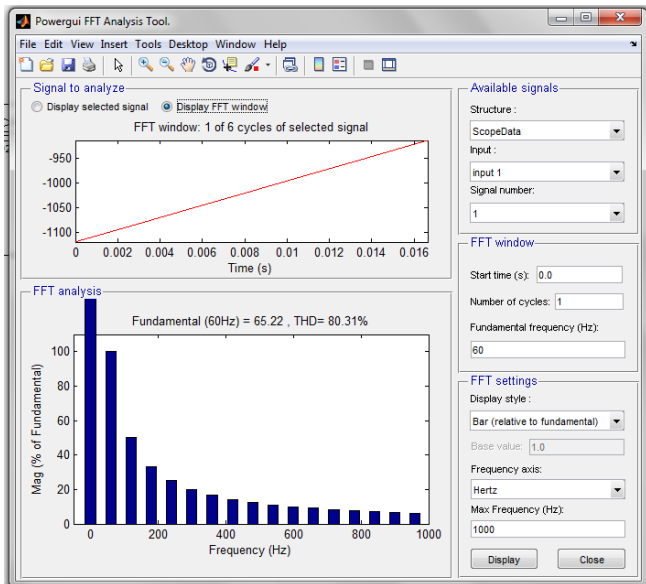


Fig. 2 Boost converter (THD=80.31%)

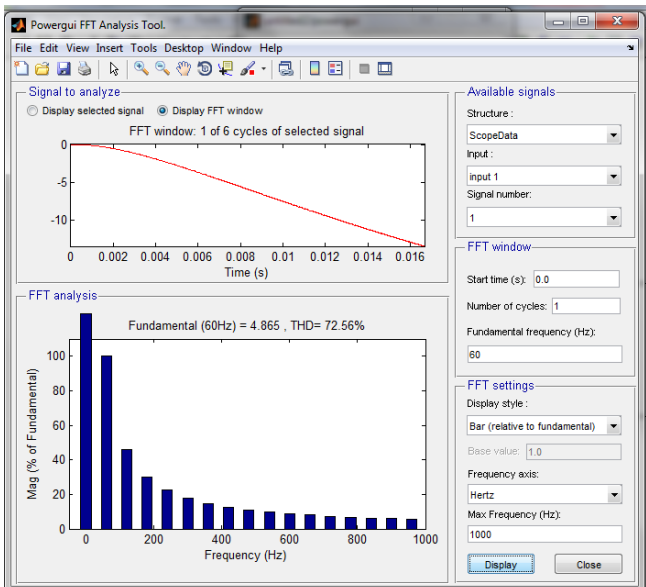


Fig. 3 Buck-Boost converter (THD=72.56%)

Fig. 9. Analysis of Total Harmonic Distortion(THD) for (a) Buck converter (b) Boost converter (c) Buck-Boost converter

6. CONCLUSION

In this paper we have analysis the state space model, nonlinear behavior for buck, boost, buck-boost converter. MATLAB/SIMULINK is useful to design the proposed circuit of the converters and it is suitable to learn dynamic or nonlinear behavior of different converter in open loop control scheme and the close loop boost converter is simulated using cascaded control. The simulation result show the inductor current and the output voltage can be return to steady state, when it is affected by input voltage and load variation with a very small overshoot and settling time.