Non Isolated Buck, Boost and Buck-Boost Converter via MATLAB/SIMULINK in Open and Closed Loop Environment

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Abstract— The design of power electronic converter circuit with the use of closed loop system require a modeling and then the simulating the converter using the modeled equations. This can simply done with the help of state equations and MATLAB/SIMULINK as a tool for simulation of those state equations. An attempt has been made in this paper to simulate all basic non-isolated power converters like buck, boost and buck-boost converter. So that these models can be readily used for any close loop design (say using pi, fuzzy, or sliding mode control etc.). Buck, Boost and Buck-Boost converter provides constant output which will control by PWM controller and feedback control system. Feedback control system has compensation network with different types and parameters. Based on parameters and controlling method, we have to decide stability analysis using Bode Plot. This analysis is done with the help of using MATLAB software.

Key words: Buck Converter, Boost Converter, Buck-Boost Converter, Pulse Width Modulation (PWM)

I. INTRODUCTION

Controller design for any system require proper knowledge about system behavior. Usually this comprises a mathematical description of the relation among inputs to the process, state variables, and output. This description in the form of mathematical equations which define behavior of the system (process) is called model of the system.\cite{11}This paper based on 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 set can be advantageously used to simulate power converters. This study aims at development of the models for all basic converters like buck, boost and buck-boost 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 \cite{1}\cite{2}\cite{3}.

In industrial application DC-DC converter is required to convert a fixed voltage DC source into a variable voltage DC source. The function of DC-DC converter converts directly from DC to DC and is simple called as a DC-converter. A DC-DC converter can be consider as ac transformer with a continuously variable turn’s ratio. The function of ac transformer is step down or step up the voltage, same function doing by the DC-DC converter \cite{1}. The dc-dc converter is used as a power supply in a wide Variety of applications. Basically, there are two standard types Of dc-dc converters that are buck converter which decreases The voltage level and boost converter which increases the Voltage level from an input dc source. Alternatively, the Buck-boost converter, which has abilities of either decreasing Or increasing the voltage level from an input dc source, is a Combination of buck converter and boost converter.\cite{1}\cite{2}

II. PULSE WIDTH MODULATION (PWM)

A. Waveform of PWM

The duty cycle $k$ can be obtain by comparing a dc reference signal $v_r$ with a saw tooth carrier signal $v_{cr}$. This is shown in fig.2.1.4, where $V_r$ is the peak value of $v_r$, and $V_{cr}$ is the peak value of $v_{cr}$. The reference signal $v_r$ is given by \cite{11}

$$v_r = \frac{V_r}{t}$$

Which must equal to the carrier signal

$$v_{cr} = V_{cr} = kT.$$ 

That is, $V_{cr} = \frac{V_r}{T} kT$

Which gives the duty cycle $k$ as

$$k = \frac{V_{cr}}{V_r} = M$$

![Fig. 2: modeling of PWM](image_url)

![Fig. : waveform of PWM](image_url)
### III. BUCK CONVERTER

Buck converter is one kind of switch mode non-isolated DC-DC converter. In the buck converter, the average output voltage (V<sub>o</sub>) is less than the input voltage (V<sub>i</sub>), hence the name “buck” and it is called as buck converter. In simply we can say the buck converter is one kind of step down converter which is decreases the voltage [1].

**Fig.:** Equivalent circuit of buck converter

**Fig.:** Open loop modelling of buck converter

**Fig.:** Waveform of open loop buck converter

#### A. Closed loop buck converter

Simulink model of closed loop Buck converter shown in the below block diagram. Closed loop Buck converter is completed with the help of three main components that is the following [11]:
- A/D converter
- Discrete time integral compensator
- Digital PWM

A Simulink modeling of closed loop Buck converter is same as the open loop Buck converter only the feedback path is provided in the closed loop Buck converter. In closed loop converter also provide the digital controllers. These all controllers introduce above. The voltage stability of closed loop Buck converter is better than the open loop Buck converter. Shown the wave form output voltage for closed loop Buck converter in fig. 2.1.8. Formulating state equation for Simulink model is same for the closed loop Buck converter as well as open loop Buck converter. [11]

In the closed loop Buck converter input voltage is 12V and the output voltage of the Buck converter is less than the input voltage that is the 4.99V shown in the output voltage wave form of the closed loop Buck converter.[4][11]

\[
\frac{d i_L}{dt} = \frac{1}{L} (V_g d - i_L R_L - v_o)
\]

\[
v_c = v_c + R_{\text{eff}} (i_L - i_{\text{out}})
\]

\[
\frac{dv_c}{dt} = \frac{1}{C} (i_L - i_{\text{out}})
\]

**Fig.:** Modelling of closed loop buck converter

**Fig.:** Waveform of closed loop buck converter (output voltage)

**Fig.:** Waveform of inductor

**Fig.:** Equivalent circuit of boost converter

**Fig.:** Waveform of open loop boost converter (output voltage)

#### B. Boost converter

Boost converter also one kind of switch mode non isolated DC-DC converter. In boost converter the output voltage is higher than the input voltage hence the name “boost” and it is called as boost converter. In simply we can say the boost converter is the step up converter which is increases the voltage.[1][2][3]
C. Buck-boost converter

Buck-boost converter is the combination of two converter buck-converter and boost-converter. Shown in the below diagram. Buck-boost converter is also one kind of switch mode non-isolated DC-DC converter. In this converter both the function step down voltage and step up the voltage. A buck-boost converter provides an output voltage that may be less than the input voltage or may be greater than the input voltage hence the name “buck-boost”; the output voltage polarity is opposite to that of the input voltage polarity. This converter is called as an inverting converter. [1][2][3]

D. Bode plot[4]

% Bode plotter using linearization tool requires simulink control design toolbox mdl = buckcpm4vmodetester'; % set to file name of simulink model. Must have i/o points set within this model Io = getlinio.mdl); % get i/o signals of mdl op = operspec.mdl); op = findop.mod,op) % calculate model operating point lin = linearize(modl,op,io) % compute state space model of linearized system LtiVIEW(lin) % send linearized model to LTI Viewer tool[11]

- Save this as a script (".m file") and run it at any time you want to generate a Bode plot
- This script discover the steady-state operating point and linearizes the model
- The end(last one) line opens the LTI Viewer tool, which generates various small-signal plots including Bode, step response, pole/zero, Nyquist, etc.

REFERENCE