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Modeling and Design of High Quality Boost Converter with Conventional Converter

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ABSTRACT

In this paper the derivation of state feedback gain matrix for Boost converter under continuous time are explained using pole placement method. Similar to the Observer controller for Buck converter, the derivation of the observer controller for the Boost converter under both the continuous and discrete time domain is derived. The simulation and results are also presented.

I. Design of Boost Converter

In this section the design and state space modeling of the Boost converter is explained and the schematic diagram of a Boost converter is shown in the Figure 1. In this converter, the output voltage is always greater than the input voltage. It has a very simple structure, continuous input current, step up conversion ratio and it also has a clamped voltage stress and more over clamped switch voltage stress to the output voltage.

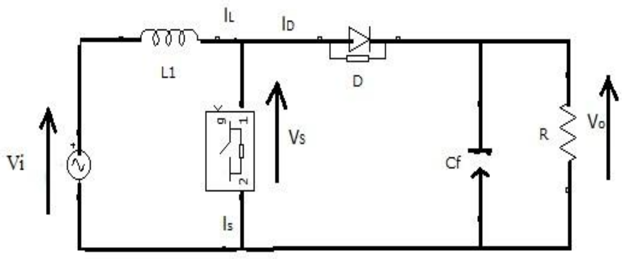


Figure1: Schematic diagram of the Boost converter

II. Modeling of Boost Converter

The output voltage is given by,

$$V_0 = \frac{V_S}{1-d} \quad \text{..................(1)}$$

The inductor and capacitor values of the Boost converter are derived by having the same assumption as that of the Buck converter. Now the critical value of the inductor L_C which decides the condition for the Continuous current mode of the operation is given by,

$$L_C = \frac{d(1-d)R}{2f_s} \quad \text{.....................(2)}$$

Where f_S is the switching frequency. The inductor value is determined by using the following equation,

$$\Delta I_L = \frac{V_s d}{f_s L} \text{..................(3)}$$

Similarly the capacitor value can be determined by assuming appropriate ripple voltage and by substituting the necessary values in the following equation:

$$\Delta V = \frac{I_o d}{f_s C} \text{............(4)}$$

In this type of converter, a very high peak current flows through the switch. It is very difficult to attain the stability of this converter due to high sensitivity of the output voltage to the duty cycle variations. When compared to Buck converter the inductor and capacitor sizes are larger since high RMS current would flow through the filter capacitor. Based on the above discussion the parameters designed for Boost Converter is shown in Table1.

Table 1 Design values of Boost converter

S.No	Parameters	Design Values
1	Input Voltage	24 V
2	Output Voltage	50 V
3	Inductance, L	72 μH
4	Capacitance, C	$216.9X10^{-6}$ F
5	Load Resistance, R	23 Ω
6	Switching frequency, f_S	20 kHz

The design details of Boost converter are perceived above and using the designed values the open loop response of the Boost converter is obtained and shown in the Figure 3.2, where the peak overshoot and steady error are found to be maximum. The voltage ripples are also observed which requires the design of closed loop control.

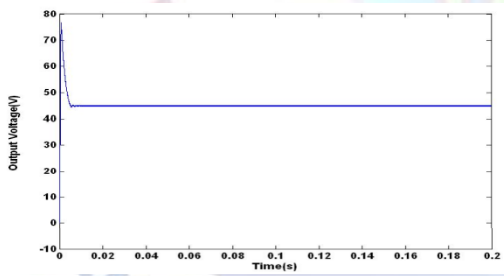


Figure 2 : Open loop response of Boost converter

III. State Variable Representation of Boost Converter

The differential equations describing the Boost converter can be explained in the following section by assuming two modes of operation. The inductor current, I_L and the capacitor voltage, V_O are the state variables. The semiconductor Switch is in on condition for the time interval, $0 \le t \le T_{On}$ and hence the inductor L gets connected to the supply and stores the energy. Since the diode is in off condition, the output stage gets isolated from the supply. Here the inductor current flows through the inductor and completes its path through the source. The equivalent circuit for this mode is shown in the Figure 3.

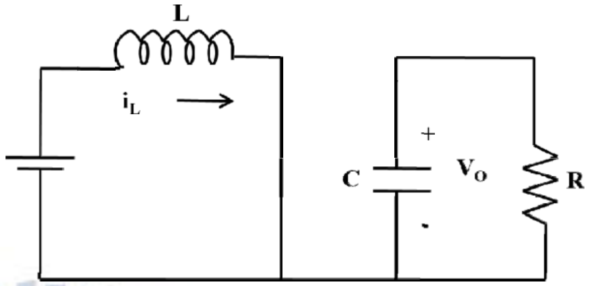


Figure 3 Equivalent circuit of Boost converter for mode 1

Applying Kirchhoff's laws, the following equations describing mode1 are obtained as, $\frac{di_L}{dt} = \frac{V_s}{L}$

$$\frac{dV_0}{dt} = -\frac{V_o}{RC}$$

Now the coefficient matrices for this mode are obtained as,

$$A = \begin{bmatrix} 0 & 0 \\ 0 & -1/_{RC} \end{bmatrix}$$

$$B = \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix}$$

During the time interval $T_{On} \le t \le T$, the diode is in on state and the switch is in off state and hence the energy from the source as well as the energy stored in the inductor is fed to the load. The inductor current flows through the inductor L, the capacitor C, the diode and the load. The equivalent circuit for this mode is shown in Figure 3.4.

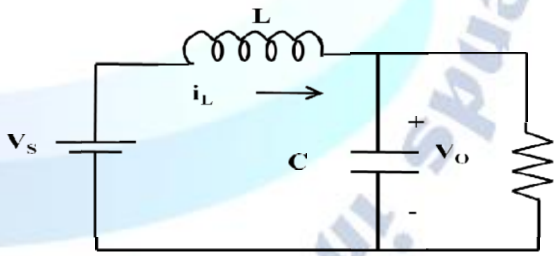


Figure 4 Equivalent circuit of Boost converter for mode 2

Applying Kirchhoff's laws, the following equations describing mode 2 are obtained,

$$\frac{di_L}{dt} = \frac{V_s}{L} - \frac{V_0}{L}$$

$$\frac{dV_0}{dt} = \frac{i_L}{C} - \frac{V_o}{RC}$$

The coefficient matrices for this mode is defined as follows,

$$A = \begin{bmatrix} 0 & \frac{-1}{L} \\ \frac{1}{C} & -1/_{RC} \end{bmatrix}$$

$$B = \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix}$$

The output voltage V_O *(t)* across the load is expressed as,

$$V_o(t) = [0 \quad 1]x(t)$$

Thus the design and modeling of the Boost converter has been done which further leads to the design of Observer controller. In the next section, the derivation of the state feedback matrix for the Boost converter is carried out which is the first step for the design of Observer controller transfer function. By substituting the values of *L* and *C* thus designed, the state coefficient matrices for the Boost converter is obtained as follows:

$$A = \begin{bmatrix} 0 & -6944.33 \\ 6944.33 & -200 \end{bmatrix}$$

$$B = \begin{bmatrix} 13.8887 \times 10^3 \\ 0 \end{bmatrix}$$

C=[0 1]

D=[0]

The general derivation of the state feedback matrix for the DC-DC converter has already been discussed in detail in above. Now in this section, the state feedback gain matrix for the Boost converter is explained as follows. The root locus of the Boost converter under continuous time is drawn as shown in the Figure.5. The open loop poles of the Boost converter is shown by cross in the figure. The desired poles are arbitrarily placed in order to obtain the state feedback matrix.

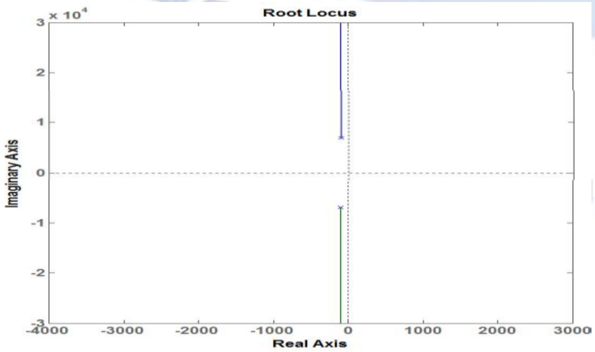
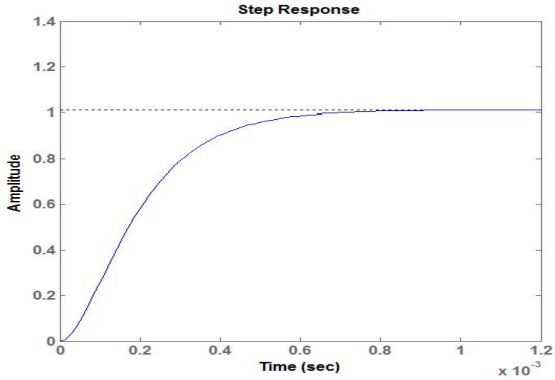


Fig 5 Root locus of Boost Converter in S-domain

The derivation of the state feedback matrix for the Boost converter is carried out in same manner as that for the buck converter using pole placement technique which has already been explained in the second method. Now ,the state feedback matrix for the Boost converter is derived as follows:

$$V_0 = \frac{V_s}{1-d}$$

In order to check the robustness of the control law,the step input is used and the output response has been illustrated in the figure3.from the figure6,it is very well understood that the system settles down faster and the state feedback matrix is capable enough to realize the stability of the boost converter.



IV. Results and Discussion of Boost Converter (Continuous Time Domain)

In this paper clearly explain the derivation of the Observer controller for the Boost converter under continuous time domain. Now the simulation results are exemplified and are discussed in detail. The design and the performance of Boost converter is accomplished in continuous conduction mode and simulated using MATLAB/ Simulink. The ultimate aim is to achieve a robust controller for the Boost converter in spite of uncertainty and large load disturbances. The performance parameters of the Boost converter under consideration are rise time, settling time, maximum peak overshoot and steady state error, which are shown in the Table1. It is evident that the converter settles down at 0.015 s and the rise time of the converter is 0.01s. No overshoots or undershoots are evident and no steady state error is observed. The simulation of the Boost converter is also carried out by varying the load, not limiting it to *R* load and it is illustrated in the Table.

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