Input Voltage Feed Forward Based TSBB Converter

M.Sujith, A.Mahendran

Abstract — Two switch buck boost (TSBB) converter is suitable to achieve high efficiency over the entire input range .It operates in buck at high input voltage and boost mode in low input voltage. The objective of this paper is to propose an input voltage feed forward technique to reduce the influence of input voltage disturbance on the output voltage of the buck boost converter. The small signal models of TSBB converter are built and IVFF functions under different operating modes of the TSBB converter are derived. The two mode control scheme with IVFF compensation is then proposed for the TSBB converter, which realizes automatic selection of operating modes. TSBB converter has improved input transient response and high efficiency over the entire input voltage range with proposed control scheme.

Keywords: Input voltage feed-forward, small-signal model, two mode control, two switch buck boost converter.

I. Introduction

Compared with the basic converter like Cuk, Zeta, and SEPIC converter, two switch buck boost converter have the ability of both step up and step down with low voltage stress. Two switch buck boost converter there are two switches which are operated independently. When Q_1 and Q_2 switch ON and OFF simultaneously it operate similar to the single switch buck boost converter. This is called one mode control scheme. When input voltage is greater than the output voltage Q_2 is always kept off and Q_1 is control to regulate the output voltage at the mean time TSBB converter is equivalent to a buck converter and other side input voltage is less than the output voltage Q_1 is always kept ON and Q_2 is control to regulate the output voltage Q_2 is always kept off and Q_1 is control to regulate the output voltage at the mean time TSBB converter is equivalent to a buck converter and other side input voltage is less than the output voltage Q_1 is always kept ON and Q_2 is control to regulate the output voltage. Compare with one mode control scheme two mode control scheme reduce the conduction loss and switching loss. In two mode control scheme with automatic mode switching there is only one voltage regulator is enough for both buck and boost modes. To improve the transient response of TSSB converter, average current mode control, current programmed mode control and voltage programmed mode control with two mode proportional-integral-derivative(PID) type-111(2-zeros and 3-poles) compensator, or passive RC-type damping network are employed.

M.Sujth is working as Senior Assistant Professor in Department of EEE, IFET College of Engineering, Villupuram, India, Email: sujiifet@yahoo.in
A.Mahendran is working as Assistant Professor in Department of EEE, IFET College of Engineering, Villupuram, India, Email: mahendran3836@gmail.com

By this two mode control scheme method (Fig.1), the influence of the input voltage and load disturbance on the output voltage can be reduced, but cannot fully eliminated. IVFF compensation is very attractive approach for improving the transient response of the converter.

It has been achieved by varying the peak and valley values of carrier signal in proportional to the input voltage. In this paper section II introduces the two mode control scheme with mode switching ability for TSBB converter, and section III derives its small signal models are derived. Section IV presents the simulation circuit and its output and finally, section V concludes this paper

II. INPUT VOLTAGE FEED FORWARD METHODS

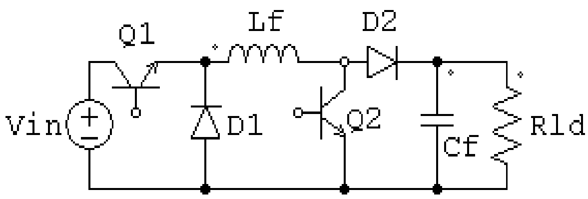


Fig.1. Two switch buck boost converter

Method 1:
It can be implemented in several methods. By varying the amplitude of carrier signal and the modulation signal according to the output voltage. Implementation of this method is complicated for TSBB converter.
Method 2:
It was done by calculating the duty ratio for each inverter. This calculating of buck converter inversely proportional to the input voltage .It is little complicated relatively in TSBB converter.
Method 3:
IVFF function producing zero audio susceptibility through the small signal mode. It has been achieved by varying the peak of valley value of the carrier signal in proportional to input voltage in buck and boost converter mode .In this method the selection of switching of operation modes and IVFF compensation are not automatic

III. TWO MODE CONTROL SCHEME WITH AUTOMATIC MODE SWITCHING ABILITY

The voltage conversion of the TSSB converter operated in continuous current mode is

$$V_0 = d_1 / 1\text{-}d * V_{in} \quad (1)$$

Where d_1 and d_2 are the duty cycle of switches Q_1 and Q_2 respectively. In two mode control scheme, d1 and d_2 are controlled independently. When the input voltage is higher than output voltage, the TSSB converter operates in buck mode where d_2=0, Q2 is always OFF, and d1 is controlled to regulate the output voltage. When the input voltage is lower than the output voltage, the TSSB converter operates in boost mode d_1=1,Q_1 is always ON and d_2 is controlled to regulate to output voltage. Two mode control scheme based on two modulation signal and one carrier signal. The maximum and minimum values of the carrier are V_h and V_l and the peal value of carrier is $V_{saw}=V_h-V_l$.Where, V_H peak voltage and V_L is the valley voltage. It is based on input and output difference with carrier and modulation signal.

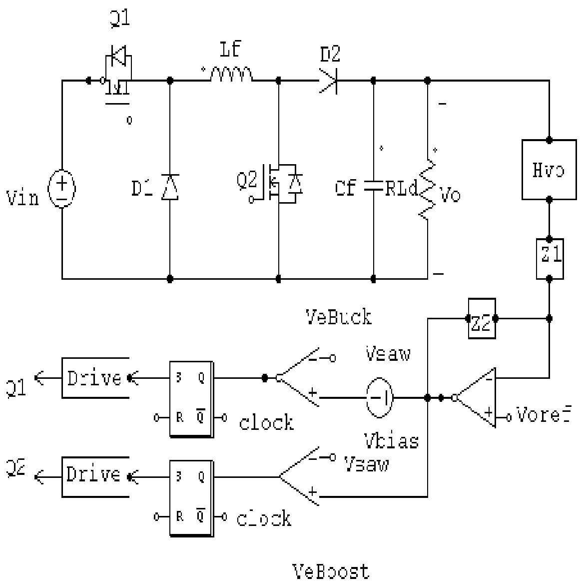


Fig.2. TSSB converter under the two mode control scheme

TABLE I
OPERATING MODES

MODES OF OPERATION	S1	D 1	S 2	D 2
BUCK	ON	C	OFF	0
BOOST	ON	1	ON	C

C-Controlled, **S**-Switch, **D**-Diode

IV. IVFF FOR TWO MODE CONTROL SCHEME

A. Derivation of DC and small signal models of the TSBB converter

In the average switch model of a dc-dc converter, the switch is modelled by a controlled converter source with the value equaling to average current flowing through the switch where $i_{q1}=d_1i_l$ and $i_{q2}=d_2i_l$,which are the average currents flowing through switches q_1 and q_2, respectively and V_{D1}=Vin and $V_{D2}=V_0$, which are the average voltages across diodes D_1 and D_2, respectively. The average values of voltage , current , and duty cycle in the averaged switch model can be decomposed into their dc and ac components ,so i_{Q1}, i_{Q2},V_{d1},V_{d2} can expressed as

$$i_{Q1} = I_{Q1}+I_{Q2} = (D_1+d^1) (I_l+ i_l)$$

$$= D_1I_l+D_1i_l+d_1I + D_1i_l \quad (2)$$

$$i_{Q2} = I_{Q2}+i_{Q2} = (D_2 + d_2) (I_L + I_L)$$

$$= D_2I_l+D_2i_l+d_2I_l+d_2i_2 \quad (3)$$

$$V_{D2} = D_1+V_{D1}=(D_1 + d_1)(V_{in} + vin)$$

$$= D_1V_{in} + D_1V_{in} + d_1Vi_n+d_1v_{in} \quad (4)$$

$$V_{D2} = V_{D2} + V_{d2} = (D_2 + d_2)(V_o + V_o)$$

$$= D_2Vo + D_2Vo + d_2Vo+ d_1Vo \quad (5)$$

denotes the small signal perturbation. The small signal model of TSBB converter can obtained by first order dc component.

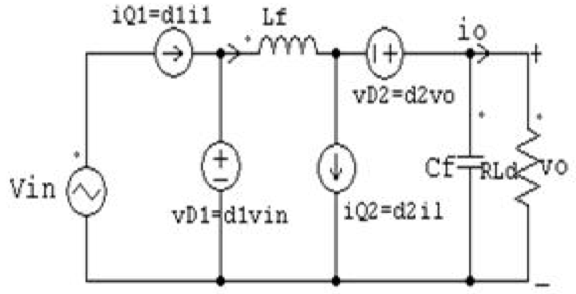


Fig.3(a) Average switch model

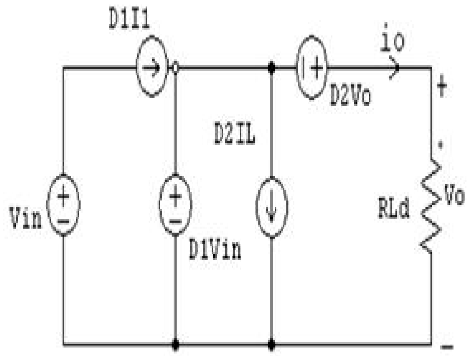


Fig.3(b)DC model

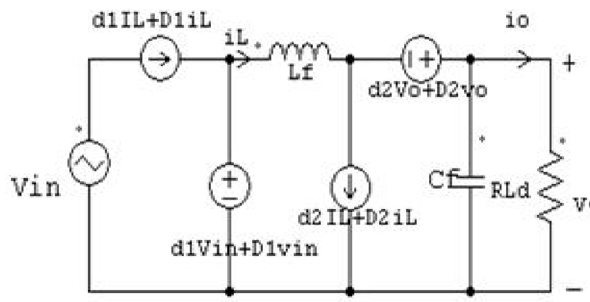


Fig.3(c) Small signal model

The average value in (2)-(5) can solved by neglecting the second order ac terms (1). Then the dc models of TSBB converter can be obtained by replacing the average values in Fig 3(a) with dc components in (2)-(5) shown in Fig 3(b). The inductor Lf is the short circuit and capacitor Cf is open circuit in the dc model. Similarly, by replacing the average value of in Fig 3(a) with first order ac components in (2)-(5), the small signal model of two switch buck boost converter can be obtained which has been illustrated in Fig.3(c) represents the small signal models in buck boost modes can be derived.

B. Two mode control scheme with Input voltage feed forward compensation

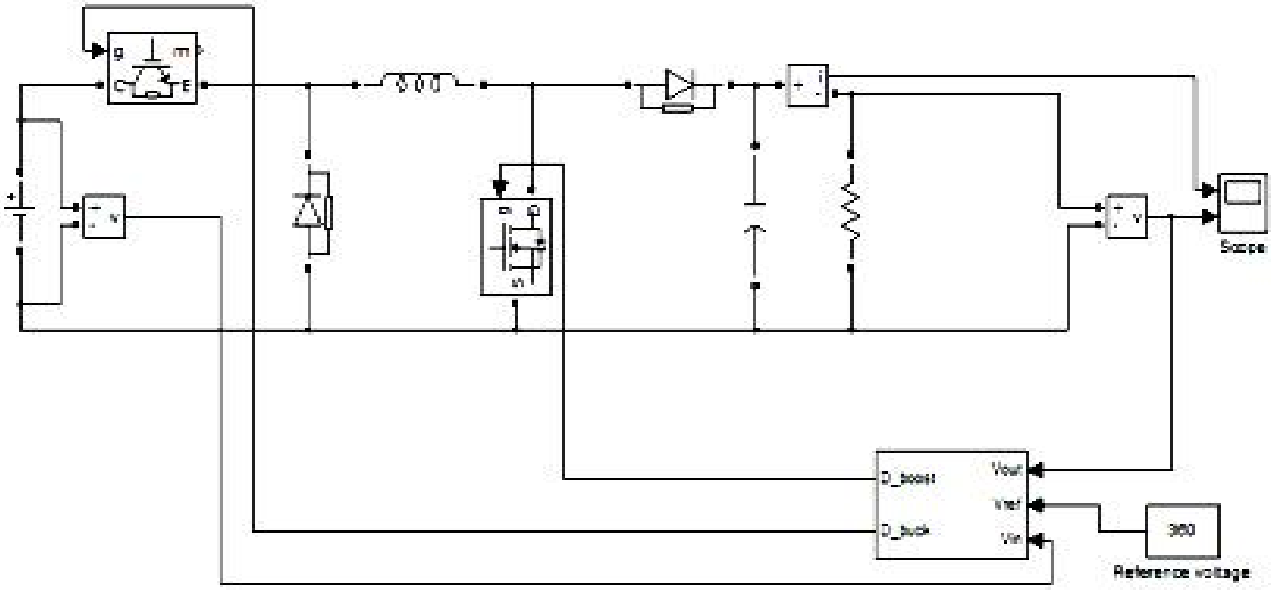
The TSBB converter can operate in buck boost mode, and the IVFF transfer for two operating modes are different, it is important to ensure that the Two switch buck boost converter operates in correct mode with correct input voltage feed forward transfer function and switches between the two modes automatically. The output signals of the Input voltage feed forward path under different operating modes can expressed as

$V_{ff\_buck} = G_{ff\ buck} V_{in} = -(V_0 / (V_{2in} - V_{dc}))\ \ V_{saw} V_{in}$ (6)

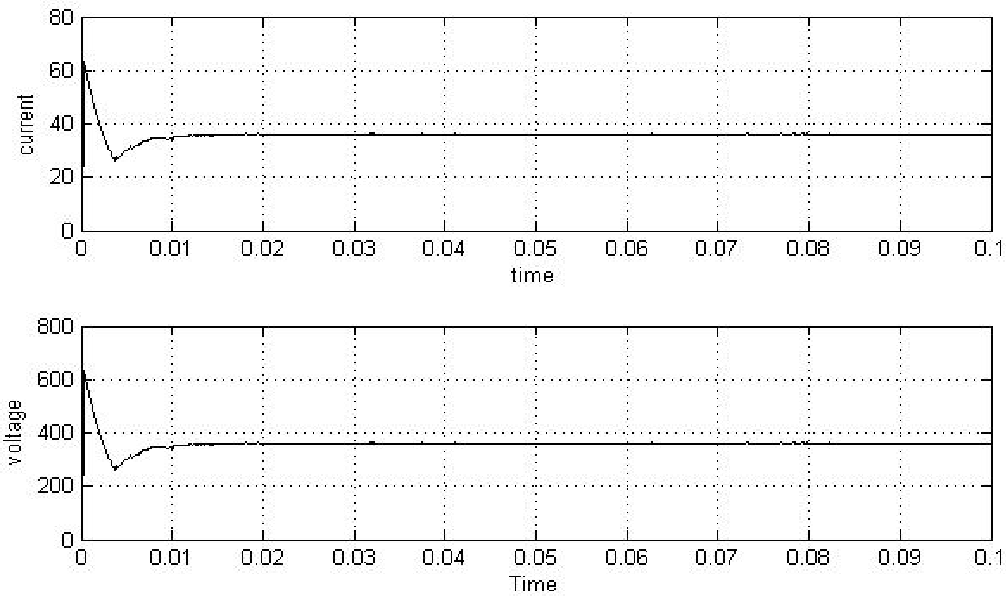
$V_{ff\_boost} = G_{ff\_boost} V_{in} = -(1 / V_0) V_{saw} V_{in}.$ (7)

V. SIMULATION RESULTS AND DISCUSSION

The output of the proposed converter has been verified by the use of mat lab software.



(a)



(b)

Fig.4.Proposed Simulation model and output

To verify the effectiveness of the proposed two mode control scheme with input voltage feed forward compensation, a 250-500V input, 360V output has obtained. In this paper the converter only operates on boost mode to step up the voltage.

VI.CONCLUSION

The small signal model for buck boost modes are built , based on detailed derivation of IVFF function under different operating modes .IVFF compensation is proposed to achieve automatic selection of operating modes for TSBB converter. The smooth switching operation can be achieved in this proposed model without switching losses Finally 250-500V input , 360 V output and 6 kw rated power prototype model is designed and verified using MATLAB simulation. High efficiency over the whole input output range and improved input voltage transient response are achieved for TSBB converter.

ACKNOWLEDGMENT

The author's are thankful to Management trustee Mr.V.Raja Chairman ,Mr.A.Mohamed Ilyas Vice chairman and Dr.G.Mahendran Principal, Prof S.Matilda Dean Academics, Prof J.Asha Dean Placement/ Student Affairs P.Pugazhendiran HoD/R&D, and R.Malar HoD/EEE, IFET College of Engineering, Villupuram for providing necessary facilities for the preparation of the paper.

REFERENCES

[1] R. W. Erickson and D. Maksimovic, *Fundamentals of Power Electronics*.Norwell, MA, USA: Kluwer, 2011.
[2] D. C. Jones and R. W. Erickson, "A nonlinear state machine for deadzone avoidance and mitigation in a synchronous noninverting buck-boost converter," *IEEE Trans. Power Electron.*, vol. 28, no. 1, pp. 467–480, Jan.2013.
[3] C. Yao, X. Ruan, and X.Wang, "Isolated buck-boost dc/dc converters suitablenfor wide input-voltage range," *IEEE Trans. Power Electron.*, vol. 26,no. 9, pp. 2599–2613, Sep. 2011.
[4] X. Ren, X. Ruan, H. Qian, M. Li, and Q. Chen, "Three-mode dual frequency two-edge modulation scheme for four-switch buck-boost converter," *IEEE Trans. Power Electron.*, vol. 24, no. 2, pp. 499–509, Feb.2009.
[5] Y. J. Lee, A. Khaligh, A. Chakraborty, and A. Emadi, "A compensation technique for smooth transitions in a noninverting buck-boost converter," *IEEE Trans. Power Electron.*, vol. 24, no. 4, pp. 1002–1016, Apr. 2009
[6] R. Redl and N. O. Sokal, "Near-Optimum dynamic regulation of dc-dc converters using feed-forward of output current and input voltage with current-mode control," *IEEE Trans. Power Electron.*, vol. PE-1, no. 3, pp. 181–192, Jul. 1986.
[7] P. C. Huang, W. Q. Wu, H. H. Ho, and K. H. Chen, "Hybrid buck-boost feedforward and reduced average inductor current techniques in fast line transient and high-efficiency buck-boost converter," *IEEE Trans. Power Electron.*, vol. 25, no. 3, pp. 719–730, Mar. 2010.
[8] J. J. Chen, P. N. Shen, and Y. S. Hwang, "A high efficiency positive buckboost converter with mode-select circuit and feed-forward techniques," *IEEE Trans. Power Electron.*, vol. 28, no. 9, pp. 4240–4247, Sep. 2013.
[9] Y. Liu and P. C. Sen, "A general unified large signal model for current programmed dc-to-dc converters," *IEEE Trans. Power Electron.*, vol. 9,no. 4, pp. 414–424, Jul. 1994.

BIOGRAPHY

M.Sujith received the B.E. degree in Electrical and Electronics Engineering and M.E. degree in Applied. He is currently pursuing Ph.D in the area of digital control engineering. He published 9 international journals, 2 books and presented papers in 6 national and international conferences. He is currently working at I.F.E.T College of Engineering as Senior Assistant Professor/EEE. His main research interests include power electronic converters, Harmonic compensators and digital controllers.

A.Mahendran received B.E. degree Electronics & Instrumentation Engineering and M.E. degree in Control and Instrumentation. He is currently working at IFET college of Engineering as Assistant Professor/EEE. He attended two international and one national conference. His main area of interest are control systems, nonlinear system and instrumentation.