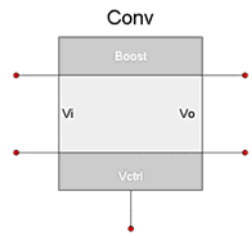

"Boost Converter" VTB Model

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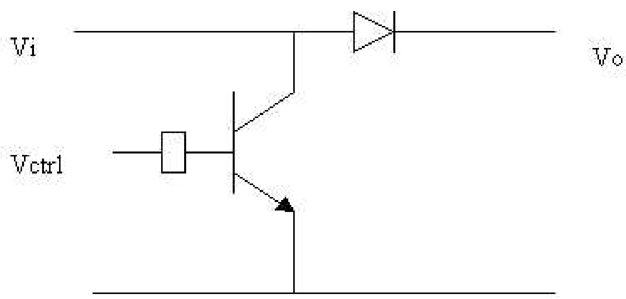
Date: 04/07/2002
Executable file name: BoostConverter.vtm
Version number: 1.0

Description

Indicated below in the figure is the switch topology, based on which BoostConverter model (no filter elements included) is developed. The switching waveform (without transients) is obtained according to the circuit behavior, the duty cycle inputs, and the frequency parameters.



Validity Range and Limitations

To have an input-to-output power flow, the conditions of Vi > (1-D)Vo and Vi > 0 should be satisfied. The range of duty cycle (Vctrl) is set from 0 to 0.98. Not included here are also switching transients and rating limits to voltage and power.

Connections

Label	Description
Terminal 0 & 1	Input connectors
Terminal 2 & 3	Output connectors
Terminal 4	Control connector

Adjustable Parameters

Name	Description	Valid Range	Default Value	Units
R_{ton}	Transistor on-resistance	(0,1)	1.0 E-3	Ohm
R_{toff}	Transistor off-resistance	> 1000	1.0 E8	Ohm
R_{don}	Diode on-resistance	(0,1)	1.0 E-3	Ohm
R_{doff}	Diode off-resistance	> 1000	1.0 E8	Ohm
f	Switching frequency	(0, 1/(10*timestep))	5000	Hertz

Output Variables

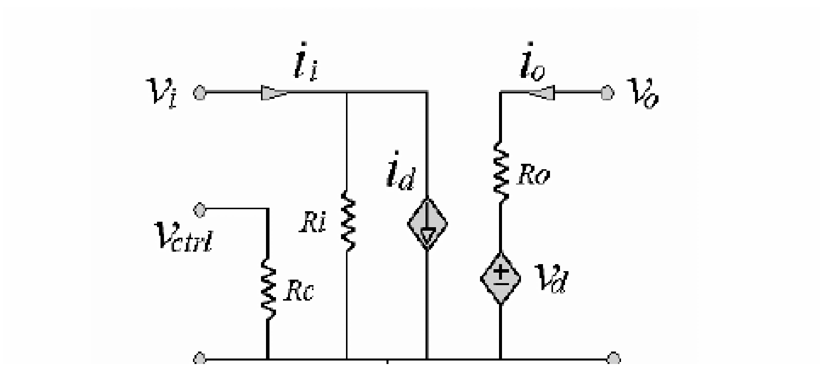
Name	Description	Units

Input Voltage Vi	Voltage at input terminals (V1-V2)	Volt
Input Current Ii	Current into the input terminal	Ampere
Output Voltage Vo	Voltage at output terminals (V3-V4)	Volt
Output Current Io	Current out of the output terminal	Ampere

Model Assumptions
Neither device physics nor parasitic parameters are included. An equivalent on-resistance is used in the case of forward bias of the switch while an off-resistance in the reverse bias.

Mathematical Description

Summarized below is the mathematical description of the behavior-modeling circuit. The voltage and the current sources shown in this model are time dependent and change with switching. The variation of these is explained by using the mathematical description summarized below.



$$i_i = \frac{Vi}{R_i} + i_d \quad (1)$$

$$i_o = \frac{1}{R_o}(V_O - V_d) \quad (2)$$

$$i_c = \frac{1}{R_c} V_{ctrl} \quad (3)$$

where the resistance of the transistor (R_{ton} and R_{toff}) is modeled by the input resistance R_i and the resistance of the diode (R_{don} and R_{doff}) is represented by the output resistance R_o.

R_c, an inaccessible parameter to users, is the base resistance of the transistor.

For $0 \le t < \frac{D}{f}$

$$i_d = 0$$
$$v_d = 0$$
$$R_i = \begin{cases} R_{ton} & \text{If Vi >0} \\ R_{toff} & \text{otherwise} \end{cases}$$
$$R_o = R_{doff}$$

For $\frac{D}{f} \leq t < \frac{1}{f}$

$$i_d = -i_o$$
$$v_d = v_i$$
$$R_o = \begin{cases} R_{don} & \text{If Vi >Vd} \\ R_{doff} & \text{otherwise} \end{cases}$$
$$R_i = R_{toff}$$

where D is the duty cycle and f is the switching frequency.

$$D = V_{ctrl} \qquad 0 \leq D \leq 1$$

Model Validation

Example Application

This example is to use the BoostConverters together with external filters.

Parameter values

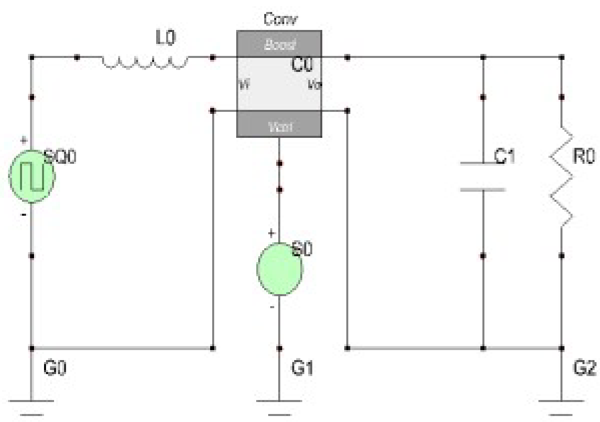
Square Source

magnitude:	10 Volts
resistance:	0.000001 Ohm
frequency:	1 Hertz
duty cycle:	100% (Note: so as to approximate the DC Source)

<u>BoostConverter</u>

R_{ton}	Transistor on-resistance	1.0 E-3 (Ohm)
R_{toff}	Transistor off-resistance	1.0 E8 (Ohm)
R_{don}	Diode on-resistance	1.0 E-3 (Ohm)
R_{doff}	Diode off-resistance	1.0 E8 (Ohm)

f	Switching frequency	5000 (Hertz)
Controller		
V_{ctrl}	Duty Cycle	0.75 (Volts)
Inductor		
L0	Inductance	0.4 (mH)
Capacitor		
C1	capacitance	0.6 (mF)
Load (resistor)		
R0	resistance	2 (ohm)
Simulation parameters		
Time step		1E-5 (s)



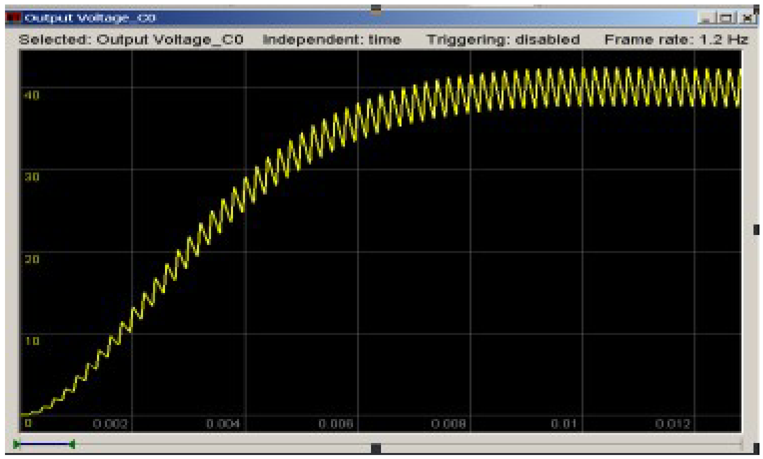
Model Verification

a) Relation of Outputs and Inputs

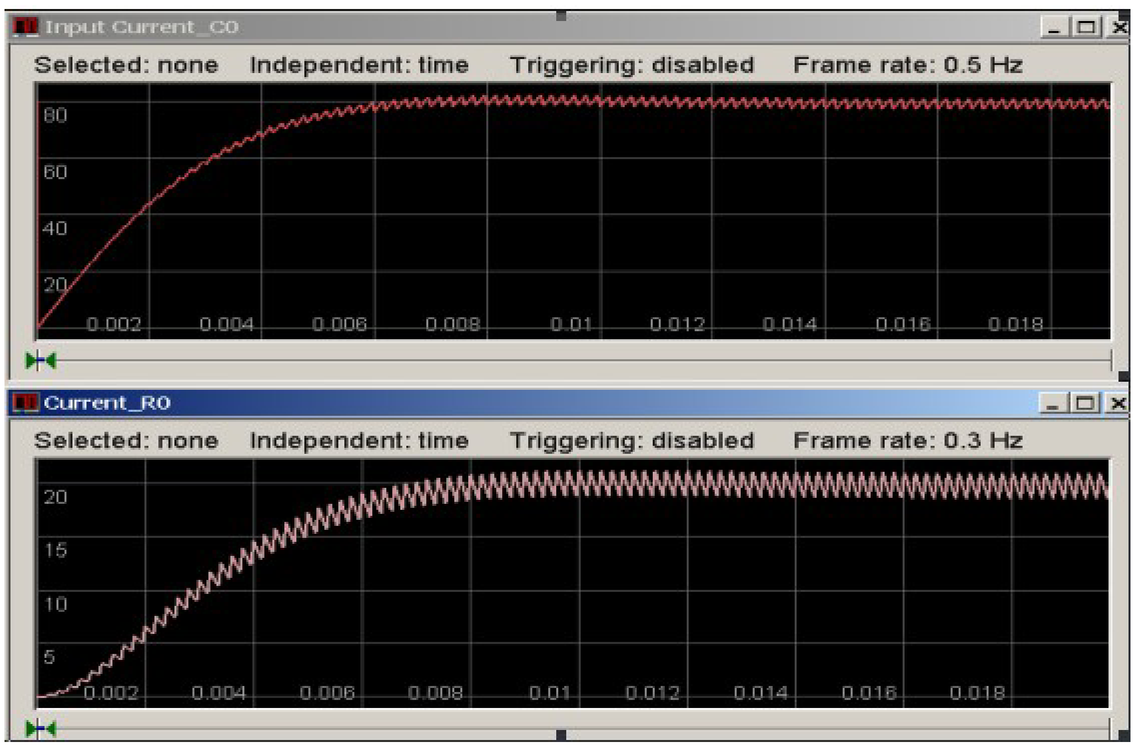
In the theoretical analysis: $V_o = \frac{V_i}{1-D}$

$$I_0 = (1-D) \cdot I_i$$

In the example: V_i=10 Volts and D=0.75, according to the theoretical prediction, the output V_o should be 40 Volts. After running simulation, the output voltage is right 40 Volts, thus verified.

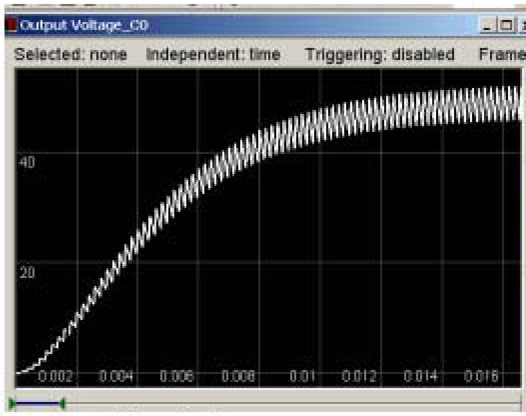


Similarly, the ratio of output current to input current gained after simulation is 20/80=0.25, matching the theoretical analysis $1-D = 0.25$, therefore verified.

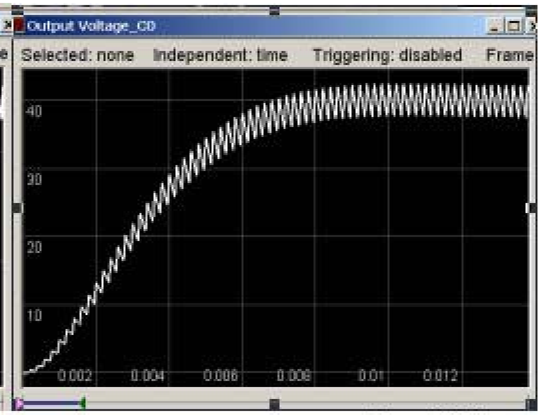


b) Duty Cycle Effect

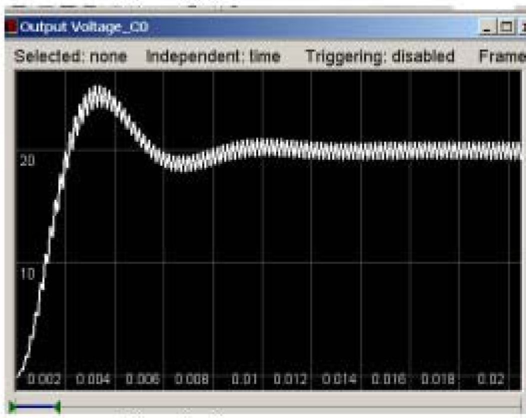
To see the duty cycle effect on the load voltage by decreasing the duty cycle.



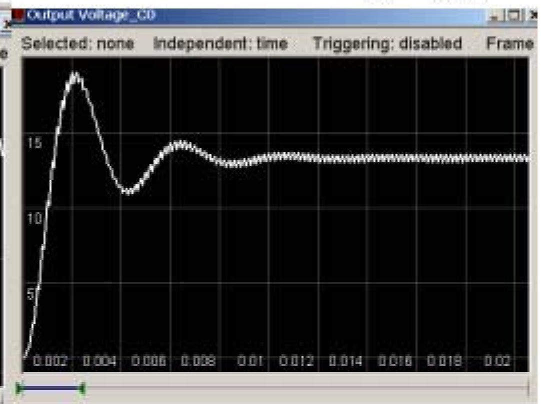
D = 0.8



D = 0.75



D = 0.5



D = 0.25

As can be seen from above, the relation of the input and output voltages always satisfies $V_o = \frac{V_i}{1-D}$.

References

- Dr. Liu, Shengyi (University of South Carolina) "Basic Boost Converter Model Helpfile"
- Erickson Maksimovic "Fundamentals of Power Electronics", 2nd Edition