English Research Express@NCKU Volume 22 Issue 5 - June 8, 2012
[http://research.ncku.edu.tw/re/articles/e/20120608/1.html]

Transformerless DC-DC Converters with High Step-up Voltage Gain

Lung-Sheng Yang, Tsorng-Juu Liang* and Jiann-Fuh Chen
Department of Electrical Engineering, College of Electrical Engineering and Computer Science, National Cheng Kung University

tjliang@mail.ncku.edu.tw

IEEE Transactions on Industrial Electronics, Vol. 56, No. 8, pp. 3144-3152, Aug. 2009.

Abstract -- Conventional DC-DC boost converters are unable to provide high step-up voltage gain due to the effect of power switches, rectifier diodes, and the equivalent series resistance of inductors and capacitors. A topology is presented to achieve high step-up voltage gain, as shown in Fig .1. However, this converter has two issues: 1) Three power devices exist in the current-flow path during the switch-on period, and two power devices exist in the current-flow path during the switch-off period, and 2) the voltage stress on the active switch is equal to the output voltage. This paper proposes transformerless DC-DC converters to achieve high step-up voltage gain without an extremely high duty ratio, as shown in Fig. 2. In the proposed converter, two inductors with the same level of inductance are charged in parallel during the switch-on period, and are discharged in series during the switch-off period. The structure of the proposed converter is very simple. Only one power stage is used. Compared with the converter in Fig. 1, the proposed converter has the following merits: 1) Two power devices exist in the current-flow path during the switch-on period, and one power device exists in the current-flow path during the switch-off period; 2) the voltage stresses on the active switches are less than the output voltage; and 3) under the same operating conditions, including input voltage, output voltage, and output power, the current stress on the active switch during the switch-on period is equal to the half of the current stress on the active switch of the converter in Fig. 1. Finally, to verify the performance of the proposed converter, a 40-W prototype circuit is built in the laboratory for use in an automobile headlamp application. The circuit specifications and components are selected as V_{in} = 12 V, V_o = 60 – 100 V, f_s = 100 kHz, P_o = 40 W, L_1 = L_2 = 100 μH, and C_o = 68 μF.

Under the conditions V_{in} = 12 V, V_o = 100 V, and P_o = 40 W, some experimental results are shown in Fig. 3. Fig. 3(a) shows that iL1 is equal to iL2. Moreover, the input current is equal to twice the level of the inductor current during the switch-on period, and is equal to the inductor current during the switch-off period. Fig. 3(b) shows the current waveforms i_{S1} and i_{S2}. As can be seen in Fig. 3(c), the voltage stresses on S_1 and S_2 are equal to $(V_o+V_{in})/2$. Fig. 3(d) shows the voltage and current of the output diode. Fig. 4 shows the dynamic response under the output power variation between 5-W light-load and 40-W full-load. One can see that the output voltage is well regulated. Fig. 5 shows the ideal and experimental voltage gains under V_{in} = 12 V, V_o = 60 – 100 V, and P_o = 40 W. Fig. 6 shows the experimental efficiency of the proposed converter and the converter in Fig. 1 under V_{in} = 12 V, V_o = 60 – 100 V, and P_o = 40 W. It is seen that the proposed converter has higher efficiency than the converter in Fig. 1.

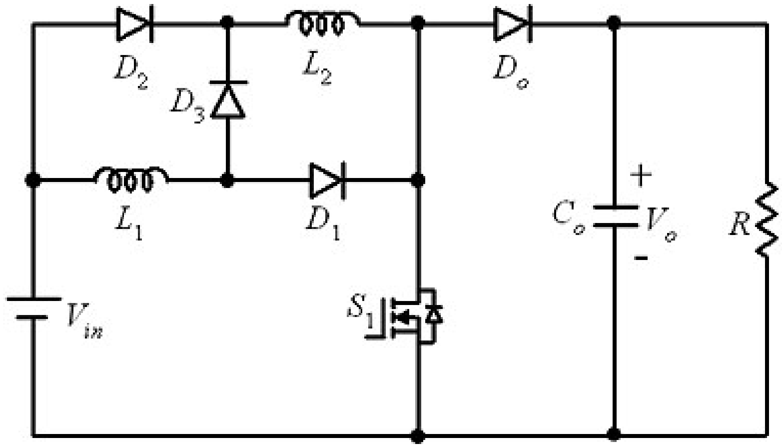

Fig. 1. Transformerless DC-DC high step-up converter. (Reference as follows)

B. Axelrod, Y. Berkovich, and A. Ioinovici, "Switched-capacitor/switched-inductor structures for getting transformerless hybrid DC-DC PWM converters," *IEEE Trans. Circuits Syst. I, Reg. papers*, vol. 55, no. 2, pp. 687-696, Mar. 2008.

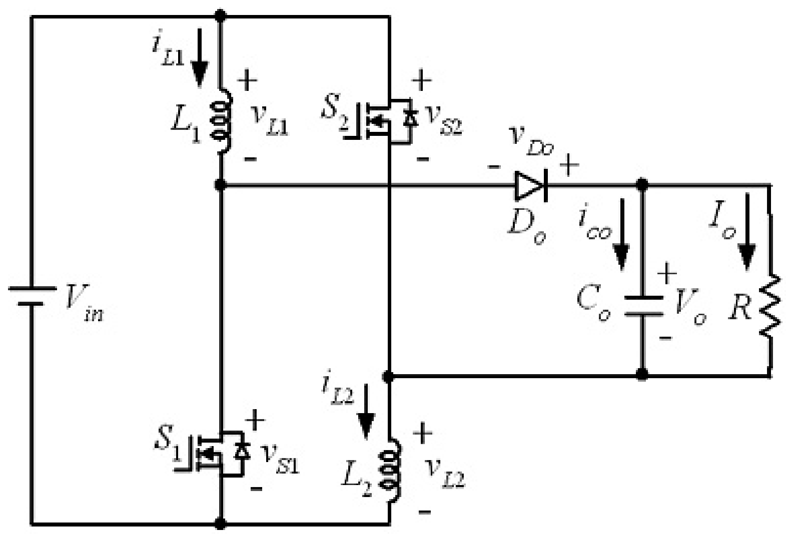

Fig. 2. Proposed high step-up DC-DC converter.

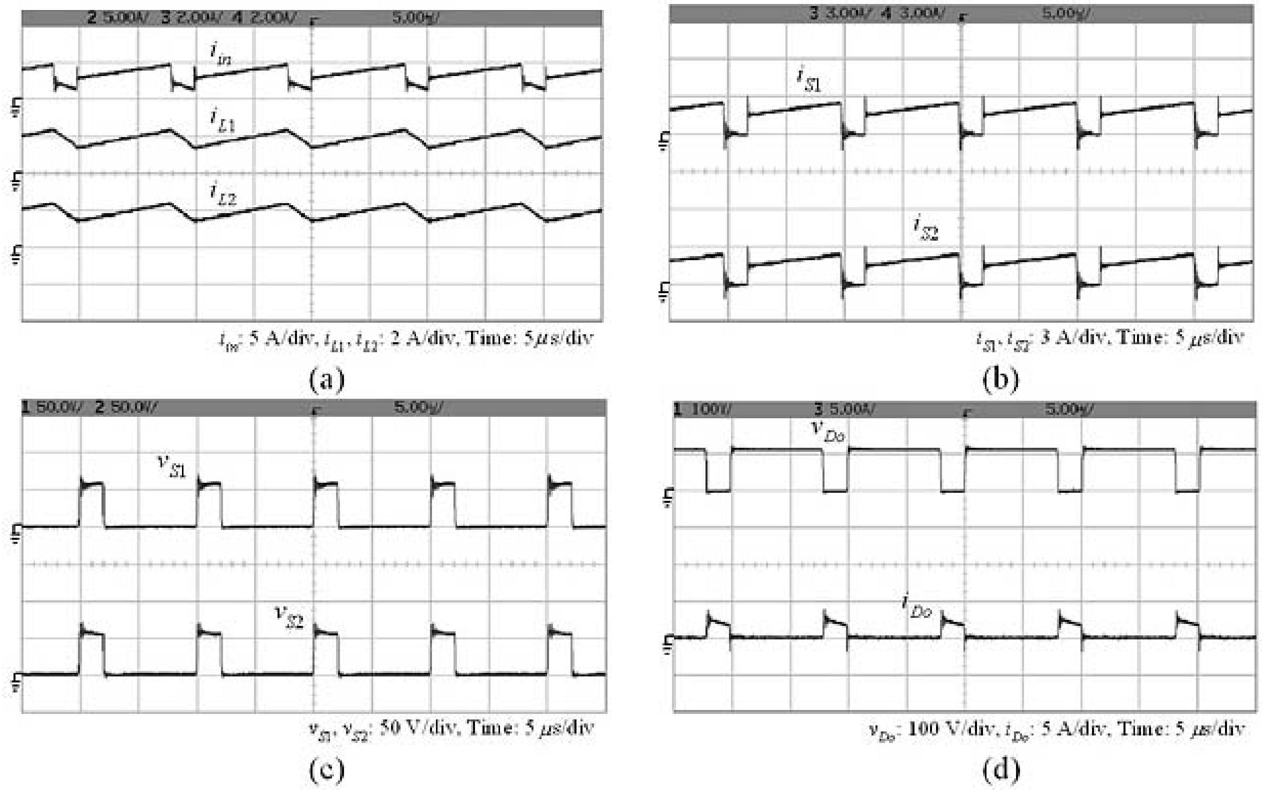

Fig. 3. Some experimental waveforms of the proposed converter.
(a) i_{in},i_{L1} and i_{L2} ; (b) i_{S1} and i_{S2} ; (c) v_{S1} and v_{S2} ; (d) v_{Do} and i_{Do}

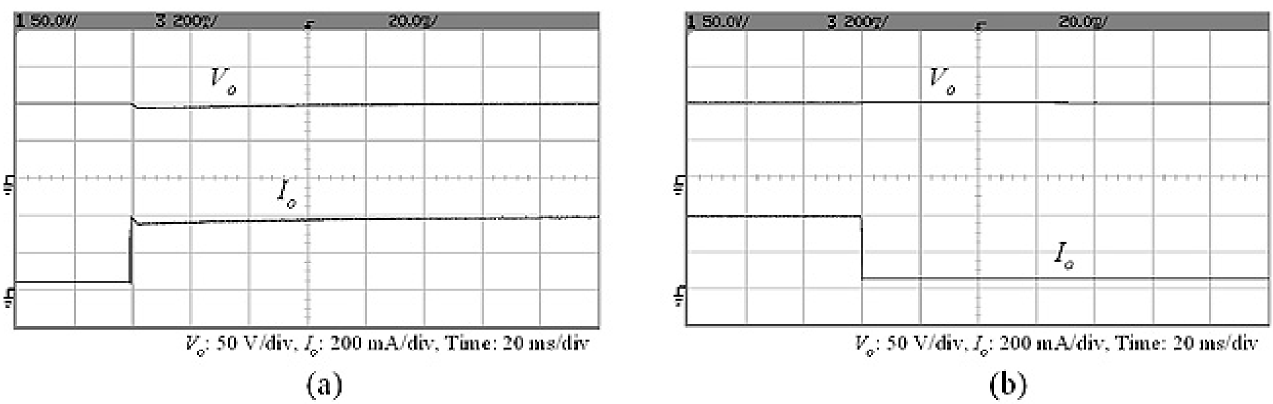

Fig. 4. Dynamic response of the proposed converter.
(a) P_o is charged from 5 to 40 W. (b) P_o is charged from 40 to 5 W.

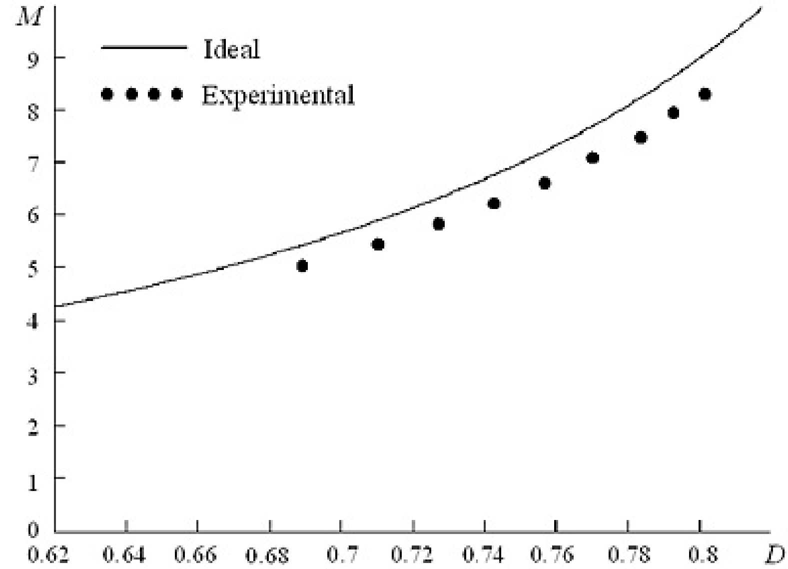

Fig. 5. Ideal and experimental voltage gain of the proposed converter under V_{in} = 12 V, V_o = 60 – 100 V, and P_o = 40 W.

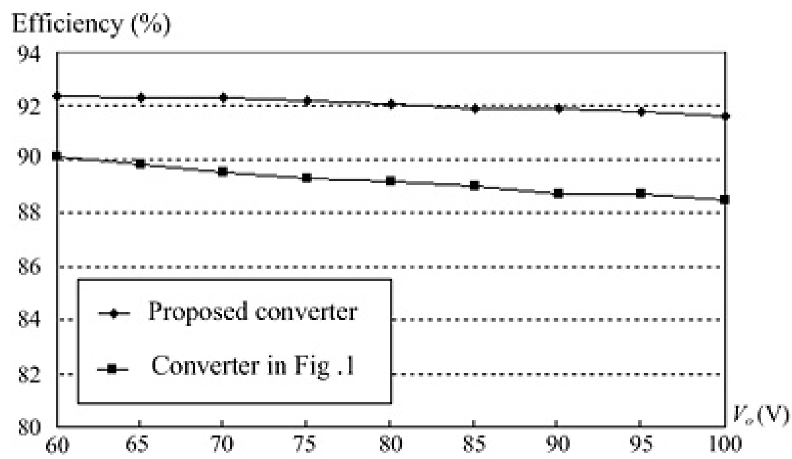

Fig. 6. Experimental efficiency of the proposed converter and the converter in Fig. 1 under V_{in} = 12 V, V_o = 60 – 100 V, and P_o = 40 W.