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Design of Soft Switched Synchronous Boost Converter

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Abstract

In this paper, we designed a soft switched synchronous boost converter, which can perform discharging the battery, is simulated, and experimented designed. The converter operates synchronous operation to increase efficiency of the converter. The converter has very small switching losses because of its soft switching characteristics. In this paper, battery discharger with a switching frequency of 100 kHz have been designed. The designed converter also simulated and experimented to prove the converter's characteristics during synchronous operation. The simulated and experimental results have confirmed that the battery discharger had soft switching characteristics. In addition, the experimental results confirm that the converter has high efficiency characteristics. The efficiency of the circuit exceeds 97%, the efficiency of soft switched synchronous boost converter is at least 6% higher than that of conventional PWM boost converter.

Keywords: *Soft switched converter, Synchronous boost converter, Low switching loss, Battery discharger.*

1. INTRODUCTION

Converters used in industry have mostly used pulse width modulation (PWM) converters.[1] In the case of moving objects such as cars, satellites, and aircraft, the converter need to minimize weight and volume. Minimizing the weight and volume of the converters requires minimizing filters with inductors, capacitors, which make up the bulk of the weight and volume. [2] This requires that the switching frequency of the converter shall be operated at a high frequency.[3] Therefore, many researches have been conducted on the converter of the soft switching method for the high frequency operation of the converter.[4-6] However, resonant converters usually have the advantage of low switching losses, but also It has the disadvantage of increasing conduction loss.[7] The disadvantage of these research methods is the conduction loss of the converter due to the voltage drop characteristics of the diode.[8-10] In addition, synchronous PWM converters continue to be studied as a way to reduce the conduction loss of the converter.[11 ,12]

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In this study, the soft switched synchronous boost converter has the characteristics of very low switching loss because of its soft switching characteristics. Also, the conduction loss has much reduced by synchronous operation of the converter. Therefore, the switching loss and conduction loss can be very low even in the high frequency operation of the converter, which has the characteristics of high efficiency. The compact design of the converter can be possible. In this paper, the soft switched boost converter has simulated by piecewise linear electrical circuit simulation (PLECS) and experimented. The simulation results confirmed that the designed battery discharger had soft switching and synchronous characteristics during operation. In addition, the experimental results confirm that the battery discharger has soft switching characteristics and high efficiency characteristics. The efficiency of the circuit exceeds 97%, in addition, the efficiency of soft switched synchronous boost converter is at least 6% higher than that of conventional PWM boost converter.

2. Soft Switched Synchronous Boost Converter

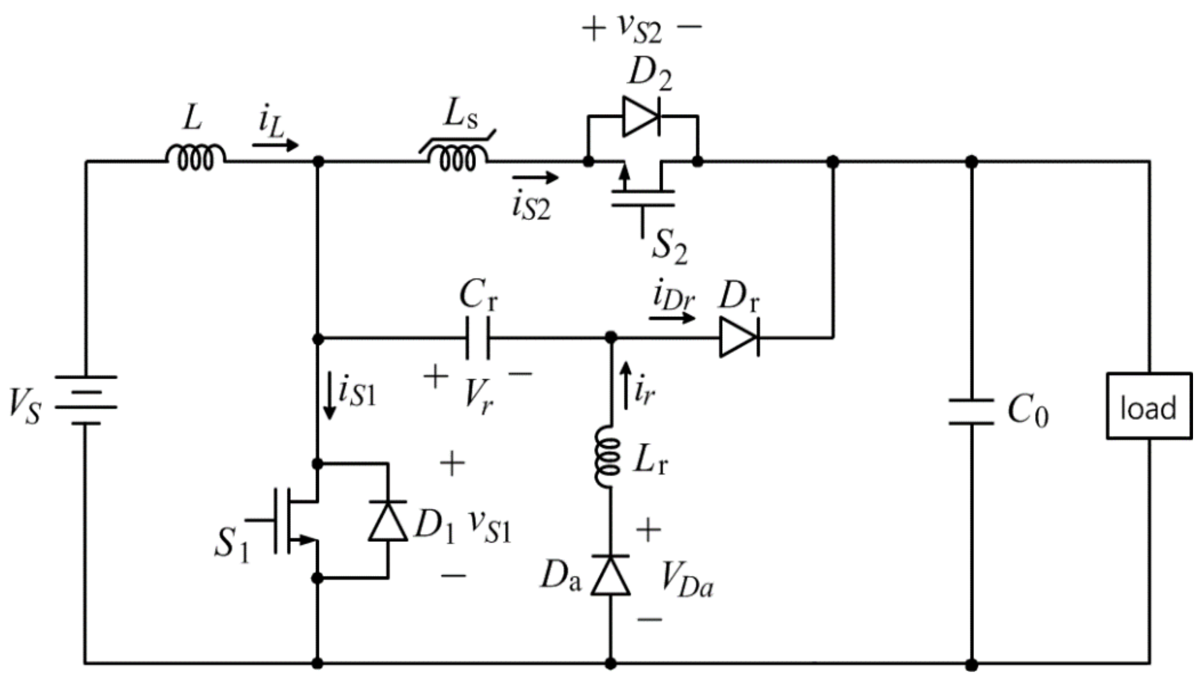

Figure 1. Soft switched synchronous boost converter

Figure 1 shows a converter with a boost type synchronous converter in which the switch operates at zero current or zero voltage with switching operation. In Figure 1, the inductance of the saturated inductor L_S is L_{S1} when the inductor is saturated and L_{S2} in the inductance of inductor when the inductor is not saturated. The saturation current of the inductor L_S is assumed to be I_{LS} . C_r and L_r are resonant capacitor and inductor.

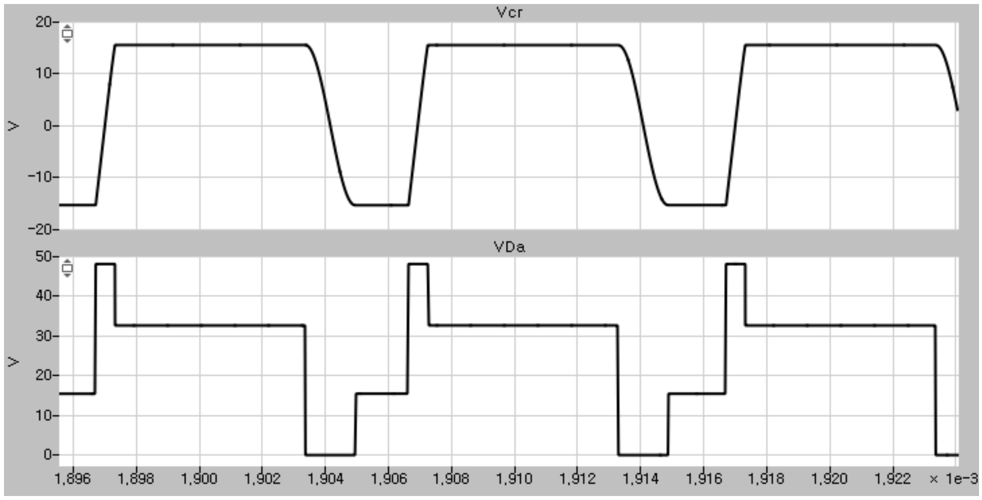

Figure 2. Simulations result of the capacitor v_{Cr} and diode v_{Da} voltage wave

Figure 2 shows the capacitor voltage v_r and the diode voltage v_{Da}. As the battery discharge current increases to designed value, the energy of the saturated inductor L_{S1} increases, and soft switching turned off operation of MOSFET S_1 is performed by resonant operation of Figure 1.

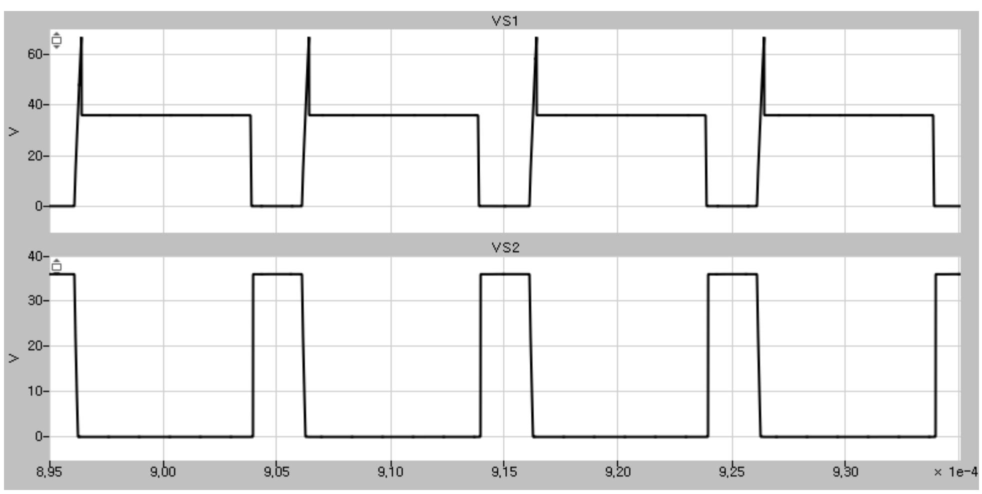

Figure 3. Simulations result of the MOSFET switches S_1 and S_2 drain-source voltage wave

Figure 3 is the simulated drain-source voltage waveforms of the MOSFET by PLECS software. As shown in Figure 3, switches S_1 and S_2 operate under soft switching conditions because their switches are turn on and off at zero current or zero voltage.

3. Designed and Experimental Results

In this paper, we designed and tested a 96 W battery discharging converter. Input of the converter is the battery which normal voltage is 28 V, the converter regulates the output voltage to 48 V. Table 1 is the specifications of the designed soft switched boost converter. We designed and manufactured the converter with specifications of Table 1. As shown in Table 1, the output current was selected to be 2 A for 96 W. The converter operating frequency is designed to be 100kHz. The Experimental environment of soft switched synchronous boost converter is shown in Figure 4.

Table 1. Boost converter specifications

Soft Switched Synchronous Boost Converter	
Converter type	Boost converter
Input voltage	28 [V]
Out voltage	48 [V]
switching frequency	100 [kHz]
Input Current	3.428 [A]
Output current	2 [A]
load	24 Ω

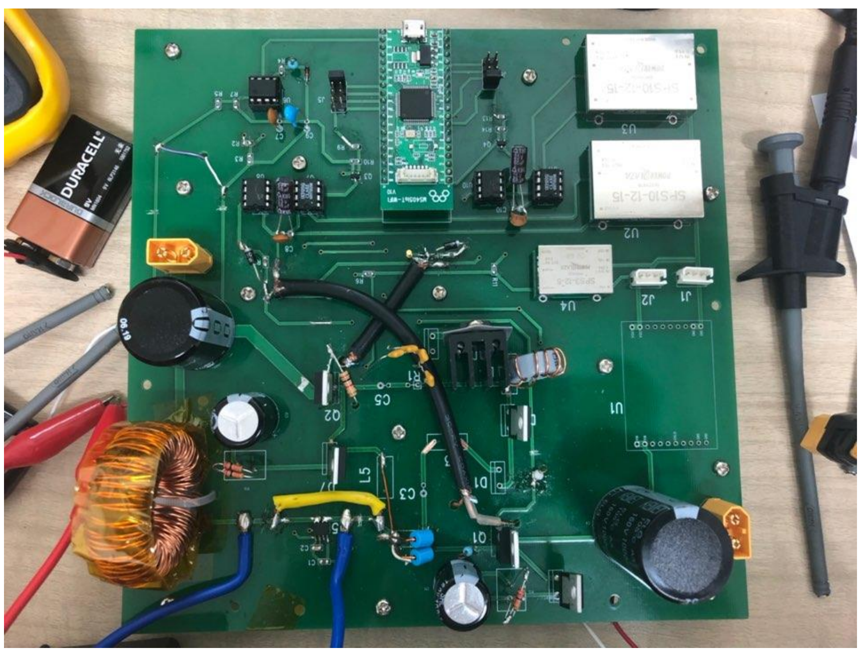

Figure 4. Experimental environment of soft switched synchronous boost converter

Figure 5 shows the gate-source voltage waveforms of MOSFET 1 and MOSFET 2, and the inductor current I_L waveform for input voltage of 28 V and output voltage of 48 V.

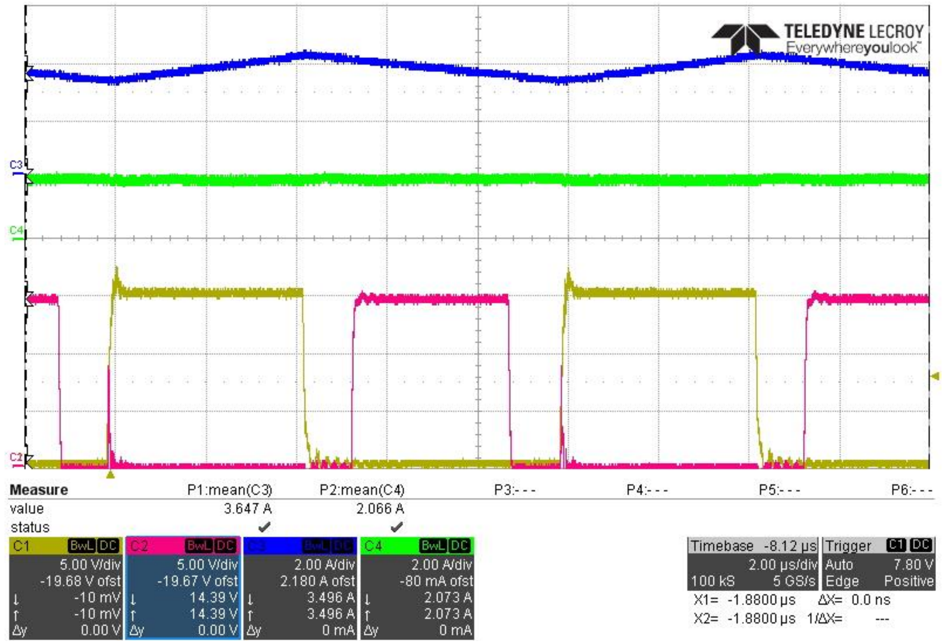

Figure 5. Inductor and gate-source voltage waveforms of MOSFET 1, 2

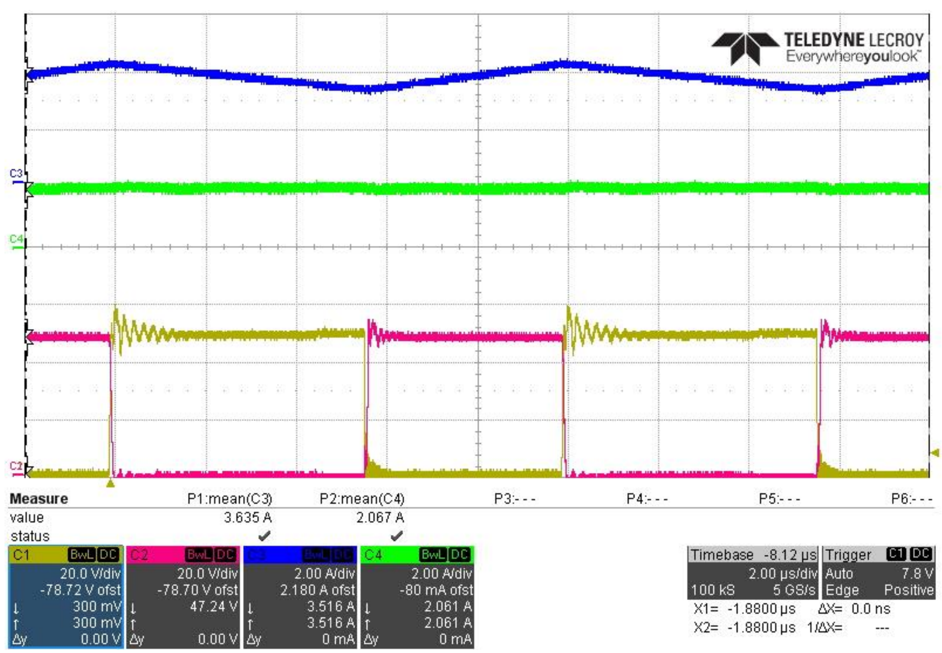

Figure 6. Inductor and drain-source voltage waveforms of MOSFET 1, 2

Figure 6 shows the drain-source voltage waveforms of MOSFET 1 and MOSFET 2, and the inductor current I_L waveform for input voltage of 28 V and output voltage of 48 V. As shown in Figure 3 and Figure 5, the simulated drain-source voltage waveforms are similar to the actual experimental drain-source voltage waveforms.

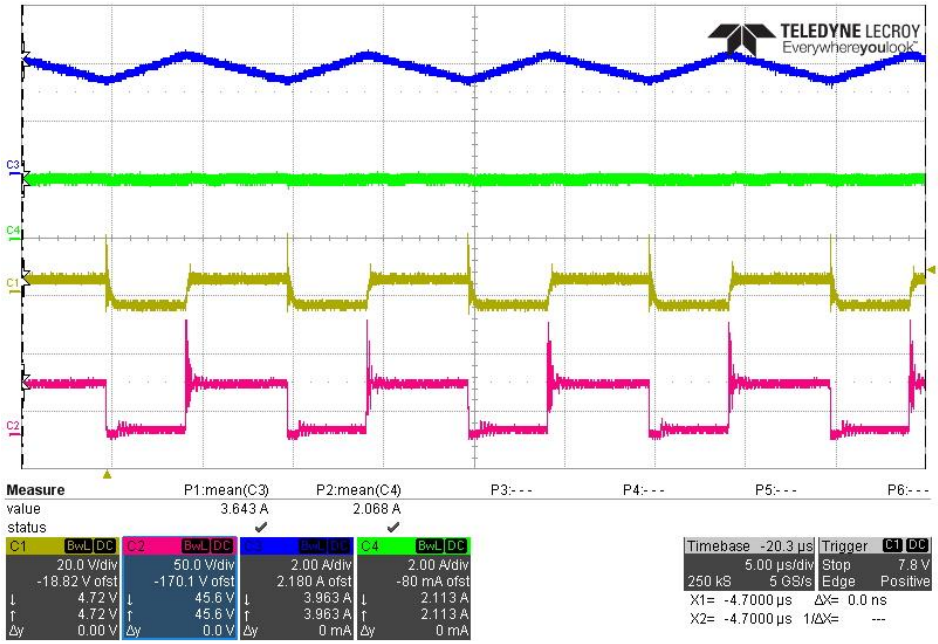

Figure 7. Experimental capacitor and diode voltage waveforms

Figure 7 are the experimental waveforms of capacitor voltage v_r and the diode voltage v_{Da}. In these figures, the input voltage is 28 V and the output voltage is 48 V. As shown in Figure 2 and Figure 6, the simulated capacitor voltage v_r waveforms are similar to the actual experimental diode voltage v_{Da} waveforms.

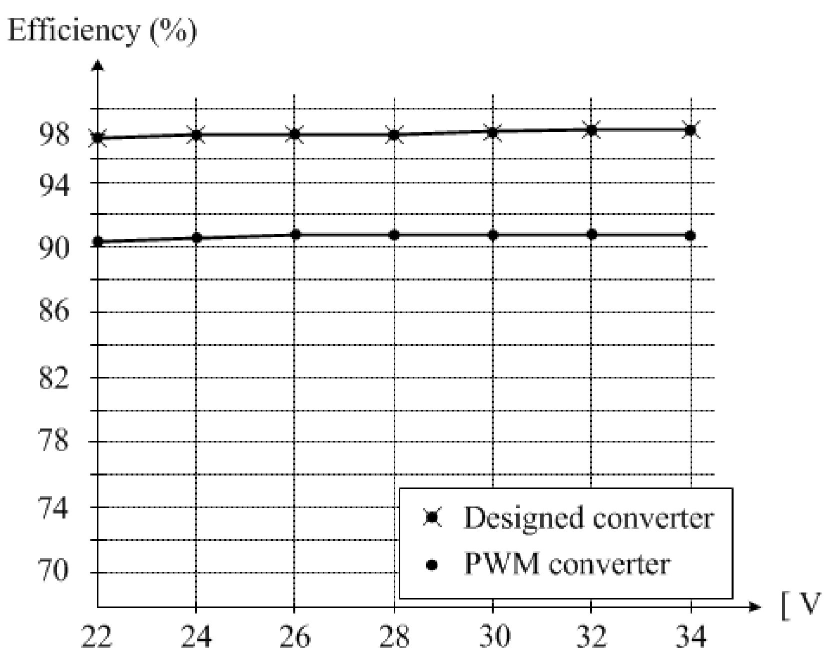

Figure 8. Efficiency comparison soft switched synchronous boost converter and conventional PWM converter

As you can be seen surely in Figure 8, when the input voltage is 22~34 V, the efficiency of the conventional boost converter does not higher than 92%. On the contrary, the soft switched synchronous boost converter circuit for the same input voltage range and the same load conditions, the efficiency always exceeds 97%. The efficiency of soft switched synchronous boost converter is at least 6% higher than that of conventional PWM boost converter. Therefore, the experimental results prove that the soft switched synchronous boost converter has the characteristics of high efficiency.

4. CONCLUSIONS

In this study, a synchronous boost converter with soft switching for battery discharge was designed. The converter has very low switching losses due to its soft switching characteristics. The operation of the converter is synchronous and can be designed to significantly reduce conduction losses. The high frequency switching operation of the converter also enables the small design of the converter. There is a wide range of application markets in the commercial field. The converter for battery discharge was simulated by PLECS and experimented. The simulation and experiment results demonstrated that the battery discharger operates with soft switching and synchronous characteristics. The efficiency of the converter always exceeds 97% for varying input voltage range. The efficiency of soft switched synchronous boost converter is at least 6% higher than that of conventional PWM boost converter. Therefore, the experimental results prove that the soft switched synchronous boost converter has the characteristics of high efficiency.

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