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# Design and Simulation of Synchronous Buck Converter in Comparison with Regular Buck Converter

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ABSTRACT

In a variety of low-power applications, a step-down dc-dc converter is used to reduce the voltage from a higher level. The two types of dc-dc converters are a regular buck and synchronous buck. The synchronous buck utilizes two switches and one diode, whereas the regular buck uses one switch and one diode. Many converters rely on the power components' switching qualities to work. A second MOSFET is required due to the diode's higher conduction losses. Because of the diode's conduction losses, the converter's efficiency may be reduced. The use of a synchronous buck converter improves efficiency by reducing diode losses. The main goal of this study is to compare and contrast these two low-power step-down converters. The simulation in this work was performed using the LTSPICE program.



## 1. Introduction

Nowadays, power electronics play a very significant role in each part of the electrical system [1]. There are quite a few devices that work by low dc voltage. For instance, in each computer, there are so many parts that require low voltage between 1 V to 10 V [2]. The output voltage of the power grid is AC voltage. Therefore, there is a need to convert AC voltage to DC. Then, after converting 120 V ac to dc, for reducing the voltage, a step-down dc-dc converter is utilized [3][4][5]. A step-down converter contains some semiconductor components and some other components [6]. Each dc-dc has at least one or two capacitors, one inductor, one switch, and one diode. However, in some buck converters, in order to reduce the losses of the diode, a second switch is used instead of the diode, which is known as a synchronous dc-dc converter [7]. A buck converter is a step-down converter that successfully lowers the voltage level to meet the needs of the low power application [8][9]. As a result, a synchronous buck converter is presented to attain great efficiency. When a MOSFET replaces a diode, the voltage drop will go from 0.7V to 0.2V. As a result, the converter's efficiency is increased [10]. Fig. 1 shows a regular buck converter.

According to Fig. 1, a regular buck contains one MOSFET, one diode, one inductor, and two capacitors [11]. This paper compares the regular buck with a synchronous buck [12]. The simulation results indicated that the output power of the synchronous buck is higher than the regular buck owing to the fact that the power losses of the diode will be eliminated, and therefore there is more power [13][14]. Several types of research about designing power converters have been done. In [15], the author investigated switched quadratic capacitor converter in order to reach the wide stepping down. Also, ref. [16] shows the effects of using common source inductance to reduce power losses. Authors in [17] proposed an idea of resonant approach to decrease the output losses dramatically. In [18], the author utilized laterally double-MOSFET to optimize the circuit performance and finally reduce the power losses. Main goal of the research is to lower the power losses when using power converters. The paper structure is Introduction, Synchronous step down DC-DC converter, Simulation result, and Conclusions.

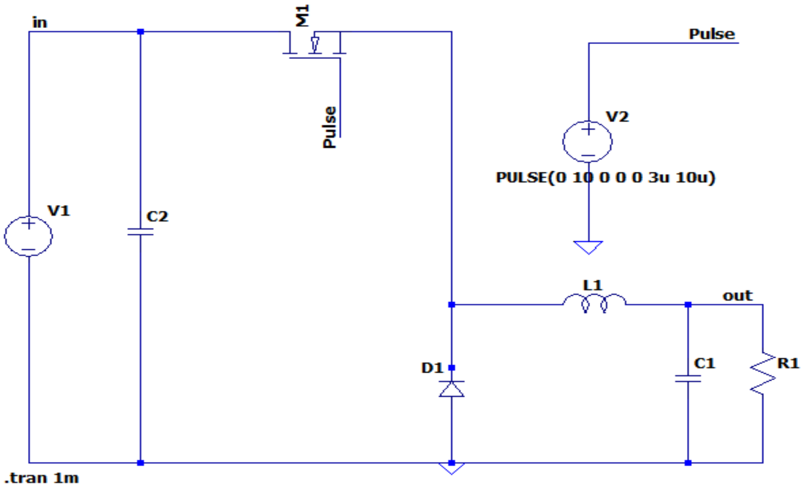


**Fig. 1.** Regular step down dc-dc converter

## 2. Synchronous Step-Down DC-DC Converter

Asynchronous buck converter uses another switch instead of the diode, as can be seen from Fig. 2. In some step-down converters, for the two switches, two IGBTs are utilized. However, in this paper, two MOSFETs are used for the design and also simulation [19][20].

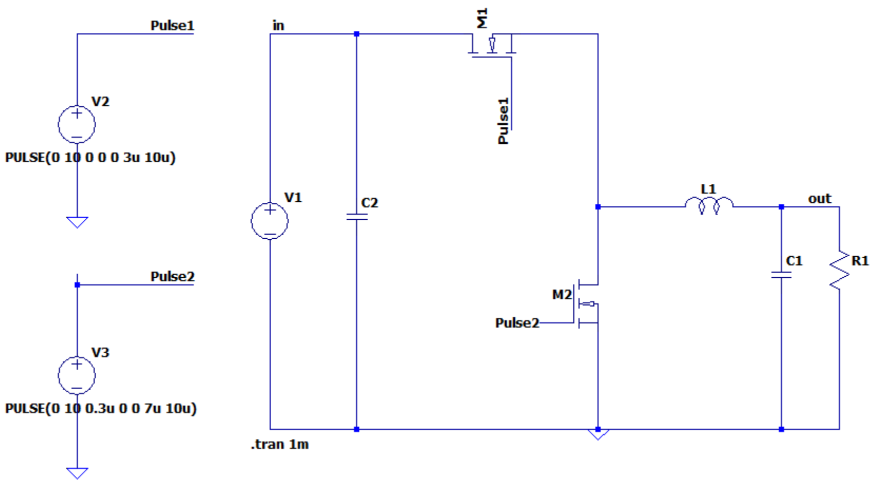


**Fig. 2.** Synchronous step-down DC-DC Converter

The most crucial aspect of creating a voltage converter is selecting the appropriate components [21][22]. The MOSFETs in this study have a rated dc voltage of 30 V. The rated voltage must be 20% higher than the input voltage, according to a rule of thumb [23]. Fig. 2 depicts the design of a synchronous step-down. A converter's primary components are two MOSFETs, one inductor, and one output capacitor. The synchronous buck converter must be run in continuous current mode since the MOSFET would allow the inductor current to go negative. The current in the inductor constantly flows in continuous conduction mode. The synchronous buck has two different modes of operation and control system [24][25][26]. The energy from the DC source will charge the inductor and also feed the output in the first mode since switch 1 is on and switch 2 is off. When switch 1 is off and switch 2 is on in the second mode of operation, the inductor's stored energy feeds the load and is discharged through switch 2 [27][28]. Eqs. (1), (2), and (3) will be utilized to construct the step-down where D is the duty ratio and $\Delta V_o$ is the output voltage ripple.

$$Duty\ cycle = \frac{V_{out}}{V_{in}} \tag{1}$$

$$L = \frac{DT_s(V_{in} - V_{out})}{2I_o} \tag{2}$$

$$C = \frac{V_o T_s (1 - D) T_s}{8\ L\ \Delta V_o} \tag{3}$$

## 3. Results and Discussion

The characteristics of the system are shown in Table 1.

**Table 1.** Characteristics of the buck converter

| Components | values |
|---|---|
| Vin | 10 V |
| Vout | 3 V |
| Inductor | 70 $\mu$ |
| Capacitor | 25 $\mu$ |
| Switching frequency | 100 kHz |
| Duty cycle | 30 % |
| Rated voltage of the switch and diode | 30 V |

### 3.1. Simulation Results of the Regular Buck

Needless to mention that in the regular buck, a diode is used to make a path for discharging the inductor [29][30]. The output voltage and current of the conventional buck are shown in Fig. 3.

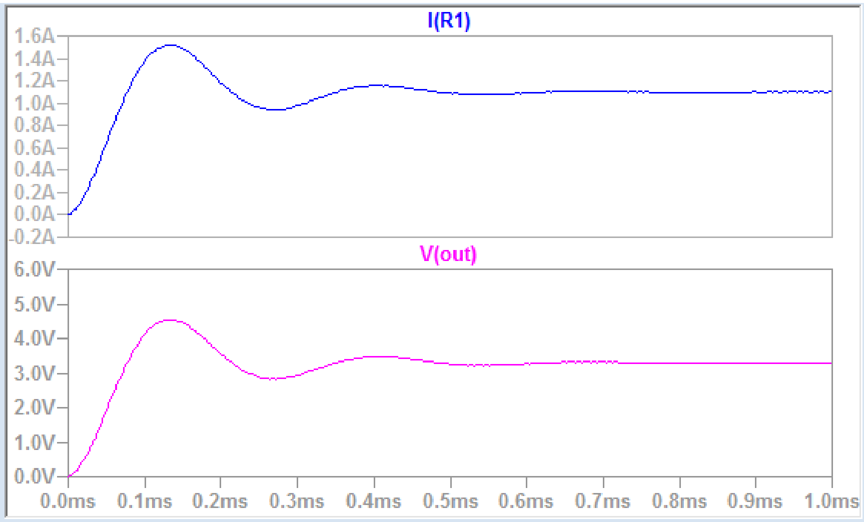


**Fig. 3.** Output voltage and current

As we can see from Fig. 3, the output generated voltage is 3 V and the output generated current is 1 A. therefore, the output power is near 3 watts. The voltage and current across the MOSFET (switch) are indicated in Fig. 4.

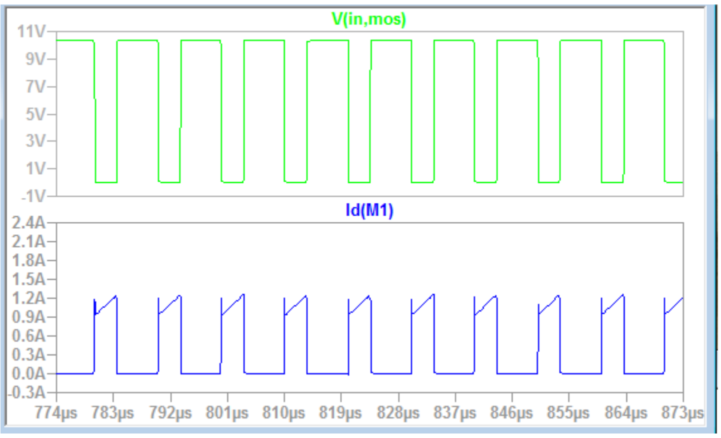


**Fig. 4.** Voltage and current waveform across the switch

According to Fig. 4, when the switch is on, the voltage across the switch is zero, and the current across the MOSFET is 1 A. Also, when the switch is off, the voltage across the MOSFET is equal to the input voltage. The voltage and current across the diode are shown in Fig. 5.

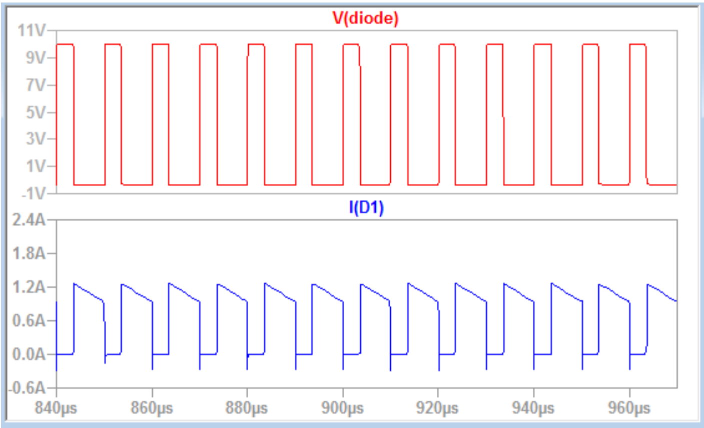


**Fig. 5.** Voltage and current through the diode

Based on Fig. 5, when the diode is on the forward bias, the voltage across the diode is zero, and the current across it is 1 A. Also, when the diode is on the reverse bias, the voltage across the diode is 10 V. Fig. 6 describes the current through the inductor L1.

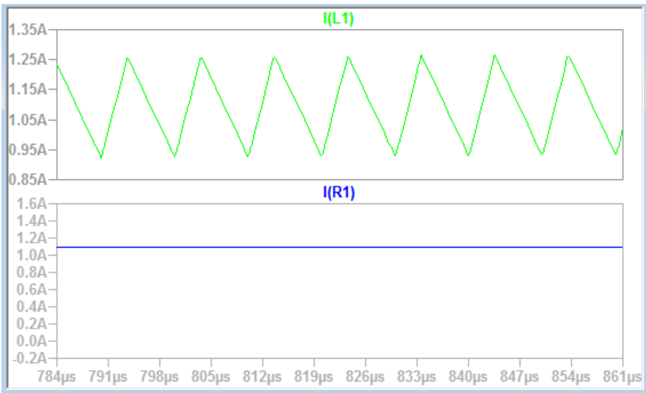


**Fig. 6.** Inductor current

Based on Fig. 6, the whole system is in continuous conduction mode (CCM) because the peak-to-peak inductor current is higher than zero all the time.

### 3.2. Simulation results of the synchronous buck

It is obvious that in the synchronous buck, there are two switches instead of using one switch and one diode. Both switches in this paper are MOSFETs. The voltage across both switches of the synchronous buck converter is shown in Fig. 7.

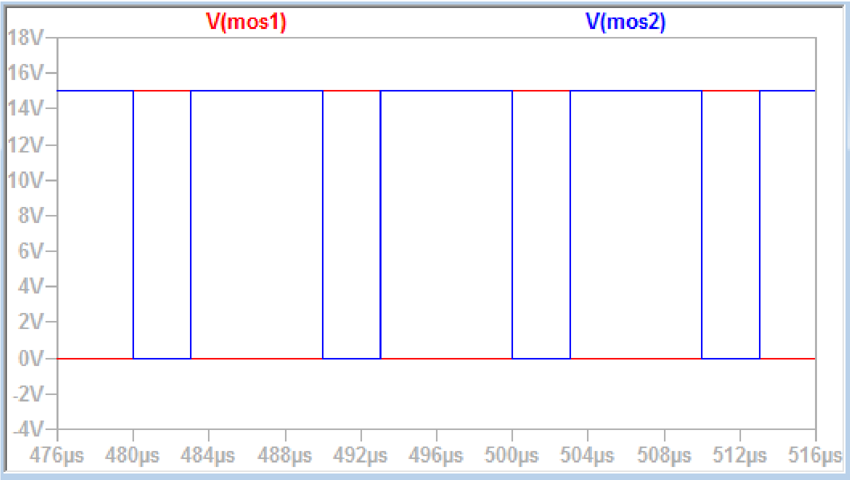


**Fig. 7.** The voltage across both switches in the synchronous buck

As we can see, the voltage across both switches is the exact opposite of one another. When switch 1 is on, the other switch is off. And we can see the duty cycle of switch 1 is 30 %, and the duty cycle of switch 2 is 70 %. The output voltage and current of the synchronous buck are shown in Fig. 8.

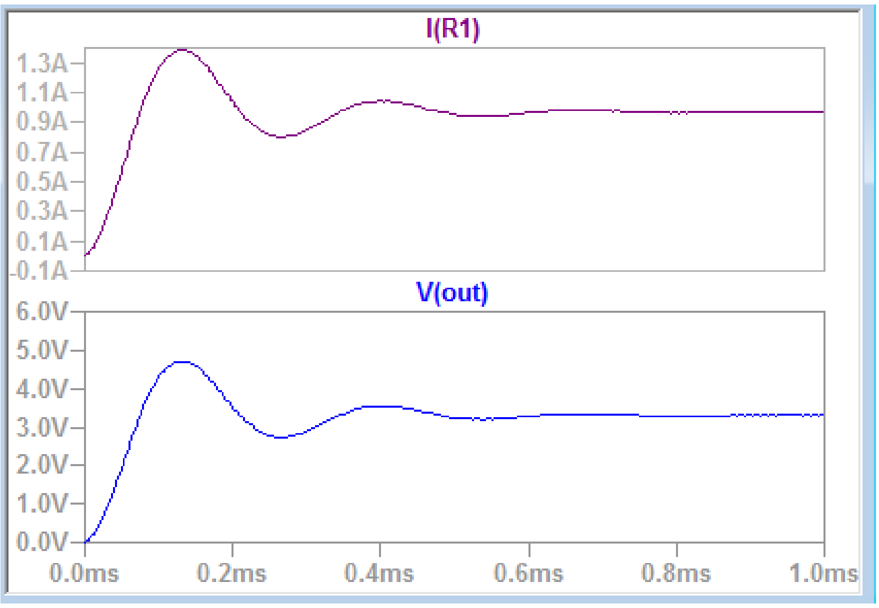


**Fig. 8.** Output voltage and current of the synchronous buck

As we can see from Fig. 8, the output voltage and current by utilizing synchronous buck are a little higher, and the power losses are lower.

### 3.3. Comparison Between Regular Buck and Synchronous Buck Converter

The output power of both converters is different due to the lower power losses of the synchronous buck converter. Table 2 shows the comparison table of both DC-DC step-down converters.

**Table 2.** Comparison of the two different step-down converters

| | Output power | Efficiency |
|---|---|---|
| **Regular buck** | 3.32 W | 94.67 % |
| **Synchronous buck** | 3.61 W | 96.27 % |

Based on Table 2, the output power of the synchronous buck is 3.61 watts, and the output power of the regular buck is 3.32 watts, which indicates that by using synchronous buck for low power application, the losses will be lower. In addition, the efficiency of the system when using a synchronous buck converter is higher.

## 4. Conclusion

The two types of buck converters are compared in this research, as well as their design and modeling. The efficiency of the step-down converter can be improved by using an additional MOSFET instead of a diode. In LTSPICE, both approaches' modeling and simulation are provided. According to simulation data, employing a synchronous step-down converter increases the output power of a system with identical components, implying that using a synchronous buck causes fewer losses. The future research will focus on using synchronous buck converters for high-power applications by using IGBT instead of MOSFET.

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