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Research of a Wide Input Range SMPS

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Abstract

In some cases the input voltage of a switching mode power supply (SMPS) is lower than a normal value. Therefore, a new SMPS with wide range input voltage based on boost and flyback converters is presented in this paper. There are two working modes include low-voltage-mode and universal-voltage-mode. In low-voltage-mode where the input voltage is lower than a given value, this input voltage will be stepped up by a boost converter controlled by L6561 firstly, and then a flyback converter which is controlled by TOPSwitch will convert this voltage to an expected one. In universal-voltage-mode where the input voltage is higher than the given value and in a universal range, this voltage will be connected to flyback converter directly. Which working mode is selected as the current mode is determined by a hysteresis comparator. The experimental result shows that when input voltage is about 25 to 265 AC voltage, the output voltage of this SMPS is stable with good electrical performance.

Keywords: wide input range, SMPS, boost, flyback, hysteresis comparator

Introduction

Nowadays, switching mode power supply (SMPS) has been widely used. And requirements for them are constantly improving, such as high efficiency, high power factor, high power density and high reliability.

When SMPS is asked to adapt to both 110VAC and 220VAC power specifications, it is always designed with 90-265VAC input. Such as laptop charger, computer power supply and so on. However, working conditions are even worse in some cases. For example, when input voltage is higher than 265VAC or lower than 90VAC, SMPS is still asked to work properly. Many scholars have researched in this area and achieved some results. Such as the use of TOPSwitch to improve the characteristic of switching power supply, the AC input voltage can be extended from 80 to 400 volts. But there is few people research in the area when the input voltage is less than 80 volts, even 20 volts. [1,2]

In this paper, a novel SMPS was designed based on step-up circuit and the flyback converter. The output voltage is stable as input voltage range from 25 to 265 volts, which ratio exceeds 1:10.

Principle of system

System diagram. Considering the input voltage range of a single circuit is limited, so two different converters are connected to work together. When the input voltage is relatively high, the input voltage V_{AC} will be rectified and connected directly to flyback converter as the input voltage of it, as shown in Fig.1. Two relays in Fig.1 are working in the normally closed state, and the step-up converter does not work. If the input voltage is low enough, the two relays will switch to the normally open state. Therefore, the voltage V_1, rectified voltage of V_{AC}, will step-up to voltage V_2 through Boost converter firstly, and then as the input voltage of the flyback converter. Comparator

with hysteresis works to determining whether the input voltage is high or low, and a hysteresis range makes the system more stable.

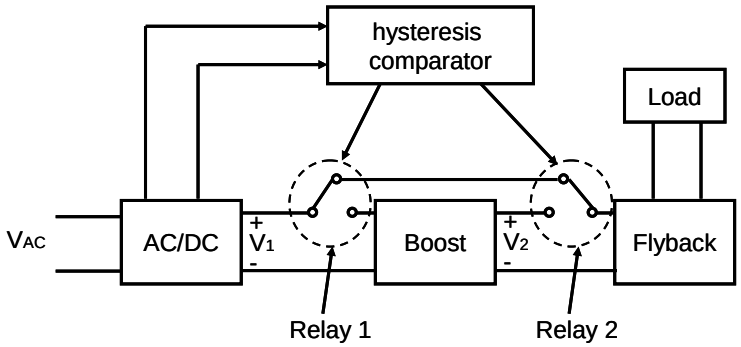

Fig.1 Power supply system diagram
(Relays are both in normally closed state)

Design of Boost converter. The control chip of Boost converter is L6561. L6561 is a quasi-continuous current mode APFC controller chip, that is, the inductor current in critical of continuous mode and discontinuous mode. Therefore, the system has PFC function in low voltage input. [3,4]

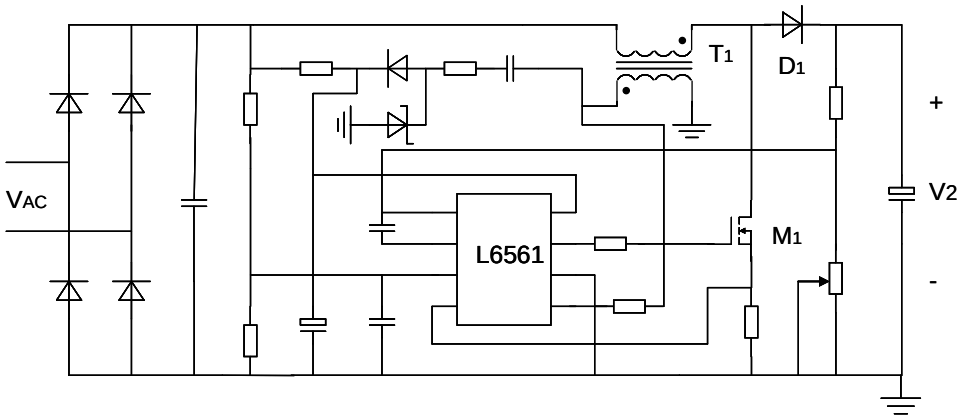

Fig.2 Schematic of Boost converter

Schematic of the Boost converter is shown in Fig.2. Primary side of the transformer T_1, diode D_1, MOSFET M_1 composed of Boost main circuit. Voltage of secondary side of T_1 is power of L6561. As the boost circuit only works in low input voltage, the input voltage of it was designed from 25 to 90VAC, and the output voltage of it is 140VDC. Design of the specific parameters of the converter can be seen in reference [4].

Design of flyback converter. When the input voltage VAC is lower than 90V, the input voltage of flyback converter is the output voltage of Boost converter, which is 140VDC constantly. When the input AC voltage is higher than 90V, the flyback converter works alone, so the input range of the flyback converter can be set 90-265V. As a result, when the range of input AC voltage is 25-265V, the flyback converter can always work properly.

The flyback converter adopts PI's fourth-generation single-chip switching power supply TOPSwitch-GX, whose maximum output power is about 290W. The chips integrated high-voltage power MOSFET, PWM control, fault protection and other control circuits. And it also has function of soft start to eliminate overshoot and reduce the stress of the device, small EMI, under-voltage protection and over-voltage shutdown, programmable current limit and the unique technique of automatic frequency down when light-load. [5,6]

TOPSwitch-GX-based flyback converter schematic is shown in Figure 3. Whether the input voltage of the flyback is V_1 or V_2 depends on the state of two relays. Circuit parameters can be

designed by software PI-Expert to shorten design cycle. Two outputs of it are 12V/1A and 5V/1A, as shown in Fig.3.

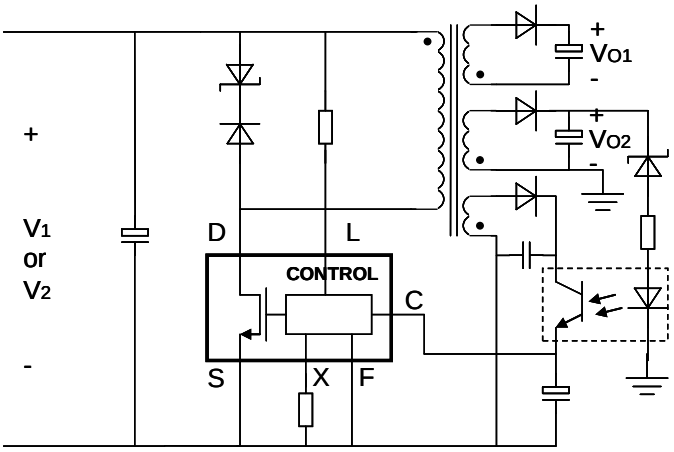

Fig .3 Flyback converter schematic

Design of hysteresis comparator. When the input voltage is equal to the design switching voltage (here is 90V), in order to prevent the relay from acting frequently, a hysteresis comparator is adopted. Circuit schematic is shown in Fig.4, and there is only one relay.

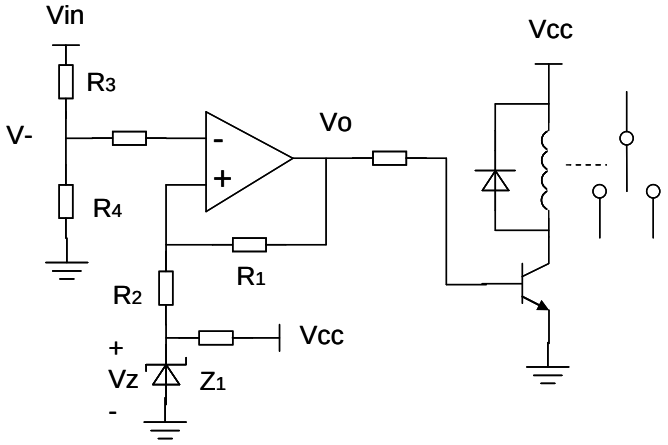

Fig.4 Schematic of hysteresis comparator

In figure 4, the comparator using a single power supply Vcc, the same supply of the diode regulator Z_1. The breakdown voltage of Z_1 is V_Z. V_{in} in Fig.4 is the DC component of voltage V_1 in Fig.1. After the voltage divider R_3 and R_4, the voltage V- is the reverse side input voltage of the comparator.

According to the principle of the hysteresis comparator, when

$$V_- > \frac{R_1}{R_1+R_2}V_{CC} + \frac{R_2}{R_1+R_2}V_Z \quad (1)$$

the output voltage Vo in Fig.4 is in low level. It shows that the input voltage V_{AC} is relatively high. And the relays are in a normally closed state. At this time only the flyback converter works. [7]

When

$$V_- < \frac{R_2}{R_1+R_2}V_Z \quad (2)$$

the output voltage Vo is in high level. It shows that the input voltage V_{AC} is relatively low. And the relays are in a normally open state. At this time the Boost and the flyback converter work together. [7]

The voltage divider and value of R_1 and R_2 should be choosen reasonablely. So it is possible to get a more reasonable switching time and hysteresis range of the comparator. Experimental input and output waveforms of hysteresis comparator are shown in Fig.5. V_H is high threshold voltage of the hysteresis comparator, and V_L is the low one.

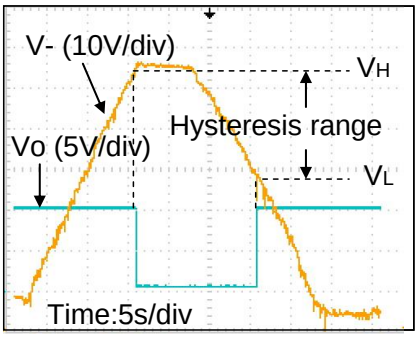

Fig.5 Experimental waveforms of hysteresis comparator

Experimental results

An experiment has been performed to verify the present theory. Main experimental parameters are demonstrated as follows, skeleton of T_1 in boost converter is EE28, the primary side of T_1 is 23 turns and the secondary is 8 turns, the primary inductance is about 200uH, MOSFET M_1 is IRF840 and diodes D_1 is MUR860. TOPSwitch of flyback converter is TOP244Y, and skeleton of it is EE25. The primary side is 78 turns and the primary inductance is about 85uH. Secondary side of 12V is 9 turns, another secondary of 5V is 4 turns, and control side is 9 turns.

Fig.6 and 7 show input voltage and current waveforms when the input voltage V_{AC} is 25V and 90V respectively. Because the Boost converter is working then, the input current is also sinusoidal.

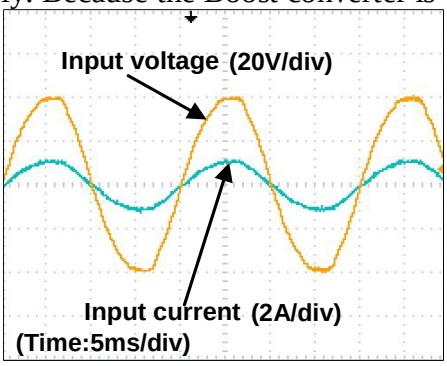

Fig.6 Waveforms when input voltage is 25V

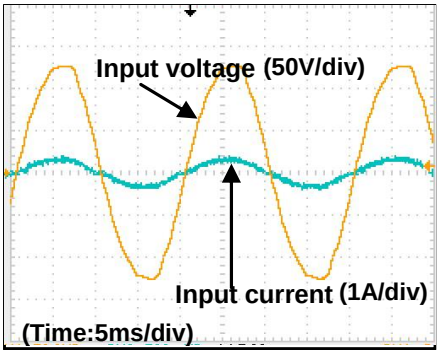

Fig.7 Waveforms when input voltage is 90V

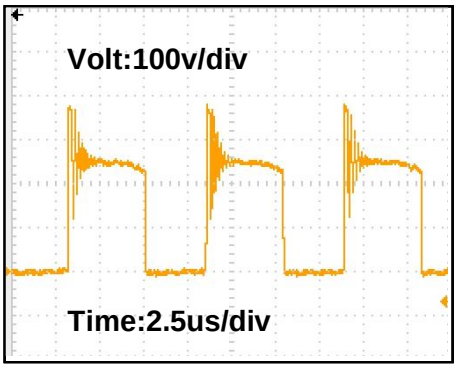

Fig.8 DS waveform 1

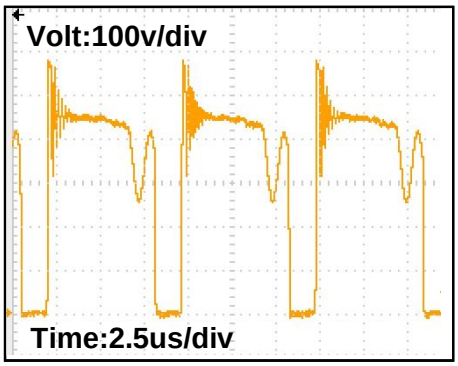

Fig.9 DS waveform2

When the boost converter and the flyback converter work together, because of input voltage of the flyback converter has been constant about 140VDC, drain to source voltage waveform of MOSFET in the TOPSwitch is also constant, as shown in Fig.8. When only the flyback converter works, the input voltage of it increases with the input AC voltage rise, so the corresponding drain to source voltage waveform will also change. When the input AC voltage is about 250V, this waveform is shown in Fig.9.

With different input AC voltage VAC, output voltage of the system is shown in Table 1. It can be seen that the output voltage has remained stable when the input voltage is in the range.

Table 1 Output voltage data (unit : V)

V_{AC}	25	50	100	150	200	250
V_{o1}	5.00	5.00	5.00	4.99	5.00	4.99
V_{o2}	12.39	12.41	12.42	12.37	12.36	12.36

Conclusion

A kind of novel switching power supply was presented with wide range of input voltage. When the input voltage is low, the Boost converter and the flyback converter work together. And when the input voltage is high, only the flyback converter works. The experiment results show that the input AC voltage in the range 25-265V, and the output voltage has remained stable, which proves the method is correct and feasible.

Acknowledgment

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