Design of high efficiency dc switching power supply based on soft switch

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Abstract. At present, due to the small size, high power density, high efficiency, a variety of switching power supply is getting more and more widely used. With the improvement of automation degree of power system, especially the microcomputer of protection device, the program control of communication device and the requirement of power efficiency are also increasing. In order to solve the problem of high power consumption and unstable output of linear circuit in the process of energy conversion, this paper proposes a stable switching power supply based on SG3525 control. The constant voltage source USES PWM control principle to control the duty ratio of the switch tube to achieve the output voltage of 24V. Since the switch power supply design is usually based on the ideal state of the device, SABER simulation software is used to verify the feasibility of the circuit. At the same time, through physical verification, the circuit performance when the input voltage fluctuates. And test the load capacity and work efficiency of the circuit.

1. Introduction

Switching power supply is a modern power electronics technology, which can control the time ratio of switching on and off. A power supply that maintains a steady output voltage. Used in industrial automation control, military equipment, scientific research equipment, LED lighting, industrial control equipment, communications equipment, electrical equipment, instrumentation, medical equipment, semiconductor refrigeration and heating, air purifier, electronic refrigerator, LCD, LED lamps and lanterns, communications equipment, audio and video products, security, computer case, digital products and equipment. The high frequency of switching power supply is the direct ion of its development. Especially in the high-tech field of application, promote the development of switching power supply, products in the light, small, thin, low noise, high reliability and anti-interference direction on the continuous development. This paper introduces the design of buck circuit with SG3525 chip as the core and Boost circuit as the main structure. The efficiency of stabilized voltage power supply can reach more than 99% theoretically, with the characteristics of low cost, small size, high precision and fast speed. It includes real-time monitoring and feedback of output voltage, and can effectively suppress ripple and some high-frequency resonant input interference. Widely used in electronics, communications, energy, aerospace, military and other fields. In the circuit design, the conversion effect from 12V to 24V, deviation less than 100mV, and rated current Iomax = 2A are realized.

1.1. Implementation plan

This design adopts BOOST circuit based on switch power supply technology and improves its main topology. This paper presents a new type of passive and lossless soft switching circuit which is suitable for Boost circuit. And all of them realize soft break. At the same time, the soft switch circuit itself also
realizes the soft switch, the device stress is small. The series inductor L suppresses the peak current caused by the reverse recovery and realizes the zero current conduction of switch transistor VS. Capacitor C is responsible for the zero voltage shutdown and energy transfer of the on/off transistor VS. Inductor L suppresses the peak current of resonant current caused by soft switching circuit during operation and reduces the device stress of switching transistor VS soft switching circuit. Finally, capacitor C returns resonant energy to the load terminal, thus realizing zero loss of switching transistor in one cycle.

1.2. The solution
SG3525 PWM control integrated chip, including all functions required for switching power control. Widely used for single end forward double tube, half bridge, full bridge switching power supply. It is a fixed frequency pulse width modulation circuit, built-in linear sawtooth oscillator. The width of the output pulse is achieved by comparing the voltage of the positive sawtooth wave on the capacitor CT with the other two control signals. Power output transistors Q1 and Q2 are controlled by the NOR gate and are gated when the clock signal of the bistable flip-flop is low. That is to say, gate only when the sawtooth voltage is greater than the control signal. With the increase of control signal, the width of output pulse will decrease. The main topology is passive and lossless soft switching circuit, as shown in figure 1. Passive lossless soft switching circuits are widely used because there are no auxiliary switches. It is precisely because of the non-time variability of inductive and capacitive devices that the soft switch function is realized. However, with the increase of frequency, the peak voltage caused by inductive and capacitive devices can easily damage the diode in the main topology, so the performance requirements of the secondary tube in the circuit are improved.

2. Debugging environment
Sabre is an excellent electronic design automation software developed from American human rights. Sabre has become an industry standard mixed signal, mixed technology design and validation tool in many areas. Saber has two sections, one is saber-sketch and the other is saber-design. Saber-sketch is used to draw schematic diagrams, which are completed in saber-design, and the simulation is viewed in saber-scope and design-probe. The advantages of Saber are:

(1) Very high integration: from drawing circuit schematic diagram to simulation, it can be implemented in the environment interface, without switching the working environment from left to right.
(2) powerful graphical search method: there are two kinds of simulation results to view, one is saber-scope and the other is design-probe, among which saber-scope has powerful functions.
(3) Powerful analysis functions: dc analysis, ac analysis, transient analysis, deviation point analysis, temperature analysis, Monte Cano analysis, stress analysis and deformation analysis.
(4) modularization and layering: in large and complex circuits, a part of special function circuits can be turned into blocks and symbols, which can also be used for layering design of circuits and simulation of the whole circuit.
3. Hardware debugging

The maximum duty ratio is:

$$\Delta_{\text{MAX}} = 45 - \left( \frac{8}{1+P_1/P_2} \right)$$

By adjusting the values of external capacitor resistance of RT and RC, the output duty ratio of the main control chip is changed, and the result is as follows:

![Figure 3. Pin wave pattern of control circuit](image)
Figure 4. Voltage of each node of the additional circuit

Figure 5. Main inductance current

Figure 6. Output voltage wave pattern
4. **Index parameter test**

The original design of the switching power supply is to reduce the loss of voltage transformation, so the voltage output is stable, adjustable and efficient. Representative input, output voltage and current will be selected to test the efficiency and stability of the circuit. Under no load, the input voltage is 10V, the
current is 0.01 A, and the output rated voltage is 24V. The output voltage will fluctuate slightly with the input voltage.

| Input voltage VI (V) | Actual output voltage (V) | Voltage deviation (V) | Deviation ratio % |
|----------------------|----------------------------|-----------------------|-------------------|
| 5                    | 20.3                       | 3.7                   | 15.41             |
| 5.5                  | 22.6                       | 1.4                   | 5.83              |
| 6                    | 23.8                       | 0.2                   | 0.83              |
| 7                    | 23.9                       | 0.1                   | 0.42              |
| 8                    | 23.9                       | 0.1                   | 0.42              |
| 9                    | 24                         | 0                     | 0                 |
| 10                   | 24                         | 0                     | 0                 |
| 11                   | 24                         | 0                     | 0                 |
| 12                   | 24                         | 0                     | 0                 |
| 13                   | 24                         | 0                     | 0                 |
| 14                   | 24                         | 0                     | 0                 |

Under load condition, the input voltage is rated at 12V, the output voltage is rated at 24V, and the circuit efficiency and fluctuation are as follows:

| Input voltage VI (V) | Input current (A) | Output current (V) | Effectiveness% |
|----------------------|-------------------|-------------------|----------------|
| 12.1                 | 1.99              | 0.96              | 99.5           |
| 13                   | 1.86              | 0.96              | 99.4           |
| 14                   | 1.73              | 0.96              | 99.5           |
| 15                   | 1.6               | 0.96              | 99.6           |
| 11                   | 2.26              | 0.95              | 99.3           |
| 10                   | 2.51              | 0.95              | 99.1           |

It can be seen that when the fluctuation of input voltage exceeds the rated input voltage of 3V, the output efficiency can reach more than 99%.

In order to meet the requirements of output voltage level, the design can adjust the output voltage through feedback adjustment. In the process of output voltage conversion, the energy conversion efficiency (with a load of 50 ohm resistance and a 12V voltage as the input rated voltage) is as follows:

| Output voltage VI (V) | Input current (A) | Input current (V) | Effectiveness% |
|-----------------------|-------------------|-------------------|----------------|
| 16                    | 0.31              | 0.44              | 96.4           |
| 18                    | 0.36              | 0.57              | 96.7           |
| 21                    | 0.41              | 0.74              | 96.6           |
| 24                    | 0.47              | 0.98              | 96.2           |
| 27                    | 0.53              | 1.26              | 94.6           |
| 30                    | 0.59              | 1.57              | 94.0           |
| 31                    | 0.6               | 1.68              | 92.3           |
5. Analysis and summary

5.1. Analysis
This design effectively solves the problem of unstable output voltage and high voltage grade conversion loss in the distributed weak energy collection process, providing multiple output solutions.

As can be seen from table 5-1, when the input voltage changes, the output value can basically be maintained at the rated output voltage, but when the input voltage is much lower than the rated input voltage, it is difficult for the circuit to maintain stable output voltage, and the output voltage deviates from the rated output voltage.

It can be seen from table 5-2 that, under the condition of rated output voltage and stable load parameters, the conversion efficiency of voltage level is almost zero loss. However, the input current will increase with the decrease of input voltage, and the weak energy converter may be damaged.

As can be seen from table 5-3, when the rated input voltage is kept at 12V, the conversion efficiency decreases with the increase of the output voltage value. However, this system adopts passive soft switch technology, so even when the maximum output voltage is 35 v, 90% conversion efficiency can be maintained.

To solve the above problems, we can start from the input end and the auxiliary circuit, and increase the voltage of the input end by means of multi-group parallel connection, so as to avoid the input voltage falling to the valley bottom. At the same time, the auxiliary circuit can also be used to realize efficient conversion of low-grade voltage through the auxiliary circuit.

5.2. Summary
Increasing the switching frequency of the converter can effectively improve the power density of the system, but the switch loss and electromagnetic interference limit the further increase of the switching frequency. Soft switching technology can effectively reduce switching loss and EMI noise. For the resonant converter, the circuit itself works in the resonant state, and can use its own resonant operation to realize the soft switch of the device. However, resonant converters usually need to operate in a variable frequency modulation mode, the device voltage or current stress is large, and the optimal design of magnetic devices is difficult.

Pulse width modulation (PWM) converter is the most widely used switch converter. By changing the topology or control of PWM converter, the resonant state is formed when the switch is on and off, so as to realize the soft switch action. Soft switching methods can be divided into two categories: passive soft switch and active soft switch. The former does not need additional active switches, is relatively simple to control and implement, and has high reliability. It is widely used in engineering.

In order to further reduce the circuit loss in the design, the use of high frequency switch technology and soft switch technology, including auxiliary circuit diode switch plays an important role, but to improve the load capacity of the circuit, must improve the current topology, this will increase to the requirement of diode, needs not only has high frequency and high current.

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