Design of short-circuit protection circuit for switching power supply

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Abstract. Short-circuit protection circuit for switching power supply is designed. The circuit is for sampling and protection based on capacitance ripple characteristics. It has the advantages of rapid fault protection adjustable trigger time and recovery time. It shows that the circuit scheme has a good protective effect on the power converter in various load environments, and it has reached desired effect, according to the simulation results and the circuit application results.

1 Introduction

Compared with power converters with other circuit topologies, flyback converter has irreplaceable advantages such as simple circuit topology and control strategy, low electromagnetic interference and economy. At present, flyback converters are almost used in medium and small power applications, most of which are closely related to people's life, such as mobile phone charger, notebook computer power adapter, electric bicycle charger, router adapter, etc. [1]. Due to the large number of applications, the traditional flyback converter circuit topology should strictly prevent the short circuit and fire of the power converter.

In this paper, a short-circuit and overload protection circuit is cleverly designed for the switching power supply converter, which mainly solves the contradiction between the capacitive load carrying capacity of the switching power supply and the untimely short-circuit protection, ensures the capacitive load capacity of the switching power supply, improves the load adaptability of the power supply, and ensures the reliability of the protection circuit under harsh environmental conditions.

2 Scheme design

2.1 Design of short circuit protection circuit

The principle of switching power supply converter is shown in Fig. 1. The full wave

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rectifier bridge is composed of diodes D2, D3, D4, D5. Through Filter capacitor C4, The DC voltage TS, primary switch Q1, energy storage capacitor C4, The flyback power converter transmits energy to the output through transformer T1.Diode D5, inductance L1 and capacitance C2, DC output voltage after rectification and filtering. When the converter is working, by changing the duty cycle of PWM, the output voltage is adjusted [2] [3]. Under the normal operation of the power supply, AC ripple current in C4, which forms an AC ripple voltage accordingly. When overcurrent or short circuit occurs, the voltage ripple at the capacitor voltage will increase sharply. According to the characteristics of the switching power converter, the working state of the power supply can be determined and the level of the different AC component protection points can be set by referring to the magnitude of AC component increment to complete the design of short circuit protection circuit[4] [5] [6].

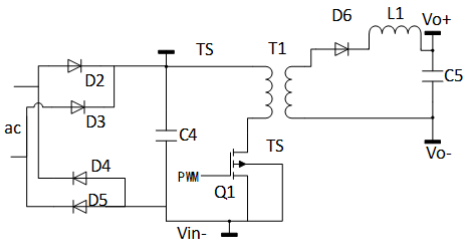

Fig. 1. Schematic diagram of switching power supply with flyback topology.

The principle of short-circuit protection circuit of switching power converter is shown in Figure 2. Capacitor C1 is a high-voltage isolation capacitor. The ripple voltage of C4 is transmitted to the low-voltage side through C1. A ripple voltage waveform is formed at both ends of resistor R2. It is rectified by diode D1. After filtering, resistor R1 and capacitor C2 are rectified to DC level and input to the same direction input end of operational amplifier IC1, It is compared with the reference voltage V_{ref} through the voltage division level of resistor R3 and resistor R4. When the switching power converter works normally, the voltage at the reverse input terminal of IC1 is higher than the voltage at the same input terminal, the output voltage of IC1 is low, Q1 is off, the PWM signal is normal, and the switching power converter works normally.

When the power converter is short circuited or overcurrent, the ripple of capacitor C4 becomes larger, and the ripple voltage is rectified to DC level through C1, R1, R2 and C2 and input to the same direction input end of comparator IC1. At this time, due to the increase of ripple voltage at the sampling end, the level of the same direction input end of operational amplifier IC1 is higher than that of the reverse input end, and the output end of operational amplifier IC1 is reversed, the output state changes to high level. At this time, Q1 is turned on and the PWM signal terminal level is pulled down, and the switching power converter stops working.

After the switching power converter stops working for a preset time, the sampling ripple level through capacitor C1 becomes low, capacitor C2 discharges through R7, the negative input level of operational amplifier IC1 is greater than the positive input level, which is lower than the output level of operational amplifier IC1, Q1 is closed, the switching power converter enters the normal working state and completes the whole working process of burping short-circuit protection, Realize the self recovery protection function of short circuit and overcurrent of switching power converter.

As shown in Fig. 2 short circuit protection circuit diagram, the regulating resistor R1 can adjust the charging time of C2 in reverse proportion, and realize the adjustment of short-circuit protection time. By adjusting the R7 size, the discharge time of C2 can be adjusted, thus adjusting the recovery time of short-circuit protection.

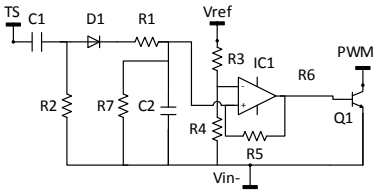

Fig. 2. Short circuit protection circuit diagram.

3 Calculation and analysis of protection circuit

3.1 Computational Analysis

The performance of short-circuit protection circuit depends mainly on the circuit's high capacitive load capacity while accurately judging the working state of power supply. According to the characteristics of power supply circuit, the judging conditions of abnormal power converter are as follows:

$$\Delta V > \left(\frac{V_{ref} \cdot R_4}{R_3 + R_4} + V_{D1} \right) \frac{X_C + R_2}{R_2} \cdot 2 \tag{1}$$

wherein ΔV is the ripple voltage of the filter capacitor of the power supply converter, V_{D1} is the forward tube voltage drop of the diode, and X_C is the complex impedance of the capacitor C1.

According to the different capacitive load capacity of the power converter, the action time of short-circuit protection is set as follows:

$$T_1 = R_1 C_2 Ln\left(1 - \frac{R_3 \cdot V_{ref}}{(R_3 + R_4) \cdot \Delta V} \right) \tag{2}$$

wherein T_1 is the operation time of protection circuit in power converter when short circuit overcurrent occurs, V_{ref} is the reference voltage.

3.2 Circuit simulation analysis

Using Multisim software, the simulation circuit diagram of Short Circuit Protection as shown in Fig.3 is built. The simulation results are shown in Fig. 4.

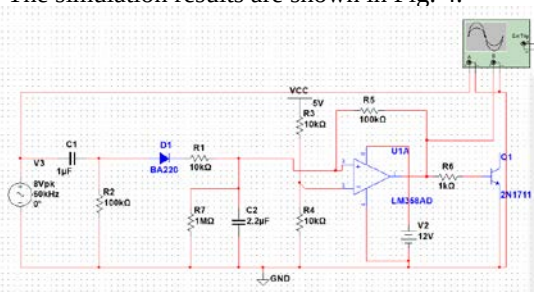

Fig. 3. Short circuit protection simulation results.

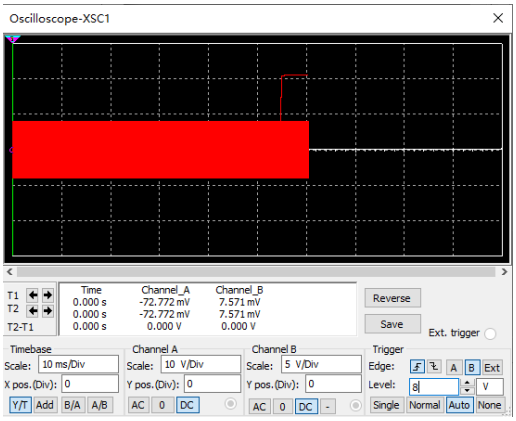

Fig. 4. Short circuit protection simulation results.

4 Conclusion

Through the simulation circuit, it can be seen that when the power converter has a short circuit, the ripple of the filter capacitor increases sharply, which can trigger the short circuit protection within a predetermined time, quickly close the driving end of the switch, and realize the reliable protection of the power supply.

The papers funded by science and technology project of State Grid Corporation of China (5500-201927267A-0-0-00)

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