Design of Flyback Switching Power Supply

Ronghui Xue

Xi'an Aeronautical University, Xi'an, Shaanxi 710077, China.

Abstract

At present, the requirements of the volume of secondary power supply, the range of input voltage, the type of output voltage, the power and efficiency of small electronic equipment are becoming higher and higher. A flyback switching power supply is designed based on single ended flyback topology. The selection of components is analyzed and the system design scheme is finally determined. In this paper, the basic working principle and working process of flyback switching power supply are deeply studied. Through constant debugging, flyback switching power supply is designed. The design circuit includes input protection circuit, electromagnetic interference filter, input rectifier filter circuit, flyback transformer, control circuit and feedback circuit. The parameters of each module are selected, designed and adjusted The test results are satisfactory, the output is stable, and the performance is good in the test.

Keywords

Single ended flyback converter; High efficiency; Switching power supply.

1. Introduction

Switching power supply technology is widely used in many fields, such as automobile, aerospace, military industry and so on. Generally, it can be divided into two forms: non isolated and isolated. The non isolated type includes buck, boost, buck boost and other circuits. According to the structure, isolated mode can be divided into forward type and flyback type . Flyback converter topology has many advantages, such as no need of output filter inductor, small size and low cost, and has been widely used. The power supply is divided into linear regulated power supply and switching power supply. Generally, high-frequency switching mode is used for power conversion. Switching power supply gradually replaces traditional technology to manufacture phase controlled power supply, and is widely used in various electronic equipment. Single chip switching power supply has various performance indexes with high integration, high cost performance ratio and the simplest shape. It has become the development of preferred integrated circuits such as medium and small power switching power supply, precision switching power supply and switching power supply module. The development of flyback switching power supply is helpful to the country's long-term and purposeful strategic goal in the field of circuit development, which can provide stable power supply for all aspects in the future. For us, the power supply has become a necessity for our daily necessities. The short-term power failure has a great impact on our life. Therefore, having a stable and reliable power supply can help people improve their quality of life and improve the quality of housing and life we want. This paper designs the parameters of switching power supply, input 50-110V, 50 Hz AC / 50-150v DC, output 20V 4A DC, switching frequency 70kHz, maximum duty cycle 0.4. After completing the overall test of the prototype, it is proved that the power design index meets the design requirements, the output is stable, and it performs well in the test.

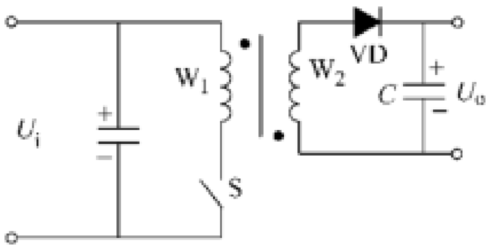

Fig.1 Circuit diagram of single flyback converter

2. Single Ended Flyback Converter

The circuit diagram of single ended flyback converter can be generally expressed as Figure 1. The variables in the circuit can be analyzed by using the switching elements as a whole, so that the flyback converter circuit can be abstracted as a two port network. The equivalent circuit composed of controlled voltage source and controlled current source can be analyzed by studying the relationship among the variables of the port.

After the flyback converter is switched on, the energy in the primary inductance of the transformer is stored. Pay attention to the same end of the transformer. When the switch is turned off, the input voltage should be lower than the drain voltage, and the ground voltage should be lower than the secondary voltage of the transformer. The output capacitance and load provide power supply because the diode is on. A flyback converter can have multiple windings on one side of the transformer, which makes it easy to output multiple sets of voltages. Each output voltage is isolated from the original phase, and the output voltage of each group can be realized by changing the regulator. The resistor can work in discontinuous current mode or current mode, and the most common operation mode of flyback converter is discontinuous current mode.

2.1 Current continuous mode

When the switching device is turned on as the ideal switch s, the current in the transformer W2 has not dropped to zero, that is, there is still current at the secondary side of the transformer, which is called the current continuous state (CCM). Generally, there are many researches on CCM state, and there are many analysis methods for DC / DC converter at home and abroad, such as state space average method. The relationship between the ideal output voltage and the input voltage is as follows:

$$\frac{U_o}{U_i} = \frac{N_2}{N_1}\frac{t_{on}}{t_{off}} = \frac{N_2}{N_1}\frac{q}{1-q} \tag{1}$$

2.2 Intermittent current mode

When the current in W_2 has dropped to zero before the switching element s is turned on, it is said that it works in the intermittent current mode. Discontinuous conduction mode (DCM) has the advantages of small primary excitation inductance, fast response and high output voltage gain, and can maintain its advantages in the case of input voltage fluctuation or load mutation, but the process is complex, so the corresponding research modeling is less than that of current continuous state. Fig.2 shows the working waveform of intermittent current.

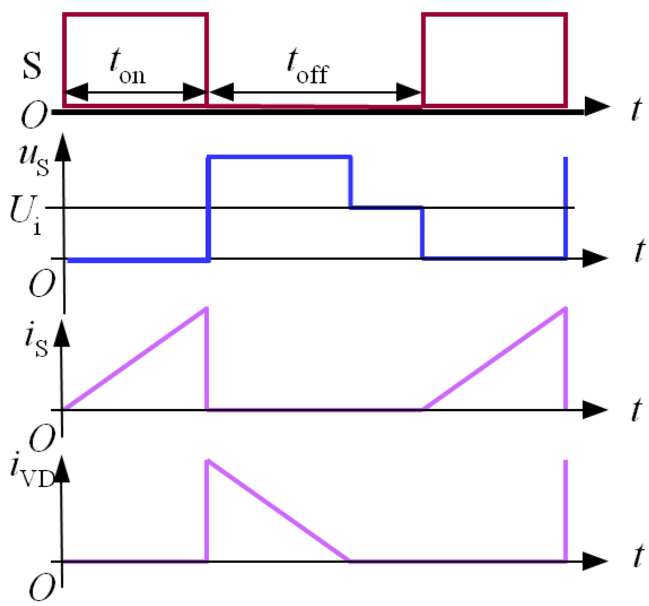

Fig.2 The working waveform of flyback circuit

When the circuit works in intermittent state, the output voltage is higher than that calculated by Formula 1, and the output voltage increases with the decrease of load, so the load cannot be zero.

3. Flyback Transformer

Transformer design and calculation is the key of power supply design. Transformer is responsible for energy transfer, voltage regulation, isolation and insulation. Therefore, transformer is the primary task of main circuit design. The quality of transformer design directly affects the performance of circuit.

3.1 Selection of magnetic core

Magnetic core is an important part of manufacturing high-frequency transformer. Reasonable design and correct selection of core material, parameters and structure will have a vital impact on the performance and reliability of the transformer. The core of high frequency transformer can only work in the first quadrant of hysteresis loop. When the switch is on, only the energy is stored and the energy is transferred to the load when it is switched off. Because the switching frequency is 70kHz, which is a relatively high model, the material with this frequency should be selected, and the ferrite with higher efficiency should be selected.

3.2 Initial parameters

Input voltage range:Vinmin Vinmax AC

Power grid frequency: (50 Hz in China)

Output power: (equal to the sum of output power of each channel)

The efficiency of the converter is preliminarily estimated as follows: η (for low-voltage output, η is 0.7-0.75, for high-voltage output, η is 0.8-0.85)

$$P_{out}=V_{out}I_{out}=80w \tag{2}$$

(1) Determine input capacitance

The value of C_{IN} is related to the input power,in the past, 2-3 μ f / W was used for wide range input voltage (85-265VAC), 1 μ f / W for narrow range input voltage (176-265VAC), and 0.2 was generally taken as the duty cycle of capacitor charging.

Generally, 0.2 is the duty cycle of capacitor charging Doh.flyback converter is designed at the minimum voltage v_{Inmin} after rectification.

$$V_{INmin}=50V \tag{3}$$

$$V_{IN\max}=110\times\sqrt{2}=156V \tag{4}$$

Voltage withstand value of input filter capacitor 200V,The capacitance value is taken as 1uF / 1W,100uF。

(2) Determine the maximum duty cycle

CCM and DCM have their own advantages and disadvantages. DCM model has good switching characteristics, and the secondary rectifier diode is turned off at zero current, so there is no diode reverse recovery problem in CCM mode. At the same power level, the size of DCM transformer is smaller because it stores less energy than CCM mode. However, compared with CCM mode, DCM mode increases the RMS of primary current, which increases the on loss of MOS transistor and the current stress of secondary output capacitor. Therefore, CCM mode is often recommended when using low voltage and high current output, and DCM mode is often recommended when using high voltage and small current output. For CCM mode flyback converter, the input gain of output is only determined by duty cycle. In DCM mode flyback converter, duty cycle and load condition determine the input of output voltage gain at the same time, which makes the design of DCM mode circuit more complicated. However, if we use CCM mode (BCM mode) to design DCM mode flyback converter in DCM mode, the minimum input voltage (V_inmin The problem is simplified. Therefore, whether flyback converter is in CCM mode or DCM mode, we can design according to CCM model. When the MOS transistor is turned off, the input voltage V_{In} and the secondary reflection voltage nV_out is superimposed on both ends of DS of MOS. When determining the maximum duty cycle $D_{\_max}$, the reflected voltage is v_ Or (or, NV_out The maximum voltage of the secondary rectifier diode is v_D and MOS transistor maximum voltage V_DSmax can be obtained from the following formula:

Where Dmax is 0.4.

$$V_{OR} = \frac{D_{\max}}{1-D_{\max}} \times V_{IN\min} = 33V \tag{5}$$

$$V_D = \frac{V_{IN\min}}{V_{OR}} \times V_{out} + V_{out} = 50V \tag{6}$$

$$V_{ds\max} = V_{IN\max} + V_{OR} = 190V \tag{7}$$

(3) Inductance Lm

For CCM mode flyback, the converter may switch from CCM mode to DCM mode when the input voltage changes. For both modes, the primary inductance LM of the transformer is designed under the worst conditions (minimum input voltage, full load). It is determined by the following formula:

$$L_m = \frac{(V_{IN\min} \times D_{\max})^2}{2 \times P_{IN} \times f_{SW} \times K_{RF}} = 114\mu F \tag{8}$$

4. Feedback Circuit

Basic feedback circuit, improved basic feedback circuit, voltage regulator with optocoupler feedback circuit, TL431 optocoupler feedback circuit, switching power supply are four types of feedback circuit. In this design, the adjustable precision parallel voltage regulator TL431 and linear coupling PC817 are used to form a feedback loop. The feedback loop is mainly composed of PC817, TL431, capacitors and resistors. U_2 is TL431, which can debug the precise shunt voltage regulator, and obtain the basic voltage value by using R_{20}, R_{22} partial voltage. Setting of feedback voltage:

$$((R_{20}+R_{22})/(R_9+R_{20}+R_{22})+1)*2.5=V_{out} \tag{9}$$

When R_9=22K、R_{20}=2.2K

$$V_{outmax}=(22/2.2+1)*2.5=27.5V \tag{10}$$

$$V_{outmin}=(22/3.2+1)*2.5=19.6V \tag{11}$$

By adjusting the values of R_{20} and R_{22}, the output voltage can be adjusted to stabilize the voltage. The C_{12} and R_{21} frequency compensation capacitors of TL431 will increase the transient frequency response of TL431.

PC817 is a linear optocoupler, while 4N25 and 4n26 optical couplers commonly used in China are nonlinear optical couplers. The transmission ratio of PC817 is higher, which can better meet the design requirements of feedback loop. Therefore, 4N25 and 4n26 should not be used. The optocoupler (PC817) is used for isolation. When the voltage applied to the optocoupler input is high, the output voltage of the phototransistor is smaller, fed back to the 2 pin, and then the duty cycle output is adjusted to 20V.

5. Hardware Circuit Diagram

Based on the analysis of flyback switching power supply system and the analysis, design, parameter calculation and selection of specific circuit modules in this chapter, the overall design circuit schematic diagram of flyback switching power supply is drawn with software. As shown in Fig. 3.

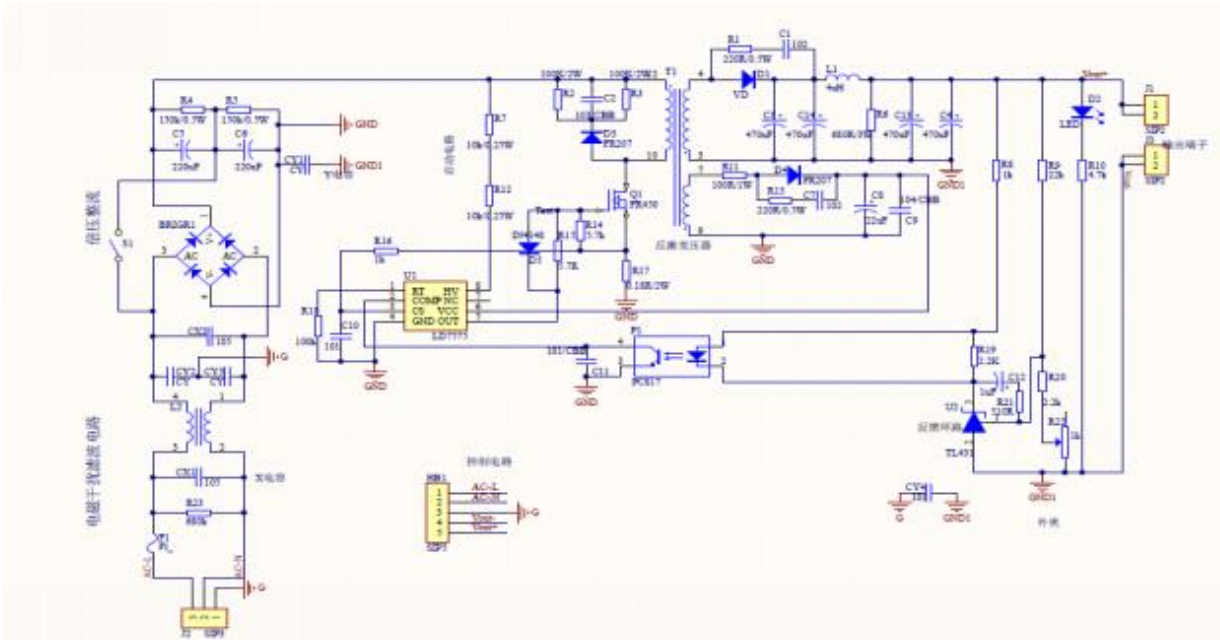

Fig.3 hardware circuit

(1) Protection circuit

The input protection circuit is composed of fuse F_1 and thermistor R_{23} to protect the input terminal from over-voltage and over-current. Fuse F_1 is used to cut off the circuit in case of line fault to avoid over-current and protect circuit components from damage; the higher the temperature of thermistor R_{23} is, the smaller the resistance is. In order to prevent the instantaneous power capacitor charging plug from being in the spark due to the low initial power supply temperature and high resistance, it can suppress the starting impulse current and avoid the damage of rectifier diode and fuse due to too large instantaneous current the design of the power supply can effectively cause damage to the thermal resistance.

(2) Starting circuit

R_7 and R_{12} are starting resistors, which provide low current for ld7575 power supply starting for the first time. When the chip is started for the first time, R_7 and R_{12} do not need to be powered on. The power supply circuit of the transformer is directly used for power supply, and C_8 is the filter energy storage capacitor of the power supply circuit.

(3) Design of capacitor

The output of the circuit is 20V, 4a, and the capacitor is charged by the transformer diode. The higher the capacitance of the capacitor is, the smaller the output voltage ripple is. Among them, C_3, C_{14}, L_1, C_{13} and C_4 form a π type filter to reduce the output ripple. R_1, C_1, R_{13} and C_7 are used for diode reverse voltage spike absorption. D_2 and R_{10} can be used as output power indicator and as false load.

(4) Control circuit

In the control circuit, R18 is used to set the oscillation frequency. The 3-pin is the switching current sampling terminal of ld7575 chip. When the R_{17} voltage at both ends of the sample exceeds 0.8V, the 5-pin outputs the low-level MOS transistor immediately. R_{15} is the MOS transistor driving current limiting resistor. MOS transistor Q_1 controls the MOS transistor on and off through the 5-pin output of ld7575. When the output voltage is higher than 20V, it is fed back to pin 2 through optocoupler Reduce the duty cycle of 5-pin output and output 20V to achieve stable voltage output.

6. Conclusion

Single ended flyback switching power supply has the advantages of simple structure, small number of components and low cost. Especially for multi power output. Due to the low utilization rate of transformer and the large current peak value of switching devices, it is not suitable for high power switching power supply. In this paper, the simulation software is used to model, analyze the waveform and verify the data. The simulation results show that the data selection is reasonable, the design results are correct and the performance index meets the requirements.

Acknowledgements

Fund Project: project of science and Technology Department of Shaanxi Province (2019GY-014).

Project Name: equipment development of industrial image surface defect detection and classification system based on deep learning.

Fund Project: Xi'an Aeronautical University (2020HX019).

Project Name: Research on LCL control stability technology of grid connected inverter.

References

[1] Liu Xiang, Li Xiaofeng, Ding Lianggui, Jiang Fei. Steady state analysis and modeling simulation of DCM flyback converter [J]. Acta Ordnance Equipment Engineering, 2020,41 (03): 205-210.

[2] Cheng Hongli, Zhang Zhicheng, Jia Longfei. Design of a low power flyback converter [J]. Power electronics technology. 2018,52 (05): 1-4.

[3] Yan Huihui, Han min. design of a single ended flyback switching power supply [J]. Information communication, 2019 (10): 81-82.

[4] Wang Zhaoan, Liu Jinjin, et al. Power electronics technology [M] 5 edition. Beijing: China Machine Press, 2009.

[5] Yang Lei, Cao Yang, Xu Zhen. Design of single ended flyback switching power supply based on uc2842 for high voltage converter [C] Power Quality Committee of China Power Supply Association, Asia power quality industry alliance. The 4th national power quality academic conference and power quality industry development forum: power quality and efficient and high-quality power consumption theory collection. Power quality professional committee of China Power Supply Association, Asian power quality industry alliance: power quality professional committee of China power supply Association, 2015:273-285.