*Applied Mathematics, Modeling and Computer Simulation*
*C. Chen (Ed.)*


*doi:10.3233/ATDE220064*

# Design and Simulation of a Flyback Switching Power Supply

Geng ZHOU, Haitao CUI, Yuhua MA, Yiming LUO, Cuixia WANG, Bin LIAN[1]
*CSSC Haiwei Zhengzhou High Tech Co., Ltd, China*

**Abstract.** This paper describes the design of an IC+MOS switching power supply, including EMI filter circuit, rectifier filter circuit, self-excited power supply circuit, switching converter, output filter circuit and control circuit, and the parameters and design process involved in each part of the circuit are analyzed. The rationality of the design is verified by simulation and circuit construction, and the stable output of voltage is realized, the core components are domestic components.

**Keywords.** AiP3842, flyback type, PWM control, domestically produced.

## 1. Introduction

With the development of society, the application of electronic products in life is more and more extensive, stable and reliable power supply is particularly important.Power supply can be roughly divided into switching power supply and linear power supply difference, switching power supply as a combination of a number of passive, active devices for continuous switching and continuous storage, release energy to complete the power conversion of the power supply circuit system, its good isolation, wide voltage range, low power consumption, high efficiency.In addition, the weight of the switching power supply is 1/4 of the linear power supply, and the corresponding volume is about 1/3 of the linear power supply [1-2].The traditional switching power supply in addition to the power switch tube also includes about 50 discrete components, low integration.With the maturity of production technology, the low-voltage control unit can be integrated into the same chip, and then the application range of switching power supply is gradually extensive.

## 2. Working Principle

In a broad sense, the main circuit that converts one form of power supply into another form by using semiconductor power devices as switches is called switching converters.When the transition with automatic control closed loop, stable output and protection link is called switching power supply.

The basic structure of flyback switching power supply designed in this paper is relatively simple, as shown in figure 1. It is mainly composed of four parts: input rectifier

[1] Corresponding Author, Bin LIAN, CSSC Haiwei Zhengzhou High Tech Co., Ltd, Henan, Zhengzhou, China, E-mail: neulian@163.com.

filter circuit, switching converter, PWM control circuit and output rectifier filter circuit.Firstly, the input AC signal is processed by EMI filter and bridge rectifier filter circuit to suppress the differential mode and common mode interference and convert AC into DC signal.Then, the PWM control circuit controls the on-off of the VDMOS power tube, and then controls the on-off of the original side of the transformer to ensure the voltage stability of the secondary side of the transformer.Finally, the output signal is filtered by the rectifier circuit to eliminate the interference signal caused by the high frequency on and off of the power tube, and then the DC with small voltage pulsation is obtained to realize the voltage conversion of AD-DC.In this way, one or more channels of high quality and stable DC output voltage can be efficiently converted.

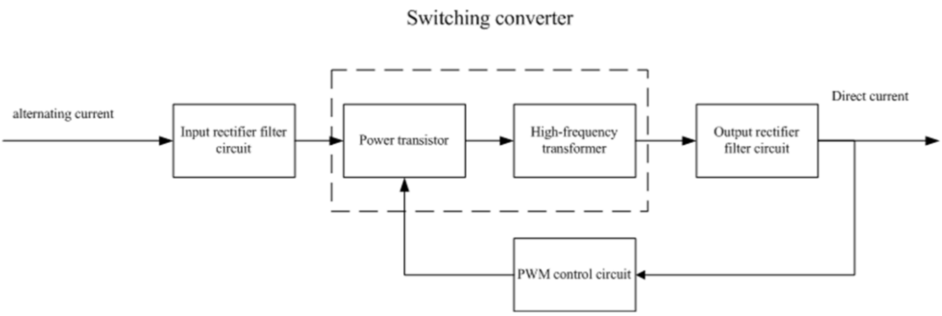


**Figure 1.** system block diagram

## 3. Design of High Frequency Transformer

High-frequency transformer has energy transmission in switching power supply, voltage transformation, and the role of electrical isolation, is the core component of switching power supply, high frequency transformer performance is good or bad, not only directly related to the technical index of the power supply and electromagnetic compatibility, but also to the influence of the power conversion efficiency is larger, so the high frequency transformer design is an important link in the design of switch power supply.

### *3.1. Selection of Magnetic Core Materials*

The high frequency transformer in switching power supply mostly adopts EE or EI magnetic core. EI magnetic core has the advantages of simple shape, large effective area of magnetic core, high reliability, good thermal characteristics, small leakage and so on. EI magnetic core is used in this design.

Manganese-zinc ferrite and nickel-zinc ferrite are two series of magnetic core components with the largest variety and the most extensive application among the soft ferrites produced at present. Manganese-zinc ferrite has high permeability and compact structure, while nickel-zinc ferrite has low permeability and porous structure. The resistivity of manganese-zinc ferrite is about103 Ω·CM, and that of nickel-zinc ferrite is about106 ~ 1012 Ω·CM. Due to the high resistivity and porous structure of ni-Zn ferrite, its performance is inferior to that of Mn-Zn ferrite when the application frequency is less than 1MHz, but its performance is much better than that of Mn-Zn ferrite when the application frequency is more than 1MHz.Manganese-zinc ferrite can be used in frequency range of 2MHz below the occasion, is commonly used in high frequency transformer materials. Manganese zinc ferrite core material is selected in this design.

### *3.2. Transformer Design*

Design index: switching power supply ac input range :220VAC±20%;DC voltage range after rectification :240 ~ 380V. ;Output voltage/ current: ±24V±5%@1.8A, Ripple is less than 20mV; Output power 43W; Efficiency η=90%. The calculated maximum duty cycle is about 0.367.

1) Magnetic core selection

Magnetic core model [3] is selected according to AP method, and the minimum magnetic core that meets the requirements is EI33.

$$AP = A_W A_e = \frac{P_t}{2\eta f_{osc} K_c B_m j} * 10^4 = 0.425cm^4 \tag{1}$$

2) The number of turns in the primary winding

$$N_P = \frac{U_m * 10^4}{5.5 f \sqrt{PBS}} \approx 44 \tag{2}$$

Where, B is the flux density, S is the cross-sectional area, and P is the output power.

3) The number of turns in the secondary winding

$$N_s = \frac{N_P}{U_{OR}} (U_O + U_F) \approx 11 \tag{3}$$

Where, $U_F$ is forward pressure drop of rectifier tube, Quick recovery diode takes 0.7V;$U_{OR}$ is Secondary maximum reflected voltage, At a margin of 120V, $U_{OR}$=100V.

## 4. Flyback Switching Power Supply Circuit Design

The system mainly includes: EMI filter, input rectifier filter circuit, converter (including power switch tube, buffer absorption loop, high-frequency transformer and RCD clamp circuit), output filter circuit, control circuit, etc.

The input of the system is 220V AC. The noise from the power grid is filtered out by EMI filter circuit. After further bridge rectification and filtering, the AC is converted into DC.Transformer by coupling provide meet the demand of electric power load, the power transformation of the process, to ensure the stability of the output voltage, feedback regulation mechanism is introduced, and the voltage and current feedback signal input to the control chip AiP3842, after sampling, comparison, control chip to adjust the output of the PWM pulse width,Thus the duty cycle of switch tube is controlled to stabilize voltage.The structure diagram of switching power supply is shown in figure 2.

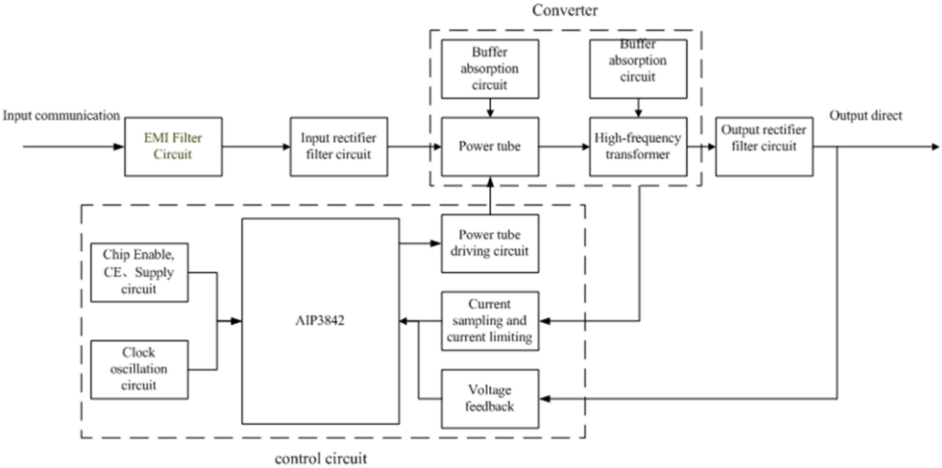


**Figure 2.** Structure diagram of switching power supply

### *4.1 Aip3842 Peripheral Circuit Design*

By setting up AiP3842 peripheral circuit and processing voltage and current feedback signals, the switch tube is controlled on and off, and then the coupling time of transformer is controlled to ensure stable voltage output. In figure 3, DC is the DC voltage after rectification, T1 and T2 are connected to transformers, and DCSAMP is connected to voltage feedback signals.

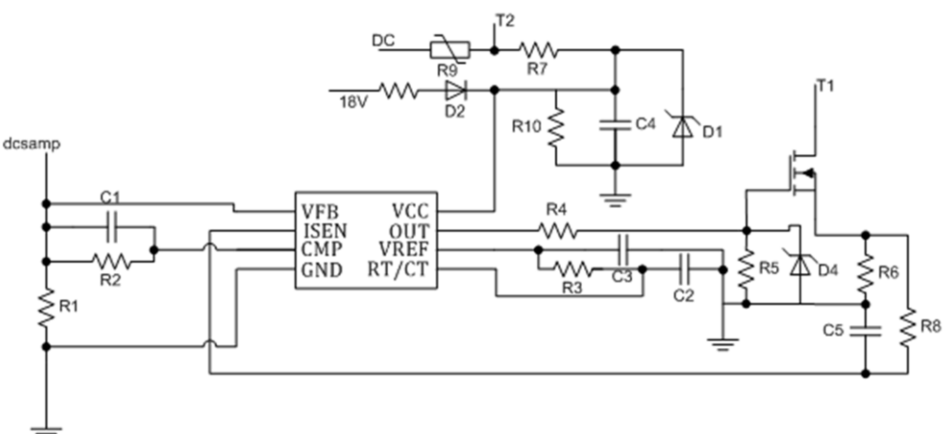


**Figure 3.** Chip peripheral circuit diagram

1) Chip supply circuit

The power supply of AiP3842 in this design circuit can be divided into start-up stage and working stage. Start-up stage: the starting circuit is composed of R7 and C4. After the system is powered on, the rectified direct current is limited through the thermistor R9, and the C4 is charged to 16V after passing R7.After entering the normal operation phase, the transformer outputs 18V to power the AiP3842.In order to ensure normal startup, the tolerance of C4 must be large enough, which is selected as 100uF/50V. According to Formula (4), R1=308K ω, where UI is the DC voltage after rectification.

$$R1 = \frac{DC - VCC}{1mA} = 308K\Omega \tag{4}$$

AiP3842 ensures the reliability of PWM signal by inputting clock signal.AiP3842 has a sawtooth oscillator inside, this design through C2, C3, R3 to set the AiP3842 working frequency.

$$f_{osc} = \frac{1.72}{R_T \times C_T} \tag{5}$$

2) Current feedback and voltage feedback

The current change is converted into voltage change through resistance, and the signal is introduced into AiP3842, which is processed by the error amplifier inside the chip, and then the PWM output is adjusted to adjust the power supply.The recovery of the rectifier tube and the capacitance between the transformer lines will cause a large spike in the front edge of the current waveform. In order to eliminate this spike and prevent AiP3842 from triggering by mistake, a simple RC filter circuit is connected.The RC time constant should approximate the duration of the current spike, which is usually measured as several hundred nanoseconds. Common values are taken in this design R8=1KΩ, C5=500pF, Then the time constant $\varsigma = \mathrm{R8} \times C5 = 500ns$.

In AiP3842, the voltage of the inverter input of the current detection comparator is clamped at 1V. When the voltage of the in-phase input of the comparator (3 pins of AiP3842) ISENSE reaches this threshold, the voltage of the ISENSE pin is reduced by adjusting the PWM output, thus playing the role of current limiting.

In order to ensure the stability of output voltage, a voltage feedback circuit is introduced. The voltage feedback circuit is built by HPC817 and 7W431, with AiP3842 to achieve a good effect, and the adjustment rate of output power supply is ± 0.2%.The voltage feedback circuit is shown in figure 4.

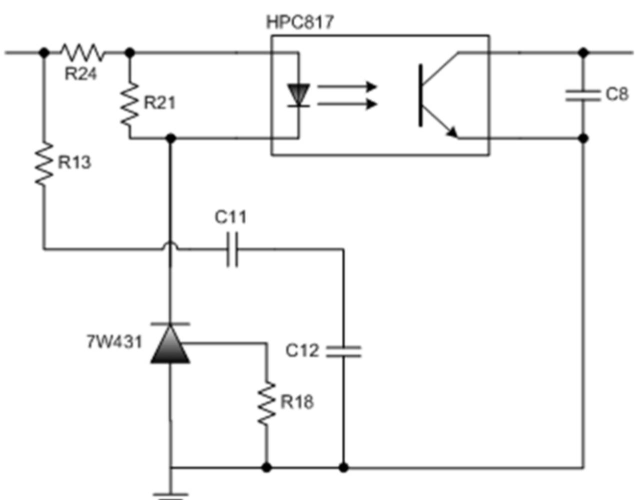


**Figure 4.** Voltage feedback circuit

### *4.2 Power Tube Drive Circuit*

The on-off of the MOS tube is controlled by changing the gate voltage. In order to ensure the stability of THE PWM signal and avoid the level uncertainty due to the pin hanging, the problem of misdirection will appear under the influence of the interference voltage, the gate is connected with the pull-down resistor R5.The drain of MOS tube is connected to the transformer. Due to the leakage inductance of the transformer, some energy cannot be transmitted from the primary side to the secondary side when THE MOS is turned off. Therefore, part of the energy storage inductor of the transformer will store a certain amount of charge during the shutdown state of the system, thus generating a peak voltage [4].If it is directly applied to the drain of MOS tube without processing, it is easy to break down the power switch tube. C7, D3 and R14 form a buffer absorption circuit, while D7 performs voltage clamp. TVS can suppress high-voltage pulse instantly to prevent damage of MOS tube due to high drain voltage (figure 5).

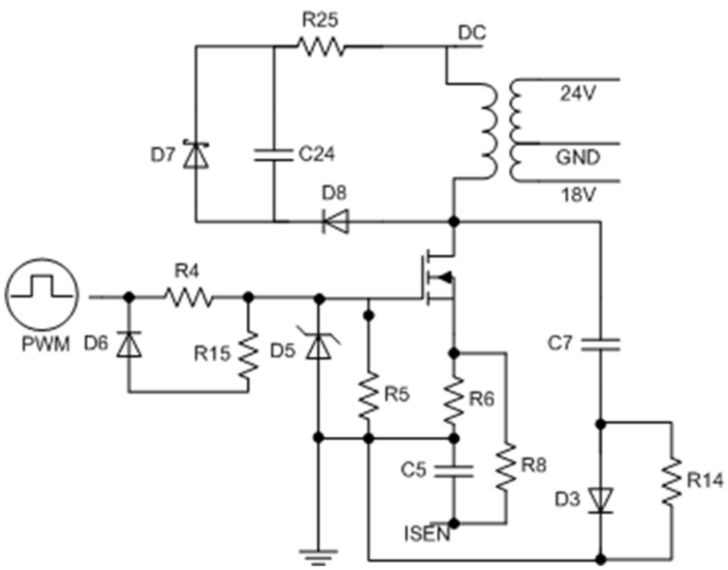


**Figure 5.** Switch tube drive circuit

Due to the inherent process structure of the device, there is junction capacitance between drain-gate and source-gate of MOS, which are $C_{DG}$ and $C_{GS}$ respectively. When the MOS tube is turned off, the current will not disappear immediately, and the changing voltage will generate a current path. When the current is large enough, the MOS tube will be turned on, and D6, R4 and R15 will play a role of current limiting [5]. In the process of mosFet on and off, a large peak voltage and current will be generated. Increasing the driving resistance will reduce *du/dt* and *di/dt* and reduce mosFet switching rate, but will increase power consumption. The reduction of driving resistance will increase *du/dt* and *di/dt*, resulting in voltage and current spikes may cause misoperation, should be based on the application environment, the resistance of the choice of compromise.

## 5. Simulation and Experimental Results

In the circuit design process, through Multisim circuit simulation, in the case of normal simulation results for physical construction, the realization of input AC120V (50Hz), output DC24V, through LDO step-down to meet the load voltage demand. The power efficiency reaches 85% and the switching frequency reaches 75kHz.The output stability and reliable performance of the switching power supply are verified. Right in figure 6 shows the PWM waveform output by AiP3842. Left in figure 6 shows the 24V output voltage. The load of 16W, 32W and 64W were connected respectively, and the $V_{DS}$ voltage of MOS tube was measured at the same time, as shown in figure 7. Under different loads, the voltage fluctuation generated in the switching process of MOS tube was stable, and the peak-to-peak voltage of $V_{DS}$ did not change greatly due to the increase of current.

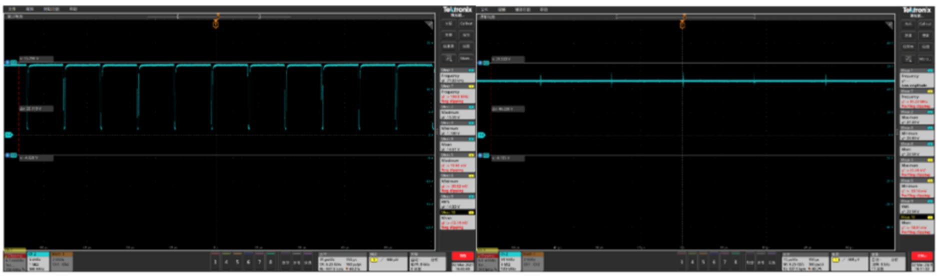

**Figure 6.** PWM waveform and 24V output

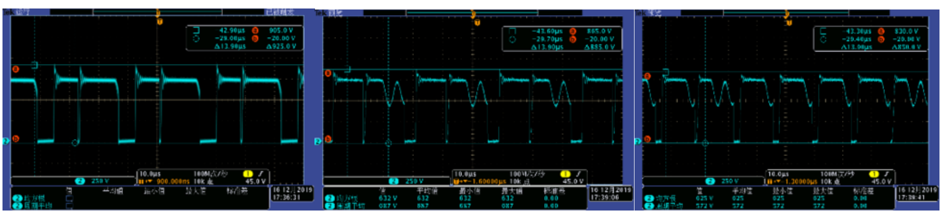

**Figure 7.** 16W、32W and 64W

## 6. Conclusion

This paper designs a switching power supply, adopts flyback topology, based on domestic components, while completing the functional verification of the flyback switching power supply, the performance verification of domestic components. The test results show that the flyback switching power supply has stable output and reliable performance.

## References

[1] Zhang T, Qian Q, Xu M, et al. Analysis on ringing effect of auxiliary winding in primary side regulated flyback converter [C]. Energy Conversion Congress and Exposition (ECCE), 2014 IEEE. IEEE, 2014:2727-2733.

[2] Meng Jianhui, Liu Wensheng. Analysis and Comparison of DCM and CCM Modes of Flyback Converter [J]. Communication Power Supply Technology, 2010,27(06):33-35+38.
[3] Liu Mengke,Tang Haiyang.Design of single - end flyback switching power supply[J]. Electronic Design Engineering, 2017,25(01):175-178
[4] Yan wei,Zhao yang,et al.Mechanism analysis and suppression of radiated EMI noise in complex electronic system[J]. Proceedings of the CSEE, 2013,33(15):173-180+1.
[5] John H.Optimizing MOSFET and IGBT Gate Current to Minimize dv/dt induced Failures in SMPS Circuits[Z].Advanced Power Technology,2001.