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Design of a Flyback Switching Power for Smart Meter

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Abstract

With switching power supply being widely used in Smart Meter, there exists more restrictions on the performance of it. This paper designs a single-ended flyback switching power supply based on LNK364DN chips which is used in intelligent single-phase table, Compares the advantages and disadvantages of the switching power supply and the traditional linear regulated power supply, and introduces the reaction type switching power supply design principle and working process. In order to satisfy the security requirements, this paper also designs the EMI suppression circuit, surge suppression current, clamp circuit, etc. The design process, including the maximum duty cycle including transformer, the primary inductance calculation, etc, of the flyback type switch power supply transformer is introduced in detail. The experimental results show that the switch regulated power supply has small volume, good electromagnetic compatibility, small ripple, low power consumption, high efficiency of AC/DC transform and excellent performance .

***Keywords**: switching power supply, the fyback transformer,LNK364DN,AC/DC*

1. Introduction

With the rapid development of electronic technology, the relationship between electronic equipment and people's work and life is becoming more and more closely. And the power supply is the heart of all electrical equipment, any electrical equipment can not be separated from reliable power supply, and the power requirements are also getting increasingly higher with the rapid development of electronic technology.The development of modern electronic equipment have the requirements of small volume and low cost, high reliability, high conversion efficiency, which makes the switching power supply came into being[1]. Switching power supply originated in the 50's of last century. In the early 80's, St Semiconductor Co, Ltd. was the first to introduce the L4960 series monolithic switching regulator. In 1994, American power company in the world firstly succeeded in developing three terminal isolation type pulse width modulation type single chip switching power supply, known as top off power, then it launched the efficient, low-cost spaces, small power four terminal monolithic switching power supply Tiny Switch series.By 2000, National Semiconductor Corporation Ns developed a high efficiency 0.5A Simple Switch voltage converter, its efficiency as high as 96%. Thus, in foreign countries, the rapid development of switching power technology is increasingly mature[2].

In China, the research and development of switching power supply began to start in the 60's of last century, it entered the practical research in the middle of the 60's,by the early seventy's,our country can independently developed No power frequency buck type

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switching power supply.Generally speaking ,the development is slow, in the last two decades, China's many research and development centers, enterprises and institutions began to invest in high frequency switching power supply research. Over the years, China has made great efforts in switching power supply and achieved great results. But, at present, the technology of switching power supply in our country still has a considerable gap compared with some advanced countries[3].

For different use scenarios, having development of efficient and stable switching power supply is the direction of our efforts. In smart meter, first of all, it requires that the power source has the advantages of high reliability, , the power supply needs to be used for more than 10 years in actual power grid, and it needs to have the characteristics of anti saturation, low leakage inductance and high insulation. Secondly,it has requirements with high pressure resistance, the general requirements of insulation pressure up to 4000VAC. Thirdly, it has requirements with high EMC performance, static test, lightning surge EMC test with national standards completely; Fourthly, it has requirements with high efficiency of more than 65%; Fifthly, it has requirements with small ripple and ripple coefficient is less than 5%; The last, it has requirements with small volume and it can promote the development of smart meter because of the miniaturization and light weight.

Based on the development and application of smart meter, this paper design a flyback switching power supply, put forward the schemes of the whole design and carry out the corresponding modules hardware circuit design and experimental verification according to the requirements of technical specifications.

2. The Overall Design Scheme

Currently, high performance switching power supply is usually used as the power supply system in the design of smart meter in foreign countries. And in the domestic, most still stay in the use of traditional linear regulated power supply. Conventional linear voltage stabilized power supply has the characteristics of small ripple and simple structure, but its disadvantages are also very apparent.So it both results in a waste of energy and can not meet the needs of the development of small electronic products increasingly sophisticated. In the relative, switching power supply is in low energy consumption in the opening and closing of two kinds of state, more power can be transferred to the load,so it has high efficiency and low fever compared to conventional linear power[4][5].With the component technology more advanced, capacitors, inductors, chip controller, switches and other devices, whose costs continue to drop and performance continues to increase, coupled with high efficiency and excellent properties of the switch power supply, so its application is more and more widely, in many occasions, it gradually replaced the traditional linear regulated power supply.

In this paper, a flyback switching power supply is designed, which is applied to the smart meter. The power supply is mainly used for the electric energy measurement module, the digital processing module and the communication, display, storage, control and protection module of the intelligent electric energy meter to provide a stable and reliable voltage[6,7,8].

2.1. The overall design requirements

Flyback switching power supply is mainly by the power MOS transistor, high-frequency transformers, passive clamp circuit and the output of the rectifier circuit. The core switching power supply chip, scilicet feedback control chip is a new intelligent high-frequency switching power supply integrated chip by the United States company (Power Integration Inc) development and design of LNK Switch series. The design uses a PWM (pulse width modulation) control to achieve the AC/DC conversion, by adjusting the duty cycle to achieve a stable output voltage [9,10].

The design of the technical indicators are as follows:

Table 1. Requirements of Design Parameters

Parameter	Norm
Input voltage	220VAC（±20%）
Output voltage	12V（±5%）
Conversion efficiency	80%（±5%）
Ripple factor	≤5%

The design has system requirements that its voltage output is 12V under various conditions, and it meets the design performance index, power supply requirements for smart meter electric energy metering module, a digital processing module and a communication circuit and so on. The design prevents electromagnetic interference and restrain surge to achieve the stability and reliability of the system [11,12].

2.2. The Principle and Structure of the Switching Power Supply

Flyback switching power supply has the characteristics of low energy consumption and high efficiency, and can be obtained in a small volume of the power output is higher than the traditional linear power supply. Therefore, more and more widely application in intelligent electric energy meter research and development. In this paper, a PWM (pulse width modulation) flyback switching circuit which is composed of a MOS tube and a power controller is used to achieve the purpose of voltage regulation by changing the pulse width to achieve the adjustment of the duty cycle.

The typical structure flyback switching power supply as shown in Figure 1. Structure generally includes an input circuit, a transformer, a control circuit, output circuit and protection circuit,etc.

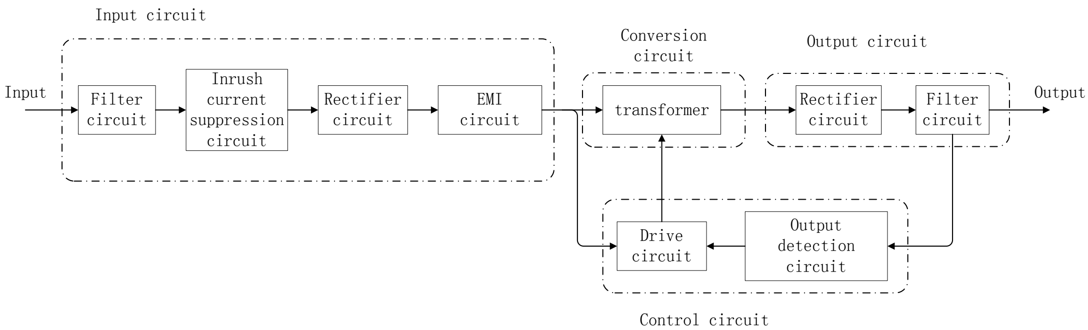

Figure 1. Flyback Switching Power Supply Structure Diagram

3. Design of Hardware Module

In order to adapt to the bright prospects of Switching Power supply, promote the application of switching Power supply, and simplify the design of the switching Power supply, nowdays the number of semiconductor manufacturers have introduced integrated switching power supply controller chip that integrates on a single chip controller and switch, and improve overcurrent and overvoltage protection, so that the user can use fewer external components,complete a performance and quality are more superior switching power supply design. This design of the control circuit used LNK364DN chip of LNK Switch series which is launched by the United States company Power Integration.

LNK364DN is a new intelligent and high-frequency switching power supply integrated chip. The chip has a built-in switch, PWM generator, and has a thorough output short circuit protection function and overheating protection function. Its output voltage is controlled by a feedback pin to achieve, it can be said to be a full-featured switching power supply control chip.

3.1.Design of Input Rectifier Filter Circuit and EMI Circuit

For filter design, first can suppress the power grid harmonic interference, effectively improve the system of internal electromagnetic environment. On the other hand, the filter can be seen as a blocker to prevent electromagnetic interference into the internal switching power supply grid, blocking the flow of electromagnetic interference in switching power supplies and power grid. The design of the input rectifier filter circuit design shown in Figure 2, the 220VAC input, through the rectifier filter circuit obtained after the output waveform shown in Figure 3.

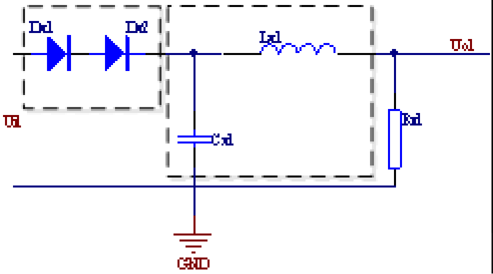

Figure 2. Input Rectifier Filter Circuit

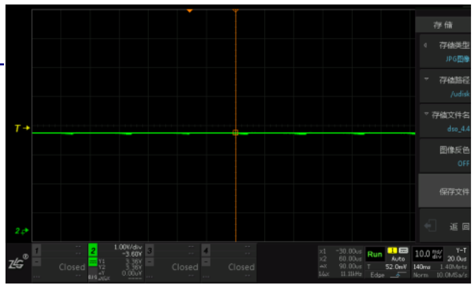

Figure 3. Rectifier Output Waveform

In the design, 220VAC power supply firewire access to primary, 50Hz frequency alternating current through two half-wave rectified rectifying diodes, having a peak of about $220\sqrt{2}$ = 311V, 50Hz frequency pulsating DC. After the pulsating DC current through a shunt resistor, applied to the gate of the switching tube. The switch tube should be an N-channel enhancement mode MOS FET, it turns on in the pulsating DC when gate - source voltage is positive.Therefore, switching tube turns on when the positive half cycle of conduction, a capacitor C is connected behind. The pulsating direct current is applied to the filter capacitor C poles. Since the effect of the capacitor charging and discharging, the pulsating direct current approximation becomes about 311V DC to provide power source for the devices behind the switch.

In figure, Cx1 and Lx1 constitute an EMI filter circuit, have the function of the noise attenuation grid. Since the capacitance and inductance and other energy storage components in the circuit, at the moment of power on the circuit, there will be a large inrush current. Adding resistor R in front rectifier diode can inhibit the inrush current and protection circuit element. Meanwhile connectting a varistor RVvaristor RV, its resistance decrease with the increase of voltage on both ends. Because of the complexity of the electricity grid, there may be a transient high voltage spikes due to lightning or high-power inductive load in the grid. When it came to the high-voltage spikes, RV may transiently reduce the resistance, discharge the high-voltage spikes, blocking high pressure into the circuit.

3.2. Design of Clamp Circuit

Power MOS During shutdown, the leakage inductance energy can not be delivered, it will produce a peak voltage across the primary winding of the transformer. If you can not try to absorb flux leakage inductance energy, it will have a significant voltage spikes, causing MOS tube is damaged. In orser to this, the best solution is to re-use to make it returns the input capacitance. Using clamp design can solve the problem, the circuit design shown in Figure 4.

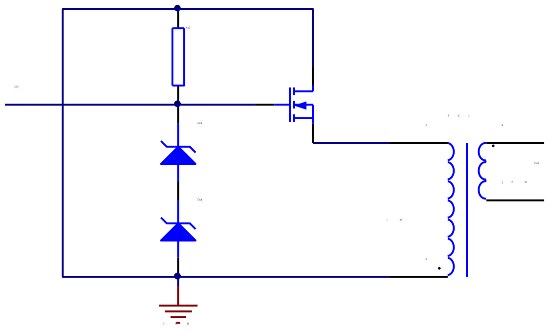

Figure 4. Transient Voltage Clamping Circuit

Two Zener diodes Dx3, Dx4 can give MOS transistor gate voltage clamping. If due to interference, the electric shock, as a result of lightning strikes have come at too high a voltage, the Zener diode reverse breakdown voltage regulator into the area, the gate potential of the MOS transistor in the clamp voltage value, to prevent MOS transistor gate is breakdown.

3.3.Design of freewheeling circuit

As shown in Figure 5, Rx3, Rx4, Dx5, Cx2 and other elements constituting the transformer primary inductance freewheeling circuit. Since the inductor induced electromotive force, at the moment of controller is turned off , will appear across the inductor high reverse voltage, the controller may be damaged. The freewheeling circuit may be provided for this reverse high-pressure discharge path to protection controller, simultaneously increasing the turn-off speed, improved signal quality.

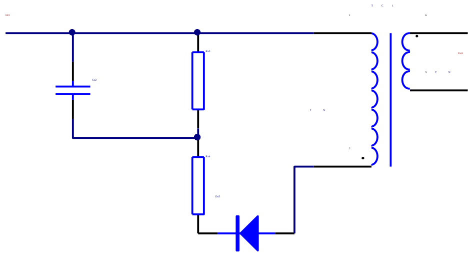

Figure 5. Freewheeling Circuit

3.4. Design of Output Filter Circuit

Primary transformer switching tube turns on and off repeatedly. Energy transfer by magnetic coupling to a transformer secondary, secondary gets a high frequency pulse current with the change of switching tube turning on and off, The output of the filter circuit shown in Figure 6.

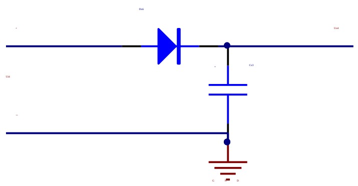

Figure 6. Output Filter Circuit

The high frequency ripple current through the diode rectifier D to charge the capacitor C. When the switching tube is turned off, the energy from the transformer delivery stop, at this point the load is powered by a capacitor C4. The controller through a feedback mechanism to sense the energy storage capacitor C in the case. If the energy storage capacitor C deficiency, the output voltage is decreased. In this case the controller will turn on the switching tube, the capacitor C is charged, the output voltage rises. After the C adequate storage controller close the switching tube, the load continues to be supplied by the C. This process again and again, The voltage across the load at rated output voltage of the power supply fluctuations, to achieve the purpose of regulation.

3.5. Design of Transformer

Flyback transformer has a simple circuit, high conversion efficiency and stable output characteristics. When the MOS transistor is turned on, the transformer primary N pole generates a current I, and the energy stored in it. At this time, due to the N1 and N2 pole poles hace the opposite polarity, Dx6 diode reverse bias is turned off to stop the energy transfer to the load.When the MOSFET is turned off, the transformer primary winding will generate a reverse electric potential, the diode forward at same time, stored magnetic energy is released to the load side, the load generated current flows, to obtain the desired voltage value. Detailed design go as follows:

(1)Power specifications

1)Input voltage

V_{min}=220VAC, so the transformer primary voltage V_{inmin}=190V， V_{inmax}=1311V；

2)Output voltage when the load of 1.5W

V_{out}=12V(±0.5)；

3)Conversion efficiency

η=80%

(2)Calculation of the maximum duty cycle

1) Reflected voltage from the secondary reflected to the primary

$$V_{PR} = n * V_o = 7.1 * 12 = 85.2V \quad (1)$$

Among them, n is turns ratio,value of 7.1； V_o is output voltage with value of 12V 。

2)The maximum duty cycle

$$D_{max} = \frac{V_{PR}}{V_{PR} + (V_{min} - V_{DS})} = 42\% \quad (2)$$

Among them, V_{DS} is on-state voltage of MOSFET's drain-source, value of 10V。

(3)Calculate the primary inductance of the transformer

$$L_P = \frac{V_{max} D_{max} \eta 10^3}{2 P_T f_S} = 1243 \mu H \quad (3)$$

(4)The selection of the transformer core

$$A_P = A_w * A_e = \frac{P_t * 1000000}{[2 * K_o * K_C * fosc * B_m * j * \eta]} \quad (4)$$

Among them, P_t is Output Power; K_o is copper fill factor; K_C is the core fill factor; B_m is the magnetic flux density of the transformer; j is the current density. After the calculation of the table, EE12 cores are suitable. Taking into account the auxiliary winding and other factors, choose EE13 core.

(5)Primary and secondary winding turns

$$N_P = \frac{V_{\min} D_{\max} T_s}{\Delta B \times A_e} \times 10^4 = 215$$

（5）

Among them， B is the core operating flux density change values.

$N_S = N_P / \mathrm{n} = 30.28$ circle， rounded to the 30 circle.

3.6.Design of the Control Circuit

This paper uses LNK364DN chip design feedback control circuit, specifically shown in Figure 7. Integrated circuit design can reduce system cost, reduce component count and improve efficiency.

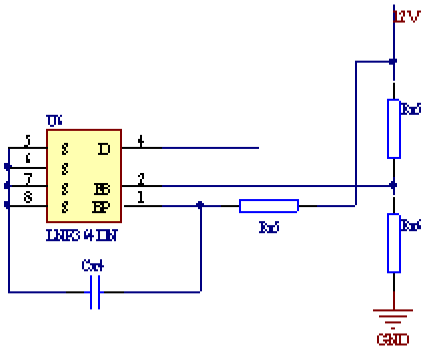

Figure 7. Control Chip and Peripheral Circuits

Chip pin D connect power MOS tube, provides internal operating current for the start-up and steady state operation. Bypass pin BP pin connection point for an external bypass capacitor 0.1μF Cx4, external bias winding to provide a 5.8 V supply voltage for internal use. Feedback pin FB is the control pin under normal operating. When the input current of this pin exceeds 49μA, MOSFET turns off.

The controller through a feedback mechanism to achieve tracking control of the output voltage. LNK364DN chip feedback loop has a current mirror MOSFET structure. This current mirror and on-resistance MOS tube generated a reference voltage (about 1.63V). Controller compared to feedback voltage from the output and this reference voltage. When the feedback voltage is lower than the reference voltage, the PWM generator is started, and drive switch, the secondary output power replenished; on the other hand, when the feedback voltage is too high, PWM generator is turned off, the secondary output capacitor for energy.

Resistance $Rx5$ 、 $Rx6$, dividing the output voltage, then determining the size of the output voltage. The output voltage

$$\frac{V_o - V_{FB}}{Rx5} = \frac{1.60 - 0}{Rx6} \qquad (6)$$

Among them, V_{FB} is the reference voltage, value of 1.63; $Rx5$ is value of 11KΩ, $Rx6$ is value of 1.8KΩ, so get the output voltage is 12V.

3.7.Design of the Overall Circuit Design

Through design and analysis about the input-output circuit, control circuit and transformer module, as well as EMI, clamp circuit, wheeling circuit protection circuit to give the whole design shown in Figure 8 whice based on the LNK364DN chip.

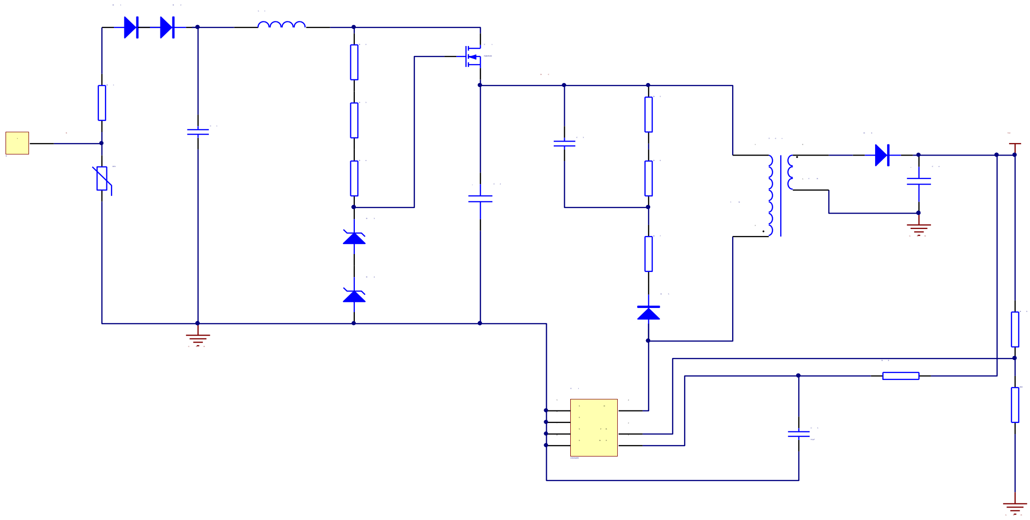

Figure 8. Switching Power Supply Schematic Design

4. Results

Making a test at room temperature, respectively, in the no-load and light load, full load and at 220VAC input voltage, measured waveform across the output using the twist method with an oscilloscope. Since the switching tube works in the on-off state, equivalent to intermittently supply power to the load, which causes the output voltage can not be very precise and stable at a certain voltage value, but around the rated output voltage fluctuates slightly up and down. Therefore, switching power supply output ripple is a measure of an important indicator of the quality of the switching power supply. Through the test of design circuit obtain a voltage waveform diagram shown in Figure 8, electrically coupled rippleis shown in Figure 9, Figure 10, Figure 11. From the test data obtained by the figure could known, the output voltage is about 12.2V, the error is 1.6%, the full load output error less than 5% of the design requirements. In the no-load, load 1.2W, and load 4.8W(approximate full load at this time) ,the ripple were 140mV, 130mV and 114mV, Through calculation can get the ripple coefficient was 1.14% , 1.06%, 0.9% respectively at no load, light load and full load, , accuracy is much higher than 5% of the design requirements.

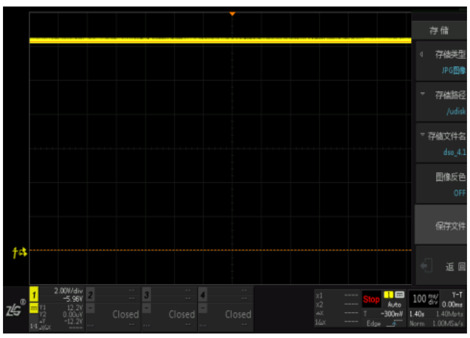

Figure 8. Output Voltage Waveform when the Load 1.5W

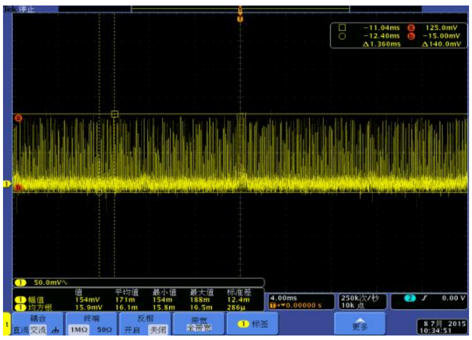

Figure 9. Output Ripple when No-load

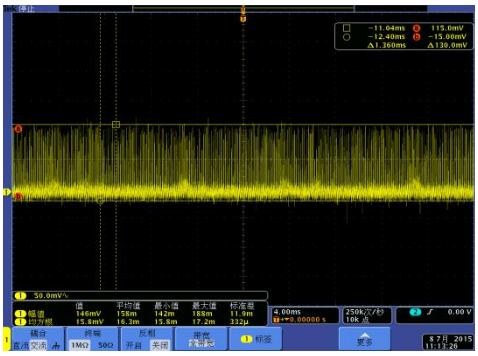

Figure 10. Output Ripple when the Load 1.2W

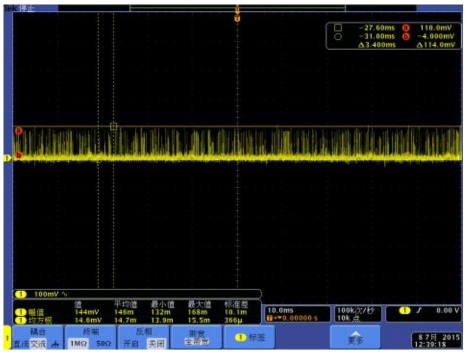

Figure 11. Output Ripple when the Load 4.8W

Switching power supply's efficiency is also an important indicator to verify the success of switching power supply design. By direct measurement can be measured,the designed switching power supply's conversion efficiency is 0.786 with no load, the conversion efficiency is 0.791 with no load at 25% load, the conversion efficiency is 0.798 under full load. After calculation of the value of the test, the average efficiency of the design of the power is 79%, the paper pre-designed efficiency is 80%, that error is 1% which is less than 5% of the design requirements.

In summary, the design of switching power supply has the advantage of small size, high efficiency, high accuracy, reliability,etc. By electrostatic discharge immunity, fast transient burst immunity, electromagnetic compatibility laboratory tests prove that it complies with the GB/T 17215.211.

5. Conclusion

In the paper, tThe flyback switching power supply design and development which based on the LNK364DN control chip as the goal. Make a detailed analysis and explanation about the basic design of the structure and Flyback converter circuit and control method, LNK364DN chip and its peripheral circuit design for switching power supply, high-frequency transformer, input and output rectifier filter circuit, clamp design, the primary freewheeling transformer, EMI protection circuit. This design has made remarkable achievements in the following areas: First, sophisticated circuit design and small size, can effectively promote the development of smart meter; the second is the conversion rate, applied to domestic smart meter switching power supply efficiency general requirements for 65% or more, the design can be up to 79% conversion efficiency, and high design accuracy, ripple accuracy to within 1.2%. Third, system design a efficient clamp circuit to resolve the problem of spike voltage ,then prevent damage of MOS tube grid is punctured. For inductor's induced electromotive force, designed a freewheeling circuit to protect the controller effectively , increase the turn-off speed, improve signal quality, and improve the stability and reliability of the system.

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