Design of control algorithm based on high voltage transformer

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Abstract: Based on the application of transformers in switching power supplies, the article makes a kind of digital algorithm control. Through the 32 series' chip to control the start and maintain state of the equipment, the node voltage is continuously collected and the output is corrected in real time to ensure that the equipment remains stable. The article provides a complete algorithm design process and ideas including the calculation of the timer parameters, the configuration process of ADC voltage acquisition. Finally, the experimental verification is carried out to ensure the feasibility of the algorithm.

1. Introduction
With the rapid development of large-scale and very large-scale integrated circuits, the large and bulky linear regulated regulated power supply using a power frequency transformer has become obsolete. Instead, it is a miniaturized, lightweight, and highly efficient isolated switching power supply. Based on the application of transformers in switching power supplies, the article makes a kind of digital algorithm control. Through the 32 series' chip to control the start and maintain state of the equipment, the node voltage is continuously collected and the output is corrected in real time to ensure that the equipment remains stable. The hardware design and PCB drawing work have been completed in the early stage. The article mainly describes the entire process of algorithm implementation.

2. Hardware
We use fly-back switching power supply to generate high voltage as the power source for starting and maintaining. The principle is shown in Figure 1. The fly-back switching power supply is a switching power supply that uses a fly-back high-frequency transformer to isolate the input and output circuits. "Fly-back" means that when the switch is turned on, the inductance in the output line is discharged when the input is high; on the contrary, when the switch is off, when the input is high, the inductance in the output line is the state of charge to drive the load. Figure 2 is output waveform of fly-back switching power supply.
3. Algorithm

3.1 Algorithm ideas

After the circuit design, we need to use algorithms to let the power supply with a voltage of about 2500V to start the device, and then immediately drop to about 600V to keep the device in the state, and need to continuously feedback control according to the working state of the device, and correct the output voltage in real time, to compensate for the unstable output of the voltage of some important nodes as the working time increases, so that the output of the entire system can maintain a certain steady state. Here, the STM32G4 series chip is used to control the circuit, and the three channels of the internal ADC of the chip are used to collect the voltage values of three places in real time. The sampling cycle is one hundred times a second, and then the voltage value is obtained by filtering the hundred times average value. By comparing the threshold and the collected voltage value, the internal timer parameter of the chip is set to adjust the frequency and duty ratio of PWM to control the output voltage of the transformer, so as to realize the real-time control of the equipment power supply voltage.
3.2 Algorithm flow

3.3 Algorithm implementation

We use a 12-bit DAC to output a stable 1V voltage, and use the three channels of the 12-bit ADC inside the chip for voltage acquisition. The reference voltage is 2.5V, and use 2 general-purpose timers. One is set to interrupt mode, and the voltage is AD The acquisition provides a fixed beat, one is set to PWM output mode, and used to adjust the frequency and duty cycle to change the output voltage, to start and maintain the state jump and maintain the steady state. The main frequency is 170MHZ as the
system clock frequency. First, you need to configure the initialization status of the resources used. In the HAL library, we can directly call the initial functions of the clock, DA, AD, SWD and timer to complete the initial configuration, and then declare the required variables. Since the DAC is 12-bit, according to the formula $2.5 \times 1638 \div 4095 = 1$, the voltage output of 1V can be configured, and the difference between the DA output and the ideal situation is shown in Figure 3:

![Figure 3. Accuracy of DA](image)

Configure the timer interrupt coefficient to 170M, so that the system executes an interrupt callback function every second. In the interrupt function, start ADC voltage acquisition, and perform average filtering operation after 100 consecutive acquisitions to reduce accidental errors. Then compare the collected voltage value with the threshold value to determine whether a larger ignition voltage or a smaller sustain voltage should be output. According to Figure 4, the corresponding relationship between frequency duty cycle and voltage:

![Figure 4. The relationship between frequency duty cycle and voltage](image)

We choose 50KHZ, 30% duty cycle as the ignition output voltage, at this time the voltage is about 2500V. 170KHZ, 25% duty cycle is the sustaining voltage output, at this time the voltage is about 600V. Adjust the frequency and duty cycle by using Set_Compare and Set_Count in the HAL library to change the voltage value. The calculation formula is as follows:

\[
pwm \text{ frequency} = \text{main frequency} \div \text{frequency division factor} \div \text{counting period} \quad (1)
\]

\[
pwm \text{ duty cycle} = \text{high period} \div \text{counting period} \quad (2)
\]

First output 50KHZ, 30% PWM to start the device, and then compare the voltage values collected
by ADC1 and 2 channels with the sustaining voltage. If the voltage is higher, it means that the device has not been started, and continue to provide high voltage. If the collected voltage is smaller than the sustain voltage, use the above formula to change the PWM frequency to 170KHZ, and output the sustain voltage with a 25% duty cycle. Then compare the voltage value collected by the ADC3 channel with the set threshold, and control the voltage stability by changing the duty cycle to achieve the steady state of the system.

4. Conclusion
Through experimental verification, it can be seen that the device is successfully activated at high voltage. At this time, the output voltage is reduced to 600V to enter the maintenance state as figure 5, and it fluctuates back and forth at the stable point we set. The power supply required for the normal operation of the experimental equipment is provided, and the PID algorithm is used to maintain a certain steady state of the equipment through voltage acquisition and feedback, and the expected goal is achieved.

![Figure 5. Voltage stabilized waveform](image)

5. Prospect
The artical carries on the circuit hardware design according to the working principle of the fly-back switching power supply and uses the STM series chip to adjust the voltage output by outputting different PWM or duty and uses the voltage feedback to keep the steady state. Of course, we can also design through other power principles, which will be discussed in subsequent experiments.

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