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Design and Implement of Low Ripple and Quasi-digital Power Supply

Li Xiangli ,Wei Yanjun ,Qi Hanhong , Ma Yan

Key Lab of Power Electronics for Energy Conservation and Motor Drive of Hebei Province,
Yanshan University Qinhuangdao, 066004, China
E-mail：LXL@ysu.edu.cn

Abstract

A switch linearity hybrid power supply based on single chip microcomputer is designed which merged the merits of the switching and linear power supply. Main circuit includes pre-regulator which works in switching mode and series regulator which works in linear mode. Two-stage regulation mode was adopted in the main circuit of the power. A single chip computer (SCM) and high resolution of series D/A and A/D converters are applied to control and measurement which achieved continuous adjustable and low ripple constant current or voltage power supply

Keywords:low-ripple, quasi-digital, phase shift control, linear power supply.

1. Introduction

Today, with the development of power technology, switching power supply holds important status for its superior performance of high efficiency and small size. To overcome the shortcomings of traditional linear power supply, switching power supply obtained the widespread application in the power drive, micro-computers, household appliances and so on. The flaw (big ripple, noise, EMC and lower output accuracy) has also hampered his development in the specific areas. For example, many sensitive electrical equipment to high frequency interference such as stereo and inverter are still using the linear power supply at present. The high-precision instruments of requirements for high stability and ultra-low ripple, switching power supply also cannot be competent. Similarly, in the field of low noises, high reliability, high flexibility and the volume and the efficiency not too important, the linear power source was still the most reasonable choice. Its typical application areas are audio, apparatus, control domains.

However, in recent years, people proposed many methods to compensate low ripple and low stability in the switching power supply. (1) For low-power, we can add active filter in the input and use multi-lever filter in the output so as to eliminate high frequency and low frequency ripple separately [1,2]. (2) A novel

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power conversion mode is structured by hybridizing switch power conversion mode with linear amplification mode to acquire the trade-off merits of them [3~8]. But the result can only make switch power supply ripple targets close to the level of linear power supply and these improvement's methods made the power supply structure complex and higher cost so that lost the practical application value.

In a word, although the switching power supply technology is in the core of power technology for the past ten years, in some special applications and scientific researches such as instrument power, military power and other areas, bulky linear supplies are still operated in low efficiency due to its excellent performances such as high stability, accuracy and strong robustness, which is hard to be replaced by smart switch power supply [9,10].

This paper designed a quasi-digital DC hybrid power supply which have the performances of low-ripple, high stability, cost-effective and adjustable output in a row. The power is applicable in the field of high-precision instruments power supply.

The hybrid power supply is constituted by the two units: the pre-regulator and the series regulator. A pre-regulator in series in front of power stage could keep voltage dropping to a small value and decrease power dissipation so that the efficiency of power supply is increased. The control strategy of current and voltage control is separately to realize constant current and constant voltage. The current regulator use high precision amplifier OPA2277. The reference value and digital display make use of the high-precision DAC(DAC7631) and ADC(LTC2420). Using the single bond flying shuttle and liquid crystal display can increase the accuracy of voltage and current to 1‰.

2. Analysis and design of the main circuit

Basic requirements of the power: Input: 220V single phase AC power, Output voltage: 0~15V adjustable; Output current: 0~5A adjustable.

Performance: Ripple coefficient: $\delta \le 1‰$.

According to the functionality and performance requirements, the program design as follows:

Figure 1 shows the main circuit, mainly includes: AC input, transformer T, rectification bridge D, pre-regulator Q1, filter C, series regulator Q2 and DC output.

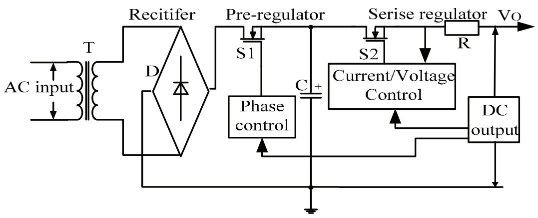

Fig. 1 Main circuit

Pre-regulator Q1 and series regulator Q2 select MOSFET(IRFP150). The pre-regulator Q1 is controlled by the phase shifting control IC TCA785 which works in on-off state. The series regulator Q2 works in the linear conditions through changing the Q2 of the turn-on voltage drop to regulate the output voltage.

This phase control IC TCA785 is composed of zero detector, discharge monitor, synchronization register, control comparator, pulse formation and logic. Its pulse diagram is showed in figure 2. The synchronization signal is obtained via a high-impedance resistance from the line voltage (voltage V_5). A zero voltage detector evaluates the zero passages and transfers them to the synchronization register. The ramp voltage V_{10} exceeds the control voltage V_{11} (triggering angle φ), a signal is processed to the logic. Dependent on the magnitude of the control voltage V_{11} the triggering angle φ can be shifted within a phase angle of 0° to 180°. For every half wave, a positive pulse appears at the outputs Q1and Q2. If pin 12 is connected to ground, pulses with a duration between φ and 180° will result.

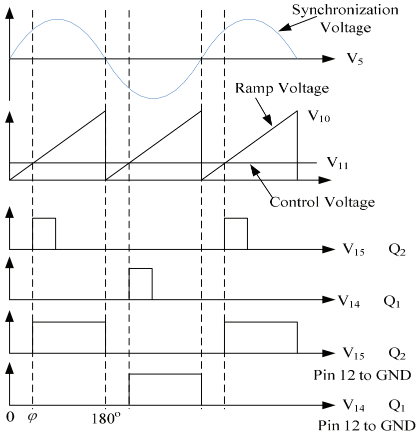

Fig. 2 TCA785's pulse diagram

3. Main Design of control circuit and digital display

In order to achieve high-speed response the power use analogous circuit for mature, facilitate and real-time. The 89C52 microprocessor is used to realize digital display. Its control circuit diagram as shown in Figure 3.

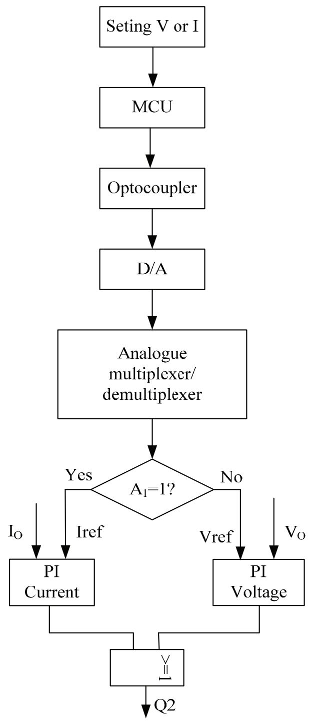

Fig.3 Control circuit diagram

As show in Figure 3, shuttle set of reference voltage and current, through microcontroller, optocoupler，D/A converter, analogue multiplexer/de-multiplexer and the current/voltage PI regulator to control series regulator Q2.

The current regulator uses dual high precision operational amplifier OPA2277 for its high performances in ultra low offset voltage (35uV typically), low bias current (1nA max), high common-mode rejection (140dB) and high power supply rejection (130dB). OPA2277 operates ±2 to ±18V supply. It is stable in unity gain and provides excellent dynamic behavior over a wide range of load conditions. Its regulating process is one channel differential input, single output for output current, by the PI to control series regulator Q2 after comparing with reference value in another channel.

The voltage regulator use low noise and high speed J-FET dual operational amplifier TL072C, its regulation is same to the current regulation.

The DAC7631 is a serial input, 16-bit, voltage output Digital-to-Analog converter. Data is shifted into the device through the SDI and CLK pins and arrives in a shift register. A chip select input (CS) is provided to simplify device selection in systems with multiple devices. Once all 16 bits have been transferred, the LOAD pin which is level sensitive should be brought low to latch the data into a buffer register called the DAC input register. To latch the new data into the DAC itself, the LDAC pin, which is edge-sensitive, must be brought high. When this is done, the DAC will assume the new value and the output voltage will change.

Figure 4 shows the display process of output voltage and current. The actual detected V_o and I_o pass through analogue multiplexer/de-multiplexer, A/D converter to microcontroller. Then the data is displayed in liquid crystal which was processed by microcomputer.

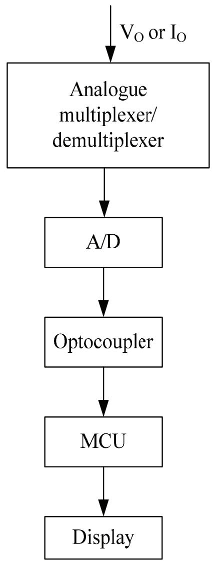

Fig.4 The display process of output voltage/current

The LTC2420 is a 20-bit A/D converter with an integrated oscillator and accepts any external reference voltage from 0.1V to V_{CC}.

In this article, frequency control pin F_0 is driven by an external clock signal with a frequency f=1MHz, so the digital filter first null is located at a frequency f /2560(390Hz), sampling frequency:

$$f_s = f/20480 = 48.8Hz$$

This timing mode uses an external serial clock to shift out the conversion result (SCK is used as digital input for the external serial interface). Note: To select the external serial clock pin SCK must be LOW at power-up or during each CS falling edge.

4. Experimental Results

A prototype based on Figure 1 is designed. The experimental parameters are as followings: Input voltage: AC 220V, Transformer: custom-made power frequency, AC 220V input, 21V, 18V, 9V many grade output, the power is 100W.

Figure 5 shows the drain-source voltage and driven pulse waveform f pre-regulator Q1.

Figure6 shows the drain-source voltage and driven pulse waveform f series regulator Q1.

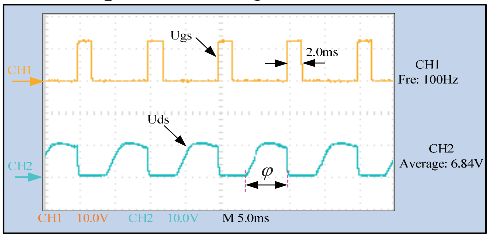

Fig.5 The waveform of u_{ds} and u_{gs} of Q1

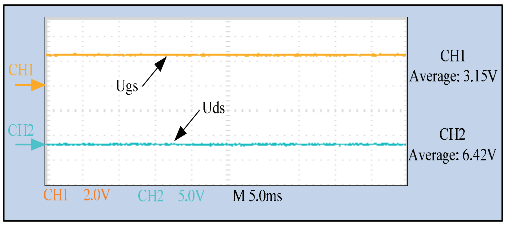

Fig.6 The waveform u_{ds} and u_{gs} of Q2

Figure 7 shows the waveform of the rectifier output voltage waveform VA, the filter capacitor DC voltage VB and output voltage V_o

Figure 8 shows the waveform of the output voltage. Its pk-pk is 16mV. It is obviously that its ripple factor is $\delta = 0.94‰$. It shows the system has a low ripple to output voltage.

Figure 9 shows the waveform of the output current. Its pk-pk is 1.78mA. It is obviously that its ripple factor is $\delta = 0.98‰$. It shows the system has a low ripple to output current.

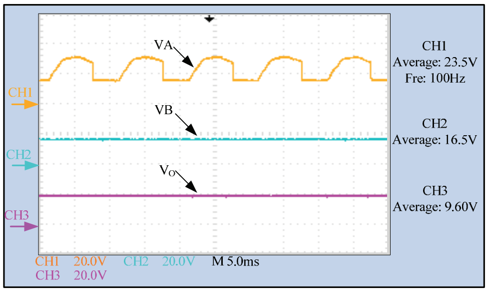

Fig.7 The waveform of VA, VB and V_O

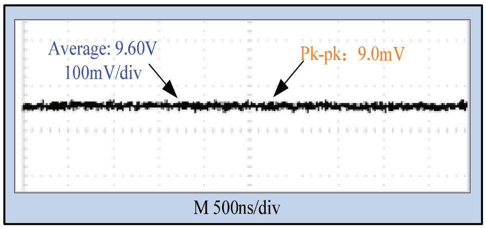

Fig.8 The waveform of output voltage Vo

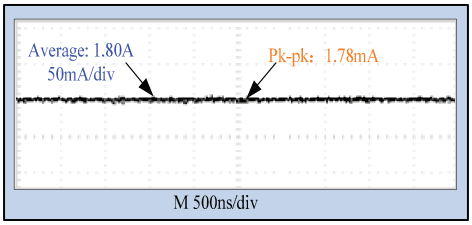

Fig.9 The waveform of output current Io

5. Conclusions

A switch linearity hybrid power supply based on single chip microcomputer in the field of high-precision instrument is designed. The control circuit uses high-precision components to achieve high accuracy and low loss. Finally through the experimental verification, the power supply reaches the low ripple requirement. Simultaneously the digital display by LCD is also designed.

Acknowledgement

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