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DESIGN OF BEAM POSITION FAST-CORRECTION MAGNET POWER SUPPLY FOR HALS *

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Abstract

Hefei Advanced Light Source (HALS) is the fourth-generation radiation light source that is being pre-researched in China. Ultra-low emittance of the beam requires higher performance of power supply system. We designed a fast correcting power supply for the beam measurement needs. We adopted the all-digital method, the current closed-loop feedback used the AD7766 with 24-bit resolution as its A/D converter. And we added the corresponding constant temperature control, chain protection, etc. The small-signal frequency response of this system can reach more than 5 kHz. The detail design scheme is described in this paper.

INTRODUCTION

In the actual operation of the accelerator, it plays a very important role in monitoring and correcting the beam position. The position of the beam is based on the correct magnets. We use the magnet power supply controller to adjust the current of the magnet coil to achieve the purpose of changing the beam position, so the demand for a magnet power supply controller is high[1]. The response speed of the whole correction system must keep pace with the change of beam position to meet the requirement. In the current beam feedback system of HLS II, the power supply current response bandwidth requirements are better than 1 kHz. Fig. 1 shows the HLS II Storage Ring beam measurement element distribution map. As a new generation of light source with lower emissivity and higher energy, HALS has higher requirements for the fast-correcting power supply system, including small signal bandwidth, data acquisition and processing speed, remote communication time, etc. Under these circumstances, we have designed a new magnet power controller to optimize communication protocols and data acquisition. In addition, our power modules draw on the advantages of the amplifier circuit, its power supply current response bandwidth can be better than 5 kHz or even higher.

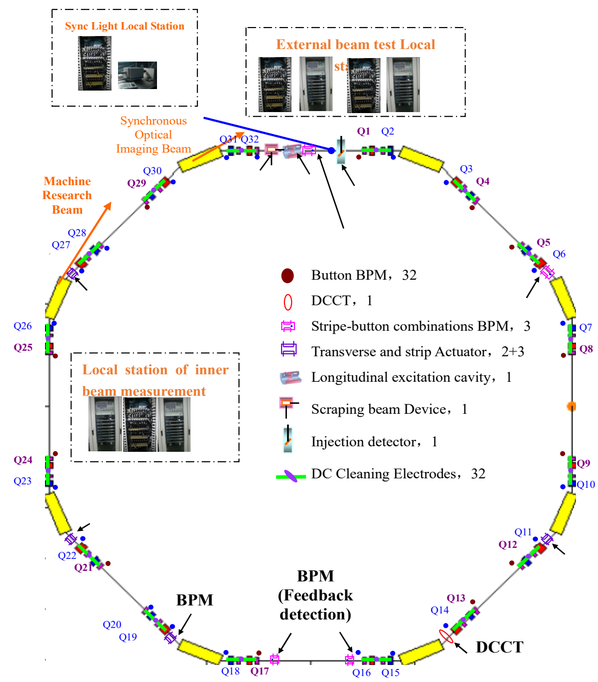

Figure 1: HLS II Storage Ring beam measurement element distribution map.

STRUCTURE OF POWER SUPPLIES

The power supply is composed of two parts, the power converter and the adjuster. Power converter is the power of the main circuit, the realization of the power form changes, such as AC conversion to DC, or high voltage conversion to low voltage. In the Power form transformation, the part that uses the automatic control principle to stabilize the output through the closed loop feedback is the power supply regulator, for example, the steady current power supply through the regulator control achieves the steady output. The core of the power supply is the regulator, the realization of the regulator can be analog circuit or digital circuit mode. The traditional analog power supply adopts analog feedback control to realize its control loop, the parameters of control loop are determined by the capacitance resistor and so on, it is difficult to adapt to the change of load and loop parameters, and the analog level is susceptible to interference and its performance[2].

HALS Magnet power supply will use all-digital power supply, digital management, control module to achieve the power simulation and digital information, high-speed program processing and intelligent management, to achieve fast response, high-precision control

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requirements. Fig. 2 shows the schematic diagram of fast correcting magnet power supply.

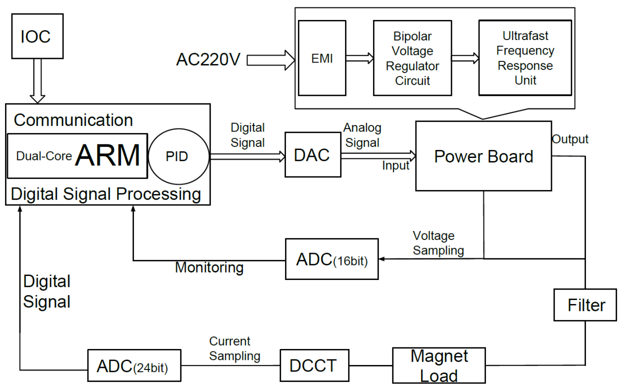

Figure 2: Schematic diagram of fast correcting magnet power supply.

DIGITAL ADJUSTER FRAMEWORK AND DEVICE SELECTION

The digital adjuster is the key to realize high performance index of digital power supply. In our design, the ARM microcontroller is the core module. We choose the STM32F407ZGT6 as the CPU, it can operate at 168 MHz, with 1 Mbyte Flash and 196 Kbytes of SRAM. And compared with the previous generation arm chip, the floating point operation unit is added, which provides the guarantee for the subsequent power supply feedback control algorithm[3]. The digital adjuster diagram is shown in Fig. 3.

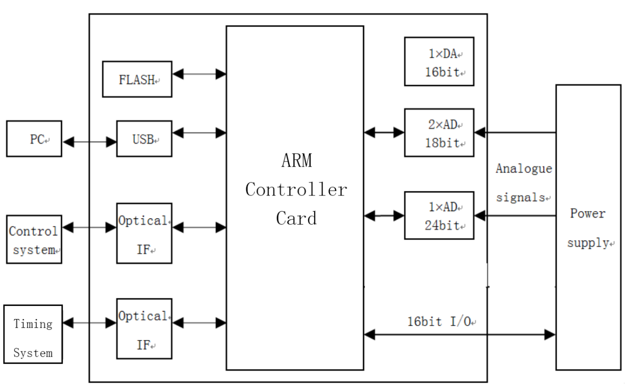

Figure 3: Diagram of the digital adjuster.

The controller mainly completes the power control algorithm realization, the power module input signal generation, the feedback channel ADC control and the modulation circuit as well as with the long-distance communication and so on function. The feedback signal needs to be converted to digital by ADC to enter DRL (digital regulating loop). Therefore, ADC is the key design of digital power regulator. The digital adjuster designed two feedback loops, that is, current closed loop feedback and voltage closed loop feedback[4][5]. Each regulating loop requires a A/D converter. Generally speaking, the bandwidth of the current loop is narrow, but the resolution and stability required is high, the bandwidth of the voltage loop is wide, the response speed is more than 10 times of the current loop, and the stability requirement is lower than the current loop. Therefore, different A/D converters are considered for different control loops.

Voltage-feedback analog-to-digital conversion devices are intended to select 2 AD7609 chips, which are responsible for collecting feed-forward voltage and load voltage signals; The A/D converter provides 18bit resolution with a sampling rate of up to 200 ksps and a maximum clock frequency 15 MHz when reading the converted data. Current closed-loop feedback required A/D converter to be as high as possible resolution and stability, so select AD7766, its resolution of the bit, single channel differential input, datum input 2.4~5 V, read the conversion data maximum clock frequency 1 MHz.

Circuit development digital power supply in order to save cost and space, intend to adopt current-type DCCT, so the regulator needs to design the corresponding I/V conversion circuit, to ensure that the current to the voltage conversion of 1 ppm stability requirements. Fig. 4 is the DCCT we use

Figure 4: DCCT IT 200-S.

OPTIMAL CONTROL ALGORITHM

The method of digital PID controller is to use summation instead of integral change, and to obtain the digital PID control algorithm of the corresponding discrete system with difference instead of differential change method. Usually according to the relationship between controller output and actuator, the basic digital PID algorithm is divided into positional PID and incremental PID which are shown below.

$$u(k) = K_p \times e(k) + K_i \times \sum e(j) + K_d \times [e(k) - e(k-1)] \quad (1)$$

$$\Delta u(k) = K_p \times [e(k) - e(k-1)] + K_i \times e(k) + K_d[e(k) - 2e(k-1) + e(k-2)] \quad (2)$$

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Only need to know the recent three cycles of sampling error, you can find the amount of control increment, if there is a previous period of control, you can find the number of the control of the K-cycle size. This kind of control algorithm is called increment digital PID control algorithm. Choosing incremental Digital PID control algorithm is more suitable for design needs. Digital PID module is mainly for data processing, the symbolic number and unsigned number in the design of the logic operator cannot be directly calculated, the operation data needs to be processed, and the method is as follows: using adder to realize subtraction, such as using a-b=a+(-b) =a+b (complement) when the error value e (k) is obtained. The negative number is indicated by the complement, which replaces subtraction with the addition of the binary complement. Add the same number of symbols to take into account the possible results of the operation of the number of digits overflow, resulting in errors in the calculation results, the results of the data operation is an extension to prevent data errors.

TEST RESULTS

Because the design scheme of the magnet technology of the HALS light source storage ring is not complete, the specification parameters of the magnet power supply are not yet determined. The prototype is planned to produce several standard power modules, series or parallel simulation of various specifications of the power supply prototype. Here we take the characteristics of the power amplifier circuit, using a signal generator instead of our DAC to generate analog signals. Input signal we use 50 kHz square wave, oscilloscope shows the entire power plate response is very fast, probably only 1.28us. The actual power circuit board is shown in Fig. 5 and the test results are shown in Fig. 6.

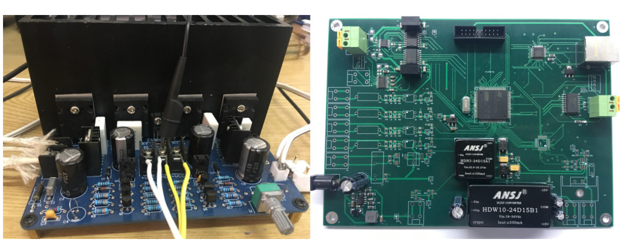

Figure 5: Actual power circuit board and digital control board.

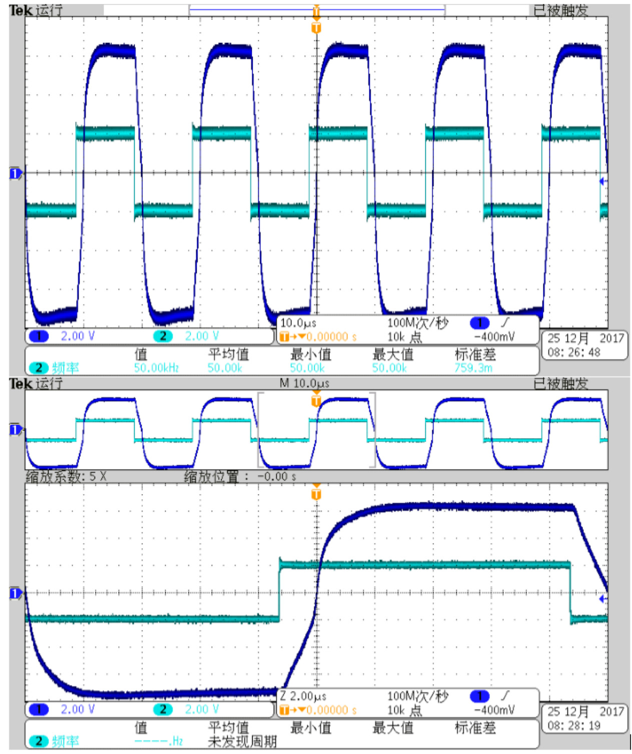

Figure 6: Response test for 50 kHz square wave.

CONCLUSION

In this paper, a new fast-correcting power supply module was designed. It replaces the traditional switching power supply and the current response bandwidth of the power supply can meet the requirements of HALS.

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