ISSN: 2688-8645

High-speed Gamma Spectrum Acquisition Circuit Test

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Abstract

In this paper, through the investigation of the chip and the high-temperature circuit design, many system experiments under high-temperature conditions have been carried out. The digital multi-channel circuit design of the high-temperature, high-speed lanthanum bromide neutron gamma logging tool has been completed. The system is mainly composed of detector, preamplifier circuit, ADC, FPGA and communication circuit. The collection speed reached 100M, reaching the expected goal.

Keywords

Digital multi-channel, High speed.

1. Introduction

With the rapid development of computer technology, nuclear signal processing technology has been greatly developed and advanced. [1, 2, 3] Digital energy spectrum measurement system appeared. The digital spectrometer system has many advantages compared with the analog spectrometer system, which is the current development direction. [4] The system uses a high-speed digital-to-analog conversion chip ADC for pulse sampling, and there is no dead time in the circuit. At the same time, FPGA is used as a signal processing chip. In the process of controlling the ADC for high-speed acquisition, data buffering, pulse filtering, Pulse shaping, amplitude analysis, energy spectrum counting and other functions [5]. The improvement of hardware computing power has also improved the nuclear signal processing method [6,7,8]. The use of filter shaping algorithms can effectively reduce the impact of electronic noise and ballistic loss in nuclear pulse signals on energy resolution [9]. The pulse filter shaping methods mainly include Gaussian shaping, ladder shaping, and apex shaping. The system uses ladder shaping. The algorithm effectively reduces the white noise of the nuclear signal and the loss of count rate.

2. Research and Innovation

The key innovation is to design a fast-test preamplifier circuit, shape the detector output signal to a width of 150ns, and reduce the accumulation pulses generated by high-intensity gamma rays during the logging process. At the same time, the baseline recovery technology is used to estimate the baseline of the acquired signal in real time, and to compensate for the fluctuation of the baseline in real time, to solve the problem of spectral line drift caused by the high temperature downhole and the space charge effect of the photomultiplier tube.

3. System Composition

3.1. Electronic Circuit Composition

The digital multi-channel analysis system is divided into a fast preamplifier part, a nuclear signal processing and storage part, a power supply part, a circuit board temperature

ISSN: 2688-8645

monitoring part, and a communication part. The key part of the design is to solidify the nuclear signal processing algorithm and CAN bus communication in the form of IP core In the FPGA. In the high temperature state, considering the need to detect the real-time temperature of the circuit board, a real-time temperature detection module is added to the design. Since high temperature conditions need to be considered when selecting chips and designing circuits, this brings many challenges to the design. From the power supply to the high-speed ADC, the entire system uses chips that can withstand high temperatures. The block diagram of this digital multi-channel system is shown in Figure 1.

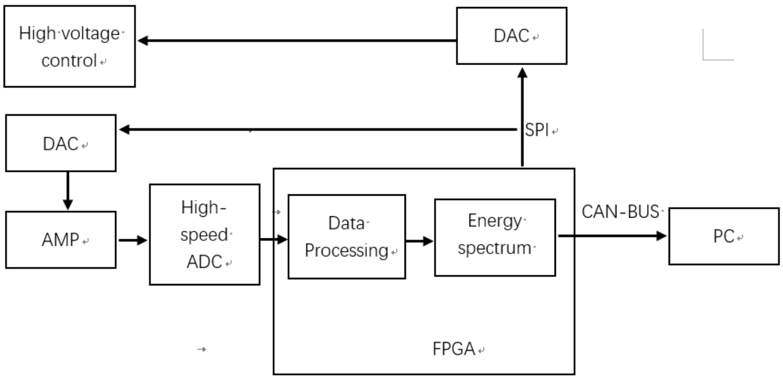

Figure 1. Block diagram of energy spectrum acquisition circuit

3.2. Overall Circuit PCB Design

The technical indicators of the subject require the diameter of the instrument to be 24mm, so the width of the circuit needs to be limited when designing the high-temperature energy spectrum acquisition circuit, and the component layout needs to be compact. The PCB design uses a 6-layer board, which is convenient for wiring and makes the PCB design more compact. The PCB circuit entity is shown in Figure 2.

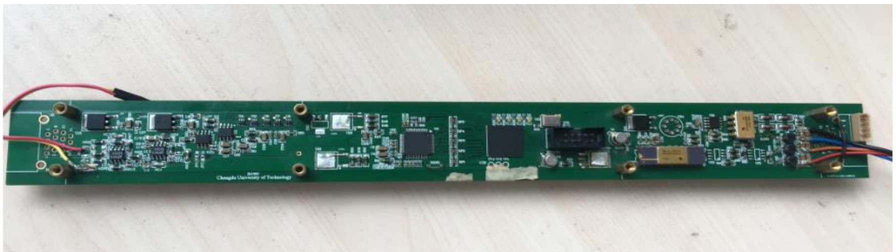

Figure 2. Digital multi-channel physical circuit

4. Instrument Test

The test is carried out for 3600 seconds. The test mainly focuses on the energy linearity of the instrument. According to the host computer, the command is sent to the instrument to make the instrument change the high voltage of the photomultiplier tube, so as to measure the energy linearity of the instrument under different high voltage conditions of the photomultiplier tube. . During the preliminary test, due to the interference signal that has always existed, the peak position of the signal collected by the high-speed energy spectrum acquisition circuit is inaccurate, which causes errors in the energy spectrum statistics. The overall field test diagram of the instrument is shown in Figure 3. The capture spectrum obtained by the measurement is shown in Figure 4.

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Figure 3. Instrument test site

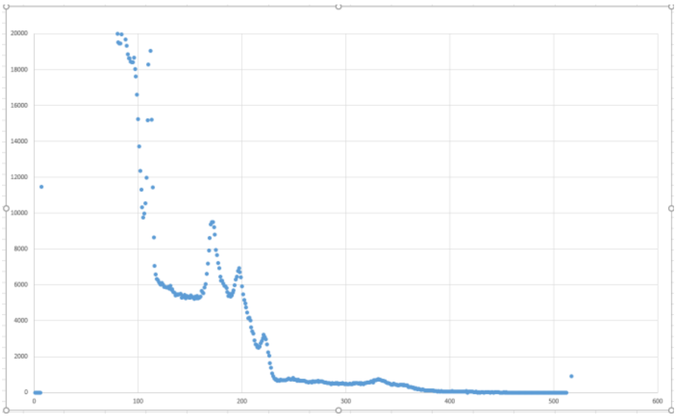

Figure 4. Capture spectrum measured by the instrument

5. Conclusion

(1) The first consideration is that the power supply of the instrument may have noise, so the power supply of the instrument was replaced, but after the replacement, the signal input of the acquisition circuit was detected with an oscilloscope and there was still noise interference, so the possibility of power noise interference was ruled out; Subsequent analysis may be that there is noise in the voltage and high voltage of the photomultiplier tube, resulting in noise in the signal output from the photomultiplier tube, so a filter module is added before the negative high voltage input of the photomultiplier tube as shown in Figure 5.

Figure 5. Filter module

ISSN: 2688-8645

After the oscilloscope measurement, the filtering effect is not obvious, so the speculation that the noise of the photomultiplier tube's voltage and high voltage affects the input signal of the acquisition circuit is eliminated; the final analysis problem may be the part of the detector, the output signal itself has noise interference, It is found that the ground wire of the detector does not share the ground with the housing. Therefore, connect a ground wire from the screw position of the housing of the detector and share the ground with the voltage and high voltage of the photomultiplier tube. A layer of high-temperature tape is wrapped on the outside of the product as shown in Figure 6.

Then use the oscilloscope to detect the input signal of the acquisition circuit, which effectively reduces the interference signal.

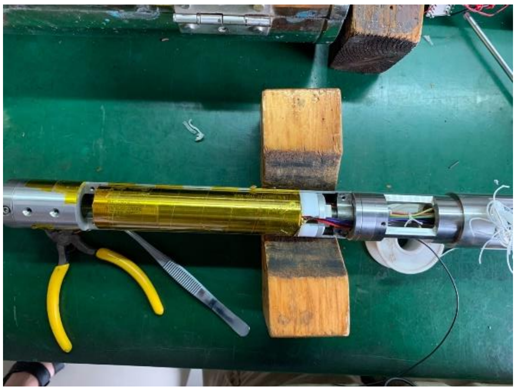

Figure 6. The improved detector assembly

(2) The linearity of the instrument is not very stable when adjusting the high voltage of the photomultiplier tube. When the high voltage is adjusted higher, the linearity will deteriorate. In order to solve the problem of poor linearity, the preamplifier of the acquisition circuit is replaced. The collection resistance of the circuit part widens the pulse width of the collected signal to 400ns, as shown in Figure 7.

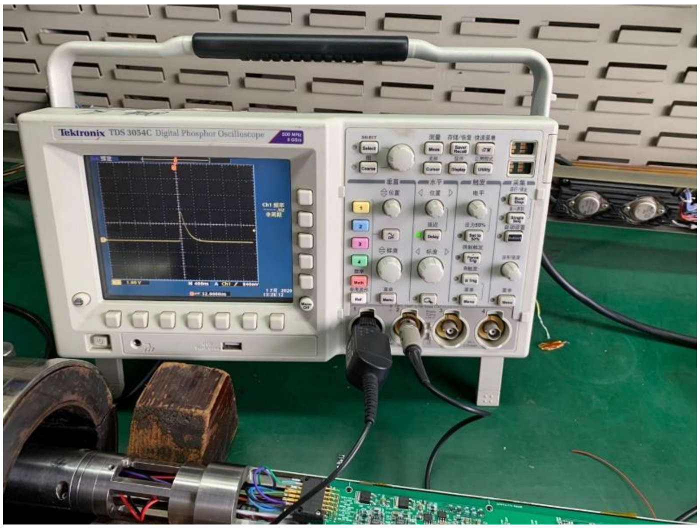

Figure 7. The signal received by the acquisition circuit

After testing, the energy linearity of the instrument has been improved and basically remains at 0.9999.

ISSN: 2688-8645

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