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Low Power Micro Analog Multichannel

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Abstract

With the rapid development of China's economy and society, the contradiction between energy shortage and environmental deterioration has become increasingly prominent. As a clean energy, the nuclear power industry has ushered in an unprecedented development opportunity. More and more attention has been paid to the issue of nuclear radiation safety protection. The acquisition and processing of nuclear signals becomes more and more important. As a common research means, the acquisition and processing of nuclear information plays an important role in many basic and applied scientific research. Nuclear energy spectrum measurement system has the advantages of high sensitivity, good accuracy and non-destructive, and is widely used in particle physics, material science and nuclear radiation environment monitoring. The content, position and time of elements in the nuclear radiation field can be obtained by energy spectrum analysis, which needs to be captured by the nuclear radiation detector. A multi-channel pulse amplitude analyzer (energy spectrometer) is used to extract useful nuclear radiation information from the output signal of the detector, so as to obtain information on the energy, category and radiation intensity of the input radiation. With the demand of field analysis and the development of miniaturization of electronic technology, the demand for portable instruments or handheld instruments is more and more obvious, and there are more and more field analysis instruments. At present, all on-site nuclear measurement instruments are developing in the direction of small size, light weight, low background, low power consumption, high performance, and fast analysis speed. Therefore, this paper chooses the low-power ARM chip as the microprocessor, and designs a low-power micro multichannel circuit with programmable amplifier, CR-RC circuit, peak holder and other circuits. The size of circuit board is 20 mm × 46 mm. The multi-channel power consumption is between 200 mW and 250 mW. In addition, corresponding probes and corresponding communication methods can be installed in intelligent robots, UAVs and places where measurement cannot be realized manually. It can also be integrated into various equipment and instruments to achieve nuclear signal acquisition and processing

and energy spectrum analysis. In this paper, a low-power micro analog multi-channel is designed and implemented. The detector collects the radiation and obtains the signal amplitude information, so as to carry out nuclide identification and further dose quantitative analysis. It is of great significance for nuclear radiation safety protection.

Subject Areas

Nuclear Physics

Keywords

Micro, Low-Power, Energy Spectrum, Portable

1. Introduction

Pulse amplitude analysis technology is to classify the signals with different pulse amplitudes according to the amplitude size and count them into the corresponding memory address to obtain an amplitude distribution spectrum [1]. The early pulse amplitude analysis can be realized by a single channel pulse amplitude analyzer: count the pulse amplitude between the specific upper and lower thresholds for a certain time, and then change the threshold to count the other pulse amplitude to achieve multi-channel measurement; this method has complex operation, large error and poor system stability [2]. With the development of electronic technology, such as the development of ADC and microcontroller, it is applied to pulse amplitude analysis technology; the pulse signal after peak sampling is quantized and coded by ADC, and then counted by microcontroller. This is one of the early analog multi-channel pulse analyzer technologies. Compared with the single channel, the early analog multi-channel has greatly improved the energy resolution, the convenience of operation and the stability of the system, but the performance is mainly limited by the circuit structure and the development of analog electronic technology [3].

Nuclear power in foreign developed countries started earlier, the nuclear instrument technology is relatively mature, and the division of labor is detailed [4]. One enterprise focuses on one aspect of products. For example, Ortec company in the United States focuses on electronic instruments, Hamamatsu company in Japan specializes in various types of detectors, and automatic company only produces some portable environmental monitoring instruments. At present, there are several well-known representative and powerful foreign radiation measuring instrument companies, such as Ortec of the United States, canbera of Europe, thermo of the United States, w of MGP of France and Berthold of Germany [5]. With the appearance of new detectors, large foreign companies have launched energy spectrometers based on new detectors, investigated several typical handheld nuclide recognizers w abroad, and found that the main characteristics of the products are serialization, digitization, networking and on-site through compar-

ison of product parameters. Compared with foreign instruments, most of the domestic instruments are bulky in structure, and need to be improved in miniaturization, intelligence, appearance technology and stability and reliability. It is of great significance for nuclear radiation safety protection.

2. Overall System Design

Low power micro analog multichannel can be divided into three parts. The first part is programmable gain amplifier and cr-rc circuit; the second part is a peak sample and hold circuit and a fast and slow channel signal trigger circuit; the third part is signal acquisition communication circuit. The components used in the multi-channel are all low-power micro devices, and the board size is 20 mm × 46 mm.

The multi-channel working principle of this paper is shown in **Figure 1**: the nuclear pulse signal collected by the detector generates an exponential attenuation signal through the preamplifier. The exponential attenuation signal is sent to our multi-channel for acquisition and processing. The principle of multi-channel signal processing is that firstly, the exponential attenuation signal is sent to the programmable gain amplifier to adjust the signal size, then the signal is sent to the cr-rc circuit for processing, and then sent to the peak holding circuit to find the peak signal. Finally, the peripheral ADC of the ARM chip is used to collect the peak information for statistics, and finally, the data is sent to the upper computer through USB communication. The upper computer performs spectral display and analysis.

Peak value extraction is the core part of the whole circuit. The principle of peak value extraction is shown in **Figure 2**. After cr-rc filtering and shaping, the input signal is divided into two channels to enter the comparator, one is a fast signal and the other is a slow signal; the fast signal is directly sent to the Comp1 comparator to judge the arrival of the signal. When the signal is greater than the comparison threshold, the nuclear signal enters, and then the slow signal is judged and collected. The slow signal will output the peak signal after passing through the peak holder, and then send the peak signal to Comp2 for comparison. When the peak signal is greater than the original signal, the ARM chip ADC will collect the total signal of the peak holder.

3. Hardware Design

The hardware circuit has several parts, such as power supply circuit, programmable gain amplification circuit, cr-rc circuit, peak holding circuit, arm peripheral circuit, USB circuit, etc. Several important circuits are described below.

3.1. Programmable Gain Amplification Circuit

The programmable gain circuit is composed of DAC and operational amplifier, as shown in **Figure 3**; the circuit uses 12 bit DAC, and the DAC model is ad5452.

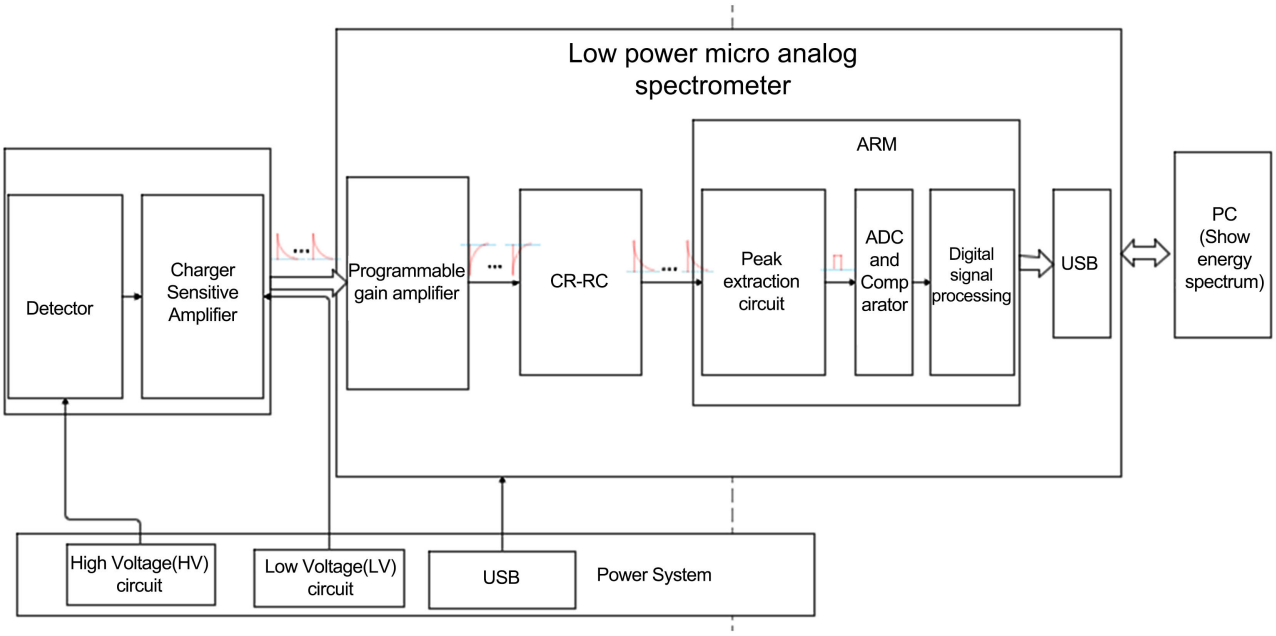

Figure 1. System working principle diagram.

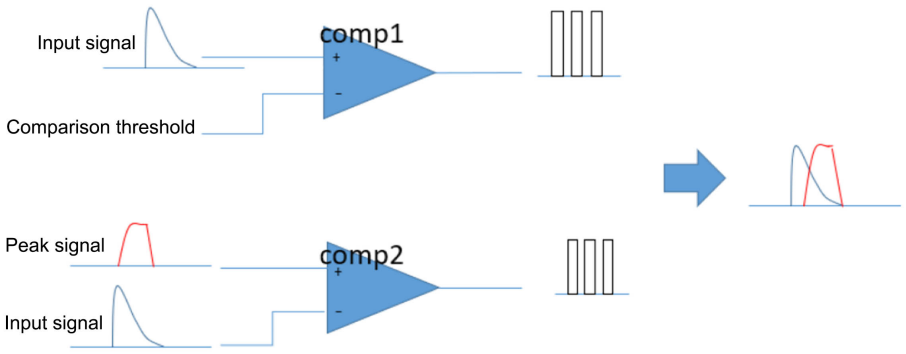

Figure 2. Peak signal extraction processing diagram.

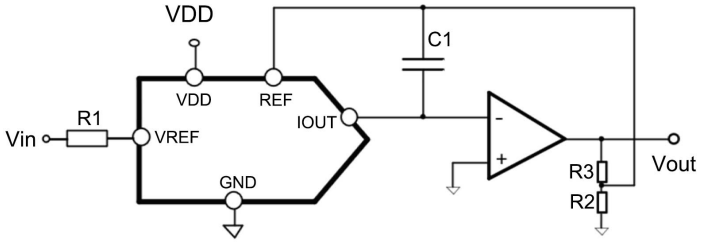

Figure 3. Programmable gain amplifier circuit.

3.2. Deconvolution Circuit

After the nuclear signal is ionized by the detector, it is an extremely fast current pulse. However, after being amplified by the preamplifier, the signal edge is pulled very long. As a fast channel pulse, it must ensure fast rise time and short pulse width [6]. Therefore, the deconvolution circuit (**Figure 4**) is designed to recover the fast pulse signal from the amplified signal.

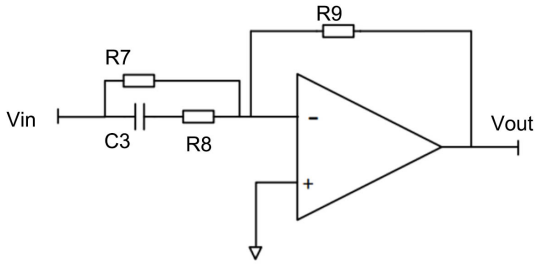

Figure 4. Deconvolution circuit.

The time constant of the deconvolution circuit shall be consistent with the time constant of the exponential function after the pole zero cancellation of the previous stage. The function of the resistor R8 in the circuit is to prevent the capacitive reactance of the capacitor C3 from being too small, resulting in excessive conduction current and damaging the subsequent stage operational amplifier. The circuit shall ensure that the value of R8 * C3 is far less than the value of R7 * C3, and ensure that the time constant of the deconvolution circuit is not affected by the resistance R8.

3.3. Peak Hold Circuit

The peak holding circuit is composed of op amp, capacitor and light [7]. Polyester capacitor is selected as the capacitor, which can ensure a fast charge and discharge of the circuit.

4. Multi Channel Program

The multi-channel in this paper uses the low-power ARM chip stm32l432kbu6, and the power supply voltage is 1.71 v - 3.6 v power arm ® 32-bit Cortex ®-M4 CPU, frequency 80 MHz, resources such as comparator, ADC and DAC meet the design requirements. Use Hal library for programming.

Figure 5 is a multi-channel program flow chart. The program is mainly divided into program-controlled gain amplifier control, peak signal extraction, peak signal statistics, and communication between the system and the upper computer.

5. PCB Layout and Physical Drawings

The circuit board is composed of power supply layer, stratum and signal layer. The relative position of power layer, stratum and signal layer and the division of power and ground plane are very important to the EMC index of a single board [8]. In full consideration of the signal characteristics and power supply layout of our equipment, we decided to adopt a 4-layer board layout. The layout is set as top layer, GND layer, power layer and bottom layer. Among them, the top layer is the main component distribution layer, and most components are arranged in the top layer because the GND adjacent to the top has lower ground impedance and better signal decoupling effect. When the top layer is inconvenient for layout,

the bottom layer is the second choice. In case of interference, the power layer also has a relatively good impedance to the ground and has a good effect on decoupling. The upper and lower layers of PCB adopt orthogonal wiring to avoid parallel wiring, so as to reduce the mutual coupling interference in the signal transmission process of the upper and lower layers.

Considering the characteristics of weak signals and sensitive signals, we should try to make the routing of weak signals and sensitive signals on the circuit board as short as possible to reduce the possibility of interference. Meanwhile, the wiring of weak signal and sensitive signal shall avoid other signal lines as much as possible. Or immediately arrange a signal amplification chip at the weak signal outlet to amplify the signal and improve the signal-to-noise ratio.

The following Figure 6 and Figure 7 are the PCB diagram and the physical diagram respectively.

6. Test Results

The bromine LAN probe of Beijing Yuecheng Photonics Technology Co., Ltd. is used to detect the output of 137Cs radiation source. The output signal amplified by the preamplifier is input into the low-power micro multi-channel. Figure 8 output signal diagram of each part displayed by oscilloscope. Figure 9 spectrum line measured by upper computer. The spectral line resolution is 2.81.

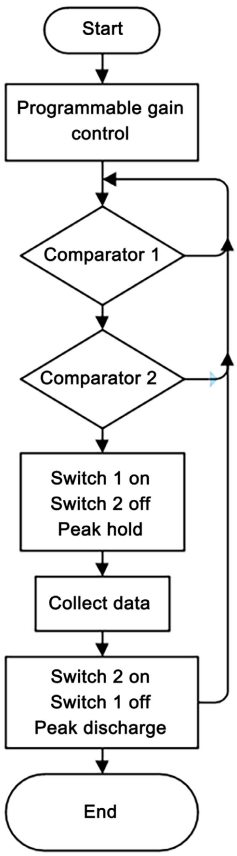

Figure 5. Multi channel program flow chart.

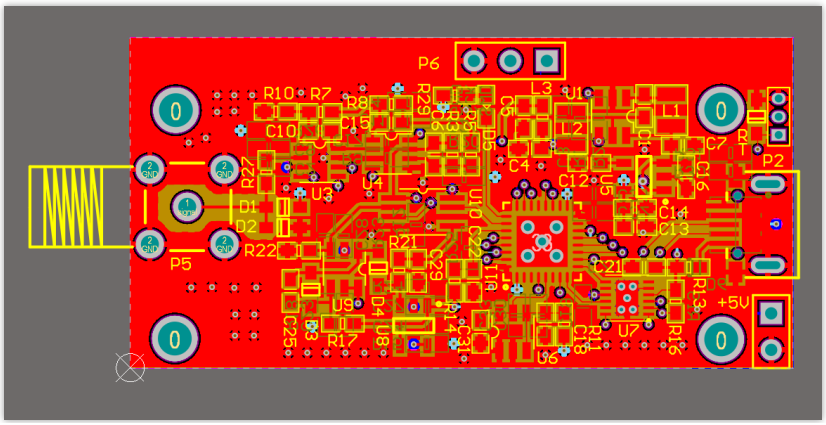

Figure 6. PCB diagram.

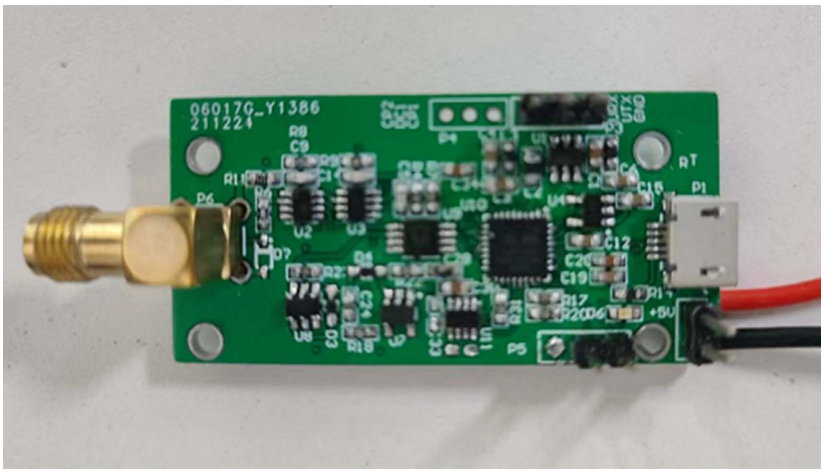

Figure 7. Physical map.

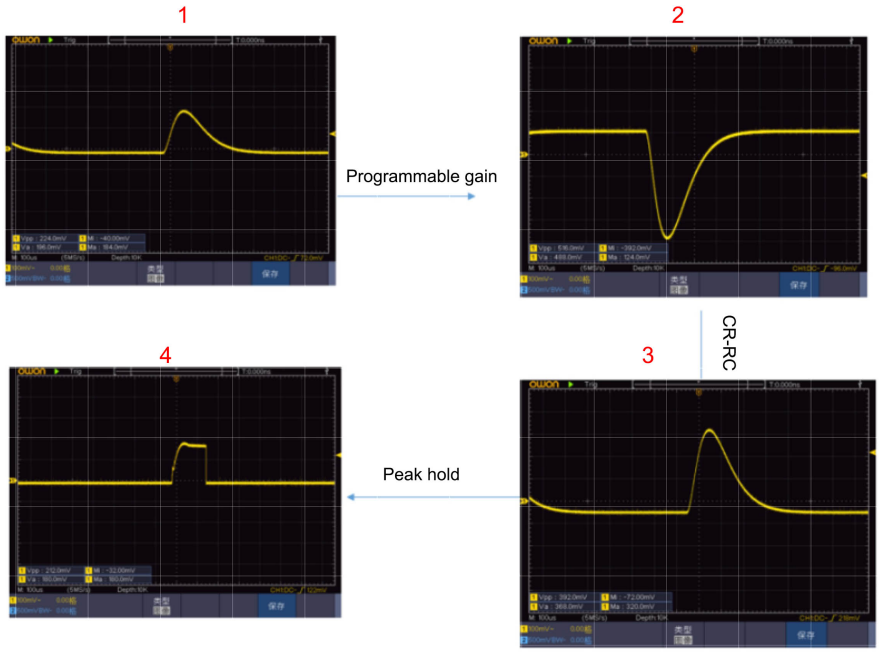

Figure 8. Output signal diagram of each part displayed by oscilloscope.

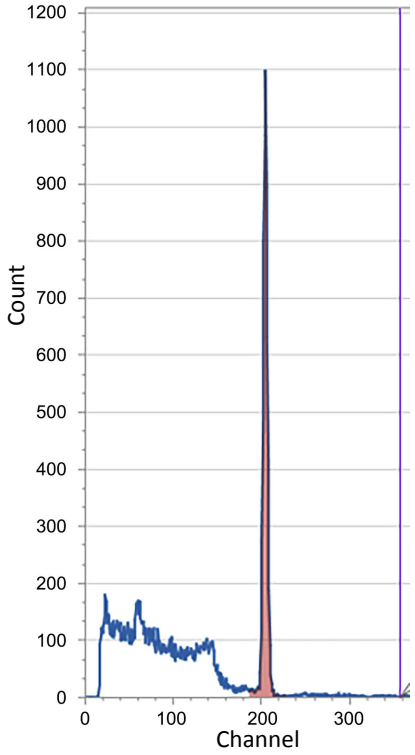

Figure 9. Display effect of upper computer.

7. Summary

The low-power micro multi-channel designed in this paper has a circuit board size of 20 mm × 46 mm and a multi-channel power consumption of 200 mw - 250 mw. According to the test results of the 137Cs radiation source detected by the bromine LAN probe, it has a good resolution, the counting rate can reach 50 K, and the long-term test performance is stable, which can meet many applications. In addition, corresponding probes and corresponding communication methods can be installed in intelligent robots, UAVs and places where measurement cannot be realized manually. It can also be integrated into various equipment and instruments to achieve nuclear signal acquisition and processing and energy spectrum analysis.

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Conflicts of Interest

The authors declare no conflicts of interest.

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