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Electronics Equipment of Coal Analyzer Based on Neutron Methods

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Abstract: **Coal Analyzer has been developed, capable of measuring the major and minor chemical elements contained in coal. The system utilizes nuclear reactions produced from fast and thermal neutrons, as well as from neutron activation of isotopes with half-lives of seconds or minutes. Characteristic gamma rays detected with BGO detectors are used for the identification of the various chemical elements. We have designed the electrical system and research position of some equipment and the way of their connections. For some redundant components, the electronic system is optimized to improve the accuracy and stability of the system. According to the preliminary performance test, the system has achieved the expected design target.**

Keywords: **Coal Analysis, Neutron Generator, Multi-Channel Card, Ion Source, Main Amplifier.**

I. INTRODUCTION

Neutron generator is developed an artificial neutron sources with high energy neutrons, fine monochromaticity, controlled, safe and easy to use, has been applied more and more extensively in production and scientific research. NIPGA (neutron induced prompt γ-ray analysis) method elemental analysis of the material has applied to the actual production and industrial online analysis, such as health care, well logging, testing water, coal and other areas of measurement technology, It created significant social and economic benefits[1,2]. NIPGA is a bulk material analysis technique, which makes it possible to detect elements in coal in a short time. It will be a valuable analysis method. In recent years, many overseas scholars have studied a lot in this field [3-7], Mainly coal industry projects of pulsed neutron experimental system include total moisture, ash, volatile and low calorific value analysis, it does not include coal elemental analysis, and coal analysis project includes the coal industry analysis and elemental analysis, can provide technical data for the coal chemical industry. Coal analysis includes many methods, such as chemical method, infrared method, microwave method, NIPGA method; it has the characteristics of on-line, high sensitivity, no damage to the sample and simultaneously measure many elements, it has become an effective means of analysis in the coal industry. The technology combines nuclear technology, electronics, computers, machinery processing and other technology, at present the Germany, Australia and other countries large companies, have commercialized and industrialized effectively, the technology is advanced, neutron tube and all kinds of electrical equipment Electrical apparatus has the characteristics of high integration, and high precision, but the equipment is extremely expensive, the introduction of China takes nearly one million.

US dollars each. In this regard, our country began to study very late, research institutions are not more than three, and less than the talent, domestic product measurement accuracy is still to be improved, which is a key determinant electronics system measurement accuracy, we conducted a study to optimize the electronic system structure, improve the measurement accuracy, reduce product cost.

Figure 1 is a block diagram of the coal quality analysis system based on neutron method, the principle is that the pulsed neutron generator produces neutrons, then γ-ray produced by nuclear reaction between the neutron and coal sample, the energy of γ-ray reflected the distribution of the material elements. The waves of the different amplitude are obtained by BGO detector, and then the voltage of the same amplitude is transmitted into the multi-channel spectrometer for counting

statistics, and finally the material contents of coal sample obtained by computer analysis and processing [5-6]. The function of the main amplifier is to amplify and shape the weak voltage signal which is output by the detector, so as to get the 1-5V of the Gauss wave, this will be advantageous to the analysis of the spectrometer. The design of the amplifier can be referred to the literature [6], which is no longer discussion in this paper. Because the pulsed neutron generation time is generally 10μs, stop time is 90μs, the working time of spectrometer is the stop time of neutron, so we must separate them from the control, which is the function of the gate circuit.

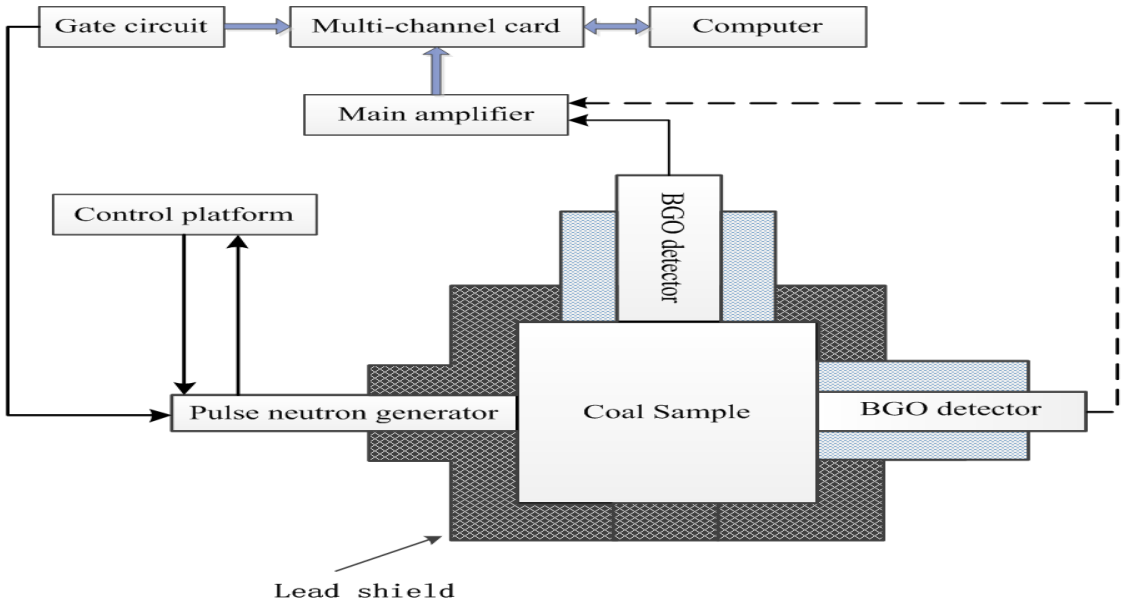
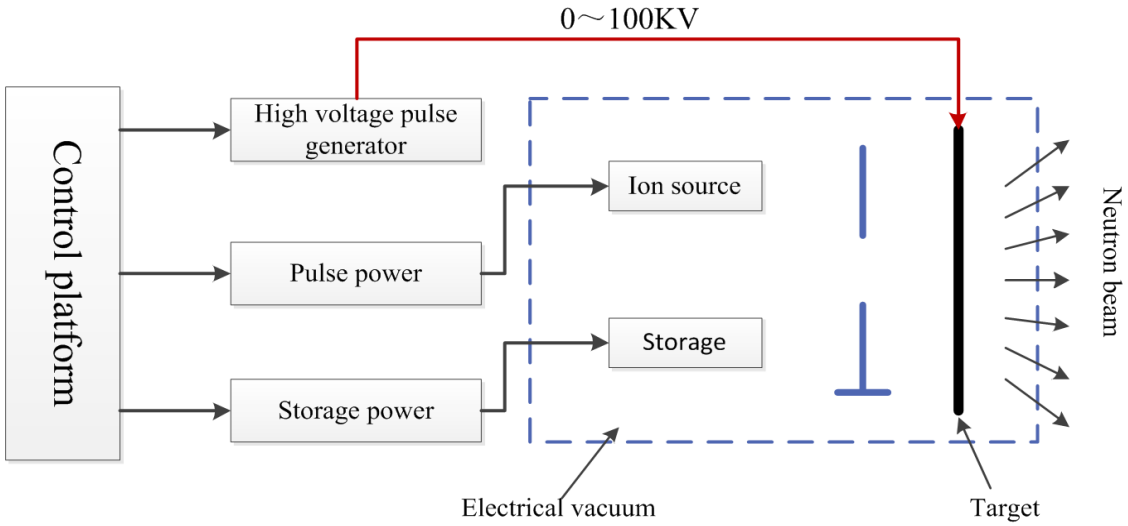


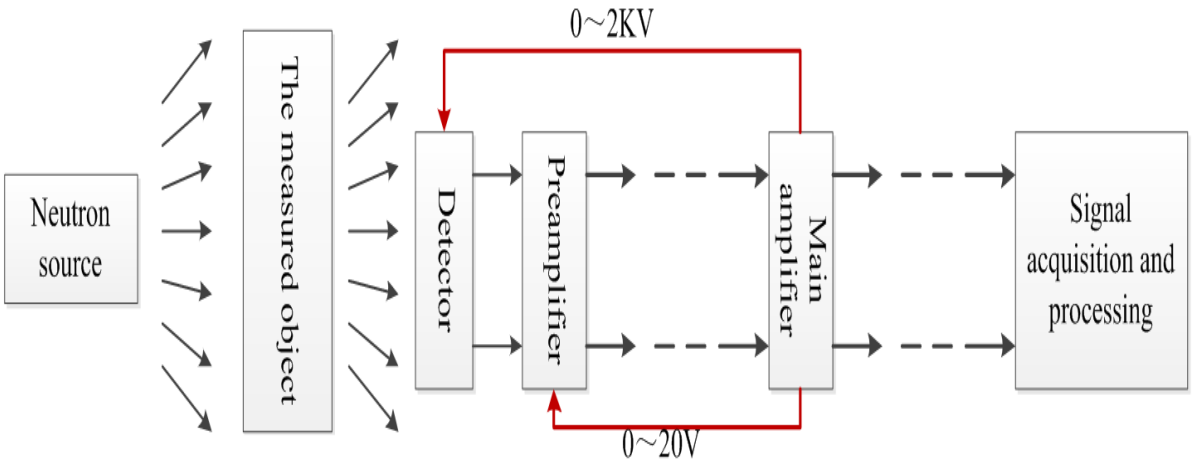
Fig. 1 Block diagram of coal analysis system

II. ELECTRONICS EQUIPMENT OVERALL DESIGN

Neutron detection system can be divided into two parts: the neutron generating part and ray measurement part, each requires its own electrical equipment, the principle shown in Figure 2. Figure 2(A) includes four parts of electrical equipments, which are control platform, high-voltage generator, the ion source high-voltage pulse power and storage power. Figure 2(B) includes preamplifier; main amplifier, five-channel power of detector and amplifier, multi-channel card multiple devices and other devices. In order to ensure detection accuracy, usually the preamplifier is placed in the inner detector, the main amplifier is placed in the vicinity of the device (within one meter), and in order to facilitate adjustment, we put the 0-2KV DC power supply of photomultiplier and two-way power supply of the preamplifier in the main amplifier. This design optimizes the circuit structure, reduces the noise interference and the system is more stable, temperature drift and time drift are lower [7-9].



（A）Neutron generating



（B）Ray measurement

Fig. 2 The electronic system structure of neutron detection (A neutron generating B ray measurement)

III. KEY EQUIPMENT DESIGN

A. High Voltage Circuit of Target:

Target high voltage circuit uses ‘voltage stabilizing circuit - high frequency inverter - double voltage circuit’ topological structure, the circuit structure shown in Figure 3. Target high voltage circuit provides a negative high voltage to target, and accelerates the deuterium ion to make its high-speed motion. Target high voltage circuit is an important part of the neutron generator. In order to achieve portability of the neutron generator, it is the key to reduce the volume of the high voltage power supply. Inverter technology can be used to improve the operating frequency [10-12]. Thus, the volume of transformers, filter capacitors and silicon reactor can be very small and reduced the size of the entire power supply. Experimental results show that the neutron yields is proportional to the target current and the 3.58 powers of target voltage [13-14]. So the development of high-yields neutron generator need to improve the voltage and current of target high voltage power supply, and increase the power output voltage can be faster to improve the neutron yield. When needed to reach 108n/s of neutrons, the generator target voltage shall not be less than 150KV, and the target current shall not be less than 5mA

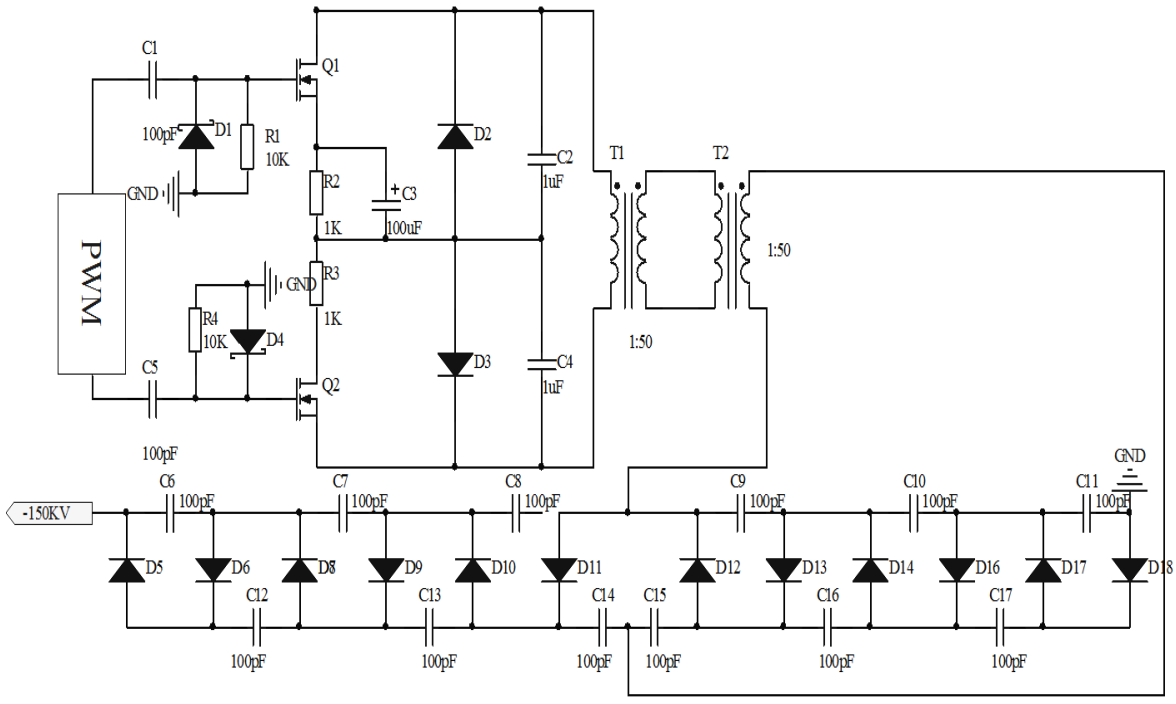


Fig.3 Neutron tube target pole high voltage power supply circuit schematics

B. Storage Heating Circuit:

The storage is a core component of gas pressure regulator. Usually, the storage composed of powder with hydrogen absorbing ability (such as titanium powder, zirconium - graphite powder) and heating wire. At a certain temperature, it will absorb a certain amount of deuterium and tritium gas, and can emit deuterium and tritium gas at elevated temperatures. When the neutron tube is working, the circuit of storage power provides a heating current to regulate its temperature, and control the air intake, then control the air pressure in the tube. Realization of neutron tube gas pressure regulation, and make it stable, the experimental results show that the variation of gas pressure in the tube has a great influence on the stability of neutron yields. The key element is the LM350 in the circuit in Figure 4, it is a three-terminal adjustable voltage stabilizer that can provide more than 3A current at 1.2V to 33V output range. This series voltage stabilizer can set the output voltage with two external resistors.

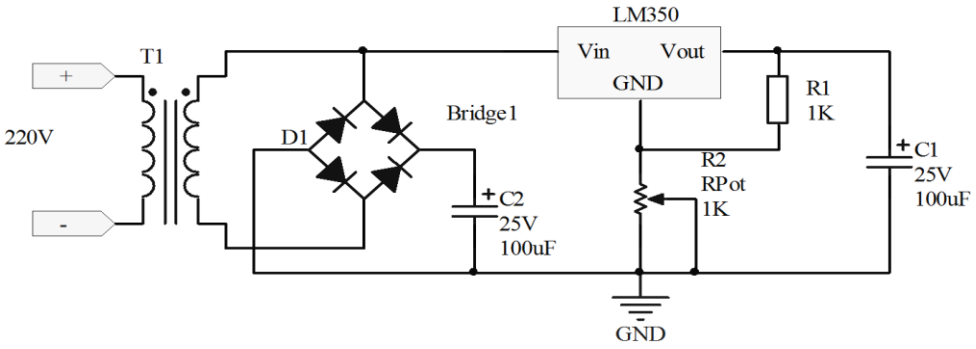


Fig. 4 The storage power circuit schematics

C. Ion Source High-Voltage Pulse Power:

In fact, the neutron generator has two operating modes: DC mode and pulse operation mode. Inelastic gamma ray is instantly generated in a (n, n') nuclear reactor by the fast neutron elastic and inelastic scattering, it becomes thermal neutron, at this point, capture gamma ray produce. Therefore, it delay 10-6～10-3s than inelastic gamma ray, and the activation decay γ rays produced in 10-3s after the (n, p) and (n, a) nuclear reaction. That is to say, the inelastic γ and other γ-ray can be separated in the time coordinates. Apparently DC mode measured accuracy is not high, especially N characteristic peak cannot be found. So we designed a 10μs pulse power [15], and pay attention to keep pace with the gating circuit.

D. Multi-Channel Spectrometer:

The basic function of multi-channel pulse amplitude analyzer is classified and counted according to the magnitude of the input pulse. Pulse amplitude range will be divided into many intervals, the number of these intervals is the channel of the pulse amplitude analyzer, and the width of interval is the channel width. The more of channel, the more precision amplitude analysis, and the number of each channel is also reduced, it need more time to measure. Of course, this make hardware circuit is more complex, so it should not blindly increase the number of channel, Typically, half the width of the peak amplitude should has 5 to 10 channels. For multi-channel spectrometer detector with NaI (T1), because of its relatively poor energy resolution, 128-256 will be able to meet the measurement requirements, and for the semiconductor detector, it needs 1024 to 8192 channels.

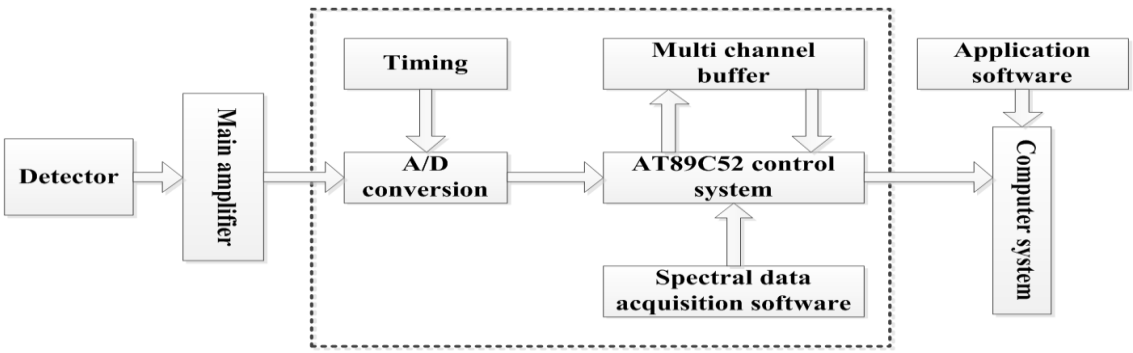


Fig. 5 Structure figure of spectrum gathering system

The structure diagram of multi - channel spectral acquisition system is shown in Figure 5. BGO detector includes a BGO crystal, a photomultiplier tube and a preamplifier. The dotted frame in Figure 5 is the structure of the analyzer, it's include discriminator circuit, control circuit, A/D converter circuit, and these are necessary for the multi-channel card, the analyzer includes two parts of peak collection and data upload.

E. Data Acquisition Interface Circuit:

AT89C52 is a low-voltage, high-performance CMOS 8 bit single-chip microcontroller-chip what include a Boolean processor and Flash storage cell. The microprocessor and flash storage combined together, especially repeatedly rewritable flash storage can effectively reduce the development costs. The controller AT89C52 and ADS7807 data acquisition interface circuit shown in Figure 6.

Pulse amplitude analyzer is classified and counted according to the magnitude of pulse, and the pulse amplitude value is converted by A/D. In order to convert the pulse amplitude, we must depend on the time sequence control circuit to realize the dead time control. Although AT89C52 and ASD7807 usually perform "MOVX instruction" bus-type interface, due to the special nature of the timing control, the interface of ASD7807 and AT89C52 cannot be used to implement the bus type interface of "MOVX instruction". According to the system resources of AT89C52 chip, the P1 port of AT89C52 is connected with ASD7807. I/O port of the user's P3 port, the 8 lines can be a bit operation. Others, taking part of the port line as the A/D conversion handshake signal.

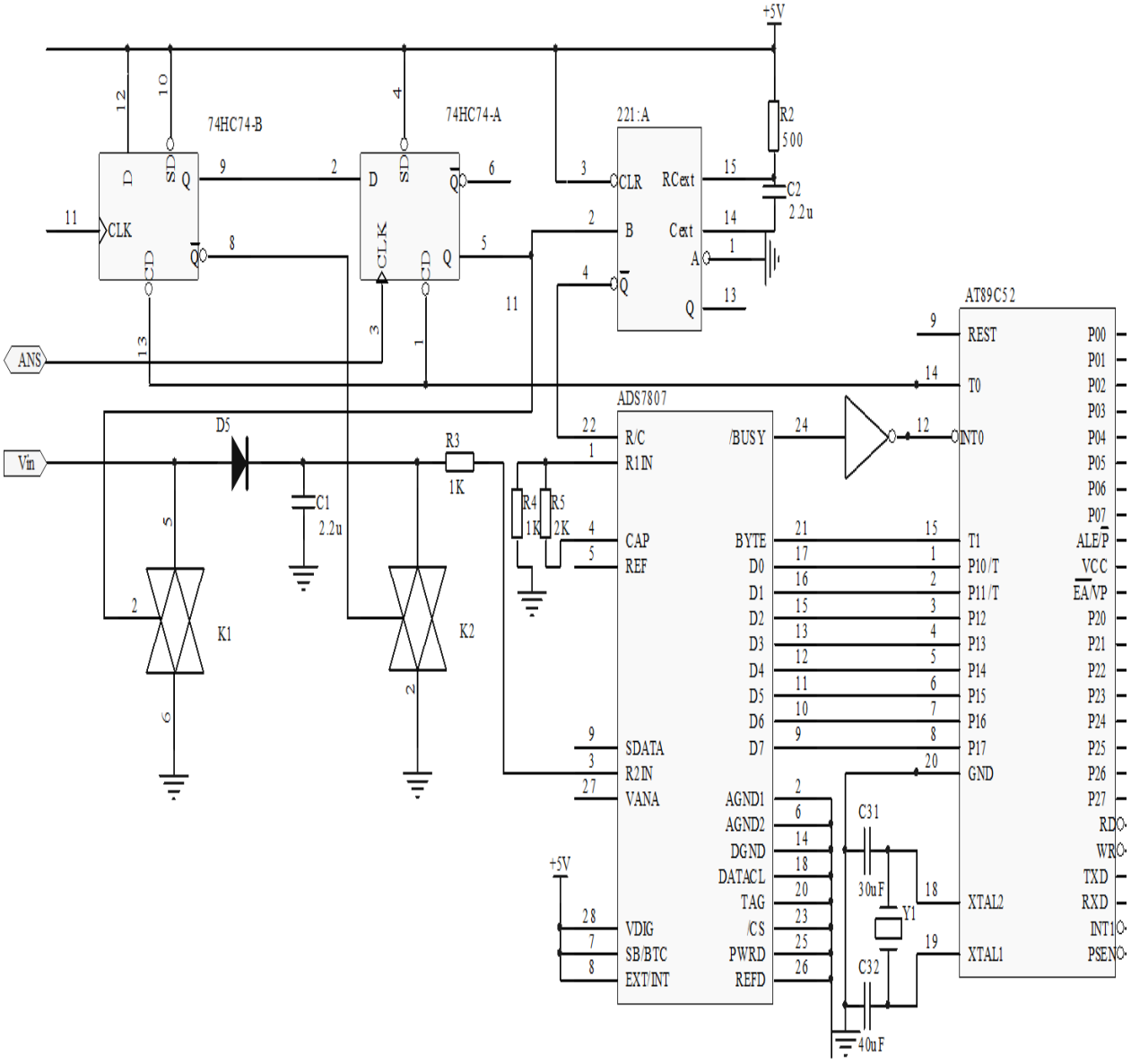


Fig. 6 Data gather interface circuit.

IV. EXPERIMENTAL STUDY

Experimental device body located in the ground 5m of underground neutron hall, the neutron hall is constructed in accordance with relevant state regulations, and meets the requirements of the protection. The analyzer consists of a coal sample, a BGO probe and a neutron generator, which is surrounded by a paraffin containing boron. Ground staff gives orders to control underground neutron hall equipments and achieved data transmission on the ground. After multi - channel card collection data, we write a program to complete a series of processing procedures, such as searching peak, taking peak area, substituting into the equations, calculation and statistics. Finally, the industrial analysis value is calculated by program through simple operation.

We collected 10 standard samples from Jixi and Hegang coal mine, each sample was 10L. 4096 MCA is divided into two areas; one area for storing spectrum Ⅰ, another area is stored spectrum Ⅱ. Spectrum Ⅰ is overall spectrum which include inelastic spectrum, capture and activation spectrum, its scope is from 2049 to 4096 channel. Spectrum Ⅱ is sum spectrum which include capture and activation spectrum, its scope is from 1 to 2048 channel, In the 900s measurement time, the resulting gamma spectrum is shown in Figure 7. The choice of 900s is based on the results of different time tests. Some of the important elements of coal, such as H, C, O, Al, Si and Fe are marked in Figure 7(Ⅱ).

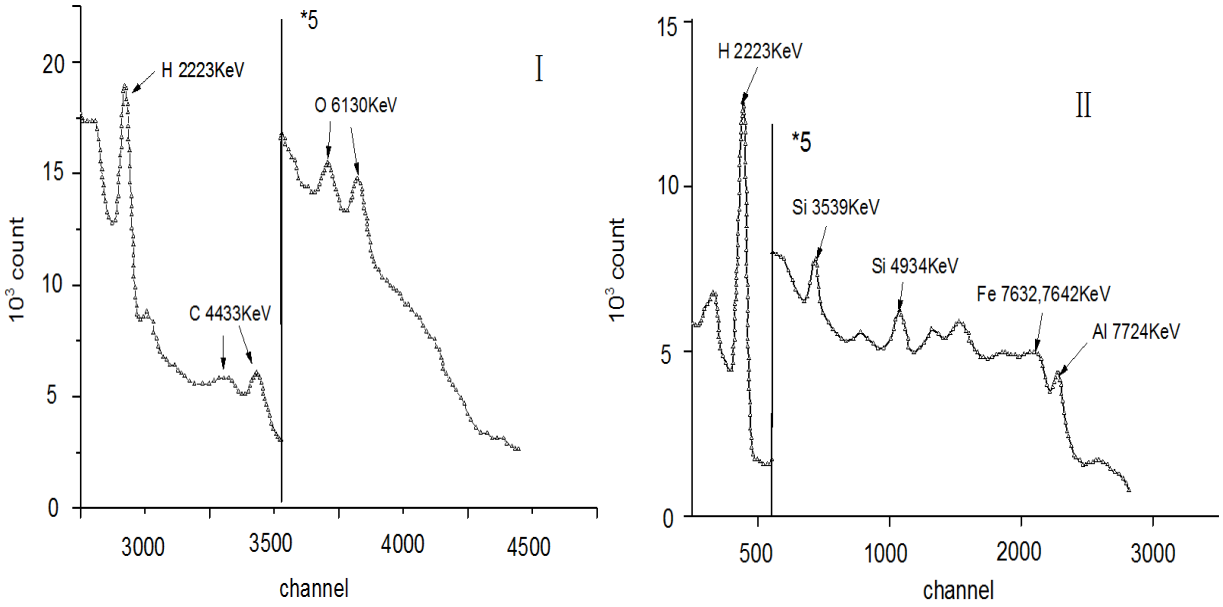


Fig. 7 γ spectrum of coal elements typical (Ⅰ: overall spectrum; Ⅱ: sum spectrum)

The accuracy of the test results is compared with the chemical analysis method, and the deviation is within the allowable range. The precision of the test result is as follows:

Total Moisture: ≤0.5%	carbon: ≤1.0%
Ash: ≤1.0%	hydrogen: ≤0.25%
Volatile: ≤1.5%	sulfur: ≤0.05%

V. CONCLUSIONS

The principle of coal analysis based on neutron method is introduced, and the main structure of the system is analyzed, it consists of two parts, namely, neutron generating portion and radiation measurement section, we optimize the whole electronics device, and give the key circuit diagram. Through the experimental study, the measurement accuracy of the system are improved obviously, temperature drift has been well suppressed and measurement error were within the national standard, This new approach has shortened the analysis time and effort from several days to 15 min and from several workers to two operators. However, we must point out that the measurement results of the regression equation are very strong, and the corresponding mathematical model should be set up to make the system adapt to different coal types and coal mines. The work can provide the basis for the intelligent design of nuclear electronic systems in the future.

REFERENCES

[1] Sibiya B, Adeleke A A, Popoola, A P I, et al. An Evaluation of the Calibration Process of a Neutron-Gamma Ray Online Coal Analyzer. International Journal of Coal Preparation and Utilization, 2014, 34 (1): 10~18.

[2] He L, Deng Z, Liu YN, et al. Development of a multi-channel readout ASIC for a fast neutron spectrometer based on GEM-TPC. Chinese Physics C, 2014, 38 (10): 129-135.

[3] Gu Deshan, Qiao Shuang, Jing Shiwei et al. Development of experimental system of pulsed neutron coal industry analyzer [J]. Nuclear technology, 2004, 27 (6): 73~75. (in Chinese)

[4] He, Lilin, Melnichenko Y B, Mastalerz M. Pore accessibility by methane and carbon dioxide in coal as determined by neutron scattering. Energy and Fuels, 2012, 26 (3): 1975-1983

[5] Chen Chunkai, Guan Xuemei. Study on the working characteristics of double circuit for high voltage power supply [J]. Nuclear electronics and detection technology, 2008, 29 (1): 95~98. (in Chinese)

[6] Guan Xuemei, Qiao Shuang, Chen Chunkai et al. Design of programmable gain linear pulse amplifier. Nuclear electronics and detection technology, 2006, 30 (3): 231~232. (in Chinese)

[7] Chen Chunkai, Qiao Shuang, Guan Xuemei et al. Design of high voltage pulse power supply for inelastic scattering spectra and capture spectra measurements. Nuclear electronics and detection technology, 2007, 122(1):123~125. (in Chinese)

[8] Wang Minghuang, Zeng, Qiusun, Jiang Jieqiong. Neutronics Analysis and Optimization for Fusion Driven Subcritical Spent Fuel Burning System. Journal of Fusion Energy, 2015, 34 (3): 598-603.

[9] Lim C S, Abernethy D A. On-line coal analysis using fast neutron-induced gamma-rays. Applied Radiation and Isotopes, 2005, 63 (4): 697–704.

[10] Barzilov, A, Kessler, B, Womble, P C. Analysis of 14-MeV neutron induced gamma-ray spectra using multiwavelets. Radiation Measurements, 2015, 79 (6): 43-49.

[11] Jallu F, Loche F. Improvement of non-destructive fissile mass assays in a low-level waste drums: A matrix correction method based on neutron capture gamma-rays and a neutron generator. Nuclear Instruments and Methods in Physics Research B, 2008,266 (9): 3674–3690.

[12] Sowerby B D. Nuclear techniques for the on-line bulk analysis of carbon in coal-fired power stations. Applied Radiation and Isotopes, 2009, 67 (10):1638–1643.

[13] Lim C S, Abernethy D A. On-line coal analysis using fast neutron-induced gamma-rays. Applied Radiation and Isotopes, 2005, 63: 697-704.

[14] Gu, Deshan; Cheng, Daowen; Yin, Jie et al. Rapid analysis of coal properties: A computerized coal analyzer using a pulsed neutron beam. IEEE Instrumentation and Measurement Magazine, 2005, 8 (5): 22-27.

[15] Potapov V N, Ignatov, S M, Ivanov O P. A combined spectrometric detector of fast neutrons. Instruments and Experimental Techniques, 2015, 58 (3): 329-336.