ISSN: 2414-1895 DOI: 10.6919/ICJE.202208_8(8).0092

A New Design of γ Radiation Detection System

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Abstract

With the rapid development of nuclear technology, nuclear energy, as a clean and efficient energy, accounts for an increasing proportion in the energy system of all countries in the world. However, in the decades of nuclear energy development and utilization, there have been many serious nuclear accidents, such as the explosion of Chernobyl nuclear power plant in 1986 and the Fukushima nuclear leak in 2011. Therefore, nuclear radiation monitoring in nuclear sites has attracted more and more attention. With its strong penetration ability and its damage to human body, γ Radiation is one of the key monitoring objects in nuclear sites. The volume detector GM counter is an area γ Radiation monitoring system is one of the important detectors. However, the GM counter is used as the detector γ Radiation monitoring can work normally only under the high voltage of hundreds of volts, which greatly reduces its service life. In this paper, a double terminal voltage controllable high-voltage circuit is proposed as the driving power supply of GM counter, and a low-cost device is designed with high-speed FPGA as the data acquisition unit γ Radiation detection system.

Keywords

Nuclear Radiation Monitoring; γ Ray; GM Counter.

1. Introduction

With the rapid development of nuclear science and technology, nuclear energy, as a clean and efficient new energy, accounts for an increasing proportion in the production and life of the national economy. According to the annual report of the International Atomic Energy Agency, there are 441 nuclear reactors under construction in China and 27 in operation in the world by the end of 2010. By 2020, China has 49 nuclear power units in operation, ranking third in the world, and 13 nuclear power units are under construction, ranking first in the world [1]. When nuclear energy brings a steady stream of clean energy to people's lives, its related risks and accidents have gradually attracted attention.

We are exposed to both natural and artificial sources of radiation in the air all the time. Artificial radiation sources include radionuclides existing due to nuclear weapon experiments and radioactive radiation produced by nuclear power industry. When radioactive nuclides decay, they release α, β, γ Isoradiation and enters the human body in a variety of ways, causing radioactive damage. among γ Radiation and neutrons will cause ionizing radiation damage to the surrounding environment and personnel. Therefore, in the region γ Real time monitoring of dose level is a necessary means to ensure people's life, health and safety [2].

Geiger Miller counter tube (GM counter tube) can effectively detect air pollution γ Ray intensity is the most widely used detector in regional radiation measurement [3].In this paper, a regional radiation monitoring system based on FPGA is designed by using GM counter. Its hardware circuit includes detector double terminal high voltage controllable circuit, signal processing circuit, RS-485 communication circuit and so on. The dual terminal high voltage controllable circuit of the detector

Volume 8 Issue 8, 2022
DOI: 10.6919/ICJE.202208_8(8).0092

can quickly switch the positive and negative high voltage amplitude, and effectively prolong the service life of GM counter.

2. Hardware Circuit

The overall hardware design of the system is divided into signal processing circuit, double terminal high-voltage controllable circuit, FPGA core circuit and RS-485 communication circuit. The overall structure block diagram of the system is shown in Figure 1:

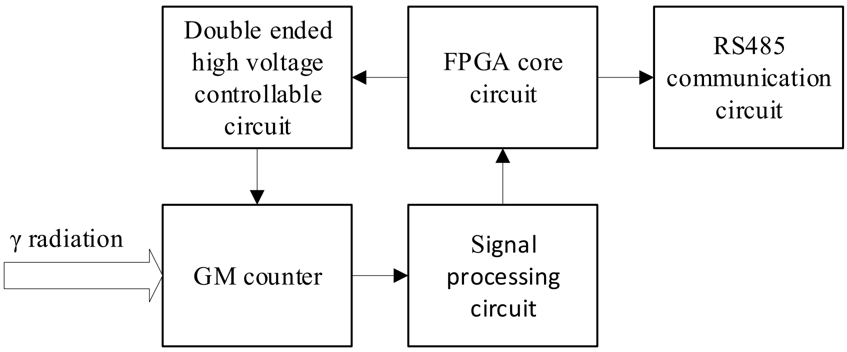

Figure 1. overall system block diagram

γ After the radiation irradiates the GM counter tube, the GM counter tube generates signal output. After being processed by the signal processing circuit, the signal is converted into a pulse signal with a certain width. FPGA counts the signal and transmits the data to the upper computer through RS-485 communication circuit. And multiple radiation detectors are networked through RS-485 bus to realize regional radiation monitoring.

GM counter needs to input hundreds of volts high voltage at both ends to work normally [4], but long-term application of high voltage at both ends of GM counter will greatly shorten its service life and affect the stability of the system. When a single nuclear decay occurs, the generation of each event is independent of each other, that is, the probability of decay of each atom is equal at the same time. The nuclear event conforms to Poisson distribution, and Poisson intensity is the radiation intensity of the radiation source. In this way, the GM counter does not need to be in the working state of high voltage all the time, and can maintain high voltage during the measurement time and reduce the voltage during the sleep time. Double ended high voltage controllable circuit is shown in Figure 2:

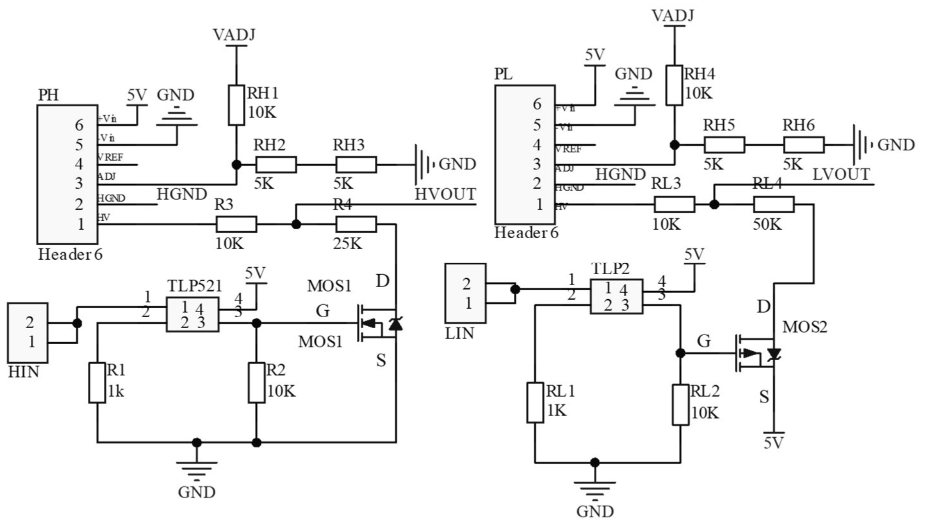

Figure 2. double ended high voltage controllable circuit

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PH is a positive and high-voltage module. Its 3 pins are output voltage regulation ports and 1 pin is high-voltage output. The output high voltage is connected to both ends of GM counter tube after being divided by two resistors. Hin is the control signal input, which is isolated by optocoupler to control NMOS on or off. When NMOS is turned on, the output voltage after voltage division is the voltage after voltage division of resistors R3 and R4, which is the sleep voltage; When NMOS is cut off, its internal resistance approaches infinity, and the output voltage is no longer divided, which is the working voltage. The advantage of this is that the switching time between working voltage and sleep voltage is very short, which is almost only the switching time of MOS tube. GM counter can quickly switch between working voltage and sleep voltage, effectively reducing the measurement error.

The negative exponential pulse signal generated by GM counter needs to be processed before it can be better collected by FPGA. Because the signal amplitude is large and reaches hundreds of MV, the signal can be shaped directly by tlv3501 comparator. The reference voltage of tlv3501 is generated by dividing the voltage of TLV431 reference power supply. In this way, the back-end FPGA can directly collect the square wave pulse signal with amplitude of 3.3V.

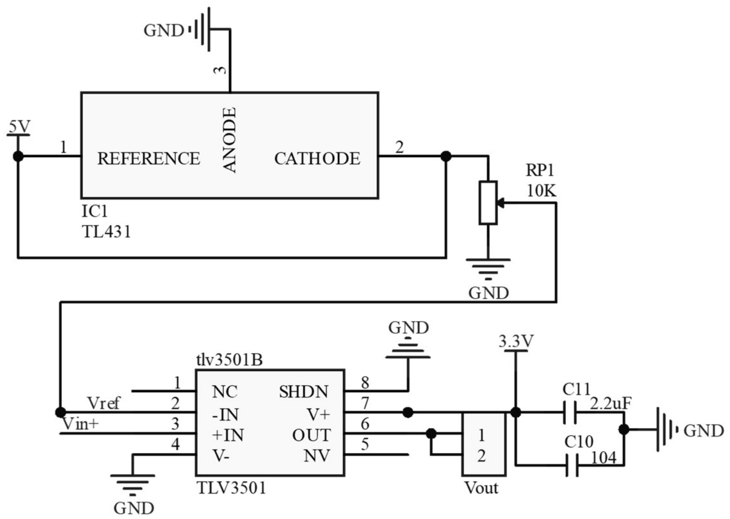

Figure 3. signal processing circuit

3. Software Design

FPGA is a field programmable gate array. Compared with the traditional single chip microcomputer, its circuit is not fixed and can be customized. And FPGA runs in parallel based on look-up table, and MCU is serial instruction. FPGA has higher efficiency in processing parallel tasks, which is also a major advantage of FPGA. FPGA software module design is the core of the whole system γ As the core of radiation detection system, its main functions include GM counter work and sleep state switching control, pulse signal acquisition, data transmission, etc. module design is adopted between various software functions. The software module block diagram is shown in Figure 4:

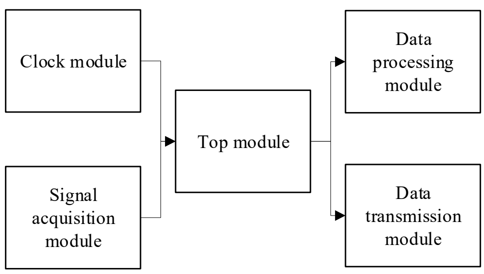

Figure 4. software module block diagram

Volume 8 Issue 8, 2022
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Before counting, the GM counter is in the dormant state. When counting starts, the FPGA controls the GM counter to enter the working state, and then enter the dormant state after radiation monitoring. Accumulate the number of pulse signals collected in a period of time, and then calculate the dose rate according to the relevant formula. The flow chart is shown in Figure 5.

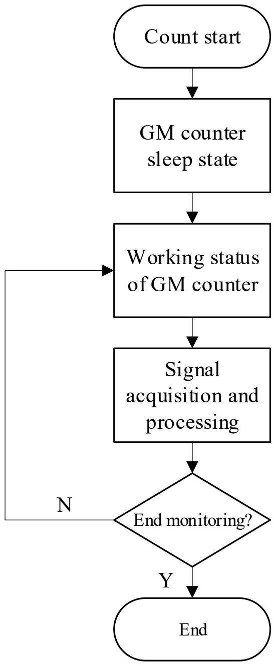

Figure 5. software flow chart

4. Experimental Results

In the experimental test, 60Co is used as the standard radiation source and tested under the condition of known dose rate. The test results are shown in Table 1:

Table 1. test results

Dose rate/μSv/h	Counting rate/cpm
1.8	220
1.58	187
1.3	143
1.05	120
0.6	90
0.35	55
0.22	23

It can be seen from the above table that this method can be used in the case of radiation sources with different dose rates γ The counting rate of the radiation detection system is directly proportional to the dose rate, which shows that the system can γ Effective detection of radiation.

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5. Conclusion

This paper presents a new type of double ended high voltage controllable γ For the radiation detection system, the overall software and hardware of the system are designed and developed, and the actual test of the system is carried out with standard radiation source. Experiments show that the system can well measure the regional radiation level, with low cost and simple structure. It can be networked through RS-485 bus, and can deploy multiple measurement nodes in large areas to complete regional radiation monitoring.

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