https://doi.org/10.46813/2024-151-040

DEVELOPMENT OF A RADIOMETER FOR MEASURING THE RADON CONCENTRATION IN THE AIR

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The results of the development of an experimental sample of a radiometer for measuring the concentration of radon in the air are presented. The application of an air pumping system and a combination of four Si planar detector plates made it possible to increase the sensitivity of the radiometer, which significantly expands its possibilities for use in both open and closed air ventilation systems. The developed software allows to measure and analyze the spectra of alpha particles in real time and evaluate the radon content in the specified time.

PACS: 07.85.Nc, 07.05.Tp

INTRODUCTION

Radon is a radioactive, colorless, tasteless, and odorless gas 7.5 times heavier than air. Three natural isotopes of radon are widely distributed: actinon (^{219}Rn), thoron (^{220}Rn), and radon (^{222}Rn).

All of them are members of the natural radioactive series: ^{219}Rn – ^{235}U family, ^{220}Rn is of the ^{232}Th family, ^{222}Rn is of the ^{238}U family, and are daughter products of the decay of radium. After decay, radon isotopes form polonium isotopes. Most isotopes in the decay chain emit alpha particles with an energy of about 5 MeV. Recently, radon and its decay products have been considered one of the main sources of natural human exposure, and radon in residential premises poses a danger [1].

1. MEASURING MODULE DESIGN

The measuring module is a light-tight ventilated chamber in which the detection system and a charge-sensitive pre-amplifier (CHPA) are located.

The detector system is a set of four silicon planar detectors developed by NSC KIPT, 300 μm thickness, with an active area measuring 10x10 mm^2. Serial samples of radon radiometers use detection systems of a larger area [3]. To increase the measurement accuracy, using a smaller detector area, active sampling is used in the measuring module. Those air is pumped through the measuring chamber. The main elements included in the measuring chamber are presented in Fig. 1.

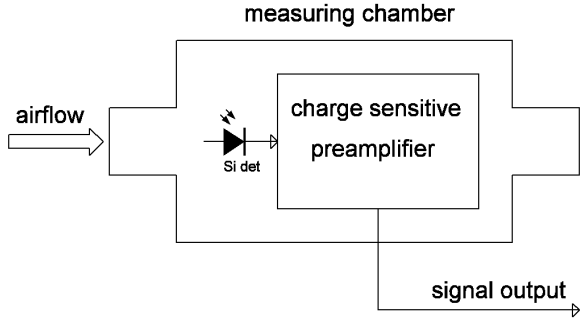

Fig. 1. Scheme of measuring chamber

2. THE RADIOMETER ELECTRONIC COMPONENT COMPOSITION

The block diagram of the electronic scheme of the radiometer is shown in Fig. 2.

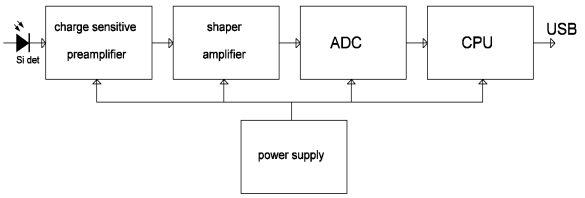

Fig. 2. Radiometer block diagram

The electronic block diagram of the radiometer can be conditionally divided into two functionally complete parts – the spectrometric path and the information processing unit (CPU).

To detect alpha particles in the spectrometric mode, electronics for reading the signal from a large-area planar silicon detector have been developed. This readout system consists of a charge-sensitive preamplifier (CSP) capable of driving planar detectors up to 200 pF, a conditioning amplifier (CA), a quasi-Gaussian CR-(RC)^n driver, and an analog-to-digital converter (ADC). To reduce noise, two 2SK932 transistors connected in parallel are used at the CNC input. The spectrometric measuring line has no special features; a more detailed description is given in [2]. For optimal filtering of signals from planar detectors at room temperature, the formation time was selected on the order of 1 μs.

To test the possibility of long-term operation of the spectrometric line, the alpha activity spectrum of natural granite was measured. The spectrum is presented in Fig. 3. Clear room measuring time was equaled 10 h. The CPU block diagram is shown in Fig. 4.

The Atmega 328P chip was selected as the control microprocessor. Information about the current activity and measurement time is displayed on the 16x2 LCD display. Information about the current time (year, month, day of the week, hours, minutes) comes from the real time clock (RTC) module. To communicate with a higher-level computer, a standard USB interface assembled on a CH340 chip is used. Operating modes are controlled using a 3x4 matrix keyboard.

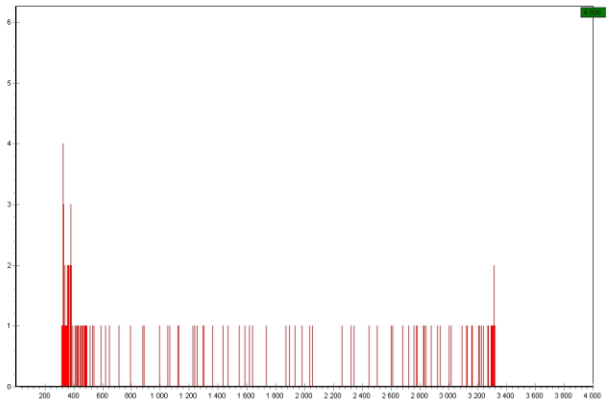

Fig. 3. Typical spectral distribution of alpha particles emitted by granite

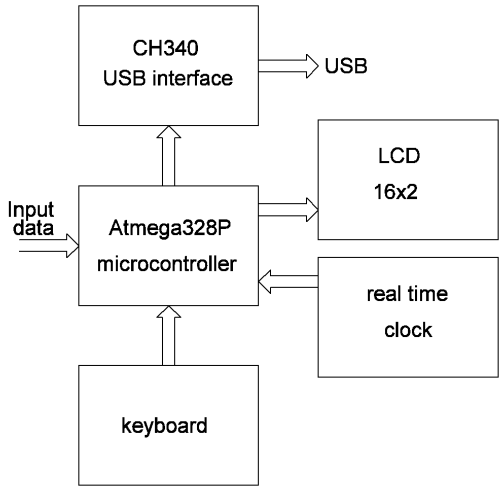

Fig. 4. Block diagram of the information processing unit

3. SUPPORTING SOFWARE

The program recorded in the microcontroller counts the number of pulses in the given energy interval and displays the information on the LCD. In addition, information about the time and date of dialing is displayed on the indicator. After the end of the exposure, the information is recorded in the non-volatile memory of the microcontroller. Setting the set time and energy interval is carried out from the keyboard included in the unit.

The software is written using the WinAVR package, which has a General Public License.

CONCLUSIONS

As a result of the conducted studies:

– the design of the prototype of the radon radiometer was developed;

– modules of the charge-sensitive pre-amplifier for work with detectors possessing high capacity are developed and manufactured;

– studies of the characteristics of the experimental sample of the radiometer and the possibility of their improvement are ongoing.

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Article received 30.04.2024

РОЗРОБКА РАДІОМЕТРА ДЛЯ ВИМІРЮВАННЯ ВМІСТУ РАДОНУ В ПОВІТРІ

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Представлено результати з розробки експериментального зразка радіометра для вимірювання концентрації радону в повітрі. Використання системи прокачування повітря та комбінації чотирьох кремнієвих планарних детектуючих пластин дало змогу підвищити чутливість радіометра, що значно розширює його можливості щодо використання як у відкритих, так і замкнутих системах вентиляції повітря. Розроблене програмне забезпечення дозволяє отримувати та аналізувати спектри альфа-частинок в реальному часі і проводити оцінку вмісту радону за вказаний час.