

Development of Background Radiation Monitoring System based on Arduino Platform

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Abstract—In the paper, the background radiation monitoring system has been developed. It has been built on the Arduino Uno microcontroller board, Geiger-Mueller counters, alphanumeric LCD module and high-voltage power supply module for counters. The system measures power of the equivalent radiation dose and accumulated dose and outputs the information via the serial port to PC, and also sends warning signals when the equivalent dose rate is exceeded.

Keywords: background radiation, monitoring system, Geiger-Mueller counter (tube) CBM-20, Arduino Uno, ATmega328P-PU microcontroller (MC), Arduino IDE, embedded software, Proteus Design Suite.

I. INTRODUCTION

The radiation is dangerous not only by its high ability of defeat, but also by the fact that radiation is not perceived by our organs of perception. None of the human receptor organs is able to warn of the presence of radiation source. This enabled to conceal information about nuclear accidents and their consequences. Even after events at the Chernobyl Nuclear Power Plant, the radioactive effects have been reflected in the European countries, for several years in the USSR it was forbidden to have devices for determining the level of radiation pollution. With the advent of free sale of radiometers and dosimeters it became possible to better ensure the radiation safety of citizens [1].

The action of radiation cannot manifest itself immediately. The effects of radiation can be attributed to decades later in generations, in the form of cancer diseases, genetic mutations, etc. With an increase in the level of irradiation in the human body the violations appear that can lead to death in a few days or hours. After the determination of the elevated radiation level, it is necessary to immediately detect the radioactivity source by using a radiometer – dosimeter [2].

The appearance of microcontroller platforms (Arduino, Raspberry Pi) and various digital sensors made possible to create inexpensive programmable measurement and control systems [3,4]. Such an information-measuring system can be used to monitor the radiation background.

The aim of the work is to develop hardware and software of the background radiation monitoring system based on the Arduino platform.

II. HARDWARE DESIGN OF BACKGROUND RADIATION MONITORING SYSTEM

The system has to measure the radiation level, process the collected data, transmit them to PC via serial interface, and inform about the radiation level excess. In Fig. 1, the proposed structure of the background radiation monitoring system has been shown. The hardware of the system consists of: battery charging module; radiation detector (Geiger-Mueller counter CBM-20); converter DC6v-DC12v; 400 volt anode voltage shaper for feeding CBM-20; single-vibrator; Arduino Uno board [5,6]; indication module; sound and light signaling; push button (start-stop) for selecting the MC operation mode.

The dosimeter-radiometer operates at a 6-Volt 1.2AH battery. For the battery recharging, the module shown in Fig. 2 is used. At the inputs AC1, AS2 an alternating voltage of 10...18 volts is supplied, which is straightened by the diode bridge BR1 and is fed to the chip U1 (DC-DC converter), which supports 6.8 Volt output voltage - for the battery charging.

To supply the high-voltage converter, a stabilized voltage of 12 volts is used, which is obtained from the DC-DC converter (Fig. 3), which converts the input voltage from the battery (a voltage can be 5.5...6.8 Volt) at 12 Volts.

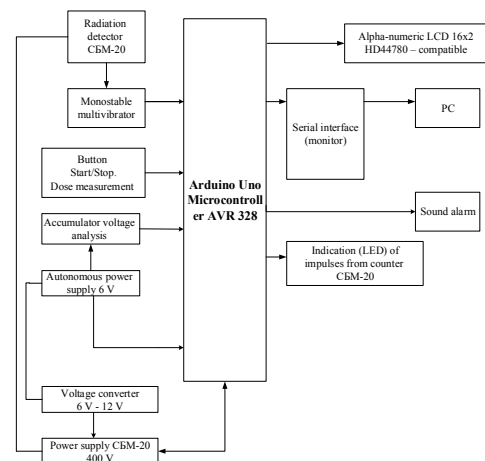


Fig. 1 Structure of the background radiation monitoring system based on the Arduino platform

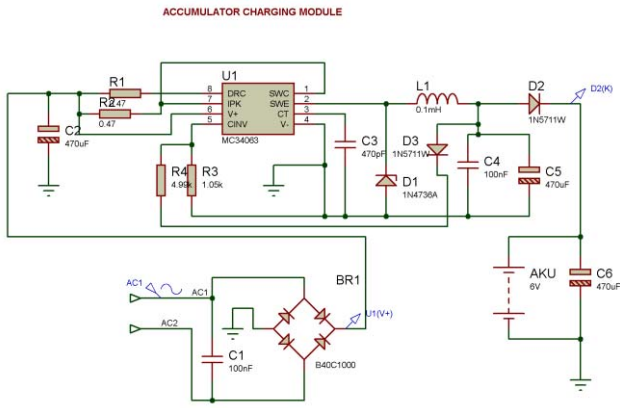


Fig. 2 Battery charging module

The DC-DC converter circuit is designed with MS34063 which is turned on according to the STEP-UP converter circuit. The transistor Q1 increases the converter power converter to 3A. The output voltage can be adjusted with the potentiometer RV1.

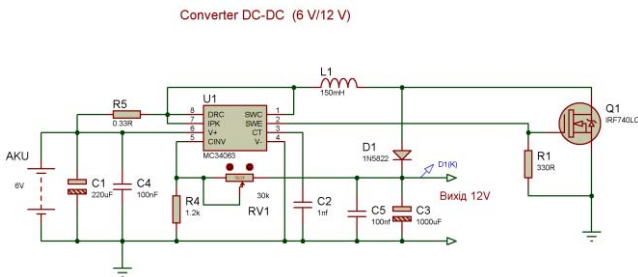


Fig. 3 Converter DC 6V - DC 12V

For power supply of the Geiger-Mueller counters, a high voltage source is required. Such sources usually are autonomous. One of the classical converters from 12V to 400V is shown in Fig. 4.

High voltage generator for power supply of Geiger-Mueller counter

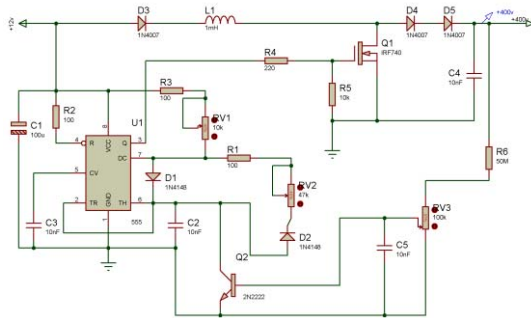


Fig. 4 High-voltage power supply generator for Geiger-Mueller counter

Using the 555 timer chip a PWM generator is implemented. By using the potentiometer RV1, the generator frequency is regulated and by using the potentiometer RV2 - its duty cycle. The pulses of the required frequency and duty cycle are applied to the gate of the transistor Q1 which increases the voltage on the coil L1 to 400 Volts, the exact voltage value is regulated by using the potentiometer RV2. From the C4 capacitor, the high voltage is applied to the Geiger-Mueller counters. The pulse

frequency of the generator is 4.14 kHz. The high-voltage generator can be implemented using a microcontroller, having put on it PWM functions. The circuit is simplified and has the following look, as shown in Fig. 5.

Power supply for Geiger-Mueller counter on MC

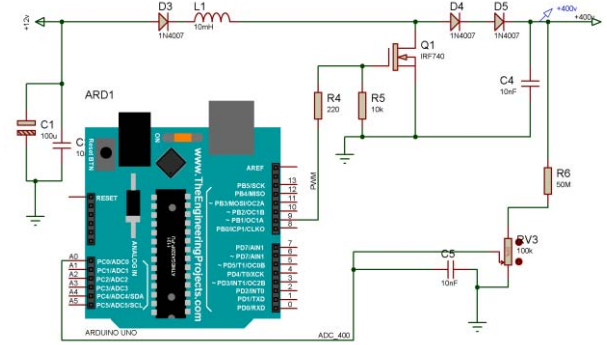


Fig. 5 Power supply circuit for Geiger-Mueller counter based on the Arduino Uno board in Proteus VSM

From the output of PE3 (OC3A) - the input Q1 receives the PWM sequence that sets the voltage to 400 Volts.

For regulation (maintaining) of the output voltage in the desired range, it is applied to the ADC input ADC0 of the MC through the divider R6 - RV3. Depending on its value at the output of PE3 (OC3A) - the required PWM sequence is formed. In Fig. 6 the monovibrator is shown that generates a short, tangent impulse of the Geiger counter - a pulse of the rectangular form of the fixed duration for the MC correct operation.

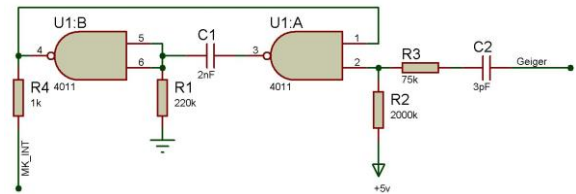


Fig. 6 Monostable gate multivibrator circuit for correct operation of the MC in CAD Proteus VSM

Arduino Uno based on the AVR MC ATmega328 is the main data processing unit, from the Geiger-Mueller counter, for outputting the necessary information to the LCD, data transmission through the serial port to PC.

In Fig. 7 the circuit of the background radiation monitoring system is shown. The system continuously monitors the power of the radiation background and displays the information on the LCD and transfers it via the serial port (via UART) to PC. When the radiation power exceeds more than acceptable limits (0.3 $\mu\text{Sv/h}$), the sound (PSP LS1) and light alarms (flashing red LED - "Alarm") are turned on. The intensity indication of the radiation pulses occurs with the blue LED1. The display constantly shows the information about the radiation power in $\mu\text{Sv/h}$ and CPM (number of pulses per minute). When the START-Stop button KH1 is pressed, the timer is switched on and the display additionally shows the received dose of radiation during the period (μSv).

For the correct operation of the system, a state of the battery charge and the supply voltage of the counter СБМ-20 are additionally measured (ADC inputs Arduino Uno A1, A0 - respectively). The high voltage of the meter is generated by PWM from the output of 9 Arduino Uno, and controlled by the ADC input A0. The high voltage generator consists of the coil L1, the transistor Q1, the diode D4, the resistors R6, R5, R11, RV3. The short pulses from the СБМ-20 counter come via the monostable gate multivibrator circuit (U1 chip, elements C1, C2, R10, R9, R8, R7) to the INTU input of the Arduino Uno board for detection and analysis.

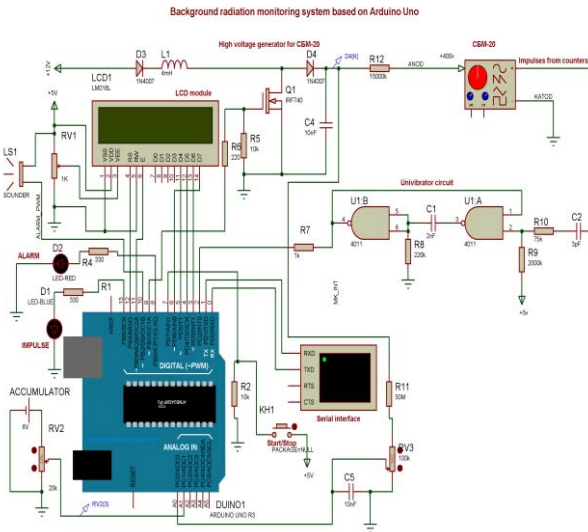


Fig. 7 Hardware of the background radiation monitoring system based on the Arduino Uno (designed in Proteus ISIS)

III. DEVELOPMENT OF THE OPERATION ALGORITHM FOR THE BACKGROUND RADIATION MONITORING SYSTEM

The operation algorithm of the system for background radiation monitoring is shown in Fig. 8. The software of the algorithm implementation has been created in Arduino IDE with the maximum use of libraries of this environment and tools for downloading the code to the board and Proteus ISIS for simulation.

IV. SIMULATION OF THE BACKGROUND RADIATION MONITORING SYSTEM USING PROTEUS ISIS

The compiled embedded software in Arduino IDE is a hex file which is flashed into the AVR ATmega328 MC of the Arduino Uno board [7]. For checking the operation ability of the developed background radiation monitoring system, its model is developed and simulated using Proteus ISIS [8]. In Fig. 9, the simulation results are illustrated.

In the radiometer mode (Fig. 9), the radiation power in $\mu\text{Sv/h}$ and number of pulses per minute are displayed on the LCD module. The blue LED "Impulse" flashes when the next pulse is detected. Simultaneously, the information is shown on the LCD and sent to PC via the serial port. The information updating occurs every minute.

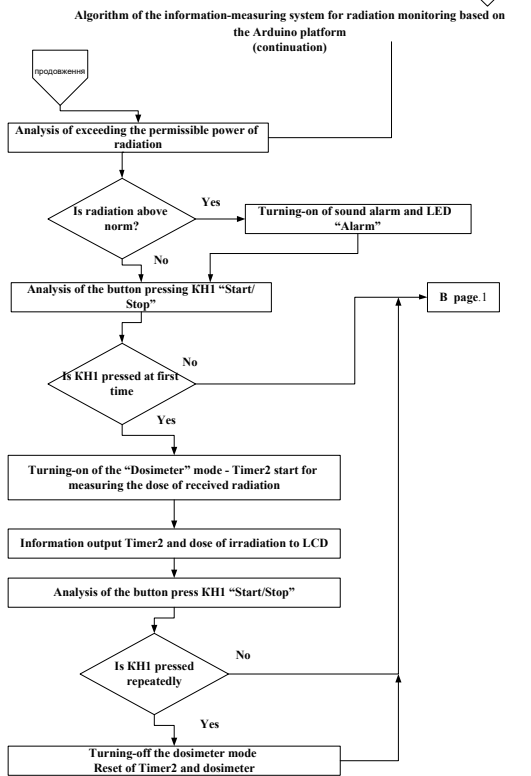
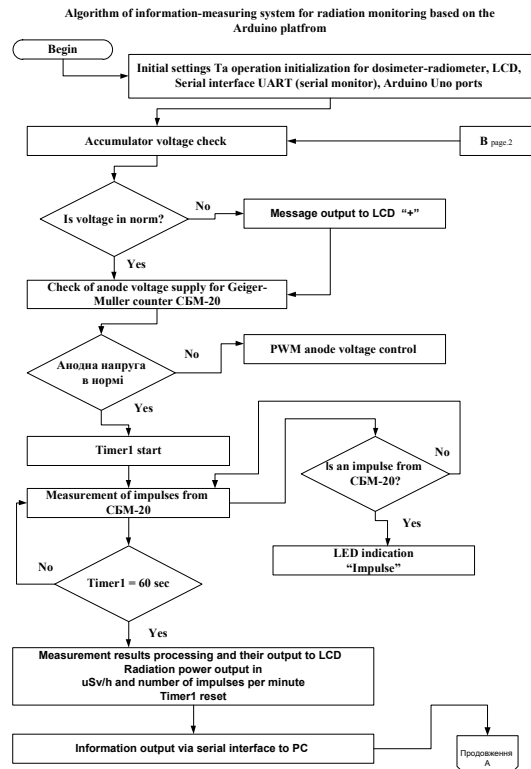


Fig. 8 Operation algorithm of the background radiation monitoring system

rapid response of the system in emergency situations: the exceeding of the permissible power of the equivalent radiation dose, controlling of the battery charge. The timely messages can protect people from excessive radiation and detect its sources and eliminate invisible dangers in proper time. The developed background radiation monitoring system can be used for both stationary and mobile measurements.

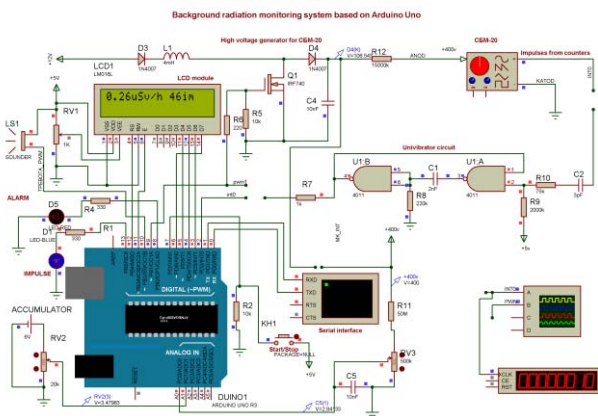


Fig. 9 Simulation of the background radiation monitoring system in Proteus ISIS – operating mode radiometer

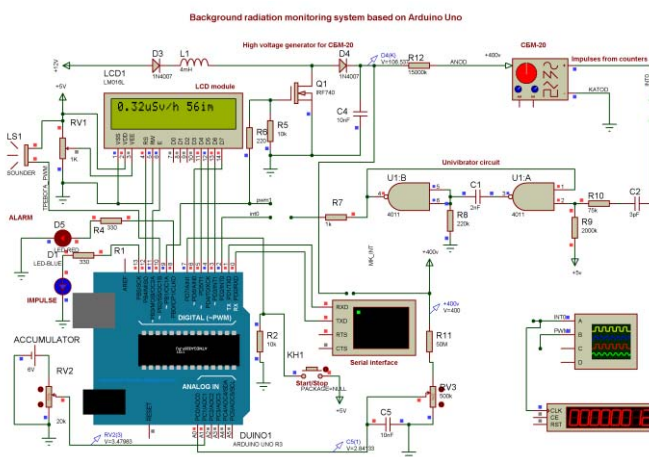


Fig. 10 Simulation of the allowable radiation dose excess in Proteus ISIS

In Fig. 10, the excess of the radiation dose is simulated. The critical radiation dose is set $0.3 \mu\text{Sv/hr}$ during programming. When this dose is exceeded, the red “Alarm” LED and alarm sound (LS1 messenger) are turned on. If the radiation is within set ranges, the “Alarm” signals are turned off. In Fig. 11, the system is simulated in the dosimeter mode. When the START/STOP button KH1 is pressed, the timer is switched on and the accumulated radiation dose is displayed during the timer operation. The maximum timer count is 24 hours then account from scratch. The timer displays minutes and hours. The accumulated radiation dose is in μSv . By pressing the KH1 button repeatedly the dosimeter mode is stopped and the LCD indication is reset.

V. CONCLUSION

Using the widespread Arduino hardware platform (Arduino Uno based on the Atmel ATmega328 microcontroller), the background radiation monitoring system has been developed. The system measures the power of the equivalent radiation and the accumulated dose during a period and outputs the received information via the serial port to PC. When the equivalent dose rate is exceeded, it sends warning signals. The high reliability of the background radiation monitoring system is provided by the

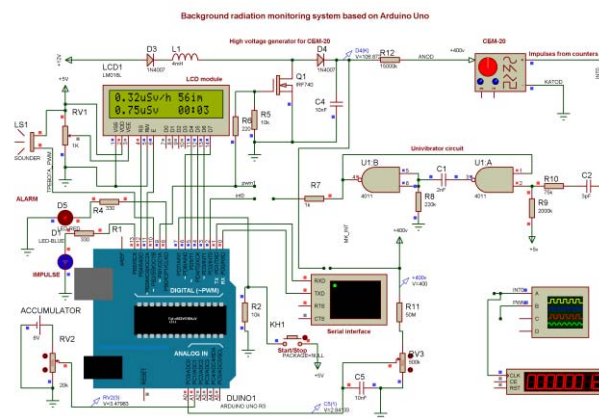


Fig. 11 Simulation of the system operation in the dosimeter mode

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