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SCIENTIFIC INSTRUMENT MAKING
AND MEASUREMENT DEVICES

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A BATTERY - OPERATED DOSIMETER BASED ON A MICROCONTROLLER CIRCUIT

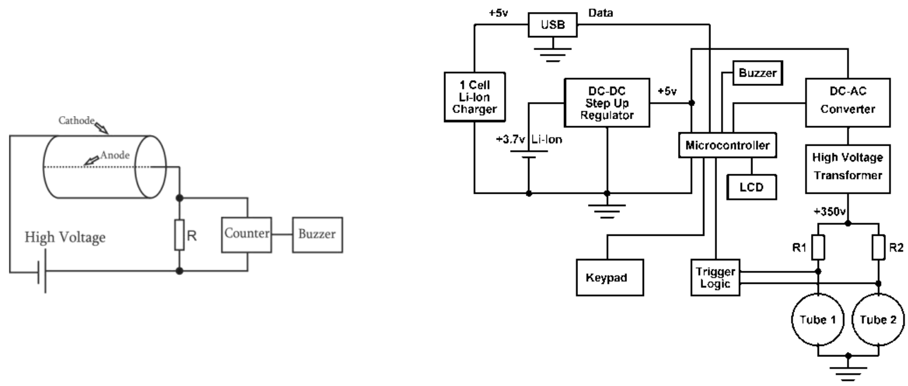
The present article describes a small-sized device, designed and initiated in the framework of the study on the particle detection method and algorithm development. The device has been tested under both a normal radiation background and against a known radioactive sample, showing successful results in both cases. When compared with other available dosimeters, this device stands out for its small size, ultra-low power consumption and the ability to be connected to different devices, enabling collection of information for later analysis. This research focuses on the development of radiation-tolerant electronics for particle detection and analysis. The device described in this article is designed to work in parallel with particle-detection electronics in order to keep the radiation exposure monitored.

Keywords: dosimeter, radiation, microcontroller, Geiger counter, detection, particle, measurement, collect, analysis, low-power consumption.

Introduction. The availability of radiation exposure measurement equipment in different fields of science and even everyday life is essential. There exist different devices that provide information on environment radiation exposure, from pocket sized dosimeter pens to desktop devices. Small portable models (such as PEN2R, PEN5mSv) present live radiation reading, and are not designed to interface with other devices such as for storing and analyzing information. More advanced devices such as GeGi allowing connectivity features are also available, but they are not portable and are quite expensive. Of course, the above mentioned devices are designed to serve different purposes, but none of them can be used in this research project as a portable dosimeter with low power consumption that can be set and controlled by a computer. After a search for such a device that meets the project needs, it became clear that a custom one needs to be designed to satisfy all the parameters of the research.

The concept of the well-known Geiger counter [1] lies in the base of the device. The classical Geiger counter consists of a tube filled with inert gas such as helium, argon or neon, in some cases a Penning mixture, and a quench gas of 5…10% of organic vapor or halogen gas to prevent multiple pulsing. Also, a buzzer or a light emitter (in some cases both)is present as a notification method for the operator. The tube is built from glass or similar material, which has two electrodes, one of which is the thin wire going across the tube (anode), and the contacts on the sides or one side of the glass (cathode). Using the high voltage transformer, a pre-adjusted fixed voltage is applied to the tube electrodes. The voltage for most of the common devices is a couple of hundred volts. When a particle passes through the tube, the gas is being ionized and a certain current passes through anode and cathode. The current causes a voltage drop, which is used to trigger certain logic to make the buzzer beep and the light to turn on. So for every particle passing through the tube, a short beeping and a short flash of light occurs for the operator.

Block diagrams of the simple Geiger counter and the one that has been designed for research purposes is shown in Fig.1.



a) Block diagram of a basic Geiger counter

b) Block diagram of the designed device

Fig.1. Basic Geiger counter (a) and the designed device (b)

The new dosimeter has been developed on the basis of traditional concepts, but with further developed technical abilities, using modern advanced technologies. The device consists of two gas tubes, instead of one, which increases the detection sensitivity. Depending on the particle angle and the direction it comes from, it can be absorbed by the body parts of the detector device or not meet the tube surface at all [2]. So, by making the detection surface larger, the possibility of detecting particles and the quantity of the detected particles in a certain given time window increases. As a power source for the circuit's operation, a standard mobile phone battery is used. It runs the device continuously for more than a week, without the need to charge it. Using a DC-DC step-up IC (MAX1674, Fig.2), the 3.7 *V* of the battery is converted into 5 *V*, which is used for the most logical elements of the circuits, including the microcontroller.

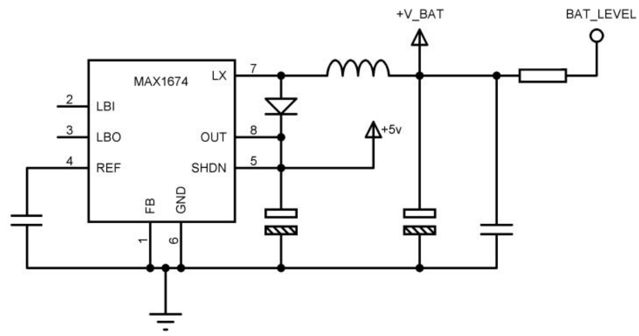


Fig.2. DC-DC Step-Up Converter

A mini-USB connector is mounted on the PCB for charging the device. The power lines of the USB port (+V_USB and GND) are connected to the on-board IC called LTC4054 (Fig. 3), which regulates the charging current. If the device is connected to another device which only uses the power lines of the USB port, the charging process begins. If it is connected to a computer in which data lines (D+ and D-) of the USB port are also present, the dosimeter enters into communication mode, which enables the user to set certain settings and start automatic measurements, logging the results in the computer. Charging also takes place in this mode.

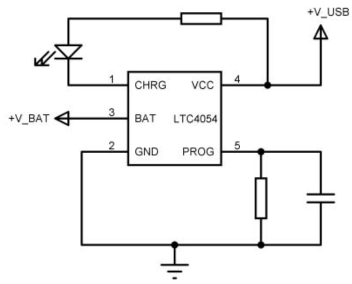


Fig.3. Charging circuit

The fragment of the circuit presented in Fig. 4 is responsible for generating around 300 *V* for the tubes and the trigger mechanism. The wire called AC is connected to the microcontroller to enable the high voltage transformer. Whenever logic 1 (5 *V*) is present on the base of the NPN transistor, pulses with a frequency of around 200 *kHz* occur on the collector, starting high voltage generation. This type of design enables the device to enter the sleep mode, which increases the battery life by 70%. The second bipolar transistor, the base of which is connected to the tubes (J7 and J8), drives the NAND gates [3] that change the state of the PULSE_OUT wire at each event [4].

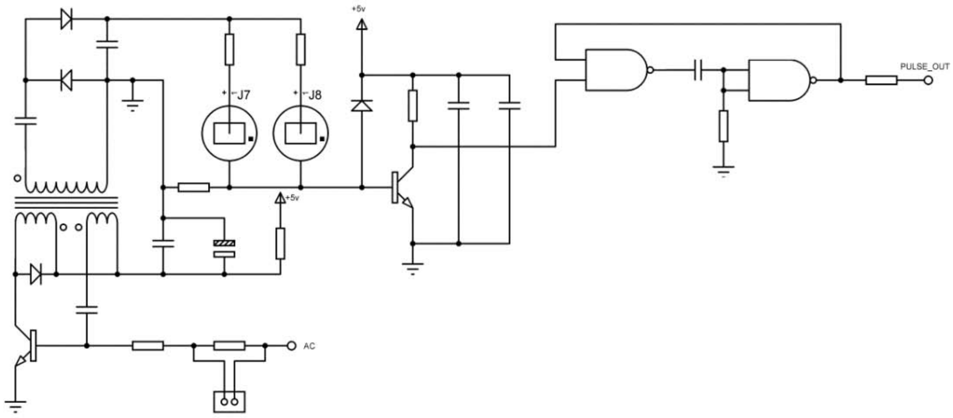


Fig. 4. High voltage transformer and detector logic

The voltage changes on the tubes have been measured with an oscilloscope and recorded (Fig. 5) during the triggering process. The red line shows the threshold voltage and voltage peaks that cross the threshold border represent particle events. In this dosimeter circuit the threshold voltage is around 300 *mV*. In the following picture one horizontal grid represents 1 *s*, and the vertical grid represents 100 *mV*. The average pulse width after it has crossed the threshold has been calculated to be around 25 *ms*.

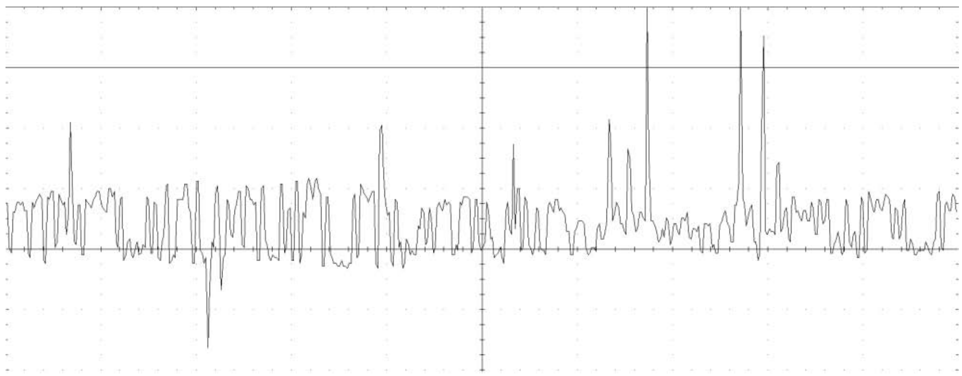


Fig. 5. Tube noise and threshold voltage

Fig. 6 was recorded when the device had been in operation in a higher background radiation.

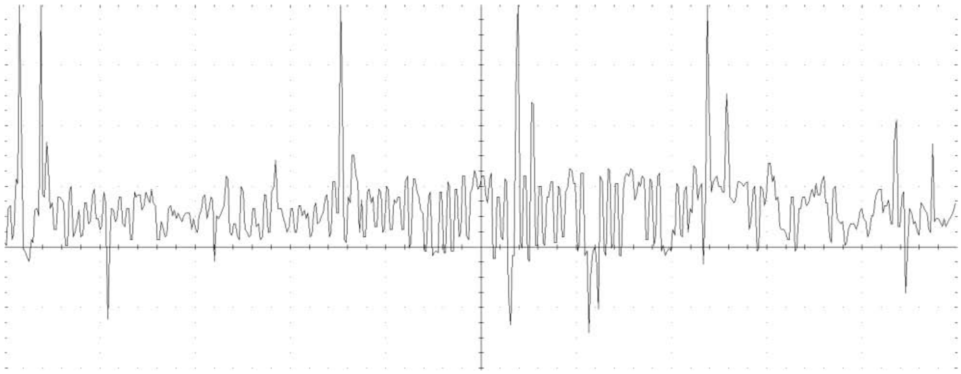


Fig.6. Higher radiation background

The full device parameters are presented in the table below:

Table

Device parameters

Operating voltage	3.7 *V*
Maximum in-circuit voltage	350 *V*
Maximum power consumption	50 *m*
Power consumption during the sleep mode	1 *mA*
Minimum operating temperature	-20º *C*
Maximum operating temperature	+100º *C*
Maximum recommended charge cycles	300 cycles
Maximum life for gas filled tubes	5 years

The minimum operating temperature is stated as -20º*C*, since it is the lowest limit for the LCD present on the device. If the device is operated without an LCD, the minimum operating voltage drops to -35º*C*.

The Li-Ion battery capacity drops from around 89...95% to about 73...80% after approximately 230 charging cycles. This means that if the device is used continuously, it can last for at least 4 years without the need to replace the battery.

Conclusion. The development of the radiation exposure meter presented in this article significantly contributed to the research of particle detection and method development. With the help of this custom-made programmable device, it is possible to explore different critical parameters of electronics components used in the design. The parameters change when operating in a high radiation background. Taking those changes into account, it is possible to design detection electronics more reliably. The analyzed device has been tested and certified in the National Institute of Metrology, and received a certificate of parameters.

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ՄԱՐՏԿՈՑԻՑ ՍՆՎՈՂ ՃԱՌԱԳԱՅԹՄԱՆ ՄԱԿԱՐԴԱԿԻ ՉԱՓԻՉ ՍԱՐՔ՝ ՄԻԿՐՈԿՈՆՏՐՈԼԵՐԱՅԻՆ ՇՂԹԱՅԻ ՀԻՄՔՈՎ

Նկարագրվում է ճառագայթման մակարդակի չափման համար նախատեսված սարք, որը մշակվել, կառուցվել և փորձարկվել է մասնիկների գրանցման մեթոդի և ալգորիթմի մշակման աշխատանքների շրջանակում: Գոյություն ունեցող նմանատիպ սարքավորումների համեմատ՝ տվյալ սարքն առանձնանում է իր փոքր չափերով, հոսանքի նվազագույն ծախսով և այլ սարքերի միացվելու կարողությամբ: Սա հնարավորություն է տալիս տեղեկություններ ստանալ մասնիկների գրանցման մասին՝ հետագա ուսումնասիրությունների իրականացման համար: Քանի որ հետազոտության հիմնական խնդիրն ուղղված է մասնիկների գրանցման մեթոդի և ալգորիթմի մշակմանը, ուստի առաջարկվող սարքը, աշխատելով մյուս համապատասխան սարքերի հետ, հնարավորություն է ստեղծում կատարելագործել փորձարկվող սարքերի էլեկտրական շղթաները:

Առանցքային բառեր. ճառագայթում, միկրոկոնտրոլեր, Գայգերի հաշվիչ, գրանցում, մասնիկ, չափում, կուտակում, ուսումնասիրություն, հոսանքի փոքր ծախս:

В.В. ГАБРИЕЛЯН, В.О. АКОПЯН

ДОЗИМЕТР НА ОСНОВЕ МИКРОКОНТРОЛЛЕРНОЙ СХЕМЫ, РАБОТАЮЩИЙ НА БАТАРЕЙКЕ

В рамках работы по разработке метода и алгоритма детектирования частиц создан прибор для измерения радиации. Проведены испытания прибора в разных радиационных фонах, показаны удовлетворительные результаты. По сравнению с другими аналогичными приборами, данное устройство отличается размером, низким потреблением электроэнергии и способностью подключаться к другим устройствам, которые позволяют накопить полученные данные для дальнейших анализов. Поскольку основное исследование направлено на разработку электронных устройств, которые должны работать в средах с высоким радиационным фоном, описываемый прибор рассчитан на параллельную работу с этими приборами.

***Ключевые слова*:** дозиметр, радиация, микроконтроллер, счетчик Гейгера, детектирование, частица, измерение, накопление, анализ, низкая электропотребность.