Current Applied Science and Technology Vol. 23 No. 5 (September-October 2023)

Research article

Radiation Measurement with Data Acquisition Using LabVIEW

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Received: 18 May 2022, Revised: 7 July 2022, Accepted: 24 January 2023

DOI: 10.55003/cast.2023.05.23.004

Abstract

Keywords

GM counter;

high voltage generation

radiation detection;

data acquisition

Radiation monitoring and measurement are important for radiation safety. Such monitoring and measurement must be carried out in order to investigate workplace conditions and individual exposures, to ensure that radiological conditions in the workplace are acceptable, safe, and satisfactory, and to keep records of radiation monitoring over a long period of time in accordance with regulations or as good practice. However, radiation monitoring instruments and system are expensive. A cost-effective radiation monitoring system using Geiger Muller (GM) radiation detector was developed. A high voltage generation circuit and data acquisition were implemented using LabVIEW software. The cost-effective radiation monitoring system is easy to use, and it can detect radiation, analyzed and record the data in a personal computer. This newly developed system is simple and can provide the radiation dose data for further analysis. An experiment was conducted to compare and calibrate the collected data at the Secondary Standard Dosimetry Laboratory (SSDL). The result shows that the new developed GM detector provides good correlation between counts per minute (cpm) and dosage units, which is good characteristic of a radiation counting system.

1. Introduction

GM tubes are filled with an inert gas such as helium, neon, or argon mixed with a halogen quenching gas. When ionized particles hit the tube area, two electrodes transmit the conductive number of interactions that occur as counts. To develop a cost-effective radiation measurement system, data acquisition (DAQ) and LabVIEW were used to record dose rate data and store it in a computer. The GM counter needs a high-voltage generating circuit. A personal computer is used to store, process

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and monitor the recorded data. Quraishi *et al*. [1] designed a high voltage generation unit for the GM counter with a basic DC-DC converter along with data acquisition and monitoring using LabVIEW. Gandhiraj and Jayapandian [2] developed an embedded read-out for the GM counter using the Programmable System on Chip (PSoC), for which the counting function is done by an internal module on a specific platform. However, it had a number of limitations and required improvements. A schematic circuit diagram for a HV generating unit was developed, and the timer chip was operated in a stable multivibrator mode to generate pulses. The output was stepped up via a transformer and voltage multiplier [3]. For radiation detection and measurement with an ionization detector, data acquisition based on LabVIEW was utilized. The ionization chamber detector produced ionizing current as a function of the radiation dosimetry. The more the ionizing current was produced in a particular amount of time, the higher was the radiation dose. An automatic system with low or reduced human interaction was introduced for radiation measurement systems using various control devices and data acquisition systems [4]. A low-cost GM detector for gamma-ray measurements using distinctive programming strategies and instrument solutions for radiation measurement was implemented [2]. A new design and adjustment with an advanced GM detector and LabVIEW graphical program were developed to improve the function and running of a sophisticated radiation measurement system [5]. The newly developed system in this study adds more value to the previously system mentioned in Quraishi *et al*. [1] and Gandhiraj and Jayapandian [2] in terms of simplicity of the circuit, more variations to the measuring unit display, and the capability of the system to store the measured data for further analysis. Radiation safety was a prime concern in this experiment, and the three basic principles of radiation protection: justification, optimization, and dose limitation were followed.

2. Materials and Methods

Radioactive emissions, such as beta particles and gamma rays, are detected by Geiger Muller (GM) counters. The GM counter is comprised of a tube filled with an inert gas that becomes electrically conductive after being hit by a particle. A detector is used together with high voltage generation unit and data acquisition unit as shown in Figure 1. The GM counter is biased by a high DC voltage supplied to the two electrodes. The operational voltage range of the LND712 detector is 450-650 volts [6]. LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) is a dataflow programming language that can be used to design measurement and control instruments by use of graphical icons and connecting wires that look like flowcharts. For analysis and data visualization, LabVIEW also has a robust connection with physical devices. The Arduino Uno SMD R3, a microcontroller board, includes 14 digital input/output pins (six of which can be used as PWM outputs), six analog inputs, and a ceramic resonator with a frequency of 16 MHz (CSTCE16M0V53-R0). By connecting it to a computer, it can provide support for the microcontroller. Arduino Uno SMD R3 and Arduino IDE software were used in this study to connect with LabVIEW program, and the radiation measuring value is displayed in counter per seconds (cps) and μSv/h.

The high voltage generation unit is essentially a DC-DC converter that has been stepped up to 600 VDC from a 9VDC source. The high voltage is applied to the GM detector. The pulse rate output is generated by the GM detector, and is triggered by a monostable circuit. The equipment consists of timer IC (LM555), transformer, diode (IN4007, IN4148), capacitors (0.01-0.1 μF), resistors, and a 9 V battery. Figure 2 shows a schematic diagram for the GM counter circuit.

To generate a switching pulse, the LM555 timer (U1) is configured as a stable multivibrator mode. The timer's output pulse is generated with a frequency of 102 Hz and a duty cycle of 0.48. The voltage output can be adjusted by changing the duty cycle and frequency for high voltage generation. A transformer is used to step up the switched output. The transformer's output is stepped up further by passing it through a voltage multiplier circuit. The voltage multiplier's final output is 600 VDC. The timer LM555 (U2) is configured in a monostable mode, as shown in Figure 2. The trigger pulse from GM detector triggers the monostable, resulting in the generation of radiation pulse signal. The output pulse was counted via a microcontroller input port, and LabVIEW was used to interface with the computer and acquire the radiation count data from the GM counter. Figure 3 shows the GM detection signal and pulse rate waveform of the circuits of the developed GM counting system as obtained from an oscilloscope. At the standby condition, the current used from the battery is 40 mA. The prototype of the GM counter with interfacing system is shown in Figure 4. The developed system was applied as a radiation area monitoring system.

LabVIEW and the Arduino Uno SMD R3 are used for data acquisition, computer interfacing, data storage, and radiation dose recording. Data acquisition records physical conditions and converts them into digital numerical data that the computer can manipulate.

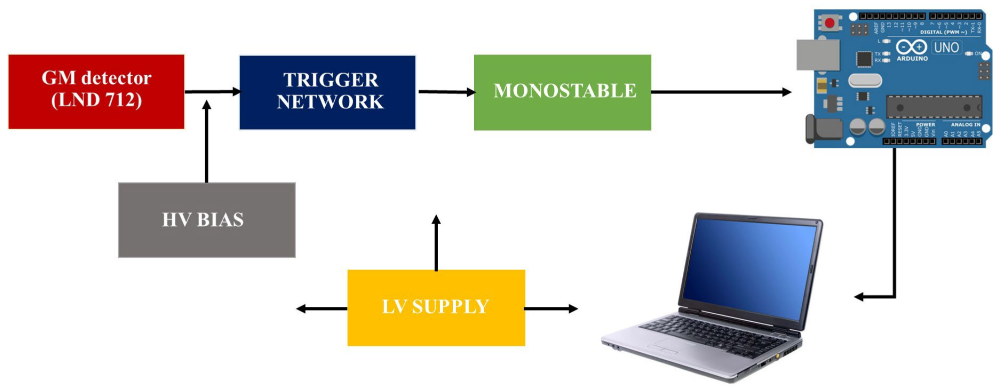


Figure 1. Block diagram for GM counter circuit and data acquisition unit

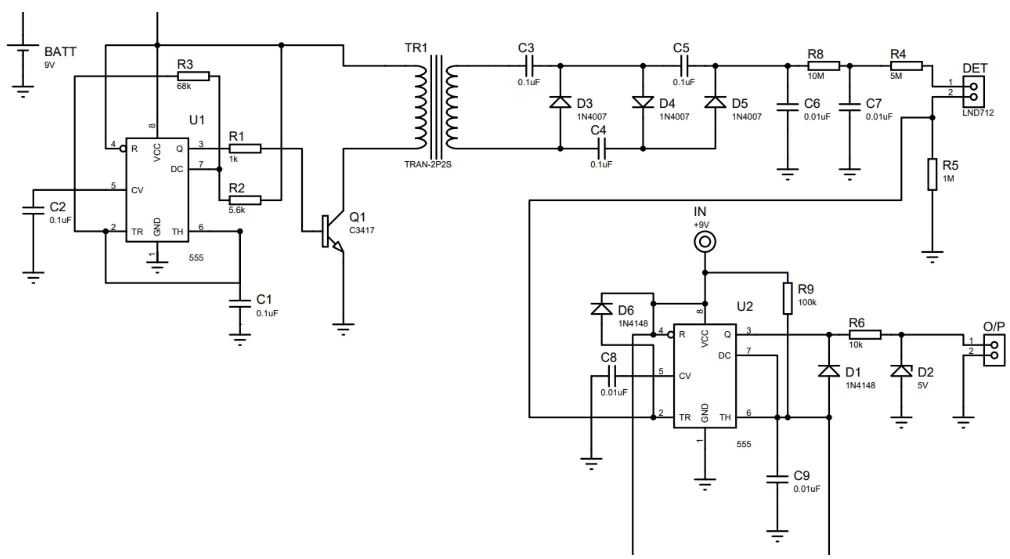
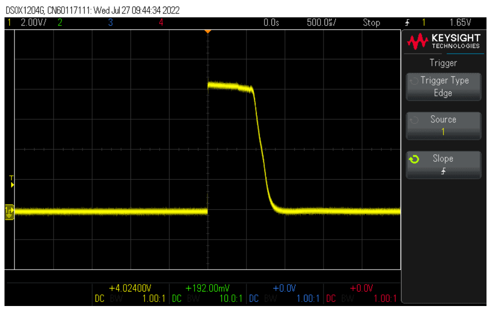
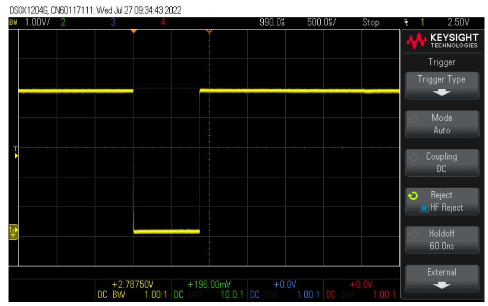


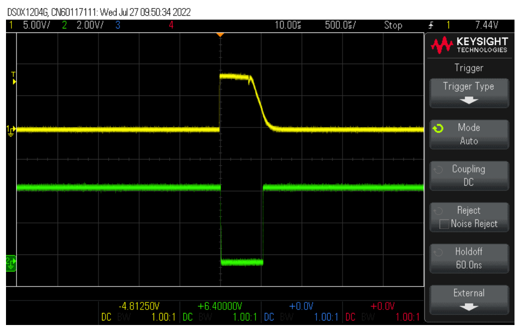
Figure 2. Schematic diagram for GM counter circuit



(a) Input signal (from a detector)



(b) Output signals (for counting)



(c) Comparison between input and output signals

Figure 3. Input-Output signals of the developed system

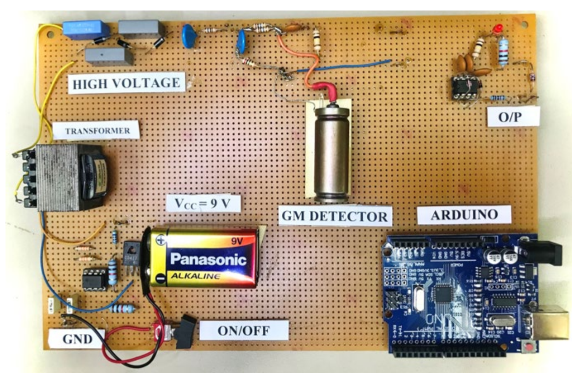


Figure 4. Prototype of radiation area monitoring system.

3. Results and Discussion

When radiation is detected, the output signal from the GM counter is delivered to the Arduino, which must be programmed in advance to collect the high-count rate signals received by the counter, to count, and to provide a measurement result that can be used to determine the level of radiation exposure rate (mR/h) and dose rate (μSv/h) present in the measurement location. A virtual instrument is created in LabVIEW to ensure proper radiation collection, storage, and monitoring of the count rate from the GM detector. Figure 5 shows the LabVIEW block diagram of a virtual instrument that detects and monitors radiation data. Figure 6 shows the real time radiation dose rate profile on the instrument's front panel. The x axis represents time, and the y axis represents dose rate in µSv per hour.

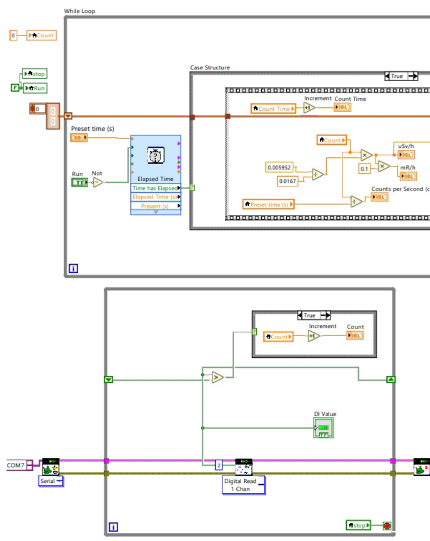


Figure 5. Block diagram of LabVIEW for data acquisition of radiation area monitoring

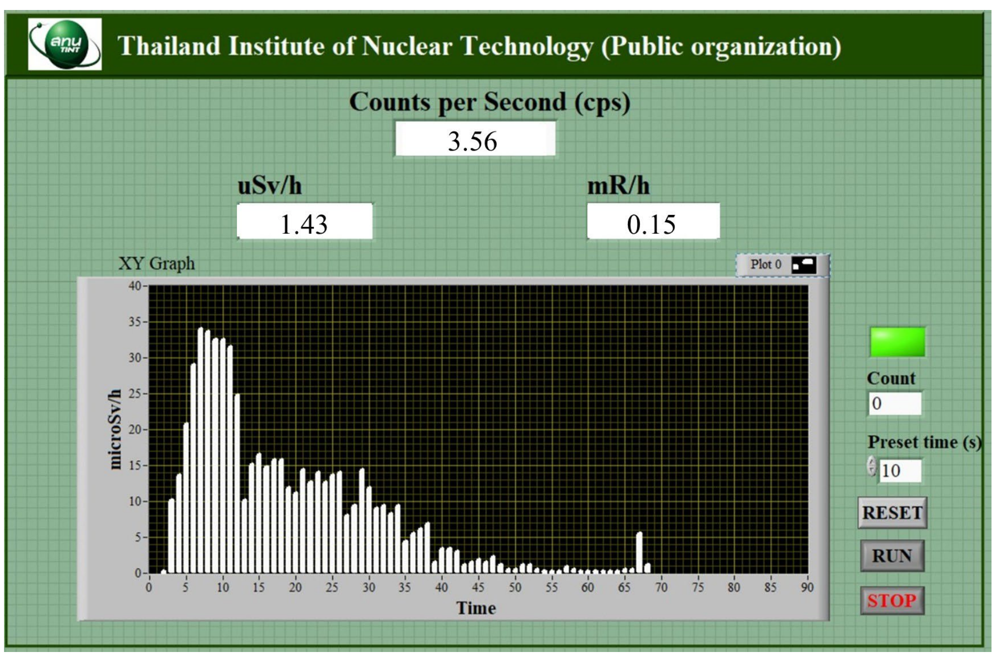


Figure 6. Front panel of LabVIEW for real time radiation dose rate profile display

The developed radiation area monitoring system was calibrated at the Secondary Standard Dosimetry Laboratory (SSDL), Office of Atoms for Peace, Thailand, in order to determine the credibility of the new system. Table 1 shows the calibration results using Co-60 as the standard source at different dose levels (11.5, 33.6, 136 µSv/h). It shows that the developed radiation area monitoring system can detect dose level correctly with correction factor (C.F.) approximately 1.3-1.5.

Table 1. Dose rate calibration results of the developed radiation area monitoring system

Distance (m)	Substance	Shield	STD.	Range	$Mean_{First}$	$Mean_{Final}$	%Uncertainty	Correction Factor
1	Co-60	A	33.6		26.41	26.41	8	
Read first	24.88	24.46	28.09	27.56	27.08	%S.D.	%Uc	1.27
Read final	24.88	24.46	28.09	27.56	27.08	6.20	3.74	
1	Co-60	AB	11.50		9.11	9.11	13.00	
Read first	7.98	8.63	11.01	9.23	8.69	%S.D.	%Uc	1.26
Read final	7.98	8.63	11.01	9.23	8.69	12.66	6.19	
1	Co-60	no	136.00		91.86	91.86	6.00	
Read first	92.43	93.27	91.54	91.78	90.29	%S.D.	%Uc	1.48
Read final	92.43	93.27	91.54	91.78	90.29	1.20	2.57	

* %Uc is %Uncertainty

The radiation monitoring data can be utilized to create a daily radiation database for the environment of the working area. It can be recorded as an environmental radiation history and presented as daily, monthly, and yearly monitoring data. If LED and alarm block are connected to compare with the dose rate alarm level setting in LabVIEW program, the system can be used as radiation warning device. The monitoring system can also detect the presence of radioactive material, but it cannot identify the types of radiation or energy levels. In addition, the developed system can measure high dose rates in the linear range up to100 µSv/h [6].

4. Conclusions

A simpler, cost-effective environmental monitoring radiation detector was developed. The cost of the newly developed system is lower than the price of existing commercial radiation area monitoring systems available in the market. The system can also be extended by modifying it with additional instruments and programs for future work. The features of warnings or alarms for high radiation levels in the area can be added into the developed system in order to ensure the safety of the workers during the performance of their work. The main aim of this study was to design a novel system for radiation detection using locally inexpensive devices. However, the design is of limited use in the case of high radiation fields (due to the choice of detector selected in this study), which can cause high deadtimes. This problem can be solved by using a scintillation detector to give better results for high radiation count rates. Moreover, it can be modified to improve radioactive source detection in security systems. Internet and wireless controls can be embedded into the design for wireless communication using LabVIEW. The design can also be used for education in radiation measurement and detection.

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