IMPLEMENTATION OF RADIATION MONITORING SYSTEM

*Saja S. Hasan¹

Abbas H. Miry¹

Tariq M. Salman¹

1) Electrical Engineering Department, College of Engineering, Mustansiriyah University, Baghdad, Iraq

Abstract: Multiple atomic accidents urge for the development of radiation monitoring systems which has the capability to measure and display radiation level in the contaminated zones. This paper presents the design and implementation of such systems using Geiger Müller (GM) counter nuclear kit which can be used in any radiation contaminated area. GM counter transmits readings of radiation at fixed intervals to the Arduino microcontroller in real-time. This proposed system utilizes liquid crystal display (LCD) as an interface for displaying the information. This system is easy to use and modular. The experimental data and the obtained results shows that this proposed radiation monitoring system is feasible and efficient.

Keywords: *Geiger Müller, Count per Minute, Radiation, Arduino, Alpha, Beta, Gamma.*

1. Introduction

Nuclear research is increasing all over the world. People are worried concerning their wellbeing and other related issues such as diseases and tumors [1]. The implementation of radiation monitoring systems has gained a lot of attention due to Fukushima nuclear calamity triggered in 2011[2]. Using of such systems may help security forces as well as the authorities in determining radiation's levels of contaminated zones.

Monitoring systems have been utilized for the environmental monitoring in agricultural, indoor

living, habitat, climate, greenhouses, forest, and animal tracking [3-6]. Major incidents may cause the dispersion of very high levels of radioactive pollutants within the plant and this would consequently threaten human in addition to the biological life [7]. Therefore, it is important to have a radiation monitoring system used in the contaminated area and it should be able to provide real-time measurements of radiation's level. The International Atomic Energy Agency (IAEA) in its nuclear safety report says that there is more and more which could be done to strengthen the management of radiation devices through using technology [8]. Although multiple sensors had investigated such as the glass scintillators [9] and the silicon dosimeter [10] but these sensors are unsuitable since its ability in detecting is very limited to gamma rays and neutrons only. In this paper, GM tube had utilized because of its capability in detecting a very wide range of radiation types [11]. The LCD allows the users for displaying the radiation data that detected by GM tube.

2. Related Works:

Ghughe, et al. discussed a radiation detector of thin-end window tube. Radiation detectors are used in multiple industrial applications in addition to its use in research surveys to detect

*Corresponding Author: Eng.sajasattar@yahoo.com

emissions of radioactive pollutants. This paper describes the implementation of a radiation monitoring system where the large sized and complicated detectors are replaced by a small size, uncomplicated, and compact GM tube detector, for the preparation of a small sized, easy to use, mobile, and inexpensive radiation detection and monitoring device based on a low cost microcontroller [12]. Newaz, et al. developed a low cost detector that has the ability for detecting radiation only. The GM tube, is a very useful as well as inexpensive way for detecting radiation. GM tube can only detect the presence as well as the radiation's intensity [13]. Singseeta, et al. designed and constructed a portable survey meter that is used to measure radiation dose. The system includes four major parts which are low voltage power supply, radiation measurement, radiation detection, as well as data display part using android phones. The results show that maximum integral counts are 104 count per second [14]. Sivasailanathan, et al. gave the ideas concerning beta rays counting system using GM tube for detecting beta contamination presents in placket samples and filter paper samples. The system counts the samples at different distances from the position of detector to the position of sample. Efficiency of the system is provided by the manufacturer which is tested and calibrated using a standard source [15]. A summary of the mentioned related works is shown in table 1.

Table 1. Summary of Related works and Review Papers

Author	Technique	Year	shortcoming
Ghuge, et al.	GM With PIC16F877	2010	Less Accuracy
Sivasailanath, et al.	GM Beta counting system	2016	measures Beta rays Only
Singseeta, et al.	GM tube with ESP8266	2017	Circuit's complexity
Newaz, et al.	GM counter with Arduino	2018	Need internet connection to display data

3. Background Theory

3.1. Radiation:

There are several types of radiation like alpha (α), beta (β), gamma (γ), Neutrons, and x-ray radiation. Also, there are many portable radiation devices and monitors which include GM tube. It is a simple, two-terminals; anode and cathode, gas-filled detector which generates a pulse at any time when the radiation photons or particles impinge on the sensitive tube [16].

3.2. Geiger Müller Counter:

It was appeared in 1928, as a radiation finder that used today broadly. One of radiation monitoring popular devices is GM counter which is generally called Geiger counter. It is a type of radiation detectors that based on ionization's phenomenon [17]. GM counter is a handy device that used for counting alpha, beta, and gamma rays, with different degrees of efficiency. GM tube's sensitivity is such that any particle capable of ionizing a single atom of the tube's filling gas will cause electrons and ions avalanche in the tube [12]. It has basic guideline of activity, minimal effort. It is an ionization finder and it utilizes the Townsend slide for creating an effectively electronic heartbeat from meager and solitary ionizing occasion because of the radiation molecules [1].

4. Implementation of The Designed System

4.1. Proposed System Architecture:

In this paper we developed an Arduino-Based-Radiation-Monitoring-System that could be used to monitor the levels of radiation. It includes a low cost and a small size radiation detector and Arduino mega 2560 microcontroller. It displays the level of radiation in cpm units on 20X4 LCD to make the persons monitor radiation around them very easily. The designed system consists of three main components which are Arduino mega 2560 microcontroller, Geiger Counters Kit Geiger

Counter Module Müller Tube GM Tube Nuclear Radiation Detector with Sound and Light Alarm for collecting data. The detector was connected to Arduino and when the Arduino powers-on, the detector will start collecting data at real-time. The obtained data will be then transferred from GM detector through Arduino to the computer software via the COM port. Users can display, document and also plot the collected data in real-time on Arduino software. This data consists of radiation's level measurements where high values means high level of radiation and low values means low level of level of radiation. The system is of small size and it might be utilized as a hand-held system for radiation's measurement. The block-diagram which summarizes the designed system is appeared in Figure 1.

Figure 1. A block Diagram explains the Proposed System

The purpose of using Arduino is its high accessibility and cheapness. Detector used in this system is so handy and replaceable. Using these components returns to the fact that all of them are user-friendly and very easy to understand by people. When Arduino mega 2560 is powered on using USB power supply or 5volt batteries, the system will become functional and GM detector will produce its readings. Arduino Mega 2560 microcontroller board is in the heart of this system. Figure 2 describes the implementation of our proposed system.

Figure 2. Implementation of the proposed system

4.2. Software of the Proposed System:

We developed a software code in order to collect data from the designed system and display it in real-time. Software of the proposed Arduino-based-radiation-monitoring system includes-coding of Arduino Mega 2560 microcontroller board-in the Integrated Development Environment of Arduino (ARDUINO-IDE-1.8.13 software). Serial connection between computer, Geiger Counter Kit, and Arduino was formed using Arduino's serial library [18].

4.3. Hardware Components of the Proposed-System:

Hardware components of the system comprises of Geiger Counter Kit, 20X4 LCD, Arduino Mega 2560 microcontroller board in addition to the jumper wires. The developed system measures level of radiation and it collects data in real-time. This obtained data can be displayed on the computer-screen using Arduino software or on the LCD screen.

4.3.1. Assembled Geiger Müller counter tube nuclear radiation detector kit with sound and light alarms:

It needs 5V power supply, or one can use 1.5Vx3 battery; It is used for the detection of gamma rays and beta rays. It has a light and sound alarms. It has an output interface, through which the kit can be connected to microcontroller board and then display its readings on the LCD. It is Arduino compatible and it supports multiple Geiger tubes such as M4011, SBM20, STS-5, as well as J305 that we used in the design of this system. It supports the computer data acquisition, Matlab analysis and processing. Figure 3 shows the assembled GM nuclear counter kit.

Figure 3. Assembled GM nuclear counter kit.

4.3.2. Arduino microcontroller:

It is a small board and flexible programmable platform that developed for designers, artists, and makers of things. It is an open source device with compact design and small size. The core language Arduino C is a subset version of the standard C language and the underlying compiler of Arduino C is actually the open source C++ language compiler [16].

4.3.3. Liquid Crystal Display (LCD):

This is a very popular 20x4 LCD which has a blue back light display. It's easy to interface with most types of microcontrollers. Its popularity ensures that no matter which microcontroller platform is used with it. The LCD screen is an electronic display module that has multiple applications. It is very basic and commonly use in different circuits and devices. A 20x4 LCD means that it has the ability to display 20 characters in each line of the 4 lines that it has.

4.4. Implementation of the Proposed System:

The major chip of the system is Arduino Mega 2560 that is a modern-microcontroller-board based on ATmega328P. It could be linked directly to computers via USB cables. Geiger Counter Kit is connected to Arduino board using jumper wires. The average of normal readings of the detector is 50 cpm which is the background of the GM tube. The pins of the Geiger Counters Kit are connected to the pins of the Arduino-board such that +5V pin on the detector was connected to Vcc pin (5V) at Arduino-board and ground pin (GND) on the detector unit was connected to ground pin (GND) at the Arduino board correspondingly at Arduino-board. The Vin pin of the detector is conned to D2 pin on Arduino board. The 20X4 LCD is connected to Arduino for displaying readings of GM detector when the system is working. Several measurements is done using GM detector using Cs-137 radioactive source and Sr-90 radioactive source at different distances and it may be considered as a perfect detector which could be used for radiation monitoring systems. When we connect the detector to Arduino mega, it begin to detect the Gamma and Beta rays, and according to this we will soon get radiation's level in count per minute unit (cpm). Figure 4 shows a flowchart of the system.

Figure 4. Flowchart of the system.

This System is extremely simple and this monitoring-circuit appears to be perfect for utilizing at hospitals, radiation contaminated sites or even factories that may use any radioactive materials. Figure 5 shows the proposed system and all its components.

Figure 5. The proposed system

5. Results and Discussion

The design of Arduino-based radiation's level-monitoring system includes software, hardware parts, and data collection from GM detector through Arduino's code. To get a real-time data for radiation level in cpm displayed on LCD, measurements had been taken using this designed system in different contaminated sites and we had used multiple and different distances between the system and the radioactive sources; 0 cm (touch), 5 cm; for checking the system. Radiation's level differs from one radioactive source to another and from one distance to another. The system seems to work in a perfect manner as a data recording device and it's able to keep monitoring radiation's levels in the surrounded environment. When system is powered-on GM detector will turn on and generate data and send it immediately to the system's com-port to make the end user watches data on the system's computer screen in addition to the LCD. The

readings in cpm that recorded in the middle of the detector with a zero distance using Cs-137 is shown in table 2 and figure 6 shows the system and Cs-137 point source whereas output seen from system's computer screen is shown in figure 7.

Table 2. Readings in cpm measured in the middle of GM using Cs-137

No.	Value in cpm	No.	Value in cpm
1	9256	11	9716
2	9364	12	9508
3	9236	13	8984
4	9124	14	9728
5	9460	15	9420
6	9544	16	9360
7	9440	17	9520
8	9325	18	9252
9	9321	19	9232
10	9332	20	9484

Figure 6. Cs-137 at middle of GM detector with zero distance between them

Figure 7. Serial output seen from system's computer screen when Cs-137 at middle of GM with zero distance between them

Figure 8 shows the readings of radiation appear on the LCD.

Figure 8. Radiation measurement on LCD

The readings in cpm that recorded in the middle of the detector with a 5 cm distance between Cs-137 point source and GM detector is shown in table 3 and figure 9 shows the system and Cs-137 point source at this distance whereas output seen from system's computer screen at the same distance is shown in figure 10.

Table 3. Readings in cpm measured in the middle of GM using Cs-137 at a distance of 5cm between them

No.	Value in cpm	No.	Value in cpm
1	736	11	704
2	652	12	764
3	740	13	756
4	796	14	776
5	760	15	716
6	732	16	876

7	740	17	724
8	728	18	756
9	696	19	772
10	660	20	696

Figure 9. Cs-137 source at a distance of 5 cm from the middle of GM detector

Figure 10. Serial output seen from a computer screen when Cs-137 source at a distance of 5 cm from the middle of GM detector

The readings in cpm that recorded in the middle of the detector with a zero distance using Sr-90 is shown in table 4 and figure 11 shows the system and Sr-90 point source whereas output seen from system's computer screen is shown in figure 12.

Table 4. Readings in cpm measured at middle of GM using Sr-90

No.	Value in cpm	No.	Value in cpm
1	37884	11	37244

2	36848	12	36912
3	37940	13	37472
4	37828	14	37180
5	37244	15	38056
6	37256	16	37044
7	37812	17	37452
8	36624	18	37476
9	37116	19	37608
10	37272	20	37672

Figure 11. Sr-90 at middle of GM detector with zero distance between them

Figure 12. Serial output seen from system's computer screen when Sr-90 at middle of GM with zero distance between them

The readings in cpm that recorded in the middle of the detector with a 5 cm distance between Sr-90 and GM detector is shown in table 5 and figure 13 shows the system and Sr-90 point source at a 5 cm distance between them whereas

output seen from system's computer screen at the same distance is shown in figure 14.

Table 5. Readings in cpm measured at middle of GM using Sr-90 at a distance of 5 cm

No.	Value in cpm	No.	Value in cpm
1	3116	11	3254
2	3064	12	2589
3	3264	13	2993
4	3180	14	2789
5	2932	15	3245
6	3164	16	2950
7	3278	17	2990
8	3642	18	3120
9	3057	19	3650
10	3117	20	2856

Figure 13. Sr - 90 source at a distance of 5 cm from the middle of GM detector

Figure 14. Serial output seen from a computer screen when Sr-90 source at a distance of 5 cm from the middle of GM detector

6. Conclusion

Arduino-based radiation monitoring system had been designed and implemented with low cost. It's modular, portable, easy to use, effective, user-friendly. Its functions are concerned comparable to existing radiation detection devices that have high cost. We can obtain real-time data for level of radiation. System uses Arduino mega to control access to GM detector kit. The system-is great for measuring the radiation's level in outdoor and at indoor for daily and efficiently monitoring. It's useful for measuring radiation's levels in areas with radioactive contamination or places that deals with radioactive materials such as hospitals, factories etc. This system with its high sensitivity may be used for chemical industries or defense agencies for detecting them from radiation attacks as well as it may be used for more researches on the field of radiation monitoring since it can store the collected data which helps in making decisions in addition to mathematical models. The collected data will be immediately displayed on the LCD. In the future, such a system could be put at different places and sites for monitoring radiation.

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Conflict of interest

The authors confirm that the publication of this research causes no conflict of interest.

Abbreviations

LCD	Liquid Crystal Display
Cpm	count per minute
GM	Geiger Müller

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