Design and Development of Microcontroller Based Portable Digital Surface Contamination Monitor

M. A. A. Mashud, M. R. A. Bhuiyan, M. A. Masud, Md. Serajul Islam

Abstract—The microcontroller based portable digital surface contamination monitor serves as a guide for evaluating workplace hazards caused by surface contamination. It also assists physicians in determining whether special protective measures for workers are necessary in contaminated areas. The system's design concept is useful for measuring surface contamination. In this design, a Geiger Muller detector with an ultra-thin mica window detects β radiation as well as γ radiation. A microcontroller PIC16F676 controls system function. A C language program was developed to control the function of the microcontroller, using PCWH Compiler. The reading is displayed in a seven segment display. It is user-friendly for specialists and non-specialists alike, and the device is easily decontaminated. The device's many advantages include its smaller size, on-device display, lower cost and improved portability.

Keywords—β-γ radiation, PIC16F676 microcontroller, PCWH Compiler, GM detector, low-cost, digital, nuclear medicine, radioactive material

1 INTRODUCTION

CONTAMINATION is defined [1] as the presence of undesirable radioactivity, either in the context of health or for technical reasons, such as increased background or interference with tracer studies. Contamination may result from radioactive gasses, liquids or particles. Radioactive contamination may exist on surfaces or in volumes of material or air. The design concept of a Portable Surface Contamination Monitor is very convenient to detect the surface contamination in the Nuclear Medicine Centers, Nuclear Reactor, Radioisotope Laboratories, Radioactive Waste Management, Industrial Environment and any other places where radioactive material is used.

Several radiation monitoring systems are designed locally in Bangladesh. A portable radiation survey meter using GM detector is explained in S. Islam et.al [2]. However this option cannot obtain a statistical analysis of digitally stored data, or any other form of analysis. The device's battery backup time is approximately 150 hours. The sensitive radiation survey meter as β-γ radiation monitor using scintillation detector NaI(TI) is explained in S. Islam et.al [3]. This device's battery backup time is approximately 180 hours. The above two systems are fully analog and a large number of components were used. However these systems are quite costly and complex in design.

We developed an alternative approach: a microcontroller based digital surface contamination monitor. The developed system has one detector that measures β-γ radiations. The battery backup time for our developed system is over 220 hours. The analog outputs of the GM-detector will be analysed and converted to digital data using a microcontroller. The BCD converts the digital data to the corresponding decimal number and display. Using readily available components and simple circuitry, the system is portable, low-cost, simple in design and fully digital.

2 EXPERIMENTAL METHODS

The system is divided into three parts: the detector circuit, the microcontrolling unit and the display circuit. The detector circuit contains the GM tube and regulated high voltage power supply.

The analog output of the detector is converted into digital data using the microcontroller and fed into the BCD 7-segment decoder for display. The block diagram of the overall system and complete circuit diagram of the developed system is depicted in Figure 1 and Figure 2 respectively.

- *M. A. A. Mashud is with the Department of Applied Physics, Electronics and Communication Engineering, Islamic University, Kushtia-7003, Bangladesh. E-mail: ms.mashud@yahoo.com*
- *M. R. A.Bhuiyan is with the Department of Applied Physics, Electronics and Communication Engineering,Islamic University, Kushtia-7003, Bangladesh.*
- *M. A. Masud is with the Department of Computer Science and Information Technology, Patuakhali Science and Technology University, Dumki, Patuakhali, Bangladesh.*
- *Md. Serajul Islam is with the Institute of Electronics, Atomic Energy Research Establishment, Savar, Dhaka, Bangladesh.*

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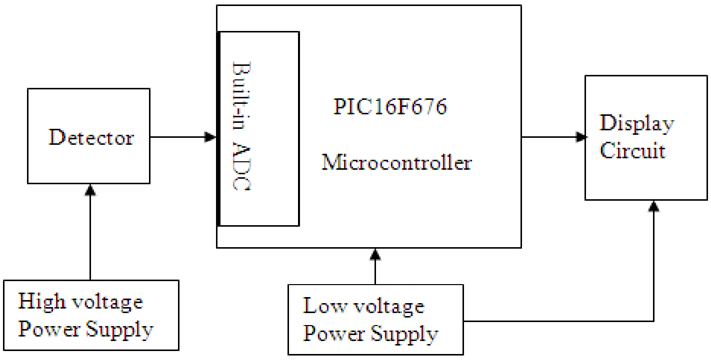

Figure 1: Block diagram of the developed system

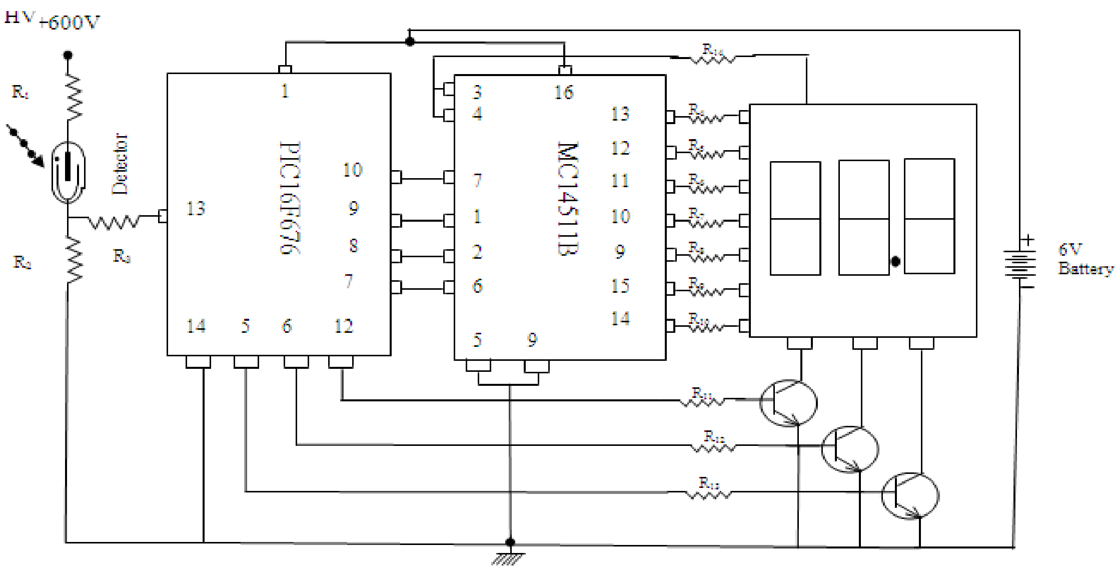

Figure 2: Complete circuit diagram of the developed system

2.1 The Detector Circuit

The common cathode detector [4] circuit was deployed in this work. The high voltage +600 volt [5] is connected to the anode of the detector through a current limiting resistor R_1. The resistor R_1 limits the current through the GM tube and assists advanced ionization to the quenched. The cathode of the detector is connected to the resistor R_2 and generated by the detection of radiation, which is fed to the microcontroller through resistor R_3.

2.2 Microcontroller Unit

The output of the detector is fed to the microcontroller PIC16F676 through resistor R_3. The microcontroller converts data from analog to digital, analysis data and display data. The pin diagram of the microcontroller is displayed in Figure 3.

The PIC16F676 is a 14-pin packages [6]. It has a 10-bit A/D converter and 32 MHz of processing speed [7], [8]. A "C" programming language was developed to control the microcontroller's function using PCWH Compiler [9].

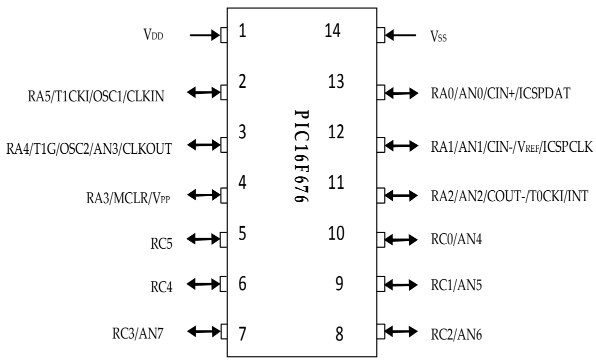

Figure 3: Pin diagram of PIC16F676 microcontroller

2.3 The Display Circuit

Three common cathode 7-segment LED modules display radiation value. When the pin of PIC microcontroller is used efficiently, the display is achieved by using a BCD 7-segment detector (MC14511B) [10]. The microcontroller sends the output signal to the input pins 7,1,2,6 of BCD-to- Seven-Segment Decoder, whose output pins13,12,11,10,9,15,14 are connected to the input of common cathode segment LED [11].

3 SYSTEM PROGRAM

The system program and flow chart is depicted below:

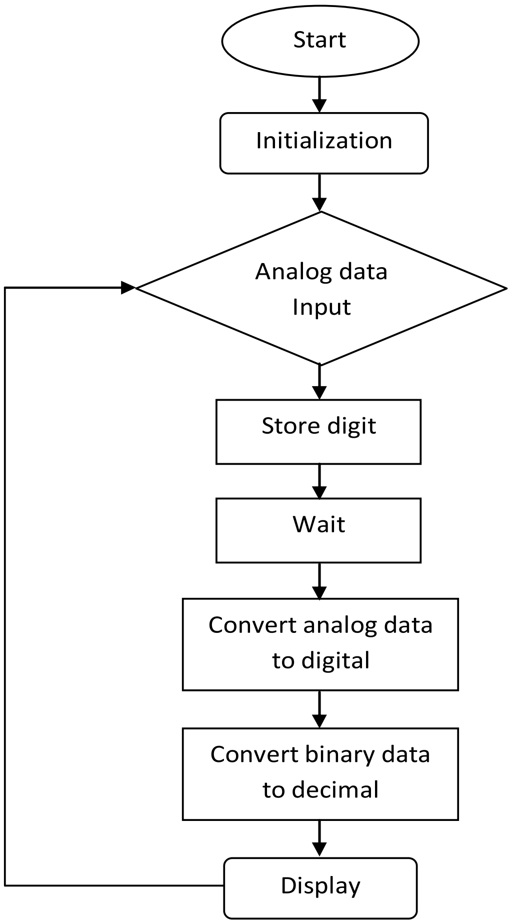

Figure 4: Flow chart of the system program

4 RESULTS AND DISCUSSION

The system was successfully developed and its performance was strong. The system employed a local, low-cost PIC16F676 microcontroller. To avoid the complex comparator and A/D converter circuit, we used an internal comparator and A/D converter for the microcontroller. Furthermore, the internal frequency successfully avoided the external oscillator circuit. Thus the entire system function depends on the developed software. The circuit design is simple and compact.

Each output pulse from the GM tube was counted. Figure 5 depicts the counts per second and the corresponding Bq/cm^2 reading. The counts per second give an approximation of the radiation field.

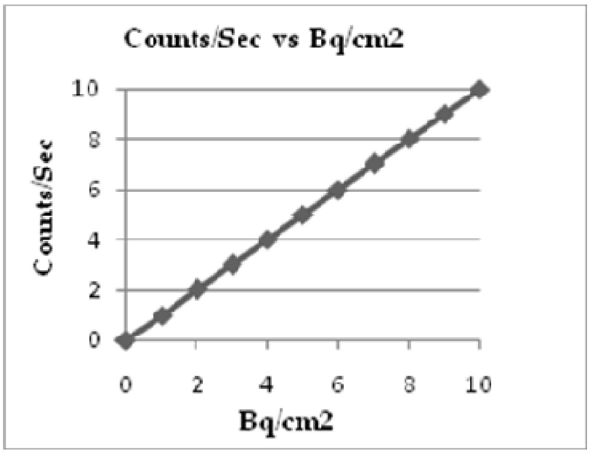

Figure 5: Counts/Sec vs Bq/cm^2 curve

The instrument underwent thorough tests, with satisfactory results. The system was calibrated using a radiation source from SSDL. Contamination linearly varies with count/s. The instrument detects the presence or absence of contamination on a sample surface.

The radiation survey meter currently being used in Bangladesh is fully analog and its cost is high. In contrast, our developed system is fully digital and its price is comparatively lower.

Several portable radiation survey meter devices available in the market were compared with the developed system, in terms of features, accuracy and cost. The comparisons are listed in Table 1.

TABLE 1
COMPARISON OF OTHER RADIATION MONITORING DEVICES WITH THE DEVELOPED SYSTEM

	Portable Radiation Survey Meter[2]	Sensitive Radiation Survey Meter[3]	Developed System
Accuracy	± 10% of full scale deflection	± 10% of full scale deflection	± 2%
Module	Transistor	Transistor	Microcontroller
Measuring system	Analog	Analog	Digital
Battery life time for continuous use	Approx. 150 hours	Approx. 180 hours	More than 220 hours
Price (US$)	1500	1200	700

Table 1 demonstrates that the developed system is highly accurate. The cost is significantly lower than other systems with similar features. The specifications of the developed system are shown in Table 2.

TABLE 2
SPECIFICATIONS

Item	Description
Battery type	D-size, 1.5 volt (4 batteries)
Detector	CANBERA series 2000/8676
High Voltage	600 Volts dc
Measurement range	0 – 10 Bq/cm^2
Control system	Fully automatic control by micro-controller
Display	7-segment LED

5 CONCLUSION

In recent times, the cost of electronic equipment has fallen significantly, though nuclear equipment remains expensive. However due to the rapid development of micro electronics, all designed components and instruments are inexpensive. A Surface Contamination Monitor from the international market costs around US$ 2,000, while the price of the developed Portable Digital Surface Contamination Monitor is less than US$700. Moreover, when the features of the presently used system are compared with the developed system, the latter emerges as a better choice in terms of cost, portability and design. Particularly in developing countries, the use of the deigned instruments will be accessible for many users.

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M. A. A. Mashud was born on Nov.15, 1980 in kushtia, Bangladesh. He received the B.Sc. (Hons) degree in Applied Physics, Electronics and Communication Engineering (AECE) from Islamic University, Kushtia, Bangladesh in 2003, and M.Sc degree from the same department in 2004. He was a Lecturer in the department of Medical Physics and Biomedical Engineering at Gono Bishwabidyalay, Bangladesh from 2008 to 2010. He is currently a Lecturer in the department of AECE, Islamic University, Bangladesh. His current interest is microprocessor / microcontroller applications in control, automation, medical instruments, environmental monitoring, low cost electronic systems and assessment.

Dr. M. R. A. Bhuiyan was born on Dec.10, 1972 in Comilla, Bangladesh. He received the M.Sc. degree in Applied Physics and Electronics from Rajshahi University, Bangladesh in 1995, and Ph.D. degree from Islamic University, Kushtia, Bangladesh in 2008. He is currently an Associate Professor in the department of APE & Com. Engineering, Islamic University, Bangladesh. His current interest is thin-film solar cell and microcontroller based low cost electronic systems design. His work has produced nearly 25 peer-reviewed scientific International and National papers.

M. A. Masud was born on Nov. 08, 1982 in Meherpur, Bangladesh. He received the M.Sc. degree in Information and Communication Engineering from Islamic University, Kushtia, Bangladesh in 2004. He is an Assistant Professor in the department of Computer Science & Information Technology, Patuakhali Science and Technology University, Bangladesh. He works currently as a Ph.D. student in the School of Shinawatra University, Thailand.

Md. Serajul Islam was born in Panchagar, Bangladesh. He received the M.Sc. degree in Physics from Rajshahi University, Bangladesh. He was a Chief Scientific Officer and Director in the Institute of Electronics, AERE, Atomic Energy Commission, Savar, Bangladesh. Now he is retired. His work is design, development and analysis of electronic instruments and reactor control. His work has produced nearly 65 peer-reviewed scientific papers and 02 patents.