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Design and Development of a Microcontroller Based Nuclear Counting System

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Abstract: In this study, researchers attempt to describe a 4-digit micontroller based Nuclear Counting System. The system includes PIC microcontroller as the key device that avoids lots of conventional analog circuitry. Hence, the system is compact, low cost, least noise, better accuracy and independent of nominal memory mapping. The system has been designed with GM detector and locally developed high voltage power supply. MPlab, assembly language program development environment, controls the operation of the designed system. The system has been tested with standard pulser from accredited manufacturer for its performance verification.

Key words: PIC16F84A, MPlab, GM detector, pulser, HV supply, Bangaldesh

INTRODUCTION

Digital Counting Systems are used for counting the number of items passing through a given point on a production line (Mithal and Gupta, 2001). The basic unit of the Nuclear Counting System is a free-run counter which is in fact a register whose numeric value increments by one in even intervals, so that by taking its value during periods and hence, researchers can determine how much particle has been emerged. This is a very important part of the microcontroller whose understanding requires most of the time (Matic, 2000).

Design and development of Portable Scintillation Radiation Survey Meter to measure the low level gamma radiation. The system utilized a Scintillation NaI (T1) detector and PIC16F84A microcontroller to control the function (Akter and Hafiz, 2009). A Nuclear Radiation System has been designed and developed for gamma ray measurement to continuously monitor a radiological condition resulting from the natural and commercial sources. A Geiger Muller tube has been used as a radiation detector and an asynchronous ripple counter was used to count the detector signal. A source code was developed in C language to store and process data (Alam and Haque, 2009). The proposed system has been designed to count nuclear pulses comprises of PIC microcontroller, GM detector and locally developed HV power supply.

Operating principle: Gamma rays and X-rays ionize the gas indirectly by interacting with the metal wall of the GM tube via the photoelectric effect, Compton scattering or pair production in such a way that an electron is knocked off the inner wall of the detector (Knoll, 1988). Nuclear Counting Systems are being used to count the radioactive particles coming from a source or nuclear installations for environmental monitoring and health hazards. The system consists of a radioactive source, GM detector, PIC microcontroller and 7-segment LED displays. This electron then ionizes the gas inside the tube. The electric field created by the potential difference between the anode and cathode causes the negative member of each ion pair to move to the anode while the positively charged gas atom or molecule is drawn to the cathode. If the electric field in the chamber is of sufficient strength approximately 10^6 V m^{-1} these electrons gain enough kinetic energy to ionize the gas and create secondary ion pairs.

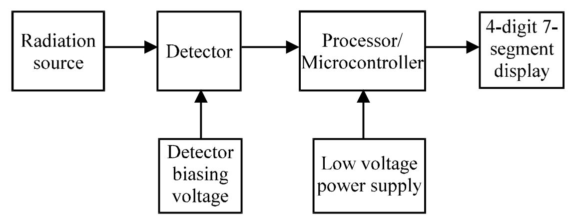

Fig. 1: The block diagram of the complete system

The result is that each electron from a primary ion pair produces a cascade or avalanche of ion pairs. Hence, these ions are collected by charge collection circuit and passes through a unity gain buffer amplifier for more stabilization.

Therefore, the pulses produced then are processed and counted by microcontroller and displayed through 4-digit LED displays (Fig. 1 and 2).

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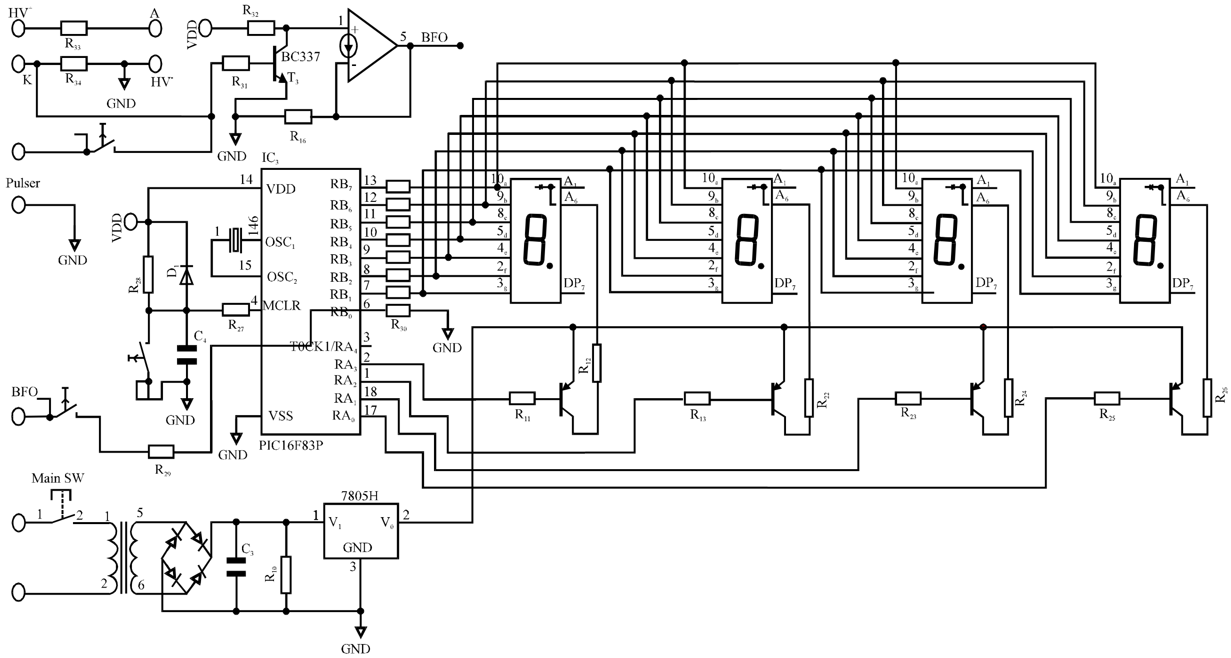

Fig. 2: The complete circuit diagram for the developed system

MATERIALS AND METHODS

Circuit description: Figure 1 shows the schematic diagram for developed Microcontroller Based Nuclear Counting System. The detail description of the schematic has been given as:

Power supply: A power supply must provide stable and ripple-free DC output voltage independent of line and load variations (Islam and Quamruzzaman, 1992). The unit consists of a low voltage transformer, rectifier bridge, C1, R1 and regulator, IC1.

High voltage supply: A high voltage power supply unit is sessential for operating of the detector and electronic systems. The unit belongs to an oscillator, a step-up transformer, rectifier, filter and control circuit for stabilization.

Detector: The system comprises of a Geiger Muller (GM) detector. It is also possible to use of Scintillation.

Charge collection circuit: The charge collection circuit is for the collection of electrons from the detector consists of R16, T8 and R17.

Buffer amplifier: The unity gain buffer amplifier is used for signal stabilization and separation between charge collection circuit and processor circuit belongs of IC2.

Table 1: Shows the performance data for the developed system

Ludlum rate meter reading signal amplitude (50 mV to 5 V)			Developed system reading	
Counts/ min	Reading No.	Counts	Counts	Elapsed time (min)
100	i)	100	0098	1.00.57
	ii)	1000	0999	1.00.63
	iii)	10000	9997	1.00.55
	iv)	100000	9998	1.00.54
1000	i)	100	0098	1.00.34
	ii)	1000	0996	1.00.59
	iii)	10000	9994	1.00.57
	iv)	100000	9995	1.00.58
10000	i)	100	0098	1.00.41
	ii)	1000	0997	1.00.53
	iii)	10000	9995	1.00.61
	iv)	100000	9993	1.00.33

Start circuit: The start circuit has resistor R17 and push switch, SW1.

Stop circuit: The stop circuit has resistor R16 and push switch, SW2.

Reset circuit: The reset circuit, initialization or resumption of a process, consists of D1, R14, R15 and C2.

Processor circuit: The processor circuit is the heart of the developed system comprises of PIC 16F876 28 pin DIP package. It consists of built-in-oscillator, CPU, 4-ports, reset, memory for data and program, interrupts and free-run timer TMR0. An assembly language program developed using MPlab controls the function of the processor.

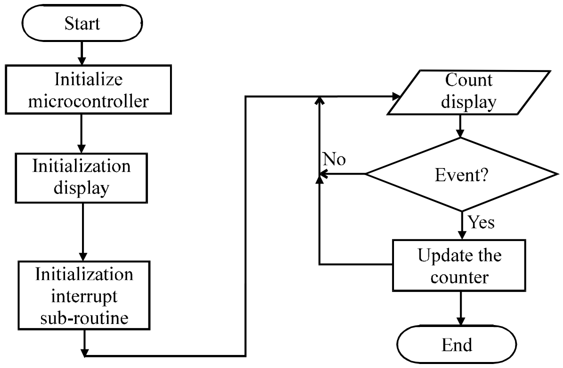

Fig. 3: The program flowchart for the developed system

Display driver circuit: 7-segment LEDs has been driven with transistor driver circuit consists of R2, T2, R3; R4, T3, R5; R6, T4, R7; R8, T5, R9; R10, T6, R11 and R12, T7, R13.

Display circuit: Multiplexed 6 digit 7-segment LEDs has been used to display the counts consists of IC3, IC4, IC5, IC6, IC7 and IC8 (Table 1, Fig. 3).

RESULTS AND DISCUSSION

Nuclear Counting System is a very important module in the conventional Nuclear Instrument Module (NIM) for detection and measurement of radiation. In this regard, microcontroller based Nuclear Counting System has been developed. The system is very user friendly and there are few front panel controls like start, stop and reset. The data has been shown in Table 1 for verifying the system performance. The system has been periodically tested with several counting situations and compared the result with commercially available accredited system like Ludlum rate meter. Firstly at 100 CPM, the system has been employed to count 100, 1000, 10000 and 100000. While, the standard system gives the same reading but the same for developed system has been observed as 98, 999, 9997 and 9998, respectively. Thereafter at 1000 CPM, the present system reading has been recorded as 98, 996, 9994 and 9995 accordingly. Finally at 10000 CPM, The system results are as follows 98,997, 9995 and 9993 for 100, 1000, 10000 and 100000, respectively. There are three count/rate situations has been observed for the developed system. At low intensity measurement, the deviation from the standard system not so pronounced. The error encountered with the system has slightly deteriorated at 1000 C/M. At the extreme intensity measurement level, the system has deviated from the standard manufacturer to a little extent. The errors are due to manual time keeping with a stop watch and inevitable dead time.

CONCLUSION

The designed system has been tested repeatedly with several counting situations. The system is capable of handling GM type detector like ZP1324 is the special feature. The performance was found very satisfactory. The system is cheap, compact, user friendly and reliable in operation. The system can be used for environmental radiation monitoring and detecting health hazards in nuclear installations.

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