International Journal of scientific research and management (IJSRM)
||Volume||1||Issue||6 ||Pages|| 346-351||2013||
Website: www.ijsrm.in ISSN (e): 2321-3418

Design and Development of a 6-Digit Microcontroller Based Nuclear Counting System

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Abstract
6-digit microcontroller based nuclear counting system has been described in this paper although it is possible to extension upto 12-digit or so on. As the system is independent of nominal memory mapping and large pin configuration. For the ease of testing and simplicity, it has been built upto 6-digit. The system includes PIC microcontroller as the key device that avoids lots of conventional analog circuitry. Therefore, the system is compact, low cost, least noise, better accuracy .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: PIC16F876A, MPlab, GM detector, Pulser and HV supply.

1. Introduction

Digital Counting Systems are used for counting the number of items passing through a given point on a production line [1]. 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 we can determine how much particle has been emerged. This is a very important part of the microcontroller based system whose understanding requires most of our time [2]. 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 [3]. 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 [4]. The proposed system is 2-digit extension of previously published design and development of a microcontroller based nuclear counting system [5]. It has been designed to count nuclear pulses comprises of PIC microcontroller (PIC16F876), GM detector (ZP1324) and locally developed HV power supply.

2. Methodology 2.1: Block Diagram

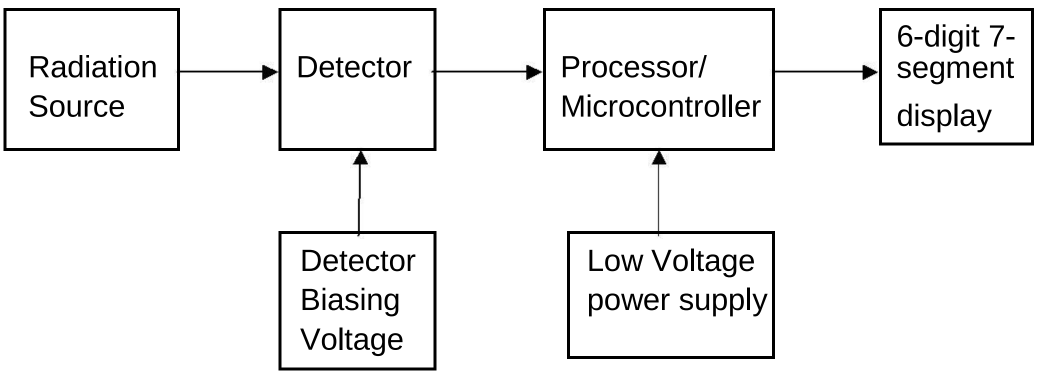

Fig.2.1.1: Shows the Complete Block Diagram of the Developed System.

Fig2.1.1 above shows the complete block diagram of the developed system. The block contains radiation source (point source ^{60}Co), detector (ZP1324), detector biasing voltage, 28-Pin Enhanced Flash Microcontroller (P16F876A), 6-digit seven segment displays and low voltage power supply.

2.2: Schematic Diagram

Fig.2.2.1 shows the schematic diagram for the developed 6-digit Microcontroller Based Nuclear Counting System. The detail description of the schematic diagram has been given below.

2.2.1. Power Supply: A power supply must provide stable and ripple-free DC output voltage independent of line and load variations. [8, 9].The unit can be built of a low voltage transformer, bridge rectifier, filter and IC Regulator.

2.2.2. High Voltage Supply: A high voltage power Supply unit is essential 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 [10].

2.2.3. Detector: The system comprises of a Geiger Muller (GM) detector ZP1324. It's also possible to use of Scintillation.

2.2.4. Charge Collection Circuit: The charge collection circuit is for the collection of electrons from the detector consists of R13, T7 and R14.

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

2.2.6. Start/Stop Circuit: The start circuit has resistor R17 and ST/SP Switch.

2.2.7. Reset Circuit: The Reset circuit, initialization or resumption of a process, consists of D1, R16, R15, C1and Reset Switch.

2.2.8. Processor Circuit: The processor circuit is the heart of the developed system comprises of PIC 16F876 28 pin DIP Package Enhanced Flash Microcontrollers. It consists of Built-in-Oscillator, CPU, 4-port, active low MCLR, Memory for data and Program, Interrupts and free-run timer TMR0 [11]. An assembly language program has been developed by using MPlab to control the function of the processor.

2.2.9. Display Driver Circuit: 7-segment LEDs has been driven with transistor driver circuit consists of R1,T1,R2; R3,T2,R4; R5,T3,R6; R7,T4,R8; R9,T5,R10 and R11,T6,R12.

2.2.10. Display Circuit: Multiplexed 6-digit 7-segment LEDs has been used to display the counts consists of DIS1, DIS2, DIS3, DIS4, DIS5 and DIS6.

2.3: Operating Principle

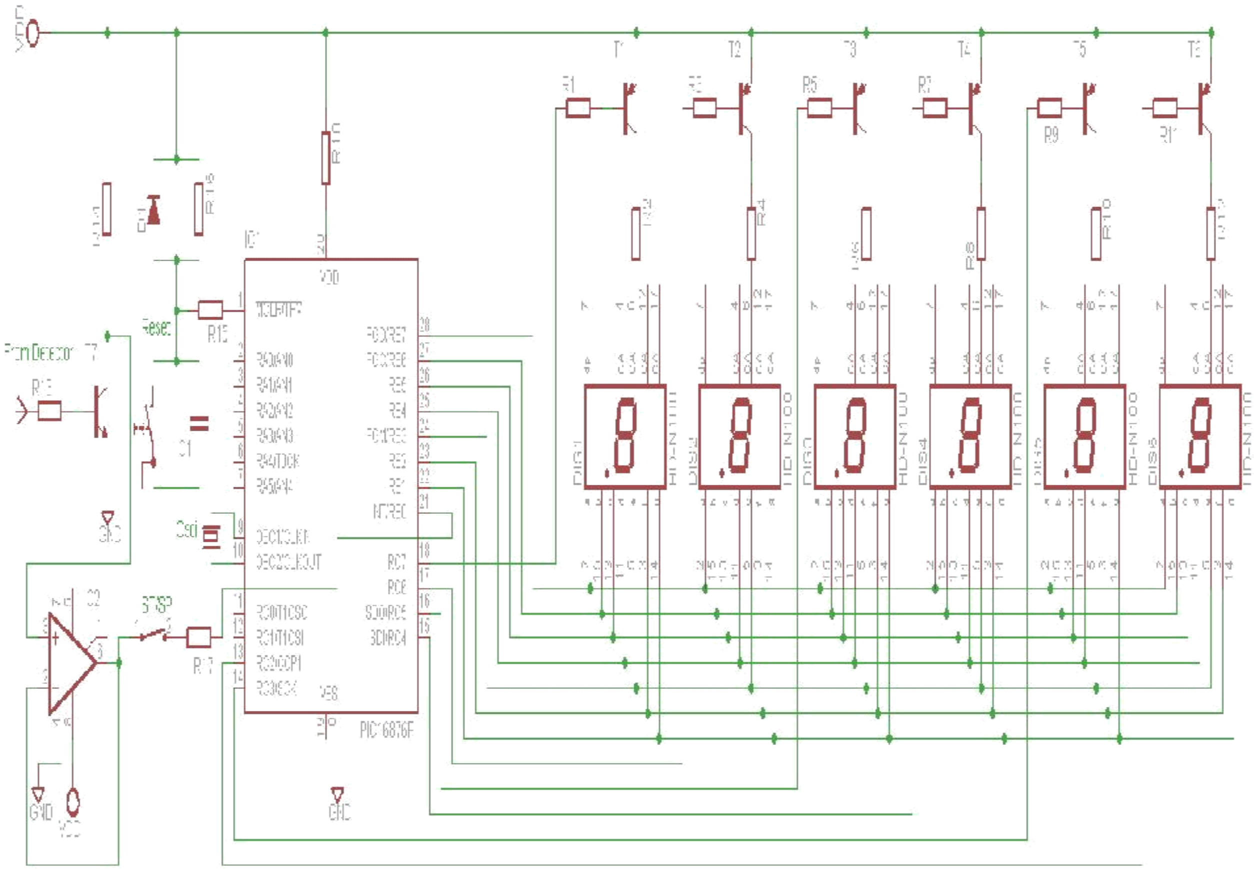

Fig.2.2.1: Shows the Complete Circuit Diagram of the Developed System.

Fig.2.2.1 shows the schematic diagram for the developed 6-digit microcontroller based nuclear counting system. The fig.2.3.1 shows the program flow chart of the proposed system. The data has been provided in the table2.4.1 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.

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 [6, 7].

Nuclear Counting Systems are being used to count the radioactive particles coming from a source or nuclear installations for environmental monitoring and detecting health hazards. The system consists of a GM Detector, Detector Bias Voltage, 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 these electrons gain enough kinetic energy to ionize the gas and create secondary ion pairs.

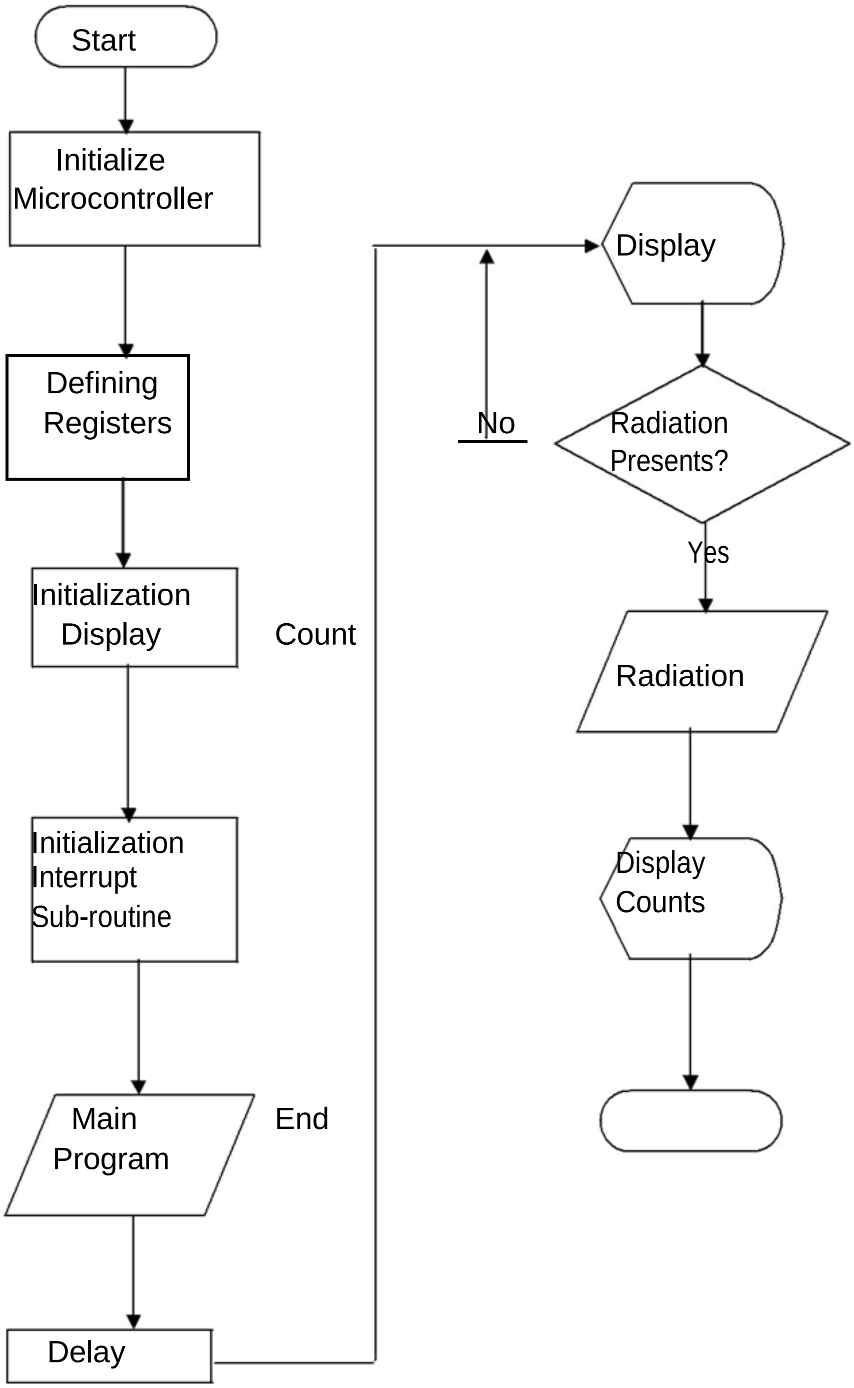

Fig.2.3.1: Shows the Program Flowchart for the Developed System.

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 6-digit or more 7-segment LED displays.

2.4: 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 provided in the table2.4.1 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 99998 respectively. Thereafter, at 1000 CPM, the present system reading has been recorded as 98, 996, 9994 and 99995 accordingly. Finally, at 10000 CPM, The system results are as follows 98,997, 9995 and 99993 for 100,1000,10000 and 100000 respectively. There are three count/rate situations has been observed for the developed system.

At 100 CPM, low intensity measurement, the deviation from the standard system is negligible. The error encountered with the system has slightly deteriorated at 1000 CPM. Lastly, at 10000 CPM, the high 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.

Sl No.	Ludlum Rate Meter Reading Signal Amplitude (50mV to 5V)			Developed System Reading	
	Counts/min	Reading No.	Counts	Counts	Elapsed Time (min)
1.	100	i)	100	000098	1.00.57
		ii)	1000	000999	1.00.63
		iii)	10000	009997	1.00.55
		iv)	100000	099998	1.00.54
2.	1000	i)	100	000098	1.00.34
		ii)	1000	000996	1.00.59
		iii)	10000	009994	1.00.57
		iv)	100000	099995	1.00.58
3.	10000	i)	100	000098	1.00.41
		ii)	1000	000997	1.00.53
		iii)	10000	009995	1.00.61
		iv)	100000	099993	1.00.33

Table 2.4.1: Shows the performance data for the developed system

3. 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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