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Design and Development of a Nuclear Counting System using ATMEL Microcontroller

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Key words: Nuclear detector, high voltage power supply, nuclear pulse processing, ATmega8L, LCD display and BASCOM AVR IDE

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Abstract: Design, Development and Simulation of a Nuclear Counting System using ATMEL Microcontroller has been presented in this study. The Nuclear Counting System (NCS) consists of Nuclear Detector GM (ZP1324)/Scintillation NaI (Tl) followed by Nuclear Detector Signal Channel (NDSC) Preamplifier-Amplifier-Shaper-Discriminator. The charge-sensitive preamplifier decay time constant (τ) is 10 µs. The gain of amplifier used in this channel is 26. Shaping amplifier which is the combination of high pass and low pass filter with equal time constant ($\tau_1 = \tau_2 = \tau$) of 5 µs to increase the signal-to-noise ratio. Single ended or integral discriminator function is to eliminate the system noise and pulse height discrimination. Atmel-AVR ATmega8L 8-bit Microcontroller is High-performance, Low-power with 8Kbytes In-System Programmable Flash as the Processor, LCD display (16 ch, 2-line), High Voltage Power Supply (HVPS) for detector bias voltage and Low Voltage Power Supply (LVPS). An assembly language counting program based on BASCOM AVR IDE has been developed to control the operation of the designed NCS. The system has been designed and verified in Proteus 7.7 simulation platform.

INTRODUCTION

Digital Counting Systems are used for counting the number of items passing through a given point on a production line[1]. Thus, the basic unit of the Nuclear Counting System (NCS) is a free-run as well as external input assigned counter which is in fact a register whose numeric value increments by one in even intervals, so that by taking its value during the periods and hence we can determine how much particles/events have been emerged. This is a very important part of the microcontroller whose understanding requires most of our time. In this regard, design and development of a microcontroller based nuclear counting system includes PIC microcontroller PIC16F84A as the key device that avoids lots of conventional analog circuitry, GM detector and locally developed High Voltage Power Supply (HVPS) and 4-digit 7-segment LED display[2]. 6-digit microcontroller based nuclear counting system consisting GM detector and locally developed high voltage power supply, PIC16F876A microcontroller and 6-digit 7-segment LED display has been described in this study, although, it is possible to extension up to 12-digit or more depending on the large pin configuration. And the system is independent of nominal memory mapping. For the ease of testing and simplicity, it has been built upto 6-digit[3]. 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[4]. 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[5]. In the current research, Design, Development and Simulation of an ATMEL Microcontroller Based Nuclear Counting System

(NCS) have been presented. The designed NCS consists of Nuclear Detector GM (ZP1324)/Scintillation NaI (Tl) followed by Detector Front-end Electronics Preamplifier-Amplifier-Shaper-Discriminator, Atmel-AVR ATmega8L 8-bit Microcontroller, LCD display (16 ch, 2-line), a HVPS for detector bias voltage and Low Voltage Power Supply (LVPS). An assembly language counting program based on BASCOM AVR IDE has been developed to control the operation of the designed NCS. The system has been designed and tested in Proteus 7.7 simulation platform.

MATERIALS AND METHODS

Block diagram: Block diagram of the proposed the Nuclear Counting System (NCS) using ATMEL Microcontroller has been shown in Fig. 1. The individual description of the each block has been provided as follows.

Schematic diagram: Complete simulation model of the developed Atmel Microcontroller Based Nuclear Counting System (NCS) has been shown in Fig. 2. The detail description of the schematic diagram has been given as below.

Low voltage power supply: A low voltage power supply must provide stable and ripple-free DC output voltage independent of line and load variations[6, 7]. Therefore, the low voltage power supply is essential for the NCS and a built-in 5V DC power supply has been used in Proteus 7.7 simulation platform.

High voltage power supply: A High Voltage Power Supply (HVPS) unit is required for biasing the Nuclear Detector GM (ZP1324)/Scintillation NaI (Tl) would be used while testing and finally fabrication as a complete Nuclear Counting System (NCS).

Nuclear detector: The system comprises of a Geiger Muller (GM) detector (ZP1324). It’s also possible to use of a Scintillation detector NaI (Tl).

Coupling capacitor: The system consists of a coupling capacitor, C1 47nF to connect the signal in Nuclear Detector Signal Channel (NDSC) Preamplifier-Amplifier-Shaper-Discriminator the nuclear detector front-end electronics and separate the high voltage from the system.

Nuclear detector signal channel: The Nuclear Detector Signal Channel (NDSC), nuclear pulse processing circuits, comprises of charge-sensitive preamplifier, single-stage variable gain amplifier, CR-RC shaping amplifier and integral discriminator.

Charge-sensitive preamplifier: The charge-sensitive preamplifier feedback circuit has 1M resistor R1 and 10 pF capacitor C2 that gives its decay time constant (τ) of 10 μs. This pulse processing circuit also has an op amp LM324 U1: A and a buffer U2.

Gain amplifier: The non-inverting gain of the amplifier used in the NDSC is 26 consists of Resistor R2, Resistor R3, Resistor R4 and an op amp LM324 U1:B.

Shaping amplifier: The shaping amplifier which is the combination of high pass and low pass filter with equal time constant ($\tau_1 = \tau_2 = \tau$) of 5 μs to increase the signal-

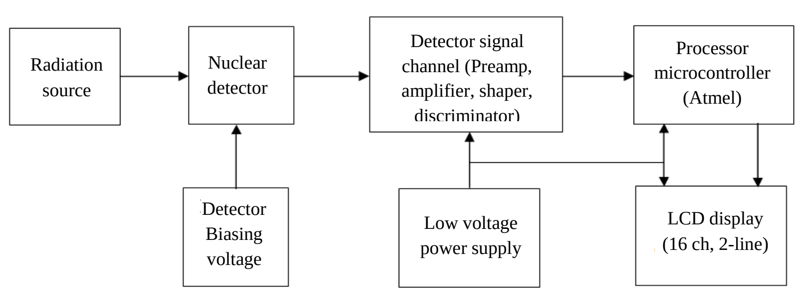

Fig. 1: The complete block diagram of the proposed nuclear counting system

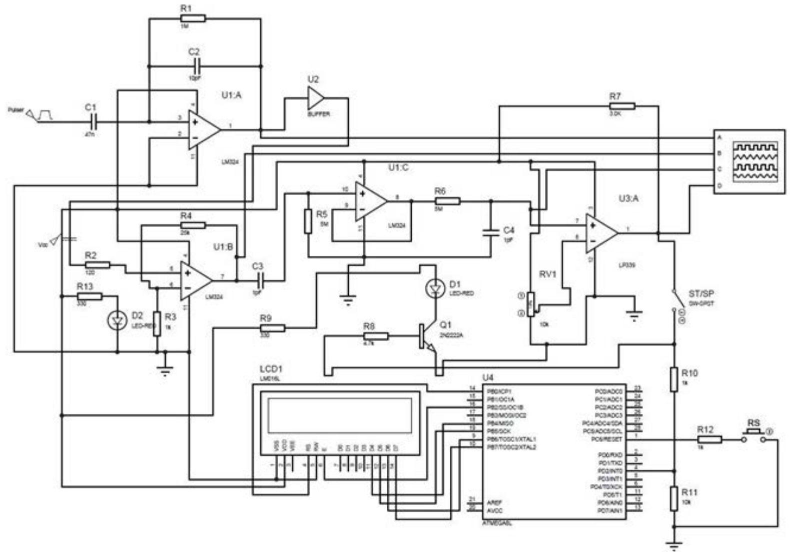

Fig. 2: The complete schematic diagram of the proposed Nuclear Counting System (NCS)

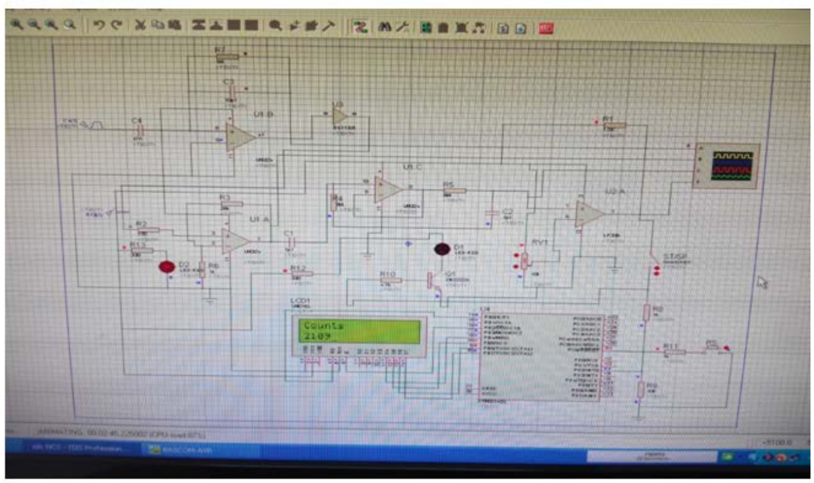

Fig. 3: The complete simulation model of the developed Atmel microcontroller based Nuclear Counting System (NCS) running in Proteus 7.7 simulation platform

to-noise ratio comprises of capacitor C3, Resistor R5, unity gain buffer amplifier LM324 U1:C, resistor R6 and capacitor C4. 2.2.5.4: Integral Discriminator: Single ended or integral discriminator, eliminate the system noise and pulse height discrimination, consists of multi-turn variable resistor RV1, open collector resistor R7 and the IC comparator LP339 U3:A[8] (Fig. 3).

Processor circuit: The High-performance, Low-power with 8Kbytes In-System Programmable Flash, 8-bit Microcontroller Atmel-AVR ATmega8L has been used as the Processor. The 28 pin DIP package microcontroller consists of CPU, 3-ports, Oscillator, Reset, Memory for data and Program, Interrupts and free-run timer TMR0. A BASCOM counting program has been developed by using BASCOM AVR IDE to control the operation of the designed Nuclear Counting System (NCS).

LCD display: A Liquid-Crystal Display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome. LCDs are used

Table 1: Power indicator the power indicator circuit is the combination of R13 and D2 (LED-RED)

Input signal amplitude 5V		Developed system reading number of event/pulse
Frequency	Rise time- fall time (μ sec)	
50 Hz	10 ns-200, 10 ns-400	300+
100 Hz	10 ns-200, 10 ns-400	345+
500 Hz	10 ns-200, 10 ns-400	533+
1 KHz	10 ns-200, 10 ns-400	2109+

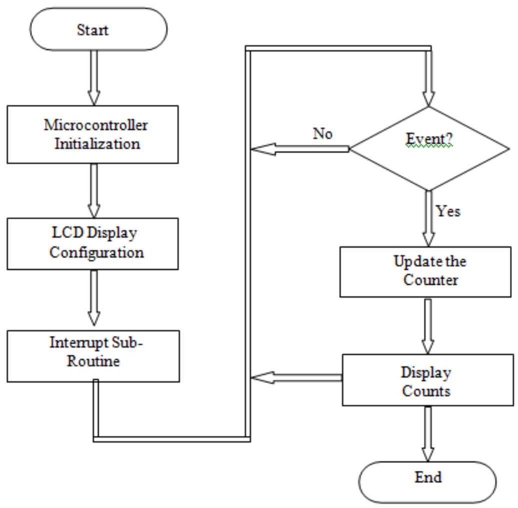

Fig. 4: The program flowchart for the proposed Nuclear Counting System

in a wide range of applications including LCD televisions, instrument panels to clocks. Therefore, the LCD display (16 ch, 2-line), LCD1, LM016L has been used in the designed NCS to display the counts/incoming events (Fig. 4).

Start/ stop circuit: The start/stop circuit has the resistor R10 and a switch SW-SPST.

Reset circuit: The reset circuit, initialization or resumption of a process, consists of a Resistor R12 and the push switch RS.

Signal indicator: The signal indicator circuit comprises of R8, Q1 2N2222A, D1 (LED-RED) and R9. Table 1 shows the performance data for the developed system. AMETEK ORTEC 480 Pulser simulates radiation detector output signals may be calibrated to read directly in terms of equivalent energy deposition in semiconductor radiation detectors, exponential pulse shape with 10-n sec rise time and 200-or 400-μs decay time constant, various frequency pulse rate positive polarity, direct 0-5 V output ranges from 50 Hz to 1 KHz in Proteus 7.7 simulation platform.

RESULTS AND DISCUSSION

Nuclear Counting System (NCS) is very important in the development and deployment of handheld instruments and field based instruments as well as conventional Nuclear Instrument Module (NIM) for detection and measurement of radiation even for remote and unattended operations. In this regard, ATMEL Microcontroller based Nuclear Counting System (NCS) has been designed, developed and tested. The system has been tested and verified in Proteus 7.7 simulation platform. The system is very user friendly and there are few front panel controls like start, stop and reset. The signal indicator and the power indicator have been added as well. The data has been provided in Table 1 for verifying the system performance. The system has been periodically tested with several counting (pulse/sec) levels. The pulse generator properties were resembles with AMETEK ORTEC 480 Pulser which simulates radiation detector output signals may be calibrated to read directly in terms of equivalent energy deposition in semiconductor radiation detectors, exponential pulse shape with 10-ns rise time and 200-or 400-μs decay time constant, various frequency pulse rate positive polarity, direct 0-5 V output ranges from 50 Hz to 1 KHz in Proteus 7.7 simulation platform.

Firstly, at 50 Hz, the system has been employed to count and display up to three digits that is to say 300+ counts in LCD (16 ch, 2-line). Secondly, at 100 and 500 Hz, the ATMEL Microcontroller based Nuclear Counting System (NCS) reading has been observed as 345 and 533+ counts respectively. Finally, at 1 KHz, The system results have been recorded upto 4-digit as 2109+. There are four counting (pulse/sec) levels has been observed for the developed system suitable for low intensity measurement especially in workplace and environmental monitoring, although, there are good agreement with the electronics design of the NCS from nuclear pulse processing to LCD display configuration and BASCOM counting program development as well as data dimension assignment as Long (4-Byte) variable. Taking into above mentioned considerations, the reason for the deviation from the standard measurement/testing data of the NCS is difficult to determine. The gross counts 2100+ interrupted with the system were slightly at 1000 pulse/sec. The same for the NCS at 100 and 500 Hz were deteriorated gradually. And at 50 pulse/sec situations, the gross counts interrupted with the system were 300+ only. At the highest intensity measurement level 10,000 pulse/sec, the system did not display any count but the reason is quite unknown. The gross counts interruption with the system might be eliminated/ improved with the help of PCB fabrication and performance testing.

CONCLUSION

Design, development and simulation of a Nuclear Counting System (NCS) using ATMEL Microcontroller consists of a Nuclear Detector GM (ZP1324/Scintillation NaI (Tl) followed by the NDSC: Preamplifier-Amplifier-Shaper-Discriminator, The Processor Atmel-AVR ATmega8L 8-bit Microcontroller, a LCD display (16 ch, 2-line), a HVPS and a LVPS have been presented in this research. The design and verification of the ATMEL Microcontroller based NCS in Proteus 7.7 simulation platform has been completed successfully. The designed system is cost effective, simple and reliable in operation. The NCS has been tested repeatedly and its performance was found satisfactory.

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