Development of a Low-cost Radiation Monitor with Quadruple Detectors

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1. Introduction

Radiation monitoring system is one of the key systems used in many industrial fields such as a nuclear plant, research reactor, radioactive waste management facility,, and medical center. Korea atomic energy research institute (KAERI) has the legal obligation to protect the public and workers on site from any unjustified exposure to radiation. Thus, there are various types of radiation monitoring devices, of which gamma radiation monitors are the most.

Recently, commercial gamma radiation monitors have widely employed a silicon (Si) detector; they provides wide measurement range with compact size and low bias voltage for a detector. Some monitors have gamma detector module integrated with the Si detectors, amplifiers and pulse shaper circuit as shown in Fig.1 [1]. The Si detector in the module interacts gamma radiation and produces charge pulse whose magnitude and frequency are proportional to the incident energy and dose rate. Theses charge pulses are amplified and shaped to produce a series of voltage pulses. Then, the pulses are transferred to a radiation monitor.

In this paper, a low-cost radiation monitor with the commercial quadruple gamma detectors. By employing a verified gamma detector module, the developer enables to get more reduced project period and more stable product development. In addition, it has the advantage of being able to customize various functions for improving user convenience and device maintenance efficiency.

2. Development of Low-cost Radiation Monitor with Quadruple Detectors

2.1 Target Radiation Detector Module

For the development of the customized radiation monitor, we employed the Si detector module of G64 (CANBERRRA). G64 can be used as various type of radiation monitor using a local display and signal processing unit (ratemeter) with single hardware platform. Regardless of what kind of detector module is applied, a series of voltage pulses proportional to the radiation level are transmitted to the ratemeter.

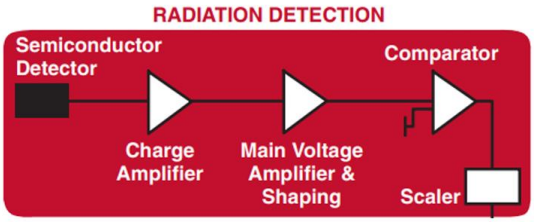

Fig. 1. Radiation detector module configuration

2.2 Developed System Configuration

The developed system configuration of radiation monitor using commercial gamma detector module. The monitor is designed based on TMS320F2800137 (Texas instrument, TI); it is a 32-bit floating point microcontroller unit (MCU), which provides 200MHz of signal processing performance [2]. With its powerful computing performance, TMS320F2800137 has various peripheral modules and subsystems such communication peripherals (SCI, CAN, SPI, USB 2.0), analog subsystem (ADC, DAC, comparator), Enhance control peripherals (PWM, eCAP, eQEP). The roles of each component are as follows:

1) Pulse Counting from detector modules

To count a number of pulses per second when a negative edge occurs for pulse signals transmitted from the detector module, the external interrupt function of TMS320F2800137 has been used. TMS320F2800137 provides up to five external interrupt ports, allowing a single CPU to count pulses from multiple detector modules.

2) Serial communication interface (SCI)

In TMS320F2800137, there are 3 independent SCI modules. Among them, one port is dedicated to RS-485 communication with an external system (i.e., server), another to RS-232 for maintenance, and the last to interfacing with an HMI screen such as a touch screen.

3) Serial peripheral interface (SPI)

The SPI communication module is employed to interface with the EEPROM, primarily for storing configuration parameters including the device name, slave number, settings, detection efficiency, and dead time

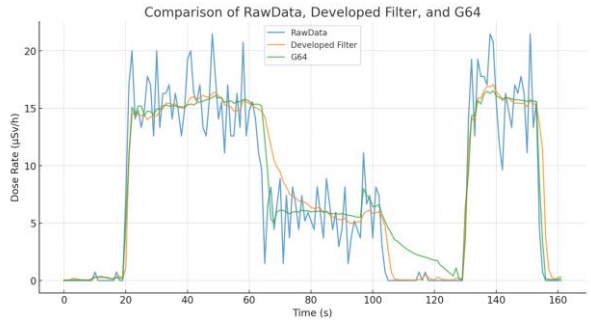

Fig. 2. Developed signal filter performance

4) General purpose I/O (GPIO) Ports

They are used to operate the lamp, buzzer and relays.

2.3 Radiation Counting Signal Processing Method

To remove noise and ensure accurate and stable signal processing implements an adaptive exponential smoothing filter that adjusts its gain according to fluctuation detection. A sliding buffer (up to 10 samples, analysis block size 8) is maintained, and for each new input the mean, standard deviation, and relative standard deviation (RSD) are computed. Expected RSD values are defined for transient ranges, with stricter thresholds applied during decreasing trends to enhance sensitivity. Change detection follows a two-step process (suspicion → confirmation), using an anchor point to prevent false triggers. Once a change is confirmed, the gain G is set to its maximum and then gradually decreased toward a minimum value by a fixed decrement. In stationary conditions, the gain remains at its minimum. The filter output is recursively updated with the new sample and the previous filtered value. This mechanism allows rapid adaptation to sudden variations while maintaining stability in steady-state conditions. Fig 2. shows developed signal filter performance. The developed filter removes the noise components of the raw data while following its overall trend. In addition, compared with the existing commercial product G64, the developed filter provides more stable data and demonstrates a sufficiently fast response speed

3. Conclusions

The developed low-cost radiation monitoring system employing quadruple Si detector modules and a TMS320F2800137 MCU successfully demonstrates stable performance and flexibility. By integrating a verified commercial detector module with customized signal processing, the system achieves reliable pulse counting, efficient communication, and user-friendly maintenance features. The proposed adaptive exponential smoothing filter effectively suppresses noise while preserving data trends, offering both stability and rapid response compared to conventional G64 monitors. These results confirm the feasibility of a cost-effective, customizable radiation monitor with improved accuracy and operational efficiency for diverse industrial and research applications.

REFERENCES

[1] G. F. Knoll, Radiation Detection and Measurement, John Wiley & Sons, New York, pp.612-613, 1999.
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