Design Consideration for Radiation Monitor Development Using Commercial Gamma Detector Module

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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 Si detectors, the 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. These 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, the design consideration and development method are introduced for a radiation monitor using commercial gamma detector module. By employing a verified gamma detection 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. Design Consideration for Radiation Monitor Development Using Gamma Detector Module

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. 2 shows the existing G64 ratemeter response according to the transferred pulse signal from a function generator.

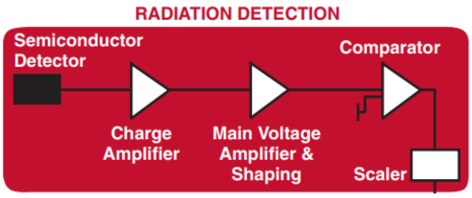


Fig. 1. Radiation detector module configuration

<1Hz = 1 μSv/h> <1000Hz = 1010 μSv/h>

Fig. 2. G64 ratemeter response according to pulse signal with different frequency.

The ratemeter, which receives signals in parallel from the function generator, represents 1usv/h for a series of pulse signal at 1 Hz and 1.01mSv/h for the pulse at 1000 Hz, respectively. From Fig. 2, it is noticed that the ratemeter serves as a pulse counter from the detector module's point of view.

2.2 Proposed System Configuration

Fig. 3 shows the system configuration of radiation monitor using commercial gamma detector module. The monitor is designed based on TMS320F28377S (Texas instrument, TI); it is a 32-bit floating point microcontroller unit (MCU), which provides 200MHz of signal processing performance [2].

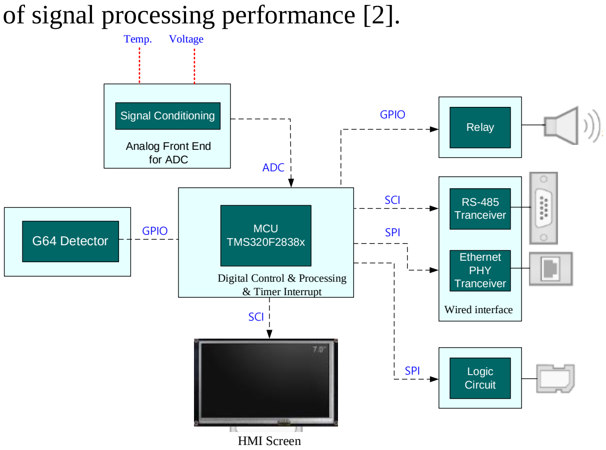


Fig. 3. Proposed System Configuration

With its powerful computing performance, TMS320F 28377S 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). In Fig.3, the roles of each component are as follows:

1) ADC
: To diagnosis the condition of the monitor, system voltage and ambient temperature are measured using ADC function.

2) External interrupt
: It is used to count a number of pulse per second when a negative edge occurs for pulse signals transmitted from the detector module. Experimentally, linearity is shown for up to 1,000,000 pulse signals per second.

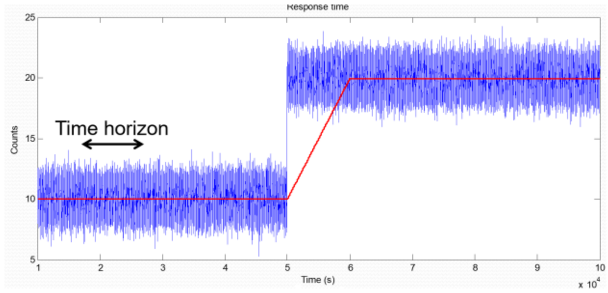
3) Serial communication interface (SCI)
: In TMS320F28377S, there are 4 independent SCI modules. Among them, 2 modules are enabled; one is used for the data communication between server and monitor, and another is used for interfacing with the HMI screen. We choose NEXTION's product line as HMI screen.

4) Serial peripheral interface (SPI)
: SPI module is activated for interfacing with a SD card. Recording and storing gamma radiation data yielded from the monitor is important in event analysis and post-accident response. It is especially useful when remote data communication with a server is impossible.

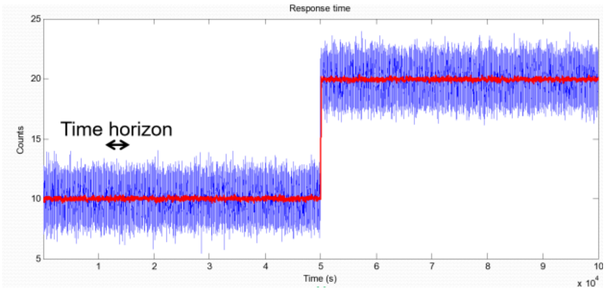
5) General purpose I/O (GPIO) control
: In Fig. 3, it is used to operate the buzzer for the purpose of propagating the situation if current measurement exceeds the set point or if the equipment fault occurs.

2.3 Radiation Counting Signal Processing Method

Signal yielded from radiation detector has stochastic characteristic. Estimating the value of a stochastic process, such as a Poisson process requires long-term estimations of the mean or variance. Thus, signal processing for raw counting value from radiation detector module is necessary for stable and accurate radiation measurement. As one of the radiation counting signal processing method, the signal smoothing filter such as the moving average filter and IIR filter has been commonly used. However, there is trade-off between response time and accuracy. If the signal is highly filtered, the result is as shown in Fig. 4a. In the opposite case, it provides a fast response speed as shown in Fig. 4b, but the filtered value fluctuates greatly.



(a)



(b)

Fig. 4. Trade-off between response time and accuracy in traditional filter method.

To overcome the aforementioned problem, the proposed system employs the exponential filter with adaptive gain as shown in (1).

$$\bar{x}(n+1) = [1-G(n)]\cdot\bar{x}(n) + G(n)\cdot C(n)$$

$$where\ G(n) = Min\left(\frac{2}{1+\dfrac{\sigma^2_{Mes(n)}}{\sigma^2_{Est(n)}}};\ 1\right) \qquad (1)$$

The gain $G(n)$ involves the measured standard deviation $\delta_{Mes}(n)$ and the standard deviation estimated from the lookup table $\delta_{Est}(n)$. The measured standard deviation is calculated once every cycle; from which is deduced the relative standard deviation, and then the gain G(n). From (1), it noted that the gain is close to 1 in high activity; it means that it is almost no filtering. On the other hand, the gain is almost 0 in the low activity, which provides high filtering.

3. Conclusions

This paper presents the design consideration and development method for the radiation monitor using commercial gamma detector module. It introduced methods and tools for implementing various functions, including the overall system configuration, and also introduced effective signal processing techniques for radiation counting signals. In conclusion, the radiation monitoring system (RMS) configuration capable of improving user convenience and maintenance efficiency is possible through a verified commercial radiation detector module.

REFERENCES

[1] G. F. Knoll, Radiation Detection and Measurement, John Wiley & Sons, New York, pp.612-613, 1999.
[2] TMS320F28377S Datasheet.