Study on the method of measuring radiation energy by measuring the rising slope of the signal waveform

Seung-Jae Lee [a,b*], Hakjae Lee [c]
[a]*Department of Radiological Science, Dongseo Univ., Busan, 47011*
[b]*Center for Radiological Environment & Health Science, Dongseo Univ., Busan, 47011*
[c]*ARALE Laboratory Co., Ltd., Seoul, 02559*
[*]*Corresponding author: sjlee@gdsu.dongseo.ac.kr*

Keywords : photon counting, pile up, signal waveform, slope, detector

1. Introduction

X-ray photon counting detectors are used in various systems such as medical and material analysis [1]. For this purpose, dedicated ASIC type systems have been developed [2-5]. These systems have the disadvantage of being very expensive and not being applicable to other systems. Therefore, in this study, we propose a general photon counting acquisition method that can be used in photon counting detectors. As the energy of radiation changes, the time to reach the peak value in the signal waveform is the same. Fig. 1 shows the waveform of the signal measured using the Hamamatsu SiPM S13360-3075CS model [6]. In other words, if the slope of the signal reaching the highest value from the lowest value is measured, it can be converted into the energy of radiation. To verify this, a basic experiment was performed using the data acquisition system of the ALARE laboratory [7].

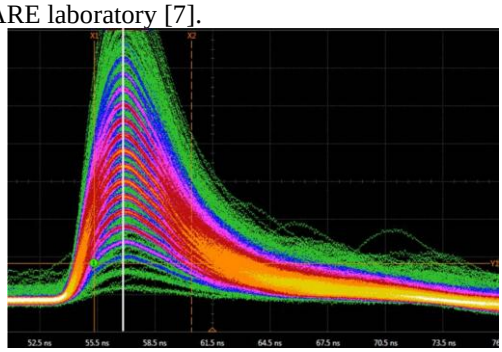

Fig. 1. Waveforms of signals measured using the Hamamatsu SiPM S13360-3075Cs model [12].

2. Methods and Results

2.1 Detection System Configuration

In order to measure the energy of radiation by measuring the rising slope of the signal, the data acquisition system of ALARE Laboratory was used as a signal measurement system. The data acquisition system consists of a preamplifier, a signal summation circuit, and a DAQ. This system uses a 100 MSPS ADC, which can sample the signal waveform every 10 ns.

2.2 Experimental Setup

The data acquisition system was connected to the MPPC (S13361-3050AE-08 model of Hamamatsu). A 3 mm x 3 mm x 5 mm GAGG scintillation pixel was placed on the MPPC to interact with the radiation and collect the light generated. Na-22 was used as the radiation source and was placed on the scintillator for measurement.

2.3 Data Acquisition

The signal waveform of the Na-22 radiation source was measured using the constructed system. The energy spectrum was constructed by measuring the rising slope of the generated signal, and it was compared and evaluated with the energy spectrum constructed by measuring all values of the signal. The method of measuring the slope through the signal waveform is as shown in Fig. 2. When the signal size exceeding the threshold value is detected, the signal is set to be collected, and the first signal value is sampled at the first clock, and the next signal value is sampled at the second clock. Then, at the last third clock, the signal collection process is completed by initializing the generated signal value by connecting to the ground.

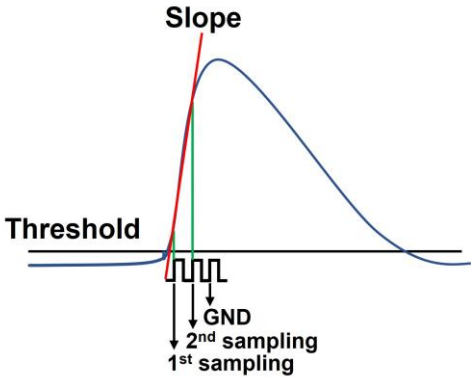

Fig. 1. The process of measuring slope through a signal waveform.

3. Results and Discussion

For photon counting of X-rays and energy measurement of radiation in very strong radiation fields, a very fast measurement system is required. Such a system is also required to prevent signal overlap. We

developed a method to solve the signal overlap phenomenon and enable fast radiation measurement even in existing general-purpose systems. By measuring the rising slope of the signal, we were able to prevent signal overlap and secure a very fast measurement time. Fig. 3 shows the energy spectrum measured by the Na-22 radiation source. It shows the energy spectrum obtained by sampling all the signals and the energy spectrum constructed by measuring the rising slope. The energy resolution is 7.9% in (a) and 17.7% in (b), which indicates that it is preferable to measure all the signal waveforms. It can be confirmed that the photoelectric peak region is clearly shown in both energy spectra. It took about 200 ns to sample all the signal waveforms, and only 30 ns to measure the rising slope. In other words, it showed a very fast measurement time compared to the existing method. It is expected that the measurement time will be shortened further if a faster ADC is used.

The method of measuring the slope was measured with a lower energy resolution than the method of measuring all signals. It is thought that additional research is needed to find a way to solve this. However, the most important key to the method of measuring the slope is to resolve the signal overlapping phenomenon by measuring at a very fast speed. It is considered that additional research is needed in the future to study energy linearity and stability.

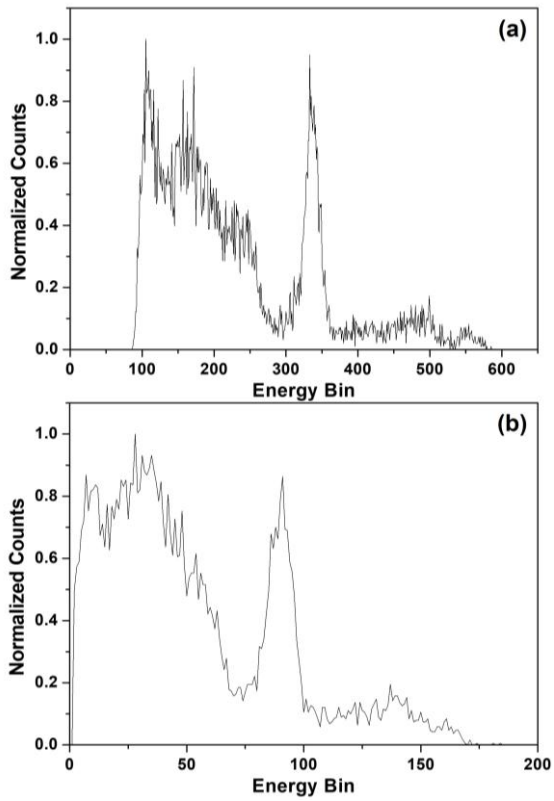

Fig. 3. Energy spectrum of the Na-22 radiation source. (a) Measuring all the waveforms of the signal, (b) Measuring the rising slope

3. Conclusions

We developed a method to measure a very large amount of radiation in a very short period of time using a data acquisition system and to resolve the signal overlapping phenomenon. By measuring the rising slope of the signal, fast measurement was possible, and thus the signal pile up could be prevented. Since it can be applied to a general-purpose data acquisition system, it can be used to develop a detector that exhibits excellent performance without developing a dedicated system.

REFERENCES

[1] K. Shimazoe, D. Kim, M. Hamdan, Y. Kobayashi, K. Kamada, M. Yoshino, Y. Shoji, K. Sakamoto, F. Acerbi, and A. Gola, An energy-resolving photon-counting X-ray detector for computed tomography combining silicon-photomultiplier arrays and scintillation crystals, Communications Engineering, Vol. 3, Art. No. 167, 2024.
[2] P. Otfinowski, G. W. Deptuch, and P. Maj, FRIC-a 50 μm pixel-pitch single photon counting ASIC with Pattern Recognition algorithm in 40 nm CMOS technology, Journal of Instrumentation, Vol. 15, Art. No. C01016, 2020.
[3] R. Ballabriga, J. Alozy, G. Blaj, M. Campbell, M. Fiederle, E. Frojdh, E. H. M. Heijne, X. Llopart, M. Pichotka, S. Procz, L. Tlustos and W. Wong, The Medipix3RX: a high resolution, zero dead-time pixel detector readout chip allowing spectroscopic imaging, Journal of Instrumentation, Vol. 8, Art. No. C02016, 2013.
[4] T. Poikela, J. Plosila, T. Westerlund, M. Campbell, M. De Gaspari, X. Llopart, V. Gromov, R. Kluit, M. van Beuzekom. F. Zappon, V. Zivkovic, C. Brezina, K. Desch, Y. Fu and A. Kruth, Timepix3: a 65k channel hybrid pixel readout chip with simultaneous ToA/ToT and sparse readout, Journal of Instrumentation, Vol. 9, Art. No. C05013, 2014.
[5] R. Bellazzini, G. Spandre, A. Brez, M. Minuti, M. Pinchera and P. Mozzo, Chromatic X-ray imaging with a fine pitch CdTe sensor coupled to a large area photon counting pixel ASIC, Journal of Instrumentation, Vol. 8, Art. No. C02028, 2013.
[6] S. Gómez, D. Sánchez, J. Mauricio, E. Picatoste, A. Sanuy, A. Sanmukh, M. Ribó and D. Gascón, Multiple Use SiPM Integrated Circuit (MUSIC) for Large Area and High Performance Sensors, Electronics, Vol. 10, Art. No. 961, 2021.
[7] Data acquisition system, ALARE Laboratory Web. https://www.aralelab.com/index.html#section-02