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A simple and versatile data acquisition system for software coincidence and pulse-height discrimination in 4πβ–γ coincidence experiments

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ABSTRACT

A simple but versatile data acquisition system for software coincidence experiments is described, in which any time stamping and live time controller are not provided.

Signals from β- and γ-channels are fed to separately two fast ADCs (16 bits, 25 MHz clock maximum) via variable delay circuits and pulse-height stretchers, and also to pulse-height discriminators. The discriminating level was set to just above the electronic noise. Two ADCs were controlled with a common clock signal, and triggered simultaneously by the logic OR pulses from both discriminators. Paired digital signals for each sampling were sent to buffer memories connected to main PC with a FIFO (First-In, First-Out) pipe via USB.

After data acquisition in list mode, various processing including pulse-height analyses was performed using MS-Excel (version 2007 and later). The usefulness of this system was demonstrated for 4πβ(PS)–4πγ coincidence measurements of ^{60}Co, ^{134}Cs and ^{152}Eu. Possibilities of other extended applications will be touched upon.

1. Introduction

For several decades, 4πβ–γ coincidence counting method (Campion, 1959) has been employed as the major technique for radionuclide standardization, in which extrapolation techniques are often used to determine most of efficiency dependent corrections. For the determination of the efficiency functions required in this procedure, it is necessary to perform many 4πβ–γ coincidence measurements for different β-efficiencies. To change β-efficiencies, adjustments of self-absorption and/or additions of absorber foils have historically been used. As an alternative, electronic discrimination techniques based upon pulse-height discrimination of signals from a pressurized 4πβ–counter or a plastic/liquid scintillation detector has come into wide use (Baerg, 1973a). Pulse-height discrimination can be done manually by the adjustments of discrimination level or by the use of ladder type discriminators in a conventional 4πβ–γ coincidence counting system. In measuring complex decaying nuclides, the slope and shape of the efficiency functions are dependent on the γ-window setting, and hence the 4πβ–γ extrapolation curve should be determined for each of different γ-window settings. In order to avoid such tedious procedures, the use of a two dimensional list-mode-measurements (Miyahara et al., 1987) or software coincidence techniques has become more popular instead of the use of a conventional 4πβ–γ coincidence counting. So far techniques and various applications of such digital coincidence systems were already reported by several authors (e.g.,: Buckman and Ius, 1996; Park et al., 1998; Hwang et al., 1999; Butcher et al., 2000; Hevelka et al., 2002, Chernyshev et al., 2004) and are currently used in some of standardizing institutes (Keightley and Park, 2007; Bobin et al., 2010). In this paper, we will describe a very simple but versatile data acquisition system developed in NMIJ for such purposes.

In order to demonstrate the performance and usefulness of this system, 4πβ(PS)–4πγ coincidence measurements with a detector configuration of a sandwich type plastic scintillator(PS) and a well type NaI(Tl) scintillation detector were carried out for ^{60}Co, ^{134}Cs and ^{152}Eu using this digital coincidence counting system. It should be emphasized that all data analyses including pulse-height analyses, bi-dimensional analyses for making efficiency functions and extrapolations can be performed by the conventional MS Excel from a huge number of list-mode data-pairs.

2. Data acquisition system

The basic concept of our system succeeds to the first design described by Buckman and Ius (1996). However, since no time stamping system or live time controller are provided in our system, the system becomes simpler in both of hard- and softwares, and is very easy to operate.

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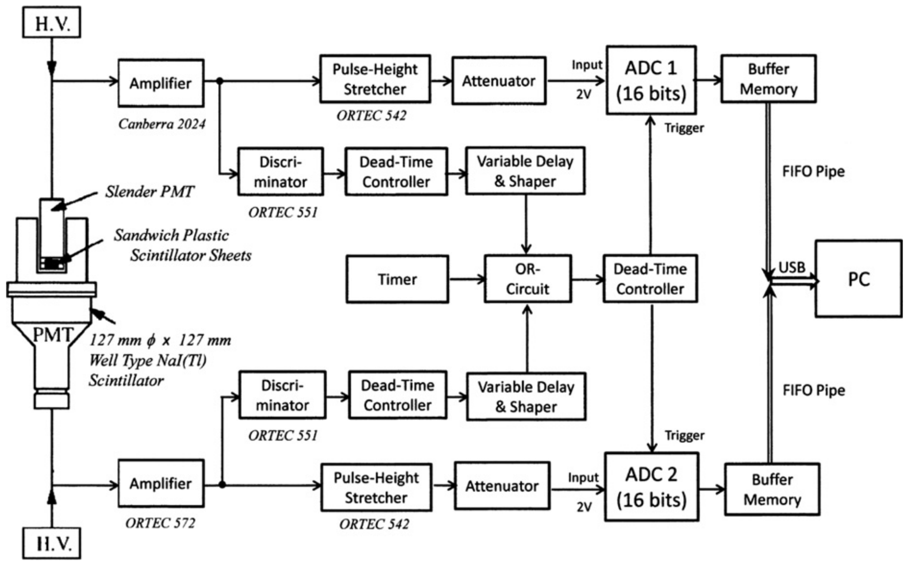
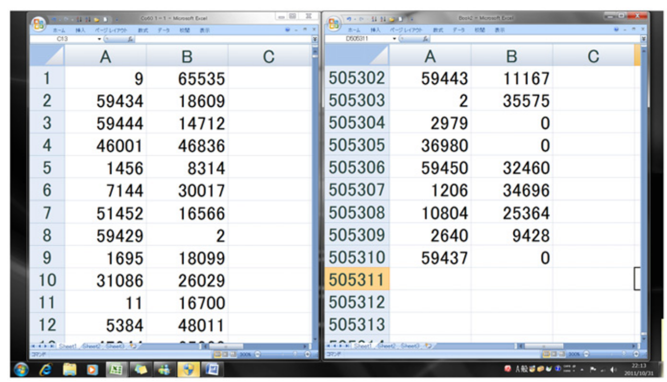


Fig. 1. Schematic diagram of our bi-dimensional data acquisition system with a $4\pi\beta-4\pi\gamma$ detector configuration composed of a sandwich type 4π plastic scintillation detector and a well-type NaI(Tl) scintillation detector.

The basic diagram of our data acquisition system is shown in Fig. 1. In order to demonstrate the performance of this system, we used a $4\pi\beta-4\pi\gamma$ detector configuration composed of a 127 mm$\phi\times$127 mm well type NaI(Tl) scintillation detector (well diameter: 30 mm) as the γ-detector and a slender plastic scintillation detector as $4\pi\beta$–detector (Kawada et al., 2004; Yamada et al., 2006). The source was sandwiched between two 1 mm thick plastic scintillators. In both of the β- and γ-channels, the amplified pulses from an amplifier (Canberra 2024 for β-channel, ORTEC 572 for γ-channel) are fed to separately to a fast ADC (16 bits, 25 MHz clock in maximum) via a pulse-peak-height stretcher (ORTEC 542) and an attenuator. To meet the requirement for the input voltage level of the ADC (2V maximum) and to accept the saturated pulses especially in the β-channel, use of a variable attenuator in the final stage of the analog electronics is important. In the output of the linear amplifier a conventional pulse-height discriminator (ORTEC 551 timing single channel analyzer as an integral mode) was connected whose discrimination level was set for slightly higher than the noise level. The output logic pulses from both discriminators were fed to a mixer circuit (logic OR) after passing a dead-time controller and a variable delay. Most of logic circuits including dead-time circuits, variable delay circuits etc. are laboratory made by the use of TTL ICs, and installed in a two span IEC module. These two ADCs (manufactured by Turtle Industries Co. Ltd. Japan together with the USB interface) in both channels are controlled with a common clock signal (25 MHz in maximum), and triggered simultaneously by the logic pulses from the mixer. In the use of this system, timing adjustments between the two analog pulses and two trigger signals are very important. Different time constant settings of the two linear amplifiers of β- and γ-channels are therefore not recommended, and critical timing of the relative delay can be adjustable with ORTEC 542 pulse stretcher in a range within 5 μs. A variable delay circuit and dead-time controller were provided prior to digitization. The resolving time of the OR circuit was usually chosen as 1 μs. The width of stretched analog pulses can be also adjusted up to 5 μs in a case of ORTEC 542. The delay in the process of pulse-height stretching was somewhat dependent on the pulse-height especially for the saturated pulses, considerably large relative time jitter being observed. In order to avoid inadequate samplings, the pulse width of stretched analog pulse was chosen as 4 μs, but this pulse-width can be shortened by the use of a strobe technique including clock pulses. In order to suppress the effect of after-pulses in the use of plastic scintillator, the dead-time of β- and γ-channel were set equal to 10 μs or more in the present experiments. If a pressurized $4\pi\beta$–counter is used, however, shorter dead times are permissible. Paired digitized signals obtained with both ADCs in each sampling are sent to a temporary buffer-memories (2 MB each) which are connected to the main PC with FIFO (First-In, First-Out) pipes via USB in a form of binary code. By the use of this system, the total acquisition number of the data-sets has no limits in practice. However, when MS Excel is used, the total triggering number is restricted below $2^{20}=1{,}048{,}576$ for one data acquisition. This will be solved by using multiple columns in the Excel spreadsheet, in which many more acquisition numbers can be treated. After finishing data acquisition, the binary code files are converted to CSV files for use with MS Excel, as shown in Fig. 2, where the column A is for β-channel, column B for γ-channel, respectively. In this figure, only the first and last parts are shown for the illustration. The data pairs can be classified the following three categories;



	A	B	C
1	9	65535	
2	59434	18609	
3	59444	14712	
4	46001	46836	
5	1456	8314	
6	7144	30017	
7	51452	16566	
8	59429	2	
9	1695	18099	
10	31086	26029	
11	11	16700	
12	5384	48011	

	A	B	C
505302	59443	11167	
505303	2	35575	
505304	2979	0	
505305	36980	0	
505306	59450	32460	
505307	1206	34696	
505308	10804	25364	
505309	2640	9428	
505310	59437	0	
505311			
505312			
505313			

Fig. 2. Examples of data-pairs obtained in an Excel table. Only first and last parts are shown for illustration.

(1) Only a β-channel event is detected. In this case, a pulse-height information was recorded in the column A, and column B showed a small pulse-height near the noise level for the γ-channel (see rows 8 in Fig. 2).
(2) The converse of (case 1). (see rows 1 and 11).