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Improve ordinary low alpha particle detector by digital filter signal processing

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ABSTRACT

In this article, we focus on certain digital filter signal process with the capacity in both reducing the environmental noise and improving the efficiency of the ordinary low alpha particle detector. Through specific digital filter technique, noise used to be recognized as current signals could be successfully removed. Which could be quite practical in conducting the ordinary low alpha particle detector in a general environment as in an electric power clean environment.

1. Introduction

The operation and the techniques applied at low background particle detectors have become more and more important, due to the need of high energy physics and semiconductor main-stream industry. Since the reducing of gate width will cause single event effect or soft error rate, ultra-low alpha materials for wiring will be required once the gate length line down to 65 nm. Moreover, by the recent development for space traveling, a comprehensive design for radiation resist circuit/chip is still needed.

Since the lack of consistency in the measurements of cosmic ray flux due to soft fails, the new measurements are seldomly agree with old measurements. Therefore, Ziegler., et al [1,2] addressed that the measurement of cosmic ray flux would face difficulties in maintaining the accuracy during the measurement process, such as the influence of surroundings on the experiment. So to develop a reliable noise resistance method for acquisition data is very important for the future technology development. In the traditional methods, the low alpha counting rates were measured by using the proportional counter; therefore, it has been employed in estimation of alpha emission from electronic materials. The proportional counter can translate analogue data into digital data through the combination of preamplifier, sharping amplifier and analog-to-digital converter. However, in general the noise used to combines with real-time signal and recorded as real data. Gordon, Michael S., et al. [3–5] used the algorithm based on both the rise time and signal amplitude, and proposed that, the gap between cathode and anode to be significantly greater than the range of alpha particles in Argon (~5 cm for energy of α = 4.5 MeV). In this study, we want to develop a real-time signal processing method that can prevent the noise out of signal. Therefore, we can recognize that the acquired signals are true or false for long periods of measurement.

In the past, the acquired analog data has digitized by using the shaping amplifier, which have better signal to noise ratio. Even without the original meaning, the signal height could be gained through peak detect circuit. Which revealed that the signal could not be distinguished as real or false one immediately. If noise is larger enough then the shaping amplifier will recognize it as a true signal, as like the Analogue to Digital Converter (ADC). This traditional method will increase counts include noise in counting alpha emission event. In the circuit model, if data can converge towards to the detector, then we can use the original signal to distinguish true or fake signals in the acquired data. As a result, one can reduce false count significantly in the measurements. Thus, our algorithm is to use a fast ADC to get data from preamplifier, meanwhile, we analyze the acquired data to determine the real data or false one.

When we measure the low alpha events (low flux), sometimes the random noise will cause the misjudgment of shaping amplifier by considering the noise as a true signal and results in output as Gaussian signal into ADC module. It will be accepted by Multichannel Analyzer (MCA). Usually, the noise caused by surrounding environment or from wireless communication etc. would lead to the

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noise interfering during the counting process. These phenomena were observed by digital oscilloscope, as shown in Figs. 1 and 2 . In case of real signal, the output signal from the preamplifier has shown as curve I in Fig. 1, which depicts the exponential decay with longer decay time. When this output signal of preamplifier sent through the shaping amplifier, the resultant signal appears with Gaussian shape (Curve II in Fig. 1). In case of the noise or fake signal, the output signal of preamplifier is not an exponential curve (curve I in Fig. 2). Even though, when this noise signal sent through the shaping amplifier, the output signal exhibits with Gaussian shape (Curve II in Fig. 2). Thus, the noise or fake signal will cause the wrong counting rate, especially in dirty environment.

For low alpha counting, there are only 2–6 counts every hour, so the noise will appear unwantedly during the measurement. In traditional way, one may use LC or RC passive filter to screen out high frequency noise. Therefore, ferrite coils used to employ in the amplifier circuit, transmission line cable or power line to remove possible noise coupled into co-axial cable and then feeding the signal into shaping amplifier. Due to the complexity of the components within a low alpha counting system, it is difficult to reset the system and usually takes long time to find out a noise source in a new environment. In this study, we have proposed a digital data acquisition method that can remove the noise from the original signal to recognizing the real signal efficiently and easier to install or move a low alpha counting system.

2. Method and results

In this article, a real-time DSP *(Digital Signal Processing)* algorithm has been developed and tested to discriminate real pulses form the noise events (Fig. 3). First, we used a DSP system to replace the former shaping amplifier and correction circuits. When we started to search the alpha particle pulse, attained the data by 666 k/s sampling rate at Analog-to-Digital Convertor (ADC) with a single digital system that processes the sampled waveform from the preamplifier. In the past, design of analog devices has limitations in components size, number and cost. Therefore, it is not able to separate noise from the pulse signals easily. In the other hand, acquired digitized data translation requires a sufficient speed and effective counting capacity for achieving the digitally determined pulse height, the rise time and the decay time of pulse. In this paper, we analyzed the raw data directly without using electronic circuits from pre-amplifier. Through USB high-speed protocol (480 Mb/s), ADC data could transfer to personal computer (PC) and then distinguish the digital sampled data to be noise or pulse events for real-time counting. In order to test our algorithm, we use Am-241 sample for the detector.

2.1. Search the peak for a pulse event

There are many applications in determining pulse peak algorithm as physiological signals like Electrocardiography (ECG) [6–8] etc. Jacobson [7] issued the auto-threshold peak detection method for physiological signals and mentioned that ECG is a type of signal alike to alpha particle pulse signal. Similarly, the methods above could be applicable in searching of peaks in alpha particle application. Since the signals from preamplifier are weak, ADC hardware drivers has been employed for impedance match (low impedance) and translate voltage level to fit ADC input voltage, which process can strengthen the signals gained in this research. In addition, we have set the offset level to 1.6 V for avoiding negative values from preamplifier by viewing those negative records as unreasonable ones. Therefore, the voltage for 12-bit ADC device located from 1.6 V to 3.3 V.

Peaks are defined as the maximum values within two consecutive local minima. Hence, it is necessary to define threshold value v as the minimum value (Eq. (1)).

$$ify(t) > y(t-1)\ and\ y(t) > y(t+1)\ and\ y(t) > v \tag{1}$$

where $y(t)$ refers to time series data.

However, there are still so many local peaks caused by noise or the sampling errors from ADC device. Use the Least Squares Fitting method [9,10] to (1) filters the local smaller peaks and (2) find local maxima, which could be viewed as a peak point candidate for a pulse event. Least Squares Fitting needs a parametric model to relate the response data and the raw data with polynomials coefficients. The fitting process is an estimate of the model coefficients; by setting the least squares method to minimize the summed square of residuals, we can obtain the coefficient estimates. The summed square of residuals of random noise signals is much larger than the real world signals. Hence we could use this method to filter noise signals by their random characteristic. By using this algorithm, the random noise events (shown in Fig. 2) can be filtered out successfully through our test.

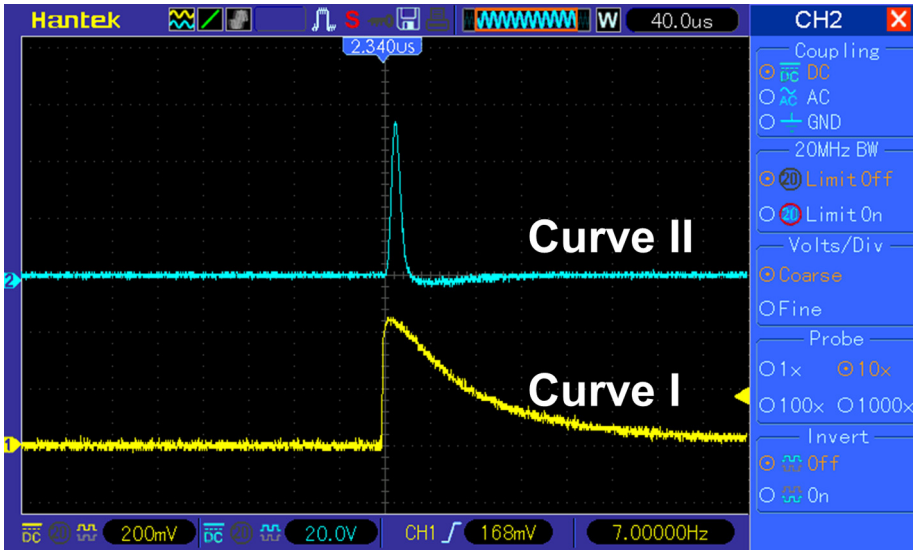

Fig. 1. In case of real signal, the outputs signal of preamplifier (Curve I) and the output signal of shaping amplifier (Curve II).

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