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Review of research on nuclear signal pulse shaping

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Abstract

Pulse shaping can greatly improve the signal-to-noise ratio and has been widely used in nuclear signal processing. This paper gives a brief overview of the current research status of nuclear signal pulse shaping at home and abroad. It describes in detail the three traditional pulse shaping methods of quasi-Gaussian shaping, triangular shaping and trapezoidal shaping, and discusses the nuclear pulse signal shaping that has appeared in recent years. And a brief introduction to the nuclear pulse signal shaping methods that have emerged in recent years is also given.

Keywords

Pulse shaping; Quasi-Gaussian shaping; Trapezoid shaping; Triangular shaping.

1. Introduction

Exponential pulse is an essential output of nuclear detector, and pulse shaping is needed to reduce the influence of electronic noise, pulse accumulation and ballistic deficit on the energy resolution of nuclear detector [1-3].There are many researches on nuclear pulse shaping at home and abroad. Xiao Wanyun et al. from Tsinghua University obtained the trapezoidal shaping algorithm [4] through theoretical derivation, and analyzed part of the performance of the algorithm. The results showed that the shaping effect of the algorithm could meet the requirements of the nuclear spectrometer system under the condition of obtaining appropriate parameters. Liu Yinyu et al. from Sichuan University started with the analysis of CR-(RC) M circuit [5], deduced the transfer function of digital CR-(RC) M system, and tested and analyzed its shaping characteristics in frequency domain and time domain. Li Dongcang, lanzhou University, et al., based on the two-level Sallen-Key shaping model based on discrete components [6-7], used different types of simulation signals to complete the implementation of each simulation platform and FPGA on-chip algorithm, and compared and analyzed the influence of parameter selection on system performance. Zhang Huaiqiang et al. from Donghua University of Technology studied the key technologies of digital Gauss shaping algorithm in the digital system of nuclear spectrometer and carried out comprehensive analysis and verification on the test platform.Valentin. T.j. Danov et al. [8-10], an American researcher, used ADC to perform analog-to-digital conversion of signals and realized the filtering process of digital core signals with the help of computer, which verified the feasibility of the shaping algorithm of real core signal filtering. Alberto Regadio et al. [11] from Spain studied the real-time adaptive digital filtering shaping method in the nuclear spectrometer system, mainly studying the correspondence between ADC sampling frequency and the flat top of trapezoidal shaping. Alberto Regadio et al. used genetic algorithm to study the digital shaping algorithm of nuclear pulse signals under arbitrary noise. Marco Salathe et al. [12] from Germany studied digital filtering shaping technology in nuclear radiation detection based on HPGe detector, and mainly compared and analyzed the influence of trapezoidal shaping and quasi-Gaussian shaping on energy resolution of energy spectrum data. In recent years, more and more scholars have carried out researches on bipolar shaping methods, such as bipolar trapezoidal shaping, bipolar triangle shaping, bipolar tip shaping, bipolar zero-area shaping, etc. [13-15]. These new methods provide new ideas for future nuclear signal processing.

2. Basic requirements of digital shaping

The basic requirements of digital shaping are as follows: the shaping output is linear, that is, the output amplitude of the signal is proportional to the energy of the incident particle; The shaping principle is simple and the shaping parameters in the numerical model can be adjusted to control the amplitude and pulse width of the output signal. The input signal which produces the accumulation should have certain recognition and resolution ability; For the continuous input nuclear pulse signal, the shaping scheme can accurately reflect the amplitude information. The signal processed by digital shaping model has a high signal-to-noise ratio.

3. Traditional pulse shaping method

Quasi-Gaussian shaping

Quasi - Gaussian shaping is widely used in nuclear electronics because of its simple principle, superior performance and easy realization. Among them, CR-(RC) M and Sallen-Key are the most classic Gaussian shaping filters. With the development of digital nuclear spectrum measurement system characterized by the application of high-performance digital signal processor (FPGA, etc.) to effectively analyze the nuclear pulse signal, the nuclear signal is collected by a fast and high-resolution ADC. By using CR-(RC) M and Sallen-Key digital Gaussian filter shaping recursive model, the gaussian filter shaping of digital core pulse signal can be realized effectively. Digital Sallen-Key shaping has better energy resolution performance. And the digital CR-RCM shape has better counting ability.

Trapezoid (triangular) shaping

Trapezoidal shaping algorithm is commonly used in digital nuclear signal pulse shaping processing method, the algorithm is simple, rapid, pulse falling fast, pulse width, etc, is helpful for real-time processing, as long as the pole zero compensation can eliminate the pulse to return to baseline right down, and the energy resolution and pulse passing rate optimization choice. The edge width and top width of the trapezoid are adjustable. The triangle can be considered as a special case of the trapezoid with zero top width. The recursion model of digital trapezoid (triangle) is generally derived by Z transformation or functional convolution.

4. Summary

Filtering is to improve the signal-to-noise ratio Angle to shape the output signal into a certain shape. In energy spectrum measurement, there are other factors that require the signal shape: in order to reduce the impact of accumulation and baseline fluctuation on the energy spectrum line, the width of the signal is required to be as narrow as possible, and the trailing time is short. In order to reduce the influence of trace loss, the top of waveform is required to have a certain degree of flatness, etc. In addition to satisfying the shape of a high signal-to-noise ratio, the amplitude is required to have a linear relationship with charge Q. The pulse width is as narrow as possible to accommodate high count rates and to minimize accumulation and baseline fluctuations; In order to prevent large signals will block the circuit, try not to appear in the tail recoils. These requirements are put forward from different angles, and sometimes they are contradictory. Therefore, in the specific experiment, the requirements on the shape of the output signal should be put forward according to the actual situation.

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