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Efficiency of background suppression by tagged neutron technology

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Abstract

The possibility of background suppression by spatial and time discrimination of events stipulates the potentialities of the nanosecond tagged neutron technology (NTNT) for neutron analysis. For practical application of NTNT, the multi-detector systems and high intensity (up to 1×10^8 1/s) neutron generator should be used. The total intensity of signals can exceed 1×10^6 1/s from all gamma-detectors and 1×10^7 1/s from all alpha-detectors. A preliminary "on-line" data processing by hardware sufficiently facilitates the data transmission interface and computer equipment. The basic criteria of processing (selection of useful events) are the presence of signals from alpha- and gamma-detectors in the certain time interval (tracking interval), range of gamma-ray energy and absence of foldover of the signals. The suggested architecture of data acquisition and control system is discussed. The basic components of background and factors affecting the total time resolution are examined. The preliminary results demonstrate high efficiency of NTNT for suppression of background by spatial and time discrimination of events.

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1. Introduction

One of basic challenges of neutron technologies of remote control is the high background affecting the accuracy of measurements. Last years, the nanosecond tagged neutron technology (NTNT) has been rapidly progressing [1]. This technology provides effective (by 2–4 orders of magnitude) suppression of background by spatial and time discrimination of events. NTNT is the most effective for solving such tasks as the detection, identification and localization of chemical explosives. The composition of the object is identified by analyzing the spectrum of gamma-rays induced by inelastic neutron scattering on carbon, nitrogen and oxygen nuclei (that enter into the composition of explosives).

NTNT is based on the following principle. Neutrons are produced at the $T(d,n)^4He$ reaction, while deuteron beam bombards the tritium target. Vectors of escape of neutron and associated alpha-particle (^4He) are uniquely correlated [2]. A multipixel position- and time-sensitive alpha-detector measures the time and position of incident alpha-particles. It provides the angle and time of neutron escape (the "tags" of neutron). The fast "tagged" neutrons are directed to an object of interest and induce characteristic gamma rays produced through the inelastic scattering of neutrons. Individual nuclei inside the object are identified by recording energy spectrum of emitted gamma-rays by a gamma-detector array.

A data acquisition and control unit traces the number (position) of gamma-detector, gamma-ray energy and recording time, as well as pixel number and recording time of alpha-particle. The speed of 14 MeV neutron is as high as 5.2 cm/ns. Thus, the precision of timing for event

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localization with the accuracy of several cm should be around 1 ns.

For practical application of NTNT, the multi-detector systems and high intensity (up to 1×10^8 1/s) neutron generator should be used [1]. The total intensity of signals can exceed 1×10^6 1/s from all gamma-detectors and 1×10^7 1/s from all alpha-detectors. The transmission of such stream of data to the computer and its processing might heavily complicate the data transmission interface and computer equipment. Thus, it is reasonable to implement the on-line preliminary data processing by hardware. The basic criterion of selection of useful events is the presence of signals from alpha- and gamma-detectors in the certain time interval (tracking interval), range of gamma-ray energy and absence of foldover of the signals.

2. Data acquisition and control system for NTNT

The flow block of data acquisition and control system (DAC) system suggested by Russian Research Center "Kurchatov Institute" [2] and then realized in several versions is given in Fig. 1. The signals from gamma-detectors come to the gamma-channel units; each unit processes signals from several gamma-detectors. The master is always the signal from gamma-detector. The constant fraction discriminator CFD at the input of each gamma-channel generates the logic signal T_γ that starts the time-digital converter TDC and encodes the number of activated gamma-detector (R_γ). The shaping amplifier ShA provides the required resolution of measurements of signal amplitude by analog digital converter ADC.

The alpha-channel unit issues a logic signal T_α (time stamp of alpha-particle recording) and code of the number of activated pixel of alpha-detector (R_α). These signals are transmitted to the timing and address buses of alpha-channels and shared by all units of gamma-channels. As far as the counting rate of gamma-detectors is much less than those from the alpha-detector the master is always the signal from the gamma-detector. However, as far as the signal from associated alpha-detector comes first, the delay line DL (several dozens ns) is shifted the time of arriving of the T_α signal to TDC after the T_γ signal for proper timing.

The univibrator UV_T generates the pulse with duration equal to the tracking interval. If the T_α signal from the alpha-channel comes during the tracking interval, it initiates ADC to measure the amplitude of gamma-signal A_γ and stops TDC that issues the code of time between signals from alpha- and gamma-channels $T_{\alpha\gamma}$. After completing the measurements, the codes A_γ, R_γ, R_α and $T_{\alpha\gamma}$ are packed by the microprocessor and sent to the computer PC. The anticoincidence unit AC and foldover discriminators prevent the writing of the event at the presence of two or more signals from detectors during the tracking interval.

The main features of DAC systems developed by this scheme are as follows:

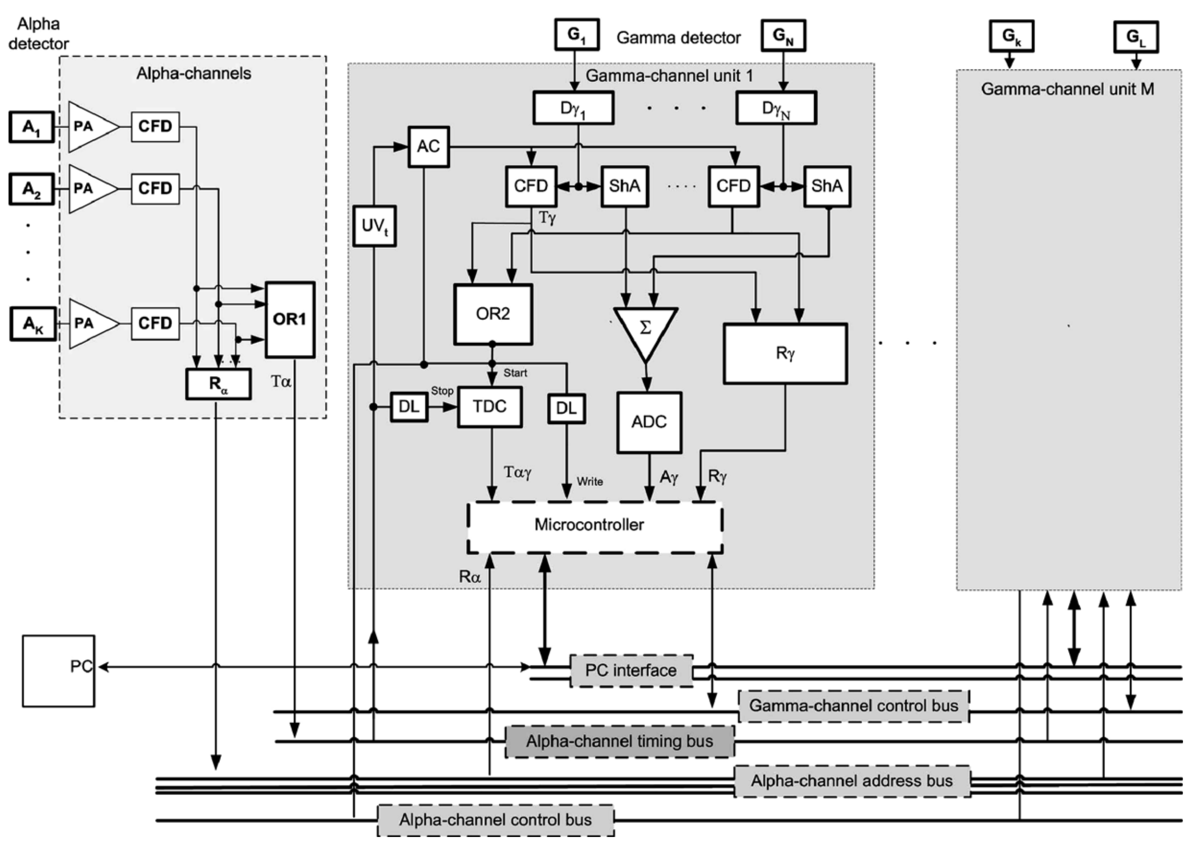

Fig. 1. Flow block of DAC system.