Design of Electronic System with Simultaneous Registering of Pulse Amplitude and Event Time Applied to 4πβ−γ Coincidence Method

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Abstract– **In the present work, a new data acquisition electronic system for 4πβ-γ coincidence measurements is proposed which allows simultaneous recording of pulse height and time of occurrence for each nuclear event. The present paper work discusses the conceptual design of the Data acquisition System (DAQ)-based electronic unit that has been specifically developed for this system, focusing on reliability and low cost.**

I. Introduction

THE 4πβ-γ coincidence method for absolute radionuclide activity measurement is a primary standardization method in Nuclear Metrology due to: high accuracy and because it depends only on observable quantities.

A typical system is composed by a 4π proportional detector for detection of X-rays, electrons, alpha and beta particle, coupled to a single or a pair of scintillation or semiconductor detectors for gamma-ray spectrometry. Usually, in order to obtain the activity value the Linear Extrapolation Method [1] is applied. In this method, observed activity is measured as a function of a parameter associated to the efficiency of the 4π detector, and the extrapolated value for unitary efficiency corresponds to the activity of the radioactive sample.

The attained accuracy depends on the curve behaviour and on the number of experimental points in the fit. Usually tens of points are required, which demands measurements than may span for several days, to achieve the desired accuracy.

In order to overcome this difficulty, some acquisition systems have been proposed [2-4] which allow simultaneous recording of pulse height and time of occurrence for the events from each of the channels, namely: beta and gamma, so that the whole analysis can be performed after the measurements is completed. In this way, a single measurement is required, making the process much faster.

The Nuclear Metrology Laboratory (Laboratório de Metrologia Nuclear - LMN) from the Nuclear and Energy Research Institute (Instituto de Pesquisas Energéticas e Nucleares - IPEN) is developing a 4πβ-γ Digital Coincidence System (DCS), using a data acquisition and recording card from National Instruments [5].

The present work includes the development of a special software designed in LabVIEW, Version 8.5, for data acquisition control and analysis, based on a methodology known as Digital Coincidence Counting or Software Coincidence Counting. In the following sections the basic design and desired characteristics of this DCS are discussed.

II. Methodology and System Description

The activity measurement is executed on two steps: the *Data Acquisition* in which pulses heights and time of occurrence are measured, and *Analysis* in which the stored data is processed, in order to obtain the radioactive source activity.

The operation is based on registering the nuclear pulse characteristics (amplitude and time) onto independent data files for each measurement channel: beta and gamma. The beta channel is composed by a proportional counter and associated electronics and the gamma channel consists of two NaI(Tl) scintillation counters and associated electronics.

The pulse heights and respective arriving times of detected beta and gamma events are the representative information, necessary for software coincidence analysis. Additional information may be required, depending on the needs, such as pulse time widths or the whole shape, in order to verify what event is responsible for the detected pulse.

The software reads the registered data from the files, computing all measurement counts such as: beta, gamma and coincidences and performing all calculations necessary to obtain the radioactive sample activity and corresponding uncertainties, including the extrapolation curve.

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Digital Coincidence System (DCS)

In this system, the pulse height and the time information are collected for each event. Signals from up to three detectors can be processed by the data acquisition card from National Instruments, version NI PCI – 6132 [4]. This card has four independent channels with analog-to-digital converter (ADC) and two 24 bits counters. The DCS diagram is shown in Fig. 1.

Software for Data Acquisition and Analysis

The software designed for the analysis reads the registered data from the files, computing all the measurement counts, beta, gamma and coincidences, and performing all calculation to attain the radioactive sample activity and uncertainties.

Each record contains the data from each of the three inputs. The dead time is composed by a constant-time length part common to all channels, set to a value long enough for processing all pulses, and a second part that changes with the pulse arrival time.

The present system uses the National Instruments (NI) software for data acquisition LabVIEW 8.5. With this NI technology, a wide variety of instruments can be implemented, using personal microcomputers (virtual instruments, or VI technology). LabVIEW contains a comprehensive set of tools for acquiring, analyzing, displaying, and storing data, as well as tools for helping code troubleshooting. With this software system, user interfaces can be developed, including the necessary control units (knobs, sliders, buttons, etc.) and data indicators (numerical, graphs, led's, etc.). After setting up the user interface, VIs and structures can be added, in order to control front panel objects. This kind of code is implemented by means of a block diagram.

The conception of the present system establishes a limit for coincidence acceptance to 2μs time interval. This limit represents a restriction only to cases when metastable level transitions must be analyzed.

The coincidence analysis software is designed to read data from beta/gamma record files, search for coincidence events (taking into account the beta-gamma time jitter) and determine beta, gamma and coincidence counting.

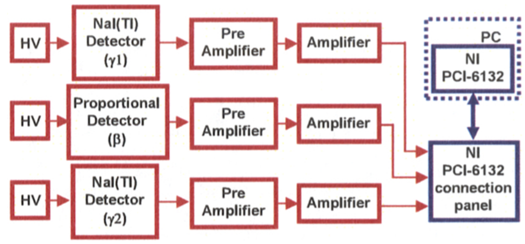

Fig. 1. Block. Diagram of the DCS System.

III. Results

Preliminary measurements were performed using 12 bit resolution setting for analog channels, and input voltage in the range of 0-10 V from a nuclear spectroscopy amplifier coupled to a NaI(Tl) crystal. A ^{137}Cs radioactive source was used for generating the pulse height spectra, as shown in fig. 2.

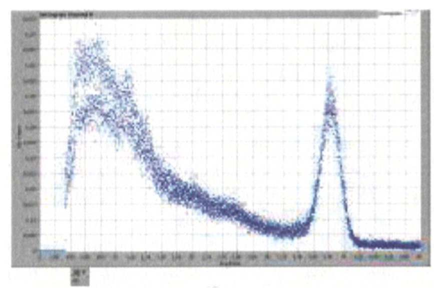

Fig. 2. Channel 0 *DCS* ^{137}Cs Spectrum.

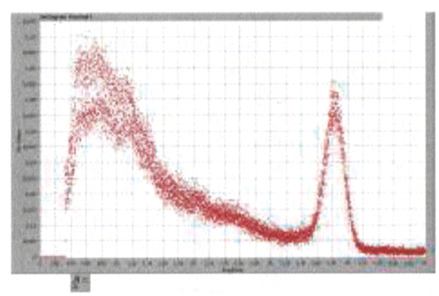

Fig. 3. Channel 1 *DCS* ^{137}Cs Spectrum.

An additional measurement was performed connecting the same gamma signal to both channels 0 and 1. The measurement time was also kept the same and an identical spectrum was observed, as shown in fig. 3.

Fig. 4 shows a graph display, one of the several frontal panel objects developed in the present work.

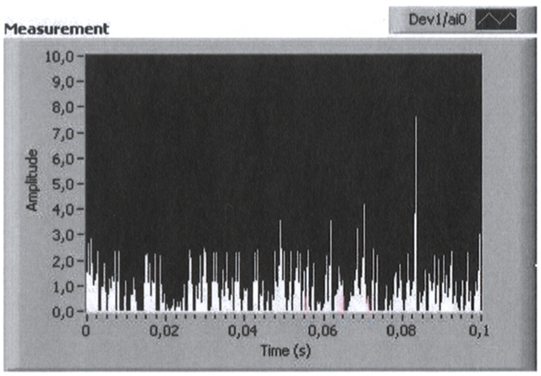

Fig. 4. A front panel object showing the input gamma pulses at *DCS* Channel 0.

Another measurement was performed with a ^{60}Co radioactive source, using the same acquisition configuration as explained above for the ^{137}Cs sample. Differently, another set of beta/gamma detection system was used: a NaI(Tl) scintillation (gamma) and a gas proportional counter $4\pi\beta$. The deposited beta energy spectrum and the gamma spectrum were obtained in a 2000 s measurement. These spectra are shown in fig. 5 and fig 6.

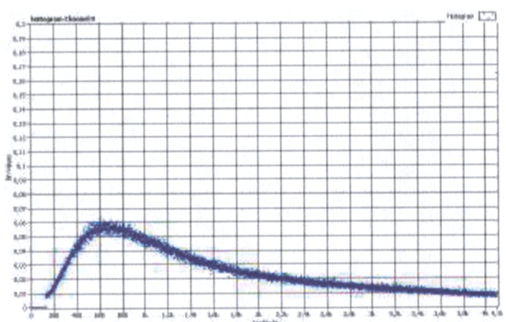

Fig. 5. Channel 0 ^{60}Co deposited beta energy spectrum.

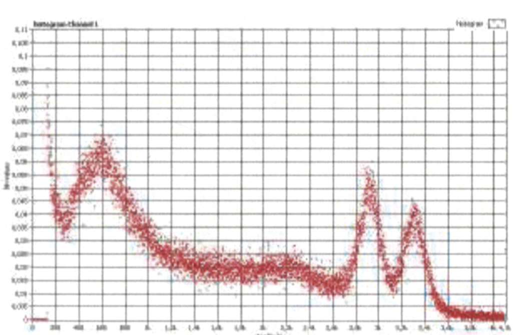

Fig. 6. Channel 1 ^{60}Co gamma energy spectrum.

At present, the coincidence analysis software is under development. The binary data files were obtained by Monte Carlo simulation. The system data files are in ASCII format, to make analysis easier. For the final version, the data files format will be changed to binary in order to reduce the file size.

IV. Conclusions

The concept of digital coincidence counting has been introduced and the system under development is described. The prototype comprises a custom-built data acquisition system and associated PC software, independent ADC's coupled to channels with a 14-bit maximum resolution. The preliminary experiment used 12-bit limit. Continuous sampling and storage of the pulse trains were achieved through hardware compression of the data. Stored pulse trains are processed "off-line" by dedicated software; therefore the system is extremely versatile. It is anticipated the development this system will lead to improvements in the radionuclide standardization methods by the LMN.

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