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PERFORMANCE OF A PIN PHOTODIODE USED AS A RECOIL-PROTON SPECTROMETER UNDER NEUTRON-GAMMA FIELD FROM AN IRRADIATOR FACILITY (AmBe SOURCE) USING PULSE SHAPE DISCRIMINATION ANALYSIS.

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ABSTRACT

As a requirement in Radiation Protection, there is often a need to determine the relative number of neutron and photon radiation fields for personnel dosimetry and for determination of irradiation effects on materials. A PIN photodiode performance under a gamma-neutron field (flux around 4.10^4 $n.cm^{-2}.s^{-1}$) using pulse shape discrimination technique has been investigated. Pulse-shape discrimination (PSD) has been used for about 40 years as a method to obtain estimates for dose in mixed neutron and photon fields. The pulse-shape discrimination used in this work was based on an implementation of a Labview virtual instrument in order to process signal pulses from the semiconductor detector and preamplifier to perform discrimination of neutron and gamma pulses. This study intends to be used as a laboratory experiment in nuclear training courses and as a proposal for a neutron monitoring instrument in Radiation Protection routines in the IEA-R1 nuclear research reactor.

1. INTRODUCTION

Knowledge of effective dose due to neutrons for radiation protection purposes is of importance in controlled areas of nuclear power plants, research laboratories and facilities involved in the nuclear fuel cycle, since neutrons often account for a substantial fraction of the total effective dose. Due to the high variation in neutron spectra in the laboratories, area monitoring is not sufficient and personal neutron dosimetry is definitively required.

The two main problems of an individual neutron dosimeter are (a) to provide a high sensitivity to neutron and a low response variation as a function of the neutron energy, and (b) to separate the contribution of neutron and photon components from the radiation field to the total dose equivalent.

Semiconductor detectors are able to meet them at least partially. In this paper a PN junction covered with an aluminum B-loaded converter is used. Neutron dose equivalents are calculated by alpha particles and the photon study is based on a pulse shape analysis. The PN junction can be divided into two parts: the depleted layer and the remainder of the silicon detector usually called the “wafer”.

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Protons and alpha particles, generated in the converter (polyethylene or ^{10}B-loaded aluminum converter), interact inside the depleted layer and the interactions in the wafer are negligible. Electrons generated by the photons interact in both zones. Charge carrier velocities are different in these two regions, as they are grater in the depleted layer because the electric field is higher in this region. For this reason, rise times of heavy-charged particle pulses are shorter than those of photon pulses.

Fig. 1 shows a schematic of the pulses: (1) Fast pulses are due to interactions occurring exclusively in the depleted layer and collection times are short and depend slightly on penetration depth. (2) Slow pulses – are due to interactions that occur exclusively in the wafer, diffusion is the collection mechanism, rise time depends on the diffusion time and the pulses are due to electrons generated by photons. (3) Mixed pulses – they present two slopes, are due to electrons, generated by photons, interacting in both depleted layer and wafer, the highest slope is due to interactions occurring in the depleted layer.

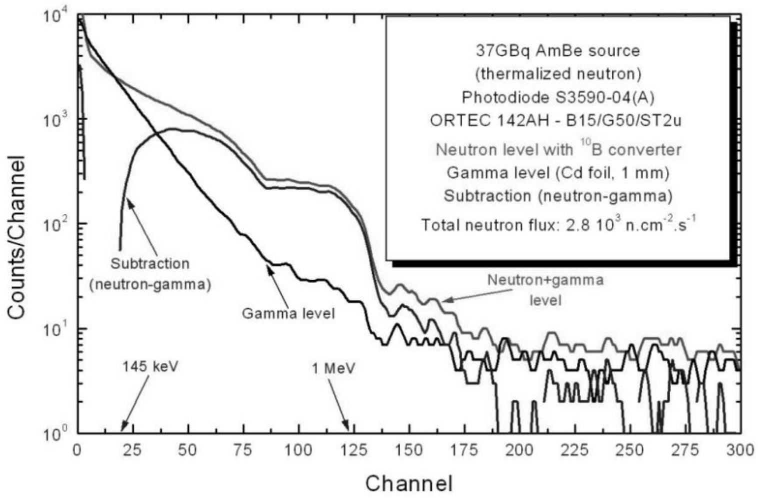

FIGURE 1. Response of photodiode S3590-04(A), covered with boron converter for thermal neutrons fluxes from AmBe source.

It is a well-known fact that shapes of electronic pulses generated by nuclear radiation detectors depend significantly on the species of the detected particles. Various techniques using this property have been employed to achieve particle identification through pulse shape analysis (scintillators, gas detectors, etc).

In Fig. 2 there are roughly three kinds of pulses: “Fast pulses” (a) are due to interactions occurring exclusively in the depleted layer. For particles stopped inside the depleted layer, collection times are short and depend slightly on penetration depth.

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"Slow pulses" (b) are due to interactions that occur exclusively in the wafer. The collection mechanism is the diffusion. Rise time depends on the diffusion lime, i.e. (he carrier mobilities and the distance between the point of interaction and the depleted layer. These pulses are mainly due to electrons, generated by photons, interacting exclusively in the wafer.

"Mixed pulses" (c) are also found. They present two slopes. These are due to electrons, generated by photons, interacting in both wafer and depleted layer. The highest slope is due to infractions that occur in the depleted layer (4, 5).

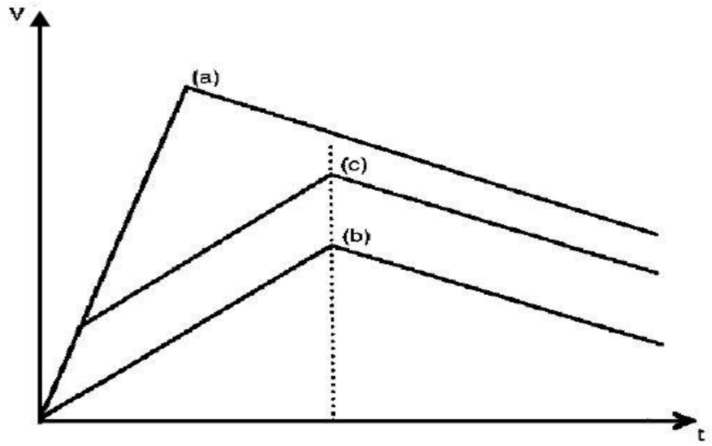

Figure 2 – Schematic of the pulse shapes at the output of the preamplifier with provides typical values of the rise time.

In the present work, a new data acquisition electronic system for individual neutron dosimetry measurements is proposed which allows the simultaneous acquisition and analysis of pulse height and rise time, for each nuclear event. This paper discusses the conceptual design of the unit based on a data acquisition board and software developed with Labview (6) which must be developed specifically for this system, with a focus on reliability and low coast.

2. EXPERIMENTAL SETUP

Fig. 3 shows a schematic view of the proposed system; the signal coming from the PIN detector is amplified, then the pulses are analyzed and separated according to the amplitude and rise time, generating three outputs: So1 (neutrons), So2 (neutrons and possibly photons) and So3 (photons and possibly neutrons); in outputs So2 and So3 the rise time of the pulses is analyzed: in So2 go the pulses with 10ns<t<700ns and in So3 the ones with a rise time larger than 700ns.

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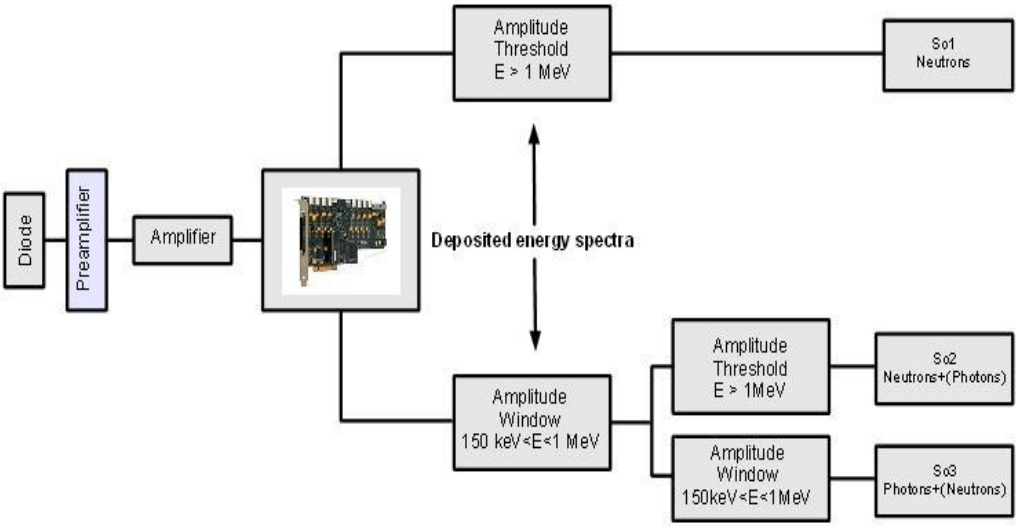

Figure 3 – Block diagram of the experimental set-up

2.1. PIN Detector

The detector used consists of a PIN silicon photodiode Hamamatsu S3590–04 [3]. In this work a ^{10}B converter was used for thermal neutron detection which covers the radiation sensitive face of the semiconductor [3, 4].

For fast neutron detection a polyethylene converter, used as as recoil proton generator, was used. In order to fit the thicknesses *X* (cm) and counting rate *R* (cps), a mathematical model was implemented from a previous work [6]. Fig. 4 shows the detector set-up.

Figure 4 - Detector, preamplifier, ^{241}Am source calibration and boron converter

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2.2. General description of electronic system and software

The block diagram of the electronic system is presented in Fig. 5, consisting of three parts: (a) PIN detector and ORTEC 142A preamplifier; (b) commercial NIM standard spectroscopy amplifier and (c) National Instruments NI PCI-6132 data acquisition board and a PC computer.

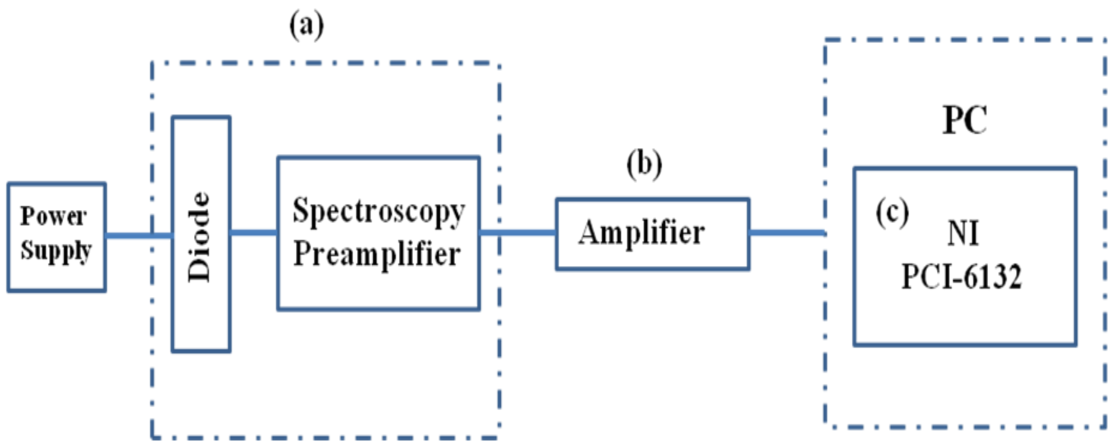

Figure 5 – Block diagram of the electronic system

The system is managed by a software developed in the LabVIEW 2010 graphical programming tool. The hardware records the amplitudes and rise time of all the detected pulses from the detector PIN silicon photodiode detection arrangement in disk files.

Software developed in LabVIEW are called Virtual Instruments (VIs), and contain three main components: the front panel, the block diagram and the icon and connector panel.

With LabVIEW the user interface – or *front panel* – can be developed including all the necessary controls (data entry field, buttons, etc.) and indicative data (numbers, graphics, LEDs, etc.); this is then linked using the block diagram – which is similar to a fluxogram – so that the software may perform the needed operations with the inputted data. The front panels shown in Figs. 6 and 7 are the user interface of the proposed software, presenting controls and indicators, i.e., the input and output interative terminals of the VI (6).

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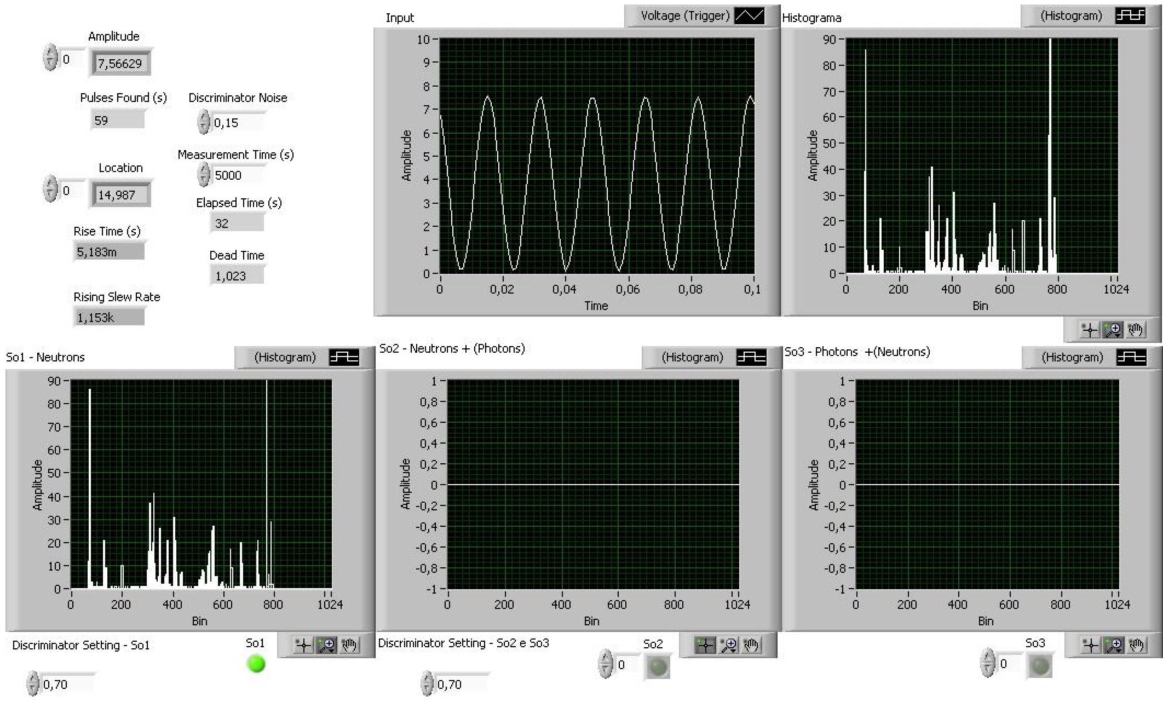

Figure 6 – Front panel designed to input the conditions of measurement and data visualization.

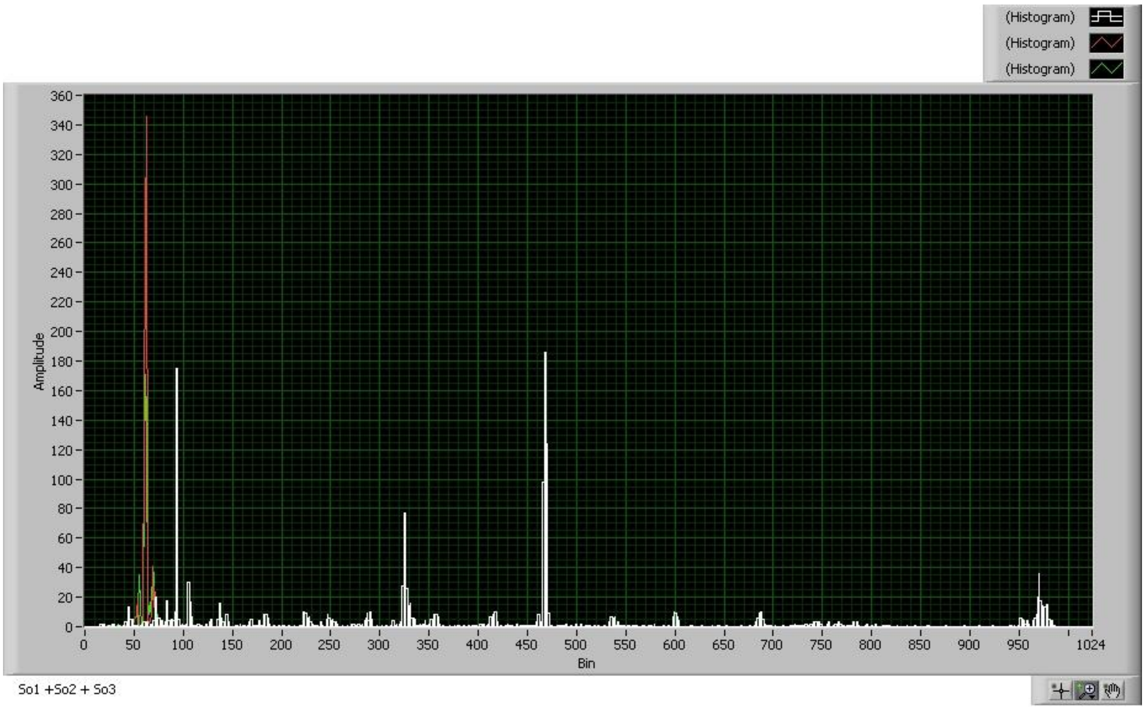

Figure 7 – Front Panel of the channels So1, So2 e So3.

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After the development of the front panel, the controlling code for the objects in the front panel – i.e., the block diagram - was developed (see Fig. 8).

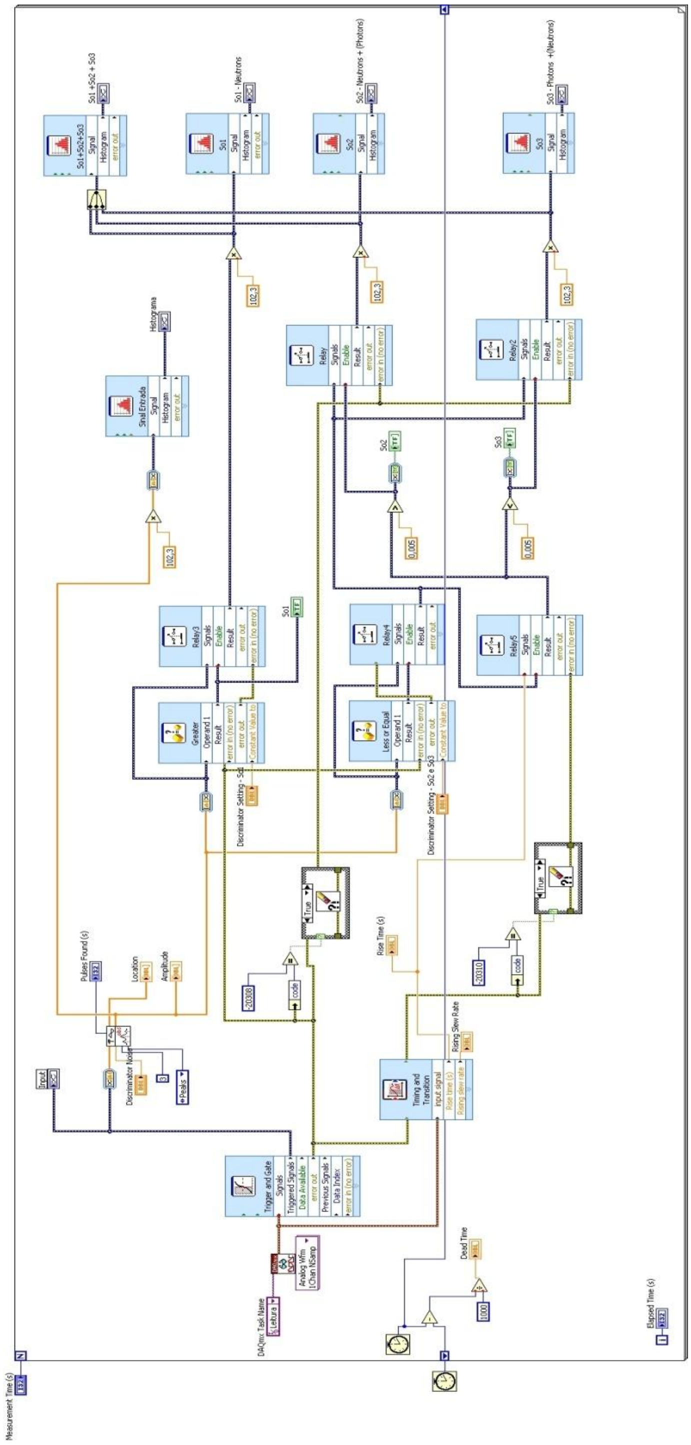

Figure 8 – Block Diagram developed with Labview 2010.

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3. CONCLUSION

The present work is an initial stage of the development of an electronic system using a software-based pulse shape discrimination (PSD) technique. The preliminary tests shown here gave satisfactory results, indicating that the software PSD technique can be used with a real detector. The all-software system proposed in unlike any other found in the literature and has many advantages over similar systems, as the need for less electronic modules, the direct recording of events in the disk, allowing for a later analysis, and the flexibility of the system, which can be adapted and improved via changes in the software, without the need for hardware changes. There is a great potential for improvement of the method and many features can be added, allowing new areas to be investigated.

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