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Portable Radiation Detector with PIN Photodiode for X-Rays and CsI(Tl) Scintilator with Photodiode for Gamma Rays

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1. Introduction

PIN photodiodes are capable of detecting X-rays and low-energy gamma radiation [1]. The PIN photodiode is a variation of the PN junction diode, but it has an intrinsic region between the P and N junction. This configuration increases the junction volume and, consequently, the efficiency as a detector. At the same time, to increase the detection efficiency for radiation with energies higher than those of X-rays, PIN photodiodes coupled to CsI(Tl) scintillating crystals have been used [2]. These crystals may be manufactured in various volumes, with a high atomic number and with luminescence in a sensitive range of the photodiodes.

In this work, in addition to the construction of the entire electronic set from the detector signal to the counting unit, the configuration presenting the lowest noise was studied. The silicon photodiode is sensitive to energies from a few keV units, but the noise of the whole set may be mixed with these values, not allowing its detection. Thus, building a detector set with the lowest possible noise implies increasing the sensitive range of energies.

In a detector set using semiconductors, the noise present in the detected signal is a sum of the leakage current in the detector, the electronic components that make up the system and noise due to the detector's capacitance [3, 4]. This noise is produced by the charge sensing preamplifier, although this is the most suitable for use with semiconductor detectors [5]. This type of preamplifier has high stability, since the conversion of the charge produced in the detector into voltage only depends on the value of the feedback capacitor. Despite this advantage, these preamplifiers produce a noise proportional to the input capacitance (detector capacitance), thus requiring that the detector may have the lowest input capacitance possible.

Due to this characteristic, the behaviors of the preamplifier set were compared using two photodiodes in parallel, which in this case would have the added capacitances, with a single preamplifier and independent photodiodes and preamplifiers, but with their parallel outputs, which would add up the noise of the sets, seeking the configuration that presented less noise incidence.

2. Methodology

Two identical preamplifiers were built, according to the Fagionato circuit [4], with the photodiode coupled to a field effect transistor model 2SK152 and, this one, to an AD8011AN operational amplifier. The PIN photodiodes used were S5106 from Hamamatsu, with 25 mm^2 of area [6]. According to Figure 1, the arrangement A with the photodiodes in parallel was tested, with a single preamp, and in B, with two preamps in parallel, plus their respective photodiodes. To compare the noise produced, the two detector associations were exposed to an ^{241}Am source because its low-energy emission spectrum is suitable for comparing the noise in this region. In these tests, the scintillator has not been connected to the photodiode yet, because the noise evaluation was only at low energies.

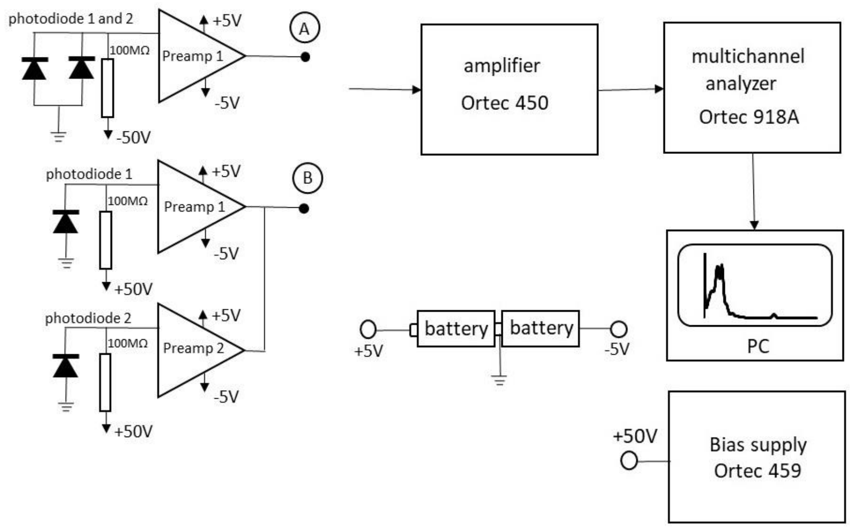

Figure 1: Block diagram of the arrangements built to study the configuration with less noise.

3. Results and Discussion

Figure 2 shows the energy spectra of ^{241}Am in the characteristic X-ray region and gamma emission at 59.6 keV, for the tested detector configurations. The red spectrum was obtained at output A, with the two photodiodes connected in parallel with a single preamplifier and in red, output B, two preamplifiers in parallel and with their respective photodiodes.

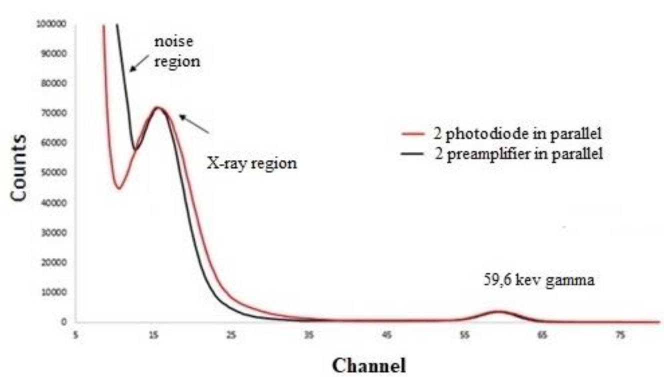

Figure 2: Energy spectra of ^{241}Am in the characteristic X-ray region and gamma emission at 59.6 keV for the tested detector configurations.

The noise obtained with the pre-amplifier does not allow the individualization of the two X-ray photopeaks characteristic of ^{241}Am, at 13.9 keV and 17.8 keV. These two photopeaks appear only as one, but demonstrate that the noise present at the output of the preamp used does not substantially compromise the detection of energies as low as 13.9 keV. As it may be seen by comparing the spectra, two photodiodes in parallel presented lower counts in the noise region than two preamplifiers, therefore it was the configuration used in this work. After defining the configuration with two photodiodes in parallel, one of the photodiodes was coupled to the scintillator to constitute the detector of higher X-ray energies. The optical coupling of the scintillator to the photodiode was made with Sinteglas® model ACRICOL 900UV acrylic glue, which showed good adhesion and has shown durability without chemical attack to the CsI(Tl) crystal. This crystal was grown at IPEN/CNEN-SP, according to Cortese et al [7].
With the set in its final version, photodiodes in parallel with a single preamplifier, the energy spectra of a ^{129}I source, gamma emitter in 29 keV and a source of ^{137}Cs, 662 keV were obtained, due to the fact that their energies have great applicability in the medical and industrial areas. The detector assembly demonstrated sensitivity at both 29 keV and 662 keV. As the two photodiodes are close to each other and their signals are mixed, when the arrangement is subject to 662 keV photons, it was observed a large number of counts due to partial energy deposition at scintillator free photodiode. This was not a problem because the counts only increase the detection efficiency. Figure 3 shows the spectra obtained for these two radioisotopes and demonstrates the response of the detector set for these two energy bands.

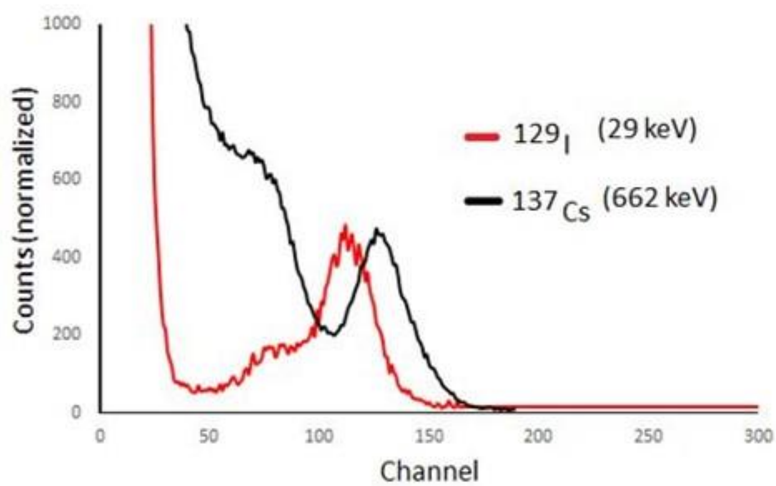

Figure 3: Energy spectra obtained with two photodiodes in parallel, one of them coupled to a CsI(Tl) scintillator, showing the detection capacity in these two energy ranges.

4. Conclusions

The use of PIN photodiodes for X-ray energies, and coupled to CsI(Tl) scintillators for gamma radiation, make the energy range of the detectors built with these components wide enough to be used in various applications. The use of photodiodes in parallel, or with pre-amplifier circuits in parallel, depends on the noise behavior of the pre-amplifier, as a function of the input capacitance and, thus, they should be studied for each circuit developed.

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