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DEVELOPMENT OF A CHARGE-SENSITIVE PREAMPLIFIER USING COMMERCIALLY AVAILABLE COMPONENTES

Esnel A. Fagionato, Frederico A. Genezini and Guilherme S. Zahn

Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
esnelfag@usp.br
fredzini@ipen.br
gzahn@ipen.br

ABSTRACT

Signals produced in radiation detectors are very fast and with low intensity; these signals are not able to directly excite a regular MCA mutichannel circuit, so some sort of amplification is needed. This work proposes the construction of a nuclear detector preamplifier using commercially available components that are not specifically designed for the use in nuclear instrumentation. The preamplifier was then tested and its performance was compared to that of an Ortec 142 preamplifier.

1. INTRODUCTION

The electrical signal produced by a typical solid state nuclear detector usually has very low intensity, so it needs to be amplified before it's inputted in a multichannel analyzer system.

The usual approach is to use a charge-sensitive preamplifier (PSC). The incident particle deposits an electric charge in the detector's sensitive volume the PSC integrates this signal, producing as output an electric signal with amplitude proportional to this electrical charge. Afterwards, there's an additional stage where a shaping amplifier delivers an output signal compatible with the MCA input – in this stage the signal's shape is adapted, too, so that the output signal has a Gaussian shape, with baseline restoration and pole-zero adjustment.

As particle detectors have very high output impedance, with very low output current, the PSC input has to be of very high impedance, too. Even the very common Operational Amplifiers, which present high input impedance, may have the impedance reduced by the polarization circuit, so that it is usual to have a Field Effect Transistor (FET) before the Operational Amplifier.

One of the common problems in a PSC is noise, which can sometimes be larger than the signal itself. In some semiconductor detectors, for instance, the PSC is refrigerated to reduce the thermal noise; also, the FETs used are chosen in order to present the lowest possible intrinsic noise.

Another source of noise is the PSC's polarization circuit, and is mainly due to the coupling capacitors, to parasite capacities inherent to the building process, to polarization resistors and to the electrical wires, which must be kept as short as possible in the link between the detector and the PSC.

An important characteristic of the PSC is its speed, i.e. the capacity to produce an output signal in the shortest time possible – this is measured by the risetime of the electrical output [1]. In high-quality PSCs this risetime is close to 10 ns, and the goal of this work is to have a similarly fast output signal.

2. MATERIALS AND METHODS

In this work, aiming at developing a low-cost system composed of electronic components easily found in the market, several assembly possibilities were evaluated. After thorough research both on the scientific literature and in electronics aficionado bulletin boards, the design shown in Fig. 1 was chosen.

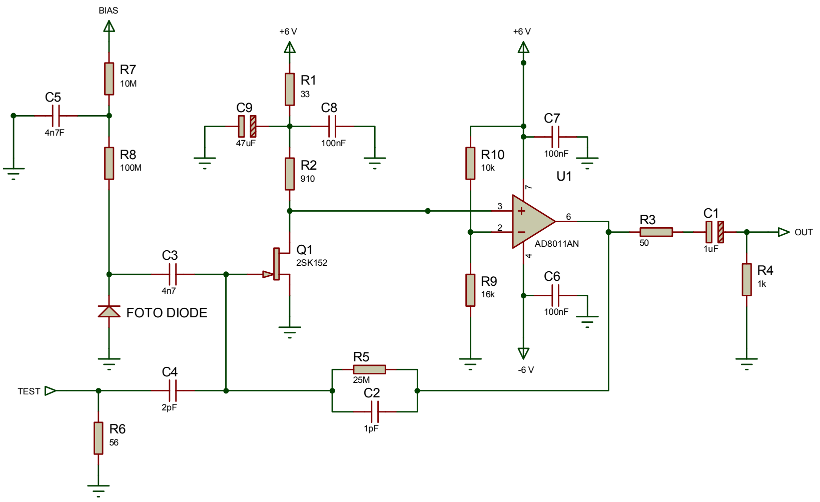

Figure 1. Electric scheme of the PSC

Due to the high impedance required in the input, a FET (Sony 2SK152 [3]) was added to the input of the PSC. The output of this FET is connected to the non-inversing input of the AD8011 Operational Amplifier from Analog Devices [4]. This is a Current Feedback-type amplifier used mainly in video amplification, with a very fast response – according to the datasheet, it present a Slew Rate of up to 3500v/µs and a risetime of 0.4ns. In the output of this amplifier there's a 50Ω resistor to couple the impedance to that of modern digitizers and of the cables frequently used in nuclear electronic setups.

3. RESULTS

The performance of the PSC was tested using a Ortec 419 pulse generator (20mV signal amplitude, 3ns risetime) to simulate the output of a detector. The output signal from the PSC, with a risetime of approximately 8.8ns, is shown in Figs 2 and 3. All the measurements were made with an 1GHz oscilloscope (Agilent DSA7104A).

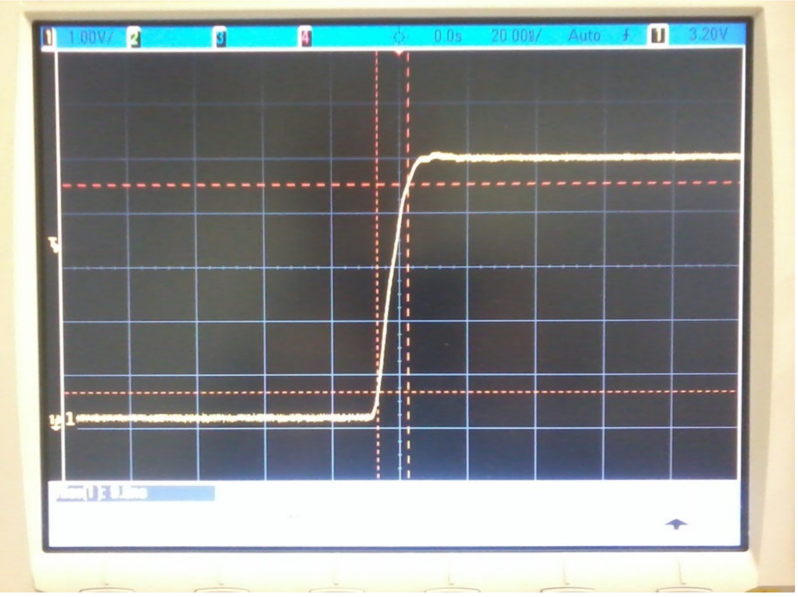

Figure 2: Output from the PSC.


Rise(1): 8.8ns

Figure 3: Detail of the PSC risetime measurement.

As a comparison, an Ortec 142 PSC [2] was tested using the same input signal, and the output presented a risetime of approximately 14.8ns, as shown in Figs 4 and 5.

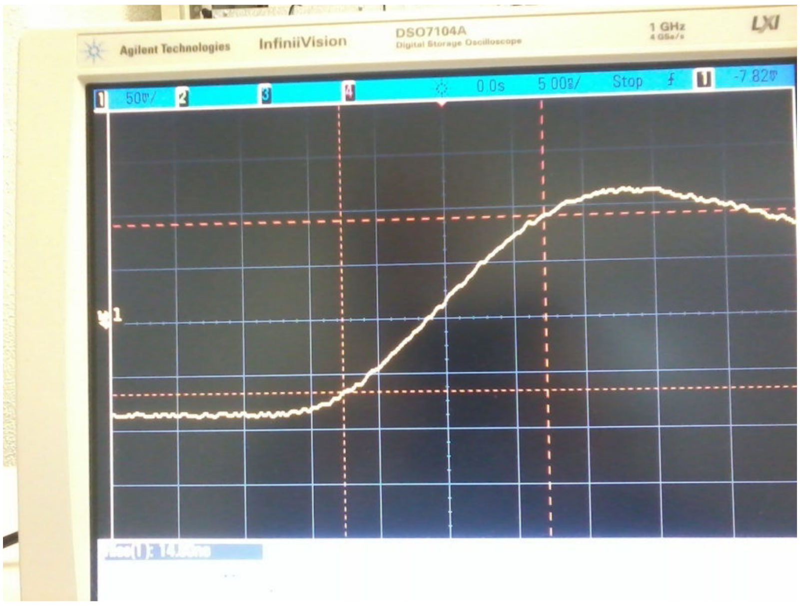

Figure 4: Output pulse obtained using the Ortec 142 PSC.

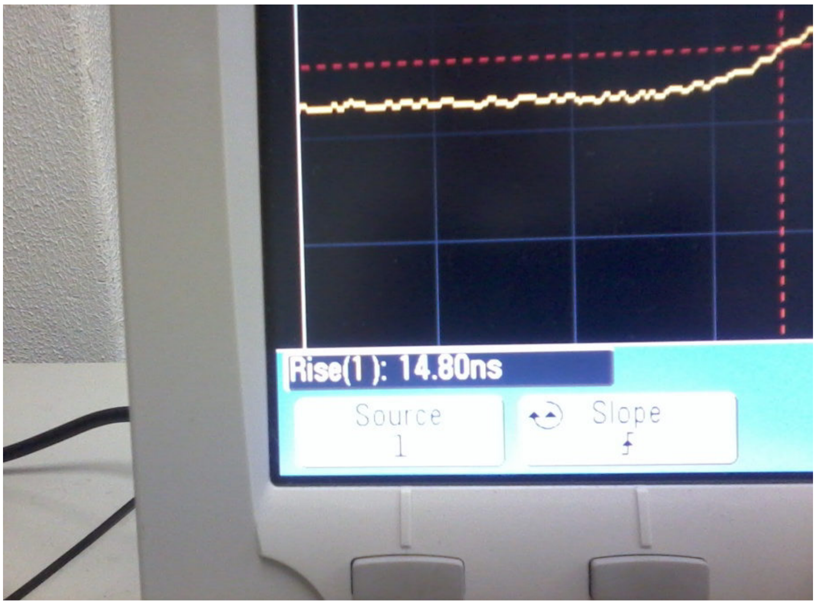

Figure 5: Detail of the risetime measurement for the Ortec 142 PSC.

Fig. 6 shows the IC board built for this work.

Figure 6: PSC IC board.

4. CONCLUSIONS

This work pinpoints that the developments in the commercial electronic circuit technology allow the development of nuclear electronic modules – in this case, a charge-sensitive preamplifier – with quality and performance to match the equipments developed specifically for this purpose by traditional manufacturers.

In fact, even with the nuclear acquisitions systems progressively migrating to a minimalist philosophy, with a single digitizing board performing most of the usual tasks, a pre-amplifier is still required, so the development of new approaches for PSC development is still justified.

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