A Low Noise Preamplifier for HPGe Detectors with Auxiliary Output for Over Range Signal Spectroscopy

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***Abstract*–We present a low-noise Charge-Sensitive Preamplifier for HPGe detectors able to swiftly recover from saturation, featuring an auxiliary output signal used for high-resolution pulse-height spectroscopy of the over-range signals. Using the auxiliary output for analyzing the signals larger than ~15 MeV (mostly charged particles and heavy ions) and the principal preamplifier output for analyzing all other signals (ionizing radiations and charged particles) a wide overall spectroscopic energy range of 5keV to 180MeV is obtained. A single Pole-Zero adjustment serves both the principal preamplifier channel as well as the auxiliary output channel. The energy resolution of the auxiliary channel is better than 0.1% typically. The Equivalent Noise Charge of the preamplifier is 115 electrons r.m.s., i.e. ~0.8 keV fwhm, using a BF862 as input transistor operated at room temperature while simulating the detector with a capacitance of 22 pF.**

I. Introduction

A new generation of nuclear-physics experiments with radioactive ion beams is foreseen in the near future. In these experiments 4π arrays of monolithic multi-electrode position sensitive germanium detectors will be used for spectroscopy and tracking of γ rays [1]-[6]. In these experiments the electronics must comply with strict specifications. Besides having a low noise, it must provide a fast rise time, because the shape of the leading edge of the preamplifier signal is a key signature of the physical position of the γ-photon interaction point inside the detector [7]. A large dynamic range is also required for a class of experiments where giant-dipole resonances can produce γ photons in the 20 MeV range. Another key requirement is a reduced dead time in the presence of a background of charged particles (pions, kaons) in the 10 to 100 MeV energy range.

Advanced low-noise preamplifiers have been developed for these applications [8]-[10] able to swiftly recover from saturation. Moreover an original approach has been proposed which allows accurate estimate of the amplitude of large signals even when the preamplifier's output voltage gets saturated, as based on a Time-over-Threshold measurement technique [11]-[13]. This technique requires a precise measurement of the time width ΔT of a suitable square pulse provided by a Schmitt trigger comparator. The amplitude of the large signal is then evaluated by putting into a proper mathematical equation ΔT and a few other parameters derived from the sampled preamplifier waveform [14]-[16]. We propose here a new circuit and technique where the energy of the large signal is obtained in a much simpler way by processing a suitable auxiliary pulse through a precise Pulse-Height Analyzer.

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II. Experimental Results

In Fig. 1 a picture of the realized hybrid circuit implementing the new technique is shown. It is built on an alumina substrate for optimization of the noise performance [17] and is installed in a shielded box located 20 cm apart from the detector.

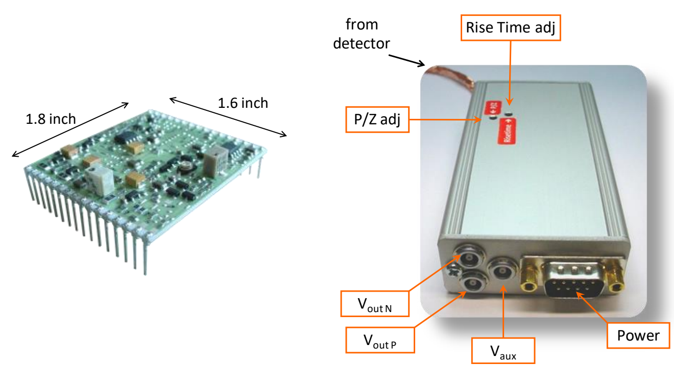

Fig. 1. Picture of the circuit board (left) and of the circuit as installed in its shielded box (right). The preamplifier output signal is differential, V_{outP} and V_{outN} are the positive and negative signals. V_{aux} is a single-ended auxiliary signal used for spectroscopy of the large saturated events. A 10-turn trimmer allows precise Pole-Zero cancellation, which turns the ms long decay time of the detector into a shorter preamplifier decay time of ~50µs.

In Fig. 2 the experimental signals observed on the scope are shown for large equivalent events in the range from 10MeV to 100MeV with 10MeV step. Event (1) is under threshold and, as expected, V_{out} is an exponential decay function. Events (2)-(10), instead, yield saturation of V_{out}. In these cases a fast-reset cycle gets triggered which turns the exponential decay function into a narrow trapezoid. As shown in the middle of

Fig. 2 when a normal spectroscopy amplifier (shaper) is connected to V_{out} the amplitude of the shaped signal V_{sh} does not grow with the event energy because of saturation of its input signal, and no pulse-height spectroscopy is therefore possible. In order to retrieve the amplitude information the Time-over-Threshold scheme could be used, as mentioned in [11], with a price to be paid in terms of complexity. However a completely different behaviour is observed looking at the output of the auxiliary circuit, as shown in the top of Fig. 2. Now the pulse height nicely grows with the event energy for all considered cases, which allows spectroscopy of the large signals by simply using a precise Pulse-Height Analyzer. Note that for lower signals <10MeV the amplitude of V_{aux} becomes too little for high-resolution spectroscopy. For these cases signals V_{out} or V_{sh} must instead be used. Signal processing in these cases is performed by using a digital filter or an analog shaper amplifier. The structure and all details of the circuit used to generate pulses "V_{aux}"of Fig. 2 will be shown elsewhere in a dedicated paper.

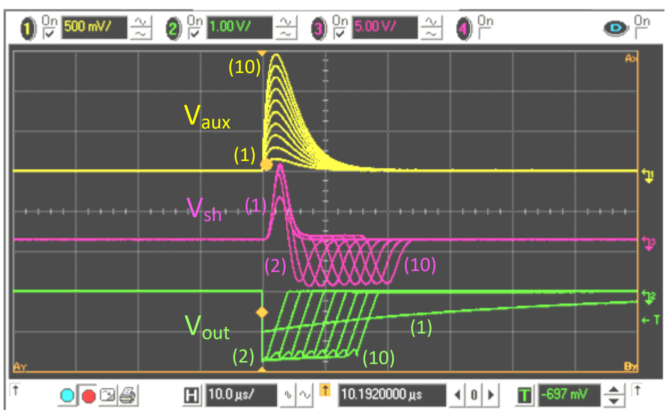

Fig. 2. Relevant signals as seen on the oscilloscope. V_{out} is the preamplifier output signal as given by V_{outN}-V_{outP}; V_{sh} is the signal obtained by processing V_{out} through a quasi-Gaussian spectroscopy amplifier. V_{aux} is the auxiliary signal used for high-resolution spectroscopy of the large events.

We finally measured the noise of the charge preamplifier by filtering the signal with a commercial quasi Gaussian spectroscopy amplifier as connected to V_{out}. The detector has been simulated by connecting a capacitance of 22pF at the preamplifier input. We used a feedback capacitance of 1pF. The input transistor is a BF862 operated at room temperature. An Equivalent Noise Charge of 115 electrons r.m.s. has been obtained at a shaping time of 6 µs which corresponds to a pulser line width of 0.8 keV fwhm in Ge.

Overall an exceptional spectroscopic dynamic range is obtained by using the shown technique, from ~5keV to ~180MeV with a non linearity of less than ±0.2%.

Research and development is being conducted in parallel towards the implementation of a similar technique in an Application Specific Integrated Circuit (ASIC) form [18]-[21].

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