Charge sensitive preamplifier with an active ultra fast recovery circuit.
A possible solution for the gamma-flash in neutron sources.

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INTRODUCTION
All neutron time-of-flight facilities and in particular those based on the spallation mechanism, are affected by a prompt intensity signal, called gamma flash, whose importance depends on the intensity and energy of the primary beam.

At the neutron time-of-flight facility n_TOF at CERN [1], in which the neutron beam is produced by spallation of 20 GeV/c protons on lead target, an intense flux of gamma-rays and high-energy particles is generated in the target and propagates to the experimental hall through the beam pipe, giving rise in the detectors to a prompt saturated signal. Often a gas detector is used in order to reduce the gamma flash effects due its low sensitivity. The price to be paid is a low energy resolution and problems related to gas flow. Solid state detectors could be a better solution due to their higher energy resolution, stability and easiness of operation. Unfortunately, the pulse associated with the gamma-flash in silicon detectors, such as those used for the neutron flux monitor or to study (n,α) reactions [2] has a typical duration of tens microseconds at n_TOF facility (see figure 1). During this relative long time, events produced by neutrons above few MeV cannot be detected, thus hindering the full potential of the n_TOF neutron flux, which extends up to 250 MeV.

FIG 1: Typical γ-flash signal of a Silicon detector used in SiMON at n_TOF [2]. The saturated pulse and the long time oscillations followed are clearly present. The signal has been recorded by the n_TOF DAQ which is based on Acqiris Flash ADC [4].

In order to decrease the duration of the effects of the gamma-flash, and in order to allow the measurements of reactions at neutron energies above a few MeV, we have developed a charge sensitive preamplifier with an active circuit for an ultra fast de-saturation.

WORKING PRINCIPLE
The working principle of the device is: when the preamplifier output exceeds a threshold value the reset circuit becomes active and a constant current starts to flow in the input node. When the injected charge is equal to that released from the gamma-flash, the output comes to zero and the current stops. Because of the high stability of the injected charge, the time duration of the current can be used to estimate, with 1% accuracy, the energy of the gamma flash, adding an independent measure of the stability of the neutron flux.

Tests results of the hybrid preamplifiers, performed in the laboratory using a pulser, have shown very good performance. We have obtained a complete discharge of a simulated gamma flash event correspondent to 250 MeV in a time of 300 ns after the start of the signal. If it is used in the n_TOF neutron flux SiMON detectors, it would allow the detection of events coming from neutrons of an energy of 300 MeV.

CIRCUIT DESCRIPTION
Figure 2 shows a schematic diagram of the charge sensitive preamplifier with the active ultra fast recovery circuit. The recovery circuit is composed by an ultra fast comparator and an enabling constant current generator directly connected to the input of the charge sensitive preamplifier section [3].

Because of the direct feedback, particular care has been given to design this stage, where a possible leak current can have a dramatic effect on the output noise level. We have used a high frequency PNP transistors (Q1 in fig 1) in common base configuration, with base to ground and the collector directly connected to the Gate of the FET input (J1 in figure 1) of the charge sensitive preamplifier. In normal operation the Q1 emitter, which is connected to comparator output, is at zero voltage because the J1 node is a virtual ground. Thus all Q1 terminals are at same potential and no current can flow through it, so the presence of the recovery circuit does not affect the noise performance and the base line shift of the preamplifier.
FIG 2: Simplified schematic of the ultra fast recovery preamplifier.

When a saturated event occurs, the preamplifier output exceeds a threshold value (we settled at +2.5V) the comparator section toggle and the output voltage go to +1V allowing a current of \((1V - V_{th})/R\) to flow inside the input node. The charge accumulated into the input node by the saturated event is rapidly discharged and the preamplifier output exit from the saturated region in a short time, depending on the value of the current. The signals from the preamplifier output in presence of gamma flash measured with the digital oscilloscope are simulated using a pulser (see figure 3).

FIG 3: Trace 1: Preamplifier output when the ultra-fast recovery is active. Trace 2: Complementary output of the hysteresis comparator.

The presence of comparator section toggles again when the preamplifier output returns close to the zero. At this point the comparator output goes to zero and the discharging current stops. The recovery time is settled by the discharging current \(I_{dis}\) with a sustainable value of 10µA, so gamma flash event of 250 MeV is completely recovered in less then 300 ns. Due to the constant current the injected charge is proportional to the time and in this way the measure of the discharge time gives also an estimate of the energy released in the detectors by the gamma-flash. In figure 4 is reported the results of the measurements of the linearity of the discharge time as function of input energy. A precision of less the ±1% has been obtained, as reported by the black line in figure 4.

FIG 4: Discharge time linearity.

The preamplifier has been realized with hybrid technology and has a compact size of 38x17 mm, with a pad pitch of 2.54 mm. In Table I the main characteristics of the preamplifier are summarized. The noise level is very low, even in presence of the recovery circuit and a discharge slope which is very steep. It represents the proportionality constant between the energy of a saturated event and its discharge time and can be increased if a higher noise level could be accepted.

TABLE 1: main characteristics of the preamplifier.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Energy sensitivity</td>
<td>90 mV MeV</td>
</tr>
<tr>
<td>Output voltage</td>
<td>8V max</td>
</tr>
<tr>
<td>Decay Time</td>
<td>200µS</td>
</tr>
<tr>
<td>Noise (FWHM) Si</td>
<td>1.4 KeV 0pF (15 eV slope)</td>
</tr>
<tr>
<td>Reset Threshold</td>
<td>28 MeV (2.5V)</td>
</tr>
<tr>
<td>Discharge slope</td>
<td>0.9 MeV / ns</td>
</tr>
<tr>
<td>Power consumption</td>
<td>350 mW</td>
</tr>
</tbody>
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