# Miniball Preamplifiers

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**WARNING: this documentation describes the old preamps and is now obsolete. Since 2022 we now use the AGATA preamplifiers.**

## Contents

# 1 The Miniball Preamplifier

The requirements of the front-end electronics developed for the Miniball array have been imposed firstly by the use of highly segmented 6-fold HP-Ge detectors and secondly by the early decision to use a DAQ based on commercial fast digitizers [1] in order to implement the pulse-shape analysis technique to extract not only the energy and time information but to determine also the two-dimensional position of the first $\gamma$-ray interaction in the Ge crystal.

The use of the pulse-shape analysis technique for the signals collected from highly segmented detectors raises an additional issue to the preamplifier specification, namely a fast rise time (faster than the fastest collection time of electrons and holes in a detector) and moreover a very clean transfer functions in the time domain. The good transfer function has to be preserved in cryostats equipped with multiple highly segmented detectors and real wiring thereby also the crosstalk between channels has to be as small as possible (by design it is in the order of magnitude of $\sim 10^{-3}$ or less).

A very large dynamic range at high counting rates is mandatory, to detect $\gamma$ rays alone in the range up to 10-20 MeV and additionally in the presence of pile-up effects induced by some energetic charged particles. Special care has to be taken in the design of the front-end analog electronics to avoid saturation due to pile-up effects of those signals above 30 kcps.

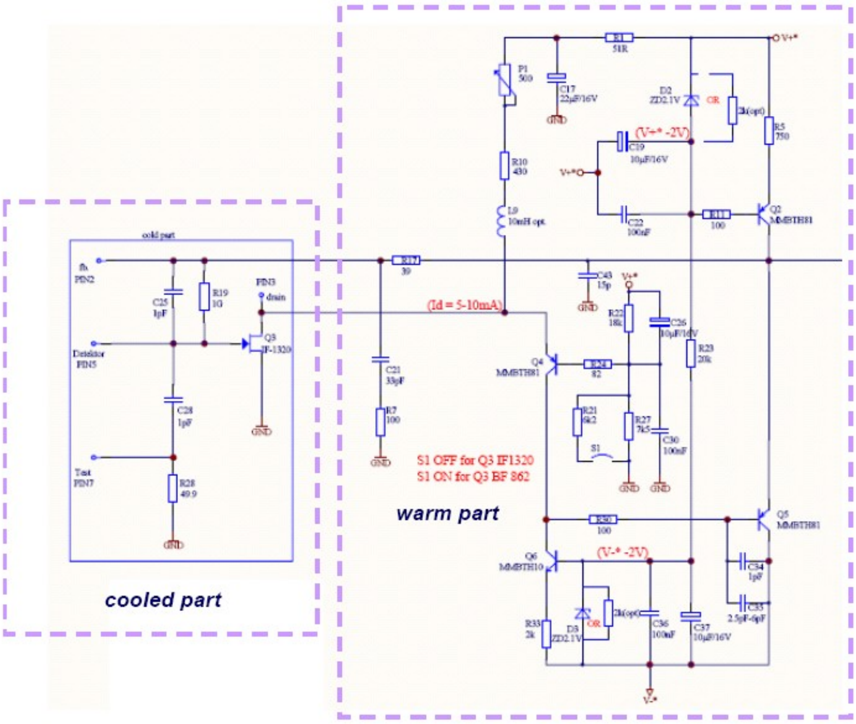
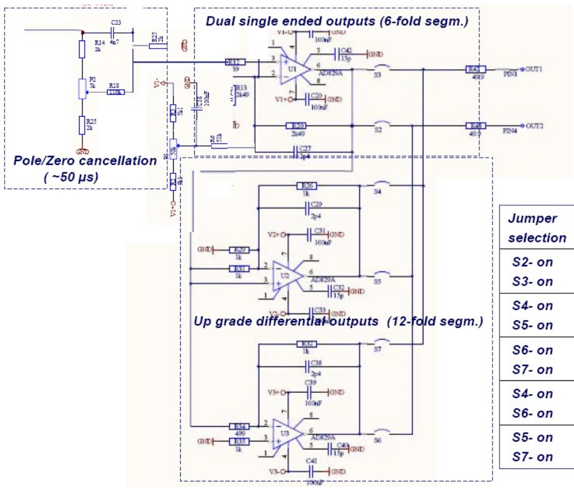



Figure 1: Miniball-preamplifier charge-sensitive loop (left, cold part placed in cryostat and right, warm part, placed outside cryostat)

The structure of the front-end electronics is presented in Fig. 1. It consists




| Jumper selection | 6-fold segmented | 12-fold segmented |
|---|---|---|
| S2- on<br>S3- on | Inverting | ~175 mV/MeV |
| S4- on<br>S5- on | Non-Inverting | ~350 mV/MeV |
| S6- on<br>S7- on | Inverting | ~350 mV/MeV |
| S4- on<br>S6- on | Differential<br>a) ⇔ (+/-) | ~350 mV/MeV |
| S5- on<br>S7- on | Differential<br>b) ⇔ (-/+) | ~350 mV/MeV |

Figure 2: Pole/Zero cancellation and output buffer stage with dual single ended signals (standard version for the 6-fold segmented detectors) and the up grade version with fully differential outputs (developed for the Miniball 12-fold segmented detectors).

of the following stages: a charge-sensitive loop including a part cooled at about 150 K, a pole-zero cancelation with integrated fast reset circuitry, an output buffer designed in two versions,

- with two unipolar outputs in the case of 6-fold segmented detectors and
- with a balanced differential output $s$ of either polarity, jumper selectable.

The input stage is collecting electrons from the central electrode or holes from each of the 6-fold (or 12-fold) segmented detectors. The connection to the central electrode is AC (1nF/5 kV) due to a 4-5 kV bias voltage applied to this electrode and DC to the all segments. The charge-sensitive cooled part comprises an input stage with a very low noise jFET transistor and a passive feedback network. These components are placed in a cryostat near the detector contacts, to reduce the noise and the micro-phonic effects. A temperature between 150 K ± 25 K was chosen for the input jFET in order to optimize its equivalent noise voltage down to 0.6 nV/$\sqrt{\text{Hz}}$. The feedback network time constant of the first stage is 1 ms (1GΩ and 1pF, respectively) to optimize both, noise and bandwidth in the first stage.

The Transimpedance Amplifier (TA) designed with discrete components is operated at room temperature outside the cryostat. A 'cascode' structure was adopted for the TA stage (Fig. 1). The TA is optimized for a wide unipolar output range of $\sim$ 10 V positive or negative swings. As the closed-loop gain is $\sim$ 53 mV/MeV and the output voltage range of the TA stage is about $\sim$ 10 V we obtain an energy range of $\sim$ 180 MeV with an intrinsic noise of $\sim$ 600 eV @150 K and with a slope of 8 eV/pF (the total detector bulk capacity being $\sim$ 39 pF)

To get a fast rise time at lowest possible noise, several jFET structures have been tested and the IF1320 (InterFET) with a working point at $U_d \sim$ 5V, $I_d$

| Property | Value | Tolerance |
|---|---|---|
| Conversion gain for core segments | ~ 175 mV / MeV (optionally 350 mV) | ±10 mV |
| Noise | < 0.6 keV FWHM ($C_d$ = 0 pF @ 150 K) | |
| Noise slope | + 8 eV / pF | ±2 eV |
| Rise time | ~ 13 ns (0 pF) | ±2 ns |
| Rise-time slope | ~ 0.3 ns / pF | |
| Decay time | 50 $\mu$s | ±2 $\mu$s |
| Integral non linearity | <0.025% (dynamic range ~ 8.75V) | |
| Output polarity selectable:<br>- dual single: pos. or neg.<br>- fully differential | <br>Single ended, $Z_0$=50Ω (default)<br>Differential, $Z_0$=100Ω (option for 12-fold) | |
| Power supply | ±12.0 V | ±0.5V |
| Power consumption jFET | 50 mW IF1320 (6-fold)<br><20 mW BF862 (12-fold) | |
| Power consumption at low counting rates | < 350 mW warm part + jFET power consumption (cold part) | |

Table 1: Technical specification of the Miniball front-end electronics

~ 10 mA (~ 50 mW) was selected for the 6-fold segmented detector and later on (for the 12-fold segmented detectors) this was exchanged with the BF862 (Philips) even faster and requesting less power consumption in the cryostat, namely only $U_d$ ~ 2 V, $I_d$ ~ 8-10 mA (~ 16-20 mW). The PCBs for the cold part are designed for both type of jFETs and moreover the adjacent channels are shielded to minimize the EMI interferences and the crosstalk between channels.

The second stage of the preamplifier section is a passive Pole-Zero cancellation (P/Z Adj.) network and a buffer stage as impedance matcher. The P/Z Adj. stage has the purpose of reducing the decay time of the first charge-sensitive stage (of 1000 $\mu$s) down to 50 $\mu$s. Therefore, the baseline restoration is faster and the event-by-event pile-up is much reduced. The P/Z Adj. works properly up to 30-40 kcps for mean energies up to 5-6 MeV.

The output buffer designed in two versions,

- with two unipolar outputs in the case of 6-fold segmented detectors and
- with a balanced differential output *s* of either polarity, jumper selectable.

For the 6-fold segmented detector configuration, a second amplifier serves as an output buffer and allows preamplifiers conversion gains of 175 mV/MeV or 350 mV/MeV, solderable jumper selectable.

For the 12-fold segmented detector configuration, a more complex reconfigurable output buffer has been designed (Fig. 2). The two outputs of the preamplifiers can be configured either as unipolar outputs of either polarity. In such a way also a fully differential signal transmission mode can be implemented, to enhance the rejection to common-mode noise and disturbances picked up along the output cable. The operational amplifiers selected for the output stage, namely the LM6172 in the case of single ended outputs or the LM6171 in the case of optional differential outputs, features low noise, low power and fast settling time. They have been chosen due to the overall power consumption limitation of the triple cryostat, holding the three segmented detector with a total number of 21 (or 39) spectroscopic channels, namely, - the core channels (3x1) and - 18 (or 36) segment channels (in the of 6-fold or 12-fold segmentation, respectively).

The preamplifiers intrinsic rise time is about $\sim$ 13 ns (0 pF detector capacity and cold part at $\sim$ 150 K) with a slope of $\sim$ 0.3 ns/pF (detector capacity seen in the position of the gate pin of the cold jFET) without noticeable overshoots or undershoots. The full technical specifications of the Miniball front-end electronics are shown in Table 1.

In its standard way of cabling in the Miniball frame, the preamplifiers output signals are transmitted from the triple-cryostats to the remote fast ADCs of the DGF-4C modules through 15 m coaxial cables, which make the preamplifier assembly suitable for clean experimental environments. By using the upgraded preamplifiers with differential buffer output stages, the signals can be transmitted to the remote ADC modules through individually shielded twisted pair cables assemblies, preserving the original quality of the signals over 10-15 m cable length, which makes the preamplifier assembly suitable also for much noisier experimental environments.

## References

[1] DGF-4C Rev.D(E) 40 MHz Multichannel Digital Gamma Finder in CAMAC format, XIA LLC, 31057 Genstar Rd., Hayward CA 94544. *http://www.xia.com.*