Test of a Fully Integrated CMOS Preamplifier for HPGe Detectors

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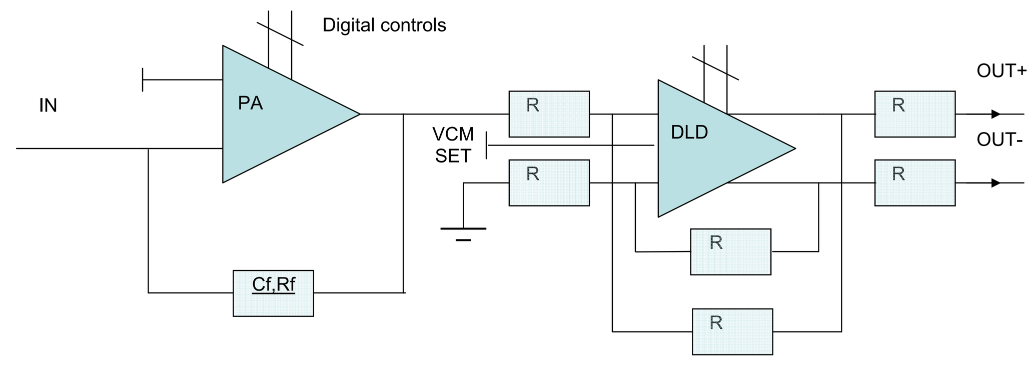
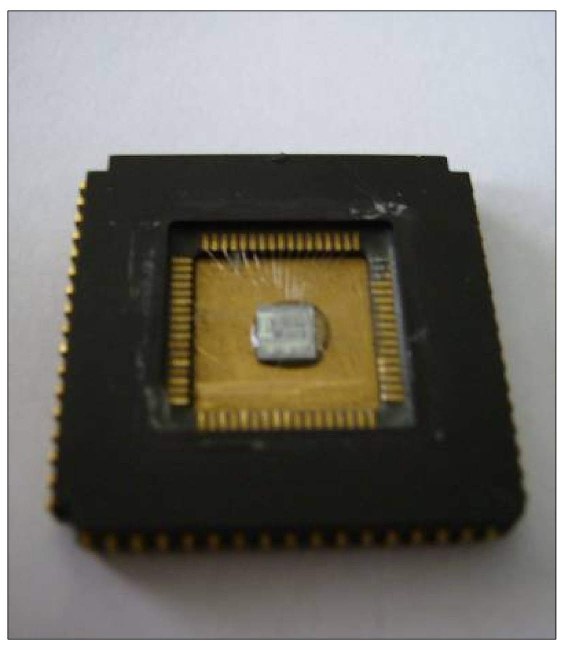
Research target:

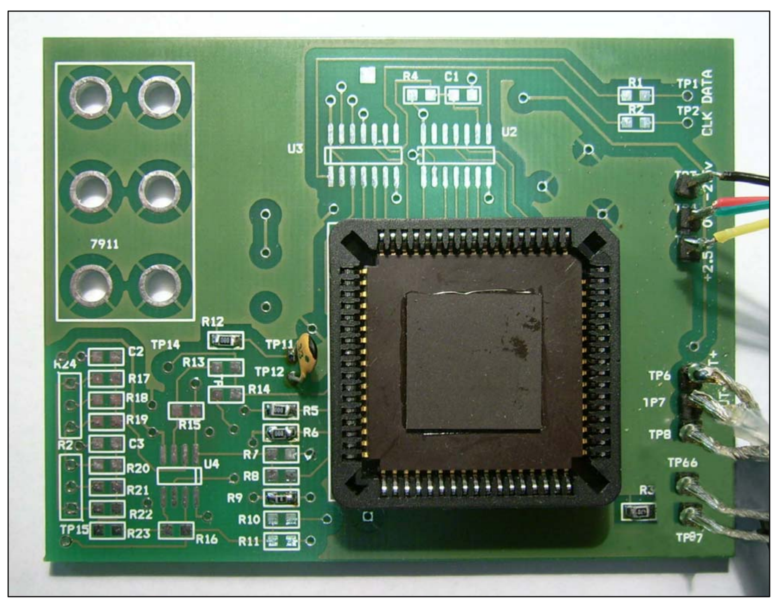
- Low noise preamplifier for HPGe detectors
- Differential output signals into low Z terminated cables
- Power consumption
- Reliability
- Specifically designed for the Gerda experiment *(http://www.lngs.infn.it)*
- Operation at both Room Temp. and Cryogenic Temp. (77K)
- Small volume



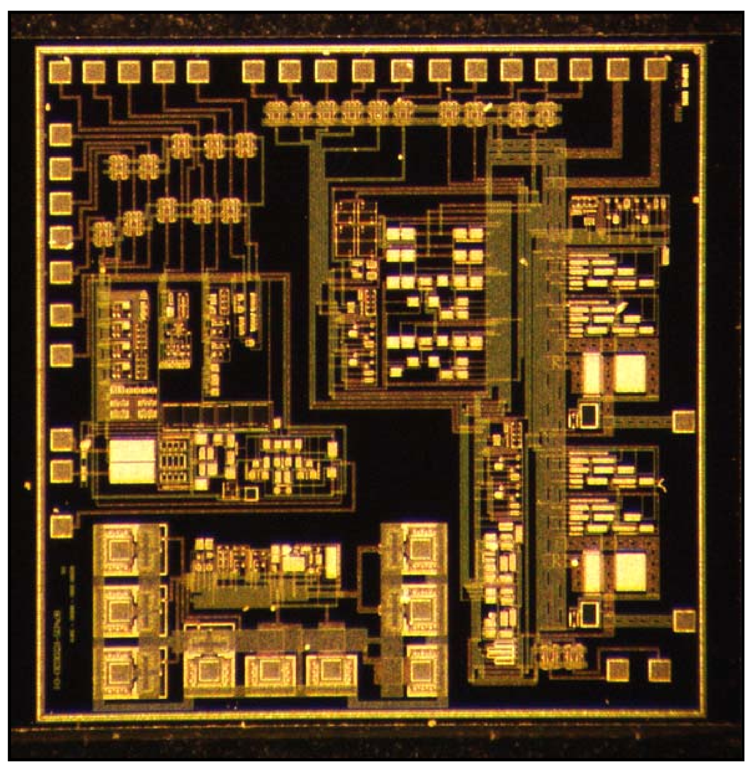
Schematic design of the front-end electronics, showing the preamplifier (PA), the fully differential line driver (DLD) and a few discrete passive elements on the PCB (resistors and capacitors) that will be also integrated in the forthcoming version of the electronics. The DLD line driver has an additional input to set the common mode voltage of the output signals.



Ceramic chip carrier (LCC 68 pin) containing the bonded IC (preamplifier and fully differential line driver). This chip carrier allows easy removing and substitution of integrated circuits during tests.



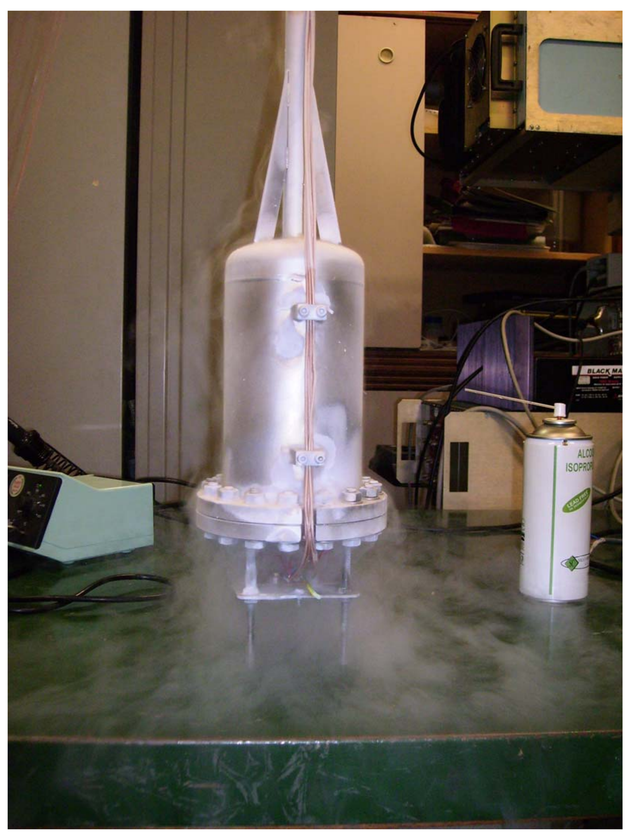
Two layers prototype printed circuit board to test the integrated circuit. The six mounting holes on the upper right side of the board are specifically designed to suspend the electronics in the liquid nitrogen tank of the Gerda experiment. Size of board and integrated circuit ceramic carrier are optimized for functionality and not for area. A few discrete SMD resistors have been allocated on the board to allow easier debugging and will be integrated in the future version of the circuit.



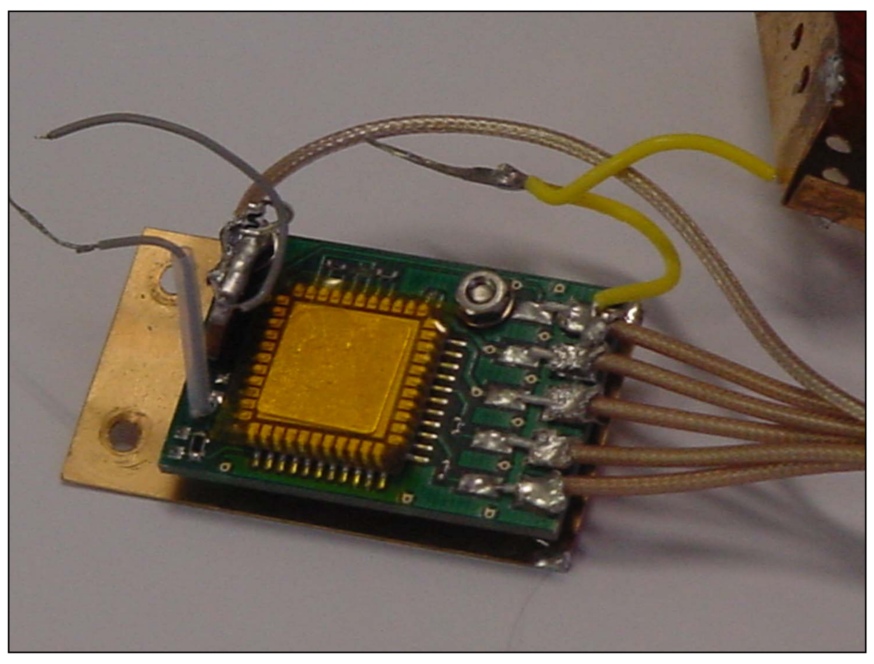
The integrated circuit, in CXZ high voltage 0.8 um CMOS technology by AMS. Actual area of the single channel prototype is 3 mm by 3 mm, substantial area reduction is possible in multi-channels prototypes.
14 Pads are just used to set the bias current levels in the integrated circuit through digital voltage levels and will be substituted by a serial to parallel converter with only 3 input pads. A few more pads will be eliminated by connecting the preamplifier to the differential line driver directly on chip.

Set-up of the energy resolution measurement test in Milan. The encapsulated germanium detector, Dewar container, mechanical holders and vacuum pump have been provided by the Gerda experiment.

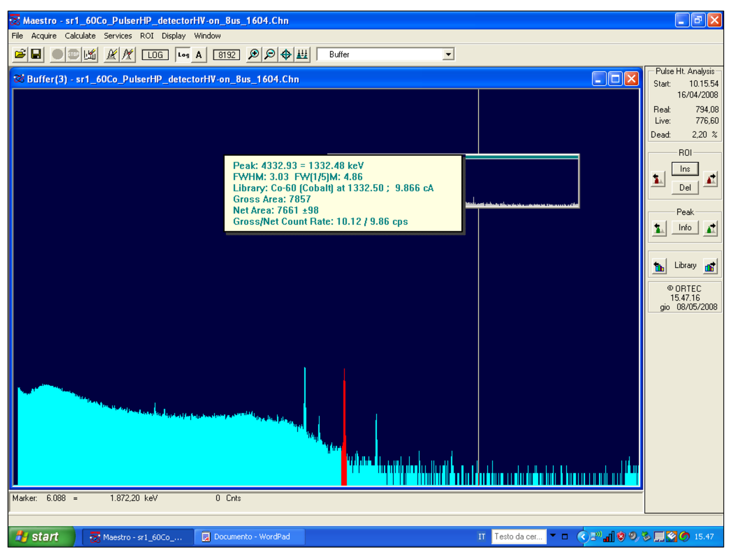
In order to simulate as much as possible the experimental set-up of the Gerda experiment, we used a specifically designed Dewar container filled up with liquid nitrogen to cool down an encapsulated p-type HPGe detector

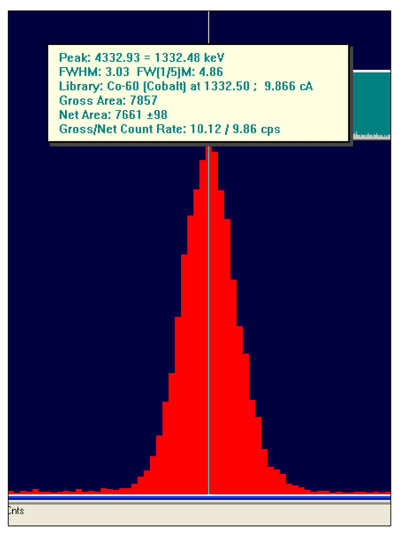


The encapsulated HPGe detector just removed from the dewar container. Special care has been taken to avoid excessive ice deposition on the electrodes and the electronics.



The new prototype printed circuit board to test the integrated circuit. Board size (25 x 40 mm) is much less than the previous one, in order be able to test the circuit inside small volume cryostats. Connection to the detector are provided by the two single wires. The high voltage capacitor is also visible on the left of the board. On the right of the board five coaxial cables provide connections for power supply, test signal and output signals. This smaller printed circuit board equipped with 0.5 pF feedback capacitor, 600 MOhm feedback resistor and a different bonding wire scheme will make it possible to test the preamplifier also with lower capacitance n-type HPGe detectors and consequently improve the energy resolution.

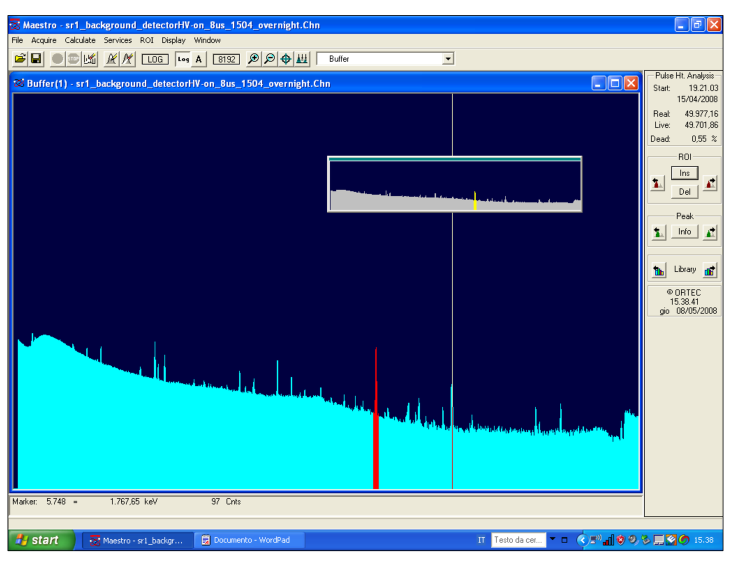


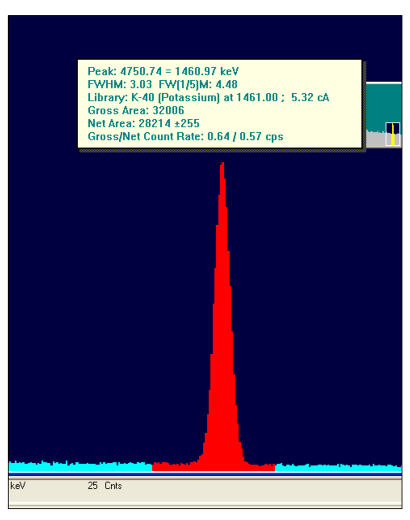


60Co spectrum obtained at relatively high counting rate (4000 events/s)
Energy resolution of the 1.32 Mev 60Co peak is 3.03 Kev FWHM and energy resolution on the pulser line (≈ 1 Mev) is 2.4 Kev FWHM, both at 8us shaping time, worse than expected from previous measurements with spectroscopy pulsers and simulated detector capacitance (1.2 Kev @ 12 us shaping time).
This may be seen as a result of: i) encapsulated detector capacitance (indirectly estimated to be 60/70 pF during high voltage ramping) larger than the expected value of 33 pF; ii) detector leakage current larger than expected and feedback resistor lower than before (1 GOhm resistor produced too much pile-upped pulses for the MCA), which didn't allow operation at longer shaping times; iii) stray capacitance on the preamplifier input node due to parasitic effects of the bonding wires (15/20 pF).

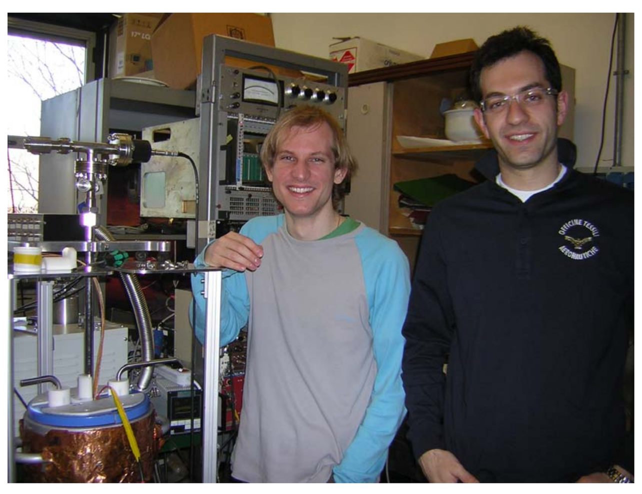
Cf = 1 pF, Rf = 300 MOhm, Rout = 50 Ohm, Power supplies = ± 2.5 v, FDA gain = 2.4	
BW (PA+FDA)	≈14 MHz
Rise time (PA+FDA)	25 ns
Idle bias current	9 mA
Output voltage swing (before 50 Ohm series res.)	± 2 v

Main results from the prototype front-end electronics setup.





Natural background spectrum acquired overnight (16 hours) at very low counting rate
Energy resolution of the 1.46 Mev peak of 40K is 3.03 Kev FWHM,
with no noticeable evidence of peak shifts.



Conclusions:

- Operation at both room temperature and cryogenic temperature (77 K)
- Low noise preamplifier for HPGe detectors (< 200 e rms with Cdet = 33 pF)
- Relatively fast (< 27 nS) rise time for 2v amplitude output signals, not significantly slew rate limited
- Differential output signals into low Z terminated cables (100 Ohm)
- Large dynamic range (8v differential) into 100 Ohm terminated cables
- Power consumption (< 50 mW / channel)
- Flexibility (e.g. from 10 pF to 50 pF detector capacitance with no change of feedback capacitor but only polarizing currents)
- Reliability (both for human and machine ESD)
- Specifically designed for the Gerda experiment *(http://www.lngs.infn.it)*
- Operation at both Room Temp. and Cryogenic Temp. (77K)
- User controlled tuning of input PMOS transconductance
- Small volume (expected 2 mm^2/channel in multichannel applications)