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Development and test results of a readout chip for the GERDA experiment

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The F-CSA104 is a low noise, fully integrated, four channel preamplifier produced in the CMOS 0.6um XFAB XC06 process, which has been developed for the GERDA experiment. Each channel contains a charge sensitive preamplifier (CSA) followed by a fast differential line driver for driving a 100 Ohm twisted pair cable over 10m. It has a measuring sensitivity of 5.8 mV/fC with an expected ENC of 220e- after 20us CR-(RC)4 filtering when connected to a 30pF load and operating at room temperature. Depending on pulse rate and noise requirements the preamplifier's feedback resistor may be adjusted in fine steps from 1 MOhm to 2.2 GOhm. F-CSA104 has been particularly designed to operate in liquid nitrogen (T = 77K/-196℃).

Summary

The GERDA experiment under construction at the Gran Sasso Laboratory is searching for neutrinoless double beta decay of 76Ge. Germanium diodes immersed in liquid nitrogen serve as sources and detectors. Since the detectors are operated in an unprecedented low background environment the amplifiers, which are operated close to the diodes in liquid nitrogen, have to fulfil stringent requirements on low radioactivity, noise performance and be able to drive the signal off detector. The F-CSA104 has been designed to fulfil these requirements by an appropriate technology choice and optimised architecture.

The F-CSA104 has been fabricated in the XFAB 0.6 um CMOS process as it offers a large signal output voltage swing (5V operation voltage), bulk-effect-less(i.e. substrate isolated) NMOS FET devices and no noticeable noise penalty over XFAB's 0.35um CMOS technology. For the low operating temperature of -196℃ the simulation's temperature was matched to the measured device characteristics.

For the GERDA experiment it is desirable to have a completely integrated circuit so as not to degrade the radio-purity of the liquid nitrogen vessel. In particular, integrating the large feedback resistor of the CSA. However, integrating such a large resistor required the use of a substrate isolated NMOS FET operating in the sub-threshold region. Special electronic circuitry and layout has been used to allow the NMOS FET resistor to work in both signal input polarities and to maintain a reasonably accurate and stable resistance.

The F-CSA104's noise performance has been optimized for use with capacitive detectors of 1 - 100pF. Measurements have shown that a PMOS input transistor suffered less flicker noise than an NMOS; Flicker noise being the dominant noise contributor at liquid nitrogen temperatures for optimal filter constants. To minimise the thermal noise, a large width over length PMOS input transistor channel of 9000/0.6 has been implemented. Layout techniques for this transistor have been used to reduce the stray capacitance and to screen the input line from bulk noise. So as the F-CSA104 may find use in other applications where the noise matching to higher capacitance detectors is vital, an external PMOS FET may be connected to the IC and thus operates in place of the integrated input transistor.

A range of F-CSA104's parameters, including offset and preamplifier decay constant, can be programmed by I2C commands for optimisation. Further to this, several options exist to select various reference points for sensitive nodes.
An example of this would be the bulk node of the input transistor which can be selected to be either supplied externally (to further reduce bulk resistance noise) or be on chip ground.

F-CSA104's linearity and offset have been designed for use with 14 bit ADC systems. Linearity requires a large open loop gain of both preamplifier and buffer core cells (120 db and 92 db, respectively). This large open loop gain also minimises signal-induced input voltage shifts (max. 0.44 uV) and thus minimises charge collection deficit. Offset cancellation is achieved by a triple DC offset suppression scheme.

The F-CSA104's measured power consumption, noise, S/N and signal output rise and fall times are presented for both room and liquid nitrogen operating temperatures. Other measurements of interest are also presented such as the power supply rejection ratio, channel cross-talk and common mode rejection ratio.

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