



A Low-Noise Charge-Sensitive Amplifier for Gain-less Charge Readout in High-pressure TPC

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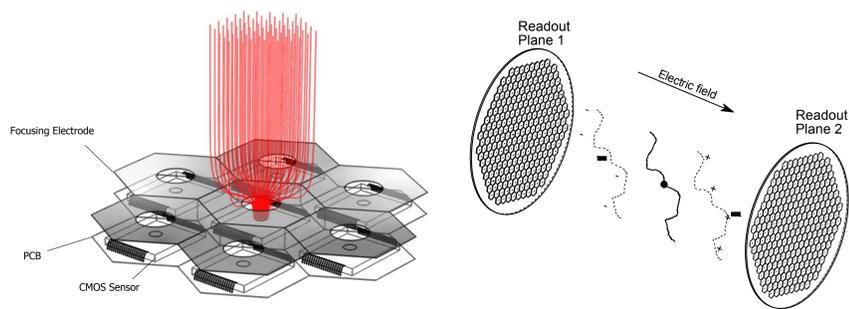
Abstract

We present a low-noise Charge-Sensitive Amplifier (CSA) manufactured in a standard 0.35 μm CMOS process. The CSA is part of an integrated sensor named Topmetal-S, with an array of which, forms a charge readout plane in a high-pressure gaseous Time Projection Chamber (TPC) for $0\nu\beta\beta$ search. A single-ended folded cascode amplifier with a 73 dB open-loop gain and 340 MHz gain-bandwidth product forms the main amplification stage in this CSA. Measurements show that the conversion gain of the CSA with a 3 fF feedback capacitor is 168 mV/fC. The equivalent noise charge of the CSA after a trapezoidal pulse shaper is $28.7e^-$ rms with a 5 pF detector capacitance.

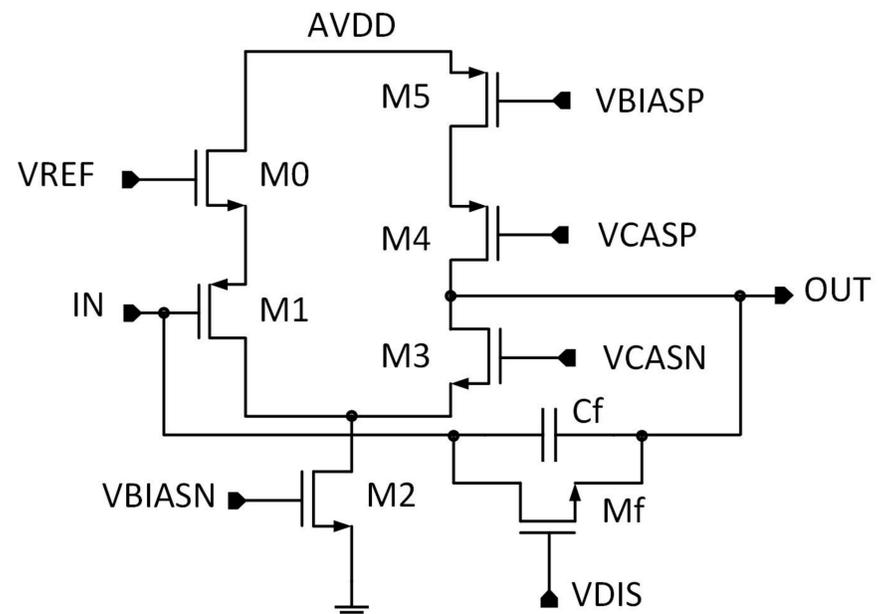
Introduction

Topmetal sensor for a next-generation high-pressure gaseous (TPC) to search for neutrinoless double-beta decay ($0\nu\beta\beta$):

- Topmetal sensor advantage: directly collecting ionization charges without gas-electron multiplication
- Energy resolution: < 1% FWHM
- Charge Collection Electrode : 1 mm diameter
- Pitch: 5 mm
- 105 sensors for a large plane



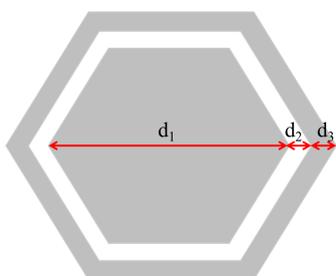
Charge-Sensitive Amplifier (CSA)



CSA:

- A regulated single-end folded cascode amplifier is proposed in this CSA.
- A p-type transistor is chosen as the input device because it has a lower flicker noise contribution compared to an n-type transistor.
- The open-loop gain of the amplifier is about 73dB.
- All biases could be tunable through digital-to-analog converters with low-pass filters, respectively.
- The total current consumes about 2mA.
- The gain-bandwidth production is around 340MHz.
- The rise time (20% ~ 80%) is less than 440ns.
- $C_f = 3\text{fF}$

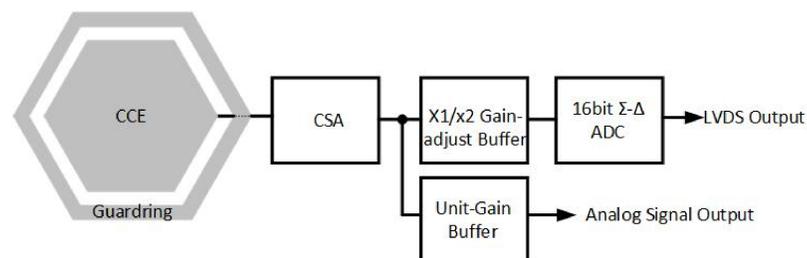
Charge Collection Electrode (CCE)



CCE:

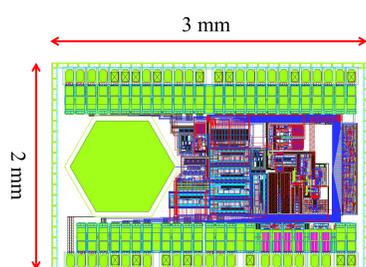
- top metal exposed around media
- directly collecting ionization charge
- DC coupled to the front end
- hexagon shape with a diameter of $d_1 = 1\text{ mm}$
- 5 pF capacitance
- top-metal guardring surrounding the CCE with a spacing of $d_2 = 45\ \mu\text{m}$ and a width of $d_3 = 4.7\ \mu\text{m}$
- injecting charge by a parasitic capacitance of 1.186 fF
- focusing electric field

Test Chip - Topmetal-S

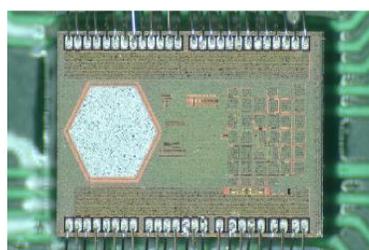


Building Blocks:

CCE, CSA, $\times 1/\times 2$ Gain-adjust Buffer, Unit-gain Buffer and 16 bit $\Sigma\text{-}\Delta$ ADC

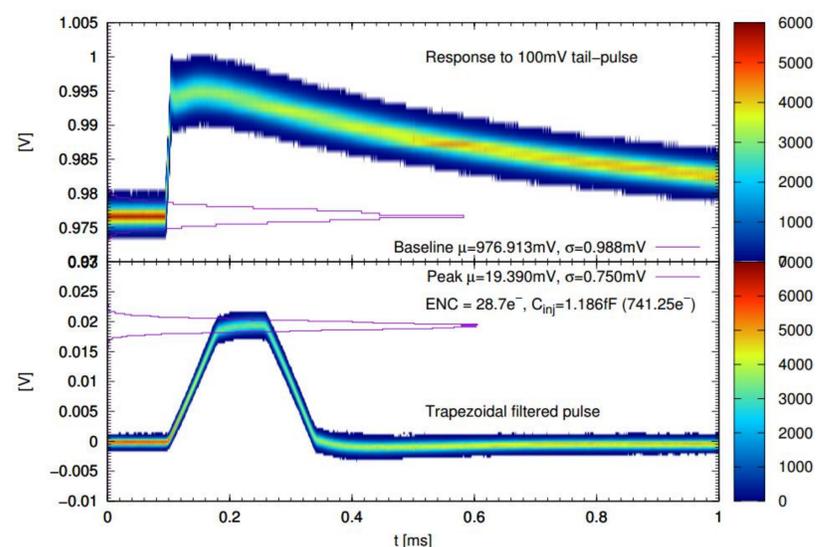


layout



microphotograph

Measurement Results



- The conversion gain of the CSA with a 3fF feedback capacitor is about 168 mV/fC.
- The equivalent noise charge of the CSA after an off-chip digital trapezoidal pulse shaper is $28.7e^-$ rms with a detector capacitance of 5 pF.

Summary and Outlook

A low-noise charge-sensitive amplifier has been manufactured in a 0.35 μm process. Measurement shows it has an equivalent noise charge of $28.7e^-$ with a detector capacitance of about 5 pF. The characteristic satisfies the requirement of the $0\nu\beta\beta$ experiment. We will also study and design a new charge-sensitive amplifier with a lower noise in the future.