Sensor Interface for a Resonator-type Mass Spectrometer

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A highly sensitive sensor interface has been developed for application in ion mobility spectrometers or mass spectrometers based on ion oscillation, such as linear electrostatic ion traps, to sense the ions flying back and forth through ring electrodes. The detection principle has been validated with a discrete implementation, before the realization of a dedicated ASIC.

The electronic interface described here is an ion detector for a mass spectrometer, where focused ion bunches, accelerated to 4 kV, oscillate between two electrostatic mirrors. The oscillation frequency is mass-dependent: it is inversely proportional to the square root of molecular mass. For ion sensing, a metal, ring-formed sensing electrode is used. The ring electrode is electrically biased at a constant potential versus the system ground and is supposed not to disturb the trajectories of flying ions. Keeping the ring electrode at constant potential requires that, when charged particles pass through the ring, a mirror charge is induced electrostatically at the ring electrode. That charge is converted to voltage by an amplifier as a differential, continuous-time signal for off-chip analog-to-digital conversion. The gain of the sensor can be expressed in equivalent inverse capacitance, or in microvolt per electron. After analog to digital conversion, the data is post-processed to extract the information about ions flying through the ring electrode: peak amplitude corresponds to the amount of particles in each bunch and the frequency of the peaks is related to the molecular mass.

In a first step a discrete amplification chain embedded on a PCB has been used to test the principle under real conditions. Figure 1 shows measurement results where a bunch of Xe+ ions crosses two electrodes flying first in one direction (white trace first, then red) and then the same electrodes flying in the opposite direction (first red, than white).

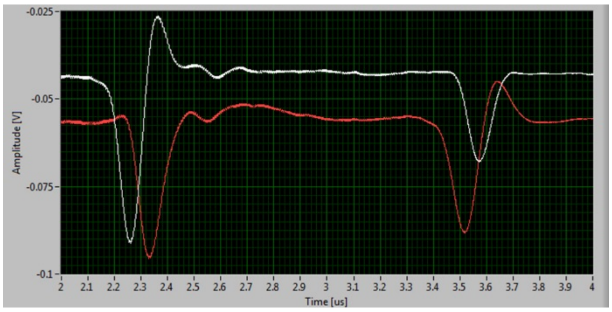

Figure 1: Measurements with a bunch of ions.

To further increase both sensitivity and bandwidth, a dedicated ASIC has been designed.

The most relevant parameters of the ASIC are: noise level, dynamic range and bandwidth. The noise floor limits the minimum number of particles that can be resolved. Since the detection noise – in terms of electron charges – is a product of the input-referred noise of the front-end amplifier by the input capacitance of the front-end amplifier, both have to be minimized for optimum performance. In order to minimize the input capacitance down to 900 fF, the ring electrode is directly manufactured on top of the ASIC through a special pad. The bandwidth of the detector needs to be large enough to correctly amplify even the shortest pulses of 1.3 ns duration, caused by highly-focused hydrogen ions.

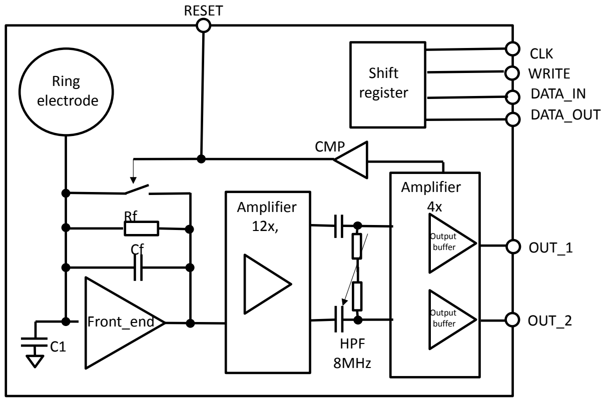

Figure 2: ASIC architecture.

Figure 2 presents the architecture of the ASIC. The first stage of the amplification channel is realized by the front-end amplifier, where the charge-to-voltage gain is determined by a feedback capacitor Cf. In parallel there is also a feedback resistor Rf to DC-bias the amplifier input. Since the effective gain of the whole ASIC is 29 µV/e-, the remaining amplification and single-ended to differential conversion, is performed by a cascade of two amplifiers with a respective gain of 12x and 4x. Those amplifiers are separated by a high pass filter. The last stage is the output buffer designed to drive 50 Ohm / 20 pF output to the external analog to digital converter. The reset can be activated externally, or when the comparator CMP detects an output stack in case the ring electrode acquired too much charge because of a large ion bunch. The configuration of the sensor is controlled by a shift register.

Figure 3 shows the layout of the ASIC, realized in a 65 nm process. Area is 2.85 mm^2. Noise floor is 117 e- rms. The signal bandwidth spans from 8.5 MHz to 350 MHz.

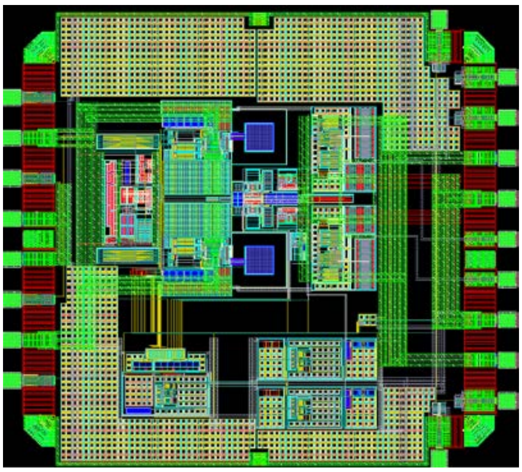

Figure 3: ASIC layout.