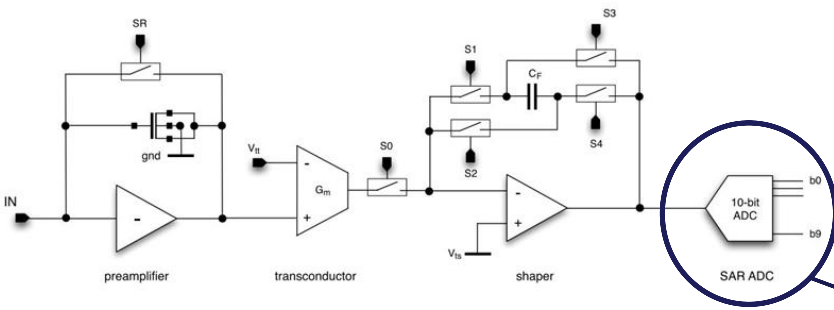
In-pixel conversion with a 10 bit SAR ADC for next generation X-ray FELs

Luca Lodola on behalf of the PixFEL collaboration
luca.lodola01@universitadipavia.it

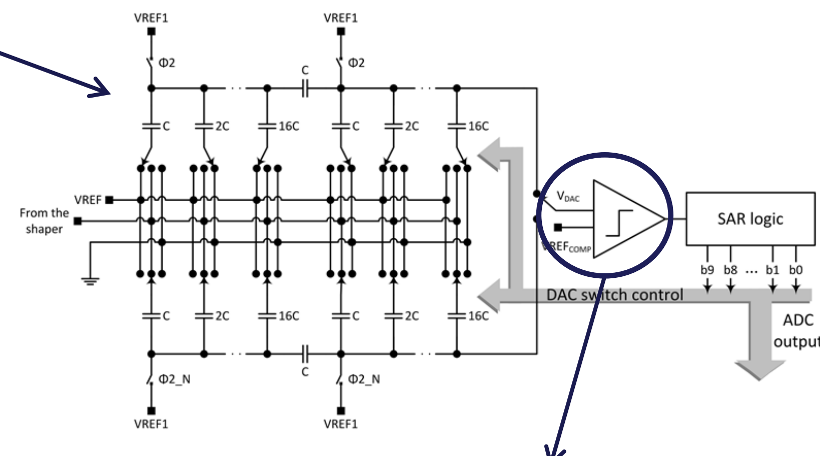
This work presents the design of an interleaved Successive Approximation Register (SAR) ADC, part of the readout channel for the PixFEL detector. The PixFEL project aims at substantially advancing the state-of-the-art in the field of 2D X-ray imaging for applications at the next generation free electron laser (FEL) facilities, developing the fundamental microelectronic building blocks for the readout channel.



- Charge sensitive amplifier with a dynamic compression feature based on the nonlinear behaviour of a MOS capacitor in the feedback network.
- Transconductor with enhanced linearity properties.
- Fip-capacitor filter performs trapezoidal, time-variant shaping of the signal.
- A-to-D.

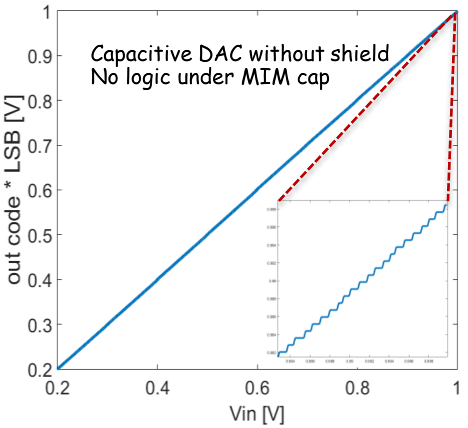
SAR ADC:

- 10 bits resolution
- Charge redistribution architecture, with a split capacitor approch: area reduced by a factor $2^{N/2}$.
- Time-interleaved structure to speed up the ADC operation, while avoiding large current peaks during the charging phase of the capacitive DAC, with the drawback of doubling the area occupation. During each sampling period, one DAC is precharged directly by the output stage of the previous block of the readout channel (the shaper), while the sample stored in the other during the previous sampling period is being converted.



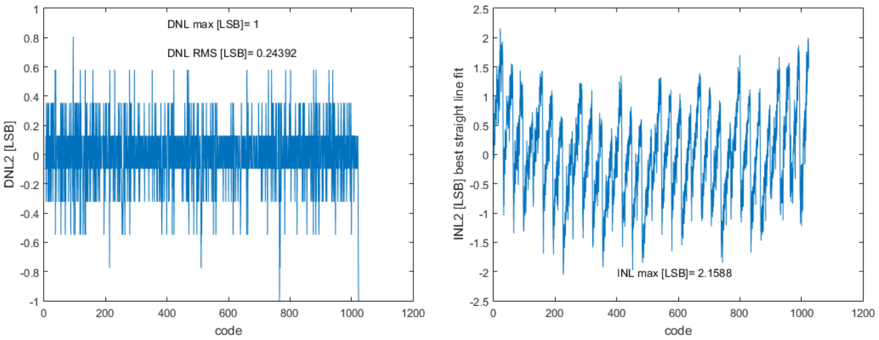
The discriminator is a three stage circuit including a preamplification block and a dynamic latched comparator consisting of a second gain stage and a latch.

Experimental results

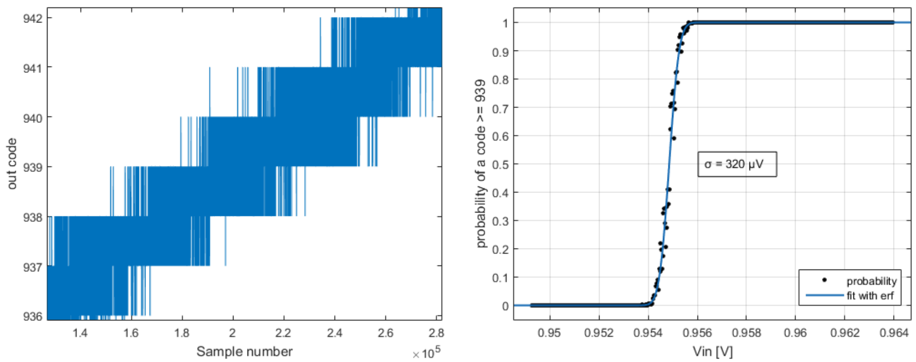


- Complete static characteristic through the whole input range.
- Inset showing the final part of the characteristic, where single photon resolution is required for FEL application.
- DNL and INL in that region is less than 0.5 LSB.

- Linearity performance measured with the ADC operated with a 20 MHz clock (~1.8 MHz conversion rate).



- Input referred noise about 320 μV (~0.4 LSB).



Layout version	Area [μm^2]	DNL max [LSB]	DNL rms [LSB]	INL max [LSB]
Capacitive DAC shielded; no logic under MIM cap	97 × 74	2,2	0,45	2,1
Capacitive DAC shielded; logic under MIM cap	97 × 58	2,3	0,40	2,4
Capacitive DAC without shield; logic under MIM cap	97 × 58	1,6	0,33	3,6
Capacitive DAC without shield; No logic under MIM cap	97 × 74	1,0	0,24	3,2

- A 10-bit SAR ADC for application to X-ray FEL with extremely small area and power consumption for application to X-ray FEL experiments has been designed.
- Different solutions have been integrated to investigate the effects of digital signal switching and metal shielding on the performance of the converter.
- The first static characterization results show that a good performance, with a DNL ≤ 1 LSB and smaller than 0.5 LSB in the single photon resolution region, is obtained for at least one of the four tested versions of the ADC.