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# LOW POWER CMOS FRONT-END FOR MEDIACAL APPLICATION


## Edoardo Bianco

## Supervisor: Prof. Angelo Rivetti


## Research context and motivation

- During the Phd. my focus was mainly on developing mixed signal electronics for monolithic silicon pixel particle sensors for medical applications useful in different types of therapies.
- However, this kind of sensor is used in many industries such as:
- High physics energy, Astroparticle Physics, Biophotonics & Science and 3D ranging (automotive , LIDAR).

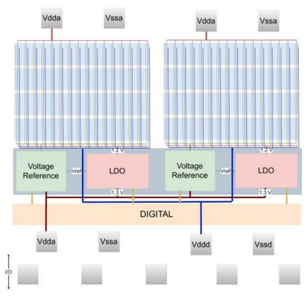
- High granularity active pixel detectors employed in medical applications can be found in two main flavors:

1. Hybrid pixels are composed of two silicon substrates joined by a bonding layer.
2. Monolithic pixels have the sensor array and its front-end electronics embedded on the same CMOS wafer

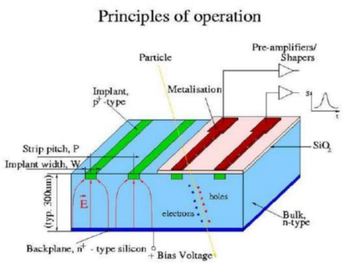
- My work is developed inside the ARCADIA's framework. The pixels developed in this framework are not only monolithic but also fully depleted. Hence, this type of pixels, require more complex wafer processing but the charge is collected mainly by drift, which leads to a faster collection time and allows to higher Signal to Noise Ratio

## Addressed research questions/problems

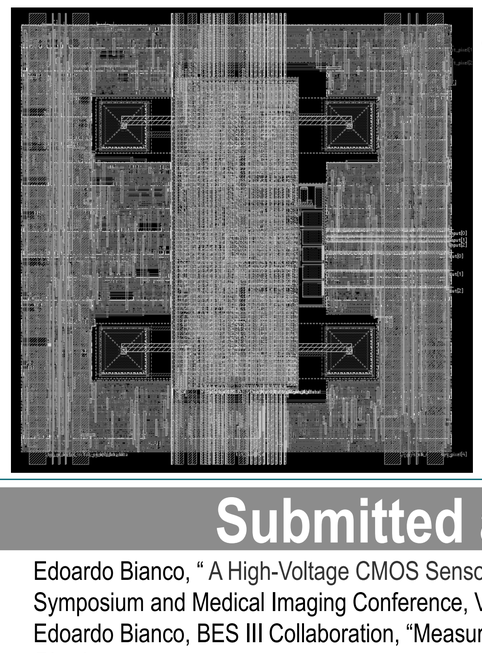
- The focus of my Ph.D. was to follow the development of different components within ASICs for particle detection, through monolithic pixels, developed in the ARCADIA projects. The major challenges were working in a low-power, low-noise and mixed-signal environment.
- In the first work, I participated within a project that set out to create a particle detector be entirely modular. In this project I made the power managment system modular through a compact LDO that could be inserted inside chips. Specifically, the system was distributed, so 16 LDOs were inserted.




- In the second job I was able to work for ASTRA, a microstrip particle detector with monolithic technology. In this chip, it was necessary to digitize the signal internally so as to decrease the noise on the analog signal. Therefore, I developed a 16-channel Wilkinson ADC (dealing with both the analog and digital parts) to be inserted internally




- In my third job I worked on a chip for medical purposes currently under patent trial. In this project, compactness and the number of outputs was of vital importance, which had to remain 3: one for power, one for ground and one for signal. Through the signal line there was a need to carry both analog and digital data for internal DAC programming. Consequently, I developed a very compact digital block capable of being programmed through a single data line.



- Finally in my last job I collaborated within a project for medical x-ray detection. Specifically, this chip takes charge sharing as well as setting different energy thresholds. In this project I was in charge of the entire analog part of the chip, so developing a front end that would allow both intra-pixel communication and be able to sum charge from different channels. In addition to that I was responsible for the entire top-level implementation part of the chip.

## Submitted and published works

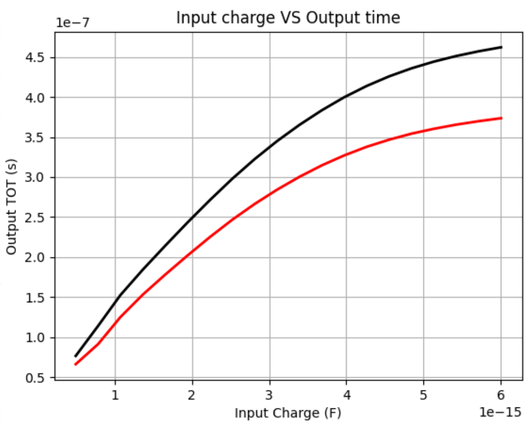
- Edoardo Bianco, " A High-Voltage CMOS Sensor with a Distributed Power Management System", IEEE Nuclear Science Symposium and Medical Imaging Conference, Virtual 2021.
- Edoardo Bianco, BES III Collaboration, "Measurement of e+e- -> omega pi+ pi- above 4.0GeV", *Journal of High Energy Physics.*
- Edoardo Bianco, BES III Collaboration, "Inclusive production of pi0/KS0 in e+e- annihilation at energies from 2.2324 to 3.6710 GeV", Physical Reeview Letter.

## Novel contributions

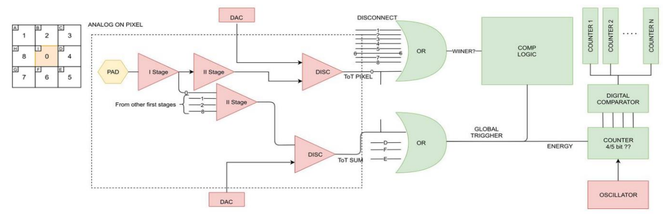
Having collaborated on several projects, the innovative contributions have been many:
Regarding the ARCADIA demonstrator, it has many innovative aspects including being the first monolithic pixel ASIC for particle detection that mounts a distributed power management system.
Within X-ray counter my contributions have been multiple. The chip is the first to have a fully digital charge sharing system and thus without the need for n comparators for charge management. It also possesses energy discrimination unique to this kind of chip. My contribution in addition to developing the entire chip was to design an analog front end capable of satisfying these particular features.

## Adopted methodologies

After an initial part of studying the issue through various journal articles. I moved on to the design phase, in which through specific tools and software I was able to study and simulate different solutions. Then, after completing the layout, we move on to post-layout simulations that determine whether excessive resistances or parasitic capacitances were inserted during the layout phase. If these simulations are successful, the design can be considered finished and it is sent to the foundry for fabrication.

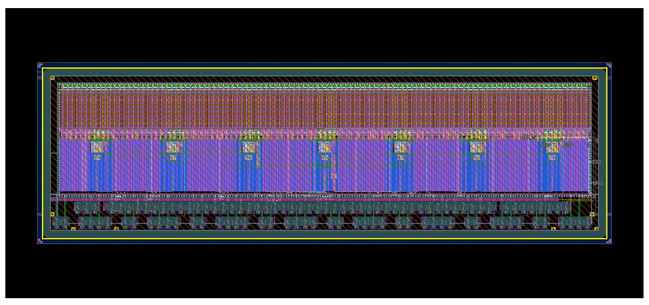



In this section we can see the output time caratteristic of the analog front end . In addition, it is possible to see simulations made by computer and the front-end schematic block of the X-ray counter.




## Future work

For X-ray counter after being tested, it will be possible to move to a chip beyond the prototyping stage. Then DACs and digital logic capable of appropriately programming the chip will need to be inserted internally. Finally after the results of the testing, it will be possible to go on to improve the deficient aspects of this version.



During the pandemic, we experienced a period when chips sent to foundries were severely delayed. Now, that the situation has been restored, and the chips are arriving regularly I can begin the testing campaign of the various projects that I have collaborated on.

## List of attended classes

- 01UJBRV – Adversarial training of neural networks (1/7/2020, 25.00)
- 01SIHRV – Bio-Nano Electronics and BioMolecular Computing (29/5/2020, 32.00)
- 04QRHRV – Life Cycle Assessment (LCA)(8/6/2020, 33.33)
- 01LXBRW – Microelectronics for radiation detection II (20/7/2021, 32.00)
- 02LWHRV – Communication (26/11/2019, 6.67)
- 01SHMRV – Entrepreneurial Finance (25/5/2020, 6.67)
- 08IXTRV – Project management (26/11/2019, 6.67)
- 01SWQRV – Responsible research and innovation, the impact on social challenges(23/2/2021, 6.67)
- 01RISRV – Public speaking (27/11/2019, 6.67)
- External - Techno week 2021 " Course on semiconductor radiation detectors" (2021, 30)

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**Electrical, Electronics and Communications Engineering**