Ph.D. in Information Technology
Thesis Defense

February 9th, 2026
At 1:00 p.m.
Room Aula 21.6.1 - Building 21

Andrea FAGNANI – XXXVIII Cycle

NEXT-GENERATION AFE-LESS READOUT ELECTRONICS FOR PIEZORESISTIVE SENSING INTEGRATED IN MEMS-BASED APPLICATIONS
Supervisor: Prof. Giacomo Langfelder

Abstract:

Piezoresistive (PZR) sensors are extensively employed in MEMS applications due to their simple implementation and compatibility with standard semiconductor fabrication processes. In MEMS-based micromirror devices, for example, PZR sensors are typically exploited to measure the angular displacement of the mirror, providing essential feedback information for closed-loop actuation. Despite their suitability for such applications, PZR sensors are inherently affected by relatively high noise levels, particularly at low frequencies, which can significantly degrade the overall system performance.

The primary objective of this work is the design of a dedicated readout chain for a PZR bridge integrated within a MEMS sensor, with particular emphasis on minimizing the noise contribution within the bandwidth of interest. Noise reduction can be pursued through two complementary strategies: (i) the investigation of methods to reduce the intrinsic noise of the piezoresistive sensing element and (ii) the emoval or optimization of circuit blocks that introduce additional electronic noise, thereby also reducing the overall power consumption and silicon area.

An initial experimental phase focused on the electrical characterization of the piezoresistive bridge and the implementation of noise-reduction techniques, with particular attention to flicker noise mitigation. Building on these preliminary results, the research progressed toward the design of an innovative readout chain architecture. The proposed architecture eliminatesa circuit block traditionally employed in comparable systems, the analog front-end, thereby simplifying the signal path.

Gabriele LAITA – XXXVIII Cycle

PIEZORESISTIVE M&NEMS GYROSCOPES: ANALYSIS AND IMPROVEMENTS FOR NAVIGATION APPLICATIONS
Supervisor: Prof. Giacomo Langfelder

The purpose of the research presented in this dissertation is to investigate and improve piezoresistive M&NEMS gyroscopes, a class of inertial sensors that combines nanoscale piezoresistive elements with micromechanical structures. These devices, despite their compact size, can reach levels

of precision once reserved for much larger and more complex navigation-grade instruments. The research began with a practical question: how much can the performance of silicon-based M&NEMS gyroscopes be enhanced through a detailed understanding and compensation both from a system and a design point of view? Addressing this question required a multi-level approach, spanning from analytical modeling and numerical simulation to device characterization, packaging analysis, and electronic system design. The research first focuses on understanding the origin of non-linearities that limit the dynamic range of piezoresistive gyroscopes and proposes an intrinsic compensation method based on the tuning of quadrature electrodes.
It then extends the analysis to long-term stability, demonstrating that slow variations in the zero-rate output can be directly related to mechanical stress in the sensing nano-gauges. By exploiting this correlation, a strategy for real-time bias compensation is introduced, showing the potential of using the sensing elements themselves as in-situ stress monitors. Finally, novel structural concepts are proposed to overcome fundamental trade-offs between sensitivity, linearity, and robustness, paving the way for new generations of high-performance piezoresistive gyroscopes.
Beyond its specific technical results, this work contributes to the broader effort of developing fully integrated MEMS gyroscopes that can maintain stable performance in real-world, uncontrolled conditions. Such progress brings these devices closer to practical use in advanced navigation, robotics, and precision sensing systems.

PhD Committee

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