Ph.D. in Information Technology: Final Dissertations

DEIB Conference Room

February 13th, 2017

9.00 am

First Ph.D. presentation and discussion:

Stefano DELLEA – XXIX Cycle

"MEMS Gyroscopes Based on Nems Piezoresistive Elements: a Comprehensive Analysis of Design, Reliability and Experiments"

Advisor: Prof. **Giacomo Langfelder**

Abstract:

The thesis discusses the design, the characterization and the development of innovative MEMS gyroscopes based on piezoresistive NEMS sensing elements. At the same time, the Thesis provides a characterization and a knowledge improvement on several aspects of the used, innovative, piezoresistive technology. In particular, the Thesis presents the design, the layout and a detailed characterization of tri-axial gyroscopes for consumer and for medical applications. These two different application fields share the same requirements: low power consumption and miniaturization. The obtained results satisfy the defined performance given by the targets specifications for both applications.

In parallel with the design of the gyroscopes, dedicated test structures are developed in the framework of the Thesis and thus described in this work. These devices enable particular characterization of mechanical and technological issues of the NEMS gauges, that are the peculiar elements of the technology. Then, the performance in terms of linearity, reliability, critical tensile and compressive stress and fatigue are discussed. The end of the Thesis is the presentation of a gyroscope which includes a further step of innovation.

Second Ph.D. presentation and discussion:

Giacomo GERVASONI – XXIX Cycle

“A Novel Architecture of Digital Lock-In Amplifier for Extremely High Resolution Measurements”

Advisor: Prof. **Giorgio Ferrari**

Abstract:

Lock-in amplifiers (LIAs) are extensively used for synchronous AC signals detection and measurement in a wide range of scientific fields, from Atomic Force Microscopy (AFM), Raman spectroscopy, to sensors and actuators (e.g. MEMS). The thesis treats the resolution limit of LIAs, leading to the development of an extremely high resolution instrument. Ideally, when using LIAs, it would be possible to measure a signal variation given by the instrument input equivalent noise and the chosen filtering bandwidth, as for the minimum detectable signal. Instead, a detailed characterization of digital LIAs has shown an unforeseen 1/f noise at the instruments demodulated output, proportional to the total signal amplitude. The signal-proportionality and 1/f nature of the measured noise, pose a fundamental limit to the LIAs achievable resolution, defined as the ratio between the minimum detectable signal variation and the total signal amplitude, typically expressed in ppm. This limit has been found to be dependent from the instrument maximum operating frequency, from few ppm for LIAs operating up to few hundreds of kHz, to few tens of ppm for LIAs operating up to few MHz or tens of MHz. The additional noise is due to slow gain fluctuations that the modulated signal experiences from the generation stage to the acquisition one, in particular due to the DAC and ADC. To compensate them, a switched ratiometric technique based on two ADCs alternately acquiring the signal coming from the DUT and the stimulus (STIM) signal has been conceived. The idea is that both DUT and STIM signals should experience the same gain fluctuations, which can be successively removed by means of a division on the outputs of the synchronous demodulation. An FPGA-based LIA working up to 10 MHz and implementing the technique has been realized and results demonstrate a resolution improvement of more than an order of magnitude compared to standard implementations working up to similar frequencies (from tens of ppm down to sub-ppm values).

Third Ph.D. presentation and discussion:

Giacomo LAGHI – XXIX Cycle

"MEMS Magnetometers: from Application Specifications to the Development and Characterization of a Prototype Beyond the State of the Art"

Advisor: Prof. **Antonio Longoni**

Abstract:

The aim of the project was to develop a 3-axis Lorentz-Force based MEMS magnetometer for heading and navigation applications, capable of overcoming several limitations of other types of commercial magnetometers, fabricated with different technologies. The development of the magnetometer has been based on the ThELMA process from STMicroelectronics, and exploits different techniques to enhance the performance of the sensor. Off-resonance operation, along with the design of multi-loop structures, allows to obtain a 30-fold improvement in terms of power dissipation for the same resulting resolution and a good stability with temperature. This is also enhanced by the design of a MEMS resonator within the same die.

A first prototype has been characterized through a custom discrete components electronics and a custom measurement setup, demonstrating the possibility to achieve performances comparable with or beyond the state of the art of commercial. A further step in the direction of area occupation and offset drifts reduction has been the re-design of the structure, switching from three 1-axis structure to a single 3-axis device. The development has been carried out with the aim to fit the magnetometer into a 2x2 mm2 package together with a 3-axis accelerometer, in order to obtain a full 6-axis electronic Compass.

PhD Committee:

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