Ph.D. in Information Technology: Thesis Defenses

July 2nd, 2021
online by Teams – at 9.00

Marco BESTETTI – XXXiII Cycle

Fully Integrated Lissajous Frequency Modulated Gyroscope

Supervisor: Prof. **Giacomo Langfelder**

Abstract:

Lissajous Frequency Modulated Gyroscopes have been recently introduced in literature and are part of a new class of gyroscopes based on frequency modulation which can revolutionize the world of MEMS rate sensors, filling the gap between consumer and high-end market segments.

This Thesis presents the development of the first fully integrated LFMG system. Advantages and issues on this working principle will be addressed, thanks to the extensive characterization routine made on a former implementation of such system featuring partial digital-output signals. Experimental results confirmed the high stability performances of this type of gyroscope, showing a bias stability of 5 °/h after 20 minutes of observation time, obtained without any calibration routine.

The exhaustive characterization made on the former system enabled to identify a set of second-order non-idealities which are first theoretically analyzed and modeled either with analytical expressions or behavioral simulations. To solve these non-idealities, some architectural changes will be presented.

The redesign of the integrated system is then discussed.

Firstly, the new MEMS structures are introduced which will be operated with the new designed ASIC. The latter is composed by three main subsystems: (i) the analog front-end oscillators, which are used to keep the moving mass in oscillation, and the secondary amplitude-control loop, which is used to set the amplitude of the displacement of the proof mass on both axes. One main achievement of this thesis is the design of a novel adaptive control loop which automatically changes the bandwidth depending on the operating condition of the MEMS sensor. The front-end subsystem provides the frequency modulated signal to (ii) the frequency-to-digital converter and a reference extraction circuit. This circuit is crucial for the whole operation of the system and can compromise its performances as pointed out from the measurement results. A novel approach on the

implementation of this block will be also presented which solves the issues found on the former version. Finally, (iii) the design of the digital processing unit is addressed, which has the role of filtering the digital signal at the output of the frequency converter and demodulating it with the reference signal on both axes. The ASIC features an SPI interface to receive the configuration of the trimming registers inside the system and to output the 24-bit signals of both channels before the resampling stage and the 24-bit signal at its output. A PCB is then designed to characterize the integrated LFMG system. The ASIC is interfaced with a STM32 microcontroller which sends the output digital signals to the PC. Preliminary measurements on the developed integrated system are finally presented.

Marco GADOLA – XXXiII Cycle

Navigation-Grade NEMS Gyroscopes

Supervisor: Prof. **Giacomo Langfelder**

Abstract:

During the last two decades, MEMS gyroscopes have spread over countless fields of application thanks to their low cost, footprint and power consumption. The continuous performance growth made this technology appealing also for the high-end markets, dominated by expensive and bulky kind of sensors. The goal of the next few years is to fulfill the requirements of inertial navigation applications, thus being able to rely on inertial sensors only to retrieve the orientation of an object. The aim of the work reported in this Ph.D. thesis is thus to analyse, design and characterize high-performance 3-axis miniaturized gyroscopes with piezoresistive readout that can fulfill the requirements of next-generation applications. The sensors presented in this work are fabricated with the M&NEMS technology by CEA-Leti, a standard MEMS process with few additional process phases, in which is possible to embed thin piezoresistive beams with nanometric cross-section for the mass movement readout. This allows to design high-performance sensors while keeping mass production costs. First, a complete design of several single axis rate sensing devices has been carried out, focusing on the electromechanical structures that allow to improve both noise and stability performances in a sensor footprint of less than 2 mm2. In particular, an innovative sensing lever system for pitch/roll devices is here presented which allows to reach sensitivity levels comparable to those of yaw gyroscopes, a fundamental achievement toward a fully planar 3-axis high-performance sensor. The characterization campaign confirmed the expected results, reaching for several yaw gyroscopes noise levels in the order of 100 µdps/√Hz and stability lower than 0.02 °/h up to 1000 s. Promising results have also been achieved with pitch gyroscopes reaching a noise of 600 µdps/√Hz, despite not having the chance to characterize the designed structure with the best expected performances. Finally, the design of a low-noise integrated circuit is presented, with a focus on the front-end architecture, aiming to reach the same performances of the discrete electronic.

PhD Committee
Prof. **Daniele Ielmini,** DEIB
Prof. **Piero Malcovati,** Università di Pavia
Prof. **Luca Pellegrino**, Università di Genova