PhD in ELECTRICAL, ELECTRONICS and COMMUNCIATIONS ENGINEERING

Research Title:
Magnetic MEMS speaker - Micromechanical structures with applications in MEMS speaker (and magnetometer) systems

Funded by	Bosch Sensortec

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Context of the research activity	In recent years, following market acceptance of MEMS microphones in mobile applications, interest in MEMS implementations of speakers has significantly increased, with the aim of improving power consumption and energy conversion efficiency, at lower cost. Structures based on both capacitive and piezoelectric actuation principles have been proposed. A device following the first approach is shown in [1]. It exploits electrostatic bending actuators distributed over all silicon area and great attention is dedicated to the optimization of the volume available for air displacement. An example of the second approach is found in [2], where a silicon membrane is piezoelectrically driven. The membrane is divided into parts separated by a small gap, thereby achieving a larger displacement with respect to a continuous membrane and hence a greater acoustic output. In the past, also electromagnetically driven solutions were proposed, more similar to macroscopic classical designs.

In [3] a device based on a permanent magnet coupled with a moving silicon membrane holding the voice coil achieves an extremely wide membrane displacement and hence a good acoustic performance. It is a miniaturized but not integrated solution. More recently, a device [4] is described that integrates a permanent magnet on an organic membrane. It reaches good performance for in-ear applications.

The proposed PhD activity is focused on the development, analysis and characterization of magneto-mechanical structures, obtained by micro-magnet deposition on silicon, that can have application in the MEMS Speaker system (and potentially in other systems, too).

The main idea is to couple such structures with coils, achieving a fully integrated MEMS Speaker solution.

The PhD student will identify, theoretically and by FEM physical simulations, the best magnetic structures and determine their key performance parameters, as well as the optimal mechanical structure for maximal acoustic output.

He will characterize the dynamics of the mechanical structure, both by simulation and by vibrometry. He will contribute to the definition of the process steps for the integrated realization of the magneto-mechanical structures.

The PhD activity will include the theoretical/simulation evaluation of the overall system performance (SPL, THD, efficiency) and, if eventually possible, its experimental characterization.

The implementation of audio signal amplification embedded into the speaker system (on ASIC wafer) will also be taken into consideration. Both class-D and class-AB solutions will be reviewed, analyzing the possibility to drive the MEMS Speaker in current mode. Topologies of both classes of amplifiers may be analyzed in order to identify new solutions or possible optimizations with respect to full system performance and cost.

These studies will possibly open the way to a low-cost MEMS Speaker implementation, both for mobile and in-ear applications.

[1] B. Kaiser et al., *Concept and proof for an all-silicon MEMS micro speaker utilizing air chambers*, Microsystems & Nanoengineering, 2019.
[2] F. Stoppel et al., *New integrated full-range MEMS speaker for in-ear applications*, MEMS 2018, Belfast, Northern Ireland, UK.
[3] E. Sturtzer et al., *High Fidelity MEMS Electrodynamic Micro-Speaker Characterization*, Journal of Applied Physics, American Institute of Physics, 2013.
[4] B. Y. Majlis et al., *Compact electrodynamics MEMS-speaker*, IEEE 2017 China Semiconductor Technology International Conference

Objectives	The PhD candidate will carry on theoretical and simulation activities, but possibly also experimental activity, whose objectives are described below. - Definition of deposited magnetic structures. - Characterization of magnetic structures in terms of the generated magnetic field. - Identification of the best magnetic structure in relationship with the electrodynamic driving function. - Identification of the best mechanical structure in relationship with the electrodynamic driving function. - Definition of process steps for the realization of the magneto-mechanical structure. - Simulation/characterization of MEMS Speaker performance parameters: SPL, THD, energy efficiency. - Feasibility analysis of on-chip audio signal amplification, impact on system - Analysis of “current mode driving” of the coils, impact on system performance

Skills and competencies for the development of the activity	The candidates should hold a Master Degree in Physics, Physics Engineering, Electrical or Electronic Engineering, Nanotechnology or related disciplines. Knowledge of MEMS processes, technology process steps and methodologies as well as experience in magnetics, magnetic devices and magnetic simulations are mandatory requirements. Basic knowledge of integrated electronic amplifiers, in class-AB and class-D, is very well considered. The candidate should speak fluent English, possess an experimental attitude and be keen to work in a multi-disciplinary research team.