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Concept and proof for an all-silicon MEMS micro speaker utilizing air chambers

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Abstract

MEMS-based micro speakers are attractive candidates as sound transducers for smart devices, particularly wearables and hearables. For such devices, high sound pressure levels, low harmonic distortion and low power consumption are required for industrial, consumer and medical applications. The ability to integrate with microelectronic circuitry, as well as scalable batch production to enable low unit costs, are the key factors benchmarking a technology. The Nanoscopic Electrostatic Drive based, novel micro speaker concept presented in this work essentially comprises in-plane, electrostatic bending actuators, and uses the chip volume rather than the its surface for sound generation. We describe the principle, design, fabrication, and first characterization results. Various design options and governing equations are given and discussed. In a standard acoustical test setup (ear simulator), a MEMS micro speaker generated a sound pressure level of 69 dB at 500 Hz with a total harmonic distortion of 4.4%, thus proving the concept. Further potential on sound pressure as well as linearity improvement is outlined. We expect that the described methods can be used to enhance and design other MEMS devices and foster modeling and simulation approaches.

Introduction

There is great demand for high performance micro electromechanical systems (MEMS) micro speakers by the consumer and by the hearing aid industry. Key factors, such as high sound pressure level (SPL), low total harmonic distortion (THD), low power consumption, small device footprint and batch fabrication possibilities are needed to outperform classic micro speaker technologies like moving coil and balanced armature receiver technology. MEMS-based micro speakers achieve all these key factors. Successful devices made with MEMS, like inertial sensors, timing devices and pressure sensors, are ubiquitous in many electronical applications. These applications range from vehicles to wearables. A prominent example is smartphones, which have all the types of MEMS mentioned above. They also include acoustic transducers, most likely appearing as multiple MEMS microphones, to aid their original primary application, voice communication. In contrast to fabrication, pricing and integration logic, today's smartphones include fine mechanical engineered, non-MEMS micro speakers. Hearables, which are wearables plugged directly into the ear canal and relying mostly on acoustics for their human-machine interface, are expected to take over the acoustic functionality of smartphones and extend their application to that of personal assistant. In earbuds, the available space is limited, thus demanding exceptional miniaturization and integration of all components including electronics, sensors, batteries, and acoustic transducers.

Several concepts for MEMS-based micro speakers have been reported in the literature. Among them are the following examples. Cheng et al.[1] published an electromagnetically driven MEMS micro speaker comprising an electroplated, micro machined membrane with a diameter of 3.5 mm and a permanent magnet assembled underneath. The device reached 93 dB at 5 kHz in a 2 cm^3 closed cavity, consuming 320 mW of power. No results for the THD were published. Chen et al.[2] used a 3.5 mm

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