Highly Miniaturized MEMS Loudspeakers for In-Ear Applications

MEMS loudspeaker chip for in-ear headphones.

Motivation

The constant trend toward miniaturization and emerging new audio applications lead to an ever-increasing demand for small yet powerful loudspeakers.

The Fraunhofer ISIT develops highly miniaturized microelectromechanical (MEMS) loudspeaker technologies suitable for in-ear applications, such as true-wireless stereo (TWS) headphones, hearables, and hearing aids. The concept is based on piezoelectrically actuated cantilevers, which are manufactured using semiconductor technologies, enabling high miniaturization as well as cost-efficient production in high volumes.

Our MEMS loudspeakers are characterized by extraordinarily high area-normalized sound pressure levels (SPLs) above 95 dB / mm² over the entire reproduction range. By varying the actuator design and integrating multiple speakers on a chip, the SPLs are almost arbitrarily scalable. Besides the unrivaled potential for miniaturization, our MEMS speakers offer high fidelity, high bandwidth, and low power consumption. Ongoing research focuses on further miniaturization, design upgrades, and the integration of new materials, such as aluminum scandium nitride, to further improve energy efficiency, sound pressure level, damping, and linearity and allow for a fully CMOS-compatible process.

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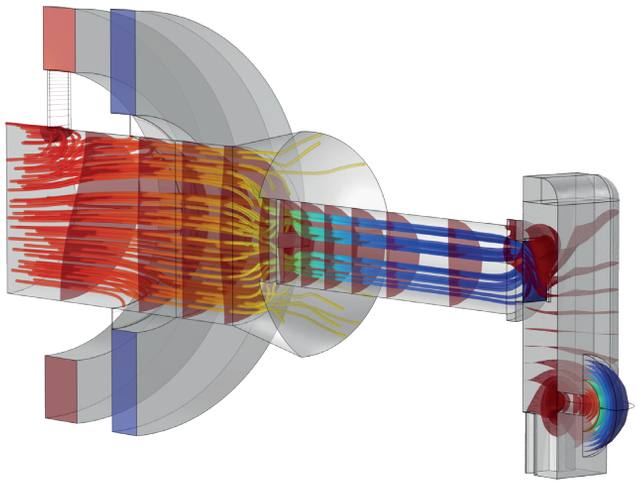
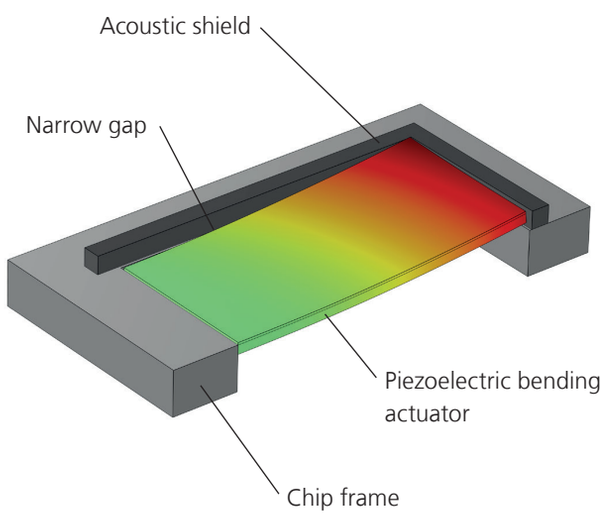


Multiphysics simulation of MEMS speakers (FEA)

MEMS loudspeaker mounted in in-ear housing

Technology

Our MEMS loudspeaker technology is based on piezoelectric unimorph bending actuators. Utilizing the inverse piezoelectric effect, an alternating electric field causes the cantilever to vibrate and create sound waves. A narrow 3 µm gap surrounding the actuator enables free vibration while making use of thermo-viscous effects to suppress any noticeable airflow through the gap. Hence, our MEMS loudspeakers acoustically behave like a closed membrane while being mechanically decoupled at the same time. The distinctive feature is the acoustic shield, which inhibits any significant gap widening when deflecting the actuator and allows for arbitrary actuator geometries, e.g., rectangular actuators, with high area-averaged deflections.



MEMS speaker concept with open membrane (section view)

Our service

- Patent-protected technologies
- Comprehensive development of MEMS loudspeakers: concept, design, manufacturing, and characterization
- Pilot fabrication of MEMS loudspeakers
- Expertise for innovative applications
- Partnership for future developments in the field of MEMS acoustics

Technical data

Our MEMS loudspeakers offer

- High miniaturization and small footprints
- SPL > 95 dB / mm² and high scalability
- High bandwidth from 20 Hz up to 40 kHz
- Outstanding reproduction quality and low distortion
- Low energy consumption
- Low cost in mass production due to semiconductor technology

Applications

Our MEMS loudspeakers are suitable for

- In-ear applications, e.g., TWS headphones and hearables
- Medical applications, e.g., hearing aids
- Free field applications, e.g., smart glasses