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XXXVII Cycle

Design of a MEMS-based electrodynamic loudspeaker

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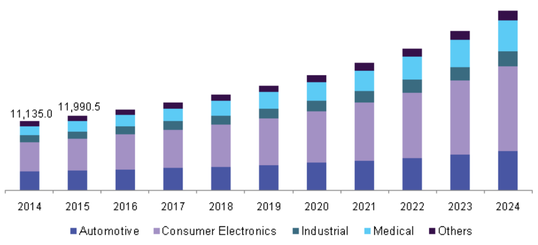
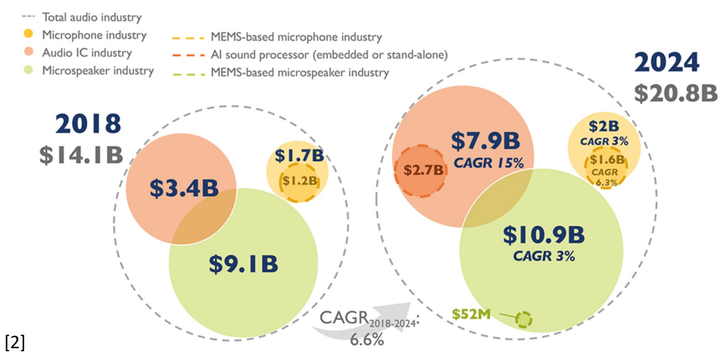
Research context and motivation

- MEMS market size is expected to be worth USD 18.88 billion by 2022, at a CAGR of 9.8% between 2017 and 2022.



[1]

- MEMS-based audio product are expected to grow consistently next years, with MEMS microspeaker industry forecasted to worth almost $11B itself.

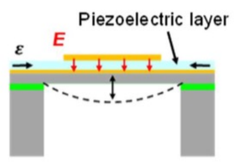


[2]

Addressed research questions/problems

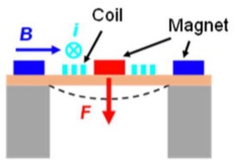
- MEMS-based loudspeaker are classified based on their transduction mechanism.

Piezoelectric



[3]

Electrodynamic



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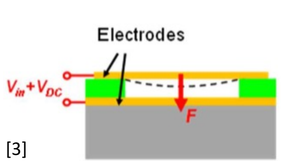
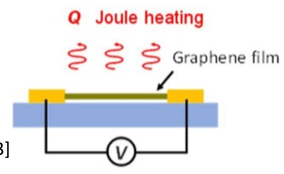
Electrostatic



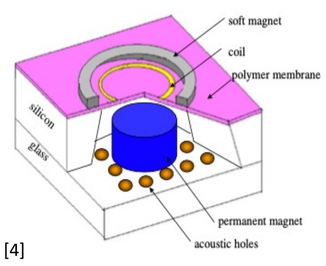
[3]

Thermoacoustic

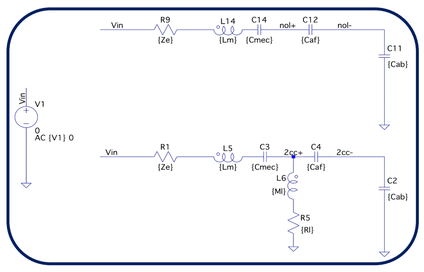


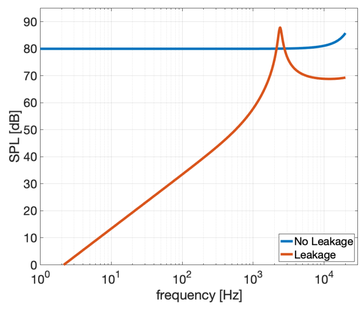
[3]

- The lumped element modeling is the fastest way to extrapolate some preliminary figures of merit from the device.



[4]





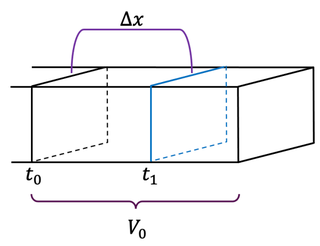
- The most important parameters to consider in a preliminary analysis are schematized here.

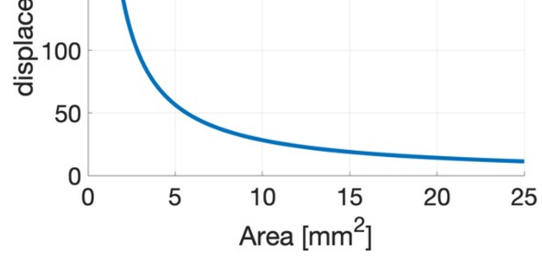
Novel contributions

- Model and simulations made starting from the gas theory in a close chamber, considering only adiabatic expansions.

Piston-like model assuming:

- Closed volume
- $\frac{dP}{P} = -\beta \frac{dV}{V}$
- $SPL = 20 \log \frac{dP_{rms}}{P_{ref}}$

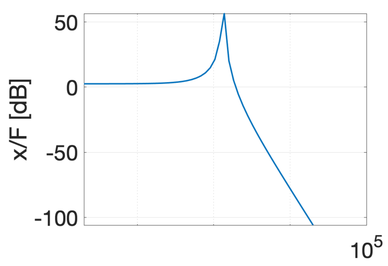




- The frequency behavior was evaluated modeling the structure as a second order oscillator, neglecting the damping at first.

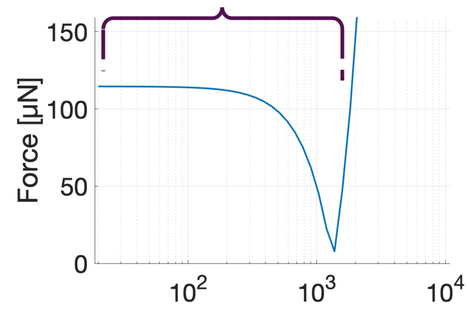
Second order oscillator:

- $F_0 = (\omega_0{}^2 - \omega^2) \cdot m \cdot x_0$



16 mm^2 active area

$\approx 2\ kHz$

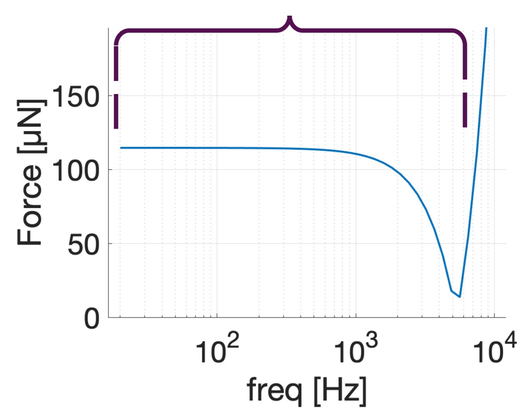


- Theoretically using a module design with multiple 1 mm² active squares, it'd possible to uncouple the area from the total mass, resulting in a larger resonance frequency $\omega_{0,1mm}$ given by the area of a single module, but with the same displacement $x_{0,16mm}$ given by the correspondent 16 mm² area. Also the total power is reduced over the linear frequency range.

Module design (16 x 1 mm²):

- $F_{0,M} = (\omega_{0,1mm}{}^2 - \omega^2) \cdot m \cdot x_{0,16mm}$
- $P = V \cdot I = V \cdot \frac{F}{Bl}$

$\approx 7.5\ kHz$



Future work

- Future work will focus on static FEM analysis using one or multiple CAD softwares, in order to describe the structure as a whole, looking at the force generated by the magnetic circuit and the relative displacement generated in the membrane.
- A careful review of the most prominent out-of-plane springs designs will also be conducted in order to guarentee the required standard from a mechanical point of view. It may be necessary to review different technologies too in case the electrodynamic will not prove able to reach the objectives set.
- Plan first PoC to characterize the response of a membrane in a magnetic circuit and possibly modify the design accordingly.

References

[1] Microelectromechanical Systems Market Size, Share & Trends Analysis Report By Application (Automotive, Consumer Electronics, Industrial, Healthcare), By Region (NA, Europe, APAC, MEA, LA), And Segment Forecasts, 2018 – 2024. Report ID: 978-1-68038-769-8

[2] Microphones, Microspeakers and Audio Solutions Market and Technology Trends 2019 report, Yole Développement, 2019

[3] H. Wang, Y. Ma, Q. Zheng, K. Cao, Y. Lu, and H. Xie, "Review of recent development of MEMS speakers," Micromachines, vol. 12, no. 10. MDPI, Oct. 01, 2021. doi: 10.3390/mi12101257.

[4] M. C. Cheng, W. S. Huang, and S. R. S. Huang, "A silicon microspeaker for hearing instruments," Journal of Micromechanics and Microengineering, vol. 14, no. 7, pp. 859–866, Jul. 2004, doi: 10.1088/0960-1317/14/7/004.

List of attended classes

- 03MLIKG – Corso seminariale del dottorato di ricerca in fisica (20h)
- 01LDVRU – Magnetismo nei materiali e misure magnetiche (13/7/2022, 20h)
- 01RHCRR – Principi, materiali e applicazioni della robotica nella biomedicine (30/5/2022, 20h)
- 02SFURV – Programmazione scientifica avanzata in matlab (26/5/2022, 30h)
- 01UNRRV – Entrepreneurship and start-up creation / I4C (4/7/2022, 40h)

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