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Dielectric elastomer loudspeaker driver

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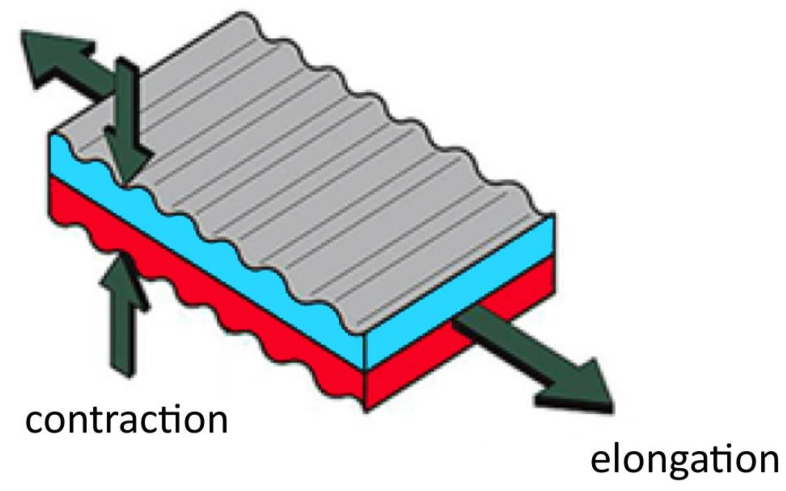
Abstract

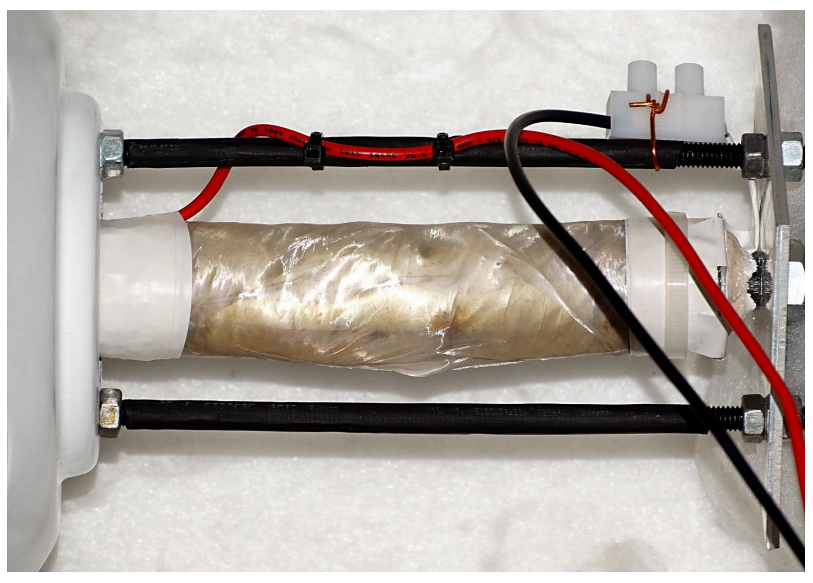
Dielectric Elastomers (DE) offer promising benefits for acoustic applications due to their large achievable strain, high energy density and small response time. Although the usage for loudspeakers is often mentioned, only few concepts have been developed and realized. Most prominent are speakers based on vibrating DE-diaphragms. However, these speakers are not competitive to conventional electrodynamic speakers so far. The main reason is their inability to produce significantly large sound pressure levels due to their low mechanical and acoustical impedance. We investigate and realize an alternative approach to loudspeakers based on DE. The driving unit of the speaker is a core-free rolled DE-actuator with improved electrical contacts for optimized frequency response and reliability. An electromechanical network model is designed to describe the actuator's dynamic behavior. The network parameters are determined by extensive measurements with different mechanical loads and bias voltages. The model is extended to the acoustical domain introducing a speaker cone and enclosure. Due to the gyratory behavior of the radiating surface the mechanical behavior can be transformed to maximize the sound power output. This approach allows the realization of DE-based speakers for a versatile range of applications with many benefits to conventional concepts.

Construction

- material: "Danfoss PolyPower" (corrugated polysiloxane, 80 µm thickness, 90 nm silver electrodes, breakdown voltage <5 kV)
- corefree roll-actuator, approx. 5.5 m material
- 13 cm length (9 cm active material length, 2 x 1.5 cm electrode contacts)

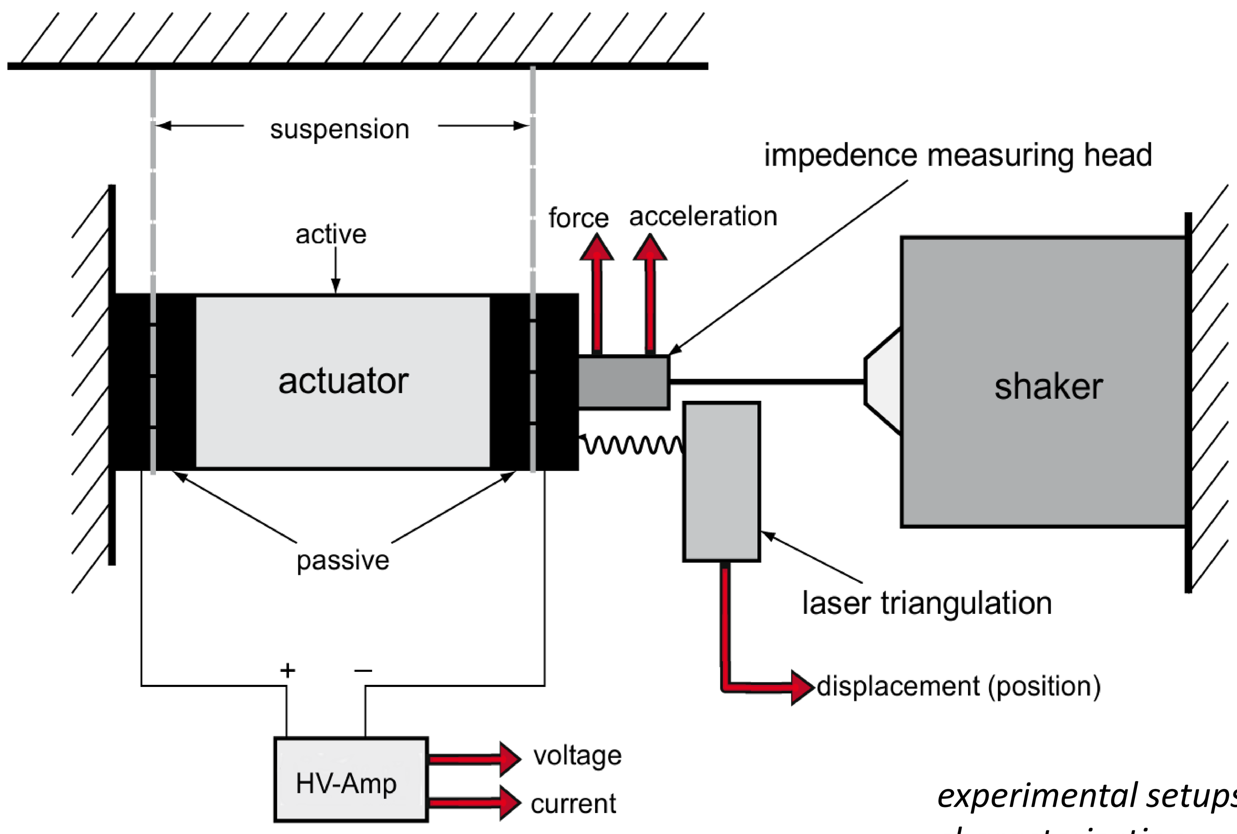


Danfoss PolyPower material (laminate of 2 composites) [1]



Actuator assembly and mounting

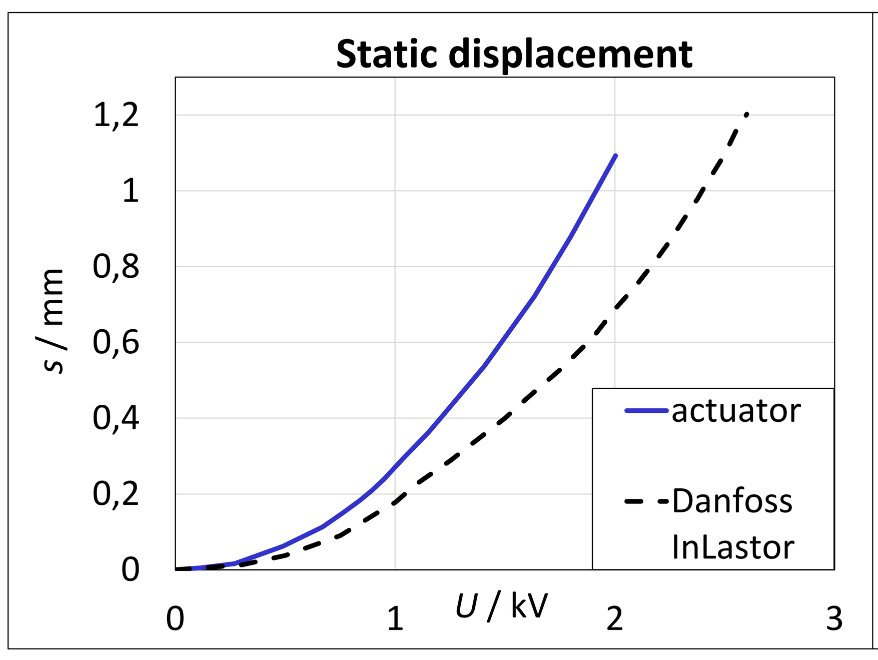
Characterisation measurements

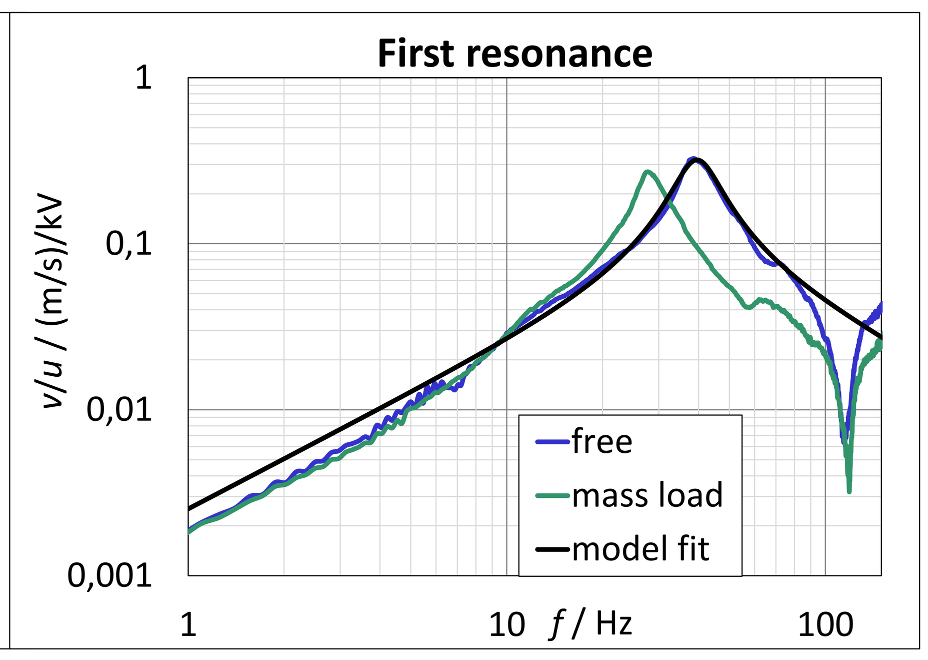


experimental setups for actuator characterization

- static displacement
- blocked force
- electrical resistance and capacitance (static and dynamically)
- dynamic excitation and resonance with different mass loads
- mechanical impedance (with external excitation)

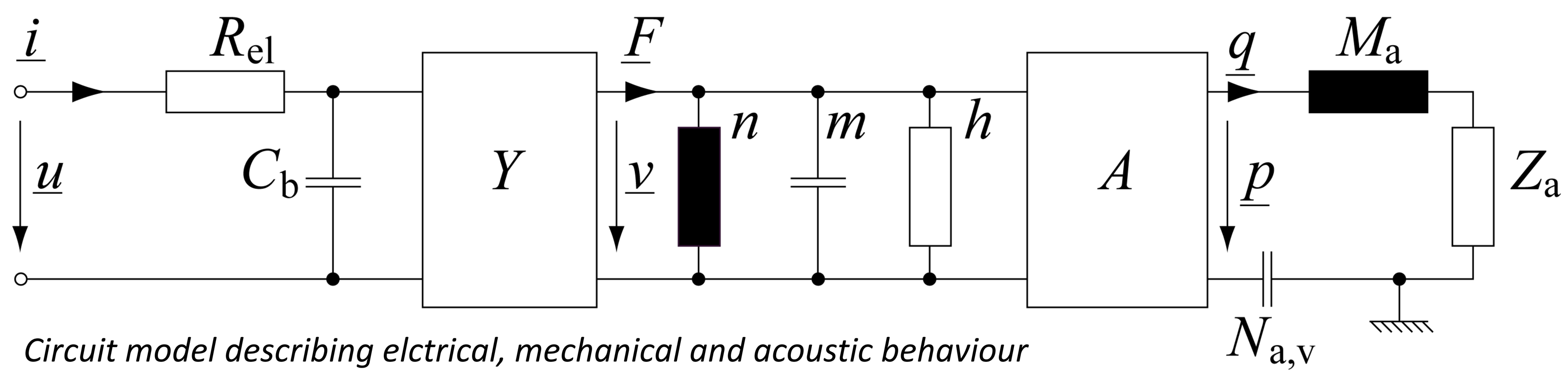
} variation of polarization voltage U_0 between 0 and 2.5 kV



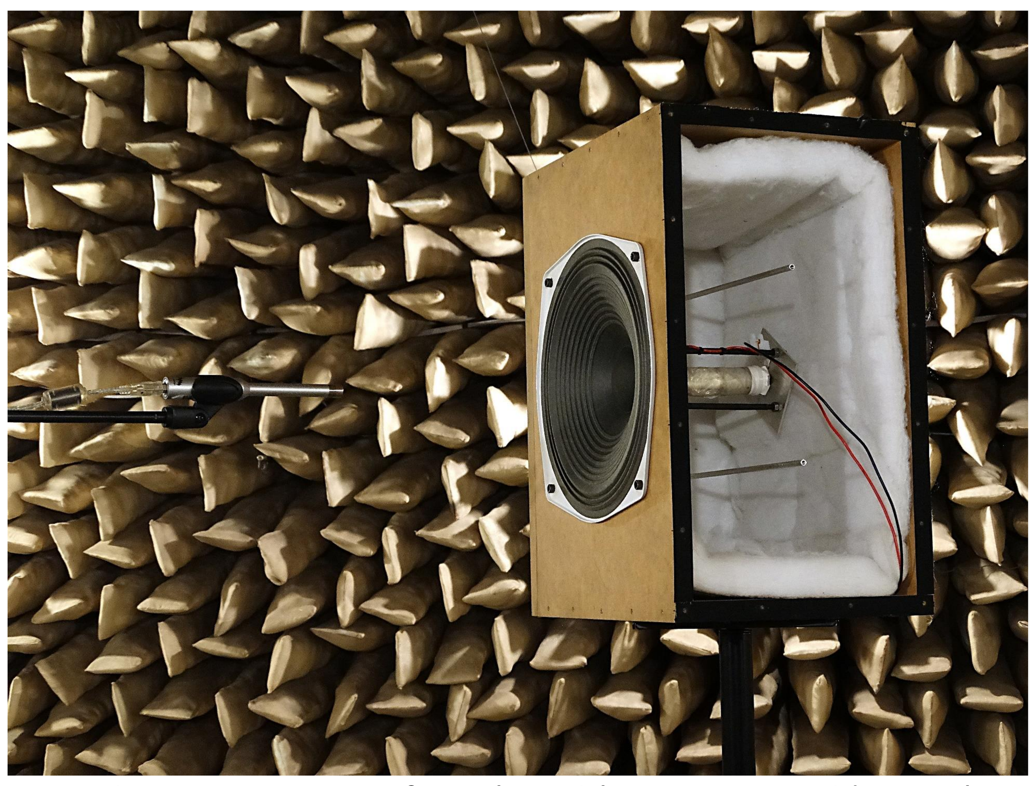


Modeling, speaker assembly and testing

- an electromechanical circuit model from the characterization data is created [2], [3]
- The model and construction is expanded to the acoustic domain after determining suitable acoustic load parameter (speaker cone & suspension, back volume) for specific working point
- very fast parameter variations are feasible
- prediction of expected sound power and sound pressure level
- measurement of the assembled loudspeaker and long term stability test



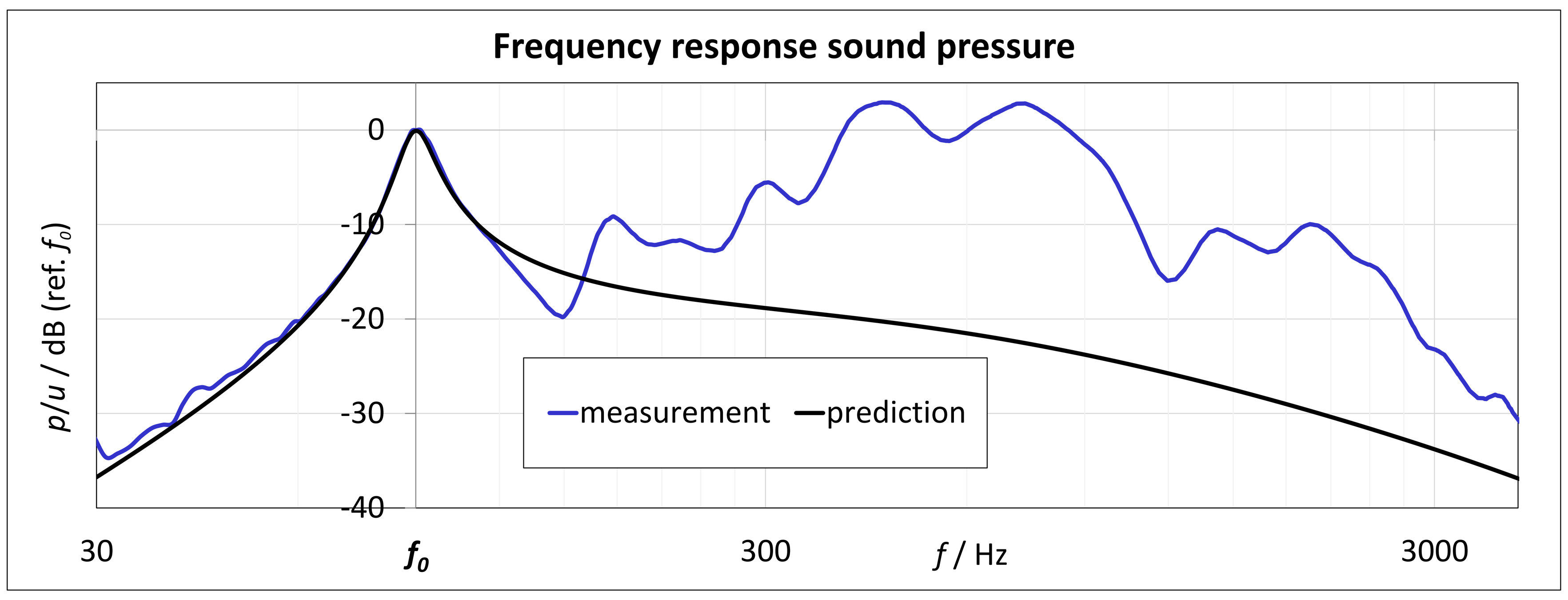
Circuit model describing elctrical, mechanical and acoustic behaviour



Acoustic measurements of speaker with transparent side panel

R_{el}	2 kΩ
C_b	131,6 nF
Y	1 N/kV
n	134 µm/N
m	52 g
h	0,35 N/(m/s)
A	0,0506 m²
M_a	0,035 Ns²/m⁵
$N_{a,v}$	2,82e-7 m⁵/N

Model parameters (U_0 = 1.5kV, u = 50 V_{pp})



Conclusion

- The DE-speaker driver is a successful proof of concept with high sound pressure levels (> 84 dB) and wide frequency response. It signifies the potential technological benefits of DE in the application for sound sources like power- and size scaling options, weight reduction compared to conventional sound sources, as well as the possibility to forgo the use of rare earth.
- Future challenges:
  - availability of suitable amplifiers for the needed high polarization voltages
  - significant influence of the frequency response by the modal behavior of the actuator
  - applied design process including electromechanical and material system optimization
  - extended research on high-frequency behavior of DE-materials

References

[1] DANFOSS, "PolyPower A/S - White Paper," **2012.**

[2] LENK, Arno, BALLAS, Rüdiger, WERTHSCHÜTZKY, Roland and PFEIFFER Günther *Electromechanical systems in microtechnology and mechatronics*. Springer, **2011.**

[3] MARSCHNER, Uwe; WERTHSCHÜTZKY, Roland. *Aufgaben und Lösungen zur Schaltungsdarstellung und Simulation elektromechanischer Systeme: In Mikrotechnik und Mechatronik*. Springer-Verlag, **2015.**

Acknowledgements

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