EuroEAP Society Challenge 2021

FINAL SUBMISSION FORM

Fill in this form electronically (not manually). Use the following format: Times New Roman, 11pt.

Title of the demo/project:
"DEUM-Driver"
Dielectric elastomer-unimorph-membrane-Headphone-Driver

Name of the team leader and his/her affiliation:
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Description of the final demo

Introduction

Dielectric elastomers (DE) are often referred to as being suitable for acoustic applications. Especially silicone based DE are utilized because of their comparably fast response times and little creep.
Nevertheless, only few concepts have been developed and realized so far, which can hardly compete with conventional electrodynamic loudspeakers. The most prominent examples are vibrating DE-diaphragms that are inflated by a bias pressure. However, adding support or other mechanical systems (pressure pump, magnets, springs, etc.) usually prevents achieving the desired technological advantage using DE and can be further detrimental to broad frequency behavior.
We investigate alternative concepts to achieve out of plane movements of surface areas which can be used to create sound. Our goal is to create sound sources which can utilize technological advantages of DE that are competitive to existing solutions.

Method

The unimorph-configurations consist of a stack of materials with different mechanical properties.
While applying a stimulus, the materials react (expand) differently and thus creating a bending motion.
The configuration we used is the following:

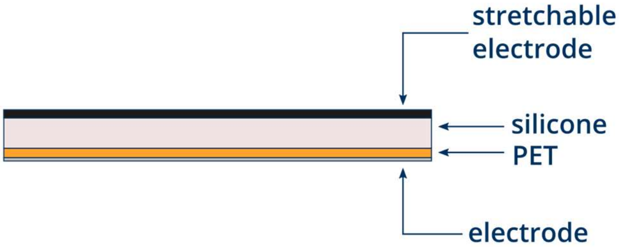

Figure 1: DEUM-Driver layer schematic

When applying a high voltage to the electrodes, the generated Maxwell-pressure compresses the layered structure. The soft non-compressible elastomer (1-3 MPa) wants to expand sideways, but the PET layer (2000 MPa) is nearly uncompliant and blocks the sideways expansion. This difference in behaviour creates a bending motion in the direction of the PET-Layer.

Instead of using the usual flexure beam configuration we clamped the layered structure with a ring, creating a membrane. By applying a high voltage, the membrane performs an out of plane movement to the side of the elastomer. Modulating this bias voltage with a smaller AC-voltage the membrane emits soundwaves.
We call this dielectric elastomer unimorph membrane configuration, short DEUM-Driver.

Construction

The DEUM-Driver consists of a metallized PET-film. The PET film is 5 to 20 µm thick. The metallization is a 20 to 40 nm thick Aluminium layer and applied as non-compliant electrode.
By using masks, we structured the different layers to the desired diameter with some additional area for the contacts. The silicone (PDMS) layer 20 to 120 µm is processed with a film applicator.
This compliant electrode consists of carbon black in a PDMS-matrix and is sprayed on the DE, creating a layer of about 20 µm. The actuator is then cut into shape and ready to use. Due to the rigid PET-layer the actuator is very easy handleable compared with the sticky pure PDMS films.
For the demonstrator we used the housing of conventional headphones with a 40 mm electrodynamic driver.
Therefore, we removed the old drivers and replaced the driver holding structure to a simpler one to accommodate for the new membrane with a diameter of 40 mm too. The driver-membrane weighs only about 0.25 grams. It is clamped with lowest possible tension.
The contacting is realised by copper electrodes pressed against the protruding contact areas of the driver-membrane maximising the contact area to minimise the resistance.
The polymer layer is facing to the ear to achieve the right phase relation to the signal.

Safety

When operating headphones at such high voltages, measures must be taken to insure safety.
The positive electrode is connected to the metallized layer always facing away from the ear. Furthermore, the distance of the membrane to the ear is sufficiently large and incorporates additional acoustic transparent cushions. The headphones were operated in the demonstration with a combined voltage up to 4.5 kV (AC+DC). However, the breakdown voltage exceeds 10 kV. One of the main reasons for this stability is the incorporation of the PET-layer as an additional insulation. Thereby, the increase in voltage stability outweighs the additional demand of voltage due to the increased distance.

Testing and application

The following schematic shows the test- and preliminary operating setup:

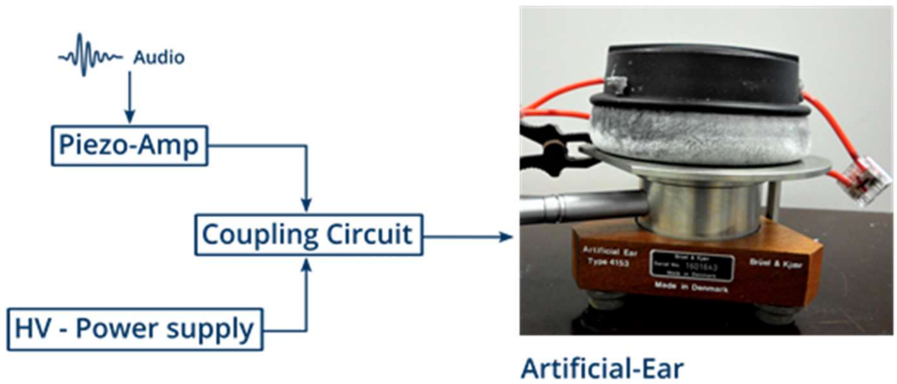

Figure 2: Test setup of the DEUM-Driver headphone

The bias voltage is provided through a high voltage power supply and the audio is amplified with a conventional piezo-amplifier (*Trek 2205*). They are combined through a special coupling circuit (presented at EuroEAP 2019). For the measurements and audio recordings, we used an artificial head and an artificial ear (*B&K 4153*).
During the work on this project, a multitude of tests on different configurations were performed. The following chart shows the frequency response of a DEUM-Driver used for the demonstration.

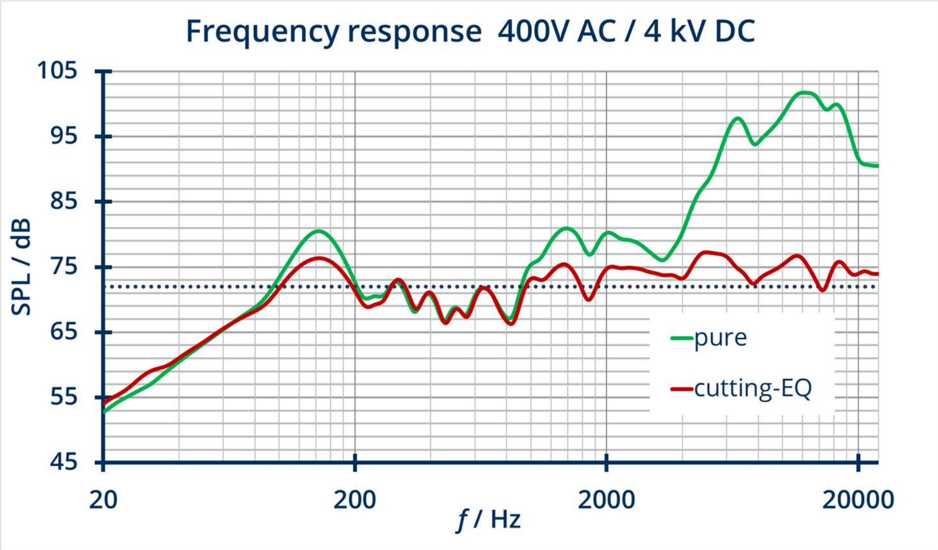

Figure 3: Frequency response of DEUM-Driver Headphone with and without cutting equalizer applied

It has to be noted, that the frequency response is strongly influenced by the interaction of the driver and the acoustic environment (headphone case and headphone positioning) and that the used headphone case was not specifically optimized to suit the characteristics of the DEUM-Driver.
It can be seen that the DEUM-Driver headphones have a good and wide frequency response and are especially effective at high frequencies. Using a cutting equalizer in a DSP (*freeDSP*) it is easily possible to obtain a very linear frequency response beyond 20 kHz. The reduction of the high frequency band (up to 20 dB) leads also to a significant and benificial reduction in current demand of the driver to the amplifier.

Conclusion and Future Work

The DEUM-Driver for headphones is a good sounding alternative to conventional headphone driver based on soft polymers. It combines simplicity of design with great robustness, easy handleability and very lightweight. It can potentially be produced very cost-efficient in a roll-to-roll process and automated, greatly reducing the demand of manual labour.
When using amplifiers with charge recuperation, they can potentially outperform electrodynamic drivers by far in terms of efficiency. They are also suitable in application where the absence of magnets and ferroelectric materials is required.
I future work, we are planning to reduce the size of necessary electronics significantly, to the size of conventional headphone preamplifiers. Furthermore, we want to improve the sound quality characteristics and effectiveness of the driver.

Link to download a video file of the demo.

https://www.dropbox.com/s/63q1ty8xfqdj0i7/DEUM%20-%20Driver%20_EuroEAPChallenge2021%20%28HD%2050p%29.mp4?dl=0

SIGNATURE OF THE TEAM LEADER

SUBMSSION