



Semester 3

TRANSDUCERS MEASUREMENT

Work 2: Loudspeaker dynamic behavior, feedback u_{emf} , and creep effect

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Practical Organization

This practical is divided into two main parts, each focusing on distinct aspects:

1. Measurement of the dynamic compression/expansion nonlinear behavior of a loudspeaker.
2. Step response measurement of the loudspeaker under two different conditions: with and without the motional feedback electromotive force (u_{emf}).
3. Creep effect measurement.

Equipment


The following equipment is required for this practical:

- Data Acquisition Module NI USB-4431
- Audio amplifier
- Displacement sensor Panasonic HG-C1030-P (sensitivity = 2 mm/V)
- Z-box circuit for current and voltage measurement
- Electrodynamic loudspeaker
- DC Voltage source (5 V, only for part 2)
- Switch-box (only for part 2)
- **Warning!** The displacement sensor introduces a significant signal delay of approximately 1 ms, which may require compensation.

1 Dynamic Compression and Expansion

In this section, you will measure the frequency response functions $X(f)/U(f)$ and $X(f)/I(f)$ of an electrodynamic loudspeaker for various amplitude levels and plot them in a single graph.

1.1 Preparation

- Set up the measurement according to the schematic in Fig. 1. Note that this setup is the same as in the previous experiment (Work 1).
- Open the Python file `TP02_01_FRF_measurement.py`, which uses a swept-sine signal to measure the frequency response functions $X(f)/U(f)$ and $X(f)/I(f)$.
- You would need to specify the name of the USB-4431 device recognized by your operating system. On the System Tray (the menu with small icons on the bottom right-hand corner of the Windows taskbar), find the icon , click on it, and note the device number (e.g., Dev4). Modify the line with the device name in the Python file as follows:

```
""" Parameters """  
Dev = 'Dev4' # name of the NI device
```

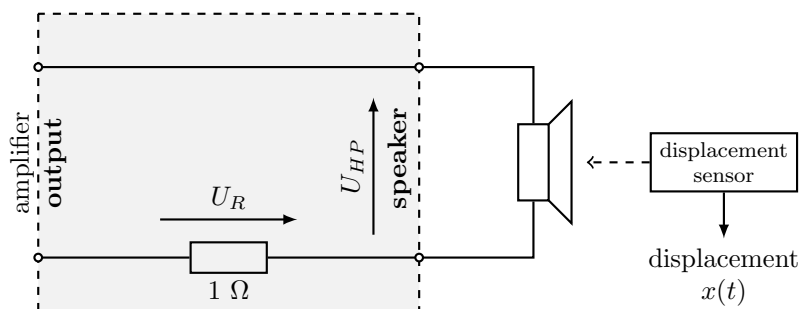


Fig. 1: Block diagram of the experimental setup for the loudspeaker measurement.

1.2 Measurement

- Run the Python file and adjust the amplifier amplitude to maintain a voltage level of approximately **2 V_{rms}** during the measurement (indicated in the graph's legend).
- Next, you will conduct the measurement for **various amplitudes**. To do this, comment the variable `amplitudes` with one value:

```
# amplitudes = [1]
```

and uncomment the variable with multiple values:

```
amplitudes = [0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1]
```

- Run the measurement and display the results and **save** the figures as `.png` files to be able to quickly compare the data with the next measurements.

- **Exchange loudspeakers with other groups**, as each group has a different loudspeaker, change the filename (to not overwrite the data)

```
""" SAVE """
np.savez('results_part_1/meas_data_speaker_02.npz',
        f_axis=f_axis, fs=fs, U=U, I=I, X=X)
```

and repeat the measurement.

- **Provide comments on the results.** Based on your knowledge of the nonlinear behavior of $Bl(x)$ and $K_{ms}(x)$, explain the observed behavior you would expect. Discuss the observed behavior, whether it indicates compression or expansion.

Note that you will find a paper [1] dedicated to this work, which is available on umtice.

References

- [1] Novak, A., “Compression and expansion nonlinear effects in an electrodynamic loudspeaker: experiments vs. model failure”, *Proc. Forum Acusticum*, Lyon, France, 2020

2 Step Response Measurement

This experiment demonstrates the effect of the motional electromotive force (emf). You will measure the step response under two different measurement conditions and compare them.

2.1 Preparation

- **Disconnect and remove the amplifier** from the previous measurement setup, as it is no longer needed.
- **Connect the switch-box and the z-box** with the loudspeaker as shown in Fig. 2. Ensure both **switches are** in the "off" (**disconnected**) position for now.
- Connect the **5 V DC Voltage source** to the switch-box.
- Open the Python file `TP02_02_step_response.py`, which will be used for acquiring displacement ($x(t)$), voltage ($u(t)$), and current ($i(t)$) signals.
- You would need to specify the name of the USB-4431 device recognized by your operating system as in the previous step.

```
""" Parameters """  
Dev = 'Dev4' # name of the NI device
```

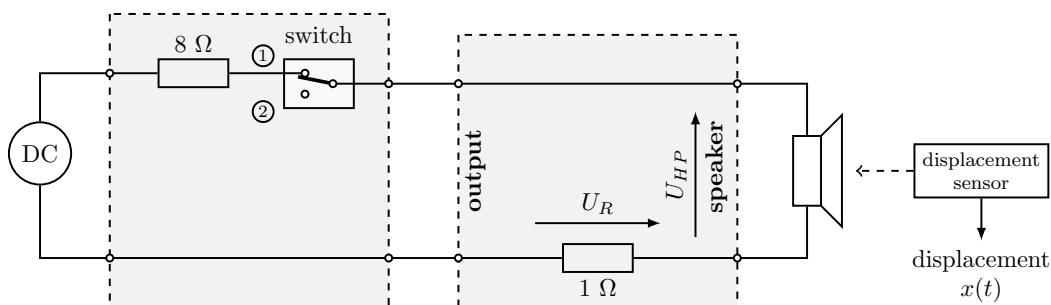


Fig. 2: Block diagram of the experimental setup for current step function measurement.

2.2 Measurement - Open Circuit

- For this measurement, you will use the switch illustrated in Fig. 2. The second switch (not shown in Fig. 2) remains disconnected during this step.
- The measurement will be conducted in **three sequential steps**. Please read through all the steps before proceeding with the measurement.
 1. Set the switch shown in Fig. 2 to position 1 (connected to the DC source). You should observe the loudspeaker membrane exhibiting a DC excursion.
 2. Execute the Python script `TP02_02_step_response.py`. Wait until the blue LED diode labeled ACTIVE on the USB-4431 device starts blinking.

3. One second later, switch to position 2 (open the loudspeaker circuit). The blue diode should still be blinking when you make this switch.

- Verify the presence of a **noticeable step function** in the acquired current signal $i(t)$.
- **Zoom in** on the transient response to ensure its visibility (approximately 200 ms width for x-limits) and **save** the figure in .png format for future reference.

2.3 Measurement - Closed Circuit

- For this measurement, you will use the switch depicted in Fig. 3. The second switch (not shown in Fig. 3) remains connected (allowing the current to run) during this step.
- To avoid overwriting your previous results, make sure to rename the filename when saving the signals as follows:

```
""" SAVE """
np.savez('results_part_2/meas_data_closed.npz', u=u, i=i, x=x)
```

- **Repeat the step function measurement**, as described in the previous step. This time, when switching to position 2, you will **short-circuit** the loudspeaker. Just like in the previous step, ensure that this transition occurs around 1 second after the blue LED begins blinking. Additionally, make sure that a distinct step function appears in the recorded voltage signal $u(t)$.
- **Disconnect the DC source** to prevent unnecessary current dissipation in the $8\ \Omega$ resistor.
- **Save the current figure** without closing it, and open the figure from the previous measurement to compare the results (see subsection below).

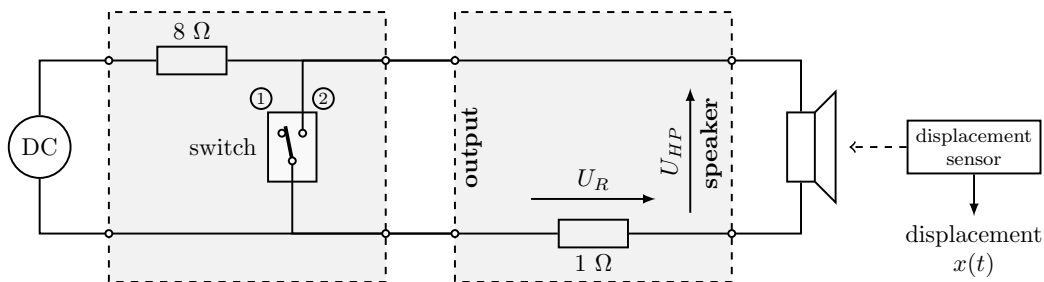


Fig. 3: Block diagram of the experimental setup for voltage step function measurement.

2.4 Comparing Results and Discussion

- Show both sets of results side by side.
- Compare all three signals: voltage $u(t)$, current $i(t)$, and displacement $x(t)$ for both configurations, as illustrated in Fig. 2 and Fig. 3.

- Discuss and provide explanations for the observed step responses. Explain any differences in quality factors that you may have noticed.
- Additionally, discuss the relationship between voltage-driven and current-driven loudspeakers. It's important to note that loudspeakers are typically operated with a voltage source. When measurements are conducted using a current source, the behavior of the loudspeaker can change. Refer to Fig. 4 for a block diagram of a traditional linear low-frequency electrodynamic loudspeaker model and explain how the feedback loop due to the motional electromotive force U_{emf} is avoided when driving the loudspeaker from a current source.
- How is the previous information related to this experimental work ?

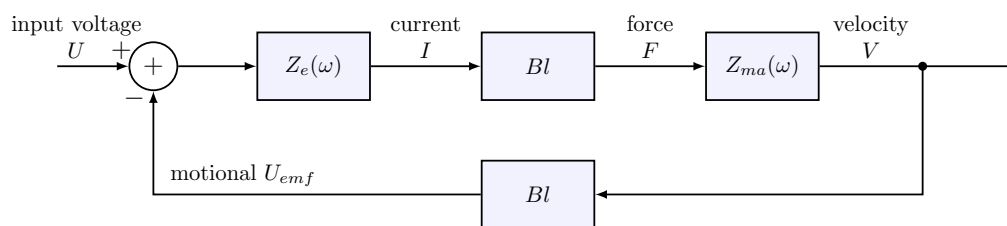


Fig. 4: Block diagram of a traditional linear low-frequency electrodynamic loudspeaker model.

3 Creep Effect

This experiment aims to demonstrate the creep effect of the suspension parts, i.e., the surround and spider.

3.1 Preparation

- Maintain the same setup as in the previous measurement.
- Keep both switches in the "off" (disconnected) position for now.
- Connect the 5 V DC voltage source to the switch-box.
- Open the Python file `TP02_03_creep.py`, which will be used for acquiring displacement ($x(t)$), voltage ($u(t)$), and current ($i(t)$) signals. It will run the signals recording for 5 minutes at a low frequency sample rate (2 kHz).
- Specify the name of the USB-4431 device recognized by your operating system, as done in the previous step:

```
""" Parameters """  
Dev = 'Dev4' # Name of the NI device
```

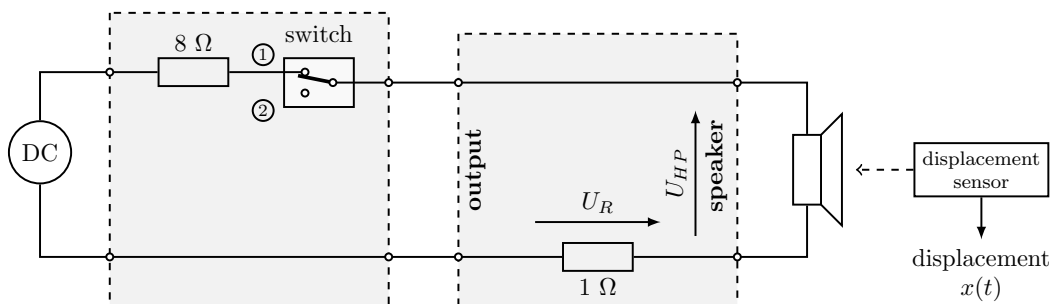


Fig. 5: Block diagram of the experimental setup for measuring current step functions.

3.2 Measurement

- Run the Python file `TP02_03_creep.py`. Wait until the blue LED diode labeled ACTIVE on the USB-4431 device starts blinking. After 1-3 seconds, switch to position 1 (close the loudspeaker circuit), and observe the membrane moving from the rest position.
- Wait until the measurement is complete. This takes 5 minutes, providing you with a break. Do not switch back after the measurement.
- The results are depicted on a `semilogx` scale. Provide comments on the outcomes.

References

- [1] Novak, A., “Compression and expansion nonlinear effects in an electrodynamic loudspeaker: experiments vs. model failure”, *Proc. Forum Acusticum*, Lyon, France, 2020
- [2] Knudsen, M. H., and Jensen, J. G., “Low-Frequency Loudspeaker Models That Include Suspension Creep.”, *J. Audio Eng. Soc.*, vol. 4, no. 1-2, pp. 3—18, 1993.
- [3] Thorborg, K., Tinggaard, C., Agerkvist, F. T., and Futtrup, C., “Frequency dependence of damping and compliance in loudspeaker suspensions.”, *J. Audio Eng. Soc.*, vol. 58, no. 6, pp. 472—486, 2010.
- [4] Novak, A., “Modeling viscoelastic properties of loudspeaker suspensions using fractional derivatives.”, *J. Audio Eng. Soc.*, vol. 64, no. 1-2, pp. 35—44, 2016.