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
```

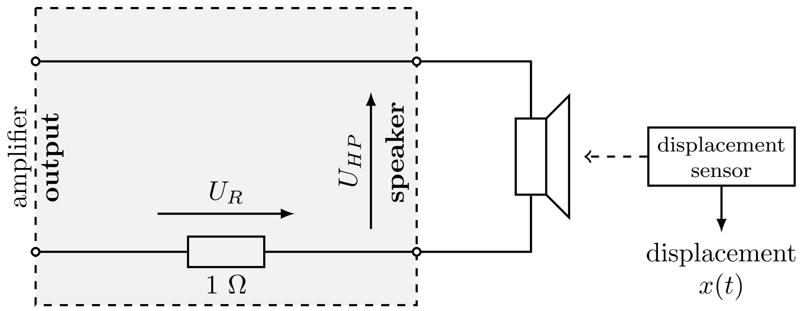

Fig. 1: Block diagram of the experimental setup for the loudspeaker measurement.

1.2 Measurement

- Run the Python file and adjust the amplifier amplitude to maintain a voltage level of approximately 2 Vrms during the measurement (as indicated in the graph's legend).
- Next, you will conduct the measurement for various amplitudes. To do this, comment out 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.

- Exchange loudspeakers with other groups, as each group has a different loudspeaker, 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.

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
```

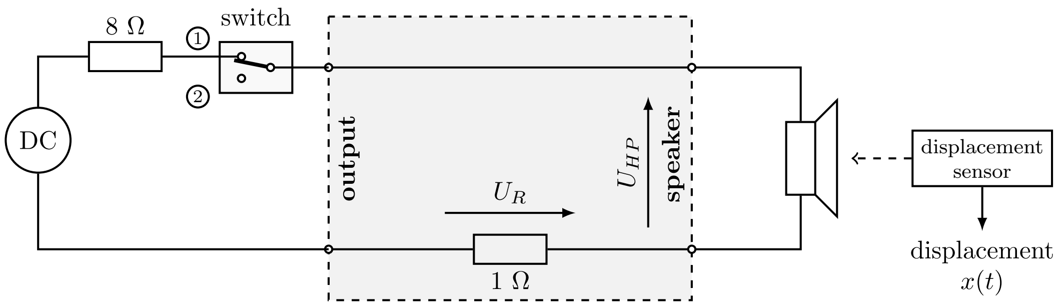

Fig. 2: Block diagram of the experimental setup for current step function measurement.

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.
- Set the switch from Fig. 2 to position 1 (connected to the DC source). You should observe the loudspeaker membrane exhibit a DC excursion.
- Run the Python file `TP02_02_step_response.py`. Wait until the blue LED diode `ACTIVE` on the USB-4431 device starts blinking. After 1-3 seconds, switch to position 2 (open the loudspeaker circuit). The blue diode should still be blinking when you switch to position 2.

- Verify that there is a noticeable step function in the acquired current signal ($i(t)$) as shown in the Python figures.
- Disconnect the DC source from the switch-box.
- Save the figure so that you can open in later.

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 within 1-3 seconds after the blue LED begins blinking. Additionally, make sure that a distinct step function appears in the recorded current signals depicted in the Python figures.
- After the measurements, disconnect the DC source to prevent unnecessary current dissipation in the 8 Ω resistor.
- Save the current figure without closing it. Additionally, open the figure from the previous measurement to compare the results (see subsection below).

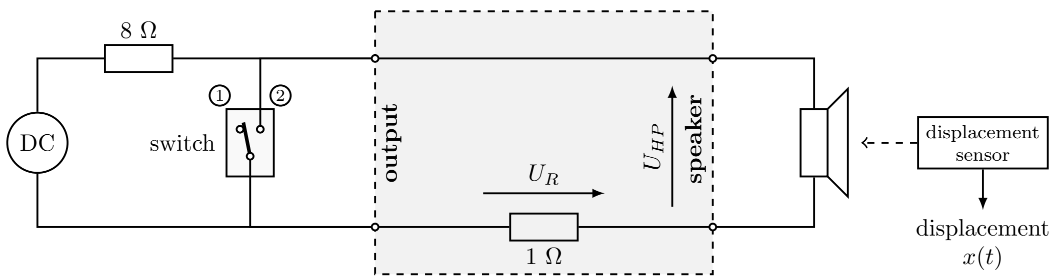

Fig. 3: Block diagram of the experimental setup for voltage step function measurement.

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 ?

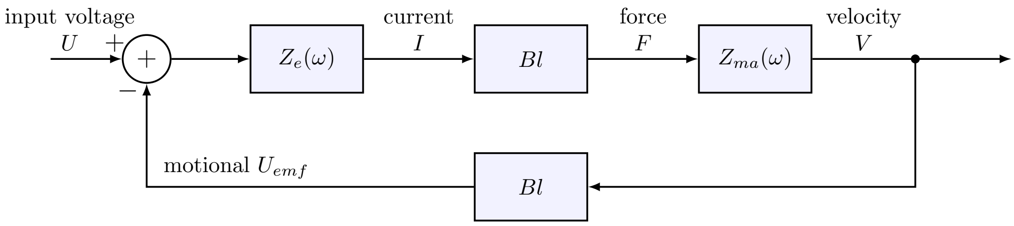

Fig. 4: Block diagram of a traditional linear low-frequency electrodynamic loudspeaker model.

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
```

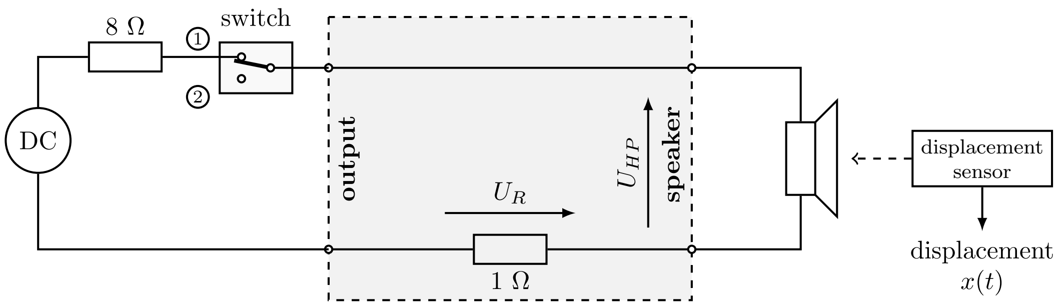

Fig. 5: Block diagram of the experimental setup for measuring current step functions.

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 should take approximately 5 minutes, providing you with a break.
- Plot the results on a `semilogx` scale and 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.