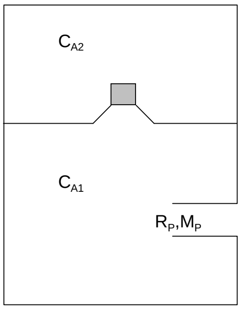
Kurt Heutschi, Acoustics II, 2014-03-23

Exercise A2-6: Loudspeakers

1. Find the equivalent electrical network for the bandpass loudspeaker cabinet shown in the Figure below. Determine in a qualitative sense the transfer function W/U of the system with W: radiated sound power and U: voltage at the loudspeaker terminals.



2. The Thiele-Small parameters of three loudspeaker chassis are given. After mounting in a cabinet, a total quality factor of 0.7 shall result. Which chassis yields the lowest resonance frequency and what is the corresponding cabinet volume?

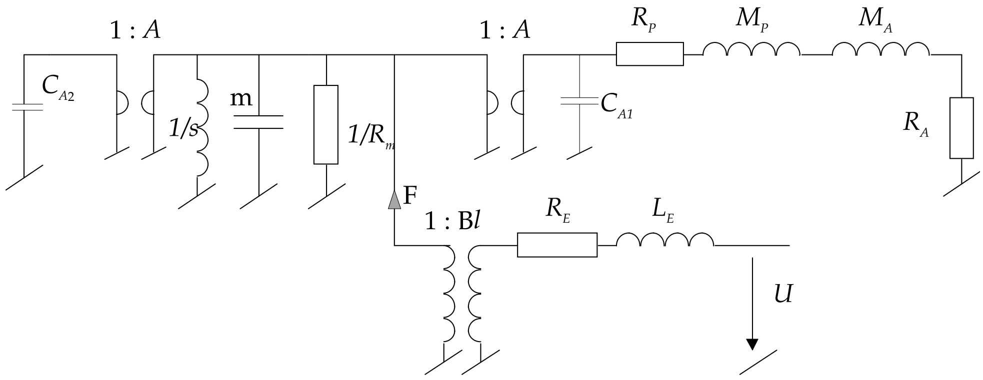
	chassis 1	chassis 2	chassis 3
resonance frequncy [Hz]	19	20	35
total quality factor Q_{TS}	0.28	0.40	0.21
compliance equivalent volume V_{AS} [l]	715	860	153
membrane area [m2]	0.089	0.130	0.054

3. Demonstrate how the membrane velocity can be determined by a measurement of current and voltage at an electrodynamic loudspeaker chassis. With this concept, control circuits can be realized to enlarge the low frequency range of subwoofers (M. R. Bai, H. Wu, Robust control of a sensorless bass-enhanced moving-coil loudspeaker system, Journal of the Acoustical Society of America, vol. 105, p. 3283-3289 (1999)).

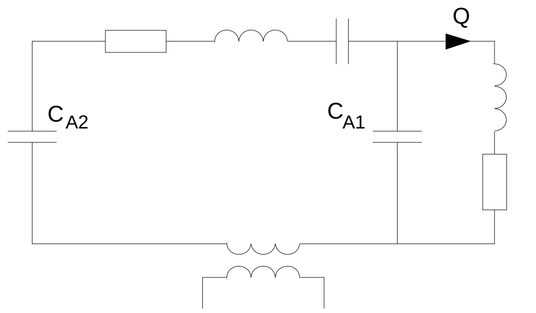
4. The membrane of an electrodynamic loudspeaker chassis is mechanically blocked (velocity = 0). Describe the frequency response of the electrical impedance at the speaker terminals.

Solutions to Exercise A2-6: Loudspeakers

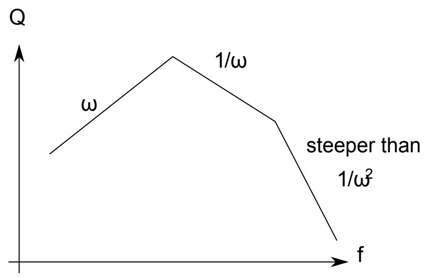
1.
The complete equivalent network is



After suitable dual conversion to remove the gyrators and combination of elements;



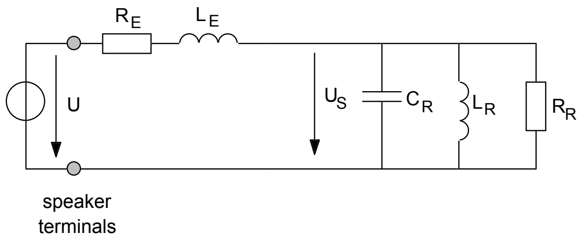
The frequency response of the volume flow Q relevant for radiation is:



In combination with the ω^2 dependency of the radiation impedance a frequency independent radiation is obtained for $Q \sim 1/\omega$. Below and above, the radiation gets significantly weaker ($\rightarrow$ bandpass filter).

2.
For the chassis mounted in the cabinet, the total quality factor is $Q_{Tc} = Q_{Ts}\sqrt{\frac{V_{AS}}{V_B} + 1}$ and the resonance frequency $f_c = f_s\sqrt{\frac{V_{AS}}{V_B} + 1}$ where V_B is the cabinet volume. For the chassis 2 the resonance frequency is lowest (35 Hz) with a cabinet volume of 420 l.

3.
With $U_S = Bl \times \mathsf{membraneVelocity}$ the problem reduces to the determination of U_S in the equivalent network below.



From $U_S = U - i(R_E + j\omega L_E)$ follows: $\mathsf{membraneVelocity} = \frac{1}{Bl}(U - i(R_E + j\omega L_E))$ where U is the voltage at the speaker terminals and i is the speaker current.

4.

The impedance is determined solely by the electrical properties (R_E, L_E) of the moving coil.