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Clinical Audiologists May Find It Confusing When Engineers Talk About Inductors, Resistors, And Capacitors As Simulators Such As “The Earmold Vent Functions As A Capacitor”. Audiologists Really Only Talk About Why A Certain Structure Such As An Earmold Vent Allows For The Reduction Of Low Frequency Sound Energy.

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In the real world, motion of molecules is governed by the laws of physics. It just happens that many of those laws are expressed by equations involving complex numbers, which are real and imaginary numbers such as magnitude and phase representations. This is a direct match to the physics-based laws concerning the flow of current and the existence of voltages. What joins the voltage-to-current relationship is impedance, which can also have real and imaginary relationships. Electrical analogs are popular because of the well-developed methods for performing circuit analysis. For example, Inductors make a good method representing a mass since after an oscillating force (voltage) is applied there will be a resulting volume velocity (current). Just like in an inductor where the current lags the voltage by 90 degrees the volume velocity lags the application of the force. Audiologists and Speech-Language Pathologists learn about volume velocity and standing waves in their speech acoustics courses.

A well-known comparison chart between electrical components, mechanical structures, and acoustic behaviours has been very useful to develop electrical simulations of acoustical and mechanical systems such as the outer and middle ear function or the effect of venting in a hearing aid.

Electrical System	Mechanical System	Acoustic System
Voltage *e*	Force *f*	Pressure *p*
Current *i*	Velocity *u*	Volume Velocity *U*
Inductance *L*	Mass *m*	Acoustic Mass $_{A}$
Capacity *C*	Compliance k^{-1}	Acoustic Compliance C_A
Resistance *R*	Damping *d*	Acoustic Damping R_A

Electrical analogs can be very useful in simulations since the output can be measured as a result of a small change in the value of an inductor, a resistor, or a capacitor. However, modeling some phenomena as a group of "lumped elements" can be problematic, especially in some frequency regions. For example, lumped elements work very well and can be used to explain the "Helmholtz resonances" found in the vocal tract for high vowels [i] and [u], but fails when higher frequencies are involved. This is why in speech acoustics only the first two formants F1 and F2 can be Helmholtz-related (below 2500 Hz). All higher frequency formants (e.g., F3 and F4) are wavelength related and only have to do with the length of the vocal tract, and not constrictions such as those found in the high vowels.

In hearing aid acoustics, we use a lot of small diameter tubes which require modelling that accounts for viscous and thermal effects due to the effects of the inner tube surface area. We have to use "lossy transmission lines" to account for this effect.

One restriction is that most electrical analogs are one-dimensional so aren't good for representing Head Related Transfer Functions (HRTF) in a general way. You can make models that match any specific azimuth and elevation but they don't typically generalize. I frequently use a diffuse field model in my simulations which is fine because there is by definition no direction information in the diffuse field.

It is also possible using electrical models to capture some interesting physical behaviours. In transducer development one can encounter things that require a semi-inductor or semi-capacitor. These are easily modeled as well.

Best of all, really good analog simulation tools are freely available! Key to the simulations is the use of complex numbers and efficient matrix solvers.