by **Christopher J. Struck (/authors/23324/christopher-j-struck)**

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Article

Voice Coil Lab Notes: Improved Zobel Network

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Passive crossover filter networks for multi-way loudspeakers generally require a resistive termination for optimum performance. The driver itself generally presents a reactive load. Recall that the inductive rise with frequency above resonance of the loudspeaker electrical impedance is semi-inductive due to eddy current losses [1], see Figure 1.

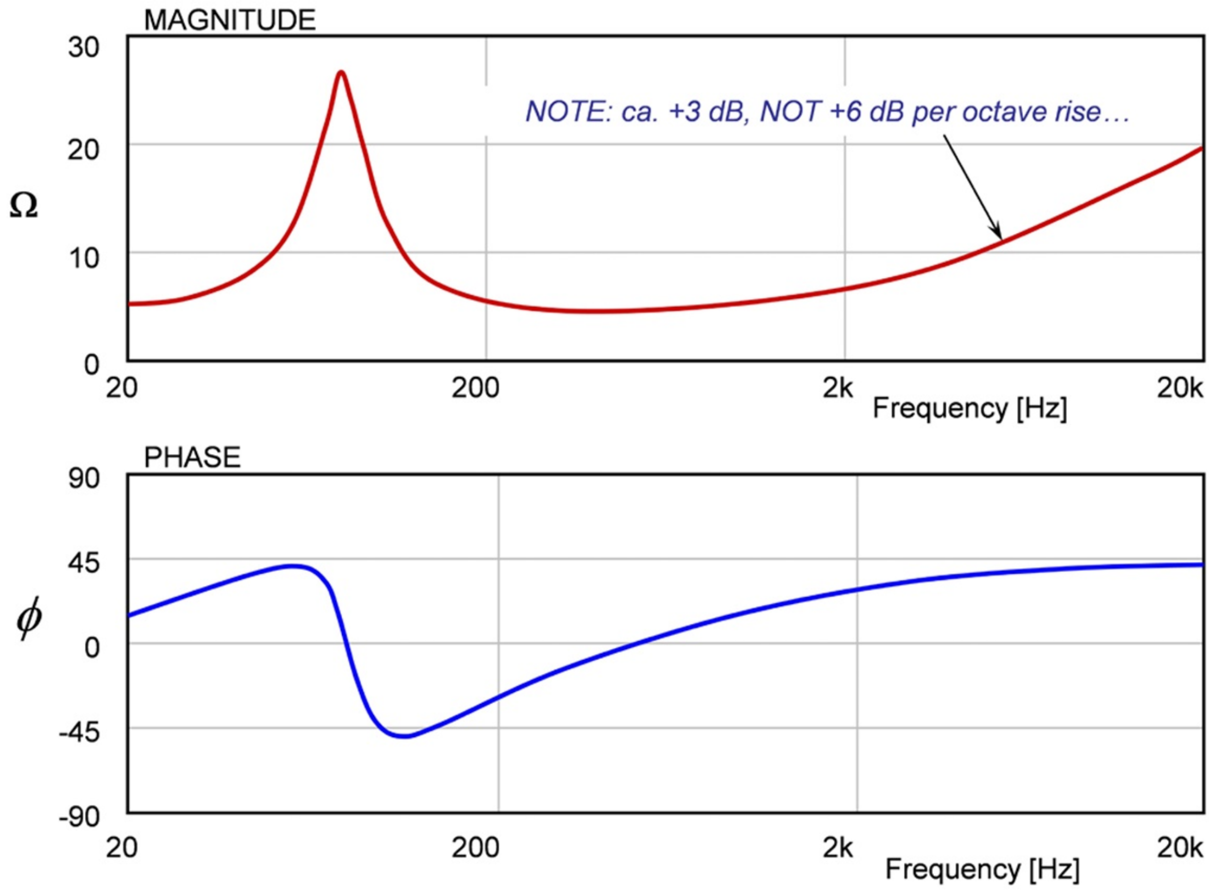

Figure 1: Typical loudspeaker electrical impedance with a semi-inductive rise above resonance.

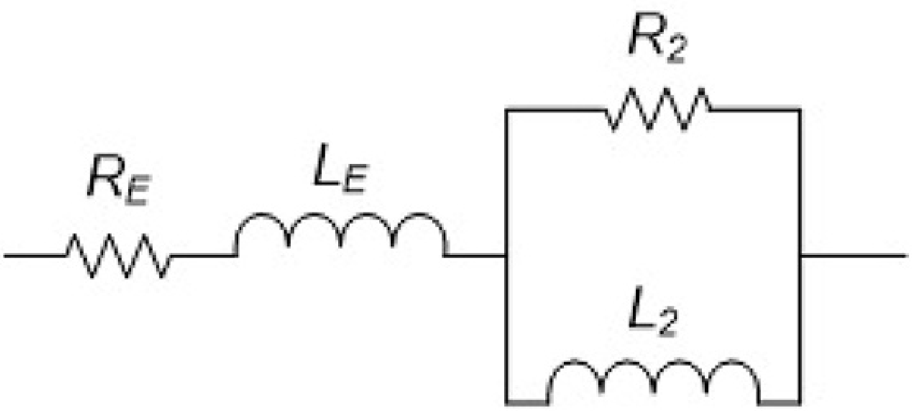

Figure 2: L2/R2 loudspeaker electrical impedance model.

The L2/R2 impedance model [2], [3], depicted in Figure 2 represents the electrical impedance as seen by the amplifier output. The typical Zobel network [4], used to make the driver impedance appear closer to an ideal resistive load above resonance is a simple series resistor and capacitor shunted across the driver terminals (see Figure 3).

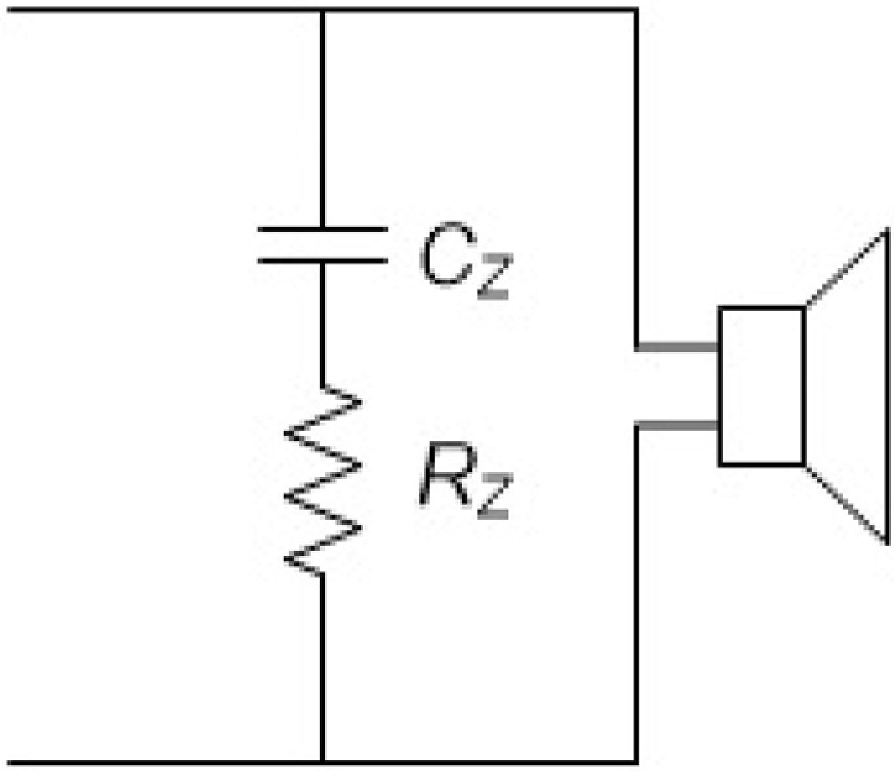

Figure 3: Typical Zobel impedance compensation network.

The component values are calculated as:

$$R_z \approx 1.25 R_E \qquad [1]$$

$$C_z = \frac{L_E}{R^2_Z} \qquad [2]$$

with:

$$P_R = \frac{V^2_{MAX}}{R_Z} \qquad [3]$$

The resistor value is approximate and may need to be adjusted for more extreme voice coil impedances. The resistor should be power rated as shown to handle the current to the loudspeaker. The flatness of the compensated impedance magnitude above resonance is typically limited when using this simplified compensation network.

More complex and accurate compensation networks are possible [5]. An improved compensation network can be realized by using the analogous circuit “dual” of the L2/R2 model, assuming the values for the driver impedance model are known. Recall that a circuit “dual” replaces series impedances with shunt impedances and vice versa. Capacitors become inductors and inductors become capacitors. Resistors remain resistors. Applying these principles to the network of Figure 2 results in the network shown in Figure 4.

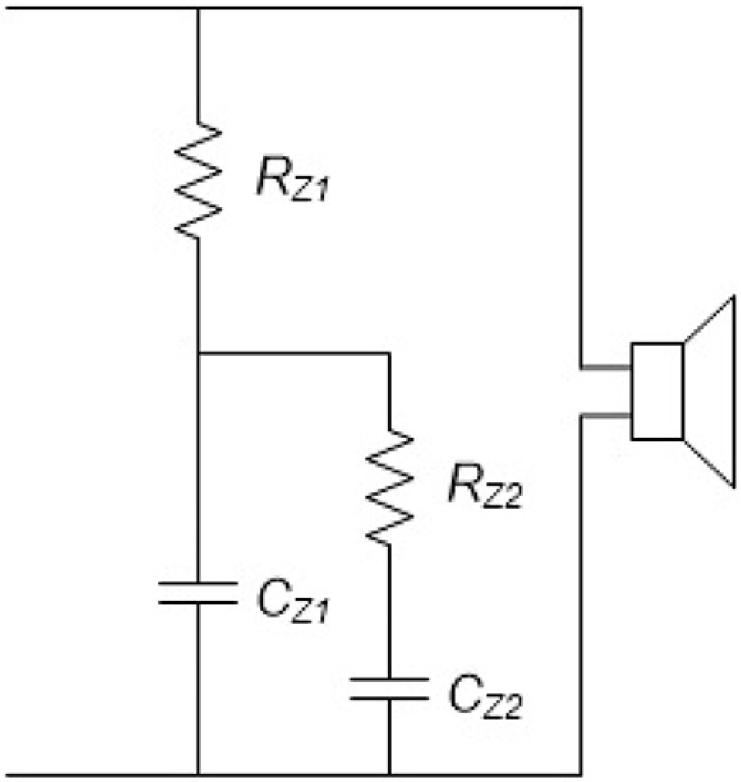

Figure 4: Improved Zobel compensation network realized as the circuit "dual" of the L2/R2 impedance model.

The component values for this improved compensation network are calculated as:

$$R_{Z1} = R_E \quad [4]$$

$$R_{Z2} = R_2 \quad [5]$$

$$C_{Z1} = \frac{L_E}{R^2_E} \quad [6]$$

And,

$$C_{Z2} = \frac{L_2}{R^2_2} \quad [7]$$

This represents a dramatic improvement to the basic two-component Zobel network and compensates for the non-ideal semi-inductive behavior of the loudspeaker driver across the entire frequency band. The component values are easily found if the L2/R2 impedance model values are known. Again, the resistor values should be power rated to handle the current to the loudspeaker as per Equation 3. Additional circuitry is required to compensate for the motional impedance at resonance.

The cost, however, is increased size, complexity, and component count. **VC**

Editor's Note: "Improved Zobel Network" was originally published in CJS Lab Notes, Vol. 12, Issue 4 by CJS Labs.

That article is available at [www.cjs-labs.com (http://www.cjs-labs.com)](http://www.cjs-labs.com).

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