3. Crossovers: Even Further Knowledge

Part three of these crossover reference sheets is devoted to the complete formula collection for all sorts of filters. These formulae do always assume a -3 dB attenuation at the crossover frequency, hence a quick check with paper no. 2 would be required if any of the filters are chosen which require a -6 dB attenuation. Don't forget to multiply/divide their crossover frequency by the factor stated in the according paragraphs.
The notation in the following formulae states Z as the complex impedance of the drive unit at the frequency of desired crossover action, L in Henries, C in Farads and f in Hertz.
The subscript H always refers to the high pass filter section, whereas the subscript L always refers to the low pass filter section.

3.1. First Order Networks

3.1.1. Butterworth

$$C_1 = \frac{0.159}{Z_H \cdot f}$$

$$L_1 = \frac{Z_L}{6.28f}$$

3.2. Second Order Networks

3.2.1. Linkwitz-Riley

$$C_1 = \frac{0.796}{Z_H \cdot f}$$

$$C_2 = \frac{0.796}{Z_L \cdot f}$$

$$L_1 = \frac{0.3183 \cdot Z_H}{f}$$

$$L_2 = \frac{0.3183 \cdot Z_L}{f}$$

3.2.2. Bessel

$$C_1 = \frac{0.0912}{Z_H \cdot f}$$

$$C_2 = \frac{0.0912}{Z_L \cdot f}$$

$$L_1 = \frac{0.2756 \cdot Z_H}{f}$$

$$L_2 = \frac{0.2756 \cdot Z_L}{f}$$

3.2.3. Butterworth

$$C_1 = \frac{0.1125}{Z_H \cdot f}$$

$$C_2 = \frac{0.1125}{Z_L \cdot f}$$

$$L_1 = \frac{0.2251 \cdot Z_H}{f}$$

$$L_2 = \frac{0.2251 \cdot Z_L}{f}$$

3.2.4. Chebychev (Q = 1)

$$C_1 = \frac{0.1592}{Z_H \cdot f}$$

$$C_2 = \frac{0.1592}{Z_L \cdot f}$$

$$L_1 = \frac{0.1592 \cdot Z_H}{f}$$

$$L_2 = \frac{0.1592 \cdot Z_L}{f}$$

3.3. Third Order Networks

3.3.1. Butterworth

$$C_1 = \frac{0.1061}{Z_H \cdot f}$$

$$C_2 = \frac{0.3183}{Z_H \cdot f}$$

$$C_3 = \frac{0.2122}{Z_L \cdot f}$$

$$L_1 = \frac{0.1194 \cdot Z_H}{f}$$

$$L_2 = \frac{0.2387 \cdot Z_L}{f}$$

$$L_3 = \frac{0.0796 \cdot Z_L}{f}$$

3.4. Fourth Order Networks

3.4.1. Linkwitz-Riley

$$C_1 = \frac{0.0844}{Z_H \cdot f}$$

$$C_2 = \frac{0.1688}{Z_H \cdot f}$$

$$C_3 = \frac{0.2533}{Z_L \cdot f}$$

$$C_4 = \frac{0.0563}{Z_L \cdot f}$$

$$L_1 = \frac{0.1000 \cdot Z_H}{f}$$

$$L_2 = \frac{0.4501 \cdot Z_H}{f}$$

$$L_3 = \frac{0.3000 \cdot Z_L}{f}$$

$$L_4 = \frac{0.1500 \cdot Z_L}{f}$$

3.4.2. Bessel

$$C_1 = \frac{0.0702}{Z_H \cdot f}$$

$$C_2 = \frac{0.0719}{Z_H \cdot f}$$

$$C_3 = \frac{0.2336}{Z_L \cdot f}$$

$$C_4 = \frac{0.0504}{Z_L \cdot f}$$

$$L_1 = \frac{0.0862 \cdot Z_H}{f}$$

$$L_2 = \frac{0.4983 \cdot Z_H}{f}$$

$$L_3 = \frac{0.3583 \cdot Z_L}{f}$$

$$L_4 = \frac{0.1463 \cdot Z_L}{f}$$

3.4.3. Butterworth

$$C_1 = \frac{0.1040}{Z_H \cdot f}$$

$$C_2 = \frac{0.1470}{Z_H \cdot f}$$

$$C_3 = \frac{0.2509}{Z_L \cdot f}$$

$$C_4 = \frac{0.0609}{Z_L \cdot f}$$

$$L_1 = \frac{0.1009 \cdot Z_H}{f}$$

$$L_2 = \frac{0.4159 \cdot Z_H}{f}$$

$$L_3 = \frac{0.2437 \cdot Z_L}{f}$$

$$L_4 = \frac{0.1723 \cdot Z_L}{f}$$

3.4.4. Legendre

$$C_1 = \frac{0.1104}{Z_H \cdot f}$$

$$C_2 = \frac{0.1246}{Z_H \cdot f}$$

$$C_3 = \frac{0.2365}{Z_L \cdot f}$$

$$C_4 = \frac{0.0910}{Z_L \cdot f}$$

$$L_1 = \frac{0.1073 \cdot Z_H}{f}$$

$$L_2 = \frac{0.2783 \cdot Z_H}{f}$$

$$L_3 = \frac{0.2294 \cdot Z_L}{f}$$

$$L_4 = \frac{0.2034 \cdot Z_L}{f}$$

3.4.5. Gaussian

$$C_1 = \frac{0.0767}{Z_H \cdot f}$$

$$C_2 = \frac{0.1491}{Z_H \cdot f}$$

$$C_3 = \frac{0.2235}{Z_L \cdot f}$$

$$C_4 = \frac{0.0768}{Z_L \cdot f}$$

$$L_1 = \frac{0.1116 \cdot Z_H}{f}$$

$$L_2 = \frac{0.3251 \cdot Z_H}{f}$$

$$L_3 = \frac{0.3253 \cdot Z_L}{f}$$

$$L_4 = \frac{0.1674 \cdot Z_L}{f}$$

3.4.6. Linear Phase

$$C_1 = \frac{0.0741}{Z_H \cdot f}$$

$$C_2 = \frac{0.1524}{Z_H \cdot f}$$

$$C_3 = \frac{0.22}{Z_L \cdot f}$$

$$C_4 = \frac{0.0632}{Z_L \cdot f}$$

$$L_1 = \frac{0.1079 \cdot Z_H}{f}$$

$$L_2 = \frac{0.3853 \cdot Z_H}{f}$$

$$L_3 = \frac{0.3285 \cdot Z_L}{f}$$

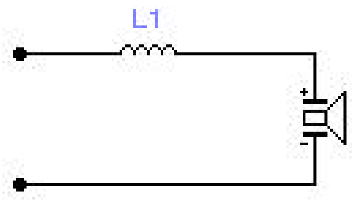
$$L_4 = \frac{0.1578 \cdot Z_L}{f}$$

After all these formulae there is one more important point to mention - The filter topology. The filter orders 1 - 4 will now be shown for low pass and high pass filters. For these graphic illustrations please turn ove to page 6 of this paper.

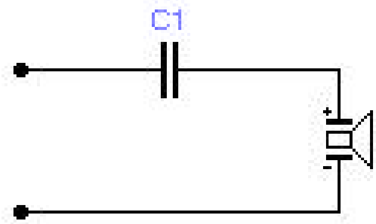
4. Filter Networks and Filter Topology

First of all the filter topology is very important when considering filters with a higher order. Here it is important to place the components in the given order, as a change in order would turn the whole "tuning" of the filter upside down. In this paragraph, the filter topologies for the filter orders 1 - 4 are shown. Note the labeling of the components and, if in doubt, check with the formulae given in paragraph 3 of this paper.

4.1. First Order Filters

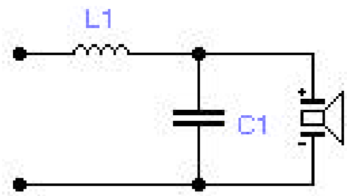


1st Order Low Pass Filter

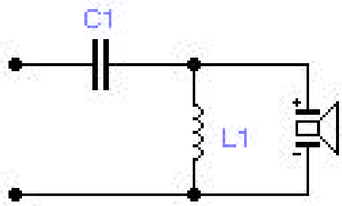


1st Order High Pass Filter

4.2. Second Order Filters

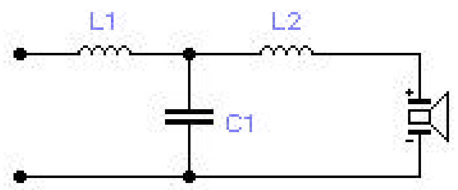


2nd Order Low Pass Filter

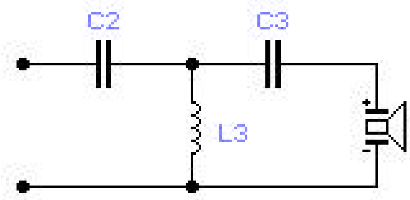


2nd Order High Pass Filter

4.3. Third Order Filters

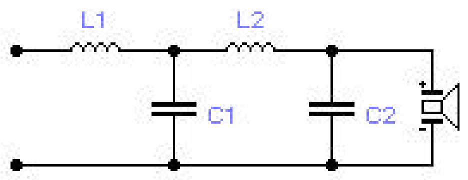


3^{rd} Order Low Pass Filter

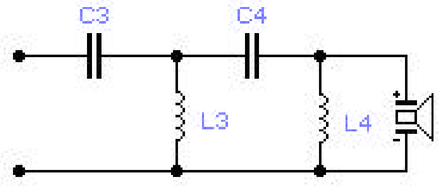


3^{rd} Order High Pass Filter

4.4. Fourth Order Filters



4^{th} Order Low Pass Filter



4^{th} Order High Pass Filter

5. Acknowledgments

Again this paper has been put together from different source material, the most important source being Vance Dickason's "Loudspeaker Cookbook". Please respect the Author's copyright and do not publish unless you have asked the Author for written permission.

The next, last and final paper about crossovers will discuss the three-way crossover technology in some detail and might be very complex to understand. A fair deal of reading about crossovers (i.e. parts I - III of the Crossover Papers) should be considered before attempting to read paper no. 4. Apart from that good luck in the construction of crossovers. May the phase shift be with you.