

Crossover design for speakers



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Crossover Design

In terms of crossover design, there are two distinct options; passive or active crossovers. Passive crossovers are the most common implementation, since only one amplifier is required. In this case, filters comprising passive components (inductors, capacitors and resistors) are used to ensure that the correct frequency range is supplied to each driver. Low-pass, high-pass and band-pass filters are commonly used and need to be matched to ensure that the frequency roll-offs compliment each other, such that in the crossover zone(s) the combined acoustic output of the drivers maintains a flat frequency response.

In terms of these passive filters, it is the order of the filters used that is the primary consideration. A first order filter has a roll-off of -6dB per Octave and a Butterworth characteristic. First order filters are undesirable for two reasons; a +3dB peak is introduced at the centre of the crossover band and the crossover bandwidth is large due to the gentle roll-off, which means the drivers need to be capable of handling a greater frequency range. However, first order filters require the least components, incur less power loss as a result and do not introduce a phase change in the output.

Second order filters are the most commonly used type in passive crossovers, since they are relatively simple but solve the problems associated with first order filters. The roll-off is -12dB per octave and the filters may be designed with a Linkwitz-Riley characteristic which maintains a flat frequency response across the crossover band, unlike the combination of Butterworth filters.

Third order filters offer a roll-off of -18dB per octave, however there is a problem of phase separation; in a two-way configuration there is a phase shift of 270 degrees which “ can result in lobing and tilting of the coverage pattern” (DellaSala, G. 2004). Some designs such as the D’Appolito configuration ^[1], which uses three drivers, actually make use of this phase separation in order to minimise lobing, however the D’Appolito configuration is notoriously complex and difficult to implement well without precise driver measurements.

If a high-order crossover is desired, fourth order filters are perhaps the best choice. Although they are more complex in terms of design and require more components, the advantages are a small crossover bandwidth (roll-off is -24dB per octave) and a 360 degree phase shift; hence no phase correction is required. Passive crossovers beyond fourth order are generally not considered. Borwick (2001, p. 267) notes these “ are seldom used in passive crossover designs because of their complexity, cost and insertion losses”.

The other approach to crossover design is the active crossover. In this case active filters (normally based around op-amps) are used to divide the input signal into the required frequency bands prior to amplification; the crossover has multiple outputs and a separate power amplifier is needed for each frequency band. Some audiophiles complain that active crossovers (which normally employ high-order active filters) are not a good choice, due to the poor transient response of high order filters. However as Elliot (2004) notes, “ the additional control that the amp has over the driver’s behaviour *improves* the transient performance, and especially so at (or near) the

crossover frequency – the most critical frequency point(s) in the design of any loudspeaker”.

Apart from the increased complexity and multiple power amplifier requirement, active crossovers are far superior to their passive counterparts in almost every way, although some purists may disagree. Good quality op-amps are cheap, as are the required resistors and capacitors (since these do not need to handle much power). The active solution means frequency response is no longer defined by the quite complicated combined resistive, capacitive and inductive load of the passive crossover and drivers. Thus the frequency response of the crossover is independent of dynamic changes in the load. Furthermore, the active crossover makes it easy to tune the crossover dynamically; with most commercially available active crossovers one can simply dial in the required frequency bands.

Efficiency is improved with active crossovers, since no power is lost by the amplifier in driving passive inductors or resistors. The amplifier also has the best possible control over transient response, since there is nothing between it and the driver other than cable. Thus the amplifier can respond directly and “presents the maximum damping factor at all times, regardless of frequency” (Elliot R. 2004).

In view of the above one may then wonder why passive crossovers continue to remain so popular, since it seems far more logical to implement frequency division before amplifying the signal. Ease of installation is perhaps the main factor. Almost all commonly available hi-fi systems use speakers with

passive crossovers. For the consumer this makes things easy; the speakers are simply connected to the amplifier and installation is complete.

In contrast, turnkey active solutions for the average consumer are not forthcoming, although rack-mounted “ professional” active crossovers can be obtained for quite reasonable prices (around £150 for a 4th order 2 way Linkwitz-Riley design) ^[2]. However, these require a fair amount of audio engineering expertise to set up correctly and the typical home listener simply does not possess this knowledge.

For the high-budget client seeking the best audio reproduction, active crossovers are certainly the best option; the technical advantages have been seen to be numerous. This is offset by the fact that the system will be far more complicated to correctly install, but it is assumed in this case that complexity of installation is of little concern to the high-budget client who is unlikely to handle the installation themselves in any case.

For the low-budget client, the best solution is the passive crossover. It is a simple option, only requires one amplifier and yet produces acceptable sound quality. It is far from the best solution, but adequate if a competitive price point is desired.

In conclusion, all but a few dyed-in-the-wool purists will agree that the active crossover is a superior solution in terms of quality and control. What it lacks in simplicity is outweighed by a far superior level of control over frequency response and the drivers themselves. However, due to issues of complexity

one can expect that the traditional passive crossover shall continue to lead a healthy existence in the majority of loudspeaker designs.

Sources

Borwick, John. (2001). *Loudspeaker and Headphone Handbook* , Focal Press.

DellaSala, G. (2004). *Filter & Crossover Types for Loudspeakers* , Audioholics Magazine.

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Elliot R. (2004). *Active vs Passive Crossovers* , Elliot Sound Products.

Rossing, T. (1990). *The Science of Sound* , Addison-Wesley.

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[1] D'Appolito's full 1983 paper may be obtained here: <http://www.aes.org/e-lib/browse.cfm?elib=11762>

[2] For example the Samson S-2: <http://www.inta-audio.com/products.asp?partno=sto-oth-sam2w>