ACTIVE VS PASSIVE CROSSOVERS FOR MID-PRICED HiFi LOUDSPEAKERS

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ABSTRACT

Loudspeakers with active crossover networks have been available for some time. Traditional thinking is that they can out-perform similar loudspeakers with passive crossovers, but at a price penalty. Nowadays, high-quality, mass-produced electronics are available at ever lower prices, so the concept of a competitive, mid-priced, active HiFi loudspeaker has become feasible. Currently, active crossovers are only found in higher-priced hi-fi loudspeakers and studio monitors.

This paper explores the possibility of designing and building a loudspeaker with active electronics for the same cost as a closely equivalent passive loudspeaker. The two loudspeakers were designed and constructed from scratch using readily available, off-the-shelf components. The price of the active electronics included the crossover filters, and a regulated power supply. Comparisons are drawn between the objective performance and subjective sound quality of the two loudspeakers through anechoic measurements and a series of in-room listening tests.

1 CURRENT & TARGET MARKETS

To find a budget that the speaker packages should be aiming for, preliminary research was conducted into observing the current prices of active speakers on the market. This was mostly through looking at comparative reports and the information of the manufacturers and retailers of loudspeakers.

It was found that only very high-end speakers, generally costing £1000+, were completely active. For this reason, the speakers used in this investigation will be aimed at introducing fully active loudspeakers into the ~ £400 - 500 price range.

As previously introduced, the two crossovers (active & passive) will be given the same budget; however, the cost of the active crossover is to include the cost of a regulated power supply for the filters. Both filters were designed to a cost of £30.

2 CABINET DESIGN

The objective of the cabinet is to sound as 'neutral' as possible so as the differences in the crossover circuits are made distinguishable. From this, the cabinets were designed as follows, for use with Peerless WF 165 low frequency and LPG 26T high frequency drive units.

The use of 3 ports allows the tuning of the reflex system to be altered to account for the acoustic environment in which the speakers are to be placed [1], whilst the metal bolts act as bracing to stiffen the cabinet and hence reduce any panel vibrations of the plywood [2]. The recessed tweeter in the front plane of the cabinet is to time align the drive units and hence improve their transient (impulse) response [3].

Two identical cabinets were built of this design, and two of each high frequency and low frequency drive units were purchased for use in the study.

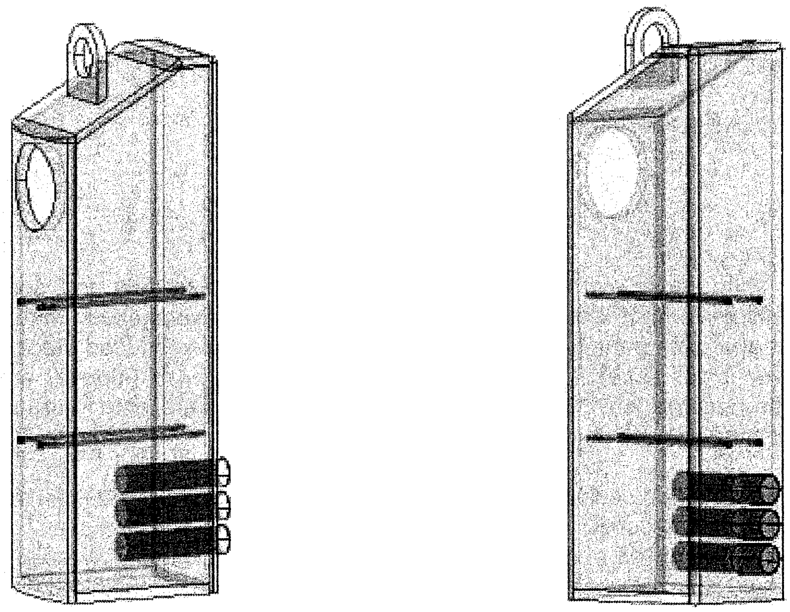

Figure 1 Scaled 3D drawings of the front and back of the chosen cabinet design

3 CROSSOVER BACKGROUND

An active crossover is connected directly to a signal input (e.g., from a compact disc player or similar), and subsequently the low-pass filter (LPF) / high pass filter (HPF) outputs from the crossover are connected to power amplifiers, which forward the signals to each of the drivers.

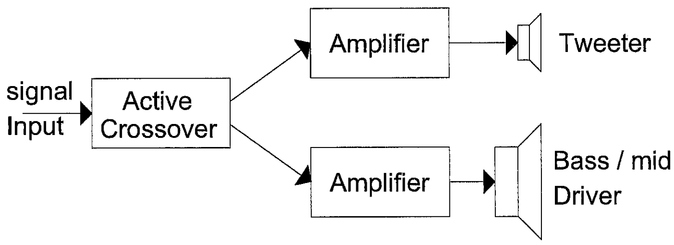

Figure 2 Active Crossover Set-up

There are documented theoretical advantages [4] to the connection set up of the active crossover. Firstly, a reduction in distortion due to the modulation in each of the amplifiers is experienced due to the fact that each of the amplifiers is operating over a narrower bandwidth. Also, with the power amplifiers connected directly across each of the drivers, each driver unit is driven with a constant voltage. This generally suppresses the fundamental resonance of the driver due to electromagnetic damping, although the effect of this is dependant on the Q-factor of the driver.

Further, in subjective (listening) tests, well-designed active systems tend to be preferred to equivalent passive systems. Descriptions such as 'louder' and 'clearer' are commonly made, and this could be due to a reduction in 'stressful' loading on each of the amplifiers.

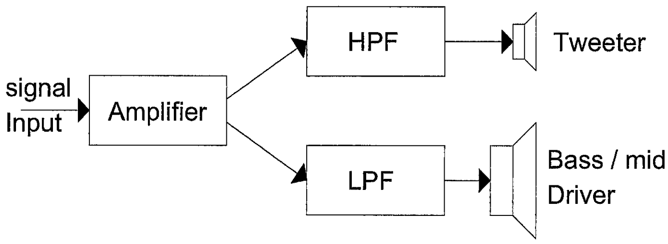

Figure 3 Passive Crossover Set-up

Passive crossovers are far more widespread than active crossovers, used in many levels of loudspeaker design and manufacturing ranging from entry to top level. Passive crossovers are easier to implement as the filtering stage is conducted after the amplification, and hence can be without difficulty enclosed inside the loudspeaker cabinet.

However, as the filtering is conducted after amplification, passive crossovers require high power electrical components. Such components are inherently less accurate and more expensive - hence making it harder to implement higher order filters, as they will be both more expensive and incur more electrical losses than the equivalent active circuits.

Another drawback of a passive (in comparison to an active) crossover is that in the active set-up the amplifier has a direct connection across the drive units, which means that the back EMF can be easier controlled (damped) around resonance. This is an advantage that cannot be realized in a passive set-up due the components in-between the drive units and the amplifier.

4 FILTER DESIGN

In order to design the HPF & LPF sections of the active and passive crossover circuits, measurements were taken in an anechoic chamber of each of the high frequency and low frequency drive units in the cabinets. The measurements showed no significant differences between like units in each cabinet (within the tolerance of the measurements).

The measurements were used to determine the requirements of the filters to equalize the response of the drive units, and hence provide as linear response from the system as feasible.

4.1 Active Crossover

An active crossover was designed which, when its filter gains are convolved with the measured responses of the drive units in the cabinet, produces a predicted response as shown in Figure 4

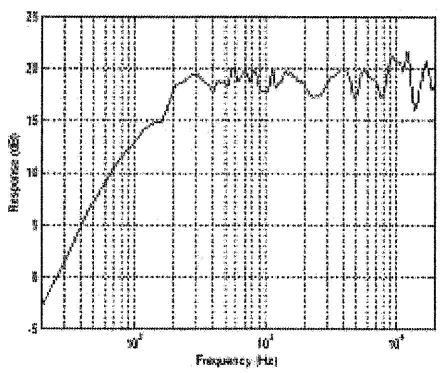

Figure 4 Predicted Active Loudspeaker Response

The apparent roll-off of the response below 200 Hz is not accurate as this is due to a low number of samples in the (low frequency drive unit) measurement in this frequency band, and the fact that the Anechoic Chamber performs worse below 70 Hz.

4.2 Passive Crossover

A passive crossover was designed which, when its filter gains are convolved with the measured responses of the drive units in the cabinet, produces a predicted response as shown in Figure 5

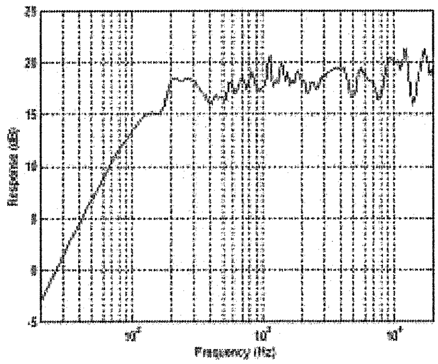

Figure 5 Predicted Passive Loudspeaker Response

As with the prediction for the performance of the active loudspeaker, data below 200 Hz cannot be considered as an accurate prediction of the loudspeaker system.

5 SUBJECTIVE TESTING

Subjective testing was conducted on the completed loudspeakers, as the human perception of the differences between the active and passive crossovers is crucial (arguably more so than anechoic test results) in determining if there is an opening in the market for an active loudspeaker of this nature.

5.1 Procedure

It was decided these tests would be conducted in a 'real environment' as opposed to in the anechoic chamber. This was due to the fact that if these loudspeakers were to be compared in a situation in which a buyer would decide on one over the other, this choice would be made on the subject's perception of the in-room ability of the loudspeaker to reproduce an accurate sound field. The environment's under which loudspeakers are placed in order to be listened to daily are widely varying and rarely ideal. These tests were conducted in a typical front room that was chosen for its apparent lack of acoustic features, and similarity to many other listening environments.

A panel of 30 subjects was selected, consisting of many various different types of people and background (especially regarding audio 'experience'). The foundation for this test was a simple evaluation form adapted from Colloms [4] which asks the subjects to rate various aspects of the loudspeaker's sound on a scale range of 11 (0 – 10). Definitions of the categories (also taken from Colloms) were supplied with each test form.

Three test programs were chosen to play through each speaker in turn (i.e., one program was played though one of the loudspeakers then the same program played through the other loudspeaker directly afterwards). The three programs, all of which were regarded to be well-engineered recordings, were chosen to test different general aspects of the loudspeakers.

The equipment used to test the loudspeaker systems is listed in Table 6.

Amplifier	NAD C320
CD Transport	Marantz CD5000
CD DAC	Creek OBH-14: 128x Delta Sigma type
Digital Interconnect	Escosse Reference "The Producer"
Analogue Interconnect	Van Den Hul DH 103 Hybrid III
Speaker Cable	QED Silver 25th Anniversary Edition Bi-Wire

Table 6 Test Equipment List

5.2 Results

The seven sections of the evaluation form can be divided into two defining categories and analysed as follows.

Firstly, those which measure distinct features / problems of the sound which the loudspeaker produces. These were (in this test); Fullness, Brightness, and Softness. In these categories midway (labelled as 5) would be the best possible score to rate the loudspeaker. Under these categories, a comparison was made on the active loudspeaker relative to the passive loudspeaker. If the speaker with the active crossover was marked (by a subject) closer to 5 than the passive, it received a +1 score. Further away and it received a –1 score.

These comparison scores were then summed for all subjects in each test, and later totalled over all tests. This method appears to work for two reasons: firstly there should be no difference (in these fields) between a sound that, for example, is too dull or too sharp; they are simply both inaccurate. Secondly, there were no large variations in the results given by each subject for each test. For example, in the same test one loudspeaker was not marked perfect and the other wildly dull or sharp (by, say, 3-4 points) by any subject.

The second category in which the sections of the evaluation could fall under, are those which measure an overall impression of the loudspeaker. Namely in this test Clarity, Spaciousness, Pleasantness, and Fidelity. In these the higher the mark awarded, the better the loudspeaker is judged to sound. These results were analysed by again comparing the active loudspeaker to the passive, but this time by simply subtracting the mark awarded to the passive speaker from the mark awarded to the active speaker. These comparison values were summed over all subjects in each test, and then averaged over all tests. Using these methods, the average comparison between the active and passive loudspeaker systems is shown in Figure 7.

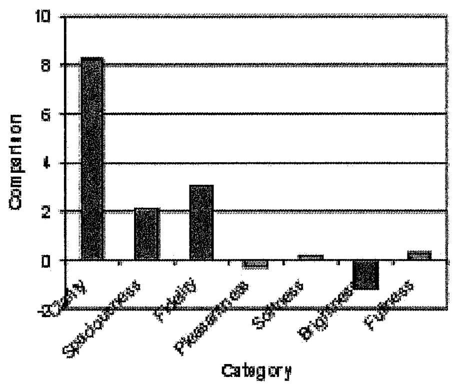

Figure 7 Subjective Testing Results

Looking at Figure 7 it seems that the loudspeaker using the active crossover seemed to out perform that using passive in most areas. This was however far more noticeable in the sections that concerned a general impression of the loudspeaker, only falling slightly short on Pleasantness. Descriptions of the active speaker sounding too 'harsh' being the major cause of this (seen in the active crossover performing worse in the brightness category).

In the other category, that which refers to specific details of the loudspeakers sound (i.e. Fullness, Brightness, & Softness), the results are very similar for both crossovers. When considering the range of equalisation available in an active crossover, this leads one to believe that the active loudspeaker should have out performed the passive. This may have been the fault of the process in selecting the listening panel. Many subjects on the panel had not properly heard a 'Hi-Fi' active loudspeaker and so reported being indecisive as to which aspects of the sound they preferred in what tested to be the clearer signal of the active crossover.

This speculation is supported by the standard deviation of the results for this category concerning specific qualities to stand out as higher, by a noticeable margin. In addition, many of these subjects reported to have 'warmed' or 'grown used to' the sound of the active loudspeaker. Indeed, the only subject to participate twice (by request; once at the beginning of testing, and then again at the end) scored the active loudspeaker distinctly higher the second time. In this one-off test, the order of speakers playing each program, and the programs themselves, were once again shuffled and the subject was unaware of which loudspeaker was connected to each crossover.

5.3 Criticisms

Certain criticisms have arisen with the conduct of the subjective testing. Firstly, panel selection. Instead of the initial school of thought in which an attempt was made to get as many different types of people involved, perhaps a more conscientious effort to include more (or perhaps a complete panel of) subjects thought of as audiophiles should have been made. Such people will probably have more significant opinions to voice in their descriptions of the reproduction quality.

Furthermore, whilst every effort was made, the room in which the tests were conducted was not an official listening room. As at one point up to three subjects were participating at the same time, it meant that not all three could be on axis with the respective speakers, and the acoustics of the room may have varied between the positions of each of the subjects.

In order to recreate a full recording through a single speaker, a stereo-to-mono mixing circuit was implemented, which slightly decreased the quality of the signal playing through the loudspeakers. Although this disadvantage would have been shared across both crossovers, it may have affected the ability of the subjects to distinguish between intricate sounds in the recordings, and so the reproduction of each speaker.

6 ANECHOIC TESTING

The completed loudspeakers were tested using MLSSA in the anechoic chamber. The results for the two speakers are shown in Figures 8 and 9.

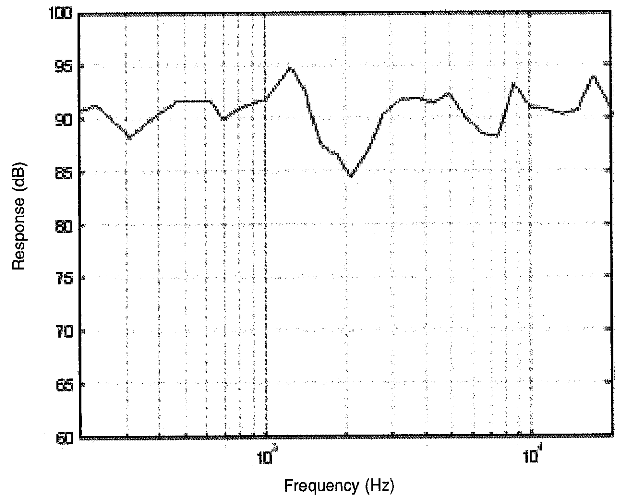

Figure 8 Passive Loudspeaker Response

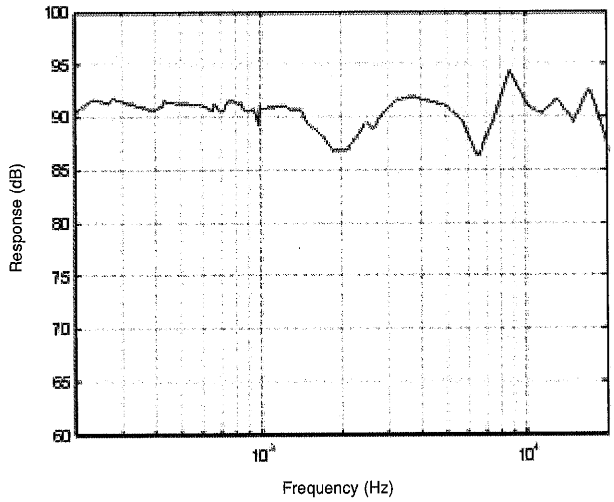

Figure 9 Active Loudspeaker Response

The most immediately noticeable characteristic of Figures 8 & 9 are the dips in both of the responses at 2, 6, and 12 kHz. However it was noticed during testing that these dips were most probably due to diffraction / interference patterns cause by the corner between the sloping top and the front baffle of the cabinets. When acoustic absorption was added to this corner, the drop in level was less significant at these frequencies.

It is also noticeable from these two graphs that while the two loudspeakers had very similar high frequency response's (over 2 kHz), the mid-frequency (200 Hz – 1 kHz) response of the two speakers differs significantly.

7 CONCLUSION

As is clear from sections 5 and 6, both the subjective tests and objective anechoic measurements favoured the active crossover over the passive crossover. In the passive crossover, it is evident that with so few components available the diffraction rise was not completely compensated for, which led to a poor objective measurement. As both crossovers cost very similar amounts, it seems this initial study has shown there is a market for an active loudspeaker in the mid price band.

Further research should be conducted into this field, with potentially larger studies being conducted. The first companies to produce such a loudspeaker may have an advantage in marketing their product as it would be extremely rare to find other similar products in this price range, and the loudspeaker would- presumably- out perform competing passive loudspeakers.

8 REFERENCES

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[3] Long, Edward M., 'A Time-Align Technique for Loudspeaker System Design', Proc. 54th A.E.S. Convention, April 1976.

[4] Colloms, M., 'High Performance Loudspeakers, 5th Edition', England, John Wiley, 1997