Fig 1. This sub is driven by a Quad 405. Speakers are in series. The ESL-63 is driven by Marc Levinson No 23. The ESL's are still original after more than 30 years. They are often driven up to 50Volts top to top

Fig. 2 The electronic crossover and correction unit.

Filter Scheme and Graphs

Anti-malaria drones. A marvelous project to combat the spreading of malaria! Guido Welter, Richard Mukabana and Bart Knols.

The Contrapunt, a dipole sub woofer for the Quad ESL-63

The ESL-63, though an excellent loudspeaker, cannot produce the full contra octave and cannot produce sound levels higher than 96 dB. The contrapunt is designed to cover these aspects, but when these extremes are not met the use of the sub woofer should be inaudible when it is compared to the ESL63 full range.

For me It was quite a discovery that it is possible to build a sub without an enclosure. Compared to normal sub woofers there could be several specific advantages with dipoles. Normal subs with an enclosure excite many more room modes, due to their omnidirectional character. This can lead to an uneven frequency response at the listening position. In contrast, due to the directional nature of a dipole there are no standing waves to the ceiling and side walls. The bass of the dipole is deep because the resonance frequency of the woofer is not shifted upwards by an enclosure. Energy is transmitted without the delay and the back-lash that is caused by a box. Bass energy build up is immediately.

I have given this sub a name, the Contrapunt. It can be used with speakers for the upper range that can be crossed at 110Hz. For every channel a sub woofer should be used. Combined with a Quad ESL-63, the ESL can play up to 10dB louder and the lower bass range is extended. An extra advantage of the Contrapunt is that when it is used with the Quads, the dipole frequency characteristic of the combination of the ESL and the sub woofer will be the same on both sides.

The design of the sub woofer is simple, but at the expense of an extra amplifier and an electronic crossover/correction filter. Measured frequency range is 24 to 110Hz within 3dB. They should be placed at least one meter before the rear wall. In my living room they have 4 meters free space behind.

For a excellent briefing on dipole sub woofer theory see Brian Steele's subwoofer page or Sigfried Linkwitz' elaborate DIY speaker building page.

Sound

The quality of a dipole sub is different from what most listeners anticipated as the sound of an open bass system. Also for me. The sub is precise, no matter if it has to generate pressure and attack for electronic dance music or to reveal the delicacy of a slap bass. Bass doesn't need time to build up, it is very well damped, better than when a enclosure is used. Low-frequency tones are reproduced life-like. The combination of the Quad ESL-63 and the sub woofer shows in symphonic works precise positioning and discrimination of instruments, and a great dynamic range while maintaining an impressive reproduction of sound stage and space. Don't be fooled, the sound pressure with 2 subs in a 50m2 living room is 100dB at 31,2 Hz. The dipole sub doesn't add coloration. When the extremes this dipole subwoofer is designed for are not existent, i.e. SPL below 96dB and no content below 40Hz, switching off the contrapunt

- Scheme of the electronic crossover and correction filter. The 10k pot is for level control. The phase of the connection between power amp and the dipole sub should be reversed.
- Frequency characteristic of the combination filter and speakers, simulated.
- Phase characteristic of the combination filter and speakers, simulated.
- Frequency characteristic of the dipole 6dB/octave compensation filter.
- Frequency characteristic of the 110Hz high pass filter .
- Frequency characteristic of the 110Hz low pass filter.
- Frequency characteristic of the 25Hz high pass filter. +3dB correction for Q factor
- FAQ Frequently asked questions

Although the slope of the high pass is electrically 12dB/oct, the acoustic slope is determined by the combination ESL and filter. The same applies to the acoustic combination of the woofer+filter. The slopes are carefully tailored with the characteristics of the speakers to give a flat frequency response. In the crossover region the phase response of the low pass (subwoofer+filter) and high pass (ESL+filter) are nearly the same (20 degree difference). Two other features are incorporated in the filter. The characteristic of the subsonic high pass filter at 20Hz has also some compensation for the fall off due to the Q factor of the woofer. The high pass section in front of the ESL gives the region between 150-200Hz a lift of 1.6dB to compensate for a nearly inaudible flaw in the frequency characteristic of the ESL. Although the filter seems quite normal, it is carefully designed and tested to function for the combination of an ESL63 with this dipole sub.

A digital filter with an ADAU1701 DSP is also tested. With the PGA2311 analog volume control placed behind the filter this gave very good results. In this way the filter could always work at the maximum bit size!

and switching on the ESL-63 to full range is (nearly) inaudible. When it is not needed it is not there.

Design considerations

A specific characteristic of a dipole is the cancellation frequency that is determined by the size of the baffle. A compensation of +6dB/octave is needed below the cancellation frequency of the baffle, which starts when the shortest path between the positive front and the negative back wave is 0.5 wave length. This quality is also the cause of the directional radiation pattern that looks like the figure 8, giving less standing waves in the listening room than a traditional woofer design. A lot of acoustic power is principally lost with a dipole. The size of the folded baffle is a compromise between efficiency and the higher frequency at which the dipole becomes a comb filter. The size of the baffle is chosen to let it work solely in the 6dB decrease region. The region in which the dipole woofer reacts as a comb filter is well above the crossover frequency. The woofers should be able to move a lot of air to compensate for the acoustic loss.

Technical backgrounds

The resonance frequency of the drivers should be below the lowest note to be produced. The Qts factor should be between 0.6 and 1. A speaker with a 0,7 to 0,8 Qts has a flat frequency response on an infinite baffle and drops down to -3dB at the resonance frequency. Low Qts woofers shouldn't be used. Normally a low Q woofer gets efficient when the Q is raised by an enclosure, but with a dipole the Q is not shifted upwards. For the same acoustical output at the resonance frequency a 0,27 Q speaker needs in a dipole configuration more than 100 watts power, versus 20 watts for a 0,7 Q speaker (when the efficiency of the drivers is the same). And it gets worse. When the thermal compression due to the higher power -100w versus 20 Watt- is taken into account, only 10% output power will remain. (-10dB)
Woofers with 2 voice coils are advantageous, when only one voice coil is connected, the Q factor doubles while power rating may be only 10 percent less. In the first version two Peerless 831857's (CCX315) were used. Nowadays I use Adire Shiva's ($229,-) with one voice coil connected (!) and with a 10mm felt pad at the back of the magnet to eliminate noise at full stroke. The Adire Shiva woofer exhibits low distortion figures, even at large strokes. Also AE speakers makes cleverly designed woofers for dipole use with a low distortion underhung lambda motor.
Maximum used power for full stroke in this design is 40 Watts per woofer at 30Hz with 0.7 Q factor woofers. With contemporary heavy bass music this is enough to keep up with the ESL 63 (clipping at 50Volts peak to peak).
The push-pull configuration reduces even harmonic distortion with approximately 50 %. The uneven distortion is not reduced. There may be some misunderstanding, even harmonic distortion is the same as **uneven order** harmonic distortion.
More information on dipole sub woofer aspects and the design of another dipole sub can be found at the FAQ page of Sigfried Linkwitz and at Brian Steele's subwoofer page. I have build these subs from scratch in the carpenter shop of Intri with the aid of Ruud Loos. The curved wooden panels of ESL-63 were used as a guide for the router for the upper and lower panel of the sub woofer.

Motional Feedback Woofers

When one is used to the undistorted clean bass response of the Quad's, sometimes -the human ear is not very sensitive to harmonic distortion in the bass region- the need is felt for a further reduction of

harmonic distortion of the sub woofer. This can be accomplished by using a servo controlled woofer. Distortion can become below 3% at high levels. On the picture is in the middle the acceleration element of a Philips 12" MFB woofer. In a dipole the MFB is less advantageous than in a closed box. The Shiva or AE woofers already have a very low free air distortion.

Geert Meddens, this page started in sept. 1999.