Using SE Optimizer For Quick Loudspeaker Design

This short paper, describes a couple if issues frequently encountered during loudspeaker design process. (1) An example design of a two-way loudspeaker system, with Linkwitz-Riley, 4th order crossover at 1.5kHz, and (2) amplitude peak equalization. The tool used for both processes is the Optimizer Function. Since the crossover is of the 4th order, the drivers are connected in-phase for normal operation. At this stage, we are not concerned about the availability of components with exact calculated values. Capacitors are easily paralleled, and coils can be easily modified to the required values.

Our drivers are: Woofer (pink) and Tweeter (green) SPL curves. Drivers have been fully edited and are minimum-phase.



Woofer (green) and Tweeter (blue) Phase response curves



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Original System Frequency Response (pink) and Reverse Null (green)



It is observable, that raw frequency response of the system is tilting upwards. This suggests, that tweeter efficiency is too high for the given woofer. Also, the "reverse null" is non-existent. This suggests, that phase responses at the crossover frequency are not 180deg and amplitudes are not -6dB both drivers. This loudspeaker would be lacking bass and sound overly bright.

Optimizing Acoustic Response of the Woofer

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Optimization Parameters – 4 components: L0, C2, L3, C5. This is the whole low-pass section.

CAD Optimization Control	CAD Optimization Control	×
Targets Optimization Nodes	Targets Optimization Nodes	
Reference Configuration Reference Type L-P Passive, -12dB/oct Butlock selected L-P Passive, -2ddB/oct Butlock selected 3. Reference Filter Cut-Off Qo Target High-Pass F3dB 1500 Hz 2.002-Pass F3dB 1500 Hz 4. Optimize Within This Frequency Range From: 100.0 From: 100.0 Hz To: 5. BUT Exclude This Frequency Range From: 6.0 From: 0.0 Hz To: 6. Additional Reference Curve Shape Control From: 0.0 From: 0.0 Hz To: 6. Additional Reference Curve Shape Control From: 0.0 From: 0.0 Hz To: 6.1-off: 0.0 dB/dec Add Ripples Attenuation: -5.0 dB, positive number for gain Show Target Clear Print	Doubleclick to Highlight ==> Optimize These Items IO = 1.200000 mH R1 = 0.000100 ohm C2 = 15.83125 uF I.3 = 0.600000 mH R4 = 0.000100 ohm C5 = 3.500000 uF W6 Woofer 1 C7 = 5.275000 uF Abort Lock ALL New Val Old Val Accept New Values Print Clear Step = 25 %	

Optimized Woofer Filter SPL curve (brown).



Optimizing Acoustic Response of the Tweeter

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Optimization Parameters – 6 components: C7, L8, C10,L11 + L-Pad R14, R15

CAD Optimization Control	CAD Optimization Control
Targets Optimization Nodes	Targets Optimization Nodes
Reference Configuration Reference Type H-P Passive, +12dB/oc Bullock selected H-P Passive, +18dB/oc Butterworth selected H-P Passive, +24dB/od Linkwitz selected 3. Reference Filter Cut-Off Qo Target High-Pass F3dB 1500 Hz Qo .333 Low-Pass F3dB 1500	Doubleclick to Highlight ==> Optimize These Items I.8 = 0.660767 mH R9 = 0.000100 ohm C10 = 14.36615 uF L11 = 98.76871 mH R12 = 0.000100 ohm T13 Driver R14 = 7.923940 ohm R15 = 7.787771 ohm
4. Optimize Within This Frequency Range From: 300.0 Hz To: 20000.0 Hz 5. BUT Exclude This Frequency Range From: 6.0 Hz To: 10.0 Hz 6. Additional Reference Curve Shape Control From: 0.0 Hz To: 0.0 Hz Roll-off: 0.0 dB/dec Add Ripples Attenuation: -5.0 dB, positive number for gain Show Target Clear Print	Optimize Zin [ohm] Constrained Abort Lock ALL New Val Old Val New Val Old Val Accept New Values 100.0 Print Clear Step = 25 % Zin [ohm] Conjugate 6.0 Apply Cmp = 6, Error = 370.5, ZinErr = 398.38, Trial = 150 Zmin = 4.0, Zin = 7.98, Ztar = 6.0 [ohm]

Optimized Tweeter Filter SPL curve (brown).



Complete Optimized Values



Optimized SPL (green) and Reverse Null (pink)



Before (pink) And After (Green) Comparison





Zin Before (violet) and After (blue)

Phase Response Before (green) and After (blue)



It is observable, that after the optimization, the Input Impedance (Zin) curve if flatter and the System Phase response transitions at 1500Hz – which is what is expected. Frequency response is now flat, the reverse null is sharp and almost -20dB deep.



Optimized crossover



Optimizer Has Re-designed the Crossover.

C5 = 80.7nF (very small) is NOT NEEDED. When set to Open Circuit, is does not have any influence on the crossover operation.

L11 = 98.8mH (very large) is NOT NEEDED. When set to Open Circuit, is does not have any influence on the crossover operation.





Compensating Amplitude Peak



Frequency response has a +10dB amplitude peak – see figures below.



Amplitude Peak Equalizer generated component values as shown

above. The peak is greatly reduced, but not eliminated.



Now, the optimizer is engaged. Optimization Parameters are as follows:

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Targets Optimization Nodes	_
Reference Configuration Reference Type	
L-P Passive, -6dB/oct A L-P Passive, -12dB/oct L-P Passive, -18dB/oct Butterworth-Type se	
3. Reference Filter Cut-Off Qo Target High-Pass F3dB 450.0 Hz Q 0.333 Low-Pass F3dB 500000	
4. Optimize Within This Frequency Range	
From: 100 Hz To: 10000 Hz	
5. BUT Exclude This Frequency Range	
From: 6.0 Hz To: 10.0 Hz	
From: 0.0 Hz To: 0.0 Hz	
Roll-off: 0.0 dB/dec Add Ripples	
Attenuation: 0.0 dB, positive number for gain	
Show Target Clear Print	

Optimization was performed in two stages. Stage 1 – C1 + L2 resulting in SPL curve improvement (blue) as shown below.







Further down are the comparison results between the values calculated by the Amplitude Peak Equalizer (green), and values optimized by two-stage optimization process (olive). Original SPL curve is pink. Please note, that the vertical resolution dB scale was set to 1dB. Otherwise, in 5dB scale, the optimized curve was a flat line.



Conclusions

- 1. Loudspeaker system has been designed and optimized without single manual tweak of any component.
- 2. Optimizer handled up to 6 components at a time, even though it is not recommended to exceed 3 components.
- 3. All of the parametric performance curves exhibit good characteristics after optimization.
- 4. Optimized SPL curves for individual filters do not follow 4th order LR filters, but the acoustic responses from the drivers do. This was the design goal.
- 5. Optimizer has also eliminated two components from the crossover circuit.
- 6. Local SPL irregularities (10dB peak, for example) are also handled very well by the optimizer, using two-stage process.