Pacific Northwest Audio Engineering Society Presentation

Evolution Of DIY Loudspeaker Design

Dana Olson, Terry Olson

Introduction

AES Member – New Committee Member

DIY contest selected as Oct Topic

Blind contest, Ugly speakers can win!

Contents

DIY Contest: 2014 Rene’ with Terry Olson

Contest Rules

- **The speakers will be driven by the system the club supplies.**

- **We intend that judging will be totally blind.**

- **Judges are seated, and all hear nine selections on each speaker.**

- **Original Design Categories:**
- **One way ----under $75/over $75**
- **Two way ----under $200/over $200**
- **Three way -- under $300/over $300**
- **Unlimited ---- no limit**

Contest History

- Previous years winner was three way designs with large woofers
- A lot of loose talk about 18” woofers around the club
- Several Open Baffle designs coming
- The room is large and the speakers will be away from the walls.

Entries Waiting To Be Tested

Design Goals / Requirements

- Directivity Possibilities ?
  - Omni
  - Dipole
  - Wide Forward
  - Narrow Forward
- Constant Directivity With Frequency (Gedes)
- Point Source / Line Source ?
- Fixed Source Position

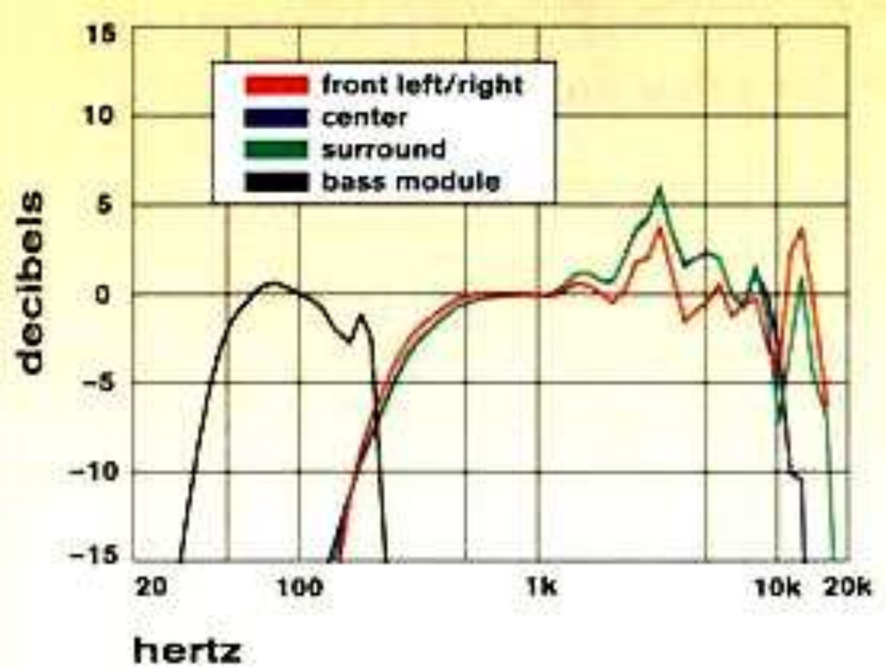
Design Goals / Requirements

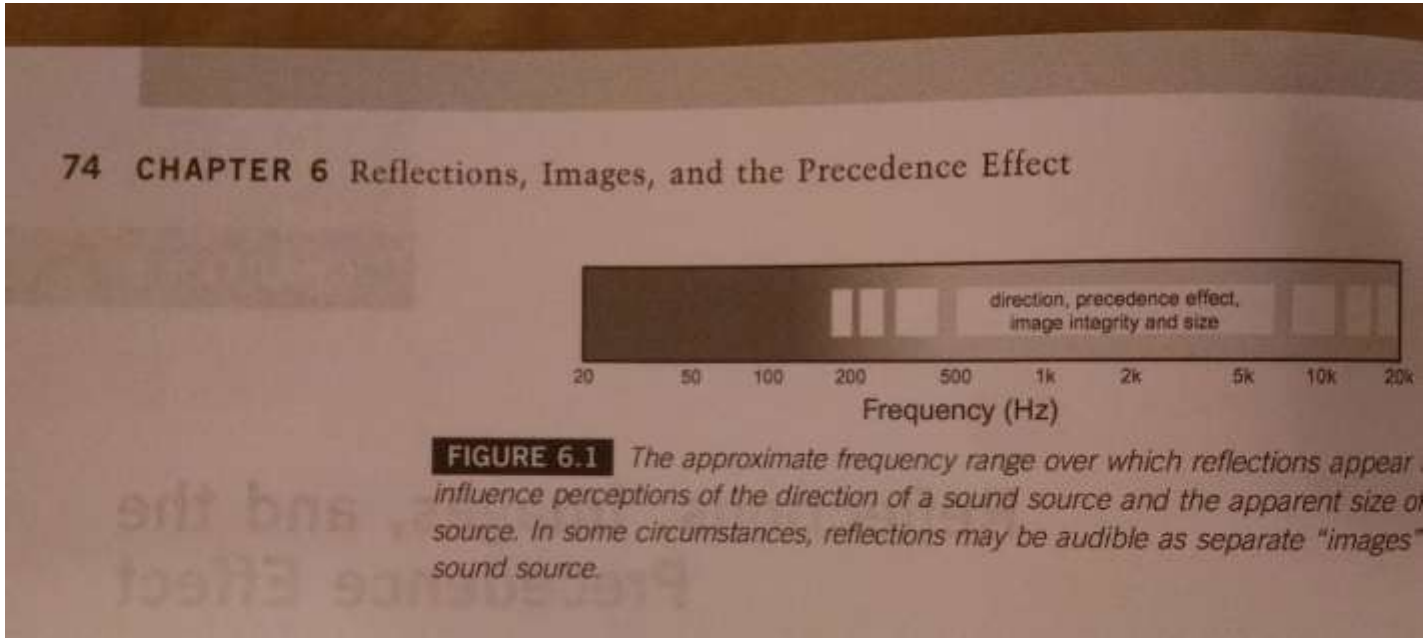
- No Monkey Coffins (Peter Aczel)
  - No resonances / energy storage

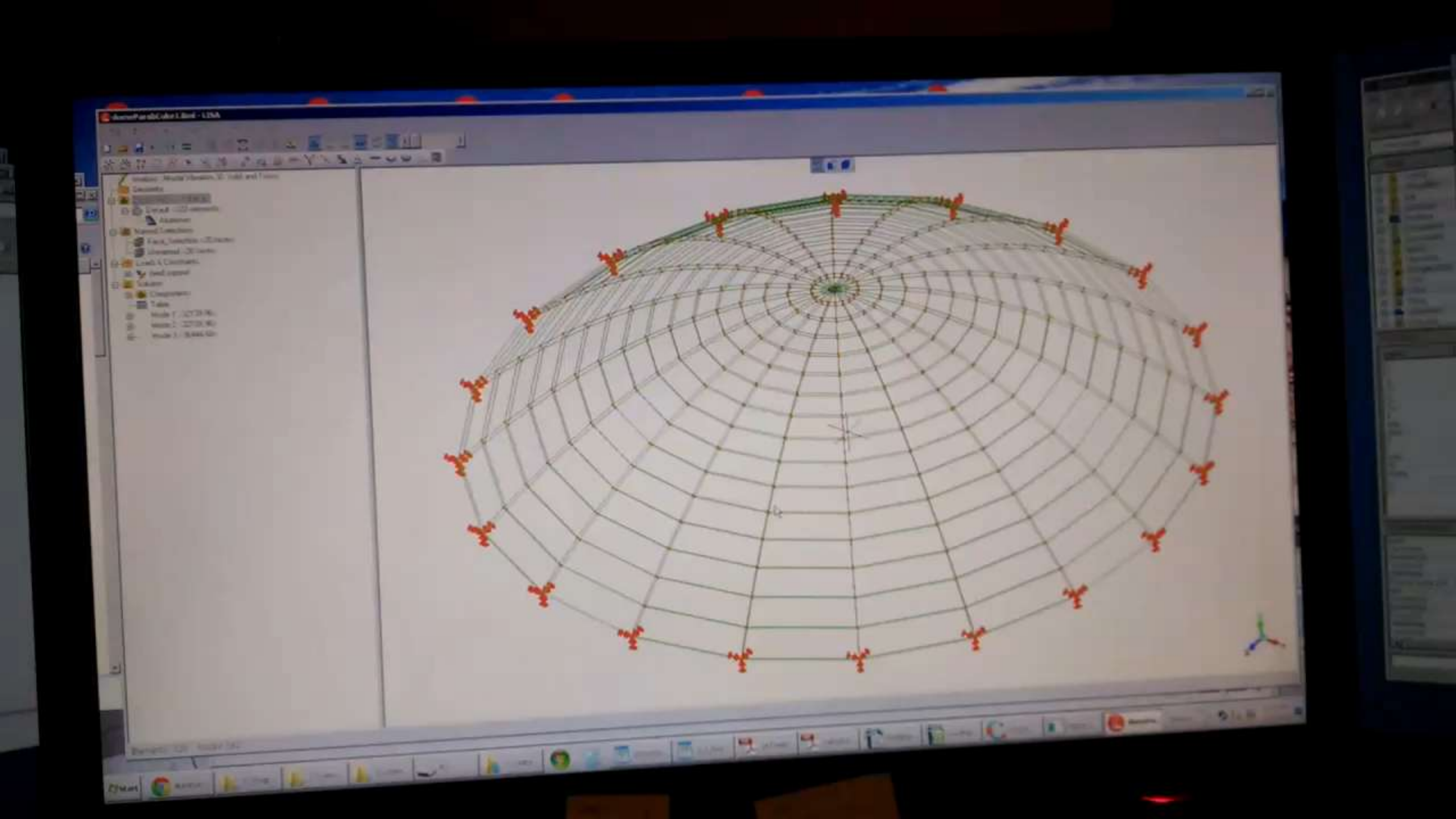
- Specs like a piece of wire
  - Flat frequency Response
  - Low distortion / non linearity

Tweeter Criterion

- Near Full Range: Cover frequency range ear locates sound with one driver (Toole & Bose)
- Piston Behavior
- Low Distortion Driver (Linkwitz)







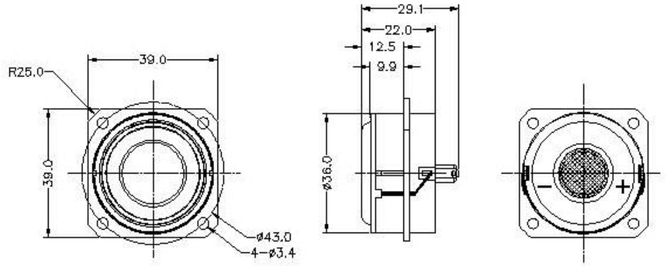
- Dome Acts As Piston Full Range
- Long Throw
- Low Cutoff Frequency
- Low Distortion

AURA SOUND

NSW1-205-8A

1 inch Extended Range Loudspeaker

- ***High Output Sensitivity***
- ***Ultra Compact Design***
- ***No Stray Magnetic Fields***



Nominal Diameter	1 inch (25 mm)
Nominal Impedance (Z)	8 ohms
Sensitivity, 1W/1m (E)	78 dB @ 1 kHz
Power Capacity, RMS (Pe)	5 W
Power Capacity, Peak	20 W
Frequency Range (-10dB)	220 Hz - 1.5 kHz
Minimum Impedance	7 ohms
Voice Coil Diameter	20.5 mm
Voice Coil Winding Length (h)	3 mm
Voice Coil Number of Layers (n)	2
Voice Coil Former Material	Aluminum
Voice Coil Wire Composition	CCAW
Magnetic Material	Neodymium radial
Stray Flux Shielding	Inherent
Magnetic Gap Depth (He)	6 mm
Cone Material	Titanium
Surround Material	Foam
Polarity, Outward Motion	Positive voltage on (+) terminal
Net Weight	52.3 g
Maximum Excursion	6 mm peak to peak

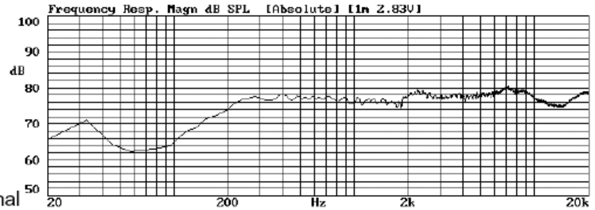
Thiele / Small Parameters

Resonant Frequency (Fo) - Fs	220 Hertz
Voice Coil DC Resistance - Re	6.3 ohms
Total Q - Qts	0.7
Mechanical Q - Qms	2.1
Electrical Q - Qes	1.1
Equivalent Volume of Air - Vas	0.04 L
Radiating Piston Area - Sd	5.31 cm ^{2}
Xmax	3 mm peak to peak

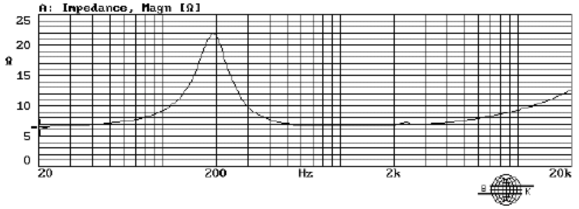
Electrical / Mechanical Parameters

Flux Density x Length - BL	1.9 Tesla-meters
Compliance - Cms	.1155 μm/N
Total Mass - Mms	0.5 grams

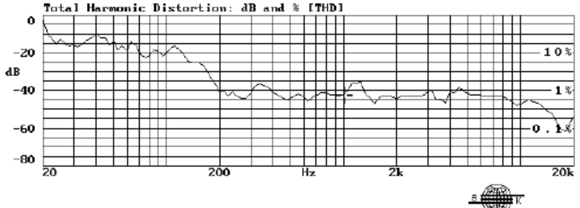
Frequency Response (1W, 1m)



Impedance

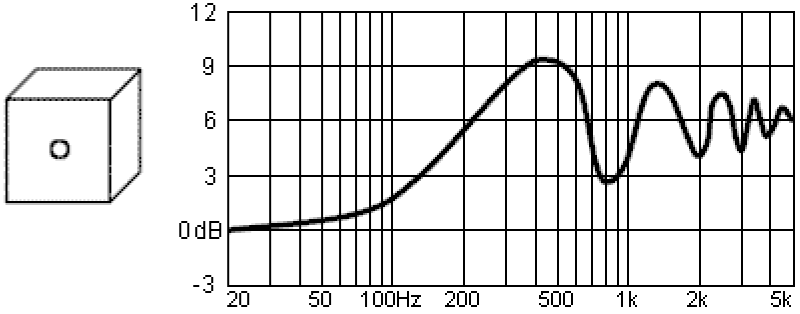


Distortion (1W,1m)

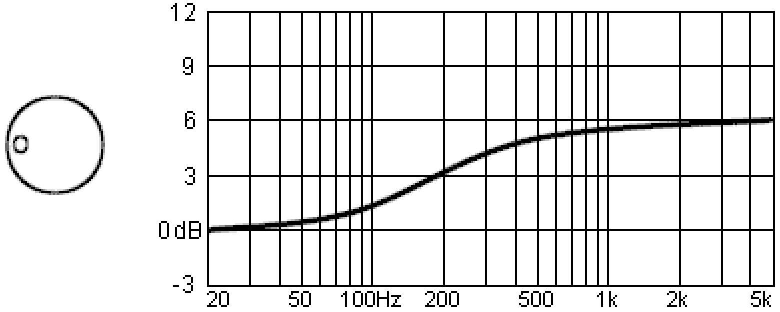


Baffle Diffraction Effects   Olson 1969

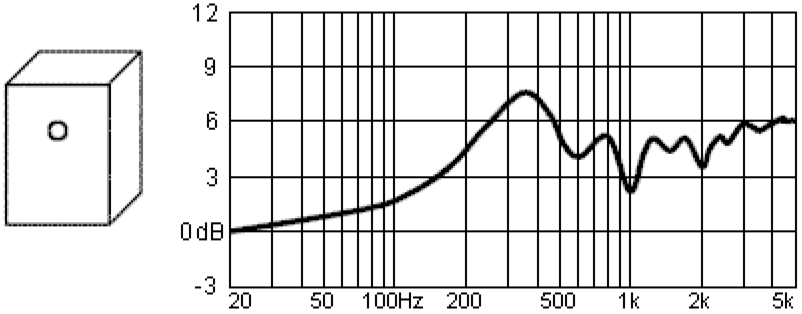
1” Driver On Various Baffles



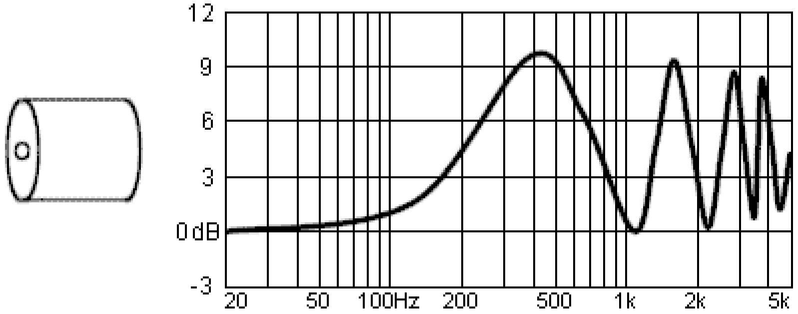
Diffraction Loss of a 24" Cube Face (after Olson)



Diffraction Loss of a 24" Sphere (after Olson)



Diffraction Loss of a Rectangular Enclosure (after Olson)



Diffraction Loss of a 24" Cylinder Face (after Olson)

Commercial Designs

- IRS, IRS Beta, RS4




Baffle Prototypes

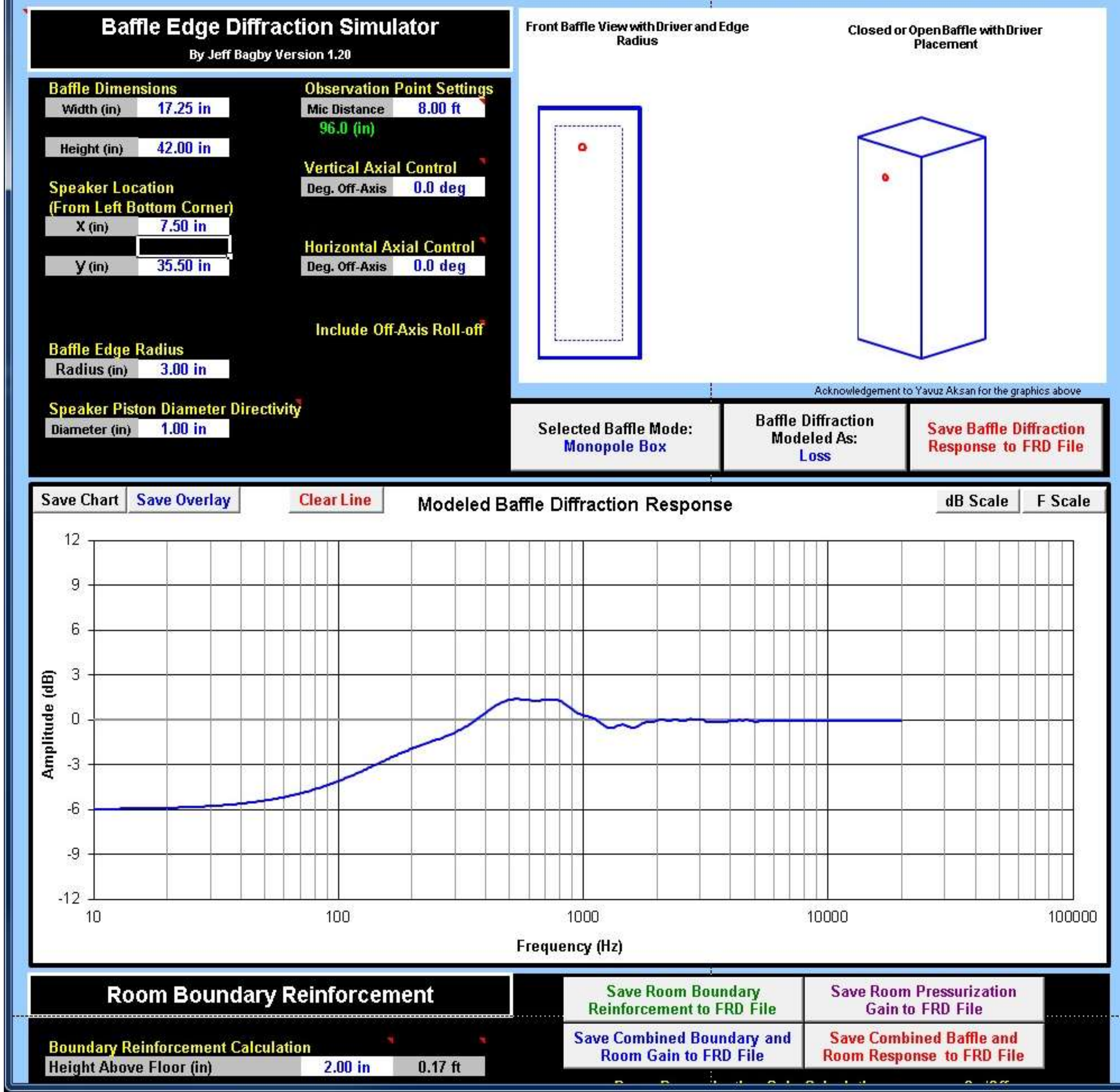
Baffle Prototypes

Baffle Design:

Jeff Bagby Excel

Locate Drivers On Baffle To Minimize Ripple

Centered

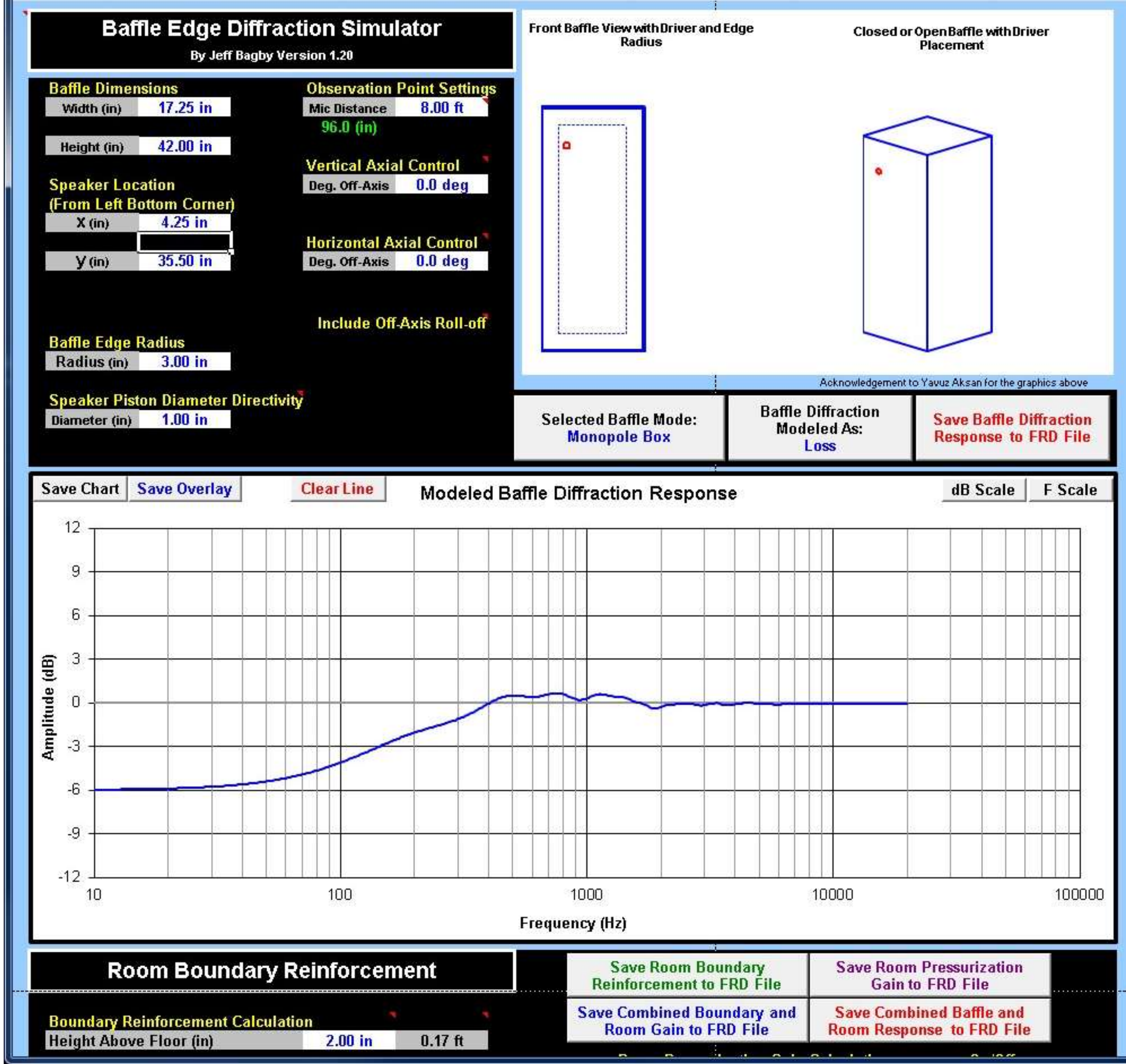


Baffle Design:

Jeff Bagby   Excel

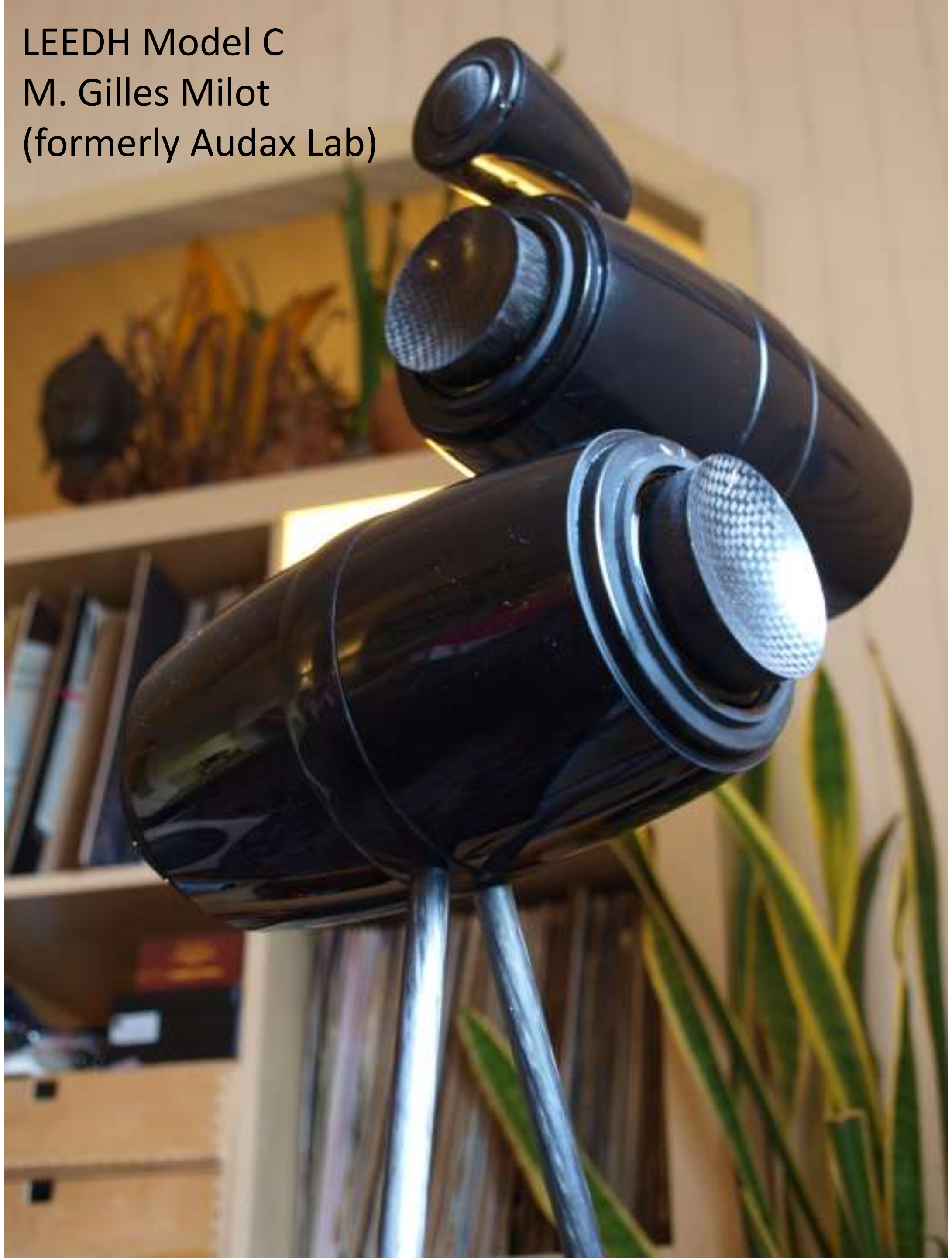
Locate Drivers On Baffle To Minimize Ripple

Offset

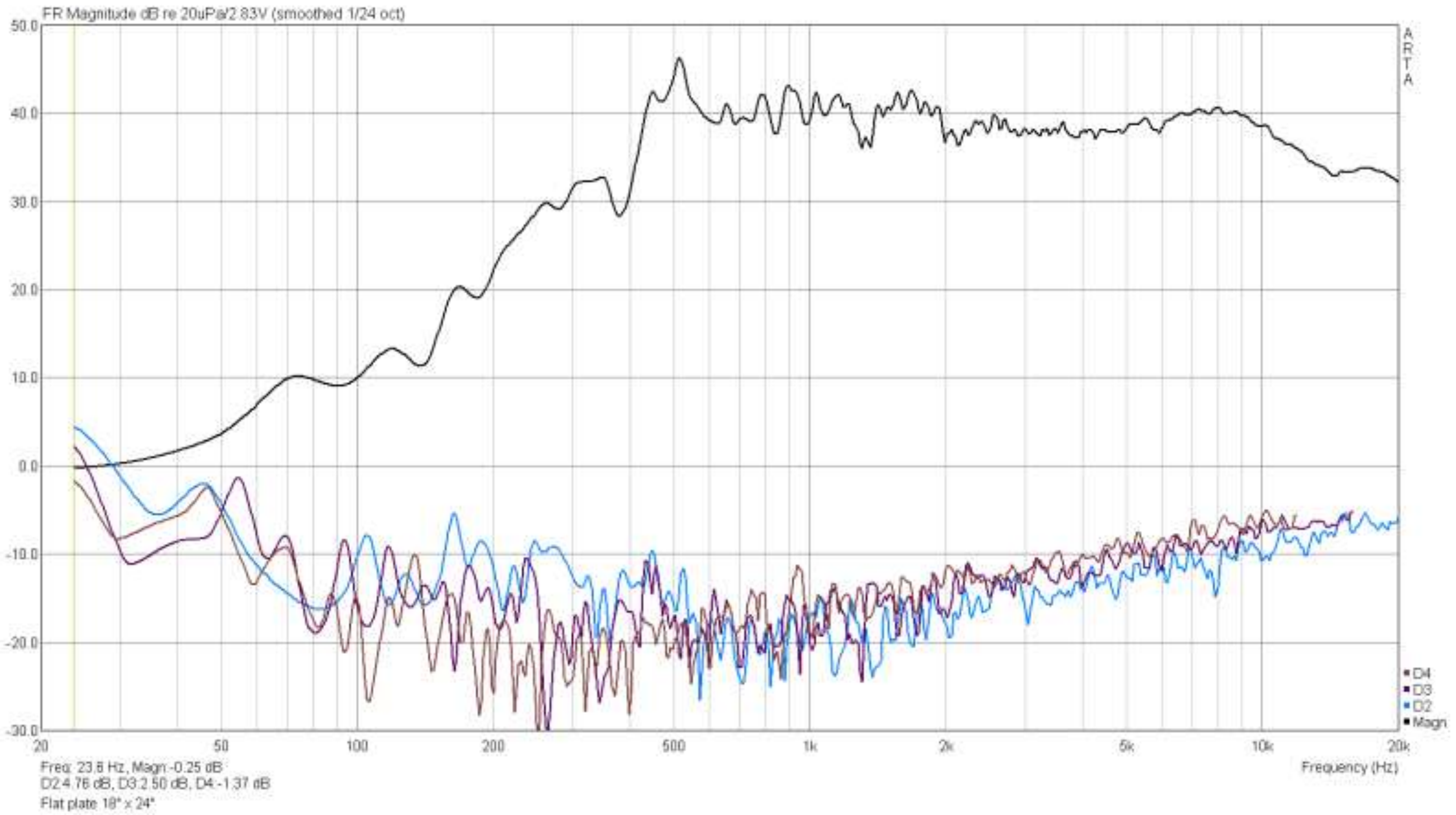


Vibration Reduction

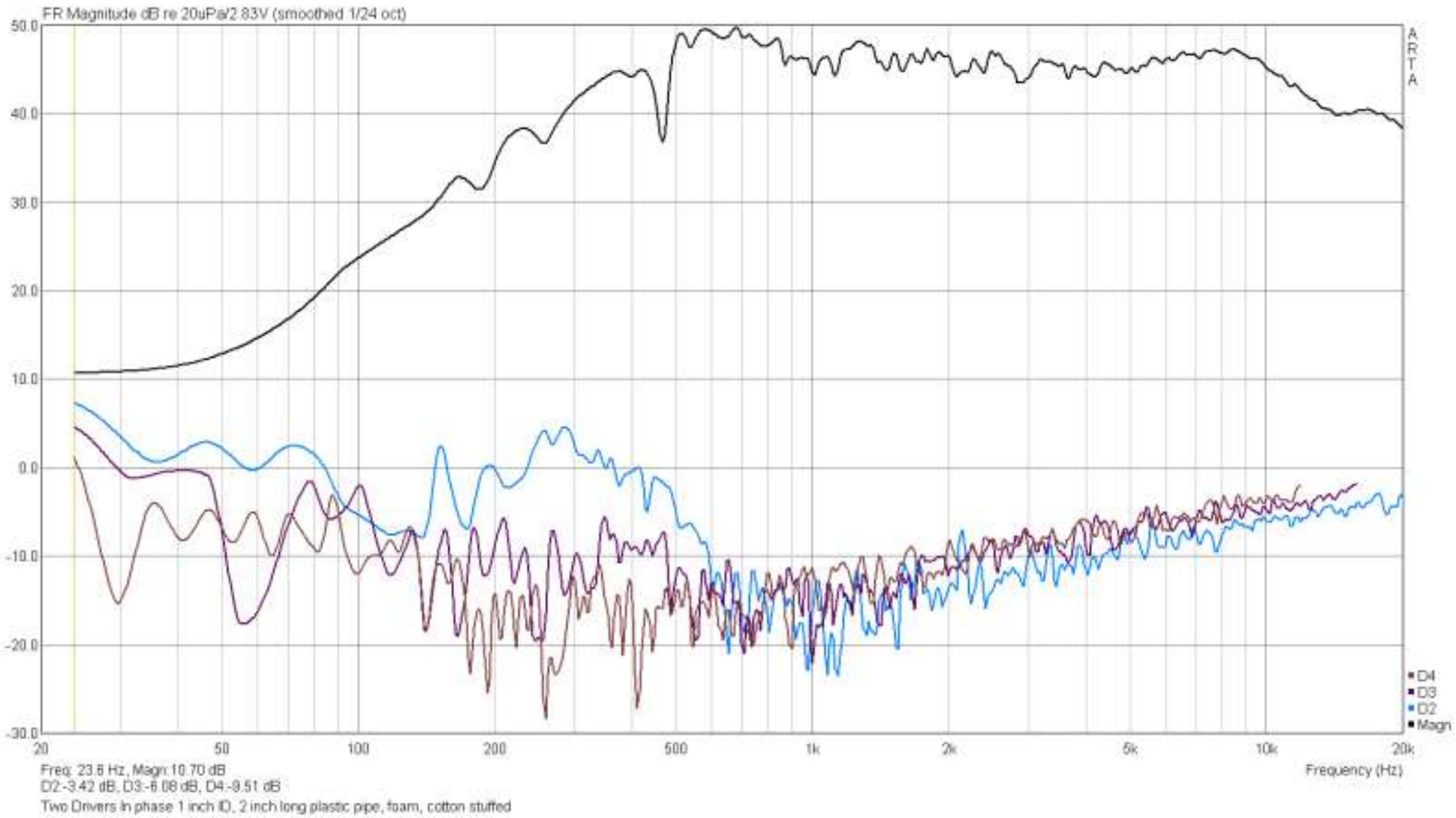
- Back to Back Drivers - Active Bucking
- Anvil – Passive Bucking



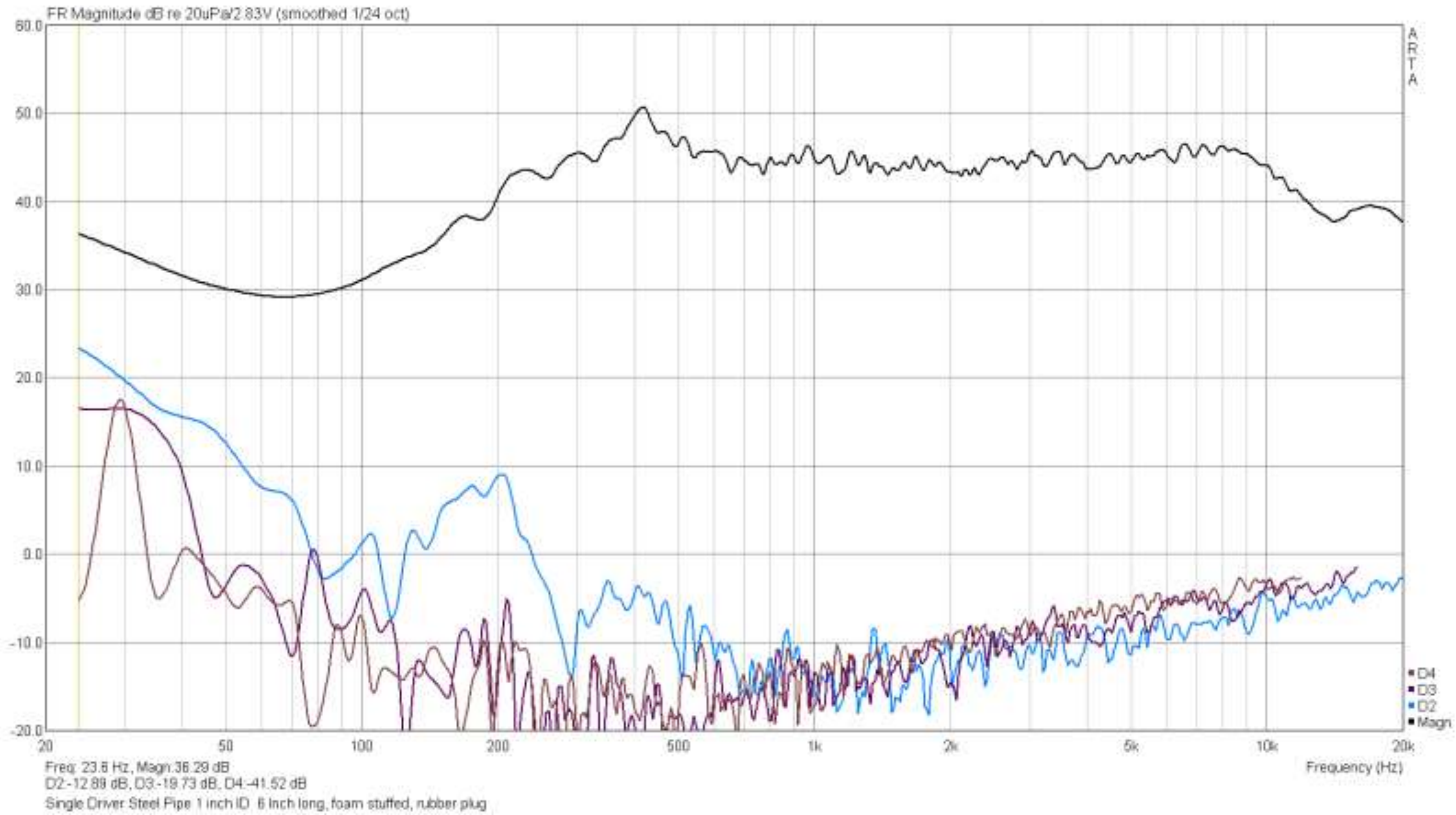
1” Cougar Driver Mounted On Plywood



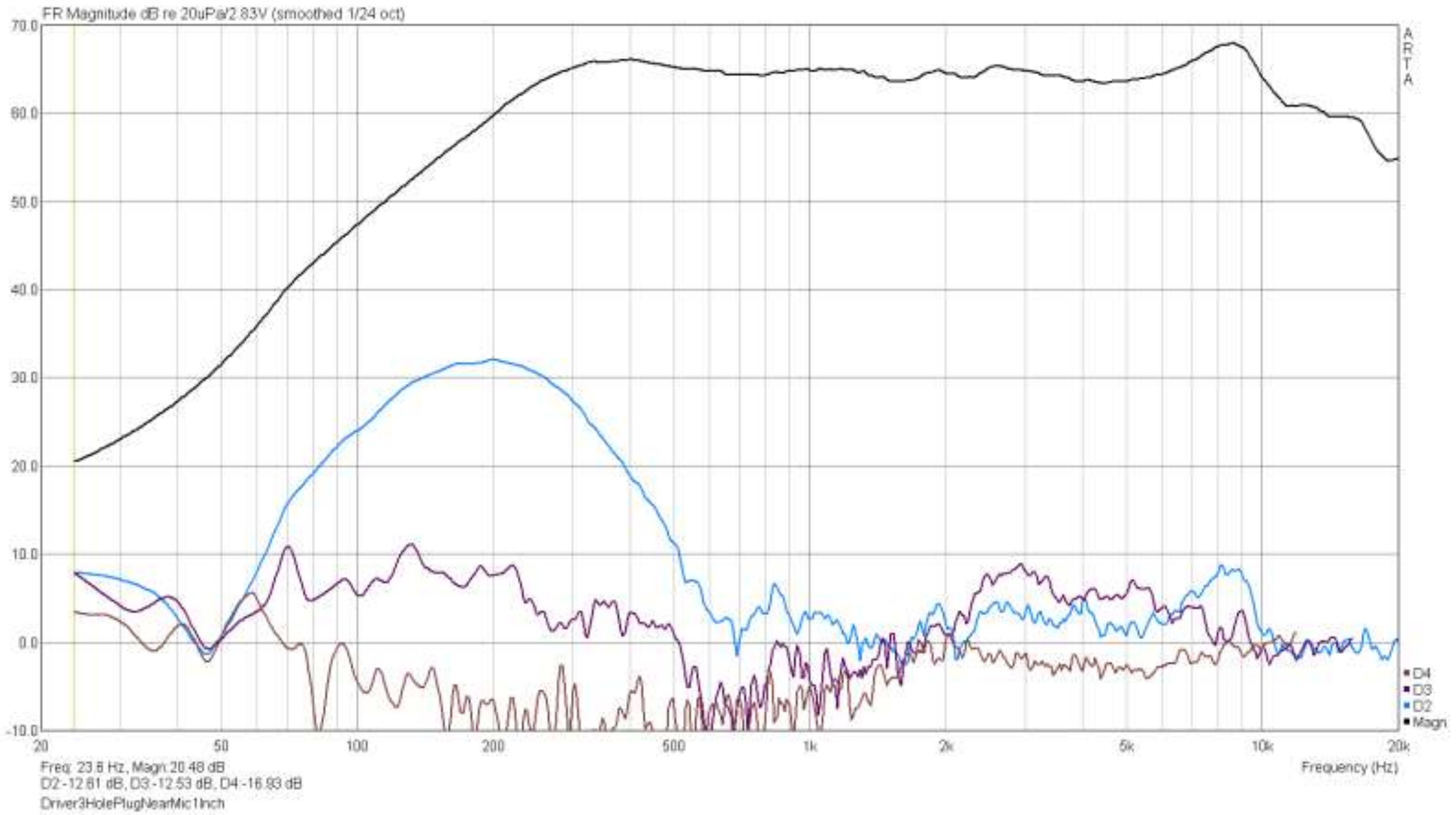
Cougar Driver Mounted on rectangular plywood panel, Bucking Driver Plastic Pipe



Cougar Driver Mounted on rectangular plywood panel, Steel Pipe Enclosure



Cougar #3 Finished enclosure close mic



Midrange Selection

- Buy
- Very carefully test
- Return the losers*

* Unless the loser is so beautiful you can’t and it fits somewhere in the house or garage or car trunk or at a friends house.

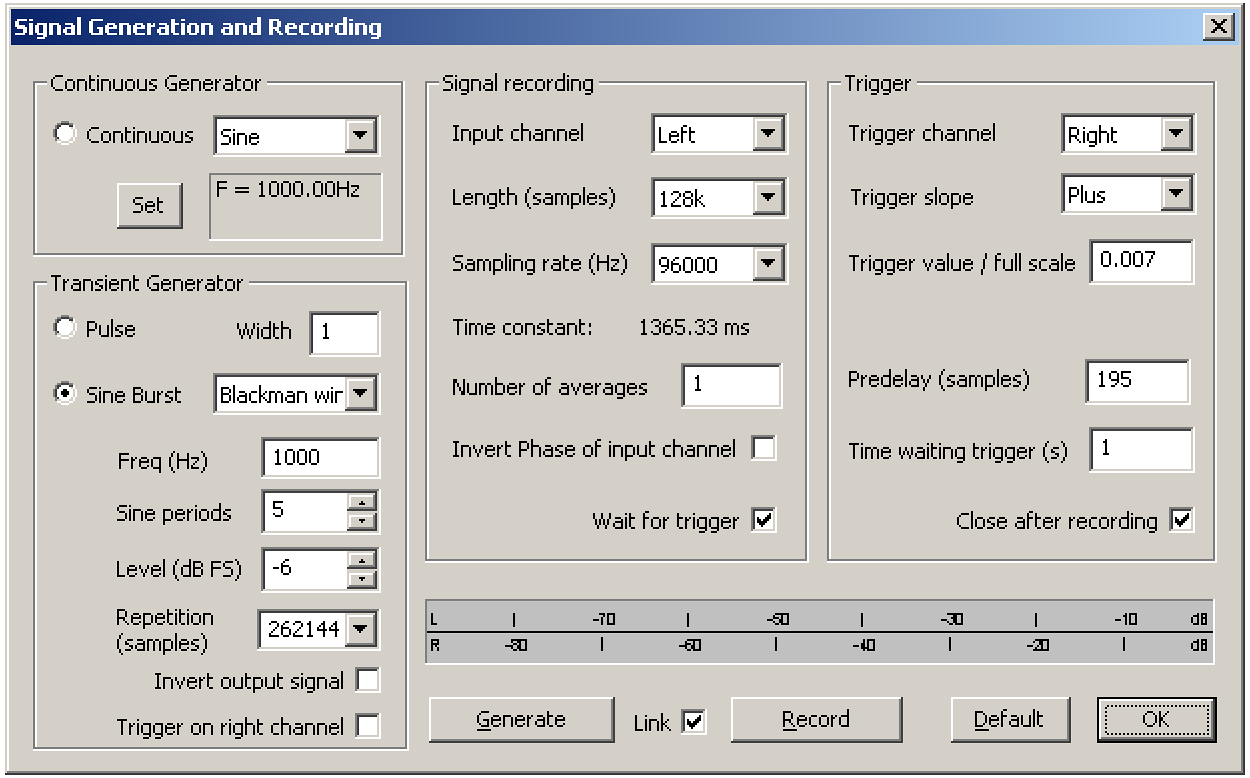
Midrange Selection: Echoic Chamber

Midrange Selection

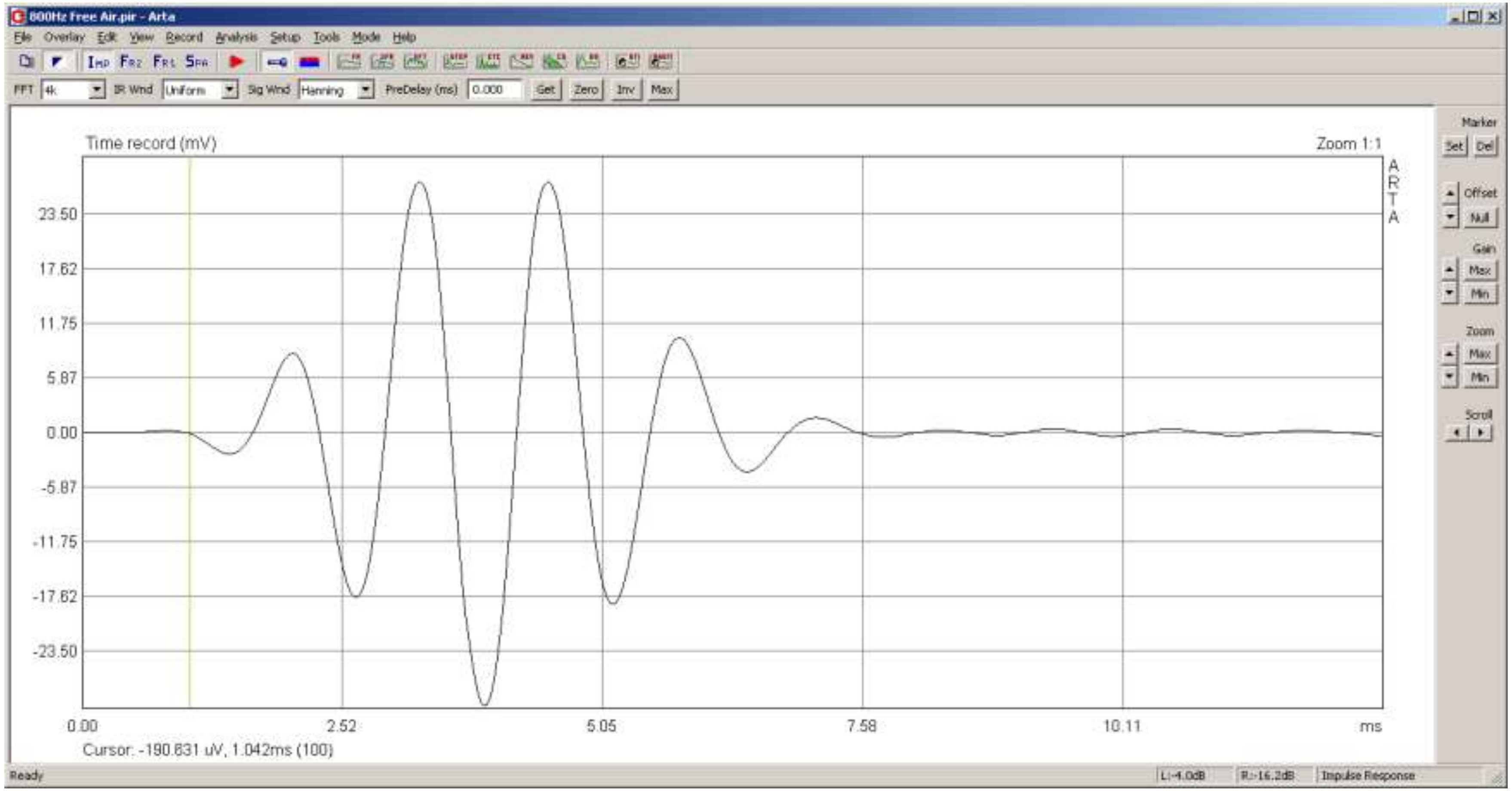
Driver Testing: Measuring what’s not in published specs

- Perform Linkwitz linear and non-linear distortion tests
- *Go read the website for a clear understanding of what is about to happen here.* http://www.linkwitzlab.com/mid_dist.htm
- On a reference woofer and selection of other candidates for design.
- 800 Hz Tone burst tests for linear energy storage related distortion.
- Steady two tone tests (135Hz and 165Hz) for Intermodulation distortion resulting from nonlinearities in the driver. Record the level of adjacent harmonic products in a table for comparison (table 1).

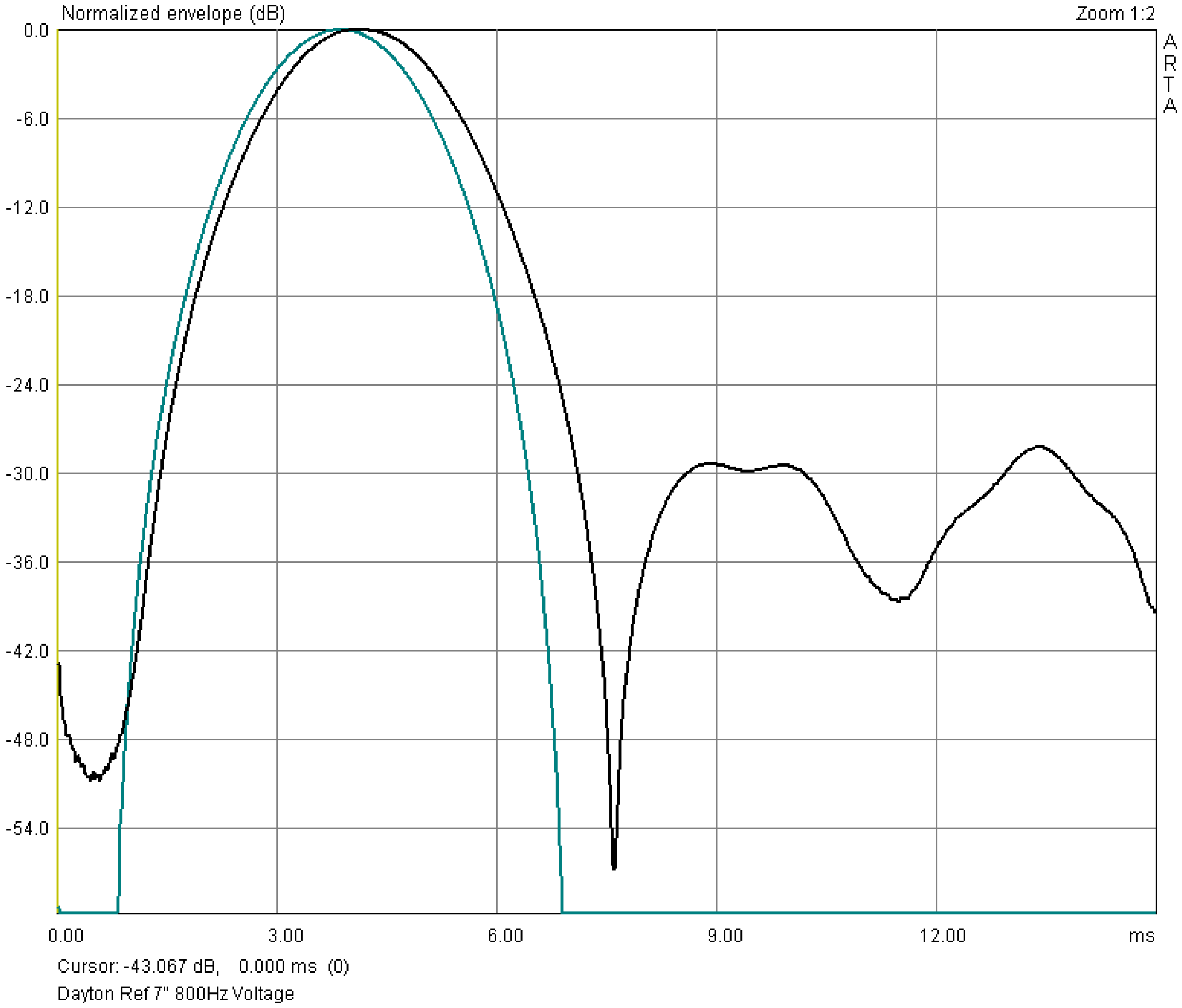
Tone Burst test in Arta software



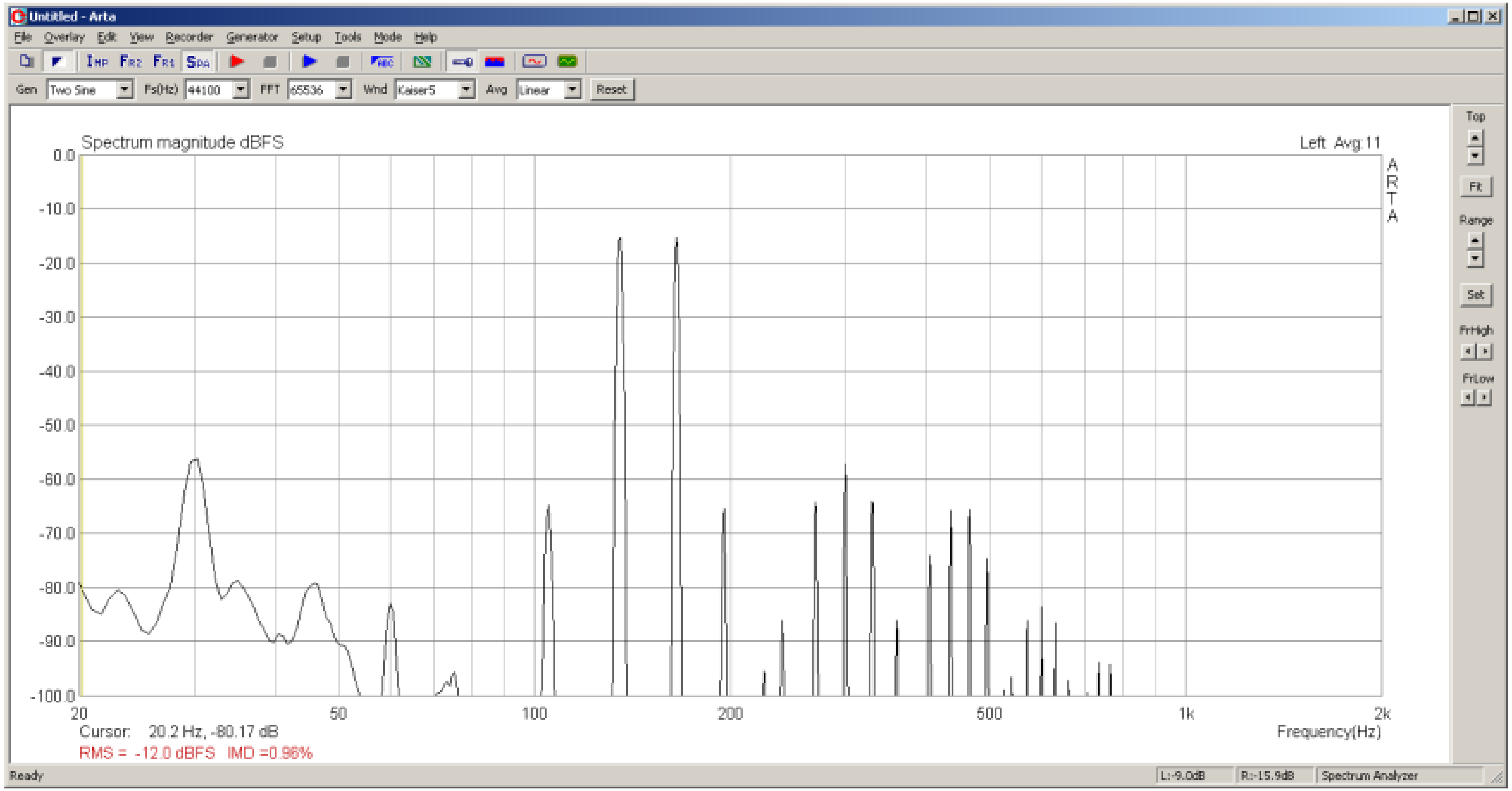
Tone Burst Waveform



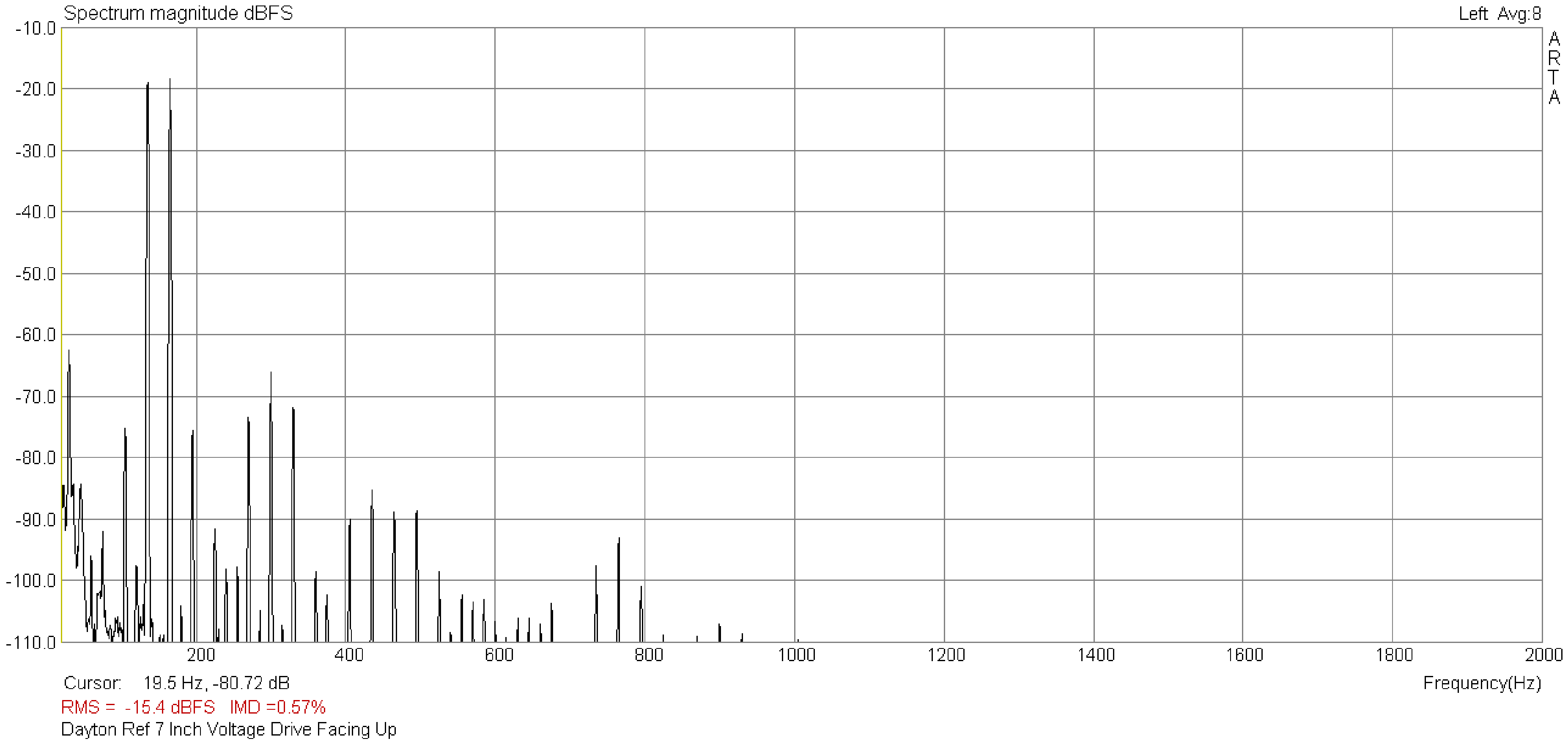
Tone Burst Test analysis



Two Tone Intermodulation Test
135 Hz + 165 Hz



Two Tone Intermodulation Test



Driver Testing: Results

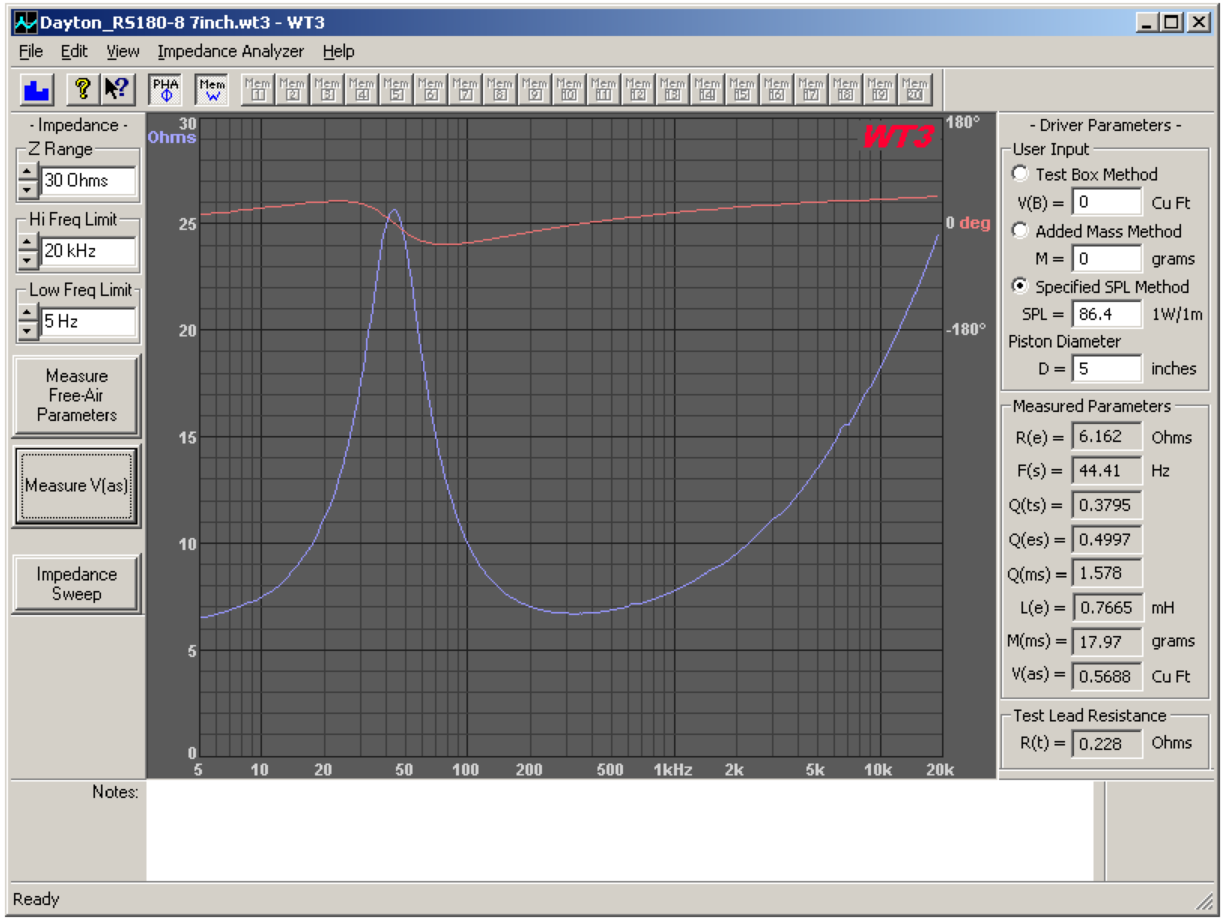
Driver	Diameter	Two Tone (dB) Closest, Highest Harmonic	T Decay -30dB, Current Drive	T Decay -30 dB Voltage Drive
RadioShack	6	-38		
Tang Band	6.5	-45 *		
ScanSpeak Illuminator	7	-42, -42	1.5 ms	0.8 ms
Seas W18EX001	7	-50,		1.2 ms
Dayton Ref	7	-48	0.8 ms	
Seas W22EX	8	-50, -42	1.5 ms	
Dayton Ref	8	-48	1.4 ms	
HiVi M8N	8	-38, -38	1.1 ms	

Table 1: Two Tone Harmonic Tone level and 800 Hz Tone burst decay times for Current output amplifier (I) and Voltage output amplifier.

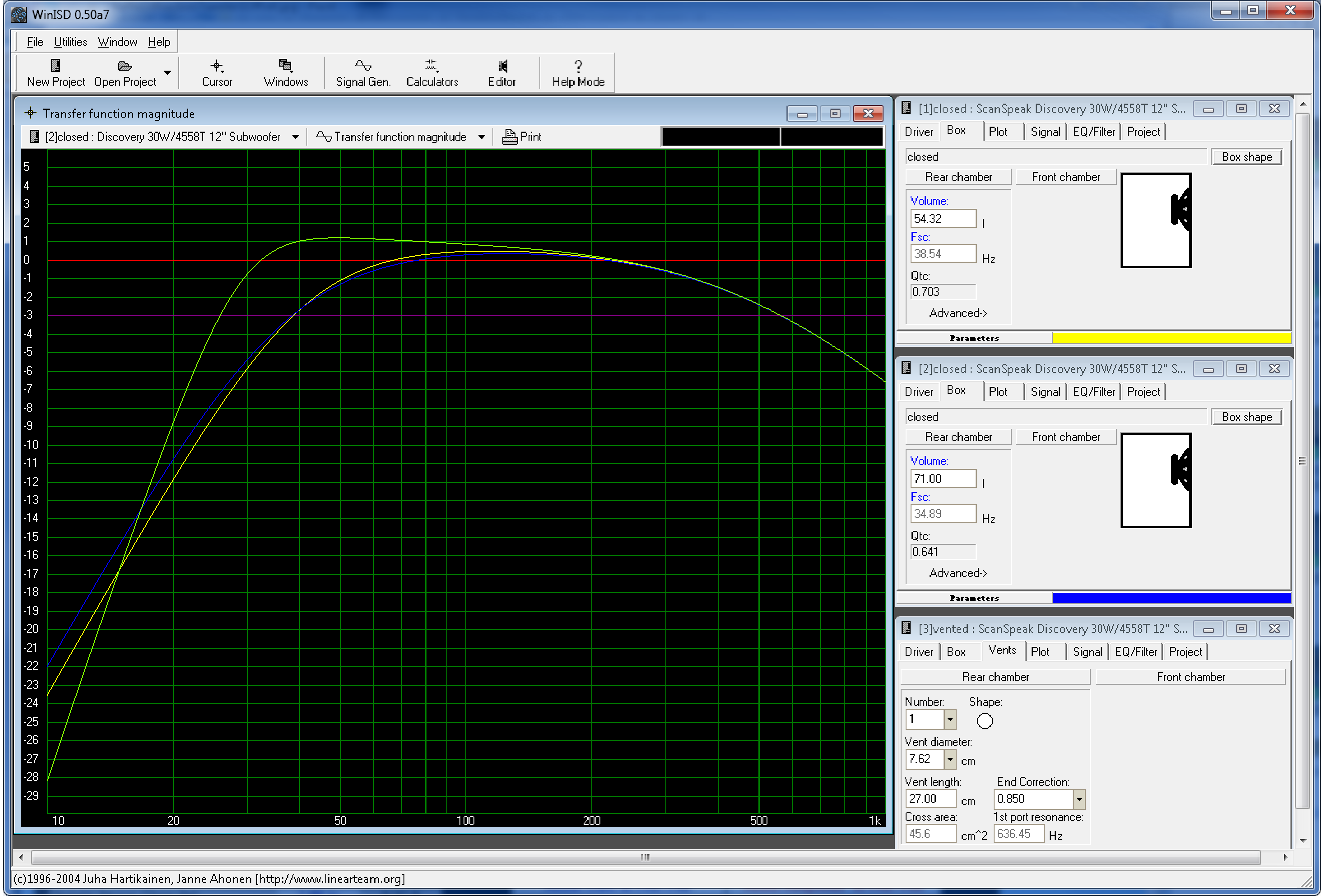
Midrange Selection:

- Low Frequency Cutoff: Box “Tuning” Thiel Small
- Box Resonances, Stuffing
- Cabinet Panel Modes, Bracing

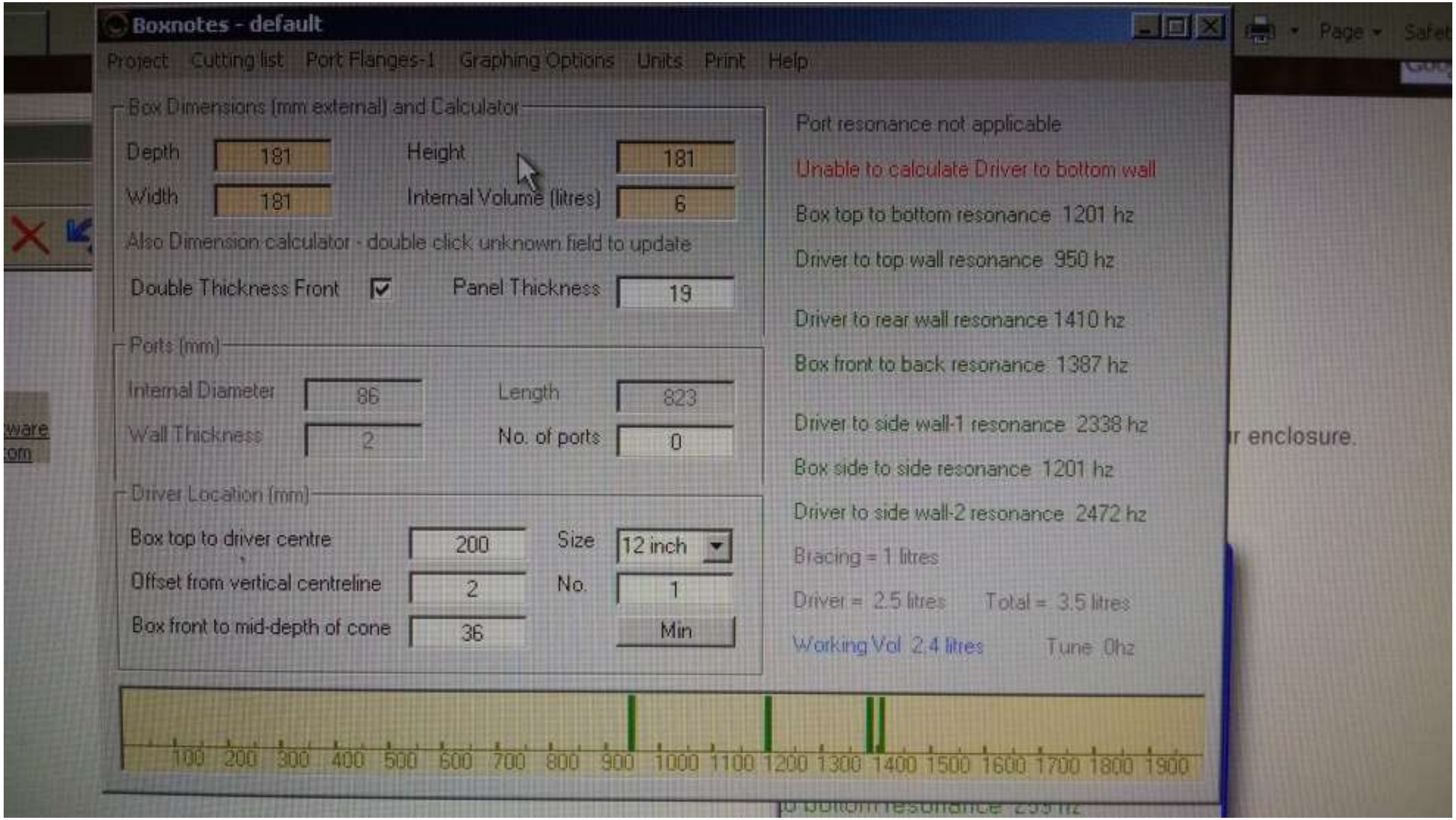
Measuring TS parameters
Dayton RS180-8 7”



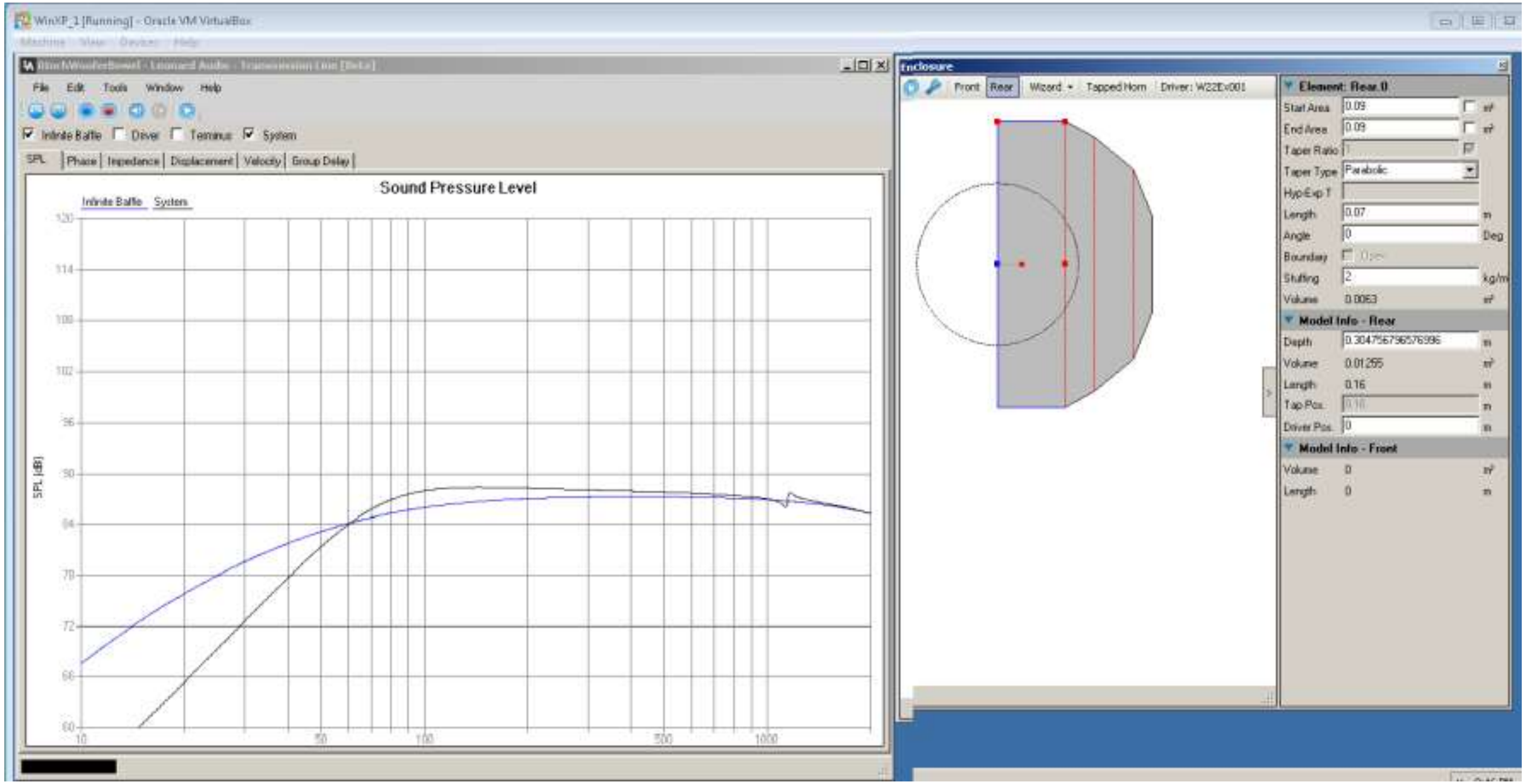
WINISD: TS Box Response



Box Design: Midrange: Helmholtz Resonance



Box Design: Midrange: Effect of stuffing



Box Design: Panel Resonances

- >> rectangular_plate_fea
- rectangular_plate_fea.m   ver 1.9   February 26, 2013
- by Tom Irvine   Email: tom@vibrationdata.com
-
- This script calculates the natural frequencies and mode shapes of a flat, thin, rectangular plate.
-
- Enter the length (inch) along the x-axis 8
- Enter the width (inch) along the y-axis 8
- Enter the number of nodes along the x-axis 10
- Enter the number of nodes along the y-axis 10
- Unconstrained model statistics
-
- nodes=100 elements=81   degrees-of-freedom=300

Enter plate type:
1=homogeneous 2=honeycomb-sandwich 1
Enter thickness (inch) .75

Select material
1=aluminum 2=steel 3=G10 4=wood 5=other 4

Enter uniform nonstructural mass?
1=yes 2=no 2

structural mass = 1.176 lbm
nonstructural mass = 0 lbm
total mass = 1.176 lbm
volume = 48 in^3
total mass density = 0.0245 lbm/in^3

Select boundary Condition
1=all free 2=corners pinned 3=corners fixed 4=other
4

Select BC for bottom edge
1=free 2=simply supported 3=fixed
3

Select BC for right edge
1=free 2=simply supported 3=fixed
3

Select BC for top edge
1=free 2=simply supported 3=fixed
3

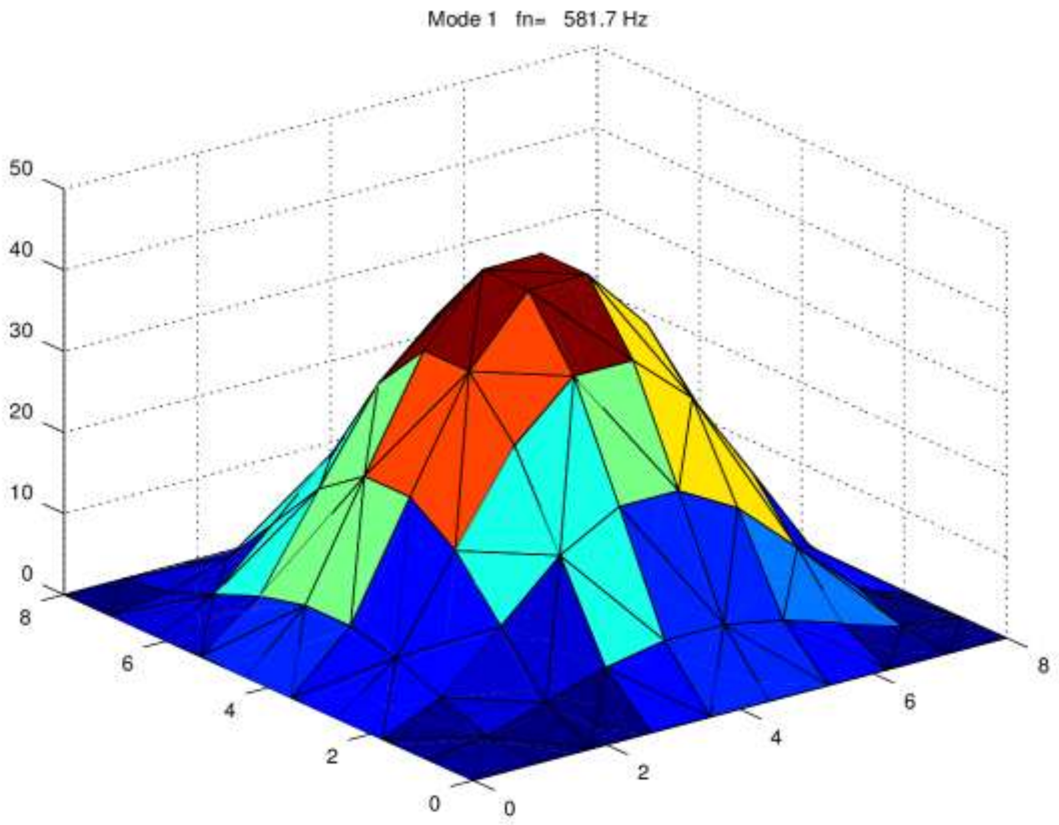
Select BC for left edge
1=free 2=simply supported 3=fixed
3

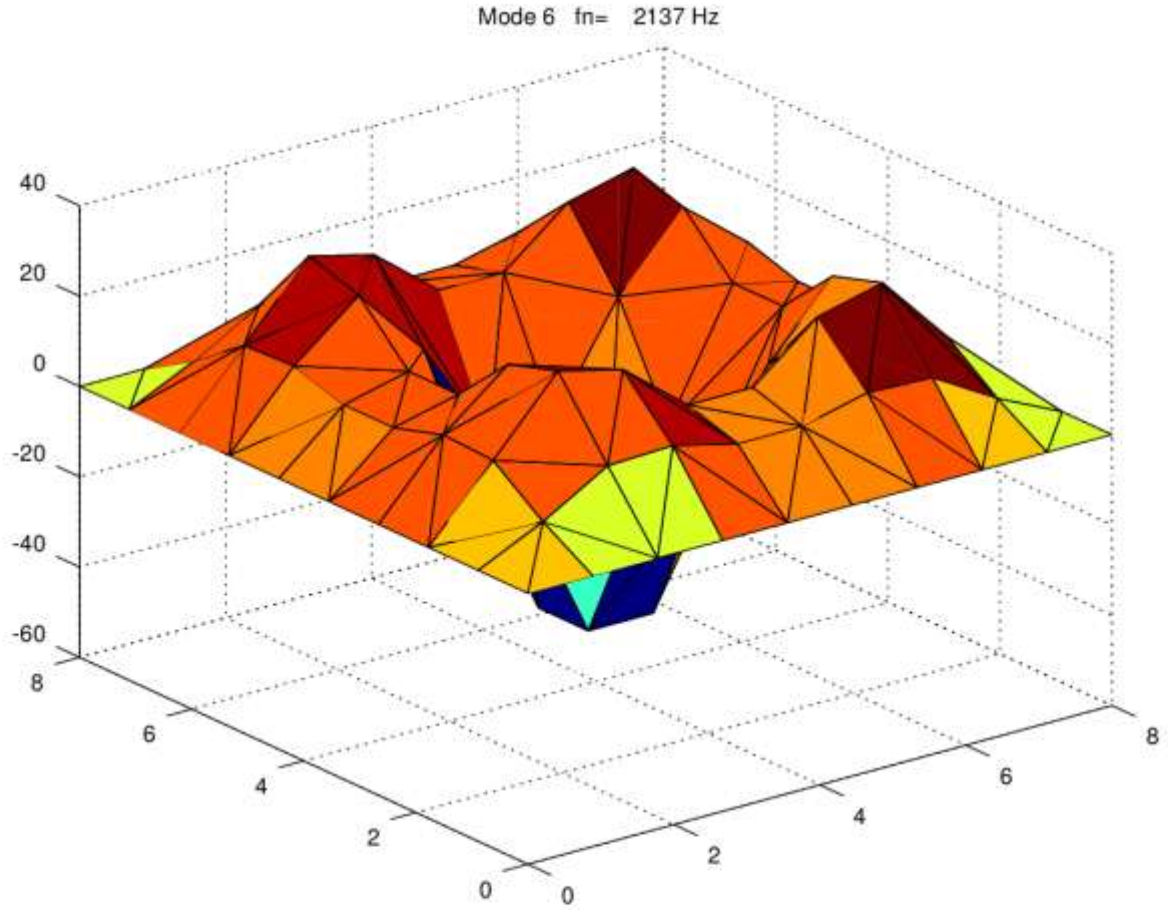
Midrange Box: Panel Resonances

Eigenvalue calculation time
Elapsed time is 5.55121 seconds.

Mode	Natural Freq(Hz)	Participation Factor	Modal Mass (lbm)	Effective Mass Percent
1	581.74	0.03857	0.57425	48.831
2	1183.3	0.00000	0.00000	0.000
3	1183.3	0.00001	0.00000	0.000
4	1716.6	0.00000	0.00000	0.000
5	2123.7	0.00000	0.00000	0.000
6	2136.6	0.02359	0.21480	18.266
7	2602.7	0.00000	0.00000	0.000
8	2602.7	0.00000	0.00000	0.000
9	3412.2	0.00003	0.00000	0.000
10	3412.2	0.00000	0.00000	0.000
11	3413.1	0.00561	0.01216	1.034

Panel Flex Mode Shapes

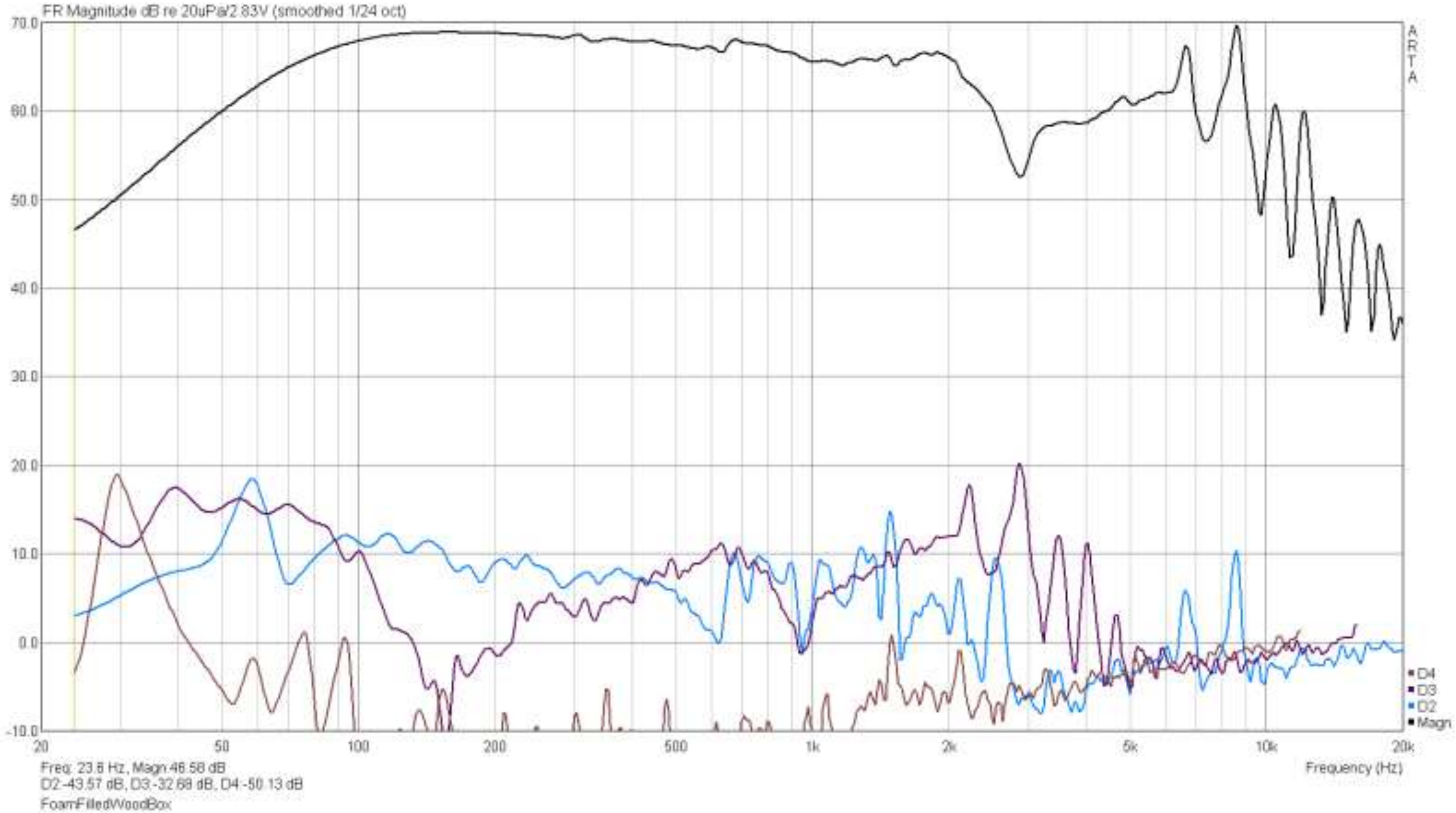


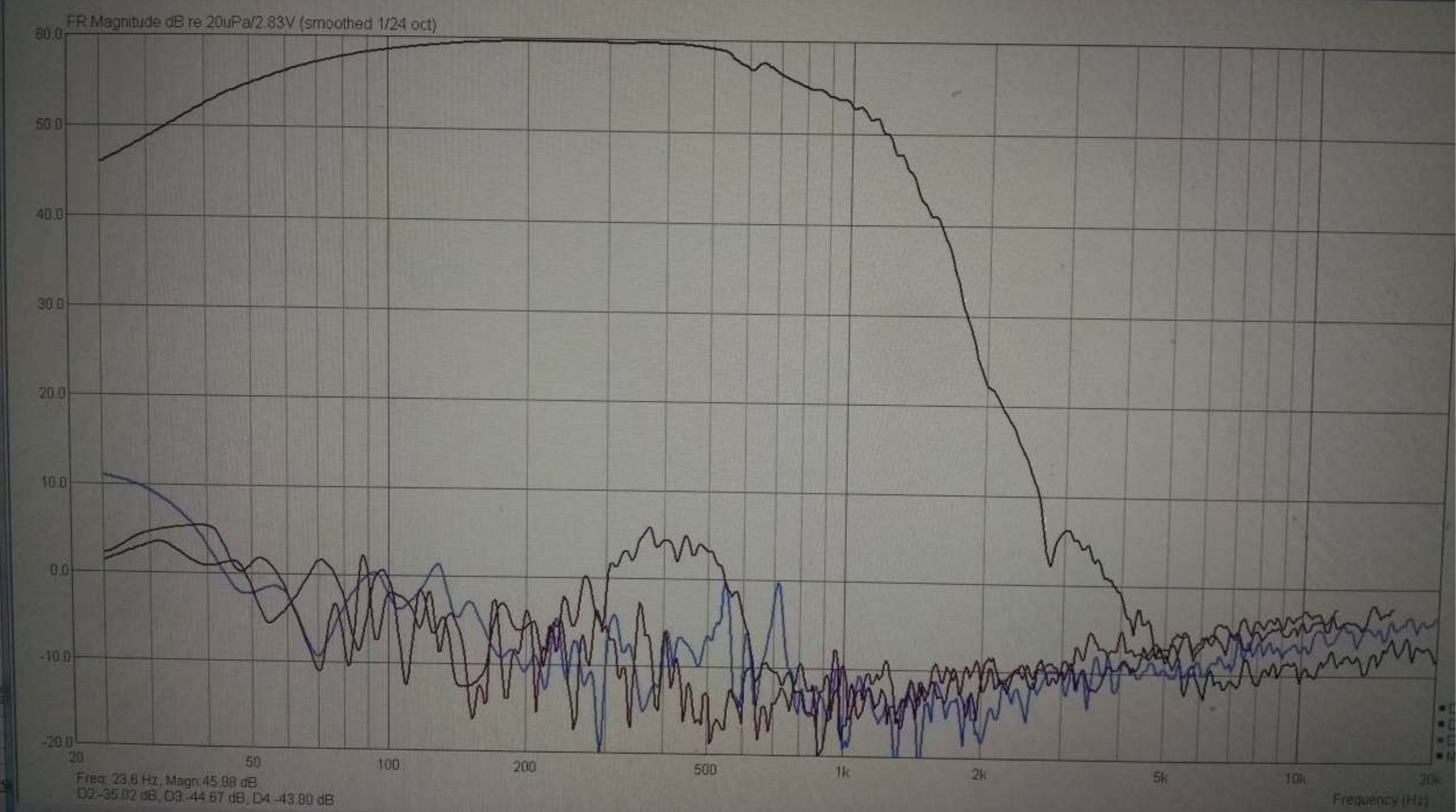


Box Design: Howards Fancy German Saw

Box Design: Midrange Plywood Cube

Response In Box

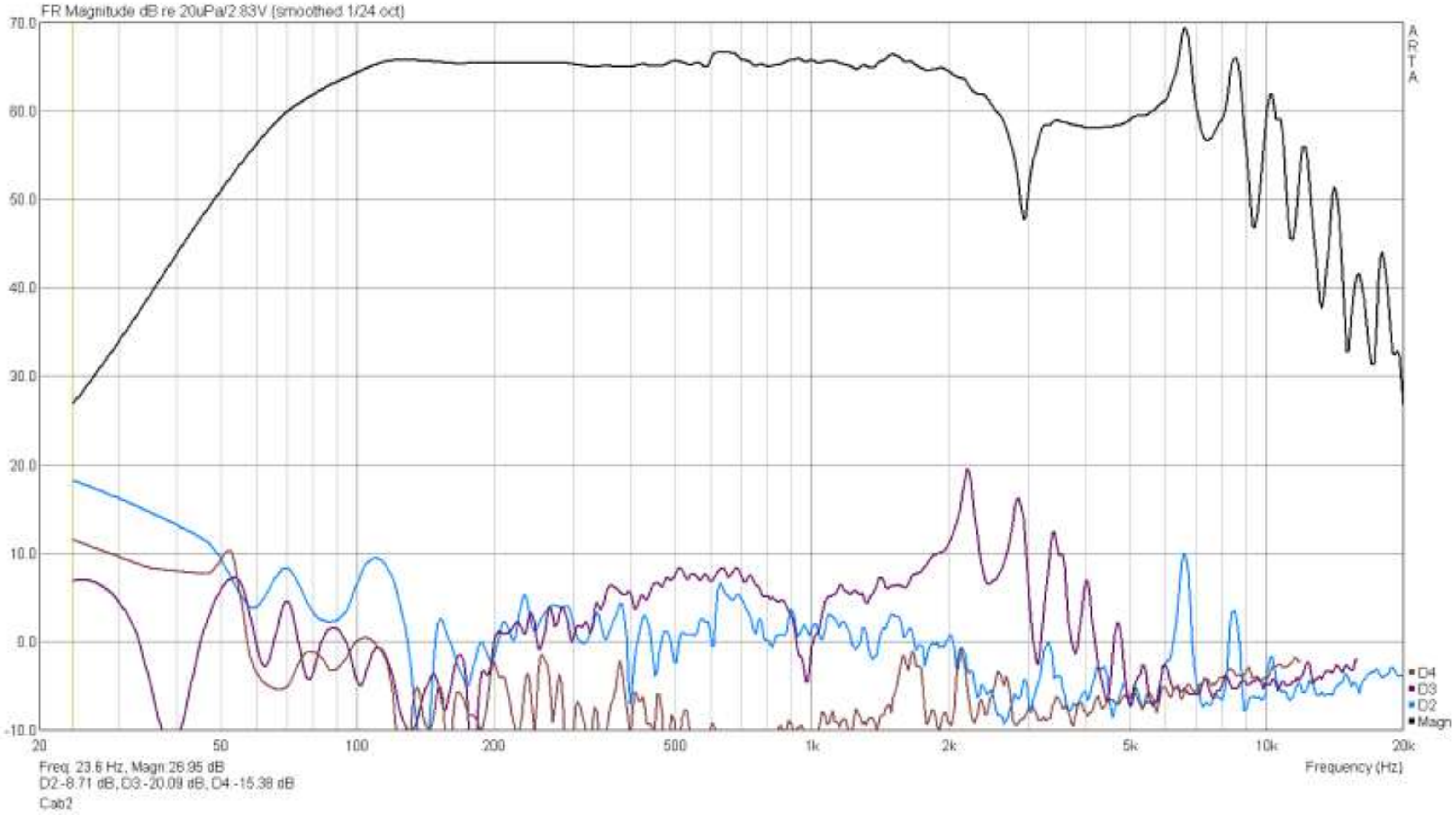




FR Magnitude dB re 20uPa/2.83V (smoothed 1/24 oct)
80.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
20
50
100
200
500
1k
2k
5k
10k
20k
Freq: 23.6 Hz, Magn:45.98 dB
D2:-35.02 dB, D3:-44.67 dB, D4:-43.80 dB
Frequency (Hz)


25
25
DEWALT

Midrange Response: Weight In Box



My 7” Midrange Rolls off at 90 Hz

1. The other guys are bringing 18” woofers
2. I Want 30 Hz bass.
3. Need to move a lot of air with a box I can lift.

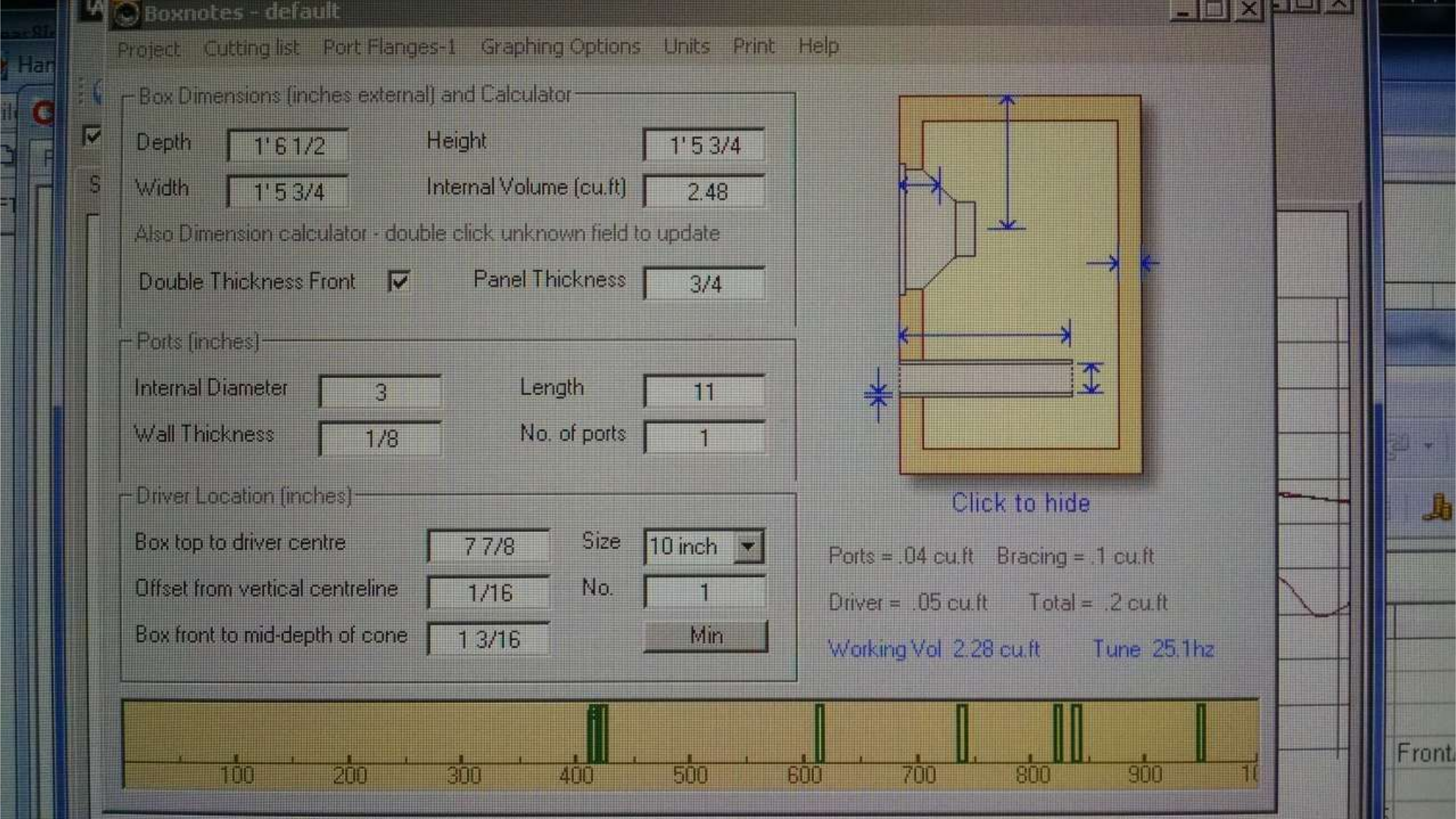
Create Woofer Selection Spread Sheet
Sorted by figure of merit

Woofer Selection

liter	Hz	Hz		in	in	Hz	ohm	mH	liter			cm3	mm	liter	Hz	cm3	cm3/liter
	Resonance	Half Pwr												Recommendec		Sd*Xmax	Vcone/Vbox
Vbox	Fbox	F3dB	Name	Size	Dcone	Fs	Re	Le	Vas	Qes	Qms	Sd	Xmax	Vb	Fb	Vcone	Box Eff
256.0	25.2	25.2	Rythmik Servo 15	15	12.6	15.4	3	2.50	430.0	0.52	5.2	809	18.0	100	18	1456.2	5.7
309.8	27.9	27.9	Dayton IB385-8	15	12.9	20.8	5.2	3.08	248.9	0.63	8.92	845	14.3	850	15	1208.4	3.9
134.1	31.9	31.9	Dayton UM15-22	15	12.7	19.5	3.4	1.31	224.1	0.59	2.4	814.6	19.0	3.98	33	1547.7	11.5
123.3	32.6	32.6	Dayton RSS390-HF	15	12.9	18	3.3	1.00	281.6	0.49	3.1	840	14.0	280	16	1176.0	9.5
137.3	34.6	34.6	Dayton DCS380-4	15	12.9	20	3.1	2.30	274.7	0.5	4	845	8.5	375	18	718.3	5.2
43.0	40.2	40.2	ScanSpeak 30w/4885t-12	12	10	17	4	0.83	197.0	0.34	5.01	466	12.5	70.25	27	582.5	13.5
35.0	42.0	42.0	Dayton 12" Titanic MKIII	12	10	24.9	3.1	2.79	64.3	0.49	7.03	510	18.7	100	20	953.7	27.3
97.9	42.1	42.1	Dayton 15" Titanic MKIII	15	12.9	26.2	3.8	3.11	154.6	0.52	6.75	840	20.5	250	20	1722.0	17.6
23.0	43.4	43.4	Dayton RSS210-HF	6.5	5.8	28	3.3	0.68	32.3	0.6	3.08	170	9.0	56	21	153.0	6.6
28.2	43.7	43.7	Dayton RSS265-4 Reference HF	10	8.4	25.6	3.5	0.96	54.0	0.53	3.06	356.3	12.3	56	22	438.2	15.5
41.1	44.2	44.2	Eminence LAB12	12	10.1	22	4.29	1.49	124.5	0.39	13.32	520	13.0	100	22	676.0	16.4
40.6	45.7	45.7	Seas L26RFX/P	10	8.1	20	6.3	1.83	171.0	0.39	2.15	330	14.0			462.0	11.4
19.1	46.8	46.8	HIVi SP10	10	7.8	34	3.4	1.35	17.0	0.65	4.83	305	15.5	28	25	472.8	24.8
69.4	47.3	47.4	Aurum Cantus AC300/75C2C	12	9.9	22	7	1.31	251.9	0.42	2.16	500	8.5	52.921	50	425.0	6.1
33.8	45.2	45.2	Dayton RSS315-HF 12"	12	10.1	24.2	3.1	0.96	84.1	0.45	2.83	514.7	14.3	100	20	736.0	21.8
37.4	48.0	48.0	Dayton RSS390-HO	15	12.9	24.2	3.3	1.83	109.5	0.42	4.48	840	12.0	85	24	1008.0	27.0
16.9	50.0	50.1	Dayton RSS315-HO	12	10	26	3.4	1.75	45.9	0.44	4	510	12.3	56	22	627.3	37.0
17.3	54.0	54.0	Seas L26ROY 10"	10	8.5	22	3.1	0.53	87.0	0.33	4.14	363	14.0			508.2	29.4
10.6	56.6	56.7	Dayton TS280D-4 10"	10	8.2	29.6	3.3	3.09	28.3	0.43	5.52	343	18.0	40	25	617.4	58.1
32.6	57.1	57.2	Seas W22EX001 8" meas	8	6.6	33.6	6.025	0.76	61.7	0.5381	2.879	220	5.0	24	63.25	110.0	3.4
24.3	59.6	59.6	Eminence Lab 15 - 85L	15	12.8	26	4.6	3.23	103.6	0.35	5.36	824	11.8	85	21	972.3	40.0
27.5	61.2	61.2	Eminence Lab 15	15	12.8	28	4.9	3.23	103.6	0.37	5.36	824	11.8	56	21	972.3	35.4
15.8	61.3	61.3	Dayton RS225-8 8"	8	6.6	29.61	6.342	0.83	52.0	0.4962	1.4	220	7.0	23.2	55.13	154.0	9.8
34.3	**62.0**	**62.0**	**HiVi M8N Measured-8"**	8	6.5	**47.1**	**6.265**	**1.34**	**25.1**	**0.662**	**6.64**	**214**	**5.8**	**28**	**34**	124.1	3.6
6.9	62.6	62.6	Dayton RSS265-HO	10	8.3	30.3	3.4	1.90	22.6	0.4	4.48	345	12.3	28	24	424.4	61.3
56.4	63.2	63.2	TC-1808"	18	15.4	27.9	3.01	2.31	232.6	0.35	6.9	1195	6.4	123.64	32.67	764.5	13.6
81.7	65.3	65.3	Eminence 4015LF	15	12.9	42	5.04	1.49	116.0	0.54	6.73	845	9.0	200	32	760.5	9.3
63.2	69.5	69.6	Eminence 4018LF	18	15.4	32	6.19	4.78	235.2	0.36	10.38	1195	7.9	150	35	944.1	14.9
11.0	71.9	71.9	SB17NRXC35-8 6.5" woof	6.5	4.8	32	5.7	0.15	44.5	0.36	5	118	5.5			64.9	5.9
10.8	81.7	81.7	MISCO 6102-4 6.5" Poly cone	6.5	5.8	28.6	3.4	0.40	77.1	0.27	7.28	170	3.5			59.5	5.5
5.8	87.9	87.9	Seas W18EX-001 E0017 meas	7	5	37.01	5.53	0.72	27.1	0.364	2.42	126	5.0			63.0	10.8
5.3	89.0	89.0	Dayton RS180-8 7" meas	7	5	44.4	6.126	0.77	16.1	0.4997	1.578	124.5	6.0			74.7	14.0

Woofer Spec: Suggested Box Tuning

- **ScanSpeak Discovery Line 30W/4558T 12" Subwoofer - 4 ohm**
- Aluminum Cone, Black Anodized
- Fiberglass/Paper Sandwich Dust Cap, Black Coated
- **56 mm peak excursion – 25mm linear (X-max)**
- Aluminum Short Circuiting Ring
- Aluminum Pole Piece Extension to reduce distortion and power compression
- Titanium Voice coil former
- Vented cone / dustcap
- Nomex spider
- Low damping rubber surround
- Litz wire woven into the spider
- Suggested box alignments:
  - One cubic foot sealed for use in autosound systems.
  - One cubic foot sealed with a plate amp and boost for use in home systems. With our KG5230 the F3 would be 38Hz.
  - The 30W/4558T and the 30W/0-00 passive radiator in a 2.5 cubic foot box should be 3dB down at 30Hz.
  - **For a vented box of 2.5 cubic feet, 3" vent by 11" long, your F3 is 27Hz.**


Boxnotes - default
Project
Cutting list
Port Flanges-1
Graphing Options
Units
Print
Help
Box Dimensions (inches external) and Calculator
Depth
1' 6 1/2
Height
1' 5 3/4
Width
1' 5 3/4
Internal Volume (cu.ft)
2.48
Also Dimension calculator - double click unknown field to update
Double Thickness Front
Panel Thickness
3/4
Ports (inches)
Internal Diameter
3
Length
11
Wall Thickness
1/8
No. of ports
1
Driver Location (inches)
Box top to driver centre
7 7/8
Size
10 inch
Offset from vertical centreline
1/16
No.
1
Box front to mid-depth of cone
1 3/16
Min
Click to hide
Ports = .04 cu.ft
Bracing = .1 cu.ft
Driver = .05 cu.ft
Total = .2 cu.ft
Working Vol 2.28 cu.ft
Tune 25.1hz
100
200
300
400
500
600
700
800
900
Front

Woofer Box: Panel Resonances

Mode	Natural Freq(Hz)	Participation Factor	Effective Modal Mass (lbm)	Mass Percent
1	372.73	0.05315	1.09041	49.673
2	478.85	0.00000	0.00000	0.000
3	671.19	0.02122	0.17383	7.919
4	949.43	0.00001	0.00000	0.000
5	970.84	0.00001	0.00000	0.000
6	1066.3	0.00000	0.00000	0.000
7	1234.1	0.00000	0.00000	0.000
8	1310.2	0.01401	0.07577	3.452
9	1480.8	0.00000	0.00000	0.000
10	1751.6	0.00002	0.00000	0.000
11	1809.3	0.00000	0.00000	0.000
12	1872.7	0.02374	0.21763	9.914
13	1957.5	0.00000	0.00000	0.000
14	2105.1	0.00773	0.02308	1.051
15	2220.7	0.00000	0.00000	0.000
16	2273.8	0.01085	0.04547	2.071

Woofer Box

Cube Shape
    Maximize Frequency of first Helmholtz
Resonance
    Maximize Frequency of first Panel Resonance

Crossover Design Goals

- What matters? You don’t want to hear it!
  - Notching happens with offset / angle

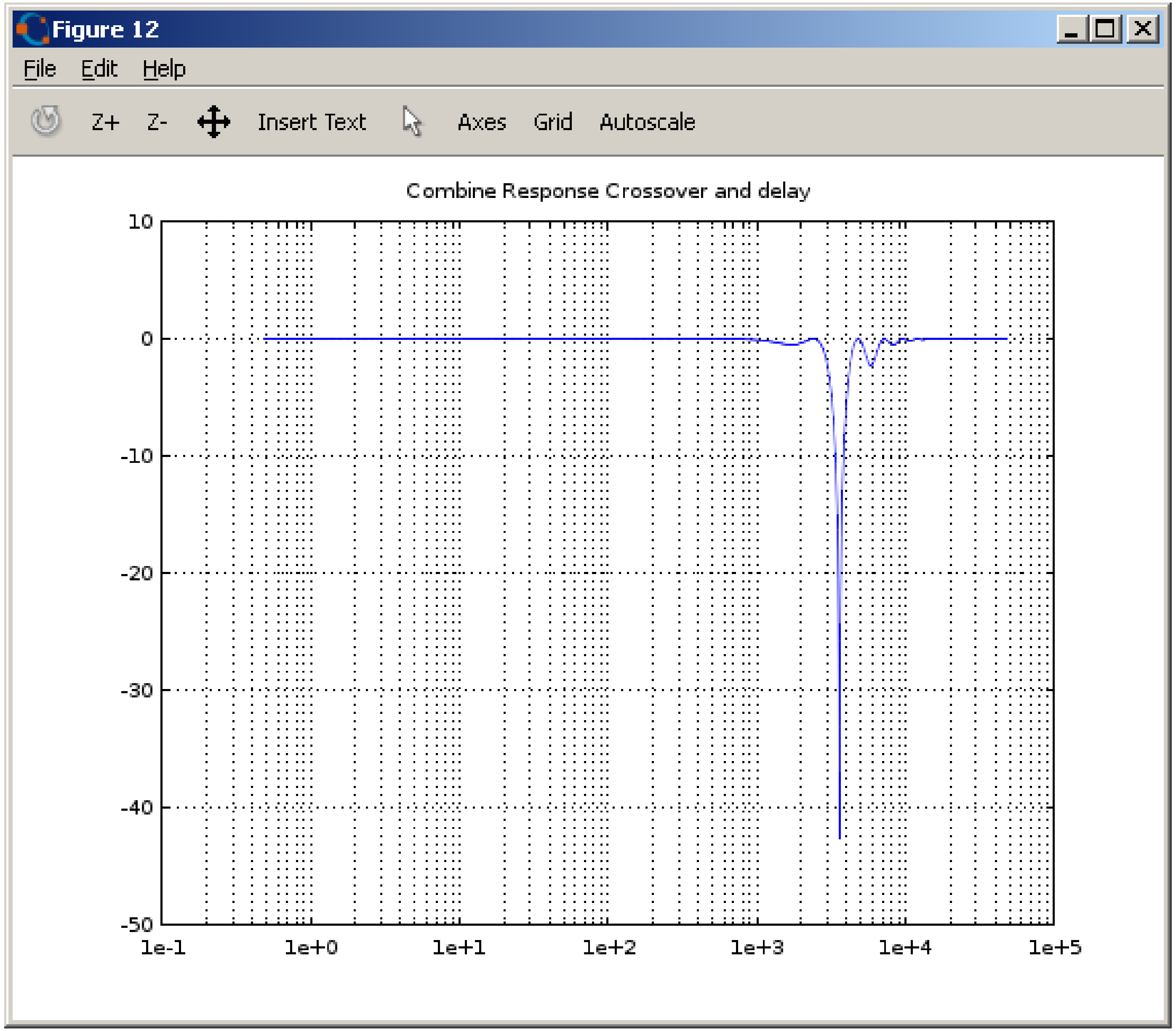
- Modeling
- Simulation
- Listening to the simulation

Crossover Audibility Research

- Modeling
  - Software (Matlab   or Octave)
  - AES Convention Paper 5908: A Virtual Loudspeaker Model to Enable Real-Time Listening Tests in Examining the Audibility of High-Order Crossover Networks. Cochenour & Rich

Crossover

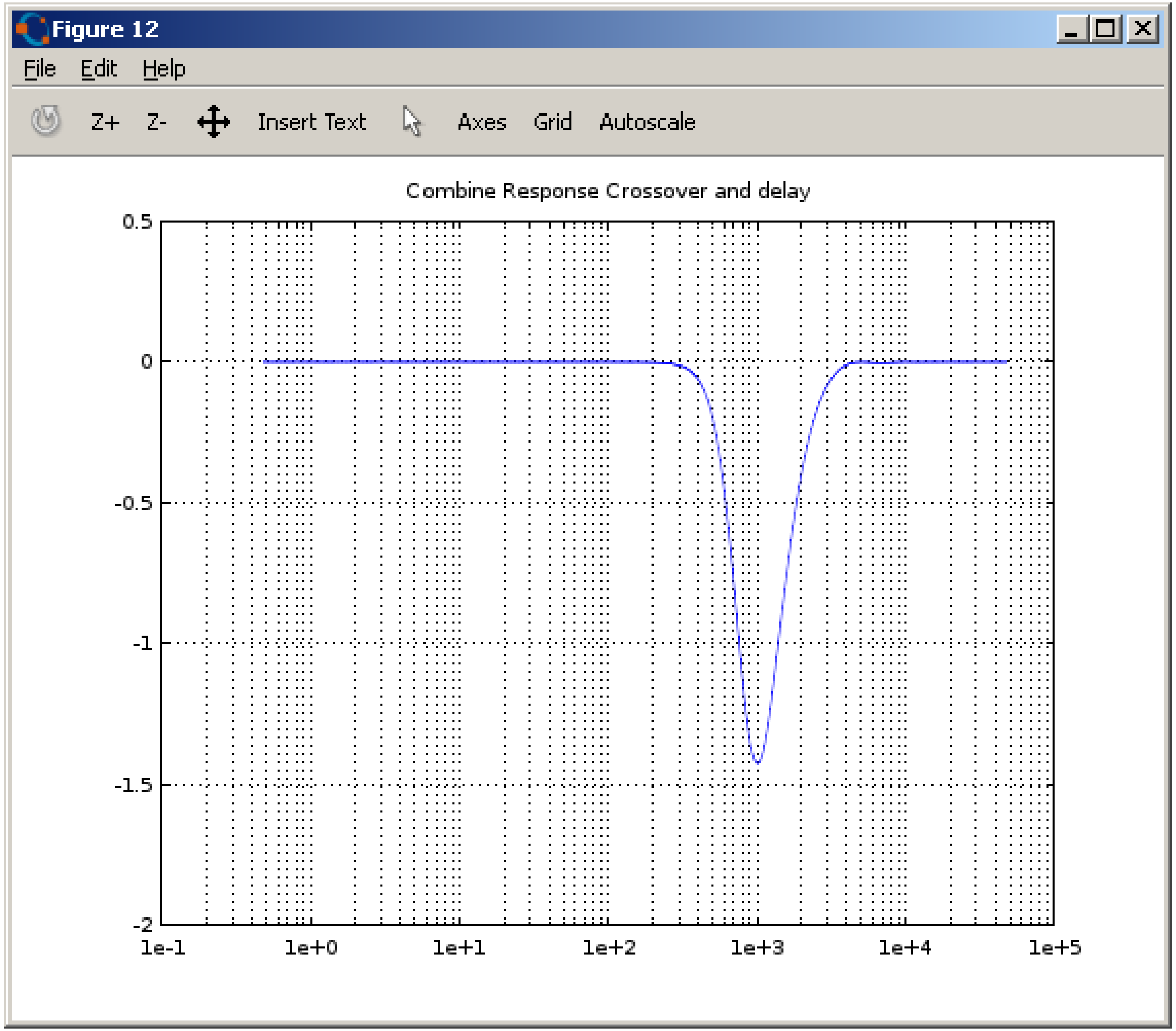
Audible Defect



3,500 Hz 4th order Linkwitz,
417 us delay, 5.6" offset.

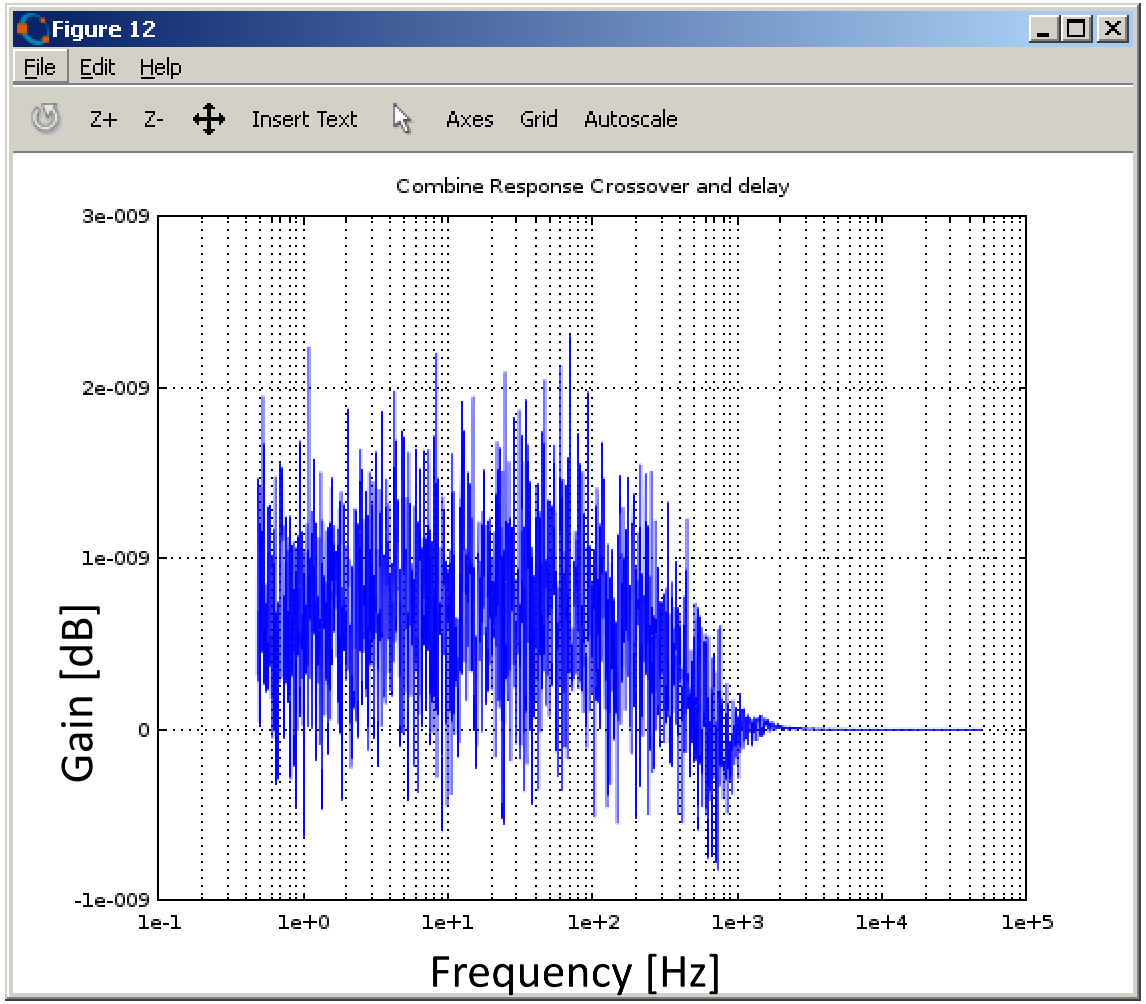
Crossover

Inaudible Defect?



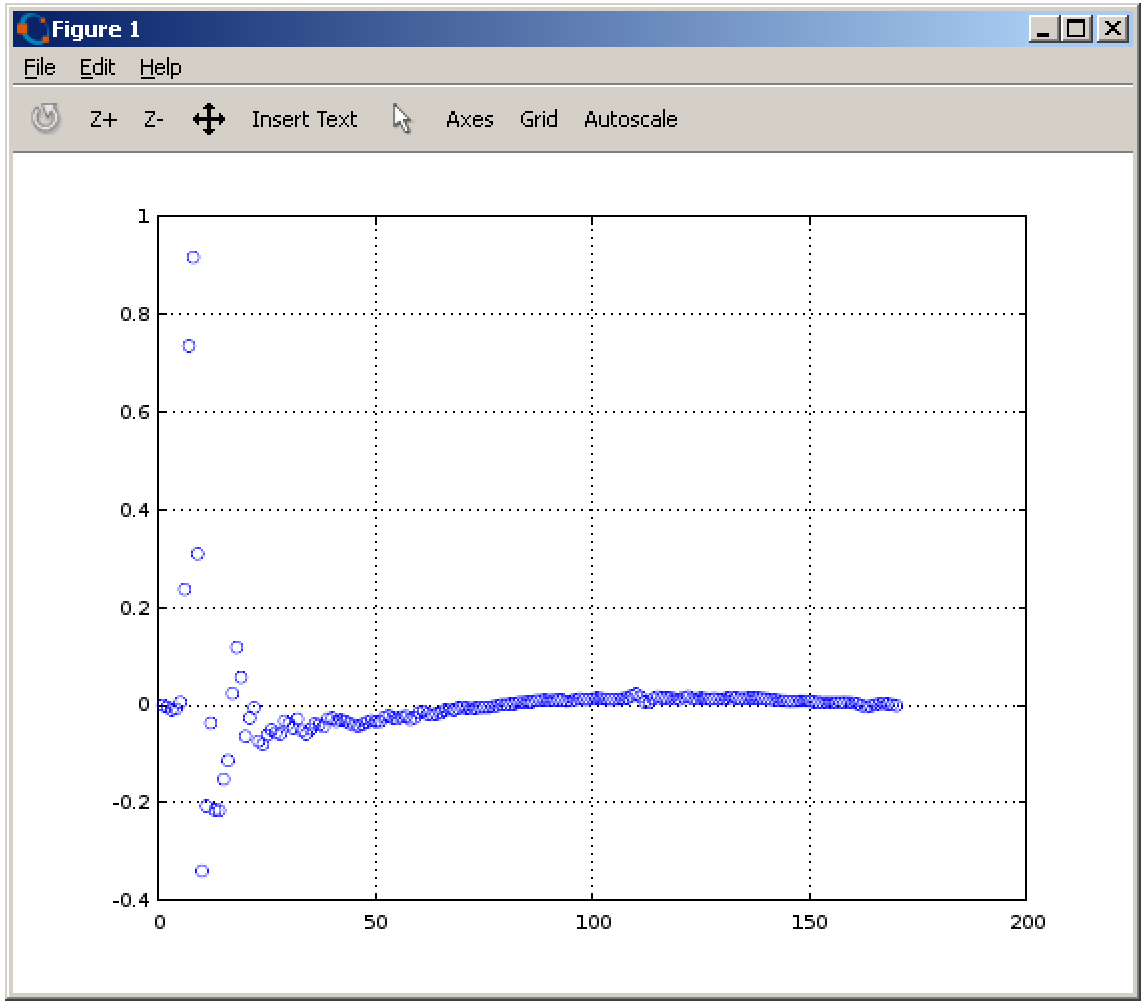
800 Hz 4th order 200 us (2.6") offset.

Crossover



Fourth Order Linkwitz, zero offset summed high pass and low pass response.

Impulse Response



Crossover: Design Decisions

- High order cross over minimize driver overlap
- Perfect Summing - Linkwitz 4^{th} order
- Offset Induced Notch - Low Frequency -> long wavelength -> phase shift

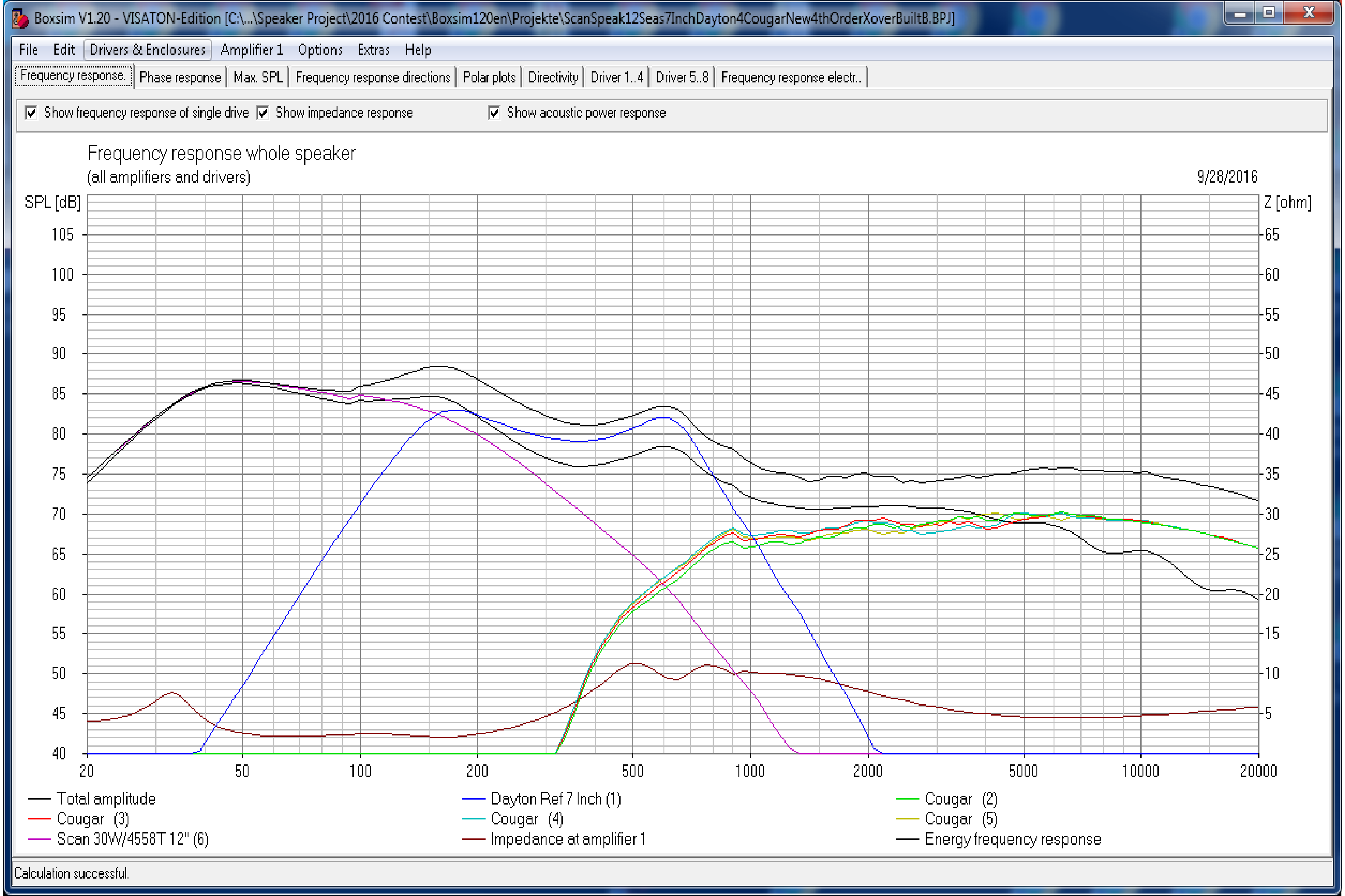
Crossover Implementation: Modeling and Design

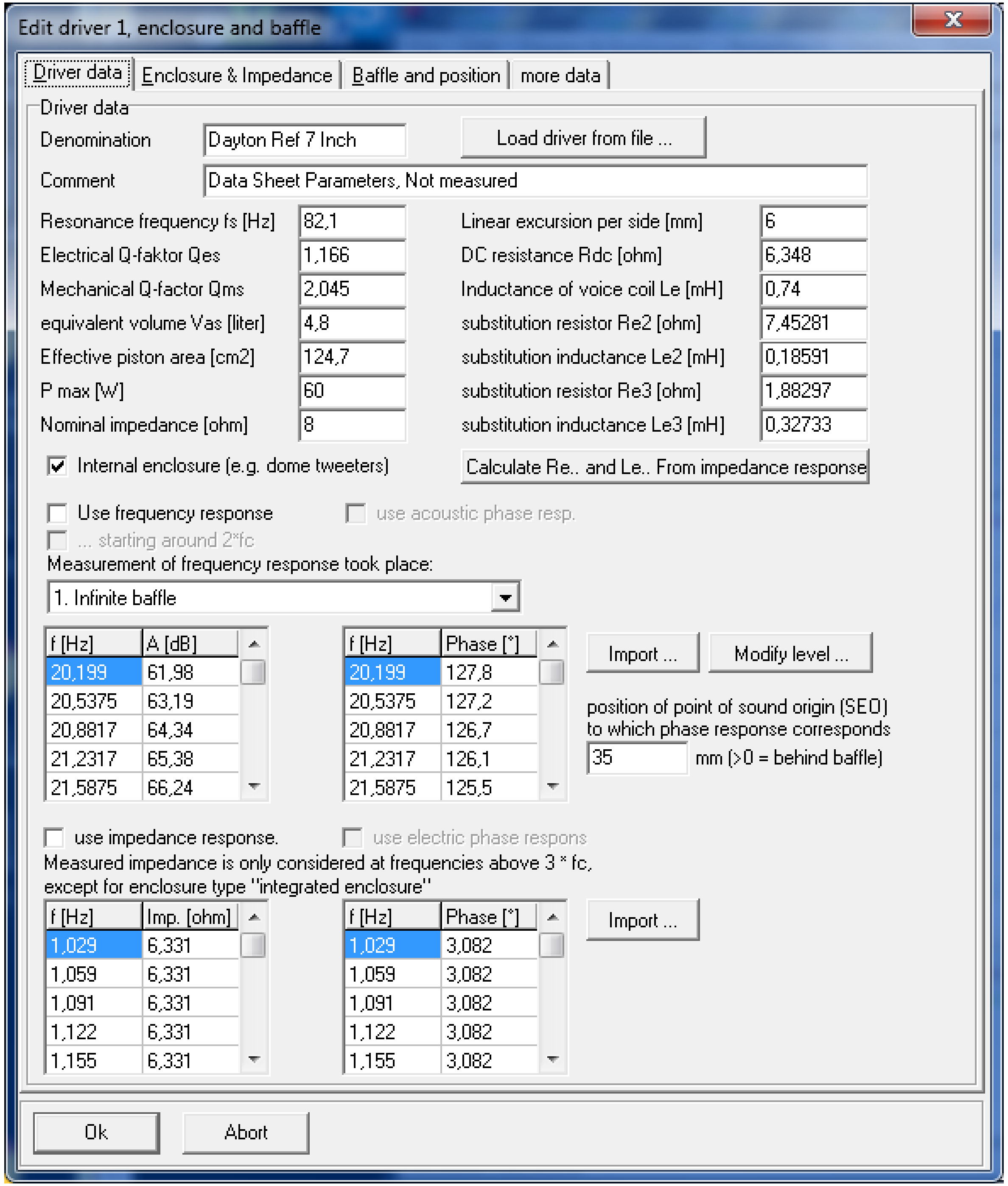
- Active
  - DBX rack mount pro gear, (easiest, intuitive knobs, prototyping)
  - miniDsp, others (software configurable, most flexible)

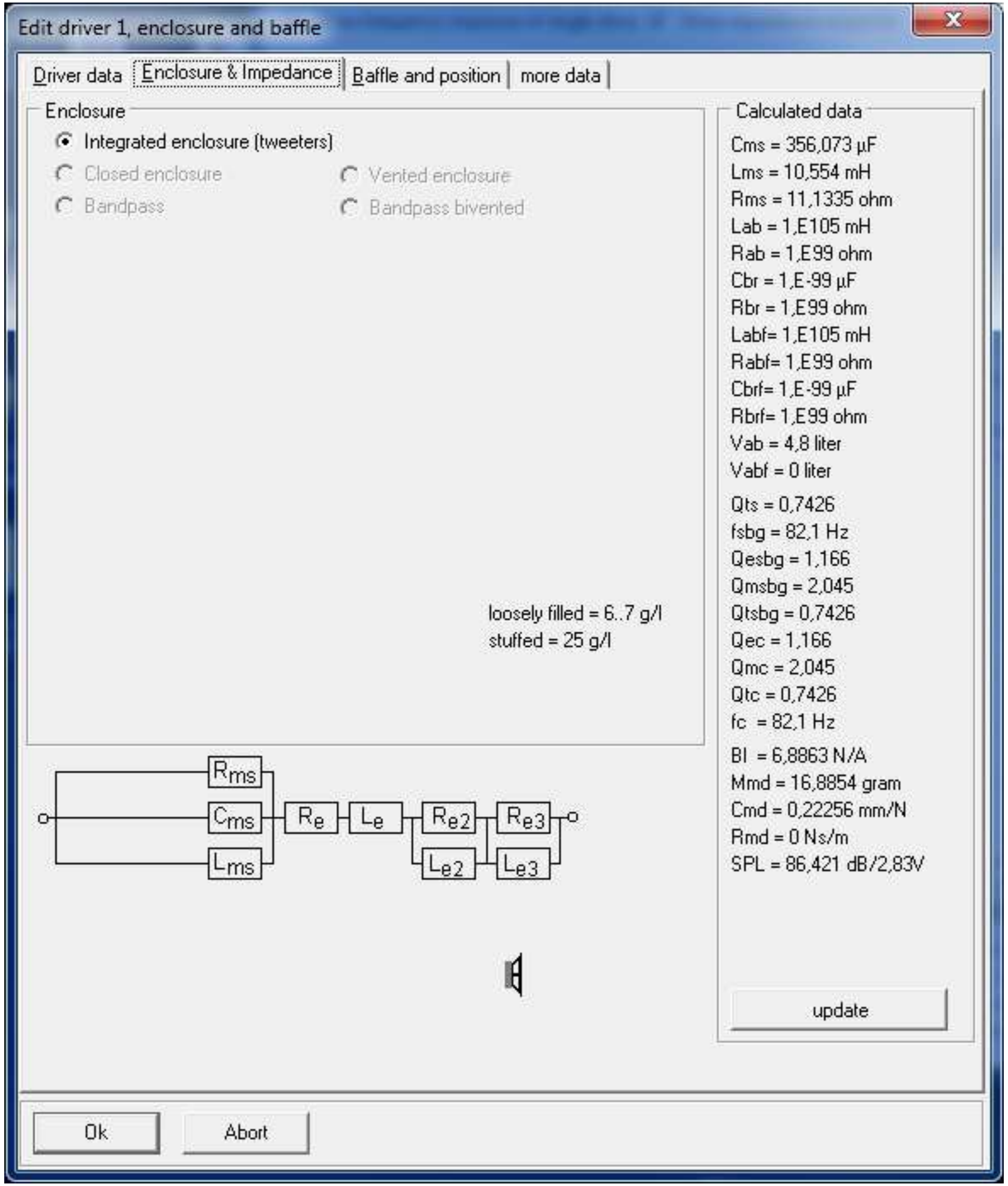
- Passive
  - Coils, Caps and Mechanical (difficult to design, worst results, most accepted)

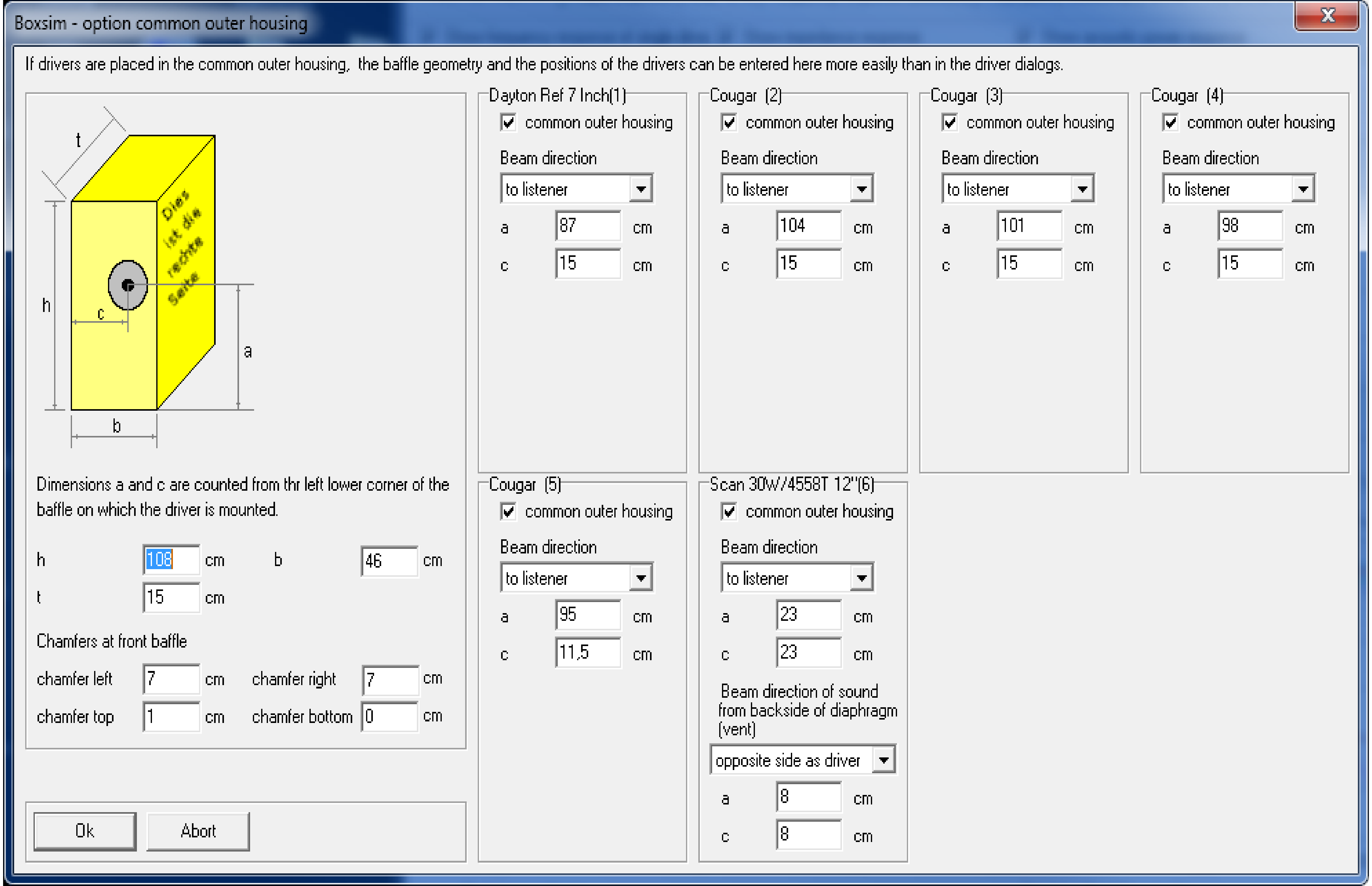
- Modeling
  - Pspice (Linear Tech)
  - Boxsim (V) (passive and active modeling)

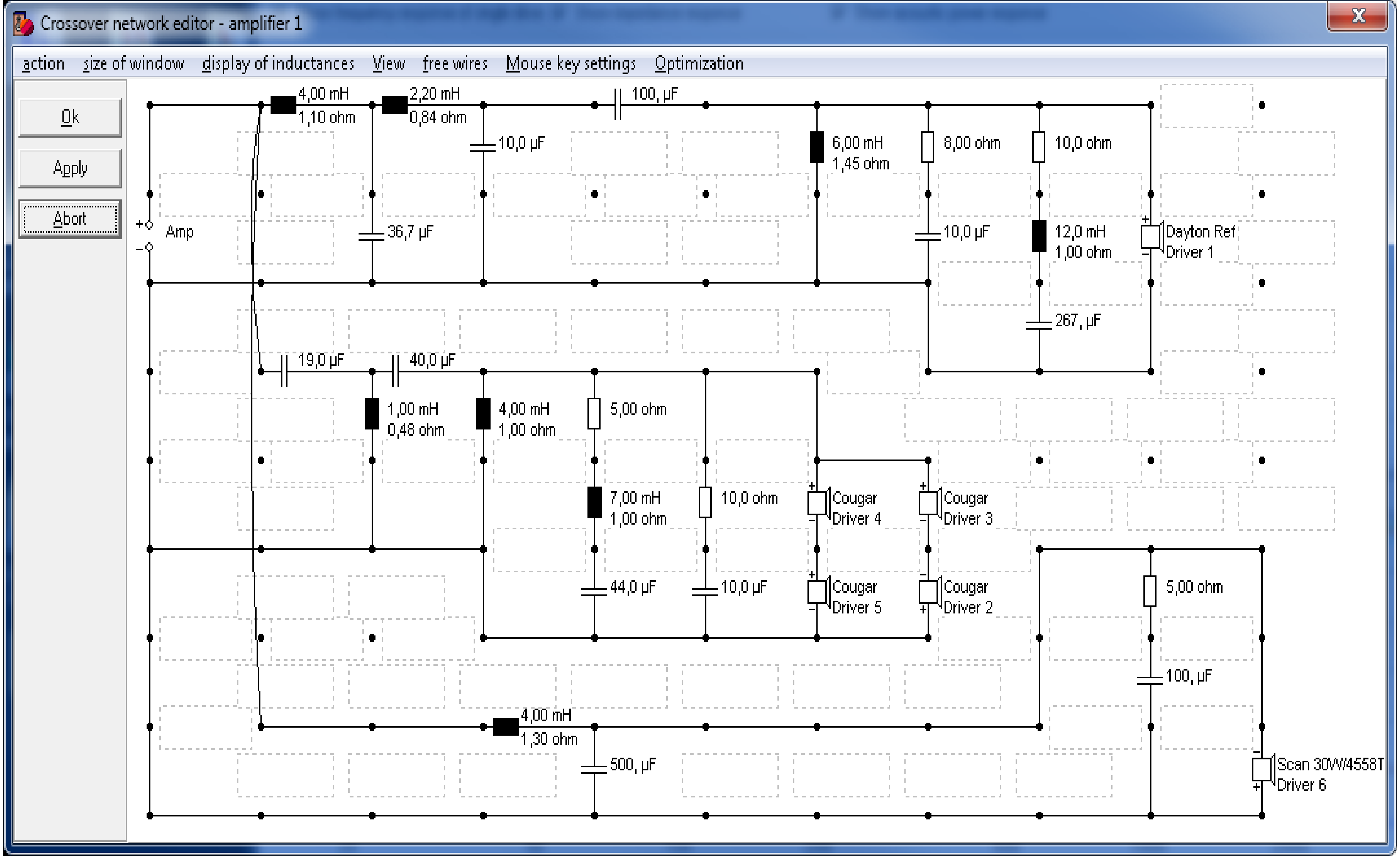
Boxsim by VISATON

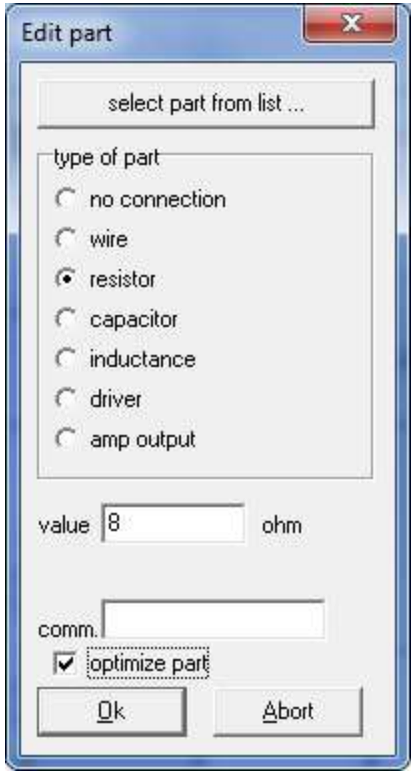



Edit driver 1, enclosure and baffle
Driver data
Enclosure & Impedance
Baffle and position
more data
Driver data
Denomination
Dayton Ref 7 Inch
Load driver from file ...
Comment
Data Sheet Parameters, Not measured
Resonance frequency fs [Hz]
82,1
Electrical Q-faktor Qes
1,166
Mechanical Q-factor Qms
2,045
equivalent volume Vas [liter]
4,8
Effective piston area [cm2]
124,7
P max [W]
60
Nominal impedance [ohm]
8
Linear excursion per side [mm]
6
DC resistance Rdc [ohm]
6,348
Inductance of voice coil Le [mH]
0,74
substitution resistor Re2 [ohm]
7,45281
substitution inductance Le2 [mH]
0,18591
substitution resistor Re3 [ohm]
1,88297
substitution inductance Le3 [mH]
0,32733
Internal enclosure (e.g. dome tweeters)
Calculate Re.. and Le.. From impedance response
Use frequency response
use acoustic phase resp.
... starting around 2*fc
Measurement of frequency response took place:
1. Infinite baffle
f [Hz]
A [dB]
20,199
61,98
20,5375
63,19
20,8817
64,34
21,2317
65,38
21,5875
66,24
f [Hz]
Phase [°]
20,199
127,8
20,5375
127,2
20,8817
126,7
21,2317
126,1
21,5875
125,5
Import ...
Modify level ...
position of point of sound origin (SEO)
to which phase response corresponds
35
mm (>0 = behind baffle)
use impedance response.
use electric phase respons
Measured impedance is only considered at frequencies above 3 * fc,
except for enclosure type "integrated enclosure"
f [Hz]
Imp. [ohm]
1,029
6,331
1,059
6,331
1,091
6,331
1,122
6,331
1,155
6,331
f [Hz]
Phase [°]
1,029
3,082
1,059
3,082
1,091
3,082
1,122
3,082
1,155
3,082
Import ...
Ok
Abort

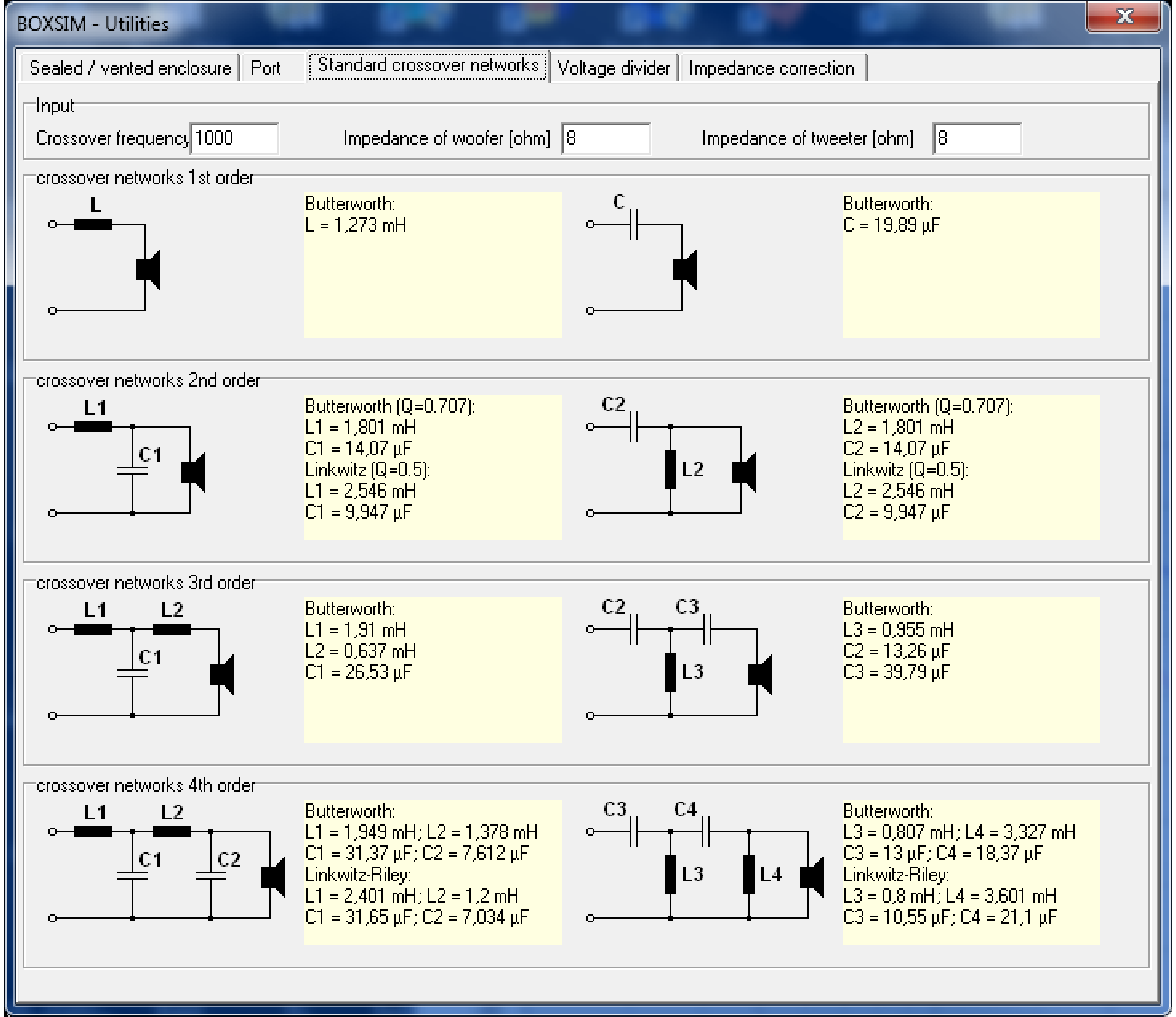

Edit driver 1, enclosure and baffle
Driver data
Enclosure & Impedance
Baffle and position
more data
Enclosure
Integrated enclosure (tweeters)
Closed enclosure
Vented enclosure
Bandpass
Bandpass bivented
loosely filled = 6..7 g/l
stuffed = 25 g/l
Rms
Cms
Lms
Re
Le
Re2
Re3
Le2
Le3
Calculated data
Cms = 356,073 µF
Lms = 10,554 mH
Rms = 11,1335 ohm
Lab = 1,E105 mH
Rab = 1,E99 ohm
Cbr = 1,E-99 µF
Rbr = 1,E99 ohm
Labf= 1,E105 mH
Rabf= 1,E99 ohm
Cbrf= 1,E-99 µF
Rbrf= 1,E99 ohm
Vab = 4,8 liter
Vabf = 0 liter
Qts = 0,7426
fsbg = 82,1 Hz
Qesbg = 1,166
Qmsbg = 2,045
Qtsbg = 0,7426
Qec = 1,166
Qmc = 2,045
Qtc = 0,7426
fc = 82,1 Hz
Bl = 6,8863 N/A
Mmd = 16,8854 gram
Cmd = 0,22256 mm/N
Rmd = 0 Ns/m
SPL = 86,421 dB/2,83V
update
Ok
Abort

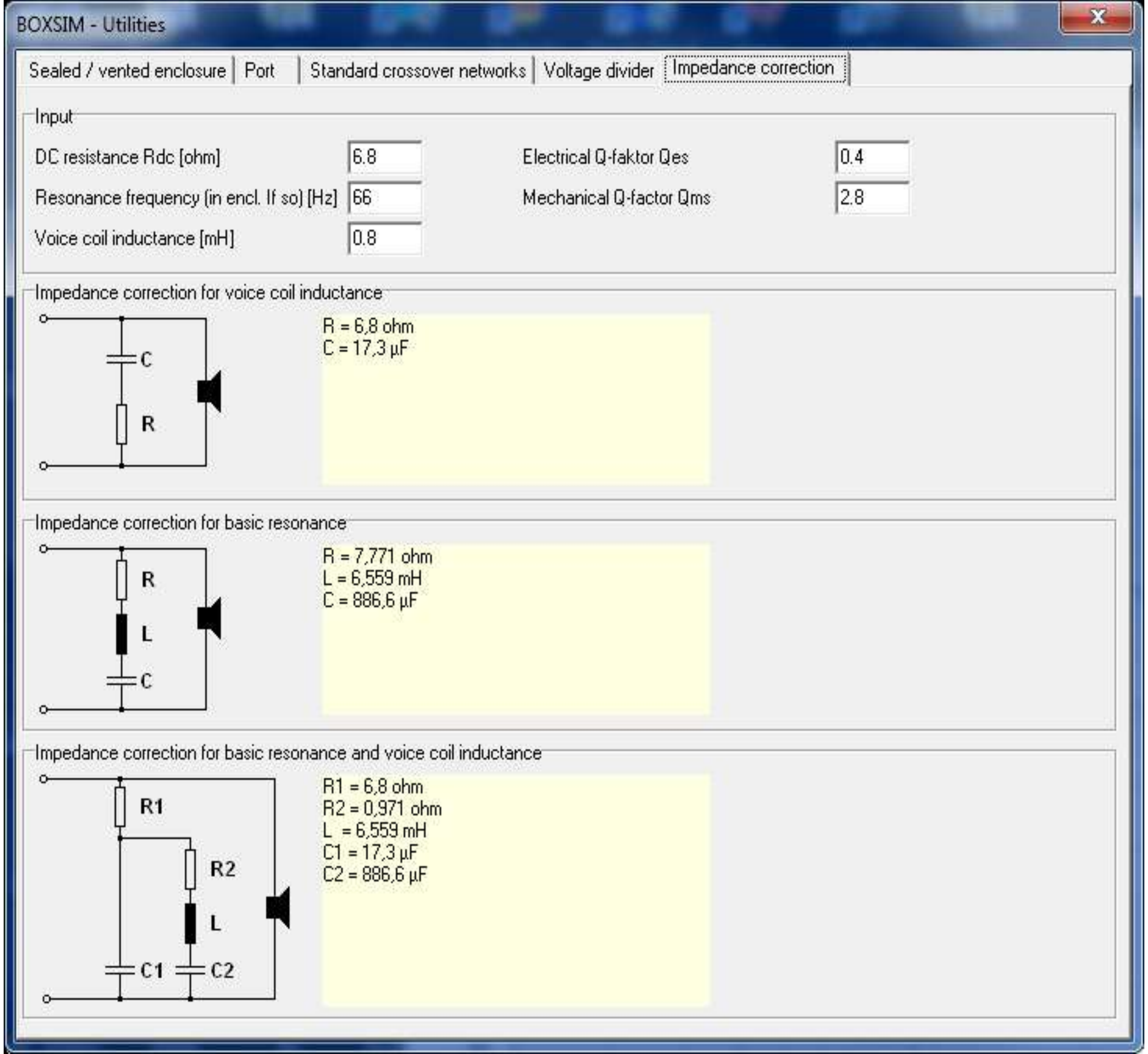

Boxsim - option common outer housing
If drivers are placed in the common outer housing, the baffle geometry and the positions of the drivers can be entered here more easily than in the driver dialogs.
t
h
c
a
b
Dies ist die rechte Seite
Dimensions a and c are counted from thr left lower corner of the baffle on which the driver is mounted.
h 108 cm
b 46 cm
t 15 cm
Chamfers at front baffle
chamfer left 7 cm
chamfer right 7 cm
chamfer top 1 cm
chamfer bottom 0 cm
Ok
Abort
Dayton Ref 7 Inch(1)
common outer housing
Beam direction
to listener
a 87 cm
c 15 cm
Cougar (2)
common outer housing
Beam direction
to listener
a 104 cm
c 15 cm
Cougar (3)
common outer housing
Beam direction
to listener
a 101 cm
c 15 cm
Cougar (4)
common outer housing
Beam direction
to listener
a 98 cm
c 15 cm
Cougar (5)
common outer housing
Beam direction
to listener
a 95 cm
c 11,5 cm
Scan 30W/4558T 12"(6)
common outer housing
Beam direction
to listener
a 23 cm
c 23 cm
Beam direction of sound from backside of diaphragm (vent)
opposite side as driver
a 8 cm
c 8 cm


Crossover network editor - amplifier 1
action
size of window
display of inductances
View
free wires
Mouse key settings
Optimization
Ok
Apply
Abort
Amp
4,00 mH
1,10 ohm
2,20 mH
0,84 ohm
100, µF
10,0 µF
36,7 µF
6,00 mH
1,45 ohm
8,00 ohm
10,0 ohm
10,0 µF
12,0 mH
1,00 ohm
267, µF
Dayton Ref
Driver 1
19,0 µF
40,0 µF
1,00 mH
0,48 ohm
4,00 mH
1,00 ohm
5,00 ohm
7,00 mH
1,00 ohm
10,0 ohm
44,0 µF
10,0 µF
Cougar
Driver 4
Cougar
Driver 3
Cougar
Driver 5
Cougar
Driver 2
5,00 ohm
100, µF
4,00 mH
1,30 ohm
500, µF
Scan 30W4558T
Driver 6

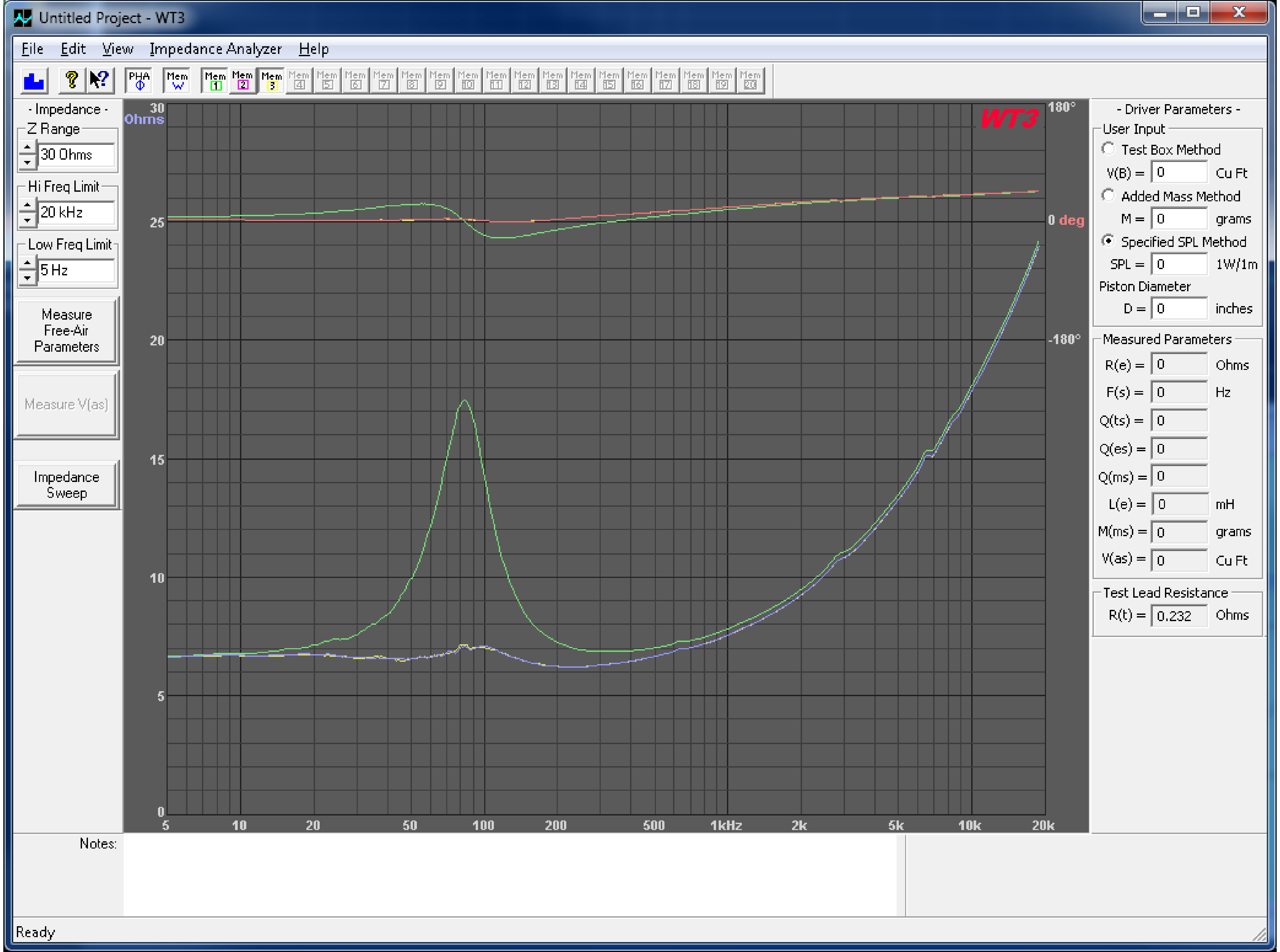


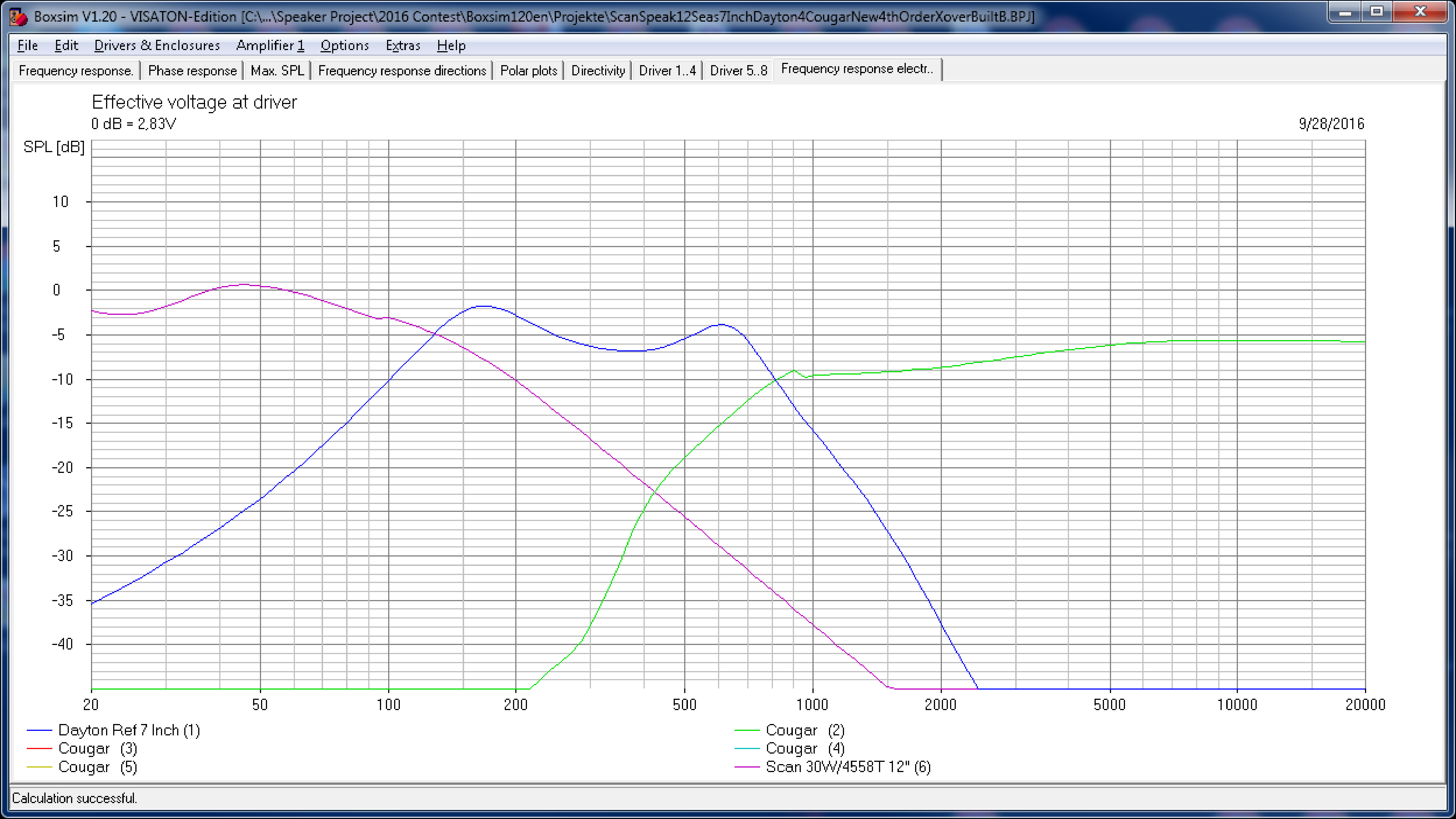
Edit part
select part from list ...
type of part
no connection
wire
resistor
capacitor
inductance
driver
amp output
value
8
ohm
comm.
optimize part
Ok
Abort

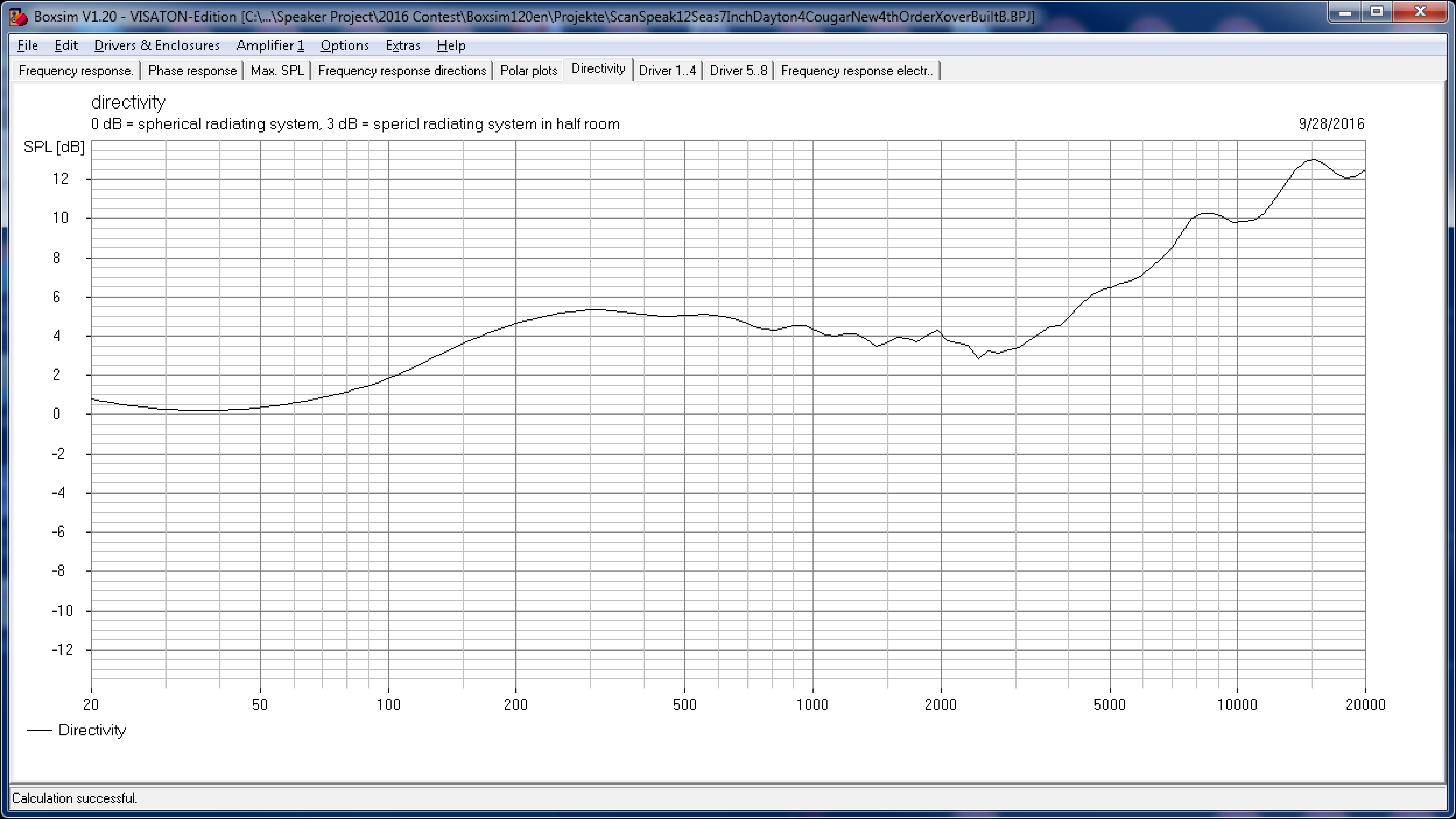

BOXSIM - Utilities
Sealed / vented enclosure
Port
Standard crossover networks
Voltage divider
Impedance correction
Input
Crossover frequency 1000
Impedance of woofer [ohm] 8
Impedance of tweeter [ohm] 8
crossover networks 1st order
L
Butterworth:
L = 1,273 mH
C
Butterworth:
C = 19,89 µF
crossover networks 2nd order
L1
C1
Butterworth (Q=0.707):
L1 = 1,801 mH
C1 = 14,07 µF
Linkwitz (Q=0.5):
L1 = 2,546 mH
C1 = 9,947 µF
C2
L2
Butterworth (Q=0.707):
L2 = 1,801 mH
C2 = 14,07 µF
Linkwitz (Q=0.5):
L2 = 2,546 mH
C2 = 9,947 µF
crossover networks 3rd order
L1
L2
C1
Butterworth:
L1 = 1,91 mH
L2 = 0,637 mH
C1 = 26,53 µF
C2
C3
L3
Butterworth:
L3 = 0,955 mH
C2 = 13,26 µF
C3 = 39,79 µF
crossover networks 4th order
L1
L2
C1
C2
Butterworth:
L1 = 1,949 mH; L2 = 1,378 mH
C1 = 31,37 µF; C2 = 7,612 µF
Linkwitz-Riley:
L1 = 2,401 mH; L2 = 1,2 mH
C1 = 31,65 µF; C2 = 7,034 µF
C3
C4
L3
L4
Butterworth:
L3 = 0,807 mH; L4 = 3,327 mH
C3 = 13 µF; C4 = 18,37 µF
Linkwitz-Riley:
L3 = 0,8 mH; L4 = 3,601 mH
C3 = 10,55 µF; C4 = 21,1 µF

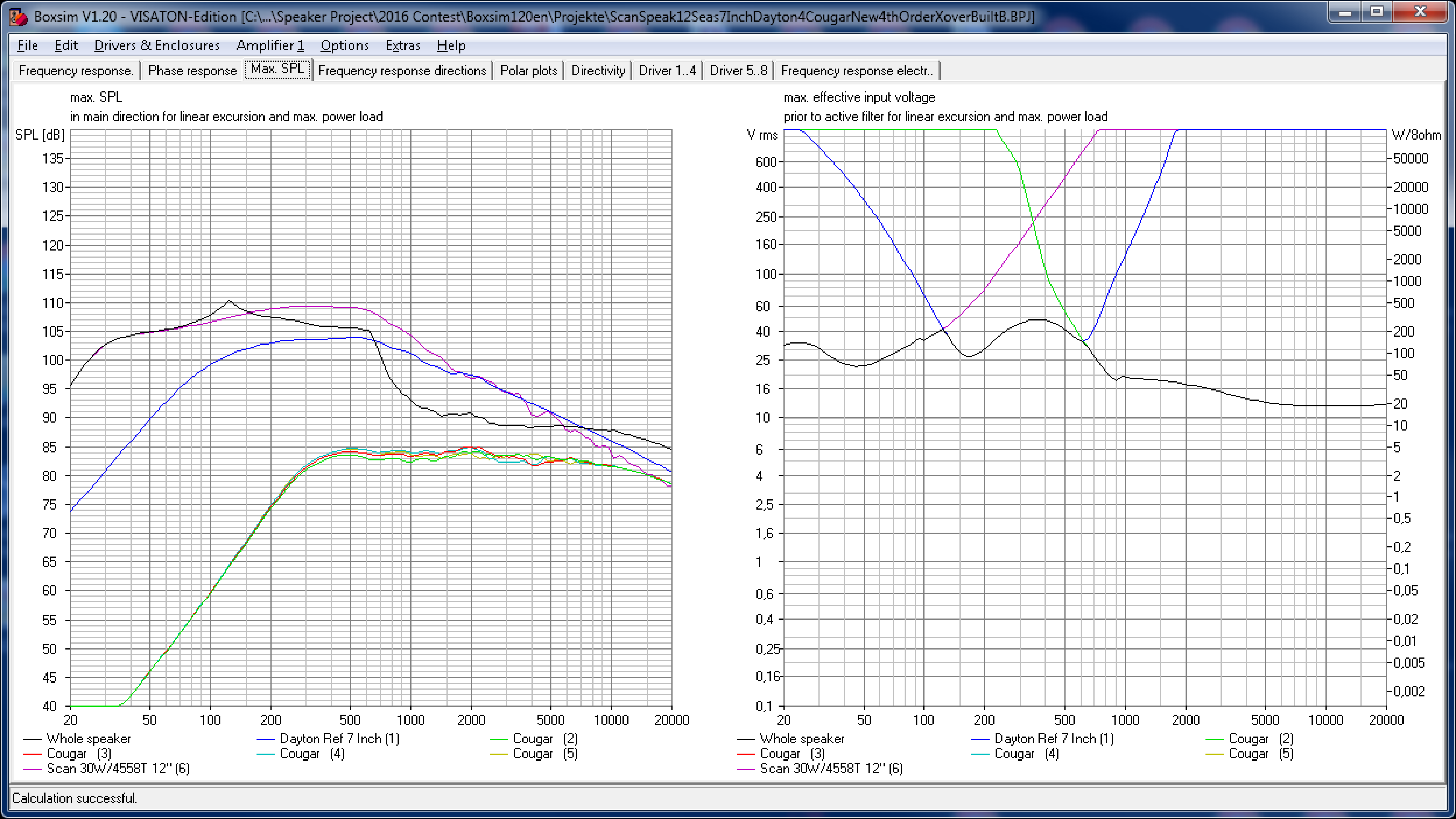


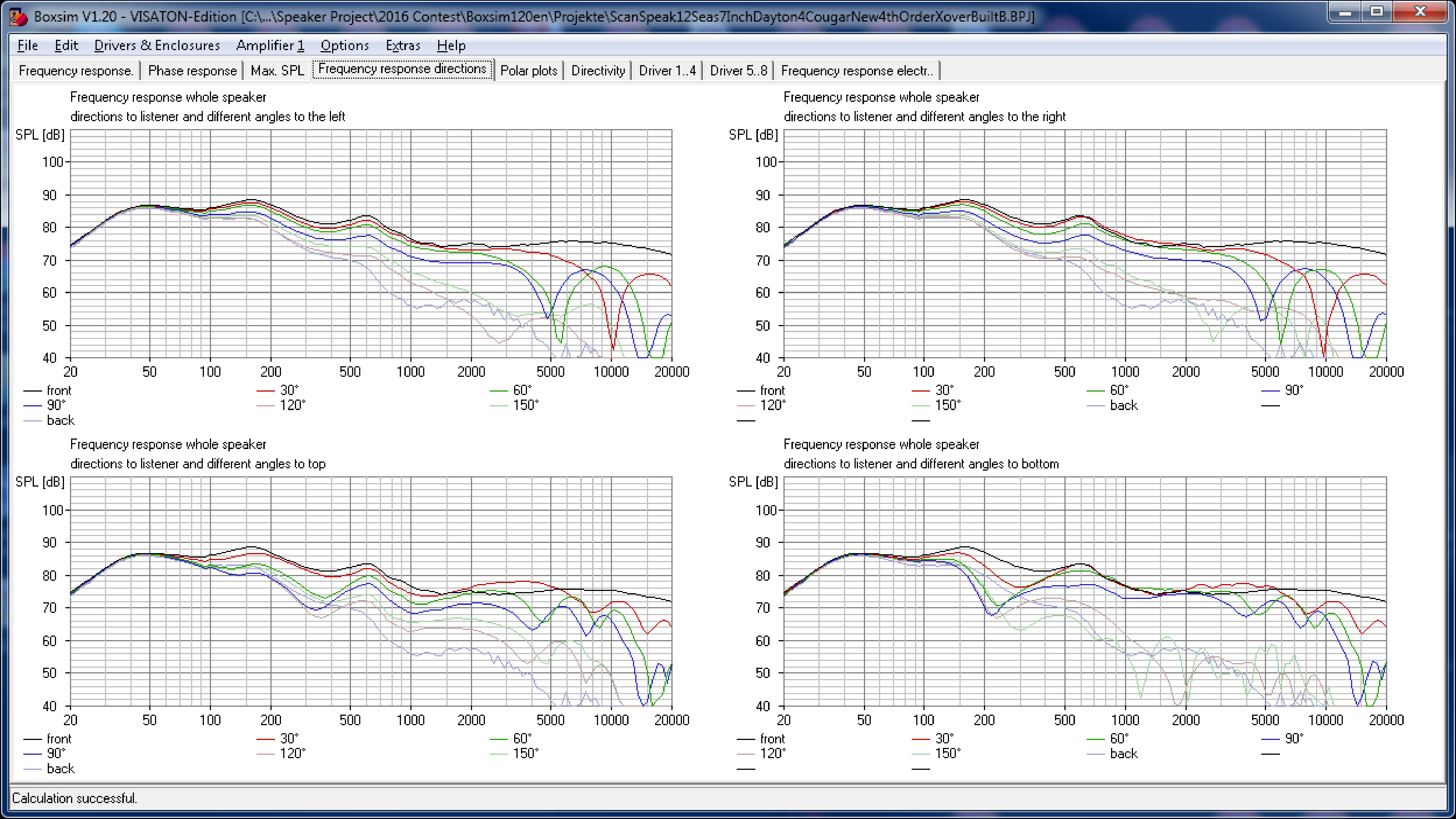
BOXSIM - Utilities
Sealed / vented enclosure
Port
Standard crossover networks
Voltage divider
Impedance correction
Input
DC resistance Rdc [ohm]
6.8
Resonance frequency (in encl. If so) [Hz]
66
Voice coil inductance [mH]
0.8
Electrical Q-faktor Qes
0.4
Mechanical Q-factor Qms
2.8
Impedance correction for voice coil inductance
C
R
R = 6,8 ohm
C = 17,3 µF
Impedance correction for basic resonance
R
L
C
R = 7,771 ohm
L = 6,559 mH
C = 886,6 µF
Impedance correction for basic resonance and voice coil inductance
R1
R2
L
C1
C2
R1 = 6,8 ohm
R2 = 0,971 ohm
L = 6,559 mH
C1 = 17,3 µF
C2 = 886,6 µF

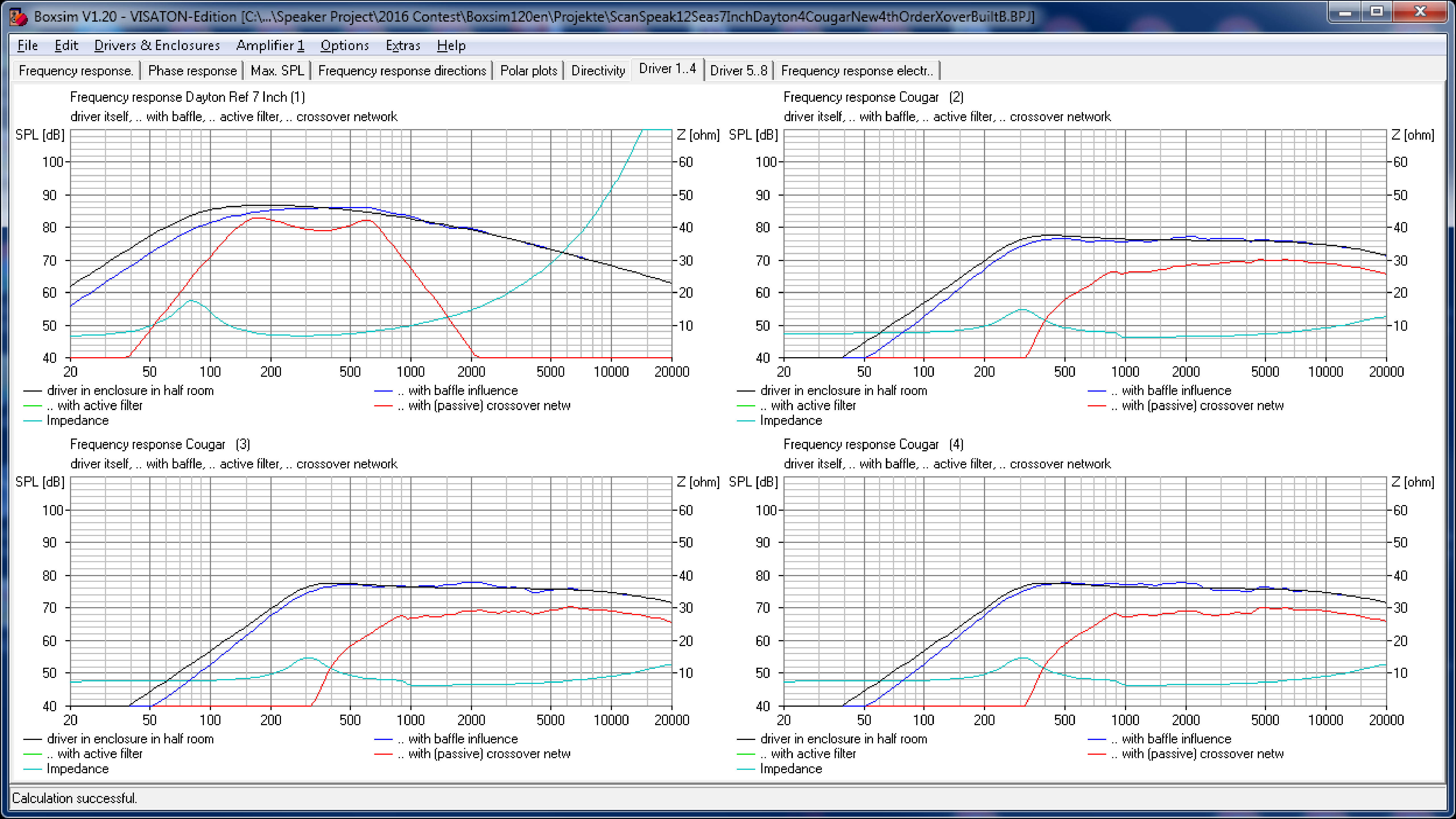

Untitled Project - WT3
File Edit View Impedance Analyzer Help
- Impedance -
Z Range
30 Ohms
Hi Freq Limit
20 kHz
Low Freq Limit
5 Hz
Measure Free-Air Parameters
Measure V(as)
Impedance Sweep
30 Ohms
25
20
15
10
5
0
5 10 20 50 100 200 500 1kHz 2k 5k 10k 20k
180°
0 deg
-180°
WT3
- Driver Parameters -
User Input
Test Box Method
V(B) = 0 Cu Ft
Added Mass Method
M = 0 grams
Specified SPL Method
SPL = 0 1W/1m
Piston Diameter
D = 0 inches
Measured Parameters
R(e) = 0 Ohms
F(s) = 0 Hz
Q(ts) = 0
Q(es) = 0
Q(ms) = 0
L(e) = 0 mH
M(ms) = 0 grams
V(as) = 0 Cu Ft
Test Lead Resistance
R(t) = 0.232 Ohms
Notes:
Ready

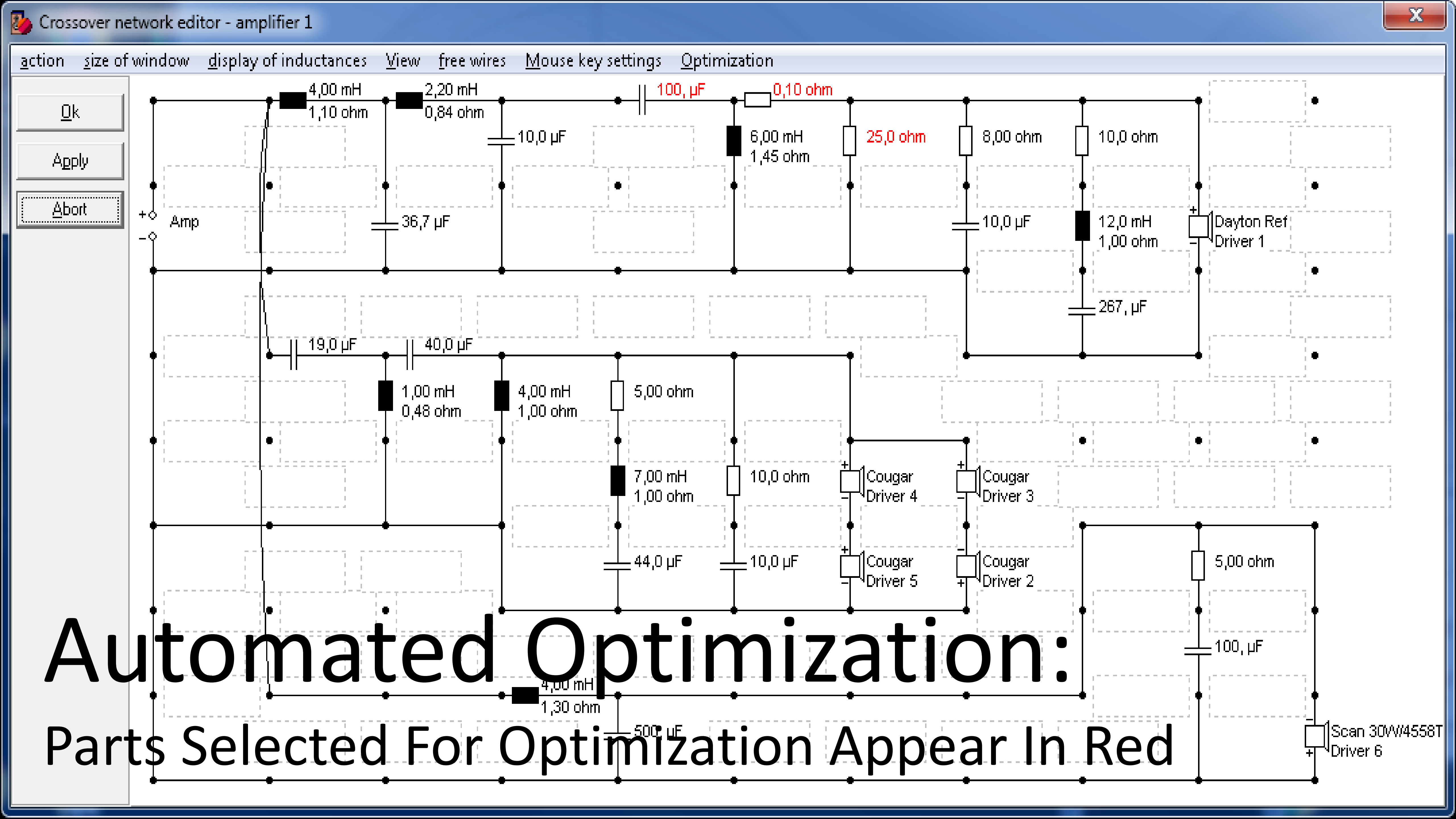

Boxsim V1.20 - VISATON-Edition [C:\...\Speaker Project\2016 Contest\Boxsim120en\Projekte\ScanSpeak12Seas7InchDayton4CougarNew4thOrderXoverBuiltB.BPJ]
File Edit Drivers & Enclosures Amplifier 1 Options Extras Help
Frequency response. Phase response Max. SPL Frequency response directions Polar plots Directivity Driver 1..4 Driver 5..8 Frequency response electr..
Effective voltage at driver
0 dB = 2,83V
9/28/2016
SPL [dB]
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
20
50
100
200
500
1000
2000
5000
10000
20000
Dayton Ref 7 Inch (1)
Cougar (2)
Cougar (3)
Cougar (4)
Cougar (5)
Scan 30W/4558T 12" (6)
Calculation successful.


Boxsim V1.20 - VISATON-Edition [C:\...\Speaker Project\2016 Contest\Boxsim120en\Projekte\ScanSpeak12Seas7InchDayton4CougarNew4thOrderXoverBuiltB.BPJ]
File
Edit
Drivers & Enclosures
Amplifier 1
Options
Extras
Help
Frequency response.
Phase response
Max. SPL
Frequency response directions
Polar plots
Directivity
Driver 1..4
Driver 5..8
Frequency response electr..
directivity
0 dB = spherical radiating system, 3 dB = sphericl radiating system in half room
9/28/2016
SPL [dB]
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
20
50
100
200
500
1000
2000
5000
10000
20000
Directivity
Calculation successful.


Boxsim V1.20 - VISATON-Edition [C:\...\Speaker Project\2016 Contest\Boxsim120en\Projekte\ScanSpeak12Seas7InchDayton4CougarNew4thOrderXoverBuiltB.BPJ]
File Edit Drivers & Enclosures Amplifier 1 Options Extras Help
Frequency response. Phase response Max. SPL Frequency response directions Polar plots Directivity Driver 1..4 Driver 5..8 Frequency response electr..
max. SPL
in main direction for linear excursion and max. power load
SPL [dB]
135 130 125 120 115 110 105 100 95 90 85 80 75 70 65 60 55 50 45 40
20 50 100 200 500 1000 2000 5000 10000 20000
Whole speaker
Dayton Ref 7 Inch (1)
Cougar (2)
Cougar (3)
Cougar (4)
Cougar (5)
Scan 30W/4558T 12'' (6)
max. effective input voltage
prior to active filter for linear excursion and max. power load
V rms
600 400 250 160 100 60 40 25 16 10 6 4 2,5 1,6 1 0,6 0,4 0,25 0,16 0,1
W/8ohm
50000 20000 10000 5000 2000 1000 500 200 100 50 20 10 5 2 1 0,5 0,2 0,1 0,05 0,02 0,01 0,005 0,002
20 50 100 200 500 1000 2000 5000 10000 20000
Whole speaker
Dayton Ref 7 Inch (1)
Cougar (2)
Cougar (3)
Cougar (4)
Cougar (5)
Scan 30W/4558T 12'' (6)
Calculation successful.

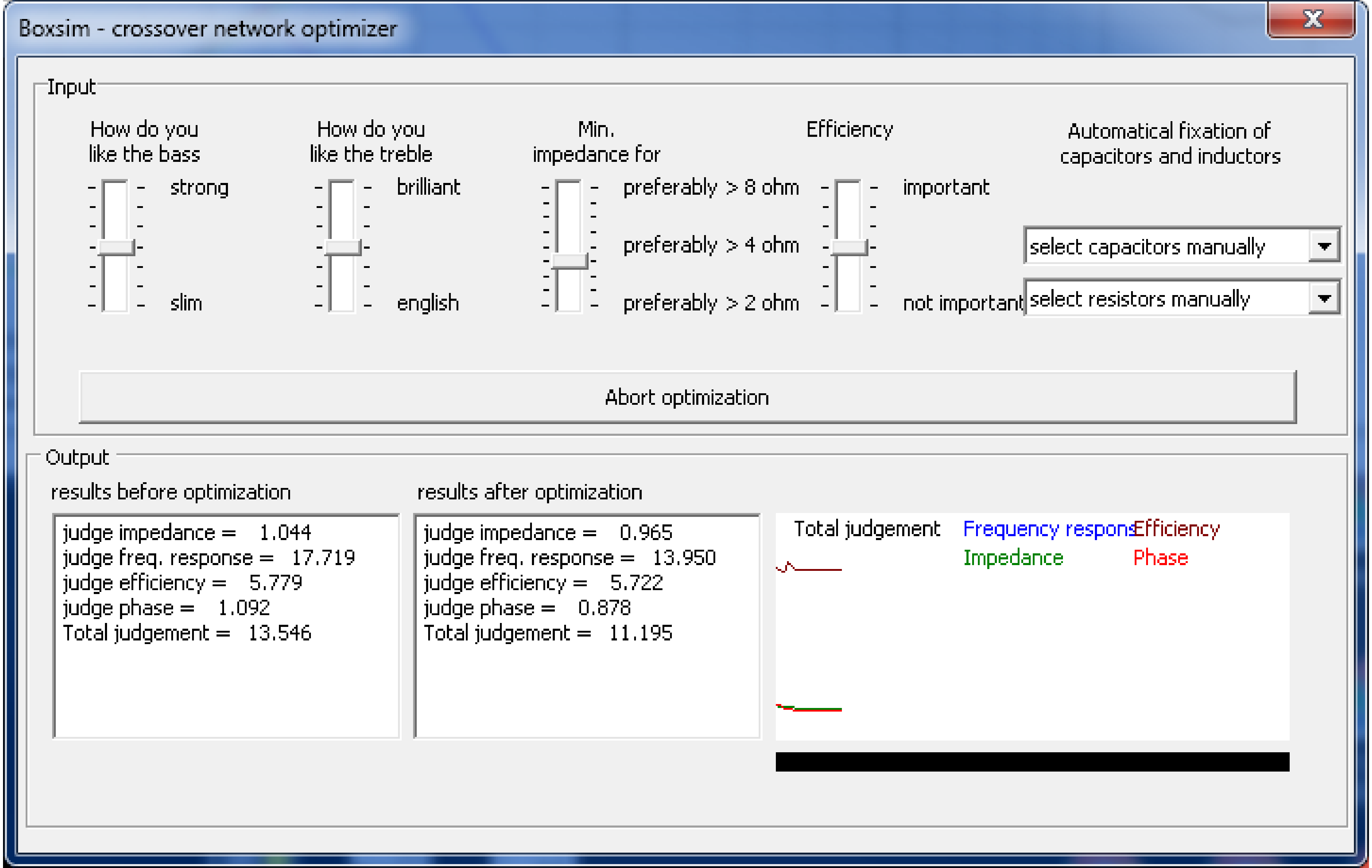

Boxsim V1.20 - VISATON-Edition [C:\...\Speaker Project\2016 Contest\Boxsim120en\Projekte\ScanSpeak12Seas7InchDayton4CougarNew4thOrderXoverBuiltB.BPJ]
File
Edit
Drivers & Enclosures
Amplifier 1
Options
Extras
Help
Frequency response.
Phase response
Max. SPL
Frequency response directions
Polar plots
Directivity
Driver 1..4
Driver 5..8
Frequency response electr..
Frequency response whole speaker
directions to listener and different angles to the left
SPL [dB]
100
90
80
70
60
50
40
20
50
100
200
500
1000
2000
5000
10000
20000
front
30°
60°
90°
120°
150°
back
Frequency response whole speaker
directions to listener and different angles to the right
SPL [dB]
front
30°
60°
90°
120°
150°
back
Frequency response whole speaker
directions to listener and different angles to top
SPL [dB]
front
30°
60°
90°
120°
150°
back
Frequency response whole speaker
directions to listener and different angles to bottom
SPL [dB]
front
30°
60°
90°
120°
150°
back
Calculation successful.


Boxsim V1.20 - VISATON-Edition [C:\...\Speaker Project\2016 Contest\Boxsim120en\Projekte\ScanSpeak12Seas7InchDayton4CougarNew4thOrderXoverBuiltB.BPJ]
File Edit Drivers & Enclosures Amplifier 1 Options Extras Help
Frequency response. | Phase response | Max. SPL | Frequency response directions | Polar plots | Directivity | Driver 1..4 | Driver 5..8 | Frequency response electr..
Frequency response Dayton Ref 7 Inch (1)
driver itself, .. with baffle, .. active filter, .. crossover network
SPL [dB]
Z [ohm]
100
90
80
70
60
50
40
60
50
40
30
20
10
20
50
100
200
500
1000
2000
5000
10000
20000
driver in enclosure in half room
.. with baffle influence
.. with active filter
.. with (passive) crossover netw
Impedance
Frequency response Cougar (2)
driver itself, .. with baffle, .. active filter, .. crossover network
driver in enclosure in half room
.. with baffle influence
.. with active filter
.. with (passive) crossover netw
Impedance
Frequency response Cougar (3)
driver itself, .. with baffle, .. active filter, .. crossover network
driver in enclosure in half room
.. with baffle influence
.. with active filter
.. with (passive) crossover netw
Impedance
Frequency response Cougar (4)
driver itself, .. with baffle, .. active filter, .. crossover network
driver in enclosure in half room
.. with baffle influence
.. with active filter
.. with (passive) crossover netw
Impedance
Calculation successful.



Automated Optimization:

Parts Selected For Optimization Appear In Red

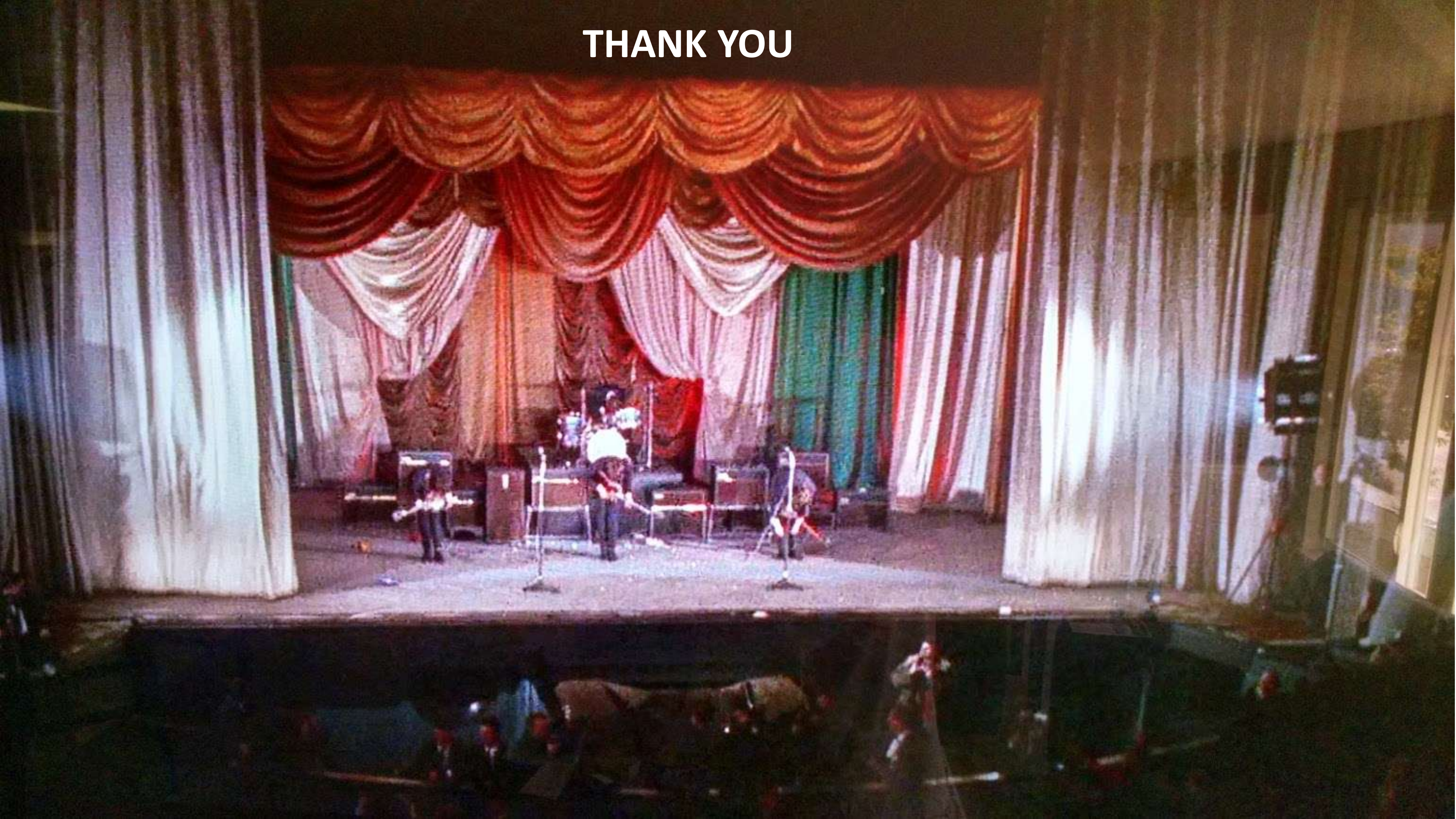

Boxsim - crossover network optimizer
Input
How do you like the bass
strong
slim
How do you like the treble
brilliant
english
Min. impedance for
preferably > 8 ohm
preferably > 4 ohm
preferably > 2 ohm
Efficiency
important
not important
Automatical fixation of capacitors and inductors
select capacitors manually
select resistors manually
Abort optimization
Output
results before optimization
judge impedance = 1.044
judge freq. response = 17.719
judge efficiency = 5.779
judge phase = 1.092
Total judgement = 13.546
results after optimization
judge impedance = 0.965
judge freq. response = 13.950
judge efficiency = 5.722
judge phase = 0.878
Total judgement = 11.195
Total judgement
Frequency respons
Efficiency
Impedance
Phase


4.000
220AC@60HZ
441P
SPRAGUE
10.0±10%
DAYTON
MPT 20uF 250V 5%
AUDIO GRADE
DAYTON
DAYTON
MPT 10uF 250V 5%
AUDIO GRADE
-SPRAGUE-
15.0±10%
220AC@60HZ
441P
-SPRAGUE-
20W8ΩJ
TYH 14.31
NON-IND
JANTZEN AUDIO
255-250
1mH 0.48Ω 18 AWG


ANALOG DEVICES
DANA
2016 – THE PUGET SOUND
2016 – THE PUGET SOUND
THE

Hey, those look a lot like …

THANK YOU



Software Tools:

- ARTALABS, Ivo Mateljan: Arta, Steps (Measurement Software)
- WT3 (woofer tester 3)
- Jeff Bagby: Baffle Edge Diffraction Simulator 1.20 (Baffle size / location)
- VISATRON: Boxsim V1.20 (Crossover design)
- WinISD pro Alpha (woofer box simulation)
- Bill "Collo" Collison: Boxnotes (midrange, woofer box resonance calculation)
- Leonard Audio: Transmission Line [Beta] (tweeter tubes sim)
- by Tom Irvine Matlab™ scripts FEM rectangular plates

Speaker Bill Of Material

Drivers:
ScanSpeak Discovery 30W/4558T 12" Subwoofer 4 Ohm (Madisound)
Dayton Audio RS180-8 (295-355 Parts Express)
AuraSound Cougar NSW1-205-8A 1" Extended Range Driver 8 Ohm (296-250 Parts Express)

Cabinets: 4.7 cu,in / tweeter, 2 liter mid range, 70 liter woofer:
BOM: 2 x sheets 4x8' 3/4" Birch plywood, 1 x 25 lb Barbell, 4 x 6" x 1" ID Steel Pipe, 4 x Rubber stoppers, Acoustic foam rubber, Hot glue, poster putty. 2' section of 6" ID plastic drain pipe, two half pipes per side (Home Depot), 3" Flared Port tube kit (268-350 PE) Cut to approximately 11".

Crossover: 150 Hz, 700 Hz Mid to Tweet is 4th order, Woofer to Mid is second order.

Attempted to tune box to 24 Hz with 11” long 3” diameter port. Added Foam for damping.

References

- http://www.leedh-acoustic.com/Documents/Presse/Stereo%20&%20Image/Stereo-Image-42-Fevrier-2010.pdf (worlds best drivers)
- www.linkwitzlab.com (speaker testing)
- Current-Driving Of Loudspeakers (how speakers actually work)
- AES Convention Paper 5908: A Virtual Loudspeaker Model to Enable Real-Time Listening Tests in Examining the Audibility of High-Order Crossover Networks. Cochenour & Rich
- Sound Reproduction, Floyd E. Toole
- Acoustics, Jean-Louis Migeot

References

- The Audio Critic, www.theaudiocritic.com Peter Aczel
- www.diyaudio.com
- www.douglas-self.com Douglas Self (amplifier design)

- On Youtube.com (Scientific method applied to audio)
  - Audio Myths Workshop (excellent demo of distortion audibility)
  - AES Damn Lies Workshop
  - Retrospective of the SMWTMS Audio Club (ABX testing)
  - Earl Geddes on Software Assisted Audio System Design (Dispersion)