AJHorn 6

Contents

1 Introduction

1.1 Licence agreement

AJHorn is a software for specialized users with relatively small number of copies but high expenditure for development. The program only could and can be developed when numbers of licences can be sold. As we want to protect against infringement, every delivered version has its' **unique serial number**. This can be found if you click in the main menu on "?" and then on "Info". The last number after the version number (for example 6.0.**127**) is the personal serial number of each licence. Due to this clear assignment, a complete solution is guaranteed in case of missuse. Generally it is not allowed to pass on an AJHorn licence, because AJHorn is licenced to the buyer at the date of purchase. The buyer has the responsibility to keep AJHorn secure.

1.2 Functionalities

AJHorn is an unique program for horn loudspeakers, transmission lines and special cases of this type, in which a quick and easy input of the parameters is paramount.
The types that can be simulated are for example:

- **Frontloaded Horns**
- **Frontloaded Hörner with bassreflex rear chamber**
- **Rearloaded Horns**
- **Rearloaded Horns with internal driver**
- **Classic Transmissionlines**
- **Transmissionlines with front chamber**
- **Transmissionlines with absorber chamber (Helmholtz absorber)**
- **Transmissionlines with two drivers**
- **Driver position along the Horn- or Transmissionline free eligible**
- **Bandpass-Horns**
- **Bandpass-Transmissionlines**
- **Bandpass with vented rear chamber**
- **Passive multiway systems**
- **Mid- and high frequency horns**
- **7 contoures eligible, e.g. conical, exponential or Traktrix**

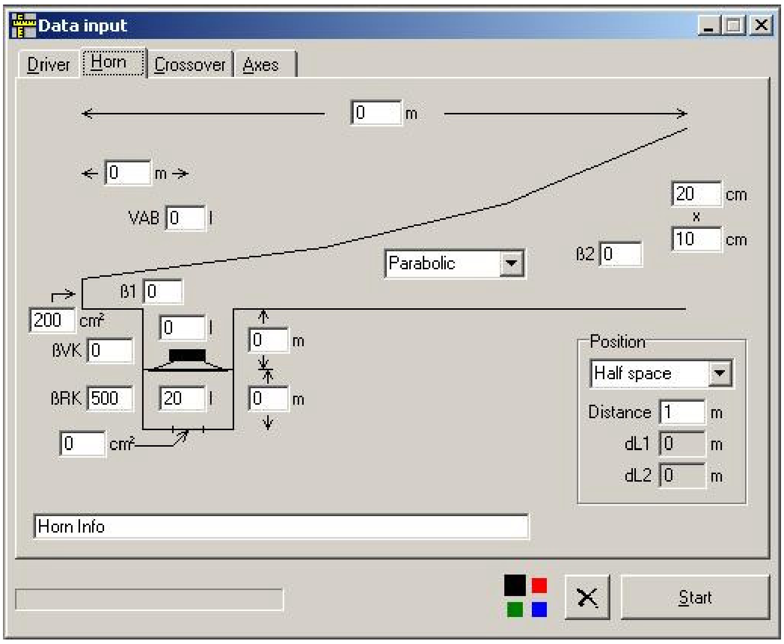
The various output-parameters of the simulations are:

- **Sound pressure frequency response** in dB in any distance (dependent of position)
- **Frequency response of the electric impedance** in ohms
- **Frequency response of the cone excursion** of both drivers
- **Frequency response of the linear maximum sound pressure** in dB
- **Frequency response of the necessary electrical power** for the linear maximum sound pressure
- **Frequency response of the unified acoustic radiation impedance** on the horn throat
- **Radius of opening function** in cm (plot)
- **Area, height and radius of the opening function** (ASCII-numbers)

The predictions of the model has been confirmed through accurate testing. The program runs with WINDOWS version 95/NT or later.

1.3 AJHorn 6 innovations

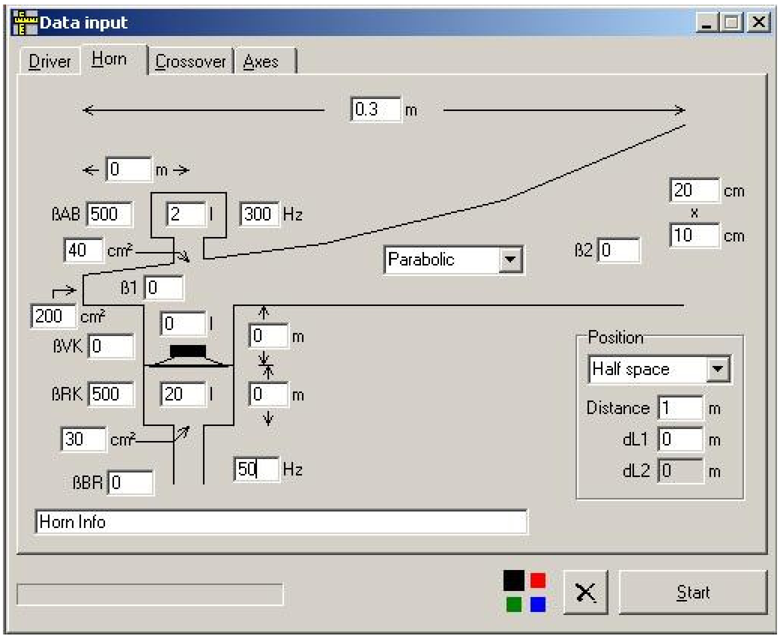
The changes for version 6 are technical an graphical. It was tried to build more functionalities user requested and for optimization of existing constructions. The new features of AJHorn 6 are unique and bring the user nearer to the optimum.



0 m
0 m
VAB 0 l
20 cm x 10 cm
Parabolic
ß2 0
ß1 0
200 cm²
ßVK 0
0 l
0 m
ßRK 500
20 l
0 m
0 cm²
Position: Half space
Distance 1 m
dL1 0 m
dL2 0 m
Horn Info

Visual Horn representation

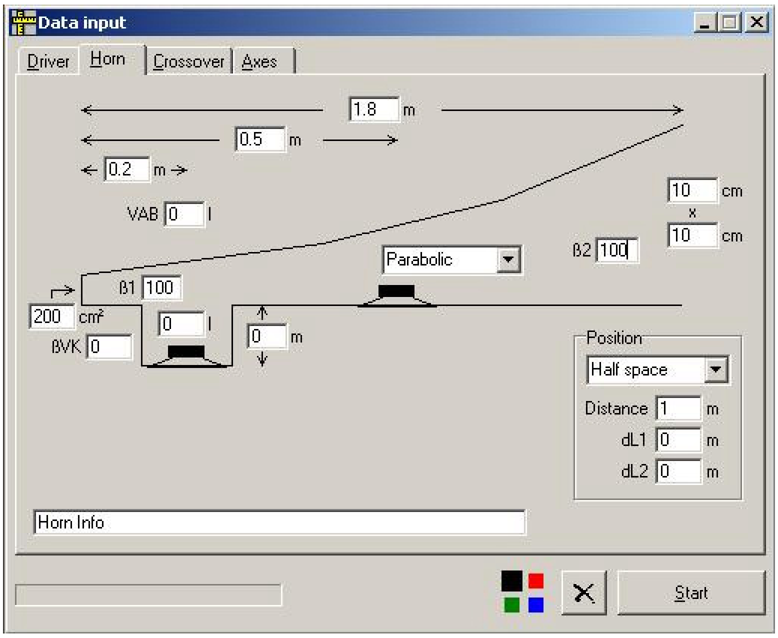
The data input simplifies considerable with the visual representation in comparison with the formular symbols of previous versions. The user can klick on different positions of the horn graphic to select intuitively the different properties (Frontloaded, Rearloaded, second driver, second rear chamber). After a small training period the perfect input of the various dimensions is very easy. Some mouse klicks later, the user has added an absorber chamber and a bassreflex rear chamber.



0.3 m
0 m
ßAB 500
2 l
300 Hz
40 cm²
20 cm x 10 cm
Parabolic
ß2 0
ß1 0
200 cm²
ßVK 0
0 l
0 m
ßRK 500
20 l
0 m
30 cm²
50 Hz
ßBR 0
Position: Half space
Distance 1 m
dL1 0 m
dL2 0 m
Horn Info

Second driver

With AJHorn 6 it can be added a second driver at any position between driver 1 and the horn mouth. As a practical application the user can simulate with AJHorn 6 the popular transmissionlines with two drivers.



1.8 m

0.5 m

0.2 m

VAB 0 l

10 cm x 10 cm

Parabolic

ß2 100

ß1 100

200 cm²

ßVK 0

0 l

0 m

Position

Half space

Distance 1 m

dL1 0 m

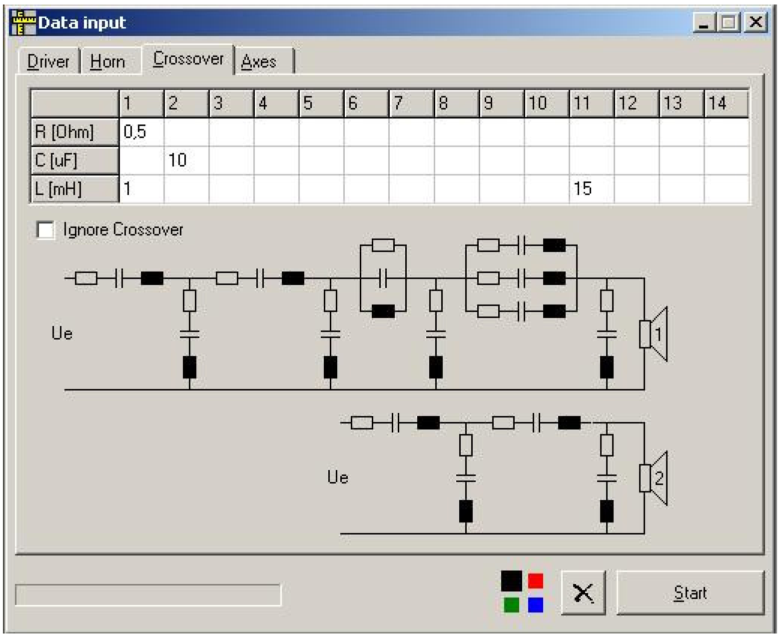
dL2 0 m

Horn Info

The two drivers can have the same or different Thiele Small Parameters. Driver 2 can also have its own rear chamber. The advantages of such an arrangement aren't well-known until now. With this setup constructions of e.g. mixtures of Front- and Rearloaded Horns with the bass performance of a Frontloaded Horn an the clear midrange reproduction of a Rearloaded Horn are possible. By turning over or changing the polarity of driver 2 the projects can be optimized, too.

Crossover for driver 2

For each of the both drivers a passive crossovers can be designed to reach best possible flexibility.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
R [Ohm]	0,5													
C [uF]		10												
L [mH]	1										15			

☐ Ignore Crossover

Compatibillity with earlier AJHorn versions

Projects from earlier versions of AJHorn can be loaded and modified without problems.

Extension of the AJHorn impedance theory

One of the most important technical reforms (and also the time-consumingest) is hardly visible on the first view. Now also the front chamber, the rear chamber and the bassreflex port are simulated with the AJHorn impedance theory, and not only the horn itself. Now projects with for example with relatively large or long front chambers or long bass reflex ports are simulated more exactly. Time- and phase differences are also better considered now.

Frequency dependant damping

In practice it appeared that damping material has a stronger effect with increasing frequency. The input of the beta values remains unchanged, however in the simulation the damping is now frequency dependent.

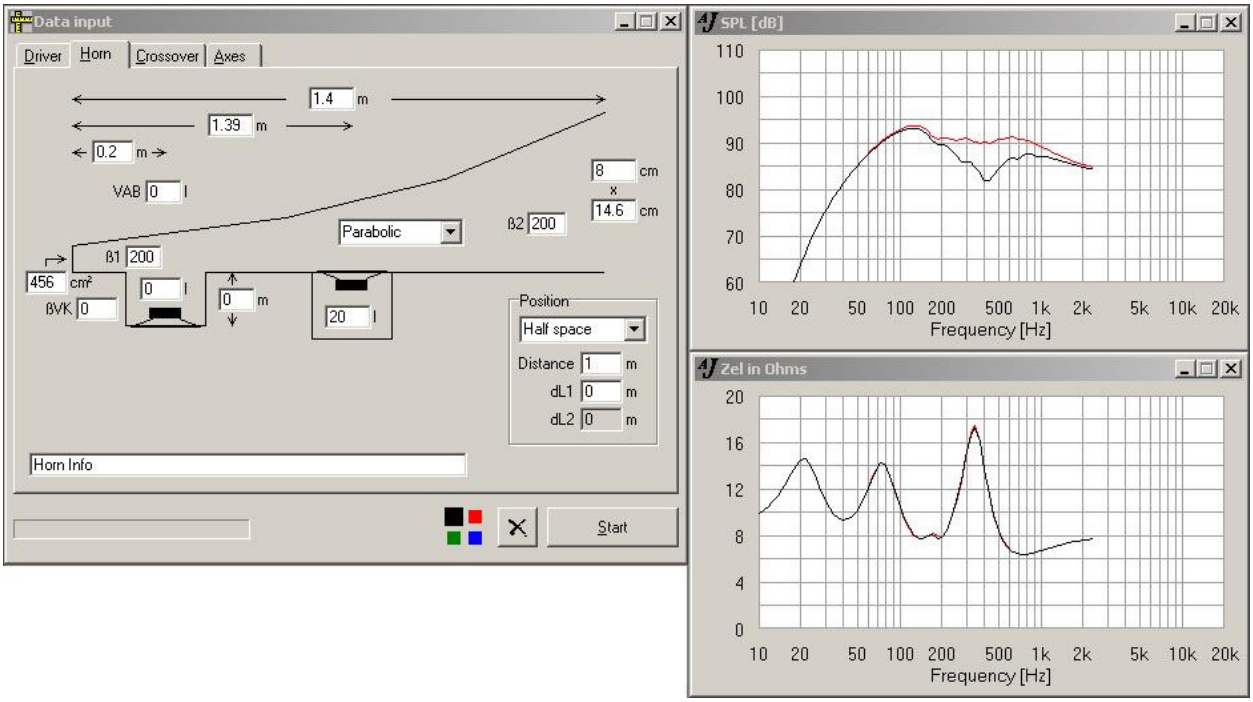
Colors of the output graphs

The different output graphs change no longer automatically their color, but through manual selection of one of the four colors in the input window.

Multiway systems

Often the optimization of the passive crossover causes problems, just between bass and midrange. Phase problems are the reason for that because the resonance frequencies of the single drivers lie often in the separation area. AJHorn is not supposed to be able to be offer the last possibility to optimize a crossover – this happens also today yet and in the future only through precise measurements and hearing – however the program can give hints in the optimization.

The following image shows the input data and the accompanying simulation result for the separation of two drivers at approx. 400 Hz. Driver 2 (midrange) has its own closed chamber and is set very nearly at the horn exit (driver position 2 = 1.39 m). That means, it radiates without influence of the horn. The black curve shows the simulation with driver 2 turned around, the red curve with driver 2 not turned around (therefore like on the picture below). Because driver 2 is not mounted in the practice with the magnet outward, the red simulation result arises also if one changes the polarity of driver 2 and mounts it with the magnet interior.



1.4 m

1.39 m

0.2 m

VAB 0 l

8 cm x 14.6 cm

Parabolic

ß2 200

ß1 200

456 cm²

ßVK 0

0 l

0 m

20 l

Position: Half space

Distance 1 m

dL1 0 m

dL2 0 m

Horn Info

1.4 History of the horn loudspeaker

Horns were used at the beginning of sound reinforcement to increase the efficiency of mechanical and electrodynamic drivers. A good example of this increase in efficiency is the gramophone, which converted the vibrations of the stylus from the record groove into audible vibrations of the air. Later, drivers were inserted in place of the stylus which were in turn fed by electrical signals. The sound quality of such horns was generally quite poor by today's standards. Eventually, primarily because of the development of more powerful amplifiers, direct radiator systems took the place of horn loudspeakers in most areas of sound reproduction and especially in the home.
Today, horns are used for many different reasons. In the case of public address systems, the demands for loudness and precise directivity have increased to the point that, in high quality systems at least, horns must be used. Other applications of horns are the standard installations in discotheques and commercial theaters. Finally, horns are built for home useage in High-End and Ultra-Fi systems. For PA systems at low frequencies, horns make possible efficient reproduction with high maximum sound pressure and acceptable cabinet size. For High-End or HiFi-use the linear sound pressure frequency response is a priority.

All of these horn types can be simulated and optimised by AJHorn.

1.5 To the theory

If you aren't knowledgeable about the theory of electrical-mechanical-acoustical systems, you can skip this section. It is not required for the operation with the program.
The complete theory of horn loudspeakers is too complex to describe here in this manual. Moreover AJHorn does use partly modified attachments, but regardless, the classic theory will be explained roughly. After the theory of one-dimensional acoustic wave guides, the pressure and velocity response versus horn length can be described with the fundamental horn equation (Webster, 1919)

$$\frac{\partial^2 p}{\partial x^2} + \frac{1}{A}\frac{\partial A}{\partial x}\frac{\partial p}{\partial x} + k^2 p = 0$$

This differential equation of the 2nd order has solutions which are dependent on its' boundaries. Through the use of boundaries for the hornthroat and hornmouth, the specific radiation impedance of the hornthroat can be determined as a function of the specific radiation impedance of the hornmouth. In case of a cylindrical tube, the radiation impedance devided by ρ*c (ρ= densitiy of the air, c= speed of the sound) results in a relatively wavey curve with some resonance peaks. This function can be seen very clearly with AJHorn. Because the radiation impedance has its mark immediately in the radiated acoustic power, the resulting sound pressure frequency response of a cylindrical tube must also be very wavey. This is not in accordance with lifelike sound reproduction.
If the unified radiation impedance of a continuously enlarged cone is calculated, it will be established that with increasing moutharea, a linearisation of the impedance occurs. This phenomenon is well-known as “impedance transformation”.
With the clever choice of the opening function (horncontour), the loudspeaker perameters, and front- and rear-chamber volume, a linear sound pressure frequency response can be obtained. This is the primary requirement for lifelike music reproduction.

During the attempts at finding the optimal horn for use, when you change the values you will find that nearly all parameters affect each other. So it's possible for example, that the front chamber volume could affect the low cut-off frequency or the linearity of the sound pressure. Also the throat area can have an effect on the linearity or the efficiency in the middle frequency range. Also it's possible with certain parameters, that a conical horn can have a lower cut-off frequency when compared to a hyperbolic horn.
The program will accurately record the influence of a passive crossover. At this point an investment in a high quality simulation program like AJHorn is recommended because the complex impedance has an important influence on the crossover.

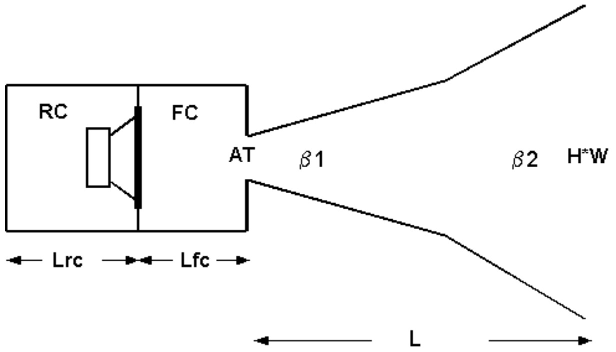
As you can see from these examples, it is not very useful to calculate the low or high cut-off frequency of a horn with the help of simple formulas and a pocket calculator. This is quiet possible and with very good results for a closed or a bass-reflex enclosure, but the only way to calculate the frequency response of a horn (and also of a Transmissionline) with high precision is through a computer simulation program like AJHorn.

2 Simulation of the various enclosure types

Through its modular construction, AJHorn offers the simulation of different enclosure types with the same calculation algorithm. This is interesting, as the theory for the horn calculation is not confined to a single enclosure type. It is the perfect solution of the acoustic conditions. The borderline cases -- transmissionline, bass-reflex, band-pass and closed box types -- are included as well. If a bass-reflex enclosure will be described as a Helmholtz resonator or as a rearloaded conical horn with a relatively big frontchamber whose throat area is equal to the mouth area – that's a purely matter of definition. In practice, both types are identical and the following examples will show this clearly.

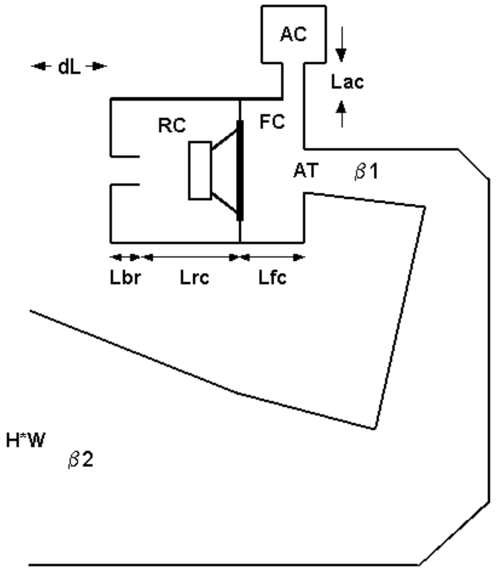
2.1 Frontloaded Horn

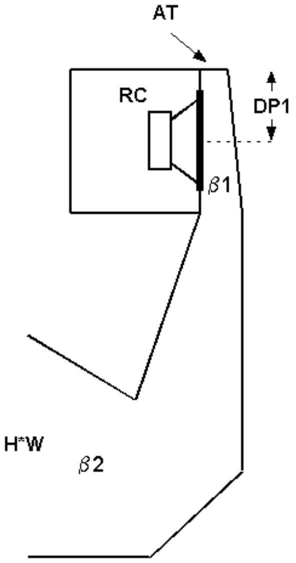
You can see from the folowing figure, that a Frontloaded Horn constitutes a situation in which the front of the driver contributes acoustic power along with the horn. The backside of the driver radiates in a closed or vented chamber (RC) with the volume VRC. The length of the closed back chamber does with sufficient damping not have influence on the simulation result.



In front of the cone is a front-chamber (FC). The length of the front-chamber (Lfc) is defined as the acoustic distance between driver diaphragm and throat. The horn itself will be described through its mouthheight (H), the mouthwidth (B), the length (L) and the throat area (AT) as well through its contour (parabolic, conical, exponential, hyperbolical, geometrical or tractrix). Also, the influence of damping material is taken into consideration through the choice of the coefficients of friction ß1 and ß2. The coefficient ß1 is the damping result on the horn throat and ß2 on the hornmouth. Between these points, the damping will be assumed to be linear. The difference length (dl) is playing no part when the rear chamber is closed.

The following schematic figures describe the usage of the absorber chamber (AC) and the driver position (DP).





The left horn has a vented rear chamber (RC, “bassreflex rear chamber”) and an absorber chamber (AC, “Helmholtzabsorber”). There is eventually a difference in distance between horn mouth and the bassreflex port exit relative to the listener position (microphone). To describe this influence the variable “dL” (difference length) is used. The variable dL is defined as

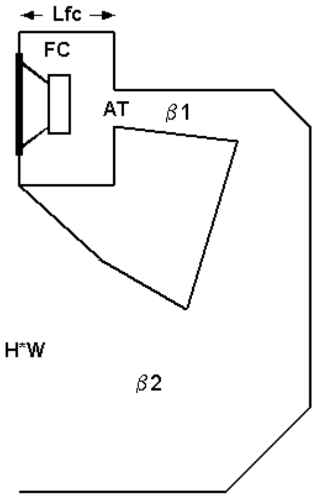
$$dL = \overline{\text{listener, port exit}} - \overline{\text{listener, horn mouth}}$$

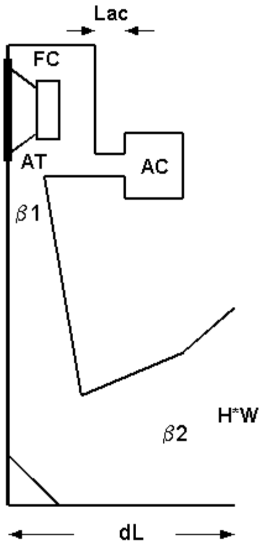
The difference length is positive, when the horn mouth is nearer to the listener than the port exit.

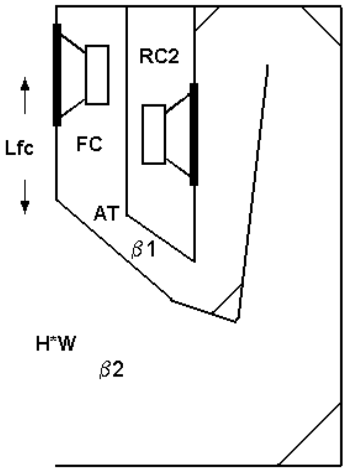
The right horn functions like many frontloaded horns at the market. To reduce the total volume, the front chamber is as small as possible (VFC = cone volume of the driver). This design results in unsymmetries in the front chamber region, which have influence in the sound pressure response. AJHorn simulates this phenomenon by typing in the correct value of DP1 (**“driver position”**).
Attention! The throat area (AT) is the area at the beginning of the horn, not the area at the driver position.

2.2 Rearloaded Horn

The difference between the Rearloaded and the Frondloaded Horn is the dropped rearchamber in the Rearloaded Horn. The driver1 radiates the sound directly over the cone and indirectly over the horn.
Schematic examples show the three following pictures.







The horn has the mouthheight (H), the mouthwidth (W), the hornlength (L), the difference length (dL), the throat area (AT) and a frontchamber. There can exist an absorber chamber (AC) connected to the front chamber. The horn can open with different contours as explained on the Frontloaded horn. The influence of damping material can be described with the coefficients ß1 and ß2. The difference length (dL) is the length difference between both sound radiating media referred to the listening position. It can be calculated with the following equation.

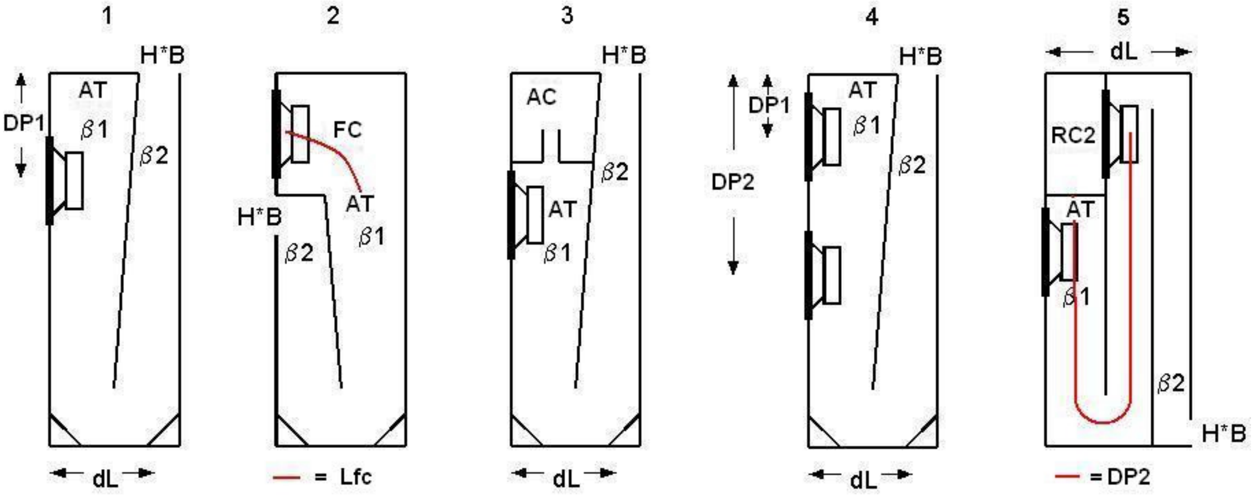
$$dL = \overline{\text{listener, horn mouth}} - \overline{\text{listener, cone}}$$

The difference length is positive, when the cone is nearer to the listener than the horn mouth. If the sound of the cone and the hornmouth must take the same path to the listening position, so the difference length is 0. This length between the cone sound and the sound of the hornmouth is playing a part by the phase-correct addition of both pressures.

The right horn possesses an interior driver (driver2), through whose closed back chamber the bass output gain can be increased. With this simulation possibility, older constructions (classic Rearloaded horns) can be improved if yet unused volume is available. Whether and like so a construction then functions, lets simulate and optimize itself with AJHorn.

2.3 Transmissionline

A Transmissionline is an enclosure type like the Rearloaded Horn. The horn however is not increasing itself, but it tapers its area with length, or it keeps the same cross-section. It can also have a frontchamber. The folowing figures show different possibilities of realization of a Transmissionline.

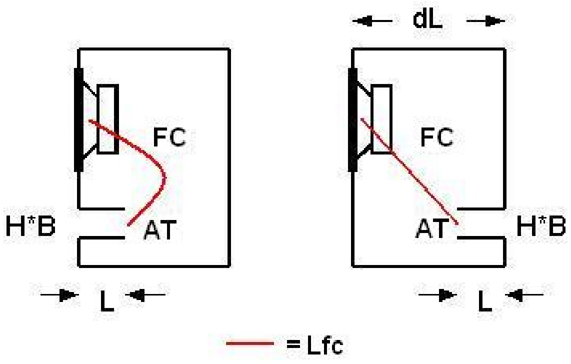


1. shows a classic transmissionline folded one time.
2. is a classic transmissionline with front chamber.
3. has a similar function as No. 1, but with an absorber chamber (AC). This chamber functions like an internal “Helmholtz” absorber.
4. shows a transmissionline with two drivers at the positions DP1 and DP2
5. is a combination out of classic transmissionline with additional interior driver. Through adept choice of the position of driver2 (DP2) resonances of the line can be suppressed and let reinforce other frequency ranges.

The Transmissionline has the mouth height (H), the mouth width (B), the length (L), a possible difference length (dL), the throat area (AT) and a frontchamber (FC). Influences of damping material are taken into consideration over the coefficients ß1 and ß2. Because it's an open construction, you must choose the Rearloaded Horn as horntype. Attention! The throat area (AT) is the area at the beginning of the transmissionline, not at the driver position.

2.4 Bassreflex enclosure

This type of a loudspeaker enclosure will also be named as a Helmholtz resonator. There exist many theories about the acoustic simulation of this enclosure type; some partly tabular, but others in the form of calculation programs. AJHorn calculates the frequency responses in the view of the radiation impedance of the cone and the resonance frequencies of the port. Damping phenomenon, like the influence of absorption material in the tunnel or losses of the port, are also taken into consideration over the coefficients ß1 and ß2. The folowing firgures show the construction of a bass-reflex enclosure.



The input-data are the mouthheight (H), the mouthbreadth (B), the length of the vent (L, Hornlength), a possible difference length (dL), the area at the beginning of the vent (AT, throat area) and the volume (FC, frontchamber volume). The length of the front chamber (Lfc) is the acoustical length between driver and port beginning.

Ports with a round cross-section have throat area (AT) and mouth area (H*B) and should be selected such that the cross-section are in accordance with the area. The form plays a secondary part. The area of a port with diameter d is

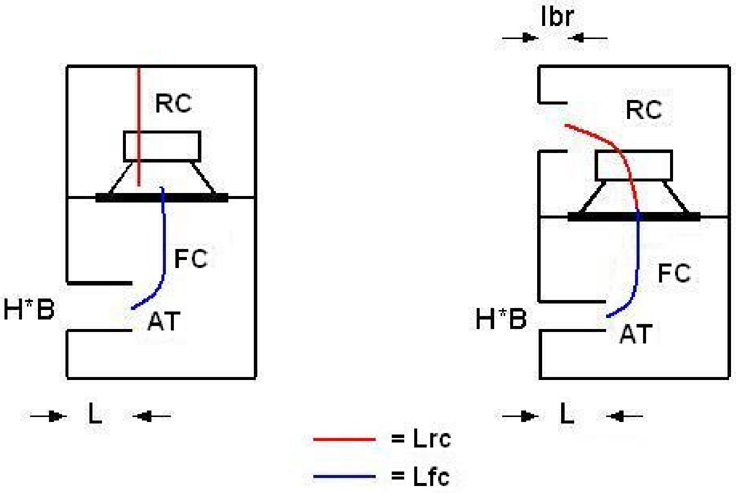
$$A[cm^2] = \frac{\pi \cdot d^2}{4}$$

d = inner port diameter in cm.

Damping material in the front chamber as well as the influence of absorption material in the tunnel or canal losses are considered over the coefficients βvk, β1 and β2 bvk also.
The difference length again describes the difference from the cone to the port exit relative to the listening point. Because it's an open system, the Rearloaded Horn as horntype must be chosen. Of course, the vent can increase or taper its area with length, so there are many different enclosure types possible, of which we cannot give a precise assignment. The results of the simulation, however, are correct.

2.5 Bandpass enclosures

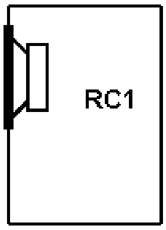
A Bandpass-enclosure consists of a closed or vented rearchamber (RC) and a frontchamber (FC) with a connecting vent of length (L). It's a special case of the Frontloaded type. The folowing figures show the construction of a classic bandpass and a bandpass with vented rear chamber.

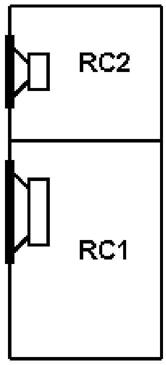


Also, the port with a constant cross-section can run over the length, can open itself, or taper its area with length. The different enclosure types like Bandpass-Transmissionline or Bandpass-Horn open themselves to a simulation. The throat area (AH), the mouthheigth (H) and mouthwidth(B), the length of the rear chamber (Lrc) and front chamber (Lfc) are defined like the enclosure types above.
Each chamber of the vented bandpass should have different tuning frequencies otherwise a acoustic short circuit is the result (one wave erases the other). AJHorn simulates through the expanded impedance theory in version 6 also the resonance frequencies of both ports and the chambers.

2.6 Closed box

The closed box is the simplest solution to operate a low frequency loudspeaker. It prevents, because of the closed rearchamber, sound output from the front and back of the cone from cancelling each other (acoustic short-circuit). This enclosure type is also calculable with AJHorn, because it's a special case of the Frontloaded Horn. An example for a closed system will be loaded on every start of AJHorn. The folowing figures show the construction of a closed box.





The closed box is a Frontloaded Horn, on which the frontchamber volume and the hornlength are set to zero. The throat area corresponds just as the mouth area (H*B) to the cone area (SD) of the Chassis (s. also 4.2).
Also - by adding of driver2 - systems with two bass chambers and different crossover frequencies or multiway systems can be simulated.

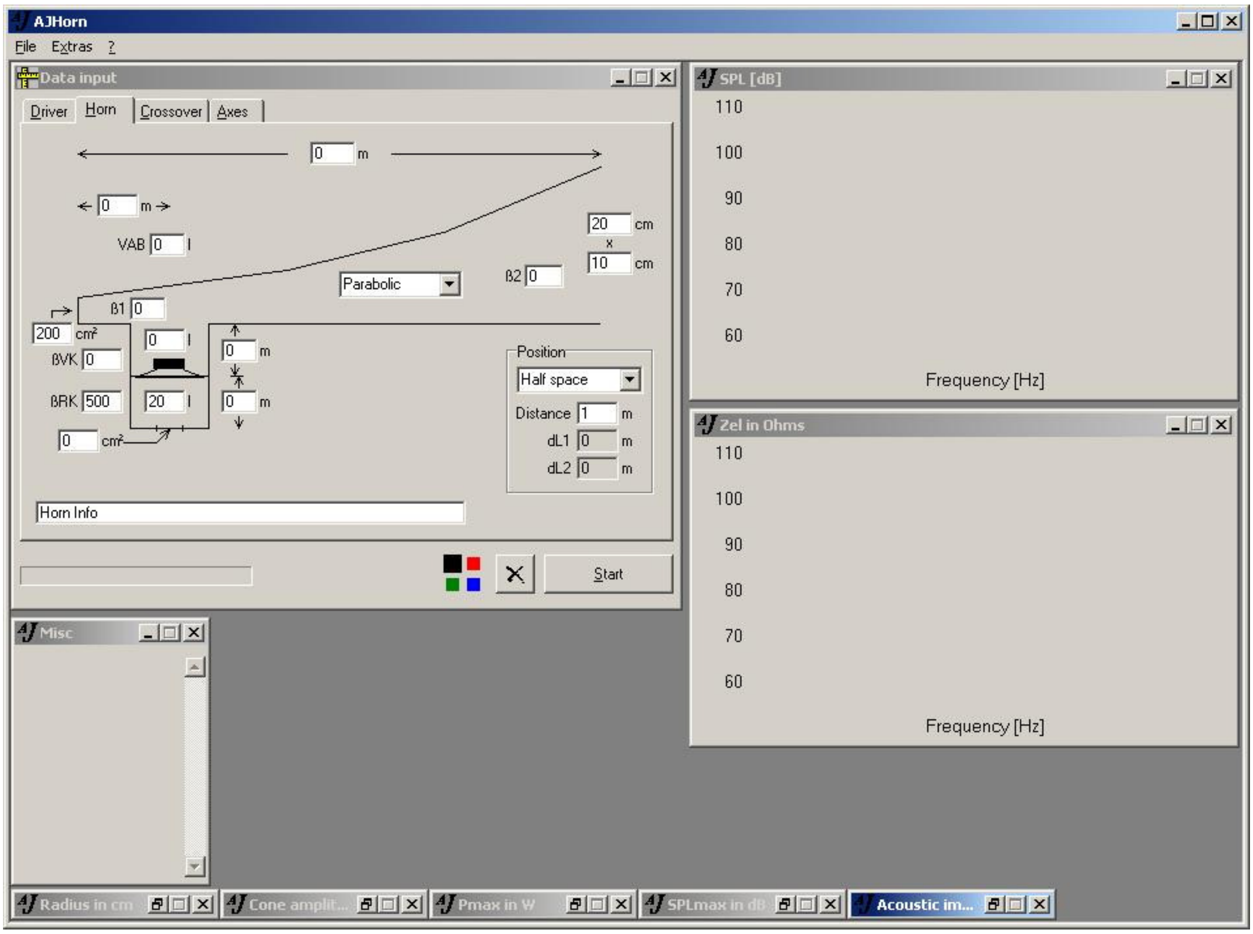
3 First steps

3.1 Setup

AJHorn places no special demands on the relevance of the operating system and runs on all 32 bits Windows versions (95, 98, NT4.0, ME, 2000, XP, …). For the installation, the file SETUP.EXE must be executed. Follow the instructions on the screen. AJHorn is then installed on your computer.

3.2 Starting AJHorn

For the start of AJHorn use the Task-strip /programs/AJHorn. You can see now the main window of AJHorn.



0 m

0 m

VAB 0 l

20 cm x 10 cm

Parabolic

B2 0

B1 0

200 cm²

BVK 0

BRK 500

0 l

20 l

0 m

0 m

0 cm²

Position: Half space

Distance 1 m

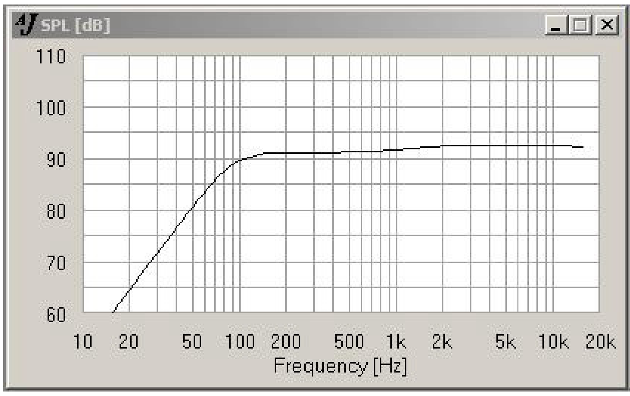
dL1 0 m

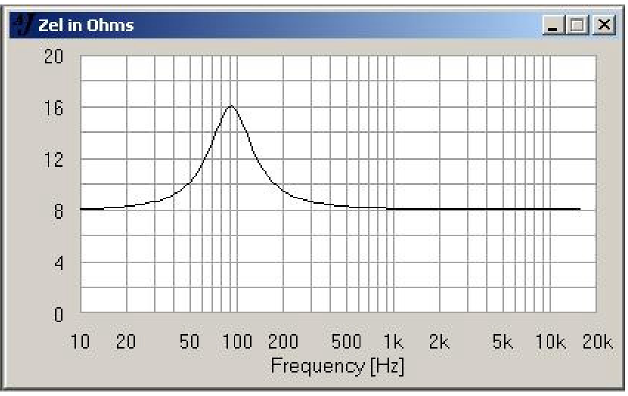
dL2 0 m

Horn Info

3.3 First simulation

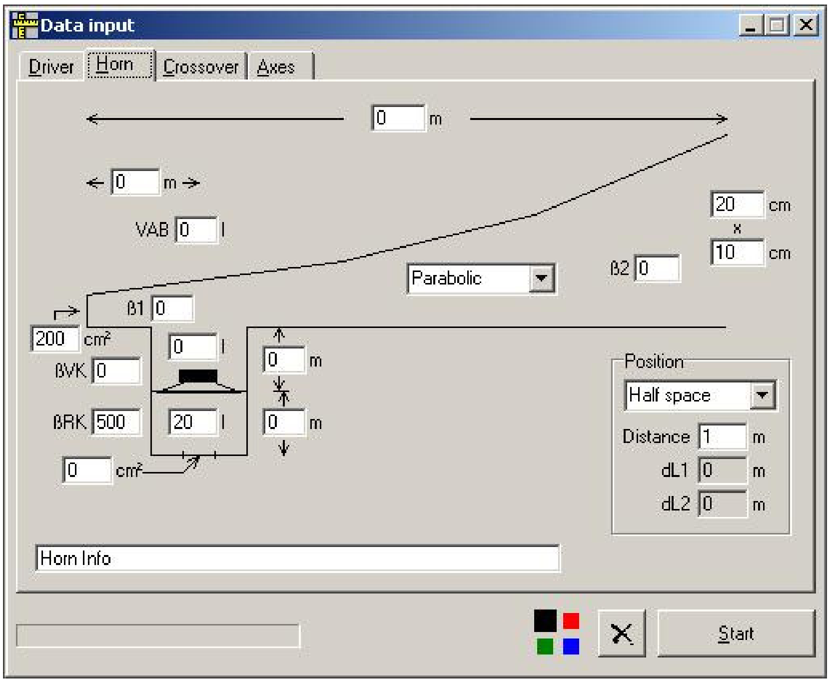
At startup, AJHorn loads standard values into the file NEW.HRN. This filename is reserved for AJHorn. Click on "Start" in the menu and AJHorn starts to calculate. After the calculation you can see the following graphic.





NEW.HRN is a loudspeaker with a closed box and a Q-factor QTC of 0.71 (Butterworth). This you can see on the smooth fall of the sound pressure to lower frequencies. AJHorn calculated the other responses, which you can see if you activate the minimized windows.

As mentioned, NEW.HRN is a loudspeaker in a closed box. It has neither a frontchamber nor a hornport. You can see that the frontchamber volume (VFC) is 0 and the hornlength (l) is 0. Also, the throat area (AT) and the mouth area (H*B) is like the cone area (SD). The input data for the horn shows the following depiction.



0 m

0 m

VAB 0 l

20 cm x 10 cm

Parabolic

ß2 0

ß1 0

200 cm²

ßVK 0

0 l

0 m

ßRK 500

20 l

0 m

0 cm²

Position: Half space

Distance 1 m

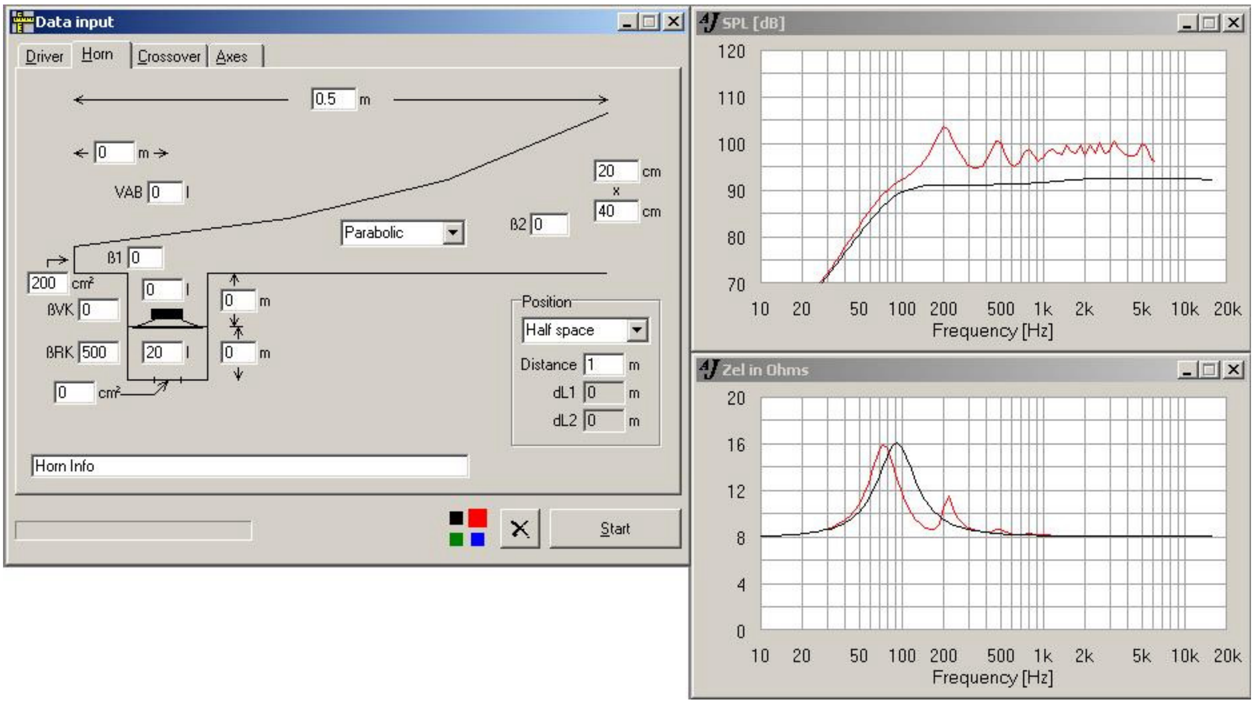
dL1 0 m

dL2 0 m

Horn Info

3.4 Second simulation

Next, a parabolic horn will be simulated in which the throat area is like the cone area and the mouth area corresponds to the fourfold throat area (H*B = 800 cm²). The length of the horn is 0.5 m. The color of the output graph ist changed to red. The input data for AJHorn and the simulation results are shown in the following depiction.



0.5 m

0 m

VAB 0 l

ß1 0

200 cm²

ßVK 0

ßRK 500

0 cm²

0 l

20 l

0 m

0 m

Parabolic

ß2 0

20 cm x 40 cm

Position: Half space

Distance 1 m

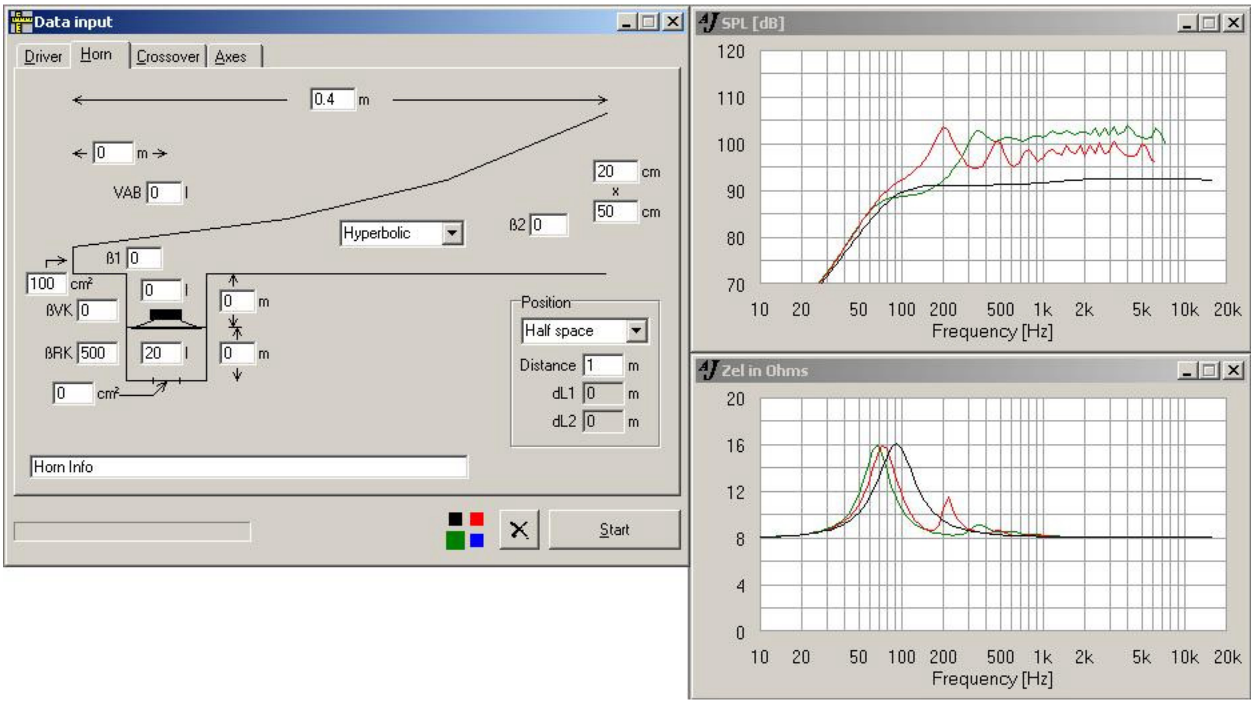
dL1 0 m

dL2 0 m

Horn Info

Concerning the first version, there is an increase in efficency at the middle frequencies of about 5 dB, but this is accompanied by a more uneven frequency response.

Through the clever choice of the input parameters you can get a smooth frequency response for a pleasant sounding loudspeaker. The result of such an optimisation is shown in the following depiction.



0.4 m

0 m

VAB 0 l

ß1 0

100 cm²

ßVK 0

ßRK 500

0 cm²

0 l

20 l

0 m

0 m

Hyperbolic

ß2 0

20 cm x 50 cm

Position: Half space

Distance 1 m

dL1 0 m

dL2 0 m

Horn Info

This horn loudspeaker can be used from 300 Hz. It has a much better frequency response and a higher efficency than the non-optimised version.

3.5 Outlook

Using the method from the previous section, any Horn- or Transmissionline loudspeaker can be optimised on the computer. Not until the simulation is succesfull, the loudspeaker will be built.

For an exact understanding of the input parameters in the directory \examples will be shown of various standard simulations for loudspeakers with the closed, the Bassreflex-, the Horn- and the Transmissionline principle. TML2.hrn shows how you can, by changing the mechanical data of a Transmissionline, reduce the famous “Transmissionline-hole” of about 10 dB at TML1.hrn to below 3 dB.

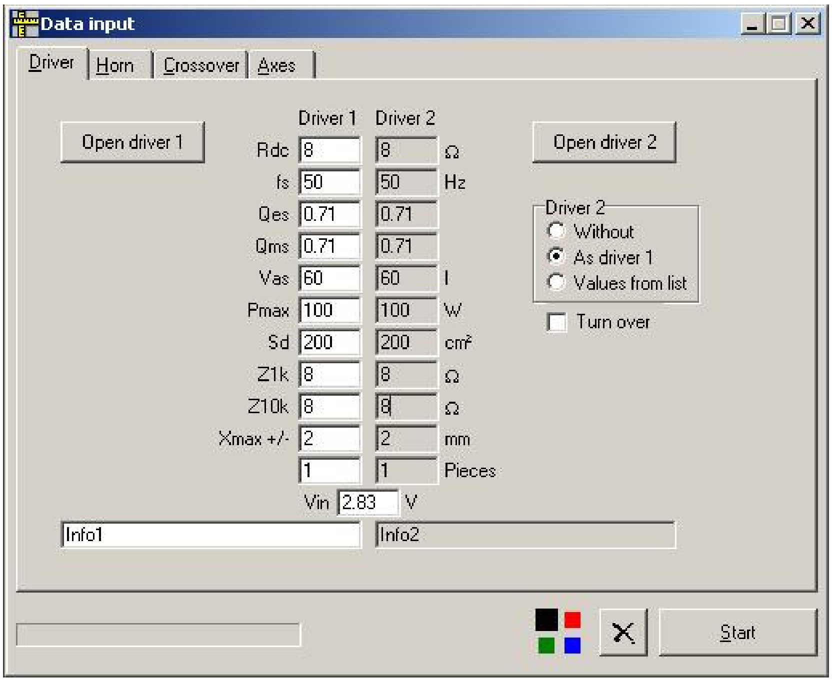
From this input data you can see what should be taken into consideration. For the modification and for the receipt of the data the file should be stored under another name (for example in \[your name]\[filename]).

4 Data input

After the presentation of the different enclosure types which can be simulated with AJHorn, we now turn to the data input. We have tried to make the data input as easy as possible in order not to confuse.

4.1 The driver

Loudspeaker-Chassis will be described through the Thiele – Small – Parameters (TSP), which are in common use today. They give information about the features of the loudspeaker near its resonance frequency. The frequency response of a horn depends, as with the simpler enclosures, for the most part on the loudspeaker selected and its TSPs. Therefore, it's important to know these parameters. They will be published in specialist journals, in the data sheets of the manufacturer, or they are available as a data base. You can also consult the manufacturer or the sales departments directly. In addition to this, the TSP can be determined relatively easy with computer-controlled measurement-systems, which are common and affordable. For the determination of the parameters without a computer measurement-system books about acoustics may provide useful suggestions.



	Driver 1	Driver 2	
Rdc	8	8	Ω
fs	50	50	Hz
Qes	0.71	0.71	
Qms	0.71	0.71	
Vas	60	60	l
Pmax	100	100	W
Sd	200	200	cm²
Z1k	8	8	Ω
Z10k	8	8	Ω
Xmax +/-	2	2	mm
	1	1	Pieces

Vin 2.83 V

Info1

Info2

Driver 2
○ Without
● As driver 1
○ Values from list

☐ Turn over

Button “Open driver”
Here you can select an AJHorn file (.hrn), from which only the driver data is loaded. The remaining data of the current project remain untouched. To the compatibility with older versions, allways the values of DRIVER1 are selected and assigned to driver1 or driver2 of the current project.

Rdc (DC-Resistance)
This value, which is given in electrical ohms, describes the resistance of the coice coil when constant current flows through it.

Fs (Free Air Resonance)
This value in Hz (Hertz) describes the resonance of the mechanical pendulum consisting of the cone mass and the compliance of the suspension.

Qes (Electrical Q-Factor)
This dimensionless value describes the influence of the electrical damping.

Qms (Mechanical Q-Factor)
This dimensionless value describes the influence of the mechanical damping.

Vas (Equivalent Volume)
This value in L (litres) describes the volume which is necessary to achieve the same spring stiffness as the suspension through the cone-edge termination and the spider.

Pmax (Power Handling)
This value in Watts indicates the speaker's maximum electrical power handling capacity. This will be needed for the calculation of the linear electrical power capacity and for the maximum sound pressure.

Info
Here you can write down comments for the selected driver, e.g. the driver type.

Sd (Cone Area)
This value in sq.cm describes the effective oscillating area of the loudspeaker-cone.

Z1k and Z10k (Impedance at 1 kHz and 10 kHz)
The voice coil inductivity of a loudspeaker is not constant for all frequencies, as generally it declines at higher frequencies. Also, the voice coil inductivity has an imaginary part, which depends on frequency, too. This phenomenon will be calculated when the electrical impedance in ohms is put in for two frequencies (1 kHz and 10 kHz). From the impedance response of a loudspeaker, you can read these two values very well.
Attention! If these values are not available, the value for the DC-resistance should be selected for both values. However, it must be taken into account that the simulation of middle and higher frequencies won't be correct. Also, the influence on the passive crossover, especially with a higher crossover frequency, is not correct.

Xmax (Linear excursion)
This value indicated in +/- mm, describes the maximum excursion of the voice coil to the point it leaves the homogeneous field of the magnetic field. If this value is exceeded, the force on the voice coil will be reduced and it behaves with non-linearities (harmonic distortion). The maximum nonlinear excursion can be much higher than Xmax. When this value is not indicated in the data sheet of the loudspeaker, it can be calculated with the following equation:

$$X_{\max} = \frac{H_{VC} - H_{AG}}{2}$$

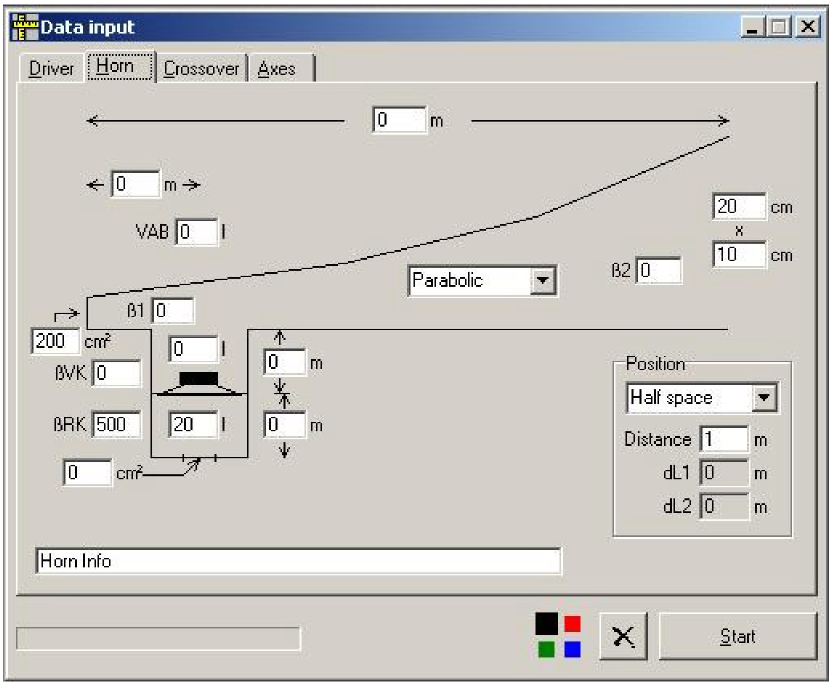
HVC is the winding height of the voice coil and HAG is the height of the top plate (upper air gap).

Number of drivers (pieces)
This value describes the number of the parallel connected drivers in a horn. Please take into account that all these are working together in one horn with the mouthheigth H, the mouthwidth B, the rearchamber volume VRC etc.

Ue (Input Voltage)
At this point, the electrical input voltage can be put in in volts (V). When a simulation at one watt should be made then for 4 Ohms drivers 2 V and for 8 Ohms drivers 2.83 V are the input values.

4.2 Horn

In this section the dimensions and volumes of the horn, the horntype, and the shape function of the horn will be indicated. For the illustration of the input parameters, the graphics in section 2 are useful, as well.

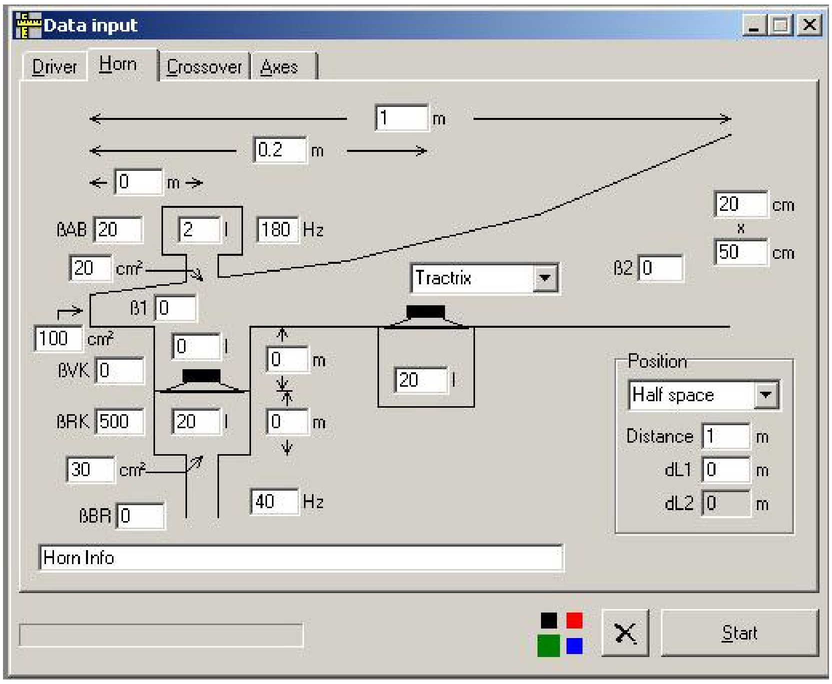


0 m
0 m
VAB 0 l
20 cm x 10 cm
ß2 0
Parabolic
ß1 0
200 cm²
ßVK 0
0 l
0 m
ßRK 500
20 l
0 m
0 cm²
Position: Half space
Distance 1 m
dL1 0 m
dL2 0 m
Horn Info

The horn graphics can be clicked on at different places in order to select so between the different types. Individually these are

- Click on the rear chamber ► change between front and rearloaded.
- Click on the rear chamber 2 ► adding / removing the rear chamber 2.
- Input VAB (volume of the absorber chamber) > 0 l ► Absorber chamber is added.
- Area of the bass reflex port > 0 cm² ► bass reflex port is added.

Possibly must be clicked to the activation of the field yet on any other field. The activation of all elements leads to following construction, that is to be optimized in most cases however hardly.



1 m
0.2 m
0 m
ßAB 20
2 l
180 Hz
20 cm²
20 cm x 50 cm
Tractrix
ß2 0
ß1 0
100 cm²
ßVK 0
0 l
0 m
20 l
ßRK 500
20 l
0 m
30 cm²
40 Hz
ßBR 0
Position: Half space
Distance 1 m
dL1 0 m
dL2 0 m
Horn Info

Contour

The naming of the shape functions is based on historical statements. In accordance with this, the contour will be considered as the radius of a circular horn. People without well-grounded knowledge in the function theory can leave out this section. They can plot the various functions with AJHorn, or list the values with an editor.

Parabolic	A Parabolic Horn is a type which increases its radius with the square root function. The area is therefore proportional to the length.
Conical	A Conical Horn is a type which increases its radius linearly with the length. The area is therefore quadratic to the length.
Exponential	The radius of an Exponential Horn increases itself with the exponential function (e-function). Through the peculiarity of this function, the area also increases itself exponentially.
Hyperbolic	The radius of a real Hyperbolic Horn increases with the cosine hyperbolic function (cosh). The area, therefore, varies with the square of cosh.
Octo Hyperbolic	The radius of an Octo Hyperbolic Horn goes with the 8th power of the cosh-function. The area goes therefore with the 16th power of cosh.
Geometric	The area of a Geometric Horn is defined as sum of the infinite series A(x)=konst.* (1+x+x^2+x^3+x^4+ ...) At the beginning it is similar to the Exponential Horn, but it opens itself quicker and quicker with increasing length.
Tractrix	The radius of a Tractrix horn (spherical horn) follows the tractrix-function. This contour is said to have advantages in the wave transmission inside the horn. AJHorn can simulate this horn contour acoustically and mechanically like the other contour types, too. AJHorn plots the area, height and radius as a function of the horn length (explicit). This we mention, because mathmatically, the tractrix function is an implicit function.

According to the driver used and the separate hornparameters chosen, different frequency responses occur. Some are more linear than others, some have a lower frequency cut-off and some have the highest efficency and/or the lowest cone amplitude. The user is therefore in the position to adjust for the contour he wants.

Position

This parameter determines the efficency and the linearity in the lower, the middle and the high frequencies. Various non-reflective positions will be taken up and can be chosen.

Free	This position can be found in a non-reflective measurement-room (“anechoic-room”). It is for now the only way to carry out reliable, complete measurements with high exactness. All measurements in section 7 were taken in this way. The free position is available when the horn opening is not much smaller than the dimensions of the baffle and the loudspeaker can radiate freely in all directions. A complete measurement, which is carried out correctly, shows the exactness of AJHorn.
Floor	With this variant, the loudspeaker of free position is standing on the floor. Therefore, it has a baffle that isn't much bigger than the horn opening.
Half space	This position is based on the calculations of Thiele and Small. The results refer to the installation of the loudspeaker or the horn in an infinite baffle.
Floor + Wall	This position refers to the radiation of the loudspeaker in a quarter space.
Corner	This position refers to the radiation of the loudspeaker into eighth-space.

Distance
The distance (r) in metres defines the distance between the hornmouth or cone and the ear or the measurement microphone. For frontloaded types, this is the distance between the hornmouth and the measurement microphone, and for rearloaded types it is the distance from the driver cone to the measurement microphone.

Mouth height and mouth width
Like described in section 2, this is the height and width of the hornmouth in cm. The program uses the one-dimensional solution of the horn equation. For the hornfunction, therefore, only the area in dependence with the length is necessary. So, for example, only the moutharea and not the ratio from the mouthheigth to the mouthwidth is important. Operation of the program will be easier through the input of the mouthheigth and mouthwidth. You can simulate, therefore, a conversion to circular horns.

L (hornlength)
This is the way between hornthroat and hornmouth in m.

Position of driver1 and driver2
This is the distance between the center of the driver cone and the beginning of the horn (throat). A detailed description show the figures in chapter 2.

dL (difference length)
This value plays a part by the correct addition of the magnitude and phase of the sound pressures from different sources. The difference length is the path difference between two sound radiating media relative to the listeners position. It has different meanings for the front- and rearloaded types. Chapter 2 describes its usage.

Throat area
This area in cm^2 is the area at the beginning of the horn (throat).

Frontchamber volume (Vfc)
This value in l (litres) defines the volume between the loudspeaker cone and the hornthroat (for DP = 0).

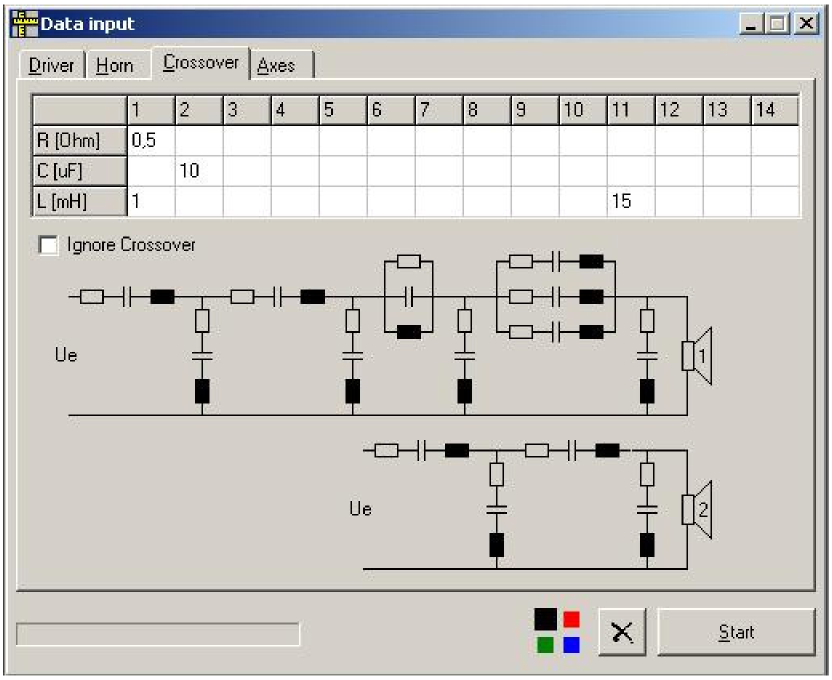
Absorbing coefficients (ß1, ß2, ßab, ßfc, ßrc, ßbr)
With these coefficients, the influence of absorbing material will be described. It will be assumed that from the throat (ß1) to the mouth (ß2) of the vent, the absorbtion is linear. All remaining coefficients preface homogeneous filled housings. From AJHorn 6, the damping is frequency dependent. The input of the betas values remains unchanged, however the damping becomes now in the simulation observed as frequency dependent. Useful values are between 0 (no absorbtion, smooth walls) and 1000 (complete filling with damping material). It is recommended to set all betas to zero except for the back chamber and then observe the influence of changing absorbtion values.

Rear chamber
The input values for the rear chamber are the rear chamber volume Vrc, the bassreflex-frequency fbr, the area of the bassreflex port Abr and the damping coefficient βbr. The length of the bassreflex port (lbr) is calculated by AJHorn and shown in the window “misc”. All these values are not used with Rearloaded Horns.

Absorber chamber
The absorber chamber is placed at the end of the front chamber (position driver1). The input values for the absorber chamber are the absorber chamber volume, the absorber chamber frequency, the area of the absorber port and the damping coefficient βab. This chamber should be filled with damping material (βab > 0), otherwise it adds resonances, that AJHorn simulates correct. The length of the absorber chamber port (lab) is calculated by AJHorn and shown in the window “misc”.

4.3 Crossover

In this section, a passive crossover can be simulated. The resistance Ri will be defined in ohms (Ω), the inductive elements Li (coils) in mH and the capacities Ci (capacitors) in µF. The follwing depiction shows the structure of the passive crossover.



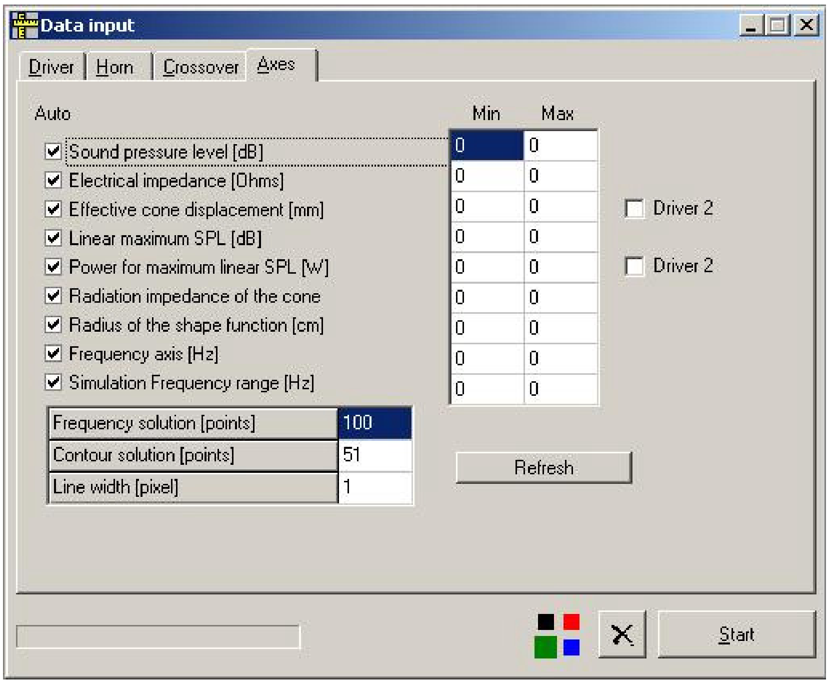
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
R [Ohm]	0,5													
C [uF]		10												
L [mH]	1										15			

☐ Ignore Crossover

By clicking at one crossover symbol the cursor is set to the appropriate position in the table above. Then the value of the device can be typed in. If one input field remains empty, the device will be disregarded with respect to the calculation. When there are no values specified, the project has no passive crossover.

4.4 Axes

As you know, AJHorn can simulate various capabilities of a horn loudspeaker. With this option, you can establish an automatic or a manual scale reference of the output frequency response.



Auto	Min	Max	
☑ Sound pressure level [dB]	0	0	
☑ Electrical impedance [Ohms]	0	0	
☑ Effective cone displacement [mm]	0	0	☐ Driver 2
☑ Linear maximum SPL [dB]	0	0	
☑ Power for maximum linear SPL [W]	0	0	☐ Driver 2
☑ Radiation impedance of the cone	0	0	
☑ Radius of the shape function [cm]	0	0	
☑ Frequency axis [Hz]	0	0	
☑ Simulation Frequency range [Hz]	0	0	

Frequency solution [points]	100
Contour solution [points]	51
Line width [pixel]	1

A check at the column "Auto" means, that AJHorn makes an automatic scale of the output graphs. When a check is removed AJHorn expects reasonable values for "Min" and "Max". In the row "Simulation frequency" the user can input the smallest and highest simulated frequency. Between them the points are set logarithmic. With the value "contour resolution" you can define the number of contour steps in the output contour text file. The highest value is 10000 steps. With the button "Refresh" the graphs are ploted new, but no calculation is made.

5 Simulation results

5.1 SPL (Sound pressure level in dB)

This well-known value defines the simulated pressure frequency response of the loudspeaker at a distance of r meters on axis. It belongs to the standard measurement of each loudspeaker and it allows many conclusions as to the sound characteristic of the loudspeaker, because the ear works as pressure sensor as well. It should be as smooth as possible. Narrow peaks in the frequency response of more than ca. 3 dB are absolutely audible and are to be avoided.

5.2 Electrical impedance in Ω

This frequency response also belongs to the standard measurement and assessment of loudspeakers.

5.3 Cone amplitude in mm

This value shows the frequency response of the effective excursion with a definite input voltage. The peak-peak value is the effective value multiplied by 2.83.
With a horn, the cone amplitude will be reduced in a decisive measure and at the same time the sound pressure will be increased. This is the reason for the nearly incredible sound pressures which can radiate from a correctly constructed horn and for the legendary reputation of this type of loudspeakers.

5.4 SPLmax (maximum linear sound pressure in dB)

This frequency response defines the maximum sound pressure which the loudspeaker could produce. It is limited by the effective value of Xmax and the electrical power handling.

5.5 Pmax (Necessary electrical power in watts for SPLmax)

This frequency response shows the required power for the maximum linear sound pressure.

5.6 Radius of the shape function

This window shows the horn radius contour function in cm. For a more precise set of the values and to aid practical construction later, you can list the values in the main menu under "Extras" → "List contour". The columns of th text file show the actual length, the area, the height and the radius of the contour function.

5.7 Acoustic impedance of the cone

When the front chamber is zero, this value is identical with the radiation impedance of the horn throat. This value, which is normally hard to find with measurements, is a value for the radiated acoustic power. The impedance is normalized by rho*c. Fundamental literature of acoustics and theoretical publications will refer to this quantity. Because of the completeness of AJHorn, this value will be displayed for comparison to values found in literature. The real part is displayed solid, and the imaginary part is displayed dashed.

6 Limitations of simulation accuracy

AJHorn is a precise, scientific program with which Horn Loudspeakers and Transmissionlines and their special cases can be simulated. For a better calculation, some approximations are assumed. Therefore we can't give a guarantee for the simulation results. It's in our interest, too, to tell you the limits of simulation accuracy, because we want, that you can calculate your project as exact as possible.

6.1 The chassis itself

The cone of a loudspeaker chassis oscillates like a piston up to a certain frequency. That means the cone oscillates at all points with the same amplitude. If a cone doesn't oscillate like a piston (e.g. for higher frequencies), it will not have a uniform pressure response. It is obvious that this will influence the frequency response of the Horn.

6.2 The front and rear chamber

These chambers are described in AJHorn 6 with the AJHorn impedance theory as a cylindrical tube of the length l (therefore as a horn). In contrast to earlier versions, so time difference and cavity resonance of the chambers can be described well. Also for not cylindrical chambers, this model is applicable and astonishingly precise. It can come however through the detailed dimensions of the front chamber to resonance in the sound pressure at relative high frequencies. These appearances are described further below fair technical. If a horn should be used for the upper frequency ranges, the front chamber should be as small as posible. The exact geometry of the front chamber is then important, too (phase correction).
The rear chamber is in most cases filled with damping material (ßrc > 100) and places so no big problem there.

6.3 Absorber chamber and absorber port

AJHorn describes the absorber chamber with a relatively simple model[1]. This theory is only correct where the dimensions of the front chamber are smaller than the wavelength at the radiated frequency.

Are the dimensions of the chamber in the region or above the wavelength of sound, the chamber shall be filled with damping material. The frequency from which we strongly recommend a damping is

$$f_0[Hz] \approx \frac{17000}{x[cm]}$$

The variable x is the maximum of length, whidth and height of the chamber.

The port of the absorber chamber forms standing waves, which can have bad influence in sound reproducton. The standing wave with the lowest frequency is

$$f_0[Hz] \approx \frac{15000}{lab[cm]}$$

The variable lab is the length of the absorber port.

Because the absorber chamber frequency lies in most cases in the low frequency range, the volume a few liters and the length a few centimeters, this characteristic hardly disturbs noticeably uncoloured reproduction.

6.4 Horn shape

AJHorn uses the one-dimensional solution of the horn-equation. Plane waves are assumed. For slow opening shapes this is very accurate. If the gradient of the shape and the frequency is very high, however, the wave is not plane (no, it is also not a sphere-wave). For most bass and mid-frequency horns, you will have no problems. The simulations are very precise for these types. Problems can occur with high-frequency-horns with, in ratio with the wavelength, very big horn mouths. The simulations for these types are good, too, but not as dreamlike as for low-frequency-horns.

---

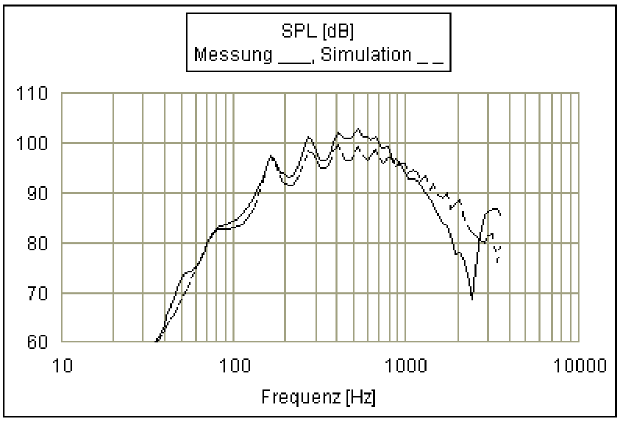
[1] Acoustic compliance, acoustic mass

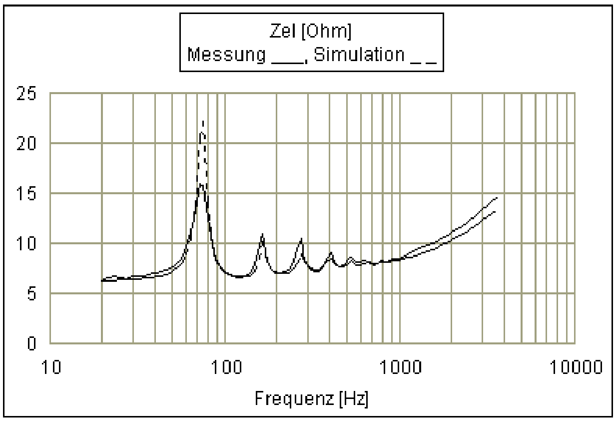
7 Comparison with measurements

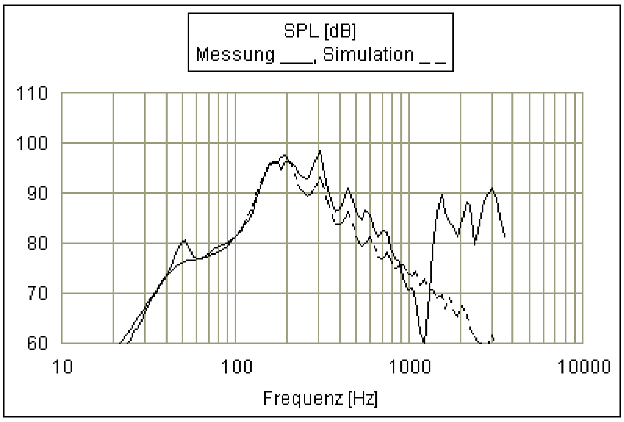
What use is a simulation programm when nobody knows whether the calculated responses are describing the practical measurement? The sense behind a simulation programm is to save time from building costly prototypes and to see what happens when one parameter is changed relative to any others. The prerequisite for this is confidence in the simulation. We have tried to prove this with the folowing examples.
The measurement equipment was a full-automated computer-controlled meassuring-system with high resolution sine-steps. All measurements where made in an anechoic room with a low frequency limit of 70 Hz. The meassurements and simulations are described in the following paragraphs.

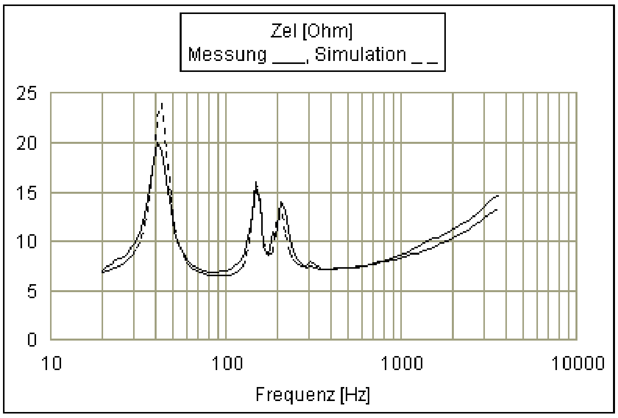
7.1 Variable test horn

The variable test-horn is a frontloaded midrange horn which is not constructed to have a linear frequency response, but with characteristic resonance peaks, to compare the simulation with the measurement. It is built of several parts to change the length, throat area and the mouth area. The shape-function is the e-function. The various simulations with AJHorn and the related meassurements show the following figures.



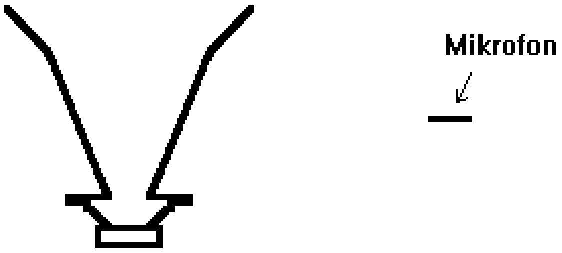




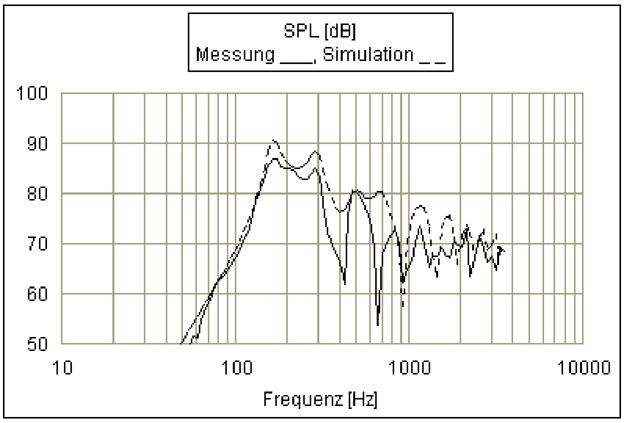


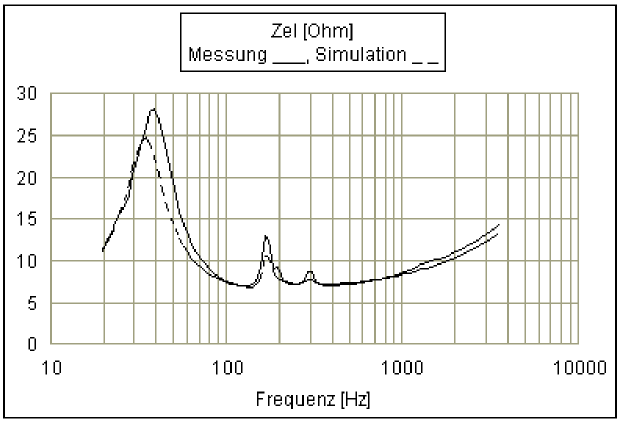
7.2 Little rearloaded horn

The little rearloaded horn is built from the variable testhorn by removing the rear chamber. It is also not constructed to achieve a linear response. It only should compare the simulations with the measurement. The length difference from zero is achieved by positioning the microphone as in the fillowing figure.



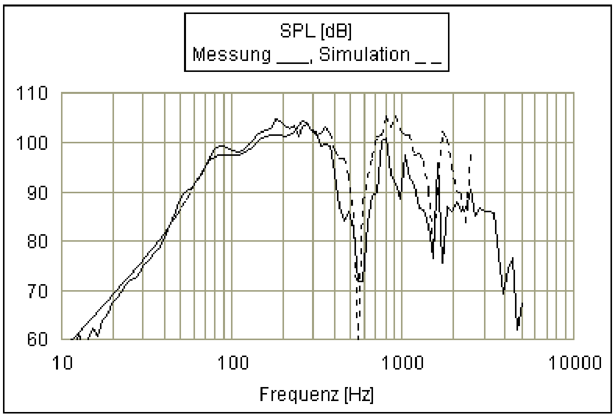
This is only correct for low frequencies because the sound from mouth and cone is then radiated in circular fashion.

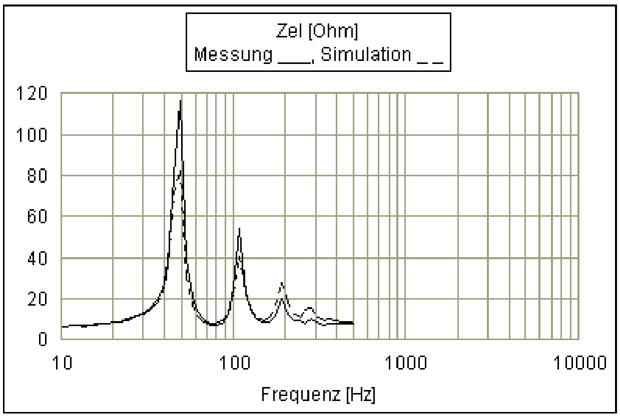


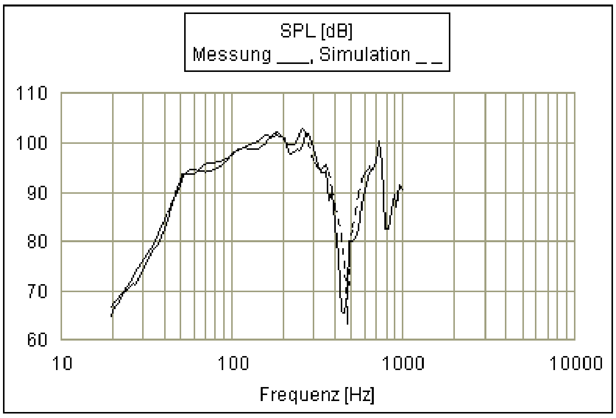


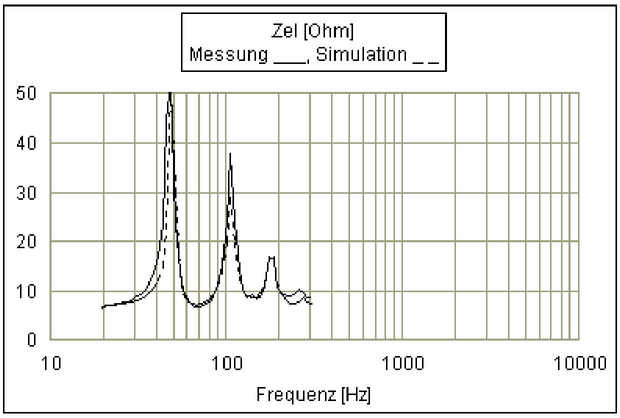
7.3 Folded frontloaded low frequency horns

These are folded low frequency horns with PA-Drivers. The efficiency in free field is very high in comparison to the volume of approx. 200 Liters (>98 dB, >80 Hz, 1 W). In halfspace (Thiele-Small) the efficiency is increased by 6 dB. The results of the simulations with AJHorn and the measurement results show the following figures.







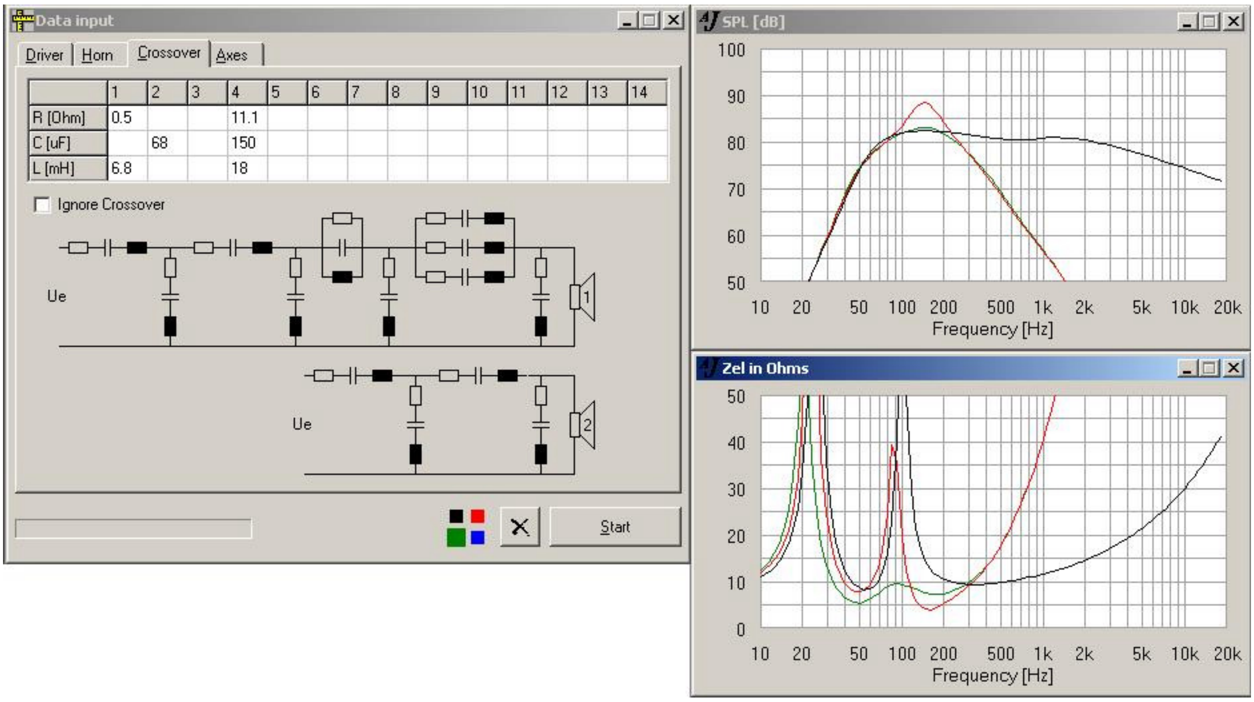


The input value “driver position” (DP) 0.15 and 0.2 meters result in minima of SPL which are simulated correctly. The measurement shows good agreement with the simulation, especially in the low frequency range.

7.4 Crossovers, RCL-circuits and notch-filters

Focal 5V4411[2]

AJHorn can simulate RCL-circuits parallel to the loudspeaker for the linearization of the electrical impedance in the case where a passive low-pass is added. The following figure shows the simulated Driver Focal 5V4411 in a bass-reflex enclosure without crossover, with a conventional low-pass (0.5 Ohms, 6.8 mH, 68 µF) and with RCL-circuit (11.1 Ohms, 18 mH, 150 µF). The comparison with the HobbyHifi measurements are better +-1 dB (30 to 700 Hz).

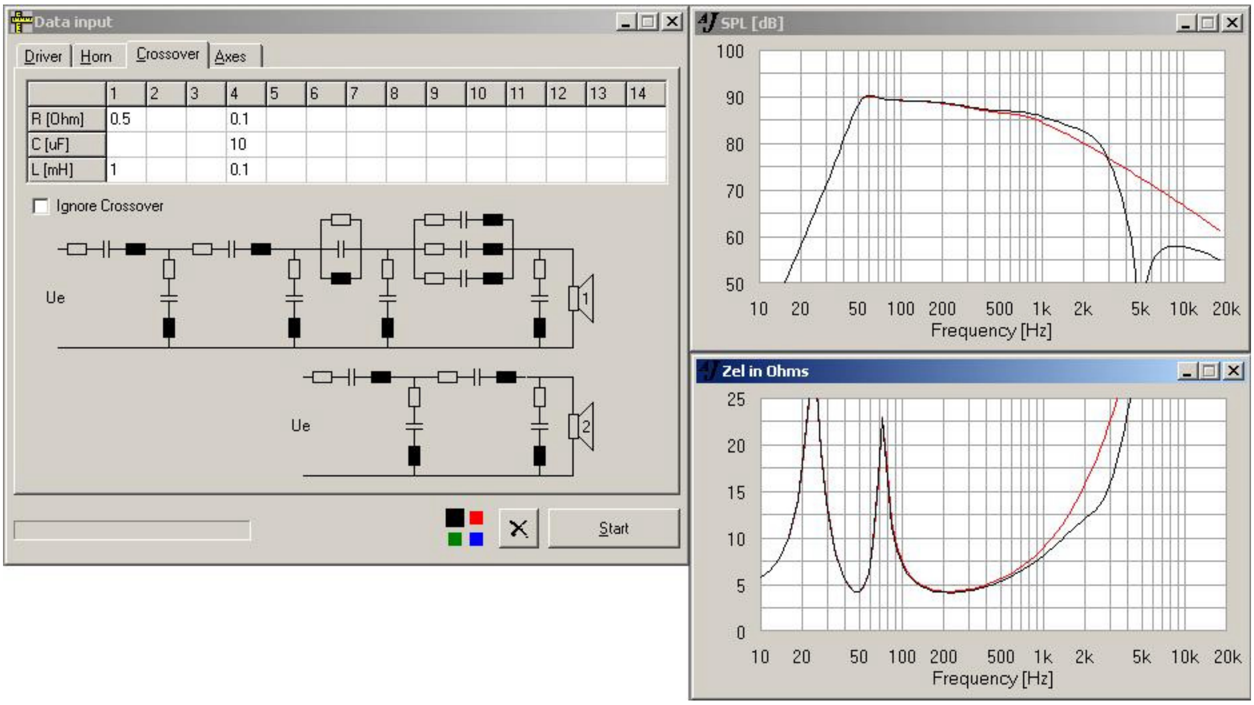


	1	2	3	4	5	6	7	8	9	10	11	12	13	14
R [Ohm]	0.5			11.1										
C [uF]		68		150										
L [mH]	6.8			18										

☐ Ignore Crossover

Excel 17EX002[3]

Because of a better description of the voice coil inductivity added in version 4.0, AJHorn can simulate passive crossovers for higher frequencies with very good aggreement to measurements. The following figure shows the simulated frequency response of a filter designed for the 17EX002. The resonance of the magnesium cone between 4 and 5 kHz is filtered out quite well with this design.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
R [Ohm]	0.5			0.1										
C [uF]				10										
L [mH]	1			0.1										

☐ Ignore Crossover

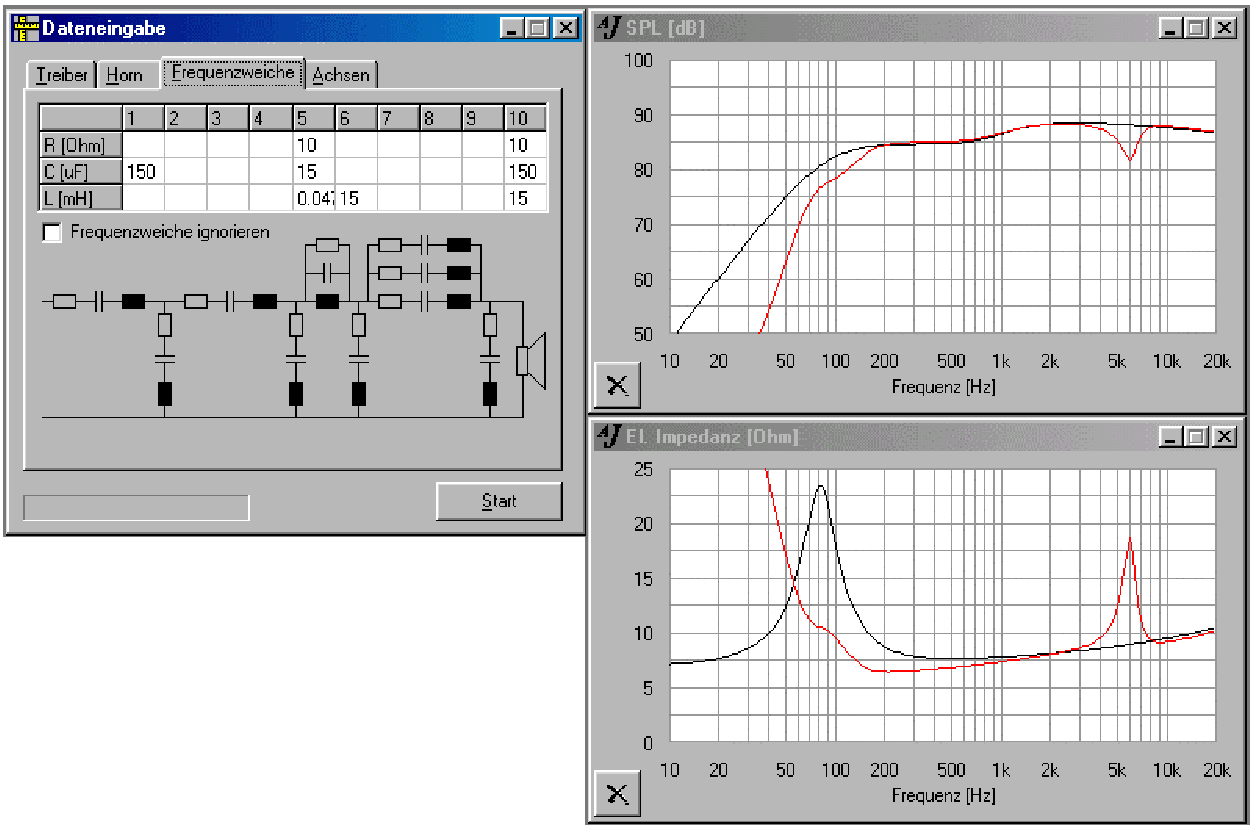
---

[2] Ref.: German magazine „HobbyHifi“ 6/99 p.71

[3] Ref.: German magazine „Klang+Ton“ 4/00 p.19, data sheet Excel W17EX002

"Open Source" with Ciare HX 132[4]

Many fullrange drivers must be equalized by a passive (notch-) filter to achieve a smooth frequency response of sound pressure. The influence of such a filter shows the next picture, wich shows the simulation results of the Ciare HX 132 with and without passive crossover.



	1	2	3	4	5	6	7	8	9	10
R [Ohm]					10					10
C [uF]	150				15					150
L [mH]					0.047	15				15

☐ Frequenzweiche ignorieren

The influence of the notch-filter (R5, C5, L5) acts around 6 kHz. It mirrors the peak of the driver at this frequency. All components of the crossover are simulated correctly.

8 Synopsis

We hope to have given you an overview of the capacity and user-friendly nature of AJHorn. With a little practice you will be successful in finding the best geometry for your projects. The costly making of prototypes will be reduced to a minimum, and you can immediately observe the changes to frequency response that your design decisions make. So, it is hoped, AJHorn will save you a lot of time and trouble.
We wish you every success with your projects.

AJ

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[4] Ref.: German magazine „HobbyHifi" 3/05 p.14 ff