This application calculates the theoretical acoustical impedance, SPL response, electrical impedance, diaphragm displacement, phase response and group delay versus frequency characteristics of finite and infinite horn loaded loudspeakers.

Finite horns radiating into free space, half space, quarter space or eighth space can be analysed (4 x Pi, 2 x Pi, Pi or Pi / 2 steradians solid angle).

Horn systems can have an oblate spheroidal waveguide, a single Le Cléac'h, tractrix, spherical wave or Salmon's family hyperbolic-exponential flare segment, or up to four conical, exponential and/or parabolic flare segments connected in series, coupled to a throat chamber, loudspeaker driver and acoustically lined or vented rear chamber. Horns with multiple drivers and arrays of multiple loudspeakers can be modelled. The driver diaphragm is assumed to be a rigid plane piston.

Horn segment parameter values can be reset to zero by entering a blank for the throat area, mouth area, axial length, flare cutoff frequency, flare parameter or throat entry half-angle.

For multiple-segment horns, the greater the value of Cir (mouth circumference in flare cutoff frequency wavelengths) is above 1 for any horn segment, the less accurate the calculated throat acoustical impedance and other results become.

Moving the mouse pointer over an object or message on the input parameters window displays a context-sensitive explanatory note in the status bar panel at the bottom of the window.

After calculating results by pressing F5 or Calculate, press F2 to move to the next window, Shift+F2 to move to the previous window or Esc to return to the input parameters window from any result window.

Notes 6 to 14 on pages 18 to 20 explain how to model a mass-loaded horn, an offset driver horn, a tapped horn, a compound horn, a back-loaded horn, a horn-loaded vented-box enclosure or a direct radiator in a vented-box enclosure, closed-box enclosure or infinite baffle.

To enter a length, area or volume value in Imperial inch or foot units, press F6 in edit mode when the relevant input parameter has the focus.

Ang	Solid radiation angle (steradians) *Enter 4, 2, 1 or 0.5 for finite horn, 0 for infinite horn, or double-click the angle parameter.*
Eg	Amplifier open circuit root-mean-square voltage (volts) *Enter 0 for driver diaphragm constant rms velocity of 10 centimetres per second.*
Rg	Amplifier output resistance (ohms)
Cir	Free space normalised horn mouth circumference in flare cutoff frequency wavelengths
Fta	Horn mouth flare tangent angle (degrees)

S1 Horn segment 1 throat area (sq cm)
S2 Horn segment 1 mouth area and horn segment 2 throat area (sq cm)
L12 Horn segment 1 axial length (cm)
To select Con, Exp or Par flare in edit mode, press C, E or P when the relevant horn segment length parameter has the focus or double-click the length label. To select Hyp, Lec, Obl, Sph or Tra flare in edit mode, press H, L, O, S or T when the L12 length parameter has the focus.
F12 Horn segment 1 flare cutoff frequency (hertz)
T Hyperbolic-exponential and Le Cléac'h horn flare parameter
Enter 0 for catenoidal, < 1 for cosh, 1 for exponential, > 1 for sinh or 99999.99 for conical.
AT Horn throat entry half-angle (degrees)

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                                              S5 |
                                         S4 |    |
                                    S3 |    |    |
                               S2 |    |    |    |
THROAT    S1 | - - - - | - - - - | - - - - | - - - - |   MOUTH
                  L12  |   L23   |   L34   |   L45   |
                                 |         |         |
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Sd Driver diaphragm piston area (sq cm)
Bl Driver magnetic flux density x voice coil conductor length (tesla.m)
Cms Driver diaphragm suspension mechanical compliance (m/newton)
Rms Driver diaphragm suspension mechanical resistance (newton.sec/m)
Mmd Driver diaphragm and voice coil dynamic mechanical mass (gm)
Mmd equals Mms (total moving mass) minus air load.
Le Driver voice coil inductance (millihenrys)
Re Driver voice coil dc resistance (ohms)
Nd Number and position of drivers in loudspeaker
Specify driver system configuration using the Driver Arrangement tool.

Vrc Rear chamber volume (litres)
Lrc Rear chamber average length (cm)
Fr Rear chamber acoustical lining airflow resistivity (rayls/cm)
Tal Rear chamber acoustical lining thickness (cm)
Ap Chamber port or throat adaptor entry cross-sectional area (sq cm)
Lpt Chamber port tube or throat adaptor length (cm)
Vtc Throat chamber volume (cc)
Atc Throat chamber average cross-sectional area normal to axis (sq cm)
Set relevant values to zero if no throat chamber, rear chamber, acoustical lining or port tube.

Schematic Diagram	Loudspeaker schematic diagram and system volume. The design is assumed to be axisymmetric. *Use the mouse pointer to identify component parts and show scale.*
Acoustical Impedance	Horn throat acoustical resistance and reactance in normalised acoustical ohms versus frequency in hertz. The actual acoustical resistance and reactance can be determined by multiplying the chart values by the given scaling factor.
SPL Response	Sound pressure produced at a point source normalised distance of one metre when the driver is supplied with a signal of a given voltage, versus frequency in hertz. The level is expressed in decibels relative to the standard reference sound pressure of 20 micropascals. *The default response assumes constant directivity. The Directivity Response tool can be used to take into account the frequency dependent directional characteristics of finite single-segment horns.*
Electrical Impedance	Loudspeaker electrical input impedance magnitude in ohms versus frequency in hertz.

Diaphragm Displacement	One-way maximum displacement of the driver diaphragm from its mean position in millimetres for a specified input signal, versus frequency in hertz. The actual displacement can be determined by dividing the chart value by the scaling factor, where given. *Behaviour at all input voltage levels is assumed to be linear. No allowance is made for low frequency high power amplitude compression. Each diaphragm in a multiple driver configuration has the same displacement, as given by the calculated value.*
Phase Response	Phase-angle difference in degrees between voltage Eg and the output sound pressure of a loudspeaker system, versus frequency in hertz. By default, the phase is corrected by adding a linear phase offset equivalent to the mean group delay across the -12dB delimited SPL bandwidth. Use the Delay tool to specify a different value.
Group Delay	Negative derivative in milliseconds of the loudspeaker system phase response, versus frequency in hertz. *Group delay is a measure of the rate of change of phase with respect to frequency, and is positive when the phase slope is negative.*

Copy Driver	Copies the current record driver parameter values.
Paste Driver	Pastes previously copied driver parameter values to the current record.
Find	Searches for records that match the given comment text and filter. *The Page Up, Page Down, Home, End and Enter keys can also be used to move from one record to another, when the input parameters window is displayed.*
Sort	Sorts records in comment-ascending alphanumeric order.
Import	Loads input parameter data values from an exported record file.

Export	When selected from the input parameters window, saves current record input parameter data values to an AkAbak script file. *Record must be valid.* When selected from the schematic diagram window, saves schematic diagram data values to a tab-delimited text or comma separated values file. See also Notes 15 and 16 on pages 20 and 21. *Axial length values for each horn segment increase linearly from zero to the segment length. The length increment for each segment can be set to a specified value in centimetres.* When selected from a chart window, saves data values for all calculated charts to a tab-delimited text or comma separated values file. SPL and Ze magnitude and phase files can also be exported for use with other loudspeaker design software tools. *Frequency values increase logarithmically from 10 to 20000 hertz.*
Print	Prints the input parameter values and displayed schematic diagram or chart.
Exit	Closes the Hornresp application.

Horn Segment Wizard

Calculates either the throat area, mouth area, axial length, flare cutoff frequency, flare parameter, throat entry half-angle, mouth circumference in cutoff frequency wavelengths or mouth flare tangent angle, given the other relevant horn segment parameters. Cir or Fta can be set to a specified value when the mouth area or flare cutoff frequency calculation option is selected.

The Tools menu command is enabled when any horn segment parameter or the Ap1 throat adaptor parameter has the focus. The tool can also be selected by double-clicking the parameters in edit mode. The mouth area calculation option can be used to determine the cross-sectional area at any point along the axial length of a horn segment. For system volume, double-click segment volume.

Calculate Parameter

Derives Bl, Cms, Rms and Mmd values from relevant Thiele-Small parameters, calculates Eg given the power delivered to a specified load and determines Lpt given the Helmholtz resonance frequency. When selected from Sd, displays the driver Thiele-Small parameters.

The Tools menu command is enabled when Eg, Sd, Bl, Cms, Rms, Mmd or Lpt has the focus. The tool can also be selected by double-clicking the parameters in edit mode.

Chamber

Specifies a lined or vented rear chamber, a ported throat chamber or a throat chamber coupled to the horn throat by a conical adaptor.

The Tools menu command is enabled when the input parameters window is in edit mode. The chamber configuration can also be selected by double-clicking the Fr, Tal, Ap, Ap1 or Lpt label.

Driver Arrangement

Specifies the number and position of drivers connected elecrically in series and/or parallel.

Multiple drivers share the horn system, throat chamber and rear chamber as defined by the input parameter values and as shown in the schematic diagram. An offset driver horn, a tapped horn or a compound horn can be specified. Select the tool by double-clicking the Nd, OD, TH, TH1 or CH disabled text box in edit mode.

System Design

Determines the optimum design for a hyperbolic-exponential horn loudspeaker given either the driver or system parameter values, and the required operating frequency range.

Horn flare parameter T can be entered into the System Design With Driver tool as an optional input, by double-clicking the upper rolloff corner frequency label.

Loudspeaker Wizard	Automatically re-calculates the results for a specified loudspeaker system in real time, as input parameter values are changed. The tool is applicable to single segment conical and parabolic horns, and all multiple segment horns. The initial slider control settings and chart results are saved as a reference baseline when the tool is selected. Up to four sets of values can be stored and recalled by clicking the appropriate memory button or pressing the equivalent function key. Press the S key to to instantly check the schematic diagram. *To change the flare of a horn segment, double-click on the label above the length slider control. To change the Manual / Auto setting of an area slider control, double-click on the label above the area slider. To change the frequency range, double-click on the chart frequency label. To directly set a slider control to a specified value, key in the value and then press Enter while the control has the focus. To reset a slider control to its baseline value, press B while the control has the focus. To reset all slider controls to their baseline values, press Ctrl+B. To save a new baseline with the current slider control settings and chart results, press Ctrl+Alt+B.*
View Schematic	Displays the loudspeaker schematic diagram and system volume.

Sample	Calculates the acoustical impedance, SPL response / electrical input power / acoustical output power / system efficiency / air velocity, electrical impedance, diaphragm displacement / diaphragm velocity / diaphragm acceleration, phase response, group delay or beam width at any given frequency between 1 and 20000 hertz. When the SPL response of a single-segment horn is sampled, the second-harmonic distortion is also calculated. When the maximum SPL response is sampled, the acoustical output is shown as either power or displacement limited, and the input voltage and Pmax diaphragm displacement are given. *Press F3 or double-click chart to select.*
Compare	Displays the current and previous or captured acoustical impedance, SPL response, electrical impedance, diaphragm displacement, phase response, group delay or beam width results on the same chart. *Previous results are used in comparisons by default. Press Ctrl+C to capture the current results or Ctrl+X to release captured results. Results can also be captured or released by right-clicking any chart. Press F4 to show or hide the previous or captured results.*

Directivity Response	Displays the SPL response of a finite single-segment non-negative flare horn at a specified off-axis angle, taking into account the frequency-dependent directional characteristics of the horn. *Select from the SPL response chart window.*
Directivity Pattern	Displays the directional characteristics of a finite single-segment horn at a specified frequency. The polar diagram shows the far-field sound pressure at a fixed distance as a function of the off-axis angle, expressed relative to the on-axis pressure with the maximum value normalised to 1. The sound pressure ratio can be indicated directly or in decibels. The on-axis directivity index and -6 dB beam width are also given. Click on the polar diagram to show the pressure level at a specified angle. *Select from the SPL response or beam width chart windows.*
Directivity Beam Width	Displays the angular distance in degrees between the two points on either side of the principal axis of the directivity pattern where the sound pressure level is down 6 decibels from its value on axis, versus frequency in hertz. *Only applicable to finite single-segment horns.*

Directivity Polar Map	Displays the far-field sound pressure at a fixed distance as a function of the off-axis angle in degrees, versus frequency in hertz. *Only applicable to finite single-segment horns.*
Impulse Response	Displays the impulse pressure versus time response of a loudspeaker system. The peak amplitude value is normalised to 0.9. *Select from the SPL response chart window. Click the Export button to save the impulse response data values to a wave sound file. Click the Compare or Clear button or press F4 to show or hide the comparison with the previous result.*
Impulse Spectrogram	Displays the impulse spectral density, or normalised amplitude in decibels as a function of frequency, versus time in milliseconds.
Maximum SPL	Displays the maximum sound pressure level in decibels that can be achieved at 1 metre without exceeding the driver rated thermal limited electrical input power Pmax or the diaphragm linear mean-to-peak displacement limit Xmax, versus frequency in hertz. Black indicates power limited, red indicates displacement limited. *Press Ctrl+S to permanently save the entered Pmax and Xmax values.*

Combined Response	For a finite back-loaded horn loudspeaker system, combines the direct radiator output with the default displayed horn SPL response. *The direct radiator cannot be located inside the horn mouth.* For a finite horn-loaded vented-box loudspeaker system, combines the port output with the default displayed horn SPL response. *The port outlet cannot be located inside the horn mouth.* For a direct radiator vented-box loudspeaker system, combines the port output with the default displayed direct radiator SPL response. *The path length from the rear side of the driver diaphragm to the port outlet is assumed to be equal to Lrc plus Lpt, as shown in the schematic diagram. The distance from the port outlet to the listener can be adjusted if necessary using the path length difference parameter. A positive value for path length difference increases the listener distance.* Destructive interference nulls are often not as deep as predicted, due to the directional characteristics of the front and rear radiated sound.
Multiple Speakers	Displays the normalised far-field SPL response of a given multiple loudspeaker array connected to a single amplifier. *Not applicable to infinite horns.*

System Efficiency	Displays the system efficiency in percent versus frequency in hertz. *Click on the chart to show the efficiency value at a specified frequency.*
Sound Pressure	Displays peak sound pressure in pascals versus frequency in hertz. *Click on the chart to show the sound pressure value at a specified frequency.*
Particle Velocity	Displays peak particle velocity in metres per second versus frequency in hertz. *Click on the chart to show the particle velocity value at a specified frequency.*
Range	When selected from the electrical impedance chart window, sets the electrical impedance chart range. *Select Zoom to optimise the scale for the resonance peak.* When selected from the group delay chart window, sets the group delay chart range.
Delay	Sets the phase response chart offset delay correction. *Select zero delay to show standard wrapped phase.*

Wavefront Simulator	Models sound wave propagation in horn loudspeakers. *Isophase wavefronts are shown.*
Options	Sets the throat chamber and rear chamber resonance masking and default result window options.

1. The application assumes that the velocity of sound in air is 344 metres per second, and that the density of air is 1.205 kilograms per cubic metre.

2. The driver diaphragm is modelled as a rigid plane circular piston. No allowance is made for frequency-dependent directional characteristics due to driver cone angle or cone material, or for changes in moving mass, acoustical impedance or radiated power caused by diaphragm resonance modes. Also, horn flare directional characteristics are not taken into account when calculating the constant directivity SPL response. This means that the actual upper frequency rolloff for a cone type drive unit coupled to a straight-axis horn can in some cases be more than one octave higher than the predicted value.

3. The constant directivity SPL response is also the acoustical power response.

4. No provision is made for horn transmission losses.

5. The rear chamber volume is the effective enclosed air volume behind the driver diaphragm, including any space occupied by acoustical lining material but excluding port tube, driver magnet and chassis assemblies. The throat chamber volume is the effective air volume between the driver diaphragm and the throat chamber port, the throat adaptor entry or the horn throat. The locations of the throat chamber and rear chamber are as shown in the schematic diagram.

6. To model a mass-loaded horn specify the mouth cover plate as a conical segment having negative flare (mouth area < throat area) and a length of 0.01 cm, and the mouth mass-loading port tube as a cylindrical exponential segment having zero flare (mouth area = throat area).

7. To model an offset driver horn specify at least two conical, exponential and/or parabolic flare segments connected in series, and select the offset driver option from the Driver Arrangement tool or double-click Nd, TH or CH in edit mode to set the OD flag. The driver entry point is at S2. Vtc and Atc can be used to specify a chamber between the diaphragm and the throat entry point. Ap1 and Lpt can be used to specify a port opening between the chamber and the horn (not required if the cross-sectional area of the opening is equal to Atc).
By default, with no rear chamber specified only the horn output is calculated. The Combined Response tool can be used to determine the rear output or the overall front plus rear SPL response.

8. To model a tapped horn specify three or four conical, exponential and/or parabolic flare segments connected in series, set Vrc and/or Lrc = 0 and select the tapped horn option from the Driver Arrangement tool or double-click Nd, OD or CH in edit mode to set the TH flag. TH can be double-clicked to set the optional TH1 flag. Driver entry points are at S2 and S3 for a three segment TH horn, S2 and S4 for a four segment TH horn, and S2 and S3 for a four segment TH1 horn. Vtc and Atc can be used to specify a chamber between the diaphragm and the throat entry point. Ap1 and Lpt can be used to specify a port opening between the chamber and the horn (not required if the cross-sectional area of the opening is equal to Atc).
The Loudspeaker Wizard tool can be used to change the driver position without altering the horn length or flare.

9. To model a compound horn select the compound horn option from the Driver Arrangement tool or double-click Nd, OD or TH in edit mode to set the CH flag. Horn 1 is specified using segment 1 plus segments 2 and 3 if required. Horn 2 is specified using segment 4.
By default, only the horn 1 output is calculated. The Combined Response tool can be used to determine the horn 2 output or the overall horn 1 plus horn 2 SPL response.

10. To model a back-loaded horn set Vrc and/or Lrc = 0.
By default, only the horn output is calculated. The Combined Response tool can be used to determine the direct radiator output or the overall horn plus direct radiator SPL response.

11. To model a horn-loaded vented-box enclosure select the 'Rear Vented' option from the Chamber tool.
By default, only the horn output is calculated. The Combined Response tool can be used to determine the port output or the overall horn plus port output SPL response.

12. To model a direct radiator in a vented-box enclosure select the 'Rear Vented' option from the Chamber tool and set S1 to L45 = 0.
By default, only the direct radiator output is calculated. The Combined Response tool can be used to determine the port output or the overall direct radiator plus port output SPL response.

13. To model a direct radiator in a closed-box enclosure select the 'Rear Lined' option from the Chamber tool and set S1 to L45 = 0.

14. To model a direct radiator in an infinite baffle set Ang = 2 x Pi, S1 to L45 = 0 and Vrc and/or Lrc = 0.

15. The flat profile of the left and right side walls of a square or rectangular cross-section horn can be determined by plotting the schematic diagram exported Height / 2 values against Side Len as the X-axis centre line. The flat profile of the top and bottom horn walls can be determined by plotting Width / 2 values against Top Len as the X-axis centre line. The flat profile of a petal horn side wall can be determined by plotting Width / 2 values against Side Len as the X-axis centre line.

16. The 2007 flare profile used in the Le Cléac'h horn simulation model becomes slightly inaccurate near the horn mouth. The error is not large enough to make any practical difference to predicted results.
For construction purposes the exact axisymmetric profile can be exported by selecting the appropriate option when prompted.