Virtual Voice Coil 2.x

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INTRODUCTION

ABOUT THIS MANUAL
This User's Manual explains the ***VVC*** software version 2.x

WHAT THIS USER MANUAL DOES COVER
The ***VVC*** software is a design tool for voice coils and magneto-dynamic loudspeakers efficiency, this manual allows the user to quickly become efficient with the user interface *VVC* software.

LICENSE AGREEMENT AND WARRANTY

THANKS
Thank you for purchasing your ***VVC*** software. We hope that your experiences using ***VVC*** will be both productive and satisfying.

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SpeakerLAB provides detailed electronic manuals and on-line help within the program as the primary source for user information and assistance regarding the use of this product. If these sources do not contain the answers to your questions, for technical problems, bug reports, or suggestions for future software enhancements contact SpeakerLAB via any of the following methods:

website: www.speakerlab.it
e-mail: info@speakerlab.it

Technical support is free at this time; however, we reserve the right to charge for this service in the future as conditions, overhead, and support personnel requirements dictate.

INSTALLATION

SYSTEM REQUIREMENTS

VVC software is a low intensive numerical application. *VVC* software requires a full 32 or 64 bit operating system and can be installed in any personal computer with the following minimum system requirements:

- 1.3 GHz CPU speed
- 500 MB RAM
- Mouse and Keyboard
- 350 MB free HDD space
- Optimized size of screen resolution 1920x1080
  Minimum resizing dimension 950x600
  Minimum size of screen resolution 1024x768
- Microsoft Windows XP, 7, 8, 8.1, 10, 11
- Adobe Acrobat Reader

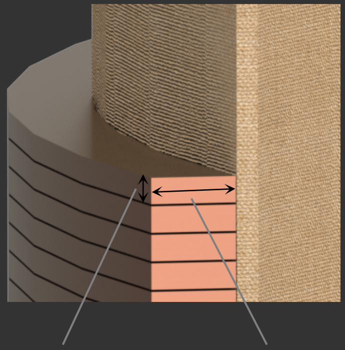
SOFTWARE INSTALLATION

- Delete all previous installations, included Demo Version
- From the installer folder, locate and run the Setup.exe file as administrator user (right click: Run as Administrator)
- Follow the instructions on the screen
- After installation Shutdown and Restart OS
- Run *VVC* from relative link on desktop or from SpeakerLAB folder on Start Menu
- At first launch *VVC* creates a code on desktop, send this code to the factory: copy or attach it in the e-mail info@speakerlab.it

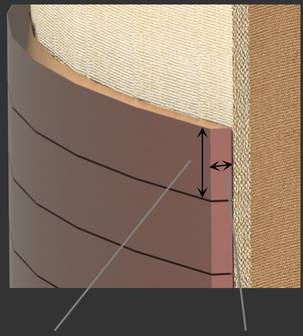
WIRE TYPE SPECIFICATIONS

NOTE: *VVC* always considers <u>diameter</u>, <u>width</u> and <u>thickness</u> related to a wire section as reported on this page

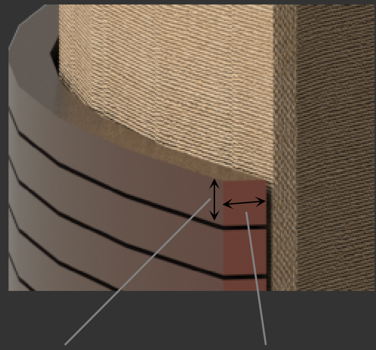
Rectangular Wire Edge Wound



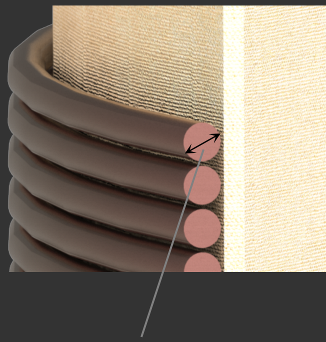
Rectangular Wire Flat Wound



Square Wire



Round Wire



All wire sheets (*.VVC files) are recorded on program folder path >>*\SpeakerLAB\Virtual Voice Coil\wire type*

.VVC files can be edited with a simple text editor like Notepad.
When you buy Virtual Voice Coil you can ask for available sheets to SpeakerLAB, you can also ask for wires sheets to your suppliers or add your own sheet.

There are two main sections related to *Round Wire Conductor* and then *Rectangular or Square Wire Conductor.* Please check for the *_EXAMPLE.VVC files supplied with the demo software as standard examples.

```
%SpeakerLAB Virtual Voice Coil Wire Sizes File
%Dimensions in [mm]
%The standard format is a decimal point (.) separator with a TAB delimiter. Anyway, VVC convert decimal points for systems that use a comma (,) as decimal separator, so it is possible to use both.

%Note: You can edit or duplicate this file, adding new wires or deleting wires.
%Min N. Round wires + N. 10 Rectangular/Square wires. Max N. 100 Round wires + N. 100 Rectangular/Square wires.
%It's not necessary to respect a particular order, VVC will compare and reorder all wire dimensions eliminating possible wire duplicates.

%DO NOT delete the # symbol before and after wire sizes, in the program it is always used as pointer to contain Round wires and then Rectangular/Square wires.

%Round Wire Conductor:
%Nominal Diameter        Max. Diameter, using always Max>Nominal
#
...
0.20        0.241
0.21        0.249
0.22        0.264
0.225       0.267
...
#

%Rectangular/Square Wire Conductor. The square wires have Thichness=Width.
%Nominal ThicknessxWidth        Max. Finished ThicknessxWidth, using always Max>Nominal.
#
...
0.08x0.25   0.106x0.31
0.08x0.30   0.107x0.36
0.09x0.40   0.117x0.46
0.45x0.45   0.49x0.51
…
#
```

For wire sheets provided with the <u>nominal</u> size only (without column of <u>max</u>), selecting the desired **Insulation Class** the program automatically calculates the relative max dimension for each wire.

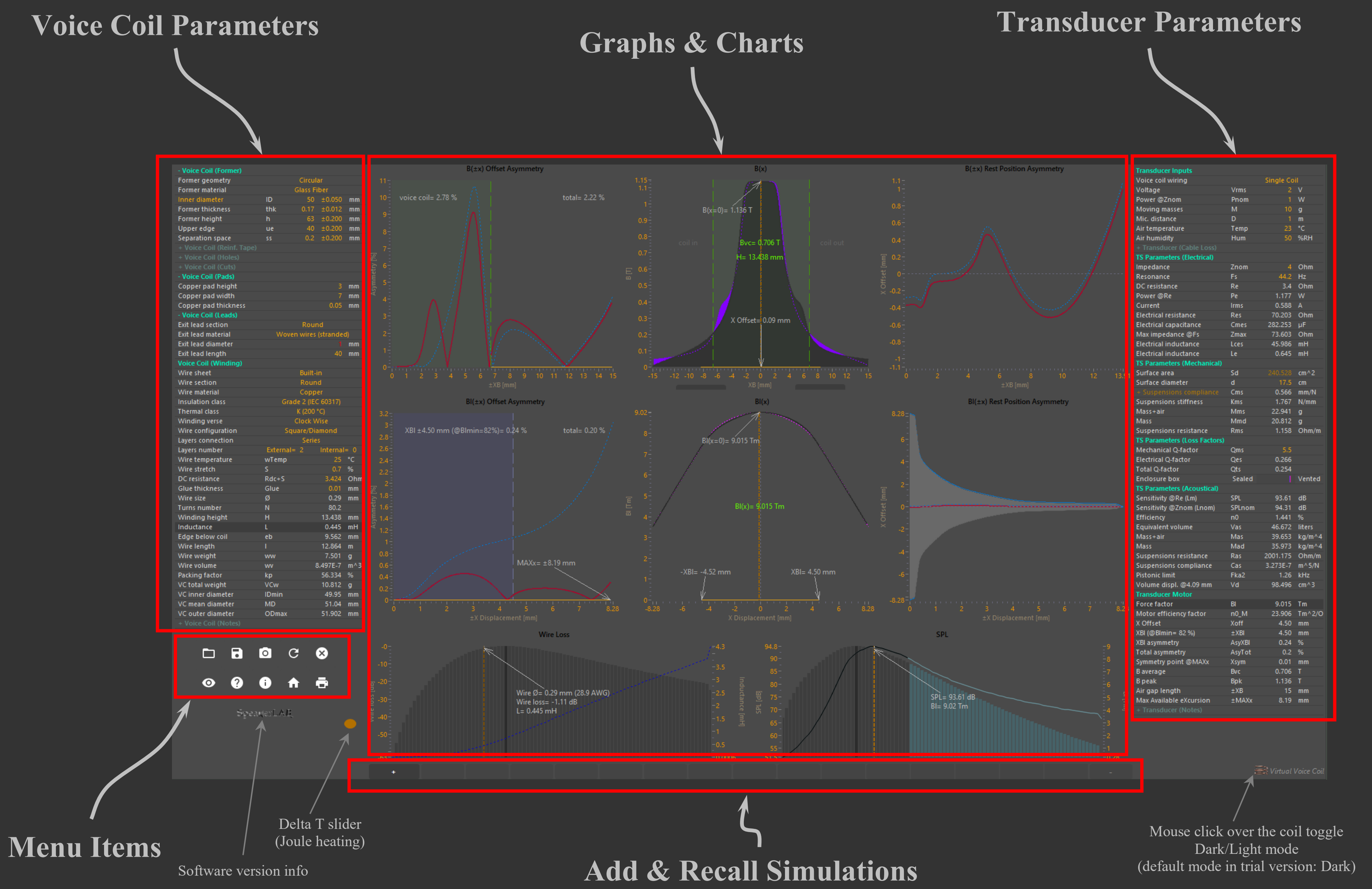
(If <u>max</u> dimension column is present in your wire sheet file these values have priority on **Insulation Class** selection). The default *Built-in* wire sheet includes the max dimension column.

```
%Round Wire Conductor:
%Nominal Diameter
#
...
0.20
0.21
0.22
...
#

%Rectangular/Square Wire Conductor.
%Nominal ThicknessxWidth
#
...
0.08x0.25
0.09x0.40
0.45x0.45
…
#
```

INTERFACE OVERVIEW

Macro Sections



INTERFACE OVERVIEW

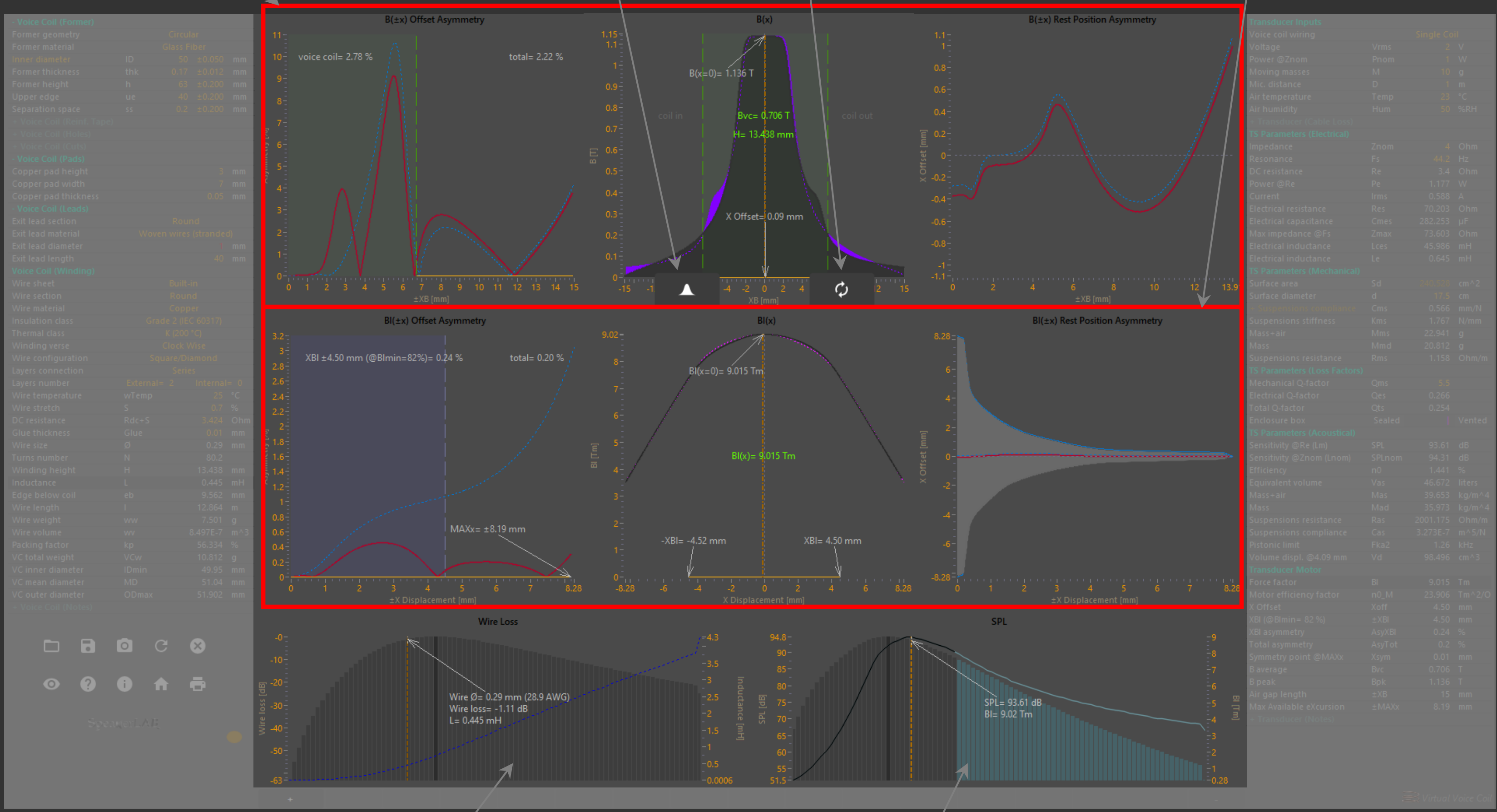
Macro Sections (Graphs & Charts)

Magnetic flux B(x) profile (center)
B(x) Mirror/Offset Asymmetry (left)
B(x) Rest Position Asymmetry (right)

Import button*

Swap (-x) button*

Force Factor Bl(x) profile (center)
Bl(x) Mirror/Offset Asymmetry (left)
Bl(x) Rest Position Asymmetry (right)



Wire Loss chart

Sound Pressure Level chart

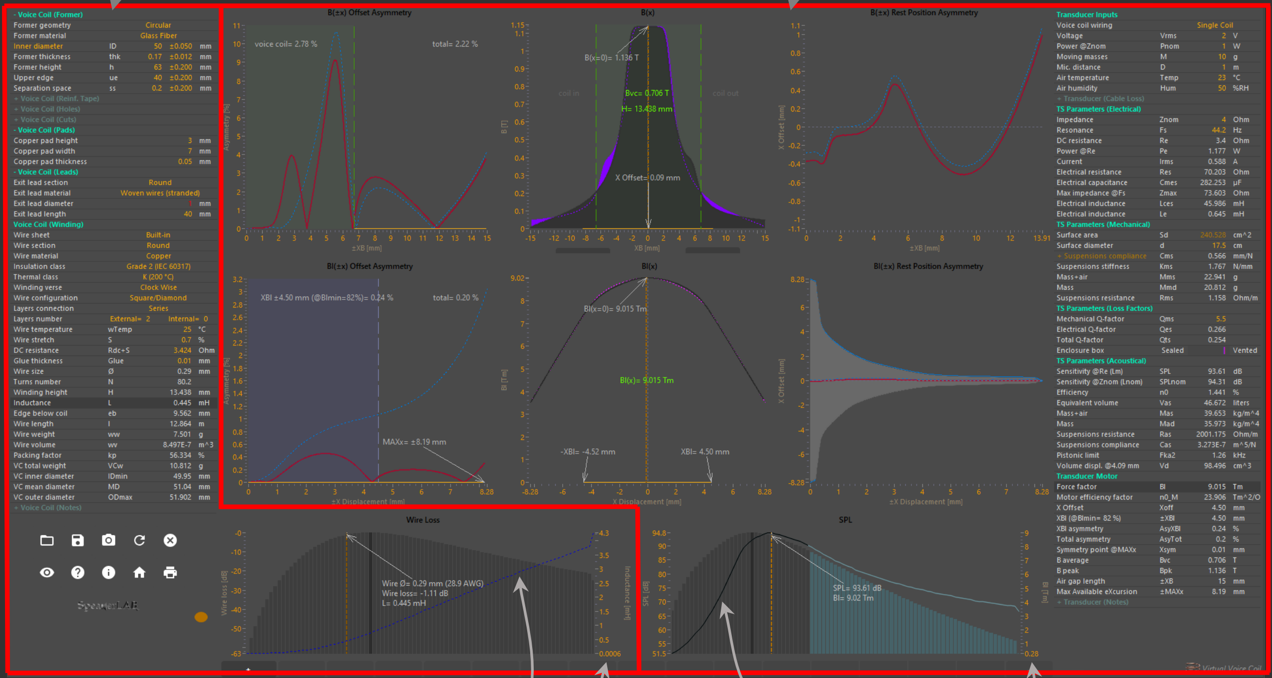
* Buttons are partially hided by default, move mouse over to show the whole button

INTERFACE OVERVIEW

Macro Sections

Magnetic Flux <u>independent</u> elements

Magnetic Flux <u>dependent</u> elements

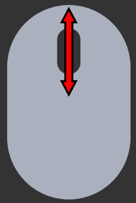


Moving mouse over the **Voice Coil** list to instantly plot a specific parameter calculated for each wire size. Mouse click to retain the *dashed blue line plot*. The amplitude is measured with the second scale on the graph right side. Voice coil *Inductance* is the default plot.

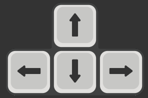
Moving mouse over the **Transducer** list to instantly plot a specific parameter calculated for each wire size. Mouse click to retain the *solid line plot*. The amplitude is measured with the second scale on the graph right side. Transducer *Force Factor Bl* is the default plot.

INTERFACE OVERVIEW

UI actions

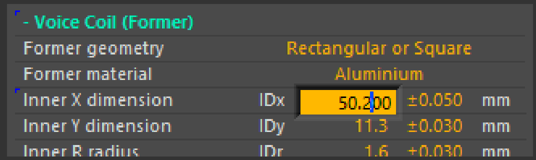


Mouse Wheel actions



(Keyboard arrow keys are also accepted)

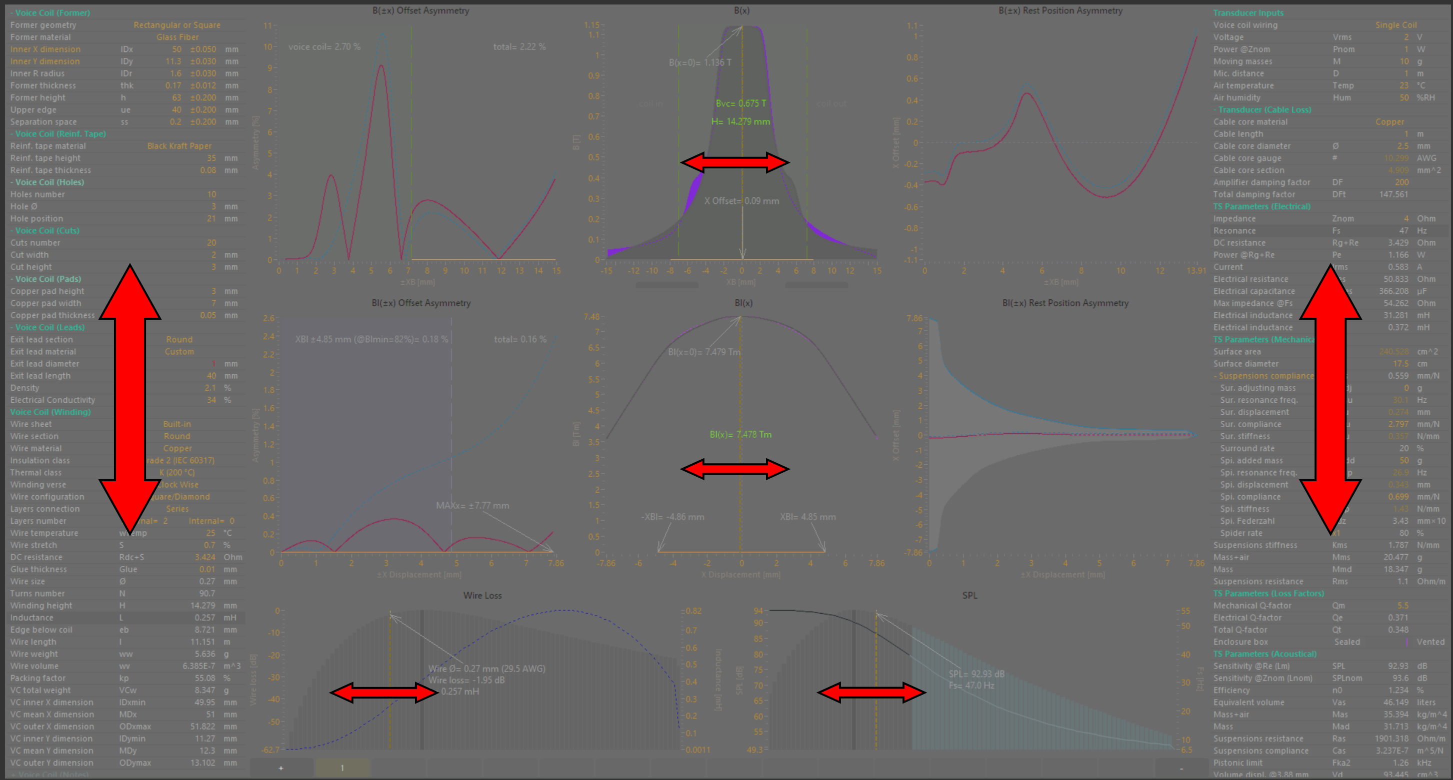
Use mouse wheel to progressively increment/decrement selected decimal point or type a specific value



Mouse wheel over a control value acts as a *virtual slider* permitting to gradually change all parameters simultaneously

Move Cursors (Left/Right keys)

Scroll table *
(Up/Down keys)



Scroll table *
(Up/Down keys)

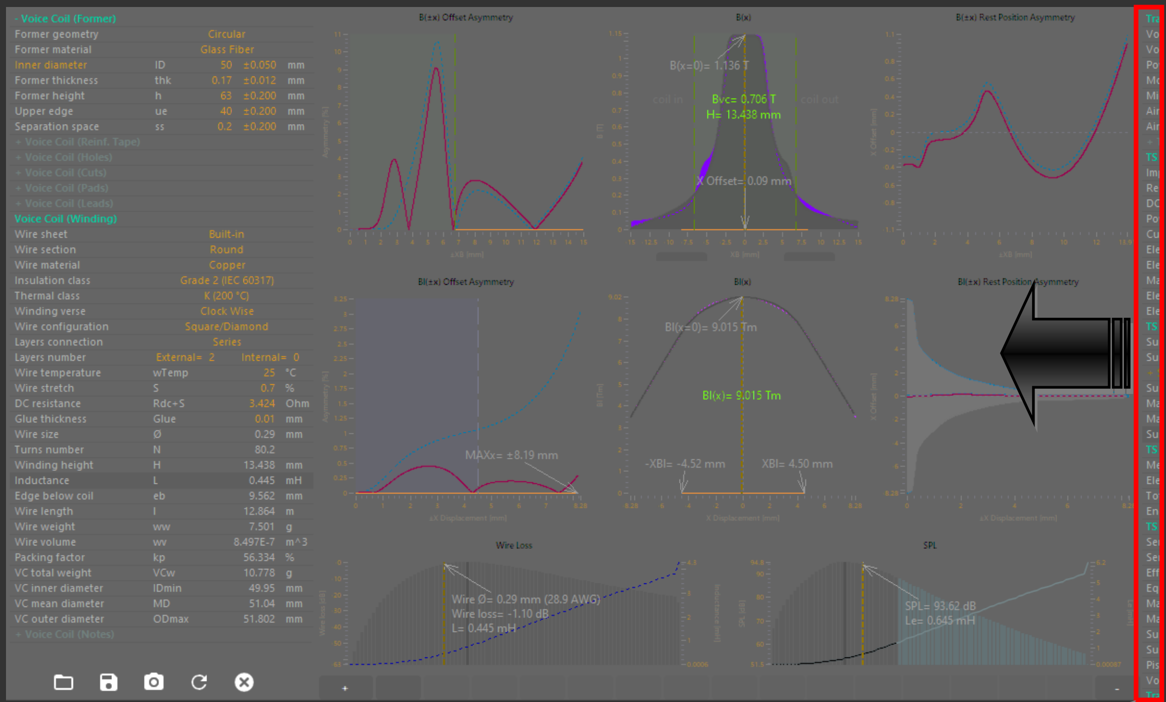
* Scroll (Up/Down keys) is activated when table vertical dimension goes outside the window bounds

INTERFACE OVERVIEW

UI actions

When the panel is resized in a small window the transducer parameters turn into a *sliding door*, allowing an adaptive resolution of graphs.

When the door is partially masked, mouse over it opens the transducer parameters.
When unmasked, mouse over it preserves the transducer parameters opened; while if mouse leaves transducer parameters, the door returns partially masked after 4 seconds.



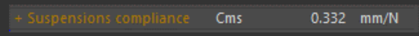
Mouse over this area for a full view of transducer parameters

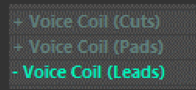
Door partially masked

INTERFACE OVERVIEW

UI actions

\+ means element is expandable
\- means element is compressible





When expanded: the element is enabled and included in the calculation
When compressed: the element is disabled and excluded from the calculation

ORANGE color always means that the element is editable by the user:

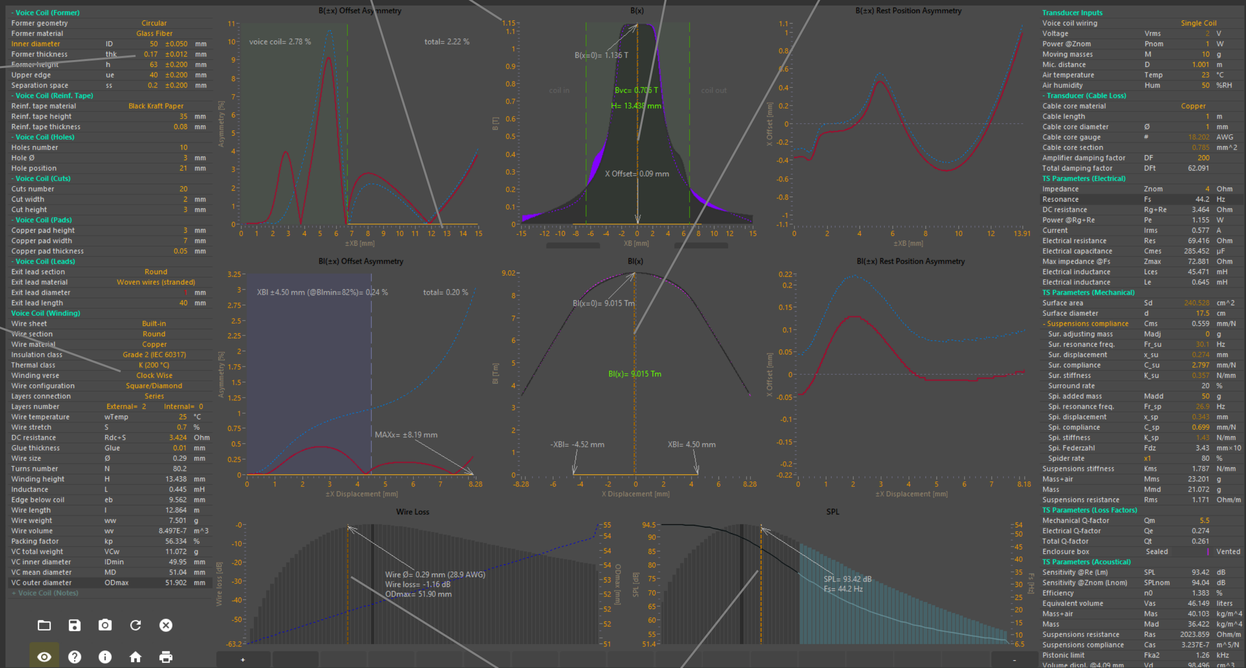
Offset Cursor *

***X* and *Y* scales values** *

***XBl* Cursor** *

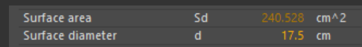
Controls

List boxes



When the **orange color** turns into **dark orange** means that the element is calculated from a correlated value.

Wire size Cursors



In this case, it shows *d* is set by the user and *Sd* is calculated

* Graphs scales are recalculated and cursors are reset to x= 0 when a wire size cursor or voice coil input parameters are modified

VOICE COIL PARAMETERS

Former

Mouse click to enable/disable the former.
Disabling the former, it automatically disables elements related to former (reinforcement tape, holes, cuts, pads).

+ Voice Coil				
Voice coil geometry		Circular		
Inner diameter	ID	50	±0.050	mm
+ Voice Coil (Reinf. Tape)				
+ Voice Coil (Holes)				
+ Voice Coil (Cuts)				
+ Voice Coil (Pads)				

Mean sizes are available in Version 2.1

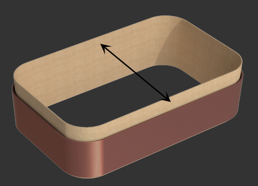
Former geometry includes circular voice coils and Rectangular or Square ones (mostly used for micro-speakers).

- Voice Coil (Former)				
Former geometry		Circular		
Former material		Aluminum		
Inner diameter	ID	50	±0.050	mm
Former thickness	thk	0.17	±0.012	mm
Former height	h	63	±0.200	mm
Upper edge	ue	40	±0.200	mm
Separation space	ss	0.2	±0.200	mm
- Voice Coil (Reinf. Tape)				
Reinf. tape material		Black Kraft Paper		
Reinf. tape height		35		mm
Reinf. tape thickness		0.08		mm
- Voice Coil (Holes)				
Holes number		10		
Hole Ø		3		mm
Hole position		21		mm
- Voice Coil (Cuts)				
Cuts number		20		
Cut width		2		mm
Cut height		3		mm
- Voice Coil (Pads)				
Copper pad height		3		mm
Copper pad width		7		mm
Copper pad thickness		0.05		mm
- Voice Coil (Leads)				
Exit lead section		Round		
Exit lead material		Woven wires (stranded)		
Exit lead diameter		0.5		mm
Exit lead length		30		mm
Voice Coil (Winding)				
Wire sheet		Built-in		
Wire section		Round		
Wire material		Copper		
Insulation class		Grade 2 (IEC 60317)		
Thermal class		K (200 °C)		
Winding verse		Clock Wise		
Wire configuration		Square/Diamond		
Layers connection		Series		
Layers number	External= 2		Internal= 0	
Wire temperature	wTemp	25		°C
Wire stretch	S	0.7		%
DC resistance	Rdc+S	3.424		Ohm
Glue thickness	Glue	0.01		mm
Wire size	Ø	0.29		mm
Turns number	N	80.2		
Winding height	H	13.438		mm
Inductance	L	0.445		mH
Edge below coil	eb	9.562		mm
Wire length	l	12.864		m
Wire weight	ww	7.501		g
Wire volume	wv	8.497E-7		m^3
Packing factor	kp	56.334		%
VC total weight	VCw	10.812		g
VC inner diameter	IDmin	49.95		mm
VC mean diameter	MD	51.04		mm
VC outer diameter	ODmax	51.902		mm
+ Voice Coil (Notes)				

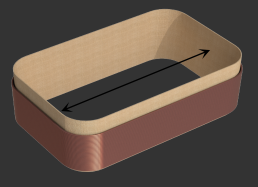
- Voice Coil (Former)				
Former geometry		Rectangular or Square		
Former material		Aluminum		
Inner X dimension	IDx	50	±0.050	mm
Inner Y dimension	IDy	11.3	±0.030	mm
Inner R radius	IDr	1.6	±0.030	mm
Former thickness	thk	0.17	±0.012	mm
Former height	h	63	±0.200	mm
Upper edge	ue	40	±0.200	mm
Separation space	ss	0.2	±0.200	mm

Former Material includes:
- Aluminum
- Anodized Aluminum
- Black Anodized Aluminum
- Polyimide
- Polyimide-Glass Composite
- Kapton
- Nomex 410
- Glass Fiber
- Kraft Paper
- Copper
- Titanium

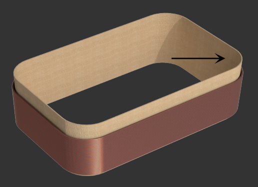
Inner X dimension (IDx)



Inner Y dimension (IDy)

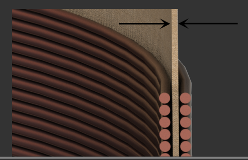


Inner R radius (IDr)

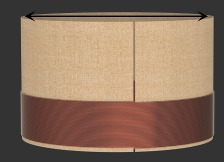


If Voice Coil (Former) is enabled, the **inner dimensions** (IDx, IDy, IDr) are always referred to the former.
If Former is disabled, they are referred to the winding

Former thickness (thk)

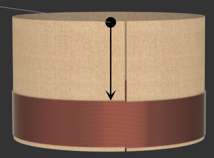


If Voice Coil (Former) is enabled, the **inner diameter** (ID) is always referred to the former. If Former is disabled, the **inner diameter** is referred to the winding

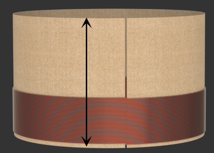


You can fix the **inner** or the **mean** diameter of the voice coil

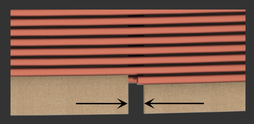
Coil to former **upper edge** (ue) is the position of the winding referred to the former upper edge.
If the value becomes red color reduce it or increase former height (h)



Former height (h) must be > **winding height** (H), otherwise this value became red



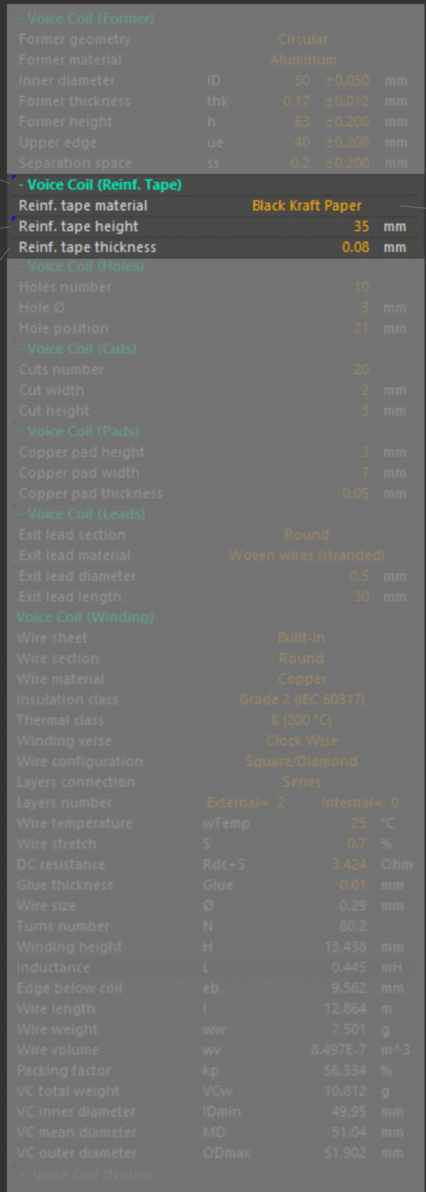
Former **separation space** (ss).
If the value becomes red color it must be reduced



VOICE COIL PARAMETERS

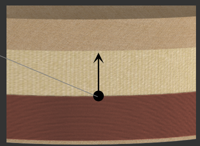
Former Reinforcement Tape

Mouse click to enable/disable

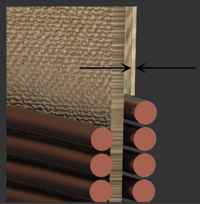


Reinforcement tape height

Ref. point



Reinforcement tape thickness



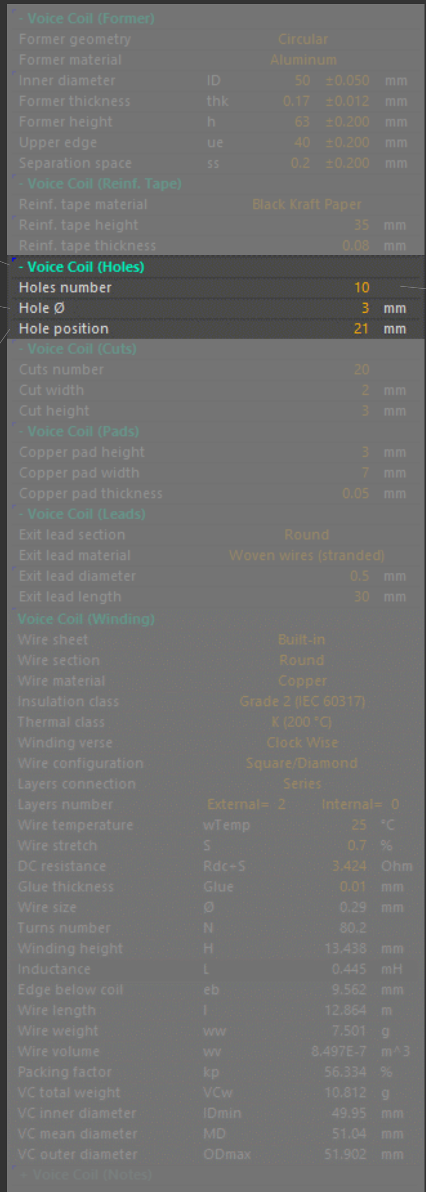
Reinforcement tape material includes:

- Kraft Paper
- Black Kraft Paper
- Red Kraft Paper
- Senka Paper
- Black Senka
- Blue Senka
- Green Senka
- Red Senka
- TKB
- Nomex 411
- Green Nomex 411
- Nomex 410
- Green Nomex 410
- Spunlace Nomex
- Black Spunlace Nomex
- Glass Fiber
- Black Glass Fiber
- Aluminum
- Polyimide
- Cequin
- Tufquin
- Micro-Holes Kraft Paper

VOICE COIL PARAMETERS

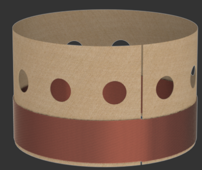
Former (venting) Holes

Mouse click to enable/disable

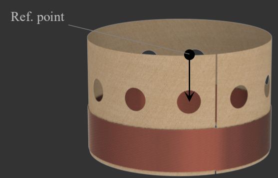


Hole diameter value must be < of the **coil to former upper edge** (ue). If the value becomes red color it must be reduced

Number of holes on former (arranged at equal distance).
If the value becomes red color it must be reduced



Hole position is the distance between former upper edge and holes center.
If the value becomes red color reduce it or modify related data



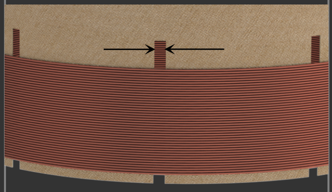
VOICE COIL PARAMETERS

Former Cuts

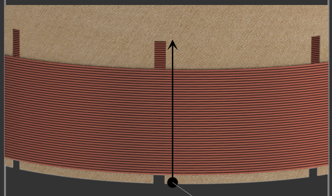
Mouse click to enable/disable

- Voice Coil (Former)				
Former geometry		Circular		
Former material		Aluminum		
Inner diameter	ID	50	±0.050	mm
Former thickness	thk	0.17	±0.012	mm
Former height	h	63	±0.200	mm
Upper edge	ue	40	±0.200	mm
Separation space	ss	0.2	±0.200	mm
- Voice Coil (Reinf. Tape)				
Reinf. tape material		Black Kraft Paper		
Reinf. tape height		35		mm
Reinf. tape thickness		0.08		mm
- Voice Coil (Holes)				
Holes number		10		
Hole Ø		3		mm
Hole position		21		mm
- Voice Coil (Cuts)				
Cuts number		20		
Cut width		2		mm
Cut height		3		mm
- Voice Coil (Pads)				
Copper pad height		3		mm
Copper pad width		7		mm
Copper pad thickness		0.05		mm
- Voice Coil (Leads)				
Exit lead section		Round		
Exit lead material		Woven wires (stranded)		
Exit lead diameter		0.5		mm
Exit lead length		30		mm
Voice Coil (Winding)				
Wire sheet		Built-in		
Wire section		Round		
Wire material		Copper		
Insulation class		Grade 2 (IEC 60317)		
Thermal class		K (200 °C)		
Winding verse		Clock Wise		
Wire configuration		Square/Diamond		
Layers connection		Series		
Layers number	External= 2	Internal= 0		
Wire temperature	wTemp	25		°C
Wire stretch	S	0.7		%
DC resistance	Rdc+S	3.424		Ohm
Glue thickness	Glue	0.01		mm
Wire size	Ø	0.29		mm
Turns number	N	80.2		
Winding height	H	13.438		mm
Inductance	L	0.445		mH
Edge below coil	eb	9.562		mm
Wire length	l	12.864		m
Wire weight	ww	7.501		g
Wire volume	wv	8.497E-7		m^3
Packing factor	kp	56.334		%
VC total weight	VCw	10.812		g
VC inner diameter	IDmin	49.95		mm
VC mean diameter	MD	51.04		mm
VC outer diameter	ODmax	51.902		mm
+ Voice Coil (Notes)				

Cut width. If the value becomes red color it must be reduced

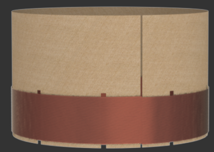


Cut height is the distance between former bottom edge and the top of cuts.
If the value becomes red color it must be reduced



Ref. point

Number of cuts on bottom side of the former (arranged at equal distance). If the value becomes red color it must be reduced



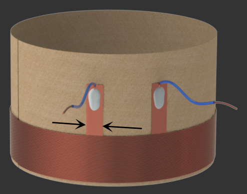
VOICE COIL PARAMETERS

Copper Pads on Former

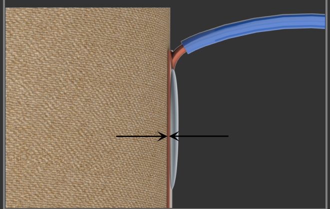
Mouse click to enable/disable

- Voice Coil (Former)				
Former geometry		Circular		
Former material		Aluminum		
Inner diameter	ID	50	±0.050	mm
Former thickness	thk	0.17	±0.012	mm
Former height	h	63	±0.200	mm
Upper edge	ue	40	±0.200	mm
Separation space	ss	0.2	±0.200	mm
- Voice Coil (Reinf. Tape)				
Reinf. tape material		Black Kraft Paper		
Reinf. tape height		35		mm
Reinf. tape thickness		0.08		mm
- Voice Coil (Holes)				
Holes number		10		
Hole Ø		3		mm
Hole position		21		mm
- Voice Coil (Cuts)				
Cuts number		20		
Cut width		2		mm
Cut height		3		mm
- Voice Coil (Pads)				
Copper pad height		3		mm
Copper pad width		7		mm
Copper pad thickness		0.05		mm
- Voice Coil (Leads)				
Exit lead section		Round		
Exit lead material		Woven wires (stranded)		
Exit lead diameter		0.5		mm
Exit lead length		30		mm
Voice Coil (Winding)				
Wire sheet		Built-in		
Wire section		Round		
Wire material		Copper		
Insulation class		Grade 2 (IEC 60317)		
Thermal class		K (200 °C)		
Winding verse		Clock Wise		
Wire configuration		Square/Diamond		
Layers connection		Series		
Layers number		External= 2	Internal= 0	
Wire temperature	wTemp	25		°C
Wire stretch	S	0.7		%
DC resistance	Rdc+S	3.424		Ohm
Glue thickness	Glue	0.01		mm
Wire size	Ø	0.29		mm
Turns number	N	80.2		
Winding height	H	13.438		mm
Inductance	L	0.445		mH
Edge below coil	eb	9.562		mm
Wire length	l	12.864		m
Wire weight	ww	7.501		g
Wire volume	wv	8.497E-7		m^3
Packing factor	kp	56.334		%
VC total weight	VCw	10.812		g
VC inner diameter	IDmin	49.95		mm
VC mean diameter	MD	51.04		mm
VC outer diameter	ODmax	51.902		mm
+ Voice Coil (Notes)				

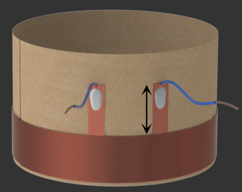
Copper pad width. If the value becomes red color it must be reduced



Copper pad thickness



Copper pad height.
If the value becomes red color it must be reduced



VOICE COIL PARAMETERS

Exit Wire Leads

Mouse click to enable/disable

Exit wire leads material includes:
Beryllium Copper (solid)
Phosphor Bronze (solid)
Copper (solid)
Woven wires (stranded)
Custom

(Generally, ribbon solid materials could be used in compression drivers and micro-speakers.
For tweeters both ribbon or round sections and both solid core (one strand of conductor per wire) or stranded wire (a bundle of thin strand of conductors) are used.
For high excursions (woofers and sub-woofers) multi-filar woven material, filled with a cloth core or Litz tinsel wires are necessary.
For special cases or for a different stranded or solid material it is possible to personalize a Custom one.)

Exit lead material		Custom	
Exit lead diameter		0.5	mm
Exit lead length		30	mm
Density	rho	2.1	%
Electrical Conductivity	sigma	34	%

Custom material **density** (rho) is a normalized parameter referred here to solid gold (100%). Considering for example solid copper is 45% and solid aluminum is 14%.
Woven materials are often filled with very flexible materials, like a cloth core consisting of thin meta-aramid or para-aramid fibers, thus they have a very low density (rho could be lower than 10%) compared to solid ones, useful for high excursion of transducer membrane.

Custom material **electrical conductivity** (Sigma) referred to IACS Standard.
VVC considers solid copper material as 100% IACS Standard, anyway custom material reaches high grade of impurities reduction for copper.
Currently processing techniques of pure copper products have improved since the adoption of the IACS standard in 1913, so now more impurities can be removed from metals. Currently it is possible to reduce impurities from copper over 103% IACS, considering that copper grades around 101% are oxygen free for electronic use.

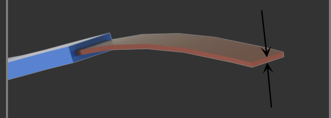
Silver 106% (max value)
Gold 77%.
Aluminum alloys are in the range 53% -> 62%.
Phosphor Bronze usually is below 20%.
Beryllium Copper alloys are in the range 20% -> 50%

- Voice Coil (Former)				
Former geometry		Circular		
Former material		Aluminum		
Inner diameter	ID	50	±0.050	mm
Former thickness	thk	0.17	±0.012	mm
Former height	h	63	±0.200	mm
Upper edge	ue	40	±0.200	mm
Separation space	ss	0.2	±0.200	mm
- Voice Coil (Reinf. Tape)				
Reinf. tape material		Black Kraft Paper		
Reinf. tape height		35		mm
Reinf. tape thickness		0.08		mm
- Voice Coil (Holes)				
Holes number		10		
Hole Ø		3		mm
Hole position		21		mm
- Voice Coil (Cuts)				
Cuts number		20		
Cut width		2		mm
Cut height		3		mm
- Voice Coil (Pads)				
Copper pad height		3		mm
Copper pad width		7		mm
Copper pad thickness		0.05		mm
- Voice Coil (Leads)				
Exit lead section		Round		
Exit lead material		Woven wires (stranded)		
Exit lead diameter		0.5		mm
Exit lead length		30		mm
Voice Coil (Winding)				
Wire sheet		Built-in		
Wire section		Round		
Wire material		Copper		
Insulation class		Grade 2 (IEC 60317)		
Thermal class		K (200 °C)		
Winding verse		Clock Wise		
Wire configuration		Square/Diamond		
Layers connection		Series		
Layers number		External= 2	Internal= 0	
Wire temperature	wTemp	25		°C
Wire stretch	S	0.7		%
DC resistance	Rdc+S	3.424		Ohm
Glue thickness	Glue	0.01		mm
Wire size	Ø	0.29		mm
Turns number	N	80.2		
Winding height	H	13.438		mm
Inductance	L	0.445		mH
Edge below coil	eb	9.562		mm
Wire length	l	12.864		m
Wire weight	ww	7.501		g
Wire volume	wv	8.497E-7		m^3
Packing factor	kp	56.334		%
VC total weight	VCw	10.812		g
VC inner diameter	IDmin	49.95		mm
VC mean diameter	MD	51.04		mm
VC outer diameter	ODmax	51.902		mm
+ Voice Coil (Notes)				

Exit wire leads section (Round or Ribbon).

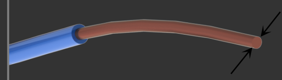
- Voice Coil (Leads)		
Exit lead section	Ribbon	
Exit lead material	Woven wires (stranded)	
Exit lead width	0.5	mm
Exit lead thickness	0.05	mm
Exit lead length	30	mm

Exit wire lead thickness, excluding insulation.
If the value becomes red color it is a reminder advising that the value is bigger than the winding depth

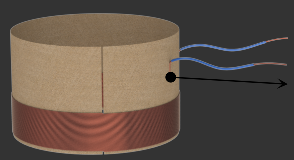


Exit wire lead width, excluding insulation

Exit wire lead diameter, excluding insulation. If the value becomes red color it is a reminder advising that the value is bigger than the winding depth



Exit wire lead length



VOICE COIL PARAMETERS

Winding

Select **wire sheet**. The default sheet is the internal Built-in.
You can edit or create new files with custom round, rectangular or square wire sizes (see **Wire Type Specifications** section for further details)

Switch between **wire cross section** shapes:
1) Round
2) Rectangular or Square

(see **Wire Type Specifications** section for further details)

Voice coil conductor **material**:
1) Copper
2) Aluminum
3) Silver
4) Gold
5) CCAW (Copper-Clad Aluminum Wire)
6) HCCAW (High-Tension Copper-Clad Aluminum Wire)
7) UCCAW (Ultra High-Tension Copper-Clad Aluminum Wire)

NOTE: *VVC* considers 15% of copper cladding wires

Insulation class. Breakdown voltage depends on the thickness of wire insulation, so wire max dimension depends on its insulation class.

IEC 60317 Standard has 3 types:
Grade 1 (single)
Grade 2 (heavy)
Grade 3 (triple)

Higher **IEC** grades have thicker insulation and thus higher breakdown voltages.

JIS 3202 Standard has 4 types:
Class 0
Class 1
Class 2
Class 3

In this case lower **JIS** grades have thicker insulation and thus higher breakdown voltages

NOTE: Insulation Class calculates wires max dimensions for sheets with nominal wire sizes only (without max dimension). If the max dimension column is included in your wire sheet file (like the *Built-in* wire sheet), this value has priority in *VVC* (see **Wire Type Specifications** section for further details), thus **Insulation class** selection doesn't modify the wire size (in this case **Insulation class** selection could be useful to remind the used wire for supplier).

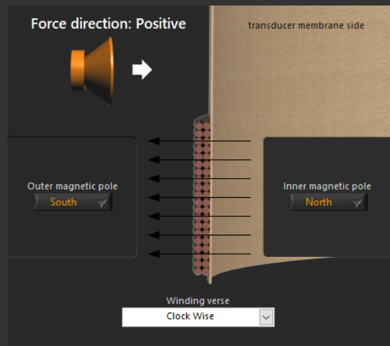
- Voice Coil (Former)				
Former geometry		Circular		
Former material		Aluminum		
Inner diameter	ID	50	±0.050	mm
Former thickness	thk	0.17	±0.012	mm
Former height	h	63	±0.200	mm
Upper edge	ue	40	±0.200	mm
Separation space	ss	0.2	±0.200	mm
- Voice Coil (Reinf. Tape)				
Reinf. tape material		Black Kraft Paper		
Reinf. tape height		35		mm
Reinf. tape thickness		0.08		mm
- Voice Coil (Holes)				
Holes number		10		
Hole Ø		3		mm
Hole position		21		mm
- Voice Coil (Cuts)				
Cuts number		20		
Cut width		2		mm
Cut height		3		mm
- Voice Coil (Pads)				
Copper pad height		3		mm
Copper pad width		7		mm
Copper pad thickness		0.05		mm
- Voice Coil (Leads)				
Exit lead section		Round		
Exit lead material		Woven wires (stranded)		
Exit lead diameter		0.5		mm
Exit lead length		30		mm
Voice Coil (Winding)				
Wire sheet		Built-in		
Wire section		Round		
Wire material		Copper		
Insulation class		Grade 2 (IEC 60317)		
Thermal class		K (200 °C)		
Winding verse		Clock Wise		
Wire configuration		Square/Diamond		
Layers connection		Series		
Layers number		External= 2	Internal= 0	
Wire temperature	wTemp	25		°C
Wire stretch	S	0.7		%
DC resistance	Rdc+S	3.424		Ohm
Glue thickness	Glue	0.01		mm
Wire size	Ø	0.29		mm
Turns number	N	80.2		
Winding height	H	13.438		mm
Inductance	L	0.445		mH
Edge below coil	eb	9.562		mm
Wire length	l	12.864		m
Wire weight	ww	7.501		g
Wire volume	wv	8.497E-7		m^3
Packing factor	kp	56.334		%
VC total weight	VCw	10.812		g
VC inner diameter	IDmin	49.95		mm
VC mean diameter	MD	51.04		mm
VC outer diameter	ODmax	51.902		mm
- Voice Coil (Holes)				

Thermal class. ASTM D 2307: *Standard Test Method for Thermal Endurance of Film-Insulated Round Magnet Wire.*
O (90 °C)
A (105 °C)
E (120 °C) IEC
B (130 °C)
F (155 °C)
H (180 °C)
K (200 °C)
M (220 °C)
C (240 °C)
250 °C IEC

For the Institute of *Electrical and Electronics Engineers* (IEEE), the thermal class of insulation defines the temperature index as the temperature of the wire where it has a 20,000 hours service life. At lower temperatures the service life of the wire is longer (about a factor 2 for every 10 °C lower temperature).
Wire max dimension is independent on Thermal Class

Winding verse (top view):
Clock Wise
Counter Clock Wise

Opening **Transducer Phase** interface, it is also possible to select inner and outer magnetic poles checking for membrane force polarity:



Wire configuration:
Square/Diamond
Hexagonal

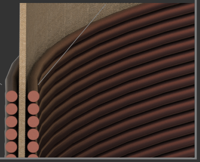
Geometric **wire configuration** in a multilayer voice coil represents round wires position among layers.
Square configuration has the worst Fill Factor and has the same value for the *Diamond* configuration (square rotated 45 degrees).
Selecting *Hexagonal* configuration, you have the best Fill Factor, impacting on *Packing Factor*.
Hexagonal configuration considers a full occupancy window, but in a real productive condition the *Fill Factor* has a lower value

VOICE COIL PARAMETERS

Winding

Layers number (max 20):

External Layers= N   Internal Layers= N



If the former is disabled layers are not separated and **edge below coil** (eb) results always zero:

Layers number		Total= 4	
Wire temperature	wTemp	20	°C
Wire stretch	S	0	%
DC resistance	Rdc+S	3.4	Ohm
Glue thickness	Glue	0.031	mm
Wire size	Ø	0.37	mm
Turns number	N	130.2	
Winding height	H	13.672	mm
Inductance	L	1.18	mH
Edge below coil	eb	0	mm

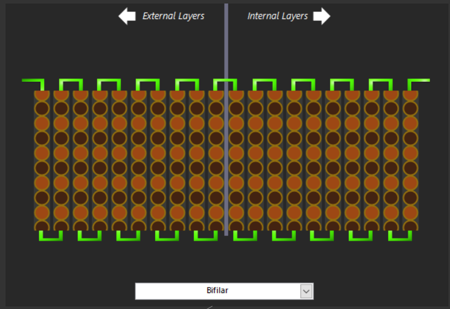
% of **Stretch** for the selected wire. Stretch is a model of the strain induced into the wire during coil winding, it depends on many factors as wire size/material, temperature, mandrel size/shape and moreover on related load force used for the winding production process. *VVC* already calculates automatically wire elongation due to wire material, size and temperature, so the % Stretch (S) here is the remaining stretch due only to the winding tool force. Common values are between 1% and 3%, if you don't know the right value, start your project pressing **Reset Values** button, *VVC* automatically calculates a suggested stretch, otherwise set S= 0 or ask to your supplier for fine tuning the stretch value.

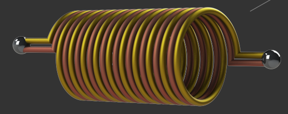
VVC calculates also the maximum stretch for all wires, for safety it is not possible to exceed this value. The max value is based on considering the minimum elongation a wire must have before any damage for high tension produced by tools during voice coil production. If the value becomes red color S must be reduced, because it is outside the wire limit.

Always try to limit stretch to less than 5%, because it decreases the isolation film thickness, leading to a deterioration in properties. Particularly in case of soft copper or aluminum and, more generally, when a metal wire is stretched, before the yield point, microcrystals within the material tend to rearrange and become less densely packed, reducing electrons mobility in atoms and thus require more energy to move through the metal than they would in an unstretched state.
This behavior develops not only a longitudinal resistivity, and thus an increase of Re, but also a radial resistivity gradient in the voice coil wire.
Hence why DC resistance per unit length will increase and then, as a consequence, more voltage is required for the same amount of current flow after stretching occurs.
As reported in "CRC Handbook of Chemistry and Physics (E81: Resistivity of metals)" the bulk resistivity increases on external side of the wire diameter and this effect is a current distribution towards the inside of voice coil turns, with consequent reduction in the effective radius. This factor is considered on related parameters calculus

- Voice Coil (Former)				
Former geometry		Circular		
Former material		Aluminum		
Inner diameter	ID	50	±0.050	mm
Former thickness	thk	0.17	±0.012	mm
Former height	h	63	±0.200	mm
Upper edge	ue	40	±0.200	mm
Separation space	ss	0.2	±0.200	mm
- Voice Coil (Reinf. Tape)				
Reinf. tape material		Black Kraft Paper		
Reinf. tape height		35		mm
Reinf. tape thickness		0.08		mm
- Voice Coil (Holes)				
Holes number		10		
Hole Ø		3		mm
Hole position		21		mm
- Voice Coil (Cuts)				
Cuts number		20		
Cut width		2		mm
Cut height		3		mm
- Voice Coil (Pads)				
Copper pad height		3		mm
Copper pad width		7		mm
Copper pad thickness		0.05		mm
- Voice Coil (Leads)				
Exit lead section		Round		
Exit lead material		Woven wires (stranded)		
Exit lead diameter		0.5		mm
Exit lead length		30		mm
Voice Coil (Winding)				
Wire sheet		Built-in		
Wire section		Round		
Wire material		Copper		
Insulation class		Grade 2 (IEC 60317)		
Thermal class		K (200 °C)		
Winding verse		Clock Wise		
Wire configuration		Square/Diamond		
Layers connection		Series		
Layers number		External= 2	Internal= 0	
Wire temperature	wTemp	25		°C
Wire stretch	S	0.7		%
DC resistance	Rdc+S	3.424		Ohm
Glue thickness	Glue	0.01		mm
Wire size	Ø	0.29		mm
Turns number	N	80.2		
Winding height	H	13.438		mm
Inductance	L	0.445		mH
Edge below coil	eb	9.562		mm
Wire length	l	12.864		m
Wire weight	ww	7.501		g
Wire volume	wv	8.497E-7		m^3
Packing factor	kp	56.334		%
VC total weight	VCw	10.812		g
VC inner diameter	IDmin	49.95		mm
VC mean diameter	MD	51.04		mm
VC outer diameter	ODmax	51.902		mm
- Voice Coil (Holes)				

Opening **Layers Connection** is possible to modify *Series/Parallel* layers connections or *Bifilar* windings.
VVC offers all possible combinations useful to obtain target parameters; some combinations represent a way to reduce inductance, to modify thermal dissipation or can help to increase Mms in some drivers like sub-woofers.





A Bifilar coil winding is wound using two wires, side by side at the same time, as showed in this image. It can be used to reduce voice coil inductance L.

When layers number changes, *connections selector* always resets to *Series*.
You can work with this window open; all modifications are updated in the main program.

NOTE 1: Parallel connection may have intensive inductance computational time, depending on coil turns number, reducing UI speed. The L calculus for each wire is always done in background and its progress is visible on L and Le respectively in Wire Loss chart and SPL chart.

NOTE 2: Series/Parallel calculus is always intended for coupled layers. Images of connected layers don't indicate current polarity thus, during transducer assembly, pay attention to maintain the same radial current in the same direction for each voice coil layer connection.

NOTE 3: Series/Parallel combinations could have a delta difference of circulating currents among layers.

NOTE 4: Some Series/Parallel combinations could have wires which ends on both sides of the coil winding.

Wire temperature (wTemp) represents the environment temperature at which the voice coil is assembled. In other words, it is the temperature of the supplier factory during voice coil winding phase. This temperature defines materials thermal expansion, VVC calculates voice coil wire length, partial stretch, sizes variation, etc

Electrical voice coil **DC resistance** (*VVC* automatically includes stretch) referred to the **wire temperature**. This is the target Rdc value used for supplier voice coil drawings

Glue thickness (Glue) is the average value of additional resin thickness among layers.
Usually, this value is near to zero, because the maximum outer wire diameter (or thickness in case of rectangular/square wire) comprises the bonding (self-bonding wires).
Use additional Glue Thickness if you need to consider a thermo-bonding glue among layers (professional audio applications).

If >0 this value is involved in voice coil dimensions, in inductance calculus (it represents the radial pitch for multi-layers coils) and also in the total voice coil weight (considering a fixed glue density of 0,5 g/cm^3)

VOICE COIL PARAMETERS

Winding

Total **wire length** (l)

Wire weight (ww) is the total weight of pure wire, excluding resins or glues. The precision tolerance is ±2% of the value

Wire **nominal volume** (wv) could be useful on your FEA or analytical calculations involving Bl. This is the real volume occupied by solid conductor, it is more precise compared to some simplified FEA analysis, because in this case it considers also the Wire Packing Factor

Packing Factor (kp) represents the ratio between conductive wire area and total winding area. The Packing Factor includes Wire Porosity, that is the ratio between conductive and insulated wire area. The Packing Factor also includes the Wire Fill Factor, that is the fraction of conducting area between wires. Selecting Hexagonal geometric configuration to increase round wire Packing Factor

Voice Coil Weight (VCw) is the total weight of wire + former + glue + reinforcement tape + copper pads + exit leads + bonding + insulating films of the wire. The precision tolerance is ±4% of the value

Voice coil **IDmin**, **IDxmin**, **IDymin** are the minimum internal dimension of the voice coil

Voice coil **MD**, **MDx**, **MDy** are the mean dimension of the voice coil. Including only winding material

Voice coil **ODmax**, **ODxmax**, **ODymax** are the maximum external dimension of the voice coil

- Voice Coil (Former)				
Former geometry		Circular		
Former material		Aluminum		
Inner diameter	ID	50	±0.050	mm
Former thickness	thk	0.17	±0.012	mm
Former height	h	63	±0.200	mm
Upper edge	ue	40	±0.200	mm
Separation space	ss	0.2	±0.200	mm
- Voice Coil (Reinf. Tape)				
Reinf. tape material		Black Kraft Paper		
Reinf. tape height		35		mm
Reinf. tape thickness		0.08		mm
- Voice Coil (Holes)				
Holes number		10		
Hole Ø		3		mm
Hole position		21		mm
- Voice Coil (Cuts)				
Cuts number		20		
Cut width		2		mm
Cut height		3		mm
- Voice Coil (Pads)				
Copper pad height		3		mm
Copper pad width		7		mm
Copper pad thickness		0.05		mm
- Voice Coil (Leads)				
Exit lead section		Round		
Exit lead material		Woven wires (stranded)		
Exit lead diameter		0.5		mm
Exit lead length		30		mm
Voice Coil (Winding)				
Wire sheet		Built-in		
Wire section		Round		
Wire material		Copper		
Insulation class		Grade 2 (IEC 60317)		
Thermal class		K (200 °C)		
Winding verse		Clock Wise		
Wire configuration		Square/Diamond		
Layers connection		Series		
Layers number		External= 2	Internal= 0	
Wire temperature	wTemp	25		°C
Wire stretch	S	0.7		%
DC resistance	Rdc+S	3.424		Ohm
Glue thickness	Glue	0.01		mm
Wire size	Ø	0.29		mm
Turns number	N	80.2		
Winding height	H	13.438		mm
Inductance	L	0.445		mH
Edge below coil	eb	9.562		mm
Wire length	l	12.864		m
Wire weight	ww	7.501		g
Wire volume	wv	8.497E-7		m^3
Packing factor	kp	56.334		%
VC total weight	VCw	10.812		g
VC inner diameter	IDmin	49.95		mm
VC mean diameter	MD	51.04		mm
VC outer diameter	ODmax	51.902		mm
+ Voice Coil (Notes)				

Nominal round bare wire **diameter** (Ø), or **Thickness x Width** (TxW) in case of a rectangular/square wire, selected on the Wire Loss chart moving the orange vertical cursor

Turns number (N) is the total number of turns of the winding

Winding height (H).
H is showed also on B(x) plot and H/2 on the B(±x) Offset Asymmetry plot

Voice Coil **Inductance** (L) stands for the low frequency voice coil inductance.

Depending on physical voice coil parameters, L is a combination of self-inductance (*first kind* and *second kind elliptic integrals* are both rounded to the second decimal point), mutual inductance and internal inductance due to the skin effect (*VVC* calculates the skin effect for L at a frequency of 1 kHz). Proximity effects are neglected.

For single-layer voice coils the current sheet method with *Nagaoka function* is used and the **L** precision tolerance is <±1.3 % for a copper round wire.
Multi-layers coils use *Maxwell's method* computing mutual inductance among filamental conductors *GMD*, in this case the precision is <±4.3 % for a series multi-layers voice coil.
Inductance of multi-layers circular voice coils with parallel connection of layers have a precision <±7%.

You can find the **L** value, calculated by *VVC*, measuring the voice coil in free air (@1 kHz), as a raw material, then when the voice coil is assembled inside the transducer motor gap, **L** will be different (see **Le**).

NOTE1: parallel or series calculus is always intended for coupled layers connection

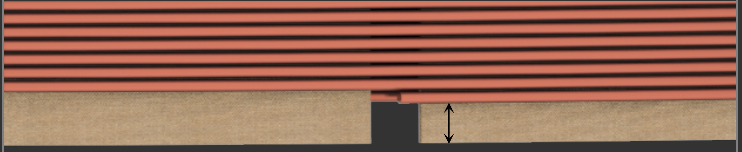
NOTE2: the symbol § means calculus is in progress in background

NOTE3: turns number per layer must be greater or equal to half turn, otherwise L= 0

NOTE4: layers combination involves matrix systems in analytical method, whose complexity generates a summation of errors and computational time, the related incrementing rates depend on layers and turns number. In some conditions it could be a cause of some spikes in the L and Le curves, in this case, please consider spike values as outliers.

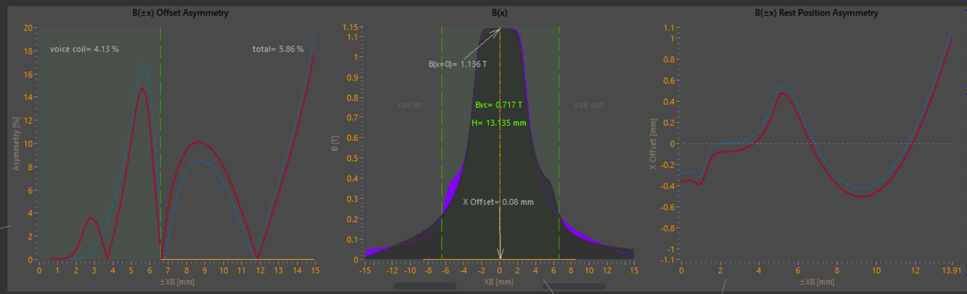
Edge Below Coil (eb) is the resulting position of coil referred to the former lower edge, including involved tolerances.

Note: If the value is red color but negative it's necessary to reduce coil to former **upper edge** (ue) and/or increase **former height** (h), including their tolerances.
If the value is red color but positive it is a warning because various voice coil manufacturers could not accept it



GRAPHS & CHARTS

B(x)



B(±x) Offset Asymmetry
B(±x) Offset or Mirror Asymmetry, <u>red line</u>. It is a parameter calculated for B>0 for measuring the goodness of flux density motor symmetry for its full ±*XB* length.

The B(±x) Offset Asymmetry plot, red line, regardless of the voice coil, it is calculated along the flux density profile from the point of view of the x offset.

The lower to 0 the B(±x) Offset Asymmetry, the better the flux symmetry. The ideal loudspeaker has the red line coincident with 0% line.

The <u>dashed blue line</u> represents B(±x) Offset Asymmetry @X Offset= 0. Use this as a reference curve to check the transducer motor B(x) offset symmetry.

The <u>yellow line on the base of the graph</u> represents the ±***M****aximum* ***A****vailable mechanical e****X****cursion* (±MAX) @X Offset.
If the air gap length is the real max available mechanical space, we can consider **MAXx= Xmech** (as defined in 15.2.3 of the *IEC 62458: Sound system equipment - Electroacoustical transducers - Measurement of large signal parameters*).

<u>Green filled color</u> is relative to the voice coil half winding height.

<u>Voice coil percentage</u> is the amount of B(x) asymmetry along the voice coil winding height at its rest position.
<u>Total percentage</u> is the total amount of B(x) asymmetry.

The lower to 0 the voice coil winding height, the higher become the priority of B(x) symmetry over Bl(x) symmetry, therefore a motor with a symmetrical B(x) always gives a symmetrical Bl(x).

The B(±x) Offset Asymmetry reduction is useful for example when you need a unique motor for many loudspeaker types which use different voice coils geometries.

If you are optimizing a design, for example if you want to check asymmetries inside an excursion range, or if you are searching for the most symmetrical motor among different designs, you can import and compare all your batch FEA simulations, using the parameters offered by the asymmetry graphs.

B(x)
B(x) Magnetic Flux Density, <u>filled dark grey</u>, represents the magnetic flux B inside the transducer air gap, along a line perpendicular to the flux direction and passing through the voice coil winding center, for the full available length (*XB*).

Thus, *VVC* considers the bounds of ±*XB* line as the physical limit for the maximal travel, equal to a voice coil mechanical bottoming, so the <u>yellow line on the base of the graph</u> indicating the ***M****aximum* ***A****vailable mechanical e****X****cursion* (MAX). If the air gap length is the real max available mechanical space, we can consider **MAXx= Xmech** (as defined in 15.2.3 of the *IEC 62458: Sound system equipment - Electroacoustical transducers - Measurement of large signal parameters*).

$MAX_{@x=0}$= *XB - Voice Coil Winding Height*

B(-x), <u>purple plot</u>, is the mirrored B(x) profile.

<u>Green color</u> is related to the voice coil dimension and position.
Between the two green vertical lines there is the selected <u>voice coil winding height</u> (H).
<u>Bvc</u> is the flux average value calculated on voice coil.

<u>B(x=0)</u> is the value of the flux at the center point.

<u>Bpk</u> is the peak value of the magnetic flux. Asymmetrical fluxes could have peaks not equal to B(x=0), in this case the Bpk is displayed, because this is the common value measured using a Gaussmeter probe inside the magnetic gap.

Drag the <u>orange cursor</u> to enable offset and move voice coil future position inside the air gap, the resulting offset is visible on Bl(x) graph.
When the mouse pointer is inside the graph bounds it is possible to use mouse wheel to move the cursor with more precision.

VVC can manage negative B flux values, usually used for electromagnetic breaks.
The negative values are sampled in absolute value and showed in the positive Y but using a complementary color compared to the dark grey flux.

<u>Dashed grey line</u> represents the voice coil offset zero reference, this is the current rest position.

B(±x) Rest Position Asymmetry
B(±x) Rest Position Asymmetry, <u>red line</u>, represents the center point between two points on the B>0 curve producing the same B value:

B[T] (X Offset[mm] + XB[mm])= B[T] (X Offset[mm] - XB[mm])

If the red line is constant along the ±*XB* it means that the B(x) shape is symmetrical compared to the voice coil rest position and this asymmetry will be compensated by the offset.

<u>X Offset= 0</u> represents the voice coil offset zero reference, this is the current rest position. The ideal geometry of a magnetic field has the red line coincident with X Offset= 0 line.

Note: pay attention to the X Offset scale for the evaluation of B(±x) Rest Position Asymmetry variation, because when the red line is touching the zero line small values of the X Offset scale means a good symmetry.

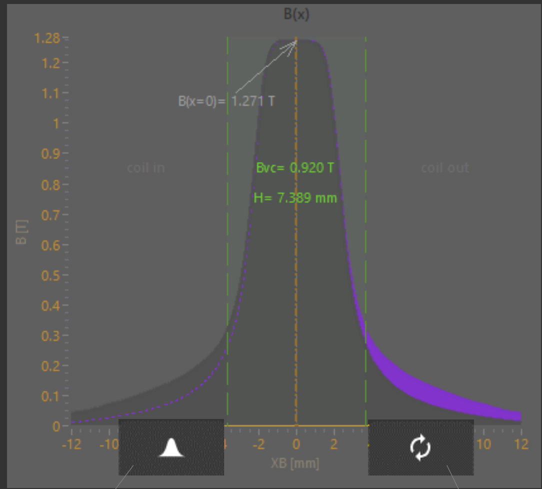
The <u>dashed blue line</u> represents B(±x) rest position asymmetry @X Offset= 0.

Shifting the B(x) offset in order to reduce the distance with the rest position, using the dashed blue line as a reference curve to find a better arrangement.

<u>Dashed grey line</u> represents the voice coil offset zero reference, this is the current rest position.

GRAPHS & CHARTS

B(x)



Import button
Import *Flux* profile *B* inside the air gap, along a line passing through the voice coil center for its full length (*XB*).
It is calculated by external *FEA* software, the saved unit of the flux density *B* must be *Tesla* and the *x* length must be *mm*.

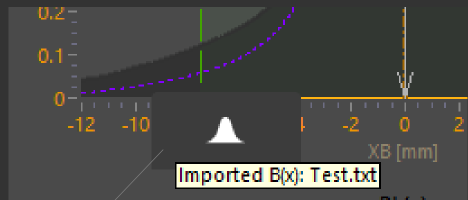
To obtain the correct graph *x* direction, the first values of the file must be on the COIL IN side and last values towards COIL OUT side. Otherwise, you can always use *Swap (-x)* button to invert *x* direction.

VVC considers *XB/2* as the center of the B flux line and the current rest position *Offset*= 0.

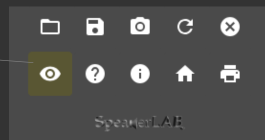
File must be a *TAB delimiter* format, with period (.) or comma (,) decimal separator, for example a period separator:

[mm]	[T]
0	**0.01**
0.1	**0.02**
...	

Swap button
Swap (-*x*) for inverting *x* direction

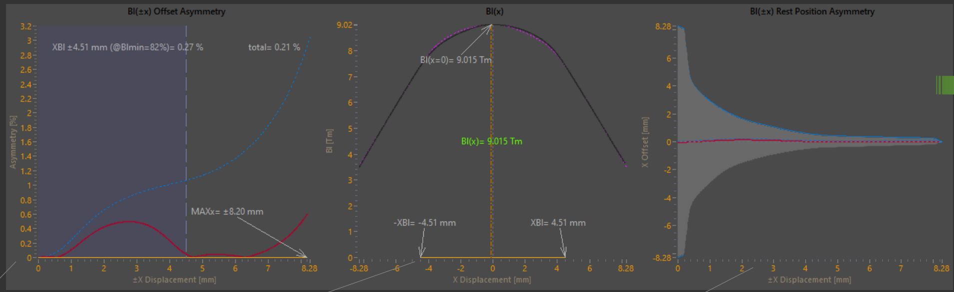


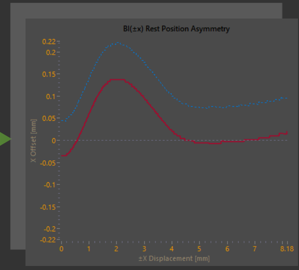
When SHOW TIP STRIP is enabled, mouse over the import button permits to show the imported file name



GRAPHS & CHARTS

Bl(x)





A five seconds zoom (focusing X_{sym}) occurs when the offset of the coil is virtually shifted or if mouse pointer enters the graph bounds. It permits to visualize and select the optimal voice coil position with the maximum precision.

Bl(±x) Offset Asymmetry

Bl(±x) Offset or Mirror Asymmetry, red line. It is a parameter calculated for B>0 for measuring the goodness of force factor offset symmetry for its full ±***M****aximum* ***A****vailable mechanical* ***eX****cursion* (±MAX) @X Offset.

Bl(±x) Offset Asymmetry is given by the formula:

n^-1 Sigma {t= 1}^n (|(Bl(X Offset + X Displacement) - Bl(X Offset - X Displacement))| / (f + |Bl(X Offset + X Displacement)| + |Bl(X Offset - X Displacement)|))

where the term *f* represents the weighting filter of the function.

The lower to 0 the *Bl(±x) Offset Asymmetry*, the better the force factor symmetry. The ideal loudspeaker has the red line coincident with 0% line.

Transducer force factor Bl(x) non-linearities are directly linked to this graph.

$$\lim_{l\to 1} Bl(\pm x)\ MirrorAsymmetry = B(\pm x)\ MirrorAsymmetry$$

The dashed blue line represents Bl(x) asymmetries @X Offset= 0. Shifting the offset of the selected voice coil to compensate Bl(x) asymmetries, using the dashed blue line as a reference curve for finding a better arrangement.

The yellow line on the base of the graph represents the ±***M****aximum* ***A****vailable mechanical* ***eX****cursion* (±MAX) @X Offset.
If the air gap length is the real max available mechanical space, we can consider **MAXx= Xmech** (as defined in 15.2.3 of the *IEC 62458: Sound system equipment - Electroacoustical transducers - Measurement of large signal parameters*).

The filled blue color indicates the maximal displacement amplitude ±XBl limited by motor distortion $@Bl_{min}$= 82%.
The filled blue color disappears and XBl value shows * when ±XBl ($@Bl_{min}$= 82%) doesn't cross the symmetry line of the current rest position.

The percentage of XBl ($@Bl_{min}$= 82%) is the amount of Bl(x) asymmetry when voice coil displacement is inside the XBl range.
Total percentage is the total amount of Bl(x) asymmetry for the full available excursion ±MAX.

It is possible to improve Bl(x) symmetry shifting voice coil offset and/or in some cases increasing the voice coil winding height, otherwise it's necessary to work on motor design and improve the B(x) symmetry.

Bl(x)

Bl(x) Force Factor, dark grey plot.

Bl(-x), dashed pink line, is the mirrored Bl(x) profile.

Bl(x= 0) is the value of Bl when voice coil offset is at the center point B(x= 0).

Bl(x) is showed and calculated when differs from Bl(x=0), that is when an X Offset occurs.

$$\lim_{l\to 1} Bl(\pm x) = B(\pm x)$$

The yellow line on the base of the graph represents ±XBl ($@Bl_{min}$= 82%). The two values -XBl and XBl indicate the displacement limits $@Bl_{min}$= 82%.

Note: The threshold of Bl_{min}= 82% is recommended because it corresponds with 10% modulation distortion according to *Clause 24* of *IEC 60268-5* for a two tone signal comprising a tone at resonance frequency *f1= fs* and a second tone at *f2= 8.5 fs*.
Anyway, all values of XBl at different % Bl_{min} can be found moving the vertical orange cursor.

Drag the orange cursor to calculate the percentage reduction along the Bl(x) curve and its relative XBl position, for example you can get related XBl $@Bl_{min}$= 75%, 50%, etc.
When the mouse pointer is inside the graph bounds it is possible to use mouse wheel to move the cursor with more precision.

VVC can manage negative Bl(x) force factor values, usually used for electromagnetic breaks.
The negative values are sampled in absolute value and showed in the positive Y, but using a complementary color compared to the dark grey force factor.
This is useful to permit evaluations of the applied negative force on brakes compared to the positive force along the voice coil excursion.

Dashed grey line represents the voice coil offset zero reference, this is the current rest position.

Bl(±x) Rest Position Asymmetry

Bl(±x) Rest Position Asymmetry, defined the Symmetry Point $X_{sym}(X_{ac})$ in *IEC 62458*, red line represents the center point between two points on the Bl>0 curve producing the same Bl value:

$$Bl(X_{sym} + X\ Displacement) = Bl(X_{sym} - X\ Displacement)$$

where
X_{sym}= *x @maximum ±X Displacement*

If the red line is constant along the ±X Displacement it means that the Bl(x) shape is symmetrical compared to the voice coil rest position and this asymmetry will be compensated by the offset.

If the red line varies along the ±X Displacement it means that the Bl(x) shape is not symmetrical compared to the voice coil rest position and the offset cannot completely compensate Bl non linearities.
In this case the cause is due to the asymmetrical geometry of magnetic field.

$$\lim_{l\to 1} Bl(\pm x)\ Rest\ Position\ Asymmetry = B(\pm x)\ Rest\ Position\ Asymmetry$$

X Offset= 0 represents the voice coil offset zero reference, this is the current rest position. The ideal loudspeaker has the red line coincident with X Offset= 0 line.

Note: pay attention to the X Offset scale for the evaluation of Bl(±x) Rest Position Asymmetry variation, because when the red line is touching the zero-line small values of the X Offset scale means a good symmetry.

The dashed blue line represents Bl(±x) rest position asymmetry @X Offset= 0. Transducer force factor Bl(x) non-linearities are directly linked to this graph.

Shifting the offset of the selected voice coil to compensate asymmetries, reducing distance with the rest position, using the dashed blue line as a reference curve to find a better setup.

The dashed blue line contour is given by the formula:

|((Bl(X Offset(X Displacement) + X Displacement) - Bl(X Offset(X Displacement) - X Displacement)) / (Bl(X Offset(X Displacement) + X Displacement) + Bl(X Offset(X Displacement) - X Displacement)))|

it represents Bl(±x) symmetry range, when asymmetries don't exceed 5%, keeping X Offset= 0.

The filled grey area is given by the same formula and it represents Bl(±x) symmetry range, for asymmetries< 5% @X Offset.

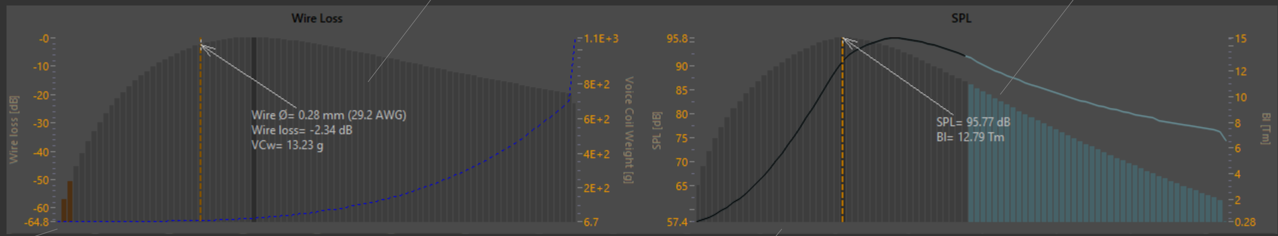
Dashed grey line represents the voice coil offset zero reference, this is the current rest position.

GRAPHS & CHARTS

Wire Selection

Wire section indicated in mm and (AWG)
Wire Loss of current wire (scale on the left side)
Amplitude of dashed blue line (scale on the right side)

Transducer SPL using current wire (scale on the left side)
Amplitude of solid line (scale on the right side)



Wire Loss Chart
This chart represents the relative wire efficiency (*dB-Loss*) calculated for all wires size (both round and rectangular/square) present in the selected **wire sheet** and considering a constant loudspeaker magnetic flux along the voice coil ± excursion.

In this chart dB is linked to the wire efficiency loss, it is independent from the magnetic flux.
Wire *dB-Loss* is different from the dB_{SPL} linked to the loudspeaker sensitivity for which the magnetic flux is known.

Moving the orange cursor to select wire size from the Wire Loss chart.
When the mouse pointer is inside the graph bounds it is possible to use mouse wheel to move the cursor with more precision.

The dark bar indicates the best efficiency among all wires, that is the golden ratio linked to the selected voice coil and all other mechanical parameters independent from magnetic flux.

The bars in bronze color indicate wires for which calculated turns number per layer is below 1 turn.

The dashed blue line shows, for each wire, the selected line from the voice coil list, its amplitude is measured with the second scale on the right side.
Inductance is the default plot.

Wire Loss chart stand alone is a raw indication for round wire voice coils with Under-hung magnetic topology designs, while for Over-hung and Well-hung magnetic assembly it offers some information for loudspeaker motor design, on how to maximize efficiency. Anyway, always refer to SPL chart.

Use the Wire Loss chart as a starting point for a loudspeaker motor design, in order to evaluate the transducer efficiency tendency.
Consider the wire marked as the golden ratio a limit to tend for a motor design.
Taking in consideration that, using the current voice coil settings, the lower is the distance between selected wire and golden ratio bar, the better could be the loudspeaker efficiency if your loudspeaker motor design permits to reduce this distance.

Read the Wire Loss chart like the "available potential"

SPL Chart
Transducer Sound Pressure Level (SPL) calculated on DC resistance for all wire sizes and measured at transducer terminals.

Moving the orange cursor to select wire size from the SPL chart.
When the mouse pointer is inside the graph bounds it is possible to use mouse wheel to move the cursor with more precision.

The dark bar indicates the highest SPL among all wires, linked to the defined voice coil inside the imported magnetic flux.

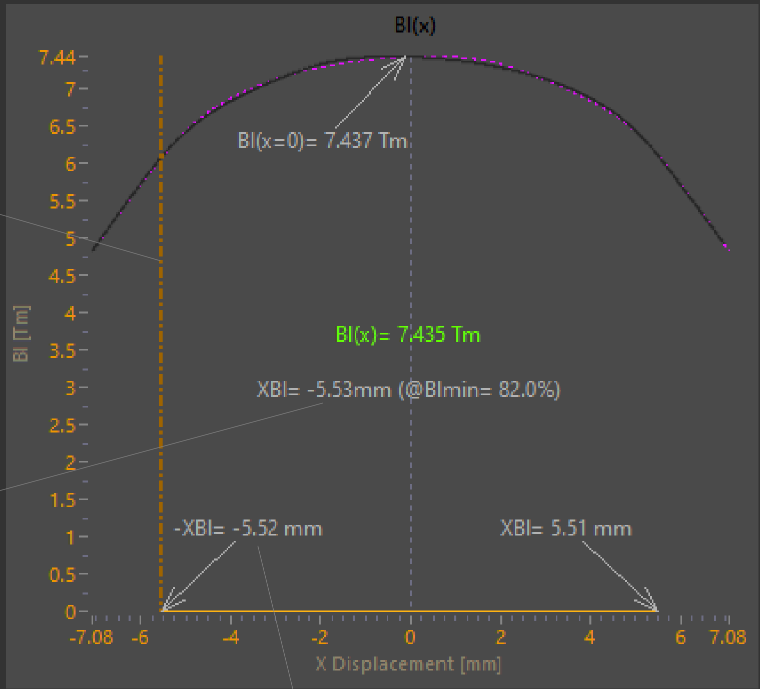
The solid line shows, for each wire, the selected TS parameter from the Transducer list, its amplitude is measured with the second scale on the right side. Bl is the default plot.

The bars in steel blue color indicate wires for which the **winding height** (H) calculus goes outside the imported ±*XB* bounds.
If the air gap length ±*XB* is the real max available mechanical space, we can consider **MAXx= Xmech** (as defined in 15.2.3 of the *IEC 62458: Sound system equipment - Electroacoustical transducers - Measurement of large signal parameters*).
In this case the use of one of these steel blue color wires is physically unfeasible

The maximum cursors error along the X Displacement in *VVC* graphs is ±8 µm.
For this reason, in some cases, it could appear a small difference for the same x point.

In the following example, in *Bl(x)* graph, the ***XBl cursor*** is shifted to the negative *XBl* point @-5.52 mm, then in the central data of the graph (cursor track) we are reading here -5.53 mm. The two points are both given @Bl_{min}= *82 %*.

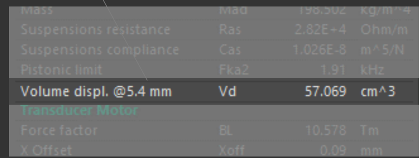
XBl Cursor



-5.53 mm is the graphical value.
It is read, interpolated and rounded by the cursor directly from the curve

XBl Cursor calculates the percentage of the force factor variation along the *Bl(x)* curve for the related *X* displacement. Moving ***XBl Cursor*** it is possible to assess all *Bl(x)* values along the available *MAXx*, finding for example the X_{var}

Use the ***XBl Cursor*** also for calculating *Volume displacement* (**Vd**) at different membrane excursions.



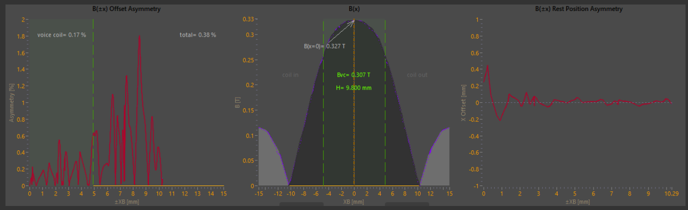
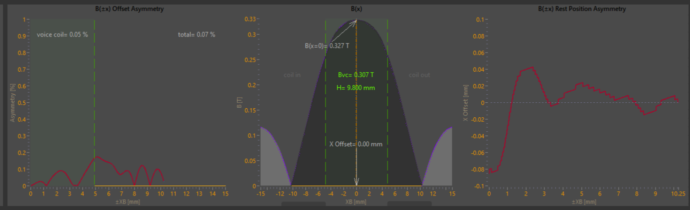
Mass	Mad	198.502	kg/m^4
Suspensions resistance	Ras	2.82E+4	Ohm/m
Suspensions compliance	Cas	1.026E-8	m^5/N
Pistonic limit	Fka2	1.91	kHz
Volume displ. @5.4 mm	Vd	57.069	cm^3
Transducer Motor			
Force factor	BL	10.578	Tm
X Offset	Xoff	0.09	mm

-XBl= -5.52 mm is the calculated and accurate value.
Always refer to this value.

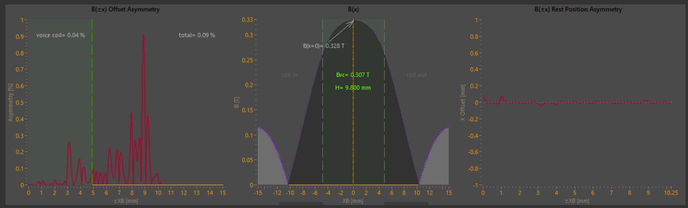
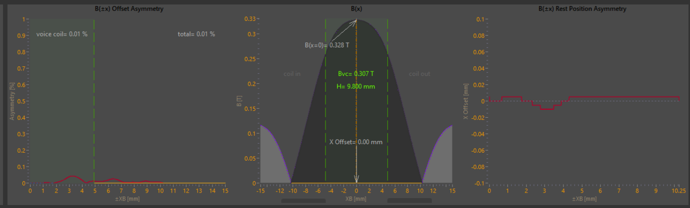
GRAPHS & CHARTS

Import data

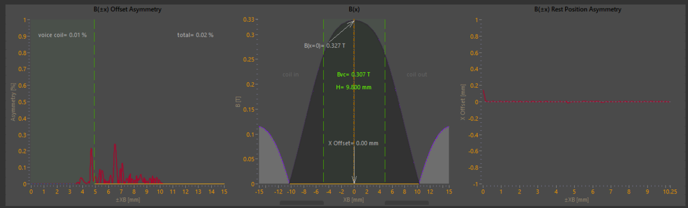
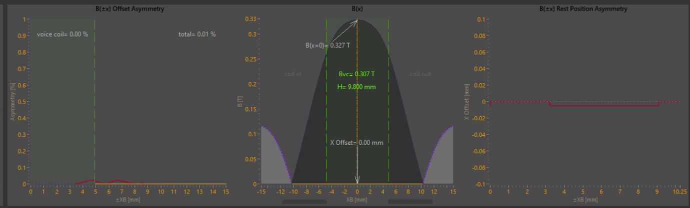
For motor designs with an axis of symmetry it is always a good practice to operate with partial models, dividing them along the symmetry axis and using only one side of the entire model.
But for the evaluation of the algorithm behavior related to symmetries, a *FEA* of the whole symmetrical model is done and imported in *VVC*.
For symmetrical designs, small differences between the two opposite mirror sides of the *B(x)* and *Bl(x)* profiles could yield to plots values of asymmetries >0 %.
These differences are not due to design, because it is perfectly symmetric, but they are due to finite element mesh, particularly *FEA* mesh nodes and their positions in space, then also to the geometry of the mesh elements, their dimension and distribution.
When a flux density is imported, *VVC* operates a resample of *B* to set cursor in an independent mode compared to imported points step, then an automatic weighting filter is applied.
The *Auto Tune Filter* (*ATF*) depends on inflection points biased to the curve gradient of imported data. The exclusive *ATF* filter is useful to reduce errors due to different *FEA* mesh methods avoiding curve buckles.
On the right side there are 4 examples of the result for different *FEA* meshes of the same design, using different elements dimension; worst case on top (2 mm) and best case on bottom (0.1mm).
In worst-cases, using a coarse FEA mesh, values below 0.3% could represent symmetrical ±*x* points. Anyway, you can test your own *CAD-FEA-VVC* chain, designing, simulating and importing a symmetric motor flux density, examining the symmetry goodness.

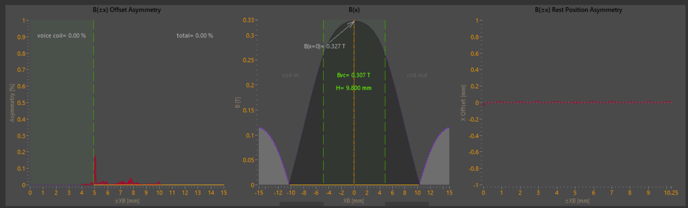
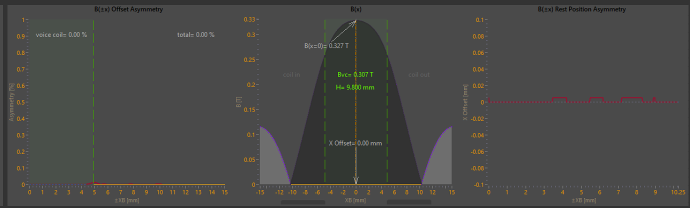
Mesh max element dimension= 2 mm   x step along cut line= 0.226 mm

Mesh max element dimension= 1 mm   x step along cut line= 0.215 mm

Mesh max element dimension= 0.5 mm   x step along cut line= 0.167 mm

Mesh max element dimension= 0.1 mm   x step along cut line= 0.065 mm

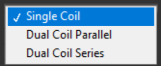
Asymmetry graphs, before (left side images) and after (right side images) the *ATF* filter is applied

VVC can manage negative *B(x)* and *Bl(x)* values, usually used for electromagnetic breaks.
The negative values are sampled in absolute value and showed in the positive Y, but using a complementary color (light grey) compared to the dark grey force factor.
This is useful to permit evaluations of the applied negative force on brakes compared to the positive force along the voice coil excursion.

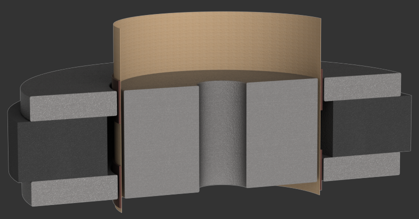
TRANSDUCER PARAMETERS

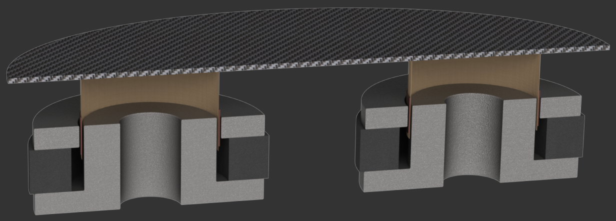
Inputs

Voice coil wiring (Version 2.1)
Select **single voice coil** for a standard configuration, otherwise it combines two voice coils in **parallel** or in **series**.



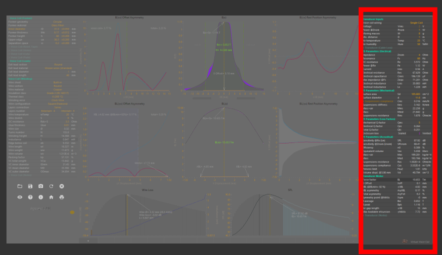
It's useful to predict parameters of a dual-coil driver (a subwoofer for example), two separate coils in two separate magnetic gaps, pushing the same membrane. These are two schematic examples for considering a dual-coil wiring:





Regarding the equivalent *Le*, **Dual voice coil** configurations are considered magnetically uncoupled.

Dual voice coil configuration recalculates the Transducer Parameters table.



Transducer Inputs			
Voice coil wiring		Single Coil	
Voltage	Vrms	2	V
Power @Znom	Pnom	1	W
Moving masses	M	8	g
Mic. distance	D	1	m
Air temperature	Temp	25	°C
Air humidity	Hum	50	%RH
+ Transducer (Cable Loss)			
TS Parameters (Electrical)			
Impedance	Znom	4	Ohm
Resonance	Fs	60	Hz
DC resistance	Re	3.572	Ohm
Power @Re	Pe	1.12	W
Current	Irms	0.56	A
Electrical resistance	Res	67.645	Ohm
Electrical capacitance	Cmes	196.065	µF
Max impedance @Fs	Zmax	71.217	Ohm
Electrical inductance	Lces	35.887	mH
Electrical inductance	Le	1.228	mH
TS Parameters (Mechanical)			
Surface area	Sd	105.683	cm^2
Surface diameter	d	11.6	cm
+ Suspensions compliance	Cms	0.316	mm/N
Suspensions stiffness	Kms	3.163	N/mm
Mass+air	Mms	22.258	g
Mass	Mmd	21.642	g
Suspensions resistance	Rms	1.678	Ohm/m
TS Parameters (Loss Factors)			
Mechanical Q-factor	Qms	5	
Electrical Q-factor	Qes	0.264	
Total Q-factor	Qts	0.251	
Enclosure box	Sealed	|	Vented
TS Parameters (Acoustical)			
Sensitivity @Re (Lm)	SPL	87.92	dB
Sensitivity @Znom (Lnom)	SPLnom	88.41	dB
Efficiency	n0	0.389	%
Equivalent volume	Vas	5.037	liters
Mass+air	Mas	199.281	kg/m^4
Mass	Mad	193.766	kg/m^4
Suspensions resistance	Ras	1.503E+4	Ohm/m
Suspensions compliance	Cas	3.531E-8	m^5/N
Pistonic limit	Fka2	1.91	kHz
Volume displ. @3.91 mm	Vd	41.322	cm^3
Transducer Motor			
Force factor	BL	10.655	Tm
X Offset	Xoff	0	mm
XBL (@BLmin= 82 %)	±XBL	4.75	mm
XBL asymmetry	AsyXBL	0.5	%
Total asymmetry	AsyTot	0.92	%
Symmetry point @MAXx	Xsym	0.1	mm
B average	Bvc	0.653	T
B peak	Bpk	1.116	T
Air gap length	±XB	15	mm
Max Available eXcursion	±MAXx	7.82	mm
+ Transducer (Notes)			

Transducer electric input RMS voltage (**Vrms**)

Transducer electric input power (**Pnom**), calculated on nominal impedance **Znom**

Editing one between **Vrms** or **Pnom**, *VVC* will automatically recalculates the other one (dark) value, keeping in consideration **Znom**.

Moving masses (**M**).
Total mechanical moving masses of transducer mobile parts (excluding voice coil and air load): **Diaphragm + half of the suspensions + dustcap + added glues or resins**.

NOTE: *VVC* automatically calculates air load mass and all other masses involved in voice coil:
winding
glue
former
reinforcement tape
pads
exit wire leads

They are automatically added to the final parameters

Mic. distance (**D**)
Transducer measuring distance from the microphone

Air temperature (**Temp**)
Environment working temperature at which the transducer is measured

Air humidity (**Hum**)
Environment working humidity at which the transducer is measured

TRANSDUCER PARAMETERS

Cable Loss (Version 2.1)

When **Cable Loss** window is expanded VVC automatically recalculates related TS parameters.
Cable loss is useful for dimensioning cables for your project, controlling for example *dB SPL* reduction or how the *Loss Factors* will change.
If *Cable Loss* window is expanded a resistance *Rg* is added in series to the *DC* resistance. Then Power and Current are calculated considering the total DC resistance. Moreover, *Loss Factors* will be recalculated, changing in Qm, Qe and Qt.
Cable material electrical conductivity is referred to Temp, the air temperature at which the transducer is measured.

Cable core diameter (excluding insulations)

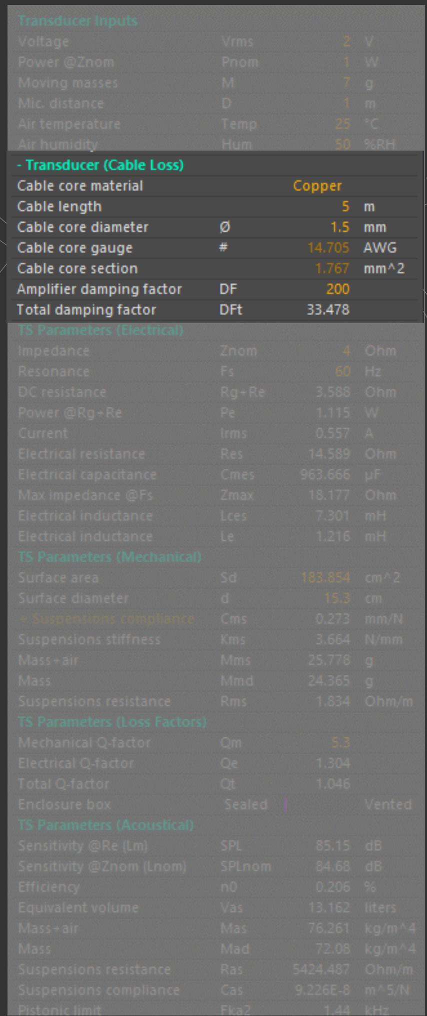
Min size 0.0799 mm= 40 AWG
Max size 11.684 mm= 0000 (4/0) (-3) AWG

Cable core gauge
American Wire Gauge is the logarithmic stepped standardized wire gauge, excluding insulations, given in *ASTM Standard B 258-02* (specification for standard nominal diameters and cross-sectional areas of AWG sizes of solid round wires used as electrical conductors).

Min size 40 AWG= 0.0799 mm
Max size 0000 (4/0) (-3) AWG= 11.684 mm

Cable core section (excluding insulations)

Min section 0.0050 mm^2= 40 AWG= 0.0799 mm
Max section 107.219 mm^2= 0000 (4/0) (-3) AWG= 11.684 mm



Cable core material
Available 4 different materials: Copper, Aluminum, Silver, Gold

Cable length (only one way)

Editing one among **Cable core diameter**, **AWG** or **section** *VVC* will automatically recalculates the other two (dark) values

Amplifier Damping Factor

Total Damping Factor
It is an important value to consider in order to control *back-EMF* (*ElectroMotive Force*) of transducer moving masses, especially in subwoofer applications

TRANSDUCER PARAMETERS

TS Electrical Parameters

Thermal Power (Pe)
Electric power, dissipated on all the electric resistances in series with the transducer voice coil.

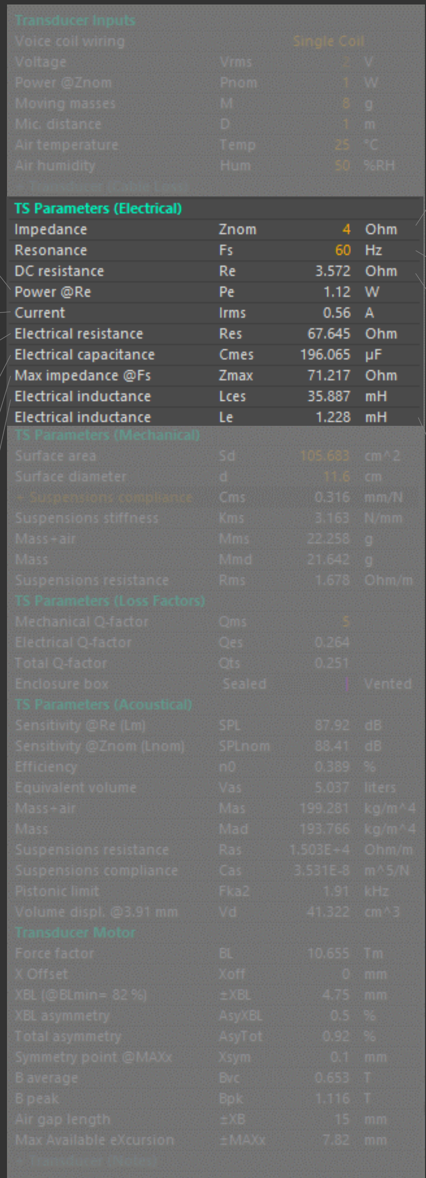
Electric rms current (Irms)
Rms value of the electrical input current.

Electrical resistance (Res)
Electrical resistance due to transducer suspensions frictions.

Electrical capacitance (Cmes)
Electrical capacitance due to transducer moving masses.

Maximum impedance (Zmax)
Maximum value of the impedance module at transducer resonance frequency.

Electrical inductance (Lces)
Electrical inductance due to mechanical compliance of transducer suspensions.



Transducer Inputs			
Voice coil wiring		Single Coil	
Voltage	Vrms	2	V
Power @Znom	Pnom	1	W
Moving masses	M	8	g
Mic. distance	D	1	m
Air temperature	Temp	25	°C
Air humidity	Hum	50	%RH
TS Parameters (Electrical)			
Impedance	Znom	4	Ohm
Resonance	Fs	60	Hz
DC resistance	Re	3.572	Ohm
Power @Re	Pe	1.12	W
Current	Irms	0.56	A
Electrical resistance	Res	67.645	Ohm
Electrical capacitance	Cmes	196.065	µF
Max impedance @Fs	Zmax	71.217	Ohm
Electrical inductance	Lces	35.887	mH
Electrical inductance	Le	1.228	mH
TS Parameters (Mechanical)			
Surface area	Sd	105.683	cm^2
Surface diameter	d	11.6	cm
+ Suspensions compliance	Cms	0.316	mm/N
Suspensions stiffness	Kms	3.163	N/mm
Mass+air	Mms	22.258	g
Mass	Mmd	21.642	g
Suspensions resistance	Rms	1.678	Ohm/m
TS Parameters (Loss Factors)			
Mechanical Q-factor	Qms	5	
Electrical Q-factor	Qes	0.264	
Total Q-factor	Qts	0.251	
Enclosure box	Sealed		Vented
TS Parameters (Acoustical)			
Sensitivity @Re (Lm)	SPL	87.92	dB
Sensitivity @Znom (Lnom)	SPLnom	88.41	dB
Efficiency	n0	0.389	%
Equivalent volume	Vas	5.037	liters
Mass+air	Mas	199.281	kg/m^4
Mass	Mad	193.766	kg/m^4
Suspensions resistance	Ras	1.503E+4	Ohm/m
Suspensions compliance	Cas	3.531E-8	m^5/N
Pistonic limit	Fka2	1.91	kHz
Volume displ. @3.91 mm	Vd	41.322	cm^3
Transducer Motor			
Force factor	BL	10.655	Tm
X Offset	Xoff	0	mm
XBL (@BLmin= 82 %)	±XBL	4.75	mm
XBL asymmetry	AsyXBL	0.5	%
Total asymmetry	AsyTot	0.92	%
Symmetry point @MAXx	Xsym	0.1	mm
B average	Bvc	0.653	T
B peak	Bpk	1.116	T
Air gap length	±XB	15	mm
Max Available eXcursion	±MAXx	7.82	mm

Transducer nominal impedance (**Znom**)

From *IEC 60268-5* and *AES2-2012* revision of *AES2-1984* Standards, the lowest value of the modulus of the impedance (**Zmin**) in the rated frequency range shall be not less than 80 % of the rated impedance (**Znom**).

Commonly in loudspeakers **Zmin** is higher than the DC resistance measured on loudspeaker terminals, *VVC* considers Re + 3.5% as a limit.

Thus, Znom becomes red color when Re is near this limit. It is only a visual alarm helping designers

Resonance (**Fs**) is the fundamental resonance of the transducer

While **Cms** window is expanded **Fs** is not editable and it will be recalculated for any parameter variation. In this case it is possible to plot **Fs** for all wires.

Total DC resistance
Transducer DC resistance, including all resistances in series to the voice coil.
VVC calculates all resistances in series to Rdc, like the exit wire leads and cable (Rg+Re). VVC considers also an increased value of Re due to solder between winding wire and leads.
Re is the final resistance, subjected to temperature variation, measured at transducer terminals, or at the cable end if **Transducer (Cable Loss)** window is expanded.

Electrical inductance (Le)
Electrical Inductance Le is the frequency and position independent part of transducer inductance.

The absolute value is a rough estimation. Anyway, for a given reference value, its relative variation is quite precise, so it could be useful to study a relative variation for all wires, plotting Le on chart and comparing them with the current Le as reference.

About the absolute Le value:
the showed Le variation could be ±35%, it depends on materials type (ferro-magnetic, shorting rings, ...), position and quantity around the voice coil inside the magnetic gap rest position, in static conditions.
Then, the interaction with the external magnetic field, in dynamic conditions, influences Le too (proximity effect).

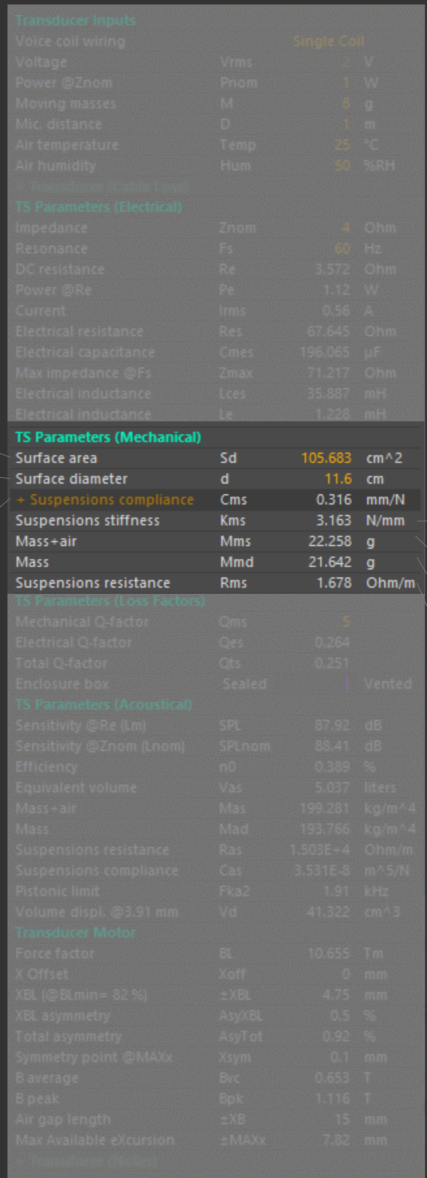
Please consider to reduce the showed Le value towards the minimum tolerance for example in ironless motors, or more if shorting rings are present (eddy-currents in a shorting ring decrease the overall coil inductance at high frequencies, reducing alternating inductance below the free air value).

NOTE1: the symbol § means calculus is in progress.

NOTE2: Turns number per layer must be greater or equal to half turn, otherwise L= 0.

TRANSDUCER PARAMETERS

TS Mechanical Parameters



Transducer diaphragm effective surface area (Sd).

Transducer diaphragm equivalent diameter (d) corresponding to the diaphragm effective surface area Sd.

Suspensions compliance (Cms)
Mechanical compliance of transducer suspensions.
If *Cms* window is expanded *Fs* will be recalculated for any parameter variation.
In this case it is possible to plot *Fs* for all wires (moving mouse over *Fs* row).

Mouse click to enable/disable (dark) suspensions compliance separation.

Editing one between ***Sd*** or ***d***, *VVC* will automatically recalculates the other one (dark) value.

Suspensions stiffness (Kms)
Mechanical stiffness of transducer suspensions. Stiffness *K* reciprocal of the compliance *C*.

Mass + air (Mms)
Mechanical mass including air load.

Mass (Mmd)
Mechanical mass excluding air load.

Suspension resistance (Rms)
Mechanical resistance due to transducer suspensions frictions.

TRANSDUCER PARAMETERS

TS Mechanical Parameters (Suspensions Compliance*)

Transducer Inputs			
Voice coil wiring		Single Coil	
Voltage	Vrms	2	V
Power @Znom	Pnom	1	W
Moving masses	M	8	g
Mic. distance	D	1	m
Air temperature	Temp	25	°C
Air humidity	Hum	50	%RH
+ Transducer (Cable Loss)			
TS Parameters (Electrical)			
Impedance	Znom	4	Ohm
Resonance	Fs	60	Hz
DC resistance	Re	3.572	Ohm
Power @Re	Pe	1.12	W
Current	Irms	0.56	A
Electrical resistance	Res	67.612	Ohm
Electrical capacitance	Cmes	196.065	µF
Max impedance @Fs	Zmax	71.183	Ohm
Electrical inductance	Lces	35.897	mH
Electrical inductance	Le	1.228	mH
TS Parameters (Mechanical)			
Surface area	Sd	105.683	cm^2
Surface diameter	d	11.6	cm
- Suspensions compliance	Cms	0.316	mm/N
Sur. adjusting mass	Madj	-1	g
Sur. resonance freq.	Fr_su	47.8	Hz
Sur. displacement	x_su	0.109	mm
Sur. compliance	C_su	1.583	mm/N
Sur. stiffness	K_su	0.632	N/mm
Surround rate		20	%
Spi. added mass	Madd	50	g
Spi. resonance freq.	Fr_sp	35.8	Hz
Spi. displacement	x_sp	0.194	mm
Spi. compliance	C_sp	0.395	mm/N
Spi. stiffness	K_sp	2.531	N/mm
Spi. Federzahl	Fdz	1.94	mm×10
Spider rate	x1	80	%
Suspensions stiffness	Kms	3.162	N/mm
Mass+air	Mms	22.258	g
Mass	Mmd	21.642	g
Suspensions resistance	Rms	1.679	Ohm/m
TS Parameters (Loss Factors)			
Mechanical Q-factor	Qms	5	
Electrical Q-factor	Qes	0.264	
Total Q-factor	Qts	0.251	
Enclosure box	Sealed		Vented
TS Parameters (Acoustical)			
Sensitivity @Re (Lm)	SPL	87.92	dB
Sensitivity @Znom (Lnom)	SPLnom	88.41	dB
Efficiency	n0	0.389	%
Equivalent volume	Vas	5.038	liters
Mass+air	Mas	199.281	kg/m^4
Mass	Mad	193.766	kg/m^4
Suspensions resistance	Ras	1.503E+4	Ohm/m
Suspensions compliance	Cas	3.532E-8	m^5/N
Pistonic limit	Fka2	1.91	kHz
Volume displ. @3.91 mm	Vd	41.322	cm^3
Transducer Motor			
Force factor	BL	10.655	Tm

Spider added mass (Madd)
The default added mass is 50 g.
Usually, the spider mobile mass is omitted, but for maximum precision always consider *Madd*= added mass + mobile mass of the spider part.

The minimum value for *Madd*= 0. In this case *Fr_sp*= ∞ and *x_sp*= 0.

Spider resonance frequency (Fr_sp)
Resonance frequency of the harmonic oscillator given by the spider mass/spring combination.

Spider displacement (x_sp)
x_{ac} is the instantaneous displacement in case of a dynamic measurement condition.
In case of a static condition, the deflection x_{dc} is measured adding a known mass (*Madd*) and detecting the difference of the suspension position.

Spider compliance (C_sp)
Always consider a static compliance higher than a dynamic compliance.
Dynamic measurements better represent the real operation conditions.

Spider stiffness (K_sp)
Always consider a static stiffness lower than a dynamic stiffness.
Dynamic measurements better represent the real operation conditions.

Spider Federzahl (Fdz)
Spider *Federzahl flexibility*. *Madd* is considered as *nominal mass*.
Keeping all spider parameters, put a standard mass of 50g, 100g, ... in *Madd* to obtain the corresponding *Federzahl* value.

Spider rate
Spider % contribution (**xN** number of used spiders, Version 2.1) to *Cms* or *Kms* of the transducer suspensions system.

When *Cms* window is expanded for the first time, the default value of the spider rate is 80% of the total *Cms* or *Kms*.
It is a suggested starting point (from "Loudspeaker Design Cookbook" by Vance Dickason), because in some suspension systems it is not possible to satisfy the ratio 20/80.

Surround adjusting mass (Madj)
Use *Madj* as a correction factor for a dynamic condition or as an added mass for a static condition.

Madj: Diaphragm + surround Load Mass.
Madj will be added (algebraic sum) to the moving masses (***M*** in Transducer Inputs).

Consider that moving masses *M* in Transducer Inputs include dust cap mass, spider mass, ect. so, you can conveniently use a negative *Madj* value to eliminate these masses from *M*, in order to consider only the real mobile parts involved in surround *Cms* calculus, obtaining the most accurate value.

For example, if moving masses *M*= 12g (including dust cap + spider + glues= 3g):
In static conditions for example if you want to add a 10g weight, put *Madj*= 10 – 3= 7g.
While in dynamic conditions (without added mass) put *Madj*= –3.

Otherwise leave *Madj*= 0 if *M* corresponds to the effective mass of surround *Cms* calculus.

The minimum value for *Madj*= –*M*, in this case *Fr_su*= ∞ and *x_su*= 0.

Surround resonance frequency (Fr_su)
Resonance frequency of the harmonic oscillator given by the surround mass/spring combination.

Surround displacement (x_su)
x_{ac} is the instantaneous displacement in case of a dynamic measurement condition.
In case of a static condition, the deflection x_{dc} is measured adding a known mass (*Madj*) and detecting the difference of the suspension position.

(Static measurement condition is uncommon for surrounds, to use only if you don't have alternatives).

Surround compliance (C_su)
Always consider a static compliance higher than a dynamic compliance.
Dynamic measurements better represent the real operation conditions.

Surround stiffness (K_su)
Always consider a static stiffness lower than a dynamic stiffness.
Dynamic measurements better represent the real operation conditions.

Surround rate
Surround % contribution to *Cms* or *Kms* of the transducer suspensions system.
When Cms window is expanded for the first time, the default value of the surround rate is 20% of the total Cms or Kms.
It is a suggested starting point (from "Loudspeaker Design Cookbook" by Vance Dickason), because in some suspension systems it is not possible to satisfy the ratio 20/80.

* IEC 62459: Sound system equipment - Electroacoustical transducers –
Measurement of suspension parts

4 Test conditions
The test should be made at 15 °C to 35 °C ambient temperature, preferably at 20 °C, 25 % to 75 % relative humidity and 86 kPa to 106 kPa air pressure, as specified in IEC 60268-1.
Prior to the measurement the suspension part under test should be stored under these climatic conditions for 24 h.

TRANSDUCER PARAMETERS

TS Loss Factors Parameters

Transducer Inputs			
Voice coil wiring		Single Coil	
Voltage	Vrms	2	V
Power @Znom	Pnom	1	W
Moving masses	M	7	g
Mic. distance	D	1	m
Air temperature	Temp	25	°C
Air humidity	Hum	50	%RH
+ Transducer (Cable Loss)			
TS Parameters (Electrical)			
Impedance	Znom	4	Ohm
Resonance	Fs	44.2	Hz
DC resistance	Re	3.476	Ohm
Power @Re	Pe	1.151	W
Current	Irms	0.575	A
Electrical resistance	Res	107.879	Ohm
Electrical capacitance	Cmes	166.981	µF
Max impedance @Fs	Zmax	111.355	Ohm
Electrical inductance	Lces	77.732	mH
Electrical inductance	Le	1.849	mH
TS Parameters (Mechanical)			
Surface area	Sd	105.683	cm^2
Surface diameter	d	11.6	cm
+ Suspensions compliance	Cms	0.505	mm/N
Suspensions stiffness	Kms	1.981	N/mm
Mass+air	Mms	25.719	g
Mass	Mmd	25.103	g
Suspensions resistance	Rms	1.428	Ohm/m
TS Parameters (Loss Factors)			
Mechanical Q-factor	Qms	5	
Electrical Q-factor	Qes	0.264	
Total Q-factor	Qts	0.251	
Enclosure box	Sealed		Vented
TS Parameters (Acoustical)			
Sensitivity @Re (Lm)	SPL	88.11	dB
Sensitivity @Znom (Lnom)	SPLnom	88.72	dB
Efficiency	n0	0.406	%
Equivalent volume	Vas	8.041	liters
Mass+air	Mas	230.268	kg/m^4
Mass	Mad	224.753	kg/m^4
Suspensions resistance	Ras	1.278E+4	Ohm/m
Suspensions compliance	Cas	5.637E-8	m^5/N
Pistonic limit	Fka2	1.91	kHz
Volume displ. @4.01 mm	Vd	42.379	cm^3
Transducer Motor			
Force factor	Bl	12.411	Tm
Motor efficiency factor	n0_M	44.315	Tm^2/O
X Offset	Xoff	0.09	mm
XBl (@Blmin= 82 %)	±XBl	4.64	mm
XBl asymmetry	AsyXBl	0.21	%
Total asymmetry	AsyTot	0.18	%
Symmetry point @MAXx	Xsym	0.01	mm
B average	Bvc	0.693	T
B peak	Bpk	1.136	T
Air gap length	±XB	15	mm
Max Available eXcursion	±MAXx	8.02	mm
+ Transducer (Notes)			

Mechanical Q-factor
Qms is the mechanical Q of the transducer.
Qm is the mechanical Q of the transducer + cable, if cable is expanded.

Electrical Q-factor
Qes is the electrical Q of the transducer.
Qe is the electrical Q of transducer + cable, if cable is expanded.

Total Q-factor
Qts is the total Q of the transducer.
Qt is the total Q of transducer + cable, if cable is expanded.

Suggested enclosure box.
The position of the pink cursor indicates the suggested box type: Sealed or Vented.

TRANSDUCER PARAMETERS

TS Acoustical Parameters

Transducer Inputs			
Voice coil wiring		Single Coil	
Voltage	Vrms	2	V
Power @Znom	Pnom	1	W
Moving masses	M	7	g
Mic. distance	D	1	m
Air temperature	Temp	25	°C
Air humidity	Hum	50	%RH
+ Transducer (Cable Loss)			
TS Parameters (Electrical)			
Impedance	Znom	4	Ohm
Resonance	Fs	44.2	Hz
DC resistance	Re	3.476	Ohm
Power @Re	Pe	1.151	W
Current	Irms	0.575	A
Electrical resistance	Res	107.879	Ohm
Electrical capacitance	Cmes	166.981	μF
Max impedance @Fs	Zmax	111.355	Ohm
Electrical inductance	Lces	77.732	mH
Electrical inductance	Le	1.849	mH
TS Parameters (Mechanical)			
Surface area	Sd	105.683	cm^2
Surface diameter	d	11.6	cm
+ Suspensions compliance	Cms	0.505	mm/N
Suspensions stiffness	Kms	1.981	N/mm
Mass+air	Mms	25.719	g
Mass	Mmd	25.103	g
Suspensions resistance	Rms	1.428	Ohm/m
TS Parameters (Loss Factors)			
Mechanical Q-factor	Qms	5	
Electrical Q-factor	Qes	0.161	
Total Q-factor	Qts	0.156	
Enclosure box	Sealed		Vented
TS Parameters (Acoustical)			
Sensitivity @Re (Lm)	SPL	88.11	dB
Sensitivity @Znom (Lnom)	SPLnom	88.72	dB
Efficiency	n0	0.406	%
Equivalent volume	Vas	8.041	liters
Mass+air	Mas	230.268	kg/m^4
Mass	Mad	224.753	kg/m^4
Suspensions resistance	Ras	1.278E+4	Ohm/m
Suspensions compliance	Cas	5.637E-8	m^5/N
Pistonic limit	Fka2	1.91	kHz
Volume displ. @4.01 mm	Vd	42.379	cm^3
Transducer Motor			
Force factor	Bl	12.411	Tm
Motor efficiency factor	n0_M	44.315	Tm^2/O
X Offset	Xoff	0.09	mm
XBl (@Blmin= 82 %)	±XBl	4.64	mm
XBl asymmetry	AsyXBl	0.21	%
Total asymmetry	AsyTot	0.18	%
Symmetry point @MAXx	Xsym	0.01	mm
B average	Bvc	0.693	T
B peak	Bpk	1.136	T
Air gap length	±XB	15	mm
Max Available eXcursion	±MAXx	8.02	mm
+ Transducer (Notes)			

Mass (Mad)
Acoustic mass of transducer moving parts.

Suspensions resistance (Ras)
Acoustic resistance dues to transducer suspensions frictions.

Suspensions compliance (Cas)
Acoustic compliance of transducer suspensions.

Pistonic limit (Frequency @*ka*= 2) *
The frequency for which *ka*= 2 is calculated as theoretical maximum limit given by the loudspeaker membrane dimension, before the membrane breakup effect (it is added to the TS acoustical parameters).
ka represents the ratio between the loudspeaker nominal circumference and the emitted wavelength, considering a rigid piston in an infinite rigid baffle (2 *pi*, hemisphere radiation).

For *ka* values lower than 0.5 in theory we can consider the piston as a point source, for *Fka2*/2 directivity start to increase gradually, for *ka* values greater than 3 we can consider the piston a highly directional source.

SPL @Re
Sound Pressure Level (SPL) sensitivity, calculated *@Re*.
It is called L_m in Klippel system

SPL @Znom
Sound Pressure Level (SPL) sensitivity, calculated *@Znom*.
It is called L_{nom} in Klippel system

Efficiency n0
Efficiency given @Re and @2 pi-radiation

Equivalent volume (Vas)
Acoustic volume related to transducer suspensions compliance

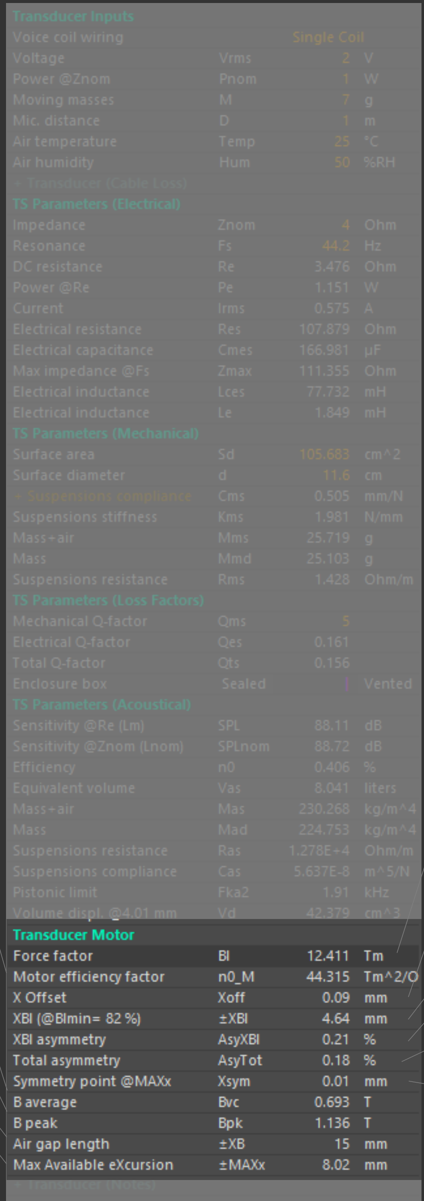
Mass + air (Mas)
Acoustic mass of transducer moving parts (including air load)

Volume displacement (Vd) *
Volume displacement is given at MAX/2 by default. To calculate Vd at different excursions move the Bl(x) orange cursor

* *Pistonic limit* and *volume displacement* (*Vd*) are here added to the acoustical TS parameters for convenience

TRANSDUCER PARAMETERS

Transducer Motor



Transducer Inputs			
Voice coil wiring		Single Coil	
Voltage	Vrms	2	V
Power @Znom	Pnom	1	W
Moving masses	M	7	g
Mic. distance	D	1	m
Air temperature	Temp	25	°C
Air humidity	Hum	50	%RH
+ Transducer (Cable Loss)			
TS Parameters (Electrical)			
Impedance	Znom	4	Ohm
Resonance	Fs	44.2	Hz
DC resistance	Re	3.476	Ohm
Power @Re	Pe	1.151	W
Current	Irms	0.575	A
Electrical resistance	Res	107.879	Ohm
Electrical capacitance	Cmes	166.981	µF
Max impedance @Fs	Zmax	111.355	Ohm
Electrical inductance	Lces	77.732	mH
Electrical inductance	Le	1.849	mH
TS Parameters (Mechanical)			
Surface area	Sd	105.683	cm^2
Surface diameter	d	11.6	cm
+ Suspensions compliance	Cms	0.505	mm/N
Suspensions stiffness	Kms	1.981	N/mm
Mass+air	Mms	25.719	g
Mass	Mmd	25.103	g
Suspensions resistance	Rms	1.428	Ohm/m
TS Parameters (Loss Factors)			
Mechanical Q-factor	Qms	5	
Electrical Q-factor	Qes	0.161	
Total Q-factor	Qts	0.156	
Enclosure box	Sealed		Vented
TS Parameters (Acoustical)			
Sensitivity @Re (Lm)	SPL	88.11	dB
Sensitivity @Znom (Lnom)	SPLnom	88.72	dB
Efficiency	n0	0.406	%
Equivalent volume	Vas	8.041	liters
Mass+air	Mas	230.268	kg/m^4
Mass	Mad	224.753	kg/m^4
Suspensions resistance	Ras	1.278E+4	Ohm/m
Suspensions compliance	Cas	5.637E-8	m^5/N
Pistonic limit	Fka2	1.91	kHz
Volume displ. @4.01 mm	Vd	42.379	cm^3
Transducer Motor			
Force factor	Bl	12.411	Tm
Motor efficiency factor	n0_M	44.315	Tm^2/O
X Offset	Xoff	0.09	mm
XBl (@Blmin= 82 %)	±XBl	4.64	mm
XBl asymmetry	AsyXBl	0.21	%
Total asymmetry	AsyTot	0.18	%
Symmetry point @MAXx	Xsym	0.01	mm
B average	Bvc	0.693	T
B peak	Bpk	1.136	T
Air gap length	±XB	15	mm
Max Available eXcursion	±MAXx	8.02	mm
+ Transducer (Notes)			

Motor efficiency factor (n0_M)
Motor efficiency factor Bl^2/Re, it represents also the electrical damping.

B average (Bvc)
B average is the average of the flux density values in the input sequence, calculated along the voice coil winding height.

B peak (Bpk)
Bpk is the peak value of the flux density inside the air gap. *Bpk* is the common value measured using a Gaussmeter probe inside the magnetic gap.

Air gap length (±*XB*)
Available full length of the imported line perpendicular to the flux density B.

±MAX @x
Maximum **A**vailable mechanical e**X**cursion (*MAX*) given *@X Offset*.
When *X Offset* differs from zero, a reduction of *MAX* will occur.
If the air gap length ±*XB* is the real max available mechanical space, we can consider *MAXx=Xmech* (as defined in 15.2.3 of the **IEC 62458**: *Sound system equipment - Electroacoustical transducers - Measurement of large signal parameters*).

Force Factor (Bl)
Force Factor of the transducer.

X Offset
Voice coil virtual offset position inside the air gap.

XBl (*@Blmin*=82%)
Maximal displacement amplitude ±*XBl* (*@Blmin*=82%) limited by motor distortion. It is given @Blmin= 82 % by default, to calculate XBl at different excursions move the Bl(x) orange cursor.

The value appears with an asterisk (*) when ±*XBl* (*@Blmin*=82%) doesn't cross the symmetry line of the current rest position.

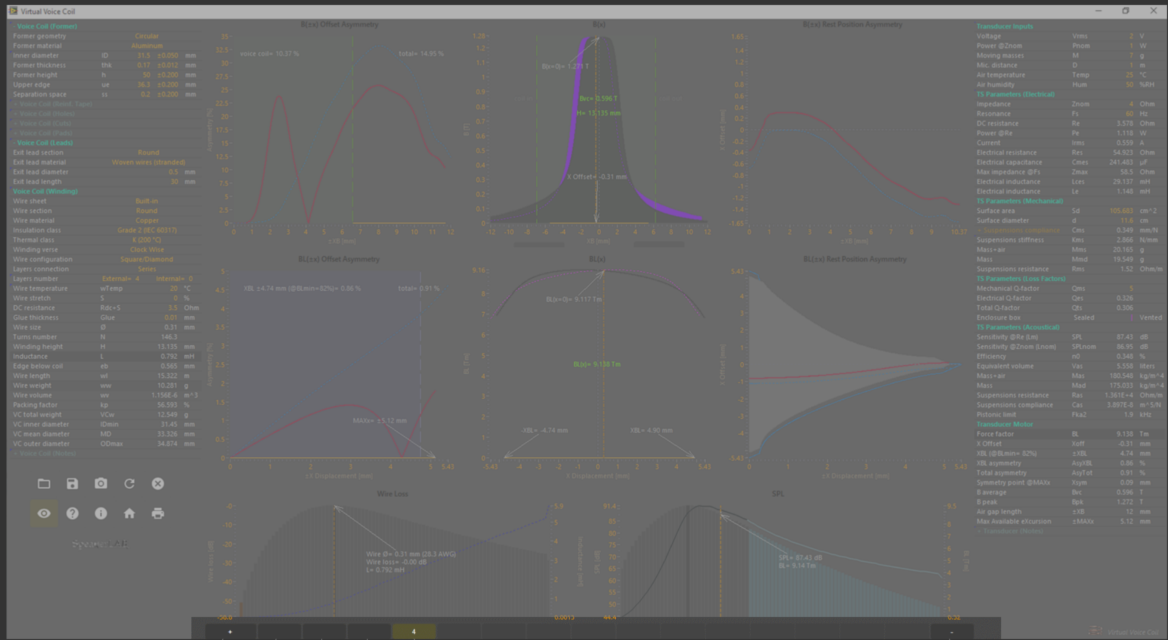
Formally ±*XBl* <= *MAXx*, particularly *XBl* takes the same value of *MAXx* when, compared to current rest position, a virtual offset is moved near the extreme bounds of ±*XB*.

AsyXBl (*@Blmin*=82%)
The percentage of *XBl* (*@Blmin*=82%) is the amount of *Bl(x)* mirror asymmetry when voice coil displacement is inside the *XBl* range.

AsyTot
The percentage of total asymmetry is the total amount of *Bl(x)* mirror asymmetry for the full available excursion ±*MAX*.

Symmetry point *@MAXx (Xsym)*
Xsym point is the value of the symmetry point (as reported in **IEC EN 62458** Standard *Sound system equipment - Electroacoustic transducers - Measurement of large signal parameters*) given @**M**aximum **A**vailable mechanical e**X**cursion (*MAX*).

ADD & RECALL SIMULATIONS



Current simulation

Recall recorded simulation 3

Recall recorded simulation 2

Recall recorded simulation 1

Add Button
Add current simulation in memory, enabling the record button for a fast comparison (max 15 simulations).

Remove Button
Remove the current selected simulation. If no simulations are selected it deletes the latest added simulation.

MENU ITEMS

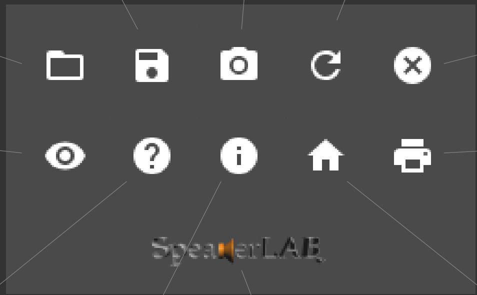
SCREENSHOT
Take a screenshot and open it automatically in a HTML page. The saved file is inside the project folder database (Voice Coil db).

SAVE PROJECT
Save the current project inside database (Voice Coil db).

RESET VALUES & TOLERANCES
Reset to standard values & general tolerances.

OPEN PROJECT
Open a project from database (Voice Coil db).

EXIT
Close Virtual Voice Coil application.



SHOW TIP STRIP
Show instant strips, resuming information when mouse is over a control or a graph.

PRINT REPORT
Create a HTML report with all tables and graphs.
Graphs print dimension depends on current screen visualization.
To enlarge graphs, maximize VVC window.

SHOW CONTEST HELP
Show instant full information when mouse is over a control or a graph.

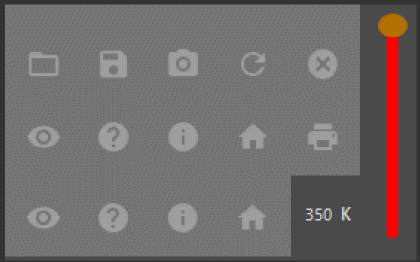
OPEN SPEAKERLAB
Open www.SpeakerLAB.it web page.

VIEW DATASHEET
Open VVC .pdf datasheet.

About SpeakerLAB...
It shows info & license window.

DELTA T

(Version 2.1)



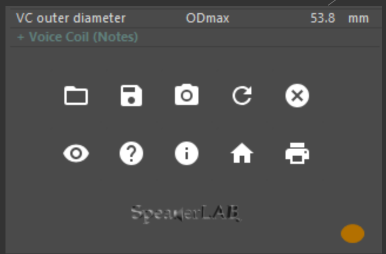
DeltaT is the relative voice coil temperature increase, in *Kelvin* degrees [K], due to *Joule* heating.

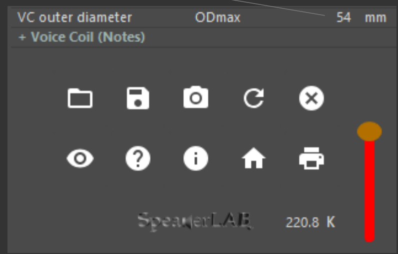
Max Delta T= 350 K
If DeltaT= 0 the digital display is invisible

Use mouse wheel over the slider to increment/decrement of 0.5 K steps

Moving *DeltaT* slider *VVC* recalculates in real time all involved electrical parameters as the DC resistance and related electric power and current variations, or some acoustical parameters as the transducer sensitivity reduction *dBSPL* (power compression) or *Loss Factors* variation.

Moreover, *VVC* calculates mechanical dimensional variations as voice coil *Height*, *IDmin* and *ODmax* due to wire thermal expansion, this is helpful to understand and optimize clearances inside the air gap.
In the following example we can see that at the environment temperature (DeltaT= 0), the loudspeaker has *ODmax*= 53.8 mm, but when the voice coil reaches 220.8 K, the clearance inside the magnetic gap is reduced of –0.2 mm





Adding **DELTA T** *VVC* offers a complete map of all involved loudspeaker temperatures:

- **Wire temperature** related to voice coil winding phase
- **Environment temperature** related to loudspeaker measurement
- **Joule Effect** (DeltaT) related to materials elongation and resistance variation due to power heating
    - <u>Materials elongation</u> is useful for example to check the increase of the outer voice coil diameter for defining the right magnetic gap clearance.
    - <u>Resistance variation</u> is useful for example to check power compression or *TS* parameters variation with temperature.

www.speakerlab.it

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Please consider the environment before printing!