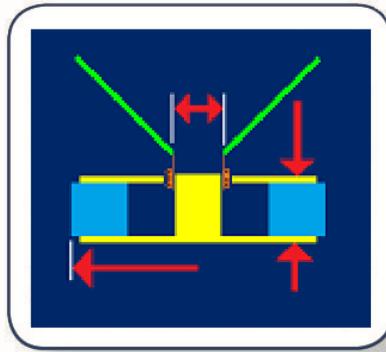


MANUAL



FINEMotor PRO™

Magnet System & Voice Coil
Design Program

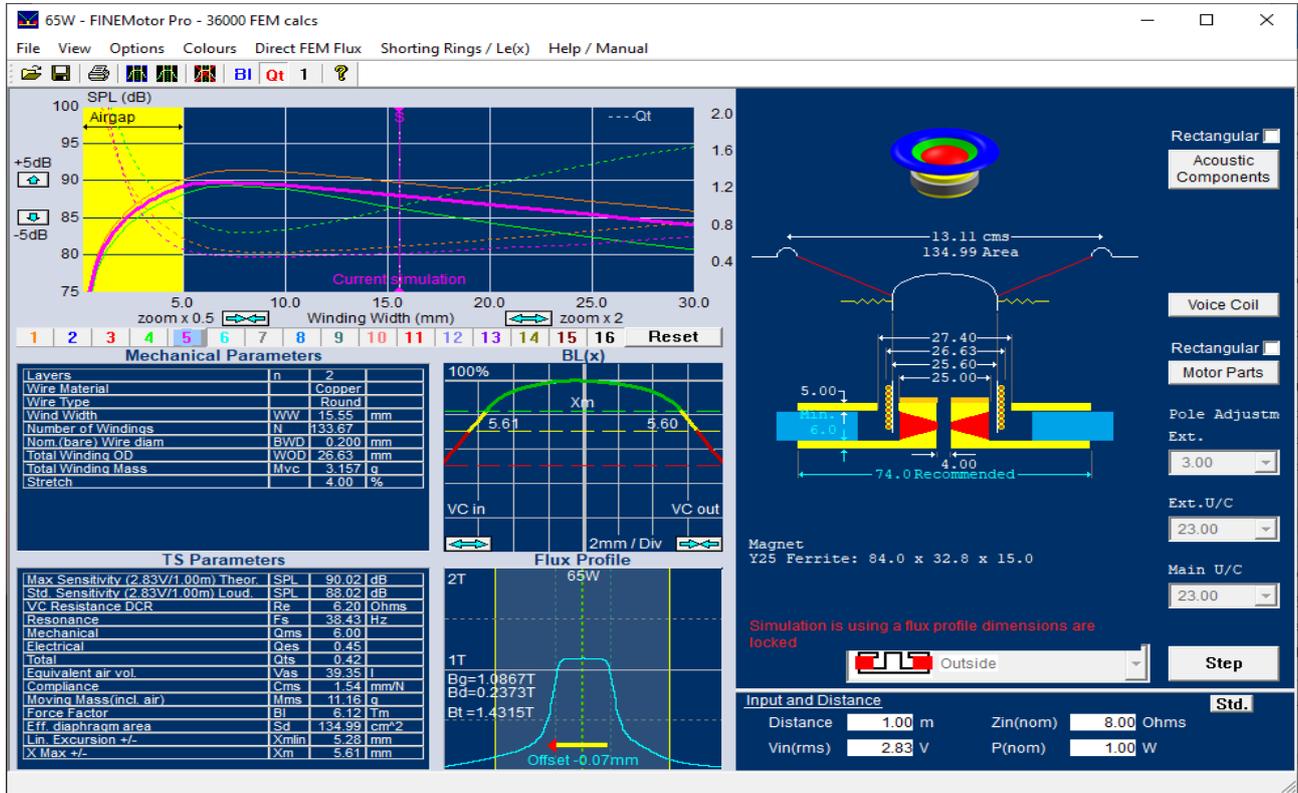


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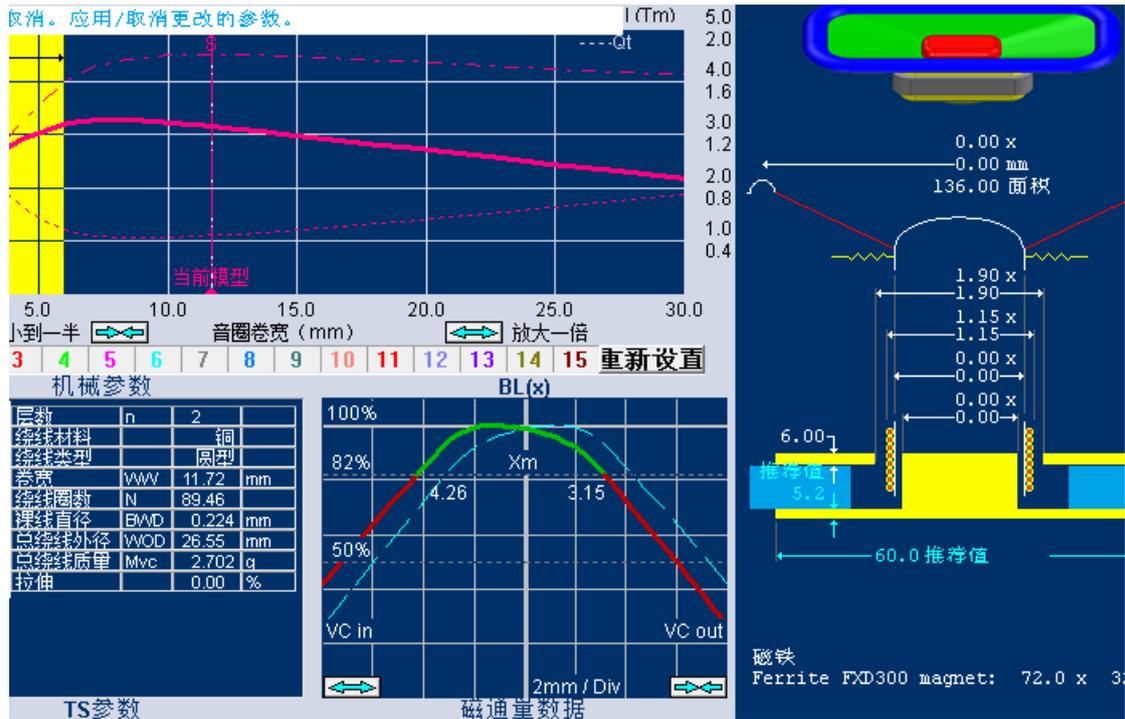
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1. Overview



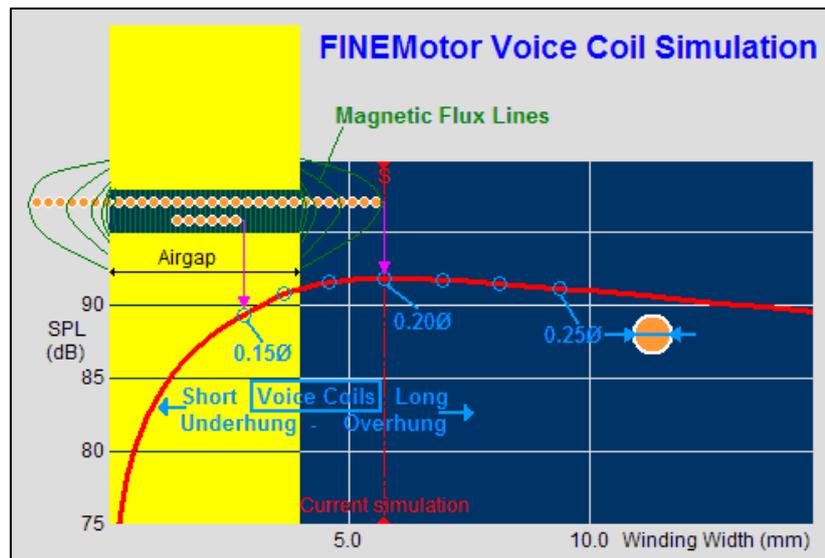
FINEMotor contains 36000 pre-calculated Magnetic Finite Element calculations and is ideal for designing the magnet system and voice coil for all audio drivers. This includes not only woofers and domes but also receivers, headphones, and micro speakers etc.



Chinese interface will show on Chinese Windows

Note: Now you can buy a second FINEMotor license for another PC with 75% Discount!

1.1 How FINEMotor works



First input DCR, Cone mass and a magnet size. FINEMotor then calculates all TS parameters and plots SPL with the thinnest wire at left, thickest to the right. The 0.15Ø (nom wire diam.) is a short 3mm Voice Coil winding, which is underhung = shorter than the air gap (4mm). In contrast, the 0.20Ø shows an overhung 6mm winding, which is longer than the air gap and picks up some stray magnet field giving higher SPL.

1.2 Sound Pressure Level (SPL) window

Above is shown the Sound Pressure Level (SPL) window. This window displays the simulated SPL of the current setup along with setups using different parameters. Each time a parameter is changed, a new curve will be displayed along with the previous ones. It is then possible to see what differences the changes make. The window is capable of displaying 16 different curves. Left clicking on one of the buttons under the graph will choose that specific curve as the highlighted one. Right-clicking one of the buttons will show/hide that specific curve. This makes it easier to compare specific curves. See also section 2.1.9.

1.3 Physical Overview

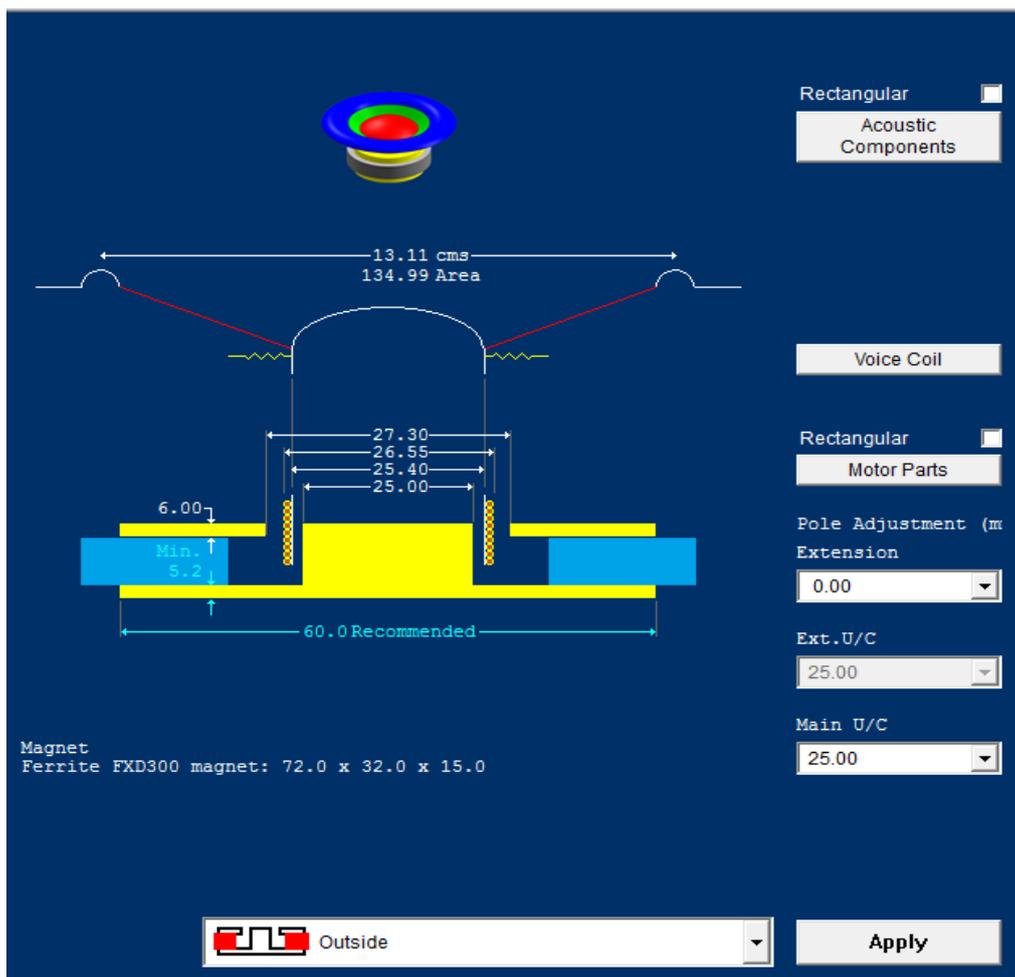
This window (right) displays the physical dimensions of the current setup.

The top portion includes a cross section of the diaphragm, dust cap, surround and spider. The dimensions of these components can be changed in the [Acoustic Component](#) section.

Below the acoustic components a cross section of the Voice Coil (VC) is shown. Parameters concerning the VC can be changed in the [Voice Coil](#) section. When parameters are changed in a way that leads to saturation, this will be shown on the cross section.

The motor is shown surrounding the VC; however, FINEMotor can also simulate motors inside the VC. This is done by selecting the one of the “inside” options in the drop-down menu seen in the following two images.

The dimensions and materials of the motor can be changed in the [Motor Parts](#) section.





1.4 Acoustic Components

Effective Area	Sd	134.99	sq. cm
Effective Diameter	D	13.11	cm
Fixed Mass (Incl. air load)	Mms-Mvc	9.00	g
Air Load	Mair	0.89	g
Diaphr. Mass (Incl. ½sur/½spider/DC)		8.11	g
Specify Qms	Qms	3.00	
Estimate Qms (from VC Former mat.)	<input checked="" type="checkbox"/>	3.00	
Specify Fs	Fs	45.00	Hz
Use calculated Fs	<input type="checkbox"/>	0.00	Hz
Cone+Surround Resonance	Fo	0.00	Hz
Surround Compliance (Approx.)	Cms(sur)	0.00	mm/N
Spider Load		50.00	g
Spider Resonance (loaded, dyn.)	Fsp	0.00	Hz
Spider Deflection (loaded, static)		0.00	mm
Spider Compliance		0.00	mm/N
Spider Flexibility (German Std)		0.00	Fdz

134.99 Area
13.11

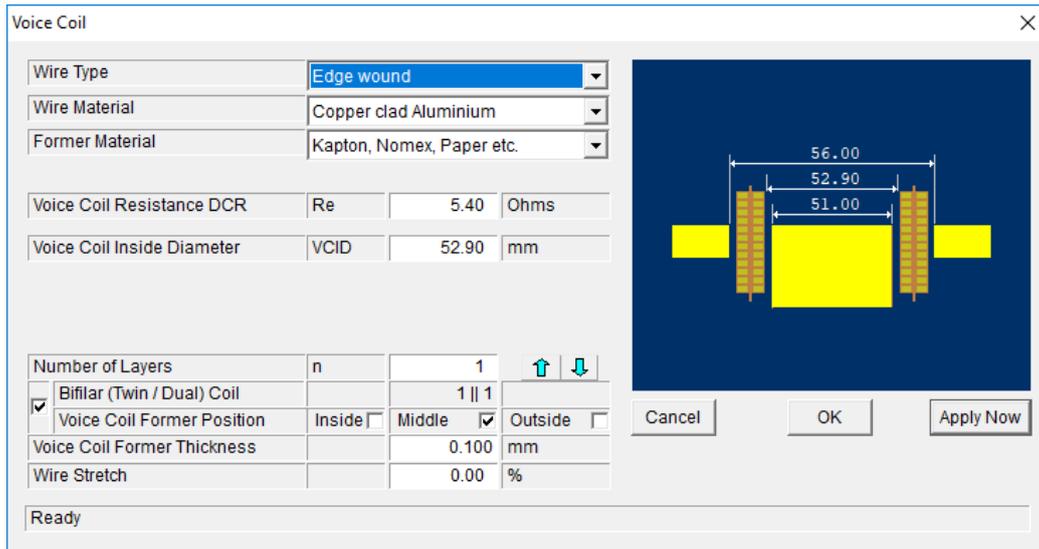
25.40
26.55

Cancel OK Apply Now

In this window you can change the physical parameters of the acoustic components. When entering data FINEMotor will automatically recalculate the values of related parameter, i.e. Effective Area will update when a new Effective Diameter is entered. This happens in real time.

You can choose to have FINEMotor calculate and estimate Qms by checking the box “Estimate Qms” or enter one from a similar speaker by unchecking the box. The same goes for the resonance frequency Fs, where you check the box “Use Calculated Fs”.

1.5 Voice Coil

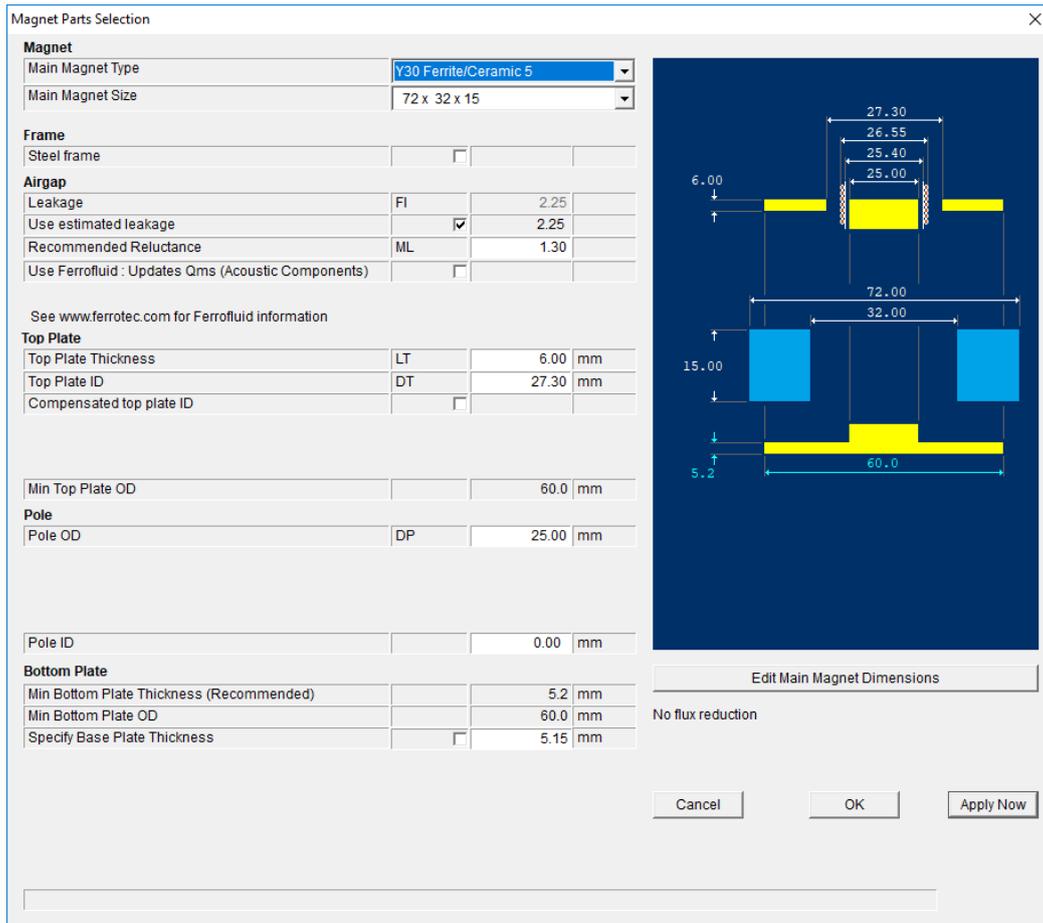


The Voice Coil window offers different choices of wire type, wire material and former material. These are all selected from the three drop-down menus located at the top of the window. The rest of the parameters are entered as numbers. See also:

1. section 2.1.3 Multiple-layer VC
2. section 2.1.4 Twin/bifilar VC
3. section 2.1.7 Edge Wound/ Flat wire VC

1.6 Motor Parts

In the Motor Parts window, you will find a drop-down menu containing a wide selection of the most common Chinese magnets. Below that you can choose the dimensions of the magnet or you can use your own by clicking on the button “Edit Main Magnet Dimensions” in the lower right corner.



Note: Your own special magnet material/grade and standard dimensions can be defined in the Magnet List, see Appendix 5.2.

You can choose to have a steel frame by checking the box “Steel Frame”. This, however, will increase the leakage.

You can also choose to use Ferrofluid by checking the box “Use FerroFluid”. For more information, see section 2.4.4.

Finally, you can choose to use a compensated top plate by checking the box “Compensated Top Plate ID”. This will automatically change the top plate ID by allowing a specified Coil clearance. This feature is extremely useful for multi-layer or flat wire Voice Coils.

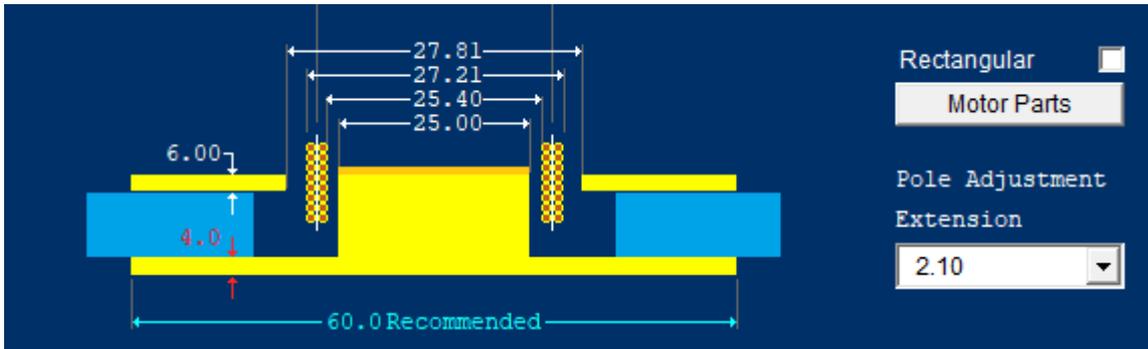
1.7 Back Plate Thickness

Min Top Plate OD		60.0	mm
Pole			
Pole OD	DP	25.00	mm
Pole ID		0.00	mm
Bottom Plate			
Min Bottom Plate Thickness (Recommended)		4.8	mm
Min Bottom Plate OD		60.0	mm
Specify Base Plate Thickness	<input checked="" type="checkbox"/>	4	mm

Flux adjustment will be a factor of 98.8%
SPL and BI adjustment will be -0.10dB

In Motor Parts you can specify the thickness of the back (bottom) plate in the last line. In the above example the back-plate thickness was set to 4 mm, caused a loss of -0.10 dB.

This is now show in red on the main sketch, shown below:



1.8 Mechanical Parameters

Layers	n	2	
Wire Material		Copper	
Wire Type		Round	
Wind Width	WW	11.72	mm
Number of Windings	N	89.46	
Nom.(bare) Wire diam	BWD	0.224	mm
Total Winding OD	WOD	26.55	mm
Total Winding Mass	Mvc	2.702	g
Stretch		0.00	%

This window gives an overview of the mechanical parameters of the VC. If Ferrofluid is used information about it will also appear in this window. This window updates in real time.

1.9 Thiele-Small Parameters

Max Sensitivity (2.83V/1.00m) Theoretical	SPL	92.68	dB
Std. Sensitivity (2.83V/1.00m) Loudsoft	SPL	90.71	dB
VC Resistance DCR	Re	3.20	Ohms
Resonance	Fs	45.00	Hz
Mechanical	Qms	3.00	
Electrical	Qes	0.52	
Total	Qts	0.44	
Equivalent air vol.	Vas	27.36	l
Compliance	Cms	1.07	mm/N
Moving Mass(incl. air)	Mms	11.70	g
Force Factor	Bl	4.51	Tm
Eff. diaphragm area	Sd	134.99	cm ²
Lin. Excursion +/-	Xmlin	2.86	mm
X Max +/-	Xm	3.15	mm

This window contains all the Thiele-Small parameters, which updates in real time.

1.10 BL(x)



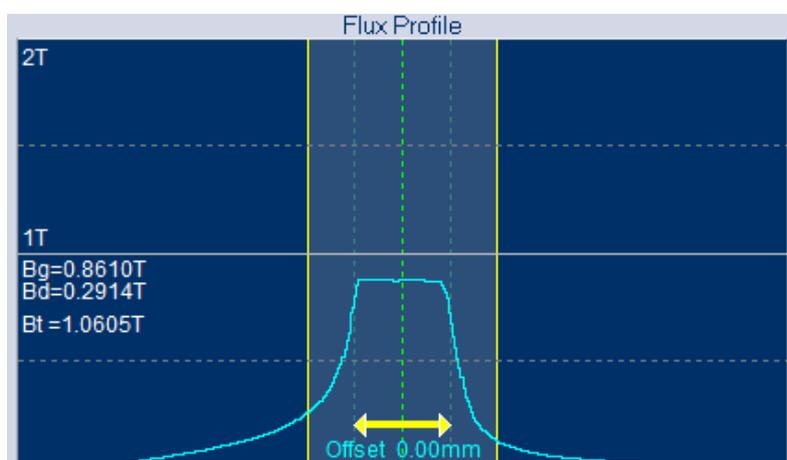
In FINEMotor you can directly simulate the non-linearity of BL as a function of the VC excursion. This is displayed as the BL(x) curve, which in this case is non-symmetrical left/right (= in/out of the motor). The dashed light blue line is the mirror curve of the BL(x) curve, which makes it easier to see if the BL(x) curve is symmetrical. In that case the two curves would overlap.

The BL(x) curve seen above is not symmetrical, since BL is higher when the VC is inside the motor. This will change in real time as the design of the VC and motor is changed. The green part of the BL(x) curve indicates when BL=82% of the BL at the rest position, so the green curve normally ensures that the distortion is sufficiently low. 70% is useable in many cases and 50% indicates the highest maximum excursion.

That also defines the acceptable Xmax, namely $-X_m$ (in) and $+X_m$ (out). In this case $-X_m=4.26$ mm and $+X_m=3.15$ mm.

The arrows in the corners allows you to zoom in and out.

1.11 Flux Profile



The Flux Profile window shows the flux as a curve with the centerline being the center of the VC. You can offset the VC by clicking and dragging to either left or right. This will then update the BL(x) curve in real time

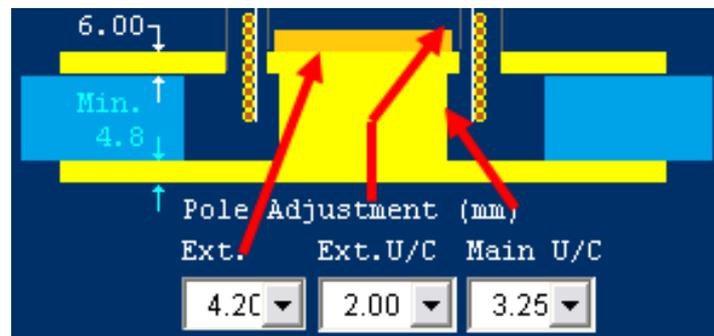
It also displays the average B gap flux (B_g), the operating point of the magnet (B_d), and the B flux in the top plate (B_t). Since most iron top plates will saturate at approx. 2T B_t turns red when that happens to indicate that the top plate might be saturated.

1.12 Pole Geometry

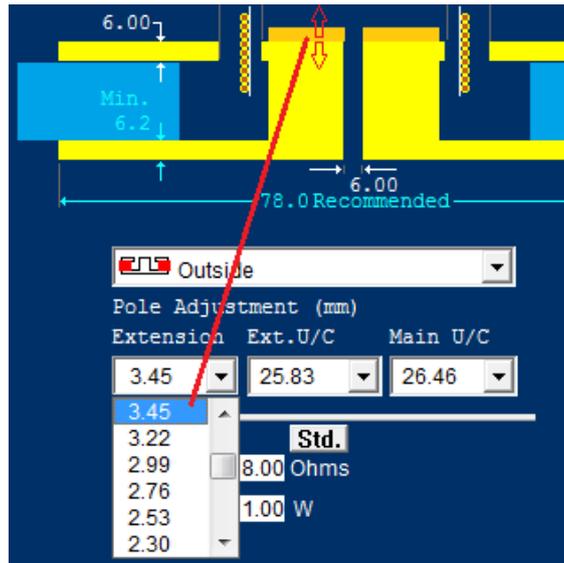
The pole geometry is very important for the BL(x) linearity and thereby distortion and X_{max} . You can, in FINEMotor, fine-tune the dimensions of the pole piece in great detail due to 36.000 Magnetic Finite Element (FEA) calculations that is already implemented in the software.

You can alter:

- Pole Extension (Ext.)
- Extension undercut (Ext. U/C)
- Pole undercut (Main U/C)
- Hole diameter (found in Motor Parts)



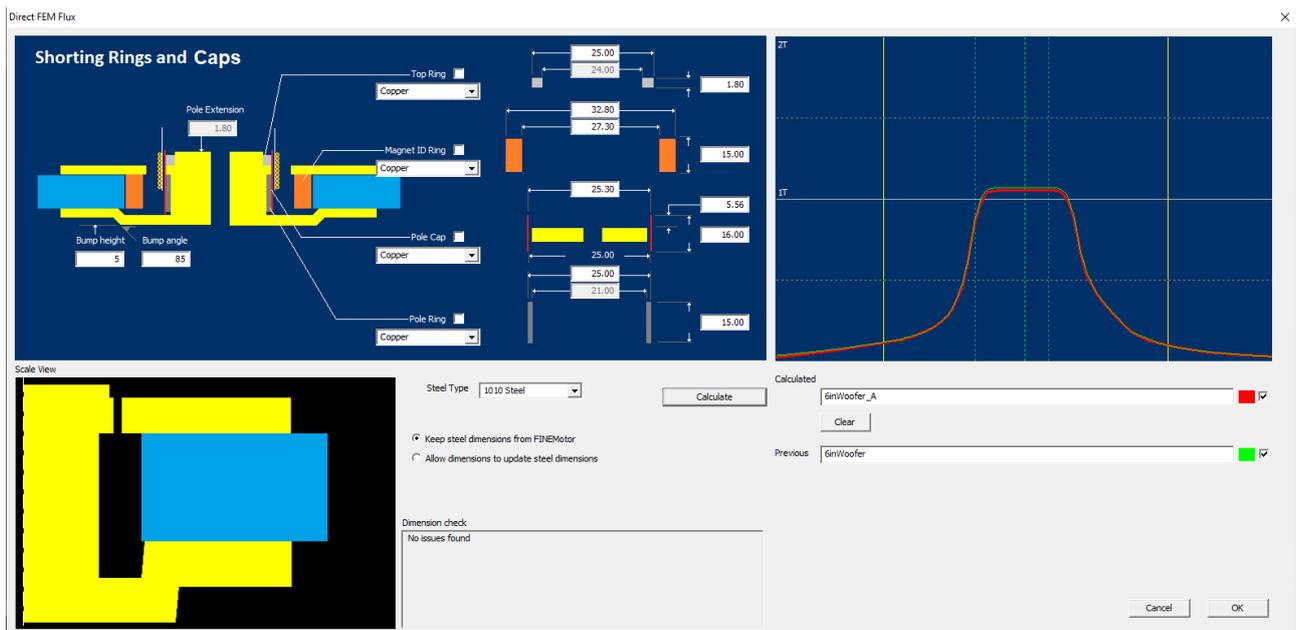
These adjustments can be done by either selecting a specific value or using the mouse wheel to scroll through the different values and see the changes update in real time. Watch the DEMO VIDEO and see how the new controls work with the mouse wheel: <https://youtu.be/j70o-WnAXyc>.



Note: Be careful with smaller VC diameters or large holes in the pole, as the pole piece steel may saturate, because the total flux ($B \times \text{area}$) pass through the pole piece. See the example below where both the pole and top plate are saturated, which will automatically show in red



1.13 Direct FEM Flux



Pressing the Direct FEM Flux button makes it possible to perform an extremely accurate magnetic FEM calculation using the exact dimensions you have just set in FINEMotor.

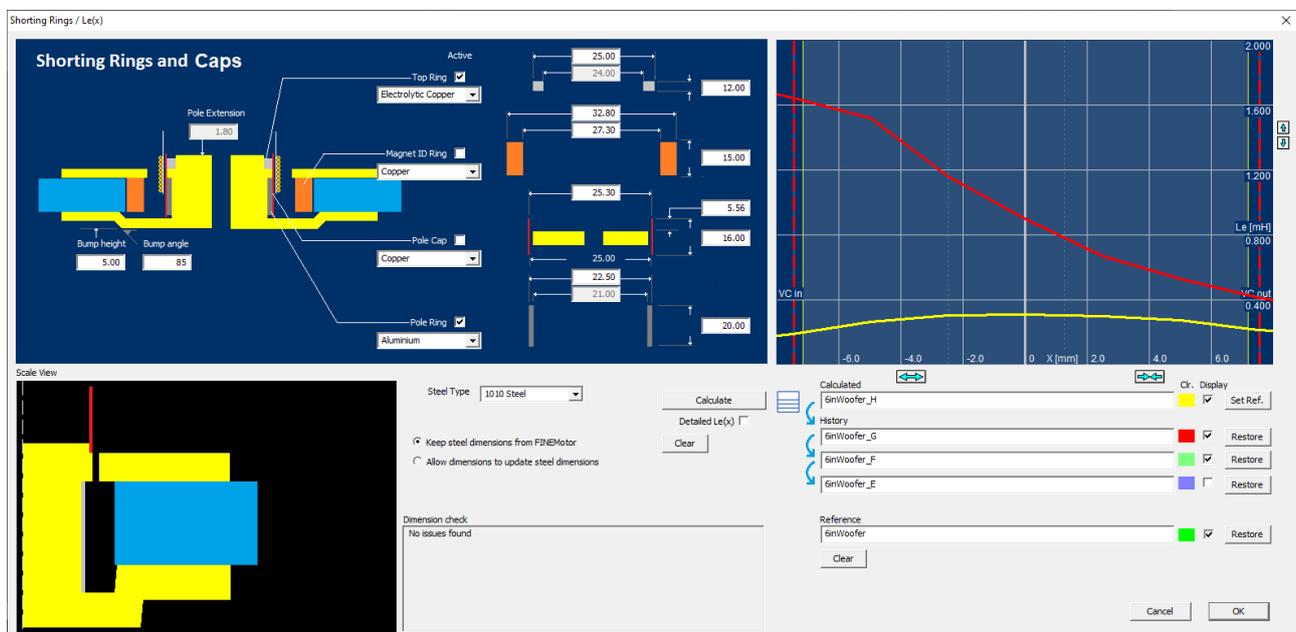
After pressing [Calculate] you get the precise B flux profile curve shown to the right in the next picture (green). The red B-curve was calculated after specifying a 5mm bumped back plate at a 85deg angle.

Note that the exact magnet system is shown as the **Scale View**.

The calculated flux profile will be inserted in the main FINEMotor window after OK.

You can select one of the standard steel grades (1006-1010-1018-1020). You may allow other dimensions to be set, see next.

1.14 Shorting Rings and Caps / Le(x)



Pressing the Shorting Rings / Le(x) button will open the above screen, where you can insert various rings and calculate the VC induction versus travel X: Le(x).

The red curve at right is the Le(x) curve for the magnet system in the Scale View (lower left), **without** any shorting ring. When the VC is far down in the motor, the induction is quite high (1.6mH) because the VC is fully surrounding the steel. Therefore, the induction is much lower at right (0.4mH) where the VC is almost out of the air gap.

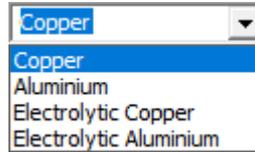
In contrast the yellow curve is much lower and is symmetric about the vertical axis. This kind of Le(x) curve will produce very little (intermodulation-) distortion and DC-offset.

This was obtained by inserting two rings: one below the airgap (Pole Ring: Aluminium) and one above the airgap (Top Ring: Electrolytic Copper). The top ring was automatically inserted in the recess from the extension undercut, and you only need to set the height (here: 12mm).

Note: The vertical red dashed lines indicate the practical X-range, where BL has dropped below 50% of the max value.

You can change the dimensions and material of all 4 kinds of rings within practical limits:

- Top Ring
- Magnet ID Ring
- Pole Cap
- Pole Ring



You have the option to change the dimensions, which were specified in the FINEMotor main view. But be careful, as that will also change the magnetics / B-flux. If you have selected other steel dimensions, be sure to check the Direct FEM Flux.

Note: If the “Allow dim to update steel dimensions“ option is on, you may not get the dimensions which were set in the main view!

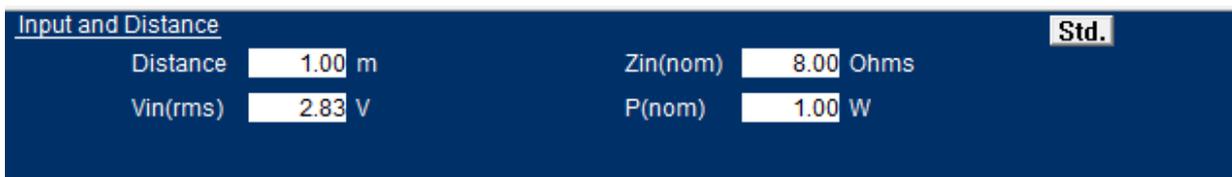
As soon as you insert or change rings, you must press calculate to view the result of the change. When you change the next time, the previous result (curve +color) will move one step down the stack.

You have the option to save a calculated curve as Ref (lowest) for comparison.

The Detailed Le(x) will calculate a high-resolution curve, which takes longer (~ minutes).

See also the example: **3,5in Neo Motor with flat Le(x)** in section 2.1.9 page 30

1.15 Input and Distance



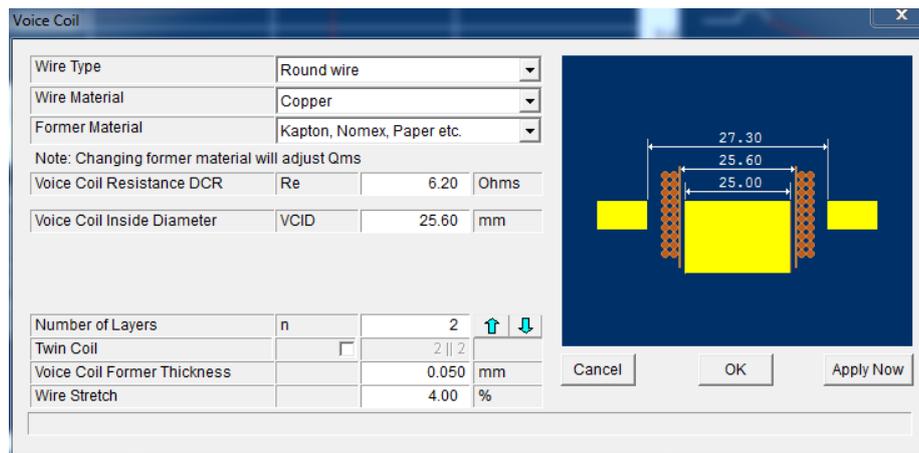
The Input and Distance window allows you to change the simulated distance of the microphone, the input voltage, the impedance, and the power. Furthermore, you can reset to the standard values by clicking the “std.” button.

2. Design Examples

2.1 6.5” Woofer Design Example

Start FINEMotor and select “New” or _Default.fm3. For this new design we will try to use an existing VC with a Kapton former, a winding width (WW) of 9.75mm and VCID= 25.60mm.

First press the “Voice Coil” button and this window should appear:



- Set Wire Type to Round Wire.
- Set Wire Material to Copper.
- Set Former Material to Kapton. Note: use the Kapton setting for all non-conducting VC formers
- Set Voice Coil Resistance (Re) to 6.2 ohms
- Set Wire Stretch to 4%. This is done to match the existing VC.
- Click apply now

In the main window use the mouse to drag the green line marked “Current Simulation” until it is close to the 9.75mm WW.



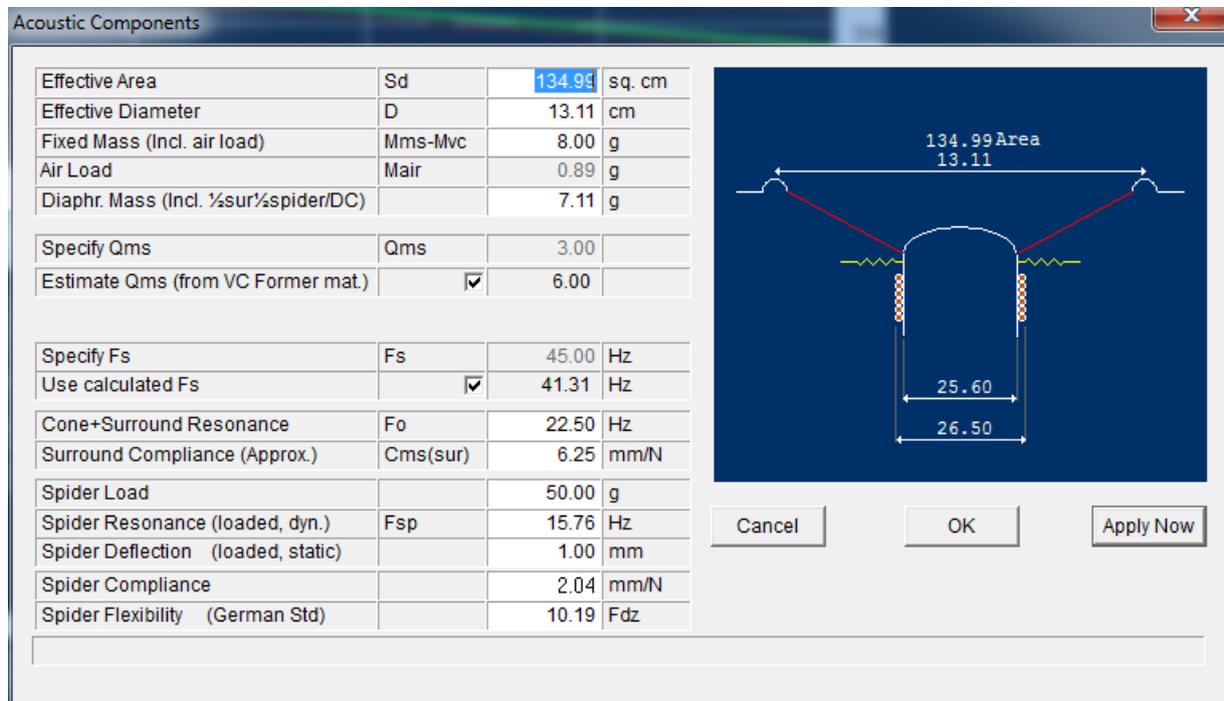
The window underneath, “Mechanical Parameters”, updates in real time, so drag the line back and forth until you reach a WW of around 9.75. In this example, we reach a WW of 9.69 mm with a Wire Diameter of 0.17 mm.

Layers	n	2	
Wire Material		Copper	
Wire Type		Round	
Wind Width	WW	9.69	mm
Number of Windings	N	96.81	
Nom.(bare) Wire diam	BWD	0.170	mm
Total Winding OD	WOD	26.50	mm
Total Winding Mass	Mvc	1.656	g
Stretch		4.00	%

Note: In a nominal 8 ohms system you can go down to DCR= 5.5 ohms and still keep the minimum impedance of 6.4 ohms. This is because the min. impedance (Z_{min}) is at least 0.5 ohms higher than DCR, and the crossover inductor normally has a resistance (R_L) of 0.3-0.5 ohms or more. A 4 ohms system can use a DCR of 2.5-3 ohms or lower while keeping the min. 3.2 ohms impedance.

2.1.1 Acoustic Components

Click on “Acoustic Components” and you should see this window:

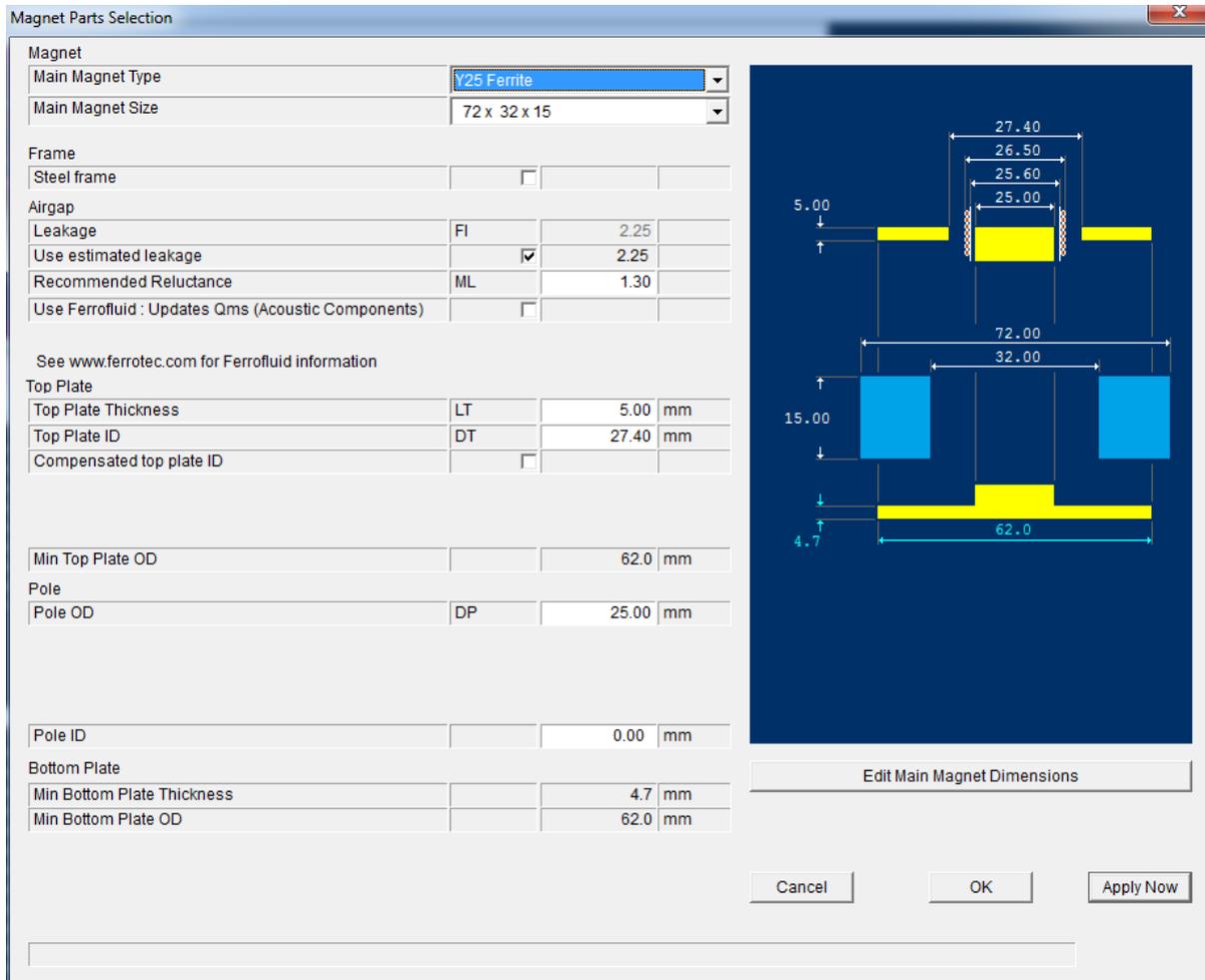


Note: For micro speakers you may wish to have up to 4 decimal digits. Go to Options and select “Display values with extra precision”

- Set Effective Diameter to 13.11 cm, and the software will then automatically compute the Effective Area of the cone.
- Set Diaphragm Mass to 7.11 g.
To find the diaphragm mass add the weight of half of the active surround, the cone, the dust cap, the VC former, half of the spider and the glues used. In this example this gave a Diaphragm Mass of 7.11 g.
The Air Load will automatically be calculated by FINEMotor and added to the Fixed Mass. The Fixed Mass is the total moving mass excl. the mass of the VC, which is calculated by FINEMotor.
- The Qms is calculated by FINEMotor to be 6 for a Kapton Voice Coil Former.
In this example, we will have FINEMotor calculate the Fs for us, since it is not known. Click in the box “Use Calculated Fs”.
- Set the Cone+Surround to 22.5 Hz, which is the resonance of our cone.
The Surround Compliance is then automatically calculated to 6.26 mm/N.
- Set Spider Deflection to 0.59 mm and make sure Spider Load is set to 50 g. This is the deflection of an existing spider design.
Unfortunately, it gives an Fs of 51 Hz, which is too high. Often a Spider Deflection of 1 mm is used, so it will be tried here.
- Set Spider Deflection to 1 mm. This gives an acceptable Fs of 41.31 Hz.
If the mass of the VC changed later the Fs is updated automatically.

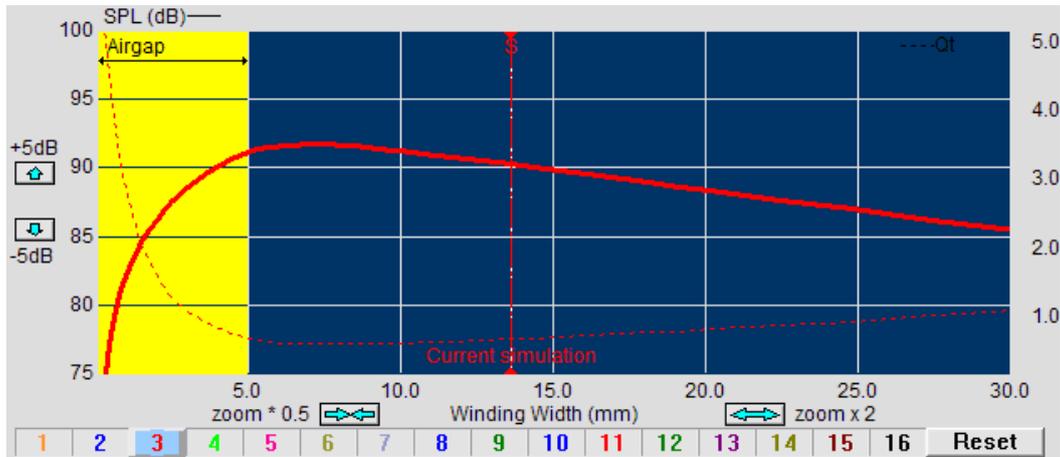
2.1.2 Motor Parts

Then we will take a look at the magnet system. Press “Motor Parts” and make sure “Use estimated leakage” is checked [x]:



- Set Main Magnet Type to Y25 Ferrite (Most Chinese magnet grades are available)
- Set Main Magnet Size to 72x32x15
- Set Top Plate Thickness to 5.00 mm
- Set Top Plate ID to 27.40 mm
- A steel frame can also be selected, which will result in a lower BL due to increased leakage. Make sure it is NOT checked for this example.
- Click apply

The main window shows a curve for all possible VCs satisfying the criteria we have defined previously:



In the beginning we chose a WW of 9.69 mm. In the “TS Parameters” window we can now see that this will give us a Q_{ts} of 0.49 and an X_{max} of 2.60 mm.

Let us say that the woofer in this example is to be used in a bass reflex design. For a bass reflex design, we want a Q_{ts} of about 0.33-0.38. To achieve such a Q_{ts} we will try a larger magnet.

- Open Motor Parts
- From the drop-down menu in Main Magnet Size, choose 84x33x15.
- Click apply

Note: Using this magnet, the back-plate thickness must be increased from 5.0 mm to 6.0 mm. This is automatically updated.

After clicking apply, we can now see that the Q_{ts} has fallen to 0.31 due to an increase in BL from 5.40 T/m to 6.90 T/m. This is a decent solution; however, from experience we know that we can use a longer WW, i.e. 15.55 mm.

To increase the WW, we again drag the “current simulation” line, this time to the right, until the WW is 15.55 mm. Increasing the WW increases the Q_{ts} slightly to 0.35, which is still acceptable, while also increasing X_{max} to 4.89.

Next, we will find the optimal resting position for the VC. This is done in the “Flux Profile” window by clicking in the window and dragging the curve to the left or to the right. In this example we need to drag the curve 0.62 mm to the left to achieve a more symmetrical BL(x) curve, which can be seen in the “BL(x)” window located above the “Flux Profile” window.

The only problem with this solution is that we need this woofer to be magnetically shielded, if it is to be used near magnetically sensitive equipment, such as CRT monitors. In FINEMotor that is done by using the drop-down menu in the lower right.



Selecting “Outside Shielded” we get a shielded motor with the same Thiele/Small parameters. All the dimension of the shielding can and the optimal back plate are found in “Motor Parts”.

In “Motor Parts” it is also possible to specify the diameter of a center hole in the pole (Pole ID); a 4 mm. hole is chosen for this example. If the hole is too large the pole will turn red to indicate saturation. When the saturation is just starting you may not notice a big loss, so that may still be useable.

You can find this solution saved as 6,5wfr1a.fm3 in the examples on the install CD and also in C:\Program Files\Loudsoft\FINEMotor20\Examples. (The VC position is offset for symmetry, see later)

2.1.3 Multi-Layer Voice Coils

A different approach is trying a 4-layer VC instead of a larger magnet. However, a 4-layer VC will need a thicker wire and therefore we have to modify the air gap.

- Open Motor Parts
- Set Main Magnet Size to 72x32x15
- Check Compensated Top Plate ID. This will ensure that VC Clearance is kept constant and at the same time recalculate the magnet gap field.
- Set Coil Clearance to 0.35 mm
- Click apply
- Open Voice Coil
- Set Number of Layers to 4
- Click apply

In the Main Window, drag the Current Simulation line till it shows a WW close to 10mm, which should give a Qts of 0.29. This is too low.

We then increase the WW until we get an acceptable result. Increasing the WW to 14.56 mm, the Qts will increase to 0.34. This is still low, but acceptable. The Xmax is now 5.07 mm.

Note: The Top Plate ID increases automatically to keep the preset clearance and the calculated Fs decreases due to a higher VC mass.

This solution is saved as 6,5wfr2a.fm3

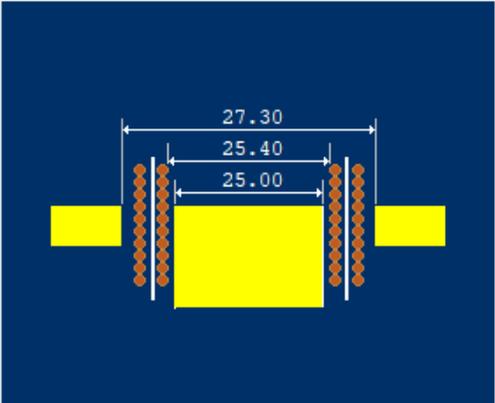
2.1.4 Twin Coil / Bifilar VC

Voice Coil
✕

Wire Type	Round wire		
Wire Material	Copper		
Former Material	Aluminium		
Note: Changing former material will adjust Qms			
Voice Coil Resistance DCR	Re	3.20	Ohms
Voice Coil Inside Diameter	VCID	25.40	mm

Number of Layers	n	2	↑ ↓	
<input checked="" type="checkbox"/> Bifilar (Twin / Dual) Coil		2 // 2		
<input checked="" type="checkbox"/> Voice Coil Former Position	Inside <input type="checkbox"/> Middle <input checked="" type="checkbox"/> Outside <input type="checkbox"/>			
Voice Coil Former Thickness		0.050	mm	
Wire Stretch		0.00	%	

Cancel OK Apply Now



A special form of Voice Coil is the Twin Coil or Bifilar VC. As the name indicates this is a kind of double Voice Coil. In the above is used 2 // 2 layers.

The simplest version has just two layers. Usually these two layers are connected in parallel, for example each layer is 8R (ohms), giving $8R // 8R = 4R$.

The VC former can be placed inside or in the middle of the two windings, as shown above.

Each winding can have from 1-10 layers, and may also be using edge wound /flat wire. The number of windings is shown as 127 // 127 as in the example below.

Layers	n	2 // 2	
Wire Material		Copper	
Wire Type		Round	
Wind Width	WW	14.31	mm
Number of Windings	N	127 // 127	
Nom.(bare) Wire diam	BWD	0.190	mm
Total Winding OD	WOD	27.30	mm
Total Winding Mass	Mvc	5.622	g
Stretch		0.00	%

Note: The latest version of FINEMotor will report and use the actual X_{max} value (X_m), which is often larger than the X_{lin} .

However, the $BL(x)$ is still not perfect. Fortunately, we can change the shape of the $BL(x)$ curve by modifying the pole piece, see next.

2.1.6 Pole Geometry

First try extending the pole piece by clicking in the drop-down menu under Pole Adjustment and either selecting a value or using the mouse wheel. The $BL(x)$ curve will update in real-time.

We will now try to get a more linear and more symmetrical $BL(x)$ curve by adjusting the pole geometry.

- Set the offset in the “Flux Profile” window to 0.
- Extend the pole piece to 3.40 mm. This can be done either by selecting the specific value or using the mouse wheel. The $BL(x)$ curve will update in real-time.

This solution is almost symmetrical, which is a considerable improvement, with an X_{max} of ~5.40 mm in both directions. This is a good solution for subwoofers. The solution is saved as 6,5wfr3a.fm3.

The best solution is found by adjusting the two remaining drop-down boxes Ext. U/C (Extension Undercut) and Main U/C (Pole Undercut).

- Reduce the Ext. U/C to 21.50 mm.
- Reduce the Main U/C to 22.50 mm.
- Increase the pole piece to 4.00 mm.

This concentrates more flux in the air gap due to the undercuts both above and under the air gap. The resulting $BL(x)$ curve is close to perfect being very symmetrical and having a flatter green center curve up to X_{max} , and X_m is increased to 5.67mm in both directions:



The penalty is a slightly lower BL giving a higher Qts due to reduced leakage above and under the air gap.

This version is saved as 6,5wfr4a.fm3.

Finally, the user may export the *.fm3 files from FINEMotor into FINEBox to check the performance in the actual box. That is the very best way to decide if the found solution(s) in FINEMotor are suitable in your system.

2.1.7 Edge Wound / Flat Wire Voice Coils

Voice Coil [X]

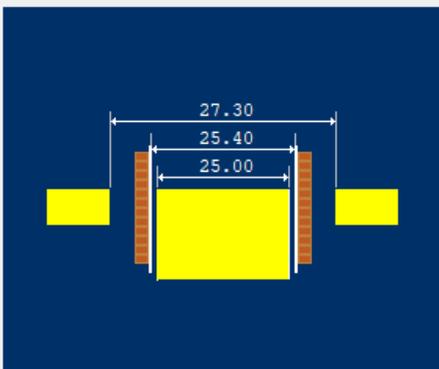
Wire Type	Edge wound		
Wire Material	Copper		
Former Material	Aluminium		

Note: Changing former material will adjust Qms

Voice Coil Resistance DCR	Re	3.20	Ohms
Voice Coil Inside Diameter	VCID	25.40	mm

Number of Layers	n	1	↑ ↓
<input type="checkbox"/> Bifilar (Twin / Dual) Coil		1 1	
<input type="checkbox"/> Voice Coil Former Position	Inside <input checked="" type="checkbox"/>	Middle <input type="checkbox"/>	Outside <input type="checkbox"/>
Voice Coil Former Thickness		0.050	mm
Wire Stretch		0.00	%

Number of layers (1 to 10)



Cancel OK Apply Now

Voice Coil [X]

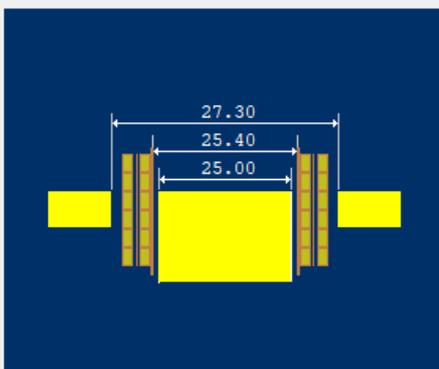
Wire Type	Flat wire		
Wire Material	Copper clad Aluminium		
Former Material	Kapton, Nomex, Paper etc.		

Note: Changing former material will adjust Qms

Voice Coil Resistance DCR	Re	3.20	Ohms
Voice Coil Inside Diameter	VCID	25.40	mm

Number of Layers	n	3	↑ ↓
<input type="checkbox"/> Bifilar (Twin / Dual) Coil		3 3	
<input type="checkbox"/> Voice Coil Former Position	Inside <input checked="" type="checkbox"/>	Middle <input type="checkbox"/>	Outside <input type="checkbox"/>
Voice Coil Former Thickness		0.050	mm
Wire Stretch		0.00	%

Number of layers (1 to 10)



Cancel OK Apply Now

Above is shown Edge Wound Voice Coil (top) and Flat Wire Voice Coil (bottom). The top version, is wound with the rectangular (flat) wire perpendicular to the VC former, as show in the right-hand picture.

In contrast the bottom version is wound with the rectangular (flat) wire parallel to the VC former, as show in the right-hand picture (bottom).

The Edge Wound VC is primarily used for PRO speakers. It has a better fill factor (than round) and can obtain higher BL in comparison. When used as one-layer VC, all windings are in direct contact with the VC former, which provides better cooling. However, it requires a special winding technique.

Likewise, the Flat Wire VC has a better fill factor (than round) and can obtain higher BL in comparison. When used as multiple-layer VC however, all windings do not have direct contact with the VC former. But it does not require a special winding technique.

2.1.7.1 Edge Wound Example

Let us assume there is a requirement for high power and sensitivity. We will then consider an edge wound VC.

A 1-layer edge wound VC will have more windings compared to a round wire VC, because the wires are wound on their “side”. The advantage is higher BL and less inductance, especially compared to a 4-layer VC. In addition, the power handling is increased, because the wires are closer together and the one layer is better cooled.

Note: You can import such FINEMotor files into FINEBox and calculate the high-power temperatures and power compression.

For this example, we revert the settings back to the original design with the settings given in section 2.1.1-2.1.3.

- Load 6,5wfr1a.fm3 from the Examples folder in the FINEMotor installation folder.
- Remove Outside Shielding
- Open Motor Parts
- Set Main Magnet Size to 72x32x15
- Check Compensated top plate ID
- Click apply
- Open Voice Coil
- Set Wire Type to Edge Wound Wire
- Set Number of Layers to 1
- Click apply

This configuration gives a high sensitivity and BL even with the smaller 70x32x15 Y25 ferrite magnet. Therefore, giving a low Qts of 0.33, which may be another possible solution.

This version is saved as 6,5wfr5a.fm3. The flat wire VC's are normally very difficult to design, but FINEMotor makes it easier by displaying all solutions in a simple and logical manner. The dashed curve shows Qts. It is also possible to have the BL displayed in the main window by clicking the little “BL” button in the upper left corner.

2.1.8 Estimated Leakage FL

So far, we have used the default setting (“Use Estimated Leakage”) for the magnetic leakage FL, because it gives a fast and quite accurate simulation. In very complicated cases you may perform a separate FEA from a Magnetic FE program like MagNet, FEMM etc., and then import a flux profile taken through the air gap. This flux profile may be imported into FINEMotor from the clipboard by CTRL+V or imported as a text file using the  button. The VC may also be offset in that case; however, you cannot change neither the magnet nor pole geometry, because they are defined in the FEA program.

Magnetic FEA calculations are very precise, but the material data are not always representing the quality you receive from vendors. Manufacturers may not always have magnetized the magnets fully or they might have used a cheaper material than specified.

Therefore, you should always verify your simulations by building and measuring prototypes. When you find a difference in BL you can modify the leakage FL (in “Motor Parts”) to give the most precise simulations results for your similar motors.

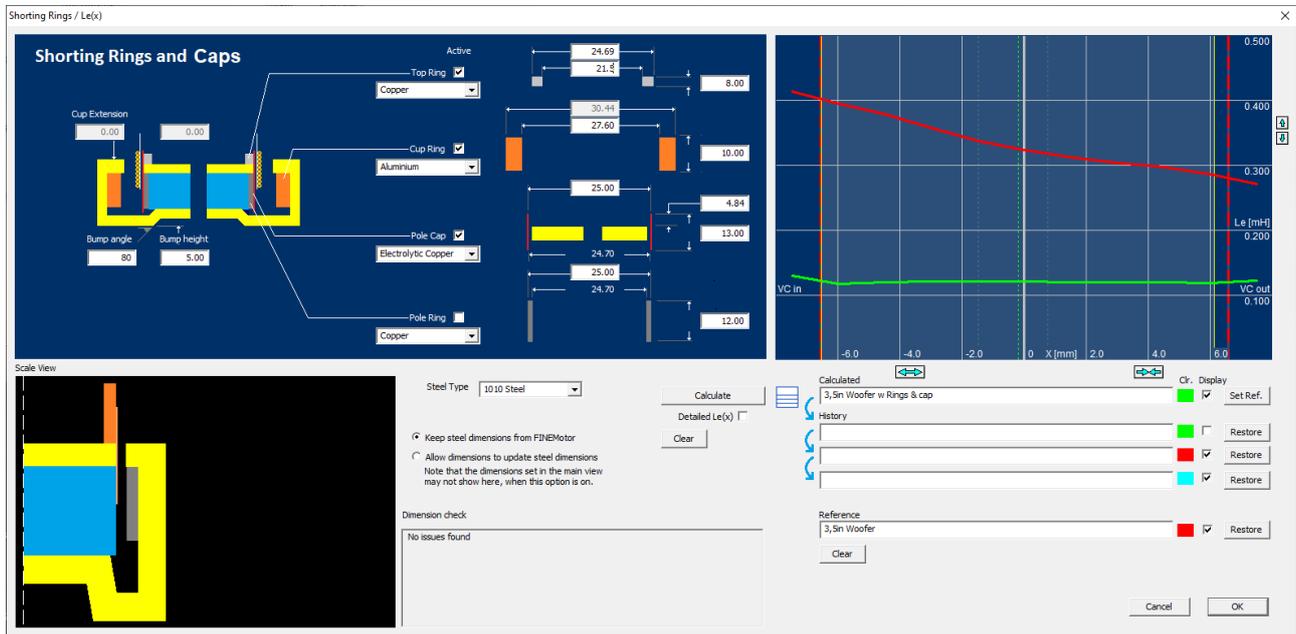
Note 1: For the above reasons you may find that the imported flux profiles from magnetic FEA programs appear optimistic when compared to actual TS parameter measurements. At this time, we assume that it is caused by the actual magnet material properties being below spec (or being average rather than max). FINEMotor has been verified using imported flux profiles from FEMM. See appendix 4.4.

(Magnetic FEA freeware: <http://www.femm.info/wiki/HomePage>)

Note 2: Be sure to measure the TS parameters correctly! Very low-level impedance measurements may lead to wrong TS parameters due to nonlinearities in the spider. This is especially true for small drivers where the resonance Fs may appear 10-30% higher than when measured at 2.83V!

(The FINE R+D system from LOUDSOFT will measure the TS parameters at the same level as the SPL; see www.loudsoft.com)

2.1.9 3,5in Neo Motor with flat Le(x)



This is an advanced example applying a combination of rings in different materials and shapes for obtaining a flat $Le(x)$ curve, see the green curve to the right. The red curve is $Le(x)$ without rings and is much higher for negative X values.

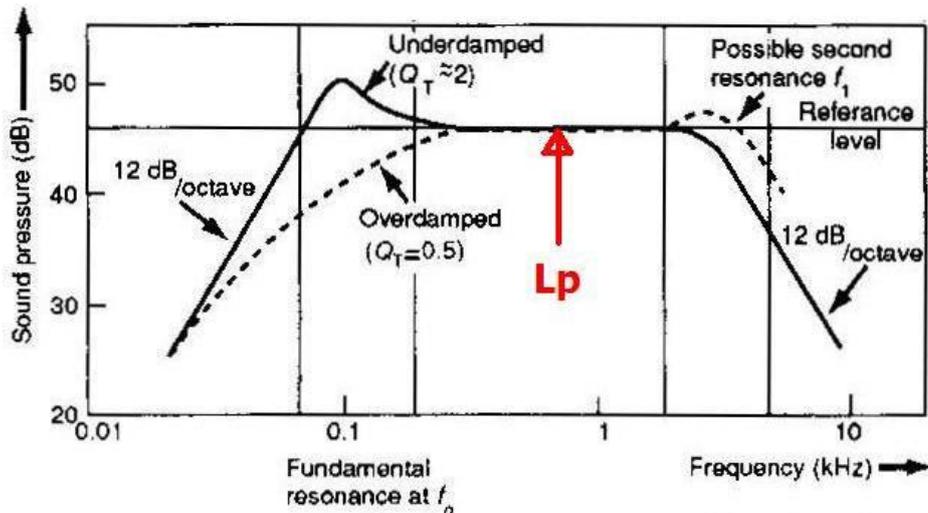
First a thin and extended pole cap in electrolytic copper has been inserted over the top plate. In addition, another ring was inserted in the U-cut steel yoke. The height and material were chosen to flatten the $Le(x)$ curve for negative X values. For the same reason, a copper ring was added on top of the pole for controlling $Le(x)$ for positive X values.

Note: The vertical red dashed lines indicate the practical X -range, where BL has dropped below 50% of the max value.

2.1.10 SPL Sensitivity

The standard SPL sensitivity for 2.83V/1m has been used in FINEMotor since 1995. This is based on 45 years' experience designing loudspeakers and fits standard and Hi-Fi drivers quite well but is slightly conservative.

The SPL sensitivity is defined as L_p , which is the basic flat level above F_s and before break-up, measured in baffle (half space / 2π), see the figure below. L_p (SPL) is calculated using the estimated **minimum impedance R_z** (Ref. N. Thiele section 9: THE LOUDSPEAKER PARAMETERS AND THEIR EVOLUTION).



From L. Beranek: Acoustics

In contrast the **Theoretical** SPL is calculated using R_e (DCR) instead of the (correct) minimum impedance R_z , which is why it gives a **too high and optimistic** SPL. Unfortunately, this method is used by Klippel, which is why you often see higher SPL being reported from Klippel measurements. For convenience, the latest versions of FINEMotor calculates **both sensitivity** numbers, see below:

TS Parameters		
Max Sensitivity (2.83V/1.00m) Theoretical	SPL	92.74 dB
Std. Sensitivity (2.83V/1.00m) Loudsoft	SPL	90.77 dB
VC Resistance DCR	R_e	3.20 Ohms
Resonance	F_s	45.00 Hz
Mechanical	Q_{ms}	3.00
Electrical	Q_{es}	0.52
Total	Q_{ts}	0.44
Equivalent air vol.	V_{as}	27.77 l
Compliance	C_{ms}	1.07 mm/N
Moving Mass(incl. air)	M_{ms}	11.70 g
Force Factor	Bl	4.51 Tm
Eff. diaphragm area	S_d	136.00 cm ²
Lin. Excursion +/-	X_{mlin}	2.86 mm
X Max +/-	X_m	3.15 mm

LOUDSOFT correct std. SPL and Theoretical SPL (used for Klippel comparison)

When measuring small inexpensive speakers with much break-up and micro speakers, you sometimes get a slightly higher sensitivity SPL. In such cases you may find the Theoretical SPL to be closer to your measured SPL.

When comparing with Klippel results you can use the Theoretical SPL.

2.2 Rectangular Micro Speaker Example

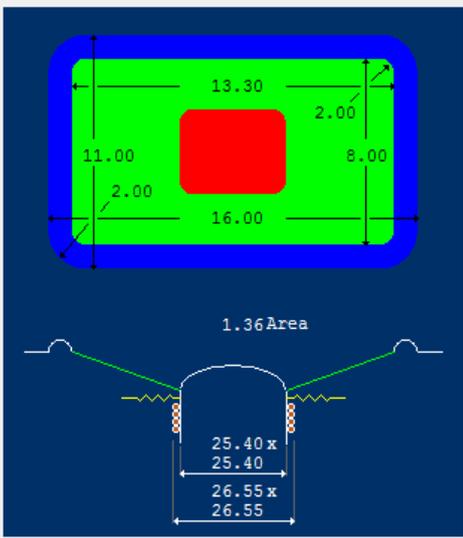


This is a design example for a typical 18x13mm rectangular micro speaker where the neodymium magnet, VC and diaphragm are rectangular. After selecting both a rectangular speaker and motor (which then assumes a rectangular VC) we have entered the shown dimensions, and the effective cone area is automatically calculated.

Note: It is also possible to use a round VC in a rectangular speaker by leaving the rectangular motor box [] unchecked)

When you have entered the rectangular dimensions the effective cone area is automatically calculated:

Effective Area	Sd	1.36	sq. cm
Overall X	D	16	mm
Overall Y	D	11	mm
Overall Radius	D	2	mm
Piston X	D	13.30	mm
Piston Y	D	8	mm
Piston Radius	D	2	mm
Fixed Mass (Incl. air load)	Mms-Mvc	0.06	g
Air Load	Mair	0.00	g
Diaphr. Mass (Incl. 1/2sur/1/2spider/DC)		0.06	g
Specify Qms	Qms	2.00	
Estimate Qms (from VC Former mat.)	<input type="checkbox"/>	3.00	
Specify Fs	Fs	400	Hz
Use calculated Fs	<input type="checkbox"/>	0.00	Hz
Cone+Surround Resonance	Fo	0.00	Hz
Surround Compliance (Approx.)	Cms(sur)	0.00	mm/N
Spider Load		50.00	g
Spider Resonance (loaded, dyn.)	Fsp	0.00	Hz
Spider Deflection (loaded, static)		0.00	mm
Spider Compliance		0.00	mm/N
Spider Flexibility (German Std)		0.00	Fdz



1.36 Area

25.40 x 25.40

26.55 x 26.55

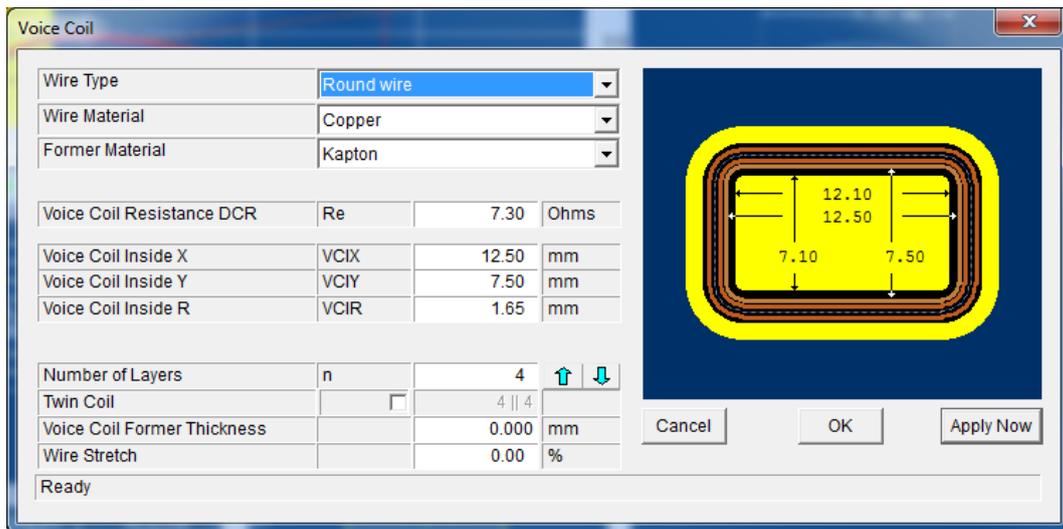
Cancel
OK
Apply Now

Effective cone radiating area [edits will recalculate cone diameter] (cm^2)

2.2.1 Rectangular Voice Coil

The rectangular VC is normally the component which defines the motor design. First, we enter the inside dimensions of the VC. There is no former, so Voice Coil Former Thickness=0. If the thin VC wire is stretched during winding, you may input a stretch percentage, which will adjust the WW to fit actual VCs.

This design is using a 4-layer copper VC, but you may select copper-clad aluminum CCAW wire and even flat wire.



2.2.2 Rectangular Motor

Normally, you need to input all the possible dimensions for the rectangular motor; however, most can be done automatically by specifying a coil clearance (CL) (outside the VC) in the U Cup section. In this example the CL=0.20mm. Likewise you can specify an inside Pole Clearance (PL), which in this case is equal to the CL (=20).

This implies that the steel parts of the U-cup and the pole plate will be automatically designed in FINEMotor (see the previous figure). This includes the outside dimensions. The magnet chosen is an N40 Neodymium.

Next, we will change the dimension of the magnet. This is done in Motor Parts → Edit Main Magnet Dimensions:

Magnet Parts Selection

Magnet

Main Magnet Type: N40 Neodymium

Main Magnet Size: User Specified

Frame

Steel frame:

Airgap

Leakage	FI	1.90
Use estimated leakage	<input type="checkbox"/>	1.90
Recommended Reluctance	ML	1.30
Use Ferrofluid : Updates Qms (Acoustic Components)	<input type="checkbox"/>	

See www.ferrotec.com for Ferrofluid information

U Cup

Top Plate Thickness	LT	0.45 mm
Coil clearance	CL	0.20 mm
Compensated U Cup ID	<input checked="" type="checkbox"/>	
U Cup IX	DTX	13.71 mm
U Cup IY	DTY	8.71 mm
U Cup IR	DTR	2.25 mm

Pole

Pole Clearance		0.20 mm
Compensated Pole OD	<input checked="" type="checkbox"/>	
Pole ODX	DPX	12.10 mm
Pole ODY	DPY	7.10 mm
Pole ODR	DPR	1.45 mm
Centre Hole ID		0.00 mm

Bottom Plate

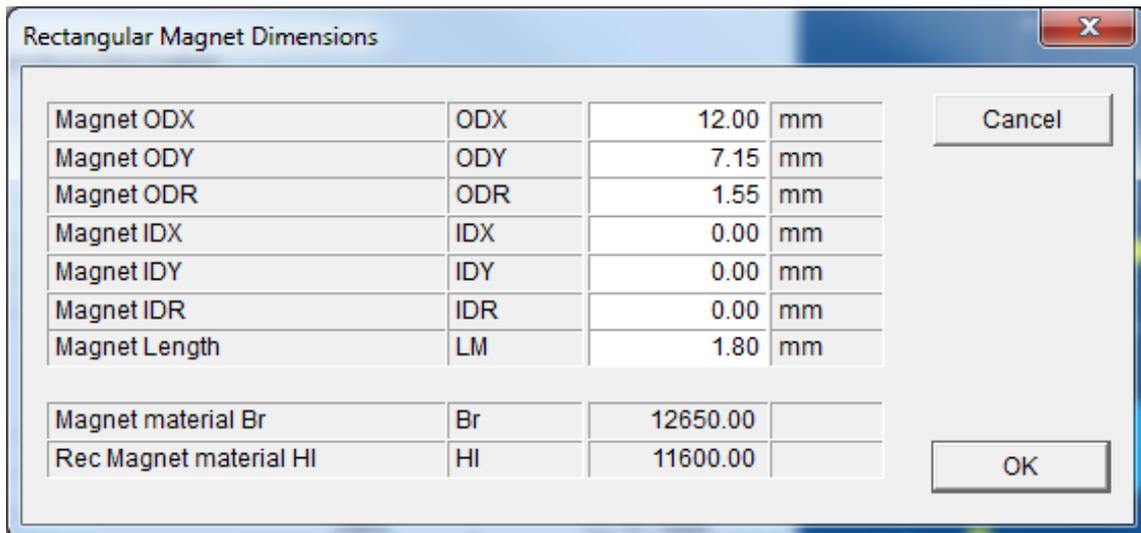
Min Bottom Plate Thickness		0.6 mm
Min Bottom Plate OD		14.8 x 9.8 mm

Recommended minimum bottom plate thickness (mm)

Edit Main Magnet Dimensions

Cancel OK Apply Now

The outside dimensions used in this example are shown in the picture below. If needed an inside rectangular hole can be specified.

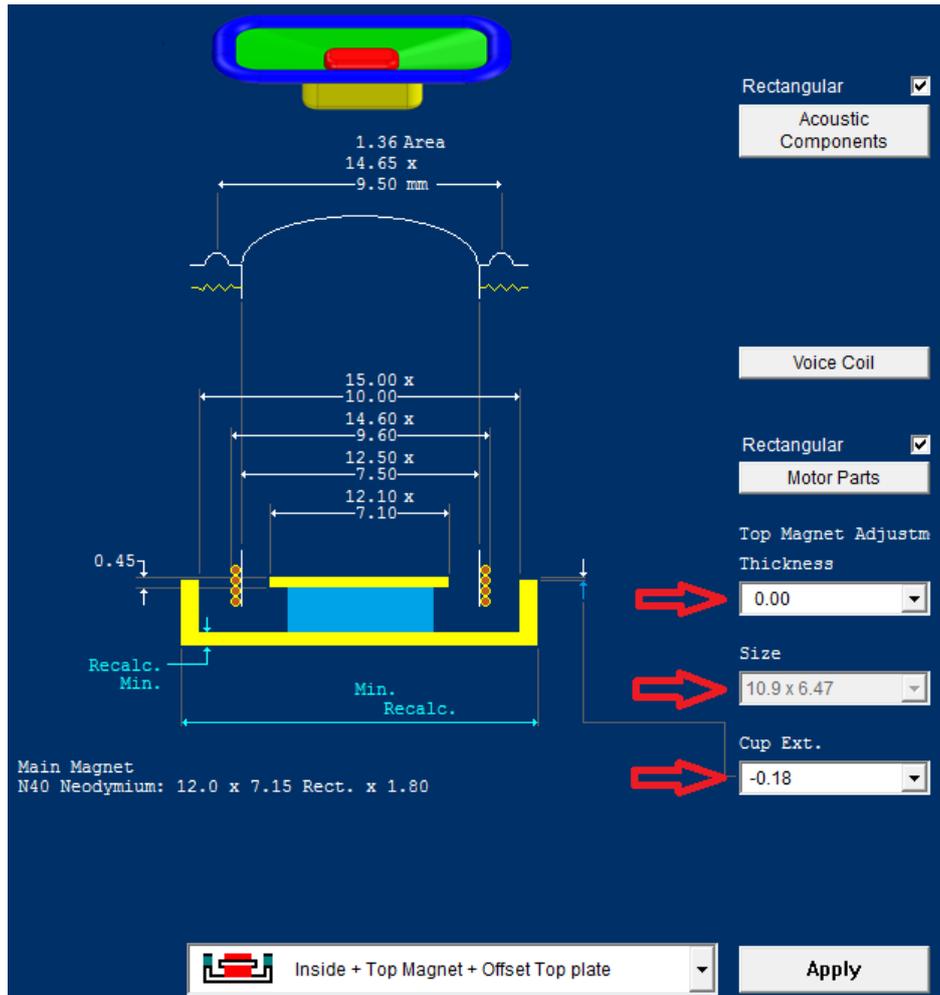


2.2.3 Offset Top Plate / Cup

Micro speaker design is very often critical regarding the total thickness. The new offset feature is therefore most welcome to introduce an offset between top plate and the U-cup. To use this feature, you must change the motor type to Inside + Top Magnet + Offset Top Plate:



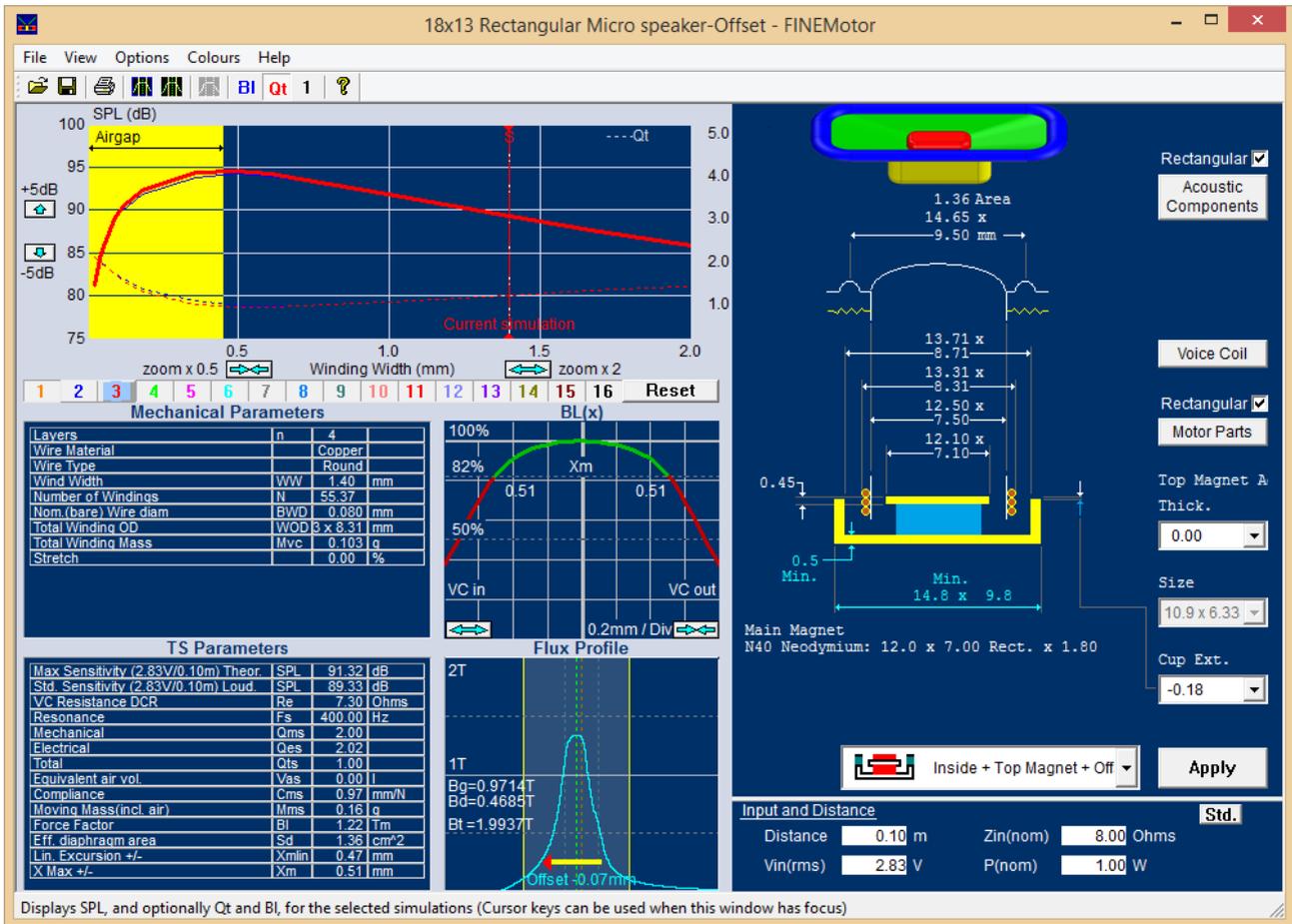
When this is selected, new options appear on the right:



The top one allows adjustment of the top magnet. For this example, we will set it to 0, which is equal to having no top magnet.

The bottom one dictates the Cup Extension. For this example, we will set it to -0.18.

2.2.4 Final Rectangular Micro Speaker Design



Final 18x13mm Rectangular Micro Speaker Design

The final 18x13 micro speaker design is shown above. The U-cup has a (negative) offset of -0.18mm, meaning that the U-cup is 0.18mm below the upper side of the top plate. That is many times an advantage giving more space for shallow designs. In this case a perfect symmetric and flat $Bl(x)$ was also obtained.

Note: The flux has been offset -0.07 mm in the Flux Profile window and the measuring distance has been set to 0.1m in the Input and Distance window to achieve the results shown above.

2.3 Neodymium Dome Tweeter Example

You can also design woofers with inside magnets. But in this section, we will design a 1-inch dome tweeter using a neodymium magnet disc.

Select Inside Motor:



Then enter the data shown below in Acoustic Components:

Effective Area	Sd	7.07	sq. cm
Effective Diameter	D	3.00	cm
Fixed Mass (Incl. air load)	Mms-Mvc	0.18	g
Air Load	Mair	0.01	g
Diaphr. Mass (Incl. 1/2sur/1/2spider/DC)		0.17	g
Specify Qms	Qms	3.00	
Estimate Qms (from VC Former mat.)	<input checked="" type="checkbox"/>	3.00	
Specify Fs	Fs	2000.00	Hz
Use calculated Fs	<input type="checkbox"/>	0.00	Hz
Cone+Surround Resonance	Fo	0.00	Hz
Surround Compliance (Approx.)	Cms(sur)	0.00	mm/N
Spider Load		50.00	g
Spider Resonance (loaded, dyn.)	Fsp	0.00	Hz
Spider Deflection (loaded, static)		0.00	mm
Spider Compliance		0.00	mm/N
Spider Flexibility (German Std)		0.00	Fdz
Additional moving mass of cone and half of the surround (g)			

7.07 Area
3.00

25.40

25.99

Cancel
OK
Apply Now

For this design we want a WW close to 2.1 mm. By moving the slider in the main window, we can get a WW of 2.16 mm, which is close enough.

The VC is 2-layer copper with $R_e=6.3$ ohms. Stretching the winding 4% will get us closer to the real VC WW of 2.1mm. We use an aluminum VC former, which gives an estimated $Q_{ms}=3$.

Wire Type	Round wire		
Wire Material	Copper		
Former Material	Aluminium		
Note: Changing former material will adjust Qms			
Voice Coil Resistance DCR	Re	6.30	Ohms
Voice Coil Inside Diameter	VCID	25.40	mm

Number of Layers	n	2	↑ ↓
Twin Coil	<input type="checkbox"/>	2 2	
Voice Coil Former Thickness		0.050	mm
Wire Stretch		4.00	%

Cancel OK Apply Now

The magnet used is a N42H Neodymium magnet. This is the strongest neodymium magnet grade with an extended temperature range.

Magnet			
Main Magnet Type	N42H Neodymium		
Main Magnet Size	User Specified		
Frame			
Steel frame	<input type="checkbox"/>		
Airgap			
Leakage	FI	2.25	
Use estimated leakage	<input checked="" type="checkbox"/>	1.75	
Recommended Reluctance	ML	1.30	
Use Ferrofluid : Updates Qms (Acoustic Components)	<input type="checkbox"/>		
See www.ferrotec.com for Ferrofluid information			
U Cup			
Top Plate Thickness	LT	2	mm
U Cup ID	DT	0.2	mm
Compensated U Cup ID	<input type="checkbox"/>		
Pole			
Pole OD	DP	25.00	mm
Centre Hole ID			
		5.00	mm
Bottom Plate			
Min Bottom Plate Thickness		0.4	mm
Min Bottom Plate OD		1.0	mm

Edit Main Magnet Dimensions

We also change the dimension of the main magnet:

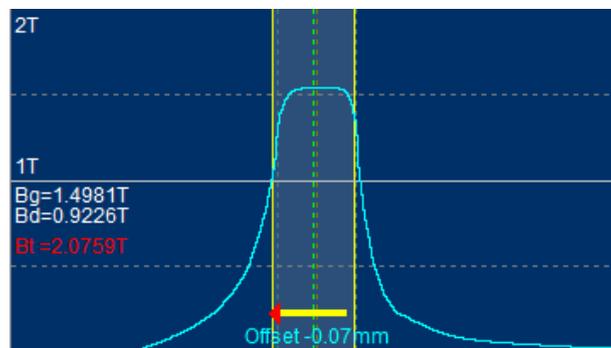
Magnet OD	OD	25.00	mm
Magnet ID	ID	5.00	mm
Magnet Length	LM	3.00	mm
Magnet material Br	Br	13000.00	
Rec Magnet material HI	HI	12000.00	

When using this motor, an SPL of 87.34 dB is achieved and an Xmax of +/- 74 mm (after -0.07 mm offset).

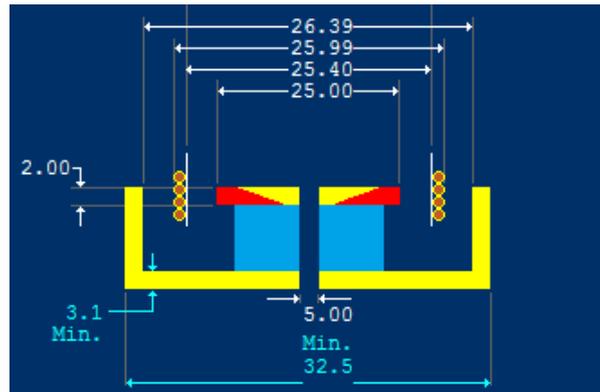
This version is saved as 1in Neo Dome a.fm3

2.3.1 Saturation of Top / Pole Plate

As we still want to increase the sensitivity let us input a thicker 4mm neo disk under “Edit Magnet Dimensions”. However, the SPL is now only increased by 0.80 dB to 88.14 dB



There are two reasons why we do not get much more output by increasing the thickness of the magnet. The picture above shows the flux profile through the air gap, and in the left side we can see $B_g = 1.4981\text{T}$, which is the average B gap flux. Below that is $B_d = 0.9226\text{T}$, which is the operating point of the magnet. That is pretty high for this neodymium material, which is best utilized with a B_d of 0.5-0.8 T, so in this case we don't get much more output by a thicker magnet.



Secondly, we see that the top plate is saturated, indicated by the partially red top plate and $B_t = 2.07$, where B_t is the maximum top plate flux density (before saturation). Normal (1010) steel is saturating above 2.0T, but starts to limit already around 1.8T. The SPL loss is around 0.5 dB due to saturation. This increases when B_t is much higher than 2T, so thin top plates are not a good idea.

2.3.2 Copper Clad Aluminum (CCAW)

Therefore, let us try using another wire.

First, we revert to the previous magnet dimensions (25x5x3).

Then, we select a Copper Clad Aluminum Wire (CCAW) in "Voice Coil". This wire is lighter, but the (thin) copper coating ensures that it is easy to solder.

Wire Type	Round wire		
Wire Material	Copper clad Aluminium		
Former Material	Aluminium		
Note: Changing former material will adjust Qms			
Voice Coil Resistance DCR	Re	6.30	Ohms
Voice Coil Inside Diameter	VCID	25.40	mm
Number of Layers	n	2	↑ ↓
Twin Coil	<input type="checkbox"/>	2 2	
Voice Coil Former Thickness		0.050	mm
Wire Stretch		4.00	%

Cancel OK Apply Now

Moving the slider in the main window until a CCAW wire diameter of 0.110 is achieved gets us an SPL of 88.91 dB, which is an increase of 1.6 dB

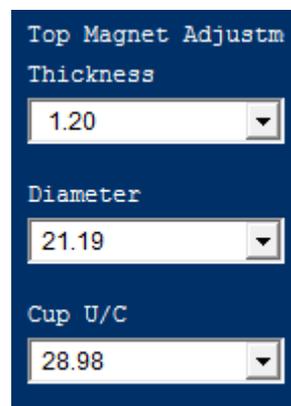
This version is saved as 1in Neo Dome CCAWa.fm3.

2.3.3 Extra Magnet on Pole

Another option to increase sensitivity would be to place a second neodymium magnet on top of the top plate. This will reduce the magnetic stray field, and provide a well shielded motor if small or increase sensitivity when chosen larger. Select Inside + Top Magnet in the drop down menu:



Next, we alter the dimension of the magnet and the cup undercut via the three drop down menus:



By clicking in each of the 3 drop-down boxes you can cycle through comprehensive FEA calculations in small steps using the mouse wheel. The top box adjusts the top magnet thickness, the center box adjusts the diameter, and the bottom right box will adjust the undercut in the magnet cup. For the numbers used in this example, see above.

The sensitivity has now increased to 90.54 dB SPL.

This is saved as 1in Neo Dome SHa.fm3.

2.3.4 Magnetic Ferrofluid in Air Gap

Finally, we have the option to (partly) fill the air gap with magnetic Ferrofluid. The main effect is a much better heat transfer from the VC winding. The Ferrofluid will also provide some damping, which depends on the viscosity of the fluid. Fortunately, this is also handled by FINEMotor.

Go to "Motor Parts" and check the box "Use Ferrofluid: Updates Qms (Acoustic Components)". A new line appears below: "Ferrofluid Viscosity". The default input is 1000cPs. (centipoise). This is a fairly thick Ferrofluid, which will provide much mechanical damping i.e. reduce Qms.

Airgap			
Leakage	FI	2.25	
Use estimated leakage	<input checked="" type="checkbox"/>	1.75	
Recommended Reluctance	ML	1.30	
Use Ferrofluid : Updates Qms (Acoustic Components)	<input checked="" type="checkbox"/>		
Ferrofluid Viscosity		100.00	Cps

Using a 100cPs Ferrofluid, Qms is reduced to 2.51 in the “Adjust Qms for Ferrofluid” field (see Acoustic Components). This is only light damping and causes the Qts to be reduced from 0.96 to 0.91.

Specify Qms	Qms	3.00	
Estimate Qms (from VC Former mat.)	<input checked="" type="checkbox"/>	3.00	
Adjust Qms for ferrofluid	<input checked="" type="checkbox"/>	2.51	

This version is saved as 1in Neo Dome CCAW SH FF.fm3.

For the most demanding applications, a thin Ferrofluid may be the best choice, which means a low cPs value, usually around 100 cPs. These fluids will cause little damping, but still provide essential heat transfer, giving much improved cooling of the VC, because the Ferrofluid has much better heat conductivity than air, which acts as an isolator. Therefore, the VC resistance is rising considerably less giving a much lower power compression.

It is essential to add a precise amount of Ferrofluid to the air gap; too little gives poor performance (sometimes two resonance peaks around Fs) and too much may splash and increase costs. Fortunately, FINEMotor calculates the precise volume (3rd last line in the window below):

Layers	n	2	
Wire Material		CCA	
Wire Type		Round	
Wind Width	WW	7.03	mm
Number of Windings	N	70.21	
Nom.(bare) Wire diam	BWD	0.170	mm
Total Winding OD	WOD	26.30	mm
Total Winding Mass	Mvc	0.529	g
Stretch		4.00	%
Ferrofluid Volume	FF vol	72.38	uL
Ferrofluid Saturation	FF sat	200 - 100	Gauss
FerroTec recomm. Viscosity		1000.00	Cps

The necessary Ferrofluid volume is calculated exactly using the criteria from FerroTec, who supplies Ferrofluid. The required Ferrofluid Saturation (Gauss) is also calculated using the actual FINEMotor simulation. It is advised to use the higher number for high excursion and power.

Contact www.ferrotec.com for further info and design advice on Ferrofluid regarding Magnetization, compatibility with materials and glues etc.

The Ferrofluid damping can also be used to save components in the crossover. In some cases, it is possible to use a 1st order cross-over instead of a 2nd order, saving at least one component (parallel coil). We recommend using our FINE X-over program to design your cross-over, where you also get the actual power that goes to the tweeter calculated.

Our FINEBox program can simulate the effect of the heat transfer and power compression of drivers, and the effects of the Ferrofluid heat transfer is included when you import the FINEMotor file into FINEBox.

Note: It is necessary to provide good venting of the VC to avoid splashing of the Ferrofluid!

The Ferrofluid will seal the gap, which may cause a higher resonance Fs if not properly designed. LOUDSOFT offers expert consulting regarding this and tweeter optimization in general.

Demo video:

<https://youtu.be/i70o-WnAXyc>



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3. FAQ - Frequently Asked Questions

3.1 Why can't I drag the simulation line further to the right?

The problem usually happens when using edge wound wire, although it can happen with round wire as well. The reason is that FINEMotor does not contain wire enough larger dimensions for such large winding widths. It is, however, easy to add larger wire dimensions to the text database, See appendix 4.2.

3.2 My wire dimension is not on the list

Like explained in FAQ 3.1, you can easily add any special wire dimensions to the text database, See appendix 4.2.

3.3 My magnet is not on the list

FINEMotor contains most common Chinese magnets in various sizes. Should you want to add one not already in FINEMotor you can easily add it to the text database, see appendix 4.3.

3.4 My top plate is saturated

Increasing the top plate thickness will add more steel, thereby preventing the magnetic saturation.

3.5 My pole piece is saturated

Try reducing the center hole diameter if present. That will add more steel, thereby preventing the magnetic saturation. If the pole piece has an undercut, you may try less undercut by increasing the undercut diameter.

If you are not able to avoid (heavy) saturation, it may be better to use a larger voice coil diameter, because the pole piece will be larger and having more steel.

3.6 I am unable to achieve the desired sensitivity / SPL

The normal sensitivity standard in the industry is SPL at 1m, with 2.83V input. Therefore, you can go very low with R_e (DCR). For 4 ohms nominal impedance the minimum impedance is 4 ohm -20% =3.2 ohms. The DCR can then be lower, maybe down to 2.7 ohm, or even lower.

Low mass, and large cone area and high BL gives higher sensitivity. However, be aware that the Q_{ts} has to be controlled. You can use FINEBox to simulate various TS parameters in different boxes and volumes. If you import the FINEMotor (Fm3) files directly into FINEBox you can also calculate VC excursion and see the effect of high power input, which is Power Compression.

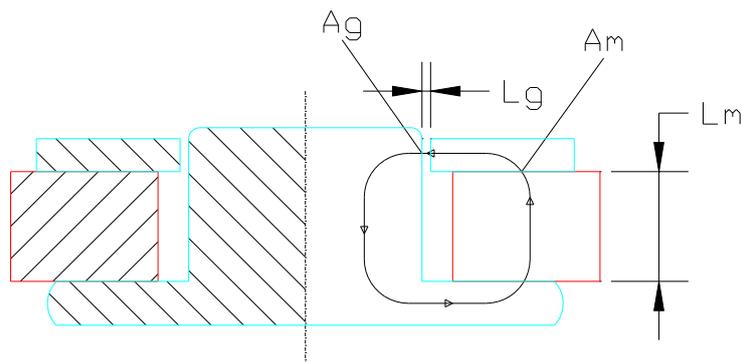
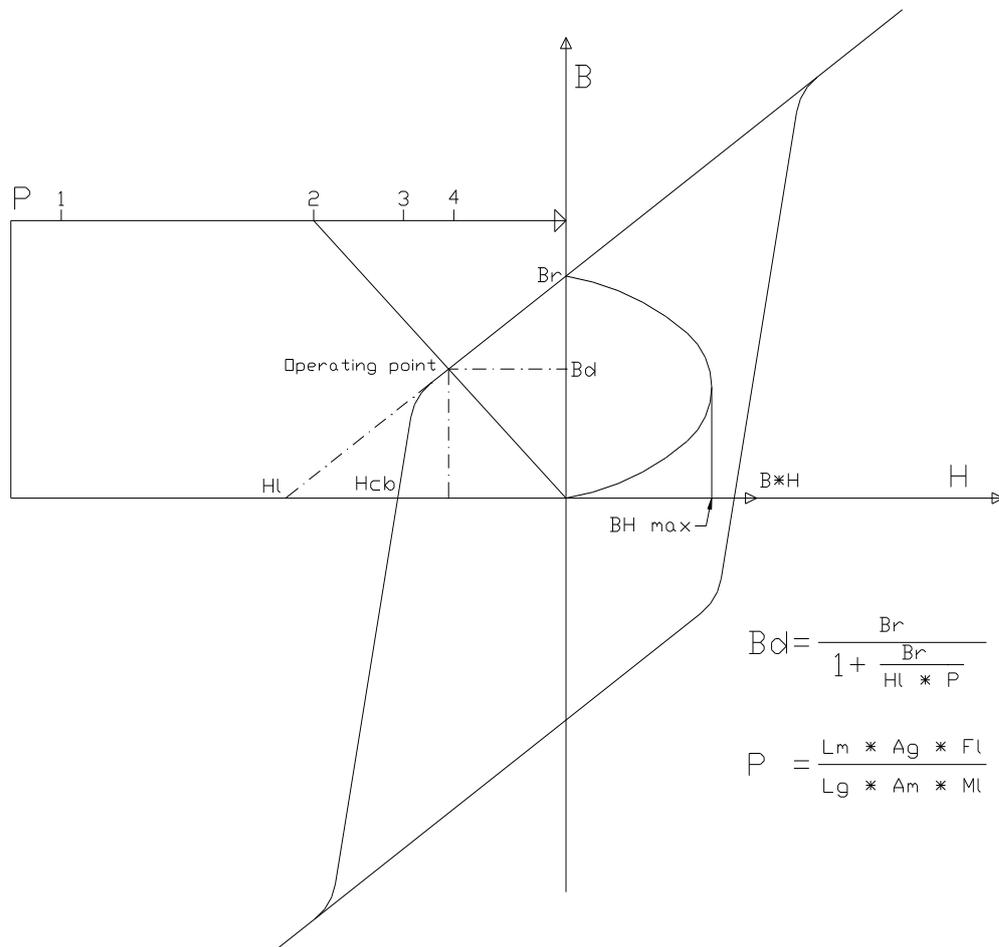
3.7 The X_{max} is too high/low

If X_{max} is too low, select a longer VC winding to the right on the right side in the upper graph, see 1.1. And if the X_{max} is too high, select a VC winding to the left side of the graph.

These examples are valid only for VC windings that are longer than the air gap (thickness). For long VC's you may have to consider bumping the back plate to allow full movement of the VC.

4. Appendix:

4.1 Appendix A - Hysteresis curves and basic formulas



Bd is the working point on the load line ($HL-Br$) according to general magnetic theory.

P is the Permeance coefficient as defined above, where FL is the leakage coefficient and ML is the reluctance coefficient.

4.2 Appendix B - Custom Wire Tables

The user can edit a custom round wire table, called DEFROUND.FMW and a custom square (flat) wire table, called DEFSQUAR.FMW. These can be edited with a text editor like notepad.

FINEMotor looks for the files DEFROUND.FMW and DEFSQUAR.FMW in the same directory as the FINEMOTOR.EXE executable at start up (usually C:\Program Files/Loudsoft/FINEMotor20)

1. The content is text, and the file must include a new line after the last line.
2. The top 2 lines of each file explain what is in the file and they must not be deleted.
3. You MUST use a decimal point (.) because the comma separates the values.
4. The values can be in any order, they are sorted on read and, as far as we know, duplicates are not a problem.
5. The read values replace the code values, so if you only enter 10 sizes the smaller 10 are the only ones changed; the other sizes are the same.
6. The square wire table contains 4 dimensions IX, IY, OX, OY. It does not matter if you get the X's and Y's the other way round, but you MUST have $OX > IX$ and $OY > IY$
7. The round wire file needs only 2 dimensions ID and OD and you must have $OD > ID$.

Note: FINEMotor files (Setups) are saved with the actual wire dimensions. If the wire specified in a setup is not in the wire sizes loaded, then you get a warning message that an approximate size has been used.

4.3 Appendix C – Custom Magnet Material Tables

The user can edit and create custom Magnet Material table(s), having the extension *.FMM. These can be edited with a text editor like notepad.

FINEMotor looks for files xxxxx.FMM in the same directory as the FINEMOTOR.EXE executable at start up (usually C:\Program Files/Loudsoft/FINEMotor20). See this example:

```
FINEMotorMagnetMaterialFile
```

```
Version=1.0
```

```
** All lines starting with ** are seen as comments
```

```
** The 2 first lines above are required and must NOT be erased or changed.
```

```
Parameters
```

```
**The next 3 lines must be the name and 2 magnet material parameters:
```

```
Name=Y25 Ferrite
```

```
Br=3750
```

```
Hl=3409
```

```
**Note: Br (G) is the Remanence in Gauss (1G=0.0001T)
```

```
**Note: Hl (Oe) is the Coercivity in Oersted for B=0 (Extrapolated load line).
```

```
**Note: Hl=Br/urec - urec is recoil permeability
```

```
**  $1[\text{kA/m}] = 4 \cdot \pi [\text{Oe}]$ 
```

```
EndParameters
```

```
** Use these lines to add your own comments.
```

```
** More lines starting with ** can be added
```

```
** Then the list of magnet sizes should follow with no blanks or comment lines.
```

```
Sizes: (OD; ID; Length; Name)
```

```
72.0; 32.0; 15.0; 72 x 32 x 15
```

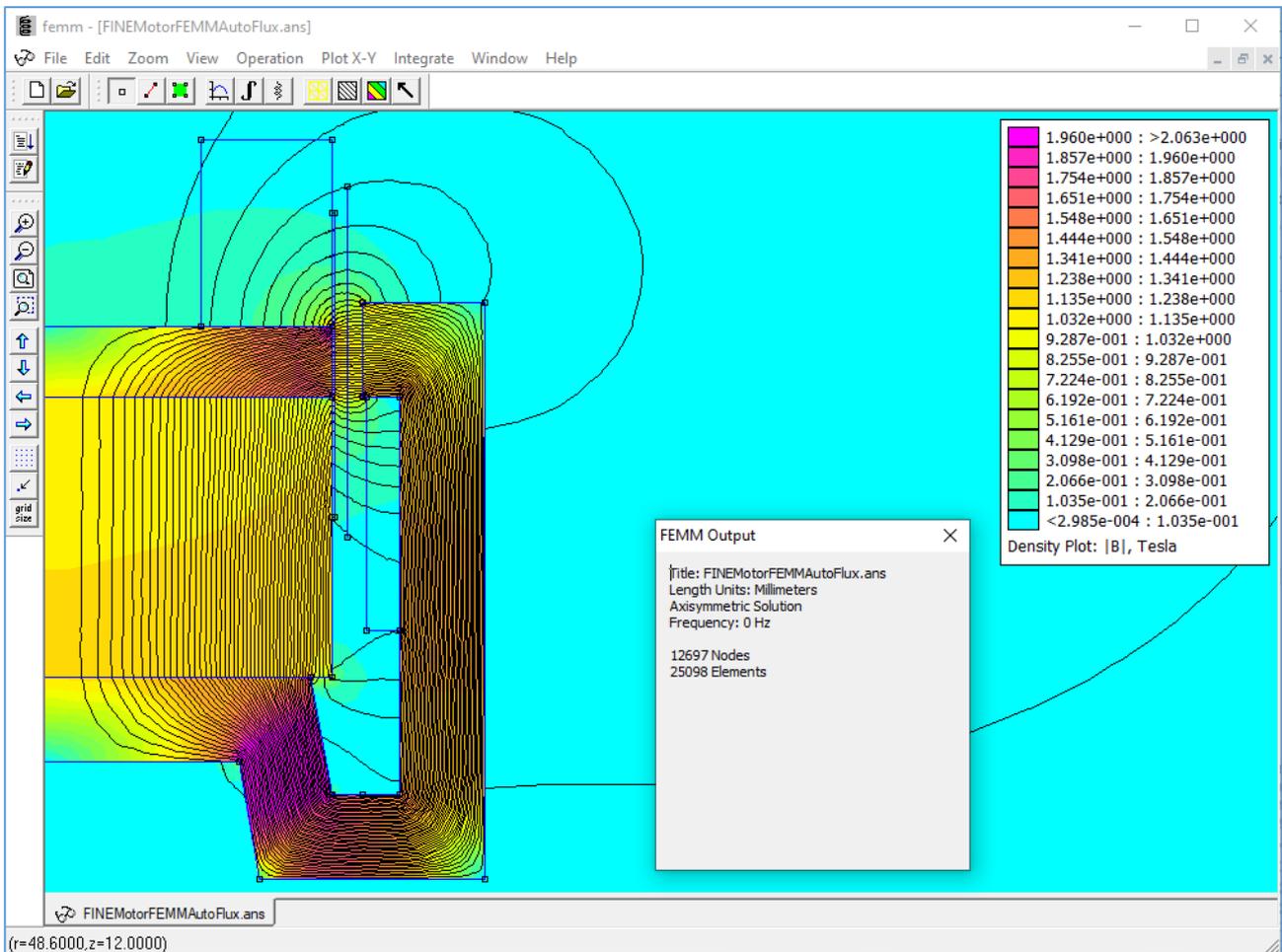
```
84.0; 32.8; 15.0; 84 x 33 x 15
```

4.4 Appendix D – Display FEM results

4.4.1 Flux line Display

You can view the result of the latest Direct FEM calculation by starting the FEMM program and open the FINEMotorFEMMAutoFlux.ans file. If you don't find it in under Files, it is in the temp folder: %temp%

The flux lines are shown in black, and the flux density B in colors, with legend at right. Note that the flux lines are passing through the copper/CU and Alu/AL rings

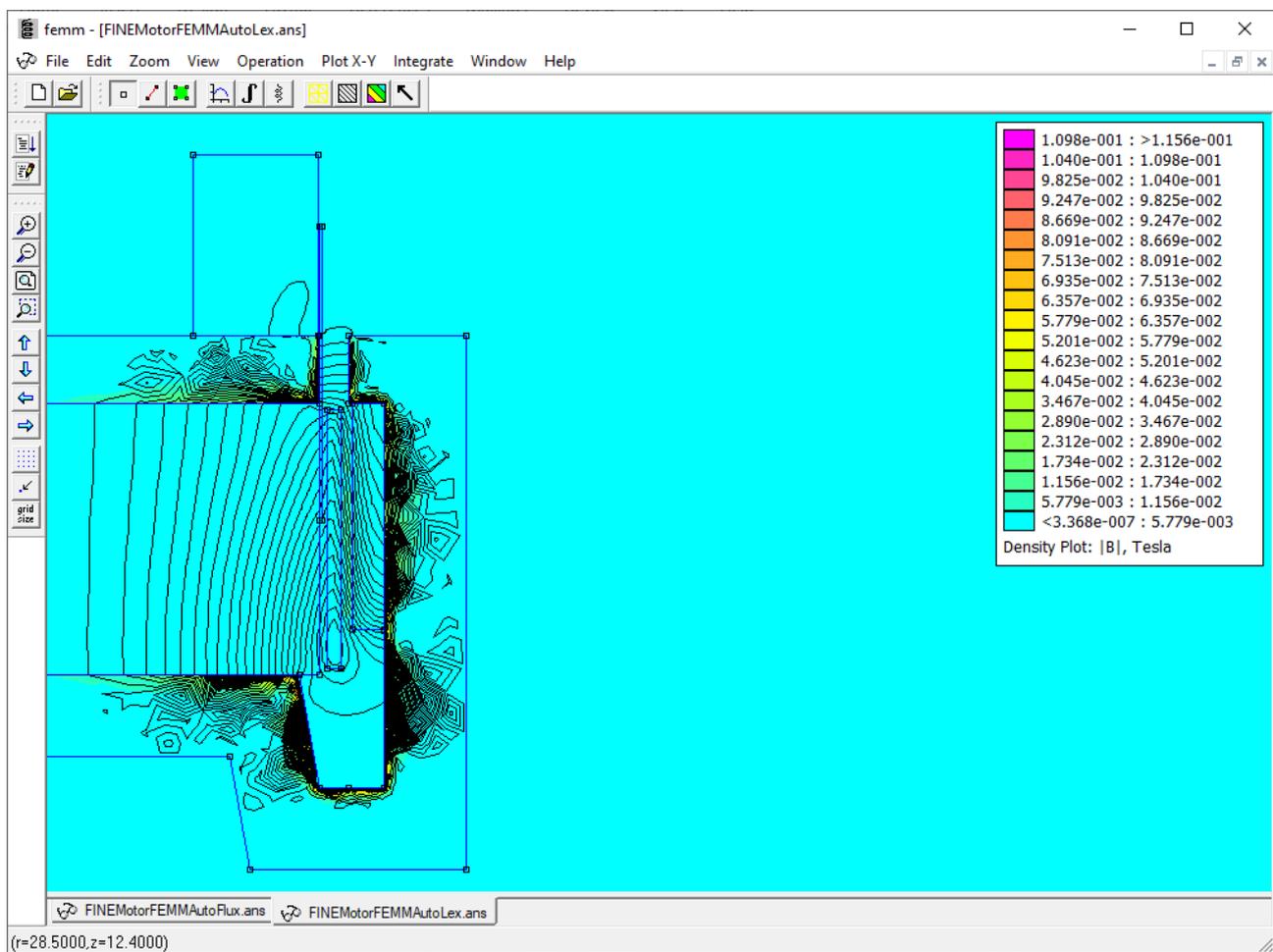


4.4.2 Time-Harmonic Magnetic Display (AC analysis)

You can view the result of the latest Shorting Rings / Le(x) calculation by starting the FEMM program and open the FINEMotorFEMMAutoLex-X0.ans file, which is for the center VC position. (If you do not find it in under Files, it is in the temp folder: %temp%).

You can also find the file for the latest VC position (down): FINEMotorFEMMAutoLex.ans

This analysis shows how the rings affect the high frequency behavior, and especially penetration / skin effect into the steel. The standard frequency is 1kHz.



4.5 American Gauge Wire conversion table

AWG	Diam mm	Sect. mm ²	Resist. ohm/m	AWG	Diam mm	Sect. mm ²	Resist. ohm/m
0000	11.7	107,0	0.000161	19	0,91	0,6530	0.0264
000	10.4	85.0	0.000203	20	0,81	0,5190	0.0333
00	9.26	67.4	0.000256	21	0,72	0,4120	0.0420
0	8.25	53.5	0.000323	22	0,64	0,3250	0.0530
1	7,35	42,4	0.000407	23	0,57	0,2590	0.0668
2	6,54	33,6	0.000513	24	0,51	0,2050	0.0842
3	5,83	26,7	0.000647	25	0,45	0,1630	0.106
4	5,19	21,2	0.000815	26	0,40	0,1280	0.134
5	4,62	16,8	0.00103	27	0,36	0,1020	0.169
6	4,11	13,3	0.00130	28	0,32	0,0804	0.213
7	3,67	10,6	0.00163	29	0,29	0,0646	0.268
8	3,26	8,35	0.00206	30	0,25	0,0503	0.339
9	2,91	6,62	0.00260	31	0,23	0,0415	0.427
10	2,59	5,27	0.00328	32	0,20	0,0314	0.538
11	2,30	4,15	0.00413	33	0,18	0,0254	0.679
12	2,05	3,31	0.00521	34	0,16	0,0201	0.856
13	1,83	2,63	0.00657	35	0,14	0,0154	1.08
14	1,63	2,08	0.00829	36	0,13	0,0133	1.36
15	1,45	1,65	0.0104	37	0,11	0,0095	1.72
16	1,29	1,31	0.0132	38	0,10	0,0078	2.16
17	1,15	1,04	0.0166	39	0,09	0,0064	2.73
18	1,02	0,82	0.0210	40	0,08	0,0050	3.44



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