OLE WOLFF

Advanced magnet system design technology for moving coil drivers & micro speakers for portable devices

WP16

Sep. 2026

Table of Contents

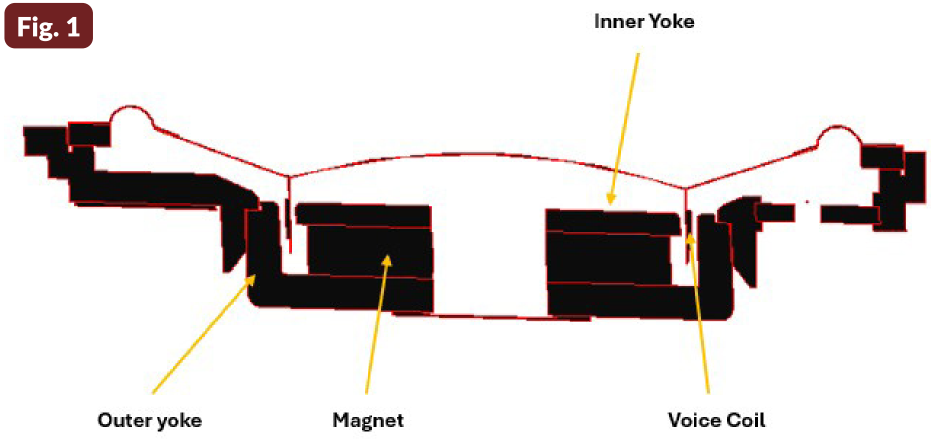
Scope

The magnet system in the headphone driver and micro speaker can be perceived as the “heart” in the component transforming the current running in the voice coil to mechanical force activating the diaphragm creating sound.
Optimization of the magnet system with respect to maximum magnetic field strength in the air gab for the voice coil is vital for assuring a high-power efficiency of the driver/micro speaker resulting in best battery power economy and operation time before charging.

Most magnet systems consist of a magnet and an outer and inner yoke. The distance between the inner and the outer yoke defines the air gap for the voice coil to operate in. See *Fig. 1*.

A narrow air gab improves the magnetic field strength but places greater demands for tight assembly tolerance for allowing the coil to move freely without touching the yokes.
Furthermore, a proper design should take care that the same magnetic field strength passes through the same total length of wire in the voice coil independent of the full stroke of the voice coil and thereby ensuring best linearity/lowest distortion.

Fig. 1



Magnet types for headphone drivers, earphone drivers & micro speakers

Magnet types for headphone/earphone drivers & micro speakers are almost exclusively so called “rare earth” magnets due to their high energy density compared to ferrite magnets.

The major types are:

- Alnico (Al-Ni-Co)
- Samarium Cobalt (SmCo)
- Neodymium (NdFeB)

Where Neodymium magnets are the most widely used.

In *Fig. 2* an illustrative comparison of different magnet types is shown with respect to magnet size needed for attracting a 5kg block of iron. In this setup, NdFeB is a clear winner.

Fig. 2

Neodymium magnets come in different grades with respect to their magnetic strength, with grade N54 being the strongest of all (see table below).

However, the higher grade, the more sensitive they are for degrading in strength at high temperatures.

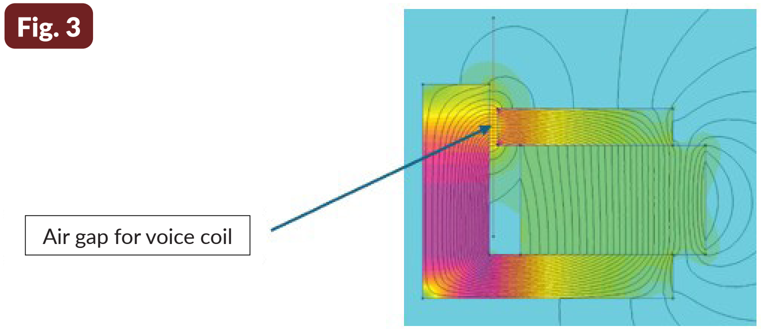
Magnetic Properties of Sintered NdFeB Magnets

		Remanence		Coercivity		Intrinsic Coercivity		Max Energy Product		Max Working Temp	
Series	Grade	Br		Hcb		Hcj		(BH)Max		Tw (L/D≥0.7)	
		kGs	T	KOe	kA/m	KOe	kA/m	MGOe	KJ/m3	°C	°F
N	N35	11.7-12.2	1.17-1.22	≥10.9	≥ 868	≥12	≥955	33-36	263-287	80°C	176
	N38	12.2-12.5	1.22-1.25	≥11.3	≥ 899	≥12	≥955	36-39	287-310		
	N40	12.5-12.8	1.25-1.28	≥11.4	≥ 907	≥12	≥955	38-41	302-326		
	N42	12.8-13.2	1.28-1.32	≥11.5	≥ 915	≥12	≥955	40-43	318-342		
	N45	13.2-13.8	1.32-1.38	≥11.6	≥ 923	≥12	≥955	43-46	342-366		
	N48	13.8-14.2	1.38-1.42	≥11.6	≥ 923	≥12	≥955	46-49	366-390		
	N50	14.0-14.5	1.40-1.45	≥12.0	≥ 955	≥11	≥876	48-51	382-406		
	N52	14.3-14.8	1.43-1.48	≥11.0	≥ 876	≥11	≥876	50-53	398-422		
	N54	14.5-15.0	1.45-1.50	≥11.0	≥ 876	≥11	≥876	52-55	414-438		

Soft iron and alloys for yokes in magnet systems

The purpose with the outer and inner yokes is to direct and concentrate the magnetic field from the magnet in the air gap for the voice coil to operate in between the two yokes as can be seen in *Fig. 3*.

Fig. 3



The yokes are made of iron due to its excellent magnetic properties. Specifically, "soft iron" is used because it can be easily magnetized and demagnetized, unlike "hard iron," which retains magnetization.

Soft iron has a magnetic saturation of about 2T, which can limit the magnetic field in the air gap if the yokes are undersized, creating a tradeoff between performance and available space in the loudspeaker design.

When space is limited, higher-saturation soft iron alloys can be used, though they are significantly more expensive. These typically contain iron and cobalt, sometimes with vanadium. One example is Vacoflux 50 (49% Fe, 49% Co, 2% V), which has a saturation level of 2.3T.

Performance parameters affected by the magnet system design

Designing the magnet system with tight tolerances allowing for a narrow coil slit is giving the strongest magnetic field running through the windings of the voice coil. As a rule of thumb, a minimum of 0.16mm of free air distance on both sides of the coil is recommended for production reasons. This will optimize the overall power efficiency of the driver, which is essential in relation to battery lifetime.

At the same time, a strong magnet system results in a low Qes factor of mechanical resonance of the driver (F0) with the use of minimum resistive damping (mesh).
This will ensure a controlled Q factor as well as maintaining maximum power efficiency.

Below is shown the formula for calculating the Qes factor and it is seen that the B field appears in the denominator in a second order resulting in a low Qes factor when the B field is high.

$$Q_{es} = \frac{2\pi \cdot F_s \cdot M_{ms} \cdot R_e}{(Bl)^2} = \frac{R_e}{(Bl)^2}\sqrt{\frac{M_{ms}}{C_{ms}}}$$

Magnet system simulation

Magnet system design optimization is done using simulation software either a Finite Element based like Comsol or Ansys, or a software system dedicated to simulating magnetic systems.

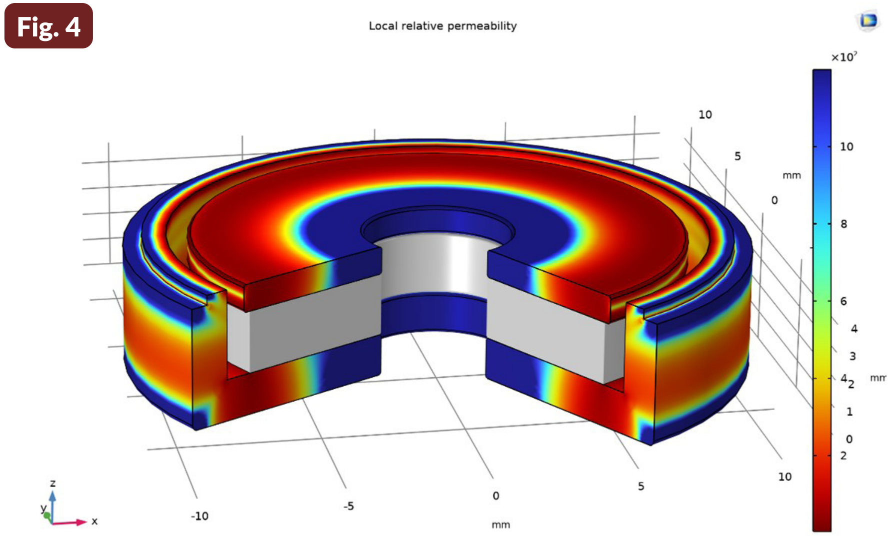
When we simulate magnetics in Comsol, it enables the use of optimization routines. We define some points on Bl curves and then ask Comsol to change different mechanical dimensions on:

- Magnet height
- Magnet diameter
- Magnet grade
- Top yoke thickness
- Top yoke diameter
- Outer yoke thickness
- Outer yoke diameter
- Voice Coil position

Then Comsol runs a lot of simulations automatically with different values we specify and ends up with a result giving the highest Bl and the most linear Bl curve possible.

An example is shown in *Fig. 4 that is* based on the headphone driver OWR-4009T-36NF.
This shows the magnet system of this driver with flux intensity in the yokes, where red color is the highest intensity and close to magnetic saturation.

Fig. 4



Same magnetic system, but in a cross-sectional cut is shown in *Fig. 5*.

Fig. 5

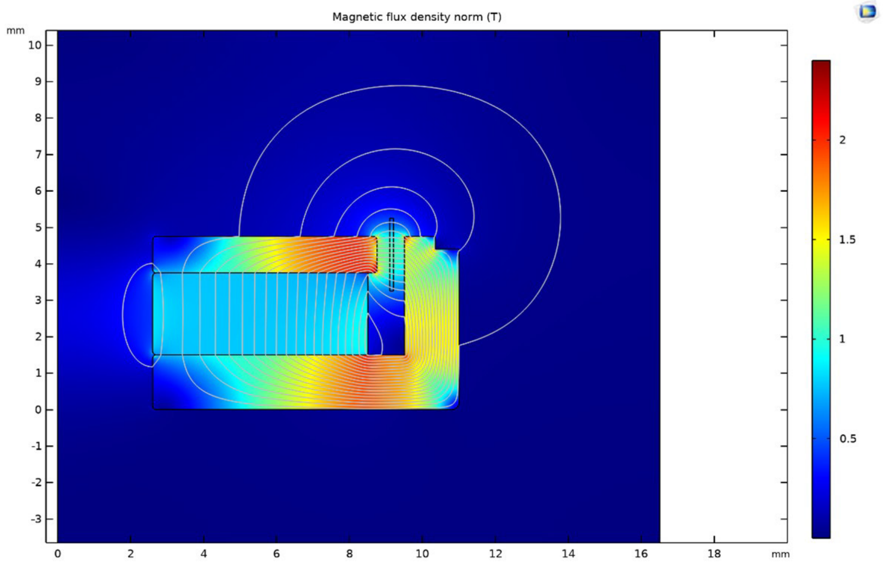
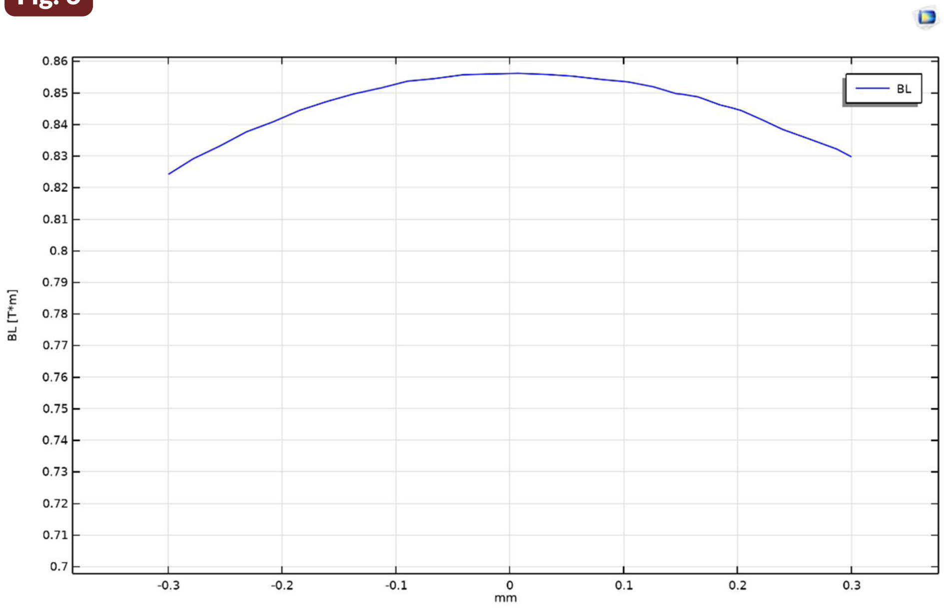


Fig. 6 shows the result of the force share on the voice coil (Bl) as a function of the displacement of the voice coil (x) in the air gab. (the Current in the coil multiplied will define the actual force imposed to the voice coil).

The ideal performance would be a straight horizontal curve, but in practical, the curve is lowered at the very outer positions of the voice coil in the air gap, where the voice coil has its larges strokes due to the slightly decreased magnetic flux in these outer positions.

Fig. 6



Conclusion

Ole Wolff takes advantage of the most sophisticated tools such as **Comsol Finite Element simulation** software when designing our magnet systems as well as in designing the total structure of our drivers for earphones, headphones and loudspeaker segments.

This will ensure the highest performance to size ratio for our acoustic products, which is crucial for all earphones, headphones and other portable audio devices due to the striving for design freedom and lowest possible power consumption.