



Technical Note Volume 1, Number 33

Title: JBL's Differential Drive® Transducers

1. Introduction:

JBL Professional introduced the *Differential Drive* concept in the EON System in 1995 as a means of attaining maximum system performance with minimum weight. Compared with traditional driver designs, JBL's patented Differential Drive makes use of a pair of in-line voice coils in separate magnetic gaps instead of a single voice coil-gap combination. This permits a more effective use of available space, and allows more efficient removal of heat from the motor structure. Specifically, the voice coils are reversely wound and are immersed in magnetic fields of opposite polarity. This ensures reduced magnetic leakage flux and focuses more magnetic energy in the gaps where it is needed. Both ferrite and neodymium-iron-boron (NIB) magnets can be used, depending on the relative importance of weight in a given system design. When coupled with the light weight and high energy density of NIB magnets, Differential Drive transducers can be constructed that are only about one-third the weight of traditional designs of comparable performance.

Differential Drive provides many design options for the engineer. The size, impedance, and spacing of the two voice coils can be independently adjusted relative to each other to attain a desired set of electromechanical performance features. Independently of these, the overall size and mass of a system can be adjusted as required. JBL has been granted numerous patents on multiple aspects of Differential Drive dual-coil, dual gap designs.

We will compare the traditional approach with

Differential Drive technology in detail.

2. Anatomy of a Differential Drive transducer:

The simplest way to understand Differential Drive is to compare it directly with JBL's traditional motor structures. Figure 1 shows a section view of a traditional JBL magnet-voice coil assembly and a Differential Drive system. As a starting point, let us design the Differential Drive system so that its parameters are identical to those of the traditional motor structure, with the same electrical-to-mechanical coupling and the same moving mass.

In the traditional design, magnetic flux density B crosses a gap in which a coil of wire of length l is placed. The coil has an electrical resistance, R_E . These quantities establish the value of $(Bl)^2/2R_E$, which is the electromechanical coupling factor of the driver.

Now we inspect the Differential Drive topology. In this design there are two magnetic gaps that have opposing flux fields, and each gap has a B field equal to that of the traditional design. Two reversely-wound coils are used, each using wire with one-half the cross-section width as before. The coils are scaled so that they are one-half the length of the traditional coil. In addition, the masses of the two thinner coils will equal that of the single traditional coil.

Each of these thinner coils will then have a coupling factor of $0.5(Bl)^2/R_E$, or one-half that of the traditional driver. Since there are two such voice coils, both acting in the same direction, the total coupling factor for the new motor structure will be identical to that of the traditional design. This relationship is shown in Figure 2.

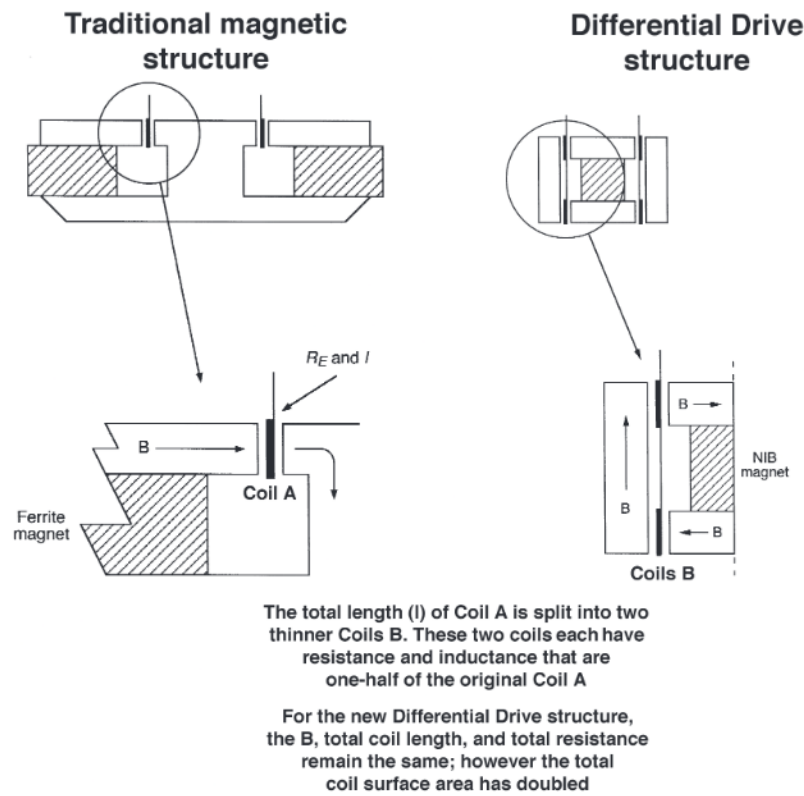


Figure 1. Comparison of standard and Differential Drive technologies.

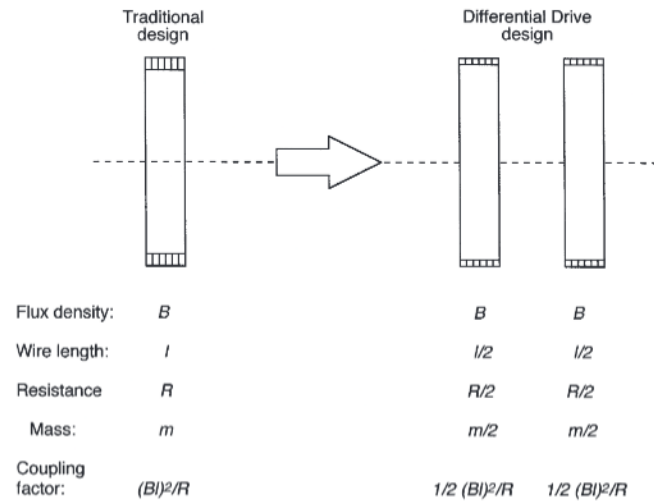


Figure 2. The equivalence of standard and Differential Drive technologies.

In redesigning the system as shown here we have gained some significant design advantages:

A. Better heat dissipation. The physical separation of the two coils can be adjusted for optimum heat transfer from each coil to the outer structure of the driver. In addition, the total surface area of the two coils has doubled, creating twice the heat radiation capability.

B. The new voice coil arrangement will have *less* effective inductance than the standard one, since the reversely wound coils will have negative mutual inductance between them. This translates into a more uniform impedance curve and extended output at higher frequencies.

C. The compact nature of the Differential Drive motor structure requires much less iron in the magnetic return path. If NIB (neodymium-iron-boron) magnet material is used, a Differential Drive transducer can weigh as little as *one-third* the equivalent traditional ferrite design. This advantage shows up primarily in overall system weight and ease of installation.

D. The structure is inherently shielded mag-

netically, especially at 90 degrees away from the axis of the structure. The result is very little stray magnetic field interference with CRT video systems.

E. Nesting the small overall magnet structure in a large aluminum heat sink results in efficient dissipation of heat from the coils, as shown in Figure 3A. Aluminum, with its high specific heat and low thermal resistance, is the ideal material for this. The section view shown at B illustrates the use of ferrite magnet material in the design of a Differential Drive transducer which includes a braking coil, as discussed in Section 5.

F. Design flexibility. The two voice coils may be driven in electrical series or parallel, depending on the system design impedance. Typical applications call for a nominal 8-ohm driver, with two 4-ohm coils operating in electrical series.

G. Push-pull operation. In an analogy to Class AB operation of a power amplifier, the motion a Differential Drive system reduces even-order distortion components, due to the exact symmetry of the motor structure along its operating axis.

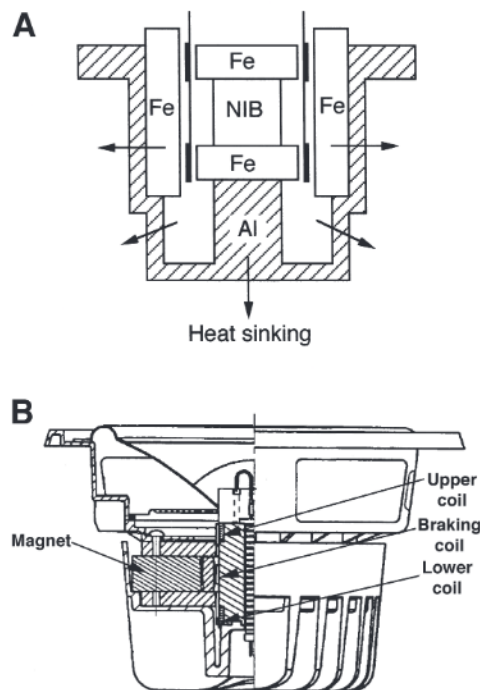


Figure 3. Nesting of the dual coil structure in an aluminum heat sink (A); section view of a ferrite-based Differential Drive transducer which includes a braking coil (B).

See Section 5 for a discussion of the braking coil.

3. Transducer magnetic circuit linearity:

The neodymium magnet material used in most Differential Drive transducers is much less prone to flux modulation than ferrite materials. As a result, the flux shorting ring, an essential part of JBL's Symmetrical Field Geometry™, is not usually necessary with neodymium-based structures. Figure 4 shows the demagnetization characteristics for typical NIB and ferrite magnet materials. We can see that a typical operating point for the neodymium magnet is much higher along the B-axis than that of a fer-

rite magnet. Therefore, for a given change in magnetizing force produced by signal current in the voice coil, the resulting change in induced flux ($\Delta B/B_{NIB}$) will be fairly small. By contrast, the resulting change in induced flux for the ferrite magnet will be $\Delta B/B_F$. Since B_F is less than B_{NIB} , the total variation in induced flux will be greater with the ferrite magnet. There is about a three-to-one ratio between the amount of flux modulation of the two magnet materials, corresponding to an approximate 10 dB advantage for neodymium over ferrite at any operating level.

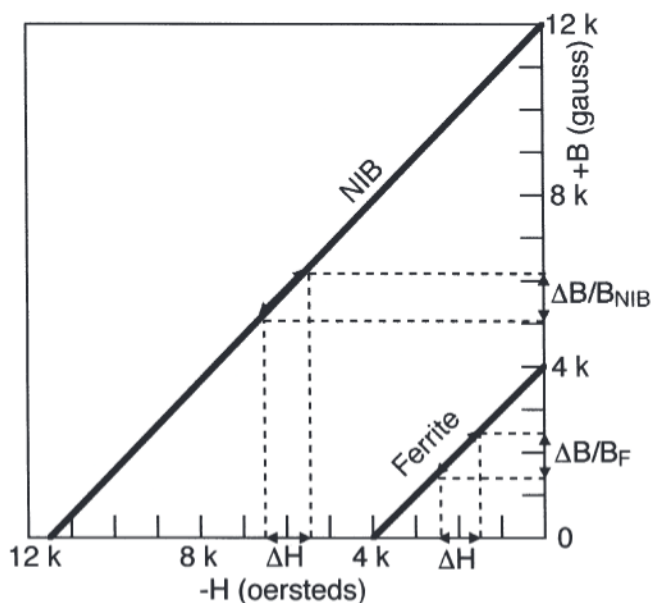


Figure 4. Flux modulation in ferrite and NIB magnet structures.

4. Performance of Typical Drivers:

The transducers in all of these curves are mounted in a 280-liter (10 cu. ft.) sealed enclosure. Low-frequency response and distortion performance would be further enhanced in an appropriate vented enclosure.

The model 2262H 300 mm (12-inch) Driver:

Figure 5 shows the second and third harmonic distortion for the model 2262H LF driver operating with a power input equal to one-tenth (-10 dB) the transducer's rated power of 700 watts. The applied signal is 23.7 Vrms across a nomi-

nal 8-ohm load, corresponding to normal program operation of the driver.

Note that the third harmonic distortion at 40 Hz is no greater than 10% (where the distortion and fundamental curves intersect). Over the broad range from 100 Hz to 2500 Hz, second and third harmonic distortion values are below 2% at 113 db SPL at 1 meter. This driver was designed with the general characteristics of the traditional 2206H in mind, and it can function as either a LF horn driver or as a upper-bass, lower MF direct radiator.

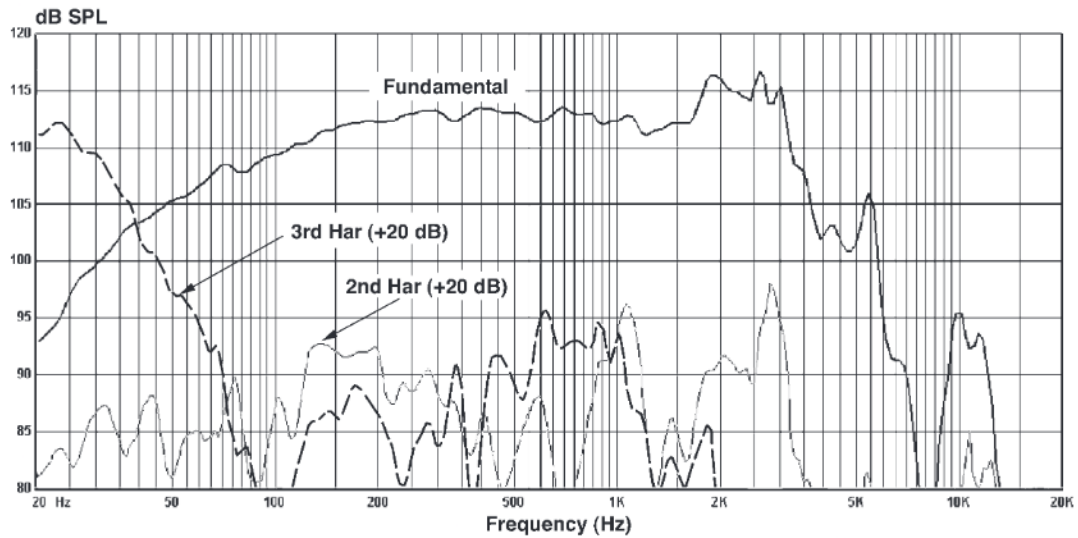


Figure 5. Second and third harmonic distortion components, raised 20 dB relative to the fundamental, in the 2262H driver at one-tenth rated power.

The model 2265H 380 mm (15-inch) Driver:

Figure 6 shows similar data for the model 2265H driver. Here, the second harmonic distortion is 10% at about 33 Hz, while the distortion components in general are below 2% from 50 Hz to 2 kHz at approximately 114 dB SPL at 1 meter.

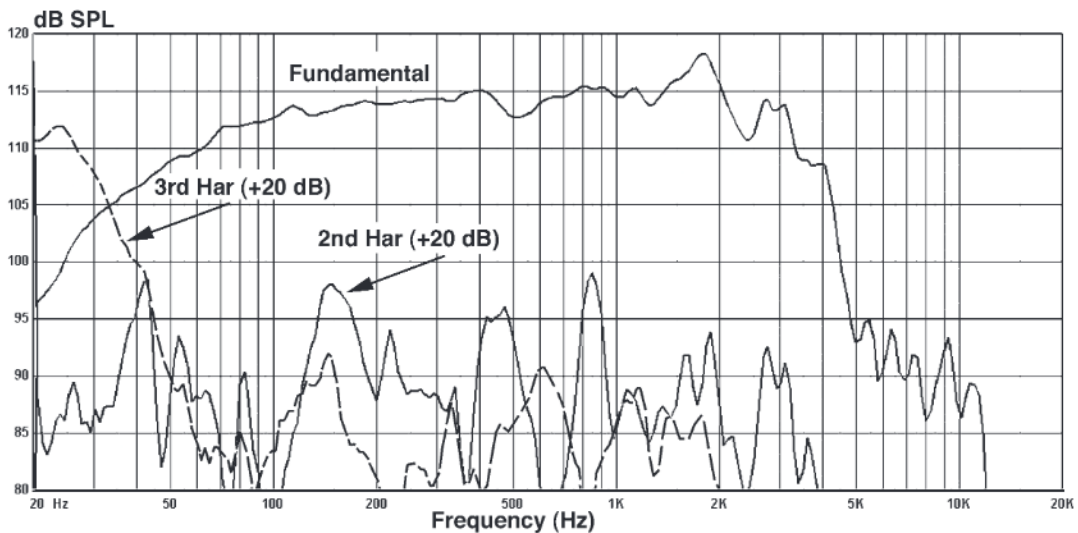


Figure 6. Second and third harmonic distortion components raised 20 dB relative to the fundamental, in the 2265H driver at one-tenth rated power.

The model 2268H 460 mm (18-inch) Driver:

Figure 7 shows a set of data for the model 2268H driver, which is intended for subwoofer use in the same general performance category as the traditional ferrite VGC™ Vented Gap

Cooled 2242H driver. Second harmonic distortion is 10% at a frequency of about 33 Hz, and overall distortion from about 50 Hz upward is well below 3% at 115 dB SPL output at 1m.

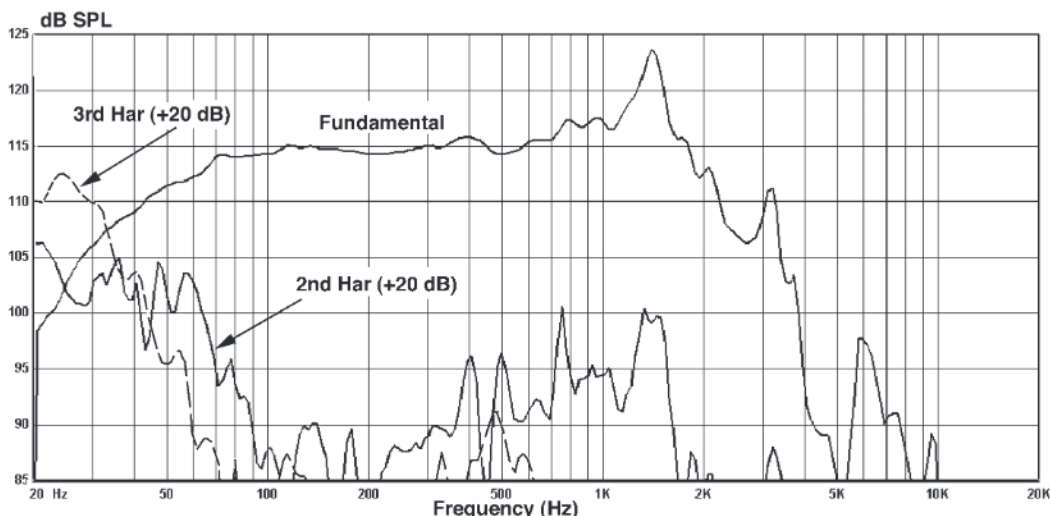


Figure 7. Second and third harmonic distortion components raised 20 dB relative to the fundamental, in the 2268H driver.

5. The Dynamic Braking Coil:

The JBL LSR6300 Series studio monitors utilize Differential Drive with an added feature. During high drive conditions at low frequencies there is a tendency for cone excursions to approach and even exceed normal limits of linear travel. When this occurs there will be a rise in distortion due to two factors: mechanical nonlinearity of the suspension and loss of Bl product as the voice coils move out of the linear gap range.

Earlier solutions to this problem involve so-called *progressive* inner suspensions whose mechanical stress-strain curves have been tailored to compensate – and cancel – the rise in distortion. With Differential Drive systems we have an additional tool here: the dynamic braking coil.

Figure 8 shows three section views of an LF driver using a braking coil. The moving system at rest is shown at *A*; the moving system at the upper extreme of displacement is shown at *B*;

and the moving system at the lower extreme of displacement is shown at *C*.

At the rest position *A*, the short-circuited braking coil is well outside the influence of either the upper or lower magnetic gap and as a result does nothing.

At *B*, the cone has moved to its maximum forward position, and the braking coil is fully immersed in the upper magnetic gap. As this takes place a counter-current is developed in the braking coil that causes a reverse force in opposition to the cone's movement. At *C*, we see the opposite reaction as the cone's movement reaches its maximum inward position.

Figure 9 shows the effect of the dynamic braking coil in terms of displacement versus loudspeaker drive voltage. The data shows the beneficial restraint of excessive cone motion under high drive conditions, which translates into reduced distortion.

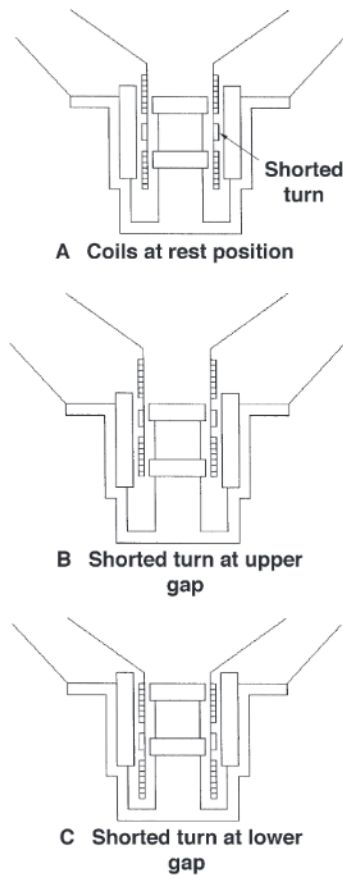


Figure 8. The shorted-turn dynamic braking coil. Cone at rest position (A); cone at maximum outward position (B); cone at maximum inward position (C).

Voltage required to attain a peak displacement in a dual 10-inch LF driver, with and without braking coil.
Drive signal at 30 Hz. At 0.6 inches, braking coil is fully immersed in gap.

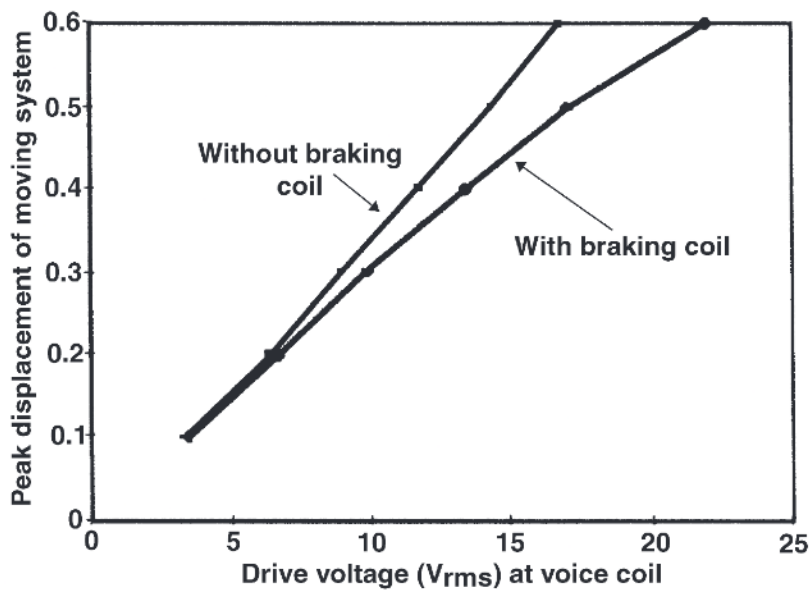



Figure 9. Cone excursion versus signal voltage with and without braking coil in model 252 driver.

References:

1. JBL Technical Note Volume 3, Number 2A, JBL's New LSR6300 Series Studio Monitors, JBL Professional (Northridge, CA, 2004)
2. Button, D., "Magnetic Circuit Design Methodology for Dual-Coil Transducers," *J. Audio Engineering Society*, Volume 50, Number 6 (June 2002)
3. Eargle, J., *The Loudspeaker Handbook*, 2nd edition, Kluwer Academic Press (Boston 2003)
4. Borwick, J., editor, *Loudspeaker and Headphone Handbook*, 3rd ed., Focal Press (Boston 2001)
5. U.S. Patent Number 5,748,760, "Dual Coil Drive with Multipurpose Housing"
6. U.S. Patent Number 5,828,767, "Inductive Braking in a Dual Coil Speaker Driver Unit"
7. U.S. Patent Number 6,768,806, "Shorting-Rings in Dual-Coil Dual Gap Loudspeaker Drivers"
8. U.S. Patent Number 6,774,510, "Electromagnetic Motor with Flux Stabilization Ring, Saturation Tips, and Radiator"



JBL Professional
8500 Balboa Boulevard
Northridge, California 91329 U.S.A.

 A Harman International Company
© Copyright 2004 JBL Professional

TN VOL 1 NO 33
CRP 2M
6/05