

► Ferrofluids

Improve performance and reduce cost in surround satellite woofers and full-range microspeakers.

By Steve Tatarunis and Mike Klasco

For over 35 years, ferrofluids have been successfully applied to tweeters in hi-fi, pro-sound, home theater, and autosound products. Over 275 million speakers containing ferrofluid were manufactured last year, and since its introduction in 1972, close to 3 billion speakers have received the benefits of this space-age technology. Originally developed by AVCO scientists working on a NASA project for magnetic control of liquid fuel in the non-gravity of outer space, the technology was later licensed to the scientists for the development of commercial applications. Ferrofluidics (now Ferrotec Corporation) was founded.

The application of ferrofluids in the voice coil gap provides many benefits to loudspeakers. Because the ferrofluid is roughly 400% more thermally conductive than the air it replaces, voice coil operating temperatures are reduced. Short-term power handling is dramatically increased, and at elevated power levels, electrical and thermal parameters are more stable (less power compression effects).

The viscosity of a ferrofluid may also be selected to better control the damping of a loudspeaker at its resonant frequency. The use of ferrofluid can also result in a reduction in distortion and smoother frequency response. Another benefit is the centering effect of ferrofluid. A ferrofluid provides a uniform radial centering force to the voice coil, enhancing voice coil centering while the lubricating properties of the fluid reduce the harsh sounds associated with coil scrapes and rubs.

A recent trend that takes full advantage of the centering effect is the increasingly common use of ferrofluids in compact extended range (and full-range) speakers. The application of ferrofluid to these micro-full-range speakers such as the fashionable inverted dome used in the seemingly endless proliferation of iPod-docking stations has enabled manufacturers to simplify their designs while improving their production yields.

A derivation of this class of high-performance micro-speaker is the use of ferrofluids in mid-bass woofers such as those used in satellite speakers in home theater AV systems. These speakers require higher voice coil excursion than



PHOTO 1: Panasonic home theater system with integrated center channels into the left/right towers with the midrange and tweeter ferrofluid cooled.



PHOTO 2: Ferrofluid responds to an applied magnetic field.

tweeters and thus require special consideration for the use of ferrofluid.

In this article, we will discuss design techniques for low- and medium-power satellite speakers used for home theater in a box (HTiB). Additionally, we will introduce new low-cost ferrofluids for multimedia and home theater

mid-bass speakers. Of particular interest to designers is the discussion of single-sided use of ferrofluid, i.e., placing the fluid between the I.D. of the voice coil bobbin and the pole piece or between the O.D. of the coil and the top plate. This new technique significantly reduces the amount of ferrofluid required and also eliminates the need for the type of cavity venting typically required to reduce pressure forces on the ferrofluid. A secondary benefit is that this single-sided gap filling technique minimizes the ferrofluid's effect on raising the resonance frequency due to trapped air within the magnetic structure cavity.

Single-Sided Application of Ferrofluid in the Voice Coil Gap

Multimedia docking stations, portable DVD players, laptop audio systems, smart phones with MP3 and integrated speaker systems, cell phones with speakerphones and portable GPS systems are just a few of the emerging applications where higher voice coil/diaphragm excursion is required, yet power dissipated in the voice coil is low—and voice coil operating temperatures are not excessive. This high efficiency and low power operation is driven by the designer targeting longer battery life.

Altec Lansing's original InMotion iPod docking station was quite a market success with well over 1 million units shipped. Harman's multimedia PC sound systems and the JBL InConcert micro audio systems are other examples

of single-sided ferrofluid use for voice coil centering. There are dozens of micro sound systems featuring high-excursion inverted dome speakers that are used down to the mid-bass. Many of these extended range microspeakers have

secondary suspensions besides the surround, and most of these suspension techniques are proprietary. One non-proprietary solution for high excursion coil centering available to designers of these unique microspeakers is the application of ferrofluid to one side of the voice coil.

Practical experience of most users of ferrofluid—whether for the established application of tweeters, or the newer use for high-performance microspeakers—report dramatic reductions in both production line rejects and field returns due to the centering effect. This is partially due to reduction in voice coil operating temperature preventing the voice coil from expanding and then scraping the top plate and also from the centering effect of ferrofluid, also known as *magnetostatic* centering. This centering effect can easily be demonstrated by injecting ferrofluid into the gap of a reject extended range speaker. The coil will typically be forced into concentric position, eliminating the noise and rubbing. This test demonstrates the power of the centering effect.



PHOTO 3: Altec-Lansing InMotion.

Some Aspects of Magnetostatic Centering

1. The centering force stability of a speaker's suspension decreases with excursion. The centering force of ferrofluid increases with excursion as the volume of fluid displacement increases. *Ferrofluid comes into play when it is needed most!*
2. In the case of satellite mid-bass woofers, the spider is attached above the top winding of the voice coil in order for adequate clearance during the rearward stroke. Otherwise, the spider will hit the back of the speaker basket (the plateau). Because the spider is not in the same plane as the voice coil, any rocking of the spider results in a greater displacement offset when the rocking motion of the bobbin reaches the voice coil in the gap. Ferrofluid is located in the gap and on the same plane as the coil. The ferrofluid counteracts the rocking from the spider, somewhat like a secondary suspension, but with the added benefit of being on the same plane as the coil.
3. A common design issue with 50-100mm diameter satellite woofers in compact enclosures is reaching down to the target crossover frequency. One of the contributing factors increasing the F_0 (resonant frequency) of the speaker is the spider. While the woofer's moving mass and back volume of the enclosures are significant contributors, you can use a much more compliant and lighter spider (or maybe no spider at all) when ferrofluid is used.

Design Considerations

There are a half-dozen opportunities for cost reduction and performance improvement in satellite HTiB speakers when ferrofluids are used in the mid-bass (or full range) speakers. Consider the following:

Reduced voice coil diameter—since the ferrofluid, even in single side of the coil applications, provides some reduction in the operating temperature, you can use a smaller diameter voice coil. Reducing the voice coil diameter also enables the designer to scale down the magnetic structure size while retaining adequate power handling. Reducing the size, weight, and cost of the magnetic structure on the satellite speaker even a few cents adds up when you consider that there are at least five channels in every system.

Because HTiB is a closed system where the speaker designer controls (or at least knows) the maximum power the speaker must endure, thermal design reserve does not need to be excessive. Reduced voice coil diameter enables more extended top-end response and a higher crossover point. Moving the crossover upward invites a lower-cost higher F_0 tweeter. Finally, the mid-bass speaker's smaller magnetic structure allows the back volume of the enclosure to increase, extending the satellite speaker's mid-bass extension, an area that typically needs a bit of help.

New Multimedia Ferrofluid Series

Ferrotec Corporation recently introduced two new series of ferrofluids which have been designed specifically for the single-sided gap filling technique in home theater and multimedia loudspeakers.



PHOTO 4: Harman-Kardon SoundSticks.

APG W Series of ferrofluids consists of two models, APG W05 and APG W10. Both ferrofluids possess the high saturation magnetization value (400 gauss) needed for voice coil centering. In most cases, APG W05 will be

the preferred choice by the designer because its properties are tailored for use in low- to medium-power designs. However, when power requirements and voice coil temperatures increase, APG W10 should be utilized due to its higher thermal stability and extended life at higher operating temperatures.

FRM Series of ferrofluids are designed for typical applications in cost-sensitive full-range speakers (flat panel TV, multimedia, MP3 docking station, PC, laptop, and so on) used in low-power designs. FRM offers high performance at low cost and comes in a wide range of magnetization and viscosity values.

CONCLUSION

The APG W and FRM series of ferrofluids from Ferrotec, used in conjunction with single-sided application of the ferrofluid in the gap, have brought the advan-

tages of ferrofluids to multimedia and HTiB midbass/full-range speakers without the need for complex venting for cavity pressure relief.

Ferrofluid offers the benefits of improved voice coil centering, higher production yields and fewer field returns due to voice coil scraping. The heat transfer characteristic of ferrofluid significantly reduces power compression effects and further reduces incidence of voice coil failure due to burnout. In particular, the use of ferrofluid in cost-sensitive designs allows the designer to reduce the voice coil and magnet size, leading to beneficial savings in cost, weight, and size without compromising system performance.

Successful application of ferrofluid to any specific transducer still requires competent engineering on behalf of the designer, but guidelines to resolve most problems have now been mapped out. Application notes detailing material compatibility with ferrofluid, calculating volume of ferrofluid, reprints of technical papers and other support materials are available from Ferrotec (www.ferrotec.com). The engineering staff of Ferrotec provides technical support to loudspeaker engineers interested in exploring the application of ferrofluids to their design projects. **VC**

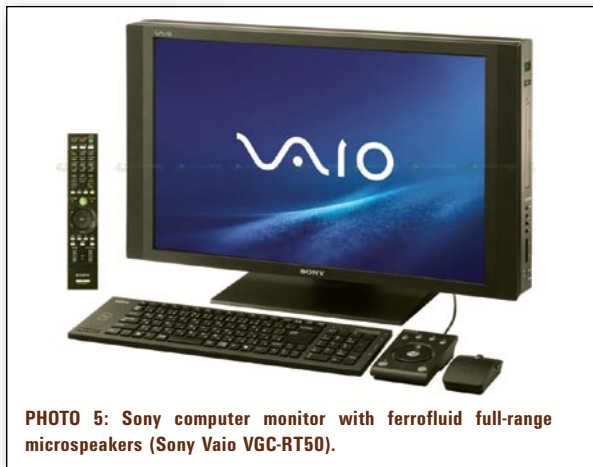


PHOTO 5: Sony computer monitor with ferrofluid full-range microspeakers (Sony Vaio VGC-RT50).



PHOTO 6: Sony flatscreen TV with ferrofluid full-range microspeakers (Sony Bravia KDL-46XR1).