

Loudspeaker University

April 15-17, 2004
Crown Plaza Hotel
Nashua, New Hampshire

MAXXBASS® APPLICATIONS WITH HIGH-BL DRIVERS FOR SMALL, FULL RANGE LOUDSPEAKERS

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ABSTRACT

Recent technical papers from Keele¹ and Vandercooy et al. discuss the efficiency improvements in loudspeaker systems when a high BL neodymium magnet is combined with a class-D switching-mode amplifier. When the BL is raised dramatically, the input impedance magnitude rises, and its phase shifts from a resistive to a reactive load. Through SPICE model simulations, Keele indicates that dramatic efficiency improvements of 500 percent and more could be realized in these systems. However, there are a few drawbacks, one of the most important being that a large bass frequency equalization is required. This paper discusses the application of MaxxBass combined with this speaker design methodology to reduce the amount of bass equalization and system headroom requirements. The paper also examines the commercial benefits of combining MaxxBass in a loudspeaker system with a digital amp and high-BL driver.

1 INTRODUCTION

The consumer electronics industry is beginning to widely adopt digital or class-D switching amplifiers to improve power efficiencies. Traditional analog amplifiers (A/B) provide efficiency as high as 40 percent with full scale inputs, while a digital amplifier can operate at more than 80 percent efficiency reducing heat dissipation of the amplifier and lowering power supply requirements. The loudspeaker system efficiency improvements with digital amplification are substantial, but this does not consider the most inefficient component in the loudspeaker system, which is the electrical to acoustic efficiency of the loudspeaker itself.

Direct-radiator loudspeakers are not very efficient at converting electrical energy into mechanical motion and acoustical energy. The voicecoil magnet structure is designed

to be relatively inefficient in order to balance mechanical and acoustic loading and provide a flat frequency response. The design example from Keele discusses a traditional 8" driver design with 5.1 percent maximum efficiency, while some subwoofer loudspeakers can be less than 1 percent efficient.

If the loudspeaker system uses equalization or another signal processing method to flatten frequency response, then the magnet efficiency can be improved. The best way to do this is by using neodymium magnetic material. Today, the vast majority of woofer drivers use ferrite or ceramic magnets since they are very inexpensive. Another magnet material that provides almost a tenfold increase in magnetic energy with the same magnet mass is neodymium, which has been used for more than a decade in higher performance applications requiring more output power such as public address drivers and higher sensitivity applications like tweeters, microphones, and notebook PCs. However, because neodymium is expensive, it has not been used in mainstream driver applications. This may soon change though: part of the reason for neodymium's high price is that it was a patented material from Sumitomo and Magnequench, and now that these patents have expired, the price of neodymium is dropping rapidly.

Keele analyzes the system efficiency improvements by increasing the magnetic energy (Bl) from 8 to 40 without other changes to the loudspeaker design. The paper concludes that the maximum true power transfer efficiency with air loading increases from 5.1 percent to 25.6 percent. Furthermore, the efficiency improvement occurs across all frequencies with as much as 14dB or a 25-fold improvement at high and low frequencies.

2 LIMITATIONS OF HIGH BL SYSTEMS

The performance improvements of 500 percent are discussed in this paper, which are significantly greater than the relatively modest 100 percent improvement obtained by the migration from class A/B (linear) to class D (digital) amplification systems alone. With such dramatic improvements, why isn't everyone using this approach?

According to Keele, this design approach has three drawbacks:

1. The neodymium drivers may add additional cost
2. The amplifier needs to provide greater voltage swing
3. Significant bass equalization is required to drive the speaker to flat response

Each of these disadvantages are discussed further below.

The first drawback is the additional cost of the high Bl neodymium drivers. As result, it seems likely that this design approach will be used initially in small full range drivers since these magnets are relatively small. It is also likely to be adopted in applications where higher power efficiency offers additional customer perceived value. The most immediate need for improved power efficiency is in portable applications, and these may be able to support a higher customer price due to the benefit of dramatically improved power efficiency. Additionally, the ability to use smaller drivers may be valuable to applications with significant space constraints, such as LCD televisions.

The second drawback is the increase in voltage swing of the amplifier. This may be reduced simply by using a driver with lower resistance (for example, migrating from 8Ohms to 4Ohms), which more than offsets the higher voltage requirement. This drawback is not a major obstacle to adopting this design approach.

The third and final drawback is that a bass boost of +12dB or more may be required to flatten the system frequency response. The boost directly adds to the system headroom requirements, which further adds to peak amplifier and speaker excursion requirements. This is the most severe drawback in the design methodology discussed.

An alternate method to re-equalization with a large bass boost is Waves patented MaxxBass® technology. Based on the proven psychoacoustic Phenomenon of the Missing Fundamental, MaxxBass allows bass extension without additional headroom requirements and enables a practical design for cost effective consumer applications.

3 PHENOMENON OF THE MISSING FUNDAMENTAL

The Phenomenon of the Missing Fundamental was discovered by pipe organ builders during the 1700s. In the Middle Ages, large pipe organs installed in cathedrals used pipes up to 40 feet long to generate really low frequencies that drew crowds to church services to feel the bass, which helped generate emotion as they listened to spiritual messages. Some pipe organ music composers found that they could trick the listener into hearing low bass tones that weren't really there if they played a certain combination of notes that were higher than the low tone or "fundamental" that they wanted to be heard. For example, if they wanted the listener to hear a low C then they could play a C an octave higher and a G above that, and the low C would magically be heard in the listener's head.²

The Phenomenon of the Missing Fundamental has also been studied and proven by many distinguished audio scientists such as Helmholtz, who discovered how vented ports and vents operate. The perceived pitch of a combination of tones spaced equally in frequency is usually not that of the mean frequency, but rather that of the constant difference frequency,³ which is the missing fundamental.

4 MAXXBASS

Meir Shashoua, the CTO of Waves, developed a theory on how the Phenomenon of the Missing Fundamental could be applied to loudspeaker reproduction limitations. Waves, the leader in audio signal processing plug-in tools for the professional audio market, improved and sharpened this psychoacoustic effect. This technology, called MaxxBass, was patented in the U.S. and Japan.

Waves MaxxBass and second generation Renaissance Bass plug-ins utilize this technology and in the past few years, have become standard tools in creating much of the world's most popular music. These software tools are used to improve bass punch on bass limited systems, which is important for playing music on everything from dance floors with subwoofer arrays to small portable systems with severely limited bass capability. Christina Aguilera's "Lady Marmalade" is just one example of today's popular music that is mixed with MaxxBass technology.

Since MaxxBass can be tuned to specific loudspeaker parameters, it is even more effective when implemented directly in consumer audio reproduction systems. This is now possible due to a cost-effective MX3000AS ASIC (Application Specific Integrated Circuit) as well as DSP software licensing from Waves.

Another advantage of implementing MaxxBass in consumer audio equipment is that it includes a high pass filter (HPF) which removes the original bass frequencies that cannot be reproduced by the loudspeaker and which are no longer needed since MaxxBass reproduces these through psychoacoustics. The HPF eliminates damaging speaker excursion, unnecessary power consumption and undesirable intermodulation distortion in the loudspeaker.

Boosting the low-frequency performance of a speaker by up to 1.5 octaves normally requires increased headroom in the amplifier, increased excursion in the driver, and extra BI to maintain control at high excursion, all of which are substantially more expensive than implementing MaxxBass.⁴ MaxxBass technology is a powerful and cost-effective way for audio system designers to improve bass response. It can be used for a number of applications including car stereos, home theater systems, TVs and portable and personal electronic audio devices.

5 DRIVER DESIGN OPTIMIZATION

As discussed in Section 2, small full range neodymium drivers with high BI may have the most immediate commercial applications. These driver designs may be further optimized for MaxxBass by considering that HPF (High Pass Filter) reduces peak speaker excursion requirements. These optimizations may include the following characteristics:

- a) Overhung coils can have reduced overhang, further increasing driver efficiency in the passband and lowering DCR with less wasted signal outside the gap.
- b) Underhung coils (such as Aurasound NRT) can have more turns in the gap for even higher BI.
- c) Lower peak excursion requirements allow the cone weight to be reduced for higher sensitivity/efficiency in the passband.
- d) The dominant failure mode for speakers is pushing the magnet outside of reliable excursion range, so MaxxBass inherently improves system reliability. The lower excursion requirements also enable use of ferrofluids which improve thermal properties of the speaker. This is the next most significant failure mode, so the system reliability can be improved even further.

6 APPLICATIONS

Designing small, full-range, high BI neodymium drivers combined with a digital amplifier and MaxxBass is highly attractive for consumer products like portable loudspeakers and LCD TVs, which need to save power and space. The first consumer products with MaxxBass are now available to the public.

One of these products is the Altec Lansing inMotion™, which is a portable loudspeaker system for the Apple iPod™. It weighs only 15 ounces, folds to the size of a paperback book and will operate continuously for up to 24 hours on four AA batteries. The inMotion combines MaxxBass (with MX3000AS MassBass ASIC) with a digital amplifier and neodymium magnets. The size and power efficiency of the inMotion may make traditional portable loudspeaker systems obsolete.

Techsan is now shipping the first LCD TVs with MaxxBass technology. Since many LCD TV manufacturers are now using digital amplifiers, it is likely that the highly competitive LCD TV market may adopt the combination of MaxxBass technology, digital amplifiers and high BI neodymium magnet structure technologies discussed in this paper.

References

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Photo of Altec Lansing inMotion



Photo of Techview LCD TV

