Back

INCREDIBLE SPEAKER

I've built the proposed speaker enclosure in Aren van Waarde's "A Simple Audio System" (March '05 *aX*). The supplier, Digitex, from Florence (Italy), where I ordered the two Fostex F103 sigma, was out of stock of this model but they suggested a *re-logoed* model remarketed in Switzerland– FE103S ACR, which, they claim, is nothing but the original Fostex.

I built the box according to the drawing but using a 25mm multilayer pine wood, damping the inside with two layers of different material: One was a 6mm-thick foam used in our house construction to acoustically isolate floors and, on top of it, a 5mm thick felt used underneath carpets.

I hooked up my excellent, evergreen, Heathkit AR 1500 amp to test it. Well, I was astonished by its sound. It is almost incredible how a 100mm speaker is capable of reproducing the bass. All this and more is well described in the article, but you've got to hear to believe it!

An excellent, economic set of speaker boxes for lovers of good sound.

Bravo, Aren!

Atto Rinaldo
Tambre, Italy

Aren van Waarde responds:

Nice to hear that you have built Petite speakers and that they work well in your system. The ACR driver is indeed the original Fostex; I used ACR FE103S drivers myself, which I ordered from Spectrum Audio (Bremen, Germany).

However, your praise should go to Gérard Chrétien and the people from *L'Audiophile* in Paris, who originally published this column-shaped enclosure.

SATELLITE RADIO

In response to my letter regarding satellite radio, which appeared in the June '05 issue of *audioXpress* (p. 49), I received two replies. From them, I found that XM uses Advanced Audio Coding, which the National Association of Broadcasters says is better than Sirius' Perceptual Audio Coding. Both services use enhanced versions of these codecs, and they both cut off brick wall at about 15kHz. I have heard highly mixed reports as to which is better, although XM has over four times the music library size of Sirius. More information can be found on www.XM411.com and www.siriusbackstage.com.

Because the music on traditional AM and FM stations has become abysmal, I took the plunge at the beginning of 2005 and bought a Sirius Sportster receiver and took out a one-year subscription. Because the receiver came with a car kit and the home kit would be $50 more, I cut the cigarette lighter plug off the provided car kit and connected the wires into an old 12V 7812 regulated video camera power supply. First off, the FM transmitter option adds considerable distortion; by all means use the direct audio output connection into your amplifier.

Even with this connection, upon hearing a song played on a Sirius program and then immediately playing a CD or record copy of that same song, the Sirius quality is more like that of a 45 rpm record than a CD. The news/talk/sports channels have an even more swirly sound due to their much lower sampling rates. I heard the Polk Audio XM component tuner in a local audio salon, and noticed it also had some swirl in its sound.

On the positive side, satellite radio does provide a variety of music and other programming rarely found on traditional radio, and without all the commercials. The audio is better than the FM stations, which highly compress their audio, sometimes to utter clipping. However, the few still good FM stations are better than satellite. I wish to thank Scott and Peter who responded to my letter.

Michael Kiley
Crestwood, Ill.

SPEAKER DAMPING

I am writing in response to the article titled "Speaker Damping," by Cornelius Morton (Aug. '05). In the beginning of his article, Mr. Morton talks about adding resistance to reduce damping. This statement initially confused me because it is normal to see a loudspeaker's system Q go up with an increase of electrical source resistance. However, a few paragraphs further on, he stated that most drivers typically have a Q of 4 or more, and from this I think he must be referring to the mechanical Q (which is more usually described as Qms), and the resistance he mentioned must be mechanical resistance, not electrical resistance.

Intrigued to see where Mr. Morton's line of rhetoric was leading, I read on, only to realize that he did not appear to be making any distinctions between a driver's Qms, Qes, or Qts, all of which play an important role in the frequency response and system Q of a loudspeaker system, especially when the possibility of wide variations of an amplifier's output impedance are included.

Mr. Morton then goes on to describe Photo 1 as a near-field measurement (microphone positioned within 2″ of the driver's cone) of a driver mounted in an over-stuffed sealed enclosure, which to me appears plausible. After this, he describes the same type of measurement on a loudspeaker that employs a ported enclosure as shown in his Photo 2. On examining Photo 2, I believe that the response was made without the contributing response of the port.

I should point out that the driver has a minima in its excursion at system resonance, but the port output will be at its peak. Indeed, the output from a microphone when making near-field measurements of the driver and port can easily differ by 20dB and more at resonance. I therefore strongly suspect that Photo 2 is demonstrating this phenomenon and thus gives a highly distorted view of this loudspeaker's response.

At the end of the article, he states that there is a phase shift of 90° from the voltage applied to the loudspeaker terminals, compared with the voltage appearing at the output of the microphone. The reason for this is most likely the group delay of the system at resonance, which is where the group delay approaches its maximum. As frequency goes up, the group delay will rapidly drop to a low value.

For those interested in this, I recommend checking the group delay of a 2nd order HP function with a -3dB response at, say, 30Hz. Such a filter should equate well with the acoustic response of a loudspeaker in a sealed enclosure with similar parameters. You should find a group delay of about 7.5mS at 30Hz and about 0.7mS at 100Hz.

After this, Mr. Morton describes two methods he used to measure the electrical impedance of drivers at their terminals. These methods are the constant-current and constant-voltage methods. He then states that the Qs of several drivers were calculated as listed in his Table 2 and provides the reader with the equation Q = Fs/Bandwidth; however, he does not define how bandwidth is measured. I would be grateful if Mr. Morton can define this for me.

I assume that because Mr. Morton started the paragraph by describing impedance measurements, that he determined the Q of these drivers from his measured impedance data and, furthermore, that because the impedance data changed between impedance measuring methods, he then declares the Q of the drivers changed as a function of the output resistance of the impedance measuring system.

Theoretically speaking, the impedance of any driver should not change, regardless of the measurement method used. If the impedance of a driver were made equivalent to an electrical network as described by Mr. Morton's Fig. 2, then for the impedance to change it would require one or more of the driver's equivalent components to have changed (i.e., like the moving mass or the suspension's compliance, and so on)!

Having said all this, I should emphasize that I am quite sure that Mr. Morton's measured data is quite accurate and I have no intention of disputing this. However, it is my belief that Mr. Morton did not measure the two sets of data under exactly the same conditions; i.e., the voltage across the drivers terminals was not made the same for the two measurement methods, which was the major reason for his obtaining two conflicting sets of impedance data.

It is here that I should point out that it is indeed possible for equivalent component values in Mr. Morton's Fig. 2 to vary considerably depending upon the Cone's excursion, which in turn is dependent on the voltage applied to the driver's terminals. These variations have become well known in the loudspeaker industry with parameters such as the driver's free-air resonance (Fs) varying by as much as 27% when comparing low-level measurements with those of even modest cone excursions of 2mm peak. This data came from one of the many excellent papers published on the Klippel website http://www.klippel.de/, where many more examples of nonlinear functions are described. So the reason for the change in Q that Mr. Morton observed was, in my opinion, almost certainly due to the significant nonlinear components in the drivers he was measuring, brought about by different measurement conditions for the two measurement methods.

Peter L. Bath
San Gabriel, Calif.

Cornelius Morton responds:

Thanks for your interest in my article. I will attempt to answer your questions in order.

First, concerning damping and resistance, I totally agree with your statement that adding source resistance decreases damping. However, I believe the exact wording of the article was "by inserting a fixed resistance into the system dissipating those lurking frequencies, damping the resonance." "System" indicates the driver, not the external source.

The effect of inserting a lossy element into the workings of the driver is to dissipate energy, both applied and stored. The stored energy is what you are after, but the lossy element loses applied energy as well as stored, so the end result is a lower Q (good) in conjunction with a loss of sensitivity (bad). It was a bit of a fad in the fifties and sixties to coat the surrounds and spiders with a viscous fluid that increased the friction generated by cone movement to increase damping; it also reduced the compliance of the surround and spider which lowered the resonant frequency of the driver. Figure 2 illustrates the equivalent electrical components of a typical cone driver.

Your question of which "Q" I measured—Qms, Qes, or Qts—is certainly valid. I attempted to qualify that the measured Q was the measure of energy stored in the driver system per cycle against the energy lost in the system per cycle. The closest Thiele parameter to this is Qms.

Qes is the measure of control—losses—of the electrical system of the driver. Qts is a calculated parameter that relates to the most suitable enclosure type for the driver and is defined as $(1/Qms + 1/Qes)^{-1}$. The value of Qms will be typically higher than the measured Q of the driver due to a multiplier used in the Thiele measurements. The multiplier used is $ro^{1/2}$, where ro is defined as the ratio of voice coil current off resonance to the current at resonance or the impedance at resonance to the impedance off resonance.

Your concern for variations of amplifier output impedance variations could be valid for the constant voltage measurements when using tube or solid-state amplifiers without feedback. For the most part, modern solid-state amplifiers have a Zo of 0.05Ω or less, which is small compared to a 4 or 8Ω speaker. The constant-current measurements were made with a simulated Zo of $1k\Omega$, which, compared to the speaker, is, for all practical purposes, an open, as intended. The constant voltage measurements were made with a simulated Zo of 0.24Ω, which represents a 3% error (a damping factor of 33) when measuring the impedance peak and a 4.2% error at the –3dB points. These values are certainly within the tolerances required for a valid representation of the effect of amplifier damping on driver Q.

Ported speakers *do* have a minimum in cone excursion at resonance, and—yes—the port adds to the sound levels at resonance. The problem is the resonance peak below and above the system resonance due to the overcoupling between the tuned port and the driver. If you examine the impedance and phase curves for a ported speaker, the low- and high-frequency peaks are quite evident, with the phase showing a maximum positive at the low-frequency 3dB point and a minimum negative at the high-frequency 3dB point of each peak. This is the signature of a resonance energy storage point that promotes the sonic signature of a ported system.

The impedance null and zero phase shift at the port/driver frequency indicates that there is no energy storage at that frequency. Sonically, the greater the amplitude of the lower and upper peaks, the more sonic coloration the system will exhibit. Note that cone excursion is at a maximum at the lower and upper peak frequencies.

The comment about phase shift or delay at resonance was tossed in for general information and to illustrate the difficulty of trying to time-adjust a subwoofer to the rest of the speaker systems.

Frequency, bandwidth, and Q measurements seem to cause you some problems, especially when derived from a constant-current drive and a constant voltage drive. There are two sources of impedance in a cone-type loudspeaker. One is the DC resistance of the voice coil and the second is the velocity of the voice coil through the magnetic field of the gap.

Figures 1 and 2 detail the electrical equivalences. This is the source of the impedance peak at resonance where the cone/voice coil velocity is highest. The moving voice coil generates a back (opposing) emf that is determined by the length of wire on the coil, the magnetic intensity through the gap, and the velocity of the voice coil within the gap.

As long as the coil remains within the constant magnetic field area of the gap and the coil length is unchanged, the determining function is the voice coil velocity. When performing constant-current measurements, the voice coil is effectively shunted with 1kΩ Zo, which limits the current caused by the back emf to about 1mA per volt with a power dissipation through the 8Ω voice coil of about eight microwatts per volt.

When driven by the constant voltage drive, the voice coil is shunted by 0.24Ω, and the current caused by the back emf is now limited by the 8Ω DC resistance of the voice coil plus the 0.24Ω Zo. Now the current approaches 121mA per volt of back emf and the power dissipated is approximately 117mW per volt. The result slows the voice coil velocity, reducing the effective impedance and damping the system. The only difference between the constant-current and the constant-voltage measurements is that the latter allows the back emf to generate a current limited by the voice coil DC resistance, whereas the former essentially reduces currents generated by the back emf to zero.

To get a sense of the braking action involved, take your favorite bass driver with the voice coil disconnected and gently flex the cone; you will basically feel the stiffness of the suspension. Then do the same with a clip lead shorting out the voice coil terminals. The difference is the braking effect of the voice coil. The preceding ignores the effect of voice coil inductance, but in the frequency range below 100Hz this represents a fraction of an ohm and may safely be ignored.

To measure frequency and bandwidth, I used standard techniques. For the constant-current drive, I placed the voltmeter across the driver terminals and adjusted the drive for a reasonable level, about 20mV. I also adjusted the frequency of the drive to achieve a peak level and recorded the frequency, Fr. I reduced the drive level by 3dB, recorded the resulting voltage, and then returned the drive to the original level. I then adjusted the drive frequency to achieve the recorded –3dB level below and above Fr. These frequencies were recorded as Fl and Fh.

For the constant-voltage measurements, I read the voltage across the 0.24Ω resistor, set the initial off resonance value to 15mV, then adjusted the frequency to achieve a null reading and recorded Fr. I increased the drive by 3dB and recorded the voltage, and then reduced the drive to the original level and adjusted the frequency to achieve the recorded voltage below and above Fr. These frequencies were recorded as Fl and Fh.

The values for Fr measured with a constant-current drive and with a constant voltage drive were typically within a cycle or two of each other for the same driver, which is an indication of good data. The low drive levels—30mW maximum at the voice coil terminals—ensured that the measurements were taken well within the linear portion of cone excursion.

A comment on your last paragraph: Simply put, you state that Q variations measured with a constant-current drive and a constant-voltage drive are due entirely to nonlinear variations in driver parameters induced by measurement differences. However, in your initial paragraph you state, "it is normal to see a loudspeaker's system Q go up with an increase of electrical source resistance." Yet here you are insisting that when the source resistance is decreased, the observed decrease in Q must be caused by measurement irregularities.

Because the data is consistent with loudspeaker theory and the test methods and results do not show the irregularities that would indicate bad data, I must disagree with your conclusions. For additional material on this subject, I refer you to *Elements of Acoustical Engineering*, second edition by Harry F. Olson, EE, Ph.D. D. Van Nostrand Co., 1947. This is an oldie but still a premiere reference for the field. Chapter 6 is devoted to direct radiating loudspeakers.

One of the major thrusts of this article was to explore the limits of speaker damping versus amplifier output impedance. The results indicate that the limiting factor is the DC resistance of the voice coil for amplifiers with a moderately high to high damping factor.

The second objective was to explore the availability of damping methods that lowered the system Q below that which is achievable by electrical damping alone. I believe that both objectives have been met. *aX*