THE LOUDSPEAKER SPEC SHEET GAME
2005 Revision

by Jon M. Risch, Senior Project Engineer, Peavey Electronics Corporation

Introduction
Oftentimes, when looking at the spec sheets from different manufacturers, it may seem as though almost everything from a 10" based speaker system to an 18" based system has the same performance, regardless of price. If these specifications are examined closely, only then can one begin to understand what is really being claimed as the product's performance. In this paper, we will explore what to look for on a loudspeaker spec sheet in order to properly assess competing products.

Consistency & Qualifications
The biggest single reason that specifications from different manufacturers are not consistent is a failure to specify the qualifying conditions for the measurement. All too often, only a dimensionless number is provided, without any qualifying information or conditions given. In order to be able to compare specs between two different speaker systems, there are several measurement conditions that will need to be stated or defined, such as the drive level, mic distance and position, the frequency range of the measurement, and the deviations across that range.

The second biggest reason for inconsistent specification numbers is the exact opposite: qualifying conditions that are extremely specific and limited in their range. Using a very limited bandwidth or calculated results can change the numbers from what one would expect.

The three specifications that are of primary interest, and not so coincidentally, are the most inconsistent, are: Sensitivity, Frequency Response, and Power Handling. In order to fully understand the qualifying conditions necessary to make sense of these specifications, we will need to delve into some of the measurement details with respect to each one of these specifications.

Sensitivity
First, let's take a look at speaker system sensitivity. In the case of sensitivity, a decibel (dB) number is given. In order for this number to have real meaning, it must also specify the measurement conditions regarding the distance from the speaker system to the microphone, and the input level to the speaker.

Mic Position
It is also customary to either imply, or explicitly state, the position of the microphone with respect to the speaker system front/baffle, i.e., "on axis", or "centerline of speaker". If no position is given, or called out, then it is assumed that the mic was on axis, typically on axis with the HF horn or tweeter in a

system. Sometimes, the measurement is taken on what is called a design axis, usually somewhere on the centerline, in between the woofer and the horn/tweeter axis.

So, what difference does where the mic was positioned make, as long as it was at the specified distance? Well, the usual distance is 1 meter (39.37"), which is a lot closer than a speaker system is usually listened to. At a 1 meter distance, a small vertical difference in the position of the mic can make a relatively large change in the apparent frequency response, sometimes causing a dip, or a peak in the response. If the speaker system is measured for sensitivity with the mic at a position where a large apparent peak is present, then the sensitivity of the speaker system could be elevated compared to the rest of the frequency spectrum.

EXAMPLE 1: The Brand E model 1 speaker system specs a sensitivity of 101.5 dB at 1W, 1m, but is derived from a limited band of frequencies, in this case, from 300 Hz to 2 kHz. The E model 1 also happens to have a peak in the midband compared to the rest of the spectrum, and is rolling off gently as the frequencies go below 250 Hz. If the E model 1 system were rated according to the full reproduced spectrum, then it would be rated lower, perhaps 99 or 100 dB. Other brands also use bandlimited sensitivity ratings, where the sensitivity is rated over a band from 500 Hz to 2.5 kHz, etc.

If the mic position is not fully specified for the different parameters, then it may have been in a different position for the sensitivity measurements compared to the frequency response measurements.

Drive Level

Another measurement condition to keep an eye on is the input (or drive) level to the speaker system under test. The industry standard is 1 watt, or 2.83 volts AC RMS for a nominal 8 ohm load, and 2.00 VAC RMS for a 4 ohm nominal load. Sometimes a speaker system that is a nominal 4 ohm or 6 ohm load is driven with 2.83 VAC RMS, and since many people are used to seeing 2.83 V as a measurement condition, they don't really look that closely. But if the speaker was a 4 ohm load, and was being driven by 2.83 V, it is actually being driven by 2 watts, and would put out 3 dB more output than if it were driven by 2.00 V or 1W. This would make that speaker system seem to have a higher sensitivity than it actually did at a true 1 watt drive level.

EXAMPLE 2: Brand Y spec sheet, a 6 ohm speaker driven by 2.83V.

Sometimes lower price range speakers can have very high sensitivity specs by letting a horn or piezo tweeter run "hot", that is, without proper level matching to the woofer. This puts the whole upper frequency range at an average level higher than the woofer, and can artificially raise the sensitivity spec. Of course, the speaker then sounds shrill and thin, lacking apparent bass, because the woofer isn't keeping up with the tweeter in relative output level.

Pie or Pi? 4 π VS. 2 π Measurement Space

Sometimes sensitivity or frequency response is measured using a 2 π space (π = Pi) instead of a 4 π space. This is also called a “full space” measurement. What does 2 π mean? Well, most loudspeaker measurements, whether they originated in an anechoic chamber or not, are referenced to a 4 π, or totally open space around the speaker, or an *anechoic* space. In terms of the loudspeaker sound energy, it means the sound can spread out all around the speaker without reflection or reinforcement.

A 2 π space is not a totally open space around the loudspeaker, but represents a plane surface nearby, the totally open space is "cut in half" by a planar surface (usually a floor, or in the middle of a large open single wall). This is also referred to as “half space”. In restricting how much the sound energy spreads out from the speaker, the 2 π space effectively boosts the low frequencies below approximately 250 Hz by about 6 dB.

This provides an obvious benefit in specsmanship: Subwoofers or the woofers in multi-way systems can be rated 6 dB hotter than normal, and the low frequency -3 dB point can be usually be rated at a lower number.

While it true that most all loudspeaker systems are used on, or just above the floor/ground, and therefore operate into a 2 π load for the bass, most measurements are traditionally taken into an anechoic or 4 π space.

Where Peavey provides 2 π information, it is usually provided in conjunction with the more traditional 4 π data, ensuring that the customer always knows the whole story.

Given all of the above information, let’s look at one example of how much a sensitivity rating can vary for the same exact speaker system.

Let’s take a speaker system that would conservatively be rated at 97 dB at 1W 1m with a 4 ohm rated impedance, on the design axis. Now if we drive it with 2.83V instead of 1W, we get an additional 3 dB of output for a rating of 100 dB, place the mic where a frequency response peak adds another couple of dB and limit the sensitivity bandwidth to 500Hz to 2 kHz , and we are up to 103 dB, measure in a half space environment, and the low end comes up and we add another couple of dB, up to 105 dB now.

The exact same speaker, but which is it? Is it 97 dB sensitivity, or is it 105 dB sensitivity? Unless the measurement conditions are fully qualified, then it is going to be hard to tell exactly how this speaker compares to one from another manufacturer, who must also fully qualify the measurement conditions.

If we were to look at a speaker system that had a “hot” tweeter, that is, the tweeter level was much greater than the output level of the woofer, then it might be possible for two different speaker systems with identical woofers to be rated at 97 dB for one, and at 107 dB or some other inflated number for the other.

Frequency Response

For specifying frequency response, we have already discussed the mic position. Then there is the matter of how the data for the curve was averaged. Very seldom are frequency response curves published in their fully raw form. Almost every manufacturer uses at least 1/3 octave averaging, and sometimes more averaging, in order to smooth out the rapid variations with frequency that all real systems tend to have. By smoothing the response curve, oftentimes an apparent extension of the frequency extremes occurs, as well as an apparent reduction in response variations.

The standard method of specifying a frequency response curve is to find the point at which the output is 3 dB down from nominal at the frequency extremes. Three dB down from nominal would be the 1/2 power point. Sometimes the -10 dB point is used, as 10 dB roughly corresponds to what humans perceive of as 1/2 or twice as loud. Obviously, it will be difficult, if not impossible, to directly compare a speaker system that is rated for frequency response using -3 dB points to one using -10 dB points.

EXAMPLE 3: Brand J spec sheets almost all use the -10 dB point as the frequency response defining limits. This makes their speakers seem to have a wider frequency range when compared to a manufacturer such as Peavey, which uses -3 dB points. (However, we do supply the -10 dB LF points as well.)

The allowable tolerance of the speakers response within the band defined by those points at the frequency extremes is also not always the same. Some manufacturers use +/- 10 dB, or +/- 5 dB. These wider tolerances allow for a much wider variation in the relative levels across the entire frequency range covered by the speaker system, with the potential for the sound to be rougher and more ragged than a system specified using a +/- 3 dB tolerance window.

EXAMPLE 4: Brand F rates it's PA speaker line at +/- 6 dB tolerance, and implies that the specified frequency response range is at the - 6 dB points. The variation possible across the range is a total of 12 dB !

What if the numbers are given without any qualifiers or dimensions?
Just 99 dB. Just 30 Hz to 25 kHz. Or even just 99 for sensitivity.
Unqualified numbers have no meaning. If a specification is given without enough information to properly define it, there is no way to know what the manufacturer actually is saying. Usually this is done because the properly defined information would not look very impressive. For frequency response ranges, if the speaker makes any sound at that frequency, no matter how weak or low level, then it could be said to "respond" to that frequency, hence the 2" multimedia speakers with "30 Hz to 20 kHz" specified as the frequency response !

EXAMPLE 5: Brand A provides no qualifiers or conditions under which their speaker's sensitivity was measured. How sensitive are they? Who really knows? Brand S and Brand Y do not fully qualify the conditions that the "frequency range" is specified under, no tolerances, no +/- dB points. They could be +/- 20 dB! You can't assume that it is +/- 3dB, in fact, if the tolerance information is not given, then it is usually safe to assume that some tolerances wider than +/- 3dB were used!

Power Handling

There are many different approaches to rating power handling. The difficult part is trying to compare a speaker rated one way with one rated using a different method. Many manufacturer's provide only a program or peak power rating, with no qualifying conditions specified, and some do not even say what the power rating method is, but just state: "Power handling of 600W".
Is this continuous? Program? Peak? We don't know, and as noted before, if no conditions or qualifying specifications are provided, then it is likely that the condition that provides the highest number is what was used.

The most consistent method of rating power handling is a continuous power rating. However, there are several different ways of arriving at a continuous power handling rating.

Continuous Signal Test Methods: Continuous Sine Wave
The simplest method is the continuous sine wave method. A sine wave is played at a given frequency, usually 1 kHz or 400 Hz, at an input level calculated to generate the rated power into the nominal impedance of the speaker system. There is no standardized length of time to test the speaker system with this method. With a single tone at such a frequency, there will be little mechanical stress on the speaker system. If the tone is at 400 Hz, there will be no stress at all on the tweeter in a two way system. With a crest factor (crest factor = Peak levels divided by the RMS levels) of 3 dB, a sine wave tone is not very demanding of the speaker system. As you can see, the continuous sine wave method doesn't relate well to the world of PA usage.

EIA RS-426A
Another attempt to provide a power rating that relates to real world usage was defined years ago (1980) by the Electronics Industries Association, Standard RS-426A. It's predecessor was the IEC Standard 268-5 (1972), which is still referred to by some manufacturers today. RS-426A consists of a white noise source filtered with 1st order filters set to roll-off corners of approximately 40 Hz and 320 Hz. With the natural 3 dB/octave upward slope of white noise, use of these filter frequencies mean that the highs are then falling off at approximately 3 dB/octave above 1.6 kHz, and the lows are rolling off at a rate of 9 dB/octave below approximately 90 Hz. This gives maximum output at approximately 320 Hz, and

20 Hz is down about 13 dB, and 20 kHz is down about 12 dB. This filtered signal is then peak limited to a 6 dB crest factor. The specified test duration is 8 hours.

While it is a broader band signal, with a larger crest factor, it still doesn't stress a loudspeaker system quite as much as live music does. Extreme low and high frequency stress is absent, making it an easier test than live music, one that is particularly easy on tweeters, and doesn't stress a woofer that much, and certainly not providing much stress on a subwoofer.

AES Standard 2-1984
The AES published a recommended AES Standard 2-1984 for power handling rating of separate components (woofers and compression drivers), that is bandlimited to more accurately reflect each components typical use. It uses pink noise that has been peak limited to a 6 dB crest factor. The test duration is specified at 2 hours. The power into the speaker under test is based on the minimum impedance of that speaker within the speaker's operating bandwidth, and the drive level is based upon that minimum impedance.

Peavey has adopted a wide-range noise signal version of this test to rate all of our full-range sound reinforcement speaker systems. Instead of bandlimiting the signal to a decade, as for woofers, the signal is bandlimited to the audio band, 20 Hz to 20 kHz, using a 2nd order Bessel filter in order to avoid transient overshoot at the frequency extremes. The combination of audio-band signal and industry standard drive levels for a given power rating mean that the power rating will be closer to most competitive ratings.

Because the noise signal is pink noise (equal energy per octave band) instead of white noise (equal energy for equal linear frequency increments), the low frequency content is very strong, and provides a good test for the woofer or subwoofer. And because the pink noise is not bandlimited until the audio band extremes, the high frequency content is strong, but not unreasonably high.

Intermittent Signal Test Methods: Program Material
Program (or music) power handling ratings are typically derived from the continuous power handling rating, with the continuous rating being doubled (3 dB) to give the program rating. Depending on which test method was used to determine the continuous rating, this procedure is usually a safe bet. For test methods that use a signal with crest factor of 6 dB, the speaker has already been tested to peaks 4 times the continuous level.

Live music itself, when used as a test signal, is highly variable, without a defined frequency content, and a very high crest factor, typically 15-20 dB or more. This is very stressful mechanically to the speaker system, especially if the amplifier is not constantly driven into overload or compression. All Peavey speakers are lab and field tested with a wide variety of recorded and live music in order to assure that the system will provide superior performance and reliability in the real world.

Peak Power Ratings
Some types of peak power ratings have already been mentioned, but there is no guarantee that each manufacturer will specify peak power handling in a similar manner. Using the peak power level that the continuous tests achieve is one valid approach, but remember that the different test methods stress the speaker system differently, and the peak power the speaker actually experiences during such a test may only occur in a defined band of frequencies (such as with RS-426A).

Another type of peak power rating uses pulses or tone bursts to reach very high signal levels for a brief amount of time. Impulses are commonly used for FFT measurements, so this type of test signal is readily available. However, the crest factor is atypically high, a single wideband impulse (Red Book CD data) calculated over a time period of 1 minute has a crest factor in excess of 60 dB! If you run a series of impulses, one after the other, you can raise the level of the RMS factor, but this type of test signal is very hard on tweeters, and not very hard on woofers.

Shaped tone bursts are very useful, allowing the designer to hone in on specific frequency ranges more readily. The tone burst is shaped to help restrict the energy to a limited band, typically 1/3 octave wide. If an unshaped tone burst were used, the "sharp edges" of the start and stop of the toneburst act like the edges of an impulse or square wave, containing many high frequency components, and spreading the energy content of the toneburst out over more than 1/3 of an octave.

When comparing power handling specs, always make sure that you are comparing continuous to continuous, or program to program, etc., because of the 3 dB difference in level. If no qualifier is provided, it is pretty safe to assume that the power handling number is at least for program power, and may even be for the peak power handling.

Conclusion

When comparing loudspeaker specifications, all the numbers need to be stated under the same conditions, if they are not for the same conditions, this can throw the numbers off by more than 10 dB for sensitivity, by 1/3 to ½ an octave for frequency response, or by 3 to 6 dB or more for power handling.