TECHTALK: Target SPL and Required Amplifier Size

Understanding the driving signal to make an educated guess. ***by Charlie Hughes***

IN A PREVIOUS ARTICLE ("Loudspeaker Sensitivity," Live Sound International, December 2009), I examined the topic of loudspeaker sensitivity and how it may or may not relate to the overall sound pressure level (SPL) produced by a loudspeaker. One of the conclusions of that article is that the SPL produced will be dependent on the spectral content of the signal driving the loudspeaker. Thus, having knowledge of the driving signal (i.e., program material) or being able to make an educated assumption about it may aid in the design of a loudspeaker or sound reinforcement system so that the required bandwidth and SPL is delivered to the audience. The output capability of the amplifier driving the loudspeaker is of equal importance to achieving the target SPL from the direct field of a loudspeaker. This can also be related to the driving signal or the intended program material.

Pat Brown authored a very interesting and enlightening article ("Loudspeaker Toaster," Syn-Aud-Con Newsletter, Vol. 34, No. 1, Winter 2006) on testing loudspeakers to determine what I refer to as their maximum usable continuous output SPL. While a loudspeaker may be capable of producing greater continuous SPL, it is accompanied by significant changes (greater than 3 dB) in the transfer function (frequency response) of the loudspeaker. For most applications this is undesirable and thus deemed not usable.

This "toaster test" primarily focuses on the thermal effects the input signal has on the loudspeaker system; the individual driver's voice coils, the resultant impedance increase, and the passive crossover components (if present). The result of the toaster test yields a maximum RMS voltage (max Vrms) that can be applied to the loudspeaker without driving it past this Maximum Usable Continuous Output SPL (SPLMUCO). This max Vrms may then be used to calculate an Equivalent Amplifier Size, which can deliver the max Vrms when driven by this same test signal. This signal, by the way, is specified by the standard IEC 60268. It is a broadband, shaped noise signal with a spectral content that is the average of a variety of program material, including both speech and several different types of music. This test signal has a crest factor of 6 dB.

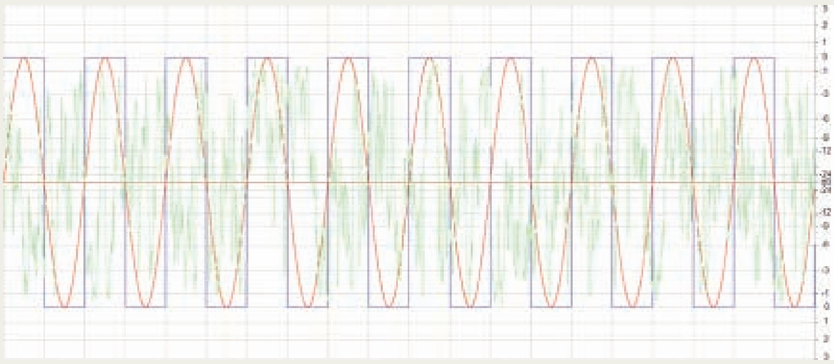

Figure 1 – Square wave (blue), sine wave (red), and IEC268 noise (green) all with the same peak level, 0 dB.

To get the most out of the rest of the article, we need to understand crest factor, so let's briefly explain it. The crest factor of a signal is simply the difference between the RMS level and the peak level of the signal. A square wave has a crest factor of 0 dB; it has the same RMS level as its peak level. A sine wave has a crest factor is 3 dB, that is its RMS level is 3 dB less than its peak level. For more complex waveforms the crest factor may be different, and is usually higher. Many waveform editing programs have analysis capabilities that will calculate the RMS and peak levels of an entire .wav file or a selected segment. In **Figure 1** we see 100 ms segments of a 100 Hz square wave, a 100 Hz sine wave, and IEC60268 noise. All of the signals shown here have been normalized to have a peak level of 0 dB.

Now that we understand crest factor, we can use the results of the toaster test performed on a particular loudspeaker to help determine the required amplifier size for our sound reinforcement system design. Differences between the spectral content of our program material and that of the signal used for the toaster test to determine max Vrms may lead to inaccuracies in our results. However, as long as these spectral differences are not dramatic, the results should be reasonably valid. Alternatively, one may carry out a toaster test using a test signal having a spectral content more closely resembling the intended program material for the application at hand.

For our application, the program material to be reproduced by our loudspeaker system will be live speech or music with little or no compression (amplitude compression, not data compression). This should give us a relatively broadband signal very similar to the IEC 60268 specified noise signal. However, our signal will have a crest factor of approximately 15 dB. A time domain comparison of this type of signal to the IEC268 noise and a sine wave is shown in **Figure 2**. Here again the peak level of all three signals is 0 dB. It should be easy to see that the RMS level of this new speech signal is much less than the noise.

The loudspeaker we have selected to use has a reasonably flat frequency response from 50 Hz-12 kHz and a sensitivity of 98 dB referenced to 2.83 Vrms at 1 m. At a distance of 10 m this loudspeaker will reproduce the IEC268

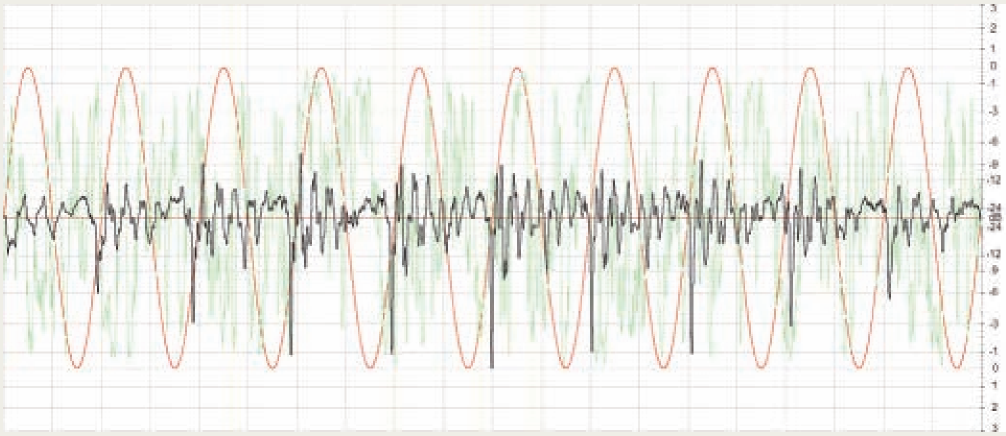

Figure 2 – Sine wave (red), IEC268 noise (green), and speech (black) all with the same peak level, 0 dB.

noise at 78 dB SPL when driven with an input of 2.83 Vrms. We measure this at 10 m to assure that we are in the far-field for this loudspeaker. It will also reproduce our speech signal at 78 dB SPL at 10 m when driven with an input of 2.83 Vrms. The reason the measured SPL is the same for both signals is that the RMS input voltage is the same. SPL measured with a slow integration time, as we are referencing here, will correspond well with the RMS value of the input voltage. This is why an RMS meter on a mixing console may be used as a fairly good indicator of SPL once it has been referenced to a particular SPL. Of course at high input voltage levels the output of the loudspeaker may not remain completely linear and some power compression may occur.

When each of these signals is at the same RMS level, as described above with the input to the loudspeaker, their peak levels will be different. This is shown in **Figure 3**. Here the RMS level of each signal is the same. Now we can see that to cleanly pass the speech signal without clipping we will need a much larger amplifier than required to pass the IEC268 noise cleanly; but exactly how large?

The sound system design requirements dictate that our loudspeaker needs to produce approximately 88 dB SPL at 20 m with our speech program material. At half this distance, 10 m, this equates to 94 dB. We know the loudspeaker will produce 78 dB at 10 m when driven with 2.83 Vrms. We need an additional 16 dB, or 17.9 Vrms, to reach 94 dB SPL at 10 m. This loudspeaker has a rated maximum input of 32 Vrms as determined by the toaster test. This gives us 21 dB of gain relative to 2.83 Vrms without the thermal limitations of the loudspeaker causing its response to change by more than 3 dB. This tells us our loudspeaker can produce the SPL required. In fact, it can be driven 5 dB harder. This is a good thing as thus far we have not accounted for any power compression that may occur.

Because the toaster test limits the response change of the loudspeaker to no more than 3 dB, we are assured that this is the maximum SPL reduction that will be encountered. It is much more likely that this 3 dB variation will occur not over the entire frequency range of the loudspeaker, but instead over a limited bandwidth. This being the case our overall SPL reduction will typically be much less. If we know the SPLMUCO of the loudspeaker when driven at max Vrms then we can calculate the resulting reduction in SPL due to the thermal effects. Including this data on the loud-

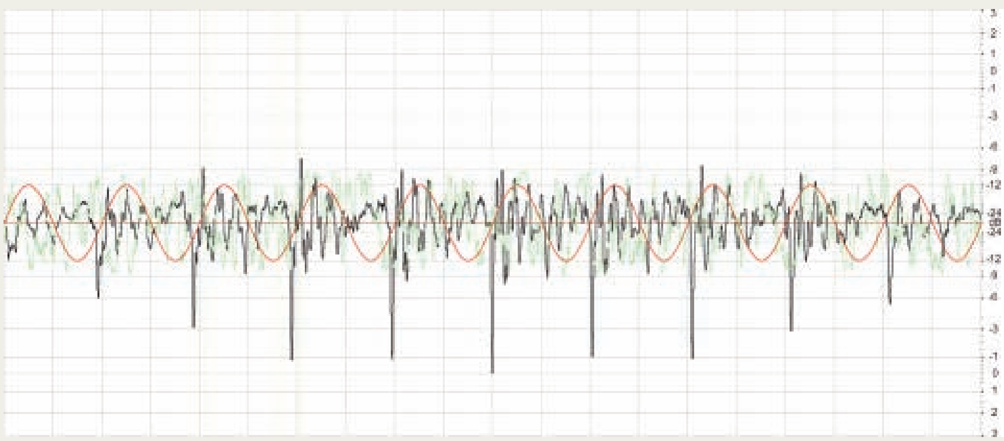

Figure 3 – Sine wave (red), IEC268 noise (green), and speech (black) all with the same RMS level, -15 dB.