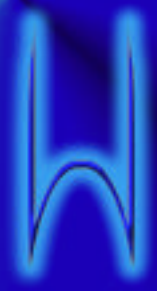

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Sound IS the Experience !™

"DIGITAL" SUBWOOFERS

BY

JOHN F. ALLEN

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"DIGITAL" SUBWOOFERS

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Ever since subwoofers began being used in modern theatre sound systems, the questions of required amplifier input power as well as acoustic output power have been discussed and often misunderstood. The amplifier power required for any loudspeaker depends simply on how loud one wants it to play at some distance, and the sensitivity of the speaker itself. Sensitivity is a measure of a speaker's loudness with, typically, a one watt input. The louder you wish a speaker to play or the greater the distance you wish to hear the desired level, the greater the amplifier and acoustic power you will need. As a loudspeaker's sensitivity is increased, the less amplifier power it requires for any given output level. These issues are, by themselves, fairly fundamental.

The peak program sound levels required of the speakers in a motion picture sound system are now fairly well established. For digital systems, these are 105 dB Sound Pressure Level (SPL) for each channel as measured in the center of the theatre. For these purposes, the surrounds are considered as a total group. In other words, the individual left and right groups in a stereo surround system are each required to deliver half (-3 dB) of the total surround power, or 102 dB SPL. Recent guidelines published by Dolby Laboratories call for a subwoofer peak level of 115 dB SPL. I have personally measured peaks of this level and greater in several digital soundtracks.

It's important to understand that the peak levels are one thing and the average levels are quite another. We would never listen to continuous levels as high as 100 dB, let alone 115 dB. Average levels are considerably lower. For instance the average dialog level is recorded around 80 dB, with peaks around 85 dB. However, short duration peaks of 115 to 120 dB SPL are perfectly acceptable in normal music and sound, particularly in the bass region. It takes these levels to "feel it." Without such peaks, there would be no such thing as dynamic range.

POWER BASICS

A prudent sound system designer would *NEVER* design a sound system with the exact power needed to deliver the peak levels. Operating amplifiers above their maximum or "clipping" levels causes gross distortion, speaker destruction and reduced amplifier life. An additional safety margin, or headroom, of some amount is required to prevent any of this from happening. Since motion picture recordings and their peak levels are reasonably standardized, a safety margin of as little as 6 to 8 dB would seem adequate.

This may not represent a large difference in level. But since every increase of 3 dB is a doubling of power, 6 dB is four times the power. This can get very expensive. Adding such a safety margin to the 105 dB program peak levels yields a design specification of 111 to 113 dB SPL per channel.

As mentioned above, the amount of amplifier power needed to do this depends on the size of the theatre and the sensitivity of the loudspeakers. Consider two theatres; one is 80 feet long, the other is 100 feet long. If one is using a modern two-way screen speaker, the power required to reach 111 dB in the middle of the 80 foot theatre is about 1871 watts. The 100 foot theatre would require 2924 watts. This assumes a one-watt/one meter speaker sensitivity of 100 dB SPL which is typical for these systems. (Though only 25 percent longer, the 100 foot long theatre needs more than 50 percent more power due to the fact that sound levels decrease with the square of the distance, according to the inverse square law). Such power is usually obtained with the use of multiple low frequency cabinets and two or three amplifiers per speaker wired for bi-amplification. If one chooses to install the more efficient three-way or four-way screen speakers, the amplifier power required becomes 250 watts for an 80 foot long theatre and 390 watts for the 100 foot theatre. This lower power requirement assumes a greater one-watt/one-meter speaker sensitivity of 109 dB SPL, which is typical of these more efficient systems. This relatively small power requirement will not require bi-amplification, provided each of the speaker's sections has the same high sensitivity and the crossover network is well designed.

SUBWOOFER SENSITIVITY

Subwoofers can be the least sensitive of screen speakers. One-watt/one-meter sensitivities of 95 dB SPL are encountered. This sensitivity is comparable to that of a small home HI FI speaker, yet these subwoofers must deliver low frequency peaks of 115 dB SPL in a room the size of a theatre. Adding a 6 dB or so safety margin the subwoofer channel provides exactly the same sound quality and reliability benefits as with any other speaker. This totals a minimum design requirement of 121 dB SPL in the center of the room for the subwoofer channel.

Assuming a speaker sensitivity of 95 dB, calculating the amplifier power required for one subwoofer to deliver 121 dB SPL in the middle of an 80 foot long theatre yields a need for 59,177 watts. The 100 foot long theatre will need over 92,463 watts. As a comparison, the high efficiency woofers with a sensitivity of 109 dB will reduce the amplifier power requirement to "just" 2,512 watts in an 80 foot theatre and 3,925 in a 100 foot theatre. These impossible power needs are the reasons multiple subwoofers are required in movie theatres.

SELF PROTECTION

Many subwoofers, whether intended for the professional or consumer market, are available in a self-powered package. For the less efficient direct radiator type subwoofer designs, this approach offers many advantages. As shown above, subwoofers can be voracious power eaters. Without some protective means these speakers would self destruct very quickly. Manufacturers have built in various schemes to protect these subwoofers such as increased sensitivity, signal limiting, current limiting and peak excursion limiting. Excursion limiting prevents the speaker cones from being forced out of their frames by high level low frequencies. This problem is made more acute by the fact that in order to maintain a constant output level, a loudspeaker cone must move a four times greater distance, as the frequency it's asked to reproduce is cut in half. One self-protection approach has been to literally "turn down the bass" as levels increase. The louder the bass gets in these systems, the more the lowest frequencies are reduced. In other words such self-powered devices should not be able to hurt themselves, even though failures do occur. This also means that they can only deliver so much output and that's it. As more signal may be applied, like an engine with a governor, they just stay at their maximum. Since bass is the name of the game and since delivering deep bass requires very high sound pressure levels, turning down the bass as we approach these very levels is the last thing we need.

HOW MANY SUBWOOFERS ARE REQUIRED?

Obviously, one must install enough subwoofers so that limiting and bass reduction is minimized or, even better, eliminated altogether. Only a system of multiple subwoofers that never limits, can accurately and fully reproduce the levels which are recorded on digital soundtracks. To determine the number of self-powered type subwoofers a theatre needs, one must find the maximum output capability in the speaker's specification sheet. If it says 130 dB at one meter, for example, we can use the inverse square law to determine what that level would be reduced to in the center of a theatre. For each doubling of distance, the sound pressure level drops 6 dB. Recalling our 80 foot theatre, 130 dB at 1 meter calculates to 108.28 dB SPL at the room's center, 40 feet from the source. Since we need 115 dB to play the soundtracks and would like to have 121 dB total capability, a maximum output of 108.28 is 12.72 dB too low.

Fortunately at low frequencies, we benefit from a phenomenon known as mutual coupling. Placing two woofers close enough together increases their combined sensitivity by 3 dB. Factoring in the additional amplifier included in the second woofer, means the total power has doubled as well. This power doubling provides another 3 dB for a total of 6 dB, or four times the power from two times the subwoofers. It's a case where one and one equals 4. So each time one doubles the number of subwoofers and their amplifiers, one

gains 6 dB of output.

If the 80 foot theatre requires 12.72 dB more than what is available form one unit, we simply double the number of subwoofers twice to get 12 dB. Therefore, a total of four subwoofers with an individual output maximum of 130 dB SPL are required to deliver about 121 dB SPL in the middle of an 80 foot long theatre. A 100 foot theatre would require six such subwoofers. Reducing these quantities by half, or 6 dB, theoretically still provides the 115 dB peak program level required. But such systems will be self-limiting when they are asked to work so hard and may be prone to failure. The sound quality, of course, will suffer as well and the audience will be deprived of the full experience of the film.

Even a couple of decibels can mean a lot. If the self powered subwoofer's maximum output was reduced only 2 dB to 128 dB SPL, an 80 foot long theatre would need six such units. The 100 foot theatre would require seven.

Since non-powered woofers require outboard power, we generally use the biggest reliable amplifiers we can get. If, for example, we assume an 1800 watt amplifier and a subwoofer with a sensitivity of 95 dB, crunching the numbers gives us the following: Our 80 foot theatre will need six of these combinations. The 100 foot theatre will need eight.

It is also recommended that each subwoofer or dedicated subwoofer amplifier in a motion picture theatre sound system should have its own single outlet AC circuit.

Increasing speaker efficiency significantly reduces the hardware needed. In choosing a woofer with a 109 dB SPL sensitivity as an example, the 80 feet theatre would need two woofers and one 600 watt stereo amplifiers to deliver 121 dB SPL in the middle of the theatre. The 100 foot theatre would still need two woofers with a power requirement of two 1000 watt amplifiers.

In the proper quantities, all the self-powered, non-powered and high efficiency subwoofer approaches can deliver the same peak levels, though there are some substantial cost differences. In addition, there are space, weight and AC power considerations as well. All these factors must be taken into account when designing a theatre sound system. One factor remains constant: Without sufficient acoustic power output and the additional headroom required for reliability and an easier work load, motion picture subwoofer performance will fail to deliver the quality, quantity, punch and emotional impact the soundtracks contain.

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