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Determining Speaker Power Requirements for the Integrator

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INTRODUCTION

In this paper, we will discuss how to use simple "rule-of-thumb" formulas to determine how much power is required for a loudspeaker to produce the required sound pressure level (SPL) for a typical distributed speaker system design.

One of the most often asked questions that Lowell Manufacturing receives from customers, is "What power tap should I use on my speaker transformer?" Whether you are using an 8 ohm voice coil speaker, or a speaker with a 25V, 70V, or 100V matching transformer, the method to determining how much power that loudspeaker needs for a particular application is still the same (as long as the insertion loss of the transformer is negligible).

RULE-OF-THUMB

In order for the sound from a speaker system to be heard and understood, the sound pressure level (SPL) that a speaker system must be able to achieve is a **minimum of 10dBSPL over the average ambient noise level**.

Notice this rule of thumb states **minimum of 10dBSPL.** Many designers prefer to use 15dB over the ambient noise level so there is plenty of headroom in their sound system to handle changing conditions. For the purpose of this paper, we will use the 10dBSPL design criteria.

So for the integrator that wants to design a sound system, how do you know what the ambient noise level is?

Method 1: Simply stated, if the sound system is being designed for an existing building where the acoustic environment and background noise conditions already exist, take a sound pressure meter to the site and take multiple readings at the listening height during a typical day and use the average of those readings as your average ambient noise level. *Note: Your sound pressure meter should be set on the A-Weighted scale. A properly designed distributed speaker system must be able to achieve a minimum of 10dBSPL above that average ambient noise level.*

Method 2: If the building is under construction, or if the inhabitants have not moved into the building yet, then an educated guess is required. The chart below gives some design guidelines for "Maximum Sound Pressure Levels Required for Adequate Sound System Performance." Note that this table includes the 10dBSPL above the average ambient noise level. Some judgement on your part will be required to adjust your target SPL design level depending upon your particular application, so SPL ranges are given. If your sound system design can achieve greater than these SPL levels, you can be even more confident that your customer will be satisfied with the performance of the system that you have designed.

<table>
<tr><th colspan="3">Rule of Thumb Maximum SPL Level Required for Adequate Sound System Performance
(in selected venues assuming typical background noise levels)</th></tr>
<tr><th>Venue</th><th>Application Type</th><th>SPL in dB</th></tr>
<tr><td rowspan="3">Church</td><td>Speech reinforcement only.</td><td>80-85</td></tr>
<tr><td>Speech reinforcement with moderate-level worship music.</td><td>85-95</td></tr>
<tr><td>Speech reinforcement with higher-level rock contemporary music.</td><td>95-100</td></tr>
<tr><td rowspan="2">Auditorium</td><td>Speech reinforcement only.</td><td>80-90</td></tr>
<tr><td>Speech reinforcement with contemporary music (not rock concert).</td><td>90-100</td></tr>
<tr><td rowspan="2">Factory</td><td>Quiet factory - speech reinforcement only.</td><td>80-90</td></tr>
<tr><td>Loud factory - speech reinforcement only (Note: Osha may limit SPL).</td><td>10dB over average ambient noise</td></tr>
<tr><td rowspan="2">Office</td><td>Quiet office – speech and music - no sound masking.</td><td>55-60</td></tr>
<tr><td>Quiet office – speech and music - with sound masking.</td><td>60-65</td></tr>
<tr><td rowspan="4">Club
Or
Lounge</td><td>Quiet background entertainment, ex. vocalist with piano or guitar.</td><td>75-85</td></tr>
<tr><td>Louder background entertainment, ex. small band.</td><td>85-95</td></tr>
<tr><td>Recorded loud rock foreground dance music.</td><td>90-105</td></tr>
<tr><td>Very loud rock band (less than typical concert level of 110-120dBA)</td><td>100-110</td></tr>
<tr><td>Gymnasium
Arena or
Stadium</td><td>Cheering sports crowd.
SPL depends on the size of the crowd (and the score in the game).
Loud crowd cheer may exceed the capability of any sound system.</td><td>100-110</td></tr>
</table>

SENSITIVITY SPECIFICATIONS

Manufacturers (including Lowell) give the average sensitivity of a speaker driver or a complete speaker system on their specification sheets. *Note: Never use a sensitivity that is stated as "peak sensitivity." That is a meaningless specification that describes the sensitivity at only one frequency. Always use the average sensitivity specification.*

The average sensitivity specification is typically given measured with a 1W input to the speaker and with the measurement microphone at 1 meter directly on-axis (directly in front of the speaker). In reality though, you are interested in the sound pressure level at some distance greater than 1M. That calculation requires the use of the "Inverse-Square Law."

The Inverse-Square Law is based on the fact that a sound wave emitted by a loudspeaker travels as a sphere away from the loudspeaker. The formula for the area of a sphere is $4\pi r^2$. That means that as the distance from the speaker (the radius "r") doubles, the area of the sphere that the sound from the speaker has to cover is 4 times as large because the radius term in the formula is squared.

In the formula for sound pressure level, the sound energy from the speaker is divided by the area of the sphere to find the SPL at a certain point. Note that if X = Y/Z, that is the same mathematically as X = 1/Z times Y. In math terms, 1/Z is called the inverse. In the sound pressure level formula, the sphere area $4\pi r^2$ is in the denominator of the formula, so that is mathematically the same as an inverse. In other words, the squared radius term is an inverse in the SPL formula and that's where the Inverse-Square Law gets its name.

Inverse-Square Law: $SPL_2 = SPL_1 - 20 \log (D_2/D_1)$

- SPL_1 is the sound pressure level at the first location.
- SPL_2 is the sound pressure level at the second location.
- D_1 is the distance from the speaker at the first location.
- D_2 is the distance from the speaker at the second location.

The Inverse-Square Law says that every time you double the distance from the speaker, the sound pressure level decreases by 6.02dB (most sound guys just round that off to 6dB).

Because sensitivity specifications are given in metric at 1 meter, an inexpensive metric conversion calculator is a must for any sound system designer.

The Inverse-Square Law formula can be simplified even further for use in SPL calculations for speaker sensitivity.

D_1 in the formula above will be 1 meter since sensitivity specs are given at 1 meter, so it does not affect the formula.

$SPL_{(1\ watt\ input)} = S - 20 \log (D)$

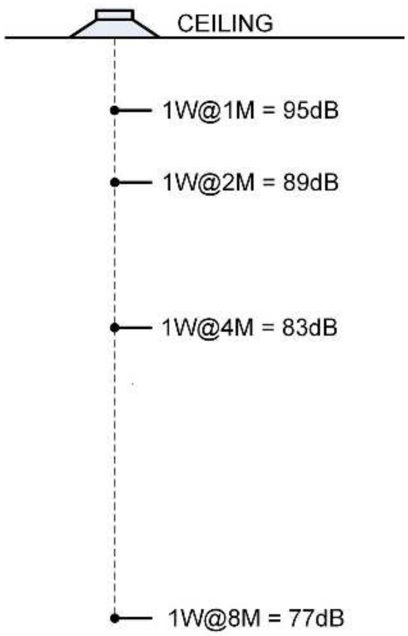
- SPL is the SPL at the listening height with 1 watt input to the speaker.
- S is the manufacturer's specified average sensitivity with 1 watt input at 1 meter.
- D is the distance from the speaker *in meters* to the average listening height.

EXAMPLES

Example 1: The average sensitivity of a speaker is given on the specification sheet as 95dB 1W 1M. My speaker will be mounted 4 meters above the 4' average seated listening height.

SPL = 95dB – 20LOG(4 meters) = 83dB

The sound pressure level at the 4' listening height will be 83dB with 1W input to the speaker as shown in the detail below:



So what if we adjust the input power to more than 1W? The formula for SPL as is relates to input power is:

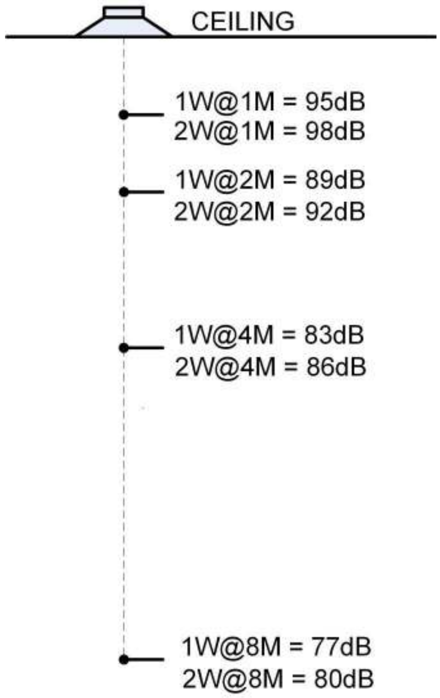
$SPL_{(at\ 1\ meter)}$ = S + 10LOG (P)

- SPL is the SPL at 1 meter.
- S is the manufacturer's specified average sensitivity at 1 watt 1 meter.
- P is the input power to the speaker.

Example 2: The average sensitivity of a speaker is given on the specification sheet as 95dB 1W 1M. My speaker will be mounted 1 meter above the 4' average seated listening height, but the speaker will be tapped at 2 watts.

$SPL_{(at\ 1\ meter)}$ = 95dB + 10LOG(2W) = 98dB

The sound pressure level at the 4' listening height will be 98dB with 2W input to the speaker (as shown in the following illustration).



These formulas can be combined so that both input power and distance calculations can be done at the same time. This formula handles any power input at any distance.

SPL = S + 10LOG (P) - 20LOG(D)

- SPL is the resulting SPL at the listening height.
- S is the manufacturer's specified average sensitivity with 1 watt input at 1 meter.
- P is the input power to the speaker.
- D is the distance from the speaker to the average listening height.
- *Note: Seated listening height = 4' (1.2192M) and standing listening height = 5' (1.524M)*

You may have heard sound guys using the old rule of thumb:

- Double the input power adds 3dB to the SPL.
- Double the distance from the speaker lose (subtract) 6dB from the SPL.

Let's see if that rule of thumb works out in the following example.

Example 3: Speaker is mounted 4M above the average listening height. The speaker transformer is tapped at 4W. The speaker sensitivity is given on the specification sheet as 92dB 1W 1M.

Using the formula: SPL = S + 10LOG(P) - 20LOG(D) = 92 + 10LOG(4W) – 20LOG(4M) = 86dB
Using the rule-of-thumb: 92dB(1W1M) 95dB(2W1M) 98dB(4W1M) 92dB(4W2M) 86dB(4W4M)

Same result!

So far we've talked about the input taps of transformers (notice that we've ignored transformer insertion loss). What if your design includes an 8 ohm speaker without a transformer? All of the formulas work the same as illustrated in the following example.

Example 4: Design is for a convention center distributed sound system. The speaker is mounted 44' above the floor. The design assumes a seated average listening height of 4'. Distance from the speaker to the average listening height is 40'. I use my handy metric conversion calculator and determine 40' = 12.192 meters. The speaker has a maximum input power of 250W. The speaker sensitivity is given on the specification sheet as 98dB 1W 1M.

Using the formula: SPL= S+10LOG(P) – 20LOG(D) = 98 + 10LOG(250W) – 20LOG(12.192M) = 100.26dB

So with the system delivering the maximum 250W to this speaker, there will be 100.26dB of sound pressure level at the 4' average listening height.

SUMMARY

Calculating the expected sound pressure at the average listening height simply requires the average sensitivity from the manufacturer's specification sheet, the proposed input power to the speaker, and the distance from the speaker to the listening height (in meters). Plugging those figures into the formula gives the resulting SPL.