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# POWERING UP FOR DIGITAL

BY

JOHN F. ALLEN

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# POWERING UP FOR DIGITAL

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**Now that digital stereo motion pictures are in regular production and exhibition, the subject of the needed amplifier power is, once again, being discussed. Determining the exact amount of power a theatre speaker requires to play "X" loud at a distance "Y", is easy. See tables 2 and 3. Understanding the issue and the sometimes confusing equipment data is more complicated.**

## BASICS REVIEWED

**Loudspeakers are rated in several ways. Sensitivity is one of the most important. It tells us the sound output level of the speaker at a given distance, with a given input - usually 1 watt.**

**The Inverse Square Law states that the sound level will drop by a factor of four (-6 dB), at each doubling of distance from the source. This also means that the sound level will drop -20 dB at each ten times distance. Recognizing the way the Inverse Square Law works simplifies questions of needed power because the reverberation of the room is not part of the calculation. This is the best approach since the sound from a speaker which arrives at our ears first is, for practical purposes, free of the room's reverberation.**

**Consider a speaker with a 1 watt / 4 foot sensitivity of 100 dB Sound Pressure Level (SPL). At 8 feet from the speaker, with a 1 watt input, the level will drop to 94 dB SPL. At 16 feet, the level will drop to 88 dB SPL. At 32 feet, the level will be 82 dB SPL. At 40 feet, the level will be 80 dB SPL. At this point, we would be in the middle of an 80 foot long theatre. The center of a theatre is a good place to specify a peak program level (per channel).**

**Using the Inverse Square Law and keeping our calculations in decibels makes life easy. No matter if you are working in power, voltage or pressure, a decibel is a decibel. By simply subtracting the 1 watt level calculated for the center of the theatre from the peak program level, we learn, in decibels, the amplifier watts required. This is designated as dBw.**

**The digital peak program level for theatres is 105 dB SPL per channel, including both of the surrounds taken together. In the center of an 80 foot theatre, 105 dB - 80 dB = 25 dB. Using the dBW conversion table 1, we see that 25 dBW is 316 watts.**

**dBW AMPLIFIER POWER IN WATTS**

| dBW | WATTS | dBW | WATTS |
|---|---|---|---|
| 20 | 100 | 30 | 1000 |
| 21 | 126 | 31 | 1259 |
| 22 | 158 | 32 | 1586 |
| 23 | 200 | 33 | 2000 |
| 24 | 251 | 34 | 2516 |
| 25 | 316 | 35 | 3162 |
| 26 | 400 | 36 | 4000 |
| 27 | 501 | 37 | 5012 |
| 28 | 631 | 38 | 6310 |
| 29 | 794 | 39 | 7943 |
| | | 40 | 10000 |

**Table 1**

## LET'S NOT BE FOOLISH

Were we to connect a 316 watt amplifier to a 100 dB (1 watt / 4 feet) speaker, we would have a direct sound level (first arrival, before reverberation) of 105 dB SPL at 40 feet, when the amplifier runs out of power and clips. Clearly this would be a foolish design practice as no amplifier should be run at clipping levels. A safety margin of some additional power is required so that the amplifier never clips. This protects both the amplifier and the speakers from the damage and ultimate failure caused by repeated clipping.

How much this margin should be is up to the sound system designer. However, 6 dB (about the difference in raising your voice) would seem to be a minimal safety margin. This brings the amplifier clipping level for digital stereo up to 111 dB SPL in the center of a theatre. Returning to our 80 foot theatre, 6 dB above the program peak totals 31 dBW (25 + 6 = 31 dBW). Table 1 shows that we now need 1259 watts, or four times more power as each 3 dB increase doubles the power. If a larger speaker is installed and its sensitivity is just 3 dB greater, or 103 dB SPL, the power required is reduced to 631 watts, or half that demanded by the 100 dB speaker.

It becomes obvious that an understanding of loudspeaker sensitivity is critical to sound system design and determining amplifier needs. Unfortunately, manufacturers don't always make it easy. For one thing, in the specification wars, the bigger numbers win. The greater the sensitivity number, the better. Since 1 meter is closer to a speaker than 4 feet,

**specifying the sensitivity at 1 meter yields a number 1.72 dB greater, (2 dB in round numbers). Therefore, most speakers today are rated at 1 meter.**

**The speaker which yields 100 dB SPL at 4 feet, yields 101.72 dB SPL at 1 meter. 40 Feet is 12.19 meters. The Inverse Square Law shows a level drop of 21.72 dB at 12.19 meters.**

$$101.72 - 21.72 = 80$$

$$111 - 80 = 31 \text{ dBW or } 1259 \text{ watts.}$$

**So we can work in either the standard or metric system. But since we usually work in feet and not meters, we must deduct 1.72 dB SPL from 1 meter speaker sensitivity specifications to determine the 1 watt / 4 foot sensitivity.**

## WHEN IS A WATT A WATT

**So far, things are just a little more complicated than they need to be, but finding a speaker's 1 watt sensitivity, at any distance, has been made difficult (sometimes impossible) by some manufacturers, due to a lack of information.**

**We know that amplifier power in watts "P" is equal to the square of the output voltage, divided by the "speaker resistance" "R".**

$$P = V^2/R$$

**To get P to equal 1 watt, both values of $V^2$ and R must be equal. If we know R, then the amplifier output voltage V must be set to the square route of R to achieve 1 watt.**

$$V = R^{1/2}, \text{ when } P = 1 \text{ watt}$$

## IMPEDANCE

**With loudspeakers systems, the total resistance is made up of several things and is referred to as impedance. Here is where confusion can begin. A speaker's specification sheet may list impedance as a "nominal" 8 ohms. Since the impedance of a speaker varies with frequency, a complete impedance graph will show a large range of values. This graph is essential but is not always published. The 8 ohms often specified might only be an average, or maybe just the closest conventional number to an average. It could even mean the minimum impedance. We can't tell.**

**When designing a sound system, one should examine the loudspeaker's impedance curve very carefully. It may be found that between 250 and 500 Hertz, the impedance reaches a minimum of 4 ohms, while it may be 10 to 20 ohms at the other frequencies. The manufacturer has CHOSEN to call it an 8 ohm speaker. But which is it; 8 or 4 or something else? In this case, my recommendation is to call it a 4 ohm speaker and reduce its 8 ohm sensitivity rating by -3 dB.**

**This is because about half of the acoustic power in most program material is in the region between 250 to 500 Hertz, the so called power band. If about half of our total amplifier power will be used in this one of nine octaves, a speaker's minimum impedance in this area is of great interest.**

**In designing theatre sound systems, I recommend that a loudspeaker's minimum impedance be used, particularly if the minimum occurs in and around the power band.**

## DETERMINING TRUE SENSITIVITY

**The final area of confusion concerns the way speaker sensitivity is measured. This has changed. In the past, manufacturers clearly stated a 1 watt level at either 4 feet or 1 meter. If the speaker can justifiably be said to have an 8 ohm impedance, the amplifier must drive the speaker under test at 2.83 volts.**

$$1 \text{ watt} = 2.83^2/8 = 8/8 = 1$$

**However, if another speaker has an impedance of 4 ohms, the amplifier must drive that speaker at 2 volts to achieve a 1 watt level.**

$$1 \text{ watt} = 2^2/4 = 4/4 = 1$$

**Here's the problem: Many modern speaker impedances are recognized to be 4 ohms. If one decides to rate a 4 ohm loudspeaker and drives it with 2.83 volts (a growing practice) rather than 2 volts, the output of the speaker will be increased by 3 dB SPL.**

$$2.83^2/4 = 8/4 = 2 \text{ watts}$$

**Two watts is 3 dB more than 1. And more important, in the specification wars, a 3 dB greater sensitivity number is thought to help sell more speaker systems to those who don't read carefully.**

**So, to determine the amplifier power required for a theatre speaker, we must first determine the speaker's true 1 watt sensitivity. If the speaker's specification states a given dB SPL at 1 meter and it is an 8 ohm speaker operating with an input of 2.83 volts, use the given sensitivity figure. At 4 feet, deduct 1.72 dB SPL.**

**If a 1 watt / 1 meter rating is listed for a 4 ohm loudspeaker system operating at an input of 2 volts, then again, use the given sensitivity figure. If, however, a 2.83 volt signal is used (this is usually stated), to determine the sensitivity of a 4 ohm speaker, then deduct 3 dB. A 2.83 volt figure is, in reality, -3 dB SPL for 1 watt @ 1 meter or -4.72 dB less for 1 watt at 4 feet, with a 4 ohm speaker.**

**Failure to account for this when calculating power needs can result in an under-power error of 3 dB + 1.72 dB = 4.72 dB, which is 67 percent too low.**

**Table 2 shows the single screen speaker power requirements for digital sound systems in theatres ranging in length from 60 to 120 feet, in 5 foot increments. All sensitivity 1 meter to 4 foot conversions are included. From the theatre's length, simply find the power needed under the appropriate 1 meter speaker sensitivity column. These figures include a 6 dB safety margin. The actual digital peak program power level is found by dividing by 4.**

**Table 3 gives the surround channel total power requirement. Rather than the length of the theatre, use the width. If, however, there are (as there should be) surround speakers across the rear wall, you may use the distance from the rear wall to the front row, but ONLY if this distance is less than the width of the auditorium. If the distance from the rear wall to the front seats is greater than the width, as is typically the case, use the width figure with table 3.**

**It should be pretty clear from the tables 2 and 3 that the less sensitive speakers will be destroyed by the power levels which they would require for digital stereo in the larger theatres. Speaker sensitivity is too often taken as it comes, with little or no regard to its impact on design and performance. This has always been a faulty and naive approach to sound system design. When considering a modern digital stereo sound system, designers must select a speaker with the appropriate sensitivity and mate it to the proper amplifier power for each specific theatre.**

## POWER REQUIRED PER SCREEN SPEAKER
## IN DIGITAL SOUND SYSTEMS
## FOR A SOUND PRESSURE LEVEL OF 111 dB IN THE THEATRE'S CENTER
## AT FULL AMPLIFIER POWER (CLIPPING LEVEL)

| THEATRE | 1 WATT, 1 METER SPEAKER SENSITIVITY | | | |
|---|---|---|---|---|
| LENGTH I | 100 dB | 103 | 106 | 109 |
| 60 Feet | 1052 Watts | 527 | 264 | 132 |
| 65 | 1235 | 619 | 310 | 155 |
| 70 | 1432 | 718 | 360 | 180 |
| 75 | 1644 | 824 | 413 | 207 |
| 80 | 1871 | 938 | 470 | 236 |
| 85 | 2112 | 1058 | 530 | 266 |
| 90 | 2368 | 1187 | 595 | 298 |
| 95 | 2638 | 1322 | 663 | 332 |
| 100 | 2923 | 1465 | 734 | 368 |
| 105 | 3223 | 1615 | 809 | 406 |
| 110 | 3537 | 1773 | 888 | 445 |
| 115 | 3866 | 1937 | 971 | 487 |
| 120 | 4209 | 2110 | 1057 | 530 |

Table 2

**TOTAL POWER REQUIRED PER SURROUND ARRAY
IN DIGITAL SOUND SYSTEMS
FOR A SOUND PRESSURE LEVEL OF 111 dB IN THE THEATRE'S
CENTER AT FULL AMPLIFIER POWER (CLIPPING LEVEL)**

| THEATRE | 1 WATT, 1 METER SPEAKER SENSITIVITY | | | |
|---|---|---|---|---|
| WIDTH | 89 dB | 92 | 95 | 98 |
| 30 Feet | 3312 Watts | 1660 | 832 | 417 |
| 35 | 4508 | 2259 | 1132 | 567 |
| 40 | 5888 | 2951 | 1479 | 741 |
| 45 | 7452 | 3735 | 1872 | 938 |
| 50 | 9199 | 4611 | 2311 | 1158 |
| 55 | 11131 | 5579 | 2796 | 1401 |
| 60 | 13247 | 6639 | 3328 | 1668 |
| 65 | 15547 | 7792 | 3905 | 1957 |
| 70 | 18031 | 9037 | 4529 | 2270 |
| 75 | 20699 | 10374 | 5199 | 2606 |
| 80 | 23550 | 11803 | 5916 | 2965 |
| 85 | 26586 | 13325 | 6678 | 3347 |

**NOTE: EACH CHANNEL OF THE SURROUND ARRAY
REQUIRES HALF OF THE POWER SHOWN HERE.**

**Table 3**



***John F. Allen is the founder and president of High Performance Stereo in Newton, Mass. He is also the inventor of the HPS-4000® cinema sound system and in 1984 was the first to bring digital sound to the cinema. John Allen can be reached by E-mail at JohnFAllen@aol.com.***