

Why all the fuss about POWER?

Part 2 - The Equivalent Amplifier Size

by Pat Brown

Of all of the specifications necessary for sound system design, perhaps the most confusing, vague, and often misleading is the loudspeaker power rating. In our last issue, I pointed out some of the problems with power ratings in general (See "Why All the Fuss About Power - SAC Newsletter Vol. 33 No. 1). In Part 2 of this installment I will provide a logical and defensible method of providing a meaningful minimum recommended amplifier size for a given loudspeaker.

The Dilemma

Consider the dilemma that faces the sound designer when given a loudspeaker power rating. Let's say that the specification says "500 watts." Does this mean:

1. A 500 watt amplifier should be used.
2. A larger amplifier should be used to allow room for program peaks.
3. The maximum RMS SPL will be 27 dB higher at one meter than the sensitivity rating, or
4. The actual level will be lower than this, due to the high crest factors of typical audio program material?

It can be a research project to find a meaningful answer to this simple question.

Power Testing

Loudspeaker thermal limits are tested by applying a weighted pink noise spectrum (Fig. 1) to the loudspeaker-under-test for a specified period of time. If no permanent damage occurs, the applied RMS voltage (E_{RMS}) is increased by some nominal amount (i.e 3 dB) and the test repeated. Once the E_{RMS} voltage limit is reached (as evidenced by system failure), it is customary to calculate the equivalent power rating based on the loudspeaker's impedance. This is not as straight forward as it might seem. The power equation is simple: $W = (E^2/Z)\ PF$, where W is watts, E is the applied RMS voltage, Z is the impedance of the voice coil, and PF is the power factor due to the phase angle between the voltage and current. Clearly the power is impedance-dependent, so the problems becomes "What impedance do I use?"

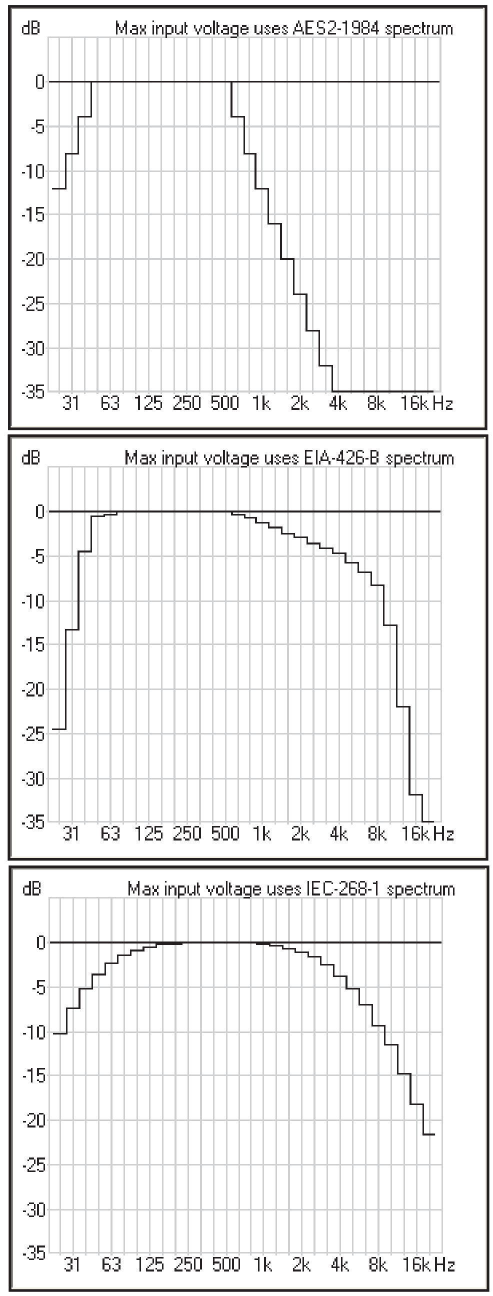


Figure 1 - Standard input spectra for loudspeaker power testing. Courtesy CLF Viewer.

The Typical Scenario

Consider the following scenario: A large format loudspeaker is "power tested" by feeding it a 6dB crest factor waveform of a standard spectrum shape for a specified period of time. The applied signal is increased at 1-hour intervals, and finally the amplifier begins to clip on signal peaks. Conveniently, the loudspeaker is showing signs of thermal distress, so it is reaching its "power limit" with regard to the applied signal, which is measured at 50 V_{RMS}. The amplifier has a peak voltage output of 100 V, and a corresponding sine wave power rating of 625 watts continuous average power (70.7 volts across 8 ohms) with a sinusoidal input. The minimum impedance of this loudspeaker (Fig.2) is 4 ohms (not apparent at 1/3-oct resolution), the minimum 1/3-oct average impedance is 5 ohms, the nominal impedance is 8 ohms and its average impedance is 12 ohms. What is the "power rating" of this loudspeaker?

Here are some possible answers:

1. 625 watts, arguing that the full "rated" output of the amplifier was applied to the loudspeaker.

2. 312 watts, arguing that the voltage waveform had a 6dB crest factor, not the 3dB crest factor of the sine wave used to rate the amplifier.

3. 625 watts, calculated from the applied E_{RMS} and the minimum impedance of the loudspeaker.

4. 208 watts, calculated from the applied E_{RMS} and the average impedance of the loudspeaker.

5. 2500 watts, calculated from the peak voltage and the minimum impedance.

Confused? You have a right to be. This is the typical scenario faced when assigning power ratings to loudspeakers. The answer is surprisingly simple if we ask the right questions.

What do we know for sure at the conclusion of the power test? The answer is *"We know the maximum E_{RMS} of a Standard spectrum signal that can be applied to the loudspeaker for a time span without damage."* **If I want to either duplicate the test on my own or achieve a similar level of performance in the field, what do I need to know?** The answer is *"The rating of the amplifier used to conduct the test, since it represents the limit that the loudspeaker can handle without failure."* So, we don't really care what the "power rating" of the loudspeaker is. We have already shown it to be a very shaky number with many possible derivations and interpretations. We can instead proceed to determining the required amplifier size to duplicate the test condition (which will produce the maximum SPL (L_{MAX}) that can be delivered by the loudspeaker without damage).

Since the amplifier already has a rating from the manufacturer, we will need to work within those guidelines. **How are amplifiers rated?** Typically, they are driven with a sinusoidal waveform and driven to just below clipping into a

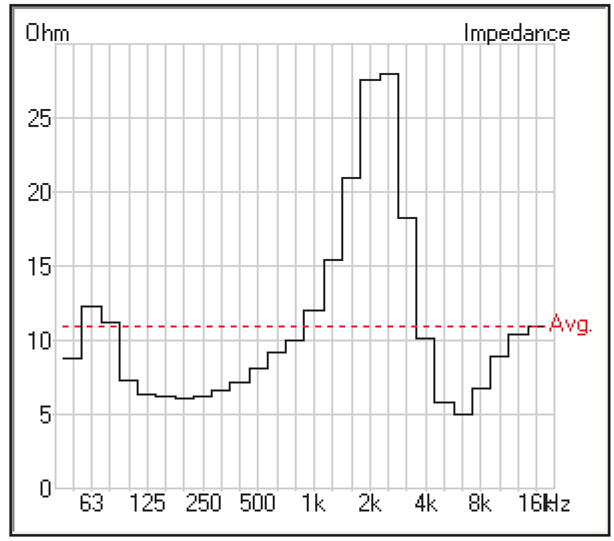


Figure 2 - The impedance vs. frequency curve for a typical full-range loudspeaker system. (CLF)

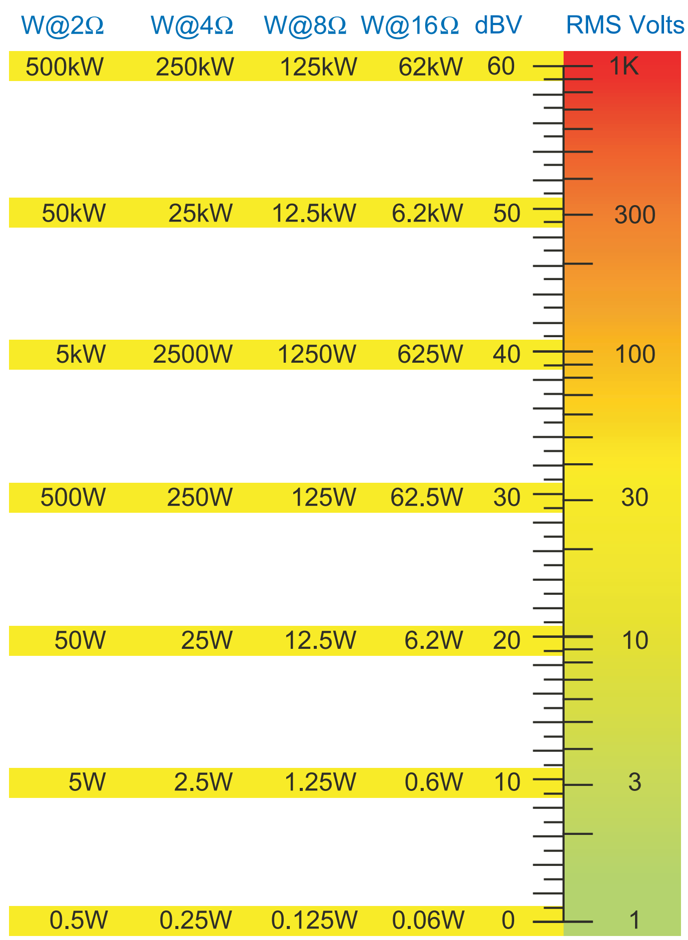


Figure 3 - The E_{RMS} applied can be easily converted to dBV, but power calculation is trickier due to frequency-dependent impedance.

nominal resistive load (usually 8 ohms). So the loudspeaker voltage rating must be "normalized" to a sine wave, 8 ohm power rating to allow an appropriate selection to be made.

The right hand column of Figure 3 depicts the range of RMS voltages available from amplifiers. Were one of these voltages applied to a loudspeaker, the horizontal yellow bars show the approximate power transfer that would result at various loudspeaker impedance ratings. A major problem with this method is immediately apparent - the power rating is grossly sensitive to the value of the impedance, and the loudspeaker's impedance is grossly frequency-dependent. It should be apparent that neither the impedance selected (nor the subsequent power calculation) affect the sound level produced by the loudspeaker. It is determined by E_{RMS}.

Once the maximum E_{RMS} that the loudspeaker can "handle" has been determined, it can be converted to dBV without controversy. At this point, with a knowledge of E_{RMS} we have the information needed by the system designer, and the additional steps to represent this as power are both unnecessary and potentially misleading.

To see why let's go back to our previous example: The maximum voltage has been determined to be 50 V_{RMS} (34 dBV). But, the average impedance is 12 ohms. The power equation yields a rating of 208 watts for the loudspeaker. Yet, the loudspeaker handled the full voltage swing of an amplifier rated at 625 watts into 8 ohms (sine wave rating). If the end user buys an amplifier rated at 200 watts, or even 300 watts (into 8 ohms), they will not be able to achieve the level determined by the power test. Again, what is really needed is the sine wave rating of the amplifier used to perform the power test. We will call this the Equivalent Amplifier Size.

The Equivalent Amplifier Size - EAS

Fortunately, we already have all of the information necessary to determine the rating of the amplifier. We know:

1. The peak voltage of the power test waveform $dBV_{PEAK} = dBV_{RMS} + 6dB$ (the crest factor of the power test waveform).

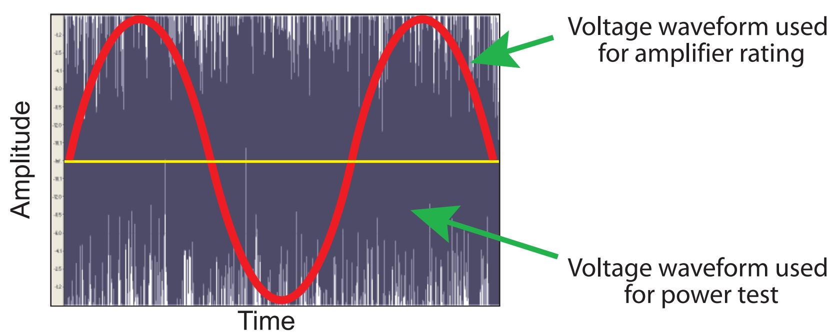
2. The RMS sine wave voltage of an amplifier that can pass the same peak voltage (dBV_{PEAK} - 3dB, due to the crest factor of a sine wave).

3. The equivalent amplifier power at 8 ohms (subtract 10log(8) which is 9 dB). This yields the sine wave rating of the amplifier into an 8 ohm load, which is the Equivalent Amplifier Size in watts.

What the EAS is Not

The EAS is not the thermal power rating of the loudspeaker. This would require knowledge of the voltage and current delivered to the loudspeaker during the test, and it is completely dependent on the load impedance. Since the amplifier's output voltage in largely independent of the load impedance (a constant-voltage interface), it is extremely misleading to associate the loudspeaker's SPL with the applied power.

Converting the Applied RMS Voltage to an Equivalent Amplifier Size

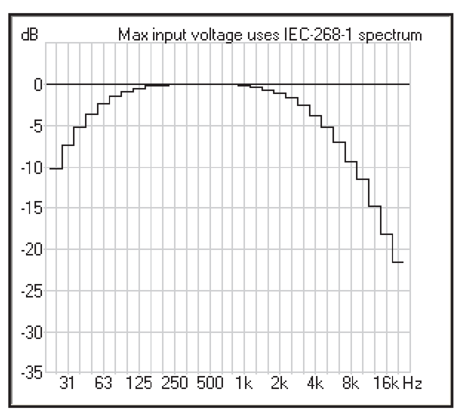


1. Determine maximum RMS volts in dBV
2. Determine peak voltage (+6dB)
3. Determine RMS of sine wave (-3dB)
4. Normalize to 8 ohm rating (-9dB)

$$EAS_{dBW} = dBV_{RMS} - 6$$

$$EAS_{watts} = 10^{EAS_{dBW}/10}$$

Quick Method!



$$L_{MAX} = L_{SENS} + dBV_{RMS}$$

The maximum SPL can be determined from the above relationship.

Amplifier Ratings

It is still useful to have an amplifier specification for its sine wave E_{RMS} at various load impedances. This can help the system designer determine if the amplifier will current limit if multiple loudspeakers are paralleled across its output terminals. While it is true that the amplifier is a constant voltage source, the load impedance can get too low for it to remain so. Most amplifiers will drive an 8 ohm load without problems. If the load is reduced (by paralleling loudspeakers or connecting a very low impedance loudspeaker) then the designer should consult the amplifier spec sheet to evaluate its performance at lower-than-8-ohm impedances. Just as with the electrical outlets in our homes, we seldom consider current requirements of general household appliances since they are typically well below what is available. But current must be considered when connecting long cables or demanding appliances, and we need more information in special cases. The scenario is similar in sound systems. We can assume sufficient current unless we create a scenario that excessively loads the amplifier.

It is noteworthy that the EAS is the *minimum* suggested amplifier size to duplicate the conditions of the thermal power test. As long as the E_{RMS} determined by the thermal test is not exceeded, an amplifier larger than the EAS can (and should) be used.

Why Test to Destruction?

Loudspeakers will usually have impaired performance prior to a total meltdown, so why is "destruction" the criteria for loudspeaker testing? It makes more sense to increase the voltage until the response of the loudspeaker shows a significant change. While no standard or universal practice applies, we feel that a response change of 3dB is defensible, since it is likely to be audible. Consider the following scenario for a loudspeaker endurance test:

1. Apply a standard spectrum at an E_{RMS} well below the loudspeakers thermal limits.
2. Perform a real-time difference test comparing the resultant SPL from a measurement mic to itself. This will produce a "flat line" display on the analyzer (Fig. 5).
3. Increase the applied voltage by 3dB each hour, noting the increase on the analyzer. As long as the line remains flat as it increases in level, the loudspeaker's response has not undergone a significant change.
4. When more than 3dB of deformation is indicated on the analyzer, the loudspeaker's response is drifting and it is assumed that it is approaching its thermal limit. The applied voltage is returned to the last level that did not produce a 3dB change, and this is the level that is used to determine the EAS.

This rating method would allow a designer to quickly select an amplifier based on an actual power test with no need to interpret the specification. They would also know the maximum SPL that the loudspeaker can produce at 1 meter (L_{SENS} - 9 + dBV_{RMS}). The 9dB correction is required because the L_{SENS} is measured a 2.83V (9dBV). The amplifier size can be predictably reduced if less SPL is required, or predictably increased if more peak room is desired.

Conclusion

Power ratings have long confused system designers and manufacturers alike. When something consistently fails to address the needs of users, then the methods or motivations involved should be examined.

The methods described herein do not represent a radical departure from past methods of rating loudspeakers. They differ only in how the results are presented and utilized by the system designer. A simple specification that describes the 8-ohm rating of the amplifier used to perform the power test establishes the necessary conversion from an applied RMS voltage to the traditional power rating used by manufacturers and designers.

The new Common Loudspeaker Format supports all three power test Standards (Figure.1), as well as specification of the Equivalent Amplifier Size. *pb*

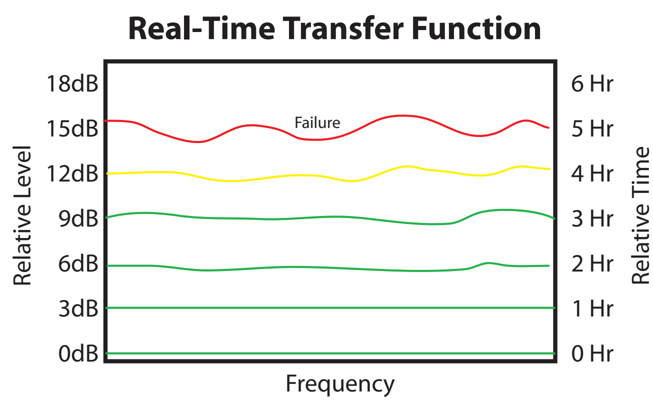


Figure 5 - The E_{RMS} is gradually increased until the loudspeaker non-linearity exceeds 3dB. This correlates well with the onset of impedance rise due to heat (power compression). Loudspeakers should be operated below this level to maintain good fidelity and reliability.
Note: The time span used for the power test varies from 2 to 8 hours depending on the Standard being adhered to. A one-hour test as described above can be used to verify a power rating, assuming that it has already been established by a Standard method.