SCIENTIFIC ACOUSTICS

Excellence by Design

Peter Patrick A.A.A.S., A.A.E.S.
10 Harth St
PO Box 1981
Toowoomba
4350
Phone 0500 878989
Fax 07 46344 771
Email: peter@scientific-acoustics.com.au
Website: www.scientific-acoustics.com.au

ABN: 59 423 015 921

14/5/05

Practical Application of Loudspeaker Power Ratings

Abstract.
Tweeters are burnt out occasionally by acoustical consultants in testing the properties of windows , doors etc. This informal paper sets out to explain loudspeaker input power ratings and proposes a simple formula for avoiding such burn – outs.

Introduction

Loudspeaker Power Rating is as confused as any specification which tries to simplify complex information into a simple single number. The expression "It depends" applies nowhere more aptly than to this seemingly simple measure of performance.
In the first place the power rating applies only to input power dissipation capacity …. Never to acoustic output power capacity (dBW) It might be useful to recall that we all feel happy when purchasing 100W light-bulbs and never consider the output power in Lumens. All this in spite of the fact that there is an enormous difference between professional lighting modules wherein 400Watt versions of Sodium Vapour, Mercury Vapour, Quartz Halogen & Regular Incandescent produce a wide variety of lighting output in Lumens.

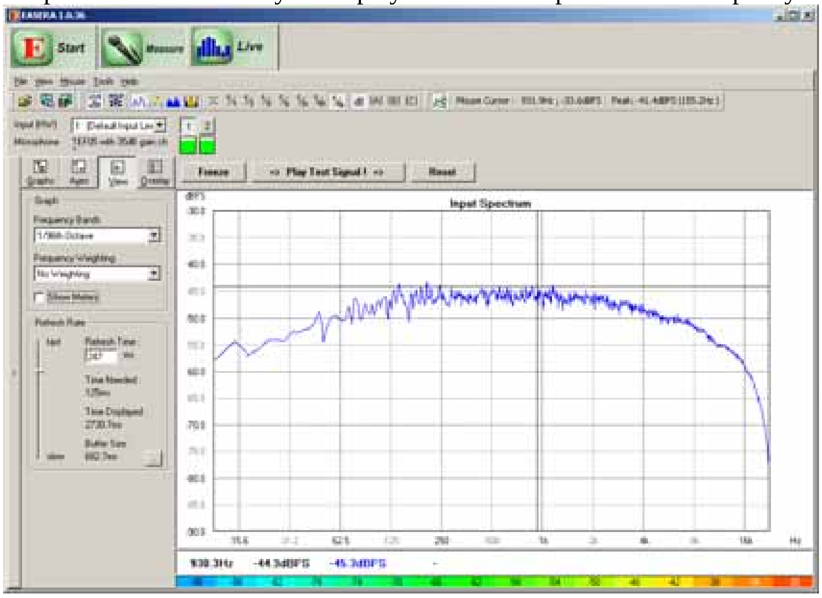
Spectral distribution of power in real world audio reproduction:-

At least one reputable manufacturer now specifies loudspeaker power rating three ways …. For example "40Watts Noise, 80 Watts Program, 160 Watts Peak". There are two Loudspeaker power rating standards known to the author, AES and IEC. Without down-loading the standards and referencing this paper the author prefers to quote from a reputable manufacturers note which refers the reader to ANSI EIA RS 426-A 1980. (Apparently a third power rating method) "The EIA test spectrum is applied for eight hours. To obtain this spectrum, the output of a white noise generator is applied to a shaping filter with 6 dB per Octave slopes below 40Hz and above 318Hz.. This spectrum, when measured on a 1/3 Octave real time analyser, produces a spectrum whose 3dB down points are 100Hz and 1,200Hz with a 3dB per octave slope above 1,200Hz. The shaped signal is sent to the power amplifier with continuous true RMS power set at 300Watts for a 300 Watt loudspeaker of 5.8 Ohm equivalent impedance (41.7Volts RMS). Amplifier clipping sets instantaneous peaks at 6dB above the continuous power or 1,200 watts peak (83.4Volts Peak). This test provides a rigorous test of both mechanical and electrical failure modes". The author is aware of 100Hour test standards and more but since this paper is intended as a forum contribution, only the AES document and a manufacturers web-site documents are listed

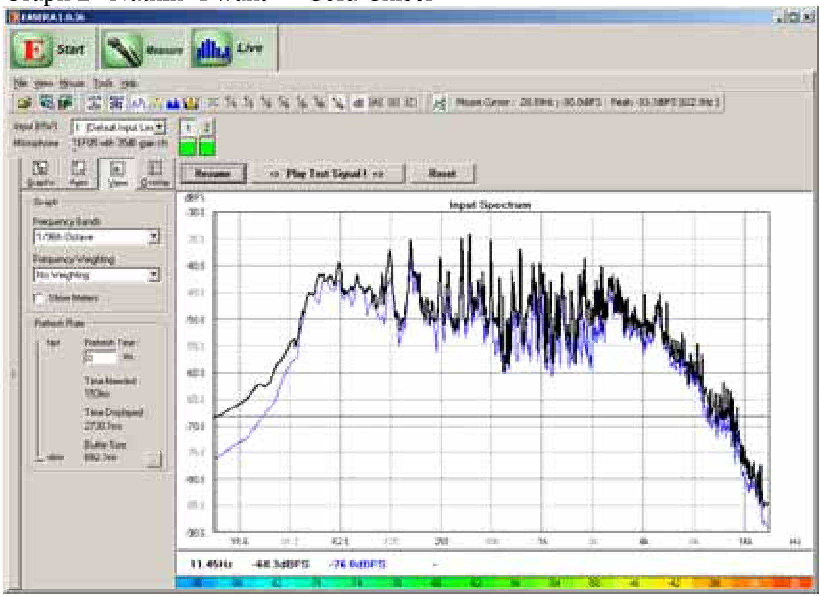
The author has acquired a CD recording of the IEC standard, similar to the power rating described above, and applied it to a modern high resolution (1/96 Octave band) real time analyser. The results is shown in Graph 1 below.
Graph 2 shows a Rock Music Passage spectra measured on the same scales. The test track was "Nuthin' I want" by Cold Chisel. Compare this to "Annie's Song" by James Galway on Flute in Graph 3.

Note:- The black lines showing on Graphs 2 and 3 are a "Peak Hold" function switched on to better describe the more dynamic program in the recorded music. The blue line is the instantaneous value.

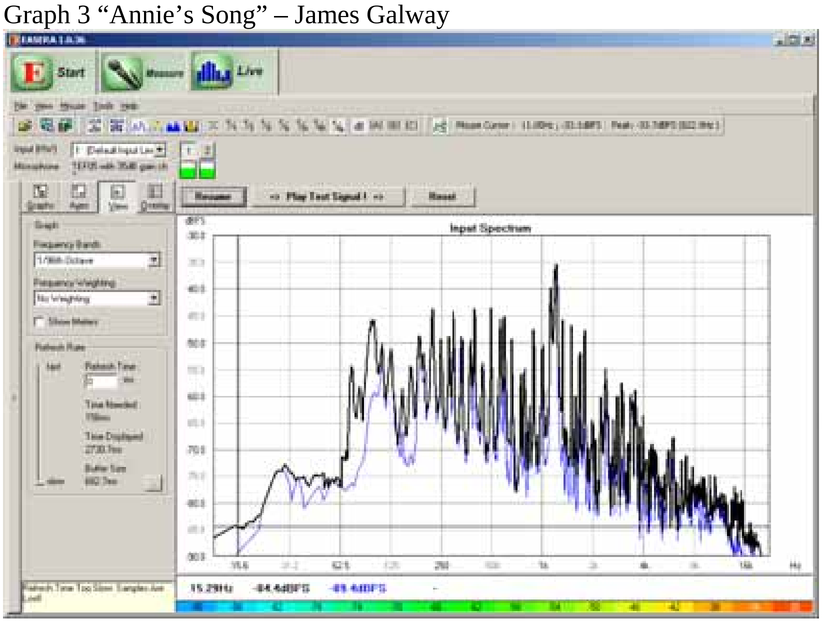
Graph 1. Real Time Analyser display of IEC Loudspeaker Power capacity test noise.



Graph 2 “Nuthin’ I want” – Cold Chisel



Graph 3 “Annie’s Song” – James Galway



The author wishes to draw the readers attention to the spectral content of the graphs shown so far. The power contained in the upper portion of the spectra is somewhat less than the power content of the low to mid audio range. That is the bass & fundamental voice range contains much more energy than overtones and harmonics.

Practical Loudspeaker construction techniques:-

The application of this real world circumstance is that full range loudspeakers, of the type that the average acoustician is happy to carry, are usually made up of two electro acoustic drivers. A Robust Paper Cone driver is used for bass and mid frequency reproduction and a less robust lightweight driver for the HF end of the spectrum. Typically a 300 Watt cabinet will contain a 300 watt paper cone low frequency reproducer and a 50 Watt HF reproducer with the crossover point set at about 1,200Hz. The practical side of building high power loudspeakers is shown in photographs 1 to 5 below. Photograph 3 shows the old vs new comparison for very high power professional sound system components. The new driver is shown mounted on the impedance matching horn. It is rated at 100 watts RMS continuous and has a 16 ohm nominal impedance. The efficiency is rated much the same as the old version, shown at the base of the horn, at around 110 dB SPL @ 1 metre with 1 Watt of energy impressed on the voice coil. Retail Price of the new driver in Australia is around $1,500.oo The difference most obvious to the author is the frequency response. The new driver, with a little equalisation, delivered a response flat within 2.5 dB to 20 KHz. The older unit, typical of the best in it's day, delivered little beyond 15KHz. HF drivers like these are found only in high power concert sound rigs. They inhabit cabinets usually considered exceedingly heavy by the average acoustician.

Please Note .The 600 and 300 Watt Cone driver voice coils shown in the photographs are burnt out and thereby removed from the frame of the original loudspeakers. The 600 Watt driver was incinerated by a DJ after the installation technician forgot to password protect the electronic limiters that preceded the power amplifiers. There were more spectacular examples of voice coil destruction in the authors "Junk Box" but the photograph below shows more of the construction technique than is afforded by the charred remnants otherwise available for this article. It should also be noted that there are side issues such as power compression at work in cases like this. Any loudspeaker will deliver a non linear acoustic output vs electrical input well before the voice coil former ignites or the copper wire fuses. The power rating addresses the loudspeakers capacity to dissipate energy. It does not relate well to its acoustic output. Power compression of 6dB is not unheard of at the loudspeakers maximum dissipation. That is 100 dB @ 1 Watt / 1 Metre might translate to 119 dB in the real world at full power of 300 Watts instead of the expected 125 dB.

The confinement of acoustic dispersion provided by the HF horn delivers very high SPL's at any distance. The more omni directional nature of the cone drivers dispersion characteristics means that the 100 Watt HF driver assembly is capable of a greater output SPL than a 600 Watt 15" cone driver …. When measured on axis at the front of the cabinet. Typically a 600 Watt 15" cone driver will exhibit an efficiency rating of around 100 dB SPL @ 1m with 1 Watt electrical power applied. The true acoustic output of the LF driver in acoustic watts is greater than that of the horn loaded HF driver but the frequency response is flat, more or less, when measured in front of the cabinet. Behind the cabinet the result will be predominantly bass energy rolling off sharply as the directivity of the HF horn takes over. Most acousticians will baulk at the prospect of carrying loudspeaker cabinets of this genre given the 40 to 70 KG weight. The purpose of this portion of text was to explain the limits of real world loudspeaker capabilities. A 200 or 300 watt RMS, full range cabinet with a cone driver and a HF driver weighs about 25 to 30 KG. The 20 Watt HF driver at the foot of Photograph 2 is typical of a 150 to 200 Watt budget quality cabinet.

Power amplifier considerations:-

The readers attention is now drawn to the power amplifier specification in the above text concerning spectral distribution. It means we need a very large amplifier to test the power capacity of a 300 Watt loudspeaker. An amplifier capable of delivering just 300 Watts RMS is very likely to produce HF driver failure because it will clip at about 300 Watts. Clipping alters the spectral distribution of the test signal by increasing the HF content. Graph 6 below shows a comparison between clipped (Blue trace) and unclipped (red Trace) signals delivered by a budget quality mixing console. (Clipping was deliberately induced by mis-operation) It will be seen that good quality equipment and operation well below clipping are essential ingredients of a well controlled test spectrum. Clipping, in any part of the signal chain, alters the spectral distribution of power in ways that can be quite dangerous to a HF driver. The crossover network in a two way full range cabinet very effectively differentiates the signal from the power amplifier. Typically an amplifier capable of 300 watts into a nominal 8 ohm load is capable of delivering roughly 49Volts RMS. It would typically be constructed with DC power supply rails of around 80 Volts. When driven to clipping the output swings rapidly from +80 Volts to –80 Volts. This represents a 160 Volt signal swing which, if differentiated by the crossover network, is impressed across a HF driver designed for 20 Volts RMS with 40 Volt peaks. If the power amplifier is clipping the signal in the output stage the result can be shown by simple differentiation to equate to a spike of 3,200 watts. Herein lies the reason for placing the crossover network ahead of the power amplifiers in high power systems. Each transducer has it's own dedicated power amplifier. The worst situation then is that the power amplifier delivers 3dB more power at full clip than at full undistorted sine wave power. The case of a 300 Watt amplifier delivering 3,200 Watt spikes or even full undistorted sine wave power, into the 50 Watt HF driver is thereby avoided. For inquiring minds the burnt 600 watt LF driver voice coil in photographs 1 and 4 came from a high power, separate amplifier for each transducer, system. The author is convinced that the sound quality was appalling some hour or so before the smoke escaped the voice coils and silence descended on the audience.

Photograph 1 Comparison of 600 Watt and 300 Watt Voice coil assemblies.
The authors HP41CV calculator is shown inside the 600 Watt Voice Coil.

Photograph 2 Comparison of 70 Watt and 20 Watt HF drivers
The 70 Watt magnet assembly is under the LHS of the calculator and the Voice coil assembly under the RHS

Photograph 3 High power HF drivers Old Vs New

Photograph 4 600 Watt Cone Driver Voice Coil close -up

Photograph 5 70 Watt HF driver Voice Coil Close - up

Loudspeaker – Amplifier interaction:-

The robust and thereby heavy voice coil assembly of the high powered cone driver shown in photograph 4 brings yet another set of parameters to be considered. The Cone and Voice coil assembly form a high mass device. Compare the size and bulk of the voice coil to that of the HF driver in photograph 5. Mass implies inertia. If an electrical signal initiates forward movement of the LF driver assembly then a considerable inertia exists when the cone arrives at the destination defined by the voltage applied to the voice coil. The cone thereby tends to move beyond the limit of excursion implied by the voltage applied to the voice coil. The applied voltage ceases but the mass wants to keep travelling. The excess motion of the speeding cone / voice coil assembly is controlled by dynamic braking. This is derived from the voice coil which becomes a generator the instant it moves past the destination defined by the voltage applied to it. The electrical signal produced by the voice coil as it over swings the intended destination is applied to the connecting wire and amplifier output stage which form something approaching a short circuit. A short circuit on a generator is a very effective means of stopping the generator. In other words the very low impedance of the amplifier output stage and copper wire to the loudspeaker are used as a dynamic brake to minimise over excursion of the cone / voice coil assembly. The process has been defined as “damping factor”. Damping factor is defined simply as the ratio of the voice coil impedance to the combined impedance of the driving circuitry. For professional speakers with stiff (read high power) cone suspensions a minimum damping factor of 20 is desirable. This means the amplifier plus wiring impedance for an 8 ohm speaker should not exceed 0.4 ohms. A modern amplifier will typically exhibit very low output impedance in the order of .05 ohms or less. The wiring between the amplifier and the loudspeaker is thereby the major determinant in damping factor. Home Hi Fi speakers typically have less stiff suspensions, and less mechanical damping on the cone / voice coil assembly and thereby require a larger damping factor of 50 or more.
It may thereby be seen that resistive voltage dividers have a particularly deleterious effect on damping factor. The result is poorly controlled low frequency excursion with attendant distortion and stress on the mechanical suspension.

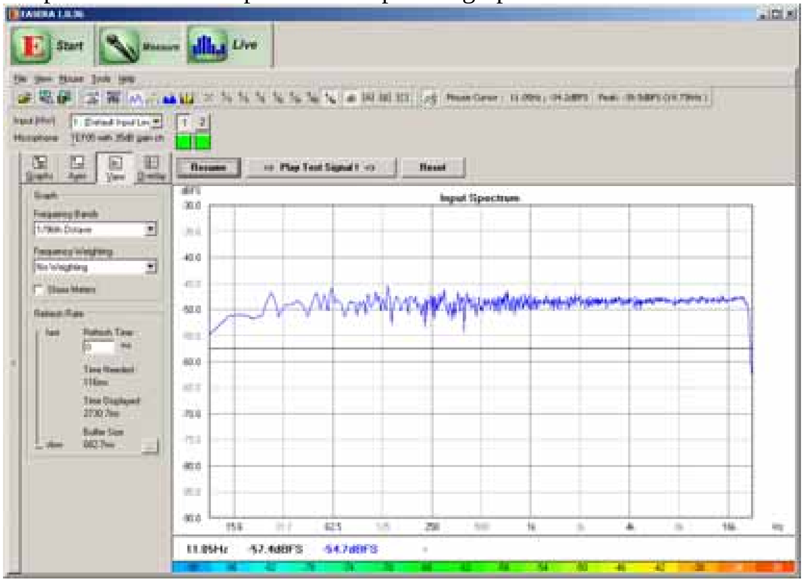
Delivering pink noise acoustic test signals:-

Graphs 4 and 5 below show the spectral distribution of signals commonly used by acousticians.
Note the power dissipated in the HF driver of a full range two way cabinet is markedly increased in comparison to the IEC spectrum (The most arduous test in graphs 1 to 3)

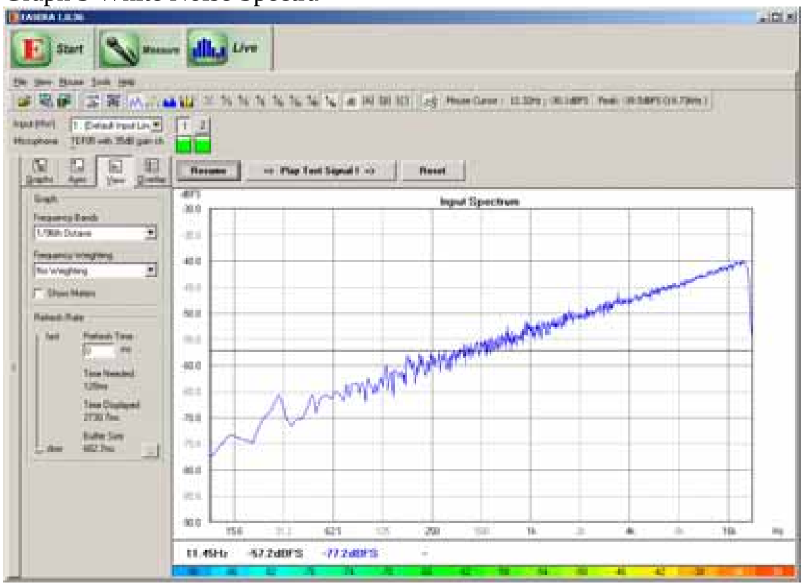
The author postulates that there is merit in the development of a band limited spectra for acousticians to apply when performing Rw tests or the like. A 4^{th} order cut off filter set just above 5 KHz would be helpful.

There are loudspeaker manufacturers who build cabinets loaded with small full range drivers and no crossover network. (The acoustic output rolls off markedly above about 3 KHz but a “Processor” applies equalisation) Cabinets of this ilk are intrinsically more capable of delivering high SPL’s up to and including the 5KHz Octave band required of most acoustical test regimes.

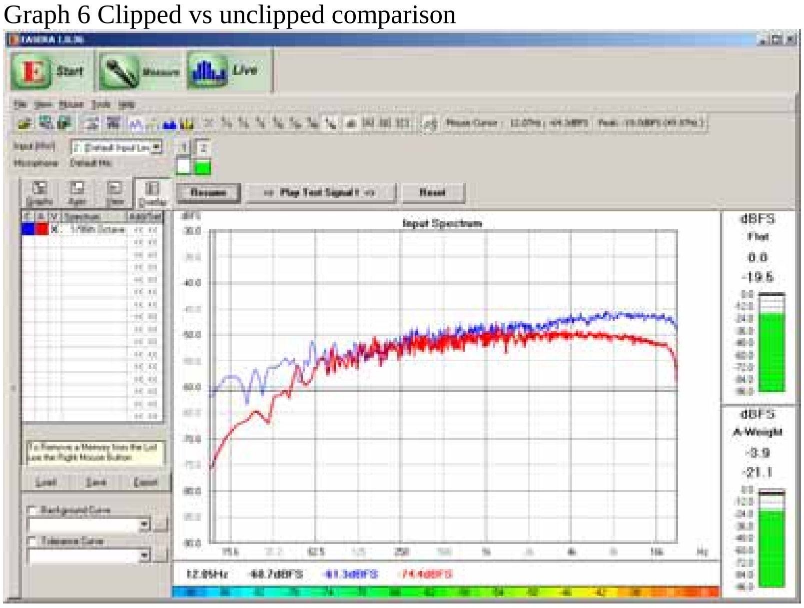
Graph 4 Pink Noise Spectra – compare to graph 1.



Graph 5 White Noise Spectra



Graph 6 Clipped vs unclipped comparison



Avoiding HF driver burn out:-
The author operates a hire system designed to cope with high SPL's which uses a different approach. The low frequencies are delivered by a separate amplifier driving high efficiency cabinets containing a pair of 600Watt RMS, 15" low frequency transducers. The mid range is delivered through four, 300 watt 12" drivers. (The imperial measurement is still used to describe transducer size – possibly the American influence.) HF drivers are not voice coil driven devices at all but are Piezo effect transducers using a slice of Quartz as the fundamental transducer. These devices include a positive temperature coefficient resistor in the signal path which makes it nigh on impossible to destroy the transducer with excess drive signal. The down side to using these devices is low sensitivity, typically 85 dB SPL @ 1m with 1 Watt applied. The simple answer is to use a large number of transducers which, thankfully, are not particularly expensive. The requirement would be for 316 Piezo devices to deliver the same maximum SPL as is available from the high power transducer. This isn't clever economics but in practical terms sufficient SPL can be obtained from 48 Piezo devices costing a similar amount to the high power drivers while providing peace of mind for the operator. There are also quite a number of mid range cone driver transducers with high power ratings and a frequency response extending well past 5KHz. It is thereby possible to build a high power system capable of delivering high SPL test signals without using any regular HF drivers at all. Reproducing 10 to 20KHz mostly dictates the use of a very low mass transducer somewhat less robust than really suits high SPL pink Noise testing of partitions and walls.

The simple non critical case of using a single loudspeaker and amplifier combination to deliver sufficient noise to test a door, window or office wall can be resolved simply enough. Use an amplifier capable of delivering approximately the same RMS power as the loudspeaker cabinet is capable of dissipating. Measure or calculate by ohms law, the maximum undistorted output voltage the amplifier can deliver. Set the amplifier gain to deliver no more than half the undistorted maximum RMS output using a pink noise signal source and a true RMS voltmeter. For a 300 watt amplifier / loudspeaker combination this will deliver 75 Watts of energy into the cabinet. This level is quite unlikely to damage any drivers. Furthermore it avoids power compression which invariably comes into effect near a loudspeakers maximum power capacity. The effect can be measured by increasing the input to a loudspeaker in 1dB steps. A point will be reached, well before thermal destruction occurs, where a 1dB increase in electrical input no longer produces a 1dB increase in acoustical output. Different manufacturers transducers exhibit different amounts of power compression at the maximum RMS power rating so it is well to avoid operating close to this region. Running an amplifier at half voltage delivers a 6dB crest factor which when delivered to a loudspeaker of the same power capacity, should be reproduced properly in the acoustic domain without damaging anything.

Please Note:- Whilst this author has made every effort to provide a test set-up procedure which is technically correct there is no accounting for defects and even lies told by unscrupulous manufacturers who, thankfully, seem to be few in number. That is, every care has been taken but no responsibility will be accepted.

Further Reading:-
AES 2 – 1984 (r2003) AES Recommended Practice- Specifications of loudspeaker components used in professional audio and sound reinforcement www.aes.org - a search in the Standards area for the word "power" will bring up the document description and purchasing facility.

Manufacturer JBL provide some very useful papers free of charge on their web-site www.jblpro.com Go to the Technical Library where papers on "Speaker Power Requirements" and "Danger – Low Power" will be found.

Peter J. Patrick