THE PA BIBLE

ADDITION NUMBER TWO
POWER HANDLING CAPACITY

Excessive power is one of the worst enemies of a loudspeaker. Overpowering is probably the number one killer of loudspeakers, with rock bands jamming their guitar necks through the cones being a close second. To understand how speakers operate and what happens when they fail to do so will be covered in the following discussion.

LOUDSPEAKER PARTS AND OPERATION

Loudspeakers convert electrical energy into acoustic energy, which you hear, and another form of energy, heat, which you don't hear (more on heat later). To understand what happens in a normal operating cone loudspeaker (woofer), see Figure 1. When alternating electrical energy (power) is applied to the leads of the voice coil, it creates forces which interact with the magnetic field in the gap of the magnetic assembly. This interaction results in cone motion (excursion). Since the electrical energy is alternating in nature, the speaker voice coil will move in and out of the gap. Because the voice coil is rigidly connected to the cone, the cone, spider and surround move with the same motion as the voice coil. This motion moves air and this produces sound. Everything works great until some part is stressed beyond its design limits.

HOW POWER DESTROYS LOUDSPEAKERS

There are two different ways of overpowering a loudspeaker. First, excessive power applied over a long period of time will cause "thermal failure" of the loudspeaker by heating the voice coil to the point where some part of its structure literally melts, breaks, or actually burns up. Temperatures in the voice coil may exceed 300 degrees fahrenheit under normal operating conditions. Second, "mechanical failure" occurs when excessive power input moves the cone so far that the cone becomes separated from the voice coil form, the voice coil separates from the coil form, the surround rips, or the spider rips. Any one of these will cause the loudspeaker to fail. When the surround or spider rips, this will eventually lead to voice coil rubbing because the cone assembly is not suspended properly. Small rips will usually go unnoticed, but after some time they become large ones, and the failure is soon to follow.

Failure can be a composite of the two above failures. For example, when a very large transient is delivered by the power amplifier (such as dropping a microphone on the stage), the loudspeaker will try to reproduce the waveform. This **may** end up with the voice coil assembly traveling outward so far it leaves the magnetic gap and, when it tries to return, it may be stressed off center and miss. This causes the whole operation to become locked up with the cone protruding forward from its normal rest position. Even though the loudspeaker is motionless, power is still being applied to the voice coil. Since the coil is out of the gap (which, under normal conditions, acts as a nice heat sink to keep temperatures of the voice coil in operating range) it will quickly overheat and burn.

A properly designed woofer should be able to sustain the necessary excursion at the manufacturer's rated power and frequency range. High power woofers can usually handle maximum mechanical excursions of about one inch peak-to-peak if distortion is ignored. If distortion is considered, the linear, not mechanical, excursion limits might be 1/8 to 1/3 this value, depending on the particular design.

So far this has dealt only with cone loudspeakers (such as woofers). The same failures common to cone speakers can occur in midrange loudspeakers or tweeters. A mechanical failure which may occur in some high-performance compression drivers is dome shattering. Shattering of metal domes is caused by overstressing the metal by constant flexing. What happens when the dome is over-flexed is that it

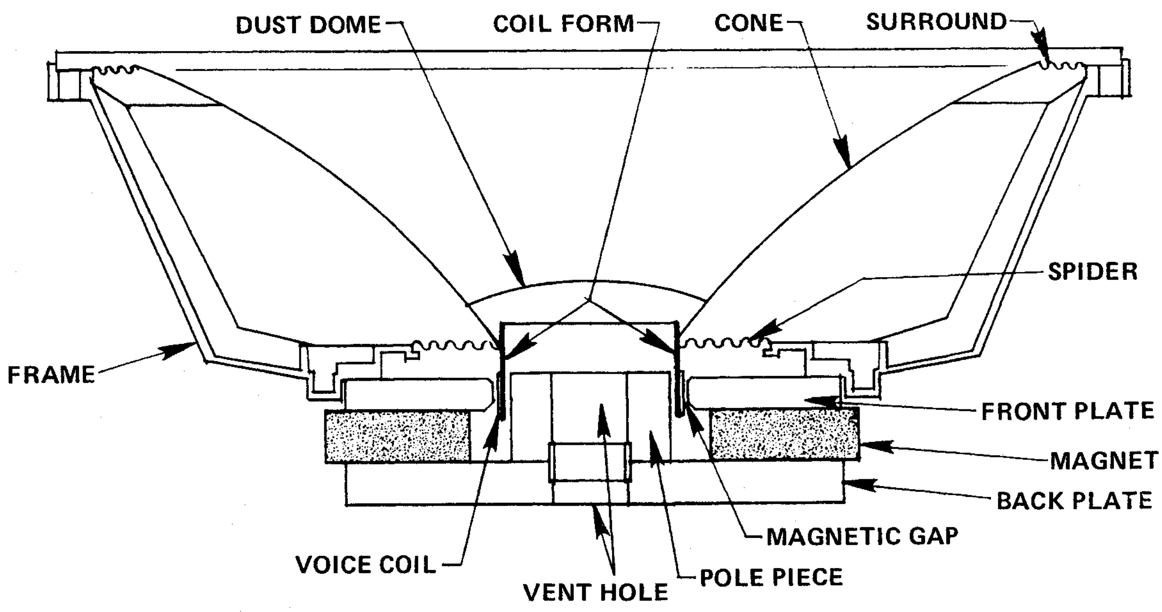

FIGURE 1 — Parts of a Cone Loudspeaker

breaks up into many small pieces similar to shattered glass and ceases to function. (See Addition Number 1 of our "PA Bible" for details on high-performance drivers.)

THE RELATIONSHIP BETWEEN THERMAL AND MECHANICAL FAILURE

Real-world vocal or instrumental program material has, first, a "long-term average level" (anything from a second on up) which pretty much determines how "loud" the sound is to our ears. Second, this material has short duration peak power levels (small fractions of a second) which can be on the order of ten times the long-term average levels. Although these peaks contribute little to perceived loudness, they are necessary for clean, accurate reproduction. It is the long-term average power input which heats up the voice coil (thermal failure). The short-duration peaks, even if they are many times greater in maximum power than the long-term average, will not damage the voice coil thermally because they are not applied long enough to increase its temperature. Also, the peaks found in typical real-world program material – say 4-to-10 times the long-term average (6-to-10 dB) – will not damage the usual speaker mechanically, either. However, large peaks from various "accidents" (like dropping a microphone or electronics turn-on transients) can cause enough mechanical stress to damage the speaker.

THE RATING GAME

Since every manufacturer would like to claim their loudspeaker can handle more power than anything else on the market, there are almost as many power ratings as there are manufacturers. The Electronic Industries Association (EIA) and the Audio Engineering Society (AES) have attempted to define standard testing procedures for the industry, but most manufacturers have not adopted the outlined methods for one reason or another. Therefore, you will find ratings with absolutely no definition at all as well as ratings that are well defined, but do not effectively accomplish a power test that means much in the real world. Some of the words are "program," "continuous," "peak," and "music power."

TEST SIGNALS

In order to understand how rigorously a speaker or speaker system is being power tested, you need to know two things about the input signal. First you need to know what frequencies are being applied. For instance, if you use a 1,000 Hertz single tone in a system with multiple drivers and an appropriate crossover network, only the speaker which reproduces the 1,000 Hertz tone is being tested. Such a test would tell you nothing about how rugged the woofer and tweeter were.

Some sort of real-program material would provide a more realistic test, in that the various frequencies that make up the real material would be appropriately fed to the test speaker. The problem with using program material is that it is not repetitive enough. In other words, it is pretty hard to get real "program material" out of a lab instrument in a repeatable way. Another possibility is to make use of some sort of "random noise." Random noise, over a period of time, contains all frequencies. It sounds quite similar to inter-station hiss on an FM tuner without inter-station muting. "White noise" is a type of random noise which has, over time, equal power at every frequency (for example, the same power in the region from 40 to 80 Hertz as in the region from 4000 to 4080 Hertz). "Pink noise" is another kind of random noise arranged to produce constant power in each musical octave (like 100-200 Hz, 200-400 Hz, 400-800 Hz, etc.) (The power content in each octave of white noise increases as you go up in frequency since there are many more frequencies in the 10,000-20,000 Hertz octave than, say, the 100-200 Hertz octave.) Both pink and white noise, although they contain all frequencies in a manner similar to general program material, have far more power at the frequency extremes than typical vocal or instrumental program material. Thus, they do not represent a particularly realistic test, as they will subject woofers and tweeters to a **much** more rigorous test than they would generally be subjected to in a real life.

The second thing you need to know about the input signal is how long it is applied. This is especially important in view of the above discussion about how most speakers take much greater power for a very short time than they can withstand for a long period of time. A 1,000 Hertz RMS sine wave test is not very good in this respect. If it is applied for a long time, it tests the thermal limit of the speaker at that frequency. However, the instantaneous peak power of a sine wave is only two times greater than the long-term RMS value. This means that the mechanical portions of the speaker are hardly put to a test at all, since real-program has instantaneous peaks that can be ten or more times the long-term average. Random noise can offer a more realistic test. Random noise can be arranged to have instantaneous peaks many times the average value in the manner of real program material. In addition, tests involving random noise are repeatable.

A MEANINGFUL TEST

Since random noise is closely related to real-program material, it becomes the heart of a meaningful power or "life" test. To just use pink noise would be too demanding on a speaker or speaker system in the extremes of the spectrum (low frequencies and high frequencies). Therefore, shaped or filtered pink noise can be used for a more realistic test. The shaping usually conforms to the bandwidth of the speaker or speaker system being tested or to a standard specification. Even though shaping is applied, the signal can be arranged to contain more energy at extremely high and low frequencies than the typical actual program which the speaker or speaker system would normally be required to reproduce, resulting in a product with an extra measure of reliability.

The noise test signal generates not only the overall "long-term average" or "continuous" level which our ears interpret as loudness but also the short-duration peaks which are many times higher than the average, just like actual program material. The long-term average level stresses the speaker thermally and the instantaneous peaks test mechanical reliability.

So far, noise appears to be a test which duplicates the real-life situation, but there is one more thing – how long will the speaker withstand this punishment? The length of time a speaker can sustain (without failure) a given input is the other factor important to a meaningful test. In actual use, long-term average levels exist from perhaps a second on up, but a practical test involves a number of hours.

Electro-Voice became interested in noise testing in 1968, and has continued to utilize it to present day. The EIA standards adopted a similar test for loudspeakers in 1975 (RS–426). If all manufacturers would subscribe to a standard noise test (such as the EIA test), the end user would have his life simplified considerably. Unfortunately, this is not the case at present, so undefined power ratings are worth about as much as confederate money.

EFFICIENCY VS. POWER CAPACITY OR WANT TO BUY A 400-WATT LOUDSPEAKER?

If all you plan to do when purchasing a loudspeaker is examine the power rating, someday some sharp salesman may sell you a light bulb. Light bulbs can handle lots of power, but they don't put out much sound. Remember what speakers really do? They convert electrical energy into (1) sound (great) and (2) heat (not so great). So, beware of buying a super-power 400-watt speaker on that consideration alone. You might be getting a device that takes all the power claimed but is less efficient than another speaker, therefore giving less actual sound output with a given power amp.

For example, start with a 200-watt speaker that delivers 120 dB at a distance of 4 feet with an input of 200 watts. Then go to a 400-watt speaker that puts out only 117 dB at 4 feet with 200 watts in. Although the second speaker takes more power, it requires a 400-watt input to get the 120 dB you got from the first, more efficient speaker with only 200 watts in. (Remember, to make up the 3-dB difference between 120 and 117 dB you need two times the amp power.) Therefore, before you buy a speaker with a big power rating – even if its a realistic rating and not just some number resulting from adding up the digits on an advertising guy's paycheck – consider its efficiency and see how much SPL it produces with a given power input.

HOW BIG AN AMP CAN I USE WITH MY SPEAKER?

Now that we have a realistic power test all you need to do is determine the power rating of the loudspeaker, buy an amplifier with the exact same size power rating and enjoy perfection – right? **WRONG!** If it were only that easy, everything would work perfectly and people who re-cone speakers would be in the bread line. That is not to say that a 100-watt amp won't work well with a loudspeaker rated for 100 watts (per some specification). It may very well work fine.

The matter of mating an amplifier rating with a loudspeaker system is frankly a pain in the posterior. We feel it would be very difficult for anyone who is intimately acquainted with the details of power testing procedures and loudspeaker failure modes to make absolute statements involving this subject with a clear conscience. Getting that off our chest, we will attempt to offer some guidelines that should be of help in making selections based on having a reasonable base to proceed from. That reasonable base is, testing the loudspeaker with a noise spectrum over a substantial portion of its operational range for a long period of time. It may be the EIA eight-hour form of noise test (RS–426) or some other test at least as rigorous. Unqualified ratings such as "100 watts" or "75 watts peak" are very difficult to deal with since so much is left open to question.

Assuming a reasonable rating to work from exists, we can divide almost all systems into two categories; those using full-range, single-cone loudspeakers (one-way systems) and those which are multi-way (two and three-way systems). We will consider multi-way systems first.

Multi-Way Systems

A. **To use a speaker system to full capacity,** skilled experts in sound system installation and operation will obtain the best results if the power amplifier is 2-to-4 times the long-term average noise power rating of the speaker system. (The woofer rating may be thought of as the system rating if a separate system rating is not given.)

   The caution cannot be made strongly enough, however, that **this arrangement is only for experts** or for those people who can discipline themselves against "pushing" the system for ever-higher sound levels and who can avoid "accidents" such as catastrophic feedback or dropping microphones. Dropping a mike causes a peak which can mechanically damage a speaker. Feedback can thermally destroy speakers, especially the mid- and high-frequency components which handle the frequency range where most feedback occurs. Big amps can destroy speakers with ease, and mishandling will be very expensive.

   The large amplifier in this recommendation is to permit driving the speaker system near to its long-term average rating with enough reserve power left to handle the typical short-duration program peaks which do not harm the speaker. (See "The Relationship Between Thermal and Mechanical Failure" section.) The amplifiers in this recommendation allow short-duration peaks of 3-to-6 dB above the long-term average capacity of the speaker. This makes it easier to approach with program material the speaker's long-term average rating without clipping the program peaks. However, if the level is pushed so that the amplifier starts clipping a substantial portion of program peaks (and you can stand the resultant harsh, irritable distortion), the thermal limit of the speaker may be exceeded.

   Non-experts can safely obtain the "best" or "expert" results by using amplifiers which have special circuitry to do the expert's job. Such circuitry allows the long-term average power output to be set to the speaker's rating, but still allows the entire muscle of the amp for short-duration program peaks. The power amplifiers made by E-V/TAPCO incorporate a powerlock feature which provides this performance.

B. **A more conservative, "nominal" amp size,** which will produce audible results nearly equal to those of the "expert" system, is one equal to the long-term average noise power rating of the speaker system.

   The caution here is to studiously avoid the amplifier clipping described above. Although the small amplifier is less likely to produce damaging long-term average power output, it is more likely to be driven into clipping on program peaks. The harsh, irritating distortion products generated are high in frequency and are thus fed to the high-frequency components of the system. This output is not present in normal program material and can overload tweeters and midranges – creating a one-way system without a tweeter. As a result, if you pick the relatively conservative "nominal" amp size – and end up driving the system into hard clipping – you may end up frying the tweeters sooner than if you had picked the large amp of the "expert" system (above). The problem of over-powering system high-frequency components is minimized if they are protected in some manner, such as relay interrupting devices (such as the Electro-Voice STR) or electronic limiting devices (such as the Electro-Voice High-Frequency Auto Limiting circuit). However, such devices are not foolproof, especially if they are continuously being cycled.

C. **To be very conservative,** one can use an amplifier rated at .5-to.7 times the long-term average noise power rating of the loudspeaker. This will provide an extra margin of safety while still making reasonable utilization of speaker capability. The comments made above on clipping and the generation of potentially damaging high-frequency distortion products apply here also.

One-Way Systems

In general, the suggestions and comments made about multi-way systems apply also to one-way systems. However, the high-frequency distortion products generated by amplifier clipping will not, in general, be damaging.

Musical Instrument Speakers. Special consideration should be given to the one-way speakers typically used in musical instrument applications, such as guitar and bass. Amplifier clipping is often part of the desired "sound," so that the peaks of such program are not very far above the long-term average. Thus, if you take the "expert" option and couple an 800-watt amplifier to a 200-watt guitar speaker you may be more likely to exceed the speaker's long-term average noise rating than if the program material were voice or miked acoustic instruments. The importance of this warning is heavily influenced by your personal playing style.

Bi-Amped and Tri-Amped Multi-Way Systems. Such systems become, in effect, one-way systems when considering amp-to-speaker matching. Be alert to the lower power ratings typical on mid- and high-frequency speakers, and avoid over-powering them with amps the size of those used to drive woofers. (The efficiency of horn-loaded midranges and tweeters is higher than that of a cone woofer, so that a smaller amp is usually appropriate.)

VITAMIN C FOR LOUDSPEAKER LIFE EXTENSION

Some comments on ways to keep your speakers performing for years to come seem to be in order after all this discussion of power testing, blown speakers, and big repair bills.

Actually, loudspeakers are fairly forgiving and dependable devices. When you stop to think, a loudspeaker cone is a piece of paper which may only weigh half an ounce, and the voice coil is sometimes made from wire only .01 inch in diameter! It is pretty impressive that speakers can withstand high power, cycling thousands of times a second without coming apart. If speakers are not mistreated, they can provide many years of excellent service. A few quick pointers may be of use in extending the life of your speaker:

1. Provide some means of high-pass filtering in the electronics to prevent sub-sonic frequencies from bottoming the speaker. Such frequencies are typically below the frequency which the system can reproduce but cause large cone excursions which mechanically strain the speaker mechanism and modulate ("muddy up") the bass which the system is capable of reproducing. A high-pass filter is a filter designed to pass all material above a certain frequency and reject everything below. For instance, if a system only has low-frequency response down to 50 Hertz, a high-pass filter at 45 Hertz would be desirable.

   Some power amps and mixers incorporate high-pass filters of this type; at least one separate high-pass filter is available. The Electro-Voice XEQ-1 active crossover (for bi-amped systems) features a 20-Hz high-pass filter.

2. Don't use speaker connecting cords with AC plugs on them, because some day the speakers will get accidently plugged into 120 volts AC. You might enjoy 60 Hertz for a millisecond, if you are lucky.

3. Look for power amplifiers that have DC (direct current) protection, turn on delay, and peak output indicators. Any or all of these features would be desirable. If an amplifier fails and puts out DC, the voice coil will go critical and melt-down will occur. Turn on delay will keep the amplifier from sending a large transient to the speaker which could cause many bad effects. Peak indicators are useful for operation. They will indicate when you have reached the maximum safe power from the amplifier (remember clipping?).

4. On the subject of power amplifiers, if a system uses a separate power amplifier and mixer, the mixer should be switched on before the power amplifier. If this is done in reverse sequence and the mixer puts out a turn-on transient, the amplifier will amplify it and send it to the speakers. When turning off equipment, turn the power amplifier off first, then the mixer, for the same reason. (This is great unless you left an extension cord where someone will catch his foot on it and unplug the whole system. Being a good guy, he quickly plugs the whole thing in at once and the system takes the lumps.)

CONTEST WINNER

We would like to congratulate Randy Cook of Charlotte, Michigan, for finally finding the mystery mistake. We made an error (obviously on purpose) on page 4, line 10 of "Double Distance Rule Gets You" in the "PA Bible." The word "decreased" should read "increased." Now we know who has been reading closely!

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