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TECHNOLOGY UPDATE

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TRANSDUCER FAILURE MODES & INSTANTANEOUS PEAK POWER

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Background:

Over the years loudspeaker manufacturers have concerned themselves with two primary causes of loudspeaker failure; overheating and over-excursion. Our processors and those of our competitors were developed to protect loudspeakers from damage due to these overload conditions; and most do an excellent job of preventing damage from these two types of overload.

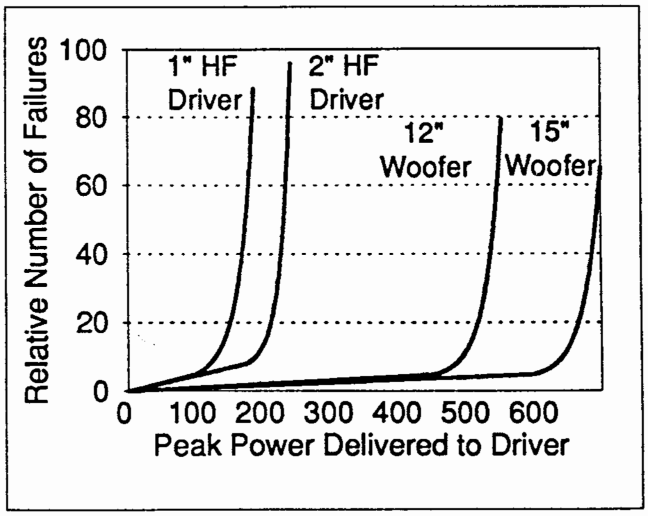
Over the last two years we have become aware that a third overload condition or failure mode exists; damage from high level transients. In high frequency drivers this failure mode is characterized by the tearing or shattering of the diaphragm. In woofers, the symptoms are a torn cone or perhaps a separated voice coil assembly. Failure occurs even though neither the diaphragm nor the voice coil show any signs of overheating or of over-excursion.

The Third Failure Mode

Extensive in-house testing combined with field experience has shown that these failures are the result of material fatigue. This occurs when the transducer is subjected to very high instantaneous peak power levels within the transducer's normal frequency range.

We have found that it is possible to stay within the speaker's RMS power rating and still destroy it with high instantaneous peak power.

We have also found that for any given transducer there exists a sharply defined power threshold which, if exceeded, causes fatigue failures in a short period of time, often within minutes. The following chart graphically illustrates this phenomenon.



These critical-threshold loudspeaker ratings are traditionally un-published, although this is sure to change as more component manufacturers become aware of the problem and its significance. Conventional RMS ratings are just not adequate to describe all aspects of a loudspeakers power handling capabilities.

On the other hand, we now know that by assuring that these critical thresholds are not exceeded, we can guaranty reliable operation for a very long time.

The Source of the Problem

Much of this problem stems from the instantaneous peak power capabilities of today's high power professional amplifiers. These amplifiers are characterized by extremely high damping factors, i.e. by very low internal "source" impedances. They also contain large amounts of "onboard" energy storage in the form of huge filter capacitors. In fact, the ability of these amplifiers to pass extremely high level transients is one of their selling features.

In today's high-power amplifiers, the amount of instantaneous peak power that can be delivered is limited only by the available peak voltage swing. This figure varies from amplifier to amplifier, but in general is a function of the amplifier's output power rating. The larger the amplifier, the greater the potential voltage swing, and therefore, the greater the likelihood that it may cause transient-related damage to loudspeakers.

Table 1 shows a list of the RMS and instantaneous peak power levels that are attainable with several popular amplifiers. All of these amplifiers have a damping factor of 400:1 at 1 kHz with an 8 Ohm load, which translates into a source impedance of less than 0.1 Ohms. This low source impedance means that as long as the filter capacitors in the power supply are fully charged, the load resistance (loudspeaker load) has little effect on the amount of instantaneous voltage the amplifiers can deliver; they are capable of putting out the same high instantaneous voltages into 4 and 2 ohm loads as they deliver to 8 ohm loads.

AMPLIFIER:	R-H P-2000	R-H P-2500	Crest 8001
RMS Watts into 8 Ohms	300	400	720
RMS Watts into 4 Ohms	500	600	1100
RMS Watts into 2 Ohms	600	700	1400
Max **PEAK VOLTAGE** Swing	**85V**	**99V**	**129V**
PEAK Watts into 8 Ohms	903	1225	2080
PEAK Watts into 4 Ohms	1806	2450	4160
PEAK Watts into 2 Ohms	3612	4900	8320

Table 1

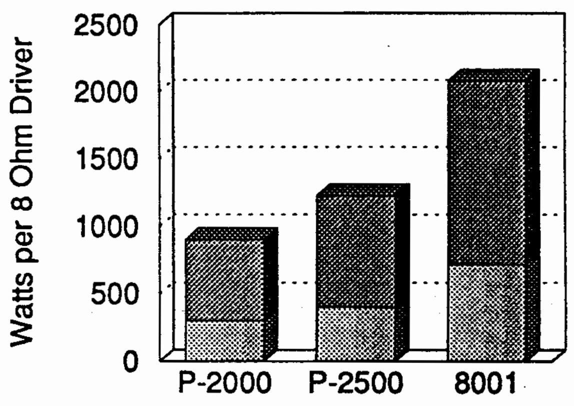
It must be understood that these peak power capabilities are valid for instantaneous (very low duty cycle) signals only. They are theoretical (calculated), and don't take into account differences in the source impedance (damping factor) of the amplifiers at different loads and frequencies. As you can see, the differences between the RMS and the theoretical instantaneous peak powers are substantial.

An amplifier's peak power capability is of more than theoretical interest since these high level instantaneous peaks are present in normal program material. Generally speaking, audio program material has a peak-to-average voltage ratio of five-to-one. This translates into a power ratio of 25 to 1, meaning that a 250 watt continuous-program signal can produce instantaneous peaks of up to 6,250 watts! This assumes the power amplifier is capable of reproducing these high peaks and many of today's high power amplifiers are.

Examples: Let's look at a typical 15" woofer with an RMS (continuous program) rating of 300 Watts, a nominal impedance of 8 Ohms and a critical peak power limit of 800 Watts. It seems reasonable to utilize an 8001 amplifier to drive four of those woofers in parallel, since with 1400 total watts available, 350 watts is available to each loudspeaker and some headroom is provided. (Providing for headroom in the amplifier is a common practice.) However, in this arrangement each woofer can also be subjected to instantaneous peaks of 8,320 divided by 4 or 2,080 watts. This is more than twice the instantaneous peak power this woofer can handle.

<u>Unless the maximum peak power can be limited to roughly 800 watts per woofer, damage will almost certainly occur.</u>

As a second example, using the 400 watt per channel P-2500 amplifier to drive two of the 300 watt 15" woofers in parallel will match the 300 watt RMS rating of the woofers, but will also provide a much reduced 1,225 watt peak power capability. This still exceeds the peak power rating of the loudspeaker, but it is a much safer way to operate these loudspeakers. Using the even smaller 300 watt per channel P2000 amplifier would further increase the safety margin, however, amplifier clipping may then become a problem.



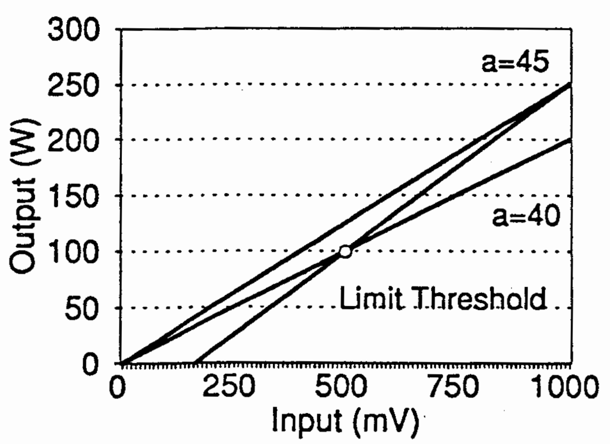
RMS vs Peak Power Output

<u>The point is that while smaller amplifiers usually present no problem, larger amplifiers present a problem unless some other method of limiting the instantaneous peak power is provided.</u>

For reliable operation we have always suggested the use of properly matched Renkus-Heinz amplifiers or at least similarly rated competing products. In other words, there is no problem if the amplifier peak power is within reason. On the other hand, the use of oversized amplifiers is sure to cause transducer failures unless precautions are taken.

Conventional compressor-limiters are useless in preventing these failures as their attack times are usually set too slow to catch high level transients. In fact, fast attack times in these devices are considered undesirable since they translate into excessive modulation (distortion) of the program material.

One solution to this problem is the use of a fast-acting "hard limiter" in the signal processing chain to prevent the high level transients from reaching the power amplifier and being reproduced. This method has two serious drawbacks. First, most hard limiters introduce distortion into the system even when they are properly adjusted. Additionally, when the "hard limiter" is placed ahead of the power amplifier in the signal processing chain, the amplifier's internal gain must be taken into account when setting the limiter's threshold level. This can be true even when the amplifier's output is used as a sense input for the limiter. As you can see from the graph shown below, the gain slope of an amplifier varies with the overall gain and the limit threshold shifts with it. This means the hard limiter can only be effective when the amplifier's voltage gain is set to a pre-determined level and not tampered with.



a = amplifier gain

A Solution

Renkus-Heinz has developed a revolutionary new "adaptive limiter" that eliminates all of the problems that we have discussed. The circuit is entirely transparent when not activated. For that matter, it is electrically disconnected from the signal chain when inactive. Triggered by the absolute voltage present at the output of the protected amplifier it is not affected by changes in the amplifier's voltage gain. Finally, the adaptive limiter is extremely fast-acting, usually able to limit a transient after one or two cycles even at high frequencies. Since the recovery time is even faster than the attack time, it operates only on signal peaks without affecting the rest of the signal. As a result, the circuit does not add audible distortion. **In fact, listening tests have shown that there is a reduction in audible distortion in systems where the adaptive limiter is in use.**

We believe that this is the result of two factors: First, the power amplifiers are prevented from going into clipping, meaning that there is much less likelihood of oscillation and other side-effects related to amplifier clipping. Second, the loudspeakers are kept out of the destructive non-linear regions. **Tests have proven that adaptive limiters provide significant protection of loudspeakers against damage due to high-power transient signals.**

We believe that the adaptive limiter is a significant step in the evolution of loudspeaker-protection schemes.

As of February 1, all of our TSC controllers are being equipped with adaptive limiters on each output and all our TSC program modules contain speaker-specific peak-power protection settings. We also plan to add this circuitry to other SMART system processors