# Setting up Limiters
Application Note DE3457-01

## Scope

This application note discusses some approaches to setting up protection limiters.
NOTE: The views expressed in this document are no more than suggestions. The Loudspeaker/Driver manufacturer's guidelines should be followed in order to keep drive levels within safe limits. We cannot be held responsible for any damage caused as a result of using the techniques outlined in this document.

## Overview

There can be a considerable investment in the plant representing a sound system. Limiters are essential for constraining the signals so they fall within the capabilities of the equipment. Being essentially mechanical devices, loudspeakers are particularly prone to damage if used beyond the limits they were designed for. Good limiters may allow you to avoid unnecessary gain reduction, preserving the power levels you have invested so much to attain.
This guide discusses how the Limiter Suite in most Linea Research products may be set up for a given loudspeaker system.

## Why Limit?

Modern Loudspeakers are very resilient, but they have several failure mechanisms which result from abuse. The primary failure mechanisms are:

**Heat Damage**

Where too much power is applied for too long. Loudspeakers are not very efficient; typically 90% of the applied power will be converted to heat. This heat is dissipated in the voice-coil, which will, due to the properties of the coil former materials, have a finite upper temperature limit, albeit up to perhaps 300°C. Clearly then, we need to constrain the heating effects to keep the temperature of the voice-coil within its safe operating range.

**Mechanical damage**

The cone and voice-coil assembly move on the suspension in sympathy with the applied AC voltage. If this movement is too extreme, then permanent damage to the suspension can result. Again, we must constrain the applied voltage to keep this movement within safe limits.

## Specification

**From the manufacturers**

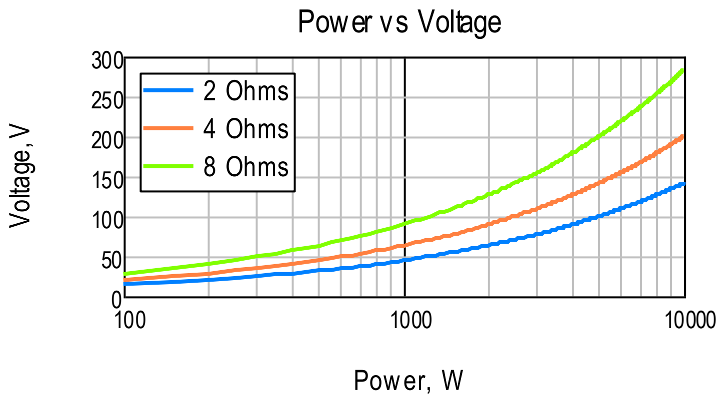
In order to apply the appropriate limiter parameters, we need to be working with a specification for these parameters. Such a specification will usually come from the manufacturer of the loudspeaker system. The manufacturer is likely to base their specification on a combination of the characteristics of the driver components, based on the driver manufacturer's recommendations, and the characteristics of the enclosure, which can have a dramatic effect on the loading and hence mechanical excursion of the driver components. The resulting specification will have been informed by prolonged power testing at the published rated power.
The loudspeaker manufacturer may provide 'Presets' which contain all the appropriate limiter settings for a given system. Where no such presets or specification can be obtained, there may be little choice but to calculate some safe settings based on the available information.

**From first principles**

The most basic requirement is to find out the maximum power handling specification (*the Continuous Power Rating* or *AES/IEC Power Handling*), and from this calculate the maximum applied voltage, using the nominal impedance of the driver:

$$\text{Voltage} = \sqrt{(\text{Power X Impedance})}$$

The following graph and table provide some examples of this relationship:




| Rated Power | Nominal Impedance | Maximum Volts |
|---|---|---|
| 2000 | 4 | 89 |
| 800 | 8 | 80 |
| 200 | 8 | 40 |

# Threshold Calibration

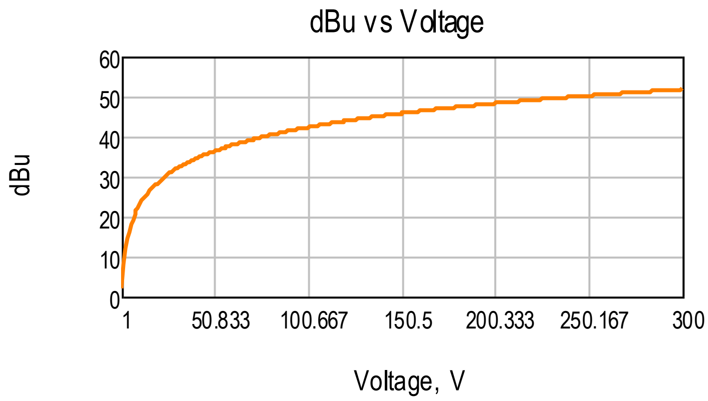
**Volts, dBs**

The 'Threshold' parameter for a limiter may either be represented in terms of Volts or dBu. You can convert between these using the following formulae:

$$dBu = 20 \text{ X } \log(Voltage/0.775)$$

$$Voltage = 0.775 \text{ X } \exp(dBu/20)$$

The following graphs and table provide some examples of this relationship:




| Volts | dBu |
|---|---|
| 5 | 16.2 |
| 20 | 28.2 |
| 100 | 42.2 |

**RMS, Peak**

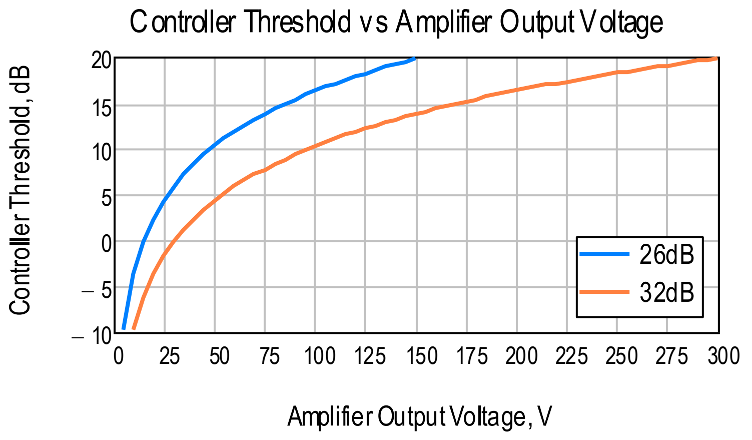
Some threshold parameters are entered as RMS and some as Peak. If you have a specification which is stated as a Peak value and the device requires an RMS value, then first multiply the Voltage value by 0.707, or reduce the dBu value by 3dB. If you have a specification which is stated as an RMS value and the device requires a Peak value, then first multiply the Voltage value by 1.414, or increase the dBu value by 3dB.

**Amplifier Gain**

If you are setting up the limiter on a Controller (such as the ASC48) and you wish to limit to a given voltage at the output of an Amplifier, then the amplifier Gain must be taken into account. The ASC48 Thermal and Excursion limiters allow the Amplifier Gain to be set so that the limiting action will be correctly calibrated at the output of the amplifier without any further modification.
The VxLimiter in the ASC48 however is calibrated in dBu at the output of this device, so it will be necessary to reduce the Threshold value you set on the ASC48 by an amount equal to the voltage gain of the amplifier. So, to calculate the dBu value required on the Controller for a given Amplifier output voltage, you need to convert the voltage to dBu and subtract the Amplifier Gain in dB:

$$dBu = (20 \text{ X } \log(Voltage/0.775)) - AmplifierGain$$

The following graph and table provide some examples of this relationship for different amplifier gains:




| Amplifier Gain (dB) | Output Voltage (V) | Threshold **(dBu)** |
|---|---|---|
| 26 | 20 | 2.2 |
| 26 | 100 | 16.2 |
| 32 | 20 | -3.8 |
| 32 | 100 | 10.2 |

## VX Limiting

At its heart of the Linea Research VX Suite is the **V**irtual **X**over pseudo-peak limiter (RMS calibrated).

The VxLimiter may be used in one of two distinct styles –VxMode *on* or *off*.
When VxMode is off, the functionality is very similar to a conventional limiter, except that it operates in a ‘multiband’ form, so that different parts of the spectrum are independently limited, with their own optimised attack and release characteristics, resulting in a more natural sound with less ‘pumping’.

The VX Mode parameter determines the style of limiter. When VirtualCrossover (VX) mode is off, the limiter is controlled in a conventional manner, the only controls being Threshold and Overshoot (time-constants being fully automatic). This mode is suitable for most applications which do not involve passive crossover networks.

When VX mode is engaged, you get to choose the crossover point of a ‘virtual crossover’ (actually a low-latency linear phase crossover), which gives you two limiters per output with different Threshold and time-constant characteristics.

It is important to realise that this is not merely a frequency-conscious limiter (which could be implemented simply using a filter in the side-chain of the limiter). Rather, the spectrum of the output will alter depending on the degree of limiting of each of the sub-limiters. The effect would thus be similar to having bi-amped drivers with an independent conventional limiter on each amplifier. This is very useful since it not only prevents the entire spectrum from being needlessly attenuated, but also provides better-targeted protection for a tweeter for example (a lower Threshold and faster Attack/Release times). The parameters available for adjustment on the VX Limiter are:

**Threshold**
Set this to the RMS dB value as discussed in *Threshold Calibration* above.
**Overshoot**
This determines the absolute maximum output level above the threshold value which the limiter will allow through. A value of 6 to 8dB is typical. Very low values (less than 4dB) should be avoided as these can tend to sound ‘hard’.
**Split Frequency (Vx Mode on)**
This would usually be set to the crossover frequency of the passive crossover network.
**Threshold Hi (Vx Mode on)**
This determines the limit threshold which high frequencies will be constrained to, expressed as a dB offset from the primary threshold setting. So, if you were to set the main Threshold to say 50V and the Threshold Hi parameter to -6dB, then the high frequencies will be limited to 25V (6dB lower).
**Overshoot Hi (Vx Mode on)**
Again, this is relative to the Threshold Hi setting, so a value of 6 to 8dB would be typical.

## Thermal Limiting

The part of a loudspeaker which is most susceptible to overheating is the voice-coil. As stated earlier, much of the energy you push into a driver will become heat in the voice-coil. Because of its close proximity to the magnet assembly, there is much heat transfer from the voice-coil to the magnet assembly, and so it is primarily the thermal Time Constant of the magnet assembly which determines the rate at which the temperature of the voice-coil can change. However, the transfer of heat is not perfect, so the temperature of the voice-coil can change somewhat faster than that of the magnet assembly.

Although it is possible to estimate what the voice-coil temperature will be based on the signal being fed to it, this would require a very great many driver parameters to be known with great accuracy, usually making this completely impractical.

However, a powerful approach using just three parameters (Threshold level, Attack time, Release time) has been found to be very successful in protecting against thermal damage.

The Thermal Limiter models the temperature of the voice-coil, and constrains the output signal level in order to keep the RMS output power below a predetermined limit, applying attack and release characteristics to model the thermal circuit of a driver's voice coil and magnet assembly.

Three parameters are available for adjustment:

**Threshold**

The continuous RMS voltage that the driver should be able to withstand. This is calibrated at the output of the amplifier. The Thermal Limiter can be defeated by setting the Threshold to the maximum "Off" value.

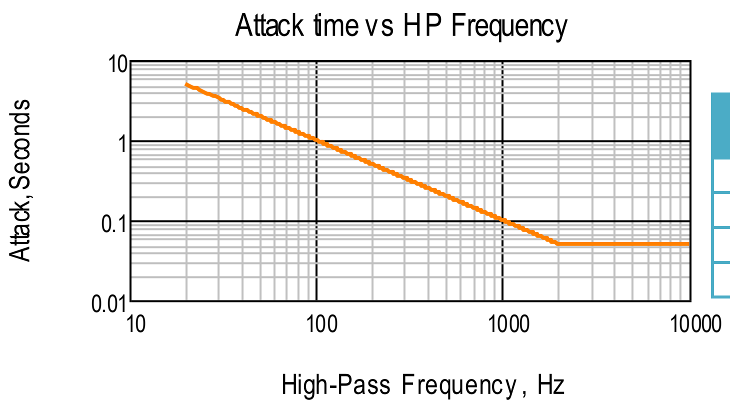
**Attack**

The time-constant of the speed at which the driver heats up (in seconds). This specification is rarely published. If it is, then use this as the Attack time.

The thermal Time Constant which is most pertinent to thermal limiting is that of the magnet assembly. This will be roughly proportional to its mass, and thus roughly proportional to its volume. A value of 50ms would be suitable for the very smallest HF drivers, rising to perhaps 5 seconds for the largest cone drivers. Faster (lower) values will provide more protection at the expense of a lower average output level. As a very rough guide, you can base the Attack time on the High-Pass frequency recommended by the manufacturer (Fhp). It is recommended that the Attack time value is no less than 50ms. Use the relationship:

Attack Time = 100/Fhp

The following graph and table provide some examples of this relationship for a range of High-Pass Frequencies:




| High-Pass Frequency (Hz) | Attack Time (Seconds) |
|---|---|
| 40 | 2.5 |
| 200 | 0.5 |
| 800 | 0.125 |
| 2000 and above | 0.05 |

**Release**

The time-constant of the speed at which the driver cools down (expressed as a multiple of the Attack time). A value of 2.0X will suit most applications. A value of 3.0X would offer better protection at the expense of a lower average output level.

## Excursion Limiting

The Excursion Limiter protects the driver against excessive linear movement of the cone and voice-coil that could otherwise cause mechanical damage. Since this movement (excursion) is largely related to the inverse of the signal frequency, drivers are prone to being damaged by very low frequencies. This limiter is progressively more sensitive at lower frequencies and, rather than varying the gain to provide the limiting action, it uses a sliding high-pass filter to progressively curtail the low-frequency response, effectively limiting the linear excursion to below the X-max specification of the driver.
To set the limiter up, it is necessary to know the shape of the family of Excursion vs. Frequency curves of the driver for various drive voltage levels. A curve should then be chosen where the slope is high where it passes though the specified X-Max value for the driver. The peak voltage and frequency of this point should then be noted. The Xmax limiter is usually then set up using just two parameters:

**Threshold**

The *peak* voltage of the point arrived at above (so multiply the RMS value by 1.414 and enter that). This is calibrated at the output of the amplifier. The Excursion Limiter can be defeated by setting Threshold to the maximum “Off” value.

**Frequency**

The frequency at which the above threshold voltage is appropriate.

**Minimum Frequency**

A further parameter “*Min*” may also be available for more advanced applications. This allows the increasing limiting action at lower frequencies to level-off below a certain frequency. In most applications, this would be left set to its default value of 5Hz.

If you do not have access to the Excursion vs. Frequency curves for your driver and you wish to use Excursion limiting, then the following rule-of-thumb will offer some protection:

**Threshold**

Set this to a value which represents the published rated power for the driver (see the section on *Threshold calibration* above). However, since this limiter uses the peak value, first multiply the (RMS) voltage by 1.414 and enter that.

**Frequency**

Set this to the High-Pass frequency recommended by the manufacturer.

## Putting it all Together

If you are using both the VxLimiter and the Thermal limiter, then it makes sense to use them in harmony to get the best from your system.
If you have access to both the AES Power handling and the Maximum Power Handling specifications, then set the Thermal Limiter Threshold to the voltage equating to the Continuous Power Rating (AES Power), and the VxLimiter Threshold to the Maximum power (Program Power), which is usually twice the Continuous Power (6dB more power, 3dB more voltage).
However, if the VxLimiter has VX mode active, then set the Threshold of the section with the lower Threshold value to the voltage equating to the Continuous Power Rating (AES Power).
To summarise:

When the VX Limiter is used with VX Mode *off*:

| Thermal | VxLimiter |
|---|---|
| Continuous Power | Maximum Power |

When the VX Limiter is used with VX Mode *on*, and the Hi band has a lower threshold (negative dBr):

| Thermal | VxLimiter Lf | VxLimiter Hf |
|---|---|---|
| Continuous Power Lf | Maximum Power Lf | Continuous Power Hf |

When the VX Limiter is used with VX Mode *on*, and the Hi band has a higher threshold (positive dBr):

| Thermal | VxLimiter Lo | VxLimiter Hi |
|---|---|---|
| Continuous Power Lf | Continuous Power Lf | Maximum Power Hf |