Whitepaper - **Speaker protection: how to correctly configure the Apex Intelli-X^2 limiter**

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Foreword

Each output of the Intelli-X^2 System Manager is provided with a two-stage limiter, intended to protect loudspeakers against damage whilst preserving sonic transparency at high sound pressure levels.

It is of paramount importance that all limiter parameters are correctly configured in order to minimise the risk of speaker damage. As such, it is necessary to understand the causes of loudspeaker damage and how the Intelli-X^2 limiters can help prevent this.

Principal of operation

The first limiter stage in the Intelli-X^2 responds to the RMS level of the signal, the second stage is a very fast-acting limiter responding to signal peaks. The thresholds of each may be set independently.

The RMS limiter is intended to protect the speaker against **thermal damage** when excessive power is applied for extended periods of time, resulting in the voice coil overheating and finally burning.

The role of the peak limiter is to protect against mechanical damage due to **over-excursion** when the speaker voice coil is driven out of the magnetic gap (where displacement exceeds Xmax). The peak stage may also eventually be used to **prevent the amplifier from clipping**.

Warnings and disclaimer

It is of primary importance that the amplifiers will not be overdriven as they must be able to deliver the necessary power without clipping. The required power depends on the application. If the full capability of the loudspeaker is needed to achieve the desired sound pressure level then **we recommend that an amplifier capable of continuously delivering at least twice the loudspeaker's power handling be used**. If several loudspeakers are to be connected in parallel to the same amplifier output channel, then it should be able to deliver the loudspeaker's power handling multiplied by the number of loudspeakers connected, multiplied by two. Some amplifiers have in-built clip prevention circuits and if this is the case then we recommend that they be enabled.

Note: Always follow the loudspeaker manufacturer's recommendations regarding crossover filters in order to avoid driving speakers outside of their operational frequency range.

Due to the high degree of variance between loudspeaker and amplifier manufacturers' specifications, Apex can not guarantee total protection against loudspeaker damage or failure. Furthermore, even when the limiters are correctly configured, improper system operations such as sustained microphone feedback, excessive equalisation, clipping anywhere in the signal chain, turntable rumble etc., may lead to loudspeaker damage. Apex therefore does not accept any liability or responsibility for any damage to equipment.

Limiters: configuration procedure

The limiter settings in the Intelli-X^2 fundamentally depend on the amplifier voltage gain (otherwise known as input sensitivity) and loudspeaker power handling capabilities. The voltage reaching the loudspeaker (V_L) has to be kept under control and within an acceptable range in order to avoid any damage. This voltage is simply equal to the Intelli-X^2 output voltage ($V_{out\ max}$) augmented by amplifier gain (G_A).

1.Loudspeaker maximum driving voltage

First, look for the nominal impedance (Z_L) and power handling (P_L) of the cabinet (or each driver in the case of a multi-way system). This information can be found in the unit's datasheet or user manual. The nominal impedance can be found easily, however things are not that straight-forward for power handling. You will need to look for the continuous power, otherwise referred to as "average power", "Watt AES" or "Watt RMS". **Do not use program or peak power for limiter settings**!

Using the impedance and power handling, we can compute the maximum RMS voltage (V_L) in dBu that may be applied to the loudspeaker:

$$V_L = 20 \cdot \log\left(\frac{\sqrt{P_L \cdot Z_L}}{0.775}\right)$$

With P_L, the power handling in Watts

Z_L, the nominal impedance in Ohms

As we are working with voltage, you may connect several identical cabinets (or drivers) in parallel without making any changes to your limiter settings; in fact, the same voltage will be applied to all of them. Nevertheless, you need to ensure that your power amplifier is capable of driving the reduced load impedance. The total load as seen by the amplifier will be:

$$Z_{Ltotal} = \frac{Z_L}{N}$$

With Z_L, the impedance of one cabinet or component in Ohms

N, the number of cabinets in parallel

2. Power amplifier voltage gain

Look for the voltage gain specifications of the amplifier (G_A) in its documentation. Some amplifier manufacturers specify the voltage gain in dB (e.g., 26 dB) or as a multiplier (e.g., x 40). Some other manufacturers specify input sensitivity as volts (or dBu) for full rated power (e.g., 0.775v or 1.4v). Furthermore, some amplifiers are fitted with switches (usually located on the rear panel) that adjust gain/sensitivity.

Caution: we strongly recommend the use of identically rated amplifiers, all with the **same voltage gain settings** within one system. We also recommend that all level control knobs are set to maximum. Any gain mismatch between amplifier channels will not only impact limiter settings, but will also require adjustments to be made to the overall balance of the system.

If the voltage gain is specified in dB disregard the next two sections and move directly to Section 3.

2.1. Linear voltage gain conversion to dB

If the gain of the amplifier is specified as a multiplier we need to convert it to dB using the following formula:

$$G_A = 20 \cdot \log(M_A)$$

With M_A: the amplifier gain multiplier

2.2. Input sensitivity conversion to voltage gain in dB

If only input sensitivity is specified then calculating voltage gain in dB will be a little more complicated. The sensitivity of an amplifier depends of the impedance of the load. Amplifiers have a lower input sensitivity at lower impedances because the voltage gain remains the same.

In the amplifier's technical specifications, you will find that sensitivity is specified for a given load impedance. To calculate the voltage gain we will therefore need: a) input sensitivity, b) the impedance at which the sensitivity is given and c) the full rated power for this sensitivity (and impedance). You may then compute the voltage gain in dB using the following formula:

$$G_A = 20 \cdot \log\left(\frac{\sqrt{P_A \cdot Z_A}}{S_A}\right)$$

With P_A: the amplifier's full rated power in Watts for the given sensitivity

Z_A: the load impedance in Ohms at which the sensitivity is rated

S_A: the amplifier input sensitivity in Volts

If the sensitivity is expressed in dBu instead of volts, you may convert it using this formula:

$$S_{A\_volt} = 0{,}775 \cdot 10^{\frac{S_{A\_dB}}{20}}$$

3. Calculating the RMS limiter threshold

Now that the maximum RMS voltage (VL) that may be applied to the speaker and the amplifier gain (GA) are known, we can compute the maximum RMS voltage at the output of the Intelli-X² (V_{rms_max}):

$$V_{rms\_max} = V_L - G_A$$

Note: Manufacturers determine power handling of a loudspeaker by the applying a test signal (usually pink noise) over a period of several hours. After this test, the driver should not show any appreciable damage, which is expressed as a percentage of change in the specification. As our goal is to protect the loudspeaker against **any damage**, we need to ensure that the power is kept below the given rated power handling figure.

Furthermore, all previous formulas are correct for purely resistive loads and use of a steady sinusoidal tone. Loudspeakers are not pure resistors (and you probably won't just play sine waves), but these assumptions are sufficient provided that some margins are taken into consideration.

We therefore recommend using a margin of at least 2 or 3 dB on the previously calculated Intelli-X² maximum output voltage. The formula to obtain the RMS limiter threshold is amended as follows:

$$V_{rms\_max} = V_L - G_A - 3$$

4. Calculating the peak limiter threshold

Returning to the way manufacturers test their speakers; the applied test signal usually has a crest factor of 6 dB. You may also have noticed that loudspeaker peak program power is mostly specified as being 4 times the continuous power. Quadrupling the power into a resistor is equivalent to doubling the applied voltage, which means adding 6 dB of gain. So we could deduce that setting the Peak limiter 6 dB above the RMS stage would be ideal. However, loudspeaker drivers can usually withstand momentary power peaks well in excess of those they are subjected to during power handling tests. Furthermore music has a far higher crest factor than pink noise. We recommend the **Peak limiter threshold should be set no higher than 9dB above RMS limiter threshold**. This should ensure sufficient protection against driver over-excursion.

We now have to consider the clipping point of the amplifier. Driving an amplifier in clip may have dramatic and disastrous consequences on your loudspeakers. If the amplifier is not powerful enough or its voltage gain is very high, there is a risk that the amplifier will clip before the limiter peak threshold is reached.

4.1. Preventing amplifier clip

To prevent clipping, the peak limiter threshold (V_{peak_max}) of the Intelli-X² must match or be set just below the amplifier maximum input level. The maximum input level, sometimes referred as input clipping may usually be found in the technical documentation in the form of a gain value in dBu (e.g. +15dBu or +21dBu) or tension value in volt (e.g 16v). If the clipping point is written in dBu, no further investigation is required and this value may directly be use to set the peak limiter threshold. A small margin may be required.

Some amplifier manufacturers do not specify the maximum input level but a maximum output voltage. The maximum input level may be calculated as follows:

$$V_{peak\_max} = 20 \cdot \log\left(\frac{V_{A\_peak\_max}}{0.775}\right) - G_A$$

With $V_{A\_peak\_max}$: the amplifier's maximum output level in Volts

V_{peak_max}: the peak limiter threshold in dBu

5. Calculating attack and release time constants

The Intelli-X2''s attack and release time constants are mainly related to the RMS limiter stage. The Peak limiter has a virtually instantaneous attack time and a release time logarithmically proportional to the release time set in the RMS stage.

The primary purpose of the time constants is for sonic enhancement, although the faster the attack time, the more efficient the protection. However, if the attack time is too short, transient suppression would result (which typically is unwanted). Similarly, the release time has no real protection purpose, but correctly calculating the release time is necessary in order to prevent the limiter from modulating the programme material, which may sound unpleasant.

As a rule of thumb the Attack (T_{attack}) and Release ($T_{release}$) time constants should be set depending on the frequency of the crossover's high-pass filter:

$$T_{attack} = \frac{1000}{f_{HPF}}$$

$$T_{release} = 16 \cdot T_{attack}$$

With T_{attack}: limiter attack time constant in milliseconds

$T_{release}$: limiter release time constant in milliseconds