TECH PAPER
2016

Audiology for loud, dynamic environments

INTRODUCTION

Loud environments occur often in course of a normal day. Environments such as noisy traffic, busy restaurants, bars, sporting events, and music venues are some of the most common ones. The hearing aid must process these environments authentically and undistorted, every time. The new Velox platform enables an extension of the dynamic input range up to 113 dB SPL. This allows for better sound quality and higher signal fidelity of loud inputs.

When increasing the range of undistorted inputs coming into the instrument, care must be exercised to make sure that this does not allow for sudden, uncomfortable loudness in the ear of the user. The traditional limits on input level have had the benefit of shielding the user from high outputs, even before reaching MPO. This protection changes when louder inputs can be faithfully reproduced as being loud. Therefore, the output controls in the instrument must be adjusted and updated to ensure that uncomfortably loud output does not occur.

This paper describes the new extended input range provided by Clear Dynamics and the benefits this may provide users in loud environments with speech or listening to music. How widening the input range affects the demands on the handling of comfort-related features like Transient Noise Management and maximum power output (MPO) is also described.

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In 2012, the Los Angeles Times[1] explored the loud experience of dinning out. They visited five restaurants, five different weeknights during peak hours and found that the noise levels peaked around 83-90.3 dB dB SPL. This is just the peak, the article describes that levels consistently were between 80-90 dB SPL. The combination of sound reflecting interior features - floor to ceiling windows, open steel kitchens, concrete floors, high ceilings, hard tabletops – multiple, loud and animated conversations and background music contributed to the loud environment found at the restaurants. Noise at a restaurant or at a music venues is seldom steady state or monotonous. Often "noise" at the locations just mentioned is not only noise, but part of the "scene" and experience of going out. Speech and music are dynamic signals that vary in amplitude with peaks and pauses that are important for understanding and/or enjoying what you are hearing.

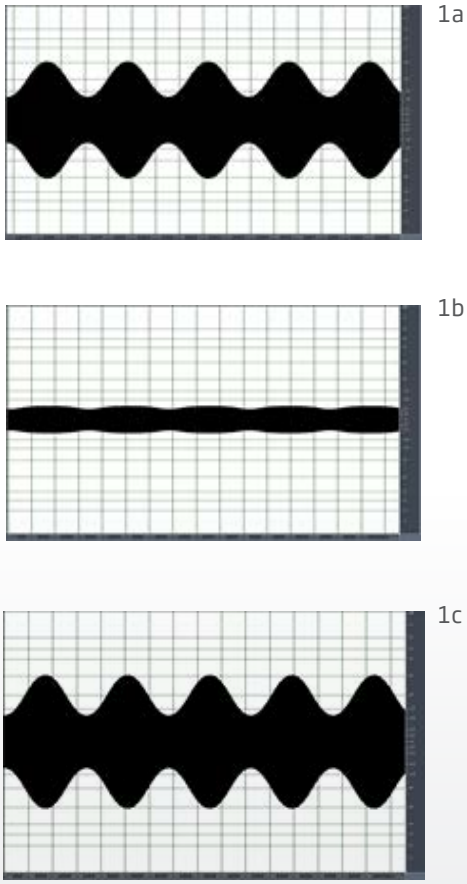
School can also be a loud experience. Cruckley[2] set out to describe the acoustic environments and listening situations encountered by children across an entire day at school or daycare. He measured sound levels across various school settings throughout a day. The youngest children, toddlers, (and their caregivers) were in the environments with the highest level of all environments followed by pre-school children at the daycare, with maximum levels reaching more than 90 dBA both places. The noise levels went down to 50-60 dBA around naptime, but at all other times the level was between 75-90 dBA.

Sporting events are known to be loud, very loud. The average volume during an NFL game is in the mid-90-decibel range[3]. Watching a game at a sports bar instead of the stadium is also quite loud. On average bar noise was in the 70 decibel range, about the noise level of a vacuum cleaner. It ratcheted up to nearly 110 decibels during touchdowns and even higher to 111.2 decibels during big plays[3-6]. Swanepoel and Hall[7] measured the sound pressure levels at premier soccer league match at a designated FIFA 2010 training stadium in Gauteng, South Africa. The average sound exposure level during the match was 100.5 dBA, with peak intensities averaging 140.4 dBC.

Surroundings can be loud, but this should not mean that they are compressed, distorted, or unpleasant for users of hearing aids.

Limitations on conventional processing of loud inputs

One of the limitations of current hearing instrument systems lies within the "translation capabilities" of the analog-to-digital converter (A/D converter). It sets the limit of the range of inputs that can be translated from physical sound pressure to a complex number (i.e. digitization). Thus, the system spans over a range of input levels, beyond these levels the system will compress the input to make it "fit" into the range of the A/D-converter. This means an input louder than the upper limit of the system will be compressed and then treated as being lower in sound pressure than it originally was. Thus, peaks and dynamics in music played at loud levels will be removed or compressed by the instrument and not faithfully reproduced through the instrument to the user. Another drawback is that the loud level coming into the instrument and directly into the ear through a vent or an open solution will possibly be louder than the output of the instru-



Figures 1 a, b, and c show the input (l1a, top), with limitations/without Clear Dynamics (1b, middle), and output without limitations/with Clear Dynamics (1c, bottom).

ment into the ear. The two inputs will be competing in intensity and negative affect the sound quality, and thus, the wearer will not get the benefits from help systems and other signal processing as the external signal will dominate the sound picture.

Figures 1 a, b and c show how compression of peaks at loud levels change the signal fidelity.

Figure 1a (top) shows the input that is coming into the hearing aid. It is a 2kHz signal modulated with 5 Hz played at 106 dB SPL. When the adaptive gain compression kicks in to make the signal fit the A/D-converter, the signal is changed and looks like the signal found in figure 1b (middle), but when the A/D-converter is **not** allowed to limit the instrument, what is relayed for further processing is identical to the input (figure 1c, middle). This is a stylized example, but a similar process takes place in real environments with loud speech, music, noise etc. Peaks are compressed and reduced and signal fidelity lost.

Music, especially, causes problems for a limited A/D-converter, as music has a higher crest factor than speech. The crest factor is the difference between the highest peak and the long-term average of the sound. As a rule of thumb, speech is usually said to have peaks that are 12-14 dB louder than the long-term average speech level. For music, the crest factor is up to 30 dB; and more of the dynamic peaks of music are in danger of being compressed to "fit" into the range of the A/D-converter.

Loud environments with Velox

Clear Dynamics extends the dynamic input range of the hearing aid. It increases signal fidelity, reduces distortion and compression of loud inputs and maintains level- and envelope cues at loud levels.

Technically, it does so by adding a dynamic component to the input adaptive gain control that enables at high input levels, but not at low levels. As the input signal intensity increases, Clear Dynamics initiates at 80 dB SPL to ensure that the A/D converter preserves the needed headroom. Therefore, it does not add quantization noise[I] for soft inputs and thus the digital platform and the microphone determine the lower limit or noise floor of the platform. This combined with the efficient silencer for internal microphone noise ensures high sound quality for lower level input signals.

This extends the dynamic input range to an upper limit of 113 dB SPL while keeping distortion at a minimum (< 5% total harmonic distortion, figures 3a & b).

[I] *Quantization noise is the difference between the input value and the quantized (digital) value e.g. when values are rounded-off to nearest value.*

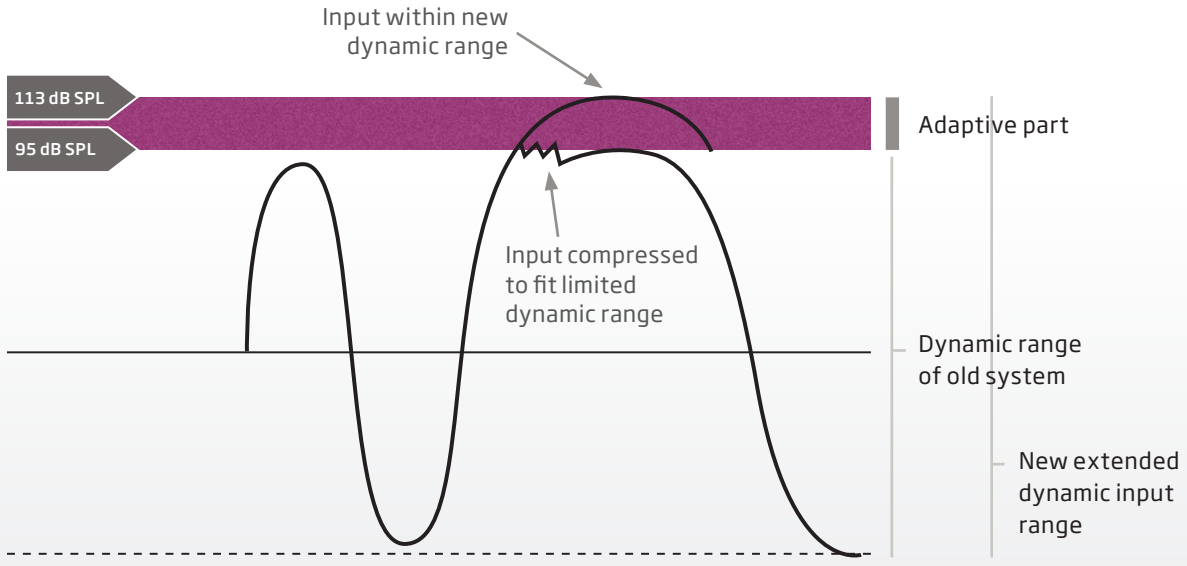
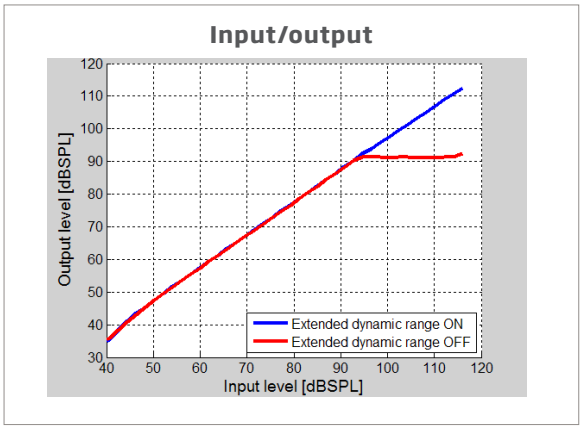


Figure 2 shows how the input is compressed to fit into the dynamic range of the system. By extending the dynamic range, the peaks of input signals are allowed through and delivered undistorted in the hearing aid output.



Figures 3 a & b show the input/output curve for 1 kHz pure tone measured in a 711 coupler (left) and the measured total harmonic distortion (THD) of Oticon Opn (right).

Transient Noise Management LX

Transient Noise Management (TNM) from the Inium Sense platform products has been updated to comply with the new extended input range of the hearing aid as sudden, loud transients can be very uncomfortable for the user. With a higher input range, a higher risk of even louder transient exists. Instead of conservatively reducing gain on the input side, TNR reduces uncomfortable transients by performing output-based prediction of what is going to be too loud and then selectively performing gain reduction to sudden, loud peaks.

MPO

Clear Dynamics opens the dynamic input range of the instrument. When the input range is extended, the loud inputs that used to be compressed on the input side are now allowed to pass through the hearing aid signal processing. This necessitates diligent handling of instrument output levels to make sure that the hearing aid wearer is not subjected to uncomfortable loudness. The extended range increases the chance of reaching the maximum power at the output end of the instrument.

Therefore, attentiveness must be given to ensure good sound quality and minimal distortion of loud output. The target is to quickly restore normal compression after MPO and slowly release the compression for better sound quality. Consequently, the MPO has been strengthened in two ways to react quickly and maintain good sound quality close to the output limit

a. The MPO uses the Speech Guard-like ability of adaptive release after compression. This means that compression is released in two stages; quick restoration to approach normal compression and then continue slowly until the compression is fully released.
b. The MPO uses a "look-ahead"-method to adjust gain to avoid reaching MPO. This means that the system uses the very small delay in the instrument to predict if the output will be over MPO if gain is not reduced. This way gain is adjusted and distortion can be avoided.

Conclusion

The paper described how the linear input range of the Velox instruments is now extended up 113 dB SPL. This provides higher signal fidelity and avoids unnecessary compression for loud inputs. When the input range is extended, the features that ensures user comfort must be updated and enhanced as well. Transient Noise Reduction and MPO is enhanced for the Velox platform safeguarding the user from sudden, uncomfortably loud transients.

A special thanks to valued colleagues, David Thorn Blix, and Jan Pedersen, in Oticon R&D for their efforts providing technical explanations, advice and measurements.

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