Compression Basics: An Overview

Starkey Education & Training

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CAN YOU HEAR ME?

If you are having technical problems, please stay logged on and call Audiology Online at 1-800-753-2160

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This session is available for 1/.1 CEU

Must stay logged on for the full session

Must successfully complete a short quiz

Learning Objectives

After this course:

1. Participants will be able to identify the different types of compression
2. Participants will be able to define compression threshold kneepoint
3. Participants will be able to define compression ratio
4. Participants will know the rationale behind wide dynamic range compression

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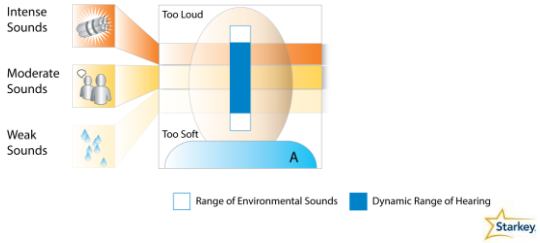
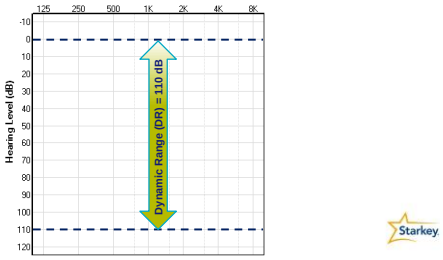
WHY Compression?

Normal Hearing Dynamic Range

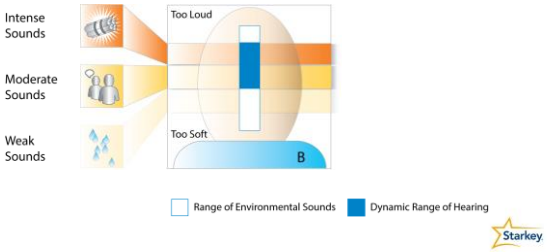


Normal Hearing Dynamic Range

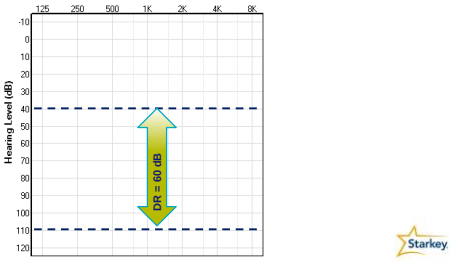


HOW does this change in the case of hearing loss?

HEARING IMPAIRED dynamic range



HEARING IMPAIRED dynamic range



Recruitment

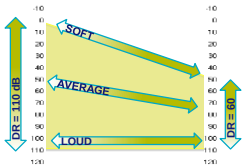
Sounds get louder more quickly for someone with sensorineural hearing loss

Mimicking the dynamic nature of the intact auditory system

Squeezing an Elephant Into a Suitcase

Goal

Fitting the world of sound (the elephant) into the dynamic range of the individual with hearing impairment (the suitcase).

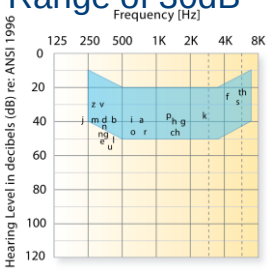


Bottom Line

- Soft sounds must be made audible
- Loud sounds cannot become uncomfortably loud
- Speech should remain at a comfortable level

WHAT are the most important sounds for a person to hear?

Average Conversational Speech Spans a Range of 30dB

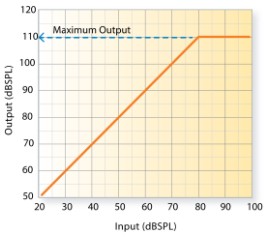


Signal processing approaches

Compression in the Modern Hearing Aid

Linear Approaches

Linear Amplification



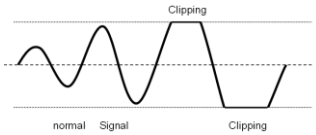
A fixed amount of gain regardless of input level

- 1:1 Ratio (gain : output)

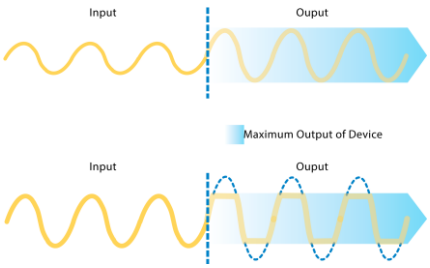
Maximum output

Maximum Output

- **Highest possible signal** that a hearing aid capable of delivering
  - Saturation (Peak Clipping)
    - Input level and gain exceed the maximum output



Peak Clipping



Limitations of Linear Approaches

While making soft sounds audible…

- Average conversational speech is now loud
- Intense sounds are amplified beyond the upper end of the dynamic range making them uncomfortably, or even painfully, loud
- Peak clipping is distortion

Cases in which linear approaches still apply

- Long-time linear technology users
- Severe to profound hearing losses
- Conductive & mixed hearing losses

Non-linear Amplification

Compression Terms

- Threshold kneepoint
- Compression Ratio
- Attack and Release Time
- Output compression limiting

Compression Terms

Threshold Kneepoint (TK)

- Point at which compression is activated
- Also referred to as Compression Threshold (CT)

*Advanced hearing aids have multiple kneepoints

Compression Threshold/Threshold Kneepoint (TK)

Controls how long linear gain and/or expansion is in effect

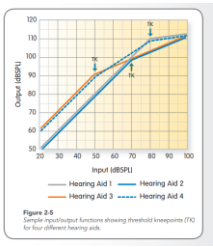


Figure 2-5
Sample input/output functions showing threshold kneepoints (TK) for four different hearing aids.

Threshold Kneepoint

Considerations:

- Higher TK
  - Linear longer
  - May be beneficial for more severe hearing losses and previous hearing aid wearers

Compression terms

Compression Ratio (CR)

- Determines how much the signal will be compressed
- Expressed in a ratio:
  - 1:1 = linear
  - >1.1:1 = compression

Compression Ratio

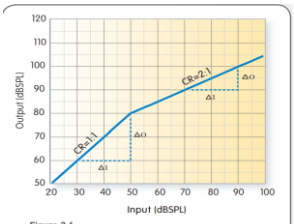


Figure 2-6
Calculating compression ratios (CRs) from an input/output function. ΔI = Change in input, ΔO = Change in output.

Compression Ratio

Considerations:

- Lower CR
  - Improves audibility of the softer components of speech
  - Restores loudness perception
  - May be beneficial for more mild hearing losses and new hearing aid wearers
  - May over amplify softer, non-important environmental sounds

Compression Ratio (CR)

Considerations:

- High CR
  - May provide comfort to sounds, but may adversely affect the clarity and pleasantness of the amplified sound
  - Muffled sound quality

Attack and Release Times

Lengths of time it takes for a compression circuit to respond to intensity changes of input/environmental sounds

(Venema, 2006)

Attack time

Length of time it takes a hearing aid to go into compression and reduce gain.

Release Time

The length of time it takes for the hearing aid to come out of compression, and restore gain

(Venema, 2006)

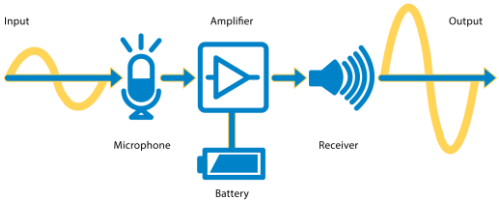
Attack and Release Times

Considerations

- Faster AT:
  - The faster they benefit from compression – soft sounds audible, loud sounds not too loud etc.
  - BUT if too fast: can negatively impact sound quality
- Longer RT
  - Ensure variability doesn't impact the processed signal
  - BUT if too long: can effect intelligibility of speech following transient sound

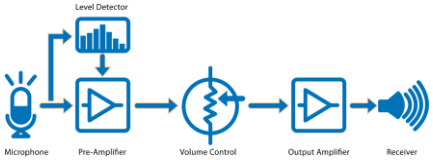
How does the volume control interact with compression settings?

Basic Hearing Aid Components



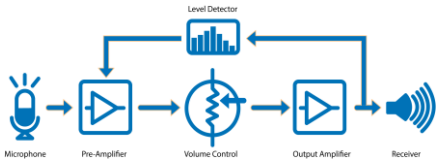
Input Compression (AGC-i)

- Compression acts before the volume control
- TK is not effected by volume control changes
- Most commonly used with wide dynamic range compression



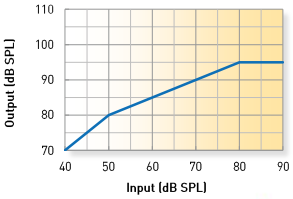
Output Compression (AGC-O)

- Compression acts after the volume control
- TK is effected
- The volume control has no input on maximum output of hearing aid



Compression limiting

- Use of compression to control or limit loud sounds without causing distortion
- High TK's (70 dB or greater)
- High CR's (8:1 or greater)

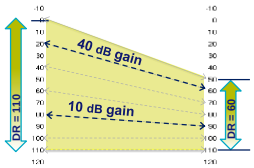


Wide Dynamic Range Compression & Expansion

Wide Dynamic Range Compression

The hearing aid provides different degrees of amplification depending upon input level

- Softer sounds are given more amplification than louder sounds
- Attempts to reproduce the full dynamic range of the world into the reduced dynamic range of the listener



Wide Dynamic Range Compression

WDRC

- AGC-I
- Low TKs: Below 50 dB SPL
- Variety of CRs: 1.1:1 to 4:1
- Variable AT & RT

Expansion & Limitation of Compression

In Compression:

- Soft sounds are amplified to a greater extent than moderate & intense sounds
- This improves speech intelligibility

BUT…

- Unwanted sounds are made audible as well

Expansion

Principle:

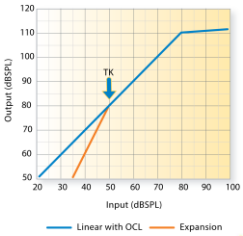
- Soft sounds are not amplified
- Ensure you do not provide any gain below a certain input level

How it functions:

- It only applies to the weakest sounds in the environment
- Different amounts of gain are applied dependent on input level

Expansion Threshold (XT/TK)

- Input level below which expansion operates
- Expansion acts BELOW the TK/XT



Expansion Ratio (XR)

Extent which an input signal is expanded.

$$XR = \frac{\Delta \text{ Input}}{\Delta \text{ Output}}$$

Expansion threshold Considerations

Low XT:

- 40 dB or lower
- Pro: Ensures speech audibility at lower levels
- Con: May still be a 'noisy' hearing device

High XT:

- 50 dB or greater
- Pro: Quieter hearing device
- Con: Negative impact on speech audibility

Expansion ratio vs. Compression ratio

Remember…

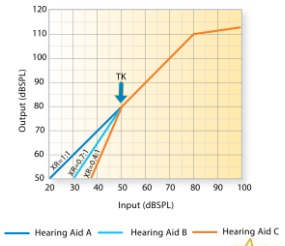
- A CR of 1 is linear
- CR when compression is acting is always greater than 1

XR:

- Always between 0 and 1 when expansion is being applied.

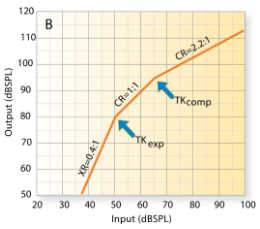
Expansion Ratio

The steeper the slope, the greater degree of expansion



Expansion

XR is typically separate from CR in hearing aids



Quiet

Enhancing Expansion with our patented fast-acting noise management, **Acuity Quiet** makes hearing aids quieter in low level environments than what is possible with Expansion alone.

Applications of Compression

Compression in the Modern Hearing Aid

Channels/Bands & Prescriptive Formulas

Channels vs. bands

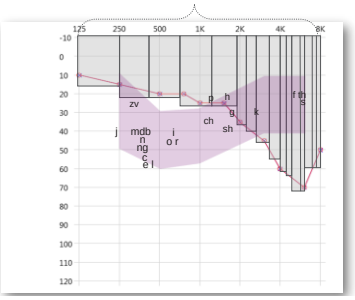
- Terms often used interchangeably
- Specifics of how defined can slightly differ in the literature or between manufacturers

BANDS

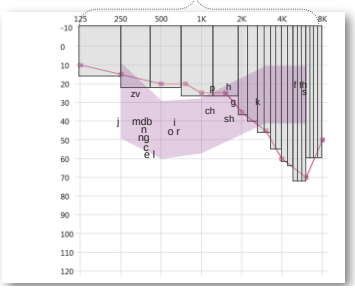
SHAPE FREQUENCY RESPONSE of the hearing aid

Accommodate **LOUDNESS TOLERANCES**

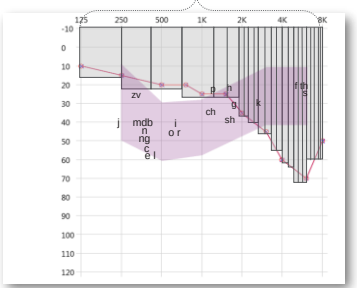
16 Bands



20 Bands

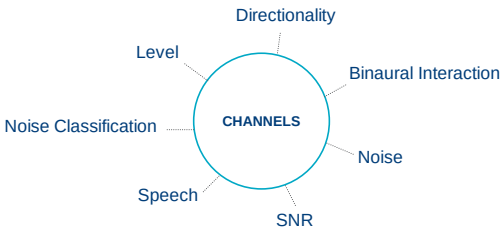


24 Bands



CHANNELS

Implementation of
ADVANCED FEATURES
to provide more
PRECISE NOISE CONTROL



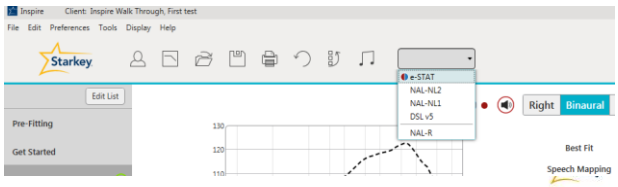
Prescriptive Fitting Procedures/Fitting Formulas

The compression architecture:

- Proprietary fitting formulas
  - Manufacturer specific
- Generic fitting formulas, not manufacturer specific
  - NAL-1/NAL-2, NAL-R
  - DSL

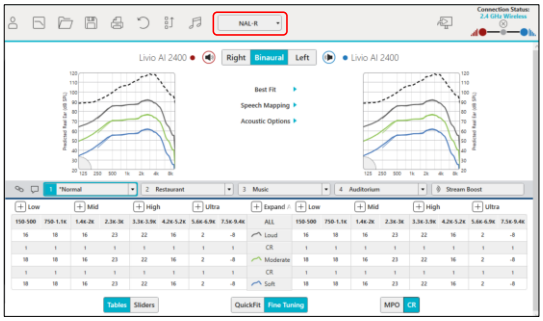
Fitting Formulas Within Inspire

- Variety of fitting formulas are available
- e-STAT is the default



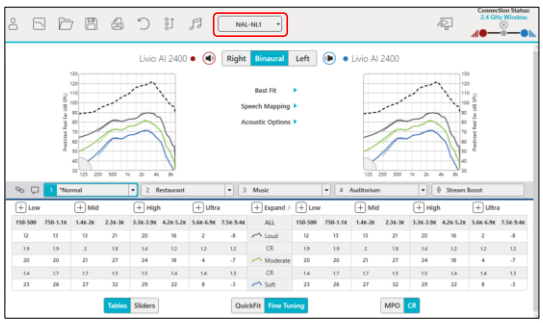
NAL-R

- Linear formula
- Utilizes a loudness equalization rationale



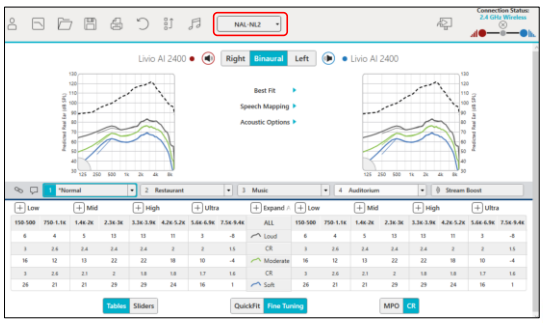
NAL-NL1

- Development based of NAL-R
- WDRC
- Based upon predictive model for speech intelligibility
  - Derived ANSI SII
- Utilizes a loudness normalization rationale



NAL-NL2

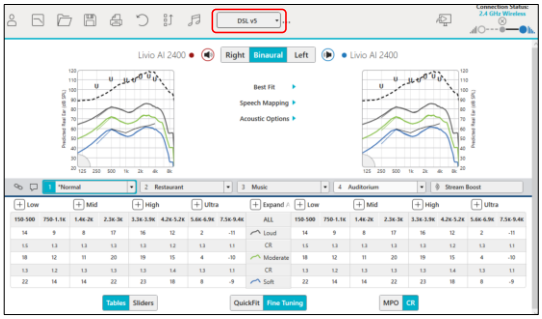
- Developed based empirical data collected over a decade regarding NAL-NL1
- Still WDRC
- Primary goal remained the same
  - Loudness normalization
  - Predictive model of speech intelligibility



DSL v5.0

- Desired Sensation Level
- Developed for pediatric fittings

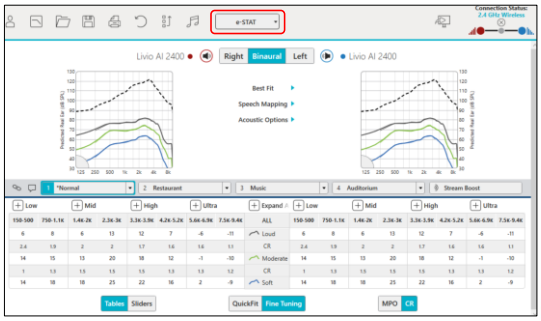
- Compression characteristics:
  - Dependent on the severity of loss.
  - Closer resembles a loudness equalization rationale: full audibility, including in quiet environments is the priority.

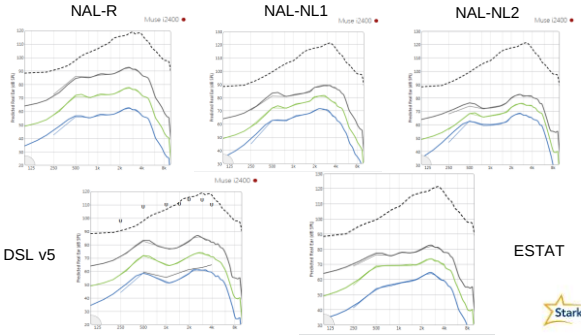


Evidence-Based Statistic Analysis (eSTAT)

Starkey proprietary formula:

- Developed to work specifically with Starkey products
- Main goal:
  - To maximize audibility and speech understanding
- Utilizes WDRC principles:
  - Low CR, low CT & fast-acting.
- Continues to be optimized for the best fitting starting point possible
  - Based on research and professional input





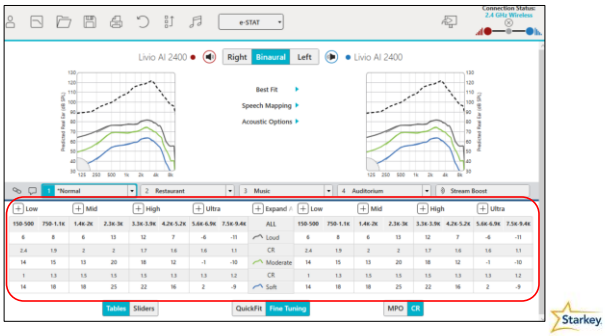
Independent Speech Optimization (ISO-C)

Goal:

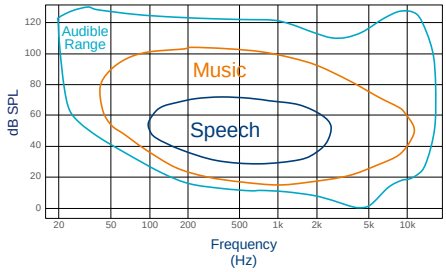
- Provide the best sound quality possible for soft speech
- Provide independent gain controls for soft vs. moderate vs. loud sounds within the Inspire software

Speech Optimization: Starkey Compression

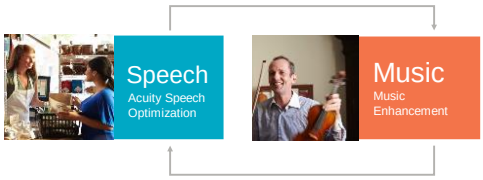
- Starkey WDRC compression system gain changes track speech input smoothly, quickly and accurately
- Allows for precise, intuitive management of speech by allowing discrete gain adjustments
  - Per channel changes to soft, moderate and loud speech inputs
- Compression Kneepoints based on the Long Term Average Speech Spectrum (LTASS)
  - Provides max gain at soft speech inputs
- Compression Ratios change based on the gain required at each frequency and input level
- Compression architecture defines sound quality



Speech vs. Music



Twin Compressor Technology



Unique Music Compression

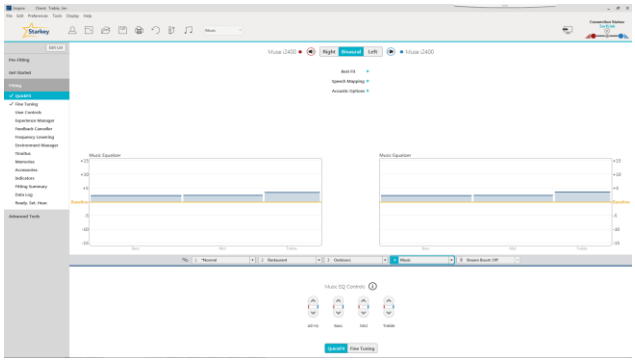
10 kHz Bandwidth

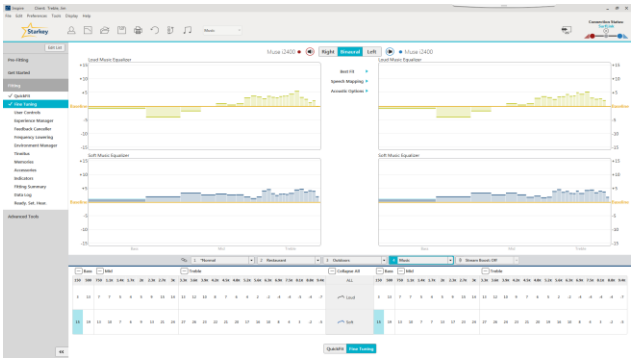
Compression Variables Optimized for Music

Loud Music Processed without Distortion

Proprietary music fitting formula

Linear Gain at High Inputs to Restore Loudness





Why not the same approach for everyone?

- Linear alone does not accommodate a reduced dynamic range
- WDRC is not for everyone
- Not everyone prefers the same fitting formula
- People have different preferences for sound quality and reactions to amplification
- Dynamic Range varies greatly from person to person
- Digital products offer the ability to combine various approaches

Thank you

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