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Rethinking Compression Adjustment

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TOPICS IN TECHNOLOGY

Rethinking Compression Adjustment

By Steve Armstrong and Don Shaver

Over the last few years, new circuit technology has been introduced to hearing instruments at a rapid pace. In many cases, this new technology has provided significant benefits in terms of hearing instrument functionality and versatility. However, advances in hearing instrument circuit technology are only as good as the ease with which that technology can be applied by the hearing health professional for the benefit of the hearing-impaired individuals.

With the introduction of DynamEQ® technology, Gennum has received a number of inquiries regarding the compression adjustment methodology on which these circuits are based. This methodology is admittedly quite different from that used in traditional compression instruments. In fact, to some the approach is completely opposite. However, there are fitting benefits to be derived from the new approach and once, it is properly understood, these benefits become clear. In response to the confusion, this paper provides a brief review of compression, a description of the adjustment approach used and the resulting fitting benefits derived from this approach in comparison to previous compression technology.

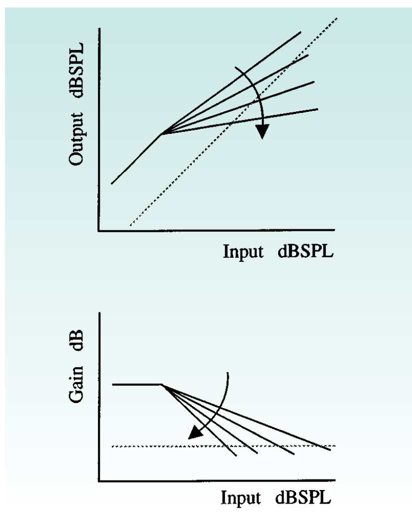

Fig. 1: *(Top) Effect of I/O curve of increasing the compression ratio. (Bottom) Corresponding decrease in gain for loud sounds resulting from increasing compression ratio.*

Why Compression?

All electronic circuits have a limited output capability, and hearing instrument circuits operating on a low 1.3V battery are certainly no exception. The distortion that results when a circuit goes into saturation can reduce both sound quality and speech intelligibility. Output saturation results when an incoming sound combined with the gain it receives exceeds the drive capability of the amplifier. To reduce the chances of circuit overload, linear hearing instruments have relied on increased output or "Headroom." Alternatively, the gain could be reduced to prevent overload.

This is precisely the approach taken in Automatic Gain Control (AGC) designs. Broadly speaking, high compression ratio AGCo (compression limiting) has traditionally been used to achieve this design goal. In this application, speech is not normally loud enough to activate the AGC action and thus, the AGC-O instrument behaves as though it were linear in most listening conditions.

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Recruitment Compensation & Wide Dynamic Range Compression

Beyond the goal of distortion reduction, some hearing instruments also try to tackle the problem frequently referred to as recruitment. Recruitment can be defined as the abnormal growth in loudness level in the pathological ear in comparison to the normal ear.

Compression used for the purpose of loudness growth compensation works over a much wider range of input levels, since it must provide the most gain for quiet sounds and progressively less gain for louder sounds. Typically, hearing instruments designed for this purpose feature lower compression ratios than circuits designed solely for distortion reduction. Most are of the AGCi type where the user's volume control has the effect of adjusting the gain given to all sound levels.

The greater range of input signals over which the AGC operates has led to their common description as Wide Dynamic Range Compressors (WDRC).

Variable Compression Ratio Adjustment

Compensation for abnormal growth in loudness level, a primary goal of WDRC, implies the ability to adjust compression ratios, since the individual need for recruitment compensation will vary with the degree of hearing loss. Pictorially this action from a traditional viewpoint can be seen in Fig. 1. The upper graph shows the Input versus Output (I/O) curve, which features a linear region at low input levels where the gain is constant. Above the threshold point lies the compression region where the effects of varying the compression ratio can be seen. The bottom graph shows an alternative view, where gain is shown as a function of input level. This representation has the advantage of driving home the point that higher compression ratios result in a quicker reduction of gain as input sound levels increase.

The parameters that can potentially be adjusted include gain, threshold kneepoint and compression ratio. Unfortunately, owing to the challenges presented by the space constraints of today's modern hearing instruments, only two of these parameters are usually available to the hearing health care professional. This is especially true for multichannel instruments which could conceivably have these parameters adjustable in two or more frequency bands.

In applying this technology, a typical approach might be to set the gain to achieve good performance in quiet conditions, then adjust the compression ratio (or threshold as the case may be) to match the reduced gain requirements for louder sounds. The compression ratio setting could be based on the needs predicted by a variety of techniques such as LGOB, IHAFF, DSL I/O or FIG6 to name a few.

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Adjustment for Reduction of Feedback

The observant reader may note that, according to the bottom panel of Fig. 1, the greatest gain for a wide dynamic range compressor occurs in quiet. This makes sense, since quiet sounds need the most amplification. However, this also hints that the greatest chance of acoustic feedback occurring is also for quiet conditions!

Assuming that squealing is an issue, the volume control could be turned down to stop the feedback, but then it would have to be turned back up in louder environments to get the required gain (since the circuit will reduce the gain automatically in response to the increase in input sound level). If the instrument user is forced to do this sort of balancing act with the volume control, the benefit of the “automatic” in AGC will have been somewhat negated.

Alternatively, the maximum gain of the hearing instrument can be reduced for quiet sounds. Of course, it would then have to adjust the other compression parameters to achieve the desired gain for louder sounds. The upper graph of Fig. 2 shows how higher-level performance may remain unaffected by adjusting the threshold upwards as gain is reduced downward, assuming these two adjustments are available to the practitioner. Conversely, the compression ratio could be made less in conjunction with a reduction in gain, as shown in the bottom graph of Fig. 2, resulting in similar high level gain and only moderate changes to the mid-level performance.

High Level Pivot Adjustment

Sometimes, when the fix to a problem becomes over-complicated, it makes sense to go back and review the goals of a product, in an effort to find a simpler solution. The goal being discussed is the compensation of abnormal loudness growth, which Killion[1] puts quite nicely as: “...‘a loss of sensitivity only for quiet sounds,’ which would, perhaps, have led to a totally different design philosophy.” This different design philosophy has been incorporated into the high level pivot approach to compression adjustment in new circuit technology including DynamEQ and K-Amp.

For many hearing losses, gain is only required for quiet sounds while little or no gain is required for loud sounds. We can take advantage of this observation by designing a hearing instrument that has a family of I/O

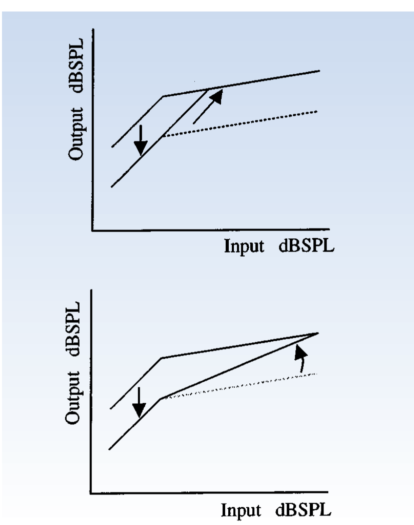

Fig. 2: *(Top) Gain reduced and threshold increased to reduce maximum gain without changing gain above threshold. (Bottom) Gain reduced and compression ratio reduced to give similar gain to loud sounds.*

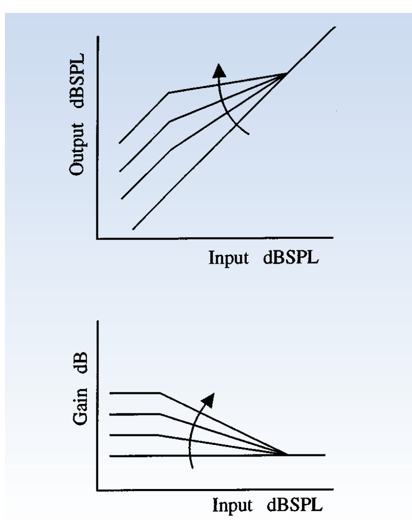

Fig. 3: *(Top) Effect on I/O curve of increasing the compression ratio. (Bottom) Corresponding increase in gain for quiet sounds resulting from increasing compression ratio.*

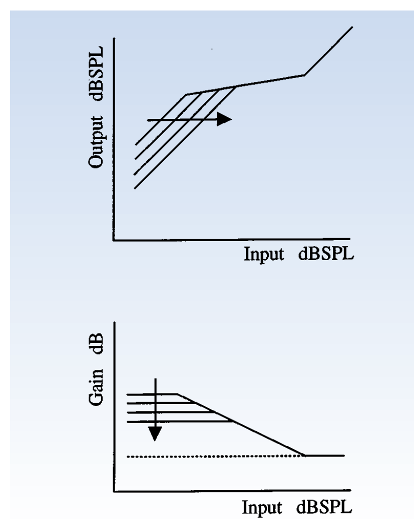

Fig. 4: *(Top) Effect on I/O curve of increasing the threshold kneepoint (TK). (Bottom) Corresponding reduction in gain resulting from increasing the TK.*

curves as shown in the upper panel of Fig. 3. This diagram and the gain curves on the bottom of Fig. 3 show that, as the compression ratio is adjusted, the gain given to loud sounds is unaffected. This control simultaneously adjusts both the compression ratio and the gain in quiet. In fact, some manufacturers who have applied this technology simply refer to it as the gain control.

The lower Threshold Kneepoint (TK) is also adjustable, but as Fig. 4 shows, increasing the threshold only changes the performance in quiet. This has led some to refer to this control simply as the “Maximum Gain in Quiet Trimmer.” This is a key advantage to the high level pivot adjustment approach used in DynamEQ® and K-Amp®. TK can be adjusted without affecting the response at high levels.

This implies that patients exhibiting recruitment can be fit properly for average speech and high level sounds where correctly adjusted gain and compression can be key to a successful fitting. Then, without negatively impacting the average speech/high level response, the hearing health care professional can adjust the hearing instrument’s response in quiet using TK to reduce feedback and/or adjust gain in quiet to alleviate circuit noise complaints. The end result is a more accurate and comfortable fitting.

Indeed, all other things being equal, two hearing instruments—one using the traditional approach where gain and compression ratio are independent and the other having gain and compression ratio tied together—will provide identical speech intelligibility and sound quality ratings (assuming matching I/O curves have been achieved). However, fine tuning of the instrument’s response in quiet using traditional compression adjustment requires somewhat of a balancing act between the gain control and TK. This is in contrast to the simplified adjustment made possible with DynamEQ® technology and other circuits based on similar approaches to compression adjustment.

By changing how the controls affect the operation of a hearing instrument, the ease of fitting can be facilitated, perhaps enabling greater benefit from existing technology.

Although hearing instrument design is constantly changing, sometimes the advances aren’t always in the technology used to manufacture the circuitry. By changing how the controls affect the operation of a hearing instrument, the ease of fitting can be facilitated, perhaps enabling greater benefit from existing technology. ◆

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