Sonic Spotlight

Eliminate Feedback Before it Starts - with the Adaptive Feedback Canceller from Sonic

Under the right circumstances, the sound of a whistling hearing instrument can be music to one's ears – the battery is charged, the microphone and receiver are functioning, and the sound outlet is free from wax or debris. Now hear that same whistle with an instrument in the ear, and the perspective changes immediately. For the wearer, frustration and compromised hearing occur all at once. Sonic is committed to developing hearing solutions that effectively control the occurrence of feedback in the ear. This paper describes how Sonic identifies and eliminates feedback, with the Adaptive Feedback Canceller.

Satisfaction Guaranteed?

Think that improving hearing for speech guarantees user satisfaction with hearing instruments? Think again. Feedback alone can cause user dissatisfaction with hearing instruments, to the point where they end up in the 'dresser drawer'.[1] Advancements in feedback cancellation technology have dramatically improved consumer satisfaction over the last decade, and indeed have led to the current popularity and success of open canal fittings.[2] Yet feedback issues still negatively affect 18% of hearing instrument users.[3] It follows, then, that hearing instruments must effectively control feedback in order to be fully accepted. Although easy to achieve for mild gain needs, controlling feedback becomes increasingly difficult with moderate to higher gain, or open fit instruments.

Physics of Feedback

Since the advent of hearing instruments, the physical properties that influence the likelihood of feedback remain unchanged. Besides the distance from microphone to receiver, these may include any of the following conditions related to the instrument, fit, or ear:

Instrument	Fit	Ear
Type (Open BTE, CIC)	Fit of the instrument in the canal	Pinna size and shape
Frequency response	Length and diameter of the earmold, earpiece, or canal shell	Residual ear canal volume
Gain	Angle of the sound bore in the canal	Eardrum impedance
Output	Amount of slit leakage around the earmold, earpiece, or canal shell	Reflective surface (phone, hat) near ear
Increased volume levels	Venting	Movement (chewing, bending)

Any or all of these factors may influence whether feedback will occur and at what frequency.[4] In certain circumstances, the amplified sound from the hearing instrument has a greater propensity to leak from the ear canal. The microphone captures the amplified sound escaping from the receiver and amplifies it repeatedly, until reaching maximum output level. This ongoing loop creates the phenomenon of audible feedback, as shown in Figure 1.

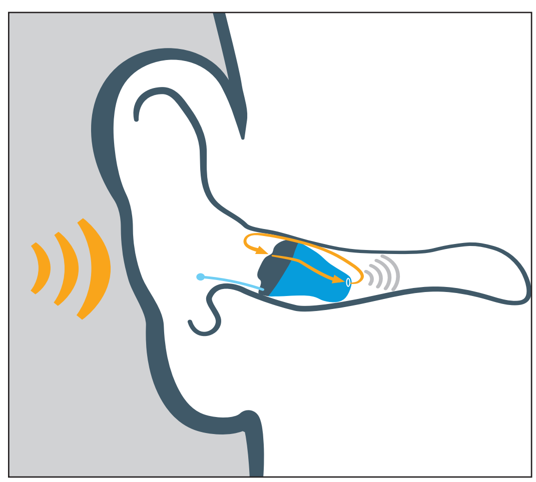


Figure 1: Feedback loop

Early Methods of Feedback Control

In the analog era, physically manipulating the hearing instrument response or acoustic pathway was the only way to control for feedback. That meant decreasing the gain or lowering the volume, inserting a damper, remaking the shell or mold, plugging the vent, or removing the reflective component (e.g., telephone) causing the interference. None of these solutions were ideal, since they typically resulted in a suboptimal hearing experience for the user. Inadequate gain for hearing, discomfort, occlusion of one's own voice while talking or chewing, or removing the aid during phone use frequently occurred.

With the introduction of digital hearing systems in the nineties, the development of digital feedback suppression algorithms (e.g., via notch filtering or gain reduction) started to make remarkable progress keeping feedback at bay. Most notably, it paved the way for open canal fittings to increase in popularity. However, design limitations with technology available at the time continued to hinder hearing. Many still required additional gain in the high frequencies, open venting for occlusion or outer ear concerns, or using a telephone without a telecoil, for example.

Adaptive Feedback Control

Current state-of-the-art feedback cancellation systems use adaptive methods of feedback control, which are greatly improved compared to methods used in the past. While some feedback cancellers act on a feedback signal after it becomes audible, others – like the Sonic Adaptive Feedback Canceller – act on the transfer function of the feedback path to stop feedback before it becomes audible. This type, based on phase cancellation, uses an adaptive filter to model the feedback path from receiver to microphone. This occurs whether the path is static (e.g., sitting still), or dynamic (e.g., placing a phone to the ear). The adaptive filter generates a new signal of equivalent magnitude to the feedback path. Finally, the phase canceller subtracts the generated signal from the microphone signal to cancel out feedback.[5]

An important factor in how accurately a feedback cancellation algorithm works relates to its speed. The Adaptive Feedback Canceller (AFC) from Sonic employs an exceptionally fast adaptation speed that reacts immediately to changes in the feedback path – whether from increased gain or volume, open dome acoustics, placement of a telephone, etc. – and quickly removes the offending signal before it has a chance to become audible to the listener, or others nearby.

In addition to its fast speed, the AFC incorporates a feedback monitor to further identify and eliminate feedback. The feedback monitor supports the adaptive algorithm to identify acoustic signals previously amplified. The monitor also helps to differentiate tonal sounds (beeps, music notes) from feedback.

The process is simple. As the microphone directs incoming sound into the instrument, the digital signal processer memorizes signal characteristics for later recognition. Feedback-free signals are processed and go directly to the receiver. As the microphone continues signal detection, the feedback monitor continuously observes new signals coming through. When the monitor detects a signal memorized by the system within the previous 5 milliseconds, it immediately routes the identified signal to the inverse phase canceller which removes the feedback before sending it to the receiver. In this manner, the system effectively identifies memorized sounds (feedback) from tonal sounds (beeps, music notes) and removes only the feedback before it becomes audible to the listener. Music and other tones remain clear and free from distortion. Figure 2 outlines the decision process that occurs in instruments when the Adaptive Feedback Canceller is active.

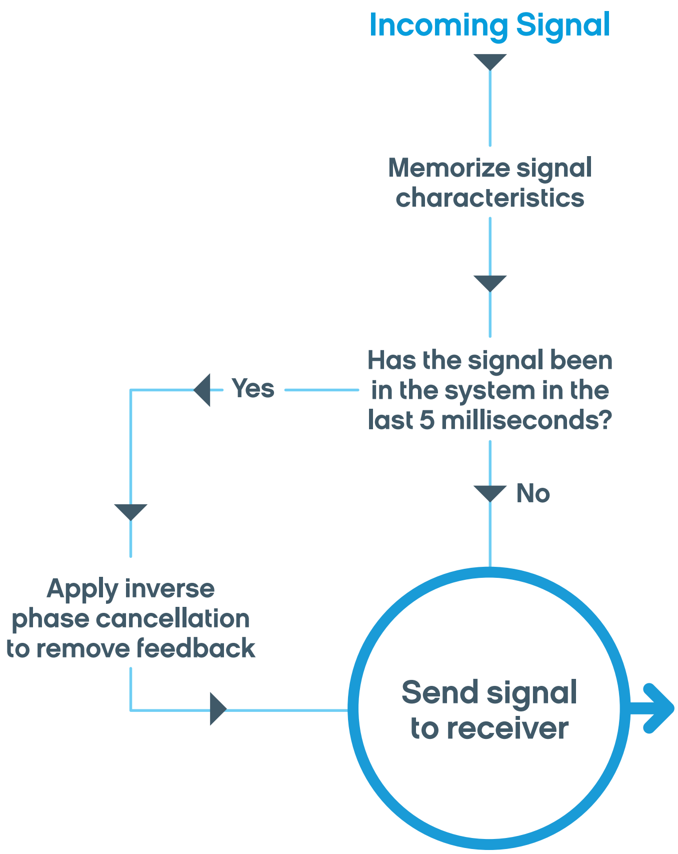


Figure 2: The Adaptive Feedback Canceller removes feedback signals before they are noticeable.

Added Stable Gain

By its robust design, the Adaptive Feedback Canceller allows feedback-free performance with more gain than otherwise possible when activated. One way to quantify this amount is by measuring Added Stable Gain. Added Stable Gain refers to the difference between a hearing instrument's maximum stable gain when the feedback canceller is on, compared to off. With the AFC on compared to off, Sonic instruments can support up to 20 dB additional gain between 1700 – 6800 Hz, within the limits of the fitting range. This allows the full high-frequency fitting range of the device to be used – beneficial not only because it is the region where amplification is often needed the most, but also because it is the region where feedback generally occurs due to the frequency response peak typical of most receivers.

Comparative Evaluation

To see how the AFC from Sonic compares to other commercially available adaptive cancellers, duration of feedback was investigated. Five competitor hearing instruments were matched, programmed with moderate gain levels (40-65 dB sloping hearing loss), and configured with open dome acoustics. Each was placed on a KEMAR manikin head inside a hearing instrument test box (Figure 3). The test set-up comprised two parts. First, a Sound Effect Sequence was selected as an audible stimulus to elicit feedback. The Sound Effect Sequence is a type of input stimuli composed of various high-frequency tones and intensity levels ranging from 50-86 dB SPL. Second, a mechanically rotating cup on a sliding track was engineered inside the test box to simulate dynamic changes to the feedback path. The automated set-up provided consistency for varying the feedback path on each of the six instruments. Once set in motion, the input signal was presented to each instrument for a total duration of 550 seconds. Recording of feedback started at the onset, and for the entire duration, of the presented signal via an in-the-ear microphone on KEMAR in the test box.

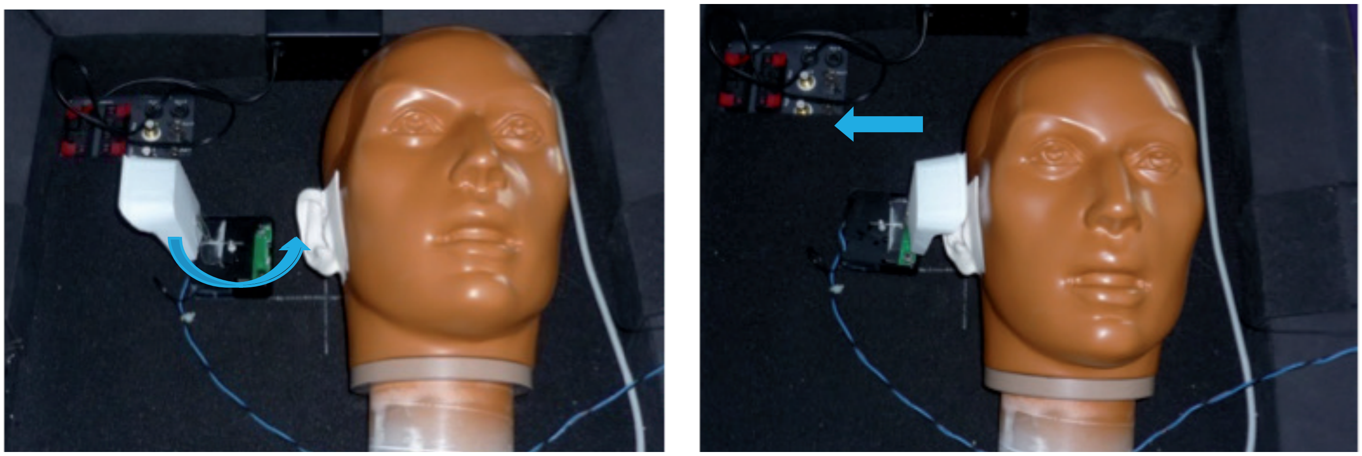


Figure 3: Test set-up with KEMAR

Duration of feedback: The first study question investigated the length of time for feedback cancellation to occur - between onset and removal of feedback squeal - in a dynamic feedback path with stimuli. Figure 4a shows the duration of audible feedback for the six devices tested. The AFC from Sonic had the shortest duration before feedback cancellation occurred, demonstrating it has the fastest feedback cancellation system compared to five competitors.

Figure 4a: Duration of total audible feedback for six commercially available adaptive feedback cancellers. Length of time before feedback cancellation occurred ranged from 3 s (fastest) to 764 s (slowest). The AFC from Sonic had the fastest feedback cancellation rate, outperforming all five competitors.

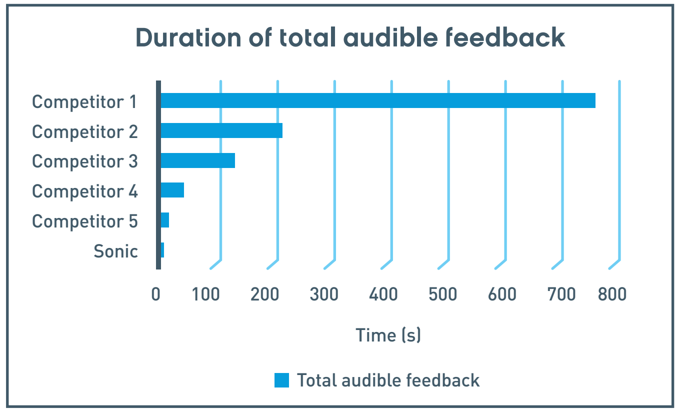


Figure 4a

Feedback intensity level: The second study question investigated the loudness of feedback in relation to feedback duration. Whereas Figure 4a shows the total duration of all audible feedback, Figure 4b shows only the duration of audible feedback greater than 80 dB SPL. The AFC from Sonic cancelled all feedback above 80 dB SPL before it had a chance to occur, relative to the five competitors which elicited feedback greater than 80 dB SPL during the feedback test.

Figure 4b: Duration of feedback greater than 80 dB SPL for the six adaptive feedback cancellers shown in Figure 4a. Length of time for feedback cancellation to occur ranged from 0 s (fastest) to 630 s (slowest). The AFC from Sonic allowed no feedback levels over 80 dB SPL, outperforming all five competitors.

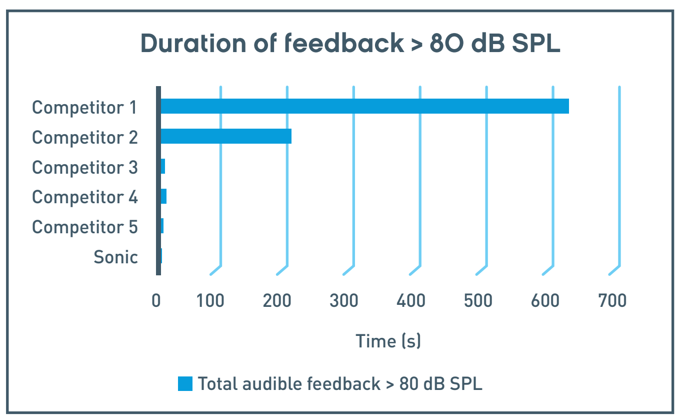


Figure 4b

Feedback-to-signal ratio: The final study question examined the feedback-to-signal ratio. The feedback-to-signal ratio was determined by measuring the duration of feedback exceeding the input signal by 6 dB. This level of feedback is great enough to mask speech, or another signal of interest. Figure 4c shows the duration of all audible feedback that reached a feedback-to-signal ratio of 6 dB or greater. The AFC from Sonic obtained no feedback that exceeded 6 dB over the input signal, compared to all competitors that did exceed the cut-off.

Figure 4c: Duration of feedback exceeding 6 dB feedback-to-signal ratio. Length of time for feedback cancellation to occur ranged from 0 s (fastest) to 392 s (slowest). The AFC from Sonic allowed no feedback >6 dB over the signal, outperforming all competitors.

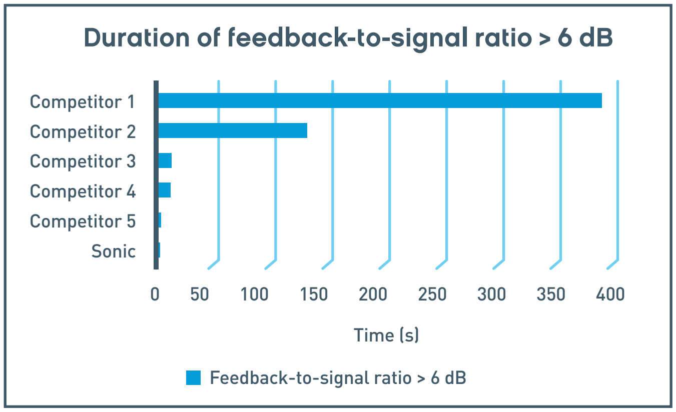
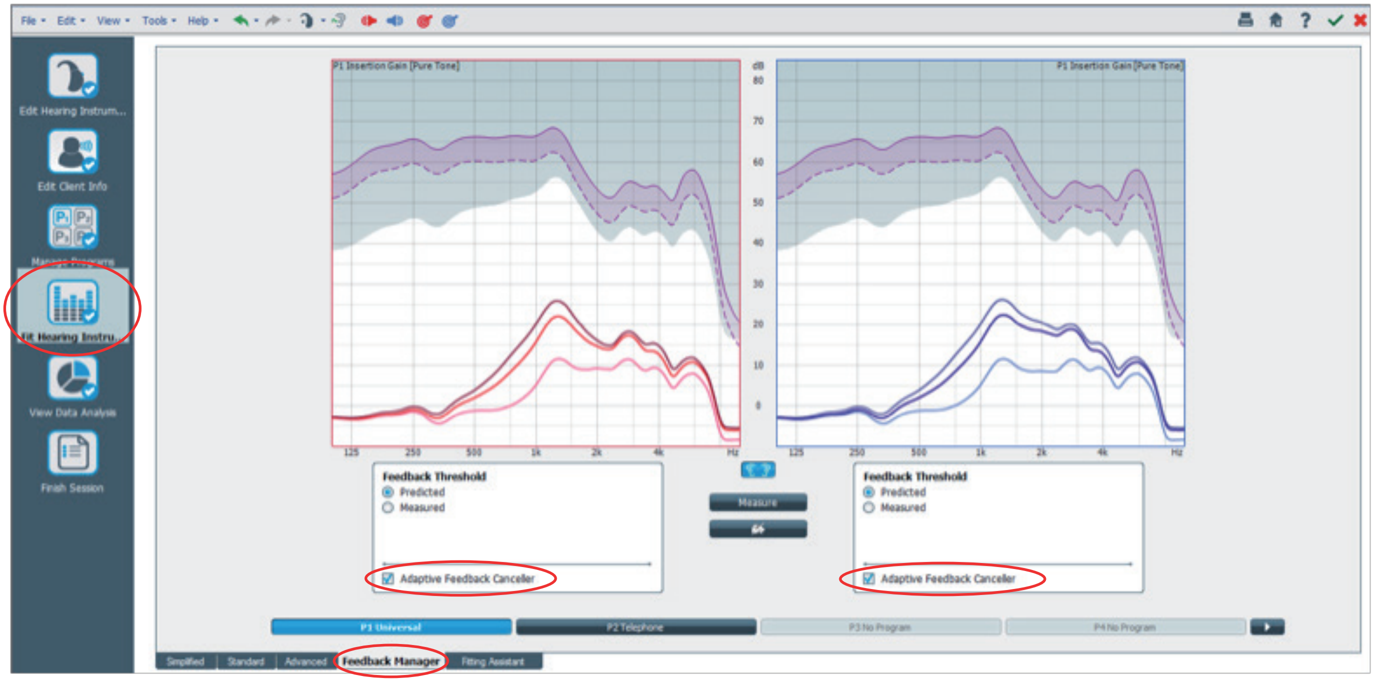


Figure 4c

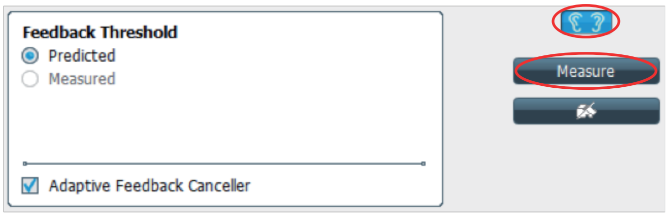
In summary, the investigation shows that not all feedback cancellers are equally effective. In dynamically changing environments using high-frequency input stimuli intended to elicit feedback, the competitors' instruments took a longer time to attenuate feedback. Furthermore, competitor feedback levels reached over 80 dB SPL, and exceeded the signal by 6 dB or more, when it did occur. The strength of the AFC from Sonic is its remarkable speed. Without reducing gain, the AFC adapts not only to rapid changes in the feedback path but also to high-frequency stimuli in the environment and eliminates feedback before it has the chance to become noticeable.

Adaptive Feedback Canceller in EXPRESS*fit*

For best results, run the Adaptive Feedback Canceller as part of the first fit protocol, even if feedback is not present during the session. In the Fit Hearing Instrument Screen, locate the Feedback Manager tab at the bottom of the screen. The AFC is on by default in each acoustic program (except Music).

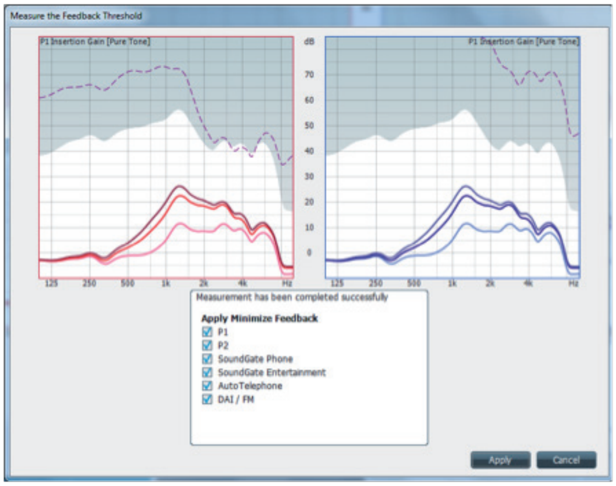


EXPRESS*fit* provides a predicted Feedback Threshold zone (in purple), modeled for the selected acoustical configuration. The Feedback Threshold establishes a zone of maximum gain without feedback. Using predicted data will save time in the fitting process. However, measuring the actual feedback limits will result in a more precise fitting. In order to measure the actual feedback limits for the Feedback Threshold, click on "Measure" and follow the prompts for one or both ears. Toggle the 'coupling' icon to select your preference for making binaural or monaural measurements.

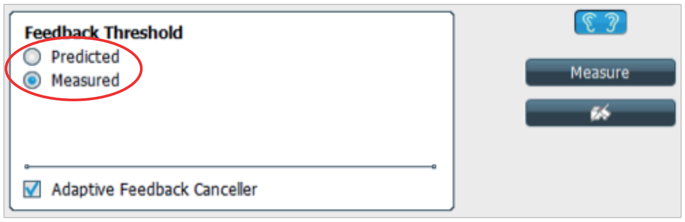


Ensure a quiet environment as the Feedback test runs.

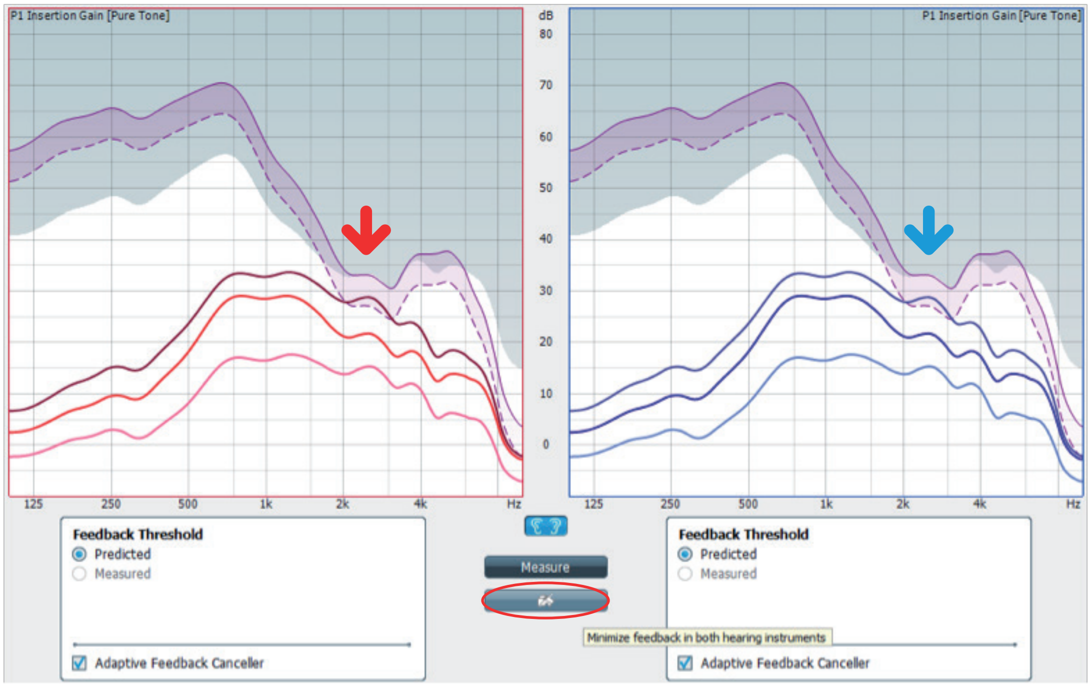
Apply the measurement to the selected or preferred programs. This allows EXPRESS*fit* to automatically control gain in the chosen programs where the fitting curves are above the measured Feedback Threshold.



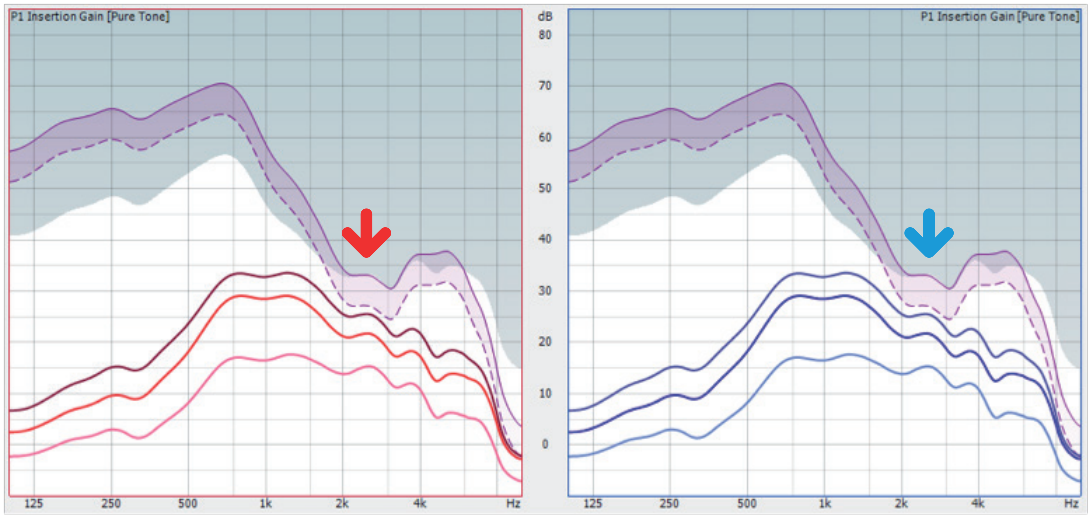
After applying the measurement, it is possible to choose between the predicted or the measured Feedback Threshold for each program.



Finally, it is possible to quickly reduce the hearing instrument gain below the "Safe Gain Limit" by clicking the Minimize Feedback button.



Note! Minimize Feedback only affects the active program.



Benefits of AFC

The speed and design of the Adaptive Feedback Canceller create numerous benefits for the hearing care professional and patient alike:

- Hearing care professionals can offer open fittings to patients with a wider variety of hearing losses who previously could not wear an open fit solution due to feedback
- Patients are more satisfied with the sound quality, additional comfort, and decreased occlusion of open fittings
- Increasing the gain or volume occurs without greater incidence of feedback, even in the high frequencies
- Placing a handset next to the ear for telephone conversation becomes possible without diminished hearing or whistling
- Wearing a hat or embracing in a hug takes place without a sound
- Music and other tonal sounds remain undistorted and clear as intended, since they are not mistaken for feedback

The AFC provides highly effective feedback control by identifying and eliminating feedback before it becomes audible. It is available in all Bliss, Charm and Flip products from Sonic.

For a demonstration or to learn more, please contact your local Sonic provider.

References

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[2] Ricketts, T.A. (2012, March). Today's Hearing Aid Features: Fluff or True Patient Benefit? Invited presentation to the Military Audiology Association JDVAC Annual Convention, San Diego, CA.

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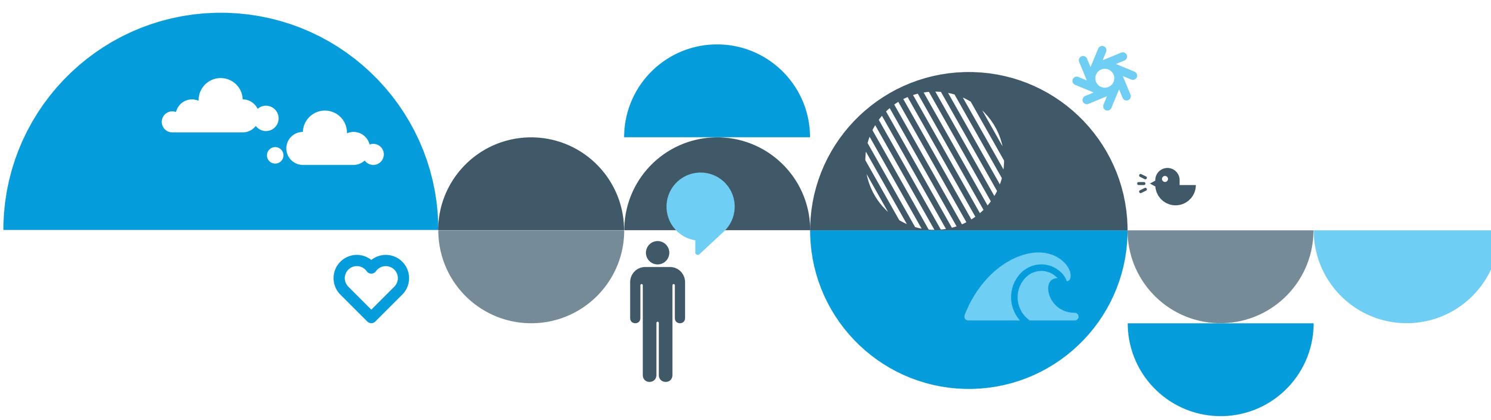
[4] Staab, W. (2012). Hearing Aid Acoustic Feedback. Hearing Health & Technology Matters Website. http://hearinghealthmatters.org/waynesworld/2012/hearing-aid-acoustic-feedback. Accessed 7/11/2014.

[5] Kates, J. (2003). Adaptive Feedback Cancellation in Hearing Aids. In Benesty & Huang (Eds.) Adaptive Signal Processing: Applications to Real World Problems (pp. 23-57). Heidelberg, Germany: Springer-Verlag.



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