Advanced
Adaptive Feedback Cancellation

Second-generation AFC technology used in the
Digital-ONE™ NR+ and inTune™ DSP amplifiers from Intricon.

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The Digital-One NR+ and inTune amplifiers have an 2nd-generation advanced adaptive feedback cancellation (AFC2) algorithm compared to the earlier Digital-One AFC and Digital-One NR amplifiers that used our first-generation AFC (AFC1). The improvements are in both the area of increasing the amount of added stable gain (ASG) and in the area of less sensitivity to miss adjustment due to certain input signals. This paper summarizes these improvements.

**Added Stable Gain**

Added stable gain (ASG) is the increase in a hearing aid gain that is made possible by activating the AFC algorithm. There are several improvements incorporated in AFC2 that increase the ASG:

1) Longer FIR filter - The AFC2 circuit works by adjusting the coefficients of an internal FIR filter so that the filter matches the external feedback path. Then by subtracting the signal from the filter, the external path is cancelled. The better the internal filter matches the external path, the better the cancellation and hence the more gain in the aid is possible. The AFC1 algorithm has an FIR filter that is 32 taps long. At the sampling rate of 16 kHz this means the filter can theoretically cancel an external path that is 2 ms long. The filter in the AFC2 is lengthened to 40 taps, allowing a path of 2.5 ms to be matched.

2) Frequency Range of Cancellation Extended - The AFC2 circuit is designed to only cancel a certain range of frequencies. This is done since feedback generally does not occur at low frequencies. The AFC1 algorithm corrected feedback frequencies in the range of 1.8 kHz to 6.7 kHz. Experiments have shown that there are some situations where a somewhat wider range is beneficial. The AFC2 has a correction range of 1.3 kHz to 6.7 kHz.

3) Adaptation Accuracy - The FIR filter is continually being adjusted to match the changes in the external path. In the AFC1 algorithm the adaptation is more sensitive to some frequencies than to others. This is true even within the range described in (2) above. The result is a sub optimum adjustment that then results in less ASG than is theoretically possible with that FIR filter. The AFC2 performs more calculations resulting in improved adjustment.

The result of the above changes can be seen in Figure 1. The graph shows the ASG for four examples of hearing aids on the KEMAR manikin in a static condition with a random noise input. The ASG of AFC2 is an average of 3.6 dB better than AFC1.

**Sensitivity to mis-adjustment due to non random inputs** – The AFC1 and AFC2 algorithms use a normalized Least Means Squares (NLMS) technique to adjust the FIR filter described above. This technique is relatively simple to implement and has been used extensively in the industry. However, it has a problem when the input signal is correlated with itself. Examples of such inputs are music, microwave buzzers and horns. In these cases the algorithm can mis-adjust the FIR filter. The result can be feedback and its associated whistling. This phenomenon is sometimes called entrainment. The AFC1 algorithm has some patent pending features that reduce the problem. The AFC2 has additional improvements:

1) Sensitivity to sinusoidal inputs – The AFC1 algorithm is able to detect the presence of one sinusoidal input and avoid entrainment in that situation. The AFC2 can detect one or two sinusoids within a 500 Hz band and avoid entrainment in that situation. This is helpful in reducing problems from organ music and other inputs that have multiple tonal characteristics.
2) Inputs with closely spaced harmonics – Inputs with strong, stable harmonics that are spaced in 100 to 200 Hz range sometimes have caused problems in the AFC1. The AFC2 detects these inputs and treats them in a special manner. An example where this is valuable is with a fog horn type of input.

3) Convergence speed – The adaptation speed is a compromise. Faster adaptation results in quicker response to changing situations while a slower response is less influenced by entrainment inputs. The AFC2 algorithm is improved by using an adaptation that changes depending on the characteristics of the input signal and the parameters of the amplifier.

Figure 1: Examples of ASG measurements. The AFC2 algorithm is better than the AFC1 by 2, 4, 6 and 2.5 dB in these examples.