IntriCon

Technology White Paper

Understanding
Layered Noise Reduction™

An advanced adaptive feature used in the Digital-ONE NR, Digital-ONE NR+ and inTune amplifiers from IntriCon.

Updated September 13, 2005

inTune™

Digital-ONE™ NR

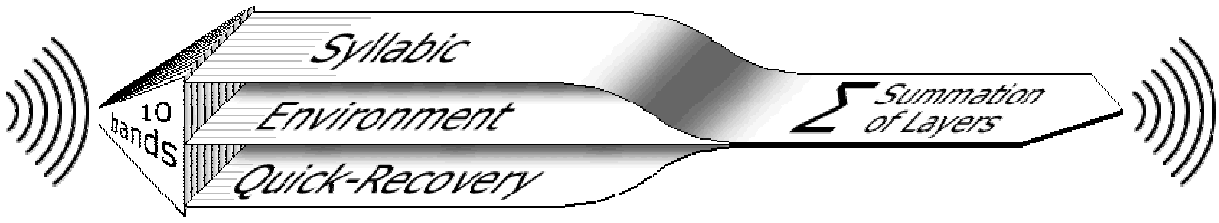
Digital-ONE™ NR+

Layered Noise Reduction

The design of noise reduction system in the Digital-ONE NR™, Digital-ONE NR+ and inTune™ amplifiers is predicated on two objectives:

1) When speech is present, to reduce the background noise in frequency regions where there is only noise energy present. In the regions where speech energy is present, keep this energy intact. This function will act to enhance speech in noise.

2) In situations where no speech is present, reduce the noise to a higher degree than when speech is present, and do this in a way that does not create an annoying loudness-change effect (so-called pumping), and also does not inhibit the audibility of speech when it starts up. This function will improve comfort and decrease fatigue in the frequent noisy non-speech use situations.



Band Divisions

NR Band	Lower Cutoff (Hz)	Band Center (Hz)	Upper Cutoff (Hz)
1	-	-	250
2	250	500	750
3	750	1000	1250
4	1250	1500	1750
5	1750	2000	2250
6	2250	2500	2750
7	2750	3000	3250
8	3250	3500	3750
9	3750	4000	4250
10	4250	5000	6250

Syllabic Layer

This layer of the system is designed to adjust the NR band gains at a rate of change that is similar to the rate of change of speech syllables. This rate of change is approximately 50 msec. The syllabic layer will monitor the power in a particular NR band, to determine if that band contains fast-changing power (fast modulation rate), or only slow-changing power (slow modulation rate). If the modulation rate is fast, it is decided that the band contains important information, so the band gain is unchanged. If the modulation rate is slow, then the decision is that the NR band does not contain important information, and the band gain is reduced. The amount of gain reduction is proportional to the changing power measurements and the NR parameter setting (off, low, medium, or high). The details of this are proprietary to RTI.

Environment Layer

This layer is designed to help reduce noise by monitoring the longer-term changes in the listening situation. This layer identifies when the hearing aid is performing in an environment without a speech signal present. The decision is made using a long time constant, so that the layer is not triggered by every gap in speech. Instead, the layer will not be triggered until speech is absent for 10 seconds. At that time, the layer will begin to decrease the NR band gain gradually over a period of about 10 seconds. The amount of gain reduction made by this layer depends on the NR parameter setting. When the Environment layer is active, it will stop reducing gain when speech is detected again. The gain will be restored gradually over 10 seconds. This provided a pleasing sound because there is not an abrupt change in gain (pumping sound).

Quick Recovery Layer

This is a specialty layer. In the Environment layer, gain changes are made very slowly to avoid pumping artifacts. There is one problem with slow changing gain. If speech has been absent for a long period, the environment layer gain reduction will be maximum. When speech starts again, it will take 10 seconds for the gain to be restored in this layer. Therefore there is a risk that the wearer will not be able to hear the speech during this first 10 seconds. This could be an important problem to the wearer. To solve this problem, we add the Quick Recovery layer. This layer also slowly reduces gain when speech is absent, but when speech starts again, it restores the gain within about 50 msec. So this layer gives some gain for this start-up period compared to having only the environmental layer. The result is more gain during speech start-up, but also not having significant pumping sound. Two layers allow the system to have a good compromise between these two limiting conditions.

Measuring Noise Reduction Action

It is very difficult in a written document to demonstrate the performance of Layered Noise Reduction. Instead we have prepared a PowerPoint presentation that shows graphically the performance, and also has sound recordings to allow one to hear the difference that LNR makes. The demonstration file can be downloaded at this link:

http://www.rtidownloads.com/D1/techdemo/Digital-ONE_NR_features.ppt

There is one example that is worth looking at from this demo, Example 2. In this example, we have recorded inside a moving car traveling on the highway. During the first segment, the car radio is also playing at a normal loudness. In the middle segment, the radio is off, and then the last segment the radio is turned on again. Figure 1 below shows the sound amplitude (in relative dB) versus time.

We have developed an analysis tool that allows one to visualize the LNR action. Figure 2 shows the gain in 4 of the NR bands. In each band, the blue line shows the gain change versus time for the Layered Noise Reduction. At the top of the vertical axis is 0 dB meaning there is no gain reduction being activated by LNR. Going down the vertical scale indicates gain reduction amounts caused by LNR. Figure 1 and 2 are aligned on the time axis.

Figure 1:

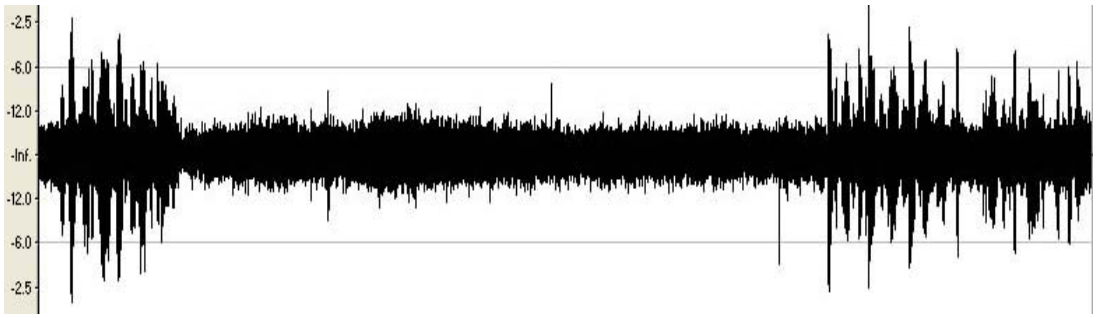
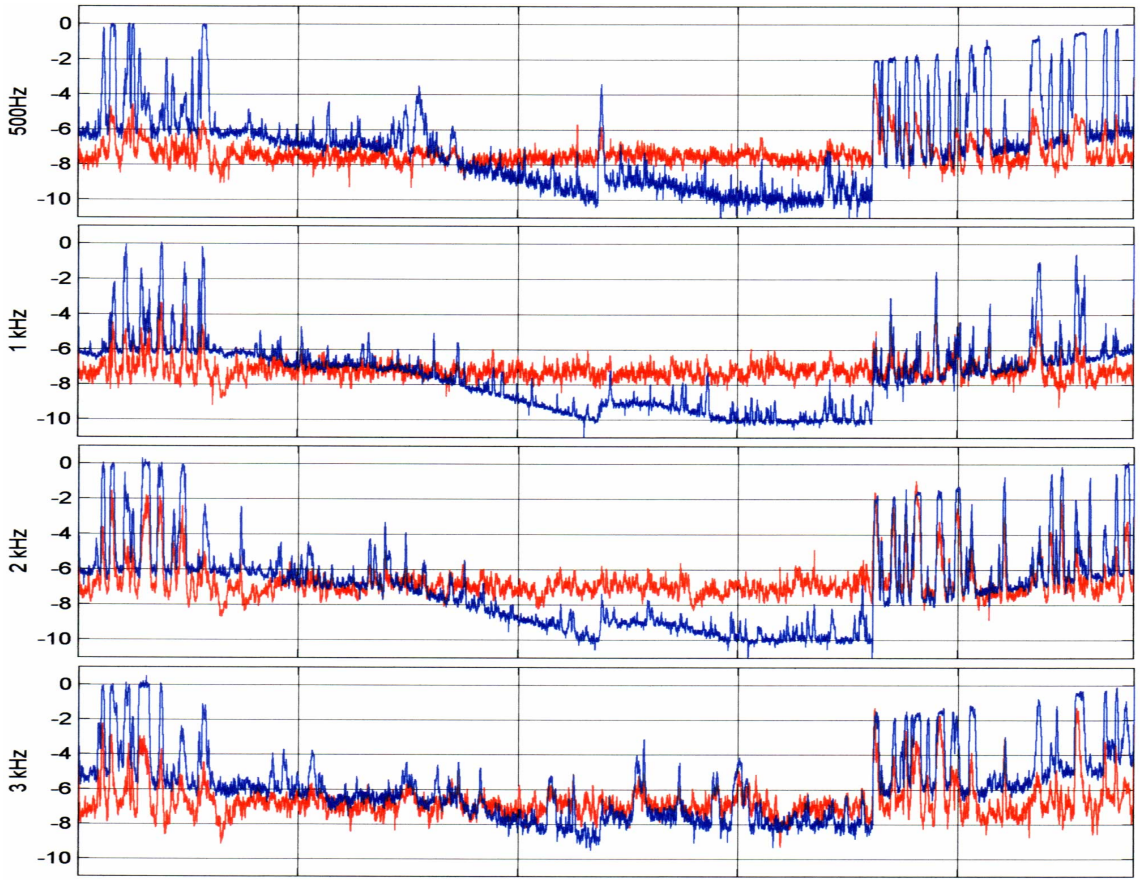


Figure 2:



In the figures, during the first segment when the radio is on, you can clearly see that the gain is changing rapidly in responses to the changes in speech syllables. Then when the radio is turned off, the gain stays reduced since the syllabic layer is in full reduction. After the radio has been of for a while, the gain starts to drop again. This is caused by the Environment layer being activated. This layer stays active until the radio is turned back on again. At that time, you can see that the gain is gradually getting higher again along with the syllabic layer triggering on speech syllables.

It is also possible to see the effect of the quick recovery layer. Right in the middle of the timeline, a short loud sound triggers a change of gain that is easily seen in the 500 Hz band. The gain change is caused by both the quick recovery layer and the syllabic layer restoring gain. Once this short loud sound goes away, the syllabic layer quickly reduces gain, but the quick recovery layer slowly drops is gain over 10 seconds. During this period of the short loud sound, the Environment layer did not change at all, since its rate of change is purposely slowed to ignore these fast events.

Noise Reduction Adjustment

Setting	Action	Software Setting for 'Noise_Reduction' Parameter
Off	All layers of the Noise Reduction system are deactivated	0
Low	The per-band gain reduction of all NR layers combined is 7 dB. Use this setting to keep speech quality at its highest when noise reduction on.	1
Medium	The per-band gain reduction of all NR layers combined is 10 dB	2
High	The per-band gain reduction of all NR layers combined is 13 dB. Use this setting to maximize the noise reduction effect.	3