Technology White Paper

Two-Channel WDRC Compression with *Dynamic Contrast Detection*™

An advanced adaptive compression feature used in the Spin™ DSP amplifier from IntriCon.

October 3, 2005

Spin™

The Spin™ amplifier features a two-channel compression system to manage situations of reduced dynamic range in a hearing aid user. The system has fixed channel crossover of 1750 Hz.

Each channel compressor can be adjusted independently for compression threshold, compression ratio, and expansion threshold. The following tables show the available settings of each parameter. 0=1:1, 1=1.14:1, 2=1.33:1, 3=1.6:1, 4=2.0:1, 5=2.65:1, 6=4.0:1

Compression Threshold
40 dB
45 dB
50 dB
55 dB
60 dB
65 dB
70 dB

Compression Threshold
1 : 1
1.14 : 1
1.33 : 1
1.6 : 1
2.0 : 1
2.65 : 1
4.0 : 1

The compression detectors in each channel are independent and take their input signal from only their respective channel output of the crossover filter. Note that the channel compressors are placed entirely before the volume control block. Therefore the compressors are referenced to the input of the amplifier, or in other words, the performance of the compressors is not affected by the volume control setting. This mode of operation is commonly referred to as 'input compression' or AGC-I.

The transient response of the channel compressors has three modes of operation: A) BASIC mode (single time constants), B) BASIC/FAST mode (dual time constants), and C) BASIC/FAST/REACH (three sets of time constants). The third mode enables a feature referred to as *Dynamic Contrast Detection*, which is unique to the Digital-ONE amplifier, and is described in more detail below. Each channel's transient mode can be adjusted independently.

BASIC Mode (single time constant)

The basic function of the compression detector is to measure the short-term average power in the channel. This is done every 500 microseconds and averages the power over the preceding 500 usec. The next step is to calculate a long-term average of the power. It is at this point where the time constants are applied. In the basic mode, the attack time is defined as the rate at which the long-term average power measurement is allowed to increase, and the release time is defined as the rate at which the long-term average power measurement is allowed to decrease. In turn, this long-term average power measurement is then used to determine the amount of gain reduction to be applied by the compressor. In the basic mode, only one attack time, and one release time are applied to the long-term-average power measurement. The choices available for BASIC mode are shown below:

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time_const driver setting	**Basic** attack (msec)	release (msec)	**Fast** attack (msec)	release (msec)	**Reach Down** range (dB)	release (msec)
0	3	120	not active		not active	
1	3	300				
2	3	800				
3	50	300	3	50		
4	100	800	3	100		
5	100	2000	3	100		
6	400	15,000	3	100	12dB	600
7	400	15,000	3	100	18dB	600
8	400	15,000	3	100	24dB	600

BASIC/FAST Mode (dual time constants)

In this mode, one of two sets of time constants are applied depending on the condition of the short-term power level compared to the long-term average. Fast changing inputs will cause the FAST time constants to trigger, whereas slowly changing inputs will trigger the BASIC slower time constants. In this mode, a *look-ahead* detection scheme is used. This is described in the next section.

The choices available for this mode are shown below:

time_const driver setting	**Basic** attack (msec)	release (msec)	**Fast** attack (msec)	release (msec)	**Reach Down** range (dB)	release (msec)
0	3	120	not active		not active	
1	3	300				
2	3	800				
3	50	300	3	50		
4	100	800	3	100		
5	100	2000	3	100		
6	400	15,000	3	100	12dB	600
7	400	15,000	3	100	18dB	600
8	400	15,000	3	100	24dB	600

BASIC/FAST/REACH Mode (triple time constants)

The third mode of the channel compressors is designed to detect a condition where two different long-duration speech signals are occurring alternately, and these signals have a significant contrast in their power levels. This is called a *Dynamic Contrast* condition. A good example of this condition is a conversation between a hearing aid wearer and soft-spoken person located a few meters away from the hearing aid wearer. The hearing aid wearer's own voice will be detected by the hearing aid as a relatively large signal, whereas the other persons voice will be detected as a small signal.

A dual time constant system will react to this condition by applying long time constants. The problem with this is that the gain right after the hearing aid wearer stops speaking will be low, due to the compression that is triggered by his own voice. During the period of the release time, if the other person speaks the hearing aid wearer may not perceive or understand the speech due to the lowered gain.

In the Digital-ONE system, the detector continually compares the short-term average power level against the long-term average power level. If the short-term level drops by more that the *reach* threshold, a third release time is applied to the rate of change allowed for the long-term average power measurement. This release time is much faster than the BASIC release time, and allows the compressor to restore gain faster, thus allowing it to *reach down* to amplify the softer sound more adequately. This feature is referred to as *Dynamic Contrast Detection*. The *look-ahead* detection scheme is also used in this mode (see description in next section).

The choices available for this mode are shown below:

<table>
<tr><th rowspan="2">time_const
driver setting</th><th colspan="2">Basic</th><th colspan="2">Fast</th><th colspan="2">Reach Down</th></tr>
<tr><th>attack (msec)</th><th>release (msec)</th><th>attack (msec)</th><th>release (msec)</th><th>range (dB)</th><th>release (msec)</th></tr>
<tr><td>0</td><td>3</td><td>120</td><td colspan="2" rowspan="3">not active</td><td colspan="2" rowspan="6">not active</td></tr>
<tr><td>1</td><td>3</td><td>300</td></tr>
<tr><td>2</td><td>3</td><td>800</td></tr>
<tr><td>3</td><td>50</td><td>300</td><td>3</td><td>50</td></tr>
<tr><td>4</td><td>100</td><td>800</td><td>3</td><td>100</td></tr>
<tr><td>5</td><td>100</td><td>2000</td><td>3</td><td>100</td></tr>
<tr><td>6</td><td>400</td><td>15,000</td><td>3</td><td>100</td><td>12dB</td><td>600</td></tr>
<tr><td>7</td><td>400</td><td>15,000</td><td>3</td><td>100</td><td>18dB</td><td>600</td></tr>
<tr><td>8</td><td>400</td><td>15,000</td><td>3</td><td>100</td><td>24dB</td><td>600</td></tr>
</table>

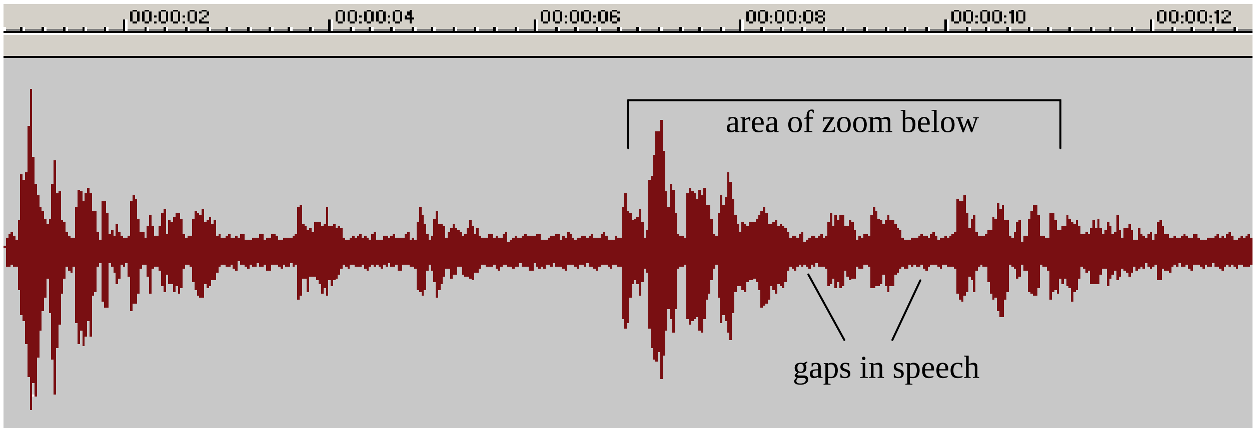
LOOK-AHEAD DETECTION

When the BASIC/FAST mode or the BASIC/FAST/REACH mode of detection is used another unique feature of the Digital-ONE and inTune amplifiers is applied, call *look-ahead* detection. In the BASIC mode of operation there is approximately a two-millisecond time delay from the amplifier input until the channel detector. In the other two modes, the detector also monitors the signal levels *before* this 2 msec. delay, to look for large transient signals that may appear. When the detector sees that there is a signal appearing at the input that is much larger than the long-term average measurement in the detector, the FAST mode is triggered, and the fast attack and release times are applied. The benefit of the look-ahead detection is that the compressor gain can be reduced by the time the large signal hits the compressor, so that 'overshoot' does not occur, which may cause clipping distortion.

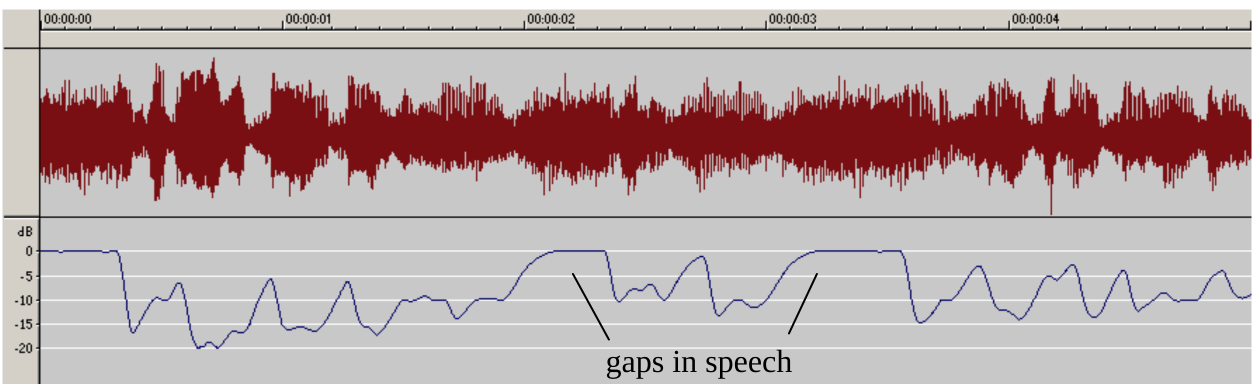
EXAMPLES OF SOUNDS PROCESSED WITH DYNAMIC CONTRAST DETECTION:

In these examples, sound waveforms are shown for various 'real-world' situations. Also, the instantaneous gain is shown for the channel compressor. Compressor gain is shown on a scale of 0 to –20dB. The level 0dB means that the compressor gain is 0dB, indicating the there is no compression being used. The level –20 dB means that the compressor is reducing gain by 20dB, indicating a large amount of compression.

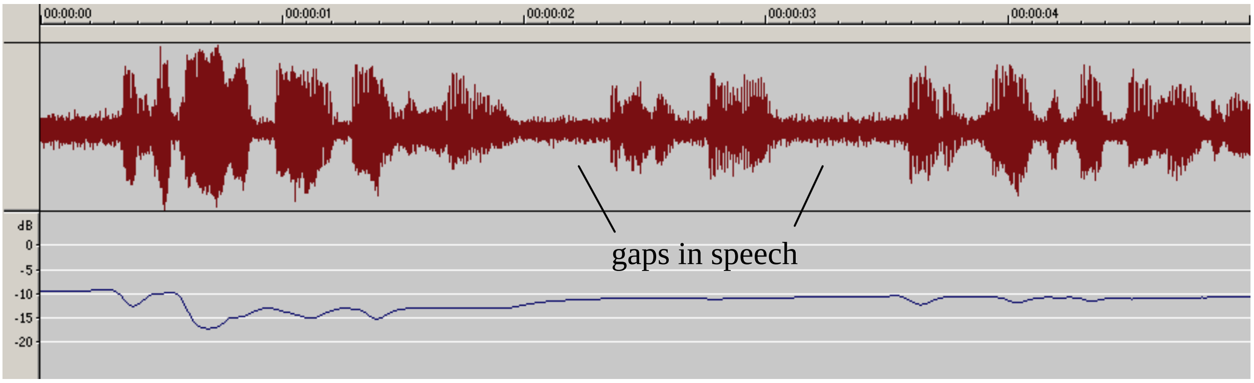
Example 1: Single speaker with background noise



This is the waveform of the input sound. Note the gaps in the speech, where you can see the background noise signal

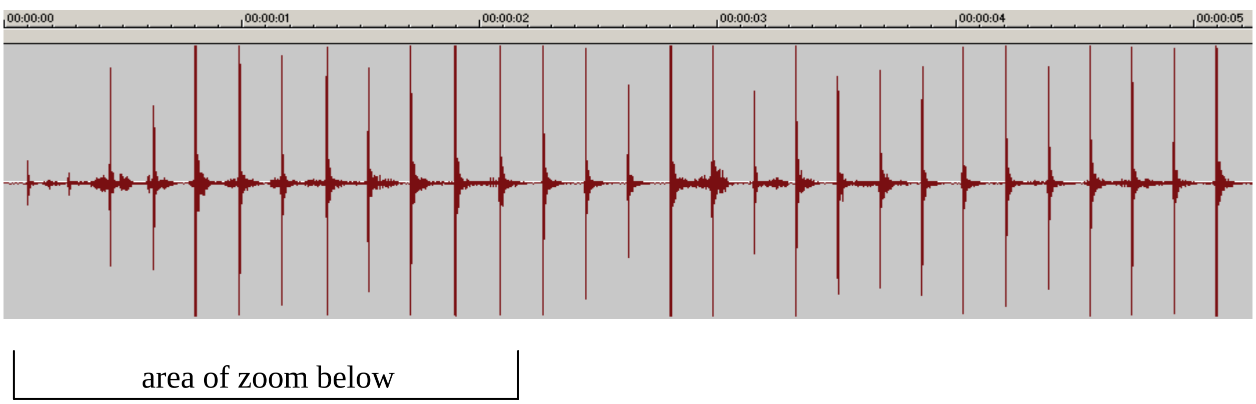


Red waveform is output of hearing aid with a single fast release time of 120 milliseconds. Blue line is instantaneous gain of compressor for this sound. Note that the compressor gain jumps up to 0dB every time there is a gap in the speech. When this happens, the background noise is overamplified, so the noise gets loud every time the speaker pauses.

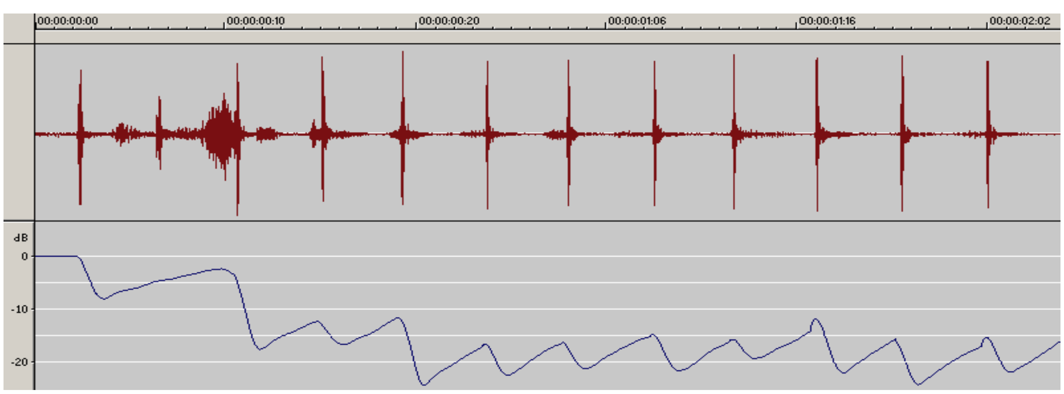


Red waveform is output of hearing aid with Dynamic Contrast Detection activated. For this sound signal, the compressor uses a long release time of 15 seconds. The Blue line is instantaneous gain of compressor for this sound. Note that the compressor gain stays relatively constant through the gaps in the speech. Therefore, the noise stays at low levels when the speaker pauses.

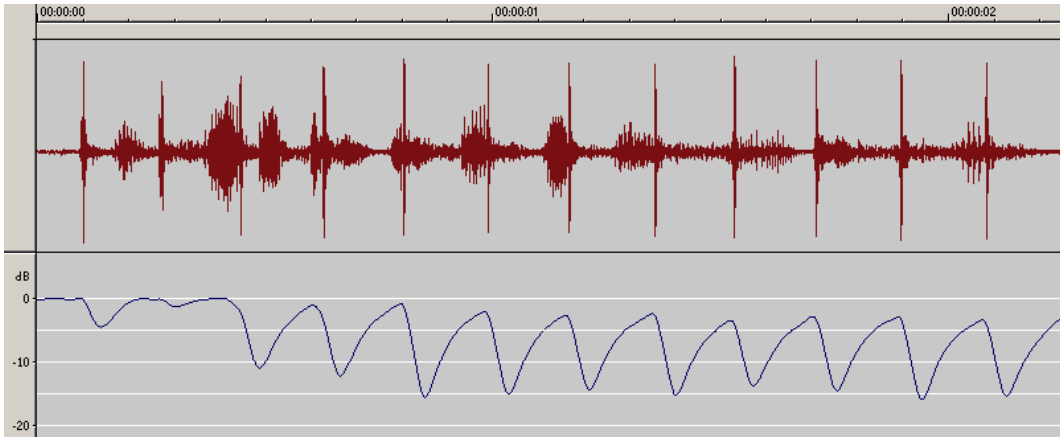
Example 2: Single speaker with periodic hand clapping impulse sound



This is the waveform of the input sound.

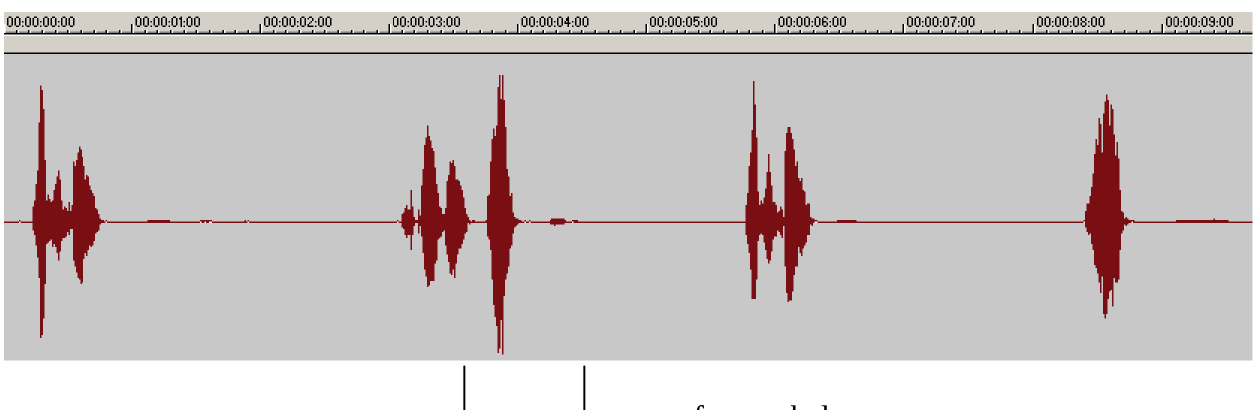


Red waveform is output of hearing aid with a single long release time of 800 milliseconds. Blue line is instantaneous gain of compressor for this sound. Note that the compressor gain drops quickly when the loud claps occur, and the gain does not recover between claps. When this happens, the underlying speech is not amplified enough.



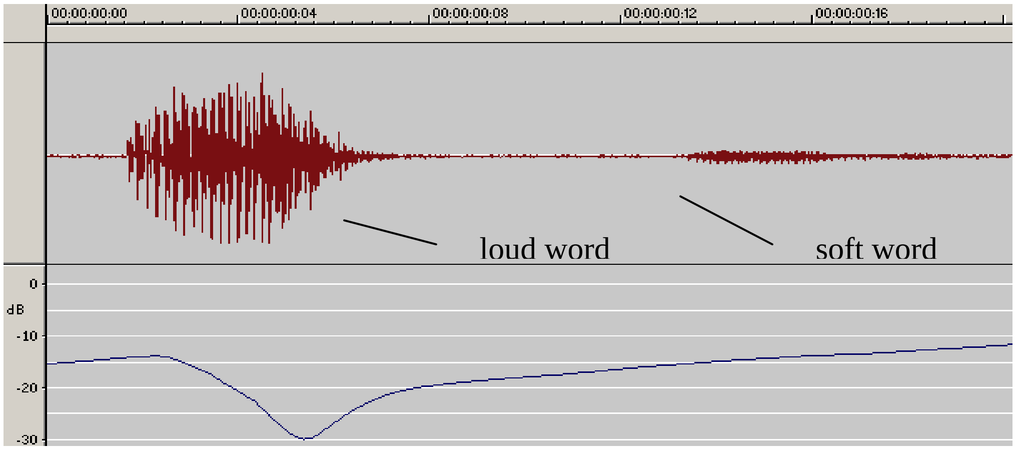
Red waveform is output of hearing aid with Dynamic Contrast Detection activated. For this sound signal, the compressor uses a fast attack, fast release. The Blue line is instantaneous gain of compressor for this sound. Note that the compressor gain recovers between claps. Therefore, the speech gets amplified by about 10 dB more than with the single long release time.

Example 3: Hearing Aid wearer speaking with another person (Loud speech contrasting with soft speech).

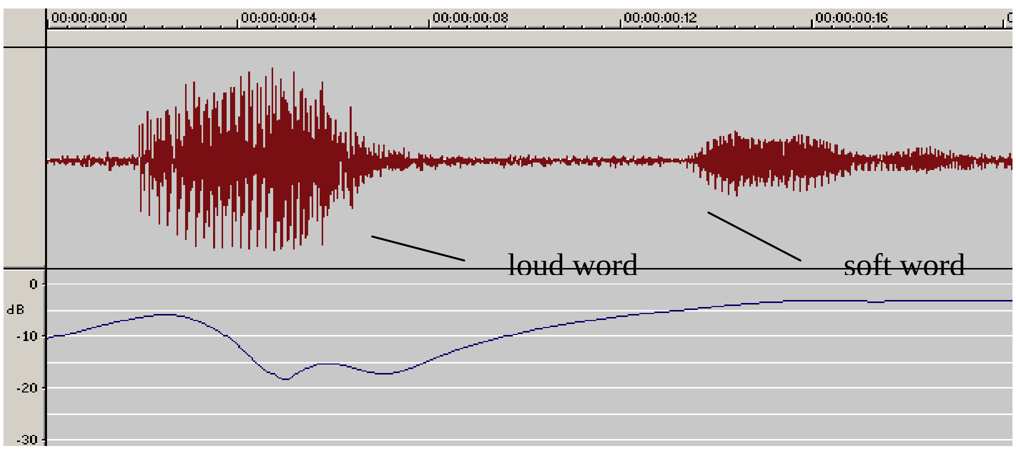


area of zoom below

This is the waveform of the input sound.



Red waveform is output of hearing aid with a dual time constants. Blue line is instantaneous gain of compressor for this sound. Note that the compressor gain recovers rather slowly after the loud speaker. The gain is at –15dB when the soft word starts.



Red waveform is output of hearing aid with Dynamic Contrast Detection activated. Blue line is instantaneous gain of compressor for this sound. Note that the compressor gain recovers more quickly after the loud speaker. The gain is at -5dB when the soft word starts. This is 10dB more gain than without Dynamic Contrast Detection.