AND90048/D

Ezairo® Preconfigured Suite Wide Dynamic Range Compressor

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APPLICATION NOTE

INTRODUCTION

This application note describes the Wide Dynamic Range Compressor (WDRC) included in the Ezairo Preconfigured (Pre) Suite firmware bundles. The WDRC is a highly−configurable multi−channel dynamic range compressor. Channels are groups of one or more frequency bands. Each channel features upper and lower−level compression kneepoints, an expansion kneepoint, and Output−Referred Automatic Gain Control (AGCo) to limit the maximum output level. Three level detectors with independent attack and release times are provided to adjust the dynamic behavior of each channel.

The sections below provide an overview of the algorithm's operation, and a detailed description of available adjustments to the algorithm's behavior. The advanced graphing capabilities available in the Ezairo Sound Designer Software Application that predict the acoustic response of a device are also covered.

DYNAMIC RANGE AND COMPRESSION OVERVIEW

Dynamic range refers to the difference between the softest and loudest possible sounds. A wide dynamic range compressor can be used to map a very wide input dynamic range to a narrower output dynamic range. In general, this involves applying more gain to softer sounds than to louder sounds. This allows the compressor to deliver the appropriate amount of gain to make softer sounds audible without making louder sounds too loud.

The gain applied by the WDRC is specified by an Input/Output (I/O) function that describes the mapping of input sound levels to output sound levels. This function is configured using a series of hard kneepoints with unique thresholds and gains. Kneepoint thresholds specify audio input levels, with the exception of the AGCo Output Limit which specifies a maximum output level.

A multi−channel WDRC maps filterbank bands into independent channels separated by crossover frequencies. This allows for different I/O functions to be applied to different frequency bands. For example, compression could be applied to high frequencies only, while allowing lower frequencies to pass through without any adjustment.

As part of the WDRC operation, the input signal energy in each channel is estimated with a level detector whose output is smoothed with configurable attack and release times. The attack and release times control the dynamics of the algorithm. For example, by using slower attack and/or release times it is possible to slow the rate at which the gain changes. This smoothing also ensures that the algorithm does not adjust the gain too rapidly which might otherwise distort the signal.

The smoothed signal energy is then used to calculate the gain that is applied using the I/O functions that have been defined for each channel. All of these concepts will be covered in greater detail in the next section.

WIDE DYNAMIC RANGE COMPRESSOR TAB

User controls for the WDRC are collected together in a single tab on the Sound Designer Control Panel screen. For example, when starting the Ezairo Sound Designer Software Application for the first time using the Demo Library, the WDRC tab appears as shown in Figure 1. Depending on the product, some (or all) WDRC parameters can be configured differently in each program memory providing customizable behavior for different situations.

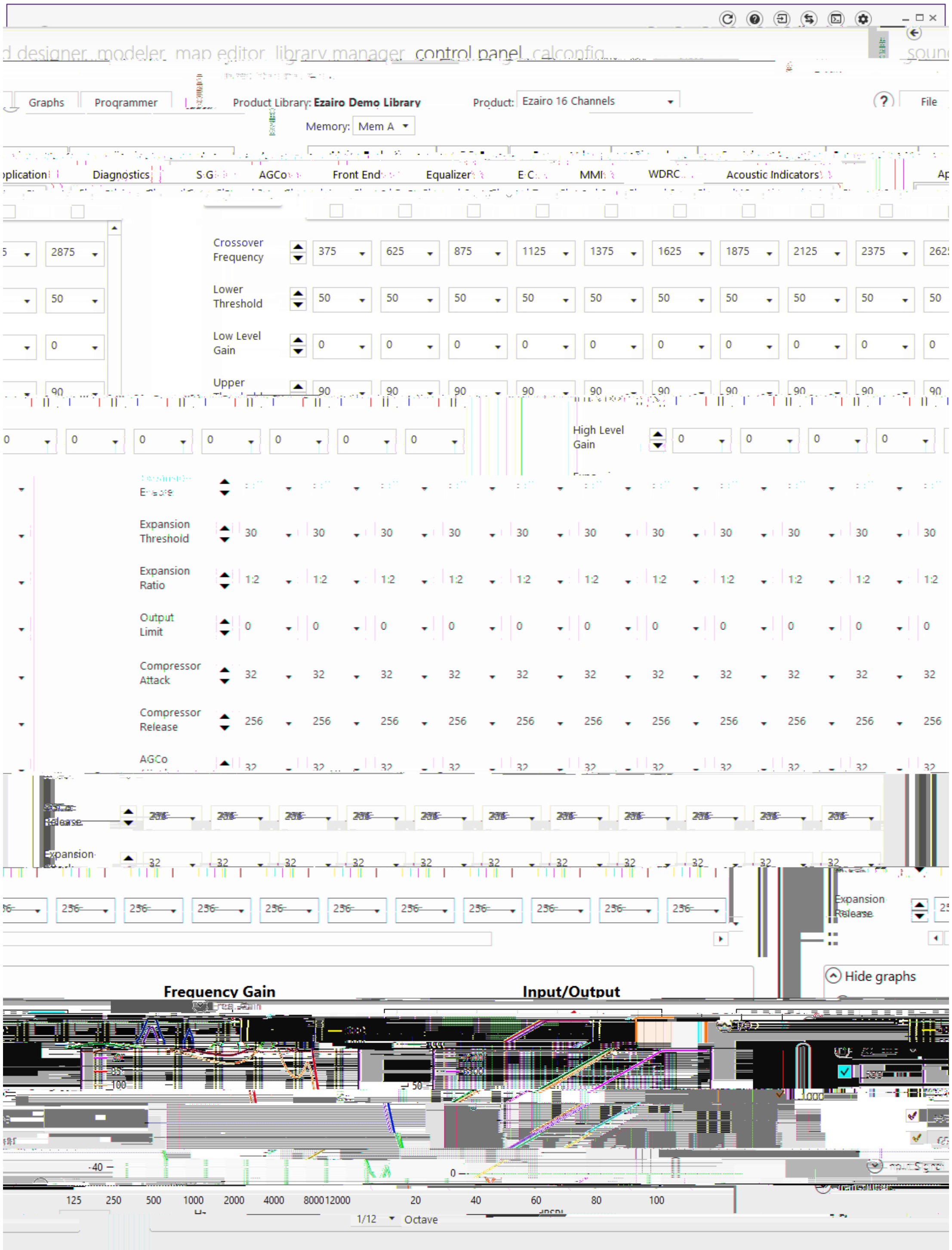

Figure 1. Example Control Panel Tab for the Ezairo Pre Suite WDRC using the Ezairo 7160 SL

The WDRC tab shown in Figure 1 is divided into two areas: user controls and graphs. The user controls section provides adjustments for all available WDRC parameters. The graphs section displays the resulting acoustic response of the device. Each of these is described in more detail below.

GRAPHS

We will introduce the graphs section first because the graphs can be helpful to understand how the user controls work. The graphs section can be revealed by clicking Show graphs at the bottom of the screen.

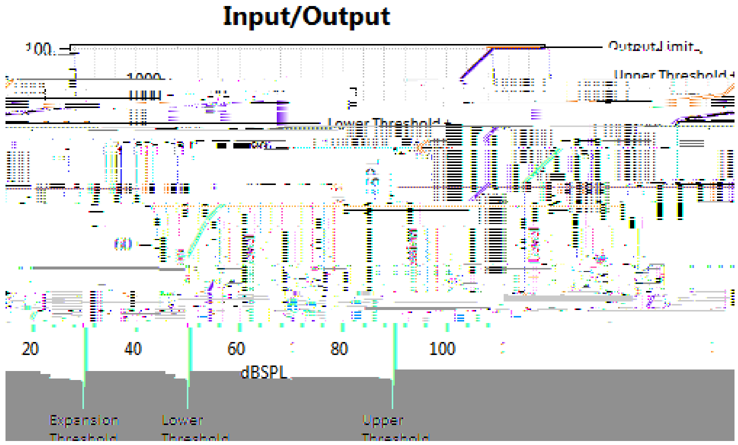

Figure 2. Input/Output Graph Illustrating the Different Gain Regions

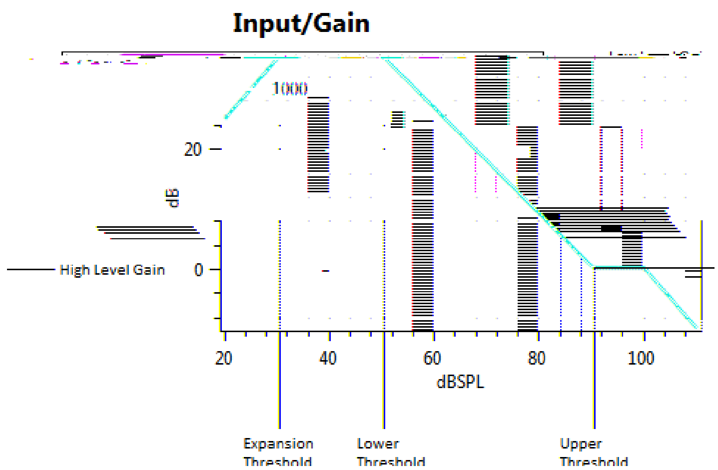

Figure 3. Corresponding Input/Gain Curve to Figure 2

Figure 2 is an example Input/Output graph taken from the Ezairo Sound Designer Software Application, and has been marked−up to illustrate the mapping between WDRC parameters and their effect described above.

Figure 3 shows the Input/Gain which provides a complimentary view of the same information found in the Input/Output curve in Figure 2. This shows the gain rather than output level as a function of input level. The Input/Output and Input/Gain curves can be calculated from each other where:

$$\text{Output Level}(X) = X + \text{Gain}(X), \text{ for every input level } X$$

Because the WDRC provides a flexible set of controls, some parameter configurations could result in inappropriate behavior for conventional hearing−aid applications. For example, it would not make sense for the WDRC to apply more gain to louder signals than softer signals above expansion. For convenience, the Ezairo Sound Designer Application Software enforces these restrictions when setting parameters in the WDRC tab.

1. Crossover Frequencies must be unique and selected in ascending order.
2. The Lower Threshold cannot exceed the Upper Threshold within any channel.
3. The Expansion Threshold cannot exceed the Lower Threshold within any channel.
4. The (Lower Threshold + Low Level Gain) cannot exceed the (High Level Threshold + High Level Gain) within any channel.

Dynamics Controls

Each channel features an AGCo, Compressor, and Expansion level detector with independent Attack and Release times. During algorithm operation, only one level detector is used in each channel as the active signal level estimator. This level is then used in all WDRC gain calculations. The active level detector is chosen depending on the operating conditions described below.

1. The AGCo level detector takes priority if it exceeds the Output Limit.
2. The Compressor level detector takes priority if it exceeds the Expansion Threshold and the AGCo level detector has not already taken priority.
3. The Expansion level detector only takes priority if the AGCo level detector has not taken priority, and the Compressor level detector is below the expansion threshold.

As a result, priority is always given to AGCo first, Compression second, and Expansion third. It follows that Expansion will be exited based on the Compressor Attack time at the onset of any signal (including speech) that exceeds the Expansion Threshold.

Attack and Release times are defined based on the *ANSI Specification of Hearing Aid Characteristics (ANSI/ASA S.22−2009).* The Standard defines a 35 dB level change, and stipulates that the settling time is defined as within 3 dB of the steady−state value for Attack, and within 4 dB of the steady−state value for Release with a tolerance of ±5 ms or 50%, whichever is greater. This test is under maximum compression (the I/O curve is horizontally flat). The following sections provide a more detailed description of

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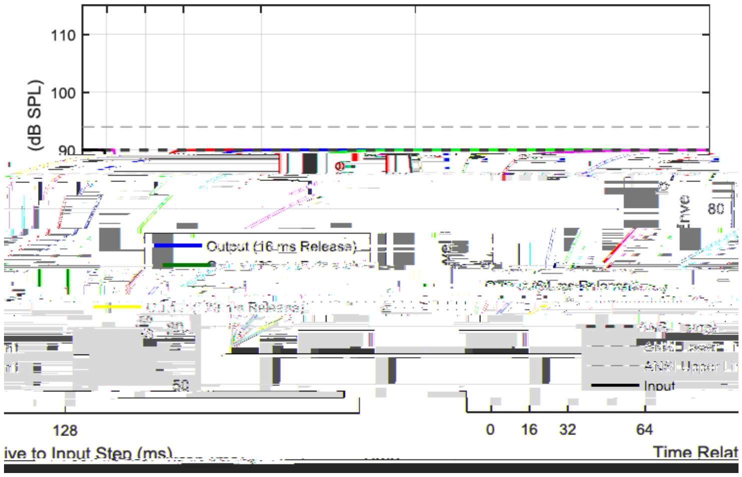

Figure 5. Compression Signal Levels for Various Release Times for a 1 kHz Tone

There are many different ways to configure Attack and Release times, and so the following serve only as very general recommendations that may be useful.

In general, consider configuring the AGCo level detector with the fastest Attack time of the three level detectors. A fast Attack time will apply harder limiting, whereas a slow Attack time will provide softer limiting but runs the risk of clipping/saturation under transient conditions.

Some configurations have tradeoffs. For example, by selecting a faster Release time, expansion will tend to engage and track the noise floor more quickly any time the Compressor level detector drops below the Expansion Threshold. This could be desirable because it will rapidly suppress noise. However, this may also result in more noticeable breathing (modulation) to the noise floor especially under quiet conditions with interruptions like speech where you may be entering and exiting expansion too rapidly. By selecting a slower Release time, expansion will tend to engage more slowly every time it engages and the transition may be less noticeable.

Changes to WDRC dynamics parameters will not be reflected in the graphs because they do not change the response of the device at steady−state.

WIDE DYNAMIC RANGE COMPRESSION EXAMPLE

The following section illustrates an example of wide dynamic range compression by taking a closer look at the Input/Output behavior over time. In this example, we have configured the WDRC with a Lower Threshold of 50 dB SPL, a Low Level Gain of 30 dB, an Upper Threshold of 90 dB SPL, and a High Level Gain of 0 dB. This results in significant compression for inputs between 50 and 90 dB SPL, which will be mapped to 80 and 90 dB SPL at steady−state (a compression ratio of 4:1). See Figure 6 and Figure 7.

To examine what happens over time, we have configured a Compressor Release time of 128 ms, and applied a 1 kHz pure tone to the input which drops abruptly from 90 to 50 dB SPL at time 0 ms. The Input and Output levels are shown in Figure 8.

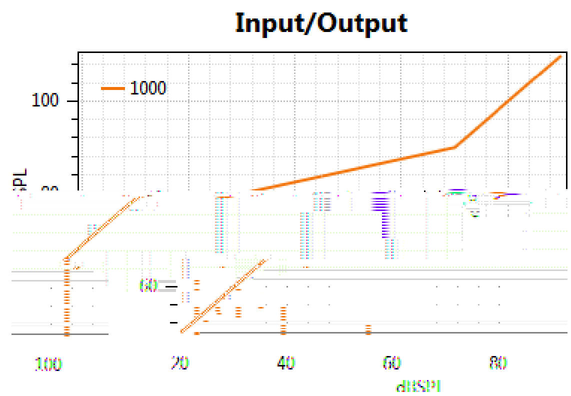

Figure 6. Input/Output Curve with a Linear Gain and Compression

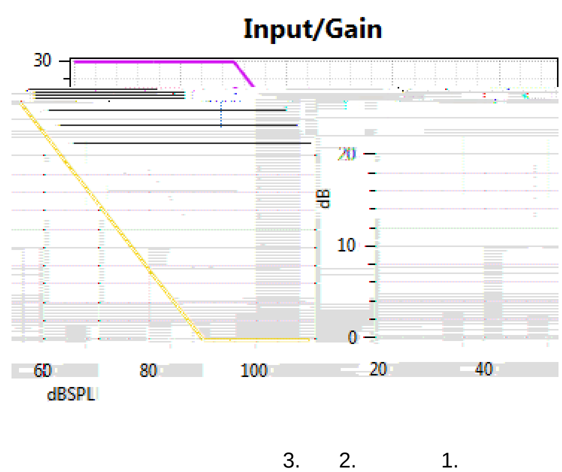

Figure 7. Corresponding Input/Gain Curve to Figure 6

1. 2. 3.

Figure 8. Input/Output Responses over Time for a Step Input