

L3—Multimaximizer

Software audio processor

User's Guide

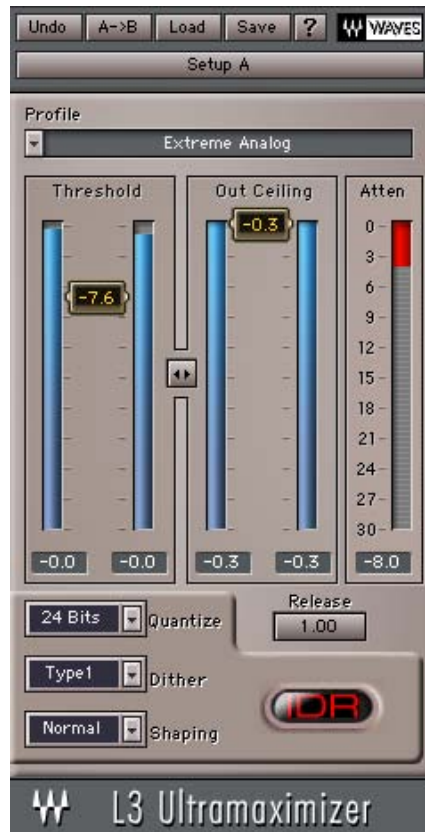


Table of Contents

1. Quick Start Guide

2. Introduction

3. Technology Overview

4. Using the L3

- The Peak Limiter Section
- Threshold and Priority
- Release Behavior Types: Manual, ARC, Smoothed, Scaled
- The IDR Section: Type1, Type2
- Noise Shaping Options: Moderate, Normal, Ultra

5. Controls and Displays

- The Peak Limiter Section: Threshold, Out Ceiling, Attenuation Meter
- Multimaximizer Master Release: Release behavior type, Master Release
- Ultramaximizer Release Control
- Profile
- Peak Limiter Multiband controls
- Crossover controls: Low, Low Mid, Hi Mid, Hi
- Separation
- Per Band Controls: Gain, Priority, Gain and Priority Link, Release
- The Gain/Frequency Graph
- The IDR Section: Quantize, Type, Shaping, IDR Active/Passive Indicator

6. Some secrets of digital audio

- Maximum Level
- Maximum Resolution
- Why use Dithering, and what is it?
- A bit more about IDR™

7. In-depth IDR™ Information

- About Dither and Noise Shaping
- Dither: Off, Type1, Type 2
- Noise Shaping: Off, Moderate, Normal, Ultra

8. 16-bit (and higher) mastering

9. Use the L3 last

10. Important notes on digital clipping

- Peak Normalized Signals

A Very Quick Start for Mastering with the L3

In a Hurry? For best results it is recommended that you read this manual through or at least the chapters – Using L3 and L3 Controls and Displays. However, just to get you started, here's a bullet proof recipe for quick mastering with the L3.

- Insert the L3 Ultramaximizer preferably after the master fader and in any case do not insert any other plug-ins after it or make any consecutive gain adjustments.
- Play the audio that you are mastering through the L3. Select a portion of the more intense part of the program.
- Grab the Linked Threshold/Ceiling control located just between the Input and Output meters. Start dragging downwards and watch the Attenuation meter.
- Once the attenuation meter begins to register gain reduction, listen carefully and continue to drag down until you start hearing degradation, distortion or reduction in level.
- When you hear any of the above mentioned artifacts, stop and drag upwards until you feel the program sounds transparent or at least not degraded.
- Take the Ceiling control to -0.2dBfs.
- Set the IDR Quantize factor to match your designated medium, i.e. 16bit for Audio CD mastering or 24bit for most other applications.
- Apply the process to the complete audio portion.

Following these instructions, you can hardly go wrong. With deeper understanding of the controls and tools that the L3 offers you could potentially do much better.

Read more of this users guide to get expert instructions of how to use the L3 to the maximum effect and optimal sound.

1. Introduction

The L3-Multimaximizer is an integrated Peak Limiter and Bit Depth Re-Quantizer. It utilizes breakthrough patented technology that takes the Waves Maximizers to the next level.

The Waves L1 and L2 Ultramaximizers staged a revolution in digital limiting and re-quantizing for mastering and other applications. They used “lookahead” technology to perform wideband dynamic gain adjustment for brick wall limiting with no overshoots.

The L3 uses Multiband dynamics processing, limiting the full band or the total of the multiple bands to a certain Threshold factor. This allows the L3 to reach unprecedented loudness with even more musical sounding results. It offers a wide variety of different sonic flavors from analog sounding to the smoothest, most transparent digital limiting you could imagine. These many flavors are easily accessed by selecting the related profiles and presets. The band split is implemented using linear phase crossovers so that no phase distortion is introduced by the crossovers. The only difference between input and output is a certain amount of pure delay which is 24-bit transparent until limiting is introduced.

The full L3 is comprised of two plug-ins that offer different interfaces to control the same essential algorithm.

- The L3 Ultramaximizer maintains the general control surface of its predecessors the L1 and L2. It also adds a *Profile* selector to select different internal settings of the multiband engine. Setting the L3 up is as easy as setting up an L2. Afterwards, you can toggle through the profiles to find the best Tuning of the algorithm for the program that you are processing.
- The L3 Multimaximizer allows full parametric control over very specific settings of the per band Gain, Priority and release factors. This allows the user to perform corrective EQ and provides fine tuning choices for the most meticulous of engineers. In fact, the L3 offers much more than just limiting. For the most part it can be used on its own as a full mastering chain.

The IDR (Increased Digital Resolution) technology offers the same good ol' Waves bit depth reduction system. This allows optimal results when going from a 24-bit source to a 16-bit CD audio stream. The whole process is double precision, so dithering to the 24th bit will already provide enhanced resolution. The superb IDR 9th order Noise Shaping filter will assure that the noise is as inaudible as possible.

2. Technology Overview

The L3 is a 5 band peak limiter that brings a new approach for multi band peak limiting. The L3 does not consist of 5 independent peak limiters operating separately on each of the bands. Instead, it has one central peak limiter controlling all of the bands. The L3 is based on a new technology by Waves called the Peak Limiting Mixer™ (patent pending).

The Peak Limiting Mixer™ examines the signals of all of its input bands. Then it calculates an optimal attenuation for each of the bands (applies automatic Gain to each of its input channels) so that the mixed result is peak limited.

In a wide band peak limiter, only one attenuation value needs to be computed to bring the input to the Threshold. In a multiband peak limiter, there is more freedom as to how the attenuation is distributed across the bands to achieve the same output peak limiting.

In the L3, the decision of how to distribute the attenuation across the bands is made through an optimization algorithm. It minimizes inter-modulation between bands while maximizing the perceived overall level.

The L3 has far less inter-modulations between the frequency bands compared with a wide band peak limiter.

The L3 GUI (Graphical User Interface) offers a global section that includes the same controls as the Waves L1 and L2 wide band limiters. These are Threshold, Ceiling, (Master) Release, and the IDR section.

The full L3 Multimaximizer offers per-band Gain, Priority and Release controls. The global Separation control allows fine control over the spectral balance of the processed output. The global Release Behavior and the per band Release controls allow for optimizing the proper Release per band, during which ARC (the Waves Adaptive Release Control technology) is always engaged. The simple L3 Ultramaximizer offers *Profiles* of the per band Priority, Release, Xover cutoffs and Separation.

Another important aspect of the L3 is that it is split into 5 bands using linear phase filters. Thus, before applying any limiting, the audio path is 24 bit clean and the only difference is a constant delay of 80 milliseconds.

3. Using the L3

The L3 user interface is divided into two main parts: the Peak Limiter section and the IDR section.

The Peak Limiter section of the L3 Multimaximizer is divided into two main parts:

- full band controls – Threshold, Ceiling, Master Release
- per band controls - Gain, Priority, Release

THE PEAK LIMITER SECTION

The single most important control is the Threshold control. Until the Threshold is set, the L3 is idle. It introduces only pure delay, and is otherwise 24-bit transparent.

Once the Threshold is set, any signal that goes over the Threshold will be limited to the Threshold. The overall Gain is automatically made up by the Threshold factor. Thus, a Threshold of 6dB will cause a 6dB boost of the Gain.

The Ceiling control will scale the output so that the maximum energy will reach the Ceiling value but won't pass it.

The Ceiling and Threshold controls are placed side by side with the actual controls placed between a set of Meters. The Threshold is between the input meters to help adjust the Threshold by the action registered in the input. The Ceiling is placed between the output meters in order to easily define the maximum output value.

Between the Threshold and Ceiling controls is the linked control which will allow you to move both the Threshold and Ceiling controls together. This is useful in order to maintain consistency in the overall volume. It also allows you to better perceive the effect of the limiting on the sound of the program rather than on just the level.

It is recommended to use the linked control and take the Threshold and Ceiling down together until sound begins to break, distort or lose loudness. At this point its recommended to take the controls slightly up and then lift the Ceiling by 0.2dB (or the value of your choice).

Once the Threshold and Ceiling are set, the choices are divided through the simplified L3 Ultramaximizer vs. the complete L3 Multimaximizer.

In the L3 Ultramaximizer, the remaining Peak Limiter settings are the Master Release and Profile. According to the selected profile, the Master Release factor will be subject to different profile settings and will serve as a general longer vs. shorter release time. The selected Profile will impose a certain

“flavor” for the limiter action. We recommend using the general purpose default, or toggling through the profiles to select the one most suitable to your program material and personal taste.

The user can select the Ultramaximizer profiles from the presets menu and further tweak each and every per band of Gain, Priority and Release as well as the Crossover frequencies, global Release behavior type and Separation amount.

Threshold and Priority

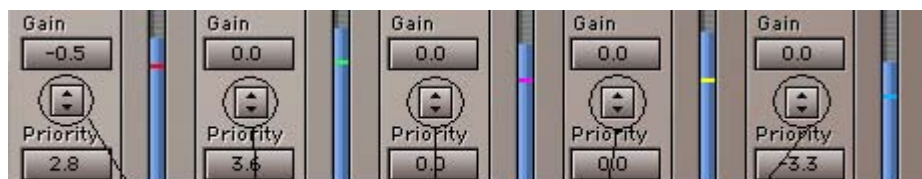
The L3 applies attenuation in 5 discrete frequency bands, the sum of which will be limited to the one Threshold. The Peak Limiting Mixer™ sets the single Threshold across the multiple bands in equal Priority according to the width of the band. If a certain band sounds too stressed compared to the rest, then the user can increase its Priority at the expense of the other bands while maintaining the summed energy to the same total peak. The result will be that per the same input energy, less attenuation will be introduced to bands with higher Priority and more to the bands with lower Priority, maintaining the same sum.



The little colored lines in the energy meter of each band show its relative Threshold and will adjust with Priority settings. When moving a certain band's Priority you may notice that the relative Thresholds of the other bands go in the opposite direction.

As you can see, the L3 Multimaximizer user can control the tone and spectral balance of the program going through the L3 without defeating the peak limiting process. However, the Gain factor is before the limiter (otherwise limiting would break).

Thus, adding Gain to a certain band will increase its continuous level. But, the peak level of that band will still be limited to the same relative Threshold. So, if you are looking to boost the Gain of a certain band, including its peaks, it will require a boost in both Gain and Priority. For this purpose we added the linking control between the Gain and Priority controls of each band.



Selecting the Crossover frequencies can also affect the Multiband properties. To make the most educated “tweaks”, we included solo buttons for each band. This enables you to adjust the boundaries of each band as you hear the audio running through each individual band.

The separation control is another unique tool that allows you to mix the side-chains of the per band energy detector. This smoothes out the differences between bands until 0 separation actually sets all bands to attenuate at once. However, the per band Gain, Priority and Release settings are still separate. This Makes it like a wide band limiter with some EQ and multiband release factors.

The per band Release controls allow you to specify a manual Release reference value. This value will become a part of the equation that the Waves ARC (Adaptive Release Control) technology will use to calculate the actual Release value. The L3 has a Master Release section that allows choosing one of five Release behavior types. The L3 also has a master control that allows you to adjust all per band release controls simultaneously.

Release Behavior Types

Waves ARC – Adaptive Release Control technology optimizes the actual release time in context with the program. In the L3 all Release behavior types use a certain amount of ARC where some are more adaptive and others less, or the amount of ARC is scaled across the bands in different ways.

ARC – This is the nominal and default release behavior type. It is set to be a overall good setting for any kind of material.

Warm – Sets more adaptive release behavior to the Low frequency bands and more Manual to the high frequencies.

Scaled – Sets more adaptive release behavior to the Hi frequency bands and more Manual to the Low frequencies.

Aggressive – Probably the release behavior type capable of the most extreme loudness, however this will work well on acoustic or electronic beat music where the drum transients dominate the peaks.

Manual - sets minimal ARC. The release time of each band will be as set in the per band Release control.

To get to know each of the Release behavior types, run some overly aggressive limiting while toggling through each one. Listen to each type with low vs. high release reference values, using the Master Release control to adjust all values. This should allow you to hear the differences between the types more obviously. Then you will be able to perceive them better when applying more moderate settings.

THE IDR SECTION

In the L3, there are two types of Increased Digital Resolution dithers: Type1 and Type2. The differences between them will likely influence your choice for your project.

- **type1** gives no nonlinear distortion with optimal dither.
- **type2** exhibits lower dither level with some low level distortion.

It is up to you to choose no distortion or lower dither level for your audio. More information is in the section **Basic control of IDR & Noise-shaping Options** (below).

Basic control of IDR

- Select Quantize level for desired output (24, 22, 20, 18, or 16-bit) by clicking the button to toggle through the choices. Alternatively, use the integrated popup menu for direct selection of the target bit-depth value.
- Select Dither (type1, type2, none) by clicking the Dither button.
- Select the type of noise-shaping (Moderate, Normal, Ultra, None) by clicking the Shaping button. (There is extensive information on these 4 options below under Noise Shaping options.)

For optimum results, level maximization (and at least normalization) should also be done! This is why the L3 includes both advanced peak controlling and IDR together: One step maximizes both.

TYPE1

This is the 'purist' technology. It is designed for no nonlinear distortion or modulation noise at low levels. Type1 combines optimal dither noise with psychoacoustic Noise Shaping. If applied several times in succession, a digital resolution enhancement technology optimized for one-stage CD mastering can produce unwanted side-effects.

Waves Type1 technology is the first optimized for use at every processing stage, allowing for the effects of cascading and subsequent signal processing. Type1 is also optimized to cause minimal side effects when used with stereo signals.

Type1 is the recommended choice for use with 20-bit and 16-bit file processing and other high quality mastering applications. By combining level maximization (peak controlling) and IDR processing, 16-bit files created from 20-bit or 24-bit masters can have an apparent 19-bit resolution — an 18dB improvement.

TYPE2

Type2 also uses dither with a similar noise-shaping curve, but the dither is of a unique kind designed to minimize the amount of noise added. This gives a lower noise level than the IDR type1 process, but at the expense of some low level distortion.

Type2 has some advantages for high quality mastering as well. It is your choice whether the ultimate in low distortion of type1 is preferred, or the additional reduction in dither level of type2. Type2 is "auto-blackening" with no input signal. In other words, if the input signal is digital black (no signal at all) there is no Type2 dither added to the output signal.

NOISE-SHAPING OPTIONS

There is another way to decrease the perceived amount of noise and increase perceived resolution. We 'shape' the frequency content of the noise so that it matches the ear's sensitivity curves. In basic terms, noise-shaping shifts the energy of the noise to the frequency ranges where we hear it the least.

The three options of Noise-shaping provided in the L3's IDR section push more of the noise energy to higher frequencies above 15 kHz, where our ears are least sensitive. This reduces the noise energy of lower frequencies. The three

Noise-shaping options differ in the amount of this 'shifting action'.

Moderate is the lightest noise-shaping curve.

Normal is the recommended option for use under most conditions and for all bit-depths.

Ultra is a very high-quality setting, suitable only for use at the very last stage of mastering high-resolution files (16-bit and higher) targeted for high-quality digital media. It is theoretically possible that the relatively high amount of high frequency energy could cause undesirable side effects *if the signal is going to be processed or digitally edited again*. Therefore, it is best that Ultra is used in the last stage of file preparation.

(However, with many thousands of L3- processed products, no such situations have been reported. Since it is *theoretically* possible, we wish to inform you of it. These theoretical side effects might cause clicks at later edit points if 'Ultra' Noise Shaping was used, if played back on poorly designed D/A converters.)

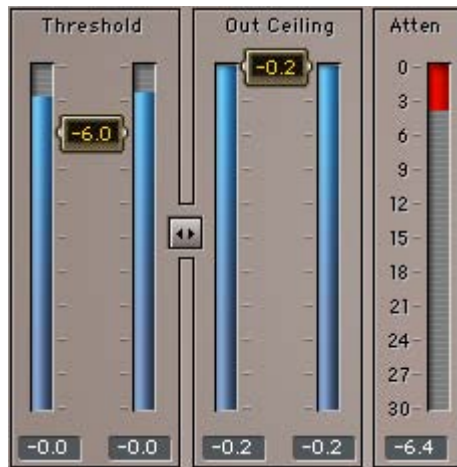
Of course, the effect of Noise-shaping is even greater when used with type1 or type2 dithering, since Noise-shaping reduces the audibility of the added dither noise. Try the full effect of IDR technology by listening to the same material, with both IDR types and different kinds of Noise Shaping. The most obvious places to examine are notes or reverb during the 'tail' (end of the sound). During this time, the quantization error is most audible, though it is present on all low-level signals (such as elements that are soft in a mix, etc).

Since the entire issue of dithering is a very subtle one, we recommend you listen to a rather long piece of audio (2-3 minutes). It should be of high-quality, say 20-bits if possible, with a good dynamic range. Jazz and classical recordings are ideal.

For a quick start, the option that will generally work well for *CD-mastering* is **type1** with **Normal** noise-shaping. For *minimum noise with 16-bit and greater files*, **type2 Ultra**; for *maximum resolution* use **type1 Ultra**.

4. Controls and Displays

THE PEAK LIMITER SECTION



THRESHOLD: 0.0 to -30dBfs, Default 0.

The Threshold value sets the point that the audio energy should be limited to. When the energy goes over the Threshold, Gain attenuation will be applied to keep it just below the Threshold. The L3 will also add make up Gain in an opposite value to the Threshold.

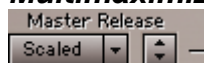
OUT CEILING: 0.0 to -30dBfs, Default 0.

The Out Ceiling value scales the output of the peak limiter to a certain maximum set by the user. By default this is 0.0 dB or the full digital scale.

ATTENUATION METER: 0 to -30dB

The Attenuation Meter shows the overall summed attenuation applied to the program material. This attenuation is happening across the multiple bands and can be seen in the L3 Multimaximizer.

Multimaximizer Master Release

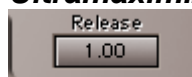


The Master Release control of the L3 Multimaximizer is comprised of two functions:

RELEASE BEHAVIOR TYPE is the left popup menu. It allows selecting 1 of 4 release behavior types that distribute different amounts of the Waves ARC technology (Adaptive Release Control) across the 5 bands.

MASTER RELEASE is a control that scales the per band release values in a linked operation.

Ultramaximizer Release Control



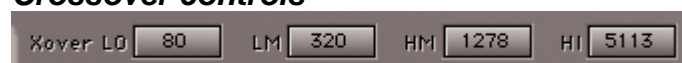
The Ultramaximizer has a single release control which controls all of the per band release values as a master control. The indicated value is a multiplier for the per band values of the currently selected Profile.

PROFILE: Default – Basic Profile. Ultramaximizer Only.

The Profile pop up menu includes combined settings for the L3 multiband engine. Each profile applies different internal settings to the per band controls, Release behavior type, Crossover frequencies and Separation.

PEAK LIMITER MULTIBAND CONTROLS – L3 MULTIMAXIMIZER ONLY

Crossover controls



Just below the graph are the Crossover frequency adjustment controls. There are 4 Crossovers in the L3. Each sets the cutoff frequency for the High Pass and Low Pass filters that cross each other.

The Xover controls will sound a click when the calculation intensive Linear Phase filters are reset to a new position. You can use the mouse to adjust the frequency or grab the markers at the bottom of the Graph. The new filter will be set only when the mouse is released. This is to avoid zipper noise. Using the arrow keys or control surface you can advance step by step to fine tune your Xover position.

Each of the four Crossovers has a unique range of frequencies as follows:

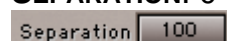
Low: 40Hz to 350Hz. Default to 80Hz.

Low Mid: 150Hz to 2997Hz. Default to 320Hz.

Hi Mid: 1022Hz to 4757Hz. Default to 1278Hz.

Hi: 4kHz to 16kHz. Default to 5113Hz.

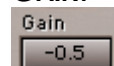
SEPARATION: 0 – 100. Default 100.



This control defines how the signal from each band will be fed into the side chain of each band's energy detector. At 100 Separation each band will be fed only to its own energy detector. At 0 Separation all bands will be fed into every band's energy detector.

Per Band Controls

GAIN: -12 to +12. Default 0.



The per band Gain is a straight forward Gain offset after the linear phase crossover. It precedes the limiter and is good for EQ type operations. It is like placing a Linear Phase equalizer before the L3.

PRIORITY: - 12 to +12. Default 0.



The per band Priority control affects the internal Peak Limiting Mixer™ optimization algorithm. When possible, the bands with higher Priority are prioritized to receive less attenuation at the expense of other bands. This allows for controlling the spectral balance of the processed output in a way that is very different from a Gain control. When you feel limiting is causing one band to be suppressed too much compared with the others, the Priority can be used to change this.

GAIN AND PRIORITY LINK



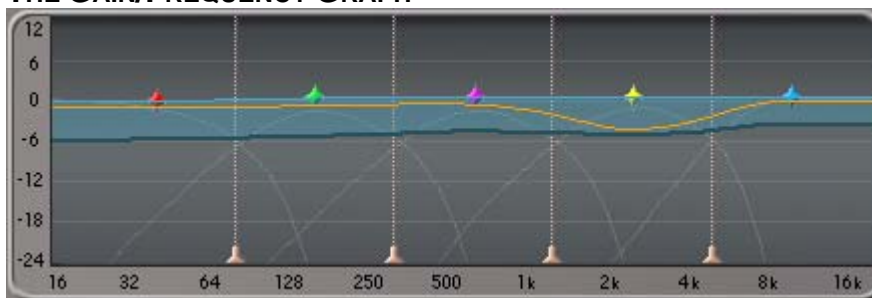
Located between the per band Gain and Priority controls, this linker allows both to move both simultaneously.

RELEASE: 0.1 to 5000.



The per band Release sets the reference Release time for each band. This reference release time will be further adjusted by the Release Behavior Type.

THE GAIN/FREQUENCY GRAPH



The Gain/Frequency graph displays a Dynamic Gain line. This is a smoothed ghost of the same dynamic Gain line and peak hold line showing the peak attenuation that happened across the frequency range.

The Orange line is the Dynamic Gain line and shows the Gain changes as they happen.

The Semi transparent blue shade is a smoothed trail of the dynamic Gain line.

The dynamic Gain line may move too fast for you to understand the overall dynamic EQ that is happening, so we added this Ghost. The Ghost will eventually join the Gain line when it settles for long enough.

The bottom darker blue line is a peak hold line of the dynamic Gain. It allows you to view the maximal attenuation that was reached across the frequency spectrum.

On the graph you will find 5 grab markers. They adjust the bands' width when moved left/right, or the linked Gain and Priority when moved up/down.

The graph also shows 4 markers for showing or adjusting the crossover frequencies.

THE IDR SECTION

QUANTIZE – 24, 22, 20, 18, or 16. Default 24-bit.



The Quantize control sets the target bit depth of the L3 output. The perceptual result will be increased by using Dither and Shaping. However, this control sets the actual output bit depth of the L3. There is no way to turn this off, thus the output of the L3 will be quantized to a maximum of 24-bits even if you are in a floating point environment. The 24-bit maximum is very relevant even for 24-bit sources as the internal process is doubled in precision.

TYPE – 1, 2, None. Default – 1.



The Dither type selects the Dither type 1 or 2, or no dither at all. To better understand the Dither types please read The IDR Sections in chapter 4, 6 and 7. The Noise Shaping is a separate process which will still work to move Quantization noise to the less audible frequencies.

SHAPING – Moderate, Normal, Ultra or None. Default – Normal.



Shaping relates to Noise Shaping. This control selects the amount of Noise Shaping that will be applied to the dither and/or quantization noise. The process of Noise Shaping lowers the energy in the main band and pushes it upward in spectrum so that the energy is higher for the less audible frequencies. Selecting None leaves the noise unfiltered.

IDR ACTIVE/BYPASS INDICATOR



Whenever Dither or Noise Shaping are engaged, the IDR status indicator will be colored red to indicate activity in the IDR section. When both Type and Shaping are set to None, the IDR logo will turn gray to indicate that no increase in digital resolution is engaged. The actual bit depth reduction system will not truncate the signal. Instead it rounds the signal. This is still better than straightforward truncation of the lower bits.

5. Some secrets of digital audio

In order to make the best use of the L3-Ultramaximizer, it is important to understand some of the less obvious implications of digital audio. Once these have been explained, you will understand why Waves thought a product such as the L3 was necessary. You will also be in a better position to make use of its powerful features. The operation of the L3 breaks down into two main areas:

- 1 - Maximum level of the digital signal through proprietary peak control.
- 2 - Maximum resolution of the signal through dithering and Noise Shaping.

MAXIMUM LEVEL

The maximum level of a digital signal is governed by the highest peak in the file. Simple normalization finds the highest peak, then raises the entire signal so that this peak is at the maximum value. However, many of these peaks may be of very short duration and can usually be reduced in level by several dBs with minimal audible side effects. Those familiar with digital editing systems may even have proved this by 'redrawing' some troublesome peaks by hand. By transparently controlling these peaks, the entire level of the file can be raised several more dB than by simple normalization. This results in a higher average signal level.

The L3-Ultramaximizer avoids the possibility of overshoot by utilizing a "lookahead" technique. This allows the system to anticipate and reshape signal peaks in a way that produces the bare minimum of audible artifacts. Because there is no possibility of overshoot, the L3 can be used with absolute confidence when brickwall limiting is important.

MAXIMUM RESOLUTION

Any digital signal processing that alters the original digital data (mixing, Gain changes, EQ, dynamic processing, etc.) generally increases the number of bits required to represent the signal. Conventional truncation results in a loss of signal-resolution each time the signal is processed. The human ear uses this low level information to construct a mental image of the stereo soundstage. Any compromise in this area manifests itself as a loss of spaciousness and transparency.

Waves' IDR prevents this loss of critical low-level detail. Even when processing 16-bit signals, it is normal to process with at least 24-bit resolution. Often even higher resolution is used, as in the L3, which is now double-precision.

As soon as the resolution is pulled back down to 16 bits by rounding or truncation (removing the bottom 8 bits), the resulting rounding error produces audible distortion at low signal levels. It also results in permanent loss of digital resolution which can never be recovered.

If the audio signal is repeatedly processed and truncated back to 16 bits, the losses accumulate. This causes a significant loss of fidelity. This fidelity loss is most evident as a loss of the tonal subtleties of low-level sounds within a mix. The solution is to properly dither and noise-shape a signal each time the wordlength is increased and reduced. Nearly every digital signal process will require this.

WHY USE DITHERING, AND WHAT IS IT?

Proper dithering is simply this: before the requantization (reduction of the wordlength), a precisely controlled amount of noise (termed 'dither') is added to the signal. Dithering can convert the low-level nonlinear distortion caused by truncation into a simple steady hiss. This removes all traces of low-level non-linearity at the expense of a very slightly increased background noise.

Obviously, increased noise levels are not ideal in high quality audio applications. Fortunately the perceived level of this dither noise can be greatly reduced. This is done by 'shaping' the noise in such a way that it falls into an area of the audio spectrum where the human ear is least sensitive. The main point of maximum resolution is simple: to 'capture' the best possible quality into a shorter wordlength (smaller bit-depth) from a longer wordlength (higher resolution).

A BIT ABOUT IDR™

IDR™ is a Waves proprietary Noise Shaping dither system developed by the late Michael Gerzon and Waves. IDR signifies a major advance in preserving and actually increasing the perceived resolution of the digital signal being processed. In order to ensure that the final signal has the maximum resolution possible, utilize IDR during each subsequent process (for 16-bit storage). Or, use IDR just once at the end of a high-resolution chain (i.e. 24-bit).

IDR is of particular benefit when data is deliberately requantized from 48-bit to 24-bit, 24-bit to 20-bit and so on.

Dithered outputs of 24, 22, 20, 18, and 16-bit are available. The L3 features double-precision resolution. For TDM (Time Division Multiplexing) systems, all internal limiting and Gains are calculated with 48-bit fixed precision. Dithering back to 24-bit output is now possible for the new DVD and other delivery media, as well as for archives of masters.

By using the IDR implemented within the L3-Multimaximizer, optimum results may be achieved during final file preparation, mastering, and quantization or requantization. The greatest possible implementation of IDR available is in the L2-hardware limiter and the software L2 and L3 plug-ins from Waves. Both feature 9th-order Noise Shaping. (The original L1 software has 2nd-order noise-shaping).

6. In-depth IDR Information

ABOUT DITHER AND NOISE SHAPING

Dithering and Noise Shaping are two independent, complementary techniques. They are used to improve the perceived quality of sound after it has been re-quantized. Each technique is responsible for the improvement of a different subjective quality of the noise imposed by re-quantization. Each can be used separately to improve that specific quality.

Dithering is done in order to change the character of the quantization noise to more closely resemble analog hiss, rather than digital quantization noise. The main effect of dithering is to reduce (or, in case of type1, virtually eliminate) all correlation between the quantization noise and the original signal. This reduces or eliminates non-linear distortion typical of digital quantization noise. The dithering process 'exchanges' these distortions for a steadier analog-hiss quality signal.

Noise Shaping is done in order to optimize the distribution of overall noise energy across the spectrum. This optimization is according to the ear's sensitivity. This means that a decrease in noise (whether distortion or hiss) in the ear's sensitive areas (1 to 6kHz), is 'exchanged' for an increase of noise in less sensitive areas (above 15kHz, toward Nyquist).

Hopefully this has helped you see that in both techniques, the issue is about 'exchanging' the character and frequency content of noise (hiss & distortion) according to subjective criteria.

How do these processes help 'capture' 3 more bits of detail? The easiest analogy is to point to dithering in graphics. This is exactly the same process, and exactly the same type of psycho-perceptual model.

The brain is capable of perceiving detail that is lower than a noise floor (in this case, dither). However, quantization noise is highly correlated to the signal. In other words, it is related to and governed by the signal. Dithering makes this noise become uncorrelated (as dither is a random signal), therefore allowing the brain to perceive the detail. The noise-shaping then helps to shift the energy of the noise to a less sensitive area of our hearing.

DITHER

No Dither <off>. This is not quite normal truncation, but rounding to the 24th bit without adding any dither. It allows a high degree of nonlinear distortion at low levels. The only reason to use this setting would be to provide a 24-bit transparent (perfect clone) output from the input. However, it's easier just to use the Bypass button! Even if you are using an external dithering system to achieve your final desired wordlength, you should use the L3's IDR to dither to a 24-bit output.

IDR type1 Dither. This dither is a wide-band dither. Type1 adds a certain amount of noise, causing a 5dB increase in background noise compared to no dither. It completely eliminates all low-level distortion and signal-dependent modulation effects. The result is a very transparent and clean low-level sound with a high resolution. It most resembles the steady low-level hiss of an excellent quality analog system with no digital quantization noise.

This is the "purist" technology. Type1 is designed for no nonlinear distortion or modulation noise at low levels. It combines optimal dither noise with psychoacoustic Noise Shaping. Type1 is also optimized to cause minimal side effects when used with stereo signals. Type1 is the recommended choice for use when processing high quality mastering applications. By combining level maximization (peak controlling) and IDR processing, 16-bit audio created from 20 or 24-bit masters can have an apparent resolution of 19 bits. This is more than an 18dB improvement!

Some signals will be subjected to more than one stage of processing and quantization back to 16-bits. In these cases, the design of resolution-enhancement must satisfy more requirements than a technology designed just for one-stage use. If applied several times in succession, a digital resolution enhancement technology optimized for one-stage CD mastering can produce unwanted side-effects. Waves type1 technology, however, is the first optimized for use at every processing stage, allowing for the effects of cascading and subsequent signal processing, when needed.

IDR type2 Dither. This dither is a narrow-band dither. It adds virtually no audible noise so it is nearly 5dB quieter than type1. There is some low-level distortion, but this distortion is generally much lower than with no dither at all.

Type2 is a unique kind of dither designed to minimize the amount of noise added. This gives a lower noise level than the IDR type1 process, at the expense of some low level distortion. Type2 does have some advantages for high quality mastering as well. It is purely your choice whether the ultimate in low distortion of type1 is preferred, or the additional reduction in noise of type2.

NOISE SHAPING

Another way to decrease the perceived level of noise is to "shape" the frequency content of the noise so that it matches the ear's sensitivity curves. In basic terms, Noise Shaping shifts the noise to the frequency ranges where we hear it the least. The three options of Noise Shaping provided on the L3 push more of the noise energy to higher frequencies above 15kHz and toward Nyquist, where our ears are least sensitive. They do this while reducing the noise energy at lower frequencies. The three Noise Shaping options progressively differ in the amount of this "shifting action". The L3 features ninth-order Noise Shaping for optimal wordlength reduction quality.

Off. No Noise Shaping, resulting in more audible noise (and distortion if dither is not used). The result has equal noise (distortion) levels at all frequencies, which is not optimal from a psychoacoustic point of view.

Moderate. This typically reduces perceived hiss (or distortion if dither is not used) by around 6dB. The HF noise Gain is about 9dB for 44.1kHz.

Normal. This typically reduces perceived hiss (or distortion if dither is not used) by around 12dB. The HF noise Gain is about 15dB for 44.1kHz. Using Normal with type1 dithering is very suitable for the creation of Production Masters. It was also designed to be excellent for masters that would be processed again for any reason, including consecutive re-dithering, with an accumulation characteristic that is optimized to be minimal.

Ultra. This gives the greatest perceived hiss/distortion reduction, typically 18dB. The HF noise Gain is about 23dB for 44.1kHz. Ultra is a very high-quality setting. It is suitable only for use at the very last stage of mastering high-resolution audio (16-bit and longer word lengths) targeted for high-quality digital media. It is best to use Ultra in the last stage of audio preparation (the Production Master). Due to the HF Gain, it is theoretically possible that the relatively high amount of high frequency energy could cause undesirable side effects if the signal is going to be processed or digitally edited again. However, with many thousands of IDR-processed masters no such situations have been reported or observed.

You can hear the effect of Noise Shaping by itself by setting Dither type to Off and selecting one of the Noise Shaping options while monitoring the output. The effect of Noise Shaping is even greater when used with type1 or Type-2 dithering. This is because Noise Shaping reduces the audibility of the added dither noise.

Now try the full effect of IDR technology by listening to the same material, with both IDR types and different kinds of Noise Shaping. The most obvious places to examine are notes or reverb during the end of the sound, or "tail". It is during this time that the quantization error is most audible, although it is present on all low-level signals (such as elements that are soft in a mix, etc.)

The option that will generally work well for CD-mastering is type1 with Normal Noise Shaping. For minimum noise with 16-bit and greater sources try type2 Ultra. For maximum resolution use type1 Ultra.

The noise reduction figures given here apply to sampling rates of 44.1 or 48kHz. They are even better for doubled sampling rates. If audibility of noise were the only factor, the choice would almost always be to use Ultra noise Shaping. But, in some situations, heavy Noise Shaping (Ultra) can theoretically have some disadvantages. So, the milder settings such as Normal or Moderate may be better.

For 16-bit applications, **Ultra** shaping should be **avoided** in the following situations:

Subsequent Digital Editing When a signal is subjected to later editing, extreme Noise Shaping might, in rare cases, cause low-level, yet audible

"clicks" at the edit points. This might occur when played on low quality CD players.

Applications in which you should avoid use of Ultra shaping include CD's with production music, sound effects libraries, or loop libraries. These would certainly be subject to further digital editing.

Poor Error Correction When errors that are not properly corrected occur, the Ultra setting (like all forms of heavy Noise Shaping and other resolution enhancement technologies) tends to cause audible background crackles, especially on very cheap CD players. While these effects generally don't occur on the majority of mid- or hi-fi CD players, they can be noticeable on very cheap products. The amount of such crackles on poor pressings is greatly reduced by the Normal Noise Shaping. An example would be a signal destined for a carrier medium with poor error correction, such as CDs pressed in pressing plants with poor quality control.

Subsequent equalization before duplication, when heavy treble boost equalization is subsequently employed. (We're referring to EQ by a pre-mastering person before duplication, not when the end user boosts the treble on their home system!) This can cause the strongly boosted higher frequencies used by Ultra Noise Shaping to become so high in level that they might feed excessive noise energy into loudspeakers. Therefore, Ultra shaping is best avoided in situations where subsequent equalization may be used in pre-mastering, such as in a compilation. Of course, if the mastering is done correctly the first time, large treble boosts would be quite unnecessary. Please note that much less HF Gain is used with the Normal and Moderate noise shapers than with Ultra (all of which could be observed on a real-time analyzer, such as Waves PAZ - Psychoacoustic Analyzer).

7. 16-bit (and higher) mastering

Here are the basic steps of using the L3 in a 16-bit, 44.1/48kHz application. These steps also apply to 24, 22 and 20-bit mastering.

- All processing, sample rate conversion, dynamic changes, etc. **MUST** be done before L3 processing. The L3-Multimaximizer should be the last processing of the file. Ideally, dithering occurs only once.
- Using a 16 or higher bit input file, set the Threshold for desired peak limiting. For suggestions on how much limiting to do for certain applications, see chapter 4. In general, set Threshold for about 4-6 dB of Gain Reduction in the Attenuation meter.
- Now take the Output Ceiling up to the maximum peak output you desire. You can take this Output all the way to 0.0 dB without any clipping. For CD's, a recommended (Factory Preset) setting is -0.2dB; (For more information please read about digital clipping in Chapter 9.)
- Leave the Release Behavior type set to ARC.
- Set Quantize output for **16-bit** (for CD/DAT; or 22, 20, 18 for higher archival or mastering medium if your hardware supports the transfer of 16+ bits).
- Set Dither type (type1 or type2). **IDR type1** is recommended for most high-resolution applications.
- Set Shaping (Moderate, Normal, Ultra, none). **Ultra** and **Normal** are recommended for most high-resolution applications.

Our Recommendations:

Application	Dither	Noise Shaping
CD-mastering	Type1	Normal
Minimum noise w/16-bit and greater files	Type2	Ultra
Maximum resolution	Type1	Ultra

8. Use the L3 last

It is recommended that L3 be used as the final process after all dynamic and EQ adjustments have been made. Only when all these processes are finalized should the question of peak level be addressed. Instinctively, it might seem appropriate to Normalize the file once all other processing has taken place. But, in practice, it may be better to set the peak levels to around 1dB below clipping using the L3. For an explanation, see the notes on digital clipping in chapter 9.

The choice of IDR setting depends on the final use to which the file will be put. Type1 or 2, Normal, is recommended for most work. Type1 or 2, Ultra, is considered best for final mass production of 16-bit and greater masters, and for producing a complete disc master which will undergo no further edits. For example, a production master CD (PMCD) run off from a hard disk editing system in a single pass when no further editing is anticipated (all timing is finalized). This PMCD would then be transferred unchanged to the glass mastering process.

Certain CD Audio authoring programs string together separate regions of sound files. When using such programs you must perform destructive processing with the L3. Since these programs are a form of editing (playing regions/songs with silence or splices between audio regions/songs), it is recommended to use Normal noise-shaping with either Dither type1 or type2. (However, thousands of IDR-processed masters have been produced with type1 Ultra with no unusual problems whatsoever.)

If you must process or EQ any previously L3-processed file, you will need to create headroom by lowering input on those later processes, then most likely re-limit to restore the average level of the file.

9. Important notes on digital clipping

The digital words representing an audio signal at each moment have a maximum possible positive value and a minimum possible negative value. These are defined by the bit depth of the file format. Any attempt to force an audio signal beyond these maximum permitted values (for example, by applying excessive gain), will result in the audio signal being clipped. There are other ways in which a signal can become clipped, and some of these are far from obvious. We all know that clipping distortion sounds quite unpleasant and is to be avoided.

PEAK-NORMALIZED SIGNALS

A '**Normalize**' process allows a file to be processed in such a way that the maximum peak level within the file just reaches (but does not exceed) the digital zero or clipping point. This is desirable because it means that the file is as 'loud' as possible without clipping. This maintains the best signal-to-noise ratio, especially at low bit word lengths.

the L3's peak limiter is useful in situations where a higher average sound level is required. It allows the typical level of signals to be even further increased by gently pulling down the Gain of waveform peaks, with no audible nonlinear distortion. The L3 can simultaneously re-scale the audio data so that the limited peak signals approach or just reach digital zero.

However, by storing soundfiles at the maximum possible level, there is a risk that any subsequent processing may take these peak levels too high. This will result in clipping distortion. Peak limiting to 0dB, by whatever means, leaves no margin for any subsequent increase in peak level.

Intuitively, you might think that simple Gain reduction could be applied without incurring the risk of clipping, while any increase in Gain would surely cause clipping. This is true. You might also think that applying an EQ boost at any frequency might result in clipping, depending on the peak energy level within the band being equalized. This is also true.

What is far less obvious is that applying an **EQ cut** also runs the risk of causing clipping. To prove this would take a lot of math, but the following description should help get the point across.

At any instant, the peak level of a signal may be the result of several components at different frequencies and at different phases relative to each other. Some components will add while others will subtract. But what happens if you 'EQ out' a frequency that would otherwise be subtracting from the peak level by virtue of its phase? The peak is now *higher* than it was. For most audio material, this effect will be relatively small. Typically, peak levels will increase by about 0.3 dB. However, it is possible that under unfavorable

circumstances or with non-typical signals, the peak level could increase significantly more than this.

The L3 forces the signal to skim the peak level more often so the likelihood of clipping in this way is further increased. In practice, filters attenuating mid or high frequency components tend to cause the kind of increase in peak level described. But, high pass filters that attenuate the bass can sometimes cause much larger increases of peaks. This can be an increase of several dBs on heavily limited signals. The phase response of certain high or low-pass filter types can also increase peak levels by up to about 4 dB.

Bearing all this in mind, it might seem logical to keep the signal peaking a few dB below digital zero until all processing has been carried out. After that, you can safely normalize the signal—or can you?

A related problem with peak clipping can arise when a normalized soundfile or signal is converted to a new sampling rate. This has to do with the sample-rate conversion process itself. During sample rate reduction, the signal is effectively being filtered. The available audio frequency range is smaller at lower sampling rates. Such filtering can increase peak sound levels in exactly the same way as attenuating equalizers can. But, even when increasing sampling rate, an increase of peak level can occur. This is because the continuous-time audio waveform is represented in the digital domain only by its values at the sampling instants.

It is perfectly possible for the peak value of the continuous-time audio waveform to occur at instants lying between two sampling instants, and thus to be higher than the peak value at any of the sampling instants. When changing the sampling rate, new sampling instants are chosen for the continuous-time audio waveform. These new sampling instants may coincide with an increased peak lying between the original sampling instants. This is especially likely to occur with signals that have a lot of high frequencies. This is because these signal waveforms change more rapidly between the sampling instants. Artificially contrived signals can be created to really show off this problem.

However, in real life, an attenuation of at least 0.3 dB or so prior to conversion should provide adequate protection against clipping. You might expect sample rate converter designers to account for the possibility by designing in a small amount of attenuation. Unfortunately, the less expensive sample rate converters generally do not account for this.

So, can you safely normalize a file that you know is at the final sample rate? Unfortunately not! Many CD players (and some other digital consumer equipment) use over-sampling digital-to-analog converters (DAC)'s to produce the analog signal fed to the amplifier. Such over-sampling converters involve a sampling rate conversion process which can (and will!) cause audible peak clipping. Once again, some designers appear to have overlooked this problem, although not as widely as they did in earlier DAC designs.

We hope that this has been a helpful guide for using your new L3. Enjoy the new Waves L3 Ultramaximizer and Multimaximizer!!!