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ADVANCED DSP TECHNOLOGIES

DeNoiser Plug-In

for

Pyramix VIRTUAL Studio

USER'S MANUAL

De-NOISER MANUAL CONTENTS

Algorithmix® DeNoiser Plug-In

Noise Removal Processor for Pyramix Systems

Introduction to Noise Removal

One of the common problems in audio production work is noisy signals. A processor that can remove the noise components while leaving the signal relatively unaffected is therefore a valuable tool for audio engineers. The standard method of extracting signal from noise is to design an appropriate filter that removes the noise components and at the same time lets the desired signal go through unchanged. This sounds plausible, but in most cases does not work. If the signal and noise spectra overlap there is no traditional filter technology that can perfectly extract the desired signal. In such cases a compromise is necessary since the noise reduction can be only done at the expense of distorting the signal we want to preserve.

Encode/Decode Schemes

Among the classical methods to prevent noise before it arises are complementary encode/ decode systems like the famous tape noise reduction system from DOLBY™ Labs. The recorded signal is processed in a special way (encoded) before recording to the tape. Then after playback a reverse operation (decode) is applied to the coded signal. The idea behind this is to reduce the noise, but keep the signal unchanged.

This works to minimize adding noise during the recording process, especially when recording to analog tape media. However, for recordings that already have a high noise component, encode/decode schemes can make no improvement. In this case, a process that can reduce or remove the noise that already exists without substantially changing the original signal is required.

Single-Ended Noise Reduction

The **Algorithmix® DeNoiser** Plug-In is a single-ended noise reduction system. This means it will operate to remove broadband noise artifacts directly from an existing signal and does not need any special encoding procedure before recording, like the DOLBY™ Labs system mentioned above. There are two broad categories of noise that may need to be processed in order to restore a signal to optimal intelligibility and fidelity:

- Impulse noises such as those arising from scratches and surface defects in old phonograph recordings or from static and crosstalk in signal transmission lines
- Broadband noise such as tape hiss or background noise from live recordings

The **Algorithmix DeScratcher** Plug-In is designed specifically to remove unwanted impulse signals such as scratches and crackling sounds, while the **DeNoiser** Plug-In is designed for broadband noise removal. Together, these processes can be used to clean up a great variety of audio material. They are especially useful in forensic applications such as cleaning up noisy dialog and telephone recordings or noise arising in bad telecommunication channels.

The order in which these processes are applied is very important to the final result achieved. It is best to remove clicks and impulse-like disturbances first with the **Algorithmix® DeScratcher** Plug-In and then subsequently use the **DeNoiser** Plug-In to clean the remaining broadband noise from the signal. Applying the **DeNoiser** directly to heavy clicks will create significant, singing-birds-type artifacts and is not recommended.

The DeNoising Process

The **Algorithmix® DeNoiser** Plug-In uses a noise profile to determine the frequency band characteristics applied by the processor when removing noise from the signal. The user can choose among three possible noise profiles:

- *White* Noise (which has equal amounts of energy at all frequencies)
- *Pink* Noise (which has equal amounts of energy per octave of the audible spectrum)
- *User* Profile (which is based on noise characteristics provided by the user).

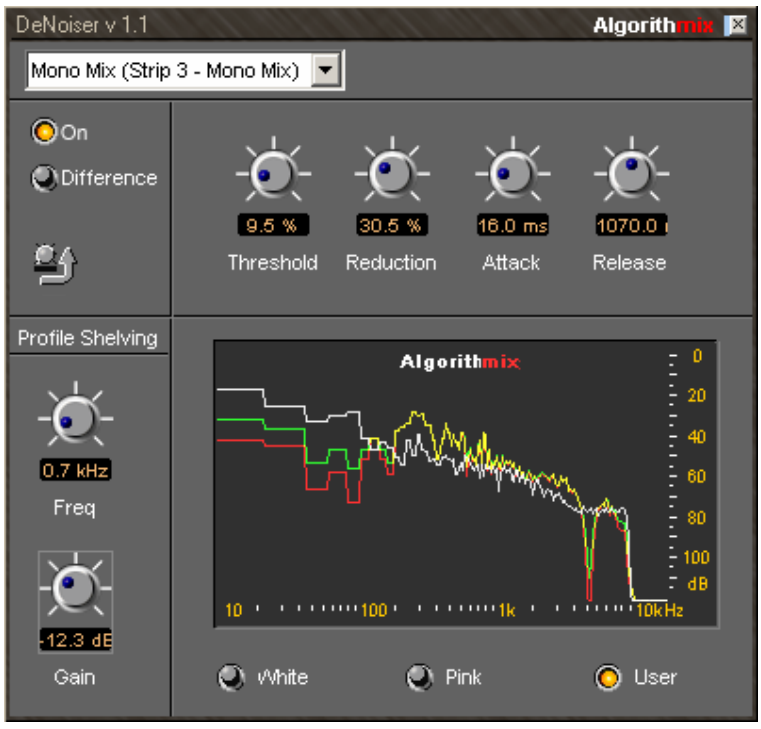
A *User* noise profile should always be recorded from a portion of the recording containing the background noise only. This means a segment of audio in which the unwanted noise is present, but there is no signal such as speech or music. This allows the best results by tailoring the action of the processor to the specific noise profile of the signal processed.

Since the entire process runs in real time, you can simply switch between the three *noise profiles* while listening to the output signal. This makes it easier to discover which *noise profile* is best suited to the audio material being processed.

Algorithmix DeNoiser Interface

The noise reduction process in the **DeNoiser** Plug-In is primarily controlled by just two parameters: *Threshold* and *Reduction,* thus allowing an easy search for optimal results depending on the given input signal. The remaining parameters are for fine-tuning the process by controlling the responsiveness of the process (*Attack* and *Release*) and by setting shelving frequency and gain applied to the profile.

The **DeNoiser** windows opens initially showing only the four main parameters, *Threshold*, *Reduction*, *Attack*, and *Release*, plus the *On* switch and the *Difference* switch. A fuller display window can be opened by clicking on the down arrow below the *Difference* button on the left side of the plug-in. This opens the *Noise Scope*, the *Noise Profile* selector buttons and the *Profile Shelving* (High Shelving EQ for Noise Profile) controls.



*Screen shot of the **DeNoiser** Plug-In*

Basic DeNoiser Controls

The *Noise Scope* interface shows the frequency spectrum of the input signal (green line), the noise profile applied (white line), as well as the output signal after the *de-noising* process (red line). This provides a real-time window into the operation of the processor. It is a graphic means to intuitively follow the effect of the *de-noising process* on the processed material.

The *noise profile* (white line) marks the threshold border, above which no noise reduction is applied. The *threshold* parameter moves this *noise profile* up and down and can be used to set up the profile just above the background noise level. For a given *Threshold,* the second parameter, called *Reduction,* controls the amount of the spectral components removed below the chosen noise profile. The *Attack* and *Release* parameters govern how quickly the processor responds. This is summarized in the following chart:

Parameter	Comment
Noise Profile	sets the frequency pattern applied to the material to effect the broadband noise reduction. It is shown as a white line in the *Noise Scope* and indicates the threshold border above which no noise reduction is applied
Threshold	moves the *Noise Profile* up and down to set the spectral boundary for the de-noising process
Reduction	controls the amount of spectral components removed below the chosen *noise profile*
Attack	determines how quickly the processor responds to signals which are above the *Threshold* setting
Release	determines how quickly the processor stops the filtering process after the signal falls below the *Threshold* setting

Primary Noise Reduction Controls

Using Noise Profiles

The *noise profile* should ideally represent the frequency distribution of the noise to be removed from the noisy input signal. It is a kind of reference *spectral horizon* used by the *de-noising* algorithm. The position of the *noise profile* relative to the input signal can be controlled with the *Threshold* parameter.

The quality of the entire *de-noising* process can be considerably enhanced by applying user-defined *noise profiles* taken from the audio material to be processed. As already pointed out, the loop should contain nothing but noise (or whatever has to be removed from the input signal). If a *noise profile* includes spectral components of the signal to be recovered, they will also be removed or at least lowered in the *de-noising* process. Consequently the audio quality of the original signal will be affected. Therefore, much care and sensitivity is recommended when preparing a user-specific *noise profile*.

To create a *User* profile, click on the *User* button while playing back a “noise-only” part of the recording. We recommend to set up a loop continuously playing back the noisy part of the signal. Try to create a loop that accurately represents the broadband noise component lasting several seconds. This way it is not so critical when the *User* button is pressed to capture the *noise profile*. In the current software version approx. 0.5 s (one half second) of noise is analyzed for the calculation of the *noise profile*.

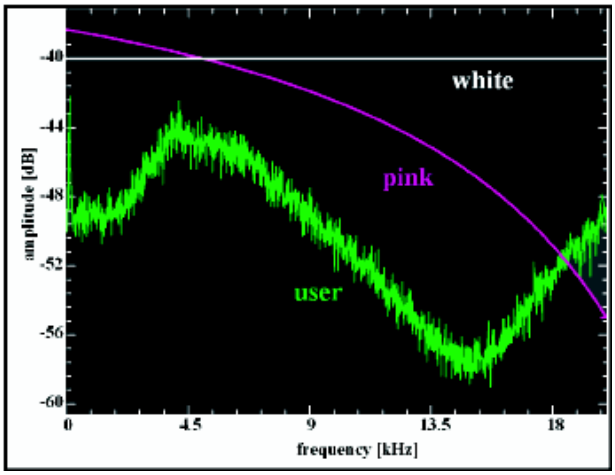
NOTE: Be aware that after subsequent switching to *White* or *Pink* the *User* noise profile is lost and must be recorded again as described above. This limitation will be addressed in the next version so that operation can be switched between the three profiles without losing the user profile content. The ability to store the *noise profiles* as presets will also be provided.

Using the Difference Monitor

The more noise to be removed, the more the operator has to be aware of possible artifacts arising from the noise removal system. These artifacts are greatly influenced by the *noise profile* used. Although the *Noise Scope* can visually help in objective comparison among different setups, the final judgment should always be made by carefully listening to the output signal with a high-quality speaker system or headphones. Most important is to avoid filtering out too much of the desired signal along with the noise. The *Difference* monitor is a very useful feature designed to help determine whether signal is being removed with the noise.

The *Difference* function monitors only the audio "garbage" being removed (the difference between the input and output signal). If some of the original signal is heard while the *Difference* function is active it means the setup (*Threshold* and *Reduction*) is too aggressive and you must lower the *de-noising* intensity. For badly damaged recordings, try to find a compromise between the de-noising amount and artifacts or distortions of the original signal.

In many cases excellent results can be achieved using just the standard noise prints: *White* and *Pink* properly modified by the *Freq* and *Gain* parameters. Sometimes after shelving modification of the *noise profile* a small readjustment of the *Threshold* parameter may be desirable. A good starting value for *Threshold* is to set the *noise profile* just above the background noise level (approx. 10 dB). A subsequent increase of the *Reduction* parameter should significantly reduce the background noise.



Frequency spectrum of different noise profiles (showing one possible User profile)

Minimizing Processor Artifacts

If noticeable artifacts in the form of so-called singing or robot-like sounds appear (this is a *time aliasing phenomenon*), decreasing the *Reduction* parameter and increasing the *Threshold* level (up to about 30 dB above the background noise) usually helps. Further reducing of artifacts can be achieved by careful setting of the remaining knobs: *Attack*, *Release*, and *Profile Shelving* (*Freq* and *Gain*).

Depending on the intensity of the *de-noising* process some artifacts in the form of "singing birds" or whistle-like tones can occur. They can be effectively minimized by proper setting of A*ttack* and R*elease* parameters. Normally attack time should be set up to the values below 0.1 second and the release time above 1 second. Longer than recommended attack times can blur the signal details. Shorter than recommended release times cause cutting of the ambience. This can be partly compensated by turning the shelving modification to negative values. Other way to keep more ambience are shorter release times, but at the cost of allowing more noise. In this case a compensation can be done by proper setting the *Freq* (usually 2 – 4 kHz) and *Gain* to positive values.

Forensic Applications

For forensic applications artifacts are usually not critical. The main goal there is to get as much valuable information as possible. For speech recordings the most important parameter is the intelligibility. So, noise reduction used there is often much more intensive compared to the restoration applications such as recorded music. In such cases, the *Attack* can generally be low (0 – 20 ms) to allow all signals above the noise print level to pass the *de-noising* part. *Release* can normally be kept quite large (seconds), but lower values gives more abrupt noise reduction. This can be advantageous at extremely noisy material. Try spectral modification with *Freq* setting *Gain* below 0 (negative values) to preserve harmonic contents of the processed audio material. An additional combination of two PEQs, one pre and one post processing, might help to extract important information. The pre-PEQ can emphasize particular spectral details before *de-noising* process and the post-PEQ flatten the spectrum to the original one. This effect can easily be followed with *Difference* function enabled.

Tweak and Practice

The fine adjustment of the parameters: *Attack, Release, Freq* and *Gain* is an iterative process requiring some experience and good feeling for the trade-off between original signal, remaining noise, and artifacts. For final decisions, listen carefully in connection with the *Difference* function to optimize noise reduction without compromising the signal.

DeNoiser Quick Reference

The **DeNoiser** Plug-In provides following controls:

- **On** – switches the Plug-In on or off (bypass function)
- **Difference** – allows to hear to the “garbage” being removed during *de-noising*
- **Threshold** – defines the reference level for the de-noising algorithm (moves the gain of the noise profile)
- **Reduction** – determines the amount of noise to be removed (even a setting of 0 already causes some noise reduction)
- **Attack** – sets up the response time of the de-noising algorithm (0 – 300 ms)
- **Release** – sets up the release time of the de-noising algorithm (0 – 2 s)
- **Freq** – cut-off frequency of the *noise profile* shelving modifier (600 Hz – 22 kHz)
- **Gain** – boost/cut gain of the *noise profile* shelving modifier (± 30 dB)
- **White/Pink/User** – selects noise profile used as a reference for de-noising process

and a display:

- **Noise Scope** – displays frequency spectrum of the input signal and the noise taken out
  (input – green, noise profile – white, output – red)

Applications Tips

The **De-Noiser** Plug-In is an easy-to-use audio cleaning tool based on efficient signal processing algorithms. In most cases, it is fairly simple to achieve good results. To maximize success, especially when working with heavily noise-polluted audio material, there are some practical rules:

- For best results, record a *noise profile* for every piece you de-noise. Choose a portion of the recording that does not contain any material you want to recover, only noise you intend to remove. If the audio piece to be processed contains more only-noise parts, try to record a few noise profiles and test them to determine the one that works best.
- If the part containing only the noise signal is very short (under 1 second), we recommend setting up a loop for repetitive playback before recording a *noise profile*.
- If you cannot find in your entire recording any noise-only piece, use pre-defined profiles and modify them with *Freq* and *Gain* parameters, or try to record a user *noise profile* from a low-level part of the signal (hopefully with pauses in the useful signal). Finally, look for the careful adjustment of the parameters *Threshold* and *Reduction* and finally *Attack* and *Release*.
- Very strongly changing noise level and noise characteristic may be problematic. In such cases try to cut the original piece in parts and treat them individually with different de-noising parameters. Later properly merge the de-noised pieces back together.
- To avoid artifacts occurring in the form of singing or robot-like sounds (*time aliasing*) don't exaggerate the *Threshold* and *Reduction* parameters. Begin with a moderate adjustment by setting the *noise profile* to just above the background noise level (approx. 10 dB) and gradually increasing the *Reduction* parameter. Try to recursively find the best relation between these two parameters. Finally use *Attack, Release, Freq*, and *Gain* parameters for fine tuning as previously described.
- If you are working on heavily disturbed material, find a good acoustical compromise between the level of remaining noise and artifacts introduced to the output signal. Be indulgent if you have hopelessly noisy material. Nobody can restore the original signal without having enough original information.
- It helps sometimes to apply the *de-noising* process two or more times consecutively with a moderate parameter setting rather than one pass with an extreme setup.
- For the best results use your own ears in connection with the *Difference* feature. Switch between the original input signal and the input/output difference, i.e., the portion of signal removed by the *de-noising* algorithm. This differential signal normally should not contain any parts of the original signal you want to preserve.

Latency when used in Pyramix Virtual Studio Mixer

The Algorithmix real-time restoration Plug-Ins (De-Scratcher and De-Noiser) are not subject to automatic delay compensation. These are highly complex processes requiring several tens of milliseconds of audio material buffering to perform their tasks. The exact latency of the De-Noiser Plug-In is 3072 samples (3 x 1024) corresponding to approx. 70 ms at 44.1 kHz while the De-Scratcher latency is even higher at 7168 samples (7 x 1024) corresponding to 162 ms at 44.1 kHz.
Due to the very real-time nature of these Plug-Ins it is not possible to time align their output with respect to unprocessed channels without severely delaying all the unprocessed channels. Rather than automatically delaying all unprocessed channels in a given mixer configuration (which we felt could be a more significant inconvenience) we recommend nudging the audio material in the tracks to be processed to the left. I.e. later by the exact Plug-In latency value. It should also be mentioned that while some users insert these Plug-Ins in the mixer's strips, most often they are inserted in the master output. In the latter case there is usually no need to compensate for any inter-channel delays.

Important Note:

The **De-Noiser** Plug-In is a very effective tool. Unlike many other systems the **Algorithmix®** **DeNoiser** not only removes unwanted noise, but keeps your original sound as natural as possible. You will be amazed at how dramatic the audio quality of noisy recordings can be improved. But please do not expect miracles if you process material containing so much noise that the original signal is no longer distinguishable. Information theory says that once the information is sunk in noise (bad signal-to-noise ratio) and there is not enough information about the properties of the original signal, or even worse, the original signal is non-linearly distorted, the de-noising process can deliver only limited-quality results.