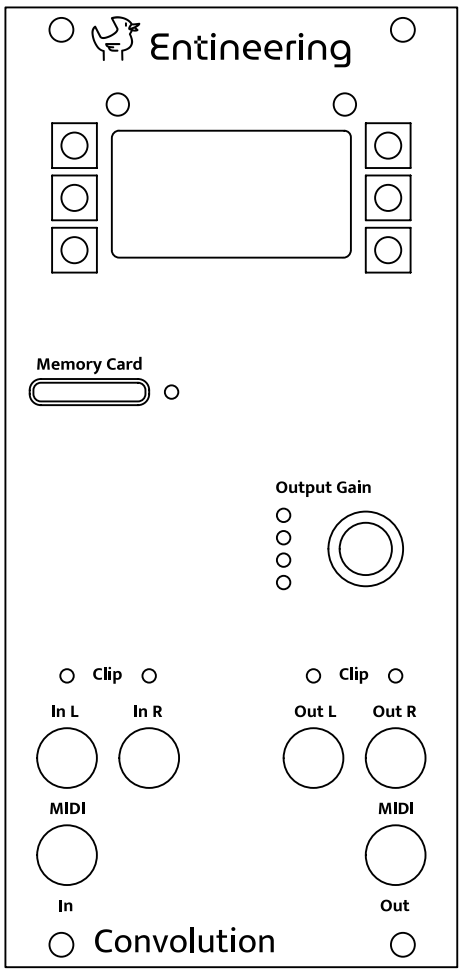
Entineering Convolution

User Manual

v1.0



Introduction

A convolution is a mathematical operation that combines two signals to produce a new one. It's often used to apply effects, like reverb, by taking the sound of a room or environment (called an impulse response) and blending it with an audio signal. This makes the audio sound as if it's being played in that specific space.

Entineering Convolution is a module for Eurorack synthesizers that does digital convolution of an analog audio signal with an impulse response that is loaded from a memory card or from internal memory.

Features

- Up to 4 seconds of impulse response at 48 kHz
- Ultra-low latency down to 1 millisecond
- 24 bit A/D and D/A conversion
- 32 bit floating point processing
- Reads impulse response files from memory card
- Integrated example impulse response files
- Mono-to-stereo and stereo-to-stereo (parallel stereo and four-way) processing
- 1.3 inch OLED display
- Firmware updates via memory card
- 99 user presets, selectable via MIDI CC commands

Typical Applications

Reverb

The most common use of convolution in audio production is the use as high-quality reverb. Impulse responses can be recorded from pretty much any physical room, from famous recording studios to churches or parking garages. Impulse responses also exist from expensive outboard gear like plate reverbs or dedicated rack units.

Speaker Cabinet Simulation

A speaker cabinet is in essence just a very small room. Impulse responses can also be recorded with different microphone positions in front of the speaker. This applica-

tion is interesting for processing amplified guitar signals without the hassle of using a real speaker cabinet.

Experimental Applications

The impulse response that is used for convolution is just an audio file. There is no requirement that it is even an actual impulse response. Any sound works! Although it works best if either the input signal or the impulse response is of percussive nature, there is really no limit to the imagination.

Limitations

Apart from the limitation imposed by the finite processing power of the module (outlined above under "Features"), there is an inherent limitation to what convolution can do: It can only reproduce **Linear, time-invariant (LTI) systems**.

- **Linear** means, for example, that an input signal that is twice as loud always produces an output signal that is twice as loud. Thus, convolution can not reproduce any form of distortion. A guitar amplifier for example can not be represented by an impulse response.
- **Time-invariant** means, for example, that an input signal that occurs a second later causes the output signal to occur a second later, with no other side-effects. This excludes, for example, a tape echo with varying speed.

In recent years, equipment has become commercially available that can indeed record and reproduce the response of distortion pedals and amplifiers. But this is not done just by convolution. Other forms of signal processing are required to achieve this.

Connecting the Module

Connecting Power

Your Eurorack synthesizer module comes equipped with a 10-pin keyed connector for power supply.

To connect the module:

1. Power Off Your System: Before connecting the module, ensure that your Eurorack case and power supply are turned off.
2. Locate the Power Connection on Your Case: Identify the power headers on your Eurorack case. These headers will have a 16-pin connector.
3. Use the supplied ribbon cable to connect the module to your Eurorack power supply. The red mark on the ribbon cable identifies the -12V supply line. On the module, the red mark points towards the bottom on the module.
4. Secure the Module: Once connected, mount your module into the case using the appropriate screws, ensuring it is securely in place.

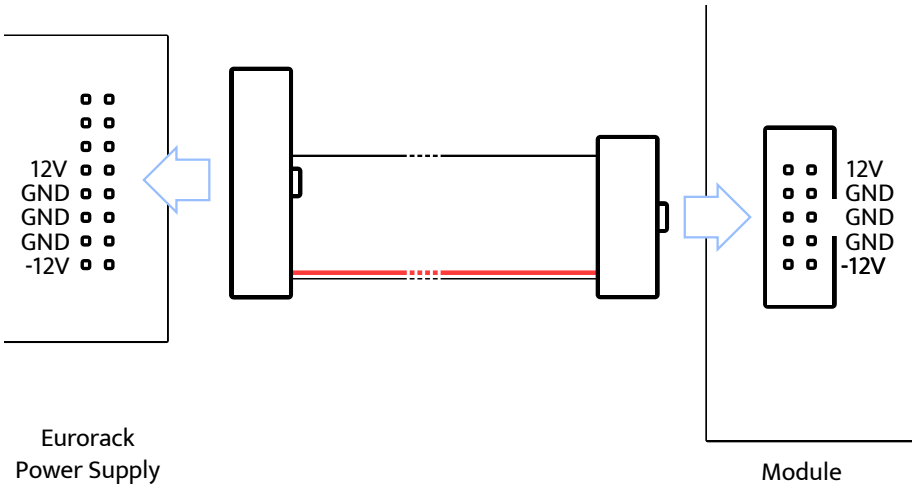


Figure 1: Connecting Power

Only use proper Eurorack power supplies with voltages of -12V and +12V.

Connecting MIDI

To connect a device with a 5-pin DIN connector to the module, you need a MIDI DIN-to-TRS adapter. The TRS jacks on the module use the A pinout that is now included in the official MIDI standard.

To be able to send MIDI data to the module, connect the MIDI Out or MIDI Thru port of your MIDI keyboard, audio interface or similar, to the MIDI In jack of the module.

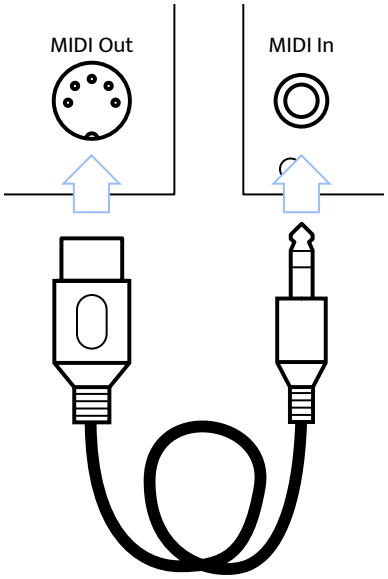


Figure 2: Connecting MIDI

Using the Module

General Interaction

Interaction with the module happens mainly via the OLED screen and the six buttons around it. Functions on the screen can be activated with the button next to it.

Inserting a Memory Card

Several example impulse response files are included on the internal memory of the module. To use your own impulse response files, copy them onto a Micro* card formatted as FAT32. Insert the card into the slot labelled “Memory Card” before turning on the module.

The memory card slot is only scanned when the module starts up. Inserting or removing the memory card while the module is turned on is not supported at this time.

Selecting an Impulse Response

To select a sound file to use as an impulse response, follow these steps:

1. While on the main screen, press the lower right button, which says “Select IR” next to it.
2. Choose the source of the file. Either the internal storage or the memory card.
3. Navigate to the file you want to use as impulse respose.
4. Select a processing profile for the file.

Figure 3: Impulse response selection.

Profiles

Processing profiles let you choose between different trade-ofs like shorter latency vs. longer impulse response, or different channel configurations. The available profiles depend on the selected file, like its sampling rate and number of channels.

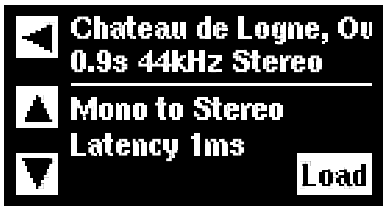


Figure 4: Profile selection.

Mono to Stereo Here, a monaural input signal (fed into the module through the left input channel) is convoluted with the left channel of the impules response to produce the right output channel. The same input signal is also convoluted with the right channel of the impulse response to produce the right output signal.

This is by far the most common and most useful type of multi-channel convolution. In term of room acoustics, this transatles to an omnidirectional sound source, reverberated by the room, and experienced by a human listener, or recorded by a stereo microphone setup.

Parallel Stereo With this setting, the left input channel is convoluted with the left channel of the impulse response, and the result is fed to the left output channel. Accordingly, the right input convoluted with the right impulse response channel goes to the right output channel.

If this setup has a physical representation depends on the impulse response file. But most of the time, stereo impulse response files are meant for Mono to Stereo setups.

Four Channel "True Stereo" Four-channel impulse response files are required to use this mode.

- The left input channel is convoluted with channel 1 of the impulse response to produce the left output channel.
- The left input channel is convoluted with channel 2 of the IR to produce the right output signal.
- The right input channel is convoluted with channel 3 of the IR and mixed into the left output channel.
- The right input channel is convoluted with channel 4 of the IR and mixed into the right output channel.

A physical representation of this would be a stereo speaker system and a stereo listener in a room. From two speakers to two ears or microphones there is a total of four paths.

Many true-stereo impulse responses you find on the web are distributed as two stereo files. Use your favorite audio editing software to combine them into a single four-channel audio file.
Pay attention to the channel order. Entineering Convolution uses the channel order L->L, L->R, R->L, R->R.

Many four-channel impulse response files you find on the web are encoded in the so-called B-format. This is a special surround-sound format which uses W, X, Y and Z channels instead of left and right channels. The Convolution module will load such files (because there is no way to distinguish the file format), but the result will not be anything meaningful. Pay attention if the file name or accompanying documentation mentions the B-format anywhere.

Adjusting Output Gain

Convolution can significantly increase the overall signal amplitude, especially if the impulse response used has high energy. Adjusting the output level prevents clipping and maintains proper headroom.

To adjust the output gain, turn the encoder knob on the front panel. Turning clockwise increases the gain, while turning counter-clockwise decreases it. Output gain can be adjusted between -30 and +10 dB.

If you see the “Clip” LEDs next to the output jacks light up, then the output gain is too high and you have to decrease it. If, on the other hand, audio output is too low, increase the output gain until the clip LEDs light up occasionally, then go back a bit until they stay off.

Saving and Loading Programs

Parameters can be saved as programs and later restored. 99 program slots are available. The following parameters are stored with each program:

- The path to the impulse response file (either on internal memory or on a memory card)
- The selected profile
- Output gain

The impulse response data itself is not stored, only the path to the file. This means that if the memory card is removed, swapped with another one or the file on the card is moved, removed or renamed, the program cannot be loaded.

Saving a Program

To save a program, press the upper right button while the “Save” label lights up on the screen. Use the buttons labelled with arrows to select a slot number, or keep the currently selected slot. Then press the “Save” button again to complete the procedure.

Restoring a Program

There are two ways to restore a program:

- Via the buttons on the module
- Via MIDI Program Change (PC) messages

Use the buttons next to up and down arrows while on the main screen to select the next and previous program respectively. The current program number and the associated file name are displayed on the screen.

MIDI Program Change messages can be sent from a controller keyboard, sequencer, DAW or similar device or software. If a MIDI channel is configured, only PC messages on that channel are taken into account. Other messages are ignored. The MIDI channel of the module can be configured in the settings menu.

Loading an impulse response file takes a few seconds.

Main Menu

The main menu can be accessed by pressing the upper left button while the “Menu” label is visible.

Figure 5: Main menu.

MIDI Channel

Use this menu item to configure the MIDI channel the module listens on, or "All" to listen on all channels. The module listens for Program Change (PC) MIDI messages on the configured channel(s).

Firmware Version

Use this to see the currently installed firmware version. Check https://entineering.eu to see if a newer firmware version is available. See the next section on how to install the new firmware.

Firmware Update

To update the firmware of the module:

- Go to https://entineering.eu to download a new firmware file.
- Copy the file onto a FAT32-formatted memory card.
- Insert the memory card into the module.
- Turn on the power supply for the module.
- Press the button labelled "Menu", then navigate to "Firmware Update".
- Select the file on the memory card.

Ensure a stable power supply during the update! If power gets interrupted while the firmware file is written to the module, the module will no longer be operational. Additional tools and knowledge are required to recover from this state.

In case of problems after a firmware update, you can try a factory reset using the method described in the next section.

Factory Reset

This menu option deletes all saved programs and resets all settings like MIDI channel to their default value.

A factory reset can also be done the following way: - Power down the module. - Press and hold the left center and left bottom soft buttons. - Turn on power to the module. - Release the buttons. - Wait until the blinking “Factory reset” disappears from the screen and the module reboots into the main screen.

Appendix A: Convolution Profiles

A convolution profile is a set of parameters the module uses internally to handle its calculations. Depending on impulse response sampling rate and channel count, different convolution profiles are available. In some cases, multiple profiles are available for the same mode. In these cases, there are tradeoffs between latency and maximum IR length.

Table 1: List of convolution profiles

Mode	Sampling Rate	Max IR Length	Latency
Mono to Stereo	44100 Hz	4.1 s	1 ms
Parallel Stereo	44100 Hz	3.6 s	2 ms
Mono to Stereo	48000 Hz	3.3 s	2 ms
Mono to Stereo	48000 Hz	4.4 s	5 ms
True Stereo	44100 Hz	0.8 s	5 ms
Mono	44100 Hz	6.4 s	1 ms
Mono	48000 Hz	5.9 s	1 ms

Check https://entineering.eu for firmware updates which might improve and extend this list as the firmware is optimized.

Appendix B: Attributions

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Example Impulse Responses

The impulse response files on the module's internal memory are included as examples free of charge. They can also be downloaded from https://entineering.eu, again free of charge.

All impulses in this archive were created with Impulse Modeler
that can be downloaded at http://www.voxengo.com/imodeler/

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