NONLINEARLABS

C15

The Synth Engine →

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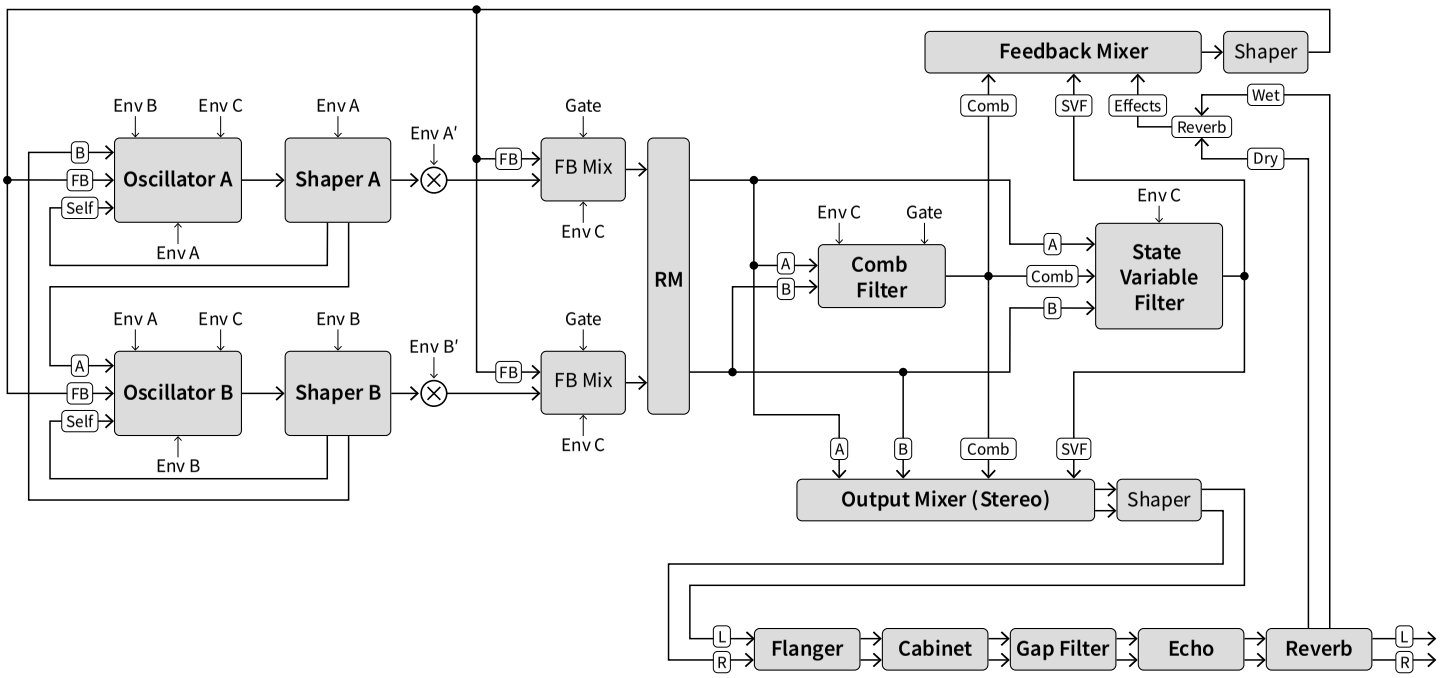
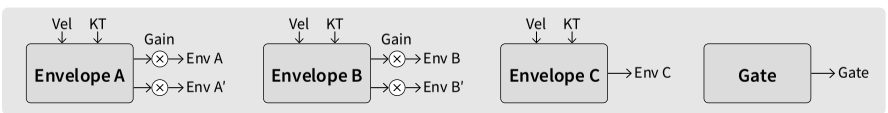
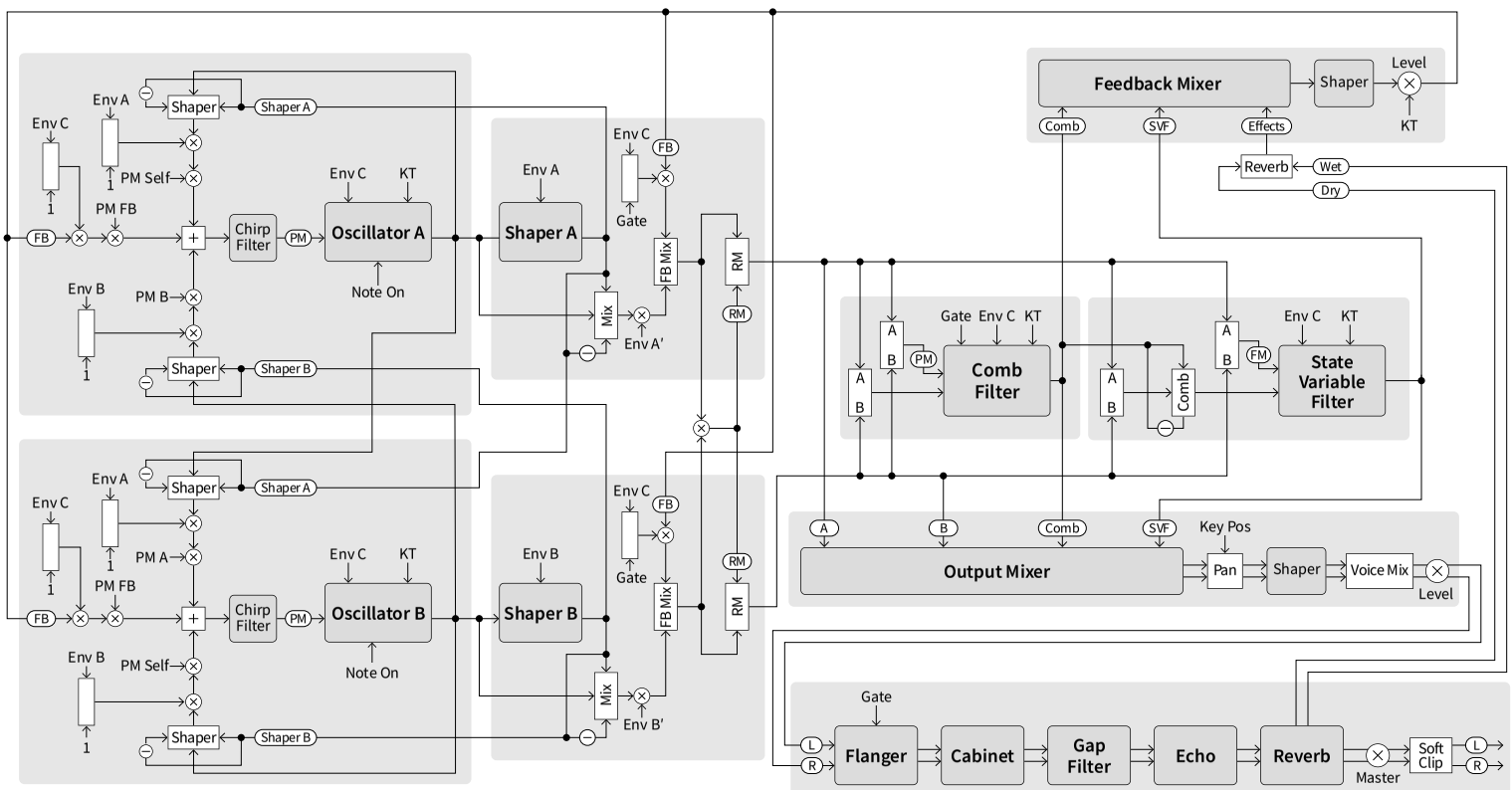
C15 Synth Engine – Overview & Detailed



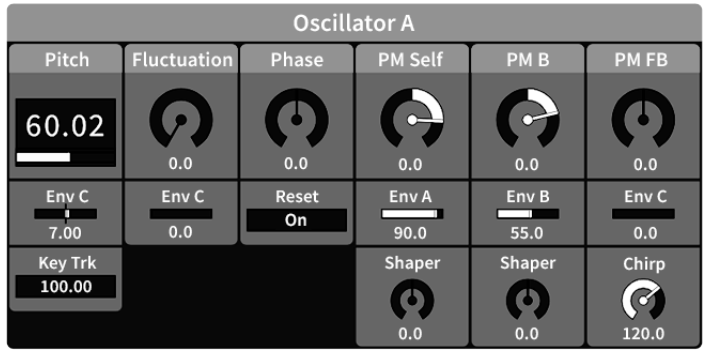




Design Concepts

The design goal for Phase 22 was to take advantage of digital synthesis algorithms in order to build an expressively playable instrument that has a strong individual character. At the same time the set of parameters should be small enough to be easily accessible.
The core structure is a phase modulation synth that is based on two sine oscillators and two sine shapers only. Their signals can be passed through a comb filter, a state-variable filter, and a chain of five effects.
The Comb Filter is a tool for complex spectral shaping and also works as a resonator. The State Variable Filter can be applied flexibly for subtractive filtering.
The signal routing is determined by the settings of the Output Mixer and the Feed- back Mixer. The feedback bus can be used to create feedback loops between different function blocks.
The filters and effects have an important influence on the feedback behavior: their amplitude and phase responses determine the frequencies where the feedback can result in self oscillation.

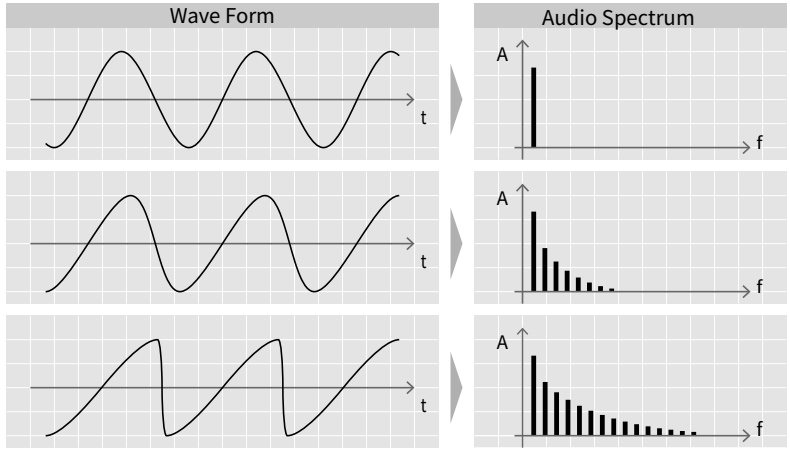
The Components in Detail



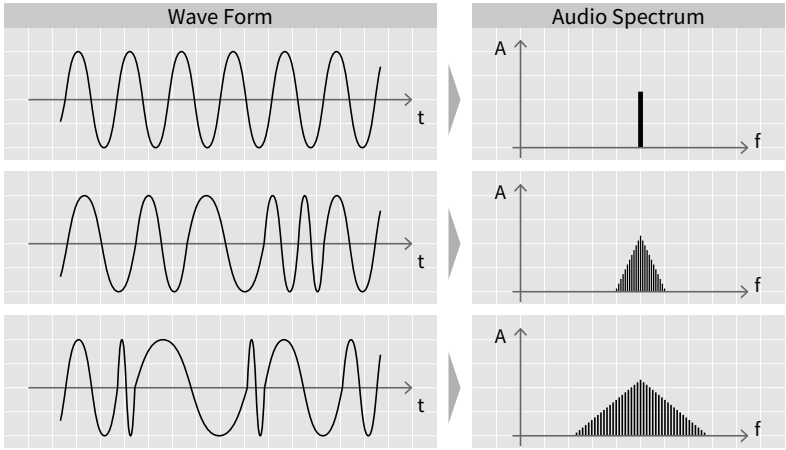
The two sine wave oscillators are the only signal sources. With a random frequency fluctuation they can also produce tunable noise. They are equipped with three phase modulation inputs for:

- self modulation
- modulation from the other oscillator
- modulation from the feedback (FB) signal

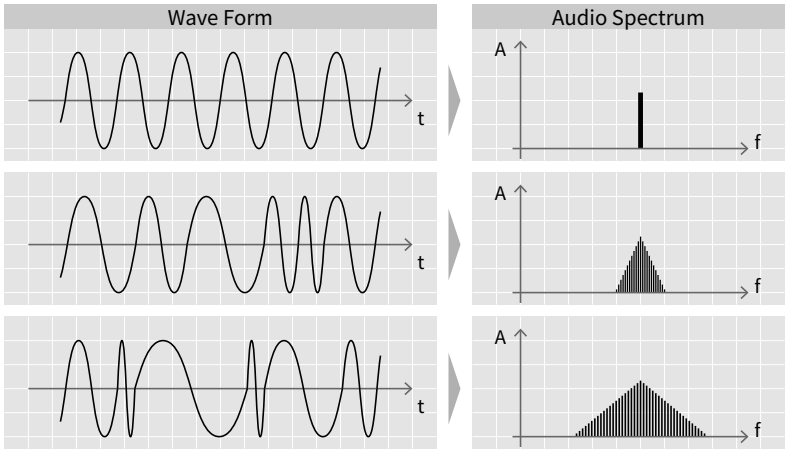
The oscillator signal for different amounts of self modulation:

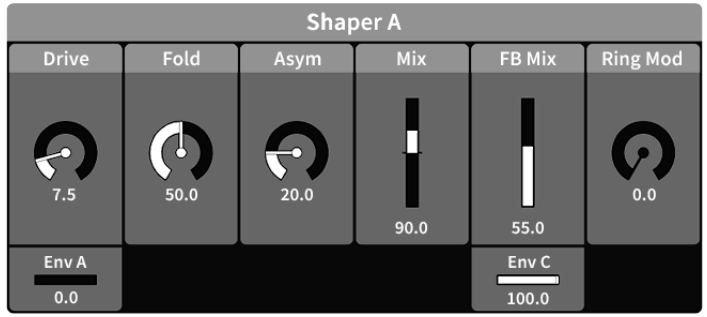


Oscillator signal without self modulation and different amounts of fluctuation:



Oscillator signal with self modulation and different amounts of fluctuation:

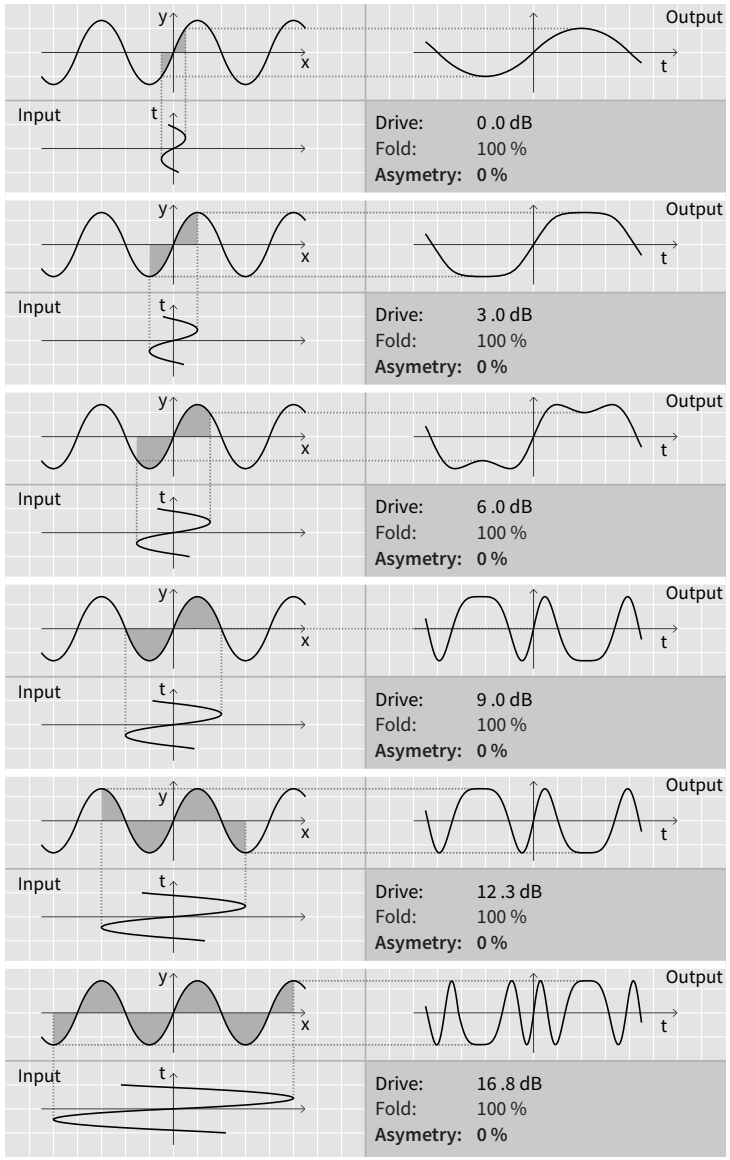




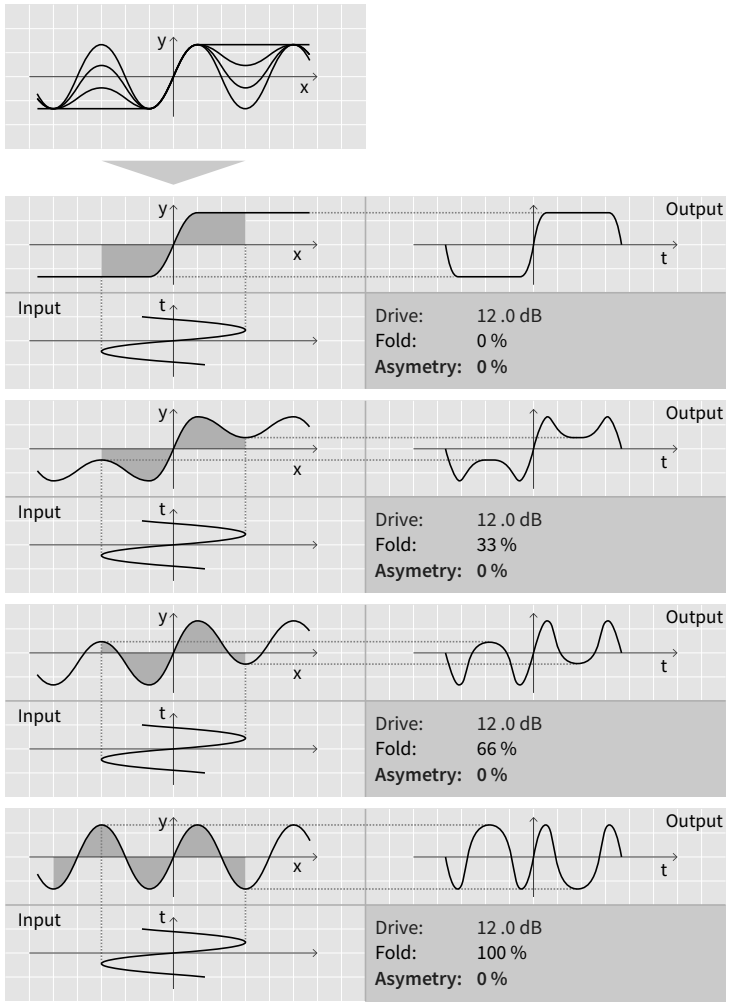
The signal of each oscillator is processed by a wave shaper. The shaping curve is a sine function with adjustable foldback and asymmetry. The mix amounts of the shaper signal can be adjusted individually for each phase modulation branch and for the output.
The Shaper block also contains mixing points for the feedback signal and the result of a ring modulation between the output signals of the branches A and B.

The diagrams on the following pages show the output signal depending on Drive, Fold and Asymmetry.

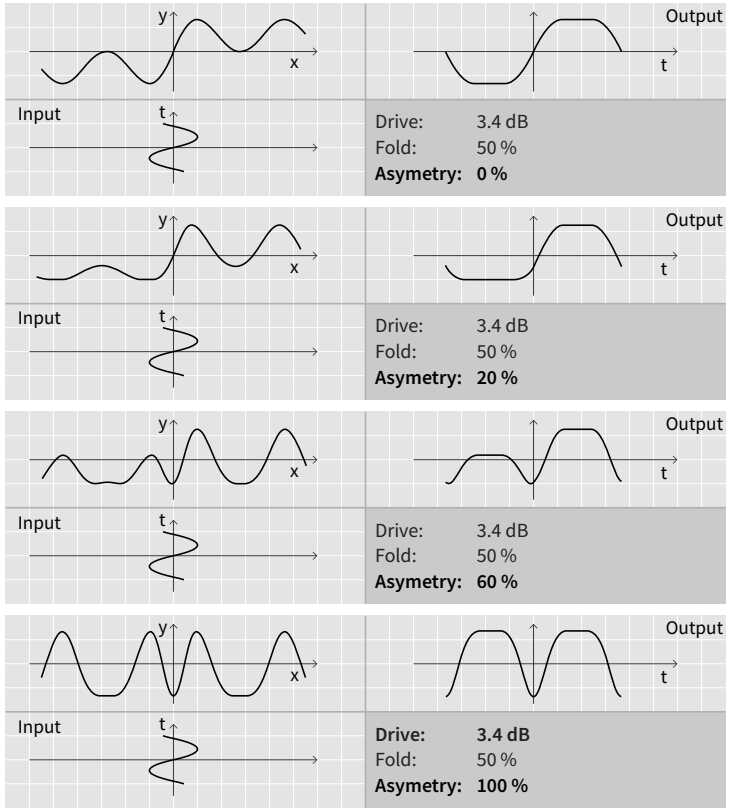
*The influence of the **Drive** parameter of the Shaper:*

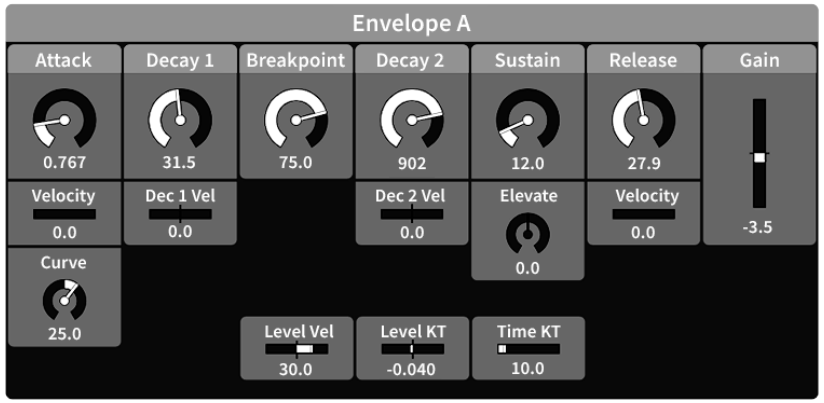


*The influence of the **Fold** parameter of the Shaper:*



The influence of the Asymetry parameter of the Shaper:

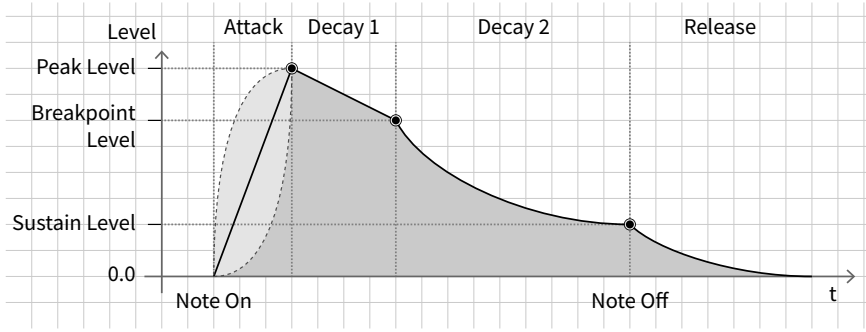




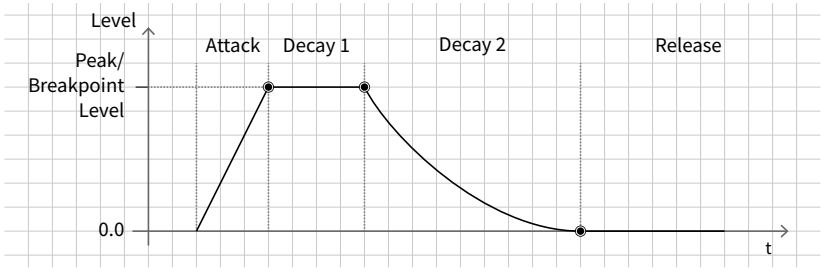
These two ADBDSR envelopes are the control sources for:

- the output amplitude of the Oscillator-Shaper branch
- the Oscillators' phase modulation depths
- the Drive (input gain) of the referring Shaper

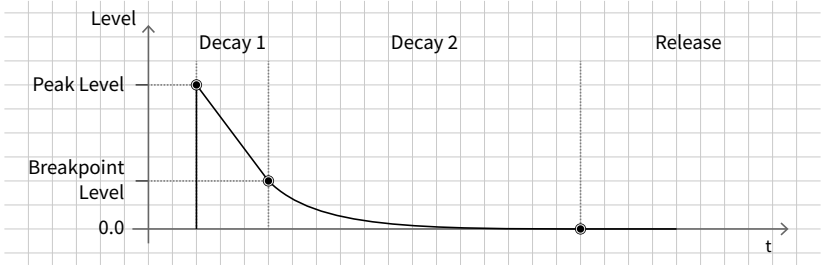
This diagram shows the segments of the envelope:



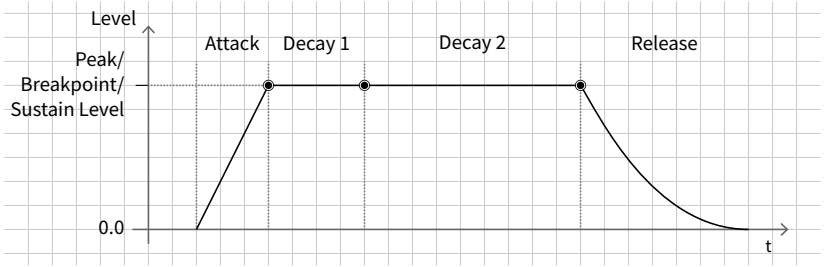
Envelope with Decay 1 as Hold Time:



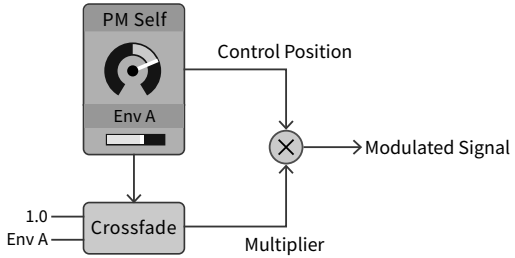
Percussive Envelope:



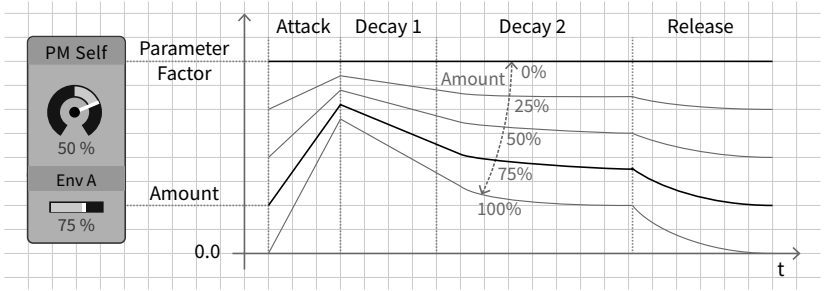
Organ-style Envelope:



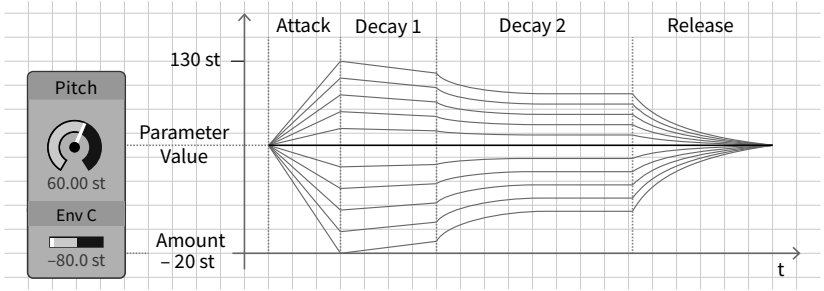
Envelope Amount:

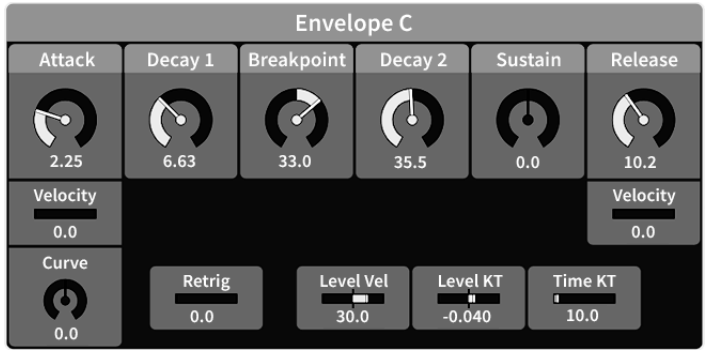


Envelope with multiplying effect:



Envelope with additive effect:

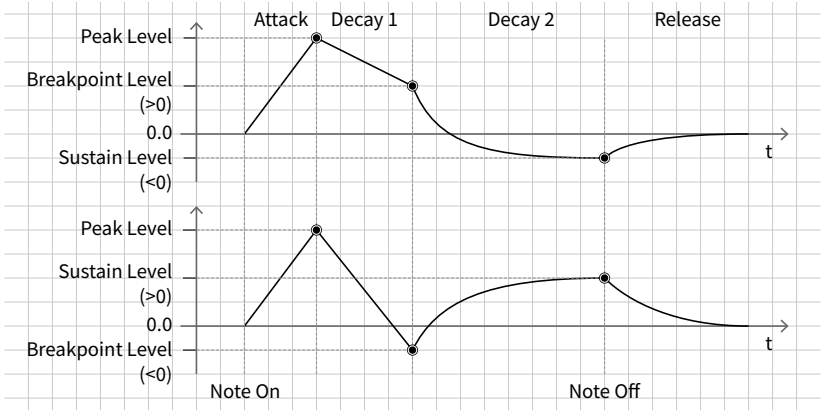




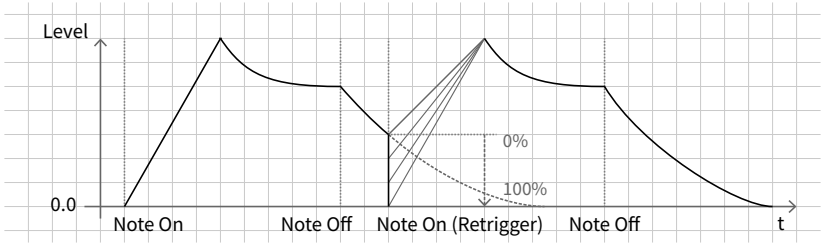
The third ADBDSR envelope has bipolar Breakpoint and Sustain levels. It can modulate:

- the pitches and fluctuations of Oscillator A and B
- the feedback signal
- parameters of the Comb Filter and the State Variable Filter

Envelope C shapes with different polarities of the Breakpoint and Sustain levels:



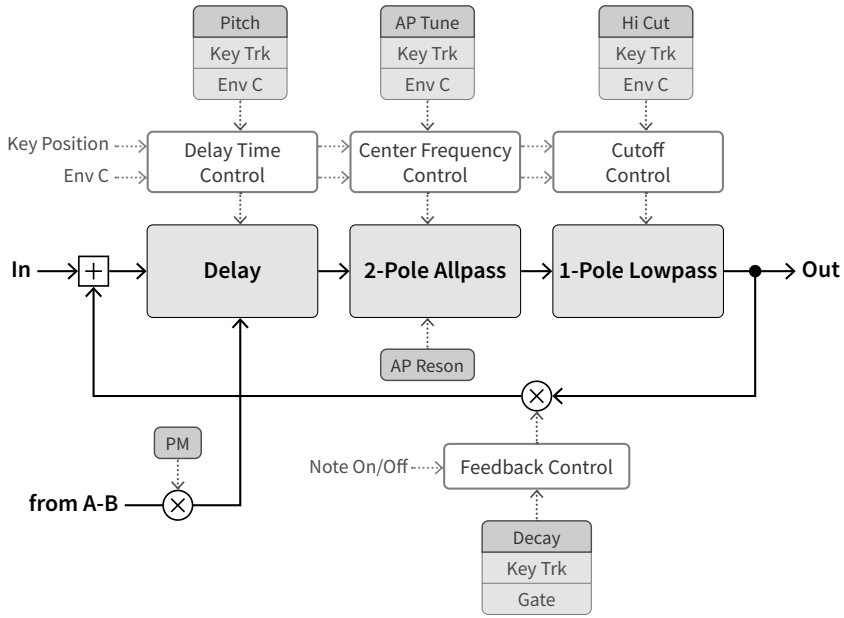
Envelope C - "Retrigger Hardness" Parameter (in monophonic mode):



The Comb Filter contains:

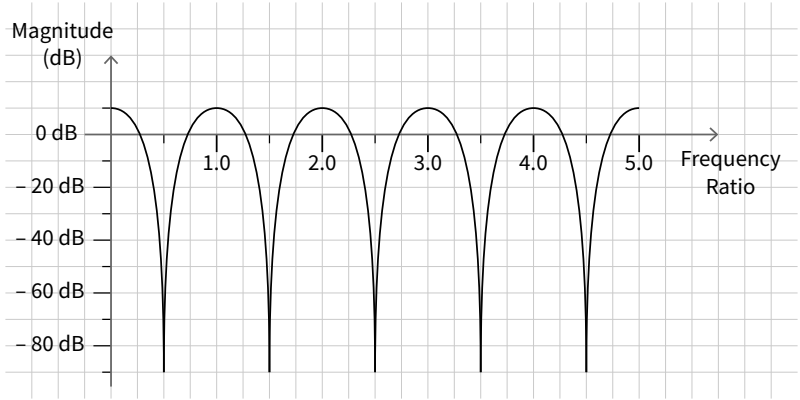
- a precisely tunable delay (Pitch)
- a control for the Decay time of the impulse response
- a second-order Allpass (AP) filter
- a lowpass (Hi Cut) in the feedback loop
- a delay modulation by the Oscillator signals, similar to phase modulation (PM)

Block diagram of the Comb Filter:

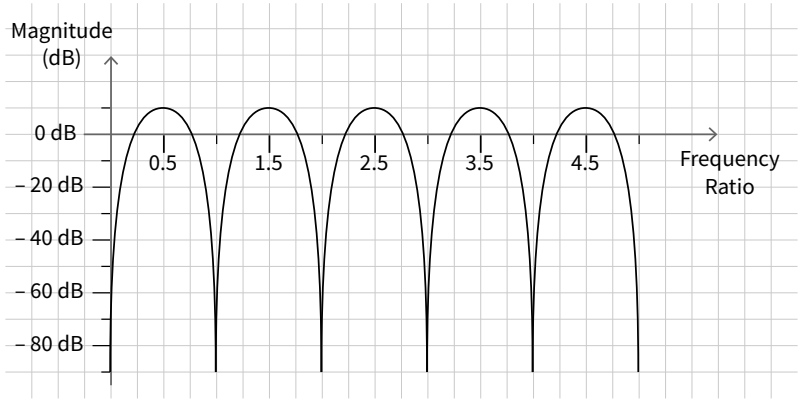


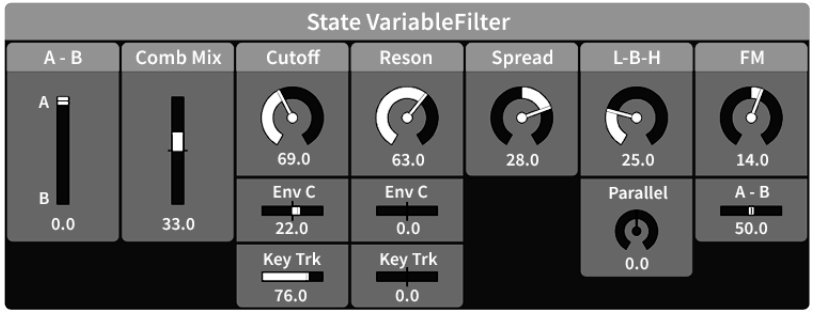
Basic frequency responses of the Comb Filter. Setting the Decay to negative values has similar results like the inverted mix.

Non-inverted Mix:



Inverted Mix:

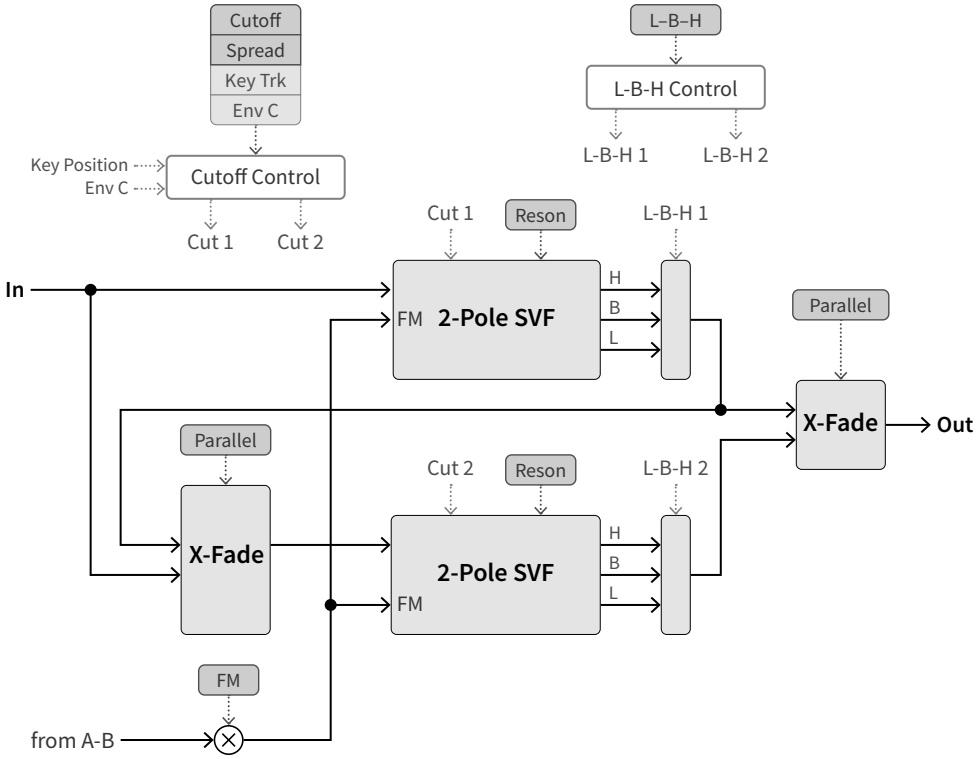




The State Variable Filter has a variable 4-pole structure with:

- two internal 2-pole filters with splittable cutoff frequencies (Spread)
- crossfade between serial and parallel modes (Parallel)
- crossfade between lowpass, bandpass, and highpass mode (L-B-H)
- cutoff frequency modulation (FM) by the Oscillator signals

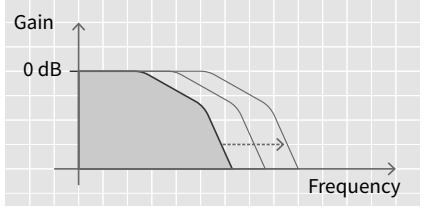
Here you see a block diagram of the State Variable Filter:



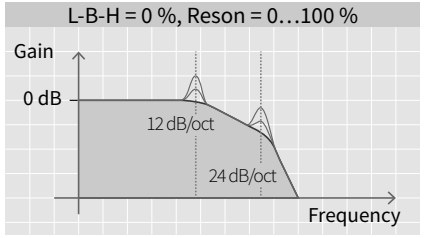
Frequency responses of the State Variable Filter with Parallel set to 0 %:

Parallel = 0 %, Spread > 0 st

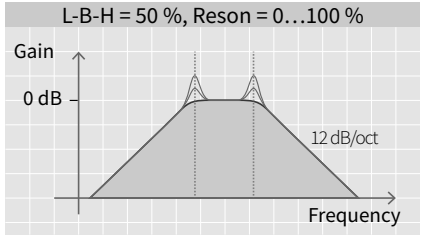
L-B-H = 0 %, Reson = 0 %, Cutoff = var.



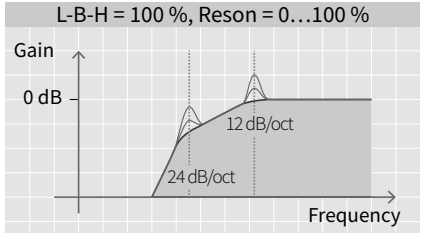
L-B-H = 0 %, Reson = 0…100 %



L-B-H = 50 %, Reson = 0…100 %

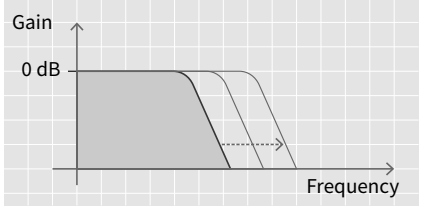


L-B-H = 100 %, Reson = 0…100 %



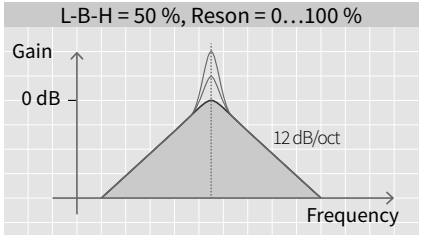
Parallel = 0 %, Spread = 0 st

L-B-H = 0 %, Reson = 0 %, Cutoff = var.

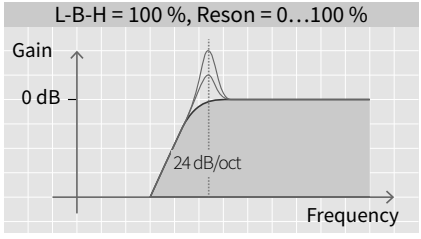


L-B-H = 0 %, Reson = 0…100 %

L-B-H = 50 %, Reson = 0…100 %



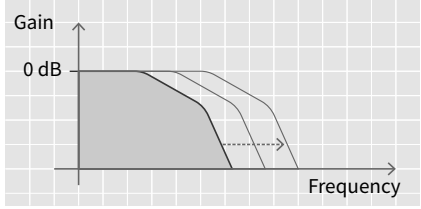
L-B-H = 100 %, Reson = 0…100 %



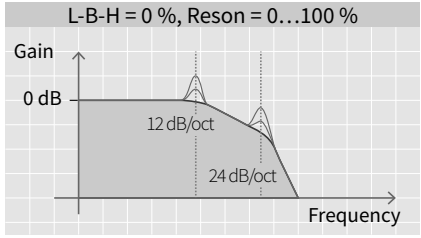
Frequency responses of the State Variable Filter with Parallel set to 100 %:

Parallel = 0 %, Spread > 0 st

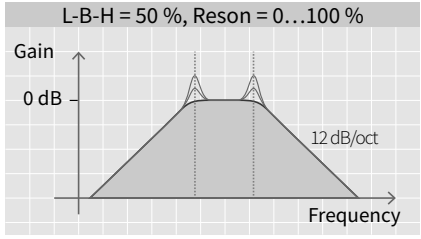
L-B-H = 0 %, Reson = 0 %, Cutoff = var.



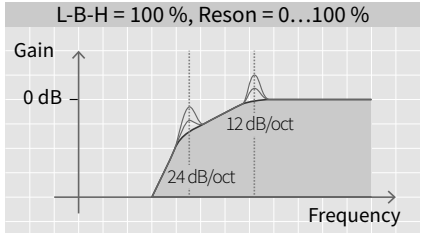
L-B-H = 0 %, Reson = 0…100 %



L-B-H = 50 %, Reson = 0…100 %

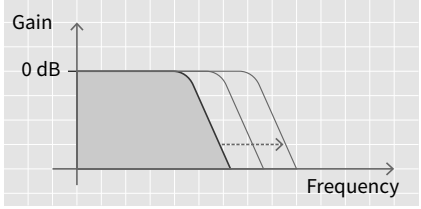


L-B-H = 100 %, Reson = 0…100 %



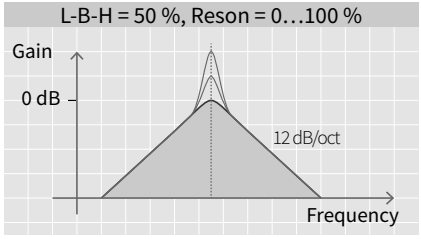
Parallel = 0 %, Spread = 0 st

L-B-H = 0 %, Reson = 0 %, Cutoff = var.

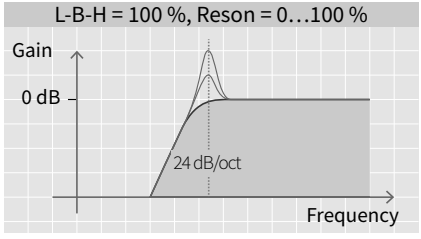


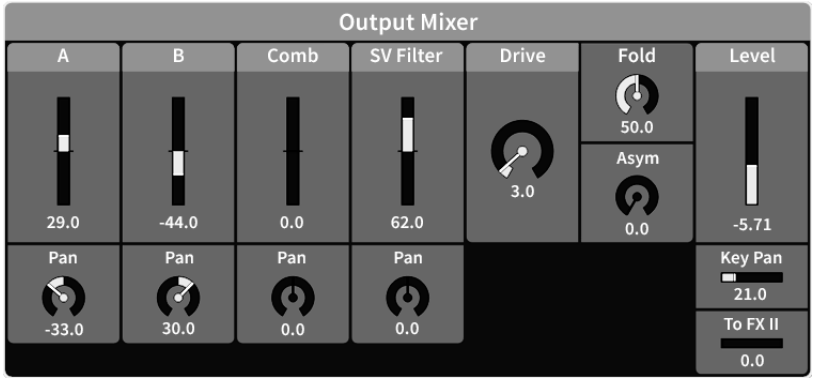
L-B-H = 0 %, Reson = 0…100 %

L-B-H = 50 %, Reson = 0…100 %



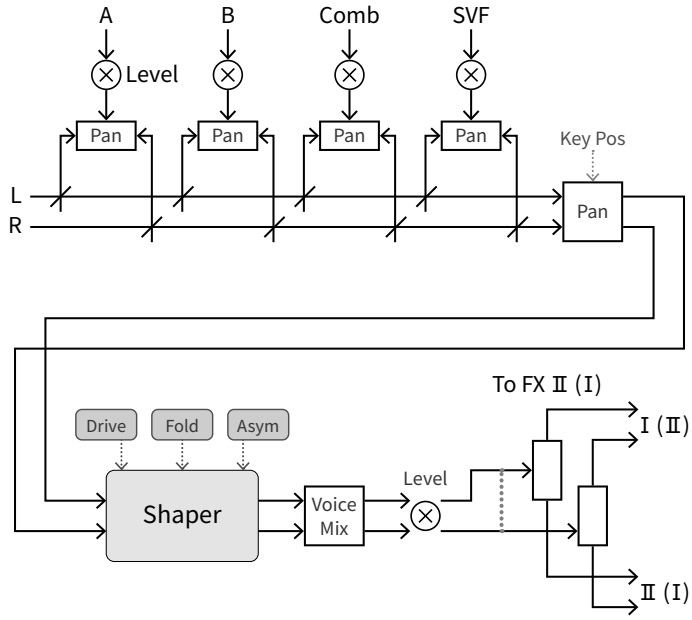
L-B-H = 100 %, Reson = 0…100 %

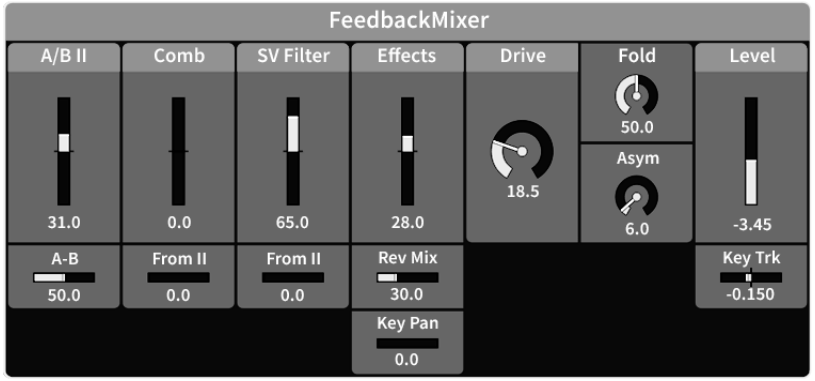




The Output Mixer creates a stereo sum of the signals from Oscillator/Shaper A and B, the Comb Filter and the State Variable Filter. It includes a sine shaper for the sum signal of each voice.

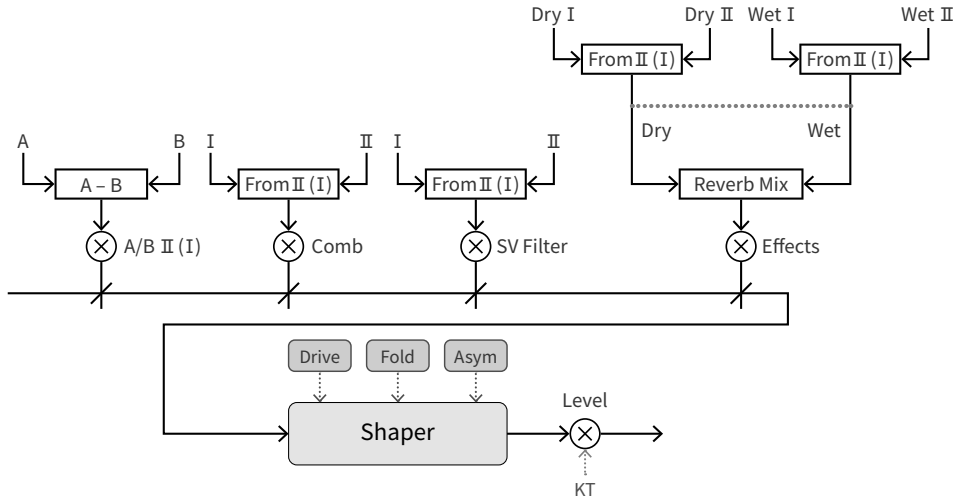
Signal flow of the Output Mixer:

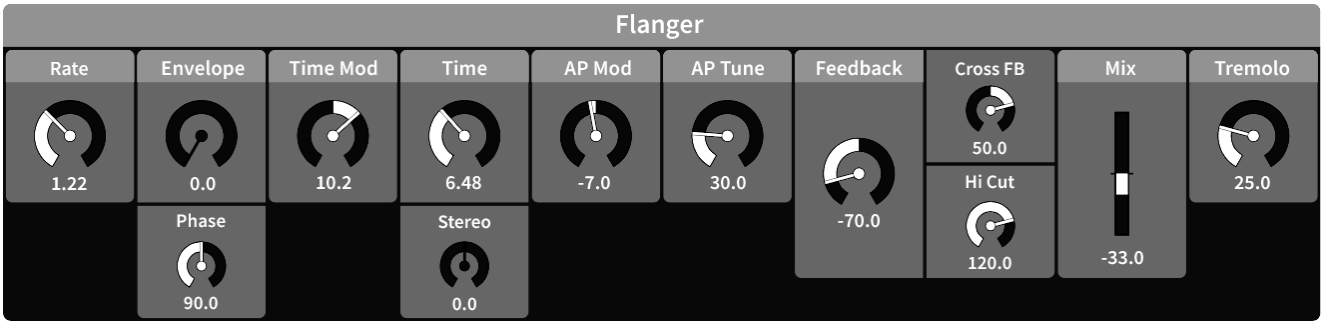




This mixer combines the following signals for the feedback bus: the outputs of the Comb Filter and the State Variable Filter and the output of the Effects chain, with a separately adjustable amount of Reverb. It includes a sine shaper for the sum signal.
The feedback bus signal (FB) can be used for the phase modulation of the Oscillators and it can be injected into the signal path behind the Shapers for direct audio feedback.
In Layer Sounds the Feedback Mixer can route signals between the layered voices. It provides an additional input for the Oscillator signals (A/B) of the other Part, and the Comb, SV Filter and Effects channels can also receive signals of the other Part.

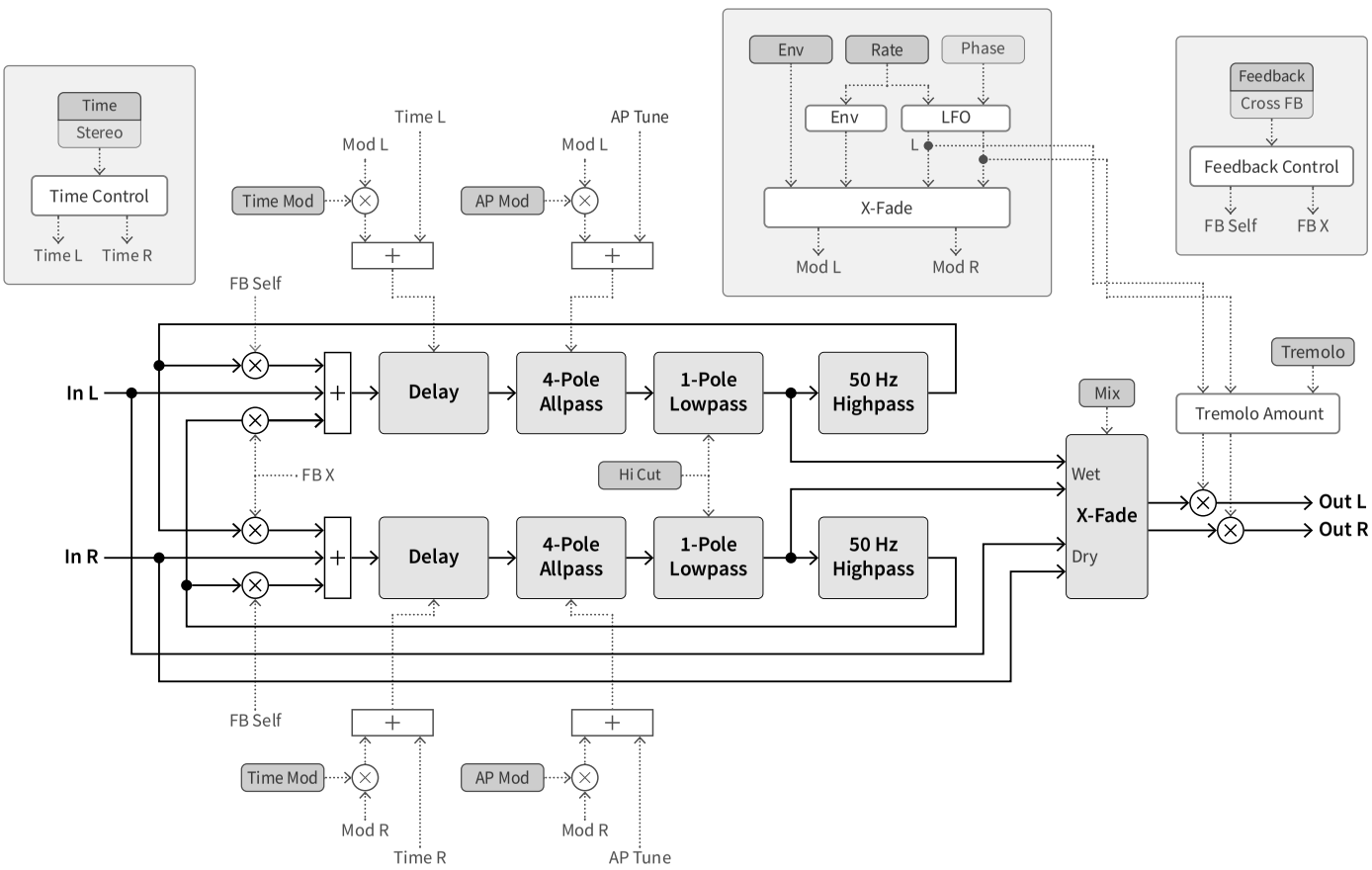
Signal flow of the Feedback Mixer. The elements with "II (I)" are only available in Layer mode:

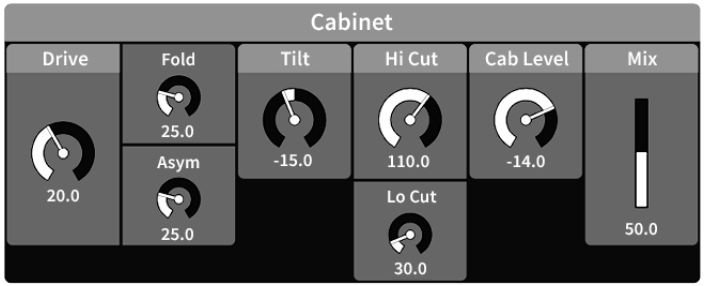




An LFO-modulated stereo delay plus a 4-pole allpass filter creating a wide range of chorus, flanger and phaser effects. The LFO can also modulate the amplitudes of the output signals for a tremolo effect.

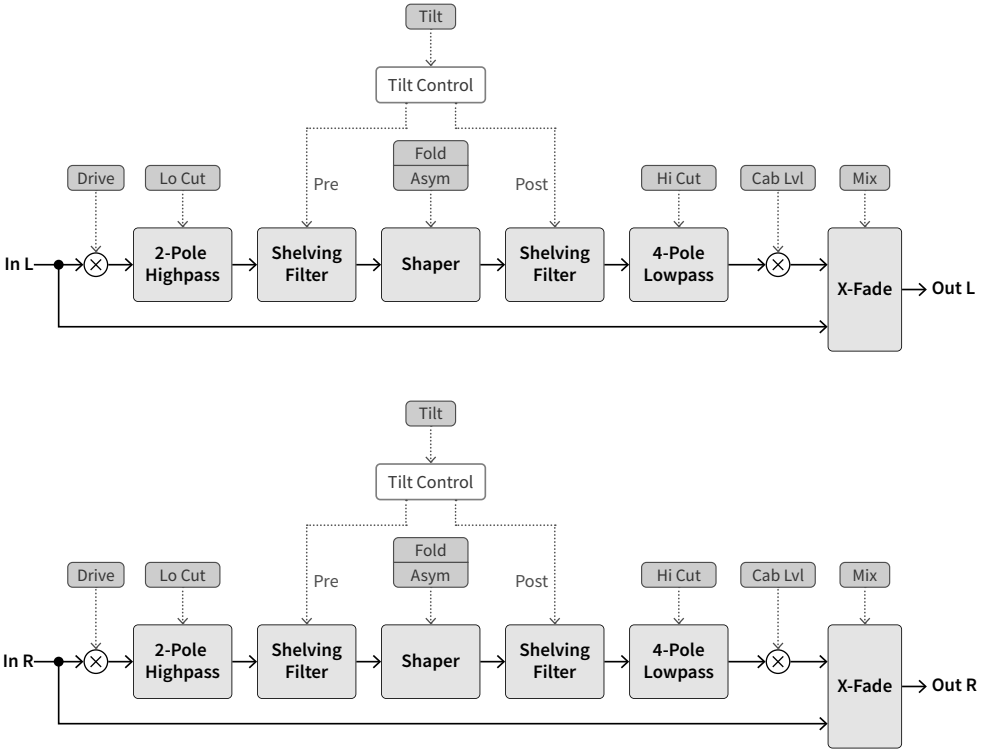
Signal flow of the Flanger:

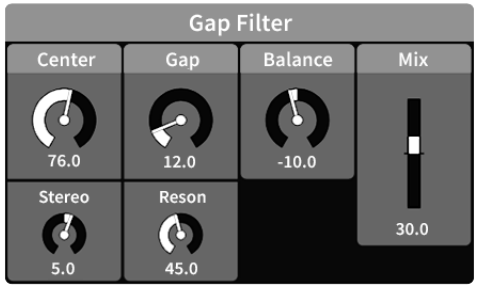




A stereo distortion unit (sine shaper) with pre and post filtering that can sound similar to a guitar amp driving a speaker.

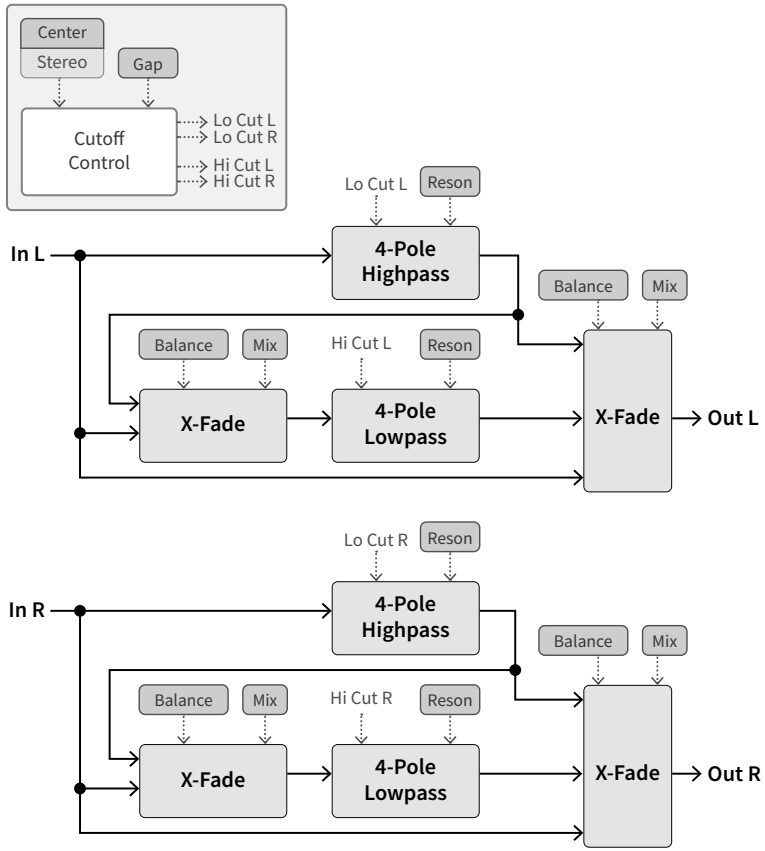
Signal flow of the Cabinet:





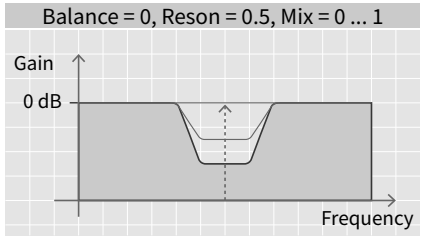
A 4-pole lowpass and a 4-pole highpass in a parallel or serial structure, creating a flexible band-rejection or band-pass filter. The offset between the center frequencies of the left and the right channel can be controlled.

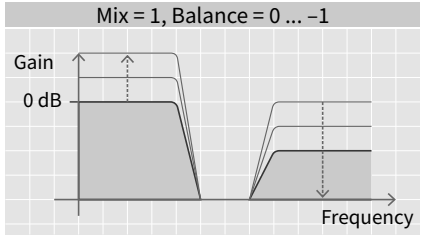
Signal flow of the Gap Filter:

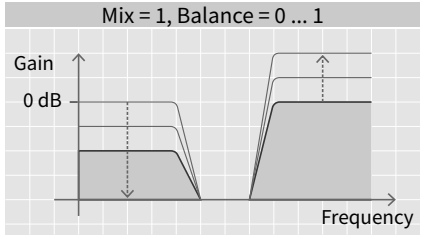


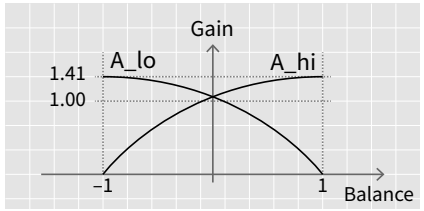
Some typical frequency responses:

Parallel/Band Reject (Mix > 0)

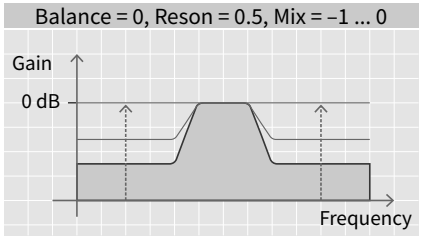


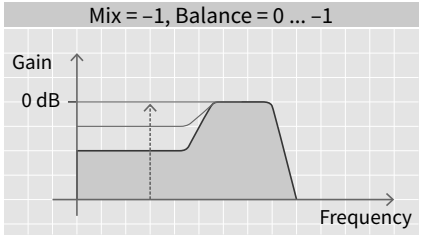


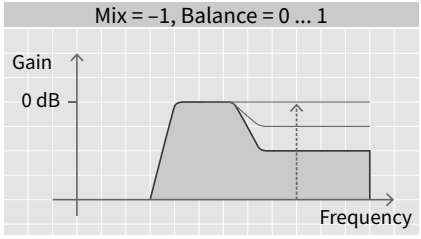


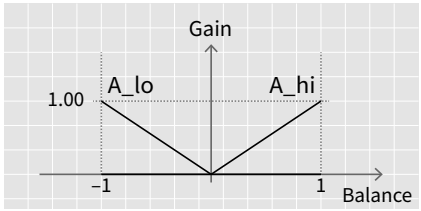


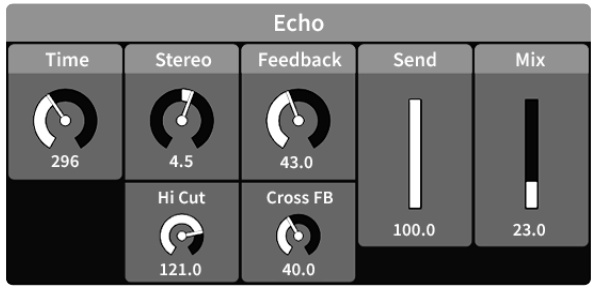
Serial/Band Pass (Mix < 0)





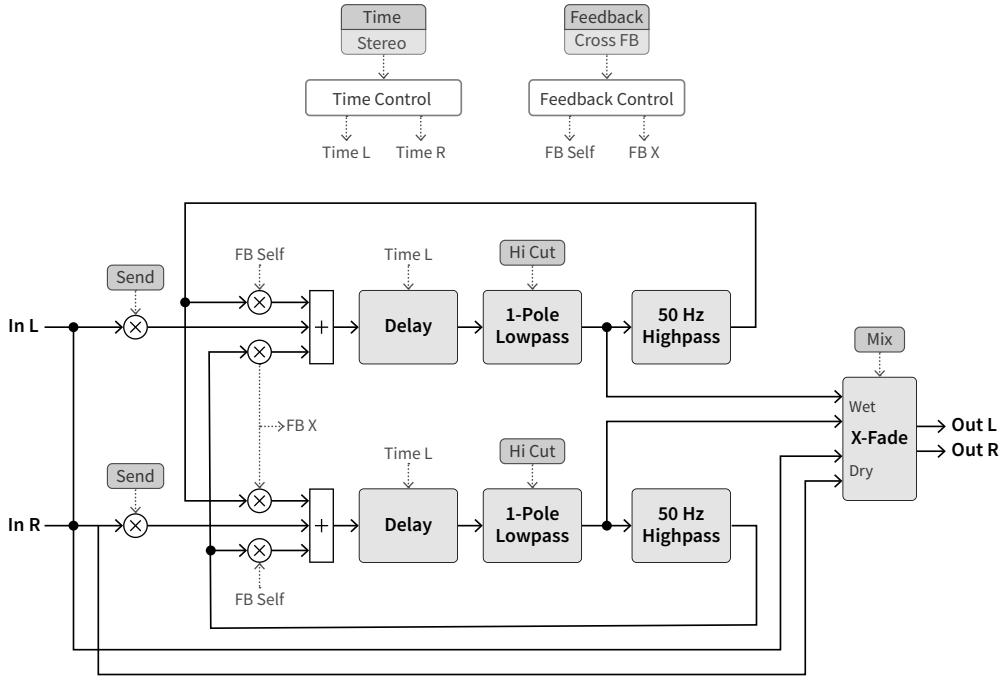


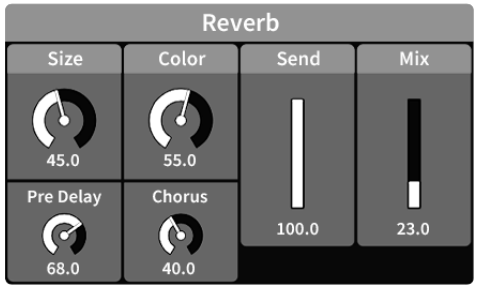




A stereo delay effect with adjustable cross-feedback.

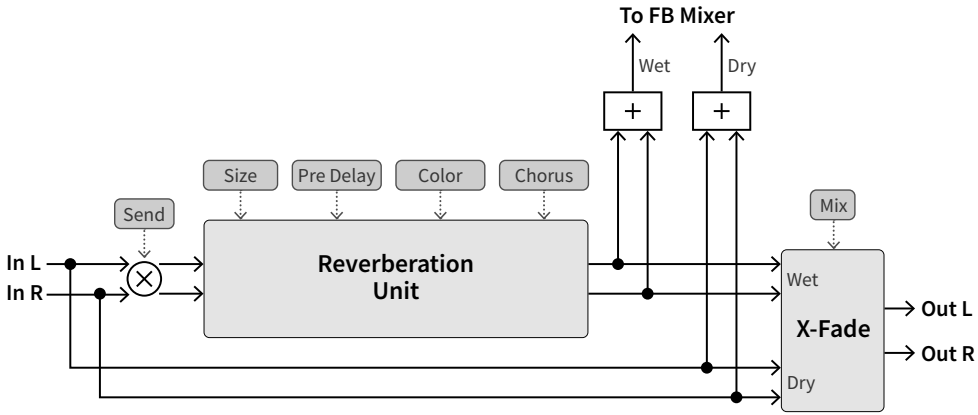
Signal flow of the Echo.



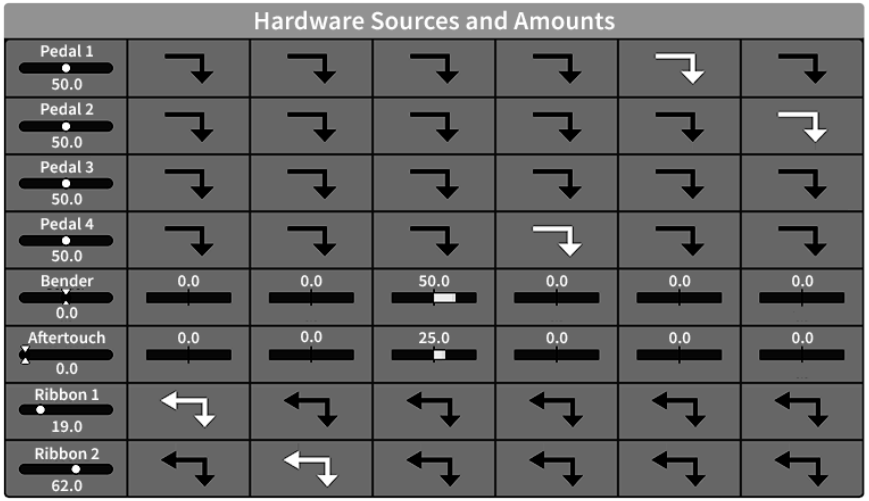


A flexible simulation of rooms and halls. The Size can be varied without artefacts.

Signal flow of the Reverb.



Six Macro Controls (A, B, C, D, E, F) are available as modulation sources. 106 parameters can be assigned as modulation targets with individual amounts. For each Macro Control a Smoothing time can be set.

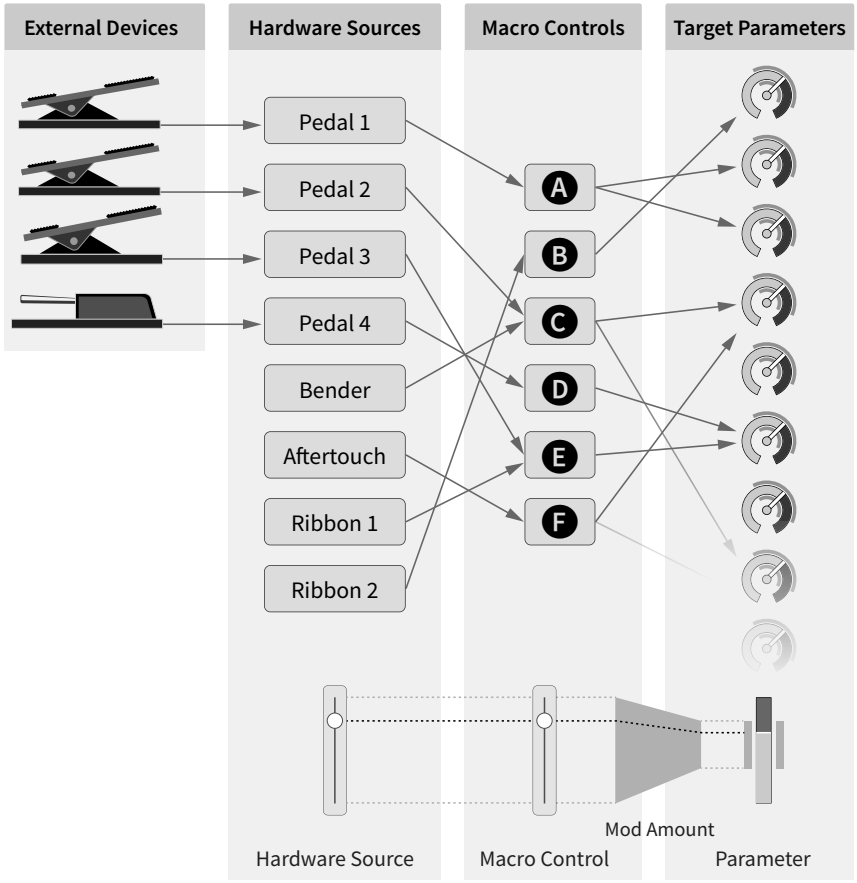


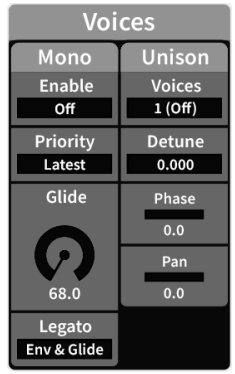
Eight physical control elements are available, that can be mapped to the six Macro Controls:

- four Pedals
- two Ribbons
- the Bender
- Aftertouch

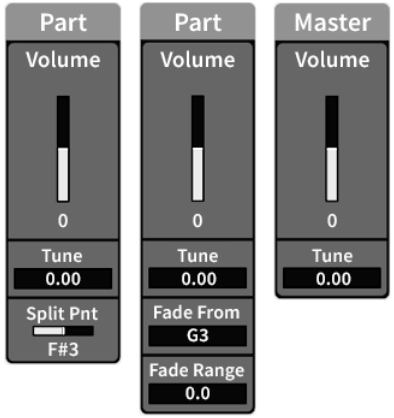
The illustration on the next page shows how the modulation works.

The modulation stages (with example mapping):

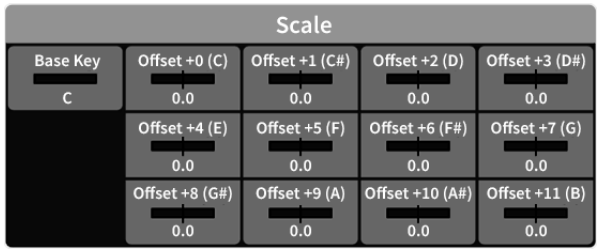




The parameters in this group control the monophonic mode and the use of the voices for Unison.

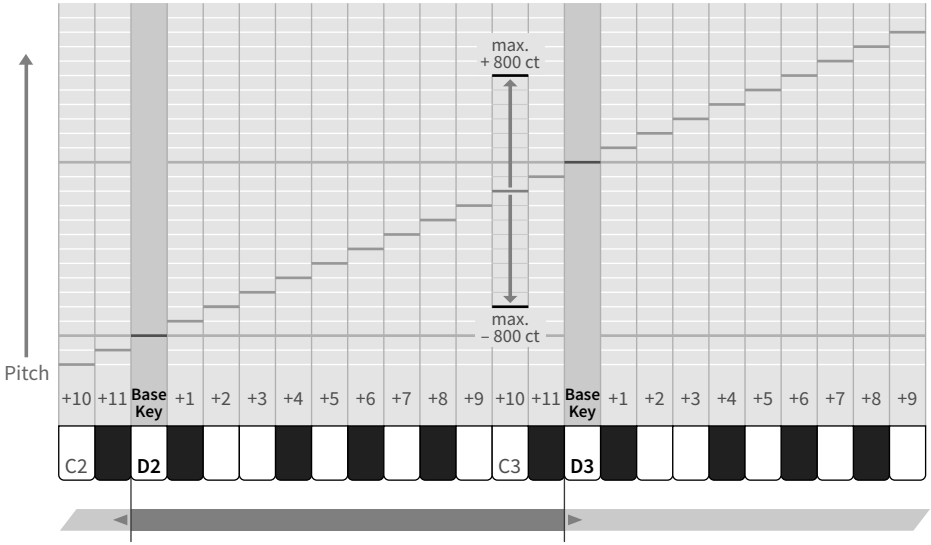


Master Volume and Master Tune are always available, while the Part groups are used to control aspects of the two Parts of a Split Sound or a Layer Sound.

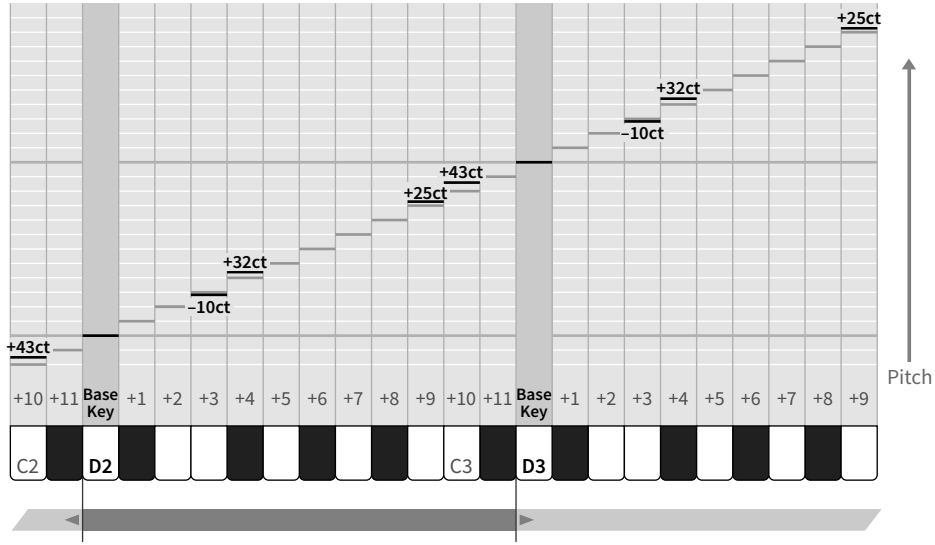


The Scale group offers twelve Offsets to tune the keys of an octave. The Base parameter can be used to shift the base key of the scale.

Equal-temperament scale and the available tuning range:



A scale where four keys have been micro-tuned:



About FM and Chaos

I have always been fascinated by FM synthesis (FM means frequency modulation but in reality, the technique used is phase modulation). John Chowning was the pioneer researcher in this field and Yamaha created the first commercially available instruments.

For a number of years - between the end of the 80's and beginning of the 90's - the Yamaha DX7-II was my main instrument. I also used several other DX/TX/TZ/SY/TG models. These instruments were based on simple building blocks but offered a vast potential for sound programming. The results were not easy to predict but worth the effort. One of their most important advantages was that they could be programmed to respond very expressively to key velocity.

The algorithms of the first FM synths already contained a feedback loop. Later, in NI's FM7 the algorithms were extended to a matrix where every operator's output signal can be sent to any operator's input, allowing even multiple feedback loops. In addition, all these signals can be mixed to the output. We also learned that a filter and a distortion operator make a lot of sense in such structures.

In an earlier stage of the Phase 22 project it was a 4-operator FM synth, but for more simplicity and focus the frequencies of two of the sine oscillators were set to 0 Hz, which means they became sine shapers.

An interesting lesson from "chaos theory" is that even a simple system can behave in a surprisingly complex or "chaotic" way. A good example is a filter with a propagation delay and a non-linear component combined in a feedback loop with enough gain. The non-linear stage could be a wave shaper, or an oscillator with an input for frequency, phase or pulse width modulation or for hard sync.

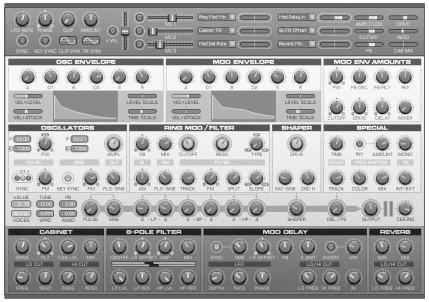
The design of Spark was inspired by the early Reaktor Ensemble Weedwacker which had a feedback from the output of the filter to the PWM input of the oscillator. Weedwacker fascinated many users because its simple structure was able to produce organic and chaotic sounds.

Synth Engine Evolution

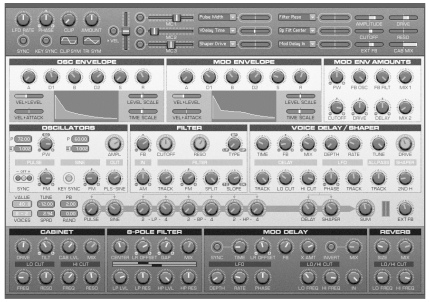
Parts of the design of Phase 22 evolved from Spark and Cha-Osc and also benefit from the experiences designing Prism and Skanner, which are all Reaktor instruments developed at NI. As with Spark and Cha-Osc, the synthesizer uses very basic waveforms — in this case only two sine wave oscillators. But the concept behind Phase 22 is at the same time more radical and more consistent compared to its predecessors. The result is a very symmetrical structure with a core which is reminiscent of a two-operator FM synthesizer.

An earlier version of Phase 22 was the basis for the development of Native Instruments' Kontour in 2014. With the learnings from the Kontour project we have improved Phase 22 in many aspects, and as part of the C15 it is still evolving..

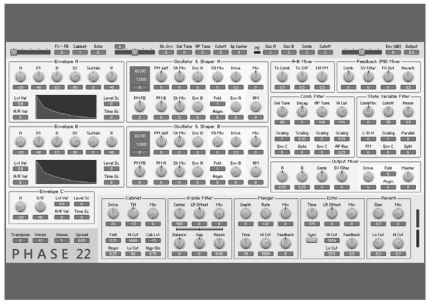
Spark (2008)



Cha-Osc (2009)



Phase 22 (2013)



Kontour (2014)

The C15 Synth Engine compared to Kontour

- Higher resolution for velocity, hardware controls and parameters.
- Six instead of four Macro Controls.
- Each of the Macro Controls can address around 90 parameters.
- Flexible mapping of eight physical modulation sources (bender, aftertouch, 4 pedals, 2 ribbons) to the six Macro Controls.
- The Oscillators got the Fluctuation feature providing a large variety of noise and random signals.
- Control over the Phase offsets of the Oscillators.
- Phase Reset option for the Oscillators.
- The new Chirp filter allows to control the bandwidth of the phase modulation.
- The Feedback Mixer got its own shaper for improved control of the feedback behaviour.
- Key tracking adjustable for the level of the feedback bus.
- The Feedback paths can be controlled by Envelope C.
- The Envelopes got adjustable Attack Curves.
- The Decay 1 segment of the Envelopes can work like a static “hold” segment.
- The Decay times of the Envelopes can be controlled by velocity.
- The Elevate parameter allows to set different Breakpoint and Sustain levels for amplitude and timbre.
- Envelope C is now ADBDSR with bipolar levels and more destinations.
- The delay of the Comb Filter can be modulated by the Oscillators (similar to phase modulation).
- The State Variable Filter has been re-designed to be more effective and flexible in band-pass and band-reject modes.
- Stereo Pan for the Oscillators and Filters in the Output Mixer.
- Adjustable key tracking for the Stereo Pan of voices.
- Adjustable Stereo spreading of Unison voices.
- The Flanger is now in front of the Cabinet.
- The Flanger extended by a 4-pole Allpass for phaser-like response.
- The Flanger can be controlled by a key-triggered envelope.
- The Flanger’s stereo LFO is available for Tremolo.
- The Cabinet is now a stereo effect.
- The Cabinet got more distortion and filter parameters.
- The Gap Filter now can also work as an 8-pole bandpass filter and offers adjustable resonances.
- More control over the stereo processing of Flanger and Echo.
- The Reverb is now based on a new algorithm with a high quality and smooth transitions between different Sizes.
- Split and Layer modes with two complete effect sections.
- Signal routing (cross feedback) between pairs of voices in Layer mode.
- Monophonic modes.

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C15 Synth Enigine
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