Grainulator

iOS Edition (iPadOS)

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1. Grainulator

Granular synthesis instrument and effect for macOS, Windows, and iPadOS.

This is a placeholder landing page. Real content arrives in Task 18.

> **The math, for the curious**
>
> A grain in granular synthesis is a short audio segment of length g samples, multiplied element-wise by an envelope function $w(n)$ commonly chosen as a Hann or Tukey window.

This paragraph contains a parameter reference: `Density`.

2. Header Bar

The header bar runs across the top of the Grainulator window. It holds the preset browser, transport, host-sync toggle, and (in compact layouts) the layer selector and tab navigation.

2.1 Preset browser

At the center of the header bar is the **preset browser**:

- **← / →** — step to the previous or next preset.
- **Name** — click to open a searchable list of factory and user presets.
- **Save** — write the current patch as a user preset (`.gv2p` file).
- **Init** — load the default "init" preset.

User presets are stored in the application support directory and are shared between the standalone app and the plugin formats.

2.2 Transport

- **Play / Stop** — toggles global playback. Behavior depends on the play mode (see below).
- **SYNC** — a toggle that locks grain density, LFO rate, and delay time to the host's tempo. In the standalone app the toggle is disabled; in a DAW it follows the host transport.

2.3 Play mode

Grainulator has two play modes:

- **Free** — grains spawn continuously as long as a layer is enabled. The Play button drives playback.
- **Instrument** — grains spawn only while MIDI notes are held, and each note sets the root pitch for the layer.

The play-mode toggle is available from the header settings menu and from any MIDI-control panel on the SYNTH tab.

2.4 Layer selector

In compact layouts (AU plugin and iPhone), only one layer's controls are visible at a time. A **Layer 1 / Layer 2** segmented control in the header (or at the top of the GRAIN panel in the full layout) switches the visible layer. The selector is highlighted in the current layer's accent color.

Internally, Grainulator calls these "voices" (parameter names start with `v1` or `v2`), but the UI uses "Layer" everywhere a user sees them.

2.5 Tab navigation

The **GRAIN**, **TEXTURE**, **SYNTH**, **FX**, and **MOD** tab buttons sit beneath the header bar. Click a tab to switch the main panel view. The MOD tab is always visible, even in layouts that collapse other panels, so the modulation matrix is reachable from anywhere.

2.6 See also

- Waveform Display
- Layer System

3. Waveform Display

The waveform display sits beneath the header bar and shows the loaded audio sample together with the current grain activity. In the full (two-row) layout there are **two** waveform displays side by side — one for each layer. In compact layouts the selected layer's display is shown full width.

3.1 What you see

- **Stereo waveform** — the loaded sample drawn as a pair of channels.
- **Position cursor** — a vertical line marking the current grain spawn position in the buffer.
- **Active grain dots** — each currently sounding grain is drawn as a small dot over the waveform. The horizontal position encodes the grain's position in the buffer; the vertical position encodes pan; the brightness encodes amplitude.
- **Loop markers** — when looping is enabled, thin vertical lines mark the loop in/out points and the region between them is tinted.
- **Freeze button** — captures the current buffer state so you can scroll the position freely without the playhead advancing (useful for holding a specific moment for manipulation).
- **Layer-link toggle** — on Layer 2's waveform display only, a chain icon toggles whether Layer 2 uses its own buffer (independent) or shares Layer 1's buffer.

3.2 Loading a sound

You can load an audio file three ways:

1. **Drag and drop** an audio file onto the waveform display.
2. **Click** anywhere on the waveform display to open a file browser.
3. **Use the Load menu** in the header (in full layout) or the layer's context menu (right-click / long-press).

Supported formats include WAV, AIFF, FLAC, MP3, and Ogg Vorbis. Files at any sample rate are automatically resampled to the current app or host sample rate on a background thread, so loading a 48 kHz file into a 44.1 kHz session plays back at the correct pitch.

3.3 Setting the position

Click and drag on the waveform to scrub the grain spawn position manually. In Free play mode the position advances according to the Speed parameter; drag sets it explicitly. In Instrument play mode, the position advances only while notes are held.

3.4 See also

- Header Bar
- Layer System

4. Layer System

Grainulator has two independent **layers**, Layer 1 and Layer 2. Each layer has its own audio buffer, grain engine, window shape, pitch variation, filter, resonator, sub oscillator, and envelopes. The two layers share the global effects chain (delay, reverb, compressor, master filter) and the modulation matrix.

Internally the code calls these "voices" and parameter names begin with `v1` / `v2`, but the UI and this manual use "Layer 1" / "Layer 2" throughout.

4.1 What each layer owns

Truly per-layer controls — independent between Layer 1 and Layer 2 — live on the GRAIN and TEXTURE tabs:

- Grain core (size, density, pitch, speed, jitter, spread, pan, level)
- Window shape, window morph, decay
- Pitch variation (probability, mode, direction, range)
- Dynamics randomisation
- Reverse probability
- Scan rate / depth
- Loop points, freeze state
- The per-layer filter (model, cutoff, resonance, drive, env depth)

On the SYNTH tab, only `Root 1` and `Root 2` are truly independent. The Resonator, Sub Oscillator, VCA envelope, Filter envelope, and Glide are all **global**: they are mounted in the UI via Layer 1's parameters, and any change applies to both layers. This is a v1.5-era simplification — the per-layer parameter slots still exist in the preset format for backward compatibility, but the audio engine runs a single shared instance.

See the SYNTH tab page for details.

4.2 What is shared between layers

The following are global and affect both layers together:

- SYNTH panel: resonator, sub oscillator, VCA / filter envelopes, glide
- FX chain: master filter, compressor, delay, reverb
- Master gain, dry/wet
- Modulation matrix (each lane can be targeted at a specific layer)
- Macro knob (the hero Morph control on the GRAIN tab)

4.3 Buffer modes

A **Link** toggle on Layer 2's waveform display controls whether the two layers share one audio buffer or use independent ones:

- **Independent** (unlinked) — each layer loads its own sample. Dropping a file onto Layer 1's waveform fills Layer 1; dropping onto Layer 2's waveform fills Layer 2.
- **Linked** (shared) — Layer 2 reads from Layer 1's buffer. Loading a new sample into Layer 1 updates both layers. Useful for building dense textures from a single source.

In linked mode, Layer 2 still has its own grain parameters — it's only the underlying audio that is shared.

4.4 Enabling and muting layers

Each layer has a power toggle that disables it entirely (no grains spawn, no CPU spent). Mute and solo buttons provide quick in-session silencing without resetting the layer.

4.5 Switching layers in compact mode

In the full two-row standalone layout, both layers' controls are visible side by side. In the compact AU or iPhone layout, only one layer's controls are visible at a time and the **Layer 1 / Layer 2** segmented control in the header bar switches the view. Changing layers never stops playback — both layers keep running, you are only changing what is visible for editing.

4.6 See also

- Header Bar
- Waveform Display

5. GRAIN Tab

The GRAIN tab is Grainulator's default view and the heart of the granular engine. It is arranged as a **four-column layout — GRAIN | MORPH | FILTER | MASTER** — and sits below a **dual waveform display** (one per layer in the full layout, or the focused layer full-width in compact layouts). The knobs edit whichever layer is currently focused via the header bar selector; the Master column shows both layers side by side.

5.1 GRAIN column

Four hero knobs — `Size`, `Density`, `Pitch`, `Speed` — sit above a secondary row of `Jitter`, `Spread`, `Level`, plus a small grain-field visualization that plots each currently active grain.

Control	Range	Description
`Size`	0.001–1.5 s	Duration of each grain. Short sizes give choppy, rhythmic textures; longer sizes produce smooth, pad-like tones. Latched at grain spawn.
`Density`	1–512 Hz	Grain spawn rate. Higher values create denser, overlapping clouds; lower values leave sparse, audible gaps.
`Pitch`	−24 to +24 st	Transposes each grain in semitones. Applied at spawn time, so moving it re-pitches only new grains.
`Speed`	−3 to +3	Internal playback speed multiplier. Negative values play in reverse; values outside ±1 combine with `Pitch` for extreme time-stretch effects. Latched at grain spawn.
`Jitter`	0–0.5 s	Random offset added to each grain's start position. Small amounts humanize the stream; larger amounts scatter grains across the buffer.
`Spread`	0–1	Stereo spread of grain pan. 0 is mono, 1 is full L/R separation.
`Level`	−70 to +12 dB	Per-layer grain level. This is the same parameter as the layer fader in the Master column — moving one moves the other.

`Size` and `Density` interact: their product is roughly the overlap. At 100 Hz with 50 ms grains you have ~5 grains at once — a continuous drone. Drop density to 5 Hz and you hear each grain individually. `Jitter` then breaks up machine-gun periodicity.

5.2 MORPH column

The MORPH column drives the **Macro** modulation — a single hero knob that sweeps a user-chosen set of parameters at once. A smaller LFO knob automates it, a bar graph below visualises current depth for each assigned target, and the gear button at the top right opens the settings popup for assigning targets and depths.

Control	Range	Description
`Morph`	0–1	Macro knob that simultaneously moves every assigned morph target. 0 leaves parameters at their base values; 1 drives them to their configured target values.
`Morph LFO`	0–0.5 Hz	LFO rate that automates the Morph knob. 0 disables the LFO. Very slow rates (below 0.1 Hz) work well for long evolving pads.
Settings (gear)	—	Opens the morph settings popup for assigning targets and depths.

Start with `Morph` at 0 while you dial in a patch, then push it up — or enable `Morph LFO` — to get the patch moving.

5.3 FILTER column

The FILTER column is the **per-layer** filter, upstream of the global master filter on the FX tab. This tab exposes only the tone-shaping controls; the filter envelope (ADSR and Env Depth) lives on the SYNTH tab.

Control	Range	Description
`Filter Model`	10 models	Dropdown selector: Stilson, Microtracker, Krajeski, MusicDSP, Oberheim, Improved, RKSimulation, Hyperion, DaisyLadder, CytomicSVF. Each model has a distinct saturation and resonance character.
`Cutoff`	20 Hz – 20 kHz	Filter cutoff frequency.
`Reso`	0–1	Resonance amount at the cutoff. High settings self-oscillate on some models.
`Drive`	0–1	Input drive into the filter stage. Adds saturation and harmonic content, especially at higher resonance.

5.4 MASTER column

The Master column is the global output mixer, moved here from the FX tab in the 2026-04-07 layout revision so layer balance and wet/dry are always visible on the default view.

Control	Range	Description
`Layer 1 Pan`	−1 to +1	Stereo pan for Layer 1.
`Layer 1 Level`	−70 to +12 dB	Layer 1 vertical fader. Mirrors the `Level` knob in the GRAIN column.
`Layer 2 Pan`	−1 to +1	Stereo pan for Layer 2.
`Layer 2 Level`	−70 to +12 dB	Layer 2 vertical fader. Mirrors the `Level` knob when Layer 2 is focused.
VU meter	—	Stereo meter on the master output (post layers, post wet/dry).
`Wet/Dry`	0–1	Global wet/dry balance between the granular output and the dry input.

5.5 Dual waveform display

Above the panel row the GRAIN tab draws **two waveform displays side by side**, one per layer, each with position cursor, active-grain dots, loop markers, and freeze. Layer 2's display also carries the layer-link toggle for switching between shared and independent buffers. See Waveform Display for the full treatment.

5.6 See also

- Waveform Display
- Layer System
- TEXTURE Tab
- FX Tab

6. TEXTURE Tab

The TEXTURE tab shapes the *character* of each grain once the GRAIN tab has decided how big, how dense, and from where in the buffer it reads. Everything here is per-layer — Layer 1 and Layer 2 each have their own independent TEXTURE settings. The tab is organised into five columns: **Shape**, **Pitch**, **Dynamics**, **Reverse**, and **Scan**.

6.1 Shape — Grain Window

Every grain has an amplitude envelope ("window") applied on playback. The window determines whether grains sound smooth and pad-like, punchy and percussive, or plucked and decaying. A live preview above the knobs shows the current shape; tweaking Tilt, Curve, or Sides updates it in real time.

Control	Range	Description
`Window Shape`	Hanning / Gaussian / Trapezoid / Triangle / Tukey / Pluck / PluckSoft / ExpDecay	Base envelope shape applied to every grain.
`Tilt`	0 – 1	Shifts the envelope peak earlier or later within the grain. 0.5 is symmetric.
`Curve`	0 – 1	Bends the attack and release slopes between linear and exponential.
`Sides`	0 – 1	Softens or sharpens the edges of the window (trapezoid / Tukey plateau width).
`Decay`	1 – 10	Exponent for the Pluck / PluckSoft / ExpDecay shapes. Higher = faster fall-off.

Hanning and Gaussian give the smoothest, most classical granular sound. Trapezoid and Triangle produce punchier, more rhythmic grains. Pluck, PluckSoft, and ExpDecay give each grain a struck-string envelope that is great for pitched percussion and pointillist textures.

Morph

A **MORPH** toggle lets the window crossfade between two shapes over time. When enabled, a second dropdown (Window B) and two extra knobs appear.

Control	Range	Description
`Window B`	same 8 shapes as Window Shape	Target window for the morph.
`Morph`	0 – 1	Static crossfade position between Window A and Window B.
`Rate`	0 – 20 Hz	Automatic morph LFO speed. 0 = static (use the Morph knob manually), higher values cycle between A and B.

6.2 Pitch Variation

Pitch Variation re-tunes individual grains at spawn time to add harmonic richness, arpeggios, or scale-snapped generative melodies. It stacks on top of the base Pitch knob on the GRAIN tab. Only grains that "win" the Probability dice roll are re-pitched.

Control	Range	Description
`Prob`	0 – 100 %	Chance that a new grain is re-pitched. 0 % = always use base pitch, 100 % = every grain.
`Mode`	Octaves / Oct+5ths / Scale	Octaves picks random octave transpositions; Oct+5ths adds perfect fifths; Scale snaps grains to a musical scale.
`Direction`	Both / Up / Down	Constrains variation to move only upward, only downward, or in either direction from the base pitch.
`Range`	1 Oct / 2 Oct / 3 Oct	Maximum transposition distance.

In Scale mode an additional scale preset (0–11) selects the quantisation scale — this lives inside the pitch-variation engine rather than as a knob on the main tab. [TODO: verify scale preset names; the code stores the index as `VarScale` (0–11) but the name list is not defined in `GrainulatorV2.cpp`.]

Note: **Glide** (pitch smoothing between notes) was previously shown here but is now on the SYNTH tab's MIDI panel.

6.3 Dynamics

Dynamics randomises each grain's amplitude at spawn, adding natural breathiness or aggressive volume jitter depending on the Range setting. The base grain level itself lives on the GRAIN tab (`Level`); this section only adds variation on top of it.

Control	Range	Description
`Prob`	0 – 100 %	Chance that a grain's amplitude is randomised.
`Range`	0 – 1	Maximum amplitude deviation. 0 = no change, 1 = grains can be fully attenuated.

6.4 Reverse

Control	Range	Description
`Reverse`	0 – 100 %	Probability that a grain plays backward. 50 % gives an even mix of forward and reversed grains; 100 % reverses every grain.

Because only the *grain's* playback direction flips — not the source buffer — Reverse works with any position, speed, or loop setting and can be modulated for rhythmic forward/backward effects.

6.5 Scan

Scan applies a slow position LFO to the grain spawn point, sweeping through the buffer over time. Combine with a static Position knob on the GRAIN tab to drift around a focal point, or with Speed 0 to replace static freezing with gentle motion.

Control	Range	Description
`Rate`	0 – 5 Hz	Speed of the scan LFO. 0 disables scanning.
`Depth`	0 – 0.5	Amount of buffer traversed by the LFO, as a fraction of the whole file. 0.5 covers half the buffer peak-to-peak.

6.6 See also

- GRAIN Tab
- SYNTH Tab
- Layer System

7. SYNTH Tab

The SYNTH tab gathers the traditional-synthesis elements that sit on top of the granular core: a **Resonator**, a **Sub Oscillator**, the **VCA and Filter envelopes** that shape each played note, and the **MIDI** panel with per-layer root notes and a glide control.

Unlike the GRAIN tab — where every knob edits one layer at a time — most of the SYNTH panels drive a single shared engine. The Resonator, Sub Oscillator, VCA envelope, Filter envelope, and Glide are **global**: they are mounted in the UI via Layer 1's parameters and any change applies to both layers. Only `Root 1` and `Root 2` are genuinely independent per layer.

7.1 Resonator

A global resonant body based on the Mutable Instruments *Rings* DSP. When `Enable` is off the resonator is bypassed and consumes no CPU. A small live preview next to the panel visualises the current harmonic structure.

Control	Range	Description
`Enable`	on / off	Bypass the resonator entirely. Default off.
`Polyphony`	1 / 2 / 3 / 4	Number of simultaneous resonator voices. Higher values give richer chords at higher CPU cost.
`Chord`	0–1	Harmonic structure. Sweeps through chord qualities and inharmonicities (internal name: *Structure*).
`Bright`	0–1	Brightness — the balance of upper partials. Higher values add treble and shimmer.
`Damp`	0–1	Damping / decay time of the resonance. Low = short ping, high = long ring.
`Scatter`	0–1	Modal position / excitation point. Shifts the harmonic balance (internal name: *Position*).
`Note`	0–127 (MIDI)	Center pitch of the resonator. Displayed as a note name.
`Mix`	0–1	Dry/wet blend between the pre-resonator signal and the resonator output.
`Distort`	0–1	Drive / saturation inside the resonator feedback path.
`Polarity`	Saw / Square	Feedback polarity of the resonator. Saw is positive feedback (softer, vowel-like); Square is negative feedback (hollow, square-wave character).

The Resonator runs post-grain, so its pitch follows the grain material by default. Lower `Mix` values keep the grains in front; crank it toward 1 to turn the plugin into a pure physical-modelled voice.

7.2 Sub Oscillator

A global monophonic sub that tracks the played note and thickens the low end. Set `Level` to 0 to disable.

Control	Range	Description
`Level`	0–1	Output level of the sub. 0 silences it.
`Note`	0–127 (MIDI)	Base pitch of the sub when no MIDI note is playing (Free mode), or the reference pitch in Instrument mode. Displayed as a note name.
`Wave`	Sine / Tri / Saw / Sqr	Oscillator waveform. Sine is pure, Triangle is soft, Saw and Square (both band-limited) add harmonics.
`Octave`	−2 / −1 / 0	Octave offset relative to the played note.

7.3 VCA Envelope

A global ADSR that shapes the amplitude of every played note. In **Instrument** play mode the envelope retriggers on each note-on; in **Free** mode it effectively holds at sustain while the global transport is running.

Control	Range	Default	Description
`A` (Attack)	0.001–3 s	1 ms	Time from note-on to peak level.
`D` (Decay)	0.001–5 s	1 ms	Time from peak down to the sustain level.
`S` (Sustain)	0–1	1.0	Level held while the note is active.
`R` (Release)	0.001–5 s	300 ms	Time to fade to silence after note-off.

7.4 Filter Envelope

A second ADSR that modulates the per-layer filter cutoff. The filter itself — model, cutoff, resonance, drive — lives on the GRAIN tab FILTER column, along with the bipolar `Depth` knob that scales how much of this envelope reaches the cutoff.

Control	Range	Default	Description
`A` (Attack)	0.001–3 s	10 ms	Time from note-on to peak envelope level.
`D` (Decay)	0.001–5 s	100 ms	Time from peak to sustain.
`S` (Sustain)	0–1	1.0	Level held while the note is active.
`R` (Release)	0.001–5 s	100 ms	Time to fade after note-off.

With `Depth` at 0 the envelope has no effect. Push it positive to open the filter on note-on and let it close back toward the static cutoff; push it negative to invert the shape.

7.5 MIDI Control

Grainulator has two play modes, selected in the header settings popup:

- **Free** — the global transport runs grains continuously; MIDI notes are ignored for pitch.
- **Instrument** — note-on / note-off gate the VCA and filter envelopes, and incoming notes transpose the grain pitch relative to the layer's root note.

The MIDI panel in the SYNTH tab exposes three knobs:

Control	Range	Default	Description
`Root 1`	0–127 (MIDI)	60 (C3)	Root note for **Layer 1**. When you play this MIDI note in Instrument mode, Layer 1 plays its source at unshifted pitch.
`Root 2`	0–127 (MIDI)	60 (C3)	Root note for **Layer 2**, independently settable.
`Glide`	0–2 s	0 s	Portamento time between consecutive MIDI notes. Applied to both layers.

Both root-note knobs render their value as a note name (`C3`, `F#4`, …) rather than a raw number, matching the `Note` knobs on the Resonator and Sub panels.

On every MIDI note-on in Instrument mode the engine calculates `note − root` for each layer and applies that offset on top of the `Pitch` knob from the GRAIN tab — so Layer 1 and Layer 2 can transpose against the same incoming note by setting different root values. The Resonator tracks the note offset from Layer 1's root as a single global reference.

`Glide` smooths pitch transitions between notes at the per-layer level; 0 disables portamento, 2 s gives a long, slow slide. It applies equally to both layers.

7.6 See also

- GRAIN Tab — the per-layer filter (model, cutoff, resonance, drive, envelope depth) lives there
- MOD Tab — route LFOs, envelopes, and step sequencers to resonator, sub, and envelope parameters
- Layer System

8. FX Tab

The FX tab holds Grainulator's post-mix effects chain. Everything on this tab is **global** — both layers are already summed by the time the signal arrives, so there is no per-layer FX. Signal flows strictly left to right: **Master Filter → Compressor → Delay → Reverb**.

The master mixing controls — Layer 1 / Layer 2 faders, pans, and Wet/Dry — used to live on FX but were relocated to the GRAIN tab MASTER column in the 2026-04-07 layout update.

8.1 Master Filter

A single post-mix filter stage applied before the compressor. The filter bypasses itself automatically when `Cutoff` is wide open (20 kHz) and `Drive` is 0, so a fully-open setting costs nothing.

Control	Range	Description
`Model`	10 models	Filter topology: Stilson, Microtracker, Krajeski, MusicDSP, Oberheim, Improved, RKSimulation, Hyperion, DaisyLadder, CytomicSVF. Defaults to CytomicSVF. Same bank as the per-layer filter on the GRAIN tab.
`Cutoff`	20 Hz – 20 kHz	Global filter frequency (log-scaled).
`Reso`	0–1	Resonance at cutoff. High values add a singing, whistling character to the full mix.
`Drive`	0–1	Saturation applied alongside the filter. Adds warmth and gentle compression even with cutoff wide open.

8.2 Compressor

A feed-forward log-domain compressor (Giannoulis / Massberg / Reiss 2012) with stereo-linked peak detection, a fixed 6 dB soft knee, and an optional brickwall limiter. The character is clean and transparent — this is a glue/bus compressor, not a coloration effect. A live gain reduction meter next to the knob grid shows how hard the detector is working. All six continuous knobs read 0–1 on the UI; the ranges in the table are the mapped musical values.

Control	Range	Description
`ON`	on/off	Master bypass for the compressor stage. Click-free. Default **on**.
`Thresh`	−60 to 0 dB	Level above which gain reduction starts. Default ≈ −3 dB (very light touch).
`Ratio`	1:1 to 20:1	Amount of reduction above the threshold. Default ≈ 4:1.
`Atk`	0.1 – 100 ms (log)	How quickly the envelope follower reacts to peaks. Short attacks catch transients; long attacks let them through for punch.
`Rel`	10 – 1000 ms (log)	How quickly gain recovers after a peak.
`Makeup`	0 – +40 dB	Output gain added after compression to compensate for reduction.
`Mix`	0–1 (dry→wet)	Parallel-compression blend. At 1.0 the signal is fully compressed; lower values blend in the uncompressed signal for NY-style parallel compression. Default **1.0** (fully wet).
`LIM`	on/off	Post-compressor brickwall limiter that hard-clips at ±1.0 (0 dBFS). Default **on** as a safety net.

The compressor only sees the wet signal; the dry path on the GRAIN tab's Dry/Wet mix skips it, so the unprocessed input is never compressed.

8.3 Delay

A stereo tape-style delay with independent L/R times, four routing modes, and two time-change behaviors. Feedback can be pushed above unity for self-oscillating runaways, and the infinite-loop toggle turns the delay into a captured loop.

Control	Range	Description
`TimeL` / `TimeR`	5 – 2730 ms	Delay time per channel (log-scaled).
`Link`	on/off	When on, TimeR follows TimeL. Turn off to set stereo offsets manually. Default **on**.
`Feedback`	0 – 1.25	Amount fed back into the delay line. Values above 1.0 are self-oscillating — use with care.
`Mod Mode`	Tape, Fade	How the delay reacts when its time parameter is changed. **Tape** re-pitches the tail as the read head moves (classic tape warp). **Fade** crossfades between old and new positions without pitch shift.
`Mode`	Dual, PingPong, Single, Cascade	Routing of the two internal delay lines. **Dual:** independent L/R. **PingPong:** L→R→L bouncing. **Single:** mono delay duplicated to both channels. **Cascade:** the two lines are chained in series for longer or more rhythmic echoes.
`Tone`	−1 to +1	Bipolar tone control on the delayed signal. Negative darkens (low-pass), positive brightens (high-pass).
`Sat`	0–1	Saturation drive inside the feedback loop. Adds warmth and iterative grit as feedback regenerates.
`Sync`	on/off	When on, delay times snap to host tempo. Uses `Clock Div` and `Sync Offset`.
`Clock Div`	1/4 – 4/1	Tempo division when `Sync` is on. Available values: 1/4, 1/3, 1/2, 2/3, 3/4, 1/1, 3/2, 2/1, 3/1, 4/1. Default **1/1**.
`Sync Offset`	−5 to +5	Integer offset from the selected clock division (steps in the divisor table) for swing and pushed/pulled feel.
`Loop`	on/off	Infinite-loop mode — the current delay buffer is captured and plays back indefinitely regardless of feedback.
`Mix`	0–1	Delay wet/dry blend for the delay stage itself (independent of the global Dry/Wet on GRAIN).

The two mode parameters are not duplicates. `Mode` is the **routing** between the two internal delay lines (Dual / PingPong / Single / Cascade). `Mod Mode` is the **time-change behavior**: Tape pitches the tail when you turn the time knob, Fade crossfades without pitch shift.

8.4 Reverb

The reverb panel has an **algorithm selector** that switches between three distinct reverb engines. The surrounding knobs (`Size`, `Damp`, `Width`, `Shimmer`, `Tone`, `Mix`, `Freeze`) are shared across all three algorithms — the UI layout never changes — but the underlying interpretation depends on which engine is active.

Algorithm selector

The three engines are named for their character, not their internal algorithm. Default is **Stormy**.

Algorithm	Engine	Character	Best for
`Misty`	Signalsmith Basics	Clean, modern, diffuse. No shimmer, no freeze behavior.	Transparent ambience, pads, realistic-sounding spaces where the reverb should get out of the way.
`Cloudy`	Mutable Rings (Griesinger)	Smooth, classic plate/hall tone with gentle modulation. No shimmer, no freeze behavior.	Warm vintage-style reverb on grain clouds and sustained textures.
`Stormy`	Oliverb (extended Griesinger/Dattorro)	Rich, heavily-modulated, with pitch-shift shimmer in the feedback loop and infinite freeze.	Shimmer pads, ambient tails, evolving textures, long drones. This is the default and the most Grainulator-like.

Common controls

Control	Range	Description
`Size`	0–1	Room size / decay length. All three engines scale decay time from this.
`Damp`	0–1	High-frequency damping in the feedback loop. Higher values make tails darker over time.
`Width`	0–1	Stereo width / diffusion. Maps to diffuser AP coefficients inside each engine.
`Shimmer`	0–1	Pitch-shift amount in the reverb feedback loop. Only audible on **Stormy** — mapped to approximately ±12 semitones around a center-off point. Ignored by Misty and Cloudy.
`Tone`	−100 to +100	Bipolar post-reverb tone shelf. Negative darkens, positive brightens. Common to all engines.
`Mix`	0–1	Reverb wet/dry blend for the reverb stage. Default **0** — reverb is off until you turn it up.
`Freeze`	on/off	Captures the current reverb state and sustains it indefinitely. Only has effect on **Stormy**: input gain, damping, and high-pass are disabled so the tail holds forever. Misty and Cloudy ignore this toggle.

Notes on per-algorithm behavior

- **Stormy** is where the personality lives: nine random modulation LFOs scattered through the topology, a dual-tap pitch shifter per feedback branch, a HP filter to keep long tails clean, and an infinite freeze. Modulation rate and depth scale automatically with `Size`.
- **Cloudy** is the previous default — the Mutable Rings Griesinger reverb. Smooth and musical, without shimmer or freeze.
- **Misty** is the cleanest of the three; best when you want the reverb to feel like a natural space rather than an effect.
- Switching algorithms briefly clears the newly-selected engine's buffers, so you will hear the tail cut on switch.
- `Shimmer` and `Freeze` remain visible in all modes on purpose — they simply do nothing in Misty and Cloudy.

8.5 See also

- GRAIN Tab — master mixing (layer faders, pans, Wet/Dry) and the per-layer filter
- TEXTURE Tab — resonator and sub stages upstream of the FX chain

9. MOD Tab

The MOD tab is Grainulator's modulation matrix — five independent lanes that each pick a **source**, a **destination**, and a set of per-lane shaping controls. Because the MOD tab is always visible (including in the compact AU layout, where SYNTH / FX / MOD live in a tab strip at the top), every modulation assignment is reachable from any other view without losing your place on the GRAIN, TEXTURE, or FX tabs.

Each lane carries its own LFO, ADSR envelope, Euclidean generator and 8-step sequencer, so you don't have to reserve a global slot to get movement on a single parameter. Sources cover LFOs, envelopes and two rhythmic generators added on 2026-04-05 — a clock-divided **Euclidean LFO** and a tempo-synced **step sequencer**. Destinations reach 38 per-layer and global targets covering the grain core, window, filter, resonator, spectral block, master filter, global effects and the compressor.

Mod lanes always respect the layer model. Each lane has a `Target` that picks which layer(s) it applies to, and the UI uses the **Layer 1 / Layer 2** naming throughout even though the underlying parameters are stored as `Voice 1` / `Voice 2`.

9.1 Overview

Every lane exposes the same set of core controls:

Control	Description
`Source`	What drives the modulation. Per-lane LFO, envelope, Euclidean LFO, or step sequencer.
`Dest`	Which parameter is modulated. One of 38 targets grouped by category.
`Amount`	Bipolar scale from −1 to +1. Negative values invert the source.
`Curve`	Response shaping applied to the source before it hits the destination.
`Target`	Which layer(s) the modulation applies to: both, Layer 1 only, or Layer 2 only.
`Enable`	Lane on/off without having to reset `Source` or `Dest`.

The `Curve` menu offers nine shapes — `Linear`, `Exponential`, `Logarithmic`, `S-Curve`, `Stepped`, `RandomSmooth`, `Threshold`, `Inverted` and `Bipolar`. `Threshold` is particularly handy with the `Spectral Freeze` destination: it converts any bipolar source into a clean gate (1 above zero, 0 below).

9.2 Sources

The `Source` dropdown on each lane lists every available modulation source. The previous Macro / Velocity / Pressure entries are retained in the underlying parameter enum for preset compatibility but are hidden from the UI and produce zero output at runtime — the four live sources are described below.

Per-lane LFO

Classic free-running or tempo-synced LFO. Each lane has its own, so you never run out.

Control	Range	Description
`LFO Shape`	enum	`Sine`, `Triangle`, `Saw`, `Square`, `Random`, `S&H`.
`LFO Rate`	0.01–50 Hz	Free-running rate when the lane's `Sync` toggle is off.
`LFO Depth`	0–1	Output scale applied before `Amount`.
`LFO Retrig`	toggle	When on, the LFO resets to phase 0 on every MIDI note-on (Instrument mode). When off, the LFO runs free.

When the lane's shared `Sync` toggle is on the LFO is driven by the rhythmic clock described below and `LFO Rate` is ignored.

Per-lane envelope

A full ADSR envelope, one per lane. In Instrument mode it is triggered by MIDI note-on and released on note-off; in Free mode it triggers alongside the global play transport.

Control	Range	Description
`Env A`	0.001–10 s	Attack time from 0 to peak.
`Env D`	0.001–10 s	Decay time from peak to sustain.
`Env S`	0–1	Sustain level held while the note is active.
`Env R`	0.001–10 s	Release time after note-off.

Rhythmic sources (added 2026-04-05)

Two phase-driven generators share a single clock with the LFO. The clock can free-run at a Hz rate, or lock to host tempo at a musical division (1/32 through 1/1, straight / dotted / triplet), so all three time-based source types line up with the rest of your project.

Euclidean LFO distributes `Euc Hits` evenly across `Euc Steps` using Bjorklund's algorithm, rotates the pattern by `Euc Rot`, and renders each hit according to `Euc Shape`: at 0 each hit is a gate (square pulse), at 1 it's a ramp that decays linearly to zero over the step, and 0.5 sits between the two.

Step Sequencer plays back an 8-step pattern of bipolar slider values at the lane's clock rate. `Seq Len` truncates the sequence to anywhere from 1 to 8 active steps, and `Glide` slews between adjacent steps over a fraction of the step duration (0 = instant, 1 = full step slew). When the lane's `Dest` is `Pitch` the sliders snap to integer semitones and the hybrid pitch path emits a full ±12 semitone range, bypassing the usual `Curve` and `Amount`.

Every rhythmic source shares the same 18 per-lane parameters:

Control	Range	Description
`Sync`	toggle	Lock this lane's clock to host tempo. Off = use `Free Rate`.
`SyncDiv`	0–15	Division index (1/32 → 1/1, including dotted and triplet variants). Used when `Sync` is on.
`Free Rate`	0.01–50 Hz	Free-running clock rate. Used when `Sync` is off.
`Euc Hits`	0–16	Number of active hits in the Euclidean pattern.
`Euc Steps`	1–16	Pattern length for the Euclidean LFO.
`Euc Rot`	0–15	Pattern rotation. Shifts which step the pattern starts on.
`Euc Shape`	0–1	Hit rendering: 0 = gate, 0.5 = pulse, 1 = ramp.
`Step 0` … `Step 7`	−1…+1	Eight bipolar step values for the sequencer. On pitch destinations they snap to integer semitones.
`Seq Len`	1–8	Active step count. Steps beyond the length are skipped and dimmed in the UI.
`Glide`	0–1	Fraction of step duration spent slewing between step values.
`Reserved`	—	Reserved for future use; has no effect.

One clock "cycle" is one full pass through the source's period — the Euclidean pattern's step count, or the step sequencer's length. A lane synced to 1/4 at 120 BPM therefore produces one full pass every two beats.

9.3 Destinations

Each lane's `Dest` dropdown lists 38 modulation targets grouped by category. Per-layer destinations are routed through `Target`; global destinations (master filter and effects) ignore `Target`.

Group	Destinations
Grain	`Position`, `Speed`, `Pitch`, `Size`, `Density`
Window	`Tilt`, `Curve`, `Morph Amt`, `Morph Rate`
Filter	`Cutoff`, `Resonance`
Resonator	`Chord`, `Brightness`, `Damping`, `Scatter`, `Mix`, `Note`
Amplitude	`Level`, `Pan`, `Spread`
Master	`M.Cutoff`, `M.Reso`
Effects	`Delay Mix`, `Reverb Mix`, `Reverb Size`, `Rev Freeze`
Spectral	`Formant`, `Tilt`, `FrzBlend`, `Charcter`, `Focus`, `Freeze`
Compressor	`Comp Thresh`, `Comp Ratio`, `Comp Attack`, `Comp Release`, `Comp Makeup`, `Comp Mix`

9.4 Layer targeting

Each lane's `Target` picks which layer(s) the lane applies to:

Value	Behaviour
`Both`	Apply to both layers.
`Voice 1`	Apply only to Layer 1.
`Voice 2`	Apply only to Layer 2.

The underlying enum labels still read `Voice 1` / `Voice 2`, but the layer they address is Layer 1 / Layer 2 as named everywhere else in the UI. Global destinations (master filter, delay, reverb, compressor) ignore this setting.

9.5 See also

- Layer System
- GRAIN Tab
- TEXTURE Tab

10. Parameter Reference

Grainulator's parameters are documented on the per-tab pages under **Reference → Tabs**. This page is a quick lookup for "which tab is parameter X on?". For ranges, defaults, and descriptive prose, follow the link to the tab page.

10.1 Quick lookup

Area	Parameters	Tab
Grain core	Position, Speed, Pitch, Size, Density, Jitter, Spread, Pan	GRAIN
Per-layer filter	Model, Cutoff, Resonance, Drive, Env Depth	GRAIN
Master mixer	Layer 1/2 Level, Layer 1/2 Pan, Wet/Dry	GRAIN
Global Morph (hero knob)	Macro, Morph LFO Rate, assignable targets	GRAIN
Grain window	Window Shape, Tilt, Curve, Sides, Decay, Window B, Morph, Rate	TEXTURE
Pitch variation	Prob, Mode, Direction, Range	TEXTURE
Dynamics	Prob, Range	TEXTURE
Reverse	Reverse probability	TEXTURE
Scan	Rate, Depth	TEXTURE
Resonator	Enable, Polyphony, Chord, Bright, Damp, Scatter, Note, Mix, Distort, Polarity	SYNTH
Sub oscillator	Level, Waveform, Octave, Note	SYNTH
VCA envelope	Attack, Decay, Sustain, Release	SYNTH
Filter envelope	Attack, Decay, Sustain, Release	SYNTH
MIDI	Root 1, Root 2, Glide	SYNTH
Master filter	Model, Cutoff, Resonance, Drive	FX
Compressor	Enable, Threshold, Ratio, Attack, Release, Makeup, Mix, Limiter	FX
Delay	Time L/R, Link, Feedback, Mode, ModMode, Tone, Sat Drive, Sync, Clock Div, Sync Offset, Infinite, Mix	FX
Reverb	Mode (Misty/Cloudy/Stormy), Size, Damping, Width, Modulation, Tone, Mix, Freeze	FX
Mod matrix — per lane	Source, Dest, Amount, Curve, Target, Enable	MOD
Mod matrix — per lane LFO	Rate, Shape, Depth, Retrigger	MOD
Mod matrix — per lane envelope	A, D, S, R	MOD
Rhythmic sources	Sync, Div, Free Rate, Euclid Hits/Steps/Rotation/Shape, 8 Step values, Step Length, Step Glide	MOD

10.2 Layer scope at a glance

Most parameters exist per layer (Layer 1 and Layer 2 can hold different values). The exceptions — parameters that are global regardless of the layer you are editing — are:

- All FX chain parameters (master filter, compressor, delay, reverb)
- The global Morph (Macro knob) and its LFO rate
- Master mix (Layer 1/2 level and pan, Wet/Dry)
- The modulation matrix (though each lane can be targeted at a specific layer via its Target setting)
- **SYNTH tab**: Resonator, Sub Oscillator, VCA envelope, Filter envelope, and Glide are all global in v1.5 even though the UI mounts them under Layer 1. Only Root Note is truly per-layer. See Layer System for the full story.

10.3 See also

- Interface — Header Bar
- Interface — Waveform Display
- Layer System

> **Note**
>
> A complete parameter table with exact ranges, defaults, units, and modulation targets will be auto-generated from the plugin source in v1.2. For v1 the authoritative ranges live on the per-tab pages linked above.