



VERDALIS
Natural sound synthesis

ThunderClap

Synthesised thunder

Version 1.7.0

CLAP instrument for Linux and Windows

Part of the Verdalis Plugin Suite

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Contents

Introduction

- What is in this manual

Installing

- Linux
- Windows
- Hosts
- Your own presets
- Building from source

A first sound

- Three things to try first

How it works

- The channel
- What each element sends
- Return strokes
- The shock wave
- Impact, and what is not linear about a close strike
- The ground under you
- Bloom, and why a clap arrives thin
- The rumble
- Echoes and space
- Dynamics
- Triggering
- Variation

The plugin window

- Gestures
- The mixer

Parameter reference

- Output
- Strike
- Sound
- Stereo
- Echoes
- Space
- Filter
- Envelope
- System
- Dynamics
- Impact

The preset library

Using it in a host

- Notes
- Automation and modulation
- Reproducible renders
- CPU cost
- Rendering and tails

Reference and limits

- Where the model comes from
- Notes and limits
- Versioning

Introduction

ThunderClap is a CLAP instrument that generates thunder. It contains no samples: every flash grows its own lightning channel, and every shock wave you hear is computed from that channel's geometry while the plugin plays. No two thunders are ever alike.

Thunder is the sound of a lightning channel — several kilometres of it, and every metre a separate source. The channel heats to twenty thousand degrees and expands in a few microseconds, which launches a shock wave from all of it at once. The listener then hears each piece when its own shock arrives: the near pieces first and loud, the far pieces late, quiet and dull, because the air soaks up the high end over distance. A crooked channel has stretches side-on to the listener whose shocks arrive together and pile into a *clap*, and stretches end-on whose shocks arrive spread out and quiet, which is the *rumble*.

All of that is geometry, and ThunderClap computes the geometry. That is why *Distance* behaves the way distance behaves rather than like a filter and a fader: move the strike and the sharpness of the crack, the loss of high end, the smearing of thousands of arrivals into a roll and the sub-bass that outlives everything all follow by themselves, because they are consequences of the model.

The approach is that of Few (1969) and Ribner and Roy (1982), who synthesised thunder this way and found it convincing. The engine's constants were then set against 38 recordings of real thunder, by measuring the recording and the plugin's own output with the same analysis code and moving values until the two agreed.

What is in this manual

Installing and *A first sound* are enough to get thunder out of the plugin. *How it works* explains the model, and is worth reading before spending time in the parameter list — the controls are the model's own quantities, so most of them make immediate sense once it does. *Parameter reference* and *The preset library* are generated from the plugin itself, so they always describe the version on the cover. *Using it in a host* covers notes, the three trigger modes, reproducible renders and CPU cost.

Installing

ThunderClap is one self-contained `.clap` file plus its `presets` folder. There is no installer, no shared library to place and nothing to register.

Linux

CLAP hosts scan `~/.clap`. Copy the plugin folder from the release archive into it so that you end up with:

```
~/.clap/ThunderClap/ThunderClap.clap
~/.clap/ThunderClap/presets/
```

Then rescan plugins in your host. X11 and Cairo are the only external dependencies of the plugin window, and any Linux machine that can run a DAW has both.

Windows

CLAP hosts scan the common CLAP folder. Copy the plugin folder into:

```
C:\Program Files\Common Files\CLAP\ThunderClap\
```

so that `ThunderClap.clap` and `presets\` sit inside it, and rescan. There are no DLLs to install beside it — the window and its Cairo are linked in.

Keep the plugin and its presets together. The plugin finds its factory presets by looking for a `presets` directory next to its own binary. Moving the `.clap` file on its own leaves it with no factory presets at all.

Hosts

Tested with Bitwig Studio and Reaper. In Bitwig, `~/.clap` is scanned by default; after installing, restart it or rescan under *Settings* → *Locations* → *Plug-in Locations*. ThunderClap then appears as an instrument under the vendor *Ravetracer*, and the factory presets are indexed through CLAP's preset discovery, so they show up in the host's own browser as well as in the plugin window.

Your own presets

`SAVE` in the plugin window writes to a user preset folder, which is created on first use:

PLATFORM	LOCATION
Linux	<code>\$XDG_CONFIG_HOME/ThunderClap/presets</code> , or <code>~/.config/ThunderClap/presets</code>
Windows	<code>%APPDATA%\ThunderClap\presets</code>

User presets appear in the browser immediately, listed after the factory ones. They are plain text, so they can be copied between machines, kept in version control, or edited in any editor.

COLLECTIONS

A preset library is a shelf, and a long one is worth tidying. Your own presets are filed in **collections**: folders one level under the user preset directory. The browser lists the library down its left side — *All*, the factory presets, each of your collections, and *Unfiled* for presets saved into none — each with the number of presets in it. Clicking one lists just that one.

IN THE BROWSER	WHAT IT DOES
<code>NEW</code>	Makes a collection. It is listed at once, empty until something goes into it

RENAME	Renames the selected collection; its presets go with it
DELETE	Deletes the selected collection and every preset in it, after asking
Drag a preset onto a collection	Moves it there — or onto <i>Unfiled</i> to take it out of one
Right-click one of your presets	Renames it, changes its description, or deletes it

SAVE asks where a preset goes: pick a collection from the list — or *New collection...* to make one on the spot — then give the preset a name and, if you like, a **description**. The description is what the browser shows while the pointer is over the preset and what the help line shows while it is loaded: a sentence for whoever loads it next. Saving over one of your own presets offers its collection and its description again.

The factory presets are locked. They are part of the plugin, not files of yours, so they cannot be moved, renamed or deleted; to change one, load it, adjust it and save it as your own.

Collections are one level deep on purpose: a preset library is a shelf rather than a filesystem, and a tree deep enough to get lost in is one somebody will get lost in.

PRESET PACKS

A whole collection can be written out as a single file — a **preset pack**, extension `.thunderclappack` — so a library can be handed to somebody else, or moved between machines, as one file rather than a directory.

With a collection selected in the browser:

BUTTON	WHAT IT DOES
EXPORT	Writes the selected collection — its presets and nothing else — as a pack into the <code>packs</code> directory beside <code>presets</code>
EXPORT AS...	The same, to a location you choose
IMPORT...	Lists the packs already in <code>packs</code> , plus <i>Other file...</i> for one from anywhere
REVEAL	Opens the folder the pack was just written to in the system's file browser

Importing adds the pack's presets to the library as a new collection named after the pack. Nothing is ever overwritten: importing the same pack twice gives two collections rather than a mixture of both versions in one.

A pack is the preset format again with a separator line between the presets, so it can be read, diffed and edited by hand like everything else here. It carries each preset's text verbatim rather than a re-serialised copy, which is what makes a round trip through a pack lossless.

EXPORT AS..., *Other file...* and **REVEAL** need the desktop's own file chooser — `zenity` or `kdiallog` on Linux, `xdg-open` to reveal, and the operating system's own on Windows. Where none is installed the buttons that need one are not drawn, and the plugin's own `packs` directory, which is where **EXPORT** writes, is enough on its own.

Building from source

The suite builds with a C++17 compiler and CMake 3.16 or newer. From the plugin folder:

```
./install.sh
```

That configures, builds, runs the self-test and installs to `~/.clap/ThunderClap/`. `ThunderClap_PREFIX=/some/where` `./install.sh` overrides the destination, and `-DCLAP_INCLUDE_DIR=/path/to/clap/include` points the build at a CLAP checkout it cannot find by itself.

A first sound

1. Load ThunderClap on an instrument track.
2. Play a single short note. One note is one flash — the note does not have to be held for the thunder to play out.
3. Open the preset browser by clicking the preset name in the window header and try **Rolling Thunder**, then **Close Strike**, then **Far Horizon**.

The three of those are the same engine at three distances, and comparing them is the fastest way to hear what the model does.

Three things to try first

Move the strike. *Distance* is the master control. Under a kilometre you get a crack with a tearing edge; past ten you get nothing but the bottom two octaves, swelling in over seconds. Nothing else needs changing for that to work.

Hold a note in Storm mode. Set *Mode* to *Storm* and hold a long note. Flashes keep coming at *Storm Rate*, as a Poisson process rather than on a grid, and *Variation* scatters each flash's distance, height, direction and stroke count. A held note is a storm rather than a loop.

Raise Compress. Thunder recorded on anything that was already limiting sounds dense, with the ground still shaking after the sky has stopped. *Compress* lifts the rumble, the far claps and the echo tail towards the crack, which is that sound. The ratio is capped at 4:1 on purpose.

How it works

The channel

Every flash grows a new channel. From the strike point — *Distance* away, at an azimuth *Variation* scatters — a random walk climbs to the cloud base at *Height*, each step remembering its direction so that the channel wanders rather than zigzags; *Tortuosity* sets how far it wanders.

At the top it turns and runs *Cloud Spread* kilometres inside the cloud. That is the part of a real channel that is longest, and the reason a distant thunder lasts twenty seconds rather than two: the listener hears the difference in path length, and a horizontal channel has a great deal of it. *Branching* adds side branches, downward from the lower channel and sideways from the cloud part, each a smaller channel of its own. The in-cloud branches are where the extra claps come from — Kappus and Vernon counted one to five claps per thunder in a storm 5 km off, and only half the time was the first one the loudest.

The channel is then cut into elements, up to *Max Shocks* of them, dealt out in proportion to length over distance: the near channel finely, where it is heard as separate shocks, and the far channel coarsely, where it is heard as a wash. An element longer than the channel's coherence length stands for several sources adding incoherently, so its amplitude goes as the square root of its length and the power per metre of channel does not depend on how finely it was cut.

What each element sends

For every element the engine works out, once, when and how its shock arrives.

When. Its distance over the speed of sound. The clock starts at the first shock anyone will hear.

How loud. $1/r$ for spherical spreading, times a directivity: a line element radiates broadside and not off its ends, so its level goes as the sine of the angle between the element and the line of sight, raised to a power *Focus* sets. Focused, only the parts side-on to you are loud, and the claps stand out from the rumble.

How long. The N-wave a shock has become by the time it arrives lengthens with a small power of the distance travelled, so far shocks are deeper, and *Weight* scales that. The channel inside the cloud radiates longer waves than the stroke below it: Kappus and Vernon, and Holmes before them, put intracloud thunder's peak near 10 Hz against 50 Hz for a cloud-to-ground stroke. An element's wave therefore lengthens with its height, to twice the length at the cloud base, and its crackle fades by the same factor. That is the deep swell arriving ten seconds after the crack. In the recording *City Thunder* is set against, that swell is the loudest thing in the file, so the cloud also radiates half again as hard — the one number in the model that is a fit and not a law.

How dull. Atmospheric absorption grows as $f^{1.3}$ in decibels, about 5 dB per kilometre at 1 kHz in the damp air under a storm; ISO 9613 gives 4.7, 10 and 24 dB/km at 1, 2 and 4 kHz at 20 °C and 70 % humidity, and *Air Absorption* scales that. No fixed filter slope fits both a strike at 300 m, which keeps its 4 kHz, and one at 10 km, which has lost 40 dB there — so each shock gets three one-poles at staggered corners, placed where the loss reaches 6, 12 and 24 dB, which sit on the real curve.

From where. Its azimuth, mapped onto the stereo field by *Width*. A channel a kilometre away spans the sky and the stereo field; one fifteen kilometres away is a point.

The ground shadow. In a normal temperature lapse sound bends upward, so the foot of a distant channel is never heard, and a far thunder swells in from the cloud instead of cracking from the strike. *Swell* sets how much of the low channel is shadowed, and the shadow grows with distance on its own.

Scatter spreads level and length from element to element, and the whole flash is normalised so that its loudest tenth of a second carries a fixed energy. *Distance* therefore changes what a thunder sounds like without deciding whether it is audible; a mild loss per kilometre on top keeps far ones further back.

Return strokes

Strokes re-light the channel, *Stroke Gap* apart, each usually quieter and a little late. Dart leaders do not branch, so only the first stroke lights the branches. Kappus and Vernon note that strokes 30 ms apart would put a peak at 33 Hz in the spectrum if they were exact repeats; they are not exact here — a per-element, per-stroke jitter sees to that — and they do put the 20 ms fluctuation into the first second of a close strike that the recordings show.

The shock wave

Each arrival is played as an **N-wave**: a pressure jump, a straight fall through zero to the mirror value, and a jump back.

Both fronts are eased over a rise time, and that rise time has its own law. A shock front does not stay a discontinuity: molecular relaxation of nitrogen and oxygen thickens it as it travels, and a thunder front measured a few hundred metres out is tens of microseconds wide where one measured several kilometres out is a millisecond and more. That is far faster growth than the wave itself lengthens, so a strike at 300 m is markedly brighter than one at 3 km rather than almost as sharp. *Crack* sets how sharp the front is allowed to be at all — at 0 % it is a dozen times slower and the shock is a thud — and the range decides how much of that survives.

A clean N-wave's spectrum falls at 6 dB/oct above its peak, and measured against the close recordings that is short above 2 kHz. So every front also carries a burst standing for the fine roughness of the channel: inside one coherent element the channel still wanders, on a scale of centimetres to a metre, and every wrinkle of it radiates its own small front.

What that burst is made of decides whether a strike tears or sizzles. It is not noise but a train of steps, sampled and held for the time one wrinkle takes to pass, whose spectrum is flat up to $c / \text{roughness}$ and falls at 6 dB/oct above it — exactly as the main front's does. *Crack* chooses the scale, from 55 cm down to 12 cm, so a hard strike tears on a finer scale and is brighter for it. White noise is flat to Nyquist instead, and against the close recordings that puts 15 to 25 dB too much into the 1.25 to 5 kHz band, which is heard as a crackle laid over the thunder rather than as the thunder's own edge. The burst goes through the same air as the wave, which is why a close strike has it and a distant one has lost it.

Impact, and what is not linear about a close strike

Everything above is linear acoustics, and a thunder heard from ten kilometres is linear acoustics. A thunder heard from four hundred metres is not: its shock is a hundred pascals and more, and *Impact* is the one control for the two things that follow from that. Both belong to the near field, which is why one knob carries them and why every factory preset sets it from its own *Distance*.

The first is the **blast**. Every element of the channel radiates its own N-wave, but the near section of a return stroke also expands as one body, and what that sends out is a blast rather than an N-wave: a near-instant jump to peak overpressure, a decay back through zero, and a longer, shallower negative phase — Friedlander's waveform, whose spectrum peaks at $1/(2\pi T)$. It is a short cluster of such pulses, one taken from the loudest arrival in each slice of the first 350 ms, so the energy lands across the onset rather than on a single sample. It fills the 40 to 150 Hz that the reference recordings put at the top of the spectrum through the first 300 ms — a band the elements' own N-waves, each one short and each arriving at its own time, cannot fill between them however many there are.

The second is the **bend in the crests**. A wave that strong carries its own crest faster than its tail: the crest is eaten away as it travels and the energy it loses goes into the body of the wave, so the near field arrives far flatter than the linear sum of its elements. The close recordings show it plainly — a hard clap reaches its level in a few tens of milliseconds and then holds within two or three decibels of it for a hundred more, where a linear sum is a spray of separate spikes with ten decibels of air between them. *Impact* bends the crests of the summed shocks towards a ceiling by that much. The rumble does not go through it, because the rumble is the far field.

Turning *Impact* up changes the level a preset reaches, so raise it and set the *Output Gain* again.

The ground under you

The nearest reflection there is, and the model stood in free air without it. A listener stands on ground, so every shock reaches the ear twice: once direct and once off the surface a few milliseconds later. The two add in phase below the first cancellation — the pressure doubling that makes a thunder land in the chest — cancel at $c/2\Delta r$, and comb above it. For a

strike a few hundred metres off, with the ear 1.6 m up, the first notch runs from about 60 Hz for the part of the channel high in the cloud to 1.6 kHz for the part near the ground, clustered through 100 to 800 Hz. Bottom lifted, low mid hollowed, top untouched — which is what a notch filter over a close strike sounds like.

Ground scales it, and it is also the cheapest density in the engine, because every arrival becomes two. On Dry Crack, 0 to 100 % takes the crest factor over the 50 ms around the peak from 11.1 dB to 8.1 and the share of the first 200 ms within 6 dB of the peak from 67 % to 86 %. Real ground is neither perfectly reflecting nor flat, and what it scatters it takes off the top first, so the bounce comes back dulled and with half the tearing; at 0 you are in free air.

Bloom, and why a clap arrives thin

A clap is a stretch of channel arriving at once, and the arrivals do not switch on — they assemble. While only a few elements of the stretch have arrived, what is heard is the sharp edge of each of them, added incoherently. As the stretch fills in, the long parts of the waves start to add coherently, with amplitude going as the number of them, while the fronts keep adding as its square root. The bottom therefore gains on the top as the clap builds.

It is not a subtle effect in the recordings. Measured over 40 ms windows hopped by 10, the 30 to 120 Hz band comes up 15 to 32 dB over the first 20 to 40 ms while the total level rises 11 to 16, and the spectral centroid falls from 225 to 430 Hz at the onset to 76 to 100 once the clap has landed. A strike that starts at its final centroid has no bright leading edge, and without one it reads as soft however loud it is.

Bloom is that, and it does two things because one cause has two consequences. The body radiating while the clap gathers is smaller, so what it radiates is shorter and higher: each arrival's N-wave and each blast pulse's time constant are scaled by how much had gathered when they landed, and a shorter wave carries less energy, which is the level ramp. And the sum of the arrivals does not yet have enough of them to add coherently at long wavelengths, which is a highpass on the shock sum that opens as they gather.

The clock restarts on every return stroke, because a return stroke is a new clap and gets its own edge. Set it from the distance: a thunder from ten kilometres has its arrivals smeared over seconds and no clap that assembles in milliseconds, and all the far factory presets leave *Bloom* at zero.

The rumble

Thousands of N-waves overlapping are a rumble, but with a finite element budget they are also a crackle, so a noise layer fills in underneath. Its level follows the energy of the shocks arriving, integrated over a fifth of a second, and its lowpass follows either *Rumble Tone* or the air, whichever has taken more off. It is a band and not a lowpass, because a close thunder has less under 40 Hz than at 100. *Rumble Width* spreads it and *Drift* lets it wander across the field while the thunder plays.

Echoes and space

Echoes are the landscape: up to eight reflectors at distances *Echo Spread* apart, each duller and quieter the further it stands, and panned where it stands. A little of what comes back goes round again, because a hill throws the echo of an echo too, and the loop gain is a property of the landscape rather than of *Echo Level* — so the tail decays at the same rate however loud the echoes are mixed. This is what lets a thunder trail off instead of stop.

Space is the suite's room model: eight early reflections and an eight-line feedback delay network built from one physical size, with Sabine's law for the decay time, and its lowest highpass moved down an octave so it does not take the bottom off the thunder. It is the room you hear the storm from — a porch, a stairwell, a hall — not the storm itself.

Dynamics

Compress is a stereo-linked compressor at the very end, before the safety clipper, with a soft knee and automatic make-up: threshold and ratio move together, from nothing to -24 dB at 4:1, and a full-scale peak still comes out at full scale. What it does to a thunder is lift everything under the crack — the rumble, the far claps, the echo tail — towards it.

Comp Attack slow lets the first snap through; *Comp Release* fast pumps with the claps. The ratio is capped at 4:1 on purpose, because a hard ratio flattens the decay of the tail, and a thunder that never quite ends is worse than one never compressed.

Triggering

Mode decides what a note means.

MODE	WHAT A NOTE DOES
One Shot	One flash per note, played out whatever the note does afterwards
Gated	One flash per note; letting go fades what has not yet arrived, over <i>Release</i>
Storm	Flashes keep coming at <i>Storm Rate</i> for as long as the note is held

Storm mode fires as a Poisson process, never on a grid, and each flash draws its own distance, height, direction and stroke count from *Variation*. *Attack* fades the shocks in as they arrive, which softens a first crack. *Velocity to Distance* puts soft notes further away, up to eight times as far, and *Velocity to Level* does the obvious.

Variation

Every flash grows a new channel, and *Variation* scatters the settings it grows from: distance, height, cloud spread, tortuosity, branching, weight, crack, the number of strokes, their gaps and the azimuth the strike stands at. At 0 % every flash is a fresh channel with the same statistics; at 100 % the same preset gives you a strike overhead and a rumble over the hills on successive keys.

The plugin window

ThunderClap draws its own window with X11 and Cairo on Linux, and Cairo on the win32 backend on Windows. There is no toolkit dependency, which is what keeps the plugin one self-contained file. It is embedded in the host's own window through CLAP's GUI extension and repainted from the host's timer, and it resizes by zooming one layout, from half size to four times.

The header carries the wordmark, the preset name with its browser, the shock-activity meter — and a lightning bolt, grown afresh for every flash. The bolt is deterministic in the flash number, so the same flash always draws the same bolt.

Gestures

GESTURE	EFFECT
Drag a knob up or down	Change the value
Shift-drag	Fine control, a fifth of the travel
Double-click a knob, or right-click anything	Back to the default
Scroll wheel over a control	Step the value
Click a knob's value	Type a value in, with units
Click a selector's name	Open its list and pick a value
Click a selector's ◀ or ▶	Step one choice
Click the preset name	Open the preset browser
◀ or ▶ beside the preset name	Previous or next preset
SAVE	Save the current settings as a user preset
MIXER	Open the layer mixer

The line at the bottom of the window shows what the control under the pointer does — the same one-line explanation that appears in the *What it does* column of the parameter reference.

The mixer

Every layer's level lives on the panel that layer belongs to, which is right for editing one layer and wrong for balancing them against each other. **MIXER** opens the same controls arranged the other way round: one strip per layer, its level as a fader, its pan and its width as slim sliders under it. They are the plugin's own parameters, not a second set — moving a fader moves the knob on the panel, and the host sees the same automation it always would.

M mutes a layer and **S** solos one, which is how a preset gets built from nothing: solo one layer, get it right, bring the next one back. Several layers can be soloed at once.

Mute and solo are **not** parameters and are not saved with a preset. They work by holding a layer's level at the bottom of its range and remembering what it was, so while either is active the preset bar shows a **SOLO ON** or **MUTE ON** chip — click it to release every hold at once. **SAVE** releases them first, so a muted layer can never be written into a preset as a silent one, and so does loading a preset. Touching a held layer's fader also releases the holds rather than fighting the hand on it. Closing the mixer does not: soloing a layer and then going to its knobs on the panels is what the mixer is for.

Parameter reference

There are 47 parameters, grouped the way the plugin window groups them. Every one is automatable and modulatable from the host, and every one can be typed in directly by clicking its value in the window. The name in `code` is the key used in preset files.

OUTPUT

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Output Gain <code>gain</code>	-inf dB ... 12.00 dB	0.00 dB	Final output level of the whole instrument.

STRIKE

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Distance <code>distance</code>	0.20 km ... 20.0 km	2.00 km	How far away the lightning strikes. Near is a crack, far is a rumble. Level is compensated.
Height <code>height</code>	1.00 km ... 10.0 km	5.00 km	Height of the cloud base the channel comes down from. Taller channels rumble longer.
Cloud Spread <code>cloud_spread</code>	0.00 km ... 20.00 km	4.00 km	Length of the channel that runs inside the cloud. This is what stretches a distant thunder out.
Tortuosity <code>tortuosity</code>	0.0 % ... 100.0 %	50.0 %	How crooked the channel is. A straight channel claps once; a jagged one crackles and rolls.
Branching <code>branching</code>	0.0 % ... 100.0 %	40.0 %	Side branches off the main channel, each a smaller thunder of its own.
Strokes <code>strokes</code>	1 ... 8	3	Return strokes down the same channel. Each repeats the thunder a little quieter.
Stroke Gap <code>stroke_gap</code>	5.00 ms ... 500 ms	60.1 ms	Time between return strokes. Short gaps thicken the clap; long ones stutter.
Variation <code>variation</code>	0.0 % ... 100.0 %	50.0 %	How far each flash may wander from these settings: distance, height, strokes, direction.

SOUND

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Crack <code>crack</code>	0.0 % ... 100.0 %	50.0 %	Sharpness of the shock fronts. All the high end of a close strike lives here.
Weight <code>weight</code>	0.0 % ... 100.0 %	50.0 %	Length of each shock wave, and so how deep the thunder sits.
Swell <code>swell</code>	0.0 % ... 100.0 %	30.0 %	Shadows the low part of the channel, so the thunder swells in from the sky instead of cracking.
Rumble <code>rumble</code>	0.0 % ... 100.0 %	50.0 %	A rolling noise floor that follows the density of arriving shocks.
Rumble Tone <code>rumble_tone</code>	0.0 % ... 100.0 %	50.0 %	Lowpass corner of the rumble, 60 Hz to 1.5 kHz: a subsonic floor or a mid growl.
Air Absorption <code>air</code>	0.0 % ... 100.0 %	50.0 %	Humidity of the air: how much high end is lost per kilometre.
Scatter <code>scatter</code>	0.0 % ... 100.0 %	50.0 %	Random spread of level and length from shock to shock.
Focus <code>focus</code>	0.0 % ... 100.0 %	70.0 %	Directivity of each channel element. Focused, only the parts side on to you are loud.

Focus focus	0.0 % ... 100.0 % 70.0 %	Directivity of each channel element. Focused, only the parts side-on to you are loud.
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STEREO

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Width width	0.0 % ... 100.0 %	80.0 %	How far the channel's spread across the sky is mapped onto the stereo field.
Pan pan	-100.0 % ... 100.0 %	0.0 %	Direction of the strike, left to right.
Rumble Width rumble_width	0.0 % ... 100.0 %	90.0 %	Stereo spread of the rumble, independent of the shocks.
Drift drift	0.0 % ... 100.0 %	30.0 %	Slow wander of the rumble across the stereo field while a thunder plays.

ECHOES

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Echo Level echo_level	-inf dB ... 6.00 dB	-12.00 dB	Level of the long echoes off hills, buildings and the cloud base.
Echo Count echo_count	0 ... 8	3	How many distinct reflectors there are.
Echo Spread echo_spread	0.10 s ... 6.00 s	1.50 s	How far away the reflectors are, as the delay of the furthest one.
Echo Damping echo_damping	0.0 % ... 100.0 %	50.0 %	How much high end each echo loses on the way.

SPACE

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Space Amount space_amount	0.0 % ... 100.0 %	15.0 %	Mix of the room you hear it from: its first reflections and its tail.
Space Size space_size	0.0 % ... 100.0 %	50.0 %	Dimension of that room, 3 m to 90 m. Reflections and decay time follow from it.
Space Damping space_damping	0.0 % ... 100.0 %	50.0 %	Absorption of its surfaces: bright stone at the left, soft and absorbent at the right.
Ground ground	0.0 % ... 100.0 %	55.0 %	How hard the surface you are standing on is. Every shock arrives twice, direct and off the ground: that lifts the bottom and hollows the low mid. At zero you are in free air.

FILTER

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Filter Type filter_type	Lowpass, Bandpass, Highpass, Notch	Lowpass	Response of the global output filter.
Highpass highpass	20.0 Hz ... 2.00 kHz	20.0 Hz	Rolls off the bottom at 12 dB/oct. Off at the far left.
Filter Cutoff filter_cutoff	20.0 Hz ... 20.00 kHz	20.00 kHz	Corner frequency of the output filter. Fully open at 20 kHz.
Filter Resonance filter_reso	0.0 % ... 100.0 %	10.0 %	Emphasis at the cutoff frequency.
Filter Key Track filter_key_track	0.0 % ... 100.0 %	0.0 %	How far the played note moves the cutoff. Follows the most recent note.

ENVELOPE

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Mode mode	One Shot, Gated, Storm	One Shot	One Shot plays a flash out. Gated fades it when you let go. Storm keeps flashing while held.
Attack attack	1.00 ms ... 15.00 s	1.00 ms	Fade-in applied to the shocks as they arrive. Softens the first crack.
Release release	1.00 ms ... 20.00 s	1.25 s	Fade-out of what is still to arrive after the note is let go, in Gated and Storm modes.
Storm Rate storm_rate	1.00 /min ... 60.0 /min	6.01 /min	Average flashes per minute in Storm mode. They arrive at random, never on a grid.
Velocity to Level vel_to_level	0.0 % ... 100.0 %	50.0 %	How much note velocity controls loudness.
Velocity to Distance vel_to_distance	0.0 % ... 100.0 %	50.0 %	Soft notes strike further away. At full depth a gentle note is eight times as far.

SYSTEM

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Max Shocks max_shocks	128 ... 4096	2048	Number of channel elements per flash. Trade CPU against detail.
Random Seed seed	0 ... 999	0	Starting point of the random sequence. Zero never repeats a thunder.

DYNAMICS

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Compress compress	0.0 % ... 100.0 %	0.0 %	Lifts the rumble and the far claps towards the crack. Threshold and ratio move together; level is made up.
Comp Attack comp_attack	0.10 ms ... 100 ms	3.16 ms	How fast the compressor grabs a crack. Slow lets the first snap through.
Comp Release comp_release	10.0 ms ... 3.00 s	251 ms	How fast it lets go afterwards. Slow is a smooth swell; fast pumps with the claps.

IMPACT

PARAMETER	RANGE	DEFAULT	WHAT IT DOES
Impact impact	0.0 % ... 100.0 %	45.0 %	How hard the near field lands. Adds the blast the channel throws off and bends the crests of the shocks the way a wave that loud really does: a slam instead of a spray.
Bloom bloom	0.0 % ... 100.0 %	45.0 %	How long the clap takes to assemble. The strike arrives thin and bright and the bottom floods in behind it; at zero it all lands at once.

The preset library

18 factory presets ship with the plugin. They are installed beside the binary and exposed through CLAP preset discovery, so they appear in the host's own browser as well as in the plugin window's.

City Thunder

Thunder between buildings, the way a phone hears it: the near channel's blast hits first, claps wander over the roofs, then a deep late swell shakes the street. *(sfx, impact)*

Close Strike

A strike a few hundred metres off: a tearing crack, then a long, rolling decay with the hills answering. *(sfx, loud, impact)*

Cloud Crawler

Intracloud lightning crawling across the cloud base: nothing reaches the ground, and the whole sky rolls for half a minute. *(ambient, evolving, wide)*

Deep Sub

The cinematic one: long shock waves, a heavy rumble and nothing above 400 Hz. Feel it in the floor. *(sfx, dark, loud, impact)*

Distant Rumble

A storm a kilometre off: no crack at all, a slow deep roll that swells in from the cloud. *(ambient, soft, evolving)*

Dry Crack

Sharp and short: one stroke, a small channel, hardly any rumble and no echo to speak of. *(sfx, impact, short, bright)*

Far Horizon

Lightning on the horizon, twenty kilometres out. Very deep, very slow, more felt than heard. *(ambient, soft, dark, evolving)*

Gated Rumble

Gated: the thunder lasts as long as the key does. Short notes for stabs of rumble, long ones for the whole roll. *(sfx, rhythmic, evolving)*

Heat Lightning

A storm too far to see properly: the odd flash on the horizon every quarter minute, barely a murmur each. *(ambient, soft, dark, storm)*

Heavy Impact

A strike close enough to arrive as one blow: the near channel's blast lands first and dark, the claps pile in behind it, and the whole thing is over in a few seconds. *(sfx, loud, impact)*

Hollow Strike

The cinematic impact: a close strike with the low mid scooped out, so the bottom and the crack land on either side of a hole. Not what a recording measures, and the one preset in the library that is a sound rather than a thunder. *(sfx, loud, impact, short)*

Mountain Echoes

A strike in a valley: every wall throws it back, and the echoes outlast the thunder itself. *(sfx, ambient, evolving)*

Overhead Crack

Right on top of you. A short, violent tear with almost no rumble: the sound of a strike two hundred metres away. *(sfx, loud, impact, short)*

Rolling Thunder

A crooked, branching channel a kilometre or so away: several claps, one after another, rolling for twenty seconds. *(ambient, sfx, evolving)*

Single Bolt

One clean bolt a kilometre off: a single stroke, a single clap, and an honest decay. (*sfx, impact*)

Storm Front

The squall is here. Flashes every few seconds, close and violent, with every setting thrown wide. (*ambient, loud, evolving, storm*)

Summer Storm

Hold a note and a storm passes: flashes every ten seconds or so, near and far, none of them alike. (*ambient, evolving, storm*)

Under The Rain

Made to sit under RainyDay's Storm Front: a storm seven kilometres off, softened, never stepping on the rain. (*ambient, soft, storm*)

Using it in a host

Notes

One note is one flash, and in One Shot mode the thunder plays out whether the note is still held or not — so a single sixteenth is enough to fire a twenty-second rumble. Use Gated when the arrangement needs the thunder to stop with the note, and Storm when it needs to keep going.

Parameters are read at the moment a flash fires, and they decide that flash. Changing *Distance* while a thunder is rolling changes the next one, not the one you are listening to. That is worth knowing when automating: put the move before the note, not on it.

There are 8 voices, with 12 flashes and 4096 shocks in shared pools, so the number of held notes cannot multiply the CPU cost without bound.

Automation and modulation

Every parameter is automatable, and host parameter modulation (`CLAP_EVENT_PARAM_MOD`) is supported globally. Per-note modulation and note expressions are ignored. Parameter changes are sample accurate.

Reproducible renders

Random Seed at 0 never repeats. Any other value renders the same thunder for the same notes every time, whatever the plugin was doing before them — the noise and the geometry come from separate generators, so idling cannot move the sequence along. Set a non-zero seed before bouncing anything that has to match a previous render.

CPU cost

A flash's channel is grown on the audio thread when it fires, which costs a few hundred microseconds at 2048 elements. *Max Shocks* is the control for that: it caps how finely the channel is cut, and halving it halves both the setup cost and the density of the crackle. After that, *Echoes* and *Space* are the next most expensive blocks.

Rendering and tails

Thunder has a long tail — the far claps, the echoes and the room can run for twenty seconds after the note. When bouncing, leave that much past the end of the last note, or the roll is cut off mid-decay.

Reference and limits

Where the model comes from

- Few, A. A., *Power spectrum of thunder*, J. Geophys. Res. 74, 1969.
- Ribner, H. S. and Roy, D., *Acoustics of thunder: a quasilinear model for tortuous lightning*, J. Acoust. Soc. Am. 72, 1982.
- Kappus, M. E. and Vernon, F. L., *Acoustic signature of thunder from seismic records*, J. Geophys. Res. 96, 1991.
- Guo et al., *Study and analysis of the thunder source location error based on acoustic ray-tracing*, Remote Sensing 16, 2024.
- Rusz et al., *Locating thunder source using a large-aperture micro-barometer array*, Front. Earth Sci. 9, 2021.
- ISO 9613-1, atmospheric attenuation, for the absorption figures.

What the recordings themselves settled is measured rather than taken from any of those: a close strike peaks at 80 to 160 Hz and is 42 dB down at 5 kHz; a distant one is nothing but the bottom two octaves; the attack is 20 ms, the clap a second and the rumble ten; and distant thunder takes seconds to swell in.

Notes and limits

- Linux and Windows, x86-64. Plugin state is stored little-endian.
- 8 voices, 12 flashes and 4096 shocks in shared pools.
- Host parameter modulation is supported globally. Per-note modulation and note expressions are ignored.
- Parameters read at the moment a flash fires decide that flash.
- Deliberately built without `-ffast-math` : on x86 GCC that links `crtfastmath.o` , which would flip the FTZ and DAZ flags for the entire host process.
- No rain and no wind — this is thunder only. RainyDay does the rain.

Versioning

Semantic versioning. **MAJOR** is an overhaul: a rewrite of the synthesis model, or a change that breaks existing presets or saved host state. **MINOR** adds something — a parameter, a layer, presets. **PATCH** is fixes that add nothing new.

License

MIT. ThunderClap contains no samples and no third-party code. The only external dependencies are the CLAP headers, which are MIT licensed, plus X11 and Cairo for the plugin window.

Reference recordings used during development are not part of the release and are not redistributable.