

## aerophone vst

Aerophone synthesizer uses physical modeling techniques to create a digital instrument with expression characteristics similar to cylindrical bore brass instruments such as trumpet and trombone.

This model consists simply of a third order mass-spring 'lip' coupled with a waveguide (tuned delay) 'bore' filtered for damping and dispersion produced by pipe curvature. Being an elementary model, it can produce timbres similar to acoustic instruments, however performance is not trivial as the model requires significant user control to approach emulative qualities.

The complexity and familiarity of conventional instruments is prohibitive for comprehensive modeling with predominant realtime technologies.

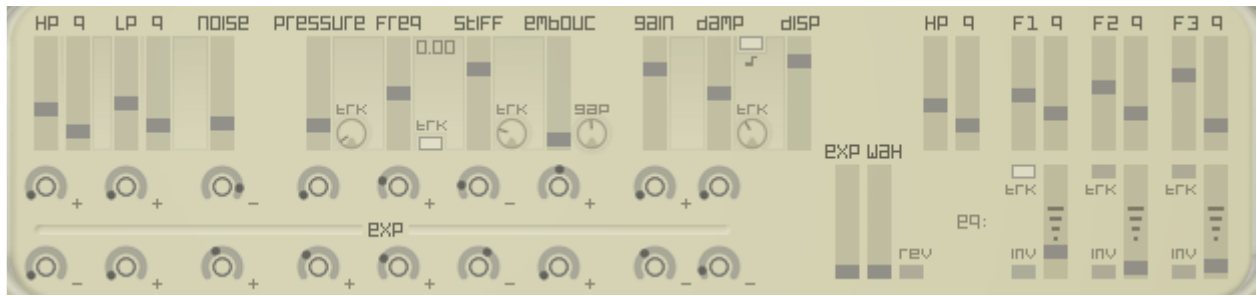
Aerophone offers the emulative synthesist a platform for an expressive regime of timbres associable with lip valve instruments. Be aware that there are a number of inherent obstacles to meeting this task in this format:

The ubiquity of the trumpet and variation of expression creates a demanding threshold for emulation. An inclusive waveguide structure (or equivalent filter structure) is necessary for convincing the ear that resonances at note transitions are produced by the physical circuit of air channels.

Various pitches on valved brass instruments are produced by resonating the lips at a harmonic relative to the fundamental of the open pipe length. It is possible to play harmonics with Aerophone with appropriate modulation, harmonics played on different notes are more timbrally similar in the reduced waveguide model.

Acoustic trumpets are complex and responsive acoustic systems that are still subject to innovation in performance technique. Factors of acoustic performance such as correct pitch are a function of the player's reaction. The reduced set of factors in the digital waveguide also produce variable conditions.

Aerophone requires the user to acknowledge the limits of the model in order to apply its advantages. A level of informed practice and application of controller performance to a varying parameter range target are necessary. A continuous hardware MIDI controller (wind controller, pad, ribbon, nl pitch stick) is advisable.



Articulations are improved by modulating several parameters to describe acoustic events. The expression and wah groups can be controlled from the front panel or from a single controller. It is necessary to modulate multiple parameters in use to produce similar expressions across the dynamic and pitch range of the instrument.

The acoustic circuit is produced by pressure waves being reflected at the bell and lip, so that changing the embouchure or other parameters affects the timbre and possibly the pitch. A primary consideration in performance is setting the stiff parameter for the desired timbre. Correct stiffness produces a bright and steady tone. Lower values produce an increasingly wavering timbre.

Higher stiffness settings produce a growling timbre, and excessive stiffness or pressure produces an unnatural pause between 'growl wavelets'.

For trumpet and similar brass timbres, steadily increasing pressure will produce a soft to bright timbre. In comparison, the transition between growling produced by high pressure and clicks from excessive pressure is not as wide. Avoiding this threshold is a consideration when performing energetic parts.

Smooth and bright loud timbres can be produced, even at high pitches, by reducing stiffness corresponding to higher pitch and pressure. For live performance, an additional manual controller assigned to stiffness can assist in voicing articulations.

A primary deficit of waveguide emulation are legato note transitions, as a tuned delay transfers previous harmonic energy to the new delay length, producing 'ping' artifacts. A conventional solution, crossfading between two delay bores at note transitions, is used here. Additionally, a short smoothed gap is applied to appropriate coefficients.

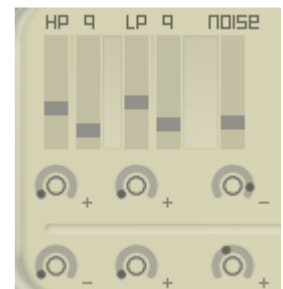
To improve emulative performance, deemphasising signal energy at note transitions can be accomplished by using a retriggered envelope to apply pressure and other parameters only during notes such as is used in several presets, and reduce them at transitions between notes.

This acoustic circuit offers challenges in the eliciting of it's emulative qualities. The mass-spring and bore are oversampled 8 times to produce fluid timbral performance in the conventional note range. Resultingly, qualities of acoustic performance are availed, such as the production of different harmonics by modulation of pressure alone.

## panel reference

A filtered noise source is summed with the pressure coefficient. While useful for adding breathiness to the attack, even high resonance does little to affect the timbre of notes voiced with high pressure.

Unlabeled dials located under sliders trim velocity responsivity. Using negative velocity modulation of noise amplitude improves the breathiness of softly played notes.





The lip or performer parameters are the primary concern during performance, relating breath pressure, resonant lip frequency, lip stiffness and embouchure, which limits movement in the mass-spring 'lip' by softlimiting the signal.

As discussed above, finding the correct settings for these parameters to cover the dynamic and note range of the instrument requires modulation. Unless other parameters are also modulated correspondingly, performance with only one parameter, such as pressure, will have a finite pitch or dynamic range.

The parameter set and ranges are intended for brass emulation with some leeway for other possibilities (such as the clarinet patches, which are fortunate considering the architecture). Some parameter options, such as pressure tracking, are less applicable to brass emulation.

The resonant frequency of the brass player's lips should be relative to the pitch. According to one study on lip valves, player's generally play slightly below the pitch. In this model, the frequency of the mass-spring 'lips' will correspond with timbral brightness, so that playing under the pitch will produce mellower tones.

In tracking mode, the numerical display indicates the frequency relative to the note in octaves (-4 to +4). Otherwise, the lip valve has a fixed frequency, more suitable for reed modeling, and displays the frequency in kilohertz (kHz).

The gap control introduces a short period between notes to emulate the loss of reflection during valve closures, which is more natural sounding with lower damping. Longer times improve emulation of some instruments while shorter times are necessary for legato phrasing with some patches.

synthesis note:

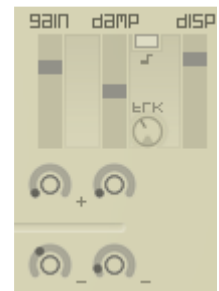
Modular synthesists may wish to know that, when compared to other waveguide systems, considerably greater numeric values are required to drive Aerophone to oscillation than eg. a plucked string model. Similarly, the stiffness coefficient represents the "returning force" in a spring operating at 8 times the samplerate. While the stiffness slider is ranged from 0 to 1, a logarithmic curve is applied so that most slider positions are between 0.99 and 1.00 (absolute stiffness, eg. the full returning force is applied on each sample, or 8 times per sample..)

This combination of 'extreme numerical representations' cultures an appreciation for the performers of brass instruments!

The bore gain, or pressure reflected at the bell, describes the overall reflectivity of the system. A small aperture will produce higher gain. Setting the gain to correspond with the instrument to be emulated should be the first step in patching, as adjusting the gain will detune the circuit. Low gain settings can be heard to be less stable, and make it difficult to produce desired pitch.

synthesis note:

Instability of the fundamental is an obstacle to both virtual and acoustic instrument design because of this, notably in the saxophone (aerophone is not appropriate for emulating conical bores, however low gain settings will produce familiar 'honking' timbres).



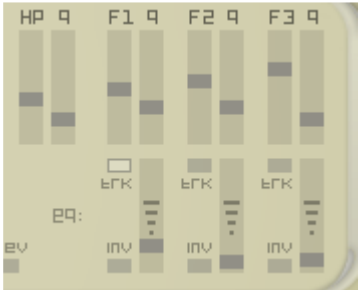
To retune Aerophone after adjusting gain or other parameters, finish patching for timbre, then use the fine tune control on the tuning panel to tune A3 (the center of key tracking). A constant value may also be applied to pitch using the send panel using the '10v constant' modulation source.

The second step to retuning is to assign tracking to pitch from the send panel. Play a note a few octaves away from A3. Holding [ctrl] while clicking will help to fine tune the tracking amount. The pitch of intermediate keys may have some slight nonlinearity but should be within a few harmonic beats per second of the correct pitch.

Damping is modeled with a 18db lowpass filter. The bell of wind instruments acts like a crossover filter, passing high frequencies and reflecting low frequencies back into the bore (generally the wavelength of the crossover frequency corresponds to the diameter of the flare.. 11cm for a standard trumpet is about 2.5kHz at the speed of sound). The steeper filter helps to reduce high frequencies that can sound unnatural and cause artifacts in the bore at note transitions (most patches use retriggering envelopes to raise damping during the note and reduce it between notes).

Damping can be set at a static level or follow the keyboard. the note icon performs pitch correction for the damping setting.

Dispersion (a second order allpass filter) models reflections in the bore caused by bends, although in most performance conditions (those with high pressure, such as trumpet patches) its effect is not audible. It can be used to disperse standing signal energy due to the frequency dependent phase response of the allpasses and create a more acoustic texture or improve other patching issues.



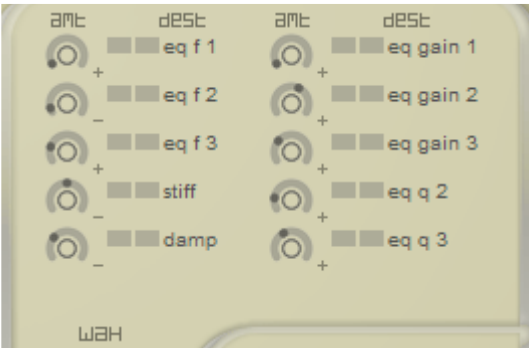
Accurately modeling the bells of wind instruments is unfortunately a strong degree of distinction between development teams. Several methods were proposed and disregarded based mostly on quality and to a much lesser degree on cpu. Technically, the effect is that higher frequencies, or higher partials of the desired note, penetrate further into the bell before being reflected. This frequency responsivity is not conveniently recreated in the predominant dsp vocabulary.

To augment timbral flexibility and utility of this instrument, an eq section is placed after the acoustic circuit. The signal is first passed through a resonant 12db highpass, then through three eq stages (Robert Bristow-Johnson biquads).

Eq frequencies can track the key or retain static values. By tracking the pitch, eq bands can be assigned to partials. The clarinet patches were created by subtracting the first three even partials.

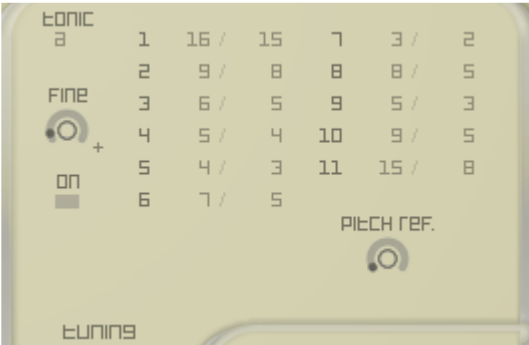
The wah panel, like the expression function, allows a group of up to ten parameters to be modulated by one controller to model manual blocking of the bell.

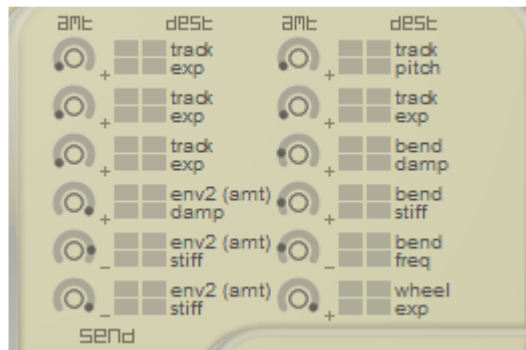
A number of the presets use the wah panel for patching fixed mutes which are not intended to be 'wah'ed.



The tuning panel allows just intonations to be applied. Note that each numeric field has two drag regions, one for the digits and tens, and one for the hundreds and thousands.

When not applying just intonations, the tuning panel auditions a sawtooth oscillator for tuning reference.



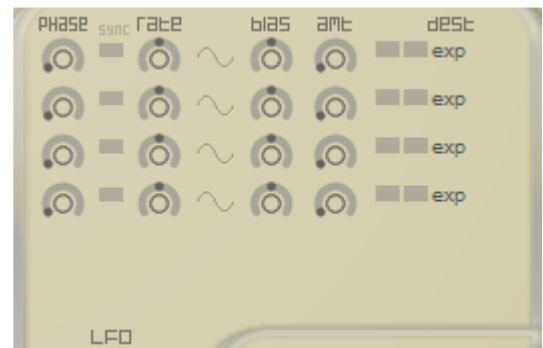


The send panel allows modulators to be assigned to multiple destinations to augment acoustic emulation. A heirachal format is applied to routing:

send	sources	destinations
10 - 12	external modulation	lfo 1-4, envelopes
7 - 9	+ lfo 3-4	lfo 1-2, envelopes
4 - 6	+ envelopes	lfo 1-2
1 - 3	+ lfo 1-2	audio signal path

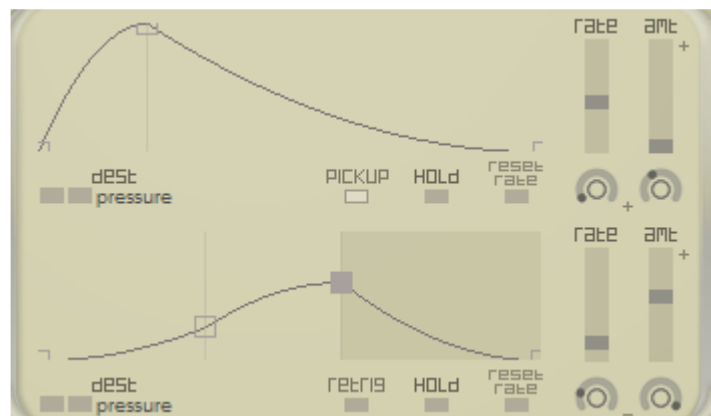
For convenience, all xoxos VST with a send panel use this same heirarchy (LFOs > envelopes > LFOs).

The standard LFO implementation may be synced to host rate at 64, 32, 16, 8, 4, 2, 1, 2/3, 1/2, 1/3, 1/4, 1/6, 1/8, 1/12, 1/16, 1/24, 1/32, 1/48 and 1/64 measures. Bias controls have a region in the center for resetting them to zero.



The graphic envelopes are created by Chris Kerry, most envelope parameters are accessed by clicking anywhere on the envelope.

In retrigger mode, envelopes are reinitialised on each note. This mode is appropriate for routing "performance" coefficients to parameters, so that a patch requiring a high pressure level isn't left at high pressure between notes, as it would be by using the pressure slider to assign playing force.



In pickup mode, envelopes continue smoothly and perform in standard legato fashion with legato playing.

Adjusting the rightmost envelope stage will change the overall envelope time. The 'reset rate' button resets the envelope to the rate determined by the rate slider

This instrument isn't for everyone! The model is capable of impressive acoustic emulation and bears shortcomings in the same respect (such as the timbral similarity between different notes when the ear expects different valves) both being evinced by the application and abilities of the user.

Knowledge of acoustic performance almost always translates to models.. for instance, trumpet players 'fluff' the bore before producing a pitched note to prevent an audible delay as the oscillation builds. Waveguide brass is also improved in attack time by using momentary envelopes at the beginning of legato phrases, and a short 'onset' will be heard when using level performance coefficients.

The objective of Aerophone is to improve the expression of brass VST instrumentation. The assets of this algorithm are more suitable for some brass applications than others, and utility is dependent on user knowledge.

## notes

I am not sure that I've done any more than heard of Perry Cook's HosePlayer model from the 1990's. I expect Aerophone is essentially similar in form. Hopefully we're closer today to having the 1990's CCRMA models in VST format.

One of the more interesting aspects of brass played in a manner suited to Aerophone's abilities (c. 1930's) is the use of vocal formants, as players often 'speak' through their instruments. To render this virtually it would be necessary to couple the bore with considerably more dsp, which would also have to be expressively articulated.

Given that this is not feasible, Aerophone has an audio input line routed to pressure if you use it in a modular environment. Based on the observation that Aerophone's timbre is primarily produced by the movement of the lip valve and tends to occlude the filtered noise section, I have not attempted to route an audio signal into the VST yet, being confident that the result will not have emulative utility.

## license

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Aerophone VST is made with SynthEdit - <http://www.synthedit.com>

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