Lux Brainwave Entrainment Instrument

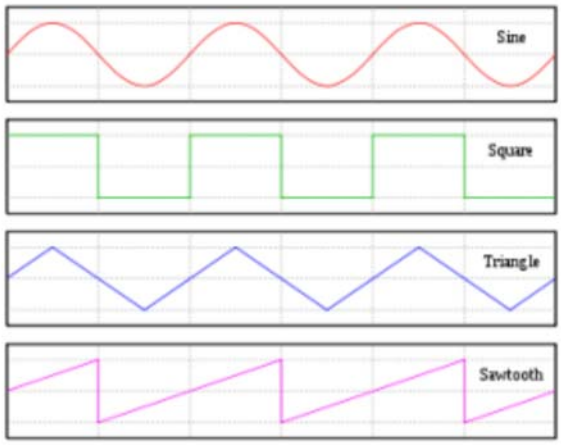
Concepts

While Lux is a synthesizer, it's not the kind of instrument you'd play with a keyboard – although that is possible. It should be thought of as "blinking" generator. It is constantly sending out signals: audiostrobe (which is a nearly inaudible, high-pitched tone which controls your AVS machine's light goggles), noise, binaural beats, and either a loaded WAV file or other audio piped in from your DAW. The guts of the plugin deal mainly with turning these signals off and on to create pulsed signals to which your brainwaves may become synchronized. Let's look at audiostrobe signals as an example.

Audiostrobe

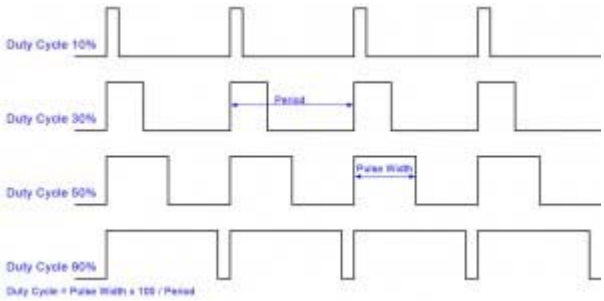
Audiostrobe is the specification for the signal that controls your AVS machine's LED goggles. If you were to send a pure sine wave tone with a pitch of 19.2 kHz to your AVS machine, it would make the LEDs in your goggles light up brightly. If you turned down the volume of that tone, they would get dimmer and dimmer. Likewise, if you raised the volume, they'd get brighter and brighter. Audiostrobe uses two signals; one in the left channel and one in the right. AVS machines that support more than one color (such as the Mindplace Procyon) let you choose which colors correspond to each channel. Mine is set up with the red LED listening to the left channel, and the green and blue LEDs listening to the right. Lux controls these audiostrobe signals by modulating their volumes with various waveforms.

Waveforms



The graph above represents volume over time. The sine wave gradually curves from full volume to zero volume and back again. The pulse wave abruptly switches from full volume to silence and back. Understanding that your AVS machine translates the volume of the audiostrobe signal to the brightness of the LED, you can see how using different waveforms on the light signal would give you different "blinking" visual effects. These same waveform concepts also apply to the other modules in Lux, only you should think of the waveforms as modulating volume, not brightness.

Pulse Width



The pulse wave may seem boring, since all it seems to do is turn off and on. In fact, it is one of the best waveforms for brainwave entrainment (see isochronic tones below). One of the things that makes it special is a parameter called pulse width (AKA "duty cycle," as labeled in the image above). For each cycle of the waveform, you can also define how long it stays on vs. how long it stays off. Playing with pulse width makes some very cool visual effects, and it sounds great on audio modulation as well.

Rate

If you modulate the light or audio signal at the right speed, your brainwaves can eventually begin to synchronize to that same rate. A lot of design went into giving you plenty of control over the modulation speed so that you can achieve the entrainment results you desire. The rates of any of the LFO modules or the Binaural Beats may be set manually, or they may be synchronized to a number of sources, such as your DAW's project tempo, the clock module, or even another module. In fact, you can set up very complex synchronization relationships. For instance, you can set the clock module to slave to your DAW's tempo, resulting in a modulation rate of 9 Hz (a nice alpha rate).

Then, you can set other modules, like the noise LFO, to modulate at 1/2 of the clock's rate (in this case 4.5 Hz), and the Audio LFO at 2 times the clock's rate (18 Hz). Once these relationships are set, they stay set. You can slow down or speed up the project tempo, and the Noise and Audio LFOs will slow down or speed up along with it, always preserving the 1/2 and 2x rate relationships respectively.

Phase

Imagine that your red and green LEDs are flashing at exactly the same rate – both turning on and off at exactly the same time. The LEDs are in phase. If you slow down the green LED for a little while, then bring it back up to the same rate, it's unlikely that the LEDs will be turning on and off together anymore. In other words, while they may be blinking at the same rate, the red one is now turning on a little before the green one. The LEDs are now out of phase. How much the LEDs are out of sync is called the phase offset. Phase offset is measured in degrees. Most of the LFO modules in Lux give you control over this parameter, with a range from -180 to +180 degrees.

Lux's brain is also programmed to keep all the various modules which are synchronized with each other in perfect phase. Most of the time, after you synchronize a module's rate to another source, you'll want it to be in phase with that source. In the background, Lux has a dedicated phase clock which constantly outputs little reference pulses to which the modules may synchronize. Sometimes, a module has to wait a while for the sync pulse to come along, and then at that point, it "jumps" into phase. You might hear this jump as a slight glitch in the audio. I wish I could find some way to avoid it, but until it's figured out, the best thing to do is to anticipate it and design your sessions in such a way that they're minimized.

Binaural Beats

> *"The sensation of auditory binaural beats occurs when two coherent sounds of nearly similar frequencies are presented one to each ear with stereo headphones or speakers. The brain integrates the two signals, producing a sensation of a third sound called the binaural beat. For example, if a frequency of 100 Hz is played in one ear and 107 Hz is played in the other ear, a binaural beat of 7 Hz is created by the brain. Brain waves match or "follow" the binaural beat. If the binaural beat is 7 Hz, an increase in brain waves of 7 Hz occurs."* – Monroe Institute

Binaural beats have 2 components: a base pitch (which is the audible pitch of the sine tones), and a beat rate, (which is the amount, in Hz, that these pitches are offset in each ear to generate the beating sensation). Lux has a dedicated binaural beat generator which gives unique control possibilities for each component. You can even play it with a keyboard.

Isochronic Tones

"Isochronic tones are regular beats of a single tone used for brainwave entrainment. Similar to monaural beats, the interference pattern that produces the beat is outside the brain so headphones are not required for entrainment to be effective. They differ from monaural beats, which are constant sine wave pulses rather than entirely separate pulses of a single tone. As the contrast between noise and silence is more pronounced than the constant pulses of monaural beats, the stimulus is stronger and has a greater effect on brain entrainment." – Wikipedia

Basically, Isochronic Tones can be achieved by modulating audio volume with a regular waveform. The Audio, Noise, and BB (Binaural Beats) LFOs can all be used to create this effect. For best results, use the pulse waveform.

Using Lux

Connections

If you want to use Lux BWEI with an AVS, or Mind Machine, the connection is basically the same as you would make if you were listening to an audiostrobe CD. Simply connect a 1/8" stereo cable from the output of your audio interface to the AUX in of your mind machine.

Tracks

When loading Lux into your DAW, you will be presented with an option to load multiple output channels. I recommend that you allow the default channel setup, as all of the bundled presets depend on the various modules having their own output channel. If your DAW does not prompt you to build separate channels for each Lux output, then it is easy to do so manually. Just create 3 new stereo audio tracks. Make 3 stereo sends from the Lux master track, then set each of your 3 new tracks to receive those sends.

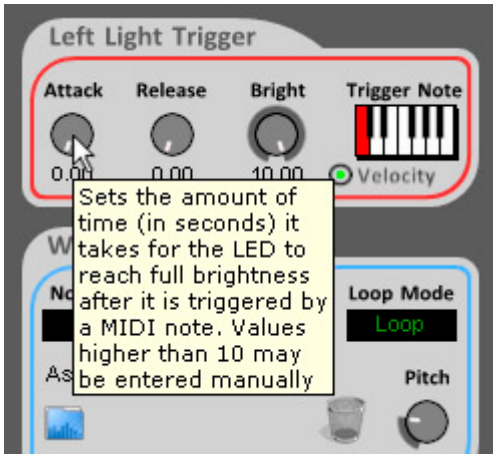
Having separate audio tracks for each of the output modules gives you a lot of control. Each of the tracks may be further processed. For instance, you could get really wild and try things like running the audiostrobe track through a phaser, or adding delay & reverb to the noise track. Separate channels also make it easy to mix and master your

composition for public release.

Please note that the audiostobe tracks (output from the Left & Right LFOs and Triggers) are automatically routed to outputs 1 & 2. They cannot be changed. All other audio producing modules give you a choice about where to send their outputs.

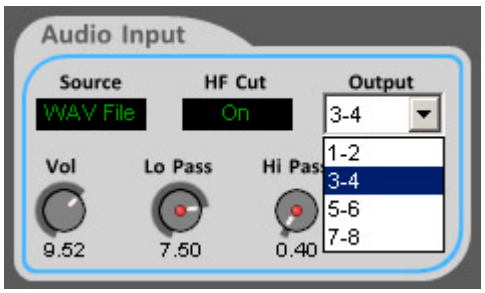
The Lux Interface

Tooltips



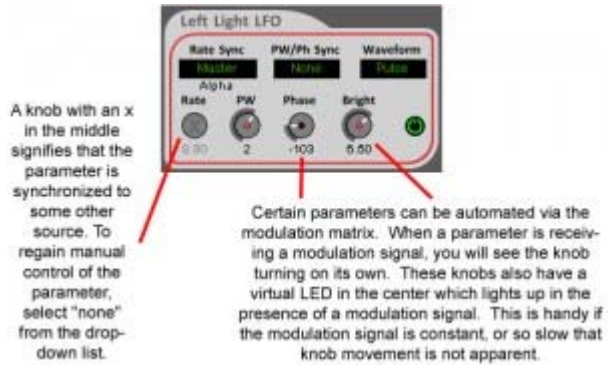
If you hover your mouse over any parameter for a few seconds, a tooltip will appear, explaining its function.

Dropdown Lists



The black bars with green text are dropdown lists. Click anywhere on the bar to display a selectable list of options.

Knobs



Knobs in Lux work just as you'd expect: click on it, then drag up to increase the value – down to decrease it. If you want the change to happen more slowly, hold CTRL while clicking & dragging.

Certain knobs within Lux will change depending on their settings. For instance, if a sine wave is selected, then Pulse Width (PW) is an invalid parameter. Lux takes this into account by showing an 'x' in the center of the knob, while the text readout displays "n/a". Knobs also change when parameters are synchronized to another source outside of the module, or when they are receiving a modulation signal from the Mod Matrix. See the illustration above for more detail about how the knobs change.

On certain knobs where it makes sense to have a default value, you can quickly double-click on the knob to restore it to the default.

Below each knob is a text readout which displays the value of the parameter. By clicking on the text, you can enter very precise values with several decimal places. Lux will accept the value, however, the text readout may not accommodate the display, since there is a fixed space for the text field. Text fields can also accept values higher or lower than their knobs allow. For instance, the LFO rate knobs stop at 30 Hz. If you need 45 Hz, simply enter it into the text field.

Modules

Below, you'll find detailed descriptions of all the various modules in Lux BWEI.

- Modulation Matrix

Clock

Since the key to brainwave entrainment is synchronization, a lot of design went into making the various components stay synchronized with each other. The core of the system is the unit's master clock. This clock can be set manually to any frequency from sub-delta (< 0.5 Hz) all the way up to the beta range (45 Hz) or even higher (although you might not want to use it at such high frequencies). The clock may also be slaved to the DAW's project tempo, or one of several fractions or multiples of it. Several other Lux modules have their own clocks, which can then be synchronized to fractions or multiples of the master clock. This allows the creation of complex sync relationships that can follow changes in tempo, yet still remain in sync.

Tempo Sync – this parameter synchronizes the clock to the DAW's project tempo. You can select musical lengths from as slow as 2 bars to as fast as 64th notes. Dotted values are also available.

(Hint: Tempos are measured in beats per minute, or BPM. This is a count of how many quarter notes can be counted in 1 minute. Therefore, 60 BPM = 1 beat per second = 1 Hz. The formula is Hz = BPM/60)

When the clock is not synchronized to tempo (that is, when Tempo Sync is set to "None"), the **Rate** knob can be freely adjusted. The text readout below the knob displays the rate value in Hz, whether the clock is sync'ed or not

The **Range Readout** appears just below the Tempo Sync dropdown list. It simply tells what brainwave range the current rate falls under, according to the following values:

Range	Frequency	Commonly Reported Effects
Sub-Delta	0 – 0.5 Hz	Unknown
Delta	0.5 – 4 Hz	Deep, peaceful sleep to deep relaxation
Theta	4 – 8 Hz	Deep relaxation, imagery, dreaming
Alpha	8 – 13 Hz	"Relaxed alertness", imagination, meditative mind
Beta	13 – 30 Hz	Heightened alertness & concentration
Gamma	30 – ? Hz	Unknown

Light LFOs

These are 2 of the 4 modules that send an (optionally) flashing audiostrobe (light) signal. They work by taking a constant audiostrobe tone and "chopping it up" with a waveform.

- **Rate Sync** – choose whether to synchronize the flashing to an outside source or set it manually ("None")
- **PW/Ph Sync** – choose whether to sync Pulse Width and Phase knobs to either the Audio, Noise, or BB LFO. This creates a cool effect which makes the lights correspond exactly to any changes to the audio module to which they're sync'ed.
- **Waveform** – choose whether to modulate the audiostrobe signal with a sine, saw, ramp, triangle, or pulse wave.
- **Rate** – When Rate Sync is set to manual, the Rate Knob lets you dial in the desired rate by hand.
- **PW** – (Pulse Width) changes the ratio of on/off for each cycle of the pulse waveform. Low values = mostly on. High values = mostly off.
- **Phase** – Waveforms usually start at zero. Phase offsets the start point of the waveform. The range goes from -180 to +180 degrees. + or – 90 degrees is perfectly out of phase.
- **Bright** – controls the volume (brightness) of the audiostrobe signal.
- **Range Readout** – appears just below the Rate Sync dropdown list. Click here for a fuller description.

Light Triggers

The light triggers use a MIDI note as a switch for turning the audiostrobe signal on and off. While the LFO is easy to program, it is only capable of one rhythm; the endlessly repeating cycle of the waveform to which it is set.

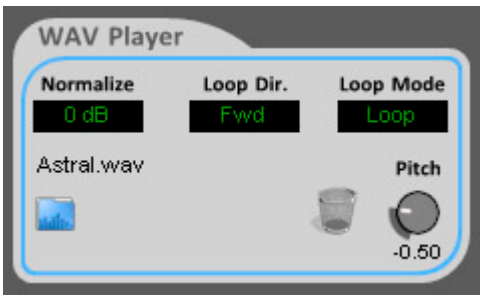
If you want to create a more interesting pattern, you can use the MIDI Light Triggers. By pressing the trigger MIDI note, you turn on the LED. Releasing the note turns it off. By varying the rhythm of your playing, you can make more complex patterns than the

LFO. Think morse code vs. a metronome. You can also use your DAW's MIDI sequencer to create very complex patterns that are impossible to play by hand.

Note that only the lowest octave of the MIDI keyboard (Notes 0 – 11) may be selected as triggers. This frees the remainder of the keyboard for playing binaural beats.

- **Trigger Note** – selects which MIDI key (on the lowest octave of the keyboard) will serve as the LED trigger.
- **Velocity** – When on, the LED brightness will vary according to how hard the MIDI key is pressed.
- **Attack** – Sets the amount of time it takes for the LED to reach full brightness after the key is pressed.
- **Release** – Sets how long it takes for the LED brightness to fall back to zero after the key is released.

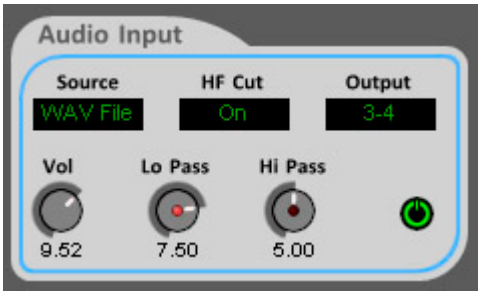
WAV Player



This module loads any WAV file and feeds it to the audio input module (see below) for further processing. It can load any size file, provided you have enough RAM to keep it in memory. I recommend using it with harmonically rich sounds which loops seamlessly.

- **Load Button** – (Blue folder icon) opens a file dialog for you to navigate to your WAV file. Note that for your saved presets to work correctly (especially when sharing with others), WAV files should be stored in the \VstPlugins\Lux BWEI_*.**\LuxData directory.
- **Clear Button** – (Trash Can Icon) clears the wav file from memory, but does not delete it from the disk.
- **Normalize** – Raises or lowers the volume of the WAV file so that its peak volume measures at the selected level.
- **Loop Direction** – Loop the file continuously forward "LOOPLOOPLOOPLOOP…" or forward, then reversed "LOOPPOOLLOOPPOOL…"
- **Loop Mode** – either loops the file, or plays it once, then stops (One-Off).
- **Pitch** – Slows down or speeds up the playback speed of the WAV file, by up to one octave. Higher or lower values can be entered manually.

Audio Input

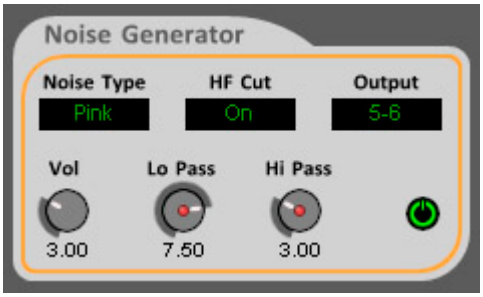


The Audio Input module receives audio from either the built-in WAV Player module, or external audio from your DAW (if your software supports it). For detailed instructions on setting up your DAW for audio input, read the advanced section.

The audio that comes through this module is sent to its own dedicated Audio LFO.

- **Source** – choose which audio source the module receives.
- **HF Cut** – Turns on a notch filter which removes a narrow band of high frequencies around 19.2 kHz (audiostrobe frequency) so that your audio doesn't accidentally trigger the LEDs.
- **Output** – selects a stereo output to which the audio will be routed after passing through the Audio LFO module.
- **Lo Pass** – Sets the threshold at which low frequencies are allowed to pass.
- **Hi Pass** – Sets the threshold at which high frequencies are allowed to pass.

Noise Generator



Noise is essentially all audible frequencies being played at the same time. If you were to count up all of the individual audible frequencies in the spectrum, you'd find that statistically, most of them are high-pitched. We therefore hear unfiltered noise as a somewhat high-pitched hiss. However, when shaped, noise has some pretty cool properties. It resembles the sound of falling rain, ocean surf, and wind. Because it has this relaxing effect, there is certainly a place for it in AVS sessions.

The noise module allows you to generate noise which can be shaped by the onboard filters and sent along to its own dedicated noise LFO.

- **Noise Type** – choose between white noise, which has more high-frequency components in its spectrum, or pink noise, which has fewer (making it sound less hissy and more dull)..
- **HF Cut** – Turns on a notch filter which removes a narrow band of high frequencies around 19.2 kHz (audiostrobe frequency) so that the noise doesn't accidentally

trigger the LEDs.
- **Output** – selects a stereo output to which the noise will be routed after passing through the Noise LFO module.
- **Lo Pass** – Sets the threshold at which low frequencies are allowed to pass.
- **Hi Pass** – Sets the threshold at which high frequencies are allowed to pass.

Binaural Beats Generator

The Binaural Beats (BB) generator lets you select various methods for setting the base pitch of the tones, as well as the rate at which the beats occur. There are also options for playing the tones with a keyboard.

Like the Audio Input & Noise Generator modules, the BB Generator has its own dedicated LFO for modulating the volume of the tones.

- **Rate Sync** – Choose whether to set the beats rate manually, or sync it to another source.
- **Range Readout** – appears just below the Rate Sync dropdown list. Click here for a fuller description.
- **Pitch Source** – Choose to set the base pitch of the sine tones manually from the Pitch knob, or via MIDI (through the keyboard).
- **Release Mode** – Sets whether MIDI key presses play forever, or whether they turn off when you release the key.
- **Output** – Selects a stereo output to which the BB signal will be routed after passing through the BB LFO module.
- **Rate** – When Rate Sync is set to manual, the Rate Knob lets you dial in the desired rate by hand.
- **Pitch** – Sets the base pitch of the sine tones.
- **Glide** – When playing the tones with a keyboard, glide creates a gradual shift from one pitch to the next when played legato. The knob controls how much time it takes to glide from one pitch to the next.
- **Attack** – Sets the amount of time it takes for the sine tones to reach full volume after a MIDI key press.
- **Release** – Sets the amount of time it takes for the volume of the tones to fall back to zero when the MIDI key is released. This only works when Release Mode is set to "manual".

Dedicated Audio, Noise, and BB LFOs

These are the modules which shape incoming audio to "flash" at various rates, either freely, or in sync with the lights. It is with these modules that you can craft isochronic tones by modulating the sources with a pulse wave. Each of these modules also constantly sends out its Pulse Width and Phase values to the Light LFOs so that you can slave the lights perfectly to the audio.

- **Rate Sync** – choose whether to synchronize the volume modulation to an outside source or set it manually ("None")
- **Range Readout** – appears just to the right of the Rate Sync dropdown list. Click here for a fuller description.
- **Waveform** – choose whether to modulate the audio signal with a sine, saw, ramp, triangle, or pulse wave.
- **Rate** – When Rate Sync is set to manual, the Rate Knob lets you dial in the desired rate by hand.
- **PW** – (Pulse Width) changes the ratio of on/off for each cycle of the pulse waveform. Low values = mostly on. High values = mostly off.
- **Phase** – Waveforms usually start at zero. Phase offsets the start point of the waveform. The range goes from -180 to +180 degrees. + or – 90 degrees is perfectly out of phase.
- **Depth** – controls the strength of the volume modulation. Set at zero, you hear no modulation at all. At 10, the volume cycles up to full blast and back down again to silence repeatedly at the set rate.
- **Smooth** – Softens the sharp edges of the saw, ramp, and pulse waveforms to minimize audible clicks.
- **Stereo** – (Audio & BB LFOs only) Delays one side of the stereo signal, giving a "widening" effect to the stereo image. Note that when set to 10, the stereo parameter effectively doubles the modulation rate. Entrainment purists may want to set the rate of the LFO to 1/2 the desired rate while using this feature at full blast.

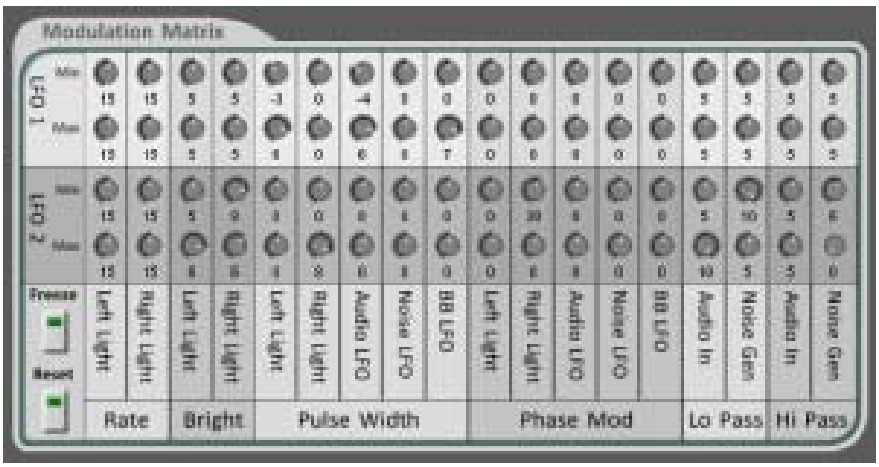
Modulation LFOs

This is where the possibilities for session design get really crazy. As you play with the parameters in Lux, you'll notice that the most amazing effects are created when parameters change over time. For instance, slowly changing the Pulse width of a Light LFO seems to create the perception of changing geometric patterns behind your closed eyelids. Tweaking the Noise Generator's Hi Pass filter sounds really cool. The Mod LFOs can be used to automate these kinds of changes over time.

The Mod LFOs do not output an audible signal. Instead, they output a waveform which can be used to control many other parameters in Lux. It is used in conjunction with the Modulation Matrix.

- **Rate Sync** – Since the type of modulation is not intended for brainwave entrainment, the sync choices available here are all divisions of the master clock rate.
- **Waveform** – Choose the waveform of the modulation signal. These modules have a much more extensive list of waveforms available. Experiment!
- **Rate** – When Rate Sync is set to manual, the Rate Knob lets you dial in the desired rate by hand.
- **Depth** – controls the strength of the modulation signal sent to the Modulation Matrix.

Modulation Matrix



Think of the Mod Matrix as a patch bay for modulation signals. It is with this module

that you take the signals from Mod LFOs 1 & 2 and tell them where to go and what to do.

Notice that there are separate horizontal rows at the top which correspond to the two Mod LFOs. Along the bottom are vertical columns which represent destination parameters. Each destination parameter has a pair of small knobs (Min and Max) for each Mod LFO, which gives control over how the parameter responds to the modulation signal.

It can be confusing, so let's look at an example: We want the Left Light LFOs brightness to change slowly over time; to gradually go from zero to full brightness. This can be achieved by sending a modulation signal from Mod LFO 1 to the Left Light Bright parameter.

First, set the Mod LFO 1 to a sine wave. Set its depth to 10 and make sure it's turned on.
In the Mod Matrix, find the Left Light Bright column and find the cell where it intersects the LFO 1 row.
Inside of this cell, set the Min knob to 0 and the Max knob to 10.

Now, when you play the session, you'll see that the Left Light LFO's brightness knob is illuminated with a red LED, and it appears to be moving on its own. If you decide you don't want the Left Light LED to turn off all the way as it's being modulated, you can adjust the Min knob to a higher value, like 5. Now, you'll see that the LED is gradually fading from full to half brightness and back again.

As you can see, the possibilities for creating visually and musically interesting sessions are greatly increased by using the modulation matrix.

- **Min Knobs** – Set the value that a parameter will take on when it receives the minimum value of a modulation signal; or in other words, at the trough of the modulation waveform.
- **Max Knobs** – Set the value that a parameter will take on when it receives the maximum value of a modulation signal; or in other words, at the crest of the modulation waveform.
- **Freeze** – "Pauses" Mod LFOs 1 & 2 at their current value, and then resumes when the button is clicked again. This is useful for investigating the cause of certain visual or audio effects. For instance, if you have a complex modulation patch set up in the Mod Matrix (with many parameters changing over time), you may notice that at a particular moment, a striking visual pattern appears behind your eyelids. If you click Freeze, you can then take off the goggles and study the various parameters to discover how that effect was achieved.
- **Reset** – Returns all of the Min and Max knobs to their default positions, effectively cutting off the modulation signal to all parameters. Individual Min or Max knobs can be reset by double-clicking on them.

A side-effect of using the mod matrix is that when you reset it, you'll notice that many parameters jump to a centered position. I have spent countless hours trying to find a solution to this behavior, but with no success. If I ever figure it out, I will certainly update the plugin. In the meantime, please just do your best to work around it.

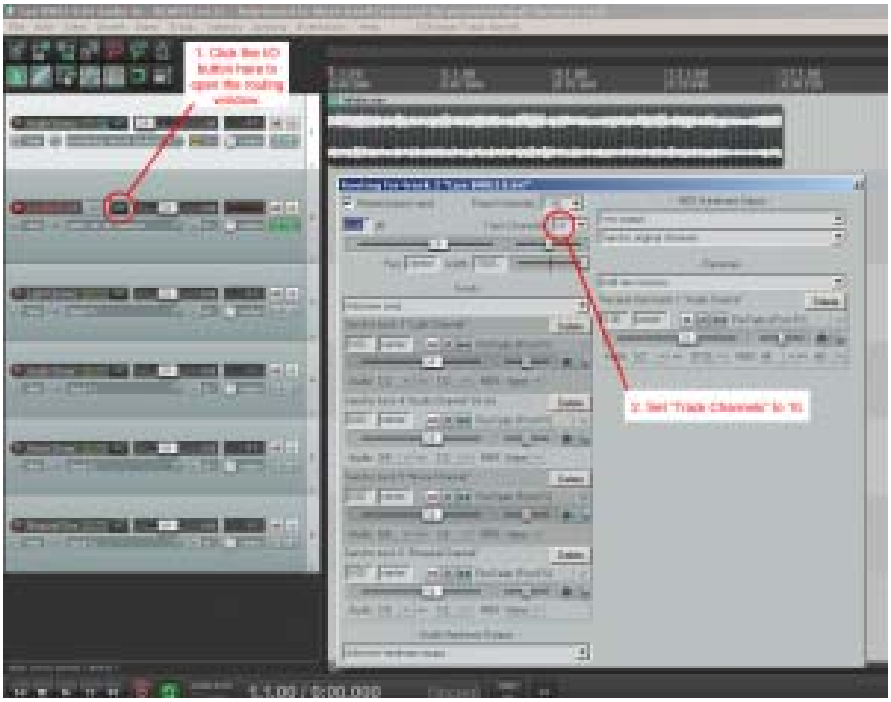
Advanced

Jump to signal flow diagrams

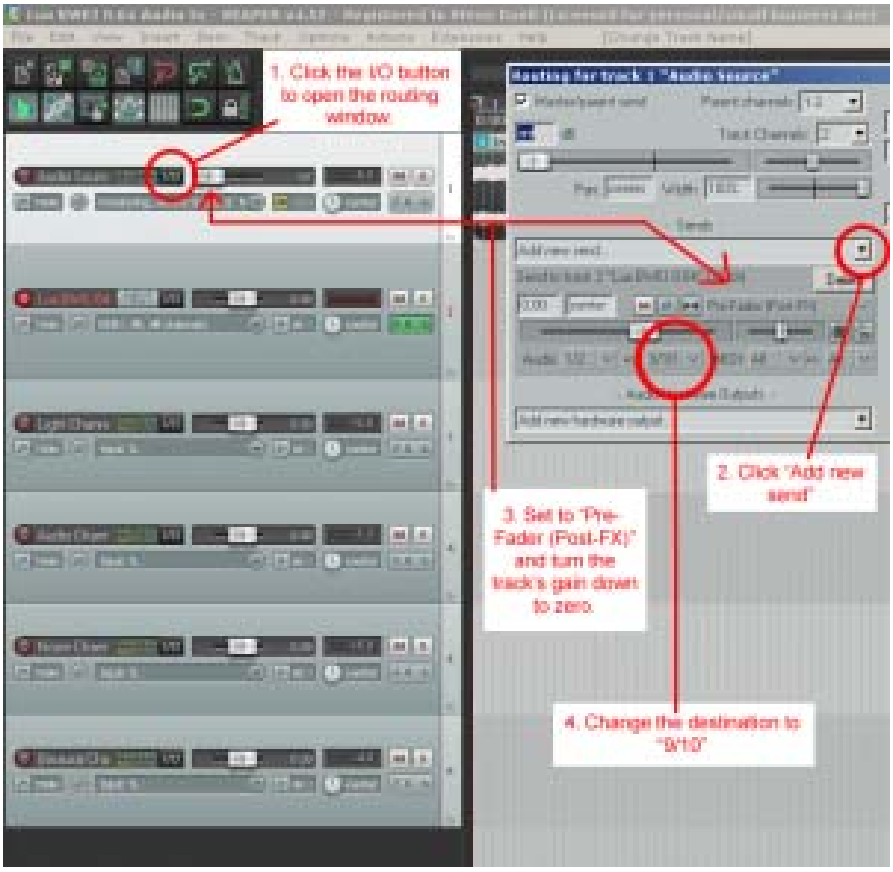
Setting Up External Audio Input in Reaper

The Audio input module can take its input from an external audio send from Reaper. This is especially useful if you compose music, and would like to make accompanying entrainment tracks that sync perfectly, even with tempo changes. Below are the steps you need to follow in Reaper to enable this feature:

- Open a project in Reaper.
- Load Lux onto an instrument channel and accept Reaper's suggested track layout.
- On the first Lux track, click on the IO button to open the routing dialog.
- Set "Track Channels" to 10.

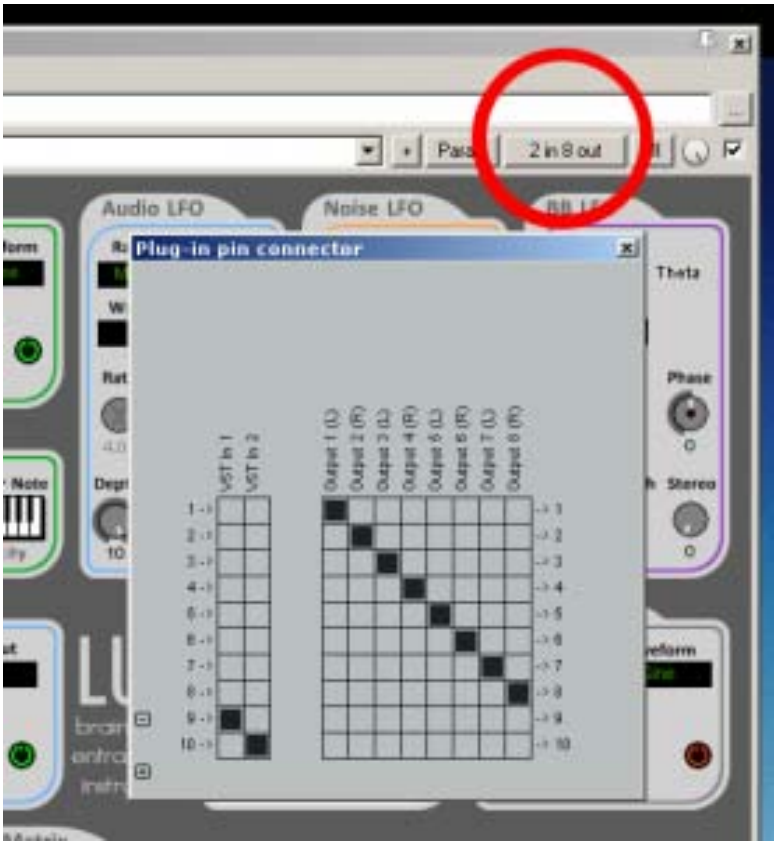


- On the Reaper track you want to send to Lux, click on the I/O button to open the routing options for the track.
- Under "Sends", click "Add new send".
- Set the output to "Pre-Fader (Post-FX)"
- On the audio track, turn down the volume to zero.
- Back on the routing options window, below the horizontal fader, change the destination to "9/10"



- On the 1st Lux, channel click on the FX button if the Lux GUI is not already visible.

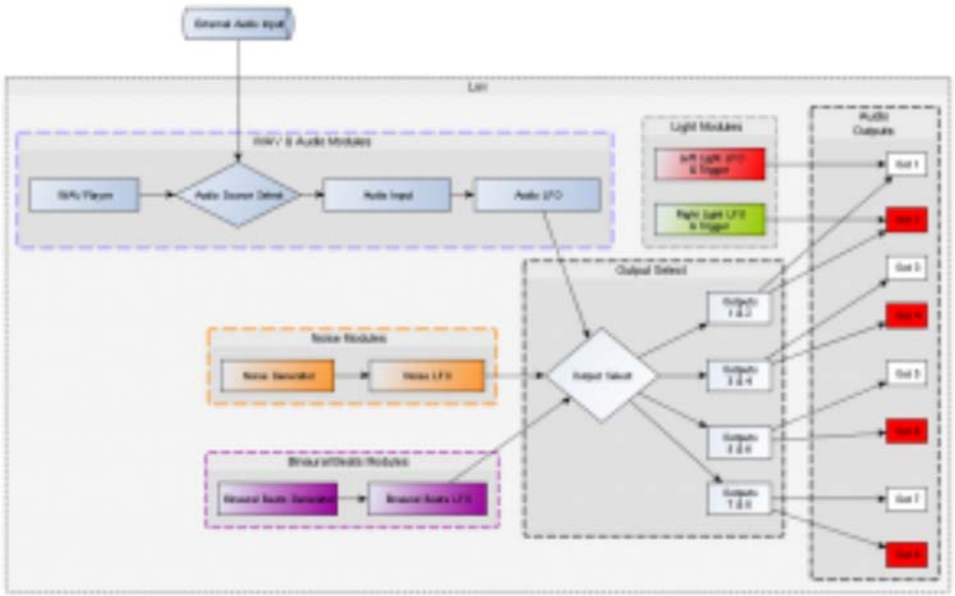
- On the Lux GUI window, click on the "2 in 8 out" button and make the grid look like the image below.



Now, you're all set! When you set the Lux Audio Input module to "Ext. Audio", any audio you pipe through that audio track in Reaper will be fed into the Audio Input module for further processing.

Signal Flow

People with engineering minds sometimes benefit from signal flow charts. Here is a diagram of the audio signal flow in Lux:



And here is a diagram of the data signal flow: