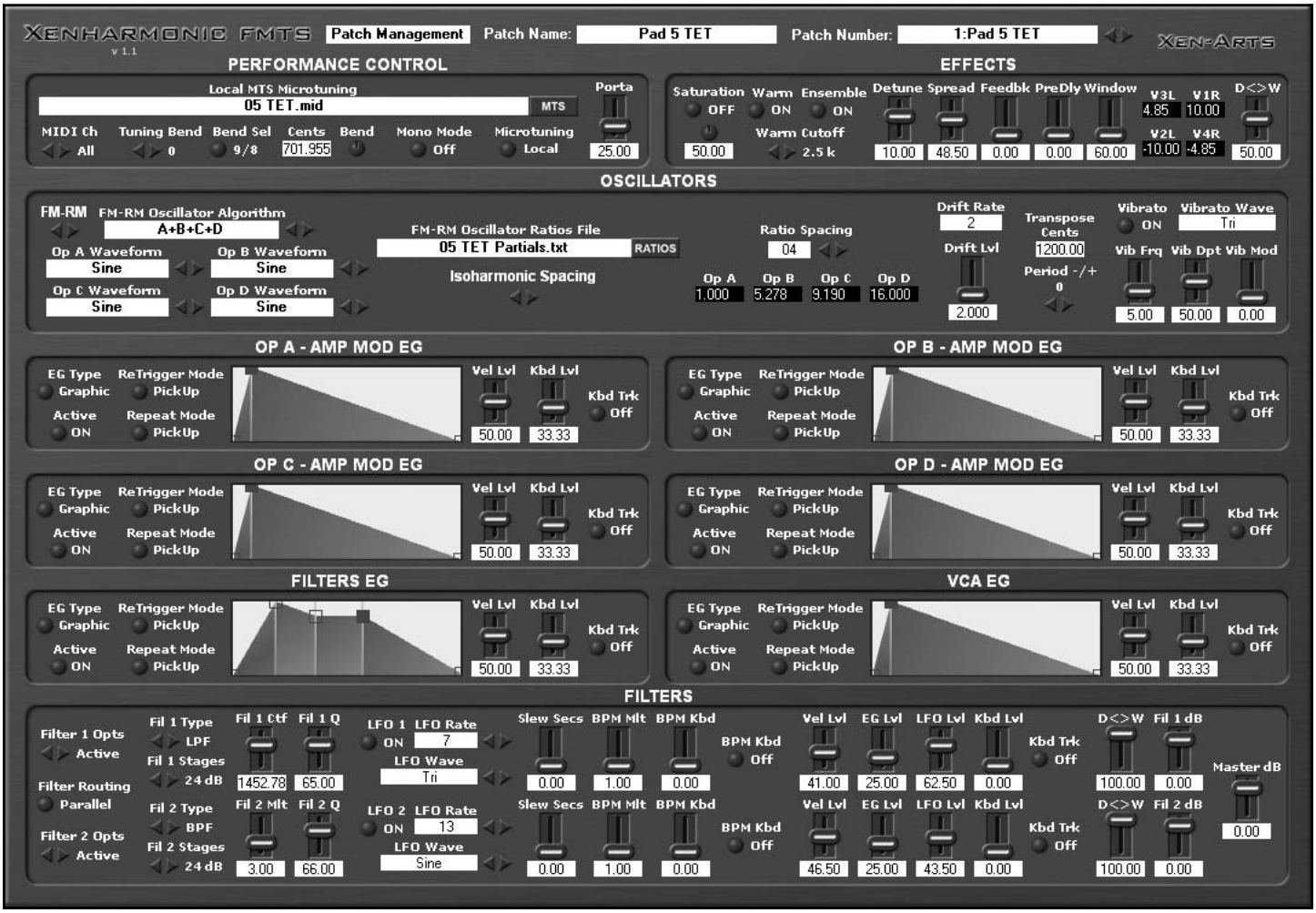
XEN-ARTS

Proudly Presents

XENHARMONIC FMTS

Version 1.1



An FM Synthesis VSTi For The Creation Of Microtonal and Xenharmonic Music

Xenharmonic fmts Manual - Table Of Contents

Xenharmonic fmts - A Message From Xen-Arts

Welcome, and thank you for your interest in downloading and making music with our Xenharmonic FMTS VSTi.

It has long been my feeling that one of the best ways to learn about the vast expressive potential of making music with alternative intonation systems is to have instruments available that include dedicated features for this kind of sonic exploration, where musicians and composers can gain firsthand experience of these intonations by actually playing them with their MIDI controllers.

This VSTi is the first in a series of Xen-Arts computer synthesis tools designed specifically for the study of musical instrument intonation and for the creation of xenharmonic and microtonal music. This instrument is inspired by the work of John Chowning (the inventor of FM Synthesis) and William Sethares (author of the book Tuning, Timbre, Spectrum, Scale), and has been created with a specialized set of features for the creation of xenharmonic and microtonal music.

Xenharmonic FMTS is capable of producing a wide range of harmonic, quasi-harmonic and inharmonic timbres. It is possible to use the instrument for synthesizing basic waveforms, as well as rich timbral effects that one might associate with ensembles of instruments playing in unison. At the former extreme, the sounds produced may display a strong sense of timbral fusion with little sonic motion, while at the latter, it is possible to design ones that feature acoustic beating and chorusing effects within the timbre itself. While there is a bank of patches provided that covers a nice range of the possibilities, creative exploration with custom sound-design is strongly encouraged. The included default presets can be viewed as starting points for creating custom timbres for particular compositional requirements.

One of the central themes of this VSTi is the feature that enables musicians and composers to easily quantize the operator ratios of the FM-RM Oscillator to values that are coincident with the intonation system being used for musical composition. Being able to quantize the operator ratios in this way can be used to produce microtuning related side-bands in the signal of the synthesizer, thereby creating an audible correlation between the intonation and timbre of the instrument.

Algorithm 1, A+B+C+D, sums all four of the operators of the FM-RM Oscillator directly to the output and can be used to experiment with simple 4-partial additive synthesis using sine waveforms. Increasingly complex timbres may also be created by using the other available algorithms (and waveforms), in which the operators are variously able to be summed together, frequency-modulate and or ring-modulate each other.

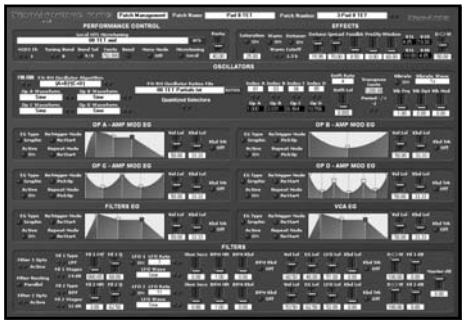
The intonation system of the VSTi may be changed by loading MTS (MIDI Tuning Standard) files, and the FM-RM Oscillator operators may be configured with text files. Included with the instrument are a basic set of MTS microtunings for equal-temperaments 5-31, Bohlen-Pierce, as well as a selection of octave-based sections of the harmonic and subharmonic series that can be used for the study of just-intonation. A small library of partials-files in the Windows TXT format are also provided for configuring the FM-RM oscillator ratios to values that are coincident with the microtunings.

Xen-Arts hopes that you will enjoy making music with this instrument and that it will inspire the deeper exploration of xenharmonic and microtonal composition and sound-design.

Best Wishes,

Jacky Ligon
Xen-Arts
January 2011

http://www.xen-arts.com



Xenharmonic fmts - Overview

The Xenharmonic FMTS VSTi is truly a collaborative effort involving many creative musicians, composers and programmers from around the world:

- Concept, construction, GUI, patch sound-design and this user manual by Jacky Ligon
- Assembled in the SynthEdit environment created by developer Jeff McClintock
- Includes modules developed by Chris Kerry, featuring his amazing CK 4-Operator FM-2 Add-Ring Oscillator, Standard Oscillator and Envelope Generators
- Includes modules developed by David Haupt
- Beta-testers included musicians Sean Archibald and Tony Dubshot who also offered many innovative design insights
- Enormous inspiration for this instrument was derived from the work of John Chowning and William Sethares

About Xenharmonic FMTS

The word **xenharmonic** in the name of this VSTi is a term coined by the late American composer, theorist and instrument builder, **Ivor Darreg**, to indicate music which is created with intonation systems that sounds distinctly different from the Western 12 Tone Equal Temperament. This type of musical practice encompasses both the use of so called microtonal intervals and tunings, having scale steps that are recognizably smaller than a 12-tet semitone, as well as macrotonal tunings, having scale steps larger than those found in 12-tet. **FMTS** is a concatenation of **FM** (Frequency Modulation Synthesis) and **MTS** (MIDI Tuning Standard).

FM (Frequency Modulation Synthesis) and Ring Modulation

FM Synthesis was discovered by **John M. Chowning** in 1967 and was later licensed to **Yamaha** who used it in the classic **DX7** synthesizer. In the most simple sense, complex timbres can be created by a **Carrier** oscillator, or **Operator**, which is frequency modulated by another **Modulator** oscillator, thereby producing **sideband frequencies** above and below the carrier frequency. The original DX7 used 6 sine-wave operators, while the Xenharmonic FMTS VSTi uses 4 operators with eleven different waveforms being available for each operator.

Ring Modulation is a signal processing technique in which two signals are multiplied and the resulting wave-form contains both the sum and difference frequencies of the two source signals. The Xenharmonic FMTS VSTi uses a special type of **Ring Modulation Synthesis** in which oscillator signals are multiplied and the source oscillator signals are mixed with the ring modulated sum and difference frequencies. The typical Ring-Mod function is replaced with ((X*Level_X) * (Y*Level_Y)) + (Y*Level_Y). This allows Wave_Y to sound alone and add in the Ring sound with Level_X.

MTS (MIDI Tuning Standard)

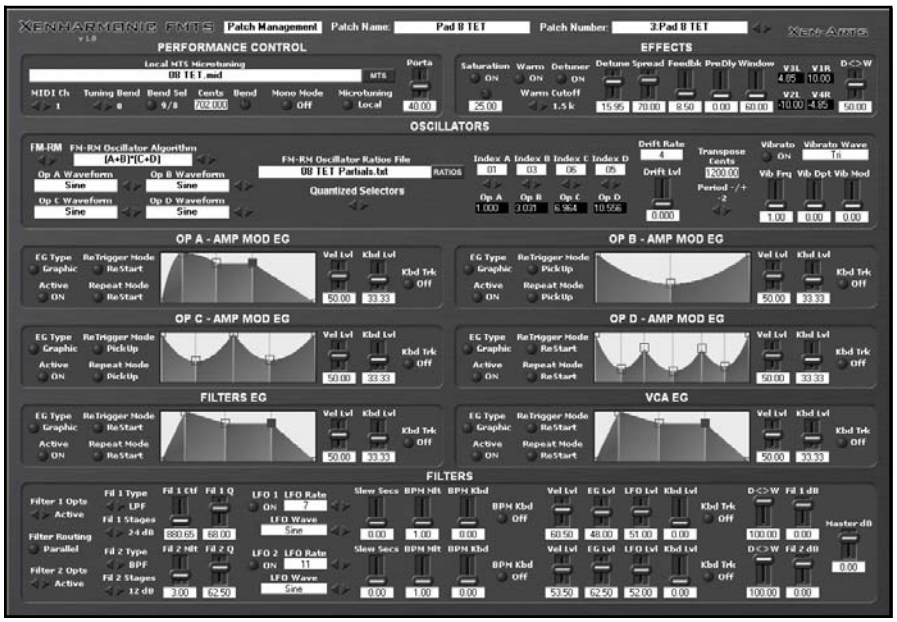
The MIDI Tuning Standard is a specification for microtuning MIDI instruments agreed upon by the MIDI Manufacturers Association and was developed by microtonal composers Robert Rich and Carter Scholz. The standard includes both Bulk Dump and Single Note microtuning with a resolution of 0.0061 cent, which essentially divides the octave into 196,608 equal parts.

The Xenharmonic FMTS VSTi can load internally, and receive externally, both Bulk Dump and Single Note MTS MIDI data.

Chris Kerry

This VSTi would not be possible without the DSP and programming skills of **Chris Kerry**, who has developed a line of **CK Module Packs** for the **SynthEdit** development environment. Xen-Arts wishes to here warmly thank Chris for his contribution to this project.

Xenharmonic fmts - Features



Xenharmonic FMTS is a 4 Operator FM Synthesis VSTi with a specialized set of features for musicians interested in exploring the expressive possibilities of microtonal and xenharmonic music making.

Microtuning Features

- Internally loads and externally receives both MTS (MIDI Tuning Standard) Bulk Dump and Single Note Microtuning Files.
- Operator ratios can easily be set to values that are coincident with the microtuning being used, thereby producing tuning related FM sidebands in the timbre of the instrument.
- Isoharmonic spacing of the operator ratios.
- Precise values may be set for microtonal pitch-bends.
- Arbitrary microtonal period shifting makes it possible to pitch transpose in both octave and non-octave increments.

FM-RM Oscillator

- 4 Operator FM Synthesis with Ring-Modulation.
- 57 Operator Algorithms.
- 11 different Operator Waveforms.

Phase & Pulse-Width Oscillator

- 22 Waveforms.
- Phase & Pulse-Width LFO Modulation.

Envelope Generators

- 6 independent Envelope Generators dedicated to modulating Operators A-D, Filters and VCA.
- Velocity sensitive.
- Keyboard tracking.

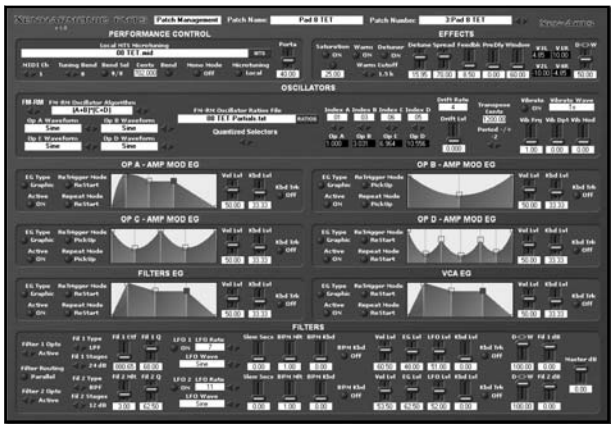
Filters

- 2 State Variable Filters with 12 and 24 dB response.
- Cutoff frequencies modulated by Velocity, Envelope Generator, LFO and Keyboard Tracking.
- Low Frequency Oscillators can be set to modulate the cutoff frequencies of the filters at audio rates, thereby producing sidebands in the signal.

Effects

- Saturator for subtle to extreme distortion.
- 6 dB LPF Warm Filter.
- 4-Voice Stereo Ensemble Detuner.

Xenharmonic fmts - System Requirements



System Requirements

OS: For Windows XP Pro or higher.

Host DAW: The VSTi was rigorously tested in Reaper, Cubase and FL Studio and is known to work without problems in these hosts.

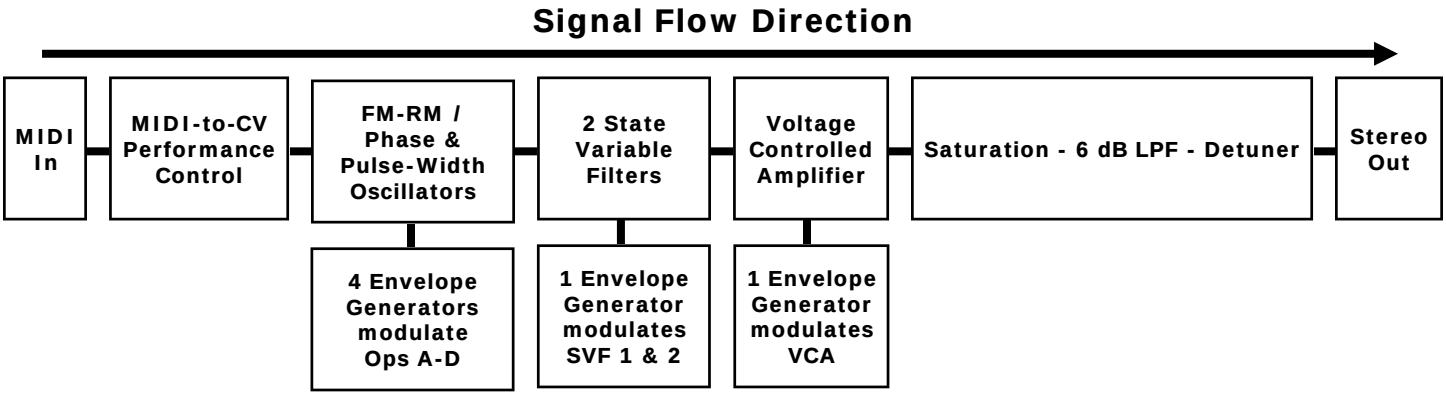
MTS Microtuning Creation: Install and use Scala to created your own custom microtunings for this instrument.

MIDI Controller: Requires the use of an external MIDI Controller such as a USB Halberstadt keyboard (standard 12-tone keyboard), a Generalized Keyboard such as the Axis-64 from C-Thru Music, the Opal Chameleon available from The Shape Of Music, the Starr Labs Microzone U-648 or U-990.

Installation

Extract the entire contents of the archive to your VST directory. This will place the VST DLL and all of the dependent files for the plugin in the required place and will insure the correct operation of all the synthesis features. Win 7 users should install the plugin in My Documents or some other directory other than Program Files due to UAC.

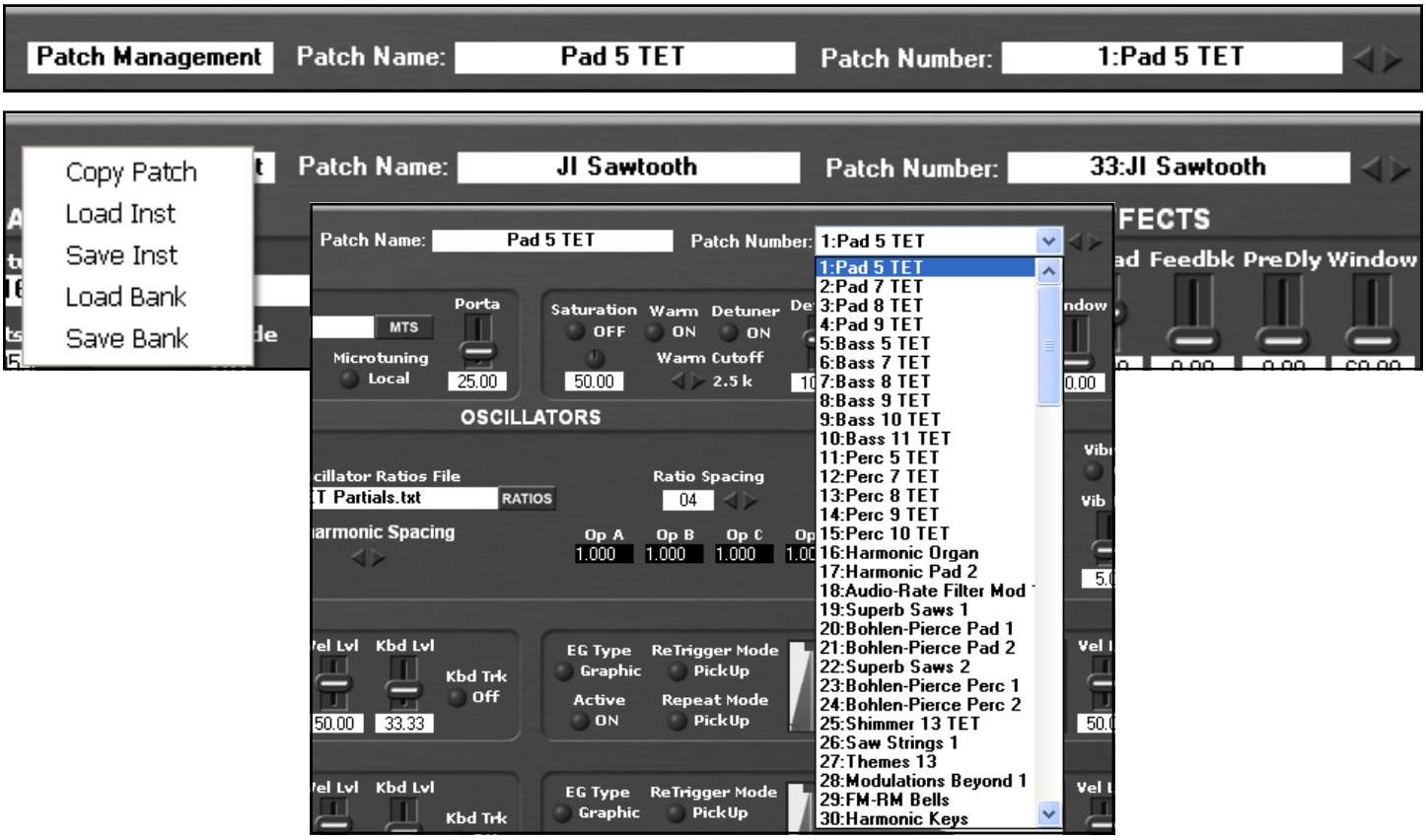
Xenharmonic fmts - Signal Flow



It is helpful in understanding the operation of the Xenharmonic FMTS VSTi by visualizing the way the various sections of the instrument are connected and interact with each other.

Internally there are five main sections: Performance Control (MIDI-to-CV), Oscillators, Filters, VCA and Effects.

Xenharmonic fmts - Patch Management



Use the Patch Management features at the top of the VSTi to load, create and store your instrument patches and banks.

Click the **Patch Management** button to access patch **Copy**, **Load** and **Save** options:

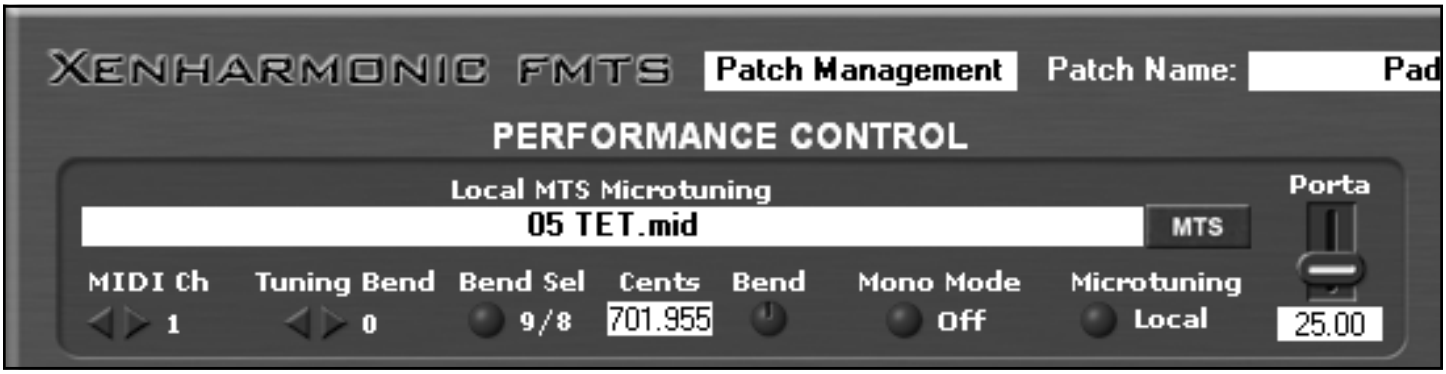
- Copy patches to a single location or to a range of patches with the **Copy Patch** menu option.
- Load an FXP single instrument patch file with the **Load Inst** menu option.
- Save an FXP single instrument patch file with the **Save Inst** menu option.
- Load an FXB bank file that can contain up to 128 patches with the **Load Bank** menu option.
- Save an FXB bank file that can contain up to 128 patches with the **Save Bank** menu option.

Type a new name for the current patch into the **Patch Name** field when designing custom timbres.

Select from the available 128 patches stored in the current bank by clicking the **Patch Number** drop-down menu, or alternatively use the left and right arrow buttons found to the right of the menu to step through the available patches in a bank.

Any changes made to the currently selected patch are automatically saved with that patch number.

Xenharmonic fmts - Performance Control



Use the **Performance Control** (MIDI-to-CV) section to make basic performance settings for the control of the VSTi.

The Xenharmonic FMTS VSTi enables musicians to load both a **Global MTS Microtuning** as well as a **Local MTS Microtuning**. The Global MTS Microtuning will stay loaded even on patch changes and can be used to play in a constant tuning while previewing the patches in a bank. The Local MTS Microtuning, however, is saved at the patch level and is restored whenever a patch with an associated microtuning is opened. Load the desired Global and Local MTS Microtuning files by clicking the appropriate **MTS** button.

Choose to play the current patch with either the loaded Global or Local MTS Microtuning by using the **Microtuning** button at the bottom right of the Performance Control section.

Select the desired **MIDI Channel** with the **MIDI Ch** selector.

Set the **Pitch Bender** to bend to precise degrees of the microtuning being used with the **Tuning Bend** selector. Set this to zero when using the **Bend Sel** features. Range is -/+ 12 degrees.

The **Bend Sel** (Bend Selection Type) is a special feature for microtonal musicians. There are 3 options: 1. **9/8**, which bends to a precise ratio of 9/8 @ 204 cents. 2. **Input** enables one to type in a value for the pitch-bender range into the **Cents** field. 3. **Off** disables pitch-bend.

The **Bend** knob is, by default, mapped to the pitch-bend controller.

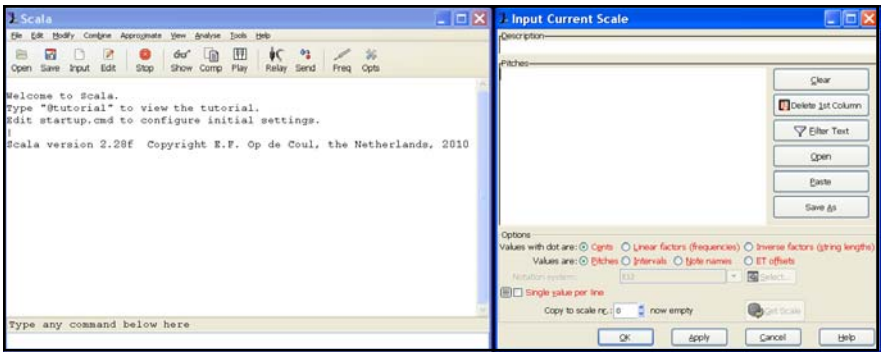
Mono Mode: Limit sound to one voice. Enables the Retrigger option.

Retrigger: Retrigger Envelopes when playing legato (you hit a note before releasing previous). Used with Mono Mode.

Portamento is only available in Mono Mode. To add **Portamento** to a monophonic patch, insure that the **Mono Mode** selector to the left of the **Porta** slider is set to **On**. Set **Portamento** depth with the **Porta** slider.

The default selection of MTS microtunings saved with the VSTi have the 1/1 of the tuning on MIDI Note C 60 with a Reference Pitch of 261.626 Hertz at note C 60.

Xenharmonic fmts - Scala: Creating MTS Files



Create MTS files for microtuning the Xenharmonic FMTS VSTi with the popular Scala microtuning software application developed by Manuel Op de Coul.

MTS is the **MIDI Tuning Standard**, which is a kind of MIDI System Exclusive (SYSEX) that is able to do full keyboard microtunings in the same way that the popular TUN format can, although there are distinct advantages over these kinds of fixed tuning-table formats, such as the ability to retune ensembles of MTS-enabled VSTi from a single track in a DAW by transmitting the MTS to a number of VSTi instrument tracks simultaneously.

MTS files can be created in **Scala** in the same way that TUN files are, with the variation of setting the synth type to a different number (107).

MTS is really just a MIDI file, with a file extension of MID, and this kind of file is basically 'played' into, or transmitted, to the synth. In the Xenharmonic FMTS VSTi, the transmission of the MTS file can be done internally using the MTS file open dialogs, or it can receive MTS externally by playing it from a track in your DAW and routing the MIDI to the VSTi track.

To create MTS files in Scala:

1. Open Scala.

2. Using the menus File/New/Scale or Ctrl+N, open the Input Current Scale dialog to create a new scale. Paste or type your tuning values into the Pitches field and click OK. Obviously, there are a number of ways to create tunings, such as opening SCL files from the Scala archive, or using the other File/New options.

3. To see your scale, type Show then press Enter, or press the Show button on the toolbar, or even press F6 on your keyboard.

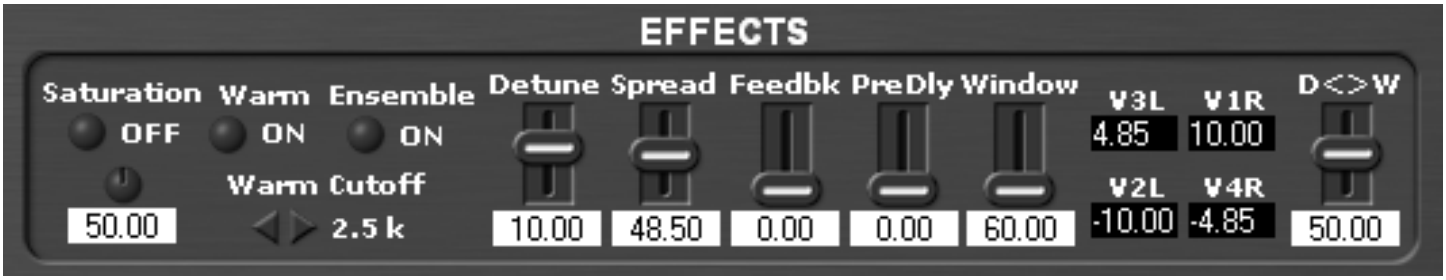
4. To set Scala to create the MTS (Synthesizer 107: MIDI Tuning Standard bulk tuning dump, 3 byte), type 'set synth 107' into the command line at the bottom of the program and press Enter. Alternatively, click the Opts button on the toolbar to display the User Options dialog. Click the MIDI button on the left to switch the dialog to the MIDI options. Under Synthesizer Tuning Options (SEND), choose Model: "107: MIDI Tuning Standard bulk tuning dump."

5. On the File menu choose Export Synth Tuning, or press Shift+Ctrl+T, to open the export dialog (Curiously, this dialog is titled Select MIDI File To Save).

6. Use the Look In field at the top to navigate to a directory where you wish to save your MTS file. Type a file name at the bottom with the file extension MID, such as '5-tet.mid'. Press OK.

Now you have saved an MTS file that can be opened by Xenharmonic FMTS.

Scala: http://www.huygens-fokker.org/scala/



The **Effects** section is placed at the final output stage of the VSTi and uses a selection of signal processors that makes the component parts of the FM timbre cohere in a pleasant way. The Effects section is made up of 3 stages: Saturation, Warm Filter and Stereo Ensemble.

Activate **Saturation** using the Saturation button, and set the level of Saturation using the **Sat Lvl** knob, or otherwise type values directly into the field beneath the knob. Higher settings produce increasing levels of distortion.

Following the Saturation stage is a 1-Pole 6 dB Lowpass Filter; here called **Warm**. This is used to gently roll off the high-frequency content of the FM-RM & DCO oscillators. Activate the Warm feature using the **Warm** button. Adjust the frequency response of the Warm filter using the **Warm Cutoff** selector. Options for the cutoff frequency of the filter are in the range of 1 k to 8 k.

Activate the **Ensemble** effect using the **Ensemble ON/OFF** selector.

Detune: Sets the amount of stereo ensemble detuning for all four voices. The maximum range is -/+ a ratio of 32/31 @ 55 cents. The Ensemble effect is mixed with the original oscillator signal according to the setting made with the D<>W Slider.

Spread: Sets the inner detuned voices V3L (Voice 3 Left) and V4R (Voice 4 Right) to a percentage of the setting made with the Detune slider. To better understand the operation of the Ensemble effect, try setting the Detuner Slider to 50 cents and the Spread to 50%. This will detune voice V1R (Voice 1 Right) +50 cents and V2L (Voice 2 Left) -50 cents, while V3L (Voice 3 Left) will be detuned +25 cents and V4R (Voice 4 Right) -25 cents.

Feedback: Adds output feedback to input.

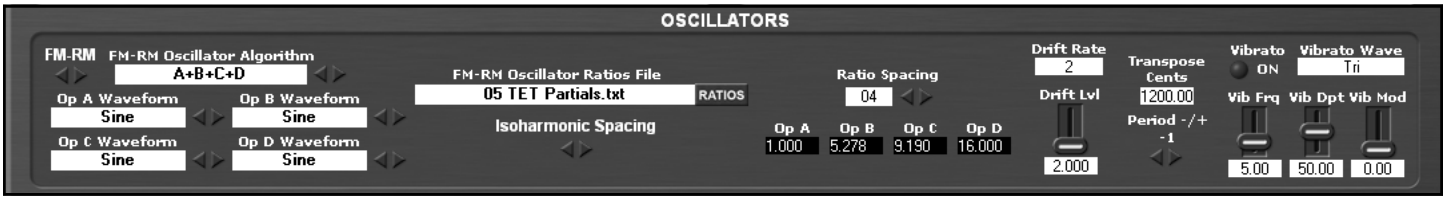
Pre-Delay: Delay time (max 1000ms @44.1Khz).

Window: Sets the Window size (max 300ms @44.1Khz). Large window sizes create an echo sound.

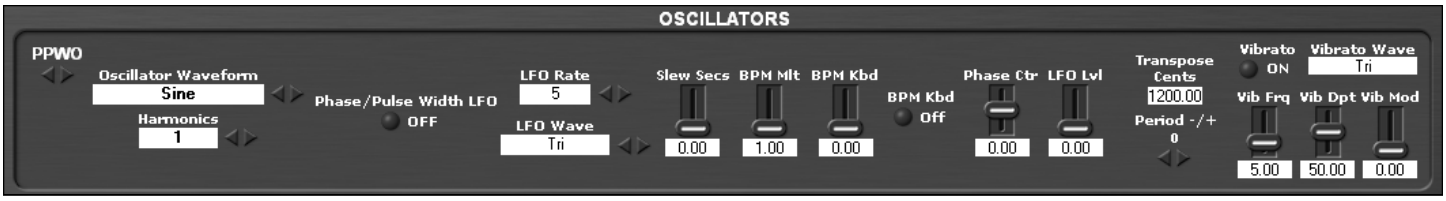
Voice Detuning Readouts: The readouts labeled **V3L** (Voice 3 Left), **V1R** (Voice 1 Right), **V2L** (Voice 2 Left) and **V4R** (Voice 4 Right) display the amount of detuning for each of the stereo panned voices in cents.

D<>W: Sets the Dry <> Wet balance between the unprocessed FM timbre and the effects.

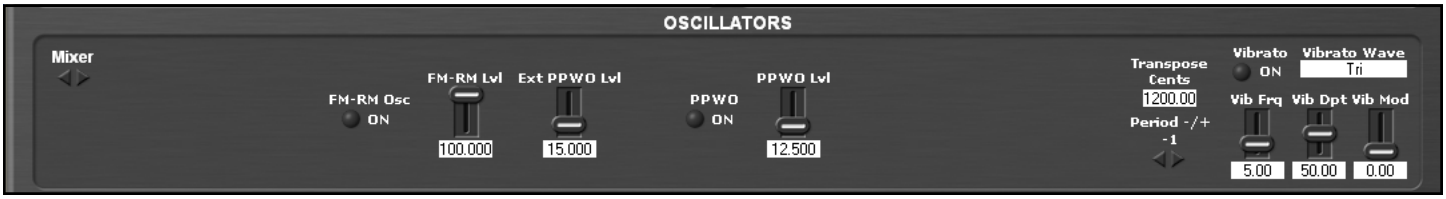
Xenharmonic FMTS - Oscillators



FM-RM Oscillator



Phase & Pulse-Width Oscillator



Oscillators Mixer

The Oscillators section of the Xenharmonic FMTS VSTi has three pages accessible by using the left and right arrow selector at the top left:

FM-RM

Accesses all of the functions for the **FM-RM Oscillator**:

- FM-RM Oscillator Algorithm
- Operators A-D Waveforms
- FM-RM Oscillator Ratios File
- 4 Ratio Selection Methods - Ratio Sliders, Isoharmonic Spacing, Quantized Selectors and Randomization Field
- Drift Rate and Level

PPWO

Accesses all of the functions for the Phase & Pulse-Width Oscillator:

- Oscillator Waveform
- Number of Harmonics
- Phase & Pulse-Width Modulation LFO

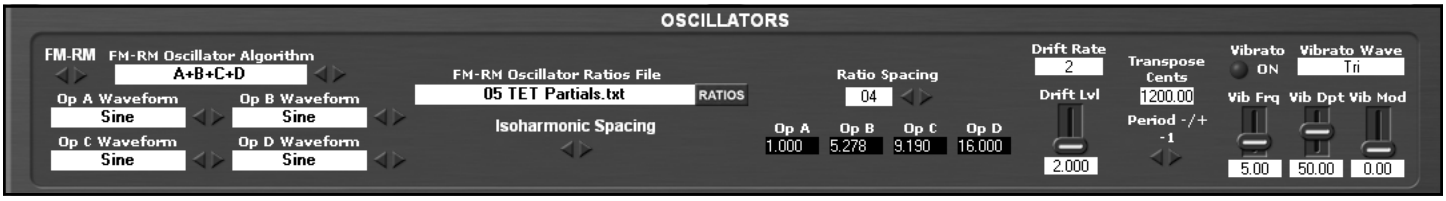
Mixer

For mixing the two oscillator types:

- FM-RM Level
- External Phase & Pulse-Width Oscillator Level
- Phase & Pulse-Width Oscillator Level

Also included in this section are controls for Oscillator Transpose and Vibrato.

Xenharmonic fmts - FM-RM Oscillator



FM-RM Oscillator

The **FM-RM Oscillator** section is the heart of the VSTi and is capable of producing a wide range of complex timbres for microtonal and xenharmonic music creation. The oscillator itself is a hybrid including both FM and Ring Modulation synthesis capabilities. Partials files may be loaded here to configure the operator ratios to values that are coincident with the MTS microtuning one has loaded in the Performance Control (MIDI-to-CV) section (which can generate tuning related FM sidebands), thereby creating an audible correlation between the timbre of the instrument and the intonation system being used for musical composition.

The FM-RM Oscillator is made up of 4 Operators - which are in fact 4 separate oscillators in one - and these operators are variously able to sum to the output, frequency modulate, and or ring modulate each other according to the selected algorithm.

To the right of this section, settings for **Vibrato** can be made. Choose from the available waveforms in the dropdown list. Set the frequency and depth with the sliders. Modulation amount is, by default, mapped to the Mod-Wheel of the MIDI Controller.

Arbitrary pitch transpositions of the instrument may be set by typing the desired offset value into the **Transpose Cents** field and using the **Period -/+** selector. The range of transposition is -/+ 16 times the value specified in the Transpose Cents field. This unique feature enables microtonal musicians and composers to transpose the pitch of the instrument to any interval required. This can be very useful where the period (or repeat-ratio) of the microtuning may be something other than the typical 2/1 of 1200 cents, such as in a scenario where one is composing with non-octave tunings and might need to transpose the instrument to a non-octave period. A good example would be the **Bohlen–Pierce** temperament, which is a division of the 3rd harmonic into 13 equal steps. To transpose the VSTi by the period of the Bohlen–Pierce temperament, type or paste **1901.955** into the Cents field. The Bohlen–Pierce temperament MTS Microtuning File, Operator Ratio File and a selection of BP patches are included with Xen-FMTS for musicians to explore this fascinating non-octave microtuning.

Drift Rate: Controls Rate of Analogue Drift. Simulates the small voltage variances of analogue synths causing pitch drifting over time.

Drift Lvl slider: Controls the depth of the Analogue Drift.

Choose from the available **57 FM Algorithms** using the **Oscillator Algorithm** dropdown list.

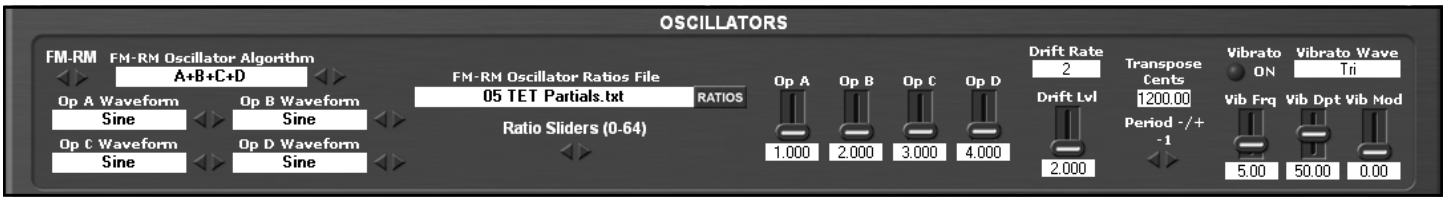
Each Operator can be set to one of eleven different waveforms, which can be selected using the **Op Waveform** dropdown lists. The **Operator Waveform** options are: Sine, Saw, Ramp, Soft Ramp, Peak Ramp, Square, Triangle, Peak, Octava, Cluster1 and Cluster2.

Besides the Vibrato and Drift features, pitch modulation of the Operators is not possible, as the theme of this VSTi is pitch stability for the creation of microtonal and xenharmonic music.

Xenharmonic fmts - FM-RM Operator Ratios

The Xenharmonic FMTS VSTi offers musicians and composers four different methods for specifying the ratios of each of the four Operators in the FM-RM Oscillator: **Ratio Sliders (0-64), Isoharmonic Spacing, Quantized Selectors** and **Randomization Field**. The user may switch between these four options using the left and right arrow selector beneath the **FM-RM Oscillator Ratios File** field.

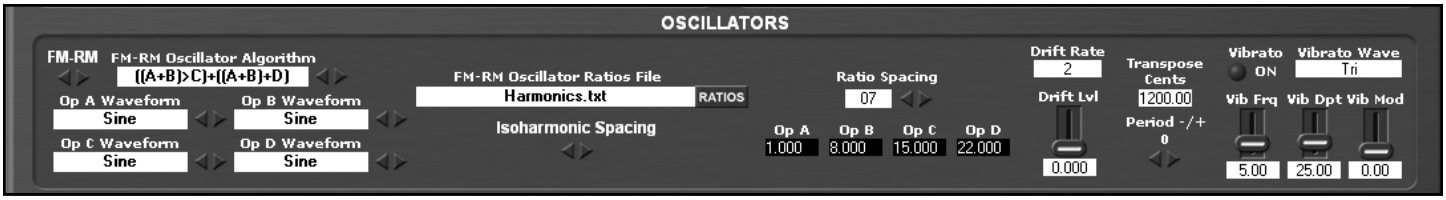
When using the **Isoharmonic Spacing, Quantized Selectors and Randomization Field**, the ratios for the Operators may be set by loading an **FM-RM Oscillator Ratios File**, which is an index of 32 ratio values contained in a text (TXT) file. In this mode, the operator ratios are quantized to the index values in the loaded file. Click the Ratios button to load an **FM-RM Oscillator Ratios File**. A selection of files are embedded by default in the VSTi, but musicians and composers may freely create their own using **Windows Notepad**. Type or paste your own ratio values into Notepad, where each of 32 lines contains a single ratio value.



Ratio Sliders (0-64)

With the **Ratio Sliders (0-64)** option selected, the row of sliders labeled **Op A, B, C, D** may be used to specify any arbitrary ratio values for the Operators within the range of 0 to 64. Values for each slider may also be directly typed or pasted into the fields beneath the controller.

IMPORTANT: This method of specifying the operator ratios does not utilize the FM-RM Oscillator Ratios Files.

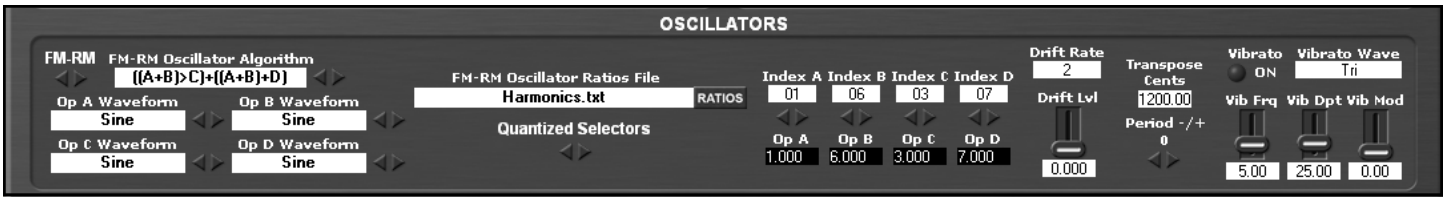


Isoharmonic Spacing

With the **Isoharmonic Spacing** option, use the **Ratio Spacing** selector to place equal numbered spaces between each index value. For instance, when one has loaded the **FM-RM Oscillator Ratios File**, **Harmonics.txt**, and with the Ratio Spacing value set to 1, the Operator ratios are set to 1, 2, 3, 4, as displayed by the readouts beneath the selector. With the Ratio Spacing value set to 2, the operator values are set to 1, 3, 5, 7, and with it set to 3, they are 1, 4, 7, 10, and so on.

The range of the **Isoharmonic Ratio Spacing** is from 1 to 30. Once the size of the Isoharmonic Spacing exceeds the index range, values are wrapped downward using a modulus function. Astonishing variations in the timbre can be created as the index values wrap, creating interesting new relationships between the operators. This is an extremely powerful feature for microtonal sound-design.

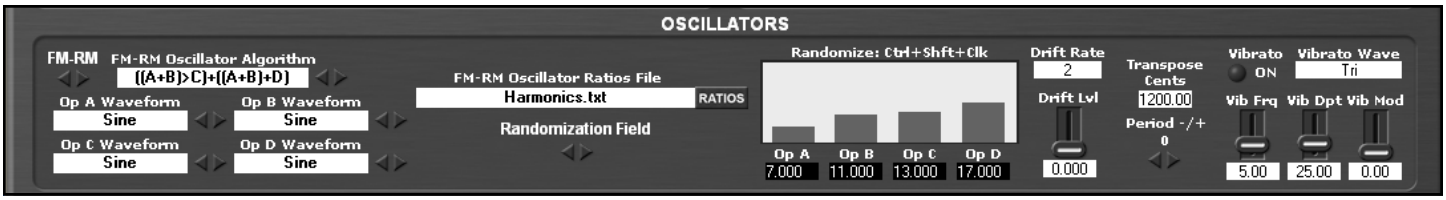
When using the Isoharmonic Spacing option for specifying the operator ratios of the FM-RM Oscillator, it is important to note that Operator A is always fixed with a value of 1, while all of the other operator's values can be changed with the Ratio Spacing selector.



Quantized Selectors

Using the **Quantized Selectors** option, each of Operators A-D may be set to any of the available 32 index values in the currently loaded FM-RM Oscillator Ratios File. Click on the Index fields to specify the ratios for the operators using a dropdown list, or otherwise use the left and right arrow selectors. Ratio value selections are displayed in the readouts beneath the selectors.

This method of specifying the ratios gives the user maximum flexibility for quantizing the values for particular algorithms.



Randomization Field

Using the **Randomization Field** option, the operator ratio values may be **Randomized** by pressing **Control + Shift + Click** inside of the field. Ratios may also be specified by clicking and dragging the gray bars. The selected ratios for each operator are displayed in the readouts beneath the field.

All of the settings made with each of these four options for specifying the operator ratios of the FM-RM Oscillator are saved at the patch level, and provide an easy way to create up to four variations of the timbre in a patch.

The most common use for creating timbres with the FM-RM Operator Ratio Files is to load a file that has ratio values made for the particular MTS microtuning one has loaded in the Performance Control section, which creates a correlation between the tuning and the timbre. For instance, load the Operator Ratios File, 07 TET Partials.txt, when using the MTS microtuning, 07 TET.mid.

7 TET Cents:	0.00	171.43	342.86	514.29	685.71	857.14	1028.57	1200.00
Partial Index	0	1	2	3	4	5	6	7
1	1.00	1.10	1.22	1.35	1.49	1.64	1.81	2.00
2	2.00	2.21	2.44	2.69	2.97	3.28	3.62	4.00
3	2.97	3.28	3.62	4.00	4.42	4.88	5.38	5.94
4	4.00	4.42	4.88	5.38	5.94	6.56	7.25	8.00
5	4.88	5.38	5.94	6.56	7.25	8.00	8.83	9.75
6	5.94	6.56	7.25	8.00	8.83	9.75	10.77	11.89
7	7.25	8.00	8.83	9.75	10.77	11.89	13.13	14.49
8	8.00	8.83	9.75	10.77	11.89	13.13	14.49	16.00
9	8.83	9.75	10.77	11.89	13.13	14.49	16.00	17.67
10	9.75	10.77	11.89	13.13	14.49	16.00	17.67	19.50
11	10.77	11.89	13.13	14.49	16.00	17.67	19.50	21.53
12	11.89	13.13	14.49	16.00	17.67	19.50	21.53	23.78
13	13.13	14.49	16.00	17.67	19.50	21.53	23.78	26.25
14	14.49	16.00	17.67	19.50	21.53	23.78	26.25	28.98
15	16.00	17.67	19.50	21.53	23.78	26.25	28.98	32.00
16	17.67	19.50	21.53	23.78	26.25	28.98	32.00	35.33
17	19.50	21.53	23.78	26.25	28.98	32.00	35.33	39.01
18	21.53	23.78	26.25	28.98	32.00	35.33	39.01	43.07
19	23.78	26.25	28.98	32.00	35.33	39.01	43.07	47.55
20	26.25	28.98	32.00	35.33	39.01	43.07	47.55	52.50
21	28.98	32.00	35.33	39.01	43.07	47.55	52.50	57.97
22	32.00	35.33	39.01	43.07	47.55	52.50	57.97	64.00
23	35.33	39.01	43.07	47.55	52.50	57.97	64.00	70.66
24	39.01	43.07	47.55	52.50	57.97	64.00	70.66	78.02
25	43.07	47.55	52.50	57.97	64.00	70.66	78.02	86.14
26	47.55	52.50	57.97	64.00	70.66	78.02	86.14	
27	52.50	57.97	64.00	70.66	78.02	86.14		
28	57.97	64.00	70.66	78.02	86.14			
29	64.00	70.66	78.02	86.14				
30	70.66	78.02	86.14					
31	78.02	86.14						
32	86.14							

The above table is an example visualization of coincident frequency ratios (partials) for 7 tone equal temperament.

1. The ratios shown in column 0 are the values that are found in the default **Operator Ratios File**, **07 TET Partials.txt**, which are a list of frequency ratios representing 32 harmonics that have been adjusted to match 7 TET. Column 0 may be thought of as the 1/1 of the tuning with its associated partial structure.

2. At the top of the table, running horizontally, the cents values for 7 TET are listed, and Row 1 shows the decimal values for this tuning. This is the same as the MTS microtuning file, **07 TET.mid**.

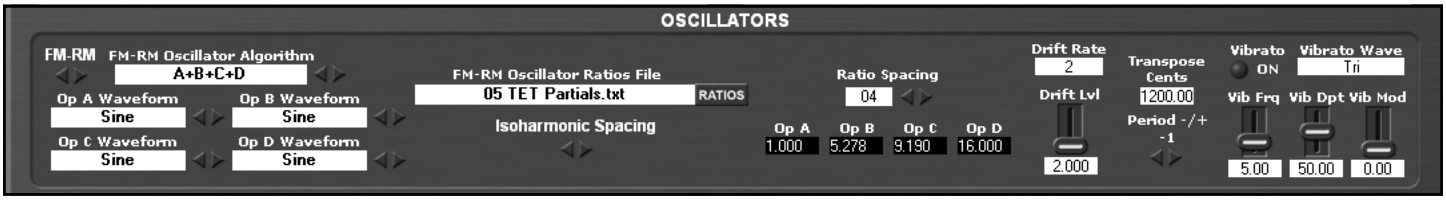
3. Each of the following columns 1 through 7 represent intervals and their partials sounded with the 1/1 in column 0.

4. The fields shown in yellow depict the partials that are directly coincident with the intervals of 7 tone equal temperament.

Loading an **FM-RM Oscillator Ratios File** with its corresponding **MTS Microtuning** file into the Xenharmonic FMTS VSTi, such as **07 TET Partials.txt** and **07 TET.mid**, creates and audible correlation between the timbre of the instrument and the tuning itself.

Using the FM-RM Oscillator Ratio File features to configure the ratios of the FM Operators to match a given microtuning enables musicians and composers to create complex timbres with tuning related sidebands.

Xenharmonic fmts - FM-RM Algorithms



FM-RM Oscillator

All of the **Algorithms** are displayed in a mathematical equation style. Functions within brackets are performed first, as is usual, and from left to right in other cases.

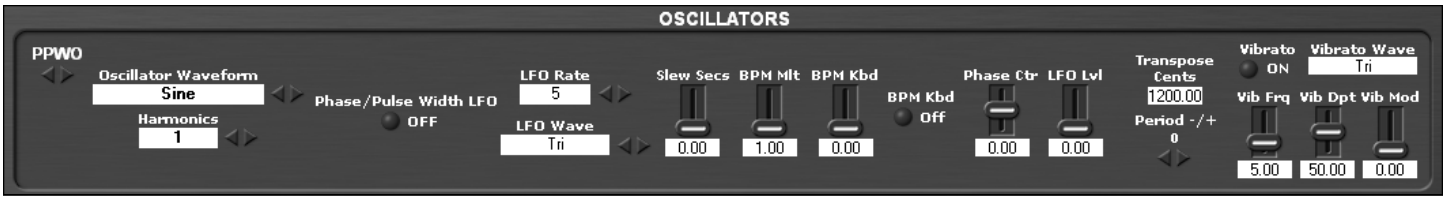
' ***** ' Indicates the **Ring-Mod** function, i.e., (A*B) Wave_A Ring-modulates Wave_B

' **>** ' Indicates the **FM** function, i.e., (A>B) Wave_A FM-modulates Wave_B

Where "A>B>C" = Wave_A FM-modulates Wave_B, the resulting Wave then FM-modulates Wave_C

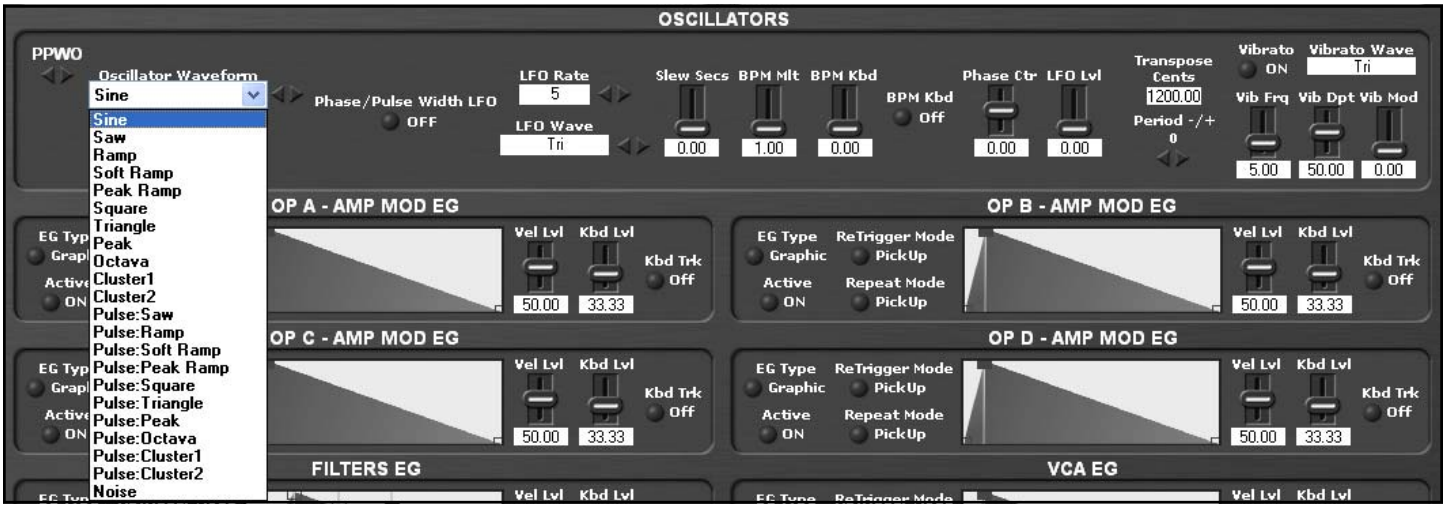
The Algorithm List:

01	A+B+C+D	34	(A>B)+(A>C)+D
02	(A+B+C)*D	35	(A>B)+(A>C)+(A>D)
03	(A+B+C)>D	36	(A>B)+(A*C)+D
04	(A+B)>C+D	37	(A>B)+(A*C)+(A>D)
05	((A+B)>C)*D	38	(A>B)+(A*C)+(A*D)
06	(A+B)>C>D	39	(A*B)+(A*C)+D
07	(A+B)*C+D	40	(A*B)+(A*C)+(A*D)
08	(A+B)*C*D	41	(A+B)+(A>C)+D
09	((A+B)*C)>D	42	(A+B)+(A*C)+D
10	(A>B)+C+D	43	(A+B)+(A>C)+(A>D)
11	((A>B)+C)*D	44	(A+B)+(A*C)+(A*D)
12	((A>B)+C)>D	45	(A+B)+(A>C)+(A*D)
13	(A>B)>C+D	46	((A+B)>C)+((A+B)+D)
14	(A>B>C)*D	47	((A+B)>C)+((A+B)>D)
15	A>B>C>D	48	((A+B)>C)+((A+B)*D)
16	(A>B)*C+D	49	((A+B)*C)+((A+B)*D)
17	((A>B)*C)>D	50	((A>B)>C)+((A>B)+D)
18	(A>B)*C*D	51	((A>B)>C)+((A>B)>D)
19	(A*B)+C+D	52	((A>B)>C)+((A>B)*D)
20	((A*B)+C)*D	53	((A>B)*C)+((A>B)*D)
21	((A*B)+C)>D	54	((A*B)>C)+((A*B)+D)
22	((A*B)>C)+D	55	((A*B)>C)+((A*B)>D)
23	((A*B)>C)*D	56	((A*B)>C)+((A*B)*D)
24	(A*B)>C>D	57	((A*B)*C)+((A*B)*D)
25	A*B*C+D		
26	(A*B*C)>D		
27	A*B*C*D		
28	(A+B)*(C+D)		
29	(A>B)+(C>D)		
30	(A*B)+(C*D)		
31	(A*B)+(C>D)		
32	(A>B)*(C>D)		
33	(A*B)*(C>D)		



Phase & Pulse-Width Oscillator

With the FM-RM Oscillator, it is possible to make combined settings of the operators and algorithms that may either remove or shift the fundamental pitch. The **Phase & Pulse Width Oscillator** provides a stable fundamental pitch for the synthesizer even with these extreme settings of the FM-RM Oscillator. Typically the Oscillator Waveform used to provide this fundamental pitch would be a Sine wave, although there are a total of 22 available waveforms with this oscillator that may be used for more complex sound-design applications.



Choose from the available waveforms from the **Oscillator Waveform** dropdown list. Waveforms **Sine, Saw, Ramp, Soft Ramp, Peak Ramp Square, Triangle, Peak, Octava, Cluster1** and **Cluster2** may be **Phase Modulated** using the **Phase/Pulse Width LFO**, while the waveforms prefaced with **Pulse** may be **Pulse Width Modulated** with the LFO. LFO-rate Phase and Pulse Width modulation of this oscillator can add evolving changes to the timbre, while audio-rate modulation can add new side-bands to the signal.

Specify the number of partials for the selected waveform using the **Harmonics** dropdown list or left and right arrows. Obviously, when using the Sine waveform only 1 harmonic is required.

Activate the **Phase/Pulse Width LFO** using its **ON/OFF** switch.

Set the **LFO Rate** by choosing from the available prime number values in the dropdown list, or use the left and right arrow selectors to increment or decrement through the options.

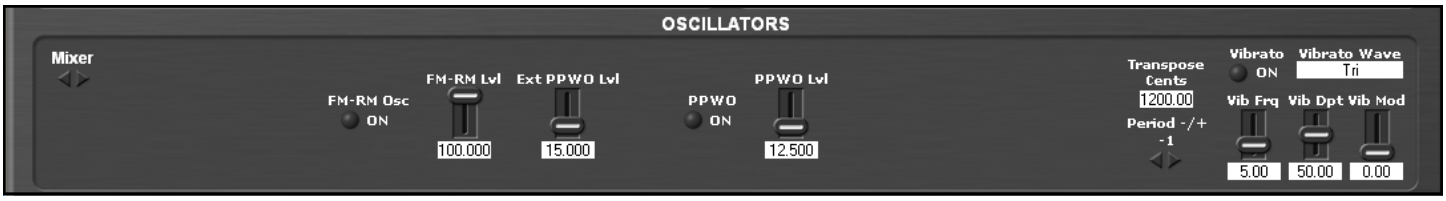
Use the **Slew Secs** slider to control the rate of change of the LFO. This can be used to smooth modulation waveforms such as Ramp and Noise waves that would otherwise create abrupt modulation changes. The range of the control is from 0 to 2 seconds.

Use the **BPM Mlt** slider to multiply the Beats Per Minute rate of the LFO. The range of the control is from 1 to 2048 times the host tempo. Higher values can be used to set the LFO to audio rate modulation values, which can add new sidebands to the signal.

The **BPM Kbd** slider may be used to set the depth of linear keyboard-tracking of the LFO. Use the **BPM Kbd selector** switch to turn Off keyboard-tracking or to set it to either positive or negative polarity. Set the LFO Phase Center around which bi-polar modulation will occur with the **Phase Ctr** slider. Set the depth of LFO modulation using

The Phase & Pulse-Width Oscillator sine wave is typically used to provide a stable fundamental pitch for the instrument when extreme settings made to the FM-RM Oscillator operators and algorithm may remove or shift it.

Xenharmonic fmts - Oscillators Mixer



Oscillators Mixer

The oscillators **Mixer** is used to set the relative volume balance between the FM-RM and Phase & Pulse Width Oscillators.

Activate or deactivate the **FM-RM Oscillator** using the **FM-RM Osc ON/OFF** switch.

Set the volume level of the **FM-RM Oscillator** using the **FM-RM Lvl** slider. The range of the control is from 0 to 100 percent.

The **Ext PPWO Lvl** slider may be used to mix the Phase & Pulse Width Oscillator level with the FM-RM Oscillator's Operator A. Combining the Phase & Pulse Width Oscillator with the FM-RM Oscillator's Operator A creates a complex composite modulation source with many interesting timbral possibilities for microtonal and xenharmonic music sound-design.

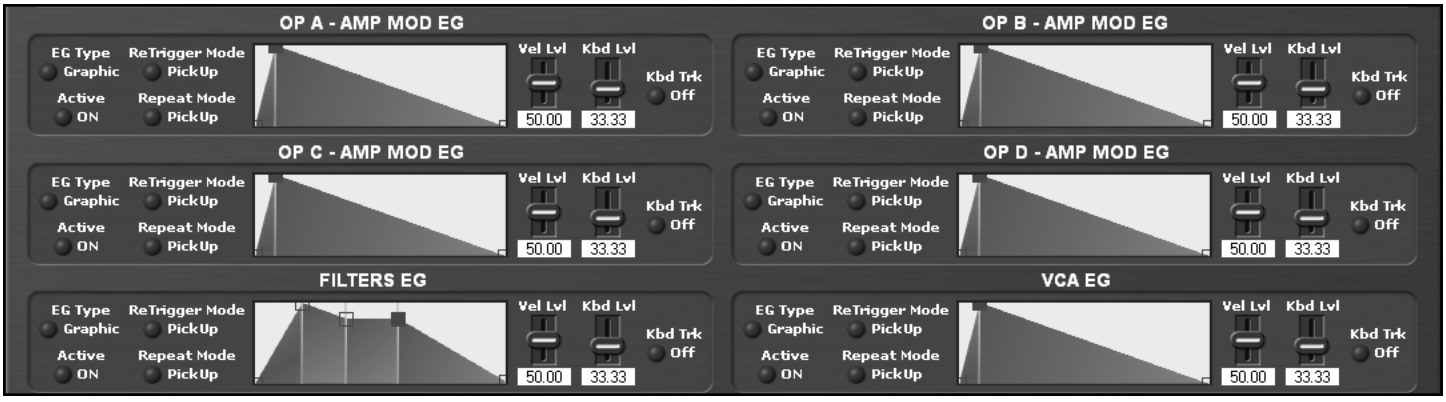
Activate or deactivate the Phase & Pulse Width Oscillator using the **PPWO ON/OFF** switch.

Set the volume level of the Phase & Pulse Width Oscillator using the **PPWO Lvl** slider. The range of the control is from 0 to 100 percent.

Often low volume mixer levels for the PPWO give the best results when using the Phase & Pulse-Width Oscillator sine wave to provide a stable fundamental pitch for the instrument, when, for instance, extreme settings made to the FM-RM Oscillator operators and algorithms may have removed or shifted it. Try to create a balanced blend between the volumes of the PPWO and the FM-RM Oscillator with the mixer.

Xenharmonic fmts - Envelope Generators

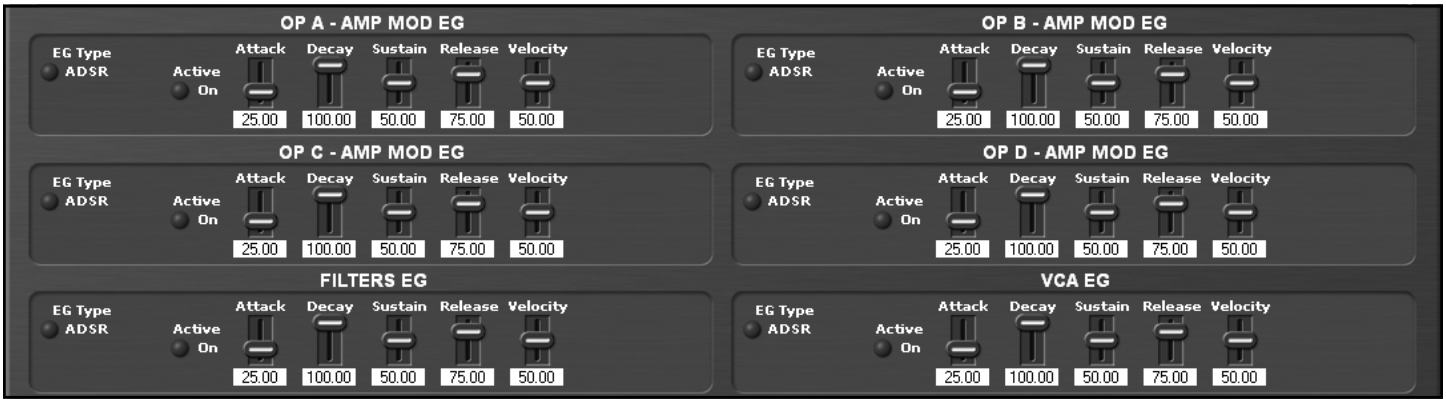
The **Envelope Generators** section of the Xenharmonic FMTS VSTi provides musicians and composers with two **EG Type** control methods: **Graphic** and **ADSR**. The user may switch between these options using the EG Type selector located at the top left of each envelope generator.



Graphic Envelope Generators

Use the Graphic EG Type when fine modulation control is required for the particular timbre and musical application. The Graphic EG option offers:

- 8 Stage Looping Envelope Generators
- Retriggering Modes
- Repeat Modes
- Velocity Modulation Level
- Keyboard Tracking

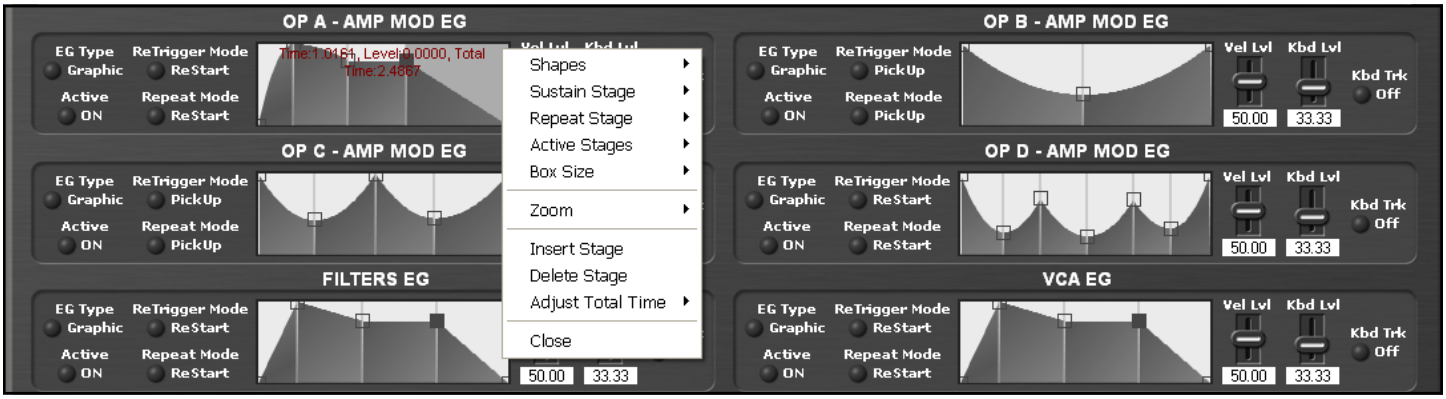


ADSR Envelope Generators

Use the ADSR EG Type for more basic envelope modulation requirements.

- Attack
- Decay
- Sustain
- Release
- Velocity Modulation Level

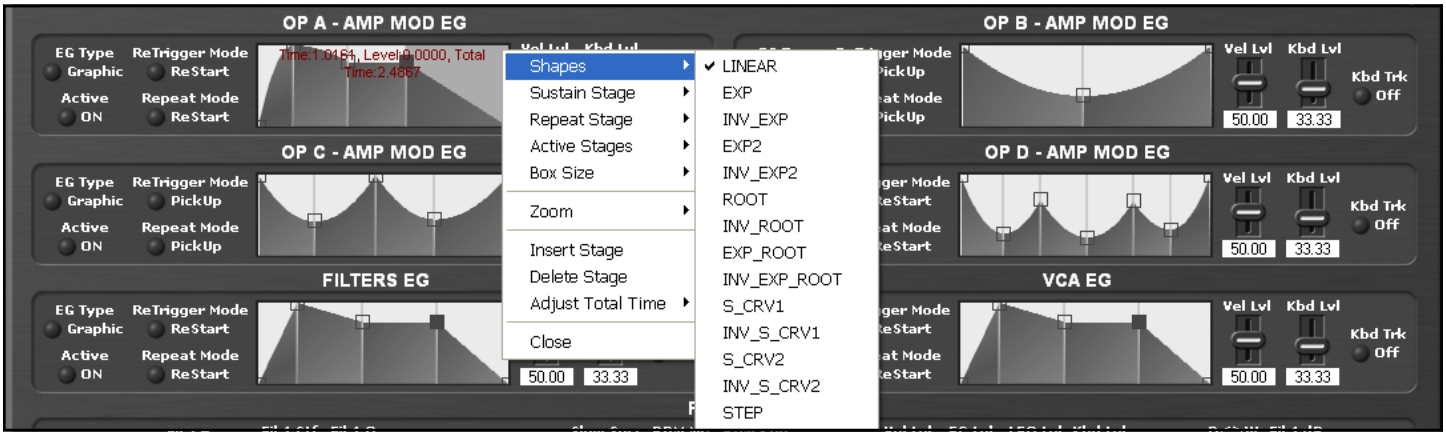
XENHARMONIC FMTS - GRAPHIC EG



There are six **Envelope Generators** with identical features. Four are dedicated to modulating the amplitude of **Operators A-D**. There is an EG also dedicated to modulating the cutoff frequency of the **State Variable Filters (SVF)**. Another is used for the **VCA**. Both the **FM-RM** and **Phase & Pulse Width Oscillators** pass through the VCA stage and are shaped by its EG.

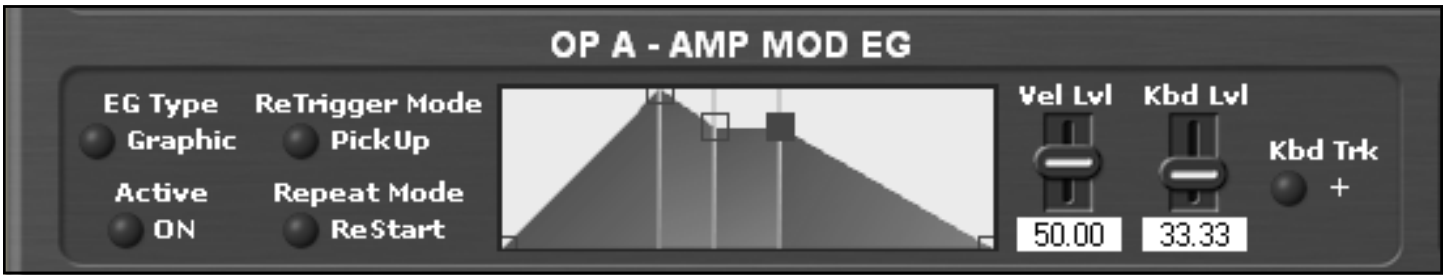
Use the **Active** button to turn an EG **On** or **Off**. Use these as a way to mute an operator when creating new patches to compare the interactions of the operators.

Use the **Retrigger Mode** to either **Restart** the EG from the beginning with each MIDI Note On, or with **PickUp** selected, with each new MIDI Note On, the EG will resume at the position from the last MIDI Note Off.



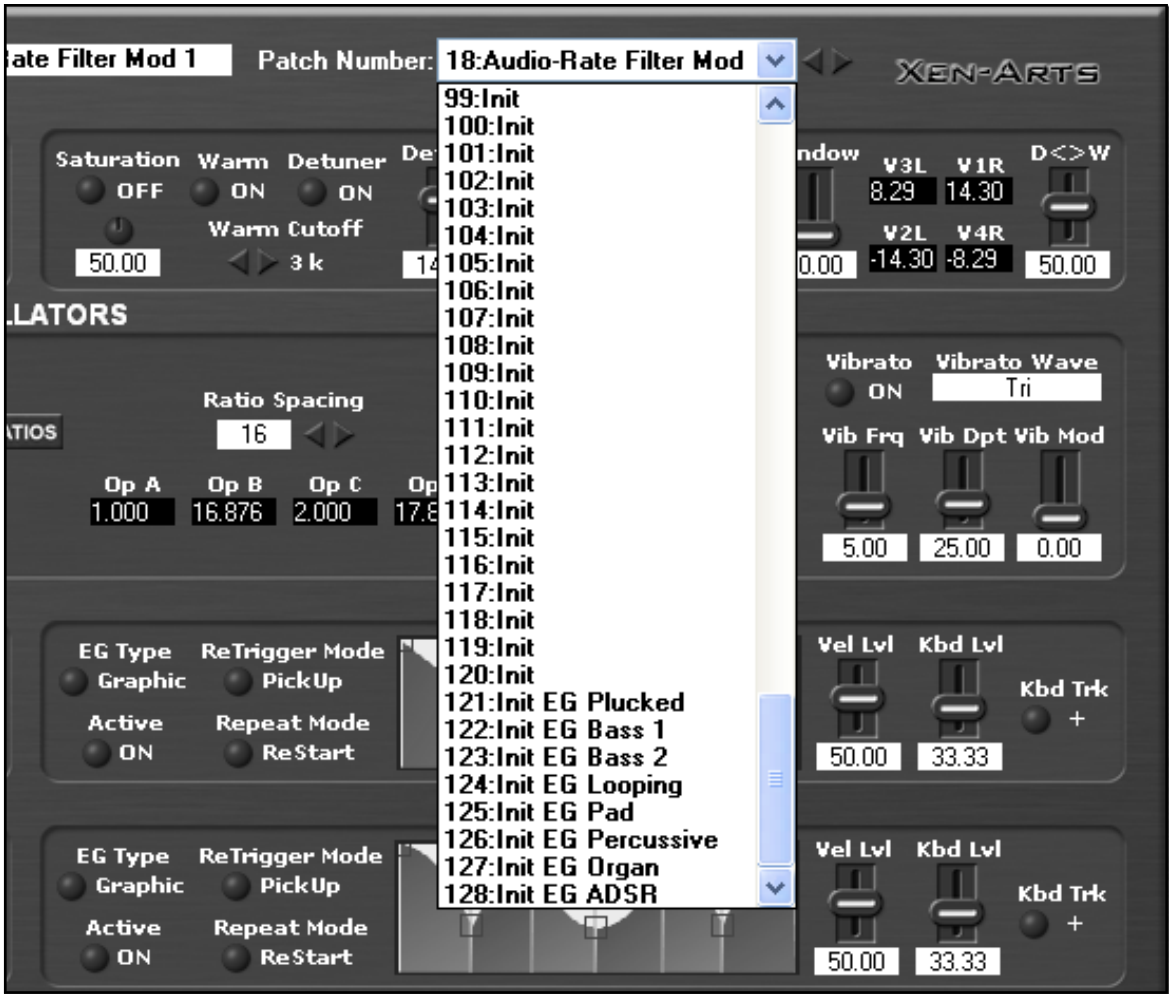
Clicking inside the **EG Display** causes a menu of options to appear for creating custom modulation settings. Choose from the available **Shapes** to create custom modulation contours for each stage of the EG. Using the **Sustain Stage** menu, specify which stage of the EG will produce sustain when a MIDI Note is held. Using the **Repeat Stage** menu, the stage at which the EG will repeat (or loop) as a MIDI Note is held may be configured. Use the **Active Stages** menu to set the number of stages for the EG. Up to 8 stages may be configured for complex modulations. Stages may be added or removed using **Insert** or **Delete Stage**. Using the **Adjust Total Time** menu, the EG time may be scaled from 10 to 1000%. Use the **Vel Lvl** (Velocity Level) slider to specify the depth of interaction between MIDI Key Velocity and the EG. Use the **Kbd Lvl** (Keyboard Level) slider and the **Kbd Trk** (Keyboard Tracking) button to make settings for the depth and polarity of the EG keyboard tracking (keyboard tracking behavior is linear): **Off** disables keyboard tracking of the EG, ' **+** ' causes the EG time to scale positive as higher MIDI Notes are played and ' **-** ' increases the time of the EG as lower MIDI Notes are played.

Note: A typical **ADSR** can be configured with an **EG** by setting the **Active Stages** to **4** and the **Sustain Stage** to **3**.

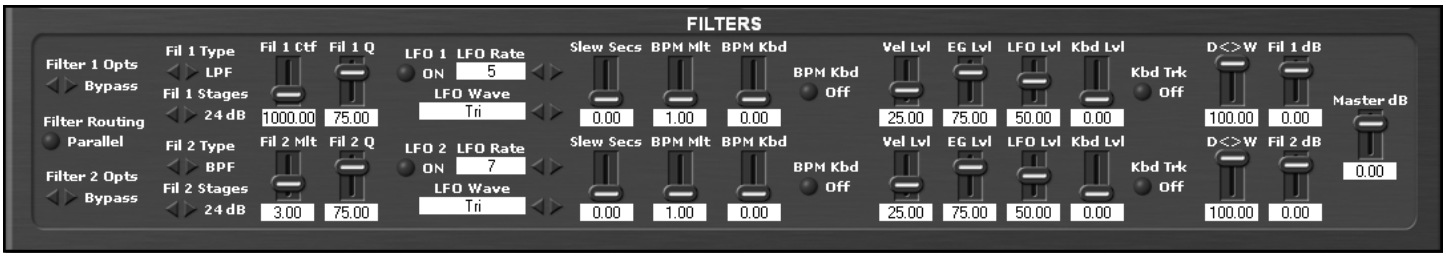


Click and drag the **boxes** in the **EG Display** to adjust the **time** for each stage of the Envelope Generator.

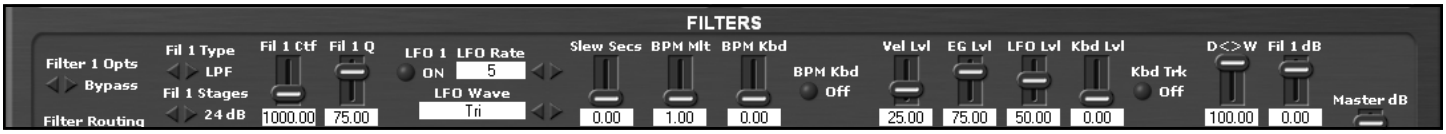
The output of the VSTi can be muted using the **Active** button on the **VCA EG**. Typically this should be left in the **On** position.



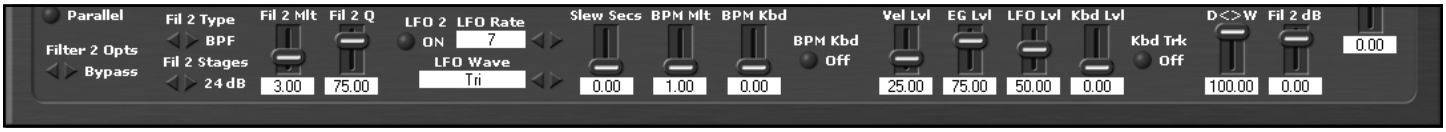
Included in the default bank, **patches 121-128** offer a selection of various **initialized states** of the EGs. Choose one of these that best matches the kind of envelope contour you wish to work with and copy it to another patch location to use as a starting point for creating your own custom patches.



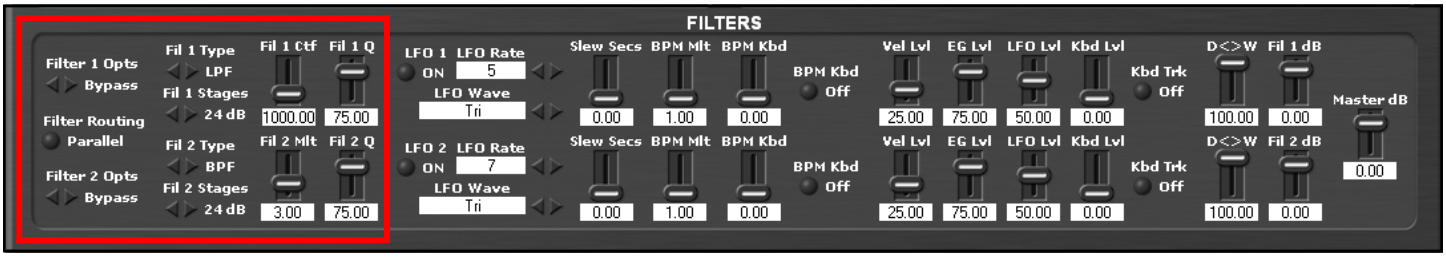
There are two **State Variable Filters.** The top row of controls are for Filter 1 and the bottom row for Filter 2.



Filter 1 Controls



Filter 2 Controls



Filters 1 & 2 Options, Routing, Type, Stages, Cutoff Frequency and Resonance

The filters can be switched between **Bypass**, **Active** and **Off**. **Bypass** passes the oscillator signals through unprocessed. **Active** activates each filter, while **Off** disables a filter.

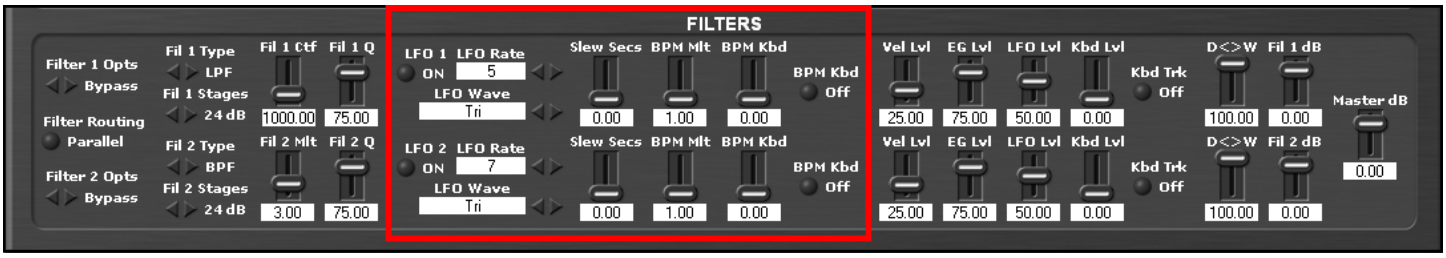
The filters may be set in a **Parallel** or **Serial** configuration using the **Filter Routing** selector.

Use the **Fil 1 & Fil 2 Type** selectors to choose the filter type. The options are **Lowpass, Highpass, Bandpass** and **Band-reject**. Each of the 2 filters may be set to either **12** or **24 dB** per octave response.

The **cutoff frequency** of **Filter 1** may be set using the **Fil 1 Ctf** slider. The **cutoff frequency** of **Filter 2** is configured as a multiple of up to 8 times the frequency specified by the **Fil 1 Ctf** slider and is set using the **Fil 2 Mlt** slider.

Being able to set the cutoff frequency of **Filter 2** as a multiple of **Filter 1** may be used, for instance, to set the filter to create a peak in the signal at some harmonic above the SVF 1. Experiment with the filters in a **Parallel Routing** configuration; setting **Filter 1** to a **24 dB LPF** with a cutoff frequency of 100 hz and set **Filter 2** to a **24 dB BPF** with the **Fil 2 Mlt** slider set to **3**. With this configuration, the **Bandpass** filter of **Filter 2** will produce a peak in the signal approximately a **3rd harmonic** above **Filter 1** at 300 Hz, which creates a very unique filter sound.

Resonance for both Filters 1 & 2 are set using the **Fil 1 & 2 Q** sliders. **CAUTION:** Be aware that under certain circumstances, setting high values for the Fil 1 and Fil 2 Q Sliders can generate extremely loud high-gain audio signals. Take precautions to protect your hearing and audio gear in the event you choose to make these settings by lowering your monitoring volume or using a limiter on the output of your DAW.



Filters 1 & 2 LFO Controls

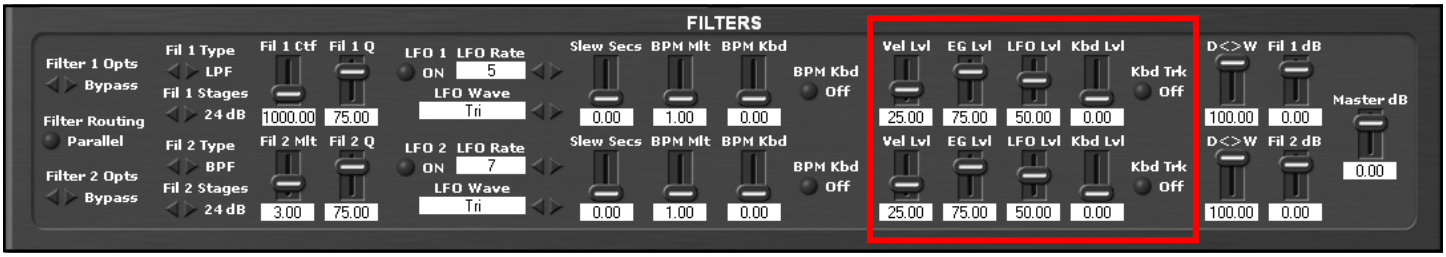
The LFOs in Xenharmonic FMTS are synced to the host DAW tempo and are used to modulate the cutoff frequencies of Filters 1 & 2. Specify the **LFO Rate** using the dropdown list, or arrow selectors, by choosing from the available index of prime numbers.

Select the **waveform** for the filter cutoff frequency modulation with the **LFO Wave** dropdown list or arrow selectors.

Use the **Slew Secs** (Slew Seconds) slider to smooth the control signal of the LFO waveforms such as Pulse, Saw, Ramps and Noise.

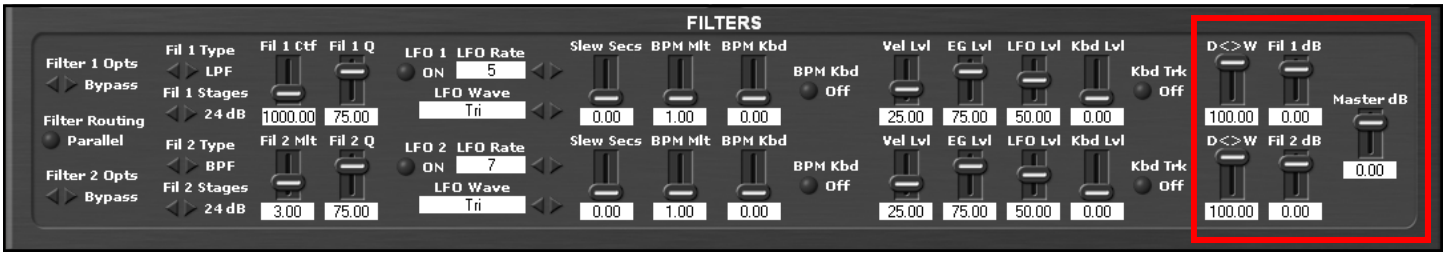
Use the **BPM Mlt** slider to multiply the **Beats-Per-Minute**, thereby increasing the LFO modulation rate. The range of the control is from 1 to 2048 times the BPM tempo setting of the host DAW application. Higher BPM multiplication values enable the filters to be modulated at **audio rates**, which can produce new **sidebands** in the signal.

Use the **BPM Kbd** (BPM Keyboard Tracking) slider and **BPM Kbd** switch to configure keyboard tracking of LFO modulation rates.



Filters 1 & 2 Modulation Control Mixer

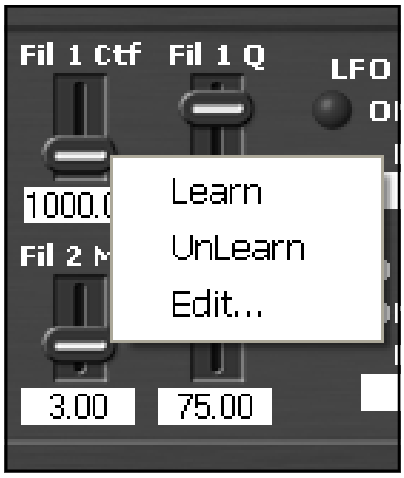
The **Vel Lvl** (Velocity Level), **EG Lvl** (Envelope Generator Level), **LFO Lvl** (Low Frequency Oscillator Level) and **Kbd Lvl** (Keyboard Tracking Level) sliders are a **control mixer** for all of the modulation sources that are routed to modulate the cutoff frequency of the filters, and are used to set the modulation depth for each of these modulation sources. Use the **Kbd Trk** selector to configure the polarity of linear **Keyboard Tracking** of the filter cutoff frequency.

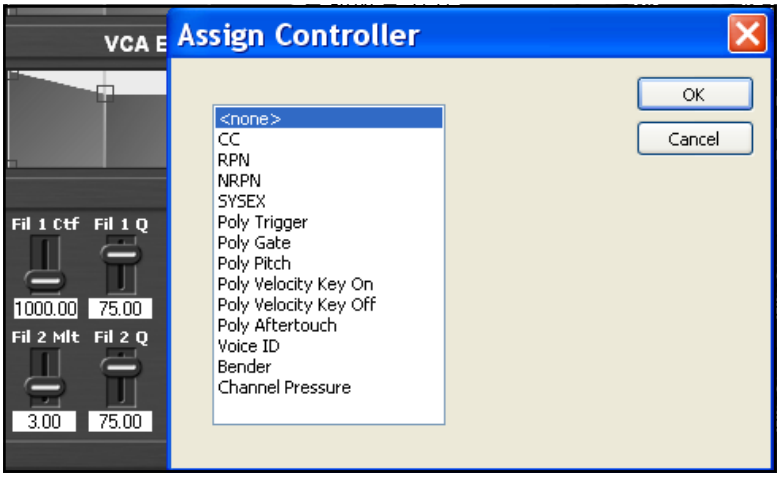


Filters 1 & 2 Dry<>Wet Balance, Filter Levels and Master Out Level

The **D<>W** sliders sets the dry-to-wet balance between the non-filtered and filtered oscillator signal, while the **Fil 1 & 2 dB** sliders control the output gain of each filter. The range of the Fil 1 & 2 dB sliders is –100 dB to 24 dB.

The **Master dB** slider controls the overall output level of the VSTi. The range is –100 dB to 24 dB.



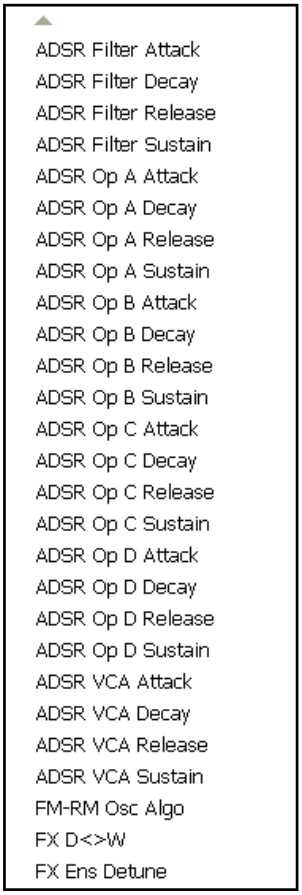


Controls in the Xenharmonic FMTS VSTi may be automated with MIDI controllers by right-clicking on a control and selecting **Learn** from the menu. After selecting the Learn option, move an external MIDI control, such as a mod-wheel on a MIDI keyboard, and then the VSTi control will be mapped to that external controller.

Choose **Unlearn** to remove a MIDI controller assignment.

Select **Edit** from the menu to map controllers to the VSTi controls using the available options found in the **Assign Controller** dialog.

Additionally, there are now 60 automation targets exposed to the host DAW. Consult your DAW manual for instructions on how to automate these parameters.



Partial list of automation targets shown in the Reaper DAW.

Xenharmonic fmts - Partials & Microtunings

Pages 25-31 provide reference materials regarding the partial (TXT) files and MTS microtuning files included with this VSTi.

For musicians and composers who may be new to the sounds of xenharmonic and microtonal intervals, the Xenharmonic FMTS VSTi will provide a nice introduction and overview of some of the expressive possibilities of making music with alternative intonation systems.

With this instrument alone, you can explore the sound of equal temperaments 5 through 31. Also it will provide a great introduction to just intonation microtuning and includes octave-based segments of the harmonic and subharmonic series as tunings that can be directly played from your MIDI controller. The popular Bohlen-Pierce temperament is also included as an introduction to the amazing sounds of non-octave microtunings.

Partials TXT Files	Description
05 TET Partials.txt	Partials for 5 Tone Equal Temperament
07 TET Partials.txt	Partials for 7 Tone Equal Temperament
08 TET Partials.txt	Partials for 8 Tone Equal Temperament
09 TET Partials.txt	Partials for 9 Tone Equal Temperament
10 TET Partials.txt	Partials for 10 Tone Equal Temperament
11 TET Partials.txt	Partials for 11 Tone Equal Temperament
12 TET Partials.txt	Partials for 12 Tone Equal Temperament
13 TET Partials.txt	Partials for 13 Tone Equal Temperament
14 TET Partials.txt	Partials for 14 Tone Equal Temperament
15 TET Partials.txt	Partials for 15 Tone Equal Temperament
16 TET Partials.txt	Partials for 16 Tone Equal Temperament
17 TET Partials.txt	Partials for 17 Tone Equal Temperament
18 TET Partials.txt	Partials for 18 Tone Equal Temperament
19 TET Partials.txt	Partials for 19 Tone Equal Temperament
20 TET Partials.txt	Partials for 20 Tone Equal Temperament
21 TET Partials.txt	Partials for 21 Tone Equal Temperament
22 TET Partials.txt	Partials for 22 Tone Equal Temperament
23 TET Partials.txt	Partials for 23 Tone Equal Temperament
24 TET Partials.txt	Partials for 24 Tone Equal Temperament
25 TET Partials.txt	Partials for 25 Tone Equal Temperament
26 TET Partials.txt	Partials for 26 Tone Equal Temperament
27 TET Partials.txt	Partials for 27 Tone Equal Temperament
28 TET Partials.txt	Partials for 28 Tone Equal Temperament
29 TET Partials.txt	Partials for 29 Tone Equal Temperament
30 TET Partials.txt	Partials for 30 Tone Equal Temperament
31 TET Partials.txt	Partials for 31 Tone Equal Temperament
Antiharmonics.txt	Musical Antimatter: Square root boundaries lying between the harmonic series
Bohlen-Pierce Partials.txt	Partials for Bohlen-Pierce tuning
Cluster Partials (1200 TET).txt	Fine Tuning: 1 cent increments
Cluster Partials (2400 TET).txt	Fine Tuning: 0.5 cent increments
Cluster Partials (300 TET).txt	Fine Tuning: 4 cents increments
Cluster Partials (4800 TET).txt	Fine Tuning: .25 cent increments
Cluster Partials (600 TET).txt	Fine Tuning: 2 cents increments
Harmonics.txt	Everyone's historical favorite: The Harmonic Series
Random Partials 01.txt	Random Partials
Random Partials 02.txt	Random Partials
Random Partials 03.txt	Random Partials
Random Partials 04.txt	Random Partials
Random Partials 05.txt	Random Partials
Random Partials 06.txt	Random Partials
Random Partials 07.txt	Random Partials
Random Partials 08.txt	Random Partials
Random Partials 09.txt	Random Partials
Random Partials 10.txt	Random Partials

MTS Microtuning Files	Description
05 TET.mid	5 Tone Equal Temperament
07 TET.mid	7 Tone Equal Temperament
08 TET.mid	8 Tone Equal Temperament
09 TET.mid	9 Tone Equal Temperament
10 TET.mid	10 Tone Equal Temperament
11 TET.mid	11 Tone Equal Temperament
12 TET.mid	12 Tone Equal Temperament
13 TET.mid	13 Tone Equal Temperament
14 TET.mid	14 Tone Equal Temperament
15 TET.mid	15 Tone Equal Temperament
16 TET.mid	16 Tone Equal Temperament
17 TET.mid	17 Tone Equal Temperament
18 TET.mid	18 Tone Equal Temperament
19 TET.mid	19 Tone Equal Temperament
20 TET.mid	20 Tone Equal Temperament
21 TET.mid	21 Tone Equal Temperament
22 TET.mid	22 Tone Equal Temperament
23 TET.mid	23 Tone Equal Temperament
24 TET.mid	24 Tone Equal Temperament
25 TET.mid	25 Tone Equal Temperament
26 TET.mid	26 Tone Equal Temperament
27 TET.mid	27 Tone Equal Temperament
28 TET.mid	28 Tone Equal Temperament
29 TET.mid	29 Tone Equal Temperament
30 TET.mid	30 Tone Equal Temperament
31 TET.mid	31 Tone Equal Temperament
Bohlen-Pierce.mid	Division of 3/1 into 13 equal parts
Harmonics 05-10.mid	Harmonics 5-10
Harmonics 06-12.mid	Harmonics 6-12
Harmonics 07-14.mid	Harmonics 7-14
Harmonics 08-16.mid	Harmonics 8-16
Harmonics 08-24.mid	Harmonics 8-24
Harmonics 09-18.mid	Harmonics 9-18
Harmonics 10-20.mid	Harmonics 10-20
Harmonics 11-22.mid	Harmonics 11-22
Harmonics 12-24.mid	Harmonics 12-24
Harmonics 13-26.mid	Harmonics 13-26
Harmonics 14-28.mid	Harmonics 14-28
Harmonics 15-30.mid	Harmonics 15-30
Harmonics 16-32.mid	Harmonics 16-32
Subharmonics 10-05.mid	Subharmonics 10-5
Subharmonics 12-06.mid	Subharmonics 12-6
Subharmonics 14-07.mid	Subharmonics 14-7
Subharmonics 16-08.mid	Subharmonics 16-8
Subharmonics 18-09.mid	Subharmonics 18-9
Subharmonics 20-10.mid	Subharmonics 20-10
Subharmonics 22-11.mid	Subharmonics 22-11
Subharmonics 24-12.mid	Subharmonics 24-12
Subharmonics 26-13.mid	Subharmonics 26-13
Subharmonics 28-14.mid	Subharmonics 28-14
Subharmonics 30-15.mid	Subharmonics 30-15
Subharmonics 32-16.mid	Subharmonics 32-16

Harmonic Model ET Spectra

Index Number	5 TET	7 TET	8 TET	9 TET	10 TET	11 TET	12 TET	13 TET	14 TET	15 TET	16 TET	17 TET	18 TET	19 TET	Harmonic Series
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1
2	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2
3	3.031	2.972	3.084	2.939	3.031	2.919	2.997	3.064	2.972	3.031	2.954	3.007	3.055	2.988	3
4	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4
5	5.278	4.876	5.187	5.040	4.925	5.147	5.040	4.951	5.124	5.040	4.967	4.905	5.040	4.979	5
6	6.063	5.944	6.169	5.879	6.063	5.838	5.993	6.128	5.944	6.063	5.907	6.014	6.110	5.975	6
7	6.964	7.246	6.727	6.858	6.964	7.053	7.127	6.817	6.896	6.964	7.025	7.079	7.127	6.914	7
8	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8
9	9.190	8.833	8.724	9.332	9.190	9.075	8.980	8.900	8.833	9.190	9.110	9.041	8.980	8.925	9
10	10.556	9.752	10.375	10.079	9.849	10.293	10.079	9.902	10.247	10.079	9.935	9.809	10.079	9.958	10
11	12.126	10.767	11.314	10.886	11.314	10.963	11.314	11.016	10.767	11.055	10.834	11.085	10.886	11.109	11
12	13.929	11.888	12.338	11.758	12.126	11.676	11.986	12.256	11.888	12.126	11.815	12.027	12.219	11.950	12
13	16.000	13.125	13.454	12.699	12.996	13.244	12.699	12.927	13.125	13.300	12.884	13.049	13.198	12.855	13
14	18.379	14.492	14.672	13.716	13.929	14.105	14.254	13.635	13.792	13.929	14.050	14.158	14.254	13.828	14
15	21.112	16.000	16.000	14.814	14.929	15.023	15.102	15.169	15.227	15.277	15.322	14.747	14.814	14.874	15
16	24.251	17.665	17.448	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16.000	16
17	27.858	19.504	19.027	17.281	17.148	17.041	16.951	16.876	16.812	16.757	16.708	16.666	17.281	17.211	17
18	32.000	21.534	20.749	18.664	18.379	18.149	17.959	17.801	17.665	18.379	18.221	18.082	17.959	17.851	18
19	36.758	23.776	22.627	20.159	19.698	19.329	19.027	18.775	18.562	19.248	19.027	18.834	18.664	19.202	19
20	42.224	26.251	24.675	21.773	21.112	20.587	20.159	19.804	20.494	20.159	19.870	19.618	20.159	19.915	20
21	48.503	28.983	26.909	23.516	22.627	21.926	21.357	20.888	21.534	21.112	20.749	21.285	20.950	20.655	21
22	55.715	32.000	29.344	25.398	24.251	23.352	22.627	22.032	22.627	22.111	21.668	22.171	21.773	22.218	22
23	64.000	35.331	32.000	27.432	25.992	24.871	23.973	23.239	23.776	23.156	22.627	23.093	22.627	23.044	23
24	73.517	39.008	34.896	29.628	27.858	26.488	25.398	24.511	24.983	24.251	23.629	24.055	24.439	23.900	24
25	84.449	43.069	38.055	32.000	29.857	28.211	26.909	25.854	26.251	25.398	24.675	25.056	25.398	24.788	25
26	97.006	47.552	41.499	34.562	32.000	30.046	28.509	27.270	27.583	26.600	25.768	26.098	26.396	25.709	26
27	111.430	52.501	45.255	37.329	34.297	32.000	30.204	28.763	28.983	27.858	26.909	27.184	27.432	26.664	27
28	128.000	57.966	49.351	40.317	36.758	34.081	32.000	30.338	30.454	29.175	28.100	28.316	28.509	27.655	28
29	147.033	64.000	53.817	43.545	39.397	36.298	33.903	32.000	32.000	30.555	29.344	29.494	29.628	28.683	29
30	168.897	70.662	58.688	47.032	42.224	38.659	35.919	33.753	33.624	32.000	30.643	30.721	30.791	29.748	30
31	194.012	78.017	64.000	50.797	45.255	41.173	38.055	35.601	35.331	33.513	32.000	32.000	32.000	30.854	31
32	222.861	86.138	69.792	54.864	48.503	43.851	40.317	37.551	37.124	35.098	33.417	33.332	33.256	32.000	32

The above table shows the coincident partials for equal temperaments 5 through 19 used in the partials TXT files. These values represent the most closely matching ratios to a harmonic series model.

It is interesting to note that at 19 tone equal temperament there is a fairly good representation of the harmonic series up to partial 32, where there is at least one harmonic identity lying within the square root boundaries between each of the first 32 members of the harmonic series. This is one of the primary reasons that 19 TET intervals sound good when played with harmonic series timbres.

Pages 28-31 provide detailed information about the just intonation microtunings included with this VSTi. These tunings, derived as octave-based sections from the harmonic and subharmonic series, represent some of the fundamental intervals of melody and harmony in music made with harmonic series timbres. Historically speaking, harmonic and subharmonic series intervals have made up an important part of the foundations of music going back to ancient Greek tetrachord theory, Renaissance and Maqam music.

As an introduction to just intonation, it is suggested to play through all of these just tunings using some of the included harmonic timbres in an effort to understand the unique sonic character each can impart to the music. Listen carefully for the wonderful acoustic blending effects that occur with this special category of microtuning.

Just Intonation: Harmonic and Subharmonic Octave Segments 1-32

Harmonic Numerary Nexus in Denominator Otonal: Major Tonality							Subharmonic Numerary Nexus in Numerator Utonal: Minor Tonality						
Degree	Harmonics: Numerator	Numerary Nexus: Denominator	Ratio Steps	Steps Cents	Ratio Degrees	Degrees Cents	Degree	Numerary Nexus: Numerator	Subharmonics: Denominator	Ratio Steps	Steps Cents	Ratio Degrees	Degrees Cents
0	1	1			1/1	0.000	1	2	1			2/1	1200.000
1	2	1	2/1	1200.000	2/1	1200.000	0	2	2	2/1	1200.000	1/1	0.000
0	2	2			1/1	0.000	2	4	2			2/1	1200.000
1	3	2	3/2	701.955	3/2	701.955	1	4	3	3/2	701.955	4/3	498.045
2	4	2	4/3	498.045	2/1	1200.000	0	4	4	4/3	498.045	1/1	0.000
0	3	3			1/1	0.000	3	6	3			2/1	1200.000
1	4	3	4/3	498.045	4/3	498.045	2	6	4	4/3	498.045	3/2	701.955
2	5	3	5/4	386.314	5/3	884.359	1	6	5	5/4	386.314	6/5	315.641
3	6	3	6/5	315.641	2/1	1200.000	0	6	6	6/5	315.641	1/1	0.000
0	4	4			1/1	0.000	4	8	4			2/1	1200.000
1	5	4	5/4	386.314	5/4	386.314	3	8	5	5/4	386.314	8/5	813.686
2	6	4	6/5	315.641	3/2	701.955	2	8	6	6/5	315.641	4/3	498.045
3	7	4	7/6	266.871	7/4	968.826	1	8	7	7/6	266.871	8/7	231.174
4	8	4	8/7	231.174	2/1	1200.000	0	8	8	8/7	231.174	1/1	0.000
0	5	5			1/1	0.000	5	10	5			2/1	1200.000
1	6	5	6/5	315.641	6/5	315.641	4	10	6	6/5	315.641	5/3	884.359
2	7	5	7/6	266.871	7/5	582.512	3	10	7	7/6	266.871	10/7	617.488
3	8	5	8/7	231.174	8/5	813.686	2	10	8	8/7	231.174	5/4	386.314
4	9	5	9/8	203.910	9/5	1017.596	1	10	9	9/8	203.910	10/9	182.404
5	10	5	10/9	182.404	2/1	1200.000	0	10	10	10/9	182.404	1/1	0.000
0	6	6			1/1	0.000	6	12	6			2/1	1200.000
1	7	6	7/6	266.871	7/6	266.871	5	12	7	7/6	266.871	12/7	933.129
2	8	6	8/7	231.174	4/3	498.045	4	12	8	8/7	231.174	3/2	701.955
3	9	6	9/8	203.910	3/2	701.955	3	12	9	9/8	203.910	4/3	498.045
4	10	6	10/9	182.404	5/3	884.359	2	12	10	10/9	182.404	6/5	315.641
5	11	6	11/10	165.004	11/6	1049.363	1	12	11	11/10	165.004	12/11	150.637
6	12	6	12/11	150.637	2/1	1200.000	0	12	12	12/11	150.637	1/1	0.000
0	7	7			1/1	0.000	7	14	7			2/1	1200.000
1	8	7	8/7	231.174	8/7	231.174	6	14	8	8/7	231.174	7/4	968.826
2	9	7	9/8	203.910	9/7	435.084	5	14	9	9/8	203.910	14/9	764.916
3	10	7	10/9	182.404	10/7	617.488	4	14	10	10/9	182.404	7/5	582.512
4	11	7	11/10	165.004	11/7	782.492	3	14	11	11/10	165.004	14/11	417.508
5	12	7	12/11	150.637	12/7	933.129	2	14	12	12/11	150.637	7/6	266.871
6	13	7	13/12	138.573	13/7	1071.702	1	14	13	13/12	138.573	14/13	128.298
7	14	7	14/13	128.298	2/1	1200.000	0	14	14	14/13	128.298	1/1	0.000

Just Intonation: Harmonic and Subharmonic Octave Segments 1-32

	Harmonic Numerary Nexus in Denominator Otonal: Major Tonality						Subharmonic Numerary Nexus in Numerator Utonal: Minor Tonality						
Degree	Harmonics: Numerator	Numerary Nexus: Denominator	Ratio Steps	Steps Cents	Ratio Degrees	Degrees Cents	Degree	Numerary Nexus: Numerator	Subharmonics: Denominator	Ratio Steps	Steps Cents	Ratio Degrees	Degrees Cents
0	8	8			1/1	0.000	8	16	8			2/1	1200.000
1	9	8	9/8	203.910	9/8	203.910	7	16	9	9/8	203.910	16/9	996.090
2	10	8	10/9	182.404	5/4	386.314	6	16	10	10/9	182.404	8/5	813.686
3	11	8	11/10	165.004	11/8	551.318	5	16	11	11/10	165.004	16/11	648.682
4	12	8	12/11	150.637	3/2	701.955	4	16	12	12/11	150.637	4/3	498.045
5	13	8	13/12	138.573	13/8	840.528	3	16	13	13/12	138.573	16/13	359.472
6	14	8	14/13	128.298	7/4	968.826	2	16	14	14/13	128.298	8/7	231.174
7	15	8	15/14	119.443	15/8	1088.269	1	16	15	15/14	119.443	16/15	111.731
8	16	8	16/15	111.731	2/1	1200.000	0	16	16	16/15	111.731	1/1	0.000
0	9	9			1/1	0.000	9	18	9			2/1	1200.000
1	10	9	10/9	182.404	10/9	182.404	8	18	10	10/9	182.404	9/5	1017.596
2	11	9	11/10	165.004	11/9	347.408	7	18	11	11/10	165.004	18/11	852.592
3	12	9	12/11	150.637	4/3	498.045	6	18	12	12/11	150.637	3/2	701.955
4	13	9	13/12	138.573	13/9	636.618	5	18	13	13/12	138.573	18/13	563.382
5	14	9	14/13	128.298	14/9	764.916	4	18	14	14/13	128.298	9/7	435.084
6	15	9	15/14	119.443	5/3	884.359	3	18	15	15/14	119.443	6/5	315.641
7	16	9	16/15	111.731	16/9	996.090	2	18	16	16/15	111.731	9/8	203.910
8	17	9	17/16	104.955	17/9	1101.045	1	18	17	17/16	104.955	18/17	98.955
9	18	9	18/17	98.955	2/1	1200.000	0	18	18	18/17	98.955	1/1	0.000
0	10	10			1/1	0.000	10	20	10			2/1	1200.000
1	11	10	11/10	165.004	11/10	165.004	9	20	11	11/10	165.004	20/11	1034.996
2	12	10	12/11	150.637	6/5	315.641	8	20	12	12/11	150.637	5/3	884.359
3	13	10	13/12	138.573	13/10	454.214	7	20	13	13/12	138.573	20/13	745.786
4	14	10	14/13	128.298	7/5	582.512	6	20	14	14/13	128.298	10/7	617.488
5	15	10	15/14	119.443	3/2	701.955	5	20	15	15/14	119.443	4/3	498.045
6	16	10	16/15	111.731	8/5	813.686	4	20	16	16/15	111.731	5/4	386.314
7	17	10	17/16	104.955	17/10	918.642	3	20	17	17/16	104.955	20/17	281.358
8	18	10	18/17	98.955	9/5	1017.596	2	20	18	18/17	98.955	10/9	182.404
9	19	10	19/18	93.603	19/10	1111.199	1	20	19	19/18	93.603	20/19	88.801
10	20	10	20/19	88.801	2/1	1200.000	0	20	20	20/19	88.801	1/1	0.000
0	11	11			1/1	0.000	11	22	11			2/1	1200.000
1	12	11	12/11	150.637	12/11	150.637	10	22	12	12/11	150.637	11/6	1049.363
2	13	11	13/12	138.573	13/11	289.210	9	22	13	13/12	138.573	22/13	910.790
3	14	11	14/13	128.298	14/11	417.508	8	22	14	14/13	128.298	11/7	782.492
4	15	11	15/14	119.443	15/11	536.951	7	22	15	15/14	119.443	22/15	663.049
5	16	11	16/15	111.731	16/11	648.682	6	22	16	16/15	111.731	11/8	551.318
6	17	11	17/16	104.955	17/11	753.637	5	22	17	17/16	104.955	22/17	446.363
7	18	11	18/17	98.955	18/11	852.592	4	22	18	18/17	98.955	11/9	347.408
8	19	11	19/18	93.603	19/11	946.195	3	22	19	19/18	93.603	22/19	253.805
9	20	11	20/19	88.801	20/11	1034.996	2	22	20	20/19	88.801	11/10	165.004
10	21	11	21/20	84.467	21/11	1119.463	1	22	21	21/20	84.467	22/21	80.537
11	22	11	22/21	80.537	2/1	1200.000	0	22	22	22/21	80.537	1/1	0.000

Just Intonation: Harmonic and Subharmonic Octave Segments 1-32

	Harmonic Numerary Nexus in Denominator Otonal: Major Tonality						Subharmonic Numerary Nexus in Numerator Utonal: Minor Tonality						
Degree	Harmonics: Numerator	Numerary Nexus: Denominator	Ratio Steps	Steps Cents	Ratio Degrees	Degrees Cents	Degree	Numerary Nexus: Numerator	Subharmonics: Denominator	Ratio Steps	Steps Cents	Ratio Degrees	Degrees Cents
0	12	12			1/1	0.000	12	24	12			2/1	1200.000
1	13	12	13/12	138.573	13/12	138.573	11	24	13	13/12	138.573	24/13	1061.427
2	14	12	14/13	128.298	7/6	266.871	10	24	14	14/13	128.298	12/7	933.129
3	15	12	15/14	119.443	5/4	386.314	9	24	15	15/14	119.443	8/5	813.686
4	16	12	16/15	111.731	4/3	498.045	8	24	16	16/15	111.731	3/2	701.955
5	17	12	17/16	104.955	17/12	603.000	7	24	17	17/16	104.955	24/17	597.000
6	18	12	18/17	98.955	3/2	701.955	6	24	18	18/17	98.955	4/3	498.045
7	19	12	19/18	93.603	19/12	795.558	5	24	19	19/18	93.603	24/19	404.442
8	20	12	20/19	88.801	5/3	884.359	4	24	20	20/19	88.801	6/5	315.641
9	21	12	21/20	84.467	7/4	968.826	3	24	21	21/20	84.467	8/7	231.174
10	22	12	22/21	80.537	11/6	1049.363	2	24	22	22/21	80.537	12/11	150.637
11	23	12	23/22	76.956	23/12	1126.319	1	24	23	23/22	76.956	24/23	73.681
12	24	12	24/23	73.681	2/1	1200.000	0	24	24	24/23	73.681	1/1	0.000
0	13	13			1/1	0.000	13	26	13			2/1	1200.000
1	14	13	14/13	128.298	14/13	128.298	12	26	14	14/13	128.298	13/7	1071.702
2	15	13	15/14	119.443	15/13	247.741	11	26	15	15/14	119.443	26/15	952.259
3	16	13	16/15	111.731	16/13	359.472	10	26	16	16/15	111.731	13/8	840.528
4	17	13	17/16	104.955	17/13	464.428	9	26	17	17/16	104.955	26/17	735.572
5	18	13	18/17	98.955	18/13	563.382	8	26	18	18/17	98.955	13/9	636.618
6	19	13	19/18	93.603	19/13	656.985	7	26	19	19/18	93.603	26/19	543.015
7	20	13	20/19	88.801	20/13	745.786	6	26	20	20/19	88.801	13/10	454.214
8	21	13	21/20	84.467	21/13	830.253	5	26	21	21/20	84.467	26/21	369.747
9	22	13	22/21	80.537	22/13	910.790	4	26	22	22/21	80.537	13/11	289.210
10	23	13	23/22	76.956	23/13	987.747	3	26	23	23/22	76.956	26/23	212.253
11	24	13	24/23	73.681	24/13	1061.427	2	26	24	24/23	73.681	13/12	138.573
12	25	13	25/24	70.672	25/13	1132.100	1	26	25	25/24	70.672	26/25	67.900
13	26	13	26/25	67.900	2/1	1200.000	0	26	26	26/25	67.900	1/1	0.000
0	14	14			1/1	0.000	14	28	14			2/1	1200.000
1	15	14	15/14	119.443	15/14	119.443	13	28	15	15/14	119.443	28/15	1080.557
2	16	14	16/15	111.731	8/7	231.174	12	28	16	16/15	111.731	7/4	968.826
3	17	14	17/16	104.955	17/14	336.130	11	28	17	17/16	104.955	28/17	863.870
4	18	14	18/17	98.955	9/7	435.084	10	28	18	18/17	98.955	14/9	764.916
5	19	14	19/18	93.603	19/14	528.687	9	28	19	19/18	93.603	28/19	671.313
6	20	14	20/19	88.801	10/7	617.488	8	28	20	20/19	88.801	7/5	582.512
7	21	14	21/20	84.467	3/2	701.955	7	28	21	21/20	84.467	4/3	498.045
8	22	14	22/21	80.537	11/7	782.492	6	28	22	22/21	80.537	14/11	417.508
9	23	14	23/22	76.956	23/14	859.448	5	28	23	23/22	76.956	28/23	340.552
10	24	14	24/23	73.681	12/7	933.129	4	28	24	24/23	73.681	7/6	266.871
11	25	14	25/24	70.672	25/14	1003.802	3	28	25	25/24	70.672	28/25	196.198
12	26	14	26/25	67.900	13/7	1071.702	2	28	26	26/25	67.900	14/13	128.298
13	27	14	27/26	65.337	27/14	1137.039	1	28	27	27/26	65.337	28/27	62.961
14	28	14	28/27	62.961	2/1	1200.000	0	28	28	28/27	62.961	1/1	0.000

Just Intonation: Harmonic and Subharmonic Octave Segments 1-32

	Harmonic Numerary Nexus in Denominator Otonal: Major Tonality						Subharmonic Numerary Nexus in Numerator Utonal: Minor Tonality						
Degree	Harmonics: Numerator	Numerary Nexus: Denominator	Ratio Steps	Steps Cents	Ratio Degrees	Degrees Cents	Degree	Numerary Nexus: Numerator	Subharmonics: Denominator	Ratio Steps	Steps Cents	Ratio Degrees	Degrees Cents
0	15	15			1/1	0.000	15	30	15			2/1	1200.000
1	16	15	16/15	111.731	16/15	111.731	14	30	16	16/15	111.731	15/8	1088.269
2	17	15	17/16	104.955	17/15	216.687	13	30	17	17/16	104.955	30/17	983.313
3	18	15	18/17	98.955	6/5	315.641	12	30	18	18/17	98.955	5/3	884.359
4	19	15	19/18	93.603	19/15	409.244	11	30	19	19/18	93.603	30/19	790.756
5	20	15	20/19	88.801	4/3	498.045	10	30	20	20/19	88.801	3/2	701.955
6	21	15	21/20	84.467	7/5	582.512	9	30	21	21/20	84.467	10/7	617.488
7	22	15	22/21	80.537	22/15	663.049	8	30	22	22/21	80.537	15/11	536.951
8	23	15	23/22	76.956	23/15	740.006	7	30	23	23/22	76.956	30/23	459.994
9	24	15	24/23	73.681	8/5	813.686	6	30	24	24/23	73.681	5/4	386.314
10	25	15	25/24	70.672	5/3	884.359	5	30	25	25/24	70.672	6/5	315.641
11	26	15	26/25	67.900	26/15	952.259	4	30	26	26/25	67.900	15/13	247.741
12	27	15	27/26	65.337	9/5	1017.596	3	30	27	27/26	65.337	10/9	182.404
13	28	15	28/27	62.961	28/15	1080.557	2	30	28	28/27	62.961	15/14	119.443
14	29	15	29/28	60.751	29/15	1141.308	1	30	29	29/28	60.751	30/29	58.692
15	30	15	30/29	58.692	2/1	1200.000	0	30	30	30/29	58.692	1/1	0.000
0	16	16			1/1	0.000	16	32	16			2/1	1200.000
1	17	16	17/16	104.955	17/16	104.955	15	32	17	17/16	104.955	32/17	1095.045
2	18	16	18/17	98.955	9/8	203.910	14	32	18	18/17	98.955	16/9	996.090
3	19	16	19/18	93.603	19/16	297.513	13	32	19	19/18	93.603	32/19	902.487
4	20	16	20/19	88.801	5/4	386.314	12	32	20	20/19	88.801	8/5	813.686
5	21	16	21/20	84.467	21/16	470.781	11	32	21	21/20	84.467	32/21	729.219
6	22	16	22/21	80.537	11/8	551.318	10	32	22	22/21	80.537	16/11	648.682
7	23	16	23/22	76.956	23/16	628.274	9	32	23	23/22	76.956	32/23	571.726
8	24	16	24/23	73.681	3/2	701.955	8	32	24	24/23	73.681	4/3	498.045
9	25	16	25/24	70.672	25/16	772.627	7	32	25	25/24	70.672	32/25	427.373
10	26	16	26/25	67.900	13/8	840.528	6	32	26	26/25	67.900	16/13	359.472
11	27	16	27/26	65.337	27/16	905.865	5	32	27	27/26	65.337	32/27	294.135
12	28	16	28/27	62.961	7/4	968.826	4	32	28	28/27	62.961	8/7	231.174
13	29	16	29/28	60.751	29/16	1029.577	3	32	29	29/28	60.751	32/29	170.423
14	30	16	30/29	58.692	15/8	1088.269	2	32	30	30/29	58.692	16/15	111.731
15	31	16	31/30	56.767	31/16	1145.036	1	32	31	31/30	56.767	32/31	54.964
16	32	16	32/31	54.964	2/1	1200.000	0	32	32	32/31	54.964	1/1	0.000

Xenharmonic fmts - Acknowledgements

Xen-Arts would also like to extend very special thanks to the following individuals and companies who have also directly inspired the creation of this VSTi with their tireless hard work and dedication to the art of xenharmonic and microtonal music, writings and software applications: X.J. Scott, Brian McLaren, Warren Burt, John Chalmers, Kraig Grady, Erv Wilson, Manuel Op de Coul, George Secor, Peter Linsener, Big Tick, Martin Fay, Camel Audio, ModArtt, Robert Rich and Carter Scholz.

Thanks goes out also to the many helpful members of the SynthEdit Users group for helping to make this instrument a reality.

This VSTi is a gift to the xenharmonic and microtonal community, as well as to musicians and composers who are interested in exploring the exciting possibilities of microtuning in their music.