Ensemble Oscillator
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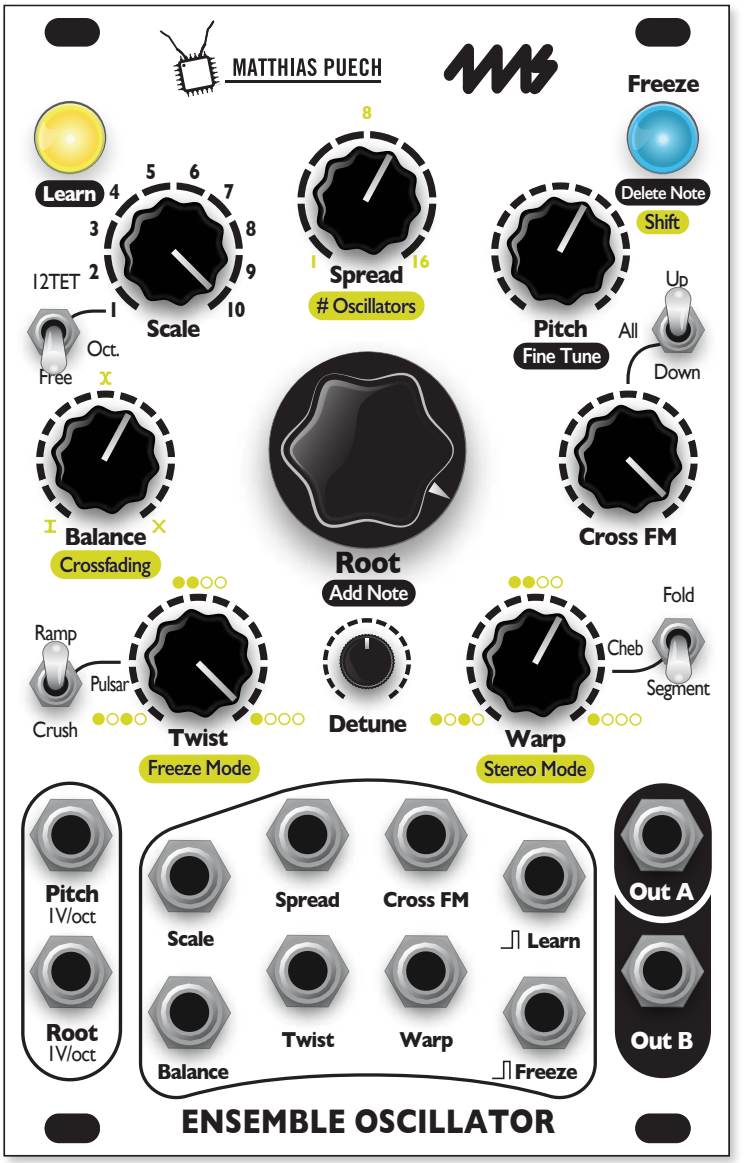

When does the superposition of tones produced by well-coordinated instruments become a single voice with a complex timbre subtly evolving over time? What are the boundaries between a rich timbre and a musically harmonic chord? From traditional overtone singing techniques and Gregorian chants to Spectral Music, Helmholtz' resonators to modern-day Fourier theory, or classical counterpoint to Xenakis' massive polyphonic clusters, the rich spectrum lying on the limit of these perceptual illusions has been a constant source of fascination, scientific study and artistic inspiration.

Combining additive, FM, phase-distortion and wavefolding synthesis techniques in new unorthodox ways, the **Ensemble Oscillator** allows you to explore this sonic boundary and exploit it musically. The eurorack-format module is a unified polyphonic voice of sixteen complex oscillators sharing the same sine-based waveforms. The oscillators take their frequency relationships from a selected scale, crossfading smoothly from one note to the next. The **Ensemble Oscillator** easily creates a wide variety of sounds ranging from aggregates of pure sine waves to pulsar synthesis or pristine harmonic tones and lush wide chords to rich dirty drones and rumbling glitches. Custom scales can quickly be "learned" and saved using a CV keyboard or by manually by entering notes with the controls.

Features

- A maximum of 16 sine-based oscillators, bound to intervals of a selected **Scale**
- 30 factory-programmed, user-writeable scales organized in three groups:
  - *12TET*: all notes quantized to equal temperament (semitones)
  - *Octave*: unquantized notes, repeating over octaves
  - *Free*: unquantized notes, repeating over the interval between the lowest and highest note
- A simple method to program (“Learn”) your own scales manually or with a CV/Gate keyboard
- Three **Twist** phase distortion effects
- Three **Warp** wave distortion effects
- Three algorithms of **Cross FM** for modulating the oscillators with each other
- Mono or stereo output with selectable panning algorithm
- **Freeze** button and jack to freeze the frequency of some of the oscillators, with selectable algorithm
- Two 1V/oct inputs: **Pitch** (non-quantized), and **Root** (quantized)
  - High-accuracy, temperature-stable, eight octave range (-2V to +6V), can be calibrated to any keyboard
- Six bi-polar CV inputs (-5V to +5V)
- Two gate inputs for automated Learning and Freezing

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Getting Started

Plugging in your Ensemble Oscillator

1. Power off your Eurorack system.
2. Connect the free end of the included power cable to a 16-pin Eurorack power header on your power supply distribution system. The red stripe should match the white line or -12V marking on the power distribution board. The other end of the power cable is a 10-pin connector which should already be connected to the **Ensemble Oscillator** with the red stripe on the power cable orientated towards the bottom of the module.
3. Using the included screws, securely attach the **Ensemble Oscillator** to the rails of your case.
4. Power on your Eurorack system.

Note: The **Ensemble Oscillator** is reverse-polarity protected, but incorrectly connecting *any* module can damage *any other* module on the power bus.

Basic Concepts

Oscillators and Frequency

The **Ensemble Oscillator** has sixteen oscillators. The pitch of each oscillator is quantized to the current scale. **Root** and **Spread** adjust the frequencies before quantization to the scale; **Pitch** and **Detune** adjust the frequencies after quantization. If an oscillator's frequency before quantization is in between two notes of the current scale, then both notes will be heard. The volume of each note will depend on how close it is to the oscillator's frequency before quantization, i.e. we crossfade between notes instead of jumping from one to the next. Once this process of quantization and blending of notes is done, the post-quantization frequency controls are applied (**Pitch** and **Detune**).

The waveshape of each oscillator is a sine wave by default. **Twist** and **Warp** modify the waveshape using a variety of algorithms, resulting in rich harmonics and complex timbres. **Cross FM** applies frequency modulation (FM) to the oscillators. The switches next to these three knobs select the algorithm used.

The oscillators output in stereo to the **Out A** and **Out B** jacks. To use the module in mono, just patch into the **Out A** jack; both outputs will be summed into it.

Scales

The currently selected scale determines which pitches the oscillators are allowed to take. A scale can be thought of as a series of notes. In the **Ensemble Oscillator**, the notes can be spaced by any amount, not necessarily just by half-steps, whole-steps, etc. like in western music scales. Also, the range of each scale can be any amount, not necessarily just an octave like most traditional scales.

Sometimes when using the **Ensemble Oscillator**, it's useful to think of a scale as a series of harmonics rather than a series of notes. The difference is purely perceptual: when many notes are played at the same time you perceive a chord, but when many harmonics are played at once, you perceive a rich waveform. If you're not familiar with the concept of a harmonic, or that any waveform can be created by adding sine waves together, the Scales and Oscillators section (page 12) has more details.

Regardless of whether you think of scales as notes or as harmonics, the notes of the currently selected scale are repeated across the entire range of human hearing to determine a "grid" of allowed pitches. This grid is what's used to quantize the oscillators. **Root** and **Spread** move the oscillators around the grid, **Pitch** moves the entire grid, and **Detune** bends the lines of the grid. See the diagram (page 13) for a visualization.

There are 30 scales in the **Ensemble Oscillator**, arranged into three groups of 10 each. The **Scale** switch selects the group, and the **Scale** knob and jack select the scale within the group. Each group has different properties regarding quantization and how the scale is repeated across the range of human hearing. See Scale Groups (page 14) for details.

Freeze

Usually, all the oscillators respond to all the controls. However, you can freeze the frequency of certain oscillators while the others continue to respond to controls. To do this, press the **Freeze** button or send a trigger into the **Freeze** jack. The button will turn blue and some of the oscillators will be frozen. Press the button again or send another trigger to unfreeze the oscillators.

Learn Mode

You can create your own scales and save them, replacing any of the factory-programmed scales. The process of programming your own scale is called “Learning”. You can Learn a new scale in two ways: 1) manually dialing-in a series of pitches using the knobs, or 2) using an external CV and gate source such as a CV/Gate keyboard, or CV sequencer. The words under some knobs are written inside black bubbles (**Add Note**, **Fine Tune**, and **Delete Note**). These are used in Learn mode. See Tutorial 2: Create Your Own Scale with Learn Mode (page 9), and the Learn Mode section (page 15).

Shift Functions

There are several advanced features that won’t need to be adjusted often, but can make important and subtle changes to the module’s behavior. Take a look at the faceplate and notice that the word **Shift,** highlighted in gold, is written underneath the **Freeze** button and that several of the knobs include an alternate name, written underneath and highlighted in gold. To use one of these alternate features, hold down the **Shift** button while turning the knob. Changes to the shift functions are saved and will persist after power down. A brief description of these features follows. For greater detail, consult the dedicated section on each feature (pages 16-18).

 # Oscillators sets the number of active oscillators (1-16).
Stereo Mode changes the way the oscillators are panned.
Freeze Mode changes which subset of oscillators is frozen.
Crossfading controls the steepness of the crossfading curve.

Controls and Jacks

Root knob and jack

The **Root** knob controls the pitch of the lowest (root) oscillator before quantization. As you adjust this knob, the oscillators move up or down in frequency, crossfading between notes in the selected scale.

The **Root** jack has the same function, with a 1V/oct response limited to voltages between -2V (two octaves down) and +6V (six octaves up).

When used with the **Pitch** knob, the range exceeds human hearing, from about 1Hz to over 20kHz.

Spread knob and jack

The **Spread** knob adjusts the spacing between the pitches of each oscillator, before quantization. Like **Root**, adjusting this knob causes the oscillators to crossfade between notes. With **Spread** at minimum, all the oscillators are tuned together, in unison. Turning **Spread** up causes them to spread apart, towards the higher frequencies, while leaving the lowest (root) note stationary.

The **Spread** jack has the same function, with a linear response for voltages between -5V and +5V. Negative voltages reduce the amount of spread (same as turning the knob down), and positive voltages increase the amount of spread (same as turning the knob up).

Pitch knob and jack

The **Pitch** knob transposes the pitch of all the oscillators continuously after quantization, similarly to pitch knobs found on common analogue VCOs. All the oscillators are shifted up or down in pitch, preserving the intervals between them. This can be used to tune the scales to other equipment , to provide a traditional pitch-sweep effect, or to FM the **Ensemble Oscillator** with external gear.

The **Pitch** jack has a 1V/oct response to voltages between -2V (two octaves down) and +6V (six octaves up). The jack works like an exponential 1V/oct jack found on common analog VCOs. When in **Learn** mode, the **Pitch** jack is used to input new notes (see Learn Jack, page 8).

When used with the **Root** knob, the frequency range exceeds human hearing, from about 1Hz to over 20kHz. Holding **Shift (Freeze)** while turning **Pitch** will fine-tune the pitch. After fine-tuning, turning the **Pitch** knob will not change the pitch until it's returned to the original position. The current fine-tune amount and whether **Pitch** is locked will be saved and restored after powering up.

Scale knob, jack, and switch

The **Scale** knob selects the scale to which the oscillators are quantized. See the Scales and Oscillators section (page 12) for details about how scales are used. There are 30 pre-programmed scales on the **Ensemble Oscillator,** arranged in three groups of ten scales each. You can also program your own scales (see Learn Mode page 15).

The **Scale** knob has ten positions, each one selects a scale.

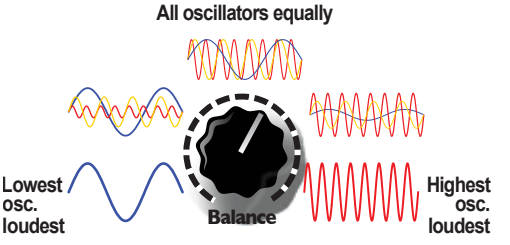
The **Scale** jack can select a scale by responding to voltages from -5V to +5V. Relative to the position of the knob, negative voltages select scales of a lower number, and positive voltages select scales of a higher number. The **Learn** button flashes white each time a new scale is selected, whether you are using the knob or the jack.

The **Scale** switch selects one of three groups of scales: *12TET*, *Octave*, or *Free*. Each group has different properties regarding allowable intervals and how the scale is repeated. See the Scales and Oscillators section (page 12) for more details.

Balance knob and jack

The **Balance** feature controls how the oscillators are mixed before reaching the output jacks. When **Balance** is turned all the way down, the lowest (root) oscillator will be loudest by a factor or 16:1. As you turn **Balance** up towards center, the other oscillators will rise in volume, with the lower oscillators being louder than the higher ones. With **Balance** at center, all the oscillators will have the same volume. As you continue turning **Balance** up, the lower oscillators will begin to decrease in volume while the higher ones will remain louder. With **Balance** all the way up, only the highest oscillator will be heard.

The **Balance** jack has the same effect, responding to voltages from of -5V to +5V. Negative voltages shift the balance towards the lower oscillators (same as turning the



knob down), and positive voltages shift towards the higher oscillators (same as turning the knob up).

Cross FM knob, switch, and jack

The **Cross FM** feature controls how much the oscillators modulate the frequency (FM) of each other. When the knob is fully down, there is no modulation. As the knob is turned up, complex sets of harmonics arise. Since the oscillators are related to each other in frequency (due to being quantized to the selected scale), the particular type of FM sounds created by this feature are often sonically interesting.

The **Cross FM** switch controls the “FM algorithm”, i.e. which oscillator(s) modulate which.

There are three positions:

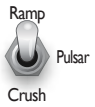
- *Up*: The lowest (root) oscillator modulates all the other oscillators (1→2, 1→3, 1→4, etc.)
- *All*: Each oscillator modulates the next higher oscillator (1→2, 2→3, 3→4, etc.)
- *Down:* The highest oscillator modulates all the other oscillators (16→1, 16→2, 16→3, etc.)

The **Cross FM** jack responds to voltages from -5V to +5V. Negative voltages reduce the amount of effect and positive voltages increase the amount of effect, with respect to the knob position.

Twist knob, switch, and jack

The **Twist** feature distorts the time base of each oscillator’s period from a pure sine wave to a more complex waveshape, a process known as *phase-shaping*. A simple way to hear (or see, if you have an oscilloscope) the effect of **Twist** is to listen to just one oscillator by turning **Balance** all the way down as you play with the **Twist** knob and switch.

With the knob all the way down, no distortion is applied and the base waveform is a sine wave (assuming no other wave-folding or modulation is present). As you turn the knob up, the sine wave morphs into another waveform, depending on the position of the **Twist** switch:



- *Ramp*: morphs the phase to an increasingly steep sawtooth, and beyond
- *Pulsar*: compresses the phase of the sine wave to create narrow “pulses”
- *Crush:* bit-crushes the oscillator phase

The **Twist** jack responds to voltages from -5V to +5V. Negative voltages reduce the amount of effect and positive voltages increase the amount of effect, with respect to the knob position.

Warp knob, switch, and jack

The **Warp** feature applies different types of wave-folding to the twisted wave, all of which modify the harmonic content in different ways. A simple way to hear the effect of **Warp** is to listen to just one oscillator by turning **Balance**, **Cross FM** and **Twist** all the way down while you play with the **Warp** knob and switch.

With the knob all the way down, no wave-folding is applied and the base waveform is a sine wave (assuming no other distortion or modulation is present). As you turn the knob up, more wave-folding is applied.

The **Warp** switch selects one of three types of wave-shaping:

- *Fold:* wave-folding inspired by analog wave-folders (maximum six folds)
- *Cheb:* Chebyshev polynomial-based wave-folding (maximum 16th order)
- *Segment*: linear (triangle-wave) based wave-shaper (8 different shapes)

The **Warp** jack responds to voltages from -5V to +5V. Negative voltages reduce the amount of effect and positive voltages increase the amount of effect, with respect to the knob position.

Detune knob

The **Detune** knob adjusts how much the oscillators are detuned after they’ve been quantized. It’s easy to create beat frequencies and/or dissonance with this feature. Using the stereo outputs with a small amount of **detuning** can create a lush stereo field.

Learn button

The **Learn** button is used to create and save custom scales. Pressing this button enters Learn mode, indicated by the button turning red. If you enter Learn mode by accident, just press the button again to exit with no changes.

Learn mode allows you to create a new scale and save it into one of the 30 scale slots. Custom scales can be recalled even after you power the module down.

See Tutorial 2: Create Your Own Scale with Learn Mode (page 9), and the Learn Mode section (page 14) for details.

Learn jack

The **Learn** jack is used in Learn mode to input notes in a scale. A CV/Gate keyboard or sequencer can be patched into the **Pitch** and **Learn** jacks. Each time the **Learn** jack receives a trigger or gate, the **Pitch** jack will be read and used to create a new note in the scale. See Tutorial 2: Create Your Own Scale with Learn Mode (page 9), and the Learn Mode: Advanced Concepts section (page 15) for more details on using this jack.

Outside of Learn mode, the **Learn** jack is not used (any gates received by this jack are ignored).

Freeze button and jack

The **Freeze** feature allows you to “freeze” a subset of oscillators while the remaining oscillators behave normally. A frozen oscillator will not respond to changes in its frequency via the **Pitch**, **Root**, **Spread**, **Scale** or **Detune** knobs or jacks. However, frozen oscillators will still respond to waveform and mixing/panning changes via the **Twist**, **Warp**, **Cross FM**, and **Balance** knobs and jacks. The **Stereo Mode** and **# Oscillators** shift functions allow you to adjust the panning and the enabled/disabled state of frozen oscillators.

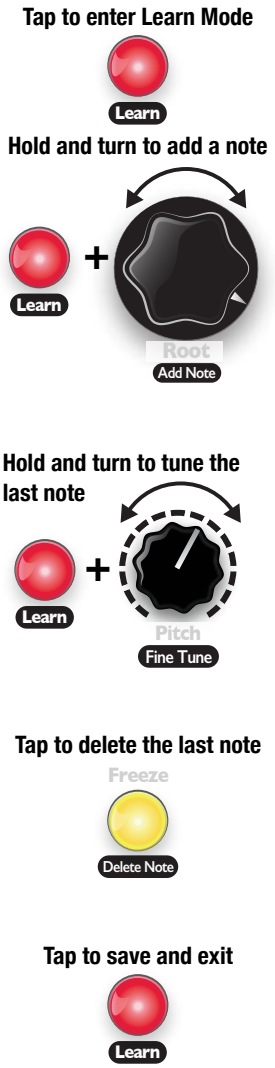
When the **Freeze** button is pressed or a trigger is detected on the **Freeze** jack, certain oscillators will freeze at whichever frequency they happen to be at that moment. The **Freeze** button will turn blue to indicate that some oscillators are frozen. Pressing the button again or firing a trigger into the jack will unfreeze the oscillators and the button will turn back to its normal yellow color.

The subset of oscillators which get frozen is determined by the **Freeze Mode** shift function. There are three options: freeze only the lowest (root) oscillator, freeze the bottom subset of oscillators (e.g. 1–8 if 16 oscillators are enabled), or freeze the odd-numbered oscillators. See the Freeze Mode section (page 17) for a complete discussion.

The **Freeze** button is also used to access the **Shift** features. Holding down this button while turning one of the knobs that has a **Shift** feature (**# Oscillators**, **Crossfading**, **Stereo Mode**, **Freeze Mode**) will modify the shift parameter instead of the main parameter. See the Shift Features section (page 16).

Tutorial I: Create your own Scale in Learn Mode using the knobs

Creating your own scale is easy. With the **Ensemble Oscillator**, the process of creating a new scale is called “Learning”. There are two ways to do it: with the knobs, or with an external CV and gate source. This tutorial covers the former.



1. Start by unpatching all cables except the **Out** jack(s), and turning down **Twist**, **Warp**, **Detune,** and **Cross FM.**
2. Turn down **Balance** so that you're just hearing the root oscillator. Turn up **Pitch** and/or **Root** so that it's playing a low frequency. This is your root note.
3. Flip the **Scale** switch to *Free* and turn the **Scale** knob to a scale you don't mind overwriting (you can restore it later).
4. Tap the **Learn** button. It’ll turn red to show you're in Learn mode.
5. Hold down the **Learn** button and turn the **Add Note** (**Root**) knob. You'll hear the original root note plus a new note whose pitch you're controlling. The new note will be higher or lower in pitch depending on which way you turn the knob. Keep turning the **Add Note** knob until you like how the two notes sound together. Release the **Learn** button.
6. Repeat the last step to add another note. You should be hearing three notes now.
7. Let’s try adjusting the pitch of the last note you added. Hold down **Learn** and turn the **Fine Tune** (**Pitch**) knob. The pitch of the last note will change by a small amount.
8. Repeat the **Learn +** **Add Note** step again to add a fourth note. This time, make the pitch obnoxiously high.
9. Oops! That last note is a mistake, let's get rid of it. Tap the **Delete Note** (**Freeze**) button and it'll go away.
10. Add some more notes if you wish (maximum of 16).
11. When you're done, tap the **Learn** button. It’ll flash green to indicate your scale saved.
12. That’s it! You've programmed a scale. It's saved in the group and slot the **Scale** knob and switch point to. You can recall it even after you power down.
13. Let’s listen to the notes of the scale. Notice that the **Freeze** button is flashing (see inset below). Turn the **Root** knob up and/or down until the **Freeze** button flashes green. Now you can slowly turn **Root** to play the notes of the scale in order.
14. Listen to how the notes sound together as a chord or waveform by turning **Balance** up towards center, and adjusting **Spread** and **Detune** until you hear a full sound.
15. Feel free to play with **Twist, Warp**, and Cross **FM** to find a timbre you like.
16. If you want to restore the original factory scale into the slot, make sure the **Scale** knob is pointing to the slot you want to restore and the **Scale** switch is selecting the correct group. Then hold down the **Learn** button for about four seconds. The button will flash blue and the sound will change when the original factory scale is restored. There is no undo for this.

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*Why is the **Freeze** button flashing?*
When you exit Learn mode, the **Freeze** button will often be flashing. This is telling you that one or more of the knobs have their values "frozen" until you turn the knob back to where it was when you first entered Learn mode (it also could mean you adjusted a Shift feature). To “unfreeze” a knob, turn it up and down until the **Freeze** button flashes green. The sound won’t change until it’s back in its original position. If more knobs still need unfreezing, **Freeze** will keep flashing. When exiting Learn mode, you usually want to unfreeze **Root** and **Pitch**. This feature keeps the pitch from jumping drastically when you exit Learn mode, and means you don’t have to retune to external equipment.

Tutorial 2: Create your own Scale in Learn Mode using a keyboard

A fast way to enter a scale with specific notes you want is to use a CV/gate keyboard or sequencer.

1. Patch the CV output from a keyboard or sequencer into the **Pitch** jack and the gate output into the **Learn** jack, unpatching all other cables except the **Out** jack(s).
2. Turn down **Twist**, **Warp**, **Detune,** and **Cross FM.**
3. Turn down **Balance** so that you're just hearing the root oscillator. Turn up **Pitch** and/or **Root** so that it's playing a low frequency.
4. Flip the **Scale** switch to *12TET* and turn the **Scale** knob to a scale you don't mind overwriting (you can restore it later).
5. Tap the **Learn** button. It'll turn red to show you're in Learn Mode.
6. If you have a keyboard, play a few notes. If you have a sequencer, play a sequence for a brief moment. The **Learn** button will flash white each time a note is added.
7. Add more notes if you wish (maximum of 16).
8. When you're done, tap the **Learn** button. It'll flash green to indicate your scale saved.
9. That's it! You've programmed a scale. It's saved in the group and slot the **Scale** knob and switch point to. You can recall your scale even after you power down.
10. Listen to the notes of your scale by slowly turning **Root** to play the notes of the scale in order.
11. Listen to how the notes sound together as a chord or waveform by turning **Balance** up towards center, and adjusting **Spread** and **Detune** until you hear a full sound.
12. Feel free to play with **Twist, Warp**, and Cross **FM** to find a timbre you like.
13. If you want to restore the original factory scale, follow step 16 on the previous page.

Patch Idea: Frozen Bass, Flowing Melodies

The lowest (root) oscillator is not modulated by the **Cross FM** feature when the switch is set to *Up*. Since the root oscillator can be frozen independently of the others, and can also be panned to its own output jack, it has a degree of independence from the other oscillators. There are many ways to take advantage of this feature; the patch below uses a clocked CV sequence and a clock divider.

Setup:

1. Patch **Out A** and **Out B** to separate channels of a mixer. It's helpful for this patch if you can independently control the level of each channel.
2. Set the **Stereo Mode** to the highest setting (●○○○). See Stereo Mode on page 18. This will send just the root oscillator out of **Out A** and all the other oscillators out of **Out B.**
3. Turn **Spread** and **Balance** somewhere around the center so that you can hear all the oscillators. Make sure the **# Oscillators** feature is set to at least two oscillators (16 is recommended). See # Oscillators section on page 17.
4. Pick a **Scale** you like.
5. Turn **Twist** and **Warp** all the way down.
6. Set the **Freeze Mode** to the highest setting (●○○○). See Freeze Mode section on page 17.
7. Adjust the mixer levels so that you're just hearing the root oscillator coming from **Out A**. Adjust **Pitch** and **Root** so that the frequency of the root oscillator is low, yet still audible. Adjust the mixer levels again so you hear the root note along with the other oscillators.
8. Flip the **Cross FM** switch to *Up.* Turn the **Cross FM** knob up a bit until you like the sound. You should hear the root oscillator as a clean sine wave and the other oscillators as complex FM'ed waveforms, all coming from **Out A**.

Playing:

9. Patch a CV source such as as sequencer or clocked LFO into the **Root** jack. You should hear the frequencies changing as the CV changes. The root oscillator will be a clean sine wave and the other oscillators will be "dirty" FM sounds.
10. Tap the **Freeze** button periodically and listen to how the root oscillator holds its note, while the other oscillators continue. Practice freezing and un-freezing periodically.

11. Try patching a divided clock into the **Freeze** jack. If you're using a sequencer, take its clock signal and run it through a clock divider (such as the RCD or QCD) and set the divisions to /6, or /8 or /12 perhaps. If the divided clock is too fast, there won't be much of an effect. The **Freeze** button should toggle on and off every few notes of the sequence. Change the division amount to get a different effect.
12. Turning up **Warp** or **Twist** even a small amount can add character to the root oscillator. Try it with the three different **Warp** and **Twist** switch settings.

Tips:

- If you're using a **QCD** with a **QCD Expander**, use the **INV OUT** jack and select the double-trigger mode. Adjust the **Gate PW** to select the amount of frozen vs un-frozen time.
- If you want to take this patch further:
    1. Split or mult the signal going from **Out A** to the mixer, then run the split **Out A** signal through an attenuator and back into one of the CV jacks on the **Ensemble Oscillator** (such as **Cross FM** or **Warp**).
    2. Adjust the attenuation amount and turn **Root**, **Pitch**, and **Spread** to play with the variations of sound.

Patch Idea: Wavefolding Pseudo-VCA

In a small system you can quickly run out of VCAs or other ways to apply an envelope to a sound source and create notes. While the **Ensemble Oscillator** doesn't have a true VCA built-in, there are some techniques to create distinct notes with an external envelope. The basic idea is to get spaces between notes using inaudibly low frequencies. Here's one technique:

1. Turn down **Warp, Twist** and **Cross FM.** Flip the **Warp** switch up to *Fold*.
2. Patch the CV output of a keyboard, sequencer, or other CV source to the **Pitch** or **Root** jacks of the **Ensemble Oscillator.**
3. Turn down the **Root** and **Pitch** knobs on the **Ensemble Oscillator** so that the frequency is just barely inaudible, or at least not prominent. You may also need to adjust **Spread** or **Balance** so that the higher oscillators aren't heard. At first you may want to try having **Balance** all the way down so you are hearing just the root oscillator.
4. Patch a gate output to an envelope generator and then patch the envelope generator to the **Warp** jack on the **Ensemble Oscillator**.
5. Adjust **Root** and **Pitch**, as well as the amplitude of the envelope until you hear distinct notes.

Variations:

- For some variations, try the other two **Warp** switch settings.
- For a more dirty sound, use the **Twist** jack instead of **Warp**.
- For a more clean sound, use the **Balance** jack instead of **Warp**. Turn the **Balance** knob all the way down.
- For FM sounds, use the **Cross FM** jack instead of **Warp**. Play with all three **Cross FM** switch positions.

Patch Idea: Self-patched Chaos

There are infinite ways to explore the realm of chaotic patches. Here's one patch to get you started:

Setup:

1. Patch LFOs and/or random CV sources to **Pitch**, **Twist**, and **Warp.**
2. Patch **Out A** to your mixer/speakers.
3. Patch **Out B** to **Root**. Optionally, split the signal and patch it to a mixer as well.
4. Turn **Root** all the way down, turn **Pitch** to center.
5. Turn **Warp, Twist, Balance, Spread**, and **Cross FM** knobs all the way down.
6. Flip the **Warp** switch to *Cheb*. and **Twist** to *Pulsar*.
7. Try to find drippy watery sounds by adjusting the rate, waveshape, and amplitude of the CV sources. In chaotic patches it can be especially nice to link the tempos of the CV sources.
8. Adjust one knob or switch at a time, paying attention to how the sound changes.

Detailed Concepts and Usage

Scales and Oscillators

The concept of scales is central to the **Ensemble Oscillator**. In western music, a scale is a series of notes with the last note being an octave higher than the first note. The spacing between the notes is always one or more semitones (i.e., half-steps, whole-steps, minor thirds, etc.) Scales in the **Ensemble Oscillator** are similar in concept but don't have to adhere to this form: the notes don't have to repeat on an octave basis and don't have to be spaced by semitones. In music theory, a scale can be defined by a sequence of intervals. No matter what note the scale starts on, the intervals will always be the same for any given type of scale (major, minor, etc.)

In the **Ensemble Oscillator** you can also think of a scale as a sequence of harmonics. It can be shown mathematically that any waveform can be broken down into a series of sine waves. For instance, a 100Hz square wave can be created from a 100Hz sine wave, plus a 300Hz sine wave, plus a 500Hz sine wave, plus a 700Hz sine wave, and so on. Each of these sine waves is a called a "harmonic". The first harmonic is called the "fundamental". Any sound, no matter how rich or complex the timbre, can be represented by its harmonic content. Just like in music theory where the intervals between notes are always the same for any given scale type, the intervals between the harmonics are always the same for any given waveform. Whether you prefer to think of the scales as being composed of notes or harmonics, we will use the term "note" in this manual for simplicity.

What's an interval?
An interval is the distance between two pitches. In music theory, common intervals have names such as "major third" and "perfect fifth". Sometimes intervals are expressed as a number of octaves, whole-steps, half-steps, or semitones. In microtonal music, small intervals are usually expressed in terms of cents, which are hundredths of a semitone. In mathematics, an interval might be expressed as a ratio between the frequencies. An octave is 2:1, and a fifth is about 1.5:1, and two notes in a particular microtonal scale might have the interval 25:24.

The currently selected scale is used to create a set of notes that the oscillators are allowed to produce. The starting note is determined by the **Pitch** knob and jack. The rest of the allowed notes are calculated using the sequence of intervals in the scale. Once the last interval is reached, the sequence starts over with the first interval. By repeating the pattern of intervals over and over, the **Ensemble Oscillator** creates a set of notes to which the oscillators will be quantized.

Oscillators
The first oscillator is called the root oscillator and has the lowest pitch. Its frequency before quantization is determined by the **Root** knob and jack. The pitch of the other oscillators is determined by the **Spread** knob and jack. With **Spread** all the way down, the oscillators are all tuned to the same pitch. As **Spread** is turned up, the space between the oscillators is widened.

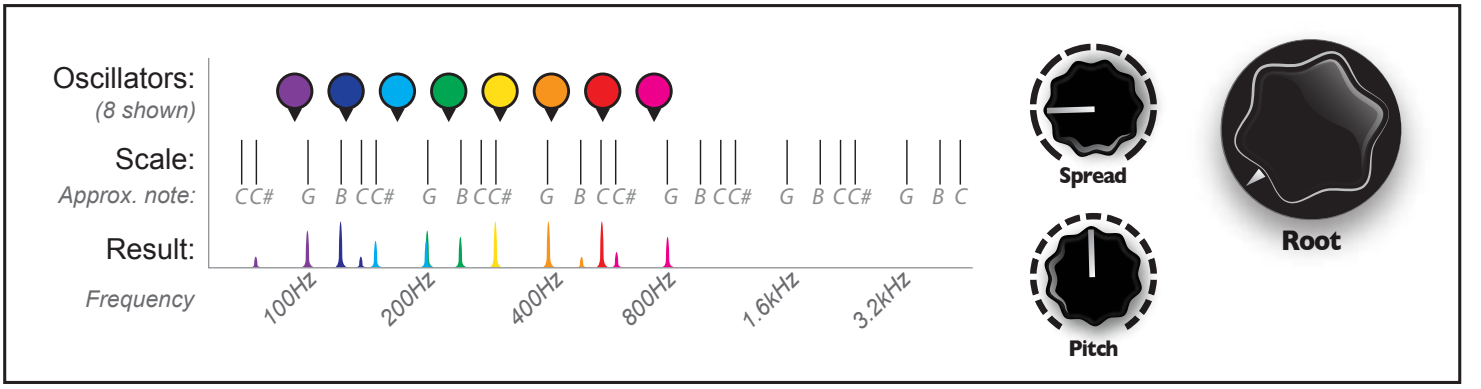
Quantization
When an oscillator is tuned between two allowed notes (which is most of the time), instead of "snapping" to the closest note like a normal quantizer would do, the oscillator produces two pitches: one tuned to each of the nearest allowed notes. The amplitude of each pitch is relative to its distance from the nearest note in the scale.

Take a look at the diagram on the next page. In the first box, the eight oscillators are spread by a small amount. The allowed notes are shown by the bars in the scale. The resulting sound is a collection of pitches, the amplitude of each being relative to how closely an oscillator is tuned to the corresponding note of the scale. For instance, the purple oscillator has a pre-quantized frequency that's between the second and third notes of the scale (C# and G). Since it's between two notes, both will be heard (as shown by the result having some of both). The third note (G) will be louder than the second (C#) because the oscillator is closer to it.

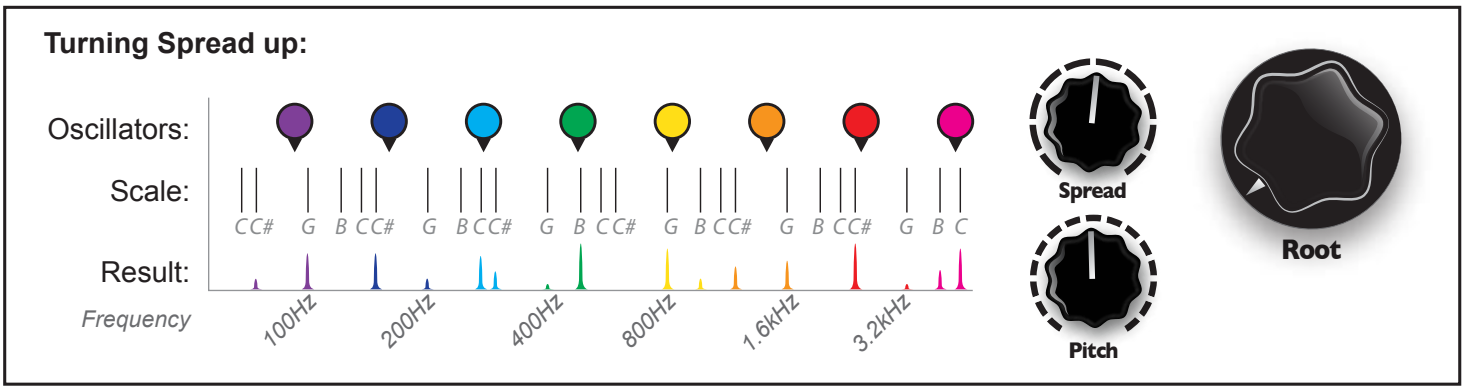
In the second box, the **Spread** knob is turned up. The notes in the scale don't change, but the oscillators are spaced further apart. The resulting frequencies cover a wider range. Notice that the root oscillator (purple) stays in place and all the other oscillators move upwards.

In the third box, **Spread** has been turned back down, and the **Root** knob has been turned up. Notice that the spacing between the oscillators is the same as in the first box, but they've been shifted up in frequency. The resulting frequencies cover about the same range as in the first box, but everything is about two octaves higher. While the **Root** knob is being turned up, each note in the scale rises and falls in volume as an oscillator passes by it. No pitch-bending or glissando effects are heard.

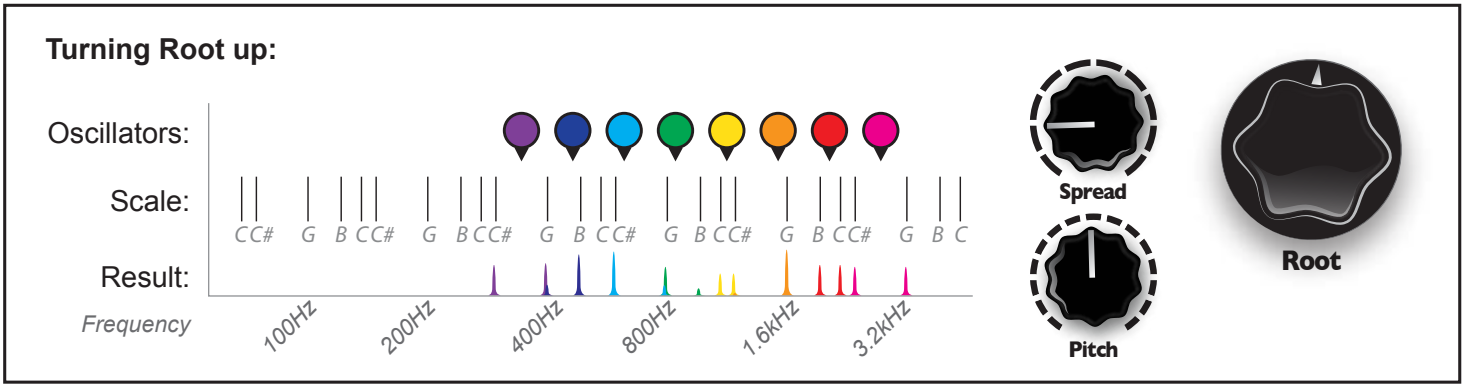
In the fourth box, **Root** has been turned back down, and the **Pitch** knob has been turned up. The result is exactly the same as the first box except everything has been transposed (or pitch-shifted) upwards. Even the allowed notes of the scale have been transposed (notice the names of the notes went from C C# G B to G# A D# G). While the **Pitch** knob is being turned up, the entire sound rises in frequency with a pitch-bending effect. Unlike turning **Root** or **Spread**, there is no rising and falling in the volume of each note.



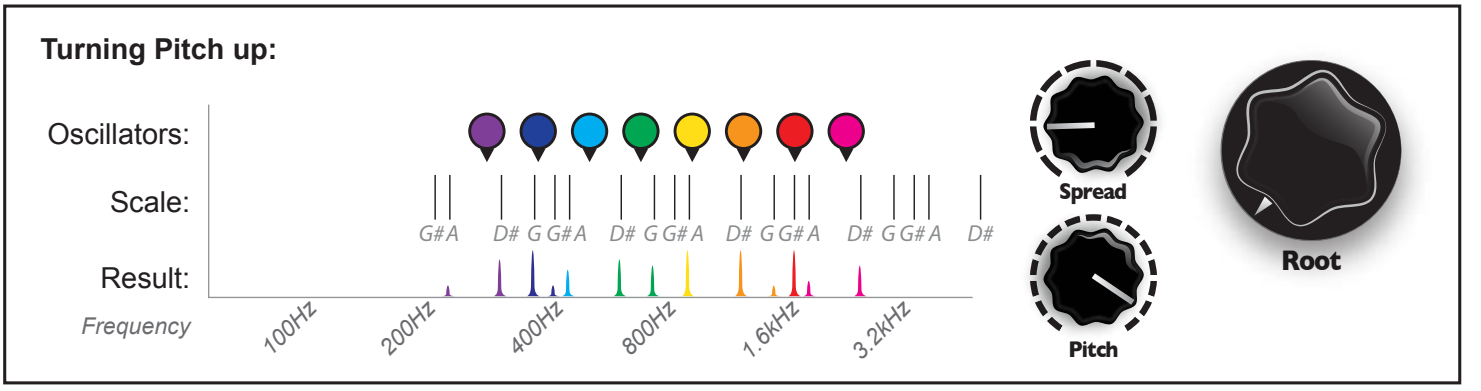
Turning Spread up:



Turning Root up:



Turning Pitch up:



Detuning
After quantization, the **Detune** feature is applied. The first (root) oscillator is not detuned at all. The other odd-numbered oscillators are detuned upwards, and the even-numbered oscillators are detuned downwards. Going from lowest to highest, each oscillator is detuned a little more than the previous one. If an oscillator is outputting two pitches because its pre-quantized frequency is between two notes in the scale, both pitches will be detuned by the same amount and in the same direction, regardless of whether they are odd or even-numbered.

Scale Groups

There are thirty scales in the **Ensemble Oscillator**, arranged into three groups of ten each. The group is selected using the **Scale** switch, and the scale within the group is selected using the **Scale** knob. The three groups are *12TET*, *Octave*, and *Free*. Each group has different properties.

12TET scale group
In the *12TET* group, all the intervals are equal-temperament semitones and multiples of semitones (whole-steps, minor thirds, octaves, etc.) Only notes from a 12-tone equal temperament scale will appear, but scales don't necessarily have to repeat every octave.

12TET group factory scales		*Intervals*	*Example Notes (assume root note is C0)*
Slot 1	Octaves	P8, repeat	C0, C1, C2, …
Slot 2	Octaves and fifths	P5, P4, repeat	C0, G0, C1, G1, C2, …
Slot 3	Major triad	M3, m3, P4, repeat	C0, E0, G0, C1, …
Slot 4	Minor triad	m3, M3, P4, repeat	C0, Eb0, G0, C1, …
Slot 5	Minor triad+	m3, M2, M2, P4, repeat	C0, Eb0, F0, G0, C1, …
Slot 6	*"Bluesy 1"*	m3, M2, P4, M2, repeat	C0, Eb0, F0, A#0, C1, …
Slot 7	Major 7th 3rd inv.	m2, M3, m3, M3, repeat	C0, C#0, F0, G#0, C1, …
Slot 8	Circle of Fifths	P5, repeat	C0, G0, D1, A1, E2, …
Slot 9	*"Bluesy 2"*	m3, M2, M2, repeat	C0, Eb0, F0, G0, A#0, C1, D1, …
Slot 10	Semitones	m2, repeat	C0, C#0, D0, D#0, E0, F0, …

Octave scale group
The *Octave* scale group allows any interval but forces each scale to repeat every N octaves. Just intonation and other octave-repeating temperaments can easily be entered here, as well as scales that repeat every 2 or 3 octaves. If you create your own scale in the *Octave* group and the highest note you enter is not exactly a whole number of octaves above the lowest note, then the module will automatically insert an extra interval at the end to "complete" the octave. This means that whenever the sequence of intervals repeats with a scale in the *Octave* group, the pitches will always be one or more octaves higher.

Octave group factory scales		*Comments*
Slot 1	Harmonics 2-3 of the harmonic series	aka. perfect fifths
Slot 2	Harmonics 4-7 of the harmonic series	
Slot 3	Harmonics 8-15 of the harmonic series	
Slot 4	Odd Harmonics 1-8 of the harmonic series	
Slot 5	Do Fa So (Pythagorean), just intonation	ratios 1:1, 4:3, 3:2, 2:1
Slot 6	Do Re Fa So La (Pythagorean), just intonation	ratios 1:1, 9:8, 4:3, 3:2, 27:16, 2:1
Slot 7	First just ratio scale	ratios 1:1, 3:2, 4:3, 5:4, 2:1
Slot 8	Second just ratio scale	ratios 1:1, 5:4, 4:3, 3:2, 5:3, 7:4, 2:1
Slot 9	5TET	five notes per octave, equal temperament
Slot 10	7TET	seven notes per octave, equal temperament

Free scale group
The *Free* scale group imposes no restrictions on the allowed intervals. Like the *12TET* group, the scales don't have to repeat every octave. This group can contain any type of scale, including microtonal and experimental scales.

Free group factory scales		*Intervals*	*Comments*
Slot 1	Perfect fifths spiral		the circle of fifth that does not repeat every octave
Slot 2	Whole tones	M2, repeat	First mode of limited transposition
Slot 3	Messiaen #2	m2, M2, repeat	Second mode of limited transposition
Slot 4	Messiaen #3	M2, m2, m2, repeat	Third mode of limited transposition
Slot 5	Messiaen #4	m2, m2, m3, m2, repeat	Fourth mode of limited transposition
Slot 6	Bohlen-Pierce	13 steps per tritave	The scale repeats every 3x the frequency
Slot 7	Bohlen-Pierce major	1, 7, 11, repeat	The scale repeats every 3x the frequency
Slot 8	Bohlen-Pierce minor	1, 5, 11, repeat	The scale repeats every 3x the frequency
Slot 9	Wendy Carlos alpha	78 cents	
Slot 10	Wendy Carlos beta	63.8 cents	

Learn Mode: Advanced Concepts

The **Ensemble Oscillator** has thirty slots for scales, all of which come factory programmed. You can replace any of the factory scales with your own custom scale. This process is called "Learning" a new scale. Read the Create Your Own Scale in Learn Mode tutorials (pages 9–10) before continuing with this section.

Root Note and Intervals

If you follow the tutorial to learn a new scale using the knobs, you'll notice that the root note of the new scale is set to the current root note at the moment you enter Learn mode. You also can set the root note by entering Learn mode in a slightly different way: instead of tapping **Learn**, hold down **Learn** and turn **Add Note**. You'll hear a single tone change in pitch as you turn the knob. Release **Learn** when you've found the pitch you want, then continue with the procedure as normal.

When adding notes using the **Pitch** and **Learn** jacks, the root note will always be the first note you enter.

However the scale is entered, the first two notes define the first interval of your scale. The next note defines the second interval, etc. Rather than storing the notes that you entered, the **Ensemble Oscillator** stores the intervals.

Changes to Controls in Learn Mode

The **Scale** knob and switch no longer select the scale to load but instead select where the new scale will be saved. If the **Scale** switch is flipped to *12TET* at the moment you enter a new note, the resulting interval will be quantized to the nearest semitone. By flipping the switch between *Free* (or *Octave)* and *12TET*, you can quantize some of the intervals and leave others un-quantized. Note that if you save a scale into the *12TET* group, all the intervals will be quantized.
The **Detune**, **Balance**, **Spread**, and **Cross FM** knobs and jacks are disabled in Learn mode. The other jacks and knobs work as normal: **Twist** and **Warp** modify the waveshape, and the **Root** jack offsets notes as they're entered. Be aware if you have CV patched into the **Scale** jack because it effects where the scale is saved.

Coarse Tuning

As described in the tutorial, you can fine-tune the last note you entered by holding down **Learn** and turning **Fine Tune**. You can also coarsely tune the last note. First, hold down **Learn** and turn **Fine Tune**. While still holding down **Learn**, turn **Add Note** and the pitch will change by larger amounts. Note that if you turn the **Add Note** knob while *not* holding down the **Learn** button, the pitch will jump by a large amount if you proceed to fine-tune the note.

Using Other CV and Gate Sources

You can use any CV and trigger or gate source patched into the **Pitch** and **Learn** jacks, a keyboard or sequencer is not required. For instance, you could run a slow LFO into **Pitch** and use a clock (or manual gates) to add notes. If the **Scale** switch is set to *12TET,* your scale can be quantized without needing an external quantizer module.

Failure to Save

When you press **Learn** to save your scale, it normally will flash green to indicate the new scale was saved into the slot and group set by the **Scale** knob and switch. If the **Learn** button does not flash green, the scale couldn't be saved because it wasn't valid. To be valid, a scale has to have at least two notes which are at least 10 cents (1/10th of a semitone) apart.

Scale Groups and Learning
When you Learn a new scale with the **Scale** switch set to *12TET* or *Octave*, the constraints described in the Scale Groups section (page 14) will be applied automatically to the notes you enter.
To demonstrate how the choice of the Scale Group will effect a new scale, we'll take a simple example of a scale and show how it would behave differently if it were added using each of the three Scale Groups. You may want to follow along on your **Ensemble Oscillator.** The notes that will be Learned are a C2, a G2, and a slightly flat A2 that's between a G#2 and an A2, but closer to an A2. (In case you're not familiar with this notation, C2 means a C note in the second octave of human hearing.)

In the *12TET* group, all notes are quantized to the 12-note per octave scale, so the slightly flat A2 will become an A2. This means the intervals in the scale will be:
Fifth (C2→G2)
Major second (G2→A2)
(Repeat)

If you tune the root note to C0 (using the **Pitch** knob or jack), then the notes the oscillators are allowed to play will be:
C0, G0, A0, E1, F#1, C#2, Eb2, etc.

In the *Octave* group, the notes are not quantized, so the notes will stay C2, G2, slightly flat-A2. However, the *Octave* group forces the intervals to add up to an octave (or a multiple of an octave), so a "hidden" C3 will be added at the end. Therefore the interval sequence will be:
Fifth (C2→G2)
Slightly-flat major second (G2→A2-ish)
Slightly-sharp minor third (A2-ish→ C3)
(Repeat)

If you tune the root note to C0, then the notes the oscillators are allowed to play will be:
C0, G0, slightly-flat-A0, C1, G1, slightly-flat-A1, C2, G2, slightly-flat-A2, C3, etc.

In the *Free* group, the notes are not quantized, and no extra intervals are added. Thus the interval sequence will be:
Fifth (C2→G2)
Slightly-flat major second (G2→A2-ish)
(Repeat)

If you tune the root note to C0 (using the **Pitch** knob or jack), then the notes the oscillators are allowed to play will be:
C0, G0, slightly-flat-A0, slightly-flat-E1, bit-more-flat-F#1, bit-more-flat-C#2, even-flatter-Eb2, etc.
It's no longer practical to represent the allowed notes using the western system of notation.

Restoring a Factory Scale
If you want to restore a scale to the factory default, set the **Scale** knob and switch to the scale you wish to restore. Then press and hold the **Learn** button for four seconds. The button will flash blue and the factory scale will be restored. This can't be undone, any scale you had programmed into that slot in that group will be lost.

Shift Features

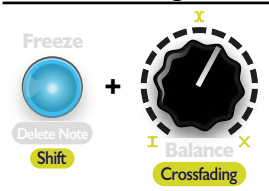
There are four features accessible by holding down the **Shift** (**Freeze**) button while turning a knob. These features are called the **Shift** features:

Shift + **Balance = Crossfading** controls the steepness of the crossfading curve, from sharp to smooth.
Shift + **Spread = # Oscillators** sets the number of active oscillators, from one to sixteen.
Shift + **Twist = Freeze Mode** changes which subset of oscillators gets frozen: odds, lower half, or root.
Shift + **Warp = Stereo Mode** changes the way the oscillators are panned: even/odd, low/high, or root/others.

The **# Oscillators**, **Freeze Mode and Stereo Mode** features have a discrete number of values to choose from. When you hold down the **Freeze** button and turn one of these knobs, the **Freeze** button will flash white whenever their values change.

When you're done adjusting a knob, you can let go of the **Freeze** button. If the knob is now in a different position than it was when you pressed **Freeze**, then the knob's normal feature will still be set to the value it was before you adjusted the **Shift** feature. That is to say, when you let go of the knob, the sound won't immediately jump. Instead, the knob's normal feature will keep its old value until you turn the knob back to the position it was in before you pressed **Freeze**. Until you do this, the **Freeze** button will flash to indicate that the knob is out of position. The more knobs are out of position, the faster the **Freeze** button will flash. When you turn a knob back to its original position, the **Freeze** button will briefly flash green.
The values you set with the **Shift** features are saved across powering down and back up.

Crossfading



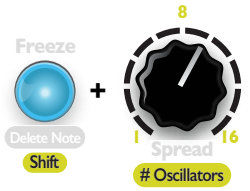
Crossfading controls what happens when an oscillator's pitch before quantization falls between two notes of the scale. To understand this feature, you must first understand how the oscillators and scales work. See Scales and Oscillators section and diagram (pages 11 to 13).
Hold the **Shift** (**Freeze**) button and turn the **Crossfading** (**Balance**) knob to adjust this feature.

The lowest setting (knob fully counter-clockwise) disables **Crossfading** and forces each oscillator to play the nearest note of the scale. With this setting, adjusting **Root** or **Scale** causes the pitches to jump from note to note. Each oscillator will only play one pitch at a time, so the sound is somewhat less full than in the other settings. There will be a discontinuity when changing from one allowed note to the next. This setting can be useful for more abrupt and harsh patches. Another use for disabling **Crossfading** is to listen to the notes of a scale one at a time. This is done by setting the **Balance** and **Spread** knobs all the way down, and turning the **Root** knob slowly to sweep through the scale.

With the knob at center, a small amount of crossfading is applied. This is the default setting. If an oscillator is tuned near (but not necessarily exactly equal to) one of the notes of the scale, it will play only that note. The other neighboring note will be silent. On the other hand, if the oscillator is far enough away from any note of the scale, then both of the closest neighbors will be heard, crossfading the volumes normally. This setting allows you to distinctly find the notes of the scale, but makes transitioning between notes more seamless.

The highest setting (knob at fully clockwise) applies maximum **Crossfading**. The two nearest allowed frequencies are always played, crossfading normally based on proximity. This setting makes it difficult to dial-in just one note, but it offers maximum smoothness when adjusting **Root** or **Spread.**

Oscillators

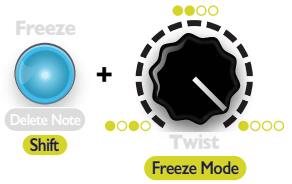


The **Ensemble Oscillator** can potentially use 16 oscillators to produce sound. By default, the module uses all 16 available oscillators, but you can reduce the number of oscillators with this feature.

Hold the **Shift** (**Freeze**) button and turn the **# Oscillators** (**Spread**) knob to adjust this feature. There are sixteen **# Oscillators** settings: 1–16. The **Shift** button will flash each time you select a different setting.Reducing the number of oscillators will reduce the density of the sound, and will also increase its overall perceived loudness, since less volume normalization is needed.

Note that disabled frozen oscillators will not remember the frequency they were previously frozen on.

Freeze Mode



When you press **Freeze**, some oscillators are frozen and others remain unfrozen. The sub-group that gets frozen can be adjusted with this feature.

Hold the **Shift** (**Freeze**) button and turn the **Freeze Mode** (**Twist**) knob to adjust this feature. There are three **Freeze Mode** settings.

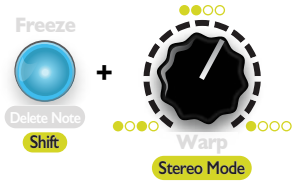
●○●○ The lowest setting freezes the odd-numbered oscillators.

●●○○ The middle setting freezes the lower half of the oscillators.

●○○○ The highest setting freezes only the root oscillator.

Changing the **Freeze Mode** while Freeze is enabled will immediately freeze the new sub-group of oscillators, and unfreeze the rest.

Stereo Mode



There are two output jacks, **Out A** ,and **Out B**. If you patch into **Out A** and leave **Out B** unpatched, then all oscillators will be routed to **Out A**. However, if you patch into both jacks, the oscillators will be panned between the two jacks. The **Stereo Mode** feature controls the panning. Hold the **Shift** (**Freeze**) button and turn the **Stereo Mode** (**Warp**) knob to adjust this feature. There are three **Stereo Mode** settings.

●○●○ The lowest setting pans the odd-numbered oscillators to **Out A**, and the evens to **Out B**.

●●○○ The middle setting pans the lower half of oscillators to **Out A**, and the upper half to **Out B**.

●○○○ The highest setting pans the root oscillator to **Out A**, and the rest to **Out B**.

Firmware and Calibration

Upgrading Firmware (audio bootloader)

You can update the **Ensemble Oscillator** firmware by playing a special audio file into the **Learn** jack. When new firmware versions are released, the firmware audio files can be downloaded at https://4mscompany.com/enosc.
Subscribe to our social media feeds to be notified of firmware upgrades, or email us through our website.

1. To enter bootloader mode, first unplug all cables and power off the module.
2. Connect a computer or phone audio output to the **Learn** jack.
3. Set the computer/phone's volume to 100%, and the audio player software to 100% volume.
4. Press and hold down both buttons (**Learn** and **Freeze).**
5. Still holding down the buttons, power on the module.
6. Release the buttons when you see the **Learn** button blink green.
7. Begin playing the firmware file. Immediately you should see the buttons animate blue and white
8. If the buttons turn red while the file is playing, there was an error.
   a. Stop the file and rewind to the beginning.
   b. Check the cable is plugged in tightly.
   c. Tap the **Learn** button. It will go back to flashing green.
   d. Play the file again from the beginning.
9. If the file loads successfully, the **Ensemble Oscillator** will do an animation of a rainbow of colors on both buttons.
10. Power off and back on, or press the **Learn** button to start playing with the new firmware!

Troubleshooting and tips:

- Some audio cards, especially laptops, play a pop when they begin to play an audio file and the error lights will turn on immediately. Try pressing the **Learn** button immediately after it turns red, but before the noise starts playing (there's a two second lead time of silence). If that doesn't work, use a different device.
- Do not play from advanced audio software like Ableton. Instead, play from basic software such as VLC, QuickTime, Windows Media Player, or Chrome. Turn off any EQ or Bass Boost settings.
- Remove your phone case; it may be preventing the cable from fully plugging in.
- Turn off all audio and vibrate notifications.
- Close any applications that make notification sounds (such as Facebook or messaging apps).
- Try downloading the .wav file rather than playing it from the browser (or vice-versa).
- Try on your phone if you used a computer (or vice-versa).
- Try adjusting the volume on your device: usually 100% volume is best, but sometimes reducing it will output a more clean signal.

If you're interested in compiling your own modifications, the open-source licensed source files (in C++) can be found on 4ms Company's github: https://www.github.com/4ms

Calibrating 1V/oct jacks

For maximum accuracy, it's recommended to calibrate the **Pitch** and **Root** jacks to your keyboard or sequencer. There are many factors that could cause incorrect tuning when using external equipment even if all the equipment is nominally 1V/oct. You also can calibrate your jacks if you want to use an external device that runs on 1.2V/octave. Calibration is fast and easy.

1) Unpatch all cables, except **Out A** and **Out B**.
2) Hold down the **Learn** and **Freeze** buttons for about 2 seconds. Release them when the colors change.
3) **Learn** will be slowly flashing blue. Input a C2* into the **Pitch** jack and press the **Learn** button.
4) **Learn** will be quickly flashing blue. Input a C4* into the **Pitch** jack and press the **Learn** button.
5) **Freeze** will be slowly flashing blue. Input a C2 into the **Root** jack and press the **Freeze** button.
6) **Freeze** will be quickly flashing blue. Input a C4 into the **Root** jack and press the **Freeze** button.
7) If the calibration was successful, the lights will flash green and the module will return to normal operation.

The calibration results will be saved even after powering the module off.

**Note that C2 and C4 should be 2.0V and 4.0V, respectively. Some controllers output different voltages for these notes. If calibration fails after several tries, try playing C0 and C2, or C1 and C3, or some other pair of C notes that are two octaves apart.*

If an error occurs, the lights will flash red and the procedure will be aborted without saving any calibration data.
One possible cause for an error is reading a value on a jack that's out of the acceptable range. The acceptable range is between 0.7V/oct and 1.3V/oct. This means a C2 must be between 1.4V and 2.6V, and a C4 must be between 2.8V and 5.2V. There will also be an error if you have any cables patched into **Root** or **Pitch** when you enter calibration mode, or if any of the other CV jacks are patched during the procedure.

Button RGB color balance adjustments

The two buttons have been color-matched at the factory, so there is usually no need to adjust the colors yourself. However, the procedure is easy.

1) Power off the module.
2) Flip all four switches to the center position.
3) Turn all knobs to center.
4) Hold down the **Freeze** button and power up the module. The two buttons will turn white (or a hue close to white).
5) Use the knobs to adjust the red, green, and blue balance of each button. The center position makes no color adjustment; left of center reduces the amount of a color; right of center boosts the amount of the color.
   - **Scale**: adjusts the amount of red in the **Learn** button
   - **Balance**: adjusts the amount of green in the **Learn** button
   - **Twist**: adjusts the amount of blue in the **Learn** button
   - **Pitch**: adjusts the amount of red in the **Freeze** button
   - **Cross FM**: adjusts the amount of green in the **Freeze** button
   - **Warp**: adjusts the amount of blue in the **Freeze** button
6) If at any time you want to see how the current color adjustments appear with the default yellow button color, flip the **Scale** switch up. Flip it back to center to go back to the white color.
7) When you're done, press the **Freeze** button to save the color adjustments.

To cancel without saving, power the module off.

Factory Reset

Performing a factory reset is an irreversible act. All custom scales, settings, CV jack calibrations, and color adjustments will be erased. It cannot be undone. If you only wish to restore the factory scales, you can restore the selected scale by holding down the **Learn** button for 4 seconds.

To perform a factory reset:
1) Power off the module.
2) Power on with both buttons down, and keep holding them down.
3) When you see the **Learn** button turn green, release **Learn** but continue holding down **Freeze.**
4) After about 10 seconds, the lights will blink rapidly. The memory is being erased. You can release **Freeze**.
5) When the memory is done being erased, the lights will slowly blink through a sequence of colors.
6) Power the module off. When you power it back on, the default scales and settings will be loaded.

If after erasing the memory the lights blink red (and no other colors), there was a memory error. Please contact 4ms Company for assistance.

Electrical and Mechanical Specifications

- 16HP Eurorack format module
- 0.98” (25mm) maximum depth (including power cable)
- 10-pin to 16-pin Eurorack power header

- **Power consumption**
  - +12V: 114mA maximum
  - -12V: 45mA maximum
  - +5V: 0mA (not used)

- **Audio outputs**
  - Frequency range: 0Hz (DC) - 20kHz
  - Typical amplitude: 10Vpp
  - Maximum amplitude: 18.5Vpp

- **1V/oct inputs (Root and Pitch)**
  - Voltage range: -2V to +6V (8 octave range)
  - Factory calibrated to 1.00V/oct
  - Per-jack user-calibration allows from 0.7V/oct to 1.3V/oct

- **CV inputs (other than 1V/oct)**
  - Voltage range: -5V to +5V

- **Gate inputs**
  - Trigger threshold: 2.5V

- **User memory (non-volatile)**
  - Scale slots: 30
  - Shift feature settings
  - 1V/oct calibration settings

Acknowledgements

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