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
  - 12TET: all notes quantized to equal temperament, repeating over octaves
  - 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
Table of Contents

Features .................................................................................................................................2

Getting Started 4
Plugging in your Ensemble Oscillator ..............................................................................4
Basic Concepts .....................................................................................................................4
Controls and Jacks ..............................................................................................................6

Tutorials and Patches 9
Tutorial I: Create your own Scale in Learn Mode using the knobs ......................9
Tutorial 2: Create your own Scale in Learn Mode using a keyboard ..................10
Patch Idea: Wavefolding Pseudo-VCA .................................................................11

Detailed Concepts and Usage 12
Scale Groups .......................................................................................................................14
Learn Mode: Advanced Concepts .....................................................................................15
Shift Features .....................................................................................................................16
Crossfading .........................................................................................................................17
# Oscillators ......................................................................................................................17
Freeze Mode ......................................................................................................................17
Stereo Mode .......................................................................................................................18

Firmware and Calibration 18
Upgrading Firmware (audio bootloader) .................................................................18
Calibrating 1V/oct jacks ..................................................................................................19
Button RGB color balance adjustments ......................................................................19
Factory Reset ....................................................................................................................19

Electrical and Mechanical Specifications 20
Acknowledgements .........................................................................................................20
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 11) 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 12) 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 13) 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 14).

**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 15-17).

- **# 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 knob 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.

Scale knob, switch and jack
The Scale knob selects the scale to which the oscillators are quantized. See the Scales and Oscillators section (page 11) 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 14). 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 11) 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, only the lowest (root) oscillator will be heard. 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 -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, jack, and switch
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, jack, and switch
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, jack, and switch
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 section (page 14) 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 16) 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 15).
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.

**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 only 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.
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 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.

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.

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.
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.
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.

<table>
<thead>
<tr>
<th>12TET group factory scales</th>
<th>Intervals</th>
<th>Example Notes (assume root note is C0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slot 1</td>
<td>Octaves</td>
<td>P8, repeat</td>
</tr>
<tr>
<td>Slot 2</td>
<td>Octaves and fifths</td>
<td>P5, M3, repeat</td>
</tr>
<tr>
<td>Slot 3</td>
<td>Major triad</td>
<td>M3, m3, P4, repeat</td>
</tr>
<tr>
<td>Slot 4</td>
<td>Minor triad</td>
<td>m3, M3, P4, repeat</td>
</tr>
<tr>
<td>Slot 5</td>
<td>Minor triad+</td>
<td>m3, M2, M2, P4, repeat</td>
</tr>
<tr>
<td>Slot 6</td>
<td>“Bluesy 1”</td>
<td>m3, M2, P4, M2, repeat</td>
</tr>
<tr>
<td>Slot 7</td>
<td>Major 7th 3rd inv.</td>
<td>m2, M3, m3, M3, repeat</td>
</tr>
<tr>
<td>Slot 8</td>
<td>Circle of Fifths</td>
<td>P5, repeat</td>
</tr>
<tr>
<td>Slot 9</td>
<td>“Bluesy 2”</td>
<td>m3, M2, M2, repeat</td>
</tr>
<tr>
<td>Slot 10</td>
<td>Semitones</td>
<td>m2, repeat</td>
</tr>
</tbody>
</table>

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.

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

<table>
<thead>
<tr>
<th>Free group factory scales</th>
<th>Intervals</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slot 1</td>
<td>Perfect fifths spiral</td>
<td>the circle of fifth that does not repeat every octave</td>
</tr>
<tr>
<td>Slot 2</td>
<td>Whole tones</td>
<td>M2, repeat</td>
</tr>
<tr>
<td>Slot 3</td>
<td>Messiaen #2</td>
<td>m2, M2, repeat</td>
</tr>
<tr>
<td>Slot 4</td>
<td>Messiaen #3</td>
<td>M2, m2, m2, repeat</td>
</tr>
<tr>
<td>Slot 5</td>
<td>Messiaen #4</td>
<td>m2, m2, m3, m2, repeat</td>
</tr>
<tr>
<td>Slot 6</td>
<td>Bohlen-Pierce</td>
<td>13 steps per tritave</td>
</tr>
<tr>
<td>Slot 7</td>
<td>Bohlen-Pierce major</td>
<td>1, 7, 11, repeat</td>
</tr>
<tr>
<td>Slot 8</td>
<td>Bohlen-Pierce minor</td>
<td>1, 5, 11, repeat</td>
</tr>
<tr>
<td>Slot 9</td>
<td>Wendy Carlos alpha</td>
<td>78 cents</td>
</tr>
<tr>
<td>Slot 10</td>
<td>Wendy Carlos beta</td>
<td>63.8 cents</td>
</tr>
</tbody>
</table>

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 13) 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 reset 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.

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

The Ensemble Oscillator was conceived by Matthias Puech and produced by 4ms Company. Core code and UI design were done by Matthias, and interface firmware and hardware design were done by Dan Green of 4ms. Portions of the bootloader code were taken from Emilie Gillet’s stm-audio-bootloader library. Thanks to our beta testers, and everyone on the 4ms team who made this module possible!