EmissionControl2 Manual

Curtis Roads, Jack Kilgore, and Rodney Duplessis

Center for Research in Electronic Art Technology (CREATE)
University of California
Santa Barbara
USA

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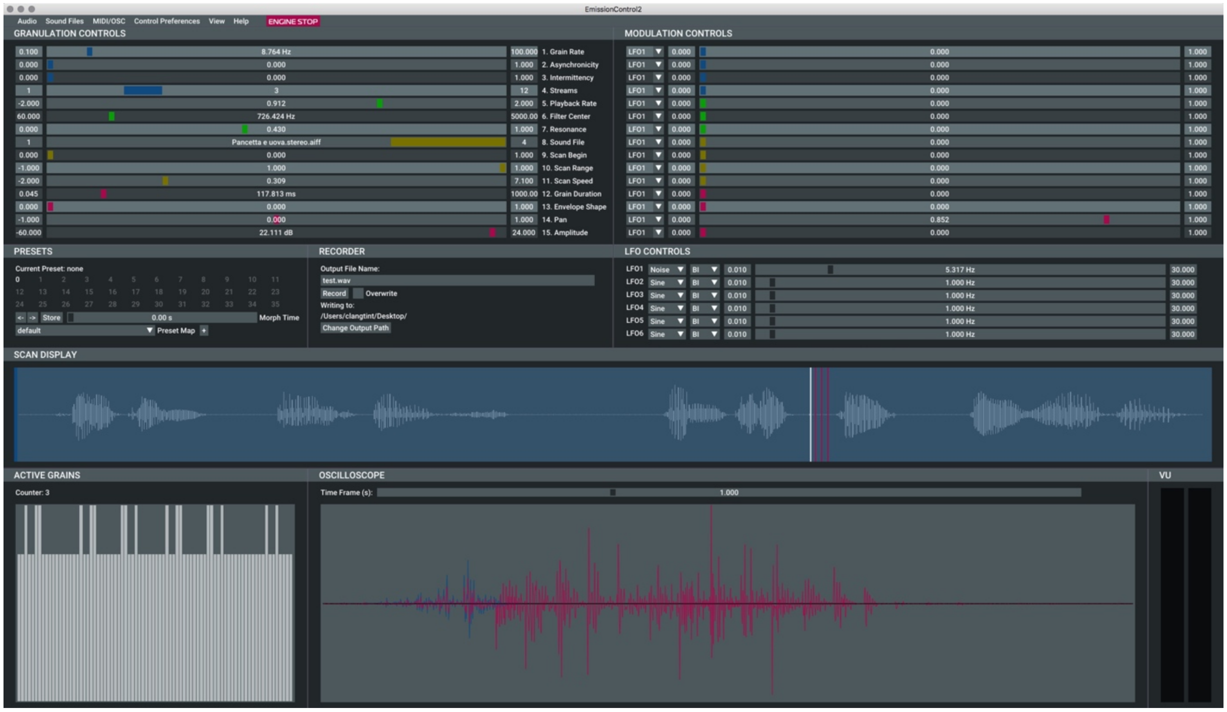
Corresponds to version 1.2 of EC2



EmissionControl2 (EC2) is an interactive real-time laboratory instrument for granular synthesis and sound file granulation for MacOS, Linux, and Windows. It runs as a standalone application. Features include:

- Per-grain signal processing (envelope, waveform, amplitude, frequency, spatial position, filter center frequency and resonance)
- Granulation of multiple sound files simultaneously
- Up to 2048 simultaneous grains
- Synchronous and asynchronous grain emission
- Intermittency control
- Modulation control of all parameters with six LFOs (bipolar or unipolar waveforms)
- Real-time display of peak amplitude, active grains, waveform, scan range, scanner, and grain emission
- Scalable graphical user interface (GUI) and font size
- Easy mapping of parameters to any MIDI/OSC continuous controller
- Algorithmic control of granular processes via OSC scripts
- Unique filter design optimized for per-grain synthesis
- Unlimited user presets with smooth interpolation for gestural design
- Open source code and free to download and use

New in Version 1.2

Version 1.2 of EC2 offers extensive OpenSoundControl (OSC) support. This means that the operation of EC2 can be fully automated. This opens up the possibility of control from an algorithmic composition system, including starting, stopping, sound file naming, and all EC2 parameter settings.

Other improvements include:

- Added option to change buffer size
- Changed look of presets panel when the window is small
- Added keyboard shortcut for starting/stopping the sound engine (Spacebar)
- Added "Clear All Sound Files" option in Sound Files menu
- VU meter displays *decibels relative to full scale* (dBFS) instead of linear amplitude

Background

The original EmissionControl was written in 2004 and updated in 2008. It was coded by David Thall as part of his masters project in Media Arts and Technology at UCSB in consultation with Curtis Roads. The program code ran in SuperCollider 3 using a custom library for granulation written in the C++ language. A limitation of this version was that the custom library was compiled for a PowerMac G5 processor only. Apple changed to Intel processors shortly thereafter.

The EC2 project began in early 2019 with an initial goal of rewriting EC to run on modern computers. Over time, EC2 evolved far beyond the original EC app.

Jack Kilgore, a computer science student at UCSB was the principle coder. Rodney Duplessis, a PhD student in Music and a masters student in Media Arts and Technology made major contributions to the graphical user interface (GUI) and OSC implementation. As we were concluding version 1.0, Apple announced a shift from Intel processors to ARM processors. EC2 currently runs in Rosetta 2 emulation on new ARM processors.

Quick-Start Theory

According to a 1946 theory of the physicist Dennis Gabor, any sound can be represented as a combination of elementary sonic grains. The composer Iannis Xenakis was the first to formulate a theory around a granular approach to music composition. For more information about granular synthesis, see the references below.

EC2 takes one or more sound files as input and extracts a series of short audio clips or grains. A grain is a segment of sound, often less than 1/10th of a second (100 milliseconds or ms). In EC2 we allow for longer-duration grains (up to 10 seconds). This provides granular-style processing of short phrases of music or other audio.

The waveform of the file is shown in the Scan Display. The user can set what portion of the file to granulate, whether to scan it forwards or backwards, and how fast to scan through it. Grains will be emitted at the rate set by the Grain Rate parameter.

Any of the Granulation Controls on the top left part of the screen can be modulated using one of the six low frequency oscillators (LFOs) shown in the LFO Controls at the middle right. The Modulation Controls at the top right set the amount of modulation to be applied to the corresponding Granulation Control parameter on the left.

EC2 has a MIDI Learn feature, which makes it easy to map a physical controller such as a MIDI fader box to the Granulation Controls. EC2 also supports Open Sound Control.

Warning

We made a decision to allow extreme ranges for certain parameters. Their interaction creates a vast parameter space. Given that the input can be any sound file, users should be aware that at certain settings, the sonic output may be unpredictable, including zones of silence.

Start

To start EmissionControl2, Double-click on the EmissionControl app.

Press the red Engine Start button at the top to commence grain emission.

Synthesis Parameters

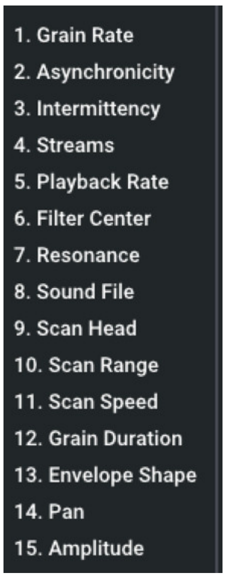


Figure 1.

The fifteen granulation control faders are on the top left side of the console (figure 1).

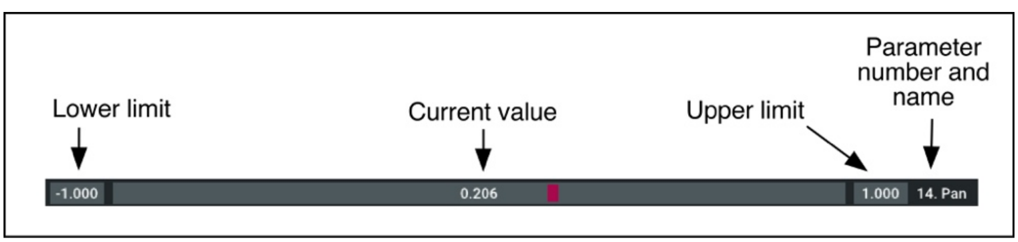


Figure 2.

As figure 2 shows, the default parameter ranges are displayed to the left and right of the fader. Pan, for example, ranges from -1 (left) to +1 (right).

A powerful feature is the ability to adjust the ranges. This can be used in either of two ways:

1. Extend the default range to an extreme range (see the default versus absolute range limits in the Appendix).

2. Narrow the range for fine control in performance.

To adjust the ranges, double-click on the lower or upper limit and type. Or click-once-and-drag left or right to set the numerical value of the limit. Shift-click-and-drag accelerates the change.

To stipulate a specific parameter value, control-click on the current value and then type.

Logarithmic scaling for all sliders can be toggled by right-clicking on a parameter and then clicking the item that says "Logarithmic". If no right-click is available, hover over a parameter and press 'l' (as in log). This logarithmic setting applies to your MIDI controller as well.

MIDI Learn

Any fader can be assigned to a MIDI controller with the MIDI Learn feature.

To learn, perform one of these actions and then move a physical controller knob or fader:

- Single button mouse - Hover over a slider and press m
- Three-button mouse - Right-click and select MIDI Learn in the drop down menu
- Trackpad - Two-finger press on a slider and select MIDI Learn in the drop down menu

To unlearn:

- Single button mouse - Hover over a slider and press Shift-m
- Three-button mouse - Right-click on a slider and select MIDI Unlearn in the drop down menu
- Trackpad - Two-finger press on a slider and select MIDI Unlearn in the drop down menu

Granulation Controls

Here is a list of the Granulation Controls with default ranges in square brackets [ ].

1. Grain Rate [0.1,100] – Rate of grain emission per second

2. Asynchronicity [0,1] – Degree of synchronicity (fader left) versus asynchronicity (fader right) of grain emission. Grain density is the same whether the stream is synchronous or asynchronous. In a perfectly synchronous stream, the grains follow one another at periodic intervals. An asynchronous stream is randomized in time.

3. Intermittency [0,1] – Degree of interruption of the grain stream, independent of whether the stream is synchronous or asynchronous. High intermittency lowers grain density.

4. Streams [1,12] – Number of parallel streams of grains. Grains from new streams are inserted in between existing grains. Overall *grain density* is a product of the grain rate, the grain duration, and the number of streams.

5. Playback Rate [-2,+2] – Changes the rate at which each grain reads through the source sound file, effectively shifting pitch and/or read direction.

[0,.99]	Pitch shift down, 0 = freeze (no sound)
[1]	No pitch shift
[1,2]	Pitch shift up
[-.99,0]	Pitch shift down and backwards
[-1]	No pitch shift, backwards
[-2,-1]	Pitch shift up and backwards

6. Filter Center [60,5000] – Center frequency in Hertz of a bandpass filter. Each grain is filtered separately.

7. Resonance [0,1] – Sets the Q or resonance of the filter. At a value of 1 it generates a sine wave.

8. Sound File – Selects the sound file to granulate. Multiple sound files can be loaded, up to 1 Gbytes total, irrespective of sample rate and bit depth. Note: sound files that are not at the sample rate and bit depth set by the user in Audio Settings will be converted. This can take a few seconds. Users can slide the fader to switch between the loaded sound files. File selection can also be modulated by an LFO.

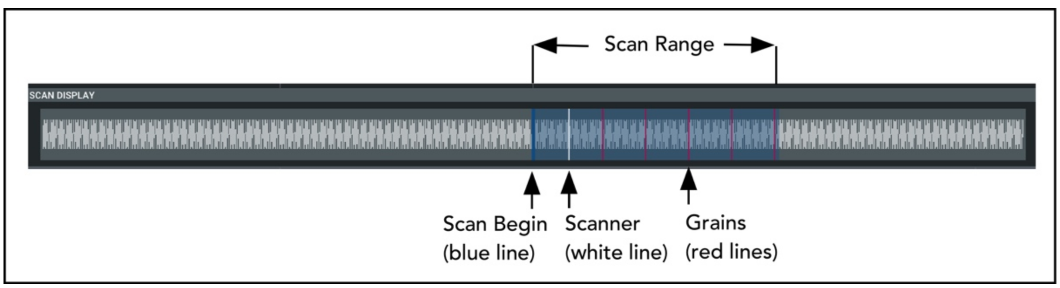


Figure 3. The Scan Display indicates:
Scan Begin - blue vertical line
Scan Region - light blue rectangle
Scanner - black vertical line (white in dark mode)
Individual grains - red vertical lines

9. Scan Begin [0,1] – Controls the starting point in the sound buffer to start granulating (figure 3). This is a relative value, where 0 indicates the beginning of the sound file, 0.5 indicates the halfway point, and 1.0 indicates the end, regardless of the length of the currently selected sound file.

10. Scan Range [-1,1] - How much of the file to scan. Shown in the Scan Display (figure 3). A value of 1 means scan the entire file. A value of 0 holds the scanner in place at the Scan Begin position. One can also set negative values to extend the range to the left of the Scan Begin position. The scan region loops around to the beginning when extended.

11. Scan Speed [-2,2] – How fast to scan the file, and in which direction. This is independent of the Playback Rate, which shifts the pitch of individual grains. The Scan Speed may be 0, for example, in which case a single grain repeats. The Playback Rate determines the pitch shift and whether the grain is read forwards or backwards.

Note: You might have set the Grain Rate to 1 grain per second but you see the scanner line (white or black depending on the display mode) looping at a fast rate. What's going on? Grain Rate and Scan Speed are independent!

Theory of Scan Begin, Scan Range, and Scan Speed

As figure 3 shows, Scan Begin, Scan Range, and Scan Speed control the *scanner:* a pointer that determines where grain waveforms are read from in the sound file. When a grain is emitted, it begins at the current scanner location. It may then read forward or backward through the sound file depending on Playback Rate (5).

Scan Begin (9) and Scan Range (10) together determine the region of the sound file through which the scanner moves. For example, if Scan Begin is at 0.50 and Scan Range is set to 0.25, then the scan area will extend from halfway through the sound file to 3/4 of the way through the sound file (see figure 3).

Scan Speed controls how quickly the scanner moves through the scan region. When the scanner reaches the end of the scan region, it loops back around to the beginning of the scan region. A positive value sets a forward motion in time. A negative value causes backwards playback.
0
Note that while the scanner always remains in the scan region, a grain may exceed the boundaries of the scan region if it begins near the edge of the scan region and Grain Duration is long enough. This is because EC2 always prioritizes grain integrity.

12. Grain Duration [0.01, 1000] - Controls the grain duration in milliseconds. The shortest possible grain duration is now dependent on sample rate, or 2000/SampleRate. As an example, if the SampleRate is 44.1 kHz the shortest grain size in ms is 2000/44.1 kHz, which is roughly 0.045 ms. If the sample rate is 96 kHz, the shortest grain size is roughly 0.021 ms.

13. Envelope Shape [0,1] – Determines grain envelope shape. Left = sharp attack, exponential decay or *expodec* (figure 4a), Middle = bell shaped (figure 4b), Right = reversed expodec (figure 4c).

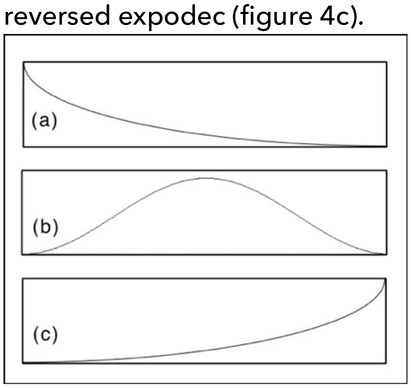


Figure 4. Grain envelope shapes. (a) Expodec. (b) Bell shaped. (c) Rexpodec.

14. Pan [-1,+1] – Spatial position of the grains. -1 is left.

15. Amplitude [-60,+24] – Adjusts the output amplitude in decibels (dB).

Granulation Controls Color Design

Parameter types are grouped by color as follows:

BLUE : WHEN grains are emitted
Grain Rate
Asynchronicity
Intermittency
Streams

GREEN : PITCH characteristics of grains
Playback Rate (or pitch shift)
Filter Center
Resonance

YELLOW : SOURCE of grains
Sound File
Scan Head
Scan Range
Scan Speed

RED : AMPLITUDE over time/space envelope
Grain Duration
Envelope Shape
Pan
Amplitude

Modulation Controls

Figure 5. Modulation Controls section.

The Modulation Controls section at top right (figure 5) contains sliders for each of the fifteen parameters. The range is 0 (no modulation) to 1 (full modulation). When the modulation is non-zero, the selected LFO (at right) will modulate the corresponding granulator control parameter (at left). Dragging the fader right increases the modulation. (The granulator control slider does not move, however.) The source of modulation is indicated by the menu to the left of the fader: LFO1 to LFO6.

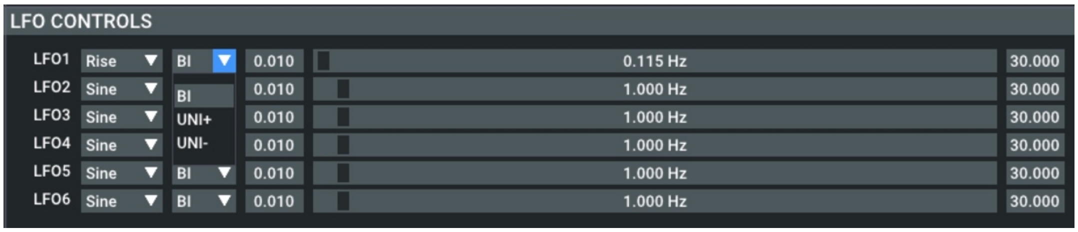


Figure 6. Selection of LFO waveform type.

The LFO Controls section (figure 6) consists of the six low frequency modulation (LFO) controls at top left: LFO1-LFO6. Here one can select the type of modulation. Figure 6 shows the linear Rise function chosen for LFO1.

Any LFO waveform can be bipolar (BI), i.e., positive and negative values, unipolar positive (UNI+), or unipolar negative (UNI-).

The LFO waveform options are
Sine
Square
Rise
Fall
Noise (a random sample-and-hold function at the stipulated frequency)

Note that Rise and Fall can also be seen as a sawtooth function.

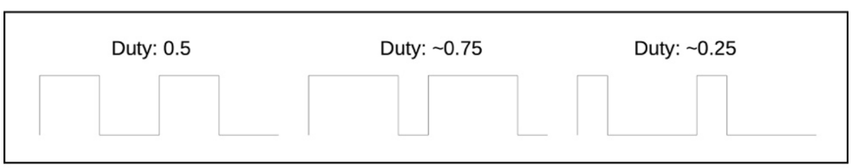


Figure 7. Duty cycle of square wave LFO.

When the Square LFO waveform is chosen, a new slider appears for that LFO to control the duty cycle of the square wave. If the value of Duty is set to 0.5, then the square's maximum and minimum states are equal in length: a standard square wave. A higher Duty value increases the time the square wave spends in its maximum state. A lower Duty value decreases the time the square wave spends in its maximum state (figure 7).

Presets

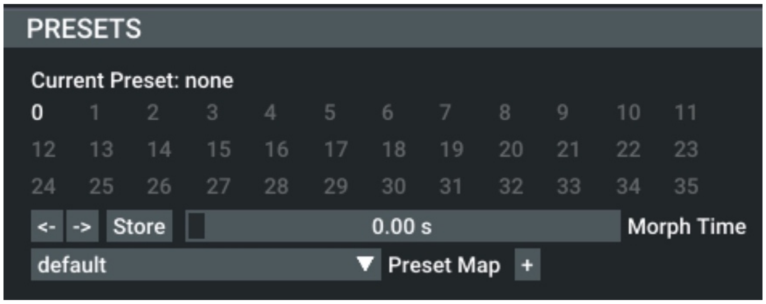


Figure 8. Presets section.

The Presets section lets one save the state of a performance to a numbered slot (figure 8). All fader settings and sound files are saved in a preset.

By default there are 240 slots. A bank of 48 are shown. The <- and -> buttons let one select the previous or next bank of presets.

A preset can be saved by clicking the Store button and then clicking a numbered slot. One can also store the preset with a descriptive name by typing in the Store Preset As box that appears once the Store button is clicked. The name shows up in the Current preset header when selected. Empty slots appear gray. Storing a preset to a slot that is not empty will overwrite the preset previously stored there. Warning: this cannot be undone!

The Morph Time fader allows one to smoothly interpolate between two preset states. example, when the Morph Time fader is set to 10.00, then clicking a new preset will trigger a smooth change to that preset over 10 seconds. If morph time is set to 0 (the default), the new state will be loaded instantaneously.

Note: Morph Time can be varied using physical controllers via MIDI Learn.

Tip: The Preset Map "+" button creates a new set of 240 preset slots. The drop down menu next to Preset Map can then be used to change which map you are using.

Sound File Loading and Presets

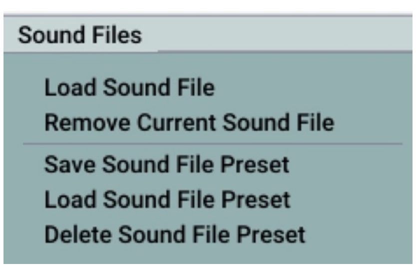


Figure 9. Sound Files menu.

To load one’s own sample files for granulating, go to the Sound Files menu at the top left (figure 9). Select Load Sound File to bring in a new file. It will show up in the Sound File slider (parameter 8). To remove a sound file, click on Remove Current Sound File.

One can also set up sound file presets that load a group of sound files all at once. Select the option Save Sound File Preset to bring up a menu that lets you name the preset and save it. Load Sound File Preset loads a preset that you name. Delete Sound File Preset removes it.

Recorder Window

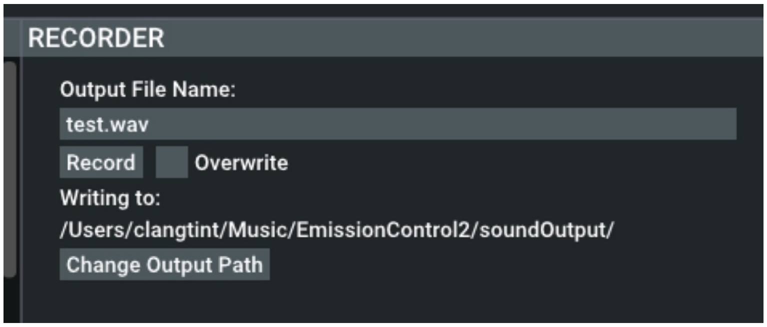


Figure 10. Recorder panel.

The Recorder window is in the center of the app (figure 10). This lets one record a session. Click on the Record button to start.

One can stipulate the output folder and name the file. You can stipulate either .aif or .wav format. Note that EC2 writes samples as 32-bit floating-point numbers.

When you click Record, EC2 will write a sound file, e.g., test.wav.
If you stop and restart to record it will write a new sound file test_1.wav, with _1 indicating the version.

When you toggle the Overwrite checkbox, the sound output will always go to the same named sound with no version suffix.

By default, EC2 sends its output to this directory:

> ***UserDisk***/Users/***YourID***/Music

To change the default output directory to Desktop, for example, select Sound Recording Folder under the Audio menu.

The Overwrite option writes over an existing sound file of the same name. Otherwise

Audio Menu and Settings

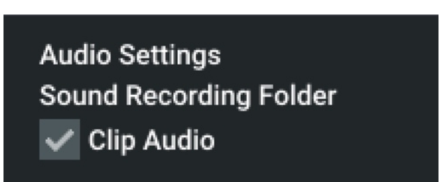


Figure 11. Audio Menu.

The Audio Menu has three options (figure 11). Audio Settings brings up the Audio Settings panel (see below).

Use the Sound Recording Folder option to specify where you would like EC2 output to be stored by default.

Audio Settings Panel

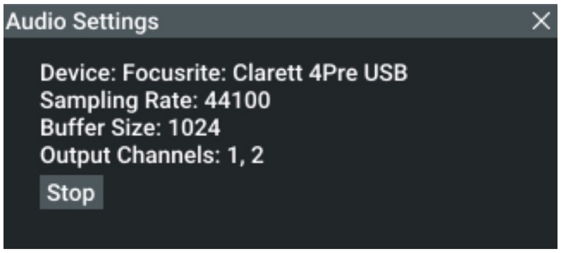


Figure 12. Audio Settings controls while EC2 is running.

One can set the audio output device and sampling rate, etc. under the Audio Settings menu (figure 12). In order to do this you need to Stop the EC2 engine. Click the Stop button.

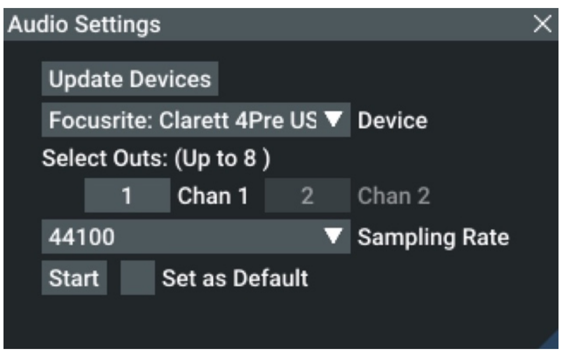


Figure 13. Audio Settings controls. when EC2 is stopped.

When the engine is stopped, the Audio Settings menu appears as in figure 13. Here you can specify your audio interface and which pair of channels to use for stereo output.

Clip Audio

Clip Audio is a checkbox in the Audio menu. By default, EC2 hard limits the live streaming sound output at high levels. This means that any sample values above a threshold are hard clipped to the threshold value. The threshold is the maximum value of 24-bits.

At all times, EC2 internally generates 32 bit floating-point samples, so the amplitude can exceed 24 bits.

You might choose to disable Clip Audio if you are routing the audio to a DAW with a high-quality dynamic range compressor that you prefer over hard limiting.

Note that sound files written by EC2 are always full 32-bit floating-point samples with no clipping.

Control Preferences

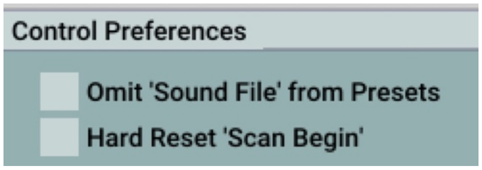


Figure 14. Control preferences panel.

The Control Preferences menu (figure 14) has two functions for alternative performance modes.

By default, sound files are saved with presets. The option Omit 'Sound File' from Presets, enables an alternative performance mode that lets the user switch between different presets without changing the sound file.

Hard Reset 'Scan Begin' is another alternative performance option. By default the position of the scanner (playback head) is independent of the position of the Scan Begin. Thus as you drag (or modulate) Scan Begin, the scanner moves independently.

If you select Hard Reset 'Scan Begin,' this forces the scanner to reset to the current Scan Begin position whenever you drag it manually or modulate it.

View

The EC2 panel can be resized by dragging the bottom right corner. It just works!

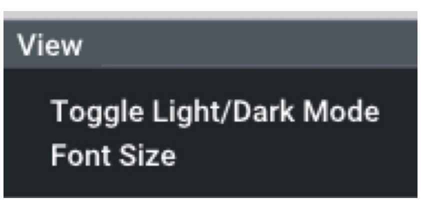


Figure 15. View controls.

The View menu lets the font size be changed independently of the main window size (figure 15). When you select Font Size a convenient fader appears to control size. (Obviously at extreme settings something has to give, but the range of usable sizes is quite variable.)

In the View menu select Light or Dark mode for the GUI color scheme of your choice.

Support for Open Sound Control (OSC)

EmissionControl2 offers extensive OpenSoundControl (OSC) support. OSC messages from a control interface (such as TouchOSC) or algorithmic composition platforms (such as SCAMP, SuperCollider, or Csound) can be used to control the following:

1. All control sliders (Granulation Controls, Modulation Controls, LFO Controls, Morph Time)
2. Preset loading
3. Stop/Start recording
4. Changing the output folder and file name for recorded sound files

With OSC, EC2 can become an algorithmic composition tool. Using OSC, scripted processes that generate many sound files can even be run without supervision by using the ability to programmatically start/stop recording and name sound files.

Quick Setup

1. Go to the MIDI/OSC menu and click "OSC Config" to bring up the OSC Configuration window.
2. Set the IP Address and Port to the same as what your OSC controller is sending to.
3. Type in the OSC address to listen to for each parameter you wish to control with OSC. These should correspond to what your OSC controller is sending.
4. Close the OSC Configuration window and click "OSC On" under the MIDI/OSC menu.

Note: Click the "OSC On" checkbox again to turn off OSC receiving.

Data Formats

Your OSC messages will begin with an argument, have an optional type string, followed by a value. See https://opensoundcontrol.stanford.edu/spec-1_0.html for more info. Here are the formats that EC2 accepts for incoming OSC data:

1. Control Sliders: Int32 or Float32
2. Preset loading: Int32 (where the integer corresponds to the preset number)
3. Stop/Start recording: Int32 (the number 0 will stop recording, any other value will start recording)
4. Changing output folder or file name: OSC-string (Make sure the named folder is a valid directory! Make sure file name ends in ".wav")

Custom Mapping

If the range of data values coming from your OSC controller does not match with the range of the slider in EC2 that you wish to control, you can use EC2's mapping functionality by clicking 'Custom Mapping' under the corresponding slider name in the OSC Configuration window. Then, input the lowest expected value from your OSC controller in the Range Min box and the highest expected value in the range Max box.

As an example of when this might be useful, say your controller is sending values between 0 and 1 and you want to use this to control the Amplitude slider, which ranges from -60 to +24.

You can either change the values that your OSC controller is sending, or you can set a custom mapping in EC2 by going to '15. Amplitude' in the OSC configuration window, clicking 'Custom Mapping', and setting Range Min to 0 and Range Max to 1.

Saving/Loading OSC presets

To save your OSC configuration, click 'Save' in the OSC Configuration window, type in a name for the preset, and click 'save' again in this window.

To load an OSC configuration, click 'Load' in the OSC Configuration window and select the preset to load.

To delete an OSC configuration, click 'Delete Preset' in the OSC Configuration window and select the preset to delete.

Example Use

An application sending OSC data (call it the "controller") and EC2 are running. In EC2, we set the IP address to 127.0.0.1 (for local network, because the controller is running on the same computer as EC2), and we set the port to 16447. We then set the same IP and port on our controller. We click "OSC On" in EC2. Now, the communication channel is open, but we need to configure the applications to send and listen to the desired messages.

In the controller, we write an algorithm that will first send the message /fileName example1.wav and then send the message /preset 3 and then \record 1 and then send a series of values descending from 200 to 5 over 10 seconds with the argument "rate. Finally, the algorithm sends the message /record 0.

In EC2, we check to make sure the arguments for File Name, Record, Preset, and Grain Rate are set to /fileName, /record, /preset, and /rate, respectively. We finally run the algorithm in the controller and see that EC2 changes to preset 3, starts recording a file called "example1.wav", the grain rate parameter goes from 200 to 5 Hz over 10 seconds, and then the recording stops and the sound file is saved.

Tip

For pure granular synthesis as per Xenakis's theory, granulate a sine wave sample.

Acknowledgments

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Report any issues to:
github.com/jackkilgore/EmissionControl2/issues

Appendix: Parameter Default Ranges and Absolute Ranges

Parameter Name	Default Range	Absolute Range
Grain Rate	[0.1 , 100.0]	[0.0 , 500.0]
Asynchronicity	[0.0 , 1.0]	[0.0 , 1.0]
Intermittency	[0.0 , 1.0]	[0.0 , 1.0]
Streams	[1 , 12]	[1 , 20]
Playback Rate	[-2.0 , 2.0]	[-32.0 , 32.0]
Filter Center	[60.0 , 5000.0]	[20.0 , 24,000.0]
Resonance	[0.0 , 1.0]	[0.0 , 1.0]
Sound File	[1st file , last file]	[1st file , last file]
Scan Start	[0.0 , 1.0]	[0.0 , 1.0]
Scan Range	[0.0 , 1.0]	[0.0 , 1.0]
Scan Speed	[-2.0 , 2.0]	[-32.0 , 32.0]
Grain Duration	[2000/SR , 1000.0]	[2000/SR, 10,000.0]
Envelope Shape	[0.0 , 1.0]	[0.0 , 1.0]
Pan	[-1.0 , 1.0]	[-1.0 , 1.0]
Amplitude	[-60.0 , 24.0]	[-180.0 , 48.0]
Modulation controls	[0 , 1.0]	[0, 1.0]
LFO frequency	[0.01 , 30]	[0.001 , 10000]