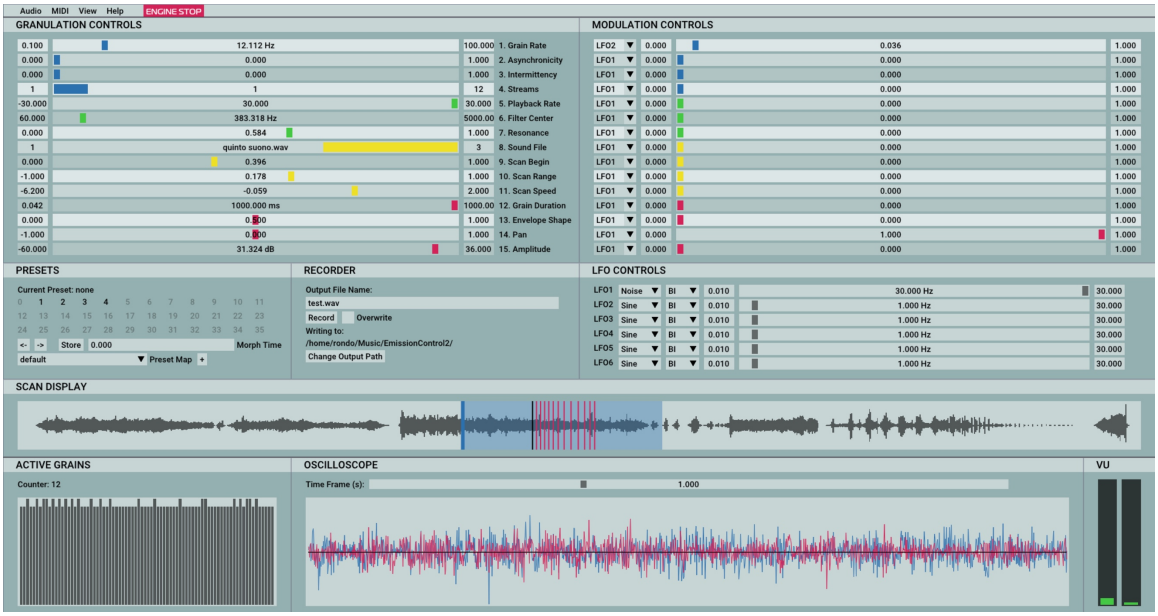
EmissionControl2 Manual

Curtis Roads, Jack Kilgore, and Rodney Duplessis

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

Version of 2 October 2020



EmissionControl2 (EC2) is a new interactive real-time application for granular synthesis and sound file granulation. Features include:

- Granulation of multiple sound files simultaneously (up to 1 Gb of samples)
- Supports up to 2048 simultaneous grains (limited by the user's hardware)
- Synchronous and asynchronous grain emission
- Intermittency control
- Per-grain signal processing (envelope, waveform, amplitude, frequency, spatial position, filter center frequency and resonance)
- Unique filter design optimized for per-grain synthesis
- Matrix modulation control of all granulation parameters with six LFOs
- Real-time display of peak amplitude, grain counter, waveform, and scan range
- Scalable GUI and font size
- MIDI Learn enables mapping to any MIDI continuous controller.
- Unlimited user presets with smooth interpolation for gestural design
- Code is open source and available at GitHub

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 has evolved far beyond the original EC app.

Jack Kilgore, a computer science student at UCSB has been 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). As we were concluding this project, Apple announced a shift from Intel processors to ARM processors before the end of 2020.

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 emits a series of grains. A grain is a segment of sound (a short sound clip), 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.

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

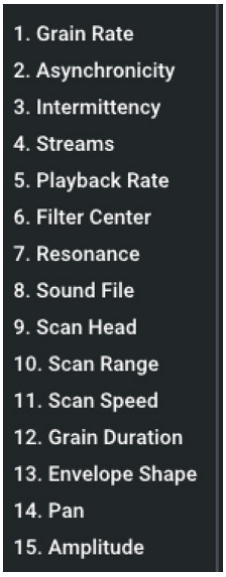


Figure 1.

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

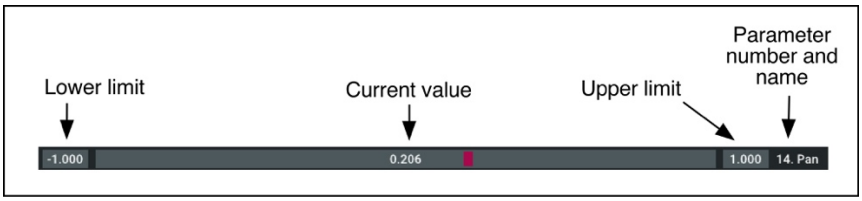


Figure 2.

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 for fine control. To adjust the ranges, double-click on the lower or upper limit and type. Or click-once-and-drag left and 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. The file selection can also be modulated by an LFO.

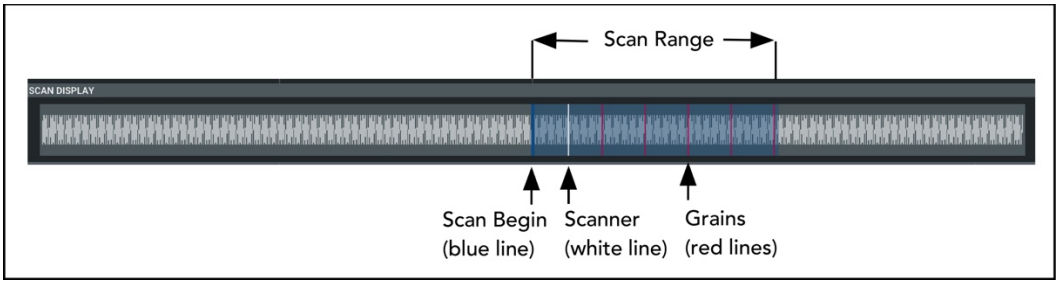


Figure 3. The Scan Display indicates:
Scan Begin - blue vertical line
Scan Region - light blue rectangle
Scanner - black vertical line (white in dark mode)
Individual grains - red vertical lines

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

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. 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 (expodec), Middle = bell shaped, Right = reversed expodec.

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 4. Modulation Controls section.

The Modulation Controls section at top right 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.

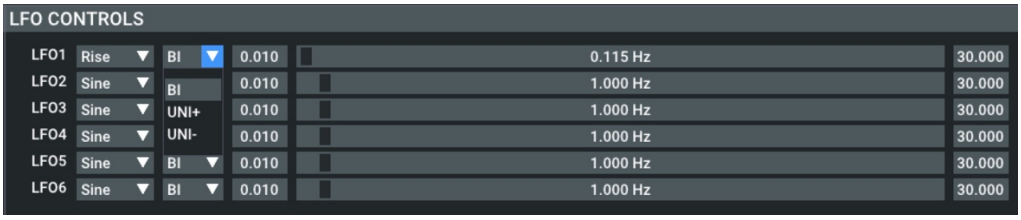


Figure 5. Selection of LFO waveform type.

The LFO Controls section (figure 5) consists of the six low frequency modulation (LFO) controls at top left: LFO1-LFO6. Here one can select the type of modulation. Figure 5 shows the linear Rise function chosen.

Any LFO waveform can be bipolar (BI), 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.

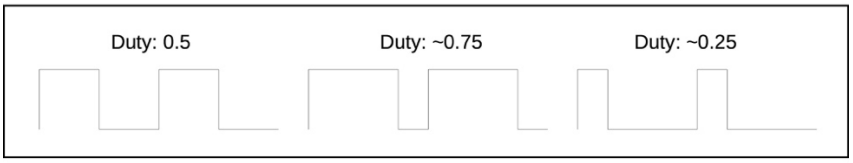


Figure 6. Duty cycle of square wave LFO.

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 6).

Presets section

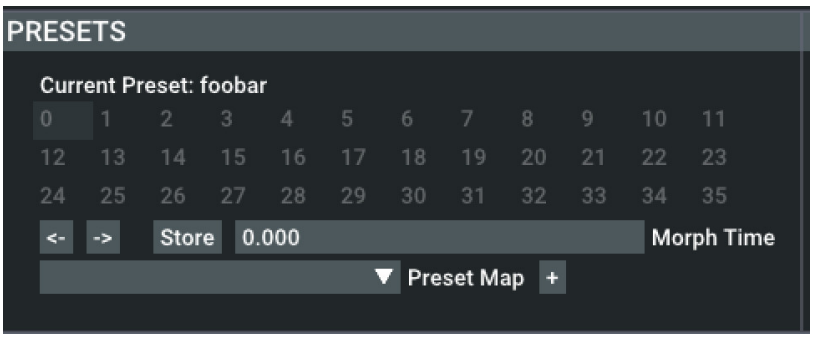


Figure 7. Presets section.

The Presets section lets one save one’s settings to a numbered slot (figure 7). There are 240 slots. A bank of 48 are shown. The <- and -> 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 feature allows one to smoothly interpolate between two preset states. For example, typing 10.0 into the morph time number box and then clicking a new preset will trigger a smooth change to that preset over 10 seconds. If morph time is set to 0, the new state will be loaded instantaneously.

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.

File loading

Figure 8. Audio menu.

To load one's own sample files for granulating, go to the Audio menu at the top left (figure 8). 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.

Recorder

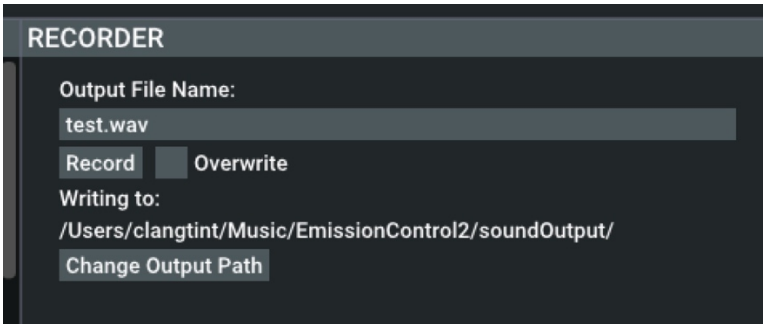


Figure 9. Recorder.

One can record a session using the Recorder function (figure 9) in the middle of the panel. One can name the file.

By default, EC2 sends its output to this directory:

UserDisk/Users/YourName/Music

To change this, for example, to Desktop, select Set Sound Output Folder under the File menu.

Audio Settings

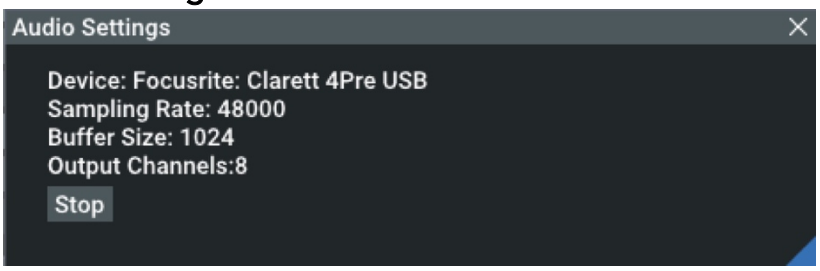


Figure 10. Audio Settings controls while EC2 is running.

One can set the audio output device and sampling rate, etc. under the Audio Settings menu item in the File menu (figure 10). In order to do this you need to Stop the app. Click the Stop button.

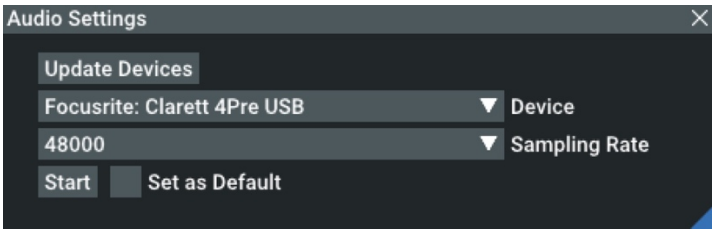


Figure 11. Audio Settings controls.

When the engine is stopped, the Audio Settings menu appears as in figure 11. Here you can make changes.

View

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

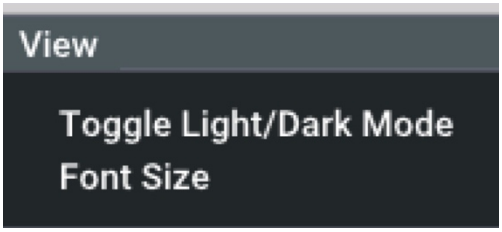


Figure 12. View controls.

The View menu lets the font size be changed independently of the main window size (figure 12). 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.

Tip

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

References

Gabor, D. 1946. "Theory of communication." Journal of the Institute of Electrical Engineers Part III, 93: 429-457.

Gabor, D. 1947. "Acoustical quanta and the theory of hearing." Nature 159 (4044): 591-594.

Gabor, D. 1952. "Lectures on communication theory." Technical Report 238, Research Laboratory of Electronics. Cambridge, Massachusetts: Massachusetts Institute of Technology.

Roads, C. 1975. "Computer music studies 1974-1975." Unpublished manuscript. 44 pages.

Roads, C. 1978a. "Automated granular synthesis of sound." Computer Music Journal 2(2): 61-62. Revised version printed as "Granular synthesis of sound" in C. Roads and J. Strawn, eds. 1985. *Foundations of Computer Music.* Cambridge, Massachusetts: MIT Press. pp. 145-159.

Roads, C. 1991. "Asynchronous granular synthesis." In G. De Poli, A. Piccialli, and C. Roads, eds. *Representations of Musical Signals.* Cambridge, Massachusetts: MIT Press. pp. 143-185.

Roads, C. 1996. *The Computer Music Tutorial.* Cambridge, Massachusetts: MIT Press.

Roads, C. 1998. "The Creatovox synthesizer project." Unpublished manuscript.

Roads, C. 2001a. "Sound composition with pulsars." *Journal of the Audio Engineering Society* 49(3).

Roads, C. 2001b. *Microsound.* Cambridge, Massachusetts: MIT Press.

Roads, C., and J. Alexander. 1995. *Cloud Generator Manual.* Distributed with the program Cloud Generator. Internet: www.create.ucsb.edu.

Thall, D. 2004. “A scheme for generalized control of particle synthesis.” MS thesis. Media Arts and Technology. Santa Barbara: University of California.

Thall, D. 2005. “Experiments in sound granulation and spatialization for immersive environments.” Presented at the Interactive Digital Multimedia IGERT Annual Research Review. Sponsored by the National Science Foundation. Santa Barbara: University of California.

Xenakis, I. 1960. "Elements of stochastic music." *Gravesaner Blätter* 18: 84-105.

Xenakis, I. 1971. *Formalized Music.* Bloomington: Indiana University Press.

Xenakis, I. 1992. *Formalized Music.* Revised edition. New York: Pendragon Press.

Disclaimer

The EmissionControl2 software is provided “as is” without warranty of any kind, either express or implied, including, but not limited to, the implied warranties of fitness for a purpose, or the warranty of non-infringement. Without limiting the foregoing, CREATE makes no warranty that the software will meet your requirements.

CREATE assumes no responsibility for errors or omissions in the software or documentation available from its web site and makes no promises to correct errors or provide updates.

In no event shall the CREATE be liable to you or any third parties for any special, punitive, incidental, indirect or consequential damages of any kind, or any damages whatsoever, including, without limitation, those resulting from loss of use, data or profits, whether or not the CREATE has been advised of the possibility of such damages, and on any theory of liability, arising out of or in connection with the use of this software.

The use of the software downloaded is done at your own discretion and risk and with agreement that you will be solely responsible for any damage to your computer system or loss of data that results from such activities. No advice or information, whether oral or written, obtained by you from the program developers shall create any warranty for the software.

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

Appendix: 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]