

# Monte-Carlo Pre-Roll

Complex Phase with i

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## Abstract

`preroll.py` generates a vivid pre-roll intro (4–16 s) preceding a musical drop. The sound arises as a sum of complex, exponentially decaying oscillations with minimal frequency detuning (beating), a 1/f noise texture (pink noise), slow phase diffusion, and smooth stereo width modulation. All computations are performed explicitly in the complex plane (Python:  $1j \equiv i$ ). The result is a stereo WAV file, ready to drop into your DAW.

## CAUTION

Deterministic modeling can cause unnatural distortions and algorithmically triggered responses. Independent safety and risk management strategies are essential.

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## 1 Core Idea & Equations

### 1.1 Complex Features

The raw signal is generated as the sum of  $K$  beating pairs:

$$z(t) = \sum_{k=1}^K A_k e^{-(t/\tau_k)} \left( e^{i(2\pi(f_k - \Delta_k)t + \phi_k^1 + \psi_k^1(t))} + e^{i(2\pi(f_k + \Delta_k)t + \phi_k^2 + \psi_k^2(t))} \right)$$

- $A_k$ : start amplitude (dB→linear),  $\tau_k$ : decay time,
- $f_k$ : base frequency,  $\Delta_k$ : small offset → beating,
- $\phi_k^{1,2}$ : initial phases,  $\psi_k^{1,2}(t)$ : phase diffusion (random walk).

Stereo channels receive a mini phase offset:

$$z_L \leftarrow z e^{+i\theta_k}, \quad z_R \leftarrow z e^{-i\theta_k}$$

Output:  $x_L = \Re\{z_L\}$ ,  $x_R = \Re\{z_R\}$ .

### 1.2 Pink Noise (1/f)

Generated in the frequency domain:

$$Y(f) = \frac{\mathcal{F}\{W\}(f)}{\sqrt{\max(f, \varepsilon)}} \implies y(t) = \mathcal{F}^{-1}\{Y(f)\}$$

where  $W$  is white noise and  $\varepsilon \ll 1$  protects the DC component.

### 1.3 Complexity Gate

$$\text{incoh} = |e_L - e_R|, \quad g(t) = 1 - \alpha \text{incoh}(t), \quad x_{L/R} \leftarrow g(t) x_{L/R}$$

$\alpha$  controls damping strength when stereo envelopes diverge.

### 1.4 Master Envelope & Saturation

$$w(t) = t^2(3 - 2t), \quad y \leftarrow \tanh(\text{drive} \cdot y), \quad \text{Normalize}_{\text{peak}}(y)$$

## 2 Pipeline (High-Level)

1. Complex bank:  $\text{sum } z(t) \rightarrow x_L, x_R$
2. Whoosh layer: pink noise + pitch glide
3. Mix:  $x \leftarrow x + \text{whoosh}$
4. Apply complexity gate
5. Musical envelope: smooth riser to 100% at drop
6. Fades, softclip, normalize
7. Export WAV (16-bit PCM)

## 3 CLI Examples

```
# 12 s, 48 kHz, EDM riser
python mc_preroll_i.py --outfile preroll.wav --seconds 12 --bpm 128 --sr 48000 --seed 42

# brighter shimmer
python mc_preroll_i.py --seconds 10 --pairs 9 --fmin 300 --fmax 6000 --beatmin 1.2 --beatmax 3.0

# darker pull
python mc_preroll_i.py --seconds 16 --pairs 7 --fmin 40 --fmax 800 --beatmin 0.2 --beatmax 1.0
```

## 4 Parameter Guide (Practical)

Group	Field	Effect	Typical Values
Length/Tempo	seconds, bpm	Riser duration & drop timing	8–16 s, 120–140 BPM
Complex bank	pairs	Density/complexity	5–9
	f_min, f_max	Timbre	60–3000 Hz
	beat_hz_range	Beat frequency	0.3–2.5 Hz
	tau_range	Decay-time spectrum	0.2–3.0 s
	amp_db_range	Pair dynamics	22 to 6 dB
	phase_diffuse_strength	“Organic/lively”	0.6–1.0
	stereo_phase_max	Width (subtle)	0.10–0.25 rad
Whoosh	pink_db	Noise layer loudness	24 to 12 dB
	riser_octaves	Pitch glide	1–3 oct
Master	gate_strength	Incoherence damping	0.10–0.25
	fade_in/out	Click avoidance	15–60 ms
	drive	Saturation	1.1–1.6
	headroom_db	Export headroom	0.8–1.5 dB

## 5 Audio Quality & Checks

- Peak 1.0 dBFS
- DC offset  $< 10^{-3}$
- Stereo correlation: 0.1–0.9
- RMS energy increasing over time
- No NaNs/Infs

```
import numpy as np, soundfile as sf
y, sr = sf.read("preroll.wav")
assert np.isfinite(y).all()
assert np.max(np.abs(y)) <= 1.0
assert abs(y.mean(axis=0)).max() < 1e-3
corr = np.corrcoef(y.T)[0,1]
print("stereo_corr:", corr)
```

## 6 Reproducibility & Performance

- Determinism: set `-seed` (NumPy PCG64)
- Complexity:  $O(KN)$ , pink noise:  $O(N \log N)$
- RAM: stereo float32  $8N$  bytes
- Example: 16s @ 48kHz  $\rightarrow N=768,000 \rightarrow 6$  MB

## 7 Presets

- **EDM Neutral:** 12s, 6 pairs, 60–3000Hz, beat 0.3–2.5Hz
- **Cinematic Warm:** 16s, 7 pairs, 40–1200Hz
- **Airy Techno:** 10s, 9 pairs, 300–6000Hz, pink\_db = 18

## 8 DAW Integration

1. Render WAV, import into DAW
2. Sidechain to kick ( $\frac{1}{4}$  notes)
3. Gentle EQ/saturation (2 dB @ 10 kHz, low-cut @ 30 Hz)
4. Time-stretch if BPM mismatch

## 9 Troubleshooting

- Too sharp  $\rightarrow$  lower fmax, drive, or pink\_db 3 dB
- Too muddy  $\rightarrow$  fewer pairs, reduce phase diffusion
- Mono issues  $\rightarrow$  stereo\_phase\_max 0.2
- Clipping  $\rightarrow$  increase headroom\_db

## 10 Mini Validation (Unit-ish)

```
def test_basic_shape():
    y = render_preroll(PreRollCfg(seconds=4.0, sr=48000, seed=7))
    assert y.ndim == 2 and y.shape[1] == 2
    assert np.isfinite(y).all()

def test_no_clipping_dc():
    y = render_preroll(PreRollCfg(seconds=4.0, sr=48000, seed=1))
    assert np.max(np.abs(y)) <= 1.0 + 1e-7
    assert abs(y.mean(axis=0)).max() < 1e-3
```

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