GenerativeGenerator

Technical Reference Manual

Generative Melodic Instrument for Eurorack

Jeff Lytle

Version 1.0 — January 29, 2026

Abstract

GenerativeGenerator is a generative melodic instrument for Eurorack that learns short musical gestures (4–16 notes) and continues playing variations indefinitely. Unlike sequencers or arpeggiators, it extracts *tendencies* from input—interval distributions, directional biases, register characteristics—and generates new material through probability-based decisions. This manual provides complete technical specifications, mathematical formulations, and parameter descriptions for all 16 control parameters across 4 pages.

Contents

1 System Overview

1.1 Hardware Platform

- **Platform:** Electrosmith Daisy Patch (STM32H750, ARM Cortex-M7 @ 480MHz)
- **Flash:** 99,820 bytes / 128 KB (76.16%)
- **SRAM:** 52,556 bytes / 512 KB (10.02%)
- **Display:** 128×64 OLED
- **Controls:** 4 potentiometers, 1 rotary encoder with click
- **I/O:** 2 gate inputs, 1 gate output, MIDI In/Out, 4 audio channels

1.2 Core Concept

The module operates in three states:

1. **IDLE:** Awaiting MIDI input
2. **LEARNING:** Capturing notes (4–16 note buffer)
3. **GENERATING:** Creating variations based on learned tendencies

State transitions occur automatically:

- IDLE → LEARNING: First MIDI note received
- LEARNING → GENERATING: Timeout (0.5–10s) or buffer full (16 notes)
- GENERATING → LEARNING: New MIDI note received (live phrase injection)

1.3 Page System

Parameters are organized into 4 pages of 4 parameters each (16 total):

- **Page 0:** Performance – Direct Control
- **Page 1:** Performance – Macro & Evolution
- **Page 2:** Structural – Shape & Gravity
- **Page 3:** Utility – Learning & I/O

Encoder rotation cycles through pages with wraparound ($0 \rightarrow 1 \rightarrow 2 \rightarrow 3 \rightarrow 0$). Encoder click returns to Page 0 or clears the learning buffer when generating.

2 Parameter Reference

All parameters have:

- **Range:** 0.0–1.0 (internally) or 0–127 (MIDI CC)
- **Smoothing:** One-pole lowpass filter, coefficient $\alpha = 0.15$
- **Soft Takeover:** Prevents jumps when changing pages (threshold = 0.05)

2.1 Smoothing Filter

Parameter values are smoothed using exponential filtering:

$$p_{\text{smooth}}[n] = \alpha \cdot p_{\text{raw}}[n] + (1 - \alpha) \cdot p_{\text{smooth}}[n-1] \tag{1}$$

where $\alpha = 0.15$ provides responsive control without jitter.

3 Page 0: Performance – Direct Control

3.1 Parameter 0: MOTION

CC 3 — Default: 50%

3.1.1 Purpose

Biases stepwise motion versus intervallic leaps. Controls the distribution of small vs. large intervals.

3.1.2 Mathematical Formulation

Motion type is selected probabilistically:

$$P(\text{motion type}) = \begin{cases} \text{repeat} & \text{(direct repeat of last note)} \\ \text{step} & \text{(1–2 semitones)} \\ \text{leap} & \text{(3–7 semitones)} \\ \text{octave} & (\pm 1\text{–}2 \text{ octaves}) \end{cases} \tag{2}$$

Probability weights:

$$w_{\text{step}} = (1.0 - p_{\text{MOTION}}) \cdot k_{\text{step}} \tag{3}$$

$$w_{\text{leap}} = p_{\text{MOTION}} \cdot k_{\text{leap}} \tag{4}$$

$$w_{\text{octave}} = p_{\text{MOTION}} \cdot k_{\text{octave}} \tag{5}$$

where $k_{\text{step}} = 0.5$, $k_{\text{leap}} = 0.3$, $k_{\text{octave}} = 0.2$.

3.1.3 Musical Effect

- **0%:** Predominantly stepwise motion, smooth melodic contours
- **50%:** Balanced mix of steps and leaps
- **100%:** Frequent large leaps, angular and disjunct motion

3.2 Parameter 1: MEMORY

CC 9 — Default: 50%

3.2.1 Purpose

Biases repetition and return to recent material. Controls how often the system revisits notes from the recent history buffer.

3.2.2 Mathematical Formulation

A sliding window of the last 8 generated notes is maintained:

$$\text{recent\_notes} = [n_{i-7}, n_{i-6}, \ldots, n_{i-1}] \tag{6}$$

Memory bias probability:

$$P(\text{use recent note}) = p_{\text{MEMORY}} \cdot k_{\text{mem}} \tag{7}$$

where $k_{\text{mem}} = 0.4$.

When triggered, a note is randomly selected from the recent buffer:

$$n_{\text{next}} = \text{recent\_notes}[\text{rand}(0, 7)] \tag{8}$$

3.2.3 Musical Effect

- **0%:** Maximum novelty, avoids repetition, exploratory
- **50%:** Occasional returns to familiar material
- **100%:** Highly repetitive, cycles through recent notes

3.3 Parameter 2: REGISTER

CC 14 — Default: 50%

3.3.1 Purpose

Controls octave displacement probability. Determines how often notes jump by ±1 or ±2 octaves.

3.3.2 Mathematical Formulation

After interval selection, octave displacement is applied probabilistically:

$$P(\text{octave displacement}) = p_{\text{REGISTER}} \cdot k_{\text{oct}} \tag{9}$$

where $k_{\text{oct}} = 0.25$.

Displacement amount:

$$\Delta_{\text{oct}} = \begin{cases} \pm 12 & \text{with probability } 0.7 \\ \pm 24 & \text{with probability } 0.3 \end{cases} \tag{10}$$

Final note:

$$n_{\text{final}} = \text{clamp}(n_{\text{candidate}} + \Delta_{\text{oct}}, 0, 127) \tag{11}$$

3.3.3 Musical Effect

- **0%:** Stays within learned register (±1 octave)
- **50%:** Occasional octave jumps for variety
- **100%:** Frequent octave displacement, wide tessitura

3.4 Parameter 3: DIRECTION

CC 15 — Default: 50%

3.4.1 Purpose

Biases ascending versus descending motion. Blends learned directional tendency with user preference.

3.4.2 Mathematical Formulation

Learned directional bias:

$$\theta_{\text{learned}} = \frac{N_{\text{asc}} - N_{\text{desc}}}{N_{\text{asc}} + N_{\text{desc}}} \tag{12}$$

where N_{asc} and N_{desc} are counts of ascending and descending intervals in the learned buffer.

Parameter-controlled bias:

$$\theta_{\text{param}} = 2 \cdot p_{\text{DIRECTION}} - 1 \quad \in [-1, 1] \tag{13}$$

Blended bias:

$$\theta_{\text{final}} = \frac{\theta_{\text{learned}} + \theta_{\text{param}}}{2} \tag{14}$$

Direction selection:

$$P(\text{ascending}) = \frac{1 + \theta_{\text{final}}}{2} \tag{15}$$

$$P(\text{descending}) = \frac{1 - \theta_{\text{final}}}{2} \tag{16}$$

3.4.3 Musical Effect

- **0%:** Strong descending bias, phrases trend downward
- **50%:** Follows learned tendency (neutral parameter)
- **100%:** Strong ascending bias, phrases trend upward

4 Page 1: Performance – Macro & Evolution

4.1 Parameter 4: PHRASE

CC 20 — Default: 50%

4.1.1 Purpose

Controls expected phrase length through soft targeting. Influences melodic direction changes and phrase boundaries.

4.1.2 Mathematical Formulation

Target phrase length:

$$L_{\text{target}} = 2 + \lfloor p_{\text{PHRASE}} \cdot 14 \rfloor \quad \in [2, 16] \tag{17}$$

Phrase position tracking:

$$\rho = \frac{L_{\text{current}}}{L_{\text{target}}} \quad \in [0, \infty) \tag{18}$$

Boundary probability:

$$P(\text{boundary}) = \begin{cases} 0 & \text{if } \rho < 0.5 \\ \frac{\rho - 0.5}{0.5} \cdot k_{\text{phrase}} & \text{if } 0.5 \leq \rho < 1.0 \\ k_{\text{phrase}} + (\rho - 1.0) \cdot k_{\text{accel}} & \text{if } \rho \geq 1.0 \end{cases} \tag{19}$$

where $k_{\text{phrase}} = 0.3$ and $k_{\text{accel}} = 0.2$.

At phrase boundaries, direction memory is reset, encouraging melodic contour changes.

4.1.3 Musical Effect

- **0%:** Short phrases (2–4 notes), frequent direction changes
- **50%:** Medium phrases (8–10 notes), natural phrasing
- **100%:** Long phrases (14–16 notes), extended melodic arcs

4.2 Parameter 5: ENERGY

CC 21 — Default: 50%

4.2.1 Purpose

Macro parameter that scales multiple systems simultaneously: interval size, octave displacement probability, and phrase looseness.

4.2.2 Mathematical Formulation

Energy scaling is applied to several subsystems:

Interval size scaling:

$$I_{\text{scaled}} = I_{\text{base}} \cdot (0.5 + p_{\text{ENERGY}}) \tag{20}$$

Octave displacement boost:

$$P'_{\text{oct}} = P_{\text{oct}} \cdot (1.0 + p_{\text{ENERGY}}) \tag{21}$$

Phrase boundary randomization:

$$L'_{\text{target}} = L_{\text{target}} \cdot (0.8 + 0.4 \cdot \text{rand}() \cdot p_{\text{ENERGY}}) \tag{22}$$

4.2.3 Musical Effect

- **0%:** Calm, small intervals, predictable phrasing, subdued
- **50%:** Balanced intensity, moderate dynamics
- **100%:** Intense, large intervals, unpredictable, volatile

4.3 Parameter 6: STABILITY

CC 22 — Default: 50%

4.3.1 Purpose

Biases stable versus unstable scale degrees. At high values, favors notes from the learned set; at low values, introduces chromatic passing tones.

4.3.2 Mathematical Formulation

Stability probability:

$$P(\text{use learned note}) = p_{\text{STABILITY}} \cdot k_{\text{stab}} \tag{23}$$

where $k_{\text{stab}} = 0.7$.

When unstable notes are chosen:

$$n_{\text{chromatic}} = n_{\text{base}} + \Delta_{\text{semi}}, \quad \Delta_{\text{semi}} \in \{-1, +1\} \tag{24}$$

4.3.3 Musical Effect

- **0%:** Chromatic, dissonant, exploratory, "outside"
- **50%:** Mix of stable and unstable notes
- **100%:** Diatonic/pentatonic, consonant, stays within learned scale

4.4 Parameter 7: FORGETFULNESS

CC 23 — Default: 50%

4.4.1 Purpose

Controls decay rate of learned tendencies. High values cause the system to gradually drift away from the learned interval distribution toward a uniform distribution.

4.4.2 Mathematical Formulation

Interval weight decay per note:

$$w_i[n] = w_i[n-1] \cdot (1 - p_{\text{FORGET}} \cdot k_{\text{decay}}) \tag{25}$$

where $k_{\text{decay}} = 0.01$ and w_i are the interval distribution weights.

Uniform distribution injection:

$$w_i[n] \leftarrow w_i[n] + p_{\text{FORGET}} \cdot k_{\text{uniform}} \cdot \frac{1}{13} \tag{26}$$

where $k_{\text{uniform}} = 0.02$.

4.4.3 Musical Effect

- **0%:** Strong adherence to learned style, stable over time
- **50%:** Gradual evolution, slight drift
- **100%:** Rapid forgetting, becomes increasingly random/uniform

5 Page 2: Structural – Shape & Gravity

5.1 Parameter 8: LEAP SHAPE

CC 24 — Default: 50%

5.1.1 Purpose

Controls exponential decay of interval size probability. Shapes the distribution from flat (all intervals equally likely) to steep (strong preference for small intervals).

5.1.2 Mathematical Formulation

Interval probability with exponential decay:

$$P(I = i) \propto w_i \cdot \exp(-\lambda \cdot i) \tag{27}$$

where $i \in [0, 12]$ is interval size in semitones and:

$$\lambda = p_{\text{LEAP SHAPE}} \cdot k_\lambda, \quad k_\lambda = 0.15 \tag{28}$$

Normalization:

$$P(I = i) = \frac{w_i \cdot \exp(-\lambda \cdot i)}{\sum_{j=0}^{12} w_j \cdot \exp(-\lambda \cdot j)} \tag{29}$$

5.1.3 Musical Effect

- **0%:** Flat distribution, large leaps as common as steps
- **50%:** Moderate decay, natural intervallic variety
- **100%:** Steep decay, strong preference for stepwise motion

5.2 Parameter 9: DIRECTION MEMORY

CC 25 — Default: 50%

5.2.1 Purpose

Controls persistence of melodic direction. High values produce long ascending or descending runs; low values produce frequent zigzagging.

5.2.2 Mathematical Formulation

Direction is chosen probabilistically, with memory of the previous direction:

$$P(\text{same direction}) = p_{\text{DIR MEM}} \cdot k_{\text{dir}} \tag{30}$$

where $k_{\text{dir}} = 0.8$.

Direction state:

$$d[n] = \begin{cases} d[n-1] & \text{with probability } P(\text{same direction}) \\ -d[n-1] & \text{with probability } 1 - P(\text{same direction}) \end{cases} \tag{31}$$

where $d \in \{-1, +1\}$ represents descending or ascending.

5.2.3 Musical Effect

- **0%:** Frequent direction changes, zigzag melodic contour
- **50%:** Moderate persistence, natural phrase shapes
- **100%:** Long runs, extended ascending/descending sequences

5.3 Parameter 10: HOME REGISTER

CC 26 — Default: 50%

5.3.1 Purpose

Sets the center of register gravity. Notes are pulled toward this center through a soft Gaussian constraint.

5.3.2 Mathematical Formulation

Register center mapping:

$$r_{\text{center}} = 36 + \lfloor p_{\text{HOME REG}} \cdot 55 \rfloor \quad \in [36, 91] \text{ (C2 to G6)} \tag{32}$$

Gaussian gravity function:

$$G(n) = \exp\left(-\frac{(n - r_{\text{center}})^2}{2\sigma^2}\right) \tag{33}$$

where σ is controlled by RANGE WIDTH (see below).

Probability modification:

$$P'(n) = P(n) \cdot (1 + k_g \cdot G(n)) \tag{34}$$

where $k_g = 0.5$ is the gravity strength.

5.3.3 Musical Effect

- **0%:** Low register center (bass), gravitates toward C2
- **50%:** Mid register (around E4), neutral tessitura
- **100%:** High register center (treble), gravitates toward G6

5.4 Parameter 11: RANGE WIDTH

CC 27 — Default: 50%

5.4.1 Purpose

Sets variance of register gravity. Controls how tightly notes cluster around the HOME REGISTER center.

5.4.2 Mathematical Formulation

Variance (standard deviation):

$$\sigma = 12 + p_{\text{RANGE}} \cdot 36 \quad \in [12, 48] \text{ semitones} \tag{35}$$

This modulates the Gaussian gravity from Parameter 10:

$$G(n) = \exp\left(-\frac{(n - r_{\text{center}})^2}{2\sigma^2}\right) \tag{36}$$

5.4.3 Musical Effect

- **0%:** Tight clustering, narrow pitch range, strong gravity
- **50%:** Moderate spread, natural register variance
- **100%:** Wide exploration, weak gravity, uses full keyboard

6 Page 3: Utility – Learning & I/O

6.1 Parameter 12: LRN TIME (Learning Timeout)

CC 28 — Default: 2.0s (16%)

6.1.1 Purpose

Controls how long to wait after the last MIDI note before automatically transitioning from LEARNING to GENERATING state.

6.1.2 Mathematical Formulation

Timeout in milliseconds:

$$T_{\text{timeout}} = 500 + \lfloor p_{\text{LRN TIME}} \cdot 9500 \rfloor \quad \in [500, 10000] \text{ ms} \tag{37}$$

Default value ($T = 2000$ ms):

$$p_{\text{default}} = \frac{2000 - 500}{9500} = 0.158 \approx 16\% \tag{38}$$

State transition condition:

$$\text{if } (t_{\text{current}} - t_{\text{last note}} > T_{\text{timeout}}) \wedge (N_{\text{notes}} \geq 4) \Rightarrow \text{STATE\_GENERATING} \tag{39}$$

6.1.3 Musical Effect

- **0% (0.5s):** Very fast, for quick patterns and rhythmic input
- **16% (2.0s):** Default, natural for keyboard playing
- **100% (10s):** Slow, for contemplative/sparse input

6.2 Parameter 13: ECHO (MIDI Note Echo)

CC 29 — Default: OFF (0%)

6.2.1 Purpose

When enabled, notes received during LEARNING are immediately echoed to MIDI output and gate output, providing auditory feedback.

6.2.2 Mathematical Formulation

Echo trigger condition:

$$\text{if } (\text{state} = \text{LEARNING}) \wedge (p_{\text{ECHO}} > 0.5) \Rightarrow \text{send MIDI} \tag{40}$$

Gate pulse duration:

$$T_{\text{gate}} = 100 \text{ ms (fixed)} \tag{41}$$

6.2.3 Musical Effect

- **OFF ($< 50\%$):** Silent learning, no output during capture
- **ON ($\geq 50\%$):** Hear notes as played, immediate feedback

6.2.4 Use Cases

- **Echo ON:** Manual keyboard input, practice mode, live performance
- **Echo OFF:** Pre-recorded sequences, scripted input, silent capture

6.3 Parameters 14–15: Reserved

CC 30–31

Currently inactive. Reserved for future features including:

- Scala .scl file selection from SD card
- Microtonal output mode (MTS/MPE/direct CV)
- Scale quantization settings
- CV calibration offsets

CC#	Parameter	Page	Pot	Default
3	MOTION	0	1	50%
9	MEMORY	0	2	50%
14	REGISTER	0	3	50%
15	DIRECTION	0	4	50%
20	PHRASE	1	1	50%
21	ENERGY	1	2	50%
22	STABILITY	1	3	50%
23	FORGETFULNESS	1	4	50%
24	LEAP SHAPE	2	1	50%
25	DIRECTION MEMORY	2	2	50%
26	HOME REGISTER	2	3	50%
27	RANGE WIDTH	2	4	50%
28	LRN TIME	3	1	16% (2s)
29	ECHO	3	2	0% (OFF)
30	Reserved	3	3	50%
31	Reserved	3	4	50%

Table 1: Complete MIDI CC mapping for all 16 parameters

7 MIDI Control Change Mapping

7.1 MIDI CC Value Mapping

All parameters use linear mapping:

$$p = \frac{\text{CC value}}{127} \quad \in [0, 1] \tag{42}$$

Exception: LRN TIME has non-uniform perceptual mapping (see Parameter 12).

8 Generative Algorithm

8.1 Note Generation Pipeline

Each trigger on Gate Input 1 executes the following pipeline:

1. **Motion Decision:** Select motion type (repeat/step/leap/octave) based on MOTION parameter
2. **Interval Selection:** Choose interval size from learned distribution, weighted by LEAP SHAPE
3. **Direction Selection:** Choose ascending/descending based on DIRECTION and DIR MEM
4. **Candidate Note:** Compute $n_{\text{candidate}} = n_{\text{prev}} + d \cdot I$
5. **Octave Displacement:** Apply with probability from REGISTER parameter
6. **Register Gravity:** Bias toward HOME REGISTER with RANGE WIDTH variance

7. **Memory Bias:** Optionally replace with recent note based on MEMORY
8. **Stability:** Adjust to learned scale or chromatic based on STABILITY
9. **Clamping:** Ensure $n_{\text{final}} \in [0, 127]$
10. **Output:** Send MIDI note, trigger gate output

8.2 Phrase Tracking

Phrase position is tracked continuously:

$$\rho[n] = \frac{L_{\text{current}}}{L_{\text{target}}(p_{\text{PHRASE}}, p_{\text{ENERGY}})} \tag{43}$$

At phrase boundaries ($\rho \geq 1$):

- Direction memory is reset
- Phrase counter resets to 0
- New target length is computed

8.3 Learned Tendency Extraction

Upon entering GENERATING state, the following are computed from the note buffer:

Interval histogram:

$$H[i] = \text{count}(|n_{j+1} - n_j| = i), \quad i \in [0, 12] \tag{44}$$

Directional statistics:

$$N_{\text{asc}} = \text{count}(n_{j+1} > n_j) \tag{45}$$
$$N_{\text{desc}} = \text{count}(n_{j+1} < n_j) \tag{46}$$
$$N_{\text{repeat}} = \text{count}(n_{j+1} = n_j) \tag{47}$$

Register statistics:

$$r_{\text{center}} = \frac{1}{N} \sum_{j=1}^{N} n_j \tag{48}$$
$$r_{\text{min}} = \min_j n_j \tag{49}$$
$$r_{\text{max}} = \max_j n_j \tag{50}$$
$$r_{\text{range}} = r_{\text{max}} - r_{\text{min}} \tag{51}$$

Most common intervals:

$$I_1 = \arg\max_i H[i] \tag{52}$$
$$I_2 = \arg\max_{i \neq I_1} H[i] \tag{53}$$

9 Input/Output Specifications

9.1 Gate Inputs

- **Gate Input 1:** Note trigger (generates new note during GENERATING state)
- **Gate Input 2:** Clock/BPM detection (measures tempo, updates display)

Both inputs use rising edge detection. Minimum pulse width: 1ms.

9.2 Gate Output

- **Trigger:** Synchronized with generated notes
- **Duration:** 50% of clock interval (from Gate Input 2)
- **Minimum:** 20ms
- **Maximum:** 500ms
- **Default (no clock):** 50ms

Gate length formula:

$$T_{\text{gate}} = \text{clamp}(0.5 \cdot T_{\text{clock}}, 20, 500) \text{ ms} \tag{54}$$

9.3 MIDI

- **Channel:** 1 (fixed)
- **Note Range:** 0–127 (C-1 to G9)
- **Velocity:** 100 (fixed)
- **Input:** Note On/Off, Control Change (CC)
- **Output:** Note On/Off

9.4 CV Output

- **Resolution:** 12-bit (4096 steps)
- **Range:** 0–5V
- **Standard:** 1V/octave
- **Calibration:** Software-defined (future: adjustable via Page 3)

CV voltage formula:

$$V_{\text{CV}} = \frac{n - 60}{12} \text{ V} \tag{55}$$

where $n = 60$ (C4) corresponds to 0V.

10 Display Interface

10.1 Main Display Layout

```
PAGE 1

MOTION      [     ]
MEMORY      [       ]  ← Pickup indicator
REGISTER    [   ]
DIRECTION   [         ]
L:4                120  CLK
```

10.1.1 Elements

- **Top left:** Page indicator ()
- **Top right:** Clock pulse indicator (flashes)
- **Parameter bars:** Filled portion shows value
- **Hollow rectangle:** Current pot position (during soft takeover)
- **Dashed border:** Waiting for pickup (pot must catch stored value)
- **Bottom left:** Learning state (L:X, G:X, or -)
- **Bottom center:** BPM from Gate Input 2
- **Bottom right:** Clock indicator (filled box when gate high)
- **Right edge:** Vertical pitch bar (current note position)

10.2 Learning State Indicators

- **"-":** IDLE state, awaiting MIDI input
- **"L:X":** LEARNING state, X notes captured (0–16)
- **"G:X":** GENERATING state, using X learned notes

10.3 LED Behavior

- **IDLE:** Shows gate input state (mirrors Gate Input 2)
- **LEARNING:** Blinks rapidly (10 Hz)
- **GENERATING:** Pulses with clock (mirrors clock pulse indicator)

11 Live Performance Features

11.1 Soft Takeover (Parameter Pickup)

When switching pages, parameters do not immediately respond to pot movements. The pot must first "catch up" to the stored parameter value.

Pickup threshold:

$$|\text{pot value} - \text{stored value}| < 0.05 \tag{56}$$

Or crossing condition:

$$\text{sign}(\text{pot}[n] - \text{stored}) \neq \text{sign}(\text{pot}[n-1] - \text{stored}) \tag{57}$$

Visual feedback: dashed border around parameter bar until pickup activated.

11.2 Live Phrase Injection

Sending MIDI notes during GENERATING state automatically transitions back to LEARNING, allowing seamless pattern changes without manual reset.

State transition:

$$\text{STATE\_GENERATING} \xrightarrow{\text{MIDI note}} \text{STATE\_LEARNING (buffer cleared)} \tag{58}$$

This enables:

- Call-and-response improvisation
- Pattern evolution during performance
- Smooth musical transitions

12 Technical Specifications

12.1 Memory Usage

- **Flash:** 99,820 / 131,072 bytes (76.16%)
- **SRAM:** 52,556 / 524,288 bytes (10.02%)
- **Learning buffer:** 16 bytes (16 notes × 1 byte)
- **Recent notes buffer:** 8 bytes (8 notes × 1 byte)
- **Tendency struct:** ˜88 bytes
- **Parameters:** 128 bytes (16 params × 2 floats × 4 bytes)
- **Debug log:** 384 bytes (64 entries × 6 bytes)

12.2 Processing Performance

- **Sample rate:** 48 kHz
- **Block size:** 48 samples
- **Audio callback latency:** ˜1 ms
- **Display refresh rate:** 30 Hz (33 ms frame time)
- **Control update rate:** 30 Hz

12.3 Random Number Generation

Uses XORshift32 algorithm for all probabilistic decisions:

$$x \leftarrow x \oplus (x \ll 13) \tag{59}$$
$$x \leftarrow x \oplus (x \gg 17) \tag{60}$$
$$x \leftarrow x \oplus (x \ll 5) \tag{61}$$

Output range: $[0, 2^{32} - 1]$, uniform distribution.

13 Future Extensions

13.1 Microtonal Support (Planned)

- Load Scala (.scl) files from SD card
- Settings menu (hold encoder 1.5s)
- Multiple output modes:
  - MIDI Tuning Standard (MTS) via SysEx
  - MPE-style pitch bend per note
  - Direct microtuned CV output
- Parameters 14–15 reserved for scale selection and mode

13.2 Potential Enhancements

- Multiple pattern banks (store/recall learned patterns)
- Crossfade between patterns
- CV control of parameters (currently pot-only)
- MIDI learn mode for custom CC assignments
- Pattern morphing (blend two learned patterns)

14 Appendix: Quick Reference

14.1 Default Values Summary

- Pages 0–2: All parameters default to 50%
- Page 3: LRN TIME = 16% (2s), ECHO = 0% (OFF)

14.2 Encoder Commands

- **Turn CW/CCW:** Navigate pages
- **Click (IDLE/LEARNING):** Return to Page 0
- **Click (GENERATING):** Clear buffer, return to IDLE

14.3 State Machine Summary

$$\begin{aligned}
\text{IDLE} &\xrightarrow{\text{MIDI note}} \text{LEARNING} \\
\text{LEARNING} &\xrightarrow{\text{timeout or buffer full}} \text{GENERATING} \\
\text{GENERATING} &\xrightarrow{\text{MIDI note}} \text{LEARNING} \\
\text{GENERATING} &\xrightarrow{\text{encoder click}} \text{IDLE}
\end{aligned}$$

15 Contact & Resources

- **GitHub:** https://github.com/jjlytle/GenerativeGenerator
- **Author:** Jeff Lytle
- **Platform:** Electrosmith Daisy Patch
- **Documentation:** https://daisy.audio/