Carbonator — DSP Manual

Carbonated Audio · v2.2.0 Five-flavour mix colour and character plug-in.

This document explains the signal processing inside Carbonator from the top down: what each control does mathematically, why the flavours are wired the way they are, and how to reason about them on a mix. It's written for engineers and producers who want to know what's behind the metaphor, not just which flavour sounds good on what.

---

1. Overview

Carbonator is a **five-character saturation and colour processor** controlled by three knobs: **Flavor**, **Fizz**, and **Carbonated**. Each flavour is a hand-designed DSP chain optimised for a specific sonic goal; the Fizz knob morphs multiple internal parameters simultaneously, and the Carbonated switch flips each flavour between its "normal" mode and an alternate mode.

There is **no wet/dry** knob. Every flavour is a full-signal chain, because the flavours are character choices — dry-blended saturation usually sounds worse than either extreme.

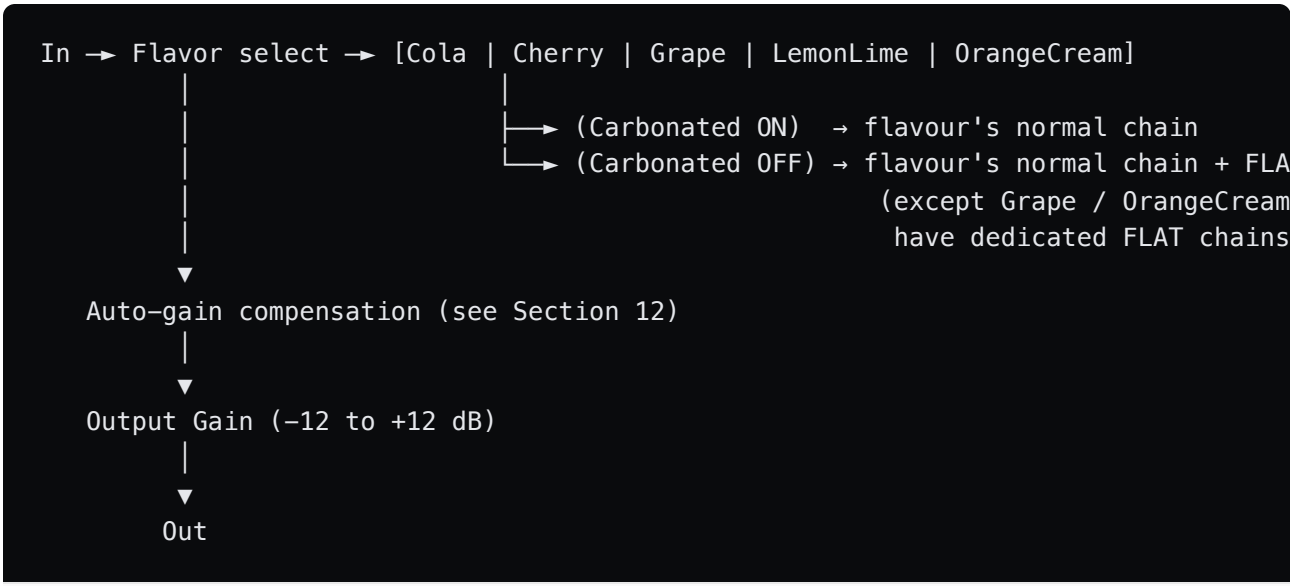
Everything in Carbonator reduces to three ideas:

1. **Flavor** picks one of five DSP chains (Cola, Cherry, Grape, Lemon-Lime, Orange Cream).
2. **Fizz** is a **morph controller** — a single 0–100% value that simultaneously drives drive, compression ratio, EQ gains, filter cutoffs, and modulation depth inside whichever flavour is selected. Fizz uses shaped curves (exponential, logarithmic, sigmoidal) rather than linear mappings, so the whole range feels musically useful.
3. **Carbonated** toggles between each flavour's normal mode and its **alternate mode** (Flat), which layers in an extra character-defining process on top of (or instead of) the base chain.

A global **Output Gain** and **HQ Mode** (4× oversampling on the saturation stage) sit over the whole thing.

---

2. Signal Flow



Inside every flavour, the **SaturationEngine** is the same shared piece: an oversampled non-linear waveshaper with selectable curves (Tanh, AsymSoftClip, WarmClip). Each flavour calls it with its own curve choice and drive values.

---

3. Fizz — The Morph Controller

Range: 0% to 100%, default 50%. Linear parameter smoothing, 20 ms.

Fizz is **not** a dry/wet. It's the single knob that morphs the flavour's internal DSP parameters. Each flavour uses a handful of these three curve shapes (`FizzCurves`):

- **`exponential(fizz, a, b, power)`** — smoothly curves from `a` to `b` with a user-defined bend. Used for drive amounts, delay depth, rate controls.
- **`logarithmic(fizz, a, b, power)`** — fast-early then flattening. Used for EQ gains so small movements at low Fizz feel musical.
- **`sCurve(fizz, a, b)`** — sigmoid from `a` to `b`. Used for parallel-blend amounts, resonance shaping.
- **`linear(fizz, a, b)`** — straight-line interpolation. Used only where linearity is musically correct (e.g. Cola's compressor threshold).

Every flavour maps roughly 3–7 internal parameters to Fizz through these curves. The result: each flavour has a "sweet spot" somewhere on the knob, but the whole range is usable. You can't accidentally push it past "too much" — the curves shape that for you.

4. Carbonated Toggle

Boolean, default ON.

Each flavour has a **normal mode** (Carbonated ON) and an **alternate mode** (Carbonated OFF, "Flat"):

Flavor	Carbonated ON (normal)	Carbonated OFF (alternate)
Cola	Console saturation + tilt EQ + compression	Adds an extra tape-stage saturation on top of the normal chain
Cherry	Parallel tanh saturation + de-harsh + presence + air shelf	Same as normal, plus a subtle chorus (1.5 Hz LFO, 0.5–1 ms depth)
Grape	Tape drive + wow/flutter modulated delay + tape LP	Runs the normal Grape chain, then stacks vinyl crackle + 40 Hz rumble + low-end mono fold
Lemon-Lime	LR4 split + HF tanh drive + compressor + presence + air shelf	Telephone EQ: 300 Hz HP + 3.5 kHz LP with resonance
Orange Cream	Warm-clip + resonant lowpass filter sweep + low shelf	Dirtier version — heavier tanh drive, lower filter cutoff, more resonance

The name "Flat" comes from the soda-can metaphor: a carbonated soda is fresh and fizzy; a flat soda is the same drink, different character. Turning Carbonated OFF never silences or bypasses — it swaps the flavour into its alternate-character mode.

---

5. The SaturationEngine (Shared)

Every flavour routes its saturation through a single shared engine that exposes a parameter struct:

```
struct Params {
    CurveType curve;       // Tanh, AsymSoftClip, WarmClip
    float drive;           // gain into the curve
    float outputGain;      // gain out (usually 1/drive to normalise)
    float dcBias;          // added before the curve, for even-harmonic bias
    float mix;             // parallel blend (0 = dry, 1 = full wet)
};
```

Curves: - **Tanh** — classic hyperbolic-tangent soft-clip. Even distortion character, symmetric. - **AsymSoftClip** — tanh with positive/negative asymmetry, generating more 2nd-harmonic content. Used by Cola. - **WarmClip** — a gentler polynomial soft-clip used when a clean warmth is wanted without the harder edge of tanh. Used by Orange Cream's normal mode.

Oversampling: when HQ Mode is on (default), the saturation stage runs at **4× oversampling** to avoid aliasing. The engine reports its internal latency via `getLatencyInSamples()` so the host can compensate PDC-wise. When HQ Mode is off, oversampling is bypassed — lower CPU, some aliasing on aggressive drives.

---

6. Cola — Analog Console Warmth

Chain (Carbonated ON):

1. **AsymSoftClip saturation** with `drive = exp(1 → 4)`, `dcBias = 0.1` (Fizz-morphed). The asymmetry produces even harmonics — the "warm" signature of a pushed analog desk.
2. **DC blocker** — 1st-order HPF at 5 Hz, cleans up the asymmetric-saturation DC offset.
3. **Compressor** with Fizz-morphed ratio (1.5 → 6.0) and threshold (–6 → –30 dB). 10 ms attack, 100 ms release — console-style.
4. **Tilt EQ** — low shelf at 200 Hz, Fizz-morphed gain (0 → +3.5 dB) and matching high shelf at 8 kHz with inverse gain (0 → –3 dB). Warmth and top-end tame in one shape.

Flat variant — adds a block of inline `tanh(drive × x) / drive` as a second saturation layer, Fizz-morphed drive (1 → 3). Runs outside the SaturationEngine to avoid double-oversampling. Gives a "pushed harder" character on top of the base chain.

---

7. Cherry — Sweet Vocal Presence

Chain (Carbonated ON):

1. **Parallel tanh saturation** through the SaturationEngine. `drive = exp(1.5 → 4.5)`, `outputGain = 1/drive` (keeps loudness constant), `mix = sCurve(0.10 → 0.65)`. The parallel blend is the key — the wet signal is fully saturated, the dry stays clean, and Fizz controls how much distortion rides alongside the original.
2. **De-harsh notch** at 3.5 kHz, Fizz-morphed gain (0 → –4 dB), Q = 2. Pulls the ugly band out before the presence bell adds brightness — classic vocal-chain trick.
3. **Presence bell** at 4.5 kHz, Fizz-morphed gain (0 → +6 dB), Q = 1.5. Musical upper-mid forward push.
4. **Air shelf** at 12 kHz, Fizz-morphed gain (0 → +4 dB), Q = 0.707. Classic "air" shelf — adds openness.

Flat variant — the base chain, then a **subtle chorus**: 1.5 Hz LFO, depth = `sCurve(0.5 → 1.0)` ms, 3 ms base delay, 30% wet mix. Stereo when available. Takes the dry-centred vocal and opens it laterally.

---

8. Grape — Lo-Fi Tape Texture

Chain (Carbonated ON):

1. **Oversampled tanh saturation** with DC bias = 0.15 — tape-bias character, adds 2nd harmonic.
2. **DC blocker** — 1st-order HPF at 5 Hz.
3. **Wow & flutter modulated delay** — 5 ms base delay, modulated by:
4. **Wow LFO** at 0.4 Hz, depth = `exp(0 → 3)` ms (sinusoidal)
5. **Flutter LFO** at 4.5 Hz, depth = `exp(0 → 0.5)` ms (triangle wave approximated via `asin(sin(x))`) Linear interpolation on the delay read; total delay is jlimited to [1, bufferSize−2] samples for safety.
6. **Tape head LP** — StateVariableTPTFilter lowpass with Fizz-morphed cutoff (16 kHz → 4 kHz). Simulates tape's high-frequency loss.

Flat variant (Vinyl mode) — Grape's normal chain, then: - Sparse **vinyl crackle** — random impulses with Fizz-morphed rate (0.001 → 0.01) and level (0.01 → 0.05). - **40 Hz rumble** — broadband white noise (generated, not filtered from anything real), Fizz-morphed level (0 → 0.015). - **Mono fold** — below 300 Hz, L/R are summed to mid and side is passed through (effectively a high-pass mid/side decoder at 300 Hz). Gives records-era narrow-bottom-end feel.

9. Lemon-Lime — Crisp Exciter

Chain (Carbonated ON):

1. **Linkwitz-Riley 4th-order crossover** at Fizz-morphed frequency (4 kHz → 1.5 kHz). Two cascaded 2nd-order Butterworth LP (Q = 0.707) → low band; two cascaded HP → high band. LR4 sums flat at unity.
2. **Oversampled tanh saturation** on the high band only, `drive = exp(1.3 → 3.5)`, `outputGain = 1/drive`.
3. **HF compressor** on the saturated high band — 4:1 ratio, –20 dB threshold, Fizz-morphed attack (10 → 0.5 ms), 50 ms release. Tames the aggressive tops.
4. **Presence bell** at 5 kHz, Fizz-morphed gain (0.5 → +6 dB), Q = 1.5.
5. **Air shelf** at 10 kHz, Fizz-morphed gain (0.5 → +5 dB), Q = 0.707.
6. **Sum** — processed high band + untouched low band. Because LR4 sums flat, no frequency-response artefact from the split.

The net behaviour: a classic exciter (distort + EQ the top band, leave the bottom clean) with Fizz lowering the crossover and raising the drive simultaneously.

Flat variant — Lemon-Lime's normal chain, then a **telephone EQ**: 300 Hz HP + 3.5 kHz LP, Fizz-morphed resonance (0.707 → 3.0). Cascaded not pre-Lemon, but after the Exciter chain — a lo-fi broadcast voice on top of a bright chain.

---

10. Orange Cream — Lowpass Filter + Drive

Chain (Carbonated ON):

1. **WarmClip saturation** with Fizz-morphed drive (1 → 2.5). Pre-filter, for analog character.
2. **Resonant 4th-order lowpass** — two cascaded StateVariableTPTFilter lowpass stages:
3. Stage 1: cutoff = `log(20 kHz → 200 Hz)`, resonance = `sCurve(0.707 → 2.5)` — the audible filter character.
4. Stage 2: same cutoff, fixed Q = 0.707 — adds steepness (24 dB/oct rolloff).
5. **Low shelf** at 200 Hz, Fizz-morphed gain (0 → +4 dB). Keeps the low end present as the filter closes down on the rest of the spectrum.

Flat variant (dirty version) — uses Tanh (not WarmClip) with heavier drive (1.5 → 4.0), lower cutoff (20 kHz → 100 Hz), steeper resonance (0.707 → 4.0), more low-shelf boost (0 → +6 dB). Both stages resonant. The gritty cousin of the normal mode.

---

11. HQ Mode

Boolean, default ON. Controls 4× oversampling on the shared SaturationEngine.

- **HQ ON** — the non-linear stage runs at 4× the host sample rate. Eliminates most aliasing from hard-clip and asymmetric distortion. Introduces a few samples of latency (reported via `getLatencySamples()` so the host can delay-compensate).
- **HQ OFF** — no oversampling. Lower CPU, aliasing possible at high drives. Use this when bouncing many Carbonator instances live, or when CPU headroom is tight.

The other flavour stages (filters, compressors, EQ) always run at native sample rate — only the saturation is oversampled.

---

12. Auto-Gain Compensation

Carbonator does not expose a per-flavour makeup-gain knob. Instead, each flavour's chain is tuned so the average output level stays close to the input level across the Fizz range. Where compression or saturation would otherwise push loudness up (e.g. Cola's compressor pulling peaks down), the chain is arranged to keep the signal feeling "at unity" without a separate knob.

If you want explicit makeup, use the global **Output Gain** after the flavour chain.

---

13. Output Gain

Range: −12 dB to +12 dB, default 0 dB.

Applied globally after the flavour chain. A simple pre-dry-out linear gain, not inside the oversampled saturation path.

---

14. Bypass

Global bypass, default off. When active, audio passes through untouched at unity gain.

---

15. Latency and CPU

Carbonator's latency is **whatever the SaturationEngine's oversampler reports**, which depends on HQ Mode:

- **HQ Mode ON** — typically around 10–20 samples at common sample rates (varies with JUCE's oversampler settings).
- **HQ Mode OFF** — zero latency.

Latency is reported to the host via `getLatencySamples()` so PDC aligns the rest of the session.

CPU varies by flavour: - Lightest: **Orange Cream** (saturation + 2 filters + shelf). - Heaviest: **Lemon-Lime** (LR4 split + saturation + compressor + 2 EQ bells).

All flavours are cheap enough to stack across a session. HQ Mode roughly doubles CPU cost of the saturation stage.

---

16. Channel Configuration

- **Main I/O:** stereo in, stereo out. Mono supported for everything except Grape's Vinyl mode (the mono-fold step is a no-op on mono input — no crash, just no mono fold).
- **Sample rates:** all sample rates supported. Oversampling recomputes when rate changes.
- **Block sizes:** arbitrary. Delay buffers (`cherryChorusDelayBuffer` , `grapeDelayBuffer`) are pre-allocated at prepare time with headroom.

---

17. Parameter Summary

Parameter	Range	Default
Flavor	Cola / Cherry / Grape / Lemon-Lime / Orange Cream	Cola
Fizz	0% – 100%	50%
Carbonated	On / Off	On
Output Gain	–12 dB – +12 dB	0 dB
HQ Mode	On / Off	On
Bypass	On / Off	Off

---

18. Credits and References

- **Linkwitz-Riley crossover** — S. Linkwitz, 1976. Used by Lemon-Lime.
- **Robert Bristow-Johnson**, *Cookbook formulae* — biquad coefficient math.
- **Zavalishin, *The Art of VA Filter Design*** — theory behind JUCE's StateVariableTPTFilter, used for Grape's tape LP, Orange Cream's resonant LP, and Cola's DC blocker.
- **Tape wow/flutter** modelling (Grape) — inspired by Chris Townsend's tape-simulation papers and classic tape-machine measurements.

Questions, bug reports, or sound-design notes: mixedbysoda@gmail.com.