O2

Stereo 3-Band Saturation & Width Processor

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O2 is a stereo three-band saturation and width processor designed to inject analog character, harmonic warmth, and spatial depth into digital recordings. Inspired by classic hardware units of the 1970s, O2 offers five families of saturation character — each with four distinct variants — applied independently across low, mid, and high frequency bands. Per-band feedback, drift, hiss, and phase controls allow further shaping of texture and tone.

1. Overview & Signal Chain

O2's window is organized into a top bar (logo, preset menu, and global utility buttons), three color-coded band strips, and a bottom bar of global controls and meters.

The O2 interface: top bar, three band strips (Low / Mid / High), and the global bottom bar (In Trim, crossovers, Out Trim, Tilt, Dry/Wet).

The top bar carries the O2 logo on the left; the preset menu with SAVE and DEL; a RESET button (far right, beside the XNULLX brand) that returns every parameter to its default in a single click; and the host-independent global controls live along the bottom.

O2 processes stereo audio through a precisely ordered signal chain. Understanding this order helps you predict how each control interacts with others.

Stage	Description
Input Trim	Global input gain before any processing. Sets the drive level entering all three bands.

Stage	Description
Crossover Filters	First-order 6 dB/oct filters split the signal into Low, Mid, and High bands. Mathematically perfect reconstruction — all three bands sum back to the original when saturation and width are at zero.
Per-Band Processing	Each band independently processes: Feedback inject → Saturation → Hiss → M/S Width → Level → Flip Phase.
Band Sum	The three processed bands are summed back to a full-range stereo signal.
Mono Collapse	Optional mono fold (activated by the MONO toggle) for mix checking.
Output Level	Global output gain after summing.
Dry/Wet	Parallel blend of the fully processed signal with the original unprocessed input.

The crossover filters use a first-order TPT (Topology-Preserving Transform) design. Unlike Linkwitz-Riley crossovers, first-order filters have a combined phase response that sums to perfectly flat when all bands are active — meaning O2 introduces no coloration whatsoever at zero drive. All harmonic content you hear comes from the saturation stages alone.

2. Global Controls

Global controls affect the entire signal regardless of band settings. The six global knobs and the toggle buttons appear in the bottom bar; SAVE / DEL / RESET sit in the top bar.

Parameter	Range	Description
In Trim	-48 to +15 dB	Input gain before the crossover split. Higher values push more signal into the saturation stages, increasing overall harmonic generation across all active bands. Think of this as the master drive level — too high will cause significant distortion across all bands at once; use band-level Drive for surgical shaping.
Lo X-Over	70 Hz – 1.5 kHz	Sets the crossover frequency between the Low and Mid bands. Audio below this point is processed by the Low band; audio above passes to the Mid and High bands. A setting around 200–400 Hz typically separates bass fundamentals from the midrange body.
Hi X-Over	800 Hz – 15 kHz	Sets the crossover frequency between the Mid and High bands. Audio below this point (but above Lo X-Over) is processed by the Mid band; audio above goes to the High band. A setting around 3–5 kHz typically separates midrange presence from high-frequency air.
Out Trim	-48 to +12 dB	Output gain applied after all bands are summed. Use to compensate for any overall level change introduced by saturation and width processing. Does not affect the Dry/Wet blend.
Tilt	-1 … +1 (±6 dB)	A global tone tilt — a spectral seesaw of up to ±6 dB pivoting around 800 Hz, applied after the bands are summed (before the mix). Negative darkens (lifts the lows, shelves the highs down); positive brightens (trims the lows, lifts the highs). A fast way to warm or open the whole processed signal without touching per-band settings.
Dry/Wet	0 – 100%	Ducked equal-power blend between the processed signal (wet) and the original unprocessed signal (dry): as the wet blooms it gently ducks the dry, so the two displace rather than simply stack. At 100% you hear only the processed output; at 0% only the dry input. Blending at 30–60% adds subtle harmonic density without significantly altering the original tone.
MONO	Toggle	Collapses the stereo output to mono by averaging left and right channels. A diagnostic tool to check mono compatibility after applying stereo width — any significant level drop or tonal change indicates phase cancellation; reduce Width accordingly.

Parameter	Range	Description
BYPASS	Toggle	Hard bypass of the entire plugin. The input passes through unaltered — for A/B comparison of processed vs unprocessed signal.
4x OS	Toggle	Enables 4× oversampling during saturation processing. Eliminates aliasing — spurious high-frequency tones from nonlinear processing near Nyquist. Recommended for high-drive settings (especially Diode and Tube types) at 44.1 kHz. Increases CPU; disable for monitoring, enable when printing/bouncing.
WIDEN	Toggle	Mono-source widening. Synthesises a stereo side channel from a short-delayed copy of the mid signal, scaled by how far each band's Width is pushed past unity. Because the synthetic side cancels in L+R, the result stays mono-compatible. Lets the per-band Width controls open up genuinely mono material (real M/S width only scales existing side content).
RESET	Button	Returns every parameter — global and per-band — to its default value in a single click. A clean starting point.

3. Per-Band Controls

Each of the three frequency bands — Low (ice blue), Mid (mint green), and High (coral) — has an identical set of controls. Changes to one band do not affect the others.

3.1 Saturation Selection

Parameter	Range	Description
Type	5 types	Selects the family of saturation character. Each type has a distinct harmonic fingerprint. See Section 4 for full descriptions of all types and variants.
Variant	4 per type	Selects a specific character within the chosen type. The variant dropdown repopulates automatically when Type is changed. Variants within a type share the same fundamental waveshaping approach but differ in knee sharpness, asymmetry, harmonic weighting, and frequency-dependent behavior.

3.2 Tone Controls

Parameter	Range	Description
Drive	0 – 10	Gain applied to the band signal before the saturation waveshaper. At 0 the saturation stage is essentially inactive — the signal passes with negligible coloration. As Drive increases, more of the signal exceeds the soft-clip threshold, generating progressively more harmonic content (its character depends on the selected Type and Variant). Levels above 6–7 produce obvious distortion; subtle settings (1–3) add warmth and density without audible grit.
Width	-5 (Mono) to +5 (Wide)	Stereo width of the band via Mid/Side processing: mid (L+R) and side (L−R) are separated, the side is scaled by the Width setting, then the image is reconstructed. At 0 the width is unchanged; negative narrows toward mono, positive widens. Rule of thumb: keep Low band width near 0 or negative (mono bass is more mix-compatible); use Mid and High for widening. Always check with MONO to detect cancellation.
Level	-48 to +6 dB	Output gain for this band after saturation and width. Because both Drive and Width affect perceived loudness, Level restores balance without touching the others. Adjust Level last, after Drive and Width are set.

3.3 Character Controls

Parameter	Range	Description
Feedback	0 – 0.90	Feeds a portion of the band's processed output back into its own input on the next sample. At low values (0.1–0.3) it thickens and enriches the saturation, adding subtle resonance and sustain; higher values create pronounced feedback coloration. Values approaching 0.90 produce heavy resonance and potential instability — approach with caution. Interacts strongly with Drive; Drift modulates Feedback slightly for movement.
Hiss	0 – 1.0	Adds a filtered analog noise floor post-saturation. The noise is pink-ish (filtered white noise ~2.5 kHz) and mono-correlated — identical on left and right — so it does not affect the stereo image. It scales gently with Drive, like a real circuit whose noise floor rises under heavier gain. Subtle settings (0.05–0.15) add subliminal analog texture; higher settings become a lo-fi aesthetic choice.
Drift	0 – 1.0	Slow, organic modulation of the saturation character. A random-rate LFO (0.05–0.5 Hz, period randomized each cycle) subtly varies Feedback (±30%) and Drive (±5%), giving a gentle breathing quality. At low values (0.1–0.3) it is subliminal but adds analog authenticity; at high values the modulation becomes noticeable. Truly random — no pitched or rhythmic artifacts.

3.4 Utility Controls

Parameter	Range	Description
BYPASS	Toggle	Bypasses saturation for this band only. The band still passes through Width and Level, so you can hear width/level changes independently of saturation. Width, Feedback, Hiss, and Drift are all inactive when BYPASS is engaged.
MUTE	Toggle	Silences this band entirely, removing it from the output sum. Use to isolate a frequency region (e.g. mute Low and High to hear only the Mid band's saturation). All Feedback state is cleared when a band is muted to prevent artifacts on unmute.
FLIP ø	Toggle	Inverts the polarity (phase) of both channels for this band. Useful for correcting phase issues when combining with other processors, creative phase relationships between bands, and mono-checking by flipping one band and listening for cancellation.

Parameter	Range	Description
GATE FBK	Toggle	Enables feedback gating. An envelope follower monitors the band's input; if the signal falls below ≈ -60 dB for a sustained period, the Feedback amount is automatically muted, preventing the feedback path from sustaining noise during silent passages. Recommended whenever using Feedback above 0.3.

4. Saturation Types & Variants

O2 provides five saturation families, each with four variants. The Type selector determines the fundamental waveshaping approach; the Variant selector refines the character within that family. All processing is performed in floating-point math — the descriptions below reflect the harmonic and tonal character each curve is designed to evoke.

4.1 Diode

Diode saturation uses asymmetric hard-knee clipping inspired by germanium and silicon diode circuits. The positive and negative halves clip at different thresholds, generating a mix of even and odd harmonics. Characteristically aggressive when driven hard — diodes clip rather than compress — making them ideal for adding edge and presence to drums, bass, and synths. At low drive, diode saturation can be subtle and musical.

Variant	Character
Germanium Sunshine	Warm, spongy asymmetric clipping inspired by germanium transistor circuits. Strong 2nd-harmonic character; rounds transients gently. Excellent for bass and lower midrange where warmth is desired alongside mild grit.
Silicon Grit	Harder knee, more aggressive. Silicon diodes clip more abruptly than germanium, a sharper transition into saturation with more pronounced odd harmonics. Useful for adding bite to drums and guitars.
Schottky Velvet	High threshold, minimal asymmetry — the gentlest diode variant. Fast response and low forward voltage; sits between barely touching the signal and refined soft-limiting. Suitable for mastering-level coloration.
Fuzz Therapy	Maximum asymmetry and high gain — a deliberately pushed germanium circuit. The heaviest diode variant: dense harmonic content and intentional roughness. Best at lower Drive where its grit is present but controlled. Not for subtle applications.

4.2 Op-Amp

Op-amp saturation uses symmetric soft-clipping curves modeled on integrated-circuit and discrete op-amp behavior. Symmetric clipping generates primarily odd harmonics (3rd, 5th, 7th) — perceived as cleaner and more controlled than asymmetric types. The variants range from gritty vintage IC character to smooth modern console tonality.

Variant	Character
741 Sweat	Classic vintage IC character inspired by early integrated op-amps. Slightly unstable-feeling odd harmonics, medium threshold; 741-class devices have a slow slew rate and audible character when pushed. Works well on vocals and room mics where some grit is welcome.

Variant	Character
Double Espresso	Tight, clean, modern console-style saturation. High threshold, minimal asymmetry, inspired by NE5532-class devices in quality consoles. Adds density without obvious coloration — a good default for transparent harmonic enrichment on any source.
Discrete Biscuit	Discrete transistor op-amp character inspired by Neve-style 2520 modules. More complex harmonic structure than IC op-amps; the discrete topology adds subtle even-order content alongside the dominant odds. Fuller and slightly warmer than Double Espresso.
Slew Daemon	Models op-amp slew-rate limiting — the inability to respond instantly to fast transients. High-frequency content is gently rounded and blended with the saturated signal, softening attacks. Excellent for taming harshness on cymbals, overheads, and bright acoustic sources.

4.3 Transformer

Transformer saturation models audio input/output transformers found in vintage preamps, consoles, and outboard gear. Transformers saturate in a frequency-dependent way — more in the lows than the highs. O2 emulates this with a pre-emphasis shelf that boosts lows into the waveshaper, then de-emphasizes them afterward, for a characteristic low-end bloom.

Variant	Character
Yorkshire Wool	Warm, smooth low-end bloom inspired by Carnhill/St. Ives character (associated with Neve consoles). Moderate pre-emphasis at 200 Hz. Adds weight and fullness to bass and kick without muddiness — the most musical and forgiving transformer variant.
Jensen's Creek	Cleaner and tighter than Yorkshire Wool. Inspired by Jensen character — precise, detailed, slightly more neutral low-end. Pre-emphasis at 150 Hz. For sources where transformer color is wanted but low-end bloom would be excessive, such as snare or midrange instruments.
Sowter Power	More aggressive low-frequency saturation, pre-emphasis at 120 Hz. Inspired by Sowter character (associated with vintage BBC equipment). A denser, more saturated low end that can add significant weight to bass-heavy material. Use with care on full mixes.
Iron Curtain	Maximum pre-emphasis (100 Hz, +8 dB) and high asymmetry — the heaviest transformer variant. Very pronounced low-end saturation and a thick, compressed feel. Effective at low Drive. Inspired by heavily loaded vintage broadcast transformers.

4.4 Tape

Tape saturation models magnetic recording media. Two behaviors distinguish it: hysteresis (the oxide's response depends on recent history — the saturation "remembers" the previous sample, creating subtle compression and warmth) and high-frequency rolloff (a de-emphasis shelf that gently attenuates treble under drive, softening harshness).

Variant	Character
Ferric Daydream	Standard ferric oxide (Type I) tape. Warm, forgiving, gentle; moderate HF rolloff at 3 kHz. The most musical tape variant — softens transients subtly and adds pleasing compression. A good starting point wherever tape warmth is desired.
Chrome Holiday	Chrome (Type II) tape — brighter than ferric with slightly harder transients; HF rolloff at 5 kHz is less aggressive. More modern sounding while retaining tape hysteresis. Useful where tape character is wanted without losing high-frequency detail.
Fahrenheit 456	Inspired by Ampex 456 — an aggressively saturating studio tape known for strong 3rd-harmonic content and a "loud" character. Rolloff at 2 kHz, higher asymmetry. The heaviest tape variant; noticeable compression and grit at moderate drive. Iconic in rock, hip-hop, and aggressive pop.
Studer Weather	Neutral, precise tape inspired by Studer and Scotch formulations. Subtle HF rolloff at 4 kHz, low asymmetry. Emphasizes the compression and gentle softening of tape without obvious coloration — a transparent option for mastering and mix bus.

4.5 Tube

Tube saturation models vacuum-tube triode and pentode circuits — strong asymmetry and a dominance of even-order harmonics (2nd, 4th), the reason tube equipment is described as "musical" and "warm." Even harmonics are octave relationships; they reinforce the fundamental rather than creating dissonance. Variants differ in asymmetry, compression, and harmonic density.

Variant	Character
Triode Sunrise	Classic 12AX7 triode preamp character. Strong 2nd harmonic, smooth onset, warm and open — the fundamental "tube warmth." Excellent on vocals, acoustic instruments, and anything that benefits from an organic, musical glow.
Octal Molasses	Dark, slow, heavily compressed. Inspired by 6SL7 octal triode circuits — higher asymmetry, heavier 2nd harmonic, compressed dynamic response. A thick, syrupy quality, good for bass synths, organ, and dense pads.
Pentode Circus	EL34 power-tube pentode character — a more complex harmonic stack including both even and odd content. Lively, energetic, slightly gritty at the edges; sounds more "electric" than preamp tube saturation. Excellent on electric guitars, aggressive synths, and drum busses.
Rectifier Dreams	Models tube rectifier sag — the dynamic compression in supplies using tube rectifiers. When transients hit, the supply voltage drops momentarily, causing dynamic saturation that breathes with the signal. Works well on drums, bass, and strong-transient material.

5. Tips & Workflow

Set Crossover Frequencies First. Before adjusting saturation, set the crossovers to match your source. A good full-mix start: Lo X-Over 250–350 Hz, Hi X-Over 3–5 kHz. Use the MUTE buttons on two bands to hear each band in isolation and confirm the crossover sits right.

Start With Drive at Zero. Set Drive to 0 on all bands and begin with Width. Confirm the stereo image behaves as intended, then gradually introduce Drive — this separates width processing from saturation coloration.

Subtle Saturation on the Full Mix. For mix-bus processing, keep Drive between 0.5 and 2.0 on all bands — density and glue rather than audible distortion. A/B frequently with BYPASS; if the bypassed signal sounds thin or fatiguing by comparison, the level is about right.

Per-Band Drive for Specific Problems. O2's strength over single-band saturation is surgical application. More weight in the kick without affecting the mix? Drive the Low band only. Vocals too harsh? A gentle Tube or Op-Amp curve on the High band at low Drive. Midrange thin? Try Transformer variants on the Mid band.

Feedback as Resonance. Feedback in the 0.2–0.4 range adds a quality like tape saturation or console "magnetism." Above 0.6 it feels more like feedback resonance. Always enable GATE FBK when using Feedback above 0.3 to avoid noise buildup.

Drift for Life. Even small Drift values (0.05–0.15) make a significant perceptual difference over long sessions — static saturation can feel fatiguing, gently drifting saturation feels like a real analog device. Add a little Drift to all three bands on any mix-bus session.

Mono Width Checking. After setting any Width values, press MONO and listen. If the low end thins dramatically, reduce Low band Width toward 0 or negative. If the mix loses level or changes tonally, reduce Mid/High Width until the mono version sounds natural.

Oversampling. Enable 4x OS when printing or bouncing; disable during live monitoring to save CPU. The difference is most audible with Diode and Tube types at high Drive — oversampling removes metallic aliasing in the upper frequencies.

Hiss as Texture. A small amount of Hiss (0.03–0.08) on the High band adds a pleasing analog air to digital recordings — the noise floor of a vintage console or tape machine, present but subliminal.

6. Quick Reference

Global Controls

Control	Range	Default
In Trim	-48 to +15 dB	0 dB
Lo X-Over	70 Hz – 1.5 kHz	300 Hz
Hi X-Over	800 Hz – 15 kHz	3 kHz
Out Trim	-48 to +12 dB	0 dB
Tilt	-1 … +1	0
Dry/Wet	0 – 100%	100%
MONO	On/Off	Off
BYPASS	On/Off	Off
4x OS	On/Off	Off
WIDEN	On/Off	Off
RESET	Button	—

Per-Band Controls (× 3 bands)

Control	Range	Default
Type	5 types	Diode
Variant	4 per type	V1
Drive	0 – 10	0
Width	-5 to +5	0
Level	-48 to +6 dB	0 dB
Feedback	0 – 0.90	0
Hiss	0 – 1.0	0
Drift	0 – 1.0	0
BYPASS / MUTE / FLIP ø / GATE FBK	On/Off	Off

Saturation Types

Type	Character	Best For	Harmonics
Diode	Aggressive, defined	Drums, bass, synth grit	Even + Odd
Op-Amp	Clean, controlled	Vocals, mix bus, console tone	Odd dominant

Type	Character	Best For	Harmonics
Transformer	Warm, low-end bloom	Bass, kick, full mixes	Even + frequency-dependent
Tape	Smooth, compressed	Everything — the most versatile	Even + hysteresis
Tube	Musical, organic	Vocals, acoustic, mastering	Even dominant

O2 is developed by XNULLX. All saturation character names are original and intended to evoke the sonic qualities of their inspiration without claiming affiliation with any hardware manufacturer. DSP implementation uses the JUCE framework.