Podium equalizer

How the EQ works, and why it lowers the volume

Podium 4.6.1 · podium-echo.online

Short answer. Podium has no loudness compensation (no automatic make-up gain). It has an automatic **pre-gain**: before the filters, the whole signal is turned down so that no band can clip. As soon as any Custom band is moved off 0 dB, the pre-gain takes:

- the height of the curve's highest boost,
- plus a fixed 2 dB,
- plus 0.35 dB for every dB of the deepest cut.

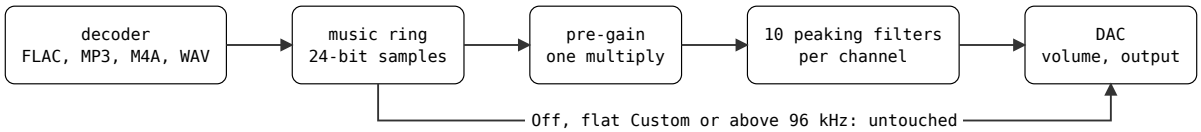
So lowering one band also lowers everything else a little: 1 kHz at –3 dB turns the whole signal down by 3 dB. This is expected. Raise the volume by a few steps (one step is 1 dB) to get the loudness back.

1 How it works

1.1 What the equalizer offers

- **Off**: the music reaches the DAC bit for bit as decoded.
- **Six presets**: Retro, Bass, Heavy, Pop, Jazz and Unique, copied from FiiO's stock firmware with stock's own pre-gains.
- **Custom**: ten bands at 31, 62, 125, 250, 500 Hz and 1, 2, 4, 8, 16 kHz, each from –10 to +10 dB in 0.5 dB steps. Eight curves can be saved in slots. Text files in the `/EQ` folder of the music storage (pairs of frequency and gain per line, as AutoEQ writes them) load into Custom; each band takes the file's gain at its centre.
- The 16 kHz band only acts on music at 88.2 and 96 kHz (see Filters).
- It works for every format (FLAC, MP3, M4A, WAV) at sample rates up to 96 kHz. At 176.4 and 192 kHz the player has no time to run it, so music at those rates plays without EQ.

1.2 Where it sits



The decoder fills a ring of 24-bit samples. The equalizer works on those samples in place: first the pre-gain, then one filter per band that isn't at 0 dB. After it the DAC applies the volume. With the EQ off or a flat Custom curve nothing in between runs.

1.3 Why the volume drops

A filter that boosts a band can push loud music past full scale, which clips: hard, audible distortion. A filter that **cuts** a band can do it too. A cut shifts the phase of the frequencies around it, so the waveform changes shape, and its peaks can rise even though no frequency got louder. Mastered music sits close to full scale, so a few dB of overshoot is enough to clip.

To leave room, Podium turns the whole signal down before the filters. For Custom the pre-gain is worked out from the curve itself:

Part	Amount
Highest boost	the peak of the combined curve. One band at +3 dB costs 3 dB; neighbouring boosts add up because the bands overlap
Fixed margin	2 dB, for any curve that isn't flat
Cut margin	0.35 dB per dB of the deepest cut, up to 7 dB more

Examples at 44.1 kHz:

Custom curve	Whole signal turned down by
all bands 0 dB	nothing (EQ bypassed)
31 Hz +0.5 dB	2.5 dB
1 kHz –1 dB	2.4 dB
1 kHz –3 dB	3.1 dB
1 kHz –10 dB	5.5 dB
1 kHz +3 dB	5.0 dB
1 kHz +10 dB	12.0 dB
31 Hz +6 dB, 62 Hz +4 dB	9.9 dB
31, 62, 125 Hz at –6 dB	6.2 dB
all ten bands +10 dB	25.2 dB

The presets keep the fixed pre-gains of FiiO's firmware:

Preset	Bands	Pre-gain
Retro	100 Hz +1, 315 Hz +1, 1 kHz +1, 10 kHz –6	–3.7 dB
Bass	63 Hz +5, 125 Hz +3	–7.2 dB
Heavy	315 Hz +3, 1 kHz +3, 3.15 kHz –3	–4.1 dB
Pop	100 Hz +4, 3.15 kHz –3, 10 kHz +3	–4.1 dB
Jazz	100 Hz +4, 315 Hz –6, 1 kHz +4, 3.15 kHz +1, 10 kHz +6	–7.2 dB
Unique	100 Hz +3, 1 kHz –3, 3.15 kHz +3	–7.2 dB

1.4 What you hear

The dashed line is the curve as set; the solid one is what plays, pre-gain included.

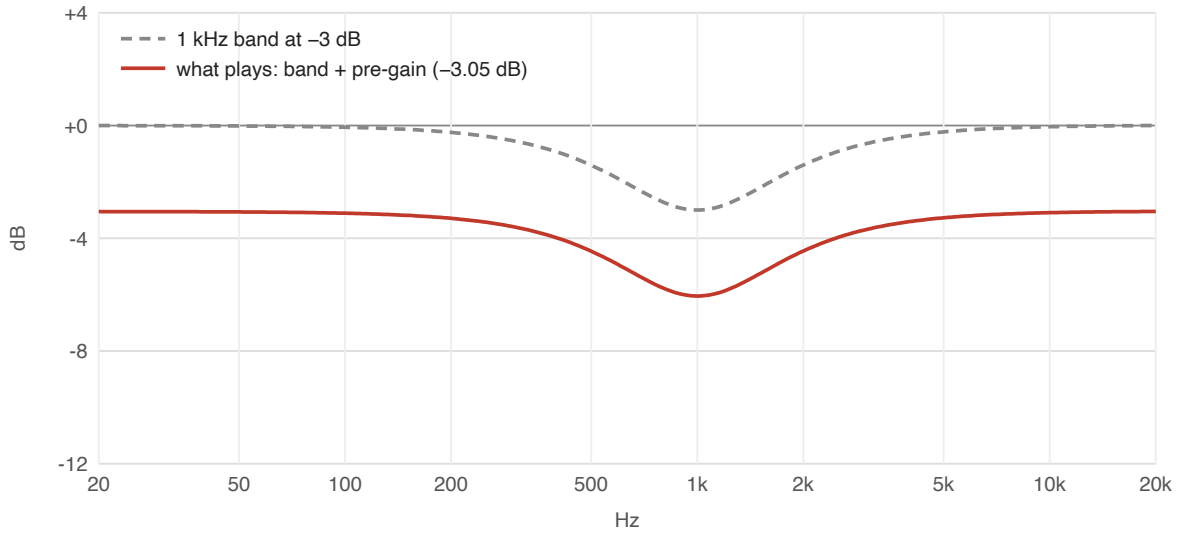


Figure 2: One band lowered: 1 kHz at –3 dB. Everything drops by about 3 dB, 1 kHz by about 6 dB.

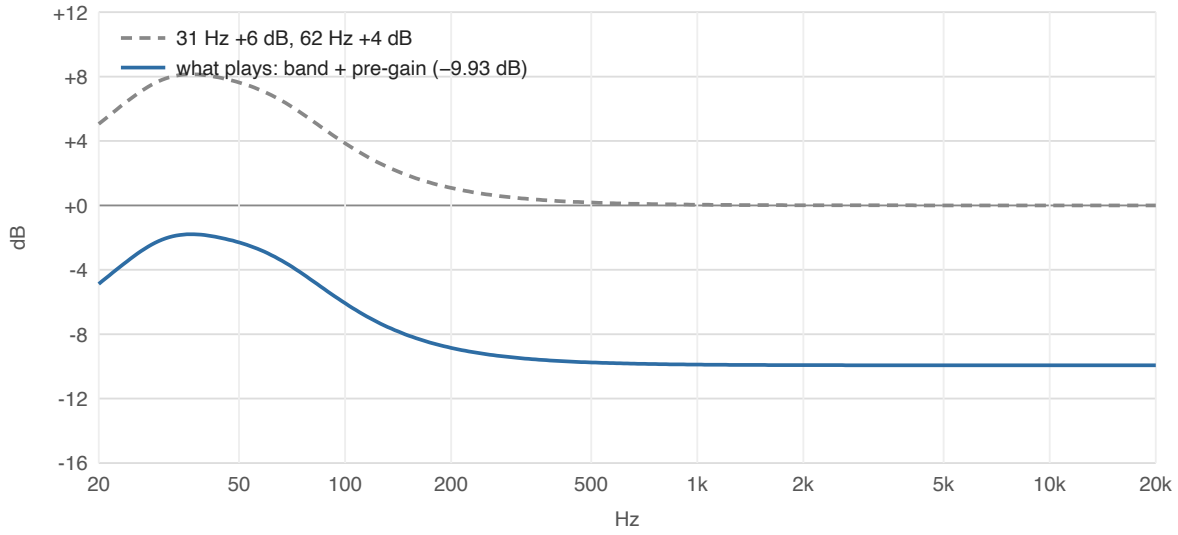


Figure 3: Bass boost: 31 Hz +6 dB, 62 Hz +4 dB. The boost now sits near 0 dB and the rest is about 10 dB quieter.

In practice: after shaping a curve, raise the volume until it is as loud as before. The volume has 60 steps of 1 dB, so 3 dB of pre-gain is 3 steps. The sound is the same as an EQ that only boosted or only cut, without the clipping.

1.5 Known issue in 4.6.1

In 4.6.1, a Custom curve whose combined cut goes deeper than about 20 dB (for example four neighbouring bands at –10 dB) gets a pre-gain of zero, and the player plays silence. 4.6.2 fixes it; the cut margin stops at 9 dB.

2 Technical details

2.1 Filters

Each band that isn't at 0 dB is a peaking biquad from Robert Bristow-Johnson's Audio EQ Cookbook, with Q = 1/√2 (about 1.9 octaves wide):

$$A = 10^{G/40}, \quad \omega = 2\pi f_0/f_s, \quad \alpha = \sin(\omega)/(2Q)$$

$$H(z) = \frac{1 + \alpha A - 2\cos\omega z^{-1} + (1 - \alpha A)z^{-2}}{1 + \alpha/A - 2\cos\omega z^{-1} + (1 - \alpha/A)z^{-2}}$$

- G is the band's gain in dB (–10…+10 in 0.5 dB steps), f_0 its centre, f_s the output sample rate.
- Coefficients are computed on the player whenever the output rate is set, so 44.1, 48, 88.2 and 96 kHz each get their own. Sine and cosine come from fixed-point series; A from a 41-entry table.
- Bands at or above a quarter of the sample rate are left out: at 44.1 and 48 kHz the 16 kHz band does nothing, since a peaking filter that close to the top of the band can't keep its shape. It works at 88.2 and 96 kHz.
- Coefficients are normalised by a_0 and stored as Q28 integers.

2.2 Running the filters

- Core 0 runs the equalizer right after each run of samples is written into the music ring. That is the one place every decoder's output passes, whether it was decoded on core 0 or core 1.
- Samples are 24-bit, stored at the top of 32-bit words.
- **Pre-gain** first: each sample is multiplied by a Q15 factor and clamped to 24 bits.
- Then each band, channel by channel, in direct form I: 32 × 32 → 64-bit multiply-accumulates, first-order error feedback (the fraction dropped from one output is added to the next sum, which keeps low bands free of rounding noise), and a clamp to 24 bits after each band.
- Cost: about 55–60 CPU cycles per band, sample and channel. Ten bands at 96 kHz take about 55 % of the 200 MHz core; nine bands at 44.1 kHz about 23 %.
- **No clicks on changes**: when a Custom gain changes at the same sample rate, each band that stays keeps its filter memory, so stepping a band while music plays doesn't click.
- **Bypass**: with Off, a flat Custom curve or a rate above 96 kHz, the filter code doesn't run at all.

2.3 Pre-gain

The pre-gain is computed on the player, in integers, each time the Custom curve changes:

1. **Response on a grid.** The combined power response of all bands is evaluated at 78 frequencies: eight per octave from about 40 Hz to 20 kHz, plus the band centres. Each band's response uses the bilinear-warped analogue form of the peaking filter at 44.1 kHz; the grid finds the true peak within 0.1 dB at 44.1 kHz and 0.5 dB at 96 kHz.
2. **Peak.** The highest point of that response (at least 0 dB). The pre-gain starts as $1/\sqrt{\text{peak power}}$.
3. **Trough.** The lowest point, with a small margin, counted in 0.5 dB steps (the deepest cut). Using the combined trough rather than the deepest single band matters: neighbouring low cuts act as a shelf, which overshoots more than one band.
4. **Margin.** The pre-gain is multiplied by $10^{-(2+0.175n)/20}$, where n is the number of 0.5 dB steps in the deepest cut, capped at 40 (20 dB). That is 2 dB plus 0.35 dB per dB of cut, from 2 dB up to 9 dB.

$$\text{pre-gain} = \frac{1}{\sqrt{\max_f |H(f)|^2}} \cdot 10^{-(2+0.175n)/20}$$

The 2 dB and the 0.35 dB per dB come from test signals: a full-scale square wave through a –10 dB band overshoots the curve's response by up to about 5 dB, because the cut moves the phase of the

square wave's harmonics. Full-scale sines through every preset and through extreme Custom curves stay below the 24-bit clamp in the player's tests.

The presets don't use this calculation; they keep the fixed factors from FiiO's firmware: Retro 21/32, Heavy and Pop 5/8, Bass, Jazz and Unique 7/16 of full level.

2.4 EQ files

A file in `/EQ` is read as text, line by line: each line with exactly two numbers is a point (frequency in Hz, gain in dB). Lines starting with `#`, `Preamp:` lines and anything else with another count of numbers are skipped. Points outside 10 Hz–30 kHz are ignored. Each band takes the nearest point at or below and at or above its centre and interpolates between them on a log-frequency scale; the result is rounded to 0.5 dB and limited to ±10 dB. The file's own preamp is ignored, since Podium computes the pre-gain itself.

2.5 Source

`src/settings/equalizer_peak.c` (pre-gain), `src/settings/equalizer_fit.c` (EQ files), `platform/device/logic/equalizer_design.c` (coefficients), `platform/device/logic/equalizer.c` (filters).