

Princeton Reverb – Distortion Characterisation Report

Scope-based diagnosis of clipping behaviour, harmonic content, and transient artefacts across drive levels | PicoScope 7, 400 Hz / 74 mV_{rms} input, 8Ω resistive load

1. Test Setup

Input signal	400 Hz sine, 74 mV _{rms} (Channel A)
Load	8Ω resistive dummy load (Channel B)
Conditions captured	1W Clean · Kink Onset · Shark Fin · Full Power · Burst/Blocking test
Instrument	PicoScope 7 (T&M software)

2. Power & Distortion Summary

Condition	Output V _{pp}	Power (8Ω)	THD (H2–H10)
1W Clean	8.0 V	1.0 W	1.4%
Kink Onset	23.5 V	8.6 W	5.5%
Shark Fin	25.9 V	10.5 W	19.3%
Full Power	26.6 V	10.7 W	33.2%

Distortion rises sharply between the clean 1 W reference and the onset of clipping — THD goes from under 1.5% to over 33% by full power, with the harmonic *character* (not just magnitude) changing in a way that points to distinct underlying mechanisms at each stage (see Section 4).

3. Time-Domain Waveforms

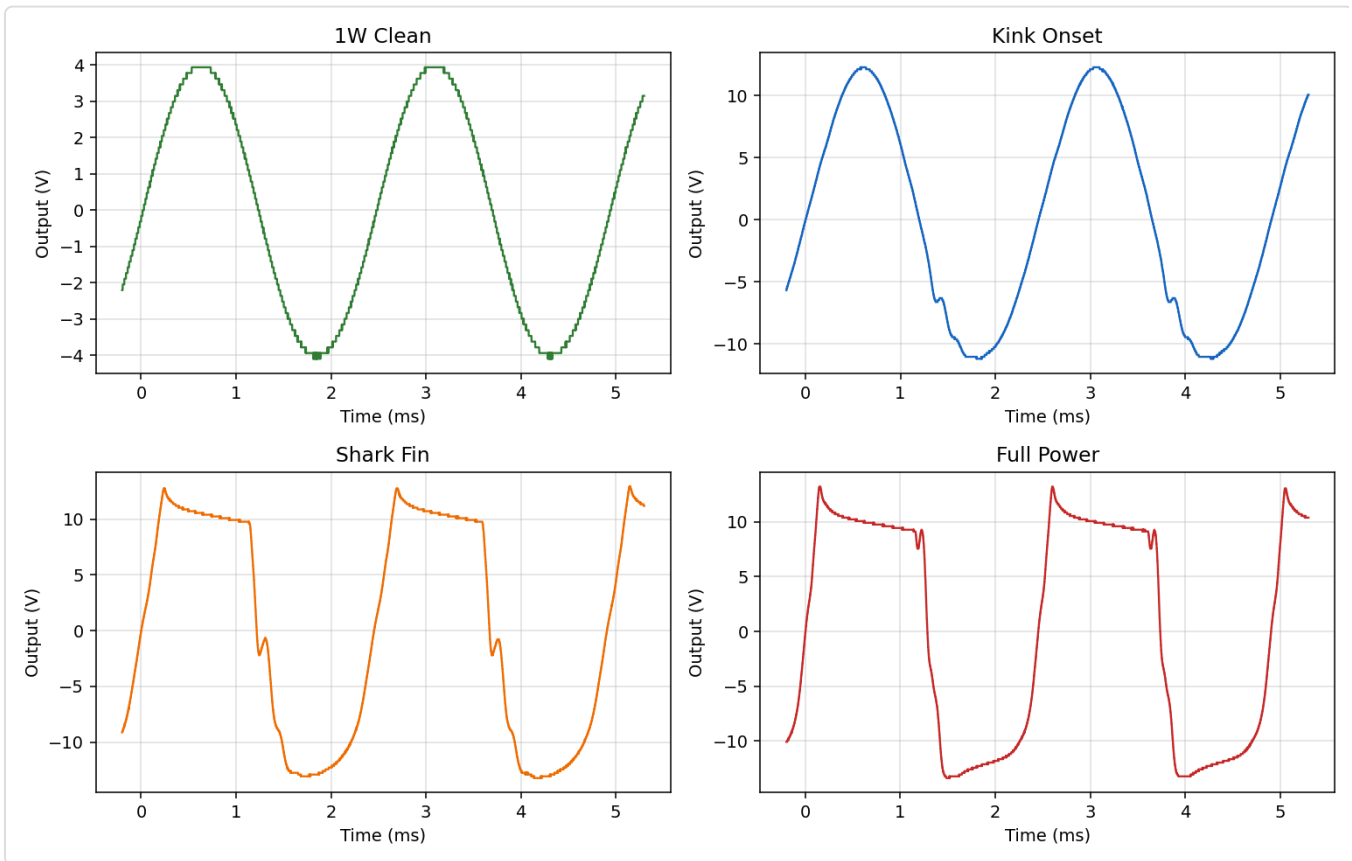


Fig. 1 — Output waveform (~2 cycles) for each condition. Clean sine at 1W; increasing asymmetric clipping, transformer-saturation "fin" shape, and falling-edge kinks appear as drive increases.

4. Frequency-Domain (FFT) Analysis

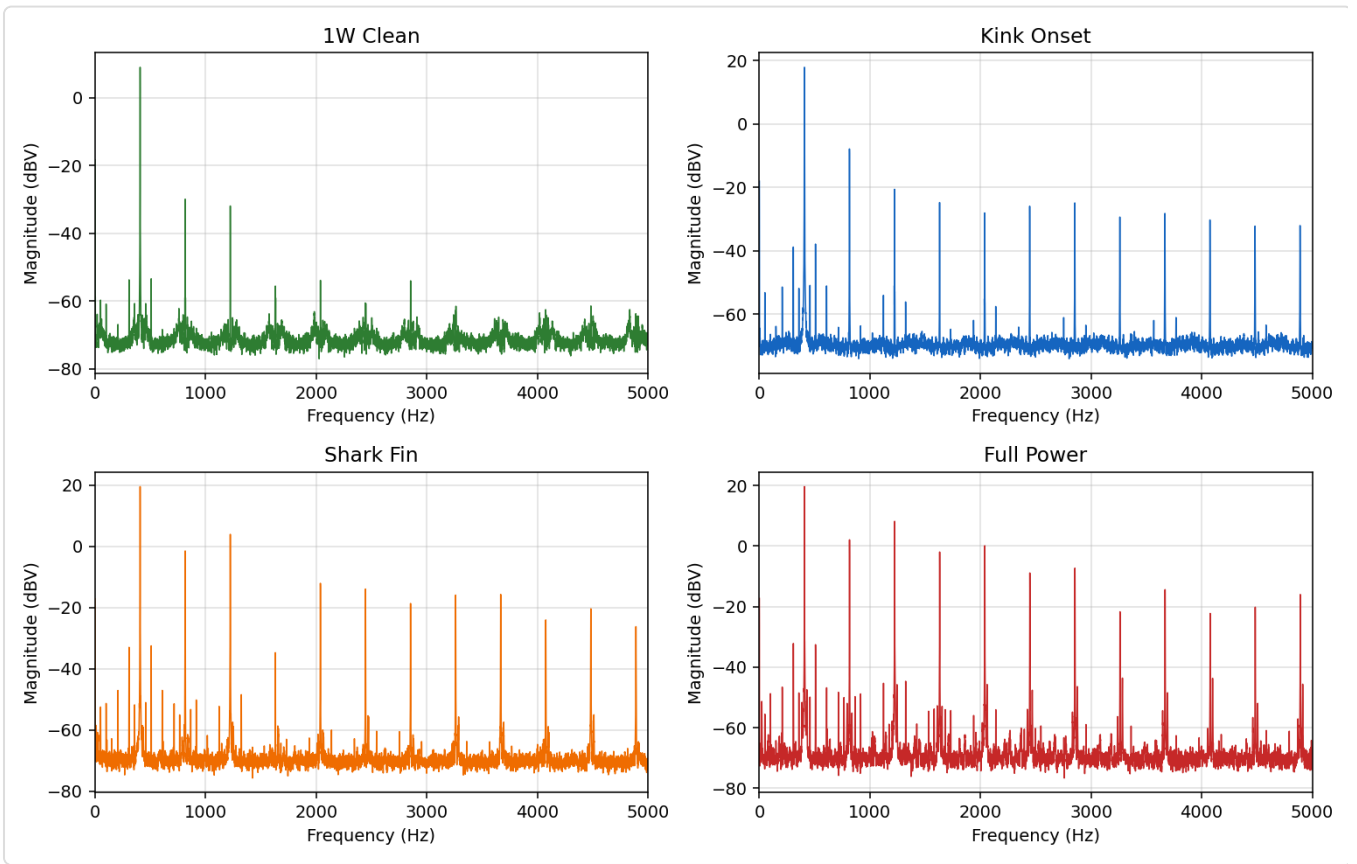


Fig. 2 — FFT magnitude (dBV) vs frequency, 0–5 kHz, for each condition. Note the growth of H2/H3 content and the rising noise/hum floor as drive increases.

Harmonic detail

1W Clean			
Harmonic	Freq	Level	Rel. fund.
H2	815 Hz	-30.0 dBV	-39.0 dB
H3	1,223 Hz	-32.0 dBV	-41.0 dB
H4	1,631 Hz	-55.6 dBV	-64.6 dB
H5	2,039 Hz	-53.9 dBV	-62.9 dB
H6	2,444 Hz	-60.6 dBV	-69.6 dB
H7	2,854 Hz	-54.1 dBV	-63.1 dB
H8	3,264 Hz	-61.6 dBV	-70.6 dB
H9	3,672 Hz	-68.6 dBV	-77.6 dB

Kink Onset			
Harmonic	Freq	Level	Rel. fund.
H2	815 Hz	-7.9 dBV	-25.7 dB
H3	1,223 Hz	-20.6 dBV	-38.4 dB
H4	1,630 Hz	-24.8 dBV	-42.6 dB
H5	2,037 Hz	-28.1 dBV	-45.9 dB
H6	2,445 Hz	-25.9 dBV	-43.8 dB
H7	2,853 Hz	-24.9 dBV	-42.7 dB
H8	3,260 Hz	-29.3 dBV	-47.2 dB
H9	3,668 Hz	-28.2 dBV	-46.0 dB

Shark Fin			
Harmonic	Freq	Level	Rel. fund.
H2	815 Hz	-1.5 dBV	-21.0 dB
H3	1,223 Hz	3.9 dBV	-15.6 dB
H4	1,631 Hz	-34.8 dBV	-54.3 dB
H5	2,038 Hz	-12.1 dBV	-31.6 dB
H6	2,446 Hz	-14.0 dBV	-33.5 dB
H7	2,853 Hz	-18.7 dBV	-38.2 dB
H8	3,261 Hz	-15.9 dBV	-35.5 dB
H9	3,669 Hz	-15.7 dBV	-35.3 dB

Full Power			
Harmonic	Freq	Level	Rel. fund.
H2	815 Hz	2.1 dBV	-17.6 dB
H3	1,223 Hz	8.2 dBV	-11.5 dB
H4	1,631 Hz	-2.0 dBV	-21.6 dB
H5	2,039 Hz	0.1 dBV	-19.5 dB
H6	2,446 Hz	-8.9 dBV	-28.5 dB
H7	2,854 Hz	-7.3 dBV	-27.0 dB
H8	3,262 Hz	-21.7 dBV	-41.4 dB
H9	3,669 Hz	-14.4 dBV	-34.1 dB

Reading the harmonic pattern: Kink Onset shows H2 dominant over H3 — a hallmark of *asymmetric* clipping (one half-cycle compresses before the other). Shark Fin shows H3 exceeding H2, with H4 strongly notched down — the classic signature of *output-transformer core saturation* rather than simple tube clipping. Full Power shows both H2 and H3 very strong — heavier, more symmetric clipping overall, consistent with its higher THD figure.

Mains hum / supply ripple (50 / 100 Hz)

Condition	50 Hz	100 Hz
1W Clean	-59.8 dBV	-60.9 dBV
Kink Onset	-53.2 dBV	-66.3 dBV
Shark Fin	-52.5 dBV	-51.4 dBV
Full Power	-55.6 dBV	-48.8 dBV

The 100 Hz component rises by roughly 10–12 dB from clean to full power — consistent with B+ rail sag/ripple increasing under the heavier current draw of sustained clipping, and a plausible contributor to a "raspy" character at higher output, independent of the harmonic distortion itself.

5. Identified Distortion Features

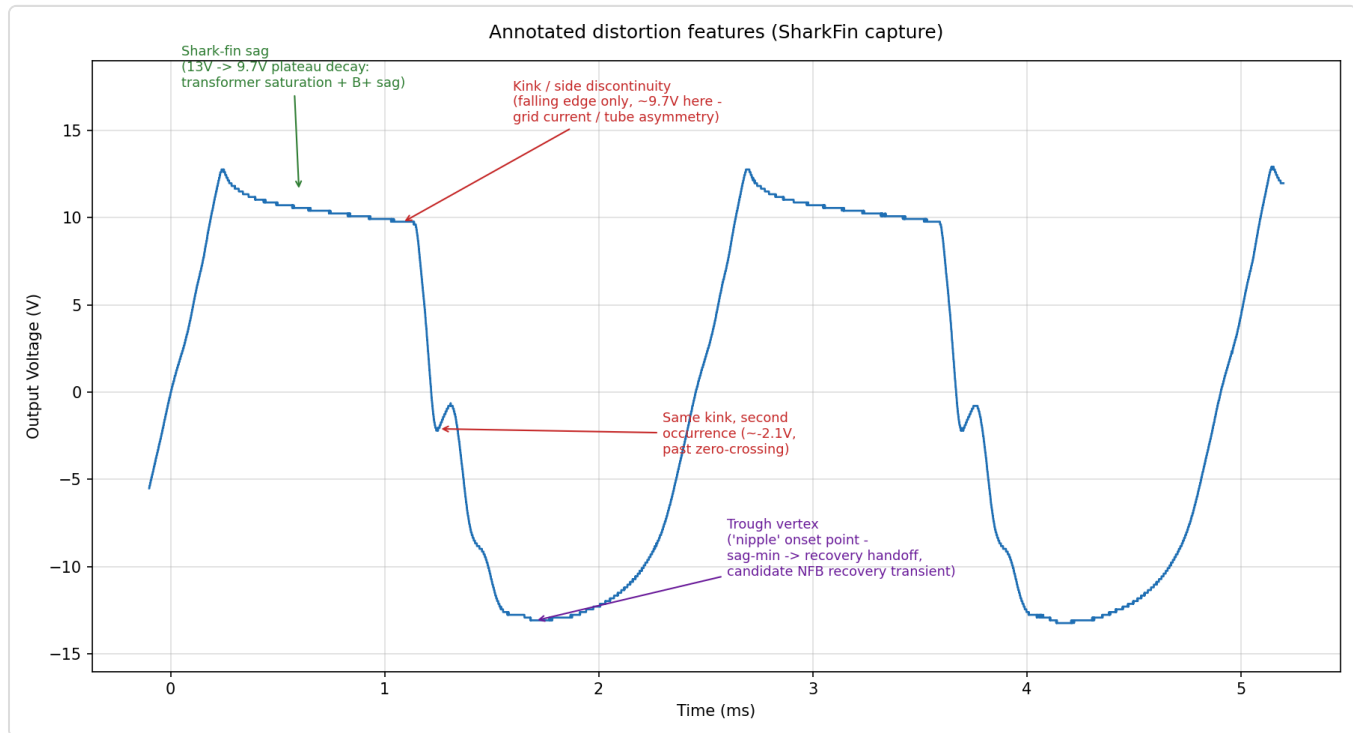


Fig. 3 — Annotated Shark Fin capture showing all three identified features in one cycle.

Feature	Location	Likely mechanism
Kink / side discontinuity	Falling edge only (peak→trough), at a voltage that shifts closer to the peak as drive increases. Confirmed absent on every rising edge checked.	One-directional onset — most consistent with grid-current conduction starting on one polarity, or an asymmetry between the two push-pull output tubes (different bias/ g_m causing one tube's conduction hand-off to glitch while the other's doesn't).
Shark fin	Top plateau, decaying from ~13V down to ~9.7V over the clipped half-cycle.	Output transformer core saturation (confirmed by odd-harmonic-dominant spectrum, $H3 > H2$, $H4$ notched), likely compounded by B+ sag under the sudden current demand of clipping.
	Trough vertex — the hand-off point between the supply sag	Best candidate: a negative-feedback loop recovery transient. While the rail is pinned at its sag minimum the

"Nipple"	bottoming out and the recovery climb beginning (visible only at the threshold of resolution in this capture set).	NFB loop has no room to act; the instant recovery begins, the loop regains authority and an imperfectly-damped hand-off could produce exactly this kind of small dip-and-recover blip. A transformer/tank ringing as current direction commutates back is a secondary candidate.
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6. Blocking-Distortion / Burst Recovery Test

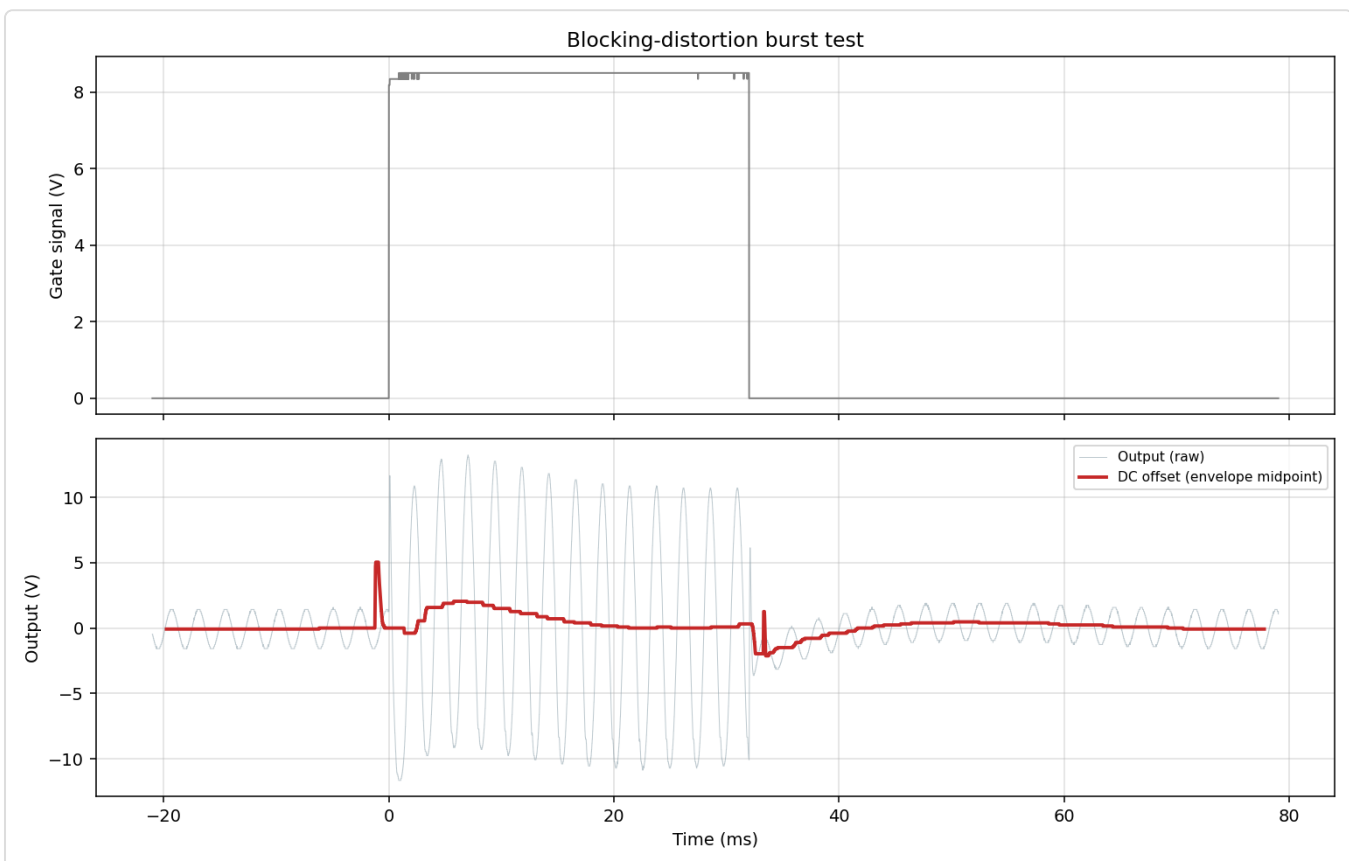


Fig. 4 — Burst-gated test. Top: gate/burst marker signal. Bottom: raw output (grey) with extracted DC-offset envelope (red) overlaid.

- **Burst onset** ($t \approx 0$ ms): output DC offset jumps to $\sim +1.9$ V, then relaxes back toward 0V over ~ 20 ms *while the burst is still playing* — a bias point shifting and partially recovering mid-burst.
- **Burst offset** ($t \approx 32$ ms): offset swings to about -2 V, crosses zero, slightly overshoots positive, and is still settling ($\sim +0.1$ V residual) by the end of the 47 ms capture tail.
- This is a textbook **blocking distortion** signature — grid current during clipping charging a coupling capacitor and shifting bias, with a slow RC-governed recovery. Worth checking the grid-leak resistor value and coupling cap on whichever stage is being driven into this region.

7. Summary & Suggested Next Steps

- **Clean headroom** extends to ~3W before any audible/visible clipping onset; the amp is fully into heavy clipping character by ~10–11W.
- **Three independent distortion mechanisms** are stacking up as drive increases: tube/grid asymmetry (kink), transformer saturation (shark fin), and a possible feedback-recovery transient (nipple) — each contributing differently to the overall harmonic signature.
- **Rising 100 Hz ripple** under heavy drive suggests B+ supply sag is a secondary but real contributor to the "raspy" character at higher output, separate from the harmonic distortion mechanisms above.
- **Blocking distortion** is present and confirmed via the burst test — worth checking grid-leak/coupling-cap values on the driven stage.
- **Recommended follow-up:** probe the NFB takeoff point or phase-inverter output simultaneously with the output, triggered on the falling edge, to directly observe whether the loop signal does something unusual at the nipple's ~-13V trough-vertex point — this would confirm or rule out the feedback-recovery hypothesis versus push-pull crossover hand-off.