## 1. WHAT IS ENHANCED SAMPLE RATE (ESR)?

Enhanced Sample Rate (ESR) is the default acquisition mode on all HDO "A" models [3]. It applies **4-point SinX/x** (sinc) interpolation to produce an effective sample rate of **10 GS/s from a 2.5 GS/s ADC**, on every single-shot acquisition [1]. The ADC itself is unchanged from non-A models; the improvement comes from carefully constructed interpolation filters optimised to the HD4096 front-end [3]. Unlike RIS, ESR does *not* require a repetitive signal and preserves all waveform variability including jitter, noise and transients.

SinX/x Reconstruction — Individual Sample Point Contributions & Combined Envelope
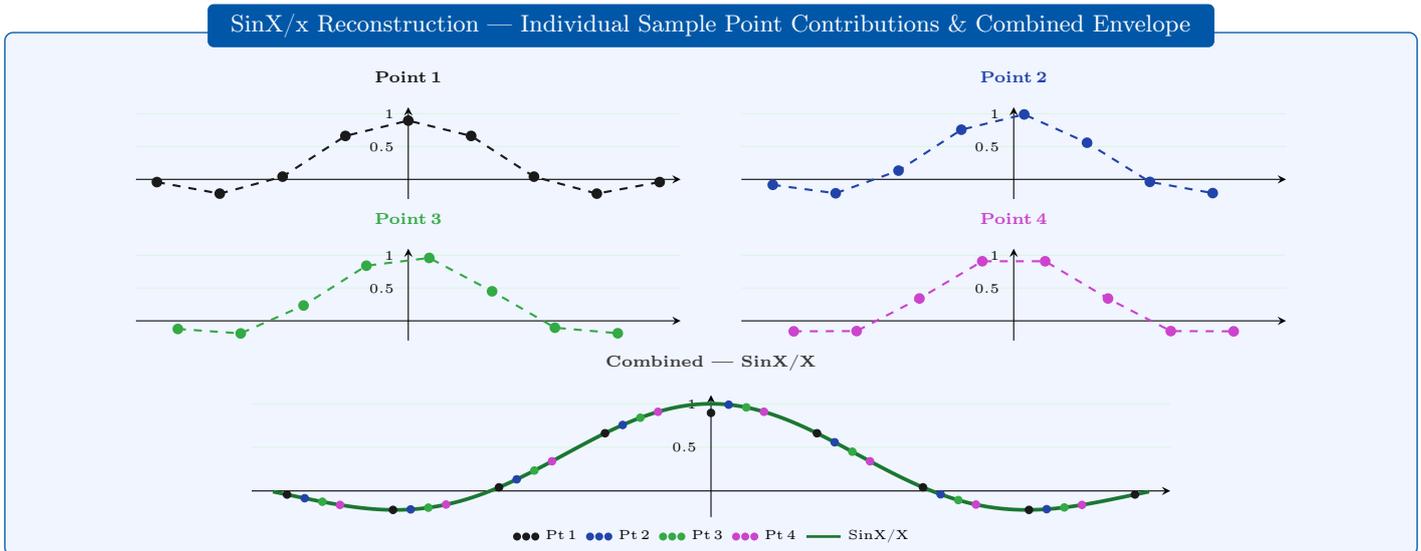
2. MEASURED PRECISION IMPROVEMENT WITH ESR [1]

Precision quantified via **1σ std. dev.** across 5,000 acquisitions. ESR tested against standard 2.5 GS/s on the *same* instrument and signal. At 816.2 MHz: amplitude precision improves ∼1.6×, frequency precision ∼4× [1].

Measured Precision — [1] *HDO6104A-MS · 816.2 MHz · 5,000 acq.*
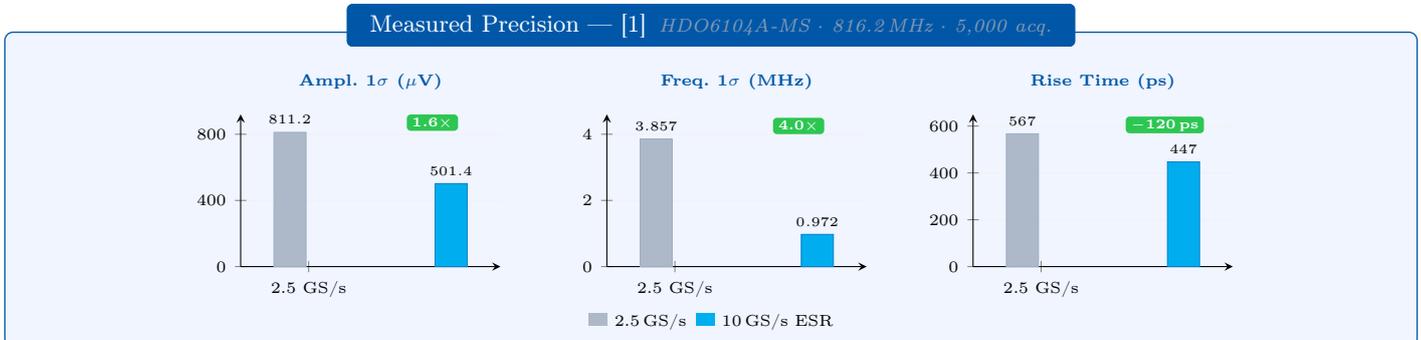
3. ESR vs. RIS — FEATURE COMPARISON (TL PUBLICATIONS ONLY)

Feature	ESR [1]	RIS [2]
Mechanism	4-point SinX/x interpolation, single-shot [1, 3]	Incremental delay per trigger cycle [2]
Signal type	Any (single-shot capable) [1]	Repetitive only [2]
Trigger	Standard real-time [1]	Synchronous, same point each sweep [2]
Variability	Jitter, noise, transients preserved [1]	Masked by multi-cycle averaging [2]
Record scope	Full record, X-Stream; memory unchanged [1, 3]	Built over many cycles [2]
Hardware	HD4096 12-bit ADC + natural anti-alias rolloff [3]	TDC for sub-sample positioning [2]
Speed impact	None — same acq. speed for given point count [3]	Slower (multiple triggers required) [2]

[1] TL Whitepaper: "Enhanced Sample Rate Mode Measurement Precision", Mar 2017 [2] TL Blog: "Back to Basics: RIS", Jun 2013 [3] TL Product Training, Apr 2017

4. WHY SinX/x INTERPOLATION IS VALID IN ESR [1]

Why SinX/x is Valid in ESR [1, 3]

▶ **Natural anti-aliasing by design**
Fast rolloff beyond 1 GHz guarantees no content above $f_s/2$ reaches the ADC [3].

▶ **2.5× oversampled ADC — minimum for good interpolation [3**
] Worst case SR : BW = 2.5:1 at 1 GHz; real signals yield $\geq$ 3:1 [1].

▶ **Pristine front-end + 12-bit ADC**
Low vertical noise enables accurate interpolation; 8-bit ADC would degrade ESR [1, 3].

▶ **No speed or memory penalty**
Same acq. speed for a given point count; memory unchanged. Applied to entire record via X-Stream [1, 3].

5. MEASUREMENT DATA — ALL FREQUENCIES [1]

Results at three input frequencies. ESR benefit most pronounced at 816 MHz where 2.5 GS/s places fewest points per cycle. At 246 MHz, amplitude precision still improves ($\sim$2×) but frequency improvement is minimal [1].

Measurement Data — [1], Table p.6   *HDO6104A-MS · HP 8648B · 5,000 acq., 5 μs each*

Input	Mode	Ampl. 1σ	Freq. 1σ
816.2 MHz	2.5 GS/s	811.2 μV	3.857 MHz
816.2 MHz	**10 GS/s ESR**	**501.4 μV**	**0.972 MHz**
506.2 MHz	2.5 GS/s	939.2 μV	0.645 MHz
506.2 MHz	**10 GS/s ESR**	**475.2 μV**	**0.637 MHz**
246.2 MHz	2.5 GS/s	1587 μV	0.587 MHz
246.2 MHz	**10 GS/s ESR**	**729 μV**	**0.592 MHz**

6. FAST EDGE MEASUREMENT RESULTS [1]

Tunnel diode pulse generator (Picosecond Pulse Labs TD-1110C, 25–30 ps rise time) — the most demanding real-world use case for ESR.

Fast Edge Results — [1], p.8   *TD-1110C · 1,000 accumulated values*

■ 2.5 GS/s   ■ 10 GS/s ESR
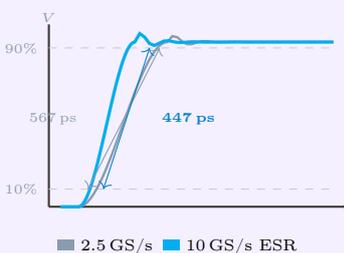
Metric	2.5 GS/s	ESR
Rise time mean	567 ps[*]	**447 ps**
Rise time 1σ	32.6 ps[*]	**22.2 ps**

ESR resolves 120 ps finer rise time with 32% lower 1σ variability [1].
[*] At 2.5 GS/s the edge is not oversampled well enough to make a good measurement [3].

ESR Prerequisites & Applicability — [1, 3]

- Fast rolloff beyond BW cutoff (natural anti-aliasing) [3]; SR : BW $\geq$ 2.5:1 [1]
- Pristine low-noise front-end + HD4096 12-bit ADC [3]
- Default on HDO4000A/6000A/8000A and MDA800A; disable by setting SR $\leq$ 2.5 GS/s [3]

[1] *"Enhanced Sample Rate Mode Measurement Precision", Teledyne LeCroy, Mar 2017.* `cdn.teledynelecroy.com/files/whitepapers/enhanced-sample-rate-whitepaper.pdf`
[2] *"Back to Basics: Random Interleaved Sampling", Teledyne LeCroy, Jun 2013.* `blog.teledynelecroy.com/2013/06/back-to-basics-random-interleaved.html`
[3] *"HDO A Model & WS510 Product Training (Rev 1.1)", Teledyne LeCroy Internal, Apr 2017, slides 45–57.*
All measured values from [1], obtained using HDO6104A-MS.