LeCroy WavePro HD

Competitive Analysis vs. S-Series

Strong Competition

LeCroy has a slight edge in signal integrity, but you can win with Keysight usability, applications and overall value. This document will help you understand this product and present a valid comparison to potential customers.

Five things you need to know about the WavePro HD

1. The 12-bit performance is not a significant advantage over the S-series. In a detailed analysis the noise has a great an effect on the signal integrity. The valid comparison of the two scopes should be done using the ENOB measurement of the scope. S-series performs better at low signals and LeCroy does better with high voltages.

2. The LeCroy WavePro HD is more expensive than the S-series. If you match memory depth and MSO the price advantage of the S-series is even more.

3. The <u>usable</u> memory of the S-series is larger than the LeCroy WavePro. While the LeCroy supports a deep capture, it can only analyze 500 Mpts. The extra memory can only be used on a single shot capture. The S-series support 800 Mpts in all operations.

4. Zone Triggering is an exclusive advantage of the S-series

5. User Interface operations support more complete "Touch" operations. LeCroy uses a very small font size that cannot be changed. Other key use advantages include; supports a single window only, no Wizards or Quick Functions, setup at the bottom is very busy and hard to navigate, No Zone Trigger, and a Single Pair of Cursors.

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Their Marketing Message: Teledyne LeCroy WavePro HD Series

WavePro HD leverages Teledyne LeCroy HD4096 technology to achieve 12-bit performance at up to 8 GHz bandwidth, giving the lowest noise and highest signal fidelity. 5 Gpts of available acquisition memory enables capture of extremely rare events over the longest timescales at full 20 GS/s sample rate.

WavePro HD features a 15.6" full HD capacitive touchscreen, new 8 GHz ProBus2 probe interface, 16 digital channels (on -MS models), and is the first Teledyne LeCroy oscilloscope to run Windows 10.

Key Features

- HD4096 Technology Meets 8-GHz Bandwidth: New 8-GHz chipset comprising a low noise front-end amplifier and 12-bit ADC.
- Next-Generation Long-Memory Architecture: Fast and responsive 5-Gpoint acquisitions, easy to find, navigate to and analyze waveform features with WavePro HD's MAUI.
- Best-in-Class Deeply Embedded Computing Systems Debug: Wide range of analog-sensor, digital logic, power-rail, serial data, and other signals.
- Unmatched Power-Integrity Investigations: High bandwidth for accurate characterization of high-speed, on-die effects (ex. ground-bounce), high dynamic range, 0.5% gain accuracy, exceptionally low noise floor, spectrum analyzer software tools, and more.
- Characterize Pulses; Pin Down Emissions: Deftly melds 2.5 or 4 GHz of bandwidth with very high sample rates and resolution for extremely accurate pulse characterization.
- Analyze Serial-Data Jitter and Noise: Serial-data analysis, 12-bit resolution, a low noise floor, and exceptionally low timebase jitter (60 fs)
- ProBus2 Interface Supports 8 GHz: New 8 GHz, BNC-compatible ProBus2 probe interface.
- Power Integrity Debug and Validation
- Deeply Embedded Computing Systems Testing
- Serial Data Jitter and Noise Analysis

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Specifications and Table of Contents

	Keysight S series	Lecroy WavePro HD	Comments.	See page
500 MHz	$18,452		500 MHz to 2.0 GHz models are not available from Lecroy. S-series upgrades are software license. Buy only the bandwidth you need today.	4
1 GHz	$22,143			
2 GHz	$26,888			
2.5 GHz	$29,524	$31,000	List price is slightly above the S-series pricing.	
4 GHz	$39,014	$39,500	Lecroy bandwidth upgrades are return to factory upgrades.	4
6 GHz	$55,885	$57,000	Both the S-series and Lecroy are 2 channel only at 6 & 8 GHz.	4
8 GHz	$71,701	$71,000		
Memory 100 Mpt/ch	$0	$4,995	This upgrade matches the memory to the standard memory on the S-series	4
Max memory	$8,000	$26,995	S-series 800 Mpt; WavePro 5 Gpt	4
MSO price	$5,272	$3,000	S-Series: 400 MHz, WavePro 250 MHz	4
ADC	10	12	ADC-bits is one of the factors that influences signal integrity. See more on ENOB performance.	5
Hi-Res	16	15	S-series uses box car averaging to store the data in hi-res mode. Lecroy uses a Math function (ERes).	6
Std memory per channel	100 Mpt	50 Mpt	The default memory is twice the Lecroy. Price of Lecroy goes up to compete.	7
Max analysis memory	800 Mpt	500 Mpt	Lecroy says "measurements and math calculations take place on only the center 500 Mpts."	7
Max capture memory	800 Mpt	5 Gpt	This is a really expensive digitizer (see point above).	7
Wfrm/sec	500/sec	175/sec	S-series has 3x the update rate.	7
Measured avg ENOB 5mV/div @ 4 GHz	5.0	4.7	At small voltages (where noise is critical) the S-series out performs Lecroy.	8
Measured avg ENOB 100mV/div @ 4 GHz	6.9	7.1	With higher voltages they have an advantage.	8
Measured avg ENOB 100mV/div @ 8 GHz	6.4	6.9	This is the worst case difference in performance. 1/2 a bit of ENOB performance.	9
5mV noise @ 4 GHz	173 uV	228 uV	The noise level is the difference in ENOB performance more than the ADC bits.	9
100mV noise @ 4 GHz	1.60 mV	1.31 mV		
Available applications	Full complement	Full complement	Both products have a full selection of sw products. However, Keysight offers packages that provide greater value at lower cost.	10
User Interface	?	?	User preference. General feedback that Keysight is more full featured.	11

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Pricing Comparison

500 MHz – 2 GHz models not available from LeCroy

The Keysight S-series supports upgrades from the basic models through all configurations through simple upgrades. All upgrades are priced with zero uplift over the original purchase configuration. This allows the customer to manage their budget to meet current project needs and maximize equipment purchases. LeCroy is also return to service center for all bandwidth upgrades.

LeCroy list prices slightly above the S-Series

List prices are similar, and you can expect LeCroy to use discounting. Make sure to get the entire solution price. LeCroy prices their software applications all individually (for example SPI and I2C are two different software applications). With capture memory upgrades and software packages, the LeCroy will be starting at an even higher price.

The WavePro default memory is half of the standard configuration of the S-series. An upgrade option, WPHD-200MPT, is priced at $4995. With this added, the WavePro is 22% more expensive then the S-series for the 2.5 GHz model.

The Maximum memory is $27,000 on the WavePro, almost the starting price of the WavePro at $31,000.

Both WavePro HD and S-Series channel limited at 6 and 8 GHz

Both products use sample interleaving in order to get 20 GSa/s acquisition speed. Both products only support 2 channels for frequencies above 4 GHz.

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ADC Comparison

ADC-bits is one of the factors that influences signal integrity. The best comparison is by using Effective Number of bits (ENOB) that factors in the signal integrity of the scope.

A 12-bit ADC does have more bits of resolution, but more bits does not mean always mean more accuracy. As we all know in measurement, there is a big difference between accuracy and resolution.

Resolution is the degree to which a change can be theoretically detected.

**Accuracy is the amount of uncertainty in a measurement.**

While the ADC has more bits, it is limited by the performance of the oscilloscope due to noise, jitter, and other factors. The largest impact is attributable to noise.

If you compare the possible resolution of a 12-bit scope vs the reality of the impact of noise, it is easy to see the resolution is not a valid comparison. The noise is many times the quantization level of the 12-bit ADC. This means that the extra bits are just bits of random noise.

The S-series uses a 10-bit ADC, which has lower resolution, but as you will see when you compare the noise performance and the ENOB analysis, is very similar to the in actual measurement accuracy.
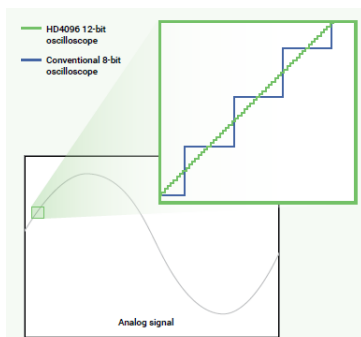
LeCroy's 12 bit ADC "promise"
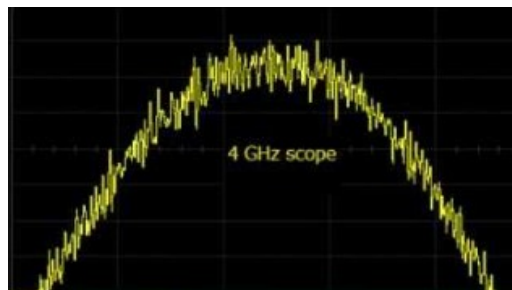
LeCroy's 12 bit ADC reality

	Lecory WavePro	
V/div	12-bit Q levels	Noise
1 mV/div	1.95 uV	228 uV
2 mV/div	3.9 uV	228 uV
5 mV/div	10 uV	228 uV
10 mV/div	20 uV	228 uV
20 mV/div	39 uV	275 uV
50 mV/div	98 uV	633 uV
100 mV/div	195 uV	1.3 mV
200 mV/div	391 uV	2.06 mV
500 mV/div	977 uV	5.16 mV
1 V/div	1.95 mV	9.17 mV

Q-Levels vs. real noise floor

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Available High-Resolution Modes

The S-series oscilloscopes have added additional High-resolution modes to support up to 16 bit vertical resolution. When applying this configuration, the scope will automatically set the sample rate and bandwidth filters to maximize signal integrity. By reducing noise and increasing bits the S-series oscilloscope can provide resolution up to 8.46 ENOB (Effective Number of bits) at lower bandwidths. See screenshot below.

S-series uses box car averaging in real-time to capture data in hi-res mode. LeCroy uses a Math function called Enhanced Resolution (ERes) to accomplish resolution of up to 15 bits. Because it is a Math function, The ERes function is limited to post capture on < 500 Mpts of captured data.

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Hi-res	Sample rate	Bandwidth
10-bit	20 Gsa/s	8.4 GHz
11-bit	5 Gsa/s	1.14 GHz
12-bit	2.5 Gsa/s	558 MHz
13-bit	1.25 Gsa/s	277 MHz
14-bit	625 Msa/s	138 MHz
15-bit	313 Msa/s	69.2 MHz
16-bit	125 Msa/s	27.7 MHz

S-Series high-res modes

Memory Configuration

Standard memory of the S-series is twice the memory of the WavePro.

- S-series: standard memory 200 Mpts (2ch) / 100 Mpts (4 ch)
- WavePro: standard memory 100 Mpts (2ch) / 50 Mpts (4 ch)

Purchase of an additional memory option WPHD-200MPT $4,995 required to match the S-series.

Deep Memory

The Lecroy does have a 5 Gpts memory option 5 GPt (2ch) / 2.5 Gpt (4 ch), that is very expensive $26,995. However, there is a big limitation to the memory. It can only be used in single-shot captures and "measurements and math calculations take place on only the center 500 Mpts."

This means for doing analysis on your captured data, the S-series with the 800 Mpts option has 60% more memory available. It also can be used in a continuous run mode, unlike LeCroy.

Waveform Update Rate

When doing analysis, the waveform update rate is very important. The comparative update rates are;

- S-series: > 500 wfm/sec

- WavePro: >170 wfm/sec

Visualization is extremely valuable when troubleshooting a problem, and the waveform display rate can be much more useful than a deep memory.

In addition, LeCroy still does not have a Zone trigger capability. InfiniiScan has many uses that can help capture hard to trigger on signals, but a zone trigger is one of the easiest and most flexible.

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Noise Comparison

These two scopes both have excellent noise floor specifications. The S-series has a lower noise floor at low voltage levels and the WavePro is tuned for better analysis at higher voltages.

This table compares the rms noise of these scopes at various voltages and bandwidths.

	uV or mV rms noise							
	2.5 GHz		4 GHz		6 GHz		8 GHz	
	S series	WavePro HD	S series	WavePro HD	S series	WavePro HD	S series	WavePro HD
1 mV/div	130	155	153	228	195	285	260	315
2 mV/div	130	155	153	228	195	285	260	315
5 mV/div	135	155	173	228	205	285	320	315
10 mV/div	172	155	220	228	256	285	390	315
20 mV/div	254	191	330	275	446	360	620	420
50 mV/div	650	429	768	633	1.3	835	1.4	983
100 mV/div	1.3	889	1.6	1.31	2.3	1.7	3.1	1.95
200 mV/div	2.8	1.44	3.4	2.06	4.9	2.7	6.4	3.16
500 mV/div	6	3.66	7.3	5.16	10	6.7	13.3	7.76
1 V/div	10.1	6.7	12.5	9.17	17.6	11.93	24.1	13.81

As discussed in the section on the ADC comparison, the noise of the scope can easily overwhelm the quantization levels available on the ADC. To get a real comparison, check out the ENOB measurements.

LeCroy does a 'digital zoom" for 1 mV/div, 2mV/div, 5mV/div for all models. With all their 12 bits of vertical resolution, LeCroy WavePro HD is not able to measure very low voltage signals with high resolution. 10mV/div is a minimum vertical resolution that this scope is able to measure!!!

Our S-Series does a 'digital zoom" only for 1 mV/div. It means that we don't have special attenuators for 1 mV/div, and as a result of that a vertical noise number is same 260 uV$_{rms}$ for 2 mV/div and 1 for 1 mV/div for all models BW, of cause.

Effective Number of Bits (ENOB)

ENOB calculations are easy to do. Input a perfect sine wave, capture it on a scope, and measure the deviation from the result vs the input. ENOB considers noise, ADC non-linearities, interleaving errors, and other error sources. Scopes will have ENOB values much less than the # of bits the ADC has. As an example, our ADC ENOB is rated up to 8.7, but the overall system ENOB will be less (up to 8.1 typical)

From this we did an evaluation to compare the ENOB performance of these scope with different input signals. As expected, the LeCroy scope performs very well with a relatively higher voltage but suffers as the signal levels goes down.

	100 mV/div, 50 Ω, 90% full screen	
	S series	WavePro HD
8 GHz	6.4	7.0
6 GHz	6.1	6.8
4 GHz	6.8	7.2
2 GHz	6.8	7.0
1 GHz	6.7	6.7
500 MHz	6.8	6.8
200 MHz	6.9	6.9

When working with relatively large signals, the WavePro HD does have a does provide a slight ENOB measurement advantage.

	2 mV/div, 50 Ω, 90% full screen	
	S series	WavePro HD
8 GHz	4.4	4.1
6 GHz	4.7	4.4
4 GHz	5.0	4.7
2 GHz	5.2	5.1
1 GHz	5.8	5.3
500 MHz	6.2	5.8
200 MHz	6.2	6.5

When you are working on finding the detail of the signals, you are often working with smaller voltages.

When you have low signal levels, the S-series has an advantage at most frequencies.

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Available Software

Protocol Decodes and Analysis:

Protocol Apps	S-Series	WavePro HD	Protocol Apps	S-Series	WavePro HD
8B/10B	Yes	Yes	10/100 Ethernet	Yes	No
CAN,LIN,FlexRay	Yes	Yes	Storage	Yes	No
CAN-FD	Yes	Yes	eSPI and Quad eSPI	Yes	Yes
DVI	Yes	No	I2C,SPI,UART-RS232	Yes	Yes
HDMI	Yes	No	SAS/SATA	Yes	Yes
JTAG	Yes	No	SPMI	No	Yes
MIPI® CSI-3	Yes	Yes	AudioBus	No	Yes
MIPI® LLI	Yes	Yes	FibreChannel	No	Yes
MIPI® RFFE	Yes	Yes	SENT Bus	Yes	Yes
PCI Express® Gen1	Yes	Yes	SpaceWire	Yes	Yes
PCI Express® Gen2	No	No	ENET	No	Yes
SVID	Yes	No	NRZ	Yes	Yes
USB 2.0	Yes	Yes	Manchester	Yes	Yes
USB 3.0, 3.1	Yes	Yes	MDIO	No	Yes
USB 3.0 SSIC	Yes	No	MIL-STD-1553	Yes	Yes
USB PD	Yes	No	ARINC 429	Yes	Yes
USB 3.2	Yes	No	HSIC	Yes	No

Compliance Applications:

	S-Series	WavePro HD
BroadR-Reach	Yes	Yes
DDR1 (200 MT/s to 1067	Yes	No
DDR2 + LPDDR2 (400 MT/s to 1067	Yes	Yes
DDR3 + LPDDR3 (800 MT/s to 1067	Yes	Yes
eMMC	Yes	No
Ethernet	Yes	Yes
Ethernet + EEE	Yes	No
10GBase-T	Yes	No
HDMI 1.4	Yes	No
MHL 2.0	Yes	No
MIPI D-PHY	Yes	Yes
MIPI M-PHY	Yes	Yes
MOST	Yes	Yes
PCIe Gen 1	Yes	Yes
UDA software	Yes	No
UHS-I	Yes	No
UHS-II	Yes	No
USB 2.0	Yes	Yes
HSIC	Yes	No
XAUI	Yes	No

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User Interface
Summary

On the whole, LeCroy has taken some strides forward with the WavePro HD. The screen is large and has no bezel. The front panel design is solid except for the bizarre Run/Stop/Single buttons. Some problems are the noticeably slow update rate, strange multi-touch and odd use of the "+" button to add measurements. The fonts are small and cannot be modified.

The biggest takeaway of the LeCroy WavePro HD is that it is clearly better than previous models, except for the update rate. The new TriggerScan feature is intriguing if it proves to be effective in finding anomalies automatically. The biggest weakness is probably the update rate. That may prove to be a decisive competitive advantage because users can't help but notice. And this implies there could be a lot they're missing.

Even with the larger screen the default font sizes are very small on LeCroy. That's fine for younger users but it still gets hard for older ones (like me). Unlike other LeCroy models, on the WavePro HD the fonts are fixed so users must live with them.

Single Window Only

While there are multiple regions within the single window, none of these areas can be sized independently. In Infiniium, there are separate windows for Waveforms, FFT, and Results. This means users can scale each to be as big or small as they want. For example, in the WavePro HD "Spectrum Analyzer" mode results in an FFT beside time domain waveforms. What if the user prefers the time domain to be larger? Users have told us clearly that the entire screen is theirs and they need the ability to control what is visible. The lack of resizing means LeCroy uses a "one size fits all" approach to windows.

No Wizards or Quick Functions

There is no alternative to figuring out the LeCroy dialogs. At times, it can be a pretty big chore to figure out what all of the parameters mean. (That's true on all scopes, not just LeCroy). But since LeCroy doesn't give users wizard or quick functions, the learning curve is steeper.

Setup at the Bottom instead of Popup dialogs

Doing setup at the bottom of the screen can have advantages in the sense that waveforms are not covered up. That's a plus for LeCroy. However, it is essential to avoid the temptation to just cram everything you can into this narrow space. LeCroy tries hard to avoid dialogs at all times, so they are continually cramming every last pixel in the setup area and at times it becomes a bewildering jumble. (They don't have room for group boxes or other methods to group widgets together well).

No Zone Trigger

On Keysight scopes, draw a rectangle and you can easily create a zone trigger. That's an extremely power addition to edge triggers because it is so visual. The WavePro HD does not support this.

Single Pair of Cursors

Now that Infiniium has multiple pairs of Markers, LeCroy falls behind.