Siglent SDS800X HD Evaluation

Revision 1.00

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Document History

Rev. 1.00 Initial Release.

Introduction

These are the results of an evaluation of the Siglent SDS824X HD.

Why the 800 and not the 1000X HD?

I suppose the SDS800X HD will be the most popular offer for hobbyists and small businesses in Siglent's lineup, eventually replacing the successful SDS1000X-E series.

Even though there are some differences, most of these are comfort features (except for the 50 Ω inputs), hence the SDS800X HD test results should be largely valid for the SDS1000X HD as well.

This is a confirmed list of differences to the SDS1000X HD:

- SDS800X HD has no external trigger input.
- Only the 200 MHz SDS800X HD have 100 Mpts memory, the lower models have only 50 Mpts.
- SDS800X HD has no 50 Ω inputs.
- SDS800X HD doesn't have the higher quality encoders with detent positions.
- SDS800X HD has fewer serial protocols: CAN-FD and FlexRay are missing.
- SDS800X HD has only 2 USB host ports.
- SDS800X HD has only 7" capacitive touch screen, but at the same resolution 1024 x 600.
- SDS800X HD doesn't support probe factor detection.
- SDS800X HD doesn't support Tektronix Mode.
- SDS800X HD doesn't support Advanced Measurements Display Mode M2.
- SDS800X HD doesn't support Measurement Histograms Secondary Zoom.
- SDS800X HD has no RTC.
- SDS800X HD supports NTP.

The first impression was very positive. The instrument feels solid, the display appears a bit small, especially for someone used to the 10.1" screens of the 2000 series, yet the resolution is the same and it's bright and crisp.

Operation feels snappy, it appears to be (at least) on par with the SDS2000X Plus/HD series in this regard.

The fan noise is about the same as in the SDS1104X-E, thus it can be slightly annoying and users will have something to optimize 😉

Boot time is less than 40 seconds in most scenarios.

I have to state in advance that there is a lot of progress when compared to the trusty 1000X-E series – it's almost a completely different world.

Basic Information

This is just a collection of key-specifications, which might not be entirely clear, or even missing from the datasheet:

SDS800X HD Boot Time: <40s

SDS800X HD codes per screen height: 3840 LSB SDS800X HD codes per division : 480 LSB

SDS800X HD best true (full resolution) sensitivity: 500 μ V/div

Acquisition

Bandwidth

Let's start with the bandwidth. We would like to get the specified bandwidth even with all channels active, yet we do not want to deal with excessive aliasing.

At first, one single channel at 2 GSa/s:

÷	Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Anal	ysis SIGLENT f = 40.97993	Trig'd 3MHz ■	Tools	
F4	0.0dBV			2				3 4	Ş		
-2	0.0dBV										
-3	0.0dBV										
-4	0.0dBV,,	F4 Marken	s List								
		Marker	Abs.Ampl.	Abs.Freq.	Delta Amp	il. Delta	Freq.				
-5	0.0dBV	1	-12.265dBV	1.00000MHz	<u>.</u>					λ	
		2	-12.317dBV	10.00000MHz	-0.052a	3BV 9.00	1000MHz	Sa= 2.00GSa/s			
		3	-12.711dBV	100.00000MHz	-0.4460	1BV 99.00	1000MHz	Curr= 8192pts			$\langle \rangle$
-6	0.0dBV	4	-14.207dBV	200.00000MHz	: -1.9430	3BV 199.00	1000MHz	ΔΙ= 244.14KHZ 			
		5	-15.222dBV	244.00000MHz	: -2.9570	3BV 243.UU	IUUUMHz	ND##= 910.04KHZ			
											- *
-7	0.0dBV										
											$ \rangle$
10	100kHz			10MHz				100MHz			N
C4 1X FUL	DC1 100m L 0.01	IM F4 F IV/ 11 DV 0	FT(C4) D.0dBV/ — I.00dBV					Timebase 0.00s 500ns/div 10.0kpts 2.00GSa/s	Trigger (Auto (Edge F	C4 DC 0.00V Rising	∲ ₩

Fig. 1 SDS824X_HD_FR_2GSa_log

Amplitude drop at 200 MHz is less than 2 dB and actual -3 dB bandwidth is 244 MHz. Frequency response is even a tad better when two channels are in use at 1 GSa/s:

202 202	🕈 Utility	🖵 Display	nî Acquire 🖡	• Trigger 🗰 C	Cursors 🔺 Mea	as 🖻 Analys	iis SIGLENT Trig'd f = 91.70147MHz	🗎 Tools
F 4	-15.00dBV			2				4
	-20.00dBV							
;	-25.00dBV	E4 Mart	vore Liet					
f	-30.00dB/V	⊢4 Marker —⊢ Marker 1	Abs.Ampl. -12.317dBV	Abs.Freq. 1.00000MHz	Delta Ampl.	Delta Freq.	Sa= 1.00GSa/s	+ + + + + +
2	-35.00dBV	2 4	-12.387dBV -12.711dBV -14.077dBV	10.00000MHz 100.00000MHz 200.00000MHz	-0.070dBV -0.394dBV -1.761dBV	9.00000MHz 99.00000MHz 199.00000MHz	Δf= 61.04kHz RBW= 227.66kHz	\
	-40.00dBV		-15.320dBV	245.75000MHz	-3.003dBV	244.75000MHz		
:	-45.00dBV							
	-50 00dRV			10MHz			100MHz	
1X FL	D3 DC1 (100m JLL 0.0	1M C4 1V/ 1X 1 0V FULL	DC1M F4 F 00mV/ 5. 0.00V -1	FT(C4) 00dBV/ 0.0dBV	—		1imebase Trigger 0.00s 2.00us/div Auto 20.0kpts 1.00GSa/s Edge	C4 DC

Fig. 2 SDS824X_HD_FR_1GSa_log

Amplitude drop at 200 MHz is <1.8 dB and actual -3 dB bandwidth is 245 MHz. Finally, we look at all four channels in use at only 500 MSa/s:

🏶 Utility	y (₽ Display	nî Acquire	🏲 Trigger ᠄	🗰 Cursors 🔺 I	Meas 🖻 Ana	alysis f = 138.7347	Trig'd MHz	Tools
F4 10.00d 	IBV				2				4
-20.00d	IBV								
-25.0Qd	BV_+	F4 Marke	rs List						
-30.00d	IBV	Marker 1 2 3	Abs.Ampl. -12.299dBV -12.387dBV -12.766dBV	Abs.Freq. 1.00000MHz 10.00000MHz 100.00000MHz	Delta Ampl. -0.088dBV -0.467dBV	Delta Freq. 9.00000MHz 99.00000MHz	Sa= 500.00MSa/s Curr= 2048pts Λf= 244 14kHz		
-35.00d -40.00d	IBV	4	-15.101dBV	200.00000MHz	-2.801dBV	199.00000MHz	RBW= 910.64kHz		
1000kH:	z				10MHz			100MHz	
C1 1X FULL	DC1N 100mV 0.00\	1 C2 / 1X / FULL	DC1M C3 100mV/ 1X 0.00V FULL	DC1M C4 100mV/ 1X 0.00V FULL	DC1M 100mV/ 0.00V	FFT(C4) 5.00dBV/ << > -5.00dBV	> Timebase > 0.00s 500ns/div 2.50kpts 500MSa/s	Trigger C4 Auto 0.0 Edge Ris	DC 🛛 🖞 💑 OV ing

Fig. 3 SDS824X_HD_FR_500MSa_log

Now the bandwidth is actually limited to the advertised 200 MHz.

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Finally the frequency response with 20 MHz bandwidth limiter:

Fig. 4 SDS824X_HD_FR_500MSa_log

Pulse Response

For all these tests, a 10 MHz square wave with 1 ns rise time has been fed into cannel 4.

SIGLENT 🏽 Utility 🖵 Display ni Acquire 🏲 Trigger 🗰 Cursors 📐 Meas 🖻 Analysis 🗎 C4 f = 10.00013MHz 00ns 100.0ns 290.00mV 285.00mV 280.00mV 1.00ns 21.00ns [₽]270.00mV. *** MEASURE Value 0.849% 1.961% 1.81ns 1.77ns 1.8061ns Mean 0.78863% 1.92229% 1.7766ns Min 0.388% 1.563% 1.76ns 1.78ns 2.442% 1.80ns 1.83ns Max 1.241% Pk-Pk 0.85285% 0.87894% 40.0ps 50.0ps Stdev 0.12415% 0.12901% 6.4ps 6.5ps Count 800 800 1600 1600 all II. Histogram Timebase 100mV/ 5.00ns/ 5.00mV/ 0.00V 0.00s 20.0ns/div Stop Edge 0.00V 21.0ns 290mV FULL 400pts 2.00GSa/s Rising

Let's start with single channel mode and 2 GSa/s:

In stop mode, we get a clear picture of the imperfections of the pulse top even when zoomed in 20x (main window: 100 mV/div, zoom: 5 mV/div). The rise time measurements yield the expected result of ~1.8 ns, which corresponds to 1.5 ns rise time for the SDS824X HD. This is well below the specified 1.8 ns for the 200 MHz model.

In Run mode we can see some modulation because of noise, yet nothing that could not be cured by averaging using a math trace:

Fig. 5 SDS824X_HD_PR_2GSa_Zoom_Stop



Fig. 6 SDS824X_HD_PR_2GSa_Zoom_Avg16

In case you wonder why the imperfections of the pulse top are so pronounced in the previous screenshot, this is simply the price we pay for less than perfect impedance matching when using a scope that lacks 50 Ω inputs. External termination is always a compromise working reasonably well up to 70 MHz at best. Fast edges like the 1 ns rise time in this example occupy 600 MHz bandwidth. The output impedance of the pulse generator isn't perfect 50 ohms either, and both phenomena combined lead to reflections showing up in the first ~16 ns of the pulse.

Of course it can be demonstrated, how better impedance matching improves things. For this I've used a quality 18 GHz cable with two 10 dB 18 GHz Narda in-line attenuators (one at each end) to ensure sufficient attenuation for any reflections between generator and DSO. Because of the 20 dB attenuation in total, I had to increase the generator output level by 20 dB as well. This would have been 6 V amplitude, but at that level, it's rise time is limited to min. 1.2 ns, hence I made do with just 3 V and increased the DSO sensitivity to 50 mV/div, in order to still get the 1 ns rise time:

🏟 Utility	🖵 Display n	Acquire 🏲 Trigger	# Cursors	📐 Meas 🛛	🔄 Analys	is SIGLENT	Trig'd 2MHz	🗐 MAT	Ή
1124 STRV	. 		.					Trace	
c4+2454900000000000000000000000000000000000							-+++-+-	Function3	
	200050.0 0005	0.2000S 0.4000S		- U.Syuus I.	.u uous	1.2000S 1.4000		Operation	
165.00mV								on	off
160.00mV	· · · · · · · · · · · · · · · · · · ·							Function	
155.00mV	//\							Average(2	(4)
150.00mV	+ + + + + + + + + + + + + + + + + + +		+++++++++++++++++++++++++++++++++++++++		+ + + + +		+ + + +	Average N	Jum
145.UUmV		\vee						64	
135.00m\/									
F3 -5.	00ns 0.00ns	5.00ns 10.00ns	15.00ns	20.00ns 2	5.00ns	30.00ns 35.00n	s 🗕	Count	
MEASURE	FOV(C4)	ROV(C4)	10-90%Rise	e(C4) = 90-109	%Eall(C4)	***		64	
Value	0.344%	2.270%	1.77ns	1.87ns	s anto iy				
Mean	0.51750%	1.91422%	1.7793ns	1.8662	2ns			Reset	
Min	0.137%	1.339%	1.75ns	1.83ns	6				
Max	1.031%	2.373%	1.81ns	1.91ns				Scale	C
Pk-Pk	0.89387%	1.03348%	60.0ps	80.0ps	6				5.00mV/
Stdev	0.16488%	0.20112%	9.8ps	20.1ps	6				
Count	16188	16188	32376	32376			-	Label	
Histogram		ռ					\bigcirc	F3	
C4 DC	1M Z4	F3 Avg(Z4)				Timebase	Trigger	C4 DC	∲ 5%
FULL -2.50r	nV 15.0ns 145m	V 5.00mV V -150mV				4.00kpts 2.00GSa/s	Auto Edge	0.00V Rising	

Fig. 7 SDS824X_HD_PR_2GSa_Zoom_Avg16_Match

With two active channels, the sample rate drops to 1 GSa/s:

🛱 Utility 🖵 Di	splay 🕅 Acquire 🏲	Trigger 🗰 Cursors	📐 Meas 🖻 Analy	sis SIGLENT f = 10.00013	Trig'd 3MHz 📋 C3
300.0mV 200.0mV 100.0mV					
<mark>c3</mark> ,0.QmV					
-100.0mV					
-200.0mV					
-308-0mV		· · · · · · · · · · · · · · · · · · ·	~	<u> </u>	\sim
_400 0mV -20.0ns	0.0ns 20	Ons 40.Ons	60.0ns 80.0ns	100.0ns 1	120.0ns 140.0ns
MEASURE	FOV(C4)	ROV(C4)	10-90%Rise(C4)	90-10%Fall(C4)	- ***
Value	1.181%	2.949%	1.76ns	1.79ns	
Mean	1.34262%	2.92463%	1.7660ns	1.7963ns	
Min	0.983%	2.511%	1.73ns	1.76ns	
Max	1.889%	3.475%	1.79ns	1.82ns	
Pk-Pk	0.90529%	0.96457%	60.0ps	60.0ps	
Stdev	0.17320%	0.18042%	9.7ps	9.3ps	
Count	272	272	544	544	_
Histogram		and the state of the			\bigcirc
C3 DC1M C	4 DC1M			Timebase	Trigger C4 DC 🛛 🜵 😽
1X 100mV/ 1X	100mV/			0.00s 20.0ns/div	Auto 0.00V

Fig. 8 SDS824X_HD_PR_1GSa

The overshoot is more pronounced now (possibly because of additional AA-filtering), yet rise time measurements haven't changed.

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🏟 Utility	🖵 Display	nî Acquire	🏲 Trigger	♯ Cursors	📐 Meas	🖻 Analys	sis SIGLENT f = 10.0001	Trig'd 3MHz	🗎 C1	
300.0mV		~~					\sim			
200.0mV										
100.0mV										
- 0.0m\/										
	+		-+	+-+-+						
-100.0mV										
-200.0mV										
_300.0mV		\checkmark			~		\sim			5
-400 0mV	-20.0ns	0.0ns	20.0ns	40.0ns	60.Ons	80.0ns	100.0ns	120.0ns	140.0ns	
MEASURE	FC	0V(C4)	- ROV(C4		10-90%Rise	(C4) —	90-10%Fall(C4)	***		
Value	3.1	126%	4.857%		2.24pc		0.00			
Mean					2.2405		2.29ns			
A 41	3.t	68651%	4.83766	%	2.24ns 2.2705ns		2.29ns 2.3177ns			
Min	3.6 2.7	68651% 784%	4.83766 3.918%	%	2.2405 2.2705ns 2.21ns		2.29ns 2.3177ns 2.26ns			
Min Max	3.8 2.7 4.8	38651% 784% 571%	4.83766 3.918% 5.785%	%	2.2405 2.2705ns 2.21ns 2.32ns		2.29ns 2.3177ns 2.26ns 2.37ns			
Min Max Pk-Pk	3.8 2.7 4.8 1.7	68651% 784% 571% 78794%	4.83766 3.918% 5.785% 1.86724	%	2.2405 2.2705ns 2.21ns 2.32ns 110.0ps		2:29ns 2:3177ns 2:26ns 2:37ns 110.0ps			
Min Max Pk-Pk Stdev	3.8 2.5 4.8 1.5 0.8	58651% 784% 571% 78794% 88779%	4.83766 3.918% 5.785% 1.867249 0.386359	% % %	2.24115 2.2705ns 2.21ns 2.32ns 110.0ps 27.1ps		2.29ns 2.3177ns 2.26ns 2.37ns 110.0ps 26.6ps		+	
Min Max Pk-Pk Stdev Count	3.8 2.7 4.6 1.7 0.3 54	68651% 784% 571% 78794% 88779% 6	4.83766 3.918% 5.785% 1.86724 0.38635 546	% % %	2.2405 2.2705ns 2.21ns 2.32ns 110.0ps 27.1ps 1092		2.29ns 2.3177ns 2.26ns 2.37ns 110.0ps 26.6ps 1092			-
Min Max Pk-Pk Stdev Count Histogram	3.8 2.7 4.8 1.7 0.8 54	38651% 784% 771% 78794% 88779% 6 6	4,83766 3,918% 5,785% 1,867241 0,386350 546	% % %	2.24ns 2.2705ns 2.21ns 2.32ns 110.0ps 27.1ps 1092		2.29ns 2.3177ns 2.26ns 2.37ns 110.0ps 26.6ps 1092		+-	0
Min Max Pk-Pk Stdev Count Histogram	3.t 2.7 4.t 1.7 0.3 54 :1M C2	58651% 784% 571% 78794% 58779% 6 5 0001M 001M 001 001 001 001 001 0001 0	4.83766 3.918% 5.785% 1.86724 0.38635 546 546 DC1M _C4	% % % 4 DC <u>1M</u>	2.24ns 2.2705ns 2.21ns 2.32ns 110.0ps 27.1ps 1092		2.29ns 2.3177ns 2.26ns 2.37ns 110.0ps 26.6ps 1092	Trigger		Ф В

With four active channels, the sample rate drops to only 500 MSa/s:

Fig. 9 SDS824X_HD_PR_500MSa

We can see hints on slight reconstruction errors together with rather pronounced Gibbs ears. Rise time measurement is off by hefty 27%, so we can safely state that this configuration is not fit for characterizing pulses with <2 ns rise time.

With a signal rise time of 2ns we can measure 2.6 ns: assuming 1.5 ns rise time for the SDS824X HD, this measurement now is only \sim 5% off and should be acceptable already. Furthermore, we can use Dots mode to get rid of any reconstruction errors:

📽 Utility	🖵 Displa	ny mi Acc	quire f	Trigger	# Cursors	📐 Meas	🗟 Analy	rsis SIGLENT f = 10.0001	Trig'd IOMHz	🗎 DISPL	.AY
300.0mV					<u> </u>			· · · · · · · · · · · · · · · · · · ·		<u> </u>	
200.0mV											
100.0mV											
<mark>с4</mark> ДДтУ	+++	++	+++-				-++		+	-+	
-100.0mV											
-200.0mV											
_309.0mV						\sim					\sim
-400 0mV	-20.0ns	0.0ns	2	0.0ns	40.0ns	60.Dns	80.0ns	- 100.0ns	120.0ns	140.0ns	
MEASURE		FOV(C4)		= ROV(C4)	10-90%Ri	se(C4) –	90-10%Fall(C4)	- ***		
Value		1.608%		2.4059	%	2.58ns		2.63ns			
Mean		1.76902%		2.4309	38%	2.5750ns		2.6081ns			
Min		1.013%		1.7729	%	2.53ns		2.55ns			
Max		2.538%		3.1479	%	2.63ns		2.67ns			
Pk-Pk		1.52509%		1.3753	33%	100.0ps		120.0ps			
Stdev	ĺ	0.30352%		0.3297	78%	20.6ps		21.1ps			
Count	:	363		363		726		726			_
Histogram				والمتلب و	and and driven						\bigcirc
C1 DC	1M C2	DC1M	C3	DC1M	DC1M			Timebase	Trigger	C4 DC	∲ 品
1X 100m FULL 0.0	nV/ 1X IOV FULL	1 /100m 0.00V	X FULL	100mV/ 1) 0.00V Fl	< 100mV/ JLL 0.00V		< >>	0.00s 20.0ns/div 100pts 500MSa/s	/ Auto s Edge	0.00V Rising	

Fig. 10 SDS824X_HD_PR_500MSa_2ns_Dots

True Vertical Sensitivity

The SDS800X HD has a specified vertical gain range from 500 μ V/div up to 10 V/div. Many contemporary DSOs have similar specs, yet only a small minority of them can provide true 500 μ V/div at full resolution. The real sensitivity of many instruments is lower, sometimes significantly so (up to 5 mV/div). As a consequence, anything above the true highest sensitivity is just software zoom and won't provide full resolution anymore. This might be not that much of a problem for a 12-bit DSO, but 8-bit instruments degraded to 6 bits at 1 mV/div could get problematic. On the other hand, most of those instruments also exhibit high noise levels, so the ENOB (Effective Number of Bits) drops below 6 bits at these higher sensitivities anyway.

For the SDS800X HD, I stumbled across the unexpected property of nearly equal noise levels for all vertical sensitivities from 500 $\mu V/div$ to 5 mV/div:

Noise De	Noise Density RBW [Hz] 889,3														
Gain															
[mV/div]		0,50			1,00			2,00			5,00			10,00	
Freq.	Level		ND	Level		ND	Level		ND	Level		ND	Level		ND
[Hz]	[dBV]	Level [V]	[nV/vHz]	[dBV]	Level [V]	[nV/√Hz]	[dBV]	Level [V]	[nV/vHz]	[dBV]	Level [V]	[nV/√Hz]	[dBV]	Level [V]	[nV/vHz]
1,0E+3	-103,17	6,95E-6	232,90E-9	-101,93	8,01E-6	268,58E-9	-101,83	8,10E-6	271,60E-9	-103,06	7,03E-6	235,79E-9	-99,19	10,98E-6	368,24E-9
3,0E+3	-103,66	6,56E-6	220,00E-9	-105,69	5,19E-6	174,17E-9	-105,08	5,57E-6	186,93E-9	-105,35	5,40E-6	181,06E-9	-103,12	6,98E-6	234,06E-9
10,0E+3	-112,56	2,36E-6	79,00E-9	-114,59	1,86E-6	62,49E-9	-113,74	2,06E-6	68,93E-9	-113,74	2,06E-6	68,97E-9	-112,36	2,41E-6	80,86E-9
30,0E+3	-126,13	493,86E-9	16,56E-9	-125,99	501,59E-9	16,82E-9	-126,44	476,49E-9	15,98E-9	-125,82	511,45E-9	17,15E-9	-121,22	869,36E-9	29,15E-9
100,0E+3	-133,30	216,30E-9	7,25E-9	-135,37	170,47E-9	5,72E-9	-133,55	210,23E-9	7,05E-9	-132,67	232,59E-9	7,80E-9	-127,63	415,29E-9	13,93E-9
300,0E+3	-141,85	80,85E-9	2,71E-9	-140,45	95,01E-9	3,19E-9	-141,44	84,75E-9	2,84E-9	-139,14	110,36E-9	3,70E-9	-130,92	284,58E-9	9,54E-9
1,0E+6	-140,83	90,89E-9	3,05E-9	-140,80	91,23E-9	3,06E-9	-142,86	71,92E-9	2,41E-9	-141,56	83,59E-9	2,80E-9	-133,60	208,98E-9	7,01E-9
10.0F+6	-142.05	79.00E-9	2.65E-9	-142.66	73.65E-9	2.47F-9	-141.00	89.18E-9	2.99E-9	-141.27	86.39E-9	2.90F-9	-135.29	172.07E-9	5.77E-9

Table 1 SDS824X HD_ND

These numbers are not totally accurate because it proves very difficult to place the markers close to the intended frequency without hitting a minor spur. Consequently, I would think that the noise level is fairly uniform across all the higher sensitivities from 500 μ V/div to 5 mV/div and the minima across all measurements would be the best representation of the truth:

Noise 500 μ V/div - 5 mV/div : 1 kHz : 232.9 nV/ \sqrt{Hz} 3 kHz : 174.2 nV/ \sqrt{Hz} 10 kHz : 62.5 nV/ \sqrt{Hz} 30 kHz : 16.0 nV/ \sqrt{Hz} 100 kHz : 5.7 nV/ \sqrt{Hz} 300 kHz : 2.7 nV/ \sqrt{Hz} 1 MHz : 2.4 nV/ \sqrt{Hz} 10 MHz : 2.5 nV/ \sqrt{Hz}

This made me suspicious: does Siglent cheat after all? Are all vertical gain settings below 5 mV/div just fake? First, I've checked the raw acquisition data for 500 μ V/div vertical gain and found the lowest voltage step to be 1.042 μ V.

Time [s]	Value [V]	Delta [V]
-4.000000000E-08	-4,166667E-05	5,208E-6
-3.950000000E-08	-4,166667E-05	000,000E+0
-3.900000000E-08	-4,270833E-05	[b] <mark>1,042E-6</mark> [/b]

The SDS800X HD has 480 LSB per vertical division (just like the SDS2000X HD), thus 3840 LSB on the visible part of the screen. Since a 12-bit acquisition system provides a total 0f 4096 LSB, there is very little headroom outside the visible screen area.

The interesting part is when we multiply the 1.042 μ V resolution with the 480 LSB of one division: 1.042 * 480 ~ 500 μ V/div; -> Bingo!

A less accurate, but quicker and simpler method to verify the resolution of the SDS800X HD is using vertical zoom; we can zoom into the noise in dots display mode, thus getting horizontal lines vertically spaced according to the true resolution of the instrument.

At a vertical gain of 500 $\mu V/div$ and a vertical zoom window at 2 $\mu V/div,$ we get the following picture:

🏟 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analysis	SIGLENT f < 2	Ready 0Hz	🗎 DISPLAY
1.500mV 1.000mV 0.500mV									
-0.500mV -1.000mV -1.500mV -2.000mV	-5.00ms	0.00ms	5.00ms	10.00ms	15.00ms	20.00ms	25.00ms	30.00ms	35.00ms 🗸 🗸
206.00uV									
204.00uV									
202.00uV									
200.00uV(
198.00uV									
194.00uV									
<mark>74</mark> 192 กกันV	-5.00ms	0.00ms	5.00ms	10.00ms		20.00ms	25_00ms	30.00ms	35.00ms 🚽
C4 DC 1X 500 FULL 0.0	:1M Z4 uV/ 5.00ms/ 2 00V 15.0ms	2.00uV/ 200uV	+			Т О 1	īmebase .00s 5.00ms/i 00Mpts 2.00GSa	Trigger div Auto a/s Edge	C4 DC ↓ ₩ -2.05mV Rising

Fig. 11 SDS824X_HD_Resolution_Demo

Since we still have 8 vertical divisions also in the zoom window, the total visible screen height covers 16 μ V at 2 μ V/div. We can count 15 horizontal lines, hence 16 steps and can conclude that each step has to be close to one microvolt.

Verdict: Siglent don't cheat. The uniform noise level at and below 5 mV/div is just a property of the integrated PGA (Programmable Gain Amplifier) used in this instrument.

DC Check

One of the advantages of a 12-bit DSO should be not only high resolution, but also good accuracy. The SDS800X HD has a typical error of 0.5% at vertical gain settings from 5 mV/div up to 10 V/div, thus entering 3.5-digit DMM territory.

Here are some checks with a 6 V DC "signal".

First the uninspired way: all default settings with the trace position at 0 V at the vertical center of the screen – we need 2 V/div vertical gain in this scenario:

🛱 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis SIGLENT f < 2.0	Auto Hz	🗎 C4	
8.00V				-					Channel	
4.00√ 2.00√ 2.00√								· · · ·	on Coupling DC BW Limit 20M	
-2.00V -4.00V									Probe 1X	>
- <u>8 NOV</u> -0.	500ms 0.0	00ms 0.500	ms 1.000m:	s 1.500ms	2.000ms	2.500ms	3.000ms 3.500r	ns	Label 4	
MEASURE Value Mean Min	Mean(* 6.0220 6.0250 8.0152	C4) — * 1193V 187848V 1942V	**	***	***		***		Apply To	
Max	6.0327	003V							Unit	
Pk-Pk	17.408	100mV							V	А
Count	416	991117							Deskew	Ċ
Histogram		al <mark>blatter</mark> ingen er						\bigcirc		0.00s
C4 DC 1X 2.00 20M 0.0							Timebase 0.00s 500us/div 10.0Mpts 2.00GSa/s	Trigger / Auto s Edge	C4 DC 0.00V Rising	∲ 84

Fig. 12 SDS824X_HD_DC_6V_G2V_0.42%

The Result is 6.025 V, this is a deviation of almost 0.42%. Now let's try something different instead:

🏟 Utility	🖵 Display 👖	i Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	is SIG	ENT Auto f < 2.0Hz	🗎 C4	
0.0014									Channel	
K HHV									on	off
5.00V									Coupling	
4.00V									DC	\sim
3.00V									BW/Limit	
0.004									20M	\sim
2.00V										
1.00V									Probe	
 0.00V									1X	
1.00v/ -0.5	500ms 0.000m	s 0.500ms	s 1.000ms	: 1 <i>5</i> 00ms	2 000ms	2.500ms	3 000ms	3 500ms	Label	lı>
MEASURE	Mean(C4)	- ***		***	***		***		4	
Value	6.0166942	V							AnnhiTa	
Mean	6.0172321	50V							Apply to	
Min	6.0151187	V								
Max	6.0191336	V				\rightarrow		<u> </u>	Unit	
Pk-Pk	4.014900n	ז∨							V	А
Stdev	725.217uV									<i>.</i>
Count	314								Deskew	0
Histogram	and the second secon	al Later a								0.00s
C4 DC1 1X 1.00 20M -3.00							Timebase 0.00s f 10.0Mpts 2.	Trigg 00us/div Auto 00GSa/s Edge	er C4 DC 0.00V e Rising	∲ ₩

Fig. 13 SDS824X_HD_DC_6V_G1V_0.29%

Now we've tried to better utilize the available dynamic range. We are able to get the entire range from 0 to 6 volts on the screen with a vertical gain of only 1 V/div, by dialing in an offset compensation of 3 V. The result tells us that we 're on the right track<. Just 0.29% deviation!

Of course we can do even better. Who says that the zero volts position need to be visible if we want to measure 6 volts? Our last attempt to accurately measure 6 volts uses a vertical gain of 100 mV/div together with an offset compensation of 6 volts. The resulting signal should be ideally zero. Deviation with regard to the vertical screen center.

The automatic measurements (always look at the mean value!) show 6.00485 V now, this is equivalent to a deviation of 0.081%!

🛱 Utility	🖵 Display	nî Acquire	🏲 Trigger	♯ Cursors	📐 Meas	🖻 Analys	is f < 2.0H	Auto z	🗎 C4	
e 200V									Channel	
0.3009									on	off
6.200V									Coupling	
6.100V									DC	\sim
<u>я даду,</u>				<u>+ + + + + + + + + + + + + + + + + + + </u>					BW Limit	
5.900V									20M	~
5 800V									Probe	h S
5 700\/									1X	
0.700×	C00 0.00	0	1.000	- 1 CDO	0.000	0.500	0.000 0.500		Label	li S
🥶 5 RAAV 🛛 -0.	.500ms 0.0L	uude.u smot	ms ruuum:	s r.ouuris	2.000ms	2.500ms	3.000ms 3.000m	is 🔻	4	112
MEASURE	Mean(C	C4) 7	***	***	***		***			
Value	6.0048	5086V							Apply To	
Mean	6.0048	523291V								
Min	6.0045	8514V							1.1	
Max	6.0051 500.04	08757				\rightarrow			Unit	
FK-FK Stdov	023.01	0000							V	A
Count	01.871 202	ouv							Deckew	Ċ.
Count	202								Deskeil	
Histogram		a state and a state of the stat								0.00s
C4 DC	1M						Timebase	Trigger	C4 DC	∲ ₩
1X 100n	זען ====						0.00s 500us/div	Auto	5.59V	
<u>nov</u> a e o							10 OMpto 2 00CColo	Edao	Distant	

Fig. 14 SDS824X_HD_DC_6V_G100mV_0.08%

In the end it had been demonstrated, that with the right method, the accuracy of a voltage measurement can approach that of an average $4-\frac{1}{2}$ digit DMM.

Peak Detect

The peak detection capability of the SDS800X HD is specified as 2 ns. Let's have a closer look at that.

First a 2 ns wide pulse with 300 mV amplitude and 500 ps rise time in normal acquisition mode at sufficient sample rate (2 GSa/s):

🏶 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	is SIGLENT f = 1.00001	Trig'd 3kHz	
	5.00me	0.00ms	5.00mc	10.00ms		20.00ms		30.00mc	
150.0mV 100.0mV 50.0mV 50.0mV -50.0mV -50.0mV -100.0mV -100.0mV	40 0 0 0	· · · · · · · · · · · · · · · · · · ·				· · · ·	- + + + + + + + + + + + + + + + + + + +		
MEASURE Value Mean Min Max Pk-Pk Stdev	Pk 284 284 284 284 286 2.0 364	-Pk(Z4) 4.3424mV 4.853631mV 4.0039mV 6.0286mV 124700mV 4.309uV	Amplituc 274.628 274.962 274.134 275.944 1.80990 424.800	ie(Z4) 9mV 969mV 1mV 0mV 0mV 0mV 0mV	+Width(Z4) 2.213ns 2.20941ns 2.200ns 2.215ns 15.00ps 2.72ps		10-90%Rise(Z4) 1.466ns 1.46337ns 1.454ns 1.454ns 1.475ns 21.00ps 4.42ps	 90-10%Fall(Z4) 1.346ns 1.34790ns 1.340ns 1.356ns 16.00ps 3.47ps 	
Count Histogram C4 DC 1X 50.0m FULL 0.0	14 IM Z4 IV 10.0ns/ 50 IV 0.00s	1 	141 	Ale han a shi da kana a sa a sa	141		141 Timebase 0.00s 5.00ms/div 100Mpts 2.00GSa/s	141 Trigger C4 DC Auto -100mV Edge Rising	 ∲ <mark>#</mark>

Fig. 15 SDS824X_HD_Pulse_W2ns_RT500ps_2GSa_Norm_Zoom

It can be seen that such a narrow pulse is already a bit too much for a 200 (244) MHz oscilloscope; the amplitude has already dropped a bit and pulse width measurement isn't quite accurate either. As expected, the rise time measurement approaches the scope's own rise time.

With all these shortcomings, we still get a fairly stable picture – look at the main window and the peak and standard deviations in the measurement statistics.

In the screenshot above, the time base was at 5 ms/div and the sample memory was already at its maximum of 100 Mpts; slowing down the time base any further will inevitably lower the sample rate:

📽 Utility	🖵 Displa	iy rîî ,	Acquire	🏲 Trigg	jer	# Cursors	📐 Meas	ধ	Analysis	SIC f	slent = 1.00001:	Trig'd 3kHz	🗎 C4	
	100,0mc,			199.0mc		200.0mc			0.0me	ا الموجسيات	 		 700 0	
150.0mV 100.0mV 50.0mV														
<mark>24</mark> 0.0,mY , , , -50.0mV -100.0mV								· · ·				Acquiring		
_200.0mV	200.0ns	-150.	.Ons	-100.0ns		-50.0ns	V.Ons	50	Ons	100.0	Dns 1	150.0ns	200.0r	1S
MEASURE		Pk-Pk(Z4	4)	— Am	plitude	e(Z4)	+Width(Z4)		- 10)-90%Ri	se(Z4)	= 90-10%	6Fall(Z4)	
Value		97.2135r	nV	80.	6445m	۱V	12.12ns		6.	62ns		6.69ns		
Mean		102.9094	164mV	86.	15414	5mV	12.2986ns		7.	3547ns		7.2647	ns	
Min		2.9753m	V	2.9	753m\	/	11.84ns		6.	46ns		6.40ns		
Max		>275.123	37mV	228	6.3411)	mV	17.48ns		11	.41ns		10.68n	s	
Pk-Pk		272.1484	100mV	223	3.3658	00mV	5.6400ns		4.	9500ns		4.2800	ns	
Stdev		88.53357	70mV	71.	75653	2mV	1.0240ns		1.	1858ns		1.0169	ns	
Count		47		47			31		44	1		44		_
Histogram			di da c			al calcol								
C4 DC1 1X 50.0m FULL 0.01	IM Z4 IV/ 50.0ns/ IV 0.00s	50.0mV 0.00	″, —						Ti 0. 10	mebase 00s)0Mpts	100ms/div 100MSa/s	Trigger Auto Edge	C4 DC -100mV Rising	∲ ₩

Fig. 16 SDS824X_HD_Pulse_W2ns_RT500ps_100MSa_Norm_Zoom

At 100 ms/div and 100 Mpts record length the sample rate has to be decimated to just 100 MSa/s – far too slow for capturing a 2 ns wide pulse. As a consequence, many pulses get lost. In the main window we would expect to see about 1000 pulses at a pulse repetition rate of 1 kHz, but there are actually much less and the amplitudes vary wildly.

This isn't a very realistic scenario; not many engineers would try to watch 2 ns wide pulses at a time base of 100 ms/div and have to use 2 million times zoom to watch the pulse details. Yet this is where Peak Detect acquisition mode comes into play:

🏶 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	is SIGLENT f = 1.00001	Trig'd I3kHz	🗎 C4	
100.00 5000.00 C4 -50008.00					· · · ·					-
<u>=1987-888% -</u> -	100.0mc	0.(<mark>ms::_</mark>	<u>-100.0ms:</u>	00.0ms	<u>- 300.0ms - 1</u>	<u>- 400.0ms</u> :	<u>- 500 0mc</u>	600.0ms		
150.0mV										
100.0mV 50.0mV					\wedge					
24 0.0mV								Acquiring		
-100.0mV								Peak Detect	t	
<u>-150.0mV</u> -200.0mV	200.0ns	_150.0ns	-100.0ns	-50.0ns		50.0ns	100.0ns	150.0ns	200.0ns	
MEASURE	Pł	-Pk(Z4)	- Amplitud	de(Z4)	+VVidth(Z4)		10-90%Rise(Z4)	90-10%F	all(Z4) —	
Value	26	9.9284mV	231.953	1mV	13.75ns		8.32ns	7.43ns		
Mean	27	1.369252mV	214.992	854mV	11.8411ns		6.4622ns	6.3979ns		
Min	22	:5.2539mV	167.760	4mV	10.96ns		5.77ns	5.69ns		
Max	>2	290.5208mV	234.563	8mV	14.25ns		8.72ns	8.36ns		
Pk-Pk	65	.266900mV	66.8034	00mV	3.2900ns		2.9500ns	2.6700ns	;	
Stdev	18	.595454mV	19.4960	54mV	724.Ups		626.2ps	505.4ps		
Count Histogram	41		41		41	1 II I	41 	41		\bigcirc
C4 DC 1X 50.0m FULL 0.0	1M Z4 1V/ 50.0ns/ 5 0V 0.00s	60.0mV/ —					Timebase 0.00s 100ms/div 100Mpts 100MSa/s	Trigger / Auto - Edge	C4 DC ↓ 100mV Rising	a

Fig. 17 SDS824X_HD_Pulse_W2ns_RT500ps_100MSa_Peak_Zoom

The main window now shows all the pulses; the amplitudes still vary a bit, but at least we don't miss any pulses anymore. Pulse shape has nothing to do with reality anymore and measurements yield just house numbers. This should be a clear warning to not use Peak Detect for anything serious, as any math and measurements on such waveforms are of artistical value at best.

All that Peak Detect really can do is to hint on any pulses within the record.

Of course, peak detection works for even narrower pulses just as well. This is not because the specification is not correct, but the simple fact that a 244 MHz DSO like the SDS824X HD simply cannot process even faster pulses:

🏟 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis SIGLENT	Trig'd 13kHz	ACQUIRE
	5.00ms	0.00ms	5.00ms	10 00ms	- 15 D0ms		25.00ms	30.00mc 35	00ms
150.0mV 100.0mV 50.0mV									
230.0m¥ -50.0m¥ -100.0m¥ -150.0m¥		· · · · ·					· · · · · · · · · ·		
<u>_200 0mV</u>	-40.0ns	-30.0ns	-20.0ns	-10.0ns	0.0ns	10.0ns	20.0ns	30.0ns 40	Ons
MEASURE	Pk	-Pk(Z4)	Amplituc	le(Z4)	+Width(Z4)		10-90%Rise(Z4)	90-10%Fall(Z	4) <u>–</u> X
Value	18-	4.0560mV	173.886	/mv 255	1.812NS		1.208ns	1.158NS	
Min	10	3.430400mm	173.192		1.8106905		1.20300ris	1.100330S	
May	18	0.0010mV 6.2174m\/	170.090	1m)/	1.80000s		1.130HS	1.144HS	
Pk-Pk	55	566400mV	5 31900	ΩmV	20.00ns		27 00ns	21 00ns	
Stdev	1.7	759383mV	1.71148	7mV	4.34ps		7.11ps	3.80ps	
Count	10	7	107		107		107	107	
Histogram			du du	da a sidada					\bigcirc
C4 DC 1X 50.0n FULL 0.0	1M Z4 nV/ 10.0ns/ 5 10V 0.00s	0.0mV/ 0.00V					Timebase 0.00s 5.00ms/div 100Mpts 2.00GSa/s	Trigger C4 / Auto -100i Edge Ris	DC 🛛 🖞 🛃 mV ing

Fig. 18 SDS824X_HD_Pulse_W1ns_RT500ps_2GSa_Norm_Zoom

This is now a 1 ns wide pulse at maximum sample rate of 2 GSa/s. The amplitude is still 300 mV, yet the SDS824X HD cannot cope with it anymore and the amplitude measurement result has dropped to just 173 mV. The pulse width is still measured as 1.8 ns, so the relative slowness of the frontend widens shorter pulses at the expense of amplitude, hence makes an even faster peak detection unnecessary.

History & Sequence Mode

Inspired by the complaint here:

https://www.eevblog.com/forum/testgear/rigol-hdo1000-and-hdo4000-12bit-oscilloscopeslaunched-in-china/msg5269170/#msg5269170

I've tried to replicate the fairly moderate test scenario described by forum member Egonotto. For this, the SDS800X HD doesn't need any special mode; the always active background history can handle that:



Fig. 19 SDS824X_HD_5ms_Hist

The test signal is a burst packet, 20 μ s long, consisting of 100 pulses. The repetition interval (burst period) was 5 ms for this test.

At 5 μ s/div, the SDS824X HD takes an average of 650 μ s/frame and a maximum of <2 ms/frame. The screenshot shows the History List displaying the time delta between the packets. It is 5 ms throughout, with the occasional 4.999 ms because of the not so accurate time base of the SDS800 (25 ppm vs. 1 ppm in the SDS2000X Plus/HD series).

For event recording, we'd rather use the dedicated Sequence mode. This provides a constant 52 μ s/trigger @ 5 μ s/div, hence can capture a burst period of 100 μ s without a single missing frame:



Fig. 20 SDS824X_HD_100us_Seq

The screenshot shows the History List displaying the time delta between the packets. It is 100 μ s throughout, with the occasional 99 μ s because of the not so accurate time base of the SDS800.

For complete information, here are my measurements for the trigger rates during normal use with vector and dots display mode as well as sequence recording from the fastest time base of 1 ns/div up to 100 μ s/div. The input signal was not optimized for this test.

				Vector		Dots		Sequence	
	RecLen	Tot. Mem		time/frm	Rate	time/frm	Rate	time/frm	Rate
TB [s/div]	[pts]	[pts]	Frames [-]	[s]	[frm/s]	[s]	[frm/s]	[s]	[frm/s]
1,00E-9	20,00E+0	1,60E+6	80000	124,45E-6	8,04E+3	124,29E-6	8,05E+3	32E-6	31,56E+3
2,00E-9	40,00E+0	3,20E+6	80000	78,57E-6	12,73E+3	72,64E-6	13,77E+3	16E-6	60,76E+3
5,00E-9	100,00E+0	8,00E+6	80000	60,49E-6	16,53E+3	44,40E-6	22,52E+3	7E-6	136,18E+3
10,00E-9	200,00E+0	16,00E+6	80000	54,15E-6	18,47E+3	34,18E-6	29,25E+3	4E-6	231,84E+3
20,00E-9	400,00E+0	32,00E+6	80000	52,54E-6	19,03E+3	29,62E-6	33,76E+3	3E-6	358,79E+3
50,00E-9	1,00E+3	45,98E+6	45976	34,22E-6	29,22E+3	8,43E-6	118,69E+3	2E-6	506,48E+3
100,00E-9	2,00E+3	91,95E+6	45976	46,40E-6	21,55E+3	14,06E-6	71,12E+3	2E-6	506,45E+3
200,00E-9	4,00E+3	92,84E+6	23209	74,99E-6	13,33E+3	66,01E-6	15,15E+3	3E-6	308,11E+3
500,00E-9	10,00E+3	103,70E+6	10370	144,08E-6	6,94E+3	136,76E-6	7,31E+3	6E-6	155,13E+3
1,00E-6	20,00E+3	110,02E+6	5501	233,08E-6	4,29E+3	226,93E-6	4,41E+3	12E-6	86,42E+3
2,00E-6	40,00E+3	117,00E+6	2925	412,59E-6	2,42E+3	408,07E-6	2,45E+3	21E-6	47,25E+3
5,00E-6	100,00E+3	117,00E+6	1170	641,09E-6	1,56E+3	643,44E-6	1,55E+3	52E-6	19,29E+3
10,00E-6	200,00E+3	117,60E+6	588	1,24E-3	807,51E+0	1,24E-3	807,51E+0	102E-6	9,78E+3
20,00E-6	400,00E+3	118,00E+6	295	1,72E-3	580,56E+0	1,73E-3	576,69E+0	202E-6	4,95E+3
50,00E-6	1,00E+6	117,00E+6	117	3,15E-3	317,73E+0	3,11E-3	321,58E+0	502E-6	1,99E+3
100,00E-6	2,00E+6	116,00E+6	58	5,64E-3	177,38E+0	5,64E-3	177,38E+0	994E-6	1,01E+3

Table 2 SDS824X HD Trigger rate

X-Y

As usual, X-Y mode is hardware accelerated with high waveform update rates and intensity or color grading.

An important property is the waveform update rate in X-Y acquisition mode and it shows that at faster time bases ($\leq 2 \mu s/div$) the trigger rate is even higher in X-Y mode than the corresponding 2-channel Y-t mode. The table below shows the trigger rates for various time base settings from 100 ns/div up to 1 ms/div and compares the trigger rates in regular dual channel Y-t mode to the X-Y mode:

Mode	X-Y		Display	default		SR [Sa/s]	1,0E+9	
		Trig. Y-t	Trig. X-Y	RecLen	time/frm Y·	Rate Y-t	time/frm X-	Rate X-Y
TB [s/div]	Signal [Hz]	[Hz]	[Hz]	[pts]	t [s]	[frm/s]	Y [s]	[frm/s]
100,00E-9	2,00E+6	17,40E+3	63,30E+3	1,00E+3	57,47E-6	17400,0	15,80E-6	63300,0
200,00E-9	1,00E+6	15,16E+3	51,10E+3	2,00E+3	65,96E-6	15160,0	19,57E-6	51100,0
500,00E-9	500,00E+3	10,80E+3	23,20E+3	5,00E+3	92,59E-6	10800,0	43,10E-6	23200,0
1,00E-6	200,00E+3	7,68E+3	12,09E+3	10,00E+3	130,21E-6	7680,0	82,71E-6	12090,0
2,00E-6	100,00E+3	4,83E+3	5,67E+3	20,00E+3	207,04E-6	4830,0	176,37E-6	5670,0
5,00E-6	50,00E+3	2,87E+3	2,45E+3	50,00E+3	348,43E-6	2870,0	408,16E-6	2450,0
10,00E-6	20,00E+3	1,64E+3	1,21E+3	100,00E+3	609,76E-6	1640,0	826,45E-6	1210,0
20,00E-6	10,00E+3	787,00E+0	546,00E+0	200,00E+3	1,27E-3	787,0	1,83E-3	546,0
50,00E-6	5,00E+3	384,00E+0	260,00E+0	500,00E+3	2,60E-3	384,0	3,85E-3	260,0
100,00E-6	2,00E+3	194,00E+0	112,00E+0	1,00E+6	5,15E-3	194,0	8,93E-3	112,0
200,00E-6	1,00E+3	28,70E+0	28,70E+0	2,00E+6	34,84E-3	28,7	34,84E-3	28,7
500,00E-6	500,00E+0	28,70E+0	19,20E+0	5,00E+6	34,84E-3	28,7	52,08E-3	19,2
1,00E-3	200,00E+0	19,23E+0	11,49E+0	10,00E+6	52,00E-3	19,2	87,03E-3	11,5

Table 3 SDS824X HD_XY_UpdateRate

The maximum speed at 100 ns/div was more than 63000 updates per second and X-Y mode limits the time base, so that it cannot get any faster than that. Up to 1 μ s/div, the update speed is always greater than 10000 per second and from there it scales as expected, i.e. the trigger speed is inversely proportional to the record length.

The figures stated above are valid for the full sample rate of 1 GSa/s, which also means record lengths of e.g. 10 Mpts at 1 ms/div. In other words, these numbers represent the worst case and X-Y operation could be accelerated by limiting the record length (thus also reducing the sample rate).

I want to show some examples, which also demonstrate the intensity and color grading. First a familiar Lissajous figure, and then some I/Q waveform patterns at 1 Mbps, which can also serve as a speed demonstration because of their complexity.



Fig. 21 SDS824X HD_Sine_1MHz_5MHz_45deg_IG



Fig. 22 SDS824X HD_QPSK_1Mbps_CG



Fig. 23 SDS824X HD_8PSK_1Mbps



Fig. 24 SDS824X HD_D8PSK_1Mbps_CG



Fig. 25 SDS824X HD_16QAM_1Mbps_CG

Aliasing

Let's have a look at aliasing with only one single channel active and 2 GSa/s.

Amplitude drop at 200 MHz is less than 2 dB and actual -3 dB bandwidth is 250 MHz. We can also see that in this configuration we have a very high protection against aliasing: >86 dB attenuation at the Nyquist frequency of 1 GHz is way more than enough even for a 12-bit acquisition system.

ŝŝ	Utility	🖵 Display	rîî Ac	quire 🏲	Trigger	# Cursors	📐 Meas	🖻 Analy	rsis f=1	ENT Trig'd 261.5804MHz	Ë	Tools
			F1N	Aarkers Lis	st					300.0n	Narke	er
			Mark	er Abs	s.Ampl.	Abs.Freq.	Delta Ar	npl. C	Delta Freq.	200.04	5	<u> </u>
			1	-1	3.659dBV	1.00000Mł	Ηz				Show	Markor
			2	-1	3.741dBV	10.00000Mi	Hz -0.08	32dBV	9.00000MHz			Marker
C4N-			3	-1	4.013dBV	100.00000Mł	Hz -0.35	55dBV 9	9.00000MHz	0,0n	n <mark>y</mark> on	off
647			4	-1	5.572dBV	200.00000MH	Hz -1.91	3dBV 19	9.00000MHz			ency C
			5	-1	6.684dBV	251.50000M	Hz -3.02	25dBV 25	50.50000MHz		IX Troque	
										-200.0n	nV 💷	
										-300.0n	1.V Nevt P	eak
	-1	00us 0.1)Ous	r.uuus	2.00US	a.upus	4.upus	5.UUUS	b.UUUS	7.00us	T NOAL T	our
cto 📰		-	4 5									
			~					S	a= 2.00GSa	/s ~ -20.0df	BV Next A	mplitude
								Λ N	un – 10504pt f= 122.07kH	5 7 00040	201	
•••••								R	BW= 455.32	-30.000 2kHz	ρ.y.	
							~			-40.0dl	BV D	Return
										50.QdB	3V	
										-60 OdF	RV	
										70.0 //		
										-/U.Udi	5.V.	
										-80.64	34	
	10	0.0MHz 20	0.0MHz	300.0MHz	400.0MH	z 500.0MHz	600.0MHz	700.0MHz	800.0MHz	900.0MHz		
C4	DC	1M F1	FFT(C4)						Timebase	Trigge	er C4 I	DC 🛛 🐺
1X	100n	י	0.0dBV/						0.00s 1	.00us/div Auto	0.00	VC
FUL	L 0.0	0V -	10.0dBV						20.0kpts 2.	00GSa/s Edge	Risi	ng

Fig. 26 SDS824X_HD_FR_2GSa

Here is the aliasing situation with two channels active and 1 GSa/s:



Fig. 27 SDS824X_HD_Aliasing_1GSa

Math trace F1 (orange) shows the frequency response in the first Nyquist zone (0-500 MHz), whereas reference trace A (yellow) represents the 2nd Nyquist zone (500 MHz to 1 GHz). Siglent SDS800X HD Evaluation Rev. 1.00 Page 29 Reference Level is about -13 dBV and the attenuation at the Nyquist frequency of 500 MHz is only ~23 dB, but is dropping reasonably fast at even higher frequencies. We get >-40 dBc at 750 MHz. For any practical signals applied to a DSO in this class the spectrum shouldn't be that aggressive, hence users will rarely experience aliasing artifacts.

Finally, the aliasing with more than two channels active, when the sample rate drops to just 500 MSa/s:



Fig. 28 SDS824X_HD_Aliasing_500MSa

Math trace F1 (orange) shows the frequency response in the first Nyquist zone (0-250 MHz), whereas reference trace B (magenta) represents the 2nd Nyquist zone (250 - 500 MHz). Reference trace C (violet) represents the 3rd Nyquist zone (500 - 750 MHz) and finally reference trace D (green) plots the 4th Nyquist zone (750 MHz – 1 GHz). Reference Level is about -13 dBV and the attenuation at the Nyquist frequency of 250 MHz is only ~11 dB, but is dropping pretty fast beyond that. We get -34 dBc at 325 MHz.

Noise

Noise & Spurs

This is a demonstration of the noise with all channels active, where the bandwidth is limited to true 200 MHz.

The noise is shown for various conditions:

Ch.1: input open, 200 MHz bandwidth; Ch.2: input open, 20 MHz bandwidth; Ch.3: input 50 ohm terminated, 200 MHz bandwidth; Ch.4: input 50 ohm terminated, 20 MHz bandwidth;

Because of the pronounced 1/f characteristic of the frontend noise below about 300 kHz, the results strongly depend on the lower bandwidth limit. Let's start with 100 kHz:

🏟 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analy:	sis SIGLENT f < 2.0H	Auto z	MATH
F4 -60.0dBV							Sa= 50 Curr=4	0.00MSa/s 096pts	
-80.0dBV							ΔΙ= 12 RBW=	2.07kHz 455.32kHz ~	
-100.0dBV							Avy- n	0	
-120.0dB					×			and the second	water water and the second
-140.0dBV								and a second	and the second
-160.0dBV									
-180.0dBV									
-200 0dRV				10MHz				100MH:	z
MEASURE	Sto	lev(C1)			Stdev(C3)		Stdev(C4)	- ***	
Value	36.	.3437uV	16.944	βuV	40.1297uV		17.0822uV		
Mean	37.	.974771uV	19.104	465uV	40.879241u	/	16.831157uV		
Min	35.	5999uV	15.726	3uV	39.8108uV		15.7414uV		
Max	53.	.6430uV	31.055	4uV	42.1164uV		19.3649uV		
Pk-Pk	18.	.043100uV	15.329	100uV	2.305600uV		3.623500uV		
Stdev	2.2	17588uV	2.5101	61uV	475.082nV		662.307nV		
Count	101	1	101		101		101		
Histogram	<u>i</u>	н <mark>и</mark> ни	<u>.</u> "I ^{III} I	 	<u> </u>	udhal kan ta ca	a allel b al		\bigcirc
C4 DC1	M E1 FF	FT(C1) F2	FFT(C2)	B FFT(C3)	F4 FFT(C	4)	Timebase	Trigger (C4 DC 🛛 🖞 🏭
1X 1.00m 20M 0.00	V/ 20. DV <u>-40</u>	0dBW .0dBV	20.0dBV/ -40.0dBV	20.0dBV/ -40.0dBV	20.0dB -40.0dE	V/ << >> 3V	0.00s 1.00us/div 5.00kpts 500MSa/s	Auto (Edge F).00V Rising

Fig. 29 SDS824X_HD_Noise_100kHz-200MHz_4Ch

Compare this with 10 kHz lower bandwidth limit:

🏶 Utility	🖵 Display	m Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis SIGLENT	Auto Iz	I MATH
F4 -60.0dBV							Sa= 5 Curr= 3	00.00MSa/s 32768pts	
-80.0dBV							- − 13 RBW= Ava= 1	56.92kHz 6	
-100.0dBV									
			and the second						
-140.0dBV									
-160.0dBV									
-180.0dBV									
-200 NdRV				10MHz				100MH	z
MEASURE	St	dev(C1)			Stdev(C3)		Stdev(C4)	- ***	
Value	48	.3298uV	21.9412u	V	42.0651uV		18.9863uV		
Mean	43	.938511uV	28.25762	3uV	42.886975u\		21.082598uV		
Min	37	.6927uV	19.9293u	V	40.9965uV		17.1383uV		
Max	57	.8971uV	51.4374u	V	50.8904uV		32.6893uV		+
Pk-Pk	20	.204400uV	31.50810	0uV	9.893900uV		15.551000uV		
Stdev	4.()54570uV	5.254011	uV	1.675920uV		2.922002uV		
Count	11	5	115		115		115		
Histogram			يون م	kanakan n		<u> </u>	nta line i i i i		Q
C4 DC1	IM F1 FI	FT(C1) F2	FFT(C2) F3	FFT(C3)	F4 FFT(C4	I)	Timebase	Trigger	C4 DC 🛛 🜵 🏪
1X 1.00m 20M 0.01	N/ 20 DV -40	.0dBV/).0dBV	20.0dBV/ -40.0dBV	20.0dBV/ -40.0dBV	20.0dB\ -40.0dB	// << >> V	0.00s 10.0us/div 50.0kpts 500MSa/s	Auto Edge f	0.00V Rising

Fig. 30 SDS824X_HD_Noise_10kHz-200MHz_4Ch

1 kHz lower bandwidth limit:

🏟 Utility	🖵 Display	nî Acquire	🏲 Trigge	r # Cursors	📐 Meas	🖻 Analys	515 SIGLENT f < 2.0H	Auto z	MATH
F4 -60.0dBV							Sa= 50 Curr= 2	0.00MSa/s 62144pts	
-80.0dBV							RBW= Avg= 16	7.11kHz 6	
-100.0dBV									
- 140 OdBV	and the second secon	urre and an internet							
-160.0dBV									
-200 NdBV				10MHz				100MHz	
MEASURE	St	dev(C1)			Stdev(C3)		Stdev(C4)	- ***	
Value	47	'.9537uV	35.78	324uV	45.1191uV		26.2973uV		
Mean	47	7.654626uV	34.54	12314uV	45.656531u\	/	26.096886uV		
Min	42	2.0072uV	27.16	522uV	42.2493uV		18.9686uV		
Max	55).3946uV	50.83	330uV	51.60070V		37.5539uV		
FK-FK Stdev	10	227250.J/	23.0	706000V 5480047	1.442012iA/		2 665757uV		
Count	92	20072000¥ 26	926	940000	926		926		
Histogram		in the second				Markenson	and Market Lawrence		0
C4 DC1 1X 1.00m 20M 0.00	M F1 F V/ 20 JV -4	FT(C1) F2).0dBV/ 0.0dBV	FFT(C2) 20.0dBV/ -40.0dBV	F3 FFT(C3) 20.0dBV/ -40.0dBV	F4 FFT(C4 20.0dB -40.0dB	4) // << >> V	Timebase 0.00s 100us/div 500kpts 500MSa/s	Trigger C ² Auto 0.1 Edge Ris	IDC 🛛 🜵 🍇 DOV sing

Fig. 31 SDS824X_HD_Noise_1kHz-200MHz_4Ch

Finally, 200 Hz lower bandwidth limit:

🏟 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analy	sis SIC	GLENT f < 2.0H	Auto z	₿ N	1ATH
F4 -60.0dBV -80.0dBV								Sa= 50 Curr= 2 ∆f= 23 RBW= Avg= 1	00.00MSa/ 097152pt: 8.42Hz 889.30Hz 6	/s 5	
-120.0dBV							+ + + +				
-160.0dBV		· · · · · · · ·		10MHz				edition i ref i re	100	MH7	
MEASURE	Sto	dev(C1)		2)	Stdev(C3)		Stdev(C4)		- ***		
Value	49.	.0574uV	34.4004u	ιν Vi	46.4748uV		27.2725u\	/			
Mean	48.	.353819uV	35.44932	21uV	46.116658u\	V	27.191267	7uV			
Min	44.	.7619uV	30.9390.	JV	44.1680uV		24.0297u\	/			
Max	53.	.8309uV	43.4320u	VL.	49.1668uV		32.6127u\	/		\rightarrow	
Pk-Pk	9.0	169000uV	12.49300)OuV	4.998800uV		8.583000	ιV			
Stdev	1.2	44870uV	1.722334	1uV	804.105nV		1.394935	ιV			
Count	46	1	461		461		461				-
Histogram		and the state of the	الانساسين	hanna an	ينه الملكين المراجد	dili dan aran a	a state of the second	a blanca and			\bigcirc
C4 DC1 1X 1.00m 20M 0.00	IM F1 FF IV/ 20. IV -40	T(C1) F2 .0dBV/ .0dBV	FFT(C2) F3 20.0dBV/ -40.0dBV	FFT(C3) 20.0dBV/ -40.0dBV	F4 FFT(C 20.0dB -40.0dE	4) V/ << >> 3V	Timebase 0.00s 2.50Mpts	500us/div 500MSa/s	Trigger Auto Edge	C4 D 0.00 Risir	c ∲∰ V Ig

Fig. 32 SDS824X_HD_Noise_200Hz-200MHz_4Ch

Here you can see the noise characteristic up to 25 MHz at a RBW of ~90 Hz. In order to prevent aliasing taking effect, the noise measurement has been done on a 20 MHz bandwidth limited input channel. Since this bandwidth limiter is only first order, a digital 30 MHz lowpass filter has been added.

🏟 Utility	🖵 Display	m Acquire	e 🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis SI	GLENT f < 2.0H	Auto z	Ë	MATH
F4						Sa	a= 50.00N	/ISa/s		Trace	e
-89.8dBV							irr= 20971 23.84H	52pts		Fund	ction4 🗸 🗸
-99.8dBV						RE	3W= 88.9	3Hz		Oner	ati∩n
	3					Av	g= 16			opon	off
Stop oddy	$\rightarrow \gamma \rightarrow \gamma$	Inna 1								U	UII
-119.8dBV			444 5							Funct	ion
-129.8dBV			"WM							FFT(Filter(C4))
-139.8dBV				All	7					Filter	Config II>
-149.8dBV					all and a second second						
1000-	100	າດມ≁	101/11-7		100/44	ing horn distances a mit	1014Httelsen			Confi	~ IIN
	Etdou/C		Steley (CD)	Etdou (CD)		deu (C4)	50K112		i en anna an	COIIII	y "/
Value	48 8116	SuV	36 4934uV	42 9501u) – 51 J – 26	uev(C4) 3 4517nV		F4 Marke	rs List		
Mean	48.7702	281uV	35.091091uV	43.577968	, 25 3uV 27	7.101726uV		Marker	Abs.Am	pl.	Abs.Frea.
Min	46.6587	7uV	32.5798uV	41.9473u\	/ 25	5.7343uV		1	-108.28	1dBV	100.00000Hz
Max	78.8518	3uV	38.4514uV	45.0703u\	/ 30).0732uV		2	-111.66	5dBV	300.00000Hz
Pk-Pk	32.1931	100uV	5.871600uV	3.123000	JV 4.3	338900uV		3	-111.08	3dBV	1.00000kHz
Stdev	2.96342	23uV	980.199nV	498.327n\	/ 69	31.443nV		4	-116.03	4dBV	3.00000kHz
Count	220		220	220	22	20		5	-125.30	3dBV	10.00000kHz
Histogram	<u>, 1</u>		والمتلك والمتلك والمسترك		da	يعايالات		6	-135.92	7dBV	30.00000kHz
- instogram	<u></u>	<u> </u>			Marillan			7	-144.22	7dBV	100.00000kHz
C1 DC1	IM C2	DC1M C3	DC1M C4	DC1M	F4 FFT(F	ilt	Timebasi	8	-150.89	4dBV	300.00000kHz
1X 1.00m FULL 0.0	₩ 1X 1. 0V 20M	00mV/ 1X 0.00V FULL	1.00mV/ 1X 0.00V 20M	1.00mV/ 0.00V	10.0c -79.8	IBV/ << >> dBV	0.00s 5.00Mpts	5.00ms/div 100MSa/s	Auto Edge	U.U Ris	sing

Fig. 33 SDS824X_HD_Noise_20Hz-25MHz_4Ch_F30M Siglent SDS800X HD Evaluation Rev. 1.00 The Noise characteristic is a combination of the 1/f noise of the MOSFET input buffer in the HF path and the FET OpAmp in the LF path, which is fed with a heavily attenuated signal that has to be amplified again before the recombination of both paths.

We can clearly see this in the previous screenshot:

At 300 kHz, the measured noise level is -150.894 dBV, this corresponds to a noise density of just 3 nV/ \sqrt{Hz} at a RBW of 89 Hz. The following table shows the complete measurements:

300 kHz:	-150.894 dBV	3.0 nV/√Hz
100 kHz:	-144.227 dBV	6.5 nV/√Hz
30 kHz:	-135.927 dBV	16.9 nV/√Hz
10 kHz:	-125.303 dBV	57.5 nV/√Hz
3 kHz:	-116.034 dBV	167.2 nV/√Hz
1 kHz:	-111.083 dBV	295.6 nV/√Hz
300 Hz:	-111.665 dBV	276.5 nV/√Hz
100 Hz:	-108.281 dBV	408.2 nV/√Hz

At 10 MHz, the noise density has dropped to about 2.4 nV/ \sqrt{Hz} .

Finally let's have a look at the spurious signals (CH.4, 50 Ω termination, 20 MHz bandwidth limit):

🏟 Utility	🖵 Display	y កា Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	is SIGU	ENT f < 2.0H	Auto Iz	Ë	MATH
F1								Sa= 50 Curr= 2	00.00MSa 2097152pt 8.42H 7	a/s ts	-40.0dBV
								RBW=	889.30Hz	<u>z</u>	-60.0dBV
								Avg= 1	6		-80.0dBV
2-++-											-100,0dBV
13 46 7	8		9							10	-120.0dBV
			dh.								-140.0dBV
and the second									alk and the off		160,0dBV
								and a distance of the local distance of the	State of the local division of the local div	a los real and a los	
	25.0MHz	50.0MHz	75.0MHz	100.0MHz	125.0MHz	150.0MHz	175.0M	Hz 2	200.0MHz	22	25.0MHz
MEASURE	25.0MHz	50.0MHz Stdev(C1)	75.0MHz Stdev(C	100.0MHz :2)	129.0MHz Stdev(C3)	150.0MHz	175.0M Stdev(C4)	Hz 2	200.0MHz	22	25.0MHz
MEASURE Value	25.0MHz 5 2	50.0MHz Stdev(C1) 16.24835uV	75.0MHz Stdev(C 33.2474	100.0MHz :2) 1uV	125.0MHz Stdev(C3) 42.16366uV	150.0MHz	175.0M Stdev(C4) 25.54949uV	Hz 2 F1 Pea	200.0MHz aks List	22	2\$.0MHz
MEASURE Value Mean	25.0MHz 5 2 2	50.0MHz 6tdev(C1) 16.24835uV 17.8763646uV	75.0MHz Stdev(C 33.2474 34.0237	100.0MHz 2) 1uV 110uV	125.0MHz Stdev(C3) 42.16366uV 42.6781756u	150.0MHz uV	175.0M Stdev(C4) 25.54949uV 26.3198724	Hz : F1 Pea Peak	200.0MHz aks List Amplitu	22 Ide	25.0MHz
MEASURE Value Mean Min	25.0MHz	50.0MHz Stdev(C1) 16.24835uV 17.8763648uV 15.52791uV	75.0MHz Stdev(C 33.2474 34.0237 29.6371	100.0MHz 2) 1uV 110uV 2uV	125.0MHz Stdev(C3) 42.16366uV 42.6781756u 40.93622uV	150.0MHz uV	175.0M Stdev(C4) 25.54949uV 26.3198724 23.09987uV	Hz 2 F1 Pea Peak 1	200.0MHz aks List Amplitu -122.76	22 ide 37dBV	25.0MHz Frequency 499.48692kHz
MEASURE Value Mean Min Max	25.0MHz	50.0MHz Stdev(C1) 16.24835uV 17.8763646uV 15.52791uV 14.13653uV	75.0MHz Stdev(C 33.2474 34.0237 29.6371 37.8505	100.0MHz 2) 1uV 110uV 2uV 5uV	125.0MHz Stdev(C3) 42.16366uV 42.6781756u 40.93622uV 44.63494uV	150.0MHz 	175.0M Stdev(C4) 25.54949uV 26.3198724 23.09987uV 29.70275uV	Hz S F1 Pea Peak 1 2	200.0MHz aks List Amplitu -122.76 -108.30	22 ide 37dBV 33dBV	25.0MHz Frequency 499.48692kHz 1.14155MHz
MEASURE Value Mean Min Max Pk-Pk	25.0MHz	50.0MHz 5tdev(C1) 16.24835uV 17.8763646uV 15.52791uV 34.13653uV 3.6086200uV	75.0MHz Stdev(C 33.2474 34.0237 29.6371 37.8505 8.21343 1.5555	100.0MHz 2) 1uV 110uV 2uV 5uV 00uV	1250MHz Stdev(C3) 42.16366uV 42.6781756u 40.93622uV 44.63494uV 3.6987200uV	150.0MHz 	175.0M Stdev(C4) 25.54949uV 26.3198724 23.09987uV 29.70275uV 6.6028800u	Hz 2 F1 Pea Peak 1 2 3	200.0MHz aks List Amplitu -122.76 -108.30 -121.47	22 ide 37dBV 33dBV 3dBV	25.0MHz Frequency 499.48692kHz 1.14155MHz 2.28333MHz
MEASURE Value Mean Min Max Pk-Pk Stdev	25.0MHz	50.0MHz 5tdev(C1) 16.24835uV 17.8763646uV 15.52791uV 34.13653uV 3.6086200uV .1921176uV	75.0MHz Stdev(C 33.2474 34.0237 29.6371 37.8505 8.21343 1.45922	100.0MHz 2) 1uV 110uV 2uV 5uV 00uV 54uV	12€0MHz Stdev(C3) 42.16366uV 42.6781756u 40.93622uV 44.63494uV 3.6987200uV 736.5274nV	150.0MHz 	175.0M Stdev(C4) 25.54949uV 26.3198724 23.09987uV 29.70275uV 6.6028800u 1.3466127u	Hz 2 F1 Peak Peak 1 2 3 4	200.0MHz aks List Amplitu -122.76 -108.30 -121.47 -130.42	22 ide)7dBV)3dBV '3dBV 20dBV	25.0MHz Frequency 499.48692kHz 1.14155MHz 2.28333MHz 3.42488MHz
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MEASURE Value Mean Min Max Pk-Pk Stdev Count Histogram	25.0MHz 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	50.0MHz 50.0MHz 6.24835uV 17.8763646uV 15.52791uV 15.52791uV 16.086200uV 1921176uV 15 0.0086200uV 15 0.000UV 15 0.001M 0.03 0.000UV 12 0.001V 12	75.0MHz Stdev(C 33.2474 34.0237 29.6371 37.8505 8.21343 1.45922 115 0.1M C 500uv/ 12 2.900(200)	100,0MHz 2) 1uV 110uV 2uV 5uV 00uV 54uV 100uV 60uV 60uV 100uV 100uV 100uV 100uV 100uV 100uV 100uV	125.0MHz Stdev(C3) 42.16366uV 42.6781756u 40.93622uV 44.63494uV 3.6987200uV 736.5274nV 115 F1 FFT(C 20.0dB	150 .0MHz J√ √	175.0M Stdev(C4) 25.54949uV 26.3198724 23.09987uV 29.70275uV 6.6028800u 1.3466127u 115 Timebase 230ns 4 230ns 4	Hz : F1 Peak 1 2 3 4 5 6 7 8 9	200.0MHz aks List Amplitu -122.76 -108.30 -121.47 -130.42 -131.12 -127.29 -129.03 -129.03 -131.05	22 ade 37dBV 33dBV 33dBV 20dBV 20dBV 24dBV 11dBV 15dBV 39dBV	25.0MHz Frequency 499.48692kHz 1.14155MHz 2.28333MHz 3.42488MHz 4.56667MHz 5.70822MHz 12.55870MHz 24.00017MHz 72.00027MHz

Fig. 34 SDS824X_HD_Spurs_200Hz-200MHz_4Ch

The Peaks List shows the 10 strongest spurious signals, where all are at or below 1 μV_{RMS} , except for a single spur at 1.14155 MHz, which is 3.85 μV_{RMS} . This is exceptionally good, especially in this class.

Noise Density (1/f)

In my previous test I've used a constant sample rate of 100 MSa/s, which allowed a 2 Mpts FFT with an effective FFT-sample rate of 50 MSa/s and $\Delta f = 23.84$ Hz. This was required, since the FFT in the SDS800X HD is limited to 2 Mpts max. and I wanted to measure the 1/f noise down to at least 100 Hz. As a consequence, I had to set up the FFT in a way that I get a frequency step (Δf) well below that.

Of course, if we want any accuracy in the spectrum plot, the Flattop window has to be used, and the RBW is $\Delta f * 3.73$ in case of Siglent's version of the Flattop Window.

Because of the low sample rate of just 100 MSa/s for the acquisition, there will inevitably be aliasing, folding back all the noise above 50 MHz to the first Nyquist zone. Then there will be even more aliasing because the FFT introduces one more decimation step, from 100 to 50 MSa/s. The latter could be countered by a digital filter, but it doesn't make that much of a difference anymore.

All this does not matter much as long as we are mainly interested in the 1/f noise below about 300 kHz, because it is much stronger than the high frequency noise anyway.

Now we want to see the real noise density up to 10 MHz without any aliasing spoiling our measurements. For this we can activate all channels, thus reducing the input bandwidth to a well-defined 200 MHz and engage the 20 MHz bandwidth limiter on top of that, so that we can be absolutely sure that there will be no aliasing products of any significance affecting the measurement at 10 MHz.



Fig. 35 SDS824X HD_ND_1mV_20MHz_500MSa

Calculation for 10 MHz: -144.58 dBV = 59 nV_{RMS}. The noise density at this point is 59 nV / $\sqrt{889.3}$ Hz = 59 nV / 29.8 = 1.98 nV/ \sqrt{Hz} ;

Here is the complete table:

	±	
10 MHz:	-144.58 dBV	2.0 nV/√Hz
3 MHz:	-142.48 dBV	$2.5 \text{ nV}/\sqrt{\text{Hz}}$
1 MHz:	-141.88 dBV	2.7 nV/√Hz
300 kHz:	-141.55 dBV	2.8 nV/√Hz
100 kHz:	-131.63 dBV	8.8 nV/√Hz
30 kHz:	-125.49 dBV	17.8 nV/√Hz
10 kHz:	-113.34 dBV	72.2 nV/√Hz
1 kHz:	-101.97 dBV	267.2 nV/√Hz

With a noise density near 2 nV/ \sqrt{Hz} , the Siglent SDS824 X HD beats most of the competition at higher frequencies, whereas the 1/f noise is nothing to write home about, but that has to do with the special split path input buffer design with its enormous offset compensation capability (±8 V starting at only 10.2 mV/div!).

PS: Of course, the above measurement was flawed, because the 20 MHz bandwidth limiter affects the 10 MHz measurement. The actual noise density, measured without bandwidth limit at 10 MHz is 2.4 nV/ $\sqrt{\text{Hz}}$, just as it was stated in the first test.



Fig. 36 SDS824X HD_ND_1mV_200MHz_500MSa

Here is the updated noise density table:

	1	5
10 MHz:	-144.58 dBV	2.4 nV/√Hz
3 MHz:	-142.48 dBV	$2.5 \text{ nV}/\sqrt{\text{Hz}}$
1 MHz:	-141.88 dBV	2.6 nV/√Hz
300 kHz:	-141.55 dBV	2.9 nV/√Hz
100 kHz:	-131.63 dBV	6.0 nV/√Hz
30 kHz:	-125.49 dBV	16.0 nV/√Hz
10 kHz:	-113.34 dBV	68.8 nV/√Hz
1 kHz:	-101.97 dBV	247.0 nV/√Hz
A noise density of <2.4 nV/ \sqrt{Hz} is still one of the best in the industry.

Attached is the binary data file for this measurement.

SDS824X_HD_Binary_C4_3.7z Channel 4, 1 mV/div, 50 ohms terminated; 500 µs/div, 2.5 Mpts, 500 MSa/s; Full Bandwidth;

Noise Density

This time I've decided to put not so much weight on the 1/f noise at really low frequencies, but do a flawless measurement where we can rule out any aliasing artefacts affecting the numbers.

I used only a single channel (Ch. 4), hence a sample rate of 2 GSa/s, which permits a 2 Mpts FFT with an effective FFT-sample rate of 2 GSa/s and Δf = 953.67 Hz, resulting in 3.56 kHz RBW with the Flattop window. This allows us to measure the 1/f noise down to at least 10 kHz and guarantees full accuracy up to 1 GHz.

Now we want to measure the real noise density up to 100 MHz without any aliasing spoiling our results.



Fig. 37 SDS824X_HD_ND_2GSa_1mV

Calculation for 10 MHz (I've used 9.9 MHz to escape a micro-spur): -137.35 dBV = 135.68 $nV_{\text{RMS}}.$

The noise density at this point is 135.68 nV / $\sqrt{3560}$ Hz = 135.68 nV / 59.66 = 2.27 nV/ \sqrt{Hz} ;

Here is the complete table:

100 MHz:	-137.73 dBV	2.18 nV/√Hz
10 MHz:	-137.35 dBV	2.27 nV/√Hz
3 MHz:	-136.64 dBV	2.47 nV/√Hz
1 MHz:	-136.54 dBV	2.50 nV/√Hz
300 kHz:	-135.01 dBV	2.98 nV/√Hz
100 kHz:	-128.72 dBV	6.14 nV/√Hz
30 kHz:	-120.57 dBV	15.70 nV/√Hz
10 kHz:	-104.51 dBV	99.67 nV/√Hz

We are getting pretty close to 2 nV/ \sqrt{Hz} at frequencies of 10 MHz and higher.

Granular Noise

This time we shall have a look at the granular noise of the 12-bit SDS800X HD. At high sensitivities like 1 mV/div, we cannot expect much of an advantage from the 12 bits, but at low sensitivities like 50 mV/div and higher, the 12 bits should clearly give us a benefit.

I used only a single channel (Ch. 4), hence a sample rate of 2 GSa/s, which permits a 2 Mpts FFT with an effective FFT-sample rate of 2 GSa/s and Δf = 953.67 Hz, resulting in 3.56 kHz RBW with the Flattop window. This allows us to measure the noise down to at least 10 kHz and guarantees full accuracy up to 1 GHz.



Fig. 38 SDS824X_HD_ND_2GSa_1V

There's little point in calculating the traditional noise density (which would have to be specified in hundreds of nanovolts or even single digit microvolts per \sqrt{Hz}), but we should consider the full-scale value of +9 dBV in this test scenario.

We get a SNR of >110 dB at 100 MHz with a RBW of 3.56 kHz.

You can download a 100 Mpts binary file for this test scenario:

SDS824X HD Channel 4, 1V/div, 50 ohms terminated; 5 ms/div, 100 Mpts, 2 GSa/s; Full bandwidth = 245 MHz;

SDS824X HD_Noise_1V_1ms_2GSa_245MHz

Display

Vertical Zoom Demo

Vertical zoom can suffer from noise, if high zoom factors are used. Some demonstrations use bandwidth limits to reduce noise when zooming in. It is in the responsibility of the user then to make sure that no relevant high frequency detail gets lost by this.

In general, the question remains: what if we need to look at higher frequencies? A 200 MHz 12bit DSO should be able to demonstrate a resolution advantage with 200 MHz bandwidth signals just as well...



Here is the signal mix: a 1 MHz 600 mV_{PP} sine with a 200 MHz 10 mV_{PP} sine riding on it:

Fig. 39 SDS824X_HD_VZ10x_Run

I've chosen straight 10 mV/div for the zoom window, i.e. a ten times magnification. The superimposed waveform is a little noisy, yet clearly visible.

This is run mode. In stop mode, we can see that all the noise is rather low frequency and lowering the bandwidth wouldn't help anyway:



Fig. 40 SDS824X_HD_VZ10x_Stop

In stop mode we basically get a clean waveform with some distortion. Yet this is just 12 bits without any additional tricks.

We can use the average math function to get rid of noise and modulation:



Fig. 41 SDS824X_HD_VZ10x_Avg16 Siglent SDS800X HD Evaluation Rev. 1.00

16 times average (Math trace F1) is enough to get the waveform pretty clean also in run mode. The implicit resolution enhancement of this measure is 4 bits, so that the DSO is effectively working with 16-bit data now.

Vertical axis labels

The new kids in town like the SDS800X HD also bring new features: apart from the logarithmic frequency axis for the FFT, as demonstrated in the noise measurements, we also got a selectable vertical label position.



Fig. 42 SDS824X_HD_VLabel_left



Fig. 43 SDS824X_HD_VLabel_right



Fig. 44 SDS824X_HD_VLabel_center

Zoom Expectations

When using a 12-bit DSO, some people tend to get enthusiastic and expect miracles. Maybe we all should come back to earth and ask ourselves what we can realistically expect.

Consider a signal that has to be viewed at a vertical gain of 1 V/div in order to fit on the screen:



Fig. 45 SDS824X HD_PR_H50ns_Stop

Now we want to zoom in, e.g. 5x:



Fig. 46 SDS824X HD_PR_H50ns_Stop_Zoom5

We already see a bit of noise creeping in. Apart from that, we should determine how much zoom is feasible, before we try to zoom in any further:

Just like the SDS800X HD, an SDS1000X HD will have 480 LSB (aka codes) per division. Consequently, 20x zoom is about the sensible limit, because then we get 24 LSB per division – and with this, there would still be a chance to see something meaningful. 20x zoom means 1 V / 20 = 50 mV/div:



Fig. 47 SDS824X HD_PR_H50ns_Stop_Zoom20

Now the noise is stronger and it already gets hard to spot any details. Yet we can take it to the extreme and try 100x zoom:



Fig. 48 SDS824X HD_PR_H50ns_Stop_Zoom100

We are now at 4.8 codes per division and what we see is just (mostly granular) noise – all this has nothing to do with the real signal anymore. Most obvious when viewing it in Dots mode.

🏟 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis SIGLENT Stop f = 10.00013kHz	🗎 DISPLAY
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2.3700V								Intensity C
🥶 2 3600V -5	0.0ns 0.0r	ns 50.0ns	s 100.0ns	150.Ons	200.0ns	250.0ns	300.Ons 350.Ons 🚽	100%
C4 DC 1X 10.0r FULL -2.4	1M <mark>F2</mark> HA nV/ 1 40V	wg(C4) 0.0mV/ — -2.40V					TimebaseTrigger0.00s50.0ns/divStop400kpts2.00GSa/sEdge	C4 DC 器 2.36V Rising

Fig. 49 SDS824X HD_PR_H50ns_Stop_Zoom100_Dots

We can take it one step further and zoom in horizontally as well (while still in Vectors mode), so that it becomes less obvious that we're actually looking at pure noise:



Fig. 50 SDS824X HD_PR_H2ns_Stop_Zoom100

As can be seen, the SDS800X HD doesn't show any Sinc artifacts, yet the much more important insight should be that it is completely irrelevant what a DSO shows at such extreme zoom levels, where we see nothing but noise anyway.

Of course, we could also do it the correct way. Whenever we need to use some extreme zoom, then we also need a means to

- a) Increase the vertical resolution
- b) Reduce the noise

The tool of choice for repetitive signals is Averaging, because it increases the vertical resolution, suppresses any modulation (hence also noise) and doesn't affect the bandwidth.

Even at the extreme 100x zoom setting we can get the following:



Fig. 51 SDS824X HD_PR_H50ns_Stop_Zoom100_Avg1024

We leave the input channel at its original gain of 1 V/div, but set the final time base while still in Run mode and set up a math trace with averaging, which can be displayed at any vertical scale, i.e. also 10 mV/div for a 100x zoom. When the desired number of averages has been processed, we can stop the acquisition, yet this is not required, as the input channel is left unchanged anyway. In this example it is 1024 averages shown at 10 mV/div, hence a 100x zoom again.

Now compare this with the previous screenshots. This one now has much less curves and kinks than even the pointless capture at 2 ns/div before, proving that it's just nonsense (=noise) what we get at such zoom levels without proper averaging.

Of course, 1024 averages are quite a lot. In theory, it would enhance the resolution by 10 bits, making for a total of 22 bits. The current platform doesn't support sample data and digital signal processing results at more than 16 bits resolution, so this is what we get as soon as we use 16x or higher averaging. The ENOB on the other hand benefits a lot more from this, even though it's limited to 16 bits as well. But it starts at just 8.4 bit according to the data sheet, and 1024x averaging will increase this by 5 bits for a total of ~13.4 bits.

Zoom Challenge

Some folks have the need for a high dynamic range, i.e. the ability to inspect small details in a signal. To accomplish this, they usually increase the vertical gain of the DSO and use the position control to center the region of interest on the screen. This way, even 8-bit oscilloscopes can display some detail – as long as the signal distortions, caused by overdriving the oscilloscope frontend, don't affect the displayed portion of the signal too much. The distortions are especially bad with general purpose oscilloscopes, as they use the well-known split path input buffer with its problematic overload recovery behavior.

Now let's examine our options with the Siglent SDS800X HD.

First, we could try to use the traditional technique in overloading the scope. Without too much thinking, we can just connect a strong signal and then "zoom in" by increasing the vertical gain of the oscilloscope.

In the following example we have a 2 Mbps PRBS-signal with 3 V amplitude connected directly, hence a 1x probe factor applies.



Fig. 52 SDS824X HD_PRBS-4_A3V_V1V_P1

Now we try to take a closer look at the pulse tops and increase the sensitivity. This works reasonably well down to 200 mV/div, but at 100 mV/div we hear a relay clicking and the signal gets distorted:



Fig. 53 SDS824X HD_PRBS-4_A3V_V100mV_P1

With a distorted signal like this, it makes no sense to try to look at any details in the signal. So, this obviously is the wrong approach.

For most applications, it is not the overload recovery of the semiconductor devices, like clamping diodes and transistors, which cause the problem. The overload recovery time of these devices is usually in the low (or even sub-) nanoseconds and is only really of concern in multi-GHz instruments.

Our problem is the clamping in the split-path input buffer, which causes clean clipping in the LF-path, but a differentiation of the waveform in the HF-path. When the clipped LF-path is recombined again with the both offset- and phase-shifted HF-path, the result is heavily distorted and has little similarity with the original signal.

Knowing all this, we are able to find a solution: just don't drive the input buffer so hard that the clamps get activated. Keep the input signal well below 1 V_{PP} by using 100x probes if necessary. This also has the advantage of a much lower capacitive load at the probe tip and the low noise of the SDS824X HD makes the use of x100 probes unproblematic.

The next screenshot demonstrates a 1 MHz square wave with 5V amplitude and a 10 mV_{PP} 40 MHz sine riding on it, using a ten times probe.



Fig. 54 SDS824X HD_OVD_5V_10mV_P10

Yes, the trace is noisy. It would be much better if we could use the 20 MHz bandwidth limiter – but unfortunately, this would also affect the 40 MHz signal we are interested in. Averaging would help a lot, but we want to be able to watch dynamic signals, hence it is not an option either.

We can still see the 40 MHz sine clear enough to know it is there – and that for a signal amplitude ratio of 1:500! That's what a low noise high resolution DSO can do for you...

There might be situations, when we just cannot get that low – maybe because the signal levels are so high that the output of even x100 probes would still exceed ~500 mV_{PP}. Then a combination of (moderately!) overdriving the scope and vertical zoom could be the best solution.

Consider a 1 MHz Square wave with 5 V amplitude – maybe as output of a x100 probe, so the original signal would be 500V - unbelievable, isn't it? It could be some 625 watt transmitter – but these wouldn't output a square wave and hopefully there wouldn't be any subtle signal details to observe, which would not be better analyzed by using the FFT, but I digress...

Here is that familiar 40 MHz sine wave again, riding on the square wave:



Fig. 55 SDS824X HD_Ref_5V_10mVpp

First step is to increase the vertical gain, i.e. dial in lower numbers, just before the relay would click. We could use the fine adjust to get 102 mV/div (because this is the highest gain we can get without changing the attenuator setting), but this shouldn't be necessary for now. We finally end up with 200 mV/div:

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We can already see the little wiggles on the top of the square, it is much smaller than the overshoot and ringing at the rising edge. Yet now we engage the Zoom mode to take a closer look:



Fig. 57 SDS824X HD_OVD_limit_5V_10mVpp_Z20mV_ERES2.0

The above screenshot demonstrates two things: first is the ERES2.0 math trace in the main window, that lets us look at the 40 MHz sine at 10 mV/div. It is ugly, because ERES cannot get rid of the 1/f noise, so there's no use displaying it in more detail in the zoom window. But secondly, we have the regular trace in the zoom window at 20 mV/div, which is at least as clear as the overdrive zoom before.

One more time it should be remembered that we have a signal ratio of 500:1 here.

Dots mode

Not every DSO has it, but Dots display mode is essential whenever the DSO gets near the limits of the sample theorem, hence signal reconstruction – or even acquisition itself – appears flawed.

As an example, consider a 12 MHz square wave with fairly moderate 3 ns rise time, hence a perfectly adequate signal for a 200 MHz oscilloscope like the SDS824X HD.



Fig. 58 SDS824X HD_Square_12MHz_3ns_1GSa_Vect

The screenshot above shows the standard use case: Auto memory with at least 10 Mpts max. record length, Sin(x)/x reconstruction, Vector display mode, no Color grading, Persistence off.

In 2 channel mode, where we get a sample rate of 1 GSa/s without aggressive AA-filter, the waveform looks pretty good. With these settings, it would be pretty hard to provoke major reconstruction errors or even aliasing on a deep memory DSO like the SDS824X HD. Yet there might still be situations where we can't get a sufficient real-time sample rate. To demonstrate this, we can use the Constant Sample Rate setting instead of Auto Memory.

As a first step, let's reduce the sample rate to 250 MSa/s, which many would consider still adequate for a 12 MHz signal:



Fig. 59 SDS824X HD_Square_12MHz_3ns_250MSa_Vect

Even though the fundamental frequency of the signal is just 12 MHz and the Nyquist frequency (125 MHz) is more than ten times higher, we still get to see massive reconstruction artefacts and aliasing already. So much for the sometimes mentioned "rule of thumb" which suggests that a bandwidth five times the repetition frequency of a square wave would be adequate...

Let's take this one step further and set the sample rate to 100 MSa/s:



Fig. 60 SDS824X HD_Square_12MHz_3ns_100MSa_Vect

With the previous settings, we still got something remotely similar to a square wave. We go one step further and reduce the sample rate to 50 MSa/s:



Fig. 61 SDS824X HD_Square_12MHz_3ns_50MSa_Vect

Now we finally got a pure sine wave with lots of amplitude modulation and jitter – certainly not a very good representation of the original waveform anymore. We still want to take it to the extreme and reduce the sample rate even further to 20 MSa/s, thus violating Nyquist even for the fundamental frequency:



Fig. 62 SDS824X HD_Square_12MHz_3ns_20MSa_Vect

This last screenshot needs not be commented, except for the fact, that the SDS824X HD won't let us use the original time base of 20 ns/div with such a low sample rate anymore. The DSO has automatically switched to 50 ns/div, so that we get at least a total of 10 samples per record.

Anyway, this is not the end – after all we've got the Dots display mode up our sleeves:

📽 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis SIGLENT f = 12.00010	Trig'd 6MHz	🗎 DISF	PLAY
				Ţ					Type	Doto
300.0mV									Color Grac	le
200.0mV				· · · · · · · · · · · · · · · · · · ·		Second Second Sec.	ο το β ₁ οτοποίο το το το τ τ		on	off
.2.00.001.1.9									Persistenc	e
100.0mV									Off	<u> </u>
				-					Clear Disp	lav
👝 (). (). ().									F	·,
									Hide Menu	1
-100.0mV									Off	
									Menu Style	;
-200.0mV									Embedded	Floating
									Grid	
-300.0mV									Full Grid)
									Intensity	ى
-2	00.0ns -15	0.0ns -100.0)ns -50,0ns	0.0 <u>n</u> s	50.0ns	100.0ns	150.0ns 200.0n	S		60%
C1 DC 1X 500r FULL 0.0	21M C4 mV/ 1X * 20V FULL	DC1M 100mV/ — 0.00V					Timebase 0.00s 50.0ns/di∨ 10.0pts 20.0MSa/s	Trigger Normal Edge	C4 DC 0.00V Rising	∲器 08:34:08 2024/2/26

Fig. 63 SDS824X HD_Square_12MHz_3ns_20MSa_Dots

Yes, with only 1 point per division (10 points for the whole record!), there is no contiguous trace and the rendering is a bit dim. Yet nothing that could not be improved by a little Persistence time:



Fig. 64 SDS824X HD_Square_12MHz_3ns_20MSa_Dots_P1

What we get now is a perfect visual representation of the original signal – within the bounds of the 244 MHz bandwidth, that is – despite the effective sample rate of only 20 MSa/s.

The trigger path is completely separate and always works at the maximum sample rate for the current channel configuration. In my example, there were two active channels and sample rate was 1 GSa/s. This data stream is fed to the trigger engine directly, but might get decimated before it is stored into sample memory, according to max. record length and time base settings.

Dots display mode can only work as long as the trigger remains stable; this is the reason why this cannot replace ETS (Equivalent Time Sampling) or RIS (Random Interleaved Sampling), i.e. we can never display signals that would violate the Nyquist criterion in the trigger path.

Trigger

Trigger Jitter

The datasheet specifies the trigger jitter as <100 ps. This doesn't sound great, considering the SDS2000X HD, where the specification is <10 ps RMS (and it has been measured as 2.02 ps actually).

Now let's measure this using a 200 MHz sine signal from an OCXO-driven AWG (SDG7102A), fed into channels 2 and 4 of the SDS824X HD via a 12.4 GHz resistive power splitter. This way we can observe the jitter in the trigger channel as well as a not triggered channel.

The high quality 200 MHz sine signal has been chosen for its low inherent jitter – after all we want to characterize the DSO and not the signal source.

We need to utilize a measurement gate, because the T@M measurement considers all rising edges in the record, whereas we only want to measure the first one.

🏟 Utility	🖵 Display ท Acc	quire 🏲 Trigger	🗱 Cursors 🖻	Meas 🖻 Analy	sis SIGLENT f = 200.0025	Trig'd 5MHz	🗎 DISPL	_AY
300.0mVA 200.0mV 100.0mV 0.0mV -100.0mV 200.0mV -30.0mV	0nsj		B 3.00ns				Type Vectors Color Grade on Persistence Infinite	Dots e off e st
MEAGUDE	ons 0.00ns	1.00ns 2.00ns	3.00ns	5.00ns	6.00ns 7.00ns		Clear Displa	ay
Value	1@M(C2)	15 7pc	70 Opc				Hido Monu	
Mean	90.8µs	11.479ns	-70.3ps					
Min	76 7ns	-2 Ans	-89 5ns				Off	
Max	105.6ps	26.6ps	-68.6ps				Menu Style	
Pk-Pk	28.900ps	28.600ps	20.900ps				Embedded	Iloatina
Stdev	4.652ps	4.852ps	3.390ps					loauny
Count	5234	5234	5234			_	Grid	
Histogram						\bigcirc	Full Grid	~
C2 DC1 1X 100m FULL 0.00	M C4 DC1M V/ 1X 100mV/ JV FULL 0.00V				Timebase 0.00s 1.00ns/div 10.0pts 1.00GSa/s	Trigger Auto Edge	C4 DC 0.00V Rising	∲ ₩

Fig. 65 SDS824X_HD_Trigger Jitter

At a time base of 1 ns/div, we cannot see any jitter in the triggered as well as the non-triggered channel after more than 10 minutes at infinite persistence.

The jitter measurements are as follows: Triggered channel: 28.6 ps pk-pk, 4.852 ps rms; Un-triggered channel: 28.9 ps pk-pk, 4.652 ps rms; Skew Ch.2-Ch.4: 20.9 ps pk-pk, 3.39 ps rms;

While this is about twice as much as the SDS2000X HD, it is still very respectable and milesahead of older designs with analog trigger system (none of Siglent's X and A series).Siglent SDS800X HD Evaluation Rev. 1.00Page 61

AC Trigger Coupling

Most of us use DC coupling for the trigger almost all the time, and there is not much to talk about it, other than that it works just as it should. We rather want to examine AC trigger coupling now.

Why and when would we need AC coupling for the trigger at all? Usually, we make that choice for the channel input and if we select AC coupling there, the trigger will inevitably be AC coupled as well. So, there we already have the answer – we have the opportunity to force the trigger into AC coupling, even when the corresponding input channel is DC coupled. This can be useful for AC signals that have a DC offset that we want to watch on the screen. The offset might change with time and we still don't want to lose triggering

AC trigger coupling does not display a trigger level indicator, simply because it would need to closely follow even a fast-changing signal offset, thus might be rather distracting instead of beneficial.

The following test uses a 200 mV_{PP} 100 ns wide pulse at 1 MHz repetition frequency that is superimposed on a $600mV_{PP}$ sine wave at 100mHz, which acts as a variable DC offset here. As if this weren't enough, this signal has a fixed DC offset of -6V on top of that, which needs to be removed by means of the vertical position control and the trigger level adjusted accordingly. Infinite persistence is used to give a hint what is going on.

With DC trigger coupling, triggering would only occur about 1/3 of the total time in this scenario and even then, the horizontal position would only be reasonably stable because of the short 1 ns rise time of the pulse edges. A signal with slower edges would move horizontally as well, because of the permanently changing trigger level (relative to the AC portion of the input signal).



Fig. 66 SDS824X_HD_Trigger_DC_VarOffset

It's totally different if we use AC trigger coupling. When using Auto-Set by pushing the trigger level control, the trigger level is set to 50% of the signal amplitude. With this, triggering occurs always at the same point on the X-axis, no matter what the DC offset or low frequency instantaneous signal level is. The waveform constantly changes its vertical position on the screen, but remains stable on the time axis – and even more important, the signal is triggered continuously.



Fig. 67 SDS824X_HD_Trigger_AC_VarOffset

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We've heard complaints about DSOs that prove unable to maintain an AC- or LFRJ-trigger without some additional jitter. Here's a test with AC trigger coupling and a 6 ns wide pulse with 1 MHz repetition frequency. The screenshot has been taken after several minutes with infinite persistence.

🛱 Utility 🖵 🛛	Display ท Acquir	e 🏲 Trigger 😫	🛊 Cursors Mea	is 🖻 Analy:	sis SIGLENT f = 1.000013	Trig'd MHz	🗎 MEA:	SURE
	V						Measure	
300.0mV	\sim						on	off
200.0mV	· · · · / · · /	· · · · · · · · · · · · · · · · · · ·	_				Mode	
100.0mV	/						Simple <mark>A</mark>	dvanced
<mark>c4</mark> ,0.Qm//							Config	
-100.0mV	/							
-200.0mV							Liea	r
-300.0mV	0.00ms 2.00		6 00ns 8 00ns	10,0005	12.00nc 14.00nc		< Туре	
MEASURE	Amplitude(C4)	+\/\idth(C4)	10-90%Rise(C4)	90-10%Fall(C4)	T = T @M(C4)	- \	Toolo	lı S
Value	594.831mV	6.058ns	1.697ns	1.714ns	-46ps		10015	"~
Mean	593.88479mV	6.05120ns	1.68985ns	1.71101ns	-37.23ps		Statistics	
Min	584.740mV	6.019ns	1.637ns	1.666ns	-52ps		Statistics	
Max	597.552mV	6.068ns	1.719ns	1.738ns	-16ps		on	off
Pk-Pk	12.81200mV	49.00ps	82.00ps	72.00ps	36.00ps			
Stdev	2.35985mV	7.47ps	13.55ps	10.96ps	6.84ps		Statistics S	ettina >
Count	2579	2579	2579	2579	2579	\mathbf{O}		

Fig. 68 SDS824X_HD_Trigger_AC_Jitter

Jitter can be measured as 36.0 ps peak to peak and 6.84 ps RMS; not quite as good as the former test with the 200 MHz sine signal, yet certainly not bad either – and also reveals that the pulse generator (SDS7102A) produces quite stable signals, even when fast edges are involved.

Triggering noisy signals

Of course, for serious measurements, our goal should be to find a reliable, stable and noisefree trigger source with sufficient amplitude. Sometimes this is not available and we need to try the next best thing by getting a stable triggering also from less ideal sources.

Let's assume a low frequency signal with high frequency spikes (maybe from fast logic circuits nearby) superimposed. To simulate this, a 600 mV_{PP} 1 kHz sine wave has a 10 mV_{PP} 3.254 MHz pulse train (10 ns wide pulses) riding on it. Standard DC trigger doesn't work with such a signal, but HF-reject coupling does:



Fig. 69 SDS824X_HD_Trig_Spikes_HFRJ

Just for fun, we can do the opposite thing and use LF-reject trigger coupling. This triggers stably on the pulses, yet because of the high waveform update rate the screen is full of traces from the 1 kHz sine.



Fig. 70 SDS824X_HD_Trig_Spikes_LFRJ

After stopping the acquisition, we can closely inspect the last record. Even better, we can look up all the previous acquisitions in the history:



Fig. 71 SDS824X_HD_Trig_Spikes_LFRJ_Hist1



Fig. 72 SDS824X_HD_Trig_Spikes_LFRJ_Hist2

Another common situation is just a noisy signal like this: Siglent SDS800X HD Evaluation Rev. 1.00



Fig. 73 SDS824X_HD_Trig_Noise_DC

Infinite persistence has been used to visualize the unstable signal phase.

We can still trigger on such a signal by simply lowering the trigger bandwidth, i.e. using HFRJ:





Alternatively, the Noise Reject switch in the trigger settings will increase the trigger hysteresis, thus making it immune to noise (within reason).



Fig. 75 SDS824X_HD_Trig_Noise_DC_NRJ

Measure

Measurements

There are the simple measurements, where we can define an arbitrary set of up to all 52 measurements that are related to a single channel. This set can subsequently be applied to any Input-, Zoom-, Math- or Reference-Channel. That's also one disadvantage of the simple measurements – the set is restricted to a single channel at a time. The other drawback is the total lack of statistics in this mode.

🛱 Utility	🖵 Display 🛛	nîAcquire 🏲	Trigger #	Cursors 🖻	Meas 🖻	Analysis S	IGLENT Trig'd f = 200.0025MHz	🗎 MEASUI	RE
300.0mV	\checkmark							Measure	
200.0mV							a a Na a a a	on o	off
100.0mV		/						Mode	
<mark>c₄</mark> ,0.Qm,V , , , , ,	/		//					Simple Adva	anced
-100.0mV	/		Ň		/				
200.0mV				X				Config	
-300.0mV									
Maria	Nos UUUns	1.UUns	2.00ns	3.00ns 🔨	207 504	Ins 6.00ns	7.00ns	💼 Clear	
Raco	366.159MV	Amplitudo	-371.432mV	PK-PK	737.591MV	Top Moon	365.768MV		
Ovele Mean	1.03990m\/	Stdev	733.200mv	Cycle Stdey	260 71155m)/		260.41571m\u		
Cycle Mean	760 71362m\u	Median	200.41103111V 3.8/1m\/	Cycle Median	200.71130mv 3.477m)/	FOV	0 0/1/%	Jan 1960	
EPRE	0.032%	ROV	0.032%	RPRE	0.044%	Period	5.0033ns		
Fred	199.87MH7	Time@may	6.2800ns	Time@min	3 7400ns	+\/\idth	2.5302ns	Source	
-Width	2 4731ns	+Duty	50 571%	-Duty	49 479%	+BW/idth	7 5418ns	C4	
-BWidth	2.4731ns	Delay	-11 8ns	Там	4 9915ns	Rise Time	1.5001ns		
Fall Time	1.4453ns	10-90%Rise	1.5001ns	90-10%Fall	1.4453ns	CCJ	***	Result Style	
+Area@DC	1.179487nVVt	-Area@DC	1.165019nVVt	Area@DC	14.468pWb	AbsArea@DC	2.344506nVVt	Embedded Flo	ating
+Area@AC	1.172195nWt	-Area@AC	1.172195nWt	Area@AC	0f/Vb	AbsArea@AC	2.344390nWt		
Cycles	1	Rising Edges	2	Falling Edges	1	Edges	3		
Ppulses	1	Npulses	1	PSlope	392.1V/us	NSlope	407.0V/us		
C2 DC1 1X 100m	M C4 D V/ 1X 100	C1M ImV/				Timebas 0.00s	e Trigger 1.00ns/div Auto	C4 DC 0.00V	∲ ₩
FULL 0.00	IV FULL 0	.007				10.0pts	1.00GSa/s Edge	Rising	

Fig. 76 SDS824X_HD_Measure_Simple_Embedded

A high number of measurements might be desirable at times, yet it takes up a lot of screen space. Siglent has now introduced a new display option for measurements; "Floating":

🏶 Utility	🖵 Display n	nî Acquire 🖡	Trigger 🛊	‡Cursors 📐	.Meas 🖻	Analysis	SIGLENT Trig'd f = 1.000012MHz	🗎 MEASURE
								Measure
300.0m\/				-				on off
				-		(Mode
								Simple Advanced
200.0mV								
100 0mV								Config 🌐
				ł				_
Max	212 222mV	hdio	200 750 mV		612 002mV	Top	202 125mV	iiii Ciear
	-296 458mV	Amplitude	-290,700mV		225 833mV	Mean	3 55408mV	
Cycle Mean	3 46736mV	Stdev	298 70672m	Cycle Stdev	298 80117m		298 72787m	Ivne 🔨
Cycle RMS	298.82129m	Median	-52.917mV	Cvcle Median	-73.333mV	FOV	0.208%	X 1990
FPRE	0.417%	ROV	1.668%	RARE	0.313%	Period	999.99ns	
Freq	1.00001MHz	Time@max	2.00150us	Time@min	2.89900us	+Width	500.02ns	Source
-Width	499.96ns	+Duty	50.003%	-Duty	49.997%	+BWidth	3.49999us	C4
-BWidth	3.49993us	Delay	-500 24ns	TQM	2.99969us	Rise Time	1.87ns	De cult Otulo
Fall Time	.1.92ns .	10-90%Rise	.1.87ns.	90-10%Fall	1.92ns	CCJ	.0.00ns	Result Style
+Area@DC	755.16615nV	-Area@DC	737.39573nV	Area@DC	17.77042nW	t AbsArea@DC	1.49256188u\	Embedded Floating
+Area@AC	746.28094nW	-Area@AC	746.28094nV	Area@AC	0.00pVVb	AbsArea@AC	1.49256188u\	
Cycles	4	Rising Edges	4	Falling Edges	5	Edges	9	
Ppulses ₋₀	.500 ⁴ us 0.0001	_{is} Npuls es oous	4 1.000us	P.Shars 2	0756V/us 2.5	ooNSlope3.000u	s 2509/980us	
C4 D0 1X 100r FULL 0.0	1M mV/					Timeba 0.00s 10.0kpt:	se Trigger 500ns/div Auto s 2.00GSa/s Edge	C4 DC ↓ ₩ 💑 0.00V Rising

Fig. 77 SDS824X_HD_Measure_Simple_Floating

This is a transparent overlay which might help to better utilize the screen space in certain situations.

We also got the Advanced Measurements., but unfortunately only mode A; mode B is available only in its bigger (and more expensive) siblings:

🏶 Utility	🖵 Display	nî Acquire 🖡	 Trigger 	# Cursors	📐 Meas	🖻 Analys	sis SIGLENT	Trig'd 013MHz	₿ N	MEASURE
300.0mV		.							Mode Simple	e Advanced
200.0mV 100.0mV									Config	>
0.0mV , -1.00.0mV			-+-+-+						Ē	Clear
-200.0mV									Ø	Туре
-0	500us 0.00)Ous 0.500us	1.000us	1.500us	2.000us	2.500us	3.000us 3.50	Dus	Tools	11>
MEASURE Value	Ppulse: 4	s(C4) – Npu 4	lses(C4)	10-90%Ri 1.88ns	se(C4) - 90 1.9	-10%Fall(C4) J1ns	+Width(C4) 500.02ns		Statisti	cs
Mean	4.00	4.00	l	1.8511ns	1.8	3864ns	500.0249ns		on	off
Min	4	4		1.82ns	1.8	35ns	500.01ns			011
Max	4	4		1.90ns	1.8	J4ns D=-	500.04ns		Statieti	ce Sotting ID
PK-PK Stdev	0.00	0.00	1	80.0ps 17.8ps	90	.ups 7ne	30.0ps		Statisti	cs Setting ">
Count	2308	2308	3	3952	45	85	3312		Result	Style
Histogram								\bigcirc	Embed	ded Floating
C4 DC 1X 100n FULL 0.0	1M 1V// ———————————————————————————————————						Timebase 0.00s 500ns/o 10.0kpts 2.00GSa	Trigger liv Auto /s Edge	C4 E 0.00 Risir)C ↓ 提)V ng

Fig. 78 SDS824X_HD_Measure_Advanced_Embedded

We can have statistics and also enable the little Histicons (History Icons) as in the screenshot above, we can also mix various channels, yet we are restricted to only 5 measurements at a time.

We can have floating measurements in this mode as well, yet it might be a good idea to turn the axis labels off to avoid text collisions:

🏶 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analysis	SIGLENT f = 1.00001	Trig'd 3MHz 🗎 Axis	Label Setting
MEASURE	Po	ulses(C4)	Npulses	C4)	10-90%Rise('C4) — 90-	-10%Fall(C4)	+Width(C4)	-~
Value	4		4		1.85ns	1.9	Ins	500.03ns	<u> </u>
Mean	4.0	0	4.00		1.8512ns	1.8	1868ns	500.0249ns	
Min	4		4		1.82ns	1.8	l5ns	500.01ns	
Max	4		4		1.90ns	1.9	l4ns	500.04ns	
Pk-Pk	0.0	0 0	0.00		80.0ps	90.	.Ops	30.0ps	
Stdev	<u>ا ا ا ا ا ا ا ا ا ا ا ا ا ا ا ا ا ا ا </u>	0	0.00		17 <mark>9ps</mark>	23	.Ops 🛌	🔜 2.8ps 🕴	
Count	31	96	3196		7504	90:	25	6864	
Histogram					-				$\langle \rangle$
C4 DC 1X 100n FULL 0.0	1M nV/ 10V					Tin 0.0 10.	nebase Os 500ns/div Okpts 2.00GSa/s	Trigger C4 E Auto 0.00 Edge Risir)C ↓ 提 iV ig

Fig. 79 SDS824X_HD_Measure_Advanced_Floating

Measurement Histograms

The small Histicons in the advanced measurements statistics can be enlarged by simply clicking or tapping on them. This opens a separate window with a more detailed version of the histogram. The last measurement result is marked by a small red dot in the histogram, so one can watch the buildup of the histogram even when there is already a lot of data collected and histogram bars don't visibly change anymore.

🏟 Utility	🖵 Displa	ay mî	Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analysis	SIGLENT f = 1.000013	Trig'd 3MHz	MEASURE
			His	togram - Pk-Pl	k(C4)					
				Percent	0	Count				
			28.09	[%] -д						100.0mV
			22.49	%_						
C4	+ + +	++	16.89	8					+ + + +	
			44.00	~						-100.0mV
			11.23	~~						-200.0mV
			5.69	‰				Init:		
				┟╸╷╹╷				nV		<u>auu.umv</u>
	-0.500us	0.00	Ous	610.55	611.22	611.90	2.000us 612	.58 2.500us 3	3.000us	3.500us
MEASURE		Pk-Pk(C	(4) COL	INT: 3U 1		rrent:610.833m		190%Rise(C4)	= 90-10%Fa	I(C4) –
Value		610.833	mV ^{Top}	.[611.44mv,611	46mvj 26.77%				4.94ns	
Mean		611.434	74mV	606.874	86mV	999.9874ns	4.	9183ns	4.9557ns	
Min		610.625	mV	606.458	mV	999.96ns	4.	87ns	4.90ns	
Max		612.500	mV	607.500	mV	1.00001us	4.	97ns	5.01ns	
Pk-Pk		1.87500	mV	1.04200	mV	50.0ps	10)0.0ps	110.0ps	
Stdev		292.28u	V	184.05u	V	6.3ps	14	1.7ps	15.7ps	
Count		3011		3011		12044	12	2044	15055	
Histogram										\bigcirc
C4 _DC	:1M							mebase	Trigger	C4 DC 🛛 🜵 🔒
1X 100r	nV/						0.	00s 500ns/div	Auto (D.00V
FULL 0.0)OV						10).0kpts 2.00GSa/s	Edge F	Rising

Fig. 80 SDS824X_HD_Measure_Advanced_Histogram

Deep Measurements

Here's some demonstration of a common exercise which cannot be solved without deep measurements.

Imagine a 16-bit PWM based on 20 MHz clock frequency. This results in a rather slow 304 Hz PWM signal that can resolve 65536 different levels of duty cycle. To analyze this, we should be able to have accurate time measurements with at least 0.001525878 % (15 ppm) resolution

A very similar demonstration has been published for the 8-bit SDS2354X Plus a while ago already (reply #4336):

https://www.eevblog.com/forum/testgear/siglent-sds2000x-pluscoming/msg5183499/#msg5183499

Let's see how the SDS800X HD fares.

Time base is set to 500 μ s/div, so that we can capture at least one full PWM period.

At 2 GSa/s, this results in 10 Mpts record length.

The PWM signal for this test has 1 ns rise time and 0.001% resolution for the duty cycle.

First the lowest at 0.001 %:
🏶 Utility	🖵 Displa	ıy rîî	Acquire	٣	Trigger	#	Cursors	A	Meas	থ] Analy	sis	sigle f=:	ENT 304.00	Trig 38H:	g'd z	₿	MEAS	URE
1.200V																			
1.000V																			
0.800V																			
,0.600¥_,																			
0.400V																			•
0.200V																			
0.000V								·				a sa sa sa							
<u>-n 200V</u>	-0.500ms	0.0	DOms	0.50	Oms	1.0	00ms	1.5	00ms	2	.000ms	2	500m:	s	3.00	Oms	3.6	500ms	
MEASURE		Cycle N	lean(C4)		+Duty(C	4)		Pe	riod(C4)			10-90%	%Rise(C4)		90-10%	%Fall(C	24)	
Value		76.08u\	/		0.001%			3.2	894320	ms		1.5ns				2.8ns			
Mean		9.7749ເ	JV VL		0.00100	%		3.2	894319	691m	IS	2.2489	ns			2.2715	ins		
Min		-752.93	luV		0.001%			3.2	894319	ms		1.5ns				1.4ns			
Max		812.47ı	JV		0.001%			3.2	2894320) 	ms		2.9ns				2.9ns			
Pk-Pk		1.5654l	JUUmV		0.00003	%		10	U.Ups			1.4000	ns			1.5000	Ins		
Stdev		307.798 400	obuv		400	%		21.	.yps n			509.5p	s			486.5p	IS		
Count		123			123			12,	3			240				240			
Histogram		الاستقصا											<u> </u>				4.4		
C4 DC 1X 200n FULL -600r	1M 1V/ — nV											Timeb: 0.00s 10.0Mp	ase 50 ots 2.0)0us/div 0GSa/s	Tri Au Ec	gger to Ige	C4 500i Ris	DC mV ing	∲ ₩

Fig	81	SDS824X	HD	Duty	0.001
rig.	01	$5D502+\Lambda_{-}$	_11D_	_Duty_	_0.001

Near full scale at 99.999 %:

🏟 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	is SIGLENT f = 304.003	Trig'd 38Hz	MEASURE
1.200V									
0.800V									
,0.600y , 0.400V									
0.200V									
-n 2nn∨	-0.500ms	0.000ms	0.500ms	1.000ms	1.500ms	2.000ms	2.500ms	3.000ms 3.5	00ms
MEASURE		ycle Mean(C4)	= +Duty(C	24)	Period(C4)		10-90%Rise(C4)	= 90-10%Fall(C	(4) – 📈
Value	1.	.00456820V	99.999%	6	3.2894320m	IS	2.7ns	1.6ns	
Mean	1.	.0055649512V	99.9990	0%	3.289431962	26ms	2.2397ns	2.2812ns	
Min	1.	.00456820V	99.999%	6	3.2894319m	IS	1.4ns	1.5ns	
Max	1.	.00641609V	99.999%	6	3.2894320m	IS	2.9ns	2.9ns	
Pk-Pk	1.	.8478900mV	0.00003	1%	100.0ps		1.5000ns	1.4000ns	
Stdev	34	43.4819uV	0.00001	%	25.1ps		508.3ps	507.5ps	
Count	<i>.</i> ا	20	125		120		200	200	-
Histogram			ш				<u>N</u>	W	
C4 DC 1X 200n FULL -600r	1M nV/ mV						Timebase 0.00s 500us/div 10.0Mpts 2.00GSa/s	Trigger C4 Auto 500r Edge Ris	DC ↓ ₩ mV ing

Fig. 82 SDS824X_HD_Duty_99.999

Half scale at 50.000 %:

🛱 Utility	🖵 Displa	ay nî	Acquire	🏲 Tri	igger	# (Cursors	A	Meas		<u>ඩ</u> /	Analys	sis	SIG f	ilent = 304.00	Tri ∃38	g'd Iz	₿	MEAS	URE
1.200V																				
1.000V									· ·									· ·		
0.800V																				
,0.600y																				
0.400V																				
0.200V																				
a nonv		1997 - 1997 1997 - 1997 - 1997 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1							· ·											
<u>-n 2nnv</u>	-0.500ms	0.0	00ms	0.500r	ns	1.00	0ms	1.5	00ms		2.0	00ms		2.500	lms	3.00)0ms	3.6	500ms	
MEASURE		Cycle N	/lean(C4)		+Duty(C	4)		Ρe	eriod(C	4)			10-90)%Ris	se(C4)		90-10	%Fall(C	24)	
Value		502.321	701mV		50.000%	6		3.3	289432	20ms			2.8ns				2.8ns			
Mean		502.513	34485mV		50.00000	0%		3.3	289431	9836	Bms		2.239	19ns			2.273	3ns		
Min		501.672	238mV	:	50.000%	ò		3.3	289431	9ms			1.4ns				1.5ns			
Max		503.240	021mV		50.000%			3.2	289432	20ms			2.9ns				2.9ns			
Pk-Pk		1.56783	300mV	1	D.000009	%		10	10.0ps				1.500	lOns			1.400	Ons		
Stdev		325.039	38uV	1	D.000009	%		12	1.5ps				502.7	ps			503.8	ps		
Count		123			123			12	3				246				123			-
Histogram		ألسب	n a Maran da Marana d	հես														4.4		\bigcirc
C4 DC 1X 200n FULL -600r	1M nV/ — mV												Time 0.00s 10.0N	base ; /lpts :	500us/di 2.00GSa/:	Tr V Ai s Ei	igger uto dge	C4 500 Ris	DC mV iing	₩ ₩

D :	01	OD OO AV	TID	Deeter	
Fig.	83	SDS824X_	$_HD_$	_Duty_	50.000

Finally, one step higher at 50.001 %:

🏶 Utility	🖵 Display	y n Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analy:	sis SIGLENT f = 304.00	Trig'd 38Hz	MEASURE
1.200V									
1.000V					· · · · ·				
0.800V									
0.600Y									
0.400V									
0.200V									
_n 200V	-0.500ms	0.000ms	0.500ms	1.000ms	1.500ms	2.000ms	2.500ms	3.000ms 3	500ms
MEASURE		Cycle Mean(C4)	= +Duty(C4) -	Period(C4)		10-90%Rise(C4)	90-10%Fall(C4) —
Value	5	502.67592mV	50.001	%	3.2894320m	ıs	2.8ns	2.0ns	
Mean	5	502.6736153mV	50.001	00%	3.28943199	54ms	2.2644ns	2.2890ns	
Min	5	501.94099mV	50.001	%	3.2894320m	าร	1.4ns	1.5ns	
Max	5	503.45664mV	50.001	%	3.2894320m	าร	2.9ns	2.9ns	
Pk-Pk	1	I.5156500mV	0.0000	3%	Os		1.5000ns	1.4000ns	
Stdev	3	324.0253uV	0.0000	1%	9.2ps		502.6ps	476.7ps	
Count	1	122	122		122		244	122	
Histogram			<u></u>					W	\bigcirc
C4 DC 1X 200n FULL -600r	1M nV/ mV						Timebase 0.00s 500us/div 10.0Mpts 2.00GSa/s	Trigger C₂ ∕ Auto 500 ⊱Edge Ri	IDC 业最)mV sing

Fig. 84 SDS824X_HD_Duty_50.001

The duty cycle measurement is spot on and stable, even though not quite as impressive as the SDS2000X Plus (look at the peak-peak and standard deviation).

Siglent SDS800X HD Evaluation Rev. 1.00

The period measurement is fairly stable too, with a standard deviation of only 9.2 ps. Peak deviation can only be measured in 100 ps steps, which is ten times more than the SDS2000X Plus. Quite obviously the peak deviation was well below 100 ps, hence gets reported as 0 s.

The Cycle Mean measurements gives an approximation of the resulting voltage level. It is far less precise than the duty cycle measurement though. No wonder – even a 12-bit DSO is still no precision bench DMM, hence measurement resolutions of ~15 μ V are not going to be stable – this also shows in the standard deviation of ~324 μ V – which is about ten times as much as with the SDS2000X Plus, but that's only because the amplitude was ten times lower for the test back then (and the required resolution there would have been ~1.5 μ V).

Finally, the rise and fall times are about as (in)accurate as can be realistically expected at 2 GSa/s. The rather high peak deviation of ~1.4 ns already hints on the averaging of many individual measurements to get the final result. Once again, we see an advantage of the SDS2000X Plus, even though the sample rate is the same. Yet this is not only about the physical sample rate, but also interpolation strategies, which require massive HW support and might be a bit simpler in the SDS800X HD. The higher bandwidth of the SDS2000X plus is helpful in this case as well.

Of course we can always get full accuracy for one local detail like the rise time by using zoom trace measurements:

🕼 Utility	🖵 Display	nî Acquire	🏲 Trigger	‡ Cursors	📐 Meas	🖻 Analys	sis SIGLENT f = 304.003	Trig'd 38Hz	🗎 MEAS	URE
C4	0.500ms	· · · · · · · · · · · · · · · · · · ·	0.500ms	1.000ms	1.500m s		2.500mc	3.000mc	3.500ms	<u> </u>
1.200V 1.000V 0.800V 0.600V 0.400V 0.200V 0.200V									· · · · · ·	
_n_2nav	-80.0ns	-60.0ns	-40.0ns	-20.0ns	0.0ns	20.0ns	40.0ns	60.0ns	80.0ns	
MEASURE	10-	-90%Rise(Z4)	***		***		***	***		$- \times$
Value	1.6	i4ns								
Mean	1.6	i499ns								
Min	1.6	i4ns								
Max DL DL	0.1 OC	07ns Ope		<u> </u>					<u> </u>	
Stdev	50	.ups Ins								
Count	17:	3								
Histogram										\bigcirc
C4 DC 1X 200n FULL -600r	1M Z4 nV/ 20.0ns/ 2 mV 0.00s 1	200mV/ — 600mV					Timebase 0.00s 500us/div 10.0Mpts 2.00GSa/s	Trigger Auto Edge	C4 DC 500mV Rising	∲ 撮

Fig. 85 SDS824X_HD_Duty_50.001_Rise

Now the rise time measurement result is much closer to the truth. The key for this is to use a time-base faster than 50 ns/div in the zoom window. Now the Sinc reconstruction generates additional data points, thus increasing time resolution and reducing the standard deviation of the measurement to just ~6 ps, which is in turn even better than the SDS2000X Plus.

Trend Plots

Let's start with the more familiar (to most) Trend charts. As the name suggests, they plot a measurement value over time. For this, the record length of the raw acquisition can be short – a single full signal period would already be enough. Shorter records have the advantage of faster processing and less memory consumption.



Fig. 86 SDS824X_HD_Measure_Trend_AM_Interval

Of course, even a 12-bit DSO is not a metrology-grade instrument, hence we cannot use Trend Plot to observe the stability of a voltage standard; yet there are still plenty of applications where 0.5% accuracy is sufficient.

For the example above, we have used a 1 s time interval Trend Plot, measuring the peak-topeak amplitude of a 10 MHz sine wave, 100% amplitude modulated by a 10 mHz ramp signal. The minimum time interval for Trend Plot would be 0.5 s.

📽 Utility	🖵 Disp	olay nî	Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analysi	is sig	LENT 10.00013	Trig'd 3MHz	₿ M	1easure	Trend
300.0mV		Trend - F	Pk-Pk(C4)										
200 pmV	\bigwedge	Unit: r 700.00	nV 0 7					A					
100.qmv		500.00	0-				hanne				Manua		
<mark>64</mark> 0.0m)	<u> </u>	300.00	0-								Vertical		
-100.0mV		100.00	0-										
-200.0mtV		-100.00	o 1		- <u> </u>							- 300, p(٩I
-300.0mv	000ns (:- Ourrent:53	200.00s 39.375mV	ns Max:658.33 3	BmV and n Min:	- 4.583mV _{ns}	-100.00s 50(Avg:346)	453mVns	Counts	319		0.00s	e 🔿
MEASURE	Fr	ea(C4)	— F	· ·k-Pk(C4)	***	***		***				20	.00s
Value	9.9	99643MH;	z 5	i43.750mV							Horizor	ital Pos	itior©
Mean	9.9	9992971N	1Hz 3	27.72701mV								0	00c
Min	1.9	99860MHz	z 3	l.542mV									.005
Max	10	.53880MH	Hz 6	i62.500mV									
Pk-Pk	8.5	5402000N	1Hz 6	i58.95800mV							Trend C	Config	>
Stdev	72	.8986kHz	1	81.61943mV									
Count	55	335	6	201						_	•		
Histogram										\bigcirc		Return	
C4 DC 1X 100n FULL 0.0	1M 1V/ –							Timebase 0.00s 2.00kpts 2	100ns/div .00GSa/s	Trigger Auto Edge	C4 D -1.67m Risin	C V Ig	∲ ₩

Fig. 87 SDS824X_HD_Measure_Trend_AM_enlarged

It can be seen that the Trend Plot has a separate statistic, as it is significantly slower than the regular measurements, hence works on a decimated subset of the original measurement data. Consequently, since the time interval of the Trend Plot is one second, the measurement rate of the Pk-Pk measurement can be calculated as ~19.4 per second, while at the same time we get 174 frequency measurements per second.

Instead of a fixed time interval, we can alternatively use sequence record mode. Now the trend plot window behaves like a scope in roll mode, i.e. the update rate is faster, but the time axis shows measurement samples instead of time units now.

🛱 Utility	🖵 Display	m Acquire	🏲 Trigger	♯ Cursors	📐 Meas	🖻 Analysis	s SIGLENT f = 10.000	Trig'd 13MHz	🗐 Me	easure Trend
000 0V	_	7	Tren	: d - Pk-Pk(C4)					Trend	
300.0mV				Init: mV					Pk-Pk(C4) 🗸 🗸
200.0mV				D.000 7					Scale M	ode
100.0mV									Manual	\sim
	\sim	\sim /	\sim 100		\sim			\sim	Vortical (Roalo (1
			30	- 000.C					ventical	
-100.0mV			40							
-200.0mV			101]				•.	Vertical	⊃osition ©
			-10	D.000				, IÞ⊺		300.00mV
-300.0mV				-1000.00		-500.00	0.	00	Horizont	al Scale – ©
-10	10.0ns 0.0n	is 100.0	ns 20 Curre	nt:130.625mV	Max:661.458	3m ⁶ V0.0ns Mir	n:3.958mV 700.0	ns 🔍		100.00c
MEASURE	Freq(C	4) — 1	Pk-Pk(C4)	- ***	***		***			100.005
Value	10.0091	MHz	130.625mV						Horizont	al Positior©
Mean	9.99959	3MHz :	308.68633mV							0 00s
Min	4.961M	Hz :	3.542mV							
Max	10.720	MHz I	661.458mV							
Pk-Pk	5.75900	OMHz (657.91600mV						Irend Co	onfig 💷
Stdev	58.86kH	Hz i	192.62549mV							
Count	35428	:	3979					_	• -	
Histogram		i		<u>""</u>				\bigcirc	сл к	eturn
C4 DC1	1M						Timebase	Trigger	C4 DC	∲ ₩
FULL 0.0						(2.00kpts 2.00GSa/	v Auto s Edge	-1.6/mV Rising	

Fig. 88 SDS824X_HD_Measure_Trend_AM_Sequence

Track Plots

Track plots also show the developing of a measurement value, but not over time but within a single record. As opposed to trend plots, this works best with long record lengths and only with certain measurements – the ones that are computed for the entire record, i.e. all the time related measurements.

Consider a 10 MHz carrier frequency modulated with a 20 kHz sine wave and a frequency deviation of +/-1 MHz. Other than e.g. AM, we cannot really see this in the regular y-t display. This is where the Track Plots come in handy; they let us "demodulate" frequency and phase modulated signals – and such modulations could also come from noise, drift and jitter.

🏶 Utility	🖵 Display	m Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analysi	s SIGLENT f = 20.0002	Trig'd 5kHz	🗐 Mea	asure Track
300.0mV	V		ck - Freq(C4)						Track Freg(C4)	
200.0mV		10.90	1000)MHz			\sim				
		10.60					X		Scale Mo	de
100.0mV		10.00		\		/	\mathbf{X}		Manual	<u> </u>
0.0mV		10,80	1000MHz			/			Vertical S	cale ඊ
C4		10.00	1000MHz				λ		20	
-100.0mV		0.700			han an an an an an Arana					
200.0m3/		9.700	IUUMHZ	~~~\	/[/[Vertical P	osition 🖒
-200.00.07		9,400	100MHz	X	/ <u></u>		λ	- <i>f</i> - ,	10.00	000MHz
_{c3} ,-300.0mV		9 100	100MHz	e e e e 🛛 🔨 e e	e e∕re fe		e e e e e Xere e			
-0.5	00me 0.000	me [] 500e			2 0000000	2.500mc.ee			Horizontal	Scale C
	5 (04)		990:00us	-970:00us	-950,00	us -93	30:00us 19 : 19 -910:	UUus		10.00us
MEASURE	Freq(C4)) – P	K-PK(C4)					$-\times$	Llavimontal	Desition
value	9.9383Mi	HZ 3	32.708mV						Horizontal	Position
Mean	10.05012	27MHZ 3	33.04784mV						-9	950.00us
Mai i	8.98 TUM	HZ 3	32.500mV							
Max DL DL	11.UZZ7N	/IHZ 3	33.750mv		<u> </u>	_ <u> </u>			Ref	Config
PK-PK	2.041700	JIMIHZ I	.20000mv							
Sidev	700.328K 405000		15.77UV							
Histogram	405000							\bigcirc	ᅿ Ref	turn
C3 DC1	и С4 с	DC1M					Timebase	Trigger	C3 DC	↓ 掃
1X 5.00\	// 1X <u>10</u>	0mV/					0.00s 500u <u>s/div</u>	Auto	2.42 <u>V</u>	
FULL -15.0	V FULL (0.00V					5.00Mpts 1.00GSa/s	Edge	Rising	

Fig. 89 SDS824X_HD_Measure_Track_FM

Take a closer look at the above screenshot: the record length is 5 Mpts and there are 1000 times more frequency measurement samples than Pk-Pk amplitude measurement samples. Experienced people could tell from the histogram that the modulation signal would very likely be a sine wave, but they would not be able to determine the deviation and modulation frequency.

From the Track Plot we can see that the modulation signal is a sine wave with exactly 50 μ s period (=20 kHz) and it alters the carrier frequency between 9 and 11 MHz.

Counting Pulses

This is a demonstration of the pulse count function. As further refinement, gated measurements can be used in order to ignore unwanted portions of the record.

First the basic pulse measurement without any bells and whistles; a 100 MHz pulse packet with 1 ns rise time and 1000000 pulses is fed into Ch.4

📽 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis SIGLENT A f = 10.01112M	lirm Hz	🗐 ME	EASURE
200.0								1	vleasure	
.300.000.0				Ť					on	off
200.0mV									Mode	
									Simple	Advanced
100.0mV									P	
									Confia	11>
-100.0mV									ർ വ	oar
-200.0mV										eai
-300.0mV								~	S Ty	pe
-2	.00ms 0.00)ms 2.00m	ns 4.00ms	6.00ms	8.00ms	10.00ms	12.00ms 14.00ms			
MEASURE	Ppulse	s(C4) 1	Npulses(C4)	- ***	***		***		Fools	11>
Value	100000)O 9	99999						10013	1.1
Mean	100000	90.00	999999.00					5	Statistics	;
Min	100000)0 9	399999						Juliono	,
Max	100000)0 9	399999						on	off
Pk-Pk	0.00	(0.00							
Stdev	0.00	(0.00						Statistics	s Setting 🕪 🛛
Count	104		104							
C4 DC 1X 100n	1M 1V/						Timebase Ti 0.00s 2.00ms/div N	rigger ormal	C4 DC 0.00V Dising	∲ <mark>&</mark>
FULL U.L							40.0Mpts 2.00G5a/s E	uge:	Rising	

Fig. 90 SDS824X_HD_Pulsecount

The scope registers the correct number of one million positive pulses. The negative pulse count naturally delivers the same number minus one. Together with the peak-to-peak deviation of zero over >100 acquisitions it is obvious that the pulse count is spot on.

Let's add a measurement gate. We define it to start 1.0 ms after the trigger point and to be 5 ms wide:

🏶 Utility	🖵 Display	m Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	is SIGLENT f = 10.01112	Trig'd 2MHz	MEASURE
300.0mV		A			В				
200.0mV		•	5.()0ms					
.100.0mV		1.00m	s						
0.0mV					6.00ms				
-200.0mV									
-300.0mV									
-400 0mV	-2.00ms	0.00ms	2.00ms	4.00ms	6.00ms	8.00ms	10.00ms 1	12.00ms 1	4.00ms
MEASURE	Pp	ulses(C4)	- Npulse	s(C4)	***		***	***	X
Value	50	0005	500005						
Mean	50	0005.00	500005	.84					
Min	50	0005	500005						
Max	50	0005	500008						
Pk-Pk	0.0	00 	1.00						'
Stdev	U.I.	JU	U.37						0
Count	17	6	176						~
C4 DC 1X 100n FULL 0.0	1M nW —— IOV	—					Timebase 0.00s 2.00ms/div 40.0Mpts 2.00GSa/s	Trigger C Normal 0 Edge Ri	4 DC 🛛 🕁 撮 .00V ising

Fig. 91 SDS824X_HD_Pulsecnt_Gate

We now get a count of \sim 500k (100 MHz x 0.005 sec.) as expected. The count is a little higher because of the limited accuracy of the time base in the SDS800.

We can engage the zoom view for a closer inspection of the waveform:

🏟 Utility	🖵 Display	កា Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	is SIGLENT f = 10.0111	Trig'd 2MHz	₿ C4	
	-2.00ms						19:00ms	12.00ms	- 14.00ms	
200.0mV 200.0mV 100.0mV		A 4 1.00ms				- <u>5 00ms</u>				B
-100.0mV										6.00ms
-300.0m	0.99999ms	1.00000ms	1.00001ms	1.00002ms	1.00003ms	/ 1.00004m	is 1.00005ms	1.00006ms	1.00007ms) i s
MEASURE	Ppi	ulses(C4)	- Npulses	(C4)	***		***	***		X
Value	500	0005	500005							
Mean	500	0005.00	500005.	83						
Min	500	0005	500005							
Max	500	0005	500006							
Pk-Pk	0.0	0	1.00							
Stdev	0.0		0.38							-
Count	115	35	1195							~
C4 DC 1X 100n FULL 0.0	1M Z4 hV/ 10.0ns/ 1 i0V 1.00ms	00mV/ —					Timebase 0.00s 2.00ms/div 40.0Mpts 2.00GSa/s	Trigger Normal Edge	C4 DC 0.00V Rising	∜ 🖧

Fig. 92 SDS824X_HD_Pulsecnt_Gate_Zoom Siglent SDS800X HD Evaluation Rev. 1.00 We can still see the gating cursors in the main window, but the detailed view with time data is in the zoom window now. Since the "B" cursor exceeds the size of the zoom window, it is drawn at the right border and the time specification of 6.00 ms is another hint that it is outside the zoom window, which is only 100 ns wide.

The gating cursors are fully independent, consequently we can still add regular cursors (manual/tracking/measurement):



Fig. 93 SDS824X_HD_Pulsecnt_Gate_Zoom_Cursors

With all these information, screen gets a bit busy, but we could also use the traditional info block for the regular cursors and place it at the least disturbing spot:



Fig. 94 SDS824X_HD_Pulsecnt_Gate_Zoom_Cursors2

Cursors

Not everyone might be familiar with the various concepts of cursor measurements, so here comes a brief explanation together with some examples.

There are three kinds of cursors: Manual, Tracking and Measure.

Manual Cursors

In *Manual* mode, the x and y cursor pairs can be moved freely and used like calipers to measure distances in both axes, even at the same time if so desired.

🕼 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analysi	s SIGLENT f = 14.00	Trig'd 0019MHz	E CL	IRSORS
	\sim	7		Ţ					Cursors	
1.500V									on	off
1.600v		AX= 1.45n		/	7				Mode	
0.500V		1/ΔX= 689	.7MHz						Manual	V
👝 ο οπον		X2= 0.66n	s						Cursor	
0.5001/		ΔY= -0.79r	N N				X2	Í	Y2-Y1	\sim
-0.5007		Y2= 1.200	V				X2->	×1	Value	Ċ.
-1.000V		Y1=-1.200	JV						Value	2.4001/
-1.500V							· Y1			- -
-2 nnnv -4.	00ns -3.0	Ons -2.00n:	s -1.(133/1s] 0.00ns []	X2 1.00ns	2.00ns	3.00 Y2		Cursors	Type
MEASURE	ROV(Z	4) — F	0V(Z4)	10-90%Ri	se(C4) 90	-10%Fall(C4)	- +	/4	<u> </u>)
Value	***	**	*	1.4594ns	***	ŧ	*1 12-1		Source	
Mean	***	**		1.464148r	1S ***	7	***		C4	
Min	***	**	*	1.4111ns	***	7	***			
Max	***	**		1.4828ns	***	7	***		Style	
Pk-Pk	***	**	*	71.700ps	***	•	***		Fixed	Following
Stdev	***	**	*	7.472ps	***	1	***		Tixed	r oliowing
Count	0	0		5656	0		0		CursorX	Ref
Histogram					_			\bigcirc	Delay	Position
C4 DC 1X 500m FULL 0.0	1M 1V/ 0V	—					Timebase -3.00ns 1.00ns 20.0pts 2.00GS	Trigger /div Auto ⊧a/s Edge	C4 DC 41.7mV Rising	⊉ 뮮

Fig. 95 SDS824X HD_Cursors_Manual

Tracking Cursors

In *Track* mode, the x-cursor pair can be moved freely, whereas the y-cursor pair will always track the selected signal trace. Of course, this makes most kind of cursor measurements much easier and also more precise.

🏶 Utility	🖵 Display	nî Acquire 🏲 Trig	ger 🗰 Cursors	📐 Meas	🖻 Analysis	SIGLENT f = 14.00019	Trig'd MHz	E CU	RSORS
1.500V		7						Cursors	
¥2								on	off
1.60 0V		AV= 1.45pc						Mode	
0.500V		1/AX= 689 7MHz	i /	i i				Track	\sim
		X2= 0.66ns	1 /	I				Index	·
<mark>€4</mark> ,0.000V,,_		X1=+0.79ns						Cursor	
0.5001/		∆Y= 2.408V						X2-X1	\sim
-0.200.		Y2= 1.200V							
-1.000V		Y1= -1.208V	i / E	.i				Value	0
			₽	+	— <i>,</i> — <u>,</u> — , — , — ,				1.45ns
<u>-1.500V</u>								X1 Source	۵
-2 NNNV -4	.00ns -3.0(Ons -2.00ns -1.	🕅 0.00ns 🗎	<2 .00ns	2.00ns 3	1.00ns 4.00ns			
MEASURE	ROV(Z4	4) — FOV(Z4)	- 10-90%Ris	se(C4) 90-	10%Fall(C4)	+Width(C4)		L C4	
Value	***	***	1.4685ns	***		***		X2 Source	e
Mean	***	***	1.464156n	IS ***		***		C4	
Min	***	***	1.4156ns	***		***			
Max	***	***	1.4828ns	***		***		Style	
Pk-Pk	***	***	67.200ps	***		***		Fixed	Followina
Stde∨	***	***	7.375ps	***		***			
Count	0	0	3961	0		0	-	CursorX F	Ref
Histogram				<u> </u>			\bigcirc	Delay	Position
C4 DC 1X 500n FULL <u>0.0</u>	1M nV/				Ti -3 20	mebase .00ns 1.00ns/div).0pts 2.00GSa/s	Trigger Auto Edge	C4 DC 41.7mV Rising	14 ∲

Fig. 96 SDS824X HD_Cursors_Track

Measure Cursors

Finally, in *Measure* mode the cursors are fully automatic and just visualize the points of the signal trace that are used by a certain automatic measurement. Here are some examples:

Rise Time

🛱 Utility	🖵 Display	nî Acquire 🏲 Tr	igger 🗰 Cursors	📐 Meas	🖎 Analysis	5IGLENT f = 14.00019	Trig'd MHz	CUI	RSORS
1.500V	▽	X1= -793.58	DS	X2= 667.92ps ΔX= 1.46 10-90%F	s 6ns Rise(C4)=1.46ns			Cursors on	off
1.000V								Mode Measure	× .
<mark>€4</mark> ,0.000,V , , ,							++	Measure 10-90%F	ltem Rise(C4)∽
-1.000V								Style Fixed	Following
-2 NNNV -4.	00ns -3.0	Ons -2.00ns -	1.Q <u>X1s</u> 0.0Qns (X200ns	2.00ns 3.00ns	4.00ns			
MEASURE	ROV(Z	4) = FOV(Z4)	= 10-90%R	ise(C4) = 90-1	0%Fall(C4) = +V	/idth(C4)			
Value	***	***	1.4625ns	***	***				
Mean	***	***	1.464234	ns ***	***				
Min	***	***	1.4111ns	***	***				
Max	***	***	1.4829ns	***	***				
Pk-Pk	***	***	71.800ps	***	***				
Stdev	***	***	7.370ps	***	***				
Count	0	0	7418	0	0		_		
Histogram				<u> </u>			\bigcirc		
C4 DC 1X 500m FULL 0.0	1M V/ — 0V				Timeba -3.00ns 20.0pts	se 1.00ns/div 2.00GSa/s	Trigger Auto Edge	C4 DC 41.7mV Rising	\$ ₽

Fig. 97 SDS824X HD_Cursors_Measure_Rise

For the 10-90% rise time measurement, the measure cursors show the corresponding positions for the 10% and 90% threshold on the time axis.

🕸 Utility	🖵 Display ㎡ A	cquire 🏲 Trigger	🗱 Cursors	🛛 Meas 🖻 Analysi	s f = 14.00017	Trig'd MHz	E CUF	RSORS
C4 	20ns	5.00ns 10.00ns	15 0 0ns	20.00ns 25.00ns	30.00ns 35.00ns		Cursors on Mode	off
<u>1,65</u> 00∨ 1/2							Measure	~
	A		<				Measure l ROV(Z4)	tem
1.4500V 1.4000V 1.3500V				Y2= 1.64\ Y1= 1.52\ ROV(Z4)=	/ / =3.92%		Style Fixed	Following
<mark>74</mark> 1 <u>3000∨</u> -5.0	Ons O.ODns	5.00ns 10.00ns	15,00ns	20.00ns25.00ns	30.00ns 35.00ns			
MEASURE	ROV(Z4)	- FOV(Z4)	= 10-90%Rise(C4) = 90-10%Fall(C4)	= +Width(C4)			
Value	3.920%	0.516%	1.461ns	1.572ns	35.776ns			
Mean	3.55937%	0.61173%	1.46562ns	1.57551ns	35.76791ns			
Min	3.153%	0.244%	1.449ns	1.552ns	35.747ns			
Max	4.086%	1.075%	1.480ns	1.596ns	35.790ns			
Pk-Pk	0.93366%	0.83132%	31.00ps	44.00ps	43.00ps			
Stdev	0.17680%	0.12509%	4.66ps	6.81ps	9.53ps			
Count	1378	1288	3490	3490	3490			
Histogram	and the second	A STREET, STRE				\bigcirc		
C4 DC1 1X 500m FULL 0.00	M Z4 V/ 5.00ns/ 50.0mV/ 0V 15.0ns 1.50V				Timebase 0.00s 5.00ns/div 100pts 2.00GSa/s	Trigger Auto Edae	C4 DC 41.7mV Risina	∲ 뮮

Rising Edge Overshoot

Fig. 98 SDS824X HD_Cursors_Measure_ROV Siglent SDS800X HD Evaluation Rev. 1.00 For the rising edge overshoot, the measure cursors show the amplitude difference between top and positive peak.

Positive Pulse Width

🏟 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	f = 14.000	Trigʻd 17MHz	🗎 CU	IRSORS
X1=	-60.21ps 🛛 🍸			ΔX= 35.76	ins		X2= 35.70ns		Cursors	
1.500V		\sim		+Width(C4	1)=35.76ns		^		on	off
1.000V									Mode	
0.500V							N		Moacura	
0.000.									Inteasure	· ·
<mark>c₄</mark> ,0.q0q∨,,_	+ + + + + +			<u>-</u>					Measure	ltem
-0.500V	Å			-					+Width(C4) 🗸 🗸
	l l								Style	
-1.000V	/							1	Eivod	Following
-1.500V									Fixeu	Pollowing
0.0004 5		le 5.00m	- 10.00m	15 D0pc	20 00pc	25.00pc	30.00nc 35[¥2	ц. —		
		13 0.00m 1) C	OV(74)		20.0013	10%Eal(C4)	= +)A(idtb(C4)	_P		
Value	***	+) r	**	1 476ns	1 F	-10%=aii(C4) 585ns	35 764ns			
Mean	***	*	**	1.46581ns	s 1.5	57572ns	35.76783ns			
Min	***	*	**	1.449ns	1.5	552ns	35.745ns			
Max	***	*	**	1.481ns	1.5	596ns	35.790ns			
Pk-Pk	***	*	**	32.00ps	44	.00ps	45.00ps			
Stdev	***	*	**	4.68ps	6.7	76ps	9.55ps			
Count	0	()	4307	43	07	4307	-		
Histogram								\bigcirc		
C4 DC	:1M						Timebase	Trigger	C4 DC	∲ R
1X 500r FULL 0.0	mV/)0∨						0.00s 5.00ns/div 100pts 2.00GSa/s	/ Auto s Edge	41.7mV Rising	

Fig. 99 SDS824X HD_Cursors_Measure_Width

For the pulse width (according to the thresholds configured in the Measurement Config, default is 50%), the measure cursors show the corresponding positions on the time axis.

Math

Identity

Since the SDS800X HD is an extremely affordable package, some corners had to be cut, one of them being the signal samples rendered as clusters of two vertical pixels.

While this hardly poses constraints to our everyday tasks, there might still be situations where we want to get the maximum visual resolution for certain measurements. This is where the math channels come into play.

The Identity function returns the original acquisition data, whereas the Average function is the preferred choice for repetitive signals, because it reduces (also) the 1/f-noise and increases the resolution, hence enables us to produce clean traces even from very noisy signals.



Fig. 100 SDS824X HD_Math_Zoom_Identity_Avg16

The screenshot shows a 12 MHz square wave with 1 ns rise time. Zoom mode has been engaged to take a closer look at the rising edge overshot details.

The channel 4 trace is always 2 pixels high, so it appears thicker than the math traces.

Math trace F2 plots the Identity function, which is basically the same as channel 4, but uses the full screen resolution, hence looks nicer.

Math trace F3 plots the a 16x Average of the signal in channel 4. It reduces the noise and increases the vertical resolution to 16 bits.

If we want to show the math trace(s) exclusively, e.g. for documentation purposes, we can hide the original signal trace in the corresponding channel menu. Siglent SDS800X HD Evaluation Rev. 1.00 Page 88

ERES

At the end of the day, ERES is just a LP-Filter, and maybe just a simple boxcar filter, see screenshot below with ERES 2.0:



Fig. 101 SDS824X HD_FR_ERES2.0_2GSa

FFT-Setup

Like all Siglent DOSs, starting with the venerable SDS1202X-E, the SDS800X HD has a very useful FFT implementation. To get the most out of it, we should be able to set it up correctly.

The FFT-length in the SDS800X HD can be up to 2 Mpts. This enables low resolution bandwidths and low noise, but it's still "only" a 12-bit DSO, hence results below -73 dBFS shouldn't be trusted blindingly. In many cases, the usable dynamic range with decent accuracy can be up to 100 dB though.

Here come some hints for proper setup of the FFT on Siglent DSOs in general and the SDS800X HD in particular.

FFT-Bandwidth and RBW

This is quite different to a traditional SA (spectrum analyzer). There is no menu for the resolution bandwidth and also no direct setting for the FFT-bandwidth, even though we have a menu item for the horizontal display parameters, i.e. start/stop frequencies for wideband

measurements and center frequency/span for narrowband applications. But this is just for zooming into a longer FFT result; for best speed and lowest RBW (resolution bandwidth) we need to make sure that no high zoom factor is required to get the desired display. The following rules apply:

- The analysis bandwidth (FFT-BW) is always half the FFT sample rate (FFT-SR).
- The frequency step Δf is the sample rate divided by the number of FFT points.
- In the Acquire menu, a constant sample rate can be set in order to also limit the FFT-sample rate.
- The resolution bandwidth (RBW) is the frequency step multiplied by a factor specific for the window function in use.

The maximum number of FFT points can be up to 2 Mpts, but it also depends on the record length, which increases with slower time base settings, which in turn might be limited by the maximum memory as defined in the Acquire menu. Apart from that, the number of FFT points can be further limited by the corresponding setting in the FFT-Config menu.

RBW = $\Delta f * k$, where k is the 3 dB bandwidth factor in bins, depending on the window function:

k: Rectangle 0.99, Blackman 1.74, Hanning 1.62, Hamming 1.64, Flattop 3.73. (according to Siglent's implementation)

Blackman and especially Flattop are the most universal and useful window functions in practice. You definitely should stick to these two as long as you cannot prove that some other window would actually work better in your specific application.

Thus: $\Delta f = RBW / 4$ (rounded) in case of the flattop window or RBW / 2 for Blackman.

To get the proper settings for any given FFT-BW and RBW pair, proceed as follows:

Determine the FFT sample rate: SR = FFT-BW * 2 [Sa/s]; Determine the number of FFT points: FFT-pts >= $SR / \Delta f$ [pts]; Determine the time base: TB >= FFT-pts / (10 * SR) [s/div];

As mentioned earlier, you can lower the FFT-sample rate by setting a constant acquisition sample rate; this can be useful when you want really low FFT-sample rates but do not want to use very slow time base settings, which would slow down the acquisition considerably.

In general, we need to keep in mind that the FFT doesn't process the entire screen width. It depends on the time base: at 500 ns/div we get a record length of 10 kpts and an FFT-length of 8192 points and this covers about 82% of the screen width. In many other scenarios, like at 100 or 200 ns/div, it would be just 51.2%.

Whenever you want to analyze a single event like e.g. a short transition, be aware that the FFT might be completely blind for the right half of the screen. As a consequence, do the following:

- place the event between 20-30% of the screen width.
- to get identical results independent of the horizontal position, use the Rectangle window.

Setting up the FFT

Even from the best FFT implementation, we can only expect good results as long as the scope has been set up properly for that specific task. How many so called "reviews" have we seen where FFT has been engaged and some scope settings randomly altered just to get a halfway plausible but actually not very meaningful FFT graph, which was then either praised or criticized?

Of course we can get away with some quick & dirty setup if the requirements are low, but even then we should never ignore the most important parameters like FFT bandwidth, which should always cover the full signal spectrum, otherwise aliasing artefacts could easily spoil our measurement results.

For optimal speed, frequency resolution and dynamic range, we need to put a little more effort into a proper setup, which has quite different requirements compared to the usual Y-t view (aka time domain). Below there is a complete checklist how to properly set up the DSO for analysis in the frequency domain (most of these topics should be obvious, but still listed for completeness):

- 1. Set acquisition mode to normal. Use ERES only for a good reason and stay away from average. Avoid Peak Detect under all circumstances and without any exception!
- 2. Use edge trigger in auto mode to make sure signal acquisition doesn't stop even when the signal amplitude drops below the trigger sensitivity. FFT doesn't require a stable trigger, so you can also use AC-line trigger for that.
- 3. Determine the lower bandwidth limit for the FFT analysis. If it is >10 Hz, use ACcoupling for the input channel to ensure maximum dynamic range even with large DC offsets and/or high input sensitivities. If DC-coupling has to be used, use the vertical position control to compensate for any DC offset, so you can optimize sensitivity and get the highest possible dynamic range.
- 4. Determine the upper bandwidth limit for the FFT analysis. In order to avoid aliasing artifacts, this should not only cover the desired analysis bandwidth, but include the highest expected input frequency. In general, it's best to start with a higher upper bandwidth limit and reduce it only after it has been confirmed that there is no significant signal content above the desired final limit.
- 5. Choose the frequency step size according to the explanations given earlier in this article, which would be about one quarter of the required resolution bandwidth when using the Flattop window.
- 6. Find an appropriate set of horizontal time base setting and the number of FFT points; refer to the explanations given earlier in this article. You should watch the displayed FFT parameters while altering the time base and double check that they match your expectations. Be aware that the desired resolution bandwidth might not be achievable due to the limited choice of sample rates and FFT lengths and/or the maximum specified FFT length of 2 Mpts.
- 7. Engage FFT mode, select the correct source channel and start with Split Screen mode.
- 8. Set the vertical gain so that the peak amplitude of the input signal is between ±2 to ±4 divisions.
- 9. Set the horizontal FFT display parameters according to the bandwidth you want to display and select linear/decade mode for the frequency axis. Decade is advantageous for wideband measurements, whereas linear is best for narrowband applications.
- 10.Set the vertical FFT display parameters, i.e. the desired level units (dBV or dBm, forget volts!) and make sure the external load impedance matches reality whenever working with power levels, i.e. dBm. Set the reference level and vertical scale so that the FFT amplitude range of interest makes best use of the available screen space.

- 11.Setup (at least) an automatic peak-to-peak measurement for the input channel. During frequency domain analysis, especially in Exclusive mode, keep an eye on the V_{PP} measurement for the input channel to make sure no overload occurs.
- 12.Make sure the desired window function is selected.

Hint: stay in Split Screen mode until the amplitude setup is finished and the levels are reasonably stable, then switch to Exclusive mode. By keeping an eye on the peak-to-peak measurement of the input signal, you can still detect an overload condition instantly; the scope indicates that by displaying > in front of the measurement value.

Example: Pk-Pk >851.875mV instead of Pk-Pk 755.000mV.

FFT Window Functions

For the ones who try to understand the consequences of certain settings in the FFT analysis – this is about the window functions.

Why are there so many different windows (only few of them available on the SDS800X HD)? What is the best window to use?

There have been times when processor systems haven't been nearly as powerful as today. Non-RISC architectures with just 1 MHz clock frequency and less than 1 kB RAM were not uncommon during the seventies of last century. Instruments that could compute a FFT at all have been rather exotic, and FFT-lengths like 64 points were quite common. In the light of this, there is no wonder that less than ideal FFT-window functions optimized for certain tasks were popular.

Sometimes there are descriptions about the benefits and drawbacks of the various window functions, yet most folks would rather not care and want a universal setting that works for them almost every time. Just like with a traditional SA (spectrum analyzer) with analog RBW (resolution bandwidth) filters in the final IF (intermediate frequency) path. And fortunately, there is one...

There are several features of a window function, and two of them are amplitude accuracy and resolution bandwidth. If we look at just these two properties, then the rectangle window would have the narrowest resolution bandwidth but the worst amplitude error, whereas it's just the opposite for the Flattop window.

So, whenever we need the best frequency resolution, we just sacrifice a bit of accuracy and use the Rectangle window?

It's not that simple. An FFT divides the entire analysis bandwidth into frequency bins. If, for instance, we have an FFT-length of 32768 points, then we get 16384 such frequency bins and at an effective sample rate of 2 MSa/s, each of them will be 61.04 Hz wide. In this case, 61.04 Hz is the bin width and the bin spacing at the same time. The center of a bin will always be an integer multiple of the bin width.

Now FFT-windows behave differently, depending on the offset of the input signal frequency from the bin center. I did a selectivity test for the various window functions available on an SDS800X HD and used the before mentioned parameters:

FFT-sample rate = 2 MSa/s

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FFT-Length = 32768 pts Bin-width = 61.03515625... Hz

The test will be for amplitude accuracy and the -20 dB, -40 dB and -60 dB selectivity. I define the latter at the frequency distance for a -20, -40 or -60 dBc signal to still produce a visible 3 dB peak in the spectrum (and not drowned out by the leakage of the neighboring 0 dBc reference signal).

The -3 dB bandwidth might be most important for characterizing the passband of any two-port network, but for a filter, where the selectivity is the main concern, the bandwidth at a useful attenuation is even more important.

The metric of a filter shape factor exists, which is usually defined as the ratio of the filter bandwidth at -60 dB and -6 dB. The shape-factor might even be the most important property of any RBW filter at all, because it ultimately defines selectivity. Consider what a proper BP (Band-Pass) filter, as it might be found in any traditional SA, looks like:



Fig. 102 Ref-BP_Cheby9_0.2dB

This is a 9^{th} order Chebyshev BP filter with 0.2 dB passband ripple. It has a -3 dB bandwidth of about 10 kHz and less than 16 kHz bandwidth at -60 dBc. The shape factor is thus ~1.57. The lower the shape factor, the higher the selectivity.

What does it mean in practice? We can distinguish a strong signal at 0 dBc together with a weak signal at -60 dBc next to it, as long as the distance is at least ~13 KHz, i.e. 1.3 times the RBW. That is excellent and makes for a useful analysis in the frequency domain.

An FFT is quite different to a classic continuously swept spectrum analyzer. If we feed a stable sine wave into a swept analyzer, we'll get the frequency response plot of the RBW-filter.

The FFT doesn't plot a continuous filter response, but simply shows the outputs of the individual frequency bins, and ideally only the one bin covering the input frequency responds with the correct amplitude (and phase, but that's not displayed). It is like a huge filter bank with a bunch (16384 in our next example) of filters, all working in parallel. What we see is different from the RBW-filter response; we rather see the "leakage", i.e. signal outputs from neighboring "filters" (bins), sometimes even far away from the signal frequency - and there are amplitude errors for the main bin.

A 0 dBm test signal of 499.99342 kHz has been used for the first test, which is equivalent to precisely 500 kHz if the time base of the SDS800X HD were accurate. this is precisely 8192 times the bin width, hence the exact center of a bin.

What do we get?

Window	Ampl.	Sele	ctivity [H	Hz]
	[dBm]	-20 dB	-40 dB	-60 dB
Blackman	0.0	236.58	236.58	236.58
Flattop	0.0	366.58	416.58	416.58
Hamming	0.0	168.58	168.58	168.58
Hann	0.0	171.58	171.58	171.58
Rectangle	0.0	98.58	98.58	98.58
/T 1 1 4 TT7' 1	1 4	1.		

Table 4 Window selectivity bin center

Look at the rectangle window, with two signals as an example. The 0 dBm reference signal (carrier) and the 2nd signal at -40 dBc (with an enormous amplitude error of 2.8 dB), which creates just a 3 dB peak at a distance of 98.58 Hz,:

ŝ	Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	⊾ м	eas 🖻	Analysis	SIGLENT f = 499,999	Trig'd 9kHz	🗎 Cor	nfig
								Sa=	2.00MSa/s		Max Poin	ts
_ 0	0dBm							Curr Af=	= 32768pts 61.04H 7		2M	\sim
F4.0			i					RBV	/= 60.42Hz		Window	
								· Avg=	:16		Rectand	• V
	10.0dBm		·····								Rectang	<u> </u>
-	20.0dBm										Full Span	
Ę.	30.0dBm,		-+-+-+-				-1-1-1-1-1				Peak to C	center
								۸Y=	-3 000dB		Display	
_4	40.0dBm							Y2=	-45.8dBm		Exclusive	• ~
	(1			1	· - -			Y1=	-42.8dBm			<u>^</u>
_	50 0dBm											e
				{							Average	
			· · · · ·								Average (Count C
t	OU.UOBM											16
	49	9.000kHz 499,	,500kHz 500.00	00kHz 500%500	kHz 501.000kH	Hz 501.	500kHz 502	2.000kHz :	502.500kHz 503.000	JkHz	Reset	
Pk	-Pk	617.500mV	Stdev	223.44444	lmγ							
C	4 DC	1M F 4 FI	FT(C4)					Ţ	imebase	Trigger	C4 DC	뮮
1X FUl	200m _L0.0	107 1 107 10	0.0dB/					0 4	.00s 2.00ms/div D.0kpts 2.00MSa/s	Auto Edge	0.00V Rising	09:49:05 2024/3/18

Fig. 103 SDS824X HD_FFT_Rectangle_0.0_S40dB_500092Hz

With a distance of just 1.615 bin widths, selectivity is quite good. Yet real-world signals will usually not be an exact integer multiple of the bin-width, so we need more tests.

In any practical application where the FFT of a general-purpose oscilloscope is to be used, we cannot freely define the signal frequencies, hence they will be more or less off center. Even if we could select a frequency, most related signals like intermodulation (mixer) products and spurs can still have any frequency offset with regard to the bin spacing. Consequently, we need to take the worst case into consideration, that is a frequency offset of half the bin-width.

A 0 dBm test signal of 500.02394 kHz has been used for the following test, this is precisely 8192,5 times the bin width, hence the exact bin-border for my individual sample of the SDS824X HD.

Window	Ampl.	Sele	ctivity [Hz]
	[dBm]	-20 dB	-40 dB	-60 dB
Blackman	-1.0	206.06	266.06	426.06
Flattop	0.0	386.06	386.06	451.06
Hamming	-1.8	196.06	196.06	-
Hann	-1.3	203.06	326.06	586.06
Rectangle	-3.8	381.06	2780.06	-

Table 5 Window selectivity bin border

This looks very different, doesn't it? All of a sudden, the rectangle window has 3.8 dB amplitude error and its selectivity isn't all that good anymore. In fact, it is unbelievable >45 bin-widths for the -40 dBc selectivity! By contrast, the Flattop window hasn't changed at all: the amplitude error is effectively zero as it was before and also the selectivity has only marginally changed. That means more than -60 dBc attenuation at 300 Hz (less than 5 bins) distance from the center.

Hamming does not have a 60 dB attenuation within a reasonable bandwidth – in fact it is so wide that I could not be bothered to measure it. The same applies to the Rectangle window, where even the -40 dBc selectivity test didn't reveal anything useful:



Fig. 104 SDS824X HD_FFT_Rectangle_0.5_S40dB_502800Hz

What do we want for a proper RBW filter for spectrum analysis, in order to get serious and accurate measurements?

- 1. High dynamic range. We have no use for a RBW filter that has no proper stopband attenuation, hence picks up all the garbage from the neighborhood.
- 2. Fast transitions into the stopband, which is equivalent to a low shape factor.
- 3. A reasonably flat passband without massive amplitude errors, as soon as the signal frequency gets off center a bit.
- 4. And most importantly, all parameters shall be constant and independent of the exact input frequency.

The only window that appears to be perfect in almost all regards is the Flattop window. It has a very high dynamic range, low shape factor, a totally flat passband, and even more important, its properties remain constant and do not depend on the signal frequency. Only downside: it has the widest bandwidth of all candidates. Yet in modern equipment, where at least 1 Mpts FFT have become standard, we need not desperately look for a windows function that sacrifices a lot of good properties just for a little narrower RBW.

Blackman is the only alternative that I can recommend from the selection in the Siglent SDS800X HD. It has less than half the RBW of the Flattop window and the shape factor is still reasonable. It works down to -60 dBc even with the worst-case frequency offset of half a bin width, and the passband flatness, hence also the amplitude error, is not too high. This is generally true for all window functions of the Blackman-family, especially Blackman-Harris. Siglent only implements the original Blackman window though.

There are special applications, like analyzing isolated single events, where the Rectangle window can have advantages, so it should still be considered in these situations.

You can take a look at all the remaining window functions in the attachment, albeit only for worst case frequency offset, indicated by "0.5" in the file name.

FFT Dynamic range

Since the introduction of the SDS1004X-E in early 2018, FFT has always been a strong point of Siglent DSOs. The SDS800X HD is no exception and numerous examples have been published already in this review, as the FFT is an incredibly universal tool to demonstrate fundamental features like frequency response, noise distribution and signal spectra in general, as well as measure distortion products, spurious signals and weak signals, deeply buried under the noise floor.

One of the concerns with the FFT in DSOs is the dynamic range. For 8-bit acquisition systems, this is only about 49 dB according to the textbook, as it is some 73 dB for 12 bits. And indeed, we need to be careful when acting outside these "guaranteed" dynamic ranges. Yet the wonders of process gain in an FFT and other resolution enhancement techniques can extend the usable dynamic range quite a bit, and this shall be demonstrated for the SDS800X HD in some best-case scenario.

What is the "best case" scenario? It is a frequency at or above 1 MHz in order to escape the 1/f noise, but at the same time the frequency should be low enough so we can get rid of all the high frequency noise by using the 20 MHz bandwidth limiter plus an additional steep 20 MHz lowpass filter. Consequently, we practice math on math (the SDS800X HD could also have combined it in one formula instead) and calculate the FFT on the filter output instead directly on the channel data.

Two signals from an AWG at 9.9 and 10.1 MHz are fed into a wideband signal combiner, where the second signal goes through a fixed 20 dB attenuator together with a 1 GHz step attenuator before it hits the combiner, whose output is connected to the SDS824X HD channel 4 input via another 10 dB inline attenuator and a 50 ohm through terminator. Of course, the tolerances of these various components sum up, so I have calibrated the whole setup for a 0 dB setting of the step attenuator first by means of the AWG output levels, but left them untouched for all subsequent measurements. As a consequence, only the tolerance of the step attenuator will affect the results. The step attenuator is a Wavetek 5080.1 with a specified tolerance of +/-1 dB up to 400 MHz. After using it many decades, I can tell from experience that it thankfully is clearly more accurate than that.

In order to get a low RBW (Resolution Bandwidth), hence also a low noise floor, we don't want an excessively high sample rate; 100 MSa/s and a Nyquist frequency of 50 MHz is plenty to deal with a 10 MHz signal and also a 20 MHz FIR filter.

Here's the calibration result:

ş	🕸 Utility	🖵 Displa	ay n Acquire	🏲 Trigger	♯ Cursors	📐 Meas	🖻 Analy	sis f=s	ENT Trig'd 9.900123MHz	🗎 MATH
E4	200.0) 200.0mV 100.0mV .0.0mV .100.0mV .200.0mV						F4 Markers L Marker A 1 2 ·	List bs.Ampl. 0.005dBm -40.043dBm	Abs.Freq. 9.90000MHz 10.10000MHz	
	-400 0mV	-1.00ms	0.00ms	1.00ms	2.00ms	3.00ms				7.00ms
F4	-0.0dBm -20.0dBm -40.0dBm -60.0dBm -80.0dBm				1	· · ·	2		Sa= 100.00MS Curr=524288pts Δf= 190.73Hz RBW= 711.44H Avg= 16	a/s 5
	-120.0dBm.	9.600MHz	9.700MHz	9.800MHz	9.900MHz	رمىيەلەر مەلبىلىد 10 000MF	Hz 10 100MI	Hz 10 200	MHz 10.300MH	z 10.400MHz
1) 2	C4 DC X 100n 0M 0.0	1M F1 nV/ 100MS	Filter(C4) F4 100mV/ a/s 0.00V	FFT(F1) 20.0dB/ 20.0dBm				Timebase 0.00s 1.0 1.00Mpts 10	Trigger D0ms/div Auto D0MSa/s Edge	C4 DC ↓ ₩ 0.00V Rising

Fig. 105 SDS824X_HD_FFT_DR_500kpts_10MHz_40dB

The error is <0.05 dB. Going from there, here's the measurement for 80 dB level difference:

ίος	🕽 Utility	₽	Display	fî i	Acquire	۲	Trigger	#	Cursors	≥ 1	vleas	ध्य	Analys	sis	51GU f = 9	ENT .900123	Trig'd 3MHz	ē	MATH	
	388.8m\/									Į		F4 Ma	: rkers L	.ist			X			
												Marker	A	os Amn	1	Ahs F	rea			1999 (March 1997)
												1		-0.0350	dBm	9.900	00MHz			
												2		80.212	dBm	10.100	00MHz			
E4⊁																				
	-300.0mV																			
	-400 0mV - 1	-1.00	Jms	0.00r	ns	1.0	Oms	2.0	Oms	3.00	lms								00ms	
F4	-0.0dBm															Sa= 10 Curr= 5	0 000MSa 24288pts	/s		
2	-20.0dBm															∆f= 19	0.73Hz			
	-40.0dBm															Ava= 18	711.44H2 3			
	-60.0dBm																			
	-80.0dBm												2							
į	-100.0dBm		*****	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	•••••••	upaneses been reached	لمعيلها	Marchataran	ruduu	n digili ya digili n	fallynnwywei lygeid ho	****	ana an Istain	way for you	*****	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	an and a second		*****
	-120.0dBm																			
	-140 0dRm	9.60	OMHz	9,700	MHz	9.8	00MHz	9.9	00MHz	10.C	000MH	lz 10	100MH	Hz 1	0.200N	1Hz 1	0.300MHz	10	.400MHz	
1× 20	04 DC (100m)M 0.0	1M hV/ 0V ⊡	F1 Filt 1 100MSa/s	er(C4 00mV 0.00\) F4 7 7	FF 20 20.	T(F1)).0dB/ 0dBm							Timeb 0.00s 1.00M	ase 1.0 pts 10	0ms/div I0MSa/s	Trigger Auto Edge	04 0.0 Ris	DC DOV Sing	∲ 🙀

Fig. 106 SDS824X_HD_FFT_DR_500kpts_10MHz_80dB

The error is < 0.25 dB, which could well be attributed to the step attenuator.

🏟 Utility	₽ D	isplay	rîî Acq	uire	🏲 Trigger	# Cursors	📐 Me	as	دي Ar	nalysis	; SIG	i lent : 9.90012	Trig'd 4MHz	Ē	MATH	
200.0-1/							Į		: F4 Marke	are lie	: †					
200.0mV									Marker	Δhs	Δmnl	Ahs F	reg			
100.0mV									1			9.900)00MHz			
0.0m)/									2	-99	3.372dBm	10.100)00MHz			
100.0ml/																
-100.000																
-200.0mV																
-300.0mV	1.00		0.00		1.00	2 00	2.00							7.0	Deno	
-400 0mV	-1.00m		0.00ms		Luums	2.00ms	3.0000							7.0	oms	
an 0.0dBm						1						Sa= 1	00.00MS	a/s		
-20 0dBm												Curr= t Af= 19	524288pt 10-73Hz	S		
40.0dDm												RBW=	711.44⊦	łz		
-HU.UUBIII												AVg= 1	b			
						· · · · · · ·										
-80.0dBm									2							
	M544 AN 1-14	agailangi laikis	man	\ ~~~~ \}	-hermony of a france	Andrew Hardenberger	which many	antoine	Manager And and an	-	رامها در میطاند. «میارد		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	مەلچىدە رەپەر رەدە ^ر		contemportan
-120.0dBm.	0.000		0.700141			0.0001411	40.000		40.40		40.00		40.00014		1001411	
-140 0dRm	9.6000	IHZ	9.700MH	Z 8	3.800MHZ	9.900MHZ	10.000	IMHZ	z tustu	JUMHZ	10.20	UMHZ	10.300MF	iz 10	400MHZ	
1X 100r	nW F	Filt	er(C4) D0mV/	F4	FFT(F1) 20.0dB/					C	1mebase 1.00s <u>1</u>	.00ms/div	Auto	C4 0.0		∦ 8
20M 0.0)0V 10	0MSa/s	0.00V	2	20.0dBm					1	.00Mpts	100MSa/s	Edge	Ris	ing	

Now let's try 100 dB with the same setting:

Fig. 107 SDS824X_HD_FFT_DR_500kpts_10MHz_100dB

The measurement error is still <0.7 dB, yet the 2^{nd} signal is almost down in the noise.

Up to now, we've only computed a 512 kpts FFT, so let's try 1 Mpts now, thus cutting the RBW in half.

j	≹ Utility	₽D	isplay	rîî Ad	cquire	🏲 Trig	gger	# Ci	irsors	4	Meas		🖻 An	alysi:	s	sigu f = 1	ENT 9.9001:	Trig'c 24MHz	1		MATH	
	3 88.8m\/										ŧ	F4	Marker	rs I io	st							
												 Ма	rker	Ahs	s Amr	il.	Ahs	Freg				
													1	-	0.971	dBm	9.90	0000MH	z			
54.													2	-10	0.122	dBm	10.10	0000MH	z			
541																						
	-400 0mV	-2.00m	IS	0.00ms	3	2.00ms	;	4.00m	s	6.0	Oms									14.	00ms	
F 4}-	0.0dBm																_Sa=_' ⊡Curr=	100.001 10485	VISa/s 76nts::			
	20.0dBm																∆f= 9	5.37Hz				
	40.0dBm																- RBM: 	= 355 16	/2Hz			
F	-60.0dBm																					
	-80.0dBm																					
	100.0dBm						- de constant de c	ليالمهل		ta de	Į.		2									
	-120.0dBm	****	ilin des del temper		h-millermanne					An initial and a second s			and the second second	ales and a second	,	t vielant og t	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	aintatur	and the states of the states o	nin meningen	489149-149491	and an and a set of a
	140 NdRm	9.600N	1Hz	9.700M	1Hz	9.800M	Hz	9.900N	/Hz	10	.000MH	Ηz	10,100	OMHz	z ć	10.200	MHz	10,300	MHz	10.4	400MHz	
0 1X 20	24 DC 100n M 0.0	:1M F nV/)0V 10	1 Filt 1 0MSa/s	er(C4) 00mV/ 0.00V	F4	FFT(F 20.0dl 20.0dB	1) 3/ m							· (;	Timet 0.00s 2.00M	base 2.0 lpts 1	00ms/di 00MSa/:	Trigg ∨ Auto s Edge	er Ə	C4 0 0.00 Risi	DC)V ng	∲ 提

Fig. 108 SDS824X_HD_FFT_DR_1Mpts_10MHz_100dB

Now the 2^{nd} signal is clearly above the noise floor, yet the total error is even slightly worse now at ~0.85 dB.

Nevertheless, taking the 100 dB dynamic range and the tolerances of the step attenuator into account, this sis till a remarkable result.

FFT Speed

The FFT speed is limited to about 18 computations per second, which can be maintained up to 64 kpts. We still get more than 10 frames per second for 128 kpts and from there it scales proportionally, i.e. 5 frames for 256 kpts and so on up to 2 Mpts, where the update rate is only about 0.75 FFT computations per second. At this setting, the highest absolute speed of ~1.6 Mpts/s is reached.

Distortion measurements

General purpose oscilloscopes cannot have ultra-low distortion frontends, especially nowadays, where even entry level instruments start at 70 or 100 MHz bandwidth. And even a low-end device like the SDS800 goes up to 200 MHz for the top model within the line, and I'd bet the integrated PGA (Programmable Gain Amplifier) in these devices has more than 0.5 GHz bandwidth.

To cut a long story short: the usual techniques to keep distortions down in audio devices, particularly global feedback, cannot be applied to wideband amplifiers. Taking this into account, it's still amazing what can be achieved with modern integrated circuits, yet it's the main reason why 12-bit DSOs fail to come even close to 12-bit ENOB.

Siglent SDS800X HD Evaluation Rev. 1.00

ş	🕸 Utilit	y 🖵 Displ	ay nî Acqui	re 🏲 Trigge	er 🗰 Curson	s 📐 Meas	🖻 Analys	sis SIGLENT f = 10.00	Trig'd 0012MHz	₿ C4
							F4 Marke	ers List		
							Marker	Abs.Ampl.	Abs.Freq.	220 0m
							1	-0.018dBm	10.00023MHz	
							2	-66.190dBm	20.00022MHz	110.0m\
24							3	-81.028dBm	30.00045MHz	0.0m
64							4	-75.001dBm	40.00044MHz	
							5	-79.289dBm	50.00067MHz	-11U.Um\
							6	-83.181dBm	60.00066MHz	-220.0m\
							7	-72.471dBm	70.00089MHz	220.0~
							8	-78.919dBm	80.00088MHz	
		-0.500ms	0.000ms	0.500ms	1.000ms	1.500ms	2.0000115	2.000005	a.oporns	- 3.500ms
F 4)			· · · 2 · · ·	· · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·	· · · 5	· · · ·	Sa: Cui Af= RB Avg	= 500 00MSa/s r= 2097152pts 238.42Hz W= 889.30Hz j= 16	5
		10 0MHz	20 ∩M⊔≁	20 NMH-	40 DMH-7	50 DMHz	60 DMU-7	70 0MH-7	90 0MH-7	-120.0dBm
_		TO JUNITZ	20:010112	JO:UMITZ	40:0IVINZ	50:pminz	00.0IVITZ			
1) Fi	C4 X ULL	DC1M F4 110mV/ 0.00V	FFT(C4) 20.0dB/ 20.0dBm					Timebase 0.00s 500us 10.0Mpts 2.00GS	/div Auto a/s Edge	C4 DC ↓ ₩ 0.00V Rising

Let's start with the harmonic spectrum of a low distortion 10 MHz sine wave:

Strongest harmonic is the 2nd at -66 dBc. Since all other harmonics have considerably lower amplitude, we can safely state that THD is about 0.05%, which isn't bad at all.

Yet such results cannot be guaranteed; the individual gain stages within the PGA can have differences in linearity, so we need to know our instrument and take note of the weak as well as sweet spots within the vertical gain range. My particular sample of the SDS824X HD has a weak spot at exactly 100 mV/div, whereas all the settings >100 mV/div up to (at least) 110 mV/div yield results like the one shown above.

Whenever we do distortion measurements of the DSO frontend, we need to be confident that the distortion products actually come from the DSO and not the signal source. It can be tricky to verify this, hence a different approach might be more precise: the dual tone intermodulation test.

Fig. 109 SDS824X_HD_FFT_THD_10MHz

4	🕸 Utility	🖵 Disp	lay rî	1 Acquire	🏲 Trigger	♯ Cu	rsors	📐 Meas	🖻 Analys	is SIGLENT f = 9.90899	Trig'd 92MHz	C4
	150.0mV							- F4 Markers	s List			
	100.0mV						· · ·	Marker	Abs.Ampl.	Abs.Freq.	Delta Ampl.	Delta Freq.
	50.0m\/							1	-10.777dBm	n 9.50000MHz		
								2	-10.904dBm	n 10.50000MHz	-0.127dBm	1.00000MHz
C4	,0.QmY							3	-80.213dBm	n 8.50000MHz	-69.436dBm	-1.00000MHz
	-50.0mV							4	-80.063dBm	n 11.50000MHz	-69.286dBm	2.00000MHz
	-100.0mV											
	-150 ÚmÝ											
		100 Oue	n	lue	100 Oue	200.00	-					
	-2000 Nmv -	-100.005	0.0	jus.	100.003	200.00						
F4	0.0dBm					1			2	Sa= 2 Curr=	.00GSa/s 1048576pts	
	-20.0dBm									∆f= 1	91kHz	
	-40.0dBm									RBW=	1.11kHz 16	
	-60 0dBm											
				3			1				4	
				1			1	-				
	f. TAN ARD.	ang tanan ang tanang tanan di sa di sa I	n an the second s	duri lugipanon	*****	and a second and a s	an pagarantan l	al particular and a second	and the second second	m	walnow low parts	with man man man and
	-120.0dBm											
	-140 0dRm	8.000MHz	8.6	500MHz	9.000MHz	9.500M	Hz	10.000MHz	10.500MH	lz 11.000MHz	11.500MHz	12.000MHz
1. F	C4 DC X 50.0n ULL 0.0	1M F4 1V/ 10V	FFT(20.0 20.0dl	C4) dB/ — Bm						Timebase 0.00s 100us/div 2.00Mpts 2.00GSa/s	Trigger 0 / Auto 0 s Edge R	24 DC 🛛 🖞 💑 0.00V Rising

Fig. 110 SDS824X_HD_FFT_IMD_10MHz_95FS

Two independent +6 dBm signals at 9.5 and 10.5 MHz are fed into a resistive wideband power combiner. To ensure proper isolation between the two signal sources and avoid intermodulation distortion at their output stages, a 10 dB inline attenuator has been added to each generator output. Together with the 6 dB attenuation of the splitter, we'd expect two -10 dBm input signals.

Quite obviously, the external termination of the DSO input, which cannot compensate for the ~ 17 pF input capacitance, is responsible for the higher-than-expected losses, hence inaccurate input level. Since we use relative measurements anyway (delta amplitude in the markers list), this doesn't matter though.

A vertical gain of 50 mV/div doesn't appear to be a weak spot in this instrument, so we get respectable -69 dBc for the third order intermodulation products.

ş	🕸 Utility	모 (Display	nî Acq	uire f	Trigger	#	Cursors	📐 Meas	🖻 Analys	is f=13	NT T 33.8858N	īrig'd ∕IHz	Ē	C4
	150.0mV								F4 Marke	rs List					
	100.0mV								Marker	Abs.Ampl.	Abs.Freq	. C)elta Ampl		Delta Freq.
	50.0mV								1	-12.236dBm	140.00000	ИНz			
									2	-11.417dBm	141.00000	ИНz	0.819di	Зm	1.00000MHz
C4	,0.QmY								3	-79.495dBm	139.00000	ИНz	-67.259dl	Зm	-1.00000MHz
	-50.0mV								4	-82.437dBm	141.998290	MHZ	-70.201dl	∃m	1.99829MHz
	-100.0mV														
	160.0-17														
	- IDU.UMV														
	-200 0mV	-100.0	Jus	0.0us	1	00.0us	200).Ous							
E A	0.0dBm							4		2		Sa= 2.0	0GSa/s		
14										,		CUIT= 10 Af= 1 01	48576pts 7747		
	-20.0dBm											RBW= 7	ni 12 V11kHz		
	-40.0dBm											Avg= 16			
	-60.0dBm							<u> </u>							
	-80.0dBm					Ý					4				
	-100.0dBm	4						- Why	and and and the	Muna					
	-120.0dBm		alender (b. Phalenie						i i i i i i i i i i i i i i i i i i i		a data da angla da a				nanini), înfrikanî der anî fer jîrden dinanî
	-140 NdRm	136.5	OMHz	137.50M	Hz 1	38.50MHz	139	9.50MHz	140.50MH	z 141.50MH	z 142.50M	Hz 14	3.50MHz	14	4.50MHz
1) F	C4 DC X 50.0n ULL 0.0	1M 1V/ 0V	F4 FF 20 20.	T(C4) 0.0dB/ 0dBm							Timebase 0.00s 10 2.00Mpts 2.00	- Ous/div / IGSa/s [Trigger Auto Edge	0.0 Ris	DC 🛛 🖞 😹 IOV ing

Fig. 111 SDS824X_HD_FFT_IMD_140MHz_95FS

Two independent signals at 140 and 141 MHz are fed into the power splitter. At these higher frequencies, the problems with the external termination get even more obvious and instead of the nominal level of -10 dBm we get up to 2.2 dB less. Once again, we don't care because we're only interested in relative levels.

The vertical gain of 50 mV/div from the last test is used again and we get respectable -67 dBc for the third order intermodulation products. Other than an OpAmp with global feedback, distortion performance does not necessarily get much worse at higher frequencies.

Analysis

Counter

The SDS800X HD does not provide a DMM, but it has at least the Counter application. It can be used as a frequency counter or totalizer. I don't see much use in the frequency counting function, chiefly because the automatic measurements can do exactly the same – and even on more than one channel at a time – and then we have the always visible 7-digit trigger frequency counter on top of that (I wouldn't ever want a scope without that feature!).

But the Counter is still not useless, because it always works on undecimated data just like the trigger frequency counter, but with complete statistics if so desired.

📽 Utilit	y 🖵 [Display	nî Acqu	iire 🏲 T	rigger	# Ci	irsors	4	vleas	🖻 Anal	ysis SI	GLENT f < 2.0H	Stop z	E Co	ounter
996.7m	nV						-		COUN		Totalizer(G	iated)(C4)		Counter	off
									Value		10.000khit	s		UIT	UII
сз , 796.7m	nV						-		Level	e el	0.00V			Mode	
596.7m	nV								GateL	evel	U.UUV			Totalize	
														Source	
396.7m	nV , _ , _ ,													C4	
196.7m	nV													Slopo	
														Dicina	Falling
<mark>c4</mark> -3.3mV														Rising	Failing
-203.3r	mV													Level	<u>ى</u>
	1.00mm	0.00) 	00	0.00	2.0	D	4.0	Orea	5.00	C 00mm	7.00			V00.0
	- i .eoms	U.U.	ums I.	- Francia	2.00ms \	3.0	oms	4.0	ums ***	o.ujums	0.00ms	7.00ms			
Value	τE	605.80	Jue(C4) 7mV	9 9751N	·) 1H7									Gate Se	tting ">
Mean		599.98	698mV	10.0001	63MHz										
Min		594.16	7mV	9.9534N	1Hz									Totalizer	Reset
Max		605.80	7mV	10.0555	MHz										
Pk-Pk		11.640	00mV	102.100	kHz										
Stdev		5.8203	1mV	10.560k	Hz										
Count		2		2000											
C3 1X FULL	DC1M 200mV/ 1) 400mV F	04 K 2 ULL -	DC1M 200mV/ 397mV								Timebas 0.00s 10.0Mpts	e 1.00ms/div 1.00GSa/s	Trigger Stop Edge	C3 DC 0.00V Rising	*₩

And then, the counter can also be configured as gated totalizer:

Fig. 112 SDS824X_HD_Totalizer_Gated

Channel 3 is fed with a 1 ms wide pulse as a gating signal, channel 4 is connected to a 10 MHz sine source. Consequently, a single shot acquisition results in 10000 hits = 10 khits. This is deadly accurate because both signals come from the same AWG, hence both signals are derived from the same OCXO (whose accuracy is irrelevant in this application, yet is specified <100 ppb)

Other than the pulse counts in the measurements, the counting process can be controlled by an external signal.

Bode Plot at a glance

Instead of showing an inexpressive first order RC-lowpass filter demonstrating less than 40 dB dynamic in the audio range, I'd rather check the most important characteristics of a Bode Plot: frequency- & dynamic range and accuracy.

For this, I've refrained from using inline terminators at the scope inputs but fed them from 50 Ω sources directly via ~25 cm long coaxial cables. The source resistance of 50 Ω , together with the cable and scope input capacitances, forms a first order lowpass filter at ~10 MHz. This can also serve as a warning how even very short cables can introduce significant amplitude errors at relatively low frequencies, as long as a transmission line is not properly terminated.

We can see this characteristic when using the "Vout" mode of the Bode Plot, where we get the absolute amplitude of the DUT output (where the DSO itself represents the DUT).



Fig. 113 SDS824X HD_Bode_1M_Vout

The amplitude drops quite significantly above 10 MHz. It is not the 20 dB/decade like a classic first order lowpass – and this is for a number of reasons that I won't discuss in this article. Bottom line is, that even with very short cables, accuracy of the absolute signal level is gone already at moderate frequencies of a couple MHz.

The phase plot does not resemble this, as it stays within $+/-1^{\circ}$ up to 120 MHz quite easily. It almost looks like this would not be a minimal phase system, yet it's just the nature of a multi-channel oscilloscope, where the input signals are always phase aligned.

When using the relative (Vout/Vin) mode (as we usually do), things look completely different:

Bode Plo	t				🗎 AM	IPLITUDE
	Freg(Hz)	Am(dB)	Phas 🔨	1(dB) 4(°)	Referenc	e Pos
001	10	-0.00	-0.08		Center	Тор
002	11	-0.01	-0.09	0.5 3		
003	13	-0.00	-0.11		Scale	C
004	14	-0.01	-0.14			0.50dB
005	16	-0.01	-0.16			
006	18	-0.01	-0.17		RefLevel	C
007	20	-0.02	-0.20	0.5		-1.00dB
008	22	-0.02	-0.22		k da ala	
009	25	-0.02	-0.23		Mode	
010	28	-0.03	-0.24		Vout/Vin	<u> </u>
011	32	-0.03	-0.24		Asia Tura	_
012	35	-0.04	-0.24	-1.5 -1	Axis type	
013	40	-0.05	-0.22		Logarith	mic 🗸 🗌
014	45	-0.05	-0.22	-2 -2 -2	Auto Sot	
015	50	-0.05	-0.19		Auto Set	
016	56	-0.05	-0.17		on	off
017	63	-0.06	-0.15	-2.5 C3 Phase -3		
018	/1	-0.06	-0.13	C2 Amplitude	S Re	eturn
019	79	-0.06	-0.12 🗸	C2:Phase	_	
				10Hz 100 1k 10k 100k 1M 10M 120MHz		
Measure	P1:U	F(C2)	P2:UF(C3)	P3:UF(C4) P4: P5:		
Value	***		***	***		
C1 1X FULL	AC1M 0 1.00V/ 1X 0.00V FU	2 / (1 JLL	AC1M C3 1.00V/ 1X 0.00V FULL	AC1M C4 AC1M Timebase Trigger 1.00V/ 1X 1.00V/	C1 DC 0.00V Rising	\$ ₽

Fig. 114 SDS824X HD_Bode_1M_S21

Bode Plot now shows the difference between reference channel 1 and the other channels. It is indicative of the quality of the SDS800X HD that the differences between channels are really negligible: less than 0.3 dB amplitude error as well as less than 1° phase error up to 120 MHz, and almost no differences between channels 2-4, speaks for itself.

Let's check the accuracy and dynamic range now. Two signals are used to visualize a 60 dB amplitude difference. This time, 50 Ω inline termination has been used.

Bode Pl	ot										₿ A	MPLITUDE
001	Freq(Hz)	Am(dB)	Phase(°)	40(dB)						180	(°)	
001	11	-59.42	-0.12	-20							36	
003	13	-59.41	-0.27								IX.	
004	14	-59.45	-0.11	8	<u> </u>						90	
005	16	-59.37	-0.10								Π	
006	18	-59.41	0.04									
007	20	-59.47	0.31	20							45	
008	22	-59.44	-0.21									
009	25	-59.42	U.13	-4 8							0	
010	28	-59.47	-0.20									
011	32	-59.45	-0.21	- ~~								
012	35	-59.43	-0.36	-60							45	
013	40	-59.43	-0.06									
014	45	-59.43	0.13	80							90	
010	50	-59.48	-0.33									
010	50	-09.40	-0.05	100 C4	Amplitude						9 <i>5</i>	
010	71	-09.40	-0.04	-10 - C4	Phase					-1	5 3	
010	70	-59.45	-0.09	C3	Amplitude					- - \		
019	79	-08.40	-0.18	10U= 1	liPhase			4000	4.6.4	40M 400M	Y _	
				TUHZ T	UU I	к п	JK	TUUK	T M		ΗZ	
Measure	e P1:UF(C	2) P2:	UF(C3)	P3:UF(C4)	P4:		P5:					
Value	***	***		***								
C1	AC1M C2	AC1M C3	AC1M	C4 AC1	м			Timebase		Trigger	C1 D	○ ↓ 믔
1X	330mV/ 1X	1.02V/ 1X	300mV/	1X 5 <u>00u</u> \	//		< >>	-300ms	100ms/div	Auto	0.00	/
FULL	0.00V FULL	0.00V FUL	L 0.00V	FULL 0.00	V			100kpts	100kSa/s	Edge	Risin	g

Fig. 115 SDS824X HD_Bode_50_S21_60dB

There is a significant phase difference, and this comes from the additional 3-stage step attenuator + Inline attenuator + some 50 cm additional coaxial cable for channel 4.

As a final experiment, here is a 100 dB amplitude difference (phase has been adjusted by means of the channel skew parameter):

Bode Pl	ot			₿ AMPL	ITUDE
001	Freq(Hz)	Am(dB)	Phase(°)	20(dB) 180(°)	
001	10	-82.48 01.65	-10.99	125	
002	13	-91.00	-8.55	-0	
004	14	-93.18	-19.56		
005	16	-90.41	-4.54	-20	
006	18	-91.70	-3.74		
007	20	-90.73	-7.53	40	
008	22	-91.02	2.99		
009	25	-91.99	5.28		
010	28	-92.33	-8.98	Man Mar	
011	32	-91.37	-7.49		
012	35	-92.77	5.39		
013	40	-94.83	-0.74		
014	45	-92.73	6.94		
015	50	-93.04	2.88		
016	56	-92.58	-9.27	C4:Amplitude	
017	63	-93.57	-13.74	-120	
018	71	-92.64	5.87	C3;Amplitude	
019	79	-91.39	0.75 🗸	C3:Phase	
				10Hz 100 1k 10k 100k 1M 10M 120MHz	
Measure	P1:UF(C2	2) P2:1	UF(C3)	P3:UF(C4) P4: P5:	
Value	***	***		***	
C1 1X FULL	AC1M C2 295mV/ 1X 0.00V FULL	AC1M C3 1.02V/ 1X 0.00V FUL	AC1M 280mV/ L 0.00V	C4AC1MTimebaseTriggerC1 DC1X500uV/160ms20.0ms/divAuto0.00VFULL0.00V100kpts500kSa/sEdgeRising	∲ 品

Fig. 116 SDS824X HD_Bode_50_S21_100dB

Noise is getting a major problem, yet amplitude measurements can still yield useable results in the range 100 kHz to ~20 MHz.

The reference level is low (~570 mV_{RMS}), hence channel 4 input sees only 5.7 μV_{RMS} !

I've not nearly exploited the dynamic range of the SDS800X HD, which could handle up to 28 V_{RMS} (but then with beefy external >16 W terminators) if the need should be.

Bode Plot Example

Here is my standard test for Bode Plot: a simple 455kHz IF filter, consisting of a Kyocera KBF-455R-20A ceramic 6 element filter with two resonant 2nd order L-matching networks for the $50/1500 \Omega$ impedance transformation at both the input and output.
Bode Plot	t				📋 BODE PLOT
200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218	Freq(Hz) 449.000k 450.000k 451.000k 452.000k 453.000k 454.000k 455.000k 456.000k 456.000k 458.000k 459.000k 460.000k 461.000k 463.000k 463.000k 465.000k 466.000k	Am(dB) -4.52 -4.73 -4.74 -4.96 -4.28 -3.90 -3.66 -3.89 -3.69 -3.57 -3.64 -3.89 -4.27 -4.72 -5.01 -5.20 -5.50 -6.44 -8.16	Phase(°) 152.12 129.04 106.83 87.93 68.95 47.99 26.66 6.34 -15.23 -37.91 -62.12 -86.34 -111.04 -135.86 -161.55 169.06 134.20 93.16 42.50	0(dB) -12 -24 -36 -48 -60 -72 -84 -24 -36 -48 -60 -72 -84 -48 -60 -72 -84 -48 -60 -72 -84 -72 -84 -72 -72 -72 -72 -72 -72 -72 -72	,°) 35 90 45
Measure Value	P1:UF(C4 466.101kF) P2 Iz 444	:LF(C4) 1.692kHz	250kHz 500kHz 750k P3:BW(C4) P4: P5: 21.409kHz	Ηz
C1 1X FULL	AC1M C3 1.00V/ 1X : 0.00V FULL	AC1M C 500uV/ 1X 0.00V FUI	4 AC1M 500uV/ LL 0.00V	Timebase Trigger -400us 50.0us/div Auto 250kpts 500MSa/s Edge	C1 DC ↓ 品 0.00V Rising

Fig. 117 SDS824X HD_Bode_50_S21_IF455kHz

A complex structure like this has a somewhat chaotic phase response, especially in the passband and the transitions into the stopband. The amplitude shows nice steep transitions into the stopband, yet there are some unwanted resonances as is typical for this type of filters. The important fact is that we need high frequency resolution to capture all the fine details. Furthermore, this test demonstrates at least 90 dB dynamic range.

The data table has been adjusted to the nominal center frequency of the filter, which should be 455 kHz. A vertical cursor marks the selected frequency in the plot and from the table we can see that insertion loss of this filter is some 3.66 dB. The frequency with the lowest attenuation of 3.57 dB is 458 kHz though. This "data cursor" is independent of the manual cursors that are available in the Display menu.

I've set up some specific measurements: UF (Upper Frequency), LF (Lower Frequency) and BW (Band Width) to characterize the most important properties of the filter. We can see at a glance that the bandwidth is precisely 21.4 kHz.

For those bothered by the complex phase plot, there is always the option to disable any trace we like:

Bode Plot	t				BODE PLOT
Bode Plot 200 201 202 203 204 205 206 207 208 207 208 209 210	t Freq(Hz) 449,000k 450,000k 451,000k 452,000k 452,000k 454,000k 455,000k 456,000k 456,000k 458,000k	Am(dB) -4.52 -4.73 -4.74 -4.96 -4.28 -3.90 -3.66 -3.89 -3.69 -3.57 -3.64	Phase(*) 152.12 129.04 106.83 87.93 68.95 47.99 26.66 6.34 -15.23 -37.91 -62.12	□ 0(dB) -12 -24 -36 -48 -48	BODE PLOT
211 212 213 214 215 216 217 218	460.000k 461.000k 462.000k 463.000k 464.000k 465.000k 466.000k 467.000k	-3.89 -4.27 -4.72 -5.01 -5.20 -5.50 -6.44 -8.16	-86.34 -111.04 -135.86 -161.55 169.06 134.20 93.16 42.50	-60 -45 -72 -90 -84 -135 -60 -45 -90 -84 -135 -72 -90 -84 -135 -750kHz 750kHz	
Measure Value	P1:UF(C4 466.101kF	4) P2 Hz 444	LF(C4) 1.692kHz	P3:BW(C4) P4: P5: 21:409kHz	
C1 1X FULL	AC1M C3 1.00V/ 1X 0.00V FULL	AC1M 500uV/ 1X 0.00V FUI	4 AC1M 500uV/ L 0.00V	Timebase Trigger -400us 50.0us/div Auto 0 250kpts 500MSa/s Edge F	C1 DC ↓ 品 0.00V Rising

Fig. 118 SDS824X HD_Bode_50_S21_IF455kHz_NP

SPI Speed Test

We could ask the question: how fast an SPI data stream can we decode with a 200 MHz DSO? Huch much oversampling do we need?

For some DSOs it is said that they need a fair bit of oversampling for proper decoding. Yet the answer is, a proper implementation doesn't require much in this regard, hence it should be perfectly adequate to have a bandwidth three times the SPI clock frequency. The sample rate on the other hand should be irrelevant, as long as the Nyquist criterion for the required bandwidth is fulfilled. That makes for more than 6 times the SPI clock frequency.

The SDS824X HD true bandwidth is limited to 200 MHz in full channel mode and its sample rate is 500 MSa/s. According to the hypothesis stated above, this bandwidth would allow a max. SPI clock of 66 MHz and the sample rate is sufficient for that. The only way to know how good this works is to try it out...

I felt adventurous, hence didn't bother with 66 MHz, but tried 100 MHz right away:



Fig. 119 SDS824X_HD_SPI_100Mbps

The above screenshot shows a bidirectional (full duplex) 100 Mbps SPI data stream with a message length of 11 bytes. No special trigger has been used, just falling edge trigger on the /CS line.

The decoding works without issues, but how can we prove that the results are correct? Here's a simple test: I've replaced the MOSI signal with a phase synchronized copy of the 100 MHz clock signal, phase shifted 90° such that it is always sampled at its low state and then shifted by another 180° so that it is always sampled at its high state. This way we're putting the maximum stress on the acquisition chain, whereas it would be an easy task if we had just static signals for MISO/MOSI.



Fig. 120 SDS824X_HD_SPI_100Mbps_0



Fig. 121 SDS824X_HD_SPI_100Mbps_1

The expected results of all 0x00 for the first test and all 0xFF for the second one has been achieved, proving that there is a good chance to decode a 100 Mbps SPI data stream correctly with only twice the bandwidth and five times the sample rate.

If we trigger on the rising edge of the clock, we can produce an eye diagram which clearly shows that there is plenty of margin for correct decoding. Even the MISO signal, while slightly delayed, causes no problem in this scenario.



Fig. 122 SDS824X_HD_SPI_100Mbps_Eye

The fast pulses look very soft on the 200 MHz scope and the clock signal is a pure sine now, since we can only capture the 2nd harmonic, but not the 3rd.

Compare this to the same clock and MOSI signals displayed at ten times the bandwidth of the SDS6204:



Fig. 123 SDS6204_Pro_H12_SPI_100Mbps_Eye

So, could we go up to even 200 Mbps maybe?



Fig. 124 SDS824X_HD_SPI_200Mbps_Eye

This is quite revealing. There might be a small chance to get it working with a fair share of luck, yet this certainly isn't a robust solution. The transitions are way too slow to give any reasonable error margin for the decoder.

The 200 Mbps SPI challenge

While we cannot decode a SPI data stream in 4-channel mode, it appears to be no problem if we stick to just two channels (I've switched to 32-bit words by now):



Fig. 125 SDS824X_HD_SPI_200Mbps_2Ch

Here's the obligate 0 and 1 test:

🏟 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analysis	SIGLENT f = 200.002	Trig'd 7MHz	🗎 C3	
									Channel	
1.600V.									on	off
- HARVA										
				-						
0.500%.										
^{C2▶}										
C1.										
-0.500M				- -						
S2 MISO							at in man in in			
MOSI 0×0	00x00	000000	0×00000000	0×00000	000 (0:	<00000000	0×00000000			
-1.60DV										
0.0001/	0.0pc 100	0pc 200.0	ne 300 One	400 Ope	500 Ope	600 Opc 70	10 Ope 800 Op	e		
-2 HIHIV	Time	.0113 200.01	MISO	400.003	000.003	MO	ରା କା	•		
1	-96.0000ns		101130			0×0000	0000			
2	64.0000ns					0×0000	0000	\sim		
3	224.000ns					0×0000	0000			
4	384.000ns					0×0000	0000			
5	544.000ns					0×0000	0000			
6	704.000ns					0×0000	0000			
								\mathbf{v}		
C1	DC1M C2	DC1M				Tin	nebase	Trigger	C1 DC	∲ 뮮
1X 5	00mV/ 1X 5	00mV/				0.0	0s 100ns/div	Auto	0.00V	
FULL	0.00V FULL	175mV				1.0	Ukpts 1.00GSa/s	Edge	Rising	

Fig. 126 SDS824X_HD_SPI_200Mbps_2Ch_0



Fig. 127 SDS824X_HD_SPI_200Mbps_2Ch_1

... and the eye diagram:



Fig. 128 SDS824X_HD_SPI_200Mbps_2Ch_Eye

The eye-diagram looks way better now, as the bandwidth is 245 MHz in this configuration and there is no digital filter. The sample rate is twice as high, and my guess is that it's the sample rate making all the difference.

Mask Test

Consistent with the previous SPI speed test, I want to demonstrate the usefulness of the full speed mask test, as it's a perfect tool for automatic eye diagram monitoring.

Let's get back to the 100 Mbps eye diagram of the previous test and set up a mask for it. For this, there is an integrated mask editor; we cannot just use the automatic mask creation here, because we don't want to define a particular waveform with certain tolerances, but rather some forbidden area, so that the "eye" stays wide open.



Fig. 129 SDS824X HD_Mask_Editor

I didn't spend much time creating a perfect mask; this one has just been cobbled together quite quickly. Furthermore, the eye most likely doesn't need to be that wide open in practical applications, yet this is just for demonstration's sake.

Now we let the mask test run. With the clean signals produced in a near ideal lab environment, we could have run that test for days without any failure, so I've added 224 mV_{RMS} noise with 500 MHz bandwidth to the data signal, hoping that I'll get a mask violation eventually:



Fig. 130 SDS824X HD_Mask_Test_run

The mask test is implemented in hardware, so we are getting a high number of passes within a short time. The screenshot has been taken a few seconds after the test started and up to this point, no mask violation has occurred. Yet it only takes a little while longer and a total of 411262 test runs until the first violation occurs.





As can be seen, the mask test was set up in a way that it would beep and stop on the first violation. Alternatively, we can also get an automatic screenshot every time the violation occurs.

This is another small difference to the SDS2000X HD: there we can also have the option "Failure to History", which means that all mask violations (and only these) are stored in the history, so we can have the mask test run overnight and then analyze all the mask violations in peace later.

The info block in the display tells us that the failure rate in this test scenario was less than 0.001%. Of course, it can be seen quite clearly that this violation wouldn't have prevented the SPI decoder to deliver correct results. It's all a matter of setting up the mask appropriately...

Probes

PP510

The frequency response plots in the "Bandwidth" section have been made with a properly terminated coax connection. A proper review should also test the associated probes – unfortunately, I don't have one, as my test unit didn't include any accessories. I suspect that the standard probes delivered with the SDS824X HD will be the well-known PP215. Even though I do have some very old PP215 (which probably aren't quite the same as the current ones), I don't have access to them right at the moment, hence make do with the only slightly younger 100 MHz PP510, just to give you an idea.

📽 Utility	🖵 Displa	y n Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analy	ysis f = 214.9877MHz	₿ MA	TH
F4 -0.00dBV			2				3 		
-4.00dBV								~	
-в.џидну	F4 Marke	ers List		.					
	Marker 1	Abs.Ampl. 0.558dBV	Abs.Freq.	Delta Amp	I. Delta	Freq.			
-8.UUdBV	2	0.365dBV	10.00000MHz	-0.1930	IBV 9.00	000MHz	Sa= 2.00GSa/s		
	3	-0.381dBV	100.00000MHz	-0.940c	IBV 99.00	000MHz	Curr= 16384pts		
-10.00dBV	4	-1.866dBV	200.00000MHz	-2.4250	IBV 199.00	000MHz			
-12.00dBV	5	-2.431dBV	274.50000MHz	-2.990c	IBV 273.50	000MHz	KBVV= 450.32KHZ		
1000kHz			1	OMHz			100MHz		
C4 DC 10X 500m FULL 0.0	1M F4 1V/ 0V	FFT(C4) 2.00dBW — 2.00dBV					TimebaseTrigge50.0us1.00us/divAuto20.0kpts2.00GSa/sEdge	er C4 DC 0.00V Rising	∜ ₩

First the frequency response up to 500 MHz:

Fig. 132 SDS824X_HD_Probe_PP510_FR

It can be seen, that even Siglent's cheapest 100 MHz probe extends the system bandwidth to \sim 274 MHz (244 MHz with direct coax connection). So much for the practical relevance of probe ratings and textbook formulas, which are way too simplistic as to actually model the real world.

Of course, the probe has been properly LF-compensated prior to the measurements:

📽 Utility	🖵 Display	m Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis SIGLENT f = 1.00001	Trig'd 3kHz	EASURE
1.500V									
1.000V									
0.500V									
<mark>с4</mark> .0.000У									
-0.500V									
-1.000V									
-1.500V									·····
-2 NNNV	-0.200ms	0.000ms	0.200ms	0.400ms	0.600ms	0.800ms	1.000ms 1	.200ms 1.400	Jms
MEASURE)-90%Rise(C4)	90-10%	Fall(C4)	Amplitude(C	4) —	ROV(C4)	= FOV(C4)	
Value	1.	82ns	2.07ns		3.006250V		1.040%	0.728%	
Mean	1.	9619ns	2.0349n	s	3.00559465\	V	1.06211%	0.79919%	
Min	1.	80ns	1.94ns		3.004167V		0.970%	0.693%	
Max	2.	30ns	2.10ns		3.006250V		1.179%	0.901%	
Pk-Pk	50)0.0ps	160.0ps		2.08300mV		0.20831%	0.20821%	
Stdev	19	30.1ps	46.7ps		537.68uV		0.03969%	0.03885%	
Count	60)4	604		302		302	302	
Histogram									O
C4 DC 10X 500n FULL 0.0	1M nV/ IOV						Timebase 0.00s 200us/div 4.00Mpts 2.00GSa/s	TriggerC4 D0Auto0.00VEdgeRising	C ↓ 撮 ✓ g

Fig. 133 SDS824X_HD_Probe_PP510_PR_1kHz

The transition times are about 2 ns, which is slightly slower than with the direct coax connection. This is another occasion, where we can see the (ir)relevance of textbook formulas when it comes to real-world performance. The bandwidth was wider, yet the rise time is slower – how can that be?

It quite obviously is the frequency response, which is a far cry from the first order low pass, that is assumed in textbooks. The sudden drop of ~1.5 dB at about 120 MHz is most likely responsible for the slower rise time.

The ultimate test for proper HF-compensation is done with a fast (1 ns) risetime 1 MHz square wave.

🏟 Utility	🖵 Display	/ n Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis SIGLENT f = 1.00001	Trig'd 3MHz 🗎 M	IEASURE
		0.000us * *	0.200us	0.400us				1.200us 1.40	
1.800V 1.700V 1.600V									
1.400V 1.300V 1.200V		50 0pc	100.000	150 000				250 0	
	u.ujis	0.001(D) (0.4)	100.0HS	TOU.UNS	200.005	200.005	300.0hs	350.00S 400.	
MEASURE	1	0-90%Rise(C4)	90-10%t	-all(C4)	 Amplitude(C4 2.024276)/ 	4) —	ROV(C4)	- FOV(C4)	
Mean	2	.0011S 10230ns	2 0485n	\$	3.034373V	/	0.27370	0.25535%	
Min	1	.83ns	1.95ns		3.032292V		0.137%	0.137%	
Max	2		2.11ns		3.037500V		0.412%	0.412%	
Pk-Pk	5	10.0ps	160.0ps		5.20800mV		0.27473%	0.27487%	
Stdev	1	91.6ps	46.3ps		958.66uV		0.03738%	0.04615%	
Count	2	132	2132		1066		1066	1066	
Histogram									\bigcirc
C4 DC 10X 500n FULL 0.0	:1M Z4 mV/ 50.0ns/ 00V 200ns	100mV/ — 1.50V					Timebase 0.00s 200ns/div 4.00kpts 2.00GSa/s	Trigger C4 D Auto 0.00' Edge Risin	C ↓ <mark>#</mark> V g

Fig. 134 SDS824X_HD_Probe_PP510_PR_1MHz_Zoom

It can be seen, that the PP510 isn't an ideal match for this scope because of an overdamped edge. In other words, the HF-compensation, which is not user adjustable, is not perfect for this probe-scope combination.

The screenshot above is also another demonstration how such details can be observed on a 12-bit DSO with proper zoom implementation, without the need to take a chance by overdriving the inputs.

Poor Men's Differential Probing

With analog scopes, we were able to combine two regular (single ended, ground referenced) channels into one differential channel. This was done by adding both channels with the 2nd channel inverted, whose gain had to be fine-tuned in order to get the maximum common mode rejection. Of course, this solution was far from ideal and sensitivity as well as common mode rejection were rather limited, especially at higher frequencies, which made it hard to get meaningful results when common mode voltages were high compared to the differential signal.

We can't do the same on a modern DSO, for a number of reasons:

- The fine adjust of the vertical gain has only ~2% resolution, so it is not suitable to balance the channels for a CMMR >34 dB.
- The difference has to be computed by a math channel, which always takes the vertical gain setting into account and scales to the true value, thus ignoring any gain adjustments.
- Finally, with only 8 bits the math result doesn't have enough resolution to properly analyze the differential signal. It is the same problem as with having vertical zoom on a 8-bit DSO.

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The screenshot below demonstrates the result of two identical 10 MHz signals fed into channels 3 and 4 at 100 mV/div and a difference math channel is set to a 100 times higher gain at 1 mV/div:



Fig. 135 SDS824X_HD_PMDiff_10MHz

Common mode rejection can be estimated from the amplitude measurements and would be $606.7/2.44 = 248.6 \sim 47.9$ dB, which is not bad at all – but we can do even better...

Of course, the balance is not perfect out of the box. Input channels and probes will both have gain tolerances, which compromise the common mode rejection. With a fairly precise instrument like the SDS800X HD we can just measure that:



Fig. 136 SDS824X_HD_PMDiff_10MHz_corr1

As expected, there are slight differences. In this particular case, we get 516.955 mV_{PP} for Ch.3 and 519.555 mV_{PP} for Ch.4, so we can calculate the correction factor as 516.955/519.555 = 0.995. Consequently, we just replace C4 in the formula by the expression C4*0.995.

The common mode rejection can be estimated from the amplitude measurements and would be $519.555/1.613 = 322.1 \sim 50.16$ dB, just 2.25 dB better than before. But the correction would certainly make a much more significant difference when the initial imbalance is more pronounced.

For best accuracy, (especially external) 50 ohms termination cannot be used at the scope input, as their tolerances could be up to 2%. Without termination, a direct coax connection of 1 meter length can work reasonably well up to a couple MHz, but at higher frequencies, amplitude accuracy and common mode rejection degrade considerably. Even at only 10 MHz, the 600 mV_{PP} signal was measured ~14 % low. The next screenshot demonstrates the same test at 100 MHz:



Fig. 137 SDS824X_HD_PMDiff_100MHz_corr1

Peak amplitude is totally off now and common mode rejection is degraded to 173.2/3.82 = 45.34 = 33.13dB, which could still be acceptable for some tasks, yet is clearly degraded compared with the 10 MHz test. Even more importantly, the amplitude ratio has significantly changed now. This means, that the correction factor is not valid over the entire DSO bandwidth.

Just for fun, we could try to alter the correction factor; now we get 173.236 mV_{PP} for Ch.3 and 170.833 mV_{PP} for Ch.4, so we can calculate the correction factor as 173.236/170.833 = 1.014.



Fig. 138 SDS824X_HD_PMDiff_100MHz_corr2

Common mode rejection would now be respectable $173.25/1.288 = 134.5 \approx 42.5 \text{ dB}$.

In most practical scenarios, we'll use probes; this is problematic because of their complex impedance and transmission characteristics, so that the tolerances cannot be eliminated by applying a simple correction factor. I'll demonstrate the use of probes for a low frequency like 1 MHz. I only have a set of SP5050A probes here, yet I'm pretty confident my test results are still representative for any suitable 10x probe:



Fig. 139 SDS824X_HD_PMDiff_SP5050A_1MHz_corr

We get 3.0097 V_{PP} for Ch.3 and 3.0633 V_{PP} for Ch.4, so we can calculate the correction factor as 3.0097/3.0633 = 0.9825.

With this, common mode rejection is $3.0633/0.02541 = 120.55 \approx 41.6$ dB. This degrades quickly at higher frequencies.

As a conclusion, thanks to 12-bit resolution, 16-bit data processing and high accuracy of 0.5%, poor men's differential probing can be an option at low frequencies with this scope, whereas it didn't work at all with the older 8-bit SDS1000X-E series.

System Performance with SP5050A Probe

Many folks worry about the adequacy of the supplied probes.

There are few situations where it would be appropriate to use passive 10x high impedance probes at a test node within a circuit carrying >100 MHz signals. With a tip capacitance of 10 pF, the impedance at 100 MHz is just 160 Ω and forms a low-pass filter together with all not extremely low source resistances. This might still be okay for low impedance nodes like the outputs of line drivers, but certainly not anywhere else.

Apart from the fact, that at higher frequencies alternative probing solutions are required, the previous test of the good old 100 MHz PP510 has shown that they do not limit the system bandwidth, but even extend it to ~274 MHz and the rise time is quite adequate at 2 ns, see chapter "PP510".

If you wonder what you could gain with a much better (and much more expensive) probe – here's a test with Siglent's top model, the 500 MHz SP5050A.

Siglent SDS800X HD Evaluation Rev. 1.00

f = 549.7353MHz O Utility F Trigger # Cursors Measure m Acquire 🖵 Display Analysis CURSORS Trig'd Cursors Mode Manual Track X2 1.096GHz M X1 Source MATH X2 Source ΔX= 1.086GHz MATH 1/ΔX= 920.81ps X2= 1.096GHz Display X1= 10MHz M1 ΔY= -3.00dB Y2= -11.58dBV Y1=-8.58dBV C4 DC1M M FFT(C4) Timebase ∲ 뫎 200mV/div 5.00dB/div -200ns 200ns/div Auto -1.67mV 02:53:31 Rising 0.00V -5.00dBV 10.0kS 5.00GS/s Edge 2018/10/7

Just to give you an idea, I've once tested the quite similar SP3050A, which is also rated 500 MHz, as always using the industry standard test with 25 Ω source impedance:

Fig. 140 SDS5104X_SP3050A_FFT_FR_2GHz_20mV_01

On a 1 GHz SDS5104X, the system bandwidth was 1.096 GHz with this "500 MHz" probe. Of course, this is useless in practice as it would only work on a terminated 50 Ω port with the supplied coax-adapter – and in that case we don't need the probe at all and would just use a direct coax connection instead.

Now here's the system frequency response with SP5050A up to 500 MHz. It can be seen, that this 500 MHz probe extends the system bandwidth to ~291 MHz (274 MHz with PP510 and 244 MHz with direct coax connection).

🏶 Utility	🖵 Displa	y fi Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analy	rsis SIGLENT f = 387.8961	Trig'd MHz	🗎 MAT	Ή
<mark>F4</mark> -0.00dBV			2				3	4		
-2.00dBV								· · · ·	5	
-4.00dBV									\	
-6.00dBV	F4 Marke	ers List								
	Marker 1	Abs.Ampl. 0.590dBV	Abs.Freq.	Delta Amp	l. Delta	Freq.				
-8.UUdBV	2	0.527dBV	10.00000MHz	-0.064d	IBV 9.00	000MHz	Sa= 2.00GSa/s			
	3	0.430dBV	100.00000MHz	-0.160d	IBV 99.00	0000MHz	Curr= 16384pts			
-10.00dBV	4	-1.218dBV	200.00000MHz	-1.808d	IBV 199.00)000MHz	Δf= 122.07kHz			
	5	-2.409dBV	291.00000MHz	-2.999d	IBV 290.00)000MHz	RBW= 455.32kHz			
-12.00dBV										
1000kHz			1	OMHz			100MH:	z		
C4 DC 10X 500m FULL 0.0	1M F4 1V/ 0V	FFT(C4) 2.00dBV/ — 2.00dBV	+				Timebase 50.0us 1.00us/div 20.0kpts 2.00GSa/s	Trigger Auto Edge	C4 DC 0.00V Rising	∲ 🍇

Fig. 141 SDS824X_HD_Probe_PP5050A_FR

Of course, the probe has been properly LF-compensated prior to the measurements:

🏶 Utility	🖵 Display	y fi Acquire	e 🏲 Trigger	# Cursors	📐 Meas	🖻 Analysis	SIGLENT f = 1.00001	Trig'd 3kHz	MEASURE
1.500V									
1.000V									
0.500∨									
0.000Y									+ + + + + + + + +
-0.500									
-1.000V									
-1.500V									
-2 NNNV	-0.200ms	0.000ms	0.200ms	0.400ms	0.600ms	0.800ms	1.000ms 1	1.200ms 1.	400ms
MEASURE		0-90%Rise(C4) — 90-10	%Fall(C4)	Amplitude(C	:4) — RC	V(C4)	= FOV(C4)	
Value	1	.69ns	1.85n	S	3.012500V	1.6	25%	0.761%	
Mean	1	.7017ns	1.838	9ns	3.01316964	V 1.7	0877%	0.67460%	
Min	1	.67ns	1.79n	s	3.012500V	1.1	41%	0.553%	
Max	2	2.18ns	2.30n	s	3.014583V	2.1	44%	0.830%	
Pk-Pk	5	510.0ps	510.0	ps	2.08300mV	1.0	0316%	0.27682%	
Stdev	2	23.2ps	87.6p	S	541.67uV	0.2	8761%	0.05139%	
Count	5	588	588		294	294		294	_
Histogram						<u> </u>	տոսներիկի		LL 🔘
C4 DC 10X 500n FULL 0.0	1M nV/					Tin 0.0 4.0	nebase Os 200us/div OMpts 2.00GSa/s	Trigger C4 Auto 0.0 Edge Ris	i DC 🛛 🔱 撮 DOV sing

Fig. 142 SDS824X_HD_Probe_PP5050A_PR_1kHz

The transition times are now in the 1.7-1.8 ns ballpark, hence very similar to the direct coax connection.

The ultimate test for proper HF-compensation is done with a fast (1 ns) risetime 1 MHz square wave.

🏟 Utility	🖵 Display	/ 🕅 Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis SIGLENT f = 1.00001	Trig'd 3MHz	MEASURE
10 H H K H 10 H K 10 H K H 10 H K H 10 H K 10 H K H 10 H K 10 H K H 10 H K 10 H K 10 H K 10 H K H 10 H K 10 H		9.000us *	0.200us	0.400us				1.200us 1	.400us
1.800V 1.700V 1.600V									
1.500¥ 1.400V 1.300V 1.200V	M			· · · · ·	· · · ·	· ·			
<mark>44</mark> 1100V	0.0þs	50.0ns	100.0ns	_150.0ns	200.0ns	250.0ns	300.0ns	350.0ns4	00.0ns
MEASURE		0-90%Rise(C4)	90-10%	Fall(C4)	 Amplitude(C4 	4) —	ROV(C4)	= FOV(C4)	
Value	1	.73ns	1.85ns		3.045833V		0.650%	0.445%	
Mean	1	.7598ns	1.8687n	S	3.04589957	/	0.73992%	0.41665%	
Min	1	.70ns	1.80ns		3.042708V		0.274%	0.308%	
Max	2		2.32ns		3.0489587		1.232%	0.548%	
PK-PK	5	20.0ps 10.0cc	520.0ps		6.25000mV		0.95844%	0.23988%	
Staev	1	TU.2ps	125.8ps		931.36UV		0.24576%	0.04269%	
Histogram		<u>,</u>				<u> </u>		<u></u>	O
C4 DC 10X 500m FULL 0.0	1M Z4 nV/ 50.0ns/ 0V 200ns	100mV/ 1.50V					Timebase 0.00s 200ns/div 4.00kpts 2.00GSa/s	Trigger C Auto O Edge R	4 DC

Fig. 143 SDS824X_HD_Probe_PP5050A_PR_1MHz_Zoom

It can be seen, that the SP5050A is a pretty good match for this scope because the initial overshoot is about the same level as the top of the pulse.

Verdict: yes, the SP5050A outperforms a PP510 in just about every regard. It's a very nice probe overall and it demonstrates what can be realistically achieved with the SDS824X HD. There still isn't a huge difference after all.

Custom Probe Factors

This is a demonstration how to use custom probe factors for current measurement.

Consider we want to measure current using channel 4 and this should be set up for a rather weird conversion factor of 0.1234567 amperes per volt. First thing to do would be changing the Channel units from Volts to Amperes:

📽 Utility	🖵 Display	n Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis f<2	Auto .0Hz	🗎 C4	
3.00A		7							BW Limit	
									Full	
2.00A									Probe	
1.00A									1V/A	>
<mark>c₄</mark> ,0.00A	+ + + + + + + + + + + + + + + + + + + +			+					Label	
-1.00A									MISO	>
-2.00A									Apply To	
-3.004										
				_				_	Unit	
-4 NNA -1	UUus U.UĻ	Jus 1.UUu:	s 2.00us	3.UUus	4.UUus	5.UUus	6.UUus 7.U	Jus	V	А
MEASURE	Stdev(C4) — *	**	***	***		***			
Value	3.7679	mA							Deskew	C
Mean	3.7899	36mA								0.00s
May	3.9928 7 1970	mA mA							Invort	
Pk-Pk	4.1049 592 10	ΠΑ		_	—				IIIVEIL	
Stdev	105.18	3uA							on	off
Count	358								Trace	
Histogram								\bigcirc	Visible	Hidden
C4 DC 1V/A 1.00 FULL 0.0							Timebase 0.00s 1.00us/ 20.0kpts 2.00GS	Trigger /div Auto a/s Edge	C4 DC 0.00A Rising	1 ↔ 문

Fig. 144 SDS824X HD_Ch_Current_1V_A

Now we have set channel 4 to measure current at a conversion factor of 1 V/A (one volt per ampere), as it is displayed in the channel tab now. But in our example, we need a different conversion factor. Consequently, we enter the Probe menu:

🏶 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis sig	i LENT f < 2.0H	Auto z	Ē	C4 PROBE	
3.00A											1.0V/A	
2.00A 1.00A										0	0.1V/A	
<mark>€4</mark>) ^{Ω ΩΩΑ} ,				+ + + + + + - + - + - + - + - + - + - +	+ + + + + + + + + + + + + + + + + + + +					0	0.01V/A	
-2.00A										0	User1 1V/A	Ċ
-3.00A	00us 0.00)us 1.00u	ıs 2.00us	3.0Dus	4.0Dus	5.0Dus	6.00us	7.0Dus		0	User2	Ċ
MEASURE	Stdev(C4) - '	***	***	***		***				1V/A	
Value	3.6882	mÁ								<u> </u>		
Mean	3.7590	43mA								~ ~	горе Спеск	
Min	3.5073	mA										
Max	4.1849	mA								•	Doturn	
PK-PK Stdev	077.0U 09.504										Rotani	
Count	1957	uA										
Histogram		and the second sec							\bigcirc			
C4 DC 1V/A 1.00 FULL 0.0							Timebase 0.00s 20.0kpts 2	1.00us/div 2.00GSa/s	Trigger Auto Edge	C4 0.0 Risi	DC	р Т

Fig. 145 SDS824X HD_Ch_Current_Probes Siglent SDS800X HD Evaluation Rev. 1.00 There is currently 1.0 V/A selected, and we can also get some more predefined probe factors, but not the one we want to use. Thankfully, there are also two permanent user settings. We can preset them to our most used custom probes and can use them just like the predefined ones from now on. Tapping on the user setting, we get the input keypad for the custom V/A setting:

🏟 Utility	🖵 Display	ள் Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 An	nalysis	SIGLENT f < 2.0Hz	Auto z	🗎 C4	PROBE
3.00A										O 1.0	V/A
2.00A 1.00A										O 0.1	V/A
<mark>64</mark> ,0.004		👝 Input Pa	d					× -	+-+-+	O 0.0	1V/A
-2.00A							\ \	//A		O Us	er1 C 1V/A
_4 NNA -1.0	00us 0.00u	s 7	8	9 В	ack	m	k	Enter		O Us	er2 C
MEASURE Value Mean	Stdev(C4 3.7284m 3.751723	4) A 4 Bm	5	6 C	lear	u	м	Мах		🥢 Prob	e Check
Min Max	3.5073m 4.1849m	A 1	2	3		n	G	Default		6	
Pk-Pk Stdev	677.600t 96.998u/	ΔL 0		+/-		p	Т	Min		⊃ R€	eturn
Count Histogram	3366								\bigcirc		
C4 DC1 1V/A 1.00 FULL 0.00		-					Time 0.00 20.0	ebase s 1.00us/div kpts 2.00GSa/s	Trigger Auto Edge	C4 DC 0.00A Rising	\$ ₽

Fig. 146 SDS824X HD_Ch_Current_Probe_Input

Here we can enter any desired conversion factor from 1 $\mu A/V$ up to 1 MA/V with at least 6 digits resolution. For example, here is 0.1234567 V/A:

📽 Utility	🖵 Display	m Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analys	sis f < 2.0H	Auto z	₿ C	4 PROBE	
24.3A									O 1	.0V/A	
16.2A 8.1A									0 0	.1V/A	
<mark>с4</mark> , <u>О</u> ДА, , , , , , , , , , , , , , , , , , ,				+ + + + + + + + + + + + + + + + + + + +	+ + + + + + +	-+			O 0	.01V/A	
-16.2A									0.12	lser1 C 234567V/A	
-32 4A -1	00us 0.00	lus 1.00u	s 2.00us	3.0Dus	4.00us	5.00us	6.00us 7.00us		οu	lser2 C	
MEASURE	Stdev(C4) — *	**	***	***		***			TV/A	
Value	29.230	mÁ							- D		
Mean	29.729	61mA							🔶 Pro	ibe Check	
Min	28.659	mA									
Max	k 31.618mA					\rightarrow			◆ -		
Pk-Pk	2.95900mA										
Stdev	569.30	цА									
Count	144										
Histogram								\bigcirc			
C4 DC 8.11 FULL 0.0							Timebase 0.00s 1.00us/div 20.0kpts 2.00GSa/s	Trigger Auto Edge	C4 D 0.00/ Risin	C ⊉器 A	

Fig. 147 SDS824X HD_Ch_Current_Probe_0.1234567

Here's a measurement example: channel 1 is set to 1x voltage probe at 500 mV/div, whereas channel 4 is set to a custom probe at 4.05 A/div.

🏶 Utility	🖵 Display	nî Acquire	🏲 Trigger	# Cursors	📐 Meas	🖻 Analysis	SIGL f = 1	ENT Trig'd	🗎 C4	
12.15A 9.104 4.05A -4.05A -8.10A -12.15A -16.20A	-0.500us	0.000us	0.500us	1.000us	1.5D0us	2.000us	2.500us	3.000us	3.5000	JS
MEASURE	Sto	dev(C1)	Freq(C1)	Stdev(C4)	— Fr	eq(C4)	— Std		
Value	1.0)6932809V	999.859	kHz	8.6866707A	. 1.0)001MHz	6.5	56976VV	
Mean	1.0	0692138256V	1.00001	261MHz	8.68546595	9A 1.0)00016MHz	z 6.5	5614022W	
Min	1.0)6852684V	998.649	kHz	8.6804997A	. 99	8.9kHz	6.5	50012VV	
Max	1.0)6998353V	1.00139	8MHz	8.6910645A	. 1.0)011MHz	6.56	61934VV	
Pk-Pk	1.4	4566900mV	2.74900	kHz	10.564800m	אר A.	200kHz	11.9	32200mW	
Stdev	19	9.4370uV	294.79H	Iz	1.675827m/	4 29	4Hz	1.93	2066mW	
Count	65	19	26076		1013	40	52	101	3	
Histogram			<u> </u>	<u> </u>	and the second secon					\bigcirc
C1 DC			O 4 to 4			Tre	nohaco	Trigge	ex ne	무

Fig. 148 SDS824X HD_Ch_0.1234567_Power

During normal use, channel 4 would be set to 500 mV/div with a 1x voltage probe. The custom probe factor of 0.1234567 V/A is equivalent to 8.1000059 A/V. This multiplied by 500 mV/div results in 4.050003 A/div, just as it is displayed in the corresponding channel tab

Just for fun, I've set up a math operation, simply multiplying the two channels to get the power. Trace F1 shows a scaling of 8.1 W/div and a vertical offset of 0.0 W.

The measurements show the standard deviation (=AC-RMS) for channels 1 in volts and for channel 4 in amperes. Formula trace F1 shows the AC-RMS power in watts.