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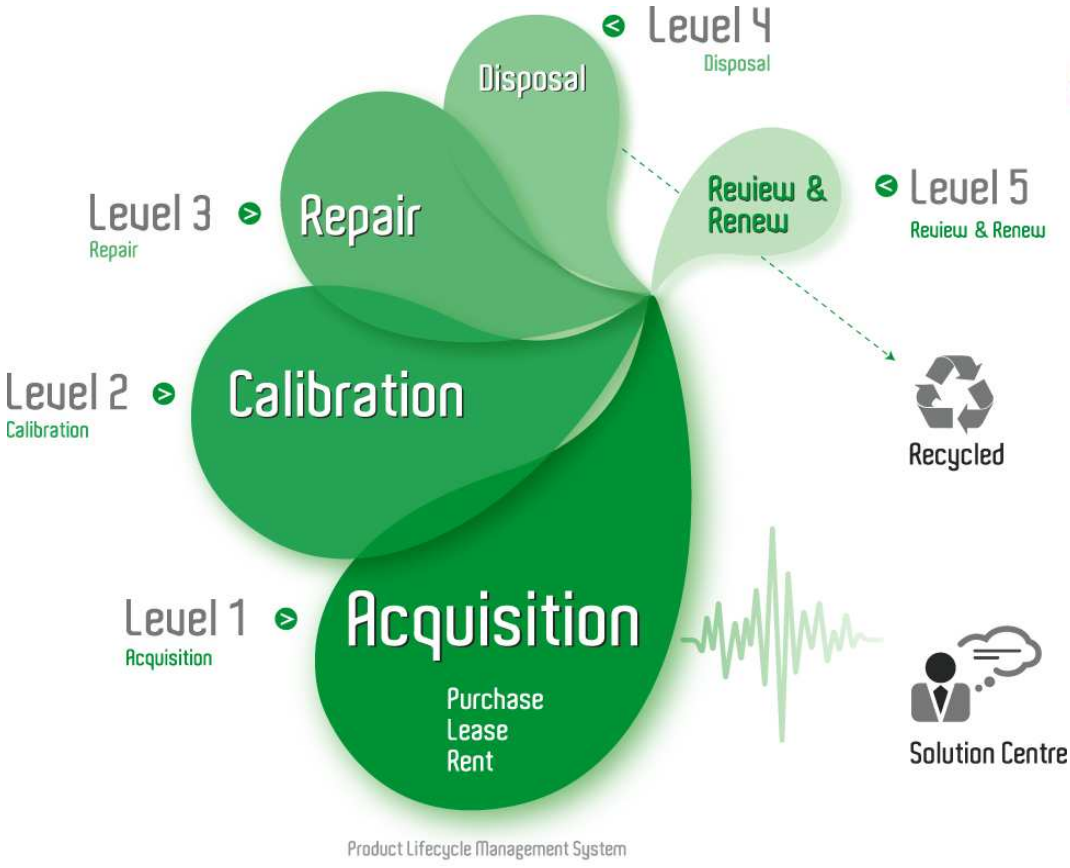


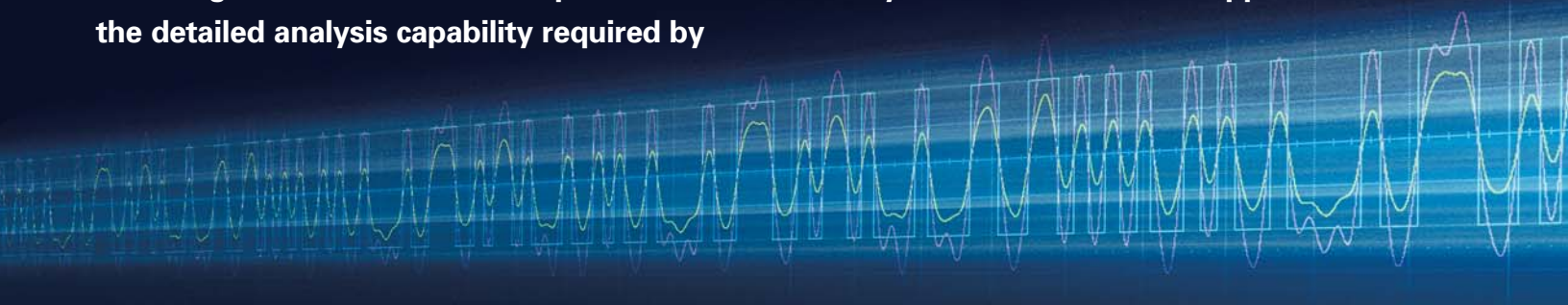
LeCroy

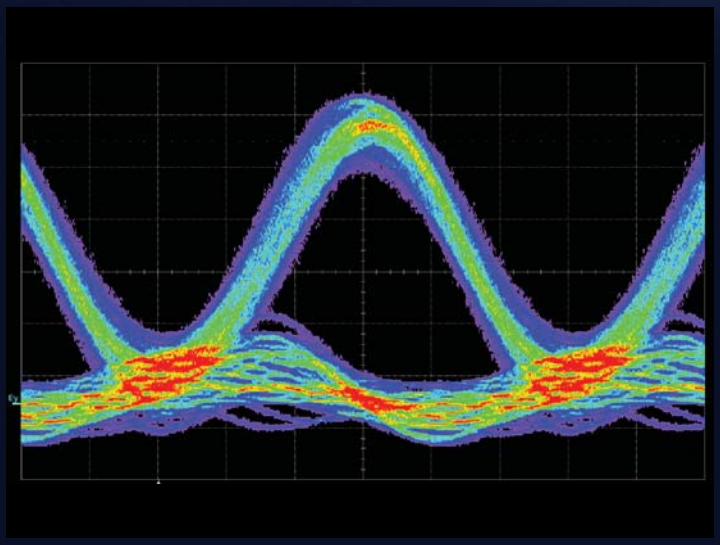
WaveExpert® 100H

Wide Bandwidth Oscilloscopes for Next Generation Serial Data Standards

The New WaveExpert 100H Sampling Oscilloscope — the Complete Workstation for Optimizing Serial Data Signal Integrity

In recent years, the rates of serial data signals have increased steadily from 2.5 Gb/s to 40 Gb/s and beyond. All this speed, of course, pushes up the bandwidth requirements of oscilloscopes. However, simply providing this bandwidth is not sufficient for qualifying these high-speed links. High bandwidth oscilloscopes must have the detailed analysis capability required by next-generation standards. Adding to the measurement complexity is the emergence of receiver equalization which allows high-speed serial data links to operate error-free even when the signal is severely distorted. The WaveExpert 100H is the ideal signal integrity analysis solution for these applications.

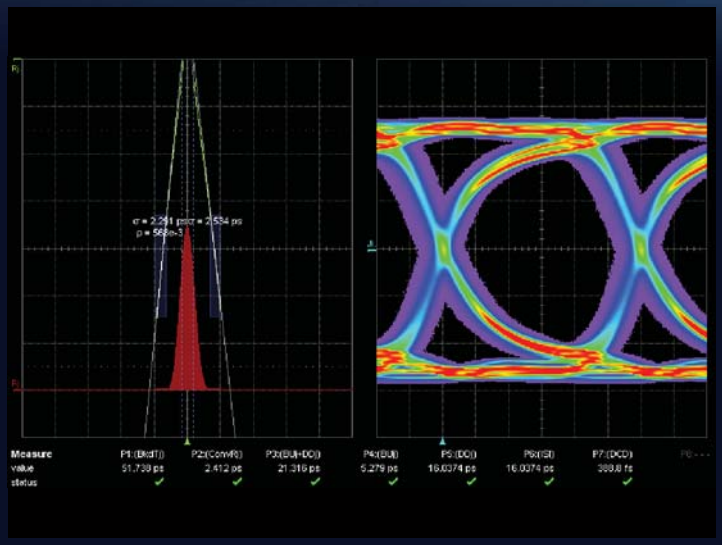




Ultra-High Bandwidth Signal Analysis

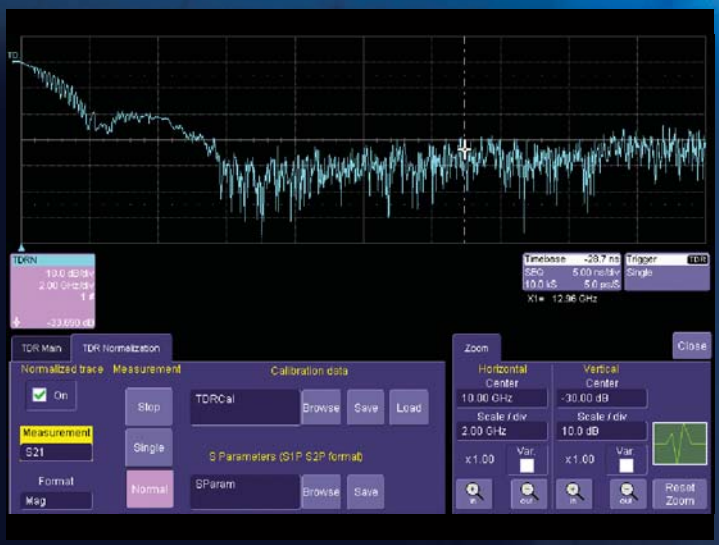
Eye pattern analysis is the primary method of signal integrity testing for optical signals, and the WaveExpert performs this analysis over 20 times faster than conventional sampling oscilloscopes.

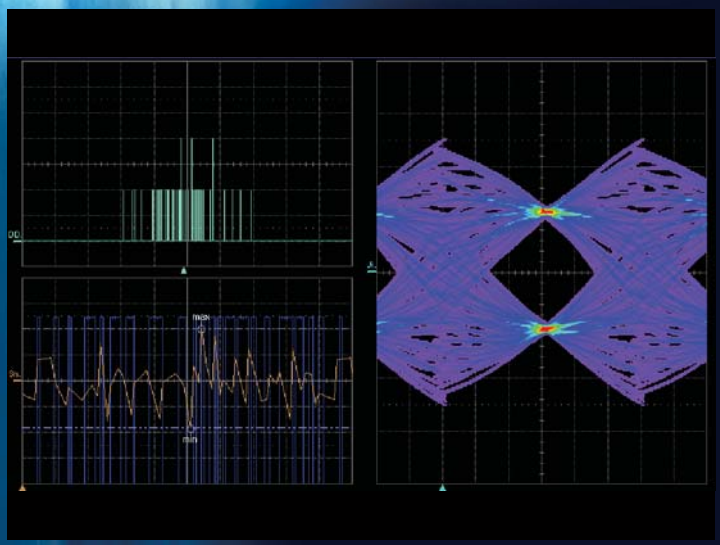
A maximum bandwidth of 100 GHz along with a 230 fs rms noise floor enables measurements on the fastest optical signals.



Highly Accurate Jitter Analysis (Pages 6-7)

The low jitter noise floor of the HCIS timebase along with LeCroy's innovative Q-Scale jitter analysis provides over 3 times the accuracy of conventional sampling oscilloscope methods for all jitter types.





Up to 20 GHz TDR with Full S-parameter Measurements (Pages 4-5)

The standard TDR analysis package included with the WaveExpert 100H offers full reference plane calibration and one- and two-port differential S-parameter measurement fully integrated into the instrument interface.

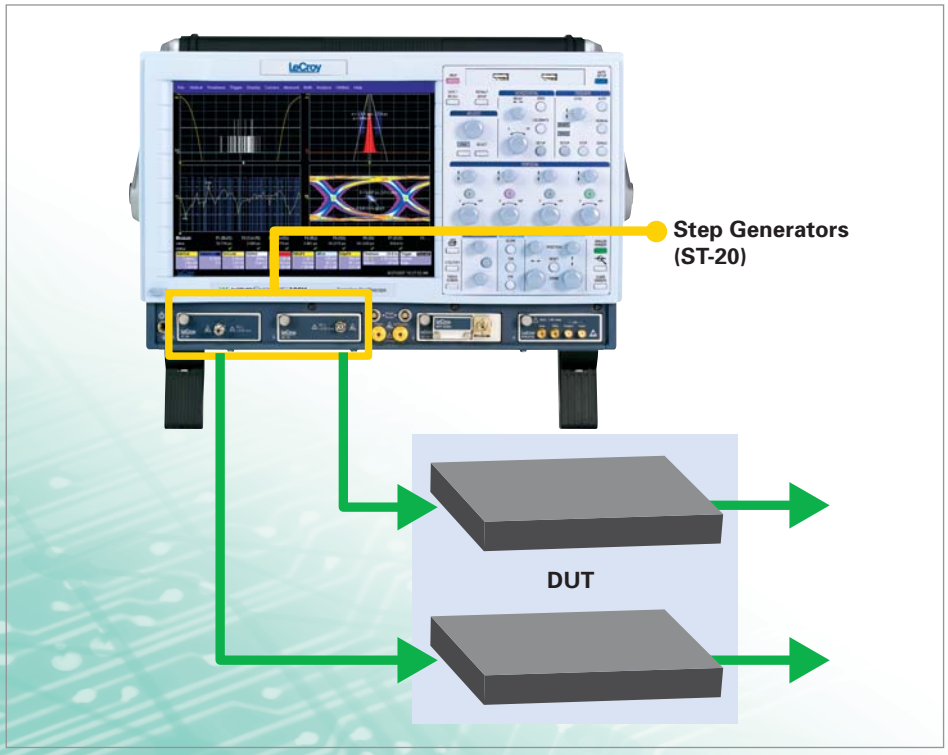
Eye Doctor™ Offers Virtual Probing and Equalized Signals (Pages 10-11)

The Virtual Probing and equalized receiver emulation features in the Eye Doctor package provide full end-to-end signal integrity analysis of serial data systems employing equalization.

Integrated TDR Analysis and S-parameter Measurement

TDR Analysis with S-parameter Measurement

- **Single-ended and differential measurements**
- **Fast step (20 ps rise time)**
- **Sub-millimeter measurement resolution**
- **Advanced OSL (Open Short Load) calibration removes effects of cables, fixtures, etc.**
- **TRUE differential TDR/TDT**
- **Automated deskew**
- **Accurate S-parameter measurements to 20 GHz**
- **Data output in Voltage, Impedance, or S-parameter (SnP) format**
- **Fully integrated TDR analysis with S-parameter analysis**



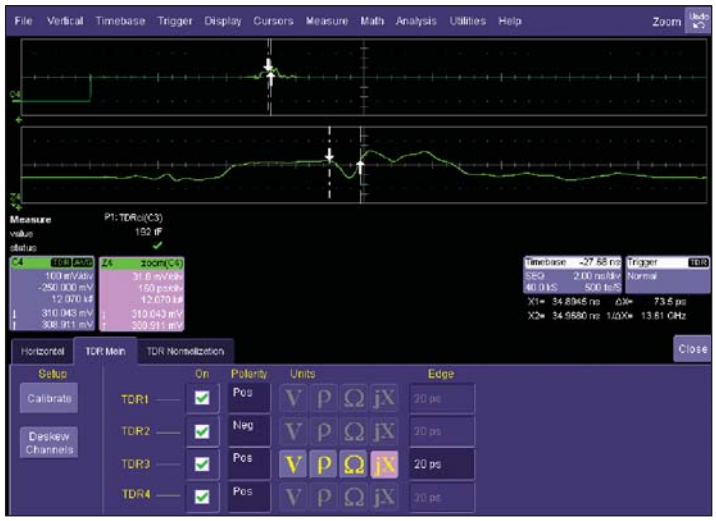
The WaveExpert 100H provides true differential TDR stimulus for TDR and TDT testing. The standard software provides impedance, return loss, and S-parameter measurements.

The TDR function in the WaveExpert is an essential tool for analyzing the response of backplanes, cables, pc boards and other devices. TDR analysis with reference plane calibration and one- and two-port differential S-parameter measurement is included standard in the WaveExpert 100H. The measurements are integrated into the user interface along with a measurement "wizard" that guides the user through the set-up and calibration process.

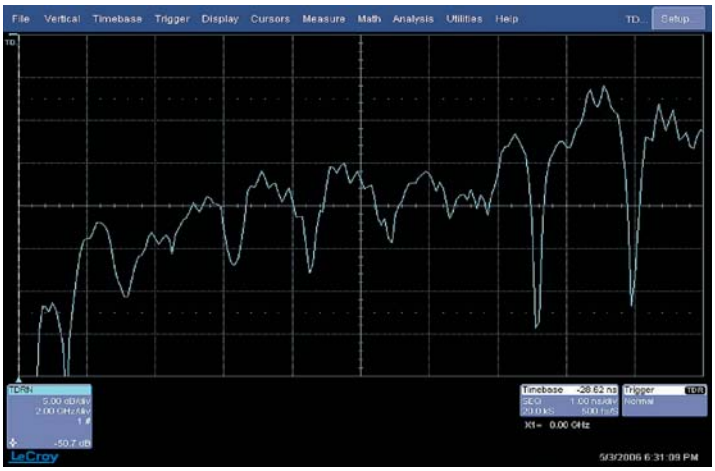
The ST-20 sampling/TDR heads allow for true differential stimulus so both single-ended and differential impedance measurements are possible. More complete analysis is available using the built-in S-parameter measurements which feature full Short, Open, Load, Through (SOLT) reference plane calibration for the highest accuracy possible. S-parameter results can be stored in industry-standard Touchstone format (SnP).

One- and two-port S-parameters can be measured either single-ended or differential. For differential measurements, the common mode and differential results are available.

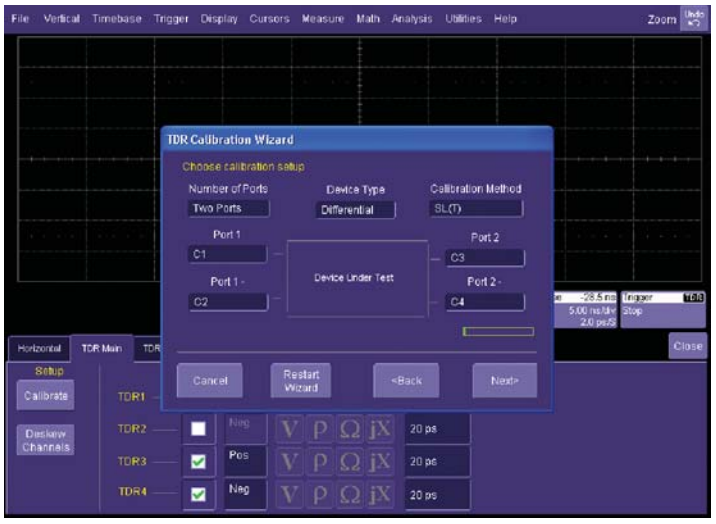
Many standards such as serial ATA require a specific rise time for the TDR step to measure the differential impedance of cables or backplanes. Rise time controls are provided to enable this adjustment.



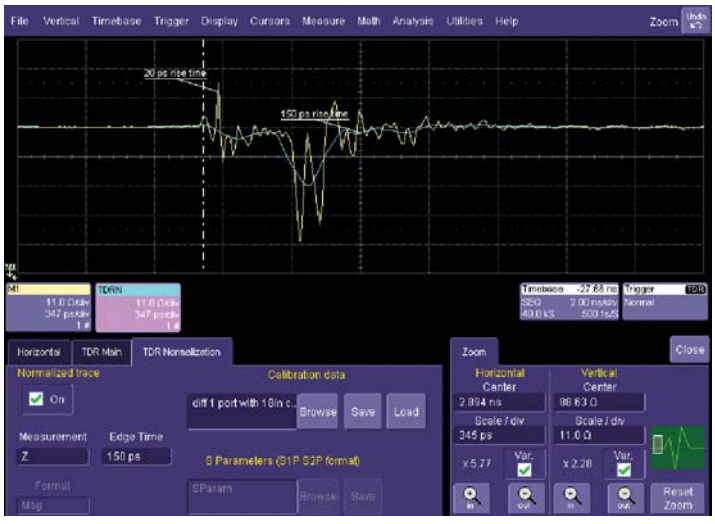
Cursor reactance measurements are available which enable the display of equivalent inductance and capacitance of the TDR trace delimited by the cursors.



Differential return loss of a 24-inch backplane measured using the standard S-parameter software on the WaveExpert.



The TDR measurement wizard guides the user through the set-up and calibration process ensuring the highest accuracy measurements. Full reference plane calibration and channel deskew is performed by the wizard.

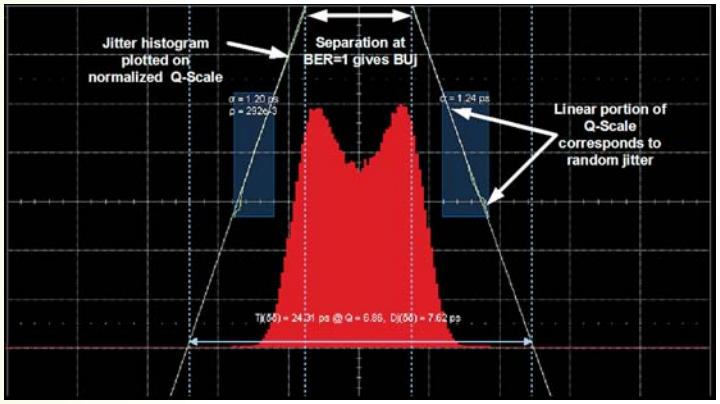


Calibrated impedance measurements are available with selectable rise time. This feature provides compliant impedance measurements of connectors, cables, and backplanes.

Highest Accuracy Jitter Analysis

Jitter Analysis

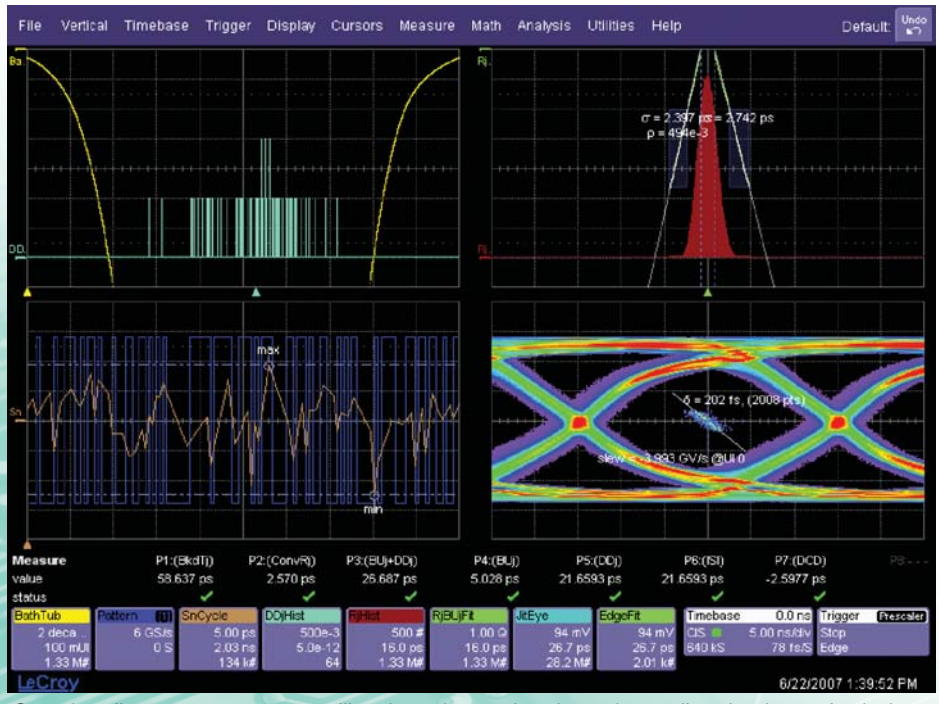
- **230 fs rms intrinsic timebase jitter**
- **Accurate total jitter analysis at any data rate**
- **Jitter breakdown using Q-Scale analysis**
  - ➤ **Random jitter**
  - ➤ **Data Dependent Jitter (DDj, DCD, and ISI)**
  - ➤ **Bounded Uncorrelated Jitter (BUj)**
- **Analysis of ALL edges in a waveform**
- **One-button access to jitter measurements**



Normalized Q-Scale analysis is performed on each edge of the data pattern. The slope of the linear portion is a measure of the random jitter while the separation of the lines at Q=0 gives the amount of Bounded Uncorrelated Jitter (BUj).

High Stability Coherent Interleaved Sampling (HCIS)—*a Breakthrough in Acquisition Technology*

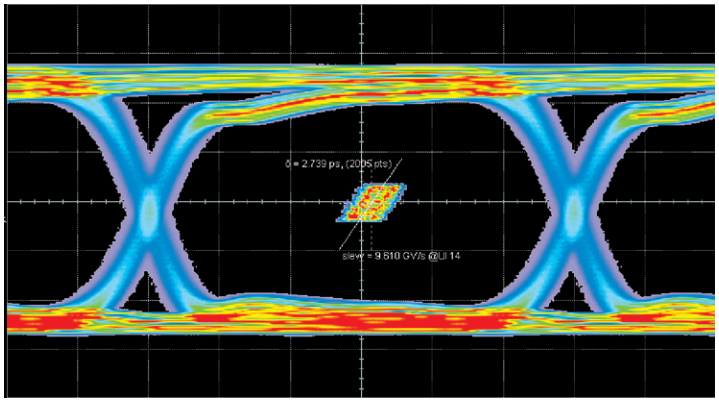
Conventional sampling oscilloscopes employ a sequential acquisition method which relies on an accurate time delay component to position the samples of the waveform in time. In addition to being slow, this type of sampling has high intrinsic jitter and requires a low jitter trigger signal. The patented HCIS timebase in the WaveExpert samples at rates 100 times faster and with 230 fs rms intrinsic jitter.



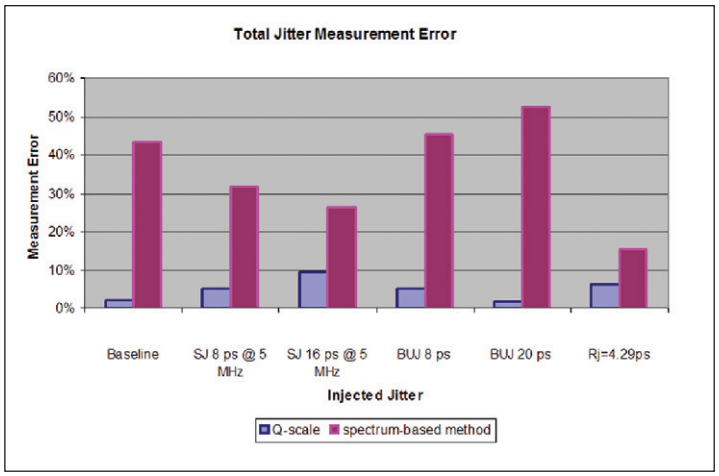
Complete jitter measurements utilize the coherent interleaved sampling timebase. Analysis includes total jitter, random jitter, deterministic jitter, and the components of deterministic jitter; DDj, ISI, and DCD.

The technology behind HCIS employs a phase-locked loop in the timebase which recovers the instrument's sampling clock from the bit clock of the signal under test. The advantages of this approach are fast sampling, high linearity, and low jitter over a wide frequency range. The fast sampling rate and long waveform memory of the HCIS timebase are essential elements for jitter analysis using the normalized Q-Scale technique.

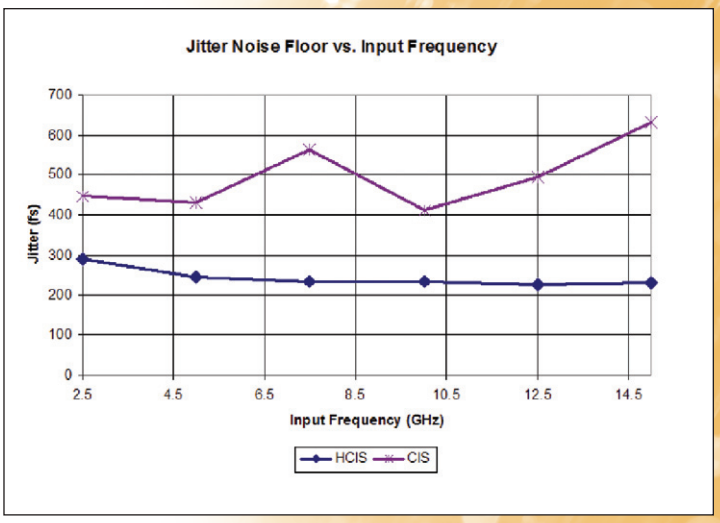
The innovative normalized Q-Scale jitter analysis software used in the WaveExpert oscilloscope provides the most accurate measurements, regardless of the jitter scenario. Conventional oscilloscope-based jitter analysis relies on the accurate measurement of the



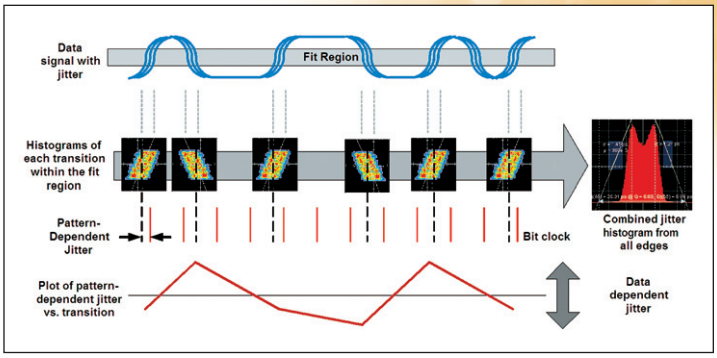
Jitter analysis uses all edges in the data pattern. The slope and mean displacement from nominal is used to measure the data dependent jitter. All individual edges can be separately viewed, as shown in the center of the eye above.



The HCIS timebase combined with normalized Q-Scale jitter analysis provides the highest accuracy jitter measurements regardless of the type of jitter present. This chart shows a set of jitter measurements on a calibrated jitter source comparing Q-Scale and the spectral method. The WaveExpert 100H gives the most accurate measurements even in cases where large SJ (sinusoidal jitter) and BUj (bounded, uncorrelated jitter) are present. The HCIS timebase has the lowest jitter noise floor, thus providing more accurate measurements than even a BERT.



The high stability coherent interleaved timebase (HCIS) provides a significantly lower jitter noise floor compared to a conventional sequential sampling timebase over a wide frequency range. The chart above shows the jitter performance of the standard and high stability coherent interleaved timebases over a range of bit rates.



Jitter analysis uses a pattern-locked signal waveform and measures every edge in the pattern. The combined jitter histogram from all edges provides the random and uncorrelated jitter.

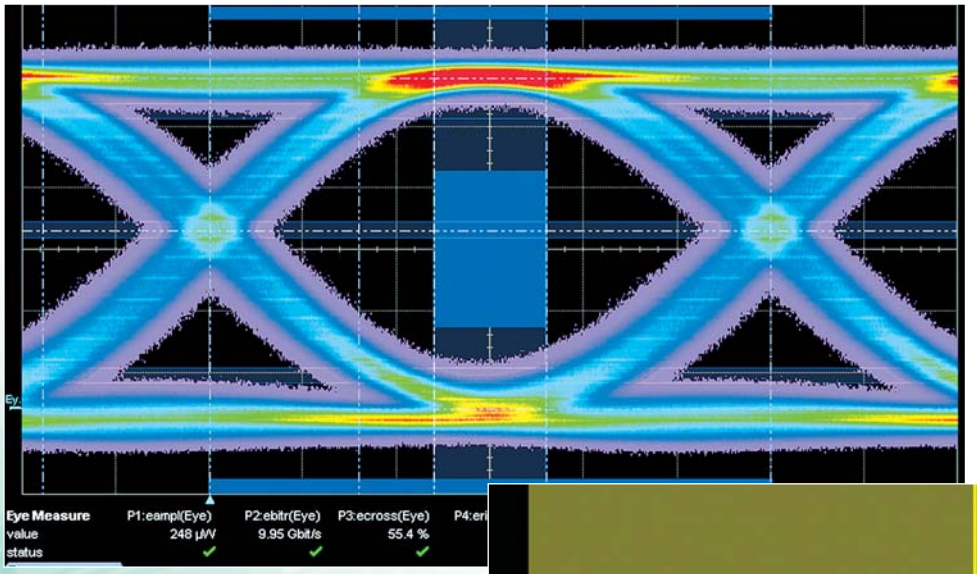
jitter spectrum. This method can become inaccurate, and can overestimate jitter in cases where there is crosstalk or power supply noise. The normalized Q-Scale method does not rely on the jitter spectrum but, instead, uses the measured jitter distribution to determine the random and bounded jitter components. When a repeating data pattern is used, the data dependent jitter can be removed from the jitter measurement, resulting in the first instrument that can measure Bounded Uncorrelated Jitter (BUj).

Optical Measurements at High Data Rates

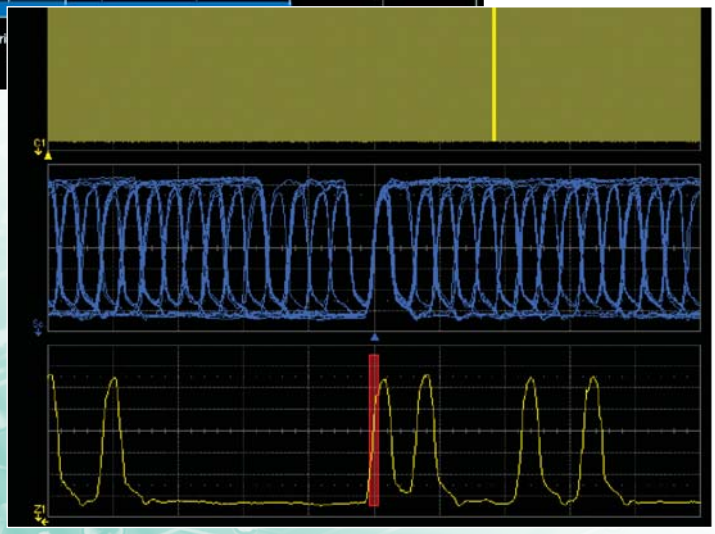
Optical Measurements

- **Fast eye pattern measurements**
- **Available 100 GHz sampling module for measurements beyond 40 Gb/s**
- **Pattern locking feature of HCIS enables analysis of PRBS23 waveforms**
- **Channel equalization using Eye Doctor feature**
- **RZ and NRZ measurements**
- **Built-in optical measurements such as Extinction Ratio, OMA, etc.**

Eye patterns remain one of the most important measures of signal quality in optical systems. In the past, designers were forced to use small statistical samples for this measurement, but the WaveExpert oscilloscope's fast coherent timebase provides a level of throughput rivaled only by bit error rate test systems. Eye patterns consisting of millions of samples can be measured in seconds, thus providing the highest level of accuracy and repeatability for a complete range of eye-based measurements such as extinction ratio, modulation amplitude, eye height and eye width. With its fast



Fast eye pattern measurements acquire millions of samples in seconds compared to minutes or hours on conventional sampling oscilloscopes. WaveExpert comes standard with a complete set of compliance masks and measurements.



Long test patterns are used to analyze the effects of channel distortions such as dispersion in optical fibers. The XXL memory option in the WaveExpert provides up to 510 M samples of waveform storage which can be viewed and analyzed on-screen. The fast acquisition rate provided by the HCIS timebase acquires a complete PRBS23 pattern in less than one minute. The analysis shown here is using the WaveScan feature to find the 20 fastest and slowest rise time edges in a PRBS23 pattern.

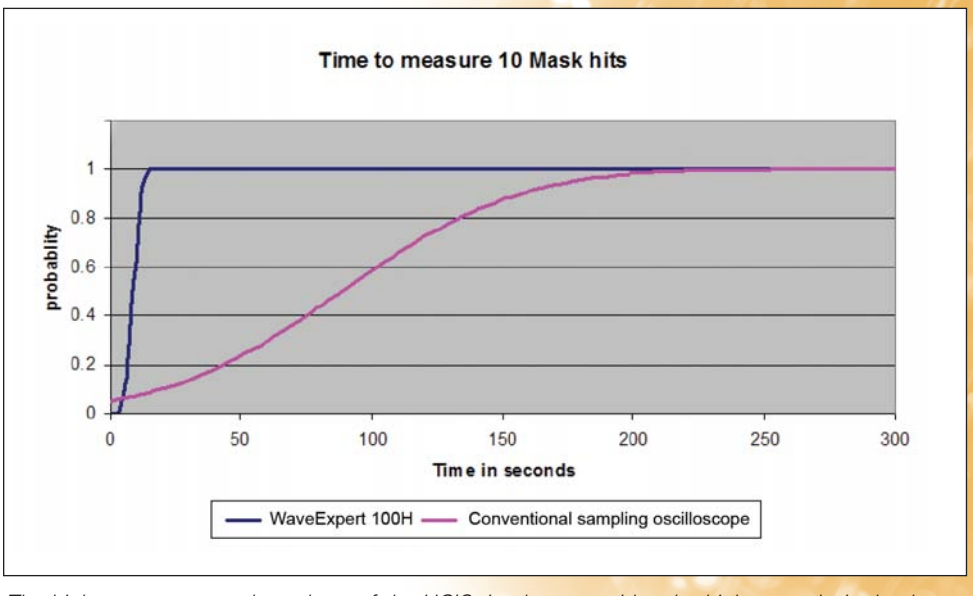
acquisition, the WaveExpert oscilloscope performs the most accurate eye jitter measurements, without the timebase drift problems present in standard equivalent-time scopes.

Telecom and datacom technologies are at 40 Gb/s in deployed systems, and 80 Gb/s and beyond in the lab. Measuring signals at these rates is pushing the limits of test equipment technology. The WaveExpert oscilloscope with its industry-leading 100 GHz bandwidth is up to the challenge. The fast acquisition, deep memory, and low jitter of the HCIS timebase provide an unprecedented level of waveform analysis. Complex measurements such as dispersion penalty, and processing functions such as equalization, are possible for the first time on pattern lengths as long as PRBS23. A complete set of optical and electrical plug-in modules provides coverage of all current and emerging standards.

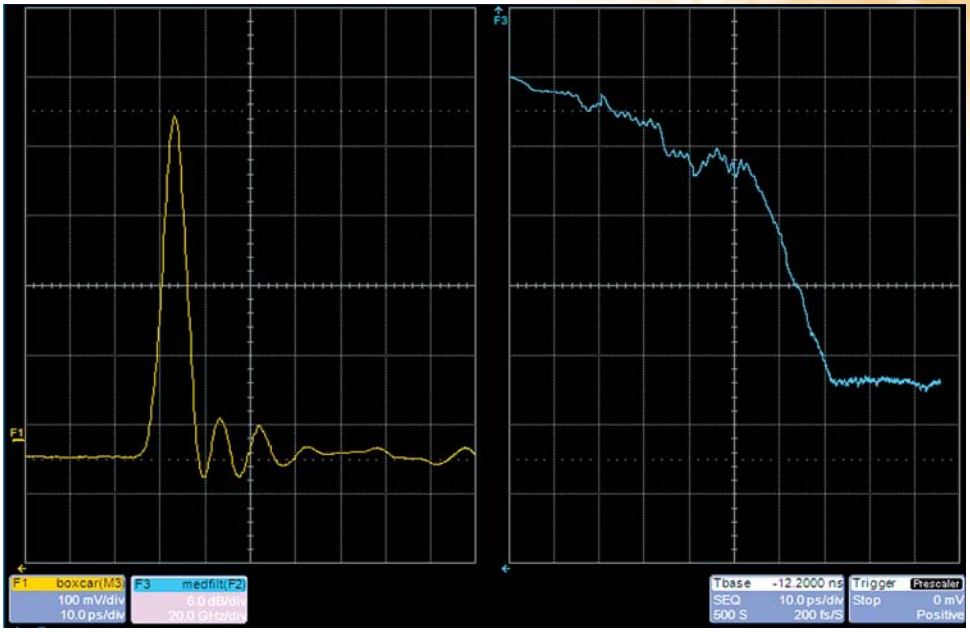
WaveScan™ Advanced Search

WaveScan is a powerful tool that provides the ability to locate unusual events in a single capture, or scan for an event in many acquisitions over a long period of time using more than 20 different search/scan modes.

- Locate problems triggers won't find
- Use measurement-based scanning modes, like frequency, to show statistical distribution of events
- Overlay events for a quick and simple visual comparison



The high measurement throughput of the HCIS timebase provides the highest analysis depth of any oscilloscope. This plot shows probability of capturing 10 mask violations as a function of measurement time. The WaveExpert requires less than 15 seconds to guarantee this measurement while a conventional sampling oscilloscope requires over 4 minutes.



An available 100 GHz bandwidth electrical sampling module enables measurements beyond 40 Gb/s. This image shows the time domain pulse from a femto-second laser and the FFT of the pulse. The HHI C05-W-22 100 GHz photodiode was used with the SE-100 sampling head to acquire the signal. The right grid scale is 20 GHz/div horizontally and 6 dB/div (3 dB/div optical).

Eye Doctor™ – A Complete Interoperability Solution

Eye Doctor™

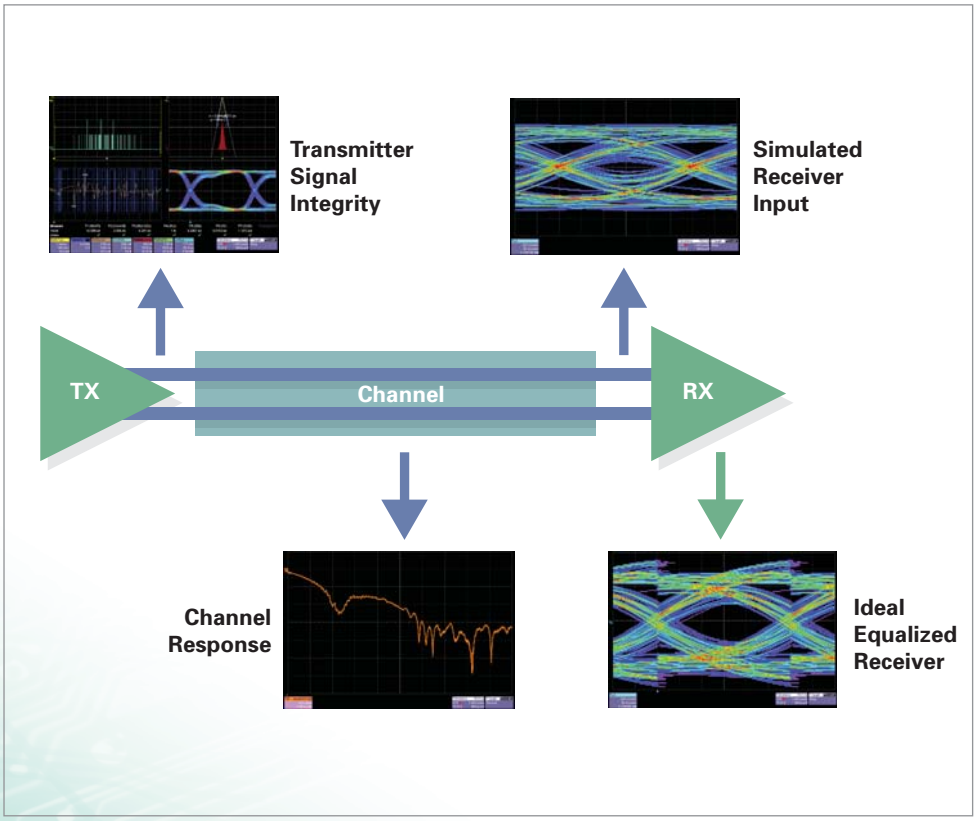
- **Full signal integrity analysis of equalized receiver signal**
- **Real time co-simulation of measured signals and measured or modeled network characteristics**
- **Performance margin analysis in equalized systems**
- **De-embedding of fixture and probe responses**
- **High accuracy far-end channel measurements**
- **Emulates any combination of DFE and FFE equalizers**
- **Automatic equalizer coefficient optimization**
- **Direct entry of FFE and DFE coefficients**

Eye doctor consists of two elements; Virtual Probing™ and equalized receiver emulation. Virtual Probing enhances the accuracy of measurements made on distorted waveforms while equalized receiver emulation allows measurements to be made from a "receiver's eye view." The ideal view of the signal within the receiver allows accurate total jitter and bit error rate measurements that are representative of actual system performance.

Virtual Probing

Probes and fixtures are not perfect and their presence in the circuit impacts both the loading on the DUT as well as the waveform seen by the oscilloscope. Virtual Probing is a powerful signal processing tool which enables the user to measure a signal anywhere within a system and then project a response at any other desired point.

This feature works by using S-parameter files of the various components in the system to derive a filter which relates the desired measured signal to the acquired waveform. For example, measurements can be made where the cleanest signal is available, usually at the transmitter, and the corrupted signal at the far-end of the channel (at the end of the backplane) can be simulated thus eliminating probe and instrument noise from the measurement.

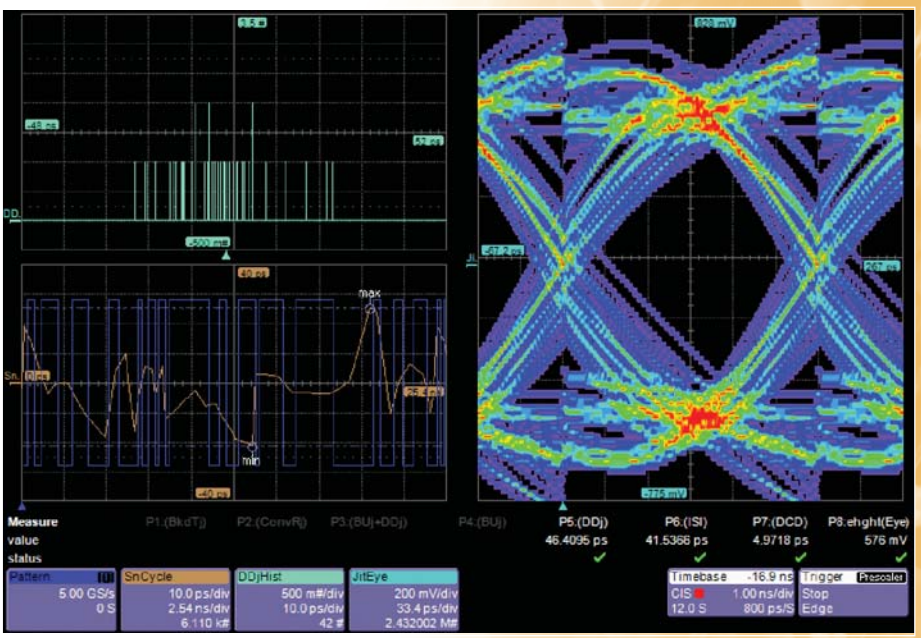


Current generation serial data systems operating at bit rates beyond 5 Gb/s represent an interoperability testing challenge. The introduction of equalization to digital receiver designs means that systems with partially or fully closed eye patterns can operate error-free. The WaveExpert 100H addresses these challenges using a combination of measurement and simulation tools including jitter analysis, true differential TDR testing with S-parameter measurement, Virtual Probing, and equalized receiver emulation.

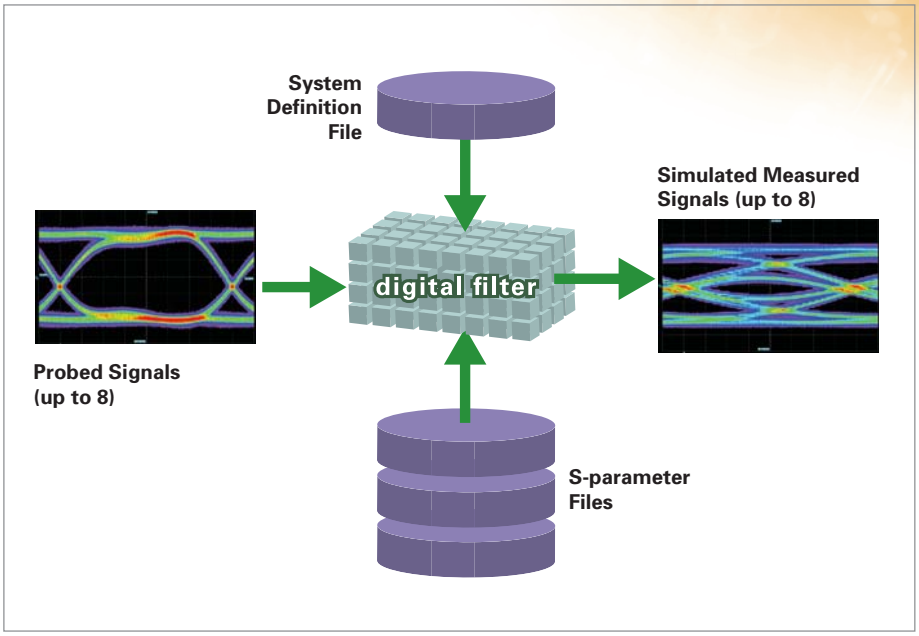
The derived filter takes into account all of the interactions among the elements of the system and transmitter signal including differential to common mode conversion, nearend and far-end crosstalk. Virtual Probing can be used to de-embed probe and fixture responses from measurements thereby improving the accuracy of signal integrity measurements.

Equalizer Emulation

Eye Doctor features equalized receiver emulation which includes both Feed Forward Equalization (FFE) and Decision Feedback Equalization (DFE), along with clock recovery and a variable decision threshold. This ideal receiver reveals the signal as seen within a real receiver at the detector where it is impossible to probe. The equalized signal can be measured using the powerful jitter and signal analysis software in the SDA, allowing the bit error rate, total jitter, and eye opening to be measured, thus giving a precise indication of the performance margin. Because the receiver emulation is ideal, the margins are measured independently of measurement system and receiver noise.



Equalizer emulation simulates the signal as viewed within the receiver. The component can automatically determine the optimum weighting coefficients for both FFE and DFE with the number of taps for each selected by the user. Coefficients can also be entered directly. Jitter and eye pattern analysis can be performed on the equalized signal using the SDA option.



Virtual Probing uses the measured characteristics of the elements of the system under test in terms of their S-parameters and the system definition file which describes how these elements are interconnected to build a digital filter which relates the waveform acquired by the oscilloscope to the desired measured waveform. Virtual Probing can be used to simulate receiver input signals as well as de-embedding fixtures and probes from measurements.

WaveExpert Module and Option Selection Guide

	bit rate (Gb/s)	ST-20	SE-30	SE-50	SE-70	SE-100	CDR-E135	CDR-O125	PPG-E135	ME-15 module extender cable	SO-10 w/ reference receiver(s)	SO-25	SO-50	WE-SDA	Virtual Probe	Equalizer Emulation	WE-HCIS	WE-CIS	WE-XXL	
SATA 1.5 Gb/s	1.5	*					*			*				*				*	*	TDR for cables and TX/RX. XXL memory measures long COMP pattern (81920 symbols)
SAS 150	1.5	*					*			*				*				*	*	TDR for cables and TX/RX. XXL memory measures long COMP pattern (81920 symbols)
HDMI 1.2	1.65	*					*			*				*				*		TDR cable testing
DVI	1.65	*					*			*				*				*		TDR cable testing
Fibre Channel	2.125	*						*			*			*				*		Fast throughput eye measurement. Jitter on CJPAT with WE-SDA
HDMI 1.3	2.2275	*					*			*				*				*		TDR cable testing
2.5 Gb SONET/SDH	2.48832							*			*	*						*	*	Fast eye pattern measurement, XXL memory for pattern dependent analysis
InfiniBand	2.5	*					*		*					*				*		Jitter on CJPAT with WE-SDA, TDR cable testing
PCIe Gen1	2.5	*					*		*					*				*		Measure 640 bit compliance pattern jitter with WE-SDA
ATCA	2.5	*					*		*					*	*	*		*		Measure 640 bit compliance pattern jitter with WE-SDA, Eye Doctor provides interoperability testing on equalized backplanes, TDR measures S-parameters
Serial ATA 3 Gb/s	3	*					*			*				*				*	*	TDR for cables and TX/RX. XXL memory measures long COMP pattern (81920 symbols)
SAS 300	3	*					*			*				*				*	*	TDR for cables and backplanes. XXL memory measures long COMP pattern (81920 symbols)
XAUI	3.125	*					*							*				*		Rj, Dj using WE-SDA
10GBASE-LX4	3.125	*					*				*			*				*		Rj, Dj using WE-SDA
Serial RapidIO	3.125	*					*							*				*		Rj, Dj using WE-SDA
FireWire	3.2	*					*				*			*				*		
Fibre Channel	4.25										*			*				*	*	Rj, Dj using WE-SDA
FB-DIMM I	4.8	*					*		*					*				*		
PCIe Gen2	5	*					*		*						*	*		*		Eye Doctor provides fixture de-embedding for TX compliance. WE-SDA enables jitter measurement on 640 bit compliance pattern
SAS Gen2	6	*					*							*	*	*		*		Virtual Probe provides fixture de-embedding for TX compliance. Equalizer provides compliant receiver testing. WE-SDA enables jitter measurement on CJPAT
SATA Gen3	6	*					*							*	*			*	*	Virtual Probe provides fixture de-embedding for TX compliance. WE-SDA enables jitter measurement on CJPAT
Fibre Channel	8.5		*	*							*			*				*		Optical compliance testing with fast eye pattern, Tj Dj measurement with WE-SDA.
FB-DIMM II	9		*				*			*				*	*			*		
10G SONET/SDH	9.953							*	*		*	*				*		*	*	XXL memory provides capture of PRBS23 for pattern dependent analysis. Equalizer allows emulation of dispersion compensation
10G Ethernet	10		*	*				*	*		*			*		*		*		Tj and Dj with SDA option, dispersion compensation with Equalizer emulation, XXL provides pattern dependent analysis up to PRBS23
802.3aq 10GBASE-LRM	10.3		*	*				*	*					*	*	*		*	*	Tj and Dj with SDA option, TWDP with Equalize emulation, XXL provides pattern delendent analysis up to PRBS23
High Accuracy Jitter Analysis	12.5		*	*										*			*		*	230 fs rms jitter noise floor with HCIS, jitter breakdown analysis up to 1M bits with XXL memory
80 Gb/s Optical	80				*	*									*	*	*			230 fs rms jitter with HCIS, 90 GHz optical bandwidth with HHI C05-W-22 photodetector and SE-100, Eye Doctor for dispersion compensation
40 Gb/s Optical	up to 43				*	*							*		*	*	*			230 fs rms jitter with HCIS for eye pattern analysis, fast eye pattern measurement. XXL memory for pattern dependent analysis. 90 GHz optical bandwidth with HHI C05-W-22 photodetector and SE-100

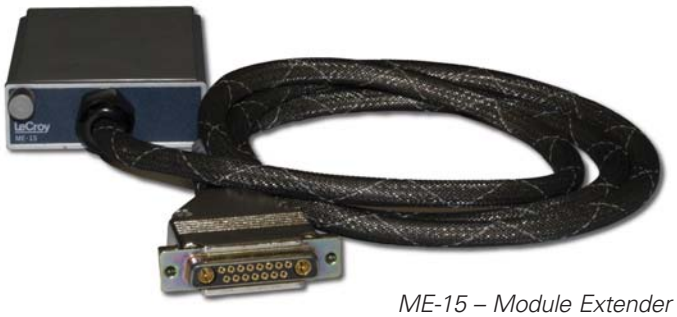
Modular Acquisition Covers Bandwidths from 20 to 100 GHz

The WaveExpert 100H mainframe accepts any combination of up to 4 modules. In addition to electrical sampling modules with bandwidths up to 100 GHz, electrical clock recovery and pulse pattern generator modules are also available. Three optical modules are also available for testing fiber optic signals, such as SONET/SDH, Fibre Channel, and Gigabit Ethernet.

Electrical Sampling, Clock Recovery and Pattern Generator Modules

Module Extender Cable

The ME-15 is a 1.5 meter extender cable which allows any of the available sampling modules to be remotely mounted from the mainframe. Remote mounting is important for maintaining signal integrity during TDR and high bandwidth measurements.



ME-15 – Module Extender Cable

Optical Clock Recovery

The CDR-O125 optical clock recovery unit features both singlemode and multimode capability and coverage from 12.5 Mb/s to 2.7 Gb/s and from 9.9 Gb/s through 12.5 Gb/s.

CDR-O125 – Optical Clock Recovery

Trigger Prescaler

The SDA-TPS prescaler extends the trigger input range to 40 GHz, allowing bit rate triggering of 40 Gb/s data streams.

SDA-TPS – Trigger Prescaler

Specifications

Timebase

Parameter	Sequential	With Coherent Timebase (WE-CIS and WE-HCIS)
Sample Rate	1 MS/s	10 MS/s
Frequency Range	DC to 5 GHz, using Trigger input 5 GHz–14 GHz, using CLK/Prescale input up to 40 GHz, using SDA-TPS accessory	62.5 MHz–125 MHz, using Trigger input 125 MHz–14 GHz, using CLK/Prescale input up to 40 GHz, using SDA-TPS accessory
Pattern Lock	N/A	YES, up to PRBS23
Minimum Time Per Division	1 ps	1 ps
Time Resolution	100 fs rms	100 fs rms
Timebase Range	1 ps/div to 1 ms/div	1 ps/div to 500 ns/div (4 M memory)
Timebase Delay Time Range	25 ns–10 ms	±1 pattern
Time Interval Accuracy	±1 ps ±0.1% of reading	Determined by trigger signal
Long Term Stability	±5 ppm	Determined by trigger signal
Maximum Record Length Standard Optional	 100k samples N/A	 64 M samples 1 Ch, 16 M samples 4 Ch 510 M/1 Ch, 256 M/2 Ch, 128 M/4 Ch
Jitter	1 ps typical, 1.2 ps guaranteed	HCIS: 230 fs rms typical, 250 fs rms guaranteed CIS: 500 fs rms typical, 600 fs rms guaranteed (3 Gb/s–40 Gb/s)

Trigger and Clock Inputs

Parameter	Trigger Input	CLK/Prescale Input
Connector Type	2.92 mm	2.92 mm
Impedance	50 Ω nominal	50 Ω nominal
Input Amplitude	±1 V	0.0 dBm ±6 dBm
Max. Input Voltage	±2.5 V	±2.5 V
Coupling	DC	AC coupled
Trigger Sensitivity	-10 dBm at 100 MHz, -5 dBm at 5 GHz	-5 dBm at 14 GHz
Trigger Gating (Sequential mode only)	Enable: 2.0–3.5 V Disable: 0–0.8 V	
Trigger Gating Delay (Sequential mode only)	Disable: 24 ns+ trigger period + time window setting Enable: 32 ns	

Electrical Sampling Modules

Parameter	ST-20 (20 GHz)	SE-30 (30 GHz)	SE-50 (50 GHz)
Connector Type	2.92 mm	2.92 mm	2.4 mm
Rise Time	18 ps	12 ps	8 ps
Bandwidth	20 GHz	30 GHz	50 GHz
Input Voltage Range	2 V_{p-p}	2 V_{p-p}	2 V_{p-p}
DC Vertical Voltage Accuracy	< 1% (800 mV_{p-p} signal)	< 1% (800 mV_{p-p} signal)	< 1% (800 mV_{p-p} signal)
Aberrations	First 40 ps: ±10%, 40 ps–200 ps: ±5%, 200 ps–10 ns ±2%	First 40 ps: ±10%, 40 ps–200 ps: ±5%, 200 ps–10 ns ±2%	First 40 ps: ±10%, 40 ps–200 ps: ±5%, 200 ps–10 ns ±2%
RMS Noise	700 µV max. (500 µV typical)	1 mV (max.)	2 mV (max.), 1 mV (typical)
Offset Range	±1 V	±1 V	±1 V

Parameter	SE-70 (70 GHz)	SE-100 (100 GHz)
Connector Type	1.85 mm	1 mm
Rise Time	5 ps	4 ps
Bandwidth	70 GHz	100 GHz
Input Voltage Range	2 V_{p-p}	2 V_{p-p}
DC Vertical Voltage Accuracy	< 1% (800 mV_{p-p} signal)	< 1% (800 mV_{p-p} signal)
Aberrations	First 40 ps: ±10%, 40 ps–200 ps: ±5%, 200 ps–10 ns ±2%	First 40 ps: ±10%, 40 ps–200 ps: ±5%, 200 ps–10 ns ±2%
RMS Noise	3 mV (max.)	3 mV (max.)
Offset Range	±1 V	±1 V

Optical Sampling Modules

Parameter	SO-10 (10 GHz)	SO-25 (28 GHz)	SO-50 (50 GHz)
Optical Bandwidth	10 GHz	28 GHz	50 GHz
Connector Diameter	62.5 µm/50 FC	9 µm	9 µm
FWHM (50%)	51 ps (max.) 48 ps (typical)	15.5 ps (max.) 15 ps (typical)	8.8 ps (typical), 8.5 ps (max.)
Wavelength Range	750 nm to 1650 nm	1280 nm to 1620 nm	1280 nm to 1620 nm
Responsivity	450 V/W (typical) 425 V/W (min.) @ 1310 nm, 425 V/W (typical) 400 V/W (min.) @ 1565 nm, 225 V/W (typical) 200 V/W (min.) @ 850 nm	17 V/W (typical) 15 V/W (min.) @ 1564 nm, 11 V/W (typical) 9 V/W (min.) @ 1310 nm	17 V/W (typical) 15 V/W (min.) @ 1564 nm, 11 V/W (typical) 9 V/W (min.) @ 1310 nm
Maximum Peak Optical Input	5 mW	50 mW (+17 dBm)	50 mW (+17 dBm)
Maximum Average Optical Input		20 mW (+13 dBm)	20 mW (+13 dBm)
Noise Equivalent Power (Unfiltered)	3 µW (max.) 2 µW (typical) @ 10 GHz optical bandwidth into 150 MHz IF bandwidth	47 µW (-13.2 dBm) @ 28 GHz bandwidth with 150 MHz IF bandwidth	83 µW (-11 dBm) @ 50 GHz bandwidth with 150 MHz IF bandwidth
Optical Power Monitor	-30 dBm to 10 dBm, ±5%	-30 dBm to +10 dBm ±5%	-30 dBm to +10 dBm ±5%
Optical Return Loss	-22 dB (SM), -14 dB (MM)	> 25 dB @ 1550 nm	> 25 dB @ 1550 nm
Sensitivity (Unfiltered)	-15 dBm 10.7 Gb/s 1550 SM, -14 dBm 12.5 Gb/s 1550 SM	-2.5 dBm	-0 dBm

TDR Step Generator (ST-20)

Parameter	Nominal
Step Rise Time	20 ps
TDR Step Voltage	250 mV
Resistance	50 Ω
TDR Pulse Rate	1 MHz
Offset Range	±1 V
Step Flatness	First 40 ps: ±10%, 40 ps–200 ps: ±5%, 200 ps–10 ns ±2%
Pulse Width	300 ns ±15 ns

Clock Recovery Modules

Electrical Clock Recovery Module (CDR-E135)

Parameter	Nominal
Frequency Range	Continuous coverage from 622 Mb/s–8 Gb/s, up to 13.5 Gb/s with option 001
Sensitivity	100 mV_{p-p} to 7 Gb/s, 200 mV_{p-p} from 7 Gb/s–13.5 Gb/s
Maximum Input Voltage	2 V_{p-p}
Clock Output Voltage	500 mV_{p-p} minimum
Data Output Jitter	.005 UI rms @ 10 Gb/s (500 fs rms typical)
Input Return Loss	15 dB from 622 Mb/s–10 Gb/s, 10 dB from 10 Gb/s–25 Gb/s
Output Clock Rise/Fall Time	30 ps (20%–80%)
PLL Loop Bandwidth	6 MHz

Optical Clock Recovery Module (CDR-O125)

(includes one multimode splitter and one singlemode splitter for both serial data and optical applications)

Parameter	Nominal
Frequency Range	12.5 Mb/s–2.7 Gb/s, 9.9 Gb/s–12.5 Gb/s
Wavelength Range	750 nm–1650 nm
Clock and Clock/8 Output Voltage	300 mV_{p-p} (typical)
Data Output Jitter	.01 UI rms (12.5 Mb/s–12.5 Gb/s)
Optical Sensitivity for Clock Recovery (Not including loss from external optical splitter)	-19 dBm, typical @ 1564 nm -17 dBm, minimum @ 1564 nm -19 dBm, typical @ 1310 nm -17 dBm, minimum @ 1310 nm -17 dBm, typical @ 850 nm -14 dBm, minimum @ 850 nm

Pulse Generator Module

PRBS Pulse Pattern Generator (PPG-E135)

Parameter	Nominal
Frequency Range	2.45 GHz–2.875 GHz 4.9 GHz–5.75 GHz 9.8 GHz–11.5 GHz
Data Patterns	2^N -1, N=7, 10, 15, 23, 31

PRBS Pulse Pattern Generator (PPG-E135) (cont'd)

Parameter	Nominal
Mark Space Density	0.5, 0.250, 0.125 0.875 or 0.750 possible with Data Invert
Data Output Voltage	500 mV_{p-p}, 1000 mV_{p-p} differential
Data Output Jitter	< 1 ps rms
Data Output Rise/Fall Time	30 ps (20–80%)
Clock Output Power	0 dBm ±3 dBm
External Clock Input Frequency	50 MHz–12.5 GHz
External Clock Input Power	> 0 dBm
Frequency Accuracy	± 3 ppm
Front Panel Connectors	
Data+, Data-	2.92 mm (3.5 mm compatible)
CLK Input, CLK Output	SMA

Power Requirements

100–200 V_{rms} (±10%) at 50/60 Hz; 115 V_{rms} (±10%) at 400 Hz, Automatic AC Voltage Selection Installation Category: 300V CAT II; Max. Power Consumption: 400 VA (400 W)

Environmental

Temperature (Operating)	+5 °C to +40 °C including CD-ROM drive
Temperature (Non-Operating)	-20 °C to +60 °C
Humidity (Operating)	5% to 80% relative humidity (non-condensing) up to +30 °C. Upper limit derates to 25% relative humidity (non-condensing) at +40 °C
Altitude (Operating)	Up to 10,000 ft. (3048 m) at or below +25 °C
Altitude (Non-Operating)	Up to 40,000 ft. (12,192 m)
Random Vibration (Operating)	0.31 g_{rms} 5 Hz–500 Hz, 15 minutes in each of three orthogonal axes
Random Vibration (Non-Operating)	2.4 g_{rms} 5 Hz to 500 Hz, 15 minutes in each of three orthogonal axes
Functional Shock	20 g_{peak}, half sine, 11 ms pulse, 3 shocks (positive and negative) in each of three orthogonal axes, 18 shocks total

Physical Dimensions

Dimensions (HWD) (height excludes feet)	264 mm x 397 mm x 491 mm; 10.4" x 15.6" x 19.3"
Weight	40 lbs; 18 kg
Shipping Weight	52 lbs; 24 kg

Certifications

CE Compliant, UL and cUL listed; Conforms to EN 61326; EN 61010-1; UL 61010-1; and CSA C22.2 No. 61010-1

Ordering Information

Product Description	Product Code
WaveExpert 100H	
Standard 4-slot Mainframe	WE 100H
Serial Data Package (Jitter Analysis)	WE-SDA
510 M (1 Ch), 255 M (2 Ch), 128 M (4 Ch) Waveform Memory	WE-XXL
Software Options	
Eye Doctor (Virtual probe and equalizer emulation bundle)	EYEDR
Virtual Probe	EYEDR-VP
Equalizer Emulation	EYEDR-EQ
Timebase Options	
CIS Timebase – 600 fs rms Jitter, Pattern Lock, 10 Ms/s	WE-CIS
HCIS Timebase – 250 fs rms Jitter, Pattern Lock, 10 Ms/s	WE-HCIS
Electrical Sampling Modules	
100 GHz Electrical Sampling Module	SE-100
70 GHz Electrical Sampling Module	SE-70
50 GHz Electrical Sampling Module	SE-50
30 GHz Electrical Sampling Module	SE-30
20 GHz Electrical Sampling Module with TDR	ST-20
Optical Sampling Modules	
50 GHz Optical Sampling Module	SO-50
28 GHz Optical Sampling Module	SO-25
High Sensitivity 10 GHz Optical Sampling Module with Plug-in Reference Receivers	SO-10
Optical Reference Receiver Kit	
Optical Reference Receiver Kit–Serial Bus	REFKIT-SBUS
Kit includes:	
1.063 Gb/s Reference Receiver Filter for SO-10	REF-01063
1.250 Gb/s Reference Receiver Filter for SO-10	REF-01250
2.125 Gb/s Reference Receiver Filter for SO-10	REF-02125
2.5 Gb/s Reference Receiver Filter for SO-10	REF-02500
3.125 Gb/s Reference Receiver Filter for SO-10	REF-03125
3.32 Gb/s Reference Receiver Filter for SO-10	REF-03320
4.25 Gb/s Reference Receiver Filter for SO-10	REF-04250
Optical Reference Receiver Kit–Serial Bus	REFKIT-SBUS
Kit includes:	
9.950 Gb/s Reference Receiver Filter for SO-10	REF-09950
10.31 Gb/s Reference Receiver Filter for SO-10	REF-10310
10.52 Gb/s Reference Receiver Filter for SO-10	REF-10520
Also available separately	
Optical Reference Receiver Kit–SONET/SDH	REFKIT-TELCO
Kit includes:	
155 Mb/s Reference Receiver Filter for SO-10	REF-00155
622 Mb/s Reference Receiver Filter for SO-10	REF-00622
2.488 Gb/s Reference Receiver Filter for SO-10	REF-02488

Product Description	Product Code
Optical Reference Receiver Kit (cont'd)	
Kit includes: (cont'd)	
3.188 Gb/s Reference Receiver Filter for SO-10	REF-03188
9.950 Gb/s Reference Receiver Filter for SO-10	REF-09950
10.66 Gb/s Reference Receiver Filter for SO-10	REF-10660
10.71 Gb/s Reference Receiver Filter for SO-10	REF-10710
11.1 Gb/s Reference Receiver Filter for SO-10	REF-11100
Also available separately	
Clock Recovery Modules	
Optical Clock Recovery Module (12.5 Mb/s to 2.7 Gb/s, 9.95 Gb/s to 12.5 Gb/s)	CDR-O125
Electrical Clock Recovery Module (622 Mb/s to 8 Gb/s)	CDR-E135
Extend Frequency Range of CDR-E135 to 13.5 Gb/s	CDR-E135-001*
Pulse Pattern Generator	
12.5 Gb/s Pulse Pattern Generator with Clock Output	PPG-E135
Coaxial Adapters	
2.92 mm F-F Adapter	ADAPT-292
2.92 mm – SMA F-F Adapter	ADAPT-292-SMA
1.85 mm F-F Adapter	ADAPT-185
1 mm F-F Adapter	ADAPT-100
1 mm – 1.85 mm F-F Adapter	ADAPT-100-185
Hardware Options and Accessories	
40 GHz Trigger Prescaler (for clock frequencies to 40 GHz)	SDA-TPS
1.5 Meter Module Extender Cable	ME-15
Blank Cover Module	WE-CM
IEEE-488 GPIB Remote Control Interface	GPIB-1
Dual Monitor Display	DMD-1
Keyboard, USB	KYBD-1
Oscilloscope Cart with Extra Shelf and Drawer	OC1024
Oscilloscope Cart	OC1021
Rackmount Adapter with 25" (64 cm) Slides	RMA-25
Rackmount Adapter with 30" (76 cm) Slides	RMA-30
Removable Hard Drive Package	WE9K-RHD
Additional Removable Hard Drive (Includes USB, CD-ROM and Spare Hard Drive)	WE9K-RHD-02
4 in.-lb. Torque Wrench	TW-4
8 in.-lb. Torque Wrench	TW-8

*Part must be ordered with the CDR-E135.

Customer Service

LeCroy oscilloscopes are designed, built, and tested to ensure high reliability. In the unlikely event you experience difficulties, the WaveExpert Series oscilloscopes and modules are warranted for a period of one year, and our probes are warranted for one year.

This warranty includes:

- No charge for return shipping
- Long-term 7-year support
- Upgrade to latest software at no charge

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