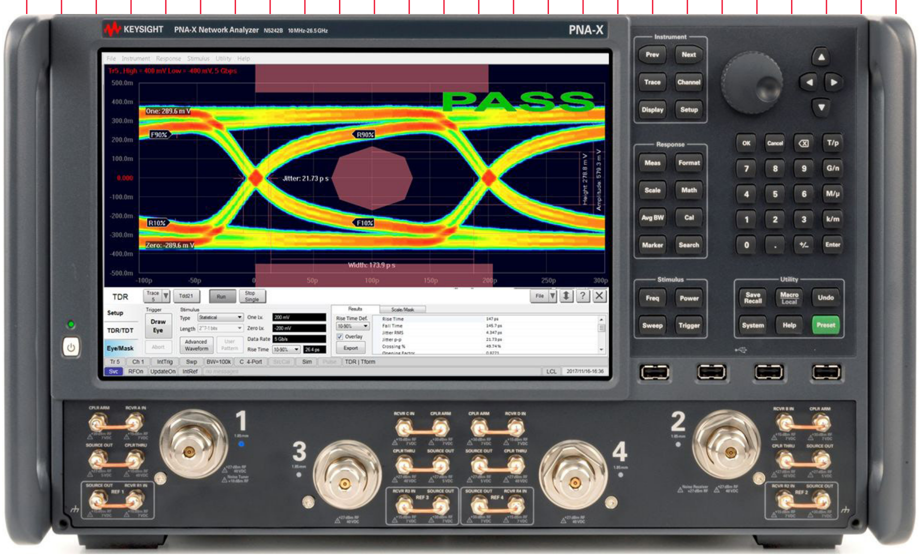
Keysight Technologies
S93011A Enhanced Time Domain Analysis with TDR

Technical Overview



KEYSIGHT TECHNOLOGIES

One-box Solution For High-Speed Serial Interconnect Analysis

Comprehensive signal integrity measurement solution for next generation high-speed digital standards

As bit rates of digital systems increase, signal integrity of interconnects drastically affects system performance. Fast and accurate analysis of interconnect performance in both time and frequency domains becomes critical to ensure reliable system performance. As managing multiple test systems becomes difficult, a single test system that can fully characterize differential high-speed digital devices is a very powerful tool.

The S93011A provides a one-box solution for high-speed interconnect analysis, including impedance, S-parameters, and eye diagrams. The S93011A is an enhancement of the S93010A time domain analysis software. The software, running on the PNA-X / PNA / PNA-L Series B-model vector network analyzers, brings three breakthroughs for signal integrity design and verification: simple and intuitive operation, fast and accurate measurements, and high ESD robustness.

Simple and intuitive operation

- The user interface is designed to provide a similar look-and-feel to traditional TDR oscilloscopes
- Easily locate source of loss, reflections and crosstalk with simultaneous analysis of both time and frequency domains
- Quickly access important tools to setup complex measurements and quickly retrieve measurement data

Fast and accurate measurements

- Accurate measurements due to unmatched performance of the PNA-X / PNA / PNA-L Series vector network analyzers
- State-of-the-art error correction techniques enables you to measure your device, not your measurement system

High ESD robustness

- Protection circuits implemented inside the instrument to significantly increase ESD robustness, while at the same time maintaining excellent RF performance
- Highly robust architecture minimizes instrument failure from ESD and frees you from worrying about instrument repair fees and downtime

Key features

- Up to 67 GHz of bandwidth with 6.66 ps rise time enables measurement to the latest high-speed serial standards
- Unmatched performance
  - Low noise floor for accurate and repeatable measurements: 20 µV rms
  - Wide dynamic range to observe the true performance of your device: > 110 dB
  - Fast measurement speed for real-time analysis: 251 msec (1601 points, 2-port cal)
- State-of-the art calibration techniques reduce measurement errors
  - Automatic deskew ensures easy removal of fixture and probe effects
  - Full calibration available for the utmost in measurement accuracy

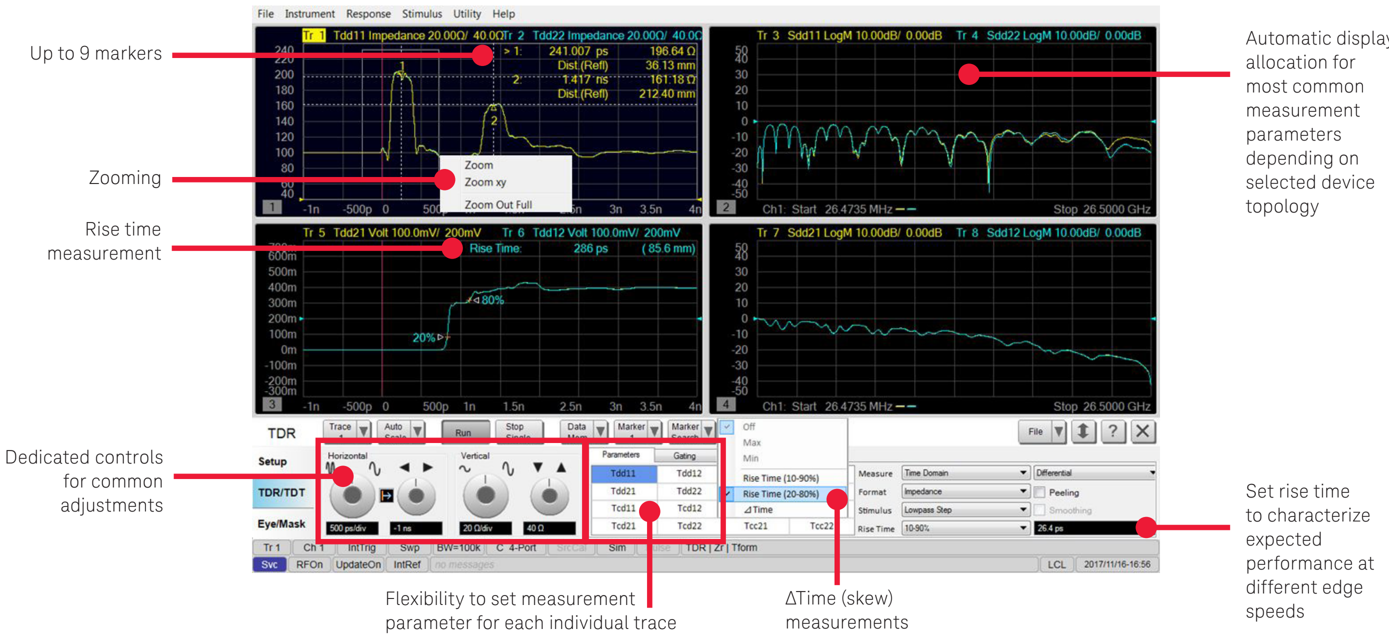
Designed for Multi-Domain Challenges

Quickly change between TDR/TDT Mode and Eye/Mask Mode with a single mouse click

TDR/TDT Mode

The S93011A measures the characteristics of a test device as a function of frequency. The frequency domain information is used to calculate the Inverse Fourier Transform for time domain results.

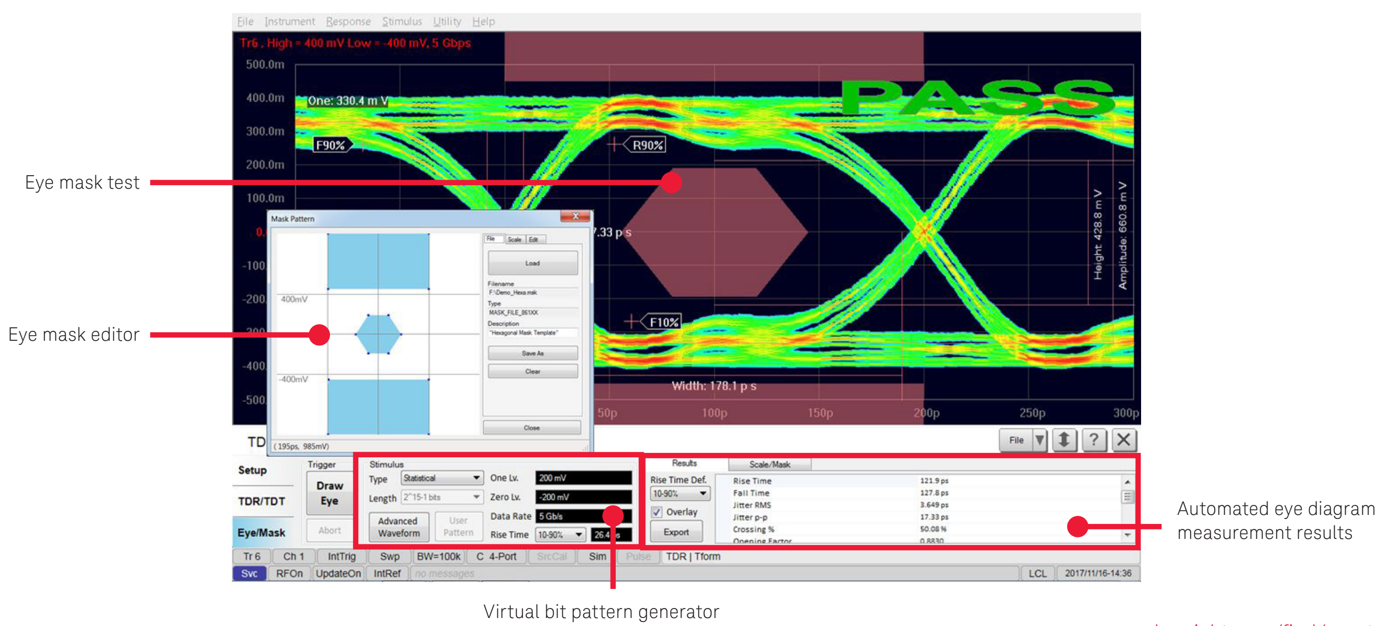
- Single connection forward and reverse transmission and reflection measurements
- All possible modes of operation (single-ended, differential, and mode conversion)



Eye/Mask Mode

The S93011A provides simulated eye diagram analysis capability, eliminating the need for a pulse pattern generator. The virtual bit pattern generator is used to define a virtual bit pattern. The defined bit pattern is then convolved with the test device impulse response to create an extremely accurate measurement based eye diagram.

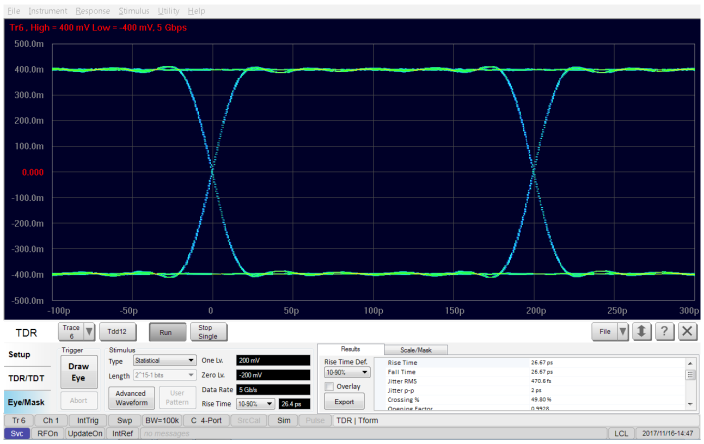
- Apply industry standard (PRBS, K28.5), or user specified patterns using the virtual bit pattern generator
- Predefined standards based eye diagram masks available for efficient waveform compliance testing
- Custom eye diagram masks can easily be created with the eye mask editor.



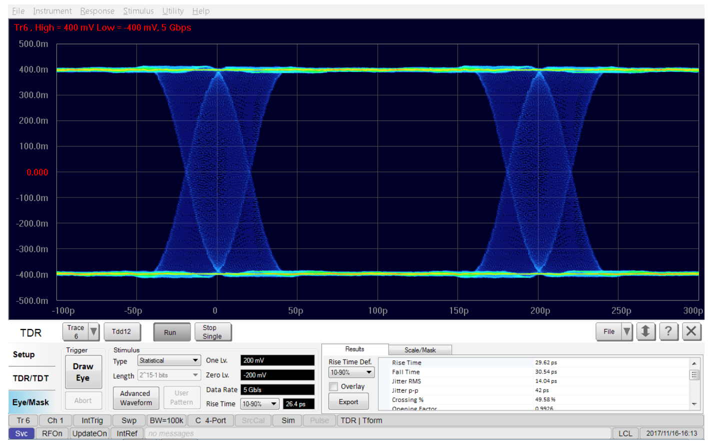
Advanced Waveform Analysis Features

Simulate real-world signals through jitter insertion

One challenge with parametric characterization of interconnects, such as loss and reflections, is how to translate the results into what the eye diagram will look like at the end of a link. A more direct approach would be to measure the eye diagram. If the interconnect can correctly transmit a stressed signal, composed of the worst case compliant signal generated by the transmitter, with eye characteristics equal to or better than what is specified at the receiver, then it should operate with any combination of compliant transmitters and receivers. This precision stressed signal input can be realized with the jitter insertion feature. Impairments such as random and periodic (sinusoidal) jitter can be configured.



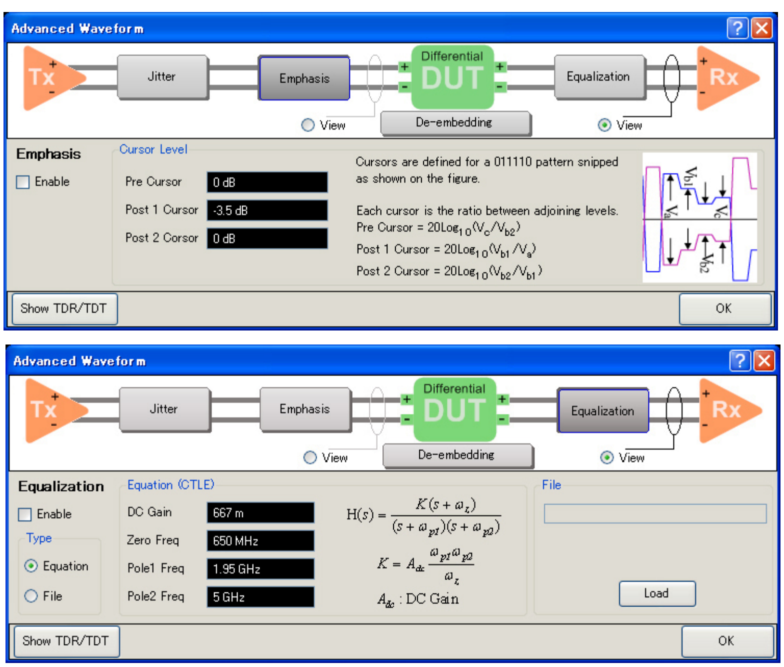
Jitter Insertion OFF



Jitter Insertion ON (periodic jitter = 200 mUI)

Determine optimal emphasis and equalization settings for your link

As data rates increase, the channel distorts the signal and can cause a partially or completely closed eye diagram that makes it impossible for the receiver to extract the data. To recover the data from the eye diagram, it must be re-opened. This is where emphasis and equalization can help. Emphasis and equalization are commonly used signal conditioning techniques when transmitting signals at gigabit data rates. The term emphasis is used to describe signal conditioning on the transmitter, while the term equalization is used on the receiver side.



Open up closed eyes by simulating emphasis and equalization via a simple GUI.

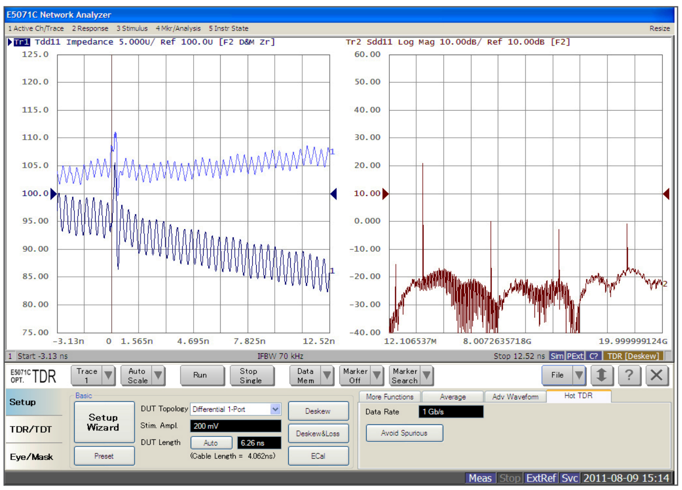
Advanced Waveform Analysis Features *continued*

Hot TDR: impedance analysis of active devices under actual operating conditions

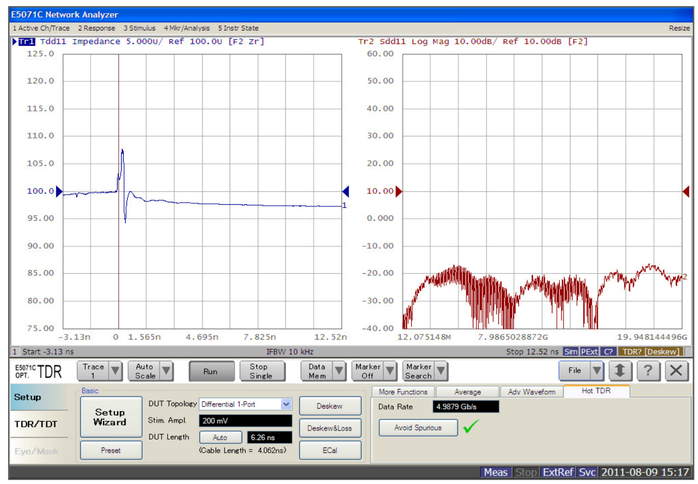
As bit rates of digital systems increase, impedance mismatch between components becomes a significant factor in system performance. A typical high-speed digital system consists of a transmitter, interconnect, and receiver. As the transmitter signal reaches the receiver, any impedance mismatch at the receiver will cause some of the signal to be reflected back to the transmitter. Once the reflected signal reaches the transmitter, any impedance mismatch at the transmitter will cause re-reflections. Once this re-reflected signal reaches the receiver, it will cause eye closure.

Hot TDR is the TDR and return loss measurement of active devices in the power-on state.

For Hot TDR measurements of transmitters (Tx), the Tx is powered on and outputting a data signal. The data signal from the Tx can cause measurement errors. A vector network analyzer (VNA) implements a narrowband receiver architecture, which minimizes the effect from the Tx signal. But as the VNA sweeps across the desired frequency range, there still may be frequencies where the spurious response from the Tx data signal overlaps the measurement frequency, causing measurement error. The avoid spurious feature determines the spurious frequencies from the data rate (user input) and sets the optimum frequency sweep to minimize measurement error.



With the default setup, the data signal from the Tx causes fluctuations on the time domain response and spikes in the frequency domain response.



After avoid spurious operation, measurement errors due to the Tx data signal are minimized.

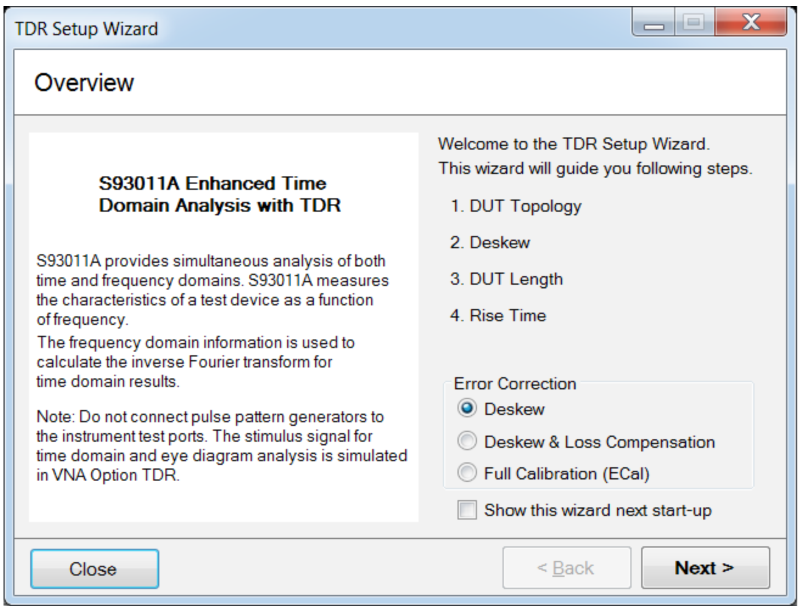
Simple and Intuitive Operation

Wizards guide you through the steps of an operating sequence to reduce operator errors

Complete device characterization with S93011A is straightforward. The graphical user interface has been designed to provide a similar look-and-feel to traditional TDR oscilloscopes and intuitive for users unfamiliar to vector network analyzers and S-parameter measurements.

TDR Setup Wizard simplifies measurement setup

The TDR Setup Wizard guides you through all of the required steps, making setup of error correction and measurement intuitive and error-free. Detailed illustrations help you make the correct connections. The instrument then configures itself automatically and provides access to results quickly.



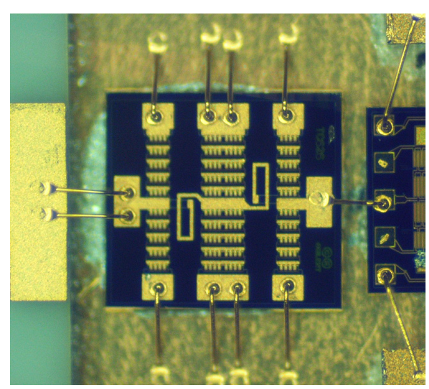
The TDR Setup Wizard automatically optimizes internal settings depending on your device to simplify setup. Manual setup is also possible for unique test requirements.

High ESD Robustness

Reduce instrument repair fees and downtime

In applications such as electrical TDR circuit board testing and cable testing, large static charges can be stored in the device. Special care is required when using traditional instruments in such situations to make sure the instrument is not damaged by electrostatic discharge (ESD). Vulnerability to ESD can lead to increased maintenance fees and long repair times.

The PNA-X, PNA, and PNA-L Series microwave network analyzers are designed for high robustness against ESD by implementing protection circuits inside the instrument. Leveraging the company's expertise in RF design, Keysight has invested in key technology blocks like our proprietary ESD protection chip to significantly increase ESD robustness, while at the same time maintaining excellent RF performance.



Keysight's proprietary ESD protection chip

Fast and Accurate Measurements

Measure the true performance of your device

Over the years, many different approaches have been developed for removing the effects of the test fixture and cables from the measurement. The level of difficulty for each error correction technique is related to the accuracy of each method. It is important to have a test system that will allow flexibility of choosing the method of error correction required for each application.

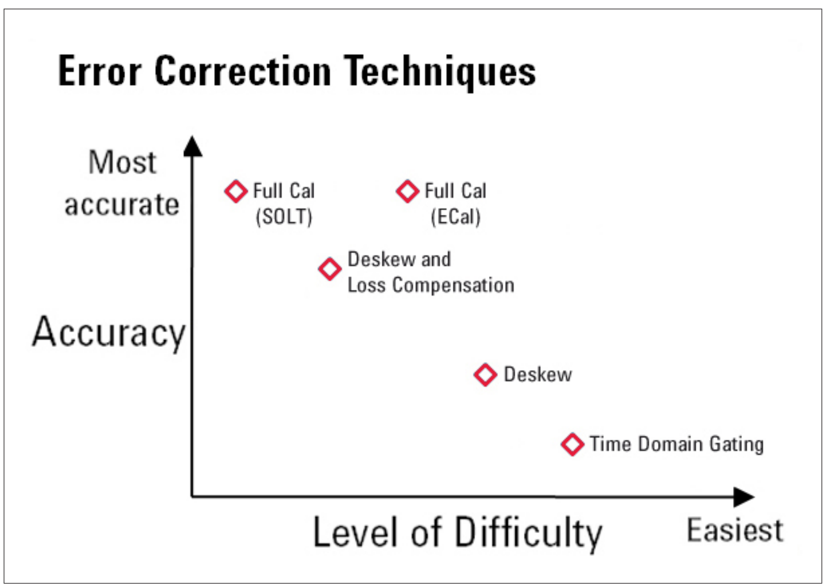
Deskew (also known as Port Extension) mathematically extends the calibration reference plane to the DUT, effectively removing the delay from the test setup. This technique is easy to use, but assumes the cable and fixture – the unwanted structure – looks like a perfect transmission line: a flat magnitude response, a linear phase response, and constant impedance. If the cable and fixture are well designed, this technique can provide good results.

Deskew and loss compensation mathematically extends the calibration reference plane to the DUT, effectively removing the delay and loss from the test setup. This technique is a good compromise between level of difficulty and accuracy.

Full calibration (SOLT) type is one of the most comprehensive calibrations. This calibration effectively removes delay, loss, and mismatch from the test setup, making it possible to perform measurements with the highest possible accuracy.

Electronic calibration (Ecal) is a complete solid-state calibration solution which makes full calibration fast and easy. Traditional mechanical calibrations require intensive operator interaction which is prone to errors. With ECal, the operator simply connects the ECal module to the instrument and the software controls the rest.

The ECal DC option (#0DC) is recommended for higher time domain accuracy.



A relative comparison of error correction techniques

Key Specifications

Refer to PNA-X/PNA/PNA-L Series Datasheet for additional specifications.

	Category[1]	N5247B N5227B N/A	N5245B N5225B N5235B	N5244B N5224B N5234B	N5242B N5222B N/A	N/A N/A N5232B	N5241B N5221B N/A	N/A N/A N5231B	N5249B N/A N/A	N/A N/A N5239B
Bandwidth	spec.	67 GHz	50 GHz	43.5 GHz	26.5 GHz	20 GHz	13.5 GHz		8.5 GHz	
Input connector	typ.	1.85 mm (male)	2.4 mm (male)	2.4 mm (male)	3.5 mm (male)	3.5 mm (male)	3.5 mm (male)	3.5 mm (male)	3.5 mm (male)	3.5 mm (male)
Input impedance	nom.	50 ohm								
DC damage level at test port	spec.	40 VDC 40 VDC N/A	40 VDC 7 VDC 7 VDC	40 VDC 7 VDC 7 VDC	40 VDC 7 VDC N/A	N/A N/A 7 VDC	40 VDC 7 VDC N/A	N/A N/A 7 VDC	40 VDC N/A N/A	N/A N/A 7 VDC
Maximum test port input voltage (Hot TDR mode)	typ.	0.8 Vpp								
TDR stimulus [2]	nom.	Step, Impulse								
TDR step amplitude [3]	nom.	1 mV to 5 V								
TDR step rise time (min) [4] (10% to 90%)	spec.	6.66 ps	8.92 ps	10.3 ps	16.9 ps	22.3 ps	33.1 ps		52.5 ps	
TDR step response resolution in free space [5] (εr = 1) (min)	nom.	1.0 mm	1.3 mm	1.5 mm	2.5 mm	3.3 mm	5.0 mm		7.9 mm	
TDR impulse width (min) [4]	spec.	9.01 ps	12.1 ps	13.9 ps	22.8 ps	30.2 ps	45.0 ps		71.0 ps	
TDR Deskew range (max) [6] (test cable length)	spec.	12.4 ns	12.4 ns	12.4 ns	12.4 ns	50 ns	12.4 ns	50 ns	12.4 ns	50 ns
DUT length (max) [7]	spec.	12.4 ns	12.4 ns	12.4 ns	12.4 ns	416 ns	12.4 ns	416 ns	12.4 ns	416 ns
TDR stimulus repetition rate (max)	spec.	67 MHz	50 MHz	43.5 MHz	26.5 MHz	20 MHz	13.5 MHz		10 MHz	8.5 MHz
RMS noise level [8]	typ.	20 µVrms	80 µVrms		40 µVrms	10 µVrms	40 µVrms	10 µVrms	40 µVrms	10 µVrms
Eye diagram data rate (max) [9]	spec.	53.6 Gb/s	40 Gb/s	34.8 Gb/s	21.2 Gb/s	16.0 Gb/s	10.8 Gb/s		6.8 Gb/s	

1. All specifications and characteristics apply over a 25°C±5°C range (unless otherwise stated) and 90 minutes after the instrument has been turned on. Specification (spec.): Warranted performance. Specifications include guardbands to account for the expected statistical performance distribution, measurement uncertainties, and changes in performance due to environmental conditions. Characteristic (char.): A performance parameter that the product is expected to meet before it leaves the factory, but that is not verified in the field and is not covered by the product warranty. A characteristic includes the same guardbands as a specification. Typical (typ.): Expected performance of an average unit which does not include guardbands. It is not covered by the product warranty. Nominal (nom.): A general, descriptive term that does not imply a level of performance. It is not covered by the product warranty.
2. The time domain function of the S93011A is similar to the time domain reflectometry (TDR) measurement on a TDR oscilloscope in that it displays the response in the time domain. In the TDR oscilloscope measurement, a pulse or step stimulus is input to the DUT and the change of the reflected wave over time is measured. In the S93011A TDR measurement, a sine wave stimulus is input to the DUT and the change of the reflected wave over frequency is measured. Then, the frequency domain response is transformed to the time domain using the Inverse Fourier Transform.
3. The TDR step amplitude setting does not vary the actual stimulus level input to the device, but is used when calculating the Inverse Fourier Transform.
4. Minimum values may be limited by the DUT length setting.
5. To convert from rise time to response resolution, multiply the rise time by c, the speed of light in free space. To calculate the actual physical length, multiply this value in free space by vf, the relative velocity of propagation in the transmission medium. (Most cables have a relative velocity of 0.66 for a polyethylene dielectric or 0.7 for a PTFE dielectric.)
6. Using high quality cables to connect the DUT is recommended in order to minimize measurement degradation. The cables should have low loss, low reflections, and minimum performance variation when flexed.
7. Maximum DUT length is the sum of the DUT and test cable lengths.
8. RMS noise level with 50 Ω DUT and default setup.
9. Maximum values may be limited by the DUT length setting.

Ordering Information [1,2,3]

Model Number	Description
S93011A	Enhanced Time Domain Analysis with TDR

1. S93011A is not supported on the following products and options:
   - PNA-X / PNA / PNA-L Series A-model vector network analyzers
   - Low frequency extension is disabled with Option 205 and 425
   - Millimeter-wave vector network analyzers: single-sweep solutions (N5290A/N5291A), banded waveguide solutions
2. Supported software license types: fixed-perpetual (1FP), transportable-perpetual (1TP), fixed-1-year (1FY), and transportable-1-year (1TY)
3. The ECal DC option (#0DC) is recommended for higher time domain accuracy.

Related Literature

Literature	Number
Keysight PNA and PNA-L Series Microwave Network Analyzers – Brochure	5990-8290EN
Keysight PNA-X Series Microwave Network Analyzers – Brochure	5990-4592EN
PNA Family Microwave Network Analyzers – Configuration Guide	5992-1465EN

Web Resources

S93011A Enhanced Time Domain Analysis with TDR	www.keysight.com/find/pna-tdr
PNA Series Network Analyzers	www.keysight.com/find/pna
PNA Series Service and Support	na.support.keysight.com/pna
Mechanical and Electronic Calibration Kits	www.keysight.com/find/ecal
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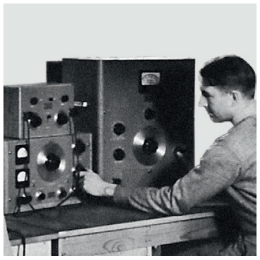
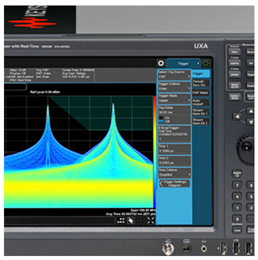


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