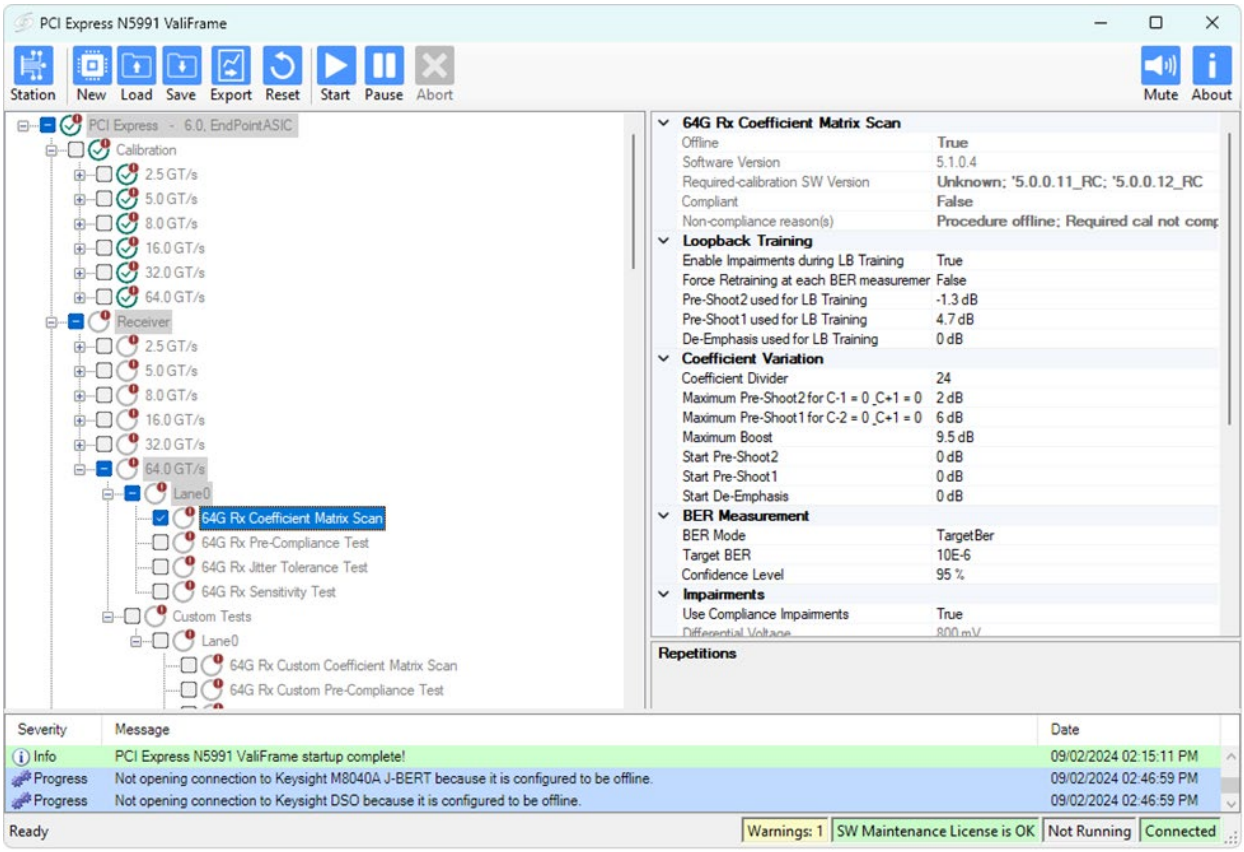
Receiver Compliance Test Automation Platform (N5991P)

Receiver Test Automation for PCI Express®

Introduction

The N5991P Receiver test automation software family for PCI Express covers various specification revisions and form factors



KEYSIGHT

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Receiver Test Product Line (N5991)

High-speed digital standards are quickly evolving to keep pace with emerging technologies such as generative AI, chiplet-based architecture, advanced driver assistance systems (ADAS), edge AI, and 6G research.

Each generational change introduces new test challenges for your digital designs. You need to test your high-speed digital designs across all product development stages — from design and simulation to analysis, debugging, and compliance testing. The N5991 product line anticipates test challenges, optimizes performance, and accelerates time-to-market of your high-speed computing interfaces, data-center connections, and consumer electronics.

- Supported standards, which include PCIe, SAS, SATA, USB, HDMI, DisplayPort, and MIPI M-PHY, C-PHY & D-PHY. Other standards will be continuously added with the requirements for higher data speed testing
- Guided setup with automated fast stress signal calibration and compliance measurement functions
- Modern look and feel with enhanced functionalities
- System modularity allows the user to enable only required functionalities
- HTML reports
- Node-locked and transportable licenses
- Expert mode for in-depth characterization
- Single and multi-lane device testing

Characterization mode for in-depth testing Single- and multi-lane device testing.

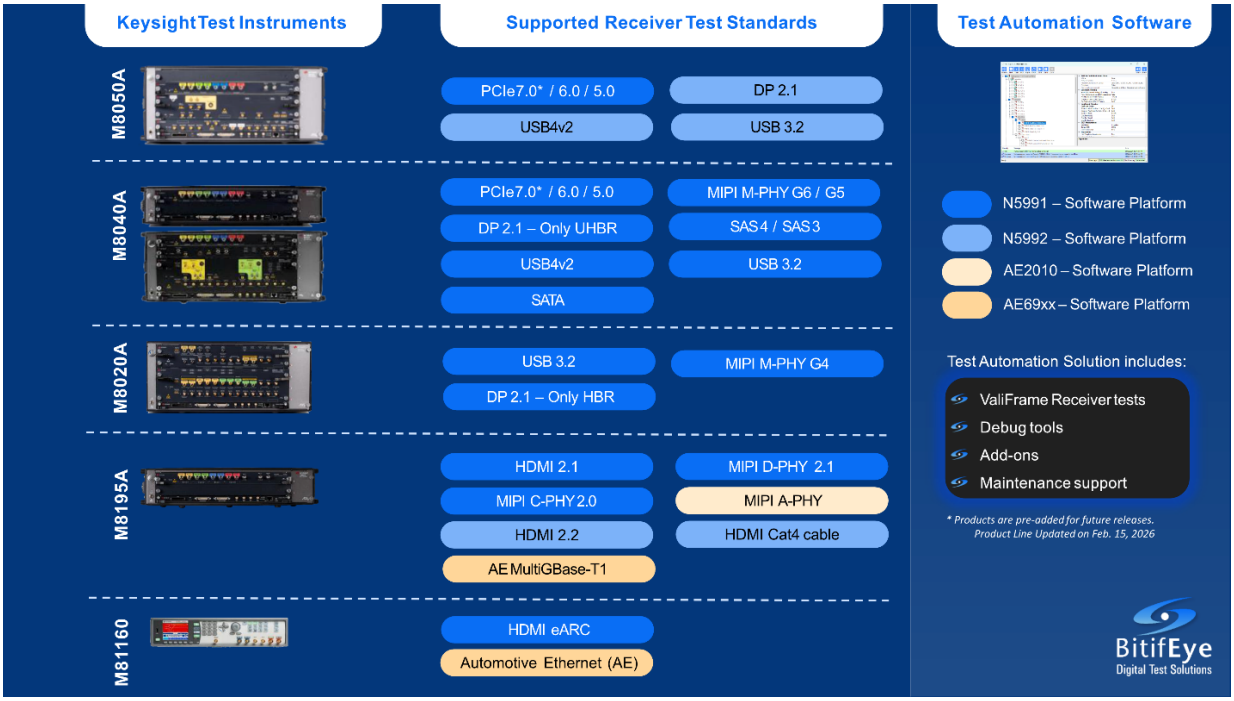


Figure 1. N5991, N5992, and AE2010 portfolio vs. pattern generator / AWG

Turn Your Instruments into a Solution

An efficient test strategy is a proven competitive advantage. The Keysight Technologies N5991 test automation software platform combines the performance of your instruments with the convenience of your PC. The system's software provides unprecedented test integration, high-throughput, and ease-of-use for a wide range of stimulus and response systems, providing a level of control that transforms a collection of instruments into a universal, user-friendly and highly productive test solution.

Standardize Your Test

The N5991 receiver-test options provide dedicated receiver compliance tests for popular and emerging digital buses. The user can choose compliance mode for fast reassurance, or characterization mode for in-depth analysis. The Receiver Test Automation Platform's compliance testing capabilities have been repeatedly proven at interoperability workshops ("plug fests"). N5991 builds on the success of previous generations to deliver significant gains in productivity. The system makes it easy to test multiple buses by using the same interface for all available standards. It delivers additional gains by using familiar HTML for reporting results.

Test Selection and Test Results

The test automation software platform lets you select tests from an intuitive tree structure with multiple levels of detail. Select the tests you want to run, together with the number of repetitions. Test results are provided in HTML format. When you measure a parameter range, it delivers a specific graph and a related data table (see Figure 2).

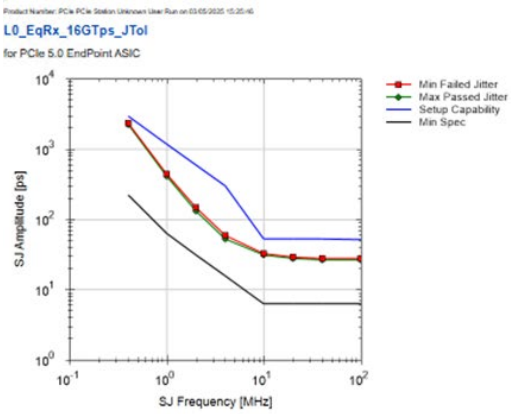


Figure 2. Jitter tolerance measurement – graphical and tabular results

Computer Bus Applications – PCI Express

The N5991 is designed to meet the needs of the data center application space, with many high-speed links within and between servers. It utilizes the Keysight M8050/M8040A High-Performance BERT with Baud rates up to 64 GBaud and the ability to encode data in NRZ and PAM4. This makes the software the center piece of Keysight's data center receiver test solutions, specifically targeting PCI Express receiver testing at transfer rates of 128 GT/s, 64 GT/s, 32 GT/s, 16 GT/s and 8 GT/s.

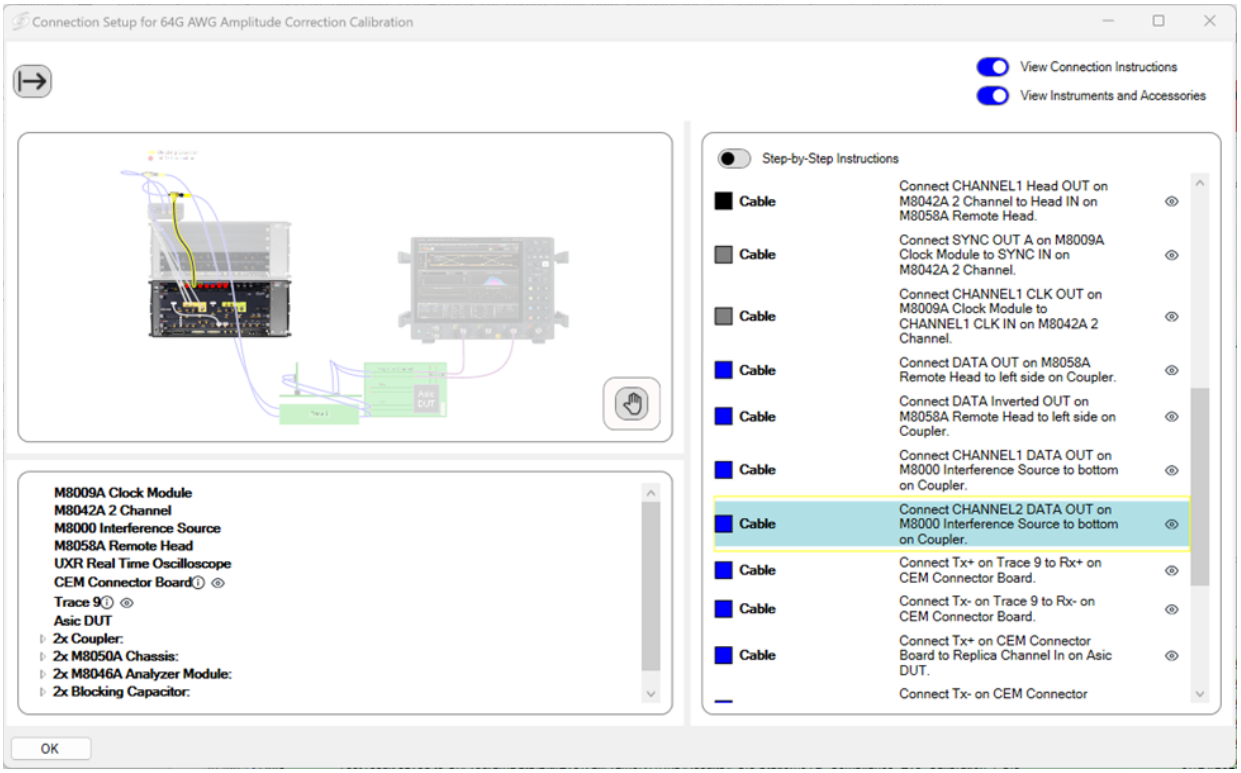


Figure 3. PCI Express 6.0 base specification receiver test setup based on M8040A high-performance BERT. Connection can be highlighted to clarify setup

Calibration and receiver testing for PCI Express 4.0, 5.0, 6.0 and 7.0

Starting with PCI Express 3.0, the receiver stress signal calibration targets are defined as eye height and eye width after applying a reference receiver, which adapts to the stress signal. The concept of transmitter de-emphasis optimization also needs to be considered. This requires special tools to determine eye height and eye width. For base specification calibrations, the preferred method is SEASIM, which simulates the stress signal and reference receiver using a step measurement through the setup to determine channel characteristics and impairment parameters. In contrast, stress signal calibrations following the PCI Express Architecture PHY Test Specification for 8 GT/s, 16 GT/s and 32 GT/s require the use of the waveform post processing tool SIGTEST. In both cases, multiple eye heights and eye width measurements must be averaged to achieve usable results per impairment and launch amplitude, de-emphasis, and pre-shoot combinations. This requires many measurements and lengthy processing times.

Actual stress signal calibration procedures differ for 8 GT/s, 16 GT/s and 32 GT/s. For instance, PCI Express 4.0 8 GT/s uses random jitter and differential mode sinusoidal interference as the main adjustments to achieve target eye height and eye width, while PCI Express 4.0 16 GT/s uses channel loss adjustment for a first eye height and eye width adjustment, followed by a tuning process using differential mode sinusoidal interference, sinusoidal jitter and launch amplitude. PCI Express 5.0 32 GT/s is like PCI Express 4.0 16 GT/s with a slightly modified stress signal calibration. Up to 32 GT/s the stressed eye is defined for a bit error rate of 1e-12. PCI Express 6.0 64 GT/s is using PAM4 signaling. New measurements for pulse width jitter (PWJ) Is required for 64 GT/s stressed eye calibration. Signal-to-noise and distortion ratio (SNDR) is required for a 64 GT/s stressed eye calibration for Base specification but not for the PCI Express Architecture PHY test specification (as of 2026/03/17). The stressed eye for 64 GT/s is defined for a first bit error rate of 1e-6.

Receiver testing for 16 GT/s for common clock architecture (CC) in PCI Express 4.0 Base specification uses residual SSC (rSSC) of 500 ps, while 16 GT/s for CC in PCI Express 5.0 Base specification uses a 33 kHz sinusoidal jitter (SJ) spur of 1 ns.

Automation software for the calibration and test process, as well as a high-power PC, are highly recommended.

Link Equalization Testing for PCI Express

The most significant change from PCI Express 2.0 to 3.0, other than the bit rate increase, is the requirement for dynamic link equalization. Link equalization is critical for PCI Express 8 GT/s, 16 GT/s, 32 GT/s and 64 GT/s because increases in data rates and server interconnect transmission path-lengths create challenges for signal integrity. Signal equalizers at one or more locations in the link compensate for signal anomalies by boosting the high-frequency components. Link equalization testing verifies the optimization of the link between a transmitter and a receiver. The test solution acts as a link partner and quickly negotiates transmitter to receiver communications using protocol handshakes.

Receiver link equalization testing exposes the device under test (DUT) to stress signals like the standard receiver tests but implements a protocol handshake process to fine tune the link's performance by requesting changes of the BERT data output's de-emphasis and pre-shoot. The link is successfully trained when the receiver achieves the required bit error ratio in a loopback.

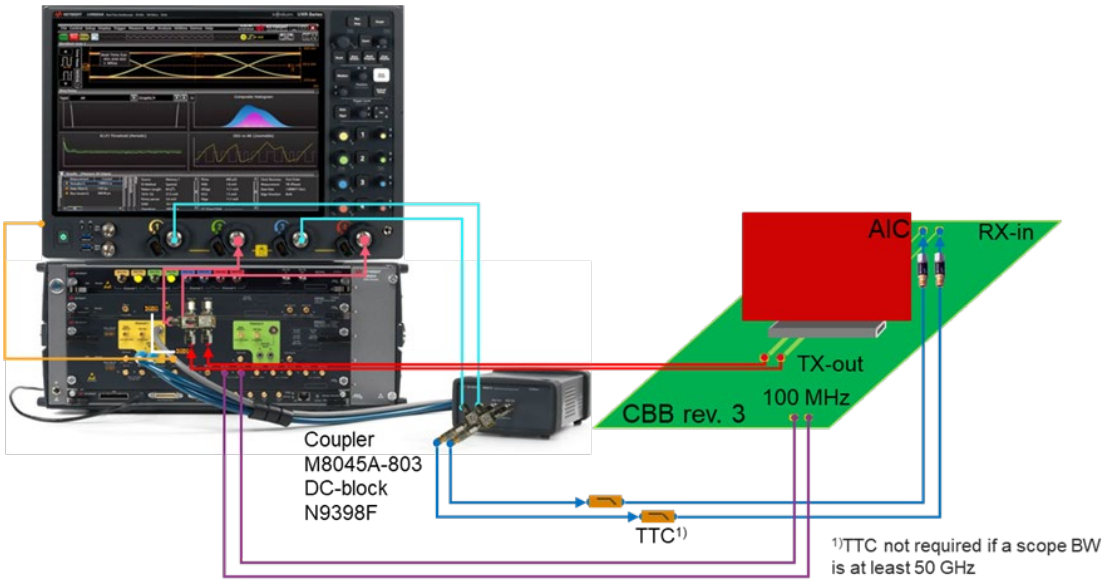


Figure 4. Link EQ response time setup

Transmitter equalization testing verifies that the DUT responds correctly to requests from the test equipment. The DUT's signal is analyzed by post-processing waveforms captured on an oscilloscope. Response times of a DUT are verified by capturing the handshake between the BERT and the DUT.

Custom Procedures

All N5991P receiver test automation products for PCI Express offer additional measurement routines for the calibration data, additional calibration routines and tests using the custom calibration routines. To activate those routines, “Expert Mode” checkbox in the “Configure DUT” window and the “Include Custom Procedure” checkbox in the “PCIe System Parameters” window must be marked.

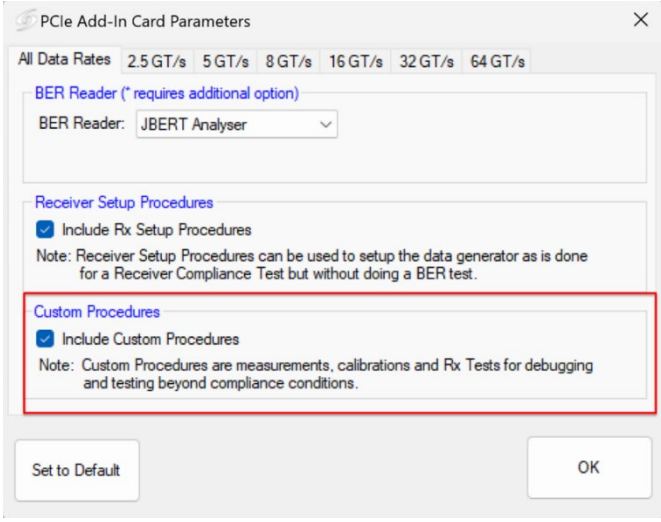


Figure 5. N5991PB65A configure DUT – show parameter window

The custom measurements provide further insight into the calibration data.

The “TxEQ and Launch Voltage Measurement” performs preshoot / de-emphasis as well as launch voltage measurement for user provided target values. The measurement reports not only the target values and measured values but also the instrument set values. This is very helpful to create TxEQ and Launch Voltage lookup tables for use in own test routines. The “TxEQ and Launch Voltage Measurement” is offered for 8 GT/s, 16 GT/s, 32 GT/s and 64 GT/s dependent on the transfer rate coverage of the used product.

The “Eye Height and Width Measurement” performs eye measurements for user provided impairment, TxEQ and launch voltage as well as reference receiver equalization parameters. The “Eye Height and Width Scan” offers multiple loop levels over relevant user provided parameter ranges for eye measurements. Both custom measurements are available for 16 GT/s, 32 GT/s, 64 GT/s and 128 GT/s dependent on transfer rate coverage of the used product.

Custom Calibrations are available for 16 GT/s, 32 GT/s, and 64 GT/s dependent on the transfer rate coverage of the product used. The “Custom Eye Calibration” is basically similar to the “Compliance Eye Calibration” routine. But it logs found impairment combinations which lead to a compliant eye and not only the one closest to eye height and width targets. The “Custom eye Scan Calibration” is very similar to the “Eye Height and Width Scan” enabling a brute force search of impairment combinations leading to compliant eyes.

The “Custom Tests” section allows performing RX compliance, JTOL and sensitivity testing for the different impairment sets determined via the “Custom Calibration” procedures.

Software Products for PCI Express 4.0, 5.0 and 6.0

Receiver tests for PCI Express base specification

N5991PB6A is the newest addition to the N5991 Receiver test automation product family for PCI Express. It calibrates a stress signal and tests a device according to PCI Express Base specification 6.0. N5991PB5A implements receiver stress signal calibrations and tests according to PCI Express Base specification 5.0, while N5991PB4A implements receiver stress signal calibrations and tests according to PCI Express Base specifications 4.0. Link equalization receiver and transmitter testing can be added with the N5991PA3A-ADD PCI Express Link EQ Test Support Add-On. Link EQ testing at 32 GT/s is possible with the M8040A and M8050A. There are no Link EQ tests for 5 GT/s and 2.5 GT/s. Other add-ons are available for multi-channel support, DUT built-in error counter support and switch matrix support.

Transfer rate	N5991PB6A	N5991PB5A	N5991PB4A (discontinued Nov. 2025)
64 GT/S	M8050A PG or M8040A PG M8040A ED	n/a	n/a
32 GT/s	M8050A PG or M8040A PG M8040A ED	M8050A PG or M8040A PG M8040A ED	n/a
16 GT/s	M8050A PG or M8040A PG M8040A ED	M8050A PG or M8040A PG M8040A ED, or M8020A 16G	M8040A PG M8040A ED, or M8020A 16G
8 GT/s	M8050A PG or M8040A PG M8040A ED	M8050A PG or M8040A PG M8040A ED, or M8020A 16G/8G	M8040A PG M8040A ED, or M8020A 16G/8G
5 GT/s	M8050A PG or M8040A PG M8040A ED	M8050A PG or M8040A PG M8040A ED, or M8020A 16G/8G	M8040A PG M8040A ED, or M8020A 16G/8G
2.5 GT/s	M8050A PG or M8040A PG M8040A ED	M8050A PG or M8040A PG M8040A ED, or M8020A 16G/8G	M8040A PG M8040A ED, or M8020A 16G/8G

M8050A PG is a M8009A-062 clock module + M8042A pattern generator + M8058A remote head
M8040A PG is a M8045A pattern generator + M8057B remote head
M8040A ED is a M8046A error detector
M8020A 16G is a M8041A with opt. C16
M8020A 8G is a M8041A with opt. C08

Figure 6. N5991PB6A (left), N5991PB5A (middle) and N5991PB4A (right) calibration steps

	N5991PB6A		N5991PB5A		N5991PB4A (discontinued Nov. 2025)	
	expert mode	**compl. mode**	**expert mode**	**compl. mode**	**expert mode**	**compl. mode**
64G Rx Pre-Compliance Test	x	-	n/a	n/a	n/a	n/a
64G Rx EQ Coefficient Matrix Scan	x	-	n/a	n/a	n/a	n/a
64G Rx Jitter Tolerance Test	x	-	n/a	n/a	n/a	n/a
64G Rx Sensitivity Test	x	-	n/a	n/a	n/a	n/a
32G Rx Pre-Compliance Test	x	-	x	-	n/a	n/a
32G Rx EQ Coefficient Matrix Scan	x	-	x	-	n/a	n/a
32G Rx Jitter Tolerance Test	x	-	x	-	n/a	n/a
32G Rx Sensitivity Test	x	-	x	-	x	-
16G Rx Stressed Jitter Eye Test	x	-	x	-	x	-
16G Rx Coefficient Matrix Scan	x	-	x	-	x	-
16G Rx Jitter Tolerance Test	x	-	x	-	x	-
16G Rx Sensitivity Test	x	-	x	-	x	-
8G Rx Stressed Jitter Eye Test	x	-	x	-	x	-
8G Rx Coefficient Matrix scan	x	-	x	-	x	-
8G Rx Jitter Tolerance Test	x	-	x	-	x	-
5G Rx Compliance Test	x	x	x	x	x	x
5G Rx Jitter Tolerance Test	x	-	x	-	x	-
5G RX Sensitivity Test	x	-	x	-	x	-
2.5G Rx Compliance Test	x	x	x	x	x	x
2.5G Rx Jitter Tolerance Test	x	-	x	-	x	-
2.5G Rx Sensitivity Test	x	-	x	-	x	-

x..implemented

Receiver testing for PCI Express base specification 7.0

N5991PB7A Receiver Test Automation for PCI Express 7, Base Specification, supports the M8050A PG and UXR real-time oscilloscope. At least 59 GHz of scope bandwidth are required. Recommended scope bandwidth is 70 GHz.

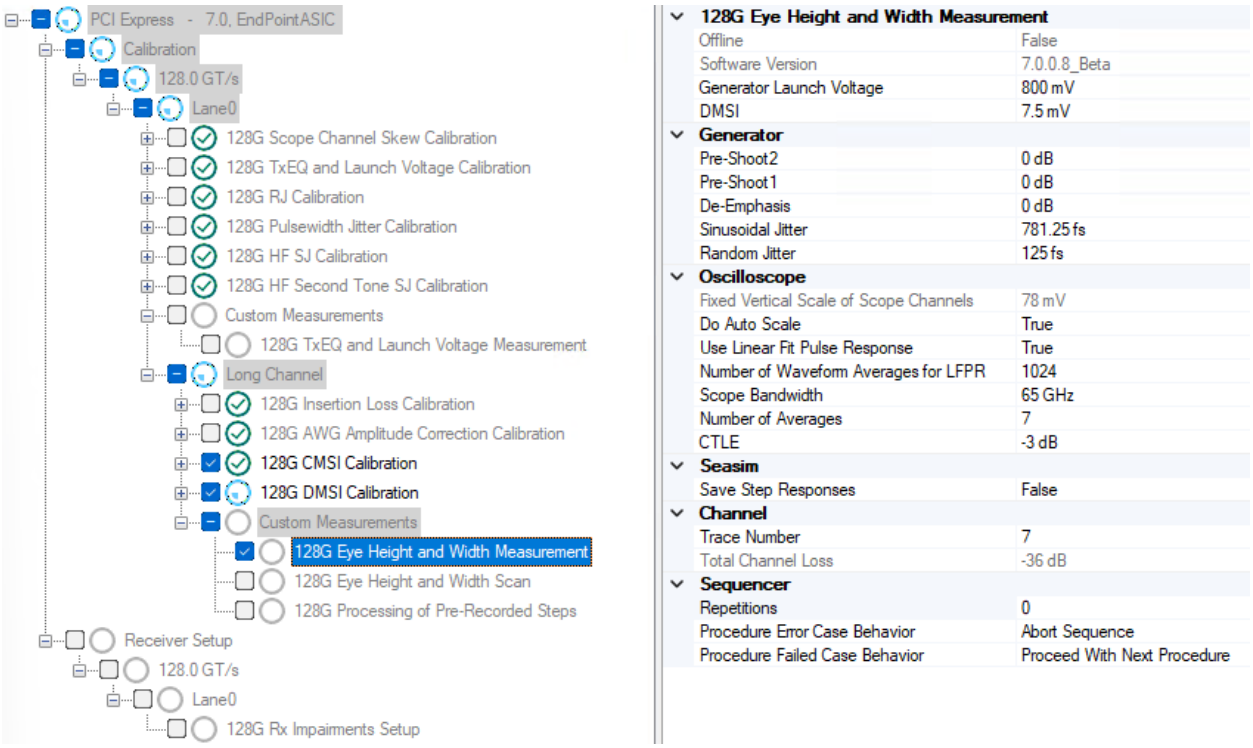


Figure 7. 128 GT/s TP3 calibration steps and TP2 calibration steps as well as 128 GT/s Rx Impairments Setup

The initial release of N5991PB7A supports 128 GT/s stress signal calibration steps TP3 as well as TP2. A complete stress signal calibration is not supported. Since a complete stress signal calibration cannot be offered at this point in time, no receiver tests have been implemented.

The Receiver Setup procedure is available for 128 GT/s.

Lower transfer rates are not supported in the initial release of N5991PB7A

N5991PB7A is installed using a special N5991P installer which does not include support for other N5991P products.

Disclaimer: At the initial release of the RX Test Automation for PCI Express 7 Base Specification software the pathfinding work for PCI Express 7 receiver stress test calibration was in progress still. Therefore, a fully automated stress signal calibration is not available, and it cannot be guaranteed that a compliant stress signal can be achieved and changes to the stress signal calibration process, used hardware, and used SW tools might happen without notice. Such changes could invalidate previously achieved results and might make a compliant stress signal harder to pass.

Receiver tests for PCI Express CEM specification

N5991PC6A covers 32 GT/s, 16 GT/s and 8 GT/s RX testing in line with the PCI Express Architecture PHY test specification 6.0 draft 0.7. 64 GT/s receiver testing is available in expert mode only. 5 GT/s and 2.5 GT/s receiver testing per PCI Express CEM specification 5.0 is included. FBER measurements require the M8070EDAB license.

N5991PC5A performs receiver stress signal calibrations and tests for 32 GT/s, 16 GT/s and 8 GT/s according to PCI Express Architecture PHY Test specification 5.0. Stress signal calibration and tests for 5 GT/s as well as 2.5 GT/s are implemented according to PCI Express CEM specification 5.0.

N5991PC4A implements receiver stress signal calibrations and tests for 16 GT/s and 8 GT/s according to PCI Express Architecture PHY Test specifications 4.0 and 5 GT/s, as well as 2.5 GT/s receiver stress signal calibrations and tests are implemented according to PCI Express CEM specification 4.0.

Link equalization receiver and transmitter testing can be added with the N5991PA3A-ADD PCI Express LinkEQ Test Support Add-On. LinkEQ testing at 64 GT/s and 32 GT/s is possible with the M8040A PG or M8050A PG plus M8046A ED There are no LinkEQ tests for 5 GT/s and 2.5 GT/s. Other add-ons are available for multi-channel support, DUT built-in error counter support and switch matrix support.

Transfer rate	N5991PC6A	N5991PC5A	N5991PC4A (discontinued Nov. 2025)
64 GT/s	M8050A PG or M8040A PG M8040A ED	n/a	n/a
32 GT/s	M8050A PG or M8040A PG M8040A ED	M8050A PG or M8040A PG M8040A ED	n/a
16 GT/s	M8050A PG or M8040A PG M8040A ED	M8050A PG or M8040A PG M8040A ED, or M8020A 16G	M8040A PG M8040A ED, or M8020A 16G
8 GT/s	M8050A PG or M8040A PG M8040A ED	M8050A PG or M8040A PG M8040A ED, or M8020A 16G/8G	M8040A PG M8040A ED, or M8020A 16G/8G
5 GT/s	M8050A PG or M8040A PG M8040A ED	M8040A PG M8040A ED, or M8020A 16G/8G	M8040A PG M8040A ED, or M8020A 16G/8G
2.5 GT/s	M8050A PG or M8040A PG M8040A ED	M8040A PG M8040A ED, or M8020A 16G/8G	M8040A PG M8040A ED, or M8020A 16G/8G

M8050A PG is a M8009A-062 clock module + M8042A pattern generator + M8058A remote head
M8040A PG is a M8045A pattern generator + M8057B remote head
M8040A ED is a M8046A error detector
M8020A 16G is a M8041A with opt. C16
M8020A 8G is a M8041A with opt. C08

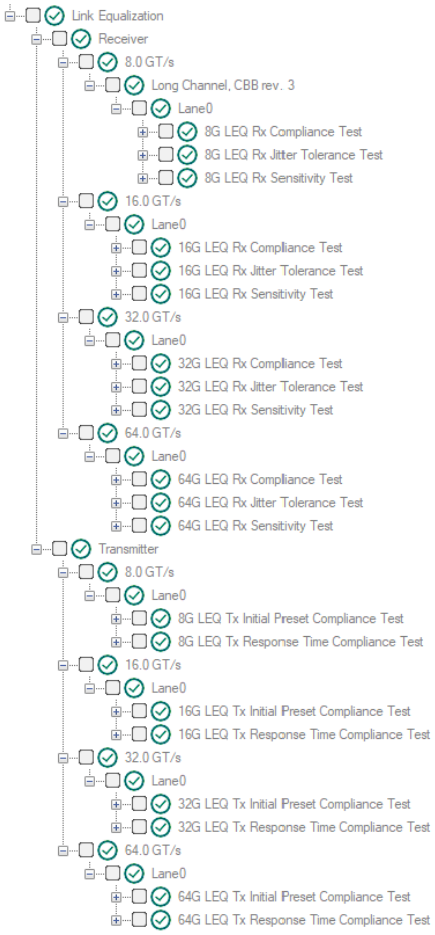


Figure 8. N5991PC6A with N5991PA3A-Add LinkEQ test support add-on compliance tests

Measurement	N5991PC6A		N5991PC5A		N5991PC4A (discontinued Nov. 2025)	
	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode
64G Rx Pre-Compliance Test	x	-	n/a	n/a	n/a	n/a
64G Rx EQ Coefficient Matrix Scan	x	-	n/a	n/a	n/a	n/a
64G Rx Jitter Tolerance Test	x	-	n/a	n/a	n/a	n/a
64G Rx Sensitivity Test	x	-	n/a	n/a	n/a	n/a
32G Rx Pre-Compliance Test	x	-	x	-	n/a	n/a
32G Rx EQ Coefficient Matrix Scan	x	-	x	-	n/a	n/a
32G Rx Pre-Shoot De-Emphasis Scan	x	-	x	-	n/a	n/a
32G Rx Jitter Tolerance Test	x	-	x	-	n/a	n/a
32G Rx Sensitivity Test	x	-	x	-	n/a	n/a
16G Rx Pre Compliance Test	x	-	x	-	x	-
16G Rx Coefficient Matrix Scan	x	-	x	-	x	-
16G Rx Pre-Shoot De-Emphasis Scan	x	-	x	-	x	-
16G Rx Jitter Tolerance Test	x	-	x	-	x	-
16G Rx Sensitivity Test	x	-	x	-	x	-
8G Rx Preset Pre-Compliance Test – short channel (AIC only)	x	-	x	-	x	-
8G Rx Pre Compliance Test – short channel (AIC only)	x	-	x	-	x	-
8G Rx Coefficient Matrix scan – short channel (AIC only)	x	-	x	-	x	-
8G Rx Pre-Shoot De-Emphasis Scan – short channel (AIC only)	x	-	x	-	x	-
8G Rx Jitter Tolerance Test – short channel (AIC only)	x	-	x	-	x	-
8G Rx Sensitivity Test – short channel (AIC only)	x	-	x	-	x	-
8G Rx Preset Pre-Compliance Test – long channel	x	-	x	-	x	-
8G Rx Pre Compliance Test – long channel	x	-	x	-	x	-
8G Rx Coefficient Matrix scan – long channel	x	-	x	-	x	-
8G Rx Pre-Shoot De-Emphasis Scan – long channel	x	-	x	-	x	-
8G Rx Jitter Tolerance Test – long channel	x	-	x	-	x	-
8G Rx Sensitivity Test – long channel	x	-	x	-	x	-
5G Rx Compliance Test	x	x	x	x	x	x
5G Rx Jitter Tolerance Test	x	-	x	-	x	-
5G Rx Sensitivity Test	x	-	x	-	x	-
2.5G Rx Compliance Test	x	x	x	x	x	x
2.5G Rx Jitter Tolerance Test	y	-	y	-	y	-
2.5G Rx Sensitivity Test	x	-	x	-	x	-

x..implemented y..not available for AIC test using M8050A PG

Receiver tests for PCI Express U.2 and M.2 specification

N5991PU4A offers 8 GT/s testing only and uses the PCI-SIG 8 GT/s U.2 fixtures. N5991PM5A and N5991PM4A use the PCI-SIG 8 GT/s M.2 fixture for 8 GT/s testing and the Wilder Technologies PCIe 5.0 M.2 fixture or the iPasslabs Technologies / Arconum Advanced PCIe 5.0 M.2 fixture for the higher transfer rates.

Transfer rate	N5991PU4A (discontinued Nov. 2025)	N5991PM5A	N5991PM4A (discontinued Nov. 2025)
32 GT/s	n/a	M8050A PG or M8040A PG M8040A ED	n/a
16 GT/s	n/a	M8050A PG or M8040A PG M8040A ED, or M8020A 16G	M8040A PG M8040A ED, or M8020A 16G
8 GT/s	M8040A PG M8040A ED, or M8020A 16G/8G	M8050A PG or M8040A PG M8040A ED, or M8020A 16G/8G	M8040A PG M8040A ED, or M8020A 16G/8G

M8050A PG is a M8009A-062 clock module + M8042A pattern generator + M8058A remote head
M8040A PG is a M8045A pattern generator + M8057B remote head
M8040A ED is a M8046A error detector
M8020A 16G is a M8041A with opt. C16
M8020A 8G is a M8041A with opt. C08

Measurement	N5991PU4A discontinued Nov. 2025)		N5991PM5A		N5991PM4A (discontinued Nov. 2025)	
	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode
32G Rx Pre Compliance Test	n/a	n/a	x	-	n/a	n/a
32G Rx Coefficient Matrix Scan	n/a	n/a	x	-	n/a	n/a
32G Rx Pre-Shoot De-Emphasis Scan	n/a	n/a	x	-	n/a	n/a
32G Rx Jitter Tolerance Test	n/a	n/a	x	-	n/a	n/a
32G Rx Sensitivity Test	n/a	n/a	x	-	n/a	n/a
16G Rx Pre Compliance Test	n/a	n/a	x	-	x	-
16G Rx Coefficient Matrix Scan	n/a	n/a	x	-	x	-
16G Rx Pre-Shoot De-Emphasis Scan	n/a	n/a	x	-	x	-
16G Rx Jitter Tolerance Test	n/a	n/a	x	-	x	-
16G Rx Sensitivity Test	n/a	n/a	x	-	x	-
8G Rx Preset Pre-Compliance Test – long channel	x	-	x	-	x	-
8G Rx Pre Compliance Test – long channel	x	-	x	-	x	-
8G Rx Coefficient Matrix Scan – long channel	x	-	x	-	x	-
8G Rx Pre-Shoot De-Emphasis Scan – long channel	x	-	x	-	x	-
8G Rx Jitter Tolerance Test – long channel	x	-	x	-	x	-
8G Rx Sensitivity Test – long channel	x	-	x	-	x	-

Setup Preparation for PCI Express (N5991PD0E)

Preparing a setup for calibration and testing is becoming more and more challenging with increasing transfer rates. Making a mistake during the fixture characterization can render an entire stress signal calibration useless for instance. And adjusting the equalization of the backchannel, the return path of the looped signal from the device under test transmitter to the error detector, is complex and time consuming since the individual equalization elements cannot be optimized independently of the other equalization elements. The Setup Preparation for PCI Express assists a user with the optimization of the backchannel equalization for 32 GT/s and 64 GT/s starting with the N5991P 5.2 release. A guided fixture characterization for the CEM interface for 32 GT/s and 64 GT/s is available starting with N5991P 5.4 release.

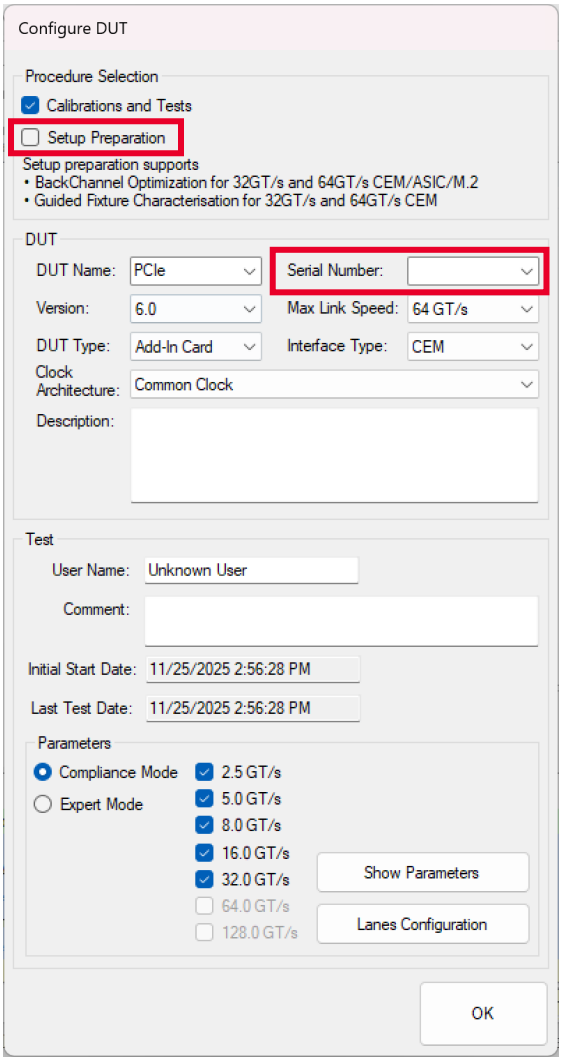
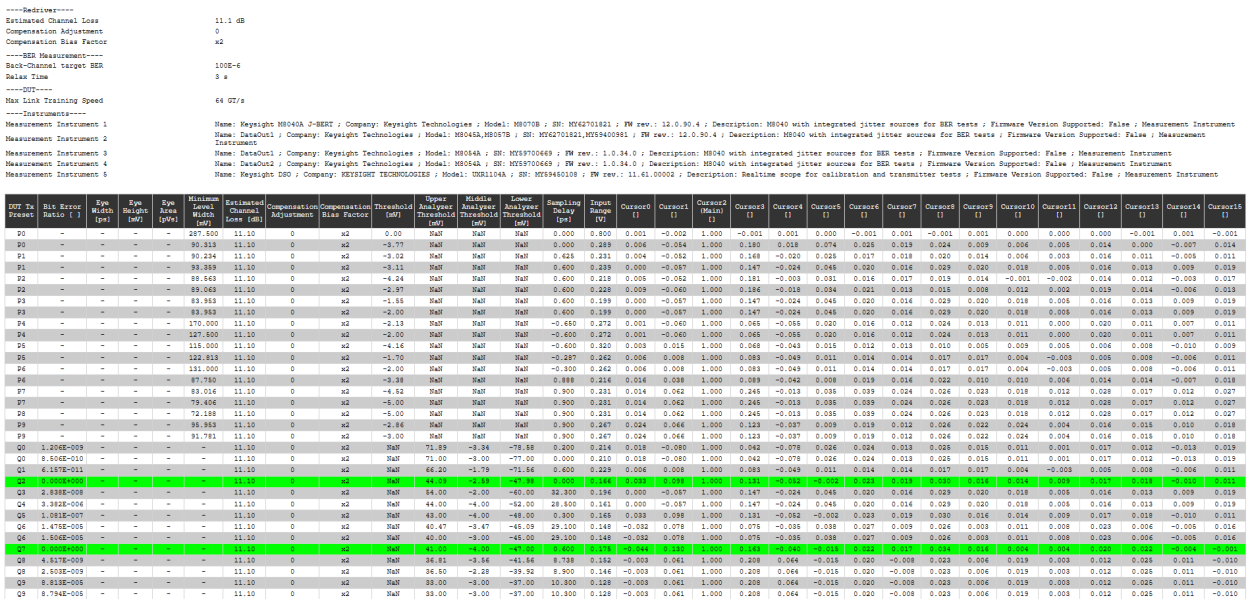


Figure 9. To provide a unique record of the backchannel equalization optimization data, a serial number needs to be assigned for the device under test. The Setup Preparation routines need to be enabled in the Configure DUT dialogue window.

The achievable bit error rate of the backchannel is dependent on many factors including device transmitter characteristics, backchannel characteristics like loss and reflections, as well as other components present in the backchannel like a switch for instance.



```
----Redriver----
Estimated Channel Loss                  11.1 dB
Compensation Adjustment                 0
Compensation Bias Factor                x2

----BER Measurement----
Back-Channel target BER                 100E-6
Relax Time                              3 s

----DUT----
Max Link Training Speed                 64 GT/s

----Instruments----
Measurement Instrument 1                Name: Keysight M8040A J-BERT ; Company: Keysight Technologies ; Model: M8070B ; SN: MY62701821 ; FW rev.: 12.0.90.4 ; Description: M8040 with integrated jitter sources for BER tests ; Firmware Version Supported: False ; Measurement Instrument
Measurement Instrument 2                Name: DataOut1 ; Company: Keysight Technologies ; Model: M8045A,M8057B ; SN: MY62701821,MY59400981 ; FW rev.: 12.0.90.4 ; Description: M8040 with integrated jitter sources for BER tests ; Firmware Version Supported: False ; Measurement Instrument
Measurement Instrument 3                Name: DataOut1 ; Company: Keysight Technologies ; Model: M8054A ; SN: MY59700669 ; FW rev.: 1.0.34.0 ; Description: M8040 with integrated jitter sources for BER tests ; Firmware Version Supported: False ; Measurement Instrument
Measurement Instrument 4                Name: DataOut2 ; Company: Keysight Technologies ; Model: M8054A ; SN: MY59700669 ; FW rev.: 1.0.34.0 ; Description: M8040 with integrated jitter sources for BER tests ; Firmware Version Supported: False ; Measurement Instrument
Measurement Instrument 5                Name: Keysight DSO ; Company: KEYSIGHT TECHNOLOGIES ; Model: UXR1104A ; SN: MY59450108 ; FW rev.: 11.61.00002 ; Description: Realtime scope for calibration and transmitter tests ; Firmware Version Supported: False ; Measurement Instrument
```

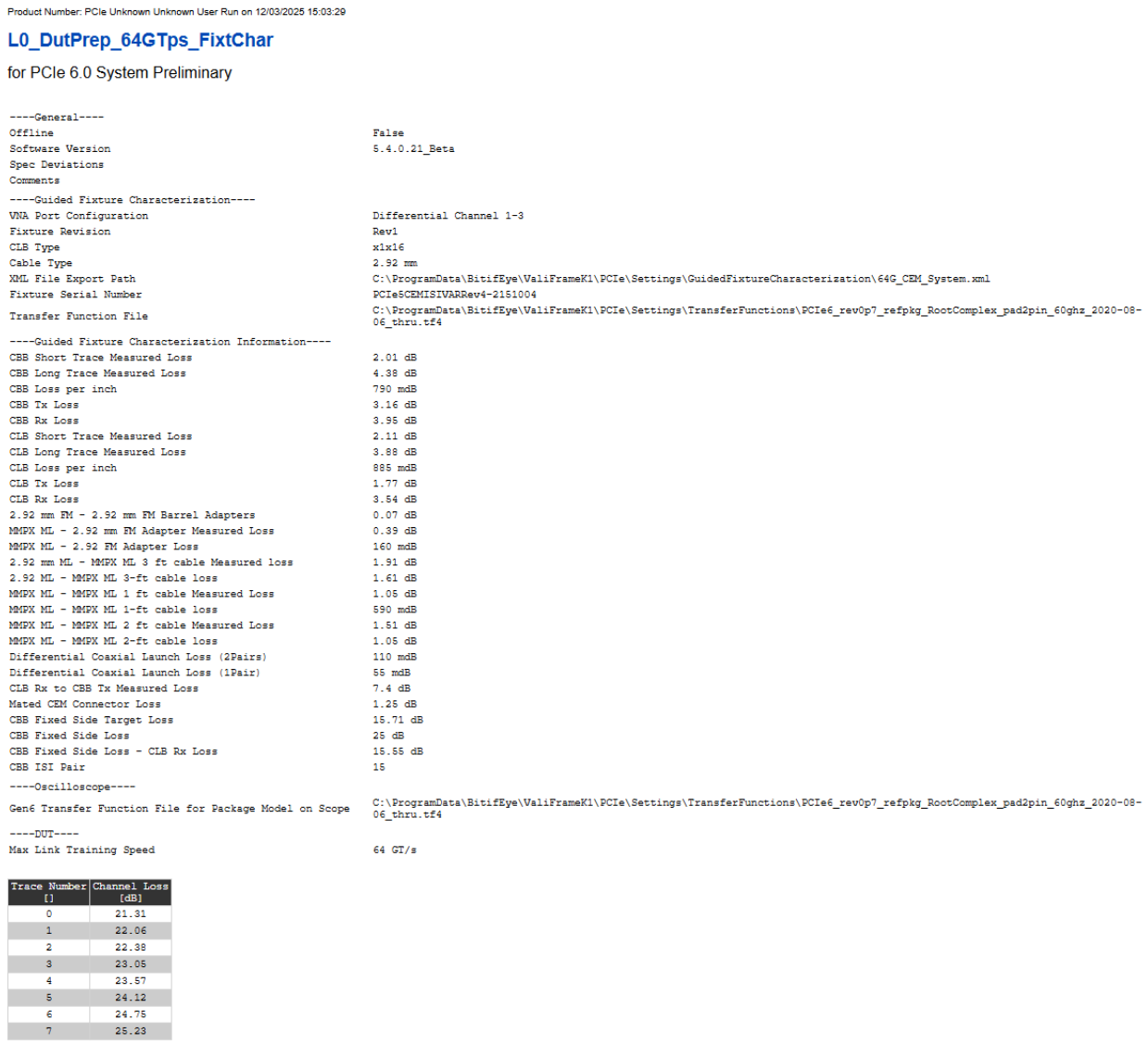
DUT Tx Preset	Bit Error Ratio ( )	Eye Width [ps]	Eye Height [mV]	Eye Area [pVs]	Minimum Level Width [mV]	Estimated Channel Loss [dB]	Compensation Adjustment	Compensation Bias Factor	Threshold [mV]	Upper Analyzer Threshold [mV]	Middle Analyzer Threshold [mV]	Lower Analyzer Threshold [mV]	Sampling Delay [ps]	Input Range [V]	Cursor0 []	Cursor1 []	Cursor2 (Main) []	Cursor3 []	Cursor4 []	Cursor5 []	Cursor6 []	Cursor7 []	Cursor8 []	Cursor9 []	Cursor10 []	Cursor11 []	Cursor12 []	Cursor13 []	Cursor14 []	Cursor15 []
P0	-	-	-	-	287.500	11.10	0	x2	0.00	NaN	NaN	NaN	0.000	0.800	0.001	-0.002	1.000	-0.001	0.001	0.000	-0.001	0.001	-0.001	0.001	0.000	0.000	0.000	-0.001	0.001	-0.001
P0	-	-	-	-	90.313	11.10	0	x2	-3.77	NaN	NaN	NaN	0.000	0.289	0.006	-0.054	1.000	0.180	0.018	0.074	0.025	0.019	0.024	0.009	0.006	0.005	0.014	0.000	-0.007	0.014
P1	-	-	-	-	90.234	11.10	0	x2	-3.02	NaN	NaN	NaN	0.625	0.231	0.004	-0.052	1.000	0.168	-0.020	0.025	0.017	0.018	0.020	0.014	0.006	0.003	0.016	0.011	-0.005	0.011
P1	-	-	-	-	93.359	11.10	0	x2	-3.11	NaN	NaN	NaN	0.600	0.239	0.000	-0.057	1.000	0.147	-0.024	0.045	0.020	0.016	0.029	0.020	0.018	0.005	0.016	0.013	0.009	0.019
P2	-	-	-	-	88.563	11.10	0	x2	-4.24	NaN	NaN	NaN	0.600	0.218	0.005	-0.052	1.000	0.181	-0.003	0.031	0.016	0.017	0.019	0.014	-0.001	-0.002	0.014	0.012	-0.003	0.017
P2	-	-	-	-	89.063	11.10	0	x2	-2.97	NaN	NaN	NaN	0.600	0.228	0.009	-0.060	1.000	0.186	-0.018	0.034	0.021	0.013	0.015	0.008	0.012	0.002	0.019	0.014	-0.006	0.013
P3	-	-	-	-	83.953	11.10	0	x2	-1.55	NaN	NaN	NaN	0.600	0.199	0.000	-0.057	1.000	0.147	-0.024	0.045	0.020	0.016	0.029	0.020	0.018	0.005	0.016	0.013	0.009	0.019
P3	-	-	-	-	83.953	11.10	0	x2	-2.00	NaN	NaN	NaN	0.600	0.199	0.000	-0.057	1.000	0.147	-0.024	0.045	0.020	0.016	0.029	0.020	0.018	0.005	0.016	0.013	0.009	0.019
P4	-	-	-	-	170.000	11.10	0	x2	-2.13	NaN	NaN	NaN	-0.650	0.272	0.001	-0.060	1.000	0.065	-0.055	0.020	0.016	0.012	0.024	0.013	0.011	0.000	0.020	0.011	0.007	0.011
P4	-	-	-	-	127.500	11.10	0	x2	-2.00	NaN	NaN	NaN	-0.600	0.272	0.001	-0.060	1.000	0.065	-0.055	0.020	0.016	0.012	0.024	0.013	0.011	0.000	0.020	0.011	0.007	0.011
P5	-	-	-	-	115.000	11.10	0	x2	-4.16	NaN	NaN	NaN	-0.600	0.320	0.003	0.015	1.000	0.068	-0.043	0.015	0.012	0.013	0.010	0.005	0.009	0.005	0.006	0.008	-0.010	0.009
P5	-	-	-	-	122.813	11.10	0	x2	-1.70	NaN	NaN	NaN	-0.287	0.262	0.006	0.008	1.000	0.083	-0.049	0.011	0.014	0.014	0.017	0.017	0.004	-0.003	0.005	0.008	-0.006	0.011
P6	-	-	-	-	131.000	11.10	0	x2	-2.00	NaN	NaN	NaN	-0.300	0.262	0.006	0.008	1.000	0.083	-0.049	0.011	0.014	0.014	0.017	0.017	0.004	-0.003	0.005	0.008	-0.006	0.011
P6	-	-	-	-	87.750	11.10	0	x2	-3.38	NaN	NaN	NaN	0.888	0.216	0.016	0.038	1.000	0.089	-0.042	0.008	0.019	0.016	0.022	0.010	0.010	0.006	0.014	0.014	-0.007	0.018
P7	-	-	-	-	83.016	11.10	0	x2	-4.52	NaN	NaN	NaN	0.900	0.231	0.014	0.062	1.000	0.245	-0.013	0.035	0.039	0.024	0.026	0.023	0.018	0.012	0.028	0.017	0.012	0.027
P7	-	-	-	-	79.406	11.10	0	x2	-5.00	NaN	NaN	NaN	0.900	0.231	0.014	0.062	1.000	0.245	-0.013	0.035	0.039	0.024	0.026	0.023	0.018	0.012	0.028	0.017	0.012	0.027
P8	-	-	-	-	72.188	11.10	0	x2	-5.00	NaN	NaN	NaN	0.900	0.231	0.014	0.062	1.000	0.245	-0.013	0.035	0.039	0.024	0.026	0.023	0.018	0.012	0.028	0.017	0.012	0.027
P9	-	-	-	-	95.953	11.10	0	x2	-2.86	NaN	NaN	NaN	0.900	0.267	0.024	0.066	1.000	0.123	-0.037	0.009	0.019	0.012	0.026	0.022	0.024	0.004	0.016	0.015	0.010	0.018
P9	-	-	-	-	91.781	11.10	0	x2	-3.00	NaN	NaN	NaN	0.900	0.267	0.024	0.066	1.000	0.123	-0.037	0.009	0.019	0.012	0.026	0.022	0.024	0.004	0.016	0.015	0.010	0.018
Q0	1.206E-009	-	-	-	-	11.10	0	x2	NaN	71.89	-3.34	-78.58	0.200	0.214	0.018	-0.080	1.000	0.042	-0.078	0.026	0.024	0.013	0.025	0.015	0.011	0.001	0.017	0.012	-0.013	0.019
Q0	8.506E-010	-	-	-	-	11.10	0	x2	NaN	71.00	-3.00	-77.00	0.000	0.210	0.018	-0.080	1.000	0.042	-0.078	0.026	0.024	0.013	0.025	0.015	0.011	0.001	0.017	0.012	-0.013	0.019
Q1	6.157E-011	-	-	-	-	11.10	0	x2	NaN	66.20	-1.79	-71.56	0.600	0.229	0.006	0.008	1.000	0.083	-0.049	0.011	0.014	0.014	0.017	0.017	0.004	-0.003	0.005	0.008	-0.006	0.011
Q2	0.000E+000	-	-	-	-	11.10	0	x2	NaN	44.09	-2.59	-47.98	0.000	0.166	0.033	0.098	1.000	0.131	-0.052	-0.002	0.023	0.019	0.030	0.016	0.014	0.009	0.017	0.018	-0.010	0.011
Q3	2.838E-008	-	-	-	-	11.10	0	x2	NaN	54.00	-2.00	-60.00	32.300	0.186	0.000	-0.057	1.000	0.147	-0.024	0.045	0.020	0.016	0.029	0.020	0.018	0.005	0.016	0.013	0.009	0.019
Q4	3.382E-006	-	-	-	-	11.10	0	x2	NaN	44.00	-4.00	-52.00	28.500	0.161	0.000	-0.057	1.000	0.147	-0.024	0.045	0.020	0.016	0.029	0.020	0.018	0.005	0.016	0.013	0.009	0.019
Q5	1.081E-007	-	-	-	-	11.10	0	x2	NaN	43.00	-4.00	-48.00	0.300	0.165	0.033	0.098	1.000	0.131	-0.052	-0.002	0.023	0.019	0.030	0.016	0.014	0.009	0.017	0.018	-0.010	0.011
Q6	1.475E-005	-	-	-	-	11.10	0	x2	NaN	40.47	-3.47	-45.09	29.100	0.148	-0.032	0.078	1.000	0.075	-0.035	0.038	0.027	0.009	0.026	0.003	0.011	0.008	0.023	0.006	-0.005	0.016
Q6	1.506E-005	-	-	-	-	11.10	0	x2	NaN	40.00	-3.00	-46.00	29.100	0.148	-0.032	0.078	1.000	0.075	-0.035	0.038	0.027	0.009	0.026	0.003	0.011	0.008	0.023	0.006	-0.005	0.016
Q7	0.000E+000	-	-	-	-	11.10	0	x2	NaN	41.00	-4.00	-47.00	0.600	0.178	-0.044	0.135	1.000	0.163	-0.040	-0.018	0.022	0.017	0.034	0.016	0.014	0.004	0.020	0.022	-0.004	-0.001
Q8	4.617E-009	-	-	-	-	11.10	0	x2	NaN	36.81	-3.56	-41.56	8.738	0.152	-0.003	0.061	1.000	0.208	0.064	-0.015	0.020	-0.008	0.023	0.006	0.019	0.003	0.012	0.025	0.011	-0.010
Q8	2.503E-009	-	-	-	-	11.10	0	x2	NaN	36.50	-2.28	-39.92	8.900	0.146	-0.003	0.061	1.000	0.208	0.064	-0.015	0.020	-0.008	0.023	0.006	0.019	0.003	0.012	0.025	0.011	-0.010
Q9	8.813E-005	-	-	-	-	11.10	0	x2	NaN	33.00	-3.00	-37.00	10.300	0.128	-0.003	0.061	1.000	0.208	0.064	-0.015	0.020	-0.008	0.023	0.006	0.019	0.003	0.012	0.025	0.011	-0.010
Q9	8.794E-005	-	-	-	-	11.10	0	x2	NaN	33.00	-3.00	-37.00	10.300	0.128	-0.003	0.061	1.000	0.208	0.064	-0.015	0.020	-0.008	0.023	0.006	0.019	0.003	0.012	0.025	0.011	-0.010

Figure 10. The backchannel equalizations results contain the estimated backchannel loss, the M8046A FFE settings, thresholds and sampling delay

Using a UXR-series oscilloscope with at least 50 GHz of bandwidth, the software can estimate the backchannel loss. The redriver M8047C is supported for 32 GT/s and 64 GT/s. The redriver M8047B is supported for 32 GT/s only.

Backchannel Equalization Optimization functionality of the Setup Preparation enabled by N5991PD0E for N5991P RX test libraries	**64 GT/s**	**32 GT/s**	**16 GT/s**	**8 GT/s**	**5 GT/s**	**2.5 GT/s**
N5991PB6A	x	x	-	-	-	-
N5991PC6A	x	x	-	-	-	-
N5991PB5A	n/a	x	-	-	-	-
N5991PC5A	n/a	x	-	-	-	-
N5991PM5A	n/a	x	-	-	n/a	n/a
N5991PB4A (discontinued Nov 2025)	n/a	n/a	-	-	-	-
N5991PC4A (discontinued Nov 2025)	n/a	n/a	-	-	-	-
N5991PM4A (discontinued Nov 2025)	n/a	n/a	-	-	n/a	n/a
N5991PU4A (discontinued Nov 2025)	n/a	n/a	n/a	-	n/a	n/a

An essential part of the stress signal calibration is the characterization of the used ISI channel and fixtures including cables and adapters. The step-by-step Guided Fixture Characterization capability of N5991PD0E Setup Preparation for PCI Express assists in the process. Instructions are provided for each step and results are collected. The network analyzer is not controlled by N5991P. The results are stored and used by N5991P and are presented in an HTML report.



Product Number: PCIe Unknown Unknown User Run on 12/03/2025 15:03:29

L0_DutPrep_64GTps_FixtChar

for PCIe 6.0 System Preliminary

----General----	
Offline	False
Software Version	5.4.0.21_Beta
Spec Deviations	
Comments	
----Guided Fixture Characterization----	
VNA Port Configuration	Differential Channel 1-3
Fixture Revision	Rev1
CLB Type	x1x16
Cable Type	2.92 mm
XML File Export Path	C:\ProgramData\BitifEye\ValiFrameK1\PCIe\Settings\GuidedFixtureCharacterization\64G_CEM_System.xml
Fixture Serial Number	PCIe5CEMISIVARRev4-2151004
Transfer Function File	C:\ProgramData\BitifEye\ValiFrameK1\PCIe\Settings\TransferFunctions\PCIe6_rev0p7_refpkg_RootComplex_pad2pin_60ghz_2020-08-06_thru.tf4
----Guided Fixture Characterization Information----	
CBB Short Trace Measured Loss	2.01 dB
CBB Long Trace Measured Loss	4.38 dB
CBB Loss per inch	790 mdB
CBB Tx Loss	3.16 dB
CBB Rx Loss	3.95 dB
CLB Short Trace Measured Loss	2.11 dB
CLB Long Trace Measured Loss	3.88 dB
CLB Loss per inch	885 mdB
CLB Tx Loss	1.77 dB
CLB Rx Loss	3.54 dB
2.92 mm FM - 2.92 mm FM Barrel Adapters	0.07 dB
MMPX ML - 2.92 mm FM Adapter Measured Loss	0.39 dB
MMPX ML - 2.92 FM Adapter Loss	160 mdB
2.92 mm ML - MMPX ML 3 ft cable Measured loss	1.91 dB
2.92 ML - MMPX ML 3-ft cable loss	1.61 dB
MMPX ML - MMPX ML 1 ft cable Measured Loss	1.05 dB
MMPX ML - MMPX ML 1-ft cable loss	590 mdB
MMPX ML - MMPX ML 2 ft cable Measured Loss	1.51 dB
MMPX ML - MMPX ML 2-ft cable loss	1.05 dB
Differential Coaxial Launch Loss (2Pairs)	110 mdB
Differential Coaxial Launch Loss (1Pair)	55 mdB
CLB Rx to CBB Tx Measured Loss	7.4 dB
Mated CEM Connector Loss	1.25 dB
CBB Fixed Side Target Loss	15.71 dB
CBB Fixed Side Loss	25 dB
CBB Fixed Side Loss - CLB Rx Loss	15.55 dB
CBB ISI Pair	15
----Oscilloscope----	
Gen6 Transfer Function File for Package Model on Scope	C:\ProgramData\BitifEye\ValiFrameK1\PCIe\Settings\TransferFunctions\PCIe6_rev0p7_refpkg_RootComplex_pad2pin_60ghz_2020-08-06_thru.tf4
----DUT----	
Max Link Training Speed	64 GT/s

Trace Number []	Channel Loss [dB]
0	21.31
1	22.06
2	22.38
3	23.05
4	23.57
5	24.12
6	24.75
7	25.23

Figure 11. Above report is for a PCI Express 6.0 CEM fixture characterization for a system. The losses of the individual parts are shown, and the valid trace range is determined

Guided Fixture Characterization functionality of the Setup Preparation enabled by N5991PD0E for N5991P RX test libraries	64 GT/s	32 GT/s	16 GT/s	8 GT/s	5 GT/s	2.5 GT/s
N5991PB6A	-	-	-	-	-	-
N5991PC6A	x	x	-	-	-	-
N5991PB5A	n/a	-	-	-	-	-
N5991PC5A	n/a	x	-	-	-	-
N5991PM5A	n/a	-	-	-	n/a	n/a
N5991PB4A (discontinued Nov 2025)	n/a	n/a	-	-	-	-
N5991PC4A (discontinued Nov 2025)	n/a	n/a	-	-	-	-
N5991PM4A (discontinued Nov 2025)	n/a	n/a	-	-	n/a	n/a
N5991PU4A (discontinued Nov 2025)	n/a	n/a	n/a	-	n/a	n/a

One N5991PD0E-1FP or N5991PD0E-1TP license plus accompanying software maintenance per host PC is sufficient to enable the Setup Preparation functionality for all N5991P RX test libraries licensed to the same host PC.

Product add-ons for PCI Express receiver test

- Different add-on licenses are available for the N5991PxxA PCI Express RX test automation product family. An add-on gives its capabilities to all test automation licenses of the family it belongs to.
- N5991PA1A-ADD Integrated BER Counter Interface Support for PCI Express
  Support of the DUT integrated BER counter interface is added by the N5991PA1A-ADD add-on.
- N5991PA2A-ADD Multi-Channel Support for PCI Express
  Support for multi-channel testing is provided by the N5991PA2A-ADD add-on. This add-on allows to configure more than two channels. It requires a multi-channel M8000 BERT system with more than two channels. Currently this is possible with M8020A systems up to 16 GT/s only. Up to two channels can be configured without the N5991PA2A-ADD option. Tests or calibrations are performed sequentially and not in parallel.

Link EQ test support for PCI Express (N5991PA3A-ADD)

Link Equalization RX tests as well as Link Equalization TX require the N5991A3A-ADD add-on.

Measurements requiring N5991A3A-ADD	N5991PB6A		N5991PB5A		N5991PC6A		N5991PC5A		N5991PB4A (discontinued Nov 2025)		N5991PC4A (discontinued Nov 2025)		N5991PU4A (discontinued Nov 2025)		N5991PM5A		N5991PM4A (discontinued Nov 2025)	
	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode
64G LinkEQ RX Compliance Test	x	x	n/a	n/a	x	o	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
64G LinkEQ JTOL	x	-	n/a	n/a	x	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
64G LinkEQ Rx Sensitivity	x	-	n/a	n/a	x	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
64G LinkEQ Initial Preset Test [1]	x	x	n/a	n/a	x	o	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
64G LinkEQ Phase 2 Preset and Response Time Test [1]	x	x	n/a	n/a	x	o	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
64G LinkEQ Phase 3 Preset and Response Time Test [2]	x	x	n/a	n/a	x	o	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
32G LinkEQ RX Compliance Test	x	x	x	x	x	x	x	x	n/a	n/a	n/a	n/a	n/a	n/a	x	x	n/a	n/a
32G LinkEQ JTOL	x	-	x	-	x	-	x	-	n/a	n/a	n/a	n/a	n/a	n/a	x	x	n/a	n/a
32G LinkEQ Rx Sensitivity	x	-	x	-	x	-	x	-	n/a	n/a	n/a	n/a	n/a	n/a	x	x	n/a	n/a
32G LinkEQ Initial Preset Test [1]	x	x	x	x	x	x	x	x	n/a	n/a	n/a	n/a	n/a	n/a	x	x	n/a	n/a
32G LinkEQ Phase 2 Preset and Response Time Test [1]	x	x	x	x	x	x	x	x	n/a	n/a	n/a	n/a	n/a	n/a	x	x	n/a	n/a
32G LinkEQ Phase 3 Preset and Response Time Test [2]	x	x	x	x	x	x	x	x	n/a	n/a	n/a	n/a	n/a	n/a	x	x	n/a	n/a

x.. implemented

o.. currently not implemented

[1] end point, AIC or device only
[2] root complex, system or host only

Measurements requiring N5991A3A-ADD	N5991PB6A		N5991PB5A		N5991PC6A		N5991PC5A		N5991PB4A		N5991PC4A		N5991PU4A		N5991PM5A		N5991PM4A	
	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode	expert mode	compl. mode
16G LinkEQ RX Compliance Test	x	x	x	x	x	x	x	x	x	x	x	x	n/a	n/a	x	x	x	x
16G LinkEQ JTOL	x	-	x	-	x	-	x	-	x	-	x	-	n/a	n/a	x	x	x	-
16G LinkEQ Rx Sensitivity	x	-	x	-	x	-	x	-	x	-	x	-	n/a	n/a	x	x	x	-
16G LinkEQ Initial Preset Test [1]	x	x	x	x	x	x	x	x	x	x	x	x	n/a	n/a	x	x	x	x
16G LinkEQ Phase 2 Preset and Response Time Test [1]	x	x	x	x	x	x	x	x	x	x	x	x	n/a	n/a	x	x	x	x
16G LinkEQ Phase 3 Preset and Response Time Test [2]	x	x	x	x	x	x	x	x	x	x	x	x	n/a	n/a	x	x	x	x
8G LinkEQ Rx Compliance Test – long channel	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8G LinkEQ JTOL – long channel	x	-	x	-	x	-	x	-	x	-	x	-	x	-	x	-	x	-
8G LinkEQ Sensitivity – long channel	n/a	n/a	n/a	n/a	x	-	x	-	n/a	n/a	x	-	x	-	x	-	x	-
8G LinkEQ RX Compliance Test – short channel	n/a	n/a	n/a	n/a	x	x	x	x	n/a	n/a	x	x	n/a	n/a	n/a	n/a	n/a	n/a
8G LinkEQ JTOL – short channel	n/a	n/a	n/a	n/a	x	x	x	x	n/a	n/a	x	x	n/a	n/a	n/a	n/a	n/a	n/a
8G LinkEQ Sensitivity – short channel	n/a	n/a	n/a	n/a	x	x	x	x	n/a	n/a	x	x	n/a	n/a	n/a	n/a	n/a	n/a
8G LinkEQ Initial Preset Test [3]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8G LinkEQ Phase 2 Preset and Response Time Test [1]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8G LinkEQ Phase 3 Preset and Response Time Test [4]	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

[3] end point, AIC or device only
[4] root complex, system or host only

Switch system support for PCI Express receiver test (N5991PA4A-ADD)

Support for BitifEye switch matrixes can be added by the N5991A4A-ADD add-on. Supported are BitifEye's BIT-2100B Switch System x4, x6 and x8. For 2.5 GT/s, 5 GT/s and 8 GT/s it is possible to calibrate each lane individually. Only lane 0 is calibrated and the user must ensure that all other lanes have similar characteristics since the lane 0 calibration is applied to all other lanes. The multi-channel add-on N5991PA2A-ADD is not required.

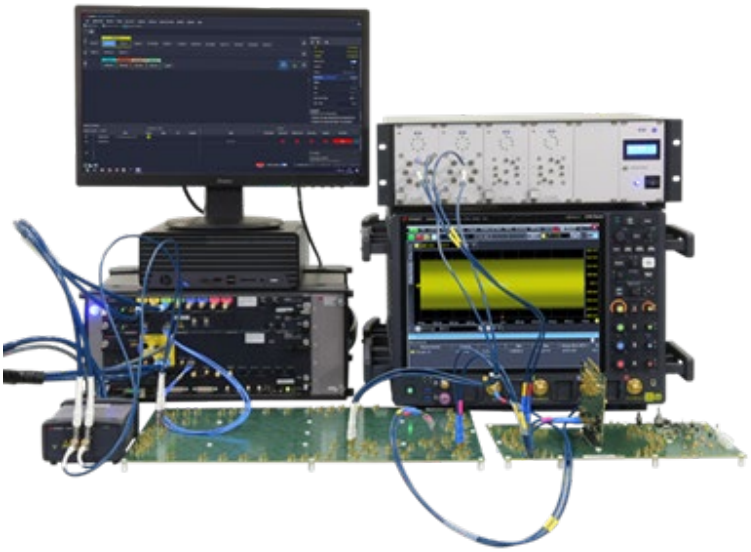


Figure 12. PCI Express RX 8-lane solution with automated switch matrix

The switch matrix is part of the stress channel and needs to be accounted for when doing the fixture characterization. It might be beneficial to use shorter cables for higher transfer rates. The switch does also impact the backchannel and might impact the achievable bit error rate for the backchannel.

Link training suite for PCI Express (discontinued November 2025)

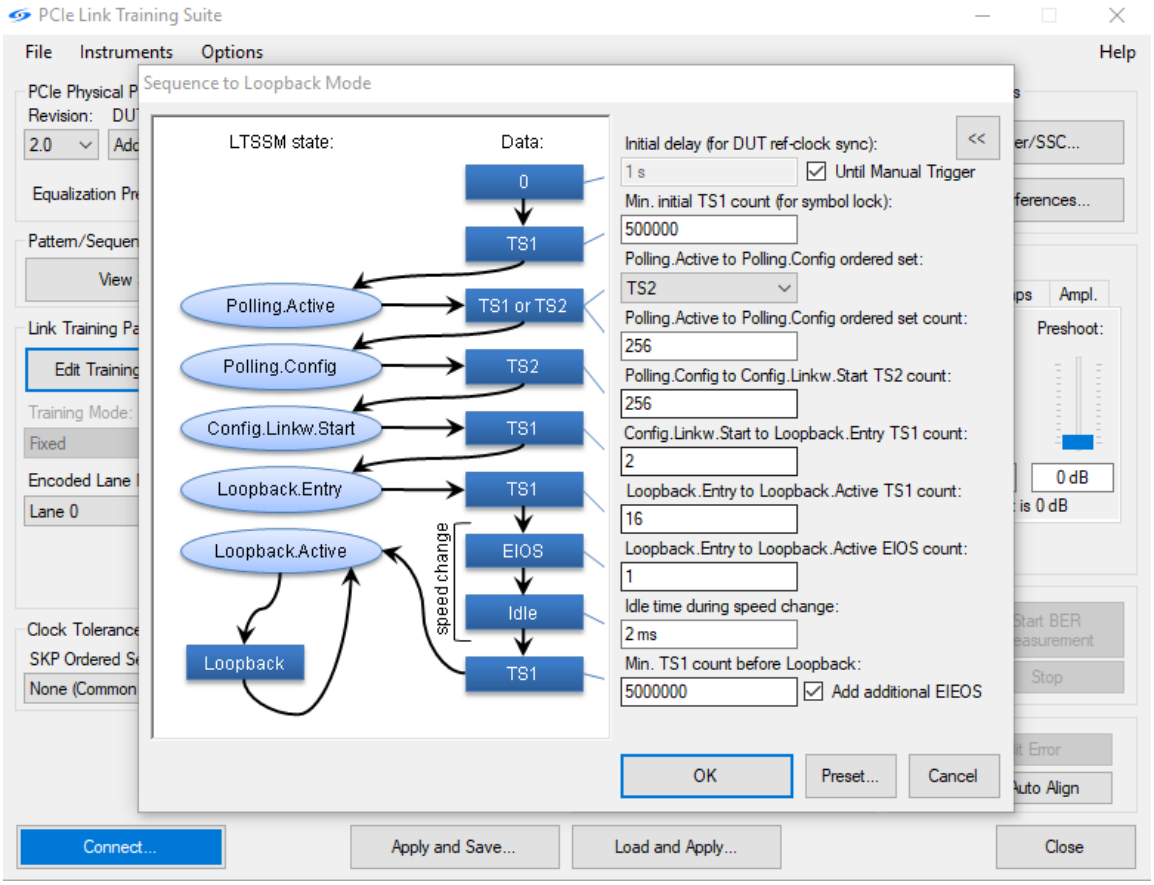


Figure 13. Generate static training sequences for PCI Express using the PCIe Link Training Suite

The PCIe Link Training Suite simplifies the process of creating static training sequences. Next to a graphical representation of the loopback path through configuration and the required parameters, the PCIe Link Training Suite software tools offer a scripting language which is helpful for the creation of more specialized sequences. N5991PL5A supports transfer rates from 2.5 GT/s through to 32 GT/s, while N5991PL4A supports transfer rates up to 16 GT/s. Both products support the M8020A BERT system, as well as the M8040A BERT system.

Instrument Requirements for PCI Express Receiver Testing

The N5991PxxA Receiver Test Automation products for PCI Express support the M8020A BERT System as well as the M8040A 64 Gbaud High Performance BERT System. Only the M8057B remote head is supported for the M8040A pattern generator. The M8050A 120 Gbaud High Performance BERT System's pattern generator is supported for stress signal generation and can be used in combination with the error detector of the M8040A BERT System. The M8050A pattern generator is supported with a clock module M8009A with option 062 and the M8058A remote head only. The BERT systems must cover the required data rates, be equipped with jitter injection and pattern generator de-emphasis capabilities. The reference clock multiplier option is required for system, host or root complex testing. RX testing can be performed using a DUT built in error counter if the error counter can be accessed programmatically. This requires the N5991PA1A-ADD PCI Express Integrated BER Counter Interface Support add-on. In most cases an error detector will be used for RX testing. The error detector must be equipped with internal CDR and SKP OS filtering. Link EQ testing requires an error detector with internal CDR and SKP OS filtering always. Additionally, required for Link EQ testing is the PCI Express LTSSM. Equalization capabilities will be required for many DUTs. FBER counting requires an M8070EDAB license.

For sinusoidal interference in case of the J-BERT M8020A BERT System and for the transfer rates up to 16 GT/s, the sinusoidal interference option of the J-BERT M8020A system is required. In case of the M8040A 64 Gbaud High-Performance BERT system or the M8050A pattern generator either a two channel M8195A AWG, a two channel M8196A AWG or the M8054A Interference Source is required. The M8045A-803 combiner pair or N1027A-2P8 pick-off pair is needed to couple the interference signal into the data stream.

Keysight Z Series and UXR Series real-time oscilloscopes are supported for PCI Express up to 5.0. For PCI Express 6.0 only the Keysight UXR Series real-time oscilloscopes are supported. The minimum bandwidth requirement for use with the M8020A BERT system is 25 GHz and for use with the M8040A BERT system is 50 GHz. The recommended scope BW for a M8040A is 59 GHz or higher. For transfer rates below and including 32 GT/s a 21 ps transition time converter can be used in combination with the M8040A pattern generator. In those case 25 GHz of scope bandwidth is sufficient for 8 GT/s and 16 GT/s, for 32 GT/s a bandwidth of 33 GHz is required. The Keysight UXR with at least 59 GHz of scope BW is required for the M8050A pattern generator. Recommended are 70 GHz or higher. The oscilloscope must be equipped with embedding capabilities as well as serial data analysis capabilities. For Link EQ testing the oscilloscope must be equipped with equalization capabilities. A four-channel oscilloscope is recommended for Link EQ testing. In case of a two-channel oscilloscope, differential probes supporting enough bandwidth and respective probe amplifiers are required. Currently, the use of differential probes is limited to 8 GT/s and 16 GT/s. The backchannel estimation of N5991PD0E works only with a UXR Series real-time oscilloscope with at least 50 GHz of bandwidth, better 59 GHz or higher.

Please ask for a complete configuration for details on instrument options, accessories, fixtures, and additional software.

Ordering Information for Software Products for PCI Express 4.0, 5.0 and 6.0

PCI Express receiver test software products – standalone products

N5991PB7A	Receiver Tests for PCI Express 7.0 Base specification
N5991PB6A	Receiver Tests for PCI Express 6.0 Base specification
N5991PC6A	Receiver Tests for PCI Express 6.0 CEM Specification
N5991PB5A	Receiver Tests for PCI Express 5.0 Base Specification
N5991PC5A	Receiver Tests for PCI Express 5.0 CEM Specification
N5991PM5A	Receiver Tests for PCI Express 5.0 M.2 Specification
N5991PB4A	Receiver Tests for PCI Express 4.0 Base Specification (discontinued Nov 2025)
N5991PC4A	Receiver Tests for PCI Express 4.0 CEM Specification (discontinued Nov 2025)
N5991PU4A	Receiver Tests for PCI Express 4.0 U.2 Specification (discontinued Nov 2025)
N5991PM4A	Receiver Tests for PCI Express 4.0 M.2 Specification (discontinued Nov 2025)

PCI Express receiver test software products – bundle products

N5991PC6X	Receiver Tests for PCI Express 6.0 CEM Specification, bundle requires N5991PB6A-1FP licensed to the same host PC
N5991PC5X	Receiver Tests for PCI Express 5.0 CEM Specification, bundle requires N5991PB5A-1FP licensed to the same host PC
N5991PM5X	Receiver Tests for PCI Express 5.0 M.2 Specification, bundle requires N5991PB5A-1FP licensed to the same host PC
N5991PC4X	Receiver Tests for PCI Express 4.0 CEM Specification, bundle requires N5991PB4A-1FP licensed to the same host PC (discontinued Nov 2025)
N5991PU4X	Receiver Tests for PCI Express 4.0 U.2 Specification, bundle requires N5991PB4A-1FP licensed to the same host PC (discontinued Nov 2025)
N5991PM4X	Receiver Tests for PCI Express 4.0 M.2 Specification, bundle requires N5991PB4A-1FP licensed to the same host PC (discontinued Nov 2025)

N5991P__X bundle products offer the calibration and test coverage as the corresponding N5991P__A products at a reduced price. The N5991P__X products require the N5991PB_A Base specification product of the same PCI Express specification generation to be licensed to the same host. This offering is available for fixed perpetual licenses only. Each N5991P__X and N5991PB_A product requires their own software maintenance coverage. It is not required that the N5991PB_A software maintenance coverage and N5991P__X software maintenance coverage are synchronized.

PCI Express link training suite software products	
N5991PL5A	Link Training Suite for PCI Express 5.0 (discontinued Nov 2025)
N5991PL4A	Link Training Suite for PCI Express 4.0 (discontinued Nov 2025)

Setup Preparation for PCI Express	
N5991PD0E	Setup Preparation for PCI Express

Licensing options for receiver test, setup preparation and link training suite products	
1FP	Perpetual node-locked license
1TP	Perpetual transportable single license
SFM	SW maintenance, 1-year, for -1FP license
STM	SW maintenance, 1-year, for -1TP license
SF3	SW maintenance, 3-year, for -1FP license – can be ordered together with respective -1FP license only
ST3	SW maintenance, 3-year, for -1TP license – can be ordered together with respective -1TP license only

Add-Ons for PCI Express receiver test products	
N5991PA1A-ADD	Integrated BER Counter Interface Support for PCI Express
N5991PA2A-ADD	Multi-Channel Support for PCI Express
N5991PA3A-ADD	Link EQ Test Support for PCI Express
N5991PA4A-ADD	Switch System Support for PCI Express Receiver Test

PCI Express Receiver Test Technology Subscription

N5991PB0A-1FL	Receiver Test for PCI Express, Base Specification, Technology Subscription, 1-year node-locked license

PCI Express Receiver Test Technology Subscriptions are offered for Base specification only and only in 1-year terms. The subscription licenses are always fixed/node-locked to one host. There are no transferable licenses offered. The coverage of the subscriptions includes access to the three currently released N5991PB_A products. Those are N5991PB7A, N5991PB6A and N5991PB5A. If a Base specification receiver test product is released for a newer PCI Express generation, access to the oldest currently supported N5991PB_A product will be dropped. At no time will N5991PB0A provide access to more than three N5991PB_A generations. During the 1-year term N5991PB0A will include software maintenance coverage for N5991PB_A on the licensed host. During this 1-year term access to N5991PA3A-ADD PCI Express Link EQ Test Support for N5991PB_A will be included on the licensed host PC. Other Add-Ons will need to be purchased separately. Access to N5991PB_A and N5991PA3A-ADD will cease with expiration of the 1-year term and continued use will require purchase of a new 1-year license. N5991PB0A licenses do not grant access to beta versions.

System Requirements

Visit https://downloads.bitifeye.com/login and read the changelog of the current software release for detailed information on software and hardware requirements.

Software

Requirements

- OS: Windows 11 (64 bit), English
- Microsoft .NET
- Keysight IO Libraries Suite
- Exact versions of software requirements are listed in the respective changelog file

Hardware

Requirement

- Connectivity hardware for instrumentation, depending on configuration e.g. USB3, Ethernet

Recommendations

- Multicore processor with 12 logical processors or more
- 32GB RAM or higher

Remote Power Cycling

All N5991 Receiver Test Automation products can control programmable remote power strips to power-cycle a DUT. Ask your contact person at Keysight about supported models.

Application Programming Interface (API)

The N5991 ValiFrame remote interface allows ValiFrame functionality (such as test setup information, calibration, and test procedures, and results) to be accessed from external programming environments. Remote interface does not need a special license to be used, it is included in the base product of particular standards. The remote interface can thus be used to control the N5991 with external software.

In typical use, a top-level external test sequencer takes advantage of ValiFrame functionality.

Software Maintenance

The purchase of one -SFM maintenance license for -1FP product licenses or one -STM maintenance license for -1TP product licenses provides the ability to install updates for one year.

With the initial purchase of a product license, it is possible to purchase a 3-year software maintenance license. A -SF3 maintenance license covers a -1FP product license and -ST3 maintenance license covers a -1TP product license.

A software maintenance license is always valid for the respective RX test or Debug Tool e.g., Link Training Suite or Frame Generator product only.

Software Maintenance includes updates to newer instrument firmware as well as procedure and test limit changes for the test specifications covered by the products the software maintenance license belongs to. Upgrades to a different test specification are not covered.

All N5991 RX test or Debug Tool / Link Training Suite licenses which were purchased after November 30th, 2020 will no longer include automatic Software Maintenance during the first year. Thus, it requires a respective software maintenance license to be able to install updates.

Products which do not have a software maintenance offering and are not an Add-On cannot be updated but are operational still when using the last version for which software maintenance was available.

Software without any extra software maintenance product associated with it, will have a maintenance expiration date of the license issue date + 14 days as a starting point. The software itself will still work, even if the maintenance is expired. If software maintenance has expired a new software maintenance license can be purchased for this product. But the new software maintenance will not grant coverage starting from the purchase date but from the date the previous software maintenance coverage expired. For example, the software maintenance expired on April 30th, 2020, and a new 1-year software maintenance is purchased on August 1st, 2020, the purchased coverage will take May 1st, 2020, and will end on April 30th, 2021.

Related Products

The N5991ST3A SATA 3 Receiver Test Automation Software covers SATA RSG testing.

The N5991SA3A and N5991SA4A SAS Receiver Compliance Test Automation Software cover SAS-3 12G and SAS-4 12G / 22.5G SAS receiver testing.

The N5991U40A USB4 Receiver Compliance Test Software covers USB4 and Thunderbolt™ 3 rates
10 Gb/s, 10.3125 Gb/s, 20 Gb/s and 20.625 Gb/s.

The N5991U32A USB 3.2 Receiver Compliance Test Software covers USB receiver testing for 5 Gb/s and 10 Gb/s.

Automated transmitter compliance testing is available. D9040PCIC PCI Express Electrical Performance Validation and Compliance Software covers PCI Express specification up to PCI Express 4.0. D9050PCIC PCI Express 5.0 Transmitter Electrical Performance Validation and Compliance Software covers PCI Express 5.0 specifications. The D9040SASC Serial Attached SCSI – 4 (SAS-4) Transmitter Test Application covers SAS transmitter testing for 1.5G, 3G, 6G, 12G and 22.5G. The D9030SATC SATA Compliance Test Software covers SATA PHY, TSG and OOB compliance testing. The D9040USBC USB4 Tx Test Software covers 10G, 10.3125G, 20G and 20.625G USB4 Tx testing. The D9020USBC USB 3.2 Tx Compliance Test Software covers USB3.2 5G and 10G Tx compliance testing.

PCI Express protocol test solutions for PCI Express 5.0 and 6.0 are available for the CEM form factor.

Automated electrical receiver testing for 400G and 100G is offered by M809256PA, M8091BSPA and M809228CA.

The N4917BSCA Optical Receiver Stress Test Application addresses test needs for optical input test of transceiver modules for 400GBASE-LR8/-FR8 as well as 200GBASE-LR4/-FR4/-DR4.

The UXR-Series oscilloscope is ideal for testing PAM4 at 32 Gbaud.

The M8040A 64 Gbaud High-performance BERT is currently the only PAM4 BERT system used for link equalization testing for official integrators list testing at PCI Express compliance workshops

The M8050A 120 Gbaud High-Performance BERT offers low enough intrinsic RJ for PCI Express 7.0 128 GT/s stress signal generation.