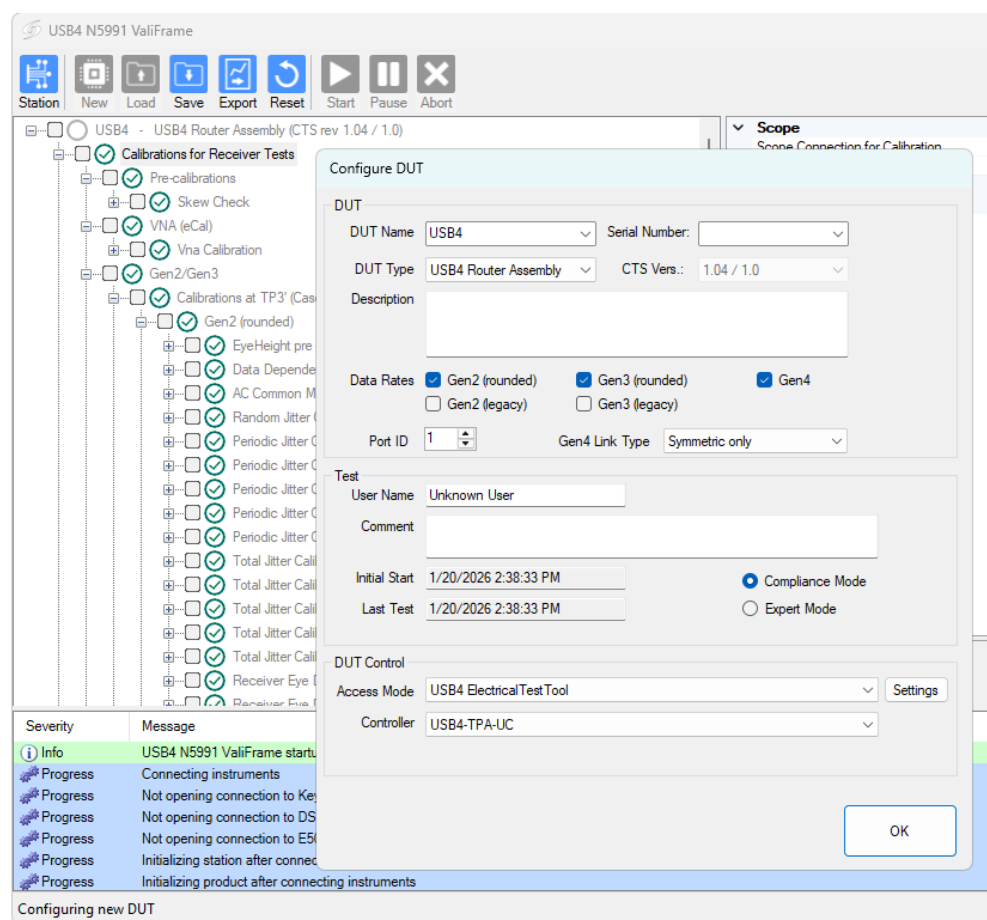


# N5991U42A

## USB4 Version 2.0 Receiver Compliance Test Automation Software

### Introduction

N5991U42A is the receiver compliance test automation software, allowing you to test and characterize USB4 Version 2.0 PAM3 designs using Keysight's M8040A BERT platforms.



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# At a Glance

High-speed digital standards are rapidly evolving to support next-generation 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, analysis, debug, and compliance testing. The N5991 software solution 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 calibrations and compliance measurement functions
- Modern look and feel with enhanced functionalities
- System modularity allows the user to enable only required functionalities
- HTML test reports
- Node-locked and transportable licenses
- Characterization mode for in-depth testing
- Single and multi-lane device testing

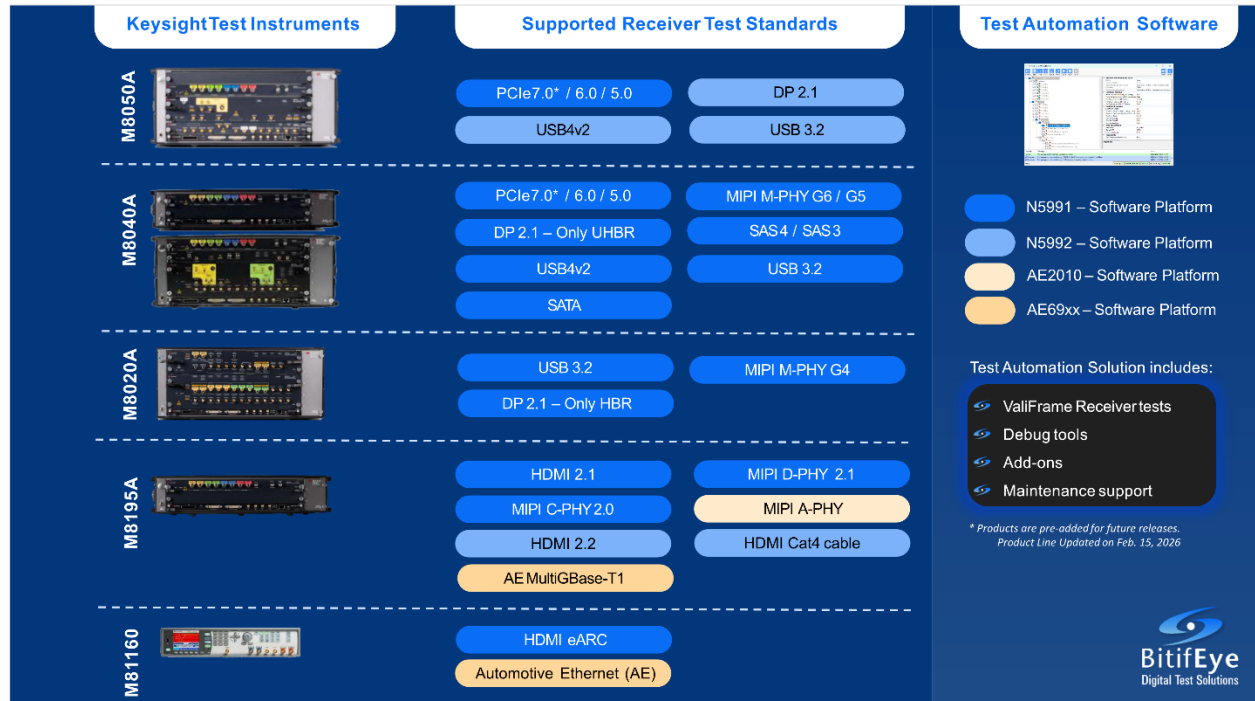


Figure 1. N5991 Software Solution Path

# 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 Tests

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"). The N5991 builds on the success of previous generations to deliver significant gains in productivity. Like its predecessor, the N5990A, the new 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, as well as 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).

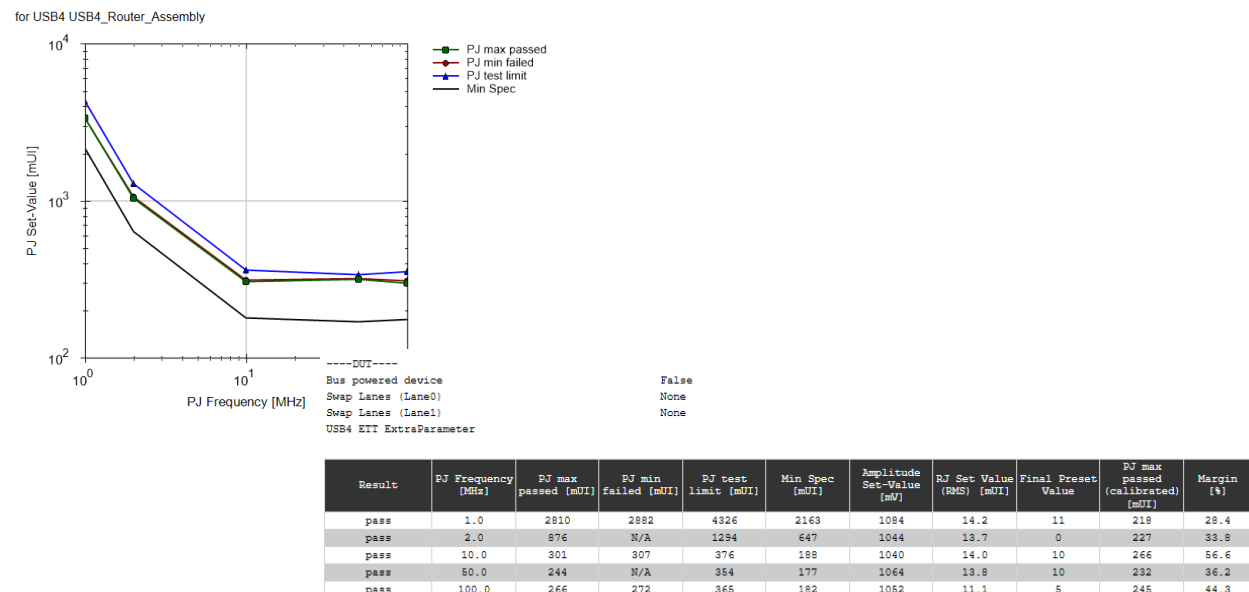


Figure 2. USB4 20 Gb/s jitter tolerance measurement – graphical and tabular result

# N5991 USB4 Receiver Tests

USB4 Version 2.0 is fully backward compatible with its predecessor USB4, doubles the PHY speed to 40Gbps per physical lane, and adds the support of asymmetric links. Asymmetric lane arrangement allocates two high-speed differential pairs on each link direction, enabling astonishing 80Gbps bidirectional transfers. The asymmetric lane arrangement allocates three high-speed differential pairs in one direction, and one differential pair in the other direction, enabling transfers of 120Gbps and 40Gbps, respectively.

The backward compatibility implies that each receiver port may have up to 2 lanes that support 10Gbps and 20Gbps, and optionally 10.3125Gbps and 20.625Gbps for Thunderbolt™ 3 compatibility. The doubled PHY rate of 40Gbps is achieved by adopting PAM3, a pulse amplitude modulation that defines 3 different signal levels at a given unit interval, running at 25.6 GSymbols/s, and applying advanced symbol encoding techniques. And finally, the asymmetric mode implies that receivers may support up to three lanes.

The following chart summarizes the information above:

| Parameter            | Gen2    | Gen2 <sup>1</sup> | Gen3    | Gen3 <sup>1</sup> | Gen4     |
|----------------------|---------|-------------------|---------|-------------------|----------|
| Line coding          | NRZ     | NRZ               | NRZ     | NRZ               | PAM3     |
| Symbol rate per lane | 10 GBd  | 10.3125 GBd       | 20 GBd  | 20.625 GBd        | 25.6 GBd |
| Data rate per lane   | 10 Gbps | 10.3125 Gbps      | 20 Gbps | 20.625 Gbps       | 40 Gbps  |
| Symmetric link       | •       | •                 | •       | •                 | •        |
| Asymmetric link      |         |                   |         |                   | •        |

1. If compatible with Thunderbolt™ 3

If the complexity of validating USB4 products transitioning from USB 3.2 increased substantially, USB4 Version 2.0 takes the complexity to an even higher level due to the additional test requirements that add up to the total product validation time, and the inherent signal integrity challenges associated with faster, multi-level signaling. Validation engineers are presented with an intimidating task that is nearly impossible to finalize at a reasonable time, unless the right tools are used.

The ValiFrame N5991 USB4 Test Automation Platform completely removes the aforementioned complexity, maximizing your productivity and allowing you to focus on what really matters: your product. N5991 implements all receiver stress signal calibration and receiver test procedures as described in the *USB4 Router Assembly Electrical Compliance Test Specification or USB4 CTS*, published by the USB Implementers Forum (USB-IF).

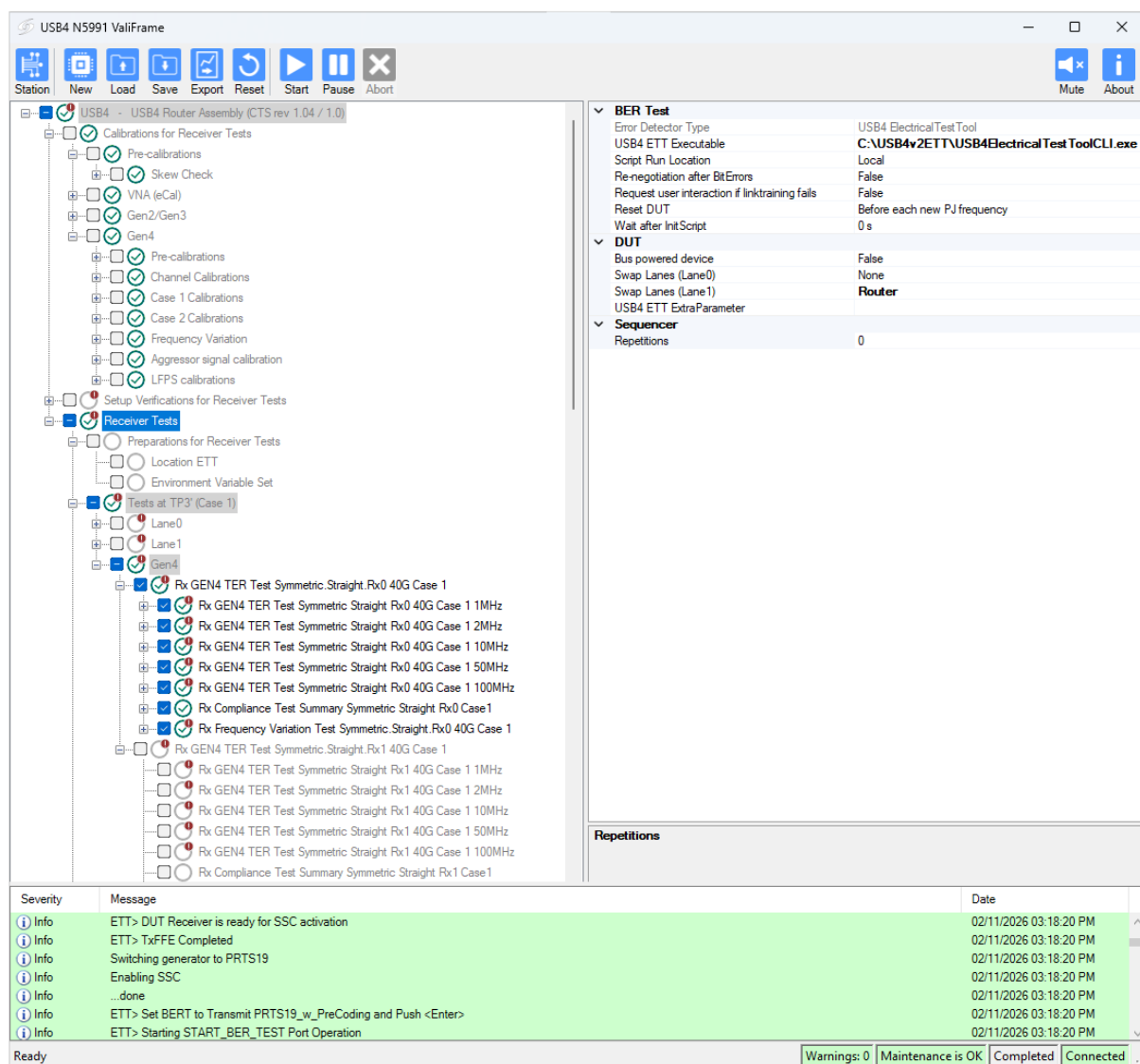


Figure 3. N5991 USB4 test tree overview

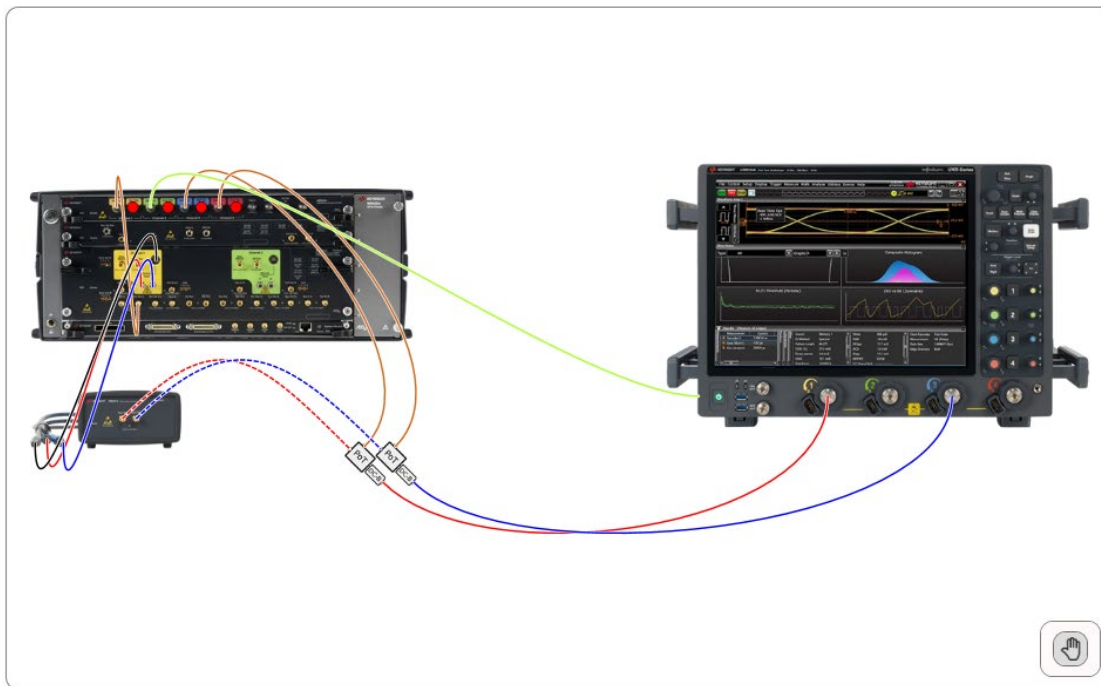
## Calibrations

Receiver stressed signal calibration is cumbersome, as it requires the fine adjustment of several signal impairments. In the case of Gen2 and Gen3, launch voltage, random jitter, sinusoidal jitter, and common-mode interference are tuned to obtain the right stress level defined in terms of total jitter and eye diagram opening. In the case of Gen4, the impairments mentioned above plus differential-mode interference and near-end crosstalk are adjusted to obtain the right stress level defined in terms of signal-to-noise-and-distortion ratio or SNDR, and jitter.

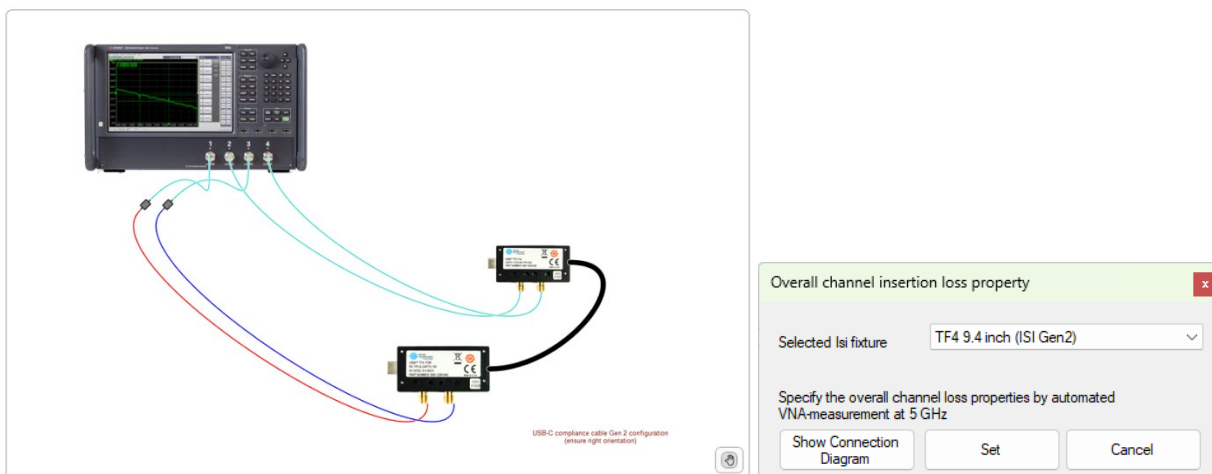
The stressed signal from the pattern generator is measured with the USB-IF SigTest utility, which is a command-line tool that takes a digitized waveform and numerous configuration parameters as input,

performs clock recovery and equalization (if applicable), and returns the measurements mentioned above.

If the validation engineer were to perform this tedious process manually, it would take a prohibitive time to complete and the slightest mistake would lead to invalid stress conditions, and thus invalid test results. N5991 USB4 fully automates the whole process, from adjusting all impairments to invoking the SigTest utility and processing its results, ensuring the highest level of accuracy and repeatability with minimal user interaction and detailed connection diagrams to minimize the sources of error.



**Figure 4.** Receiver stress signal calibration for Gen2, Gen3 and Gen4 Test Case 1



**Figure 5.** Automated insertion loss calibration for Test Case 2

### SNDR / ACCM Cal 40G (Case 1)

for USB4 N5991 ValiFrame

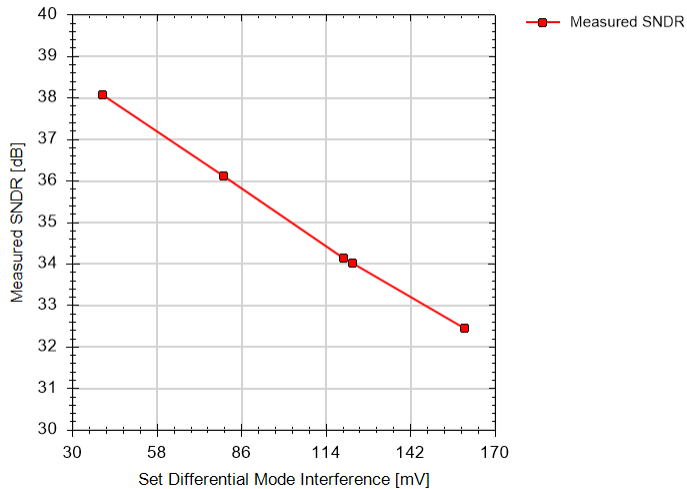
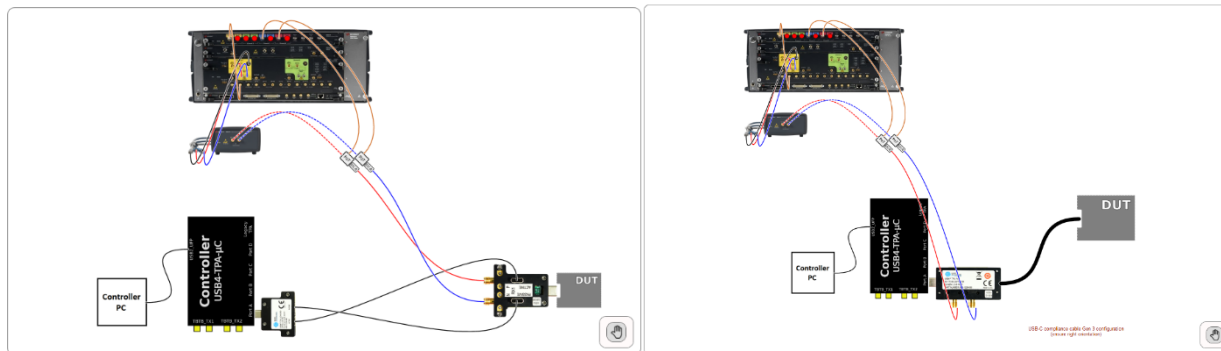


Figure 6. Receiver calibration for Gen4

## Receiver Tests

Unlike USB 3.2, USB4 receiver testing does not require an error detector and USB4 products are required to implement an error counter. The receiver test process can be divided in two phases: link training, and error count. During the link training phase, the DUT is allowed to request various equalization settings to the pattern generator and adjust its receiver equalization to improve the quality of the received signal. During the error count phase, the receiver error counter is used to perform a BER (Bit Error Rate) test in the case of Gen2 and Gen3, and a TER (Trit Error Rate) test in the case of Gen4.

The communication with the DUT is done via the USB4 Sideband channel by means of the USB-IF utility USB4 Electrical Test Tool or USB4ETT, and the USB4 Microcontroller. The USB4ETT utility has both a graphical user interface and a command-line interface, and it requires intimate knowledge of the test requirements to be operated. N5991 USB4 takes over the communication with the DUT completely, leveraging the tools just mentioned previously to offer fully automated testing.



**Figure 7.** Receiver BER test setup on Lane 0 for Test Case 1 (left) and Test Case 2 (right)

```

----DUT----
Bus powered device
Swap Lanes (Lane0)
Swap Lanes (Lane1)
USB4 EIT ExtraParameter

```

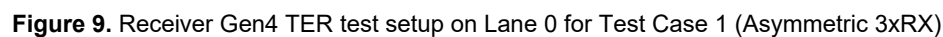
```

False
None
Router

```

| Result | PJ Frequency [MHz] | ACCM Set Amplitude [mV] | PRBS Set Amplitude [mV] | PJ Set Value (RMS) [mUI] | PJ Set Value [mUI] | Final Preset Value | Error Counter Check | Short Runs | Component       | Run #1 Errors   Symbols            | Run #2 Errors   Symbols | Run #3 Errors   Symbols | Run #4 Errors   Symbols |
|--------|--------------------|-------------------------|-------------------------|--------------------------|--------------------|--------------------|---------------------|------------|-----------------|------------------------------------|-------------------------|-------------------------|-------------------------|
| pass   | 1                  | 367                     | 1084                    | 14.20                    | 2163               | 9                  | Pass (3 of 3)       | 0/0/0/0    | Router Retimer1 | 0   11875000000<br>0   11994000000 | -   -<br>-   -          | -   -<br>-   -          | -   -<br>-   -          |
| pass   | 2                  | 367                     | 1044                    | 13.70                    | 647                | 11                 | Pass (3 of 3)       | 0/0/0/0    | Router Retimer1 | 0   11875000000<br>0   11994000000 | -   -<br>-   -          | -   -<br>-   -          | -   -<br>-   -          |
| pass   | 10                 | 367                     | 1040                    | 14.00                    | 188                | 3                  | Pass (3 of 3)       | 0/0/0/0    | Router Retimer1 | 0   11875000000<br>0   11994000000 | -   -<br>-   -          | -   -<br>-   -          | -   -<br>-   -          |
| pass   | 50                 | 367                     | 1064                    | 13.80                    | 177                | 4                  | Pass (3 of 3)       | 0/0/0/0    | Router Retimer1 | 0   11875000000<br>0   11994000000 | -   -<br>-   -          | -   -<br>-   -          | -   -<br>-   -          |
| pass   | 100                | 367                     | 1052                    | 11.10                    | 209                | 3                  | Pass (3 of 3)       | 0/0/0/0    | Router Retimer1 | 0   11875000000<br>0   11994000000 | -   -<br>-   -          | -   -<br>-   -          | -   -<br>-   -          |

**Figure 8.** Detailed receiver BER test report



| Result | PJ Frequency [MHz] | Voltage Swing Set Amplitude [mV] | Symbol 1 Level [%] | ACCM Set Amplitude [mV] | DMSI Set Value [mV] | PJ Set Value [mUI] | PJ Set Value (RMS) [mUI] | Final Preset Value | Component       | TER (Error counter check) | Received symbols | Errors | TER (test phase) |
|--------|--------------------|----------------------------------|--------------------|-------------------------|---------------------|--------------------|--------------------------|--------------------|-----------------|---------------------------|------------------|--------|------------------|
| pass   | 1                  | 1516                             | 51.5               | 302                     | 123.0               | 3010               | 7.90                     | 11                 | Router Retimer1 | 1E-06                     | 256000000000     | 0      | 0                |
|        |                    |                                  |                    |                         |                     |                    |                          |                    |                 |                           | 288600000000     | 0      | 0                |

**Figure 10.** Detailed receiver Gen4 TER test report

N5991 USB4 covers all high-speed receiver tests defined by the USB4 CTS:

| Parameter                                          | Gen2 | Gen2 <sup>1</sup> | Gen3 | Gen3 <sup>1</sup> | Gen4 |
|----------------------------------------------------|------|-------------------|------|-------------------|------|
| Receiver BER/TER test                              | •    | •                 | •    | •                 | •    |
| Receiver signal frequency variations training test | •    | •                 | •    | •                 | •    |

1. If compatible with Thunderbolt™ 3

## Beyond Compliance

Earning compliance certification is the first step to bring your product into the market. But it is not the last. Technology experts must make sure that their product will be able to interoperate with a wide range of products from other vendors once it has reached the market. N5991U42A will give you the extra confidence that you need by pushing your product beyond the limits of compliance testing. N5991U42A includes two additional receiver tests besides the compliance test suite under the Expert Mode configuration.

## Jitter Tolerance Characterization Test

The Jitter Tolerance Characterization Test, also known as Jitter Margin Test, makes use of the full jitter injection capabilities of the pattern generator to overstress your product beyond the designated amplitudes in Compliance Jitter Tolerance Test.



Figure 11. Jitter Tolerance Characterization test results

## Sensitivity Test

The Sensitivity Test will challenge your product's receiver by injecting a test signal decreasing the differential amplitude, allowing you to identify how well your product performs in worst-than compliance conditions.

| Result | Eye Height [mV] | PRBS Set Amplitude [mV] | Test Time [s] | Errors | Received Symbols | Preset Value | Rating     |
|--------|-----------------|-------------------------|---------------|--------|------------------|--------------|------------|
| pass   | 700             | 1334                    | 40            | 0      | 19218508829      | 0            |            |
| pass   | 401             | 834                     | 40            | 0      | 19199295898      | 0            |            |
| pass   | 251             | 584                     | 40            | 0      | 19205401676      | 0            |            |
| pass   | 176             | 459                     | 40            | 0      | 19252945822      | 0            |            |
| pass   | 138             | 396                     | 40            | 0      | 19140250806      | 0            |            |
| pass   | 120             | 365                     | 40            | 0      | 19452383669      | 0            |            |
| pass   | 101             | 334                     | 40            | 0      | 19143125654      | 0            | min passed |

Figure 12. Sensitivity test results

## Custom BER Test

The Custom BER test allows to set stress levels different from the Compliance test setup, skip certain link training phases and run multiple iterations for a more comprehensive characterization of the DUT.

|                                                                                                                                                        |  |                                                                                                                                                       |  |                                                                                                                                                           |  |                                                                                                                                                           |  |                                                                                                                                                              |  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|--|-------------------------------------------------------------------------------------------------------------------------------------------------------|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
| <b>General</b><br>Run Test at 1MHz True<br>Run Test at 2MHz True<br>Run Test at 10MHz True<br>Run Test at 50MHz True<br>Run Test at 100MHz True        |  | <b>Generator</b><br>Pattern PRBS 31<br>SSC True<br>SSC Amplitude downwards -5400 ppm<br>SSC Amplitude upwards 400 ppm<br>SSC Frequency 36 kHz         |  | <b>Impairments</b><br>AC CM Set Value 256 mV<br>Add CMI True<br>Add Generator ISI False                                                                   |  | <b>BER Test</b><br>Test Duration 200 s<br>Negotiate Tx FFE preset? True<br>Check error counter? True<br>Run Post Link Training Script False               |  | <b>Sequences</b><br>Procedure Error Case Behavior Abort Sequence<br>Procedure Failed Case Behavior Proceed With Next Procedure<br>Repetitions 0              |  |
| <b>Test at 1MHz</b><br>BERT Amplitude Set Value ( 1MHz) 1.043 V<br>RandomJitterRMSSetValue ( 1MHz) 10.1 mUI<br>PJ Amplitude Set Value ( 1MHz) 2.133 UI |  | <b>Test at 2MHz</b><br>BERT Amplitude Set Value ( 2MHz) 1.033 V<br>RandomJitterRMSSetValue ( 2MHz) 10.5 mUI<br>PJ Amplitude Set Value ( 2MHz) 636 mUI |  | <b>Test at 10MHz</b><br>BERT Amplitude Set Value ( 10MHz) 1.028 V<br>RandomJitterRMSSetValue ( 10MHz) 10.5 mUI<br>PJ Amplitude Set Value ( 10MHz) 186 mUI |  | <b>Test at 50MHz</b><br>BERT Amplitude Set Value ( 50MHz) 1.029 V<br>RandomJitterRMSSetValue ( 50MHz) 10.5 mUI<br>PJ Amplitude Set Value ( 50MHz) 172 mUI |  | <b>Test at 100MHz</b><br>BERT Amplitude Set Value ( 100MHz) 1.027 V<br>RandomJitterRMSSetValue ( 100MHz) 9.7 mUI<br>PJ Amplitude Set Value ( 100MHz) 178 mUI |  |

-----DUT-----

Bus powered device False  
Swap Lanes (Lane0) None  
Swap Lanes (Lane1) Router  
USB4 EIT ExtraParameter

-----Instruments-----

Data Generator Name: Keysight M9040A J-BERT ; Company: Keysight Technologies ; Model: M9070B ; SN: MY62701856 ; FW rev.: 12.5.150.12 ; Description: M9045A 56Gb/s PAM4 Generator ; Firmware Version Supported: True ; Calibrated Instrument M9054A/M9195A

AcCm Source

| Result | DJ Frequency (MHz) | AC CM Set Amplitude (mV) | PRBS Set Amplitude (mV) | RJ Set Value (RMS) (mUI) | DJ Set Value (mUI) | Final Preset Value | 3 Injected Errors Check | Component       | Errors | Symbol count 1st Run         |
|--------|--------------------|--------------------------|-------------------------|--------------------------|--------------------|--------------------|-------------------------|-----------------|--------|------------------------------|
| pass   | 1                  | 367                      | 1692                    | 14.20                    | 2163               | 1                  | Pass (3 of 3)           | Router Retimer1 | 0      | 199890780102<br>200094387757 |
| pass   | 2                  | 367                      | 1700                    | 13.70                    | 647                | 1                  | Pass (3 of 3)           | Router Retimer1 | 0      | 199841487942<br>200092784155 |
| pass   | 10                 | 367                      | 1700                    | 14.00                    | 188                | 1                  | Pass (3 of 3)           | Router Retimer1 | 0      | 128536628260<br>128767568558 |
| pass   | 50                 | 367                      | 1688                    | 13.80                    | 177                | 1                  | Pass (3 of 3)           | Router Retimer1 | 0      | 128867747247<br>129102816443 |
| pass   | 100                | 367                      | 1700                    | 11.10                    | 209                | 1                  | Pass (3 of 3)           | Router Retimer1 | 0      | 129200854557<br>129443093723 |

Figure 13. Custom BER test configuration parameters (left) and test results (right)

# Ordering Information

| N5991U42A     | USB4 Version 2.0 Receiver Test                             |
|---------------|------------------------------------------------------------|
| N5991U42A-1FP | Perpetual node-locked license                              |
| N5991U42A-1TP | Perpetual transportable single license                     |
| N5991U42A-SFM | SW maintenance extension, 12 Months, Node-locked License   |
| N5991U42A-STM | SW maintenance extension, 12 Months, Transportable License |

## License Types

**Node-locked** – License can be used on one specified computer.

**Transportable** – License can be used on one computer at a time but may be transferred to another using the BitifEye License Manager.

# Instrument Requirements for USB4 Receiver Tests

The N5991 USB4 Receiver Test application supports the Keysight M8040A High-Performance BERT platform. The BERT must be equipped appropriately to cover the required data rates, jitter injection, transmitter and receiver equalization, and USB link training capabilities.

The *USB4 Electrical Compliance Test Specification* defines a bandwidth of 25 GHz for USB4 calibrations at the fastest bit rate. To meet this requirement, Keysight recommends an Infiniium UXR-B series real-time oscilloscope with a bandwidth of at least 25 GHz. The oscilloscope must be equipped with embedding capabilities as well as serial data analysis capabilities.

| N5991U42A                          |   |
|------------------------------------|---|
| <b>Data Rates</b>                  |   |
| 10 Gb/s (NRZ)                      | ✓ |
| 10.3125 Gb/s (NRZ)                 | ✓ |
| 20 Gb/s (NRZ)                      | ✓ |
| 20.625 Gb/s (NRZ)                  | ✓ |
| 25.6 GBd (PAM3)                    | ✓ |
| <b>BERTs</b>                       |   |
| M8040A                             | ✓ |
| <b>Interference / AWG</b>          |   |
| M8195A (with M8040A)               | ✓ |
| <b>Network Analyzer (pick one)</b> |   |
| E5080B                             | ✓ |
| N522xB                             | ✓ |

Contact Keysight Technologies for details on instrument options, accessories, fixtures, and additional software.

# System Requirements

Visit <https://downloads.bitifeye.com/standards/USB4> and read the changelog of the current software release for detailed information on software and hardware requirements.

## Software

### Requirements

- OS: Windows 11
- 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
- 42GB RAM or higher (Require running the USB4 SigTest)

## 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 Extension

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

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

Software maintenance extension 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 extension license belongs to. Upgrades to a different test specification are not covered.

Products which do not have a software maintenance extension 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 extension 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 extension has expired a new software maintenance extension license can be purchased for this product. But the new software maintenance extension will not grant coverage starting from the purchase date but from the date the previous software maintenance extension coverage expired. For example, the software maintenance extension expired on April 30th, 2020, and a new 1-year software maintenance extension is purchased on August 1st, 2020, the purchased coverage will take May 1st, 2020, and will end on April 30th, 2021.

# Related Products

D9020USBC USB 3.2 Tx Compliance Test Software

D9040USBC USB4 Tx Test Software

D9050USBC USB4 Version 2.0 Tx Test Software

Infiniium UXR-B Series Oscilloscope

M8040A 64 GBaud High-Performance BERT

N5991U32A USB 3.2 Receiver Compliance Test Software

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Thunderbolt™ is a trademark of Intel Corporation

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