TELEDYNE | LECROY

All-In-One Solution for USB and USB-C® Electrical Test Compliance and Debug



USB-C has become the universal converged interface for data, display, power, and sideband control. Higher speeds in USB4® require more testing on more lanes, and the convergence makes compliance and interoperability failures harder to find, reproduce, and fix. Engineers need:

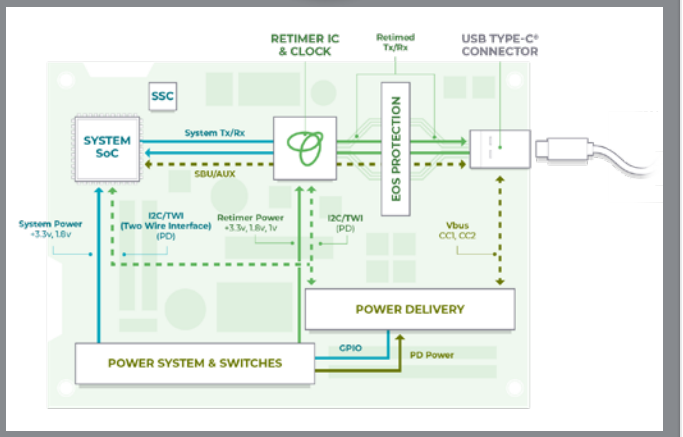
- **Faster automated pre-compliance and compliance testing**
- **Offline compliance test analysis to reduce lab bottlenecks**
- **Synchronized PHY, protocol, and sideband visibility to find the root cause of interoperability failures on real links that have passed compliance**



Compliance Test Challenges

Engineers need to complete an extensive range of compliance tests quickly, accurately, and repeatedly.

- USB compliance test to USB-IF standards requires a comprehensive range of transmitter, receiver, sideband, power delivery, repeater, cable/connector and return loss tests
- Newer, higher-speed USB standards (e.g., USB4) add more lanes at higher speeds and more tests, creating test bottlenecks
- Setup complexity and human error impact test efficiency and test quality
- PHY compliance test alone is not sufficient to understand real-world USB system performance



Interoperability Test Challenges

Products may pass compliance but still fail in a real USB ecosystem. This results in end-user dissatisfaction with real-world performance.

- Formal USB-IF CTS success can still result in compliance tested products failing in real-world links
- Higher-speed USB links and long channels require the use of linear redrivers, retimers and LTTPRs, increasing design complexity and the likelihood of link training failures
- Cross-layer failure ambiguity results in difficult to debug failures the cross electrical and protocol boundaries
- Interoperability failures are painful to the end-user and are organizationally difficult to resolve



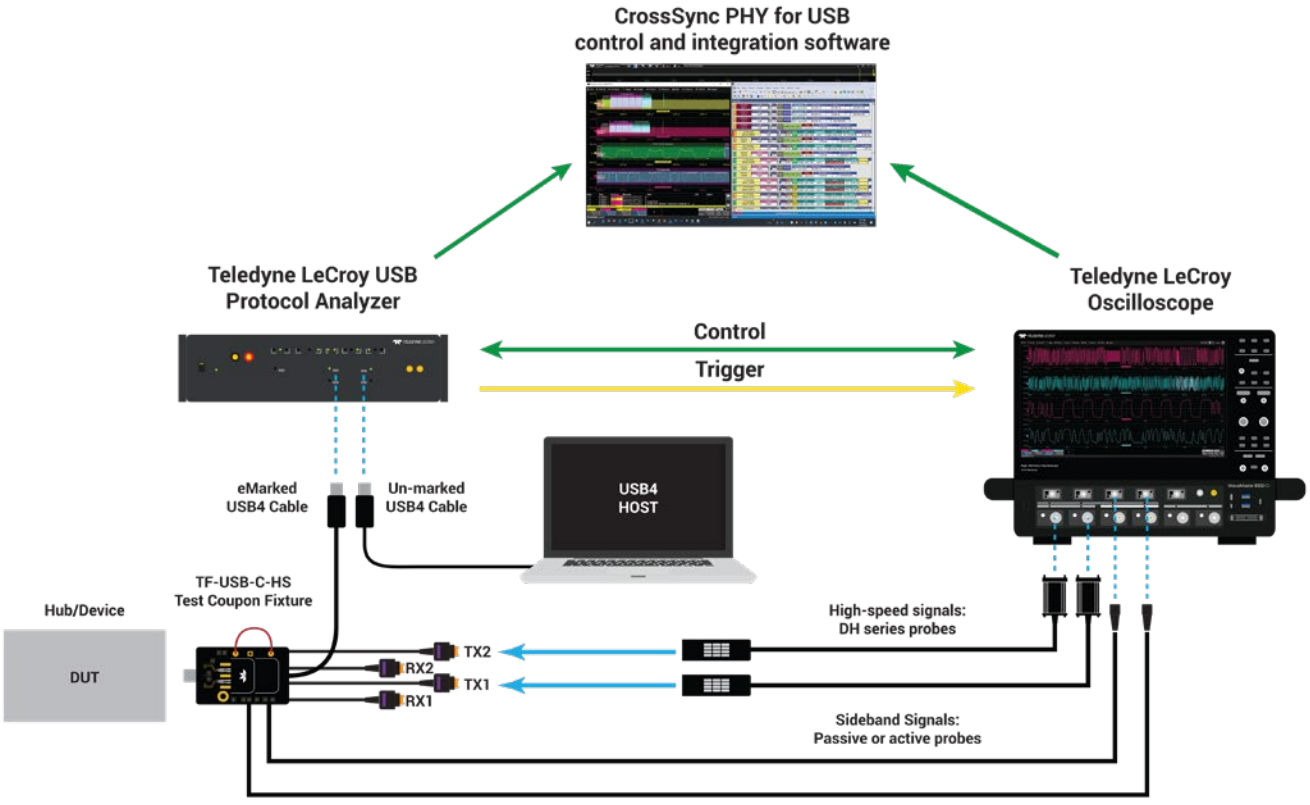
Market Needs

Testing converged USB-C links and/or higher-speed USB4 links is fundamentally different than testing USB 3.2 and previous USB interfaces. A compliance "pass" does not guarantee proper interoperability with today's high-speed USB4 links and long channels.

- Tx, Rx and Return Loss compliance needs to be better integrated and completely automated to reduce the increased knowledge burden on the test engineers
- Pre-compliance and compliance testing needs to be faster and more efficient due to the increased test requirements
- The oscilloscope needs to be focused on debugging Interoperability failures that result in end-user dissatisfaction

How Teledyne LeCroy Can Help

Teledyne LeCroy is uniquely positioned to provide fast, efficient compliance testing, the most capable high-speed serial link debug when compliance failures occur, and unique cross-layer debug tools to debug PHY-logic interoperability problems on live links.



- The WaveMaster® 8000HD oscilloscope is an all-in-one oscilloscope for low and high-speed USB-C testing. It combines high-speed and sideband testing into a single test oscilloscope – the only oscilloscope with these capabilities
- QualiPHY® 2 automated compliance test framework provides validation and compliance in a fraction of the time and QPHY2-PC permits more efficient offline testing and completes compliance testing faster
- Unmatched USB-C link testing with cross-layer analysis on live links for better interoperability debug

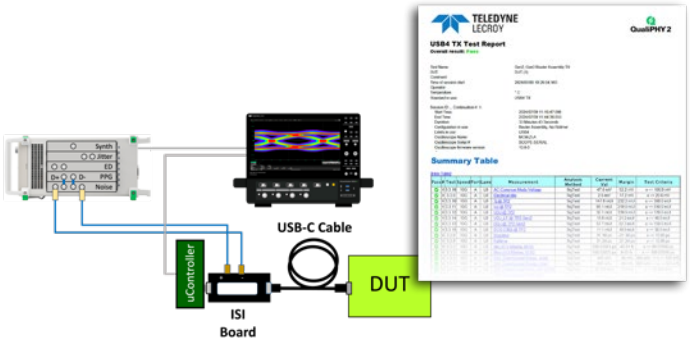
USB AND USB-C ELECTRICAL TEST LEADERSHIP

Teledyne LeCroy provides the best electrical, protocol and cross-layer (PHY-logic) solutions for USB-C Testing, including USB4, Thunderbolt™, USB 3.2, USB 2.0, DisplayPort™ 2.1, and USB Power Delivery, all over the USB Type-C Connector.

An All-In-One Oscilloscope for All USB-C Compliance and Debug Testing



1. Four 25 GHz, 80 GS/s, 12-bit ProAxial input channels for multi-lane compliance testing
2. Four 2 GHz ProBus input channels for highspeed and sideband signal access
3. Up to 8 Gpts of acquisition memory enables detailed viewing of link training
4. Sideband trigger, decode, measure/graph, and physical layer measurements
5. High-speed SDA Expert serial data analysis software for analyzing signal quality during link training
6. Mixed-signal capability – use digital channels for sideband trigger and decode
7. USB4, USB 3.2, and USB 2.0 bus decoders and ProtoSync convert analog waveforms to protocol packets for analysis





Best USB Compliance Test Integration and Automation

QualiPHY 2 automated test framework provides validation and compliance in a fraction of the time.

- Unified Tx, Rx, and Return Loss test framework for all compliance testing
- Simplified test interface that is easy to understand and operate
- Compliance on time from anywhere with offline data processing using QPHY2-PC

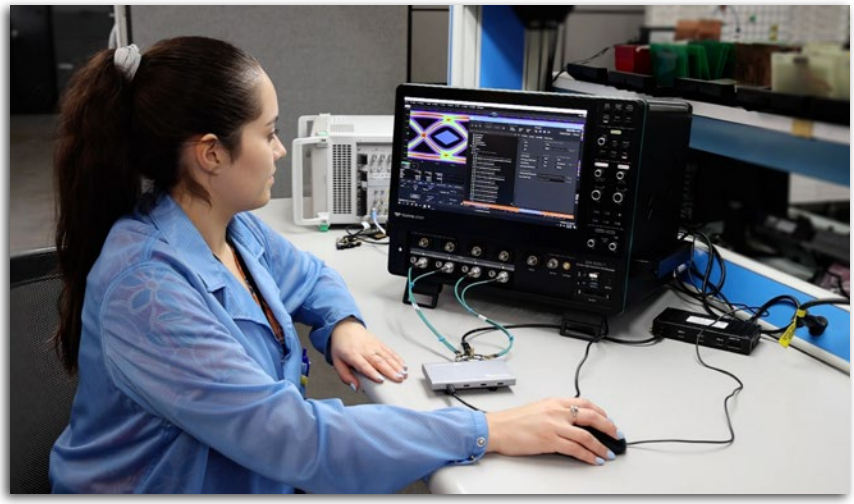
Unmatched USB-C Link Testing with Cross-Layer Analysis and PHY-logic Interoperability Debug

Seamlessly merge a protocol analyzer and an oscilloscope and view live link PHY-Logic operation.

- Validate and debug Thunderbolt and USB Type-C active link operation
- Quickly resolve interoperability issues by capturing the entire protocol stack
- Analyze link training with integrated physical and protocol views

BEST USB-C ELECTRICAL COMPLIANCE TEST

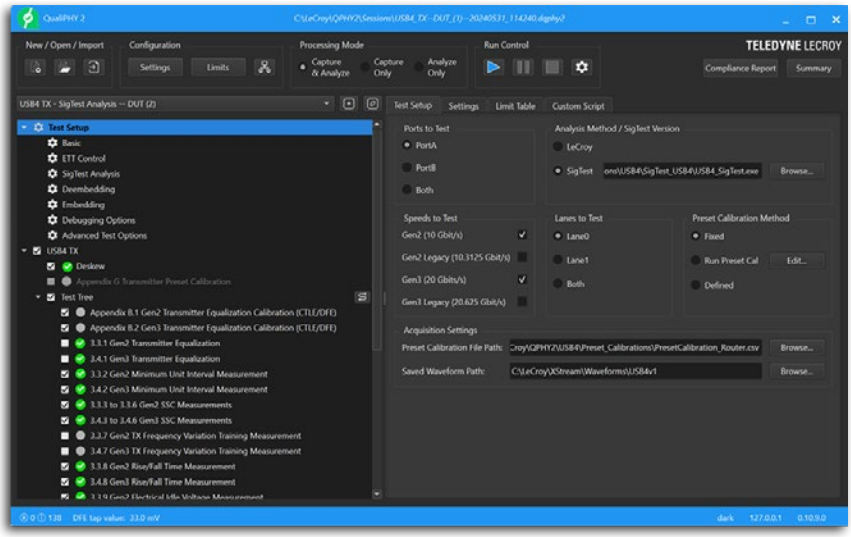
Teledyne LeCroy's QualiPHY 2 automated test framework is a single unified test framework for all Tx, Rx and Return Loss testing and permits off-line analysis for more efficiency – validation and compliance in a fraction of the time.



Unified Tx, Rx and Return Loss Compliance Test Framework

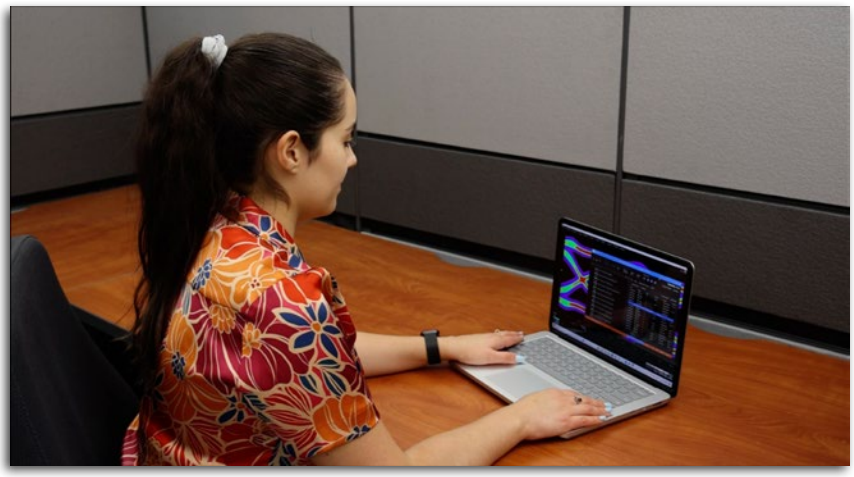
QualiPHY 2 is a single automation test framework for all Tx, Rx and Return Loss testing.

- Tx and Rx testing in one test interface
- Oscilloscope can run all tests without using an external server
- Oscilloscope can perform both Tx and Rx calibration



Simplified USB Compliance Test Interface

- Single test tree view for all settings, test selections and pass/fail test results
- Pop-up connection diagrams always accessible in test tree
- Easily retest or remove tests from database
- Test automation using powerful Python-enabled program control



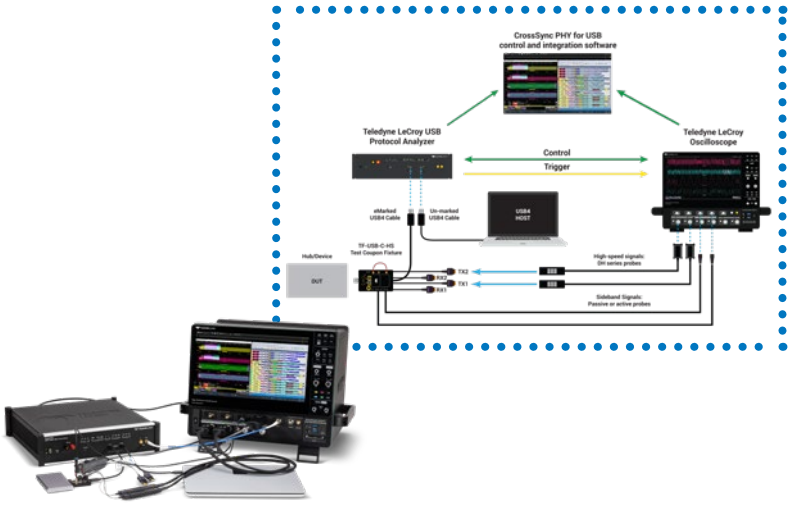
Compliance On Time From Anywhere With Offline USB Test Analysis

Be more efficient and complete testing faster using QPHY2-PC.

- QPHY2-PC processes waveform data offline and frees the oscilloscope for other testing
- More efficient use of lab resources – optimize oscilloscope usage
- Complete testing faster – share test session across multiple labs and locations

UNMATCHED USB-C LINK TESTING: *Cross*Sync™ PHY

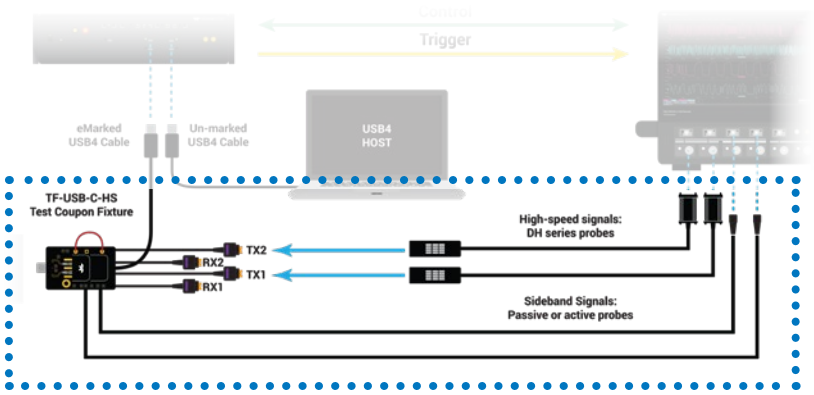
***Cross*Sync PHY seamlessly merges a protocol analyzer and oscilloscope. *Cross*Sync PHY for USB enables USB4 and Thunderbolt waveforms from Teledyne LeCroy oscilloscopes to be viewed alongside Teledyne LeCroy M4x Protocol Analyzer traces, with complete time correlation of electrical and protocol information for easy and powerful validation and root-cause analysis.**



Test Setup

Compliance testing by itself cannot discover or eliminate all interoperability failure modes. The figure at left shows an interoperability test setup:

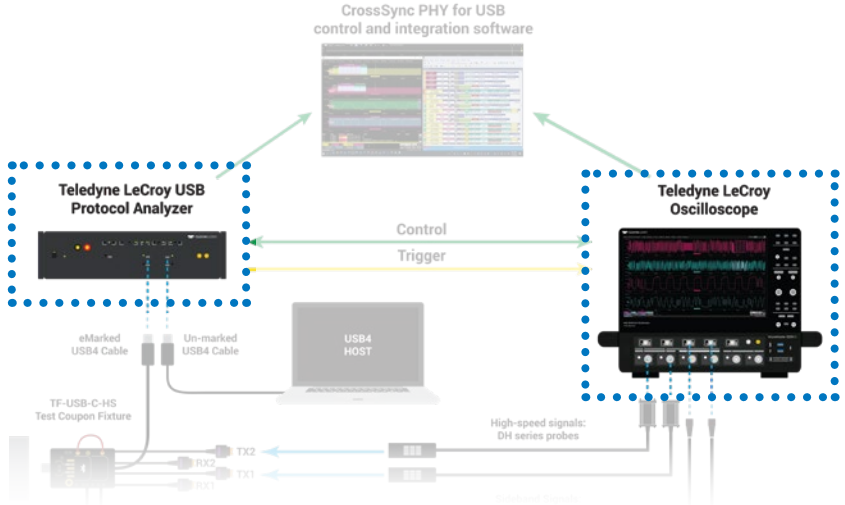
- USB protocol analyzer
- High-bandwidth oscilloscope
- *Cross*Sync PHY Cross-layer analysis software (running on the oscilloscope's internal PC)
- USB-C test coupon fixture (TF-USB-C-HS)
- Low-speed (sideband) serial data triggers and decoders (running on the oscilloscope)



Live Link Probing

The TF-USB-C-HS Test Coupon Fixture permits live system debug with simultaneous and transparent probing of both the electrical signals and the protocol traffic without link disruption.

- The fixture extends the USB-C receptacle of the DUT and maintains signal transparency
- High-speed Tx/Rx electrical signals are acquired using differential probes
- Low-speed signals are also accessed via 2.5 mm square pins
- Vbus load current is measured using a current probe
- Data signals are input to the protocol analyzer with a user-provided USB4 cable.



Hardware

Teledyne LeCroy provides both the oscilloscope for all high-speed PHY and low-speed sideband electrical signal capture and the protocol analyzer for protocol information capture.

- Teledyne LeCroy WaveMaster 8000HD Series oscilloscope is an all-in-one test oscilloscope for all USB-C electrical signal capture
- Teledyne LeCroy USB protocol analyzers are the leading protocol analyzers for USB-C, Thunderbolt and Power Delivery

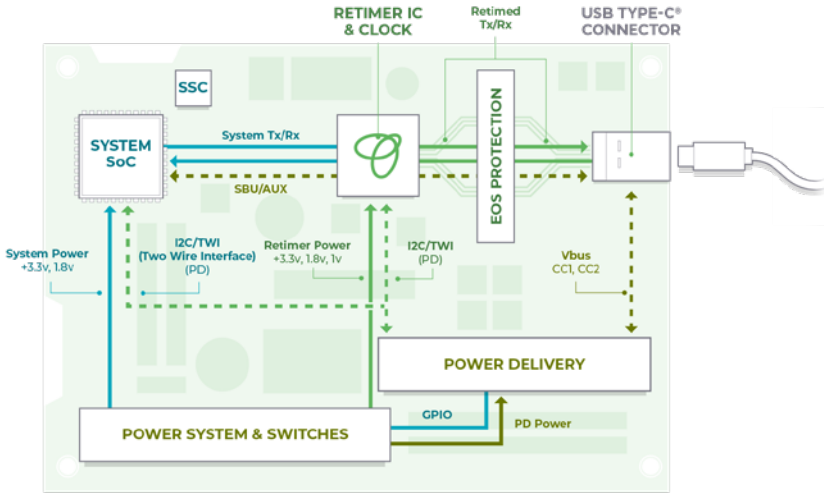
UNMATCHED USB-C LINK TESTING: *Cross*Sync™ PHY



Software

*Cross*Sync PHY software enables precise, intuitive navigation between time-correlated USB protocol analyzer and oscilloscope traces.

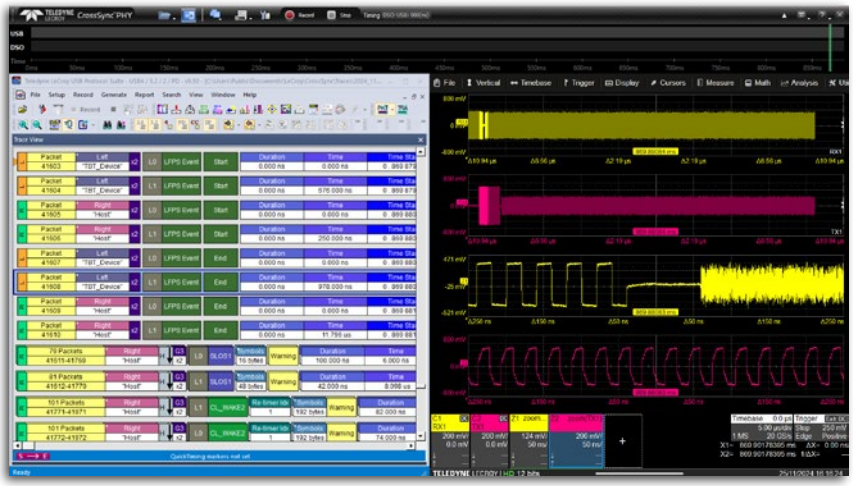
1. *Cross*Sync PHY navigation bar shows all traces
2. Oscilloscope acquisition segments are represented in the navigation bar
3. Protocol analyzer trace represented in the navigation bar
4. Common trigger point ensures precise timing alignment
5. Synchronized acquisition windows
6. Select a packet to zoom to electrical signal



Benefits

USB's host-device architecture with multiple receptacles, bi-directional power, retimers and long channels complicate the design and interoperability debug.

- Validate active link operation without disturbing the link
- Quickly resolve interoperability issues by capturing the entire protocol stack and all electrical signals
- Analyze link training by observing electrical-level results of protocol-level commands
- Get products to market faster with advertised interoperability performance



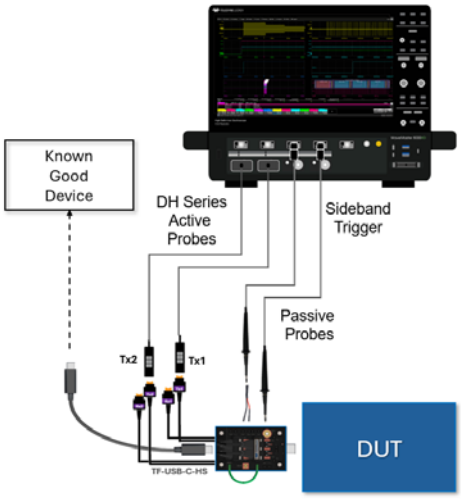
Example

Coordinating device, host retimer and host SoC exits from USB4, USB 3.2 or system low power states is complex, especially for legacy devices designed before retimers were in common use.

- Protocol Analyzer triggers on low power entry (e.g., CL1_ACK) and cross-triggers the oscilloscope
- Oscilloscope captures the electrical signals, including LFPS timings and the relative timings of device and host transmitter wake up
- *Cross*Sync PHY software time-correlates and links the two information displays

PHY-LOGIC AND SIDEBAND DEBUG

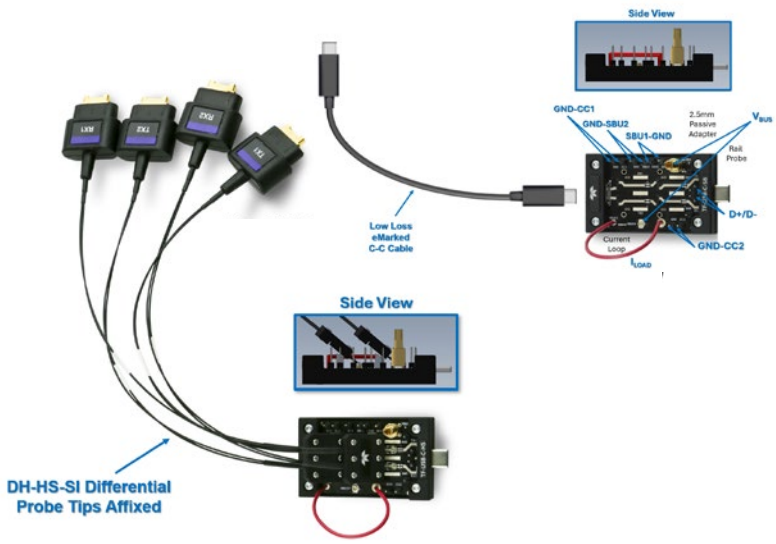
Link training and sideband negotiation failures account for many compliance and interoperability failures found on USB Type-C connected devices. These failures can be quickly identified as either physical or link layer issues by using Teledyne LeCroy's Physical Layer Logical Sub-Block and Sideband debug solutions.



Test Setup

An all-in-one oscilloscope and test coupon fixture provide ability to simultaneously probe, trigger, and analyze the high-speed and low-speed sideband signals on live links – something no other supplier can provide.

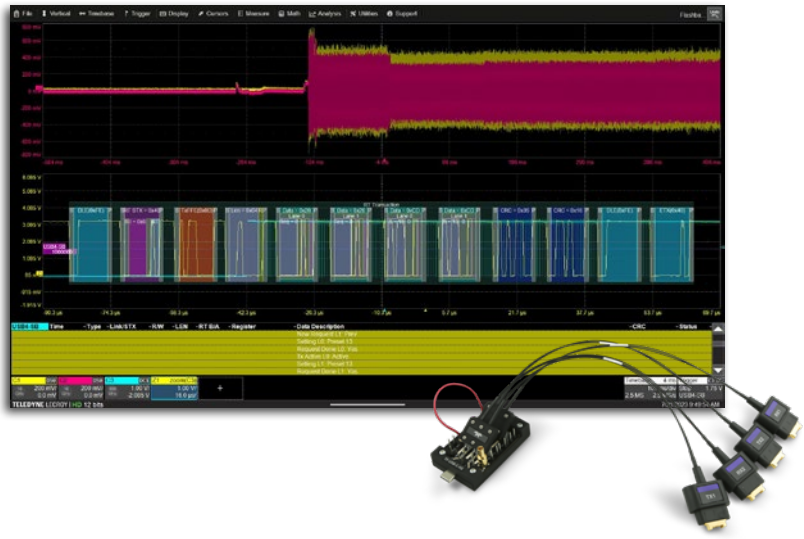
- The test coupon fixtures (TF-USB-C-HS shown) provides probing access points for all high-speed and sideband signals
- WaveMaster 8000HD oscilloscope can probe both sideband signals with 1 MΩ Probus (BNC) inputs and high-speed signals with 50 Ω ProAxial inputs
- Oscilloscope sideband trigger and decoder and protocol analyzer integration software options complete the setup



Live Link Probing

Teledyne LeCroy test coupon fixtures permit live link probing of all signals at the USB Type-C connector.

- The TF-USB-C-SB USB4 Sideband Test Coupon Fixture provides sideband signal access
- The TF-USB-C-HS adds access to high-speed Tx/Rx signals using DH Series Differential Probes
- A short low loss eMarked Cable is included with each test coupon fixture. When combined with the fixture, it provides the equivalent loss as a certified Thunderbolt 5 cable in order to ensure interoperability during debug



Sideband TD

The WaveMaster 8000HD oscilloscope triggers on a USB4 Preset change or other sideband message and then captures and decodes the sideband messages and other high-speed data lane traffic for further analysis.

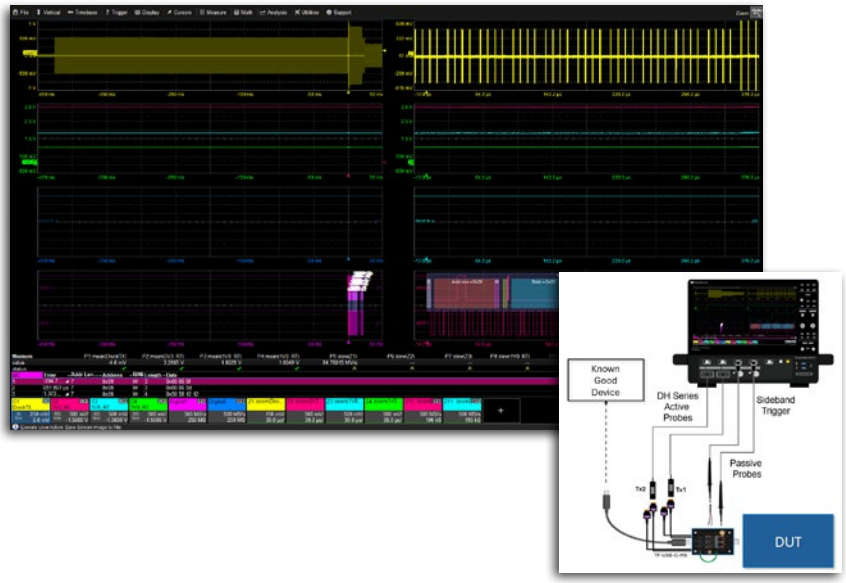
- Trigger on USB4 sideband messages using USB4-SB TDMP, and debug high-speed with USB4bus DME
- High-speed serial decode and analysis for USB4, USB 3.2, and USB 2.0, plus ProtoSync (protocol analyzer synchronizing) software
- See the whole link using USB *Cross*Sync PHY



ProtoSync

ProtoSync exports captured physical layer signals from the oscilloscope to (freely available) Teledyne LeCroy protocol analysis software. It allows the same protocol analysis views as a Teledyne LeCroy protocol analyzer but using the oscilloscope captured data, synchronized with the oscilloscope capture.

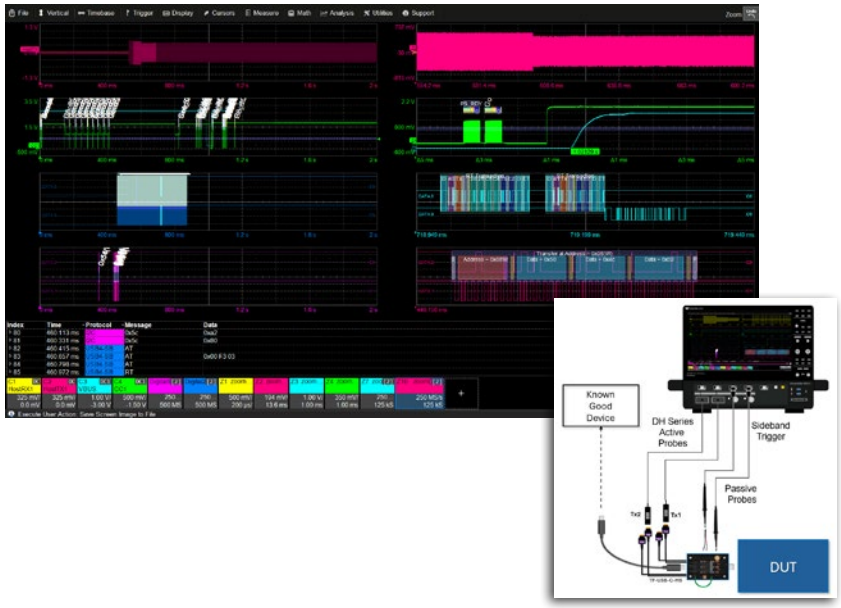
- The USB 3.2 link is analyzed while data is transferred from the Host to the Link Partner
- In the example shown, an ACK occurs on Ch1 as Data is transferred on C2
- Simply click on decoded packet in the protocol view to zoom in on electrical signal details



Example 1

USB 3.2 debugging can be more challenging than USB4 and DisplayPort because there is no low-speed sideband channel. Instead, link initialization is coordinated using LFPS transmitted on the high-speed lanes.

- Debugging such USB 3.2 initialization requires a time-aligned simultaneous capture of several hundred milliseconds of retimer power rails, reset pin and I2C communications, and USB 3.2 LFPS signals
- A complete view of the timing relationships between these signals is required to determine the PD firmware adjustments needed to solve USB 3.2 interoperability issues



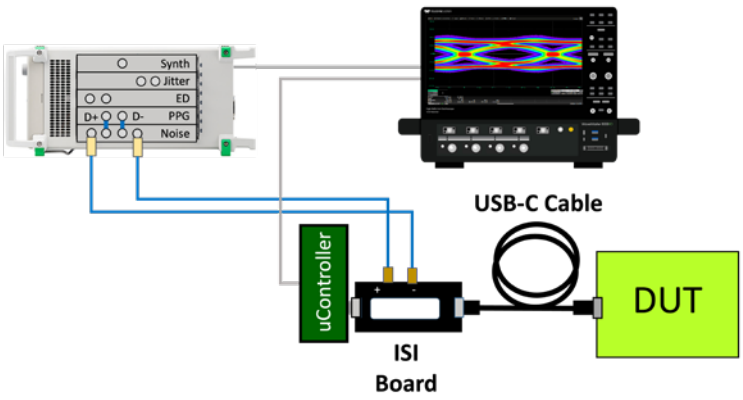
Example 2

USB-C is a reversible connector. One engineering consequence of this is that the mapping of PCB traces and retimer pins to high-speed differential pairs depends on the connector orientation.

- The traces carrying TX1 in normal orientation carry TX2 when the connector is flipped. Retimers need to know the mapping in order to transport signals correctly between the host SoC and the USB-C receptacle
- Debugging a live USB link with the Teledyne LeCroy WaveMaster/SDA 8000HD Oscilloscope and the TF-USB-C-HS Test Coupon Fixture allows an engineer to monitor USB PD controller programming (I2C signals), CC signals, Sideband Use (SBU) and high-speed lanes simultaneously

INTEGRATED AND EFFICIENT USB4 ELECTRICAL TEST

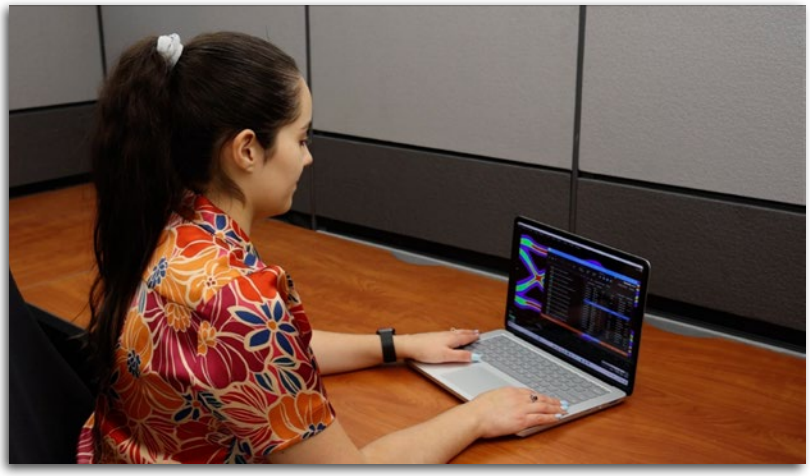
Teledyne LeCroy provides one unified test framework (QualiPHY 2) that integrates and automates all equipment (oscilloscope, BERT, and network analyzer) for all Tx, Rx and Return Loss tests per the USB-IF USB4 Compliance Test Specification (CTS). When products don't quickly pass compliance testing, Teledyne LeCroy helps you solve the problems faster with unmatched serial data electrical debug and cross-layer analysis.



Best Automated Compliance Test Integration of All Instruments

Complete test and reporting for all USB-IF required USB4 compliance tests.

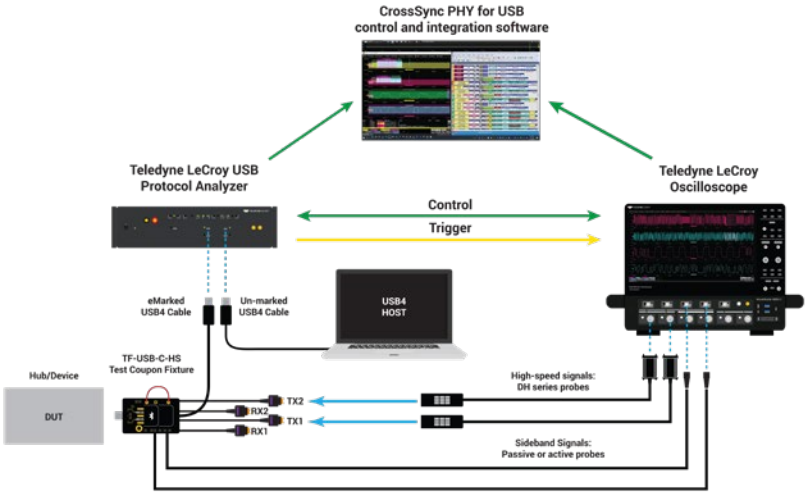
- One single unified control and automation test framework for the oscilloscope, BERT and network analyzer
- Easier to use than multiple test frameworks from multiple vendors
- Completes the validation faster - saves time



Increased Test Efficiency

Run Tx and Rx compliance testing separate from the oscilloscope.

- Utilizes QPHY2-PC to perform testing offline without connection to the oscilloscope or BERT
- Increases the use of test equipment hardware for the most important functions – as data acquisition engines
- Reduces total test time - bring products to market faster



Unmatched Compliance and Link Debug

Teledyne LeCroy helps you quickly resolve problems when they occur

- Debug compliance failures with USB4-specific Serial Data Expert tools
- Debug basic interoperability issues better with sideband message triggers, decoders and other tools
- Debug complex interoperability issues by seeing the whole link – electrical and protocol – in operation on live links

USB4 RETURN LOSS COMPLIANCE MEASUREMENTS



USB-IF Required USB4 Tx/Rx Test Cable De-Embed, Tx/Rx Return Loss and Rx Channel Measurements

Teledyne LeCroy's QPHY2-USB4-TX-RX automated compliance test software supports the following required return loss and S-parameter compliance test measurements:

- Simplified, fast and efficient testing using the QualiPHY 2 automated test framework
- Accurate S-parameter network analyzer results with the WavePulser 40iX Interconnect Analyzer
- Meets USB-IF requirements for USB4 Tx/Rx test cable de-embed, Tx/Rx return loss and Rx channel measurements

White Paper

USB and DisplayPort product and test experts from Kandou and Teledyne LeCroy collaborated on this technical white paper. It explains in detail why your designs could fail interoperability and how you can debug the problem. Six common failures and debug scenarios are described in detail:

USB4

- Entering and Exiting Low Power States
- Legacy USB 3.2 Link Initialization Interoperability
- Incorrect Flip Programming
- Sideband Use (SBU) Glitch Issues

DisplayPort

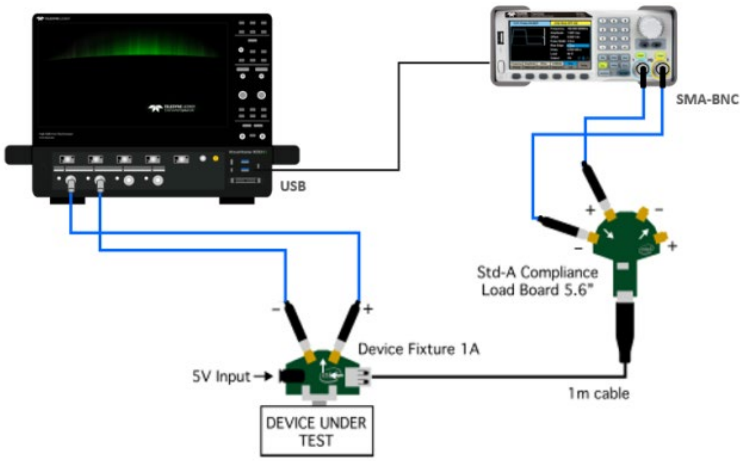
- Retimed Clock Frequency Variation
- Compliance Pattern Issues

Scan For White Paper



USB 3.2, 3.1 AND 3.0 COMPLIANCE TEST AND DEBUG

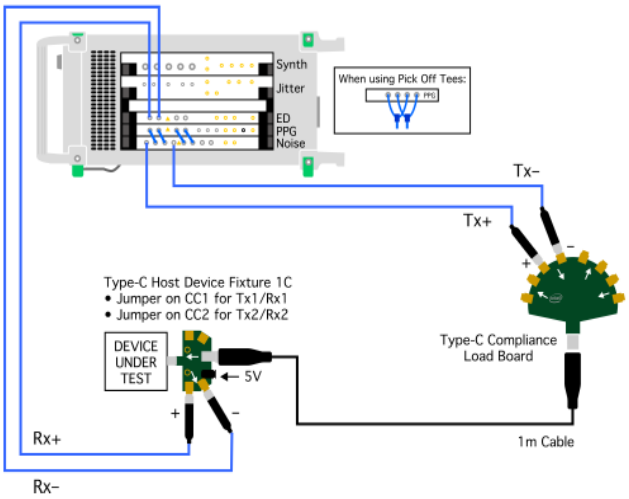
Teledyne LeCroy provides USB 3.2, USB 3.1 and USB 3.0 testing to USB-IF Gold Suite standards.



Fast and Easy Transmitter Testing and Debug

USB 3.2 compliance testing to "Gold Suite" levels

- QualiPHY automated compliance test framework supported
- LFPS/LBPM, SCD testing using a variety of LFPS generators
- Debug USB 3.2 compliance failures with SDAX-USB32 Serial Data Expert Analysis



Receiver Testing Using Industry-Standard Anritsu MP1900A BERT

Fully-automated Rx stressed signal calibration and receiver BER testing.

- Single compliance test framework for all Tx and Rx tests
- Anritsu MP1900A fully integrated into QualiPHY automated compliance test framework
- Automated short and long-channel calibration using oscilloscope, BERT and USB-IF compliance fixtures
- USB-IF compliance test report for all tests



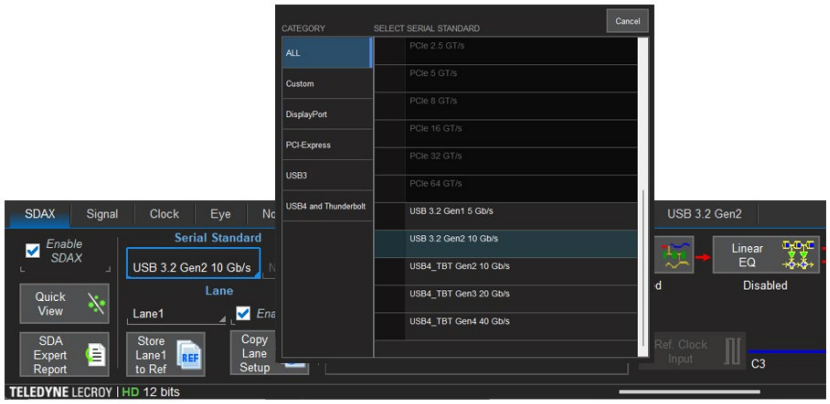
Type-C Sideband, Alt Mode and PHY-logic debug

Teledyne LeCroy provides unique capabilities for Power Delivery, Alt Mode, and USB PHY-logic testing

- USB-PD TDMP (trigger, decode, measure/graph and physical layer tools)
- DP-AUX DMP (decode, measure/graph, physical layer tools)
- USB32BUS D (decode)
- USB 3.2 protocol analyzer using ProtoSync

BUILT-IN USB-C TEST EXPERTISE IN SDA EXPERT

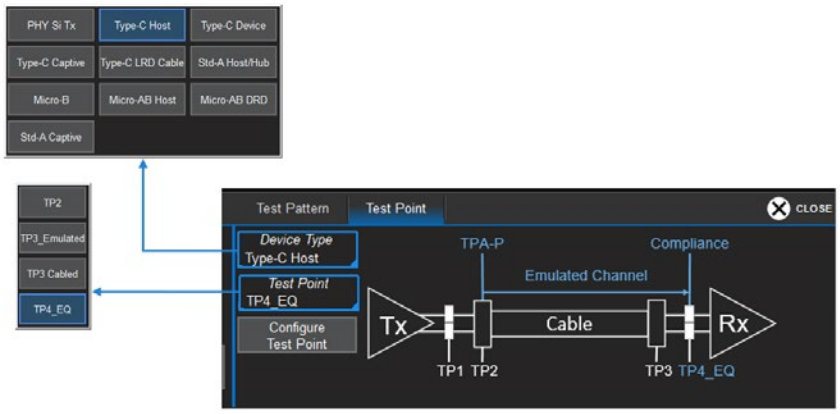
Teledyne LeCroy builds decades of industry standard expertise into SDA Expert (SDAX) serial data analysis software and options. Simply select the standard, configure the test point, and select measurements.



Select USB Standard

Simply select the USB serial standard from a pre-defined list and gain instant test expertise for measuring and characterizing USB signals. Available with USB technology options for SDA Expert.

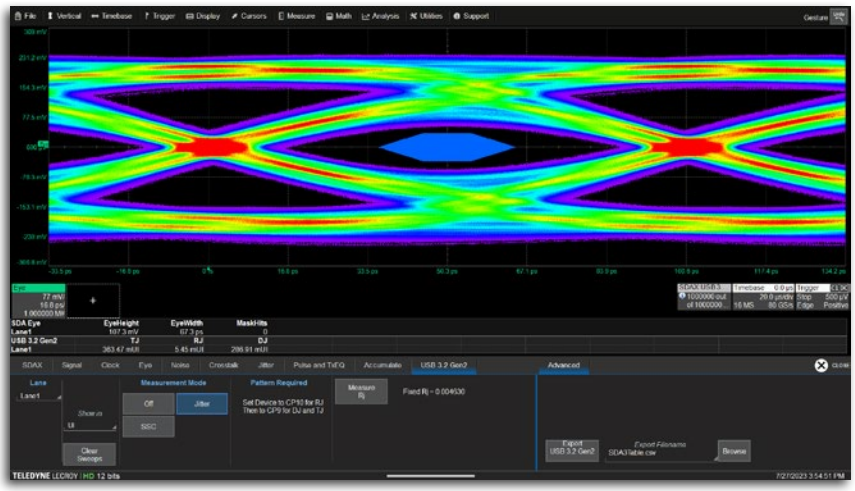
- Easily configurable test point setup
- Comprehensive Eye, Jitter, and other USB-C PHY measurements
- Simple, powerful equalization analysis



Configure USB Test Point

Test Point Configuration lets you perform transmitter testing at any test point in the link. The dynamic test point diagram changes based on your selection, in order to reduce setup errors.

- Test at the 'PHY Si' test point by using a measured S-parameter file to de-embed back to the transmitter pins
- Select TP2 and connector type to test at the device connector
- Select TP4_EQ to embed the standard's cable model and apply equalization



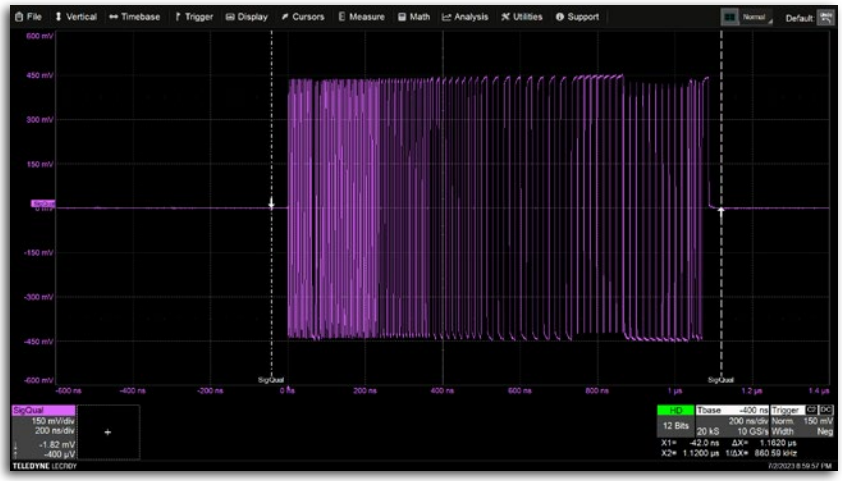
Select USB Measurements

USB-C technology specific measurements defined in the USB4, Thunderbolt, USB 3.2, and DisplayPort CTS (compliance test specifications) are accessible at a touch of a button in SDA Expert software.

- USB Transmitter Equalization (TxEq, TX-FFE) measurements
- USB Eye Testing - Eye Height, Eye Width, Eye Mask Testing
- Amplitude – ACCM (AC Common mode), Pk-Pk Voltage, SNDR
- Jitter – RJ, DJ, TJ, UJ, UDJ, OEJ
- SSC (Spread Spectrum Clock) – SSC Frequency Variation, SSC Rate, SSC Range

USB 2.0 ELECTRICAL PHY TEST SUITE AND DEBUG TOOLS

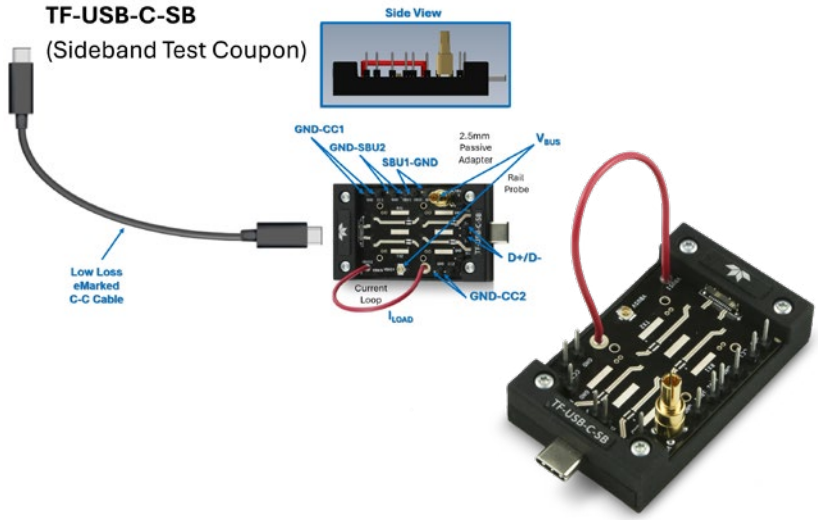
Teledyne LeCroy provides the oscilloscopes, automated compliance test software, active probes, and protocol layer tools for host, device and hub USB 2.0 electrical compliance and debug testing, whether implemented standalone or as part of a USB-C connector.



USB 2.0 Compliance

QPHY-USB test software implements a full set of USB-IF approved electrical tests for USB 2.0, including High-, Full-, and Low-speed tests.

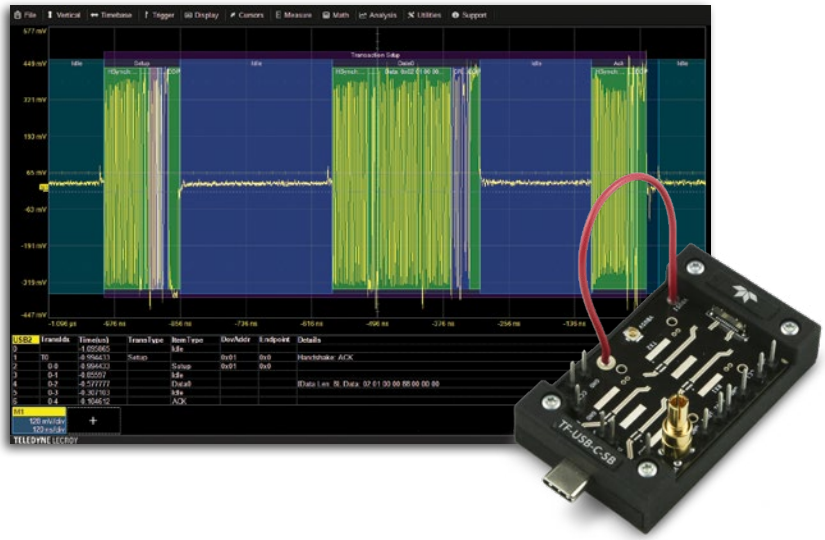
- Support for host, device, and hub testing
- Simple and easy-to-use automated testing
- Available TF-USB-B test fixture



Live Link Probing

Teledyne LeCroy test coupon fixtures permit live link probing of all signals at the USB Type-C connector.

- The TF-USB-C-SB USB4 Sideband Test Coupon Fixture provides USB 2.0 and USB4 sideband signal access (VBUS, USB 2.0 D+/D-, ILOAD, various ground signals)
- The TF-USB-C-HS adds access to high-speed Tx/Rx signals using DH Series Differential Probes



Protocol Trigger & Decode

Teledyne LeCroy offers a rich set of triggers and protocol decoders to debug interoperability failures using oscilloscope.

- USB 2.0 TDME – Trigger, Decode Measurements, Eye Diagram software
- HSIC D – High-speed Inter-Chip decode software for oscilloscopes
- USB 2.0 ProtoSync – Protocol analyzer software for a more detailed view of protocol traffic using the oscilloscope acquisition data
- Access USB 2.0 D+/D- live signal traffic using TF-USB-C-SB Sideband Test Fixtures

USB 2.0 ELECTRICAL PHY TEST SUITE AND DEBUG TOOLS



Oscilloscopes

Recommended Teledyne LeCroy oscilloscope models for USB 2.0 testing:

- WaveMaster 8000HD high-bandwidth oscilloscopes for USB-C for all USB-C testing (USB4, USB 3.2, and USB 2.0, Thunderbolt, DisplayPort) – an all-in-one test oscilloscope for all high-speed and low-speed signals
- WavePro HD oscilloscopes with up to 8 GHz of bandwidth for USB 2.0 compliance and USB-C sideband testing



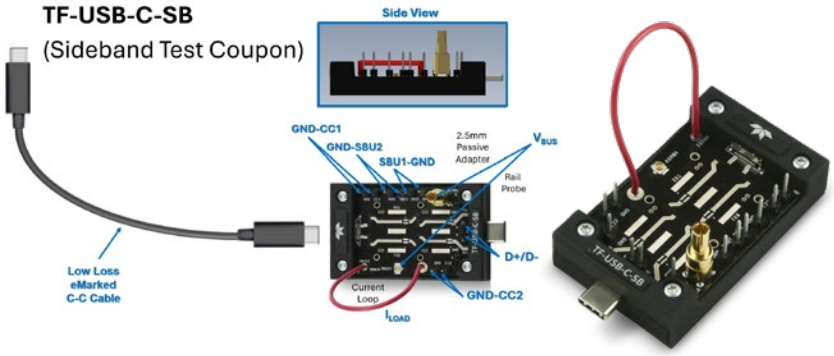
Protocol Analyzers

Recommended Teledyne LeCroy protocol analyzers for USB 2.0 testing:

- Advisor T3 – portable, affordable USB analyzer for USB 2.0 and 3.2
- Mercury T2P/T2C Pocket-sized USB Type-C and PD analyzer for USB 2.0, Power Delivery 3.2, SBU and DP AUX
- Mercury T2 classic USB analyzer for USB 2.0

USB TYPE-C POWER DELIVERY (USB PD)

USB Power Delivery (PD) signals are an integral part of the USB Type-C interface – proper correlation between PD events and other USB-C low-speed and high-speed signals must be established to ensure interoperability. Teledyne LeCroy supplies the full range of equipment for interoperability test - from electrical test and debug to protocol compliance.



Live Link Probing

Teledyne LeCroy test coupon fixtures permit live link probing and acquisition of all signals at the USB Type-C connector.

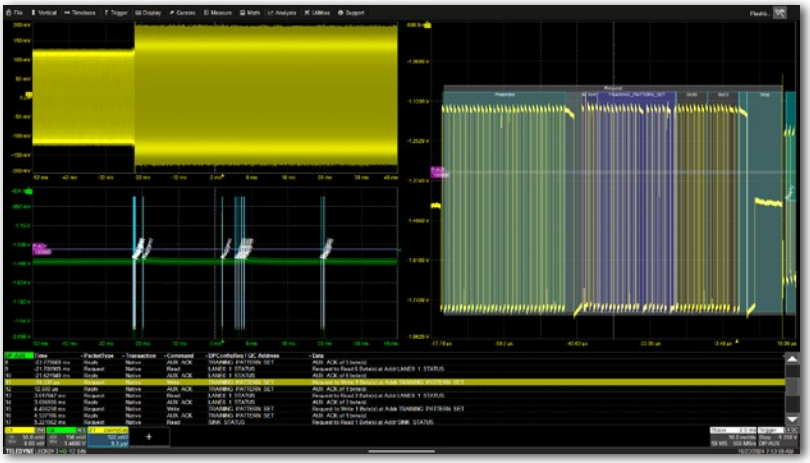
- The TF-USB-C-SB USB4 Sideband Test Coupon Fixture provides USB 2.0 and USB4 sideband signal access (VBUS, USB 2.0 D+/D-, ILOAD, various ground signals)
- The TF-USB-C-HS adds access to high-speed Tx/Rx signals using DH Series Differential Probes



USB PD Trigger & Decode

USB PD TDMP is the most comprehensive oscilloscope-based USB Power Delivery test solution.

- Access CC1/CC2, VBUS, and ILOAD using TF-USB-C-SB debug coupon
- Trigger – Trigger on PD preamble, ordered set, messages, and errors
- Decode - Decode SPR and EPR PD messages, Power Delivery Objects (PDOs), and more
- Measure/Graph and Physical Layer BMC Eye mask testing & measurements



DP AUX Trigger & Decode

DP-AUX TDMP is the most comprehensive oscilloscope-based DisplayPort AUX Channel test solution. It supports DisplayPort 2.0/1.4 and embedded DisplayPort (eDP) standards.

- Trigger and Decode DisplayPort AUX reads/ writes (native or I2C)
- DisplayPort AUX eye diagram PHY Compliance
- USB Type-C system level debug simultaneously with Main Link or USB Power Delivery



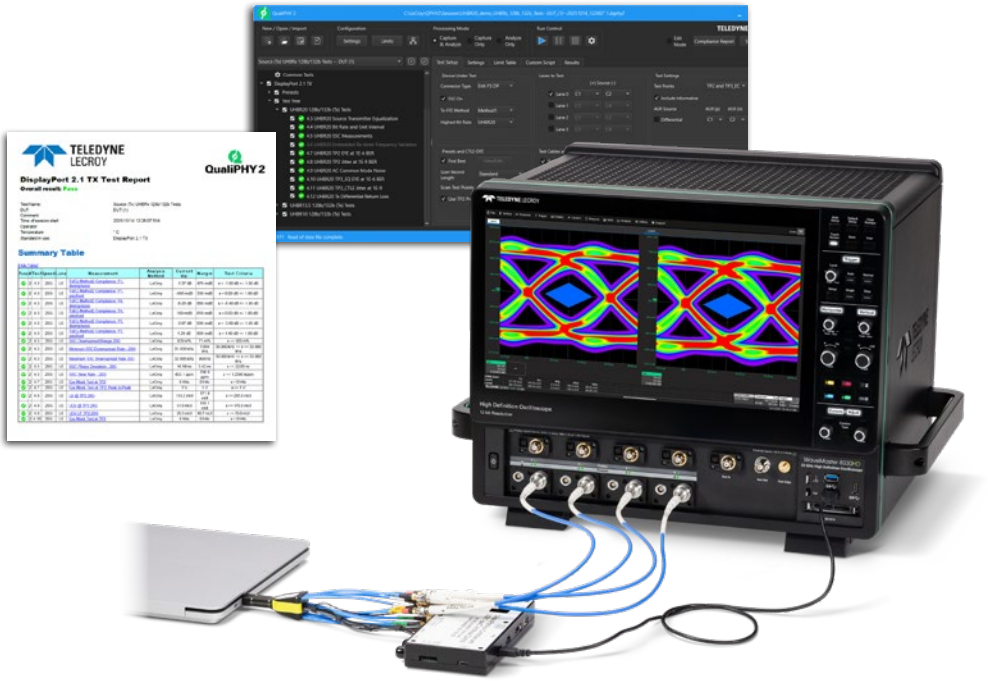
Protocol Analyzers

For DisplayPort AUX channel and DisplayPort main links.

- Mercury T2P/T2C Pocket-sized USB Type-C and PD analyzer for USB 2.0, Power Delivery 3.2, SBU and DP AUX
- DisplayPort and HDMI analyzers/generators

DISPLAYPORT TEST SOLUTIONS

VESA defines the DisplayPort PHY compliance test specification (CTS). The latest DisplayPort 2.1 version supersedes the legacy DisplayPort 1.4b and significantly increases data rates, creating more design challenges, PHY compliance test time, and likelihood of interoperability failures. Teledyne LeCroy DisplayPort 2.1 test solutions provide:



- PHY compliance source testing
- PHY compliance sink testing
- Interoperability validation with combined PHY and protocol debug

USB-C COMPLIANCE TEST SUPPORT

The Teledyne LeCroy WaveMaster 8000HD Oscilloscope, the Anritsu SQA-R MP1900A BERT, and the Teledyne LeCroy WavePulser 40iX Interconnect (Network) Analyzer with QualiPHY 2 automated compliance test software provides an all-In-one solution for characterization, compliance and debug. First-line support for the solution is available from the industry's most experienced USB-C field support team at Teledyne LeCroy.



WaveMaster 8000HD Oscilloscope

WaveMaster 8000HD oscilloscopes support all generations of USB and DisplayPort Tx/Rx testing, at all required bandwidths:

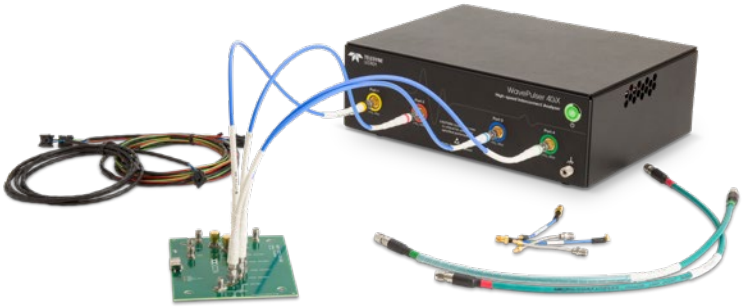
- 25 GHz for USB4, Thunderbolt and DisplayPort UHBR
- 16 GHz for USB 3.2 (Gen2) and DisplayPort HBR3
- 13 GHz for USB 3.2 (Gen1) and DisplayPort RBR/HBR/HBR2
- All models support USB 2.0



BERT

The Anritsu SQA-R MP1900A Signal Quality Analyzer high-speed BERT has the highest signal quality for the most repeatable results.

- Jitter and noise generation for all Sink and Rx calibration and BER testing
- High quality waveform PPG with integrated 10-tap emphasis
- LTSSM loopback and Error detector with variable CTLE for USB 3.2 Rx testing



Network Analyzer

The WavePulser 40iX Interconnect Analyzer makes network analysis S-parameter measurements for USB-IF required return loss and Rx channel measurements.

- Tx/Rx Test Cable De-Embed
- iTx/Rx Return Loss
- Rx Channel Measurements)



Compliance Test Software

QualiPHY 2 software options fully automate all aspects of USB-C PHY Tx, Rx and Return Loss compliance testing. Teledyne LeCroy provides full application support.

- Transmitter (Source) Testing and Receiver (Sink) Compliance Testing
- Return Loss Compliance Testing
- Sideband (USB4-SB and DP-AUX) Compliance Testing
- Report generation

QPHY2-USB4-TX-RX TRANSMITTER COMPLIANCE TESTS

USB4 Version 2 (Gen4) Transmitter Compliance Test Specification (CTS)

PAM3 Data Rate	USB4v2/TBT5: 25.6 Gbaud, 40G bps	
Lane Count	2 (Symmetric), 3 (Asymmetric)	
Max (3 Lane) Link Rate	120 Gbps	
Device Types	**Router Assembly**	**Captive Cable**
	CTS Section	CTS Section
S-Parameter Measurements*		
Transmitter Test Cable De-Embed	3.1	3.1
Transmitter Differential Return Loss	3.5.1 (Informative)	N/A
Transmitter Integrated Return Loss	3.5.2	N/A
Transmitter Test Tree:		
Oscilloscope Ch-Ch Deskew Pretest	3.1	3.1
Aggressor Check Pretest	1	
Source Transmitter Equalization	3.3.1	5.3.1
Transmitter Timing and Voltage	3.3.2	5.3.2
Transmitter Electrical Idle Voltage	3.3.4	5.3.4
Transmitter AC Common Mode	3.3.5	5.3.5
Transmitter RF Interference	N/A	5.3.6
Transmitter Return Loss*	3.3.6	N/A
Transmitter Integrated Return Loss*	3.3.7	N/A
LFPS Aggressor Check	•	•
Transmitter LaFPS	3.3.8	3.3.8

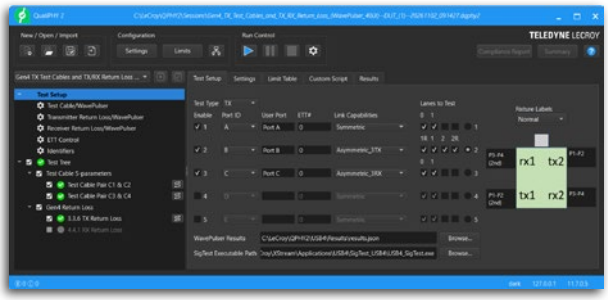
USB4 Version 1 (Gen2/Gen3) Transmitter Compliance Test Specification (CTS)

NRZ Data Rates	USB4v1: 10 Gbps, 20 Gpbs (Required) TBT4: 10.125 Gpbs, 20.25 Gpbs (Optional)	
Lane Count	2 (Symmetric Only)	
Max (2 Lane) Link Rate	USB4v1: 40 Gbps TBT4: 40.5 Gbps	
S-Parameter Measurements*		
Transmitter Test Cable De-Embed	3.1	3.1
Transmitter Differential Return Loss	3.5.1	N/A
Transmitter Common Mode Return Loss	3.5.2	N/A
	Router Assembly	**Captive Cable**
	CTS Section (Gen2 / Gen3)	
Transmitter Test Tree		
Oscilloscope Ch-Ch Deskew Pretest	•	•
Transmitter Preset Calibration	Appendix B2	
Transmitter Equalization	3.3.1 / 3.4.1	
Minimum Unit Interval	3.4.1 / 3.4.2	
Transmitter SSC Measurements	3.3.3.6-8 / 3.4.6-8	
Transmitter Frequency Variation Training	3.3.7 / 3.4.7	
Transmitter Rise/Fall Time	3.3.8 / 3.4.8	
Transmitter Electrical Idle Voltage	3.3.9 / 3.4.9	
Transmitter AC Common Mode	3.3.10 / 3.4.10	
Transmitter Jitter Measurements	3.3.11-15 / 3.4.11-15	
Transmitter Eye Diagram Measurement	3.3.16 / 3.4.16	
Wireless Band Conducted Measurement	N/A	3.3.17 / 3.4.17
Transmitter Differential Return Loss *	3.5.1	
Transmitter Common Mode Return Loss *	3.5.2	
SBTX Measurements **	5.1.1-5.1.3	
SBRX Measurements ***	5.1.5-5.1.6	

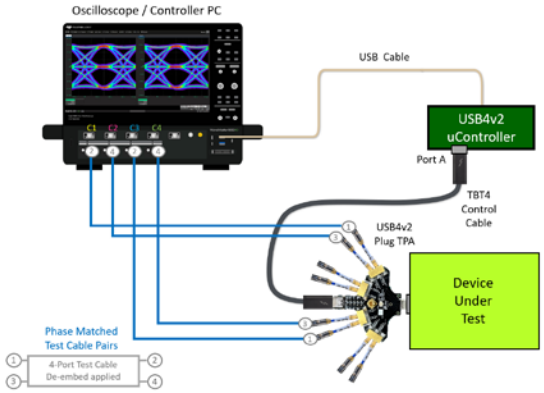
* *Automated using WavePulser 40iX Interconnect Analyzer (recommended), Imported Touchstone files also supported*

** *Requires USB4-SB TDMP Software Option*

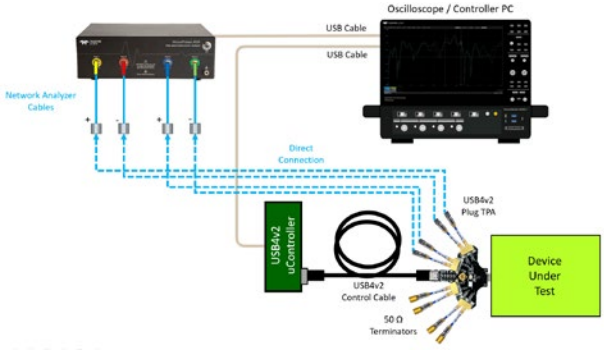
*** *Test Under Development*



USB4v2 Transmitter Test Tree and Setup



USB4 Transmitter Connection Diagram



USB4 Transmitter Return Loss Connection Diagram

QualiPHY 2 Key Automation Features

- Unified Tx/Rx and S-parameter compliance for USB4 and Thunderbolt (Gen2/Gen3/Gen4)
- Multi-lane analysis, compliance, and debug
- Gen4 Automation - Port Assignment (up to five ports), Link Capability (Symmetric Asymmetric), Dynamic Fixture Connections, Aggressor Check
- Test Cable De-Embed Method (WavePulser Automation or Touchstone File Import)
- USB-IF ETT (Electrical Test Tool) and SigTest Support
- Best Preset Identification (User Defined or Scan for Best)

Reduce Test Time

- Select Processing Mode (Capture & Analyze, Capture Only, Analyzer Only)
- Specify Preset Range (P0-P41) and Record Length
- Post-process offline using QPHY2-PC (Analyze Only) for up to 3X efficiency improvement
- DUT Control (USB4v2 Controller, USB4v1 Controller, Manual)

Advanced Automation

- Remote automation control over Ethernet
- Host Program Control provides remote interface for higher-level automation
- Python based Advanced Test Control enables customized looping and pre- and post-test functions, ideal for PVT testing

QPHY2-USB4-TX-RX RECEIVER COMPLIANCE TESTS

USB4 Version 2 (Gen4) Receiver Compliance Test Specification (CTS)

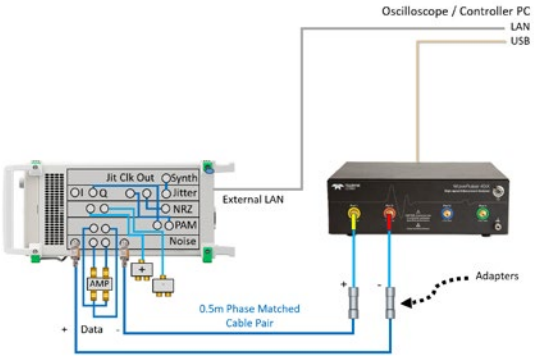
PAM3 Data Rate/Lane		
USB4 and Thunderbolt	25.6 Gbaud	
Device Types	**Router Assembly** CTS Section	**Captive Cable** CTS Section
S-Parameter Measurements*		
Receiver Test Cable De-Embed	N/A	N/A
BERT Return Loss Compensation	4.1.4.1	4.1.4.1
Worstcase Cable Insertion Loss	4.1.4.2	N/A
Receptacle Fixture De-Embed (using 2X Thru)	4.1.4.2	N/A
Total Channel Insertion Loss	4.1.4.3	6.1.3
Receiver Differential Return Loss	4.4.1 (Informative)	N/A
Receiver Integrated Return Loss	4.4.2 (Informative)	N/A
Receiver Test Pretests		
Oscilloscope Ch-Ch Deskew Pretest	4.1	6.1
BERT AC Common Mode ACCM & EOJ	•	•
Preset Coefficient Calibration	•	•
BERT Insertion Loss Compensation*	4.1.4.1.3.2, 3	4.1.4.1.3.2, 3
Receiver Stressed Signal Calibrations		
Aggressor Calibration and Verification	•	•
Case1 short channel (Swing, Mismatch, ACCM, PJ, RJ)	4.1.2	6.1.2
Case2 long channel (Swing, Mismatch, ACCM, PJ, RJ)	4.1.3	N/A
Worstcase Channel Calibration* and Operating Margin	4.1.4	N/A
Retimer Frequency Variation Calibration	4.5.1, 4.5.2	N/A
PAM3 Trit Error Rate (TER) Tests		
Receiver TER Test (Case1, Case2)	4.2.2, 4.2.3	•
Retimer Frequency Variation TER (Case1, Case2)	4.5.1, 4.5.2	N/A

* Automated using WavePulser 40iX Interconnect Analyzer (recommended), Imported VNA touchstone files also supported

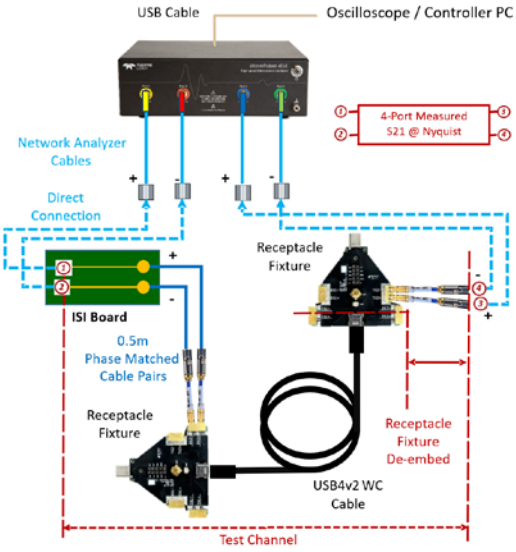
USB4 Version 1 (Gen2/Gen3) Receiver Compliance Test Specification (CTS)

NRZ Data Rates		
USB4	10 Gbps, 20 Gpbs (Required)	
Thunderbolt 4	10.125 Gpbs, 20.25 Gpbs (Optional)	
Device Types	**Router Assembly** CTS Section (Gen2 / Gen3)	**Captive Cable**
S-Parameter Measurements*		
Receiver Test Cable De-Embed	4.1	4.1
Worstcase Cable Insertion Loss	4.2.2 (Appendix B)	N/A
Total Channel Insertion Loss	4.2.2 (Appendix B)	N/A
Receiver Differential Return Loss	4.6.1	4.6.1
Receiver Common Mode Return Loss	4.6.2	4.6.2
Receiver Test Pretests		
Oscilloscope Ch-Ch Deskew Pretest	•	•
Preset Coefficient Calibration	•	•
Receiver Stressed Signal Calibrations		
TP3' Calibration - Test Case 1 (DDJ, ACCM, RJ, PJ, TJ, Eye)	4.2.1	4.2.1
TP3 Calibration - Test Case 2 (Eye Diagram)	4.2.2	N/A
Retimer Frequency Variation Calibration	4.5.1, 4.5.2	6.5.1
NRZ Bit Error Rate (BER) Tests		
Test Case1 BER at TP3'	4.3.1	4.3
Test Case2 BER at TP3	4.3.2	N/A
Retimer Frequency Variation BER	4.5.3, 4.5.4	4.5

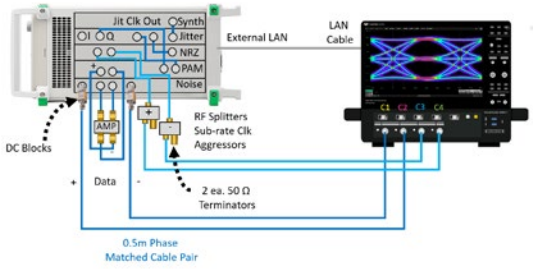
* *Automated using WavePulser 40iX Interconnect Analyzer (recommended), Imported Touchstone files also supported*



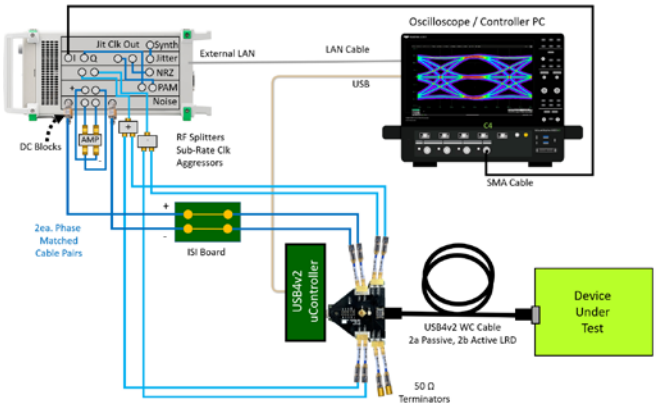
USB4v2 BERT_IL Measurement



USB4v2 Total Channel Calibration



USB4v2 Short Channel Calibration



USB4v2 TER Test

RECOMMENDED TRANSMITTER TEST EQUIPMENT

Product Description		Product Code
	Required for Teledyne LeCroy USB4 (Gen4, Gen3, Gen2) Tx Compliance Method of Implementation (MOI)	
DUT Max Data Rate Oscilloscope Performance	USB4v2 Gen4 (80 Gbps, 25.6 GBaud PAM3) Min 33 GHz oscilloscope (required to provide 25 GHz bandwidth filter response defined in USB4v2 CTS)	WaveMaster/SDA 8330HD (or above)
	USB4v1 Gen2/Gen3 (20.625, 20, 10.3125, and 10 Gbps NRZ) Min 25 GHz oscilloscope (21 GHz bandwidth required by the USB4v1 CTS)	WaveMaster/SDA 8250HD (or above)
Compliance Software	QualiPHY 2 Enabled USB4 Transmitter and Receiver Compliance Software	QPHY2-USB4-TX-RX
	USB4 SB Decode, Measure/Graph and Physical Layer (TDMP)	USB4SB TDMP
Network Analyzer	WavePulser 40iX Interconnect Analyzer - For Instrument Test Cable de-embed and USB4 (Tx/Rx) Return Loss	WavePulser 40iX
USB4 Micro-Controller Select one (refer to MOI for detail)	Wilder Technologies USB4 V2 (Gen4/Gen3/Gen2) (Microcontroller + Accessories)	*USB4-V2-uCTRLR or Equivalent*
	Wilder Technologies TB Microcontroller USB4 (Gen3/Gen2)	*USB4-TPA-UC*
USB4v1 TPA Test Fixtures	Wilder Technologies USB4v1 Kit - USB4 Type C Test Fixture Compliance ECBs	*USB4-TPAC-TF-LSX-CBL-FK*
USB4v2 TPA Test Fixtures Select One	LuxShare ICT USB4v2 Plug Kit - USB4 V2 Transmitter Test Set	LL-USB4V2-PC-A Contact Local LuxShare ICT Distributor
	Wilder Technologies USB4v2 Kit - USB4-V2-PR-K (Plug & Receptacle kit + Accessories)	*USB4-V2-PR-K*
Test Instrument Cables	2 ea. 1m 2.92 K-K matched pairs (2 cables per pair) Max IL in 10 GHz < 1.5dB, Phase matched max of ±5° @ 40 GHz	Rosenberger LU1-502-1000_V2 or equivalent
Teledyne LeCroy USB4 MOI	QPHY2-USB4-TX-RX Instructions Manual and Method of Implementation	*Download MOI*
	Recommended hardware and software options for USB4 signal integrity and Link/Interop debug	
Expert Analysis Software	USB4_TBT SDA Expert (SDAX) serial data analysis software	SDAX-USB4_TBT
Multi-Lane Analysis Software	For Multi-lane Jitter and Eye diagram testing on NRZ, PAM3, PAM4 signal	SDAX-COMPLETE
USB Type-C Debug Coupon	USB4 High-speed and Sideband Test Coupon Fixture	TF-USB-C-HS
High Speed Diff Probe(s)	25 GHz differential probe with ProAxial interface (one per lane tested)	DH-25-PX
USB4 CrossLayer Debug	USB CrossSync PHY protocol analyzer synchronization software for WaveMaster/SDA and M4x	CROSSSYNC-PHY-USB
USB4 PHY-Logic Debug	USB4 Bus Decode, Measure, and Eye Software	USB4Bus DME
USB ProtoSync	Adds USB Protocol Analyzer software to USB4, USB 3.2, USB 2.0 Decode options	ProtoSync
	Additional recommended probing and software options for other USB Type-C Technology Testing *Refer to individual technology datasheets for details*	
DisplayPort PHY Compliance	DisplayPort PHY Source-Tx and Sink-Rx Compliance Software	QPHY2-DP2-SOURCE-TX QPHY2-DP2-SINK-RX
AUX Trigger, Decode, EYE	DisplayPort AUX Decode, Measure/Graph and Physical Layer (TDMP)	DPAUX TDMP
Differential Active Probe	Differential Probe for DisplayPort AUX and USB 2.0 debug	ZD-1500
USB-PD Trigger and Decode	USB Power Delivery Trigger, Decode, Measure/Graph and Physical Layer (TDMP)	USBPD TDMP
Current Probe	30A, 50 MHz High Current Probe for USB Power Delivery measurements	CP030B
USB 3.x PHY Compliance	QualiPHY Enabled USB4 Tx/Rx Compliance Software	QPHY-USB3.2-TX-RX
USB 3.x CrossLayer Debug	USB CrossSync PHY protocol analyzer synchronization software for WaveMaster/SDA and M4x	USB-CROSSSYNC-PHY
USB 3.x PHY-Logic Debug	USB 3.2 Bus Decode Software	USB3Bus D
USB 2.0 Compliance	QualiPHY Enabled DisplayPort2 Compliance Source (Tx) Software	QPHY-USB
USB 2.0 PHY-Logic Debug	USB 2.0 Trigger, Decode, Measure/Graph and Physical Layer (TDME)	USB2Bus TDME

RECOMMENDED USB4 RECEIVER TEST EQUIPMENT

Product Description		Product Code
	Required for Teledyne LeCroy USB4 (Gen4, Gen3, Gen2) Rx Compliance Method of Implementation (MOI)	
DUT Max Data Rate Oscilloscope Performance	USB4v2 Gen4 (80 Gbps, 25.6 GBaud PAM3) Min 33 GHz oscilloscope (required to provide 25 GHz bandwidth filter response defined in USB4v2 CTS)	WaveMaster/SDA 8330HD (or above)
	USB4v1 Gen2/Gen3 (20.625, 20, 10.3125, and 10 Gbps NRZ) Min 25 GHz oscilloscope (21 GHz bandwidth required by the USB4v1 CTS)	WaveMaster/SDA 8250HD (or above)
Compliance Software	QualiPHY 2 Enabled USB4 Transmitter and Receiver Compliance Software	QPHY2-USB4-TX-RX
Anritsu MP1900A Configuration:	Signal Quality Analyzer Mainframe	MP1900A
	12.5 GHz 4 port Synthesizer	MU181000A/B
for USB4v1 (Gen2/Gen3)	Jitter Modulation Source	MU181500B
	1 ea. 1m K-SMA Cable for clock switch cross-trigger (for re-timer DUT only)	
(refer to MOI for detail)	21G/32G bit/s NRZ PPG 1ch or 2ch data output, 10 Tap Emphasis	MU195020A Option 010/011
	Noise Generator	MU195050A
Added for USB4v2 (Gen4)	PAM PPG (with Amplifier and crosstalk hardware below)	MU196020A Option -45
(refer to MOI for detail)	56 GBaud Differential Amplifier	AH54192A
	2 ea. Matched Cable Pairs (0.4m, V connector)	J1789A
	2 ea. 6 dB Attenuators	J1888A
	1 ea. Matched Cable Pair (V-K)	J1792A
	1 ea. Matched Cable Pair (0.6m, K connector)	J1949A
	CrossTalk Aggressor Hardware (used with MU19502A):	
	2ea. Matched Cable Pairs (0.8m, V K connector)	J1821A
	2ea. RF Splitters	J1748A
	4ea. Matched Cable Pairs (0.8m, V K connector)	J1821A
DC Blocks	2 ea. Matched Pair 40 GHz DC Blocks Phase matched max of ±5° @ 40GHz	HyperLabs HL8334-220-JP-M or Anritsu K261
Test Instrument Cables	2 ea. Matched Cable Pairs (0.5m, K-K) Max IL in 10 GHz < 1.5dB, Phase matched max of ±5° @ 40 GHz	Rosenberger LU1-502-500P1 or Anritsu J1551A
Network Analyzer	WavePulser 40iX Interconnect Analyzer - For Test Cable de-embed, BERT Return Loss, Rx Return Loss, and Rx Channel Calibration	WavePulser 40iX
USB4 Microcontroller Select one	Wilder Technologies USB4 V2 (Gen4/Gen3/Gen2) (Microcontroller + Accessories)	*USB4-V2-uCTRLR or Equivalent*
(refer to MOI for detail)	Wilder Technologies USB4 Microcontroller (Gen3/Gen2)	*USB4-TPA-UC*
USB4v1 TPA Test Fixtures	Wilder Technologies USB4v1 Kit: USB4 Type C Test Fixture Compliance ECBs	*USB4-TPAC-TF-LSX-CBL-FK*
USB4v2 TPA Test Fixtures Select One	LuxShare ICT USB4v2 Full Kit USB4 V2 Transmitter + Receiver Test Set	LL-USB4V2-PRC-A Contact Local LuxShare ICT Distributor
	Wilder Technologies USB4v2 Kit USB4-V2-PR-K (Plug & Receptacle kit + Accessories)	*USB4-V2-PR-K*
USB4 Rx MOI	QPHY2-USB4-TX-RX Instructions Manual and Method of Implementation	*Download MOI*

Customer Service

Teledyne LeCroy oscilloscopes and probes are designed, built, and tested to ensure high reliability. In the unlikely event you experience difficulties, our digital oscilloscopes are fully warranted for three years and our probes are warranted for one year.

This warranty includes:

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

TELEDYNE | LECROY

1-800-5-LeCroy
teledynelecroy.com

Local sales offices are located throughout the world.
Visit our website to find the most convenient location.

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