PROTOCOL INSIGHT

Protocol Insight®

Falcon G500C / G550C Instruments

UFS/UniPro Analyzers and Exerciser/Analyzers with Trace Validation™

Protocol Insight are the UFS and UniPro market leaders for protocol analysis and traffic generation and have been shipping UFS and UniPro debug and analysis tools since 2014.

Protocol Insight are the UFS, UniPro and M-PHY protocol experts.

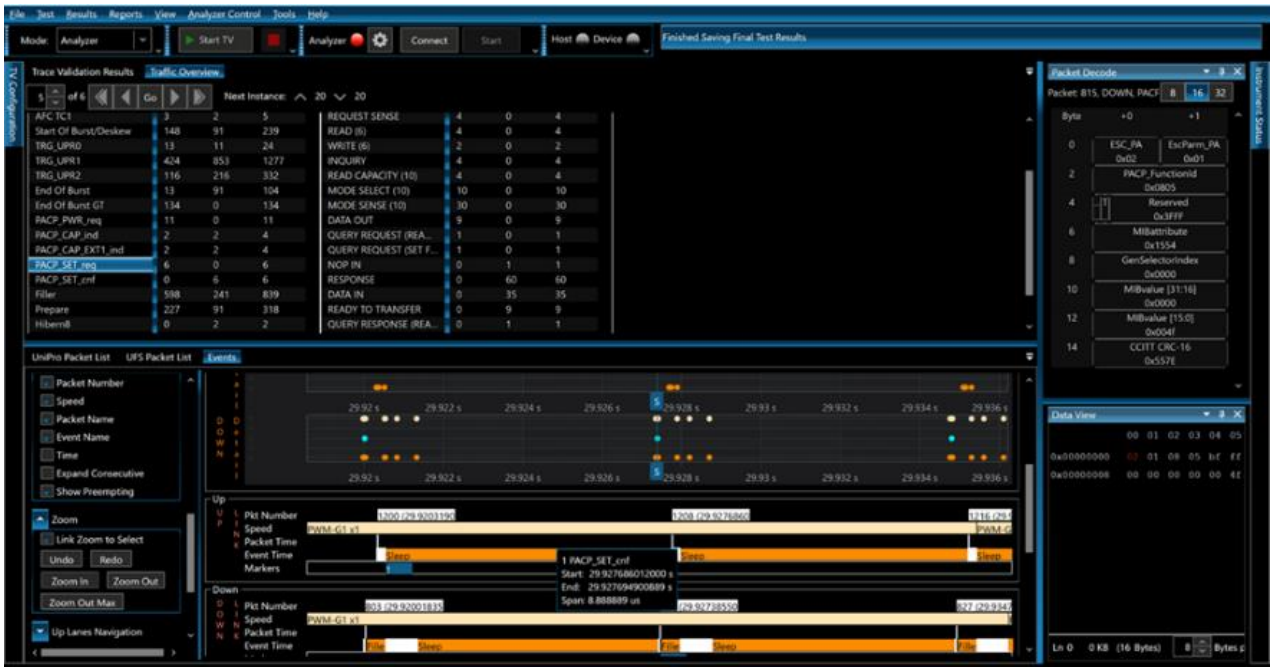
We are a contributing company to the development of the UniPro specs and Conformance Test Specs (CTS), and a member of the JEDEC J64 Embedded Memory Storage and Removable Memory Card committee.

Protocol Insight offers the only protocol test tool for verifying compliance to the UFSA Compliance Test Matrix and have supported all UniPro and UFS Interoperability (IOT) workshops since the initial events in early 2015.

Protocol Insight offers unsurpassed product leadership.

Capabilities included with the Falcon series of instruments include:

- Smart Tune™ equalization for continuous equalization of the PHY with every burst.
- Trace Validation™, a patented Artificial intelligence (AI) tool that uses complex state machine logic to analyze traces algorithmically without user inference.
- Streaming capture uses the full 40Gb/s bandwidth of Thunderbolt™ 3 to save traces to disk in real time.
- Events views displays raw symbols as packet events in a unique time-aligned display and presents a complete picture of all events with drill-down to the lowest level bytes.
- Protocol generation and exerciser capability for both UFS and UniPro.
- Test Editors for creation of custom trigger, Trace Validation, and stimulus tests.



Analyzer debugging a PACP_SET command using Events window and Traffic Overview

Product Family Description

The Falcon series of UniPro/UFS Protocol Analyzers/Exercisers are the established industry standard with powerful protocol analyzer and exerciser capabilities and unprecedented flexibility.

- The **Falcon G500C** is an analyzer that can capture x2 bi-directional links as a “sniffer”. It supports UFS 4.0, UniPro 2.0 and M-PHY 5.0 HS-G5.
- The **Falcon G500C – G4** is an analyzer that can capture x2 bi-directional links as a “sniffer”. It supports UFS 3.1, UniPro 1.8 and M-PHY 4.1 HS-G4. The G500C – G4 can be field upgraded to support UFS 4.0 and M-PHY HS-G5.
- The **Falcon G550C** is an exerciser/analyzer; it is identical to the G500C analyzer but is also a protocol exerciser that can generate link traffic on a x2 bi-directional link while simultaneously capturing the response traffic from the DUT. The Falcon G550C exerciser can perform host emulation and execute the UniPro and JEDEC Compliance/Conformance Test Suites (CTS).
- The **Falcon G550C – G4** exerciser/analyzer is identical to the G500C – G4 analyzer but is also a protocol exerciser that can perform host emulation and execute the UniPro 1.8 and JEDEC JESD224A Compliance/Conformance Test Suites (CTS). The G550C – G4 can be field upgraded to execute future UniPro 2.0 and UFS 4.0 Compliance/Conformance Test Suites (CTS).

Key Features and Benefits

Smart Tune equalization optimizes signal acquisition at the analyzer to ensure error-free MPHY symbol capture. This is critical when the DUT has poor trace routing, or the cabling to the test fixture causes signal integrity or probing issues.

Eye Monitor constructs an eye diagram of the link to determine link quality. Qualitative measurements can be done on the eye diagram for jitter, noise, and eye opening.

Trace Validation is an expert system that uses complex state machine logic to analyze captured traces algorithmically without user intervention. It analyzes bi-directional UniPro and UFS traffic, performing protocol sequence and timing analysis and packet header and payload inspection.

Events views displays raw UniPro symbols as packet events on the bus in a unique time-aligned display. UniPro Events view displays fillers, Prepare, SYNC, Hibern8, sleep, stall and other M-PHY level packets. UFS Events displays each individual UFS packet type separately. UniPro and UFS Events views presents a complete picture of all events and allows drill-down to the lowest level bytes.

Compliance/Conformance Verification executes JEDEC and MIPI CTS test cases. Performs corner case, margin, and stress testing. Users are able to create custom test cases.

Verify compliance of UFS devices with the UFSA UFS Compliance Test Matrix. UFSA-certified for the UFSA Compliance Test Matrix v1.3.

Stimulus with full UniPro stack in HW allows host emulation and the creation of specific traffic on the link and offers extensive error injection.

Run Time Control stress testing controls the DUT and executes tests automatically. Stop after any number of loops or No Result Test Cases, then analyze the results with Trace Validation.

Design custom test cases to introduce errors for corner case, margin, or stress testing.

Streaming capture uses the full 40Gbs bandwidth of Thunderbolt 3 to store link traffic directly to disk in real time. The internal capture memory buffer is configurable; the base instrument ships with 8GB of capture memory and this can be field upgraded to 30GB.

Smart Tune™ Equalization[1]

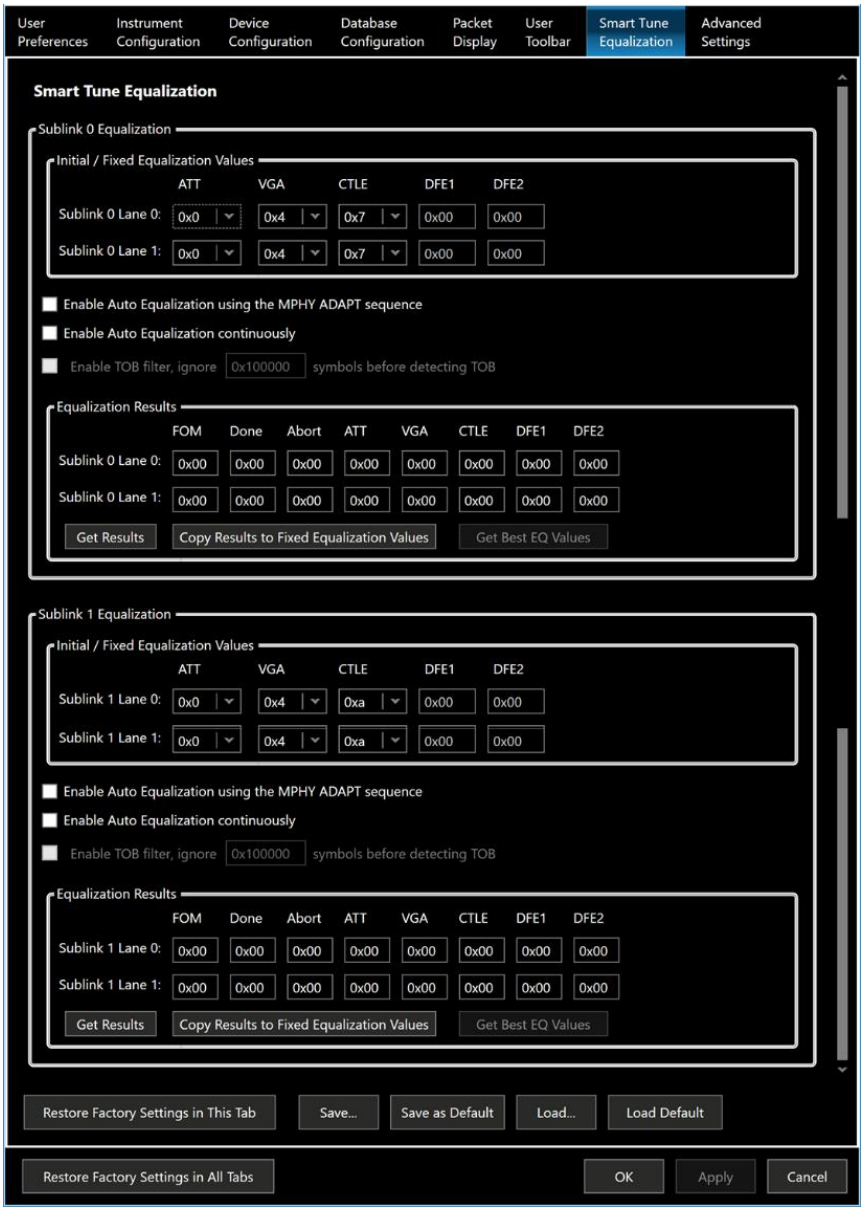
In some instances, acquiring the signal from the DUT can be problematic when test fixture trace routing or the cabling required to connect to the test fixture causes poor signal integrity or probing issues.

To optimize signal acquisition the Falcon series offer **Smart Tune™ equalization** capability. Smart Tune allows the user to choose between setting fixed equalization values manually for the front-end PHY, auto equalizing using the M-PHY ADAPT capability or running auto equalization continuously every time a Burst is opened on the link.

To **set equalization values manually** individual values can be entered in the Sublink 0 and Sublink 1 Initial/Fixed Equalization Values section or saved values can be loaded from a file.

To implement **auto equalization using ADAPT** select *Enable Auto Equalization using the MPHY ADAPT sequence,* then execute a Link Startup Sequence on the DUT and run the ADAPT sequence between the Host and Device.

To run **auto equalization continuously** select *Enable Auto Equalization continuously* and then execute a Link Startup Sequence on the DUT and change power mode.



With Auto Equalization Falcon will calculate and load the optimal ATT (Attenuation), VGA (variable-gain amplification), CTLE (continuous time linear equalization), and DFE (decision feedback equalization) values into the PHY. This capability supports all HS modes, including HS-G1 to HS-G5.

[1] Actual capability and implementation may vary between v2.6 and v3.0 FW/SW

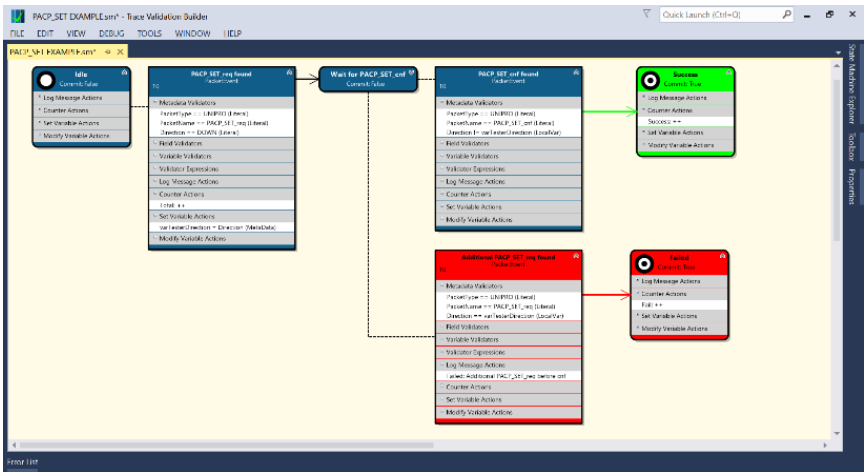
Streaming Capture

Streaming capture uses the full 40Gbs bandwidth of Thunderbolt 3 to store link traffic directly to disk in real time. As a trace is captured it is buffered through the instrument memory to the controller PC's system RAM and then saved to the SSD disk.

Streaming performance is dependent on a verity of factors including M-PHY gear, PC load, SSD speed, link bandwidth utilization and hardware filtered packets. To increase streaming efficiency the pre-capture hardware filter should be used to throw out as many unnecessary packets as possible before transmission over the Thunderbolt 3 interface. Contact your sales representative for more details on this feature.

Trace Validation

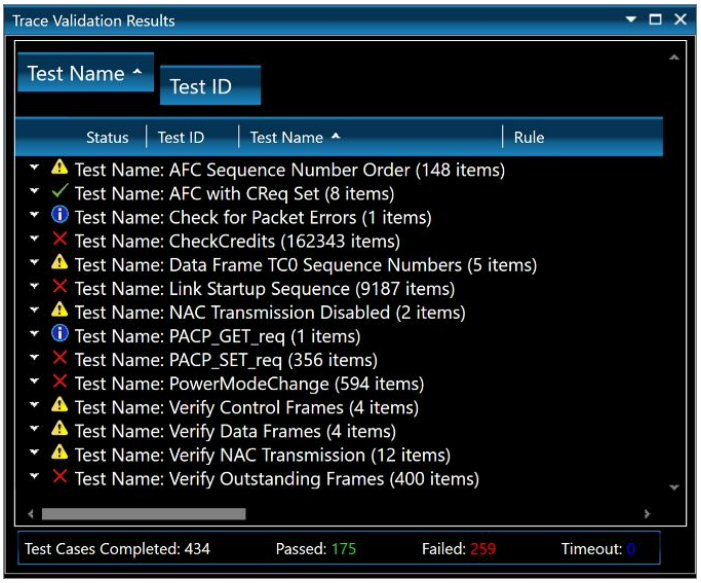
Trace Validation identifies transactions on the link by analyzing millions of packets in a trace capture, then evaluates the complete protocol sequences and individual packets for conformance to the specification.



With Trace Validation, complex transactions such as power mode changes, Link Startup Sequence and NAC/Replay events can be automatically analyzed and easily debugged. Complex measurements such as UFS packet latency can also be performed and evaluated against pass/fail metrics.

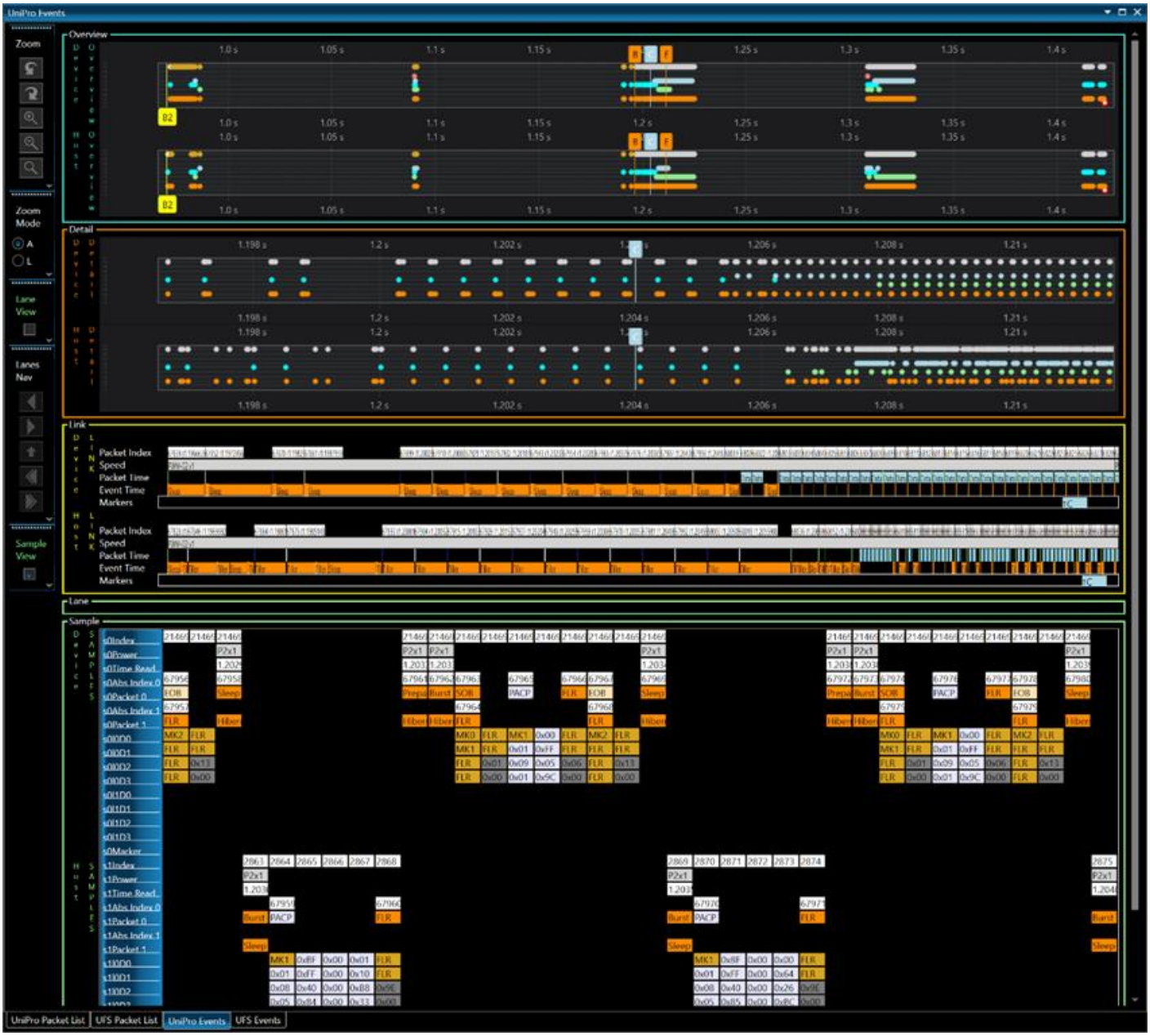
Trace Validation results are flagged as follows:

- Failure ✕ and Warning ⚠ status flags
  - A Failure is a transaction or packet that does not meet a defined primary rule. This rule may be defined by the JEDEC JESD224x CTS, UniPro CTS or by the user.
  - A Warning is a transaction or packet that does not meet a defined secondary rule. This rule may be defined by the JEDEC JESD220x spec, UniPro spec or by the user.
- Pass ✓ and Info ⓘ and Debug 🔍 status flags
  - Any transaction or packet that conforms the rule set is marked as Pass
  - Any packets not inspected due to run conditions are highlighted and explained with the Info flag
  - Information on state machine execution of an inspection rule can be provided with Debug messages



Events Views

UniPro and UFS Events views complement the Packet List windows, showing all events on the bus in both directions in one single snapshot linked to the selected packet and bookmarks. Zooming in on any event or series of events will show the time-aligned packet data and expanded packet information in detail down to raw trace K-Code information, including the One Hot and Hex values.



UniPro Events view

Compliance/Conformance Verification

The Falcon G550C and G450C can execute UFS and UniPro compliance test spec (CTS) tests, using Trace Validation to verify that the resulting protocol sequences and packets conform to the CTS. The CTS for UniPro 1.8 and the JEDEC JESD224A CTS are supported. Preliminary CTS support for UFS 3.1 is included and UFS 4.0 is planned.

Extensive reporting and analysis tools include reports by test parameters – status, individual tests, or test rules, and within tests by packet characteristics such as packet number, byte, speed, link, etc. Summary and full reports and pass/fail reports are also provided.

Falcon also supports device verification with the UFSA Compliance Test Matrix.

Pass/fail analysis using Trace Validation Results

Stimulus with full UniPro stack in HW

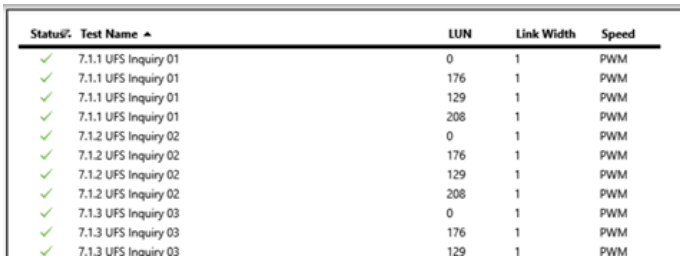
The Falcon G500C/G550C utilize a full UniPro stack embedded in hardware so the user can:

- Emulate a host
- Create specific traffic on the link
- Put the DUT into known states
- Insert errors into the UniPro or UFS traffic stream
- Create custom stimulus sequences to execute complex events, such as NAC Conditions or Power Mode Changes
- Automate with Run Control for stress testing

Run Time Control

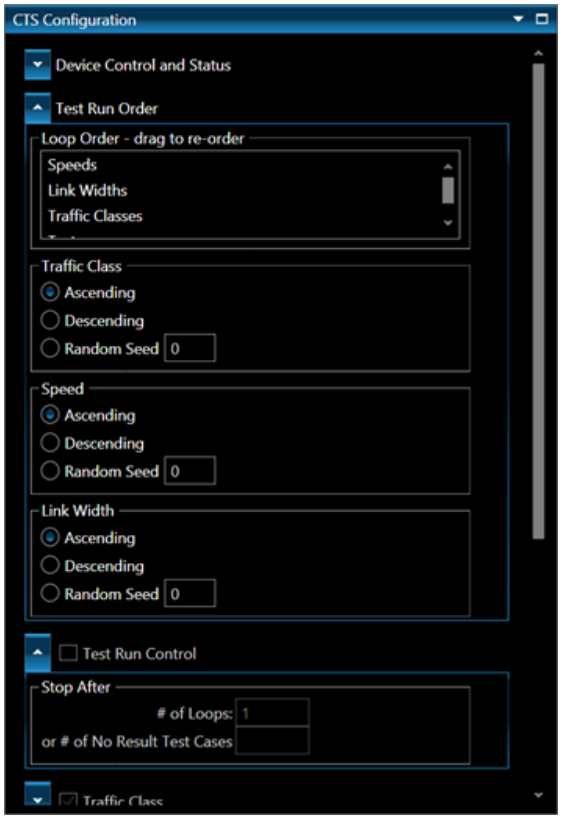
The run time control capability included with the G550C Exerciser/Analyzer can be used for compliance and conformance testing and for stress, margin and corner case automated testing:

- UFS device CTS compliance
  - Verifies test cases defined in JESD224 for JESD220B.
  - Verifies test cases defined in JESD224A for JESD220B, JESD220C and JESD220-2.
  - Preliminary test cases for UFS 3.1 JESD220D, JESD220E and JESD220-2A have been added.
  - Preliminary test cases for UFS 4.0 will be added.



Status	Test Name	LUN	Link Width	Speed
✓	7.1.1 UFS Inquiry 01	0	1	PWM
✓	7.1.1 UFS Inquiry 01	176	1	PWM
✓	7.1.1 UFS Inquiry 01	129	1	PWM
✓	7.1.1 UFS Inquiry 01	208	1	PWM
✓	7.1.2 UFS Inquiry 02	0	1	PWM
✓	7.1.2 UFS Inquiry 02	176	1	PWM
✓	7.1.2 UFS Inquiry 02	129	1	PWM
✓	7.1.2 UFS Inquiry 02	208	1	PWM
✓	7.1.3 UFS Inquiry 03	0	1	PWM
✓	7.1.3 UFS Inquiry 03	176	1	PWM
✓	7.1.3 UFS Inquiry 03	129	1	PWM

- UniPro CTS conformance
  - Verifies test cases as defined in the UniPro 2.0 CTS.



- UniPro and UFS device spec conformance
  - Trace Validation engine evaluates UniPro and UFS protocol sequences, “shall” statements and logical requirements.

- Custom test cases
  - Create stimulus and Trace Validation analysis test cases
  - Executable with Run Control
  - Build tests from scratch, or use existing CTS and debug tests cases as a starting point

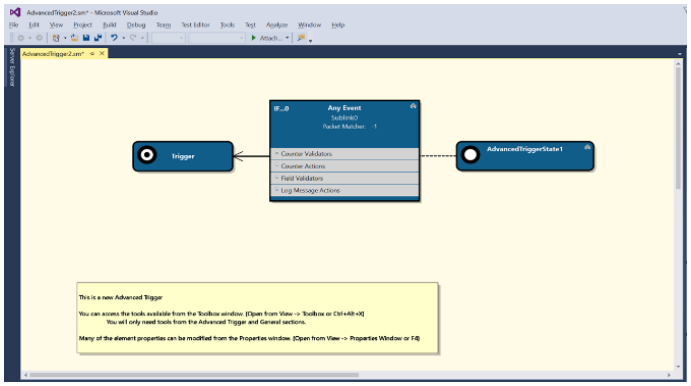
- Stress Testing
  - Execute any loop order by Speed, Link widths, LUNs or individual test cases
  - Each category can be run ascending, descending, or random seed order
  - Stop after a specified number of test case configuration loops or No Result Test Cases have occurred

- Group, filter and summarize test results by test parameters – status, individual tests, or test rules

- Summary reports and full file export

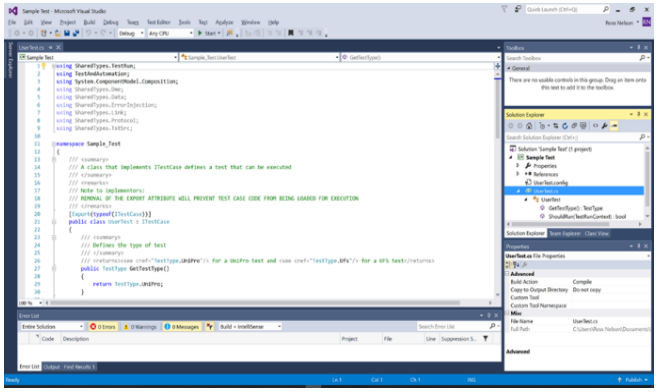
Custom Test Editors

The Falcon series include Test Editors for creating advanced triggers and Trace Validation tests, and the G550C and G450C include custom stimulus Test Editors that can be used to create unique stimulus tests. Tests created with Stimulus Test Editor can be executed with Run Time Control for automated margin, corner case and stress testing.



Custom tests can be created from scratch, or they can be based on the pre-defined tests provided in the software library.

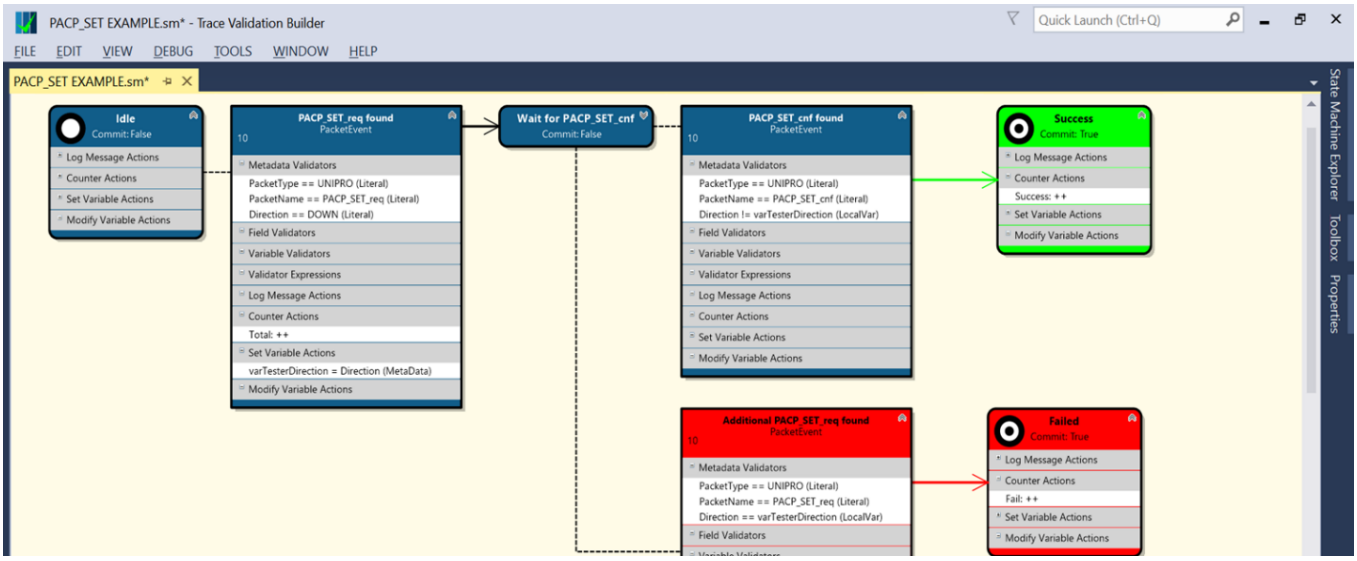
Stimulus capabilities available with custom Stimulus Editors include:



- Host emulation
- Put DUT into known states
- Create specific link traffic
- Insert errors into the traffic stream
- Create stimulus sequences to execute complex events, e.g. NAC Conditions or Power Mode Changes
- Automate with Run Control for stress testing

Analysis capabilities available with the Trace Validation Editor include:

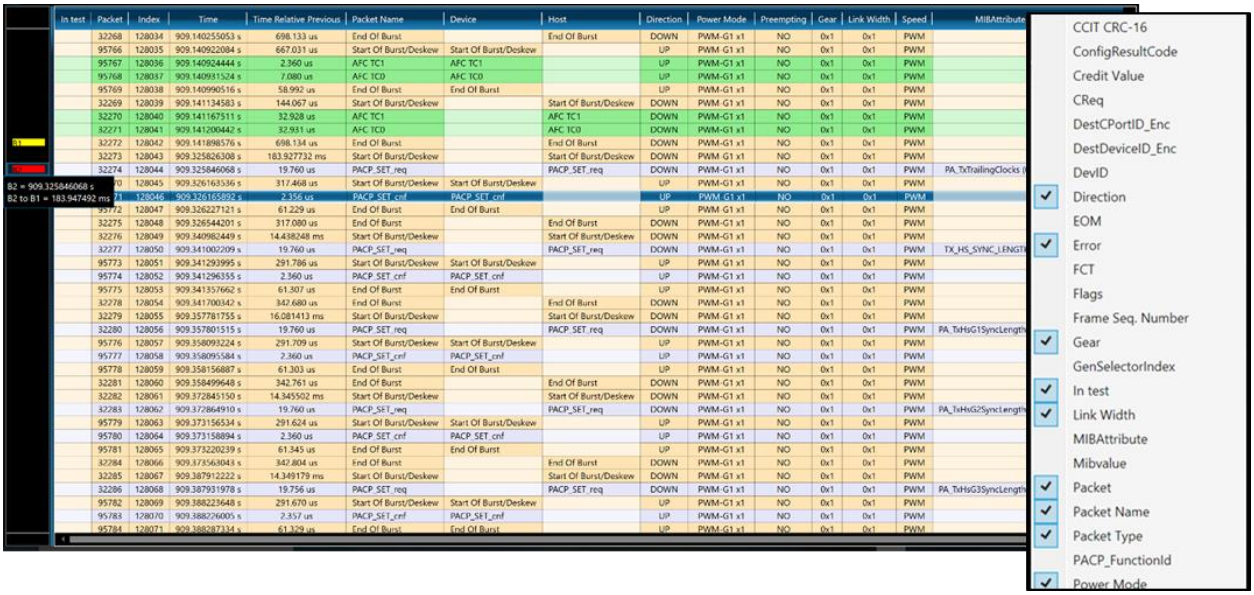
- Analyze traffic on any trace file captured “sniffer” style from any bi-directional link
- Use complex state machine logic to verify all trace attributes
- Log messages and attributes with Failure, Warning, Pass, Info and Debug flags
- Easy-to-use graphical user interface:



Powerful Debug Capabilities

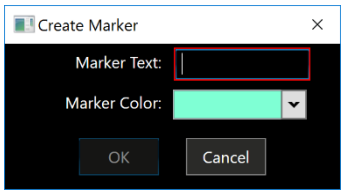
The Falcon application software includes extensive general protocol analysis capabilities, including Packet List, Packet Decode and Data windows, bookmarks and navigation, triggers and pre and post capture filters.

Packet List windows display all packets in a trace. The information displayed in the Packet List can be changed by right-clicking in the column header bar and selecting different columns from the list available.

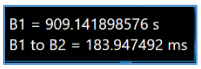


The **Packet Decode** window displays the packet header information and the **Data View** window displays the entire packet, including header and payload for a selected packet.

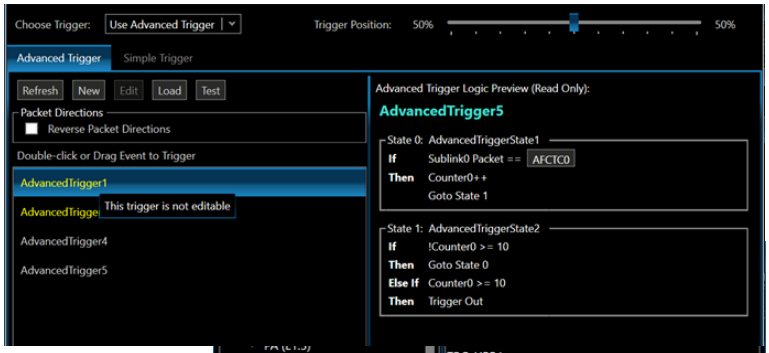
Navigation within the windows can be accomplished with **Bookmarks**. Bookmarks can be added to any packet in a Packet List window by right-clicking and selecting Add Bookmark. By right-clicking and selecting Edit Bookmark an existing bookmark can be renamed or given a different color.



Hovering over a bookmark will display a tooltip indicating timestamp and delta time to other bookmarks.



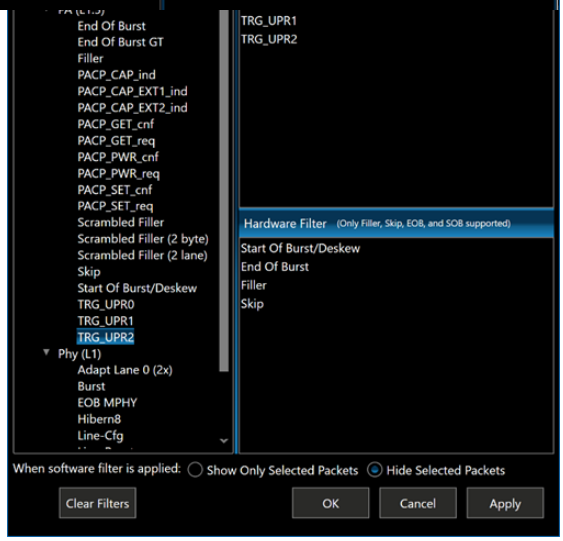
Simple and **Advanced Triggers** monitor all sublinks for any packet type, packet header or payload value and trigger the analyzer to stop capturing when the trigger criteria are met.



Filters permit the filtering of specific packet types either before or after the trace has been stored and saved.

The pre-capture Hardware Filter can eliminate Fillers, Skips, Start of Bursts, End of Bursts and AFC_TC0 packets. The UFS payload can also be filtered out. Since these are filtered out prior to trace capture they are not stored or saved with the pitx trace.

Post-Capture Software Filter captures and stores all packets, but suppresses the selected UniPro packet types from the UniPro List window. The Traffic Summary window will still display all packets but it highlights and deactivates those that have been filtered.



Specifications

Product specifications are subject to change without notice.

Falcon G500C and G550C

Supports up to UFS 4.0, UniPro 2.0 and M-PHY 5.0 HS-G5.

Available Upgrade:

- Upgrade Trace capture memory depth: 8 GB (default), 15 GB, 23 GB or 30 GB[2]

G500C Analyzer

M-PHY Type-I

Speeds:

- High-Speed (HS) Gear1, Gear2, Gear3, Gear4, and Gear5, Rate Series A/B
- Low-speed Pulse-width Modulation (PWM) Gear1 to Gear4 in Type-I LS implementation
- Link Width: x1 and x2
- Trace capture memory depth: 8 GB. Upgrade available.
- Probing options: SMP and solder-down available, with optional probe pod.

Available Upgrade:

- Upgrade Analyzer to Exerciser for UFS 4.0, UniPro 2.0 and M-PHY 5.0 HS-G5

G550C Exerciser

M-PHY Type-I

Speeds:

- High-Speed (HS) Gear1, Gear2, Gear3, Gear 4, and Gear 5, Rate Series A/B
- Low-speed Pulse-width Modulation (PWM) Gear1 to Gear4 in Type-I LS implementation
- Link Width: x1 and x2
- Trace capture memory depth: 8 GB, shared between exerciser and analyzer. Upgrade available.
- Probing: SMA and solder-down available, with optional probe pod. SMA is required for exerciser functionality.
- Compliance support: UFS 2.x, UFS 3.1 preliminary, UFS 4.x (preliminary)
- Conformance support: UniPro 1.6x, UniPro 1.8, UniPro 2.0 (preliminary)

[2] When the capture memory buffer is 16 or 24 GB, 1 GB is used for system functions and unavailable for capture. When the capture memory buffer is 32 GB, 2 GB is used for system functions and unavailable for capture.

Falcon G500C and G550C – G4 Only Option

Supports up to UFS 3.1, MIPI UniPro 1.8 and M-PHY 4.1 HS-G4.

The G500C and G550C can optionally be purchased with support only up to HS-G4. By ordering an upgrade a HS-G4 Only Analyzer / Exerciser can be upgraded to support UFS 4.0, UniPro 2.0 and M-PHY v5.0, HS-G5.

Available Upgrades:

- Upgrade Trace capture memory depth: 8 GB (default), 16 GB, 24 GB or 32 GB[3]
- Upgrade Analyzer to Exerciser for UFS 3.1, MIPI UniPro 1.8 and M-PHY 4.1 HS-G4
- Upgrade Analyzer to UFS 4.0, UniPro 2.0 and M-PHY 5.0 HS-G5
- Upgrade Analyzer to Exerciser for UFS 4.0, UniPro 2.0 and M-PHY 5.0 HS-G5.

Orderable Accessories

- Solder-down probe - HS-G5 X2 bundle – FG5PSD2
- Amp Spliiter – FG5AMPSP
- HS-G5 Interposer – FG5AMPGR
- Enhanced connectivity option – includes Thunderbolt 3 6ft/2m 40Gbps active cable and cable retention device
- Offline Viewer software with Trace Validation and TV Editor
- Offline Viewer software with Trace Validation and all Editors (TV, advanced trigger and UniPro and UFS stimulus)
- Field carry bag

[3] When the capture memory buffer is 16 or 24 GB, 1 GB is used for system functions and unavailable for capture. When the capture memory buffer is 32 GB, 2 GB is used for system functions and unavailable for capture.

Recommended Third Party Accessories

HS-G5

The HS-G5 data rate and signal budget, ~10 dB, requires the use of high-performance accessories. We recommend the use of short cables and to minimize the number of connectors, thereby avoiding unnecessary signal loss.

- Connector Savers: The front panel connectors will provide a lifetime of use if appropriate care is taken while attaching and removing cables. Optionally, you may purchase a SMP Male to Female adapter. Using these adapters will degrade the overall signal budget by ~0.4 – 0.7 dB, from 12 – 36 GHz. A 40 GHz adapter such as the Amphenol SV Microwave P/N 1112-4012 (smooth bore) SB or equivalent can be used. SMP connectors have varying levels of detent:

	Mate Force (lbs)	Demate Force (lbs)
SMP Full Detent (FD)	9	7
SMP Limited Detent (LD)	7	5
SMP Smooth Bore (SB)	2	0.5

- SMP to SMA cables: ≥40 GHz, < 2 dB of insertion loss, phase-matched, ≤305mm/12” length. Shorter cables will help to minimize signal loss.
- Power Splitter – Protocol Insight is developing an amp splitter board, details available upon request.

DUT Requirements to Sync Analyzer to a UniPro Link

Attribute	Protocol Analyzer PHY Spec
TxHsG1SyncLength (0x1552)	256 Symbols, 0x48 Capability value
TxHsG2SyncLength (0x1555)	256 Symbols, 0x48 Capability value
TxHsG3SyncLength (0x1556)	256 Symbols, 0x48 Capability value
TxHsG4SyncLength (0x15D0)	256 Symbols, 0x48 Capability value
TxHsG5SyncLength (0x15D6)	256 Symbols, 0x48 Capability value
TxHsG1PrepareLength(0x1553)	0xA Capability value
TxHsG2PrepareLength(0x1554)	0xA Capability value
TxHsG3PrepareLength(0x1557)	0xA Capability value
TxHsG4PrepareLength(0x15D1)	0xA Capability value
TxHsG5PrepareLength(0x15D7)	0xA Capability value
RxLsPrepareLength	0xA Capability value
RxPwmBurstClosureLength	0x1F Capability value
To sync to existing link	one Start of Burst

The typical settings assume configuration with a 50/50 splitter and recommended cables. Actual performance may vary depending on the probing and signal integrity of the DUT.

DUT Requirements to establish a UniPro link with the Falcon exerciser:
The device must execute a UniPro 2.0 or 1.8 compliant Link Startup Sequence.

General Characteristics

System requirements:

Basic PC configuration:

- Intel® Core™ i7 or i9 processor or equivalent.
- 32 GB RAM recommended, 16 GB minimum.
- NVMe solid state drive with 500GB free space recommended, 256GB minimum free space.
- Thunderbolt 3 enabled type-c connector required.

To take full advantage of streaming capture with v2.0.0 and later FW/SW:

- The fastest processor available, e.g. Intel i9-8950HK Processor (4.8GHz turbo)
- 64GB of RAM recommended, 32GB minimum
- **1TB NMVe SSD with Sustained Write Bandwidth of 5.0GB/s recommended, 2.5GB/s minimum**
- Thunderbolt 3 or 4 enabled type-c connector required.

For streaming capture with existing PCs you can verify if your SSD has acceptable Sustained Write Bandwidth at https://ssd.userbenchmark.com, which provides a good tool for SSD Sustained Write Bandwidth benchmarking.

Software requirements

- Windows 10 64-bit operating system
- Microsoft SQL Server 2014 or later
- Microsoft Visual Studio 2015 with Update 3 Community or Professional editions
  or
  Microsoft Visual Studio 2015 Isolated Shell
- Protocol Insight application software and firmware version 2.7 or later

Physical Characteristics

Dimensions	12.7” x 2.7” x 9.9”, 32.4cm x 6.9cm x 25.0cm
Weight	[5.9lbs, 2.7kg]

Patents: This product is protected under US Patent No. 10,613,963

Export Control Classification Number (ECCN): 3B992 b.4.b.1, No License Required

US Export Schedule-B harmonization code: 9030.89.0100

Safety, Compliance and Environmental Information

Falcon C Series
Conforms to UL STD 62368-1
Certified to CSA STD C22.2 No. 62368-1
ETL Control Number: 5009155

Complies with IEC 60950-1:2005 (Second Edition) + Am 1:2009 + Am 2:2013
Manufacturer's Declaration of Conformity to European Directive 2014/35/EU (Low Voltage Directive)
Compliant with the European Union directive 2002/95/EC and 2011/65/EU on the Restriction of the use of certain hazardous substances in electrical and electronic equipment and components (RoHS).

Compliant with
Compliant with
CISPR 16-2-3:2016 – radio disturbance and immunity measuring apparatus and methods
CISPR 16-2-1: 2014/AMD 1:2017 – specifies the methods of measurement of disturbance phenomena in general in the frequency range 9 kHz to 18 GHz
FCC 47CFR 15: 2012 – radio frequency devices
EN 55032:2015, A11:2020 - Electromagnetic compatibility of multimedia equipment
EN 55035:2017, A11:2020
IEC 61000-3-2:2020 – limits For Harmonic Current Emissions
IEC 61000-3 Ed: 5.1, 2020-07-14
IEC 61000-3-3:2021
IEC 61000-3 Ed. 3.2, 2021-03-25
ICES-003: 2020 - Information Technology Equipment - Limits and Methods of Measurement
ANSI C63.4:2014 – American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment
IEC 61000-4-2:2008 – (EMC) discharge immunity
IEC 61000-4-3:2006 – (EMC) Radiated, radio-frequency, electromagnetic field immunity
IEC 61000-4-5:2 – (EMC) surge immunity test
IEC 61000-4-6:2008 – (EMC) immunity to conducted distubances
EN 62368-1:2020+A11:2020 – Audio/video, information and communication technology equipment

Contact Information

For additional information, to request a demonstration or quote, or place an order, please contact your local Protocol Insight representative or sales@protocolinsight.com

Support materials, application notes and examples files are available at https://www.protocolinsight.com/support-materials/

For technical support please contact your local Protocol Insight representative or support@protocolinsight.com