Protocol Insight® Falcon G350/G450
Universal Flash Storage (UFS)

UFS Compliance Test - Methods of Implementation
UFSA Compliance Test Matrix v1.3

The Protocol Insight Falcon G350/G450 exerciser/analyzer provides complete protocol debug and analysis of UFS devices, including compliance testing, margin and stress testing, and custom test creation and execution.

In this MOI, the Falcon G350/G450 exerciser/analyzer is used to execute the JESD224A Test Standard to verify compliance with the UFSA Compliance Test Matrix v1.3.

The Falcon G350/G450:

- Automatically sets up the exerciser, analyzer and DUT for each test
- Allows auto-configuration and reconfiguration of speeds, link widths and LUNs during the testing process
- Allows users to select and run individual or multiple CTS tests
- Allows creation of custom test cases to test the thresholds at which marginal or critical warnings appear
- Provides detailed information for each test that has been run
- Creates a printable PDF report of the tests that have been run

Contents

Required Equipment

Instrument

- Falcon G350/G450 or G350B/G450B Exerciser/Analyzer with included external power supply
- Controller (Host) PC
- Thunderbolt 3 cable (1)
- 4-10 cables, SMP for the Falcon G350B/G450B, SMA for the Falcon G350/G450

Power requirements – external power supply

- EDAC Power Electronics Co., Ltd model EA1068
- Universal AC input 100 to 240V AC
- Output: DC +12V/6A
- Frequency: 50 to 60Hz
- Safety: UL/CUL, TUV, CB, FCC, CCC, CE, PSE, KC Mark
- Meets RoHS and WEEE

Controller (Host) PC requirements

- 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 is required.
- Microsoft Windows 10 64-bit operating system

Software requirements

- Windows 10 64-bit operating system
- Microsoft SQL Server 2014 or later
- Microsoft Visual Studio 2013 Shell (Isolated)
- Protocol Insight application software and firmware version 1.0.4872 or later. Note: v1.4.4.6327 or later software and firmware is required to support the Falcon G400 series.

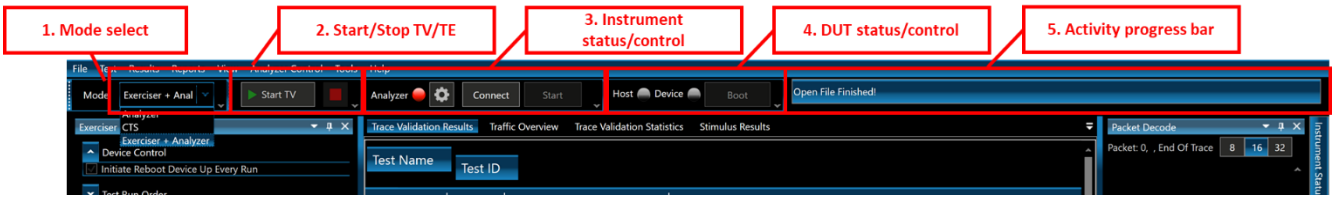
System Setup and Operation

See **REQUIRED EQUIPMENT** for information on the equipment configuration.

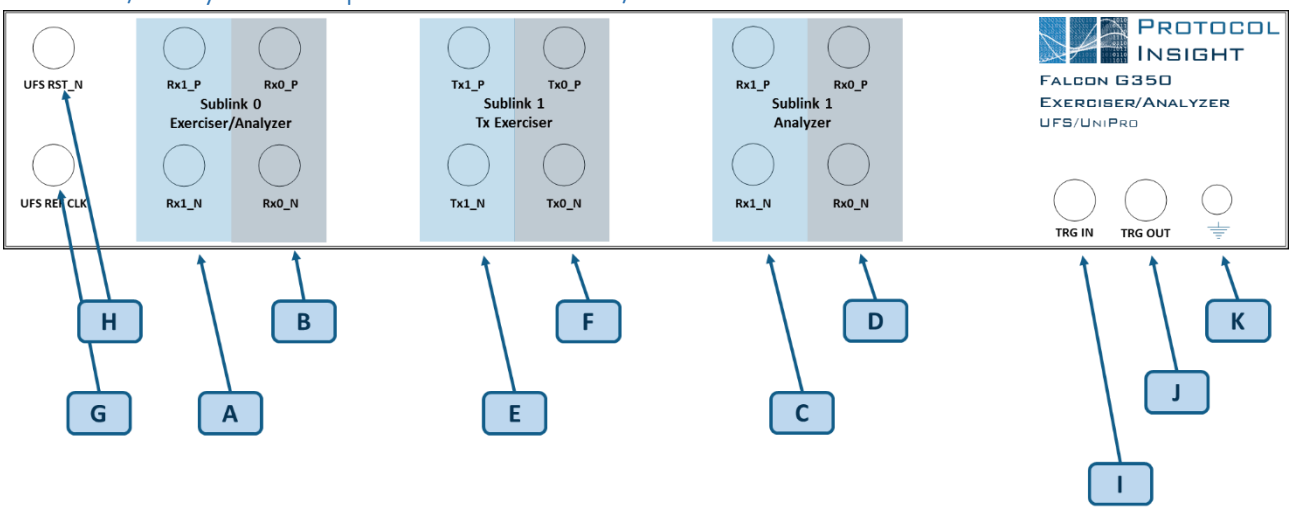
To power on the Falcon G350/G450 insert the power cable in the power connector on the right side of the Falcon chassis or press the power button on the right side (B models only).

To connect the controller PC, insert one end of the Thunderbolt3 cable into the PC and the other end into one of the two Thunderbolt3 connecters on the right side of the Falcon chassis.

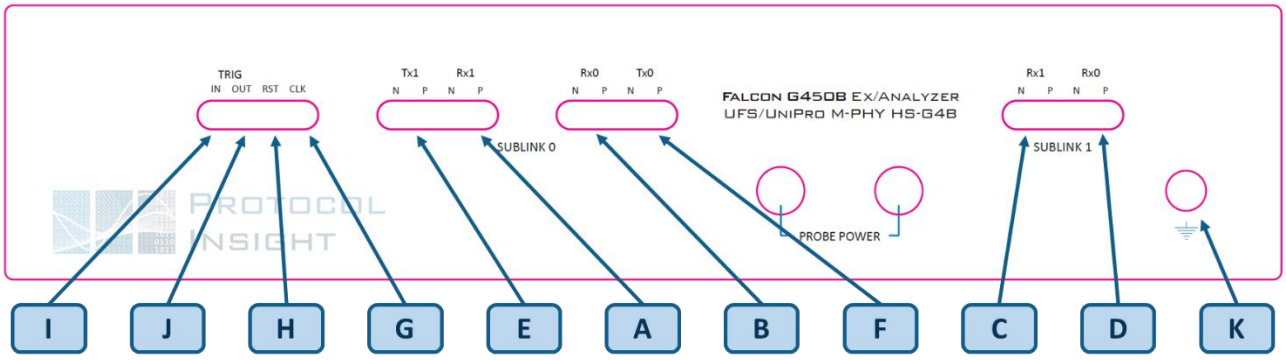
Falcon G350/G450 Exerciser/Analyzer menu toolbar



Exerciser/Analyzer front panel - Falcon G350/G450



Exerciser/Analyzer front panel - Falcon G350B/G450B



Front panel connectors:

A. Connect the TxDN and TxDP from device M-Tx lane 1 here.
B. Connect the TxDN and TxDP from device M-Tx lane 0 here.
C. Connect the RxDN and RxDP from device M-Rx lane 1 here. This is used for the analyzer only, for the Exerciser these connectors are not used.
D. Connect the RxDN and RxDP from device M-Rx lane 0 here. This is used for the analyzer only, for the Exerciser these connectors are not used.

E. Connect to the RxDN and RxDP from device M-Rx lane 1 here. This is used for the exerciser only, for the analyzer these connectors are not used.
F. Connect to the RxDN and RxDP from device M-Rx lane 0 here. This is used for the exerciser only, for the analyzer these connectors are not used.
G. Generates a UFS reference clock at 19.2 MHz or 26 MHz at 1.8V.
H. Generates a 1.8V signal to assert the UFS Hard Reset.
I. Trigger in to the analyzer, 1.8V required.
J. Trigger out from the analyzer, 1.8V is generated.
K. Ground

Step 1: Connect probes

Note: the labels on the analyzer front panel are from the instrument perspective.

1. Connect the Sublink 0 Rx_1N to TxDN from the device M-Tx lane 1.
2. Connect the Sublink 0 Rx_1P to TxDP from the device M-Tx lane 1.
3. Connect the Sublink 0 Rx_0N to TxDN from the device M-Tx lane 0.
4. Connect the Sublink 0 Rx_0P to TxDP from the device M-Tx lane 0.
5. Connect the Sublink 1 Tx_1N to RxDN from the device M-Rx lane 1.
6. Connect the Sublink 1 Tx_1P to RxDP from the device M-Rx lane 1.
7. Connect the Sublink 1 Tx_0N to RxDN from the device M-Rx lane 0.
8. Connect the Sublink 1 Tx_0P to RxDP from the device M-Rx lane 0.
9. Connect the UFS RST_N to the DUT reset signal
10. If desired, connect the UFS REF CLK to the DUT ref clock input.

Step 2: Connect reset signal (eUFS only)

Note: Reset signal is only applicable for JESD220B and JESD220C embedded UFS

1. Connect a cable from the UFS RST_N connector H on the Falcon G350/G450 to your DUT.
2. The output voltage of the reset signal coming from the Falcon G350B/G450B is 1.2V. For the Falcon G350/G450 the output voltage is 1.8V.

Step 3: Instrument Configuration

1. Settings can be configured from the Tools→Settings menu or by clicking  from the toolbar (**3**).
2. Select the Instrument Configuration tab. Set the Memory Depth to 128MB.
3. In the User Preferences tab check the Decode UFS box.
4. If using an external reference clock, in Instrument Configuration choose the appropriate Output Clock setting.

Step 4: Device Configuration

1. Settings can be configured from the Tools→Settings menu or by clicking  from the toolbar (**3**).
2. Select the Device Configuration tab and configure Device and LUN parameters by entering in all the parameters for your device and saving the configuration. See **APPENDIX B: HOW TO FIND**

DEVICE CONFIGURATION VALUES for tips on how to poll your device for this information if it is not already known.

Step 5: Configure the Falcon G350/G450 and Run Tests

1. Connect the Falcon software to the Falcon instrument by pressing Connect on the toolbar (**3**).
2. Set the Mode to CTS in the tool bar, make sure "Initiate Reboot Device Up Every Run" is unselected (**1**).
3. Go to the Configuration window. Under Device Control check UFS for the Protocol.
4. Press the "Boot" button on the tool bar to boot the device to UFS (**4**).
5. Select which LUNs, Speeds, and Link Widths to test
    a. Configured LUNs should include 1 logical unit, UFS DEVICE, REPORT LUNS, and NONE
    b. If testing an embedded UFS device also select BOOT LUN.
6. The provided device must be have bConfigDescrLock = 0 and fPermanentWPEn = 0x00
7. Under Miscellaneous in the UFS Device section of Device Configuration make the following selections:
    - bConfigDescrLock=0 = selected
    - bOutOfOrderDataEn has been written = not selected
    - bRefClkFreq has been written = not selected
    - bConfigDescrLock has been written = not selected
    - Enable Write Once Attribute Test Cases = selected
8. Select and Run the following test cases in this order, these test cases require that bConfigDescrLock = 0
    a. 7.8.3 (requires bConfigDescrLock = 0)
    b. 8.4.14 (requires bConfigDescrLock = 0)
    c. 8.5.2 (requires bConfigDescrLock = 0)
    d. 8.5.12 (requires bConfigDescrLock = 0)
    e. Note a power cycle may be needed between the above test cases (a-d)
9. Generate a Report and save results – See Generating a CTS test or UFSA Compliance Report.
10. Select and Run the following test cases in this order, these test cases require that bConfigDescrLock = 0
    a. 8.6.37 (writes bConfigDescrLock = 1), Step 13 requires that bConfigDescrLock = 1
        i. Note once this test case is run the vender must either reset the device or provide a new clean device such that such that bConfigDescrLock = 0 and fPermanentWPEn = 0 to run tests in step 8.
11. Generate a Report and save results – See Generating a CTS Test or UFSA Compliance Report.
12. Under Miscellaneous in Device Configuration in the Device tab make the following selections:
    - bConfigDescrLock=0 = not selected
    - bOutOfOrderDataEn has been written = selected
    - bRefClkFreq has been written = selected
    - bConfigDescrLock has been written = selected
    - Enable Write Once Attribute Test Cases = not selected
13. Select and Run all test cases defined in the CTM

a. These test cases require that bConfigDescrLock = 1 and fPermanentWPEn = 0 (deselect the tests listed above and below so they won't be run a second time, 7.8.3, 7.8.4, 8.4.14, 8.5.2, 8.5.12, 8.6.37,)

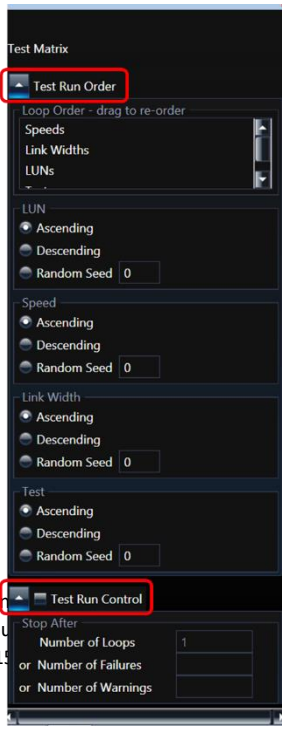
Note: Since IMMED is not supported on all devices, test cases 7.17.3 and 7.18.2 should be run using both the IMMED Supported and IMMED Not Supported versions. One of these versions must pass.

Note: since the CTM does not require the tests be run in a specific order, some UFS implementations may require a power-on reset prior to running certain tests.

14. Generate a Report and save results – See Generating a CTS test or UFSA Compliance Report.
15. The vender must either reset the device or provide a new device such that such that bConfigDescrLock = 0 and fPermanentWPEn = 0
16. Under Miscellaneous in the UFS Device section of Device Configuration make the following selections:
    - bConfigDescrLock=0 = selected
    - bOutOfOrderDataEn has been written = not selected
    - bRefClkFreq has been written = not selected
    - bConfigDescrLock has been written = not selected
    - Enable Write Once Attribute Test Cases = selected
17. Select and Run the following test cases in this order
    a. 7.8.4 (requires fPermanentWPEn = 0x00, will write to 1)
18. Generate a Report and save results – See Generating a TS test or UFSA Compliance Report.
19. Note: if you want to run the tests a multiple power modes, this is the recommended flow:
    a. Run step 8-9 at all power modes
    b. Run step 10-11 at 1 selected power mode
    c. Run step 13-14 at all power modes
    d. Run step 15-18 at 1 selected power mode

Step 6: Configure Stress Testing (optional)

Test Run Order controls the order in which tests are executed.



1. **Loop Order:** loop order specifies the nested order of test execution. Tests will be run from the bottom up, with all tests in each loop executed before the next higher loop is begun. So if the Loop Order is Speeds, Link Widths, Tests then all Tests will be completed for a Link Width before being executed for the next Link Width, etc. The loop order can be adjusted by dragging categories up or down in the Loop Order box.
2. **Ascending, Descending, Random Seed:** this specifies which order the tests are executed within the Loop. If Random Seed is selected a value can be entered to generate a random but reproducible test order based on the seed value.

Step 7: Configure Run Control (optional)

Test Run Control specifies the number of iterations of the test configuration to run, dictated by Test Run Order. Test execution will stop after the specified Number of Loops (outer loops on Test Run Control) or No Result Test Cases have occurred.

The user can specify the number of test configuration loops to run OR the number of No Result Test Cases to allow before terminating the test run. When Number of No Result Test Cases field is blank or 0, tests are run for the given number of loops. If values are provided for both conditions, then tests are run until any ONE of the conditions is met.

Interpreting Trace Validation Results

The Trace Validation engine performs protocol sequence and packet inspection with five possible status results for each rule check displayed in the Trace Validation Results window:

Failure ✗

Any protocol sequence or packet that does not meet a rule specified in MIPI UniPro v1.1 CTS, JEDEC JESD224 CTS, or as defined in a custom test case

Warning ⚠

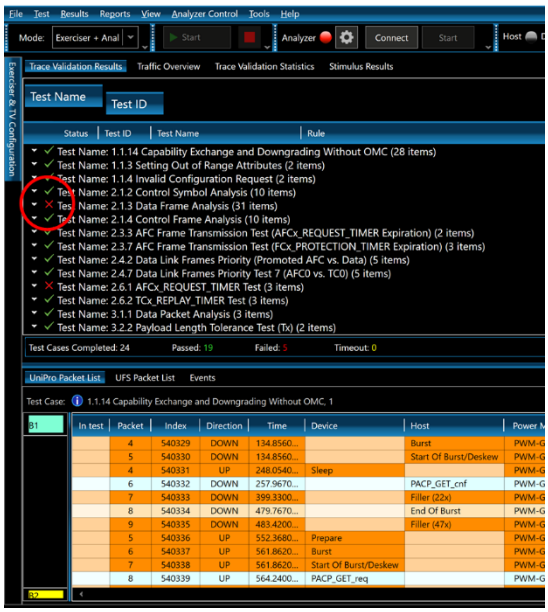
Any protocol sequence or packet that does not conform to a "shall" specified in MIPI UniPro v1.61 spec, JEDEC JESD220x spec, or as defined in a custom test case

Pass ✓

Any protocol sequence or packet that conforms to the UniPro spec and CTS and JEDEC spec and CTS.

Info ℹ

Info messages communicate the progress during the test or information about the packets, and are typically followed by a status result such as Pass or Failure. See example to the right, where there are several Info messages followed by a Success message and Pass status.



Debug 🔍 **(TV mode only)**

Provides information on state machine execution of an inspection rule in Trace Validation if debug hooks were placed in the TV test case.

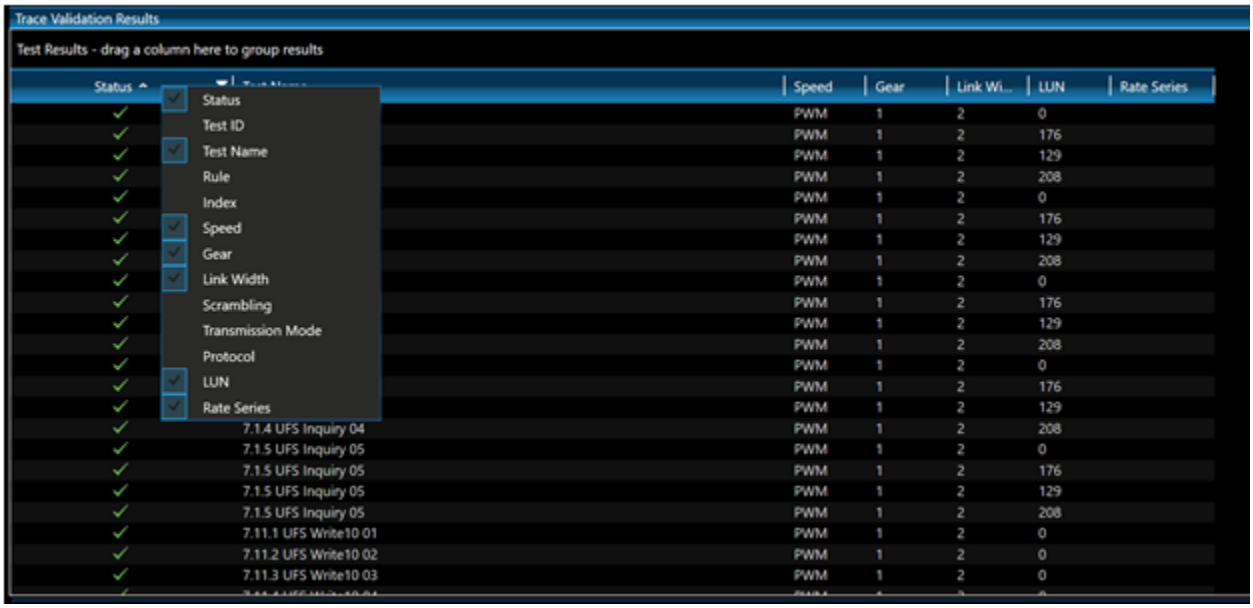
The results can be grouped, summed, sorted and filtered by various test parameters or packet characteristics. See **GROUP AND SUMMARIZE TEST RESULTS** and **SORT AND FILTER TEST RESULTS** for more information.

Generating a CTS Test or UFSA Compliance Report

To create a Compliance Report, the Trace Validation Results pane is modified to reflect the required information and then a PDF report is created from that view.

To create the Compliance Report view in the Trace Validation Results pane:

1. If necessary, drag columns to order them by Status, Test Name, LUN, Link Width and Speed
2. Right click in the column header and select only Status, Test Name, LUN, Link Width and Speed, Gear, Rate Series as below:

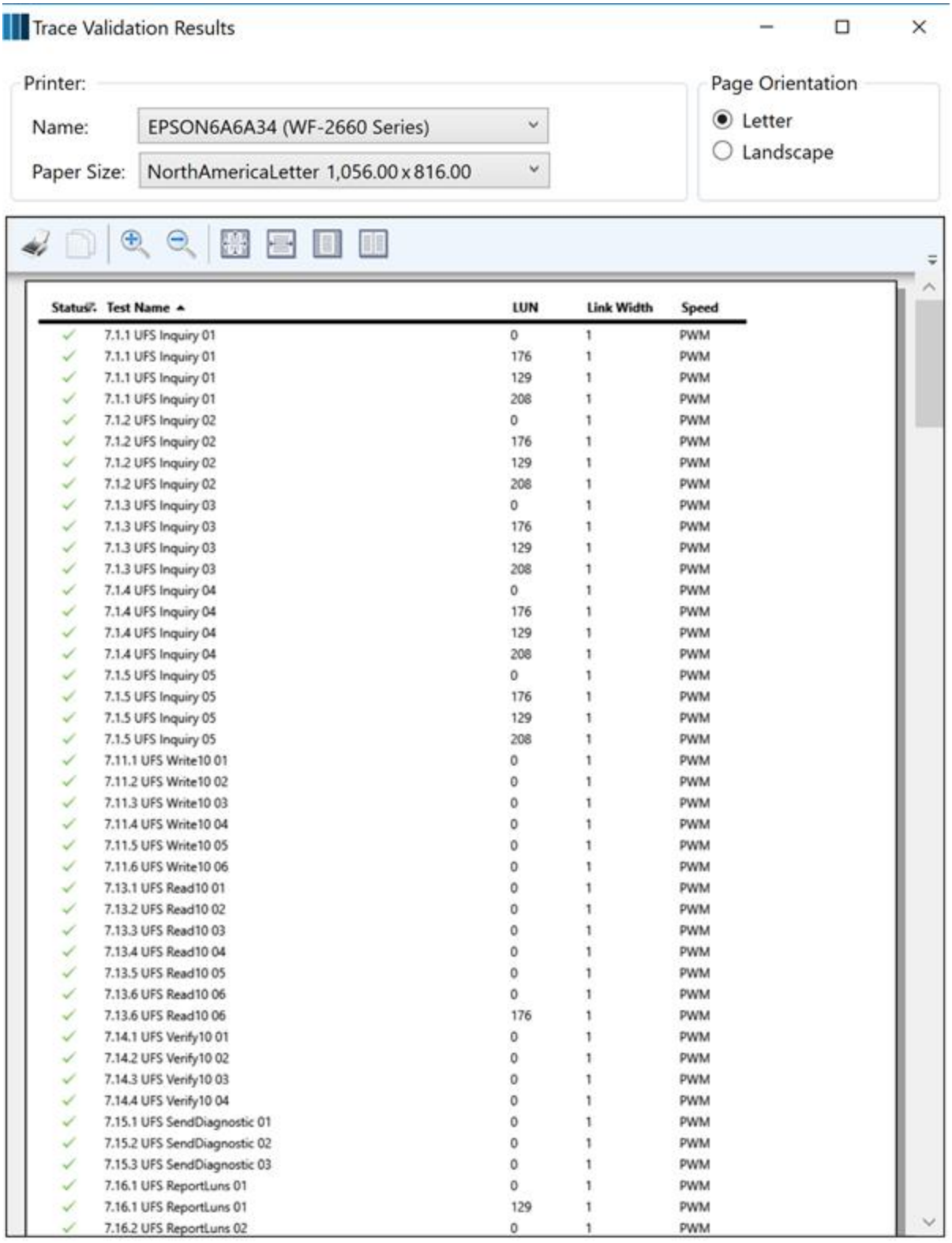


3. Sort results in ascending order by the Test Name column. Filter Status to only show Pass (Green checkmarks) or Fail (Red Xs) See **SORT AND FILTER TEST RESULTS** for more information.
4. Double click on the column dividers to expand column widths to show all description information.

To generate the Compliance PDF report:

1. From the Reports menu select Reports→Trace Validation Results→Print Preview…
2. Select a PDF printer.
3. Set Page Orientation to Landscape.
4. Print the results to a file.

The resulting Compliance report should look like this before printing:



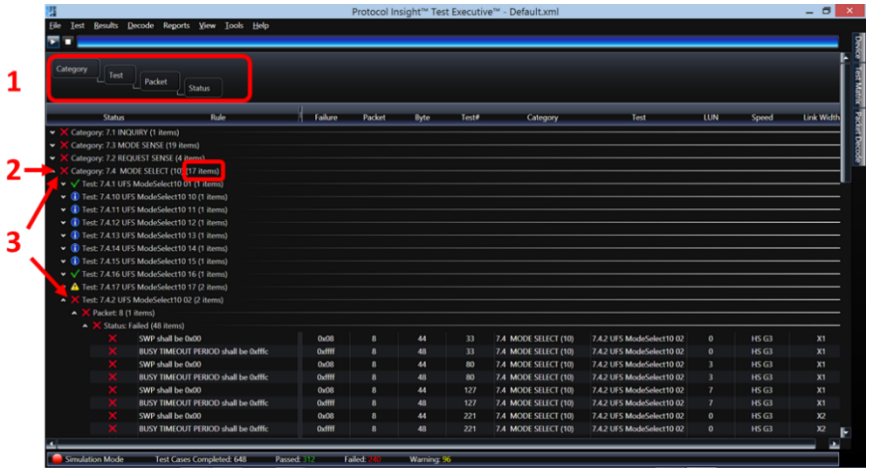
Status	Test Name	LUN	Link Width	Speed
✓	7.1.1 UFS Inquiry 01	0	1	PWM
✓	7.1.1 UFS Inquiry 01	176	1	PWM
✓	7.1.1 UFS Inquiry 01	129	1	PWM
✓	7.1.1 UFS Inquiry 01	208	1	PWM
✓	7.1.2 UFS Inquiry 02	0	1	PWM
✓	7.1.2 UFS Inquiry 02	176	1	PWM
✓	7.1.2 UFS Inquiry 02	129	1	PWM
✓	7.1.2 UFS Inquiry 02	208	1	PWM
✓	7.1.3 UFS Inquiry 03	0	1	PWM
✓	7.1.3 UFS Inquiry 03	176	1	PWM
✓	7.1.3 UFS Inquiry 03	129	1	PWM
✓	7.1.3 UFS Inquiry 03	208	1	PWM
✓	7.1.4 UFS Inquiry 04	0	1	PWM
✓	7.1.4 UFS Inquiry 04	176	1	PWM
✓	7.1.4 UFS Inquiry 04	129	1	PWM
✓	7.1.4 UFS Inquiry 04	208	1	PWM
✓	7.1.5 UFS Inquiry 05	0	1	PWM
✓	7.1.5 UFS Inquiry 05	176	1	PWM
✓	7.1.5 UFS Inquiry 05	129	1	PWM
✓	7.1.5 UFS Inquiry 05	208	1	PWM
✓	7.11.1 UFS Write10 01	0	1	PWM
✓	7.11.2 UFS Write10 02	0	1	PWM
✓	7.11.3 UFS Write10 03	0	1	PWM
✓	7.11.4 UFS Write10 04	0	1	PWM
✓	7.11.5 UFS Write10 05	0	1	PWM
✓	7.11.6 UFS Write10 06	0	1	PWM
✓	7.13.1 UFS Read10 01	0	1	PWM
✓	7.13.2 UFS Read10 02	0	1	PWM
✓	7.13.3 UFS Read10 03	0	1	PWM
✓	7.13.4 UFS Read10 04	0	1	PWM
✓	7.13.5 UFS Read10 05	0	1	PWM
✓	7.13.6 UFS Read10 06	0	1	PWM
✓	7.13.6 UFS Read10 06	176	1	PWM
✓	7.14.1 UFS Verify10 01	0	1	PWM
✓	7.14.2 UFS Verify10 02	0	1	PWM
✓	7.14.3 UFS Verify10 03	0	1	PWM
✓	7.14.4 UFS Verify10 04	0	1	PWM
✓	7.15.1 UFS SendDiagnostic 01	0	1	PWM
✓	7.15.2 UFS SendDiagnostic 02	0	1	PWM
✓	7.15.3 UFS SendDiagnostic 03	0	1	PWM
✓	7.16.1 UFS ReportLuns 01	0	1	PWM
✓	7.16.1 UFS ReportLuns 01	129	1	PWM
✓	7.16.2 UFS ReportLuns 02	0	1	PWM

Supplemental Analysis

The Trace Validation Results window allows extensive quantitative analysis of results data. Results can be grouped and summarized, sorted, and filtered by any header column.

Group and Summarize test results

To group and summarize, click on any column header and drag into the Test Results field. This will summarize the results with an item count of occurrences. Multiple column headers can be dragged into the Test Results field (**1**) to create tiered groupings for analysis:



Grouping and Summarizing

Item count: represents the number of items in the grouping below, so in this example (**2**) Category 7.4 MODE SELECT 10 counted 17 items, representing 17 different mode select tests. This item count summing function can be manipulated with a high degree of flexibility by reordering the groupings to count many different items in addition to tests, such as number of Failures (Status) or packet inspection Rules.

Summary Status flag: for any grouping of results the summary status flag represents the worst-case result of the grouping (**3**). In this example, 17 tests were executed for MODE SELECT 10, and the worst result was a Failure so MODE SELECT 10 is marked as Failure.

Sort and Filter test results

Any column header can be clicked to filter out results or to sort results by that column:

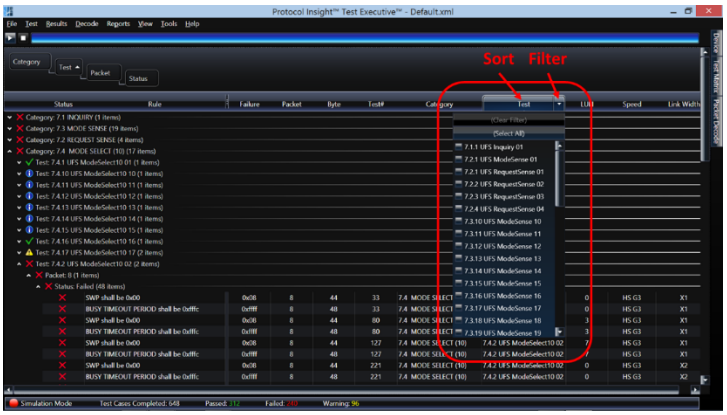
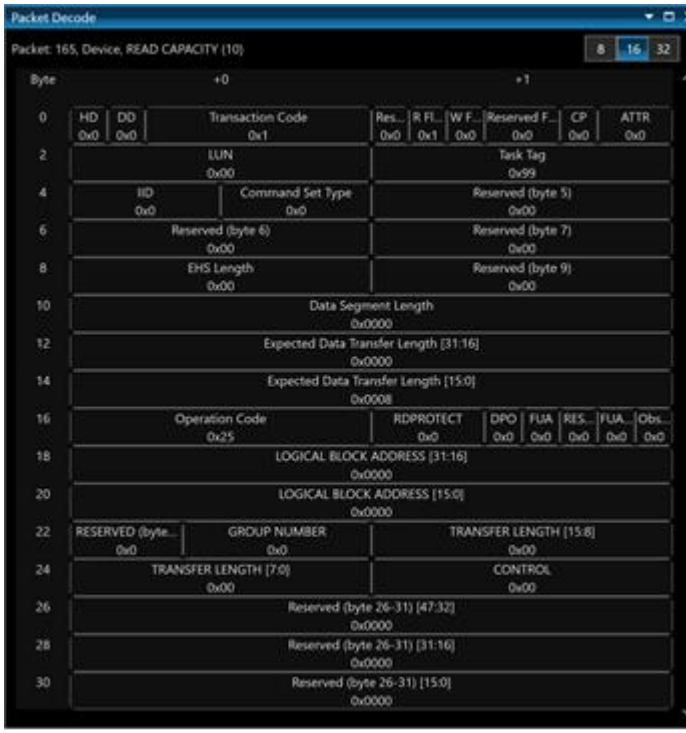


Figure 1: Sorting and Filtering



Packet Decode window

To view the Command and Response packets of a test, click on the packet of interest in the UFS Packet List window. The packet decode will be shown in the list window and also in the Packet Decode window. In the Packet Decode window, selecting 8, 16, or 32 defines the bit width of the display.

Analysis Reports

Reports→Trace Validation Results

Summary reports can be created by configuring the Trace Validation Results pane and then printing it. See **GENERATING A CTS TEST OR** UFSA Compliance Report for more information.

Appendix A: Theory of Operation

In CTS mode test cases are initiated and the Trace Validation engine is used to verify that the resulting protocol sequences and packets conform to the UFS CTS, the UFS specifications or custom tests. This flowchart shows the operation:

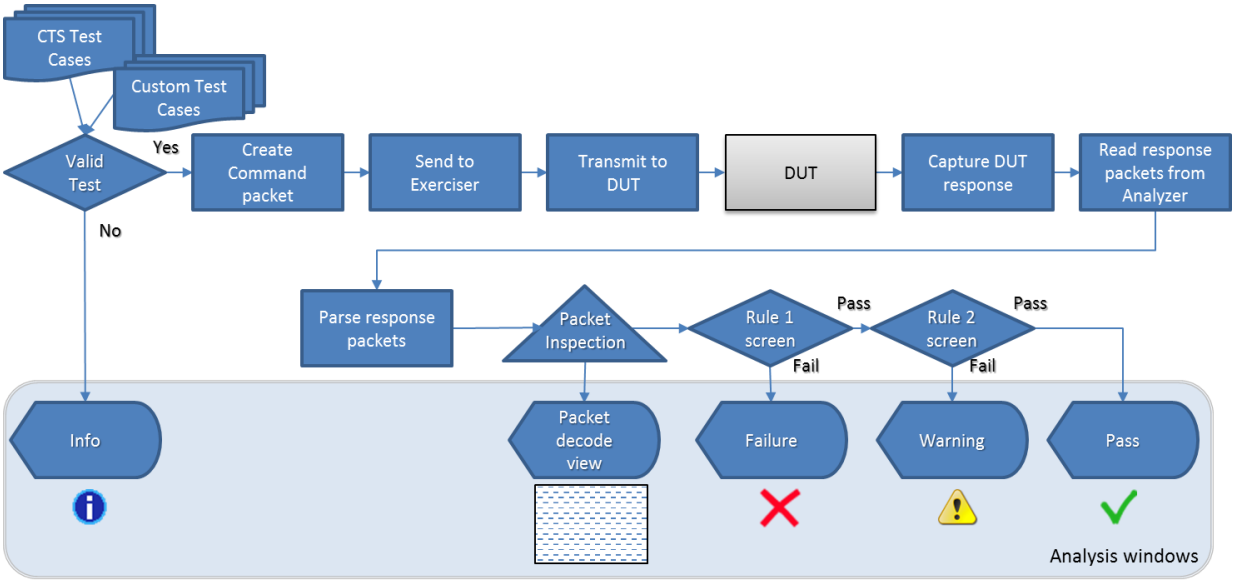


Figure 2: Test executive exerciser operation

For UFS CTS testing, to locate the beginning of each test case in the trace a NOP OUT packet is inserted with the follow reserved bits set:

- **Reserved Bytes 12 & 13** – Place the Protocol Insight Flag - 0xFFFF
  - **0xFFFF** – Test case authored by Protocol Insight
  - **0xFF00-0xFFFE** – This range reserved
  - **0xF000-0xFEFF** – Range available range for customer defined test cases.
- **Reserved Bytes 14 – 17** –The four parts of the test case ID
  - **Domain (8 bits)** – Used to define a category of test case for the given owner. Existing Protocol Insight domains are:
    - **01** - CTS specific test cases
    - **02** - Power mode tests
  - **Case ID (24 bits)** – Identifies a specific test case within a given domain. Protocol Insight test cases follow a major, minor, revision style using 8 bits for each.

Appendix B: How to Find Device Configuration Values

Select LUN 0, Boot LUN, UFS Device LUN, Report LUNs, and NONE LUN and then run the following tests to obtain the necessary device information to configurate the Device.

- Device Configuration: “Device Descriptor Values”
  - All values for this can be found by looking at the response of test case 8.4.1 ReadDescriptor_01
- Device Configuration: “Geometry Descriptor Values”
  - All values for this can be found by looking at the response of test case 8.4.9 ReadDescriptor_09
- UFS LUN Configuration: “Read-Write recovery mode page”
  - These values are vendor specific, default to unselected. The standard does not define which Read-Write Error Recovery mode page fields are changeable.
- UFS LUN Configuration:
  - Some values for this can be found by looking at the response of test case 8.4.3 ReadDescriptor_03
  - Select all configured LUNs in the Configuration window
    - Set the correct values for the following:
    - bProvisioning set to 0x2 or 0x3
    - MaxContextID=0 can be found from wContextCapabilities, bits [3:0] is MaxContextID
- Run test case 7.7.2 ReadCapacity_10. In the LUN Configuration pane set the MAX addressable LBA from the RETURNED LOGICAL BLOCK ADDRESS response field in the READ CAPACITY 10 response packet. Also set the qLogicalBlockCount and bLogicalBlockSize.
- Min Page code should be fine at 0x02 (Vendor Specific)
- IMMD (Vendor Specific)
- “Mode Page PS Values” and “Mode Saveable”
  - All values for this can be found by looking at the response of test cases 7.3.2 ModeSense_02, 7.3.6 ModeSense_06 and 7.3.10 ModeSense_10.

Contact Information

1. For additional information, to request a demonstration or quote, or place an order, please contact your local Protocol Insight representative or sales@protocolinsight.com
2. Support materials and examples files are available at http://www.protocolinsight.com/support-materials/
3. For technical support please contact your local Protocol Insight representative or support@protocolinsight.com