ITIC
PROTOCOL ANALYZERS

2500A PCI Express Protocol Analyzer
User Guide

International Test Instruments Corporation

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1. Introduction

This document describes the hardware and software functionality of the ITIC 2500A PCI Express Protocol Analyzer.

1.1. Hardware Overview

The 2500A PCI Express Protocol Analyzer supports the following features:

- PCI Express 1.1 (2.5 GBit/second) compliant
- User-selectable x4, x2 and x1 link width configurations.
- User-selectable 2 Gigabyte to 64 Kilobyte capture buffer. A selectable capture buffer size allows for smaller data files when saved to hard disk.
- A powerful 48 MHz Cypress FX2LP microprocessor implements on-demand upload of data via USB 2.0 after a completed capture. This allows you to immediately view data after the capture without having to wait for lengthy uploads of the full trace data.
- An Altera Arria II GX FPGA contains PCI Express x4 transceivers, a DDR2 Memory Controller and data upload interface to the microprocessor.
- Programmable Sequence Detectors allows the FPGA to detect the location of pre-defined as well as custom data sequences. This facilitates hardware-acceleration of PCI Express Protocol Item detection after capture. This, in turn, enables the software to display the data very quickly after a completed capture without a need for the software to locate the PCI Express Packets and Ordered Sets captured.
- An 8-level trigger with up to 2048 byte deep data detection per trigger level allows triggering on very long data sequences. In total, data sequences up to 16 Kbytes in length can be triggered upon.
- A TTL-compatible Trigger in / out port allows synchronization with external test instruments.
- A x4 slot probe with a 1 m (3.3ft) cable is included. 3rd party, custom probes can also be designed and connected to the 2500A unit.
- Microprocessor firmware and FPGA configuration are automatically updated with the PC application software. No separate and complex hardware re-programming is needed.

Overall, the 2500A hardware and software has been designed for maximum efficiency and simplicity. The hardware is small enough to fit on your pocket, the software is very easy to use but yet the complete package is very flexible and powerful.

1.2. Software Overview

The 2500A software runs on Microsoft Windows XP and newer operating systems. Both x86 and x64 systems are supported. The .NET Framework 2.0 is required.

The 2500A software supports the following features:

- The trigger position can be adjusted within the capture buffer (i.e. pre or post trigger).
- Lane Polarity, Lane Mapping and Descrambling can be adjusted / disabled as needed.
- The software dynamically acquires the data required to display the visible part of the trace as the data is browsed. This results in very quick and effortless browsing of the captured data regardless of the capture buffer size used.
- Multiple Views of the data are time-correlated; the Protocol View displays a hierarchical view of all Transactions as well as the Packets included within the transactions; the Lane View displays the raw data and control characters as they were received on the link under test; finally, the Detail View decodes details of the packet selected in the Protocol View. Together, these views give you a quick and easy way to browse the captured data from the highest to lowest information level.
- All Protocol Items in the trace are displayed in the 'Node Finder' View. This view allows direct jump to any protocol item in the trace. The Node Finder can also be used to hide / show packets of a particular type.
- The 'Search View' allows you to search for binary or string data in packet payload. Multiple searches can be started and run in the background as you continue working with the software. The Search View allows direct jumps to the search result locations.
- The 'Markers View' displays the trigger position as well as any markers you have added to the capture. Markers are saved with the project and allow you to quickly locate interesting areas in the trace at a later time.
- Protocol Item Filtering allows you to instantly hide any given Protocol Item Type from the Protocol View. Due to the dynamic data access of the Protocol View, filtering is very quick, even for a full 2 Giga-byte capture.
- The Protocol View and Lane View data can be exported to file in XML format and to the clipboard in CSV format. This allows easy post-processing of the captured data via your own or 3rd party software.
- Time can be shown in absolute (measured from capture start) or relative (measured from prior protocol item) mode.
- Protocol View and Lane View data can be print previewed as well as printed.

For best performance we recommend a newer Core i5 or Core i7 PC to be used. The minimum recommended PC requirements are a P4 / 2 GHz machine. The data upload speed as well as the Protocol View Filtering speed will be improved with the faster machines.

2. Installation

This section describes how to install the 2500A PCI Express Protocol Analyzer hardware and software.

2.1. Hardware Installation

The hardware is comprised of three components:

1) An Active Interposer Probe for analysis of 2.5 Gbps (Gen1) x1, x2 and x4 PCI Express plug-in cards.
2) A 1m external PCI Express Molex x4 iPass Cable.
3) The 2500A PCI Express Protocol Analyzer.

Figure 1 below shows how these hardware components are connected to the system under test.

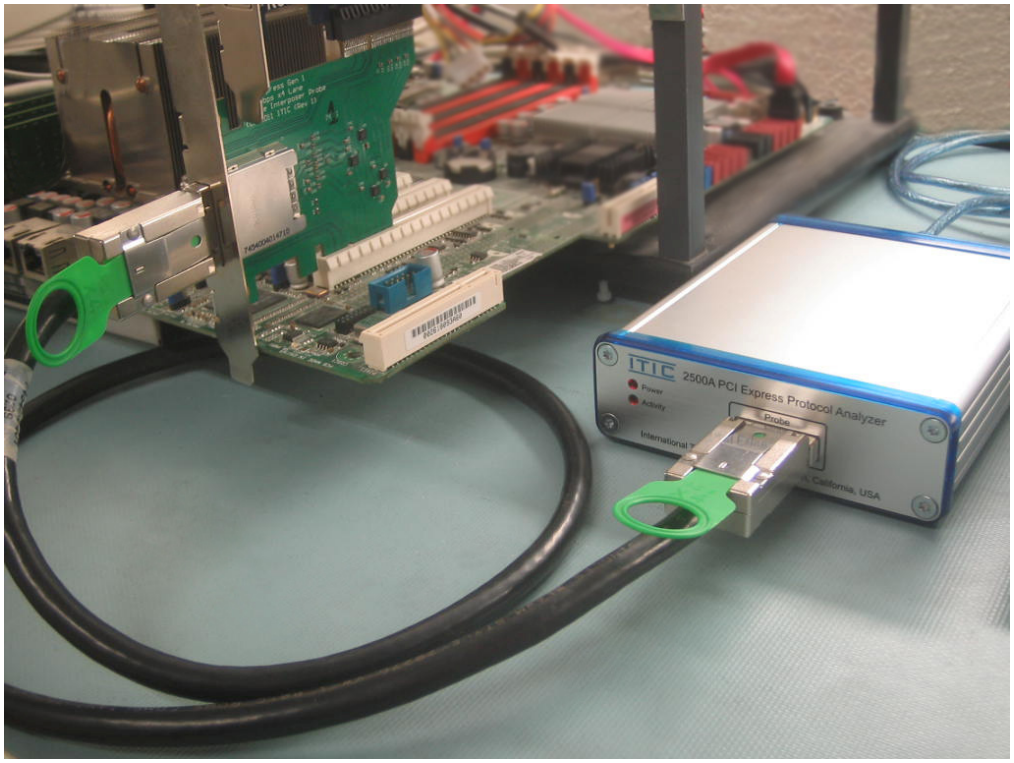

Figure 1. Probe, Cable and 2500A Protocol Analyzer attached to the target system.

2.2. Software Installation

To install the 2500A software, run the installation program and follow the instructions on screen. We recommend installing to the default directory path suggested by the installation program.

After the 2500A software has been installed to your hard disk, you need to install the 2500A Windows driver. To do this; follow the below steps:

1) Connect the 2500A PCI Express Protocol Analyzer to a high-speed USB 2.0 port on your computer.

2) Open the Windows Device Manager.

3) Right-click on the 2500A device (normally displayed as "Unknown Device") and click the 'Update Driver' menu item.

4) Direct Windows to the 'ITI2500A.inf' file located in the 'Drivers' directory within the installation directory. The driver is also located in the root directory on the CD that came with your 2500A unit.

You may have to do the above procedure twice since two different drivers are used by the 2500A unit. Once the driver is installed properly, you should see the 2500A device in the Device Manager as shown below in figure 2.

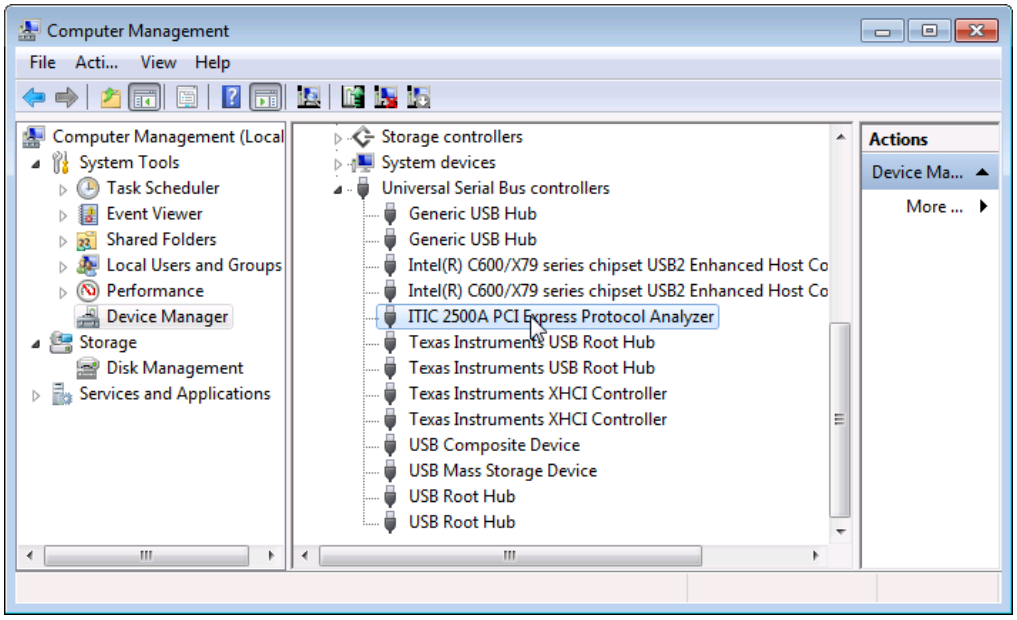

Figure 2. The 2500A device driver is installed via the Device Manager.

3. Reference

This section describes the 2500A hardware and software in more detail.

3.1. Hardware Reference

3.1.1. 2500A PCI Express Protocol Analyzer

The 2500A is designed to be extremely compact. As the below figure 3 shows, all the required 2500A electronics are integrated onto a single 120 mm x 100 mm circuit board. This makes the 2500A the most compact PCI Express Protocol Analyzer on the market.

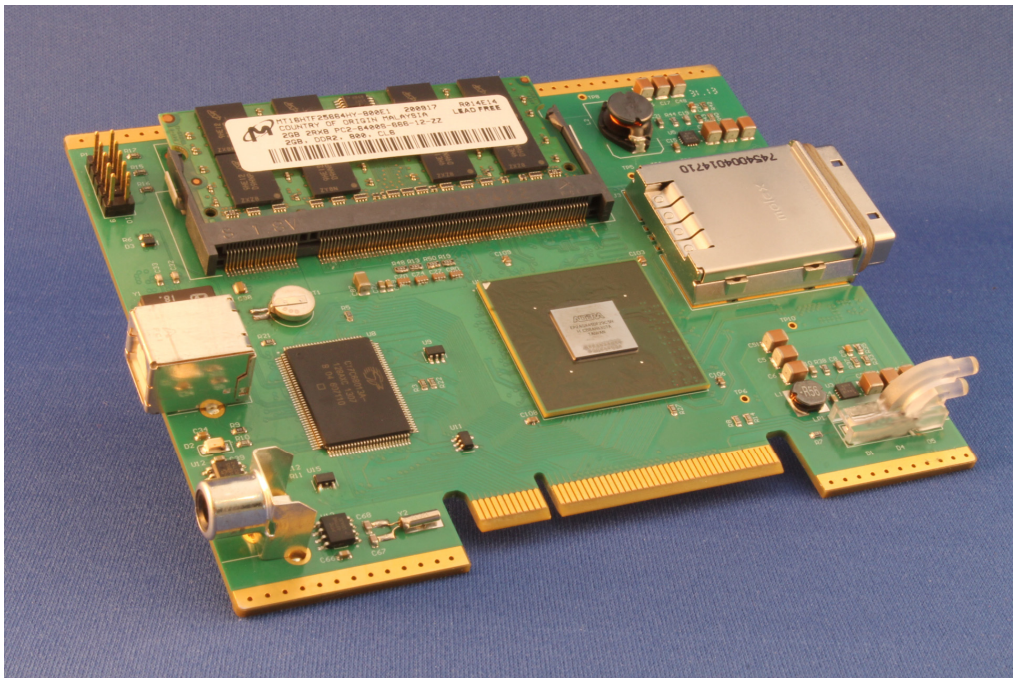

Figure 3. The 2500A unit is very compact, which allows it to be easily carried in your pocket.

10-Layer High-Speed Printed Circuit Board

The 10-layer PCB has been manufactured with highest-quality, high-speed materials to ensure superior signal-integrity and power distribution. It has been constructed with four signal layers, four ground planes and two power planes. Blind vias were additionally utilized to facilitate the very compact form-factor. The design has additionally been fully analyzed with regards to Signal-Integrity and Power-Integrity via field-solver software to guarantee robust functionality under all operating conditions.

Cypress FX2LP 48 MHz CPU

The 2500A is controlled by a 48 MHz Cypress FX2LP CPU. This handles, via USB 2.0, FPGA Configuration, PC software interaction with the FPGA as well as capture data upload.

Altera Arria II GX FPGA

The Arria II GX FPGA contains a DDR2 Controller and capture buffer logic, eight Device-to-Host (D2H) and Host-to-Device (H2D) PCI Express Transceivers, byte ordering, PCI Express descramblers and PCI Express Lane Ordering Logic. Additionally, the FPGA contains the logic required to automatically generate the meta-data that identifies the location of all PCI Express protocol items (Packets and Ordered Sets) in the capture buffer.

The FPGA also implements the digital logic required for the 8-level, 16 Kilobyte deep trigger sequencer. The FPGA Digital Design has carefully been implemented as a set of discrete state machines for maximum efficiency. This enables the FPGA to deliver a very capable set of functionality in a minimal physical package.

Micron 2 Gigabyte DDR2 SODIMM

The captured data is stored in a ring-buffer in the DDR2 SODIMM which is running at 267 MHz. This allows the captured data to be stored with a bandwidth of roughly 4 Giga-bytes per second. With the maximum 2 GByte capture buffer size configured, the SODIMM will store about 820 ms worth of bi-directional data for a x4 link. This is equivalent to roughly 200 million unique timestamps in the capture buffer.

Texas Instruments Power Regulators

The Power Distribution Network (PDN) on the 2500A has been designed to be extremely robust. The incoming 3.3V/3A from the probe connector is stepped down to 1.8V/4A and 0.9V/4A via two Texas Instruments TPS54418 Switched Mode Regulators. This powers the SODIMM and FPGA Core, respectively.

The FPGA, additionally, uses three Texas Instruments TPS74701 Linear LDO Regulators for absolutely lowest ripple. This powers various analog and digital power rails such as PLLs and transceivers.

All power rails have been carefully analyzed with field-solver software to ensure robust power rails to all FPGA, SODIMM and CPU power pins.

Molex iPass x4 Probe Connector

The 2500A unit connects to the 2500A probe via high-quality Molex iPass x4 external PCI Express cable connectors. We supply a 1m Molex iPass cable with the 2500A unit but you can replace it with a shorter or longer cable if needed. We recommend that you only replace it with an original Molex iPass x4 cable to avoid signal integrity issues between the probe and 2500A unit.

TTL Compatible Bidirectional Trigger Port

The trigger port allows you to either send a trigger signal to an external test instrument when the 2500A triggers (“Trig out”) or trigger the 2500A via an external test instrument (“Trig In”). You control the trigger port settings via the ‘Configure Trigger’ dialog box in the 2500A application. The Trigger Port is 5V TTL compatible.

Warranty and Serviceability

The 2500A unit is covered by a 3 year warranty. We also offer replacement and/or repair service for out-of-warranty units.

3.1.2. 2500A Active Interposer Probe

The Active Interposer Probe makes copies of the upstream and downstream data that is then sent to the 2500A PCI Express Protocol Analyzer for detailed analysis. A buffered copy of the 100 MHz PCI Express Reference Clock is also sent to the 2500A unit. The 2500A unit always uses the reference clock from the bus under test. This guarantees that the 2500A's transceivers never under-run or over-run with data.

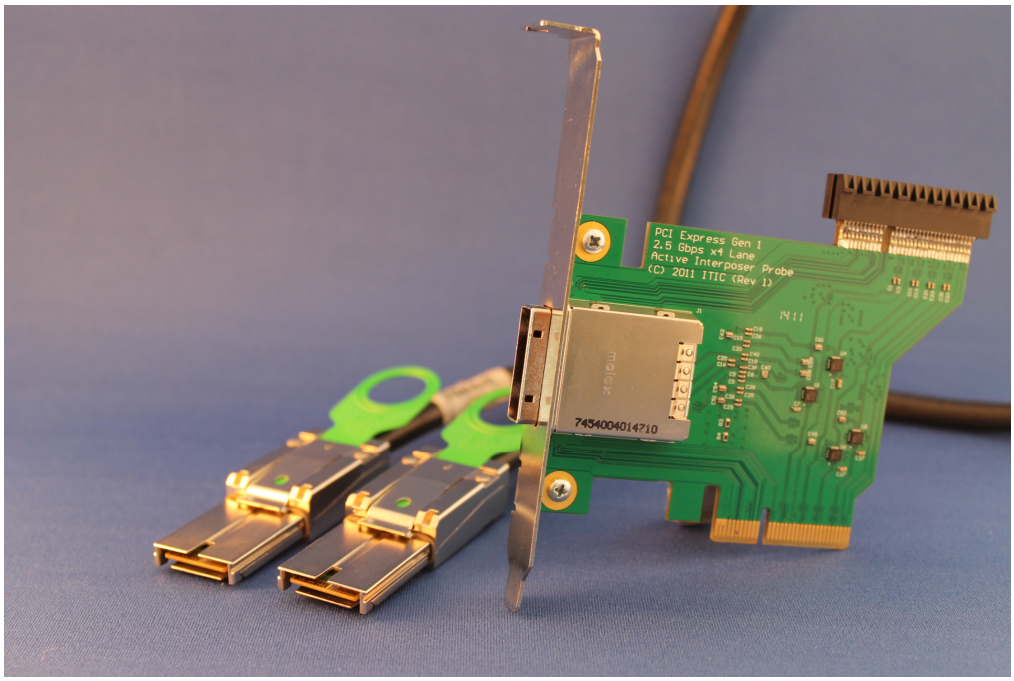

Figure 4. The Active Interposer Probe is included in the 2500A Package.

Note that the Active Interposer Probe is designed with off-the-shelf parts which allow you to easily integrate the probe electronics in your own product. This is useful, for example, for embedded PCI Express solutions where a slot connector is not available.

Please contact us for the probe schematics and parts list.

3.2. Software Reference

The 2500A is fully controlled via the 2500A software. This section describes the software features in detail.

3.2.1. The 2500A PC Application

Figure 5 below shows the various parts of the 2500A PC Application. The following tutorial describes the various features of the User Interface.

Starting the application and opening a previously saved 2500A project

When starting the 2500A Application, you will see the application main window shown below in figure 5. Note that the Protocol Analyzer is not connected and, therefore, the 'Start' and 'Stop' Capture buttons and menu items are disabled.

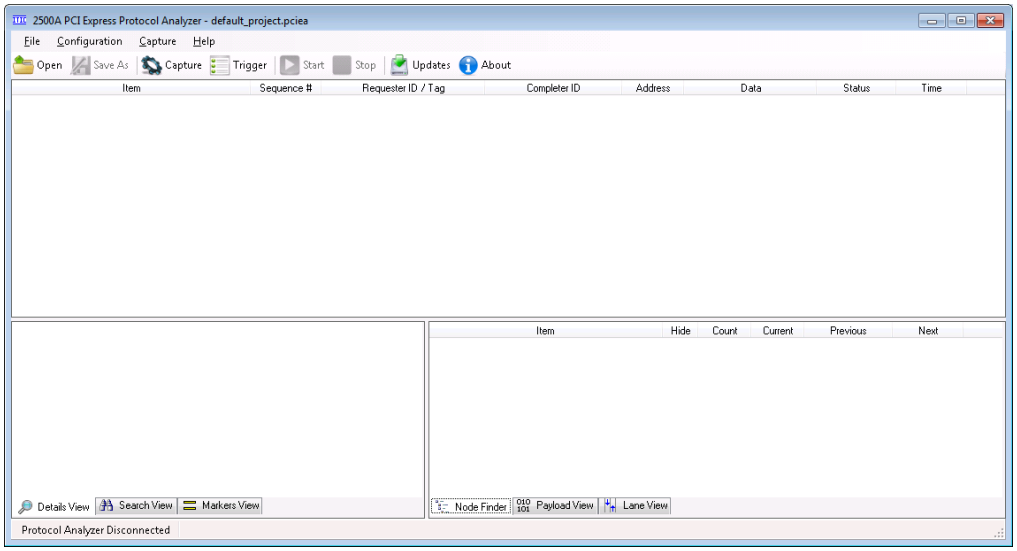

Figure 5. The 'default_project.pciea' opens automatically when the application is started.

To open a previously saved project, click the 'Open' button and select a previously saved '.pciea' project. There are sample projects in the application installation directory.

See the below screenshot (figure 6) for the 'test.pciea' project.

Protocol View, Markers, Node Finder and Timestamps

Note in figure 6 how the upper area of the window (the 'Protocol View') shows a hierarchical view of the captured protocol items. All packets within a transaction are grouped together. This makes it very easy to identify which ACK Packets are associated with TLP Packets, for instance. For example, the below ACK DLLP at timestamp 81 is associated with the Msg TLP at timestamp 0 (since identical Sequence Numbers).

Figure 6 shows, additionally, that two markers have been added to the Protocol View; the first (yellow) marker has been manually added while the second (cyan) marker was automatically added by the 2500A software to indicate the trigger location. It will be, later in this section, explained how to add, edit and delete markers.

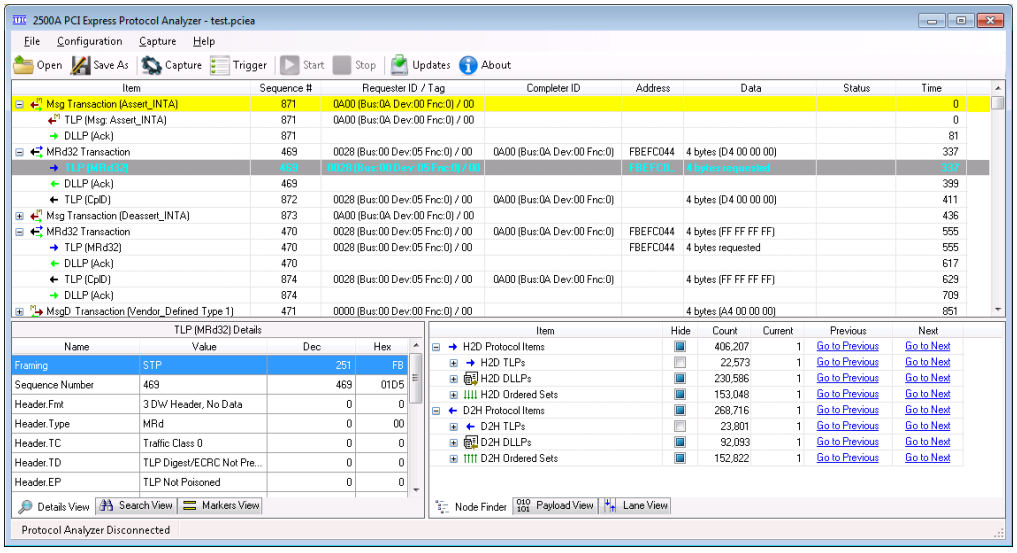

Figure 6. Protocol View (upper), Details View (lower left) and Node Finder (lower right).

The 'Node Finder' view shows the number of Protocol Items of each type in the trace data. This information is provided by the 2500A hardware so the software requires no time to index the complete trace data. The Node Finder allows direct jump to any protocol item in the trace via the 'current', 'previous' or 'next' controls. Furthermore, the 'Hide' checkboxes allows protocol items of certain types to be hidden from view.

Note that the six views at the bottom of the 2500A application can be dragged and dropped in any order. This is, for instance, useful when the Node Finder is used to locate protocol items in the Lane View (both by default located on the same side of the lower tabs). The view locations are automatically saved and later restored the next time the application is started.

Details View and Lane View

The ‘Details View’ decodes the information carried by a TLP or DLLP and clearly displays it in spreadsheet form for easy analysis. When you click on an item in the Details View, the corresponding data is highlighted in the Lane View. For example, as shown below in figure 7, when the LCRC TLP field is selected, the CC5A0593 DWORD is highlighted in the Lane View.

Multiple fields can be selected in the Details View; for example, if all the fields between the starting and ending framing characters (STP, END) are selected, you can see exactly where, in the Lane View, the packet is located.

Note that the fields in the Details View can be copied to the clipboard in CSV format by selecting and copying via the keyboard (CTRL-A, CTRL-C) or via the context menu (right-click menu).

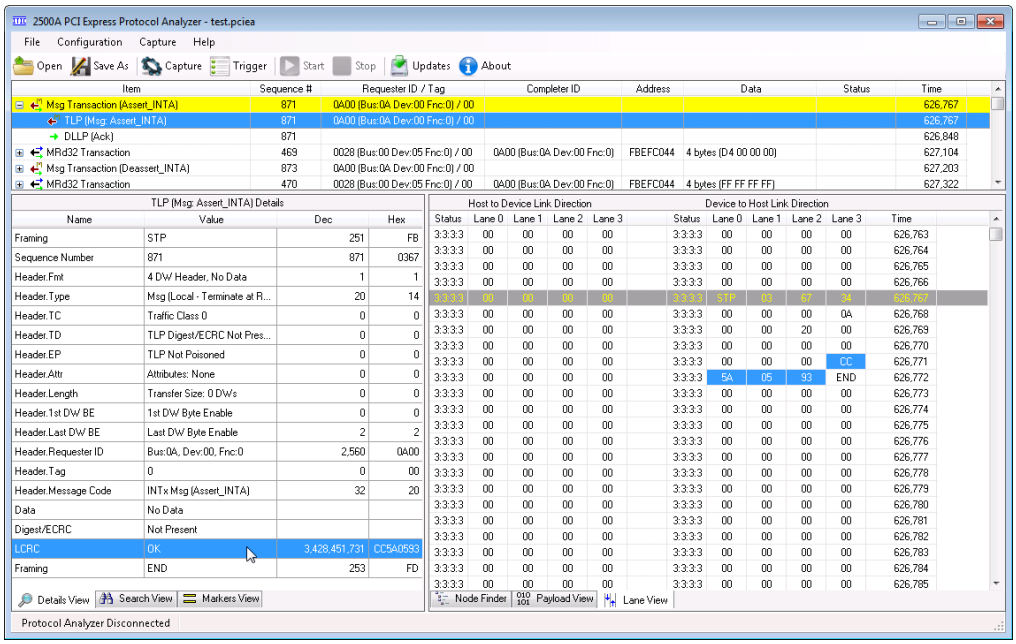

Figure 7. The Details View breaks down packet contents in detail.

The Lane View has an identical context menu to the Protocol View which allows you to select and copy Lane View Items to the clipboard, export to XML, print etc.

Note, in figure 7, how each Transaction and Package are time-stamped with a 4ns resolution (a 2.5 Gbps PCI Express link transfers one byte per lane every 4 ns). The timestamp format can be changed to seconds via most views context menus which are displayed by right-clicking anywhere in a View.

Protocol View Context Menu

As can be seen in figure 8 below, there are a number of operations that can be performed on the Protocol View Items via the Context Menu:

- Protocol View Items can be hidden / shown. Note; hidden Protocol Items can alternatively be shown again by un-checking the corresponding 'Hide' checkbox in the Node Finder.
- A range of Protocol View Items can be selected and copied to the clipboard in CSV format.
- Markers can be added, edited or deleted. Markers will be placed, time-stamp correlated, in the Protocol View, Markers View and Lane View such that easy cross-reference between the various views can be made.
- Packet Payload can be searched for binary or string patterns.
- Protocol View Items can be printed or exported to XML format.
- The time reference and timestamp format can be changed.

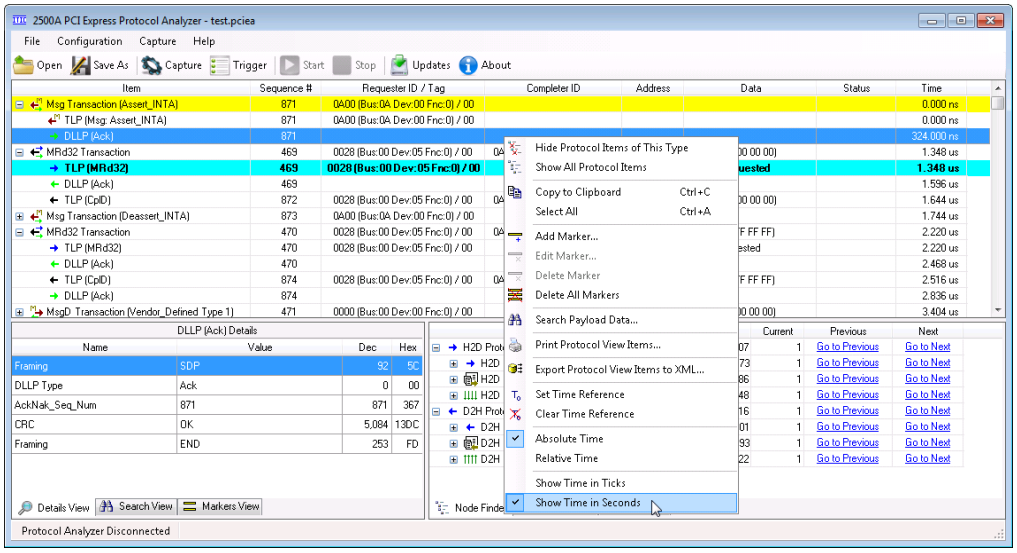

Figure 8. Each view has its own context menu with view-specific commands.

Figure 9 (on the next page) shows how markers can be added or edited via the Add / Edit Marker Dialog Box.

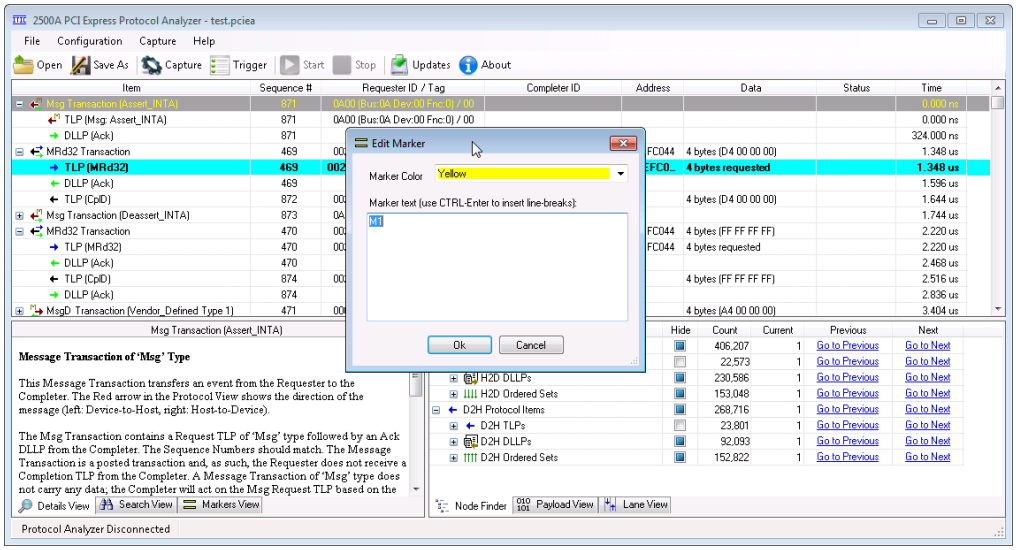

Figure 9. Markers can be added / edited via the Protocol or Lane Views.

Protocol View Payload Search

Figure 10 shows how a binary pattern search is set up. Note that the 'Search View' contains the results of the search.

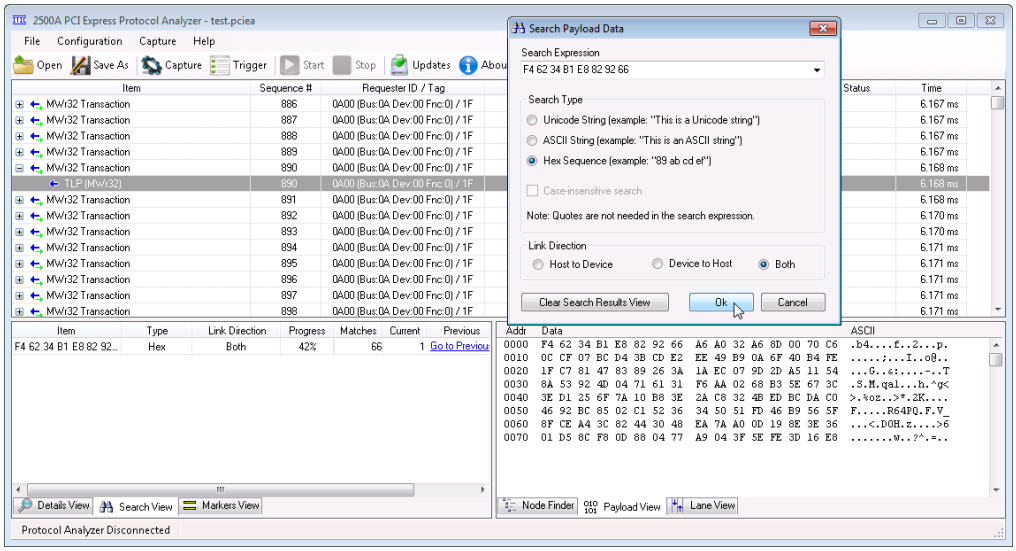

Figure 10. Payload data search setup dialog and Search View results.

Note that the one or more searches are executed on background worker threads. Therefore, you can continue working with the user interface while the background searches are active. Note the 'Progress' of the above search being 42% complete.

To jump to a search result, click one of the 'current', 'previous' or 'next' controls in the Search Results View. Search results can be deleted via the Markers View context menu (right-click menu). Search results can be navigated to at any time, even before the overall search is 100% complete.

Protocol View Print and Print Preview

To print Protocol View Items;

1) Define two markers that will define the beginning and end of the range of Protocol View Items to be printed.

2) Select 'Print Protocol View Items' from the Protocol View's context menu (right click in the Protocol View). The below dialog box will open:

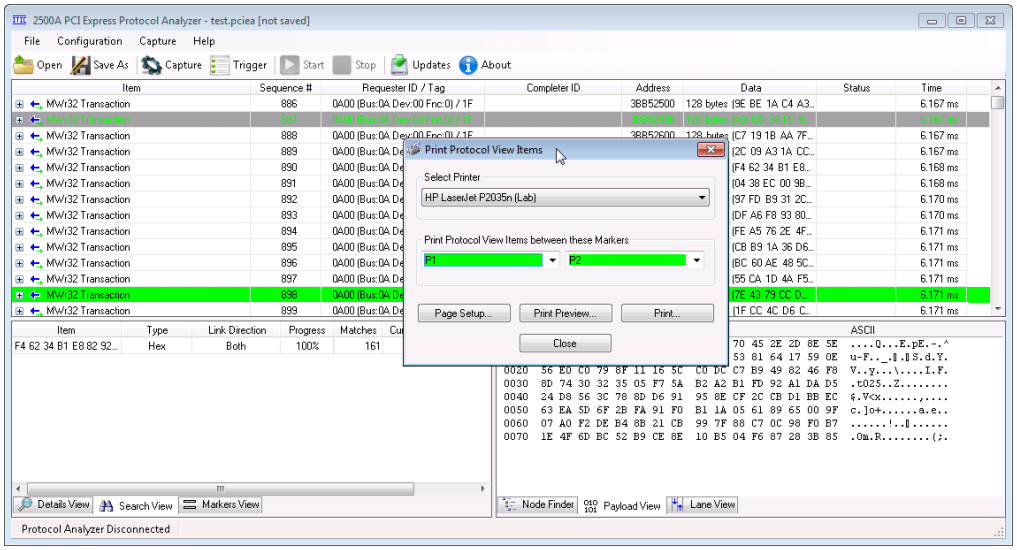

Figure 11. The 2500A Application contains advanced print and print preview functionality.

You can then select the printer to use for your printout, adjust page orientation, margins etc (via the Page Setup), Preview the printout and actually print the range of Protocol Items. Figure 12 below shows the Print Preview dialog.

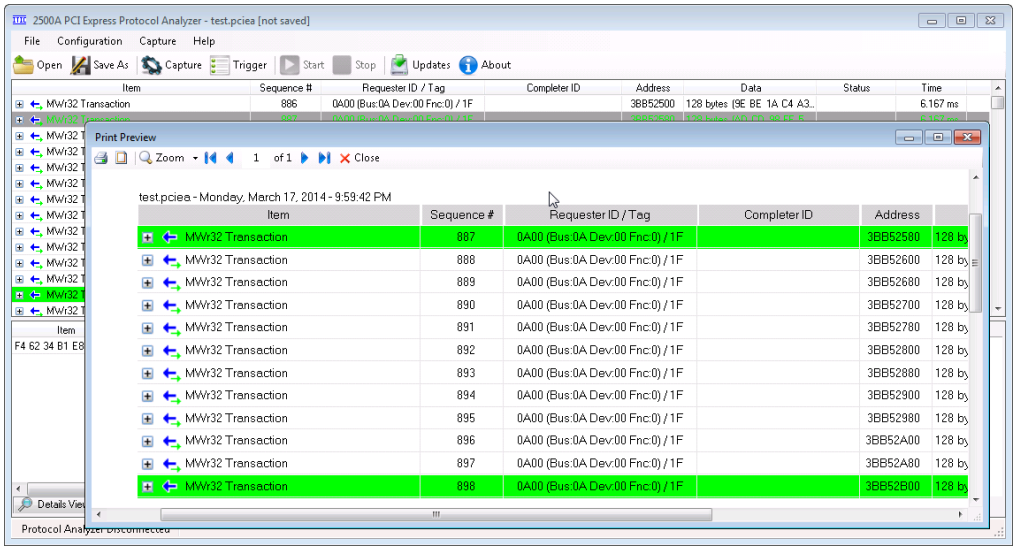

Figure 12. The print preview dialog allows zoom, page adjustments etc before printing.

Protocol View XML Export

To export Protocol View Items to XML;

1) Define two markers that will define the beginning and end of the range of Protocol View Items to be exported.

2) Select 'Export Protocol View Items' from the Protocol View's context menu (right click in the Protocol View). The below dialog box will open:

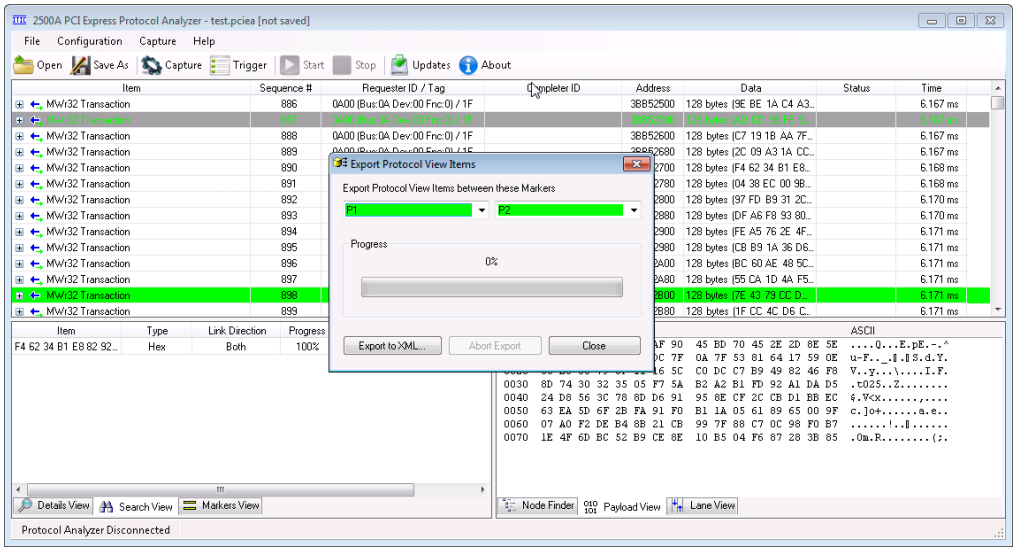

Figure 13. Export data to XML via the 'Export Protocol View Items' dialog box.

Select the output file via the 'Export to XML' button. Figure 14 below shows the resulting XML data output.

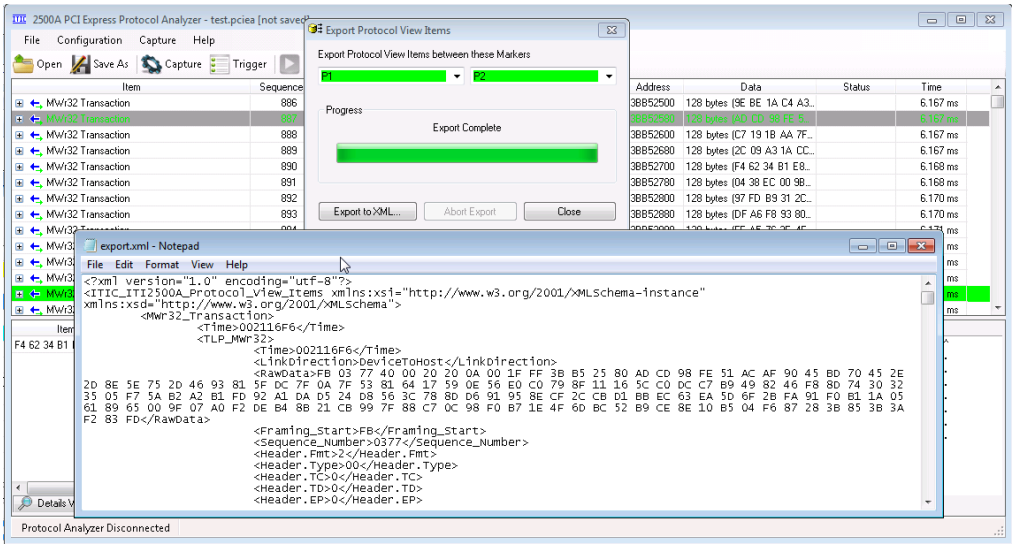

Figure 14. The exported Protocol View Items in XML format.

Note that the exported XML contains all hierarchical and detail information available in the Protocol and Details Views. Therefore, there is no loss of information in the exported XML data. This allows XML export to be used as interface to custom analysis software.

Markers View and Lane View

Figure 15 below shows the Markers View in which all markers can be sorted on any column (by clicking the column). The figure shows the markers sorted in time order. Note that the 'Time Reference' (T0) has been set to the Trigger Location (this is the default after a capture). Also note that the 'Trigger' Marker is also shown in the Lane View.

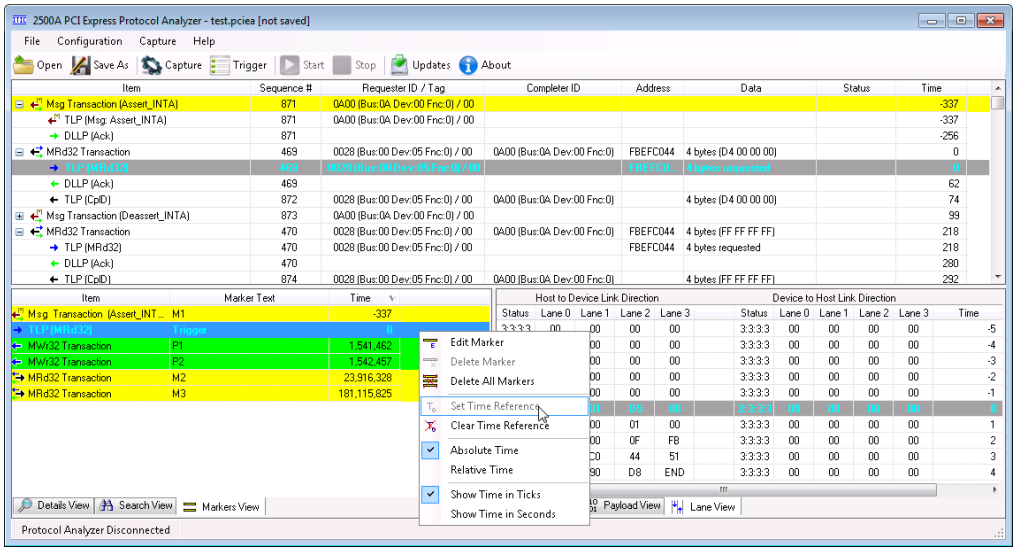

Figure 15. The Markers View allows easy analysis of the markers in the project.

Figure 15 also shows the Lane View which contains the raw data as it is received on the FPGA transceivers. Note that the FPGA first de-skews and de-scrambles the data before displaying it.

Capture Configuration Dialog Box

The descrambling can optionally be disabled via the 'Configure Capture' dialog box shown below in figure 16 (accessible via the 'Configuration/Capture' main menu item or via the 'Capture' toolbar button.

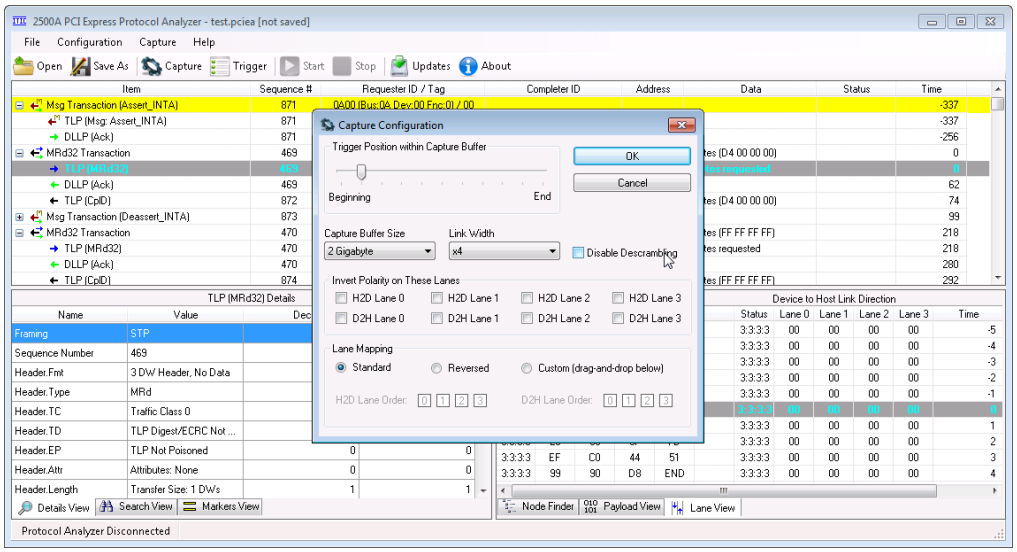

Figure 16. The Capture Configuration dialog box customizes the 2500A capture settings.

The Capture Configuration dialog box contains the following controls:

Control	Used For
Trigger Position within Capture Buffer	This allows you to adjust where, in the capture buffer, you want the trigger position to be located. If, for example, you want to capture the data that leads up to the trigger position, you would set the trigger position towards the end of the capture buffer.
Capture Buffer Size	This allows you to choose how much trace memory will be used during the capture. Smaller buffer sizes result in smaller trace files on disk.
Link Width	Used to select the number of lanes your device uses to communicate with the root complex.
Disable Descrambling	Checking this control will disable the PCI Express data descrambling. Normally, you would only check this when capturing the PCI Express Compliance Pattern which is not scrambled.
Invert Polarity on These Lanes	Checking one of these checkboxes will invert the polarity of one lane in one link direction. This compensates for inverted physical wires on the bus under test.
Lane Mapping	This allows you to reverse the normal lane order per the PCI Express 1.1 Specification. You can also assign a custom lane order if needed to compensate for a not specification compliant lane order.

Table 1. Description of the Capture Configuration Dialog Box Controls.

Trigger Configuration

The Trigger Configuration dialog box allows you to:

- Configure a Trigger Sequence Detector for each of the 8 Trigger Levels.
- Configure the Trigger Input / Output Port.

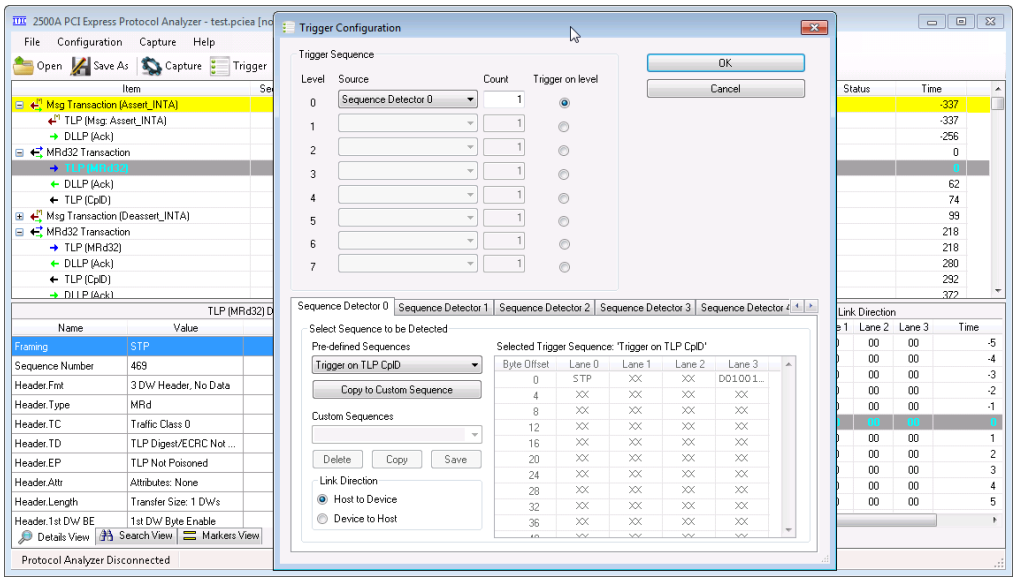

Figure 17. The Trigger Sequencer allows up to 2048 byte long sequences per level to be detected.

To Configure the Trigger Sequencer, you need to:

1) Select a Sequence Detector for a trigger level (Trigger Source).

2) Configure the Sequence Detector with either a pre-defined Trigger Sequence or a custom trigger sequence.

Note that the software includes pre-defined trigger sequences for all standard TLP and DLLP Packet types.

You'll define a custom sequence by copying a predefined sequence to a custom sequence and then editing the custom sequence in the spreadsheet in the above dialog box.

Trigger Sequence K and D symbol syntax

Specific D and K symbols can be entered in the Trigger Sequence editor per the following rules:

- Two-character cell data is interpreted as 'K don't care' hex data (i.e. either a D or K symbol will result in a match).
- Three or more characters in a cell is interpreted as binary data UNLESS one of the below explicit K character token strings (SKP, IDL etc).

- An X is interpreted as a don't care nibble (for hex data) or a don't care bit (for binary data).
- A K symbol is represented as COM/K28.5/KBC, PAD/K23.7/KF7, SKP/K28.0/K1C, STP/K27.7/KFB, SDP/K28.2/K5C, END/K29.7/KFD, EDB/K30.7/KFE, FTS/K28.1/K3C, IDL/K28.3/K7C or any other K symbol via its KXX.Y or KHH code.
- A K don't care is represented as KXX.X or KXX (i.e. any K symbol results in a match).
- Data characters can be encoded HH, DXX.Y or DHH.

Examples

You want to detect	Examples
K or D, possibly don't care nibbles, hex data. K don't care.	"6X", "XA", "6A"
Explicit 10b Code	"DXX.X", "KXX.X"
K or D, possibly don't care nibbles, hex data (explicit K/D)	"K6X", "KXA", "KXX", "D6X", "DXA", "DXX"
Explicit control character token string	"COM", "STP"
Binary data	"10101010" (K or D), "K10101010" (K binary), "D10101010" (D binary), "Kx0x01010" (K binary with don't care bits)

Table 2. Examples of trigger sequence D and K symbol syntax.

Capture Start / Stop

After the Capture Configuration and Trigger Configuration have been done, the capture is started via the 'Start' button (or menu command). Once all Trigger Sequences in all enabled trigger levels have found matching data, the capture stops automatically and the captured data is displayed in the application. The capture can also be stopped manually via the 'Stop' button/menu command.

Once the capture is stopped, the 2500A software programs the 2500A hardware to locate the location of all protocol items in the capture buffer. This data is called Meta-data since it is data describing the main data. The 2500A then uses the meta-data to build an in-memory hierarchical representation of all protocol items in the 2500A unit's capture buffer. Note that the data is retrieved on an as-needed basis from the 2500A hardware after a capture. This allows the complete 2 Gigabyte of data to be browsed effortlessly without having to upload the data to disk first. Once the project is saved via the 'File / SaveAs' menu item, the data is uploaded from the 2500A hardware and saved to disk file.

License Configuration

Certain features, such as capturing data in x2 and x4 link width configuration requires a license. Licensing is not checked when viewing data, only when new data captures are made. For example, you can capture x4 data on a 2500A unit that has a x4 license and later view the captured data on any 2500A software installation.

Licenses are tied to the 2500A hardware unit; once licensed features are unlocked for a particular 2500A unit, it will follow the unit when moved to another computer. In other words, the license is stored in the 2500A unit, not on the computer running the 2500A software.

To view the current licensed features or enter a new license key, open the License Configuration dialog box shown below in figure 18. Note that this dialog is not available if a 2500A unit is not connected to the PC running the 2500A software.

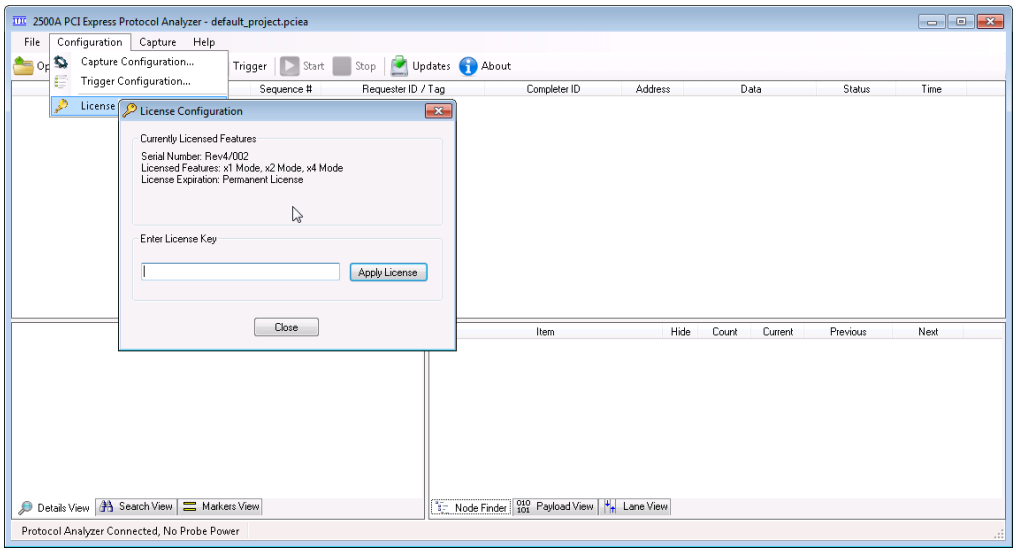

Figure 18. A temporary or permanent license is entered in this dialog box.

If you need a trial license extension or want to upgrade your license, please contact support@InternationalTestInstruments.com. Please make sure to include the serial number of your unit (shown in the above dialog box) since issued licenses are tied to a specific 2500A unit.