Precision Characterization of Ethernet Devices with LabVIEW Real-Time and FPGA

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Category:
Industrial Machinery & Control
Electronics & Semiconductor

Product(s) Used:
NI PXI-1062Q 8-Slot 3U PXI Express Chassis
NI PXIe-8840 2.6 GHz Quad-Core PXI Express Controller
NI PXIe-7820R R-Series Digital RIO with Kintex-7 160T FPGA
NI 8234 Dual Gigabit Ethernet Interface for PXI Express
NI LabVIEW 2015
NI LabWindows/CVI 2010

The Challenge
Create a complete hardware/software solution to precisely characterize Ethernet communication devices for timing, power consumption, and error response at the OSI Layer 2 level. Design the system to be easily extensible by customer's own internal resources.

The Solution
Utilize NI RT and FPGA PXIe modules with ample power to satisfy the customer's nanosecond timing requirements, along with an equally-modular LabVIEW software architecture designed around cohesive plug-in components that can be easily cloned and modified.

Introduction
Data Science Automation (DSA) is a premier National Instruments (NI) Alliance Partner that specializes in automating and educating the world leading companies. Clients choose DSA because of DSA's deep knowledge of National Instruments products, disciplined process of developing adaptive project solutions, staff of skilled Certified LabVIEW Architects and Certified Professional Instructors, and unique focus on empowerment through education and co-development.

Needed: High Precision Ethernet Testing.
The high-criticality, military applications that our customer has in mind for their custom Ethernet devices require that they are extremely well-understood in terms of timing, error handling, and power consumption. Standard NIC cards do not have the low-level capabilities of CRC error injection or sending malformed packets, so we integrated with an Absolute Analysis Investigator device which supports those features, and can also simulate attenuation along extended cable lengths. For power consumption measurements on the DUT, we were integrated an Agilent 6795B Power Analyzer. LabVIEW's wide-ranging interoperability made it

easy to interface with each of these 3rd-party devices. An intuitive, simple GUI for scripting steps related to each of these modules was created in LabVIEW and ran on a separate Windows PC.

Application Plan

Our customer is starting advanced work on a large, long-term-use application for testing new Ethernet systems for their military applications. They have some LabVIEW development experience in-house but the complexity of the system required a partnership with DSA to build the needed adaptable and extensible software framework.

The test system needed to offer the following functionality;

- A general framework for calling test steps at microsecond-level timing accuracy
- Ability to configure, load and save custom test scripts
- Execute macros (a test step that refers to another test script file)
- Test steps configurable to accomplish the following actions;
    - Configure digital channels for digital trigger output, set pulse width
    - Send trigger pulse on a particular digital line with microsecond or greater accuracy
    - Send configurable Ethernet traffic patterns to DUT on multiple twelve Ethernet ports
    - Specify explicit data to make up Ethernet frame (hex representation)
    - Inject CRC errors or send malformed Ethernet frames to DUT to test behavior
    - Simulate extended Ethernet cable lengths (configurable length)
    - Capture Ethernet data coming from the DUT on twelve Ethernet ports
    - Log captured frames, both raw data and extracted info (e.g. MAC addresses, timestamps)
    - Track and record statistics per port such as number of frames, number of CRC errors
    - Control voltage outputs on a power analyzer (levels, enable/disable)
    - Monitor and log power consumption, control voltage output to DUT

In addition to this functionality, the client received training, guidance and documentation on how to add further components to the software.

Software Architecture – Creating the Network Pipes

The software would be running independently on at least three different nodes, with different conceptual components communicating specifically to their counterparts on other nodes, so an abstraction from the one-to-one TCP or Network Stream built-in communication was convenient. We created a “Network Pipes” library that allows various one-to-one streams of different data types to be passed across the same point-to-point physical layer (Figure 1.)

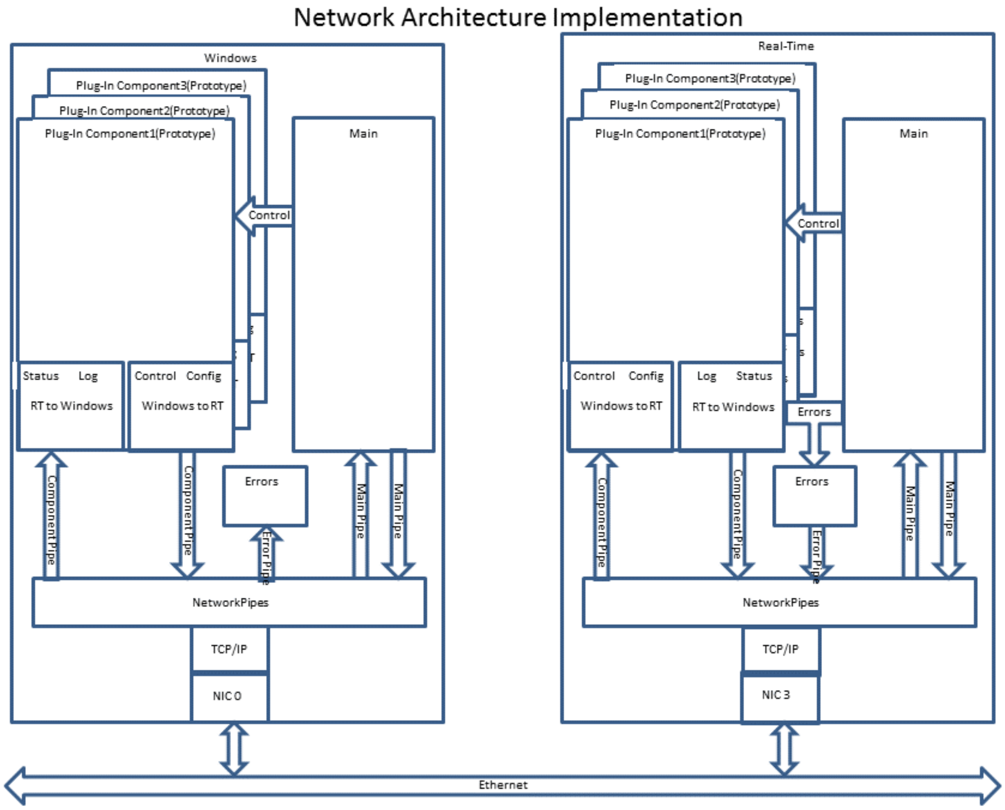

Figure 1. Network architecture for test application written in LabVIEW

Two of the three nodes are shown in Figure 1, but the third also communicates with the RT application via the same network pipes. This third node runs on the Windows system that is part of the Absolute Analysis Investigator. It accepts commands and takes corresponding actions using the shared library API provided by Absolute Analysis to configure and control the twelve customizable Ethernet ports on that system.

The API provided by Absolute Analysis is offered in the C language via header files and a .dll file, but LabVIEW's extensive interoperability allowed an easy way of integrating with this API. LabVIEW Call Library Function nodes were implemented to wrap the various C API functions exported by Absolute Analysis's .dll, and these function nodes were wrapped into VIs utilizing another Call Library Function node to Absolute Analysis's error code translator, merging these with the standard LabVIEW error cluster. These wrappers were then integrated into a library with a single polymorphic public member for convenient and fool-proof access.

The script steps themselves are executed on the RT node in Timed Loops which run deterministically at 10 MHz each, checking the current time versus the assigned step time configured in the script sent down from the Windows GUI at the start of a run. These loops utilize the Synchronized Start Timed Loop capability of the LabVIEW RT module to enable parallel loops in each component to start at a hardware-timed level of synchronization.

The highest-speed elements (digital triggers) are pulled from these components and delegated to the Complex Timing and Control (CTC) module which runs on the FPGA on the NI 7820R module. This allows extremely precise timing of these digital triggers running to either the Power Analyzer or the Absolute Analysis Investigator. The CTC module can run long test scripts by utilizing a circular buffer which is continuously read and fed by an actor on the RT controller.

Empowered User Interface and Operation

On the Windows GUI, a script may be loaded into the Event Manager, where its macros are expanded into their constituent steps, and the steps are divided amongst the various components to which they below (Investigator, Power Analyzer Module, any added components in the future). A sub-panel displays information specific to each component and provides for an interface to arm all participating components and start a test run. The system automatically detects which components are connected, and those not active in the test script are not required to be connected.

A screenshot of the Power Analyzer configuration window is shown in Figure 2.

Figure 2. Windows GUI, with Power Analyzer component screen showing in sub-panel.

Creating an intuitive and revealing graphical display of the script and data was simple using LabVIEW's native graphs and other controls. The data from the Power Analyzer is displayed in the top left, with ability to toggle visibility of plots and adjust the viewing window parameters. The Analyzer-specific script steps are shown at center and the current step is automatically scrolled to the top as the test progresses.

A third LabVIEW application ran on the Absolute Analysis Investigator Windows system in order to display status and log configuration commands, as shown in Figure 3.

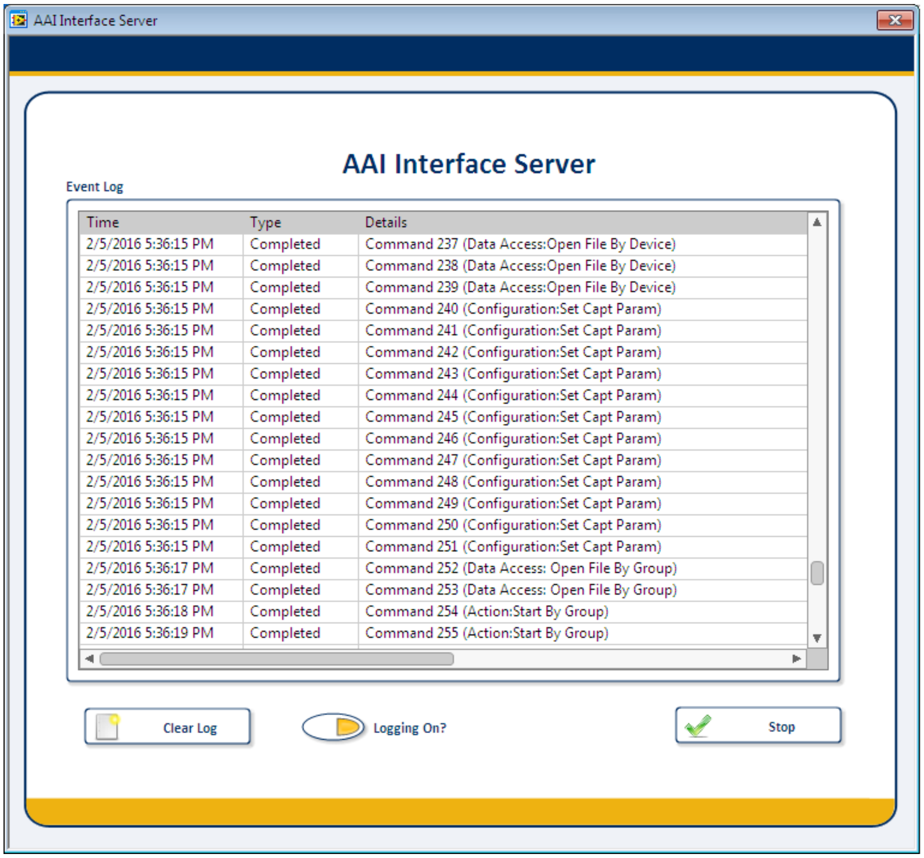

Figure 3. Diagnostics and status GUI for LabVIEW application running on Investigator unit. Shows events, status, and details

For data output, a number of portable, human-readable formats were utilized as per customer requirements. For the Power Analyzer, standard tables by time stamp, with a column for each measured and logged value, were created easily using LabVIEW's built-in API for delimited spreadsheet files. For the Ethernet data, the structured, nested nature of the objects made LabVIEW's JSON interface a convenient choice.

Cost Effective and Flexible Results

The flexibility and interoperability of LabVIEW allowed DSA to create a cohesive software framework for characterization of our customer's high-speed Ethernet devices. A simple, intuitive GUI provides access to nano-second level test scripting, hiding the diverse functionality of three network-connected software components integrating over $150,000 in 3rd-party test hardware. Our client was happy with the existing functionality, and confident that he and his team would be able to support and build on it for years to come.

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