LabVIEW and NI Instrumentation
High Speed Data Acquisition Vibration Test System for Testing Re-Entry Vehicles

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The Challenge
Sandia National Laboratories (SNL) required a system that would allow them to acquire and store up to 160 channels of vibration test data at speeds of up to the device maximum of 102.4kHz for up to 120 minutes. Each channel on each card was to be simultaneously triggered and also tightly synchronized to the same scan clock to provide data suitable for high resolution phase analysis. In addition, four channels were to be graphed run-time along with having an Fast Fourier Transformation (FFT) performed and displayed for each of the four selected channels.

The NTS Solution
Use LabVIEW in conjunction with National Instruments (NI) hardware including the unreleased NI 6653 Timing Modules to create a measurement system capable of triggering, synchronizing, acquiring, displaying and storing to disk all test data with Local Area Network (LAN) connectivity. NI was chosen as the sole hardware and software supplier based on its proven performance, reliability and ease of implementation.

Abstract
The Vibration Test System (VTS) was designed to address the vibration testing needs of SNL for testing and verifying re-entry vehicles. Utilizing the immense power, speed and storage capabilities of modern PC architecture, the powerful LabVIEW and DAQ interface in conjunction with prototype and readily available NI instrumentation, BBT was able to design a system capable of handling the demanding bandwidth and processor intensive requirements of the SNL tests in addition to providing the flexibility of having three different system configurations available that simplify the test procedure for varying channel counts and scan frequencies.

Introduction
Prior to this system, SNL had been unable to synchronize, acquire and digitally store the data from systems with such high channel counts and fast scan rates. Since card synchronization requires the use of the PXI star trigger lines which only extend to slot 14, two chassis were built each with twelve DSA cards plus a PXI-6653 Timing Module and a PXI-MXI-3 interface module. The 6653 provides the scan clock and simultaneously triggers all DSA channels. With extensive testing, it was found that the test requirements exceeded even the fastest computers' bus and bandwidth limitations resulting in the need for two workstations to handle the high channel count and high scan rate scenarios. With a data throughput of 25MB/s or 1.5GB/minute per chassis, this dictated the use of Ultra 160 SCSI storage drives instead of Ultra ATA IDE hard disk drives.

In the end, three options were provided to the customer to accommodate the wide variety of channel counts and scan rates, each of which providing LAN connectivity. The first option uses a single workstation connected via MXI-3 to a single chassis allowing the scanning and storage of up to 80 channels at 102.4 kHz for up to 120 minutes. It was found that the standard LabVIEW DAQ functions were too memory and processor intensive and as such, the unreleased LabVIEW High Speed Data Logging (HSDL) utilities had to be streamlined, customized and implemented. With two identical computers and chassis provided, SNL was given two complete, independent test systems for channel counts under eighty.

The second option uses one workstation connected to two PXI chassis piggy-backed together via MXI-3 allowing the scanning and storage of up to 160 channels at scan rates of up to 40 kHz for almost 4 hours. The maximum throughput of this system was reduced to 19.2 MB/s as a result of the increased bus activity associated with the additional cards. Both chassis were connected by the 6653s with one chassis as the master responsible for setting up the triggering and clock synchronization.

The third option uses both workstations, each connected to a PXI chassis via MXI-3 with both chassis connected by the 6653s with one of the systems as the master. The LabVIEW software requires no slave system input as all acquisition and trigger setup is performed on the master system and then transferred to the slave using VI server over ethernet. Upon test completion, the user is prompted to transfer any or all of the slave's acquired data to the master computer for further analysis. Figures 1 and 2 show the block diagram and photograph respectively of the system described above.
Figure 1. Two Workstation, Two PXI Chassis Configuration Block Diagram

Figure 2. VTS Hardware Setup for a Two Workstation, Two PXI Test Configuration
With either dual PXI chassis configurations, a great deal of software setup is required to initialize and set up the triggering and clock synchronization. The LabVIEW software only requires the input of the 6653 VISA descriptors, master and slave IP addresses, acquisition parameters and DSA slot locations and device numbers. For each system, commands must be issued in a very specific order, with handshaking between master and slave workstations and devices, to properly set up the synchronization.

**Software System Functionality**

The main panel allows software to be run for all three configurations, a Scope mode, and an Extract Channel. Once a configuration is chosen, the user is prompted to perform a system setup which requires specifying the 6653s VISA Descriptors, the master and slave IP addresses (if applicable) and the acquisition parameters such as scan rate, test duration, etc. The most complicated of the setups is the Two Workstation, Two PXI Chassis setup shown in Figure 3.

![Figure 3. Master and Slave Setup Screen for the Two Workstation, Two PXI Configuration](image)

After pressing Begin Acquisition, VI Server communication begins by rerouting scan clock and trigger signals to first setup the slave and then the master acquisition. The setup parameters are saved to a text file and then sent to the slave application (no user interaction required) to execute all slave and master triggers and timing using VI Server. Once setup has completed, the monitor window (shown in Figure 4) pops up on both systems (if applicable) allowing the user to monitor four channels (which can be changed at any time) in run-time mode in addition to performing and displaying an FFT of those channels.

![Figure 4. Typical Acquisition and Monitoring Panel.](image)
During acquisition, data is streamed to disk using LabVIEW’s HSDL utility which allows the programmer to eliminate the overhead of bringing the data into LabVIEW and then transferring it to file. Since the data is never brought into LabVIEW, it cannot be plotted or analyzed run-time except by manipulating AI Buffer Read. By reading from the end of data instead of from the read marker, the programmer is able to read data from the buffer without interrupting the data flow to disk. With this technique, the user gets the high performance of streaming directly to disk while not sacrificing the ability to monitor the data run-time.

At test completion, the program returns to the main panel where another test can be run or channels can be extracted. When extracting a channel, the user chooses the test to extract data from and in doing so, retrieves all test parameters from the text file and is then able to specify the device, channel, start offset and number of scans to extract.

**Conclusions**

With the implementation of the VTS, SNL now has an easy-to-use, robust solution that allows them to confidently acquire, monitor and digitally store accurate, synchronized vibration data from up to 160 channels at 102.4kHz taken from a re-entry vehicle. Furthermore, SNL is now able to maintain and archive digital test results which can be called upon at any time for further analysis or review.

**Products used in this Program**

**National Instruments Products**

**National Instruments Hardware**
- PXI-1006 18-Slot 3U Chassis DC (Quantity 2)
- PXI-1006 Rack Mount Kit (Quantity 2)
- PXI-4472 Dynamic Signal Acquisition (DSA) Measurement Device (Quantity 20)
- PXI-6653 Timing Module (Quantity 2)
- PXI-8335 MXI-3 Interface Module (Quantity 3)
- PCI-8335 MXI-3 Interface Module (Quantity 2)
- MXI-3 5m Fiber-Optic Cable (Quantity 2)
- PXI-GPIB Controller (Quantity 2)
- GPIB X2 2m Cable (Quantity 2)

**National Instruments Software Used**
- LabVIEW 6.1 Professional Development System (Quantity 2)
- NI-488.2 Version 1.7 (Quantity 2)
- NI-DAQ Version 6.9.2 (Quantity 2)
- High Speed Data-Logging Utilities (unreleased NI software) (Quantity 2)

**Third Party Hardware/Software Used**
- Linksys EtherFast 5-Port 10/100 Workgroup Switch (Quantity 1)
- Dell Precision 530 Workstation (see specs below for each workstation) (Quantity 2)
  - Windows 2000 Professional
  - dual 1.5GHz Xeon Processors (512 kB cache on each processor)
  - 512 MB PC800 @ 400 MHz RDRAM
  - One (1) Western Digital 80 GB Ultra ATA IDE Hard Drive
  - Three (3) 73.5 Seagate Ultra 160 SCSI Hard Drives
  - 19” Dell Ultrascan Monitor

**About NTS Test Systems Engineering**

NTS TSE, located in Albuquerque, NM, designs and integrates test, measurement, automation, data acquisition and control systems utilizing diverse hardware platforms, operating systems, and instrumentation standards. Our expertise involves projects ranging from LabVIEW instrument drivers to full-blown automated turnkey systems. The dedicated staff of electrical and mechanical engineers, project managers and technicians of NTS are well versed in designing, integrating and programming real world solutions for industrial applications for a diverse set of operating systems and standards.

**Test & Automation Services Include**
- Requirements Analysis & Development
- Hardware Design
- Software Design & Architecture
- Instrument Drivers
- Test System Management (TestStand)
- Software Development (LabVIEW)
- Data Management & Analysis (DIAdem)
- Enterprise Solutions
- Fabrication
- Integration
- Installation & Training
- Maintenance & Support
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