VXI-LXI DAQ System Ensures Mission Critical Reliability for Rocket Engine Test

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This rocket launch vehicle manufacturer is the world's largest producer of solid rocket motors (SRMs), which are used for delivering payloads both inside and outside of Earth's atmosphere. The company produces and tests small- to mid-sized rocket motors for several programs. The defense industry uses SRMs to precisely deliver a destructive force while space agencies use man-rated SRMs to carry humans into space.

Whether it's validating the development of future SRMs or verifying the production of existing designs, adequate testing is critical to the success of each launch. SRM testing requires the utmost accuracy because a launch failure can be catastrophic and result in the loss of lives. Two specific examples are space mission launches that do not go as planned and the launch of defensive missiles that malfunction or do not fly on target. Testing these launch vehicles can be complicated because of the extreme nature of the environment.

Test Setup

The rocket launch vehicle manufacturer conducts SRM tests at its rocket motor test stands, which are located in a remote part of the US where testing can be conducted safely. The test stands (or cells) are positioned so that the solid rocket motors are held in place and can be fired while hundreds of data acquisition channels collect data. During testing, personnel and equipment must be safeguarded against the firing of the motor. To do this, the equipment must be enclosed in a large cement structure over 100 meters from the launch vehicle. Operators and controlling PCs are further separated in a bunker 1,500 meters away from the test site. Therefore, Ethernet drastically simplifies the separation of personnel, instrumentation, and the motor under test by allowing data to be acquired remotely. Because of the cost associated with firing an SRM, a reliable test procedure is vital. These procedures systematically guarantee that all instrumentation is up, running, and collecting reliable data before the motor is ignited.

The Challenge – Maintaining Stability and Accuracy in an Aggressive Environment

The manufacturer was using an older generation data acquisition system that measured strain, temperature and vibration. The company wanted to upgrade to a high-performance, high-accuracy system with reduced maintenance and calibration costs. Additionally, the desire for guaranteed reliability and improved maintainability helped justify the capital costs required to upgrade the existing test cells.

To identify a replacement system, the manufacturer narrowed their options to four vendors, VTI Instruments being one. The company held a final test involving full verification during a live solid rocket booster test to see which system performed best. A space shuttle booster was used to create one of the most severe test environments. Each test system was placed underneath the SRM in a reinforced blockhouse and connected via Ethernet to the observation blockhouse 2,000 meters away. Each system was connected to similar transducers that were calibrated and mounted by the manufacturer's

technicians. The systems were required to record data for about 10 minutes, including the 300+ seconds of booster firing at full data rates. After the test, the data from all vendors was analyzed and compared with the data returned from the legacy test systems, which was used as a baseline. Due to the severe test environment, two of the competing systems suffered data loss during the test. The reliability and accuracy of VTI's test data was unmatched by the competitors.

The Solution – Robust DAQ System Ensures Accuracy and Reliability

VTI's system was selected primarily because of the integrity of the physical design, which allows it to operate normally in harsh environments. Additionally, VTI's instruments deliver exceptional accuracy and reliability. VTI provided a hybrid solution that used VXI hardware for the dynamic data acquisition, and LXI/LAN instrumentation for the static strain and temperature measurements. To facilitate a seamless integration of the system components, the VXI chassis included an LXI-VXI bridge interface which allowed the VXI mainframe to be controlled via a LAN connection.

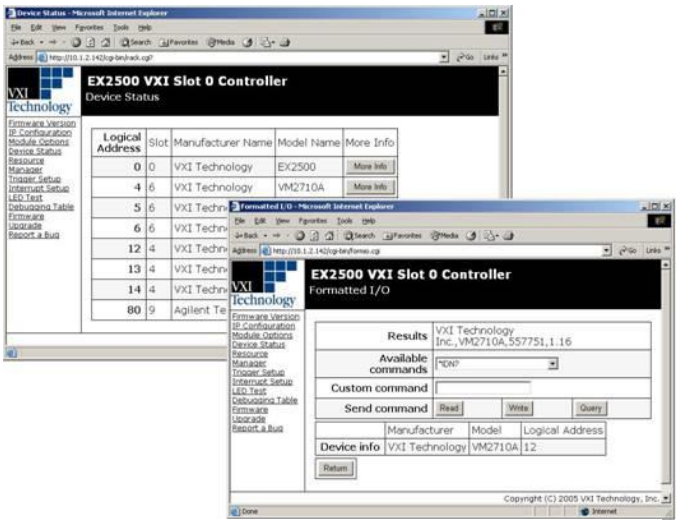
The system included the following primary components:

EX2500A, LXI-VXI Bridge Interface:

The EX2500A is a gigabit LAN-based VXI slot 0 interface, merging Ethernet's robust architecture and widespread infrastructure instrumentation with the stability of the VXIbus platform. Recognizing that many system designers require hardware that is compatible with legacy systems, but also desire to adopt new technologies, the EX2500A integrates key features of the LXI standard to create a versatile interface that extends the VXIbus to an external host through the power of Ethernet.

- Up to 10 KM distance from PC to mainframe through fiberoptic interface.
- 40 MB/s block transfer rates
- Embedded Web Interface provides interactive utility to control instruments
- Rack-Rack TTL trigger extension through on-board LXI Trigger Bus
- Backward compatiblilty with VXI 1.4 and 2.0 products
- External Clock In/Out with on-board options for TCXO/OCXO

EX2500A – LXI-VXI Interface



EX2500A – Embedded Web Interface

VT1432B, Dynamic Signal Analyzer

By combining the VXI VT1432B high-speed digitizers with the EX2500A LXI slot 0 controller, the VXIbus form factor integrates seamlessly with the LAN-based EX1629 and EX1048A. The hardware can be synchronized across platforms and used in conjunction with VTI's common software solution, DAC Express. This instrument has 24-bit ADC and superb noise filtering.

- 8 Input ranges including a 100mV range allowing for use of low sensitivity transducers
- True balanced differential inputs
- On-board user-programmable DSP greatly improves total system performance.
- FIR digital anti-alias filter provides linear phase response for accurate single and cross channel measurements.
- Multiple breakout box options with built-in signal conditioning including charge inputs, simplify tests and reduce cost.
- Optional arbitrary source or dual input tachometer.
- 32 MB on card FIFO memory plus optional local bus allows data records up to 146 GB with the VT2216A VXI data disk, and larger data files to external SCSI disks.

EX1629; 24-bit Static Strain Measurement

This instrument offers outstanding signal conditioning and bridge completion. Its flexibility in bridge configuration is unmatched by other competitors. Users can accommodate all standard bridge configurations as well as one custom definable configuration on a per-channel basis. VTI also provides exceptional signal filtering and self-calibration routines, which result in high-accuracy measurements.

- **Superior Analog Design:** The analog front-end of this device is equipped with 24-bit ADC per channel, which provides higher resolution and more dynamic range. This feature ensures that the instrument captures all the data correctly the first time without the user having to worry

about improper range settings. The front-end also uses trifilar filters to reject any common mode noise on the input signal.

- **Simplified Self-Calibration:** Users can perform a self-calibration before each test. During this process, an on-board precision voltage source verifies each input path. Based on the known value of the voltage source, the instrument can make minor adjustments to the measurement to improve accuracy and compensate for temperature variations.

- **Convenient RJ-45 Connection:** This provides a reliable, low-cost connection even in high-vibration environments. Prior to using this connector, the manufacturer coated the numerous strain gage cables with a messy ablative to protect them from the high flames of the rocket motor. Following the test, these cable bundles had to be removed, tested, and cleaned for reuse, which was a very costly process. With the convenience of the RJ-45, test engineers now use low-cost CAT-5 cabling that can be recycled and replaced after each test. This convenient connection method saves both time and money.

- **Improved Measurement Accuracy:** The accuracy of strain measurements can be affected by the voltage drop that occurs between the excitation source on the measurement device and the strain gage. If the excitation source is programmed to 5 V, the drop due to lead resistance can result in an actual bridge excitation level that is less than 5 V at the transducer, depending on the length of the wire. The EX1629 eliminates this source of error to improve measurement integrity by measuring the excitation level at the transducer, and then using the resulting value in the EU conversion.

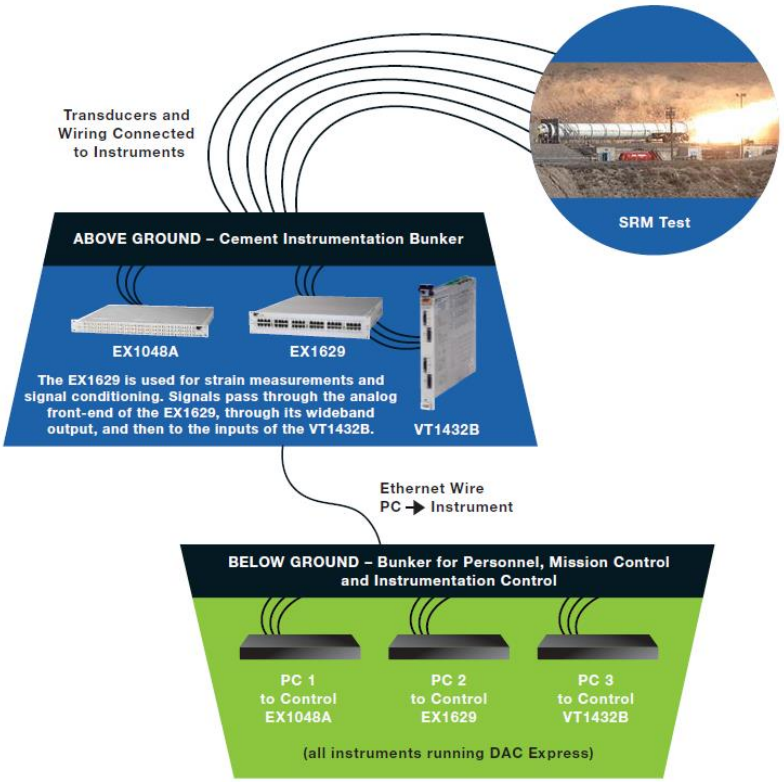
EX1048A; Precision Thermocouple Measurements

As the most accurate thermocouple instrument on the market, the EX1048A offers accuracy to a quarter of a degree and provides excellent signal conditioning. Self-calibration and cold junction compensation (CJC) help guarantee accurate test results.

- **Outstanding Analog Design:** The EX1048A's analog front-end is equipped with a 16-bit ADC to provide high resolution. It has efficient analog low-pass filters to reject any noise on the input signal. The analog design mitigates many of the problems typically seen with scanning ADCs. It also provides independent signal conditioning on a per-channel basis.
- **Simplified Self-Calibration:** Users can perform a self-calibration before each test. During this process, an on-board precision voltage source is used to verify each input path. Based on the known value of the voltage source, the EX1048A can make minor adjustments to the measurement to improve accuracy.
- **Excellent Cold Junction Compensation:** To achieve the high accuracy that VTI's customers demand, the EX1048A employs a proprietary CJC design. For every four input channels, the EX1048A takes a high-accuracy reference measurement. The reference sensor is mounted to a large isothermal mass designed to provide the highest accuracy possible right at the input connector. The EX1048A's CJC design along with its full ITS-90 thermocouple linearization enables this instrument to deliver unmatched accuracy at sample rates as high as 1,000 readings per second, per channel.

DAC Express

VTI provided this turnkey software to support each hardware component mentioned above. Therefore, the customer did not have to purchase any additional software prior to system implementation. DAC Express allows users to quickly setup, monitor and record data without any programming required.



Because of VTI's proven accuracy and reliability, the rocket launch vehicle manufacturer has selected VTI to replace all of its legacy strain, temperature, and vibration instrumentation in other similar test cells used for testing SRMs. Also, the manufacturer has been successfully using VTI hardware for numerous rocket motor tests in with excellent results.

About VTI Instruments

VTI Instruments delivers precision instrumentation for electronic signal distribution, data acquisition, and monitoring. The company continues to lead in the development of open standards for test and measurement along with scalable, modular products that maximize performance in a small footprint. With nearly two decades of experience primarily in the aerospace, defense and power generation markets, VTI helps customers maintain a competitive edge and preserve the integrity of their brand.