Jet and Rocket Engine Test System

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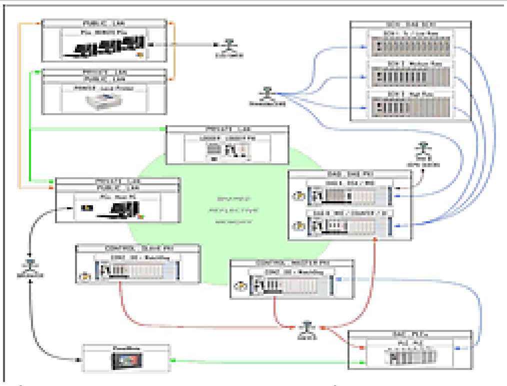
Industry:
Aerospace/Avionics

Product:
DIAdem, Data Logging, LabVIEW, LabVIEW Datalogging and Supervisory Control, LabVIEW Real-Time, PXI/CompactPCI, Signal Conditioning

The Challenge:
Developing a real-time data acquisition and control system for jet and rocket engine hot-fire testing while maintaining facility and test article safety, data recording reliability and accuracy, and configuration flexibility and efficiency. The channel count, data rates, and event recognition goals presented significant performance challenges.

The Solution:
Using National Instruments LabVIEW Real-Time to program a system of five PXI chassis to implement a data acquisition and control (DAC) system. By distributing the system features to separate components, we reliably achieved very aggressive performance requirements. A feature-rich, database-driven host application runs on a server-class PC to provide the system's user interface. The host application provides NI LabVIEW user interfaces to configure and run the system, storing relevant settings and results in a relational database. Built-in networking features in LabVIEW allow remote access to calibration and run-time data displays.

The Wyle Laboratories San Bernardino Test Facility offers cost-effective test solutions to government and industry in the aerospace propulsion market. Our jet and rocket engine test site (JRETS) DAC system is a state-of-the-art, flexible, and high-performance system. We have designed multiple rocket engine test positions to accommodate engines up to 50,000 lbs of thrust, using variable fuels such as hydrocarbons and cryogenic propellants as well as some hybrid solid fuels. The facility boasts new technologies and methods to mitigate noise and combustion product emission controls.



The JREST DAC system overview.

System Benefits

A key benefit of the JRETS DAC system is the flexibility to generate an event-driven, user-defined test sequence that allows for multiple red-line alarm channels for each event. Up to 20 simultaneous red-line channels can be defined per event in the automated test sequence, which has a maximum duration of 64 events. Automatic alarm evaluation with complex alarm clause logic allows for tight multilevel alarms during high-risk activities, and for more open criteria during the low-risk phases of a hot-fire test. This functionality provides fewer falsely aborted tests and increases facility throughput.

The DAC system includes a relational database for transducer and test configuration information storage. It provides advantages such as test run configuration traceability that increase the value of test data, adding confidence in the measurements and requiring fewer retests to verify behavior.

System Design

The JRETS DAC system is implemented via six computers, five of which are PXI controllers running LabVIEW Real-Time. The system features are distributed to these resources to provide a modular design and reliable, high-performance operation.

Eight modules perform data acquisition. Four NI PXI-4472 modules acquire data from dynamic sensors residing in the DAQ A chassis (the first controller) at 32 KHz, using the NI PXI-6653 for a timebase clock source via the star trigger lines. The DAQ B chassis (the second controller) includes three NI PXI-6250 modules programming three SCXI chassis, with timebase imported from DAQ A via an NI PXI-6651. The system uses a digital trigger to synchronize the start of all analog input tasks. The eighth input device, the PXI-6651 isolated digital input board, is used primarily for reading microswitch valve inputs to confirm valve actuation.

Every millisecond, deterministically synchronized acquired data is packaged into a contiguous block or frame and passed to the master controller PXI system (the third controller). A VMIC 5565 reflective memory card transfers data deterministically from controller to controller. The throughput (6 MB/s of raw data) and responsiveness required by the entire distributed system, together with LabVIEW Real-Time support for the VMIC 5565 via a LabVIEW Real-Time driver based on NI-VISA, drove our choice of this technology. The master system reads all input data and evaluates the control sequence and alarms to determine the output state for up to 192 devices. It has less than a millisecond to accomplish this task to be ready once the next data frame becomes available. The system then writes the output values to three NI PXI-6512 boards and adds them to the data frame in reflective memory immediately after the input data.

The real-time logger system (the fourth controller) reads all input and output data from reflective memory and then streams data to disk at the predefined rate, up to and including the full sampling rate. A server component provides engineering unit data to the host PC via TCP/IP at the greatly reduced rate of 5 Hz. The server also evaluates calculated channels for the display, such as pressure transducer differences, integrals, or derivatives of signals.

The fifth PXI controller, a watchdog system that monitors the functioning of the master controller, is a slave controller featuring parallel digital outputs that follow the master's values until it detects a failure to update a watchdog signal. In that event – which has a three-millisecond timeout duration – the slave takes control and executes a user-defined safe shutdown sequence. In the exceedingly unlikely event that both the master and slave system software fails, a third level of safety control is invoked – the hardware watchdogs on the PXI-6512 boards return each valve to its user-specified fail-safe state. While we do not anticipate having to use any of the watchdog features in the system, they represent a worthwhile facility and product safety "insurance policy" for such a hard real-time control system.

A LabVIEW graphical user interface (GUI) on the host PC provides system control for test configuration, sequence specification, transducer calibration, test preparation, test execution and real-time data display, and post-test review. Three 1600 x 1200 pixel GUIs that schematically mimic the facility layout for oxidizers, fuel systems, and the test article environment provide intuitive control capability and status feedback. A fourth GUI provides additional information – digital indicators and graphs for transducer data and an event log.

Data files are saved in National Instruments DIAdem TDM file format, providing a great mechanism to attach metadata to the raw values and associate groups of multirate data files. NI DIAdem provides both automatic quick-look reports and ad hoc data analysis capability.

Using National Instruments LabVIEW Real-Time and the NI PXI platform, we were able to implement a high-performance, flexible, and industry-comparable system within a moderate budget that can be operated and maintained by a minimum set of technicians. Including hardware, software development, technician training, and other startup costs, alternative solutions were two to three times the cost of our NI system. Tools that extend the LabVIEW development experience, such as the VISTA Statement Coverage Tool, the NI LabVIEW Execution Trace Toolkit, and the Endevo GOOP Inheritance Toolkit, enhanced our productivity, increased the quality of our deliverables, and allowed us to plan for effective software maintenance. The software application is substantial – 207,000 GOBs (lines of code). LabVIEW Real-Time will remain our first choice for deterministic control system development for the foreseeable future.

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