Characterization of the next-generation aircraft fuel pump using LabVIEW Real-Time

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The challenge: Developing an automated data acquisition and test system that incorporates jet-engine simulation to characterize a developmental Ultra-Efficient Fuel Delivery System (UEFDS).

The solution: Using LabVIEW Real-Time, we developed code to control the four outputs and a LabVIEW application for a Windows 2000 system that displays and logs all 100 analog input channels of data at 1000 samples per second along with at least 30 information channels received from the electronic control module (ECM) via RS-485.

Introduction

To test this unique fuel pump, we had to design, develop, and demonstrate a test system. The system had to dynamically simulate the behavior of a jet engine flying through a range of operating conditions as described by altitude, speed (mach-number), and throttle position (power lever angle). Of the more than 100 channels of data we needed to monitor and log, the control logic required 12 channels to determine the control of the four outputs, including the pump drive speed, fuel heat exchanger valve position, back pressure valve position, and actuation flow valve position.

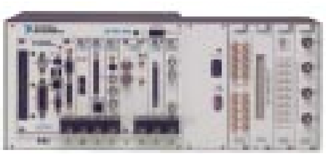

Figure 1

Based on these test system requirements, we chose PCI eXtensions for Instrumentation, or PXI, as the platform for our test system. PXI extends CompactPCI for measurement and automation applications by maintaining complete interoperability with CompactPCI while adding electrical, mechanical, and software extensions that increase system performance, improve system reliability, and simplify system integration. We used two National Instruments PXI systems to control and monitor the UEFDS test cell. The National Instruments PXI system with integrated signal conditioning modules and embedded controller can run LabVIEW Real-Time for deterministic performance or Windows for monitoring applications (see Figure 1). The four PID control loops on the real-time system along with the engine simulation model execute 100 times per second and read 12 input channels, which sample by 10X. The real-time system controls three valves and the pump drive speed. With the LabVIEW Windows application on the second PXI system, the user can monitor and log all 100 channels of data collected at 1,000 samples per second through the SCXI DAQ system, the 30 parameters collected on the RS-485 network connected to the unit under test, and the UDP status messages from the real-time system. Figure 2 illustrates the real-time main user interface.

Deterministic control

The LabVIEW Real-Time system monitors the 12 critical channels, also at 1,000 samples per second. We used 5B series modules for signal conditioning of these signals. The system buffers data from these channels and averages 100 times per second.

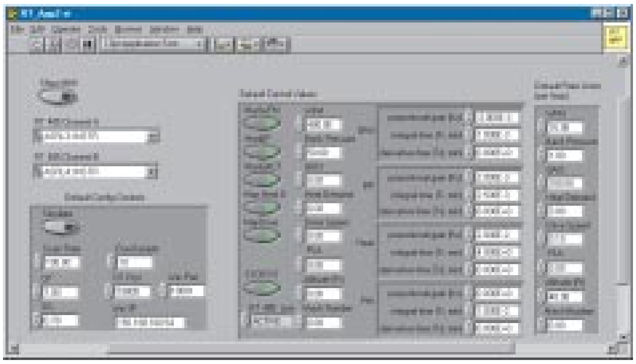

Figure 2

A hardware-timed loop executes 100 times per second, calculating and updating the four outputs. LabVIEW calculates the math necessary for the simulation, which contains four PID loops, nine rate limiters, a derivative, and 12 look-up tables.

Global variables monitor interim values during the refinement phase and pass data to a second loop. The second loop executes 100 times a second and passes critical information to the fuel pump across the same RS-485 network that the Windows system uses to monitor the status of the fuel pump. The system also contains a simulate mode so the application can run on a regular PC for testing and development without a real-time system or data acquisition hardware.

PID control

Ensuring the PID control worked reliably and fast was a challenge. Without over-sampling, the bit-noise in the analog inputs made the derivative unusable. The automatic calculation of the delta-t in the PID VIs also caused problems. Although there was no hardware jitter, a software jitter of 1 ms could cause a 10 percent change in delta-t at our loop-rate of 100 Hz. Oversampling 10X and explicitly providing the delta-t helped stabilize the system transient response, although the noise on the signal still complicated use of the derivative term.

RS-485 communication

Communication with the ECM also posed significant challenges. The data generated by the unit under test was too much for the real-time system to analyze and log; yet we needed to send the commands to the unit deterministically. We implemented a RS-485 network, enabling the real-time system to write commands to the ECM while the Windows system reads the responses and logs the unique data. The test system for the Ultra Efficient Fuel Delivery System (UEFDS) includes two PXI systems running

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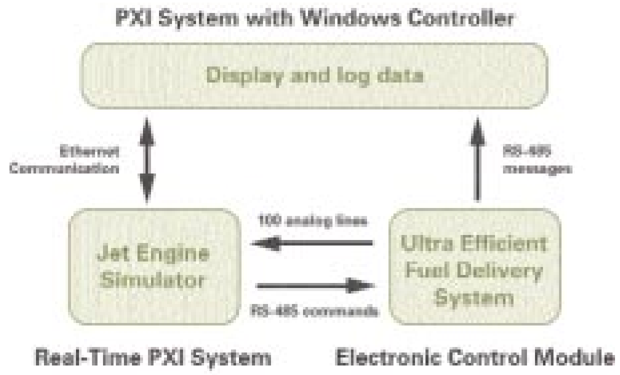

Figure 3

LabVIEW. The Windows system provides data monitoring and logging while the real-time system simulates the jet engine. With this configuration, the UEFDS can be accurately tested without directly accessing a fully operational jet engine (see Figure 3). Because the test article was a one-of-a-kind developmental system, members of the support team from three different companies developed wiring and naming conventions. Once we negotiated the protocol conventions, the RS-485 proved quite robust. Even at the wrong baud-rate and the wrong polarity, we still received data.

Data management

The system generated enormous amounts of data in response to manual triggers. It buffered 30 seconds of data from all channels to store or display pre-trigger binary data at anytime during transient events. "Snapshots" provided a more manageable data storage mechanism for steady-state conditions, in which the system averaged data during a configurable time interval. Utilities took multiple logs or snapshots and converted them to the ASCII format.

Conclusion

With the powerful features of the Measurement and Automation Explorer (MAX), we could test and calibrate each channel independently without customized software. We significantly reduced hardware problems resulting from software problems. (MAX is primarily a configuration and diagnostic tool for NI hardware, as well as VISA-based devices, including 3rd party VISA-based PXI devices. MAX has the ability to exercise hardware fully through a variety of features – virtual channels, test panels, VISA Interactive Control, etc). With the rapid development capabilities of LabVIEW and the robustness of the PXI system, we created a reliable system in a very short time. The powerful testing and debugging capabilities of LabVIEW Real-Time assured we made our deadline.

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