Customer-Driven Development of a New High-Performance Data Acquisition System

The HP HD2000 data acquisition system provides C-size VXIbus modules that are tailored to provide fast and accurate acquisition of temperature, pressure, strain, volts, and resistance data for turbine and piston engine testing applications.

by Von C. Campbell

Products from the past like the HP 2250 measurement and control processor and current products like the HP 3852 measurement/control instruments have given HP a reputation for excellent measurement integrity and throughput. However, within the turbine and piston engine test markets we found certain groups who stated that our measurement products "almost, but not quite" did their job. Obviously there was something in these applications that these products could not do. What was missing? Only customers could tell us.

We undertook an effort to find and talk to turbine and piston engine test customers so that we could understand their applications and the problems they were facing with existing products. These discussions were done in the language of the customer, which required some vocabulary development on our part. After understanding these first applications, we widened our scope to include as many customers as possible. Over 100 customer visits were conducted, including virtually every turbine engine manufacturer and larger piston engine manufacturers worldwide, many being visited more than once.

A very clear picture of these applications emerged. In turbine testing for example, we discovered three use models with similar but distinct measurement needs. The first model was found in engine design and development. In this model large amounts of data (up to thousands of test points per engine) are collected for analysis of the thermodynamic performance of the engine and for verification of the simulation models used in development. The second use model was found in production test of a finished engine immediately after manufacture. Here a smaller test system is used to verify proper engine operation. Finally, the last use model was found in the overhaul and repair of an engine. In this model an even smaller set of data is collected to determine if the engine is performing well enough to be returned to service.

Some common threads ran through all the applications. Accuracy was one of these common features. Temperature measurements to better than 0.25 °C and pressure measurements to 0.05% are required to verify the efficiency of an engine. Engine efficiency is especially important to manufacturers who guarantee fuel consumption rates to their airline customers. Another important factor is the requirement that the test system be capable of being scaled to accommodate from about 100 to over 2000 measurement points for different sized test systems. Continuous high-speed acquisition, in which data is recorded for long periods without interruption, is also an important factor. Measurement rates of up to 1000 Hz per channel on different sensor types allow a better understanding of the static and transient behavior of the engine, but the aggregate throughput of such large, fast systems is a significant challenge. Older measurement systems used many independent instruments to record the volume and variety of data taken during a test. After the test, all the various data records had to be combined to form a single integrated picture of test results. To overcome this problem of data integration it is imperative that all data be measured and recorded deterministically.

One common need that goes beyond the acquisition system is the industry-wide pressure on test departments to be more productive. The desire to reduce test times and the resources needed to install, develop, and operate a test system is universal. In some areas, there was a strong desire to have a third party develop and install the test system so that the organization could concentrate on testing. This information led to our getting in touch with the leading systems integrators to understand how we could help them solve their customers' problems.

After developing a clear picture of user needs and reviewing past implementations, we came to the conclusion that although individual measurement requirements were being met with existing products, system requirements like those mentioned above were not being met. From this conclusion, the HP HD2000 VXIbus-based data acquisition system was born (see Fig. 1).

VXIbus technology[1] has the right capabilities to meet the system issues we encountered during our customer analysis. The VXIbus architecture allows us to integrate mixed measurements from multiple sources onto one computer bus, allowing high speed and determinism in data sampling. Since VXIbus is an open standard we can include non-HP products that offer specific functions like IRIG B time stamping, MIL STD 1553, and ARINC 429 communications instruments into our system. These products help meet overall systems

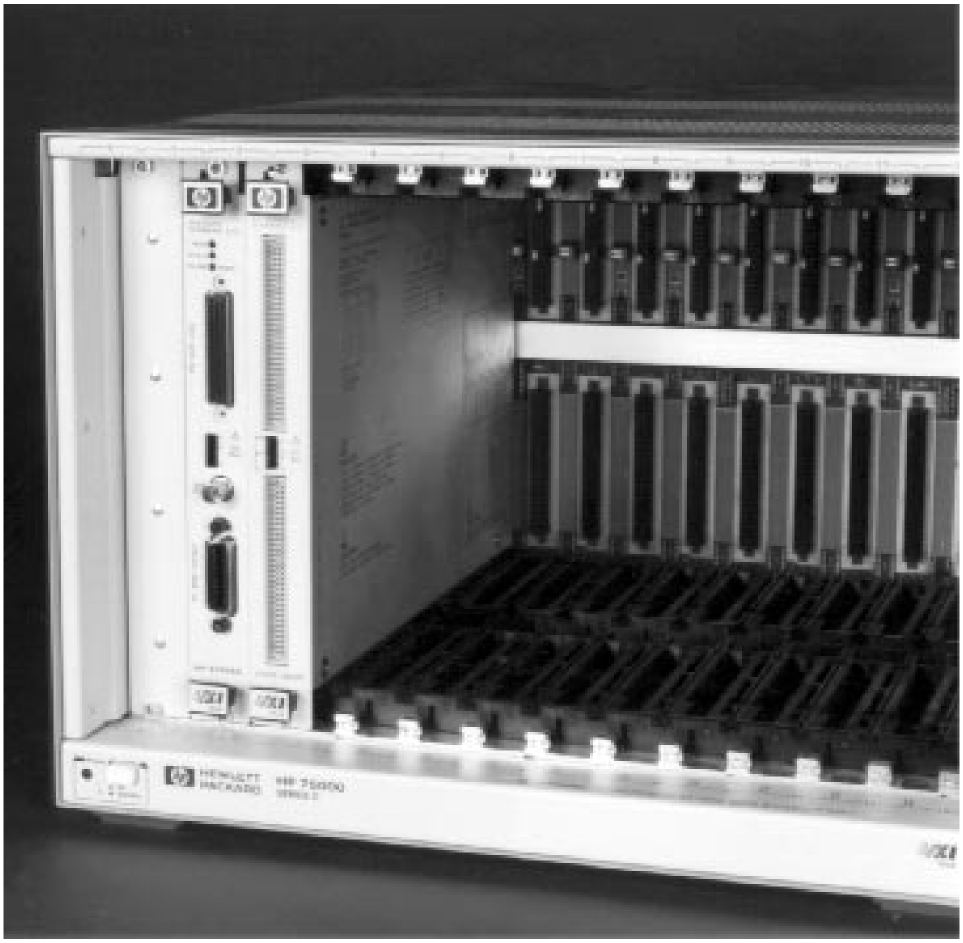

Fig. 1. The HP HD2000 data acquisition system showing the HP E1413 and HP E1414 modules.

requirements without requiring large additional development time and cost.

The Measurement Modules

The bulk of the HP HD2000 system measurements come in the form of analog input, with measurements of temperature and pressure making up about 90% of the volume of data. To meet these needs the HP E1413 64-channel scanning analog-to-digital converter and the HP 1414 pressure scanning analog-to-digital converter were developed. These converters are designed to maximize measurement accuracy, throughput, determinism, flexibility, and density while minimizing computer resource use, program development time, and cost. These modules are the first two modules of the HP HD2000 data acquisition system.

The single-slot HP E1413 combines a highly accurate 100-kHz, 16-bit, autoranging analog-to-digital converter with 64 channels of a high-speed multiplexer and eight banks of front-end signal conditioning plug-ons (such as amplifiers and low-pass filters) and has an internal calibration source for end-to-end calibration. Gain and offset errors for every channel, including signal conditioning, can be removed through the automatic calibration process, maximizing measurement accuracy. An onboard digital signal processor (DSP) controls the card's basic operation, including sequencing of multiple channel scan lists, real-time limit checking, conversion of data to engineering units, and conversion into a computer-ready, 32-bit floating-point number. These numbers are output into a 65,000-reading FIFO buffer and a current value table, which allows instant access to the most recent reading on any channel. These features minimize the amount of interaction the card needs to have with the host computer and the amount of work it has to do to make the data interpretable. This tightly coupled architecture maximizes throughput while minimizing the need for external computer resources. Fig. 2 shows a block diagram of the HP E1413.

In pressure measurement systems, which typically have a large number of test points, we found that electronic pressure scanning technology is the measurement technology of choice. The recognized leader in this technology is Pressure Systems Inc. (PSI) in Hampton, Virginia. As a continuation of our focus on user needs, we developed a partnership with PSI to develop a pressure scanning analog-to-digital converter. This product, the HP E1414, has all the features of the HP E1413 but is designed to interconnect and operate with PSI's electronic pressure sensors and pressure calibrators. The HP E1414 brings the same level of measurement performance and throughput to pressure measurements as the HP E1413 does for the other analog measurements. It also integrates the deterministic measurements of both temperature and pressure into one common system on the VXIbus backplane.

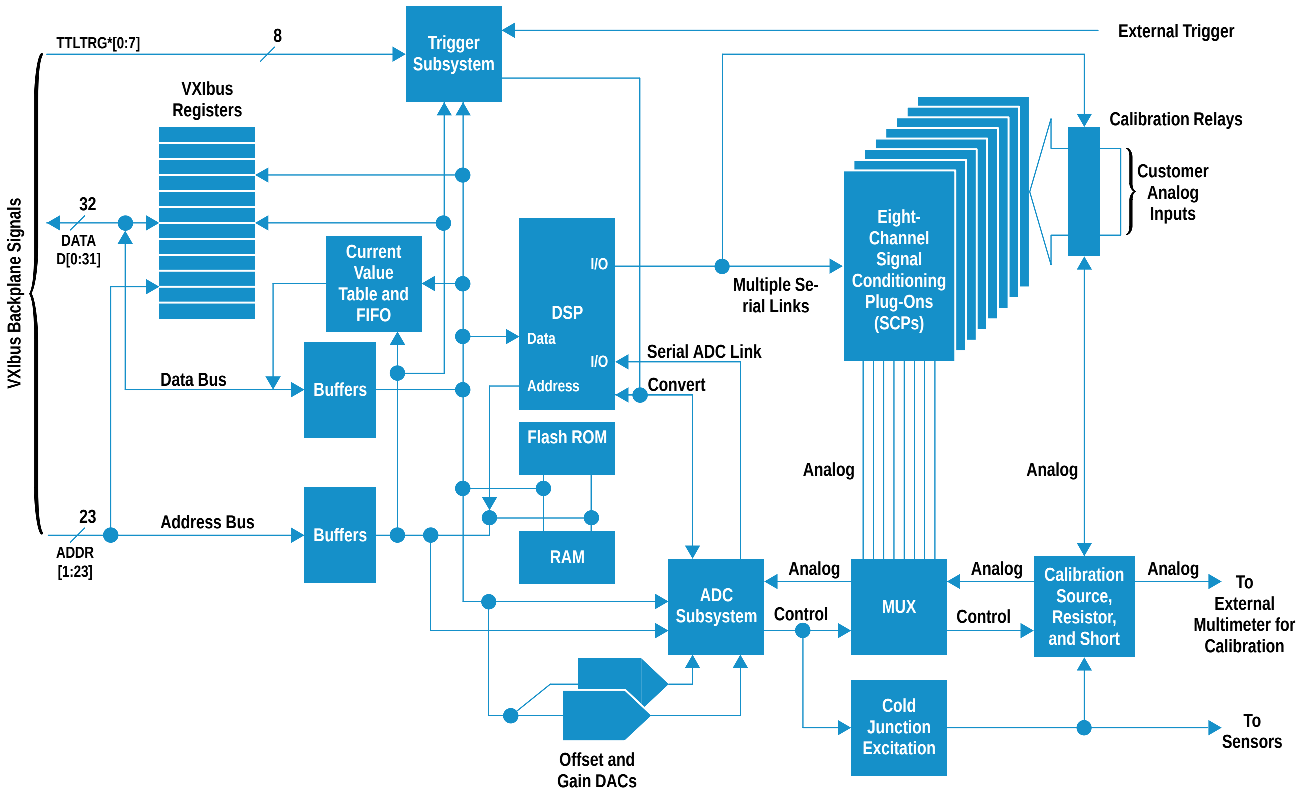

Fig. 2. A block diagram of the HP E1413 64-channel scanning analog-to-digital converter.

The HP E1413 is described in detail in the articles on pages 9, 16, 21, 25, and 30. The HP E1414 is covered in the article on page 35.

To help minimize customers' development time for the acquisition software, all the products in the HP HD2000 family have drivers that maximize their commonality and performance. These drivers allow the instruments to be controlled using the Standard Commands for Programmable Instrumentation (SCPI) language.[2] This open standard language has a programming syntax that is easy to read and understand, and it has a high level of commonality between many different instruments. This minimizes programming time and enhances supportability. To meet our users' needs for high throughput, a C language preprocessor was developed to process the standard SCPI commands into a format that, along with the driver code, can be compiled into high-speed, run-time code. This compiled SCPI (C-SCPI) gives the programmer the ease of programming in a high-level language and the execution speed of assembly code.

Conclusion

The HP HD2000 system began with understanding the users' needs from the perspective of their whole system. This understanding led us to choose the VXIbus architecture, which provides the high throughput, tight coupling, and mixed-measurement capabilities our customers need. Understanding customer needs focused our development efforts on products like the HP E1413 and HP E1414 and guided our software implementation to maximize performance without increasing development time. Finally, a clear idea of customer needs enabled us to avoid making enhancements to the products that were considered irrelevant to our customers. These enhancements frequently add cost and time to development and complexity and confusion to the end user. We let the customer tell us what was needed.

Acknowledgments

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