

Instrument-Grade DAQ via Ethernet

The economy, speed, and virtually unlimited distance potential of Ethernet-based communication continue to fuel the growth of corporate networking, and expansion of the Internet. Users of traditional communication interface technologies (e.g. RS-232, RS-422, and General Purpose Interface Bus) for distributed data acquisition and control (DAQ) systems have begun to notice the performance and cost disparity between these protocols and Ethernet. GPIB adapter cards can range from \$300 to more than \$500, and GPIB cabling can be quite expensive as well. Although RS-232 serial interfaces are usually standard on most computers, hubs and extenders to allow these buses to achieve long distances can still be expensive, and these serial interfaces are not quite as common on test and measurement equipment. In contrast, Ethernet cabling is relatively inexpensive. Prices of Ethernet NICs (network interface cards) for a PC hover around \$20, while expander “hubs” are less than \$100. Over the last few years, some manufacturers of data acquisition hardware have introduced models that use Ethernet as the communication bus. Seemingly, the promise of precision DAQ systems distributed inexpensively over long distances, all controlled by a centralized computer, has finally been realized. Or has it?

Historically, data acquisition cards, external DAQ systems, and instrument racks have been deployed relatively close to corresponding computer systems, as well as the sensors and signal sources to be monitored. Typically, these data acquisition solutions have offered limited measurement resolution (usually 12 to 16 bits), which could lead to expensive false failures and low production yields. Although a PC and high resolution GPIB-equipped instrumentation can be located at each required monitoring point, the prohibitive cost of this approach makes it impractical for large distributed DAQ systems. The integration of separate Ethernet adapters and GPIB instruments also introduces additional maintenance and troubleshooting

complexity, and can cost up to \$1000 per converter for each GPIB instrument or test location. Extending bus standards such as RS-422 and RS-485 typically involves adapters or other hardware that increase complexity and cost. Furthermore, other system requirements can collectively make it more desirable, or even necessary, to go with a simpler bus standard, and to accept or work around distance limitations.

Applications Demand Larger, Higher Performance Test Systems

Efficient production and quality control in electronic manufacturing facilities rely on burn-in/stress (HALT/HASS) testing to ensure product reliability. Such tests require repeatable, traceable measurements of parameters such as voltage, current, resistance, and temperature; tests can require hours or days to complete. Greater efficiency comes from making these tests in multiple, widely distributed burn-in chambers that can be controlled from a single computer. In R&D/university labs, users need multiple channels of accurate measurement, and a modular, easily scalable form factor in order to validate and characterize a variety of system designs, experiments, and lab processes. In many such applications, measurement points can be widely scattered or difficult to reach, making high reliability extremely important. Noisy or harsh environments further complicate measurement integrity by interfering with measurement precision, and may necessitate the use of expensive noise-rejection circuitry and specially hardened enclosures to withstand caustic, smoky, or otherwise hazardous conditions. The use of sensitive instruments, rather than generic DAQ cards and external boxes, provides a workable solution. Increased measurement integrity, signal conditioning/processing, and security translate into greater confidence in results, regardless of the process and goal. It should come as no surprise, then, that integrating an Ethernet interface directly into precision instrumentation is gaining ground as the next preferred data acquisition bus architecture.

External Ethernet Systems Emerge as a Favored Solution

Another incentive for the move to integrated Ethernet instrument solutions is being driven independently by the evolution of PCs. Present trends indicate that PCs of the future will no longer include expansion slots, making communication with the system possible only through external buses. The favored replacements for current GPIB, parallel, and serial peripheral buses are the Universal Serial Bus (USB) and FireWire (IEEE-1394). Both are fast, but are limited to a distance of approximately 50 feet (15 meters), although hubs can be used to extend distances. Up to 127 peripherals can be connected via USB, and 63 for FireWire.

In contrast, Ethernet offers longer distance communication, easy plug-in implementation, and lower cost than existing methods. Ethernet is common now in business environments, and many PCs today are offered with an Ethernet adapter as standard equipment. The current “fast” Ethernet protocol transfers data at 100Mbits per second, which is ten times faster than GPIB. Emerging Ethernet standards provide 1Gbit and 10Gbits per second, so there are even faster Ethernet developments on the horizon. GPIB’s maximum speed of 1Mbyte/second will probably never be exceeded, as manufacturers and users seem to value the robustness of the well-proven and -understood GPIB bus standard. Ethernet cabling, connectors, hubs, and tools are readily available for easy, inexpensive wiring of cable drops or whole facilities. Many enterprises are already wired with LANs, so large networks of distributed DAQ instruments can be set up without requiring the construction of a completely new network infrastructure.

The First Instrument-Grade Ethernet Data Acquisition System

Keithley Instruments, Cleveland, Ohio, recently introduced an Ethernet version of its “Integra” Series DMM/Data Acquisition platform. The Integra Series is based on a 6½-digit DMM with slots designed to accept modules from Keithley's 7700-Series switching and signal conditioning modules. The Model 2701 Ethernet-Ready DMM/Data Acquisition System is a dual-slot, half-rack unit having a built-in, industry-standard 10/100BaseTX fast Ethernet and TCP/IP protocol. Standard and optional Integra measurement capabilities include AC and DC voltage and current, digital I/O signals, temperature (using thermocouples, RTDs, or thermistors), frequency, period, resistance (including continuity, two-wire, and four-wire ohms), and event counting/totalization. Each channel can be



Figure 1. Model 2701 Ethernet-based Multimeter/Data Acquisition System

configured separately for any of 14 measurement functions, and provides built-in signal conditioning and high noise isolation of up to 1000V. Measurement speeds of up to 3000 readings per second are possible. Any two Series 7700 switching and signal conditioning modules can be installed in the Model 2701 for up to 80 differential channels of multiplexed measurement and control. Modules are available that use mechanical switching for higher voltage and isolation or solid-state switching for long-life and higher speed.

Contending with Non-Deterministic Operation

Creating an optimized Ethernet instrument requires more than simply adding an Ethernet interface to an existing instrument design. More specifically, precise timing and control become more difficult to achieve through communication over Ethernet. Systems in which a certain maximum response time can be guaranteed are said to be “deterministic.” By knowing this maximum response time, programmers can design programs to operate predictably, and also avoid applications in which the system is incapable of providing the required timing and control precision.

Ethernet is non-deterministic in nature. Microsoft Windows,, the most prevalent operating system in use today, is a non-deterministic environment as well. To satisfy the need for timing precision, the Model 2701 is controlled by a self-contained microprocessor and timing hardware that can operate independently of the PC and a network. Ethernet can transfer large blocks of data more efficient than small blocks. For that reason, a larger memory buffer capable of holding more than 400,000 samples has been included in the Model 2701. The larger buffer allows the system to hold more data without the need for frequent PC intervention or tying up the network.

On-board timing and processing are also necessary because, without full-time reliance on the controlling PC, the DAQ system must take a more active role in supplying conditional logic, triggering, and other supporting control functions. Many applications depend on pre-programmed alarm limits and analog triggers to allow automatic notification when critical events occur. In Ethernet-based systems, instruments must assume more of the burden for these services.

Other features of the Model 2701 include:

- Integrating A/D conversion, a method that's inherently superior to successive approximation A/Ds for rejecting noise.
- Signal conditioning, including built-in excitation and filtering for various types of sensors, for simplified test setups.

- Built-in math functions that automate the process of converting voltages and currents to engineering units and physical measurement parameters.
- Additional test capabilities not found in DAQ boards and external systems, such as sophisticated DC current measurement, AC volts and current, two- and four-wire resistance, and frequency/period/event counting .
- Expansion slots to accept additional signal conditioning or switching modules that increase the number of available input channels.
- An alternate RS-232 interface for added convenience in developing and troubleshooting test programs where a network is not available.

Table 1. Traditional bus-based instruments vs. Keithley Model 2701

| CRITERIA | TRADITIONAL SOLUTIONS | KEITHLEY MODEL 2701 |
|------------------|---|--|
| Resolution | DAQ cards and data loggers with 10, 12, 14, or 16 bits of resolution (3½ to 4½ digits) | DMM-like DAQ system with 22 bit (6½-digit) resolution. |
| Storage capacity | DAQ cards—used PC memory or on-card FIFO. Data capacity depended on RAM. | Buffer capacity of 400,000 readings. |
| Processing | PC processor and software, or self-contained processor and firmware | On-board processing, timing, signal conditioning, and math functions. Autonomous operation and control via “source memory” and “Trigger Link.” |
| Interfaces | DAQ Cards—straight to PC bus. Data loggers and instruments—proprietary interface cards, GPIB, RS-232, parallel. | Ethernet—simple connection via standardized networking connectors. Secondary RS-232 interface included for non-Ethernet applications. |
| Transfer Speed | Sustained rates via GPIB of 1Mbyte per second. | 10 or 100 Mbits per second Fast Ethernet. |

Increased Options for System Topologies

Ethernet-based instruments can be configured according to a number of different system topologies that can reduce the cost of distributed data acquisition, as well as providing increased system security. These range from the simplest, direct connection of a computer to the DAQ system to schemes in which the computer uses multiple NICs (network interface cards) to set up independent sub-networks. The 2701 has a built-in web page that can be used for diagnostics, network configuration and debugging. Users can communicate with the Model 2701, without installing external software, by using Internet Explorer, and entering the 2701’s IP address in the browser URL (Universal Resource Locator) line. The maximum unaided distance of 100 meters (per cable drop) with Ethernet can be extended easily using simple network hubs to chain cable drops. When coupled with the Internet, virtually unlimited distances are possible.

Conclusion

Instrument-grade, DMM-based data acquisition hardware via Ethernet opens exciting possibilities for constructing cost-effective DAQ systems that can gather data from all over the world. Greater measurement integrity, versatility, simplified programming, and true computer platform independence can also result from this combination. Perhaps more important, DAQ with Ethernet eliminates many of the compromises that are imposed by earlier DAQ architectures by providing high measurement resolution, high channel counts, expandability, and intelligence in the DAQ system.

Specifications are subject to change without notice.

All Keithley trademarks and trade names are the property of Keithley Instruments, Inc. All other trademarks and trade names are the property of their respective companies.

KEITHLEY

Keithley Instruments, Inc.

28775 Aurora Road • Cleveland, Ohio 44139 • 440-248-0400 • Fax: 440-248-6168
1-888-KEITHLEY (534-8453) • www.keithley.com

© Copyright 2002 Keithley Instruments, Inc.
Printed in the U.S.A.

0502