Ethernet Data Acquisition Improves Race Car Testing

by Robert M. Winkler, Intelligent Instrumentation

If you keep your ear to the ground for the latest trends these days, you probably hear much discussion about the use of Ethernet as an I/O network.

Visit any of the large automation trade shows, and you will find the topic to be the most hotly debated.

For the last 12 months, Ethernet has been widely discussed as a major contender in the fieldbus wars, for plant floor and sensor applications as well as industrial controls. The driving forces for this trend really are a matter of both economies of scale and the market's tendency to gravitate toward open systems and standards.

Ethernet's rise to popularity is based on the same market forces that have resulted in the dominance of PCs and Windows over other computing platforms and operating systems in nearly every industry. With such a huge installed base and so many forces lining up to endorse its use in new industries and application areas, Ethernet will continue to gain popularity and market share.

Benefits

What kinds of benefits can you realize from incorporating Ethernet into your data acquisition applications? One that comes immediately to mind is the capability to easily acquire data from remote locations. Since most facilities already have Ethernet networks installed, data acquired from one location in a facility can easily be fed to other PCs located elsewhere in the facility. It no longer is necessary to dedicate a PC to data acquisition in every location where you want to acquire data.

Ethernet also can reduce unwanted noise incurred when signals are transmitted over long sensor wires. It is not uncommon to take measurements from signal sources located 20 to 50 feet away from the PC.

Data typically is transmitted using 4- to 20-mA signals which are susceptible to noise. By placing an Ethernet data acquisition system next to the signal source instead of using a data acquisition board plugged into a PC, the level of noise induced on the desired signals is greatly diminished. This is because the signals are digitized right next to the source, before they have had a chance to incur unwanted noise.

These digitized signals are relatively immune to the effects of noise due to their discrete nature. The digital signals then are passed over low-cost unshielded twisted-pair cable which, by its very nature, protects the integrity of the signals through common-mode rejection.

Race Car Manufacturing

A classic example of how Ethernet can help in data acquisition can be seen at Dan Gurney's All American Racers (AAR). AAR was founded in 1965 by former race car driver Dan Gurney. Today, the company builds Indy-style, open-wheeled race cars for their own racing teams as well as customers. Throughout their history, AAR has built more than 150 race cars.

The company fields two racing teams that compete nationally in CART (Championship Auto Racing Teams) competition. Over the years, AAR teams have won eight championships, gathering 78 victories including the Indy 500 and 82 pole positions.

A critical element of the race car manufacturing process is the company's wind-tunnel testing facility, where aerodynamicists subject 40% scale model race cars to tests that simulate extremely high-speed driving conditions. PC-based data acquisition systems have been in place for many years to monitor and control wind-tunnel conditions and acquire data from the race car models under test. Recently, the company found that Ethernet data acquisition yields dramatically more accurate results in this facility.

Data Acquisition in the Wind Tunnel

Previously, AAR monitored race car and wind-tunnel conditions using data acquisition boards which plugged into a PC's ISA slots. Since the PCs must be located outside the wind tunnel, the data acquisition boards interfaced with the sensors and wind-tunnel controls using long signal wires. And since the inside of a wind tunnel is naturally a very noisy environment, the measurements being taken incurred a significant amount of error due to inductive and capacitive coupling. A solution that digitizes the measured signals at or near the signal source would allow AAR to eliminate the undesired effects of noise on their measurements.

AAR recently undertook a project to improve the accuracy of the data from their wind-tunnel testing. To accomplish this goal, they selected several EDAS Multifunction Ethernet Data Acquisition Systems from Intelligent Instrumentation and an Ethernet-ready pressure scanning system from Scanivalve. Each EDAS-1002E system incorporates a high-speed analog-to-digital converter and monitors up to 16 analog inputs from a variety of sources. The systems also feature 16 TTL-level digital I/O channels.

The ZOC-33 Pressure-Scanning Module from Scanivalve measures up to 128 pressure inputs. The inputs then are digitized and converted to Ethernet packets using the company's DSM-3001 Compact Digital Service Module.

Both the Intelligent Instrumentation and the Scanivalve systems use built-in TCP/IP protocol stacks to provide seamless communications with a variety of host platforms as well as intranet and Internet resources. Once digitized, measurements are sent from the wind tunnel via Ethernet to a PC located outside the tunnel. The PC runs National Instruments' LabVIEW software to process the data. The PC operating system is Windows 95.

Measuring the Car-Under-Test

When subjecting race cars to wind-tunnel testing, the most pertinent information is the side force, lift, and drag caused by the effects of the wind. AAR obtains this data from several six-component balances. Designed for wind-tunnel applications, these sensors measure force in pounds in all three axes using three-axis load cells.

The six-component balance also measures the moment (in inch-pounds) around each of the three axes. The balance provides six ±20-mV outputs which are interfaced through standard 5B-style strain gage signal-conditioning modules to the data acquisition system mounted on the roof of the model car.

The pitch and roll that the car sustains from the effects of high-speed driving are other important aspects in the design of the race car body. These phenomena are measured by a two-axis inclinometer mounted inside the model car that outputs a ±5-V signal for each axis. These also are measured by the data acquisition system through 5B signal-conditioning modules.

One other closely monitored condition is the air pressure in front of and behind the radiator inside the hood compartment of the model car. These parameters help characterize the airflow quality through the radiator, which is a very important consideration in designing high-performance race cars. AAR uses the pressure-scanning system to perform this portion of the test.

Wind-Tunnel Monitoring and Control

AAR also uses the data acquisition system to monitor and control wind-tunnel conditions. This subsystem is centered around several huge fans and what is known as a moving ground. The moving ground is a large conveyor that simulates the effect of the road passing beneath the car.

First, AAR monitors a number of sensors to ensure that the "health" of the wind tunnel and the moving ground is maintained. These include an absolute gage to monitor barometric pressure, several high-accuracy differential pressure gages, and an off-the-shelf temperature and humidity sensor kit. These sensors all output 0 to 5 V and interface to the data acquisition system through 5B signal-conditioning modules.

Meanwhile, a number of sensors are monitoring the conditions of the moving ground. Particularly, a large platinum plate across which the moving ground is pulled must be monitored to ensure that it is being properly cooled. Without this monitoring, the friction of the moving ground can cause the plate to become so hot that it will warp. Six RTDs are placed on various locations under the plate to warn an operator if the temperature is exceeding the allowable limit.

This platinum plate has several holes drilled through it to create a vacuum beneath the moving ground. This keeps the model car from pulling the moving ground off the table. The vacuum is controlled by a pump situated under the platinum plate and monitored by 10 pressure gages connected to the data acquisition system through the 5B signal-conditioning modules. The pressure measurements are used to control the vacuum pumps through thresholds defined in a software program running on the Windows 95 PC.

Another group of sensors monitors the car’s wheel speeds to ensure that slippage caused by the moving ground does not exceed 10% and invalidate the test data. Four infrared speed sensors are positioned on the outside wall of the tunnel, one corresponding to each wheel. These monitor revolutions per minute (rpm) of each wheel, using pieces of reflective tape placed on the wheels.

Each of these infrared sensors produces a TTL pulse output (maximum 60 Hz) which corresponds to rpm. The pulse outputs are monitored directly by software counters built into each of the 16 digital I/O channels on the data acquisition system.

The Results

The addition of Ethernet data acquisition to the wind-tunnel test system has allowed AAR to dramatically improve measurement accuracy without significantly increasing the overall system cost. Critical force measurements have improved by a factor of nearly eight, from a resolution of ±150 lb before the enhancements to a resolution of ±20 lb with the new system. A significant portion of this improvement can be attributed to the fact that AAR shortened the length of their signal wires by almost 70%.

With the capability to take more accurate measurements, AAR expects to design race car bodies that are more aerodynamic. Improved wind-tunnel monitoring and control also will provide added protection for the moving ground and the race car models.

Conclusion

As Ethernet becomes ubiquitous in all sorts of computing environments, from the corporate office to the manufacturing floor to the test lab, more and more useful applications for this network will come to light. While the idea of using Ethernet to solve AAR's problem is a relatively new concept, it already is being duplicated in test facilities all over the world.

About the Author

Robert M. Winkler is the product marketing engineer at Intelligent Instrumentation. Before joining the company in 1994, he served three years as a network communications officer in the U.S. Army Information Systems Engineering Command at Fort Huachuca, AZ. Mr. Winkler graduated from Lehigh University with a degree in electrical engineering. Intelligent Instrumentation, 6550 S. Bay Colony Dr., Tucson, AZ 85706, (520) 573-0887.

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