Building Intelligent Ethernet-Based Distributed I/O Systems with National Instruments LabVIEW™

Introduction

The growth of Ethernet as an industry standard has greatly improved the capability and integration of networked measurements, remote monitoring, and distributed control applications. In both manufacturing and test, engineers continue to find new ways to take advantage of this PC-based technology to build individual test stations or machines. These measurement and control systems use Ethernet to connect to management, data, and quality systems. As companies start to integrate disparate hardware with the common Ethernet link, they find that having flexible, open software becomes key. Many hardware options in test and manufacturing today have their own individual software. Sometimes it is inaccessible externally, and other times accessible only through low-level programming languages – or at the other extreme – high-level Web browsers. While these options are acceptable when using hardware as a single network node connected to a computer, they can become unmanageable when the system reaches tens or thousands of networked nodes.

With powerful yet easy-to-use Internet-enabled software such as National Instruments LabVIEW 6*i*, engineers can easily manage and connect these hardware nodes together into a unified system, whether the system is composed of a single or hundreds of networked nodes. Until recently, this intuitive graphical programming software resided only in PCs, with their associated size and power requirements. Today, with the FieldPoint 2000 Family of network modules, you can use the power and flexibility of LabVIEW to build intelligent networked hardware nodes smaller, more modular, and more durable than a PC.

With National Instruments, you can build and manage a network of individual hardware nodes connected with software that scale from large workstations to compact nodes such as FieldPoint, and to the Web (see Figure 1).

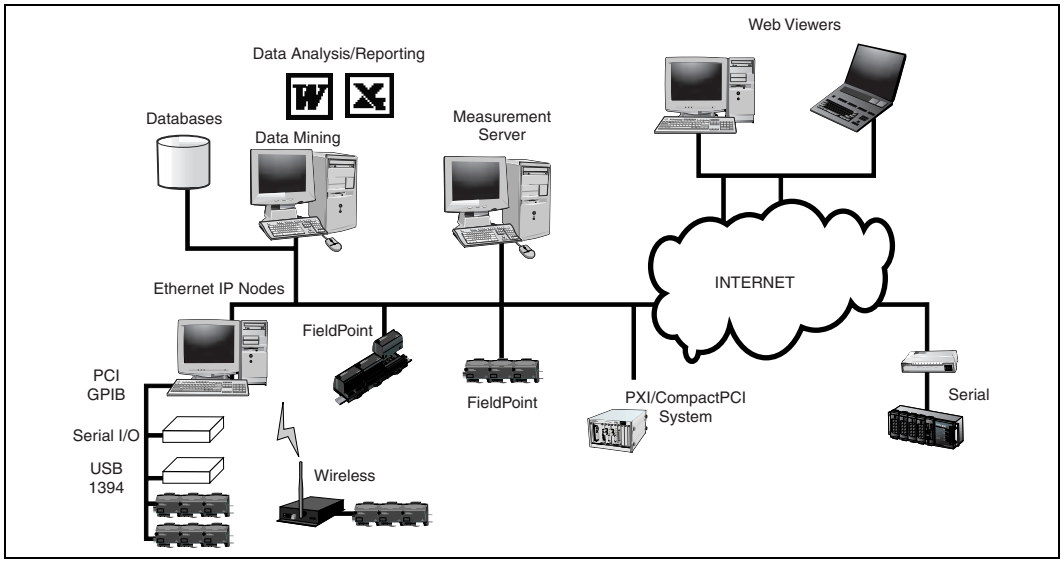


Figure 1. Software manages networked measurements from workstations to intelligent nodes.

FieldPoint 2000 Family

The FieldPoint 2000 Family consists of the FP-2000 and FP-2010 (FP-20xx) Ethernet network modules, each of which controls a user-configurable bank of I/O modules. These individual nodes, programmed with LabVIEW Real-Time, can perform machine monitoring, data acquisition, data processing, and programmable distributed control.

An FP-20xx delivers several key benefits to the development of distributed measurement and control systems. First, you can define the functionality of the module through flexible LabVIEW software and its modular hardware architecture. Second, it runs reliably as a network node or as a stand-alone unit using a real-time operating system and flash memory. In addition, its compact size and industrial specifications help you put the power of a PC in areas where a PC cannot fit or survive. Finally, because the FP-20xx network modules take advantage of industry-standard technologies such as LabVIEW development and the Ethernet network backbone, you can easily develop, deploy, and maintain these systems, reducing your cost of investment.

This paper details how you can use LabVIEW Real-Time and the FP-20xx to build robust Ethernet-based integrated measurement and control solutions.

Define Specific Functionality to Meet Your System Requirements

As the industry moves toward new integrated applications in networked test and manufacturing, existing systems will need to deliver more power and functionality. Stand-alone test stations and machines will need to be integrated with broader networked systems. In this way, companies can increase throughput and reduce cost by tracking quality and effectiveness systematically. At the same time, the increased cost of investment in these technologies requires that lower-cost systems do more. If a company moves from centralized decision making to a distributed intelligent measurement and control system, each individual node needs to contribute more to the function and productivity of the whole.

Flexible Software and Modular Hardware

With the FP-20xx and LabVIEW Real-Time, you have the flexibility to define functionality through both hardware and software. LabVIEW Real-Time is an intuitive rapid development graphical programming environment. Using LabVIEW Real-Time, you can choose from hundreds of built-in functions for data analysis, data storage, network I/O, and PID control to run on the intelligent FieldPoint module. Use these built-in libraries to reduce your development time and/or combine them with your own custom development to create the solution you need. You can develop and debug your system in the familiar Windows PC environment, then download and run your program embedded on the FieldPoint system (see Figure 2), using the dedicated processor and real-time operating system.

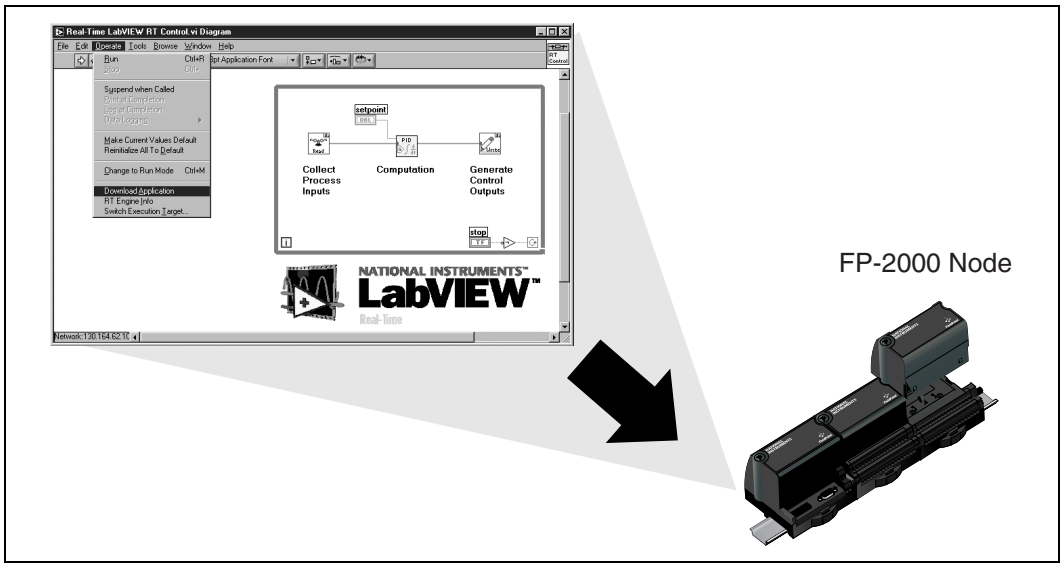


Figure 2. Download LabVIEW Real-Time to run on the FieldPoint system.

With the FieldPoint hardware architecture, you can use a network module and mix and match the I/O modules to create exactly what you need for a given task. You can select from a variety of FieldPoint I/O modules, which include analog input/output, discrete input/output, relays, counters, pulse generators, and quadrature encoders. With the different I/O modules, you can make direct signal connections to currents, voltages, thermocouples, RTDs, relays, and more.

This flexibility in choosing signal connections enables you to accurately build a system to fit the specifications you need. For systems that require even more granularity, the dual-channel modules offer 2-channel variations on most of your I/O module options. The FieldPoint 2000 Family also offers two versions of the network controller. While the FP-2000 includes 3 MB of user-accessible memory, the FP-2010 includes 11 MB for larger applications.

Integrated Measurement and Control

With the modularity of the FieldPoint hardware and the powerful functionality of LabVIEW software, you can create a single custom application that does measurement tasks as well as discrete control routines. One such system is more efficient than implementing two systems with one performing measurement, such as temperature monitoring, and the other performing temperature control. With a user-defined approach, you can create a single system that consumes less space and more efficiently monitors and controls your system.

Example – Temperature Monitoring and Control

The monitoring and control of a chamber or oven is an example of an integrated measurement and control system that can use the FieldPoint 2000 Family (see Figure 3). The FieldPoint system can monitor the temperature and continuously supply averaged data or actual values to a host machine. Simultaneously, it can adjust the temperature by controlling valves or switches, as necessary. This combined functionality can reside in a single networked system mounted near the item being tested. While it can function as a stand-alone system, you can also create a simple program to monitor the area from a remote location via a network or the Web.

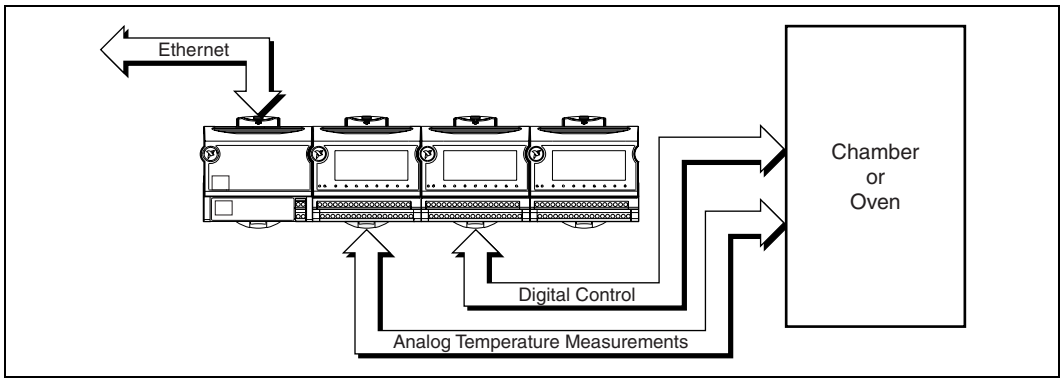


Figure 3. Temperature Control Configuration with the FP-20xx

The FieldPoint system can also perform more complex analysis, such as fuzzy logic, PID control, or signal processing functionality, on whichever measurements you need.

Distributed Intelligent Networks

You can also apply this user-defined approach to a network of FP-20xx nodes. These nodes can communicate with each other as well as with central computer systems. This capability may be useful in the monitoring and control of remote sites such as pipelines. For example, one node may detect a fault or too much stress in one section of the pipeline, alert a central monitoring station, and then immediately communicate to other control nodes that can automatically reduce or stop flow in the suspect pipe without waiting for maintenance to arrive. There are several components of distributed intelligence that create a powerful networked solution when brought together.

Logging Data

The FP-20xx also has data storage capability that enables it to acquire and store data for postprocessing or retrieval. The user has access to both RAM for temporary storage and nonvolatile flash memory for permanent data storage. The access to nonvolatile flash memory is done via the LabVIEW file I/O functions, which use the convenient file system of the modules. For example, the FP-20xx network modules can acquire data for a period of several days, run a signal analysis function to determine its statistical importance, and finally send the compiled data to a host system. Or it can continuously process and send data, and then store it temporarily if any networking problems occur.

Programmable Responses to Network Activity

The FP-20xx can receive and send both measurement data and control parameters. If you are using a network and it fails to respond, the nodes can be programmed to perform whichever procedures are necessary to shut down safely. Or it can continue independent operation, responding to changing system parameters, and storing data in nonvolatile flash memory until the network begins to function again. The FP-20xx can also monitor and use the built-in RS-232 serial port to carry on communication if the network fails.

Wireless Communication Network

You can also use the serial port as a means of communicating to the host in remote applications where Ethernet is not available. For example, the FP-20xx can use the serial port to talk to a radio modem, such as GSM, in order to communicate back to the host (see Figure 4).

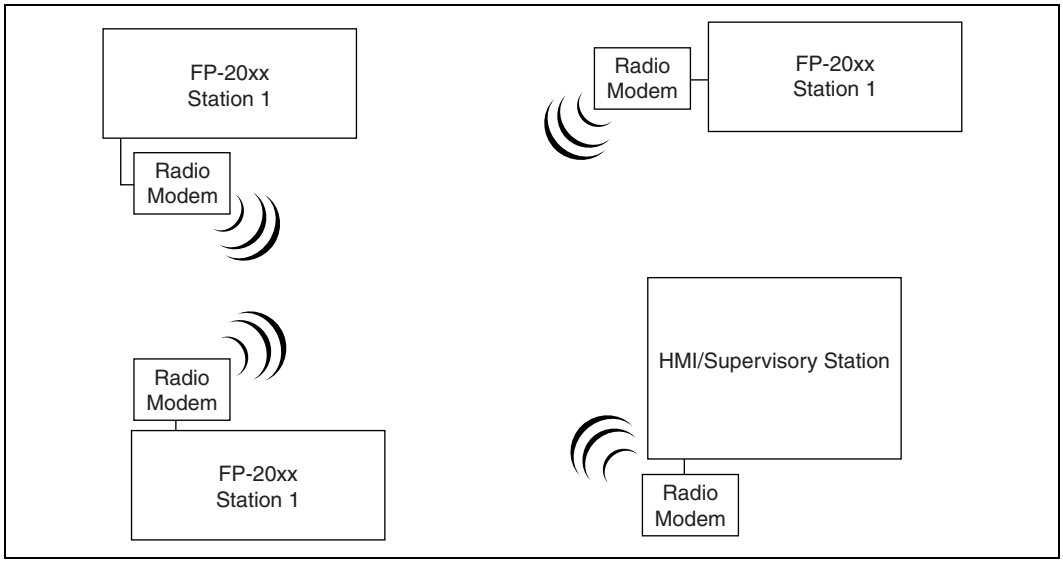


Figure 4. FieldPoint Used in a Wireless Configuration

Create Reliable Stand-Alone Systems

One of the primary concerns of engineers developing distributed systems for plant floors or remote sites is reliability. The FieldPoint 2000 Family of network modules execute LabVIEW programs independent of the Windows computer. It uses an embedded real-time operating system to run reliably and includes various features to enhance its autonomous nature such as nonvolatile memory, industrial packaging, and built-in watchdogs.

Stand-Alone Operation

Once LabVIEW code is downloaded to the module, it can execute independent of the host computer. The host computer is not required for program operation, but instead for supervision or communication only if the application requires it. This gives the FP-20xx autonomy in operation and independence from any reliability issues involving the host PC. With the dedicated processor running a real-time operating system, the reliability of the FP-20xx satisfies most distributed system requirements.

Example of Stand-Alone Operation

Many process control applications require reliable stand-alone operation. For instance, semiconductor wafer machines may need to network data from the machine to the computer for temperature trending, chemical data, alarm displays, and so on. However, the intelligent control of a semiconductor deposition process needs to continue running reliably, in real-time even if the network experiences glitches, or else it can ruin an expensive job. With the real-time FieldPoint solution, you can maintain independent control on its dedicated processor, even if the network experiences delays, or gets disconnected.

Operation in Industrial Environments

FP-20xx modules operate at temperatures between –25 and 55 °C. For module-to-module electrical isolation, FieldPoint I/O modules are rated up to 2500 V_{rms}. They are double isolated for a safe working voltage of 250 V_{rms}. These I/O modules offer self-diagnostics, plug-and-play, and hot-swappable installation for reliable installation and operation. They also feature programmable power-up and fail-safe modes for predictable operation. These specifications make the intelligent FP-20xx systems ideal for operation in areas where most PCs cannot survive.

Develop, Deploy, and Maintain Your System

Using LabVIEW Real-Time and the FP-20xx, you can rapidly develop your networked system, and then easily deploy it to run on its own or within an existing system. You can also reliably maintain and modify it after it has been in use. The durability of the products during all three phases of use reduces your overall cost in both initial development and long-term maintenance.

Rapid Development

The LabVIEW graphical development environment used to create FP-20xx systems reduces development time for measurement and automation applications. No new learning curve is required to use the real-time embedded FieldPoint system because the functionality of LabVIEW on Windows – including networking, data processing, and acquisition – is simply downloaded via a menu option to run on the target hardware. In particular, the built-in networking capabilities of LabVIEW make it easy to set up, configure, and use networking on the FieldPoint nodes for communication to applications on the host computer. You use the same LabVIEW development environment, which scales across both hardware platforms to integrate them.

Debugging is also simplified because you can use the LabVIEW Real-Time development system to automatically connect through the Ethernet port to the program embedded in the FieldPoint hardware. You can single step, probe, even run in execution highlighting mode from your Windows machine to examine operation of the program in slow motion.

With LabVIEW Real-Time, you can separate noncritical tasks that run on PC-based systems, such as interfacing to databases or Web publishing, from the critical tasks, such as control and data collection, that run on the real-time embedded OS in the FieldPoint modules. By having a single development environment that can do both, you can increase your productivity simply by not having to learn and use more than one environment.

Easy Deployment

Systems based on the FP-20xx are easy to deploy because of both the software and hardware packaging. LabVIEW Real-Time can build stand-alone executables that reside in the FieldPoint nodes so that an application can start running immediately upon power up of the system. These applications can wait for a control input from the network or simply begin stand-alone execution. There is no run-time cost associated with any of the software because the FP-20xx modules have a built-in real-time engine.

In addition, the FieldPoint systems have DIN rail or panel mounting options and other packaging features that assist you in easily and securely mounting these modules.

Finally, the built-in programmable RS-232 port helps integrate the FieldPoint nodes easily with existing systems. With this serial port, you can connect to a variety of industrial measurement and control devices, such as serial FieldPoint distributed I/O, Optomux controllers, or any other simple serial device.

Long-Term Maintenance

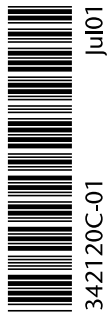
After your system is deployed, you may need to modify software or hardware to satisfy new requirements. Because LabVIEW can download new programs through Ethernet, you can upgrade or change your software without disturbing your hardware configuration. If you need to change your hardware or replace components, the FieldPoint modules are hot swappable and designed to be replaceable.

Scalibility

By using National Instruments software and hardware, you also have a migration path to other technologies. LabVIEW not only integrates a wide range of I/O, helping you reuse your knowledge across many different applications, but also adapts quickly to new industry technologies, making it easier for LabVIEW users to take advantage of them in their solutions. For example, LabVIEW users can incorporate machine vision or motion control into existing data acquisition applications while using the same environment, programming concepts, and techniques they already know. National Instruments continuously expands the capability of its software and hardware platform, making it as easy as possible to migrate those customers who want to evolve existing systems.

Over the past 15 years, LabVIEW software has grown to be an open industry standard in test, measurement, and automation. The number of engineers and scientists familiar with using LabVIEW continues to increase, making it easier to find expertise for your application. In addition, the global support services of National Instruments with its more than 700 Alliance Program partners worldwide help you remain successful.

LabVIEW Real-Time and the FP-20xx take the power and ease of use of a PC-based system and extend that to a networked system of intelligent nodes for measurement and control. The FP-20xx modules embody a convergence of major technology trends from smaller, more embedded intelligent systems, to the growth of Ethernet on the factory floor, to Web-enabled applications, to the integration of manufacturing and test. They deliver better productivity in developing, deploying, and maintaining applications in design, test, and manufacturing.



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