Developing Scalable Networked Monitoring and Control Systems with LabVIEW

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Introduction

In theory, control systems can be condensed into a simple set of tasks – measure your system, make decisions based on the input, send a control signal to adjust your system to expected operation, and then repeat. In reality, accomplishing each of these tasks can grow complex, once you take into account the types of measurements you need to make to get your inputs, the algorithms and logic needed to make the decisions, the distributed nature of many control systems, the amount of I/O to manage, the speed of the control loop, and so on. If your system is simple and digital, you may be able to find an off-the-shelf inexpensive hardware controller to do the job. But as the system grows and requires more functionality, you may want to reevaluate such controllers and choose tools that can meet your existing system needs, and then scale to address future changes or technologies as they arise.

Networked Monitoring and Control Systems

In the past, companies have been able to develop large yet simple control systems with inexpensive hardware controllers. However, as trends are pushing for more integrated systems and solutions, new control systems are being developed with the ability to communicate to other terminals such as adjacent environmental monitoring systems and system databases through Ethernet, the standard backbone of a company network. Even existing systems are being retrofitted with Ethernet connectivity to connect to existing enterprise systems, thus immediately delivering a more scalable architecture for building future control systems.

For example, consider a process control unit monitoring and controlling a temperature, which consists of measuring the temperature and turning on/off a heating coil or fan. When this temperature must be logged for historical data tracking, an external black box data logger may be required. Or the data can be logged locally and retrieved across the network for postprocessing. If the temperature must be broadcast to several plant supervisors, a Web page must be developed as well.

While there are abundant control engineering software tools to solve various simple control applications, few of them manage to solve all aspects of these new integrated control systems. When evaluating control software, key elements to consider include:

- Flexibility
- Ease of use
- Reliability
- Performance
- Open network connectivity (scalability)
- Integration with measurement and control hardware

The Integrated LabVIEW Software Platform

National Instruments LabVIEW provides an intuitive software development environment designed to help you develop scalable, networked control systems with any kind of measurements, analysis or algorithm development, and I/O you need, from simple to complex applications. The LabVIEW platform of software products, which includes LabVIEW, the LabVIEW Datalogging and Supervisory Control Module, and the LabVIEW Real-Time Module, provides powerful tools for sophisticated monitoring, data logging, supervisory control, PID control, fuzzy logic, single point analysis, control prototyping tools, machine vision, and more.

This integrated software platform empowers developers to rapidly build control systems and modify them easily as the system requirements change. Developing a measurement and control system (Figure 1) with this tightly integrated software framework delivers numerous benefits, including:

- **Significantly increased productivity** throughout the development, deployment, maintenance, and modification process with an intuitive development approach optimized for measurement and control applications
- **Higher performance** for real-time monitoring and control systems.
- **Tighter system integration** that brings together diverse measurement devices into high-level systems that connect easily to other processes throughout the organization
- **Decreased costs** throughout the product life cycle

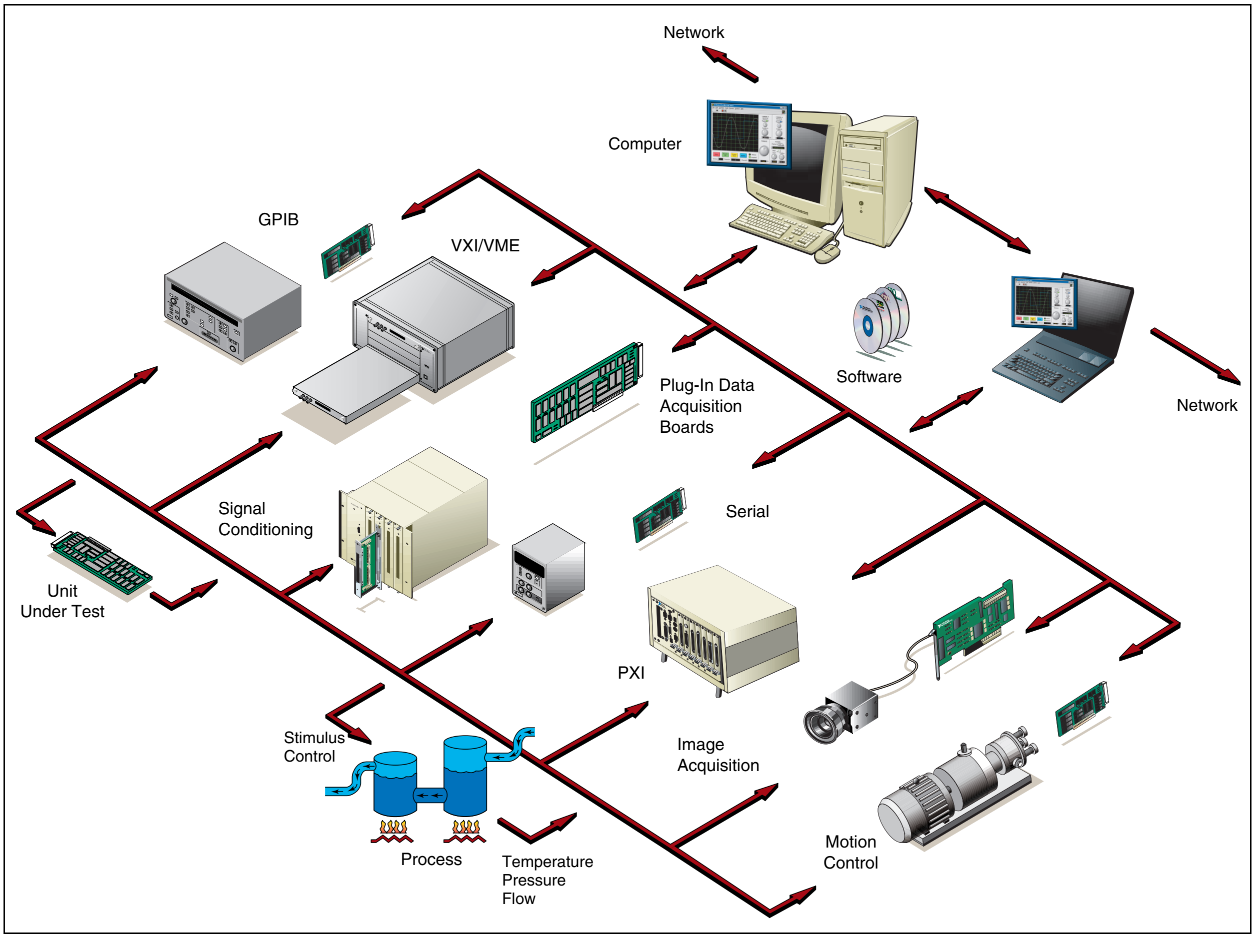


Figure 1. Integrated Measurement and Control System

Case Study – Semiconductor Manufacturing Tools

Consider a machine for manufacturing semiconductors that consists of four chambers with different temperature and pressure settings for wafer manufacture. A system must be implemented that monitors and controls the temperature and pressure in each chamber according to defined set points or according to a profile. An embedded control unit could be controlling the temperature and logging the average temperature once a minute to local storage while sending the current temperature data up to the host system for data logging. An operator may need to log into the system to view previous values up to a previous day's worth of data. A process engineer who needs to load a new temperature profile for the chambers could do this by logging in at a higher access level than the operator.

You can see that this typical monitoring and control application includes the following components:

- Data logging
- Historical and real-time data viewing
- Alarm and event management
- Security
- Networking
- Embedded control and analysis

LabVIEW provides built-in tools to address these needs so that you can spend time developing the core monitoring functionalities, rather than developing security tools, alarm management, etc. Because the number of applications including some kind of monitoring are spanning from R&D, to design and validation, and manufacturing, these same built-in tools can be used for various distributed monitoring applications.

Viewing, Logging, and Retrieving Data

When setting up a monitoring application, the ability to log the data easily is a requirement. Because the operator is not always able to or supposed to monitor the system, logging data for later retrieval is essential for data integrity, consistent report generation, postacquisition analysis, or audit trail purposes. Logging becomes even more important when the amount of data involved increases with the complexity of the system you need to monitor. And in such a system an efficient control of your monitored data needs to go necessarily through the implementation of an alarm and event management mechanism to better track down any possible failure in the process. The need for a robust system with software tools capable of logging a large quantity of data, and retrieving it in a cost-effective, efficient way is a must in today's competitive market.

An open programming language can certainly offer extensive flexibility in the development process of a monitoring application with a small number of channels.

However, the approach changes when developing a larger system. You quickly realize that logging your monitored data on a channel-by-channel basis using a standard API is challenging and time-consuming.

A configuration-based environment such as the LabVIEW Datalogging and Supervisory Control Module offers a better approach. In such a system the I/O is treated as an inherent part of the system. Different configuration settings and tasks such as logging, as well as alarms and events, historical and real-time data viewing, and scaling are managed automatically as a fundamental aspect of the system. By taking advantage of these tools you can concentrate on the development of your measurement and automation application rather than spending time developing fundamental tools to log, view, and manage your real-time and historical data. Moreover, instead of starting right away with the application development, you can easily use these built-in tools as troubleshooting and diagnostics utilities to get a quick snapshot of what is happening in the system and verify that the hardware has been properly configured and the channel connection has been established correctly.

Securing Your Monitoring System

Security is undoubtedly an important piece in a monitoring system, particularly in an industrial environment where operators, engineers, and technicians are constantly operating around the machine or process being monitored. The need for a secured environment is necessary to avoid unexpected behaviors due to improper manipulations by unqualified people. Again, using a standard API to implement system level and operator interface security can be very complex and require extra knowledge. For example, in the application description, a process engineer could log in to download a new profile to the embedded control device. This can be further extended to a third level of security.

Sharing Your Data Across the Enterprise

Finally, you want to be able to share your monitored data with other groups in the company for data storing, offline analysis, report generation, or Web publishing. Industry standards such as Ethernet with TCP/IP and OPC (OLE for Process Control) are used more and more in PC-based monitoring systems to seamlessly share your data across the enterprise, from the lab to the factory floor.

Ethernet is quickly moving from the office onto the factory floor because of its low cost, high speed, and multiprotocol ability, clearly becoming the universal network at all levels of the enterprise. Ethernet can be implemented not only at the higher level of the plant hierarchy, but also at the control level to connect distributed I/O to PLCs and data acquisition systems. Ethernet and TCP/IP form a solid framework for networking and Web connectivity. However, to easily share multiple I/O and data acquisition devices with multiple PCs, the application-level protocol plays an important role. The application-level protocol basically defines the common language used to talk to the different devices. In the industry, standards such as OPC and HTTP are rapidly gaining consensus.

OPC provides a whole new level of interoperability between automation software and hardware, removing the obstacles created by proprietary industrial device interfaces and drivers. It defines a standard for a common interface to communicate with a variety of industrial devices and communication protocols.

OPC is the answer to multivendor connectivity problems, which are specifically critical in monitoring applications.

Distributed Intelligent Networks

While security and data viewing are important components to the main operator station of a monitoring and control system, they must integrate to the actual device-level control. With the LabVIEW Real-Time Module, engineers can now download LabVIEW applications to embedded dedicated hardware targets. Engineers can take advantage of the built-in networking tools of LabVIEW such as NI DataSocket™ to easily integrate these embedded systems with the main operator station for a seamless control solution. In addition, the core functionality and tools of LabVIEW enable engineers to develop sophisticated control applications with embedded PID control, data logging, frequency analysis, etc. and download it into an independent real-time device. Choose from a variety of RT Series hardware targets to create a system that meets your exact needs today, while taking advantage of the modularity of the system as your system requirements grow:

- **RT Series PXI** – with the RT Series PXI option, you can control an entire chassis of various PXI/CompactPCI for a high-performance stand-alone real-time data acquisition and control system.
- **RT Series FieldPoint** – with the RT Series FieldPoint you can develop a distributed network of compact, industrial modules with the built-in intelligence and easy-to-use networking features of FieldPoint.
- **RT Series Data Acquisition** – with the RT Series data acquisition boards you can integrate a real-time component into a larger measurement and automation application.

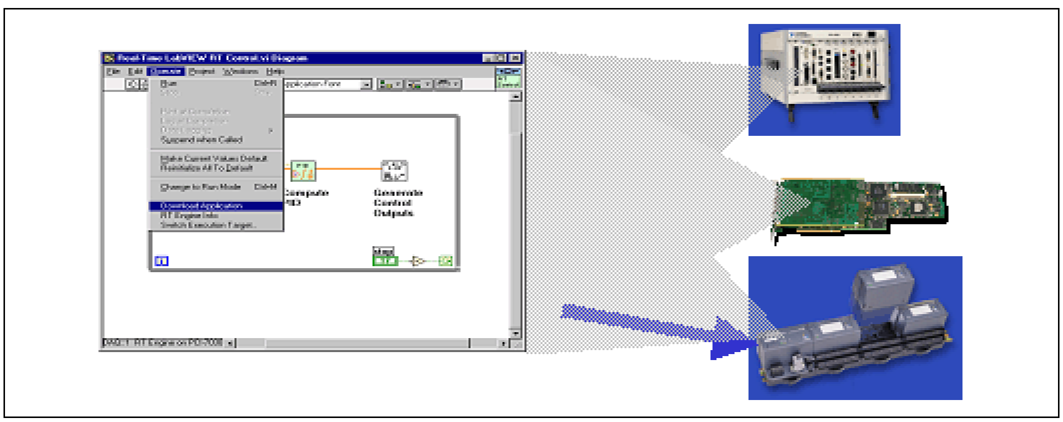


Figure 2. Download LabVIEW Real-Time to Run on Different RT Series Hardware.

Embedded Device-Level Control

As the industry moves toward embedded systems for control applications, National Instruments has met these needs with networked embedded real-time devices ranging from small footprint distributed I/O systems to modular high-performance PXI/CompactPCI systems. With the high-performance PXI system, capable of 40 kHz real-time control loops, engineers can create high-performance embedded systems such as a machine condition monitoring system that analyzes vibration. The distributed FieldPoint systems provide a low-cost, compact system that runs embedded LabVIEW code. This distributed intelligent node can easily be placed around the any factory floor or manufacturing environment for monitoring and control. With these hardware options, LabVIEW Real-Time delivers the scalability to address future requirements.

With the code running on a dedicated embedded processor, the systems deliver deterministic performance with better reliability. For instance, an engineer can develop a LabVIEW application on a Windows system and download it to an embedded FieldPoint system. Once the LabVIEW application has been downloaded, the FieldPoint system is now independent of the Windows system and can operate as a stand-alone device or be integrated into a larger networked monitoring and control solution.

Integrated Measurement and Control

With the modularity of the RT Series hardware from National Instruments and the LabVIEW Real-Time Module, you have the flexibility to define functionality through both hardware and 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.

With the RT Series FieldPoint and RT Series PXI 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 I/O types, which include analog I/O, discrete I/O, relays, counters, pulse generators, and quadrature encoders. With an RT Series PXI system, you can even incorporate signal conditioning, motion control, CAN, and third-party hardware to address expanded I/O signal requirements. With the different I/O modules, you can make direct signal connections to currents, voltages, thermocouples, and more.

Logging Data

The RT Series FieldPoint and RT Series PXI hardware targets also have data storage capability so they can acquire and store data for postprocessing or retrieval. The user has access to both RAM for temporary storage and nonvolatile memory for permanent data storage. The access to nonvolatile memory is done via the LabVIEW file I/O functions, which use the convenient file system of the modules. For example, the RT Series FieldPoint 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. At the same time, this data can be sent back up to the monitoring system with the LabVIEW Datalogging and Supervisory Control Module, which is storing data from multiple distributed FieldPoint systems.

Develop, Deploy, and Maintain Your System

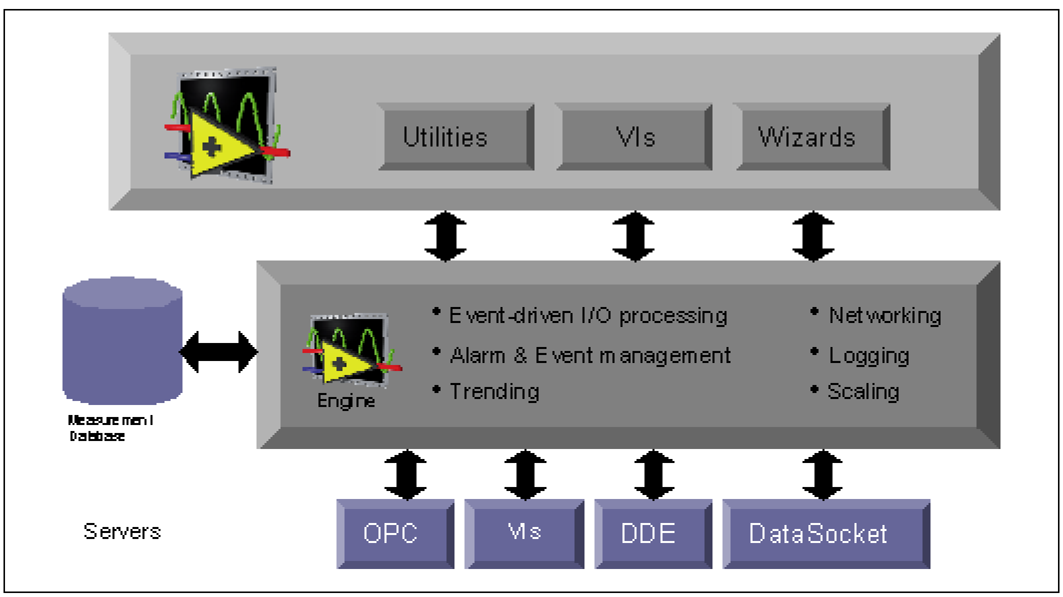
Using the LabVIEW Real-Time Module and the RT Series hardware, you can rapidly develop your networked system, and then easily deploy it to run on its own or within an existing system. You can also reliably maintain and modify it after it has been in use. The durability of the products during all three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

Using the LabVIEW graphical development environment to create real-time systems reduces development time for measurement and automation applications. No new learning curve is required to use the real-time embedded National Instruments devices because the functionality of LabVIEW on Windows, including networking, data processing, and acquisition, is simply downloaded to run on the target hardware. You use the same LabVIEW development environment, which scales across both hardware platforms to integrate different hardware targets. Debugging is also simplified because you can use LabVIEW to connect through the Ethernet port to the program embedded in the RT target hardware.

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.

Increase Your Productivity

With LabVIEW, National Instruments provides a software solution that satisfies these monitoring requirements by eliminating the need to develop your own tools. With the LabVIEW Datalogging and Supervisory Control Module, you have built-in tools to perform traditional monitoring tasks, such as alarm handling, historical logging and viewing, data management, and networking, for a significant increase in your productivity. Also, with easy networking, distributed logging, built-in security, and OPC connectivity, the LabVIEW Datalogging and Supervisory Control Module provides tremendous ease of use to get your monitoring system up and running quickly; and by adding full OPC client and server capabilities to your LabVIEW application, you can communicate with any OPC server available on the market today.



This LabVIEW add-on module also adds an event-driven engine to your LabVIEW application. This engine runs in the background and maintains the real-time database, logs historical data, processes alarm information, and communicates with device servers. You can then define your advanced control algorithms, supervisory control, analysis, and monitoring in LabVIEW.

The event-driven architecture of the engine greatly improves the performance of your system by freeing up CPU time until an event occurs. An event is generated when a data point changes, a switch is toggled, or an alarm is generated. When the event occurs, the system is notified and executes the specified functionality. The clear advantage of such architecture is that the system has more capacity for growth without performance degradation.

Integrated Software Framework for Better Productivity

With the release of LabVIEW 6.1 and its modules for monitoring and real-time control, National Instruments offers a unified environment to build your real-time applications as well as your supervisory control and monitoring applications. 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.

The LabVIEW Datalogging and Supervisory Control Module offers you built-in tools to significantly increase in productivity by easily setting up your monitoring application without worrying about developing fundamental monitoring tools to handle traditional tasks such as alarm handling, historical logging, data management, security and networking.

The LabVIEW Real-Time Module and RT Series hardware 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. Architectures such as RT Series FieldPoint 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.

Using PC-based industry standards such as TCP/IP and OPC, you can make real-time plant-floor information easily accessible to the production and business applications. And to go beyond the factory boundaries, Web-based capabilities, such as the built-in Web server in LabVIEW 6.1, are opening up new doors for an even easier access to your plant floor data from anywhere at any time with a simple browser.

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 for migration by customers who want to expand and enhance existing systems.

Finally, 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, which makes 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.

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