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Technology Comparison: LonWorks® Systems versus DeviceNet®

A Contrast in Key Features

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Contents

Figures

Tables

Introduction

This bulletin compares the key features of LONWORKS® networking technology with DeviceNet®, a proprietary master-slave control system that provides remote I/O for programmable logic controllers (PLCs). Following a brief overview of control systems, a comparison of LONWORKS and DeviceNet titled *Application of LONWORKS to Semiconductor Process Automation* that was prepared by Dr. Yamamoto of Nippon Motorola Ltd. will be presented. This presentation was translated from the original Japanese without modification and presents the view of an independent party on the merits of the two technologies and their respective capabilities.

Control Systems – The Early Days

In the early days, before the advent of control networks, control systems consisted of masses of wires connected to relays, switches, potentiometers, and actuators. Cabling was installed in a point-to-point fashion between electrical panels, effectively wire routing stations filled with terminal blocks, and sensor inputs and actuator outputs. The functionality of these control systems was relatively rudimentary and inflexible: adds, moves, and changes required extensive rerouting of wiring and connections.

The advent of solid state technology offered a means of using logic circuits to replace wire and relays. Electrical panels gave way to programmable logic controllers (PLCs), which were programmed not with a screw driver but a data terminal. As increasingly powerful algorithms were developed, tighter control over processes could be achieved. However, the issues associated with adds, moves, and changes remained and grew increasingly complex as systems grew in size. The software required to handle large systems was very complex, the PLC represented a single point of failure, and the PLC was still tethered to all of the sensors and actuators by cable bundles that were not easily modified (figure 1). Moreover, the manufacturers of DDCs developed them using proprietary internal architectures: if you wanted to expand a DDC you had to use expansion cards and software from the original manufacturer.

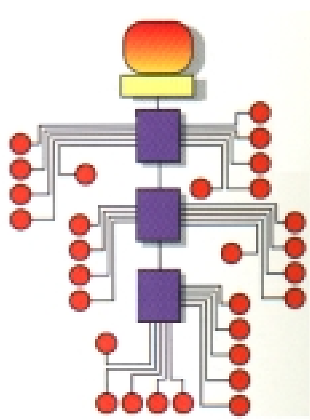

Figure 1. Closed, Wiring-intensive Architecture of PLCs

If one wanted to interconnect PLCs from different manufacturers, the incompatibilities between manufacturers led engineers to focus on linking separate systems with relays, custom gateways, and RS-232 ports. The problem was that these interfaces didn't provide a detailed, seamless view into the different systems. They allowed only limited status and control information to be passed between the different systems. Fault status information couldn't be shared, information from different sensors wasn't accessible for combinatorial logic programs, and systems couldn't adapt their responses in real-time based on receiving the overall system status.

DeviceNet control systems provide a means of extending the inputs and outputs (I/O) of PLCs to remote locations. Using a proprietary implementation of a control bus called CAN that was originally designed for automobile engine control, DeviceNet uses a master-slave bus architecture and provides high speed communications over relatively short distance twisted wire pairs.

Interoperability and Open Systems

Creating a seamlessly integrated control system requires interoperability among the components of that system, as well as other related systems that must exchange information (figure 2). Interoperability is the process by which products from different manufacturers, including those in different industries, exchange information without the use of gateways, protocol converters, or other ancillary devices. Achieving interoperability requires a standardized means of communicating between the different devices; it depends on a system level approach that includes a common communication protocol, communication transceivers, object models, programming and troubleshooting tools, and so on.

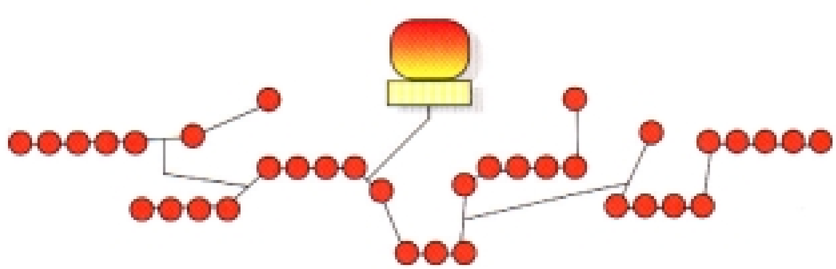

Figure 2. Open, Interoperable Control Network with Minimal Wiring

The benefits made possible by interoperability are many. Since one sensor or control device can be shared among many different systems, fewer sensors/controls are needed and the overall cost of the control system drops appreciably. For example, information on process temperature or speed can be shared with multiple sub-systems spread throughout a plant, eliminating the need for multiple redundant sensors.

For a plant owner, interoperable products offer the advantage that devices can be selected from among different manufacturers; the owner is no longer tied to any one manufacturer's proprietary technology. Aside from the cost savings achieved by open competition, the plant owner is safe in the knowledge that replacement products will be available if any one manufacturer goes out of business or discontinues products.   Service contracts can be openly bid since no proprietary devices will be used, thereby avoiding single source service contracts.

Interoperability also benefits equipment manufacturers because their products will be assessed based on their quality and functionality - not on their ability to meet a closed, proprietary specification. Interoperability levels the playing field and increases competition, insuring that the best devices for the job will win.

LONWORKS Technology

The LCA While interoperable control systems might have been a pipe dream only a few years ago, they can be built today using a technology called LONWORKS. Developed by Echelon Corporation, LONWORKS technology allows all forms of sensors, actuators, displays, and controllers to communicate with one another through a common communication protocol that is shared among all devices. Communication transceivers and transport mechanisms are standardized, as are object models and programming/troubleshooting tools to enable the rapid design and implementation of interoperable, LONWORKS -based devices. Network management software, protocol analyzers, IP routers, PC and PCMCIA interfaces, and development tools are all available off-the-shelf to speed development and reduce time to market. In short, LONWORKS offers a system level approach to interoperability, and comprises a complete set of tools, components, software, and hardware. By providing all of the infrastructure required to create open, interoperable control networks, LONWORKS minimizes development expenses, reduces the time required to bring products to market, and provides a uniform set of tools for installing, maintaining, and modifying control networks.

The heart of a LONWORKS hardware device is the Neuron® Chip, an integrated circuit that combines a sophisticated communications protocol, three microprocessors, a multitasking operating system, and a flexible input/output scheme. Manufactured under license by both Cypress and Toshiba, the Neuron Chip is sold and supported worldwide. Almost 10,000,000 have been shipped since 1992. Devices that complement and/or use Neuron Chips are available from Echelon and more than 4,000 manufacturers worldwide.

Device that use a Neuron Chip can send signals to, or receive signals from, each other without a central network computer or server. Ensuring the interoperability of these network communications is the responsibility of an independent organization called the LONMARK® Interoperability Association. Funded through member dues, the LONMARK Association defines the interoperability guidelines for LONWORKS devices, including communication transceivers and object models. Products that bear the LONMARK logo are certified to adhere to the LONMARK interoperability guidelines and can be used with confidence in integrated control systems.

The existence of interoperability guidelines helps ensure that control devices can share information. However, this capability would be for naught if there was not also an interoperable means of defining, installing, and reconfiguring a control network. After all, even a well designed control system needs to be changed from time to time. Overcoming the limitations of closed, centrally controlled systems -

including extensions of those systems like DeviceNet - dictates the need for an open, interoperable, multi-vendor installation and maintenance tool architecture. This would permit multiple technicians to simultaneously configure and maintain different portions of a control network using tools from different manufacturers.

In the LONWORKS world, the LNS operating system is "middleware" software that provides a standard platform for supporting interoperable applications on LONWORKS networks. Offering a powerful client-server architecture, LNS permits multiple installers to simultaneously configure a control system. Manufacturers can provide a unique look and feel to their products by creating customized human machine interfaces. By offering a common platform with a customized "front end," LNS makes it possible for multiple vendors to supply interoperable tools.

In order to speed the configuration of devices from different manufacturers, LNS defines a "plug-in" standard. This standard allows sensor, actuator, and device manufacturers to provide customized applications for their products. When those products need to be configured, the LNS-based tool will automatically present a configuration screen that the manufacturer has tailored to the device being configured. Regardless of the LNS-based tool being used, the configuration screen for that product will remain consistent. This capability simplifies the task of training installers, allows device manufacturers to give the programming interface a unique look and feel, and permits tool vendors to offer products that are both unique looking and interoperable.

Figure 3 shows a typical LNS-based tool that implements a Visio® user interface. Visio provides users with a familiar, CAD-like environment in which to design a control system. Visio's smart shape drawing environment offers an intuitive, simple means for creating devices. The tool includes a number of smart shapes for LONWORKS networks, and users can create new shapes for unique device configurations or complete subsystems. Stencils can be constructed with predefined devices, function blocks, and connections between them. Master shapes corresponding to complete subsystems can be created and saved. Additional subsystems can then be created by simply dragging the shape to a new page of the drawing, a time-saving feature when designing complex systems.

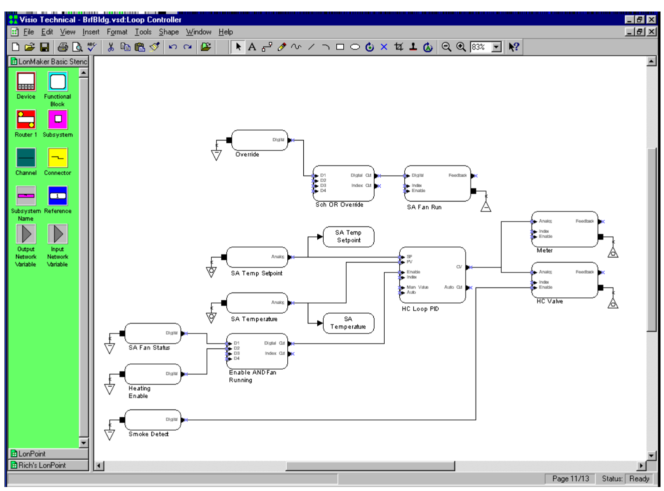

Figure 3. Typical LNS-based Tool Network Configuration Screen

To ensure interoperability, it is important that both control devices and configuration tools adhere to the LONMARK interoperability guidelines. LONMARK features such as standard functional profiles, configuration properties, resource files, and network variable aliases make it possible to achieve interoperability between tools, devices, and tools and devices.

An LNS DDE Server allows LNS-based networks to share information with DDE-compatible human-machine interfaces (HMIs) such as Wonderware's InTouch®.

Open, Interoperable Systems – An Existence Proof

While LONWORKS technology holds the potential to create open and interoperable control systems, the key is in the execution of the design. LONWORKS was designed to be deployed using an open, interoperable, distributed architecture, however, it can also be configured in a manner that is closed and proprietary - similar to traditional PLCs and other closed, hierarchical control systems. Proper execution is needed to create open LONWORKS control systems, and to realize the economies and benefits of which this technology is capable.

Overcoming the limits of traditional, closed, hierarchical systems is best accomplished with a flat, fully distributed control architecture. Such an architecture allows the owner to take advantage of the labor and equipment savings associated with networked cabling. It also minimizes the probability of a single point of failure, a shortcoming of centrally controlled systems. To be truly useful, this architecture needs to include provisions for connecting both intelligent sensors and actuators (ones with on-board networking) and legacy sensors and actuators in a common network. Multiple network management tools should be supported (reducing costs by allowing several technicians to work simultaneously) and these tools should be available from different manufacturers. Satisfying these many and diverse requirements dictates a systems approach to the architecture, hardware, and software; it cannot be accomplished with a piecemeal collection of devices and components.

An example of such a systems approach to control networks is Echelon's LonPoint® System. The LonPoint System is a family of products designed to integrate new and legacy sensors and actuators, as well as LONMARK devices, into cost-effective, interoperable, control systems. In contrast to traditional control networks based on PLCs or other proprietary controllers, the LonPoint System offers a flat system architecture in which every control point performs some control processing. Distributing the processing throughout the network lowers the overall installation and life cycle costs, increases reliability by minimizing single points of failure, and provides the flexibility to adapt the system to a wide variety of applications.

The LonPoint System includes the LonMaker™ for Windows® tool and a family of LonPoint interface, scheduler, and router modules. LonPoint digital and analog Interface Modules, Scheduler, Data Logger, and Router modules provide I/O and application processing, timekeeping and scheduling, and routing, respectively. The interface modules seamlessly integrate sensors and actuators into peer-to-peer, interoperable networks (figure 4). The Scheduler Module provides time, date, and system status to other modules on the network, and includes a programmable state machine – the Scheduler may also be configured to operate as a Data Logger that time stamps and archives system activity. The Router Modules can be used to create high speed backbones to optimize network traffic, extend the size of the network, as well as to create bridges to other channels containing third party devices.

Figure 4. LonPoint Interface Module

Resident within each LonPoint module is a configurable application program. The program includes a variety of function blocks (i.e., PID, analog function, discrete sensor, type translators) that are configured by the LonMaker for Windows tool. Linking together the software function blocks of the LonPoint modules with the resources of third party LONMARK devices creates a distributed control system that offers greater functionality, higher reliability, and lower cost than a PLC-based system. The LonPoint System may be operated as a self-contained control system, integrated with other LONMARK or LONWORKS devices, or combined with remote systems and a remote supervisory station to form a wide area control system.

Comparison of LONWORKS and DeviceNet

LONWORKS and DeviceNet have both been targeted at the broader industrial market, but using vastly different design approaches. LONWORKS was developed as an open, interoperable control network with support for multiple media and wide area network connectivity, while DeviceNet originated with a PLC vendor that wanted to extend the I/O of its proprietary PLCs. These differences are readily apparent upon closer scrutiny of these two technologies.

A comparison of LONWORKS and DeviceNet was made by Dr. Yamamoto of Nippon Motorola Ltd. as part of a presentation entitled *Application of LONWORKS to Semiconductor Process Automation*. Dr. Yamamoto's comparison is shown in Table 1 below. As part of the comparison, Dr. Yamamoto examined seventeen factors that are important in an industrial control system, and more specifically for semiconductor manufacturing applications. The two control networks are rated by Dr. Yamamoto on the basis of their performance with regard to these factors.

Table 1. A Comparison of LONWORKS and DeviceNet Networks

Importance A = very important B = important	**Description**	**DeviceNet**	**Point** 0 None 1 low 5 High	**LONWORKS**	**Point** 0 None 1 low 5 High
B	Connection Cable	Twisted Pair cable (5 leads): Signalx2, Power supply x2, Shield line	3	Twisted pair, power line, EIA-232, infrared, fiber optic, coaxial cable	4
B	Transceiver	Reconstructed RS-485 transceiver	4	Supplied by Echelon or other suppliers (based on basic design condition)	5
B	Topology	Free with many limitations	3		4
B	MAC	CSMA/NBA	4	CSMA/CA	3
B	Maximum Node Numbers	64	2	255 (subnet/domain) x 127(node/subnet) = 32,385	4
B	ID	MAC ID is set with DIP switch. Or software setting with configuration tool	3	Neuron® ID (unique 48 bit data are used for installation and commissioning time normally	4
B	Message length	8 byte	2	228 byte	4
B	Bit rate	124 bps - 500 kbps	3	600 bps- 1.2 Mbps	4
B	Cable length	500m(125 kbps) 250m(125 kbps) 100m (500 kbps)	2	2,700m (78 kbps,bus, 64 nodes), 2,200m(78 kbps, bus ,128nodes)	4
A	Communication service	P to P and Master/Slave. No P to P product has been implemented yet.	2	P to P and Master/Slave	4
B	Message service	POLL STROBE, CYCLIC, COS (Change of State)	3	Ackd, Request/Response, Unackd Repeat, Unackd	3
A	Object oriented	Insufficient support at DeviceNet Rel 1.x. Reinforced at Rel 2.0. No real product has been implemented at Rel 2.0.	3	Especially strong for distributed data object functionality support with Neuron C	4
A	Autonomy	Required one or more numbers of master PLC or PC	2	Complete autonomy - system is configurable.	5
A	Runtime library	No	0	Various application level libraries are supported.	5
A	Performance for real time facility	Different performance depends on CPU facility or program which controls CAN chip.	3	8-9 ms with 10MHz Neuron Chip, 4 ms with 20MHz Neuron Chip	4
B	Durability to noise factor	5 lead cable (Reconstructed RS-485 transceiver)	3	Fiber optic cable can be used for noisy environment.	4
B	Organization to standardize	ODVA,ODVA in Japan	4	LONMARK® Interoperability Association	3
Total Points		**DeviceNet**	**46**	**LONWORKS**	**68**

The higher rating of LONWORKS networks is the result of several factors. LONWORKS networks are media-independent and may be operated over long distances of twisted pair cabling, IP networks, power line carrier, fiber optic, radio frequency, coaxial cable, or infrared media. Intrinsically safe twisted pair operation is also supported. Transceivers necessary to support these different media are available from Echelon and a wide variety of other suppliers. Multiple-media support permits LONWORKS networks to be used in a very wide variety of applications which would be unsupportable if the network were limited to one or two media as is the case with DeviceNet.

The flexible LONWORKS addressing scheme make it ideal for very small and very large networks without concern about exceeding available addressing space. Subsystems can be divided logically into domains, subnets, and groups, allowing both industrial devices and non-industrial systems to share information yet remain distinct. The LONWORKS protocol stack[i], called LonTalk®, follows the 7-layer OSI model, and can be routed over both LONWORKS networks and IP-based networks. The combination of a large addressing range, logical address partitioning, and routing capability makes it possible to create extremely large networks, operating over both local network cabling as well as the Internet, while preserving subsystem identity and channel bandwidth. The ability to integrate multiple subsystems into one network reduces the installation and life-cycle costs of LONWORKS networks, economies that cannot be achieved with the limited addressing scheme and applications supported by DeviceNet.

LONWORKS also offers more options than DeviceNet for enhancing response times for critical nodes and messages in true peer-to-peer systems. DeviceNet offers only Collision Resolution for media access, which resolves collisions and prevents loss of packet slots, but yields unbounded response times for all but the lowest (all-zero) message ID. LONWORKS offers several media access options, including (a) collision resolution, (b) smart collision avoidance, (c) priority, and (d) collision detection, to enhance response for nodes and messages that need it.

With regard to messaging services, LONWORKS provides multicast messaging with transport layer acknowledgements, which guarantees that all of the addressed nodes in a group received a message. DeviceNet provides multicast messaging with link layer acknowledgements which ensures only that at least one – but not all - of the nodes addressed in a group received a message. This means that a DeviceNet message intended for several nodes can, in some cases, be acknowledged as received even if only one node received it, while the others did not. Guaranteed message delivery is generally viewed as *sine qua non* for any industrial control network, and is a fundamental feature of the LonTalk protocol which underlies LONWORKS.

Seven to nine milliseconds is needed for unacknowledged explicit messages of 1-8 data bytes by LONWORKS networks versus DeviceNet response varies with message size, bit rate, message services, host processor at source node as well as destination node(s), efficiency of a given implementation of protocol and scheduler plus other factors. All of this adds up to better performance by LONWORKS over DeviceNet in a real time facility.

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[i] LONWORKS is an open, interoperable control network and is included in AAR, ANSI, BACnet, CEN, EIA, IEEE, and SEMI standards.

Summary

The marketplace is folded with anecdotal stories about LONWORKS and DeviceNet control networks, and it is refreshing to have available an unbiased, technically sophisticated comparison in the form of Dr. Yamamoto's study. The conclusion of this study, namely the LONWORKS offers substantial advantages over DeviceNet for industrial control applications, has been validated in thousands of industrial applications which today use LONWORKS control networks. With almost 10,000,000 nodes shipping to date, LONWORKS has proven robust, cost effective, and extremely reliable in a wide range of demanding industrial applications worldwide. For more information on LONWORKS, please visit our web site at www.echelon.com.