Connecting Industrial Automation Control Networks

An overview of industrial field buses, connectivity and interoperability needs, and available Xilinx platform solutions.

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Industrial automation control networks are serial-bus based multidrop networks that intelligently connect industrial sensors, actuators, devices, and process control subsystems to each other and to enterprise networks. These networks demand interoperability of control functions at different hierarchical levels, ranging from field equipment to enterprise resource planning (ERP).

Open control systems still focus on data flow between devices from different vendors. Only a few efforts are underway to standardize architectures and application objects that would make systems understand each other.

A field bus is a generic term for industrial automation communication buses. More than 20 field buses have existed at various times, and current standardization attempts (the IEC IS 61158, IS 62026, and ADIS 62026) list 13 different field buses, as shown in Table 1.

IEC STANDARD	Field Bus Name	Comment
IS 61158 Type 1	Foundation Field Bus H1	US Automation Field Bus
IS 61158 Type 2	ControlNet	Control Network
IS 61158 Type 3	Profibus	Device Network
IS 61158 Type 4	P-Net	Factory, Shipbuilding
IS 61158 Type 5	Foundation Field Bus HSE	Control Network
IS 61168 Type 6	SwiftNet	Developed by Boeing
IS 61158 Type 7	WorldFIP	French Device Network
IS 61158 Type 8	Interbus	Discrete I/O
IS 61158 Type 3	Profibus DP	Control Network
IS 61158 Type 7	Acuator-Sensor Interface (Asi)	Discrete I/O
IS 62026-2	DeviceNet	Discrete I/O
IS 62026-5	Smart Distributed System	
ADIS 62026-6	Seriplex	

Note on Table 1 – Other industrial networking protocols like EtherCAT are currently undergoing integration into the IEC standards and are part of the publicly available specifications (PAS). The IEC also approved the ETHERNET Powerlink protocol in March 2005.

Table 1 – Current field buses

A unified communication between diverse field buses is driven primarily by the following requirements:

- Demand for greater control over processes
- Increased diagnostic capabilities and remote diagnostics
- Higher plant availability
- Improved wiring (reduced cabling)
- Integration of condition monitoring and plant maintenance
- Flexibility for upgrades
- Integration with enterprise (corporate) networks

There is a need for an integrated and low-cost system platform that allows intelligent features to be easily implemented. Integrating a large number and variety of legacy equipment and field buses also requires bridging disparate field buses to each other – and to the enterprise. Moreover, the IEC 61158 is not a unified standard but a collection of different field buses, ensuring that field bus "turf wars" and the need for integration will continue.

The Xilinx® Spartan™-3 generation of FPGAs, particularly the Spartan-3E family, provides a full-featured, low-cost programmable hardware platform ideally suited for the implementation of intelligent solutions in industrial automation.

Xilinx in Industrial Automation Control Networks

Xilinx offers programmable logic solutions in all networking categories and automation hierarchies. Low-cost Spartan-3E FPGAs enable extremely economical deployment in a variety of devices and controllers.

Xilinx XtremeDSP™ technology enables rapid DSP computation in hardware, bringing unprecedented resolution to multi-axis motion control through DSP digital drives. The MicroBlaze™ soft processor implemented in FPGAs enables offloading of functions that previously required external microcontrollers. This paves the way for compact, elegant, and cost-effective solutions with lower chip counts.

IP in the form of UART, Ethernet MAC, PCI, PCI Express, and CAN2.0B cores accelerate hardware design for bridging with industrial Ethernet buses and PC-based intelligent controllers.

Figure 1 shows the deployment of Xilinx FPGAs in industrial automation. In addition to being used in device and system controllers, Xilinx FPGAs address applications in the following areas:

- Media converters
- Switches
- Device servers
- Bridges
- Gateways

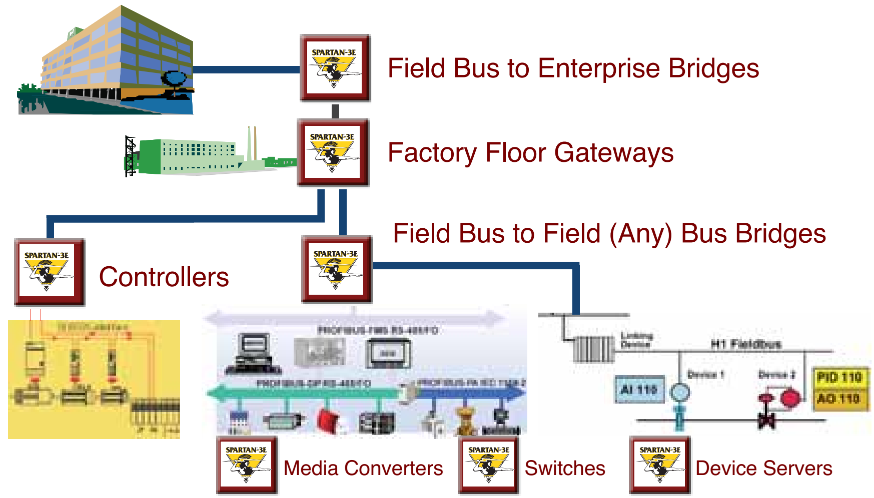
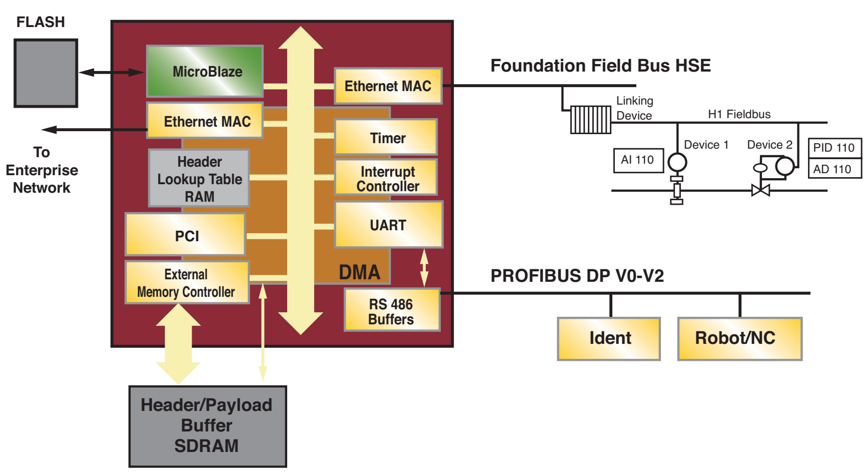


Figure 1 – Xilinx in industrial automation

The Spartan-3E family of FPGAs offers density ranges from 50,000 to 5 million system gates and 216 Kb to 1,826 Kb of block RAM to accommodate scalable processing needs. Seamless density migration over a range of devices and packages with no need for expensive re-layout protects system-vendor investments and reduces overall cost across product roadmaps (see Table 2).

In addition to the embedded MicroBlaze processor, UART and Ethernet MAC, Xilinx Spartan-3E FPGAs sport one of the world's lowest cost parallel interconnect solutions. Real PCI from Xilinx offers PCI v2.2-compliant initiator and target cores with guaranteed timing and zero wait states and a full 64-bit data path, making Spartan-3E FPGAs the family of choice for building gateways connecting field bus to field bus and field bus to enterprise, as well as field bus to intelligent PC-based controller subsystems.

A block diagram of a gateway implemented in Spartan-3E devices, along with estimated logic cell count, is shown in Figure 2. Xilinx PCI Express and CAN2.0B cores provide additional support for more industrial interfaces and modern PC-based controllers to replace programmable logic controllers (PLCs).



Functional Block	Logic Cell Count	
	Min.	Max.
MicroBlaze Processor	950	1,050
SDRAM Controller	200	250
Ethernet MAX x 2	6,594	7,520
PCI	3,950	3,950
UART	400	400
DMA Engine x3 or 4 Channels	600	800
Timer	255	255
Interrupt Controller (2 - 32 Interrupts)	46	370
Total	12,995	14,595

Figure 2 – Implementing an industrial automation gateway in Xilinx Spartan-3E FPGAs

Industrial Ethernet

Ethernet was initially ignored by the automation industry because of its perceived lack of determinism and robustness. At 10 Mbps, CSMA/CD was unable to provide the guaranteed real-time (5 to 20 ms) responses demanded by industrial control. The combination of 100-BaseFX (100 Mbps over two strands of multimode fiber per link), switched media instead of hubs, and full-duplex operation successfully overcame those limitations. Ethernet has evolved into a technology that the automation and control industry is swiftly adopting.

You can use industrial automation gateways of the type shown in Figure 2 to bridge incompatible Ethernet networks, with protocol translation implemented in software.

Xilinx sees the market for real-time Ethernet based products as strategic to industrial automation connectivity. The advent of real-time Ethernet networks offers the potential for standardization in industrial networking, starting with the physical and data link layers, as well as seamless connection to enterprise networks. Xilinx FPGAs offer low-cost platforms for the implementation of real-time Ethernet networks, and are well suited for implementation of evolving standards that require field upgradability to comply with enhancements and changes in features.

Device	XC 3S100E	XC 3S250E	XC 3S500E	XC 3S1200E	XC 3S1600E
System Gates	100K	250K	500K	1,200K	1,600K
Logic Cells	2,160	5,508	10,476	19,512	33,192
18x18 Multipliers	4	12	20	28	36
Block RAM Bits	72K	216K	360K	504K	648K
Distributed RAM Bits	15K	38K	73K	136K	231K
DCMs	2	4	4	8	8
I/O Standards	18	18	18	18	18
Max Differential I/O Pairs	40	68	92	124	156
Max Single-Ended I/O	108	172	232	304	376
Package	**User I/O**	**User I/O**	**User I/O**	**User I/O**	**User I/O**
VQ100	66	66	–	–	–
TQ144	108	108	–	–	–
PQ208	–	158	158	–	–
FT256	–	172	190	190	–
FG320	–	–	232	250	250
FG400	–	–	–	304	304
FG484	–	–	–	–	376

Table 2 – Xilinx Spartan-3E product matrix

Table 3 shows the 17 different interfaces offering real-time Ethernet performance as of November 2005. Notable among the 17 for the traction they have gained in a short time are EtherCAT, SERCOS III, and Ethernet Powerlink.

EtherCAT processes 1,000 distributed I/O in 30 µs or 100 axis in 100 µs using twisted pair or fiber optic cable. EtherCAT topology supports a simple low-cost line structure, tree structure, daisy chaining, or drop lines; no expensive infrastructure components are required.

SERCOS III merges proven mechanisms of SERCOS with the Ethernet physical infrastructure. Data rates of 100 Mbps, combined with high protocol efficiency, cut cycle times in half compared to previous SERCOS versions, setting a new standard for rugged real-time applications: a 31.25 µs cycle time for as many as 8 drives with 8-byte cyclic data.

ETHERNET Powerlink is an ISO/OSI level 2 protocol enabling deterministic, isochronous, real-time data exchange through standard Fast Ethernet (IEEE 802.3 u). It allows high-precision data communication with cycle times as low as 100 µs and network jitter well below 1 µs.

Available and ongoing Xilinx solutions in the real-time Ethernet area include Spartan-3E implementations of these interfaces.

The Software Component of Seamless Integration

The solution to seamless integration in industrial automation will probably lie in the overall adherence of all connected equipment to OPC (OLE for process control). OPC is an industry standard created through the collaboration of a number of leading worldwide automation hardware and software suppliers working in cooperation with Microsoft.

Based on Microsoft's OLE (object linking and embedding, now ActiveX), COM (component object model), and DCOM (distributed component object model) technologies, OPC comprises a standard set of interfaces, properties, and methods for use in process-control and manufacturing-automation applications.

The ActiveX/COM technologies define how individual software components can interact and share data. OPC provides a common interface for communicating with diverse process-control devices, regardless of the controlling software or devices in the process.

In the enterprise, which is predominantly a Microsoft Windows environment, OLE is already used to provide integration among applications, enabling a high degree of application compatibility. OLE technology enables the development of reusable plug-and-play objects that are interoperable across multiple applications. It also facilitates reusable, component-based software development, where software components can be written in any language, supplied by any software vendor. Phased migration to OPC support by factory automation vendors will one day make seamless factory-to-enterprise linkage a reality. Real-time operating systems such as WindRiver VxWorks AE already offer extensions like VxOPC to support OPC.

Xilinx leverages its partnerships with embedded OS vendors to complement the Spartan-3E hardware platform and deliver complete system solutions.

	Name	Organization / Main Manufacturer
1	EtherCAT (Ethernet for Control Automation Technology)	ETG / Beckhoff
2	Ethernet/IP mit CIP Sync	ODVA / Rockwell Automation
3	ETHERNET Powerlink (EPL)	EPSG / B&R
4	Precision Time Protocol (IEEE 1588)	IEEE / -
5	PROFINET	PNO / SIEMENS
6	RTPS (Real-Time Publish-Subscribe Protocol)	Modbus-IDA / Schneider Electric
7	SERCOS-III	IGS / -
8	SynqNet * (only Layer 1 based on Ethernet)	SynqNet User Group / Motion Engineering Inc. (MEI), USA
9	JetSync	– / Jetter, Germany
10	PowerDNA (Distributed Network Automation and Control)	– / United Electronic Systems (UEI), USA
11	SynUTC	– / Oregano Systems, Austria
12	Switch mit Zeit-Server	– / Ontime Networks, Norway
13	RTnet (Open Source)	– / Real-Time Systems Group of University Hannover, Germany
14	Vnet/IP	– / Yokogawa, Japan
15	TCnet	– / Toshiba, Japan
16	EPA (Ethernet for Plant Automation)	– / ZHEJIANG SUPCON INSTRUMENT, China
17	SafetyNET p	SafetyBUS p Club / Pilz

Table 3 – Real-time Ethernet industrial interfaces

Conclusion

Increasing processor power, advances in consumer electronics, mobile communication networks, and platform-independent programming languages provide the tools to implement smart functions that were previously unrealistic.

IEEE 1394, for example, can operate as a real-time capable and high-speed backbone, providing a transparent interconnection with guaranteed propagation delay for field-area network segments expected to carry multimedia traffic. Modular DSP systems employing 400 Mbps IEEE 1394 (FireWire) communications are already available for industrial automation applications, integrating high-speed digital drives for multi-axis motion control applications, digital cameras, and other FireWire peripherals.

Even the USB protocol is used in industrial automation, although its usage seems to be confined to providing a painless plug-and-play solution for migrating serial protocol (RS 232, RS 422, and RS 485) devices to Windows-based PCs, which are increasingly replacing PLCs on the factory floor.

The standardized TCP/IP protocol offers a seamless portal into the Internet; a Web server can be integrated into even small control devices, with familiar technologies such as programming languages and net browsers easily available. The eXtensible Markup Language (XML) is also a promising tool for application integration between factory and enterprise.

Wireless is likely to generate increasing interest in the industrial automation community. The benefits of wireless communication include flexibility and savings in cabling costs. Using a wireless mesh as a backbone network, for example, simplifies installation and provides an affordable, unobtrusive, and completely portable solution for both small- and large-scale deployments. In addition to being easy to install, mesh network nodes can be added virtually anywhere Ethernet is required, including time clocks, scales, surveillance cameras, and even on moving equipment such as forklifts, cranes, and conveyor systems. Wireless versions of field buses are also on the horizon.

Xilinx is committed to supporting advances in industrial automation through continued innovation, offering high-performance, feature-rich fabrics including embedded soft processors, DSP engines, and an increasing array of common discrete functions such as clock management, LVDS transceivers, and level shifters integrated on-chip. This is complemented by memory and system interface connectivity solutions to enable superior and efficient management of system cost and product lifecycles for system vendors, enabling them to exploit new market opportunities before their competitors.