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A PRIMER ON PICKING THE RIGHT PROCESS AUTOMATION BUS

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Advanced digital process automation, as exemplified by the DeltaV™ digital control system and PlantWeb® field-based architecture from Emerson Process Management, Austin, Tex., is changing the way both batch and continuous regulatory control are approached in the chemical industry. The technology rests on three pillars: (1) small modular controllers that run realtime operating systems and can be mounted remotely in non-air conditioned cabinets, (2) PC[1]-based operator and engineering workstations the operate in Microsoft Windows™ environment and can be installed in a control room or scattered around the plant, and (3) an Ethernet network tying everything together.

Modern process automation is designed from the ground up for running batch and continuous processes. Capabilities include alarming; redundancy, and safety issues; complex regulatory, multi-variable, and advanced control; and data-capture and handling requirements.

While process control has traditionally focused on analog (continuously variable) functions, today's technology provides very strong discrete (on-off and intelligent equipment) functionality. Analog functions include temperatures, pressures, flows, levels, valve or damper positioning, etc. Discrete functions include solenoid valves, switches, pushbuttons, motor control centers, variable speed drives, ID scanners, and the like. Don't confuse the words discrete and digital. Digital is the transmission method employed by modern buses; discrete and analog are the types of signals transmitted.

Last, process automation features a single global database (no mapping between controller and workstation databases), object-oriented and universally described tags that are recognizable across the entire control system, and graphical configuration of pre-engineered logic rather than programming logic from scratch.

[1] Personal Computer.

The place-them-almost-anywhere components of today's process automation have made truly distributed control possible, something never achieved with a DCS. Only one last technology had to be put in place before full distributed control could be acknowledged -- that of open digital instrumentation buses. With buses incorporated, completely field-based automation architecture emerged.

Why Bus Communications?

For a long time, the main reason why most chemical process engineers investigated a bus-structured control system was to cut wiring costs. The conventional practice of individually hardwiring every field device back to a controller in a hub-and-spoke layout is inefficient. A multidrop bus segment, emanating from a controller communications card's port and serving numerous attached field devices, makes hardwired devices unnecessary for many control applications. Further, new devices can be added by simply attaching them to the segment. A control system typically has numerous bus segments.

Advantages beyond lower wiring costs tend to be the more important in the long run, however. Although the strengths listed below are not complete and are not available in all bus formats, here is a quick summary:

- Faster control system development, installation, configuration, commissioning, calibration, debugging, startup, and lineout -- so ROI[2] begins earlier. No tracing, wringing out, or labeling circuits. Icons appear on workstations when devices are connected, a feature known as auto-sensing. One control drawing per bus segment rather than per instrument. One configuration software package for controllers, workstations, graphics, I/O, and buses.
- Field device diagnostics remotely performed from a workstation.
- Wealth of information from field instruments about their health, about process health, and for historical data capture and asset management tracking.
- Potential for distributing control and logic functions to field instruments for faster control response or to minimize load on the controller and traffic on the bus.

Analyze Your Process

Bus-connected field devices are designed for specific buses, as both the device interface and the controller's bus card incorporate microchip-based communications packages. Bus-connected field devices typically cost more than conventional analog and discrete designs, with the price differential greater for the more complex buses. Also, the installed cost of the first bus-connected device is almost always higher than the installed cost of the first traditionally wired device. At some number of devices, however, the cost curves intersect and each additional bus-connected device provides a savings.

Choosing a bus requires that the process control scheme be fully understood to determine if a bus is warranted, and, if so, what type. Each bus format has particular strengths and weaknesses, and no single bus can answer all requirements. Fortunately, the most advanced automation platforms can support several buses running simultaneously in the same controller.

[2] Return on Investment.

Factors to take into account in evaluating buses include cost, impact on existing plant controls, environmental safety, transmission distances, response speed, conduit runs and wall seals, EMI[3], process validation requirements (such as FDA[4]), data logging, recipe management, training, maintenance, future growth, etc. Also consider that even in the most bus-centric control system, a certain number of hardwired analog and discrete devices are usually required. Examples are devices not yet having a bus communications capability, as well as those whose logic requires very fast response, such as for safety shutdown circuits and fuel gas valves.

Following is a description of the four instrumentation buses of greatest interest to the process automation industry. They are often divided -- in terms of increasing sophistication -- into bit-level, byte-level, and control block-level categories. All four are based on open protocols and are supported by standards organizations. They are well-proven in process applications, well supported by vendors in North America, can be powered locally if desired. For process control, they are generally configured in a deterministic, master/slave orientation for maximum control reliability and for retransmission of garbled messages.

Bit-Level Bus

AS-i Bus

AS-i (Actuator/Sensor-interface) bus, introduced for factory automation, has become very popular in process control for operating discrete devices. AS-i's strengths lie in its low cost, ruggedness, speed, noise-resistance, easy configurability, and fast installation. It's been estimated that the cost curves for AS-i bus vs. conventional hardwiring intersect at about 10 slaves per segment.

Signals and device power are carried on each segment's single pair of wires. Power is sufficient to drive small solenoids. The most recent version will support up to 62 slaves at bus lengths to 100 m, or to 300 m if repeaters are used. Transmission is fast: a maximum cycle time of 10 mS for a full complement of slaves. A special AS-i cable allows fast, insulation-displacement electrical connections during installation. The technology's deficiencies are poor alarming and diagnostics.

Byte-Level Buses

The next step up the process instrumentation bus proficiency and cost ladder are DeviceNet and Profibus DP. Like AS-i bus, these buses are optimized for communications with discrete devices. However, their larger data packets makes them capable of operating intelligent electrical equipment such as motor starters, drives, HMI panels, weighing equipment, etc. They can carry a large amount of status, health, and diagnostic information.

DeviceNet

[3] Electro-Magnetic Interference.
[4] Food and Drug Administration.

DeviceNet is the most popular byte-level instrumentation bus in North America. It's a five-wire design having separate signal, device power, and ground conductors. Bus length varies by transmission rate; 125 kbps seems best for process control and allows 500 m long segments. Theoretically, up to 61 devices can be supported per segment. DeviceNet provides moderate alarming and diagnostics, with the information presented in very useful form.

DeviceNet is moving in a direction the process industry is happy to see -- simple analog field devices are being fitted with this communications interface. This may allow the bus to become a less sophisticated and expensive alternative to FOUNDATION fieldbus as a universal process bus.

Profibus DP

Profibus DP, the most widely used byte-level bus on European-made discrete devices and electrical equipment, is a two-conductor bus carrying no power; devices must be locally energized. In terms of functionality, data carrying capabilities, and diagnostics, Profibus DP is more sophisticated and capable than DeviceNet.

Segment reach is greater than to DeviceNet as well -- 1000 to 1200 m at similar speeds. The bus is rated for a similar number of field devices -- 64 per segment. Although possible, Profibus DP is not generally configured in North America for intrinsically-safe applications in process control; powering devices is a safety issue that must be overcome.

Function Block-Level Buses

The most proficient open digital instrumentation buses are the function block-level types that carry large packets of information. Falling into this category are FOUNDATION™ fieldbus and Profibus PA, the latter a bus-powerable extension to Profibus DP that is not chosen often in the U.S. Therefore, this paper will only detail FOUNDATION fieldbus. Block-level buses are primarily intended to communicate with analog devices. When engineers in this country refer to a field bus, they almost always mean Foundation fieldbus. Technically, all four buses discussed in this paper are field buses.

FOUNDATION Fieldbus

Fieldbus is the bus of choice for traditional process automation, which is heavy with analog signaling. It's the commissioning, calibration, alarming, diagnostics, and data transmission champion of all buses. It was developed from the start as a block-level bus, and it's the only type with a built-in capability for creating standard function blocks for complex batch, discrete, and hybrid operations as well as to map in information from bit- and byte-level buses. Data acquisition and control functions can be performed across the bus between devices of different manufacture -- which makes it truly interoperable. More upfront engineering is required with fieldbus, but good software tools exist to help.

FOUNDATION fieldbus H1 segments consist of a single pair of conductors combining data and power. The technology runs at 31.25 kbps, can extend to nearly 2000 m, and can handle up to 16 devices per controller card port -- though many fewer in intrisically safe applications. It's highly deterministic[5], thereby synchronizing control and communications without deadtime or jitter. It features a consistent device polling time independent of logic memory size, which helps avoid loop retuning after control modifications. It also provides a clock to support function block scheduling and alarm time-stamping.

Discrete devices can reside on fieldbus, but the cost is relatively high per device and the speed slow. As an alternative, a discrete fieldbus I/O card can be distributed on a fieldbus segment for local on-off control, avoiding the need to run hardwiring or a bit- or byte-level bus back to the controller. The Fieldbus Foundation has been registering quite a few discrete devices lately, primarily for application in hazardous areas.

Miscellanous Busses

The HART[6] protocol has been around since the 1980's and it is generally known as a digital data signal superimposed over the conventional 4-20 mA analog process signal of hardwired field devices. However the HART protocol can be applied in an all digital mode and configured into a multidrop network with up to 15 drops.

It also should be mentioned that two additional buses are often seen in process automation. But instead of acting in typical multidrop service, they convey data between different control systems or between a data intensive instrument -- such as an analyzer -- and a control system. One of these buses is the conventional serial link using an open protocol such as that for Modbus (originally introduced in 1979 as a multidrop bus). The other is Ethernet, which also is employed in system-to-system interconnects. Additionally, it is at the heart of the OPC[7] standard that is popular for linking incompatible equipment.

Safety Instrumented Systems and Buses

A recent development incorporating bus technology is the Safety Instrumented System (SIS) that provides an integrated approach to safety loops -- from sensor to logic solver to final control element in SIL 1, 2, and 3 applications.

The technology appliesigital communications, intelligence, and diagnostics to enable automated safety loop testing and other features that increase system availability. It relies on intelligent field devices and predictive diagnostics to identify and predict problems throughout the safety loop, thereby reducing manual proof testing.

Two digital safety buses, variants of the two byte buses, are being deployed in industry. One is Profisafe, a variant of Profibus; the other DeviceNet Safety, a variant of DeviceNet. FOUNDATION Fieldbus for SIS recently received TÜV Protocol Type Approval in early 2006.

[5] All signals are transmitted in a rigid order, avoiding contentions between signals issued randomly.
[6] Highway Addressable Remote Transducer.
[7] Microsoft Object Linking and Embedding for Process Control.