Digital Buses *For* Digital Plants

Digital plant architectures have transformed the face of modern process plants. ***Jonas Berge*****, Senior Manager, PlantWeb Consulting, Emerson Process Management Asia Pacific Pte Ltd, explains the underlying bus technologies.**

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Digital communications technology reduces wiring and improves end-to-end signal accuracy and integrity in modern digital plants. Digital technology enables new innovative and more powerful devices, wider measurement range, elimination of range mismatch, and access to more information. Overall, use of digital technology can reduce automation project costs by as much as 30 percent as well as providing a two percent operational improvement. This article explores considerations to be made in selection of bus technology for optimal digital plant architecture.

Why Digital?

There are many advantages of using digital communications and multi-drop fieldbus wiring instead of conventional wiring, including reductions in cable and connections as many devices connect to a single bus. Other benefits include better accuracy for control loops as no precision is lost in D/A and A/D conversion, and higher integrity as distortions can be detected using 8 or 16 bit error checking. Two-wire devices get more current, allowing delivery of new and faster diagnostics over the bus, enabling plants to adopt a predictive maintenance program. Further, digital values may be transferred in engineering units, allowing transmitters to be used over their full range and eliminating range mismatch. Access to more information is also key to intelligent device management.

Application Areas

Buses are used in factory automation, process automation and building automation. Tasks may vary from motion control, to machine control, to distillation column control. Since the tasks are varied, different buses were designed to meet a broad range of requirements.

Process Control

A bus for regulatory process control requires input/output sampling to be precisely periodic and synchronised with communications and PID control to avoid aliasing, prolonged response time, and instability due to jitter. The bus must also provide intrinsically safe power since the devices are often operating in hazardous areas and require live maintenance. In addition to continuously updating the input and output values to the digital automation system, the bus must enable configuration of the many settings that determine how transmitters and positioners operate and must give access to the wealth of diagnostics information in these devices as and when required. Lastly, many process industries require redundant interface cards for increased reliability. All of these requirements are met by FOUNDATION fieldbus H1.

Factory Automation

A bus for proximity switches and solenoids in a factory environment has different requirements. The application is not in a hazardous area so intrinsic safety is not required. Machinery may be fast moving but unlike PID control, logic is not sensitive to aliasing. Communication to the PLC can even be event-driven. Since these simple switches and solenoids have little or no settings and diagnostics, continuous I/O communication with the PLC is sufficient. In this application ASI and DeviceNet buses connect directly to proximity switches and solenoid valves.

A common hybrid bus solution

is illustrated by applications having conventional sensors and actuators wired one-by-one to a remote-I/O system which in turn uses PROFIBUS-DP or DeviceNet to connect to the PLC. Note also that both PROFIBUS-DP and DeviceNet may be used for variable speed drives.

System Hierarchy

Even within a control system there is a need for different connection characteristics at each tier of the control hierarchy. FOUNDATION fieldbus is used at one level, Ethernet at another, and the two complement each other perfectly. The plant information and business networks again have other requirements.

H1: Fieldbus Level

A process plant has hundreds or even many thousands of sensors, transmitters, valve positioners, and actuators. Wiring is significantly reduced by connecting these many devices with fieldbus. The fieldbus also delivers power to operate the devices.

In hazardous areas, it is required to use a fieldbus that supports intrinsic safety or non-incendive wiring to permit live connection/disconnection without switching off the other devices on the bus. FOUNDATION fieldbus H1 and HART cable can run long distances to the devices mounted in the field, far from the control room.

H2: Remote-I/O Level

The middle tier in the process control system is remote I/O subsystems where conventional sensors and actuators connect to I/O cards using conventional wiring. The remote I/O subsystems connect to the digital automation system or PLC controller using a bus that may also be used for drives. Since I/O subsystems and drives are separately powered, no bus power is required, and since control is not done at this level, peer-to-peer communication is not required. Modbus/RTU and PROFIBUS-DP are based on RS485 and are used at this level where long wire distance can be achieved by adjusting to lower speed.

Control-Network Level

At the control-level, digital automation system controllers have other networking requirements. The control network carries data gathered from all the devices in the plant or area and must therefore have a high bandwidth capacity to cope with the data volume. A control network supports peer-to-peer communication between digital automation system controllers to enable cascade and sophisticated control schemes. Digital automation system controllers are separately powered so there is no need to provide power over the network.

Today most control systems use Ethernet media and IP network layer protocol for the control-network. Controllers, data servers, and workstations are typically in close proximity of each other so 100 m distance provided by Ethernet on copper wire is sufficient, but fibre optics can be used for longer distances. Several different application layer protocols exist for Ethernet in factory automation and process control including PROFINET-CBA, PROFINET-IO, EtherNet/IP, Modbus/TCP, FOUNDATION fieldbus HSE and several more. Since reliability is paramount in process control, digital automation systems support full Ethernet redundancy with peer-to-peer communication and therefore a redundant digital automation system controller pair has a total of four Ethernet ports.

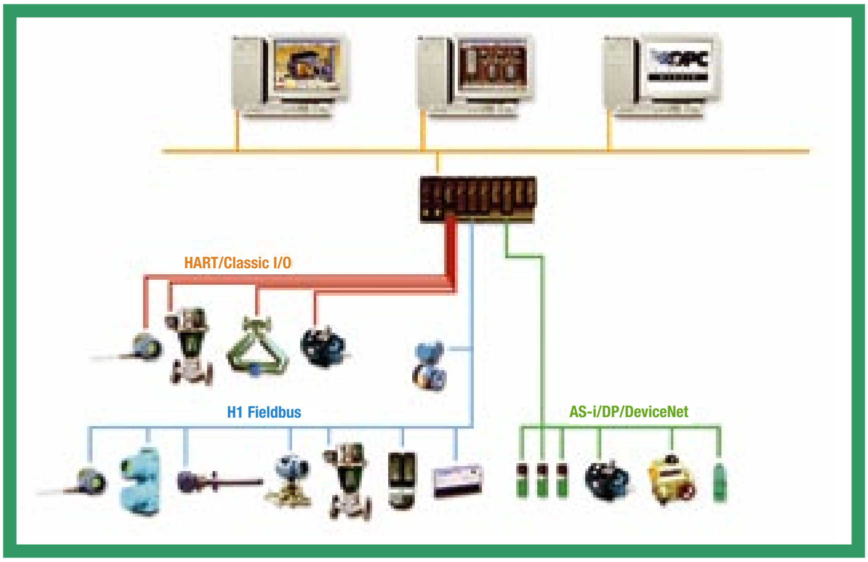
Safety

Most bus organisations have developed communication diagnostics extensions to their protocols to enable use in Safety Instrumented Systems up to SIL3. The use of fieldbus in Safety Instrumented Functions (SIF) is expected to increase over the years to come. Until that time 4-20 mA with HART remains the most popular option for transmitters in safety, and HART is also used to communicate diagnostics from the shutdown valves.

Acyclic Bus Communication

All fieldbuses that provide cyclic communication of process I/O inputs and outputs are continuously updated by repeated reads and writes. This may be sufficient for simple switches and actuators that have no configuration settings and no diagnostics. However, intelligent devices such as transmitters, positioners, and drives need to be configured, and the information they supply includes valuable information such as diagnostics. The bus technology selected to connect these devices must therefore, in addition to cyclic I/O communication, also support acyclic communication of other data in the device. Digital plant architecture uses digital device managers as part of asset management tools for device management.

Together, device management software and fieldbus device functionality typically enable:



Digital automation system architecture.

- Identification & information
- Diagnostics, performance analysis , & operational statistics
- Parameterisation, ranging, reconciliation, & audit trail
- Simulation and override
- Calibration trim and log
- Document access
- Device event capture & monitoring
- Commissioning
- Maintenance log & service notes
- Device listing
- Maintenance & calibration scheduling

Device management software allows diagnostics and performance analysis to be easily carried out.

Without a bus supporting acyclic communication, these features are not possible. FOUNDATION fieldbus, PROFIBUS-DPv1, and DeviceNet provide acyclic access to device information. HART is typically purely acyclic communication, since 4-20 mA is used for the I/O.

Value Of Fieldbus Information

Device management software is key to unleashing many of the automation project savings and operational improvements possible using digital automation architecture with fieldbus. Firstly, digital architecture with bus technology results in lower capital expenditure and an earlier startup. Then, during operation, the digital architecture with fieldbus results in increased output thanks to higher quality/yield, greater throughput, and higher availability (reduced downtime). Lastly, the digitally automated plant will realise lower operations and maintenance expenditure thanks to lower cost of safety, health, and environmental compliance, as well as lower cost of energy and reduced waste or rework.

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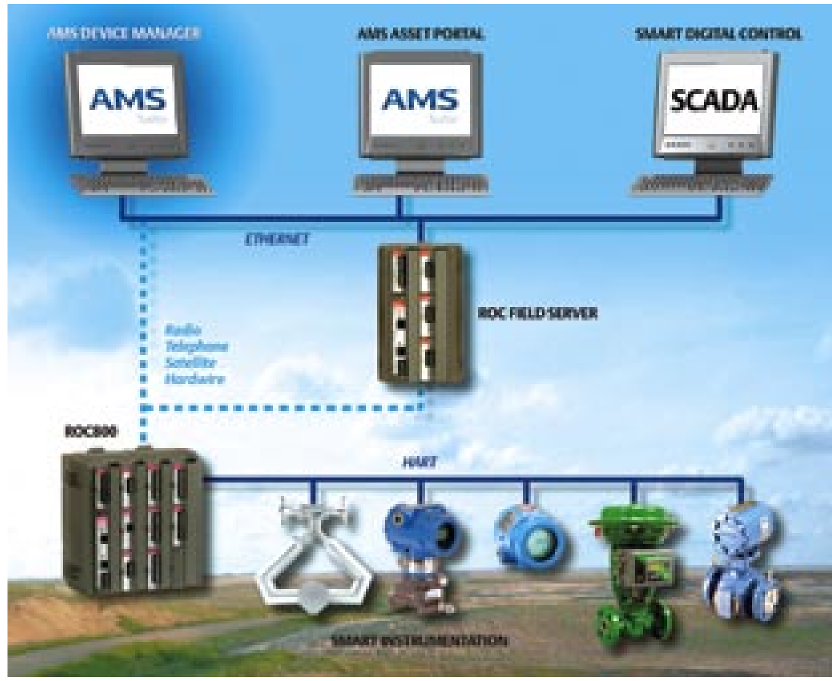


HART was designed specifically for use in process control instrumentation.

Buses And Organisations

A wide range of industry consortia were formed to manage the development of different open fieldbus protocols, ensure interoperability between products from different vendors, and promote their use in the different industries through marketing and training. The members are typically a mix of manufacturers, endusers, engineering companies, as well as academic institutions. By now the buses that they have pioneered are fully proven and well accepted.

HCF: HART

The HART (Highway Addressable Remote Transducer) technology is managed by the HART Communication Foundation (HCF) headquartered in Austin, Texas, USA. HART was designed specifically for use in process control instrumentation such as temperature, pressure, level, flow, pH/ORP, conductivity, density, concentration, resistivity, dissolved oxygen, oxygen transmitters as well as final control elements such as control valve positioners.

Because of its importance for process control, HART is supported in all modern digital automation systems, in leading SIS logic solvers, and in device management software part of asset management suites. Additionally, a handheld communicator is available to work on HART devices in the field.

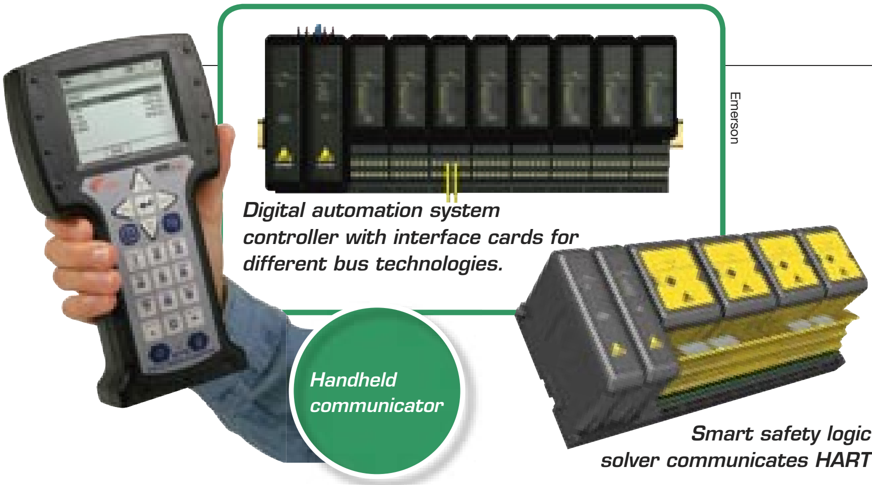
HART is a hybrid, superimposing digital communications on top of 4-20 mA signals, and is usually used in a point-to-point scheme, not multi-drop.

AS-International: AS-Interface

The actuator sensor interface technology is managed by the AS-International Association headquartered in Frankfurt-am-Main, Germany. ASI was designed specifically for use with simple discrete devices such as buttons clusters, inductive and optical switches, limit switches for level and temperature, and final control elements including motor starters, solenoids, on/off valves, pneumatic actuators, and drive interfaces.

ODVA: DeviceNet

DeviceNet is one of the bus technologies managed by the Open DeviceNet Vendor Association headquartered in Ann Arbor, Michigan, USA. A wide range of products are available using DeviceNet including conventional I/O-blocks, inductive and optical switches, encoders and resolves, barcode readers and RFID. Final control elements such as electric and pneumatic actuators and valves, AC and DC drives, motor starters, and solenoid valve manifolds.



Digital automation system controller with interface cards for different bus technologies.

Handheld communicator

Smart safety logic solver communicates HART

Modbus Organisation: Modbus/RTU

Modbus/RTU is one of the bus technologies managed by the Modbus organisation headquartered in North Grafton, Massachusetts, USA. Modbus/RTU has been adopted in a very wide range of distributed peripherals such as conventional I/O blocks, flow computers, remote terminal units (RTU), and weighing scales etc. Final control elements such as AC and DC drives are also available. Because of its simplicity, Modbus/RTU is supported in all digital automation systems, DCS and most PLCs. For this reason Modbus/RTU is often used to integrate package unit controllers to the main control system.

PI: PROFIBUS-DP

PROFIBUS-DP is one of the bus technologies managed by the Profibus International (PI) organisation headquartered in Karlsruhe, Germany. PROFIBUS-DP was designed specifically for Distributed Peripherals (DP) such as conventional I/O blocks and weighing scales. Final control elements such as drives, motor starters, circuit breakers, and solenoid valve manifolds are also available.

Fieldbus Foundation: Foundation fieldbus H1

FOUNDATION fieldbus H1 is one of the bus technologies managed by the Fieldbus Foundation organisation headquartered in Austin, Texas, USA. FOUNDATION fieldbus H1 was designed specifically for use in process control instrumentation for measuring temperature, pressure, level, flow, pH/ORP, conductivity, density, concentration, resistivity, dissolved oxygen, and oxygen transmitters as well as machinery health monitors. Final control elements such as control valve positioners, electric actuators, discrete switches, on/off valves, and signal converters are also available.

Because of its importance for process control, FOUNDATION fieldbus H1 is supported in all modern digital automation systems and in device management software residing in asset management suites. Additionally, a handheld communicator is available to work on fieldbus devices in the field.

Table 1: Organisations & Bus Systems

Organisation	Bus	Web
AS-International Association	AS-Interface	http://www.as-interface.net/
ODVA	DeviceNet	http://www.odva.org/
Modbus Organisation Inc.	Modbus/RTU	http://www.modbus.org/
PNO	PROFIBUS-DP	http://www.profibus.com/
Fieldbus Foundation	Foundation fieldbus H1	http://www.fieldbus.org/
HCF	HART	http://www.hartcomm.org/

Unique to FOUNDATION fieldbus H1 is the IEC 61804-2 function block diagram language for building control strategies that can execute in a central controller or in the field instruments, the latter referred to as control-in-the-field. The execution of the function blocks is synchronised to the execution of the communication functions, minimising dead-time.

Right Mix Of Buses

Since different areas of automation and different levels of the control system hierarchy have different communication needs, many different fieldbus technologies exist. All types of devices are not available with all the different protocol options and therefore it is necessary to use more than one protocol in control systems. For example, transmitters and valves will communicate using FOUNDATION fieldbus because the bus must be synchronised for good PID control. Electric drives will use PROFIBUS-DP because of the higher speed possible at short distances, although DeviceNet is also an option.

Discrete I/O may use either DeviceNet or AS-I. Modbus/RTU when integrating real-time control and interlock signals from OEM-packaged units to the main control system. The control system must integrate these buses, requiring that the digital system to have the interface cards for direct connection of these buses; using gateways or multiplexers is costly, time consuming, error prone, and less reliable. The engineering station and engineering software must support the different protocols being integrated, as a fully-featured engineering tool will eliminate the need for special applications software for each protocol which would be too difficult to manage.

The SIS Safety Instrumented System is dedicated to safety and separate from the process control system. The logic solver in the SIS uses HART to access transmitter and positioner diagnostics in order to see the status of each complete SIF loop.

Similarly, the device management software used for intelligent devices based on HART, FOUNDATION fieldbus and PROFIBUS must support EDDL so that it can decode and display the data.

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