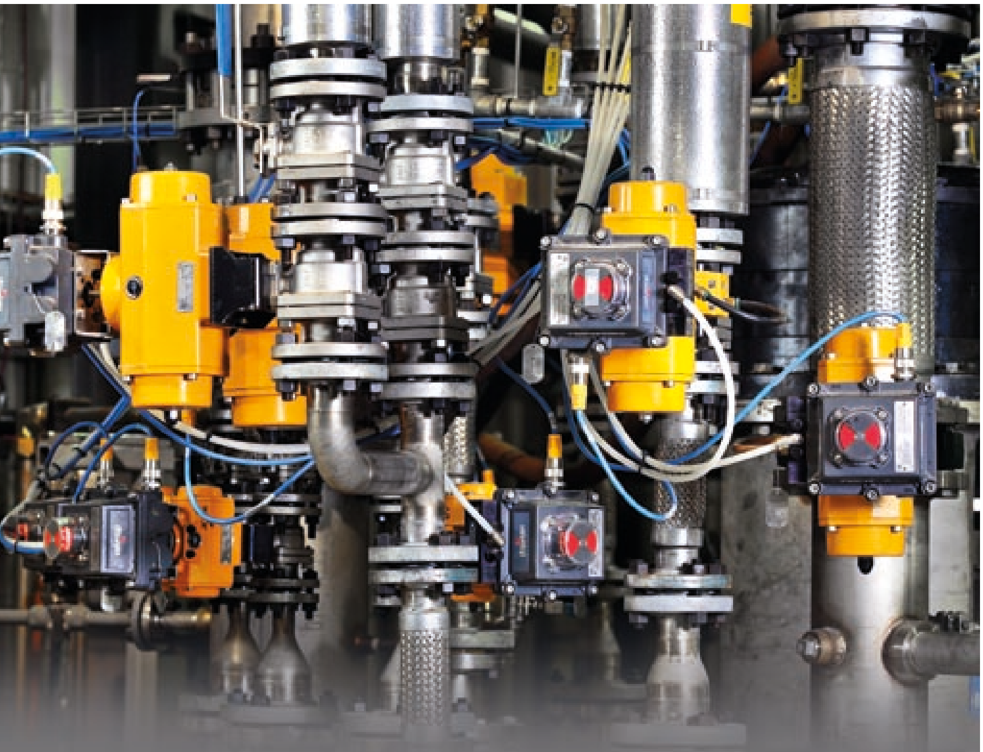


Integrated Bus Architecture

RemoVe-I/O

The architecture chosen for the control system I/O affects the price of the system, and the cost and ease of maintaining that system. By Jonas Berge, director, PlantWeb Consulting, Emerson Process Management

Plants have hundreds or thousands of transmitters, valves, discrete sensors and actuators etc. Running individual wires for each, the long distance from the field, is expensive. Alternate solutions include remote-I/O or distributed-I/O for conventional devices, and digital buses for networked devices. Architecture selection criteria include cable savings and if the solution enables new predictive maintenance practices.

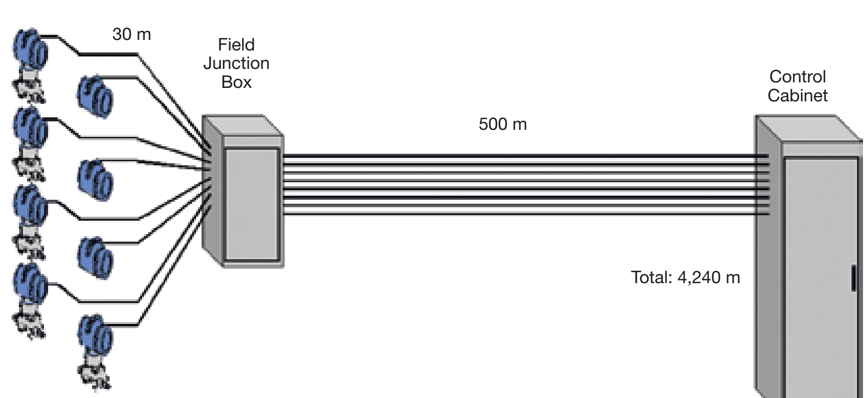


Figure 1: Wire lengths for conventional local-I/O

Local-I/O

For local-I/O the I/O cards are mounted centrally indoors in the rack room providing good protection and making I/O-subsystem maintenance such as inspection and card replacement easy. Simple devices have one signal requiring one pair of wires. Cost includes price of multi-core cable and tray, cost of labour to lay the cable and install tray.

Advanced devices with multiple signals, such as position feedback or auxiliary inputs, increase the wire and connection count. If separately powered safety barriers are used the connection count increases further. Some control systems have I/O cards with built-in safety barriers reducing the number of connections for some I/O types somewhat.

Remote-I/O Architecture

A plethora of different conventional signals exist: temperature input, pulse/frequency input, 4-20 mA input and output, plus a bewildering array of different discrete AC and DC input levels and many types of discrete outputs. Each signal needs an appropriate I/O card and safety barrier type.

The gamut of signals from the field is marshalled to the right channel on the right type of I/O card. I/O card selection and assigning I/O signals is a project

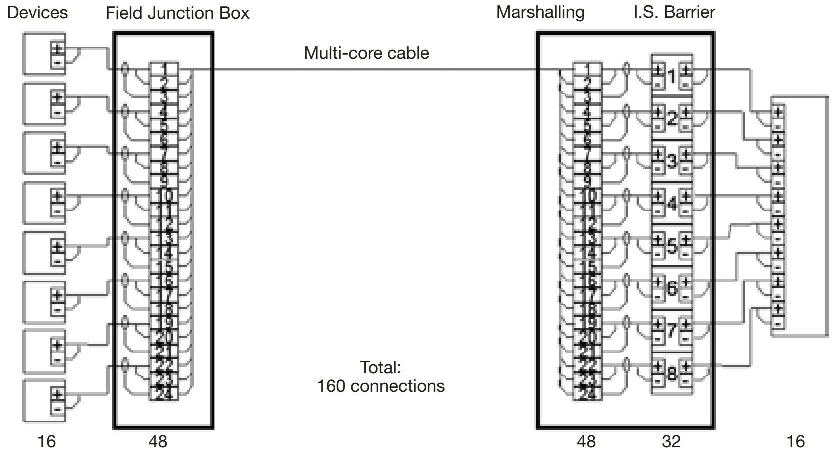


Figure 2: Number of connection points for conventional local-I/O

engineering task. Verification is done at factory acceptance test and full loop check is done at site pre-commissioning to discover any signal marshalling mix-up.

Systems that don't support digital communication cannot benefit from remote device configuration and diagnostics capabilities to distinguish between device problems and process upsets or get advance notice for predictive maintenance.

The remote-I/O architecture mounts the I/O in panels scattered around the plant closer to the field devices. The number of individual wires is still large, albeit shorter distance than local-I/O.

Digital bus technology connects the remote-I/O to the controller and should be redundant. Cabinets to house remote-I/O are significantly larger than junction boxes for local-I/O architecture since the I/O cards need space. Power for the I/O subsystem must be provided and should be redundant.

The conventional signaling prevents advantages of pure bus technology such as closed loop digital control, mult-channel and multi-variable devices, greater signal fidelity, increased device diagnostics, firmware download, and real-number data transmission.

In the tough plant environment, often outdoor, I/O cards, backplane, power supply, and communication processor are, in spite of protective enclosures, exposed to environmental stress such as heat and vibration. Maintenance inspection and card replacement becomes more difficult because I/O panels in the field are not as accessible and should not be opened unnecessarily as dust, moisture, rain, water jet from washing, offshore sea spray, may enter.

There is a tradeoff between using fewer remote-I/O panels requiring longer cable for each device, or using many panels for which the cost of the I/O-subsystems become substantial. Remote-I/O requires more engineering than local-I/O, for planning the location of the remote-I/O cabinets and defining which device connects where. Additionally, the bus system connecting the remote-I/O stations to the controller must be engineered. Heat dissipation must be calculated to comply with hazardous area requirements.

The central controller accesses the input and outputs across the remote-I/O bus. The controller I/O scan time is limited by the remote-I/O bus speed. Profibus-DP, Modbus/RTU, and other RS485-based devices run at 1.5 Mbit/s for short distances, but slower for remote-I/O due to the capacitance of long copper cables. The more I/O points sharing the same bus, the longer the update time will be.

Remote-I/O changes the traditional demarcation between system and field, by placing I/O cards in the field.

Remote-I/O has many intermediate connection points from field device to I/O card, including marshalling, and possibly safety barriers. Consider the labour cost for cutting, stripping, ferrule crimping, labeling, and screwing these wires at every point.

Valve positioner feedback and electric actuators require more wire and connections. Separately powered safety barriers require more connections than loop powered

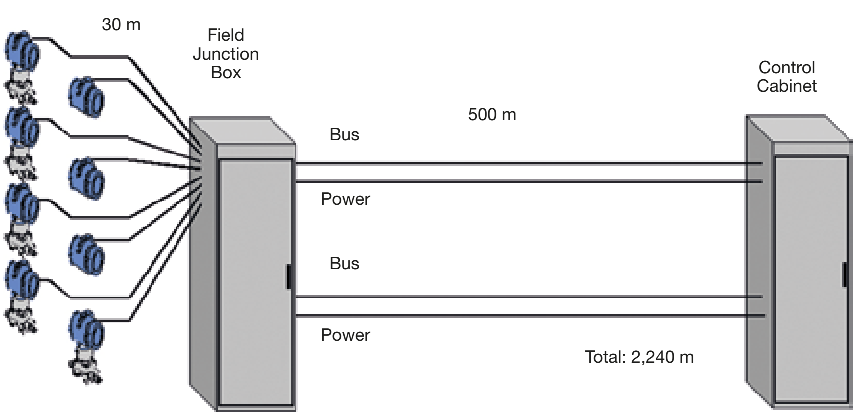


Figure 3: Wire lengths for conventional remote-I/O

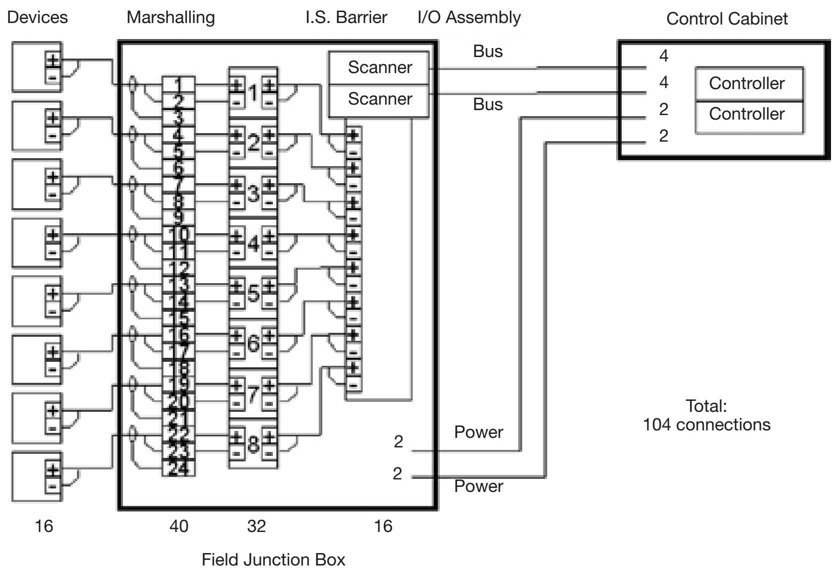


Figure 4: Number of connection points for conventional remote-I/O

barriers. However, a remote-I/O subsystem with built-in barriers reduces connections somewhat.

Distributed-I/O Architecture

A solution very similar to remote-I/O offered by several manufacturers is distributed-I/O. The difference is in how I/O and controllers are located. The remote architecture has one central controller accessing several underlying passive I/O subsystems in which the communication processor only scans I/O.

The distributed-I/O architecture has several decentralised controllers, each located together with its I/O. That is, the distributed architecture has its intelligence at the I/O level in a controller designed to operate at full industrial temperature range, just like a remote-I/O station.

In a distributed system each controller gets loaded less thus improving control response period. The additional communication latency associated with routing inputs and outputs up and down the intermediate remote-I/O bus is eliminated further improving control response.

By having one bus tier less there are fewer pieces of hardware that can fail, increasing reliability. The remote area can still continue to control totally autonomously even if there is a network failure between the controller and the operator stations.

Digital Bus Architecture

The confusing competition between different fieldbus protocols in the past is subsiding as each bus technology finds its application niche.

Many field devices are connected on the same fieldbus reducing the amount of wiring and connections by a factor of several times. In a digital bus architecture devices such as transmitters, control valves, and on/off valves have internal signal conditioning and digital communication. Therefore, devices are combined freely on a communication interface card and safety barrier.

For valve positioners the cable and connection reduction is even greater as additional wires for actual position feedback and limit switches are not required. All field devices in the plant do not sit on the same fieldbus. On average there are ten devices per fieldbus. Because few wires are used, the wiring cost is kept down even though wire is run all the way to the rack room allowing interface cards to mount indoors, protected from the harsh plant environment and easily accessible for service.

A digital bus architecture enables both easy card access and wiring savings. The longer the distance, the greater the savings.

Loading only a few devices per fieldbus ensures high performance updates.

Fieldbus For Control Loops

The integral and derivative action in PID control requires a precisely periodic sampling interval, that is the communication cycle time must be constant for effective control. Modbus and Profibus originating from the factory automation industry are good for on/off points and variable speed drives, but are not precisely periodic.

Foundation fieldbus is designed for process control with time-synchronised and scheduled real-

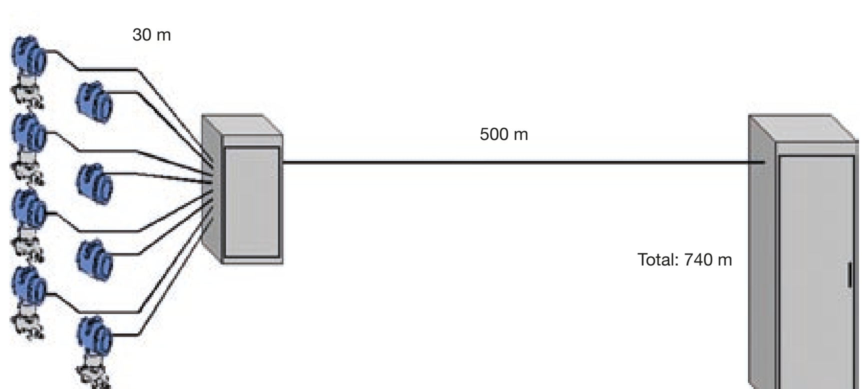


Figure 5: Wire lengths for fieldbus

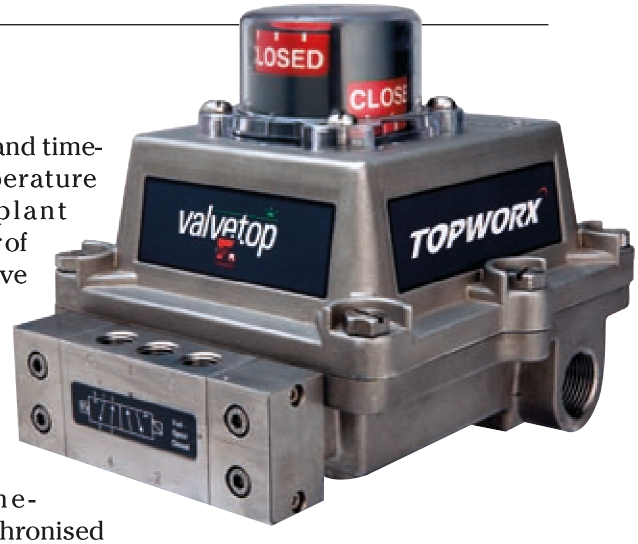
time communication ensuring precisely periodic sampling as required for PID control. Non-real-time communication is scheduled in separate slots ensuring closed-loop dynamics are not affected by non-critical data. By eliminating analogue conversions the control loop enjoys digital fidelity end-to-end.

One reason plants chose a digital bus architecture is that new innovative devices like multi-channel temperature transmitters for temperature profiling and machinery health transmitters for critical pump diagnostics are not possible with conventional signals. Fieldbus devices have advanced functionality not found in 4–20 mA devices, such as a valve positioner fall-back to I-to-P mode if the feedback mechanism fails, thus avoiding shutdown.

In a bus architecture, communication is always on, providing a path for device diagnostics. An 'OK' signal means the device need not be removed, tested, and re-installed on suspicion.

Foundation fieldbus devices have more diagnostics than 4-20 mA devices. Only in a fieldbus temperature transmitter will you find Statistical Process Monitoring for Abnormal Situation Prevention, or predictive thermocouple degradation diagnostics and time-stamped extreme temperature tracking. A digital plant architecture use the power of field intelligence to improve plant performance.

Foundation fieldbus combines intrinsically safe two-wire bus power with precisely periodic updates, prioritised communication, time-stamped alerts, time synchronised execution, and automatic addressing etc.



On/off valve coupler using Foundation fieldbus

Discrete On/Off

In a bus architecture, on/off valves are integrated using digital communication all the way to the valve. A valve coupler combine the solenoid and limit switches providing the interface to fieldbus. A fieldbus on/off actuator is the complete package. On/off valves connect directly to fieldbus to get the on/off command via communication and return the open/closed status.

Whereas one on/off valve previously required three pairs of wires for control and feedback, one single pair of wire now handles multiple fieldbus on/off valves. Diagnostics include excessive travel time as well as reversal counters used to estimate wear and tear to more accurately predict need for maintenance, as well as temperature monitoring. Cable and connections are reduced and maintenance is improved.

An electric actuator can have a total of four control signals including open/stop/close control, desired position, shut down, plus eleven feedback signals like limit switches, percentage open, local/remote status, opening/closing, torque tripped, percentage torque, and temperature tripped etc. In the past, each actuator required one multi-core cable. With fieldbus, a single pair supports multiple actuators.

Reduced Discrete I/O Points

In a digital bus architecture with Foundation fieldbus and Profibus-DP used together, the number of auxiliary I/O points required to support complex devices such as valve positioners, electric actuators, and variable speed drives etc. is reduced. So few discrete points remain that there may not be any need for a discrete bus like AS-I or for remote-I/O. Local-I/O may be the best option for the balance.

FF Removes Discrete Inputs

Discrete I/O point-count is decimated by Foundation fieldbus and Profibus-DP. Switches for

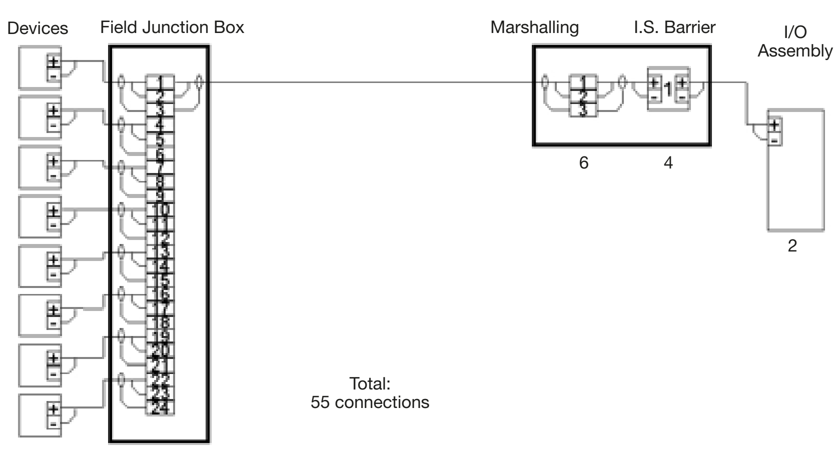


Figure 6: Number of connection points for fieldbus

pressure, flow, and level are sometimes used to detect over-pressure and high level etc. However, a system cannot tell if they fail because they lack diagnostics, which could be dangerous. A better practice is to use transmitters instead of switches, connected over Foundation fieldbus. This reduces the number of discrete I/O points.

Profibus-DP

Motor starters, variable speed drives, Motor Control Centres (MCC), and solenoid valve banks taking the place of individually wired solenoids are now integrated using Profibus-DP.

Variable speed drive commands for forward/stop/reverse, jog, preset acceleration and deceleration, local/remote, preset speed selection, and more are sent using bus technology as is feedback such as fault, alarm, running, 'at' speed/frequency/current/torque, overload, line loss, powered, ready, forward/reverse, breaking, and local/remote etc.

As many as eleven pairs of wire and conventional I/O card channels, plus a phenomenal number of connection points per drive are eliminated with Profibus-DP. Multiplied by the number of drives in a plant, a lot of hardware and labour is saved. In the past, each drive required a dedicated multi-core cable. Now, a single pair connects multiple drives.

Profibus-DP and Modbus/RTU connect to remote-I/O which in turn connect discrete sensors and actuators using conventional wiring, not direct to proximity switches or solenoids. Profibus-DP and Modbus/RTU are at a higher-level than so-called 'discrete buses' like AS-i or CompoNet.

There is no drive communicating Foundation fieldbus, thus a plant cannot be 'pure' fieldbus. Conversely, Profibus-DP and Modbus work very well for motor control such as drives, but are not ideal for PID control because their updates are not precisely periodic since these communication protocols are not synchronised. Hence a plant cannot be 'pure' Profibus either. The best available solution is to use both Foundation fieldbus and Profibus-DP.

All Integrated

Bus architecture with interface cards mounted indoors is the most effective way to reduce wire and connections while ensuring easy system maintenance, at the same time enabling remote setup and diagnostics.

The reduction for remote-I/O and distributed-I/O are the same. The reductions using a fieldbus architecture exceeds that of remote-I/O.

control devices including those using HART and WirelessHART from the same device management software.

That is, transmitters, analysers, valve positioners, and variable speed drives etc can be managed from the same single software application with a common look and feel, and are displayed with content and structure as intended by the device manufacturer.

This is far easier to use than a dedicated software or driver for each device type. A distinct advantage of EDDL over other technologies is that it is a text file, not software, which makes it easy to load to keep the system up to date with new device types and versions.

Moreover, the file does not become obsolete with new versions of Windows, thus protecting investment. Since it is not software, the EDDL files are permitted on the control system itself, enabling integrated diagnostics from the operator console making diagnostics a natural part of daily work practices. EDDL graphics and wizards make setup and calibration of advanced devices easy.

Table 1: Summary of installation for different I/O architectures (per 8 devices)

	Local	Remote	Distributed	Fieldbus
Number of connection points	160	104	104	55
Wire run	4240 m	2240 m	2240 m	740 m
Does not take into account additional savings from elimination of wiring for auxiliary points.				

Table 2: Pros and cons of different I/O architect uses

	Local	Remote	Distributed	Fieldbus
Module location	Indoor	Field	Field	Indoor
Cost	High	Low	Low	Low
Easy maintenance access	Yes	No	No	Yes
Access to device intelligence	Some	Some	Some	Yes

EDDL

In a digital plant architecture, combining the strengths of Foundation fieldbus and Profibus-DP does not have to be difficult. An interoperable system based on the IEC 61804-3 international device integration standard for Electronic Device Description Language (EDDL) provides support and guidance to fully configure, calibrate, and diagnose process control, process safety, and motor

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