

Installing Fieldbus

Many automation engineers are coming face-to-face with fieldbus applications for the first time. Fieldbus (the use of digital communications for distributed instrumentation and control networks) is an established technology with many benefits. However, fieldbus installations require some additional considerations over and above traditional 4-20mA projects.

Choosing a “Fieldbus”

Fieldbus is a generic term for a variety of communications protocols using various media, but all are simply a means to an end. What you want at commission of the project is a satisfactory and functional control system, and it is likely you will need to use multiple fieldbuses to accomplish the many tasks required. For example, you may use FOUNDATION fieldbus™ for process control, DeviceNet for discrete I/O, and PROFIBUS DP for motor drives. Every DCS can easily integrate all of these functional plant buses into the control room Ethernet-based network.

In the process control world, “fieldbus” usually means FOUNDATION fieldbus H1 or PROFIBUS PA. Both are widely used around the world in refineries and process plants as modern day enhancements to traditional 4-20mA designs.

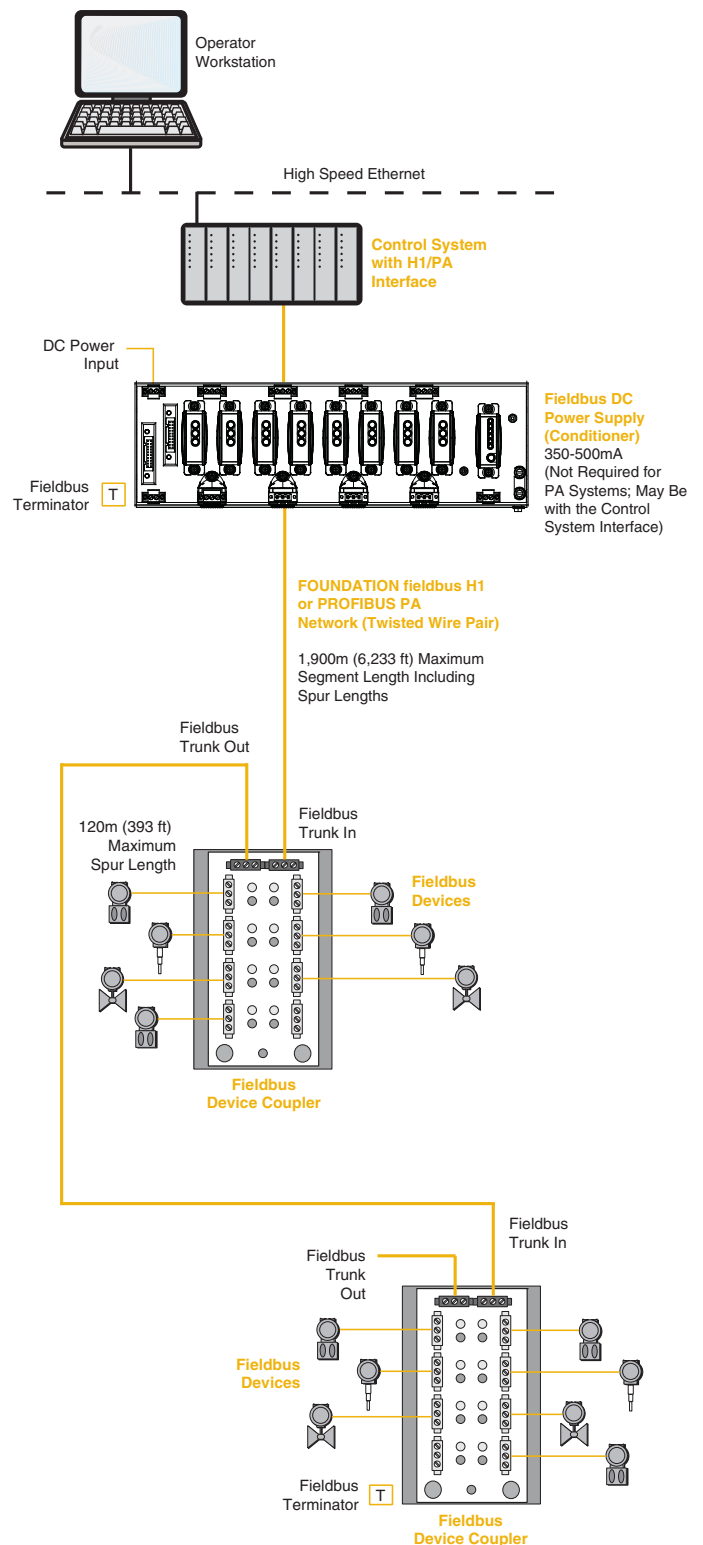
Fieldbus Segments

FOUNDATION fieldbus H1 and PROFIBUS PA are digital, parallel networks that provide power and signal to all connected devices. A typical fieldbus segment begins with a fieldbus interface device at the control system. This is followed by one or more fieldbus power conditioners, one or more fieldbus device couplers, and then on out to the distributed fieldbus devices (transmitters and control valves) themselves. All components are interconnected by a twisted wire pair communication link (Figure 1).

On a FOUNDATION fieldbus H1 system, the fieldbus interface is called an H1 card. On a PROFIBUS PA system, it is called a PROFIBUS DP/PA segment coupler. In terms of signal, wiring and power requirements, the H1 and PA networks are identical:

- Power and signal on the same cable
- Maximum of 32 fieldbus devices per network
- Minimum device operating voltage of 9V
- Maximum bus voltage of 32V
- Maximum cable length of 1900m (shielded twisted pair)
- Communication speeds at 31.25kHz, Manchester encoded

Figure 1. Standard FOUNDATION fieldbus™ Segment.



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Fieldbus Power Supplies (Conditioners)

The power required by fieldbus devices on the bus is supplied by a fieldbus power supply. The fieldbus power supply is a conditioning supply in that it provides filtering so that the signal is maintained along with the DC supply (Figure 2). Typical power conditioners make 350mA to 500mA available on the bus, and usually incorporate isolation to prevent segment-to-segment cross talk and grounding issues. In H1 segments, the fieldbus power conditioners are often separate from the H1 interface card. For PA systems, the DP/PA segment coupler usually incorporates the power conditioning component. There is no absolute requirement for the DC source to be independent per segment, but most designs provide segment isolation via DC/DC converters.

Fieldbus power supplies can, of course, fail while in service. So it is usually a good idea to specify power supplies that are redundant (one unit can continue delivering power if the other one fails), can be “hot swapped” (a new one can be replaced without shutting down the segment), and have some sort of alarm that notifies maintenance or operations when a problem occurs. Another valuable feature is surge protection per segment to protect the fieldbus power supply and DCS from surges from the field.

For FOUNDATION fieldbus H1 segments, redundant supplies can be used to improve overall segment reliability. However, when the power conditioner is an integral part of a PROFIBUS DP/PA coupler, redundant power is not available since only one coupler (which acts as a Master within the network) can be used in a PROFIBUS PA segment. Redundancy can be achieved if power conditioning is separate from the coupler or if a fault tolerant network is utilized.

Segment Power Requirements—When calculating how many devices can be used on a fieldbus segment, the primary factors that need to be taken into consideration are the maximum current requirements of each fieldbus device, current consumed by device couplers and the resistance of the segment cable (because of voltage drops along the length). The calculation is a simple Ohm’s law problem that results in at least 9V available at the farthest end of the segment, after taking into account all of the voltage drops from the total segment current. For example, driving 16 devices taking 20mA each using two device couplers requires about 340mA. So if the segment is based on cable with 44 Ohms/km/loop and a 25V power conditioner, the maximum cable length would be about 1100m to guarantee 9V at the end.

Voltage available for cable = $25 - 9 = 16\text{V}$;
Maximum allowable cable length using ohms law would be about 1.13km.

Figure 2. A fieldbus power conditioner prevents the high frequency communications signal from being shorted out by the DC voltage regulators. Typical power conditioners make 350 to 500mA available on the bus.



Note that many users also specify a safety margin on top of the 9V minimum operating voltage to allow for unexpected current loads and for adding additional devices in the future. Some users also allow a safety margin in case one or more fieldbus devices fail from a short circuit. It is recommended that segment calculations be performed on heavily loaded segments and ones with long runs. An engineer must add up all the power requirements of all the fieldbus transmitters, valve controllers, and other devices on the segment, and then factor in the length and resistance of all the cables to make sure that 9V can reach the farthest devices.

Fieldbus devices can require anything from 10mA to 30mA, with 20mA a reasonable estimate for many calculations. In most cases, the fieldbus device manufacturer will supply the necessary data. But be cautious: sometimes the information may not be entirely accurate or may be incomplete. In one case, a customer found that valve controllers specified to draw 10mA actually required 25mA when configured in a particular way. When the plant powered up the segment, they found that discrepancy the hard way, and had to add an entire segment to accommodate the high-powered controllers.

Advice: Be certain you know the current requirements of every device you plan to install on a segment, plus the additional current required if using current limited device couplers. Don’t forget the occasional handheld that could be used during start-ups or troubleshooting.

Fieldbus Device Couplers

Fieldbus cable may be virtually indistinguishable from Type A 4-20mA cable, but field wiring techniques and accessories are definitely different. Fieldbus systems are simple to design because all of the device wire-pairs are connected in parallel. In practice, however, any attempt to fill a box full of terminals and just “jump” between all positives and all negatives will result in a “rat’s nest” of cables within the enclosure. This may ultimately lead to all sorts of maintenance problems once the installers have left the site.

A better idea is to use fieldbus device couplers, which are specifically designed for fieldbus implementation (Figure 3). Device couplers automatically provide the necessary system interconnections without confusion and speed up device installation. They should incorporate the required communication link terminator with either manual or automatic activation.

Short-Circuit Protection—Short circuits are a common problem in any fieldbus installation. Maintenance technicians can jostle cables, corrosion can weaken connections, and vibration from pumps and motors can loosen cables and connectors. Segment designers must be concerned about what might happen to an entire fieldbus segment if any single instrument shorts out.

Device couplers provide active spur short-circuit protection in two basic forms: “current limiting” and “fold-back.” Current-limiting and fold-back types both auto-reset after fault removal and both normally incorporate LEDs to indicate spur status.

The current-limiting technique limits the amount of power the short-circuit can draw to between 40mA and 60mA (vendor dependent), but it also holds that fault on the segment continuously. Although this design protects the segment from the initial short, the additional current draw from the short can cause the voltage to drop below the 9V minimum causing other devices to drop off the network. If current-limiting designs are to be used, ensure that your segment power supply can cope with these additional loads.

For example, a segment may have 10 measuring devices plus two valves connected via 1200m of 50 Ohm nominal cable (250mA@60 Ohms of total cable impedance). In this case, the trunk voltage drop equals 15V, which allows 10V at the farthest device.

However, if a short occurs at a spur, the spur would be limited to 60mA, which would add 40mA additional load to the segment. This takes away enough power so that devices receive less than 9V (7.6V for the farthest

Figure 3. A device coupler provides short circuit protection on each spur. Some device couplers have automatic segment termination.



device), and some will drop off the segment. If two shorts occur, all the devices could drop off, and an entire process unit might go down.

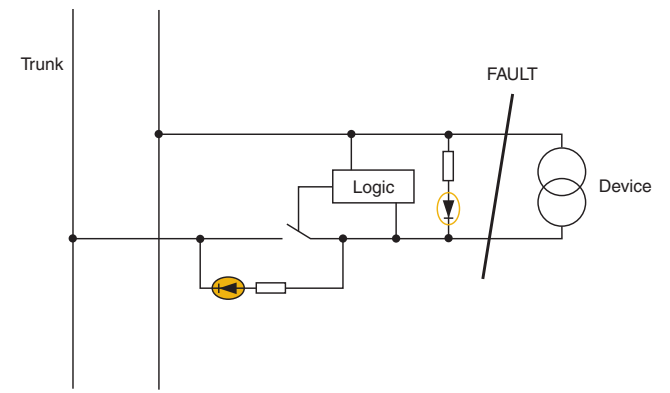
Therefore, if current-limiting protection is used in a device coupler, you must provide a 60mA safety margin. To accomplish this, design all segments with at least one fault. This will likely mean less devices per segment, but will ensure that a single fault will not cause an adverse condition.

An alternative design is the “fold-back” variety (Figure 4), where any spur that attempts to draw more than 48mA is automatically removed from the segment. A trickle current is used to determine when the short has been removed. During a short, only 4-5mA is used, so segment voltage actually goes up thus ensuring that no other devices are affected. Green and red LEDs for each spur clearly identify the status of each spur on the coupler.

With fold-back device couplers, you don’t have to worry about spur failures affecting other devices so you can confidently place more devices on fieldbus segments. Since the cost of H1 cards (US\$3,000) and other segment hardware can be cost-prohibitive, being able to place more devices on a segment can save a considerable amount. A typical FOUNDATION fieldbus segment, consisting of an H1 card, power supply, device couplers and cables, can cost about US\$5,000. A large

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Figure 4. A “fold-back” circuit, available with some device couplers, removes a short-circuit spur from the segment and uses a trickle current to determine when the short has been removed. Short-circuit current is just 4-5mA, compared to “current-limiting” short-circuit protection, which limits the short to 60mA but keeps it on the segment.



process plant may have hundreds, if not thousands of devices. If the “safety margin” approach is used, where the entire capability of fieldbus is not used, the cost of all the extra fieldbus segments can become substantial.

Fieldbus Cable

One of the central themes of fieldbus for process control is that it should be as practical as possible. Power and signal shall be available on the same cable, and that cable should not be fundamentally different from conventional instrument cable already in common use.

However, conventional instrumentation cable may not have digital communications parameters specified on its data sheet (effective impedance at 31.25kHz, attenuation rate in dB/km, etc.), and so its performance in fieldbus applications cannot be guaranteed. The Fieldbus Foundation™ now has a standard for fieldbus cable (FF-844 for H1 cable). New installations should always use cable that has the FF-844 check mark.

Advice: If you intend to use cable glands to seal the cable entry into a device coupler or junction box, check that the fieldbus cable used is properly “round.” Many less-expensive two-wire cables have a distinct “lay” evident in the outer sheath of the cable and this will not seal effectively in the cable gland.

Table 1. Maximum Length of Cables.

Cable Type	Description	Size	Max. Length
A	Twisted-pair w/shield	#18 AWG	1,900m
B	Multi-twisted pair w/shield	#22 AWG	1,200m
C	Multi-twisted pair w/o shield	#26 AWG	400m
D	Multi-core w/o twisted pairs and having an overall shield	#16 AWG	200m

Terminating the Segment

In FOUNDATION fieldbus H1 and PROFIBUS PA, the communications signal is current modulated at 31.25kHz, 20mA peak-to-peak (p-p). A terminator (the square “T” boxes in Figure 1) is required at each end of the segment cable to prevent line reflections (which may otherwise result from open-ended cables) and to source/sink the communications current.

The terminator circuit is very simple: 100 Ohm resistor and 1µF capacitor in series across the segment. The end-of-line resistor provides a nominal load for the communications signal, and the capacitor stops the DC supply draining through the resistor. Two terminators at 100 ohm give a nominal 50 ohm load for the communications current (20mA p-p) and a signal voltage for receiving devices of 1V p-p.

Care should be taken to ensure that two, and only two terminators, are installed in every fieldbus segment. Most fieldbus power supplies or DCS’ provide a terminator for the systems end of the bus. The second terminator should be supplied at the last device coupler in the segment (Figure 5). While this seems very straightforward, over or under termination is the main cause for delay in starting up fieldbus projects.

Automatic segment termination simplifies commissioning and start-up. It automatically activates when the device coupler determines that it is the last fieldbus device coupler in the segment; if it is, it terminates the segment correctly. If it is not the last device coupler, it does not terminate the segment. No action—such as manually setting DIP switches—is necessary to properly terminate a segment.

If a device coupler is disconnected from the segment accidentally or for maintenance, the automatic segment termination detects the change, and terminates the segment at what now becomes the last device coupler on the segment. This allows the remaining devices on the segment to continue operation.

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Redundant Operations

Fieldbus theoretically allows up to 32 devices to be brought in over one twisted wire pair digital. While this does save a tremendous amount of wiring, there is a potential problem with losing communication with all devices if something happens to the power conditioners, H1 card or the trunk cable.

For this reason, most process companies specify redundant power conditioners and controllers. A redundant power supply has two load sharing power conditioners per segment, and is powered by two sources of DC supply (Figure 6). Such a system can survive the failure of either 24Vdc power supply or either power conditioner. If a failure occurs, the redundant conditioner assumes the entire load.

Many fieldbus power supplies have a diagnostic master alarm that indicates when a failure has occurred. If any of the individual modules fail, replacements can be "hot swapped" into place without shutting down the segment.

Most fieldbus power supplies have a carrier board that is DIN rail mounted (Figure 2). The carrier board typically supports four segments with simplex or redundant power conditioners plugging into the carrier board.

For a redundant configuration, each pair of power conditioner modules requires two power supply inputs and one connection to the fieldbus segment. Installation is not difficult, because a redundant power conditioner requires no changes to be made to the fieldbus segment, device couplers or interface card.

Figure 6. A redundant fieldbus power supply provides redundant power conditioner modules, and has two sources of DC supply. If any single part fails, it will continue to power the segment.

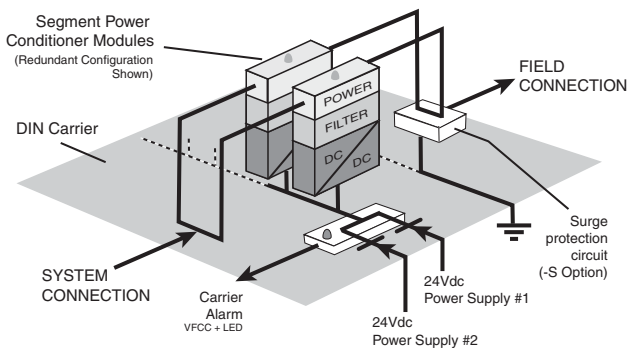
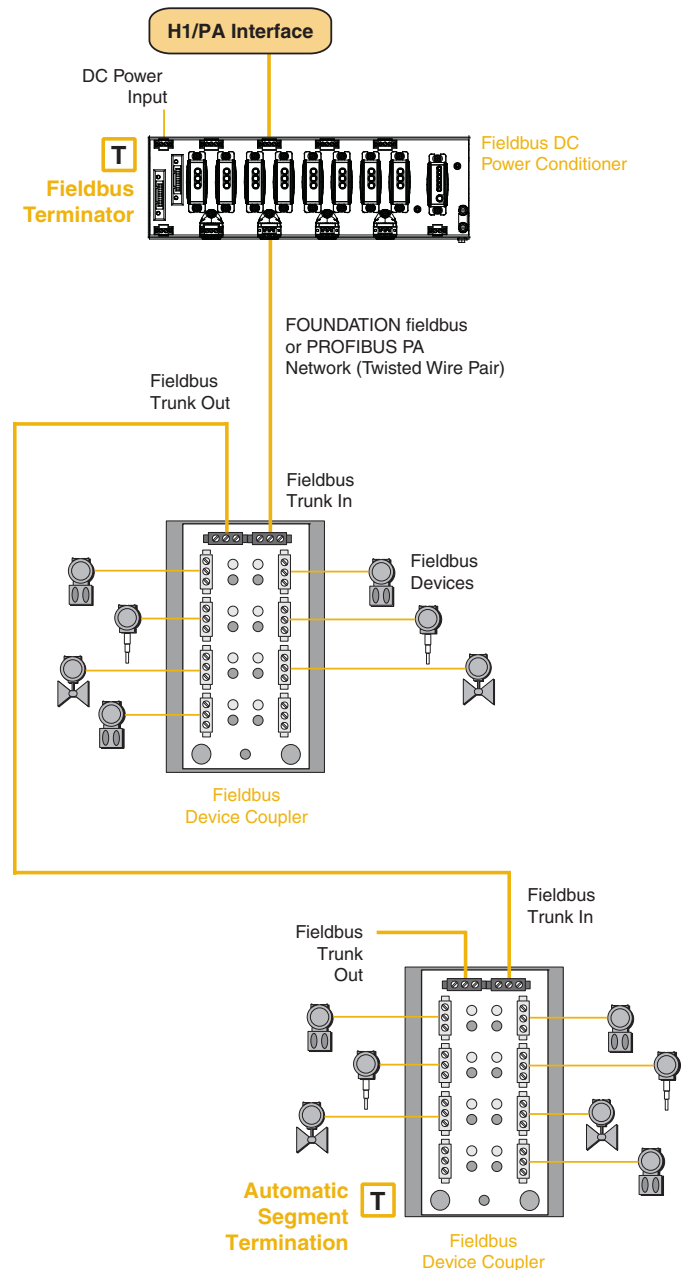


Figure 5. Terminators (shown as square "T" boxes) must be turned on at the beginning and at the end of each segment.



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Increased Segment Security

In certain process applications it may be necessary to add additional redundancy for segments. This is particularly true where there is potential for cable breakage or disruptive environmental conditions such as vibration, extreme temperature changes, high humidity levels or poor air quality (caused by chemicals, dust, etc.).

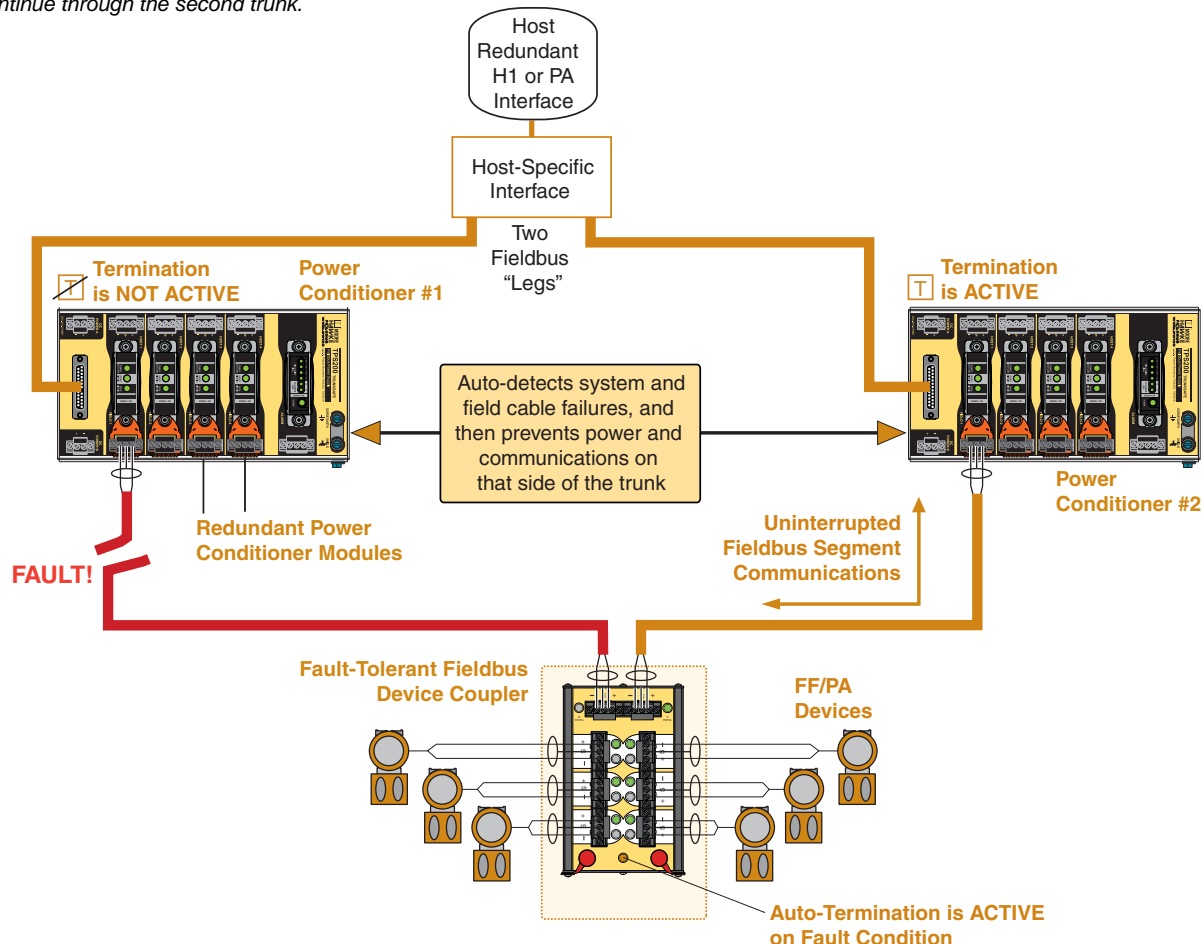
In these cases where higher levels of availability are required, there are two approaches to consider. The highest being complete redundant segments, including devices (transmitters and valves). This level requires extensive software as well as very expensive hardware additions. A second method is to use a Fault-Tolerant Segment which has a host interface, redundant power conditioners, dual trunks, and one fieldbus device coupler (Figure 7). This eliminates the need to duplicate field instruments and avoids difficult maintenance issues, while still improving the segment MTTF by 7-10 times at virtually no additional cost.

The Fault-Tolerant Segment provides two independent trunks for signal and power from the host interface to the device coupler. For any given segment, the redundant

power conditioners are mounted on separate carrier boards maintaining the “no single point of failure will shut the system down” strategy. Each power conditioner has an associated terminator so that in normal operation the segment has the required two terminators. Each path from the host interface to the device coupler continuously monitors for faults such as shorts, broken wire, power conditioner failure, etc. When a fault is detected, the trunk with the fault no longer supplies power to the device coupler. When this occurs the device coupler automatically applies a terminator so that a properly terminated signal is maintained in the second trunk path. As soon as the fault is cleared, power is returned to the device coupler and the auto-terminator is turned off. The system is returned to the normal state. A master alarm in each carrier board (diagnostic module) provides notification to the DCS via contact closure when a fault is detected.

This Fault-Tolerant Segment approach does not require any additional software or hardware other than a host specific interface that is required to split and isolate the two trunks. Ideally, the second trunk cable would be routed differently from the first trunk.

Figure 7. A Fault-Tolerant Segment has two independent trunks that provide signal, power and segment termination in normal operation. If a fault is detected in one trunk, then a terminator is activated in the device coupler maintaining proper segment termination so that communications and power continue through the second trunk.



Hazardous Areas

Three methods are available for installing fieldbus in hazardous areas:

- Intrinsically-Safe (I.S.)
- Explosion-Proof
- Non-Incendive

While all three methods have been used for fieldbus installations, the most popular—especially in Europe—is Intrinsically-Safe.

Installing Intrinsically-Safe Systems

Intrinsically-safe methods for fieldbus include:

- Entity
- FISCO
- High-Powered Intrinsically-Safe (I.S.) Trunk
- High-Powered Trunk (Non-Intrinsically-Safe)

An Entity system requires “barriers”; that is, devices that limit the amount of energy that can enter the hazardous area (Figure 8).

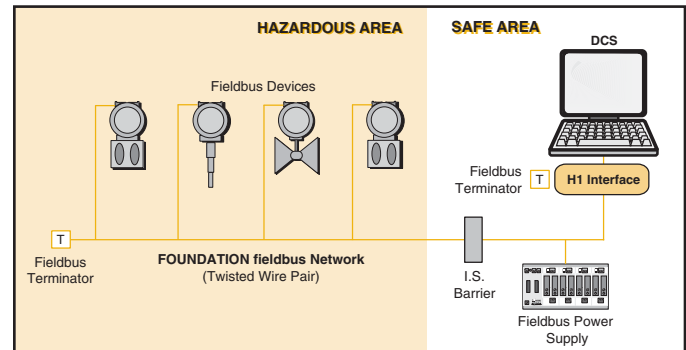
In general, intrinsically-safe fieldbus was originally based on the FOUNDATION fieldbus FF-816 specification. Entity systems are highly reliable, especially when based on simple resistive current-limiting, which allowed Entity parameters for field devices to be at least 24V/250mA/1.2W. These barriers allow about 80mA for Gas Groups ABCD (NEC) or IIC (IEC).

FISCO (Fieldbus Intrinsically Safe Concept) provides additional power for the segment that varies by gas groups and area classifications. All components of a FISCO system must be FISCO approved. The system comes with some limitations. Redundant load sharing power supplies cannot be used, and the allowable trunk and spur cable lengths are reduced.

FISCO has another drawback: the complexity of the FISCO electronic current-limiting design itself and the requirement to have multiple such circuits in series (current-limiting must still be available even if a circuit fails in an unsafe way) means that the overall MTTF of these units is much lower than users might expect. FISCO systems are also much more expensive because of the high cost of the FISCO power supplies and fieldbus devices.

Installation of FISCO is similar to an Entity system: the FISCO power supplies are mounted in the safe area. The rules for using FISCO (IIC, North American Gas Group A, B) allow only 1000m (3250ft) of cable in total and only 60m (195ft) spurs, about half that of a ‘normal’

Figure 8. Entity systems require a “barrier” which limits power to the segment, and thus limits the number of fieldbus devices.



fieldbus segment. This should not pose a problem in most installations, because of the limited number of devices on each segment.

A High-Powered Intrinsically-Safe Trunk (Figure 9) puts part of the barrier in an isolator and part of it in each of the spurs of a field-mounted device coupler. By splitting the intrinsically-safe current-limiting method in this way, the system can put a full 350mA on the trunk that leads into hazardous areas with Gas Groups C & D, and still have intrinsically-safe spurs that match FF-816 Group A & B approved devices. This overcomes both the FISCO and conventional Entity restrictions on available current. Up to 16 devices can be put on a segment, nearly four times as many as an Entity or FISCO system.

Installation is much simpler, because fewer devices and segments are required. In general, a High-Powered I.S. Trunk requires only 25% of the cabinet space of an Entity or FISCO system. One problem you may encounter during installation of a pure FISCO system is incompatibility of conventional and FISCO devices. The High-Powered I.S. Trunk is based on device Entity parameters of 24V, 250mA and 1.2W (values which the I.S. power supply must guarantee not to exceed and which are specified in IEC61158-2 and associated documents).

FISCO devices, on the other hand, are associated with Entity values of 17.5V, 380mA and 3.8W, so additional hardware (barrier) is required to integrate non-FISCO equipment. This has become an issue with some older devices that have Entity approvals but not FISCO.

A recent enhancement in High-Powered I.S. Trunk is the incorporation of FISCO-compatibility at the field device coupler. Having FISCO and Entity compatibility at the device coupler in a split-architecture design enables implementation of intrinsically-safe fieldbus with any desired mix of approved devices without the limitations in cable lengths and reduction in MTBF that results from a pure FISCO system.

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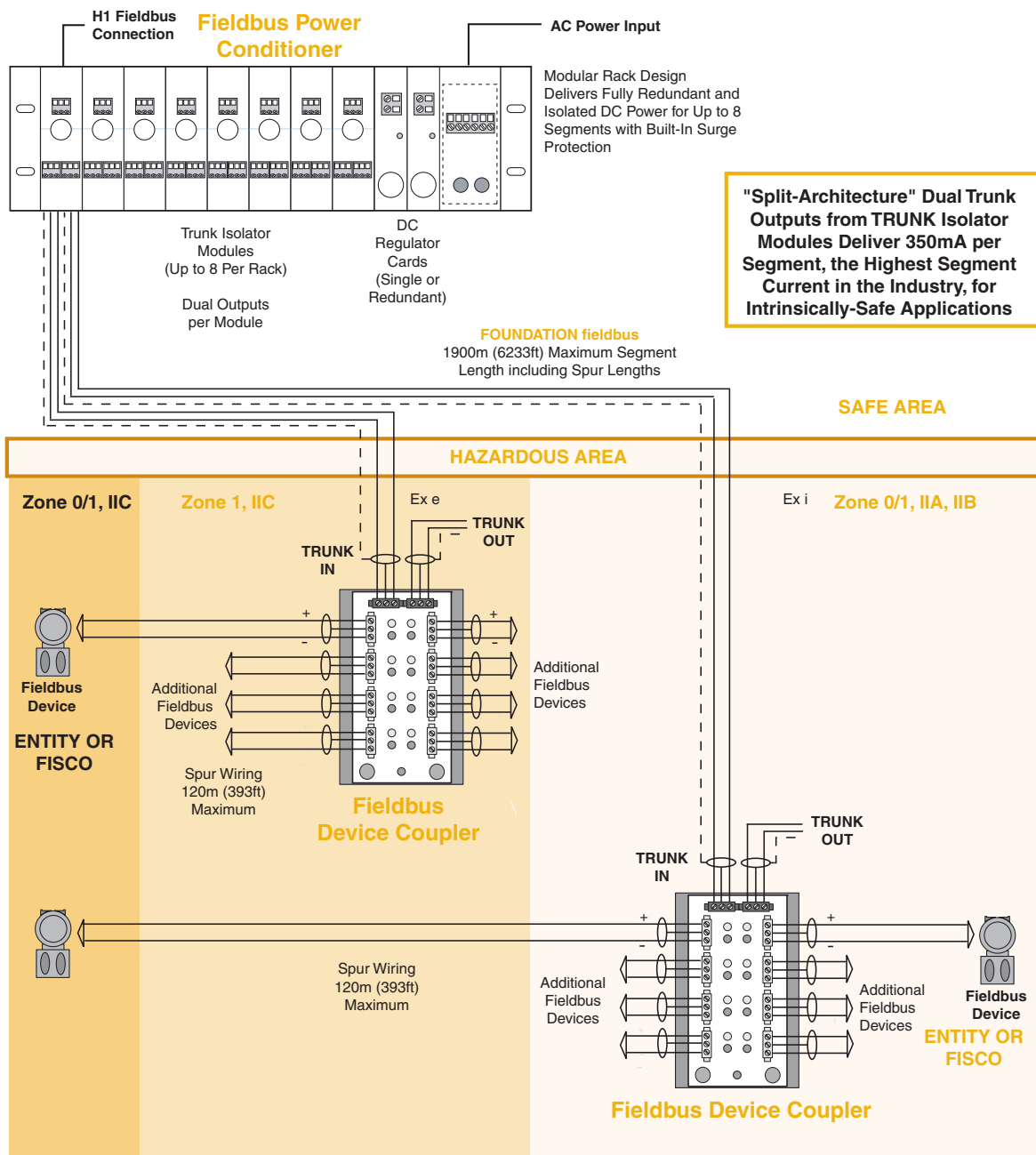
Another method used in fieldbus is the High-Powered Trunk with field barriers. In this configuration the trunk cable is not I.S. and must be wired Ex e. The field barrier then isolates the segment and provides intrinsically-safe spurs.

Of these various approaches, the High-Powered Intrinsically-Safe Trunk provides the most devices per trunk while allowing live working on the trunk and spurs and allowing both FISCO and Entity devices.

Removing and Replacing Instruments

Maintenance people want to be able to remove devices from fieldbus segments in hazardous areas without turning off the whole segment, and without going through complex disconnection procedures and mechanical interlocks, if they can be avoided. In Zone 1 applications, simply specify a device coupler approved for Zone 1 that also has a magnetic interlock on each spur. The technician puts the key in the slot, which isolates the spur, and makes it accessible for

Figure 9. A High-Powered Intrinsically-Safe Trunk allows a full 350mA on the segment, and does not limit the number of devices that can be supported.



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re-wiring without shutting down the segment (Figure 10). This works particularly well if IEC/AEx standards are being followed, since that particular device coupler can fit inside a low-cost GRP enclosure (Exe/AExe approved) with spurs fully accessible in Zone 1. Some device couplers are designed and approved for use in Zone 1 and Zone 2 with flameproof Exd devices. For flameproof, Division 1 applications, live de-mateable plug/socket combinations are available from many manufacturers. If an application demands live exposure in Division 1 or connection into Zone 0, then field barriers can be used which allow intrinsically-safe spurs to be attached to the non-intrinsically safe trunk. Cost issues involve the amount of time a maintenance technician must spend removing and replacing instruments. If the process is laborious, then it might take hours to follow all the safety procedures. If the process simply requires a key, then an instrument can be disconnected in a few seconds.

Advanced Diagnostics

Several options exist for on-line diagnostic tools associated with the physical layer, including permanently attached and portable device diagnostic methods. At minimum, diagnostic alarming should be on: Segment voltage level, noise, power conditioner failure, DC supply level and segment short circuit. If an on-line diagnostic tool is permanently installed as part of the FOUNDATION fieldbus power supply, additional information may be available over a network. Benefits of permanently installed diagnostic tools may include the ability to historize the data, and provide real-time alarming and trending of the data. Portable diagnostic tools assist in troubleshooting specific problems and may present additional data not available with permanent diagnostic tools. Permanent installed diagnostic tools should only be considered if they are well integrated with the host system. Most diagnostic tools will work with any vendors power supply and conditioners.

Simplify Your Installation

Many fieldbus installation challenges can be minimized through careful selection of fieldbus equipment at the beginning of the project.

Few end users realize that fieldbus components, such as power supplies and device couplers, are not manufactured by the DCS vendor. Instead, they are provided by associated suppliers. Therefore, regardless of the DCS vendor selected, it is possible to specify fieldbus components separately. Note that the choice of physical layer product makes no difference to the

Figure 10. Device couplers with key-operated interlock permit fieldbus devices to be de-energized for “live” maintenance in Zone 1/Zone 2 without de-powering the entire segments.



DCS operation. All fieldbus power conditioners and device couplers simply enable the fieldbus power and communications to work; they do not communicate with the DCS. To simplify installation of your fieldbus system, evaluate the components carefully from the various suppliers.

Look for:

- End of line automatic segment termination on device couplers to eliminate over or under termination, the main cause of delay in starting up fieldbus installations.
- Auto-resetting “fold-back” short circuit protection that removes the fieldbus device with a short from the segment and then uses a trickle current (4-5mA) to detect when the short has been removed. Voltage actually goes up on a short!
- Fieldbus power supplies with individual segment power conditioners (redundant), with optional pluggable surge arrestors.
- High-Powered Intrinsically-Safe Trunks with device couplers that accept both FISCO and Entity devices directly with power for up to 16 devices.
- Fault-tolerant networks that improve segment availability by simply running a second, redundant trunk.

Fieldbus is an exciting technology and there are many benefits that will accrue to end users and early adopters. Implementation of real fieldbus systems is still a new experience for many engineering companies, and many subcontractors are coming to wire up devices without any real understanding of the different requirements and problems presented by fieldbus systems. Keep some of the guidelines described here in mind when ordering your fieldbus system and when dealing with your installation subcontractor.