

TURCK works

Industrial Automation

FOUNDATION™ Fieldbus

Troubleshooting Guide



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FOUNDATION™ fieldbus Design Guide

FOUNDATION fieldbus is an industrial network system with hazardous/classified location capability and control features that make it ideally suited for process applications. This design guide is intended to assist users of FOUNDATION fieldbus networks in understanding the physical layer hardware requirements for designing these systems. The FOUNDATION fieldbus specification covers two physical network types: High Speed Ethernet (HSE) for communicating large amounts of maintenance and diagnostic data and H1 for communicating control information. This document will deal only with the FOUNDATION fieldbus H1 specification.

Like other industrial network systems, FOUNDATION fieldbus replaces traditional "point-to-point" wiring with a shared serial data bus. Control devices connected to the network each take a turn using the shared communication medium to send process variable and maintenance data to other devices on the system. Because each device on the network uses the same physical wiring, a significant savings can be realized when using FOUNDATION fieldbus instead of traditional systems. Much less wire needs to be pulled in the installation phase, and upgrading and adding to the system is very easily accomplished.

The FOUNDATION fieldbus H1 system is based on the IEC 61158 specification. This specification is derived from the Manchester encoded digital signal. This type of signal encoding reads bit values by the "transition" of digital electrical signals (low-to-high or high-to-low), providing greater noise immunity than by simply reading the amplitude (voltage or current level) of a signal. The communication transmission speed is 31.25 kbps.

Most H1 systems have both DC power (9 to 32 VDC) and the data signal on a single twisted wire pair. This configuration requires the power supply to be decoupled from the signal in order to read the digital information superimposed on the DC power. FOUNDATION fieldbus H1 systems incorporate power supply decoupling (also referred to as conditioning) by using a separate device that is installed between a bulk DC supply and the network communications trunk line. The "power conditioning" unit allows the network's digital communications to coexist with the DC power on the same single twisted wire pair without being absorbed by the bulk DC supply and its regulating effect.

A maximum of 32 field devices may be installed in a single segment according to the standard, and the maximum cable length of the entire system is 1,900 meters without incorporating repeaters. This includes the total length of all spurs and the trunk combined. The maximum drop (spur) length is 120 meters. Repeaters can be incorporated for longer runs, and up to four repeaters can be used on a FOUNDATION fieldbus H1 segment.

When designing a FOUNDATION fieldbus system you should keep in mind the basic goals that must be accomplished:

1) The layout rules of the system need to be followed
2) Each device on the system must have enough power
3) The system must be designed such that signal noise won't interfere with communication

Each of these points will be addressed here.

Layout Rules

Three basic wiring configurations are used with FOUNDATION fieldbus H1 systems.

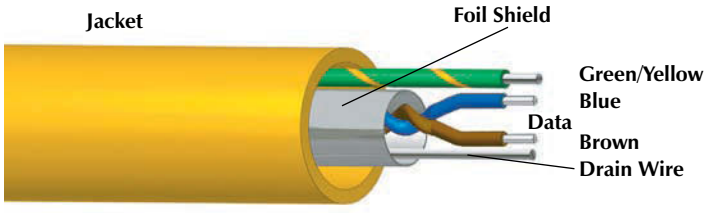
1) Separately powered devices - Each field device is separately powered using the trunk (the main communications highway) for the digital communications only. In this configuration, field devices are powered from a separate source. This separate power source is galvanically isolated from the communications on the bus. A mixture of separately powered and bus powered field devices are allowed. Assuming all devices are powered from a separate supply, up to 32 devices may be connected in this configuration.
2) Bus powered devices - Devices on the network are powered from the bus. The DC power from the bus powers the field devices and uses the same wires for data transmission. This configuration can be used in combination with the "separately powered devices" method described above. Due to voltage drop limitations it is recommended to limit the number of devices in this configuration to 12.

3) Intrinsically Safe system: FISCO or Fieldbus Intrinsically Safe Concept - The FISCO concept is based on a system approach, and specified in the IEC60079-27 standard. This standard specifies the installation and physical layer requirements for FOUNDATION fieldbus H1 for use in potentially explosive atmospheres (Classified Areas), including Division 1 and 2, and Zone 0, 1 and 2 locations. The standard also includes references to FNICO or Fieldbus Nonincendive Concept, a similar system approach to installing FOUNDATION fieldbus H1 in slightly less potentially explosive atmospheres (Classified Areas), such as Division 2 locations. FOUNDATION fieldbus H1 is uniquely suited for installation in these potentially explosive atmospheres and incorporates protection methods that are accepted worldwide.

FOUNDATION fieldbus H1 is most commonly installed using bus powered field devices (configuration method #2).

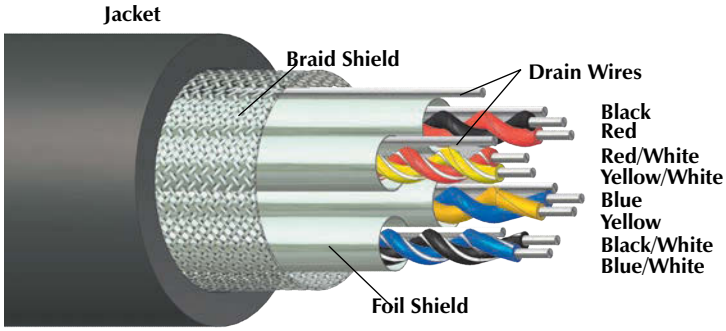
The FOUNDATION fieldbus specification defines and recommends a particular cable type to be used for the network line. The cable type recommended ensures maximum performance when installed according to the standards. Three alternate cable types are defined as well, with the intent of allowing users to easily incorporate existing cable runs when retrofitting or upgrading existing installations to FOUNDATION fieldbus H1. The four acceptable cable types are listed below. These types (with the exception of type "A"), will not provide optimum system performance, but are an acceptable alternative to installing completely new wiring in retrofits where existing cable runs are to be utilized. FOUNDATION fieldbus H1 wiring is specified by the IEC 61158 standard.

Type A cable is a shielded twisted pair of 18 AWG wires with a drain wire. This cable has a characteristic impedance of 100 Ω at 31.25 kbps. This is the defined FOUNDATION fieldbus specific cable type, and a maximum network length of 1900 meters is allowed when it is used.



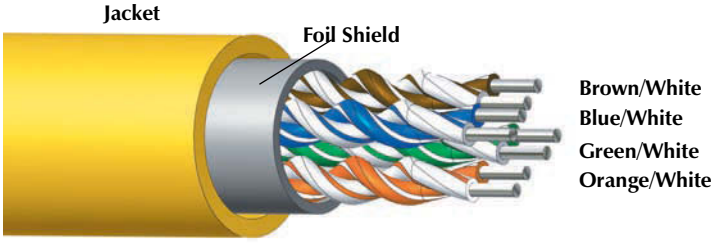
Example of Type A Cable

Type B cable is multiple shielded pairs of 22 AWG wire. This cable type also has a characteristic impedance of 100 Ω at 31.25 kbps, but a higher electrical resistance due to the smaller wire size. The maximum network length is 1,200 meters when using Type B cable. Note that the FOUNDATION fieldbus system only uses one of the pairs for its power and communication.



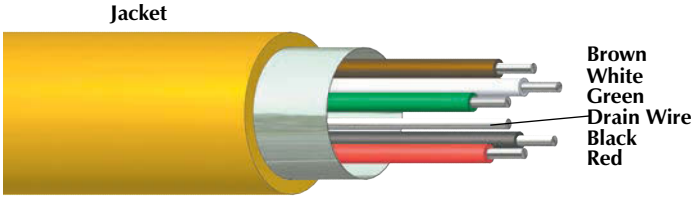
Example of Type B Cable

Type C cable is multiple unshielded pairs of 26 AWG wire. The maximum network length is further reduced when using this cable to 400 meters. This cable is generally not preferred for FOUNDATION fieldbus since it is not shielded. Again, only one of the pairs is needed for the FOUNDATION fieldbus network.



Example of Type C Cable

Type D cable is multicore unshielded and untwisted 16 AWG wires. The maximum network length is drastically reduced to 200 meters when using this cable.



Example of Type D Cable

The maximum segment lengths given above include the lengths of all spur drop cables on the segment.

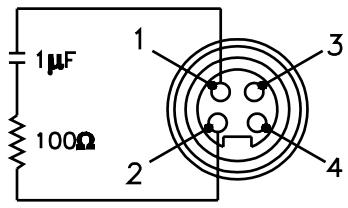
Since Type A is the preferred cable type for FOUNDATION fieldbus we will refer to it in this guide. When using other cable types, consideration for the de-rating values listed above must be taken into account in the design of the system.

When using Type A cable, the maximum length of a segment, inclusive of the trunk and all spurs, is 1,900 meters. This is defined by the standard for non-FISCO or non-FNICO segments.

If more than one device is connected on a single spur, the recommended practice is to subtract 30 meters for each device after the first from the maximum spur length.

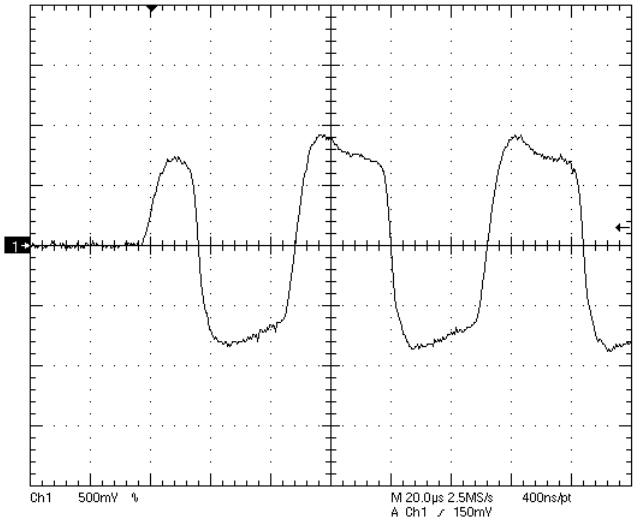
FOUNDATION fieldbus networks require a termination resistor circuit at each end of the trunk segment. The termination used is a 100 Ω resistor in series with a 1 μF capacitor or the electrical equivalent of this circuit.



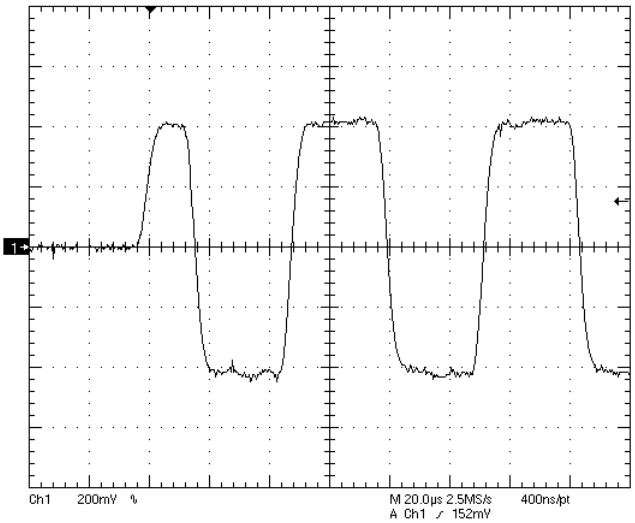


TURCK *minifast*® termination plug with circuit diagram

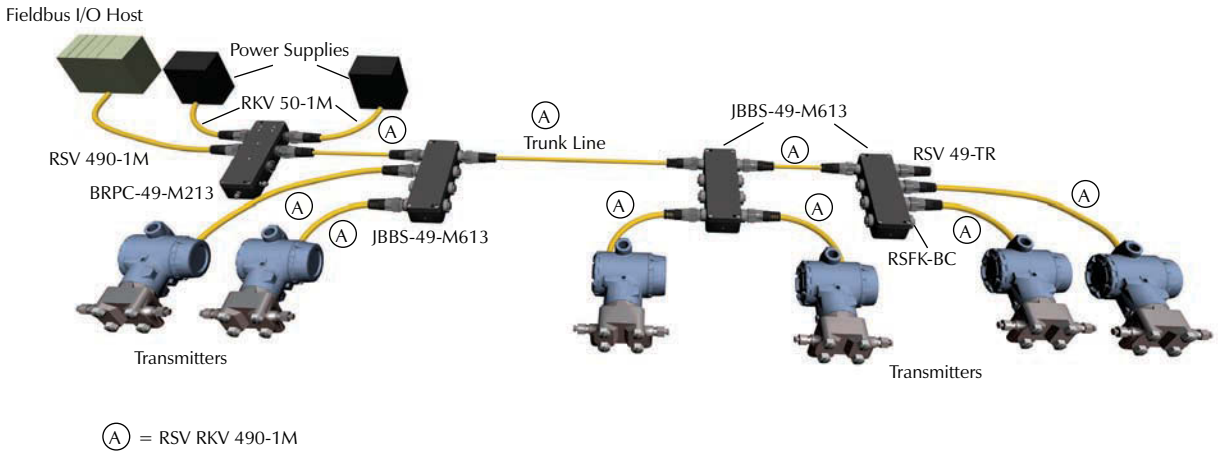
The purpose of the terminating resistor circuit is to absorb the signal energy at the end of the line. This prevents signal reflections which cause interference and can significantly affect the operation of the network.



FOUNDATION fieldbus signal with only one terminator in place.



FOUNDATION fieldbus signal with both terminators correctly installed.



In order to begin the process of designing a FOUNDATION fieldbus H1 segment, the location of each FOUNDATION fieldbus device must be defined and incorporated into a plan drawing of the plant. When that is complete, a determination must be made as to which devices should be on separate segments in order to maintain the necessary integrity of the system and to efficiently use the "control in the field" functionality of the system. The remaining (secondary) devices can then be incorporated on other segments to balance the load. With the completion of this step, there is now a clearly defined logical outline of each FOUNDATION fieldbus H1 segment in the installation.

When all the segments are defined, verification must then be made that each of the chosen field devices meet the physical layout specifications for FOUNDATION fieldbus H1 segments. These requirements include cable lengths, power requirements, short circuit protection, etc. Cable runs can now be designed. This will give a clear indication for the length requirements for individual segments regarding trunks and spurs. It is also helpful to know the specifics of the devices: what devices will be used and which manufacturers will be providing them. The information from the manufacturer's data sheets can be used to calculate current draws for individual devices, as well as to provide other useful information required to design system segments.

Connection Options

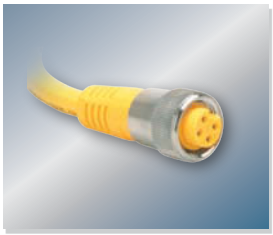
There are two primary ways to make the physical wiring connections necessary for the devices on a FOUNDATION fieldbus system to communicate with each other: terminal wiring and plug-and-play connectors. Most systems will incorporate both methods to some degree.

Terminal Wiring

The terminal wiring approach is much like the traditional way of wiring a control system, just with far fewer wires to connect. Wires are landed in screw terminal points which must be tightened down with a screwdriver (in some cases spring-loaded "cage clamp" connections could be used).

This approach is often suitable for "in-cabinet" wiring situations (where the devices being connected are mounted inside an enclosure). One of the key benefits of FOUNDATION fieldbus, though, is that the connected devices can be mounted in the field (that is, decentralized). In order to fully realize the benefits of field mounted devices a more rugged, sealed connection method is required.

Connectorized Wiring



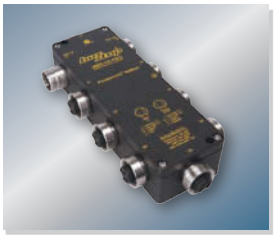
***minifast*® Connector**

The connectorized approach utilizes industrial standard connectors with rotating coupling nuts that allow the connections to be made right in the field, outside of any separate enclosures. For most FOUNDATION fieldbus systems the ***minifast***® connector is the preferred choice. Valves and transmitters can often be ordered direct from the manufacturer with these connectors already mounted on them. If they aren't available, the user can order connector receptacles that can then be mounted in standard NPT cable gland fittings. In either case, once a connectorized device is mounted in the field, connecting it to the network is as simple as plugging in the cord and tightening the coupling nut. In hazardous location installations the connectors usually must be further protected by some means to prevent them from being disconnected under power. This is easily accomplished by **TURCK**'s ***lokfast*** covers, which snap around the connectors and rotate freely, preventing the connector coupling nut from being unscrewed.





***lokfast*™ Guard**



TURCK Multiport Junction Box

Most FOUNDATION fieldbus systems will incorporate a combination of terminal and connectorized wiring. The connectorized system is typically used at the end devices in the field, while the terminal solution is used to connect to the host and power supply in the control cabinet.

Power for Each Device

When designing Fieldbus installations, calculations must be made regarding the current draw of each instrument and the resultant voltage drop along the trunk and spur lines. Note that this calculation can also affect the maximum cable length of the segment. If the current drawn by each device is high enough, the resistance of the cable for a given length may cause the voltage drop to be great enough to cause problems at the far end of the system. The minimum voltage specified for each device on the network is 9 VDC. It is recommended that the voltage be somewhat higher than this in order to ensure proper performance of the system. FOUNDATION fieldbus H1 segments are often used in mission critical areas of a plant, and therefore require high system reliability.

Short-circuit protection for each individual instrument is also highly recommended when designing FOUNDATION fieldbus H1 systems. This ensures that if a device is lost due to a short-circuit, the rest of the segment will continue to function normally. This is extremely important in mission critical applications. Junction boxes are available with integrated short circuit protection on each port to easily facilitate this wiring. Additionally, many of these junctions have appropriate approvals for use in hazardous areas.

1. A segment with seven field devices.

The assumption for this example is that the entire control system has been analyzed already and the devices on this segment have been chosen based on system specifications. This example will deal specifically with how to properly lay out the FOUNDATION fieldbus segment.

For this example we will look at a FOUNDATION fieldbus segment with seven devices on it. The devices, along with the maximum current each draws from the FOUNDATION fieldbus line, are as follows.

1 x Rosemount 3051S pressure transmitter (17.5 mA)

1 x Rosemount 8800C vortex flow meter (20 mA)

1 x Rosemount 3244MV temperature transmitter (17.75 mA)

1 x Rosemount 3095MV mass flow meter (17.5 mA)

3 x Fisher DVC6000f flow valve (18 mA)

Our host system will be the Emerson DeltaV. The FOUNDATION fieldbus H1 card for this DCS draws up to 12 mA from the Fieldbus segment. This makes our total current draw for the communication equipment on this segment:
17.5 mA + 20 mA + 17.75 mA + 17.5 mA + 3 x 18 mA + 12 mA = 138.75 mA

Other current consumption issues also have to be considered, such as the current draw of short circuit isolating ports on junctions or other possibilities. For this example we will assume that the physical location of the devices is such that three six-port junction boxes will be used to connect them to the main segment trunk. Three six-port boxes provides for a total of eighteen spurs (drops) available. This is of course much more than the seven devices we are actually connecting, but since the cost of a six-port junction is not significantly more than that of a four-port it makes sense to have plenty of extra space available for plant additions in the future. It would be possible to use a simple single-drop tee connection for each individual device, but these are not normally available with the added benefit of short circuit protection and make future additions to the system more complicated.

For our example we will use three **TURCK** JBBS-49SC-M613 junction bricks. Each of these has a segment in and segment out port as well as six spur ports. Each of the spur ports incorporates a current limiting circuit that isolates the spur in the event of a short circuit. This isolation also makes the spurs non-incendive circuits, suitable for use in Class 1, Division 2 areas.

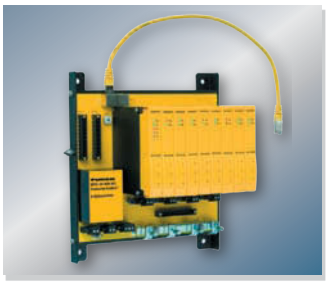
Each of these bricks draws a certain amount of current from the system, since they have some internal electronics to enable the port isolation. These particular bricks draw no more than 60 mA. This puts our total current draw for the system at:
138.75 mA + 3 x 60 mA = 318.75 mA

Our worst case scenario should also assume one or two short circuits on the network. This means that we need to know how much each of the isolated ports draws when there is a short circuit present. For the bricks we have chosen this value is 55 mA per port. If we assume two short circuits might be present on our system in the worst case our total current becomes:
318.75 mA + 2 x 55 mA = 428.75 mA

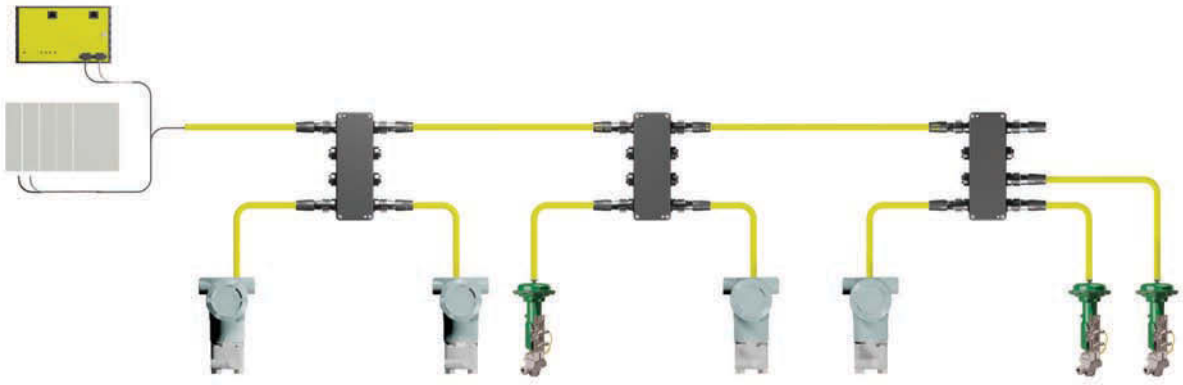
When planning a network it is also good practice to oversize your power supply by some factor, to ensure that you will always have enough current. For this example we will use a factor of 20%, making our total current requirement 514.5 mA, just over half an amp.

Now that we have a total current requirement we need to choose a power conditioner. This is a device that interfaces our standard DC power supply to the communication wires of the FOUNDATION fieldbus system (remember that this network carries data and power on the same wire pair).

TURCK provides a modular power conditioning system that allows up to four FOUNDATION fieldbus H1 segments to be redundantly powered from the same unit. This power conditioner also communicates diagnostic information, available through a web-based interface, to the asset management system via a FOUNDATION fieldbus High Speed Ethernet (HSE) connection.


TURCK Power Conditioner

TURCK's power conditioner for FOUNDATION fieldbus provides up to 800mA of current at 28 VDC for each segment. Since this is well above our required current (514.5 mA) for this segment this conditioner will be suitable. We also need to provide a power supply to the conditioner. We'll use the **TURCK** IM82-2450, which provides up to 5 A, plenty of current to run multiple FOUNDATION fieldbus segments.



The physical placement of the field devices must be within the length limitations for FOUNDATION fieldbus H1 specifications. Begin by measuring from the output terminals of the power conditioning unit to the last and physically furthest field device. The designer must then ensure that the cable routing path considers the total cable length, including any planned service loops. The total length of the cable itself is the critical value and must not exceed the specification of 1,900 meters without the use of repeaters (assuming this is a new installation and Type A cable is being used). At this point we should verify the voltage drops on the system to ensure that every device will have adequate power.

2. Segment Installation

When installing a FOUNDATION fieldbus system it is important to ensure all local codes are followed. If there is any discrepancy between the information in this document and any local electrical codes, the local codes take precedence.

Particularly in hazardous areas, care must be taken to ensure the proper equipment is used for the system. Junction boxes are available from **TURCK** which satisfy the NEC requirements for non-incendive equipment (do not contain components which are capable of providing enough power to ignite the atmosphere), and can therefore be mounted directly in a Class 1, Division 2 location.

Junction boxes with short-circuit protected (isolated) ports are also available. These boxes limit the amount of power available at each of the spur ports to a level suitable to make the connected spur a non-incendive circuit. This means that when used in a Class 1, Division 2 area there is no additional protection required for the connection of the spur to the junction.

The top ports of these junction boxes are for the segment coming in and going out (to the next junction box or another device). Since these ports feed the rest of the segment there is no internal current limitation for them. Therefore these ports cannot be rated as non-incendive circuits. When used in classified areas these ports must have additional mechanical protection to prevent them from being disconnected while in use (this act could cause a spark that may ignite the hazardous atmosphere).



Short circuit protected junction box. Note that no extra protection is required for the current limited drops.

TURCK provides clamshell lockouts (***lokfast*** covers) for these connections. The ***lokfast*** covers work by snapping over the connection port and coupling nut of the connected cordset. They fit loosely, so they rotate freely, preventing the coupling nut from being rotated, and therefore disconnected.

If junction boxes without the short circuit protection feature are being used in a Class 1, Division 2 area, ***lokfast*** covers must be used on all ports.



Non protected junction box. Note the *lokfast* covers must be used on all ports.

While some people still prefer to use conduit, there are several cable options available that allow FOUNDATION fieldbus systems to be installed completely outside of conduit.

First is the ***armorfast***® cable. This is a FOUNDATION fieldbus cable with a corrugated metal sheath (metal-clad cable), essentially a cable with its own integrated flexible conduit. While it can be used for the segments and spurs, this cable is also often used in conjunction with conduit. In this case the FOUNDATION fieldbus segment is run on cable inside conduit. Another connection device, called a Bus Conduit Adapter (BCA), provides a connection point at a standard conduit junction, giving us a convenient way to get out of the conduit with our bus signal. ***armorfast*** cordsets are then used to connect from the BCA to the end devices in the field. This method provides full protection of the cable all the way to the end device, while allowing greater ease of use and flexibility than running conduit right to the devices would.



***armorfast* cable provides added protection from the conduit to the end device.**

Another option is to use cable with a suitable crush and impact resistance rating. These are non armored cables that are still allowed to be run as open wiring. The cables used in this scenario will need to be supported by struts, channels, etc., but do not need to be run in conduit or a cable tray. There is a limitation as to how far these cables can be run as open wiring, and local codes should be consulted.

Where possible cordsets with factory installed connectors should be used. Since these connectors are pre-wired and tested before they get to the site, any field termination errors (loose or wrong connections) are eliminated, creating a significant potential savings when system testing is performed at startup.

The chief drawback often mentioned when talking about pre-molded cordsets is that the cords won't be the exact right length for the application, requiring service loops to be installed (to allow for the extra slack in the cord). There can, however, be some benefit to these service loops, as they will allow devices to be easily moved for maintenance without disconnection from the Foundation Fieldbus network.



TURCK factory molded cordsets

Another way to overcome the issue with cord lengths is to place the devices on the system first. Once all the devices and junctions are in place the lengths of all required cords can be measured using a marked rope to simulate the path of the actual installed cord. With these accurate measurements custom length cords can be ordered from **TURCK**. Custom length cords do not cost extra, and **TURCK**'s fast manufacturing time enables these cords to be delivered quickly. The benefits of using factory molded cords will be seen when the need to troubleshoot wiring errors at startup is practically eliminated.

For situations where pre-molded cords cannot be used **TURCK** has field wireable connectors available. These connectors are simple to assemble in the field, and consist of a hollow connector body with screw terminal points to land the wires at the connector head. It is common for installers to buy cords with one factory molded end and one end with open leads. In the field they will then trim the open end to the desired length and mount the field wireable connector on it. In most situations this has been found to be a good compromise between the benefits of molded cords and the customizability of the field wired solution.

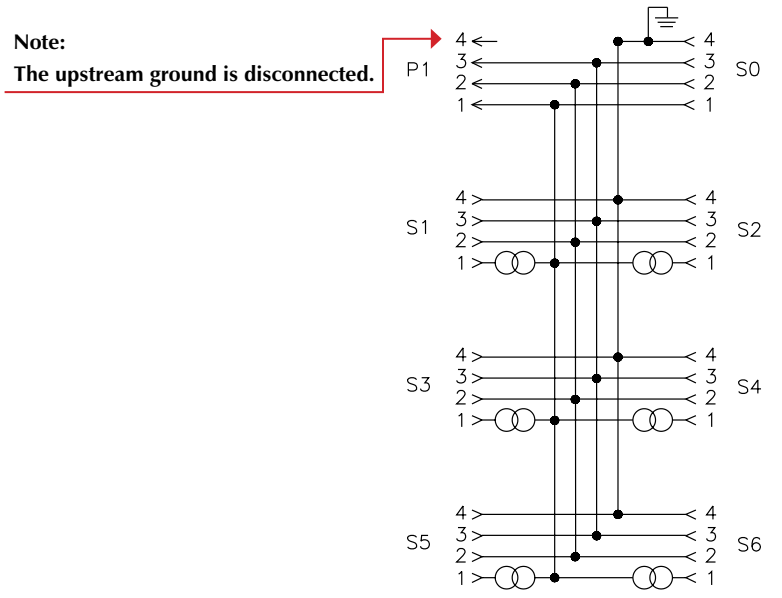


TURCK FIeld Wireable Connector

Shielding and Grounding

To ensure reliable communication the shield of the FOUNDATION fieldbus segment should be hard grounded at one point only. In North America most installations achieve this by grounding the shield at the control cabinet and leaving it open at the device end. If a good ground plane is in place it is possible to properly ground the shield at both the cabinet and the end devices, but this can be difficult to achieve in long length systems (most FOUNDATION fieldbus segments would fall in this category).

Device grounding on FOUNDATION fieldbus is handled similarly. The important thing to keep in mind is that ground loops must be avoided. One way to do this is to ground each device on the system individually, and not carry any ground potential through the communication cable (ungrounded cable). Another way is to use grounded cable and connect the grounds for a group of devices in a common physical location together. **TURCK** connectorized junction boxes easily enable this option by connecting the ground pins for all downstream ports and spurs together, while disconnecting the upstream ground pin, as shown in the following diagram.



Circuit diagram of a TURCK multiport junction box with current limited drops.

Troubleshooting

To ensure communication on the FOUNDATION fieldbus network, the required installation conditions must be met:

a) Segment lengths (including spurs) must not be longer than the values specified earlier for each cable type. Remember that for Type A cable the total segment cannot be longer than 1,900 meters.

b) Each device on the network must be provided with no less than 9 V and no greater than 32 VDC from the bus supply. Proper polarity must be ensured for most devices.

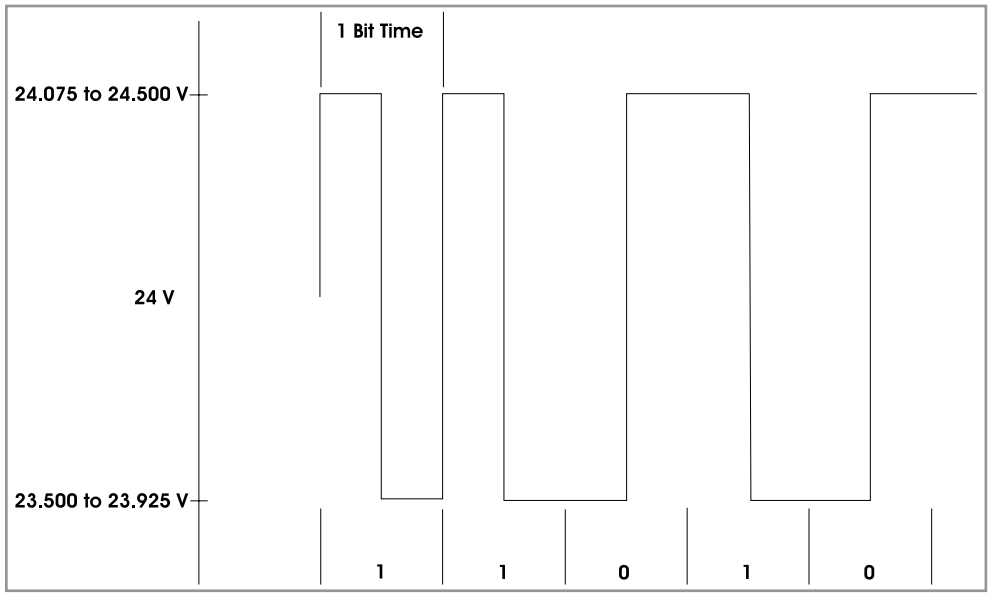
c) One terminator, consisting of a 1 μF capacitor in series with a 100 Ω resistor or the electrical equivalent of this combination, must be connected across the bus lines at each end of the segment.

d) The Fieldbus cable shield should be hard grounded next to the DCS (in the control cabinet). For improved EMC protection, capacitive grounding may be used in the field.

When commissioning the system, the best practice is to activate one device at a time. As each device is connected, take detailed measurements of the electrical parameters of the system with a multi-meter and of the communication signal with an oscilloscope. By logging these details at each step, it becomes much easier to localize a problem that might occur with a mis-wired or faulty device. It is also easy to remove the last added device and return to the last known good state.

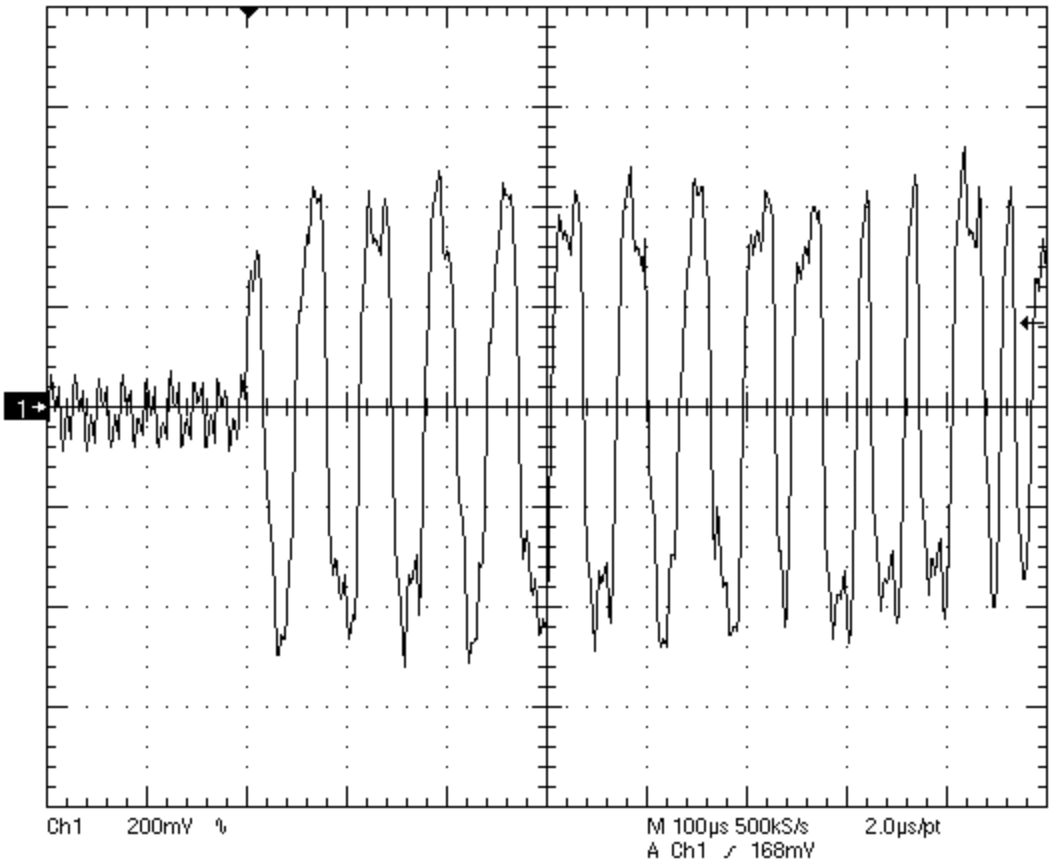
Ideally a handheld oscilloscope should be used for these measurements. If a desktop oscilloscope is used, care must be taken to view the signal as the difference between two channels in order to eliminate common mode noise introduced by the oscilloscope's ground connection.

An idealized FOUNDATION fieldbus signal is shown in the diagram below.



Idealized FOUNDATION fieldbus communication signal

A real world FOUNDATION™ fieldbus signal will also show a noise component. This can be measured by looking at the signal when no bits are being transmitted (idle state) as highlighted in the image below. The noise level must be less than 75 mV peak-to-peak for good communication.

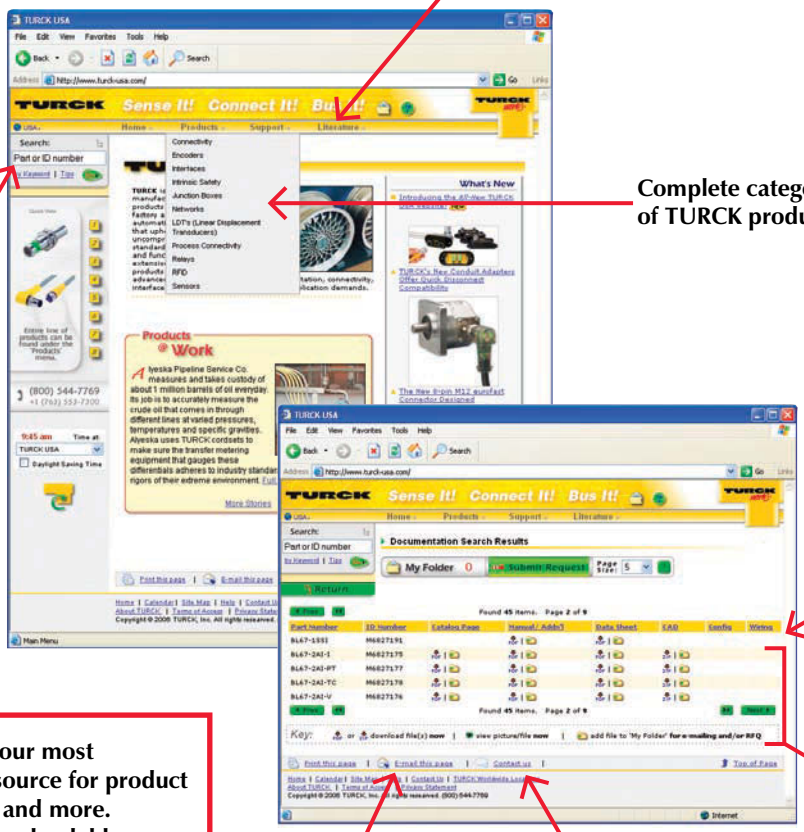


Real world FOUNDATION fieldbus signal with noise present.

Access to all TURCK catalogs, press releases, white papers and tutorials

Search for products by part number, ID number or key word

Complete category listing of TURCK products



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