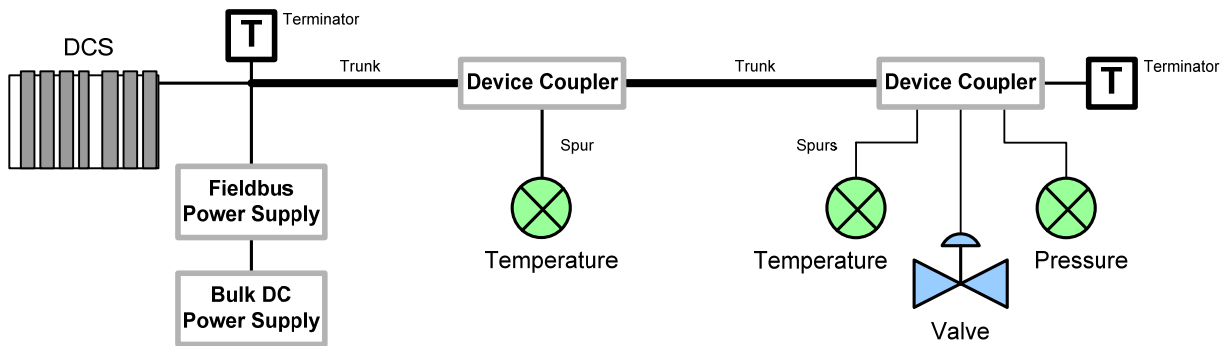


# Fieldbus

## Wiring Guide

4<sup>th</sup> Edition



# Fieldbus Wiring Guide

The purpose of this Fieldbus Wiring Guide is to provide information about the Fieldbus infrastructure so that its wiring system can be designed and installed for cost-effective and reliable operation.

There are many uses for Fieldbus and many ways it can be configured. It is not possible to give simple wiring rules that cover all cases. For this reason, this Guide will first explain how Fieldbus works so that the wiring system can be designed intelligently to achieve the best performance and most reliable operation with the lowest cost.

Fieldbus is defined in IEC standard 61158-2. Detailed implementation requirements beyond the standard are available from the Fieldbus Foundation, an industry consortium that promotes Fieldbus technology. These more detailed specifications are needed so that devices made by different manufacturers are interoperable in a control system.

There is more to Fieldbus than the wiring. For those wanting information about how Fieldbus works to control a process, refer to:

Fieldbuses for Process Control; Jonas Burge, ISBN 1-55617-760-7

*Foundation Fieldbus: A Pocket Guide*; Ian Verhappen and Augusto Pereira; ISBN 1-55617-775-5.

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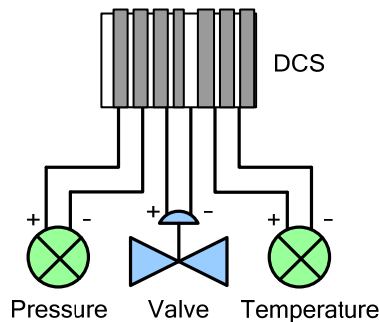
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# Chapter 1: Fieldbus Network Concept

**Summary:** Fieldbus is a Local Area Network for process control that uses a single wire pair for powering multiple devices and carrying signals between those devices.

Many different fieldbuses are currently available. This manual focuses on **Foundation™ Fieldbus** and **Profibus PA**, which will be referenced from here on as Fieldbus. Both of these networks share the same wiring and powering scheme. They are significantly different in the communication protocol area, but that is outside the scope of this guide.

In a conventional 4-20mA Distributed Control System (DCS), two wires are used to connect to a device (normally using shielded twisted-pair cable). The devices may be instruments for input measurements such as temperature or pressure. Devices can also be outputs such as actuators and valves. The wires carry electrical power to a device. The device signals its measured value to the DCS's controller by varying the current it uses between 4 and 20 milliamps (mA). The controller gathers the data from a number of devices via the dedicated I/O cards, makes the necessary calculations, and sends commands by varying the current to the actuator or valve. For example, 4 mA may mean that the valve is totally closed and 20 mA may mean the valve is fully open. This is referred to as an analog system, because the data transmitted varies continuously between 4mA and 20mA.



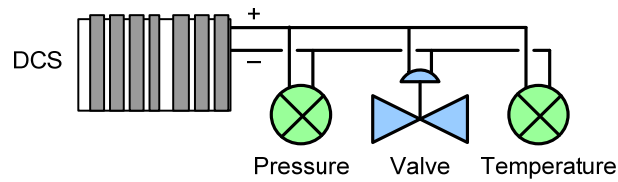
**Figure 1.1: Conventional DCS (4-20mA or HART)**

Fieldbus also uses two wires to carry power to the devices, as can be seen in Figure 1.2. For simplicity the cable shield is not shown – although it is considered required for Fieldbus. A number of devices share the same Fieldbus wires. Fieldbus devices vary the current on the two wires to send signals (See Chapter 3: Signals). The signal (data) is digital. This means that the values transmitted are discrete (not infinitely variable). This allows an error detection system to be employed to ensure that there are no errors induced by the transmission of data from the device.

Because devices share the wires, the devices can send data to each other without a DCS controller (host). Fieldbus data transmissions have more information than just a single variable about temperature, pressure, or valve position. From the data shared between the devices, the devices can be configured to control the process. The host then only supervises the operation. This is called “**control-in-the-field**”.

## Fieldbus Network Concept

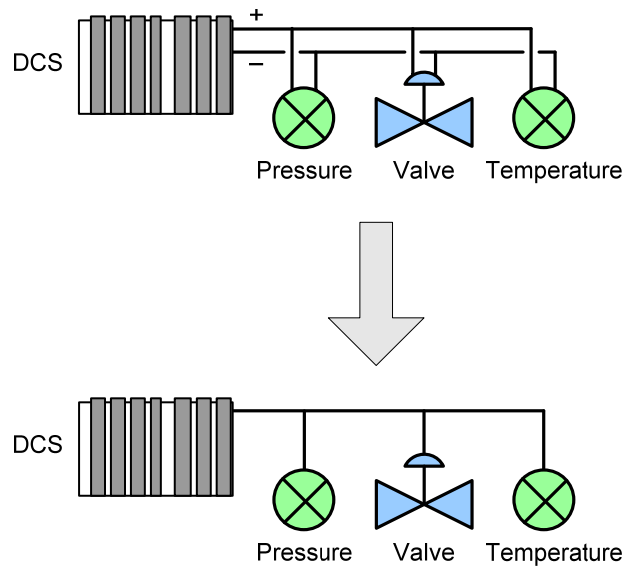
Fieldbus is a **local area network (LAN)** for process control.



**Figure 1.2: Fieldbus (Foundation™ Fieldbus or Profibus PA)**

The two wires are a twisted pair similar to the usual 4-20 mA wiring used for conventional devices. For more information, refer to *“Cable Selection, Installation, and Termination”* on page 6.

For the sake of simplicity of wiring diagrams, the wire pairs will be shown as a single line in the remainder of this document.

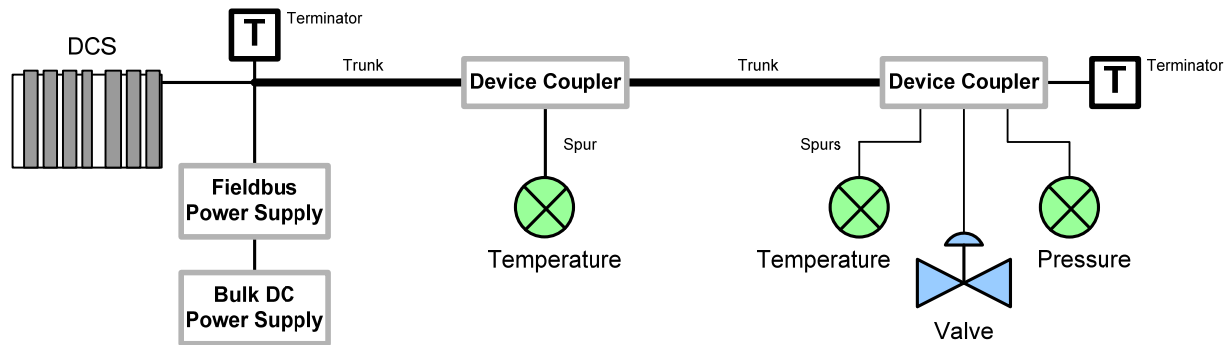


**Figure 1.3: Wiring Diagram Convention**

# Chapter 2: Fieldbus Configuration

**Summary:** A Fieldbus segment's wiring carries power to devices and signals between devices. A DC power supply and a Fieldbus Power Supply are needed to provide power to the Fieldbus segment. Two Terminators are required at each end of the segment.

Fieldbus is a process-control local area network used for interconnecting sensors, actuators, and control devices. A common type of Fieldbus configuration is shown below.



**Figure 2.1: Common Fieldbus Segment Configuration**

A **Trunk** cable connects control room equipment with a number of devices in the field (for example, sensors such as temperature or pressure transducers and actuators such as valve positioners). Multiple field devices can be connected with **Spur** cables to a Device Coupler (usually in a junction box). This is called a **Chickenfoot**, tree, or star topology. Devices can also be connected along the Trunk cable with a single-drop Device Coupler. This is called a **bus-with-spurs** topology. Multiple topologies may be used in a single segment although the most common is a single Chickenfoot.

A **Terminator** (T) is required at each end of the Fieldbus Trunk cable to avoid distorting signals and allow the twisted-pair cable to carry digital signals. For convenience, Terminators are often included in Fieldbus Power Supplies and Device Couplers, eliminating the need for separate Terminators.

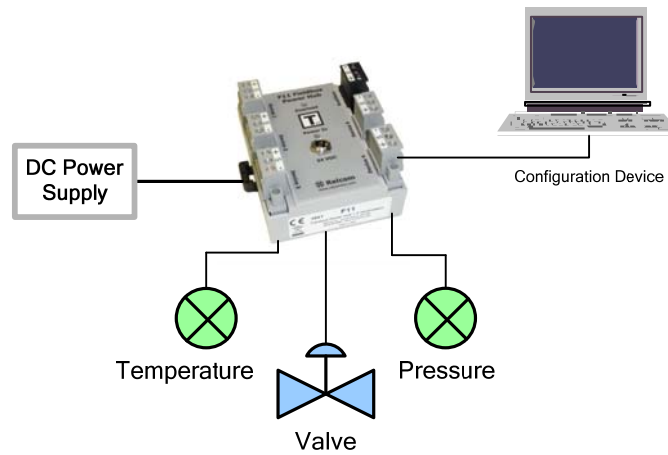
Power to the devices is provided by a Fieldbus Power Supply. The Fieldbus Power Supply is needed to separate the bulk DC power supply from the Fieldbus wiring so that the signals are not absorbed by the bulk DC power supply. The Fieldbus Power Supply is normally installed near the control room but could also be located in the field or in a marshalling panel.

A **DCS** with an **H1** interface is usually located in the control room. Its function is to oversee the operation of the control system, made up of the devices connected on the Fieldbus segment.

Often, a compact Fieldbus 'segment-in-a-box' is needed. It combines the Fieldbus Power Supply, Device Coupler, and Terminators into one box and is used on a bench top or in the field to power devices for configuration or validation. Figure 2.2 illustrates how this is done. The DC Power Supply is usually a wall transformer, but may also be a battery pack for use in the field where AC power is not readily available.

## Fieldbus Configuration

One or more devices may be connected to the unit. A configuration device that can manipulate the Fieldbus devices is also needed. This is usually an Emerson 375/475 or laptop with National Instruments hardware and software.

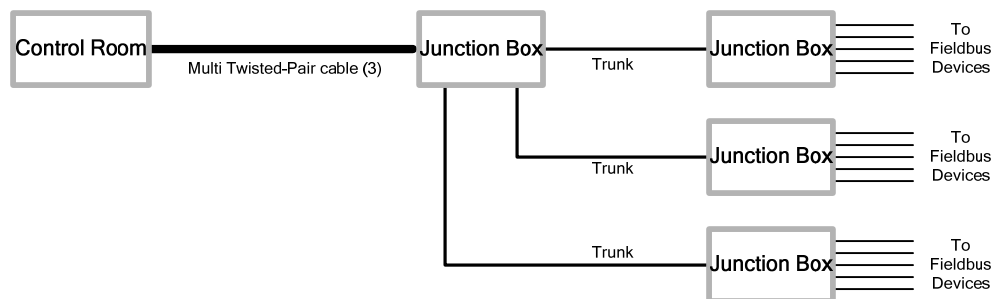


**Figure 2.2: Fieldbus “segment-in-a-box” using the Relcom F11 Power Hub**

Other Fieldbus configurations are possible. All configurations require basic signal transmission and power distribution capabilities provided by a shielded twisted-pair cable, two Terminators, and a Fieldbus Power Supply. These components are collectively referred to as a Fieldbus segment.

Although the defined device limit is 32, there are generally less than 16 devices on any single Fieldbus segment. In a large process plant, there may be several hundred segments. Each segment is powered by its own Fieldbus Power Supply. The segments are linked together in an overall control system through a software configuration within the DCS system that is beyond the scope of this Guide.

Large projects can take advantage of multi-pair Fieldbus cables. A single multi-pair cable supports multiple Fieldbus Trunks. The multi-pair cable is run to a strategically placed junction box. From there, the individual Trunks are then run to junction boxes in the vicinity of the individual devices. A Device Coupler in the junction box facilitates connection of the Spur(s) to the Fieldbus devices. This configuration helps reduce the overall cable installation cost.



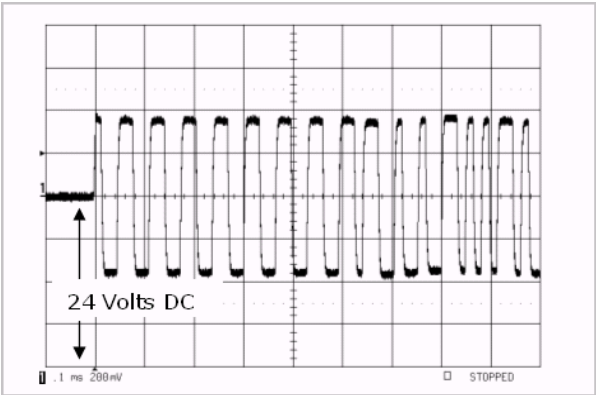
**Figure 2.3: Multiple segments installed using Multi-pair cable**

# Chapter 3: Signals

**Summary:** Devices on a Fieldbus segment transmit digital signals to each other over the same wires that power the devices. Each transmission on the segment is received by all devices. One device on the segment (the LAS) determines which device may transmit next.

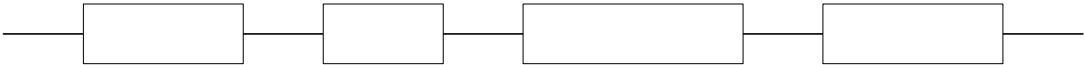
A DC bus voltage (nominally 24V but can be from 9-32VDC) is supplied to the devices on the segment by the Fieldbus Power Supply. A Fieldbus device draws a constant amount of current when not transmitting. To transmit information, the device varies the amount of current it draws from the segment to create a signal “riding” on the 24VDC. Digital data is sent on the Fieldbus at a rate of 31.25 Kbits/second.

The signal waveform is shown below. Note that the signal is above and below the 24-volt non-transmitting level on the segment. A typical Fieldbus signal is 750mV peak-to-peak, but can range from 150mV to 1000mV peak-to-peak.



**Figure 3.1: Fieldbus Signal**

If an oscilloscope were used to observe the signals on the Fieldbus, the display would show frames with gaps of silence between them, as shown below:



**Figure 3.2: Multiple Fieldbus Frames**

How Fieldbus is used for conveying specific types of process information is beyond the scope of this Guide.

More detailed information about Fieldbus signaling is contained in “Appendix A” on page 41.

# Chapter 4: Cable Selection, Installation, and Termination

**Summary:** Fieldbus uses shielded, twisted-pair cable. For reliable Fieldbus segment operation, use cable with the Foundation™ Fieldbus Checkmark, which demonstrates compliance with the FF-844 standard (also known as Type A Fieldbus cable). Use of Foundation™ Fieldbus checkmarked cable is also recommended for Profibus PA.

## Cable Selection

Fieldbus uses twisted-pair wires. A twisted-pair is used, rather than a pair of parallel wires, to reduce introduction of external noise onto the wires. A shield over the twisted-pair further reduces noise. The twisted-pair wires, the shield, and their covering jacket are called a cable.



Figure 4.1: Fieldbus Cable (Pencil shown for size comparison)

The Fieldbus Foundation released Fieldbus cable specification FF-844 to provide Fieldbus users with guidance in selecting cable. The standard requires robust cable rated for high temperatures and wires that are tinned to tolerate harsh environments.

For instances in which existing cable is intended to be reused for H1 communications, it should be thoroughly tested to ensure it is suitable for use with Fieldbus and in good condition.

Beyond the FF-844 standard requirements, it is worth considering the following:

- Conformance to existing plant standards, such as the wire insulation colors
- Roundness of the cable to get good sealing with cable glands
- Ease of removing the cable's jacket to reduce the chance of cable damage during construction.
- Multi-pair cables that can reduce installation cost
- 16 AWG cable is normally used for the Trunk because it supports longer distances
- 18 AWG is commonly used for the Spur cables because they are short

Good Fieldbus cable is critical for reliable operation of the plant. The price of good cable is relatively low; the cost of an erratic Fieldbus segment operation caused by use of substandard cable is expensive. The cost of replacing cheap cable is extremely expensive because not only must the cable be replaced but the plant will also be idle while this work is being done.

For a list of Fieldbus cables with the Foundation™ checkmark go to [www.fieldbus.org](http://www.fieldbus.org).

## Cable Installation

Cable is the base infrastructure for a Fieldbus segment. Deficiencies in the infrastructure will cause issues with communication. These issues can be difficult to pinpoint when the system is up and running. For this reason, it is extremely important to validate that the installation was done properly. Here are some important things to watch for:

- Protect from physical/environmental damage (conduit or cable tray)
- Ensure that the cable is not damaged during installation
- Pay attention to the manufacturer’s minimum bend radius
- Keep Fieldbus (low voltage) cables separated from high voltage (energy) cables – see the table below:

Type of Cable	Minimum Distance from a Fieldbus Cable
Fieldbus Cable	0 inches
60VDC or 25VAC and < 400VAC	4 inches
> 400VAC	8 inches
Subject to any electromagnetic exposure such as from a VFD (Variable Frequency Drive)	20 inches

**Table 4.1: Recommended cable separation distances (multi-level tray)**

## Cable Termination

When cable installation is complete, the next important thing is properly terminating the cable. Just like proper cable installation, proper cable termination will ensure a reliable segment for many years to come. Some things to consider are:

- Use a good cable jacket stripper to make this process quick without nicking the conductor jackets.
- A good quality wire stripper will remove the wire covering without nicking the copper strands.
- Use ferrules on the stranded wire to prevent stray wire strands which may later cause a short. Use a high quality crimping tool sized properly for the ferrules.
- Apply proper torque to screw terminals using a torque limiting screwdriver. Most people are amazed at the amount of torque it takes to meet the screw terminal manufacture’s specifications. Under-torqueing can later result in a loose connection.

Contact Relcom for recommended installation tools.

# Chapter 5: Terminator

**Summary:** A Terminator is needed at each end of the Fieldbus segment Trunk cable.

Two Terminators are required on each Fieldbus segment. Generally, one Terminator is at the control room end of the cable and the other Terminator is in the junction box in the field.

The Terminator can be a separate part, or it may be part of a Device Coupler or a Fieldbus Power Supply. The Terminator should be clearly marked so that it can be identified in an installed system.



**Figure 5.1: Terminator Examples**

A Fieldbus segment without two Terminators will not have the properly-shaped signals. A segment with only one Terminator may appear to function properly, but will have distorted signals with increased amplitude.

A segment with three or more Terminators will have decreased signal amplitude, and devices may lose the ability to communicate with one another. An extra Terminator will typically cause a 300 mV drop in signal level and a missing Terminator will cause a similar increase.

# Chapter 6: Connecting Devices

**Summary:** Fieldbus Device Couplers make wiring easier and more reliable. Only Device Couplers with the Foundation™ Fieldbus FF-846 checkmark should be used. Checkmarked Device Couplers should also be used for Profibus PA.

Device Couplers are the industry-standard method of wiring devices to a Fieldbus segment. Device Couplers provide short circuit protection that prevents the entire segment from failing if one device or Spur cable is shorted.

The Fieldbus Foundation created the FF-846 standard for Device Couplers. Device Couplers that meet the FF-846 standards are awarded a checkmark. Compliance with FF-846 ensures minimum standards are met for Device Coupler performance, including input impedance, reaction time to a short circuit, voltage drop, etc.

There are several ways to terminate cable to the Device Coupler. This includes screw terminals, pluggable screw terminals, and pluggable spring clamps. At the time of this writing, the most popular method is the pluggable screw terminal.

Two different types of Device Couplers are available: non-isolated and isolated.

## Non-Isolated Device Couplers

Non-isolated Device Couplers are used in the majority of Fieldbus installations where isolation is not required. These installations are typically classified Division 2, Zone 2, or non-hazardous. Isolation may be required for Division 1 or Zone 1, 0 hazardous area installations. See the isolated Device Couplers section for more information.

Figure 6.1 shows two non-isolated Device Couplers and a Terminator in a junction box. The black connectors are for the Trunk cable.

Figure 6.2 shows this arrangement schematically. The Trunk cable is attached to the upper left-hand terminal of the 8-Spur Device Coupler. The other end of the 8-Spur Device Coupler is connected to the 4-Spur Device Coupler with a short jumper cable. The other end of the 4-Spur Device Coupler is connected to the Terminator, (T). The ground connection on the Terminator is for surge abatement and is a feature of that particular Terminator (not an essential part of a Terminator's function).



Figure 6.1: Device Coupler Example

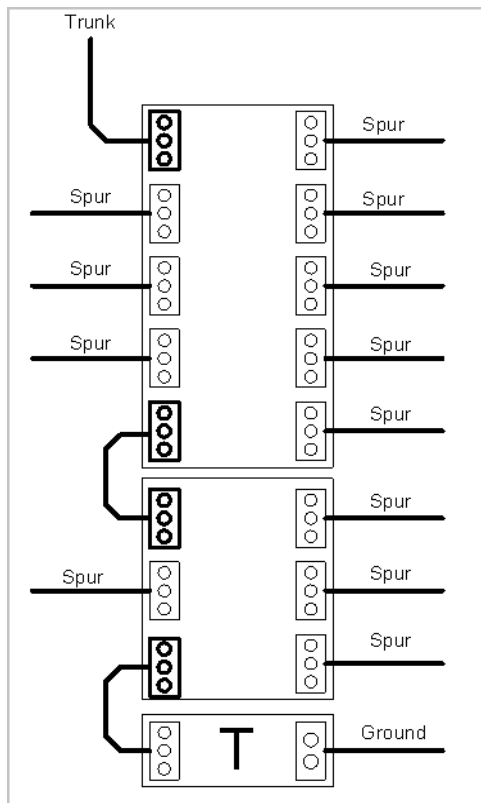
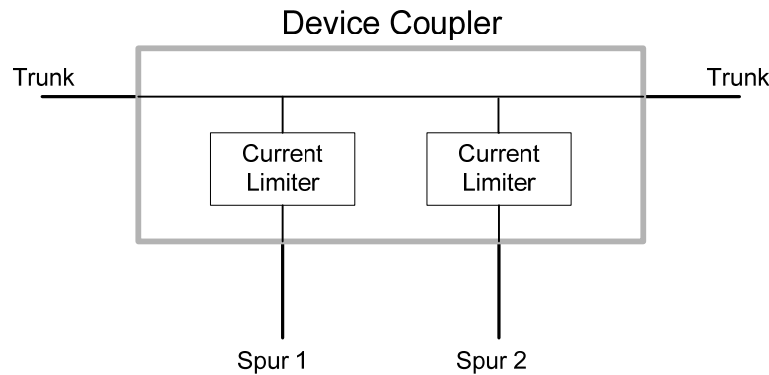


Figure 6.2: Device Coupler Example – connection diagram

This example shows how 12 Fieldbus devices are interconnected in a junction box. If the two Device Couplers had been in two separate junction boxes, the jumper cable would simply be a longer cable between the junction boxes.

Using pluggable screw terminals, the cable can be prepared and attached to the plug without reaching into the often tight spaces of a junction box. The plug is then inserted into the Device Coupler and fastened so that it does not vibrate out or become disconnected if cables are moved.

Device Couplers often have additional features, such as a DIN-rail mounting clip and an indicator light that shows if Fieldbus power is being supplied to the Device Coupler. The biggest benefit of Device Couplers is that they have current limiters built into them, which prevent a short on the Spur connection from bringing down the entire segment.



**Figure 6.3: Device Coupler Showing Current Limiters**

If a device or the Spur cable is shorted, the current is limited. The particular device on the Spur does not function, but the devices on the rest of the Fieldbus segment continue to work. For troubleshooting purposes, the Device Coupler has an indicator light that shows the shorted Spur. For more information on this topic refer to *“Reliability Considerations”* on page 16.

## Isolated Device Couplers

Isolated Device Couplers (also referred to as Fieldbus barriers) provide electrical isolation, voltage limiting, and current limiting between the Trunk and each Spur. Isolated Device Couplers are typically used in Zone 1, 0, and Division 1 hazardous area installations. Refer to *“Hazardous Areas”* on page 20 for more information.

One other impact of isolated Device Couplers is that the design must include isolating circuitry; therefore, on-line diagnostic tools installed on the Trunk will not be able to view and, hence, monitor all the segment health parameters for each of the Spurs.

It should also be noted that the characteristics of each manufacturer’s Isolated Device Coupler is different. To accurately determine bus conditions, calculations must be made from that manufacturer’s data/program instead of using a generic “segment calculator tool”.

# Chapter 7: Fieldbus Power

**Summary:** Fieldbus cannot be powered directly from a DC power supply. A Fieldbus Power Supply provides the required isolation and power conditioning to power a Fieldbus segment. Fieldbus Power Supplies with the Foundation™ Fieldbus checkmark should be used for both Foundation™ Fieldbus and Profibus PA.

Fieldbus Power Supply requirements are identified in Foundation™ Fieldbus specification FF-831. Fieldbus Power Supplies that meet these requirements earn the Foundation™ Fieldbus checkmark. Checkmarked power supplies meet minimum specifications for noise, impedance, jitter, and other important parameters.

The important components of a Fieldbus Power Supply are Isolation, Power Conditioning, and Current Limiting – see Figure 7.1 below:

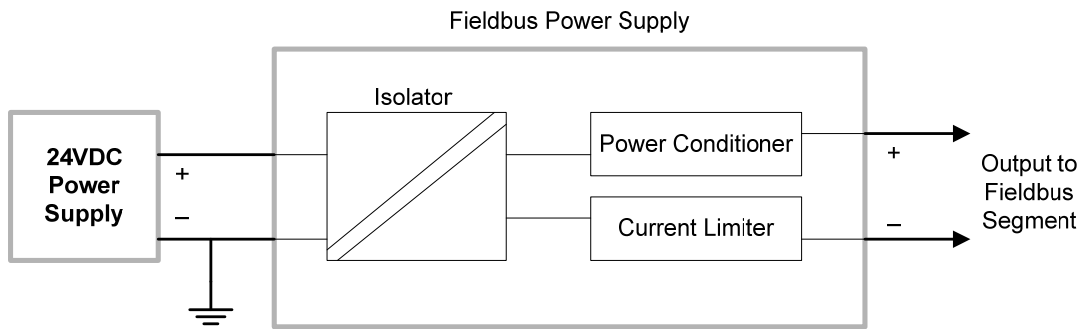


Figure 7.1: Fieldbus Power Supply

## Isolation

It is common practice for Bulk DC Power Supplies (usually 24V) to be grounded in an industrial plant. Fieldbus is required to be isolated from ground (to improve noise immunity). This is why Fieldbus Power Supplies contain an isolation stage.

## Power Conditioning

Although Fieldbus devices will power up with a normal power supply, they will not sustain communication. A DC power supply's job is to regulate the output voltage (say at 24VDC). It does its job so well that it absorbs any digital signal that a device would try to transmit. A Power Conditioner allows power to flow to the Fieldbus, but blocks the digital communication signal from flowing to the Isolator or DC power supply. It's like a one way valve.

## Current Limiting

A current limiter is provided in the Fieldbus Power Supply to prevent damage from a short-circuit or over-load condition. This also prevents the Fieldbus Power Supply from demanding too much current from the DC power supply.

## Selecting a Fieldbus Power Supply

As long as a Checkmarked Fieldbus Power Supply is used, there are only four things to consider when selecting the exact Fieldbus Power Supply for a particular segment:

- Hazardous Area
- Voltage
- Current
- Redundancy

## Hazardous Area

If any part of the segment goes into a hazardous area, the selection of the Fieldbus Power Supply may be affected. Whether it is affected or not depends on what method of protection is going to be used. For more information, see *“Hazardous Areas”* on page 20.

## Voltage

Fieldbus devices require between 9 and 32 VDC to operate (caution: some Fieldbus devices require more than the 9V minimum specified by the Fieldbus standard). Because long distances are involved in a segment installation, there is a significant voltage drop from the Fieldbus Power Supply (normally near the control room) to the Fieldbus devices. Fieldbus Power Supplies are available with various output voltages, and one must be chosen to sufficiently supply the farthest Fieldbus device.

## Current

The Fieldbus Power Supply must be able to supply all of the current requirements of the segment with some margin to the supply's rated output current. Further information is available in the *“Segment Monitoring”* section on page 19.

## Redundancy

For installations with high reliability requirements, redundant Fieldbus power supplies are desirable. See page 16 for further information on redundancy.

# Chapter 8: Fieldbus Segment Design

**Summary:** Power, distance, control system, process criticality, and area classification limit the size of a Fieldbus segment and the number of devices that can be interconnected.

## Power Distribution

The number of devices that can be on a Fieldbus segment is limited by the Fieldbus Power Supply voltage, the resistance of the wires in the cable, and the amount of current drawn by the devices.

The power distribution calculation quickly becomes complicated when multiple devices are attached to the cable at different places.

Calculators are available from some Fieldbus Power Supply manufacturers, a number of Control System suppliers, and the Fieldbus Foundation for making these Fieldbus segment calculations. The Fieldbus device characteristics, Fieldbus Power Supply, cable type, and cable lengths are entered into the calculator. The calculator indicates if the segment design is good, marginal or bad and displays the voltage at each device.

See “Appendix C” on page 45 for an example segment design calculation.

## Distance

The Fieldbus standard identifies distance limitations of Fieldbus cables.

The total length of all cables on the segment (Trunk length + Spur lengths) must be less than 1900m. The maximum Spur length is 120m. Additional limitations may apply based on the segment’s hazardous area location.

## Control System

Most Foundation™ Fieldbus control systems support a maximum of 16 devices on each Fieldbus I/O card.

Profibus PA specifies a limit of 32 devices per segment.

The control system is rarely the limiting factor when determining the maximum number of devices on a segment.

## **Process Criticality**

Plants often have design requirements limiting the number of devices and control valves on any one segment. This usually dictates the maximum number of devices on the segment.

## **Area Classification**

Installation in hazardous areas can also limit cable lengths and the number of devices on a segment. See "*Hazardous Areas*" on page 20 for further information on hazardous area location considerations.

# Chapter 9: Reliability Considerations

**Summary:** Since Fieldbus uses shared wiring, reliability precautions need to be taken for segments used in critical applications. Reliability enhancement includes short circuit protectors on Spur cables, protected Trunk cable, redundant power supplies, and surge protectors.

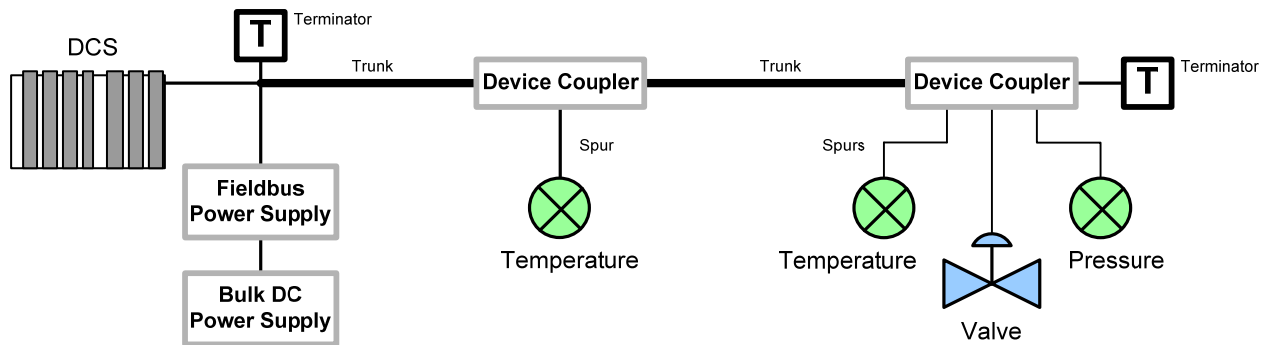


Figure 9.1: Fieldbus segment

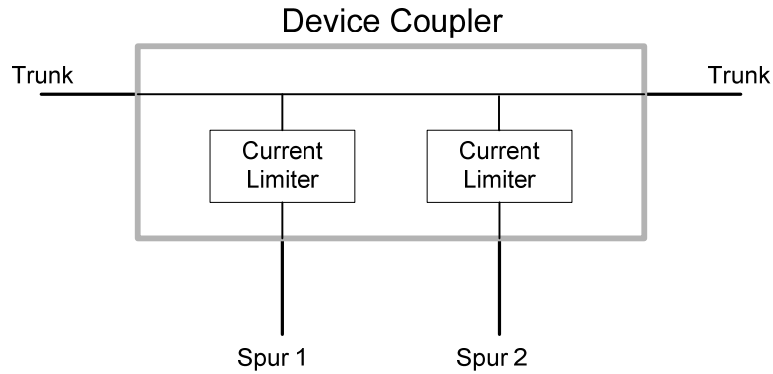
The shared wiring and the Fieldbus Power Supply are critical resources, because all the devices share the same cable and power supply. If these fail, then the whole segment is inoperative. The main Fieldbus reliability issues are:

- Spur short circuits
- Trunk failures
- Power failures
- Surges
- Segment monitoring

## Spur Shorts

Since Fieldbus wiring is shared, a short circuit in one of the devices or in its Spur cable disables the segment and the whole process that depends on it. This can happen when a new instrument is installed, an instrument is serviced, or the device becomes waterlogged.

This potential problem can be overcome by using a current limiter between the Trunk cable and the Spur cable. These are built into a Device Coupler. The current limiter only allows a given amount of current to be used by each device. If a Spur is shorted, the current will be limited within a few microseconds. Only the shorted device is affected; the rest of the devices continue to operate.



**Figure 9.2: Spur Short Circuit Protection with Active Current Limit**

Current limiters are always set at a higher value than the Fieldbus device current. For this reason, always add the current from one shorted Spur to the total current needed by the segment. This ensures that enough current is available to supply all devices and the voltage at the furthest device is above its minimum required voltage. Many segment calculators perform this function automatically.

## Trunk Cable Failures

Another vulnerability of the system is the Trunk cable. If it is cut, then the power to the field is lost. While this is true, Trunk cable vulnerability is something that is also a problem in traditional 4-20mA DCS systems because of the use of multi-pair cables.

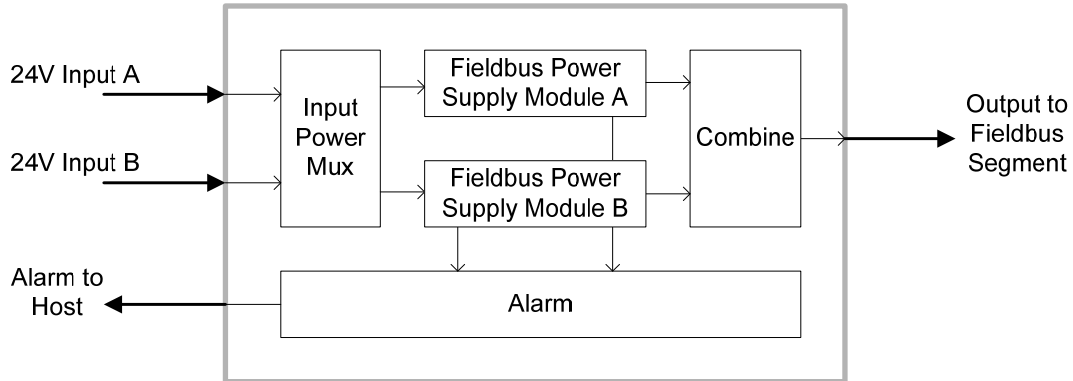
In the end, if system reliability is a concern, the Trunk cable needs to be protected in a conduit or a sturdy cable tray.

## Power Supply Failure

If Fieldbus segment power fails, the entire Fieldbus segment is taken down and control is lost. Redundant power supplies make this possibility very small.

The component parts of a redundant Fieldbus Power Supply are shown below. The Fieldbus Power Supply's input comes from two battery-backed bulk power supplies that provide 24 V power to various other pieces of equipment in the control room. The input 24 V power feeds two independent Fieldbus Power Supplies. The outputs of the two Fieldbus Power Supplies are combined to feed the Fieldbus segment.

## Reliability Considerations



**Figure 9.3: Redundant Fieldbus Power Supply**

However, redundancy alone is not enough. There must be alarming as well. Without alarming an operator is unaware of the first failure. A second failure can then take the redundant system down. The alarming shown above monitors the input power and each of the Fieldbus Power Supplies. The alarm itself can be a simple normally-closed relay contact. This relay is connected to the DCS and notifies the operator that there is a problem. Indicator lights on the redundant power supply show maintenance personnel which module of the supply is defective. The faulty Fieldbus Power Supply module can be hot-swapped with no disruption to the operation of the Fieldbus segment.

The table below shows an example **Mean Time to Failure (MTTF)** of the components of a redundant Fieldbus Power Supply.

Component	Mean Time To Failure
Fieldbus Power Supply module	54 years
Fieldbus Power Supply backplane and alarming circuits leading to failure of Fieldbus segment	88000 years

**Table 9.1: Redundant Fieldbus Power Supply Mean Time to Failure**

A more useful figure for the control engineer is the Availability of a system.

The Availability for a Fieldbus segment due to the redundant Fieldbus Power supply system can be 99.9999989% or even higher. This means that a Fieldbus system could be down due to redundant power supply failures on average for 0.3 seconds/year.

For details on the Availability calculation, see “Appendix B” on page 44.

## Lightning Surges

There is no protection against a direct lightning strike. The energy involved is too great. The struck device simply disintegrates.

Lightning strikes also have effects at great distances from the strike point. The voltage between earth points that are normally considered at the same potential becomes large. If a cable connects devices that are at some distance from each other, the ground potential difference can travel over the cable and break down the electrical isolation of Fieldbus devices. Since many Fieldbus devices share the same cable, a lightning surge can adversely affect all of them.

The general rule is that if the horizontal distance between devices is greater than 100m or vertical separation greater than 10m, lightning surge protection should be used. Given that Fieldbus devices are unlikely to all be mounted within a few meters of each other, the voltage developed between any two devices could be large enough to breakdown insulation and produce damage.

Installations must also consider that with the increased use of high voltage, high frequency equipment such as variable speed drives there are also increased risks of harmonics and other induced voltages as sources of surge currents on a segment.

For further information on Surge Protection, see technical data available from manufacturers of Surge Protection equipment for Fieldbus. Note that it is important that the Surge Protection devices are specifically designed for Fieldbus.

## Segment Monitoring

Another way to improve segment reliability is to continuously monitor the segment to get early warning of potential issues. Diagnostic products are available to monitor:

- DC voltage
- Device signal levels
- Noise levels
- Shorts to the shield
- Communication health

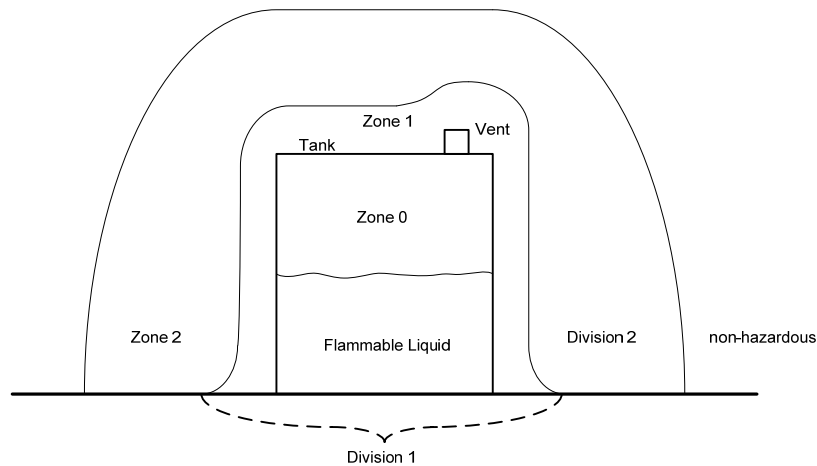
This information can be tracked by the asset management system for trend analysis. With this information, it is possible to reduce the number of unexpected failures.

# Chapter 10: Hazardous Areas

**Summary:** There are many good solutions for installing Fieldbus in a hazardous area. Choosing one method involves company policy and an analysis of the benefits and costs of each option. Special installation and design practices may need to be followed for the hazardous area.

## Defining the Hazardous Areas

The majority of hazardous areas in which Fieldbus is installed contain hazardous gases that may be present at different frequencies (hours per year). Our discussion will focus on this category. Figure 10.1 illustrates that hazardous areas are categorized in two different ways: “Divisions” are typically used in North America, while “Zones” are used in the rest of the world.



**Figure 10.1: Hazardous Area Classifications**

## Definitions:

<b>Normal Operating Conditions</b>	The condition that the apparatus is expected to operate in. This includes opens, shorts, and grounding of any wiring connected to the apparatus.
<b>Method of Protection</b>	The method used to protect from an ignition in a hazardous area.
<b>Energy limited</b>	An apparatus output or wiring that does not contain enough energy to cause an ignition even if opened, shorted, or grounded.
<b>Non-incendive</b>	An apparatus or wiring that will not cause an ignition under normal operating conditions. This does not necessarily mean it is energy limited. If an apparatus outputs high energy but is protected in some way (from shorts, opens, and grounding), it

- Non-incendive Field Wiring** can still be called **non-incendive**.  
A phrase used in the U.S. to indicate that the apparatus output or wiring is energy limited and will not cause an ignition even when opened, shorted, or grounded.
- Non-Arcing** The apparatus or wiring is not capable of generating a spark or hot surface under normal operating conditions. Typically high energy exists that could cause a spark, but some method is being used to protect against an ignition (protect from shorts, opens, and grounding).

## Methods of Protection

When planning to install Fieldbus in a hazardous area, the first thing that must be determined is the method that is being used to protect from an ignition (explosion). The method chosen may have to do with company policy, but in most cases is a function of installation cost and operational maintenance.

Explosion Proof is a method that either prevents the gases from getting to the electrical energy, or prevents an ignition from propagating (by containing it within the Explosion Proof enclosure). This method of protection may be used in all hazardous areas and does not put any restriction on the equipment used. Equipment only certified for General Purpose (non-hazardous) installation can be used with this method. The remaining methods of protection differ depending on the hazardous area. The following will now focus on the two main hazardous areas.

## Division 2 / Zone 2

Method of Protection	Trunk	Spurs
Non-Arcing	Non-Arcing	Non-Arcing
High-energy Trunk	Non-Arcing	Energy Limited
FNICO (FISCO ic)	Energy Limited	Energy Limited

**Table 10.1: Div2/Zone2 Methods of Protection**

### Non-Arcing

For Div 2 / Zone 2, a non-Arcing method of protection means that the wiring and electrical apparatus do not generate sparks or hot surfaces that could cause an ignition under normal operating conditions. In this case, the wiring must be adequately protected to prevent open, shorts, and grounding. In general, the system cannot be worked on while powered unless the area is 'sniffed' to ensure no hazardous gases are present.

Beyond the physical protection of the wiring and devices, no other special design requirements are imposed on the Fieldbus equipment. As long as the equipment is certified as non-Arcing, it can be installed as if it were in a non-hazardous area (subject to the hazardous area specific installation requirements).

## High Energy Trunk (Div 2 / Zone 2)

The term “High Energy Trunk” is used to indicate that the Trunk carries an incendive level of power and must be protected as in the non-Arcing case, but the Spurs are energy limited – in this case by the Device Coupler.

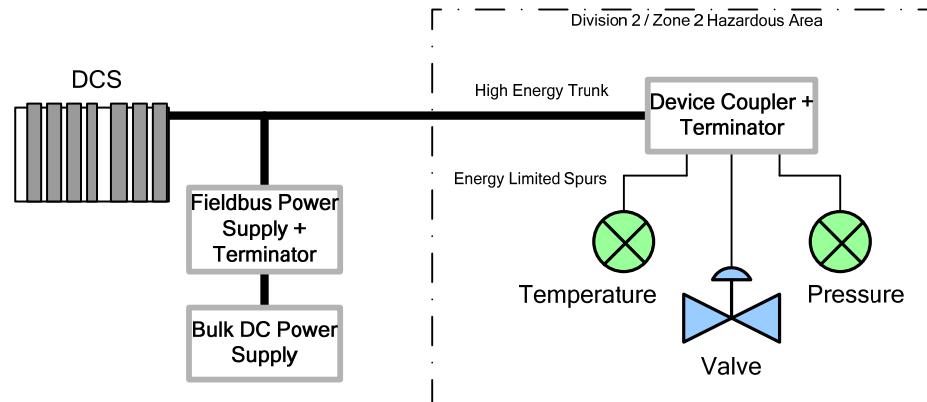


Figure 10.1 High Energy Trunk segment (Div 2 / Zone 2)

This is the most popular way to install Fieldbus in a Div 2 / Zone 2 hazardous area. Due to the high power on the Trunk, the number of devices and length of the segment are not limited due to being in the hazardous area. Current limitation is provided in the Device Coupler which limits the energy on the Spur and to the Fieldbus device. The Spurs may then be worked on while power is applied without getting a gas clearance permit (subject to local codes). Since the Trunk is high-energy, it is common for these installations to use Redundant Fieldbus Power Supplies for high reliability.

Refer to “Current Limiters for Non-Incendive Protection” on page 29 for more details about using this method of protection.

## FNICO (FISCO ic)

FNICO stands for Fieldbus Non-Incendive Concept. It is the Zone 2 version of FISCO (Fieldbus Intrinsically Safe Concept). Recently, the standards have changed and added a Zone 2 specification to FISCO, called ‘FISCO ic’. Eventually, the term FNICO will disappear.

FNICO here implies that the Fieldbus Power Supply is certified as a FNICO (or FISCO ic) device. As such, its output is limited in energy such that a short, open, or grounding of the wiring will not cause an ignition in the presence of hazardous gases. So, in this case, the entire segment (from the FNICO supply up to and including the Fieldbus Devices) is energy limited. This has the advantage of being able to live work the entire system. The disadvantage is that, because of the limited energy, the cable length will be shorter than the previous methods discussed, and the number of Fieldbus devices on the segment will be less.

## Division 1 / Zone 0,1

Method of Protection	Trunk	Spurs
Increased Safety	Non-Arcing	Non-Arcing
High-energy Trunk	Non-Arcing	Intrinsically Safe
FISCO	Intrinsically Safe	Intrinsically Safe

**Table 10.2: Div1/Zone0,1 Methods of Protection**

### Increased Safety

Increased Safety is a non-Arcing technique for Zone 1. Since gases are more likely to be present in Zone 1 than in Zone 2, the requirements on the equipment certified and installed under Increased Safety are higher to reduce the probability of an ignition. Note that this method of protection is not available for Divisions.

Details of an Increased Safety installation are beyond the scope of this guide. However, as in Div 2 / Zone 2 non-Arcing, as long as the certification requirements are met, the Fieldbus segment is installed as if it were non-hazardous - in other words, with lots of power, cable length, and Fieldbus devices.

### High Energy Trunk (Fieldbus Barriers)

In similar fashion for Div 2 / Zone 2, High Energy Trunk for Zone 1 has an incendive-level trunk which is usually installed using Increased Safety techniques. The segment then contains an **Isolated Device Coupler**, more commonly called a Fieldbus Barrier, in the field to separate the Trunk from the Spurs. The Spurs are then Intrinsically Safe (entity or FISCO).

A Fieldbus barrier uses a combination of non-Arcing and FISCO techniques to allow Fieldbus devices to work in a hazardous area. A Trunk cable going through a Div 1 or Zone 1 area carries Fieldbus power between a Fieldbus Power Supply in the control center to the Fieldbus barrier. Since the Trunk is high-energy, it is possible to use Redundant Fieldbus Power Supplies with Fieldbus barriers.

The function of the Fieldbus barrier is to provide galvanic isolation between the Trunk cable and the Spur cables. It also reduces the voltage to each Spur to an acceptable value and limits the current to each device. The Fieldbus barrier also provides a way for signals to travel between the Trunk and the Spurs.

The diagram below shows the general Fieldbus barrier arrangement. A Fieldbus barrier generally serves four to six Fieldbus devices. Multiple Fieldbus barriers may be on the same Trunk cable.

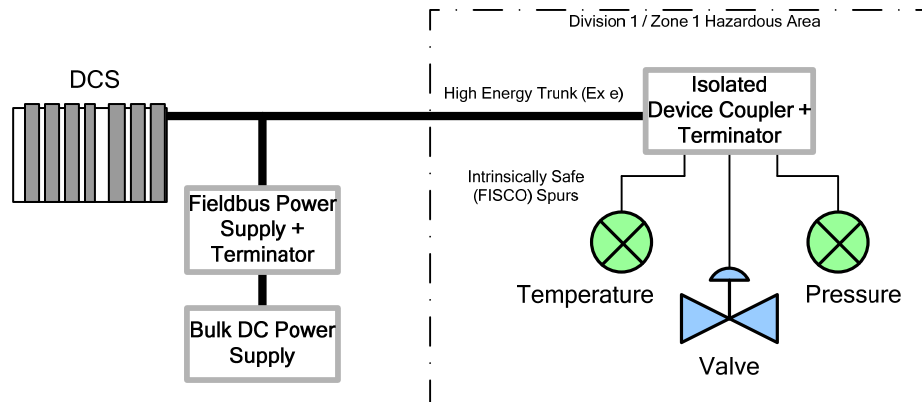


Figure 10.2 High Energy Trunk (Div 1 / Zone 1)

The Fieldbus devices and the Spur cables may be worked without determining if the area where they are located is safe (subject to local codes). The Trunk cable, however, cannot be live worked, and the area must be determined to be safe before any work is done.

It is important to remember that since the Fieldbus barrier contains active components, the required input voltage at the barrier will need to be greater than 9 volts. In addition, because each manufacturer's Fieldbus barrier has unique characteristics, a Segment Calculator tool provided by that manufacturer MUST be used when designing the segment.

## FISCO

FISCO stands for Fieldbus Intrinsically Safe COnccept. Please see chapter 11 for detailed information on FISCO.

The concept here is similar to FNICO except in Div 1 / Zone 1 areas, energy limited means Intrinsically Safe. Energy is limited to a lower level than FNICO. So, like FNICO, both the Trunk and Spurs are protected by a FISCO Fieldbus Power Supply that limits the energy to meet the Div 1 / Zone 1 requirements. This means that cable length and number of devices on the segment is further reduced from FNICO levels. However, the advantage is that the entire segment (beyond the FISCO supply) may be live worked. Recently, a Redundant FISCO Supply has been developed to improve system availability.

# Chapter 11: FISCO

The Fieldbus Intrinsically Safe COnccept (FISCO) is the result of experimental work that was prompted by practical limitations of the original FF-816 “Entity” concept for 31.25kbits/s intrinsically safe (IS) bus networks. This research showed that, provided the inductance and capacitance per unit length of field cables are kept within defined limits, the risk of spark ignition does not increase with the total length. These findings have been used to simplify the design and documentation of IS Fieldbus and to support more Fieldbus devices with greater cable lengths than was possible under the ‘Entity’ model. To assemble a FISCO Fieldbus system, the FISCO Fieldbus Power Supply, field devices, cables, and wiring components need to comply with FISCO design rules, as defined in IEC standard 60079-27.

A typical FISCO system includes a power supply and conditioner (containing the IS barrier) to provide power to the bus, and certified wiring components to make connections between the Trunk and Spur cables. Figure 11.1 shows a typical arrangement.



Figure 11.1: Typical FISCO segment

FISCO strengthens the case for a fully IS approach by increasing the available current and, hence, the number of field devices that can be supported. It therefore delivers a number of benefits over the earlier ‘Entity’ model for Intrinsically Safe fieldbus:

- The elimination of cable parameter calculations throughout the whole segment, including Trunk and Spurs. This means that modifications, such as the addition of a field device, may be undertaken without re-assessing the whole combination of devices and interconnecting cable.
- The opportunity to provide higher levels of output current in IEC Group IIB / North American C, D gas groups that are more commonly-occurring than IIC/Groups A, B. Practical FISCO power supplies for IIB/Groups C, D have an output voltage of 13.1V and a maximum current as high as 265mA.

## Why choose FISCO?

Users who have selected FISCO have done so for one or more of the following reasons:

1. *Internationally recognized*

The IEC60079-27 standard that defines the rules for selecting, installing and maintaining FISCO apparatus is internationally recognized and adopted into the national standards systems of many countries worldwide. The FISCO standard is also recognized by the Fieldbus Foundation and is comprehensively supported in the Foundation's application guides, such as AG-163 (for 31.25 kbits/s Intrinsically Safe Systems).

2. *Familiar, established, safe*

The entire field segment of a FISCO installation – including Trunk and Spurs – is intrinsically safe, meaning that conventional IS maintenance practice can be applied universally. This may be especially important for end users who are making the transition from conventional point-to-point wiring to Fieldbus, and who wish to transfer familiar and established IS practice without the need for re-training of instrument technicians. Intrinsic safety is also well-documented in the installation codes of all industrialized nations, and benefits from clearly defined rules for the opening of field enclosures and maintenance of circuits while energized.

3. *Simpler is better*

The only item required to be installed in the field in a FISCO segment is an intrinsically safe Device Coupler or *Megablock* and its associated enclosure, which, depending on the application, may accommodate up to 12 field device connections.

## Assembling FISCO segments

To ensure compliance with FISCO, the power supply and fieldbus instruments must not only be certified to conventional IS standards (appropriate to the Zone or Division of use), but they must also comply with the IEC60079-27 standard and be marked 'FISCO'. Further analysis of the safety parameters is not necessary, since compatibility is automatically guaranteed by the certification process. The "safety parameters" for FISCO power supplies and Fieldbus instruments are given in Tables 12.1 and 12.2, respectively. The Device Coupler and Terminators must also carry IS certification and have input safety parameters that are compatible with the output of the supply.

Maximum output voltage, $U_o$	$\leq 17.5V$
Maximum output current, $I_o$	$\leq 380mA$
Maximum output power, $P_o$	$\leq 5.32W$ (excluding Ex ic power supplies)
Maximum unprotected internal capacitance $C_i$	$\leq 5nF$
Maximum unprotected internal inductance $L_i$	$\leq 10\mu H$

**Table 11.1 - FISCO safety parameters for Fieldbus Power Supplies**

Input voltage parameter $U_i$	$\leq 17.5V$
Input current parameter $I_i$	$\leq 380mA$ (excluding Ex ic Field devices)
Input current parameter $P_i$	$\leq 5.32W$ (excluding Ex ic Field devices)
Maximum unprotected internal capacitance $C_i$	$\leq 5nF$
Maximum unprotected internal inductance $L_i$	$\leq 10\mu H$ ( $20 \mu H$ for Ex ic)

**Table 11.2 - FISCO safety parameters for Fieldbus Devices**

Because FISCO is based on experimental data, the total cable length of the system is limited to a maximum of 1,000m in IIC/Groups A, B gases and 1,900m in IIB/Groups C, D (limited by FF-831 and therefore identical to any Fieldbus system). The maximum Spur length for any FISCO installation is 60m per Spur. If these length restrictions are adhered to, the IEC60079-27 standard permits the cable parameter calculations (normally associated with IS circuits) to be omitted.

The IEC60079-27 standard also requires that cables used in a FISCO segment conform to specifications for resistance, inductance, and capacitance per unit length. These parameters are stated in Table 11.3. Typical Fieldbus cable has parameters of 50ohms/km, 0.8mH/km, and 120nF/km, so these limits are not restrictive. Compliance should normally be demonstrated by obtaining a specification from the cable manufacturer. However, the parameters are not restrictive since they are met by most cables that are designed specifically for Fieldbus applications. If existing, installed cables are to be used, or if no specification is available from the cable manufacturer, compliance may be shown by measurement.

Loop resistance	15 – 150 ohms/km
Loop inductance	0.4 – 1.0 mH/km
Loop capacitance	45 – 200 nF/km

**Table 11.3 - FISCO Cable Parameters (from IEC 60079-27:2004)**

## Other design considerations

Set against the advantages of FISCO are the technical boundaries that are imposed by designing for intrinsic safety. The most significant constraint is the reduced output voltage at the terminals of the FISCO power supply, which must be considered carefully when designing the Fieldbus segment.

### Influence of output voltage on segment length

The minimum output voltage of a typical FISCO power supply for IIC/Groups A, B gases is 12.4V, and is 13.1V for IIB/Groups C, D. Fieldbus instruments are required by the Fieldbus Foundation to operate at a minimum of 9.0V, and a margin on the operating voltage is sometimes applied. The permitted distance and the number of instruments supported follow Ohm's law: the more devices, the greater the total current consumption and the higher the voltage drop on the Trunk.

In practice, a typical IIC/Groups A, B unit can power a Fieldbus segment comprising 10 Fieldbus devices with a Trunk cable length of up to 400m, with Spurs at up to 60m length. A IIC/Groups C, D power

supply can typically support 6 Fieldbus devices with Trunk lengths in excess of 500m. Both examples assume an average field device current of 17mA and the use of fieldbus cable with 0.8mm<sup>2</sup> cross-sectional area, but by using higher cross-sections (such as 1.5mm<sup>2</sup>) with corresponding lower resistance per meter, the Trunk length can be increased significantly.

Note that the output of some FISCO power supplies is “Ex ib,” which restricts the field wiring to Zone 1 in IEC applications. “Spur converters” are available where field instruments need to be located in Zone 0. Individual Spurs may similarly be adapted to accommodate Entity-certified field instruments.

### ‘Multi-drop’ capability

Some FISCO power supplies function not only as a Fieldbus Power Supply and intrinsic safety barrier, but also as a Fieldbus *repeater*. Normally, repeaters are associated with extending the length of a Fieldbus segment by serially recreating a new segment “end-to-end” with the first one. An alternative use is to create parallel segments by “multi-dropping” a number of FISCO power supplies from the same DCS H1 connection, thereby creating multiple hazardous area segments. This is illustrated in Figure 11.2. The technique has the following potential benefits that have been exploited in existing FISCO installations:

- In applications where the number of field devices *per segment* is limited due to intrinsic safety constraints (such as in IIC/Groups A, B where the output voltage and current of the FISCO power supply are more limited), combining several segments can take full advantage of the logical capacity of the DCS system’s interface card. This yields hardware cost savings in the DCS system. For example, if four field devices are supported on each of three multi-dropped hazardous area Trunks, then the DCS H1 card sees twelve devices.
- The scope of loss is reduced in the event of failure of any single FISCO power supply, since other supplies on the same segment will continue to operate.

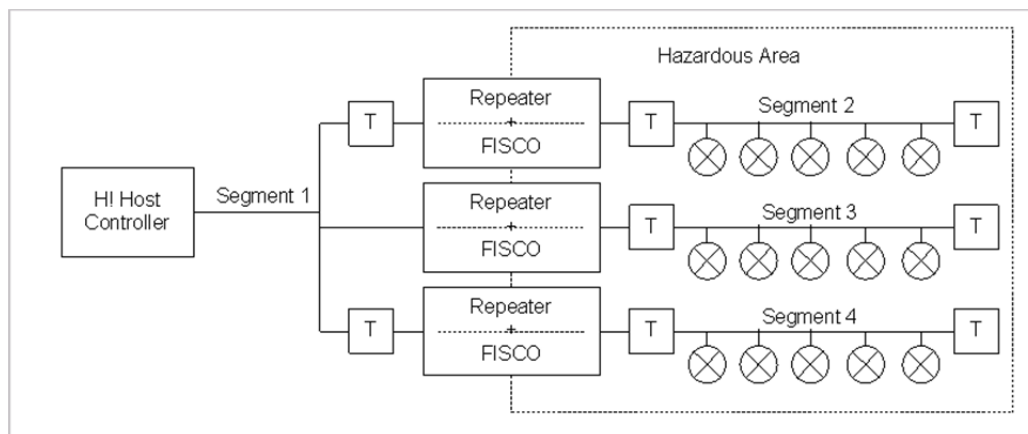


Figure 11.2: FISCO power Supplies in ‘Multi-drop’ configuration

### Redundant FISCO power supplies

This discussion on FISCO has so far assumed that the power supplies are not redundant. Redundant FISCO power supply modules are now available to increase the overall system availability by eliminating single points of failure.

# Chapter 12: Current Limiters for Non-Incendive Protection

**Summary:** Since current limiters are used on the Spur connections from the Device Coupler, the connected Spurs and Fieldbus devices in a Div 2 or Zone 2 area can be live worked without permits if the design/installation is done correctly.

Not only do current limiters in Device Couplers protect a segment from a short circuit on a Spur, they also permit a Fieldbus device to be connected or disconnected from a segment in a hazardous area without turning off the power to the segment or having to determine by sniffing if the area is safe.

This is only applicable to Div 2 or Zone 2 areas and only in places that allow live working (not in Canada, for example). In addition, since the Fieldbus Power Supply, Device Coupler, Spur Cables, and Fieldbus Devices can all affect whether the Spur is safe to live work, each one has specific requirements:

1. The Fieldbus Power Supply's only requirement is to limit the voltage to the Trunk. It must have a certified maximum output voltage. If the Spurs are to be "Ex ic" (Intrinsic safety for Zone 2), then something upstream of the Spur must limit the voltage according to IEC60079-11. This could be the Fieldbus Power Supply, Device Coupler, or some other apparatus. Suppliers of this equipment will be able to provide the necessary information.
2. The Device Coupler must be certified for this type of protection and have output parameters to ensure safety. The current limiter in the Device Coupler is limiting the current to a safe level. Typically, something upstream of the Device Coupler is limiting the voltage. The net combination limits the power and, hence, the energy to make the Spurs safe to live work.
3. Spur cables are to be less than 120m (60m for FISCO ic). This limits the capacitance and inductance to a level that is not a concern for safety. This information will still need to be documented to show that the system is safe.
4. Finally, the Fieldbus devices must also be certified with entity parameters or as a FISCO device for "Ex ic" installations. An important thing not to overlook is that the Fieldbus device must have these entity parameters with a maximum input voltage that is not exceeded by the Fieldbus Power Supply (unless some other certified device between the Fieldbus Power Supply and the Spur is further limiting the voltage).

**Note:** Device Couplers may not be connected to or disconnected from the Trunk cable without determining that the area is safe or without turning off the power to the segment.

For more in-depth coverage of Non-incendive, please see the document 502-145, "Non-incendive Fieldbus for Simplified Maintenance" on the Relcom Inc. website: [www.relcominc.com](http://www.relcominc.com).

# Chapter 13: Grounding/Earthing

**Summary:** The shield (or screen) wire on the Fieldbus cable should be grounded (earthed) in one place – typically near the Fieldbus Power Conditioner (which is usually near the DCS).

The Fieldbus standard is very clear that the twisted pair must NOT be grounded. Fieldbus is intended to be isolated from ground to improve noise immunity.

The shield (or screen) wire must be grounded. We recommend grounding the shield at **ONLY ONE POINT**, and that that point should be near the DCS or Fieldbus Power Supply. Care should be taken to prevent intentional or accidental grounding of the shield at any other location. A common mistake is to leave the shield exposed in the Fieldbus device. This can cause an intermittent ground, resulting in intermittent communication errors which are very hard to trace. Make sure that the shield wires are cut and taped off in the Fieldbus devices.

There are those who advocate other methods of grounding. Both of the other methods involve grounding the shield in multiple locations either directly or capacitively. This is not something we recommend. For more information, see the Foundation™ Fieldbus document AG-181, “System Engineering Guidelines,” for a detailed discussion of earthing and grounding. AG-181 is available as a free download from the Fieldbus Foundation website, [www.fieldbus.org](http://www.fieldbus.org).

# Chapter 14: Preventing Fieldbus Physical Layer Problems

Fieldbus is highly reliable when correctly installed and maintained. The key is in knowing what must be done to start with, and to maintain a reliable Fieldbus segment.

The purpose of this chapter is to:

- Identify common Fieldbus physical layer problems
- Discuss the causes of the problems
- Present methods for preventing Fieldbus physical layer problems

For help with diagnosing problems with a Foundation Fieldbus segment, see the Fieldbus Physical Layer Troubleshooting Guide, available at [www.relcominc.com](http://www.relcominc.com).

## Common Physical Layer Problems

Relcom have visited and helped to troubleshoot Fieldbus physical layer problems for many years. Some problems clearly stand out. The most common problems include:

- Missing or extra Terminators
- Improper grounding of the cable shield
- Water/condensation in cables, junction boxes, devices, splices, etc.
- Non-isolated Fieldbus segments
- Connectors not securely plugged in
- Damaged cable or wires
- Stray wire strands at wire terminations
- Screw terminals and hold-down screws inadequately tightened down

## Causes of Physical Layer Problems

After analyzing the list of common Fieldbus physical layer problems, it is easy to blame installers and Mother Nature. However, the root causes are deeper than that:

- Inadequate training
- Inadequate supervision
- Inadequate tools
- Inadequate monitoring

## Preventing Physical Layer Problems

These problems can be drastically reduced. The steps to minimize these problems seem expensive at first glance; however, troubleshooting just one physical layer problem can take days or weeks, resulting in large amounts of overtime, plant down time, ruined product, and lost sales. Fieldbus installations that are correct from the start save money. Monitoring the health of the Fieldbus segments and proper maintenance techniques save even more.

## Training

Training is not just critical, it is essential. Proper training prior to installation is the foundation for a Fieldbus that is trouble-free for years.

Start with the engineers designing the Fieldbus. Train the Fieldbus segment designers on proper segment architecture and design, including how many Terminators are installed on each segment, where the Terminators are installed, how long the Fieldbus segment and Spurs can be, the need for isolated Fieldbus Power Supplies, and proper shield grounding.

Installers and supervisors must know how to use the tools necessary for installation, where to route cables, how to mount Device Couplers, and how to properly terminate cables (at the Fieldbus Power Supply, Device Couplers, and devices).

Supervisors must be instructed on how to inspect the cabling and connections. They must know how to identify common physical layer problems.

## Supervision

Supervision starts in the design stage. Conduct a review of the Fieldbus segment design by knowledgeable people. These people may be co-workers or an outside contractor.

Before segment installation starts, supervisors must ensure that people working on the project are properly trained and have the right tools to do the job.

People who supervise Fieldbus installations must either inspect the installation themselves or ensure that a thorough inspection is made by a knowledgeable person. The inspector must be properly trained, as mentioned above, and walk the cable runs to check for problems. They must pull on wires and cables to verify they are tight, look for damaged cabling and connectors, confirm the shield is properly grounded, and verify LEDs are appropriately lit on the Device Couplers and Fieldbus Power Supply.

Following installation, supervisors should establish a program to monitor the Fieldbus segments and make sure the monitoring is carried out.

## Monitoring

One of the strengths of Fieldbus is the diagnostic capability available to help identify and diagnose problems. In many cases, identifying early symptoms can prevent plant down time. That is why regular monitoring is part of the routine at plants that want to maximize profitability.

Some Fieldbus Power Supplies, such as the F800 series of power supplies from MTL/Relcom, provide plug-in Fieldbus physical layer diagnostic modules. The F809F diagnostic module plugs into the Fieldbus Power Supply carrier and constantly monitors the segments connected to the power supply. Alarms can be set up to activate when the module discovers a measurement that is out of the desired range. The F809F measurements can be reviewed to identify the cause of the alarm so that it can be corrected.

Another approach is to use portable diagnostic equipment, such as the FBT-6 Fieldbus Monitor, to measure critical segment parameters. A set of data is collected when the segment is operating correctly as a baseline report. The report is transferred to a PC for storage or printing. The FBT-6 can be used every 6 months or so to generate another report to compare with the baseline report and look for changes that indicate a potential issue. If a problem is suspected, the FBT-6 can be used as a troubleshooting tool to help isolate and eliminate the cause.

## Tools

When installers and maintenance personnel do not have the proper tools to do a job, they often come up with creative ways to get it done. However, makeshift tools and methods often result in problems later.

Many tools are available to help determine the health of a Fieldbus segment and ensure proper installation. Here is a list of the more important ones.

### Digital Multimeter (DMM)

A good DMM can take resistance, voltage, and current measurements. Measurements of bus voltage and shield resistance to ground (continuity) can be taken any time. Resistance between wires and shield can only be measured when the segment is without power, such as when the segment is initially set up or when down for maintenance.



### Wire Stripper

Good wire strippers help avoid cutting strands in wire for a stronger, more reliable connection. They also help avoid excessive wire stripping by cutting to a fixed length. This reduces the possibility of shorts and wire corrosion.



## Ferrules and Crimper

Ferrules are metal sheaths with a plastic protector that are squeezed onto stripped wires with a crimping tool. Ferrules form a reliable electrical connection. They protect wires by reducing breakage due to vibration, bending, and stress. They also prevent stray wire strands which cause cable shorts.



## Torque Screwdriver

To make sure screw terminals are adequately tightened, use a torque screwdriver. The amount of force that should be applied to the screw terminals surprises most people.

Without a torque screw driver (The Wiha

TorqueFix 28503 screwdriver and replaceable 28537 3.0mm slotted blade is an example), screw terminals are most often under-torqued. Relcom products use screw terminals that should be tightened to 5 inch-pounds (in/lbs) of torque. Torque screwdrivers are expensive (~\$85 USD), but much cheaper than plant down-time.



## FBT-6 Fieldbus Monitor

The FBT-6 is a hand-held tool that measures bus voltage, noise, and the number of devices on the segment, and indicates when devices are added or removed from a segment. The noise measurement is split into 3 bands: the Fieldbus frequency band, below that, and above it. In addition, it counts retransmissions to devices, checks for the presence of shield shorts to the (+) or (-) Fieldbus wire, specifies the address and signal level of each device, and identifies which device is the Link Active Scheduler (DCS). The data collected from a segment can be saved in memory and then downloaded to a PC via a USB port.



## FBT-5 Fieldbus Wiring Validator

Fieldbus wiring can be tested using the FBT-5 Wiring Validator. It puts a DC voltage and Fieldbus signals on the wire pair. A Fieldbus Monitor, the FBT-6, is used to test the voltage, signal levels, and noise on the wiring. These tests can be performed on existing instrumentation wiring, newly installed Fieldbus cable, or a Fieldbus wiring system with Device Couplers and Terminators already installed. The FBT-5 is not for use on operating segments and cannot power a segment with Fieldbus devices.

## Examples

This section provides pictures of common Fieldbus problems encountered in the field.

This picture illustrates 3 problems.

1. The cable exiting the gland at the top of the device is exceeding its bend radius.
2. The cable exiting the gland at the top of the device is pointed straight up toward the sky. Eventually, water will get in.
3. The cable gland at the bottom of the device has both a cable and a ground wire exiting from it. Cable glands will not form a proper seal with more than one cable going through them.



The cable jacket has been stripped and the individual wires put through the cable gland. Water is likely to enter both the cable and the device.

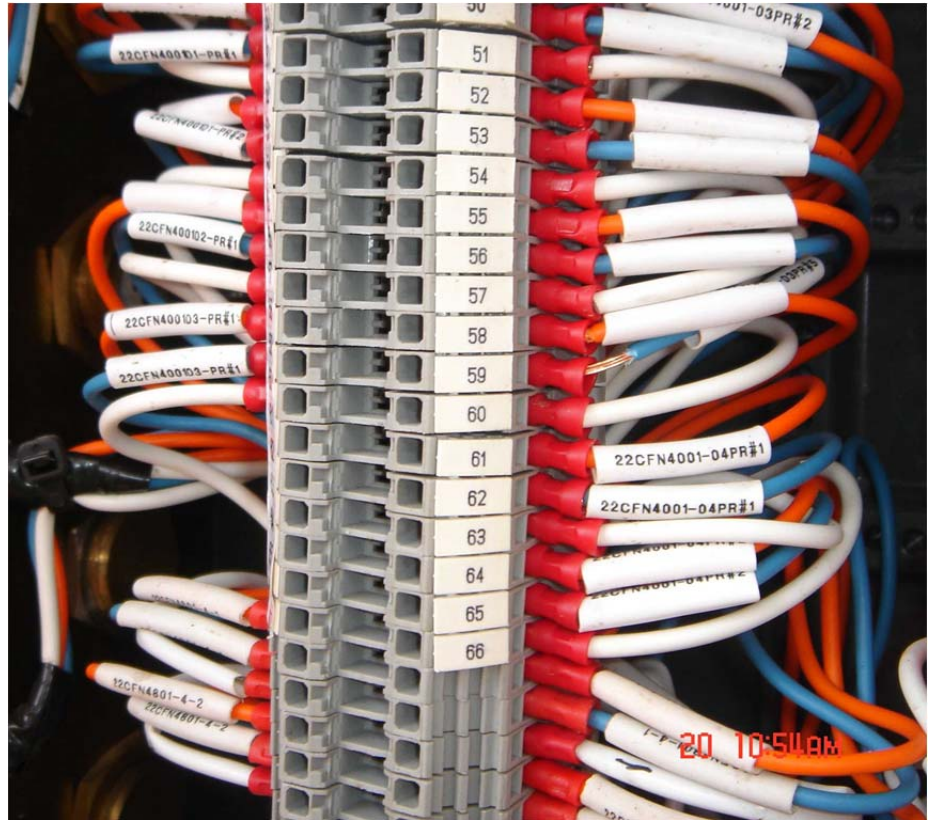


Water ingress into a Fieldbus device has corroded the wires and contacts, likely causing the wiring to short out or the device to fail.



## Preventing Fieldbus Physical Layer Problems

This is a very nice-looking wiring strip installation. Cables are labeled and color-coded. The terminals are numbered. However, the wires were not properly crimped into the ferrules and they easily pulled out.



## Preventing Physical Layer Problems

Prevention is the key to a reliable Fieldbus segment (i.e., proper training, tools, and supervision during installation and maintenance). Use quality cable and certified products from reputable companies. Save a set of data as a baseline when the Fieldbus is operating properly (using an FBT-6 for example). Perform regular segment checks, comparing current data with baseline data to look for significant changes. When problems are encountered, take a new set of data and compare it to the baseline.

# Glossary

Term	Definition
<b>Attenuation</b>	A signal getting smaller as it travels on the cable.
<b>Barrier</b>	A device for interconnecting circuits between a safe area and a hazardous area that prevents electrical power from the safe area from causing an ignition in the hazardous area.
<b>Bit Cell</b>	The time duration for one digital bit in the signal.
<b>Cable (Fieldbus)</b>	Signal wires (one or more twisted pairs), shield, and covering jacket. Each twisted pair should have its own shield.
<b>Chickenfoot</b>	A common distribution point for multiple Spur cables, usually in a junction box.
<b>Control-in-the-field (CIF)</b>	A capability of Foundation™ Fieldbus that allows the field devices to control the process without the Host (DCS) being directly involved.
<b>Device Coupler</b>	A wiring block for Fieldbus that includes short circuit protection for the connected Spurs.
<b>Distributed Control System (DCS)</b>	A computer-based controller used to control a process.
<b>Fieldbus</b>	For the purposes of this guide, Fieldbus is defined as the physical part of a Foundation™ Fieldbus or Profibus PA segment.
<b>FISCO</b>	An acronym for “Fieldbus Intrinsically Safe COnccept.” It is a set of rules (empirically-derived through testing) that expands the capabilities of a Fieldbus segment beyond the normal Intrinsically Safe standards.
<b>Foundation™ Fieldbus</b>	An open, interoperable Fieldbus standard for digital communication and control of a process.
<b>H1</b>	The hardware designation for Fieldbus at 31.25kHz. Also includes bit level communication (wrapper), but excludes the data contained in the transmitted packets.
<b>HART</b>	A 1.2kHz digital communication protocol that is superimposed over the 4-20mA analog signal of a transmitter, valve, etc.
<b>Hazardous Area</b>	A place where volatile vapors or gases may exist such that they could ignite or explode.

## Glossary

<b>High Energy Trunk</b>	The concept of an incendive level of power on a Trunk cable and a non-incendive (or Intrinsically Safe) level on the Spurs of a Device Coupler or Fieldbus Barrier.
<b>Home Run</b>	The main cable between the control room and a junction box in the field. Also called "Trunk."
<b>Host</b>	The device, usually in the control room, that controls or monitors the Fieldbus segment.
<b>Link Active Scheduler (LAS)</b>	A device that tells other devices on a Foundation™ Fieldbus segment when they are allowed to transmit.
<b>Local Area Network (LAN)</b>	A collection of devices, wired together in a limited geography, which can communicate with each other.
<b>Network</b>	For the purposes of this guide, a group of Fieldbus segments connected together in some way.
<b>Non-Incendive</b>	A device or cable that will not cause an ignition under normal operating conditions when in the presence of hazardous gases. May or may not be energy limited; if not, disturbing the device or wiring is not allowed without precautions.
<b>Non-Incendive Field Wiring</b>	A device or cable that will not cause an ignition under normal operating conditions when in the presence of hazardous gases. In this case, the energy is limited and may be worked while live (where allowed by local codes).
<b>Power Conditioner</b>	The filter between a power supply and Fieldbus wiring. Normally, it is part of a Fieldbus Power Supply.
<b>Profibus PA</b>	A Fieldbus that connects to a higher level Profibus Network (ProfiNet, Profibus DP, etc.). Its protocol is different and more limited than Foundation™ Fieldbus.
<b>Segment</b>	A Fieldbus infrastructure which consists of a Fieldbus Power Supply, two Terminators, cable, Fieldbus devices, and a DCS H1 interface.
<b>Spur</b>	A cable between the Trunk cable and a Fieldbus device, usually connected to the Trunk via a Device Coupler.
<b>Terminator</b>	A device on a segment that shapes the transmitted signals and prevents signal distortion.
<b>Trunk Cable</b>	The main cable between the control room and a junction box in the field. Also called "Home Run." Usually the cable between the two required Terminators.
<b>Twisted Pair</b>	Two wires twisted together for noise cancellation purposes, usually within a cable jacket.

# References

There are a wide range of additional resources available to help you increase your knowledge about Fieldbus. Below are a number of reference documents and websites where more information can be found. All references were accurate at the time of printing of this document and, along with all URL addresses, are subject to change; however, a search by document name and title is likely to find the most current version of the reference.

## Reference Documents

### Fieldbus Foundation

The documents below are accessible from the Fieldbus Foundation website at [http://www.fieldbus.org/index.php?option=com\\_content&task=view&id=150&Itemid=326](http://www.fieldbus.org/index.php?option=com_content&task=view&id=150&Itemid=326)

- AG-140 Wiring and Installation, 31.25 kbits/s Voltage Mode Wire Medium
- AG-163 31.25 kbit/s Intrinsically Safe Systems
- AG-181 System Engineering Guide

Another excellent resource from the Fieldbus Foundation is the Fieldbus Forum, for which you need to create a free account. The Forum can be accessed at <http://forums.fieldbus.org/>. It is a venue where presentations are posted and a searchable open discussion forum where questions and answers can be found.

### Relcom Inc.

The documents below are accessible from the Relcom Inc website at <http://www.relcominc.com/fieldbus/fbapnotes.htm>.

- 500-988 High System Availability for Foundation Fieldbus
- 500-989 The Importance of Isolation for Foundation Fieldbus
- 501-380 Fieldbus Physical Layer Troubleshooting Guide
- 501-386 Preventing Fieldbus Physical Layer Problems
- 501-375 Testing Fieldbus Cable with FBT-6 and FBT-5
- 502-145 Non-Incendive Fieldbus for Simplified Maintenance

### MTL

The following application notes are available by visiting [www.mtl-fieldbus.com](http://www.mtl-fieldbus.com).

- MTL Application Note AN9026 FISCO Intrinsically Safe Fieldbus Systems
- MTL Application Note AN9027 FNICO Non-Incendive Fieldbus Systems
- MTL Application Note TAN1010 Lightning & Surge Protection for Fieldbus Systems

## References

### ISA Books

ISA has published two reference books related to Foundation Fieldbus technology.

“Foundation Fieldbus,” 3<sup>rd</sup> Edition, by Ian Verhappen and Augusto Pereira, provides a practical guide to the various aspects of a Foundation Fieldbus project/system. This book can be accessed from:

<http://www.isa.org/Template.cfm?Section=Books3&template=/Ecommerce/ProductDisplay.cfm&ProductID=10041>

A second, more in-depth book, “Fieldbuses for Process Control: Engineering, Operation, and Maintenance” by Jonas Berge, can be found at:

[http://www.isa.org/Template.cfm?Section=Find\\_Books1&template=/Ecommerce/ProductDisplay.cfm&ProductID=7563](http://www.isa.org/Template.cfm?Section=Find_Books1&template=/Ecommerce/ProductDisplay.cfm&ProductID=7563)

### Certified Foundation Fieldbus Training Centers

For those who require a more in-depth knowledge of Foundation Fieldbus, there are a number of training centers in various parts of the world that have been certified by the Fieldbus Foundation. completion of a certified training course means you have met a minimum requirement that is verified against a Fieldbus Foundation standard.

Lee College, Texas, USA: <http://knowthebus.org/fc/index.html>

SAIT, Alberta, Canada: <http://www.sait-training.com/programs.html>

STC Brielle, Netherlands: <http://www.stc-group.nl>

Trine University, Indiana, USA: <http://www.trine.edu/>

### Web sites

A number of useful websites exist with information on Foundation Fieldbus, including the following:

ICEweb: <http://www.iceweb.com.au/Instrument/fieldbus.htm>

Romilly's HART® and Fieldbus Web Site: <http://www.romilly.co.uk/>

Fieldbus Reference List (Ron Hulsebos): <http://www.enodenetworks.com/Links.htm>

### Training CD

Foundation™ Fieldbus Concepts

Dan Dumdie

Hightech Multimedia Tutorials

PO Box 1927

Port Angeles, WA 98362

+1 (360) 928-9549

[www.hmtutorials.com](http://www.hmtutorials.com)

# Appendix A: Signals

The twisted pair cables, Terminators, and the Fieldbus Power Supply work together as a wiring system that can carry signals between Fieldbus devices.

When not transmitting, a device draws power from the cable for its internal operation. When the device transmits a high signal, it draws 10 mA less current. This increases the voltage between the wires. When the device transmits a low signal, it draws an extra 10 mA from the wires, resulting in a voltage decrease. The signal waveform is shown below. Note that the signal is above and below the 24-volt non-transmitting level on the segment.

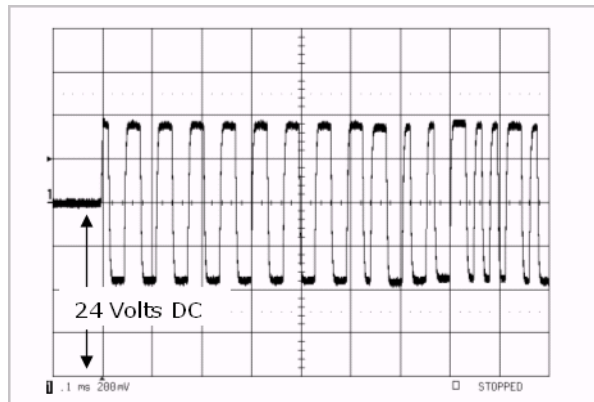
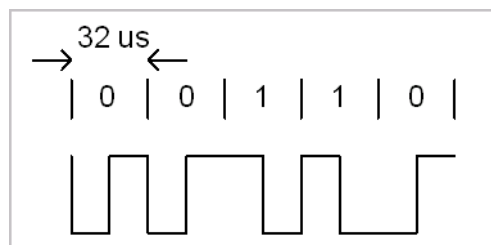


Figure A.1: Fieldbus Signal

Digital data is sent on the Fieldbus at a rate of 31.25 Kbits/second. Thus, each **bit cell** is 32 microseconds long. The digital data - ones and zeros - is represented as a **Manchester** code. A zero is a positive signal transition in the middle of a bit cell; a one is a negative transition in the middle of a bit cell.

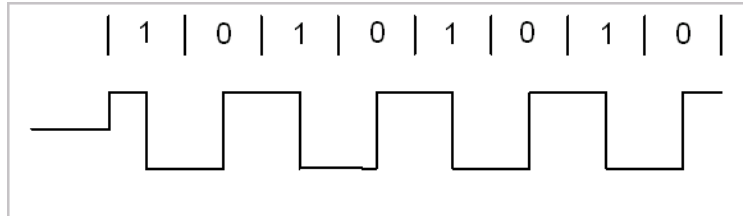
The signal voltage change is typically 750 mV peak-to-peak. Because it is a Manchester-encoded signal, the transition, rather than the magnitude, of the signal is used for communication. Signal levels as low as 150 mV and as high as 1000 mV are allowed by the standard.

A sequence of Manchester-encoded ones and zeros would look like this:



**Figure A.2: Manchester Code Signal**

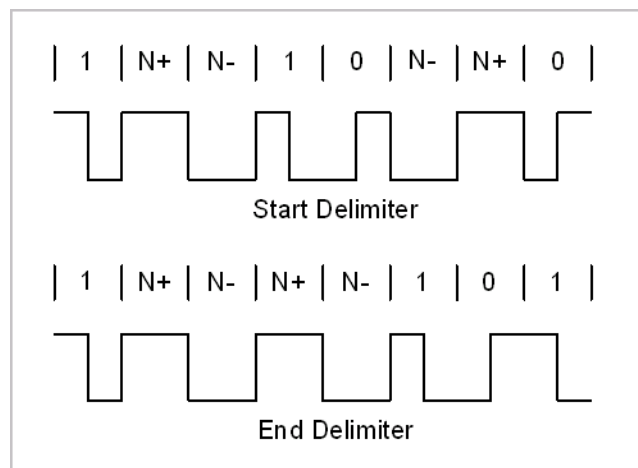
When a device begins transmitting, it puts out at least one **preamble**, an 8-bit sequence with alternating ones and zeros.



**Figure A.3: Preamble**

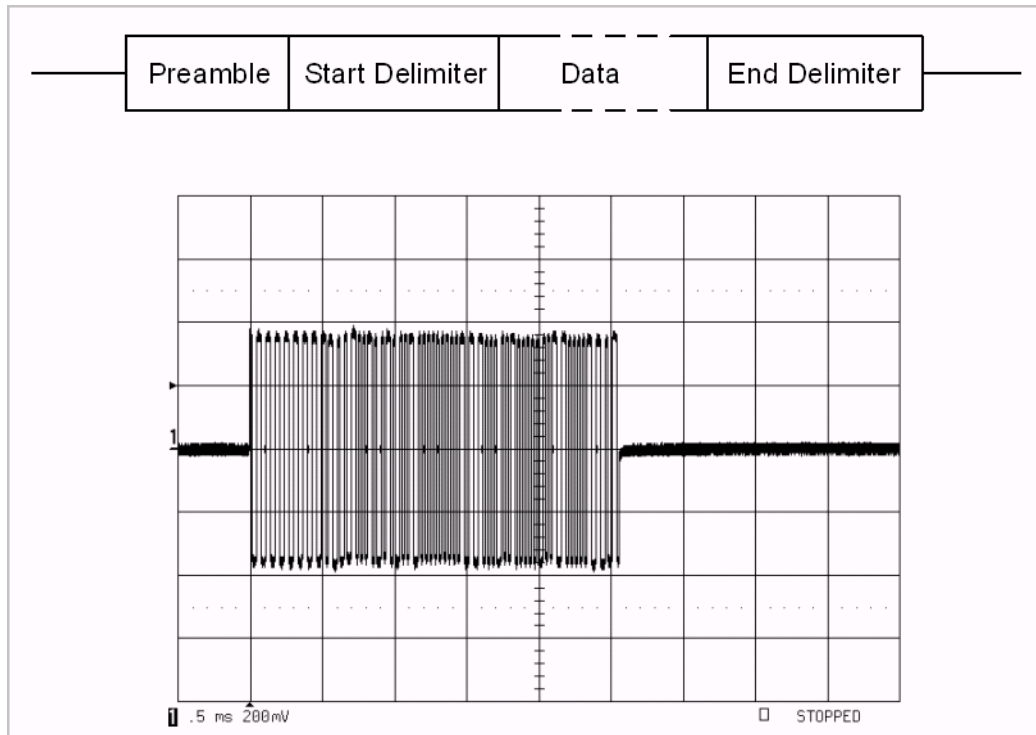
This pattern is used by receiving devices for synchronization to bit cell boundaries.

Besides ones and zeros, there are also two non-data symbols. These non-data symbols are N+, a high level during the whole bit cell, and N-, a low level during the whole bit cell. These symbols are used to make an 8-bit **start delimiter** that shows where real data starts and an 8-bit **end delimiter** that shows where data transmission stops.



**Figure A.4: Start and End Delimiters**

When a device transmits, the different parts are combined to form a data frame:



**Figure A.5: Fieldbus Frame**

The Data portion of the frame contains information such as the address of the device for which the frame is intended, identification of the type of frame, measurement values, etc. The Data portion of a frame can be up to 266 bytes long.

The delimiters are very different from any signal pattern that might be in the Data portion of the frame. This difference allows the Data portion of the frame to be unambiguously identified and allows Data corrupted by noise to be detected using a **Frame Check Sequence (FCS)**. The FCS is the very last part of the Data portion of the frame. This feature makes Fieldbus much more robust than many other control networks.

Because all devices share the cable, only one device should transmit at any given time. Otherwise, there would be chaos on the cable, with all the transmitted signals interfering with one another.

For Foundation™ Fieldbus, a special device called the **Link Active Scheduler (LAS)** selects which single device can transmit. The LAS allows each device to transmit by sending out a special frame to each device in turn. A frame might be the LAS asking a device to transmit data, a device broadcasting its data to other devices, a device reporting an error condition, etc.

Profibus PA uses a master/slave architecture rather than an LAS. The master controls when each device on the segment transmits.

# Appendix B: Availability Calculation

The following is background information on how the Availability was determined for the example on page 18.

To calculate availability, we also need to know the **Mean Time To Repair** (MTTR). The MTTR for a failure which raises an alarm is typically taken as 8 hours (1 shift) to cover the time taken to recognize the alarm, get the necessary authorizations to work on the system, collect a spare from stores, and complete the replacement.

$$\text{The Availability is } \frac{\text{MTTF}}{\text{MTTF} + \text{MTTR}}$$

To calculate the availability of the Fieldbus segment due to the power supply, we need to consider:

- The MTTF of the isolator and power conditioning modules and
- The MTTF of the common components on the backplane whose failure would result in the failure of the Fieldbus segment.

With two power supply modules operating, the Unavailability (1 – Availability) of the redundant power supply is the probability of both modules being unavailable at the same time. This is calculated as the product of the individual power module unavailabilities.

The Unavailability for the Fieldbus segment is based on:

- Both the isolation and power conditioning modules failing at the same time, or
- The common backplane components failing which affect segment availability.

The Unavailability of the Fieldbus segment is the sum of these two unavailabilities.

# Appendix C: Fieldbus Segment Design Calculation

The following example shows how to calculate the maximum number of devices that can be attached at the Device Coupler.

- The Fieldbus Power Supply minimum output is 22 Volts to the segment.
- The cable used is 18-gauge and has a resistance of 22 Ohms/km for each conductor. The Trunk cable is 1 km long. The combined resistance of both wires (round trip) is 44 Ohms.
- Each device at the Device Coupler draws 17 mA.

Although the minimum voltage for a Fieldbus device is 9V, we want a safety margin of 2V. This leaves 11 volts that can be dropped by the cable ( $22 - 9 - 2$ ). The total current that can be supplied at the Device Coupler is:

$$\begin{aligned} \text{Voltage} / \text{Resistance} &= \text{Current available} \\ 11 \text{ Volts} / 44 \text{ Ohms} &= 250 \text{ milliamps} \end{aligned}$$

We want to allow a Spur to be shorted and still have 11 volts at the Device Coupler. We also want to be able to connect a handheld tester to the Device Coupler. Finally, the current draw of the Device Coupler must also be taken into account. This leaves a current of 175mA available for devices ( $250 - 60 - 10 - 5$ ). Since each device draws 17 milliamps, the maximum number of devices at the Device Coupler of this example is:

$$\begin{aligned} \text{Current available} / \text{Device draw} &= \text{Number of devices} \\ 180\text{mA} / 17\text{mA} &= 10 \text{ devices} \end{aligned}$$

Be aware that there are many Segment Calculators available from manufacturers of Fieldbus equipment, as well as one that is available from the Fieldbus Foundation ([www.fieldbus.org](http://www.fieldbus.org)).

# **Fieldbus**

**Wiring Guide**

 **Relcom Inc.**

**2221 Yew Street  
Forest Grove, OR 97116  
(503) 357-5607  
(800) 382-3765  
(503) 357-0491 (fax)  
[www.relcominc.com](http://www.relcominc.com)**