# Fieldbus

## Wiring Design and Installation Guide

RELCOM inc.

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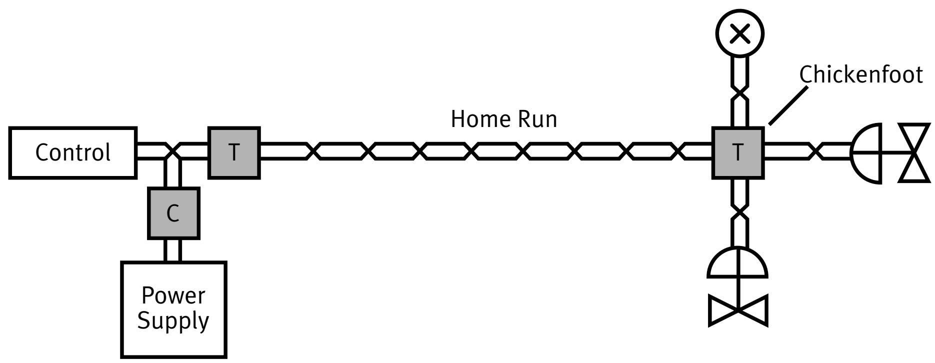
# Fieldbus Wiring Design and Installation Guide

The purpose of this guide is to provide information about the Fieldbus* network 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 rules for wiring a Fieldbus that a robot could follow and get optimum results. For this reason, this guide will first explain how the Fieldbus works so that the wiring system can be designed intelligently to achieve the best performance and the most reliable operation with the lowest cost.

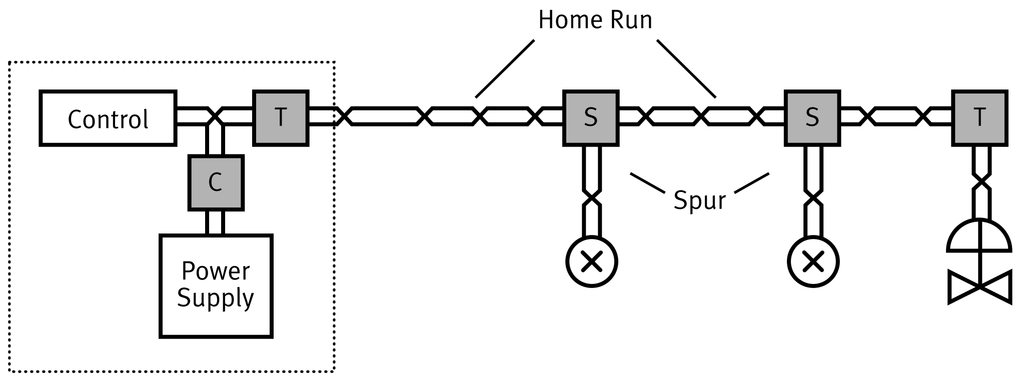
Fieldbus is a process control network used for interconnecting sensors, actuators and control devices to one another. A common type of Fieldbus configuration is shown below:



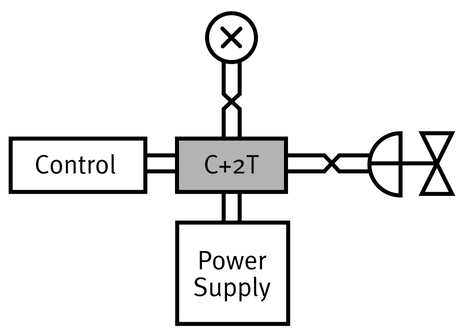

A twisted pair cable, called the **home run** connects the control room equipment with a number of **devices** in the field, sensors such as pressure transducers and actuators such as valves. The field devices can be connected to a common terminal block called the **chickenfoot**, or **crowsfoot** at a field junction box. A **terminator** (T) is needed at each end of the Fieldbus cable to allow the twisted pair to carry digital signals. The Fieldbus cable provides power to the attached devices. A **power conditioner** (C) is needed to separate a conventional power supply from the Fieldbus wiring. The devices use the shared wiring system to get their power and to send signals to one another.

***Fieldbus is defined in ISA standard 50.02, Section 24. There are several types of Fieldbusses described in that standard. The subject of this guide is referred to as H1 low power signaling and is commonly known as Foundation Fieldbus.**

Devices can also be connected along the home run cable with **spurs** (S). This is sometimes called **daisy-chain** wiring.

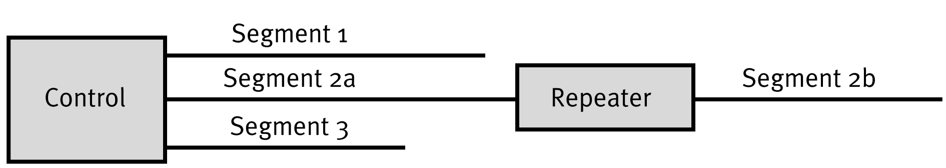



For control systems that are limited in size, all the wiring components, power conditioner and terminators, can be in a single wiring block to form a star configuration.




The diagrams above show only three of the many possible Fieldbus configurations. The power supply and conditioner could be in the field or in a marshaling panel. The control device could be in the field and only a display terminal could be in the control room. All these configurations are possible so long as the basic signal transmission capabilities are provided – a twisted pair cable, two terminators and a conditioned power supply.

While many devices can be on a Fieldbus, not all devices in a plant need to be on a single network. Usually, a control device has connections to several Fieldbus networks called **segments**. If the distance to a field device is longer than can be spanned by a single segment, a **repeater** is used to boost the signals to and from the further segment.



# Wiring

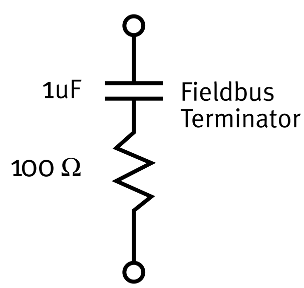
Fieldbus uses twisted pair wires. A twisted pair is used, rather than a pair of parallel wires, to reduce external noise from getting onto the wires. A shield over the twisted pairs reduces the noise further. The twisted pair and the shield combination plus any covering is called a **cable**. Fieldbus cable is similar to the type used for existing 4-20 mA device wiring and, in most cases, existing cable can be used for Fieldbus. For new installations or to get maximum performance from Fieldbus, twisted-pair cable designed especially for Fieldbus should be used. The important twisted-pair cable characteristics are:

| | |
|---|---|
| Wire Size | 18 AWG (0.8 mm) |
| Shield | 90% coverage |
| Attenuation | 3 dB/km at 39 kHz |
| Characteristic Impedance | 100 Ohms +/–20% at 31.25 kHz |

Another item to check is the colors of the twisted pair wires. If possible, to avoid confusion, the wire colors should match the color convention of existing wiring in the plant. If installing new cable, the suggested convention is to use blue for the (–) wire and orange for the (+).

# Signal Termination

When a signal travels on a cable and encounters a discontinuity, such as a wire short or open, it produces a **reflection**. This portion of the signal that echoes from the discontinuity travels in the opposite direction. The reflection is a form of noise that distorts the signal. A **terminator*** is used to prevent a reflection at the ends of a Fieldbus cable. In most networks, the terminator is simply a resistor whose value is the same as the characteristic impedance of the wire. Since the Fieldbus cable also carries power, a simple resistor cannot be used because it would use up the power intended for the devices. A Fieldbus terminator has a capacitor in series with the resistor to block the DC voltage but lets the signal through to the resistor.

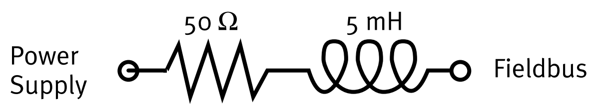



*A **terminator** used to prevent reflections is different than a wire screw **terminal block** that is used to connect wires to each other.

# Power Conditioning

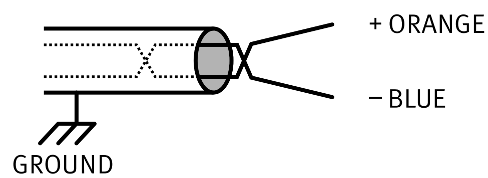
If an ordinary power supply were to be used to power the Fieldbus, the power supply would absorb signals on the cable because it would try to maintain a constant voltage level. For this reason, an ordinary power supply has to be conditioned for Fieldbus. This is done by putting an inductor between the power supply and the Fieldbus wiring. The inductor lets the DC power onto the wiring but prevents signals from going into the power supply.

The inductor together with the capacitors in the terminators forms a circuit that can “ring” and disrupt the signals. A resistor is placed in series with the inductor to stop this ringing. This combination of components is a power conditioner.




In practice, a real inductor is not used but an electronic equivalent. The electronic inductor circuit has the added advantage of limiting the current provided to the network segment if the cable is shorted.

The voltage supplied to the Fieldbus cable can be as high as 32 V. The voltage at any device can be as low as 9 V for the device to operate correctly. A typical Fieldbus device takes about 20 mA of current from the cable. The Fieldbus is configured so that one of the wires has a (+) voltage, the other wire has a (–) voltage and the shield is grounded.



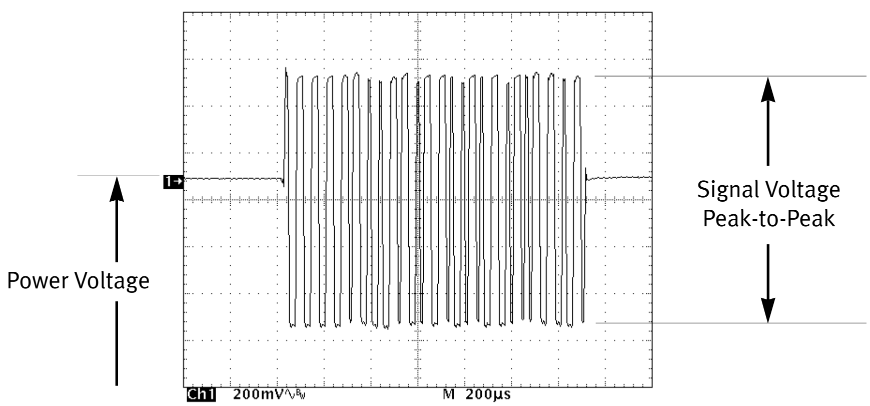

A cable with the orange wire as plus and the blue wire as minus is shown above. This type of cable is available from Fieldbus cable manufacturers. Other cables or existing plant wiring conventions may be different. Regardless of the color convention, keep the sense of Fieldbus polarity consistent throughout the plant.

# Signals

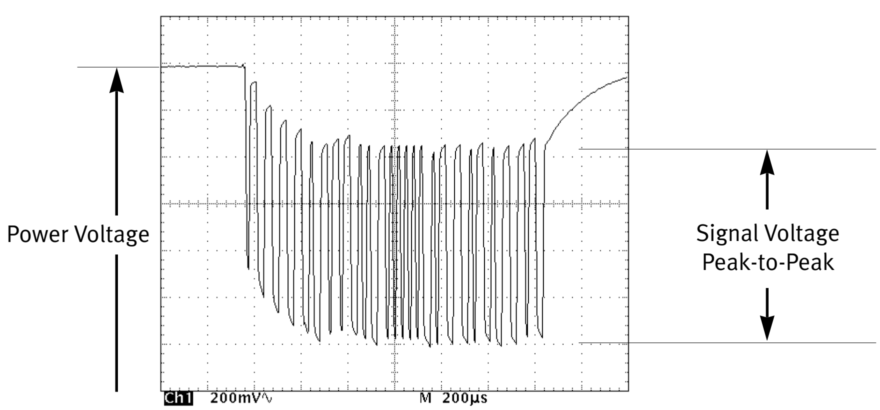
The twisted pair cables, the terminators and the power conditioner work together as a wiring system to carry signals between Fieldbus devices. Now let’s look at how the signals are transmitted.

There are two ways for a device to transmit signals onto the cable, the bipolar method and the low power, unipolar method. Both types of signals can be received by all devices so there are no compatibility issues. At this writing (1998), the bipolar signaling appears to be universally used. It works like this:

A bipolar signaling device draws power from the cable for its internal operation and it also draws an additional 10 milli-amps that it "wastes". When this device transmits a high signal, it turns off this 10 mA. This results in the signal on the wires going high. When the device transmits a low signal, it draws 20 mA from the wires. The resulting signal waveform is shown below. Note that the signal is above and below the non-transmitting voltage level.

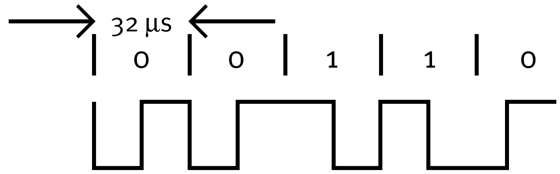



A unipolar signaling device does not draw any more power from the cable than is necessary for its internal operation. When this device transmits a low signal, it draws 20 mA from the wires. When the device transmits a high signal, it draws no power from the wires. The resulting signal waveform is shown below. Note that the signal is below the non-transmitting voltage level of the cable.

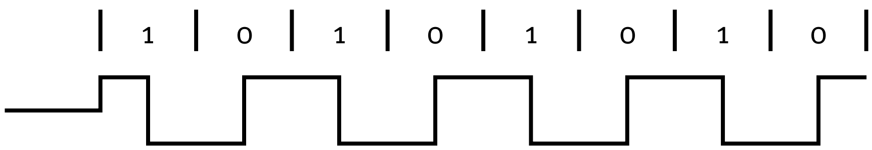



The peak-to-peak signal voltage is the same as for bipolar signaling. The advantage of the unipolar signaling is that it takes 10 mA less current from the cable.The disadvantage of the unipolar signaling is that it may cause a cable system that is not properly terminated to ring.

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** signal. 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. A sequence of Manchester encoded ones and zeros would look like this:



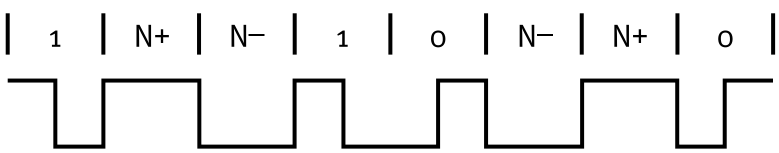

When a device begins transmitting, it puts out a **preamble**, a sequence of 8 bits with alternating ones and zeros.



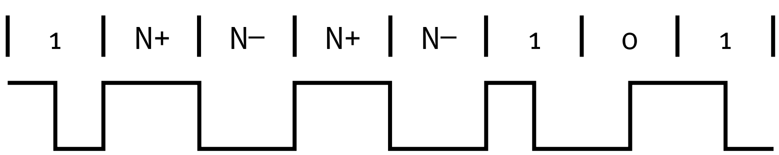

Preamble

This pattern is used by the receiving devices to get synchronized to bit cell boundaries.

There are also two non-data symbols. These are N+ that is a high level during the whole bit cell and N- that is a low 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.

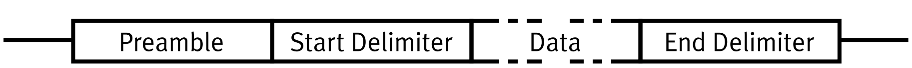



Start Delimiter




End Delimiter

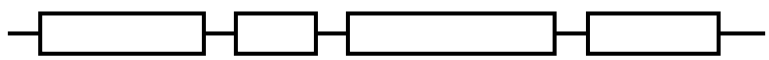
Combining the different parts, a single transmission from a device, a **frame**, looks like this:




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 allows the Data portion of the frame to be unambiguously identified and allows Data corrupted by noise to be detected. This feature makes Fieldbus much more robust than other control networks.

Because all devices share the cable, a way must be established for only one device to transmit at a time. Otherwise, there would be chaos on the cable with all the transmitted signals interfering with one another. Selecting which device can transmit is performed by a special device called the **Link Active Scheduler, LAS**. The LAS sends out a special frame to each device in turn to allow it to transmit. If an oscilloscope were used to observe the signals on the Fieldbus, the display would show frames with gaps of silence between them. A frame might be one from the LAS asking a device to transmit data, a device broadcasting its data to other devices, a device reporting an error condition, etc.



The discussion about how Fieldbus is used for conveying specific types of information is beyond the scope of this Wiring Design and Installation Guide.

Now that the basic characteristics of Fieldbus wiring are known, let's look at what happens to power and signals on the cables.

# Wiring Limitations

The size of a Fieldbus wiring system and the number of devices on a network segment are limited by power distribution, **attenuation** and signal distortion:

## Power

The number of devices on a Fieldbus segment is limited depending on the voltage of the power supply, the resistance of the cable and the amount of current drawn by each device. Consider this example:

- The power supply and power conditioner output is 20 volts.
- The cable used is 18 GA and has a resistance of 22 Ohms/km for each conductor. The home run is 1 km long. Therefore, the combined resistance of both wires is 44 Ohms.
- Each device at the chickenfoot draws 20 mA.

Since the minimum voltage needed by a device is 9 Volts, there are 20 - 9 = 11 Volts that can be used up by the cable. The total current that can be supplied at the chickenfoot is

$$\frac{\text{Voltage}}{\text{Resistance}} = \text{Current}$$

$$\frac{11 \text{ Volts}}{44 \text{ Ohms}} = 250 \text{ mA}$$

Since each device draws 20 mA, the maximum number of devices at the chickenfoot of this example is:

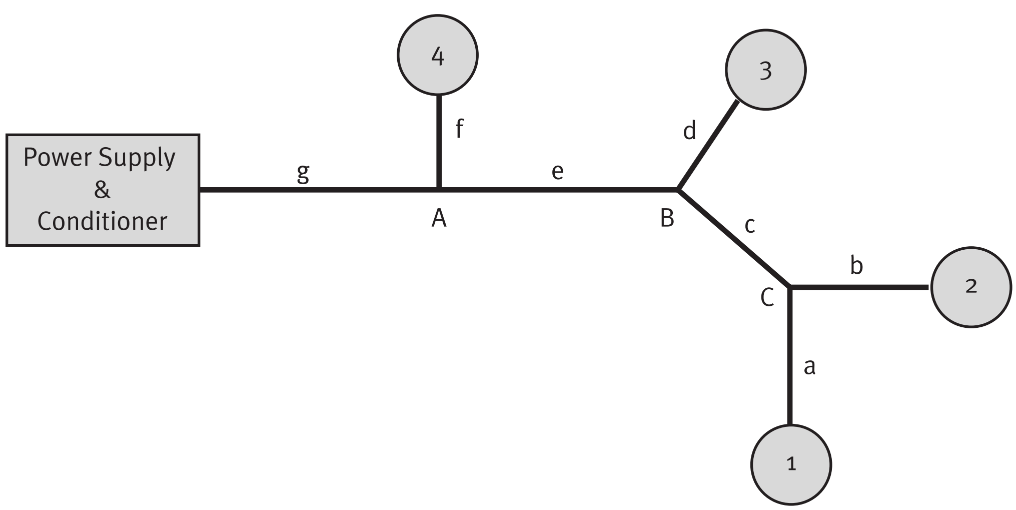
$$\frac{250}{20} = 12 \text{ devices}$$

The Fieldbus cable can be tested for power carrying capability by simply shorting out the wires at one end of the cable and measuring the resistance of both wires with an ohmmeter at the other end.

The power used by Fieldbus devices varies by device type and manufacturer. Check the device specifications to determine the device power requirements. One of the gray areas of the power specifications is the initial inrush current and the **lift-off** voltage. Some devices may use a great deal more current when they are first turned on and may require more than the 9V minimum voltage to "lift off" and begin operating. The network power distribution calculation should be based on the worst-case inrush current and liftoff voltage numbers. Otherwise the network may not start up when power is first turned on.

Normally Fieldbus is powered by 24 volt supplies. The maximum voltage that can be on the Fieldbus is 32 Volts. Devices can withstand up to +/- 35 Volts without damage. To keep the maximum voltage on the wiring below this limit, some Fieldbus wiring blocks have built-in voltage limiters.

When a number of devices are on the cable at different places, the power distribution calculation becomes more involved. Following is an example:



A network is shown with four devices designated 1 through 4. The network wiring has segments a through g. The junctions of the segments are at A, B and C. Here are the facts about the network:

| Device | Current Required, mA |
|---|---|
| 1 | 20 |
| 2 | 25 |
| 3 | 30 |
| 4 | 15 |

| Segment | Resistance, Ω |
|---|---|
| a | 5 |
| b | 10 |
| c | 7 |
| d | 9 |
| e | 6 |
| f | 11 |
| g | 20 |

From this, the amount of current in each segment can be calculated. Starting at the devices furthest from the power source:

| Segment | Resistance, Ω | Current in Segment, mA |
|---|---|---|
| a | 5 | 20 (due to device 1) |
| b | 10 | 25 (due to device 2) |
| c | 7 | 45 (due to devices 1+2) |
| d | 9 | 30 (due to device 3) |
| e | 6 | 75 (due to devices 1+2+3) |
| f | 11 | 15 (due to device 4) |
| g | 20 | 90 (due to devices 1+2+3+4) |

Because voltage equals resistance times current, the voltage drop in each segment can be calculated.

| Segment | Resistance, Ω | Current in Segment, mA | Voltage Drop in Segment, V |
|---|---|---|---|
| a | 5 | 20 (due to device 1) | 0.1 |
| b | 10 | 25 (due to device 2) | 0.25 |
| c | 7 | 45 (due to devices 1+2) | 0.315 |
| d | 9 | 30 (due to device 3) | 0.27 |
| e | 6 | 75 (due to devices 1+2+3) | 0.45 |
| f | 11 | 15 (due to device 4) | 0.165 |
| g | 20 | 90 (due to devices 1+2+3+4) | 1.8 |

From this, the voltage drop at each node can be calculated:

| Node | Voltage Drop, V |
|---|---|
| A | 1.8 (due to segment g) |
| Device 4 | 1.965 (due to segments g + f) |
| B | 2.25 (due to segments g + e) |
| Device 3 | 2.52 (due to segments g + e + d) |
| C | 2.565 (due to segments g + e + c) |
| Device 2 | 2.815 (due to segments g + e + c + b) |
| Device 1 | 2.665 (due to segments g + e + c + a) |

As the table above indicates, the largest voltage drop is 2.815 volts at device 2. The current flowing in segment g is 90 mA. Therefore, the power supply and conditioner must be able to deliver at least 90 mA. The lowest voltage that can be at the power supply/conditioner is the 9 volt minimum requires by the devices plus the 2.815 volt drop of the cable segments plus the 1 volt needed for signaling plus a safety margin of, say, 1 volt for a total of about 14 volts.

Intrinsic safety barriers can be considered segments in the network with a resistance specified by their manufacturer. This will be covered in more detail later.

## Signal Degradation Limitations

The length of a Fieldbus network is limited by what happens to the signals as they travel on the cable.

## Attenuation

As signals travel on a cable, they become **attenuated**, that is, get smaller. Attenuation is measured in units called **dB** or **deci-Bell**. This is calculated:

$$\text{dB} = 20 \log \frac{\text{transmitted signal amplitude}}{\text{received signal amplitude}}$$

Cables have attenuation ratings for a given frequency. The frequency of interest for Fieldbus is 39 kHz. Standard Fieldbus cable has an attenuation of 3 dB/km at 39 kHz or about 70% of the original signal after 1 Km. If a shorter cable is used, the attenuation is less. For example, a 500 meter standard Fieldbus cable would have an attenuation of 1.5 dB.

A Fieldbus transmitter can have a signal as low as 0.75 volts peak-to-peak. A receiver must be able to detect a signal as little as 0.15 volts peak-to-peak. This means that the cable can attenuate the signal by

$$20 \log \frac{0.75}{0.15} = 14 \text{ dB.}$$

Since the standard Fieldbus cable has an attenuation of 3 dB/km, this indicates that the Fieldbus can be as long as

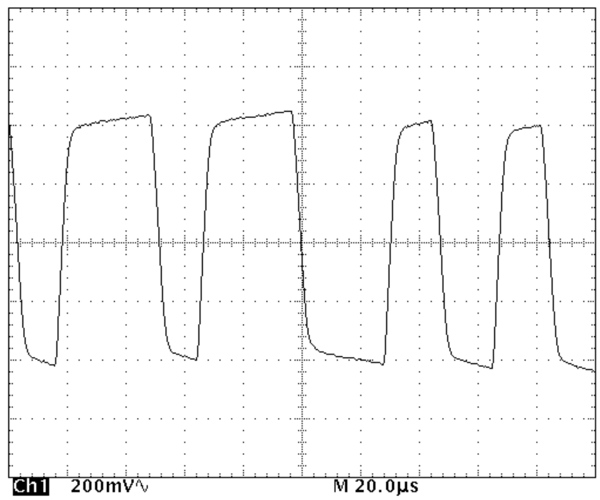
$$\frac{14 \text{ dB}}{3 \text{ dB/km}} = 4.6 \text{ km}$$

This distance may be theoretically possible, but there are other factors that have to be considered. Signals also become distorted as they travel on the cable.

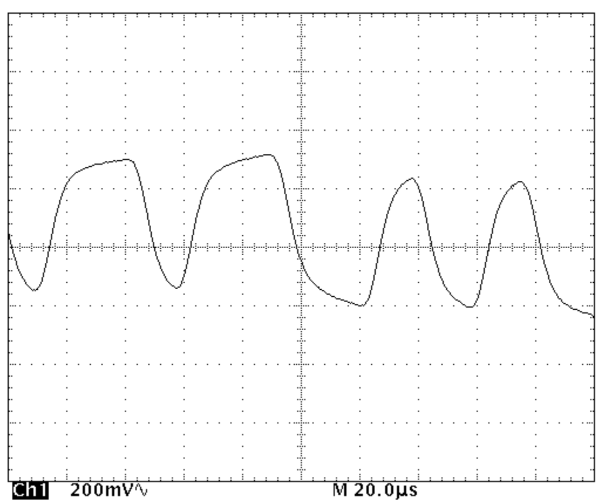
## Distortion Effects on Network Size

Shown below are a transmitted signal and a received signal at the end of a long cable.

Transmitted

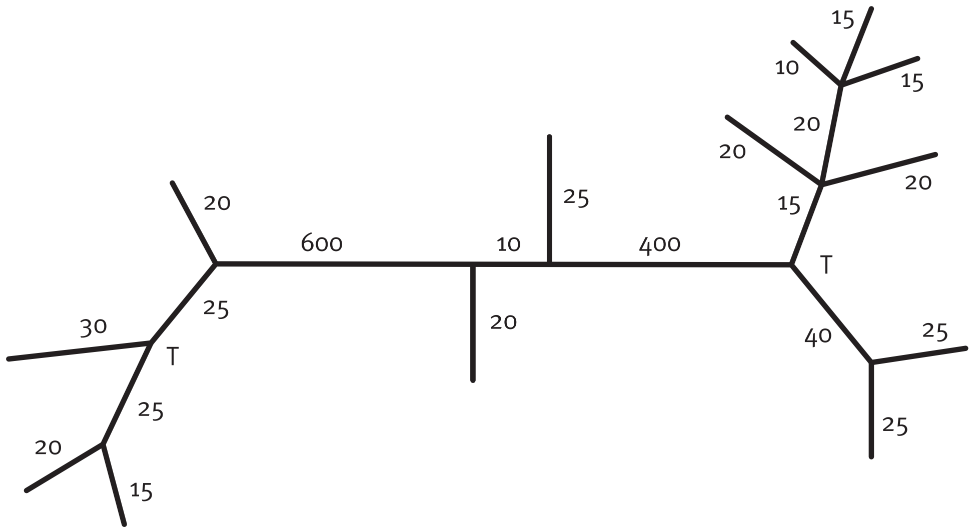



Received




The top signal is ideal in that the signal fits within the exact bit boundaries, the rise and fall time of the signal is within the Fieldbus specification and the signal tops are nearly flat. At the other end of a cable, the signal is distorted. Besides being attenuated, the signal does not fit nicely within the bit boundaries, the rise and fall times are longer and the signal top is not flat. This signal distortion is caused by varying characteristic impedance, spur connection reflections, etc. For this reason, Fieldbus cable cannot be as long as theoretically possible if only attenuation is a consideration.

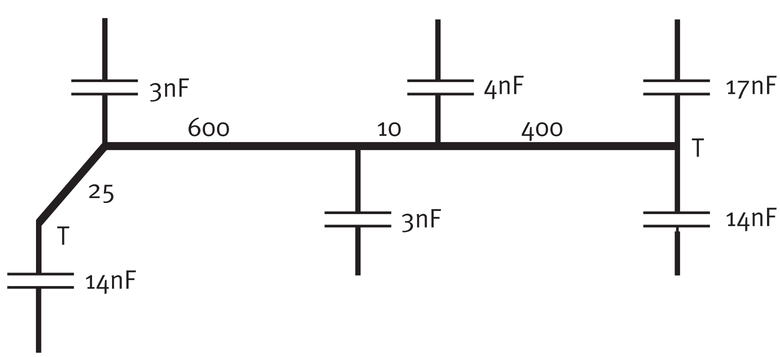
There are many causes for signal distortion. Spurs on the cable are one source. Although it is not possible to provide a definitive analysis of the effects of spurs, here are some guidelines that will help estimate if a particular network will work or is close to having problems. Consider the network below where the lengths of the cable segments are shown in meters.




It is not clear in this network which is the home run cable and which are the spurs. In such a network, place the terminators as far away from one another as possible. In this example, they are shown as "T". Consider the cable between the terminators to be the home run cable. Consider all other cables segments as spurs.

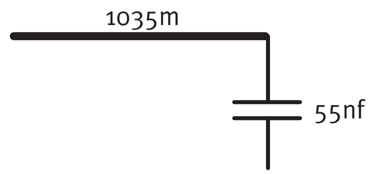
Testing of various cable configurations for signal distortion has shown that spurs up to 300 meters in length do not present a problem. The issue is to determine the allowable number of spurs. A way to estimate this is as follows:

The effect of a spur on the signal is very similar to that of a capacitor (providing the spur is less than 300 meters long). As an estimate, the capacitance of Fieldbus cable is about 0.15 nF/meter. In this example, the network can be modeled as the home-run cable with attached capacitors.




In this model, the home run cable length is 1035 meters. The capacitance is calculated from the total cable length of each spur.

From the measurements of actual cable, it has been determined that the worst case signal distortion occurs if all the capacitors are on one end of the home run cable. In this example this would be modeled as




Again, from cable measurements it was determined that signal attenuation due to capacitance is 0.035 dB/nF. In this example, attenuation can be calculated as that caused by the cable plus that caused by the capacitance:

1035 meters x 3 dB/meter + 55 nF x 0.035 dB/nF = 5 dB

This is well within the 14 dB allowed between the lowest level transmitter and the least sensitive receiver. There are other signal distortions caused by spurs, but these are insignificant.

Please note that the results of measurements of signals on long cables and the analysis of spurs in the above discussion are different from the recommended network size and spur lengths in the Fieldbus standard. The standard's recommendations are much more restrictive and are summarized below. In case there is a question about signal levels or fidelity, use a Fieldbus Tester to examine the signals before the network begins operation or during operation.

The fieldbus standard contains estimates of how long a Fieldbus cable can be and still get adequate signal quality. For the standard Fieldbus cable, and some types of existing cables used for control applications, the limits are:

| Cable Type | Distance, meters (feet) | Characteristic Impedance | Resistance, Ohms/km | Atten, dB/km | Description |
|---|---|---|---|---|---|
| Type A (Standard Fieldbus) | 1900 (6270) | 100 | 22 | 3 | Each twisted pair has a shield |
| Type B | 1200 (3960) | 100 | 56 | 5 | Multiple twisted pairs with overall shield |
| Type C | 400 (1320) | Unknown | 132 | 8 | Multiple twisted pairs, no shield |
| Type D | 200 (660) | Unknown | 20 | 8 | Multiple conductor cable, no pairing of wires |

There are also estimates in the standard for the length of spurs and how many devices can be on various lengths of cable.

| Number of Devices | Maximum Total Spur Length |
|---|---|
| 1 - 12 | 120 m |
| 13 - 14 | 90 m |
| 15 - 18 | 60 m |
| 19 - 24 | 30 m |
| 25 -32 | no spurs allowed; devices must be attached directly to homerun cable. |

These are only estimates. The quality of existing cable may vary a great deal. Some existing cable may be very good while other cable of the same type may be waterlogged, have deteriorated insulation or be mechanically damaged. The only real way to determine if existing cable is suitable for Fieldbus or if new cable has been installed correctly is to use a Fieldbus Tester.

# Cable Testing

Existing or newly installed cable should be tested to see that it is capable of carrying Fieldbus signals.

An ordinary digital voltmeter can be used to test the resistance between the wire pairs and the resistance from each wire to the shield. Good cable will have resistances of 10K Ohms or greater. The resistance of the two wires should also be measured and noted so that this information can be used in network design calculations.

The ability of the wire pair to carry Fieldbus signals can be tested using a Fieldbus Wire Tester. This consists of two parts -- a Transmitter and a Receiver. These are attached to the opposite ends of the cable to be tested. Lights on the Receiver indicate if the wire pair is able to carry Fieldbus signals.

# Wiring Polarity

Wiring polarity is important because some Fieldbus devices are polarity sensitive and have to be attached to the wiring in the right way. Wired with the wrong polarity, a device may short out the network or simply not operate.

Currently, the Fieldbus standard does not specify the colors of the conductors of the twisted pair wires nor which wire color should be positive and which should be negative. However, it has been suggested for new installations that the (+) wire be orange and the (–) wire be blue and that the fieldbus cable carry an orange jacket. Existing cables may use many different colors. Whatever the local choice of polarity colors, it is a good idea that this be consistent throughout the plant. To make the job of keeping polarities consistent in the plant, some Fieldbus wiring blocks are clearly labeled with (+) and (–) polarity designations.

# Shield

The purpose of the shield over the twisted pair wires is to keep out noise that might interfere with the signals. The shield is most effective if it is connected to ground or **earth at only one place.** Otherwise, the shield can carry ground currents that introduce noise into the twisted pair cable. The cable shield is generally grounded at the power conditioner or at the intrinsic safety barrier.

# Surge Protection

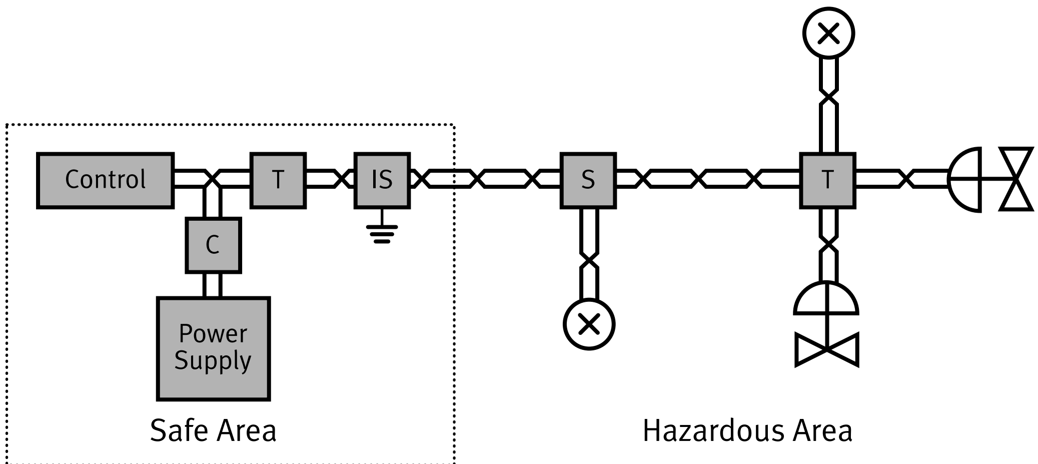
The Fieldbus is expected to be used outdoors. This exposes the wiring to possible lightning strikes or large currents or voltage **surges** induced by nearby lightning strikes. Since the shield is grounded at only one end, it can become a good lightning conductor into the control room. A way to overcome this problem is to use a surge suppressor.

The **surge suppressor** is a small gas-filled tube that has a very high resistance when the voltage across it is below 75 Volts. At higher voltages, the gas in the tube ionizes and produces a very low resistance path to ground. This can carry the very large currents as long as the voltage surge lasts. Surge suppressors are built into some Fieldbus terminators.

Even with surge suppressors, lightning may induce a large voltage between the wire pair. To prevent this from damaging the attached devices, a voltage limiter is placed between the two wires in some Fieldbus terminators.

## Intrinsic Safety Barriers

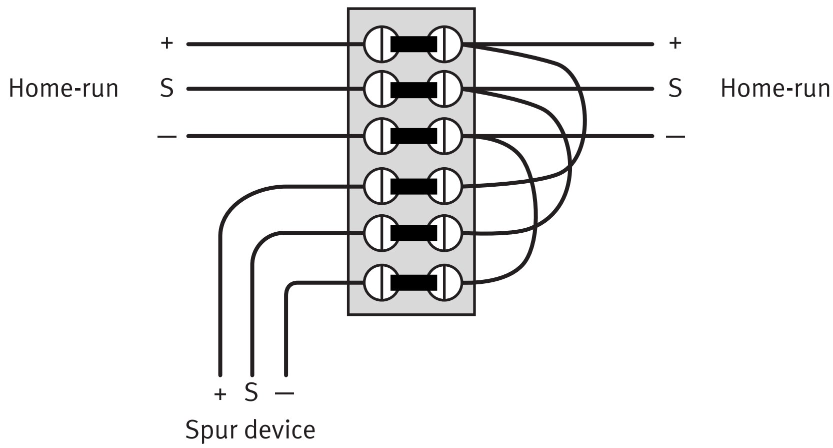
In some plants, the atmosphere may be explosive because of volatile gasses or liquids, grain dust, coal dust, etc. In these situations, all equipment has to be such that it is not hot enough to ignite the atmosphere and that electrical equipment is such that under no condition can it produce sparks that can ignite the atmosphere. These requirements also apply to Fieldbus if it is used in a hazardous area. An **Intrinsic Safety** barrier limits the available power to the Fieldbus to provide this protection. It should be noted that generally no more than 6 devices can be used on a segment with an **IS barrier** and the segment will be reduced in length because the IS barrier reduces the available power and attenuates the signal.




A detailed discussion of Intrinsic Safety and the requirements for barriers, cabling and devices is beyond the scope of this Guide. For more information, contact the Fieldbus Foundation at 512-794-8890 for Document AG-163, 31.25 kbit/s Intrinsically Safe Systems.

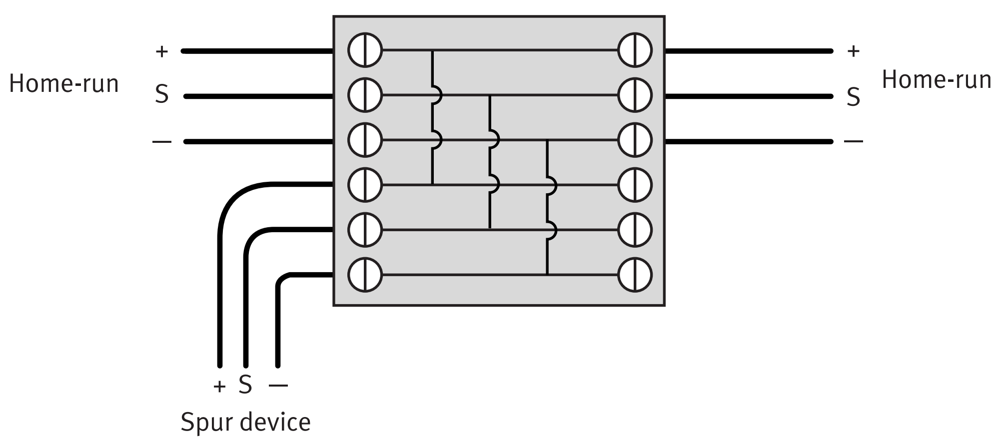
# Wire Connections

Segments of the wires that make up the wiring system for a Fieldbus network need to be connected together. Traditionally, this has been done by using terminal strips. For example, to connect two segments of a home run cable and one device on a spur, the following connections would have to be made:




While this type of wire termination works, it has some disadvantages. For example, it is easy to get mixed up and reverse the polarity of the wires. Also, multiple wires are fastened under the same screw. This has questionable reliability.

There are wire termination blocks that are designed specifically for Fieldbus. These blocks have the connections between corresponding wire terminations made internally. There are several methods of terminating the wire to the block -- spring clamps, screw terminals and pluggable connectors. The use of any particular type depends on how permanent the wiring installation is to be, on preferences of the installers, and on plant standards.



# Preparing the Wiring System

Test the installed cable before connecting any other wiring system components or Fieldbus devices to be sure it meets Fieldbus requirements. Install the terminators, power supply and power conditioner, any spurs and, if required, the intrinsic safety barrier.

Provide a substantial connection, such as a AWG #6 to #10 wire, between the chickenfoot terminator's ground stud and a good ground. The terminator has surge protectors built into it. If a nearby lightning strike induces large voltages on the cable, the surge protectors shunt the unwanted energy to ground and protect the Fieldbus devices attached to the network. Under normal conditions, the surge protector does not affect the Fieldbus operation in any way.

Before connecting the shield to ground, use an ohmmeter to check that the shield is not connected to ground or to one of the wires in the cable.

# Wiring Practices

The best designed Fieldbus wiring system, even one that uses high quality cable and components, will not be reliable if some care is not taken during installation.

- If multiple homerun cables go to a field junction box, do not attach the cable shield wires from different network segments together. This can cause ground loops and induce noise into the wires.
- Do not ground the shield of any cable in more than one place.
- At a device, do not connect the cable shield to the device ground or chassis.
- Use wire strippers that do not nick the wire as they strip the insulation.
- Use crimp ferrules or tin the wire ends to prevent stranded wires from getting loose and short to other wires. There is an added benefit to using crimp ferrules: The ferrules provide a gas-tight connection between the wire and the ferrule that is corrosion resistant. The ferrule material is the same as the wire terminal on the wiring blocks. Similar metals are much more corrosion resistant than a bare wire in wire terminal.
- Use wiring terminals that hold the wire ferrule securely and are vibration resistant.

The cable shield should be grounded at only one point. This is usually at the control room end of the cable. If an intrinsic safety barrier is used, the cable shield is grounded at the barrier.

# Testing an Operating Network

Once the Fieldbus network starts operation, there are several types of network tests that can be performed.

- The simplest test is to determine if there is sufficient power on the wiring at each of the devices. This can be done with an ordinary digital voltmeter. Another simple test is to use the Receiver part of the Wire Tester to verify the general signal levels on the network.
- The next level of testing is to determine what devices are on the network and measure the signal amplitude of each device. Measuring the noise on the network is also useful. This is done by using a Network Tester. (See p. 35)
- Beyond determining the health of the signals on the wiring, the information sent by the different devices to each other can be examined. This is done by using a computer that runs an analysis program. The computer acquires all frames on the network and shows their sequence on the screen. Discussion of protocol testing is beyond the scope of this Guide.

Generally, once a control network is operating properly, the Fieldbus communications protocols do not break. Wiring, on the other hand, can deteriorate or be damaged in a number of ways. Having the capability to identify a wiring problem and to determine its location is very useful.

# Fieldbus Wiring Products

A number of Fieldbus wiring products are listed here for the reader's convenience. These products can be ordered from Relcom or from the vendors directly. Relcom has made every effort to assure the accuracy of the information in this listing; however, Relcom is not responsible for any errors or for the fitness of purpose of the products. Relcom reserves the right to change the listing at any time without notice.

Fieldbus cable
Terminal blocks
DIN rail, end stops, terminal screwdriver
Fieldbus testers
Ferrules and crimp tool

## Fieldbus Cable

Shielded, twisted pair cable made specifically for Fieldbus has the characteristics that are important for good signal transmission and are within the requirements of the Fieldbus standard. Such cable is available from the following manufacturers:

### FURON

| | | |
|---|---|---|
| 1199 South Chillicothe Road | Tel: | 330-562-9111 |
| Aurora, OH 44202 | | 800-562-5151 |
| USA | Fax: | 330-562-5717 |

### Fieldbus Cable 1T52-8820T-234

| | Parameter | Conditions |
|---|---|---|
| Characteristic Impedance | 100 Ω | 31.25 kHz |
| Resistance, each wire | 22 Ω/km | |
| Attenuation | 3 dB/km max. | 39 kHz |
| Capacitative Unbalance | 2 nF/km | 31.25 kHz |

The twisted-pair wires are 18 AWG 7-strand bare copper with TPE flame retardant insulation. The pair colors are red and black. Other color combinations are available.

The cable shielding is aluminum-polyester film with a 20 AWG stranded tinned copper drain wire.

The cable has an orange PVC flame retardant jacket. It is listed by Underwriters Laboratories as PLTC and is suitable for use in Class 1 Division II Hazardous Areas and for outdoor use in cable trays. Other jacket colors are available.

The Fieldbus cable is available in up to 10,000 ft. reels.

## BELDEN WIRE & CABLE COMPANY

| | | |
|---|---|---|
| 2200 U.S. Highway 27 South | Tel: | 888-235-3368 |
| Richmond, IN 47374 | Fax: | 765-983-5536 |
| USA | Internet: | http://www.belden.com |

## Fieldbus Cable: Databus 3076F

| | Parameter | Conditions |
|---|---|---|
| Characteristic Impedance | 100 Ω | 31.25 kHz |
| Resistance, each wire | 7.32 Ω/1000 ft. | |
| Attenuation | 0.914 dB/1000 ft. | 39 kHz |
| Capacitative Unbalance | 3.6 pF/ft. | |

The twisted pair wires are 18 AWG 7-strand tinned copper with polyolefin flame-retardant insulation. The pair colors are blue and orange. A 20 AWG stranded tinned copper drain wire is used.

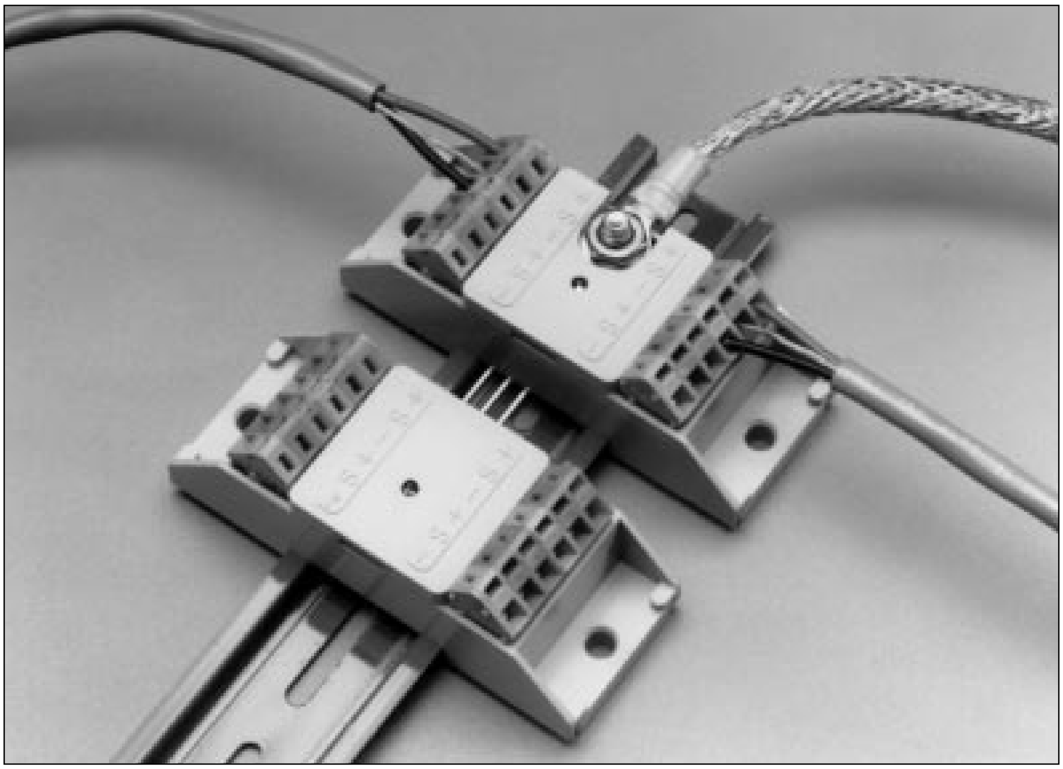
The cable has an orange PVC flame-retardant jacket. It is listed by Underwriters Laboratories as 300 volt PLTC and is suitable for use in Class 1 Division II Hazardous Areas and for outdoor use in cable trays. CPE jacket and other jacket colors are available.

## COMMSCOPE

| | | |
|---|---|---|
| 3642 Hwy. 70 East | Tel: | 800-982-1708 |
| Claremont, NC 28610-0879 | Fax: | 828-459-5099 |
| USA | | |

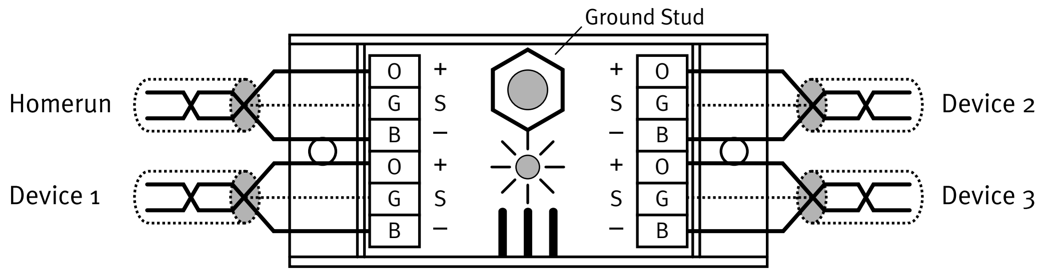
# Relcom Fieldbus Connection System

The Relcom **Fieldbus Connection System (FCS series)** provides all the parts needed to install Fieldbus network wiring and attach Fieldbus control devices. The required capability is achieved by selecting a combination of modules. All of the modules have a segment power indicator, a high quality interconnection socket that expands the number of devices which may be attached, and circuitry to limit the voltage on the Fieldbus wiring.



The grounded **Terminating Block, FCS-TG,** is used as a terminator and wiring block at the control room end of the Fieldbus. It interconnects up to four shielded wire pairs. For example, the home run cable, the DCS, the Fieldbus power supply, and one device. It contains a high quality interconnection socket that expands the number of devices which may be attached to the control room end of the segment (see Expansion Block). It provides a connection from earth ground to the shields of the Fieldbus cables via the ground stud. The shield should only be grounded at one point on each segment to prevent groundloop currents in the system. The grounded Terminating Block is easily identified by its black housing cover. Only one grounded Terminating Block is used on each Fieldbus segment.

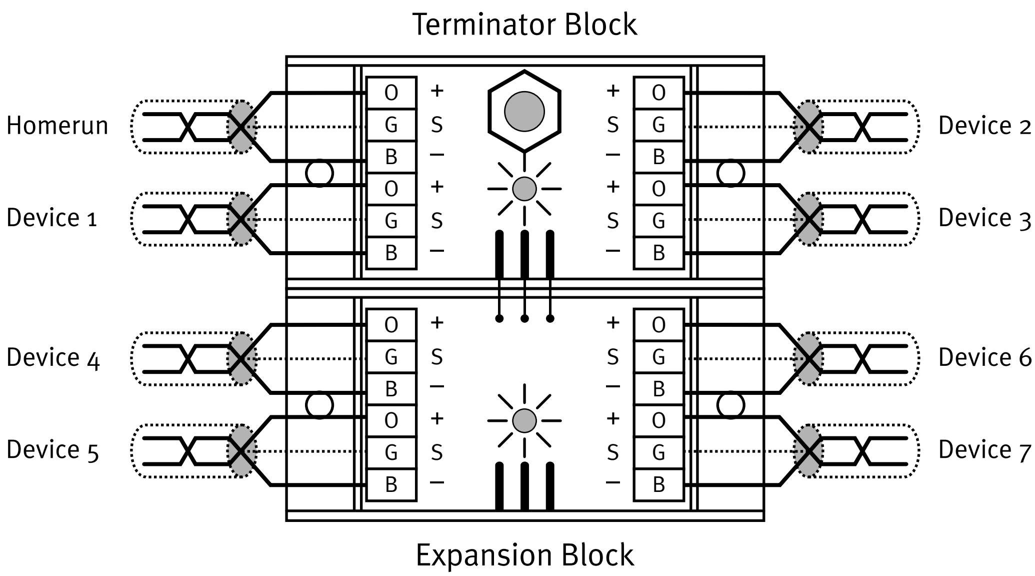
The isolated **Terminating Block, FCS-TI**, is used as a terminator and wiring block at the far end of the segment, sometimes called the chicken foot. It interconnects up to four shielded wire pairs. For example, the home run cable and three devices. It contains a high quality interconnection socket that expands the number of devices which may be attached to the chicken foot (field) end of the segment (see Expansion Block).




Terminator Block

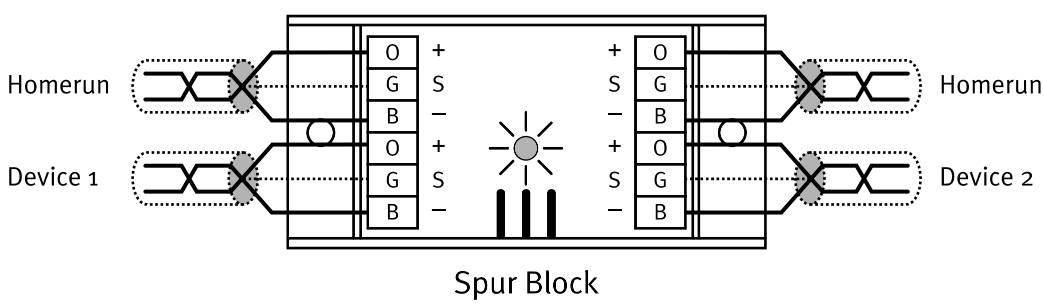
Surge suppressers built into the isolated Terminator protect the devices attached to the Fieldbus from near lightning strikes. A stainless steel ground stud is used for earthing the induced surge currents. When not discharging surges, the ground stud is isolated from the shielding of the Terminator and the wires as required by the Fieldbus standard and for intrinsic safety considerations. Except for its gray housing, it appears identical to the grounded terminator. Only one isolated Terminating Block is used on each Fieldbus segment.

Either Terminator can be expanded for additional wire pair connections by using **Expansion Block, FCS-E.** Each Expansion Block provides four more wire terminals. The Expansion Blocks plug into either Terminator, the Spur Block, or into each other so that wiring between blocks is eliminated. As many Expansion Blocks as needed can be used on a Fieldbus segment.




The expansion connectors can also be used for test equipment or hand-held devices for temporary connection to the Fieldbus. The Expansion Block eliminates inter-terminal block wiring or having to put more than one wire into a wire terminal.

A **Spur Block, FCS**, provides cable inter-connections without the built-in terminator. For example, the Spur Block can be used in the home run to attach two devices to the middle of the Fieldbus. As many Spur Blocks as needed can be used on a Fieldbus segment as long as signal quality is not compromised.



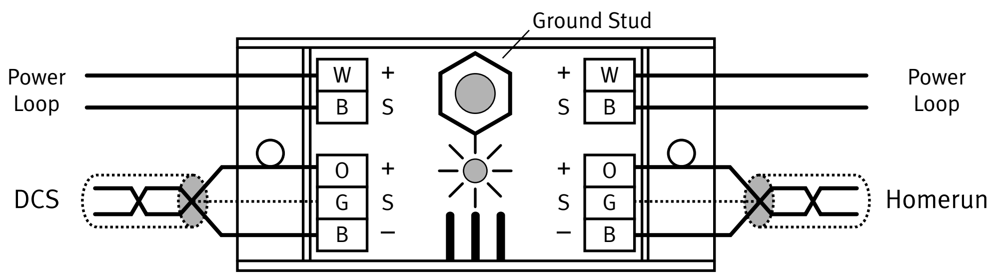

The Spur Block can also be expanded with the Expansion Block to provide additional device connections.

# Power Blocks

Two types of power blocks are used to construct a reliable power distribution system for multiple Fieldbus network segments. The power blocks allow ordinary power supplies to be used for Fieldbus applications, incorporate optional battery backup capability, and provide redundant power distribution wiring.

## Power Conditioner

The **FCS-PC Conditioner** is used to connect a conventional power source to a Fieldbus segment. Power is applied to one or both sets of power terminals; they are connected in parallel internally. The typical input voltage range is 21 to 32 VDC. An impedance control circuit in the Power Conditioner block prevents the conventional power source from absorbing the Fieldbus signaling current or otherwise interfering with the operation of the Fieldbus. Conditioned Fieldbus power is provided at two sets of terminals and the expansion connector. The Power Conditioner drops about 5 volts worst case. If the input power is 28 volts, the fieldbus voltage is at least 23 volts.



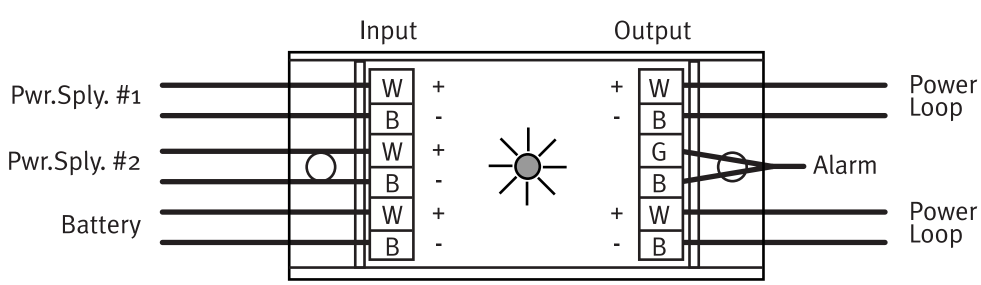

Power Conditioner

A **Power Conditioner-Terminator, FCS-PCT**, combination provides both the power supply conditioning and a terminator in the same package. Two terminators are required for each Fieldbus segment, one at each end of the home run cable. By using a terminated Power Conditioner block at the control room end of the Fieldbus segment, no external terminating devices are needed. This arrangement provides for the most common Fieldbus configuration, a control room block, which provides power for the segment, near end termination for the segment, a connection point for the DCS, and a connection point for the home run cable. If more than two Fieldbus connection points are needed, an expander block is plugged into the power conditioner block to provide four additional cable connection points. The Power Conditioner blocks are internally current limited, allowing the use of a single power source for multiple Fieldbus segments. If a short circuit or over current condition exists on one of the segments, it will not affect the operation of the other segments as long as the total current capability of the single source is not exceeded. Output power is referenced to the ground bolt and the Fieldbus segment cable shield so that it is symmetrical around earth ground.

A Conditioner with two Terminators, **FCS-PCT2,** is used on very short networks where there may not be any home run cable. In this case, all devices, the controller and the power supply are connected to a central hub. The power conditioner with two terminations provides all the Fieldbus termination and power supply conditioning requirements. This configuration is typically useful in a demo or laboratory test environment. It is not expected that this configuration would be used in an actual field installation.

## Power Multiplexer

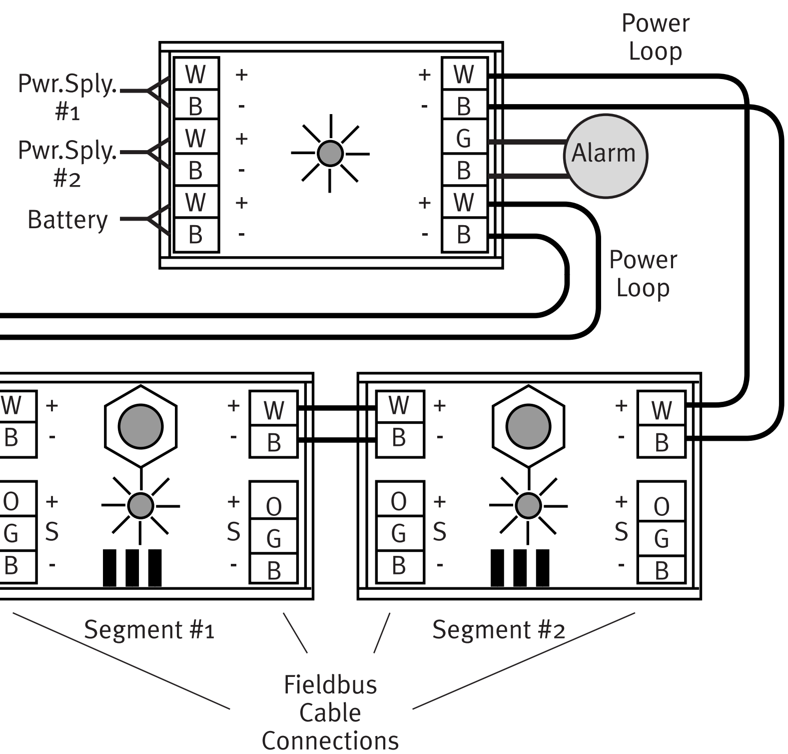
The Power Multiplexer Block, **FCS-PM,** lets two power sources provide redundant 28 VDC power to the Power Conditioner blocks. The Power Multiplexer is NOT designed to operate with an input voltage other than 28 Volts if battery backup/charging are used. The Power Multiplexer will charge a 24 V battery from either or both of the two power sources. The charging circuit is current limited at 1.5 Amperes and provides a "float" charging potential of 27.5 Volts. If both of the primary power sources fail, the battery provides the power to the Power Conditioner Blocks. A 2.3 Ampere Hour battery will provide about 40 minutes of operation at a current of 2.5 Amperes. A gray/black pair of connectors is used to connect a piezoelectric alarm device to indicate AC power failure. This output is the battery voltage in series with 5.1K ohm, suitable for direct driving of a Sonalert piezo-electric enunciator such as the Mallory model SC628 or any other device which can be actuated with 4 to 5 mA. Another use of the alarm output would be to drive the diode side of an opto-isolator. The alarm connections are: black = minus, the gray = plus. All minus connection points on the Power Multiplexer are common. The Power Multiplexer has a compliance range of about 400 mV. When both power sources are at the same potential, each will provide 50% of the load current. When the input voltage differs by more than 400 mV, the supply with the higher terminal voltage will provide all of the load current. The Power Multiplexer is protected against overcurrent and overtemperature by an internal electronic resettable fuse. The protection is equivalent to a 2.5A Slo-Blo fuse on the Power Loop outputs, and a 1.5A Slo-Blo fuse on the battery "+" terminal. Maximum voltage drop across the Power Multiplexer from input to output is 1.1V at 2.5 Amperes load current. The Power Multiplexer will survive an indefinite period output short circuit. To reset the internal "fuse", all load current must be removed for a period of time. This requirement is for internal temperature stabilization. When ready to function, the green indicator will glow with a normal brilliance.




POWER MULTIPLEXER

## Power Wiring

To provide uninterruptible power to the Fieldbus segments, the Power Multiplexer and the Power Conditioning Blocks are wired as shown:



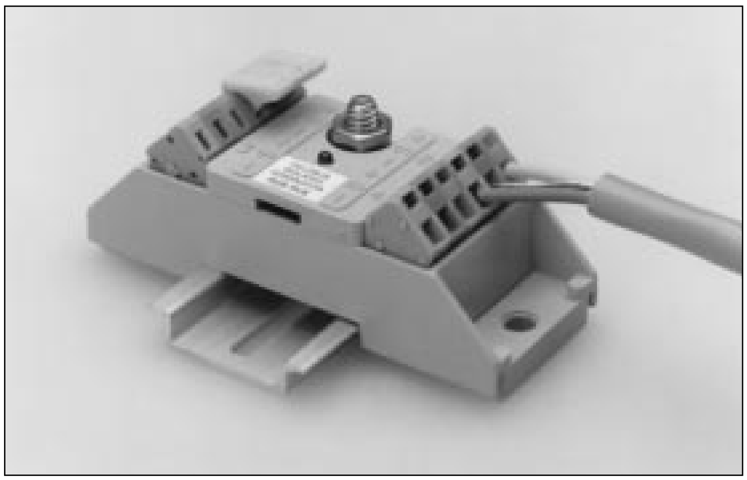

Each Power Conditioner has two power wiring paths from the Power Multiplexer. In case a power wire is cut or removed to add another Fieldbus segment, the Power Conditioners receive power from the other path. The diagram above shows only two Fieldbus segments being powered by the Power Multiplexer. In practice, more than two segments may be powered by merely adding additional Power Conditioners to the power loop. The maximum number of segments depends on the total current that the combined number of devices on all of the segments use. This current cannot exceed 2.5 Amperes.

## Features

Relcom's Fieldbus Connection System devices are made to satisfy demanding industrial requirements and have features needed for reliable Fieldbus operation in severe environments:

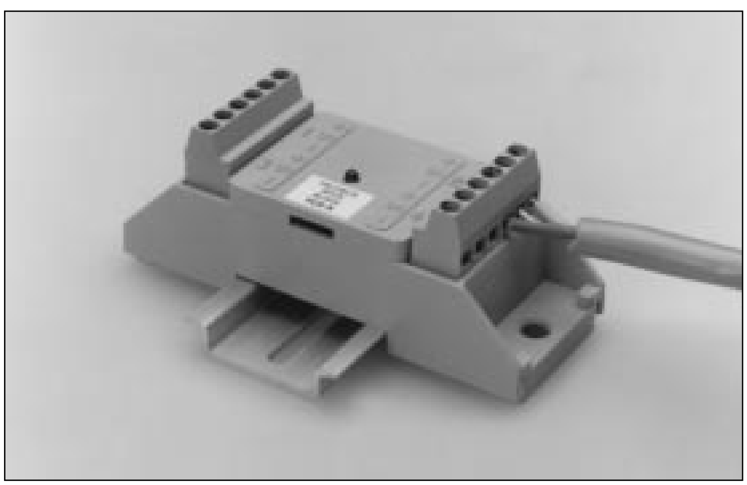
- Relcom FCS devices are currently available with three different types of connectors:

**Cage Clamps:** The wire terminals are spring loaded so that wiring installers do not have to be concerned with using the correct screw torque. No special tools other than wire strippers are needed. The wire termination cannot vibrate loose. The terminals accept 14 to 28 GA wire. When the wire ends are properly prepared, the wire-terminal connection can operate in corrosive environments.



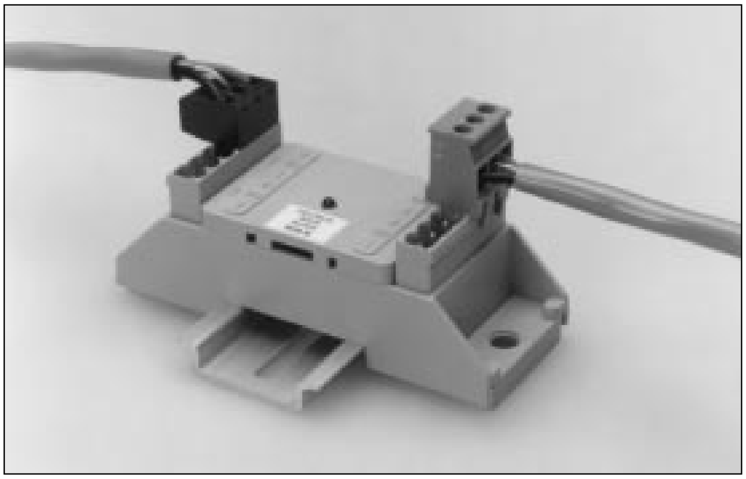
**Terminating Block with Cage Clamp Wire Connections**

**Screw Terminals:** Connections are made directly to the wiring blocks using side-entry screw terminals which accept wire ranging from 12 to 22 AWG.



**Spur Block with Screw Terminals**

**Pluggable Connectors:** Wiring blocks with pluggable connectors are available for applications where devices need to be connected and disconnected from the Fieldbus network on a frequent basis. As with other wiring blocks, up to four devices can be connected on a block. The cable connections to the blocks can be made in the field by stripping the wires, inserting them into the color-coded slots, and tightening the terminal screws. Each connector has three wire terminations. Several types of connectors are available and wire range is from 12 to 28 AWG.



**Spur Block with Pluggable Connectors Showing Both Side and Top-Entry Wires**

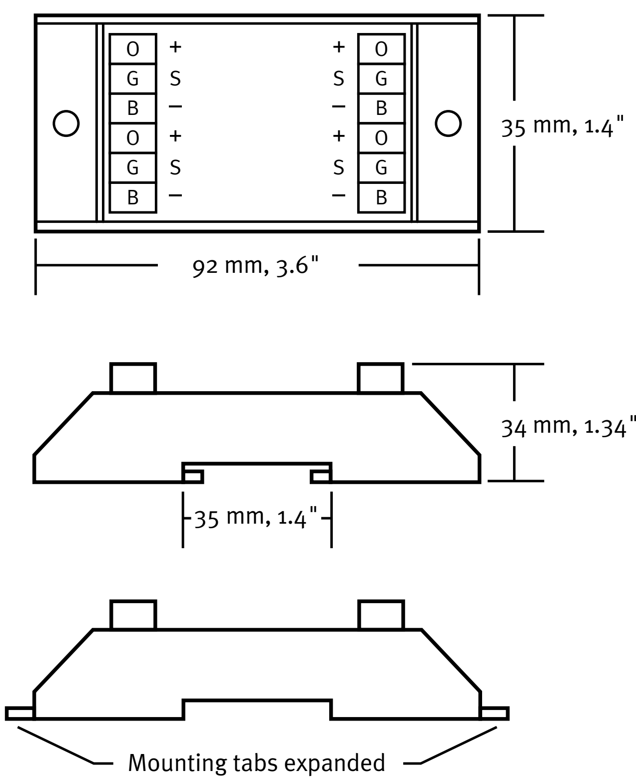
- The wire terminals are color coded for easy identification:
  Shield = Green (+) = Orange (–) = Blue
- The FCS device body is plastic and its circuits are entirely encapsulated in epoxy to prevent corrosion and to provide mechanical protection of the components.
- Each FCS block has an LED that indicates the block is receiving or providing power. This provides a quick visual check to see that the network is powered.
- The expansion connectors provide a safe and convenient way to attach test equipment or other temporary devices to the Fieldbus.
- The FCS devices can be mounted on 35 mm DIN rails or fastened to any surface through mounting holes. The FCS blocks can be snapped onto the rail by compressing the mounting tabs or removed by expanding the mounting tabs. (See next page)
- The nomenclature used to signify the various wiring modules is as follows:

| | |
|---|---|
| **FCS** | refers to the **F**ieldbus **C**onnection **S**ystem |
| **-TG-** | designates the wiring block type as a **T**erminator, shield **G**rounded |
| **-TI-** | designates the wiring block type as a **T**erminator, shield **I**solated |
| **-S** | designates the wiring block type as a **S**pur |
| **-E** | designates the wiring block type as an **E**xpander |
| **-PC-** | designates the wiring block type as a **P**ower **C**onditioner without a terminator |
| **-PCT-** | designates the wiring block type as a **P**ower **C**onditioner with one terminator |
| **-PCT2-** | designates the wiring block type as a **P**ower **C**onditioner with two terminators |

| | |
|---|---|
| **-PM** | designates the wiring block type as a **P**ower **M**ultiplexer |
| **S** | as a suffix indicates the type of Ground Bolt as **S**AE 1/4" X 20 |
| **M** | as a suffix indicates the type of Ground Bolt as **M**etric M6 |
| **CC** | as a suffix indicates the type of connector at **C**age **C**lamp |
| **PL** | as a suffix indicates the type of connector as **Pl**uggable |
| **ST** | as a suffix indicates the type of connector as **S**crew **T**erminal |

## Specifications

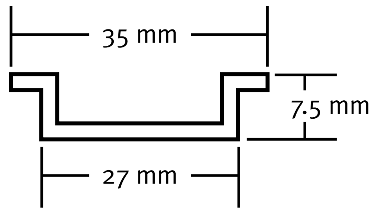
| Part Number | Wiring Device Type | Cable connections |
|---|---|---|
| FCS-TG | Terminator Block (Grounded) | 4 |
| FCS-TI | Terminator Block (Isolated) | 4 |
| FCS-E | Expansion Block | 4 |
| FCS-S | Spur Block | 4 |
| FCS-PM | Power Multiplexer | 0 |
| FCS-PC | Power Conditioner | 2 |
| FCS-PCT | Conditioner + Terminator | 2 |
| FCS-PCT2 | Conditioner + 2 Terminators | 2 |



# Wiring Block Accessories

## DIN rail FCS-A01

One meter aluminum DIN rail with mounting slots.




## End Stop FCS-A02

The End Stop screws to the DIN rail and prevents the rail-mounted parts from sliding on the rail.

## Wire Terminal Tool FCS-A03

A narrow-blade screwdriver used to open wire terminal contacts.

RELCOM Inc.
2221 Yew Street
Forest Grove, OR 97116 USA
Tel: 503-357-5607
800-382-3765
Fax: 503-357-0491
www.relcominc.com
E-mail fieldbus@relcominc.com

# Fieldbus Testers

There are two general types of Fieldbus network tests. One of these involves the content of the messages that are sent, what the messages mean, in what sequence the devices talk to each other, that is, the protocols of the network. Once the protocol issues have been worked out, the network operation seldom needs to be examined. The other type of Fieldbus tests involves the wiring and signal transmission.

The testers described below are intended to determine the ability of the wiring to carry Fieldbus signals and to determine the health of the wiring and the devices transmitting signals on an operational Fieldbus network. These are ongoing considerations because wiring can deteriorate.

## Fieldbus Wire Tester, FBT-2

The Fieldbus Wire Tester, FBT-2, is used to determine if newly installed or existing instrumentation wiring is usable for Fieldbus. The FBT-2 is intended for installation and maintenance personnel and does not require detailed knowledge of Fieldbus technology.

The Tester has two parts, a Transmitter and a Receiver. The Transmitter is typically used in the field end of the wiring. The Receiver is typically used in the control room end of the wiring.


The Transmitter and the Receiver have indicator lights that provide information about the polarity of the wiring and its condition.

When the Receiver and the Transmitter are attached to a wire pair correctly (the red probes to one wire, the black probes to the other wire), the Transmitter's **OK** light is on. If the polarity is reversed, the Transmitter's **REVERSE** light is on. This is useful for determining and documenting wiring polarity.

Before the Transmitter puts any signal on the wire pair, it first checks the cable to see if it is already carrying Fieldbus signals. If the cable is carrying signals, the Transmitter will not produce a signal but will turn the **LIVE** indicator on. This prevents the Transmitter from interfering with an operating Fieldbus network that it was connected to by mistake.

When the Receiver detects a Fieldbus signal from the Transmitter that is above the level needed for Fieldbus operation, the **GOOD** light is on. If the signal is at a higher level (the equivalent of less than 2 km of new Fieldbus wire), the **EXCEL** indicator light is on. If the signal level is below that needed for Fieldbus operation, the **SIGNAL** light is on. This indicates that the Transmitter is connected to the wire pair but the signal level is too low. From these three indicator lights, it is possible to tell that the Receiver is attached to the right wire pair and if the signal on the wire pair being tested is high enough for Fieldbus operation.

## Wire Resistance Tests

Additional wire tests need to be made using an ordinary digital voltmeter to determine if a wire pair is suitable for Fieldbus operation.

- Measure the resistance between each wire and the shield (if any) to verify that it is higher than 10K Ohms.
- Measure the resistance between the two twisted pair wires to verify that it is higher than 10 K Ohms.
- Measure the resistance between the shield (if any) and an earth ground to verify that the shield is not grounded.
- Short the wire pair on one end and measure the wire resistance. This information is needed when calculating the number of Fieldbus devices that can be powered over the wires.

Both the Signal test and the Resistance tests assume that the wires are not connected to any Fieldbus devices, terminators, power conditioners, etc.

## Fieldbus Operation Test

The FBT-2 Receiver can also be used to check the general operation of a Fieldbus network. When the Receiver is connected to an operating network, if the power on the network is greater than 10 V the POWER light comes on. The three signal lights indicate the signal strength on the network. If the signal is less than 175 mV pp only the SIGNAL light is on. If the signal is greater than 175 mV pp, the level needed for Fieldbus operation, the GOOD light is on. If the signal is well above the minimum needed, the EXCEL light is on.

## Power

The Receiver operates from an internal battery or from the wall plug-in power supply. The power plug is also used to charge the battery. The Transmitter is powered by the Receiver over the wire pair being tested.

## Specifications

Model FBT-2A-A: Fieldbus wire Tester with North American/Japanese style power plug,

Model FBT-2E-A: Fieldbus wire Tester with European style power plug,

| | |
|---|---|
| Min. signal detection level | 50 mV pp +/- 10 mV |
| GOOD signal detection level | 175 mV pp +/- 10 mV |
| EXCEL signal detection level | 375 mV pp +/- 10 mV |
| Operation temp. range | -10 to 50° C |
| Weight | 100 grams, (0.25 lb.)each unit |
| Size | 9 x 3 x 11 cm (3.5" x 1.2" x 4.3") each unit. |

## Fieldbus Network Tester, FBT-3

The Fieldbus Network Tester, FBT-3, is used to examine a live Fieldbus network without interfering with its operation. The Tester is intended for maintenance personnel to verify network operation or to troubleshoot an errant network.

A number of network parameters can be examined with the Tester. These are selected by pushing the SELECT button. This cycles the Tester through all its functions. When a function is selected, the measurement value shown initially is "???" until the needed data is gathered by the Tester. After that, the measured value is shown. The indication "OK" is shown if the measured value is within acceptable range.

**VOLTS:** The DC voltage on the network is shown. Measurements over 9 volts are OK.

VOLTS
18.4 OK

**LAS:** If there is any activity on the network, the Link Active Scheduler should be sending out Probe Node frames. The Tester measures the signal level of the Probe Node frame. The signal level is in millivolts. Measurements over 150 mV are OK.

LAS
560 OK

**Device:** If there are Fieldbus devices active on the network, the Tester counts them. If the count has remained the same since the Device function was selected, the display shows "OK".

DEVICE
7 OK

If a device has left the network the display shows a minus sign, "-". If a new one has been added, the display shows a plus sign, "+".

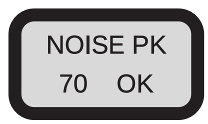
DEVICE
8 +

**Low:** The signal level of the device with the lowest signal level is shown. Measurements over 150 mV are OK. The device's address is shown behind the word LOW.

LOW 7C
350 OK

**Noise Av:** The noise on the network is measured in the silence period between frames. The value is averaged over 10 measurements. Measurements under 75 mV are OK.


**Noise Pk:** The peak noise recorded since the function was started is displayed. Measurements under 75 mV are OK.




**New:** If a new device is to be added to the network, it must respond to the Probe Node frame sent by the LAS. The Tester measures the signal level of the new device's response. Measurements over 150 mV are OK.


## Specifications

The Tester is powered from the Fieldbus itself and uses 5 mA of current. The Tester can be used in hazardous areas.

| | |
|---|---|
| Operation temp. range | -10 to 50° C |
| Weight | 100 grams, (0.25 lb.) |
| Size | 9 x 3 x 11 cm (3.5" x 1.2" x 4.3") |

# Ferrules for Stranded Wires

The reliability of stranded wire terminations can be increased by using ferrules crimped onto wire ends. The ferrules provide several benefits:

- Ferrules form a gas-tight connection to the copper wire strands. The ferrule makes contact with a similar metal in the wire terminal. This has far less potential for corrosion than if copper wire were used directly in a terminal.
- Ferrules keep the stranded conductors together. This avoids splaying and possible shorting to adjacent wires. The ferrule also provides strain relief so that individual wire strands are not fatigued and broken.

Ferrules are available for different wire sizes. They can have either an insulation sleeve or are available without one. Shown below are ferrules with insulating sleeves. A ferrule adds the equivalent of one wire size to the diameter of the wire.

| Wire Size mm | AWG | W/O Insulation WAGO Part Number | With Insulation WAGO Part Number |
|---|---|---|---|
| 0.25 | 24 | 216-131 | 216-321 |
| 0.34 | 24 | 216-132 | 216-322 |
| 0.5 | 22 | 216-101 | 216-221 |
| 0.75 | 20 | 216-102 | 216-222 |
| 1.0 | 18 | 216-103 | 216-223 |
| 1.5 | 16 | 216-104 | 216-224 |
| 2.5 | 14 | 216-106 | 216-206 |
| 4.0 | 12 | 216-107 | 216-207 |

## Crimp Tool 206-204

A universal crimp tool is used to crimp ferrules to AWG 12 to AWG 24 wires. Built-in crimping pressure control adjusts the crimping force automatically to the wire size.
A unique ratchet mechanism insures a gas-tight crimp and will release only when the tool has fully cycled. The crimping pressure is applied from four sides forming a square crimp. This insures a high wire terminal retention force and greater contact area with the wire terminal.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# Glossary

| | |
|---|---|
| **Attenuation** | Signal getting smaller as it travels on the cable (pg. 8) |
| **Bit cell** | The length of time taken by a single bit. This time is 32 microseconds for H1 Fieldbus (pg. 7) |
| **Cable** | A number of wires and shield in a single sheath (pg. 2) |
| **deci-Bell, dB** | A measurement of signal attenuation (pg. 11) |
| **Daisy-chain** | A wiring method where a number of devices are attached along the homerun cable (pg. 3) |
| **Device** | A sensor, actuator or control equipment attached to the Fieldbus (pg. 2) |
| **End delimiter** | A bit sequence used to signal the end of a frame (pg. 7) |
| **Fieldbus** | A process control local area network defined by ISA standard S50.02 (pg. 2) |
| **Frame** | A single transmission from a device (pg. 7) |
| **H1** | The 31.25 kbit/second type of Fieldbus (pg. 2) |
| **Intrinsic safety** | A characteristic of wiring or devices that cannot cause atmospheres to ignite or explode (pg. 17) |
| **IS barrier** | A device used to keep voltages and currents on wires below the levels that can ignite an atmosphere (pg. 17) |
| **Lift-off voltage** | The initial voltage required for a Fieldbus device to start operating (pg. 9) |
| **Link Active Scheduler, LAS** | The device responsible for controlling the operation of a Fieldbus (pg. 8) |
| **Manchester** | A coding method used for sending digital data on the Fieldbus (pg. 7) |
| **Preamble** | A bit sequence used to synchronize a signal receiver (pg. 7) |
| **Reflection** | An unwanted signal that results from a cable fault or improper termination (pg. 4) |
| **Segment** | A part of a Fieldbus network wiring that is electrically independent from other parts (pg. 3) |
| **Start delimiter** | A bit sequence used to signal the start of the data portion of a frame (pg. 7) |
| **Surge** | Large unwanted voltage or current on wires. Generally caused by lightning or nearby heavy electrical power use (pg. 16) |
| **Surge suppressor** | A device used to discharge surges to ground (pg. 16) |
| **Terminator** | A device used to absorb the signal at the end of a wire (pg. 2) |