FOUNDATION fieldbus solutions from ABB

Reap all the benefits of proven digital technology
**Industrial IT**

**The next way of thinking**

**Industrial IT from ABB** – dramatically improving enterprise connectivity and the quality of the information you acquire and use. Empowering you to access real-time information on a unified enterprise model – so you can make faster, more informed decisions and effectively and successfully implement them for profitable growth.

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**Understanding your needs**

You face many challenges in achieving more efficient plant-wide and global operations. While your business is unique, it consists of a multiplicity of processes that can span marketing, design, supply chain, manufacturing, quality, sales and distribution. Processes that are dependent on trouble-free access to accurate, up-to-the-minute, reliable information.

And as knowledge is the most precious commodity in business today, the challenge is to have the relevant information available at the right time in the right form for the right people.

The information needs of the people who manage, control, operate and administer an enterprise are all different but each has a common goal – increasing enterprise-wide productivity.

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**A powerful portfolio that makes automation easier**

Industrial IT integrates automation systems in real-time – right across the enterprise. It provides business information from initial order through production to delivery and to payment. ABB has aligned its products, services and people to create compatible Industrial IT building blocks that provide real-time automation and information solutions – with one common architecture. This provides a consistent infrastructure for data, operations, configuration and maintenance right across your enterprise. The suite of integrated Industrial IT solutions address the problems that you face in today’s e-business environment. The unified architecture improves productivity, provides higher asset optimization and allows for more informed decision-making.

**Industrial IT means making your best-ever decisions yet**

**Compatible products and services from ABB are raising your plant intelligence to the power of IT**
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1 INTRODUCTION
Fieldbus for process automation offers a digital only method of communication between the field and process control system. It has provided access to the vast amount of information resident in modern intelligent field devices, allowing a shift in the distribution of control functions from the system towards the field device.

Full access to device information provides the opportunity to take advantage of Asset Optimization functions at the higher system level. In this regard, fieldbus technology is assuming a greater importance throughout industry.

This document provides an overview of the technology behind FOUNDATION fieldbus to help you draw your own conclusions regarding its suitability for your applications.

1.1 Application areas and advantages of the fieldbus technology
As fieldbus technology matures, the focus has shifted from development to implementation issues in concrete process automation projects, and to the supply of all necessary devices and peripherals.

Although much progress is still required regarding true interoperability between devices, with foreign hosts and in streamlining the engineering effort, fieldbus technology has acquired a momentum of its own. Its acceptance in the market has much improved and its implementation scope has moved from pilot plants to large scale processes.

The expected benefits in installation costs, engineering and commissioning are now supplemented by those related to asset optimization. Digital communication enables real-time access and transfer of field resident information; previously unavailable to the control system.

Fieldbus is set to become the technology of choice for the future.

1.2 Automation fieldbuses and standards
PROFIBUS and FOUNDATION fieldbus dominate the Automation industry. Both buses offer power over the bus for field devices and provide digital only communications from the field to control systems. In terms of organisation they are similar with many user groups and support world-wide by the major manufacturers.

PROFIBUS International, has its headquarters in Karlsruhe, Germany and FOUNDATION fieldbus has its headquarters in Austin, Texas.

The technologies of PROFIBUS and FOUNDATION fieldbus are different in several important areas, although the installation guidelines of PROFIBUS PA and FOUNDATION H1 are similar as they share the same Physical layer (see section 2.2.1 ISO/OSI Model).

1.2.1 PROFIBUS
PROFIBUS has evolved from the high-speed buses required between PLC and I/O racks (PROFIBUS FMS and DP). This has resulted in a large well-developed range of DP devices. Support for automation was completed with the extension of DP to intelligent field devices via the PROFIBUS PA protocol. PA can supply power over the bus for devices such as pressure transmitters which can be extended into IS areas. PA segments are connected to DP via a coupler or link.

PROFIBUS operates as a master slave protocol. The master function is usually provided by devices at the high-speed DP level with slave devices at both the DP and PA level (there can be more than one master). Once the system has been commissioned, cyclic access can be optimized for the number of devices concerned. Acyclic commands (operator interaction) are allowed for as part of the network bandwidth.

Device Interoperability is via the use of Profiles - a successful method as many multivendor sites exist today. The PROFIBUS standard requires device vendors to provide a database file (GSD file) for each device to provide integration into systems and engineering tools. A more recent development for this level of support is via the Device Type Manager (DTM) and Field Device Tool (FDT). The Device Type Manager provides the user interface and all device management and configuration functions, and the Field Device Tool provides the interface to the system engineering tool used. The key features of this methodology are:

The DTM is provided alongside the GSD files (floppy disk or CD ROM). The DTM provides a rich graphic user interface (GUI) with 100% access to all field device features.

You are presented with the same user interface independent of the engineering tool used.

The device support methodology of FDT/DTM provides several cost and time saving opportunities to both vendor and end user and is already extended to the HART protocol.

ABB is investigating the implementation of FDT/DTM methodology to FOUNDATION fieldbus.

1.2.2 FOUNDATION
The FOUNDATION fieldbus protocol has been developed from the intelligent field device level with product becoming available from 1999. The protocol describes the H1 level for connection of devices requiring power over the bus, this is the H1 level, and also a high-speed backbone based upon Ethernet for topology optimization and connection of complex devices. The main thrust behind FOUNDATION fieldbus is to provide an efficient communications method that allows control, and other such functions, to be distributed into the field. Other features of the protocol include:

- There is no master or slave relationships between devices, but there is a communications scheduler with back up facilities.
- There is a method to communicate information deterministically, this enables distribution of control into the field.
- Alarms are time stamped at source not at the system.

Field devices contain standard function blocks that enable interoperability between devices and interchangeability if equivalent functions are implemented. Device integration into a control system is further strengthened with the use of device type profiles and device description files (DD – CFF). Each FOUNDATION fieldbus device is tested to comply with the standard, and once it has passed it will display the FOUNDATION fieldbus ‘Tick Mark’. This testing procedure has been extended to include the host system (HST).

1.2.3 Standards
The vision of a single fieldbus has been diluted as a result of the IEC fieldbus standards committee decision to append other protocols to its IEC61158 standard. In all there are now 8 protocols to be appended to this standard. They are shown below.

Table 1

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FOUNDATION fieldbus</td>
<td>DD238</td>
<td>EN 50170</td>
<td>ISA 550</td>
</tr>
<tr>
<td>PROFIBUS PA</td>
<td>BS EN 50170</td>
<td>EN 50170</td>
<td>None</td>
</tr>
</tbody>
</table>

1.2.4 ABB Position
ABB supports both the major automation fieldbuses, namely PROFIBUS and FOUNDATION fieldbus and also LON for medium and low voltage systems. We are an active driving force at all levels of FOUNDATION fieldbus and PROFIBUS policy and technical development with significant real installations utilizing both protocols.
1.3 User Requirements
As an all encompassing communication technology for process automation, fieldbus must meet the stringent requirements of the process industry. These can be grouped in three categories.

On the concept and standardization side, the general requirements are:
- Standardization of the communication technology
- Comprehensive product availability in terms of both diversity of suppliers and required functionality
- Availability of engineering implementation tools and services, planning aids, technical training, maintenance services
- Standardized engineering interface for transportability of devices configuration and engineering effort to different systems environments

On the technical performance side, fieldbus products and solutions must match the performance achieved today by traditional analog and parallel methods for signal exchange between control system and field instruments:
- Reliability in the transfer of information and time behaviour guaranteed performance
- Redundancy strategies
- Intrinsic safety and field devices power supply on the signal lines
- On line equipment substitution without interfering with plant operations
- Protection from electromagnetic interference from the environment
- Possibility to expand the control system and using distributed field units irrespective of the supplier
- True interoperability of field devices from different suppliers, between themselves and with other host control systems

On the present/future development side, the expectations are:
- Significant cost reductions at all stages of the life cycle; planning, procurement, engineering, installation, operation and maintenance
- Integration within the fieldbus based automation architecture of installed field inputs and outputs, whether conventional analog or hybrid HART
- Integration of available field device based information for deployment of preventive maintenance strategies

1.4 User Benefits
The application of fieldbus technology provides benefits throughout total plant life time. Cost savings to commissioning stage vary between 25% (source McDermott Engineering) and 43% depending on the layout and the technology used as a reference, with Operational and Asset Optimization benefits following thereafter.

Be aware of claims for higher cost savings. These are typically a result of extremely long cable runs and are not representative. However they make good headlines!

<table>
<thead>
<tr>
<th></th>
<th>Traditional 4-20mA</th>
<th>Fieldbus 25% Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commissioning</td>
<td>7%</td>
<td>3%</td>
</tr>
<tr>
<td>Installation</td>
<td>28%</td>
<td>17%</td>
</tr>
<tr>
<td>Design</td>
<td>14%</td>
<td>11%</td>
</tr>
<tr>
<td>Procurement</td>
<td>53%</td>
<td>44%</td>
</tr>
<tr>
<td><strong>User Benefits</strong></td>
<td>=100%</td>
<td>=75%</td>
</tr>
</tbody>
</table>

1.4.1 Pre-Commissioning
Savings here are generally made in reduced planning and documentation costs.

1.4.2 Installation & Commissioning
In this case savings are possible due to:
- Reduced cable requirements
- Reduced peripheral equipment such as IS barriers – I/O cards – marshaling cabinets etc
- Reduced engineering time. (Ability to cut and paste applications and engineer from a central location)

1.4.3 Operation and Management
With a greater view of process conditions Asset Optimization allows operation closer to plant design limits and a switch from ‘just in case maintenance to predictive maintenance’.

1.5 IndustrialIT – The next way of thinking
The advent of eBusiness is rapidly changing business needs. Suppliers are now able to tailor messages and offerings on an individual customer basis rather than using the mass marketing techniques of the past. At the same time customer demands are increasing. It is no longer adequate to simply use traditional business planning and production systems.

There is a growing need to deliver real time information across the whole enterprise – from plant floor to boardroom – to achieve greater flexibility, faster delivery times and higher customization. ABB’s IndustrialIT approach is about replacing ‘islands’ of automation with an integrated system approach that spans marketing, design, supply chain, manufacturing, quality, distribution and other processes. It is a seamless integration of real-time information (Process Control) and transactional information (Enterprise Resource Planning).

From the fieldbus perspective, IndustrialIT deals with the integration of process information to and from the field device and particularly the enhanced information made available via fieldbus. Fieldbus devices provide additional information used by IndustrialIT application to assist with the shift from preventive maintenance to predictive maintenance and all the reduced life cycle cost advantages that result.

The diagram below shows how field devices, both traditional and fieldbus, integrate within IndustrialIT as part of the FieldIT structure. It is clear that the IndustrialIT optimization applications suite OptimizeIT has access to all process information in support of its function of guiding management decisions based upon real-time data.
2 BASIC PRINCIPLES – FOUNDATION fieldbus

2.1 General Definition: fieldbus in process automation

Fieldbus Types

A simplified description of a fieldbus is a method of digitally transporting data between devices. All fieldbuses provide this function. However, it is important to understand that different fieldbuses will dominate different levels in the plant network hierarchy – at least in the medium term. Important levels are (see diagram):

- Interconnect field-based devices such as transmitters and positioners. These devices may require power over the bus and be used in hazardous environments. Protocols would include FOUNDATION fieldbus H1 and PROFIBUS PA.
- Interconnection of complex devices such as Remote I/O – analyzers etc. In this case devices are often externally powered. Protocols would include FOUNDATION fieldbus HSE and PROFIBUS DP.

The Control Systems and LAN's segment in the diagram describes the protocols used between automation systems and displays.

The Plant-Wide Network would involve communication of data between plant areas or business levels.

- Plant network level - communication between systems, PLCs and large controllers

2.2 The FOUNDATION fieldbus protocols

FOUNDATION fieldbus provides an open standard for process automation applications and is supported by all the major control and automation product manufacturers. FOUNDATION fieldbus consists of a slow speed bus (FF H1) designed for the connection of 2-wire field devices and a high-speed bus (FF HSE) allowing optimization of network design and connection of complex devices such as analysers/PLC etc.

FF H1 is designed for process automation and specifically for field devices requiring power from the bus. This includes suitability for use in hazardous areas via IS protection. FOUNDATION fieldbus H1 is designed to incorporate deterministic communications allowing control functions to be distributed into the field and providing timely reporting of process conditions.

The requirement for a high speed bus is satisfied by FOUNDATION fieldbus HSE, being based upon Ethernet and using low cost readily available components already familiar to IT departments. Its role as providing the back-bone for linking of H1 segments also includes the connectivity for complex devices such as analysers, remote I/O (for conventional device integration) or other devices, which are independently powered.

2.2.1 Protocol architecture, functions, profiles and interoperability

Protocol Architecture (ISO/OSI)

In 1978 the International Standards Organisation (ISO) defined a general, non-industry specific, reference model to help the specification of open systems. This is called the Open System Interconnection (OSI) model often referred to as the ‘ISO/OSI model’.

The ISO/OSI model defines seven layers, each layer performing a specific function for data communication. A message is passed from the top layer (7) to the bottom layer (1) when sending, the reverse when receiving. It is not necessary to use all seven layers to build an effective open communications system, and additional layers can be added.

The used set of layers is called a ‘stack’. FOUNDATION fieldbus does not use layers 3 to 6 and the Fieldbus Access Sublayer (FAS) maps the Datalink Link to the Fieldbus Message Specification (FMS). FOUNDATION fieldbus defines another layer, the User Layer, which provides standard function blocks (AI – AO – PID etc.) for use when process functions are distributed into the field.

The Physical layer used by FOUNDATION fieldbus is the IEC 1158-2 standard which is the same as that employed by PROFIBUS PA. The net result is that installation rules are the same for PA and FOUNDATION fieldbus H1 (IS guidelines are different). These rules govern topology design, cable types, devices per segment etc.
The methods of Profiles – Function Blocks and Device Descriptions are discussed next.

2.2.3 Profiles

A definition of a device profile would be ‘A definition of the minimum functionality required to provide a useful level of interchangeability for a device type’.

A profile consists of a subset of the services specified in a communication standard plus parameter definitions for applications using similar devices (e.g. a level or flow application). Because the communication standard consists of layers, the communications subset is defined as a sub-profile for each layer (see diagram).

Profiles

A complete device profile defines the minimum requirements for a device to be interoperable with others.

The advantages of profiles are:

- Fewer implementation costs – because a subset of the standard can be used
- Enhanced interoperability – because of common device parameters
- Lower configuration cost – because default values for parameters are used

In FOUNDATION fieldbus the profile is incorporated into the device description.

2.2.4 Device Description (DD) and Common File Format (CFF)

The DD and CFF files provide all the information required to configure and integrate a FOUNDATION fieldbus device into a control system.

The DD is a binary file the main task of which is to provide information regarding how device data is displayed:

- The data variables and help text
- The menu based user interface to interact with the device
- The command/response sequences to do operations on the device
- Data relationships (e.g. ‘write these data as one’ block)
- Response codes from device

The device developer uses a device description language specified by FOUNDATION fieldbus to write the device description. The device description is then passed through a tokenizer to produce the final binary code.

The DD incorporates a feature called ‘Methods’, which can be described as an action to be performed by a host. This action may include a calculation to be performed or to wait for an operator input. Methods make use of a sub-set of ANSI C and are linked to a library of Built-in functions for user and device interactions.

The Common File Format (CFF) file consists of two subclaasses, the value file and capabilities file. The CFF file is often referred to as the capabilities file, as this (capability) feature is so important. The CFF file looks similar to a Windows INI file so that it is more easily understood. The type of information contained within a capabilities file includes device functional capabilities, size and resource limitations, manufacturer-specific default values, network management and system management capabilities supported.

The CFF file has allowed device configuration tools to carry out off-line as well as on-line configuration. Device testing (as of ITK4) for requires that the DD and CFF files are available.

2.2.5 User Layer

The use of an extra layer, the User Layer, to the ISO model provides another level of interoperability. This layer is unique to FOUNDATION fieldbus and is one reason why it is becoming a preferred protocol by many user and suppliers.

It is here in the user layer that Function Blocks (see diagram) are used in FOUNDATION fieldbus to allow control functions to be carried out in field devices. To ensure interoperability there are standard function blocks which must be present in devices of a similar nature. Vendors can also add advanced functions blocks.

2.2.6 ABB and Interoperability

ABB has identified the ease of device selection and integration into a control system as a major concern for end users. In this respect ABB has several strategies within its IndustrialIT initiative to help build end user confidence in fieldbus technology. The FOUNDATION fieldbus test list is complete for each level (the device – HSE – Host) few suppliers comply with the 18 scenarios included in each HIST. And therefore ABB has implemented its own IndustrialIT-enabled procedure whereby stated functionalities can be guaranteed.

- Plug and Produce

The DD and CFF files provide all the information a system requires to display process data from a field device. ABB has gone one step further by allowing the system to automatically identify newly commissioned devices and attach display templates accordingly. These templates, or display process data from a field device. ABB has gone one step further by allowing the system to automatically identify newly commissioned devices and attach display templates accordingly. These templates, or Aspects within the IndustrialIT world, would include Trending – Status – Documentation – Asset Optimization……

- Device and IndustrialIT conformity testing ABB has set up a conformance test center to specifically test the integration of devices (fieldbus and traditional) into IndustrialIT. This will provide the confidence that a device with the IndustrialIT Enabled tick mark is compatible with ABB systems.

2.3 Transmission Technology

2.3.1 FF H1 (31.25 kbit/s)

The H1 bus cable is compatible with typical 4-20mA wire (see Installation) and is used to connect field devices to the network. Devices are connected in a multi-drop fashion such that one fieldbus segment can accommodate up to 32 devices (externally powered) or 240 if repeaters are used. If it is required to power devices from the fieldbus then the
number of devices which can be connected is reduced (see section 'Number of devices per segment') experience indicates that for H1 segments without distributed control then between 8 and 10 devices can easily be accommodated.

As with the 4-20 mA standard, fieldbus allows devices to be located in hazardous areas with the application of intrinsic safety methodology. The FOUNDATION fieldbus H1 protocol allows for deterministic inter-device communication, alarm time stamping at the device, full access to diagnostic information for asset optimization applications and interoperability assurance.

2.3.2 FF HSE (10 – 1,000mbit/s)

If a fieldbus topology is designed with many segments connected via repeaters to a home run, the data refresh rate would be reduced due to the bottleneck effect at the home run. To overcome this problem and aid network optimization FOUNDATION fieldbus released its protocol using Ethernet technology. FF HSE supports the H1 function blocks and communications relationships allowing devices to communicate across segments. FF HSE also supports configuration management of H1 devices. Installation guidelines for FOUNDATION fieldbus HSE are no different than for typical IT Ethernet. In this case with 10mbit/sec a category 5 copper wire can run for 100m and can be extended to 300m with the use of repeaters. It is also possible to use fiber optic with its advantages of greater data integrity and network distances. As you can see, the type of media used is defined by Ethernet standards and not FF. The selection of Ethernet technology allows the use of readily available low cost networking peripherals with standard IT installation and support.

2.4 Bus accessing methods and network optimization

2.4.1 Bus Access

The FOUNDATION fieldbus protocol allows the following functions to be carried out over the bus

• Cyclical (Publisher - Subscriber– Deterministic data communication Data can be transmitted periodically to suit the execution of function blocks in other devices. e.g. transfer flow value from transmitter to PID function block in a positioner, then execute the PID function

• Peer to peer (Client – Server) - communication of data between devices Device configuration – Inter-device Messaging – Operator interaction.

• Acyclic (Alarms –Events) data communications

Alarm reporting –This represents data transfer that may be triggered via an event or operator interaction.

H1 segments to single host

It would be possible to design a fieldbus solution with H1 segments connected to an H1 card and then directly to the HSI. This may be how some users will set-up a device configuration facility to configure some device parameters off-line or to calibrate devices, in practice the use of a high-speed bus is often preferred for any large installation.

2.5 Bus topologies, installation considerations and control in the field

FOUNDATION fieldbus uses a combination of a master/slave and token passing as a method of bus access control to permit these functions. A device that has the scheduling function controls the FOUNDATION fieldbus segment. This function is referred to as the Link Active Scheduler (LAS) and can be considered an extension of the FOUNDATION fieldbus stack. In this case a segment comprises of standard devices (a bit like a slave) and at least one LAS device.

The LAS controls the network bus by issuing tokens. The tokens and functions are:

• Compel Data

This token is sent to particular devices when it is time for them to publish data on the segment

• Pass Token

For acyclic communication of data

• Probe Node

Search for new devices on the segment

• Time Distribution

Synchronizes device time

Industrial IT with LD to H1 segments
2.5.1 H1 Installation

The FOUNDATION H1 bus accommodates the types of devices typified by pressure – temperature and positioners. The bus topologies allowed are a result of the Physical Layer international standard IEC1158-2 and there are guidelines to help with the design of these topologies. Simplistically the bus cable would be a twisted pair with a terminator at the extreme points, the guidelines for cable length depend upon cable parameters and are summarized in this table.

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>Cable size</th>
<th>Maximum Length (M)</th>
<th>Loop Impedence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A–shielded twisted-pair with shield</td>
<td>18</td>
<td>1900</td>
<td>44Ω/km</td>
</tr>
<tr>
<td>Type B–multi twisted-pair with shield</td>
<td>22</td>
<td>1200</td>
<td>112Ω/km</td>
</tr>
<tr>
<td>Type C–single or multi twisted-pair w/o shield</td>
<td>26</td>
<td>400</td>
<td>264Ω/km</td>
</tr>
<tr>
<td>Type D–multi-core w/o shield</td>
<td>16</td>
<td>200</td>
<td>40Ω/km</td>
</tr>
</tbody>
</table>

2.5.2 Bus with Spur Topology

The segment has terminators located at the extreme points with devices dropped off in parallel. The total length of all spurs and the segment length must not exceed the maximum length defined by the cable used (see previous table).

Daisy chain

The maximum spur length is reduced by 30m for each additional device added to that spur.

2.5.3 Daisy Chain

In this case the fieldbus segment is connected to each field device and then looped out to the next device. If a device is removed from the segment, care must be taken that the terminator is not removed with it.

2.5.4 Tree Topology

Practical if devices are located close together.

2.5.5 Wiring Considerations

Generally, good installation routines must be followed using the correct tools and suitable cable. Guidelines

- Make sure terminators are installed at the extremes of the segment and that only 2 terminators are present in any one segment
- IS areas require IS terminators
- Do not ground the shield in more than one location
- Ensure the screen is passed through any junction box or T-Piece
- Ensure shields of multiple segments are not connected together

2.5.6 Network Components (Connectors – Terminators etc.)

Each H1 segment requires two terminators and a fieldbus compatible power supply as minimum components for devices powered over the network. If you decide to use a traditional PSU you require a conditioner so that it does not effect the fieldbus signal.

For IS applications you require an IS fieldbus rated power supply and barrier (often an integrated solution) together with an IS terminator. As a result of the multi-drop bus then there is the opportunity to take advantage of new/different connector devices, some of which will have terminators built in.

The ABB MultiBarrier is available for use at the H1 level and provide IS protection for use in hazardous areas.
2.5.7 Bus Topology with Spur Components

In this case use T-Pieces to provide the spur drops. The advantages are:
- Simple and quick-fit connections in the field
- Often the T-Piece will provide a jumper to add-in a terminator (Non-IS)

You need:
- Fieldbus rated power supply
- T-Pieces for each field device
- Connector for each field device
- IS terminator if IS area

2.5.8 Tree Topology Components

In this case use Hubs to provide the spur drops. (Suppliers include TURK and RELCOM). Check if the hub you have chosen requires mounting in an enclosure.

You need:
- Fieldbus rated power supply
- 4 or 8 port hub
- Connectors for each device
- Terminator (IS or Non-IS)

2.5.9 Number of devices per segment

Several parameters affect the number of devices you can attach to a particular segment. These include:
- Segment length
- Device current consumption
- Environment (IS)
- Data refresh rate requirement

Perhaps the best way to describe the guidelines is to run through a few examples.

Case 1

Type A cable at the maximum 1.9km length with devices that draw 11ma each. Non-IS:

Assuming that the PSU provides 22V and that the cable resistance is 44 Ohms/km, and that no other load is present apart from the barrier (surge protectors etc.)

Current available = Voltage/Resistance
= \frac{(22 – 9)/((44*1.9)+105)}
=69ma

Therefore 69ma/11ma = Number of devices = 6 devices

Reduce the segment length to 1km and the number of devices on the segment increases to 8.

In this case you must assume that one device (LAS) is likely to be in the safe area and you should also account for visiting devices, this reduces the 6 devices to 4 for a 1.9km run.

2.5.10 Intrinsic Safety

Fieldbus solutions will reduce the number of IS barriers required when compared to a traditional installation. This is a result of the multi-drop nature of FOUNDATION fieldbus and also PROFIBUS. As with the traditional IS solution key is to reduce the power supplied to the field. An IS barrier is required (it may also provide power for the bus) for each segment with an IS rated terminator at the end of the segment in the field. The number of devices depends upon the current consumption of the device (some devices may be externally powered) and cable length as previously shown.

An I.S. barrier must be within 100m of a terminator and the power available past an I.S. barrier is ~600 mw. Typically four field devices can be connected plus a hand terminal in the safe area.

Key points:
- Use an IS power supply for the IS segment or use a barrier with internal PSU
- Require IS rated terminator in the field (RC components are energy storing)
- Surge protector resistance must be taken into account

Spur length from the hub in a tree configuration follows same rules as for a single spur.

2.5.11 Trouble-shooting H1 segments

An advantage of fieldbus solutions is that if a segment is working then system tools can often be used to troubleshoot. The ABB Control Builder F is a System Integrated engineering tool, which offers many features to troubleshoot the H1 BUS, possibly the simplest is the Live-List view of the bus. The live-list provides the current view of all communicating devices on the H1 BUS and so a straightforward physical comparison will identify a faulty device.

Suppliers such as RELCOM now offer FOUNDATION fieldbus test devices that will report if the LAS is active, how many devices are on the segment, noise and voltage levels etc. Tools such as this will simplify trouble shooting without being too sophisticated.

2.5.12 Control in the field

The ability to distribute functions into field devices and determine the sequence of communication and function block execution is a differentiating technology for FOUNDATION fieldbus. In this case the Link Active Scheduler (LAS) and standard function blocks resident in the user layer are the key enabling technologies.

The availability of standard function blocks in the user layer provides the interoperability between devices from different vendors, the Device Descriptor (DD) and capabilities file (CFP) provides the engineering tool with the information concerning which of these function blocks have been implemented in a device.
The advantages offered by distributing control between field devices revolve around loop integrity and efficiency of the use of communications capacity or bandwidth as it is often referred to. In the case of simple PID control distributed between a transmitter (e.g., pressure) and a positioner, the most likely and communications efficient location for the PID algorithm would be in the positioning devices. More complex loops (cascade) may require PID in the transmitter as well. To maintain loop integrity there should be a backup LAS (possibly in the positioner but not exclusively there) to maintain control functions in case of LAS failure. Other considerations should be that the transmitter and positioner should also be on the same H1 segment and not rely upon repeaters or high-speed Ethernet (FF HSE) link devices to relay control data.

The loop performance increase by distributing the function into the field is likely to be quite small and so complex loops, and loops including data across H1, segments are perhaps best performed at the DCS or supervisory system level. Control in the field device would provide a backup function.

### 2.6 Device Selection

There are several new considerations to take account of when selecting new or replacement devices. For example, if your network strategy is to place as many devices on a segment as possible then a key parameter to check would be the device current consumption.

All devices displaying the FOUNDATION fieldbus tick mark will comply with the FOUNDATION fieldbus standard and this will guarantee that the communications stack is compliant with the FOUNDATION fieldbus standard. However, be aware that not all devices will implement the full complement of function blocks in the user layer. So if you decide to use PID functions in H1 devices make sure that this function block is implemented in the device you choose.

Check:
- Device has FOUNDATION fieldbus tick mark
- Device current consumption
- Function blocks implemented
- Level of local support

### 3 SYSTEM STRUCTURE OF FOUNDATION FIELDBUS SYSTEM

New technologies – such as FOUNDATION fieldbus – open up new structures in control technology. Traditionally a system would comprise of field equipment with analog connection back to a marshaling cabinet in the central control room, and from there to supervisory/control equipment as part of a system or PID controller panel. FOUNDATION fieldbus allows a different approach where some functions can be distributed closer to the process and others such as Asset Optimization can make full use of two-way communication to field devices at the higher system level. A key feature of FOUNDATION fieldbus technology is to allow the end user to take full advantage of the open standards incorporated. This allows for the selection of the most appropriate device for the application rather than locked into the manufacturer who provided the system.

A typical FOUNDATION fieldbus system structure is shown below:

The system backbone of the whole plant uses HSE and connects all components of the automation and supervisory area like Operator Stations, Engineering Stations, Automation Units. Each automation unit uses FOUNDATION fieldbus –H1 for the automation and communication. This network is linked to the HSE backbone.

ABB IndustrialIT systems are using this structure as well:

![System Structure Diagram](image-url)
3.1 Configuration

FOUNDATION FIELD BUS provides the capability to distribute control functionality into the field device and across the bus. Each device has the capability to execute certain function blocks. A Link Active Scheduler (LAS) schedules the cyclic communication between the devices and the execution of the function blocks. This means the distributed function block application (including the cyclic communication) has a deterministic behavior. The Control Builder F, the engineering tool for an Industrial IT system, allows creating those function block application diagrams for distributed control. For reducing engineering time offline configuration is possible and you can start with configuration before any device hardware is available.

3.1.1 Import of new Devices

All device types you want to use in the application can be imported via their Device Description and Capability File into your project device library.

3.1.2 Build up of bus topology

Each H1 segment that is linked via a HSE Linking Device to the Automation and supervisory area can be build up in a graphic way using the hardware editor. Each device is represented with a bitmap and shows tag name, manufacturer, device type, device ID and bus address.

3.1.3 Function Block Application

The application, using the distributed control functionality of FOUNDATION Fieldbus is configured within the Function Block Application Diagram as you can see here:

The example shows a distributed control loop between a difference pressure transmitter and a positioner. There is an analog input function block running in the FIO100 Device, this value is cyclic communicated via the H1 line to the FC 100 device. This device executes a PID function block and an analog output block.

Each Function Block must be assigned to the executing device at a H1 Link. This can be done in a graphic way with drag and drop. All used blocks in a device are marked so it is very easy to find out which functions are still available.

3.1.4 Parameterization of Devices and Function Blocks

To make all devices and function blocks operate correctly, each component has to be parameterized. The Parameterization Dialog of each Block can be opened and parameterized with an easy mouse click on the function block shown in the Function Block Application Diagram or in the device view that you can see here:

3.1.5 Scheduling

As mentioned above, there is a deterministic execution of cyclic communication and function block application. While creating your application the Control Builder F calculates the needed schedule automatically. The execution times of function blocks and communication are shown in the schedule editor.
For special loops or time critical signals this schedule can be edited manually while moving the timing block with the mouse pointer.

3.1.6 Commissioning
After the completion of off-line/on-line configuration you can proceed to the commissioning phase. At this time all devices must be available because they are not just a supplier of measure values, they are executing the application itself and their behavior influences the loops.

Control Builder F offers you a very strong FOUNDATION fieldbus Commissioning Tool. All Editors are displayed in the same way in commissioning mode as in configuration mode but online information are added.

3.1.7 Live List
As a new device is added to a FOUNDATION fieldbus H1 segment the LAS will identify it as a result of sending a probe node token. As a result, the device will automatically be given a unique system address. With the Live List FOUNDATION fieldbus allows you to display all devices that are connected to the HSE and you can see all field devices connected to a H1 line and linked to the HSE via a linking device.

3.1.8 Device Assignment
Each device that is shown in the live list can be assigned to the field device hardware that is configured in your project. This is done by drag and drop in a graphic way and allows you to start the application.

3.2 Fieldbus enables new control system structures - ABB’s IndustrialIT
New technologies – such as FOUNDATION fieldbus – open up new structures in control technology and ABB’s IndustrialIT ensures that full advantage can be taken of these features.

In a traditional analog system each measured value from a field device would require a twisted pair in a multi-core cable and would be connected at a marshaling cabinet and then to I/O cards or stand alone controllers in the control room. Expansion of the system would be limited by some extent by any spare capacity in the multi-core cable used with advanced features such as Asset Management being restricted by the analog technology used.

Traditional Automation system
As we have seen in section 1.4 fieldbus protocols offer an open communication method for accessing data from the field device and offer flexibility in the design and installation of an automation system. FOUNDATION fieldbus takes this one step further by allowing distribution of functions into the field, functions such as PID control. In the simplistic diagram above process data is uni-directional, with one twisted pair providing one process variable. Supervisory and control functions are carried out by devices in the control room area which have access to very little diagnostic or device status information, in fact the view of the process ends at the marshaling cabinet or remote I/O.

The FOUNDATION fieldbus solution offers the advantages of a bus structure for field devices, with distributed intelligence. The result would be that control functions now exist in the field device and execute deterministically. Other functions in the field device include predictive maintenance algorithms, checking the device condition and sending an event message to the host indicating the device maintenance condition. It is intelligence such as this, which has caused the shift in the system hierarchy allowing the higher system level to develop Asset Optimization applications such as ABB’s OptimizeIT.

One of the key issues is access to information from automation equipment. It is likely that some equipment will communicate via different media (fiber optic) or other protocols (HART – MODBUS), an automation system should provide access to this Information regardless of the technology used. ABB’s IndustrialIT provides such a platform, taking advantage of open computing standards such as OPC and COM/DCOM.

3.2.1 Future Control System Structures – Today’s IndustrialIT
The structures of modern day control systems from different manufacturers have evolved into a similar design that includes:

- Process area
- Bus network area
- Automation and supervisory area

The arrival of fieldbus technology has extended the network closer to the process adding the following:

- Timely reporting of process and status information
- Flexible design
- Distribution of functionality towards the field
- New asset optimization applications
As you can see, the automation and process areas have become merged as the bus network extends out into the field. The extension of the bus and the two-way communications now available has allowed a shift in the system hierarchy. Some simple functions (totalizer – PID – alarms) can reside in field devices with sophisticated Asset Optimization applications running at the higher system level. The diagram also shows how ABB’s IndustrialIT provides real-time process information throughout the enterprise.

Operator Station:

The changes at the operator station as a direct result of FOUNDATION fieldbus applications include the following:

1 Greater confidence in the process conditions reported at the workstation

This is a consequence of improvements in maintenance scheduling (switch to predictive maintenance) – data quality messages – no analog component to degrade data accuracy. As a result the operator has greater confidence in the process conditions reported from the field and can operate closer to plant capacity.

2 Timely reporting of process information

FOUNDATION fieldbus time stamps alarms at the field device with millisecond resolution and not when the system/master sees the alarm condition. Spare communications capacity is used to report alarms/events.

Fieldbus has also been the catalyst to improve data presentation at the operator station, as there is simply more data available. ABB has taken the route of providing views of plant objects (plant equipment such as a compressor or single devices such as a transmitter) with different aspects (object related data such as trends - alarms – data sheets – calibration).

In the case of ABB’s Object/Aspect methodology the user will be presented with a data format personalized to their requirements as defined by the user log-in. The personalization will be via the creation/customization of user dashboards, a dashboard being the collection/presentation of information or aspects.

Engineer Station:

Traditionally the view of process control equipment from the engineer workstation would extend only to the I/O rack or marshaling cabinet. Fieldbus systems extend this view to the field device with reporting of diagnostic information. The engineering workflow now has to deal with multiple protocols and all the data available from automation equipment in such a way as to facilitate rapid drill down to locate faulty devices.

1 Engineering tools:

FOUNDATION uses the device descriptor (DD) to allow full access to device configuration parameters.

2 Support Information:

The same organisation of data as used for the operator (Objects and Aspects) allows the rapid call up of relevant maintenance/trouble shooting documentation for fault conditions.

Optimization Station: (Audit assistant – CMMS):

Plant Optimization is already available in a limited form for traditional analog control systems. Fieldbus offers timely reporting of diagnostic information allowing a shift from preventive maintenance to predictive maintenance enabling higher availability of plant.

1 Critical asset optimization

The analyzes of information from sources such as specific device diagnostics – related device information – historian - providing maintenance triggers is the next step, although some maintenance alarms are already available (e.g. positioner data such as valve stem travel). Maintenance triggers would allow the change from preventive to predictive maintenance.

2 Process optimization

Timely maintenance of critical assets reduces plant upsets due to equipment failure allowing control strategies to run closer to the plant capacity.

Process modelling and multivariable control would be able to adapt based on confidence levels in process data reported from the field.

Bus Networks

1 High speed bus

For FOUNDATION fieldbus the high-speed bus is based on Ethernet and allows the passing of all data including configuration of fieldbus devices. Being based on Ethernet the end user has access to all Ethernet technology including switches, optical fiber media, etc.

2 High-speed bus optimization

The ability to run the high-speed bus at faster speeds (1Gbit/sec) will offer a more predictable performance at the cost of segment length. The use of Ethernet switches will allow further optimization as devices can share a smaller communications domain.

3 H1 bus optimization

The scheduling of communications traffic allows for some flexibility in the H1 bus performance, however the more devices present on a segment the less the flexibility for optimization available (less spare bandwidth for acyclic data transfers).

4 Field device bus

The H1 bus provides power for field devices that were traditionally a 2-wire design. A link device is used to connect to the high-speed bus. The ABB device offers the connection of 4 off H1 segments to the high-speed bus.

5 Gateways to other buses

As already mentioned there is not one all-embracing fieldbus technology, other buses would link to a control system via gateways at the high-speed bus level.

Automation Area

The automation area has traditionally included I/O cards and DCS-PID supervisory devices. I/O cards may still be required to support existing analog devices however other functions may reside in field devices.

1 Fieldbus controller

This is a device that will provide access to the high-speed bus. It may provide a gateway to other protocols and also DCS supervisory functions.
2 Distributed functions
This feature of FOUNDATION fieldbus offers distribution of functions such as
- PID (Economic use of communications bandwidth)
- Alarms (time stamping at source)
- Totalizer

3 Multivariable device
Fieldbus enables the full economic use of multivariable devices as all derived data (mass gas flow – totals etc) is available over the bus.

4 ASSET OPTIMIZATION - REDUCES LIFE-CYCLE COSTS
Fieldbus is one of the main driving technologies for the next generation of Asset Optimization applications within process automation. Traditional 4-20 mA or analog devices relay little or no maintenance information to maximize asset effectiveness. Fieldbus devices, on the other hand, provide timely reporting of status and diagnostic data with the facility to implement more sophisticated maintenance applications now and in the future.

The changing hierarchy of control and supervisory functions with the wealth of process data fieldbus makes available has impact upon support workflow. This is seen from maintenance planning to work order generation, from initial fault condition drill down to adapting control strategies. Asset Optimization applications are at the center of this evolutionary change, providing the tools to guide management decisions and automate actions where appropriate. ABB has identified many of the requirements and opportunities made available by this modern technology and embraced it within their IndustrialIT program.

Intelligent field devices, such as transmitters and positioners, are able to provide critical status information to the higher system via fieldbus networks. In the simplest case, the process value is reported with a status condition that provides greater confidence in the accuracy of the value reported. Other condition events are used to provide maintenance triggers via logical comparison of data within the device or from other sources (e.g. historical conditions). In the case of maintenance triggers, fieldbus has been a prime motivator for the shift from preventive to predictive maintenance, maximizing plant availability. It is an effective tool for accumulating asset historical data (audit trails) used in failure root-cause analysis as well as giving access to comprehensive documentation for repair and installation procedures. The degree of assistance within the maintenance procedure can also include work order generation – status tracking – component inventory checking and ordering.

The user platform for asset optimization functions utilizes Internet technologies and is based on Microsoft DNA Architecture technology. It allows investigation of trends across a population of devices, tracking failures, maintenance and calibration requirements. It allows decisions to be made with real-time and historical information. A messaging service capability allows notification of a maintenance type event to the user. The event is posted to the console’s alarm and event page and the event bar, and is stored in the event history, giving the operator immediate notification of a detected maintenance condition. Messaging destinations and types of messages can be structured in a user profile and via filters.

Benefits
Asset Optimization based on fieldbus technology enables predictive maintenance for a much broader range of assets. ABB’s applications collect, compare and monitor field device data to accurately assess equipment condition in real-time, document when performance falters before breakdowns, and enables personnel to schedule maintenance accordingly. Implementing predictive maintenance greatly reduces traditional, costly corrective maintenance (unanticipated repairs) and preventive maintenance (periodic scheduled maintenance) because only the devices requiring maintenance are serviced. Equipment in good order remains undisturbed.

Some plant components, typically those performing mechanical actions (valves, motors, actuators, compressors), or complex measuring devices (flow, analytical), are prone to failure and performance degradation. Currently, maintenance procedures fall into two categories: preventive and corrective. However, for some critical equipment these approaches are insufficient and have serious cost and operational implications. In order to maximize plant utilization, the most comprehensive maintenance strategy blends corrective, preventive and predictive maintenance.

Traditionally, predictive maintenance requires expensive, dedicated condition monitoring equipment and is reserved for expensive, critical machinery. With the advent of fieldbus technology, predictive maintenance has become an affordable option. The wealth of information already available in smart field devices can be communicated to the control system to enable predictive maintenance programs with significant cost savings.

The additional processing power that fieldbus has made possible at the field device is also the driver for a level of self diagnosis and the storage of device specific data such as documentation and installation data (IS certification – materials used ...). This information will assist in installation by checking device certification and enabling ‘plug in’ procedures. ABB's IndustrialIT program ensures that all ABB devices offer the advantages of fieldbus communications.

The wealth of data available from fieldbus devices requires a more intuitive interface with related data presented for a particular asset under investigation. An example would be linking for relevant audit trails for a particular asset, audit trails such as calibration, engineering and operator actions would be compiled and presented at the asset selection by the asset optimization workplace. Some of the data used to compile the audit trails would be stored in the field device and therefore be available to all subscribers to that data over the system. ABB’s IndustrialIT program extends this concept of linking data to assets by considering plant equipment to be an object and linking various aspects (views such as trending, alarms, live video etc fieldbus is clearly the underlying driver for Asset Optimization opportunities as a result of access to device diagnostics and stored data. As technology advances further then the opportunity to distribute Asset Optimization functions and more advanced maintenance triggers in to the field device becomes possible. Again fieldbus will be the driver.
5 FUTURE PROSPECTS
Fieldbus technology has provided the full communications link from field devices to supervisory/management systems. The cost savings are evident in the installation/commissioning phases with further reduction in overall system components. In this regard user requirements have been largely satisfied. A warning against all-too-euphoric marketing pronouncements in the technical periodicals is appropriate in this context. Nothing but the shared experiences of suppliers and users will help to exploit the innovative potential of this technology fully.

The other side of the coin from the savings on input/output cards in the system is the added expenses for link devices (H1 to HSE), T-pieces and high quality field devices. The reduction in the cost of components that goes hand-in-hand with the proliferation of fieldbus technology will bring it with the desired savings in hardware.

While it was previously believed that savings had to be achieved by reducing copper lines and hardware, overall costs are the center of attention today. Fieldbus technology has provided process information with a greater level of confidence. However, further work is required in the presentation of this data at the higher system level. Rather than a host of diagnostic flags, knowledge-based messages would be preferred, perhaps as a result of a maintenance trigger generated at the device level.

Applications of fieldbus technology in safety systems is another area where fieldbus can offer benefits.

6 SUMMARY/CONCLUSION
The hard cost savings from fieldbus technology are estimated at about 24% for large installations (about 3000 I/O points) (ref. McDermott engineering). The first implementations are claiming even higher savings so the technology looks set to take off. Rivalry between different fieldbus standards remains dynamic, with certified products available. For intelligent devices in the process control area choice has settled between PROFIBUS DP/PA and FF. Of these, PROFIBUS DP has a credible installed base while PROFIBUS PA and FOUNDATION fieldbus are starting, and vying for installations. FOUNDATION fieldbus also has High Speed Ethernet, which will become the choice for high-speed plant and control networks. Sensor buses will continue to survive for low level applications such as bulk I/O because of their simplicity and low cost. They will be linked to PROFIBUS and FOUNDATION fieldbus through gateways. LON will find applications in electrical equipment such as switchgear and motor control centers. Therefore, a multi-fieldbus strategy will provide customers with the best choice of product. In this situation, a prudent strategy for customers is:

- Choose a credible supplier with multi-vendor, multi-fieldbus support and real experience
- To start with non-critical applications
- To evaluate devices from multiple vendors
- To begin with standard functionality of devices and then move to proprietary functions
- To use traditional systems as a back up when trying out fieldbus

However the FOUNDATION fieldbus technology has been accepted by major companies and is implemented in large and critical applications.

7 ABBREVIATIONS USED

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>Apects/Objects</td>
<td>ABB's method of linking information</td>
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<tr>
<td>AI</td>
<td>Analog Input</td>
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<td>AO</td>
<td>Analog Output</td>
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<td>CAPEX</td>
<td>Capital Expenditure</td>
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<tr>
<td>DD</td>
<td>Device Description</td>
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<tr>
<td>DDL</td>
<td>Device Description Language</td>
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<tr>
<td>DI</td>
<td>Digital Input</td>
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<td>DTM</td>
<td>Device Type Manager</td>
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<td>FB</td>
<td>Function Blocks</td>
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<td>FDT</td>
<td>Field Device Tool</td>
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<tr>
<td>FieldIT</td>
<td>ABB's field device level definition</td>
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<tr>
<td>FIO-100</td>
<td>This is ABB's LinkDevice</td>
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<tr>
<td>FF</td>
<td>FOUNDATION fieldbus</td>
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<tr>
<td>FIP</td>
<td>Factory Instrumentation Protocol</td>
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<tr>
<td>FISCO PROFIBUS</td>
<td>‘Fieldbus Intrinsically Safe Concept’. (Note that the I.S. guidelines for PROFIBUS &amp; FOUNDATION are different.)</td>
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<tr>
<td>FOUNDATION</td>
<td>(the name of the organisation)</td>
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<tr>
<td>GSD</td>
<td>Gerätestammdaten (Database file for PROFIBUS devices)</td>
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<tr>
<td>H1 FOUNDATION</td>
<td>Fieldbus field device bus (similar to PROFIBUS PA)</td>
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<tr>
<td>HART</td>
<td>Highway Addressable Remote Transducer</td>
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<tr>
<td>HSE</td>
<td>High Speed Ethernet</td>
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<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
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<tr>
<td>IndustrialIT</td>
<td>ABB’s integrated system (Process information – enterprise planning applications.)</td>
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<tr>
<td>ISO</td>
<td>International Standards Organisation</td>
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<tr>
<td>ISP</td>
<td>Interoperable Systems Project</td>
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<td>LAS</td>
<td>Link Active Scheduler</td>
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<td>LON</td>
<td>Local Operating Network</td>
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<tr>
<td>LD</td>
<td>Link Device (H1 to HSE)</td>
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<tr>
<td>ML</td>
<td>Manual Loader</td>
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<tr>
<td>OPEX</td>
<td>Operational Expenditure</td>
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<tr>
<td>OSI</td>
<td>Open System Interconnection</td>
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<tr>
<td>OD</td>
<td>Object Dictionary</td>
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<tr>
<td>OPC</td>
<td>Object linking and embedding for Process Control</td>
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<tr>
<td>PROFIBUS DP</td>
<td>PROFIBUS Distributed Peripheral</td>
</tr>
<tr>
<td>PROFIBUS PA</td>
<td>PROFIBUS Process Automation</td>
</tr>
<tr>
<td>PID</td>
<td>Proportional Integral Derivative action of a 3 term controller</td>
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<tr>
<td>RA</td>
<td>Ratio</td>
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<tr>
<td>SS</td>
<td>Signal Selector</td>
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SupportIT – A customer care programme that will give you what you want, when you want it, how you want it. From installation and start-up to planned maintenance and training, an ABB Customer Support programme puts your needs first - making your life easier and your instrumentation investment go even further.

Installation

To maximise your instrumentation investment skilled and experienced engineers will ensure that an instrument is correctly installed, commissioned and integrated into your process.

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