Fieldbus Technical Overview

Understanding FOUNDATION™ fieldbus technology

FISHER-ROSEMOUNT™

Managing The Process Better.™

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FOUNDATION™ fieldbus—the technology of tomorrow—available today.

FOUNDATION fieldbus technology is the basis of the next generation of process control. This overview explains fieldbus technology so you can take the next step of integrating fieldbus into your control strategy with confidence.

FOUNDATION fieldbus is an all digital, serial, two-way communication system that interconnects devices in the field such as sensors, actuators, and controllers. FOUNDATION fieldbus is a Local Area Network (LAN) for instruments, with built-in capability to distribute a control application across the network. Fisher-Rosemount offers a full range of products from field devices to the DeltaV scalable control system to help you move to fieldbus technology today.

It is the ability to distribute control among intelligent field devices on the plant floor and digitally communicate that information at high speed that makes FOUNDATION fieldbus an enabling technology. For Fisher-Rosemount, FOUNDATION fieldbus technology is a cornerstone of PlantWeb™ field-based architecture.

PlantWeb field-based architecture lets you build open process management solutions by networking intelligent field devices, scalable platforms, and value-added software. With full use of field intelligence, process management is no longer just process control. It's now also asset management: gathering and using a wealth of new information from assets—intelligent transmitters, valves, analyzers, and more. It includes configuring, calibrating, monitoring, performing diagnostics, and maintaining records from anywhere in the plant—while the process is running.

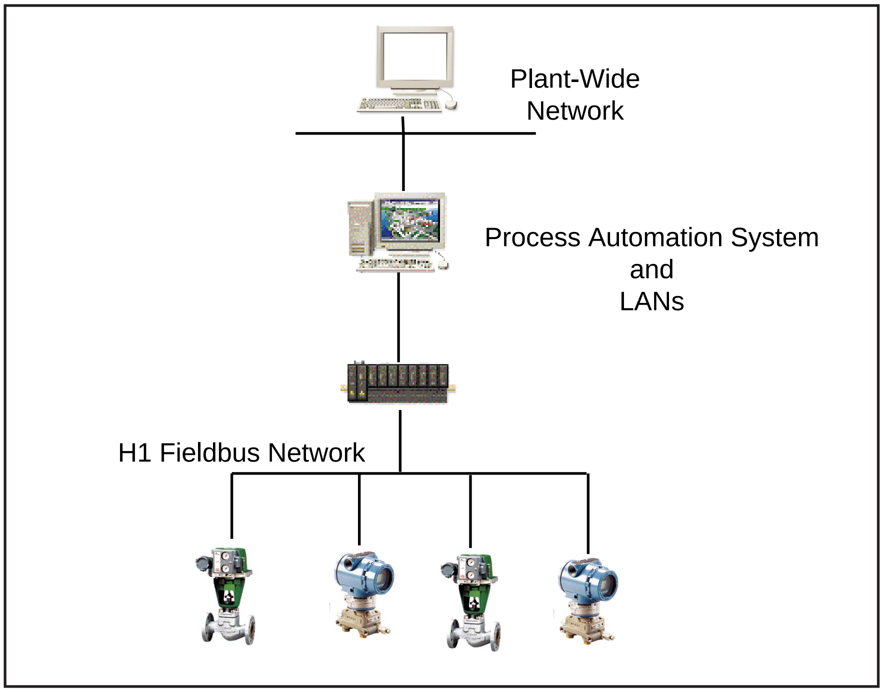

Figure 1. The fieldbus environment provides the base level group of digital networks in the hierarchy of plant networks.

You can take advantage of all of this information with Fisher-Rosemount innovative PERFORMANCE software applications that bring the information to your desktop with the familiar look and feel of Windows-based software so that the new applications are easy to learn and easy to use.

Tell me more about the benefits of fieldbus.

The benefits of fieldbus span the life cycle of your plant:

Planning and Installation

Fieldbus allows many devices to connect to a single pair of wires. This means less wire, fewer intrinsic safety barriers, and fewer marshaling panels so your installation costs are reduced. Connecting multiple field devices to a single bus also means reduced I/O and control equipment needed, including card files, cabinets, and power supplies.

Engineering and commissioning costs are also reduced because FOUNDATION fieldbus Function Blocks are quickly and easily linked to build a complete control strategy—entirely at the field device level. (See Figure 2).

The consistent block-oriented design of function blocks allows distribution of functions in field devices from different manufacturers in an integrated and seamless fashion. Powerful PERFORMANCE software applications help you configure a fieldbus device quickly. In fact, with the DeltaV™ scalable control system, as soon as you plug your H1 Fieldbus Interface into the I/O Carrier, the system automatically recognizes the attributes of the connected fieldbus devices. Once connected to the system, the powerful configuration software provided with DeltaV enables control strategies to be graphically assembled or modified using standard drag-and-drop technology.

Operation

With implementation of FOUNDATION fieldbus technology, you will realize significant operational benefits. The fieldbus allows multiple variables from each device to be brought into the process automation system for archiving, trend analysis, process optimization, and report generation. The high resolution and distortion-free characteristics of digital communications provides more reliable data for control. With control resident in the field devices, there is less chance of performance degradation than with traditional DCS control. This means better loop performance, less volatility, and better control.

And with the lower cost of control in the field, you can afford to control loops that you were unable to justify in a traditional 4-20 mA control environment. That means increased control over the entire process, not just some of the critical elements you were able to control in the past.

Maintenance

Use of fieldbus devices will revolutionize maintenance tasks in your plant. The self-test and communication capabilities of the microprocessor-based fieldbus devices help reduce downtime and increase plant safety. You no longer need to send a maintenance person to the field to check a device you think may have a problem. The fieldbus device self-diagnostics notify you when a problem occurs.

Asset Management Solutions (AMS) PERFORMANCE software, combined with the DeltaV system software capabilities, provides you with all of the tools you will need to configure, calibrate, and report on your Fisher-Rosemount fieldbus devices.

Interoperability—another key benefit of fieldbus technology.

The definition of interoperability is "the ability to operate multiple devices, independent of manufacturer, in the same system, without loss of minimum functionality."

Any manufacturer that provides a device to be used with FOUNDATION fieldbus must comply with FOUNDATION fieldbus standards to receive the

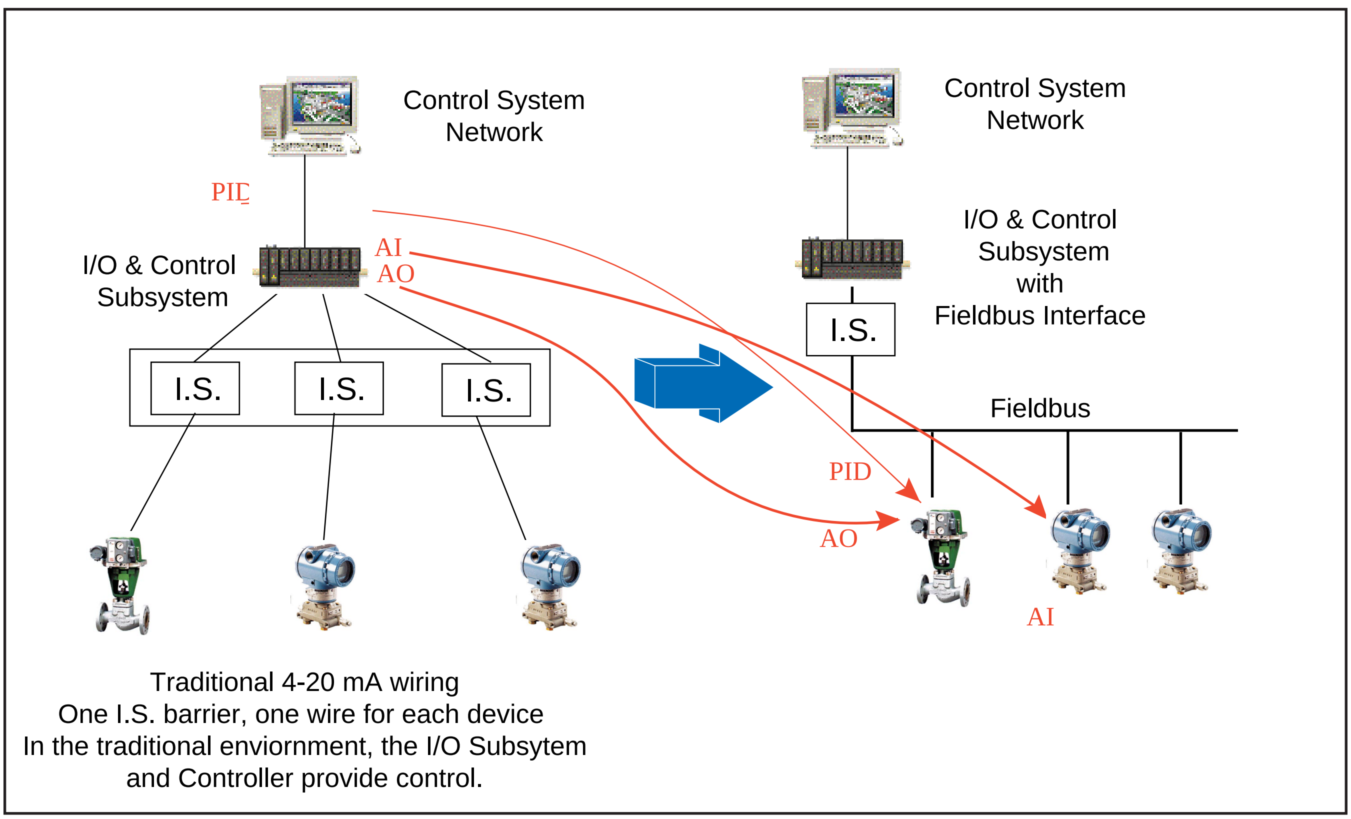

Figure 2. With fieldbus, I.S. requires only one barrier for multiple devices, and control is managed within the devices.

FOUNDATION fieldbus certification. That means that you have increased flexibility in supplier selection with the assurance that all devices will work together, regardless of manufacturer.

FOUNDATION Fieldbus Technology

FOUNDATION fieldbus technology consists of three parts:

- Physical Layer
- Communication "Stack"
- User Application

The Open Systems Interconnect (OSI) layered communication model is used to model these components. (See Figure 3.)

The Physical Layer is OSI layer 1. The Data Link Layer (DLL) is OSI layer 2. The Fieldbus Message Specification (FMS) is OSI layer 7. The Communication Stack is comprised of layers 2 and 7 in the OSI model.

The fieldbus protocol does not use OSI layers 3, 4, 5, and 6. The Fieldbus Access Sublayer (FAS maps the FMS onto the DLL.

The User Application is not defined by the OSI model. The Fieldbus Foundation has specified a User Application Model that Fisher-Rosemount has used in the development of fieldbus devices and in the development of the AMS and DeltaV PERFORMANCE software applications designed for use with fieldbus devices.

Each layer in the communication system is responsible for a portion of the message that is transmitted on the fieldbus.

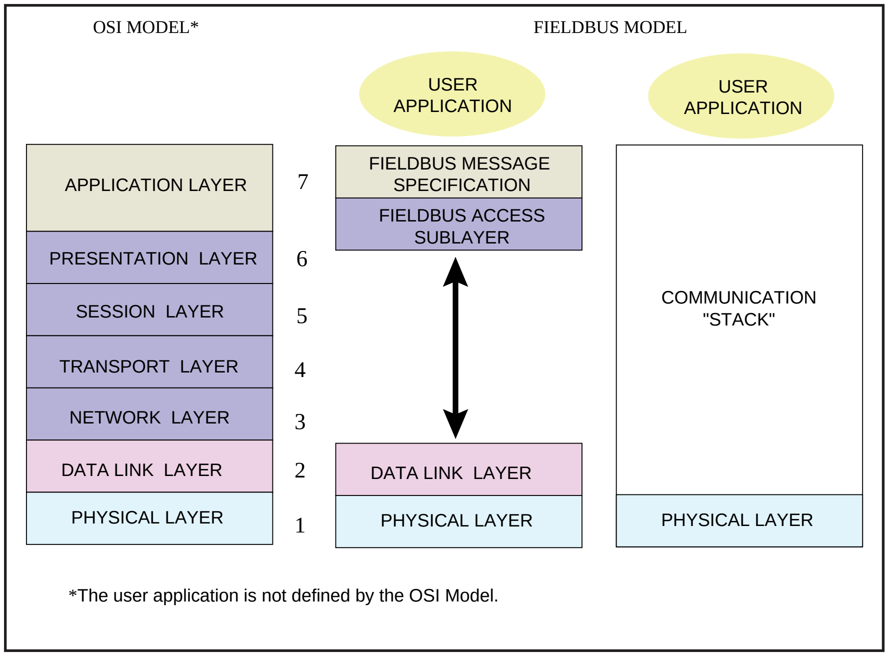

Figure 3. The Open Systems Interconnect (OSI) layered communications model.

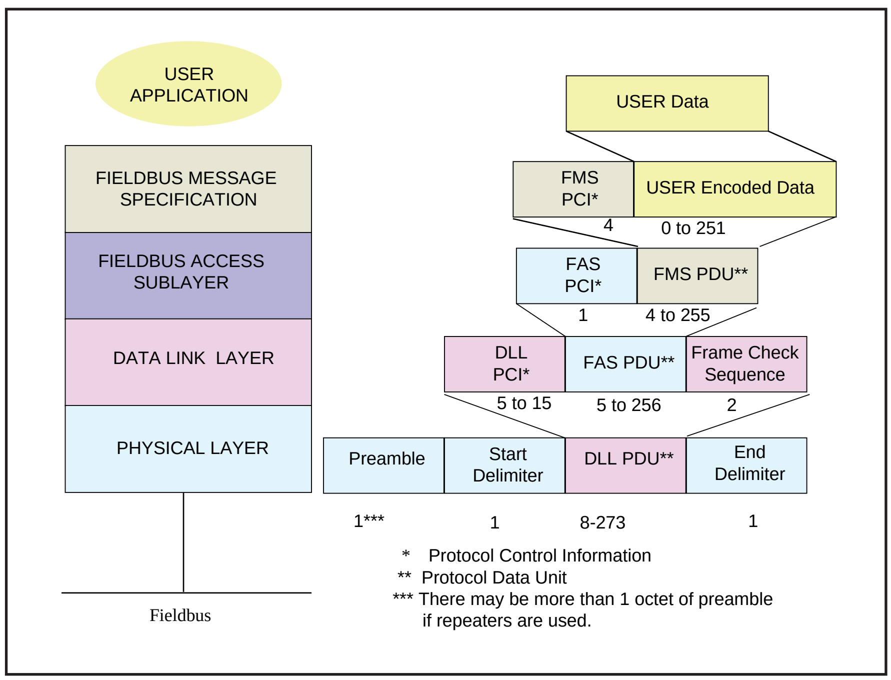

Figure 4. The number of eight bit "octets" used for each layer to transfer user data.

The numbers shown in Figure 4 indicate the approximate number of eight bit "octets" used for each layer to transfer the User data.

Physical Layer

The Physical Layer is defined by standards from the International Electrotechnical Commission (IEC) and The International Society of Measurement and Control (ISA).

The Physical Layer receives messages from the communication stack and converts the messages into physical signals on the fieldbus transmission medium and vice-versa.

Conversion tasks include adding and removing preambles, start delimiters, and end delimiters.

Fieldbus signals are encoded using the Manchester Biphase-L technique. The signal is called "synchronous serial" because the clock information is embedded in the serial data stream. Data is combined with the clock signal to create the fieldbus signal. The receiver of the fieldbus signal interprets a positive transition in the middle of a bit time as a logical "0" and a negative transition as a logical "1". (See Figure 5.)

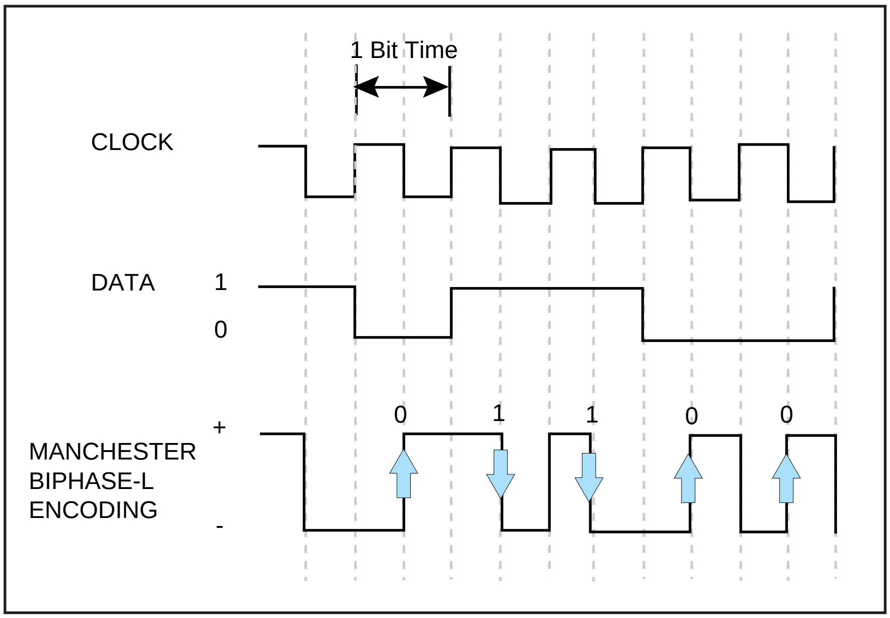

Figure 5. Fieldbus signals are encoded using the Manchester Biphase-L technique.

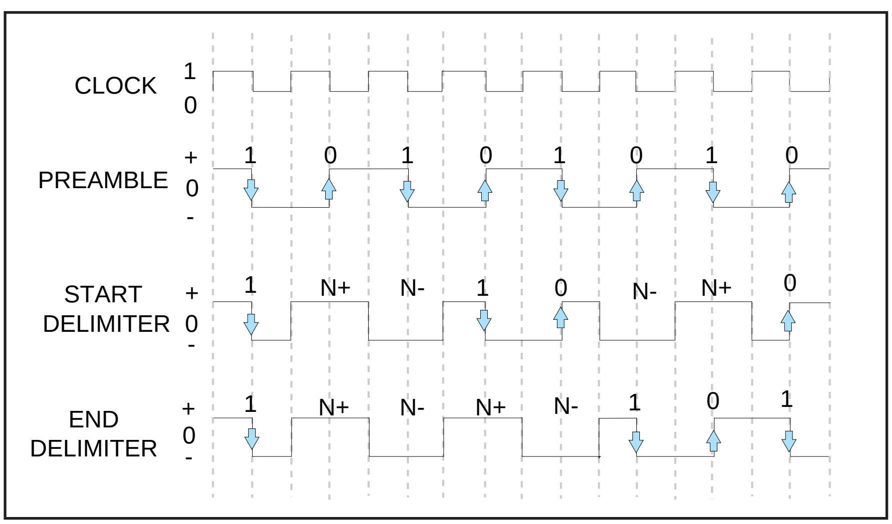

Figure 6. Special characters are defined for the preamble, start delimiter, and end delimiter.

Special characters are defined for the preamble, start delimiter, and end delimiter. (See Figure 6.)

The preamble is used by the receiver to synchronize its internal clock with the incoming fieldbus signal.

Special N+ and N- codes are in the start delimiter and end delimiter. Note that the N+ and N- signals do not transition in the middle of a bit time. The receiver uses the start delimiter to find the beginning of a fieldbus message. After it finds the start delimiter, the receiver accepts data until the end delimiter is received.

The H1 Fieldbus

The H1 fieldbus can be used for control applications such as temperature, level and flow control.

Devices can be powered directly from the fieldbus and operate on wiring that was previously used for 4-20 mA devices.

The H1 fieldbus can also support intrinsically safe (I.S.) fieldbuses with bus powered devices. An I.S. barrier is placed between the power supply in the safe area and the I.S. device in the hazardous area. (See Figure 2.)

H1 Fieldbus Signaling

The transmitting device delivers ±10 mA at 31.25 kbit/s into a 50 ohm equivalent load terminator to create a 1.0 volt peak-to-peak voltage modulated on top of the direct current (DC) supply voltage.

The DC supply voltage can range from 9 to 32 VDC (See Figure 7.) However, for I.S. applications, the allowed power supply voltage depends on the barrier rating.

H1 Fieldbus Wiring

The H1 fieldbus allows stubs or "spurs" as shown in Figure 8. The length of the fieldbus is determined by the communication rate, cable type, wire size, bus power option, and I.S. option.

The main run cannot exceed a total length of 1900 m (6,232 ft) with shielded twisted pair cable. The cable length is determined by adding together the length of the trunk cable and all of the spur lengths. As shown in Figure 8, terminators are located at each end of the main trunk cable.

If you have a choice about the length of a spur, shorter is better. The total spur length is limited according to the number of spurs and the number of devices per spur. See Table 1 for a summary of the maximum spur length allowed as a function of the total devices on the segment.

Table 1. Maximum Spur Length.

Number of Devices	Maximum Spur Length
25-32	1 m (3.28 ft)
19-24	30 m (98.42 ft)
15-18	60 m (196.8 ft)
13-14	90 m (295.2 ft)
1-12	120 m (393.6 ft)

The total number of devices possible on the fieldbus will vary based on factors such as the power consumption of each device, the type of cable used, use of repeaters, etc.

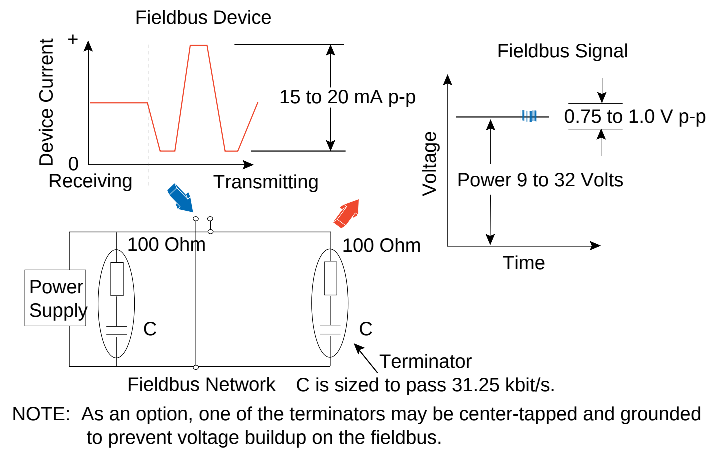

Figure 7. Signaling waveforms for the H1 Fieldbus.

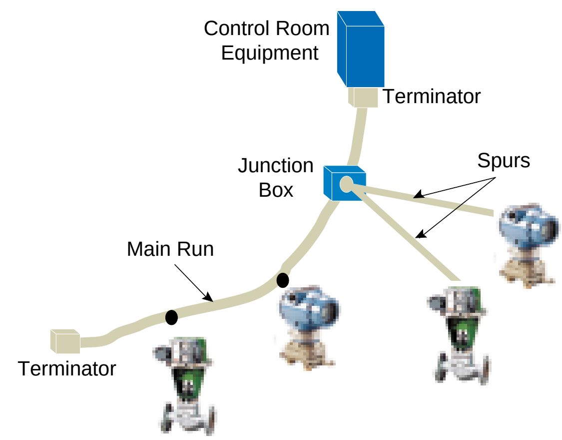

Figure 8. Total cable length is made up of trunk length plus spur lengths.

H2 Fieldbus
(Scheduled for future release.)

The H2 fieldbuses will typically be used for advanced process control, remote input/output, and high speed factory automation applications.

Although the Physical Layer standard allows for devices to be powered from the fieldbus, in most H2 applications the devices will be self-powered or will draw power from a separate power bus in the fieldbus cable (i.e. 4-wire cable).

NOTE

In April 1998 the Fieldbus Foundation announced that future development of H2 fieldbus will be based on high-speed Ethernet technology. As a result, the information in this section of the Technical Overview is subject to change. More information is available from the Fieldbus Foundation's web site at www.fieldbus.org.

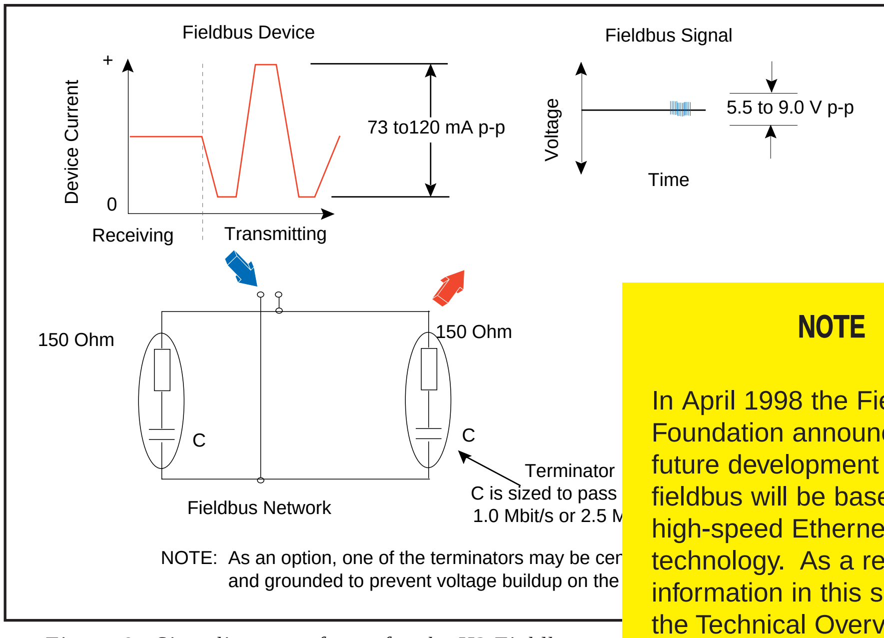

Figure 9. Signaling waveforms for the H2 Fieldbus.

> **NOTE**
>
> In April 1998 the Fieldbus Foundation announced that future development of H2 fieldbus will be based on high-speed Ethernet technology. As a result, the information in this section of the Technical Overview is subject to change. More information is available from the Fieldbus Foundation's web site at www.fieldbus.org.

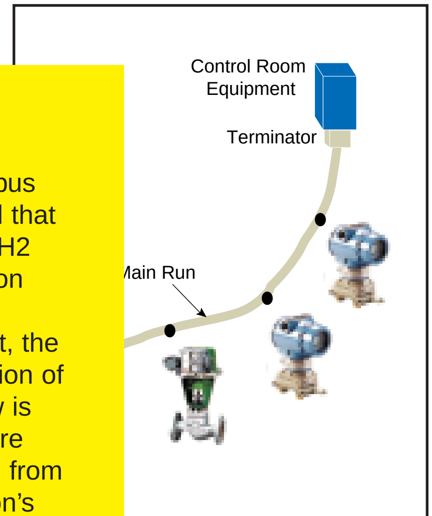

Figure 11. No spurs are allowed for H2 fieldbus.

H2 Voltage Mode Signaling (Scheduled for future release.)

The transmitting device delivers ±60 mA at 1.0 or 2.5 Mbit/s into a 75 ohm equivalent load to create 9 volt peak-to-peak voltage on the fieldbus. (See Figure 9.)

H2 Current Mode Signaling (Scheduled for future release.)

The H2 fieldbus supports a special current mode, intrinsically safe, bus-powered device option. For this option, the fieldbus signal is modulated into a 16 kHz AC power signal. (See Figure 10)

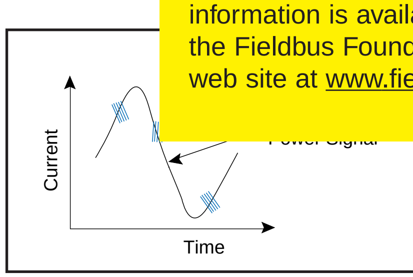

Figure 10. H2 Current Mode Signaling.

Fieldbus devices are connected to the main run using a special connector that used inductive coupling to pick up the signal and power. The special connector does not pierce the trunk line.

H2 Fieldbus Wiring (Scheduled for future release.)

The topology for the H2 fieldbus is shown in Figure 11. Due to the higher frequencies of 1.0 Mbit/s and 2.5 Mbit/s, only the bus topology is supported. Spurs are not allowed because they could cause signal reflections that may cause distortion of the fieldbus signals.

The total number of devices possible on the fieldbus will vary based on factors such as the power consumption of each device, the type of cable used, use of repeaters, etc.

Table 2 provides an example of the options available in the Physical Layer Standard.

. ***Table 2. Physical Layer Options Summary.***

Characteristics	Data Rate		
Type	31.25 kbit/s Voltage	31.25 kbit/s Voltage	31.25 kbits Voltage
Topology	Bus/tree	Bus/tree	Bus/tree
Power	none	DC	DC
Classification		Intrinsically Safe	
Number of Devices	2-32	2-32	2-32
Cable Length	1900 m	1900 m	1900 m

Communications Stack

The following sections will describe the operation of the layers in the Communications Stack. (See Figure 3.)

Data Link Layer

The Data Link Layer (DLL) controls transmission of messages onto the fieldbus. The DLL manages access to the fieldbus through a deterministic centralized bus scheduler called the Link Active Scheduler (LAS).

The DLL is a subset of the emerging IEC/ISA DLL standard.

Device Types

Three types of devices are defined in the DLL specification:

- Basic Devices that do not have the capability to become the LAS.
- Link Master devices that are capable of becoming the LAS.
- Bridges that are used to interconnect individual fieldbuses to create larger networks. (Scheduled for future release. See Figure 12.)

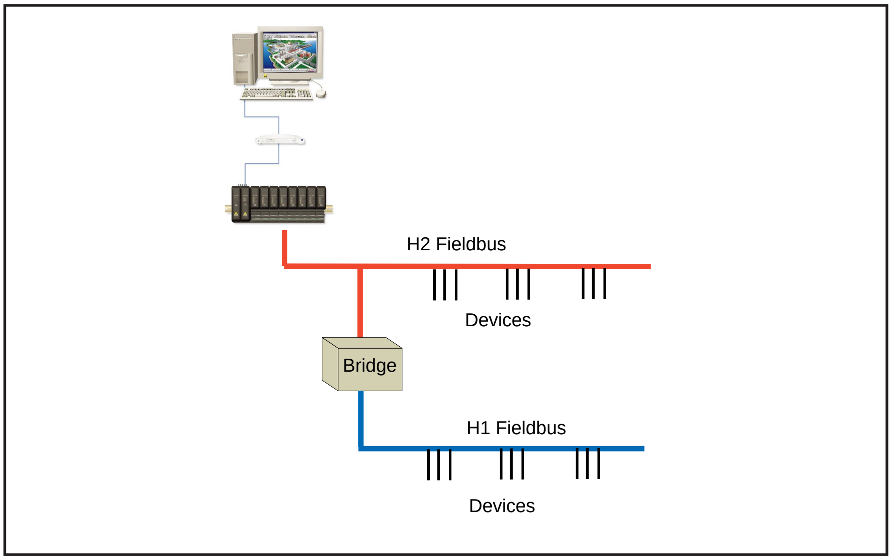

Figure 12. Bridges are used to interconnect individual fieldbuses to create larger networks.

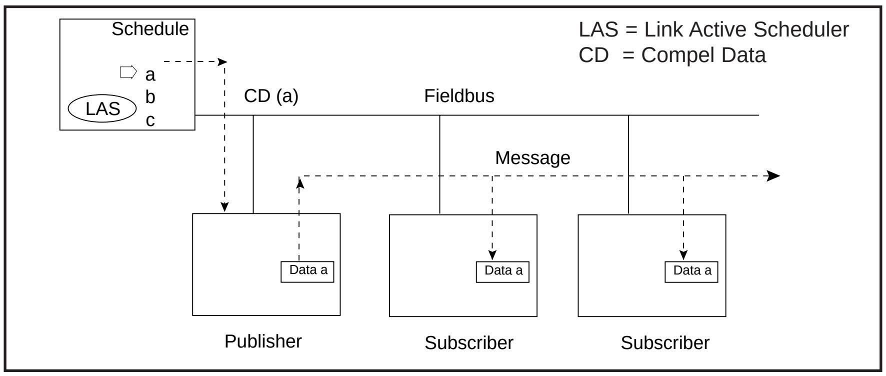

Figure 13. Scheduled data transfer.

Scheduled Communication

The Link Active Scheduler (LAS) has a list of transmit times for all data buffers in all devices that need to be cyclically transmitted.

When it is time for a device to send a buffer, the LAS issues a Compel Data (CD) message to the device.

Upon receipt of the CD, the device broadcasts or "publishes" the data in the buffer to all devices on the fieldbus. Any device that is configured to receive the data is called a "subscriber." (See Figure 13.)

Scheduled data transfers are typically used for the regular, cyclic transfer of control loop data between devices on the fieldbus.

Unscheduled Communication

All of the devices on the fieldbus are given a chance to send "unscheduled" messages between transmissions of scheduled messages.

The LAS grants permission to a device to use the fieldbus by issuing a pass token (PT) message to the device. When the device receives the PT, it is allowed to send messages until it has finished or until the "maximum token hold time" has expired, whichever is the shorter time. The message can be sent to a single destination or to multiple destinations (multicast). (See Figure 14.)

Link Active Scheduler Operation

The overall operation of the Link Active Scheduler (LAS) include the following:

- CD Schedule
- Live List Maintenance
- Data Link Time Synchronization
- Token Passing
- LAS Redundancy

The algorithm used by the LAS is shown in Figure 15.

- CD Schedule
  The CD Schedule contains a list

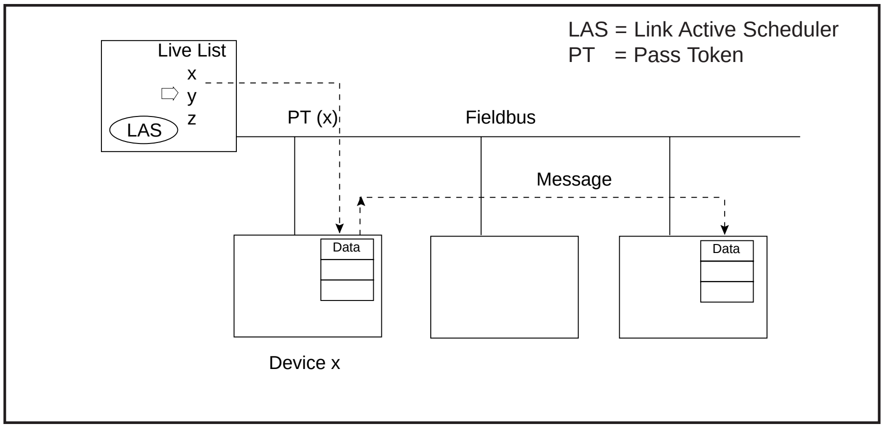

Figure 14. Unscheduled data transfers.

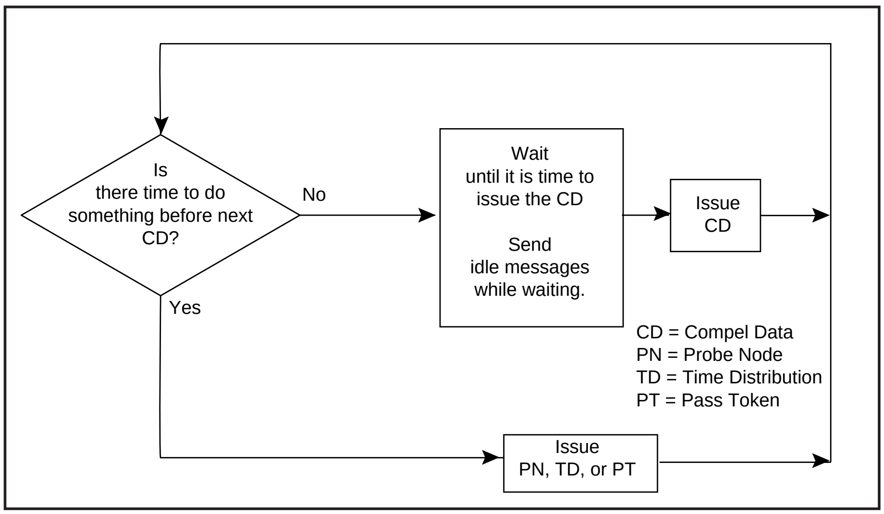

Figure 15. Link Active Scheduler Algorithm.

of activities that are scheduled to occur an a cyclic basis. At precisely the scheduled time, the LAS sends a Compel Data (CD) message to a specific data buffer in a fieldbus device. The device immediately broadcasts or "publishes" a message to all devices on the fieldbus. This is the highest priority activity performed by the LAS. The remaining operations are performed between scheduled transfers.

■ Live List Maintenance
The list of all devices that are properly responding to the Pass Token (PT) is called the "Live List."

New devices may be added to the fieldbus at any time. The LAS periodically sends Probe Node (PN) messages to the addresses not in the Live List. (See page 18 for explanation of device address assignment.) If a device is present at the address and receives the PN, it immediately returns a Probe Response (PR) message. If the device answers with a PR, the LAS adds the device to the Live List and confirms its addition by sending the device a Node Activation message.

The LAS is required to probe at least one address after it has completed a cycle of sending PTs to all devices in the Live List.

The device will remain in the Live List as long as it responds properly to the PTs send from the LAS. The LAS will remove a device from the Live List if the device does not either use the token or immediately return it to the LAS after three successive tries.

Whenever a device is added or removed from the Live List, the LAS broadcasts changes to the Live List to all devices. This allows each device to maintain a current copy of the Live List.

■ Data Link Time Synchronization
The LAS periodically broadcasts a Time Distribution (TD) message on the fieldbus so that all devices have exactly the same data link time. This is important because scheduled communications on the fieldbus and scheduled function block executions in the User Application are based on information obtained from these messages.

■ Token Passing
The LAS sends a Pass Token (PT) message to all devices in the Live List. The device is allowed to transmit unscheduled messages when it receives the PT.

■ LAS Redundancy
A fieldbus may have multiple Link Masters. If the current LAS fails, one of the Link Masters will become the LAS and the operation of the fieldbus will continue. The fieldbus is designed to "fail operational."

Fieldbus Access Sublayer (FAS)

The FAS uses the scheduled and unscheduled features of the Data Link Layer to provide a service for the Fieldbus Message Specification (FMS). The types of FAS services are described by Virtual Communication Relationships (VCR).

The VCR is like the speed dial feature on your memory telephone. There are many digits to dial for an international call—an international access code, country code, city code, exchange code, and the specific telephone number.

This information only needs to be entered once and then a "speed dial number" is assigned. After setup, only the speed dial number needs to be entered for the dialing to occur.

In a similar fashion, after configuration, only the VCR number is needed to communicate with another fieldbus device.

Just as there are different types of telephone calls, such as person to person, collect, or conference calls, there are different types of VCRs:

- Client/Server VCR Type
  The Client/Server VCR Type is used for queued, unscheduled, user initiated, and one to one communication between devices on the fieldbus.

  Queued means that messages are sent and received in the order submitted for transmission, according to their priority, without overwriting previous messages.

  When a device receives a Pass Token (PT) from the LAS, it may send a request message to another device on the fieldbus. The requester is called the "Client", and the device that received the request is called the "Server." The Server sends the response when it receives a PT from the LAS.

  The Client/Server VCR Type is used for operator initiated requests such as setpoint changes, tuning parameter access and change, alarm acknowledge, and device upload and download.

- Report Distribution VCR Type
  The Report Distribution VCR Type is used for queued, unscheduled, or user-initiated one-to-many communications.

  When a device with an event or a trend report receives a Pass Token (PT) from the LAS, it sends its message to a "group address" defined for its VCR. Devices that are configured to listen on that VCR will receive the report.

  The Report Distribution VCR Type is typically used by fieldbus devices to send alarm notifications to the operator consoles.

- Publisher/Subscriber VCR Type
  The Publisher/Subscriber VCR Type is used for buffered, one-to-many communications.

  Buffered means that only the latest version of the data is maintained within the network. New data completely overwrites previous data.

  When a device receives the Compel Data (CD), the device will "Publish" or broadcast its message to all devices on the fieldbus. Devices that wish to receive the published message are called "Subscribers."

  The CD may be scheduled in the LAS, or it may be sent by Subscribers on an unscheduled basis. An attribute of the VCR indicates which method is used.

  The Publisher/Subscriber VCR Type is used by the field devices for cyclic, scheduled publishing of User Application function block input and outputs such as process variable (PV) and primary output (OUT) on the

Table 3. Summary of VCR Types

Client/Server VCR Type	Report Distribution VCR Type	Publisher/Subscriber VCR Type
Used for Operator Messages	**Used for Event Notification and Trend Reports**	**Used for Publishing Data**
Setpoint changes. Mode changes. Tuning changes. Upload/download. Alarm management. Access display views. Remote diagnostics.	Send process alarms to operator consoles. Send trend reports to data historians.	Send transmitter PV to PID control block and operator console.

fieldbus.

Fieldbus Message Specification (FMS)

Fieldbus Message Specification (FMS) services allow user applications to send messages to each other across the fieldbus using a standard set of message formats.

FMS describes the communication services, message formats, and protocol behavior needed to build messages for the User Application. (See Figure 16.)

Data that is communicated over the fieldbus is described by an "object description." Object descriptions are collected together in a structure called an "object dictionary" (OD). (See Figure 17.)

The object description is identified by its index in the OD. Index 0, called the object dictionary header, provides a description of the dictionary itself and defines the first index for the object descriptions of the User Application. The User Application object descriptions can start at any index above 255.

Index 255 and below define standard data types such as boolean, integer, float, bitstring, and data structures that are used to build all other object descriptions.

Virtual Field Device (VFD)

A "Virtual Field Device" is used to remotely view local device data described in the object dictionary. A typical device will have at least two VFDs. (See Figure 18.)

Network Management is part of the Network and System Management Application. It provides for the configuration of the communication stack. The Virtual Field Device (VFD) used for Network Management is also used for System Management. This VFD provides access to the Network Management Information Base (NMIB) and to the System

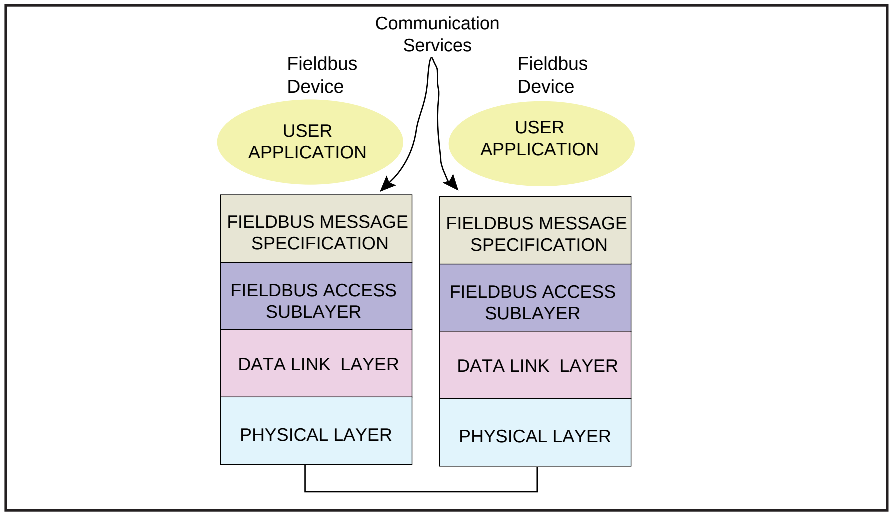

Figure 16. FMS services allow user applications to exchange messages over the fieldbus.

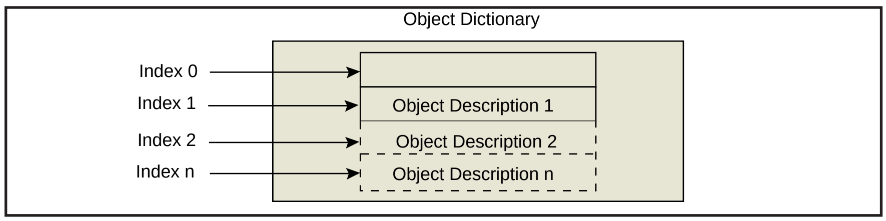

Figure 17. The object dictionary contains a collection of object descriptions.

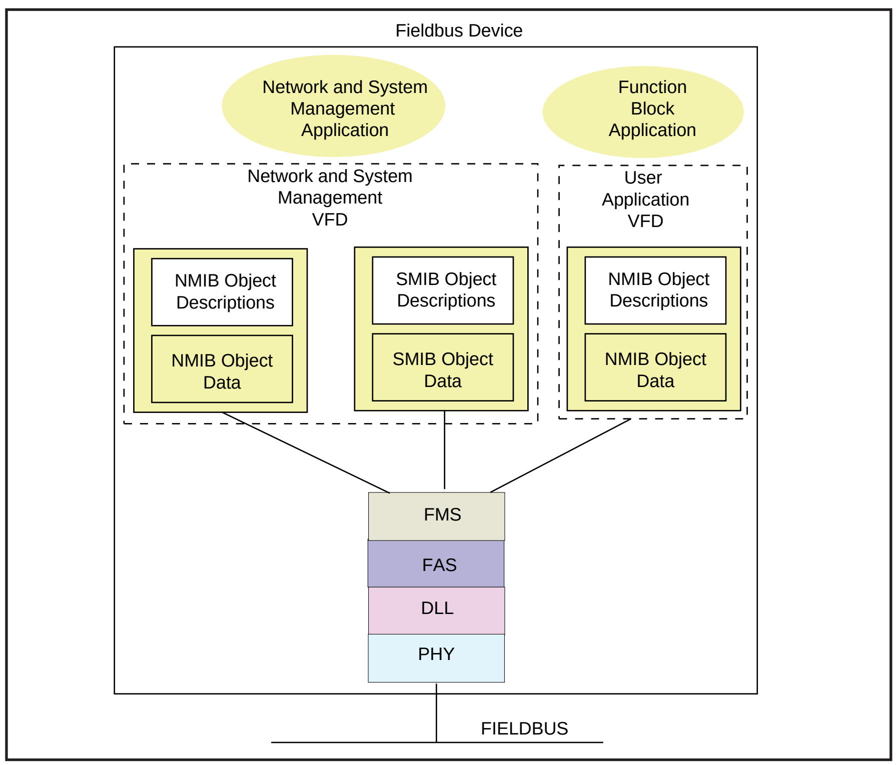

Figure 18. A typical device will have at least two Virtual Field Devices (VFDs).

Management Information Base (SMIB). NMIB data includes Virtual Communication Relationships (VCR), dynamic variables, statistics, and Link Active Schedule (LAS) schedules (if the device is a Link Master). SMIB data includes device tag and address information, and schedules for function block execution.

System Management is described further in the User Application Section.

Communication Services

FMS communication services provide a standardized way for user applications such as function blocks to communicate over the fieldbus. Specific FMS communication services are defined for each object type.

All of the FMS services can use only the Client Server VCR Type except as noted.

Communications Services include the following:

■ Context Management Services
The following FMS services are used to establish and release Virtual Communication Relationships (VCR) with, and determine the status of, a VFD.

- *Initiate*
  Establish Communications
- *Abort*
  Release communications
- *Reject*
  Reject improper service
- *Status*
  Read a device status
- *UnsolicitedStatus*
  Send unsolicited status
- *Identify*
  Read vendor, type and version

■ Object Dictionary Services
The following FMS services allow the User Application to access and change the object descriptions (OD) in a VFD.

- *GetOD*
  Read an object dictionary (OD)
- *InitiatePutOD*
  Start an OD Load
- *PutOD*
  Load an OD into a device
- *TerminatePutOD*
  Stop an OD Load

■ Variable Access Services
The following FMS services allow the user application to access and change variables associated with an object description.

- *Read*
  Read a variable
- *Write*
  Write a variable
- *InformationReport*
  Send Data*
- *DefineVariableList*
  Define a Variable List
- *DeleteVariableList*
  Delete a Variable List

** Can use Publisher/Subscriber or Report Distribution VCR Types.*

■ Event Services
The following FMS services allow the user application to report events and manage event processing.

- *EventNotification*
  Report an event*
- *AcknowledgeEventNotification*
  Acknowledge an event
- *AlterEventConditionMonitoring*
  Disable/Enable event*

** Can use Report Distribution VCR Type.*

■ Upload/Download Services
It is often necessary to remotely upload or download data and programs over the fieldbus, especially for more complex devices such as programmable logic controllers.

To allow uploads and downloads using the FMS service, a "Domain" is used. A Domain represents a memory space in a device.

The following FMS services allow the User Application to upload and download a Domain in a remote device.

- *RequestDomainUpload*
  Request Upload
- *InitiateUploadSequence*
  Open Upload
- *UploadSegment*
  Read data from device
- *TerminateUploadSequence*
  Stop Upload
- *RequestDomainDownload*
  Request Download
- *InitiateDownloadSequence*
  Open Download
- *DownloadSegment*
  Send data to device
- *TerminateDownloadSequence*
  Stop Download

■ Program Invocation Services
The "Program Invocation" (PI) allows the execution of a program in one device to be controlled remotely.

A device could download a program into a Domain of another device using the download service and then remotely operate the program by issuing PI service requests.

The state diagram for the PI is shown as an example of FMS protocol in Figure 19.

- *CreateProgramInvocation*
  Create a program object
- *DeleteProgramInvocation*
  Delete a program object
- *Start*
  Start a program
- *Stop*
  Stop a program
- *Resume*
  Resume program execution
- *Reset*
  Reset the program
- *Kill*

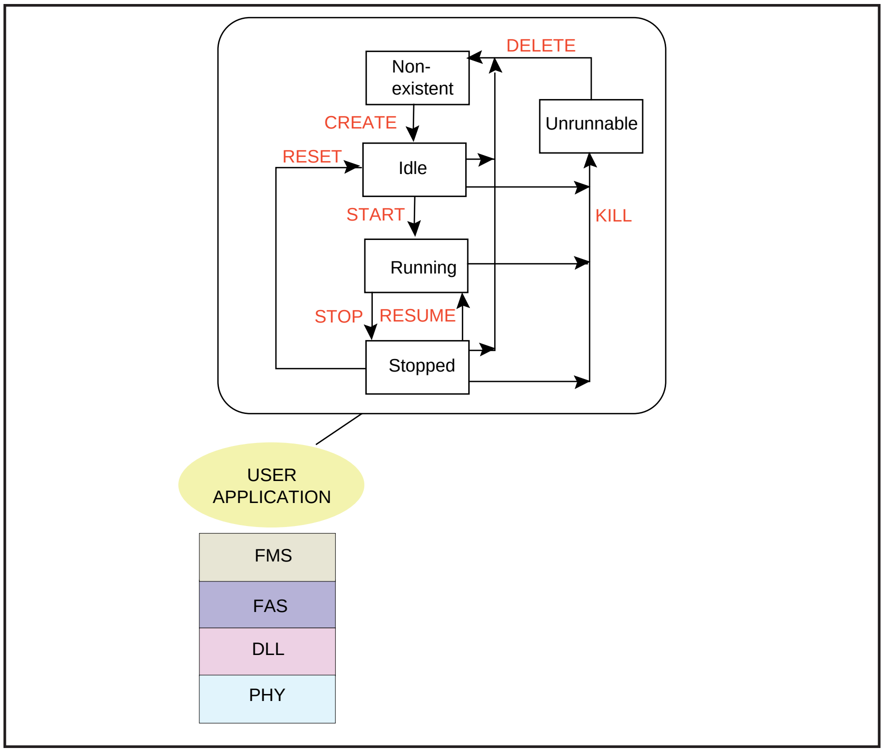

Figure 19. Behavior Rules for the Program Invocation Object.

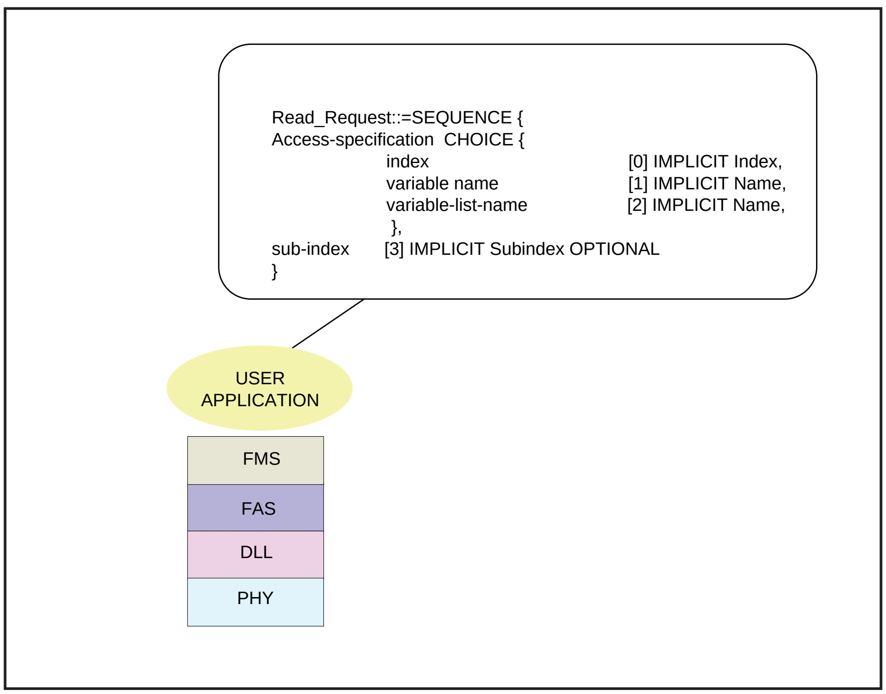

Figure 20. ASN.1 Definition of a Read_Request.

Remove the program

Message Formatting

The exact formatting of FMS messages is defined by a formal syntax description language called Abstract Syntax Notation 1 (ANS.1).

ANS.1 was developed by the International Telegraph and Telephone Consultative Committee (CCITT) in the early 1980s, as a part of the CCITT mail standardization activities.

See Figure 20 for a partial example of ASN.1 definition for the FMS read service.

This example states that the items Access-specification and sub-index occur in SEQUENCE in the message.

The Access-specification is a CHOICE of using either an index or a name to access a variable.

The sub-index is OPTIONAL. It is used only to select an individual element of an array or record variable.

The numbers in the brackets are the actual encoding numbers that are used to identify the fields in an encoded message.

Protocol Behavior

Certain types of objects have special behavioral rules that are described by the FMS specification. For example, the simplified behavior of a Program Invocation object is shown in Figure 19.

A remote device can control the state of the program in another device on the fieldbus. For example, the remote device would use the Create Program Invocation FMS service to change the program state from Non-existent to Idle.

The Start FMS service would be used to change the state from Idle to Running and so on.

User Application—Blocks

The Fieldbus Foundation has defined a standard User Application based on "Blocks." Blocks are representations of different types of application functions. (See Figure 21.)

The types of blocks used in a User Application are described in Figure 22.

Resource Block

The Resource Block describes the characteristics of the fieldbus device such as the device name, manufacturer, and serial number. There is only one resource block in a device.

Function Block

Function Blocks (FB) provide the control system behavior. The input and output parameters of Function Blocks can be linked over the fieldbus. The execution of each Function Block is precisely scheduled. There can be many function blocks in a single User Application.

The Fieldbus Foundation has defined sets of standard Function Blocks. Ten standard Function Blocks for basic control are defined by the FF-891 Function Blocks—Part 2 specification:

Function Block Name	Symbol
Analog Input	AI
Analog Output	AO
Bias	B
Control Selector	CS
Discrete Input	DI
Discrete Output	DO
Manual Loader	ML
Proportional/Derivative	PD
Proportional/Integral/ Derivative	PID
Ratio	RA

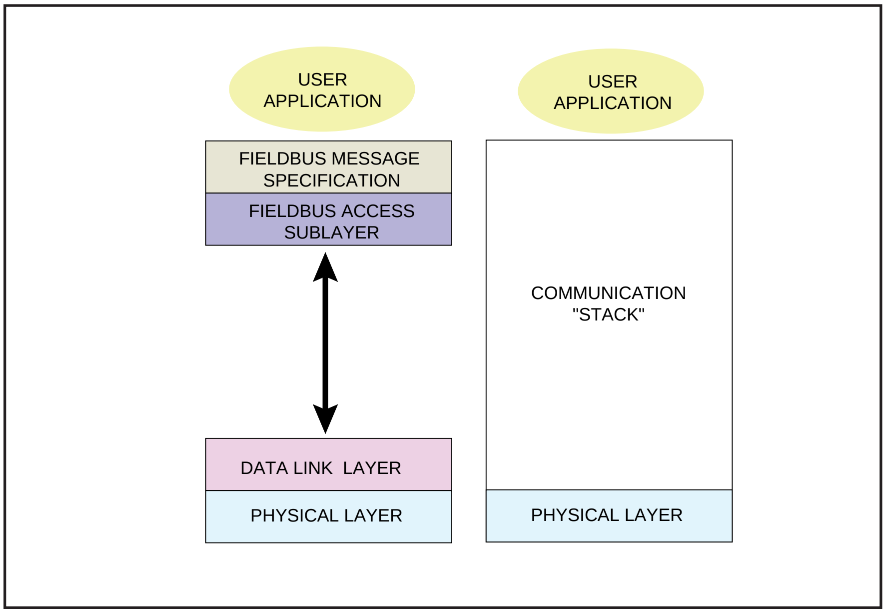

Figure 21. Blocks are representations of different types of application functions.

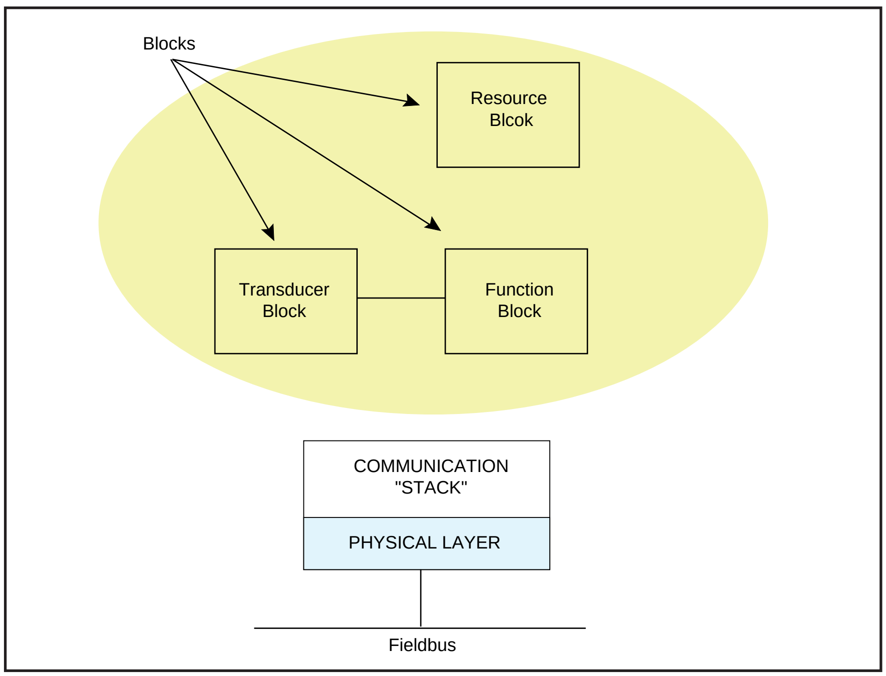

Figure 22. Types of blocks used in a User Application.

(An additional 19 standard Function Blocks for advanced control are defined in the FF-892 Function Blocks—Part 3 specification.)

Function blocks can be built into fieldbus devices as needed to achieve the desired functionality. For example, a simple temperature transmitter will contain an AI function block. A control valve might contain a PID function block as well as the expected AO block.

Thus a complete control loop can be built using only a simple transmitter and a control valve. (See Figure 23.)

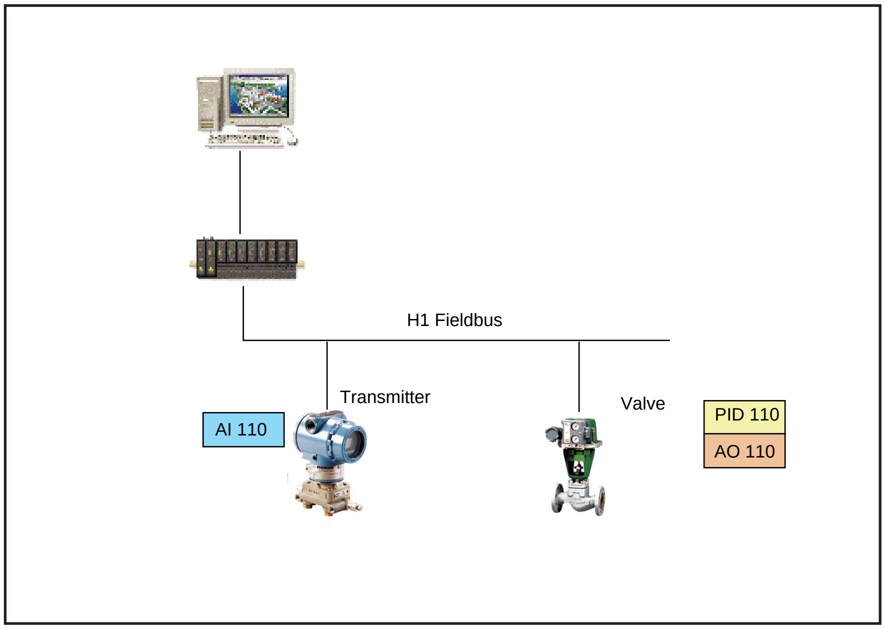

Figure 23. Example of a complete control loop using Function Blocks located in fieldbus devices.

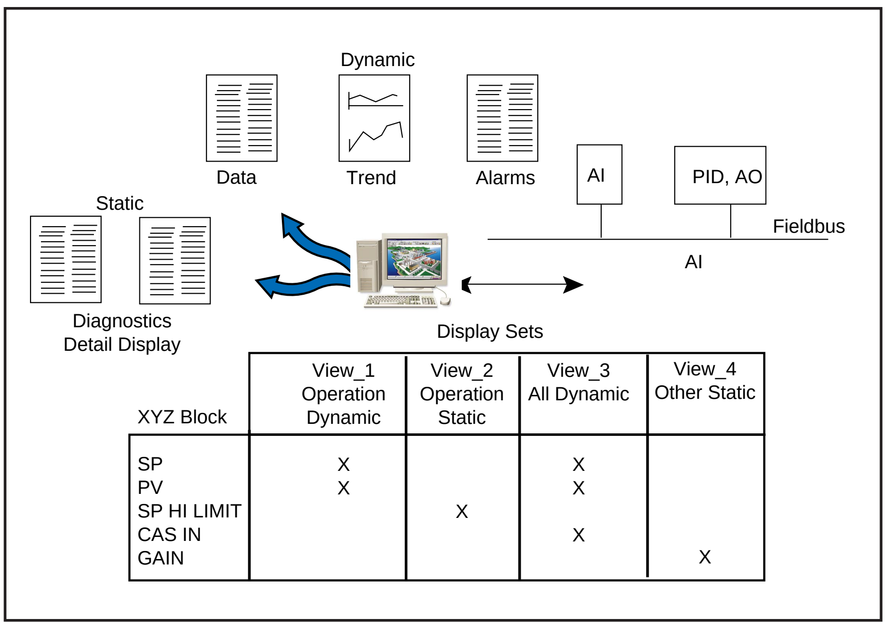

Figure 24. Example of how common Function Block variables map into the views.

Transducer Blocks

Transducer Blocks decouple Function Blocks from the local input/output functions required to read sensors and command output hardware. They contain information such as calibration date and sensor type. There is usually one transducer block for each input or output function block.

The following additional objects are defined in the User Application:

Link Objects define the links between Function Block inputs and outputs internal to the device and across the fieldbus network.

Trend Objects allow local trending of function block parameters for access by hosts or other devices.

Alert Objects allow reporting of alarms and events on the fieldbus.

View Objects are predefined groups of block parameter sets that can be used by the human/machine interface. The function block specification defines four views for each type of block.

Figure 24 shows an example of how common Function Block variables map into the views. Only a partial listing of the block parameters is shown in the example.

- VIEW_1—Operation Dynamic—information required by a plant operator to run the process.
- VIEW_2—Operation Static—Information that may need to be read once and then displayed along with the dynamic data.
- VIEW_3—All Dynamic—Information that is changing and may need to be referenced in a detailed display.
- VIEW_4—Other Static—Configuration and maintenance information.

Fieldbus Device Definition

The function of a fieldbus device is determined by the arrangement and interconnection of blocks (See Figure 25).

The device functions are made visible to the fieldbus communication system through the User Application Virtual Field Device (VFD) discussed earlier.

The header of the User Application object dictionary points to a Directory that is always the first entry in the function block application. The Directory provides the starting indexes of all of the other entries used in the Function Block application. (See Figure 26.)

The VFD object descriptions and their associated data are accessed remotely over the fieldbus network using Virtual Communication Relations (VCRs) as shown in Figure 27.

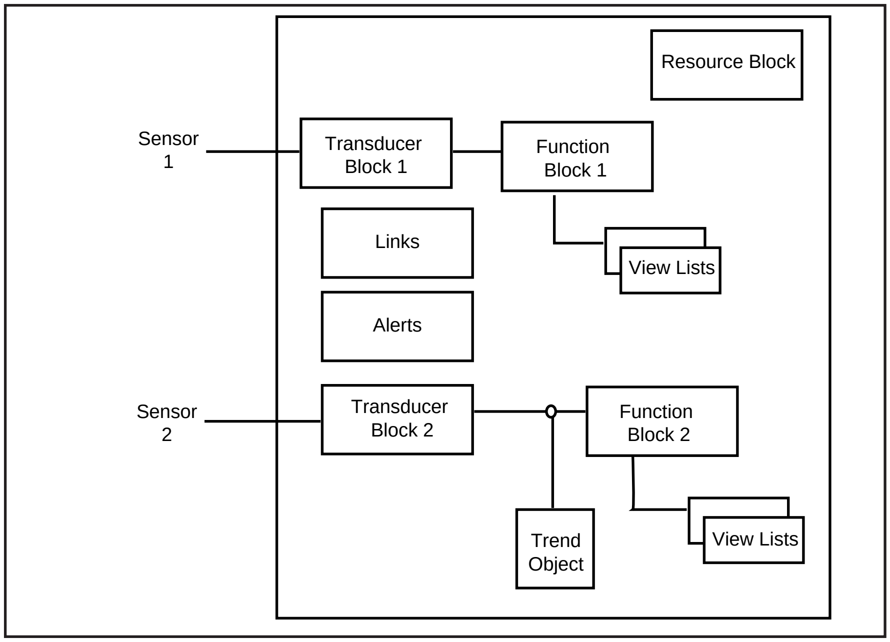

Figure 25. Function Block Application.

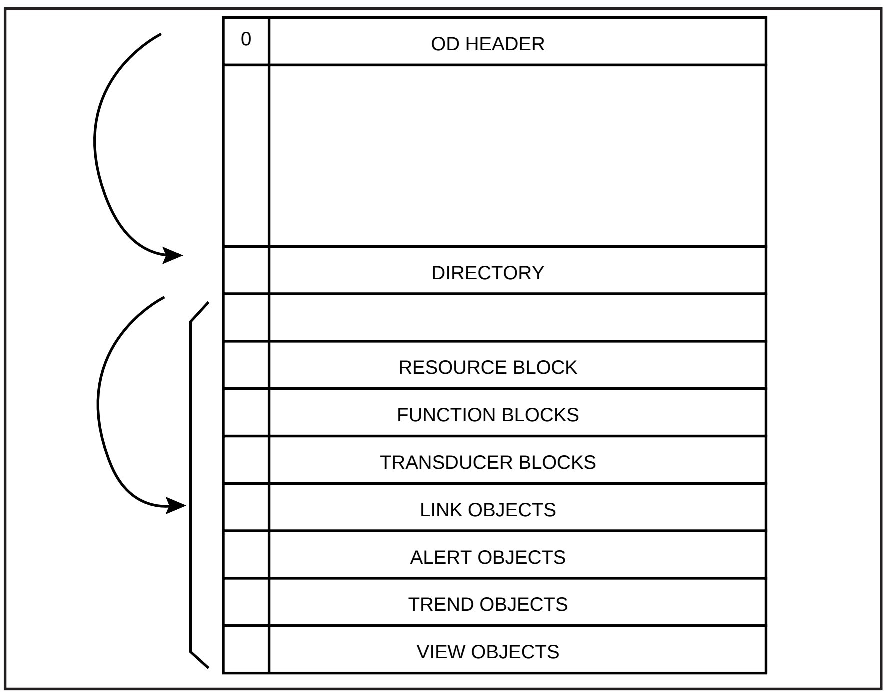

Figure 26. The Directory provides the starting indexes of all the other entries used in the Function Block application.

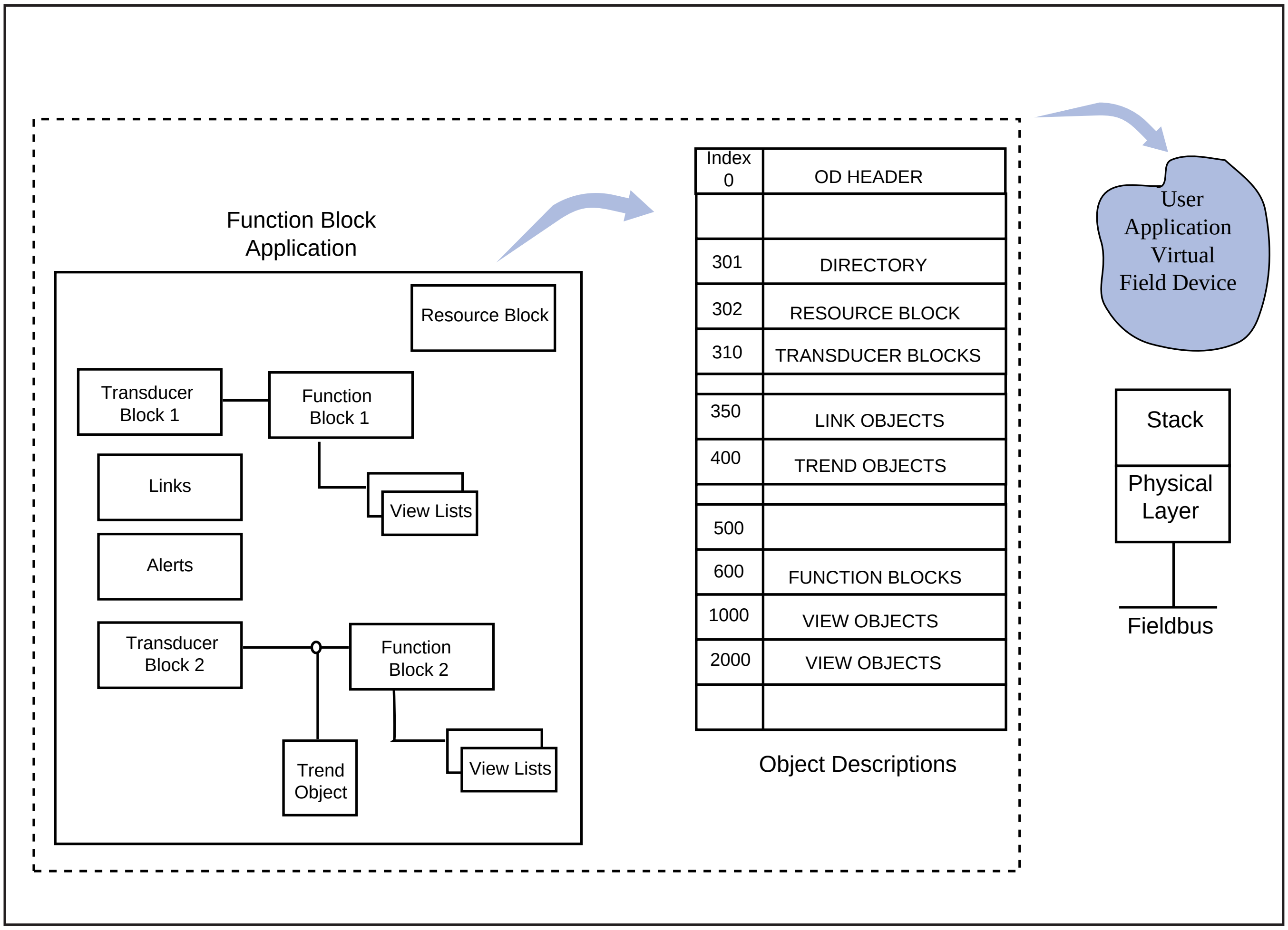

Figure 27. Virtual Communication Relationships.

System Management

Function Blocks must execute at precisely defined intervals and in the proper sequence of correct control system operation.

System management synchronizes execution of the Function Blocks and the communication of function block parameters on the fieldbus.

System management also handles other important system features such as publication of the time of day to all devices, including automatic switchover to a redundant time publisher, automatic assignment of device addresses, and searching for parameter names or "tags" on the fieldbus.

All of the configuration information needed by System Management, such as the Function Block schedule, is described by object descriptions in the Network and System Management Virtual Field Device (VFD) in each device. This VFD provides access to the System Management Information Base (SMIB) and also to the Network Management Information Base (NMIB).

Function Block Scheduling

A schedule building tool is used to generate function block and Link Active Scheduler (LAS) schedules. Assume that the schedule building tool has built the following schedules for the loop described in Figure 23.

The schedules contain the start time offset from the beginning of the "absolute link schedule start time." The absolute link schedule start time is known by all devices on the fieldbus.

Table 4. Offset from Absolute Link Schedule Start Time

	Offset from Absolute Link Schedule Start Time
Scheduled AI Function Block Extension	0
Scheduled Communications of AI	20
Scheduled PID Function Block Execution	30
Scheduled AO Function Block Execution	50

A "macrocycle" is a single iteration of a schedule within a device. Figure 28 shows the relationships between the absolute link schedule start time, LAS macrocycle, device macrocycles, and the start time offsets.

In Figure 28, System Management in the transmitter will cause the AI function block to execute at offset 0. At offset 20, the Link Active Scheduler (LAS) will issue a Compel Data (CD) to the AI function block buffer in the transmitter and data in the buffer will be published on the fieldbus.

At offset 30, System Management in the valve will cause the PID function block to execute followed by execution of the AO function block at offset 50.

The pattern exactly repeats itself assuring the integrity of the control loop dynamics.

Note that during the function block execution, the LAS is sending the Pass Token message to all devices so that they can transmit their unscheduled messages such as alarm notifications or operator setpoint changes.

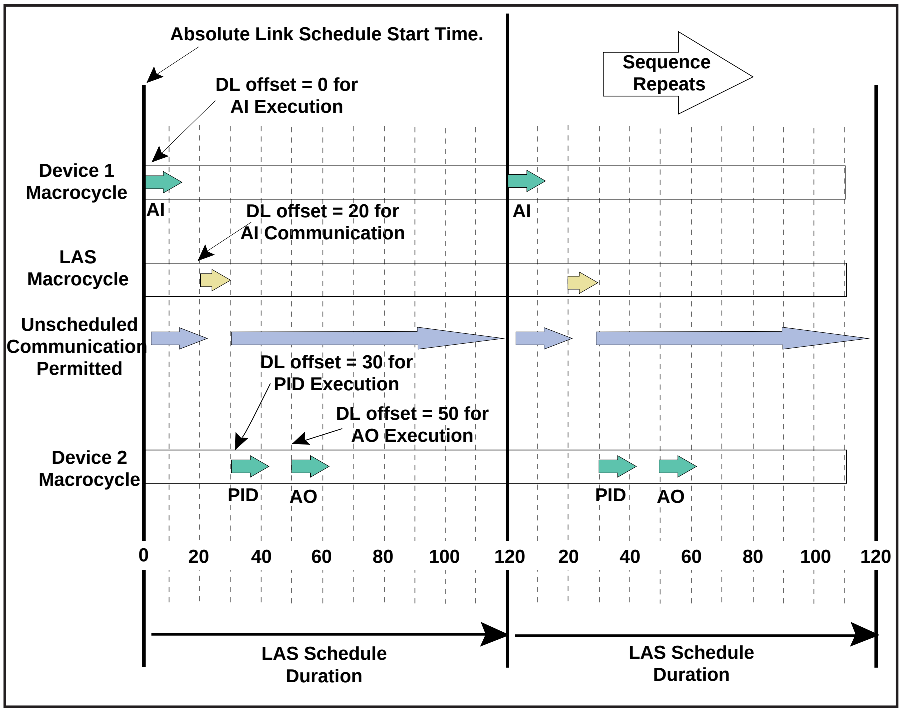

Figure 28. The start of individual macrocycles is defined as an offset from the absolute link schedule start time.

For this example, the only time that the fieldbus can not be used for unscheduled messages is from offset 20 to offset 30 when the AI function block data is being published on the fieldbus.

Application Clock Distribution

The FOUNDATION Fieldbus supports an application clock distribution function. The application clock is usually set to the local time of day or to Universal Coordinated Time.

System Management has a time publisher that periodically sends an application clock synchronization message to all fieldbus devices. The data link scheduling time is sampled and sent with the application clock message so that the receiving devices can adjust their local application time. Between synchronization messages, application clock time is independently maintained in each device based on its own internal clock.

Application clock synchronization allows the devices to time stamp data throughout the fieldbus network. If there are backup application clock publishers on the fieldbus, a backup publisher will become active if the currently active time publisher should fail.

Device Address Assignment

Every fieldbus device must have a unique network address and physical device tag for the fieldbus to operate properly.

To avoid the need for address switches on the instruments, assignment of network addresses can be performed automatically by System Management.

The sequence for assigning a network address to a new device is as follows:

- A physical device tag is assigned to a new device via a configuration device. This can be done “off-line” at a bench or “on-line” through special default network addresses on the fieldbus.
- Using default network addresses, System Management asks the device for its physical device tag. System Management uses the physical device tag to look up the new network address in a configuration table. System Management then sends a special “set address” message to the device that forces the device to move to the new network address.
- The sequence is repeated for all devices that enter the network at a default address.

Find Tag Service

For the convenience of host systems and portable maintenance devices, System Management supports a service for finding devices or variables by a tag search.

The “find tag query” message is broadcast to all fieldbus devices. Upon receipt of the message, each device searches its Virtual Field Devices (VFD) for the requested tag and returns complete path information (if the tag is found) including the network address, VFD number, virtual communication relationship (VCR) index, and object dictionary (OD) index. Once the path is known, the host or maintenance device can access the data for the tag.

Device Descriptions

A critical characteristic required of fieldbus devices is interoperability. To achieve interoperability, Device Description (DD) technology is used in addition to standard function block parameter and behavior definitions.

The DD provides an extended description of each object in the Virtual Field Device (VFD) as shown in Figure 29.

The DD provides information needed for a control system or host to understand the meaning of data in the VFD, including the human interface for functions such as calibration and diagnostics. This the DD can be thought of as a "driver" for the device.

The DDs are similar to the drivers that your personal computer (PC) uses to operate different printers and other devices that are connected to the PC. Any fieldbus-capable control system or host can operate with the device if it has the device's DD.

Device Description Tokenizer

The DD is written in a standardized programming language known as Device Description Language (DLL). A PC-based tool called the "tokenizer" converts DD source input files in DD output files by replacing key words and standard strings in the source file with fixed "tokens" as shown in Figure 30.

The Fieldbus Foundation (FF) provides DDs for all standard Function Blocks and Transducer Blocks. Device suppliers will typically prepare an "incremental" DD that references the Standard

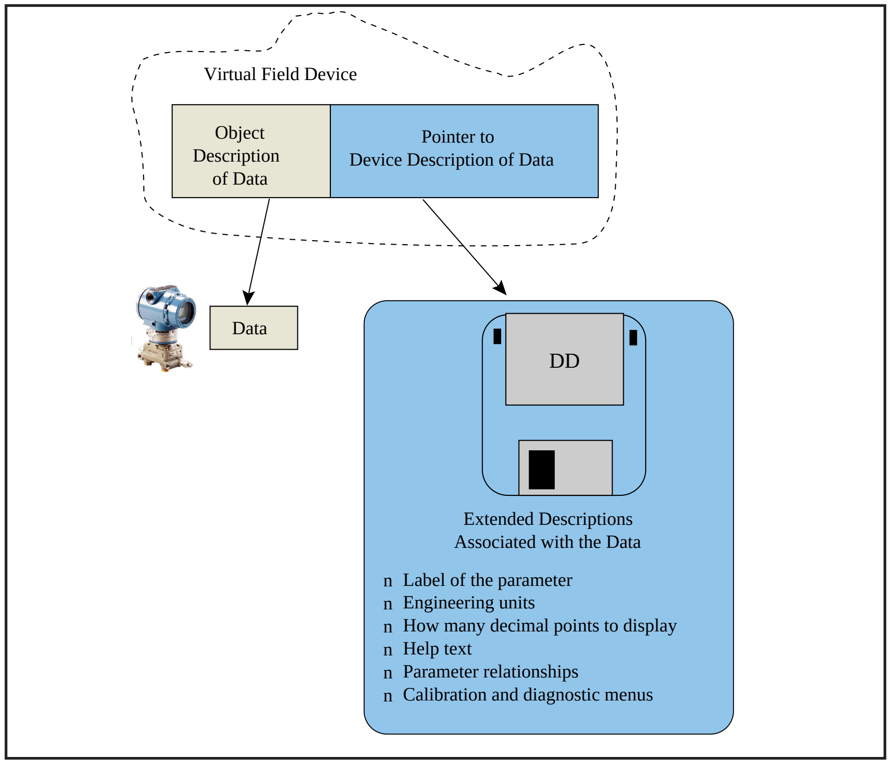

Figure 29. The DD provides extended descriptions of each object in the Virtual Field Device.

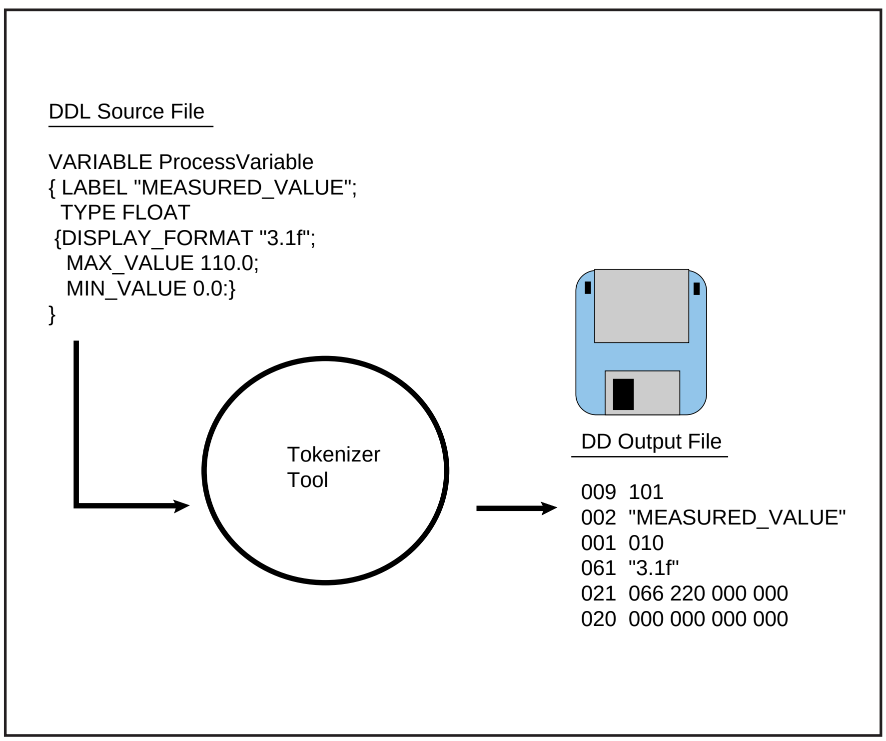

Figure 30. The Tokenizer converts DD source input files into DD output files.

DDs. Suppliers may also add supplier specific features such as calibration and diagnostic procedures to their devices. These features can also be described in the incremental DD.

The Fieldbus Foundation makes the Standard DDs available on a CD-ROM. The user can obtain the incremental DD from the device supplier or from the Fieldbus Foundation if the supplier has registered their incremental DD with the Fieldbus Foundation.

The incremental DDs can also be read directly from the device over the fieldbus, if the device supports the upload services and contains a Virtual Field Device (VFD) for the DD.

New devices are added to the fieldbus by simply connecting the device to the fieldbus wire and providing the control system or host with the standard and incremental (if any) DD for the new device.

Fisher-Rosemount supplies the DDs for all of the fieldbus devices it manufactures. Additionally, the DeltaV control system and the AMS Fieldbus Device Configurator software also supply DDs for all devices currently available—regardless of manufacturer.

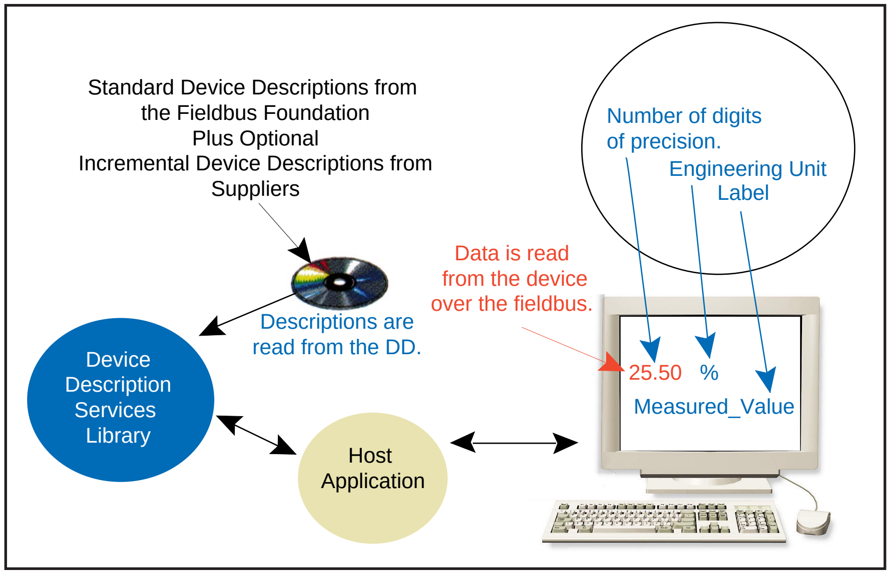

Figure 31. Library Functions called Device Description Services are used to read device descriptions.

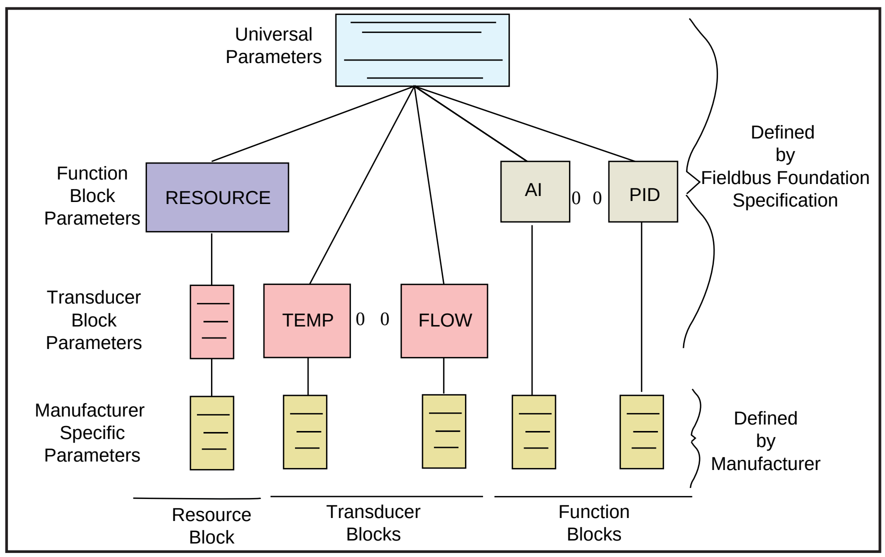

Figure 32. Hierarchy of Device Descriptions.

Device Description Services

On the host side, library functions called Device Description Services (DDS) are used to read the device descriptions. (See Figure 31.)

Note that DDS reads descriptions, *not* operational values. The operational values are read from the fieldbus device over the fieldbus using FMS communication services.

DDS technology allows operation of devices from different suppliers on the same fieldbus with only one version of the host human interface program.

Device Description Hierarchy

The Fieldbus Foundation has defined a hierarchy of Device Descriptions (DD) to make it easier to build devices and perform system configuration. The hierarchy is shown in Figure 32.

The first level in the hierarchy is the Universal Parameters. Universal Parameters consist of common attributes such as Tag, Revision, Mode, etc. All blocks must include the Universal Parameters.

The next level in the hierarchy is the Function Block Parameters. At this level, parameters are defined for the standard Function Blocks. Parameters for the standard Resource Block are also defined at this level.

The third level is called Transducer Block Parameters. At this level, parameters are defined for the standard Transducer Blocks. In some cases, the Transducer Block specification may add parameters to the standard Resource Block.

The Fieldbus Foundation has written the Device Descriptions for the first three layers of the hierarchy. These are the standard Fieldbus Foundation DDs.

The fourth level of the hierarchy is called Manufacturer Specific Parameters. At this level, each manufacturer is free to add additional parameters to the Function Block Parameters and Transducer Block Parameters. These new parameters will be included in the incremental DD discussed earlier.

Interoperability

Each manufacturer will provide the Fieldbus Foundation with an interoperability test report for each device.

The test report identifies the Universal, Function Block, Transducer Block, and Manufacturer Specific Parameters in the device. An identifier called the manufacturer's Identification is used to correlate the device type and revision with its Device Description and DD revision.

Any host using the Device Description Services (DDS) interpreter will be able to interoperate with all parameters that have been defined in the device by reading the device's DD.

System Configuration

Fieldbus system configuration consists of two phases:

- System Design
- Device Configuration

System Design

The system design for fieldbus-based systems is very similar to today's Distributed Control Systems (DCS) design with the following differences.

The first difference is in the physical wiring due to the change from 4-20 mA analog point-to-point signal to a digital signal. The same physical wire used today for 4-20 mA signals can be reused for fieldbus, but with fieldbus many devices can now be multidropped to one wire. (See Figure 8.)

Each device on the fieldbus must have a unique physical device tag and a corresponding network address.

The second difference is the ability to distribute some of the control and input/output (I/O) subsystem functions from the control system to the fieldbus devices. This may reduce the number of rack mounted controllers and remote mounted I/O equipment needed for the system design.

Device Configuration

After the system design is completed and the instruments have been selected, the device configuration is performed by connecting Function Block inputs and outputs together in each device as required by the control strategy. (See Figure 33.)

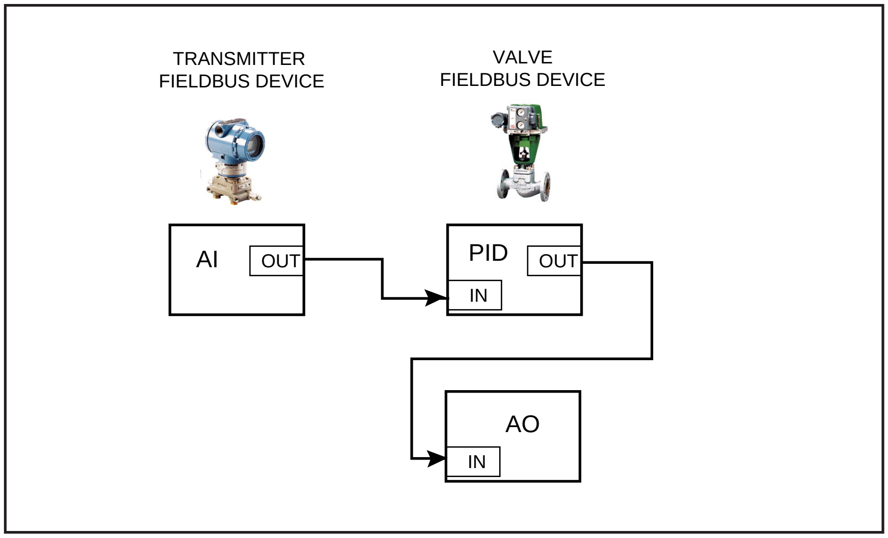

Figure 33. Device connection is performed by connecting Function Block inputs and outputs together.

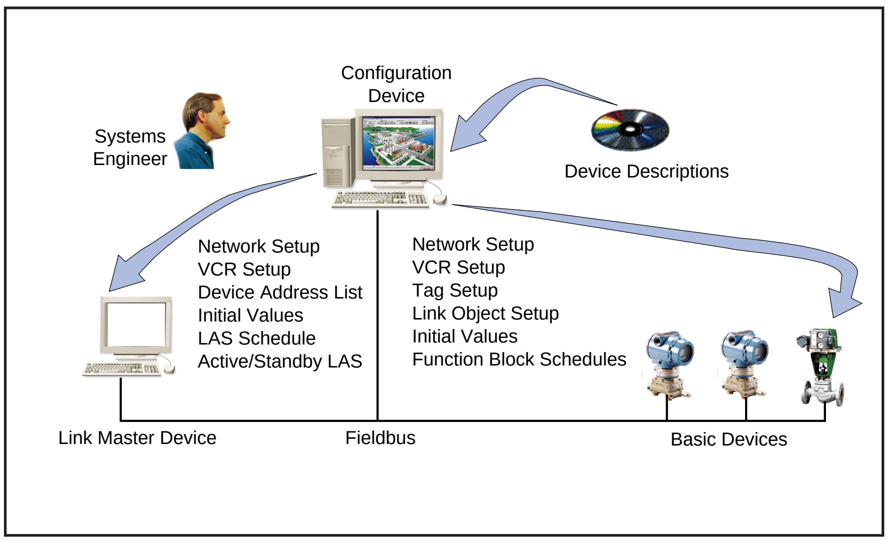

Figure 34. The configuration device generates all of the information needed to set up the fieldbus.

These connections are made using graphical objects in the configuration software, rather than by physical connections in the field.

After all of the function block connections and other configuration items such as device names, loop tags, and loop execution rate have been entered, the configuration device generates information for each fieldbus device. (See Figure 34.)

A stand-alone loop can be configured if there is a field device that is a Link Master. This will allow continued operation of the loop without the configuration device or central console.

The system becomes operational after the fieldbus devices have received their configurations.

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