Applying FOUNDATION Fieldbus

By B. R. Mehta and Y. J. Reddy
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ISA
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2.1 Introduction

FOUNDATION Fieldbus is an all-digital, serial, two-way communication system. H1 (31.25 Kbps) interconnects “field” equipment such as sensors, actuators, and I/O. High-speed Ethernet (HSE) (100 Mbps) provides integration of high-speed controllers (such as PLCs), H1 subsystems (via a linking device), data servers, and workstations. FOUNDATION Fieldbus is the only protocol with the built-in capability to distribute the control applications across the network. Management information system (MIS), enterprise resource planning (ERP), and human-machine interface (HMI) packages access the fieldbus information via the data services.

The H1 fieldbus retains and optimizes the desirable features of the 4–20 milliampere (mA) analog system such as:

- Single loop integrity
- A standardized physical interface to the wire
- Bus-powered devices on a single wire pair
- Intrinsic safety options

In addition, FOUNDATION Fieldbus enables:

- Increased capabilities from full-digital communications
Reduced wiring and wire terminations due to multiple devices on one wire

Increased selection of suppliers due to interoperability

Reduced loading on the control room equipment due to distribution of control and input/output functions to the field devices

Connection to the HSE backbone for the larger systems

The key features enabled by the FOUNDATION Fieldbus technology provide several benefits to the users.

**H1 FOUNDATION Fieldbus Benefits**

Using the FOUNDATION Fieldbus leads to some of the following direct savings in cost. In addition, there are various intangible benefits that are not listed here.

- Reduced number of wires and marshalling panels
- Reduced number of intrinsic safety barriers
- Reduced number of input/output converters
- Reduced number of power suppliers and cabinets
- Reduced size of equipment rooms
- Remote configuration of field devices
- More information available for operations
- Increased accuracy of measurements
- Easier evolution due to standardized functional blocks
- Increased sophistication and flexibility of instrumentation
- Increased uptime due to less equipment, better self-diagnostics, and remote diagnostics

**Multiple Variables with Bidirectional Communication**

The fieldbus allows multiple variables from each device to be brought into the control system for archival, trend analysis, process optimization studies, report generation, predictive maintenance, and asset management. The high
resolution and distortion-free characteristics of digital communications enables improved control capability, which can increase product yields. The difference lies in the intelligence of the field devices in a FOUNDATION Fieldbus network: each participant device is like a controller in a traditional sense. Intelligent field devices connected in the form of a bus bring the advantages that an intranet has brought to the information technology world. Bidirectional communication compared with traditional systems is depicted in figure 2-1.

**Figure 2-1. Fieldbus – Multiple Variables, Both Directions**

**Reduction in System Hardware**

FOUNDATION Fieldbus uses standard “function blocks” to implement the control strategy. Function blocks are standardized automation functions. Field devices use function blocks to perform many control system functions, such as analog input (AI), analog output (AO), and proportional-integral-derivative (PID). The consistent, block-oriented design of function blocks allows distribution of functions in field devices from different manufacturers in an integrated and seamless manner, thus reducing the risk of system failure. Distribution of control into the field devices can reduce the amount of I/O and control equipment needed, including card files, cabinets, and power supplies. Figure 2-2 represents the new paradigm of control in the field with the function blocks being the residents of the devices and hence saving hardware costs.
Wiring Savings

The H1 Fieldbus allows many devices to connect to a single wire pair, resulting in less wire, fewer intrinsic safety barriers, and fewer marshalling cabinets being required. Multiple point-to-point analog wires, each carrying a single parameter across the plant, are being replaced by a single pair of wires acting like a bus and carrying the whole set of parameters (bringing advantages such as less wiring, installation, and engineering). Figure 2-3 depicts the concept at a high level, and each of these benefits is covered in chapter 8.

HSE Benefits

In addition to the same life-cycle benefits as H1, HSE provides the control backbone that integrates all of the systems in the plant. The typical subsystems in the plant that are functionally based on the device data, such as process controllers, PLCs, and batch controllers, are integrated in the same HSE backbone. Some common examples are HMI stations, engineering stations, and historians. FOUNDATION Fieldbus enables asset management functions, such as diagnostics, calibration, identification, and other maintenance management operations, to “mine” massive amounts of information from field devices in real time. Asset management enables proactive maintenance that allocates resources to where they are really needed. Plants employing fieldbus-based field devices often have asset management software installed in
special computers connected over HSE. This improves the performance in terms of the bandwidth, latency, throughput, and reliability.

**Subsystem Interoperability**

Plants are comprised of a number of subsystems. With HSE, subsystems for burner management, gas chromatographs, paper web scanners, shutdown systems, compressor controls, tank farms, etc., integrate easily because of the open protocol. Users can mix and match subsystems for basic control, emergency shutdown, paper quality control, advanced control, compressor control, etc., from different suppliers. HSE eliminates the need for custom programming to access information. Users can select decimal subsystems to keep cost low, while reducing the configuration effort. Data integrity, diagnostics, and redundancy management are part of HSE and work seamlessly between devices from different manufacturers.

**Function Blocks**

The FOUNDATION Fieldbus function blocks used in H1 devices are used in HSE devices. The same control strategy programming language can be used throughout the entire system. The status associated with function block parameters is generated by field instruments based on failed sensors, stuck...
valves, etc., and is used for loop shutdowns, windup protection, and bumpless transfer.

Control Backbone

HSE provides peer-to-peer communication capability. Devices communicate with each other directly without having to go through a central computer. This enables powerful, advanced control strategies involving variables throughout the plant without the risk of a central computer failure, further reducing the risk of single-point failures and the associated loss of information, view, and control and shutdown in a plant. HSE can also bridge information between devices on different H1 networks at different ends of the plant. Thus, control can span between process cells and a plant area. HSE replaces enterprise, control, and remote-I/O networking levels, thus flattening the enterprise pyramid. The linking device (LD) brings data from one or more H1 fieldbus networks directly onto the HSE backbone.

Standard Ethernet Network Equipment

HSE devices use standard cable; no special tools or skills are required. Installation is simple and fast. HSE uses standard Ethernet network equipment such as switches. Standard commercial off-the-shelf (COTS) Ethernet components are made in extremely high volume. Cable, interface cards, and other networking hardware are very low cost compared to proprietary networks. Ethernet options for media include twisted pair, CAT5e fiber optics, and wireless. Networking hardware is available in both commercial and industrial grades from many suppliers.

2.2 Communications in FOUNDATION Fieldbus

The significant differentiation in devices with FOUNDATION Fieldbus is the ability to communicate with multiple devices on the same bus compared to legacy device communication technologies. The concept of communications is critical for understanding the protocol. FOUNDATION Fieldbus employs a subset of the International Standards Organization’s (ISO’s) open systems interconnection (OSI) communications model. It uses layers 1 (Physical), 2 (Data Link), and 7 (Application). It adds an additional layer called the “User Layer.” This User Layer doesn’t really fit the typical model of communications, because it is not message oriented. Instead, it models the process control data structures needed to ensure interoperability of devices. It provides a “virtual fieldbus device” (VFD), which presents the device’s functionality to the net-
work in a well-defined and understood manner, independent of how the data is actually stored within the device.

The Physical Layer defines the electrical signal and its tolerances. It defines “one” and “zero,” preamble characters, and frame check sequences.

The Data Link Layer defines the media access protocol—defining when a device has the right to transmit on the multidrop network. It also defines the sequences of messages to ensure reliable device-to-device transmission.

The Application Layer defines the data types (e.g., floating-point, 8-, 16-, and 32-bit integers, visible strings, octet strings, time, and date).

The User Layer, however, is the most important to the user. It defines process control–specific structures, such as function blocks and their parameters, modes of function blocks, statuses of variables, cascade initialization sequencing, anti-windup information, and event and alarm reporting methods. These are all essential to enable a sensor from brand X to work with a controller of brand Z.

However, any such detailed standard that ensures interoperability is likely to impede innovation, because manufacturers will not be permitted to provide features beyond the standard without violating the standard. Fieldbus addresses this concern by providing a “meta-language” by which a device may describe itself to the network for human interaction purposes. Such Device Description Language or variable description syntax is a standardized mechanism to provide nonstandard features. For example, although the PID algorithm parameters are standardized by Fieldbus Foundation, vendors may provide various self-tuning algorithms and their parameters. The PID parameters must be standard, but the self-tuning algorithms and their parameters may differ. This meta-language describes to any other devices on the network that there are nonstandard parameters, what they are named, what their data types are, the ranges of the data, and even help information. A device description language is primarily intended to provide configuration, display and entry information for a remote fieldbus node. It is not required for periodic or aperiodic data transfers between peer devices.
FOUNDATION Fieldbus communication stack falls in line with the standards of OSI layers and it consists of:

- The Physical Layer
- The Communication “Stack”
- The User Application Layer

This translates to the OSI layered communication model used to model these components.

- The Physical Layer is OSI layer 1.
- The Data Link Layer (DLL) is OSI layer 2.

The Fieldbus Message Specification (FMS) and fieldbus access sublayer are combined at OSI layer 7. Refer to figure 2-4 for the mapping of the layers in the fieldbus with the OSI layers.

Figure 2-4. The Open System Interconnect Layered Communications Model
Physical Layer (31.25 Kbps)

The Physical Layer in FOUNDATION Fieldbus is an approved standard from the International Electrotechnical Commission (IEC) and 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 and start and end delimiters. Refer to figure 2-5 for the image of voltage signaling of the FF.

Fieldbus signals are encoded using the well-known Manchester biphase-L technique. The signal is called synchronous serial, because the clock information is embedded in the serial data stream. 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.” Refer to figure 2-6 for the signal sequence in FOUNDATION Fieldbus.

31.25-Kbps Fieldbus Signaling

Fieldbus DC supply voltage can range from 9 to 32 volts. However, for intrinsically safe (IS) applications, the allowed power supply voltage depends on the barrier rating. Devices that are 31.25 Kbps can be powered directly from
Applying FOUNDATION Fieldbus

the fieldbus and can operate on wiring previously used for 4–20 mA devices. The 31.25-Kbps fieldbus also supports IS fieldbuses with bus-powered devices.

31.25-Kbps Fieldbus Wiring

The 31.25-Kbps fieldbus allows stubs or “spurs.” The length of the fieldbus is determined by the communication rate, cable type, wire size, bus power option, and IS option. Figure 2-7 helps explain the naming conventions used for wires in different parts of the bus.

Data Link Layer

The communication stack is comprised of layers 2 and 7 in the OSI model. The fieldbus 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 FOUNDATION Fieldbus has specified a user application model, significantly differentiating it from other models. Each layer in the communication system is responsible for a portion of the message that is transmitted on the fieldbus. Figure 2-8 references the approximate number of eight-bit “octets” used for each layer to transfer the user data.
Chapter 2 – FOUNDATION Fieldbus Technology

Figure 2-7. Fieldbus Wiring

* Trunk is the sum of all spurs and main trunk cable

Figure 2-8. Fieldbus Message Format in Different Layers
**FOUNDATION Fieldbus Device Types**

The FOUNDATION Fieldbus technology defines two types of devices. They are:

- **Basic Device**
- **Link Master Device**

Before we can understand the difference between these types of devices, we need to understand the concept called link active scheduler (LAS). Figure 2-9 depicts the concept of LAS, backup LAS, and the basic device in the context of an H1 bus.

LAS operates at the Data Link Layer. It provides the following functions:

- It identifies and adds devices to the link.
- It eliminates the nonresponsive devices from link.
- It distributes data link and link schedule timings; the Data Link Layer synchronizes the network-wide data link time. Link scheduling time is a link-specific time represented as an offset from data link time. It is used to indicate when the LAS on each link begins and repeats its schedule. System management uses it to synchronize function block execution with the data transfers scheduled by the LAS.
- It provides device polling at scheduled intervals for data.
Any device on the link capable of becoming the LAS is called a link master device. All other devices are referred to as basic devices.

The important criterion is that there should be backup LAS support along with the primary LAS. Ideal design is to have a link master, which can support both primary and backup link schedules. Normally the H1 link would be a primary link master, and the link master capable device acts as backup link master. In case of primary link connection failure, the backup link takes over the communication and handles the schedule so that the communication continues.

Upon startup or failure of the existing LAS, the link master capable devices on the link bid to become the LAS. The link master that wins the bid begins operating as the LAS immediately upon completion of the bidding process. The link master capable device with the lowest address usually wins the bid. Link masters that do not become the LAS act as basic devices when viewed by the LAS. They also act as LAS backups by monitoring the link for failure of the LAS, and by bidding to become the LAS when a LAS failure is detected.

Only one device can communicate at a time. Permission to communicate on the bus is controlled by a centralized token passed between devices by the LAS. Only the device with the token can communicate. The LAS maintains a list of all devices that need access to the bus. This list is called the “live list.” The LAS uses two types of tokens. A time-critical token, compel data (CD), is sent by the LAS according to a schedule. A non-time-critical token, pass token (PT), is sent by the LAS to each device in ascending numerical order according to address. The devices participate in the network and are controlled by a link master device. Basic devices do not have the capability to become the LAS.

**Device Addressing**

Fieldbus uses addresses between zero and 255. Addresses zero through 15 are reserved for group addressing and for use by the Data Link Layer. Each vendor provides a range of device addresses to be available for the devices. If there are two or more devices with the same address, the first device to start will use its programmed address. Each of the other devices is given one of four temporary addresses between 248 and 251. If a temporary address is not available, the device will be unavailable until a temporary address becomes available.
A temporary device, such as a hand-held communicator or a bus participating monitors for troubleshooting, etc., has a node address in the temporary range. If there is a conflict in the address of the two devices, the one that joined second will be changed to the temporary address range. The system will allow it to be changed to the permanent address range using configuration tools or a hand-held communicator.

New devices that do not have an assigned permanent address in the available node address range 20-247 also first appear in another reserved range of addresses in nodes 248-251 inclusive. The result of having only four temporary addresses is that if more than four devices without permanent addresses attempt to connect to the network at one time only the first four devices detected will appear on the live list. The remaining non-reserved or accessible node addresses 16-19 are reserved for the Permanent Host/DCS.

### Table 2-1. FOUNDATION Fieldbus Node Addressing

<table>
<thead>
<tr>
<th>Address</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x10 – V(FUN)</td>
<td>Address for link master class devices</td>
</tr>
<tr>
<td>0xF7 – (FUN)+V(NUN)</td>
<td>Address for basic class devices</td>
</tr>
<tr>
<td>0xF8 – 0xFC</td>
<td>Default address for devices with cleared address</td>
</tr>
<tr>
<td>0xFD – 0xFF</td>
<td>Address for temporary devices such as handheld communicators</td>
</tr>
</tbody>
</table>

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 subscriber devices on the fieldbus. The device configured to receive the data is called a “subscriber.” Scheduled data transfers are typically used for the regular, cyclic transfer of control loop data between devices on the fieldbus. Figure 2-10 provides a view of scheduled communication. Not all devices on the network subscribe to all messages, but only those that are configured as part of the control loop and the LAS (Host System).

Unscheduled Communication

All the devices on the fieldbus can 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 “delegated token hold time” has expired, whichever is the shorter time. Figure 2-11 depicts the concept of unscheduled communication. Unscheduled communication is a client/server communication with a one-to-one relationship for each message. The paths provided in the figure are possible ways for communications.

Figure 2-11. Unscheduled Communications

**Function Block Scheduling**

Figure 2-12 shows an example of a link schedule. A single iteration of the link-wide schedule is called the macrocycle. When the system is configured and the function blocks are connected or linked, a master link-wide schedule is created for the LAS. Each device maintains its portion of the link-wide sched-
ule, known as the Function Block Schedule. The Function Block Schedule indicates when the function blocks for the device are to be executed. The scheduled execution time for each function block is represented as an offset from the beginning of the macrocycle start time.

![Diagram](image)

**Figure 2-12. Example Link Schedule Showing Scheduled and Unscheduled Communication**

To support synchronization of schedules, periodically, link scheduling (LS) time is distributed. The beginning of the macrocycle represents a common starting time for all function block schedules on a link and for the LAS link-wide schedule. This permits function block executions and their corresponding data transfers to be synchronized.

### 2.3 Fieldbus Access Sublayer (FAS)

The FAS uses the scheduled and unscheduled communication features of the Data Link Layer to provide communication services for the Fieldbus Message Specification. Virtual Communication Relationships (VCR) describe the types of FAS services. The VCR is like the speed dial feature on a memory telephone. There are many digits to dial for an international call, such as the 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 to dial. Likewise, 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
- Report Distribution
- Publisher/Subscriber

**Client/Server VCR Type**

The client/server VCR Type is used for queued, unscheduled, user initiated, one-to-one, and 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 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 set-point changes, tuning parameter access and change, alarm acknowledgment, and device upload and download.

**Report Distribution VCR Type**

The report distribution VCR Type is used for queued, unscheduled, user-initiated, and one-to-many communications. When a device with an event or a trend report receives a PT from the LAS, it sends its message to a “group address” defined for its VCR. Devices that are configured to listen for that VCR receive the report. The report distribution VCR Type is typically used by fieldbus devices to send alarm notifications to the operator consoles. In most cases all the devices on the network are configured to receive all reports, so they are aware of the status of all devices to which they are connected.

**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 main-
tained within the network. New data completely overwrites previous data. When a device receives the CD, the device will “publish” or broadcast its message to all its subscriber devices on the fieldbus. Devices that wish to receive the published message are called “subscribers.” The CD may be scheduled in the LAS, or may be sent by subscribers on an unscheduled basis. An attribute of the VCR indicates which method is used. The field devices use publisher/subscriber VCR Type for cyclic, scheduled publishing of user application function block input and outputs such as process variable (PV) and primary output (OUT) on the fieldbus. Figure 2-13 provides a tabular view of the VCR types.

### FIELDBUS ACCESS SUBLAYER SERVICES

<table>
<thead>
<tr>
<th>Client/Server VCR Type</th>
<th>Report Distribution VCR Type</th>
<th>Publisher/Subscriber VCR Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used for Operator Messages</td>
<td>Used for Event Notification and Trend Reports</td>
<td>Used for Publishing Data</td>
</tr>
<tr>
<td>Set point changes</td>
<td>Send process alarms to operator consoles</td>
<td>Send transmitter PV to PID control block and operator console</td>
</tr>
<tr>
<td>Mode changes</td>
<td>Send trend reports to data historians</td>
<td></td>
</tr>
<tr>
<td>Tuning changes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upload/download</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alarm management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access display views</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remote diagnostics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### DATA LINK LAYER SERVICES

Figure 2-13. Different Types of VCRs in FOUNDATION Fieldbus

### 2.4 User Application

FOUNDATION Fieldbus defines a standard User Application Layer based on “blocks,” also called function blocks. This is often referred to as Function Block Application Program (FBAP), whose structure is illustrated in figure 2-14. The part of the FBAP that is standardized in fieldbus is called the function block
shell. For example, the block algorithms are not standardized. For each block there is a set of parameters that, to a certain extent, define the minimum functionality of a block. However, a manufacturer may implement such a block in its own way. For example, in the PID control block there must be a GAIN parameter, and the manufacturer may use this parameter as GAIN or PROPORTIONAL BAND.

![Diagram of Application Layer](image)

**Figure 2-14. Structure of Application Layer**

**Function Block**

The function block models the user-configurable part of the entire application. Typically, these functionalities were previously available in individual physical devices, but software blocks now include many of these functionalities in a single device. The different types of function blocks in a fieldbus system provide all the functionality necessary for most control systems. The function blocks are linked together to build control strategies suitable for an application. In general, function blocks use an algorithm and contained parameters to process input parameters, and produce output parameters as results.
Again, the block is just an abstraction of software and data. There are no blocks inside the device to be seen. The function block concept was designed around the PID block, since it is the most complex block. The concept of local/remote set point, automatic/manual output, cascade (remote set point) and the algorithm has been carried on to other blocks.

A particular selection of set point and output is called the block mode. The algorithm does not refer to the PID algorithm in the PID block alone, but in general to the processing function of all blocks.

Each block is identified in the system by a tag assigned by the user. This tag must be unique in the fieldbus system. Each parameter in a block has a name that cannot be changed. All parameters in the system are uniquely defined by the block tag plus parameter name. Blocks are representations of different types of application functions.

A user application, for example, uses the following types of blocks, as shown in figure 2-15:

- Resource block
- Transducer block
- Function block

Devices are configured using resource blocks and transducer blocks. The control strategy is built using function blocks.

**Resource Block**

A device can have only one resource block. The resource block describes characteristics of the fieldbus device, such as the device name, type, revision, manufacturer, and serial number.

**Transducer Block**

Transducer blocks read from physical sensors into function blocks. Transducer blocks decouple the function blocks from the hardware details of a given device, allowing generic indication of function block input and output. They contain information such as calibration date and sensor type. There is usually one transducer block for each type of input or output function block. The transducer block uses channels to link the raw data for each measurement.
to each of the associated I/O blocks. The transducer block knows the details of I/O devices and how to actually read the sensor or change the actuator. The transducer block performs the digitizing, filtering, and scaling conversions needed to provide the sensor value to the function blocks and/or make the change in the output as dictated by the function block.

![Figure 2-15. Function Blocks in FOUNDATION Fieldbus](image)

**Application Function Block**

Function blocks (FB) provide the control system behavior. Each performs a specific task, such as measurement or control with input and outputs connected to other entities in a standard way. 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 FOUNDATION Fieldbus defines multiple sets of standard function blocks.
Fieldbus defines the following 10 standard function blocks for basic control. Refer to the standard (list of standards is provided in appendix) for an updated list of function blocks.

- Analog Input – AI
- Analog Output – AO
- Bias/Gain – BG
- Control Selector – CS
- Discrete Input – DI
- Discrete Output – DO
- Manual Loader – ML
- Proportional Derivative – PD
- Proportional Integral Derivative – PID
- Ratio – RA

Additional blocks, which are not common among all the devices, but among specific devices are:

- Device Control – DC
- Output Splitter – OS
- Signal Characterize – SC
- Lead Lag – LL
- Dead Time – DT
- Integrator – (Totalizer) IT
- Set-Point Ramp Generator – SPG
- Input Selector – IS
- Arithmetic – AR
- Timer – TMR
- Analog Alarm – AAL
- Multiple Analog Input – MAI
• Multiple Analog Output – MAO
• Multiple Discrete Input – MDI
• Multiple Discrete Output – MDO

For example, a simple temperature transmitter may 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. Figure 2-16 represents the concept.

![Figure 2-16. Control Loop Using Function Blocks](image)

### 2.5 Objects in Fieldbus

A fieldbus device may have user applications that are independent from each other and do not interact. A fieldbus device consists of virtual field devices (VFD) for such individual applications.

A FOUNDATION Fieldbus device has at least two VFDs. One is the management VFD where network and system management applications reside. It is used to configure network parameters including VCRs, as well as to manage
devices in the fieldbus system. The other is a function block VFD, where function blocks exist. Most field devices have more than two function block VFDs.

A measurement or control application consists of function blocks connected to each other. Function blocks are connected through link objects in the function block VFD. A link object connects two function blocks within a device or a function block to a VCR for publisher or subscriber.

The following objects are defined in the user application:

- Block/Link objects
- Trend objects
- Alert objects
- View objects
- Multivariable container objects

**Link Objects**

Control strategies can be built by linking function block outputs to the inputs of other function blocks. When such a link is made, the input “pulls” the value from the output, thereby obtaining its value. Links can be made between function blocks in the same device or in different devices (see figure 2-17). An output may be connected to many inputs. These links are purely software, and there is basically no limitation to how many links can travel along a physical wire. Links cannot be made with contained variables. Analog values are passed as a floating point in an engineering unit, but are scaled to a percentage (e.g., in the PID control block) to enable dimensionless tuning parameters. Digital values are passed as Boolean, zero, or 255. The analog scaling information may also be used in operator interfaces to provide bar-graph readout.

An output value is always accompanied by a status informing if it is suitable for control (e.g., a value received from a sensor or forward path) or is suitable as the feedback (backward path) informing if the status is determined by the source (e.g., the output does not move the final control element). Note that the pull system is used for backward paths, also enabling the receiving function block to take appropriate action.
Links are uniquely defined by the name of the output parameter and the tag of the function block that they come from. It is therefore very easy for a user to identify links. System management resolves the block tag + parameter name construct into the short reference address + index to make communication faster. Links may also be preconfigured directly using address and index. The link management, such as link active schedules, automatically establishes the connections upon power on.

**Trend Objects**

Trend objects allow local trending of function block parameters for access by hosts or other devices at a scan rate faster than the bus communication cycle. The device can perform trending using the trend object. This eliminates periodic time-critical communication. Data are collected from 20 samples and are accessed in a single communication. This reduces communication and network overhead, leaving more time for time-critical transfers.
Alert Objects

Alert objects enable reporting of alarms and events. Many function blocks have a built-in alarm function to detect high and low process variable and deviation alarms. When alarms and other critical events occur, an alert object automatically notifies the user. This eliminates the need for the operator interface to perform periodic polling to determine if there is an alarm condition. The physical and transducer blocks detect failures in hardware and overall operation status. The alert object relieves these blocks of the alert handling so that their execution remains unaffected.

The alert object also provides an acknowledgment mechanism to ensure that the operator has been informed. If a reply is not received within a specified time, the alert notification is repeated. The operator is also informed when an alarm condition disappears.

Examples of events are:

- Mode is being forced for some reason
- Block tag has been changed
- Locked output/fail-safe conditions
- Feedback does not match desired output

The trip level, priority level, and deadband can be configured for the alarms. The alert notification to the console includes: time stamp, reason, priority, present status (the alarm may already have disappeared), and the trip value.

If a change is made to the configuration, an alert notification containing priority, configuration revision level, changed parameter, and time stamp is issued.

All alerts also inform which device and block is the source of the alarm and provide an alert key for sorting by plant division and a type code identifying enumerated messages to the operator. The messages may be among standard messages or others specified by the manufacturer. There is also an alarm summary of up to 16 alerts for each block summarizing present status: if the alarm has already been acknowledged, if it was not successfully reported to the operator, or if it is disabled.
Multivariable Container Objects

Multivariable container (MVC) objects serve to “encapsulate” multiple function block parameters to optimize communications for publisher/subscriber and report distribution transactions. It has a user-configured list to define the required parameters, whose data values are referenced in a variables list.

View Objects

View objects are predefined groupings of block parameter sets that can be displayed by the human-machine interface. The function block specification defines four views for each type of block. Figure 2-18 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 (e.g., process variable)
- VIEW_2 — Operation Static — Information that may need to be read once and then displayed along with the dynamic data (e.g., permitted mode)
- VIEW_3 — All Dynamic — Information that is changing and may need to be referenced in a detailed display (e.g., all inputs and outputs)
- VIEW_4 — Other Static — Configuration and maintenance information (e.g., all alarm configurations)

Access Rights FOUNDATION Fieldbus

The operator at the console can grant or deny access to four sets of parameters in a block to a local interface or to a higher-level device, such as a batch program. Adjustments carried out from the console, locally, or by a batch program appear the same to the function block.

The four groups for a higher level device are:

- Program — mode, set point, and output
- Tune — tuning parameters
- Alarm — alarm parameters for a hand-held terminal or local interface
- Local — mode, set point, and output
2.6 Interoperability Test Kit

Device Interoperability

Support for interoperability is one of the founding principles of FOUNDATION Fieldbus. The Interoperability Test System (ITS) tests the black box behavior of a device using only its interface to the network. Prerequisites to interoperability testing are that the device under test must use a compliant communications stack and the physical layer of the device must have been tested for specification conformance. The scope of testing depends upon the level of conformity implemented by the device manufacturer. All function blocks in a device that are implemented according to standardized block profiles are tested to verify correct implementation. The ITS tests all Device Description support files and high-level stacks.

The Fieldbus Foundation has released the latest version of the H1 Interoperability Test Kit (ITK) 6.1.0, and manufacturers typically have approximately 18 months to incorporate resulting changes in their products. The ITK is normally issued with maintenance changes on an annual basis in the fall. This tool tests the functionality of an H1 (31.25 kbps) fieldbus device and its conformity with the FOUNDATION Fieldbus’ function block and transducer block.
specifications. This includes new features to enhance device intelligence, improve consistency in instrument configuration, and simplify replacement of field devices from different automation suppliers. H1 ITK consists of a test engine, communication stack, and function block interface card. It includes all hardware and software required to ensure complete device interoperability.

H1 ITK 6.1.0 builds on the extensive library of FOUNDATION Fieldbus block test cases, offering a series of standardized function blocks and transducer blocks that enable increased test coverage for device developers. This includes test cases for new blocks that were previously unavailable, such as flow totalizer, analog alarm, control selector, and output splitter, which support expanded device applications for control in the field (CIF). A new flow transducer block is intended to simplify device integration within FOUNDATION Fieldbus networks. In addition, the release provides updated test cases for existing blocks, including flow, pressure, temperature, analog positioner, and discrete positioner.

The new H1 ITK test cases focus on backward compatibility among FOUNDATION Fieldbus devices. This enhancement supports device replacement automation and enables the test kit to verify consistent behavior between device and host implementations in fieldbus-based control systems. Automation of device replacement enables the configuration in an existing field device to be configured in a newer version of that instrument without manual intervention. This plug-and-play solution ensures features are consistent between different generations of devices without reengineering the host configuration or changing any other element of the H1 network other than the new instrument. The use of common transducer blocks also improves interoperability and simplifies device replacement by enabling a minimum level of configuration across all types of instruments. This results in greater predictability in fieldbus implementation, while reducing integration risks.
The various ITK functionalities are added at different releases of the toolkit, and the diagram shown in figure 2-19 represents this as well.
Host Interoperability Test in FOUNDATION Fieldbus

Host Interoperability Support Test (HIST) provides generic test procedures that would be performed or witnessed by qualified Fieldbus Foundation staff on FOUNDATION Fieldbus (FF) to prove that the host has the adequate test procedure for each claimed feature. Each host is defined by the manufacturer to provide specific functions within a fieldbus network. A host could be a configuration tool, a recording device, an alarm display panel, a human-machine interface, or a combination of functionality.

FOUNDATION Fieldbus FF-569 defined a set of generic FF host features that may be implemented within the host to implement a set of applicable test procedures. A host must conform to some, or perhaps all features, as defined by the host feature checklist. However, because hosts can have various definitions, not all features may be applicable to a host implementation. Therefore, it is not expected that every host must support each feature.

Each feature contains a set of test procedures that are to be run against the host or the fieldbus system using the host. The host must pass the test procedures defined by the feature for a host to claim conformance to the feature. The features themselves are generic; therefore, manufacturers develop test cases, or actual implementation steps necessary to meet the requirements of the test procedure. Many test procedures require features supported by both the device(s) and the host.

The purpose of the HIST is to reveal and confirm features that are supported by the host product being qualified against a particular HIST profile. Features that are mandatory in the HIST profile (FF-569) are essential (within that profile) to interoperability or successful adoption of the technology. A host candidate cannot achieve compliance with an HIST profile without meeting all mandatory features.

Features that are optional in the HIST Profile Table in table 2-1 are not required but are of interest to the users. Those hosts that implement and achieve an optional feature are credited for it in the HIST profile conformance report.

It is important to note that a test procedure failure may be a result of one or many circumstances, which can include:

- Invalid device implementation
Applying FOUNDATION Fieldbus

- Invalid host implementation or configuration
- Interdevice configuration problems
- Device profile incompatibilities
- Other unknown reasons

Host Interoperability Support Test Profiles

A host application consists of one or more hardware and software components specified by the host manufacturer. For example, a Class 61 integrated host may consist of a controller, engineering station, operation station, and asset management station. Individually, these components may not conform to a profile class, but collectively these components function as a single host profile class. The host manufacturer must specify all components that collectively meet the profile class. It is possible for a host to meet multiple profiles. For example, a host may meet both Class 63 and Class 64. In this case, some features in Class 63 are specified as mandatory and specified as prohibited in Class 64. The manufacturer must document how those host features are enabled in Class 63 while disabled in Class 64 (e.g., menu configuration). The details of the profiles are provided in table 2-3.

Table 2-3: Host Interoperability Test Profiles

<table>
<thead>
<tr>
<th>Group 6 Host Profile Classes</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 61 Integrated Host</td>
<td>Class 61</td>
<td>Primary, on process host that manages the communication and application configuration of all devices on a network.</td>
</tr>
<tr>
<td>Class 62 Visitor Host</td>
<td>Class 62</td>
<td>Temporary, on process host with limited access to device parameterization.</td>
</tr>
<tr>
<td>Class 63 Bench Host</td>
<td>Class 63</td>
<td>Primary, off process host for configuration and setup of a non-commissioned device.</td>
</tr>
<tr>
<td>Class 64 Bench Host</td>
<td>Class 64</td>
<td>Primary, off process host with limited access to device parameterization of an off-line, commissioned device.</td>
</tr>
</tbody>
</table>
**Class 61 - Integrated Host**
The Class 61 integrated host is the primary on-process host. Its characteristics are:

- Fixes H1 address, on process
- Sets and manages physical device TAGs (device name) for all devices
- Sets and manages the network configuration (device address, link parameters, application time)
- Manages the distributed application configuration (link schedule, backlink schedule, block instantiation, link objects, macrocycle, VCRs, alerts)
- Full access to all resource block, transducer block, and function block parameters.
- May maintain a backup/off-line database
- Confirms, manages, and handles device and process alerts

The profile is primarily used by the process control engineer (for configuration and analysis), operator (for plant operation), plant management (for plant management information), and maintenance personnel (for maintenance of instrumentation, control system equipment, and process equipment). The typical use case for such a profile is a process operational host that configures and operates instrumentation devices enabled with FOUNDATION Fieldbus.

**Class 62 - Visitor Host**
A visitor host is a secondary on-process host typically used for device maintenance. The characteristics of a visitor host are:

- Visitor H1 address, basic mode, on process
- Does not manage the physical device TAG, network configuration, or distributed application configuration
- May have read and write access to resource block and transducer blocks
- May provide read-only access to function blocks

The primary users of the profile are instrumentation and maintenance personnel. The most commonly applied use case is a technician with hand-held
equipment or a portable PC/PDA that connects to the network for device maintenance (temporary connection to bus), or a field support engineer who connects to the bus with a specialized device application (e.g., online valve diagnostics package).

**Class 63/64 - Bench Host**

The Class 63/64 bench host is the primary host on an off-process bench link for maintenance and setup. There are two identified use cases for bench hosts, which result in different profile classes. A host may conform to both profile classes, but must document how each profile is managed (e.g., software setting, user prompt).

A Class 63 bench host is the primary host for accessing and configuring non-commissioned devices. The typical characteristics are:

- Fixed or visitor H1 address, off process
- May set the network configuration (device address, link parameters, application time) for off-process testing
- May set a distributed application configuration (link schedule, backlink schedule, block instantiation, link objects, macrocycle, VCRs, alerts)
- May access all resource block, transducer block, and function block parameters

Primary users are instrumentation and maintenance personnel. The usually applied use cases are:

1. Testing of skid operation, the entire network at once: To test the skid as an entity, the FF devices have to be commissioned at the start and then decommissioned at the conclusion.

2. Setting up a new device for service or maintenance of a previously configured and operating device removed from the process network: The device may remain configured, in which case certain configuration information must not be altered. Alternatively, the device may be decommissioned, and then recommissioned upon return to the on-process H1 link.

3. Setting up a new device for device replacement service: New device is not yet commissioned.
4. Clearing used devices for potential reassignment: This is to render the device “safe” by such actions as clearing PD_Tag, H1 address, VCR’s LAS and function block schedules, link objects, and setting to basic device type.

A Class 64 bench host is a primary host for access to a previously commissioned device. A Class 64 bench host has nearly identical requirements to a Class 62 visitor host with the exception of device address configuration. The typical characteristics are:

- Fixed or visitor H1 Address, off process
- Does not configure physical device TAG, network configuration, or distributed application configuration
- May have access to and write to resource block and transducer blocks
- May provide read-only access to function block parameters

The primary users are instrumentation and maintenance personnel. The most commonly applied use case is a technician with hand-held equipment or a portable PC/PDA that connects to the network for device maintenance (temporary connection to bus), or a field support engineer who connects to the bus with a specialized device application (e.g., online valve diagnostics package).