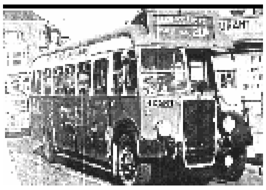
Fieldbus Training / Tutorial



FIELDBUS

is a digital, two-way, multi-drop communication link among intelligent control devices that will replace the 4-20 mA standard in future.

First of all, fieldbus is digital. Although computers, programmable logic controllers (PLCs), and remote terminal units (RTUs) communicate with each other digitally, most end devices (e.g. valves, pressure transducers, switches, etc.) still use analog signals to communicate. For example, an analog value of 4 mA might correspond to a pressure of no flow while a value of 20 mA might correspond to a 1000 GPM flow value. With discrete devices, the presence of a signal might represent a "closed" or "alarm" condition while the absence of a signal might represent "open" or "normal".

Two-way communications means that a value can not only be read from the end device but it is now possible to write to the device. For example, the calibration constants associated with a particular sensor can now be stored directly in the device itself and changed as needed.

For more details please see the files at "Fieldbus Class Room"

Fieldbus Comparison Chart 28 kb

Fieldbus and remote I/O Comparison 1.3 MB

The multi-drop capability of a fieldbus will perhaps result in the most immediate cost saving benefit for users. With analog devices, a separate cable needs to be run between the end device and the control system because only a single analog signal can be represented on the circuit. Modern distributed systems partially solve this problem by locating remote multiplexing devices out in the field. The ultimate solution, however, is to be able to connect a reasonable number of sensors all located in the same area to the same cable. This is exactly what fieldbus allows.

Finally, fieldbus will replace the 4-20 mA standard, although this will not happen overnight. There are millions of instruments in the world using this standard right now, which does in fact have some advantages. It is simple and well understood. Devices from different suppliers using the 4-20 mA standard can easily operate together (ie. interoperate).

Foundation Fieldbus

FOUNDATION FIELDBUS

is an open, integrated total architecture for information integration. FOUNDATION fieldbus is an all-digital, serial, two-way communication system. H1 (31.25 kbit/s) interconnects field equipment such as sensors, actuators and I/O. HSE (100 Mbit/s) High Speed Ethernet 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 application across the network. Management Information Systems (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 due to 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 control room equipment due to distribution of control and input/output functions to field devices
- connection to the HSE backbone for larger systems

For more details see the files at “Fieldbus Class Room” Foundation Fieldbus Overview ９３5kb

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 self-test and communication capabilities of microprocessor-based fieldbus devices help reduce downtime and improve plant safety. Upon detection of abnormal conditions or the need for preventive maintenance, plant operations and maintenance personnel can be notified. This allows corrective action to be initiated quickly and safely.

FOUNDATION fieldbus uses standard function blocks to implement the control strategy. Function Blocks are standardized

automation functions. Many control system functions such as analog input AI, analog output AO and Proportional/Integral/Derivative PID control may be performed by the field device through the use of Function Blocks.

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 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.

Foundation Fieldbus Glossary

Basic Device:

A Basic Device is any device not having the capability to control communications on an H1 fieldbus segment.

Capabilities File:

A Capabilities File describes the communication objects in a fieldbus device. A configuration device can use Device Description (DD) Files and Capabilities Files to configure a fieldbus system without having the fieldbus devices online.

Communications Stack:

A Communications Stack is device communications software which provides encoding and decoding of User Layer messages, deterministic control of message transmission, and message transfer.

Connector:

A Connector is a coupling device used to connect the wire medium to a fieldbus device or to another segment of wire.

Control Loop:

A Control Loop is a group of Function Blocks (FBs) that execute at a specified rate within a fieldbus device or distributed across the fieldbus network.

Coupler:

A Coupler is a physical interface between a Trunk and Spur, or a Trunk and a device.

Data Link Layer (DLL):

The Data Link Layer (DLL) controls transmission of messages onto the fieldbus, and manages access to the fieldbus through the Link Active Scheduler (LAS). The DLL used by FOUNDATION fieldbus is defined in IEC 61158 and ISA S50. It includes Publisher/Subscriber, Client/Server and Source/Sink services.

Device Description (DD):

A Device Description (DD) provides an extended description of each object in the Virtual Field Device (VFD), and includes information needed for a control system or host to understand the meaning of data in the VFD.

Fieldbus:

A Fieldbus is a digital, two-way, multi-drop communication link among intelligent measurement and control devices. It serves as a Local Area Network (LAN) for advanced process control, remote input/output and high speed factory automation applications.

Fieldbus Access Sublayer (FAS):

The Fieldbus Access Sublayer (FAS) maps the Fieldbus Message Specification (FMS) onto the Data Link Layer (DLL).

Fieldbus Messaging Specification (FMS):

The Fieldbus Messaging Specification (FMS) contains definitions of Application Layer services in FOUNDATION fieldbus. The FMS specifies services and message formats for accessing Function Block (FB) parameters, as well as Object Dictionary (OD) descriptions for those parameters defined in the Virtual Field Device (VFD).

Flexible Function Block:

A Flexible Function Block (FB) is similar to a Standard FB, except that the function of the block, the order and definition of the block parameters, and the time required to execute the block are determined by an application-specific

algorithm created by a programming tool. Flexible Function Blocks (FBs) are typically used for control of discrete processes and for hybrid (batch) processes. A Programmable Logic Controller (PLC) can be modelled as a Flexible Function Block device.

H1:

H1 is a term used to describe a fieldbus network operating at 31.25 kbit/second.

H1 Field Device:

An H1 Field Device is a fieldbus device connected directly to an H1 fieldbus. Typical H1 Field Devices are valves and transmitters.

H1 Repeater:

An H1 Repeater is an active, bus-powered or non-bus-powered device used to extend the range over which signals can be correctly transmitted and received for a given medium. A maximum of four Repeaters and/or active Couplers can be used between any two devices on an H1 fieldbus network.

High Speed Ethernet (HSE):

High Speed Ethernet (HSE) is the Fieldbus Foundation's backbone network running at 100 Mbit/second.

HSE Field Device:

An HSE Field Device is a fieldbus device connected directly to a High Speed Ethernet (HSE) fieldbus. Typical HSE Field Devices are HSE Linking Devices, HSE Field Devices running Function Blocks (FBs), and Host Computers.

HSE Linking Device:

An HSE Linking Device is a device used to interconnect H1 fieldbus Segments to High Speed Ethernet (HSE) to create a larger network.

HSE Switch:

An HSE Switch is standard Ethernet equipment used to interconnect multiple High Speed Ethernet (HSE) devices such as HSE Linking Devices and HSE Field Devices to form a larger HSE network.

Input/Output (I/O) Subsystem Interface:

An Input/Output (I/O) Subsystem Interface is a device used to connect other types of communications protocols to a fieldbus Segment or Segments.

Interchangeability:

Interchangeability is the capability to substitute a device from one manufacturer with that of another manufacturer on a fieldbus network without loss of functionality or degree of integration.

Interoperability:

Interoperability is the capability for a device from one manufacturer to interact with that of another manufacturer on a fieldbus network without loss of functionality.

Link:

A Link is the logical medium by which H1 Fieldbus devices are interconnected. It is composed of one or more physical segments interconnected by bus Repeaters or Couplers. All of the devices on a link share a common schedule which is administered by that link's current LAS.

Link Active Scheduler (LAS):

A Link Active Scheduler (LAS) is a deterministic, centralized bus scheduler that maintains a list of transmission times for all data buffers in all devices that need to be cyclically transmitted. Only one Link Master (LM) device on an H1 fieldbus Link can be functioning as that link's LAS.

Link Master (LM):

A Link Master (LM) is any device containing Link Active Scheduler (LAS) functionality that can control communications on an H1 fieldbus Link. There must be at least one LM on an H1 Link; one of those LM devices will be elected to serve as LAS.

Link Objects:

A Link Object contains information to link Function Block (FB) Input/Output (I/O) parameters in the same device and between different devices. The Link Object links directly to a Virtual Communications Relationship (VCR).

Network Management (NM):

Network Management (NM) permits FOUNDATION Network Manager (NMgr) entities to conduct management operations over the network by using Network Management Agents (NMAs). Each Network Management Agent (NMA) is responsible for managing the communications within a device. The NMgr and NMA communicate through use of the Fieldbus Messaging Specification (FMS) and Virtual Communications Relationship (VCR).

Object Dictionary:

An Object Dictionary (OD) contains all Function Block (FB), Resource Block (RB) and Transducer Block (TB) parameters used in a device. Through these parameters, the blocks may be accessed over the fieldbus network.

Physical Layer:

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

Resource Block (RB):

A Resource Block (RB) describes characteristics of the fieldbus device such as the device name, manufacturer and serial number. There is only one Resource Block (RB) in a device.

Schedules:

Schedules define when Function Blocks (FBs) execute and when data and status is published on the bus.

Segment:

A Segment is a section of an H1 fieldbus that is terminated in its characteristic impedance. Segments can be linked by Repeaters to form a longer H1 fieldbus. Each Segment can include up to 32 H1 devices.

Splice:

A Splice is an H1 Spur measuring less than 1 m (3.28 ft.) in length.

Spur:

A Spur is an H1 branch line connecting to the Trunk that is a final circuit. A Spur can vary in length from 1 m (3.28 ft.) to 120 m (394 ft.).

Standard Function Block (FB):

Standard Function Blocks (FBs) are built into fieldbus devices as needed to achieve the desired control functionality. Automation functions provided by Standard FBs include Analog Input (AI), Analog Output (AO) and Proportional/Integral/Derivative (PID) control. The Fieldbus Foundation has released specifications for 21 types of Standard FBs. There can be many types of FBs in a device. The order and definition of Standard FB parameters are fixed and defined by the specifications.

System Management (SM):

System Management (SM) synchronizes execution of Function Blocks (FBs) and the communication of Function Block (FB) parameters on the fieldbus, and handles publication of the time of day to all devices, automatic assignment of device addresses, and searching for parameter names or "tags" on the fieldbus.

Terminator:

A Terminator is an impedance-matching module used at or near each end of a transmission line. Only two Terminators can be used on a single H1 segment.

Transducer Block (TB):

A Transducer Block (TB) decouples Function Blocks (FBs) from the local Input/Output (I/O) functions required to read sensors and command output hardware. Transducer Blocks (TBs) contain information such as calibration date and sensor type. There is usually one TB channel for each input or output of a Function Block (FB).

Transmitter:

A Transmitter is an active fieldbus device containing circuitry which applies a digital signal on the bus.

Trunk:

A Trunk is the main communication highway between devices on an H1 fieldbus network. The Trunk acts as a source of main supply to Spurs on the network.

User Application:

The User Application is based on "blocks," including Resource Blocks (RBs), Function Blocks (FBs) and Transducer Blocks (TBs), which represent different types of application functions.

User Layer:

The User Layer provides scheduling of Function Blocks (FBs), as well as Device Descriptions (DDs) which allow the host system to communicate with devices without the need for custom programming.

Virtual Communication Relationship (VCR):

Configured application layer channels that provide for the transfer of data between applications. FOUNDATION fieldbus decribes three types of VCRs: Publisher/Subscriber, Client/Server, and Source/Sink.

Virtual Field Device (VFD):

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

Profibus

PROFIBUS

is an open, digital communication system with a wide range of applications, particularly in the fields of factory and process automation. PROFIBUS is suitable for both fast, time-critical applications and complex communication tasks.

Profibus is a family of protocols originally designed by Siemens to provide communications from real world sensors and actuators to controllers. Profibus as a family of protocols was designed to provide a communications hierarchy for a PLC system, primarily in discrete manufacturing and building automation. Profibus has historically been used in the process industry for peripheral processes such as packaging lines, and for control of prime movers such as motor and pumps in a motor control center. Extensions to the Profibus architecture in recent years are intended to extend the market of Profibus to process automation

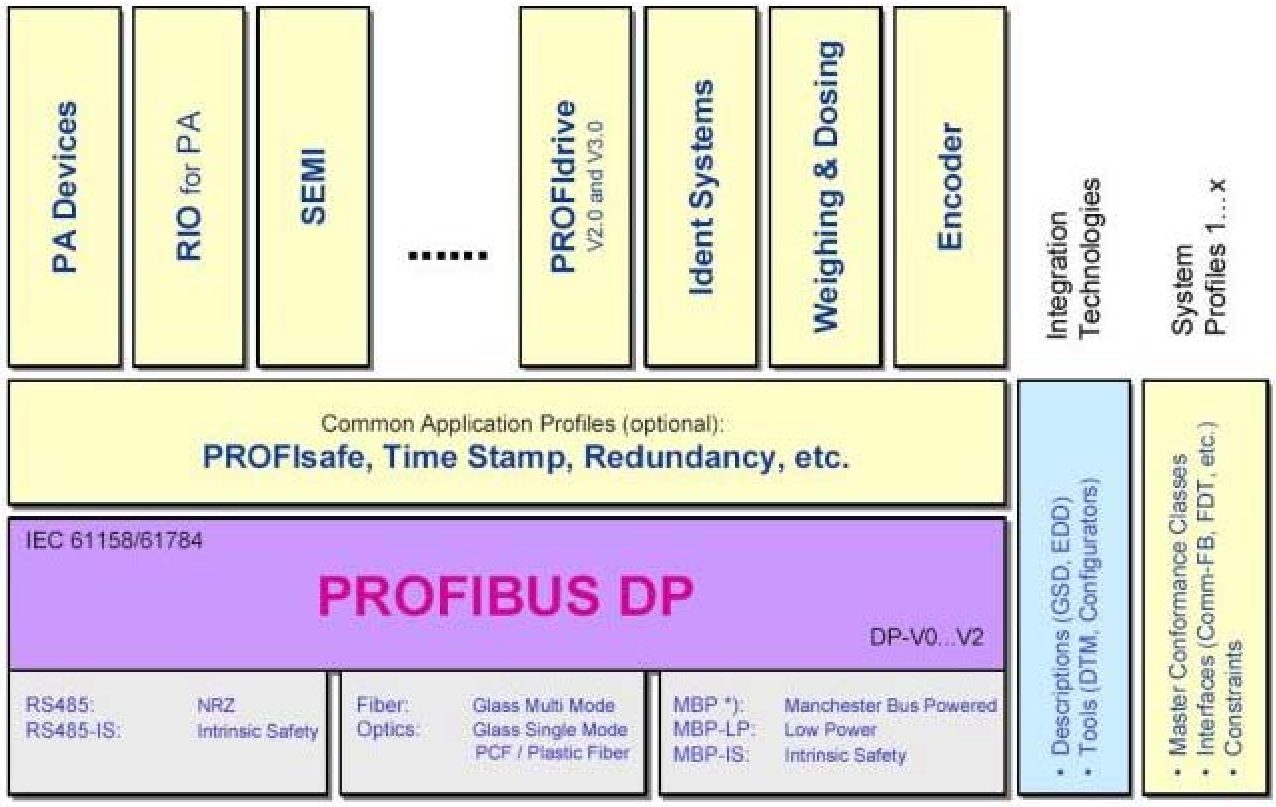


Figure: Technical system structure of PROFIBUS

To accomplish the wide variety of applications envisioned, Profibus is actually four separate protocols grouped under the common umbrella name of Profibus. The protocols are named Profibus FMS, Profibus DP, Profibus PA, and Profibus PAE. In addition, there are a number of totally proprietary protocols used by Siemens that the user must contend with when commissioning a system.

For more detail see the files at "Fieldbus Class Room" Profibus Overview 2.2MB

Modbus

MODBUS

Modbus is a communication protocol developed by Modicon (now Schneider Automation) and was initially for use with their own PLC Programmable Logic Controllers. Its originators maintain the protocol specification, independently of any professional body or association.

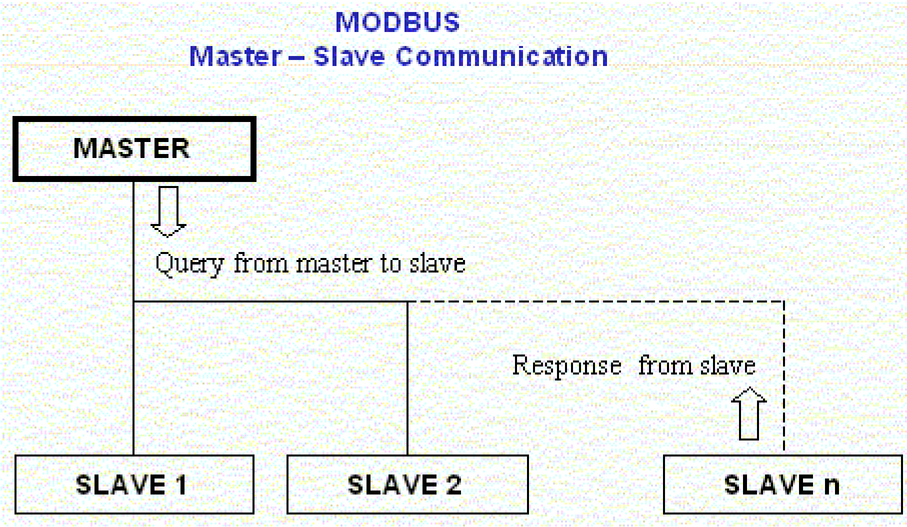
The protocol defines a message structure and format, and determines how a slave will recognize messages sent to it by the master. Standardization of these elements means that Modbus devices from different manufacturers can be interconnected, without the need for specialized software drivers.

Modbus Communication

Modbus controllers communicate using a master-slave technique, in which only one device (the master) can initiate a communication sequence.

The sequence begins with the master issuing a request or command on the bus (a 'query'), which is received by the slaves.

The slaves respond by taking appropriate action, supplying requested data to the master or informing the master that the required action could not be carried out. The master can address individual slaves or can transmit a message to be received by all slaves through a broadcast message. The response confirms that the message was received, understood and acted upon, or it informs the master that the action required could not be carried out.



If the query requests data from the slave, this will be returned as part of the response. Messages broadcasted to all slaves do not require responses.

Modbus slaves will only transmit on the network when required to do so by the master. Slaves never transmit unsolicited messages.

If the slave cannot carry out the requested action, then it will respond with an error message. This error message, known as an exception response, indicates to the master:

- the address of the responding slave
- the action it was requested to carry out
- an indication of why the action could not be completed

If the slave identifies an error during receipt of the message, the message will be ignored. This ensures that a slave does not take actions that was intended for another slave, and does not carry out actions other than those it is commanded to. Should, for some reason, the message be ignored, the master will know that it's query has not been received correctly, as it has not received a response, and will resend it.

Modbus does not specify how numerical data shall be encoded within a message. This is decided by the equipment manufacturer and a wide range of options are available.

Modbus ports frequently employ RS232-C compatible serial interfaces, although RS422/RS485 interfaces are also used. The type of interface used defines the connector pin-outs, the cabling and the signal levels; these are not defined in Modbus. Transmission rates and parity checking are not defined either and will depend on the serial interface used and the options made available by the manufacturer of each individual Modbus device.

Modbus supports up to 247 slaves from addresses 1 to 247 (JBUS 1 to 255), address 0 is reserved for broadcast messages. In practice, the number of slaves that can be used is determined by the physical communication link that is chosen. For example RS485 is limited to a total of 31 slaves.

The query-response cycle forms the basis of all communication on a Modbus network. In all situations it is the master that initiates the query and the slave that responds.

The query is mode up of four parts: 1. the device address; 2. the function code; 3. eight bit data bytes; 4. and an error check.

A slave will normally be required to provide a response (when a query has been addressed to that slave specifically, and not broadcast to all slaves), which will have the same overall structure format as was used for query.

Transmission Mode

There are two modes available for transmitting serial data over a Modbus network RTU and ASCII. The two transmission modes differ in a number of ways: the way that the bit contents of the message are defined, the way that information is packed into the message fields, the way it will be decoded and the speed of operation at a given baud rate. They cannot be used together and the mode used must be adopted by all the Modbus devices throughout the network.

The Remote Terminal Unit RTU mode is faster and more robust than ASCII and it is for these reasons that it is widely used in Modbus interfaces.

For more details see the files at "Fieldbus Class Room" Modbus Overview 249kB

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DeviceNet

DEVICENET

is a low-cost communications link to connect industrial devices (such as limit switches, photoelectric sensors, valve manifolds, motor starters, process sensors, bar code readers, variable frequency drives, panel displays and operator interfaces) to a network *and eliminate expensive hardwiring.*

The direct connectivity provides improved communication between devices as well as important device-level diagnostics not easily accessible or available through hardwired I/O interfaces. DeviceNet is a simple, networking solution that reduces the cost and time to wire and install industrial automation devices, while providing interchangeability of "like" components from multiple vendors.

The DeviceNet communication link is based on a broadcast-oriented, communications protocol - the Controller Area Network (CAN). The CAN protocol was originally developed by BOSCH for the European automotive market for replacing expensive, wire harnesses with low-cost network cable on automobiles.

As a result, the CAN protocol has fast response and high reliability for applications as demanding as control of anti-lock brakes and airbags. Chips are available in a variety of packages with high temperature ratings and high noise immunity, attributes well suited for the industrial automation market as well.

But it is consumer and commercial demand for CAN that is the key driver in lowering the price and increasing the performance of CAN chips. In 1994, four suppliers of CAN chips (Intel, Motorola, Philips, Siemens) shipped 4+ million CAN chips. Over 10 million chips are expected to ship in 1996. Whereas other industrial automation networks use custom chips with annual demand varying from 20,000-200,000 per year, DeviceNet products use the same CAN chips as are used in automotive and other consumer/commercial applications. The chips for DeviceNet products are typically 5-10 times less than chips for other networks.

AS-i Bus Interface

ASi Bus Interface

is a low-cost electromechanical connection system designed to operate over a two-wire cable carrying data and power over a distance of up to 100m. Longer distances can be accommodated if repeaters are used. It is especially suitable for lower levels of plant automation where simple - often binary - field devices such as switches need to interoperate in a stand-alone local area automation network controlled by PLC or PC. AS-Interface is a digital replacement for traditional cable architectures.

It is most often used for proximity sensors, limit switches, valves and indicators in applications like packaging machines and material handling systems. ASI Bus Interface is designed for small systems employing discrete I/O. It allows for up to 31 slaves, which can provide for up to four inputs and four outputs each for a total of 248 I/O.

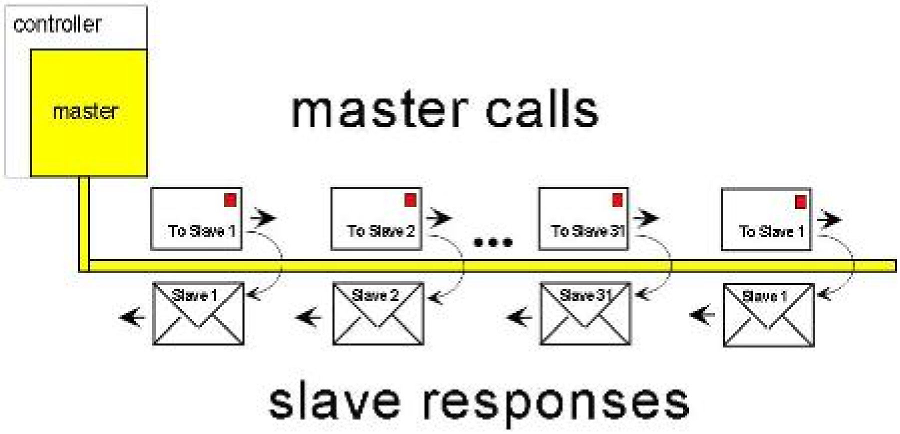


Figure: AS-Interface Principle

ASi Bus Interface

Actuator Sensor Interface. Used to network sensors and actuators. ASi is a two wire interface; Power and Data. Based around ProfiSafe [developed from Profibus DP].ASI bus was developed by Siemens Automation. This is a Unshielded 2-wire [Yellow cable], Unterminated, Ungrounded Sensor Bus. The Topology may be either Bus, Ring, Tree, or Star at up to 100 meters. Power is provided by a 24V floating DC supply, which can supply at least 8 A over the network. The AS-Interface is an open standard based on IEC 62026-2 and EN 50295. The AS Interface may also be termed the 'AS-Interface', 'ASI Bus', or 'ASi-Bus'.

For more details see the files at "Fieldbus Class Room ASI Bus Interface Overview 163kB

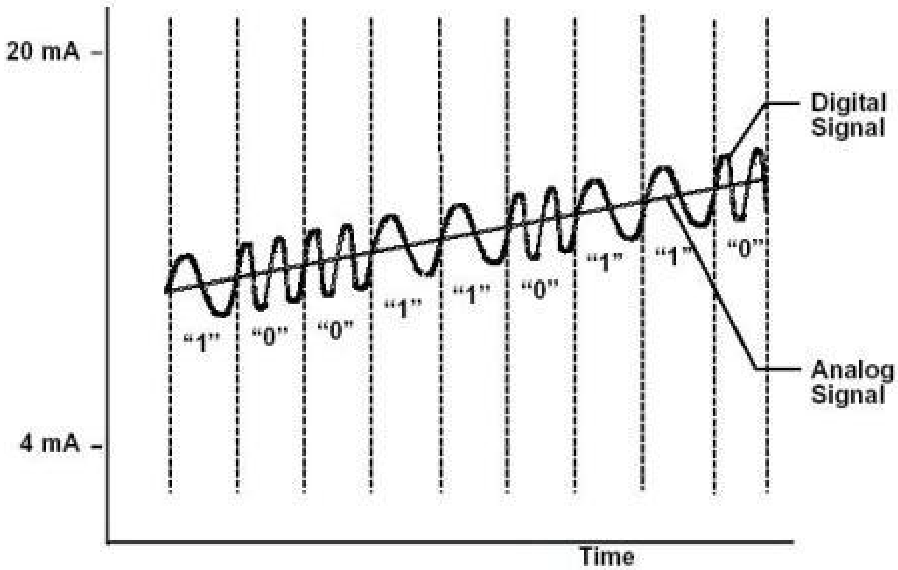
HART Protocol

HART

is a *master-slave communication protocol*, which means that during normal operation, each *slave* (field device) communication is initiated by a *master* communication device. Two masters can connect to each HART loop. The primary master is generally a distributed control system DCS, programmable logic controller PLC, or a personal computer PC. The secondary master can be a handheld terminal or another PC. Slave devices include transmitters, actuators, and controllers that respond to commands from the primary or secondary master.

Frequency Shift Keying

The HART communication protocol is based on the Bell 202 telephone Communication standard and operates using the *frequency shift keying* (FSK) principle. The digital signal is made up of two frequencies-1,200 Hz and 2,200 Hz representing bits 1 and 0, respectively. Sine waves of these two frequencies are superimposed on the direct current (dc) analog signal cables to provide simultaneous analog and digital communications. Because the average value of the FSK signal is always zero, the 4-20 mA analog signal is not affected. The digital communication signal has a response time of approximately 2-3 data updates per second without interrupting the analog signal. A minimum loop impedance of 230 W is required for communication.



BURST MODE

Some HART devices support the optional *burst communication mode*. Burst mode enables faster communication (3-4 data updates per second). In burst mode, the master instructs the slave device to continuously broadcast a standard HART reply message (e.g., the value of the process variable). The master receives the message at the higher rate until it instructs the slave to stop bursting.

For more details see the files at "Fieldbus Class Room" **HART Protocol Overview 1.3MB**

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375 HART Communicator

The 275 HART Communicator has been replaced by the 375 Field Communicator. Emerson is committet to open technologies by supporting enhanced EDDL in the 375 Field Communicator. By embracing the enhanced EDDL functions in updated versions of AMS Device Manager and the 375 Field Communicator, Emerson enables users to further leverage the intelligence available in field devic