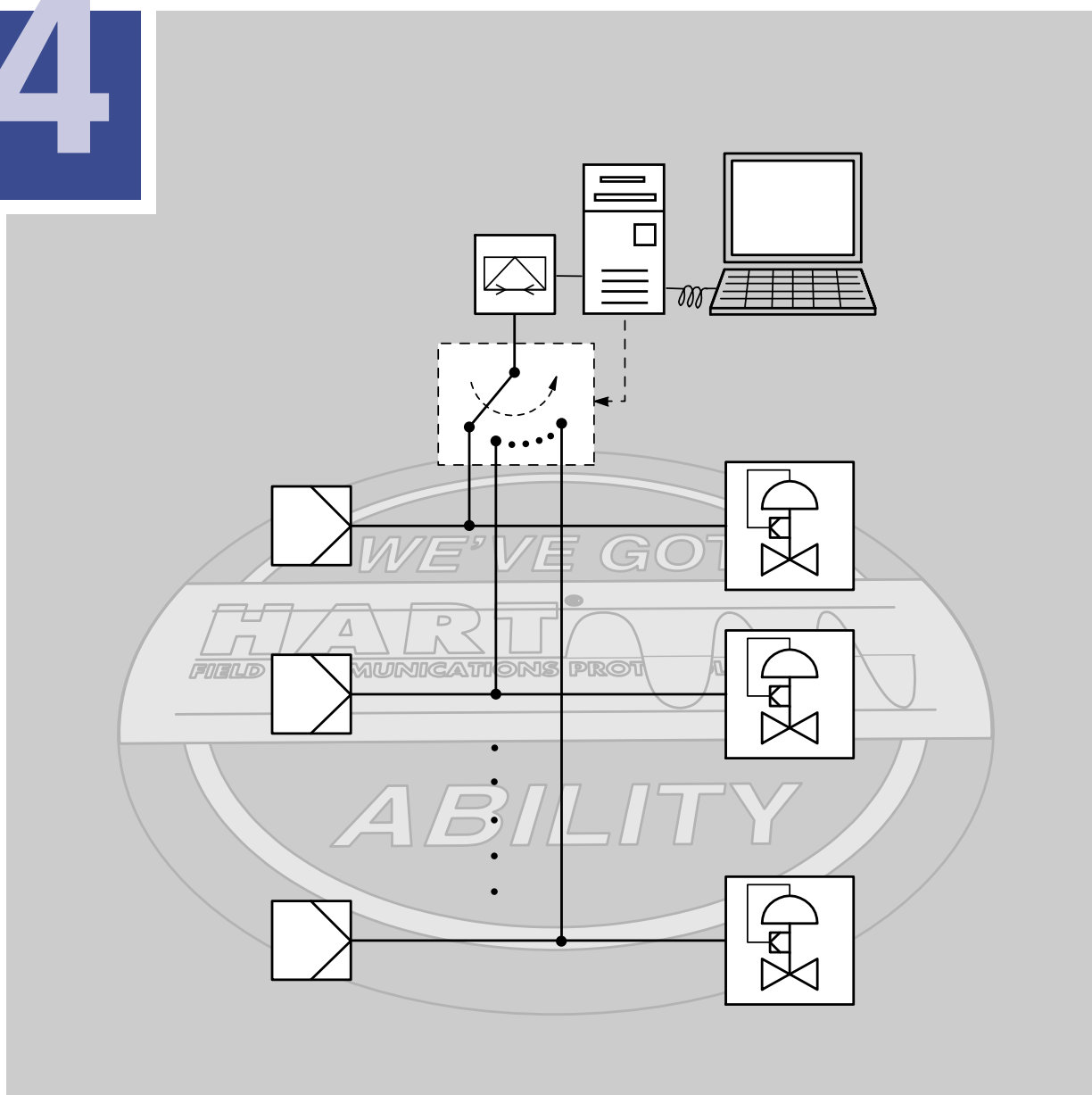


HART Communications

4

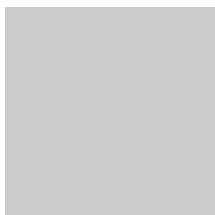
Part 4 Communications





Technical Information

- Part 1: Fundamentals
- Part 2: Self-operated Regulators
- Part 3: Control Valves
- Part 4: Communication
- Part 5: Building Automation
- Part 6: Process Automation



Should you have any further questions or suggestions, please do not hesitate to contact us:

SAMSON AG
V74 / Schulung
Weismüllerstraße 3
D-60314 Frankfurt

Phone (+49 69) 4 00 94 67
Telefax (+49 69) 4 00 97 16
E-Mail: schulung@samson.de
Internet: <http://www.samson.de>

HART Communications

Introduction	5
HCF user organization	6
Connecting HART devices	7
Number of participants and addressing	8
▶ Point-to-point connection	8
▶ Multiplexer	8
▶ Multidrop mode	9
▶ Bus for split-range operation	10
▶ FSK bus	11
▶ Higher-level communication systems	12
Two-wire technique and load impedance	13
Application in hazardous areas	14
Field device interface	14
HART communication layers	16
Physical layer	16
▶ Coding	16
▶ Wiring	18
▶ Plug connectors	18
▶ HART-compatible features	19
Services of layer 2	21
▶ Access control	21
▶ Communication services	21

▶ Telegram structure	22
▶ Noise immunity	24
▶ Transmission time and user data rate	25
Application layer: HART commands	26
DDL device description	29
Requirements to be met by the configuration devices	32
Example: IBIS	33
HART handheld master device	33
Appendix A1: Troubleshooting	35
Appendix A2: Additional literature	36

CONTENTS

Introduction

Field networks are not the only solution when plant operators want to use the advantages of smart field devices. The HART protocol provides many possibilities even for installations that are equipped with the conventional 4 to 20 mA technique.

HART devices communicate their data over the transmission lines of the 4 to 20 mA system. This enables the field devices to be parameterized and started up in a flexible manner or to read measured and stored data (records). All these tasks require field devices based on microprocessor technology. These devices are frequently called smart devices.

Introduced in 1989, this protocol has proven successful in many industrial applications and enables bidirectional communication even in hazardous environments. HART allows the use of up to two masters: the engineering console in the control room and a second device for operation on site, e.g. a PC laptop or a handheld terminal.

The most important performance features of the HART protocol include:

- ▶ proven in practice, simple design, easy to maintain and operate
- ▶ compatible with conventional analog instrumentation
- ▶ simultaneous analog and digital communication
- ▶ option of point-to-point or multidrop operation
- ▶ flexible data access via up to two master devices
- ▶ supports multivariable field devices
- ▶ sufficient response time of approx. 500 ms
- ▶ open de-facto standard freely available to any manufacturer or user

**HART protocol utilizes
4 to 20 mA lines**

**proven successful for
smart devices**

**typical
performance features**

HCF user organization

**support for
implementation and
operation**

The HART protocol is an open communication protocol which interfaces the master device with the field device and can be implemented by any manufacturer and freely employed by the user. The required technical support is provided by the HART Communication Foundation (HCF). This manufacturer-independent, not-for-profit organization encourages widespread use of the HART technology. HCF assumes the responsibility of coordinating and supporting the open protocol standard and manages within this framework the device descriptions of all registered devices (see also page 29).



Fig. 1: HART and HCF logo

Connecting HART devices

Devices which support the HART protocol are grouped into master (host) and slave (field) devices. Master devices include handheld terminals as well as PC-based work places, e.g. in the control room. HART slave devices, on the other hand, include sensors, transmitters and various actuators. The variety ranges from two-wire and four-wire devices to intrinsically safe versions for use in hazardous environments.

host and field devices

The HART data is superimposed on the 4 to 20 mA signal via a FSK modem. This enables the devices to communicate digitally using the HART protocol, while analog signal transmission takes place at the same time (see 'Coding' on page 16ff and Lit./2/).

communication over analog signal line

Field devices and compact handheld terminals have an integrated FSK modem, whereas PC stations have a serial interface to connect the modem externally. Fig. 2 shows a typical connection scheme of a HART host device and a HART field device. HART communication is often used for such simple point-to-point connections. Nevertheless, many more connection variants are possible.

FSK modem: link to analog signal

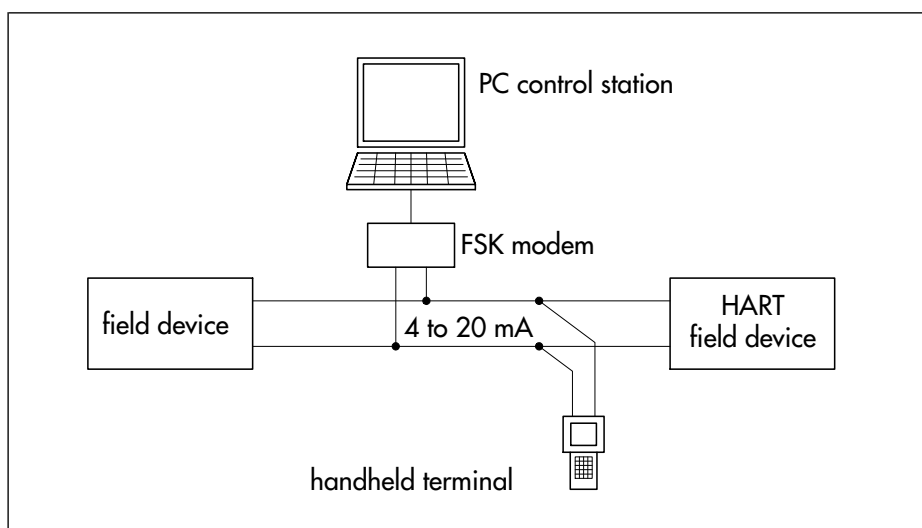


Fig. 2: Connection of HART master devices

HART networks

In extended systems, the number of accessible devices can be increased by using a multiplexer. In addition to that, HART enables the networking of devices to suit special applications. Network variants include multidrop, FSK bus and networks for split-range operation.

Number of participants and addressing

- Point-to-point connection

point-to-point communication

The HART communication shown in Fig. 2 is referred to as point-to-point connection, i.e. the HART master device is connected to exactly one HART field device. This connection variant requires that the device address of the field device be always set to zero since the operating program uses this address to establish communication.

device address zero

- Multiplexer

Fig. 3 shows the use of a multiplexer system, which enables a large number of HART devices to be connected in a network. The user selects a particular

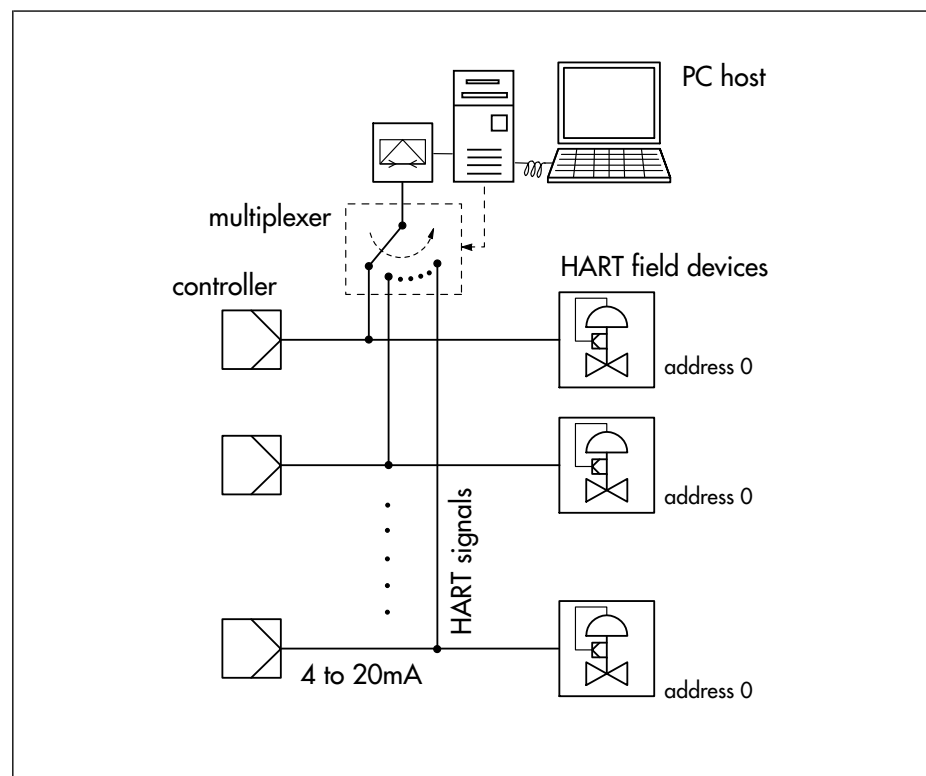


Fig. 3: HART communication via multiplexer

current loop for communication via the operating program. As long as the communication takes place, the multiplexer connects the current loop to the host. Due to the cascaded multiplexer structure, the host can communicate with many (> 1000) devices, all with the address zero.

**multiplexer selects
current loops at shifted
time intervals**

- Multidrop mode

The HART protocol was originally designed for transmitters. The multidrop mode was also developed for them. In multidrop operation, the devices exchange their data and measured values only via the HART protocol. The analog current signal serves just to energize the two-wire devices, providing a direct current of 4 mA.

**multidrop mode
for transmitters**

In multidrop mode, up to 15 field devices are connected in parallel to a single wire pair (Fig. 4). The host distinguishes the field devices by their preset addresses which range from 1 to 15.

**address range:
1 to 15**

Control valves cannot be used in conjunction with multidrop mode. As demonstrated by the calculations on page 25, the digital HART communication is too slow to preselect set points. The control signals for valves are therefore always transmitted as 4 to 20 mA standardized current signals.

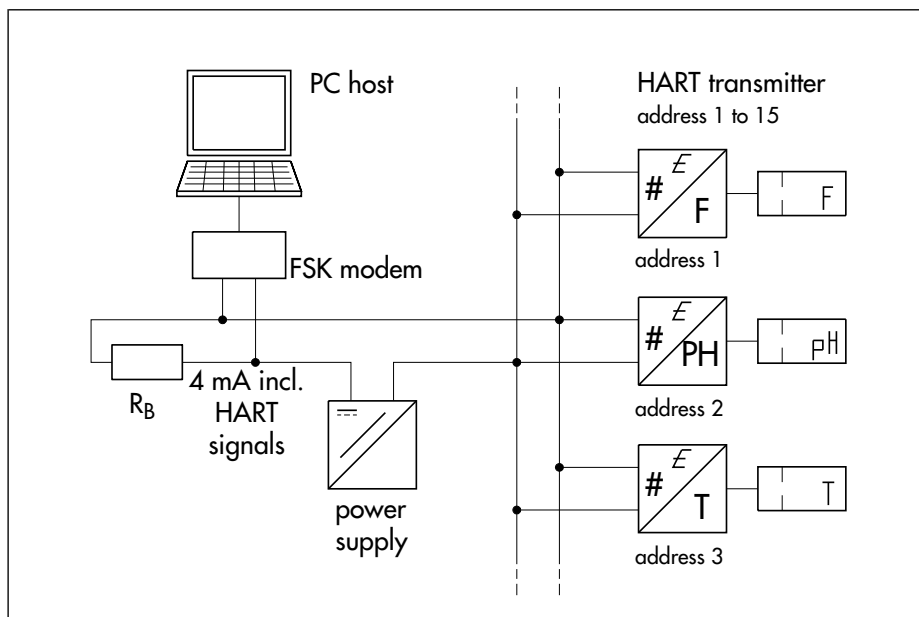


Fig. 4: Multidrop mode with HART transmitters

- Bus for split-range operation

splitting the set point range

There are special applications which require that several – usually two – actuators receive the same control signal. A typical example is the split-range operation of control valves. One valve operates in the nominal current range from 4 to 12 mA, while the other one uses the range from 12 to 20 mA.

In split-range operation, the control valves are connected in series in the current loop. When both valves have a HART interface, the HART host device must be able to distinguish with which valve it must communicate. To achieve this, the HART protocol revision 6 (anticipated for autumn 1999) and later will be extended by one more network variant.

HART address 1 to 15

analog reference variable

As is the case for multidrop mode, each device is assigned an address from 1 to 15. The analog 4 to 20 mA signal preserves its device-specific function, which is, for control valves, the selection of the required travel. To be able to use HART communications also for such applications as the split-range operation, the HART positioner from SAMSON always takes the analog current signal as a reference variable, independent of the device address (Fig. 5).

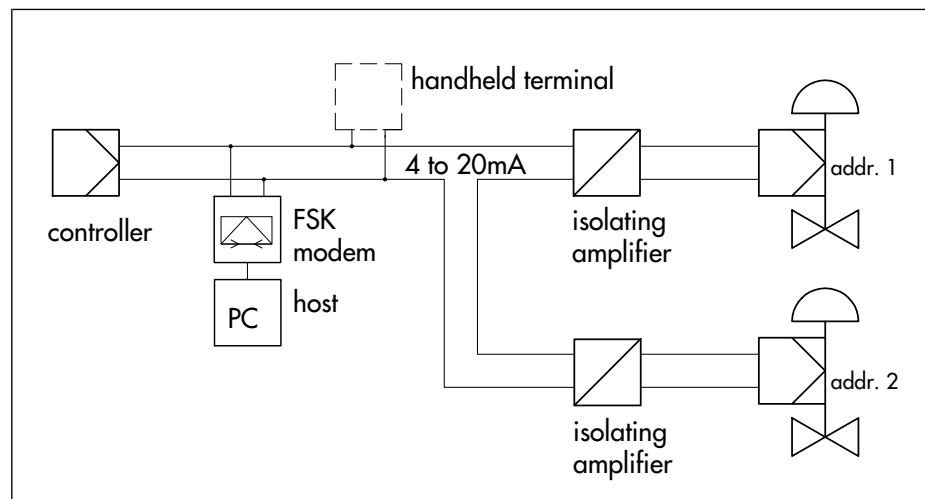


Fig. 5: Split-range operation with two HART positioners

- FSK bus

The HART protocol can be extended by company-specific functions. Hartmann & Braun, for example, developed the FSK bus. Similar to a device bus, it can connect approximately 100 HART devices and address them. This requires special assembly-type isolating amplifiers (e.g. TET 128). The only reason for the limited number of participants is that each additional participant increases the signal noise. The signal quality is therefore no longer sufficient to properly evaluate the telegram.

FSK bus for networked communication

... up to 100 devices

The HART devices are connected to their analog current signal and the common FSK bus line via the isolating amplifier (Fig. 6). From the FSK bus' viewpoint, the isolating amplifiers act as impedance converters. This enables also devices with high load to be integrated in the communication network.

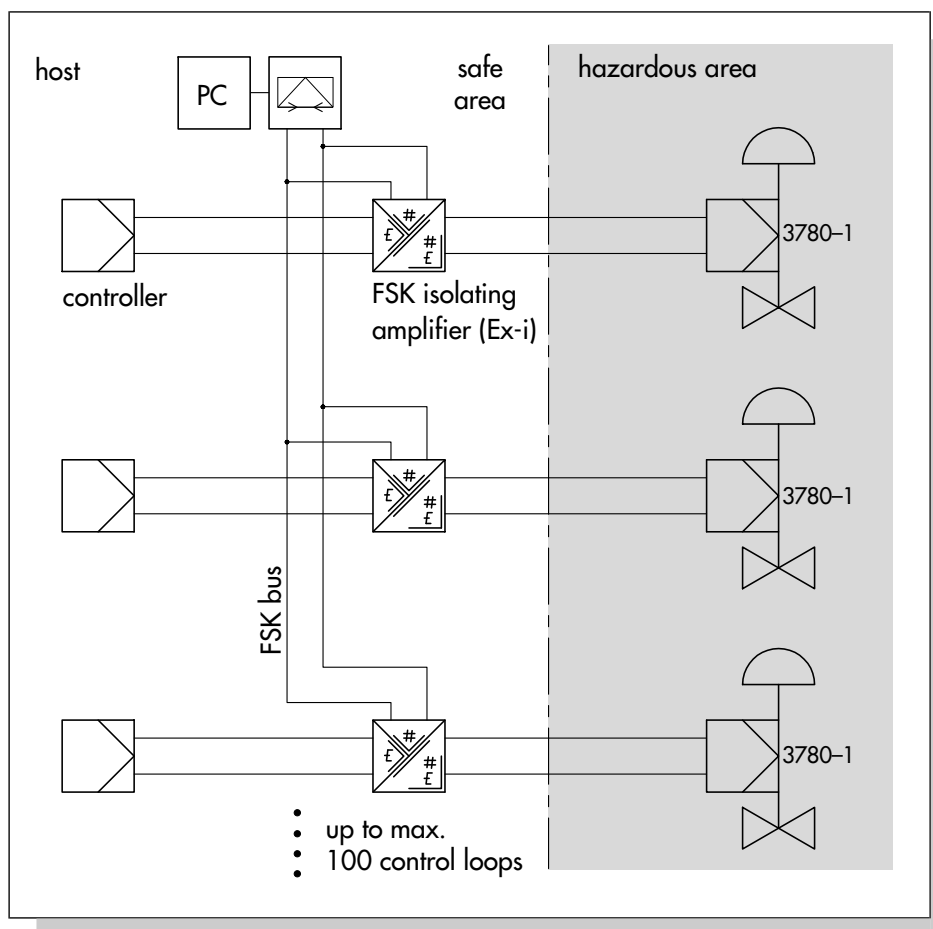


Fig. 6: Components and connection of the FSK bus

address format for many participants To address the devices, a special, long form of addressing is used (see also Fig. 15, page 23). During the configuration phase, the bus address and the tag number of each device are set via the point-to-point line. During operation, the devices operate with the long addresses. When using the HART command 11, the host can also address the device via its tag. In this way, the system configuration can be read and checked during the start-up phase.

- Higher-level communication systems

gateways to couple networks To be able to connect a HART communication system with other communication systems, gateways are used. They convert the respective protocols of the networks to be coupled.

HART protocol $\Leftrightarrow$ Fieldbus protocol

In most cases, when complex communication tasks must be solved, fieldbus systems would be the preferred choice anyway.

HART signals via phone lines Even without complex protocol conversions, HART enables communication over long distances. HART signals can be transmitted over telephone lines using HART/CCITT converters. Field devices directly connected to dedicated lines owned by the company can thus communicate with the centralized host located many miles away.

Two-wire technique and load impedance

HART signals are imposed on the conventional analog current signal. Whether the devices are designed in four-wire technique including an additional power supply or in two-wire technique, HART communication can be used for both cases. However, it is important to note that the maximum permissible load of a HART device is fixed.

The load of a HART device is limited by the HART specification (see page 17: max. 1100 ohms for the entire load in the circuit). Another limitation is caused – especially in older installations – by the process controller. The output of the process controller must be able to provide the power for the connected two-wire device.

The higher the power consumption of a two-wire device, the higher its load. The additional functions of a HART-communicating device increase its power consumption – and hence the load – compared to non-HART devices.

When retrofitting HART devices into an already existing installation, the process controller must be checked for its ability to provide the power required by the HART device. The process controller must be able to provide at

HART for two-wire and four-wire devices

Observe the load!

power output of controller is limited

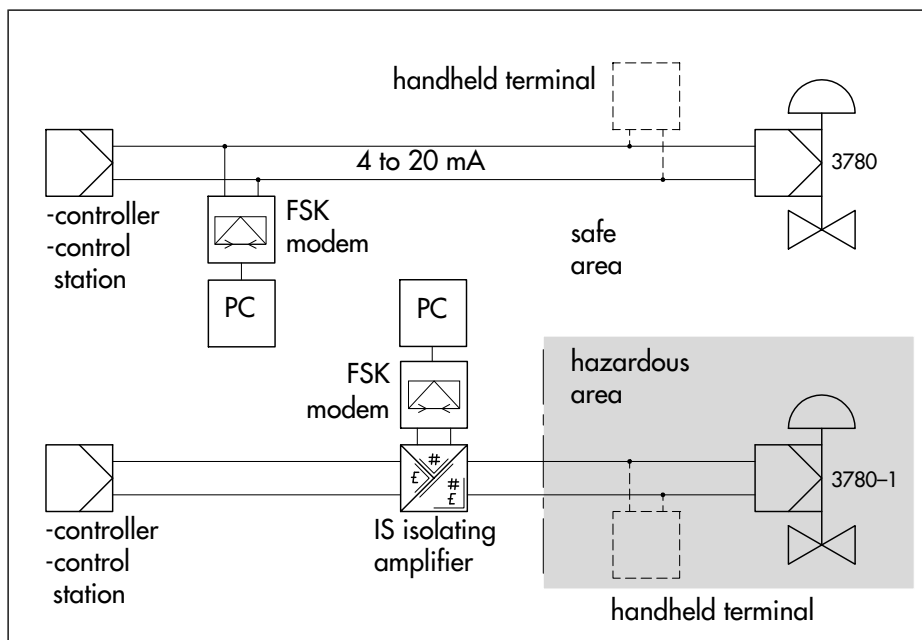


Fig. 7: Point-to-point connection: with or without IS isolating amplifier

least the load impedance of the HART device at 20 mA. The required load impedance U_B and the consumed power P_W are calculated as follows:

load impedance and
power consumption

$$U_B = 20 \text{ mA} \cdot \text{load}$$

$$P_W = U_B \cdot I = I^2 \cdot \text{load}$$

NOTE: The value of the device load is always defined for a current of 20 mA. If the process controller cannot provide the load – including the cable resistances, etc. –, a HART-compatible IS (Intrinsic Safety) isolating amplifier can be installed.

Application in hazardous areas

intrinsically safe
communication in
hazardous areas

The technical details defined in the HART specification enable HART devices with the operating mode Intrinsic Safety (Ex-i) to be used – if they are approved – also in hazardous areas.

HART-compatible
IS isolating amplifier

Upon installation in the hazardous area, make sure that the IS isolating amplifier, which acts as an amplifier and as an IS barrier, is HART compatible (for more details, see page 19).

Field device interface

integrated FSK modem

HART-communicating field devices require an appropriate communication interface. As already mentioned, field devices have an integrated FSK modem. Fig. 8 shows the components of the SAMSON Type 3780 HART Positioner in a block diagram. For signal evaluation, the following components are important:

separate processors for
application and
communication

- ▶ The analog current signal (8) is transmitted via an A/D converter to the microprocessor (2) which is responsible for the application, e.g. for position control.
- ▶ The FSK modem feeds the received HART signals (8) to the microprocessor (5) which computes the communication data.
- ▶ The FSK modem superimposes the HART signals to be sent on the analog current signal of the 4 to 20 mA line.

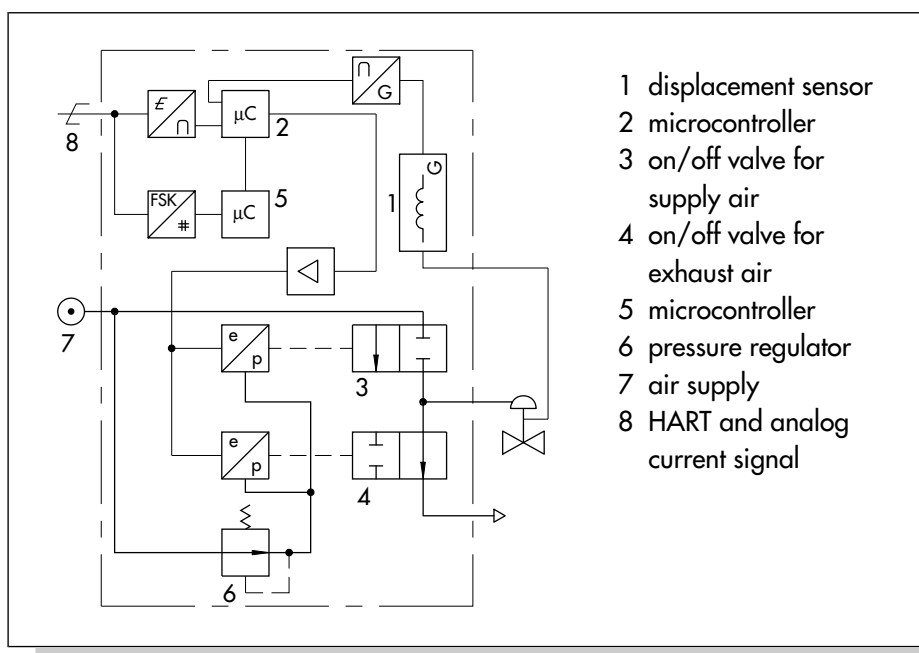


Fig. 8: HART interface of SAMSON positioner

- Both processors, one for communication (5) and the other for application (2), exchange the received data and the data to be sent.

The other function blocks show the components (3, 4, 6 and 7) which measure the position of the valve (1) and adjust the pneumatic pressure in the actuator as requested by the controller.

on/off valves adjust the actuator pressure

HART communication layers

OSI layers	HART layers
application	HART commands
presentation	
session	
transport	
network	
data link	HART protocol rules
physical layer	Bell 202

Fig. 9: HART protocol implementing the OSI model

**HART protocol
implements the OSI-
layers 1, 2 and 7**

The HART protocol utilizes the OSI reference model. As is the case for most of the communication systems on the field level, the HART protocol implements only the layers 1, 2 and 7 of the OSI model. The layers 3 to 6 remain empty since their services are either not required or provided by the application layer 7 (see Fig. 9).

Physical layer

- Coding

Data transmission between the masters and the field devices is physically realized by superimposing an encoded digital signal on the 4 to 20 mA current loop. Since the coding has no mean values, an analog signal transmission taking place at the same time is not affected. This enables the HART protocol to include the existing simplex channel transmitting the current signal (analog control device → field device) and an additional half-duplex channel for communication in both directions.

**HART protocol uses
the existing field wiring**

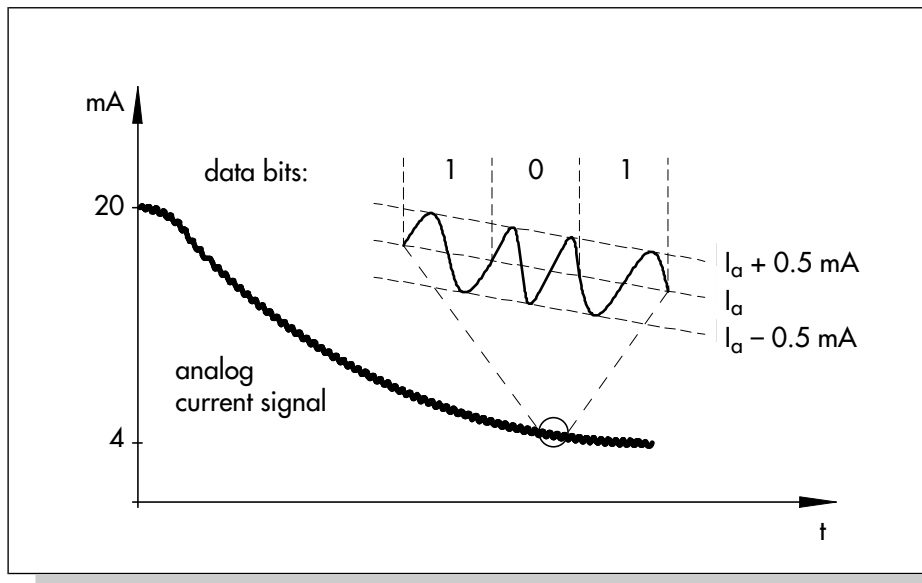


Fig. 10: Hart signal superimposed on the analog current signal

The bit transmission layer defines an asynchronous half-duplex interface which operates on the analog current signal line. To encode the bits, the FSK method (Frequency Shift Keying) based on the Bell 202 communication standard is used. The two digital values '0' and '1' are assigned to the following frequencies (see Fig. 10):

logical '0': 2200Hz

logical '1': 1200Hz

**frequency-modulated
HART signals**

Each individual byte of the layer-2 telegram is transmitted as eleven-bit UART character at a data rate of 1200 bits/s.

data rate: 1200 bit/s

The HART specification defines that master devices send voltage signals, while the field devices (slaves) convey their messages using load-independent currents. The current signals are converted to voltage signals at the internal resistance of the receiver (at its load).

To ensure a reliable signal reception, the HART protocol specifies the total load of the current loop – including the cable resistance – to be between minimum 230 ohms and maximum 1100 ohms. Usually, the upper limit is not defined by this specification, but results from the limited power output of the power supply unit (see also page 13f).

**load ensures
reception level**

The HART masters are simply connected in parallel to the field devices (e.g. Fig. 7), so the devices can be connected and disconnected during operation because the current loop need not be interrupted.

- Wiring

**quality of
transmission lines**

HART wiring in the field usually consists of twisted pair cables. If very thin and/or long cables are used, the cable resistance increases and, hence, the total load. As a result, the signal attenuation and distortion increases while the critical frequency of the transmission network decreases.

NOTE: For trouble-free transmission, the cables must have a sufficient cross section and an appropriate length.

**demands on
transmission lines**

If interference signals are a problem, long lines must be shielded. The signal loop and the cable shield should be grounded at one common point only.

According to the specification, the following configurations work reliably:

- ▶ For short distances, simple unshielded 0.2 mm² two-wire lines are sufficient.
- ▶ For distances of up to 1,500 m, individually twisted 0.2 mm² wire pairs with a common shield over the cable should be used.
- ▶ For distances of up to 3,000 m, individually twisted 0.5 mm² two-wire lines shielded in pairs are required.

Most of the wiring in the field meets these requirements and can therefore be used for digital communication.

- Plug connectors

An essential benefit is that HART integrates the existing wires. So the HART specification does not prescribe the use of a specific type of plug connector. Since the polarity has no influence on the frequency evaluation, HART signals are usually connected via simple clamp terminals.

- HART-compatible features

HART communication between two or more devices can function properly only when all communication participants are able to interpret the HART sinewave signals correctly. To ensure this, not only the transmission lines must fulfill certain requirements (see above), also the devices in the current loop which are not part of the HART communication can impede or even prevent the transmission of the data.

check all devices

The reason is that the inputs and outputs of these devices are specified only for the 4 to 20 mA technology. Since the input and output resistances change with the signal frequency, such devices are likely to short-circuit the higher-frequency HART signals (1200 to 2200 Hz).

FSK frequencies must not be suppressed

NOTE: Inputs and outputs with an internal resistance that falls below the FSK frequency range short-circuit the HART signals!

To prevent this, the internal resistance must be increased using an additional circuit. The RC low pass (250 Ω , 1 μ F) illustrated in Fig. 11 performs this function.

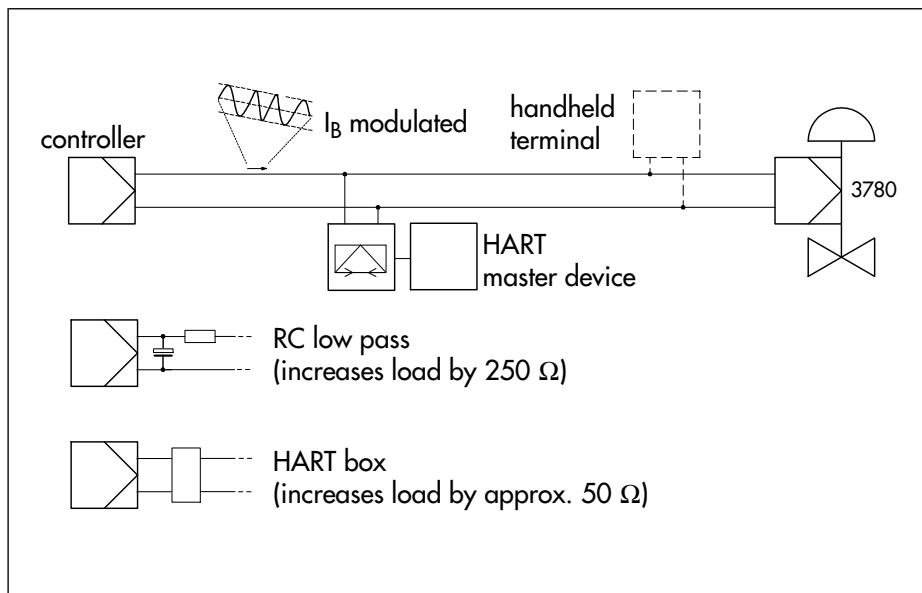


Fig. 11: Controller output must not short-circuit the HART signals

However, a disadvantage is that the serial resistance must additionally be powered by the controller.

additional circuits
increase load

Load to be powered by the controller:

RC low pass: $250\ \Omega + \text{line resistance} + \text{load of field device}$

HART box: $50\ \Omega + \text{line resistance} + \text{load of field device}$

When using the specially designed HART box, the additional load can be reduced by one fifth to $50\ \Omega$. If this value is still too high, either a signal amplifier or a controller with higher power output must be installed.

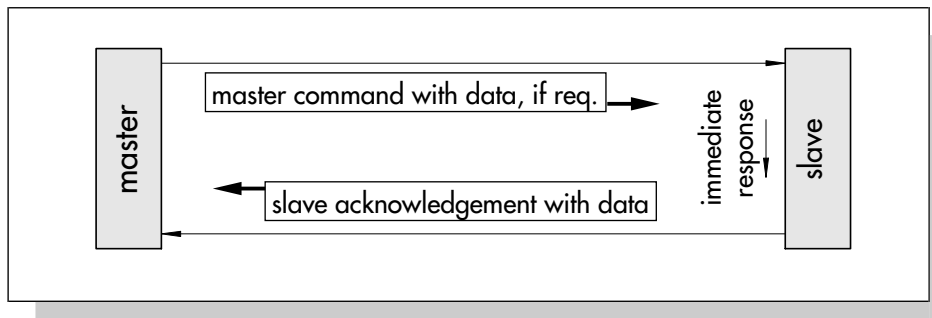


Fig. 12: HART transaction: data exchange between master and slave

Services of layer 2

- Access control

The HART protocol operates according to the master-slave method. Any communication activity is initiated by the master, which is either a control station or an operating device. HART accepts two masters, the primary master – usually the control system – and the secondary master – a PC laptop or handheld terminal used in the field.

**master controls
slave device**

HART field devices – the slaves – never send without being requested to do so. They respond only when they have received a command message from the master (Fig. 12). Once a transaction, i.e. a data exchange between the control station and the field device, is complete, the master will pause for a fixed time period before sending another command, allowing the other master to break in. The two masters observe a fixed time frame when taking turns communicating with the slave devices.

**time-controlled access
authorization**

- Communication services

The HART protocol provides standard and broadcast commands:

HART communication modes	
standard command:	master/slave data exchange
broadcast command:	HART command received by all devices

Fig. 13: HART communication modes

broadcast message

The simplest form of a transaction is a master telegram which is directly followed by a response or acknowledgement telegram from the slave (Fig. 12). This communication mode is used for the normal data exchange. When connection is established, the HART command 11 can be used to send a broadcast message to all devices to check the system configuration.

burst mode for fast transmission of measured values

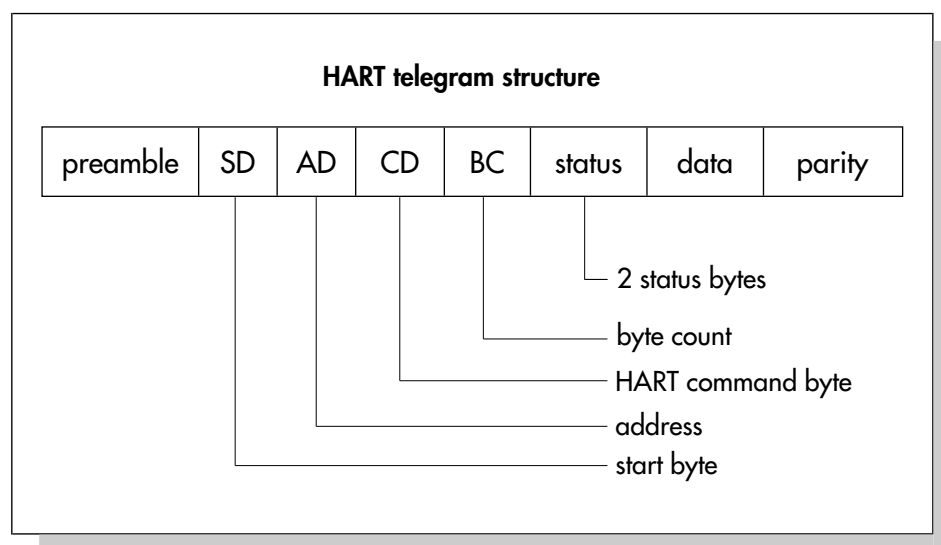
Some HART devices support the optional burst communication mode. A single field device cyclically sends message telegrams with short 75-ms breaks, which can alternately be read by the primary as well as the secondary master. While usually only two transactions per second are possible, the field device can send up to four telegrams using this method.

- Telegram structure

The structure of a HART telegram is shown in Fig. 14. Each individual byte is sent as 11-bit UART character equipped with a start, a parity and a stop bit.

two address formats possible

In the revision 5 and later, the HART protocol provides two telegram formats which use different forms of addressing. In addition to the short frame slave address format containing four bits, a long frame address format has been introduced as an alternative. This allows more participants to be integrated, while achieving more safety in case of incorrect addressing during transmission failures.



The elements of the HART telegram perform the following tasks:

- ▶ The preamble consisting of three or more hexadecimal FF characters synchronizes the signals of the participants.
- ▶ The start byte indicates which participant is sending (master, slave, slave in burst mode) and whether the short frame or the long frame format is used.
- ▶ The address field of the short frame format contains one byte (Fig. 15) with one bit serving to distinguish the two masters and one bit to indicate burst-mode telegrams. For the addressing of the field devices, 4 bits are used (addresses 0 to 15).
- ▶ The address field of the long frame format contains five bytes, hence, the field device is identified using 38 bits.
- ▶ The command byte encodes the master commands of the three categories, Universal, Common-practice and Device-specific commands. The significance of these commands depends on the definitions in the application layer 7.
- ▶ The byte count character indicates the message length, which is necessary since the number of data bytes per telegram can vary from 0 to 25. This is the only way to enable the recipient to clearly identify the telegram and the checksum. The number of bytes depends on the sum of the status and the data bytes.
- ▶ The two status bytes are included only in reply messages from slaves and contain bit-coded information. They indicate whether the received mes-

**elements of the
HART telegram**

**HART commands
control all actions**

**variable amount of
data bytes**

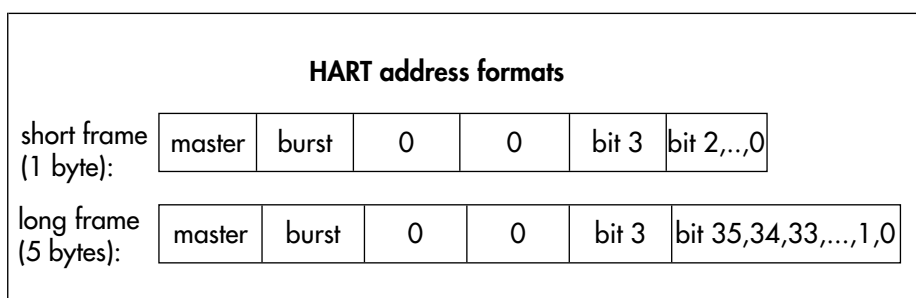


Fig. 15: Short frame and long frame HART address formats

sage was correct and the operational state of the field device. When the field device operates properly, both status bytes are set to logical zero.

- ▶ The data can be transmitted as unsigned integers, floating-point numbers or ASCII-coded character strings. The data format to be used is determined by the command byte, however, not all commands or responses contain data.

HD equals four

- ▶ The checksum byte contains the longitudinal parity of all the bytes of a telegram. According to Lit.[2], the Hamming distance of the HART transmission equals four.

- Noise immunity

noise-resistant communication

During operation the communication participants can be added or removed without endangering the components of the other devices or disrupting their communication.

For interferences that can be coupled into the transmission lines, the HART specification demands class 3 noise immunity according to IEC 801-3 and -4. So general noise immunity requirements are met. Further protection mechanisms to detect errors in the communication are implemented in the different communication layers.

error detection on the different levels

On the lower levels, the UART and the longitudinal parity check reliably detect up to three corrupted bits in the transmitted telegram (Hamming distance $HD=4$). Errors occurring on higher levels, such as HART commands that cannot be interpreted and device failures, are indicated by the slave upon each transaction using the status bytes reserved for this purpose. Polling at regular intervals enables the master device to know the state of all connected communication participants and to react as requested by the user or the operating program.

- Transmission time and user data rate

The time required to transmit a telegram results from the bit data rate (1200Hz) and the number of bits per telegram. The length of the telegram varies depending on the message length – 0 to 25 characters – and the message format. When a short frame format is used and the message contains 25 characters, a total of 35 characters must be transmitted. Since each byte is transmitted as UART character (see [Lit. 2]), we obtain the following data:

HART transaction:

byte per telegram:	25 message characters + 10 control characters	
telegram size:	35 characters * 11 bits	= 385 bits
user data rate:	25 * 8 bits / 385 bits	= 52 %
time per bit	1 / 1200 bits/s	= 0.83 ms
transaction time:	385 * 0.83 ms	= 0.32 s
time per user data byte	0.32 s / 25 bytes	= 13 ms

performance data of
HART transmission

Fig. 16: Transmission time of a HART telegram

In shorter messages, the ratio between user data and control data becomes increasingly unfavorable so that it can take up to 128 ms to transmit one user data byte. An average of 500 ms is accounted for per transaction – i.e. for both a master and a slave telegram, including additional maintenance and synchronization times. As a result, approximately two HART transactions can be carried out per second.

up to two transactions
per second

These values show that the HART communication is not suitable for transmitting time-critical data. HART can be used to determine the reference variable of a final control element in test and start-up phases, but it is obviously not suited to solve control tasks.

not suitable for
time-critical control
tasks

Application layer: HART commands

The communication routines of HART master devices and operating programs are based on HART commands which are defined in the application layer of the HART protocol.

HART command from the master... Pre-defined commands enable the master device to give instructions to a field device or send messages/data. So set points, actual values and parameters can be transmitted and various services for start-up and diagnostics performed.

... and response from the slave The field devices immediately respond by sending an acknowledgement telegram which can contain requested status reports and/or the data of the field device.

The example in Fig. 17 shows what the transmitted bytes mean in a transaction initiated using the command 33. This HART command enables the master to read four transmitter variables of the field device and the corresponding units of measurement with only one command.

classification of HART commands To enable a universal communication, the HART commands are classified according to their function into commands for master devices and for field devices (Fig. 18).

HART command 33: Read – up to 4 – transmitter variables

Master device - data in command (4 bytes):

byte 1	variable code for slot 0
byte 2	variable code for slot 1
byte 3	variable code for slot 2
byte 4	variable code for slot 3

Field device - data in reply (24 bytes):

byte 1	slot 0:	transmitter variable code
byte 2		units code
byte 3-6		measured value
byte 7-12	slot 1:	same as for slot 0
byte 13-18	slot 2:	same as for slot 0
byte 19-24	slot 3:	same as for slot 0

Fig. 17: Example of a HART transaction

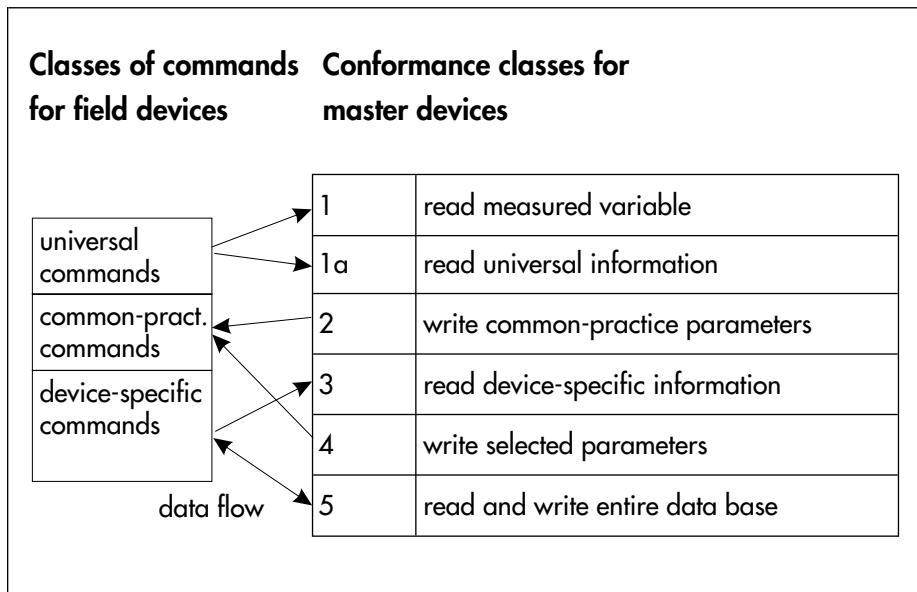


Fig. 18: Classification of HART commands in classes of commands and conformance classes

- ▶ master devices: six conformance classes
- ▶ field devices: three classes of commands

Depending on the tasks to be executed, the HART master device uses a command that can be assigned to one of the six different conformance classes. Each conformance class contains a subset of HART commands which cover a special administrative or control-related range of tasks.

conformance classes for master devices

Field devices interpret and process only those HART commands that are directed to them or to all participants. Each command belongs to one of three classes of commands. These classes distinguish how specific or universal a command is:

classes of commands for field devices

- ▶ Universal commands are understood and used by all field devices operating with the HART protocol (device designation, firmware no., etc.).
- ▶ Common-practice commands are usually supported by many, but not necessarily all, HART field devices. (Read variable, set parameter, etc.). Most of the HART field devices are able to interpret and respond to common-practice commands.

understood by all devices

more specific commands for more complex devices

**special commands for
special functions**

- ▶ Device-specific commands support functions that are unique to each device. These commands provide access to data about the type and construction of a device as well as information on the maintenance state and start-up (see also DDL device description, page 29).

Most of the field devices support commands of all three classes: they understand all universal commands, the common-practice commands tailored to them and special, device- and manufacturer-specific commands.

DDL device description

The HART commands are based on the services of the lower layers and enable an open communication between the master and the field devices. This openness and the interchangeability of the devices independent of the manufacturer are available only as long as the field devices operate exclusively with the universal and common-practice commands and the user does not need more than the simple HART standard notation for the status and fault messages.

**interchangeability of
field devices**

When the user wants the message to contain further device-related information or that special properties of a field device are also used, the common-practice and universal commands are not sufficient. Using and interpreting the data requires that the user know their meaning. However, this knowledge is not available in further extending systems which can integrate new components with additional options. To eliminate the adaptation of the master device's software whenever an additional status message is included or a new component is installed, the device description language (DDL) was developed.

**DDL describes device-
specific functions**

The DDL is not limited to the use for HART applications. It was developed and specified for fieldbusses, independent of the HART protocol, by the 'Human Interface' workshop of the International Fieldbus Group (IFG).

**DDL also for
field network
applications**

The developers of the device description language DDL aimed at achieving versatile usability. The DDL finds also use in field networks. The required flexibility is ensured in so far as the DDL does not itself determine the number and functions of the device interfaces and their representation in the control stations. The DDL rather is a language – similar to a programming language – which enables the device manufacturers to describe all communication options in an exact and complete manner (Fig. 19).

```

VARIABLE low_flow_cutoff
{
  LABEL [low_flow_cutoff];
  TYPE FLOAT;
  {
    DISPLAY_FORMAT "6.4f",
  }
}

MENU configure_io
{
  LABEL [configure_io]
  ITEMS
  {
    FLOW_UNITS,          /* VARIABLE      */
    rerange              /* edit-display  */
    operate_mode,        /* variable      */
    flow_config          /* menu          */
  }
}

```

Fig. 19: Extract from a DDL device description

The DDL allows the manufacturer to describe:

- improved operation and monitoring**
- ▶ attributes and additional information on communication data elements,
 - ▶ all operating states of the device,
 - ▶ all device commands and parameters,
 - ▶ the menu structure, thus providing a clear representation of all operating and functional features of the device.

Having the device description of a field device and being able to interpret it, a master device is equipped with all necessary information to make use of the complete performance features of the field device.

- DDL supports all extensions**
- So device- and manufacturer-specific commands can also be executed and the user is provided with a universally applicable and uniform user interface, enabling him to clearly represent and perform all device functions. Thanks to this additional information, clear, exact and, hence, safer operation and monitoring of a process is made possible (Fig. 20).

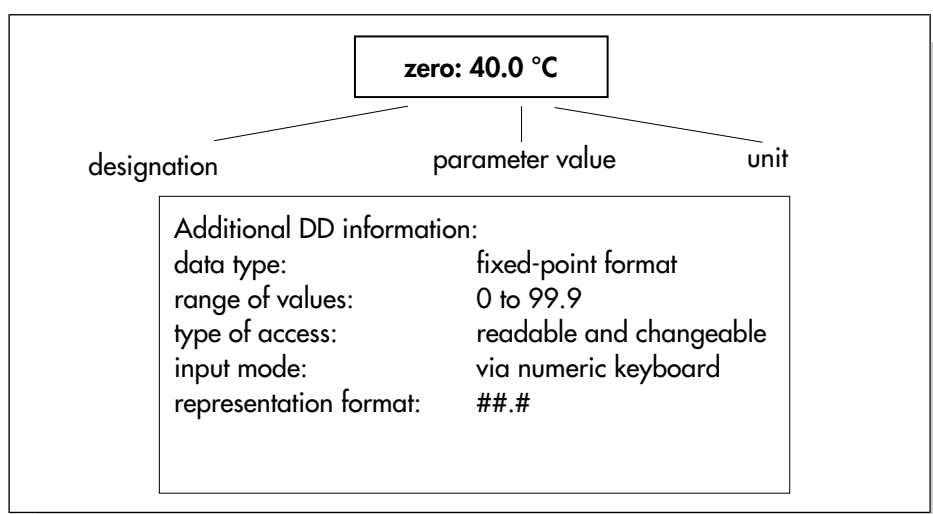


Fig. 20: Additional DD information

The master device does not read the device description as readable text in DDL syntax, but as short, binary-coded DD data record specially generated by the DDL encoder. For devices with sufficient storage capacity, this short form opens up the possibility to store the device description already in the firmware of the field device. During the parameterization phase it can be read by the corresponding master device.

DD data record is generated by the encoder

Requirements to be met by configurators

user interfaces according to VDI guideline

Universally applicable configurators (PC or handheld terminal), also from different manufacturers, should have a uniform operation structure. To ensure this, the VDI guideline 2187 was defined. It specifies the essential performance features of such a user interface as well as its structure.

Another important requirement is that any HART device must be supported. As explained above, only an open, i.e. flexible and manufacturer-independent, master device with the following features can meet this requirement:

- ▶ All commands defined in the HART protocol must be implemented and selectable as required.
- ▶ To extend the operating functions, any device description can be implemented.
- ▶ The user interface provides the user with all extended communication, information and control options.

device descriptions stored by HCF

When special, device-specific options are omitted, the basic functions of all HART devices can be performed using the universal and the common-practice commands. However, the master devices should be able to read the DDL data records of field devices, e.g. via disks. The HCF (see page 6) maintains a library in which all device descriptions of all registered HART devices are stored.

Most of the commercially available operating programs based on PC do not (yet) support this way of configuration. Therefore, HART device manufacturers often supply their own programs especially adapted to the devices with fixed implemented device-specific extensions. This, however, eliminates the flexible and open character of the system.

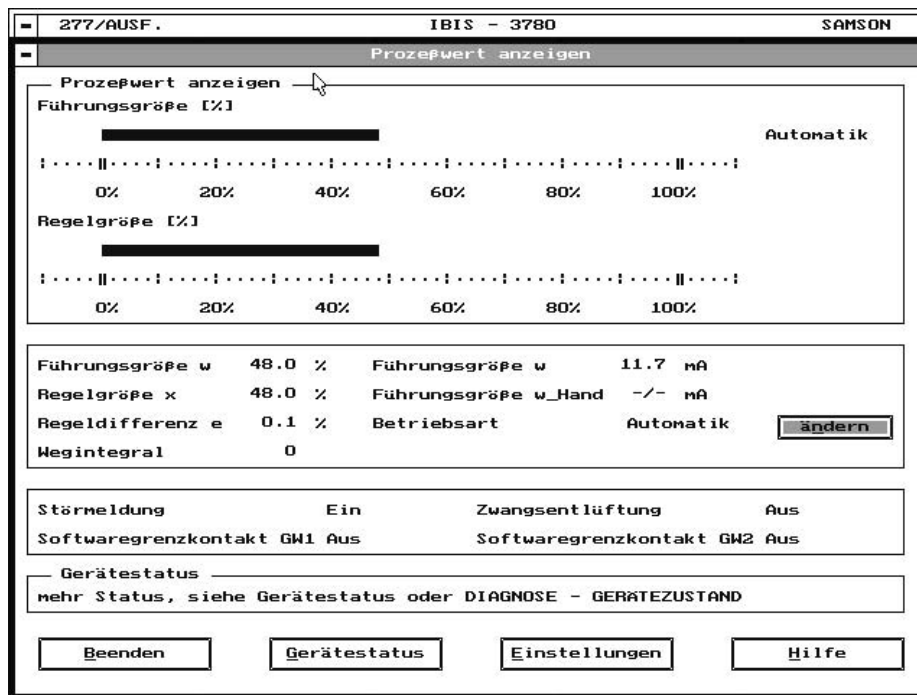


Fig. 21: IBIS user interface for the Type 3780 HART Positioner

Example: IBIS

Hartmann & Braun developed the IBIS program (Intelligentes Bedien- und Informationssystem/intelligent operating and information system) and based it on the specifications laid down in the VDI guideline 2187. This program provides a clear, window-type user interface.

user interface according to VDI 2187

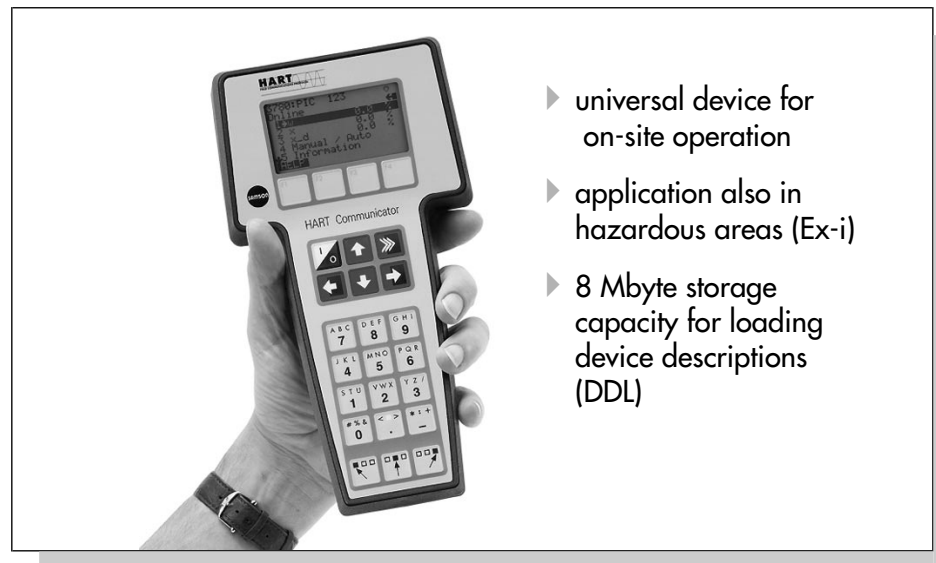
HART-DDs, however, cannot be read. Access to the complete command set of a HART device is possible only with a customized IBIS version adapted by the device manufacturer. Fig. 21 shows a window of the IBIS user interface for the Type 3780 HART Positioner from SAMSON AG.

device-specific version required

HART handheld master device

Handheld master devices support simple, on-site operation and diagnostics for HART devices. These devices are also available in intrinsically safe version for use in hazardous areas.

on-site application also in hazardous areas



- ▶ universal device for on-site operation
- ▶ application also in hazardous areas (Ex-i)
- ▶ 8 Mbyte storage capacity for loading device descriptions (DDL)

Fig. 22: HART handheld communicator

**programmable
handheld terminal
for any DDL**

The handheld master device of the Rosemount company shown in Fig. 22 can be adapted via a special programming hardware so that all required device descriptions can be stored and deleted again when they are no longer needed. This allows the user to operate with a flexible and versatile service device, enabling him to freely access all HART field devices in his installation.

Appendix A1: Troubleshooting

Should you encounter difficulties during the installation of a HART device and the start-up of the communication, check the device as described in the following:

- ▶ Did you set the proper device and bus address for your application?
- ▶ Did you connect the FSK modem at the PC control station to the interface configured in the program – COM1 or COM2?
- ▶ Are all devices in the current loop – including those that cannot communicate – suitable for HART data transmission?
- ▶ Do the length and the cross section of the transmission lines meet the requirements of HART communications?
- ▶ Can the current source (usually the controller) power the load of the HART device?

APPENDIX

Appendix A2: Additional literature

- [1] Digital Signals
Technical Information L1 50 EN; SAMSON AG
- [2] Serial Data Transmission
Technical Information L1 53 EN; SAMSON AG
- [3] Communication Networks
Technical Information L1 55 EN; SAMSON AG
- [4] Communication in the Field
Technical Information L4 50 EN; SAMSON AG
- [5] PROFIBUS PA
Technical Information L4 53 EN; SAMSON AG
- [6] FOUNDATION Fieldbus
Technical Information L4 54 EN; SAMSON AG

Figures

Fig. 1: HART and HCF logo	6
Fig. 2: Connection of HART master devices	7
Fig. 3: HART communication via multiplexer	8
Fig. 4: Multitrop mode with HART transmitters.	9
Fig. 5: Split-range operation with two HART positioners	10
Fig. 6: Components and connection of the FSK bus	11
Fig. 7: Point-to-point connection	13
Fig. 8: HART interface of SAMSON positioner	15
Fig. 9: HART protocol implementing the OSI model	16
Fig. 10: Hart signal superimposed on the analog current signal	17
Fig. 11: Controller output must not short-circuit the HART signals	19
Fig. 12: HART transaction	21
Fig. 13: HART communication modes	21
Fig. 14: Structure and elements of a HART telegram	22
Fig. 15: Short frame and long frame HART address formats	23
Fig. 16: Transmission time of a HART telegram	25
Fig. 17: Example of a HART transaction	26
Fig. 18: Classification of HART commands	27
Fig. 19: Extract from a DDL device description	30
Fig. 20: Additional DD information	31
Fig. 21: IBIS user interface for the Type 3780 HART Positioner	33
Fig. 22: HART handheld communicator.	34

NOTES



SAMSON AG · MESS- UND REGELTECHNIK · Weismüllerstraße 3 · D-60314 Frankfurt am Main
Phone (+49 69) 4 00 90 · Telefax (+49 69) 4 00 95 07 · Internet: <http://www.samson.de>