

TUTORIAL

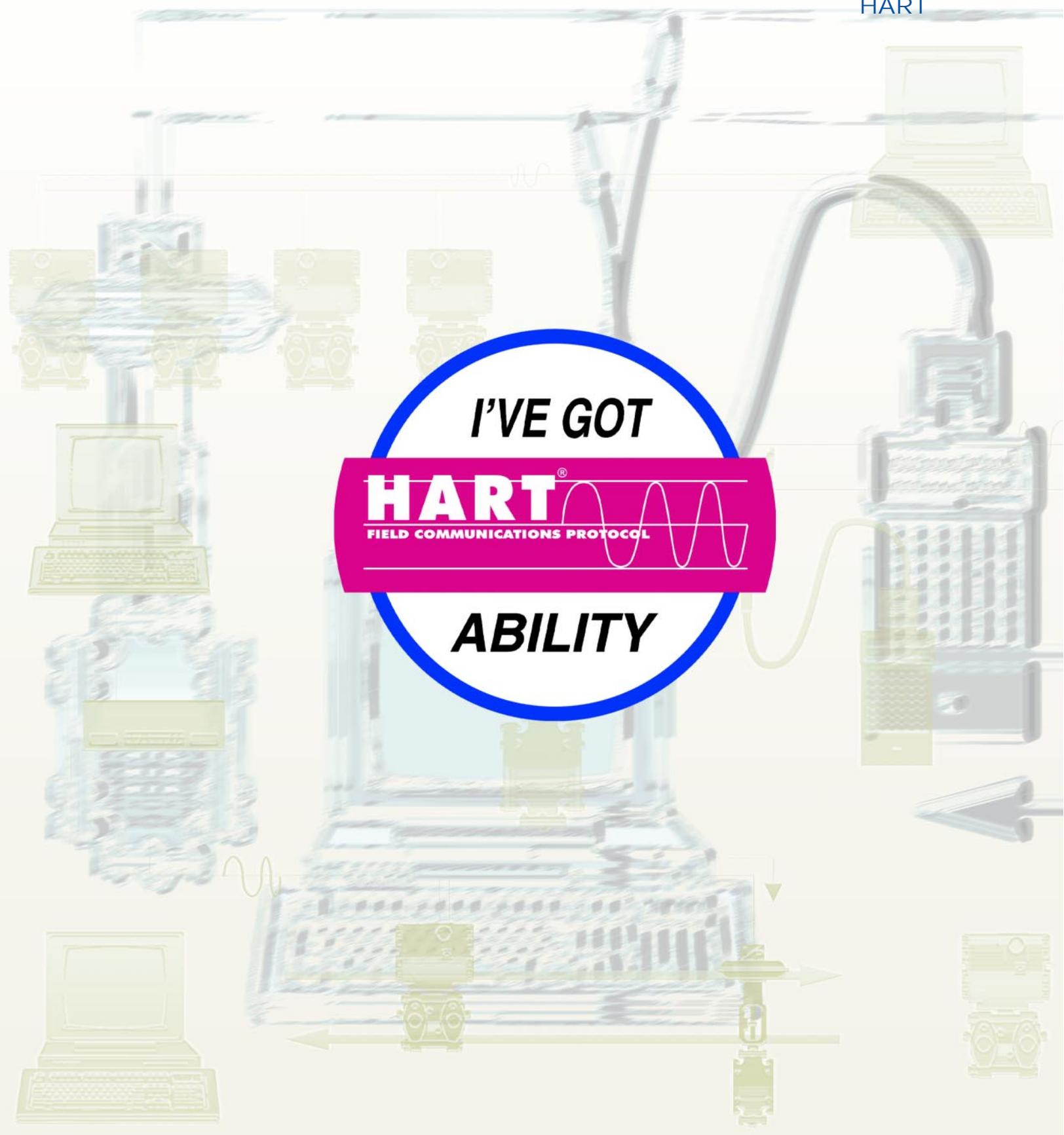
HART

I'VE GOT

HART[®]
FIELD COMMUNICATIONS PROTOCOL



ABILITY



Digital Capability

- Access to all instrument parameters & diagnostics
- Supports multivariable instruments
- On-line device status

Analog Compatibility

- Simultaneous analog & digital communication
- Compatible with existing 4-20 mA equipment & wiring

Interoperability

- Fully open de facto standard
- Common Command and data structure
- Enhanced by Device Description Language

Availability

- Field proven technology with more than 1,400,000 installations
- Large and growing selection of products
- Used by more smart instruments than any other in the industry

Introduction

HART® Field Communications Protocol is widely recognized as the industry standard for digitally enhanced 4-20 mA smart instrument communication. Use of the technology is growing rapidly, and today virtually all major global instrumentation suppliers offer products with HART communication.

The HART protocol provides a uniquely backward compatible solution for smart instrument communication as both 4-20 mA analog and digital communication signals are transmitted simultaneously on the same wiring. HART provides many benefits promised by fieldbus, while retaining the compatibility and familiarity of existing 4-20 mA systems.

This paper provides a brief overview of the HART protocol and the benefits achievable with this important technology. Per instrument cost savings benefits of \$300-500 in initial installation/commissioning and \$100-200 per year in ongoing maintenance/operations are commonly reported.

Analog + Digital Communication

For many years, the field communication standard used by process automation equipment has been a milliampere (mA)

Simultaneous Analog + Digital Communication

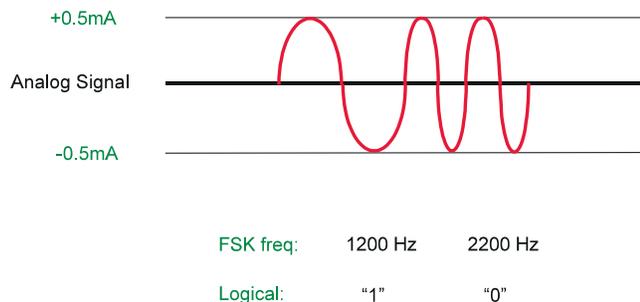


Figure 1 - HART uses Frequency Shift Keying to encode digital information on top of the 4-20 mA analog signal

analog current signal. In most applications the milliampere signal varies within a range of 4-20 mA in proportion to the process variable being represented. Virtually all installed plant instrumentation systems use this international standard to communicate process variable information.

HART Field Communications Protocol extends the 4-20 mA standard to enhance communication with intelligent measurement and control instrumentation. A major step in the evolution of process control, the HART protocol is fostering significant innovation in process instrumentation capabilities. The enhanced communication characteristics of this important technology are reflected in the protocol name, HART which stands for "Highway Addressable Remote Transducer".

The HART protocol enables two-way digital communication with smart instruments without disturbing the 4-20 mA analog signal. Both the 4-20 mA analog and HART digital communication signals can be transmitted simultaneously over the same wiring. Primary variable and control signal information is carried by the 4-20 mA (if desired), while additional measurements, process parameters, device configuration, calibration, and diagnostics information is accessible through the HART protocol over the same wires at the same time. Unlike other "open" digital communication technologies for process instrumentation, HART is compatible with existing systems.

The HART Technology

The HART protocol makes use of the Bell 202 Frequency Shift Keying (FSK) standard to superimpose digital communication signals at a low level on top of the 4-20 mA. Since the digital FSK signal is phase continuous, it does not interfere with the 4-20 mA signal. A logical "1" is represented by a frequency of 1200 Hz and a logical "0" is represented by a frequency of 2200 Hz as shown in Figures 1 and 2.

The HART FSK signaling enables two-way digital communication and makes it possible for additional information beyond just the normal process variable to be communicated to or from a smart field instrument. The HART protocol communicates at 1200 bits per second without interrupting the 4-20 mA signal and allows a host application (master) to get two or more digital updates per second from a field device.

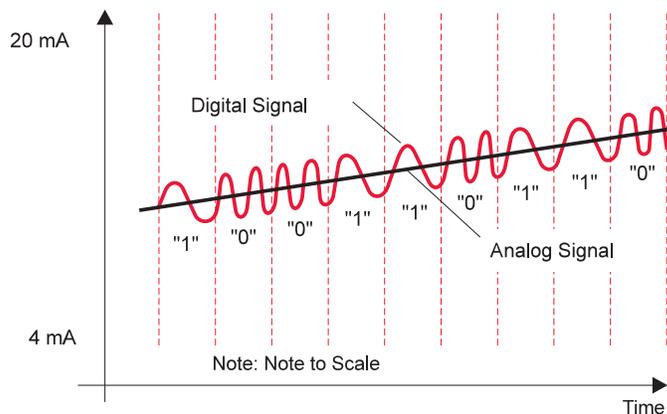


Figure 2 - HART digital communication signal superimposed on the 4-20 mA analog signal

Flexible Application

HART is principally a master/slave protocol which means that a field (slave) device speaks only when spoken to by a master. Two masters (primary and secondary) can communicate with slave devices in a HART network. Secondary masters, such as handheld communicators, can be connected almost anywhere on the network and communicate with field devices without disturbing communication with the primary master. A primary master is typically a DCS, PLC, or computer based central control or monitoring system. A typical installation with two masters is shown in Figure 3.

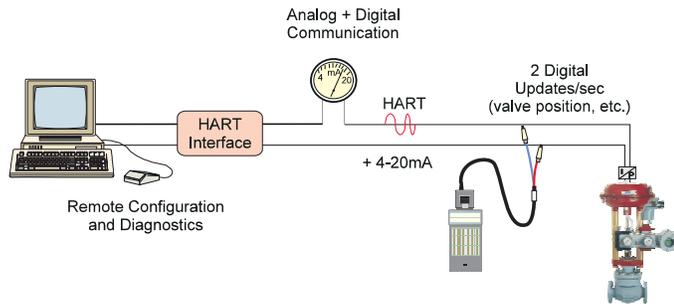
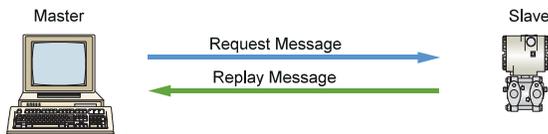


Figure 3 - The HART protocol allows two Master devices to access information in Slave (field) devices

The HART protocol can be used in various modes for communicating information to/from smart field instruments and central control or monitoring equipment. Digital master/slave communication simultaneous with the 4-20 mA analog signal is the most common. This mode, depicted in Figure 4, allows digital information from the slave device to be updated twice per second in the master. The 4-20 mA analog signal is continuous and can still carry the primary variable for control.

Master / Slave or Poll / Response

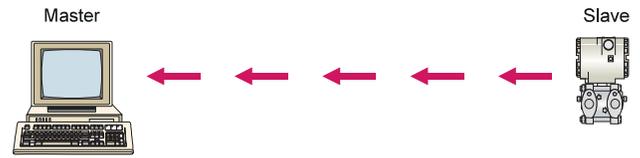


Analog + Digital or Digital Only Communication
Analog signal is not interrupted
"Slave" responds to Commands/Requests from "Master"
Typical 500 ms response (2 values per second)

Figure 4 - HART Master/Slave Communication (Normal HART Mode)

"Burst" is an optional communication mode (Figure 5) which allows a single slave device to continuously broadcast a standard HART reply message. This mode frees the master from having to send repeated command requests to get updated process variable information.

Burst or Broadcast mode



All Digital Communication Mode.
Continuous transmission of a Selected Standard Reply Message such as PV.
Gaps between Messages allow "Master" to change Command or mode
3 to 4 updates per second typical

Figure 5 - Some devices support HART Burst Communication Mode (Optional)

The same HART reply message (PV or other) is continuously broadcast by the slave until the master instructs the slave to do otherwise. Data update rates of 3-4 per second are typical with "burst" mode communication and will vary with the chosen command. Burst mode should be used only in single slave device networks.

The HART protocol also has the capability to connect multiple field devices on the same pair of wires in a multidrop network configuration as shown in Figure 6. In multidrop applications, communication is limited to master/slave digital only. The current through each slave device is fixed at a minimum value to power the device (typically 4 mA) and no longer has any meaning relative to the process.

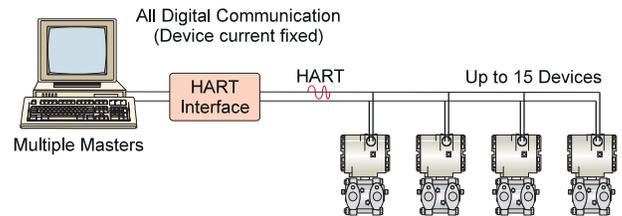


Figure 6 - The HART field devices can be connected in a Multidrop Network for some applications

From an installation perspective, the same wiring used for conventional 4-20 mA analog instruments carries the HART communication signals. Allowable cable run lengths will vary with the type of cable and the devices connected, but in general up to 3,000 meters for a single twisted pair cable with shield and 1,500 meters for multiple twisted pair cables with a common shield. Unshielded cables can be used for short distances. Intrinsic safety barriers and isolators which pass the HART signals are readily available for use in hazardous areas.

Powerful Command Set

HART communication is command based, i.e., a master issues a command and the slave responds. Three types of HART commands provide read/write access to information available in HART-compatible field instruments (see Figure 7). Universal and Common Practice Commands are defined in the HART protocol specifications. The third type, Device Specific Commands, provide freedom for product specific parameters or functions unique to a particular device.

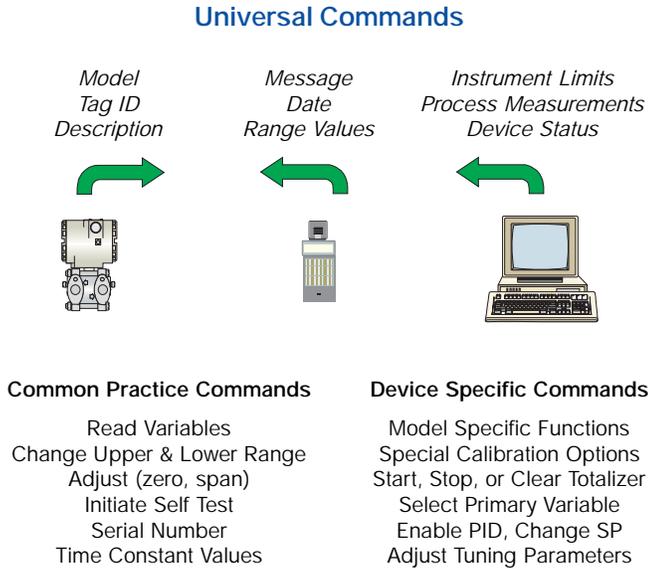


Figure 7 - HART Universal & Common Practice Commands ensure interoperability across products of different manufacture

Universal Commands ensure interoperability across the large and growing base of products from different suppliers, and provide access to information useful in normal plant operation, i.e., reading process measurements/variables, upper and lower range values, and other information such as manufacturer, model, tag, and description. A basic rule of the HART protocol is that HART-compatible slave devices must respond to all Universal Commands. These commands are powerful as for example, Universal Command 3 allows up to four dynamic variables to be read in a single command response.

Common Practice Commands provide access to functions which are implemented in many devices though not all. These commands are optional, but if implemented, must be as specified. Device Specific Commands allows access to unique product features. Mostly used for device configuration parameters, these commands can send a new set point to a PID algorithm in the device.

Device status information included in every HART command response provides increased system integrity for critical loops. The device status bits in each reply message indicate device malfunctions or other problems such as analog output saturated, variable out of limits, or communication errors. Some HART-compatible devices can monitor the device status bits continuously and provide early warning alarms or shutdowns if problems are detected.

Device Description Language

HART Device Description Language (DDL), extends interoperability beyond the Universal and Common Practice commands. A field device (slave) manufacturer uses DDL to create a software file with all relevant device characteristics, such that a DDL capable host can fully communicate with the device. A Device Description (DD) for a HART device is analogous to a printer driver in the personal computer world where the printer driver links an application to the printer such that it prints properly on the page.

Universal hand-held communicators capable of configuring any HART-based instrument through DDL are available from several manufacturers. Other host applications that understand DDL are beginning to emerge. A central library of all HART-compatible Device Descriptions is managed by the HART Communication Foundation.

Innovative Application Example

The power of the HART protocol is evident in the control diagram of Figure 8. This innovative application uses the inherent feature of the HART protocol that both 4-20 mA analog and digital communication signals are transmitted simultaneously over the same wiring.

In this application, the HART-compatible transmitter has an internal PID control capability. The device is configured such that the 4-20 mA loop current is proportional to the control output of the PID algorithm executing in the device (not the measured variable as in most transmitter applications). Since the 4-20 mA loop current is regulated by the PID control output, it is used to drive the valve position directly.

The control loop executes entirely in the field between the transmitter (with PID) and the control valve. The control action is continuous as the traditional 4-20 mA analog signal drives the valve. HART digital communication links the operator with the control loop to change set point, and read the primary variable, or valve position output. Substantial savings are possible in applications where this innovative control architecture is appropriate.

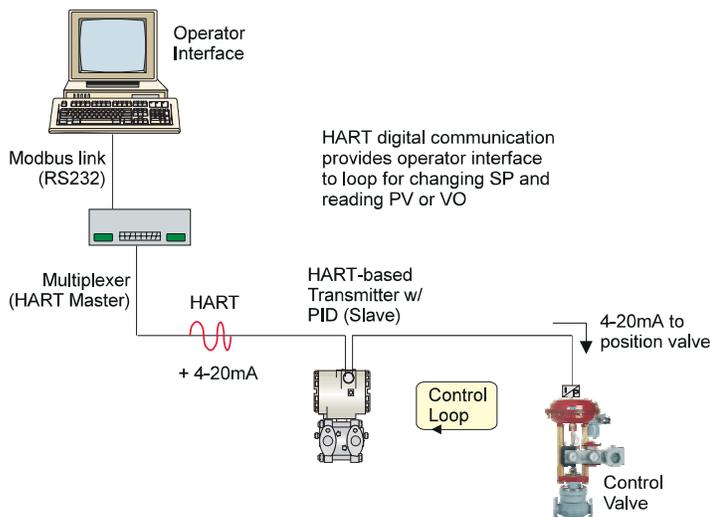


Figure 8 - Some HART-based instruments include PID algorithms for implementing cost effective control

Best Solution

The HART protocol provides users with the best solution and migration path for capturing the benefits of enhanced communication with smart instrumentation. No other communication technology can match the base of support or wide range of products that are available with HART today. The technology is easy to use and HART-compatible products are available from major instrumentation suppliers to address virtually all process measurement and control applications.

The emergence of fieldbus will not displace HART in either existing or new production facilities. HART provides users with many of the same benefits while retaining the compatibility and familiarity of existing 4-20 mA systems. HART allows the cost saving benefits of remote communication, flexible/accurate digital data transmission, field device diagnostics, and powerful multiparameter instruments to be captured without replacing entire systems.

Connection to current and future plant networks is assured by the digital communication capability and large installed base (more than 5,000,000 installations and growing rapidly). Support of the HART Communication Foundation ensures that the technology will continue to evolve for serving the needs of smart instrumentation today and tomorrow.

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