

# HART PROTOCOL: BRIDGING ANALOG RELIABILITY WITH DIGITAL INTELLIGENCE

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## Acronyms and Abbreviations

**HART:** Highway Addressable Remote Transducer

**FSK:** Frequency Shift Keying

**mA(milliampere):** A unit of electric current equal to one-thousandth of an ampere, commonly used in 4-20 mA current loops to transmit process measurements.

**Hz( Hertz):**A unit of frequency that represents one cycle per second, used in HART to describe the frequency of digital FSK signals.

**PV:** Primary Variable

**PLC:** Programmable Logic Controller

**DCS:** Distributed Control System

**PID:** Proportional-Integral-Derivative

**DD:** Device Description



## **1.Introduction**

HART (Highway Addressable Remote Transducer) is an open, bidirectional communication protocol widely used in industrial automation for smart field devices such as pressure, temperature, level, and flow transmitters. It enables reliable digital communication between field instruments and host systems.

At the same time, the traditional 4-20 mA analog signal continues to transmit the primary measured value required for real-time process control. This ensures backward compatibility with existing control systems and wiring infrastructure.

By superimposing a digital Frequency Shift Keying (FSK) signal onto the same wiring, HART allows diagnostic, configuration, and device information to be exchanged without interfering with analog control. This combination makes HART well suited for process control, maintenance, and asset management applications.

## **2.History**

The HART (Highway Addressable Remote Transducer) protocol was developed in the mid-1980s by Rosemount Inc. to overcome the limitations of traditional 4-20 mA analog signaling, which could transmit only a single process variable without diagnostic or configuration capabilities.

With the integration of microprocessors into field instruments, HART enabled digital communication by superimposing a Frequency Shift Keying (FSK) signal onto existing current loops. This approach allowed additional device information to be exchanged without the need to replace installed wiring, preserving existing infrastructure.

Its backward compatibility and practical design led to rapid adoption across the process industries. In the early 1990s, the protocol was standardized through the HART Communication Foundation to ensure interoperability among vendors. Today, maintained by the FieldComm Group, HART continues to evolve including WirelessHART and remains one of the most widely deployed and enduring communication protocols in industrial automation.

## **3.About the FieldComm Group**

The FieldComm Group is an international, non-profit organization that develops and maintains industrial communication standards to ensure reliable and interoperable communication in process automation. Formed through the merger of the HART Communication Foundation and the Fieldbus Foundation, it supports widely used technologies such as HART, WirelessHART, and FOUNDATION Fieldbus.

The group also manages protocol specifications, device certification, and Device Description (DD) files, while promoting best practices to support the adoption of smart instrumentation.

## 4. Dual Communication on One Pair of Wires

HART uses **two communication channels at the same time**:

### Analog Channel (4-20 mA)

Transmits the primary process variable (PV) for real-time control while simultaneously supplying power to the field instrument.

### Digital Channel (HART FSK Signal)

Uses high-frequency FSK signals at 1200 Hz and 2200 Hz to communicate diagnostics, configuration, and device information without interfering with the analog signal.

## 5. Host Systems and Field Instruments

In HART communication, the **host** is typically a control or monitoring system such as a PLC, DCS, industrial PC, laptop, or handheld communicator. The host initiates communication by sending HART commands to configure devices, read process variables, access diagnostics, and perform maintenance tasks.

The **field device** is a smart instrument installed in the plant, such as a pressure, temperature, level, or flow transmitter. It measures the process variable and responds to host commands by transmitting analog measurement data along with digital information related to configuration, diagnostics, and device status.

## 6. Primary and Secondary Hosts



HART allows more than one host on the same loop:

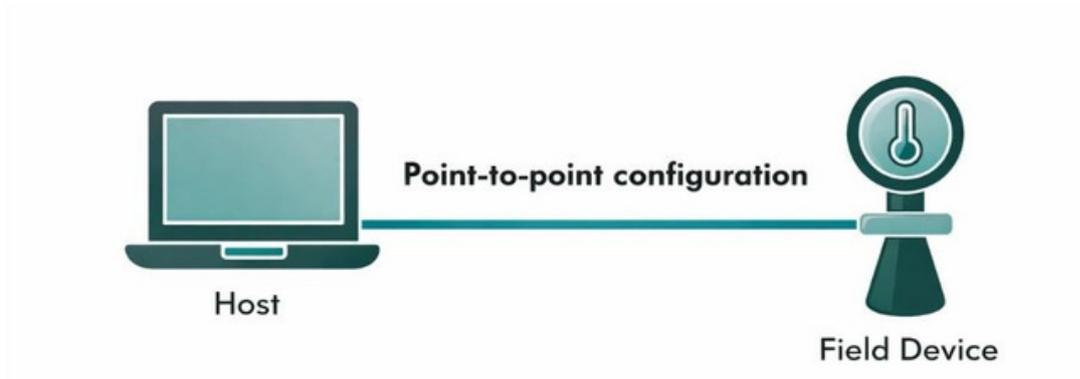
- The **Primary Host** (PLC/DCS) is used for process control.
- The **Secondary Host** (handheld or laptop) is used for configuration and maintenance.

Both hosts can communicate with the same device without interrupting normal operation.

## 7. HART Communication Topologies

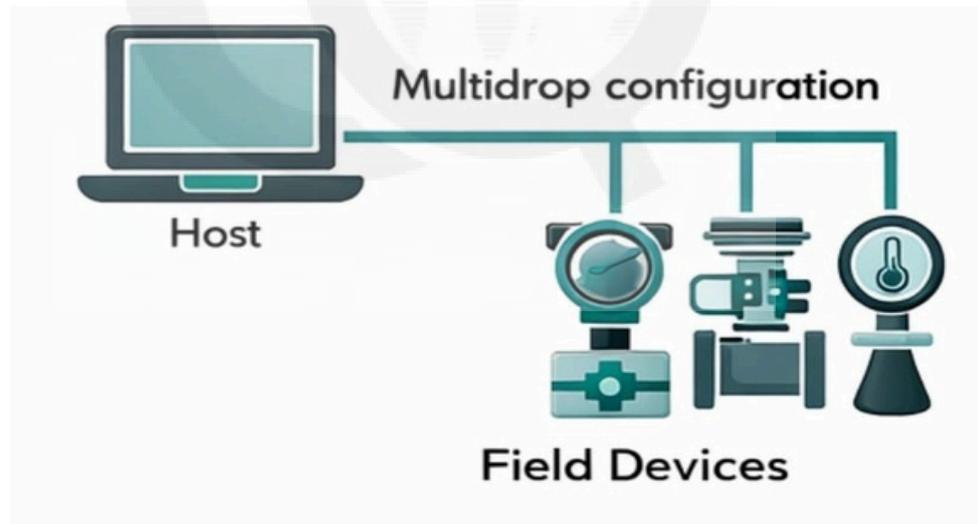
HART supports two network configurations:

### Point-to-Point



- One field device is connected to a single host system.
- The analog 4-20 mA signal is used for process value transmission.
- This is the most commonly used HART configuration in industrial applications.

### Multidrop

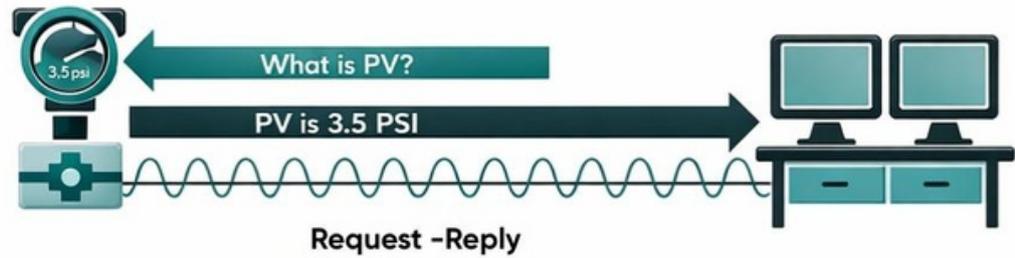


- Multiple field devices are connected on a single pair of wires.
- Each device is assigned a unique polling address ranging from 1 to 63.
- Communication is performed using digital HART signals only.

## 8.HART Communication Modes

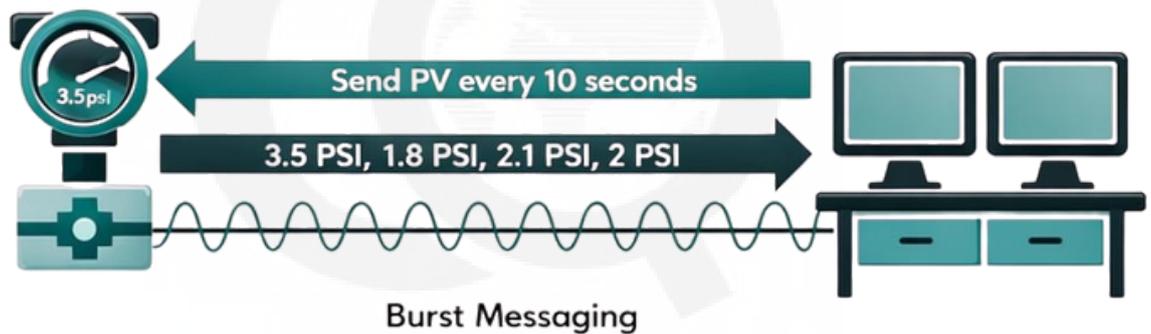
HART supports two messaging methods:

### Request-Reply Mode



- The host initiates communication by transmitting a HART command to the field device.
- The field device processes the request and responds with the requested data or an acknowledgment message.

### Burst Mode (Optional)



- The field device continuously transmits digital HART data without requiring a request from the host.
- This mode is used in applications where faster or more frequent data updates are required.

## 9.HART Commands

HART communication is based on standardized commands, ensuring interoperability between devices from different manufacturers. These commands are categorized into three main groups:

- **Universal Commands:** Universal commands are **mandatory** and must be supported by all HART-compliant devices. They provide access to essential information required for basic operation and identification. Typical functions include reading the primary variable (PV) and its engineering units, reading loop current and percent of range, accessing device manufacturer and model information, and reading or writing basic identification data such as tag name and descriptor. These commands ensure that any host can communicate with any HART device at a fundamental level, regardless of the manufacturer.
- **Common Practice Commands:** Common Practice commands are widely implemented, though not strictly mandatory for all devices. These commands support routine configuration, calibration, and maintenance activities. Examples include setting device range values, adjusting damping time constants, performing zero and span calibration, executing loop tests, initiating self-diagnostics, and configuring output behavior. Because these commands are standardized, they allow consistent handling of common operational tasks across many different HART devices and vendors.
- **Device-Specific Commands:** Device-Specific commands are defined by individual manufacturers to support advanced or specialized functionality unique to a particular device or application. These may include commands for totalizers, PID control, advanced diagnostics, valve position control, material or construction information, and specialized calibration routines. Access to these commands typically requires the appropriate Device Description (DD) file, which informs the host application how to interpret and display the device-specific features safely and correctly.

Users are not required to know individual command numbers, as host applications manage these commands internally using Device Description (DD) files.

## 10.Device Description (DD) in HART Communication

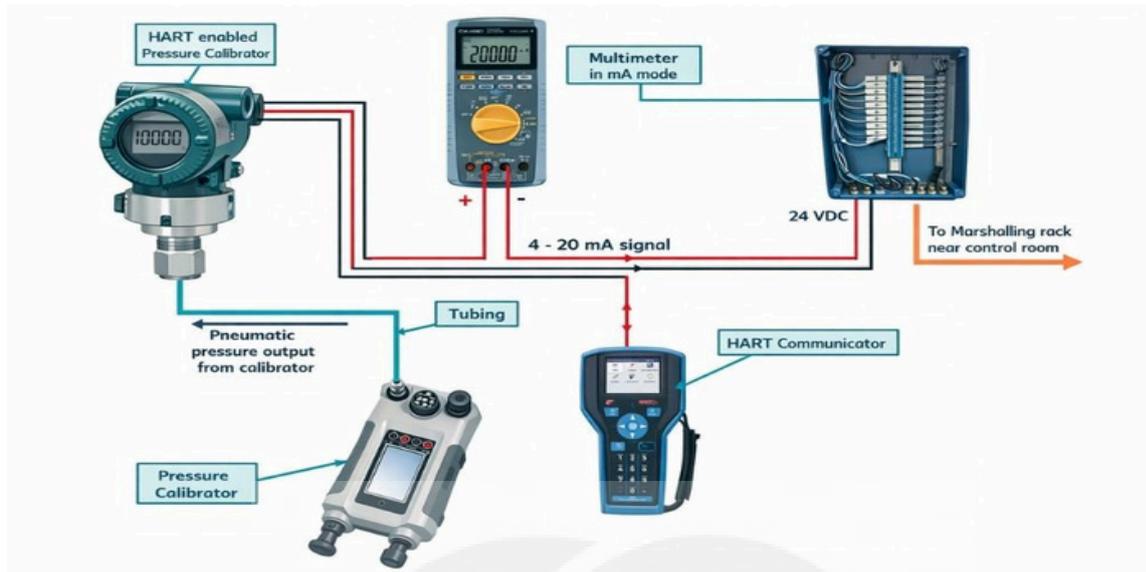
A Device Description (DD) file acts as a digital manual for a specific instrument and provides the host system with the following information:

- Supported device parameters
- Available commands and functions
- Menu structure and diagnostic display details

This enables the host system to access and manage device-specific features accurately and safely.

# 11.HART Protocol Use Cases

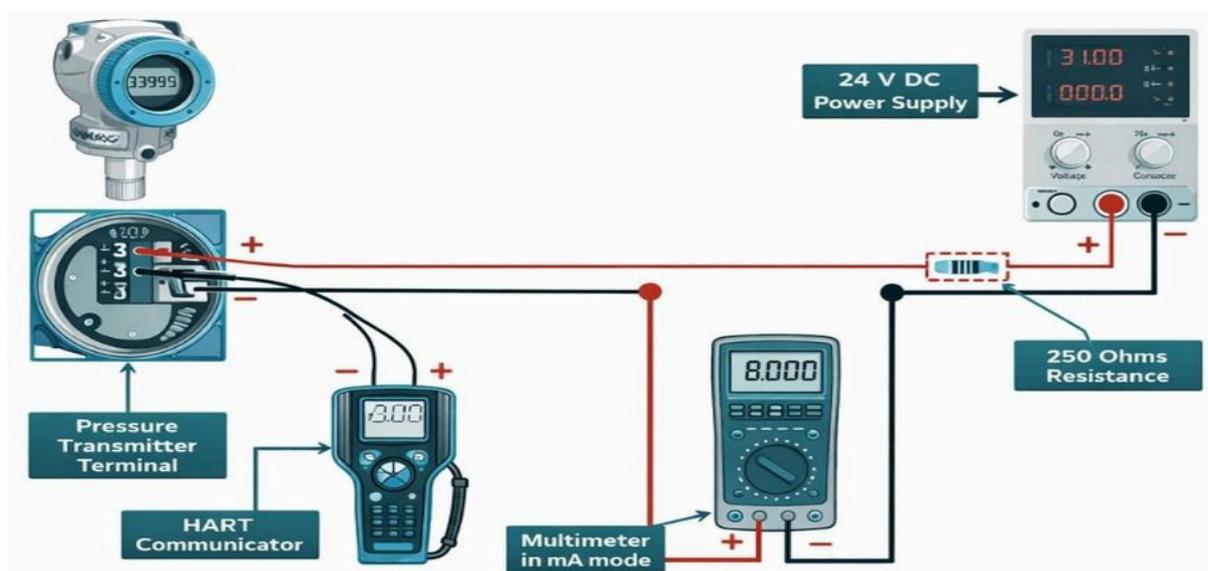
## Device Configuration and Commissioning



HART is widely used during device installation and commissioning to configure smart field instruments efficiently. By using a handheld communicator or a PC equipped with a HART modem, engineers can remotely configure devices without disconnecting them from the 4–20 mA loop. Typical configuration tasks include setting the measurement range (4 mA and 20 mA values), selecting appropriate engineering units such as °C, bar, psi, or flow units, adjusting damping and response time, and applying suitable transfer functions such as linear or square root.

This capability significantly reduces commissioning time, minimizes the need for on-site field visits, and lowers overall installation and maintenance costs, while ensuring accurate and reliable device setup.

## Calibration and Measurement Accuracy



Calibration is essential for ensuring accurate and reliable process measurements, and the HART protocol provides standardized digital commands that simplify calibration activities. HART supports key calibration functions such as sensor (transducer) trimming, zero and span adjustment, and digital-to-analog converter (DAC) trimming to ensure precise 4–20 mA output signals.

These capabilities allow calibration to be performed without removing the device from service, thereby improving measurement accuracy, enhancing process safety and product quality, and ensuring stable and efficient control system performance.

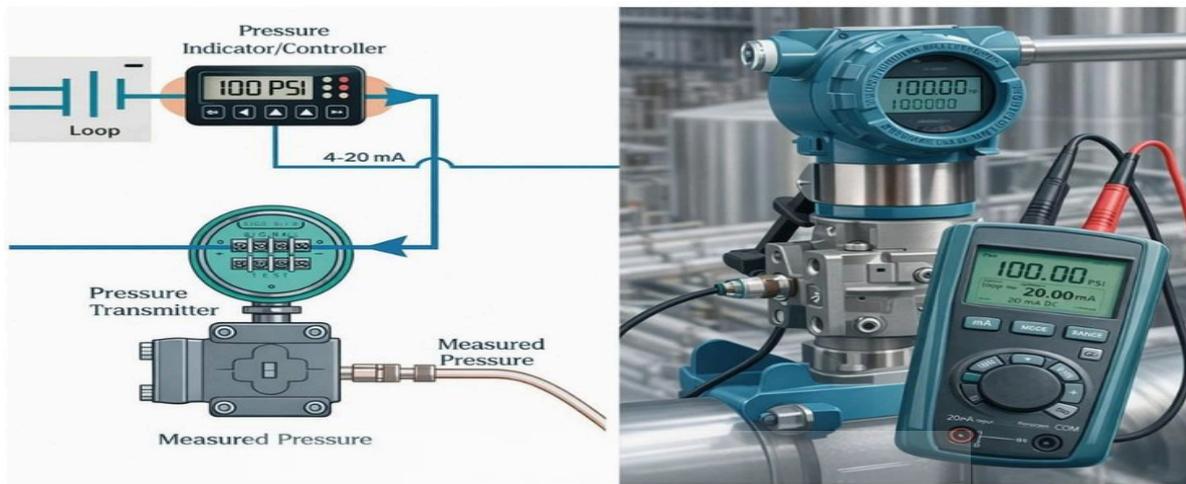
### Device Diagnostics and Health Monitoring



HART-enabled instruments provide detailed diagnostic information in addition to the traditional analog signal. These diagnostics include sensor health and failure detection, calibration status and drift monitoring, internal electronics temperature, and system warnings or alarms.

Access to this information enables early fault detection, helping to prevent unexpected device failures, reduce unplanned plant shutdowns, and improve overall plant reliability.

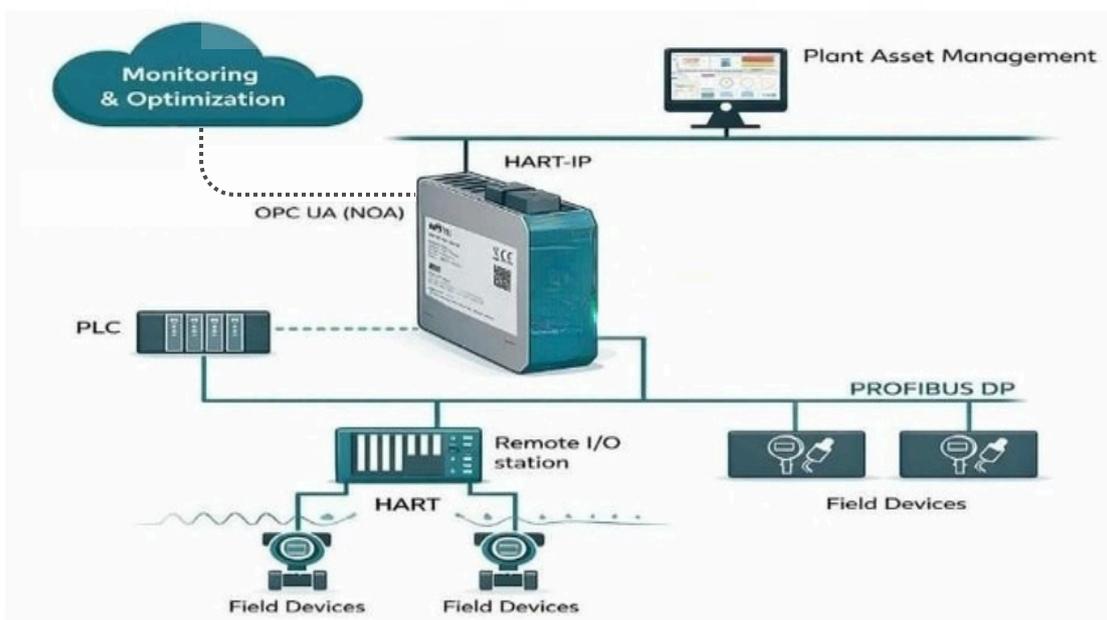
## Loop Integrity Testing and Signal Verification



HART enables engineers to verify the integrity of the 4–20 mA current loop through built-in loop test functions. Typical checks include forcing fixed output currents such as 4 mA, 12 mA, and 20 mA, verifying wiring continuity and I/O card operation, and comparing the digital process variable (PV) with the corresponding analog output.

These tests ensure reliable signal transmission and accurate interpretation by the control system, thereby improving overall system performance and reducing commissioning and troubleshooting time.

## Asset Management and Predictive Maintenance



HART devices store valuable asset information that can be accessed through asset management systems. This information includes device identification details such as tag and serial number, configuration and calibration history, and diagnostic and maintenance status.

Access to this data supports predictive maintenance strategies, reduces maintenance costs, improves overall system reliability, and simplifies activities such as audits, troubleshooting, and device replacement.

## 12. Why HART Is Still Important

HART remains essential because:

- It protects existing investments in wiring and infrastructure.
- It enables advanced diagnostics and predictive maintenance capabilities.
- It offers a reliable, simple, and widely supported communication method.
- Millions of HART enabled devices continue to be deployed and used worldwide.

## 13. HART Market Size

The global **WirelessHART** market was valued at **USD 5.85 billion in 2024** and is projected to reach approximately **USD 9.70 billion by 2030**, growing at a **CAGR of 8.8%** during the 2025–2030 forecast period. This growth is driven by increasing adoption of wireless communication technologies in process industries as part of industrial digitalization and IIoT initiatives. Based on the **IEC 62591 standard**, WirelessHART extends the widely used HART protocol into wireless environments while maintaining backward compatibility with existing infrastructure. Its secure, time-synchronized, self-organizing, and self-healing mesh network enables reliable communication in harsh industrial conditions, making it particularly effective for addressing last-mile connectivity challenges. As a result, WirelessHART supports key applications such as predictive maintenance, improved operational efficiency, enhanced safety, and advanced analytics, contributing to the development of fully connected smart plants.

## 14. Conclusion

The HART protocol effectively bridges traditional analog systems with modern digital intelligence. By enabling bidirectional communication over existing 4-20 mA wiring, HART allows industries to efficiently monitor, configure, and maintain smart field instruments without significant system modifications. As a result, understanding HART is an essential skill for engineers working in industrial automation and process control.

## References

[HART Technology Explained | FieldComm Group](#)

[HART Protocol Tutorial | Highway Addressable Remote Transducer Guide 2025](#)

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