1. The majority of smart field devices installed worldwide today are HART-enabled. But some new in the automation field may need a refresher on this powerful technology. Simply put, the HART (Highway Addressable Remote Transducer) Protocol is the global standard for sending and receiving digital information across analog wires between smart devices and control or monitoring system.

2. More specifically, HART is a bi-directional communication protocol that provides data access between intelligent field instruments and host systems. A host can be any software application from technician's hand-held device or laptop to a plant's process control, asset management, safety or other system using any control platform.

A Digital Upgrade For Existing Plants

3. HART technology offers a reliable, long-term solution for plant operators who seek the benefits of intelligent devices with digital communication – that is included in the majority of the devices being installed. In many cases however, most applications cannot retrofit their existing automation systems with a system that can accept the digital data which is provided by the HART Protocol.

4. Because most automation networks in operation today are based on traditional 4-20mA analog wiring, HART technology serves a critical role because the digital information is simultaneously communicated with the 4-20mA signal. Without it, there would be no digital communication.

A Critical, Digital Role

5. HART technology is easy to use and very reliable when used for commissioning and calibration of smart devices as well as for continuous online diagnostics. There are several reasons to have a host communicate with smart devices. These include:

(a) Device Configuration or re-configuration.

(b) Device Diagnostics.

(c) Device Troubleshooting

(d) Reading the additional measurement values provided by the device

(e) Device Health and Status.

(f) Much more: There are many benefits of using HART technology, and more users are reporting benefits in their projects on a continual basis. Years of success using these benefits explain why HART technology is the largest of all communication protocols, installed in more than 30 million devices worldwide.
6. HART Protocol tells "who" is calling. In an industrial automation network "who" is a microprocessor-based smart field device. In addition to letting such smart field devices "phone home," HART Communication lets a host system send data to the smart instrument. HART emerged in the late 1980s based on the same technology that brought Caller ID to analog telephony. It has undergone continued development, up to and including automation products now shipping with built-in Wireless HART Communication.

How HART Works

7. “HART” is an acronym for Highway Addressable Remote Transducer. 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 4-20mA. 

![Digital over Analog Signal](image)

**Note:** Drawing not to scale

**Fig : Frequency Shift Keying (FSK)**

8. This enables two-way field communication to take place and makes it possible for additional information beyond just the normal process variable to be communicated to/from a smart field instrument. The HART Protocol communicates at 1200 bps without interrupting the 4-20mA signal and allows a host application (master) to get two or more digital updates per second from a smart field device. As the digital FSK signal is phase continuous, there is no interference with the 4-20mA signal.

9. HART technology is a master/slave protocol, which means that a smart field (slave) device only speaks when spoken to by a master. The HART Protocol can be used in various modes such as point-to-point or multidrop for communicating information to/from smart field instruments and central controller monitoring systems. HART Communication occurs between two HART-enabled devices, typically a smart field device and a control or monitoring system. Communication occurs using standard instrumentation grade wire and using standard wiring and termination practices. The HART Protocol provides two simultaneous communication channels: the 4-20mA analog signal and a digital signal. The 4-20mA signal communicates the primary
measured value (in the case of a field instrument) using the 4-20mA current loop - the fastest and most reliable industry standard. Additional device information is communicated using a digital signal that is superimposed on the analog signal. The digital signal contains information from the device including device status, diagnostics, additional measured or calculated values, etc. Together, the two communication channels provide a low-cost and very robust complete field communication solution that is easy to use and configure.

Fig : Two Communication Channels

10. The HART Protocol provides for up to two masters (primary and secondary). This allows secondary masters such as handheld communicators to be used without interfering with communications to/from the primary master, i.e. control/monitoring system.

Fig : Primary and Secondary Masters

11. The HART Protocol permits all digital communication with field devices in either point-to-point or multidrop network configurations:
Multidrop Configuration

12. There is also an optional "burst" communication mode where a single slave device can continuously broadcast a standard HART reply message. Higher update rates are possible with this optional burst communication mode and use is normally restricted to point-to-point configuration.

13. Process includes measuring devices – the HART-enabled instrumentation. A Repeater is a device which routes Wireless HART messages but may have no process connection of its own. Its main use would be to extend the range of a Wireless HART network or help "go around" an existing or new obstacle (New process vessel). All instruments in a Wireless HART network have routing capability which simplifies planning and implementation of a wireless network.

14. The Adapter is a device which plugs into an existing HART-enabled instrument to pass the instrument data through a Wireless HART network to the host. The adapter could be located anywhere along the instrument 4-20mA cable; it could be battery powered or obtain its power from the 4-20Ma cable. Some adapters will be battery powered and use the same battery to power the instrument as well – in this case there
will be no 4-20mA signal to the host – all process data will be reported via *Wireless* HART.

15. **A Handheld Terminal** may come in two versions. In the first case, the handheld will be a standard HART FSK configuration unit (just add new device DDs or DOF files), just like the one used for everyday tasks such as routine maintenance and calibration checks. In the case of wireless support, the handheld is used to join a new instrument to an existing *Wireless* HART network. In the second case the handheld has a *Wireless* HART connection to the gateway and then down to an instrument and could be used for reading PV or diagnostics.

**HART Specifications**

16. The HART Protocol was developed in the late 1980's and transferred to the HART Foundation in the early 1990's. Since then it has been updated several times. When the protocol is updated, it is updated in a way that ensures backward compatibility with previous versions. The current version of the HART Protocol is revision 7.3. The "7" denotes the major revision level and the "3" denotes the minor revision level.

17. The HART Protocol implements layers 1, 2, 3, 4 and 7 of the Open System Interconnection (OSI) 7-layer protocol model: The **HART Physical Layer** is based on the Bell 202 standard, using frequency shift keying (FSK) to communicate at 1200 bps. The signal frequencies representing bit values of 0 and 1 are 2200 and 1200Hz respectively. This signal is superimposed at a low level on the 4-to-20mA analog measurement signal without causing any interference with the analog signal.

18. The **HART Data Link Layer** defines a master-slave protocol - in normal use, a field device only replies when it is spoken to. There can be two masters, for example, a control system as a primary master and a handheld HART communicator as a secondary master. Timing rules define when each master may initiate a communication transaction. Up to 15 or more slave devices can be connected to a single multidrop cable pair.

19. The **Network Layer** provides routing, end-to-end security, and transport services. It manages "sessions" for end-to-end communication with correspondent devices. The **Transport Layer** : The Data-Link Layer ensures communications are successfully propagated from one device to another. The Transport Layer can be used to ensure end to end communication successfully.

20. The **Application Layer** defines the commands, responses, data types and status reporting supported by the Protocol. In the Application Layer, the public commands of the protocol are divided into four major groups:
   
   (a) **Universal Commands** - provide functions which must be implemented in all field devices.

   (b) **Common Practice Commands** - provide functions common to many, but not all field devices.
(c) Device Specific Commands - provide functions that are unique to a particular field device and are specified by the device manufacturer.

(d) Device Family Commands - provide a set of standardized functions for instruments with particular measurement types, allowing full generic access without using device-specific commands.

**Wireless HART - How it works**

21. *Wireless* HART is a wireless mesh network communications protocol for process automation applications. It adds wireless capabilities to the HART Protocol while maintaining compatibility with existing HART devices, commands, and tools. Each *Wireless* HART network includes three main elements:

(a) **Wireless field devices** connected to process or plant equipment. This device could be a device with Wireless HART built in or an existing installed HART-enabled device with a Wireless HART adapter attached to it.

(b) **Gateways** enable communication between these devices and host applications connected to a high-speed backbone or other existing plant communications network.

(c) **A Network Manager** is responsible for configuring the network, scheduling communications between devices, managing message routes, and monitoring network health. The Network Manager can be integrated into the gateway, host application, or process automation controller.

22. The network uses IEEE 802.15.4 compatible radios operating in the 2.4GHz Industrial, Scientific, and Medical radio band. The radios employ direct-sequence spread spectrum technology and channel hopping for communication security and reliability, as well as TDMA synchronized, latency-controlled communications between devices on the network. This technology has been proven in field trials and real plant installations across a broad range of process control industries. Each device in the
mesh network can serve as a router for messages from other devices. In other words, a device doesn't have to communicate directly to a gateway, but just forward its message to the next closest device. This extends the range of the network and provides redundant communication routes to increase reliability.

23. The **Network Manager** determines the redundant routes based on latency, efficiency and reliability. To ensure the redundant routes remain open and unobstructed, messages continuously alternate between the redundant paths. Consequently, like the Internet, if a message is unable to reach its destination by one path, it is automatically re-routed to follow a known-good, redundant path with no loss of data.

24. The mesh design also makes adding or moving devices easy. As long as a device is within range of others in the network, it can communicate. For flexibility to meet different application requirements, the *Wireless HART* standard supports multiple messaging modes including one-way publishing of process and control values, spontaneous notification by exception, ad-hoc request/response, and auto-segmented block transfers of large data sets. These capabilities allow communications to be tailored to application requirements thereby reducing power usage and overhead.

**Wireless HART Applications**

25. Wireless technology offers opportunities for a wide range of applications - from adding measurements where they were previously out of physical or economic reach, to enabling plant-wide functions such as asset and people tracking, security, and worker productivity. However, the *Wireless HART* specification team recognized that no one technology is right for every application. Their approach was to focus on core process-automation functions where no appropriate wireless standard existed.

26. Like wired HART technology, *Wireless HART* therefore supports the full range of process monitoring and control applications, including:

   (a) Equipment and process monitoring.
   (b) Environmental monitoring, energy management, regulatory compliance.
   (c) Asset management, predictive maintenance, advanced diagnostics.
   (d) Closed-loop control (when appropriate).

27. Real-world use cases—developed by HART Communication Foundation member companies based on inputs from end-users—helped the *Wireless HART* development team ensure the final specification provides this broad support. *Wireless HART* technology will complement rather than replace wired instrumentation, and plants will often have both operating side-by-side. *Wireless HART* technology’s backward compatibility, including the HART command structure and Device Description Language, makes it easy to support both wired and wireless devices using the same tools.
28. *Wireless* HART also goes beyond promising device "interchangeability" to provide true **interoperability**. This means users can select the best *Wireless* HART devices regardless of manufacturer, with the assurance that compliant devices can work together in a system and be substituted for one another without loss of functionality at the host system level – just as HART devices can today.

**From Wired to Wireless**

29. Wired or wireless, HART technology provides the tools and the flexibility you need to better manage your field measurement assets.

**Wired**

30. When HART devices are deployed the Process Variable (PV) is read at the control system via the 4-20mA loop. Though used during commissioning, the HART data is not connected to the control system in real-time, limiting the value of your asset investment.

31. Retrofitting a wired connection to retrieve HART data may not be feasible. By connecting a *Wireless* HART Adapter to an existing installed device, the stranded information can be easily accessed. The HART Data is transmitted to a *Wireless* HART Gateway and interfaced to a control or asset management system.
**Wireless HART**

32. A *Wireless* HART device is a free-standing device that eliminates the analog connection to the control system. The device can be installed anywhere in the plant without the cost of wires. The PV and HART data is connected to a control or asset management system via a *Wireless* HART Gateway.

**Wired + Wireless – Works Together!**

33. In the real world, using a combination of both wired HART + *Wireless* HART technology provides a cost-effective, low-risk communication solution. Working together, your investment in installed HART devices is protected and additional HART devices can be added quickly and economically.

**Benefits of Using HART Communication**

34. Engineers operating in analog automation environments no longer need utter the words "if only" as in "if only I could get the device information without going into the field" or “if only I could get *this* configuration information from *that* pressure transmitter into my PC.” Users worldwide who have realized the benefits of HART Communication know that they can gain quick, easy visibility to devices in the field when using HART-
enabled handheld test, calibration devices and portable computers. In fact, device testing, diagnostics and configuration has never been easier. However, many have yet to realize HART technology’s greatest benefits which come from full-time connections with real-time asset management and/or control systems.

**HART technology can help you:**

35. (a) Leverage the capabilities of a full set of intelligent device data for operational improvements.

(b) Gain early warnings to variances in device, product or process performance.

(c) Speed the troubleshooting time between the identification and resolution of problems.

(d) Continuously validate the integrity of loops and control/automation system strategies.

(e) Increase asset productivity and system availability.

**Increase Plant Availability**

36. (a) Integrate devices and systems for detection of previously undetectable problems.

(b) Detect device and/or process connection problems real time.

(c) Minimize the impact of deviations by gaining new, early warnings.

(d) Avoid the high cost of unscheduled shutdowns or process disruptions.

**Reduce Maintenance Costs**

37. (a) Quickly verify and validate control loop and device configuration.

(b) Use remote diagnostics to reduce unnecessary field checks.

(c) Capture performance trend data for predictive maintenance diagnostics.

(d) Reduce spares inventory and device management costs.

**Improve regulatory compliance**

38. (a) Enable automated record keeping of compliance data.

(b) Facilitates automated safety shutdown testing.

(c) Raise SIL/safety integrity level with advanced diagnostics.
Take advantage of intelligent multivariable devices for more thorough, accurate reporting.

1. The standard features of HART technology range from simple compatibility with existing 4-20mA analog networks to a broad product selection:
   
   (a) Compatibility with standard 4-20mA wiring
   (b) Simultaneous transmission of digital data
   (c) Simplicity through intuitive menu-driven interfaces
   (d) Risk reduction through a highly accurate and robust protocol
   (e) Ease of implementation for maximum “up-front” cost effectiveness
   (f) Broad product selection, with compatible devices and software applications from most process automation providers
   (g) Platform independence for full interoperability in multi-vendor environments

**Using HART Technology**

39 The HART Communication Protocol has served as the world’s leading process communication technology for smart instruments since 1989. Today, more than 30 million HART devices are installed and in service worldwide. Industry suppliers are manufacturing and shipping HART products in record numbers -- 75% of the smart devices installed are HART-enabled. More HART products are installed in more plants around the world than any other process field communication protocol. Using HART technology today has never been easier. Putting the full power of HART-enabled devices to work is fast, easy and cost-effective. One of the best things about smart field devices is their intelligence. So called “Smart Devices” can make life easier for plant operators and technicians.

40 Most smart devices are configured using the HART Protocol. The HART Protocol provides two simultaneous communication channels – the 4-20mA analog channel and the HART-digital channel that is superimposed on the analog channel. Think of your caller ID telephone information superimposed on your phone line. The HART Data can be accessed anywhere on the 4-20mA -- at the device, at the I/O termination point or at any access point on the control loop.

41 Putting the “smart” capabilities to work can be fairly straightforward – if guidelines concerning networks, devices, and wiring are followed. As a result of using HART Technology, you can lower your operating cost, increase plant availability and shorten expensive downtime. For new and prospective HART users, help is on the way – and the price is hard to beat. To learn more about HART technology, new users can take the free online training course found in the Training Section.
42 A **Gateway** provides the connection to the host network. WirelessHART and then the main host interfaces such as Modbus – Profibus – Ethernet. The Gateway also provides the network manager and security manager (these functions can also exist at the host level – however initially they will be in the gateway). The **Network manager** builds and maintains the MESH network. It identifies the best paths and manages distribution of slot time access (Wireless HART divides each second into 10msec slots). Slot access depends upon the required process value refresh rate and other access (alarm reporting – configuration changes).

43 The **Security manager** manages and distributes security encryption keys. It also holds the list of authorized devices to join the network. The **Process** includes measuring devices – the HART-enabled instrumentation. A **Repeater** is a device which routes Wireless HART messages but may have no process connection of its own. Its main use would be to extend the range of a Wireless HART network or help “go around” an existing or new obstacle (New process vessel). All instruments in a Wireless HART network have routing capability which simplifies planning and implementation of a wireless network.

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