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Industrial Automation (ICE 3252)

Industrial Communication – HART Protocol

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HART

- In today's competitive environment, all companies seek to reduce operation costs, deliver products rapidly, and improve product quality.
- The HART (Highway Addressable Remote Transducer) protocol directly contributes to these business goals by providing cost savings in:
  - Commissioning and installation
  - Plant operations and improved quality
  - Maintenance
- The HART communication protocol is an open standard owned by the more than 100 member companies in the HCF.
- Products that use the HART protocol to provide both analog 4–20 mA and digital signals provide flexibility.

- Bidirectional, digital information utilizes the existing 4 mA to 20 mA network, making it easy to deploy on existing infrastructure.
- The key to a successful HART implementation is the ability to accurately encode and decode HART communication signals in noisy, harsh industrial environments and the attainment of registration for that system with the HART Communication Foundation.
- 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

Theory of Operation

- Communication Modes
- Frequency Shift Keying
- HART Networks
- HART Commands

Communication Modes

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

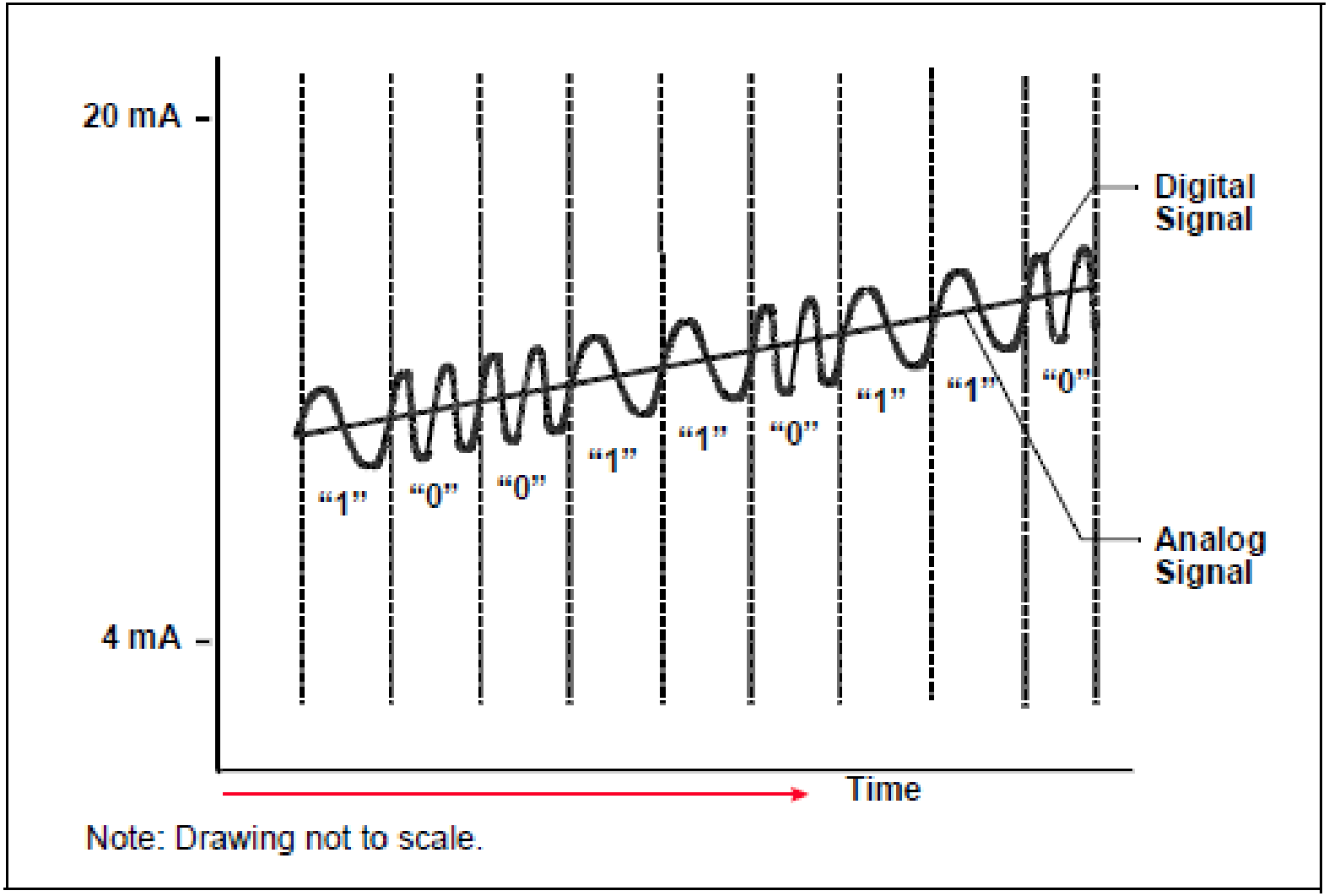
BURST MODE

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

Use burst mode to enable more than one passive HART device to listen to communications on the HART loop.

Frequency Shift Keying

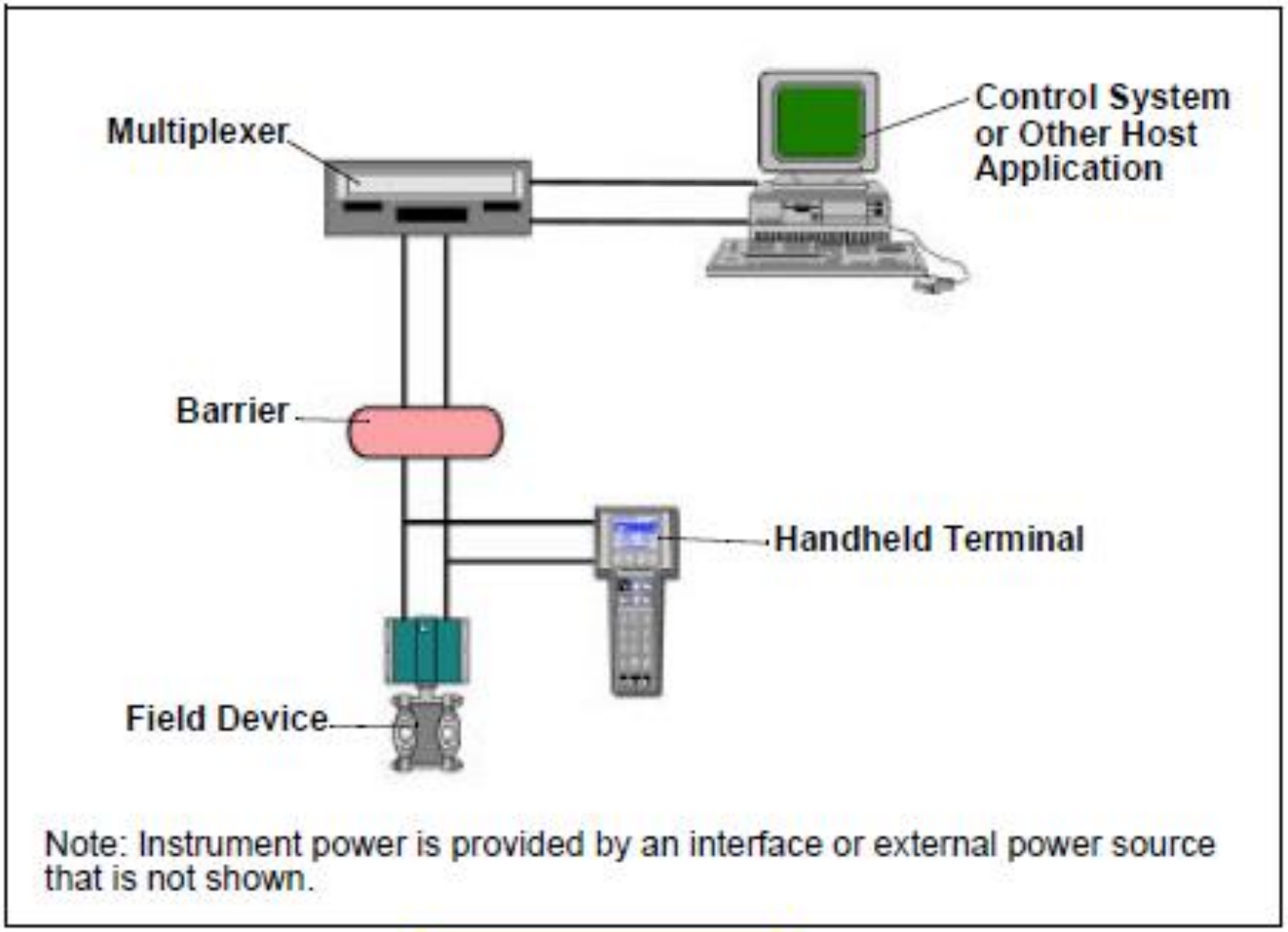
- The HART communication protocol is based on the Bell 202 telephone communication standard and operates using the *frequency shift keying* (FSK) principle.
- The digital signal is made up of two frequencies— 1,200 Hz and 2,200 Hz representing bits 1 and 0, respectively.
- Sine waves of these two frequencies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


20 mA
4 mA
"1"
"0"
"0"
"1"
"1"
"0"
"1"
"1"
"0"
Digital Signal
Analog Signal
Time
Note: Drawing not to scale.

HART Networks

- HART devices can operate in one of two network configurations—Point-to-Point or Multidrop.
- **POINT-TO-POINT**
- In point-to-point mode, the traditional 4–20 mA signal is used to communicate one process variable, while additional process variables, configuration parameters, and other device data are transferred digitally using the HART protocol.
- The 4–20 mA analog signal is not affected by the HART signal and can be used for control in the normal way.
- The HART communication digital signal gives access to secondary variables and other data that can be used for operations, commissioning, maintenance, and diagnostic purposes.

POINT-TO-POINT

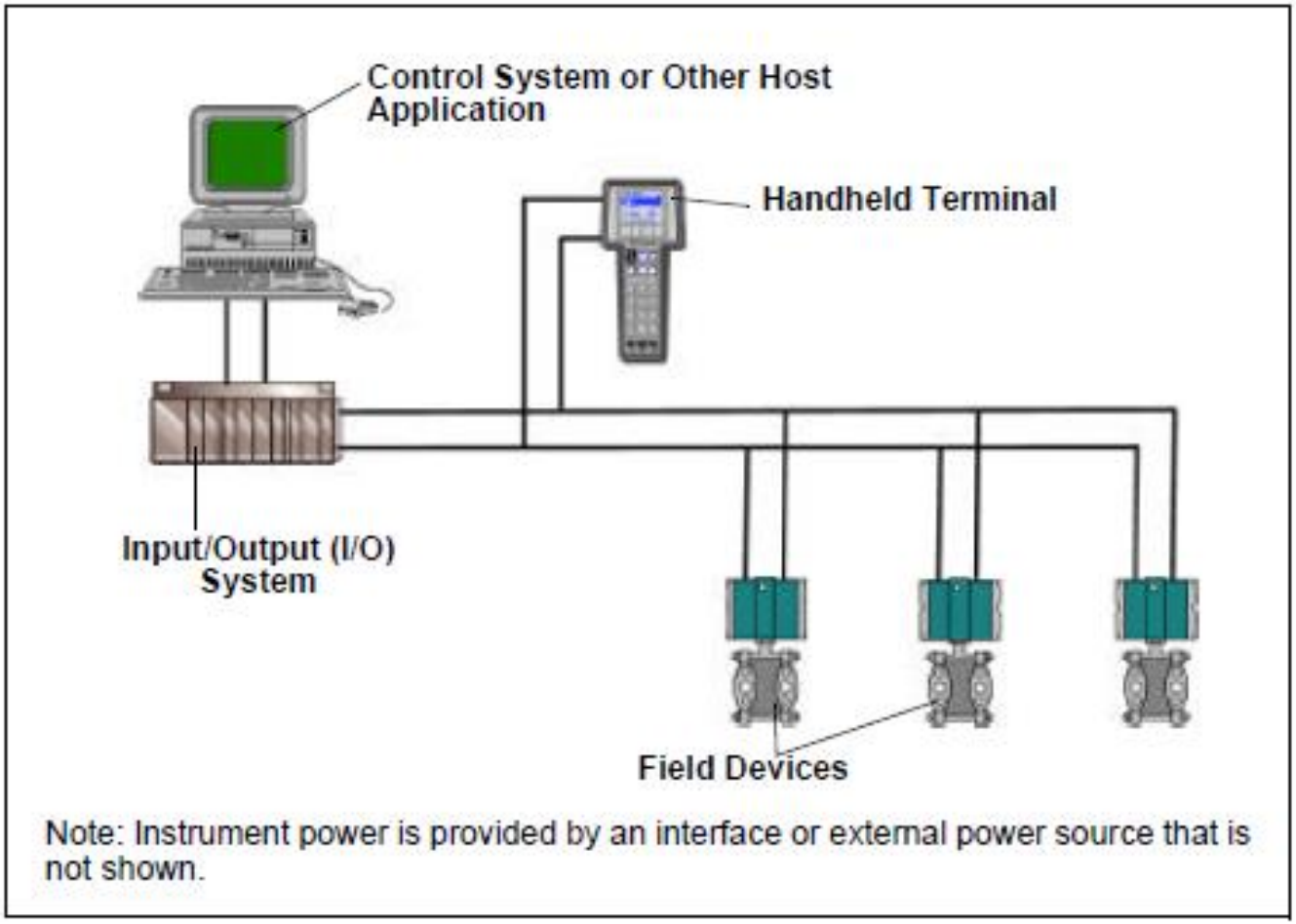


MULTIDROP

- The multidrop mode of operation requires only a single pair of wires and, if applicable, safety barriers and an auxiliary power supply for up to 15 field devices.
- All process values are transmitted digitally.
- In multidrop mode, all field device polling addresses are >0, and the current through each device is fixed to a minimum value (typically 4 mA).

Use multidrop connection for supervisory control installations that are widely spaced, such as pipelines, custody transfer stations, and tank farms.

MULTIDROP


Control System or Other Host Application
Handheld Terminal
Input/Output (I/O) System
Field Devices
Note: Instrument power is provided by an interface or external power source that is not shown.

HART Commands

- The *HART command set* provides uniform and consistent communication for all field devices.
- The command set includes three classes: *universal*, *common practice*, and *device specific*.
- **UNIVERSAL:** All devices using the HART protocol must recognize and support the universal commands. Universal commands provide access to information useful in normal operations (e.g., read primary variable and units).
- **COMMON PRACTICE:** Provide functions implemented by many, but not necessarily all, HART communication devices.
- **DEVICE SPECIFIC:** Represent functions that are unique to each field device. These commands access setup and calibration information, as well as information about the construction of the device.

Universal Commands	Common Practice Commands	Device-Specific Commands
• Read manufacturer and device type • Read primary variable (PV) and units • Read current output and percent of range • Read up to four predefined dynamic variables • Read or write eight-character tag, 16-character descriptor, date • Read or write 32-character message • Read device range values, units, and damping time constant • Read or write final assembly number • Write polling address	• Read selection of up to four dynamic variables • Write damping time constant • Write device range values • Calibrate (set zero, set span) • Set fixed output current • Perform self-test • Perform master reset • Trim PV zero • Write PV unit • Trim DAC zero and gain • Write transfer function (square root/linear) • Write sensor serial number • Read or write dynamic variable assignments	• Read or write low-flow cut-off • Start, stop, or clear totalizer • Read or write density calibration factor • Choose PV (mass, flow, or density) • Read or write materials or construction information • Trim sensor calibration • PID enable • Write PID setpoint • Valve characterization • Valve setpoint • Travel limits • User units • Local display information

HART Commands

Establishing Communication With HART Device

- Each HART device has a 38-bit address that consists of the manufacturer ID code, device type code, and device-unique identifier.
- A unique address is encoded in each device at the time of manufacture.
- A HART master must know the address of a field device in order to communicate successfully with it.
- A master can learn the address of a slave device by issuing one of two commands that cause the slave device to respond with its address:

Establishing Communication With HART Device

- *Command 0, Read Unique Identifier*—Command 0 is the preferred method for initiating communication with a slave device because it enables a master to learn the address of each slave device without user interaction.
- *Command 11, Read Unique Identifier by Tag* - Command 11 is useful if there are more than 15 devices in the network or if the network devices were not configured with unique polling addresses. (Multidropping more than 15 devices is possible when the devices are individually powered and isolated.)
- Command 11 requires the user to specify the tag numbers to be polled.

DEVICE DESCRIPTION

- Some HART host applications use *device descriptions* (DD) to obtain information about the variables and functions contained in a HART field device.
- The DD includes all of the information needed by a host application to fully communicate with the field device.
- HART *Device Description Language* (DDL) is used to write the DD, that combines all of the information needed by the host application into a single structured file.
- The DD identifies which common practice commands are supported as well as the format and structure of all device-specific commands.
- A DD for a HART field device is roughly equivalent to a printer driver for a computer.

Benefits of HART Communication

- Unlike other digital communication technologies, the HART protocol provides a unique communication solution that is backward compatible with the installed base of instrumentation in use today.
- This backward compatibility ensures that investments in existing cabling and current control strategies will remain secure well into the future.
- Major Benefits are:
  - Improved plant operations
  - Operational flexibility
  - Instrumentation investment protection
  - Digital communication

HART communication layers

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

HART protocol implementing the OSI model